Iowa State Implementation Plan for Regional Haze

Iowa Department of Natural Resources
Environmental Services Division
Air Quality Bureau
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Urbandale, IA 50322

March 2008

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8.1 Meteorological Model Performance Evaluation of an Annual 2002 MM5 (version 3.6.3) Simulation. Prepared by Matthew Johnson, Iowa Department of Natural Resources, 2007.
8.2 LADCO Nonroad Emissions Inventory Project - Development of Local Data for Construction and Agricultural Equipment, Final Report. E. H. Pechan, September 10, 2004.
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List of Acronyms

AIRS – Aerometric Information Retrieval System
AQS – EPA's Air Quality System
BART – Best Available Retrofit Technology
BEEP – Iowa Bus Emission Education Program
Bext – light extinction (typically measured in inverse megameters: 1/Mm or Mm^{-1})
BOWA – Boundary Waters Canoe Area Wilderness
CAA – Clean Air Act 42 Unites States Code Sections 7401, et seq
CAIR – Clean Air Interstate Rule
CENRAP – Central Regional Air Planning Association
CFR – Code of Federal Regulation
CM – coarse mass (PM2.5 mass subtracted from PM10 mass)
CMAQ – Community Multiscale Air Quality model
CAMx – Comprehensive Air quality Model with extensions
DOC – diesel oxidation catalysts
dv – deciview
EGAS5 - Economic Growth Analysis System model version 5
EGU – Electric Generating Unit
EPA – United States Environmental Protection Agency
FLM – Federal Land Manager
FR – Federal Register
GCVTC – Grand Canyon Visibility Transport Commission
IAC – Iowa Administrative Code
IDNR – Iowa Department of Natural Resources
IMPROVE – Interagency Monitoring of Protected Visual Environments
IPM – Integrated Planning Model
ISLE – Isle Royale National Park
LADCO - Lake Michigan Air Directors Consortium
MACT – Maximum Achievable Control Technology
MI - Michigan
MM5 – Fifth-Generation NCAR / Penn State Mesoscale Model
MO – Missouri
MN – Minnesota
MRPO – Midwest Regional Planning Organization
NEEDS – National Electric Energy Data System
NEI – National Emissions Inventory
NOx – oxides of nitrogen or nitrogen oxides
PM – particulate matter
PM2.5 – fine particulate matter; particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers as measured by an EPA–approved reference method
PM10 – coarse particulate matter; particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers as measured by an EPA–approved reference method
POG – CENRAP's Policy Oversight Group

PSAT – Particulate Matter Source Apportionment Technology
RPG – Reasonable Progress Goal
RAVI - Reasonably Attributable Visibility Impairment
RPO – Regional Planning Organization
SENE – Seney Wilderness Area
SD – South Dakota
SIP – State Implementation Plan
SMOKE – Sparse Matrix Operator Kernel Emissions
SMP – Smoke Management Plan
SO2 –sulfur dioxide
STN – Speciated Trends Network
TPY – tons per year; also listed as tpy
TSD – Technical Support Document
UCR – University of California at Riverside
USC – United States Code
VIEWS – Visibility Information Exchange Websystem (website)
VISTAS – Visibility Improvement State and Tribal Association of the Southeast
VOC – volatile organic compounds
VOYA – Voyagers National Park

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

March 7, 2008

John B. Askew
Regional Administrator
Region VII
United States Environmental Protection Agency
901 North Fifth Street
Kansas City, KS 66101

Dear Mr. Askew:

In accordance with the provisions of 40 CFR 51.308, this letter and enclosures constitute the submittal of the Iowa State Implementation Plan (SIP) for regional haze.

This SIP submittal addresses the actions the Iowa Department of Natural Resources (IDNR) has taken to adopt the regional haze program. IDNR's adopted regional haze rules are located at 567 Iowa Administrative Code 22.9.

The SIP was provided to the Federal Land Managers on November 26, 2007. The notice of public comment period and public hearing was published in the Legal Notices section of the Des Moines Register on December 26, 2007. The public was also notified by posting of the announcement on the State of Iowa's Public Events Calendar on December 6, 2007. A public hearing was held on January 30, 2008, at the Air Quality Bureau in Urbandale. The public comment period ended on January 31, 2008. Responses to public comments can be found in Appendix 2.1.

The IDNR also requests the adoption into our SIP of the most recent revisions to 567 Iowa Administrative Code 22.9. The Environmental Protection Commission adopted the revisions on May 1, 2007. The final rule was published in the Iowa Administrative Bulletin on May 23, 2007 in Volume XXIX Number 24, ARC 5900B, or at http://www.legis.state.ia.us/Rules/2007/Bulletin/IAB070523.htm. The rule was effective on June 27, 2007. A copy of this publication is included in Appendix 2.

Please approve this proposed program as the official regional haze program of the State of Iowa. If you have any questions regarding this submittal, please contact Matthew Johnson at matthew.johnson@dnr.iowa.gov, Wendy Rains at wendy.rains@dnr.iowa.gov, or Jim McGraw at jim.mcgraw@dnr.iowa.gov. These contacts may also be reached by calling (515) 242-5100.

Sincerely,

Richard A. Leopold

Richard A. Leopold
Director

Enclosures: Iowa State Implementation Plan for Regional Haze

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ii. Executive Summary

Congress addressed visibility protection at national parks and scenic areas in an amendment to the Clean Air Act in 1977. The Congressional visibility goals were most recently promulgated in the federal Regional Haze Rule on July 1, 1999. The goal of the federal regional haze program is to reach natural background visibility conditions at mandatory Class I Federal areas by 2064.

Iowa does not have a mandatory Class I Federal area. The Boundary Waters Canoe Area Wilderness (MN), Voyageurs National Park (MN), Badlands National Park (SD), Hercules-Glades Wilderness Area (MO), and Mingo Wilderness Area (MO) are the closest Class I areas to Iowa. The pollutants that reduce visibility at these Class I areas include fine particulate matter ($PM_{2.5}$), and compounds which contribute to its formation, such as nitrogen oxides (NOx), sulfur dioxide (SO_2), ammonia, and under certain conditions volatile organic compounds (VOCs).

States were required to address visibility impairing pollutant emissions from major source facilities with units constructed between 1962 and 1977. These units, if they met additional requirements, were subject to additional review and possible control. EPA's recommended tools were inappropriate for IDNR given the distances to the Class I areas. IDNR used multiple methods to determine the extent of possible visibility impairment attributable to BART units. IDNR determined that none of the 27 BART units caused or contributed to visibility impairment.

The U.S Environmental Protection Agency (EPA) created Regional Planning Organizations (RPOs) to facilitate the development of the federally mandated state implementation plans (SIP) across the country. Iowa, as a member state, worked closely with the Central Regional Air Planning Association (CENRAP) to develop this SIP. Through a consultation process, IDNR worked with Missouri, Arkansas, Oklahoma, Minnesota, and Michigan. Emissions sources in Iowa were not found to contribute to visibility impairment in the Class I areas in Missouri, Arkansas, and Oklahoma. Minnesota requested that Iowa review emissions and consider reductions that may affect Minnesota Class I areas.

Based upon results generated through the RPO process, Iowa may contribute to the visibility impairment at Class I areas in Minnesota and Michigan. The most recent EPA forecasts anticipate a decline in Iowa's SO2 emissions from electrical generating units (EGUs) by approximately 15% between 2002 and 2018. A reduction of 27% is also forecast for EGU NOx emissions. IDNR has determined that additional reductions are not needed at this time due to existing emissions controls, the projected reductions from recently mandated requirements, and the costs associated with additional controls.

The Regional Haze program requires States to revise the SIP by July 31, 2018, and every ten years thereafter. Federal land managers, with the U.S. Department of Interior and U.S. Department of Agriculture, were given 60 days to review the SIP prior to the public hearing as required in the federal Regional Haze Rule. Progress towards meeting goals is evaluated every five years following the initial SIP submittal. The IDNR will continue to work with industry, the public, and regional partners to evaluate control strategies to address regional haze, as needed.

1. Background and Overview of Federal Haze Regulations

In the 1977 amendments to the Clean Air Act (CAA), Congress added Section 169 (42 U.S.C. 7491) setting forth the following national visibility goal of restoring pristine conditions in national parks and wilderness areas:

> "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from man-made air pollution."

Over the following years modest steps were taken to address the visibility problems in Class I areas. The control measures taken mainly addressed "Plume Blight" from specific pollution sources, and did little to address regional haze issues in the Eastern United States. Plume blight is the visual impairment of air quality that manifests itself as a coherent plume. This results from specific sources, such as a power plant smoke stack, emitting pollutants into a stable atmosphere. The pollutants are then transported aloft with little or no vertical mixing.

Plume blight is controlled through the reasonably attributable visibility impairment (RAVI) regulations codified at 40 CFR § 51.302. RAVI refers only to visual impairment that results from a single source or a small number of sources. RAVI requirements do not impact Iowa sources as the transport distances are too great for a plume to have retained an applicable level of cohesion upon reaching a Class I area.

When the CAA was amended in 1990, Congress added Section 169B (42 U.S.C. 7492), authorizing further research and regular assessments of the progress made so far. In 1993, the National Academy of Sciences concluded that "current scientific knowledge is adequate and control technologies are available for taking regulatory action to improve and protect visibility."[1]

In addition to authorizing creation of a visibility transport commissions and setting forth their duties, Section 169B(f) of the CAA specifically mandated creation of the Grand Canyon Visibility Transport Commission (GCVTC) to make recommendations to the U.S. Environmental Protection Agency (EPA) for the region affecting the visibility of the GCVTC. Following four years of research and policy development the GCVTC submitted its report to EPA in June 1996. This report, as well as the many research reports prepared by the GCVTC, contributed invaluable information to EPA in its development of the federal Regional Haze Rule.

EPA's Regional Haze Rule was adopted July 1, 1999, and went into effect on August 30, 1999. The Regional Haze Rule aimed at achieving national visibility goals by 2064. This rulemaking addressed the combined visibility affects of various pollution sources over a wide geographic region. This wide reaching pollution net meant that many states – even those without Class I areas – would be required to participate in haze reduction efforts. EPA designated five Regional

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[1] *Protecting Visibility in National Parks and Wilderness Areas*. National Research Council. Washington, DC: 1993.

Planning Organizations (RPOs) to assist with the coordination and cooperation needed to address the visibility issue. Those States and Tribes that make up the midsection of the contiguous United States were designated as the Central Regional Air Planning Association (CENRAP). The State of Iowa is part of CENRAP. The Iowa Department of Natural Resources (IDNR) is the designated air pollution control agency as indicated in section 455B.132 of the Iowa Code.

On May 24, 2002, the U. S. Court of Appeals, D. C. District Court ruled on the challenge brought by the American Corn Growers Association against EPA's Regional Haze Rule of 1999. The Court remanded to EPA the Best Available Retrofit Technology (BART) provisions of the rule, and denied industry's challenge to the haze rule goals of natural visibility and no degradation requirements. EPA published the final revisions to the Regional Haze rule pursuant to the remand on July 6, 2005.

On February 18, 2005, the U.S. Court of Appeals for the District of Columbia Circuit issued another ruling, in Center for Energy and Economic Development v. EPA, granting a petition challenging provisions of the Regional Haze Rule governing an optional emissions trading program for certain western States and Tribes. EPA published revised regulations for the provisions of the governing alternative trading programs on October 13, 2006.

To facilitate the review of this State Implementation Plan (SIP) by the EPA, Federal Land Managers (FLMs)[1], stakeholders and the public, "A Guide to Locating 40 CFR § 51.308 Requirements" is provided in Appendix 1.1 of this document.

Some emissions sources within the State of Iowa may have impacts on nearby Class I areas. Figure 1.1 provides a map of all 156 mandatory Class I Federal areas and Figure 1.2 assists with the identification of nearby Class I areas. Combining the effects of distance and relevant transport patterns, nearby Class I areas considered include: Boundary Waters Canoe Area Wilderness (MN), Voyageurs National Park (MN), Isle Royale National Park (MI), Seney Wilderness Area (MI), Badlands National Park (SD), Hercules-Glades Wilderness Area (MO), and Mingo Wilderness Area (MO).

In addition, the IDNR believes that improved visibility will lead to aesthetic and environmental benefits in the affected Class I areas. More information is provided in Appendix 1.2.

List of Chapter 1 Appendices

1.1 Guide to Locating 40 CFR § 51.308 Requirements.
1.2 Benefits of Improved Visibility.

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[1] FLMs include representatives from the National Park Service, U.S. Forest service, and the U.S Fish and Wildlife Service.

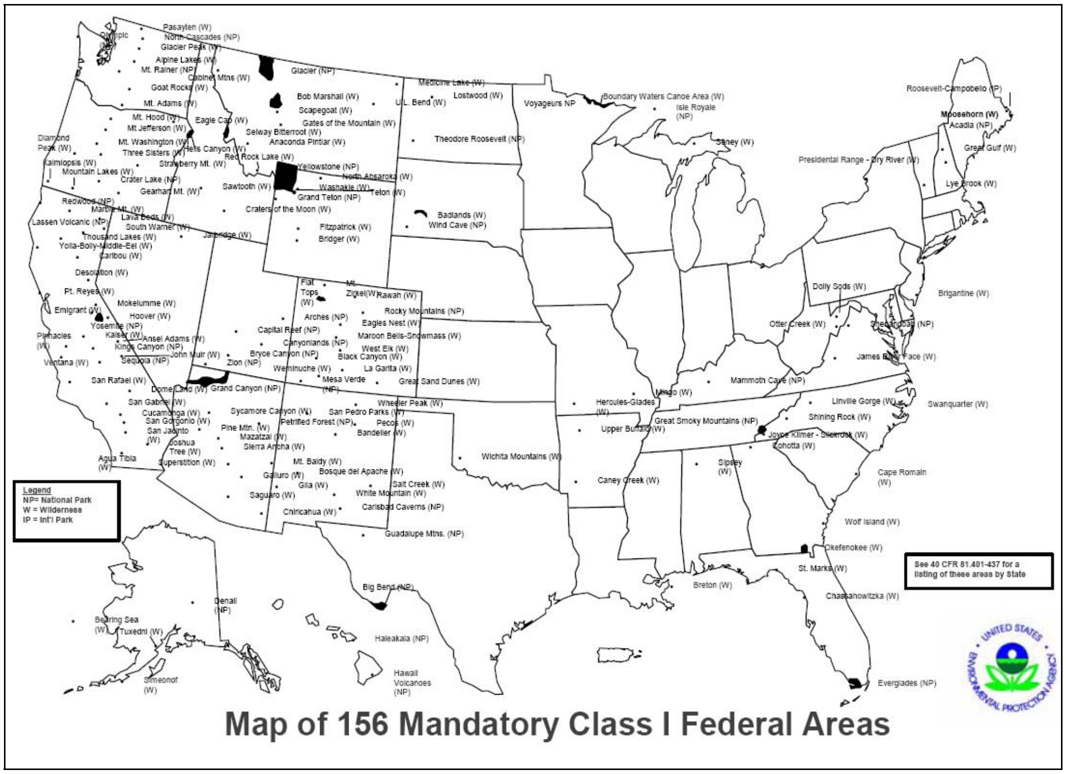

Figure 1.1. Map showing the location of the mandatory Class I Federal areas.

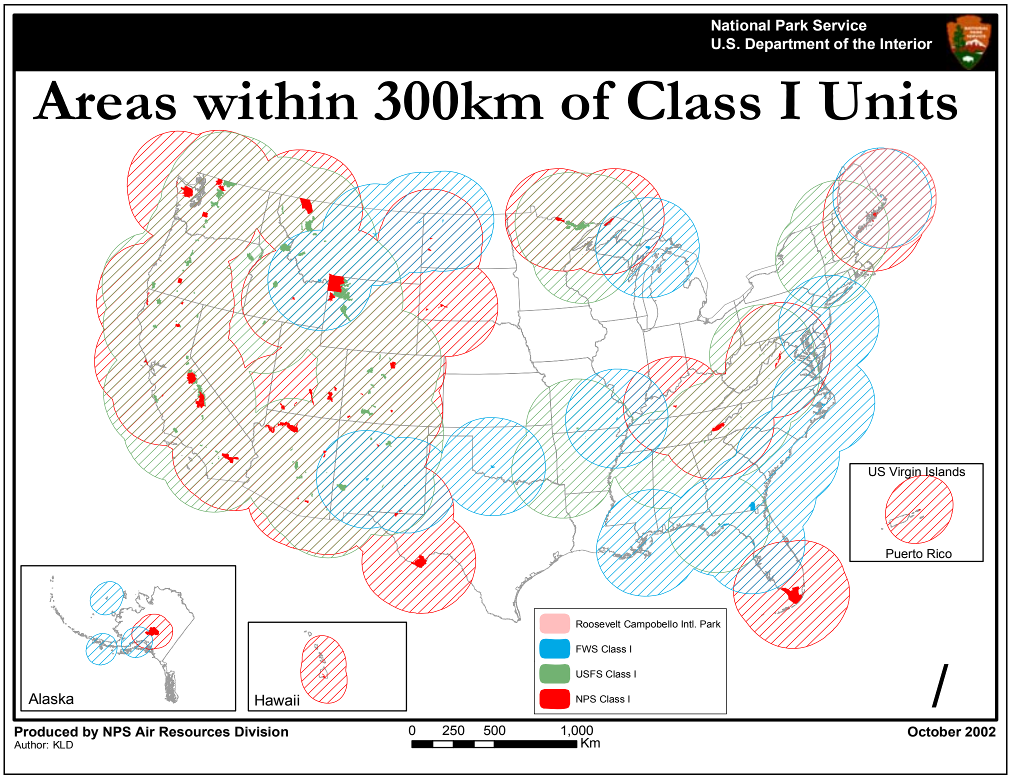

Figure 1.2. Map identifying areas within 300 km of a mandatory Class I Federal area.

2. General Planning Provisions

Pursuant to the requirements of 40 CFR § 51.308(a) and (b), the IDNR submits this SIP revision to meet the requirements of EPA's Regional Haze Rule that were adopted to comply with requirements set forth in the CAA. Elements of this plan address the core requirements pursuant to 40 CFR § 51.308(d) and the Best Available Retrofit Technology (BART) components of 40 CFR § 51.308(e). In addition, this SIP revision addresses Regional Planning, State and FLM coordination, and contains a commitment to provide plan revisions and adequacy determinations.

IDNR has the authority to adopt this SIP revision and has adopted this revision in accordance with State laws and rules. The first portion of IDNR's regional haze rule was adopted into the SIP on September 15, 2005 (70 FR 53939 – 53941). The IDNR provided public notice of the opportunity to comment on the revision to the regional haze rule (567 IAC 22.9) on January 2, 2007. The notice of public hearing was published on January 31, 2007. The public comment period started on January 31, 2007, and ended on March 5, 2007. IDNR held a public hearing regarding the rule revision on March 2, 2007. No comments were received during the public comment period or at the hearing. The rule revisions were approved by IDNR's Environmental Protection Commission on May 1, 2007. The rule revisions were published in the Iowa Administrative Bulletin on May 23, 2007 in ARC 5900B and became effective on June 27, 2007.

The IDNR provided public notice of the opportunity to comment on the SIP revision and the public hearing on December 6, 2007, in the State of Iowa's Public Meeting Calendar, and on December 26, 2007, in the Des Moines Register. IDNR held a public hearing regarding the SIP revision on January 30, 2008. A copy of this report is available at the Iowa Department of Natural Resources – Air Quality Bureau, Records Center, 7900 Hickman Rd, Ste 1, Urbandale, IA 50322, and on our website at www.iowacleanair.com. Public comments, inclusive of those made by the FLMs were addressed and are summarized in Appendix 2.1.

<u>List of Chapter 2 Appendices</u>

2.1 Summary of (a) legal authority; (b) public notice and participation process; (c) public notice documents; (d) Iowa Administrative Bulletin for revisions to 567 IAC 22.9; and (e) public comments and responsiveness summary.

3. Regional Planning

In 1999, EPA and affected States/Tribes agreed to create five RPOs to facilitate interagency coordination on Regional Haze SIPs. The IDNR is a member of the Central Regional Air Planning Association (CENRAP) RPO. Members of CENRAP are in the geographical areas listed in Table 3.1. Figure 3.1 shows a map of all five regional planning organizations. The figure covers both state and tribal areas.

Table 3.1. CENRAP states.

Arkansas	**Iowa**
Kansas	**Louisiana**
Minnesota	**Missouri**
Nebraska	**Oklahoma**
Texas	

Figure 3.1. Geographical areas of Regional Planning Organizations.

The governing body of CENRAP is the Policy Oversight Group (POG). The POG is made up of eighteen (18) voting members representing the states and tribes within the CENRAP region and non-voting members representing local agencies, the EPA, the Fish and Wildlife Service, Forest Service, and National Park Service. The POG facilitates communication with FLMs, stakeholders, the public, and with CENRAP staff.

Since its inception, CENRAP has established an active committee structure to address both technical and non-technical issues related to regional haze. The work of CENRAP is accomplished through five standing workgroups: Monitoring; Emission Inventory; Modeling; Communications; and Implementation and Control Strategies. Participation in workgroups is open to all interested parties. Ad hoc workgroups may be formed by the POG to address specific issues. Ultimately, policy decisions are made by the CENRAP POG.

CENRAP has adopted the approach that the Regional Haze Rule requires the "States to establish goals and emission reduction strategies for improving visibility in all 156 mandatory Class I parks and wilderness areas." The rule also encouraged states and tribes to work together in regional partnerships.

This SIP revision utilizes data analysis, modeling results, and other technical support documents prepared for regional haze purposes. By coordinating with CENRAP and other RPOs, the IDNR has worked to ensure that its long-term strategy provides sufficient measures to mitigate the impacts of Iowa sources on affected Class I areas. Data analyses, modeling results and other technical support documents developed through CENRAP are provided to members via CENRAP's website and ftp server.

List of Chapter 3 Appendices

There are no Appendices to Chapter 3.

4. State/Tribe and Federal Land Manager Coordination

Forty CFR § 51.308(i) requires coordination between States and the Federal Land Managers (FLMs). FLMs are an integral part of CENRAP's POG and the membership on standing committees. FLMs have contributed to the development of technical and non technical work as a result of that participation. In addition, opportunities have been provided by CENRAP for FLMs to review and comment on each of the technical documents developed by CENRAP and included in this SIP revision. The IDNR has provided agency contacts to the FLMs as required. In the development of this plan, the FLMs were consulted in accordance with the provisions of 40 CFR § 51.308(i)(2).

The IDNR provided FLMs an opportunity for consultation, in person and at least 60 days prior to holding any public hearing on an implementation plan or plan revision.

During the consultation process, the FLMs review the SIP revision to evaluate:

- Assessment of the impairment of visibility in any Class I areas
- Recommendations on the development of reasonable progress goals (RPGs)
- Recommendations on the development and implementation of strategies to address visibility impairment

IDNR sent the draft SIP revision to the FLMs on November 26th, 2007, and notified the FLMs of the public hearing held on January 30th, 2008. Comments received from the FLMs on the plan were addressed. A summary of FLMs comments and the IDNR's responses to the comments are included in Appendix 2.1 to this plan.

IDNR will continue to coordinate and consult with the FLMs during the development of future progress reports and plan revisions, as well as during the implementation of programs having the potential to contribute to visibility impairment in the mandatory Class I Federal areas. The FLMs must be consulted in the following instances:

- Development and review of implementation plan revisions
- Review of 5-year progress reports
- Development and implementation of other programs that may contribute to impairment of visibility in Class I areas

In addition to the consultation required by 51.308(i), the IDNR has consulted informally with the FLMs individually and through CENRAP during the regional haze SIP development process.

4.1 Continuing Consultation with Federal Land Managers

Forty CFR 51.308(i)(1)(4) requires the development of procedures for continuing consultation between the IDNR and Federal Land Managers on the implementation of the regional haze rule, including plan revisions, five-year progress reports, and on the implementation of other programs which may contribute to visibility impairment at a mandatory Class I Federal area.

The IDNR will continue to utilize the RPOs as the primary mechanism for consultation with the FLMs. The RPOs provided an established mechanism through which formal and informal communication can occur. Consultation is coordinated through the RPOs via conference calls, workgroup activities, meetings, and the facilitation of interagency discussions. Through the RPO process, FLMs will remain active in coordinated activities necessary for development of the five year review. As in the initial regional haze SIP, the FLMs will be provided a 60 day comment period, occurring 60 days prior to any public hearing on any five, or ten, year SIP review or revision.

The Department currently notifies the appropriate FLM in writing of proposed major source or major modifications that may affect a Class I area and requires applicants to submit ambient impact assessments for Class I areas consistent with the Prevention of Significant Deterioration (PSD) regulatory requirements for the review of impacts on Class I areas. This practice will continue in the future.

List of Chapter 4 Appendices

There are no Appendices to Chapter 4.

5. Assessment of Baseline, Current, and Natural Conditions in Class I Areas

The goal of the Regional Haze Rule is to restore natural visibility conditions to the 156 mandatory Class I Federal areas identified in the 1977 Clean Air Act Amendments. Forty CFR § 51.301(q) defines natural conditions: "Natural conditions includes naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration." The Regional Haze SIPs must contain measures that make "reasonable progress" toward this goal by reducing anthropogenic emissions that cause haze. For each Class I area, there are three metrics of visibility that are part of the determination of reasonable progress:

1) baseline conditions,
2) current conditions, and
3) natural conditions

Each of the three metrics includes the concentration data of the visibility pollutants as different terms in the light extinction algorithm, with respective extinction coefficients and relative humidity factors. Total light extinction, when converted to deciviews (dv), is calculated for the average of the 20 percent best and 20 percent worst visibility days.

"Baseline" visibility is the starting point for the improvement of visibility conditions. It is the average of the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring data for 2000 through 2004 and can be thought of as "current" visibility conditions for this initial period. The comparison of initial baseline conditions to natural visibility conditions indicates the amount of improvement necessary to attain natural visibility by 2064. Natural visibility is determined by estimating the natural concentrations of visibility pollutants and then calculating total light extinction with the light extinction algorithm. (See Figure 5.1 as an example.) Each state must estimate natural visibility levels for Class I areas within its borders in consultation with FLMs and other states (51.308(d)(2)). "Current conditions" are assessed every five years as part of the SIP review where actual progress in reducing visibility impairment is compared to the reductions committed to in the SIP.

Default and refined values for natural visibility conditions

EPA's "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program" (Sept 2003) provides States a "default" estimate of natural visibility. The default values of concentrations of visibility pollutants are based on a 1990 National Acid Precipitation Assessment Program report (Trijonis, J.C. (1990) NAPAP State of Science & Technology, vol. III). In the guidance, the United States is divided into "East" and "West" along the western boundary of the states one tier west of the Mississippi River. This division divides the CENRAP states into "East" which includes Arkansas (AR), Iowa (IA), Louisiana (LA), Minnesota (MN), and Missouri (MO) with seven Class I areas, and "West" which includes Kansas (KS), Nebraska (NE), Oklahoma (OK), and Texas (TX) with three Class I areas. In the two classifications, only sulfate and organic carbon have different values, but the calculated deciview difference is significant.

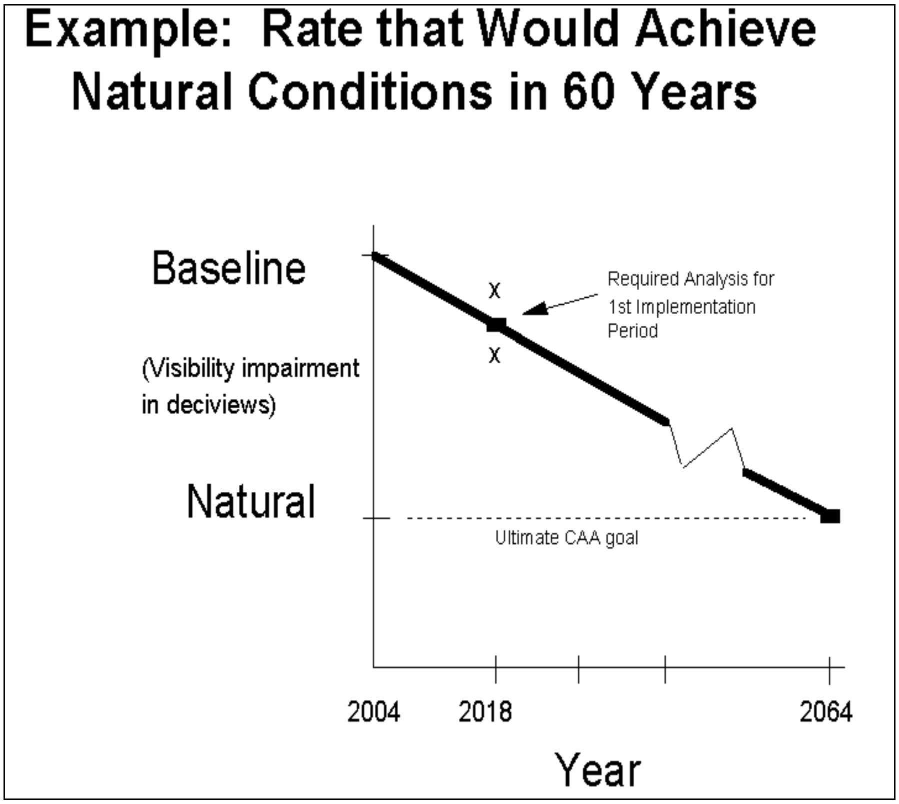

Figure 5.1. Natural background determination.

In the guidance, EPA also provides that states may use a "refined approach" to estimate the values that characterize the natural visibility conditions of the Class I areas. The purpose of refinement would be to provide more accurate estimates with changes to the extinction algorithm that may include: the concentration values; factors to calculate extinction from a measured particular species and particle size; the extinction coefficients for certain compounds; geographical variation (by altitude) of a fixed value; and/or the addition of visibility pollutants. States can choose between the default and refined equations. One equation is used to calculate baseline and current conditions of visibility due to haze-causing pollutants and, with natural concentrations of the same pollutants; the same equation is used to calculate natural visibility.

The old (default) algorithm:

$$\begin{aligned} b_{ext} \approx\ & 3 \times f(RH) \times [Sulfate] \\ & + 3 \times f(RH) \times [Nitrate] \\ & + 4 \times [Organic\ Carbon] \\ & + 10 \times [Elemental\ Carbon] \\ & + 1 \times [Fine\ Soil] \\ & + 0.6 \times [Coarse\ Mass] \\ & + 10 \end{aligned}$$

The new (refined) algorithm (differences from the default are in bold):

$$\begin{aligned}
b_{ext} \approx\ & \mathbf{2.2 \times f_S(RH) \times [Small\ Sulfate]} + \mathbf{4.8 \times f_L(RH) \times [Large\ Sulfate]} \\
& + \mathbf{2.4 \times f_S(RH) \times [Small\ Nitrate]} + \mathbf{5.1 \times f_L(RH) \times [Large\ Nitrate]} \\
& + \mathbf{2.8 \times [Small\ Organic\ Mass]} + \mathbf{6.1 \times [Large\ Organic\ Mass]} \\
& + 10 \times [\mathit{Elemental\ Carbon}] \\
& + 1 \times [\mathit{Fine\ Soil}] \\
& + \mathbf{1.7 \times f_{SS}(RH) \times [Sea\ Salt]} \\
& + 0.6 \times [\mathit{Coarse\ Mass}] \\
& + \mathbf{Rayleigh\ Scattering\ (site\ specific)} \\
& + \mathbf{0.33 \times [NO_2\ (ppb)]}
\end{aligned}$$

$$\mathbf{[Large\ Sulfate] = [Total\ Sulfate] / 20\ \mu g/m^3 \times [Total\ Sulfate],\ for\ [Total\ Sulfate] < 20\ \mu g/m^3}$$

$$\mathbf{[Large\ Sulfate] = [Total\ Sulfate],\ for\ [Total\ Sulfate] \geq 20\ \mu g/m^3}$$

$$\mathbf{[Small\ Sulfate] = [Total\ Sulfate] - [Large\ Sulfate]}$$

The same equations are used to apportion total nitrate and total organic carbon among their large and small components.

The choice between use of the default or the refined equation for calculating the visibility metrics for each Class I area is made by the state in which the Class I area is located. According to 40 CFR § 51.308(d)(2), the state will make the determinations of baseline and natural visibility conditions. It is with these calculations and in consultation with other states whose emissions affect visibility in that park or wilderness area (40 CFR § 51.308(d)(1)(iv)) that a state develops a RPG for each Class I area located within the state.

Consultation regarding the visibility metrics

Consultation among states is a requirement that is repeated in the Regional Haze Rule. As part of a “long-term strategy” for regional haze, a state whose emissions are “reasonably anticipated” to contribute to impairment in other states’ Class I area(s) must consult with those states; likewise, the state must consult with any states whose emissions affect its own Class I area(s) (40 CFR 51.308(d)(3)).

A chief purpose of the RPO is to provide a means for states to confer on all aspects of the regional haze issue, including consultation on the RPGs and long-term strategies based on the current (baseline) and natural visibility determinations. (This process is described in Chapter 3 “Regional Planning.”) CENRAP has provided a forum for the member States and Tribes to consult on the determination of baseline and natural visibility conditions in each of the Class I areas.

In addition, states in CENRAP have conferred with neighboring Class I area states outside CENRAP, both individually and through the RPOs. IDNR participated on conference calls with the Northern Midwest Class I Area Consultation Group, which were coordinated by the states of Minnesota and Michigan. Wisconsin, North Dakota, Illinois, FLMs, EPA, CENRAP, Midwest Regional Planning Organization (MRPO), and various Tribes also attended.

The IDNR monitored the activities of the Central Consultation Group. This group was coordinated by the states of Missouri and Arkansas. Other participants include the states of Ohio, Indiana, Illinois, Oklahoma, Texas, Kentucky, Tennessee, FLMs, other RPOs, and tribes. Iowa was determined not to be a contributing State to the central Class I areas of Hercules-Glades, Mingo, Caney Creek, and the Upper Buffalo Wilderness Areas.

IDNR was invited to participate in Oklahoma consultation concerning the Wichita Mountains Wilderness. Oklahoma invited states that had a projected contribution of at least 1 Mm^{-1} in 2018. Iowa was determined not to be a contributing state to this Class I area.

Forty CFR § 51.308(i) requires that States consult with FLMs, consultation topics include implementation, the assessment of visibility impairment, and recommendations regarding the RPG and strategies for improvement. This consultation requirement is treated in Chapter 4.

The State of Iowa does not contain any Class I areas. The IDNR coordinated with States and Tribes containing Class I areas which are affected by emissions from sources located in Iowa as those States assessed baseline, natural, and current visibility conditions in their respective Class I areas.

List of Chapter 5 Appendices

There are no Appendices to Chapter 5.

6. Monitoring Strategy

The federal Regional Haze Rule requires a monitoring strategy for measuring, characterizing, and reporting regional haze visibility impairment that is representative of all mandatory Class I Federal areas (40 CFR § 51.308(d)(4)).

Upon the creation of CENRAP, the newly formed Monitoring Workgroup recognized that to understand the character of regional haze in CENRAP states, they needed to fill data voids in Southern Arkansas, Iowa, Kansas, Southern Minnesota, Nebraska, and Oklahoma, including monitor placement at locations that were not mandatory Class I Federal areas. Between 2000 and 2003, five new IMPROVE sites and fifteen new IMPROVE Protocol sites were installed in CENRAP. The current network of visibility sites is indicated in Figure 6.1 below.

IDNR currently operates two IMPROVE Protocol sampling sites, one at Viking Lake State Park in southwestern Iowa, and the other at the Lake Sugema Wildlife Management Area in southeastern Iowa. The monitors began operation in June 2002. Additional monitoring equipment located at these two locations provides supplemental information on fine particles and their precursors. Data from IMPROVE and IMPROVE protocol monitors is analyzed by a national laboratory (funded via an interagency agreement between EPA and the National Park Service) and uploaded by the laboratory into two publicly available databases at http://vista.cira.colostate.edu/improve and http://vista.cira.colostate.edu/views/. The supplemental monitoring data is publicly available at http://www.epa.gov/ttn/airs/airsaqs. IDNR intends to continue to operate the two IMPROVE protocol monitors as long as the interagency agreement is in place and funding is available.

In addition to being used for the calculation of baseline visibility conditions, the IMPROVE data (including protocol sites) were analyzed to study the causes of haze within the Central U.S (see Appendix 6.1).

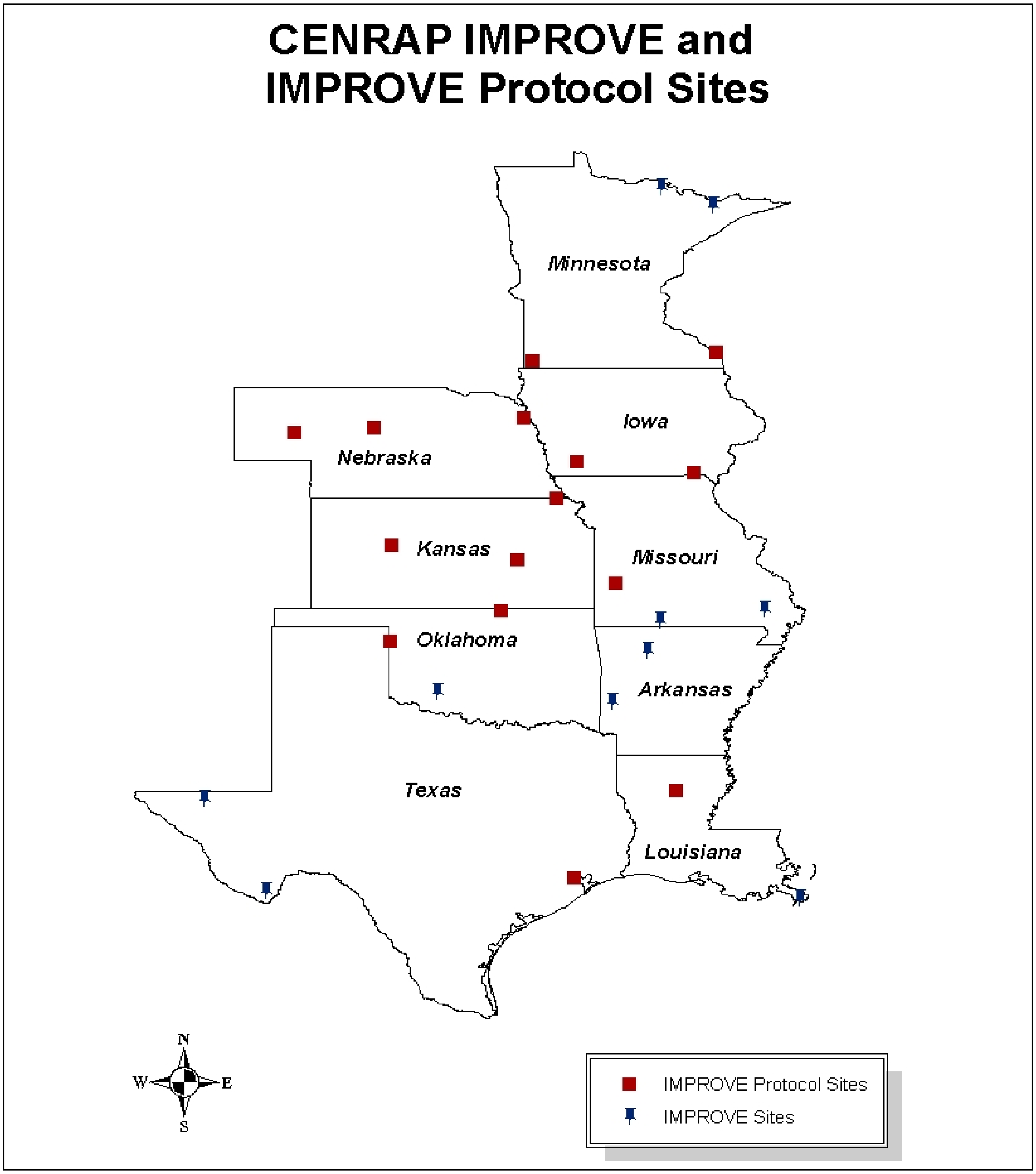

Figure 6.1. Map of CENRAP IMPROVE and IMPROVE Protocol monitoring sites.

<u>**List of Chapter 6 Appendices**</u>

6.1 Analyses of the Causes of Haze for the Central States (Phase II).

7. Emissions Inventory Summary

2002 Baseline Emissions

The federal Regional Haze Rule requires a statewide emissions inventory of pollutants that are reasonably anticipated to cause, or contribute, to visibility impairment in any mandatory Class I Federal area (40 CFR § 51.308(d)(4)(v)). The pollutants inventoried by the IDNR include species critical for determining visibility impacts such as volatile organic compounds (VOC), nitrogen oxides (NOx), PM2.5, PM10, ammonia (NH3), and SO2. An inventory containing emission rates for all pertinent anthropogenic and biogenic sources was developed for the baseline year 2002. The point source inventory was derived from the 2002 National Emissions Inventory (NEI). The remaining source categories were developed from a variety of data sources and inventory development techniques. A summary of the inventory is provided in Table 7.1. A detailed description of the 2002 emissions inventory is included in Appendix 7.1 (see Chapter 2 of the appendix).

Table 7.1. 2002 Iowa emissions inventory summary (tons per year).

	VOC	NOx	PM2.5	PM10	NH3	SO2
Ammonia	0	0	0	0	258,915	0
Area	106,712	6,782	11,540	12,182	6,560	3,184
Area Fire	1,120	138	4,681	4,893	0	160
Fugitive dust	0	0	38,666	193,331	0	0
Offroad	63,694	92,595	8,904	9,707	79	9,037
Onroad	87,392	120,621	1,747	2,373	3,064	3,200
Point EGU	1,075	81,761	4,527	9,424	0	135,833
Point Fire	545	33	594	700	48	35
Point NonEGU	41,184	35,812	7,651	17,495	3,317	51,836
Road dust	0	0	19,525	127,882	0	0
Wildfire	5	29	218	224	0	8
Biogenic	408,291	25,732				
TOTAL	**710,018**	**363,503**	**98,053**	**378,211**	**271,983**	**203,293**

Future Year Emissions

The 2002 emissions were grown to 2018 by using growth and control factors derived from the EGAS5, MOBILE6, and NONROAD models. The Integrated Planning Model (IPM) was used to forecast 2018 electric generating unit (EGU) emissions. Table 7.2 provides a summary of the 2018 BaseG emissions inventory; a detailed description of the 2018 emissions inventory and the associated growth and control methodologies is included in Appendix 7.1 (see Section 2.13). The summary data provided in Table 7.2 was compiled through a contract with E.H. Pechan.

Table 7.2. 2018 Iowa emissions inventory summary (tons per year).

	VOC	NOx	PM2.5	PM10	NH3	SO2
Ammonia	0	0	0	0	302,012	0
Area	127,849	7,476	10,677	11,510	13,304	3,224
Area Fire	1,120	138	4,681	4,893	0	160
Fugitive dust	0	0	40,608	203,044	0	0
Offroad	37,143	60,210	5,582	6,088	101	220
Onroad	36,404	33,975	708	708	4,225	400
Point EGU	1,802	65,629	9,578	11,232	713	Original: 160,733 Modified: 151,354
Point Fire	547	33	596	702	49	36
Point NonEGU	56,714	40,964	10,151	21,737	5,763	42,862
Road dust	0	0	17,712	114,889	0	0
Wildfire	5	29	218	224	0	8
Biogenic	408,291	25,732				
TOTAL	**669,875**	**234,186**	**100,511**	**375,027**	**326,167**	**198,264 (Modified)**

The 2002 and 2018 point source EGU SO2 emission rates are 135,833 and 160,733 tons per year (tpy), respectively. The IDNR has serious concerns regarding the 2018 (160,733 tpy) value. CENRAP utilized the 'RPO version 2.1.9' IPM (referred to as IPM v2.1.9) predictions to generate the 2018 BaseG scenario, in which total Iowa EGU SO2 emissions were forecast to be approximately 147,305 tpy. During review of the CENRAP BaseE2 modeling, errors were identified in the 2018 Iowa EGU emissions. Among the errors, certain EGU emissions were double counted when those sources were mistakenly grown through EGAS (as well as IPM). Following error identification, corrections were submitted for inclusion in the BaseF (and subsequent BaseG) modeling scenarios. After the corrections, EGU SO2 emissions totaled 151,354 tpy. The value of 160,733 tpy provided through the Pechan report is thus known to be inaccurate. Additionally, an EGU SO2 emission rate of 151,354 tpy is considered unreasonably conservative, given updated results from IPM version 3.0 (discussed in Chapter 11) and Iowa's participation in the Clean Air Interstate Rule (CAIR) cap and trade program.

Figure 7.1 is provided to aid in the comparison of the 2002 and 2018 estimated emission rates. For chart clarity, only anthropogenic emissions sources are plotted.

The Department does not advocate the use of the 2018 EGU emissions inventory data as incorporated within Table 7.2, or Figure 7.1. As mentioned, the EGU data in Table 7.2 and Figure 7.1 are derived from IPM v2.1.9 predictions. The IPM v2.1.9 forecasts are outdated and based upon faulty inputs and assumptions (additional details regarding EGU forecast data is provided in Chapter 11). Table 7.2 and Figure 7.1 incorporate the IPM v2.1.9 data only to reflect the emissions rates upon which CENRAP modeling is derived. The Department does not endorse the use of IPM v2.1.9 as a source for reasonable 2018 EGU emissions forecasts. The Department considers the IPM v3.0 results an improved estimation of 2018 EGU emission rates, and supports IPM v3.0 as a useful basis for planning purposes.

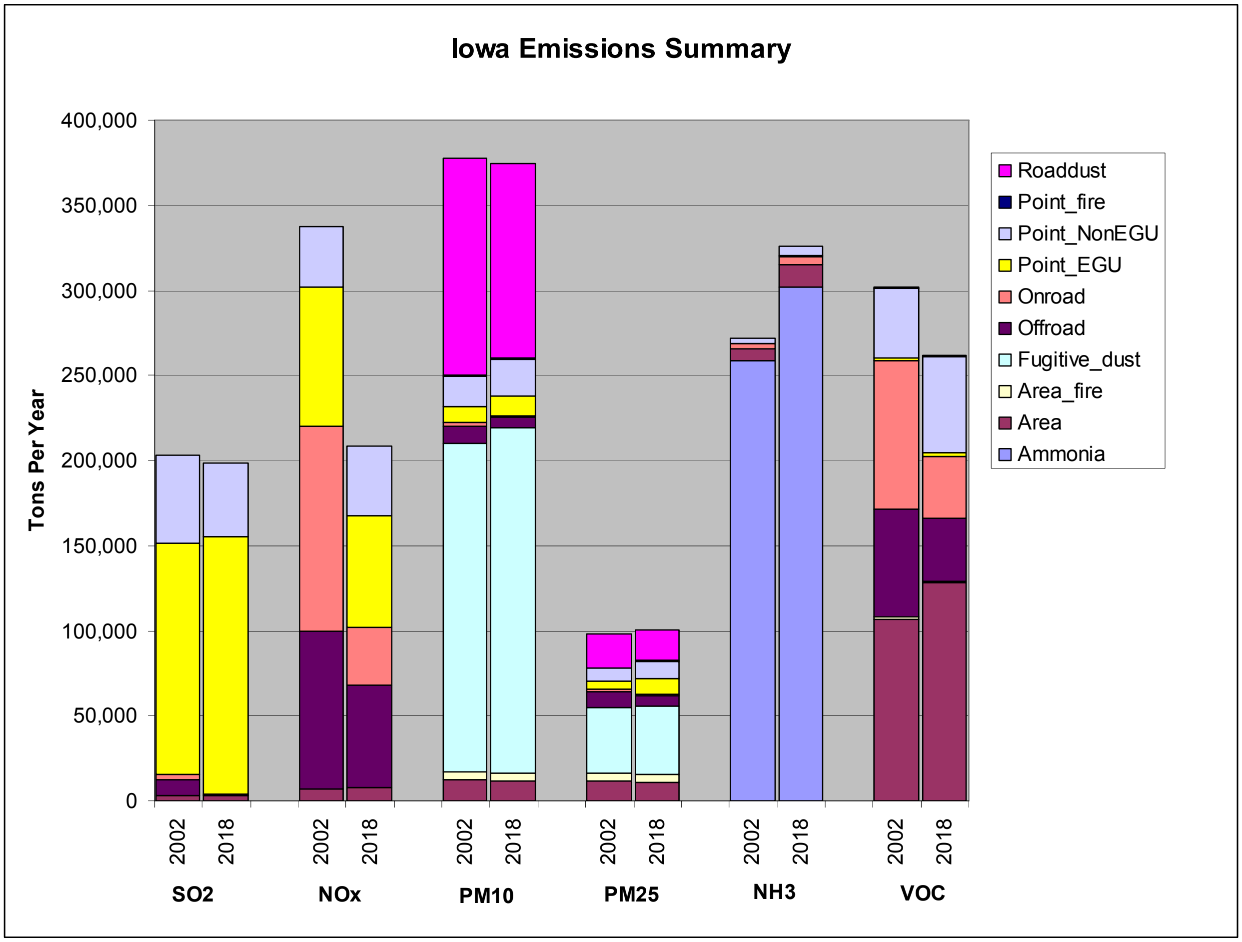

Figure 7.1. Comparison of Iowa's estimated emission rates between the 2002 and 2018 basecase simulations. The modified 2018 EGU SO2 emission rate is plotted.

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7.1 Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans. Prepared for CENRAP by Environ and the University of California at Riverside (UCR), September 12, 2007.

8. Modeling Assessment

Guidelines for conducting regional-scale modeling for particulate matter (PM) and visibility are provided in Appendix W of 40 CFR 51 and EPA's 2007 Modeling Guidance (EPA-454/B-07-002). Within the context of the Regional Haze Rule, EPA recommends the use of sophisticated one-atmosphere photochemical models equipped with state-of-the science mechanisms which simulate the pollutants and pollutant precursors leading to visibility impairment: Two peer reviewed, non-proprietary models capable of meeting such criteria are the Community Multiscale Air Quality (CMAQ) and the Comprehensive Air quality Model with extensions (CAMx). CENRAP contractors have performed regional modeling using both CMAQ and CAMx.

The CMAQ model is a sophisticated Eulerian model that simulates the atmospheric and surface processes affecting the transport, transformation, and deposition of air pollutants and their precursors. An Eulerian model computes the numerical solution on a fixed grid.

CAMx is a computer modeling system for the integrated assessment of photochemical and particulate air pollution. CAMx incorporates all of the technical attributes demanded of state-of-the-science photochemical grid models, including two-way grid nesting, a fast chemistry solver, and an optional subgrid-scale plume-in-grid module to treat the early dispersion and chemistry of point source plumes.

Particulate Matter Modeling: CAMx Mechanism 4 (M4) provides one-atmosphere modeling for fine and coarse PM and ozone. Aqueous phase chemistry is modeled using the RADM mechanism. Inorganic sulfate/nitrate/ammonium chemistry is modeled with ISORROPIA. ISORROPIA is a model that calculates the composition and phase state of an ammonia-sulfate-nitrate-chloride-sodium-water inorganic aerosol in thermodynamic equilibrium with gas phase precursors. Secondary organic aerosols are modeled using a semi-volatile scheme called Simple Object Access Protocol (SOAP). Wet and dry deposition processes are included for gases and particles. Gridded deposition information is output along with the concentrations.

In the July 1, 1999, publication of the Regional Haze Rule in the Federal Register, EPA defined the uses of regional modeling as follows:

- Analyses and determination of the extent of emissions reductions needed from individual states
- Analyses and determination of emissions needed to meet the progress goal for the Class I area
- Analyses to support conclusion that the long-term strategy provides for reasonable progress
- Analyses to calculate the resulting degree of visibility improvement that would be achieved at each Class I area
- Analyses to compare visibility improvement between proposed control strategies

In addition to the analyses listed above, attribution assessments can be completed through implementation of complex tools available within select regional scale photochemical models. For example, the CAMx model includes PM source apportionment technology (PSAT) algorithms which estimate the contributions to visibility impairment at Class I areas by source region (e.g. states) and source category (e.g. point, area, mobile, and biogenic). The implementation of PSAT techniques provides a quantitative measure of the visibility impairment attributable to a given source region or source category. Proper interpretation of PSAT results can assist by providing additional insight into model performance, and can also be used to design efficient control strategies. In development of the regional haze SIP, conclusions drawn from PSAT results are targeted primarily at review of a state's contribution to visibility impairment to a given Class I area.

A summary of the modeling methods, results, and analyses are provided below. Greater detail is contained in Appendix 7.1.

8.1 Model Inputs

8.1.1. Selection of Episodes

Following EPA's draft (2001) and final (2007) Modeling Guidance criteria, a full year was chosen as the modeling episode to ensure adequate inclusion of the various meteorological conditions which produce the best and worst 20% days of visibility impairment at Class I areas. The application of specific episode selection criteria revealed calendar year 2002 to be the ideal temporal distribution. The CENRAP Emissions and Air Quality Modeling Technical Support Document (CENRAP TSD) provides the methodologies for this process and is found at Appendix 7.1 (see Section 1.3.6).

8.1.2. Selection of Modeling Domain

Meteorological and photochemical modeling was conducted on the specifications of the RPO domains. The national RPO domain was initially developed to support a common horizontal and vertical metrological modeling structure to aid in the simple exchange and utilization of inter-organizational datasets. The basis of the horizontal domain is a Continental United States (CONUS) centric Lambert Conformal Projection centered at 90° W longitude, 40° N latitude, with true latitudes of 33° and 45° N latitude. Additional detail regarding the meteorological modeling domain can be found in Appendix 8.1. The photochemical modeling domain is discussed in Appendix 7.1.

8.1.3. Emissions Inventories

Generating a suitable emissions inventory requires the quantification of all appropriate anthropogenic and biogenic emissions processes within the modeled domain. Each emissions source and the type of pollutants it emits must be specifically identified or suitably represented. General source category classifications include point, area, mobile (on-road and off-road), and biogenics.

The emissions inventory includes VOC, NOx, CO, SO2, PM10, PM2.5, and NH3 emissions from all anthropogenic and biogenic sources. The emissions inventory information submitted by state, tribal, and local agencies to the 2002 NEI formed the basis of the 2002 CENRAP emissions inventory. The NEI data was supplemented with non-point source emissions inventories developed for CENRAP by Sonoma Technology. These CENRAP specific inventories addressed agricultural and prescribed burning, on-road and off-road mobile sources, agricultural tilling and livestock dust, and agricultural ammonia. In addition, Pechan assisted CENRAP by quality-assuring the emissions inventory and preparing day and hour specific emissions for EGUs based on Continuous Emissions Monitor (CEM) data for the model performance evaluation. To increase Iowa's level of consistency between the MRPO and CENRAP emissions inventories, Iowa area NH3 emissions (focusing upon agricultural sources) were based upon the MRPO data. Further refinement of the Iowa emissions inventory occurred through inclusion of the MRPO BaseK non-road agricultural emissions inventory. The MRPO contracted with Pechan to update and refine aspects of EPA's NONRAOD model, targeting agricultural and construction engine emissions. Details are provided in Appendix 8.2.

Emissions inputs for the air quality model were prepared using the Sparse Matrix Operator Kernel (SMOKE) emissions modeling system. The CENRAP modeling emissions inventory consists of several distinct datasets: the 2002 basecase for model performance evaluation, 2002 typical, 2018 basecase, and the 2018 control strategy scenario. Its spatial extent is the RPO 36 km modeling domain, which covers the continental U.S. plus portions of Canada and Mexico. The inventory was refined through several rounds of CENRAP workgroup review and revision, beginning with the initial BaseA version and culminating in the BaseG inventory. Emissions inventory summary information can be found in Chapter 7. Appendix 7.1 (see Chapter 2) provides the details regarding emissions inventory development.

8.1.4. Meteorology

The Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) is the latest in a series that developed from a mesoscale model used by Anthes at Penn State in the early 70's that was later documented by Anthes and Warner (1978). Since that time, it has undergone many changes designed to broaden its usage. These changes include: multiple-nest capability; nonhydrostatic dynamics, which allows the model to be used at a few-kilometer scale; multitasking capability on shared- and distributed-memory machines; a four-dimensional data-assimilation capability; and expanded physics parameterizations. The model is supported by several auxiliary programs, which are referred to collectively as the MM5 modeling system. Since MM5 is a regional model, it requires initial conditions as well as a lateral boundary conditions. To produce lateral boundary conditions for

> a model run, gridded data to cover the entire time period that the model is integrated is needed. Meteorological model configuration and performance details are provided in Appendix 8.1, with additional review contained in Appendix 7.1

8.2 Air Quality Model Performance Evaluation

The CMAQ and CAMx models were spatially and statistically evaluated against ambient measurements of PM species, gas-phase species, and wet deposition in order to qualitatively and quantitatively assess model performance. Monitoring networks available within CENRAP represented in the model evaluation include:

- IMPROVE
- Clean Air Status and Trends Network (CASTNet)
- Speciated Trends Network (STN)
- Aerometric Information Retrieval Systems (AIRS)
- National Atmospheric Deposition Program (NADP)

Emissions modeling, photochemical modeling, and model performance evaluation methods were conducted through an iterative process as errors were identified and subsequently corrected in upstream basecase simulations. Seven major baseline emissions/modeling scenarios were completed, basecases A through G. The final basecase (G) is considered to be more accurate than the preceding versions. Appendix 7.1 (see Chapter 3) contains a detailed model performance evaluation, the summary is provided below.

> "In general, the model performance of the CMAQ and CAMx models for sulfate (SO4) and elemental carbon (EC) was good. Model performance for nitrate (NO3) was variable, with a summer underestimation and winter overestimation bias. Performance for organic mass carbon (OMC) was also variable, with the inclusion of the SOAmods enhancement in CMAQ Version 4.5 greatly improving the CMAQ summer OMC model performance. Model performance for soil and coarse mass (CM) was generally poor. Part of the poor performance for soil and CM is believed to be due to measurement-model incommensurability. The IMPROVE measured values are due, in part, to local fugitive dust sources that are not captured in the model's emissions inputs and the 36 km grid resolution is not conducive to modeling localized events."

8.3 BaseG Model Simulations

The 2018 BaseG modeling run reflects emissions growth and mandated air pollution controls, which are state and federal controls that will be implemented between the 2002 base year and the 2018 future year. The 2018 emissions for EGUs were based on simulations of the IPM that took into account the affects of the CAIR trading program. In addition, reductions anticipated from BART controls for EGUs in Oklahoma, Arkansas, Kansas, and Nebraska were included. Emissions for on-road and off-road mobile sources were based on activity growth and emissions factors from the EPA MOBILE6 and NONROAD models, respectively, which reflected emissions reductions from the Tier 2 and Tier 4 mobile source rules. Area sources and non-EGU point sources were also grown to 2018 levels.

Future year conditions at Class I areas on the 20% worst and 20% best days were calculated by using results from the 2002 and 2018 CMAQ and CAMx simulations in a relative sense. Relative response factors were calculated to scale the observed PM concentrations from the 2000-2004 baseline conditions (derived from the IMPROVE monitoring network) to obtain the 2018 PM projections. These methods were used in accordance with EPA guidance procedures. Details are provided in Appendix 7.1 (see Chapter 4).

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8.1 Meteorological Model Performance Evaluation of an Annual 2002 MM5 (version 3.6.3) Simulation. Prepared by Matthew Johnson, Iowa Department of Natural Resources, 2007.

8.2 LADCO Nonroad Emissions Inventory Project - Development of Local Data for Construction and Agricultural Equipment, Final Report. E. H. Pechan, September 10, 2004.

9. Best Available Retrofit Technology

The U.S. EPA's 1999 Regional Haze Rule singles out for additional controls certain older emissions sources that have not been regulated under other provisions of the Clean Air Act. On July 6, 2005, U.S. EPA published a revised final rule "Guidelines for BART Determinations under the Regional Haze Rule" which provides direction for determining which older sources may need to install BART and for determining BART.

The IDNR has decided not to implement an emissions trading program, or other alternative measure, in place of BART. However, as indicated in Section 9.2, BART-eligible sources that are also subject to the CAIR meet their SO2 and NOx BART requirements by participating in the CAIR cap and trade program. The State of Iowa is participating in CAIR, which was adopted in the SIP on August 6th, 2007 (72 FR 43539-43544).

9.1 BART – Eligible Sources in State of Iowa

The facilities with BART-eligible units are shown in Table 9.1. The BART-eligible sources were identified using the methodology in the "Guidelines for BART Determinations under the Regional Haze Rules" or *Guidelines*. To identify BART-eligible emission units, the IDNR used the following *Guidelines* criteria:

- One, or more, emission(s) units at the facility fit within one of the twenty-six (26) categories listed in the *Guidelines*;
- The emission unit(s) were in existence on August 7, 1977 and began operation at some point on, or after, August 7, 1962; and
- The sum of the potential emissions from all emission unit(s) identified using the previous two criteria were greater than 250 tons per year of a visibility-impairing pollutant: SO2, NOx, VOC, NH3, or PM.

The *Guidelines* place greater emphasis on the visibility-impairing pollutants: SO_2, NO_x, and particulate matter (PM). The IDNR investigated these three pollutants and also addressed emissions of VOC and NH3 as part of the BART determination process. Appendix 9.1 contains detailed information on the methods and procedures used to identify BART-eligible sources.

Table 9.1 Facilities with BART-eligible units in the State of Iowa.

Source Category Name	Company Name	Facility Number	BART Emission Units
Fossil Fuel-fired Steam Electric Plant Individually Greater than 250 MMBtu/hour (Electrical Generating Units or EGUs). **Please note that these units are subject to the Clean Air Interstate Rule.**	Cedar Falls Utilities	07-02-005	Unit #7 (EU10.1A)
	Central Iowa Power Cooperative (CIPCO) – Summit Lake Station	88-01-004	Combustion Turbines (EU 1, EU 1G, EU2, EU2G)
	Central Iowa Power Cooperative (CIPCO) – Fair Station	70-08-003	Unit # 2 (EU 2 & EU 2G)
	City of Ames - Steam Electric Plant	85-01-006	Boiler #7 (EU 2)
	Interstate Power and Light - Burlington	29-01-013	Main Plant Boiler.
	Interstate Power and Light - Lansing	03-03-001	Boiler #4. Sixteen units in total.
	Interstate Power and Light - ML Kapp	23-01-014	Boiler #2. Six units in total.
	Interstate Power and Light - Prairie Creek	57-01-042	Boiler #4. Fourteen units in total.
	MidAmerican Energy Company - Council Bluffs	78-01-026	Boiler #3 (EU003)
	MidAmerican Energy Company - Neal North	97-04-010	Boilers #1-3 (EU001 - EU003)
	MidAmerican Energy Company - Neal South	97-04-011	Boiler #4 (EU003)
	Muscatine Power and Water	70-01-011	Boiler #8
	Pella Municipal Power Plant	63-02-005	Boilers #6-8
Chemical Process Plant	Equistar Chemicals	23-01-004	301 emission units
	Koch Nitrogen Company	94-01-005	Ammonia vapor flares and primary reformer/auxiliary boiler. Eight units in total.
	Monsanto Company Muscatine	70-01-008	Boilers #5-7. Fifty-seven emission units in total.
	Terra Nitrogen Port Neal Comp	97-01-030	Boiler B & Auxiliary Boiler
Petroleum Storage and Transfer Units with a Total Storage Capacity Exceeding 300,000 Barrels	BP - Bettendorf Terminal	82-02-024	Truck loading.
	BP - Des Moines Terminal	77-01-158	Truck loading.
Portland Cement Plant	Holcim (US) Inc.	17-01-009	109 emission units
Fossil Fuel-fired Boiler	ADM	23-01-006	No. 7 & 8 Boilers. These boilers will be permanently shut down by 09/13/2008.
Iron and Steel Mills	Bloomfield Foundry, Inc.	26-01-001	18 emission units
	Griffin Pipe Products Co.	78-01-012	10 emission units
	John Deere Foundry Waterloo	07-01-010	37 emission units
	Keokuk Steel Castings, A Matrix Metals Company LLC	56-01-025	67 emission units
	The Dexter Company	51-01-005	Tumblers 5 & 6.
Secondary Metal Production	Alcoa, Inc.	82-01-002	Hot line mill. Eighty-seven emission units in total.

9.2 Determination of Sources Subject to BART

Under the *Guidelines*, the State has the following options regarding its BART-eligible sources: a) make BART determinations for all sources, or b) consider exempting some sources from BART because they do not cause or contribute to visibility impairment in a Class I area.

The IDNR has chosen option b. If a State/Tribe chooses option b, the *Guidelines* suggest the following three modeling options for determining which sources may be exempt:

(1) Individual source attribution approach
(2) Use of model plants to exempt sources with common characteristics
(3) Cumulative modeling to show that no sources in a state are subject to BART

The IDNR has chosen sub-option #2 and #3 above to determine which sources are subject to BART. The *Guidelines* established CALPUFF as the preferred air quality model for the BART analysis. IDNR found that CALPUFF inadequately characterizes visibility impacts at the nearby Class I areas due to the extensive transport distances involved. IDNR conducted an approved alternative approach that included Q/d screening methods, emissions inventory scale analyses, CALPUFF model plant analyses, and regional scale one-atmosphere photochemical modeling.

In accordance with the *Guidelines*, a contribution threshold of 0.5 deciview was used for determining which sources were subject to BART. The *Guidelines* provide States the discretion to set a lower deciview threshold than 0.5 deciviews if "the location of a large number of BART-eligible sources within the State and in proximity to a Class I area justifies this approach." IDNR has determined the 0.5 deciview threshold to be adequate and did not propose alternatives.

IDNR determined that none of the BART-eligible units are subject to BART. Appendix 9.1 contains a detailed discussion of the methods and results which led to this conclusion.

For EGUs, U.S. EPA has found that, as a whole, the CAIR cap and trade program improves visibility more than implementing BART in states affected by CAIR. A State that opts to participate in the CAIR program under 40 CFR 96 AAA-EEE need not require affected BART-eligible EGUs to install, operate, and maintain BART. IDNR accepted EPA's overall finding that CAIR "substitutes" for BART for EGUs so a BART determination only needed to be completed for PM emissions. The EGU PM emissions were evaluated and the details of the evaluation are in Appendix 9.1.

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9.1 Best Available Retrofit Technology Technical Support Documentation.

10. Reasonable Progress Goals

The federal Regional Haze Rule requires States and Tribes to establish a Reasonable Progress Goal (RPG) for each Class I area within the state (40 CFR § 51.308(d)(1)). The RPG is measured in deciviews and is to provide for reasonable progress towards achieving natural visibility conditions.

10.1 Reasonable Progress Goals

As indicated earlier, Iowa does not have a Class I area within the state and therefore is not required to establish a RPG. Other states that are required to establish RPGs have made assessments regarding whether emissions sources in Iowa should make emissions reductions to avoid impacting Class I areas within their borders. The consultation process is discussed in Chapters 3, 4, 5, and 11 and in Appendix 10.1.

In addition, EPA released guidance on June 1, 2007 (*Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program*), to use in setting RPGs. Over the first 10 year SIP period, the goals must provide improvement in visibility for the most impaired days, and ensure no degradation in visibility for the least impaired days. A state with a Class I area must also provide an assessment of the number of years it would take to attain natural visibility conditions if improvement continues at the rate represented by the RPG.

The EPA guidance referenced above describes RPGs as follows:

> States must establish RPGs, measured in deciviews (dv), for each Class I area for the purpose of improving visibility on the haziest days and ensuring no degradation in visibility on the clearest days over the period of each implementation plan. RPGs are interim goals that represent incremental visibility improvement over time toward the goal of natural background conditions and are developed in consultation with other affected States and Federal Land Managers (FLM). In determining what would constitute reasonable progress, section 169A(g) of the CAA requires States to consider…four factors.

The statutory factors that the state must consider are identified in 40 CFR § 51.308(d)(i)(A) as:

1. The costs of compliance,
2. The time necessary for compliance,
3. The energy and non-air quality environmental impacts of compliance, and
4. The remaining useful life of existing sources that contribute to visibility impairment

In setting a RPG, the above factors are examined within the context of the uniform rate of visibility improvement needed to attain natural conditions by 2064. The state must demonstrate how these factors were taken into consideration in selecting the goal for its mandatory Class I Federal areas.

10.1.1 Four Factor Report

The MRPO and the Minnesota Pollution Control Agency commissioned a report to look at the four factor analysis required by the Regional Haze rule. The report, "Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis," (referred to as the "Four Factor Report") looked at the factors in a three-state area (Minnesota, Wisconsin, and Michigan) and a nine-state area (Minnesota, Wisconsin, Michigan, Indiana, Illinois, Missouri, Iowa, North Dakota, and South Dakota.). The Four Factor Report primarily looked at controls on EGUs; industrial, commercial, and institutional (ICI) boilers; reciprocating engines and turbines; agricultural sources; and mobile sources. Tables summarizing the nine-state impacts are listed in Appendix 10.2.

10.1.2 Cost of Compliance

The Four Factor Report looked at the cost effectiveness of reducing SO2 and NOx emissions using two possible control strategies categorized as EGU1 and EGU2. The EGU1 scenario would cap EGU NOx emissions at 0.10 lb/MMBtu of fossil fuel consumption and SO2 would be limited to 0.15 lb/MMBtu of fossil fuel consumption at EGUs. The EGU2 caps are more stringent at 0.07 lb/MMBtu and 0.10 lb/MMBtu of fossil fuel consumption for NOx and SO2, respectively. The caps are not enforced at the unit level but represent a proposed region wide average emission rate to be met through a trading program.

The cost of EGU controls, in terms of dollars per ton, provides a limited view of overall effectiveness. A more rigorous review requires the consideration of control costs commensurate with their potential for visibility improvement. Such a measure is achieved by coupling the anticipated visibility impacts of control projects with their associated costs to arrive at a dollar per deciview metric.

While not available for all individual states, the report does quantify dollar per deciview costs across the nine-state region. Examining the EGU1 and EGU2 scenarios, the cost effectiveness for SO2 ranges from $2,994,000,000/dv to $3,336,000,000/dv and NOx ranges from $2,332,000,000/dv to $4,045,000,000/dv for the nine-state region. Expanding this analysis beyond EGU controls, the cost effectiveness of ICI boiler controls is nearly as expensive, ranging from $2,825,000,000/dv to $3,397,000,000/dv for SO2 and from $2,034,000,000/dv to $2,473,000,000/dv for NOx.

By decoupling anticipated visibility impacts, the dollar per ton value discounts the relative effectiveness of potential visibility improvement. The estimated average costs to Iowa EGUs associated with EGU1 (applied in the nine-state region) reach $1,893/ton for SO2 control and $2,359/ton for NOx. As emission rates are further restricted under EGU2, the costs increase to $2,074/ton and $3,580/ton for SO2 and NOx controls, respectively. A combination of these two controls produces an average of 1.1 deciview improvement. IDNR does not find this solution to be cost effective for visibility improvement.

The costs provided represent a best estimate based upon supporting information and their accuracy can not be appropriately judged without review of underlying assumptions. As caveated in the report:

> "These results do not take into account fuel switching or other secondary impacts, or potential constraints that may exist for installing various control technologies at specific facilities. Thus, they reflect only an estimate of the costs which would be incurred to attain the EGU1 or EGU2 emission reduction targets."

The costs provided in the report are based upon the IPM v2.1.9 run developed in 2005. Since that time additional EGU control equipment has been permitted in Iowa. These reductions were not forecast by IPM v2.1.9, and as a result costs predicted by IPM v2.1.9 may be underestimated.

In calculating the costs of potential EGU controls IPM incorporates a least cost regression analysis that includes the basic cap and trade restriction associated with CAIR. While the IPM solution is derived from the financial principles of supply and demand economics, model accuracy is restricted by the inherent variability of factors such as the projected needs in the generation, transmission, and consumption of electricity. When predicting the impact CAIR will have upon future EGU conditions, a given IPM solution reflects only one possible scenario. This scenario, including the extent of trading versus controls and associated costs, is unlikely to accurately predict all facility responses.

The IDNR believes it is reasonable to implement CAIR as EPA intended during the first regional haze planning period considering the high costs associated with the additional EGU controls, the extensive distances to Class I areas, and Iowa's relatively small contributions to visibility impairment.[1] The impact of CAIR can not be fairly addressed until sufficient time has been allowed for program implementation and facility responses. IDNR has adopted EPA's CAIR cap and trade program and will participate fully in the SO2, annual NOx, and ozone season NOx trading programs. IDNR's intent is to allow the market forces of the CAIR cap and trade program to drive the installation and operation of cost efficient controls.

IDNR has concluded that additional review of Iowa's ICI boilers is unwarranted. Costs across the nine-state region, in terms of dollars per deciview, exceed two billion dollars. While state specific dollar per deciview figures are not available, Iowa's projected 2018 ICI SO2 and NOx emissions represent 8.2% and 6.4%, respectively, of the total emissions within the nine-state region. The combination of a low percentage of contributing emissions compounded by the necessary transport distances suggests the above ICI cost estimates would be conservative if calculated for Iowa sources alone. Such costs, in combination with a low potential for discernable visibility improvement, are unreasonable for Iowa sources to incur. Similar arguments apply to other point sources, such as reciprocating engines and combustion turbines.

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[1] Contribution assessments are discussed in Chapter 11.

The ICI Boiler NESHAP has recently been vacated. The new federal standards that will be put in place may have additional measures and reductions that the IDNR will incorporate. The revised NESHAP may expand the standard to include more sources. The likely co-benefits of the revised standard will also assist States with their regional haze goals.

Additional cost analyses are available beyond the MRPO/Minnesota Four Factor Report. Alpine Geophysics developed a spreadsheet for CENRAP to look at possible control options and the associated costs. The complete analysis for Iowa sources is in Appendix 10.2. The costs are listed in 2005 dollars. The estimated costs of controls, in combination with a conservative emissions divided by distance screening method, were used to develop and model an emissions reduction scenario as documented in Appendix 7.1 (see Section 4.5). Of the twelve Iowa facilities identified within the screening criteria, all but one were electrical generating units participating in CAIR. Based upon the Alpine Geophysics control costs, implementation in Iowa of the control measures would exceed $300,000,000 annually. Additionally, Iowa industries have commented that the costs were not accurate. Many stated that the actual cost to control emissions should be nearly doubled. Factors that lead to the difference in cost estimates were the rising costs of concrete, steel, and skilled labor.

Considering the costs and associated caveats, in combination with Iowa's estimated contribution to visibility impairment, these control measures are unreasonable for Iowa sources to incur at this stage of the Regional Haze Rule.

10.1.3 Time necessary for compliance

IDNR determined that additional emission controls are not required based on the cost of compliance. Therefore a timeline or estimated time for compliance is not necessary.

10.1.4 Energy and non-air quality environmental impacts of compliance

The Four Factor Report also demonstrates the energy and non-air quality environmental impacts of controlling emissions. In the nine-state region, carbon dioxide emissions are projected to increase from 3,766,000 tons/year to 5,302,000 tons/year due to the EGU1 and EGU2 controls, respectively.

An additional 1,128,000 – 1,919,000 gallons of wastewater per year is projected to be produced by 2018 in the nine-state region under the EGU1 and EGU2 controls, respectively. The Four Factor Report states that the additional gallons would be treated in existing facilities. Many of Iowa's water treatment facilities are aging and at capacity. The cost of treating the additional wastewater and the likelihood of new facilities increases the costs of compliance.

The nine-state region would incur a projected increase in solid waste production by 2018 of 347,000 – 538,000 tons as part of the EGU1 and EGU2 controls, respectively. That is 20% of the total municipal waste landfill in the State of Iowa in 2006. Iowa's solid waste disposal is organized into 45 planning areas. All waste generated in a planning area must be disposed of in that area. Depending on the remaining capacity of the planning area and other factors, additional landfills may be needed. The process of siting a new landfill can take decades.

10.1.5 Remaining useful life

IDNR determined that additional emission controls are not required based on the cost of compliance. Therefore it is not necessary to determine the remaining useful life of a unit.

10.1.6 Visibility Improvement

Iowa is the state furthest away from Class I areas in the country. All Iowa facilities are separated by at least 300 km from their nearest Class I area. Many of the tools available for visibility analyses are not accurate or appropriate at such distances. CALPUFF, EPA's preferred model for individual source visibility impact assessments, is recommended to be used at 250 km or less. Currently, the best methods for approximating Iowa's impacts upon nearby Class I areas requires implementation of sophisticated apportionment algorithms contained within a select few regional one-atmosphere photochemical models. CENRAP utilized such techniques through implementation of the PSAT tools contained within CAMx.

CENRAP PSAT modeling for 2002 estimated that Iowa contributed 2.4, 2.2, 3.2, and 4.5 Mm^{-1} of the total modeled visibility impairment to the Boundary Waters Canoe Area, Voyagers National Park, Isle Royale National Park, and Seney Wilderness Area, respectively. In 2018, CENRAP's modeling of on-going mandated air pollution control programs decreases Iowa's contributions slightly, to 2.1, 2.0, 3.0, and 4.0 Mm^{-1}, respectively. These values represent a percentage contribution of approximately 4-5%. Controls installed on Iowa sources may not yield any significant improvement at the Class I areas.

10.2 Consultation

Iowa does not contain any Class I areas, however, IDNR has participated in the consultation process for nearby Class I areas in Minnesota and Michigan. IDNR has also communicated with South Dakota, Wyoming, Missouri, Arkansas, and Oklahoma regarding consultation. Minnesota is in the process of establishing RPGs. IDNR has communicated with Minnesota regarding controls of Iowa sources requested in the Northern Midwest Class I Areas Consultation Conclusion. In correspondence directed to several states, Minnesota requested that further reductions of SO2 emissions from EGUs be evaluated. Additional requests made by Minnesota can be found in Appendix 10.1 in a copy of the original document. Minnesota's' requests were received September 24th, 2007.

In its correspondence with the Department, Minnesota did not request that controls be installed on specific sources. There was no justification on how such controls would lead to visibility improvement at the Minnesota Class I areas. Minnesota has not provided documentation or otherwise consulted with the Department regarding any specific visibility improvement at the Minnesota Class I areas which would result from controlling Iowa sources. Based on the Department's analyses and details provided below in Chapter 11, additional controls and further discussion with Minnesota remains unsupported at this first stage of the regional haze rule. The Department will continue to consult with Minnesota in the future on issues involving regional haze as requested and warranted.

Additional information regarding Iowa's involvement in regional haze consultation processes is provided in Appendix 10.1

10.3 Reporting

Progress will be reported to the EPA every five years in accordance with 40 CFR § 51.308 (g).

<u>List of Chapter 10 Appendices</u>

10.1 Description of Interagency Consultation Process in Establishing Reasonable Progress Goals.
10.2 Four Factor Report summaries and CENRAP control costs.

11. Long-term Strategy to Reach Reasonable Progress Goals

The IDNR is required to submit a long-term strategy (40 CFR § 51.308(d)(3)) that addresses regional haze visibility impairment for each mandatory Class I Federal area outside the State which may be affected by emissions from within the State. The long-term strategy must include enforceable emissions limitations, compliance schedules and other measures necessary to achieve the reasonable progress goals (RPGs) established by States and Tribes where the Class I areas are located.

When coordinated with other State and Tribe strategies, IDNR's long-term strategy is sufficient to meet anticipated RPGs for states containing Class I areas which may be affected by emissions from Iowa sources. Since Iowa does not have a Class I area, the IDNR is not required to establish a RPG. The absence of a Class I area does not exempt IDNR from developing a long-term strategy. A long-term strategy is required to address those emissions which may contribute to visibility impairment at a Class I area.

Emissions from Iowa sources may contribute to visibility impairment at the following Class I areas: Boundary Waters Canoe Area Wilderness (MN), Voyageurs National Park (MN), Seney Wilderness Area (MI), and Isle Royale National Park (MI). Collectively, these Class I areas are commonly referred to as the Northern Midwest Class I areas. The remainder of this chapter discusses IDNR's long-term strategy in detail and describes how the IDNR meets the long-term strategy requirements associated with the Northern Midwest Class I areas.

11.1 Consultation

IDNR is required to consult with other States and Tribes to develop coordinated emission strategies (40 CFR § 51.308(d)(3)(i)). This requirement applies where emissions from the State are reasonably anticipated to contribute to visibility impairment in Class I areas outside the State.

IDNR consulted with other States and Tribes by participation in the CENRAP and MRPO processes that developed technical information necessary for development of coordinated strategies. In addition, IDNR participated in discussions focused on Class I areas in the Northern Midwest which involved the following states and tribes: Minnesota, Michigan, Wisconsin, North Dakota, Illinois, Missouri, Bois Forte Reservation, Fond du Lac Reservation, Forest County Potawatomi, Grand Portage Band of Chippewa, Leech Lake Band of Ojibwe, Mille Lacs Band of Ojibwe, and Upper/Lower Sioux Communities. Federal land managers were active participants in this sub-regional consultation process as well. IDNR also coordinated with CENRAP and other RPOs to develop supporting documentation (Appendix 7.1) that was used to develop the State's long-term strategy. Long-term strategy development considered the impacts of Iowa's emissions on Class I areas outside the State.

Consultation with the FLMs is a separate requirement beyond the scope of 40 CFR § 51.308(d)(3)(i)). IDNR's long-term strategy development was reviewed by the FLMs as described in Chapter 4.

11.2 Contributions to Visibility Impairment

Where emissions in Iowa contribute to visibility impairment at a mandatory Class I Federal area, IDNR must demonstrate that its implementation plan includes all measures necessary to obtain its share of emission reductions needed to meet the RPG for the area (40 CFR § 51.308(d)(3)(ii)). IDNR fulfills this requirement through compliance with existing mandatory air pollution control programs. Participation in the Clean Air Interstate Rule (CAIR) cap and trade program is a critical component in this determination. Through CAIR, Iowa electrical generating units (EGUs) are anticipated to reduce not only ozone season NOx emissions, but annual emissions of SO2 and NOx. The IDNR has relied upon modeling results, source apportionment techniques, data analysis, and weight of evidence measures to assert these conclusions. A discussion of the supporting procedures and results follows.

Iowa's Cumulative Visibility Impacts

Particulate matter source apportionment technology (PSAT) modeling techniques were used by CENRAP to investigate which states contribute to visibility impairment at a Class I area. Source apportionment results are an effective tool for assessing state contributions as they assist in quantifying the amount of visibility impairment attributable to a particular state.

According to the CENRAP PSAT results, the combined effect of all Iowa emissions upon the total modeled[1] visibility impairment at the four Northern Midwest Class I is approximately 4-5% in both 2002 and 2018. These results[2] are shown in Table 11.1. The data were calculated in accordance with the new IMPROVE equation and are representative of those days which yielded the worst 20% visibility conditions. A detailed description of the source apportionment methods utilized by CENRAP is available in Appendix 7.1 (see Section 5.4).

Table 11.1. Iowa's, Minnesota's, and Michigan's percent (%) contribution to visibility impairment, as modeled by CENRAP.

Site	**Iowa**			**Minnesota**			**Michigan**	
	2002	**2018**		**2002**	**2018**		**2002**	**2018**
BOWA	3.7 3.9			25.6	28.5		2.3 2.7	
VOYA	3.8 4.0			29.1	30.4		1.4 1.6	
ISLE	4.5	4.9		11.5 12.5			11.1 12.8	
SENE	4.2	4.8 3.9			4.4		9.6	12.7

The PSAT results provided above are in terms of percentages of total visibility impairment and are useful for determining the proportion of a States' contribution in relation to the total modeled visibility impairment at a Class I area. Characterizing visibility impairment using percentages fails to identify the magnitude of the contribution. For example, Iowa's contributions, on a percentage basis, increase between 2002 and 2018. However, the actual light extinction values

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[1] Total modeled visibility impairment does not include Rayleigh scattering. The inclusion of Rayleigh scattering is only necessary when calculating deciview values. Deciview calculations require a Class I area's total visibility impairment (i.e. modeled visibility impairment plus Rayleigh scattering).

[2] Percentages were obtained from the August 27, 2007, version of Environ's source apportionment tool.

decrease. Similar results occur for many other States. Table 11.1 demonstrates that both Minnesota and Michigan see an increase in their contributions to visibility impairment, in terms of percentage contribution, between 2002 and 2018. The data in Table 11.1 yields an additional perspective in terms of a contribution analysis. Minnesota sources are responsible for approximately 7 times as much apportioned visibility impairment as are Iowa sources at BOWA and VOYA.

Iowa's contributions to visibility impairment, as calculated through light extinction constructed using the new IMPROVE equation, are provided in Table 11.2. The total modeled visibility impairment for each Class I area are also shown in Table 11.2.

Table 11.2. Iowa's absolute contribution to visibility impairment, as modeled by CENRAP.

Site	**Worst 20% Days Modeled Extinction (Mm-1)**			
	Iowa		**Class I Area Total**	
	2002	**2018**	**2002**	**2018**
BOWA	2.39	2.08	64.87	53.44
VOYA	2.16	1.97	56.45	48.84
ISLE	3.23	3.02	71.40	61.26
SENE	4.54	3.95	107.92	82.00

Iowa emissions sources cumulatively contribute only 2.2 - 4.5 Mm^{-1} of the 56 - 107 Mm^{-1} total modeled visibility impairment at the Northern Midwest Class I areas in 2002. In tandem, Iowa's percentage and absolute contributions describe the impacts emissions sources in Iowa have upon nearby Class I areas. Collectively, Iowa sources are responsible for a minimal contribution to visibility impairment at the Northern Midwest Class I area, and offer little in terms of potential visibility improvement.

An alternative means of assessing Iowa's contribution to visibility impairment can be conducted through implementation of the deciview metric. A deciview is defined in 40 CFR §51.301 as "a haze index derived from calculated light extinction, such that uniform changes in haziness correspond to uniform incremental changes in perception across the entire range of conditions, from pristine to highly impaired." A change in visibility impairment of one deciview is theoretically the minimum level detectible by a human observer. Calculations with the deciview metric reveal that the elimination of all Iowa emissions sources may not yield a perceptible improvement in visibility.

The 2018 Class I area total modeled extinction values provided in Table 11.2 are easily converted into a deciview value (as the total modeled extinction values do not include Rayleigh scattering affects, a value of 10 Mm^{-1} has been assumed for illustrative purposes). For each Class I area the level of visibility impairment which may result in the absence of all Iowa emissions sources is provided in Table 11.3. This calculation is completed by subtracting the visibility extinction attributable to Iowa sources from the Class I area total, and converting the result into a deciview value. The difference between the two deciview values provides a representation of Iowa's impacts in terms of perceptible visibility improvement.

Table 11.3. The estimated 2018 level of visibility impairment in the absence of all Iowa emissions sources.

Site	2018 Worst 20% (dv)	2018 Worst 20% Less Iowa's Contribution (dv)	Iowa's Visibility Impacts (dv)
BOWA	18.5 18.1		0.4
VOYA	17.7 17.4		0.3
ISLE	19.6 19.2		0.4
SENE	22.2 21.8		0.4

Visibility improvements resulting from the elimination of all Iowa sources yields impacts below one deciview. Based on this analysis Iowa's modeled 2018 contributions are imperceptible by a human observer. However, the elimination of all Iowa sources would alter the atmospheric chemistry from which the deciview metrics in Table 11.3 are derived. This caveat places a limit on the numerical accuracy of the results. The uncertainty does not alter the conclusion that the estimated 2018 emissions originating within Iowa have a minimal impact upon visibility impairment in the Northern Midwest Class I areas.

Comparing Impacts from Midwestern States

The above results focus solely upon contributions attributable to Iowa sources. A more complete review of visibility impairment requires comparing Iowa's contributions in relation to nearby states, including the states containing a Class I area. Evaluating Iowa's impacts in this relative sense further clarifies Iowa's minimal level of contribution.

The PSAT results allow a given state's total contribution to be partitioned among specific species. The PSAT results support previous conclusions identifying SO2 and NOx emissions as critical components to regional haze (e.g. see Appendix 6.1, the Causes of Haze (Phase II) report).

The charts provided below (Figures 11.1 - 11.4) are based upon the CENRAP 2018 source apportionment modeling. The data are ordered according to rank, with contributions decreasing by region[1] from left to right. Contributions are provided in terms of light extinction values (based on the new IMPROVE equation, see Chapter 5 for additional information on extinction metrics). While 2002 basecase results are available, only the 2018 results take into account changes in future year emissions effected by mandated air pollution control programs.

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[1] The term region is used, instead of state, as the PSAT methods tracked not only state contributions, but also tracked additional areas, such as Canadian and Mexican contributions. To reduce computational resources, distant western and eastern states' contributions were not tracked individually, but were grouped into East and West regions. See Appendix 7.1 (Section 5.4) for additional detail.

Iowa's 2.08 Mm^{-1} contribution to the 2018 total modeled visibility impairment at BOWA ranked 7th overall when considering all regions. Examining state contributions only, Iowa contributions ranked 5th (with the Canadian and boundary regions having greater contributions). As expected, Minnesota sources lead state contributions, with Wisconsin, North Dakota, and Illinois having greater contributions than Iowa. These results are depicted in Figure 11.1. The importance of sulfur and nitrogen compounds as a leading cause of regional haze is also shown in this figure, as most state contributions are apportioned among sulfates (shown in yellow) or nitrates (shown in red).

Looking at state contributions only (ignoring Canadian, Western states', and boundary condition contributions) Iowa ranks 4th at Voyageurs National Park. Again, Minnesota dominates the contribution assessment, with North Dakota and Wisconsin sources also contributing more to visibility impairment than Iowa sources. These results are depicted in Figure 11.2.

Emissions sources within Michigan are the leading cause of visibility impairment at ISLE and SENE, as shown in Figures 11.3 and 11.4. Emissions within nearby states are responsible for a greater degree of visibility impairment than emissions sources within Iowa. At ISLE, Iowa ranks 5th among state contributions to visibility impairment in 2018, with a modeled contribution of 3.02 Mm^{-1}. Emissions within Michigan, Wisconsin, Minnesota, and Illinois yield greater impacts than Iowa sources. Within SENE, Iowa contributions are 3.95 Mm^{-1}, which ranks 6th among States, below the contributions attributable to Michigan, Illinois, Wisconsin, Indiana, and Missouri.

In summary, Iowa's cumulative emissions have a much smaller impact upon the Northern Midwest Class I areas than many other states. Where emissions from Iowa sources do have quantifiable impacts, SO2 and NOx emissions are primarily responsible.

EGU Impacts

Based upon emissions inventory analyses and PSAT results from the MRPO, Iowa EGU SO2 emissions are primarily responsible for the visibility impairment attributable to SO2 emissions from Iowa (see Appendix 11.1). Iowa EGU's also contribute approximately one fourth of Iowa's total NOx emissions. Generating a skillful 2018 inventory of EGU SO2 and NOx emissions is important.

The Integrated Planning Model (IPM) is a tool used to estimate the 2018 EGU emissions of SO2 and NOx. IPM provides a prediction of EGU controls in response to CAIR. An accurate IPM forecast is necessary to develop reliable predictions of visibility impairment. However, the CENRAP modeling used an outdated version of IPM which over predicted the emissions of SO2 from Iowa EGUs. This likely led to an over prediction of Iowa's 2018 contributions to visibility impairment at the Northern Midwest Class I areas. A more recent IPM version was available, but was not used by CENRAP. The EGU emissions reductions forecast by the new IPM version achieve Iowa's share of emissions reductions, as required by 40 CFR § 51.308(d)(3)(ii).

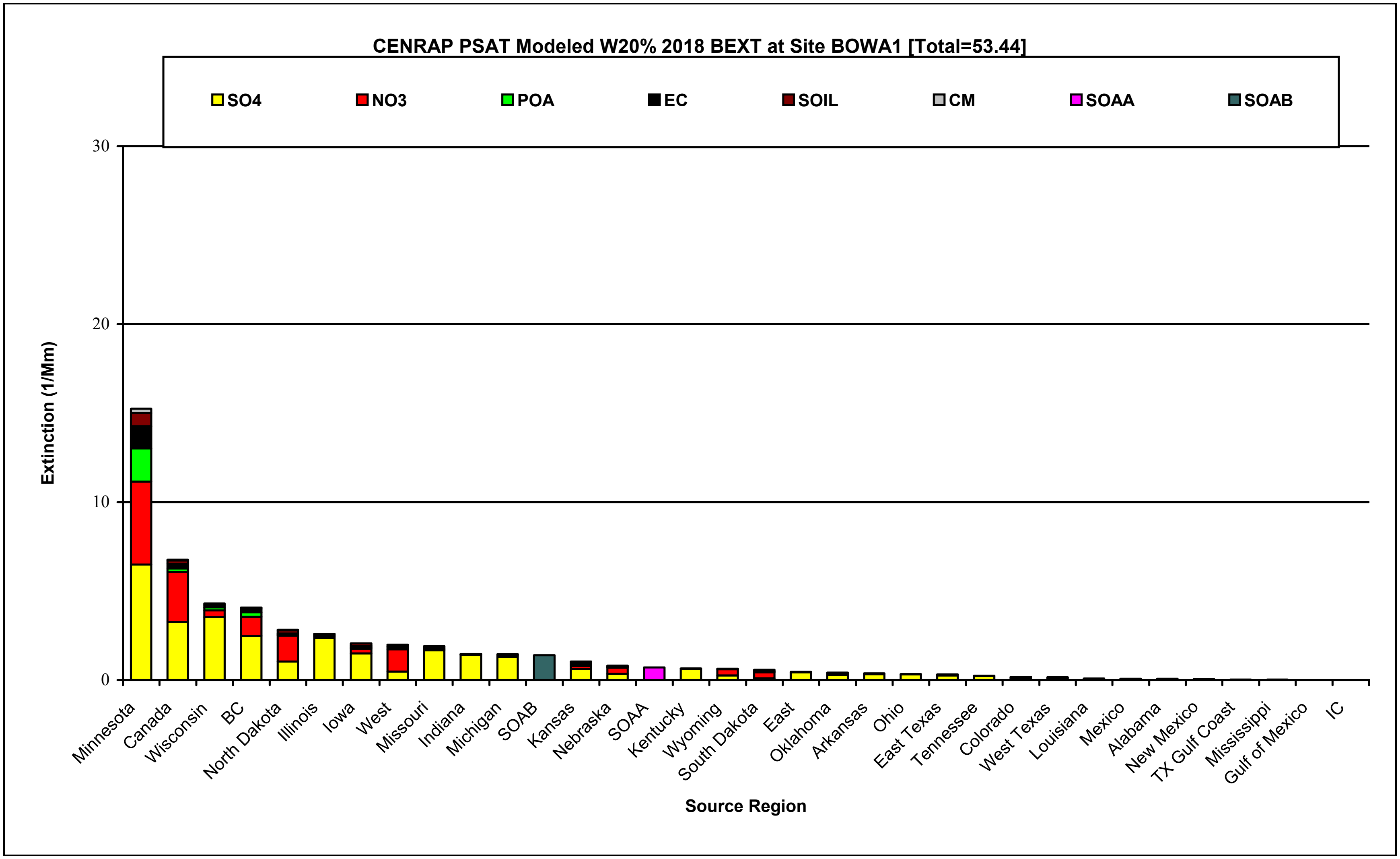

Figure 11.1. Source apportion contributions by region and pollutant to BOWA in 2018.

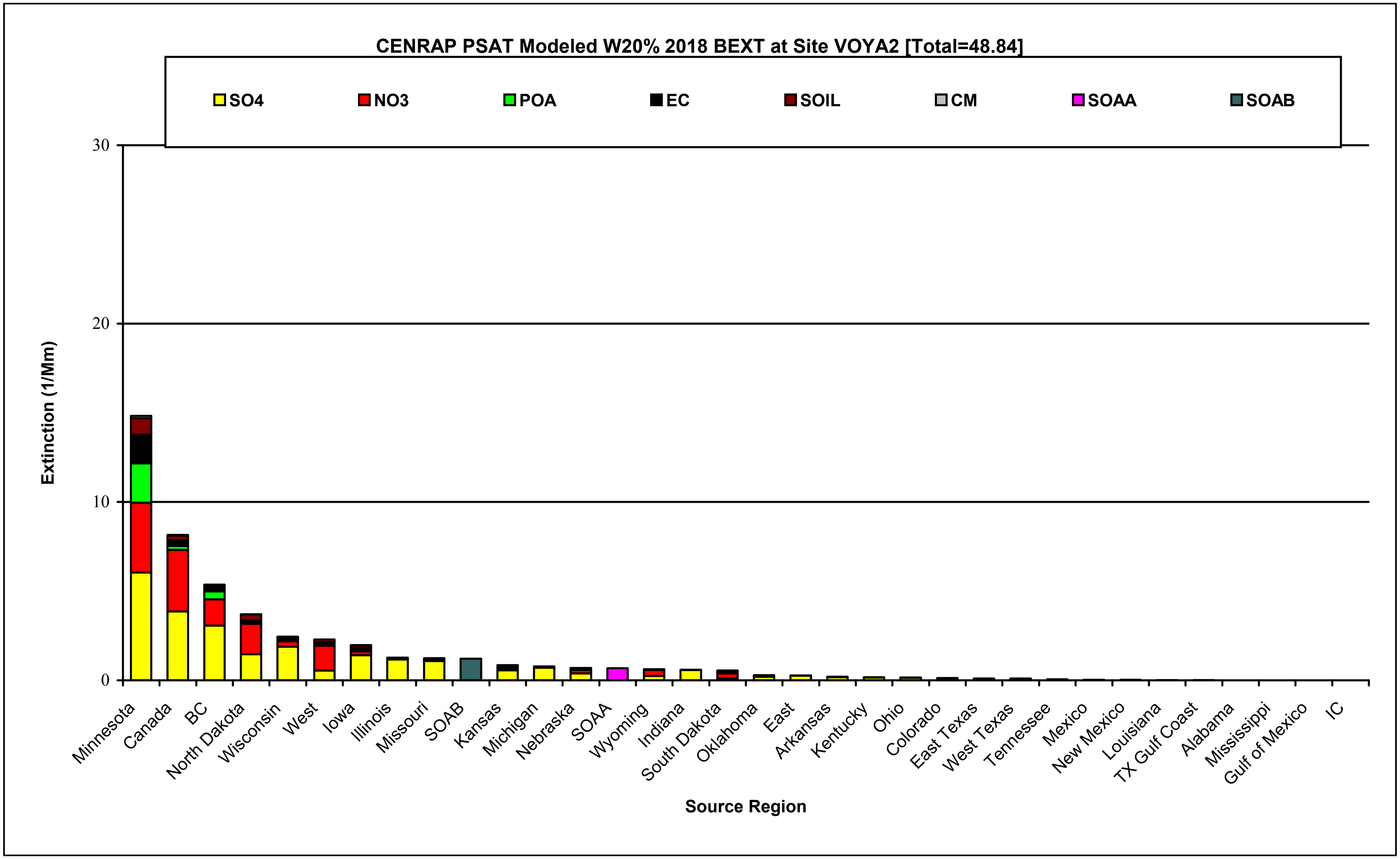

Figure 11.2. Source apportion contributions by region and pollutant to VOYA in 2018.

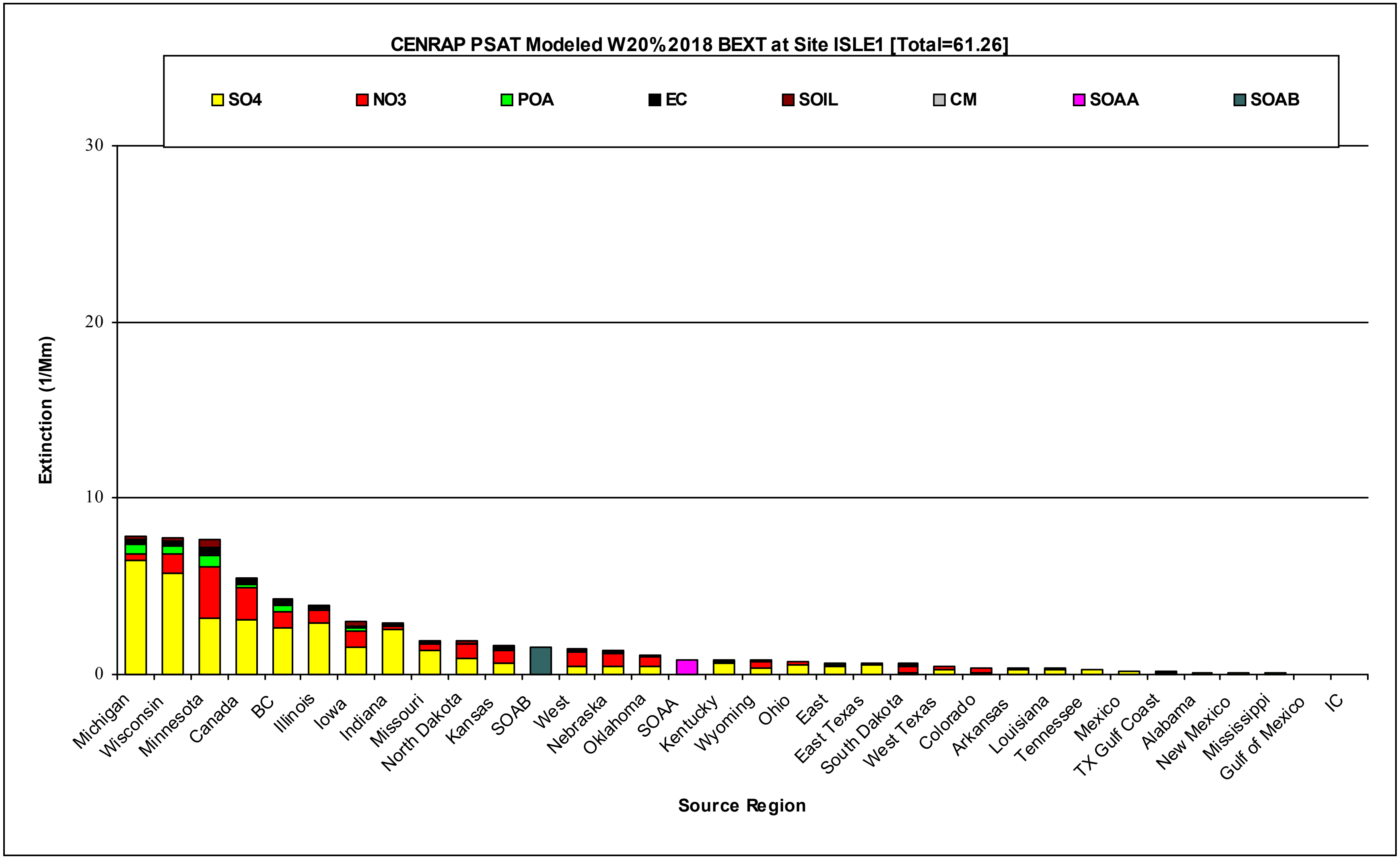

Figure 11.3. Source apportion contributions by region and pollutant to ISLE in 2018.

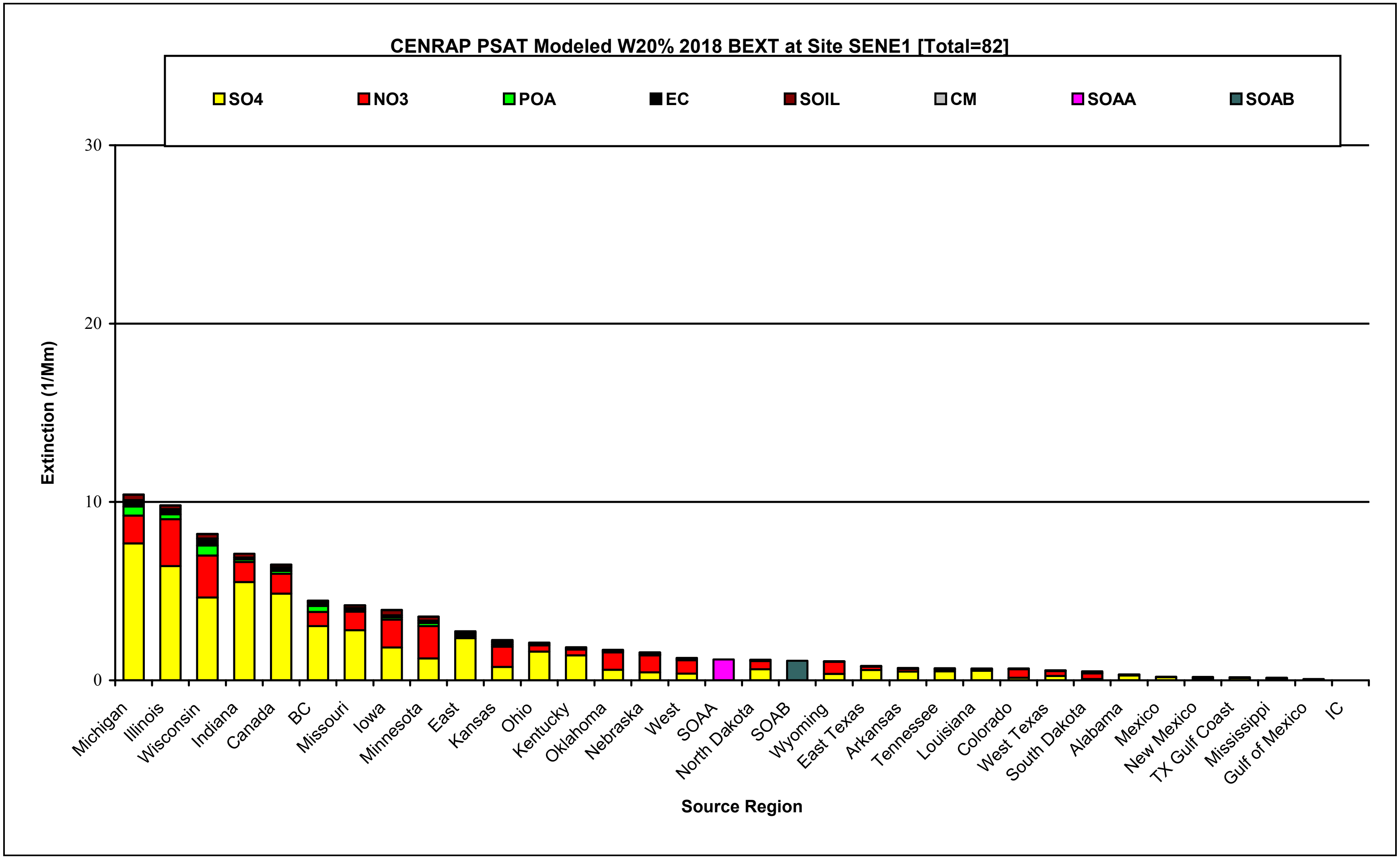

Figure 11.4. Source apportion contributions by region and pollutant to SENE in 2018.

Updates to EGU Emissions Forecasts

CENRAP utilized the 'RPO version 2.1.9' IPM forecasts (referred to as IPM v2.1.9) to create the 2018 BaseG emissions scenarios. IPM v2.1.9 was generated in the 2004-2005 timeframe using the information available at the time. More recent IPM forecasts, generated during the 2006-2007 timeframe, are now available. The updated 2018 projections utilized the latest IPM source code (version 3.0, referred to as IPM v3.0) and incorporated updated fuel costs and recent regulatory impacts. The IPM v3.0 results also reflect updates made by the IDNR to the National Electric Energy Data System (NEEDS) model input database. These improvements included updated permit conditions reflecting the addition of SO2 and NOx controls. The IPM v3.0 results also incorporate minor stack parameter error corrections not captured in IPM v2.1.9. Both EPA and IDNR therefore consider the IPM v3.0 results to be technically superior to those of IPM v2.1.9.

Based upon IDNR's updates and error corrections, in combination with all other improvements, IPM v3.0 results differ significantly from the EGU forecasts used within the CENRAP modeling. Figure 11.5 provides a comparison between the two versions of IPM. For reference, Iowa's 2002 basecase emissions are also shown. The IPM data plotted in Figure 11.5 reflect only unmodified results, thus IPM v2.1.9 values differ from the EGU emission rates provided in Table 7.2. Sulfur dioxide emission rates forecasted by IPM v2.1.9 increase above 2002 levels, in spite of IDNR's participation in the CAIR SO2 cap and trade program. The IPM v3.0 results yield a 15 percent reduction in SO2 emissions versus 2002 conditions. While the NOx emissions reductions predicted by IPM v3.0 are not as great as the v2.1.9 results, a reduction of 27% is still forecast. Considering the level of visibility impairment attributable to Iowa sources, the SO2 and NOx reductions associated with participation in the CAIR cap and trade program are sufficient to achieve Iowa's share of emissions reductions.

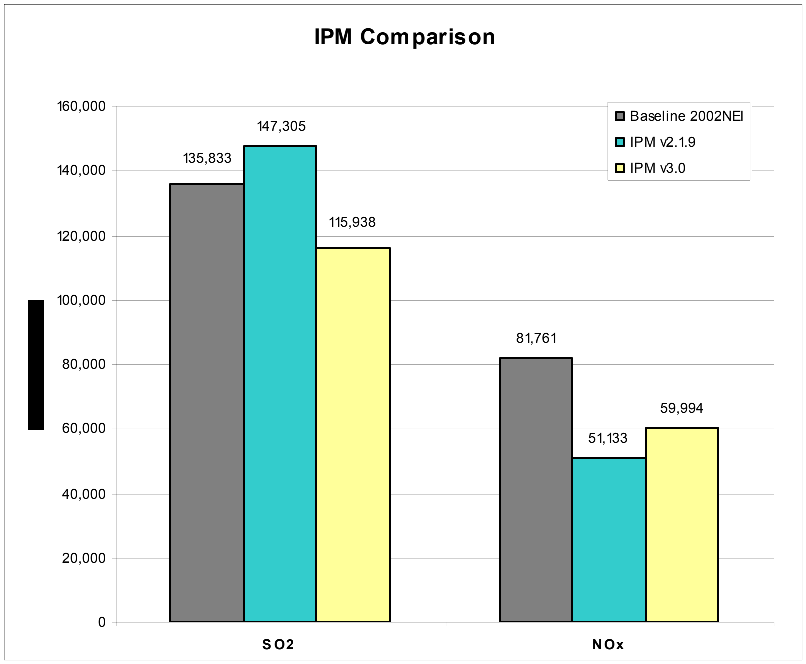

Figure 11.5. Comparison of IPM's 2018 Iowa EGU emissions forecasts.

11.3 Minnesota/MRPO Modeling Results

The IDNR is utilizing source apportionment modeling data provided by Minnesota in a weight of evidence[1] approach to support IDNR's conclusion that CAIR achieves Iowa EGU SO2 and NOx reductions appropriate to Iowa's level of visibility contributions at the Northern Midwest Class I areas.

The Minnesota modeling is based upon the 2002/2018 BaseK work completed by the MRPO.[2] Unlike previous 2018 BaseK simulations, the Minnesota/MRPO modeling included EGU forecasts derived from IPM v3.0. Instead of using the default IPM v3.0 results, Minnesota and the MRPO States modified the IPM v3.0 results to reflect known EGU emissions modifications occurring prior to 2018, but not captured within the original IPM v3.0 simulation. This EGU forecast is referred to as the 'IPM3.0-Will-Do' scenario. No Iowa EGU emission rates were adjusted within the 'IPM3.0-Will-Do' scenario.

An overview of both the 2002 basecase and 2018 Minnesota/MRPO source apportionment modeling is provided in Table 11.4. Specifically listed are the visibility impacts attributable to Iowa sources. Data are provided in terms of an absolute extinction value (calculated using the new IMPROVE equation), and are generally comparable to the data in Table 11.2. The Minnesota/MRPO PSAT modeling examines only sulfate, nitrate, and ammonium partitioning, thus state apportionments of primary species (such as primary organic aerosol, fine primary particulate, primary coarse particulate, and elemental carbon) can not be incorporated into the totals provided in Table 11.4. Values calculated through CENRAP results (Table 11.2 for example) reflect the contributions from primary species. In terms of Iowa's contribution to the Northern Midwest Class I areas, the exclusion of primary species source apportionment techniques has negligible impacts as sulfate, nitrate, and ammonium are the dominant species. For states and regions closer to the Class I areas these species can increase in importance, particularly primary organic aerosol. Sulfates and nitrates currently remain the dominant species under consideration.

Table 11.4. Iowa's contributions to visibility impairment as modeled by Minnesota.

Site	Worst 20% Days Modeled Extinction (Mm^{-1})	
	2002	2018
BOWA	2.48 2.40	
VOYA	2.10 2.11	
ISLE	3.34 3.34	
SENE	4.20 4.08	

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[1] A weight of evidence analysis consists of complementary analyses which use different data sources or methods to support a singular conclusion. Additional information is available in EPA's modeling guidance (**EPA-454/B-07-002**).

[2] The Minnesota modeling is also referred to as the 'Minnesota/MRPO' modeling to credit both organizations.

The CENRAP and MRPO 2002 basecase simulations yield similar values for the visibility impairment at the Northern Midwest Class I areas attributable to Iowa sources (see Tables 11.2 and 11.4). The CENRAP 2018 source apportionment simulations yield a slight decrease in Iowa's absolute contribution at all four Northern Midwest Class I areas despite the use of IPM v2.1.9 and the associated higher than anticipated SO2 emission rates (see Table 11.2). The predicted NOx reductions are predominantly responsible for the lower contributions modeled by CENRAP. The Minnesota/MRPO 2018 results yield a different trend, as Iowa contributions remain fairly constant between 2002 and 2018 (see Table 11.4), even though the significant reductions from Iowa EGU sources predicted by IPM v3.0 were incorporated in the Minnesota/MRPO modeling. A determination of the exact causes of the inter-project variability would require detailed analyses incommensurate with Iowa's level of contribution. Alternatively, the Minnesota/MRPO results reinforce a known consequence of the non-linear chemistry associated with visibility impairment, in which contributions to visibility impairment attributable to distant emissions sources are highly dependent upon downwind conditions and emissions nearer the affected area.

The CENRAP and Minnesota/MRPO modeling substantiate that Iowa sources can not effect visibility improvement at the Northern Midwest Class I areas without disproportionate and costly levels of control. Results in the preceding paragraphs provides evidence in support of this conclusion. The Department's conclusion is further supported through the following discussion.

The CENRAP modeling utilized EGU emissions forecasts from IPM v2.1.9. The Minnesota/ MRPO modeling runs were completed independent of the CENRAP results and were conducted in a later timeframe. Minnesota/MRPO was thus able to use the updated IPM v3.0 modeling predictions. The 2018 SO2 emissions from Iowa EGUs predicted by IPM v3.0 were approximately 30,000 tpy lower than IPM v2.1.9 forecasts. While the Minnesota/MRPO non-EGU SO2 emissions may be higher than CENRAP values, any discrepancies remain well below the level of reductions predicted by IPM v3.0. Additionally, the impacts of disparities between non-EGU emissions forecasts are minimal as the MRPO PSAT results show that Iowa's non-EGU sources yield even less influence over visibility impairment at the Northern Midwest Class I areas than EGU sources (see Appendix 11.1).

Table 11.4 shows that the Minnesota/MRPO modeling predicts Iowa's contributions to visibility impairment in 2018 will be in the 2 Mm^{-1} range. This result is similar to the CENRAP modeling, despite having accounted for additional SO2 EGU reductions captured in IPM v3.0. Only slight variations (less than ~0.4 Mm^{-1}) in Iowa's contributions to visibility impairment in 2018 at the Minnesota Class I areas is seen when comparing the CENRAP and Minnesota/MRPO regional modeling runs, despite the 30,000 tpy variation among the predicted EGU SO2 emissions. Summarizing the results, the Minnesota modeling shows little impact on visibility improvement at the Minnesota Class I areas despite EGU SO2 reductions of ~20,000 tons per year (compared to 2002 conditions). This result is not unexpected, but is a consequence of extensive transport distances combined with the relatively small visibility impairment attributable to Iowa sources. This information substantiates that Iowa sources can not effect visibility improvement at the Northern Midwest Class I areas without disproportionate and costly levels of control.

11.4 Basis for emissions reduction obligations

IDNR is required to document the technical basis for the State's apportionment of emissions reductions necessary to meet the RPG for each Class I area affected by the State's emissions (40 CFR § 51.308(d)(3)(iii)).

IDNR relied on technical analyses developed by CENRAP and the assessments provided in this chapter to demonstrate that Iowa's emissions reductions will be commensurate with the contributions from emissions sources in Iowa. The CENRAP analyses are described in detail in Appendix 7.1. Additional information and analyses, such as the weight of evidence products described in Section 11.3 and the Four Factor Report reference in Chapter 10, were supported through data products developed by the MRPO and Minnesota.

11.5 Baseline inventory

IDNR is required to identify the baseline inventory on which the long-term strategy is based. IDNR used the 2002 CENRAP inventory version BaseG as its baseline inventory (40 CFR § 51.308(d)(3)(iii)). Additional information can be found in Chapter 7 and Appendix 7.1 (see Chapter 2).

11.6 Anthropogenic sources of visibility impairment

IDNR is required to identify all anthropogenic sources of visibility impairment considered by the State in developing its long-term strategy (40 CFR § 51.308(d)(3)(iv)). Appendix 7.1 (see Chapter 2) provides the details of the 2002 emissions inventory used in developing this SIP revision.

11.7 Factors the State Must Consider

IDNR is required to consider several factors in developing its long-term strategy (40 CFR § 51.308(d)(3)(v)). These factors are discussed below.

Emission reductions due to ongoing mandated air pollution control programs.
IDNR is required to consider emission reductions from ongoing pollution control programs (40 CFR § 51.308(d)(3)(v)(A)). IDNR considered the minor and major new source review programs (NSR), prevention of significant deterioration permits (PSD), CAIR, , heavy duty highway diesel rule, clean air non-road diesel rule, other on-road and non-road mobile source programs, operating permits, pertinent new source performance standards (NSPS), national emissions standards for hazardous air pollutants (NESHAP), associated maximum achievable control technology (MACT) standards, and IPM results in developing its long-term strategy. Reductions associated with these programs assist with achieving Iowa's share of emissions reductions, as discussed above in Section 11.2.

The District of Columbia Circuit Court vacated the ICI Boiler NESHAP and Commercial/Industrial Solid Waste Incinerator (CISWI) NSPS on July 30, 2007. The court directed EPA to vacate both rules and to take further action consistent with the court's opinion. The 2018 emissions projections included the ICI Boiler NESHAP and the CISWI NSPS reductions in the future modeling scenarios. The court action will likely result in more emissions reductions and will define the schedule for the new rules.

The Iowa Bus Emission Education Program (BEEP) is a collaborative effort to reduce childhood exposure to harmful diesel exhaust. The Union of Concerned Scientists ranked Iowa's buses among the dirtiest 20 percent nationally. To improve the state's fleet, BEEP applied for and received funding from EPA's Clean School Bus USA program. BEEP partners include the School Administrators of Iowa, the Iowa Association of School Boards, the IDNR, the Iowa Department of Education, and the Iowa Pupil Transportation Association.

As of October 2007 BEEP has installed 548 diesel oxidation catalysts (DOC) in school districts around the state. Based on communication with school transportation directors, BEEP believes that all school districts wanting DOCs have received them. Essentially, almost all school buses eligible for a DOC have received one in the State of Iowa. According to the data from EPA's verification, each DOC reduces particulate matter air emissions by 20%, carbon monoxide emissions by 40%, and hydrocarbon emissions by 50%.

Biodiesel also was offered to school districts in an effort to promote its use. Based on informal comments and surveys from the school districts involved, biodiesel has been accepted as an alternative fuel. Many comments indicated that it can be difficult to acquire biodiesel higher than a 2% blend. Given the continued interested in alternative fuel production in Iowa, school districts are optimistic that higher grades will be available in the future. BEEP also received a supplement environmental project (SEP) to partially fund two hybrid electric buses. The two buses will be in use by the end of 2007.

BEEP applied for another EPA Clean School Buses grant in September 2007. The grant will request funds to replace the oldest and dirtiest diesel buses.

Measures to mitigate the impacts of construction activities.

The IDNR is required to consider measures to mitigate the impacts of construction activities (40 CFR § 51.308(d)(3)(v)(B)). IDNR's rules on fugitive dust (567 IAC 23.3(2)"c") state that reasonable precautions shall be taken to prevent the discharge of visible emissions of airborne dust beyond the lot line of the property from which the emissions originated. IDNR also requires minor NSR permits for aggregate processing plants, concrete batch plants, and asphalt plants. Portable aggregate, concrete, or asphalt plants must notify the IDNR 30 days prior to transferring the equipment to a new location to allow for review of the emissions impacts on national ambient air quality standards (NAAQS). The IDNR would notify the portable plant if there are potential adverse impacts on the NAAQS. A more stringent emission standard and the installation of additional control equipment would be required if the relocation would prevent the attainment or maintenance of the NAAQS. IDNR determined that no additional measures were needed to mitigate the impacts of construction activities. General construction activities will not impact Class I area visibility due to the extensive transport distance in combination with the relatively low emissions and release heights.

Emissions limitations and schedules of compliance.
IDNR is required to identify additional measures to meet RPGs when ongoing programs alone are not sufficient to meet the goals (40 CFR § 51.308(d)(3)(v)(C)). IDNR found that ongoing air pollution control programs were sufficient to meet anticipated RPGs through 2018.

Source retirement and replacement schedules
IDNR is required to consider source retirement and replacement schedules in developing RPGs (40 CFR § 51.308(d)(3)(v)(D). Retirement and replacement will be managed in conformance with existing SIP requirements pertaining to PSD and NSR. IDNR updated the IPM inputs for the version 2.1.9 and 3.0 runs to include permit revisions and operating characteristics. The IPM results include new and retired units.

New plants not predicted by IPM v3.0
There is one proposed new coal-fired EGU and one additional coal-fired EGU being contemplated in Iowa. It is premature to address potential emissions from either facility. Updates on new or proposed plants, and any significant growth of emissions from existing plants, will be included in the progress report due five-years after the initial SIP submittal.

Agricultural and forestry smoke management
IDNR is required to consider smoke management techniques for the purposes of agricultural and forestry management in developing the long-term strategy (40 CFR § 51.308(d)(3)(v)(E)). IDNR, at this time, has not adopted a smoke management program. The CENRAP PSAT modeling indicates that fires in Iowa do not significantly contribute to visibility impairment in mandatory Class I Federal areas. Therefore, there is no need for a smoke management plan (SMP) in this SIP revision.

IDNR has been working on developing aspects of a statewide SMP for several years. Iowa currently burns less than 25,000 acres per year, which is considerably less than most other states.

Prior to developing a statewide SMP for all prescribed burning, IDNR is developing a fire policy. This policy will specify how IDNR conducts prescribed burning on state, federal, and private lands for which the agency has management authority. Smoke management will be an important part of this policy.

Upon completion of the fire policy, IDNR intends to begin working on air quality rules for prescribed natural resource burning. These rules will require a written burn plan, and will also require smoke management consistent with the fire policy. IDNR will work with stakeholders, such as Nature Conservancy, National Resource Conservation Service, and other prescribed burners to develop a SMP. The stakeholders have already formed an Iowa Fire Council with a smoke management committee. This committee will work with the IDNR to develop an Iowa SMP.

It is expected that the Iowa SMP will be completed late in 2008. It will substantially comply with the guidelines set forth in EPA's Interim Air Quality Policy and Prescribed and Wildland

Fire (1998). However, EPA is currently working with stakeholders to revise this policy to make it consistent with the Exceptional Events rule. IDNR staff is participating in meetings discussing the policy revisions.

Enforceability of emissions limitations and control measures

IDNR is required to ensure that emissions limitations and control measures used to meet RPGs are enforceable (40 CFR § 51.308(d)(3)(v)(F)).

IDNR's program ensures that all measures used to meet anticipated RPGs are enforceable by embodying these in administrative orders, permits, and the Iowa Administrative Code.

Anticipated net effect on visibility resulting from projected changes to emissions

IDNR is required to address the net effect on visibility resulting from changes projected in point, area and mobile source emissions by 2018 (40 CFR § 51.308(d)(3)(v)(G)).

The emissions inventory for Iowa projects changes to point, area and mobile source inventories by the end of the first implementation period resulting from population growth, industrial, energy and natural resources development, land management, and air pollution control. A review of these changes is discussed in Chapter 7 for each of the pollutants addressed in the regional haze inventory. Greater detail is provided in Appendix 7.1

As indicated above, IDNR considered NSR, CAIR, heavy duty highway diesel rule, clean air non-road diesel rule, other on-road and non-road mobile source programs, operating permits, pertinent NSPS, NESHAP, associated MACT standards, and IPM results in developing its long-term strategy.

List of Chapter 11 Appendices

11.1 Regional Air Quality Analyses for Ozone, PM2.5, and Regional Haze: Technical Support Document. States of Illinois, Indiana, Michigan, Ohio, and Wisconsin. February 15th, 2008.

12. Comprehensive Periodic Implementation Plan Revisions

Forty CFR § 51.308(f) requires a State/Tribe to revise its regional haze implementation plan and submit a plan revision to EPA by July 31, 2018, and every ten (10) years thereafter. In accordance with the requirements listed in 40 CFR § 51.308(f) of the federal rule for regional haze, IDNR commits to revising and submitting this regional haze implementation plan by July 31, 2018, and every ten (10) years thereafter.

In addition, 40 CFR § 51.308(g) requires periodic reports evaluating progress towards the RPG established for each mandatory Class I Federal area outside the state which may be affected by emissions from within the State. In accordance with the requirements listed in 40 CFR § 51.308(g) of the federal rule for regional haze, IDNR commits to submitting a report on reasonable progress to EPA every five years following the initial submittal of the SIP. All requirements listed in 51.308(g) shall be addressed in the SIP revision for reasonable progress, including a review of the changes in the emission inventory, a review of the periodic reporting requirements, and a determination of whether additional action is needed according to § 51.308(h). The Department commits to submitting the required five year SIP revision by December 17, 2012.

List of Chapter 12 Appendices

There are no Appendices to Chapter 12.

13. Determination of the Adequacy of the Existing Plan for the Purposes of the Five-Year Progress Report

The IDNR has determined the SIP to be adequate. Depending on the findings of the five-year progress report, IDNR commits to taking one of the actions listed in 40 CFR § 51.308(h). The findings of the five-year progress report will determine which action is appropriate and necessary.

List of Possible Actions – 40 CFR § 51.308(h)

1) IDNR determined that the existing SIP required no further substantive revision in order to achieve established goals. IDNR provided to the Administrator a negative declaration that further revision of the SIP is not needed at this time.
2) IDNR determined that the existing SIP may be inadequate to ensure reasonable progress due to emissions from other states which participated in the regional planning process. IDNR provided notification to the Administrator and the states that participated in regional planning. IDNR collaborated with states through the regional planning process to address the SIP's deficiencies.
3) IDNR determined that the current SIP may be inadequate to ensure reasonable progress due to emissions from another country. IDNR provided notification, along with available information, to the Administrator.
4) IDNR determined that the existing SIP is inadequate to ensure reasonable progress due to emissions within the State of Iowa. IDNR will revise/has revised its SIP to address the plan's deficiencies. {State/Tribe must address the deficiencies within one year.}

List of Chapter 13 Appendices

There are no Appendices to Chapter 13.

Guidance Documents

Consolidated Emissions Reporting Rule. June 10, 2002, 67 FR 39602-39616, http://www.epa.gov/ttn/chief/cerr/cerr.pdf.

Controlling SO_2 Emissions: A Review of Technologies, EPA-600/R-00-093. November 2000. EPA Office of Research and Development.

Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations, **EPA-454/R-05-001.** August 2005. http://www.epa.gov/ttn/chief/eidocs/eiguid/index.html.

EPA Clean Air Technology Center - Control Cost Manual (5th edition). http://www.epa.gov/ttn/catc/products.html.

EPA Guidelines for Preparing Economic Analyses. http://www.epa.gov/economics/.

Guidance for Improving Weight of Evidence Through Identification of Additional Emission Reductions, Not Modeled. http://www.epa.gov/scram001/guidance/guide/addwoe1h.wpd.

Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program. June 1, 2007**.** http://www.epa.gov/ttn/oarpg/t1/memoranda/reasonable_progress_guid071307.pdf.

Guidance for Tracking Progress under the Regional Haze Rule, EPA-454/B-03-004. September 2003. http://www.epa.gov/ttncaaa1/t1/memoranda/rh_tpurhr_gd.pdf.

Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$ and Regional Haze, EPA-454/B-07-002. April 2007. http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

Guidelines for Determining Best Available Retrofit Technology for Coal-fired Power Plants and Other Existing Stationary Facilities, EPA-450/3-80-009b. November 1980.

Guidelines for Determining Natural Background. http://www.epa.gov/ttncaaa1/t1/memoranda/rh_envcurhr_gd.pdf

IMPROVE Particulate Monitoring Network - Procedures for Site Selection. Crocker Nuclear Laboratory, University of California, February 24, 1999. http://www.epa.gov/ttn/amtic/files/ambient/visible/select22.pdf

IMPROVE Particulate Monitoring Network – Standard Operating Procedures Air Quality. Crocker Nuclear Laboratory, University of California, October 15, 1998. http://www2.nature.nps.gov/ard/vis/sop/index.html

Improving Air Quality with Economic Incentive Programs, EPA-452/R-01-001. January 2001. http://www.epa.gov/ttn/oarpg/t1/memoranda/eipfin.pdf

National Park Service Visibility Monitoring internet site. http://www2.nature.nps.gov/ard/vis/vishp.html

Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis. EC/R Incorporated for LADCO and MPCA. http://ladco.org/MRPO%20Report_071807.pdf

Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations. July 6, 2005, 70 FR 39104 – 39172. http://www.epa.gov/EPA-AIR/2005/July/Day-06/a12526.htm

Regional Haze Regulations; Final Rule. July 1, 1999, Federal Register 64 FR 35714 – 35774, http://www.epa.gov/EPA-AIR/1999/July/Day-01/a13941.htm, http://www.epa.gov/ttn/oarpg/t1/fr_notices/rhfedreg.pdf.

Technical Memorandum (Final): Methods for Evaluating Statutory Factors. MACTEC Project 827007G184 for MARMA. http://www.marama.org/visibility/RPG/EvaluationMethods_TM2/RPG_EvaluationMethods_TM2%20Final_020607.pdf

Visibility Monitoring Guidance document, EPA-454/R-99-003. June 1999. http://www.epa.gov/ttn/amtic/files/ambient/visible/r-99-003.pdf

Voluntary Emissions Reduction Program for Major Industrial Sources of Sulfur Dioxide in Nine Western States and a Backstop Market Trading Program. An Annex to the Report of the Grand Canyon Visibility Transport Commission. Western Regional Air Partnership. September 29, 2000. http://www.wrapair.org/forums/mtf/documents/group_reports/ANNEX/execsum082800.pdf

APPENDIX 1

Appendix 1.1: Guide to Locating 40 CFR § 51.300 – 51.308 Requirements

Sections 51.300 – 51.308 (Included within Subpart P -- PROTECTION OF VISIBILITY)
The definitions for §51.308 are found in §51.301. Control strategy timelines are mentioned in §51.302. The BART exemption waiver is in §51.303. Integral vistas, or the forerunner to mandatory class I areas, are listed in §51.304. Sections 51.305 and 51.306 address monitoring strategies and long term plans, as related to reasonably attributable visibility impairment (may also be referred to as "plume blight", these requirements were addressed by rule in 1980). Section 51.307 explains the new source review requirements for proposed facilities that will/may impact federal class I areas. The requirements of the regional haze program are in §51.308.

This description is primarily derived from phrases found in the sections and subsections of 40 CFR § 51.300-308. Additional clarifying description has been added based on the content of the sections and subsections. The table below is intended to be a guide to locating requirements of the regional haze program.

Table 1: Description of 40 CFR § 51.300 – 51.308

40 CFR	Topic
§51.300	Establish the purpose of subpart P as requiring States to develop programs to address visibility
§51.301	The definitions for §51.308
§51.302	Control strategy timelines for reasonably attributable (plume blight) visibility impairmen
§51.303	BART controls exemption waiver
§51.304	Integral vistas, or the forerunner to mandatory class I areas
§51.305	Reasonably attributable visibility monitoring plan requiremen
§51.306	Reasonably attributable long-term strategy requirements
§51.307	New source review requirements for facilities that may impact federal class I areas
§51.308	Regional Haze Program Section
§51.308(a)	Purpose of the program
§51.308(b)	Initial SIP due date (Dec 17th, 2007)
§51.308(c)	Reserved
§51.308(d)	Core requirements for the regional haze SIP including: reasonable progress goals; baseline and natural visibility conditions; long-term strategy; monitoring strategy and other SIP requirements.
§51.308(d)(1)	Reasonable progress goals
§51.308(d)(2)	Calculations of baseline and natural visibility conditions
§51.308(d)(3)	Long-term strategy for regional haze
§51.308(d)(4)	Monitoring strategy and other implementation plan requirements
§51.308(e)	Best Available Retrofit Technology (BART) requirements for regional haze visibility impairment
§51.308(e)(1)	BART plan including: eligible sources, determinations, and compliance details
§51.308(e)(2)	BART trading program
§51.308(e)(3)	Demonstration of the BART trading program
§51.308(e)(4)	Clean Air Interstate Rule (CAIR) and BART Electrical Generation Units (EGU)
§51.308(e)(5)	Beyond BART provision
§51.308(e)(6)	BART exemption
§51.308(f)	Requirements for comprehensive periodic revisions of implementation plans for regional haze (Ten year SIP revision)
§51.308(f)(1)	Current visibility conditions and actual progress towards goal
§51.308(f)(2)	Effectiveness of the long-term strategy
§51.308(f)(3)	Affirmation or revision of the reasonable progress goal
§51.308(g)	Reasonable progress goals periodic reports (Five year evaluation)
§51.308(g)(1)	Status of all measures
§51.308(g)(2)	Summary of emissions reductions
§51.308(g)(3)	Assessment of the visibility conditions for each mandatory class I area in the State
§51.308(g)(4)	Analysis of visibility impairing emissions
§51.308(g)(5)	Assessment of changes in anthropogenic emissions within or outside the State
§51.308(g)(6)	Assessment of the current SIP in relation to the reasonable progress goals
§51.308(g)(7)	Review of the visibility of monitoring strategy and any modifications
§51.308(h)	Determination of SIP adequacy
§51.308(h)(1)	Negative declaration of no further revisions to the SIP
§51.308(h)(2)	Notification of inadequacy due to emissions from another State(s) that participated in the regional planning process
§51.308(h)(3)	Notification of inadequacy due to emissions from sources in another country
§51.308(h)(4)	Inadequacy due to emissions from sources within the State and revision of SIP within one year
§51.308(i)	State and Federal Land Manager (FLM) coordination
§51.308(i)(1)	State designee identification to FLM
§51.308(i)(2)	FLM comment period for the regional haze SIP and SIP revisions
§51.308(i)(3)	State requirement to address FLM comment(s)
§51.308(i)(4)	State-FLM continuous consultation

Appendix 1.2: Benefits of Improved Visibility

Visibility can be defined as the degree to which the atmosphere is transparent to visible light.[1] Visibility impairment is the most noticeable effect of fine particles present in the atmosphere, as particle pollution degrades the visual appearance and perceived color of distant objects and reduces the range at which they can be distinguished from the background.

Visibility impairment due to haze in Class I Areas is primarily due to fine particulate matter ($PM_{2.5}$) attributable to anthropogenic emissions. $PM_{2.5}$ is composed of ammonium sulfate, ammonium nitrate, organic carbon, elemental carbon, fine soil, and trace metals. Fine particulates can be emitted directly into the atmosphere or can be formed in the atmosphere by the transformation of gaseous emissions such as sulfur dioxide, nitrogen oxides, and volatile organic compounds.

Visibility impairment may be either "reasonably attributable" (defined in 40 CFR § 51.301 as attributable by visual observation) to specific sources (i.e. local visibility impairment) or a result of emissions from a large number of sources located over a wide geographic area (regional haze as defined in 40 CFR § 51.301). Sources of visible plumes are generally thought to be comparatively negligible contributors to the impairment of visibility in Class I Areas. According to EPA (2005), "there have been a limited number of cases in which Federal land managers have certified the existence of visibility impairment in a Class I Area as being 'reasonably attributable' to a particular source."[2]

According to EPA:

> "Regional haze impairs visibility in every direction over a large area, in some cases over multi-state regions. It also masks objects on the horizon and reduces the contrast of nearby objects. The formation, extent, and intensity of regional haze are functions of meteorological and chemical processes, which sometimes cause fine particle loadings to remain suspended in the atmosphere for several days and to be transported hundreds of kilometers from their sources (NRC, 1993). It is this second type of visibility degradation, regional haze, which is principally responsible for impairment in national parks and wilderness areas across the country (NRC, 1993).
>
> While visibility impairment in urban areas at times may be dominated by local sources, it often may be significantly affected by long-range transport of haze due to the multi-day residence times of fine particles in the atmosphere. Fine particles transported from urban and industrialized areas, in turn, may, in some cases, be significant contributors to regional-scale impairment in Class I and other rural areas."[3]

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[1] National Research Council. (1993). *Protecting Visibility in National Parks and Wilderness Areas*. Washington, DC.

[2] Environmental Protection Agency (December 2005). *Review of the National Ambient Air Quality Standard for Particulate Matter: Policy Assessment of Scientific and Technical Information*, pp 6-2.

[3] Ibid. pp 6-3.

The document goes on to state:

> "Regional trends in Class I area visibility are updated and presented in the EPA's National Air Quality and Emissions Trends Report (EPA, 2001). Eastern trends for the 20% haziest days from 1992-1999 showed a 1.5 deciview improvement, or about a 16% improvement. However, visibility in the East remains significantly impaired, with an average visual range of approximately 20 km on the 20% haziest days. In western Class I areas, aggregate trends showed little change during 1990-1999 for the 20% haziest days, and modest improvements on the 20% mid-range and clearest days. Average visual range on the 20% haziest days in western Class I areas is approximately 100 km."[4]

The benefits of improving visibility in the federally protected national parks and wilderness areas are far reaching and include environmental/ecological, health, and economic benefits.

Environmental/Ecological Benefits

The components of $PM_{2.5}$ are harmful to the environment and ecosystems. For instance, in addition to be being precursors to sulfate and nitrate fine particles, sulfur dioxide and nitrogen oxides contribute to the formation of acid rain. Acid rain has harmful effects on forests, soils, flora, fauna, waterways, materials, and human health.[5]

According to EPA, acid rain and dry deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). These effects seriously reduce the value to society of buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars. The afore-mentioned fact is reiterated in the following excerpts from the EPA review of the Particulate Matter Standard:

> "Physical damage such as corrosion, degradation, and deterioration occurs in metals, paint finishes, and building materials such as stone and concrete, respectively. Metals are affected by natural weathering processes even in the absence of atmospheric pollutants. Atmospheric pollutants, most notably SO2 and particulate sulfates, can have an additive effect, by promoting and accelerating the corrosion of metals. The rate of metal corrosion depends on a number of factors, including the deposition rate and nature of the pollutants; the influence of the protective corrosion film that forms on metals, slowing corrosion; the amount of moisture present; variability in electrochemical reactions; the presence and concentration of other surface electrolytes; and the orientation of the metal surface. Historically, studies have shown that the rate of metal corrosion decreases in the absence of moisture, since surface moisture facilitates the deposition of pollutants and promotes corrosive electrochemical reactions on metals (CD, pp. 4-192 to 4-193)."[6]

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[4] Ibid. p 6-4.

[5] U.S. EPA Acid Rain Program. *Effects of Acid Rain*. http://www.epa.gov/acidrain/effects/index.html

[6] US Environmental Protection Agency (December 2005). *Review of the National Ambient Air Quality Standard for Particulate Matter: Policy Assessment of Scientific and Technical Information*, pp 6-51.

> "In addition, the deposition of ambient PM can reduce the aesthetic appeal of buildings and culturally important articles through soiling. Particles consisting primarily of carbonaceous compounds cause soiling of commonly used building materials and culturally important items such as statues and works of art (CD, p. 4-191). Soiling is the deposition of particles on surfaces by impingement, and the accumulation of particles on the surface of exposed material results in degradation of its appearance" (EPA, 1996b, p. VIII-19)."[7]

Another environmental effect linked to $PM_{2.5}$ precursors, and thus visibility impairment, is the formation of ozone. As stated in the EPA's PM Data Analysis Workbook, "formation of a substantial fraction of secondary $PM_{2.5}$ depends on photochemical gas phase reactions."[8] Ground level ozone has been linked to foliage and ecosystem damages, as well as the more commonly mentioned respiratory problems. Reduction in visibility impairing pollutants will help non-attainment areas to attain the NAAQS for $PM_{2.5}$ and ozone.

Other environmental and ecological benefits are likely to result from the reduction of visibility impairing particulates and their precursors. For example, reduction of sulfur dioxide will reduce the amount of foliar injury, injury or death of tissues in foliage, while reduction of both nitrogen and sulfur compounds will decrease acidification and fertilization of waters and soils and eutrophication of coastal waters and estuaries. Finally, reduction of metals and toxic organics will decrease bioaccumulation in the food chain, which causes neurological and reproductive effects in fish and wildlife.

Health Benefits

Fine particulate matter poses significant health threats because it can easily reach deep into the lungs. Studies link particulate matter to a host of health problems, including premature death, aggravated asthma, and other respiratory ailments that require emergency-room care or hospitalization. The elderly are especially at risk for premature death from the effects of particulate matter. Those most at risk for respiratory impacts include the elderly, people with asthma or pre-existing heart or lung disease, and children.

> "There are several reports of associations between short-term fluctuations in ambient PM and day-to-day frequency of respiratory illnesses (6). In most cases, notably in pre-teen children, assessments have found exacerbation of pre-existing illness and related symptoms rather than de novo acute respiratory infections (7). The use of inhalers has also been shown to increase in many young asthmatics in response to air pollution in general and PM in particular."[9]

In EPA's Particulate Matter review, the following effects on the respiratory system from short-term and long-term exposures to particulate matter are discussed:

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[7] Ibid., pp 6-50.

[8] US Environmental Agency. (October, 1996). *PM Data Analysis Workbook*

[9] US Environmental Protection Agency. (July 2004). *Particulate Matter Research Program: Five Years of Progress*, pp 94. http://www.epa.gov/pmresearch/pm_research_accomplishments/pdf/pm_research_program_five_years_of_progress.pdf

> "The CD finds that the recent epidemiologic findings are consistent with those of the previous review in showing associations with both respiratory symptom incidence and decreased lung function (CD, p. 9-70). PM_{10} and $PM_{2.5}$ were associated with small decreases in lung function and increases in respiratory symptoms.…The findings from studies of physicians' office visits for respiratory offer new evidence of acute respiratory effects with exposure to ambient PM that is coherent with evidence of increased respiratory symptoms and admissions/visits to the hospital or emergency room for respiratory disease…In general…studies have indicated that long-term exposure to $PM_{2.5}$ is associated with reduced lung function…and increased risk of developing chronic respiratory illness (CD, p. 8-313)."[10]

In the same review, EPA also found that particulate matter has an impact on cardiovascular health.

> "[N]ew epidemiologic studies provide much more evidence of effects on the cardiovascular system with short-term exposure to PM, particularly PM_{10} and $PM_{2.5}$ (CD, p. 9-67). Epidemiologic studies have reported associations between short-term exposures of ambient PM (often using PM_{10}) and measures of changes in cardiac function such as arrhythmia, alterations in electrocardiogram (ECG) patterns, heart rate or heart rate variability changes, though the CD urges caution in drawing conclusions regarding the effects of PM on heart rhythm (CD, p. 8-166)."[11]

EPA has also stated that exposure to ambient PM affects the autonomic control of the heart; alters cardiac re-polarization; and can affect cardiac arrythmias and myocardial infractions.[12]

In 2002, a study by C. Arden Pope, et al, assessed the relationship between long-term exposure to ambient PM pollution and cardiopulmonary mortality.[13] The results seemed to indicate for each 10 μ/m^3 increase of $PM_{2.5}$ there was about a 6% increased risk of cardiopulmonary mortality. This study also assessed the relationship between long-term exposure to fine particulate air pollution and lung cancer, with results indicating that with each 10 μ/m^3 increase in $PM_{2.5}$ ambient air concentration there is an 8% increase in lung cancer mortality.

A press release from the National Institute of Environmental Health Sciences about this study stated:

> "Years of exposure to the high concentrations of tiny particles of soot and dust from cars, power plants and factories in some metropolitan areas of the United States significantly increase residents' risk of dying from lung cancer and heart disease…Arden Pope…the study's co-leader, said that while far less than the risks

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[10] US Environmental Protection Agency (December 2005). *Review of the National Ambient Air Quality Standard for Particulate Matter: Policy Assessment of Scientific and Technical Information*, pp 3-22 to 23.

[11] Ibid, pp 3-23 to 24.

[12] US Environmental Protection Agency. (July 2004). *Particulate Matter Research Program: Five Years of Progress.*

[13] Pope, C.A. III, et al. (2002). *Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution.* Journal of the American Medical Association 287(2002):1132-1141.

> associated with active cigarette smoking, 'we found that the risk of dying from lung cancer as well as heart disease in the most polluted cities was comparable to the risk associated with nonsmokers being exposed to second-hand smoke over a long period of time.'
>
> The study evaluated the effects of air pollution on human health over a 16-year period. Previous studies have linked soot in the air to many respiratory ailments and even death, but the new findings 'provide the strongest evidence to date that long-term exposure to fine particulate air pollution common to many metropolitan areas is an important risk factor for cardiopulmonary mortality,' as well as lung cancer deaths"[14]

Economic Benefits
Poor visibility in national parks and wilderness areas may also result in a decline in visitors, in turn affecting the socio-economic structure of the municipalities located near these areas. Tourism is a major part of the economy of regions around Class I areas, as spending in communities surrounding national park sites was approximately $10.6 billion dollars in 2001.[15] Various studies have shown that poor visibility in National Parks results in lower visitor attendance, which would decrease outside dollars coming in to these areas, and that visitors place a high value on scenic vistas.[16]

Additional economic benefits from improved visibility are linked to improved health outcomes. Incidences of asthma and other cardiopulmonary problems can cause absences from work and school and decreased productivity, as well as high medical expenses. By improving health, decreases in $PM_{2.5}$ will improve these economic indicators.

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[14] NIEHS Press Release. (2002, March 5). *Link Strengthened Between Lung Cancer, Heart Deaths and Tiny Particles of Soot, Dust.* http://www.niehs.nih.gov/oc/news/lchlink.htm

[15] Stynes, D.J. and Sun, Y. (2003). *Economic impacts of national park visitor spending on the local economy; Systemwide estimates for 2001.* Final report to the National Park Service. East Lansing MI: Department of Park, Recreation, and Tourism Resources, Michigan State University.

[16] U.S. National Park Service, Air Resources Division. *Economic Effects of Air Pollution.* http://www2.nature.nps.gov/air/AQBasics/economics.cfm and U.S. National Park Service, Air Resources Division. *Clear View: What is it worth?* http://www2.nature.nps.gov/air/AQBasics/docs/benefitsSummFinal.pdf

APPENDIX 2

Appendix 2.1(a): Legal Authority

The Iowa Department of Natural Resources (DNR) is primary state agency responsible for protecting the environment, as indicated in the Iowa Code § 455A. The Environmental Protection Commission established in the Iowa Code § 455A.6, is the governing commissions for the environmental protection portion of the DNR.

Iowa Code § 455B.133(2) provides that the Environmental Protection Commission shall "[a]dopt, amend, or repeal rules pertaining to the evaluation, abatement, control, and prevention of air pollution," and that "[t]he rules may include those that are necessary to obtain approval of the state implementation plan under section 110 of the federal Clean Air Act as amended through January 1, 1991."

Iowa Code § 455B.133(3) provides that the Environmental Protection Commission shall "[a]dopt, amend, or repeal ambient air quality standards for the atmosphere of this state on the basis of providing air quality necessary to protect the public health and welfare and to reduce emissions contributing to acid rain pursuant to Title IV of the federal Clean Air Act Amendments of 1990."

Appendix 2.1(b): Public Participation and Rulemaking Process

The DNR's rulemaking process is governed by Iowa Code § 17A, also referred to as the Iowa Administrative Procedure Act (IAPA). The IAPA details the procedures and format of state agency rulemakings. All rulemakings must be adopted within 180 days following either the published notice or the last date of the oral presentations on the proposed rule, whichever is later. Administrative rules are approved by the Environmental Protection Commission (EPC) as authorized under Iowa Code 455A.6. An example of the rulemaking process is listed below:

1. **Information:** The DNR provides an informational notice of a rulemaking to the EPC and incorporates changes requested by the EPC.
2. **Notice of Intended Action:** The DNR proposes the rulemaking through a Notice of Intended Action. A fiscal impact statement is included with this document. If approved by the EPC, the proposed rulemaking will be published in the Iowa Administrative Bulletin (IAB).
3. **Public Comment Period and Pubic Hearing(s):** The IAB indicates the length of the comment period, the agency contact, and the details of the public hearing(s). The minimum amount of time for the public comment period and public hearing date is 30 days for rules that the DNR plans to submit in a SIP revision.
4. **Initial Administrative Rules Review:** At some point during the rulemaking process, the proposed rule is reviewed by the Iowa General Assembly's Administrative Rules Review Committee (ARRC). The DNR provides an overview of the rulemaking and responds to questions at the ARRC's public meeting.
5. **Adopted and Filed:** After the close of the public comment period, the DNR returns to the EPC to request adoption of the rulemaking. A summary of public comments and responses are included with the proposed rulemaking. If adopted, the rulemaking is published in the IAB.
6. **Final Publication:** The adopted and filed rulemaking will be published in the IAB.
7. **Final Administrative Rules Review:** Upon publication of the final rulemaking, the ARRC conducts their final review at their public meeting. The ARRC does have the discretion to object to a rule. The ARRC may also delay the effective date of a proposed rule pending additional review by the Iowa General Assembly.
8. **Rule Effective:** Typically, the rulemaking becomes effective 35 days after final publication in the IAB. The DNR can propose a later effective date, if necessary.

Appendix 2.1(c) Public Notice Documents

The Des Moines Register

R473 Public Notice
Iowa Department of Natural Resources

The Iowa Department of Natural Resources (DNR) is requesting public comment on a proposed revision to the state implementation plan (SIP) to address visibility protection at national parks and scenic areas, also referred to as mandatory Class I Federal areas. The United States Environmental Protection Agency (EPA), under the authority of Section 169(a) of the federal Clean Air Act (CAA), promulgated visibility goals in the federal Regional Haze Rule on July 1, 1999, with amendments in 2005 and 2006.

This SIP revision will fulfill the requirements of Section 169(a) of the CAA. Section 169(a) of the CAA requires each state to adopt and submit a plan that addresses the state's contributions to visibility impairment at the mandatory Class I Federal areas. The mandatory Class I Federal areas were established by Congress under the 1977 Amendments to the CAA. Iowa does not have a mandatory Class I Federal area. Iowa may contribute to the visibility impairment at mandatory Class I Federal areas in Minnesota and Michigan. DNR has determined that emissions reductions of air pollutants that cause visibility impairment are not needed at this time due to existing emissions controls, the projected reductions from recently mandated requirements, and the costs associated with additional controls.

The proposed SIP revision is posted on the DNR's website at http://www.iowadnr.gov/air/prof/progdev/files/RH_SIP%20_FLM%20review.pdf. A link to the appendices is available at http://www.iowadnr.gov/air/prof/progdev/progdev.html.

Any person may make written comments on this proposed SIP revision on or before January 31, 2008. Written comments should be directed to Wendy Rains, Department of Natural Resources, Air Quality Bureau, 7900 Hickman Road, Suite 1, Urbandale, Iowa, 50322, fax (515) 242-5094, or by electronic mail to wendy.rains@dnr.iowa.gov.

A public hearing will be held on January 30, 2008, at 10:00 a.m. in the conference rooms at the DNR's Air Quality Bureau office located at 7900 Hickman Road, Urbandale, Iowa. All comments must be received no later than January 31, 2008.

Any person who intends to attend the public hearing and has special requirements such as those related to hearing or mobility impairments should contact Wendy Rains at (515) 281-6061 to advise of any specific needs.

A responsiveness summary will be prepared by the DNR following the close of the public comment period. The responsiveness summary will include any written or oral comments received during the public participation process and the DNR's response to the comments. The completed responsiveness summary will forwarded to EPA and made available to the public upon request.

AFFIDAVIT OF PUBLICATION

ERTISEMENT
it "A"

STATE OF IOWA
SS
COUNTY OF POLK

The undersigned, being first duly sworn on oath, states that she/he is the Accounting Specialist Kristi Morris of The Des Moines Register and Tribune Company, a corporation duly organized and existing under the laws of the State of Iowa, with its principal place of business in Des Moines, Iowa, the publisher of

THE DES MOINES REGISTER (Daily)

DES MOINES SUNDAY REGISTER

newspapers of general circulation printed and published in the City of Des Moines, Polk County, Iowa, and that an advertisement, a printed copy of which is attached as Exhibit "A" and made a part of this affidavit, was printed and published in The Des Moines Register (daily) on the following dates

Dec 26 2007

Subscribed and sworn to before me by said affiant this 26th day of December, 2007

Karen E. Cassels
Notary Public in and for Polk County, Iowa

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Public Hearing on Regional Haze State Implementation Plan (01-30-2008)

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Public Hearing on Regional Haze State Implementation Plan
[Jan 30, 2008 10:00 am]
Department of Natural Resources

The Iowa Department of Natural Resources (DNR) is requesting public comment on a proposed revision to the state implementation plan (SIP) to address visibility protection at national parks and scenic areas, also referred to as mandatory Class I Federal areas. The U. S. Environmental Protection Agency (EPA) promulgated visibility goals in the federal Regional Haze Rule. This SIP revision will fulfill the requirements of Section 169(a) of the federal Clean Air Act. DNR has determined that emissions reductions of air pollutants that cause visibility impairment are not needed at this time due to existing emissions controls, the projected reductions from recently mandated requirements, and the costs associated with additional controls. The proposed SIP revision and appendices are posted on the DNR's website listed below. Any person may make written comments on this proposed SIP revision on or before Jan. 31, 2008. Direct written comments to Wendy Walker, DNR Air Quality Bureau (address below), fax (515) 242-5094, or by email to wendy.walker@dnr.iowa.gov. All comments must be received no later than Jan. 31, 2008. Any person who intends to attend the public hearing and has special requirements such as those related to hearing or mobility impairments should contact Wendy Walker at (515) 281-6061 to advise of any specific needs. The DNR will prepare a responsiveness summary after the close of the public comment period. The responsiveness summary will include any written or oral comments received during the public participation process and the DNR's response to the

comments. The completed responsiveness summary will forwarded to EPA and made available to the public upon request.
Location: DNR, Air Quality office, 7900 Hickman Road, Urbandale
url: http://www.iowadnr.gov/air/prof/progdev/progdev.html
modified:

Contacts Maps Policies Translation Tools Top Hits Weather & Road Conditions Help Desk & FAQ

Walker, Wendy [DNR]

From: Iowa Air Quality Newsletter [Mindy.Kralicek@dnr.state.ia.us]
Sent: Wednesday, December 26, 2007 7:56 AM
To: Walker, Wendy [DNR]
Subject: Air List Serve for December 26, 2007

Public Notice
Iowa Department of Natural Resources

The Iowa Department of Natural Resources (DNR) requests public comment on a proposed revision to the state implementation plan (SIP) to address visibility protection at national parks and scenic areas, also referred to as mandatory Class I Federal areas. The United States Environmental Protection Agency (EPA), under the authority of Section 169(a) of the federal Clean Air Act (CAA), promulgated visibility goals in the federal Regional Haze Rule on July 1, 1999, with amendments in 2005 and 2006.

This SIP revision will fulfill the requirements of Section 169(a) of the CAA that requires each state to adopt and submit a plan that addresses the state's contributions to visibility impairment at the mandatory Class I Federal areas. The mandatory Class I Federal areas were established by Congress under the 1977 Amendments to the CAA . Iowa does not have a mandatory Class I Federal area.

Iowa may contribute to the visibility impairment at mandatory Class I Federal areas in Minnesota and Michigan . DNR has determined that emissions reductions of air pollutants that cause visibility impairment are not needed at this time due to existing emissions controls, the projected reductions from recently mandated requirements, and the costs associated with additional controls.

The proposed SIP revision is posted on the DNR's website at http://www.iowadnr.gov/air/prof/progdev/files/RH_SIP%20_FLM%20review.pdf . A link to the appendices is available at http://www.iowadnr.gov/air/prof/progdev/progdev.html .

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A public hearing will be held January 30, 2008 at 10:00 a.m. in the conference rooms at the DNR's Air Quality Bureau office located at 7900 Hickman Road, Urbandale, Iowa. All comments must be received no later than January 31, 2008.

Any person who plans to attend the public hearing and has special requirements such as those related to hearing or mobility impairments should contact Wendy Walker at (515) 281-6061 to advise of specific needs.

A responsiveness summary will be prepared by the DNR following the close of the public comment period. The responsiveness summary will include written or oral comments received during the public participation process and the DNR's response to the comments. The completed responsiveness summary will forwarded to EPA and made available to the public upon request.

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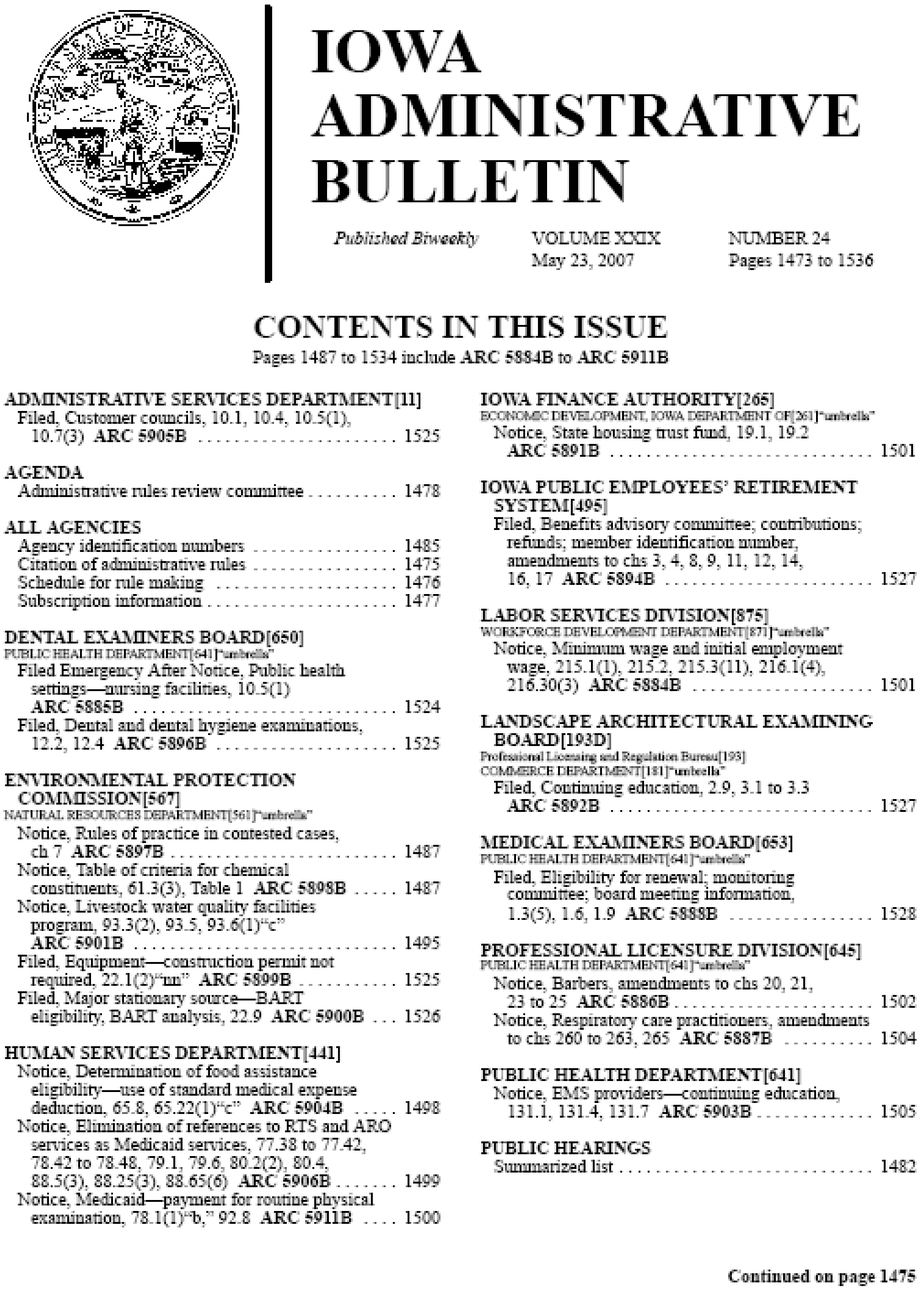
Appendix 2.1(d) Iowa Adminstrative Bulletin



IOWA ADMINISTRATIVE BULLETIN

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quently vented through a vent or stack. These facilities are considered stationary sources by definition, and the Department has the authority through the construction permitting process to regulate the emissions from the facilities.

The Department has historically not sought construction permit applications for emission points at agricultural and construction equipment repair facilities and dealerships that are only exhausting emissions from mobile internal combustion engines. The Department reviewed the technical validity of exempting emissions from agricultural and construction equipment mobile internal combustion engines at repair facilities and dealerships from the requirement to obtain a construction permit. Based on emissions and operating information obtained from the workgroup, the Department is exempting emissions from agricultural and construction equipment mobile internal combustion engines at non-major repair facilities and dealerships from the requirement to obtain a construction permit. This amendment is expected to have little or no environmental or human health consequences.

All construction permitting exemptions apply only to the requirement to obtain an air construction permit. The owner or operator of a facility retains the obligation to determine whether other air quality requirements apply to exempted equipment or processes and to meet those requirements, if applicable.

The amendment to subrule 22.1(2) adds a new paragraph "nn" that exempts emissions from agricultural and construction mobile internal combustion engines that are operated for repair or maintenance purposes at equipment repair shops and equipment dealerships that are not major sources as defined in rule 567—22.100(455B).

This amendment is intended to implement Iowa Code section 455B.133.

This amendment will become effective on June 27, 2007.

The following amendment is adopted.

Amend subrule **22.1(2)** by adopting <u>**new**</u> paragraph **"nn"** as follows:

nn. Emissions from mobile agricultural and construction internal combustion engines that are operated only for repair or maintenance purposes at equipment repair shops or equipment dealerships, and only when the repair shops or equipment dealerships are not major sources as defined in rule 567—22.100(455B).

[Filed 5/3/07, effective 6/27/07]
[Published 5/23/07]

EDITOR'S NOTE: For replacement pages for IAC, see IAC Supplement 5/23/07.

ARC 5900B

ENVIRONMENTAL PROTECTION COMMISSION[567]

Adopted and Filed

Pursuant to the authority of Iowa Code section 455B.133, the Environmental Protection Commission hereby amends Chapter 22, "Controlling Pollution," Iowa Administrative Code.

The purpose of the amendments is to adopt the federal Regional Haze Regulations and to implement the Best Available Retrofit Technology (BART) portion of the regulations.

Notice of Intended Action was published in the Iowa Administrative Bulletin on January 31, 2007, as **ARC 5695B**. A public hearing was held on March 2, 2007. No comments were presented at the hearing or during the public comment period. The public comment period closed on March 5, 2007. There have been no changes made to the Notice of Intended Action.

Previous federal regulations addressed visibility impairment attributable to specific sources near Class I areas and in Class II areas. Class I areas include national parks and wilderness areas while Class II areas are areas where businesses and industries are located. The 1999 federal Regional Haze Regulations address visibility impairment resulting from air pollution transported hundreds of miles and attributable to the cumulative emissions from widely distributed sources. Regional haze is visibility impairment caused by tiny particles that absorb and scatter sunlight, giving the sky a veil of white and brown haze.

The federal Regional Haze Regulations are mandated by the federal Clean Air Act (Clean Air Act, Section 169(a), as codified in 40 CFR 51.301, 51.308). The Department must comply with the Regional Haze Regulations by December 2007.

The amendments are the second part of a two-part rule making. The Department previously amended Chapter 22 (**ARC 4061B**, Iowa Administrative Bulletin, March 16, 2005) to specify the criteria and process for an owner or operator of a major stationary source to provide information necessary for the Department to identify sources of air pollution potentially subject to the Best Available Retrofit Technology (BART) emission control requirements established by the federal Regional Haze Regulations. Due to a lack of certainty regarding aspects of the unfinalized federal guidelines for the BART provisions of the Regional Haze Regulations, the Department proposed a two-part rule-making process.

This rule making establishes the process by which the Department will notify the owner or operator of a stationary source of air pollution whether the source is BART-eligible and whether the source needs to perform a BART analysis. This rule making defines the criteria that establish a BART source's contribution to regional haze. The Department will use these criteria as a basis for requiring a BART-eligible source to perform a BART analysis. The Department has met with a group of representatives from potential BART-eligible sources regarding the BART requirements and the time line required by the federal regulations for implementation.

This rule making also establishes a notification process for purposes of the federal Regional Haze Regulations. The initial regional haze implementation plan is due in December 2007. Every five years thereafter, a periodic review must be completed, and every ten years thereafter, a comprehensive revision is required. The Department will continue to work with stakeholders and regional planning partners as the Department works toward meeting regional haze goals.

Item 1 establishes definitions.

Item 2 adopts a modified list of stationary source category criteria for BART-eligible boilers. Previously, the criteria applied to one or more boilers that total more than 250 million Btu's per hour of combined heat input. The new BART criteria regulate boilers that individually total 250 million Btu's per hour heat input.

Item 3 specifies the Department's responsibility to notify source owners or operators of the requirements for the submission of a BART analysis if such an analysis is requested by the Department. Item 3 also outlines the additional analyses and control requirements for stationary sources that may be requested by the Department during state implementation plan development and the periodic reviews and updates required by the federal Regional Haze Regulations.

These amendments are intended to implement Iowa Code section 455B.133.

These amendments will become effective on June 27, 2007.

EDITOR'S NOTE: Pursuant to recommendation of the Administrative Rules Review Committee published in the Iowa Administrative Bulletin, September 10, 1986, the text of these amendments [22.9(1) to 22.9(7)] is being omitted. These amendments are identical to those published under Notice as **ARC 5695B**, IAB 1/31/07.

[Filed 5/3/07, effective 6/27/07]
[Published 5/23/07]

[For replacement pages for IAC, see IAC Supplement 5/23/07.]

ARC 5894B

IOWA PUBLIC EMPLOYEES' RETIREMENT SYSTEM[495]

Adopted and Filed

Pursuant to the authority of Iowa Code sections 97B.4 and 97B.15, the Iowa Public Employees' Retirement System (IPERS) hereby amends Chapter 3, "Benefits Advisory Committee," Chapter 4, "Employers," Chapter 8, "Service Purchases," Chapter 9, "Refunds," Chapter 11, "Application for, Modification of, and Termination of Benefits," Chapter 12, "Calculation of Monthly Retirement Benefits," Chapter 14, "Death Benefits and Beneficiaries," Chapter 16, "Assignments," and Chapter 17, "Public Records and Fair Information Practices," Iowa Administrative Code.

The following paragraphs itemize the amendments.

Item 1 discontinues the practice of listing specific membership organizations of the Benefits Advisory Committee (BAC).

Item 2 improves readability and clarifies effective dates for regular class member contributions.

Item 3 implements new contribution rates for special service members as provided by the Legislature, effective July 1, 2007.

Item 4 updates prior contribution rates for special service members.

Item 5 implements changes to the Pension Protection Act of 2006 that authorize defined benefit plans such as IPERS to accept direct rollover service purchases which include after-tax amounts.

Item 6 updates the implementation sentence in Chapter 8.

Item 7 removes the requirement for notarization of a member's signature when a refund is requested.

Item 8 reinstates the requirement that the employer certify the last pay date, unless the member has been out of IPERS covered employment for more than one year.

Item 9 implements provisions of the Internal Revenue Code which prohibit certain members who were previously covered under IPERS and then opted to be covered under an alternative retirement plan of a covered employer from receiving a refund of the IPERS account while employed by an IPERS covered employer even if the current position is not IPERS covered.

Item 10 adds the clarifying term "calendar" for purposes of defining a bona fide retirement period for licensed health care professionals.

Item 11 makes the administrative fees for multiple rollovers applicable to nonspouse beneficiaries who become eligible to make direct rollovers under these rule changes.

Item 12 authorizes IPERS to make direct rollovers under the more flexible provisions of the Pension Protection Act of 2006.

Item 13 updates the implementation sentence in Chapter 12.

Item 14 adds IPERS Option 6 to the list of options for members to designate a new beneficiary for the period of reemployment.

Item 15 clarifies that IPERS distributions to a member's estate include distributions to an executor or administrator approved under Iowa Code chapters 633 and 635.

Item 16 implements provisions of the Pension Protection Act of 2006 and IRS Notice 2007-7 regarding direct rollovers by nonspouse beneficiaries.

Item 17 updates the implementation sentence in Chapter 14.

Item 18 integrates the use of a member identification number for the filing of domestic relations orders.

Item 19 clarifies that the hold placed on a member's account following notice of a dissolution of marriage will be released if one year passes in which no further contacts are made by the parties.

Items 20 and 21 incorporate the use of the member identification number for requests for information.

Notice of Intended Action was published in the Iowa Administrative Bulletin on March 28, 2007, as **ARC 5804B**. A public hearing was held on April 17, 2007. No one attended the public hearing, and no written comments were received. There was one typographical error noted in Item 16 in the last line of the new rule as published under Notice. The acronym appears as "IRS" but should be "IRA." The error has been corrected in the adopted rule.

There are no waiver provisions included in the amendments.

These amendments are intended to implement Iowa Code sections 97B.4 and 97B.15.

These amendments will become effective June 27, 2007.

EDITOR'S NOTE: Pursuant to recommendation of the Administrative Rules Review Committee published in the Iowa Administrative Bulletin, September 10, 1986, the text of these amendments [amendments to Chs 3, 4, 8, 9, 11, 12, 14, 16, 17] is being omitted. With the exception of the change noted above, these amendments are identical to those published under Notice as **ARC 5804B**, IAB 3/28/07.

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[For replacement pages for IAC, see IAC Supplement 5/23/07.]

ARC 5892B

LANDSCAPE ARCHITECTURAL EXAMINING BOARD[193D]

Adopted and Filed

Pursuant to the authority of Iowa Code section 544B.5, the Landscape Architectural Examining Board hereby amends

Appendix 2.1(e):
PUBLIC PARTICIPATION RESPONSIVENESS SUMMARY

For the Regional Haze SIP

Introduction

The public notice was published in the Des Moines Register on December 26, 2007. The notice was also listed on the State of Iowa Public Meeting Calendar. The public hearing was held on January 30, 2008. Comments received from the FLMs were available during the public hearing. No comments were received at the public hearing. Three written comments were received before the public comment period closed on January 31, 2008. A summary of the comments and the Department's responses to the comments is provided below.

Each comment is followed by the Department's responses to the comments, and a description of any changes to the draft SIP being made in response to the comments.

Comments from the USDA Forest Service (FS)

FS-1) Comment: In their issues letter to Iowa, Minnesota lists Iowa as a significant contributor to visibility impairment in Voyagers National Park and the Boundary Waters Canoe Area Wilderness. The draft SIP states that collectively Iowa sources are responsible for a minimal contribution to visibility impairment at the above Northern Midwest Class I areas, and offer little in terms of potential visibility improvement. Even though Iowa is some distance away from the Minnesota Class I areas, the latest Midwest Regional Planning Organization (MRPO) modeling shows Iowa is the third largest contributing state. The draft SIP states Iowa must demonstrate that its implementation plan includes all measures necessary to obtain its share of emissions reductions needed to meet reasonable progress goals. We feel the final SIP should discuss the consultation Iowa has had with Minnesota regarding this apparent disagreement regarding Iowa's approach to reasonable progress in relation to their share of emission reductions.

Department Response

If classified only by total statewide contribution rank, Iowa's contributions may be characterized as significant as they may appear in the top three to five of the contributing states. Additional perspective is provided when statewide contributions are considered in an absolute sense (light extinction measured in inverse megameters). In these terms Iowa's contributions are in the 2-3 inverse megameter range in both the Central States Regional Air Planning Association (CENRAP) and MRPO modeling. Within the CENRAP modeling, this translates to approximately a 4% contribution to visibility impairment in 2018. Regarding the most recent MRPO modeling, it should be noted that it was completed using 2005 as the base year, while the CENRAP modeling utilized the standard 2002 base year. The 2005 Iowa point source emissions inventory utilized by the MRPO was grown from 2002 data. Iowa's 2005 point source emissions estimates generated by the MRPO have not received the same level of scrutiny from the Department as applied to the CENRAP inventory. Despite the variability in base year, both the MRPO and CENRAP modeling yield contributions from Minnesota sources which exceed Iowa's contributions in both the base year and future year scenarios. Additionally, contributions from Michigan sources considerably exceed Iowa's contributions in two of the four Class I areas in both 2002 and 2018. Accordingly, participation in Clean Air Interstate Rule (CAIR) and the associated anticipated reductions in Iowa electrical generating unit (EGU) SO2 and NOx emissions is a reasonable approach sufficient to achieve our share of emissions reductions during this first round of regional haze SIPs.

The Department's position has been voiced in the Northern Class I areas consultation calls, as well as through informal conversations at RPO functions, outside other meetings, and over the phone communications.

As indicated on page 92 of the draft Minnesota Regional Haze SIP released to the Federal Land Mangers in February 2008, Minnesota is not asking contributing states to make commitments. "It should be noted that although modeling was done to evaluate the visibility conditions if the contributing States commit to certain control strategies that Minnesota has deemed to be potentially reasonable, Minnesota is not yet asking the contributing States to make such commitments. Instead, Minnesota has simply asked the contributing States to look at the reasonableness of those control strategies that could improve visibility in Minnesota's Class I areas."

Recommended Action
No action recommended.

FS-2) Comment: The draft SIP states that the Department's long-term strategy is sufficient to meet the anticipated reasonable progress goals (RPG) for Class I areas which may be affected by emissions from Iowa sources. This statement seems contradictory given the details of Minnesota's issues letter. We feel that Iowa should provide a response and explanation to the details of Minnesota's issues letter, including: 1) considering further reductions of sulfur dioxide (SO2) from EGUs; 2) conducting a more detailed review of potential emissions reductions from industrial, commercial, and institutional (ICI) boilers and reciprocating engines and turbines; 3) contributing states with higher emission rates should evaluate potential control measures, or show why such reductions are not reasonable; and 4) any additional control measures found to be reasonable should be included in the SIP or the Five Year SIP review in an enforceable form. Without an assessment of visibility improvement based on these specific measures, it is difficult to determine whether these controls would yield significant improvement. It would be helpful for Iowa to clarify what level of visibility improvement they would consider significant, and document consultation with Minnesota regarding this level as Iowa's rejection of their issues could affect their achievement of reasonable progress goals.

Department Response
The Department's letter responding to the Minnesota issues letter (see Appendix 10.1, p. 52-54) documents and discusses each of the four Minnesota issues referenced by the commenters. A narration of this correspondence is provided in the paragraph below. Additionally, the source apportionment results discussed in section 11.2 of the draft SIP provide an extended examination of potential visibility impacts attributable to Iowa sources. An in-depth modeling review is not needed at this time in light of projected costs and contribution levels discussed in Chapters 10

and 11 of the draft SIP. Defining a specific value of visibility contribution which the Department would consider significant is not practical, given the yet unknown reductions anticipated through CAIR.

The following issues support the Department's conclusion that our long-term strategy is sufficient : 1) implementation of CAIR; 2) the extensive distances between Iowa sources and the Minnesota Class I Areas; 3) control costs across the nine state region reaching well into the billions of dollars per deciview improvement; and 4) a state-wide total contribution to visibility impairment at only around 5 percent.

Recommended Action
Chapter 12 of the draft SIP will be updated to explicitly state that the Department will review changes in the emission inventory as part of the five year SIP assessment, and will fulfill the periodic reporting requirements of § 51.308(g) and determine if additional action is needed according to § 51.308(h).

FS-3) Comment: The draft SIP states that the deciview values averaged over the 20% worst days demonstrate that Iowa's modeled 2018 contributions are imperceptible by a human observer. We believe the data presented does not support that conclusion. Iowa should evaluate all the days in a year individually to capture all the winds that can transport pollutants from Iowa. Iowa's Best Available Retrofit Technology (BART) analysis took this approach and found that Iowa's BART-eligible sources alone show maximum impacts over 4 deciviews.

Department Response
The regional haze rule requires that the impairment level be calculated through an average of the deciview values over the 20 percent worst days (64 FR 35728). Subsequently the Department's analysis focuses on the 20 percent worst days.

The requested method of examining daily impacts does not eliminate the question of human perceptibility. True visibility impacts, as perceptible to a human observer, requires instantaneous values, data which are not available through current regional modeling methods.

Regarding the comment that the BART analysis showed maximum impacts over 4 deciviews, it must be clarified that the BART analysis was required to compare visibility impacts against natural background conditions. The remainder of the Regional Haze SIP requires comparing impacts against current and estimated 2018 visibility conditions, not natural background conditions. It is not appropriate to compare the BART evaluation results, which utilize pre-industrial revolution estimated natural background conditions, against all other methods which utilize current or estimated 2018 impairment conditions.

Recommended Action
No action recommended.

FS-4) Comment: The draft SIP states that the CENRAP and Minnesota/MRPO modeling substantiate that Iowa sources can not effect visibility improvement at the Northern Midwest Class I areas without disproportionate and costly levels of control. We do not understand the basis for this statement. We feel the costs are commensurate with control costs related to other EPA regulations. The latest MRPO modeling shows Iowa to be the third largest contributing state. Additional explanation in the SIP is warranted to help clarify Iowa's reasoning.

Department Response
It is difficult to conduct a balanced control cost comparison when the EPA regulations mentioned in the comment were not specifically identified. Assuming the control costs related to other EPA regulations were developed in response to aspects of the national ambient air quality standards (and costs are in the range of several hundred to a couple thousand dollars per ton), previous costs estimates would have been evaluated against health benefits. The regional haze rule was developed in response to visibility goals, not health related mandates. Comparing costs between visibility goals and health impacts is not equitable.

Commensurate with the regional haze rule requirements for establishing reasonable progress goals, the Department considered the costs of controls in tandem with their potential for visibility improvement. Evaluating controls on a dollar per ton basis alone does not sufficiently justify their installation. Examining the Four Factor analysis report, the EGU cost effectiveness, in terms of dollars per deciview, across the nine-state region reached $2,994,000,000. This is 83% of the total estimated costs of $3,600,000,000 for CAIR. Coupling these values with both the latest MRPO and CENRAP contribution analyses that link all Iowa point sources to approximately a 1 - 2 Mm^{-1} contribution in 2018, the statements are justified.

Recommended Action
No action recommended.

FS-5) Comment: The draft SIP focuses on their contribution to visibility impairment on the 20% worst days but does not discuss the contribution to Class I areas on the 20% cleanest days. Please consider including discussion of the 20% cleanest days in the SIP.

Department Response
The modeling has consistently shown that there is no degradation on the 20% cleanest days. This information can be found in Appendix 7. Discussion of the 20% cleanest days would add little value to the SIP.

Recommended Action
No action recommended.

FS-6) Comment: Iowa cites participation in CENRAP, a regional planning organization or RPO, as the primary means for consultation with the federal land mangers and other states. How will Iowa continue to consult if the RPOs fail to exist? Will other consultation groups' conference calls continue and, if so, will Iowa continue to participate, and with what frequency?

If these calls will not continue, who will consult with whom, when, how, and what procedures will be followed. Since the majority of actions relied on in the future by Iowa to reduce haze will be for $PM_{2.5}$ and ozone, how will the federal land managers (FLMs) be consulted during that process? The SIP should outline a process for addressing these consultation concerns.

Department Response
The Northern Class I areas consultation calls are organized by the states containing the Class I areas (Michigan and Minnesota) and benefit from the support structure and funding of the RPOs. Consultations involving the Department and other states with Class I areas located in CENRAP have followed a similar approach.

The RPOs were developed specifically by EPA to address the requirements of regional haze and have provided a mechanism through which consultation is best addressed. The level of funding apportioned to support the RPOs can be construed as an indicator of EPA's commitment to congressional visibility goals. Elimination of the RPOs will undoubtedly hamper inter-organizational consultation, including coordination among States, Tribes, and FLMs. In the absence of the RPOs, Iowa can only commit to meeting the minimum requirements associated with consultation and coordination through correspondence and informal verbal communication during ten year SIP revisions and similar means of consultation as are warranted during the five year review.

Recommended Action
The Department will revise Chapter 4 of the draft SIP to include procedures to be used for continued consultation with the FLMs.

FS-7) Comment: We found no specific discussion in the draft SIP that considered contingency measures or procedures which could be triggered if the unexpected or unforeseen occurs. Are there adaptive management strategies or increased review strategies which could be implemented if emission inventory errors are discovered, or projected emissions reductions do not materialize? What will be done in five years if Iowa is over their projected emissions inventory? The SIP should provide a contingency plan to address these concerns.

Department Response
The Department cannot begin to discuss all possible unexpected and unforeseen events and the corresponding contingency measures nor can appropriate actions be designed at this time. The Department will utilize the five year review process and the ten year SIP revision provisions required in the regional haze rule to address these issues as appropriate. Depending on the findings of the five-year progress report, IDNR committed in Chapter 13 of the draft SIP to taking one of the actions listed in 40 CFR § 51.308(h). The findings of the five-year progress report will determine which action is appropriate and necessary.

Recommended Action
No action recommended.

FS-8) Comment: We feel Iowa should include language in their SIP making the link between the Regional Haze, the New Source Review (NSR) programs, and continued FLM coordination. We believe there needs to be a clear mechanism in the SIP to account for this growth. There is no mechanism in the SIP to ensure that the emissions from new stationary sources and major modifications will be consistent with making reasonable progress toward the national visibility goal (40 CFR 51.307) in neighboring Class I areas. How can Iowa continue to permit new sources and not jeopardize the RPGs in the neighboring Class I areas?

Department Response
The Department currently notifies the appropriate FLM in writing of proposed major source or major modifications that may affect a Class I area and requires applicants to submit ambient impact assessments for Class I areas consistent with the Prevention of Significant Deterioration (PSD) regulatory requirements for the review of impacts on Class I areas. This practice will continue in the future.

The PSD program does not currently require that emissions from a proposed major source or major modification be evaluated during the permitting process to determine whether the proposed emissions will interfere with reasonable progress goals. The Regional Haze Rule also does not prohibit stationary source growth and provides that the emissions changes from major stationary sources and modifications to existing major sources be considered at the five year review. The need to add additional controls to achieve the reasonable progress goals can be reviewed at the 5 year interval and evaluated in the context of all the emissions changes made throughout the region during the period since the first SIP submittal and adjusted as necessary for the 10-year SIP update.

The Department believes that this approach, in combination with the continued application of Best Achievable Control Technology requirements in the PSD permitting process, provides an adequate regulatory mechanism that is consistent with making reasonable progress towards visibility goals in nearby Class I areas.

Recommended Action
The expanded language in Chapter 4 resulting from the recommended action for comment FS-6 includes language addressing continued coordination with FLMs regarding PSD projects. No additional actions are recommended.

FS-9) Comment: We believe it would be valuable to identify in this SIP the source categories and/or individual emission units in Iowa that are likely to be able to add controls most cost effectively in the future. This list can be used as a starting point if actual emissions in the future exceed predictions and thereby threaten Iowa's commitments under reasonable progress.

Department Response
Including a list of sources or source categories in the SIP that could be evaluated for future controls would likely not be useful as source characteristics are not permanent and control costs are dynamic over time. The Department will evaluate actual emissions in relation to projected emissions during the 5-year review.

Recommended Action
No action recommended.

FS-10) Comment: The draft SIP states that the control costs in the MRPO Four Factor Analysis report and CENRAP Alpine Geophysics spreadsheet are unreasonable. Costs in the Four Factor analysis work, and in the Alpine Geophysics control costs documents, have costs that are within ranges used by other EPA programs. The Alpine Geophysics control costs spreadsheet identified individual emissions units that could install SO2 and/or NOx controls at less than $1,000 per ton. It would be helpful if Iowa would clarify what their cost effectiveness threshold is. Additionally, Iowa states that its industries do not agree the costs are accurate, but did not independently evaluate the stakeholder claims that control costs may be underestimated.

Department Response
The Department can not identify an equitable cost effectiveness threshold which is measured in dollars per ton. The degree to which costs may be reasonable should not be calculated on a dollar per ton basis alone. The potential for visibility improvement is needed to complete an equitable cost analysis, such as provided by dollar per deciview cost estimates. Additional information further clarifying the Department's interpretations and decisions are provided in response to comment FS-4 above and comment NPS-3 below.

The claims made by stakeholder groups that costs provided in the EC/R and Alpine documents were included to provide an additional viewpoint. The Department has not relied upon this information to reach any determination. The industry claims that the costs are too low have not been refuted by any source and are supported by recent increases in labor and steel prices.

Recommended Action
No action recommended.

FS-11) Comment: Minnesota has clearly identified Iowa sources as contributing to visibility impairment at their Class I areas. Iowa's long term strategy should address measures it could take to meet its share of emissions reductions necessary to meet the RPGs of these Class I areas. Iowa should consider all sources, not just EGUs, which were the focus in this draft SIP. For example, the Alpine Geophysics spreadsheet identified numerous non-EGU sources in Iowa with cost effective control scenarios for NOx.

Department Response
As previously stated, the identification of reasonable controls within the long term strategy can not be determined on a dollar per ton cost alone but must consider the potential for visibility improvement. As discussed in Section 11.2 of the draft SIP, of those Iowa emissions which yield a quantifiable visibility impact at the Minnesota Class I areas, EGU SO2 emissions are clearly the dominant source, therefore Iowa has chosen to focus on these emissions. Controlling other sources would only address facilities with low visibility impact potentials.

Recommended Action
No action recommended.

FS-12) Comment: The draft SIP discusses emissions predictions for EGUs made by the Integrated Planning Model (IPM) and the uncertainty in the model's predictions. We feel that Iowa should discuss how it will address inconsistencies between the model and the actual emissions in the future. We also feel a deadline for this evaluation should be included in this SIP.

Department Response
Differences between predicted EGU emissions and actual emissions will be assessed during the five year review and subsequent ten year SIP revisions. Unexpected trends or deviations from anticipated or expected growth and control measures will be discussed and evaluated. Appropriate actions for EGU responses that do not correlate with previous IPM predictions are best determined nearer the time they may be required given the complex interactions governing emissions and visibility impairment relationships.

Due to the staggered timeline of CAIR and the complex dynamics at work in a market-driven program, a deadline for review is not appropriate. The Department will comply with the regional haze rule five and ten year periodic review requirements, including a review of emissions inventory changes, (see the Department's response to comment FS-2 for additional information).

Recommended Action
No additional action recommended.

FS-13) Comment: We are unclear of the basis of the statement that through CAIR, Iowa EGUs are anticipated to reduce not only ozone season nitrous oxides (NOx) emissions but annual emissions of SO2 and NOx. Conflicting information is presented in different parts of the draft SIP. If Iowa is going to rely on the IPM 3.0 projection as part of its baseline inventory, we feel that point should be clarified.

Department Response
The Department believes that additional clarification is necessary. The Department discussed known problems associated with the data in Table 7.2 of the draft SIP and supported the use of IPM 3.0. Chapter 7, p. 24 of the draft SIP contains a narrative of several problems affecting the 2018 EGU SO2 emission rates listed in Table 7.2. Chapter 11 of the draft SIP not only refers to the IPM v 2.1.9 data as outdated but provides a substantial discussion on why "Both EPA and IDNR therefore consider the IPM v3.0 results to be technically superior to those of IPM v2.1.9."

Recommended Action
Chapter 7 of the draft SIP has been updated to further clarify the Department's concerns with IPM v2.1.9 and to support the use of IPM v3.0.

FS-14) Comment: Under section 10.1.4, Energy and non-air quality environmental impacts of compliance, we encourage Iowa to include the environmental and health benefits of installing additional controls. The Four Factor Analysis report notes that the health benefits of reducing SO_2 and NOx emissions are generally expected to outweigh the costs of control.

Department Response
The health benefits of reducing SO2 and NOx emissions that may result from the implementation of CAIR were evaluated and discussed at length in EPA's technical support documents for CAIR. These technical support documents are available as a part of public record; therefore, the Department does not believe that it is necessary to include discussion of possible health benefits resulting from CAIR in the regional haze SIP.

Consideration of the health benefits resulting from the installation of additional controls for regional haze purposes is not a required element of the four factor analysis. Appropriately, there is also no federal requirement to include a discussion of health related issues within a regional haze SIP.

Recommended Action
No action recommended.

FS-15) Comment: A letter was sent on June 20, 2007, regarding the BART portion of the SIP. The Forest Service has no additional comments at this time.

Department Response
N/A.

Recommended Action
No action recommended.

FS-16) Comment: Additional thought should be put into alternative resources for supporting monitoring should federal funds be cut.

Department Response
Iowa does not have a Class I area, and therefore has no monitoring obligation for regional haze. Federal funds provide for the background monitoring that is being conducted in Iowa. Iowa will continue to provide monitoring commensurate with federal funding and stakeholder support.

Recommended Action
No action recommended.

FS-17) Comment: It is unclear how Iowa will make the adequacy determinations for the purposes of the Five Year Progress Report. What data will be looked at and what decision thresholds will be used? How will Iowa determine if any inadequacy is due to emissions from Iowa or other states/areas?

Department Response
The Department can not identify in 40 CFR 51.308(h) or elsewhere a requirement that the initial regional haze SIP must identify methods, data, or decision thresholds which will be used to complete the adequacy determination during the five year review. When the adequacy determination is made during the five year review process, appropriate methods, such as methods contained within EPA guidance documents, if available, will be followed.

Recommended Action
No action recommended.

Comments from the National Park Service (NPS)

NPS-1) Comment: Baseline, Natural Condition, and Uniform Rate

The draft SIP contains a discussion regarding "Consultation regarding the visibility metrics" and concludes that IDNR coordinated with States and Tribes containing Class I areas. Iowa should confirm that it accepts the values developed through national consensus, or any modifications of those national data done by States for specific mandatory Federal Class I areas within those States.

Department Response
The uniform rate of progress for each Class I area is derived from the baseline conditions and estimated natural background conditions. According to the provisions of 40 CFR 51.308(d)(2), those States containing a Federal Class I area must determine baseline and natural background conditions. Class I area monitoring requirements also are fulfilled by those States containing a Class I area. The Department believes a State containing a Class I area is in the best position to determine baseline and natural conditions, and the resultant uniform rate of progress. During the Northern Class I Area consultation calls, baseline and natural background visibility conditions were discussed. The Department believes data adjustments to account for anomalies such as filling monitoring data gaps, correcting for bias, or making site-specific assumptions about natural conditions, are best determined by the State containing a Class I area, in coordination with the EPA Administrator or his or her designee. Based on these considerations, the Department has no objection to the values developed.

Recommended Action
No action recommended.

NPS-2) Comment: Emissions Inventories

The draft SIP notes major uncertainties associated with future year EGU SO2 emissions. We are concerned that even after the State's modification of EGU emissions rates, the EGU SO2 emissions are forecast to increase (see p. 22 -24 of the draft SIP). This increase appears inconsistent with Iowa accomplishing its "fair share" toward reducing sulfate impacts at Class I areas in Minnesota. Later in the document IPM 3.0 projections are discussed. It is unclear whether the State is adopting the IPM 3.0 run as its best projection for future emissions from EGUs. If so, the materials on p 22-23 would need to be updated. The SIP should explicitly address actions the state will take in its five year review to address any changes from projected emissions reduction between 2002 and 2018, specifically for the EGU sector. In addition, the SIP should explain how the State will evaluate future emissions under its new source review and prevention of significant deterioration program in light of overall emissions reductions goals of the regional haze program.

Department Response
The 2018 EGU SO2 emissions data provided in Table 7.2 (p. 23) is derived from outdated and inaccurate EGU emissions forecasts (IPM v2.1.9). While the Department does not support the use of the outdated EGU emissions forecasts in determining fair share emissions reductions, and does not rely upon the data in Table 7.2 in any long term strategy determination, it would be inappropriate to update Table 7.2 to reflect the more recent IPM 3.0 results because the existing data are provided to be representative of the emissions rates modeled by CENRAP The Department's support of using IPM 3.0 predictions in lieu of IPM 2.1.9 projections are further discussed in response to comment FS-13.

The NPS requests that the SIP explicitly address actions that will be taken under the five year review to address any changes from projected emissions (especially EGUs) between 2002 and 2018. This comment is addressed in the Department's response to comment FS-12, related responses are also available in response to comment FS-7.

Consideration of future emissions permitted through the New Source Review and PSD programs were discussed in response to comment FS-8.

Recommended Action
No additional action recommended.

NPS-3) Comment: Reasonable Progress Goals and Long Term Strategy (including BART)
Given the limited change in emissions projected between 2002 and 2018, IDNR should have further explored specific strategies on all sources, including BART and CAIR EGU sources. Such an examination may indicate which existing EGU facilities would be most effective in supporting neighboring States' visibility goals and provide incentives for those facilities subject to CAIR to be a priority for installation of control equipment.

A reasonable progress assessment should review all sources not just EGUs. IDNR quotes industry issues with the Alpine Geophysics control costs work, but does supply specific information to support the industry claims.

IDNR should explore specific sources within an "area of influence" for at least the Minnesota Class I areas for any cost effective controls for SO2 and NOx, based on dollars spent per ton.

Costs in the range of CAIR should be seriously considered "reasonable" and made part of the regional haze SIP.

Iowa's percentage contribution to visibility impairment at the four mandatory Federal Class I areas of the Northern Midwest increases between 2002 and 2018 (see page 39), which means Iowa's emissions management plan is not keeping pace with neighboring states. In addition, the discussion focuses on the worst days, a similar review should be evaluated for the best days to assures Iowa's emissions changes are not disproportionately affecting the cleaner days in the future.

Department Response

The Department disagrees that additional strategies should be focused on BART or CAIR-affected EGU sources. The Department's BART technical support documentation (Appendix 9.1) discusses non-EGU BART sources in detail, and demonstrates they provide no potential for achieving any reasonable improvement in visibility impairment.

The Department does not agree that it would be appropriate to seek additional controls from CAIR affected EGUs at this time, and discusses this issue above, for example, in responses to comments FS-1, FS-2, and FS-4. It is also unreasonable to explore additional controls on non-EGU sources. The reasoning for this conclusion is discussed above in response to FS-2 and FS-11. Industry claims regarding undervalued controls costs are discussed in response to comment FS-10.

The Department disagrees that control costs need to be evaluated on a dollar per ton threshold for sources within an area of influence. The EPA recognizes that use of dollar per ton thresholds can be ineffective in identifying reasonable controls. For example, the most recent EPA guidance (*Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program, June 1, 2007)* suggests the use of dollars per deciview metrics. The Department has concluded that dollar per ton estimates are inadequate in the determination of reasonable controls to reduce visibility impairment.

The comments suggest that Iowa emissions reductions are not keeping pace with neighboring states. In fact, both Minnesota and Michigan yield an increase in visibility contributions between 2002 and 2018. Additionally, changes in Iowa's percentage contributions to visibility impairment between 2002 and 2018 were based upon CENRAP modeling, which utilizing the outdated and technically inferior IPM v2.1.9 EGU predictions. The updated IPM 3.0 results in EGU SO2 emissions reduction of 15% and a 27% reduction in EGU NOx emissions, as compared with 2002. These reductions are averaged across an entire year.

Examining State specific impacts on the 20% best days would add little value to SIP as CENRAP modeling currently shows no degradation occurs on the 20% best days. See the response to comment FS-5.

Recommended Action

Table 11.1 of the draft SIP has been updated to demonstrate that Iowa's increase in percentage contribution to visibility impairment between 2002 and 2018 is not unique.

NPS-4) Comment: Verification and Contingencies
The SIP relies upon CAIR to address Iowa's impacts at Class I areas, yet the outcome of CAIR is unknown. The draft SIP indicates CAIR sources plus new sources could increase the States SO2 emissions. Iowa should address the overall emissions reductions expected from existing CAIR EGUs between 2002 and 2018 and commit to re-evaluating its reasonable progress strategy at the five year review. If EGU emissions projections, as done during the five year review show those facilities are not likely to meet the SIPs current projections, the State should examine additional controls and revise the SIP at the five year review. In addition, the SIP should address the link between permitting of new EGU sources under NSR/PSD with the overall goal of reasonable progress in the SIP.

Department Response
When based upon the best available information, the conclusions in the draft SIP do not suggest that EGU SO2 emissions could actually increase between 2002 and 2018. The Department has clearly identified in the revised draft SIP that IPM v2.1.9 results are outdated and unreliable. IPM 3.0 predicts EGU SO2 emissions will decrease approximately 20,000 tpy between 2002 and 2018.

The Department commits to a review of changes in EGU emissions at the five year review. Please refer to the response to comment FS-2 for additional detail. A discussion of contingency actions is provided in response to comment FS-7. The department discusses New Source Review in the context of regional haze in the response to comment FS-8.

Recommended Action
No additional actions recommended.

NPS-5) Comment: Coordination and Consultation
The Minnesota assessment lists Iowa as a State which contributes significantly to visibility impairment at their Class I areas. The Iowa SIP claims that Iowa sources are not significant contributors to the 20% worst visibility days. If Iowa has consulted with Minnesota regarding its ranking assessment of Iowa's effect and Minnesota agrees with Iowa's conclusion that Iowa's plan, as drafted, has included all measures necessary to obtain its share of emissions reductions needed to meet reasonable progress goals for VOYA and BWCA, please include a summary of those consultations in the SIP.

Department Response
The Department would like to clarify that the draft SIP does not use the exact terminology "are not significant contributors" when referring to Iowa sources' impacts upon Class I areas on the 20 percent worst days. The draft SIP does compare Iowa's contributions to other State contributions, both in terms of percentages and absolute contributions, and classifies the values accordingly. The Department acknowledges contributions from Iowa sources are non-zero and recognizes that emissions from these sources may contribute to visibility impairment, but maintains that no additional controls are needed at this stage of the regional haze program. The

Department has communicated its intended actions to Minnesota and has included related correspondence in the SIP (see Appendix 10.1), see response to comment FS-1 for additional information.

Recommended Action
Chapter 10 of the SIP has been modified to provide additional information regarding consultation with Minnesota. The Department's response to comment EPA-8 also elaborates on issues related to coordination and consultation.

Comments from the Environmental Protection Agency (EPA) Region VII

EPA-1) Comment: Federal Land Manager (FLM) Comments
The proposed (Regional Haze) RH SIP does not address what actions were taken in response to comments submitted by the FLMs. We request the revised draft Plan include all comments received during the review process and provide a discussion as to how each comment was addressed.

Department Response
Comments from the FLMs were not available at the time the draft SIP was provided to EPA. During the required 60 day review period, prior to our public hearing, comments were received from the USDA Forest Service and the US Department of Interior National Park Service who submitted comments in cooperation with the US Fish and Wildlife Service. The Department's responses to these comments are included in this responsiveness summary. Comments received from the FLMs were available for public review at the public hearing.

Recommended Action
No additional actions recommended.

EPA-2) Comment: Federal Land Manager Consultation
Ongoing coordination and communication with FLMs is critical during the RH SIP development and implementation process. Page 15 includes a paragraph indicating that Iowa will continue to coordinate and consult with the FLMs, and indicated three instances when the FLMs must be consulted. However, the revised RH SIP should be more specific as to when and how the FLM coordination process will be conducted, including which party or parties are responsible for initiation and maintaining the ongoing coordination and consultation efforts.

Although not required by the RH SIP, but in the spirit of maintaining an ongoing and positive relationship with the FLMs over the remainder of the regional haze program, the FLMs should be provided copies of all revisions to the Iowa RH SIP, including associated appendices, and given the opportunity to provide additional comments.

Department Response
Similar comments were raised by the FLMs. The Department has revised Chapter 4 of the draft SIP to provide additional clarification and detail regarding consultation with the FLMs. Specific points of consultation with the FLMs have also been addressed in response to comment FS-8. The Department does not wish to artificially constrain consultation opportunities by specifying any additional detail beyond what is provided in the previous comments or the modifications to Chapter 4 regarding when and through whom consultation activities must be initiated or coordinated. The Department supports an open and flexible consultation process in which either the State or the FLM may contact one another. The SIP was due December 17th, 2007. The Department must submit the SIP in a timely manner. An additional comment period is not necessary as the Department will continue to consult with FLMs and other States in preparation of the 5 year Progress Report.

Recommended Action
No additional actions recommended.

EPA-3) Comment: SIP Management
There is no information provided in the RH SIP concerning how the Plan will be managed by Iowa throughout its administrative or regulatory life. Examples of issues that must be addressed in the Iowa RH SIP to ensure all Plan-related commitments can and will be completed include:

- The Iowa agency and/or designated official that will be responsible for conducting the numerous time critical actions required throughout the SIP implementation process to achieve the State's RH visibility goals by the year 2064 deadline.
- The forms or formats in which the Plan will be both maintained by Iowa and accessible by the public and others, and least during the Plan's approximately 56 years of remaining implementation and reporting process. A digital format with specific intervals to revisit the format for periodic technology updates is suggested for long-term plan retention and accessibility. A paper copy or an easily reproducible electronic version of the entire RH SIP is recommended for providing easy public access to the entire document.

Department Response
The Regional Haze Rule and associated EPA guidance does not require that the SIP submittal include information about how the plan will be managed throughout its administrative or regulatory life. As noted in the draft SIP, the Department is designated in Iowa Code 455B.132 as the state agency with the responsibility to prevent, abate, or control air pollution. Iowa Code 455B.133 (1) and (2), designates the Department as the agency responsible for developing comprehensive plans and programs, including state implementation plans. The Program Development section of the DNR's Air Quality Bureau is responsible for coordinating the administrative and regulatory milestones of the Regional Haze Program. The section is responsible for regional modeling, SIP development, and policy review. The DNR has developed an interim plan to meet the time critical actions for the next 10 years. The plan will continually be updated as more program information is received.

The Department has a requirement to make the public record available and the Department will continue to fulfill that requirement for the appropriate period of time.

Recommended Action
No action recommended.

EPA-4) Comment: Reasonable Progress Reporting
On page 53, Iowa commits to submitting a Reasonable Progress report to EPA every five years following the initial submittal of the SIP, Iowa should establish a date certain for submission of this report so that the requirement to submit the documents is provided in the stand-alone RH SIP document.

Department Response
The regional haze rule 40 CRF 51.308(g) requires the initial review to be submitted five years following initial submittal of the SIP. The Department will comply with this requirement.

Recommended Action
Page 56 of the draft SIP will be updated to include a date certain for submittal of the 5 year review.

EPA-5) Comment: Regional Planning Organizations
Iowa relied heavily on its participation with several RPOs to ensure state to state discussions occur as part of the RH SIP coordination and consultation processes. Unfortunately, the future of the RPOs is in question and their absence would require each state to develop and maintain its interstate consultation methods to coordinate its ongoing RH SIP analysis and evaluation processes with other states. In the revised SIP Iowa should address what processes or procedures the State will follow to ensure interstate coordination responsibilities of the RPOs are continued by the State.

Department Response
Similar issues were raised by the FLMs, and related responses can be found in response to comment FS-6.

Recommended Action
No additional action necessary.

EPA-6) Comment: Emission Inventories
As part of the RH SIP development process, states are required to periodically update their emission inventory to reflect changes in numbers, types, and amounts of emissions that could adversely affect visibility at Class I areas. This commitment to periodically update the EI is not included as part of the Iowa RH SIP. At a minimum, Iowa must commit to update the EI on a periodic basis. Emission inventory updates would be most beneficial if they were completed immediately prior to submitting the Reasonable Progress report to the EPA that occurs at the five year intervals beginning in 2013.

Department Response
This issue was also raised by the FLMs, and was addressed in response to comment FS-2. In summary, the Department has modified Chapter 12 of the SIP to include emission inventory changes as part of our five year review.

Recommended Action
No additional action recommended.

EPA-7) Comment: Reasonable Progress Goals
In Chapters 10 and 11 Iowa raises a number of issues regarding Minnesota's request for Iowa to provide source controls for visibility improvement at the two CIAs located in Minnesota. Iowa concludes that (1) the Minnesota CIAs are too far from Iowa sources for controls to effect a significant visibility improvement; (2) the use of different air quality models may provide differing results as to the amount visibility improvement Iowa source controls would provide at the two Class I areas; and (3) the cost to Iowa sources, as summarized in Chapter 10 (page 34) is unreasonable to provide the requested visibility improvement to the two Minnesota sites.

CENRAP modeling results provided to Iowa indicate that Iowa's contribution to visibility impairment at the Minnesota Class I areas is projected to increase between 2002 and 2018. In addition, Iowa provided minimal support for its conclusion that the Minnesota CIAs are too far from Iowa sources to effect a significant visibility improvement. The EPA requests additional clarification of Iowa's position on the amount of visibility improvement expected at the two CIAs particularly with the State's intended implementation of the CAIR cap and trade program.

The Midwest Regional Planning Organization and Minnesota co-commissioned report, "Reasonable Progress for Class I Areas in the Northern Midwest -- Factor Analysis" (page 34), is used by Iowa to support its contention that costs per deciview of visibility improvement at the two Minnesota CIAs are too expensive to require controls on Iowa emission sources. However, an analysis of the range of cost tabulations provided in Appendix 10.2 "Ladco's Four Factor Report Summaries," suggests that when the high dollar per deciview costs are apportioned among the number of emission sources in the nine state study, those costs for individual generators may be reasonable. The other metric included in Appendix 10.2, the range of estimated costs per ton of pollutant removed, also summarized on page 34, also appears to be reasonable for emission sources. The EPA requests additional clarification on, and support for, Iowa's conclusions as to the reasonableness of costs to Iowa sources per deciview of visibility improvement, as well as the reasonableness of the costs per ton of pollutant removed from the environment.

Department Response
The Department acknowledges that the CENRAP modeling predicts Iowa's contributions are projected to increase in terms of percentage contributions between 2002 and 2018; however, both Minnesota and Michigan exhibit the same pattern. At the Northern Class I area, percentage contributions to visibility impairment from both Minnesota and Michigan increase between 2002 and 2018.

The Department would like to further elaborate on the CENRAP modeling data provided in Table 11.2 of the draft SIP shows that visibility impairment attributable to Iowa accounts for only approximately 2 inverse megameters of the total modeled contributions. Totaled modeled visibility impairment levels are approximately 25 times higher, at approximately 50 inverse megameters. The Department has utilized these analysis as justification for the statement that reductions from Iowa sources present only limited potential for visibility improvement.

Additional support for the Department's conclusions can be derived from the Minnesota/MRPO modeling results. The CENRAP modeling referenced above utilized EGU emissions forecasts from IPM v2.1.9. Minnesota completed regional modeling runs independent from the CENRAP results. The Minnesota/MRPO modeling was completed in a latter timeframe, which enabled them to use the updated IPM 3.0 modeling results. The 2018 SO2 emissions from Iowa EGUs predicted by IPM 3.0 were approximately 30,000 tpy lower than IPM v2.1.9 forecasts. While Minnesota/MRPO nonEGU SO2 emissions may be higher than CENRAP values any discrepancy remains well below the level of reductions occurring between the two IPM predictions. Additionally, the Minnesota/MRPO results show that EGU sources yield greater influence over visibility impairment than non-EGU sources. Table 11.4 shows that Iowa contributions are still in the 2 inverse megameter range, despite accounting for the additional SO2 EGU reductions captured in IPM3.0 and attributable to CAIR.

In summary, little variation in Iowa's contribution to visibility impairment at the Minnesota Class I areas is seen when comparing two regional modeling runs, in which EGU emission differ by approximately 30,000 tpy. These results are an effective demonstration that, during this phase of the regional haze rule, Iowa sources would need to enact widespread and dramatic emissions reductions in order to improve visibility conditions at the Minnesota Class I areas. Commensurate with these findings, the Department has concluded that the control costs associated with both the Four Factor report, or the Alpine Geophysics report, are unreasonable to impose at this time.

Recommended Action

The Department has updated Chapter 11 of the SIP to support the conclusion that Iowa's increasing percentage contribution trends do not justify the application of additional controls at this time. Chapter 11 has also been updated to expand the analysis of the Minnesota/MRPO modeling, as discussed above.

EPA-8) Comment: Interstate Consultation

It is apparent from consultation events summarized in Appendix 10 and statements in the draft RH SIP that Iowa's recent discussions with Michigan, Missouri, and Oklahoma over potential Iowa source impacts on those states' CIAs ended with Iowa not having to provide additional emission controls to assist those states in meeting their Reasonable Progress Goals during the first ten year Implementation Period. However, Minnesota continues to request source controls from Iowa to assist it in its effort to reduce visibility impacts at the two Class I Areas located in that State.

The EPA is concerned that there is little information in the draft RH SIP and accompanying documents regarding Iowa's efforts to resolve the dispute. The "consultation appendix," Appendix 10, includes only two letters between Iowa and Minnesota that address the Minnesota request for visibility improvement at its two CIAs.

The foundation of the Regional Haze Program is state-developed plans that, individually and collectively, direct cooperative state efforts toward the national goal of achieving natural visibility conditions at Congressionally-designated Mandatory Class I Federal Areas throughout the country. A critical component for the success of the Regional Haze Program is ongoing coordination and cooperation among the states to accomplish the Program's goal.

The EPA requests that Iowa provide more information in the revised RH SIP regarding the current status of its discussions with Minnesota. Iowa is encouraged to continue to work with Minnesota in an effort to resolve outstanding issues with respect to Minnesota's Reasonable Progress Goals and its request of Iowa to provide visibility improvements at the two Minnesota-located Class I Areas.

Department Response

The Department has outlined in a response to comment FS-2 a discussion supporting our response to the Minnesota requests; however, the Department agrees that additional discussion regarding the Minnesota consultation process is warranted.

In its correspondence with the Department, Minnesota did not request that controls be installed on specific sources. Accordingly, there was no justification on how such controls would lead to visibility improvement at the Minnesota Class I areas. Similarly, Minnesota has not provided documentation or otherwise consulted with the Department regarding any specific visibility improvement at the Minnesota Class I areas which would result from controlling Iowa sources. The Department did not see a compelling argument from Minnesota that demonstrated how Iowa’s compliance with its request would benefit Minnesota’s Class I areas. Based upon the Department’s analyses and discussions contained in the relevant responses above, and details in the SIP, additional controls and further discussion with Minnesota remains unsupported at this first stage of the regional haze rule. The Department will continue to consult with Minnesota on issues involving regional haze as requested and warranted.

Recommended Action

No additional action recommended.

APPENDIX 6

Appendix 6.1

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ANALYSES OF THE CAUSES OF HAZE FOR THE CENTRAL STATES (PHASE II)

SUMMARY OF FINDINGS

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STI-904780.08-2754-ES

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1. INTRODUCTION

The Central States Regional Air Planning Association (CENRAP) is researching visibility-related issues for its region, which includes the states of Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota, and is developing a regional haze plan in response to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas. In order to develop an effective regional haze plan, the CENRAP ultimately must develop a conceptual model of the phenomena that lead to episodes of low and high visibility in the CENRAP region.

This Executive Summary describes the findings of data analyses and assessments of phenomena that govern regional haze in the CENRAP region. (Methods, information sources, and graphical and tabular illustrations of available data are documented in the appendices.) It is intended to be used for reference during preparation for photochemical modeling and during consideration of strategies to improve or protect visibility conditions in CENRAP's Class I areas. Specifically, the findings in this document should be useful for (1) selection of year-2002 episodes and geographic areas that should be treated at 12-km spatial resolution for photochemical modeling and (2) preliminary consideration of potentially effective control scenarios. In addition, CENRAP and its member states, tribes, and stakeholders will likely build on the results of this project in the future when more air quality data are available or periodically as EPA Regional Haze Rule milestones arise. Therefore, the analyses presented in this document may be used as a foundation for future analyses.

2. PURPOSE AND OBJECTIVES

Air quality regulators are faced with the challenge of (1) characterizing the causes of impairments to visibility when visibility is reduced and when visibility is at its best (when presumably impairments to visibility are minimized); and (2) identifying the most effective means to preserve the conditions when visibility is at its best and to gradually improve the visibility when it is most impaired. Thus, the objectives of the data analyses reported in this Executive Summary, "Analyses of the Causes of Haze for the Central States (Phase II)" (CENRAP Work Assignment Number 04-0628-RPO-017), were to determine the causes of hazy conditions and variations in haziness for Class I areas and other Interagency Monitoring of Protected Visual Environments (IMPROVE)-Protocol monitoring sites in the CENRAP region. Consistent with the requirements of the Regional Haze Rule, the analyses focused on the 20% of days with the worst visibility conditions and the 20% of days with the best visibility conditions at Class I sites during the period 2000-2004 ("20%-worst" and "20%-best" days, respectively). The analyses were formulated to address several key questions and issues:

1. To what extent are visibility-impairing emissions within the control of CENRAP air regulators?
    - Can specific source types, geographic locations, or temporal patterns of emissions sources impacting Class I areas during episodes of good or poor visibility be distinguished?

    - What connections can be drawn between sample periods showing unusual species concentrations and sporadic emission sources (e.g., dust storms and large forest fires)? How can this information be used to estimate the impacts of sporadic emission sources?

2. What specific types of meteorological events should most concern CENRAP air regulators when considering strategies to improve or protect visibility?
    - What are the archetypal meteorological conditions associated with episodes of good visibility and poor visibility? On which dates of 2002 did such conditions occur?
    - Which days or episodes in 2002 best represent these good and poor visibility events and should be considered for modeling?
    - Was the meteorology in 2002 and 2003 normal compared to climatological averages?

3. Can trends in emissions on the time scale of years be related to trends in the causes of haze?
    - Are changes in the aerosol components responsible for changes in haze?
    - For any detectable changes in aerosol components responsible for haze, are the changes related to variations in meteorological conditions or emissions?
    - Where emissions are known to have changed substantially (based on emission inventory data), are there corresponding changes in haze levels?

The analyses reported in this document reflect a simplified approach to these questions and issues—they are not intended to substitute for rigorous assessments based on photochemical and meteorological modeling. Instead, they provide a preliminary understanding of the important phenomena governing haze in the CENRAP region and a preview of what might be expected to result from modeling assessments. The understanding gained from a simplified approach is useful in the interim period until modeling exercises are complete; can be used to help guide the specific modeling plans (e.g., selection of episode dates or modeling domains); and can simplify CENRAP's task of developing haze mitigation strategies. With the information presented in this document, CENRAP can begin considering likely haze mitigation alternatives, understand the types of meteorological and emissions events that are associated with episodes of good and poor visibility, and select the specific dates that would be good candidates for base-year episodic photochemical modeling.

Four representative subregions of CENRAP (illustrated in **Figure 2-1**) were identified in which aerosol extinctions and concentrations of $PM_{2.5}$ components significantly covary in space and time (for the 20%-best and 20%-worst days). Visibility conditions within each of these subregions are thought to be affected by common influences, such as emissions sources, clean-air corridors,[1] and prevailing meteorological conditions.[2] Therefore, analyses were oriented toward these representative subregions (rather than individual monitoring sites)—a cost-effective

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[1] Clean-air corridor is defined as the transport pathway predominantly associated with 20%-best days.

[2] Supporting evidence for the definition of these subregions is summarized in Section 4 and documented in Appendix A of this Executive Summary.

approach to considering most of the geographic extent of the CENRAP region. Representative sites from each of the subregions received most of the attention: Cedar Bluff (CEBL1), Kansas, for the Western Plains; Sikes (SIKE1), Louisiana, for Southeastern Plains; Hercules-Glades (HEGL1), Missouri, for the Upper Midwest; and Voyageurs National Park (VOYA2), Minnesota, for Minnesota.

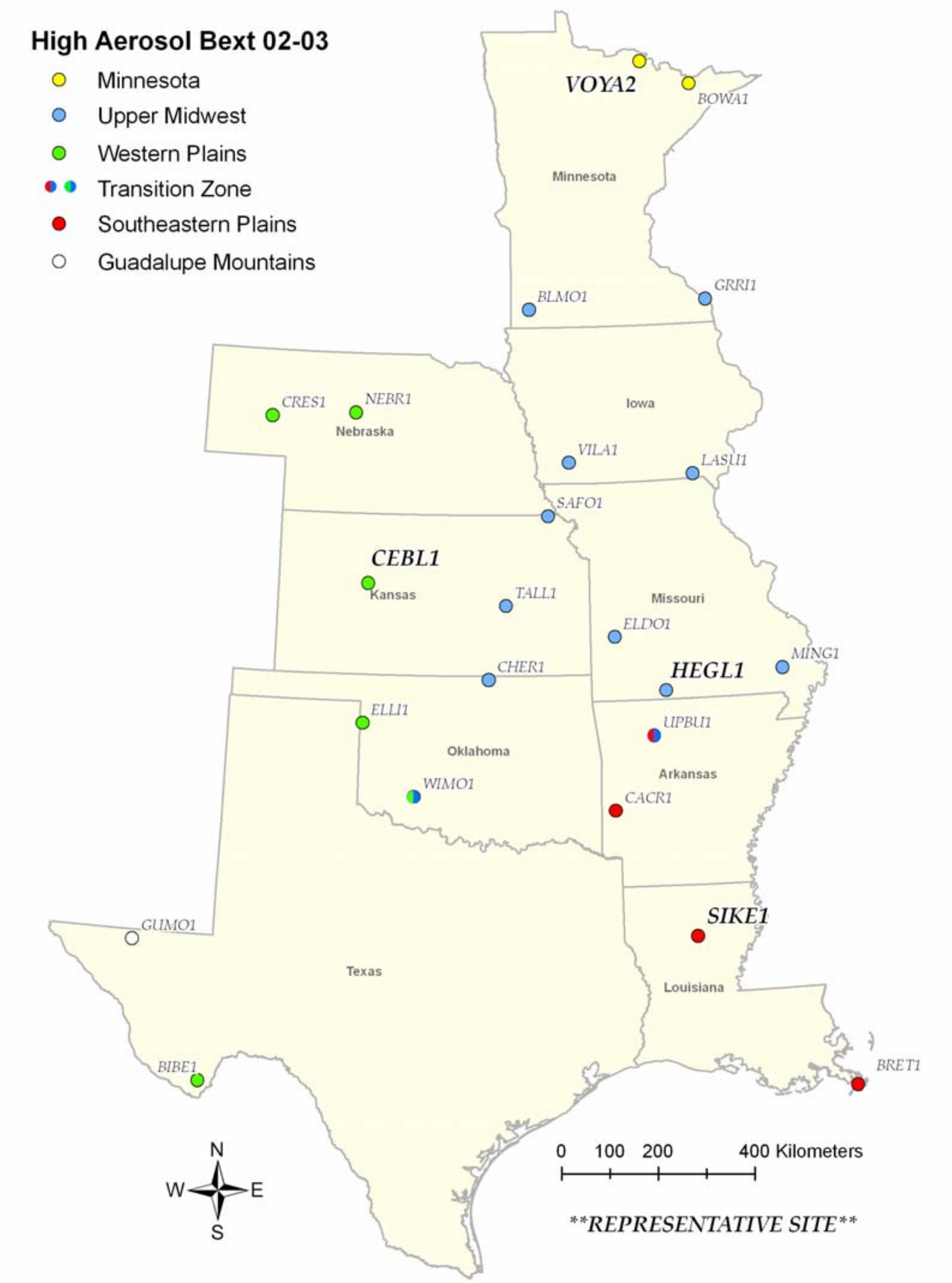

Figure 2-1. IMPROVE and IMPROVE-Protocol monitoring sites in the CENRAP domain classified by representative subregion for the 20%-worst visibility days in 2002-2003.

The following sections of this Executive Summary include a summary of primary conclusions (Section 3) followed by additional supporting evidence in Section 4. References for the Executive Summary are provided in Section 5. Several appendices follow the Executive Summary to provide additional documentation of methods, graphical and tabular summaries of data, and other pertinent information in support of the conclusions. Appendix A summarizes the Task 4 spatiotemporal analyses. Appendix B summarizes the Task 5 meteorological analyses. Appendix C summarizes the Task 6 emissions analyses. Appendix D includes two draft journal articles that summarize the source apportionment approach and results for Sikes and Hercules-Glades, respectively.

3. SUMMARY OF PRIMARY CONCLUSIONS

The primary conclusions derived from this project are provided in this section. Supporting evidence for each conclusion is discussed in Section 4.

1. To what extent are visibility-impairing emissions within the control of CENRAP air regulators?
    - Emission inventory analyses produced the following answers to the stated question. (However, an important area of weakness in the analyses was caused by substantial inconsistencies in the emission inventories of volatile organic compounds [VOCs], $PM_{2.5}$, PM_{10}, and ammonia [NH_3], both within and between various regions. Unless resolved, these problems are likely to affect photochemical modeling performance).
        - *CENRAP will need the cooperation of other Regional Planning Organizations (RPOs) or countries to protect clean-air corridors and to improve visibility conditions at some sites.* Emissions sources in the Midwest RPOs and Visibility Improvement State and Tribal Association of the Southeast (VISTAS) regions contribute significantly to visibility impairment on the 20%-worst days in the Southeastern Plains and Upper Midwest subregions of CENRAP. In addition, sources in northern Mexico and the Midwest RPO region contribute moderately to visibility impairment on the 20%-worst days in the Western Plains subregion. Areas of Canada and the Western Regional Air Partnership (WRAP) states are clean-air corridors for visibility-protected sites in the Northern Minnesota and Western Plains subregions. However, in most other respects, visibility conditions at CENRAP's protected sites are affected primarily by emissions sources or clean-air corridors located within CENRAP's boundaries.
        - *BART[3] requirements alone are unlikely to significantly alter visibility conditions of protected sites in the CENRAP.* An estimate of the impacts of emissions from potentially BART-eligible sources showed that such sources generally contribute very little to the oxides of sulfur (SO_x)- and oxides of nitrogen (NO_x)-associated visibility impairment at Class I areas in the CENRAP region. Additional emissions reductions will be needed to improve visibility conditions on the 20%-worst days.

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[3] BART = Best Available Retrofit Technology

- Source apportionment analyses corroborated the results of emission inventory analyses.
  - *Aerosol components that contribute to poor visibility include sulfate, nitrate, and carbonaceous matter.* In the Upper Midwest and Southeastern Plains subregions, ammonium sulfate accounts for 70% (on average) of visibility impairment at CENRAP's protected sites on the 20%-worst days, computed using the standard IMPROVE equation (Malm et al., 1994; IMPROVE, 2004). In the Western Plains, sulfate and nitrate combined account for 40% (on average) of visibility impairment. In Northern Minnesota, sulfate, nitrate, and carbonaceous aerosol are important, accounting respectively for 40%, 25%, and 30% (on average) of visibility impairment. In all CENRAP subregions, carbonaceous matter causes 10% to 30% of the visibility impairment (on average), although this estimate is likely to be conservatively low because the IMPROVE visibility equation does not fully account for carbonaceous aerosol scattering.
  - *Source regions both outside and within CENRAP are important contributors to visibility impairment at the protected sites.* Coal combustion in the Ohio River Valley, St. Louis area, and Gulf States accounts for 40% to 50% of the aerosol mass (and an even larger proportion of light extinction) at CENRAP's protected sites on the 20%-worst days in the Upper Midwest and Southeastern Plains subregions. "Southeastern aged aerosol" (from areas outside the CENRAP region) and "urban carbonaceous aerosol" from the Mississippi River Valley (from areas generally within CENRAP) contribute roughly one-quarter to nearly half of the aerosol mass on the 20%-worst days in these areas. Wintertime nitrate episodes were important in the Upper Midwest and were associated with impacts from ammonia and NO_x emissions sources located mostly within the CENRAP region. Of source regions outside the CENRAP region, Ohio River Valley coal combustion contributed more heavily to visibility impairment in the Upper Midwest than in the Southeastern Plains, while transport of aerosols from the southeastern United States contributed more heavily at the Southeastern Plains sites.
  - *Fires infrequently contribute to visibility impairment observed on the 20%-worst days at most sites in the CENRAP region.* Organic carbon mass (OMC) contributed to light extinction infrequently on 20%-worst days, except at a few sites. The exceptions included Big Bend during the spring months, Nebraska National Forest during the summer, and the two sites located in the Minnesota region during the summer. (More investigation is needed to determine whether these elevated OMC contributions were due to fires.) In the Southeastern Plains and Upper Midwest regions, the influences of episodic local and regional burning events, usually within CENRAP, were successfully detected through corroborative analyses, though they were not important drivers of poor visibility in those areas. Fires may threaten clean-air corridors and visibility conditions on days with clear conditions and high winds from the northwestern U.S. or Canada—conditions likely to occur on the 20%-best days.
  - *Very infrequently does geologic material contribute appreciably to visibility impairment observed on the 20%-worst days at most sites in the CENRAP region.*

Soil and coarse mass contributed to light extinction infrequently on 20%-worst days, except at Guadalupe Mountains. (More investigation is needed to determine the sources of soil and coarse mass at Guadalupe Mountains.) In the Southeastern Plains and Upper Midwest regions, the influences of dust transported over long distances were successfully detected through corroborative analyses, though they were not important drivers of poor visibility in those areas. Dust storms may threaten clean-air corridors and visibility conditions on days with clear conditions and rapid transport through the Great Plains of the U.S. or across the Atlantic—conditions likely to occur on the 20%-best days.

2. What specific types of meteorological events should most concern CENRAP air regulators when considering strategies to improve or protect visibility?

   - *Many types of weather and transport conditions occurred on the 20%-best or 20%-worst days during 2002-2003.* On average there were about five different weather and transport clusters for each of the four CENRAP subregions for both the 20%-worst and 20%-best days. The meteorological and transport characteristics associated with the clusters for each subregion are presented in Section 4.3 and in Appendix B.

   - *Representative days and episodes in 2002 were identified that are suitable for modeling.* Recommended modeling days shown in **Tables 3-1 and 3-2** were determined by selecting episodes that were coincident among the four subregions and that captured most of the common meteorological and transport characteristics identified in the clusters.

Table 3-1. Recommended modeling dates that exhibited representative meteorological and transport conditions on the 20%-worst visibility days.

Modeling Periods in 2002	Cedar Bluff	Sikes	Voyageurs	Hercules-Glades
July 6-7	No data	Worst	Worst	Worst
August 2-10	No data	Worst	Worst	Worst
September 1-14	Worst	Worst	Worst	Worst
December 2-14	Worst	No data	Worst	Worst

"Worst" = 20%-worst visibility days.
"No data" indicates samples were not available on the specified dates.

Table 3-2. Recommended modeling dates that exhibited representative meteorological and transport conditions on the 20%-best visibility days.

Modeling Periods in 2002	Cedar Bluff	Sikes	Voyageurs	Hercules-Glades
April 20-26	No data	Best	Best	Best
May 17	No data	—	Best	Best
October 14-17	Best	—	Best	Best
December 19-31	Best	Best	Best	Best

"Best" = 20%-best visibility days.
"No data" indicates samples were not available on the specified dates.
— indicates data were available but the dates were not among the 20%-best visibility days at that site.

- *In general, the meteorology of 2002-2003 was near normal for the CENRAP region and can, therefore, be considered representative with two minor exceptions*:
  - Temperatures were slightly above normal in the northern portions of the CENRAP region in 2002 and in the western portions in 2003.
  - Precipitation was slightly above normal in Texas and slightly below normal in the western portions of the CENRAP region in 2002. Precipitation was slightly below normal in most of CENRAP in 2003.

3. Can trends in emissions on the time scale of years be related to trends in the causes of haze?
   - Sufficiently long histories of IMPROVE-protocol data are available for the Upper Buffalo Wilderness site (in Arkansas), the Big Bend National Park site (in Texas), and the sites in northern Minnesota (Voyageurs National Park Site No. 1, Voyageurs National Park Site No. 2, and Boundary Waters-Canoe Area). Analyses of the available data for these sites yielded the following conclusions.
     - *Sulfur dioxide (SO_2) emissions in the Ohio River Valley states (Ohio, West Virginia, Kentucky, Indiana, and Illinois), Tennessee, and Missouri declined substantially from 1990 to 1999.* These declines in SO_2 emissions were concurrent with a decline in observed ammonium sulfate concentrations and associated light extinction at the Upper Buffalo, Arkansas site (which lies in a transitional zone and shares characteristics with the Upper Midwest and Southeastern Plains subregions of CENRAP).
     - *SO_2 emissions in Texas, New Mexico, Arizona, Louisiana, Arkansas, and Mississippi increased somewhat from 1990 to 1999.* These increases in SO_2 emissions were concurrent with an increase in observed ammonium sulfate concentrations and associated light extinction at the Big Bend, Texas site. No information was readily available to characterize the historical trend in SO_2 emissions for northern Mexico, which is also an important upwind area for the Big Bend site on its 20%-worst days.
     - *In Minnesota and surrounding states, the trend in SO_2 emissions varied from state to state.* Emissions declined substantially from 1990 to 1999 in some states (Missouri, Illinois, and Wisconsin), increased substantially in North Dakota, and changed relatively little in other states (Minnesota, Iowa, Kansas, Nebraska, and South Dakota). From 1990 to 1999, ammonium sulfate concentrations and associated light extinction declined at the Voyageurs and Boundary Waters-Canoe sites. Therefore, it appears that declining SO_2 emissions in Missouri, Illinois, and Wisconsin may have benefited visibility conditions in the Northern Minnesota representative region.

4. SUPPORTING EVIDENCE

Each primary conclusion stated in Sections 2 and 3 is restated and supported with a summary of the evidence determined through data analyses.

4.1 EVIDENCE IN SUPPORT OF DEFINING THE REPRESENTATIVE GEOGRAPHIC SUBREGIONS OF THE CENRAP

In order to simplify subsequent analyses (described in Sections 4.2 and 4.3), sites considered to be representative of subregions of the CENRAP region were identified. Each representative site was considered to generally share emissions and meteorological influences with other sites in the same subregion. This approach minimized the number of sites requiring detailed analytical treatment. Four subregions were identified:

- An Upper Midwest subregion, consisting of sites in southern Iowa, Missouri, and eastern Kansas, represented by the Hercules-Glades (HEGL1) site.
- The Western Plains, which included Big Bend but not Guadalupe Mountains, represented by the Cedar Bluff (CEBL1) site.
- Minnesota, consisting of the border sites, Voyageurs and Boundary Waters-Canoe, represented by the Voyageurs (VOYA2) site.
- Southeastern Plains, which includes sites in Louisiana and southern Arkansas, represented by the Sikes (SIKE1) site.

In addition, the Guadalupe Mountains subregion in which the Guadalupe Mountains site is located showed only a loose relationship with Big Bend and other CENRAP sites. Two more sites—Upper Buffalo and Wichita Mountains—appeared to fall in "transition zones" between the Western Plains and upper Midwest or Southeastern Plains.

The differences between Big Bend and Guadalupe Mountains were surprising given their geographic proximity to one another. However, further investigation of the light extinction budgets and the meteorological patterns on the 20%-worst days at each site demonstrated convincingly that the two sites are often affected by different emissions sources and transport patterns. Comparison of **Figure 4-1** to **Figure 4-2** shows that coarse mass is a more important factor in light extinction at the Guadalupe Mountains site than at the Big Bend site, while ammonium sulfate is a more important factor at the Big Bend site than at the Guadalupe Mountains. **Figure 4-3** illustrates the differences, using spatial probability density (SPD) and conditional probability integrated analysis (CoPIA) (detailed in Appendix A), in the geographic areas most likely to influence these two sites on the 20%-worst days. Areas of west Texas, northern Mexico, and the Big Bend area of Texas likely to influence the Guadalupe Mountains site on its 20%-worst days are very unlikely to influence the Big Bend site on its 20%-worst days. Conversely, areas around Austin and San Antonio, Texas, and areas of Tamaulipas and Nuevo León, Mexico, are important zones of influence for the Big Bend site on its 20%-worst days, but less so for the Guadalupe Mountains site.

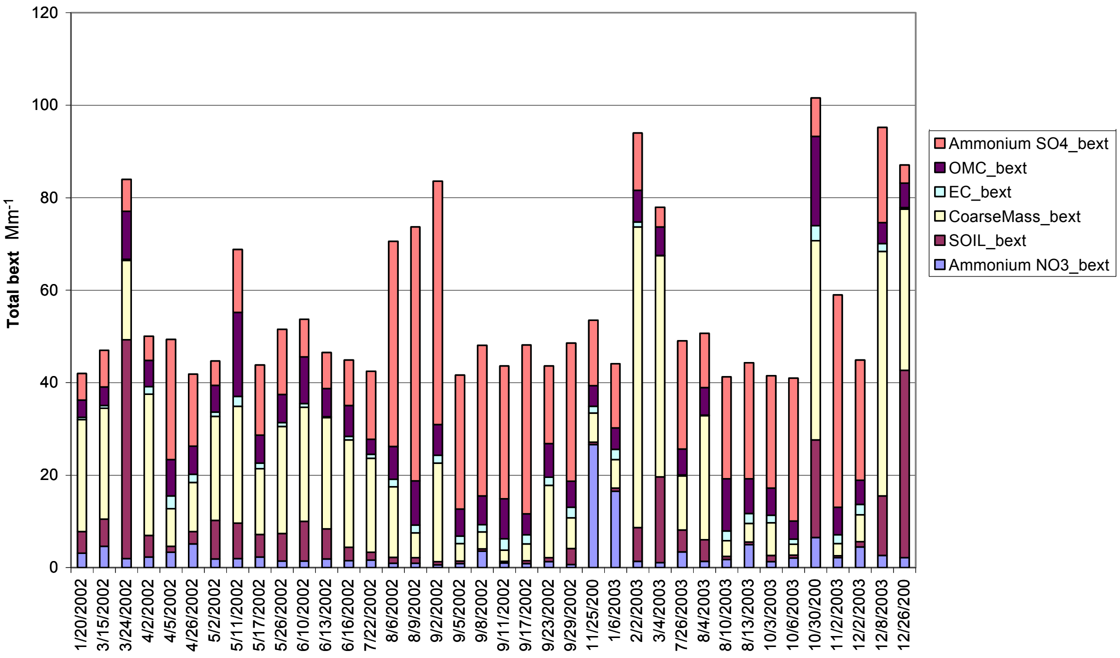


Figure 4-1. Light extinction (b_{ext}) budget by component (using standard IMPROVE calculations) for the 20%-worst visibility days at Guadalupe Mountains in 2002-2003.

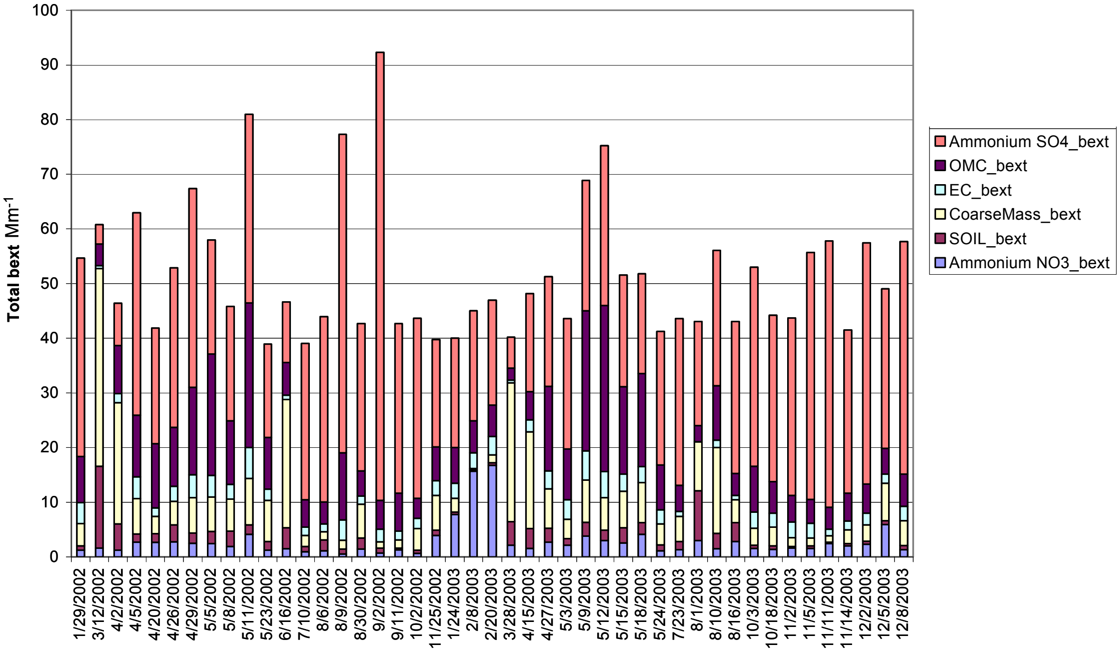


Figure 4-2. Light extinction (b_{ext}) budget by component (using standard IMPROVE calculations) for the 20%-worst visibility days at Big Bend in 2002-2003.

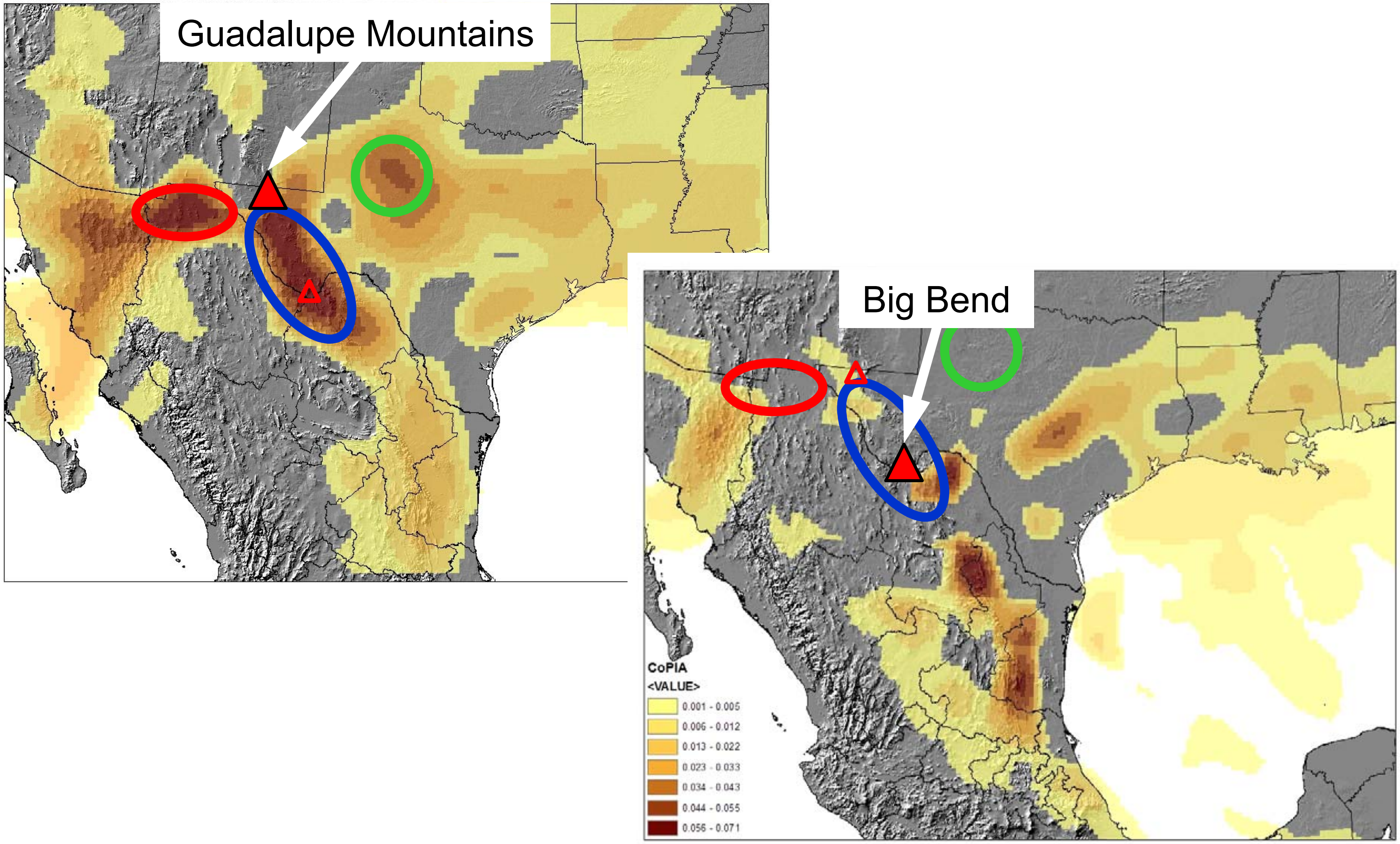
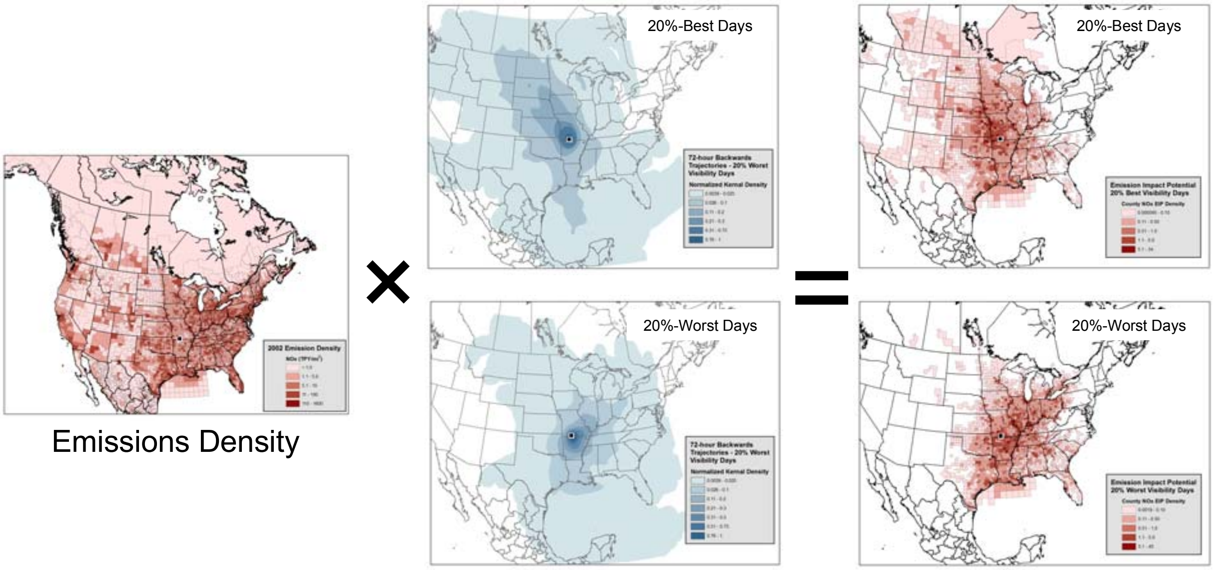


Figure 4-3. The geographic zones of influence on the Guadalupe Mountains and Big Bend sites on the 20%-worst visibility days. (Red, green, and blue ovals are placed to aid in visual comparisons of the two maps.) The resulting value for each grid cell is the conditional probability of air traveling over a grid cell on the 20%-worst visibility days relative to the probability over a grid cell for all days. Details are provided in Appendix A.

4.2 EVIDENCE FOR IDENTIFYING EMISSIONS SOURCES OR SOURCE REGIONS THAT CONTRIBUTE TO HAZE

CENRAP will need the cooperation of other RPOs or countries to protect clean-air corridors and to improve visibility conditions at some sites.

SO_2 and NO_x emission inventories and 72-hr backward wind trajectories were analyzed for four representative sites—one site from each of the four representative subregions of the CENRAP—and for the 20%-best and 20%-worst days observed at each site. The products of these analyses were maps of emissions impact potentials (EIP), where the EIP for a specific geographic area was proportional to (a) the probability of transport from that area to the receptor site and (b) the scale of emissions in the area. EIP assigns weightings to emissions according to the likelihood that the emissions will be transported to a selected receptor site. **Figure 4-4** illustrates the calculation of EIP for the Hercules-Glades site in southwestern Missouri: emissions density multiplied by the density of backward wind trajectory hourly endpoints yields EIP. More details about the methods and sources of data are provided in Appendix C.



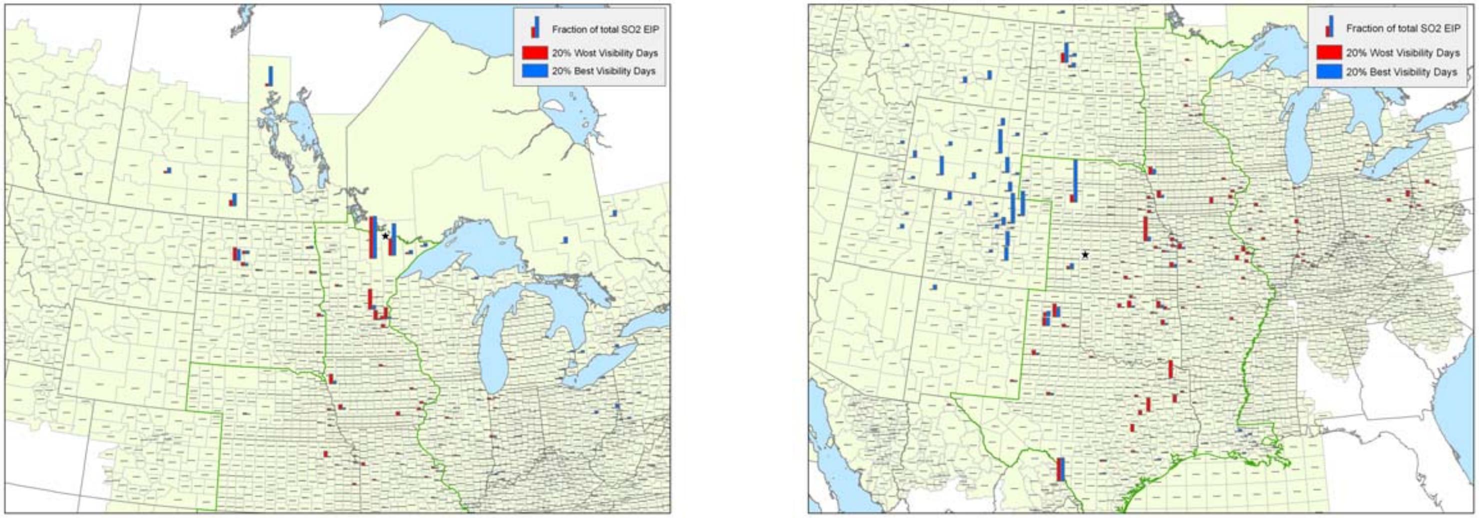
Emissions Density

Density of Backward Wind Trajectory Hourly Endpoints

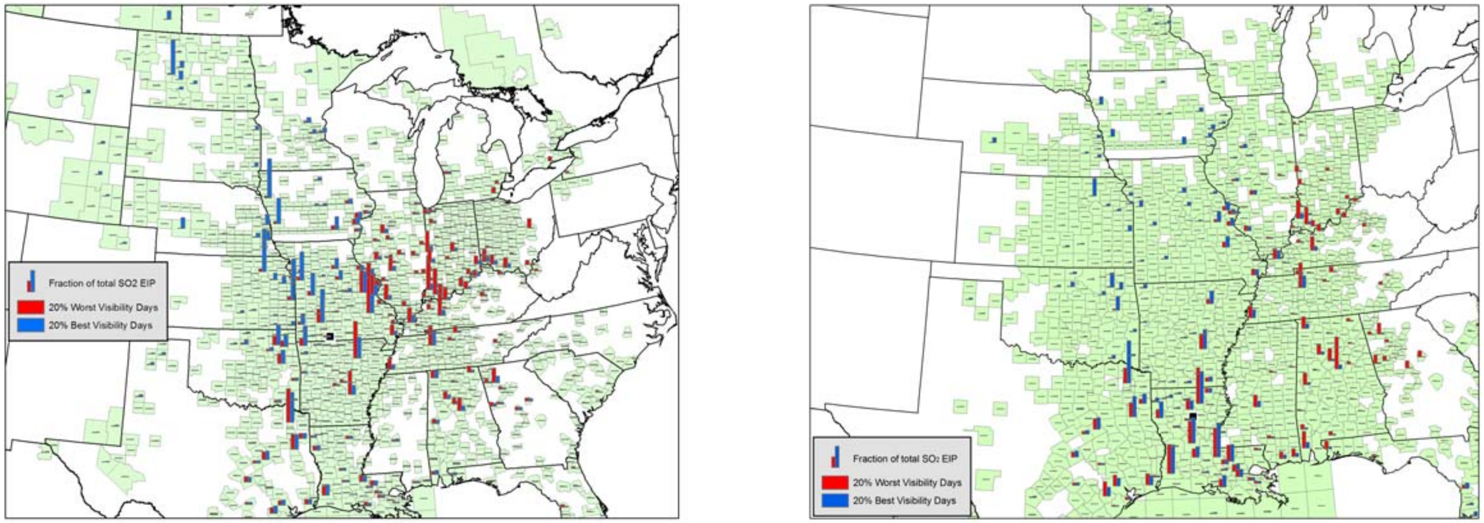
Emission Impact Potential (EIP) Density

Figure 4-4. Illustration of the procedure to calculate EIP.

Illustrations of the geographic distributions of EIP (**Figures 4-5 and 4-6**) show the locations of emissions sources most likely to impact the four representative sites and subregions of the CENRAP region. **Figure 4-7** illustrates the distribution of backward wind trajectory hourly endpoints observed on the 20%-best days, which can be used to help define the clean-air corridors for a given site. (**Table 4-1** summarizes some of the conclusions that can be drawn from these figures.) In summary, CENRAP can only partly control the clean-air corridors and emissions source regions that are important to Class I areas within its borders. Areas of Canada and/or WRAP states comprise significant portions of the clean-air corridors for the Minnesota and Western Plains subregions. In addition, emissions sources in some Midwest RPO states and VISTAS states contribute significantly to impaired visibility conditions on the 20%-worst days in the Upper Midwest and Southeastern Plains subregions.



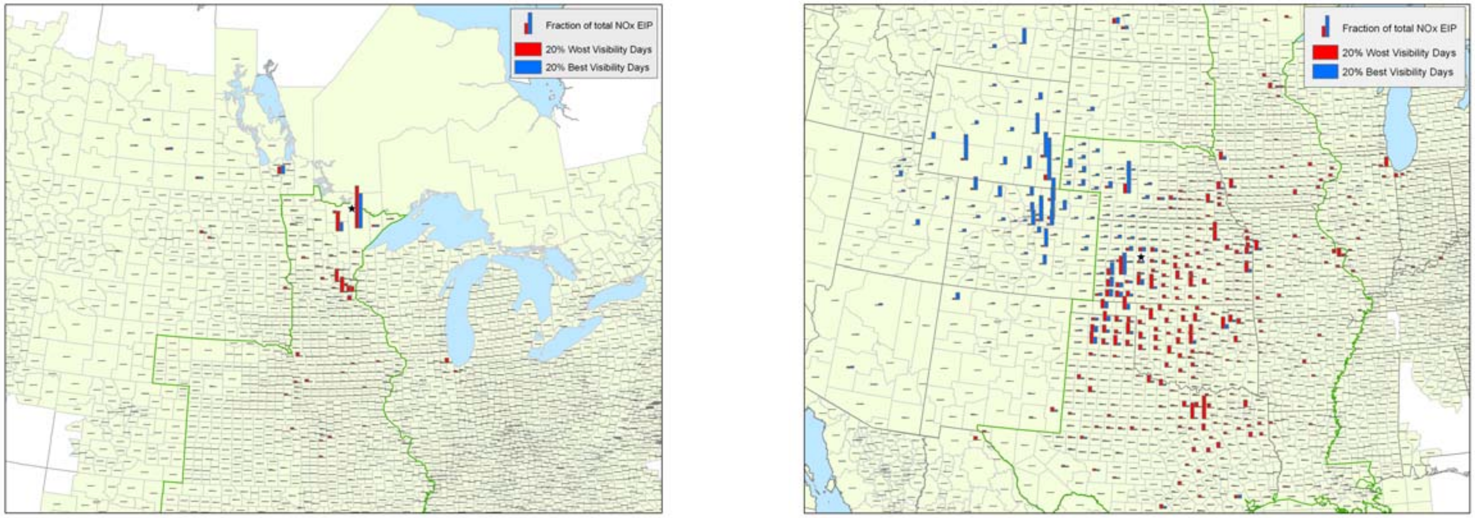
(a) Voyageurs, Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



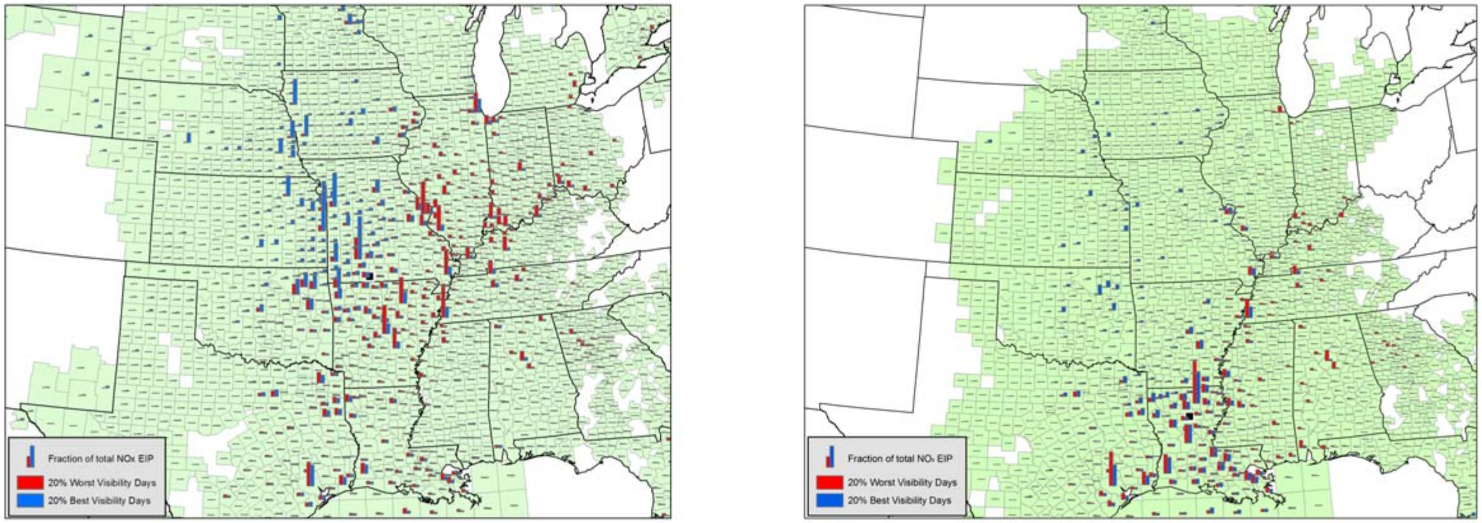
(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure 4-5. Geographic distributions of SO_2 EIP for the 20%-worst visibility days (red bars) and 20%-best visibility days (blue bars) observed at four representative sites.



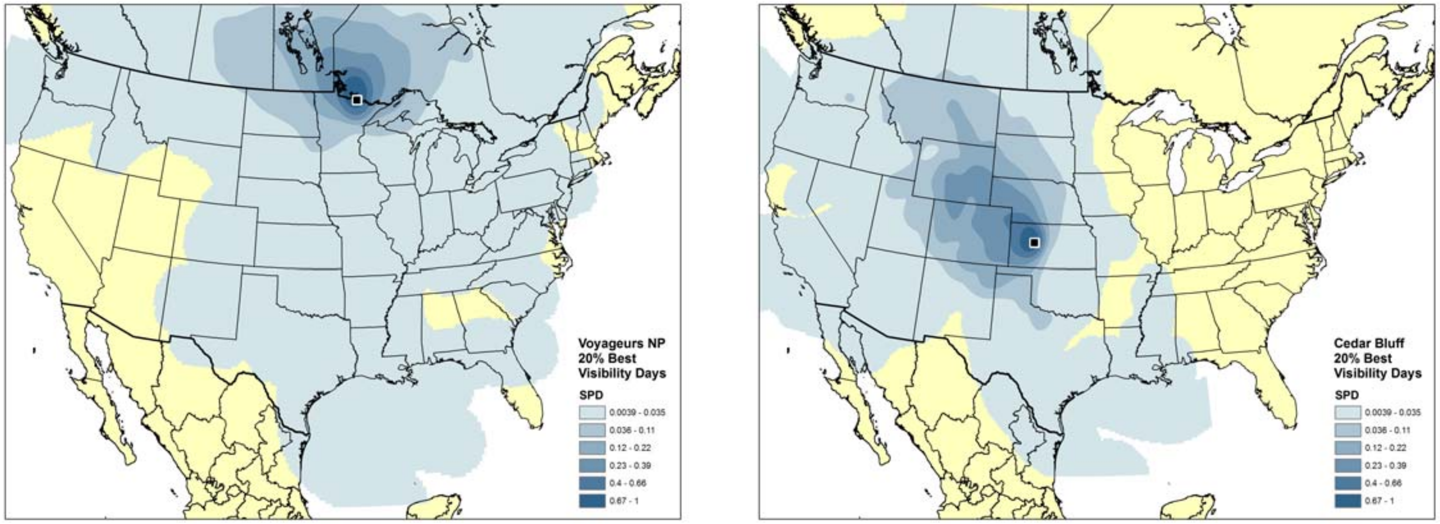
(a) Voyageurs, Minnesota (Minnesota subregion)*　　(b) Cedar Bluff, Kansas (Western Plains subregion)



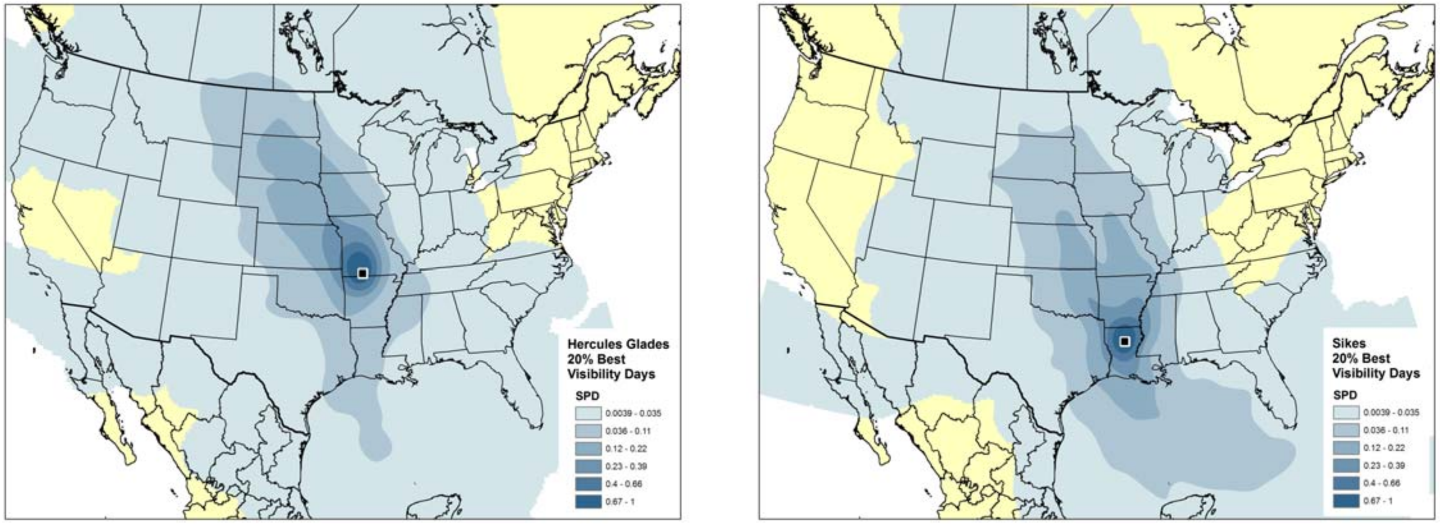
(c) Hercules-Glades, Missouri (Upper Midwest subregion)　　(d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure 4-6. Geographic distributions of NO_x EIP for the 20%-worst visibility days (red bars) and 20%-best visibility days (blue bars) observed at four representative sites.



(a) Voyageurs, Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out.

Figure 4-7. Geographic distributions of 72-hr backward wind trajectories for the 20%-best visibility days observed at four representative sites. Spatial probability density (SPD) is detailed in Appendix A. A value of one indicates that all trajectories passed near the grid cell, while a value closer to zero denotes an area over which very few trajectories passed.

Table 4-1. Summary of geographic emissions source areas impacting representative sites and subregions of the CENRAP region.

Representative Site (Subregion)	20%-Best Days		20%-Worst Days	
	Important Clean-Air Corridors	Internal or External to CENRAP	Important Emissions Source Regions	Internal or External to CENRAP
Voyageurs, Minnesota (Minnesota)	Canada* Minnesota	Largely external	Minnesota, North Dakota	Largely internal
Cedar Bluff, Kansas (Western Plains)	WRAP states, Western Kansas, Western Nebraska	Largely external	Kansas, Texas, Missouri, Oklahoma, Iowa, Illinois, Northern Mexico	Largely internal
Hercules-Glades, Missouri (Upper Midwest)	Arkansas, Oklahoma, Kansas, Missouri, Nebraska, Iowa, South Dakota, North Dakota	Largely internal	Several MRPO States, Missouri, Arkansas, Texas, Oklahoma, VISTAS states	Largely external
Sikes, Louisiana (Southeastern Plains)	Louisiana, Texas, Oklahoma, Arkansas, Kansas, Missouri, Nebraska, Gulf of Mexico	Largely internal	VISTAS States, MRPO States, Louisiana, Texas, Arkansas	Largely external

*Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the GIS analysis. However, Canada contains most of the clean air corridor for Northern Minnesota.

BART requirements alone are unlikely to significantly alter visibility conditions at protected sites in the CENRAP.

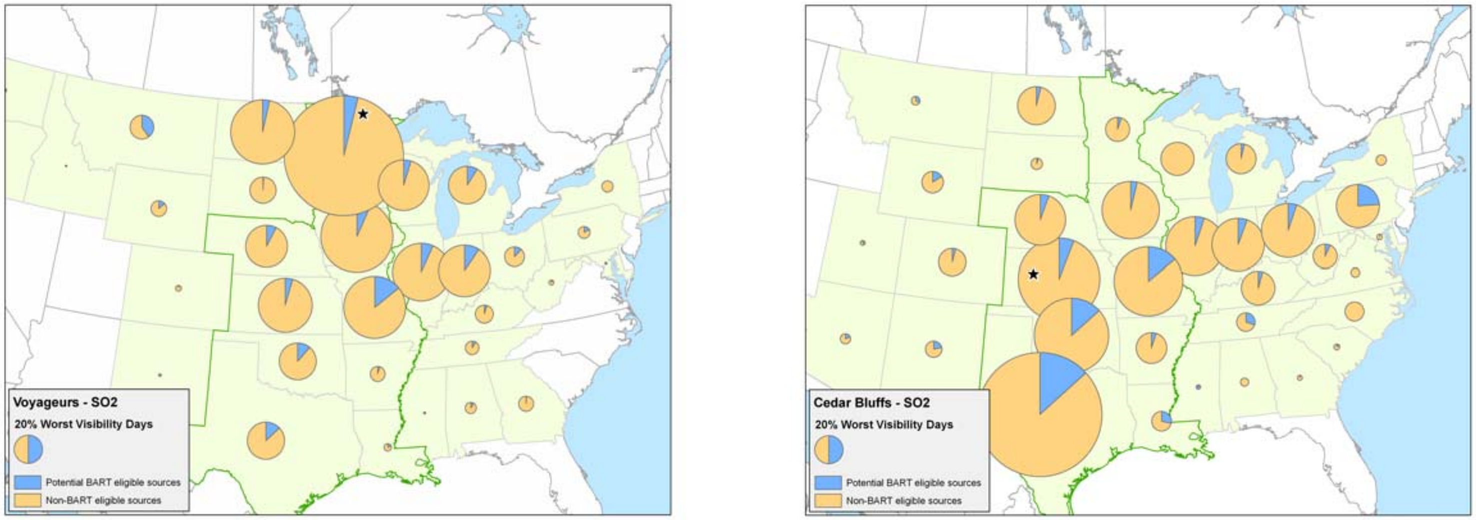
EIPs were calculated using conservatively high estimates of emissions from BART-eligible sources. BART-eligible sources are defined in the Code of Federal Regulations (U.S. Environmental Protection Agency, 2004)as stationary point sources meeting the following criteria:

1. They have the potential to emit 250 tons or more of a visibility-impairing air pollutant, including SO_2, NO_x, particulate matter (PM), or VOCs.
2. They were put in place between August 7, 1962 and August 7, 1977.
3. They are located at any of 26 specific types of facilities, such as fossil-fuel fired steam electric plants of more than 250 million British thermal units (BTU) per hour heat input, coal cleaning plants, etc. (See Appendix C for the full list of facility types.)

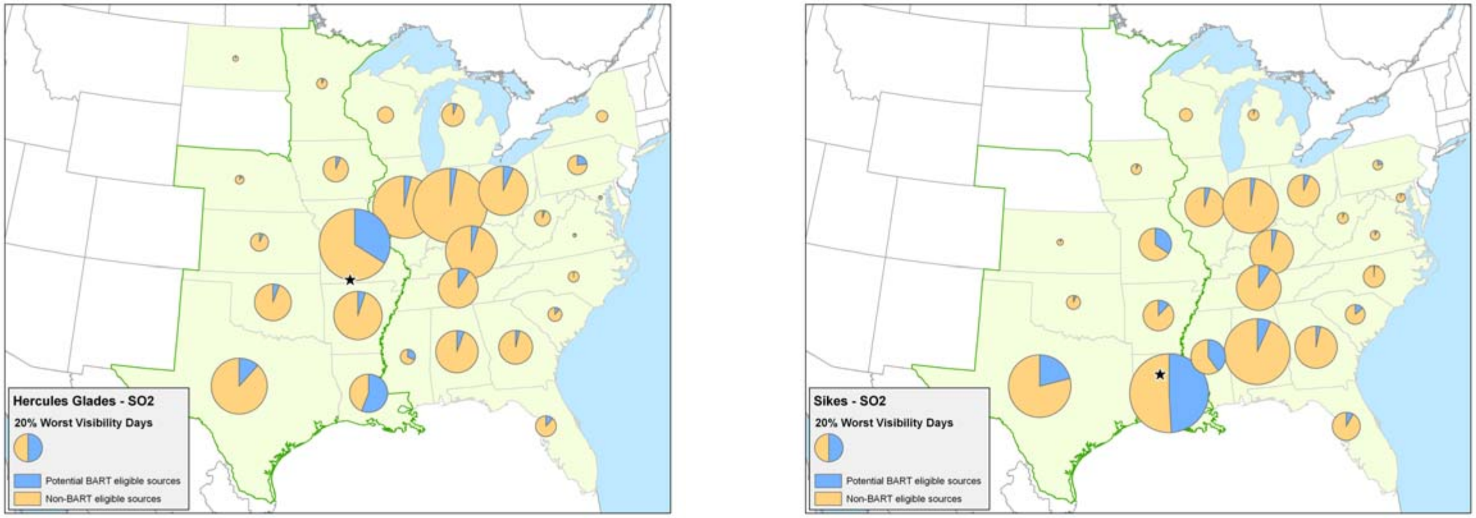
Sources meeting the third criteria were identified as *potentially* BART-eligible; however, insufficient information was available to restrict the list of sources according to the first and second criteria. Therefore, this analysis produced a conservatively high estimate of potentially BART-eligible sources (i.e., not all the sources identified will meet all three criteria).

Figures 4-8 and 4-9 illustrate the geographic distributions of SO_x and NO_x EIPs attributable to potentially BART-eligible sources and BART-ineligible point sources on the 20% worst visibility days. From 7% to 19% of point-source SO_x EIP and from 6% to 13% of point-source NO_x EIP were attributable to potentially BART-eligible sources, based on the total SO_x and NO_x EIP at the four representative sites. Note that about 90% of total United States SO_x emissions are attributable to point sources; however, only about 40% of total United States NO_x emissions are attributable to point sources. (The balances are emitted by area and mobile sources.) Therefore, the relative importance of potentially BART-eligible sources is diluted substantially by the contributions of area and mobile sources of NO_x, but only slightly by the contributions of area and mobile sources of SO_x. In addition, the inclusion of emissions from Mexico and Canada would further dilute the importance of potentially BART-eligible sources.

Because the EIPs of potentially BART-eligible sources are relatively small, we expect that enforcement of BART requirements will produce limited improvement in the visibility conditions on the CENRAP region's 20%-worst days. Therefore, we expect that additional emissions reduction strategies will be needed to meet the goals of the Regional Haze Rule.



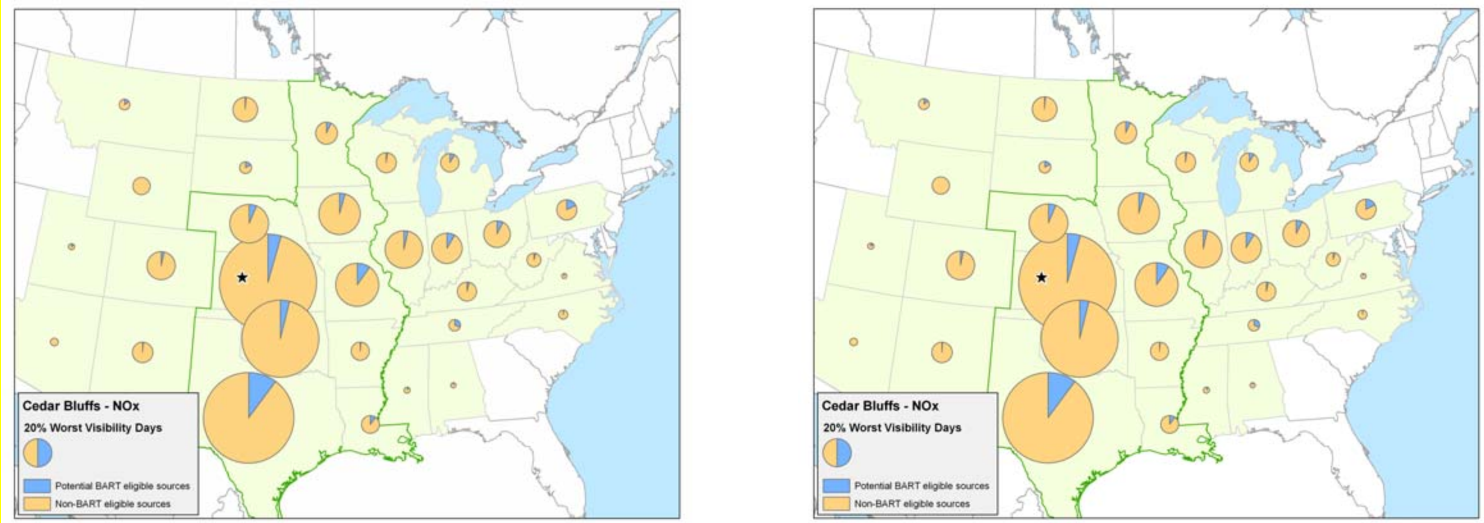
(a) Voyageurs, Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



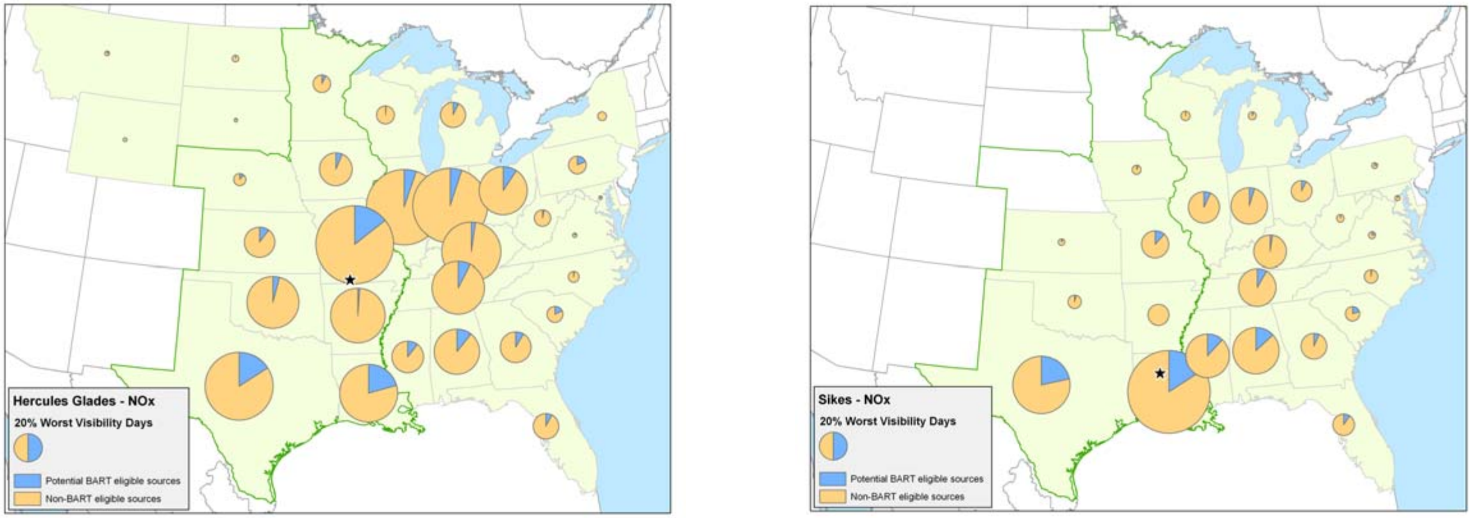
(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

*Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure 4-8. Geographic distributions of SO_2 EIP from point sources on the 20%-worst visibility days observed at four representative sites.



(a) Voyageurs, Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

*Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure 4-9. Geographic distributions of NO_x EIP from point sources on the 20%-worst visibility days observed at four representative sites.

Aerosol components that contribute to poor visibility include sulfate, nitrate, and carbonaceous matter.

Average $PM_{2.5}$ compositions for the 20%-worst days observed at each representative site are illustrated in **Figures 4-10 through 4-13**. The IMPROVE equation (Malm et al., 1994; IMPROVE, 2004) was used to calculate the total light extinction (b_{ext}) contribution of each chemical component. However, we note the likelihood that the IMPROVE equation does not fully account for extinction by OC (Lowenthal and Kumar, 2003); therefore, OC may be somewhat more important than the figures indicate.

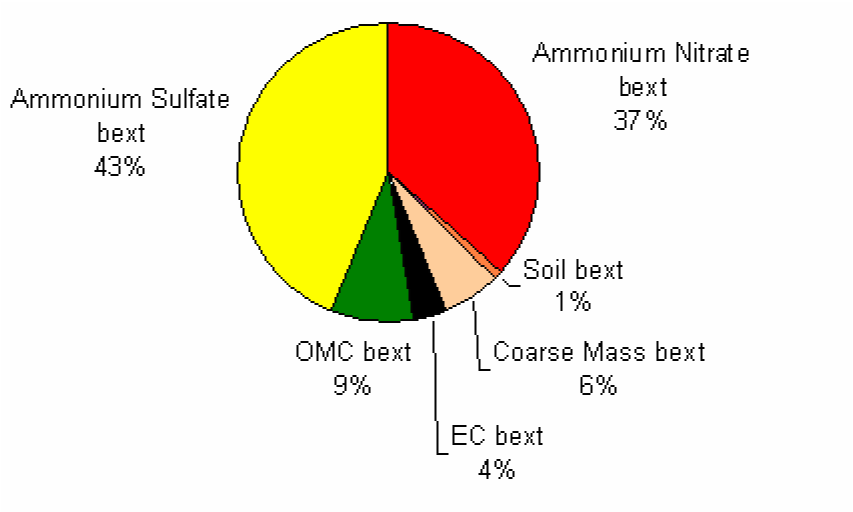


Figure 4-10. Average light extinction budget (b_{ext}, based on the IMPROVE visibility equation) on the 20%-worst visibility days at Cedar Bluff during 2002-2003.

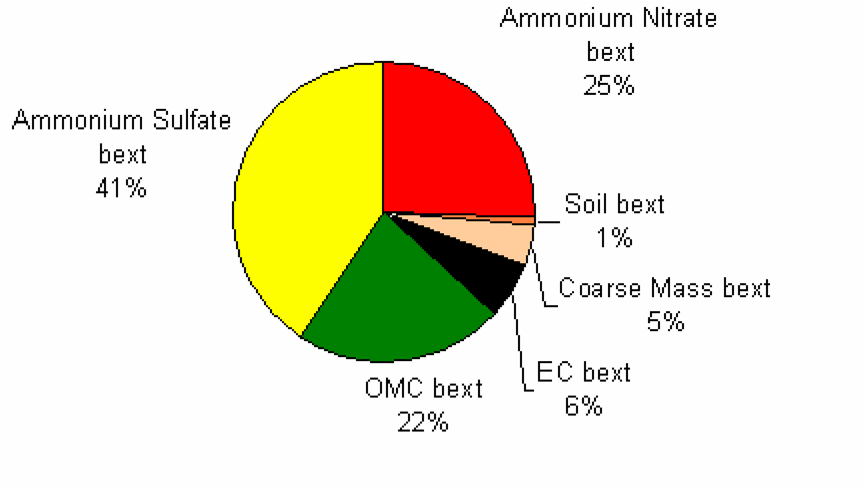


Figure 4-11. Average light extinction budget (b_{ext}, based on the IMPROVE visibility equation) on the 20%-worst visibility days at Voyageurs during 2002-2003.

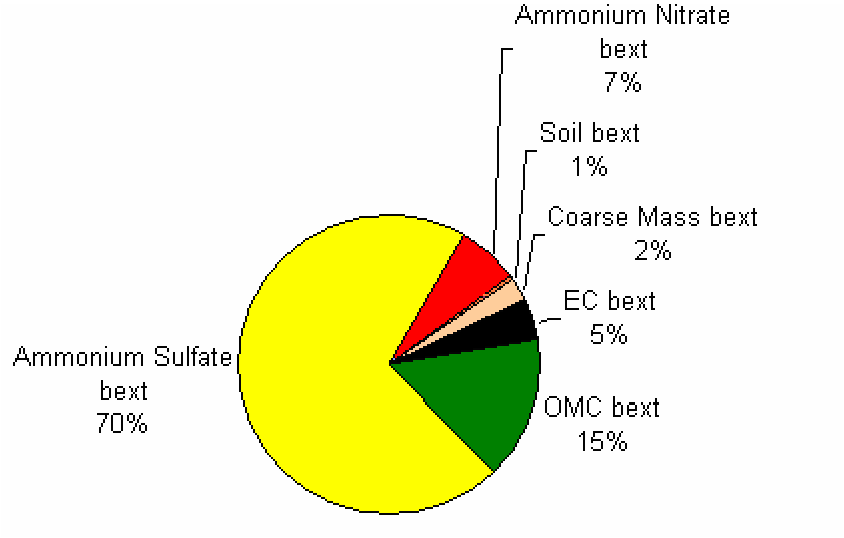


Figure 4-12. Average light extinction budget (b_{ext}, based on the IMPROVE visibility equation) on the 20%-worst visibility days at Sikes during 2002-2003.

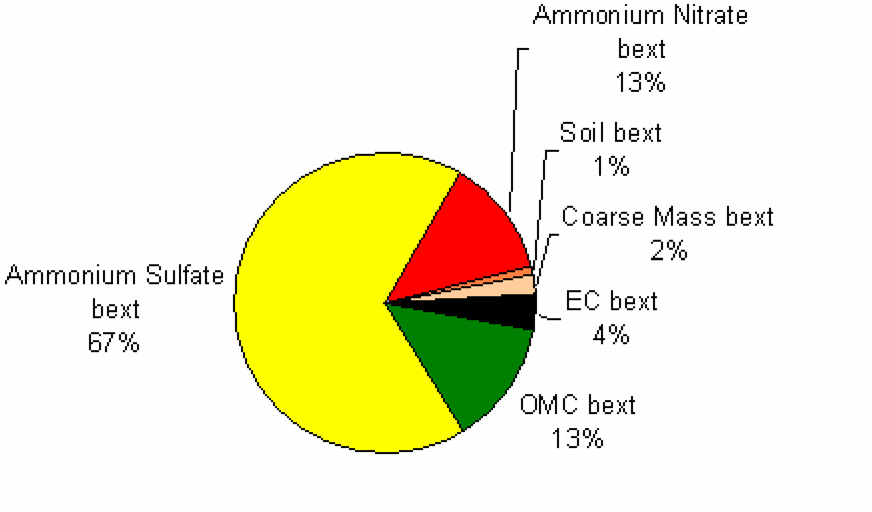


Figure 4-13. Average light extinction budget (b_{ext}, based on the IMPROVE visibility equation) on the 20%-worst visibility days at Hercules-Glades during 2002-2003.

Source regions both outside of and within CENRAP are important contributors to visibility impairment at the protected sites.

"Factors" (i.e., statistical results from which we infer types of emissions sources) contributing to $PM_{2.5}$ mass were identified at Sikes and Hercules-Glades using the receptor modeling tool Positive Matrix Factorization (PMF). At both sites, eight factors best characterized the ambient data, with predicted mass comparing well to measured mass (i.e., $r^2 > 0.97$ and slope between 0.98 and 0.99). These factors were inferred to represent specific source types. The average mass composition overall, and on the 20%-worst days observed at Sikes and Hercules-Glades, are shown in **Figures 4-14 and 4-15**.

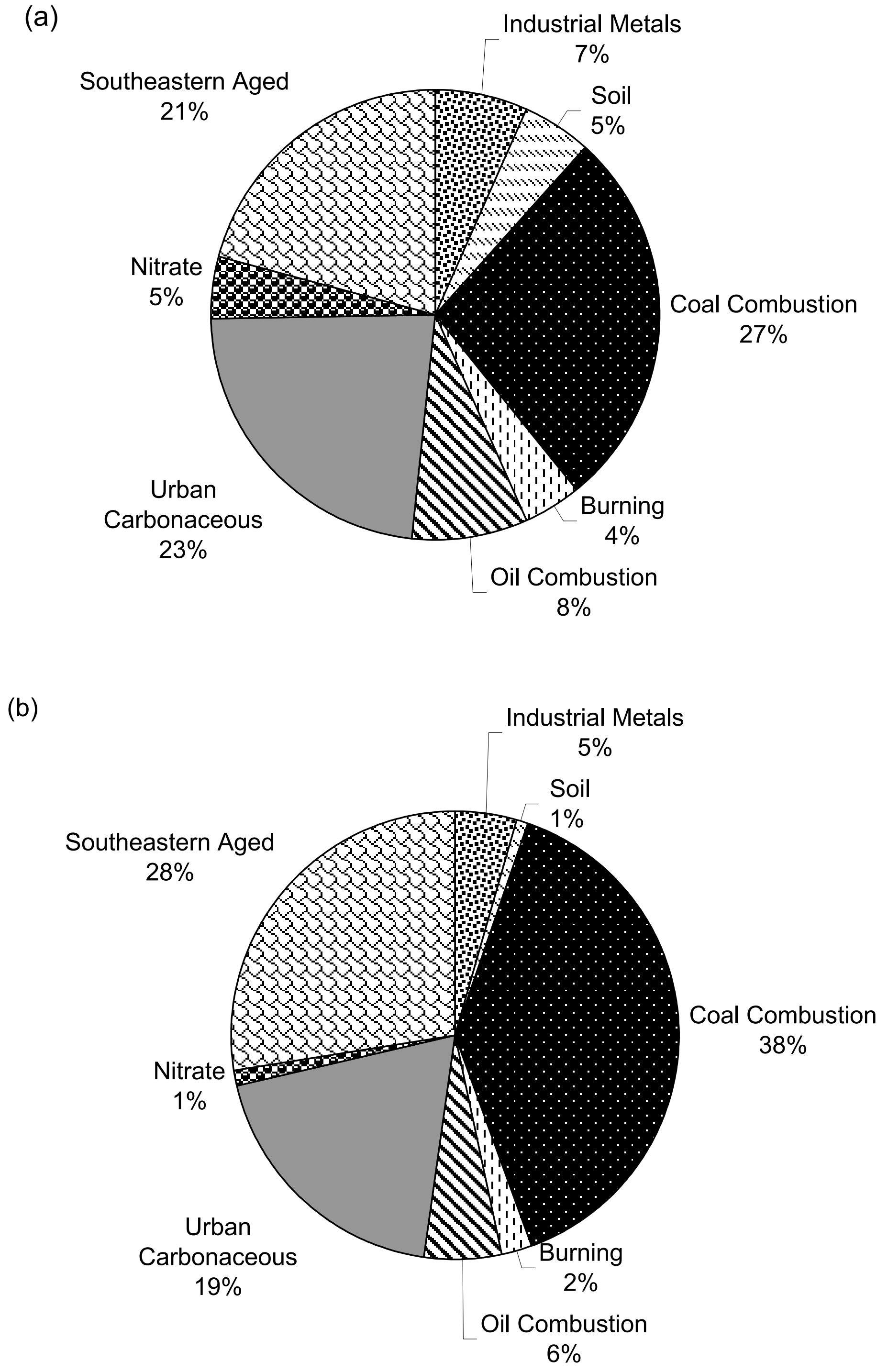
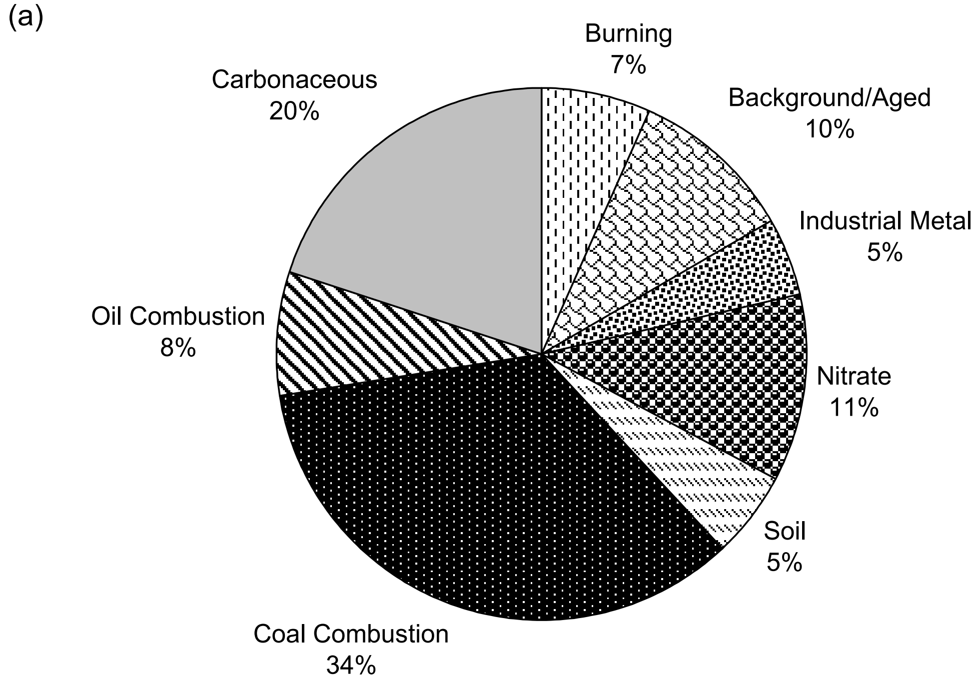


Figure 4-14. Average factor contributions to mass at Sikes for (a) all samples and (b) the 20%-worst visibility days.



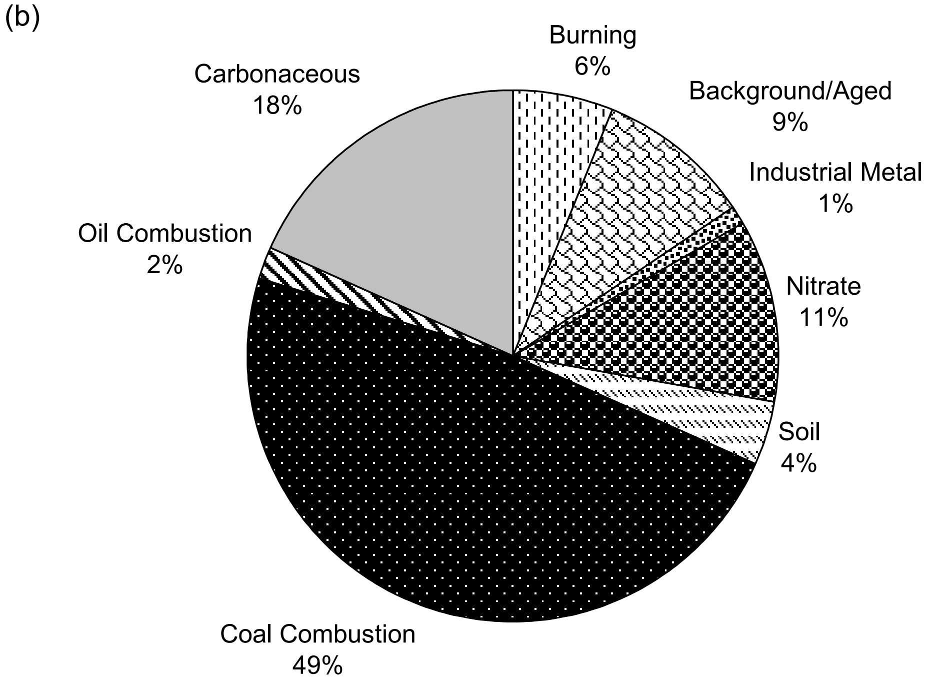


Figure 4-15. Average factor contributions to mass at Hercules-Glades for (a) all samples and (b) the 20%-worst visibility days.

Fires infrequently contribute to visibility impairment observed on the 20%-worst days at most sites in the CENRAP region.

Contributions of OMC to light extinction were evaluated for the 20%-worst days. At all but four sites, OMC contributions infrequently exceeded 20% of total light extinction on poor-visibility days.[4] The exceptions included Big Bend during the spring months, Nebraska National Forest during the summer, and the two sites located in the Minnesota region during the summer. In other areas—the Southeastern Plains and Upper Midwest regions—the results of PMF analyses were available to combine with backward wind trajectories and satellite-detected fire data (as discussed below). These types of analyses would be useful to help determine if fires are the sources of elevated OMC at the Big Bend, Nebraska National Forest, and Minnesota region sites.

A biomass burning factor inferred at the Hercules-Glades and Sikes sites did not have a clear temporal trend, but appeared to be episodic. Air mass trajectories were combined with satellite-detected fire locations and geographic extents in an attempt to better characterize the sources associated with the biomass burning factor. The analyses suggest that the biomass burning factor is significant only when local burning and conducive meteorology occur.

At Sikes, on two days when the highest levels of the biomass burning factor were present (August 4, 2003, and April 19, 2001), air mass trajectories showed transport from nearby fire locations (**Figure 4-16**), indicating the likelihood that the factor is correctly associated with impacts from biomass burning. However, none of the days on which the highest levels of the biomass burning factor occurred were among the 20%-worst days, indicating that while biomass burning is episodic and detectable, it does not appear to be an important contributor to poor visibility on the 20%-worst days at Sikes. Overall, the biomass factor accounted for only 4% of the median mass, and only 2% of the mass on the 20%-worst days.

Similar observations were made with the data analyzed for Hercules-Glades. On two days when the highest levels of the biomass burning factor were present (April 12, 2003, and May 9, 2003), air mass trajectories showed transport from nearby fire locations (**Figure 4-17**). Periods of time when the biomass burning factor was high were associated with nearby fires, rather than with long-range multi-day transport. Overall, the biomass burning factor accounted for 7% of the median mass, and 6% of the mass on the worst visibility days. Some of the days showing high levels of the biomass burning factor coincided with episodes of poor visibility. However, on average, the biomass burning factor was substantially less important than coal combustion and other factors.

We note that our analyses likely produced a lower limit estimate of the influence of biomass burning. PMF is unable to fully quantify a burning factor because the chemical fingerprint of the factor profile varies with distance from the source (or aging air mass), fuel type, and atmospheric chemistry during transport. If samples were collected every day during spring and summer, or if observations of organic molecular markers such as levoglucosan (Sheesley et al., 2003; Zheng et al., 2002; Schauer et al., 2001a; Fine et al., 2004; Brown et al., 2002; Fine et al., 2002; Schauer et al., 2001b; Nolte et al., 2001) were available, these analyses could be substantially improved.

---

[4] The contribution of OMC to total light extinction exceeded 20% on fewer than 20% of the 20%-worst days.

Very infrequently does geologic material contribute appreciably to visibility impairment observed on the 20%-worst days at most sites in the CENRAP region.

The combined contribution of soil plus course mass infrequently exceeded 20% of total light extinction on 20%-worst days.[5] The Guadalupe Mountains site was the only exception. At that site, soil plus course mass contributed from 20% to 86% of total light extinction on roughly two-thirds of the poor-visibility days. In the Southeastern Plains and Upper Midwest regions PMF results were available to combine with backward wind trajectories (as discussed below) to determine likely sources of geologic material. These types of analyses would be useful to help identify the sources of dust impacting the Guadalupe Mountains site.

An event-driven soil factor comprised of silicon, iron, and titanium was identified for the Hercules-Glade and Sikes sites. This soil factor yielded relatively high contributions to $PM_{2.5}$ mass during a few events, the two principal of which occurred on July 1 and 31, 2002. On these two dates, the soil factor approached a mass contribution of 20 $\mu g/m^3$ at Sikes and Hercules-Glades, where it more typically averaged 0.6 $\mu g/m^3$ (or 5% of the mass). Ten-day backward wind trajectories calculated for July 1 and 31, 2002, such as the example shown in **Figure 4-18**, indicate rapid transport across the Atlantic Ocean. This transport pattern suggests that Saharan dust contributed to $PM_{2.5}$ masses at Sikes and Hercules-Glades on July 1 and 31, 2002. Other days with relatively large soil factor contributions were associated with transport over the Great Plains. However, none of the days with especially large soil factor contributions occurred on the 20%-worst visibility days at Sikes or Hercules-Glades. Thus, long-range transport of dust appears to have little effect on the 20%-worst days in the Southeastern Plains and Upper Midwest regions.

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[5] The contribution of soil plus course mass to toal light extinction exceeded 20% on fewer than 20% of the 20%-worst days.

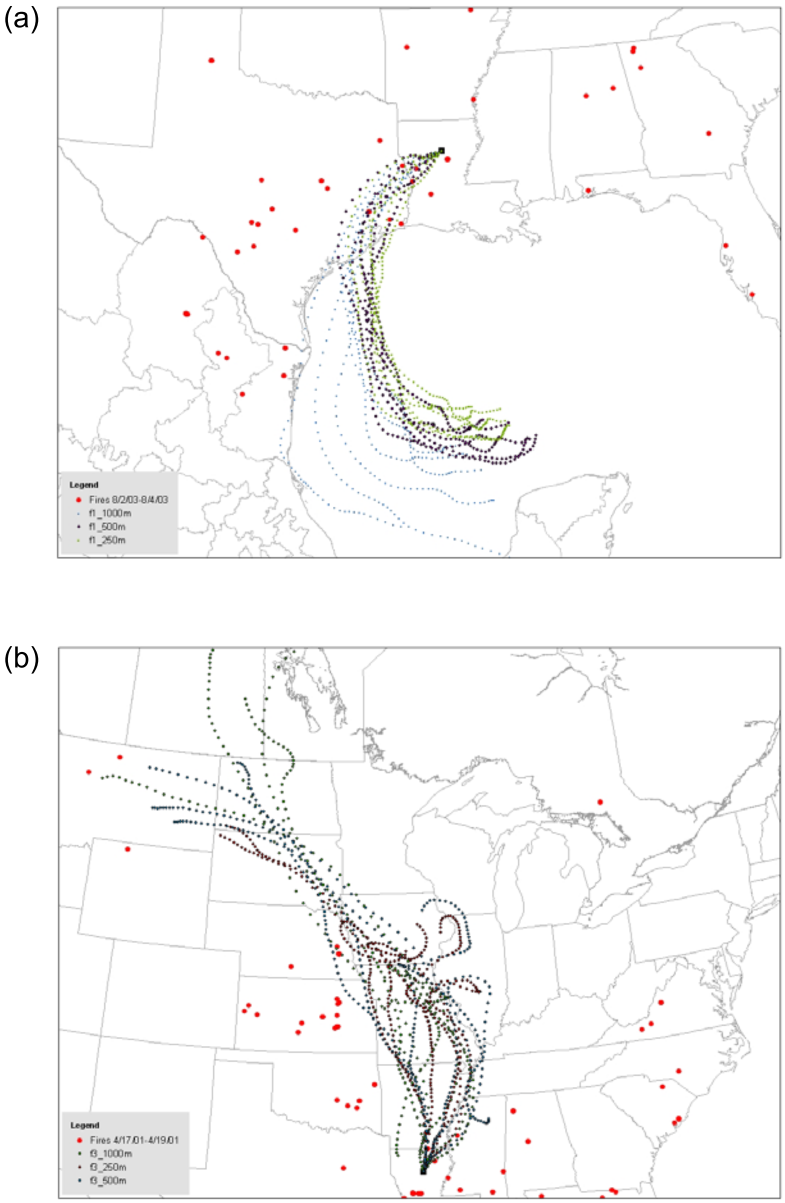
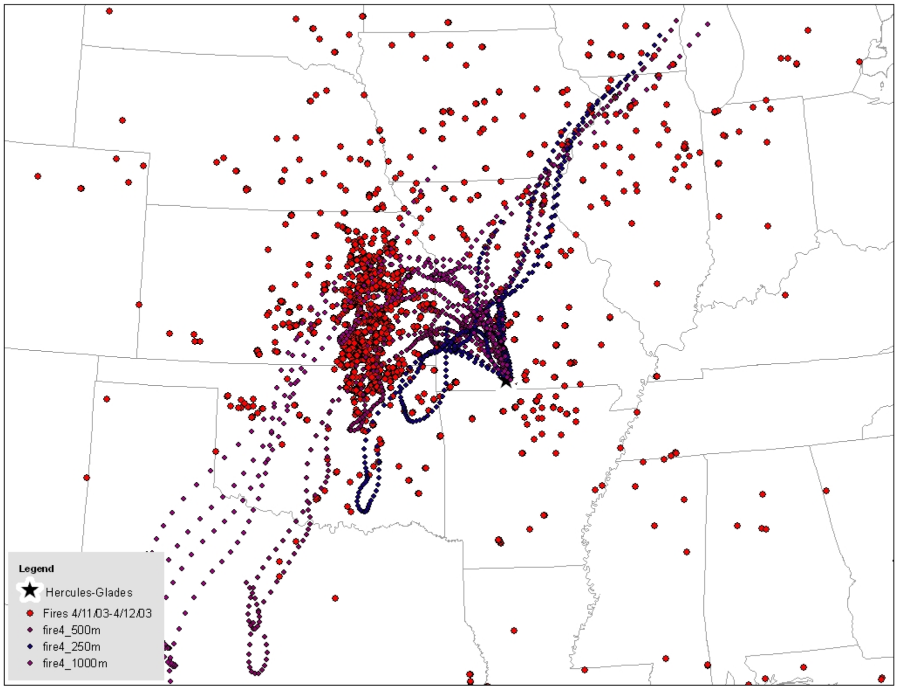


Figure 4-16. Three-day air mass backward trajectories using the NOAA HYSPLIT model with 250-m, 500-m, and 1000-m ending heights at Sikes and fire locations on (a) August 4, 2003, and (b) April 19, 2001.

(a)



(b)

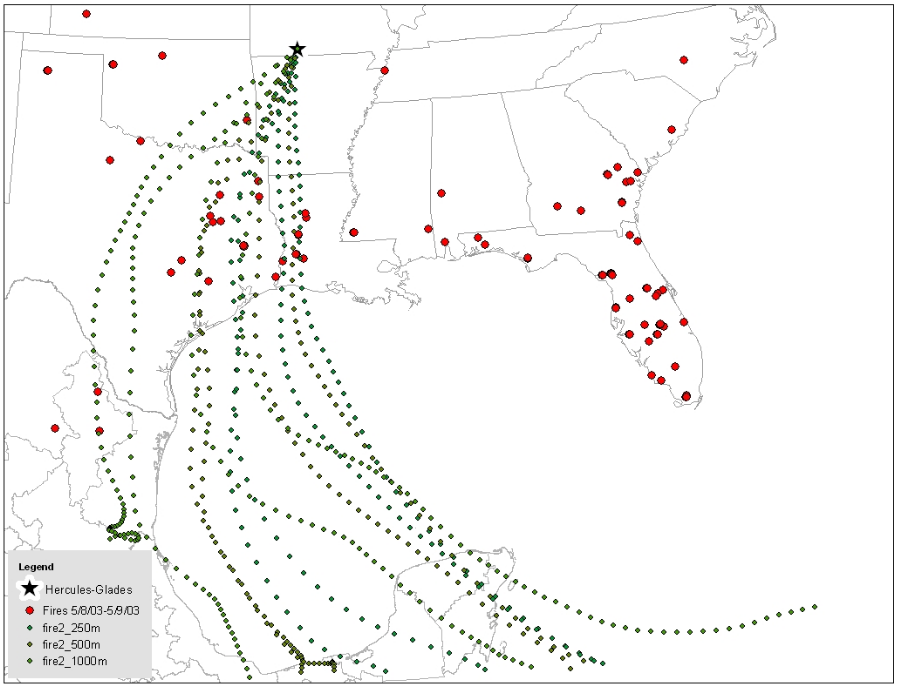


Figure 4-17. Three-day air mass backward trajectories using the NOAA HYSPLIT model with 250-m, 500-m, and 1000-m ending heights at Hercules-Glades and fire locations on the burning event day of (a) April 12, 2003, and (b) May 9, 2003.

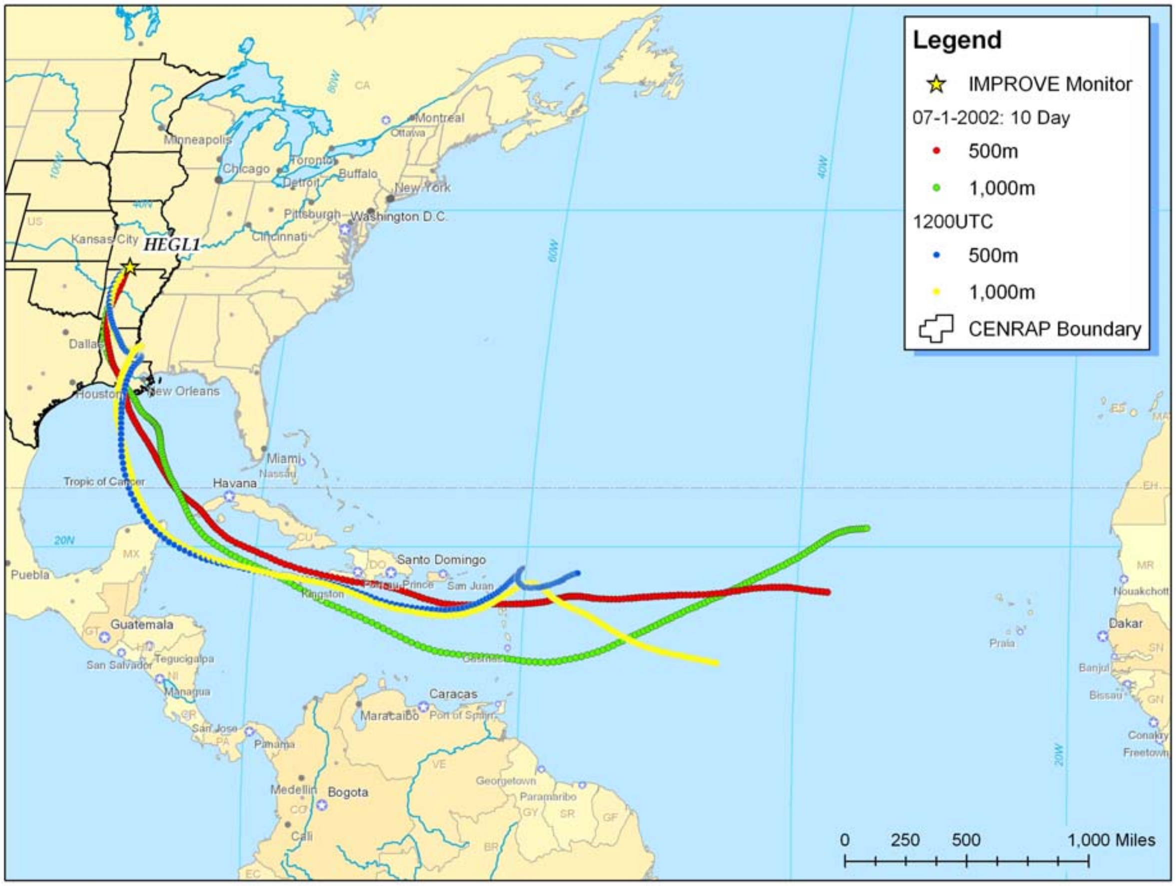


Figure 4-18. Air mass trajectories on the dust event of July 1, 2002.

4.3 EVIDENCE FOR IDENTIFYING THE PREDOMINANT METEOROLOGICAL CONDITIONS DURING PERIODS OF GOOD OR POOR VISIBILITY

In general, the meteorology of 2002-2003 was near normal for the CENRAP region and can, therefore, be considered "representative".

Figures 4-19 and 4-20 show National Climatic Data Center 2002 and 2003 state precipitation and temperature rankings in the context of the past 108 years. For example, in 2002, Texas' temperature rank was 61; over 108 years, about one-half of Texas' average temperatures were greater than, and about one-half of the average temperatures were less than, the average temperature in 2002. Thus, 2002 is classified as normal for Texas. There are four gradations on either side of normal, ranging from a near-normal to a record year. Very few states fall outside the near-normal ranking in 2002 or 2003 for either precipitation or temperature.

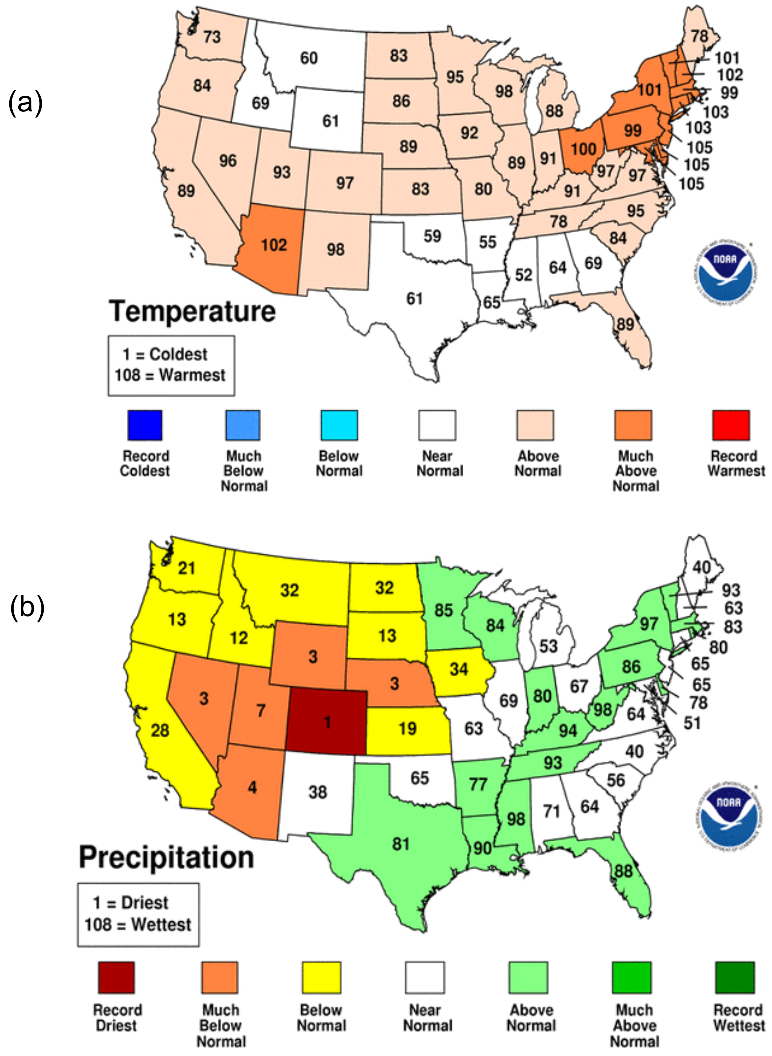


Figure 4-19. January through December 2002 statewide ranks for (a) temperature and (b) precipitation. (Figures from the National Climatic Data Center.)

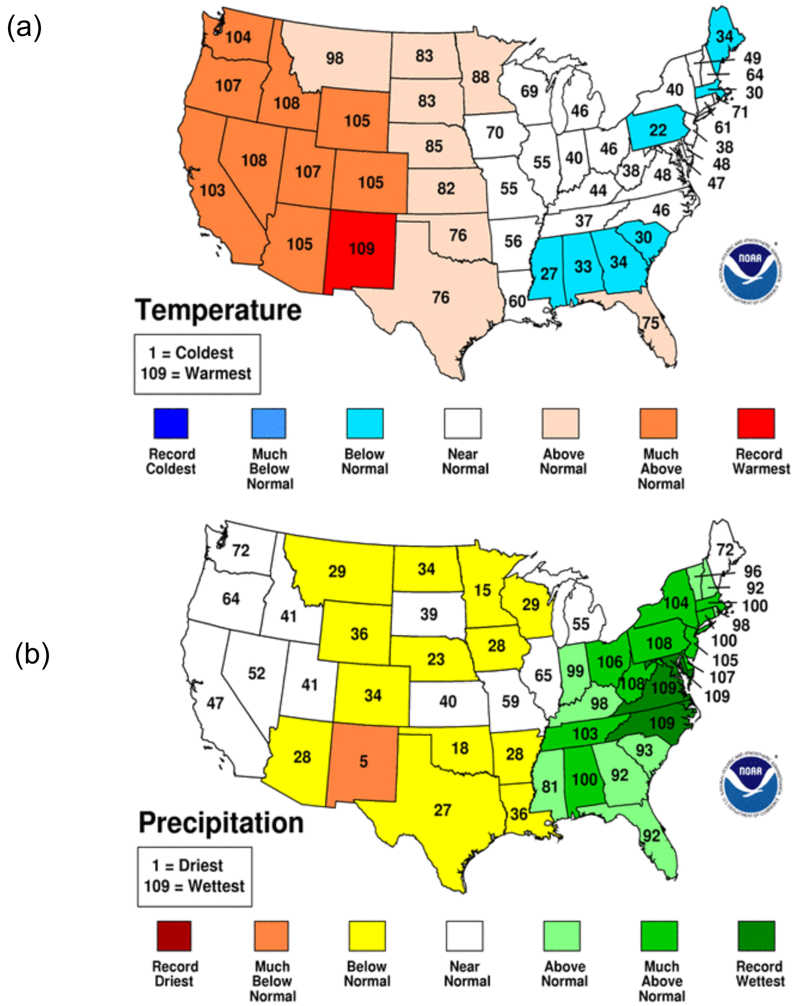


Figure 4-20. January through December 2003 statewide ranks for (a) temperature and (b) precipitation. (Figures from the National Climatic Data Center.)

There are numerous types of weather and transport conditions that occur on the 20%-best or 20%-worst days during 2002-2003, and there are representative days and episodes in 2002 that are suitable for modeling.

Cluster analysis was used to group days based on meteorological and transport characteristics for four CENRAP subregions for the 20%-best and 20%-worst days. The variables used, and the resulting clusters obtained, in the analysis are presented in the Appendix B**.** The transport and meteorological parameters that were used to define individual days are illustrated in daily schematics in Appendix B. An example of a schematic for one day is shown in **Figure 4-21**. The variables in the schematic capture large-scale weather patterns, transport, local stability, temperature, relative humidity, winds, and the predominant PM species. Based on evaluation of these schematics, days with similar transport and meteorology characteristics were grouped. On average, we identified five groups of days with the same characteristics for each subregion for both the 20%-worst and 20%-best days. The general meteorological and transport characteristics associated with the groups for each subregion are summarized below. Recommended modeling days shown in Tables 3-1 and 3-2 were determined by selecting episodes that coincided among the subregions and reflected most of the common meteorological and transport characteristics identified in the clusters.

- For the Northern Minnesota subregion (represented by Voyageurs), the 20%-worst days occurred during both winter and summer and typically coincided with high levels of relative humidity in the morning. In winter, nitrates were the predominant light-scattering species and westerly transport generally prevailed. In summer, southeasterly transport coincided with large light-scattering contributions from sulfates, while stagnant conditions were associated with relatively large contributions from OC species.
- In the Northern Minnesota subregion, the 20%-best days typically occurred during the cold season, tended to exist with weak atmospheric stabilities (compared to the 20%-worst days), and coincided with northerly transport conditions.
- For the Western Plains subregion (represented by Cedar Bluff), the 20%-worst days occurred during both cold and warm seasons and typically coincided with high morning relative humidity. In winter, nitrates were the predominant light-scattering species, and transport tended to be northerly. In summer, high light-scattering contributions from sulfates tended to correlate with southeasterly transport and quiescent upper-level meteorological patterns.
- In the Western Plains, the 20%-best days typically paired with northwesterly transport during the cold season.
- For the Upper Midwest subregion (represented by Hercules-Glades), the 20%-worst days typically occurred during the warm season when transport was easterly or southeasterly and sulfates dominated visibility impairment.
- In the Upper Midwest, the 20%-best days occurred in both cold and warm seasons when upper-level low-pressure troughs over the central or eastern United States paired with transport from the north and northwest.
- For the Southeastern Plains subregion (represented by Sikes), the 20%-worst days usually occurred during the warm season. Southeasterly or north-northeasterly transport conditions corresponded to the predominance of sulfate in visibility impairment.
- For the Southeastern Plains subregion, the 20%-best days occurred primarily in the cold season when transport patterns carried air masses from the northwest or over the Gulf of Mexico from the southeast.

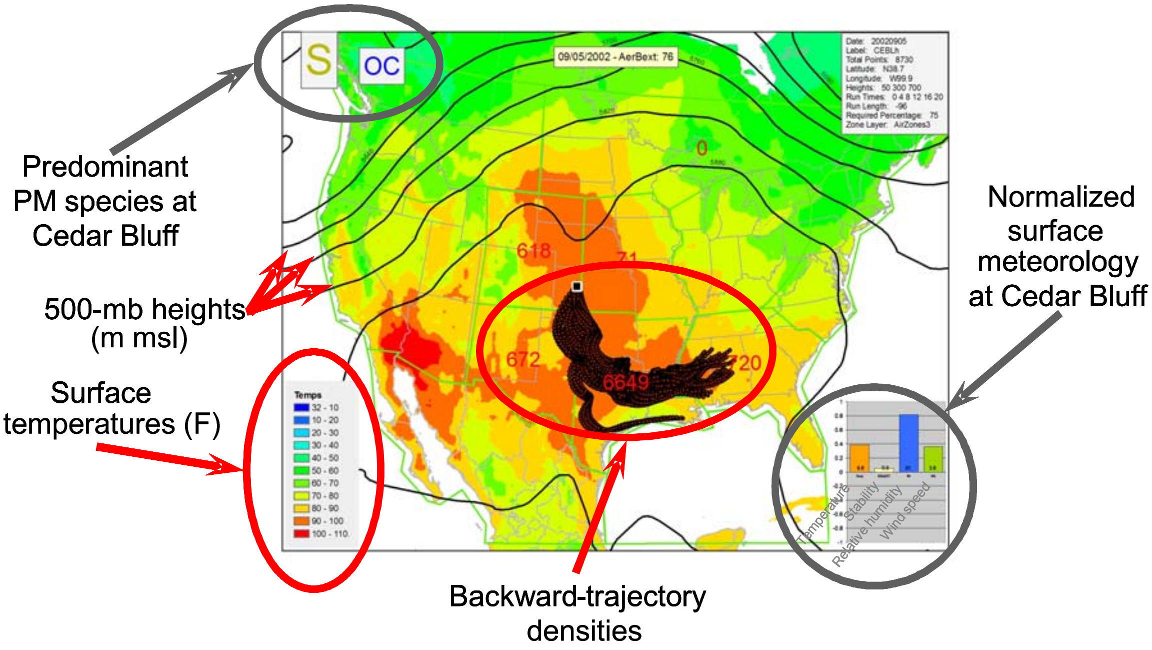


Figure 4-21. An annotated schematic depicting meteorology and transport conditions for one of the 20%-worst visibility days at the Cedar Bluff site.

4.4 EVIDENCE RELATING MULTI-YEAR EMISSIONS TRENDS TO TRENDS IN THE CAUSES OF HAZE

SO_2 emissions in the Ohio River Valley states (Ohio, West Virginia, Kentucky, Indiana, and Illinois), Tennessee, and Missouri declined substantially from 1990 to 1999.

Trends in state-level SO_2 emissions from 1990 to 1999 are illustrated in **Figure 4-22.** Five-year average ammonium sulfate concentrations observed on the 20%-worst days declined from about 11 µg/m^3 in 1993/1994 to 9 µg/m^3 in 1999/2000 (**Figure 4-23**) at the Upper Buffalo site. (Details about how five-year averages were computed and plotted are available on the VIEWS web site). Light extinction due to ammonium sulfate on the 20%-worst days declined during the same period from about 100 Mm^{-1} to 80 Mm^{-1} (**Figure 4-24**), while total light extinction declined from about 140 Mm^{-1} to 120 Mm^{-1} (**Figure 4-25**). Visibility conditions on the 20%-best days also benefited slightly from declining ammonium sulfate concentrations (**Figure 4-26**).

Figure 4-22. State-level trends in SO_2 emissions for the period 1990-1999. (Source: Schichtel et al., 2004)

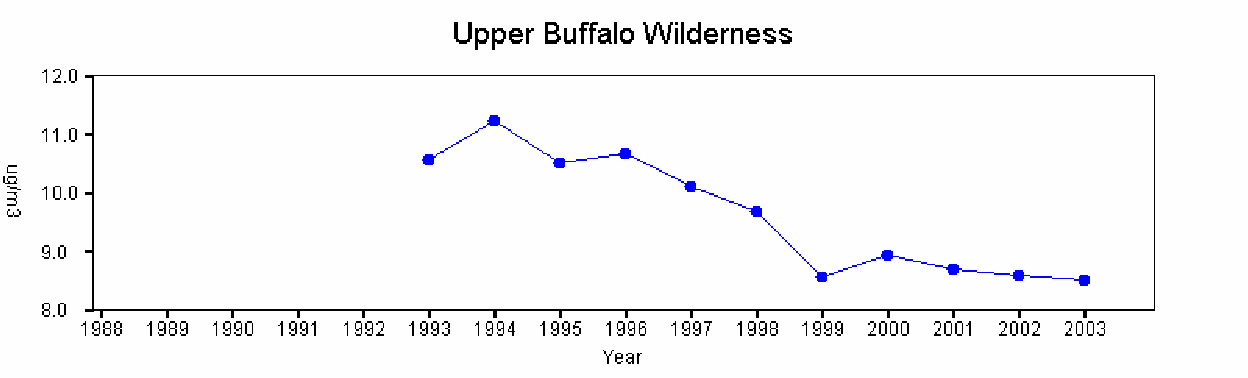


Figure 4-23. Five-year average ammonium sulfate concentrations observed on the 20%-worst visibility days at the Upper Buffalo site from 1993-2003. (Source: Visibility Information Exchange Web System)

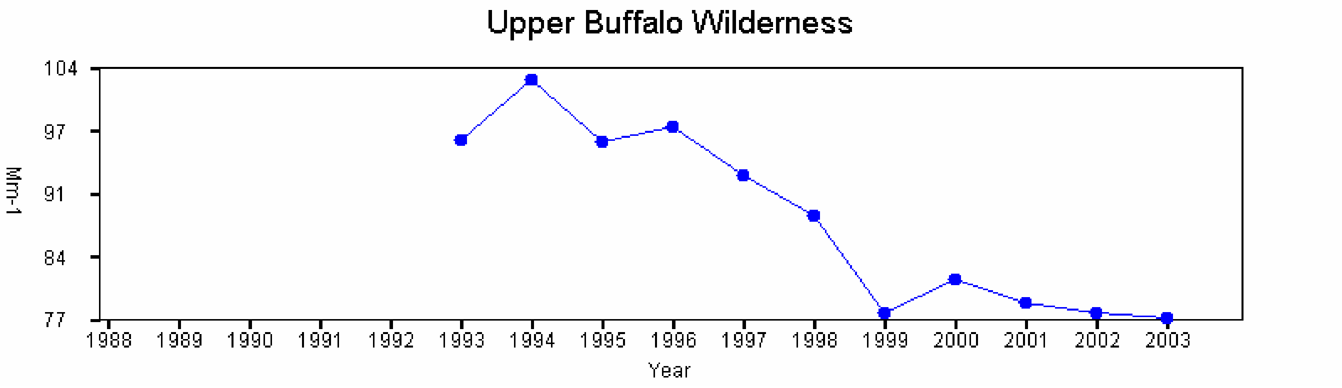


Figure 4-24. Five-year average light extinction due to ammonium sulfate observed on the 20%-worst visibility days at the Upper Buffalo site from 1993-2003. (Source: Visibility Information Exchange Web System)

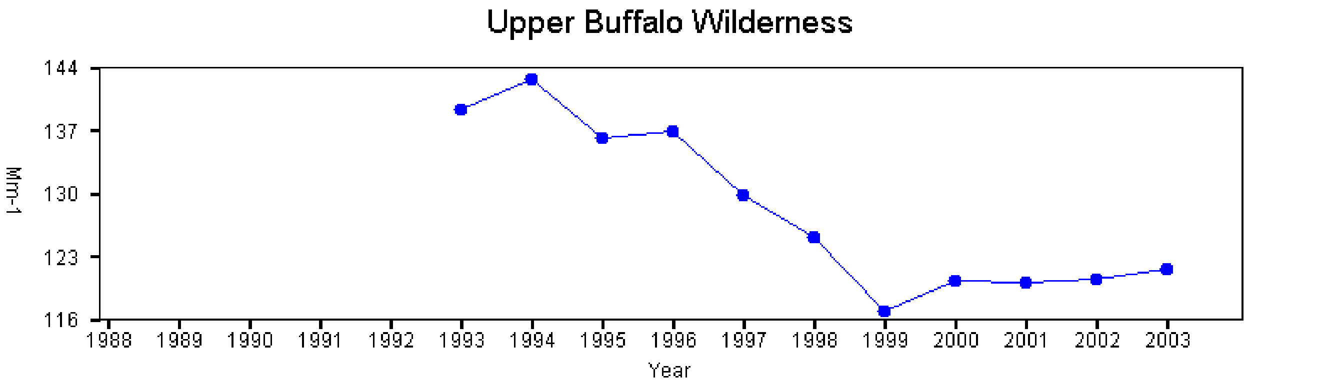


Figure 4-25. Five-year average total light extinction observed on the 20%-worst visibility days at the Upper Buffalo site from 1993-2003. (Source: Visibility Information Exchange Web System)

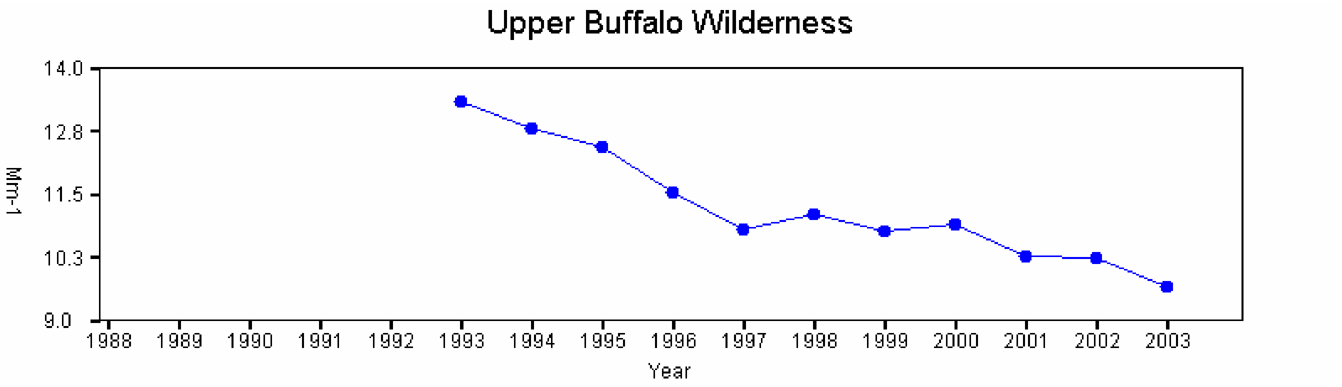


Figure 4-26. Five-year average light extinction due to ammonium sulfate observed on the 20%-best visibility days at the Upper Buffalo site from 1993-2003. (Source: Visibility Information Exchange Web System)

SO_2 emissions in Texas, New Mexico, Arizona, Louisiana, Arkansas, and Mississippi increased somewhat from 1990 to 1999.

Trends in state-level SO_2 emissions from 1990 to 1999 are illustrated in Figure 4-22. Five-year average ammonium sulfate concentrations observed on the 20%-worst days increased from about 4 µg/m^3 in 1990/1991 to 5-6 µg/m^3 in 1999/2000 (**Figure 4-27**) at the Big Bend site. Light extinction due to ammonium sulfate on the 20%-worst days increased during the same period from about 20 Mm^{-1} to 28 Mm^{-1} (**Figure 4-28**), while total light extinction increased from about 41 Mm^{-1} to 54 Mm^{-1} (**Figure 4-29**). Visibility conditions on the 20%-best visibility days did not change noticeably (**Figure 4-30**).

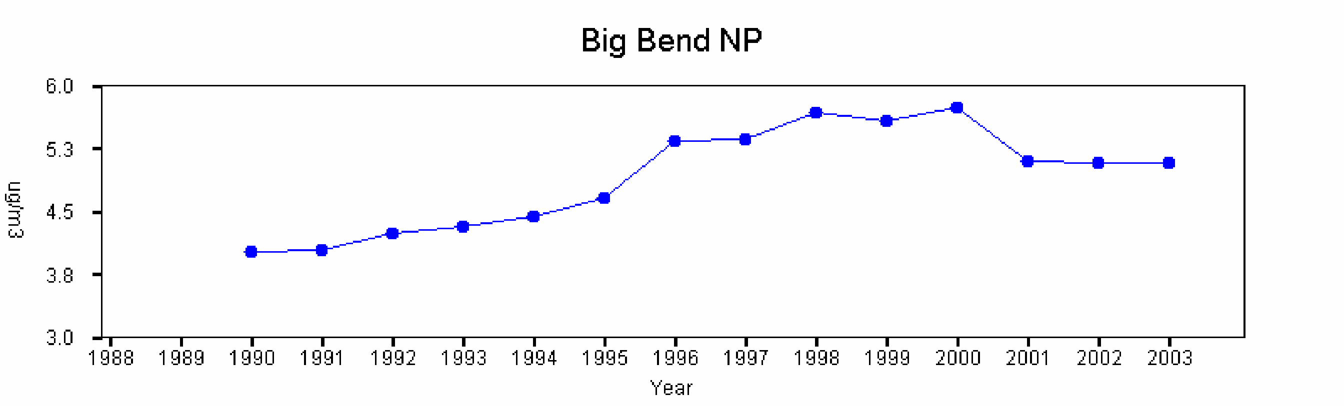


Figure 4-27. Five-year average ammonium sulfate concentrations observed on the 20%-worst visibility days at the Big Bend site from 1990-2003. (Source: Visibility Information Exchange Web System)

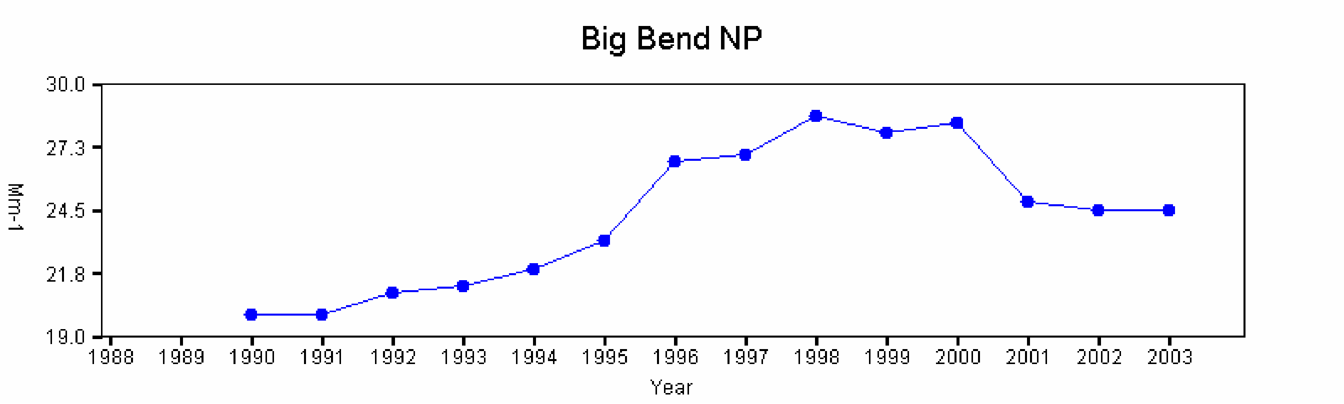


Figure 4-28. Five-year average light extinction due to ammonium sulfate observed on the 20%-worst visibility days at the Big Bend site from 1990-2003. (Source: Visibility Information Exchange Web System)

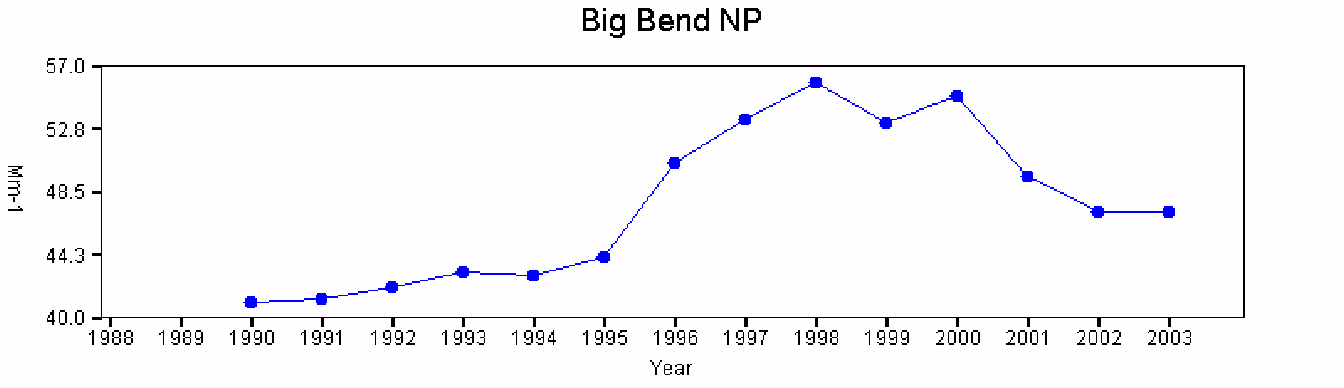


Figure 4-29. Five-year average total light extinction observed on the 20%-worst visibility days at the Big Bend site from 1990-2003. (Source: Visibility Information Exchange Web System)

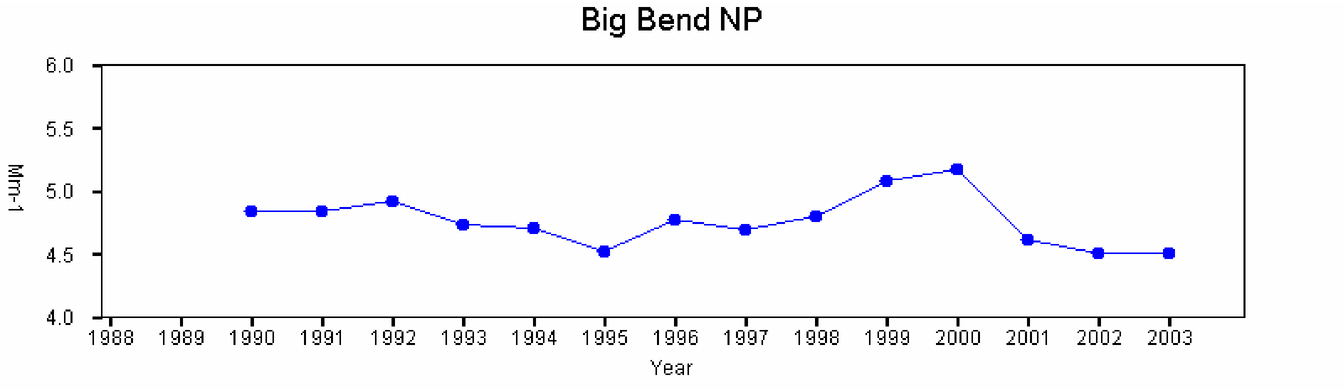


Figure 4-30. Five-year average light extinction due to ammonium sulfate observed on the 20%-best visibility days at the Big Bend site from 1990-2003. (Source: Visibility Information Exchange Web System)

In Minnesota and surrounding states, the trend in SO_2 emissions varied from state to state.

Trends in state-level SO_2 emissions from 1990 to 1999 are illustrated in Figure 4-22. . Five-year average ammonium sulfate concentrations observed on the 20%-worst days declined from about 4.5 µg/m^3 in the early 1990s to 2.8-3.8 µg/m^3 in 1999/2000 (**Figure 4-31**) at the Boundary Waters-Canoe and Voyageurs sites. Light extinction due to ammonium sulfate on the 20%-worst days declined during the same period from 35-40 Mm^{-1} to 20-30 Mm^{-1} (**Figure 4-32**), while total light extinction increased from 70-75 Mm^{-1} to 55-67 Mm^{-1} (**Figure 4-33**). Visibility conditions on the 20%-best days did not change noticeably at the Boundary Waters-Canoe site, but may have improved slightly at Voyageurs (**Figure 4-34**).

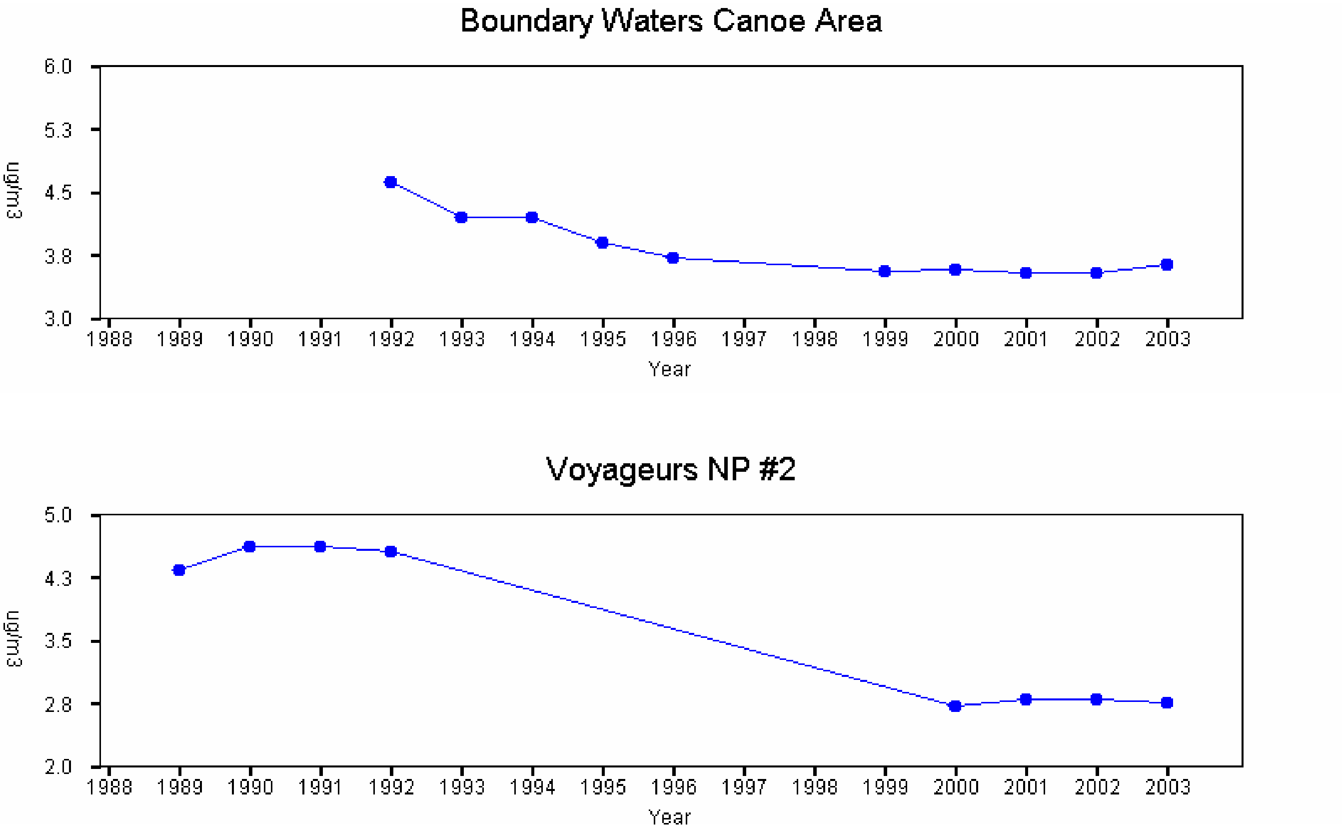


Figure 4-31. Five-year average ammonium sulfate concentrations observed on the 20%-worst visibility days at the Northern Minnesota sites, Boundary Waters-Canoe and Voyageurs (VOYA2), from 1989-2003. (Source: Visibility Information Exchange Web System)

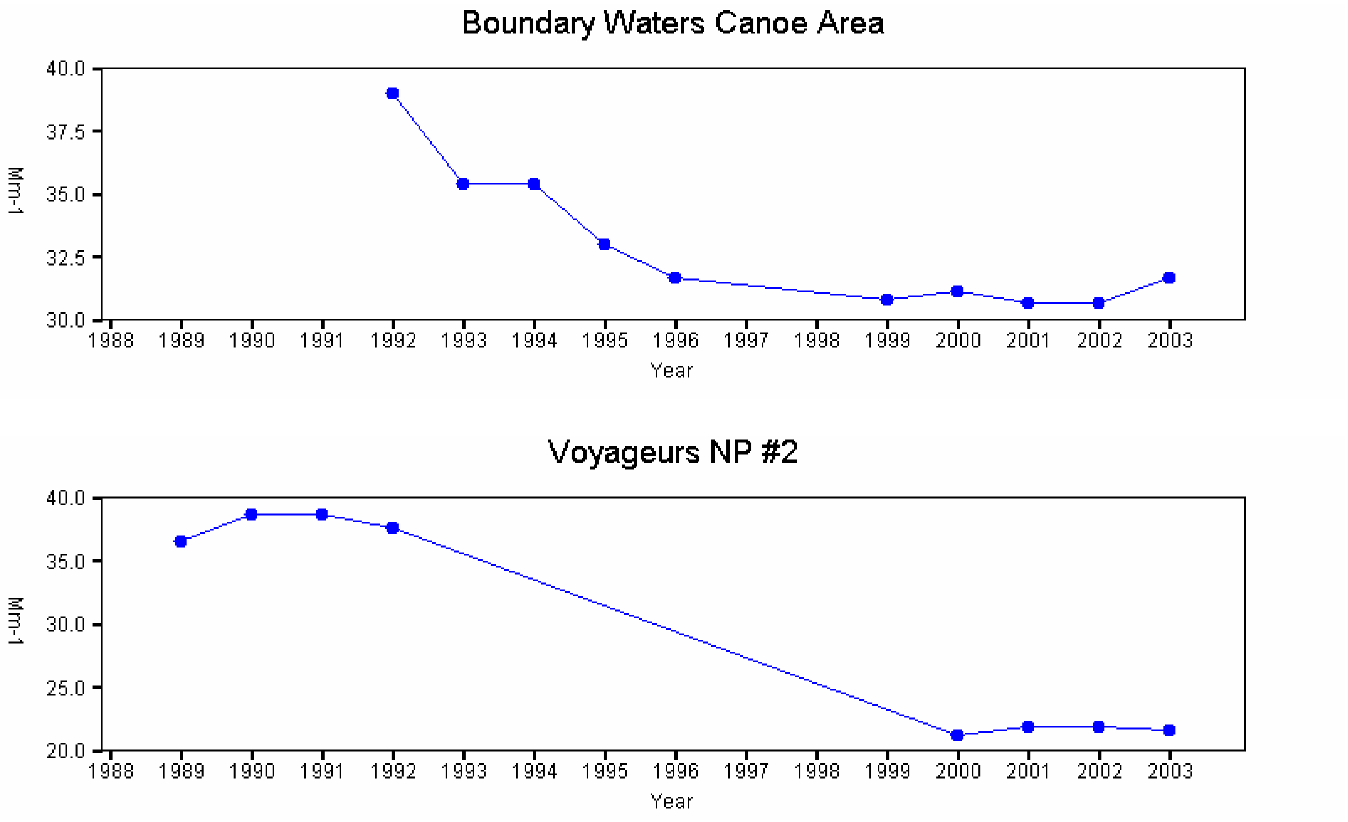


Figure 4-32. Five-year average light extinction due to ammonium sulfate observed on the 20%-worst visibility days at the Northern Minnesota sites, Boundary Waters-Canoe and Voyageurs (VOYA2), from 1989-2003. (Source: Visibility Information Exchange Web System)

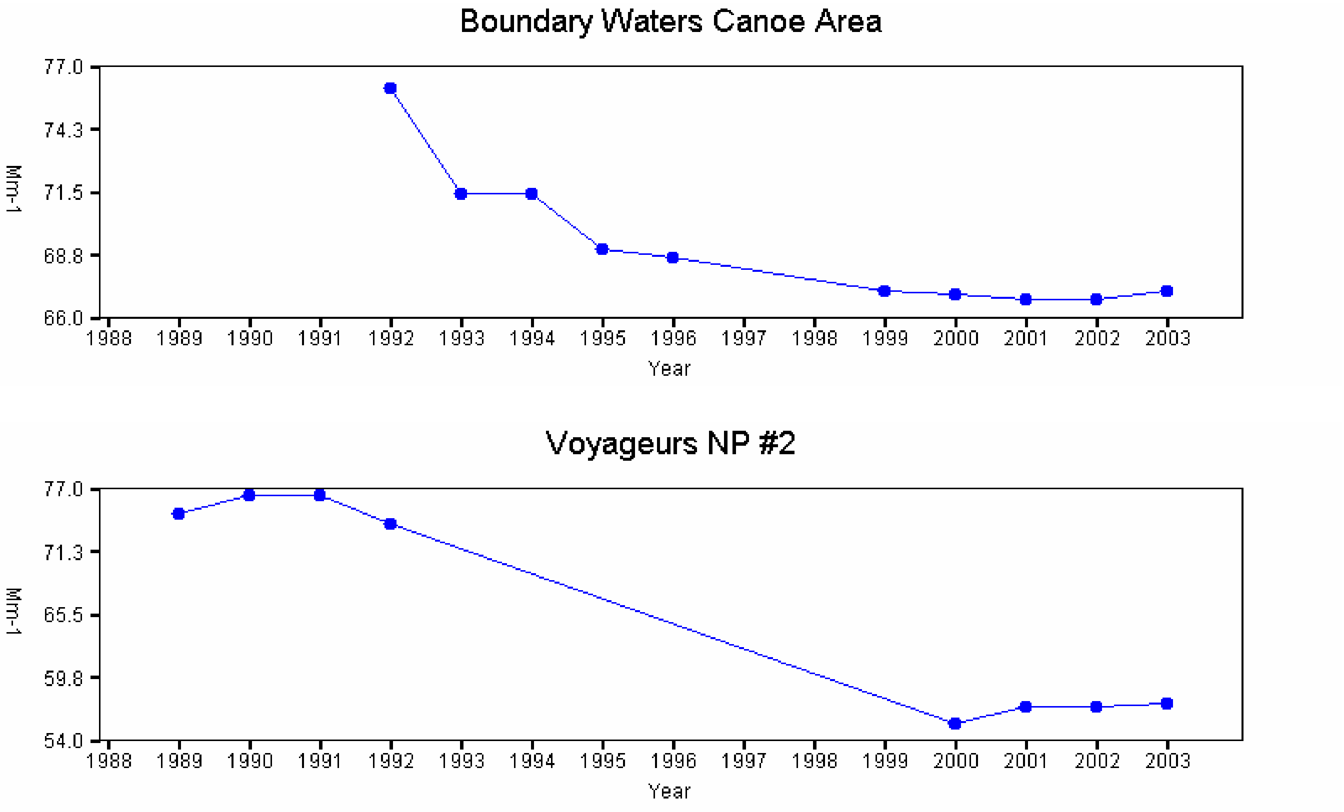
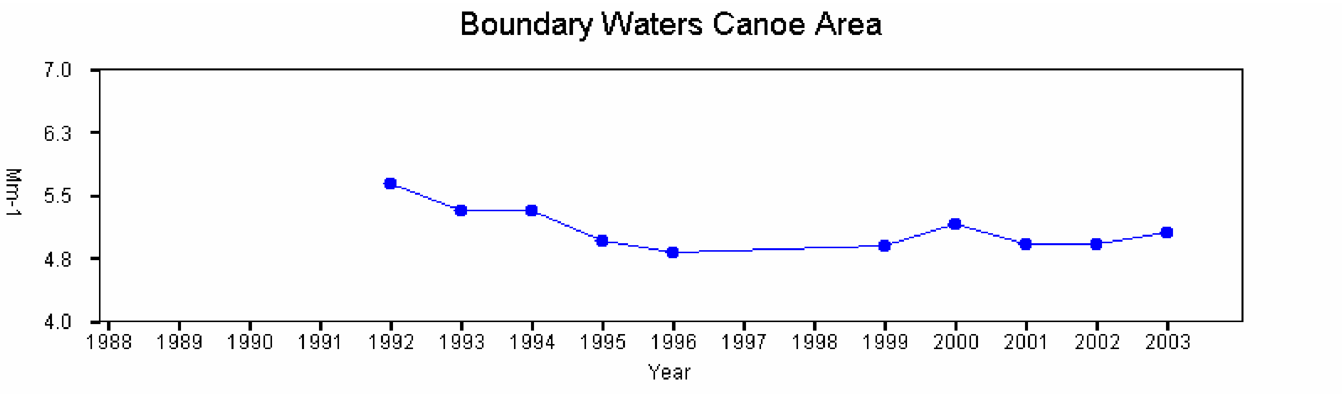


Figure 4-33. Five-year average total light extinction observed on the 20%-worst visibility days at the Northern Minnesota sites, Boundary Waters-Canoe and Voyageurs (VOYA2), from 1989-2003. (Source: Visibility Information Exchange Web System)


Boundary Waters Canoe Area

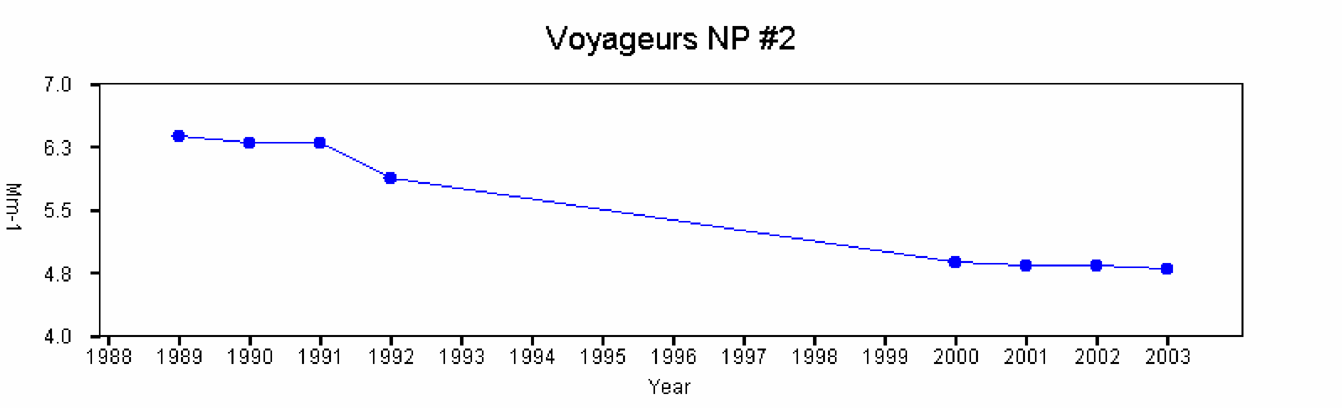

Voyageurs NP #2

Figure 4-34. Five-year average light extinction due to ammonium sulfate observed on the 20%-best visibility days at the Northern Minnesota sites, Boundary Waters-Canoe and Voyageurs (VOYA2), from 1989-2003. (Source: Visibility Information Exchange Web System)

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APPENDIX A

DOCUMENTATION OF METHODS AND GRAPHICAL SUMMARY OF DATA FOR TASK 4

SPATIOTEMPORAL ANALYSIS

A.1 INTRODUCTION

The objective of this task is to identify subregions within CENRAP where aerosol extinction and concentrations of $PM_{2.5}$ components significantly covary in space and time. This analysis will help in selecting representative sites for further analysis which will eliminate the need to model and characterize every site. This task uses recent speciated $PM_{2.5}$ data for 2002-2003 collected as part of the IMPROVE program. The primary tool used in this task is principal component analysis (PCA) with Varimax rotation. PCA was applied to identify groups of sites that have similar variance of aerosol extinction (by b_{ext}) or a given species concentration (e.g., organic carbon [OC], nitrate, sulfate, etc.) using data from all sites (Lehman et al., 2004; Eder et al., 1993). The analyses performed in this task built on previous work conducted in Phase I by Desert Research Institute (DRI), in which areas of covariance of $PM_{2.5}$ concentrations in the CENRAP and WRAP regions were identified. The results of this task are sets of sites (i.e., subregions of CENRAP) that share characteristically varying air quality on the 20%-worst and 20%-best visibility days. Representative sites for each subregion are also selected for detailed analyses in later tasks.

A.2 METHOD

IMPROVE data collected on a 1-in-3 day schedule for 2002-2003 at 23 sites in the CENRAP region were obtained from the IMPROVE web site. Basic quality control (QC) was conducted by comparing the measured $PM_{2.5}$ mass to the reconstructed fine mass (RCFM) for every sample at every site (Hafner, 2003). If the comparison showed the measured mass and RCFM were not within 50%-150%, that sample was labeled as suspect and not used in subsequent data analyses. From this check, 44 samples were labeled as suspect. Next, the 20%-worst and 20%-best visibility days at each site for 2002-2003 were determined from visibility extinction (b_{ext}). All days on which at least one site had a 20%-worst day were combined in one subset, and all days on which at least one site had a 20%-best day were combined in another subset. PCA analyses were then conducted for the 20%-worst and 20%-best days using the aerosol extinction, sulfate, OC, and nitrate concentrations. Varimax rotation was used to achieve a simple structure among factor loadings (e.g., limit components with non-zero loadings on the same variable). Data at Mingo were used, though it was recently discovered (in late summer 2005) that these data may be invalid, so results from this site should be ignored until the status of the data is confirmed.

A.3 PCA RESULTS FOR AEROSOL EXTINCTION

Results are given in **Table A-1 and Figures A-1 and A-2**. Six and five subregions were identified from the aerosol extinction on the 20%-worst and 20%-best days, respectively. These were:

- An Upper Midwest subregion, consisting of sites in southern Iowa, Missouri, and eastern Kansas.
- The Western Plains, which included Big Bend National Park (Big Bend) but not Guadalupe Mountains National Park (Guadalupe Mountains).
- The Guadalupe Mountains, which consistently showed a poor relationship with Big Bend and other CENRAP sites.
- Minnesota, consisting of the border sites Voyageurs National Park Site 2 (Voyageurs) and Boundary Waters/Canoe Area (Boundary Waters).
- Southeastern Plains, which includes sites in Louisiana and southern Arkansas.
- A “transition zone” between the western plains and the upper Midwest and Southeastern Plains, consisting of Upper Buffalo Wilderness (Upper Buffalo) and Wichita Mountains.

Table A-1. PCA results (variance explained by the factor) on the 20%-worst and 20%-best visibility days for aerosol extinction.

Subregion	% Variance on the 20%-Worst Days	% Variance on the 20%-Best Days	Representative Site
Minnesota	12	8	Voyageurs
Upper Midwest	36	42	Hercules-Glades
Western Plains	16	23	Cedar Bluff
Transition Zone	11	–	–
Southeastern Plains	10	12	Sikes
Guadalupe Mountains	7	9	–

From these results, four representative sites were selected: Cedar Bluff (CEBL1), Kansas, for the Western Plains; Sikes Aerosol (Sikes, SIKE1), Louisiana, for Southeastern Plains; Hercules-Glades (HEGL1), Missouri, for the Upper Midwest; and Voyageurs (VOYA2), Minnesota, for Minnesota. The influences on the transition zone sites are approximated by the selected sites, so neither transition zone site was selected for additional work.

The selection of the representative sites was confirmed by comparing the number of 20%-worst and 20%-best visibility days each site had in common with the other sites in its subregion. Minnesota only had two sites, so Voyageurs was selected since it had more data than Boundary Waters. In the Upper Midwest, El Dorado Springs was the most representative site, followed by Tallgrass and Hercules-Glades. However, Hercules-Glades was selected since it has twice as much data as El Dorado Springs, and is still very representative for the region. This site's representativeness was confirmed by trajectory analysis in the meteorology characterization task (Appendix B). In the Western Plains, all sites but Big Bend shared nearly all the same days, with Cedar Bluff being the most representative. The connection between Big Bend and the other Western Plains sites exists because these sites shared many of the same high-extinction days when sulfate or coarse mass were large contributors to light extinction. (A different conclusion might have been drawn if particulate mass and/or average visibility days had been of interest for these analyses.) In the Southeastern Plains, Sikes was the most representative site in its subregion.

A.4 PCA RESULTS FOR $PM_{2.5}$ COMPONENTS

In addition to aerosol extinction, groupings among sites for dominant aerosol components were explored with PCA. This analysis helped us understand the underlying variability of the PCA analysis on aerosol extinction, the representativeness of the selected sites, and the extent of regional versus local effects.

PCA results using OC, nitrate (NO_3), and sulfate (SO_4) on the 20%-worst and 20%-best visibility days are shown in **Figures A-3 through A-8**. Results were consistent with the aerosol extinction analysis, but showed some underlying trends that will be useful in later analyses:

- Nitrate concentrations varied more on a local level than on a regional level; five to seven factors were found for nitrate. The Upper Midwest factor identified by b_{ext} was split into two, which may be due to the greater availability of ammonia for ammonium nitrate formation in Iowa compared to Missouri.
- Sulfate showed a distinctive regional character, with the Minnesota, Upper Midwest, Transition Zone, and Southeastern Plains being grouped together. The Western Plains, Big Bend, and Guadalupe visibility trends are likely distinguished from the other sites by the sulfate differences.
- PCA results for OC were similar to aerosol extinction results, except that the Western Plains and Minnesota were grouped together. This may be indicative of a "western" OC influence in these subregions versus a more localized OC influence in the eastern subregions.

A.5 CASE STUDY: GUADALUPE MOUNTAINS

The Guadalupe Mountains site consistently showed different results than other sites in CENRAP, even Big Bend, which is also in western Texas. Extensive work has been conducted on Big Bend aerosol as part of the Big Bend Regional Aerosol and Visibility Observational (BRAVO) study (Pitchford et al., 2004). Sulfate is the main chemical component of poor visibility, and transport from Mexico, Texas, and the Southeast affect the worst visibility days. To investigate the differences between Guadalupe Mountains and Big Bend, we examined the extinction composition on the 20%-worst days at these two sites for 2002-2003, shown in **Figures A-9 and A-10**. Of the 38 worst days, the two sites only have 11 of the days in common. While the 20%-worst days at Big Bend are dominated mostly by sulfate and to a lesser extent OC, at Guadalupe, sulfate, OC, and coarse mass are all important.

The differences in poor visibility days and the composition on these days are likely due to different meteorological transport regimes affecting the two sites. To further investigate this, 72-hr back trajectories were run for all sample dates at each site using the NOAA HYSPLIT model (Draxler and Hess, 1997), which were then mapped as a spatial probability density (SPD^0):

$$SPD = \frac{\textit{Count of hourly trajectory endpoints within search radius}}{\textit{Count of trajectories run}}$$

The largest SPD values are in areas where the backward trajectories have spent the most time. Then, a conditional probability function (CPF) was applied to help interpret the results (Kim and Hopke, 2004; Kim et al., 2003, 2004; Ashbaugh et al., 1985). In CPF, the transport patterns of the 20%-highest concentration days of a given factor are compared to the climatological transport patterns. After finding SPD^0, back trajectories for the 20%-worst visibility days were run and mapped (SPD′). This density is then compared to the SPD for all days (i.e., the climatology), so that the differences in transport and source areas on high concentration days of a given factor are highlighted:

$$CoPIA' = SPD' - SPD^0 \qquad (1)$$

This Conditional Probability Integrative Analysis (CoPIA) is very similar to the CPF analyses employed in other studies (Kim and Hopke, 2004; Kim et al., 2003, 2004; Ashbaugh et al., 1985); however, CoPIA is adapted to take advantage of tools available in a Geographic Information System (GIS) framework. Ensemble backward trajectories were run every 4 hours to account for wind variability over a 24-hr sampling period.

CoPIA results for the 20%-worst visibility days at Big Bend and Guadalupe for 2002-2003 are shown in **Figures A-11 and A-12**; the higher values are in areas where the backward trajectories spent the most time. The results show that different transport regimes affect these two sites, confirming what was observed in the compositional analysis. Transport from Mexico, Texas, and the Southeast affect Big Bend. While, in addition to Texas, transport (likely soil and coarse mass) from western Mexico, New Mexico, and Arizona affect Guadalupe. While Guadalupe is not a representative site for CENRAP, it would be interesting to analyze this site in the future to determine west versus east trends and the importance of transport into the CENRAP region.

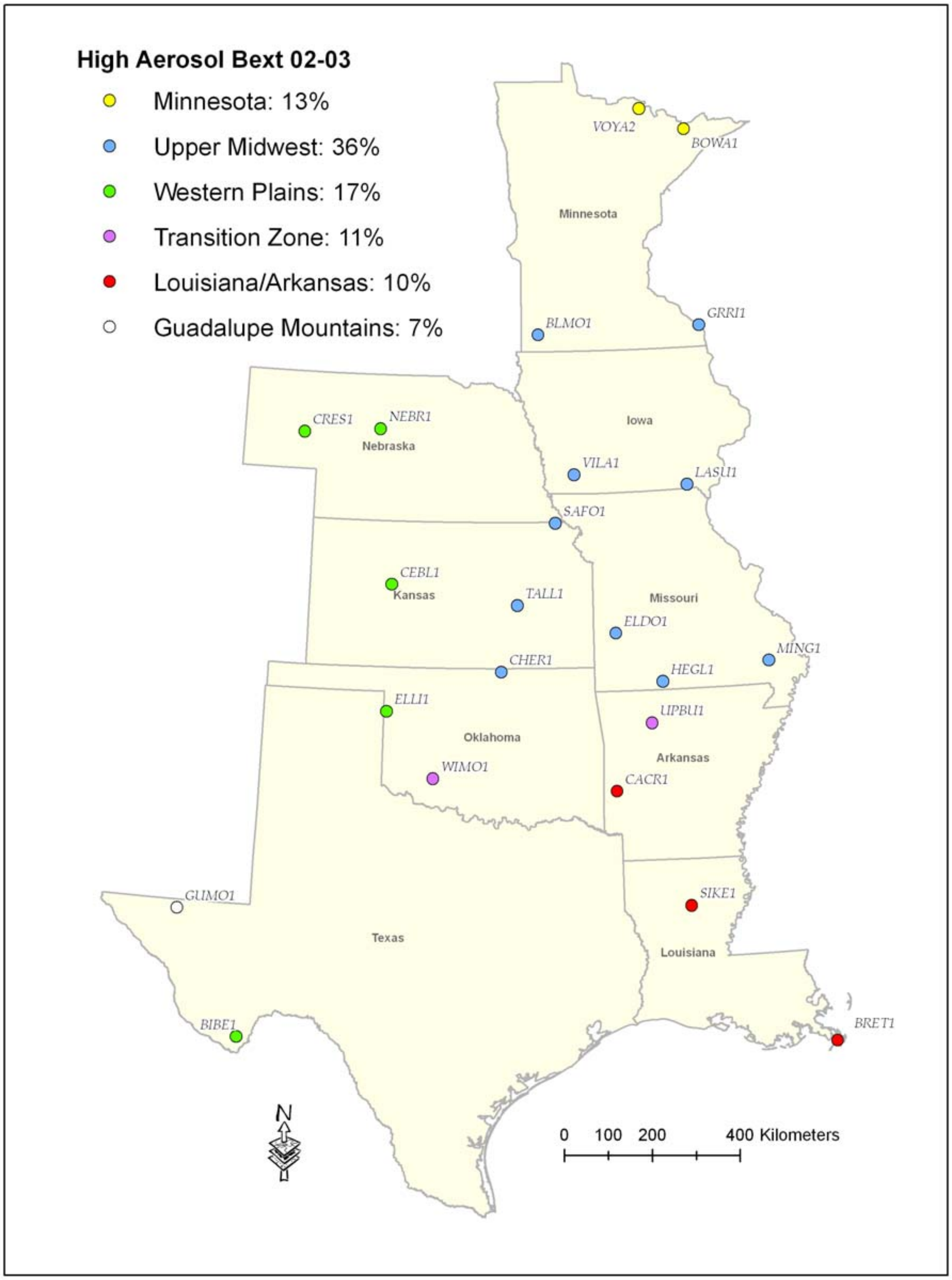

Figure A-1. PCA results (grouping and % of data variability explained) for aerosol extinction on the 20%-worst visibility days in 2002-2003.

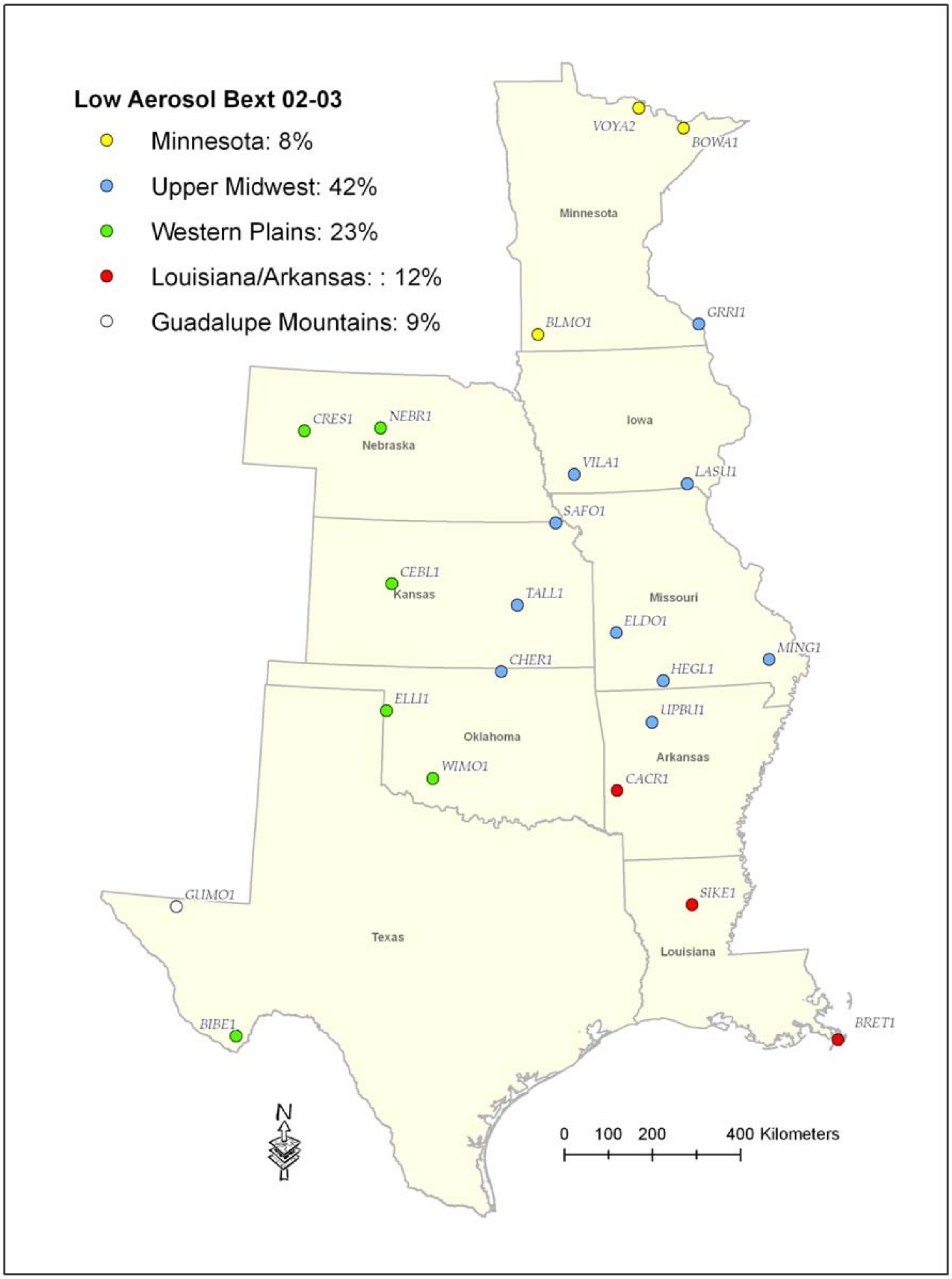

Figure A-2. PCA results (grouping and % of data variability explained) for aerosol extinction on 20%-best visibility days in 2002-2003.

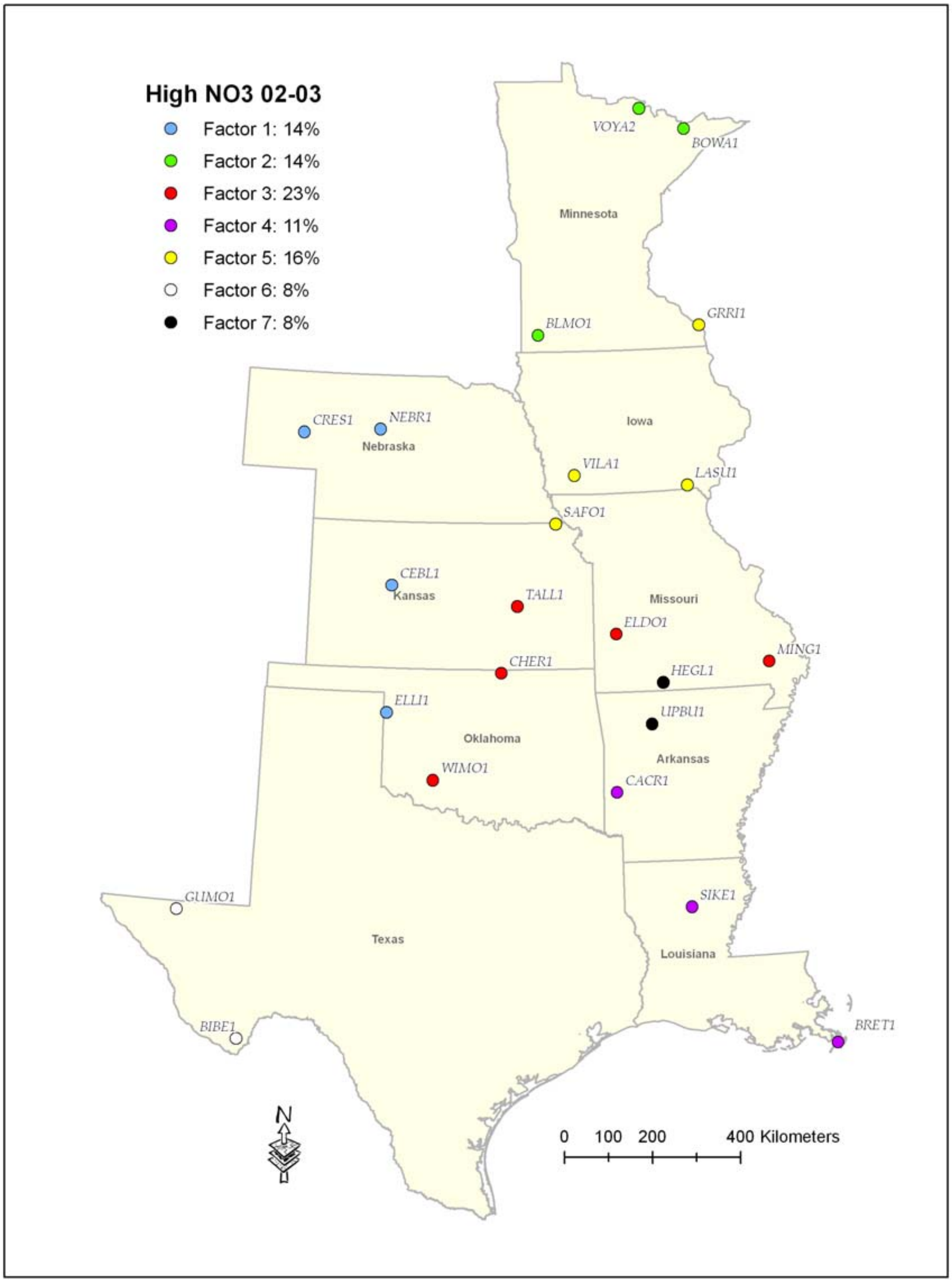

Figure A-3. PCA results (grouping and % of data variability explained) for nitrate on the 20%-worst visibility days in 2002-2003.

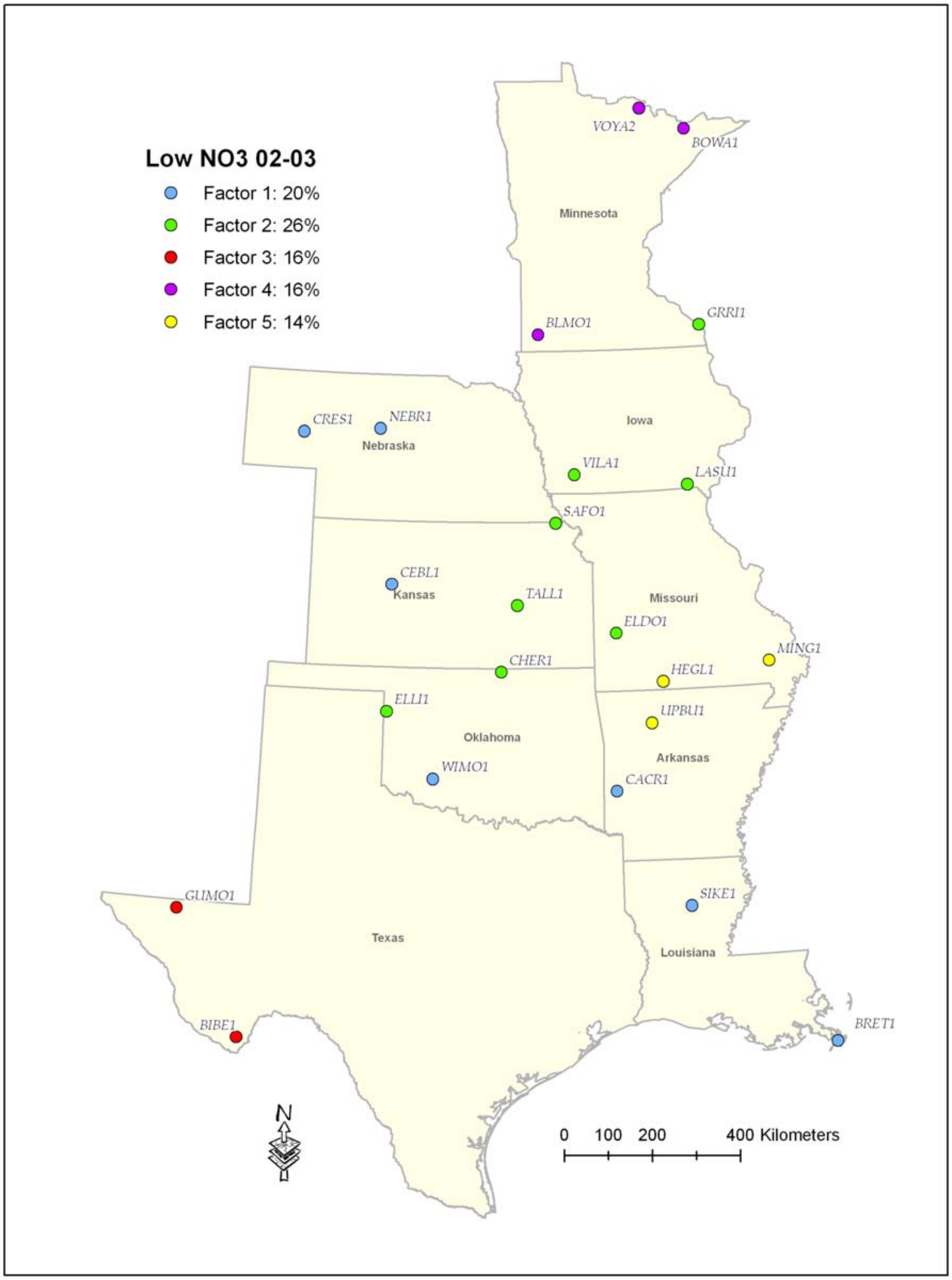

Figure A-4. PCA results (grouping and % of data variability explained) for nitrate on the 20%-best visibility days in 2002-2003.

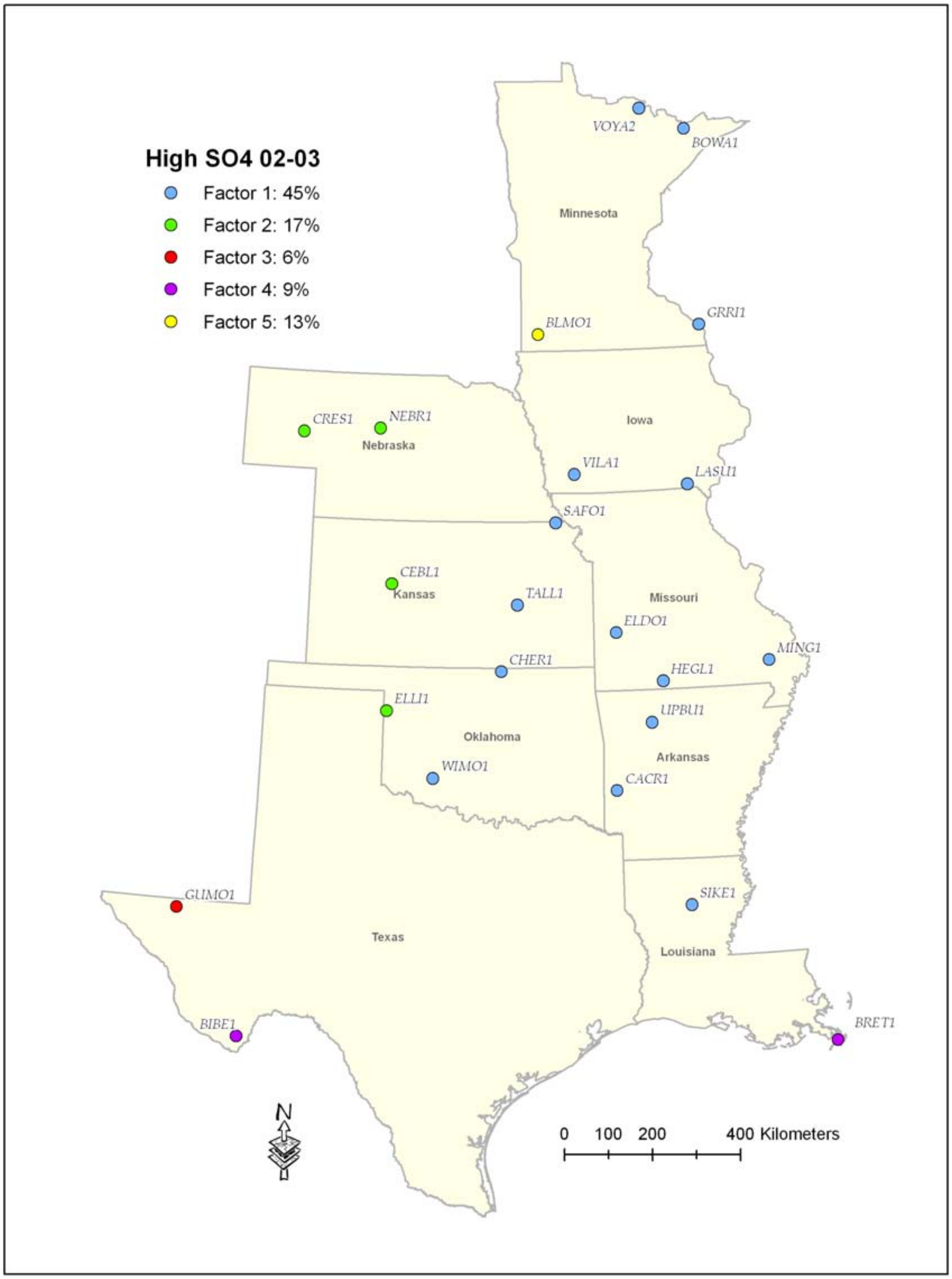

Figure A-5. PCA results (grouping and % of data variability explained) for sulfate on the 20%-worst visibility days in 2002-2003.

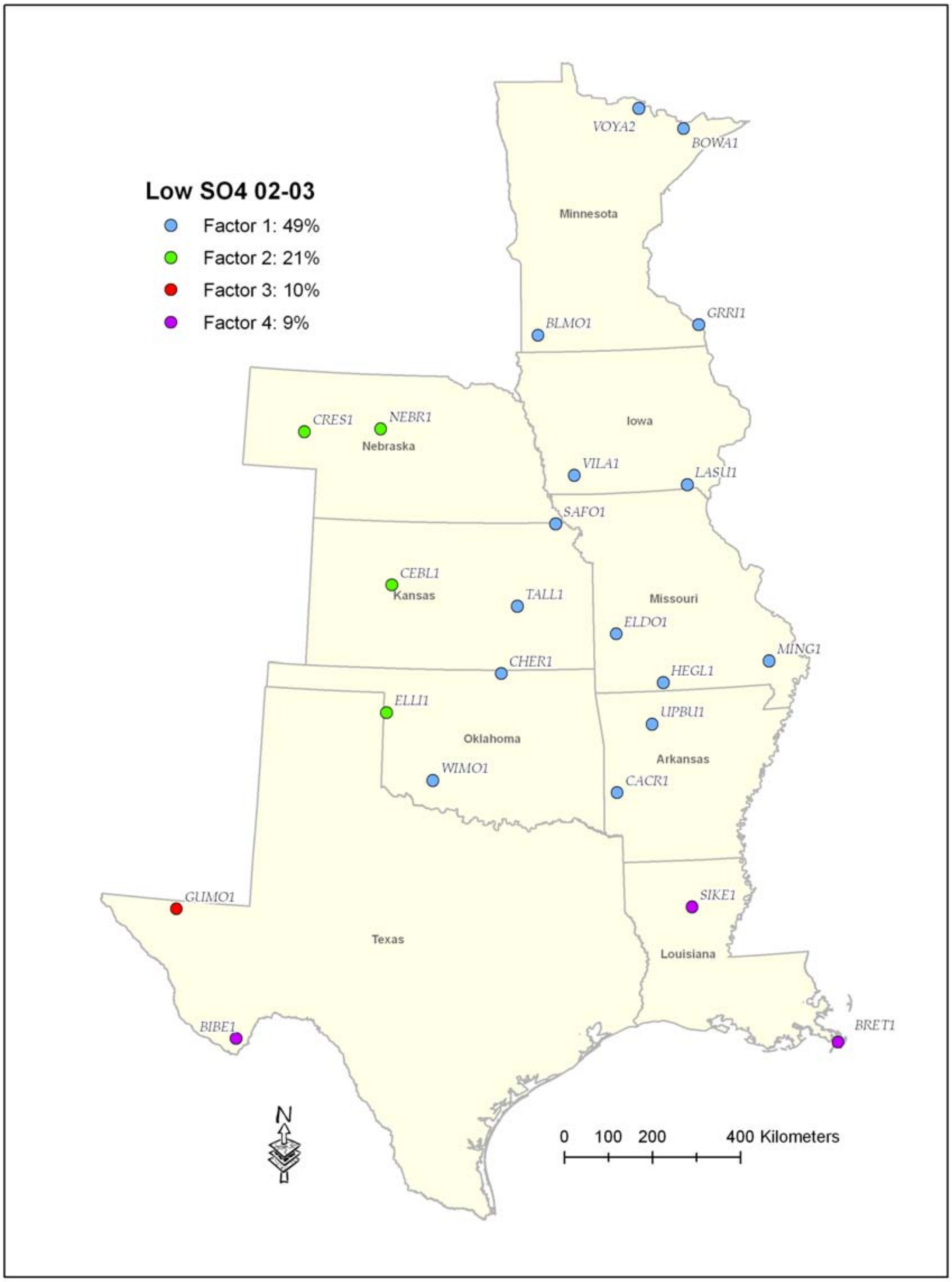

Figure A-6. PCA results (grouping and % of data variability explained) for sulfate on the 20%-best visibility days in 2002-2003.

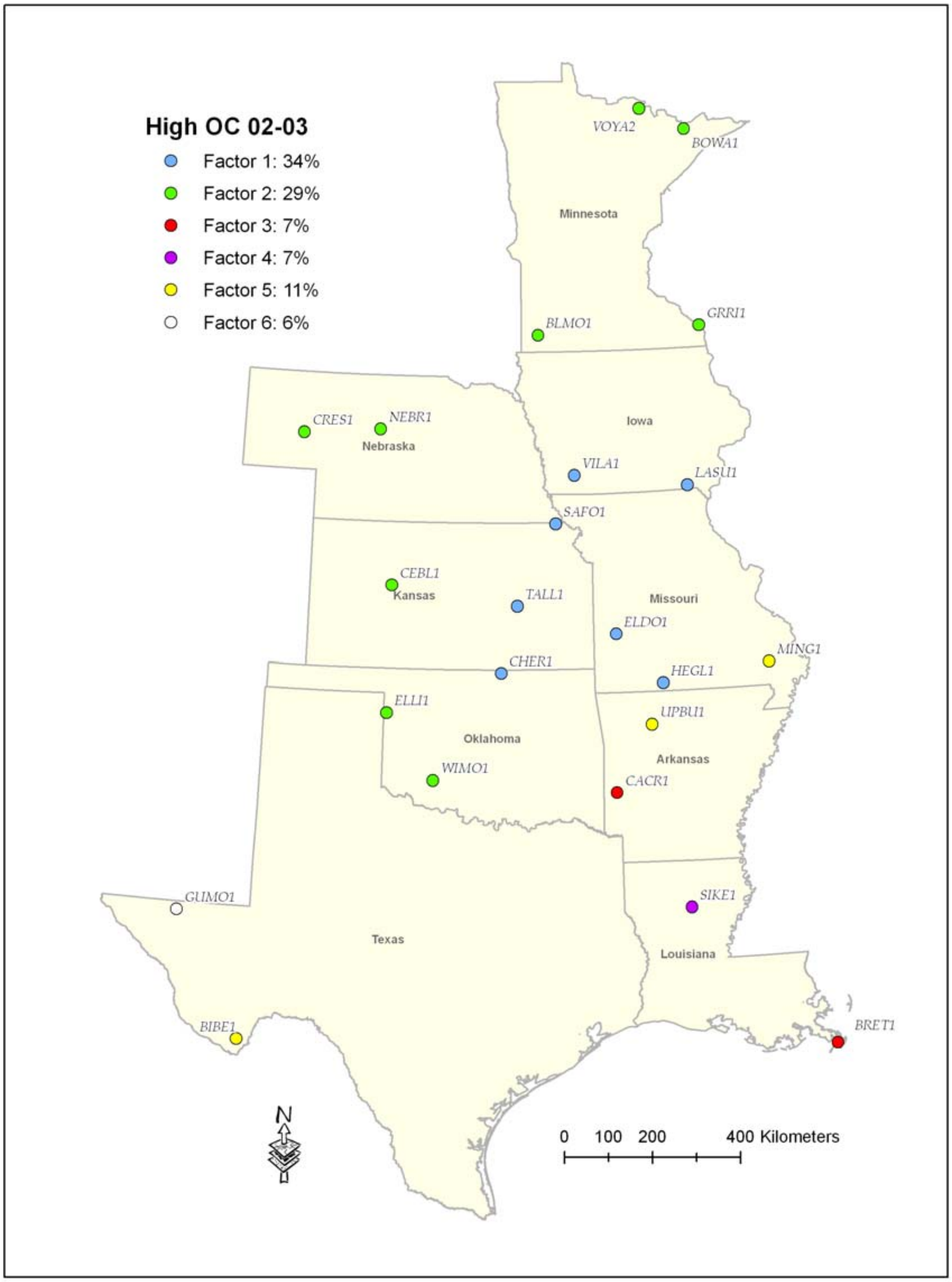

Figure A-7. PCA results (grouping and % of data variability explained) for OC on the 20%-worst visibility days in 2002-2003.

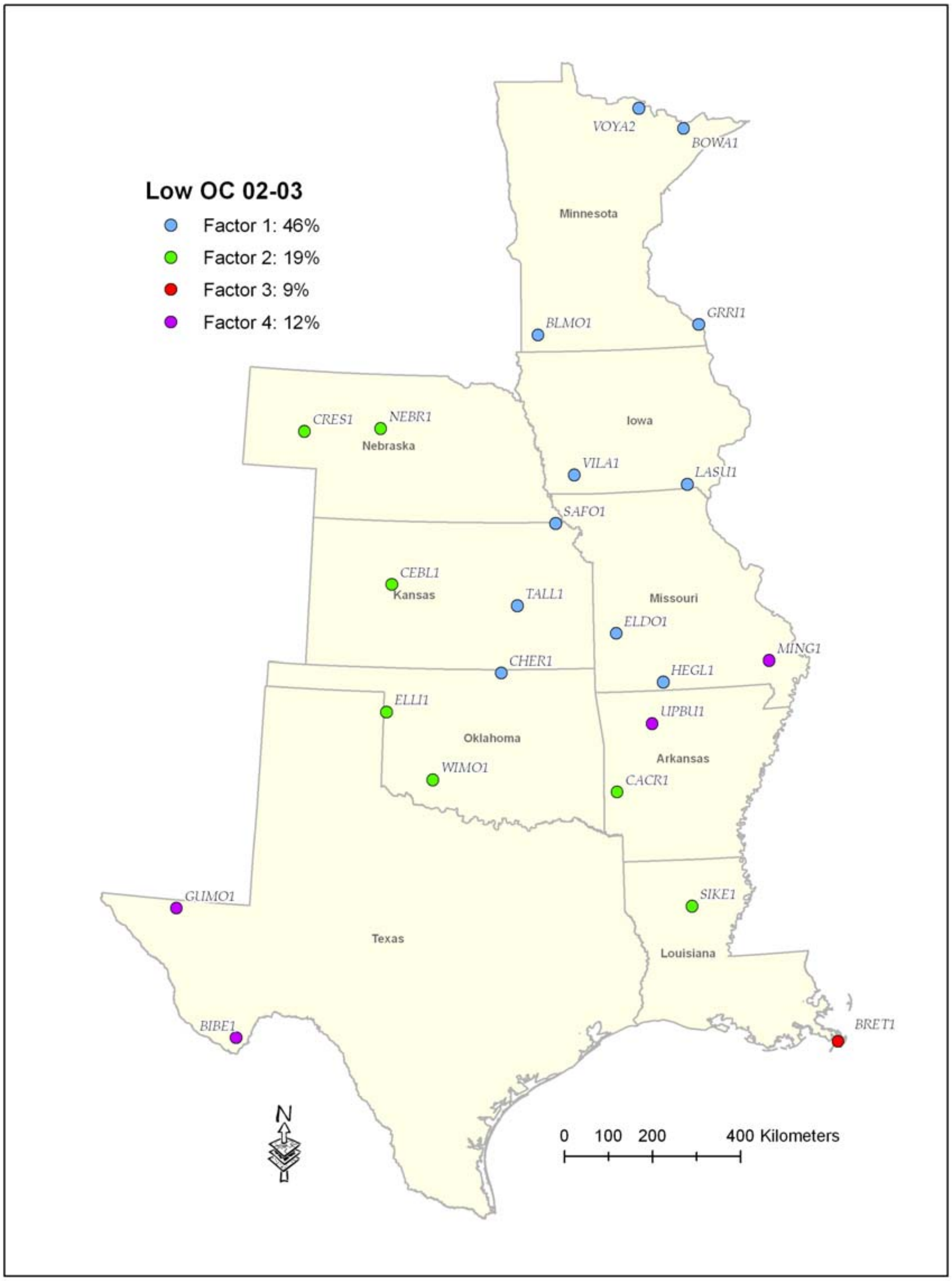

Figure A-8. PCA results (grouping and % of data variability explained) for OC on the 20%-best visibility days in 2002-2003.

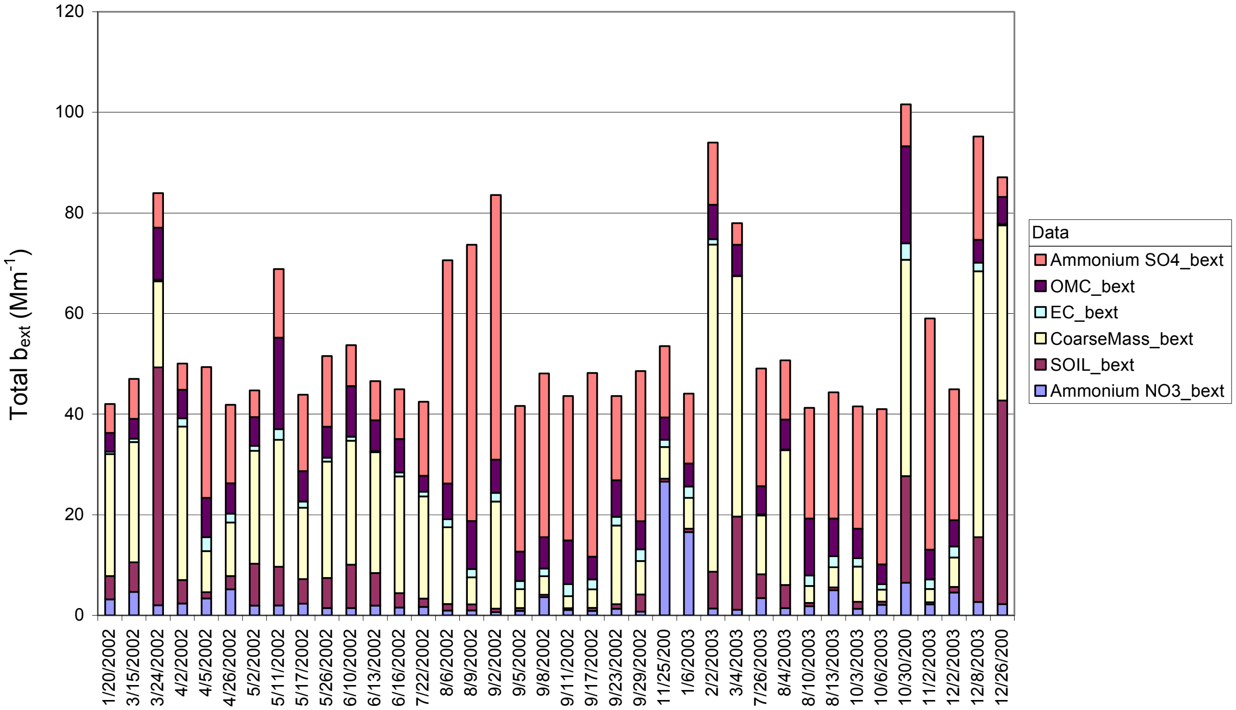

Figure A-9. Extinction (b_{ext}) composition by component (using standard IMPROVE calculations) for the 20%-worst visibility days at Guadalupe Mountains in 2002-2003.

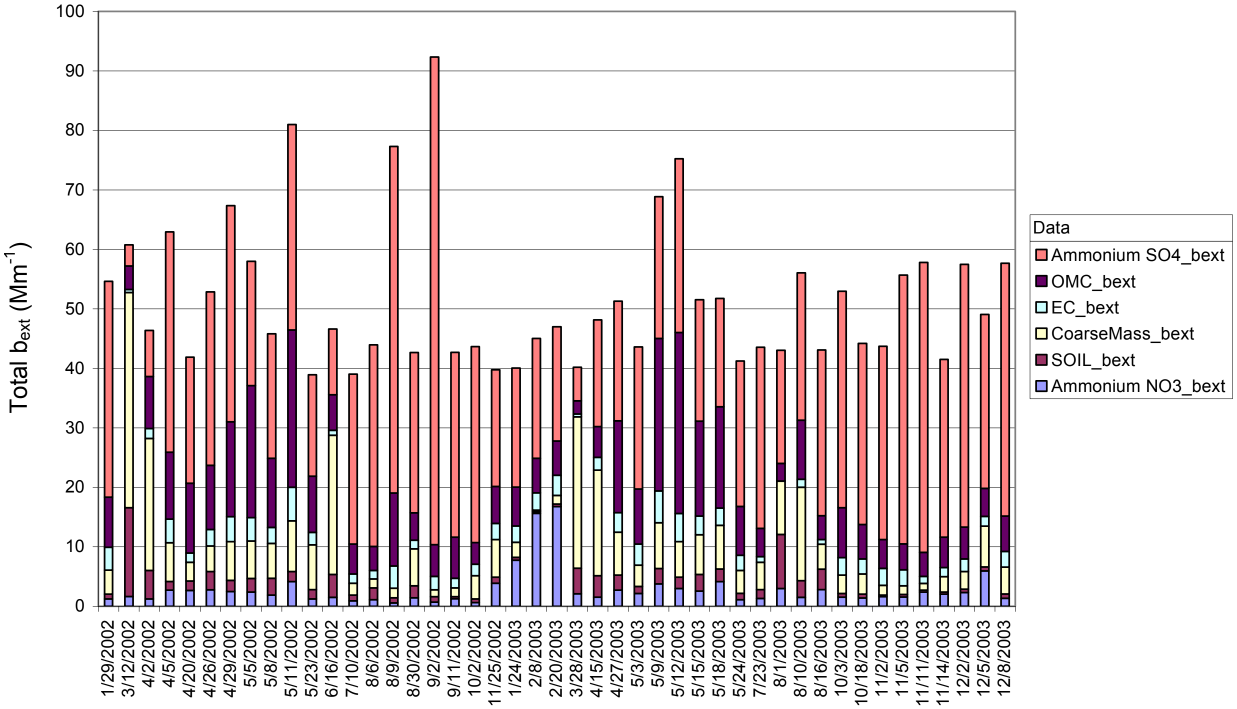

Figure A-10. Extinction (b_{ext}) composition by component (using standard IMPROVE calculations) for the 20%-worst visibility days at Big Bend in 2002-2003.

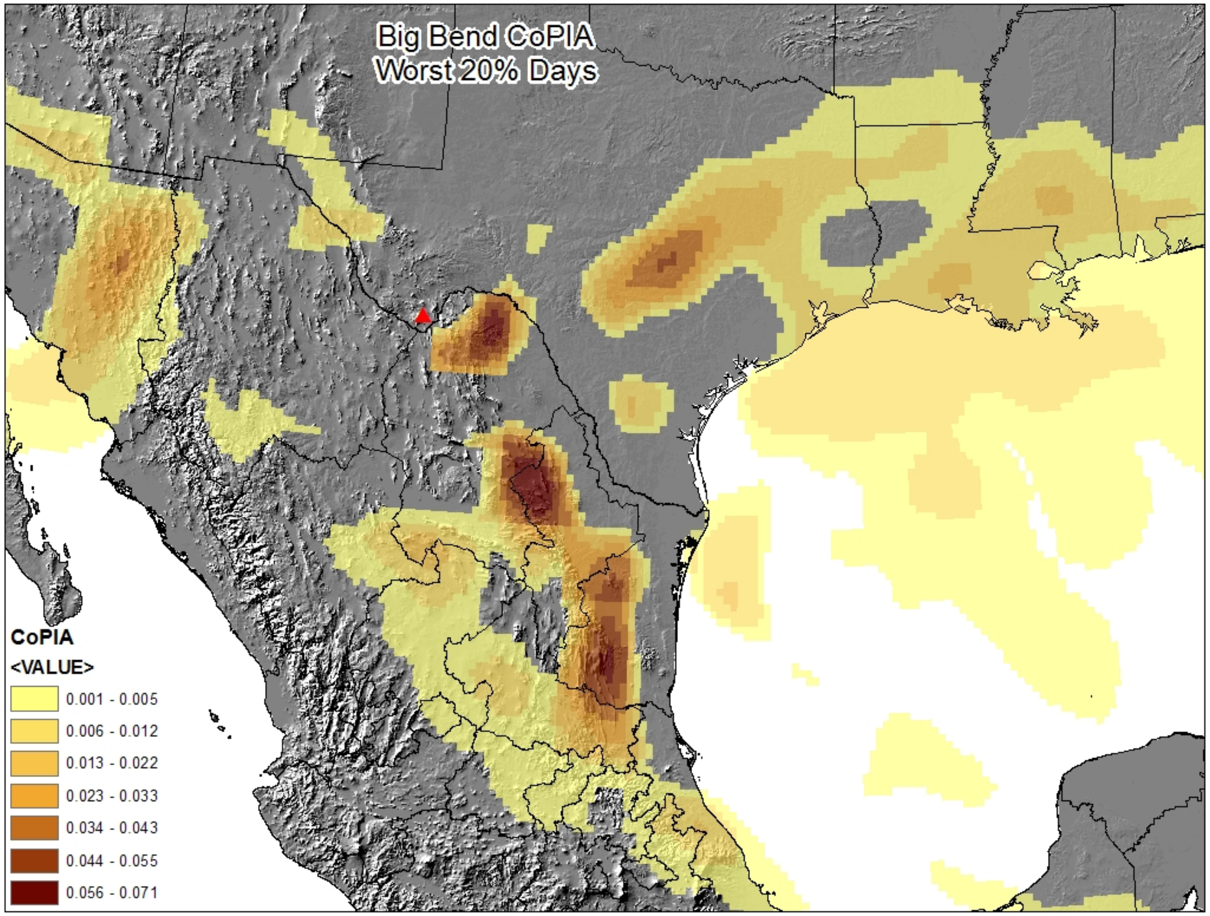

Figure A-11. CoPIA results for the 20%-worst visibility days at Big Bend for 2002-2003.

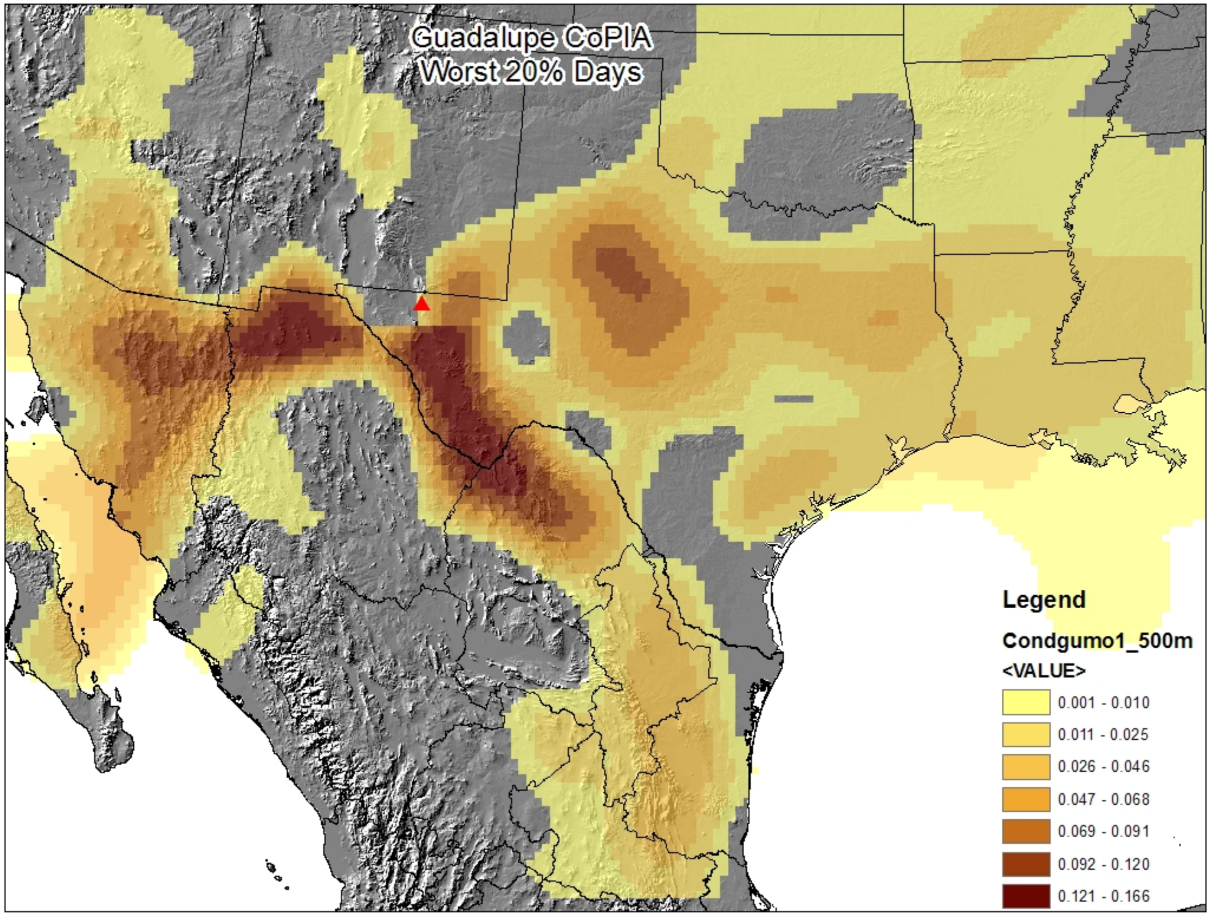

Figure A-12. CoPIA results for the 20%-worst visibility days at Guadalupe for 2002-2003.

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APPENDIX B

DOCUMENTATION OF METHODS AND GRAPHICAL AND TABULAR SUMMARIES OF DATA FOR TASK 5

METEOROLOGICAL ANALYSES

B.1 OVERVIEW

The objective of this task was to determine the types of meteorological events that should most concern CENRAP air regulators when considering strategies to improve or protect visibility. To meet this objective, days were clustered based on meteorology and transport characteristics for the four subregions defined in Task 4 for the 20%-best and 20%-worst days. The subregions include Northern Minnesota (represented by Voyageurs), Western Plains (represented by Cedar Bluff), Upper Midwest (represented by Hercules-Glades), and Southeastern Plains (represented by Sikes). The transport and meteorological parameters that were used to define each day were captured in daily schematics. An example of a schematic for one day is shown in **Figure B-1**. The variables shown on the schematic are described below.

- Ensemble backward trajectories. Locations of the backward trajectories for each hour are shown as dots. For each day, the trajectories were run back for 96 hours from each representative site starting at 0000, 0004, 0008, 1200, 1600, and 2000 CST at three levels: 50 m, 300 m, and 700 m above ground level (agl). The hours when trajectories were located in predefined subregions, for all heights and start times, were totaled and are also shown on the plots. The predefined regions are shown in **Figure B-2**. The trajectories indicate the source areas of material that arrived at the site in each subregion.
- 500-mb heights. The height contours of the 500-mb pressure surface are shown as bold lines. The 500-mb height pattern has a strong influence on local and regional meteorology and air quality. In general, a ridge in the 500-mb height pattern is associated with stable boundary conditions and poor air quality, whereas a trough in the 500-mb height pattern is associated with an unstable boundary condition and good air quality.
- Surface temperature. The spatial distribution of surface temperature is shown with colored contours. Surface temperature can influence particle formation. For example, under warm conditions, nitrate will tend to favor the gas phase (i.e., nitric acid); and under cool conditions, particle nitrate formation will be enhanced.

- Morning surface relative humidity, surface wind speed, 700-mb temperature, and the 850-mb temperature and surface temperature difference. These variables are depicted as normalized fingerprint plots in the lower right corner of the schematics. The fingerprints were used to aid in the subjective clustering of days. Relative humidity is important to particle formation. Local winds can affect dispersion of local emissions and strong winds can increase crustal material. The 700-mb temperature and the 850-mb temperature and surface temperature difference are good indicators of atmospheric stability. In general, the larger the value of the 850-mb temperature minus surface temperature difference, the more stable the atmosphere; similarly, the warmer the 700-mb temperature, the more stable the atmosphere. All variables were normalized linearly as presented below. The values used for the normalizations are typical minimum and maximum values that are observed throughout a year, ignoring extreme events. However, in the case of relative humidity, 0% was used as the lower range, even though 0% relative humidity is never observed near the ground. This minimum value was chosen so that the normalized relative humidity values could easily be translated to percentages.
  - Relative humidity is normalized 0 to 1 where 0 is 0% and 1 is 100%.
  - The 700-mb temperature is normalized –1 to 1, where –1 is –25°C and 1 is 25°C.
  - The 850-mb to surface temperature difference is normalized from –1 to 1 where –1 is –15°C and 1 is 15°C.
  - Wind speed is normalized from 0 to 1 where 0 is 0 m/s and 1 is 10 m/s.
- Predominant PM species. The two dominant species that make up $PM_{2.5}$ on each day are shown in the upper left corner of the plot. On the individual plots, nitrate is depicted as N, sulfate as S, organic carbon as OC, elemental carbon as EC, and crustal material as CM. The relative amount of each species is shown by the size of the square.

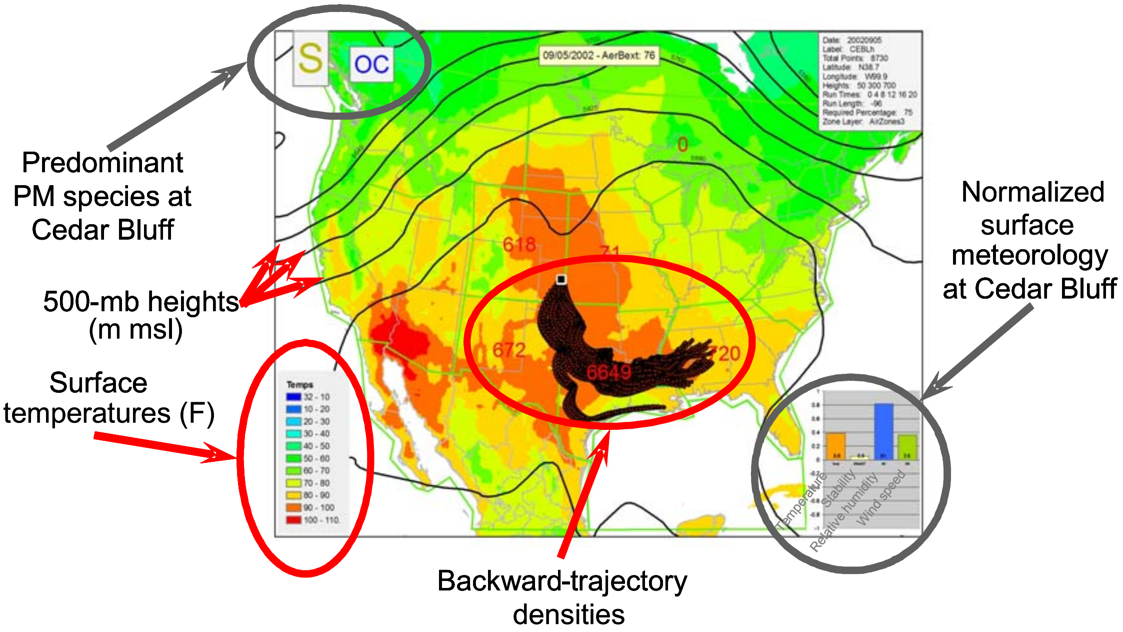

Figure B-1. Example conditions for a 20%-worst visibility day at the Cedar Bluff site.

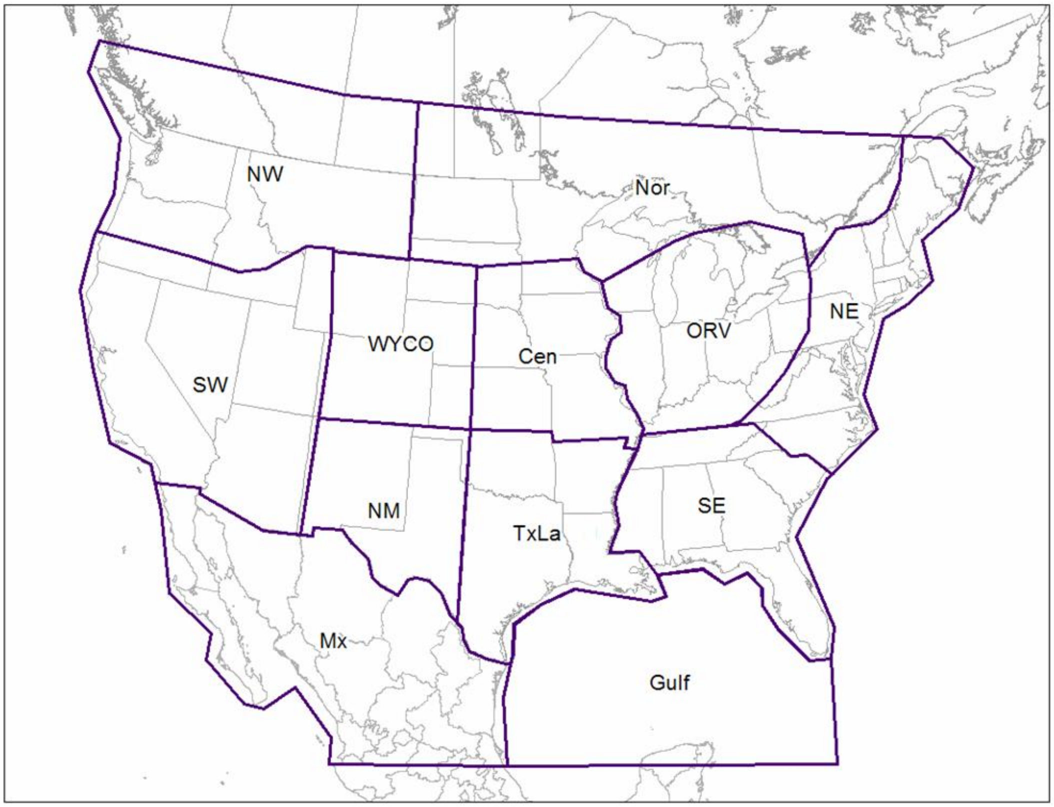

Figure B-2. Source areas defined for parcel residence time counts.

B.2 NORTHERN MINNESOTA SUBREGION

For the Northern Minnesota subregion (represented by the Voyageurs site [VOYA2]), there were five weather/transport day types for the 20%-worst days and three for the 20%-best days. The meteorological and transport characteristics associated with the 20%-worst days are summarized in **Table B-1**; in general, these days were

- characterized by high morning relative humidity (>85%) and
- as likely to occur in the winter as in the summer.

The meteorological and transport characteristics associated with the 20%-best days are summarized in **Table B-2**; in general, these days

- occurred in the cool season,
- were less stable than the 20%-worst days, and
- had a transport direction from the north.

The five weather/transport groups associated with the 20%-worst days at Voyageurs are described below and summarized in Table B-1:

1. Wintertime Westerly Transport. This worst visibility group is the most common, and its conditions occurred on 21 of the 65 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by long-range transport from the west-northwest; the Nor source area (see Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the east-central or eastern United States, with northwesterly flow aloft over VOYA2. Morning inversions are strong for this group, with the 850-mb to surface-temperature difference at an average of +7.2°C. A good example day for this group is February 18, 2001 (see **Figure B-3**).

2. Warm Season Southeasterly Transport. This group of conditions is the second most common, occurring on 20 of the 65 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by transport from the south-southeast; two source areas, Cen and Nor (Figure B-2), experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the east central United States and a trough in the western United States. A few cases showed very little upper-level dynamics with weak flow aloft. The morning relative humidity was high (~92%). A good example day for this group is September 9, 2003 (see **Figure B-4**).

3. Warm Season Stagnant. These worst visibility group conditions occurred on 10 of the 65 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of organic carbon with some sulfate. Within this group are two subgroups:

   Subgroup A conditions occurred on 7 of the 65 days and are characterized by transport from the west-northwest; the Nor source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by a weak upper-level ridge or zonal flow over the central United States and light morning surface winds. A good example day of this group is June 28, 2002 (see **Figure B-5**).

   Subgroup B conditions occurred on 3 of the 65 days and are characterized by medium-range transport from the east-northeast; the Nor and ORV source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by a weak ridge over the central United States, and light morning surface winds. A good example day of this group is May 18, 2003 (see **Figure B-6**).

4. Cool Season Pre-frontal. This group of conditions is one of the least common worst visibility groups, occurring on 7 of the 65 days. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by medium-range transport from the south-southwest; the Nor and Cen source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized as pre-cold front with an upper-level trough over the Rocky Mountains or west-central United States. This group has the least stability of all the worst visibility groups, and the average morning 700-mb temperature is -11°C. A good example day of this group is December 12, 2001 (see **Figure B-7**).

5. Fall Southwesterly Transport. This group of conditions is another of the least common, occurring on 7 of the 65 days studied. $PM_{2.5}$ on the majority of these days was composed

mainly of sulfate with some organic carbon. This group is characterized by medium-range transport from the southwest; the Nor and WYCO source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the central U.S. A good example of this group is September 17, 2002 (see **Figure B-8**).

The three weather/transport groups associated with the 20%-best days at Voyageurs are described below and summarized in Table B-2:

1. Wintertime Northwesterly Transport. This best visibility group was the most common, and its conditions occurred on 46 of the 65 days studied. $PM_{2.5}$ on the majority of these days was composed of mainly sulfate with some organic carbon. Within this group are two subgroups. Both subgroups are characterized by medium-range transport from the north-northwest; the Nor source area (Figure B-2) experienced the most parcel residence time.

   Subgroup A conditions occurred on 30 of the 65 days, and the meteorological pattern is characterized by zonal flow aloft or an upper-level trough over the central United States. The average morning 700-mb temperature is -15°C. A good example day of this group is February 8, 2003 (see **Figure B-9**).

   Subgroup B conditions occurred on 16 of the 65 days, and the meteorological pattern is characterized by an upper-level trough over the central United States. Morning surface temperatures are similar to those of Subgroup A. However, morning wind speeds are half as large as those in Subgroup A, and the morning temperature profile is considerably more stable than that of Subgroup A. A good example day of this group is January 19, 2001 (see **Figure B-10**).

2. Spring and Summer Northeasterly Transport. This group of conditions occurred on 10 of the 65 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate and organic carbon. This group is characterized by medium-range transport from the east-northeast; the Nor source area (Figure B-2) experienced the most parcel residence time. It is similar to the Warm Season Stagnant worst visibility group, with the exceptions of lower average wind speeds and lower average relative humidities. Within this group there are two subgroups.

   Subgroup A conditions occurred on 6 of the 65 days, and the meteorological pattern is characterized by an upper-level cutoff low-pressure system over the Plains or Midwest. This group has the lowest average morning relative humidity (78%), and the strongest morning wind speed (4 m/s). A good example day of this group is May 9, 2003 (see **Figure B-11**).

   Subgroup B conditions occurred on 4 of the 65 days. The meteorological pattern is characterized by an upper-level ridge over the west-central United States and lighter morning surface winds than those in Subgroup A (2.6 m/s). A good example day of this group is July 17, 2003 (see **Figure B-12**).

3. Spring Season Split Flow. This group of conditions is the least common of the best visibility groups, occurring on 9 of the 65 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by long-range transport from split directions, mainly the northwest and

south; the Nor source area (Figure B-2) experienced the most parcel residence time for this group. The meteorological pattern is characterized by both an upper-level trough in the western United States and an upper-level ridge in the eastern United States, or an upper-level ridge in the western United States and an upper-level trough in the eastern United States. The Voyageurs site is located between these upper-level features. A good example day of this group is May 8, 2002 (see **Figure B-13**).

Table B-1. The five weather/transport day types for the 20%-worst visibility days for the Northern Minnesota subregion (represented by Voyageurs [VOYA2]).

		VOYA Worst	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1	12/26/2003	N,S	long	W,NW	Nor		trough over the eastern or east-central US. NW flow aloft over YOYA.	Cold season, temperatures near freezing.	86.8	7.2	3	-9
	01/04/2001											
	01/10/2001											
	01/13/2001											
	01/22/2001											
	02/03/2001											
	02/18/2001											
	12/09/2001											
	12/18/2001											
	01/11/2002											
	03/12/2002											
	11/28/2002											
	12/10/2002											
	12/13/2002											
	01/27/2003											
	01/30/2003											
	02/26/2003											
	11/20/2003											
	12/20/2003											
	01/26/2002											
	02/01/2002											
2	06/01/2002	OC,S	medium - long	W,NW	Nor		Zonal flow or weak ridge over central US	Warm season	90.3	0.8	2.3	-4
	6/28/2002											
	09/11/2002											
	06/02/2003											
	05/26/2002											
	09/29/2002											
	07/29/2003											
3a	09/07/2001	S,OC	long	S,SE	Cen	Nor	Ridge over east central US and a trough in the western US or very weak flow aloft (little dynamics)	Warm season	91.6	1.4	3.8	6.1
	07/16/2002											
	09/02/2002											
	10/11/2002											
	06/23/2003											
	07/02/2003											
	07/26/2003											
	08/19/2003											
	09/09/2003											
	10/09/2003											
	10/31/2001											
	03/16/2003											
	11/11/2003											
	08/16/2003											
	08/25/2003											
	09/06/2003											
	07/15/2001											
	07/18/2001											
	07/07/2002											
	08/09/2002											
3b	05/27/2003	OC,S	medium - long	E,NE	Nor	ORV	Weak ridge over central US	Warm season	91.7	1	1.9	2.8
	08/07/2003											
	05/18/2003											
4	03/20/2001	N,S	medium - long	S,SW,W	Nor	Cen	Trough over the rockies or west-central US	Cool season	87.8	-4.9	3.2	-10.7
	12/12/2001											
	01/31/2001											
	03/27/2002											
	10/26/2002											
	12/05/2003											
	03/29/2001											
5	04/19/2001	S,OC	long	S,SW,W	Nor	WYCO	Ridge over the west-central or central US.	Warm season. All events were fall events.	89.4	4.6	2.7	0.7
	05/16/2001											
	11/12/2001											
	11/15/2001											
	09/17/2002											
	10/18/2003											
	11/06/2001											

Table B-2. The three weather/transport day types for the 20%-best visibility days for the Northern Minnesota subregion (represented by Voyageurs [VOYA2]).

		VOYA Best	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1a	03/24/2002	S,OC	short-medium	N,NW	Nor		Zonal flow OR trough over the west central US	Primarily cool-cold season events	85.7	-3.4	4.2	-15.2
	04/20/2002											
	04/26/2002											
	05/02/2002											
	05/17/2002											
	05/20/2002											
	09/23/2002											
	11/25/2002											
	12/01/2002											
	01/09/2003											
	02/08/2003											
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	04/03/2003											
	09/24/2003											
	09/30/2003											
	10/03/2003											
	10/15/2003											
	11/23/2003											
	10/17/2002											
	09/15/2003											
	02/09/2001											
	03/05/2001											
	03/08/2001											
	05/04/2001											
	10/04/2001											
	11/27/2001											
	12/24/2001											
	12/27/2001											
	02/16/2002											
	02/28/2002											
1b	05/05/2002	S,OC	short-medium	N,NW	Nor		Trough over the central US	Both cool season and warm season events	82.7	4.8	2	-12.5
	12/16/2002											
	12/31/2002											
	02/05/2003											
	02/14/2003											
	07/23/2003											
	01/07/2001											
	01/19/2001											
	03/11/2001											
	03/26/2001											
	06/03/2001											
	09/22/2001											
	09/25/2001											
	12/21/2001											
	01/29/2002											
	02/13/2002											
2a	04/07/2001	S,OC	medium-long	E,NE	Nor		Cutoff low over the Plains OR Midwest	Cool season - spring events	77.5	-1.5	4.1	-5.8
	12/19/2002											
	04/15/2003											
	04/21/2003											
	05/09/2003											
	10/30/2003											
2b	08/27/2002	OC,S	short-medium	N,NE	Nor		Ridge over west central US	Warm season (60's 70's)	82.6	-2.2	2.6	3.4
	07/17/2003											
	06/30/2001											
	08/06/2002											
3	05/08/2002	S,OC	medium-long	Split: NW and S	Nor		VOYA region is in between a ridge and a trough	Primarily cool-cold season events	83.5	-2	4.1	-4.8
	05/14/2002											
	09/14/2002											
	10/02/2002											
	09/03/2003											
	04/22/2001											
	05/07/2001											
	02/19/2002											
	02/25/2002											

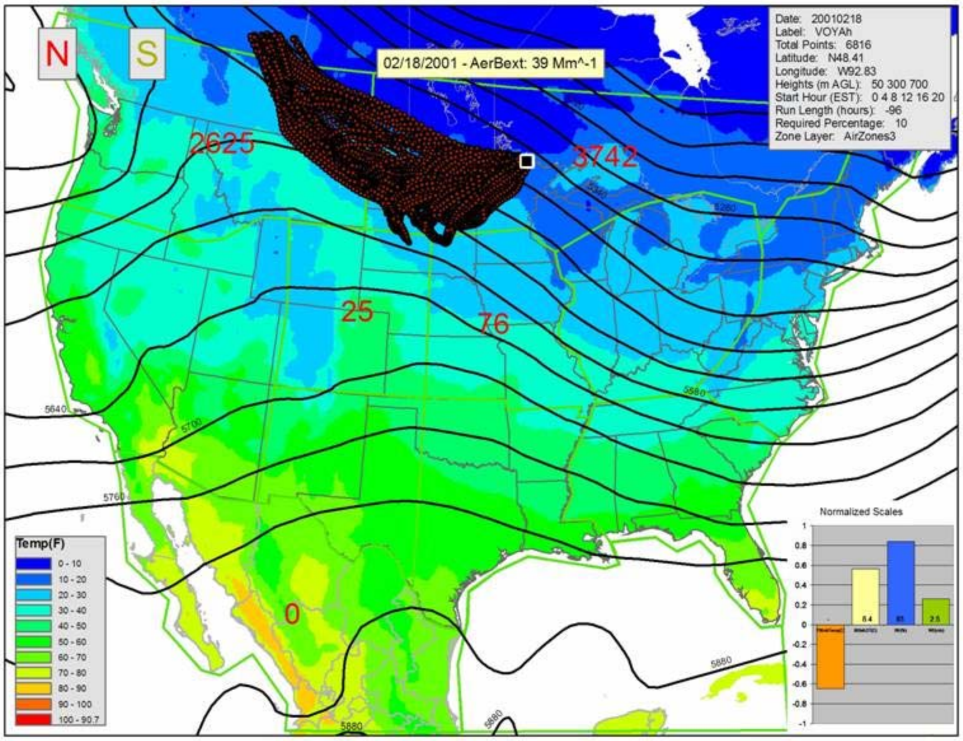


Figure B-3. Wintertime Westerly Transport example.

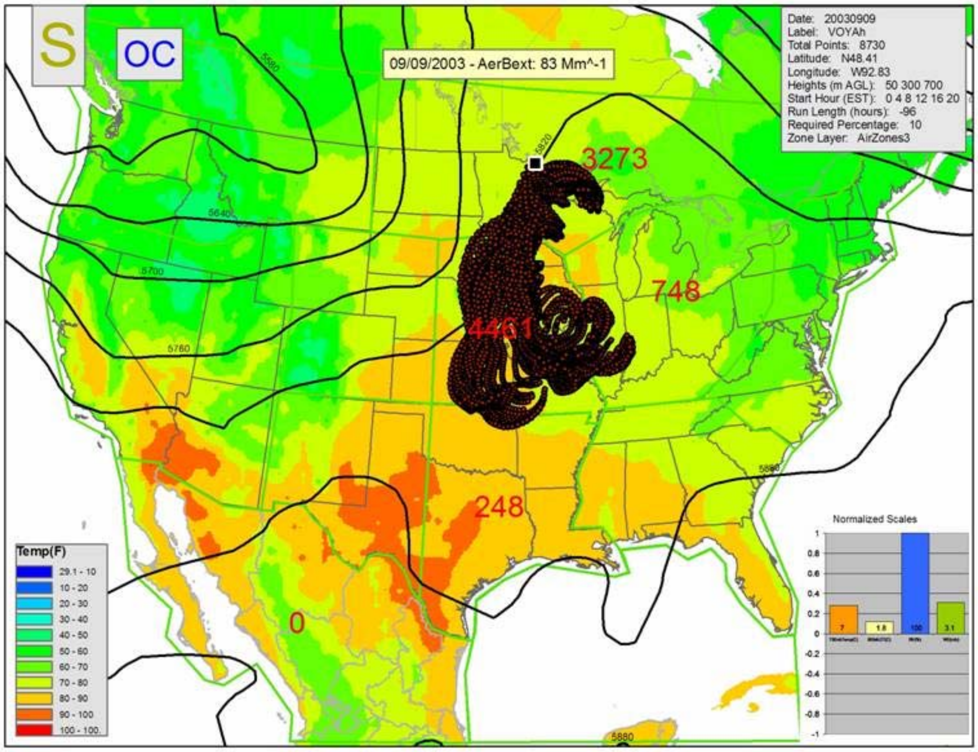


Figure B-4. Warm Season Southeasterly Transport example.

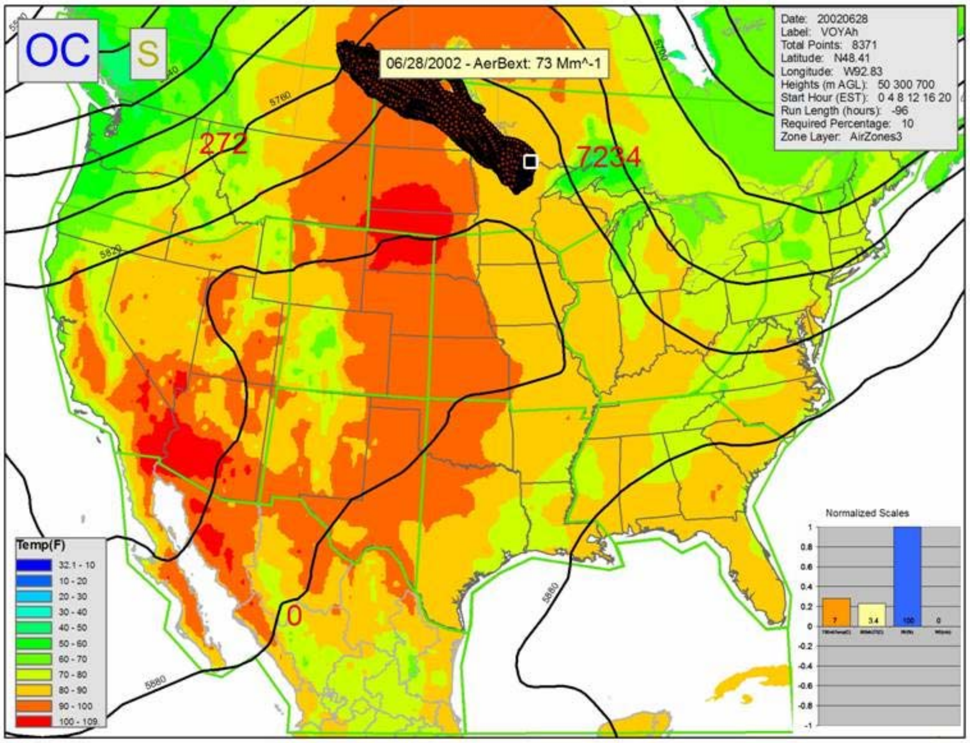


Figure B-5. Warm Season Stagnant – Subgroup A example.

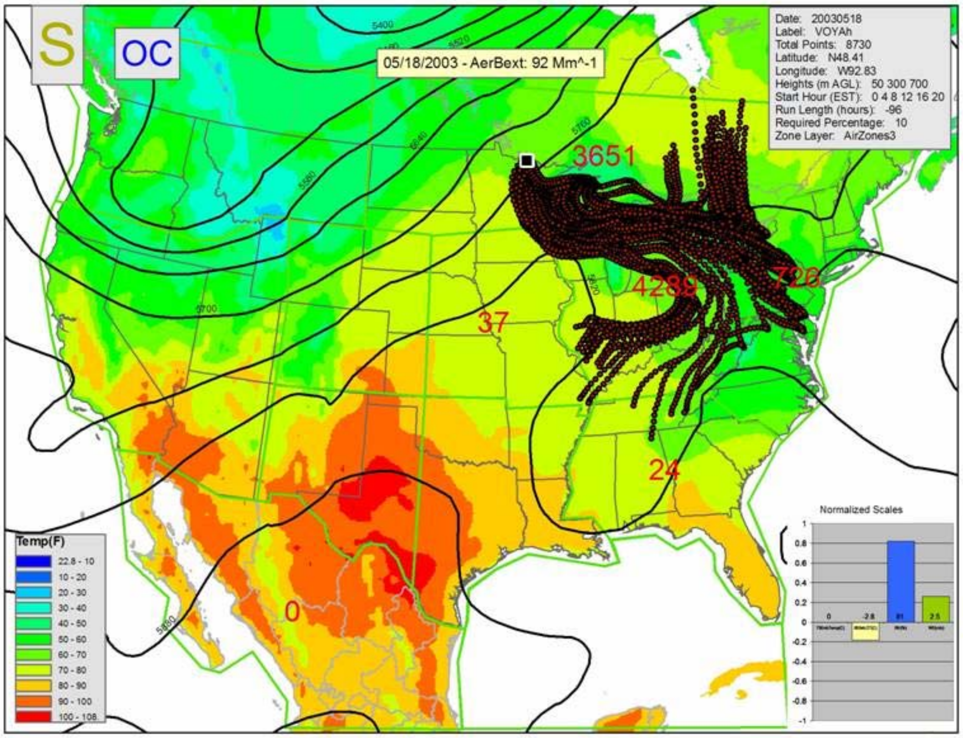


Figure B-6. Warm Season Stagnant – Subgroup B example.

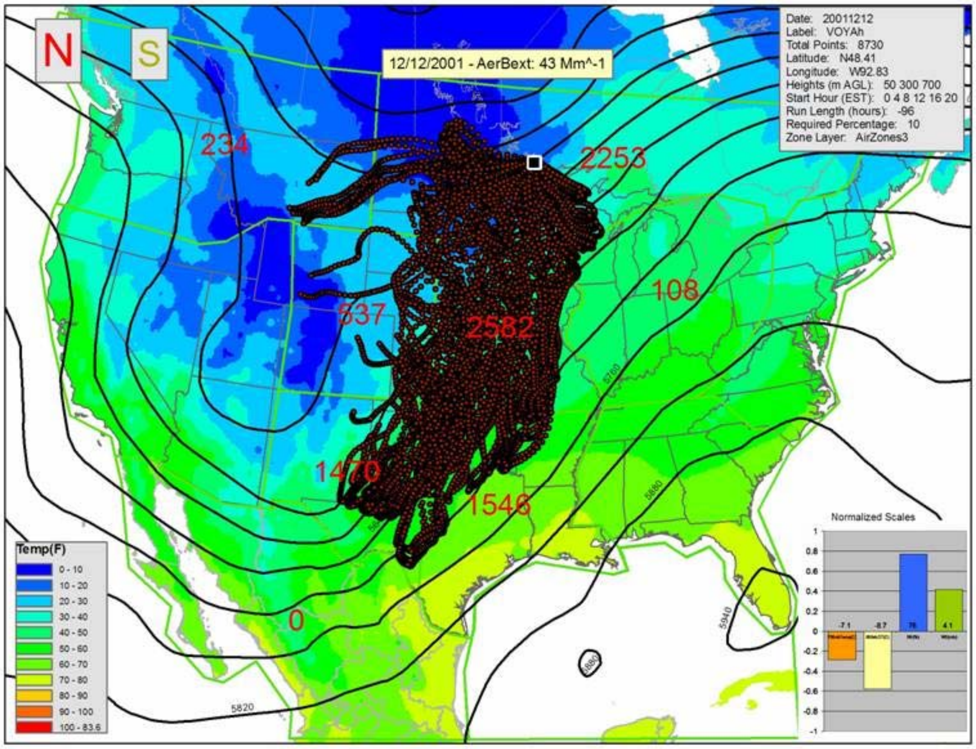


Figure B-7. Cool Season Pre-frontal example.

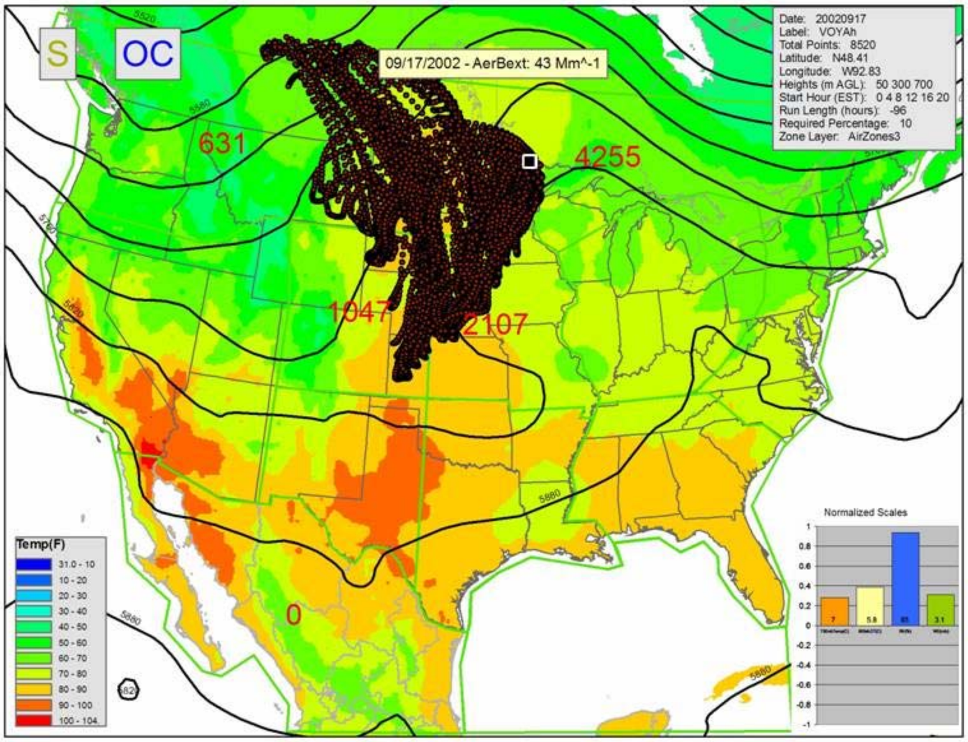


Figure B-8. Fall Southwesterly Transport example.

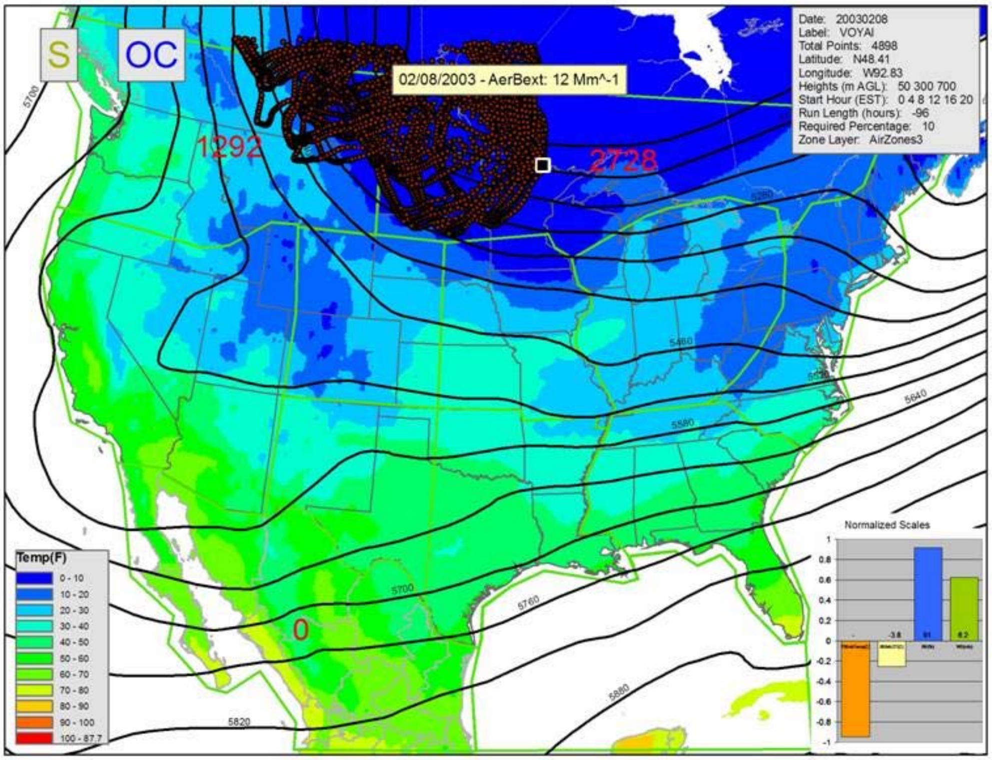


Figure B-9. Wintertime Northwesterly Transport – Subgroup A example.

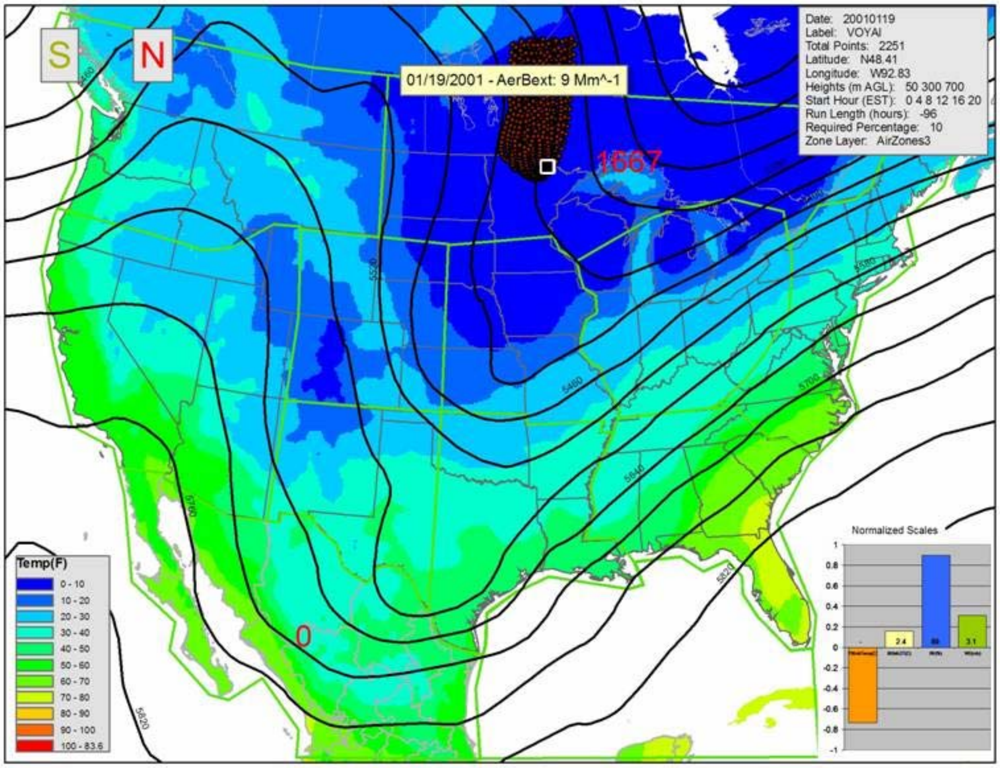


Figure B-10. Wintertime Northwesterly Transport – Subgroup B example.

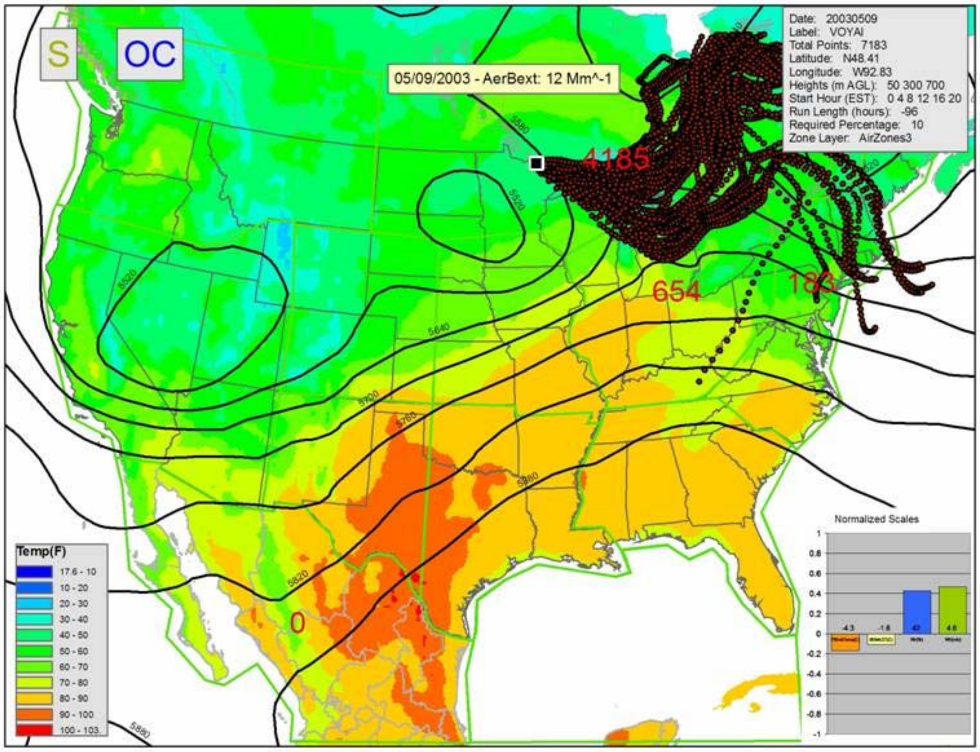


Figure B-11. Spring and Summer Northeasterly Transport – Subgroup A example.

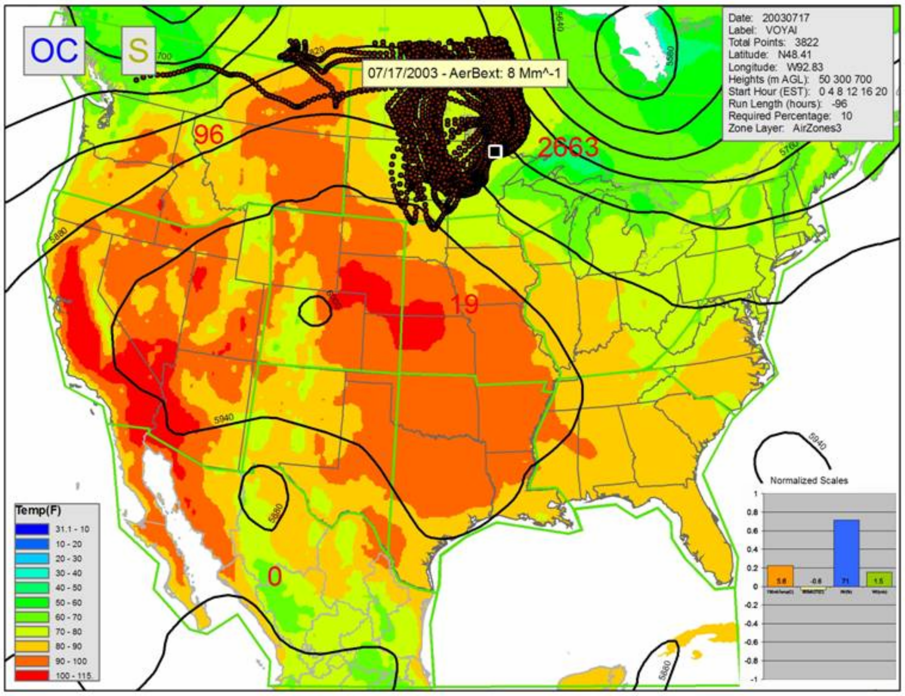
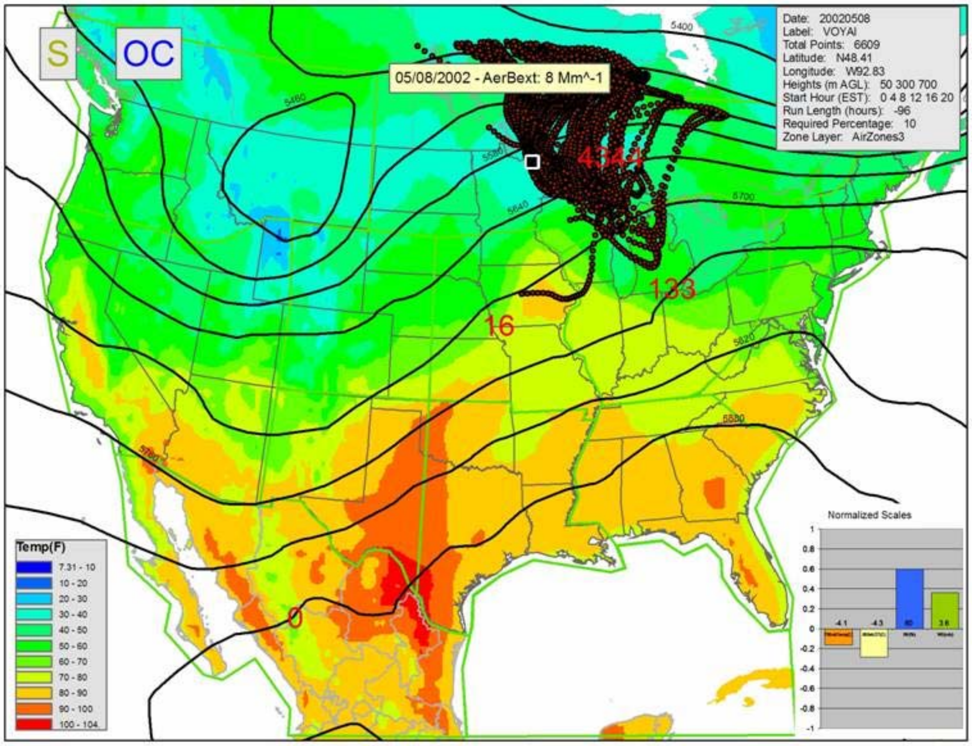


Figure B-12. Spring and Summer Northeasterly Transport – Subgroup B example.



Date: 20020508
Label: VOYAI
Total Points: 6609
Latitude: N48.41
Longitude: W92.83
Heights (m AGL): 50 300 700
Start Hour (EST): 0 4 8 12 16 20
Run Length (hours): -96
Required Percentage: 10
Zone Layer: AirZones3

Figure B-13. Spring Season Split Flow example.

B.3 WESTERN PLAINS SUBREGION

For the Western Plains subregion (represented by the Cedar Bluff site [CEBL1], there were four weather/transport day types for the 20%-worst days, and five for the 20%-best days. The meteorological and transport characteristics associated with the 20%-worst days are summarized in **Table B-3**; in general, these days

- occurred equally as often in the wintertime as in the summertime,
- were generally more humid than the days with the best visibility, and
- were characterized by weaker upper-level dynamics than the days with the best visibility.

The meteorological and transport characteristics associated with the 20%-best days are summarized in **Table B-4**; in general, these days

- occurred most often during the cool season (late fall, winter, early spring) and
- were characterized by transport from the west.

The four weather/transport groups associated with the 20%-worst days at Cedar Bluff are described below and summarized Table B-3:

1. Wintertime Regional Re-Circulation. This worst visibility group is the most common and its conditions occurred on 15 of the 33 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. Within this group are two subgroups:

   Subgroup A conditions occurred on 10 of the 33 days and are characterized by transport from the north-northwest and local recirculation; the Cen and WYCO source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by northwest flow aloft with a trough of low pressure over the eastern United States. A good example day of this group is January 24, 2003 (see **Figure B-14**).

   Subgroup B conditions occurred on 5 of the 33 days and are characterized by transport from split directions (mostly south-southwest and some north-northwest). The meteorological conditions are similar to those in Subgroup A, except for higher relative humidity and warmer 700-mb temperatures. A good example day of this group is March 4, 2003 (see **Figure B-15**).

2. Summertime Southeasterly Transport. This worst visibility group is the second most common and its conditions occurred on 13 of the 33 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate. Within this group are two subgroups:

   Subgroup A conditions occurred on 7 of the 33 days and are characterized by medium-range transport from the southeast, with additional transport from the Ohio River Valley. The Cen source area (Figure B-2) experienced the most parcel residence time for this group. The meteorological pattern is characterized by very weak flow aloft; the Cedar Bluff site is situated under zonal flow or an upper-level ridge of high pressure. A good example day of this group is June 20, 2003 (see **Figure B-16**).

Subgroup B conditions occurred on 6 of the 33 days and are characterized by transport from the southeastern United States or Gulf of Mexico; the TxLa source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by very weak flow aloft; the Cedar Bluff site is situated under zonal flow or an upper-level ridge of high pressure. This group differs from Subgroup A because the transport is longer-range, and there is more morning stability. A good example day of this group is September 5, 2002 (see **Figure B-17**).

3. <u>Wintertime Stagnant</u>. This group of conditions occurred on only 3 of the 33 days. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by short-range transport; the WYCO source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days shows very weak flow aloft. A good example day of this group is December 10, 2002 (see **Figure B-18**).
4. <u>Summertime Northeasterly Transport</u>. This group of conditions was the least common, occurring on only 2 of the 33 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by long-range transport from the east-northeast through Illinois, Missouri, and the Great Lakes area; the Cen source areas(Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the central United States, with high relative humidity at the surface. A good example day of this group is August 13, 2003 (see **Figure B-19**).

The five weather/transport groups associated with the 20%-best days at Cedar Bluff are described below and summarized in Table B-4:

1. <u>Late Fall – Winter Northwesterly Flow</u>. This best-visibility group of conditions was the most common and occurred on 12 of the 34 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of crustal material and nitrate. This group is characterized by transport from the west-northwest; the WYCO source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the western United States and an upper-level trough over the eastern United States. Despite the crustal material in the $PM_{2.5}$ composition, morning surface winds were no stronger than those in other groups. A good example day is November 22, 2002 (see **Figure B-20**).
2. <u>Fall – Spring Post-Cold Front</u>. This group of conditions was the second most common and occurred on 10 of the 34 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some crustal material. This group is characterized by long-range transport from the northwest; the NW and WYCO source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by a post-cold frontal pattern, a weak to moderately strong upper-level trough over the Cedar Bluff site, or zonal flow aloft. A good example day of this group is September 27, 2003 (see **Figure B-21**).
3. <u>Spring – Summer Pre-Trough</u>. This group of conditions occurred on 5 of the 34 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some

crustal material. This group is characterized by long-range transport from multiple directions, including the south, southwest, and northwest; the TxLa and WYCO source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the western United States, weak upper-level dynamics over the Cedar Bluff site, high relative humidity, and strong winds at the surface. A good example day of this group is May 9, 2003 (see **Figure B-22**).

4. Wintertime Stagnant. This group of conditions occurred on 4 of the 34 days analyzed, and its pattern is similar to that of Summertime Southeasterly Transport for the 20%-worst days. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by short-range transport; the WYCO source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the western United States and a trough over the eastern United States. This pattern differs from Group 2 in the 20%-worst days because it shows (1) longer transport and (2) stronger upper-level dynamics. A good example day of this group is November 28, 2002 (see **Figure B-23**).
5. Late Fall Westerly Flow. This group of conditions is the least common and occurred on 3 of the 34 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of crustal material with some nitrate. This group is characterized by long transport from the west; the WYCO and NM source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by zonal flow aloft and a low relative humidity at the surface (~60%). The surface winds were relatively strong. A good example day of this group is November 13, 2002 (see **Figure B-24**).

Table B-3. The four weather/transport day types for the 20%-worst visibility days for the Western Plains subregion (represented by Cedar Bluff [CEBL1]).

		CEB Worst	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemisty	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1a	12/04/2002 12/25/2002 01/21/2003 01/24/2003 02/05/2003 02/26/2003 03/10/2003 10/06/2003 11/08/2003 12/02/2003	N, S	Long	Local Re-circulation	Nor	WYCO	Upper-level trough over the eastern U.S. NW flow over CEB	Cool to cold season. Temperatures mainly below freezing.	79.4	5.7	5	-2.4
1b	03/04/2003 03/07/2003 03/13/2003 04/18/2003 10/03/2003	N, S	Long	Mainly SW with some NW	mixed: NM, WYCO, TxLa		Upper-level trough over the eastern U.S. Zonal flow OR	Cool season. Fall, early spring. Temps near or just above	93.9	6.9	5.2	2.3
2a	08/30/2002 03/19/2003 04/30/2003 05/03/2003 05/18/2003 06/20/2003 08/07/2003	S	Mixed. Some long, some short.	S-SE but with components from the Ohio River Valley	Cen		Weak flow aloft. Zonal flow or under a ridge.	Warm season. Temps in the 80's or above.	88.3	-1.6	5.7	7.4
2b	09/02/2002 09/05/2002 04/27/2003 08/22/2003 08/25/2003 09/09/2003	S, OC	Long	S-SE or from the Gulf of Mexico	TxLa	NM	Weak flow aloft. Zonal or under a ridge.	Warm season. Temps in the 80's or above.	77.5	3.5	4.4	10.7
3	12/10/2002 03/01/2003 12/08/2003	N, S	Short, recirculation through	Local. Some north, some south.	WYCO		Weak flow aloft. No deep	Cool season. Temps near or just above	85.9	6.8	3.6	-2.6
4	06/17/2003 08/13/2003	S, OC	Long	E-NE through	Cen		Upper level ridge	Warm season. Temps in the	84.9	1.7	3.4	4.3

Table B-4. The five weather/transport day types for the 20%-best visibility days for the Western Plains subregion (represented by Cedar Bluff [CEBL1]).

		CEB Best	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1	11/22/2002	CM,N	Medium	W-NW	WYCO		Ride over the western US and a trough over the east (or a cutoff low just east of the region)	Cool to cold season. Temps near freezing.	68.1	6.4	4.8	-0.3
	01/09/2003											
	01/18/2003											
	10/15/2003											
	10/27/2003											
	11/29/2003											
	12/13/2002											
	12/28/2002											
	01/03/2003											
	02/11/2003											
	12/31/2002											
	03/31/2003											
2	10/20/2002	S,CM	Long	NW	NW	WYCO	Weak to Moderate trough over the region or zonal flow aloft.	Mostly cool season. Late fall, early spring.	76.6	2	4.7	-2.4
	09/27/2003											
	10/12/2003											
	03/25/2003											
	09/12/2003											
	12/29/2003											
	03/28/2003											
	12/19/2002											
	10/05/2002											
	06/08/2003											
3	10/02/2002	S,CM	Long	Multipe Directions	TxLa	WYCO	Weak trough over the CEB region or very little	Warm season. Temps 60's+	87.5	1.7	5.8	6.4
	09/18/2003											
	06/29/2003											
	05/06/2003											
	05/09/2003											
4	11/07/2002	N,S	Short	W-NW - Slight recirculation from the N.	WYCO		Ride over the western US and a trough over	Cool to cold season. Temps near freezing.	69.5	5.8	5.2	-3.1
	11/28/2002											
	11/19/2002											
	12/05/2003											
5	11/20/2003	CM,N	Long	W-SW	WYCO	NM	Zonal flow aloft	Cool season. Late fall events.	59.5	7.1	7.4	2.6
	11/13/2002											
	11/10/2002											

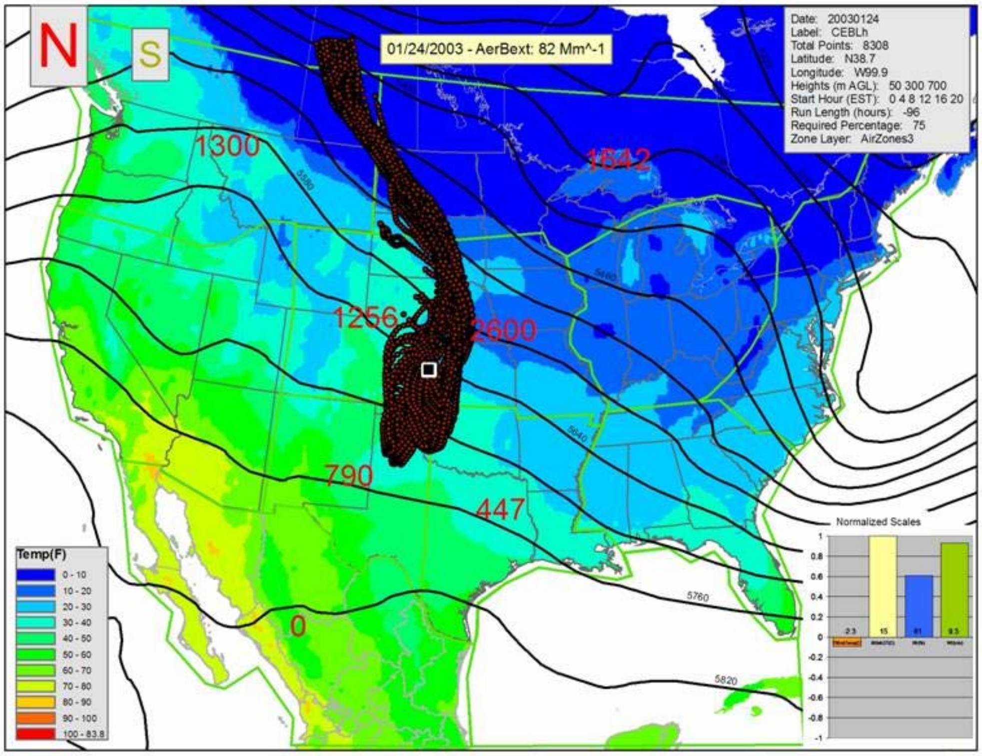


Figure B-14. Wintertime Regional Recirculation – Group A example.

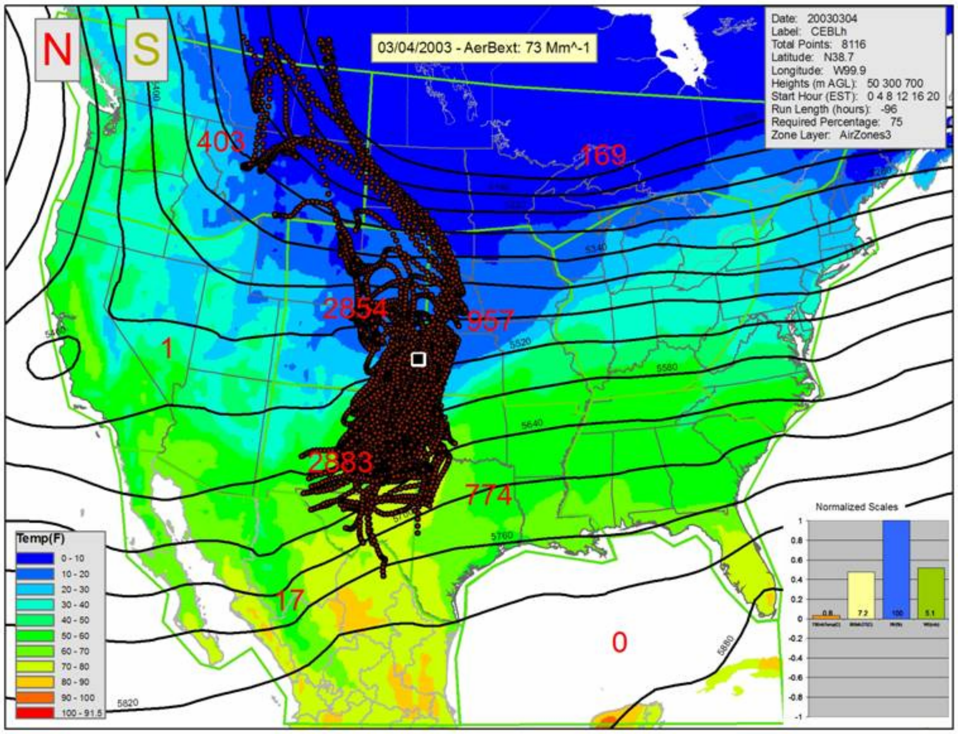


Figure B-15. Wintertime Regional Recirculation – Group B example.

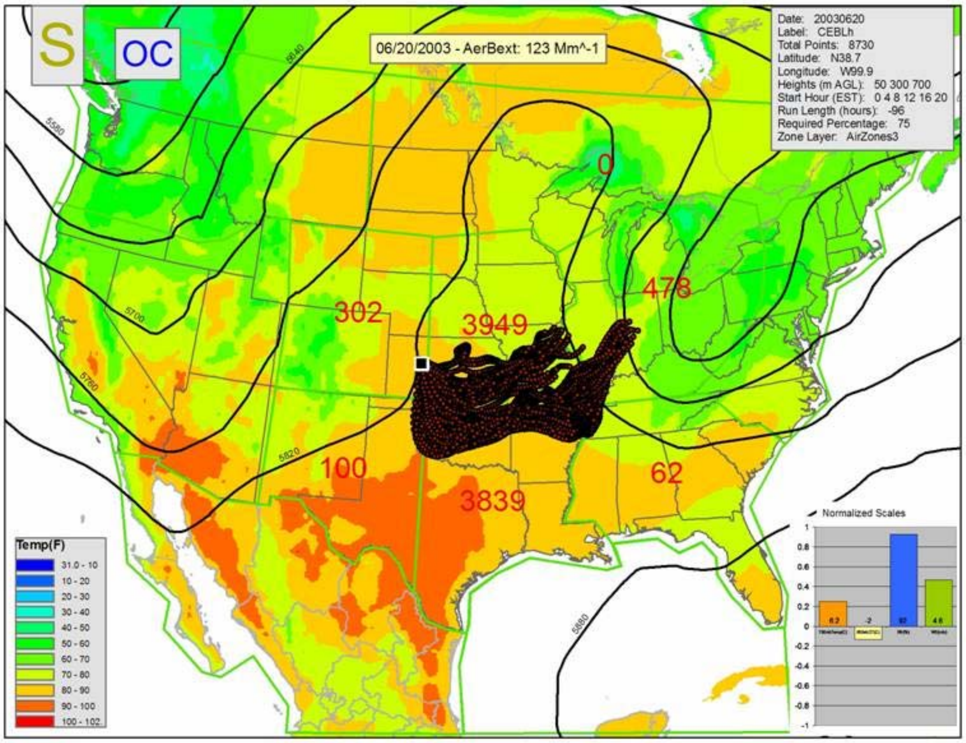


Figure B-16. Summertime Southeasterly Transport – Group A example.

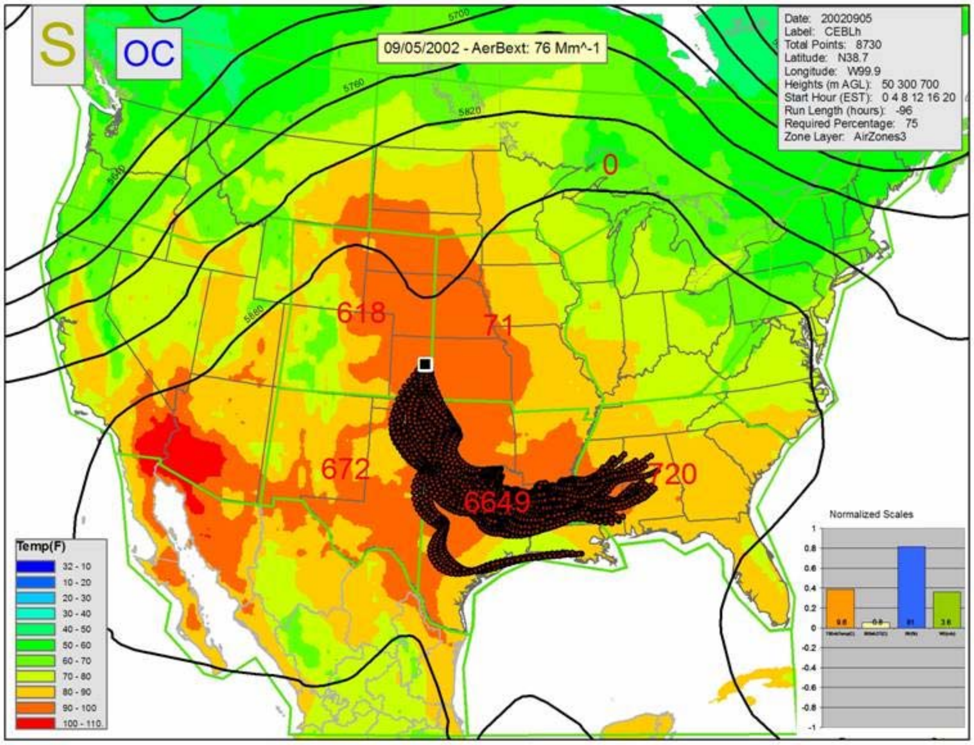


Figure B-17. Summertime Southeasterly Transport – Group B example.

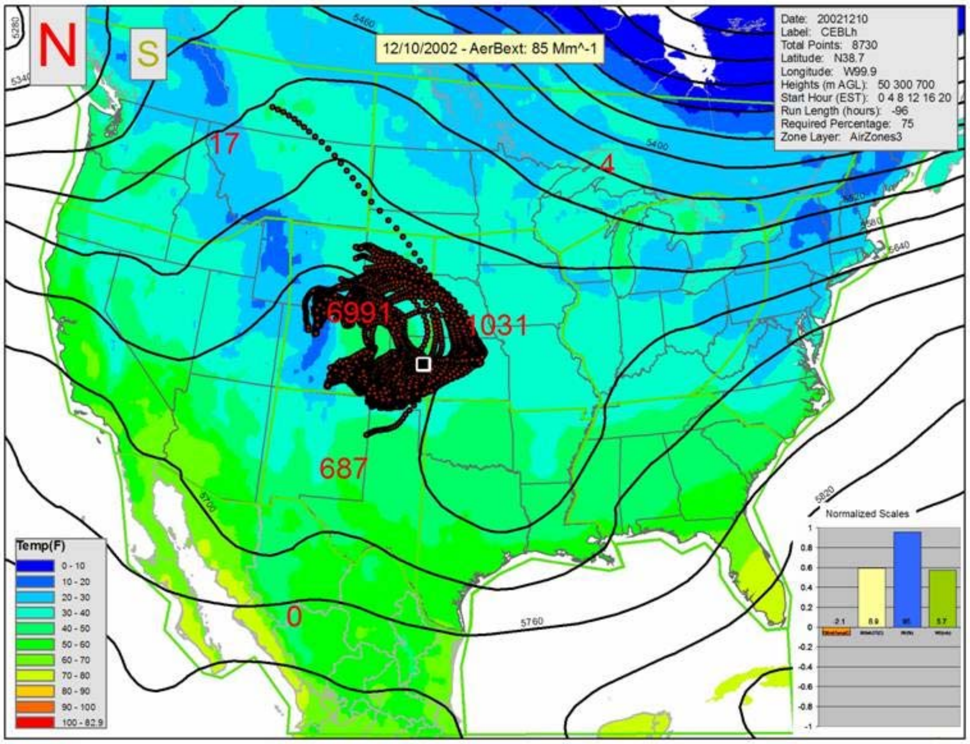


Figure B-18. Wintertime Stagnant example.

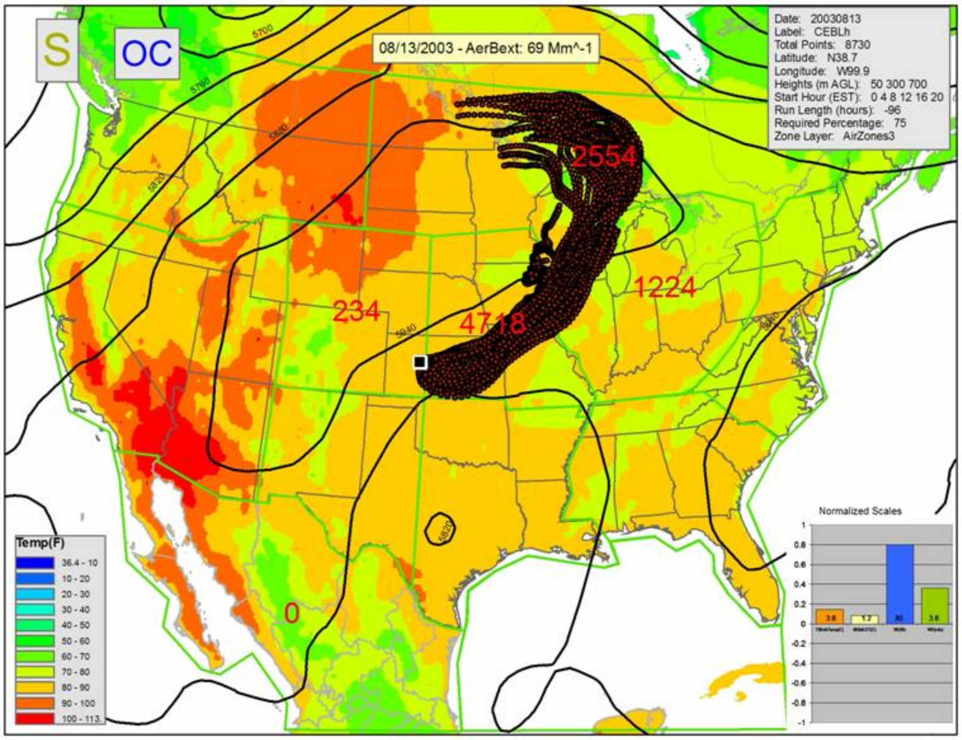


Figure B-19. Summertime Northeasterly Transport example.

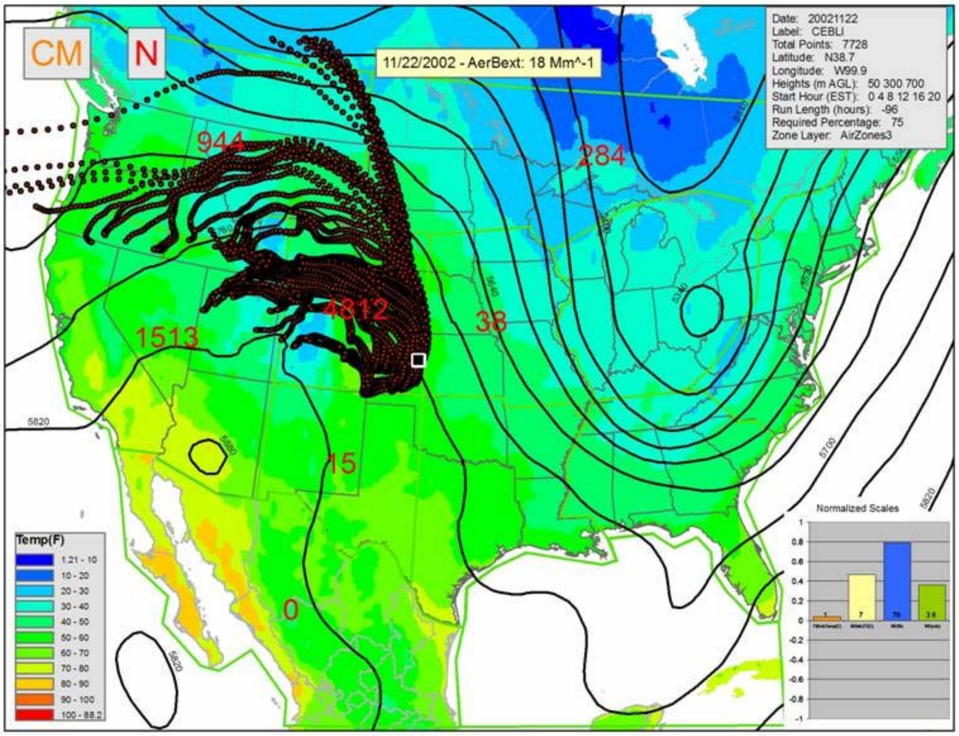


Figure B-20. Late Fall – Winter Northwesterly Flow example.

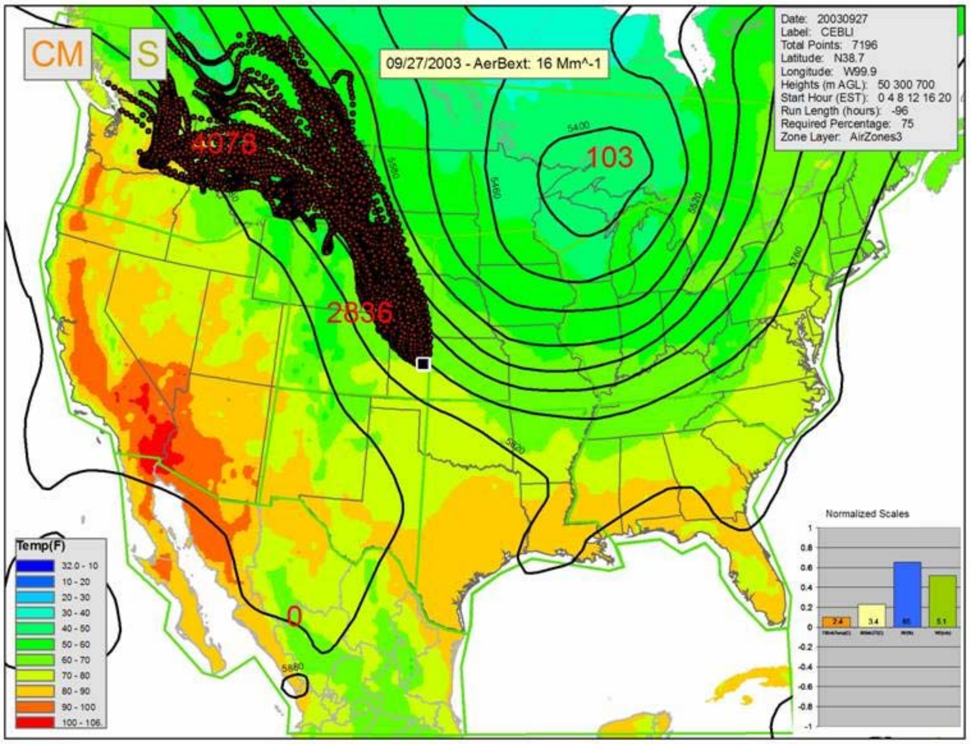


Figure B-21. Fall – Spring Post-Cold Front example.

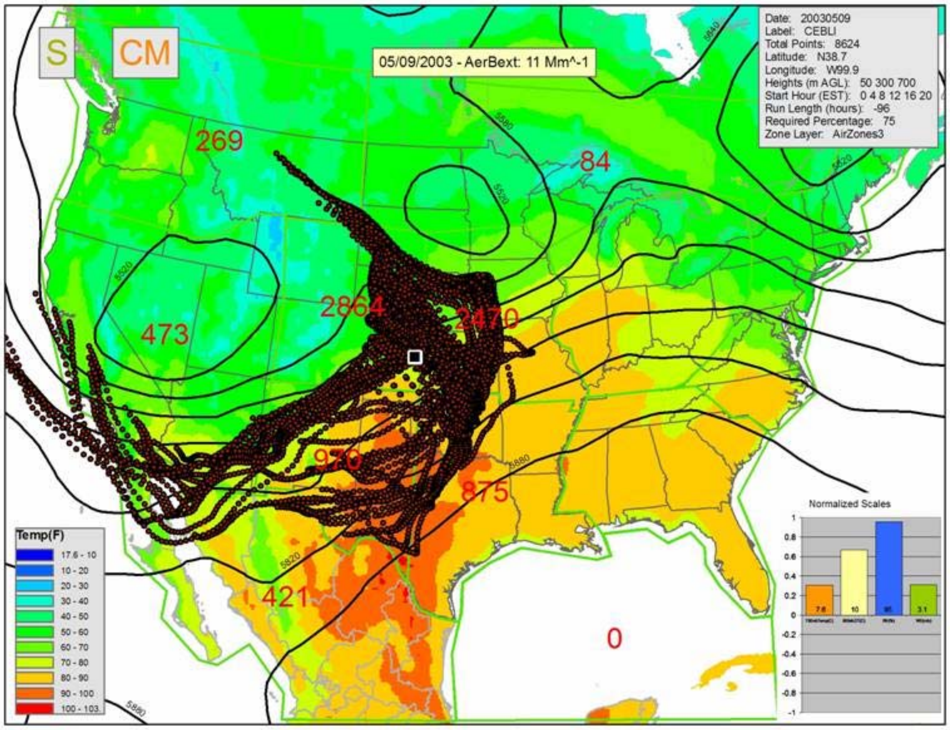


Figure B-22. Spring – Summer Pre-Trough example.

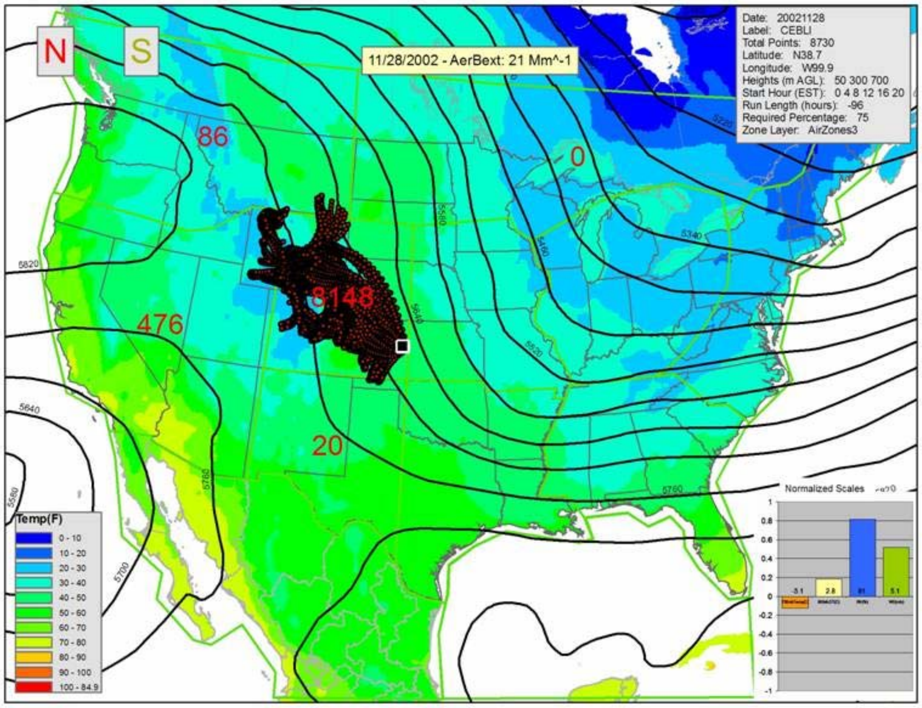


Figure B-23. Wintertime Stagnant example.

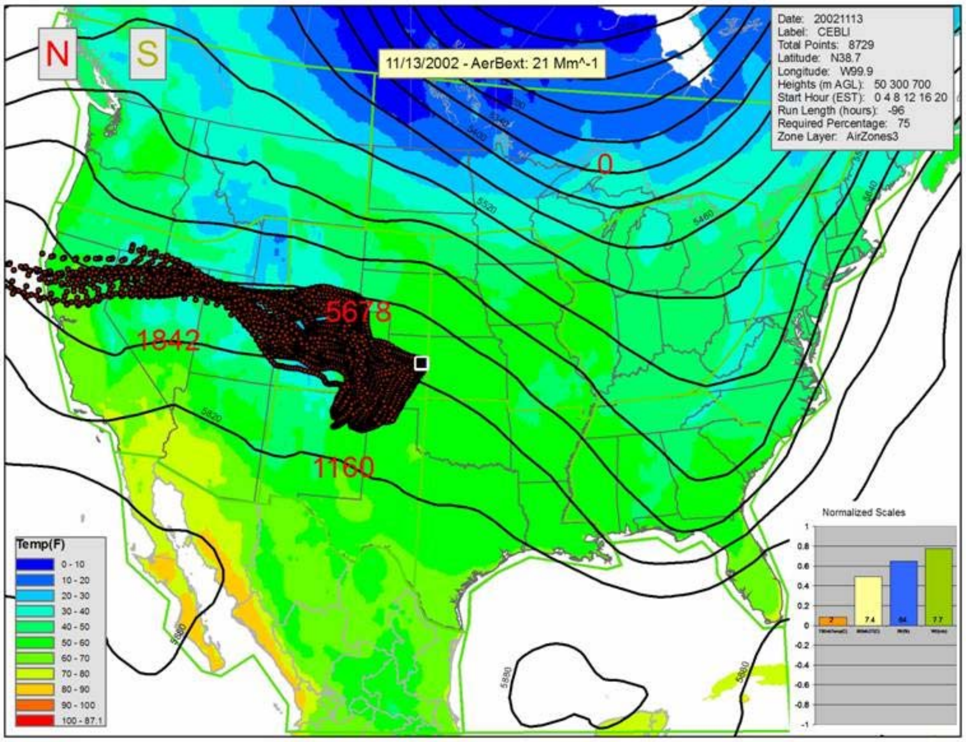


Figure B-24. Late Fall Westerly Flow example.

B.4 UPPER MIDWEST SUBREGION

For the Upper Midwest subregion (represented by the Hercules-Glades site [HEGL1]), there were five weather/transport day types for the 20%-worst days and three for the 20%-best days. The meteorological and transport characteristics associated with the 20%-worst days are summarized in **Table B-5**; in general, these days

- occurred more often in the warm season (late spring, summer, early fall),
- were characterized by sulfate-dominated $PM_{2.5}$ concentrations, and
- frequently showed transport from an easterly or southerly direction

The meteorological and transport characteristics associated with the 20%-best days are summarized in **Table B-6**; in general, these days

- occurred equally as often in the cool season as in the warm season,
- were usually associated with a weather pattern that featured an upper-level trough of low pressure over the central or eastern United States, and
- were characterized by transport from the north-northwest.

The five weather/transport groups associated with the 20%-worst days at Hercules-Glades are described below and summarized in Table B-5:

1. <u>Warm Season Northeasterly Transport</u>. These worst visibility group conditions are the most common and occurred on 26 of the 66 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. Within this group are two subgroups:

   Subgroup A conditions occurred on 17 of the 66 days and are characterized by relatively short-range transport from the northeast; the Cen and ORV source areas (Figure B-2) experienced the most parcel residence time. The meteorological conditions are characterized by a weak upper-level ridge over the central United States. A good example day of this group is August 8, 2001 (see **Figure B-25**).

   Subgroup B conditions occurred on 9 of the 66 days and are characterized by long-range northeasterly transport; the ORV source area (Figure B-2) experienced the most parcel residence time. The meteorology is characterized by a weak upper-level pattern, often with zonal winds over the central United States. The relative humidity was generally lower for Subgroup B than for that for Subgroup A. A good example day of this group is August 30, 2002 (see **Figure B-26**).

2. <u>Summertime Southeasterly Transport</u>. These worst visibility group conditions are the second most common and occurred on 21 of the 66 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. Within this group are two subgroups:

   Subgroup A conditions occurred on 12 of the 66 days and are characterized by transport from the east-southeast; the SE and TxLa source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days is characterized by a moderately strong ridge over the eastern United States. A good example day of this group is September 8, 2002 (see **Figure B-27**).

Subgroup B conditions occurred on 9 of the 66 days and are characterized by relatively short-range transport from the southeast; the TxLa and SE source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days is characterized by a strong ridge over the eastern United States and very warm temperatures. The morning winds for Subgroup B were half the speed of the morning winds for Subgroup A. A good example day of this group is July 21, 2001 (see **Figure B-28**).

3. Warm Season Southerly Transport. This group of conditions occurred most often in the spring on 8 of the 66 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by long-range transport from the south-southeast; the TxLa and Gulf source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days is characterized by a weak upper-level ridge over the southeastern United States. A good example day of this group is April 30, 2003 (see **Figure B-29**).
4. Cool Season Split Flow. This group of conditions occurred on 6 of the 66 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by long-range transport from several directions, mostly from the north and from recirculation over the Gulf of Mexico; the TxLa source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days is characterized by an upper-level trough over the west-central United States and a relatively strong morning temperature inversion. A good example day of this group is February 25, 2002 (see **Figure B-30**).
5. Cool Season Northwesterly Transport. This group of conditions is the least common of the worst visibility groups and occurred on only 5 of the 66 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of nitrate with some sulfate. This group is characterized by transport from the north-northwest; the Cen and Nor source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern on these days is characterized by a strong upper-level trough over the Great Lakes region and cold, morning 700-mb temperatures. A good example day of this group is January 6, 2003 (see **Figure B-31**).

The three weather/transport groups associated with the 20%-best days at Hercules-Glades are described below and summarized in Table B-6:

1. Northwesterly Transport. These best visibility group conditions are the most common and occurred on 38 of the 67 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some nitrate. Within this group are two subgroups:

Subgroup A conditions occurred on 21 of the 67 days and are characterized by long-range transport from the north-northwest; the Cen and Nor source areas (Figure B-2) experienced the most parcel residence time. This subgroup contains an equal number of warm-season and cool-season days. The meteorological pattern is characterized by an upper-level trough over the eastern United States. A good example day of this group is December 1, 2002 (see **Figure B-32**).

Subgroup B conditions occurred on 17 of the 67 days and are characterized by long-range transport from the north-northwest; the Cen and Nor source areas (Figure B-2) experienced the most parcel residence time. This subgroup contains both warm-season and cool-season days; the majority were warm season days. The meteorological pattern is characterized by an upper-level trough or cutoff low pressure system over the central United States and less morning stability than that in Subgroup A. A good example day of this group is June 8, 2003 (see **Figure B-33**).

2. Cool Season Split Flow. These best visibility group conditions are the second most common and occurred on 23 of the 67 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some nitrate and organic carbon. Within this group are two subgroups:

Subgroup A conditions occurred on 17 of the 67 days and are characterized by medium-range transport from several directions; Gulf and TxLa source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the west central United States and many days saw an upper-level cutoff low pressure system over the north central United States. The average morning surface wind speed for this group is also the strongest of all the best visibility groups. A good example day of this group is December 31, 2002 (see **Figure B-34**).

Subgroup B conditions occurred on 6 of the 67 days and are characterized by medium- and long-range transport from several directions: west, northwest, south, and southeast. No source areas stood out with the most parcel residence time for this group. The meteorological pattern is characterized by a weak upper-level trough over the eastern United States or zonal flow aloft. The morning stability for this group is the highest of all the best visibility groups. A good example day of this group is January 9, 2003 (see **Figure B-35**).

3. Spring Season Recirculating Transport. This group of conditions is the least common and occurred on only 6 of the 67 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate, with some nitrate and organic carbon. This group is characterized by short- to medium-range transport from numerous directions; the Cen source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the central or eastern United States. A good example day of this group is March 12, 2002 (see **Figure B-36**).

Table B-5. The five weather/transport day types for the 20%-worst visibility days for the Upper Midwest subregion (represented by Hercules-Glades [HEGL1]).

		HEGL Worst	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1a	06/09/2001 08/05/2001 08/08/2001 09/13/2001 07/25/2002 08/27/2002 09/17/2002 10/23/2002 09/26/2002 06/17/2003 08/07/2003 09/09/2003 06/12/2001 06/27/2001 09/05/2002 12/13/2002 03/16/2003	S,OC	short-medium	N,NE with recirculation over HEGL	Cen	ORV	weak ridge over the central US	Mostly warm season, 70's - 80's. A few cool season cases.	90.6	-1.9	2.7	5.8
1b	04/12/2003 07/15/2001 09/16/2001 07/07/2002 08/09/2002 08/30/2002 09/14/2002 08/13/2003 08/25/2003	S,OC	long	NE	ORV		weak ridge or zonal flow over the central US	Warm season, 70's - 80's	85.1	-1.6	2.5	6.6
2a	11/15/2001 06/22/2002 08/12/2002 09/02/2002 09/08/2002 10/09/2003 05/01/2001 05/04/2001 07/18/2001 05/29/2002 09/29/2002 11/11/2003	S,OC	long	E,SE	SE	TxLa	Ridge over the Eastern US	Warm season, 70's - 80's	89.4	-2.4	5.1	5.2
2b	06/19/2002 07/21/2001 07/24/2001 11/18/2001 06/28/2002 07/10/2002 08/03/2002 08/06/2002 08/19/2003	S,OC	short-medium	SE,S	TxLa	SE	Ridge over the central US	Hot. Summertime pattern. Temps 80's - 90's	88.6	-1.9	2.5	8.4
3	04/18/2003 04/07/2001 05/09/2003 05/18/2003 03/13/2003 04/04/2001 10/04/2001 01/29/2002	S,OC,N	long	SE,S	TxLa	Gulf	Weak upper level ridge over the Southern US	Mild - Warm season temps (50's - 60's)	88.3	-0.8	5.2	6
4	12/14/2003 03/29/2001 01/05/2002 02/25/2002 12/07/2002 12/08/2003	N,S	long	Split directions. Some Northerly, some recirculation	TxLa		Trough over the west-central US	Cool season, 30's - 50's	84.2	2.7	4.1	-2.7
5	03/08/2001 11/16/2002 11/28/2002 10/06/2003 01/06/2003	N,S	long	N,NW	Cen	Nor	trough over the great lakes region	Cool season 40's - 50's	90.9	1.7	3.3	-6.4

Table B-6. The three weather/transport day types for the 20%-best visibility days for the Upper Midwest subregion (represented by Hercules-Glades [HEGL1]).

		HEGL Best	Transport						Avg. Calcuations			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Surface Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1a	20031015	Variable - All types	long	N,NW	Cen	Nor	Trough over the eastern US	Both warm season and cool season cases.	83.7	3.7	2.8	3.7
	20010317											
	20011121											
	20031220											
	20031114											
	20031202											
	20010820											
	20010922											
	20011007											
	20020923											
	20021005											
	20021008											
	20021014											
	20021201											
	20031027											
	20010413											
	20010925											
	20030322											
	20031018											
	20021107											
	20031129											
1b	20020213	S,N	long	N,NW	Cen	Nor	Trough over central US. A few cases have cutoff lows over the central US.	Both warm season and cool season cases. Primarily more warm season than cool season.	80.1	-3.7	2.6	-3.7
	20010416											
	20010910											
	20011016											
	20020426											
	20021017											
	20030608											
	20030915											
	20030927											
	20030930											
	20031217											
	20010522											
	20011224											
	20030512											
	20030723											
	20011025											
	20020114											
2a	20021219	S,N	medium	Split directions. Recirculation near HEGL from S.	Gulf	TxLa	Trough over west central US. Many cases have a cutoff low over north central US.	Primarily cool season cases.	87.7	-0.5	4.8	-0.5
	20021231											
	20010507											
	20011124											
	20020309											
	20020517											
	20020815											
	20030626											
	20011127											
	20031229											
	20021029											
	20030319											
	20030702											
	20031105											
	20011212											
	20030214											
	20031117											
2b	20020429	S,OC	split - half long, half short	Multiple directions	none		Zonal flow or a weak trough over the eastern US.	Primarily cool season cases.	80.8	5.8	3.4	5.8
	20031012											
	20020126											
	20030109											
	20010314											
	20031120											
3	20010615	S,N.OC	short to medium	Multiple directions - Local sources	Cen		Trough over central or eastern US.	Cool to mild season (Spring) cases.	83.8	-1.6	3.5	-1.6
	20020312											
	20020330											
	20020423											
	20020514											
	20030421											

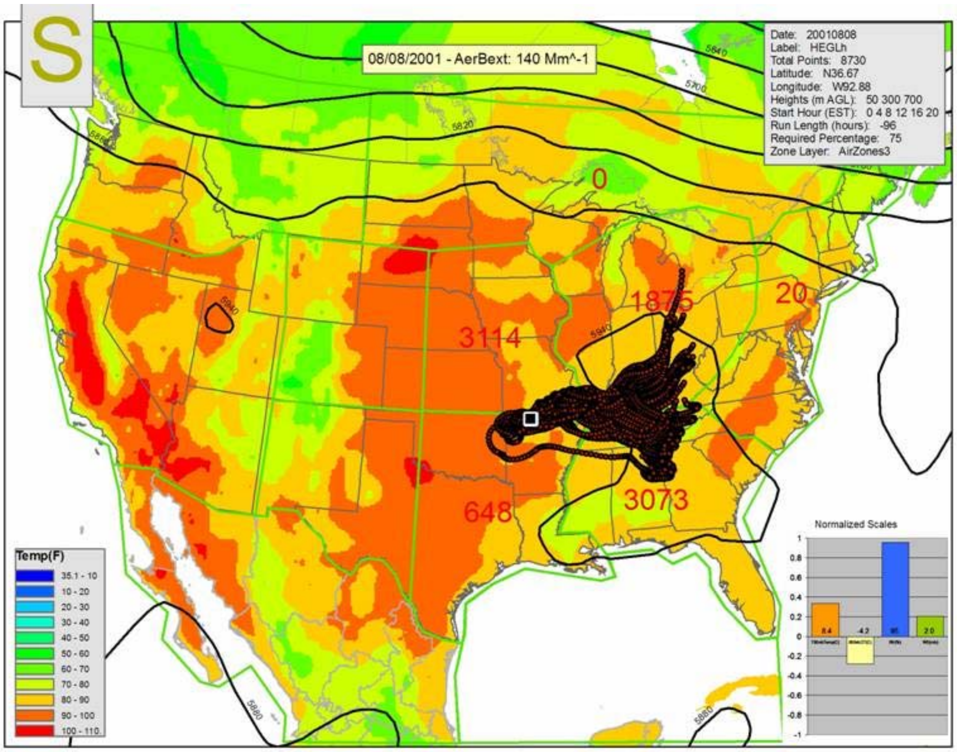


Figure B-25. Warm Season Northeasterly Transport – Subgroup A example.

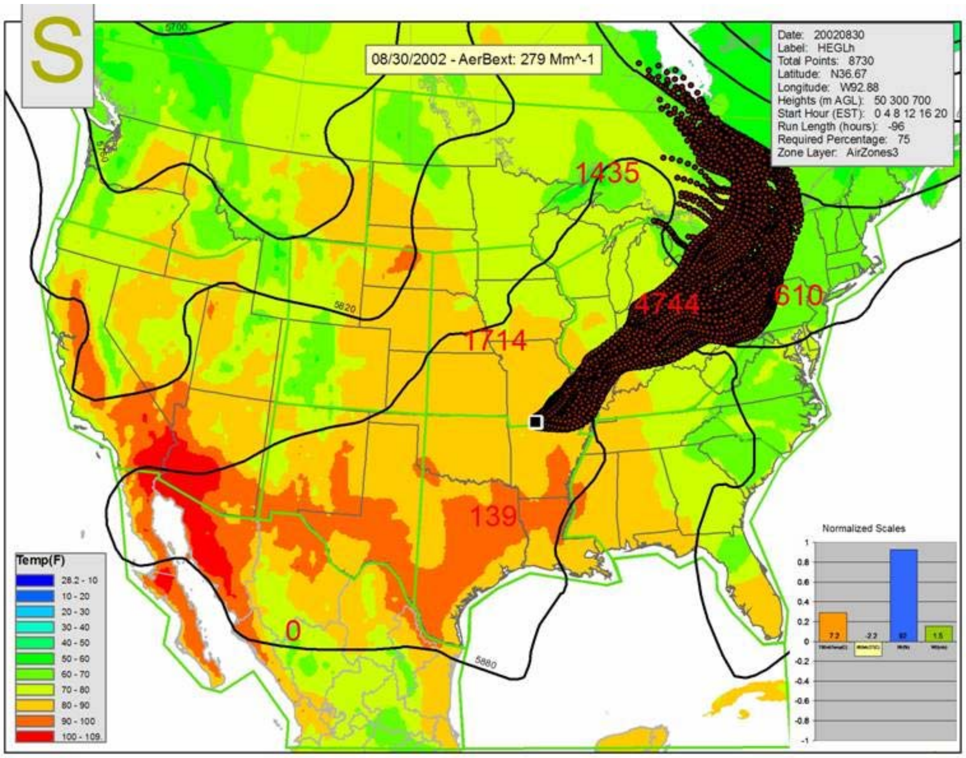


Figure B-26. Warm Season Northeasterly Transport – Subgroup B example.

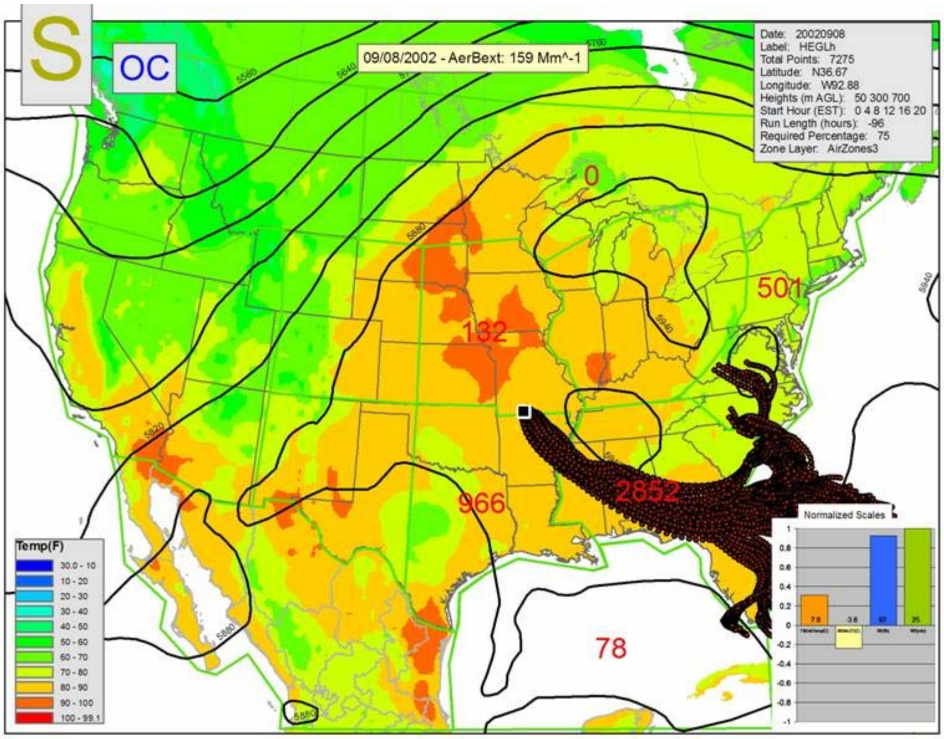


Figure B-27. Summertime Southeasterly Transport – Subgroup A example.

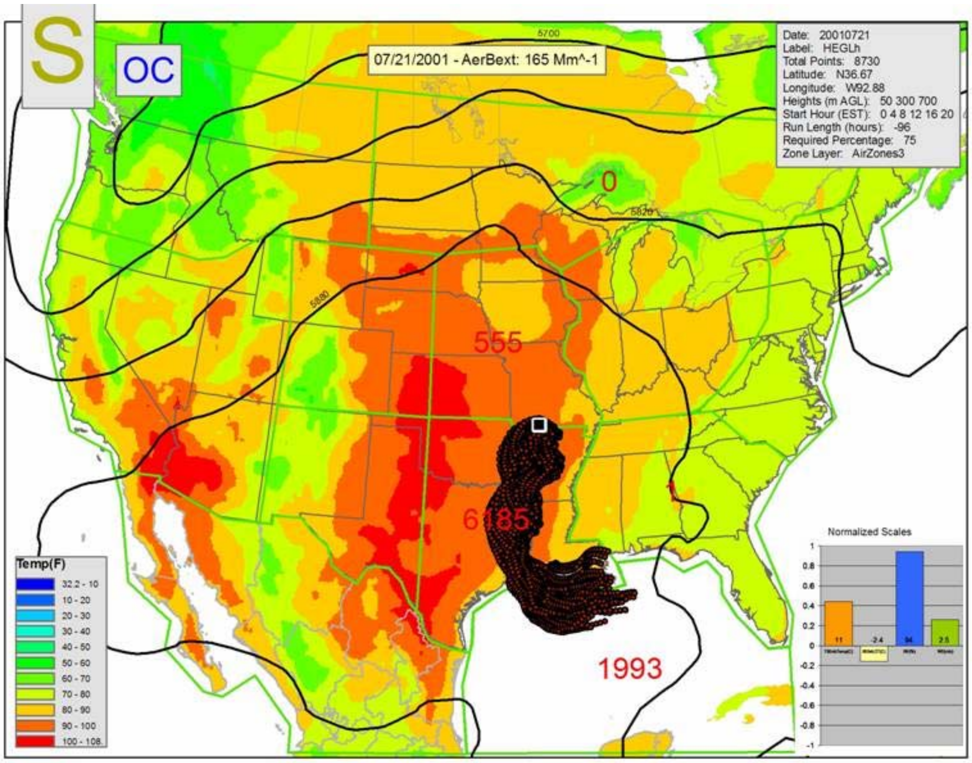
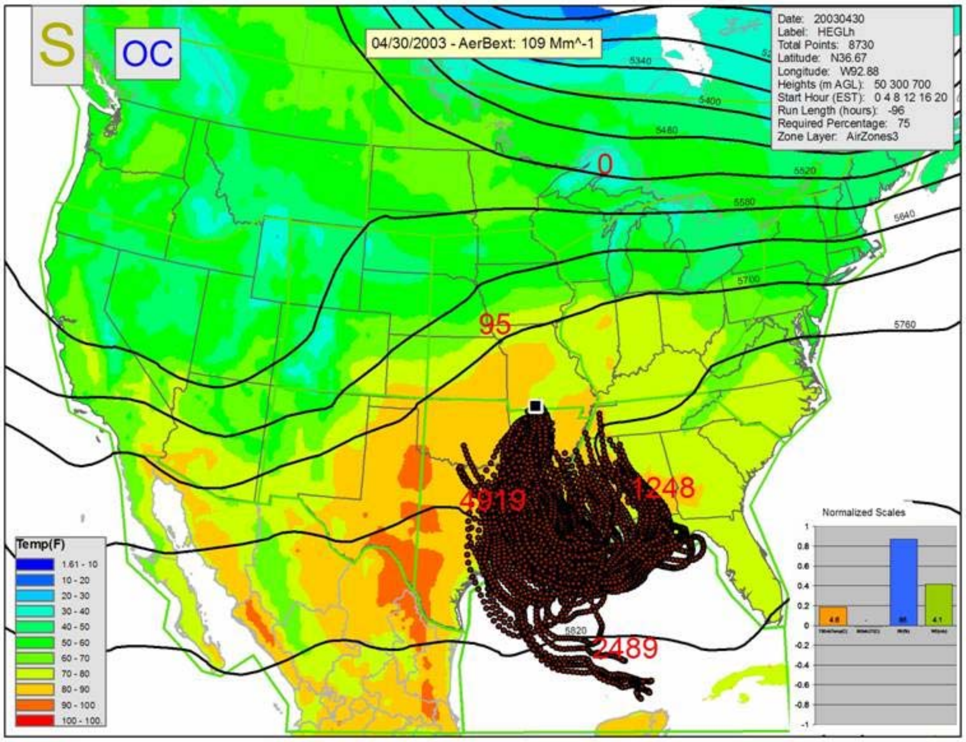
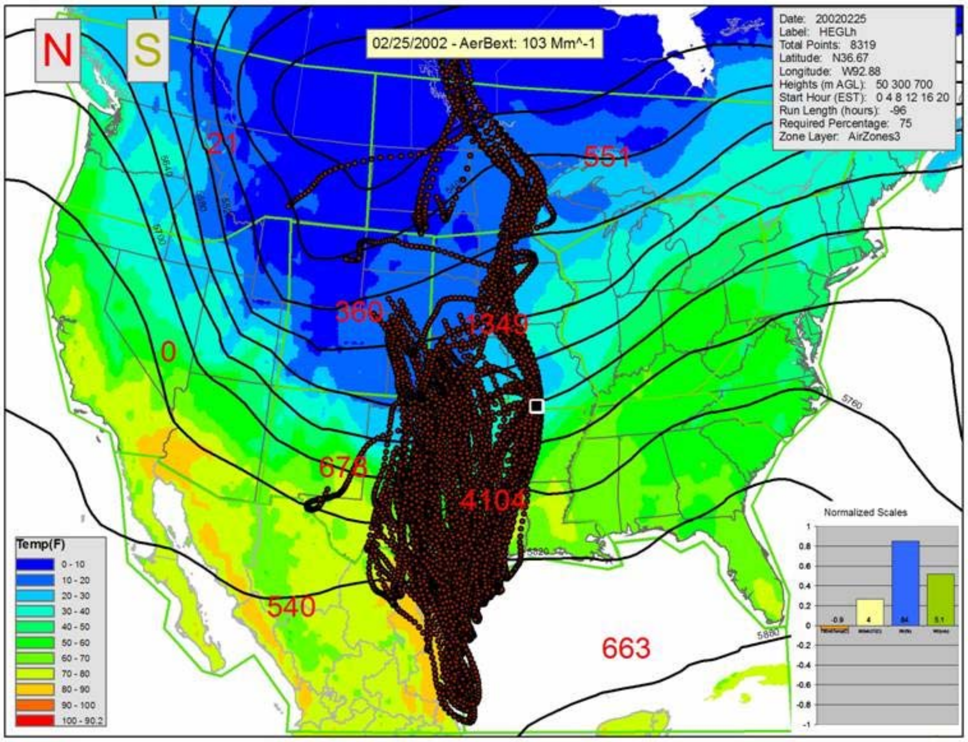


Figure B-28. Summertime Southeasterly Transport – Subgroup B example.



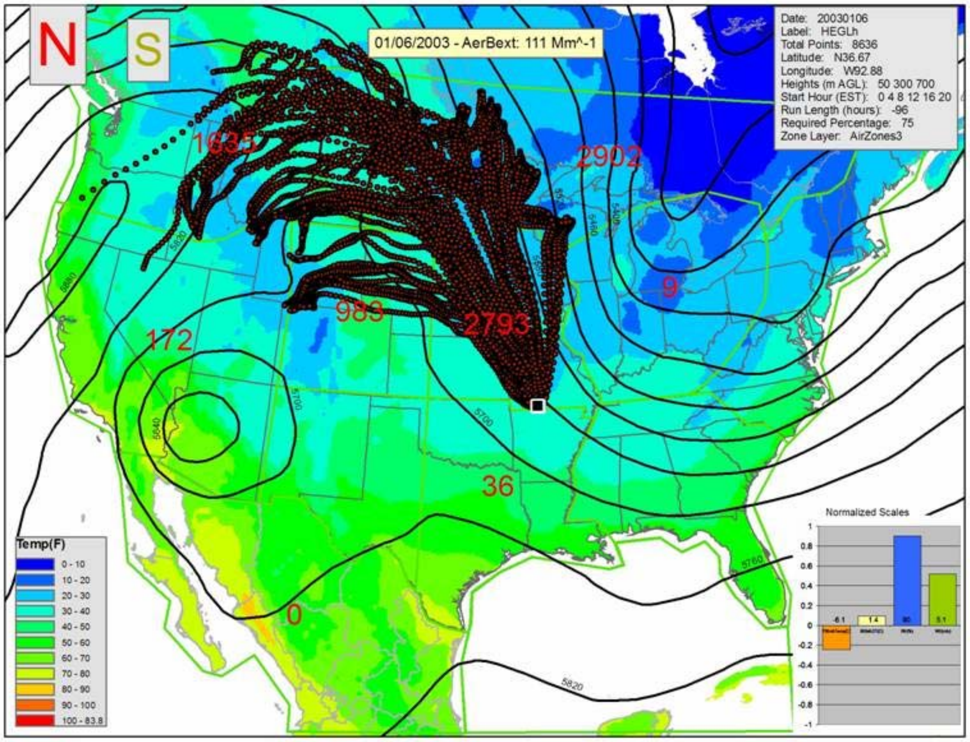
Date: 20030430
Label: HEGLh
Total Points: 8730
Latitude: N36.67
Longitude: W92.88
Heights (m AGL): 50 300 700
Start Hour (EST): 0 4 8 12 16 20
Run Length (hours): -96
Required Percentage: 75
Zone Layer: AirZones3

Figure B-29. Warm Season Southerly Transport example.



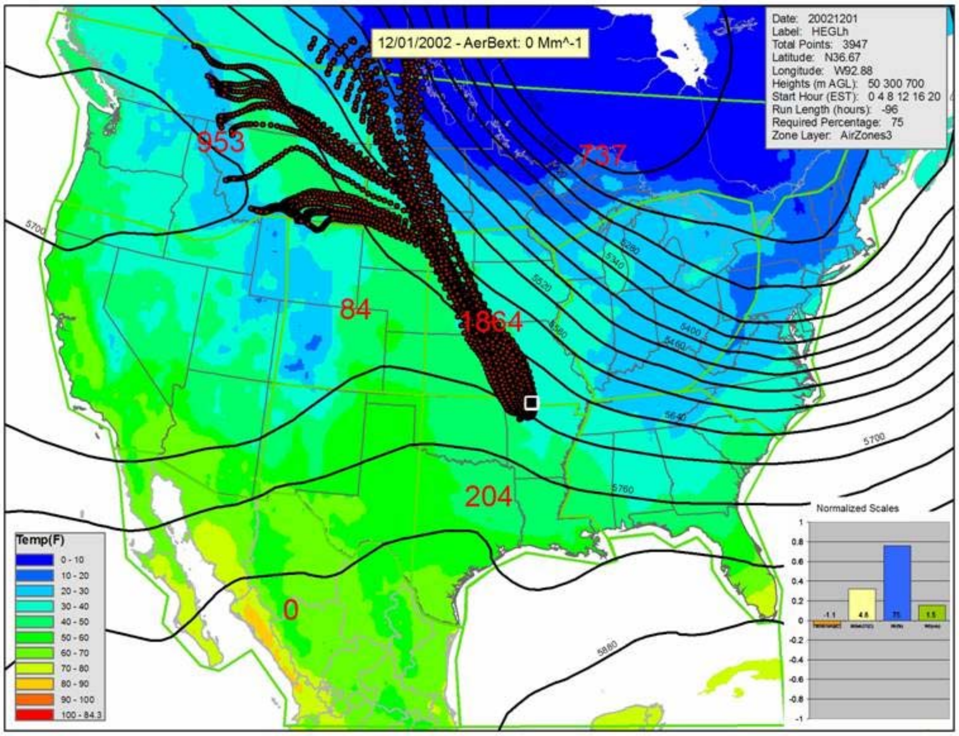
Date: 20020225
Label: HEGLh
Total Points: 8319
Latitude: N36.67
Longitude: W92.88
Heights (m AGL): 50 300 700
Start Hour (EST): 0 4 8 12 16 20
Run Length (hours): -96
Required Percentage: 75
Zone Layer: AirZones3

Figure B-30. Cool Season Split Flow example.



Date: 20030106
Label: HEGLh
Total Points: 8636
Latitude: N36.67
Longitude: W92.88
Heights (m AGL): 50 300 700
Start Hour (EST): 0 4 8 12 16 20
Run Length (hours): -96
Required Percentage: 75
Zone Layer: AirZones3

Figure B-31. Cool Season Northwesterly Transport example.



Date: 20021201
Label: HEGLh
Total Points: 3947
Latitude: N36.67
Longitude: W92.88
Heights (m AGL): 50 300 700
Start Hour (EST): 0 4 8 12 16 20
Run Length (hours): -96
Required Percentage: 75
Zone Layer: AirZones3

Figure B-32. Northwesterly Transport – Subgroup A example.

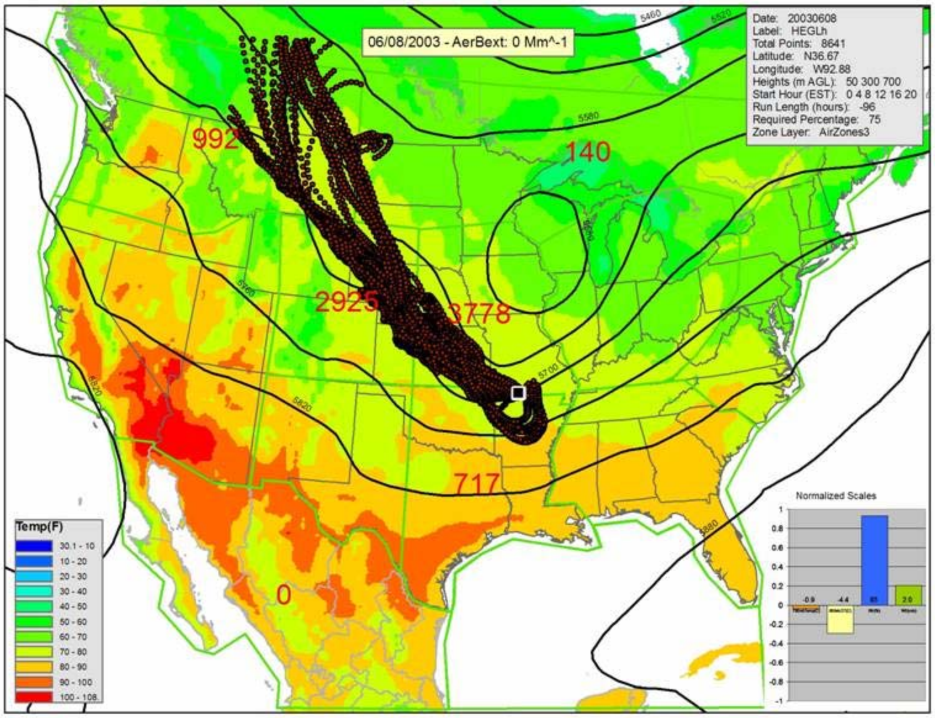


Figure B-33. Northwesterly Transport – Subgroup B example.

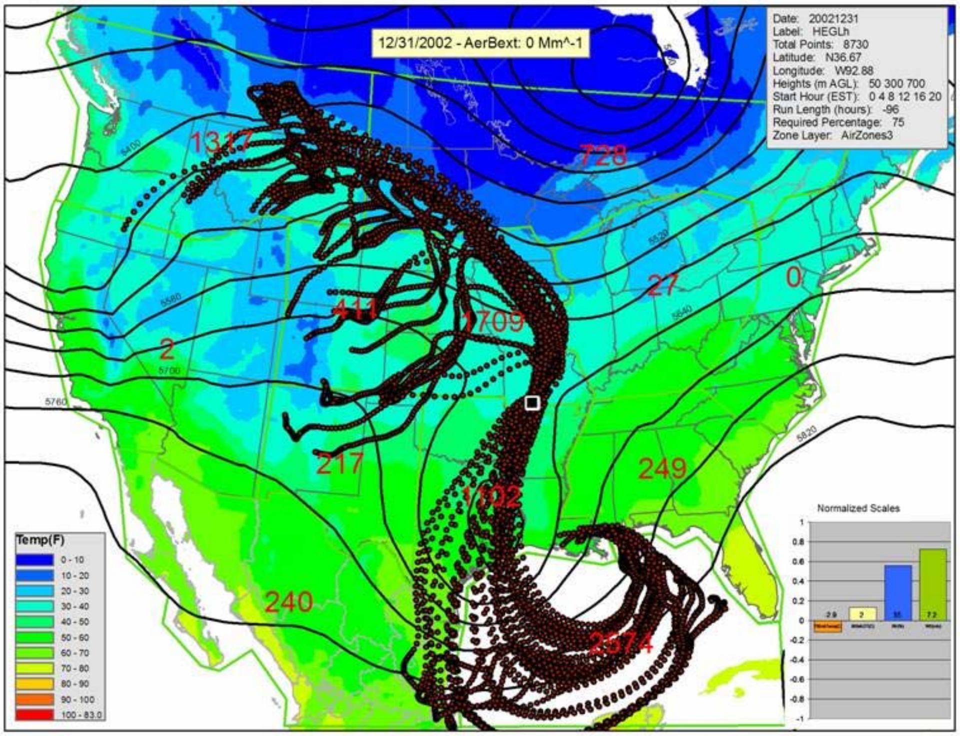


Figure B-34. Cool Season Split Flow – Subgroup A example.

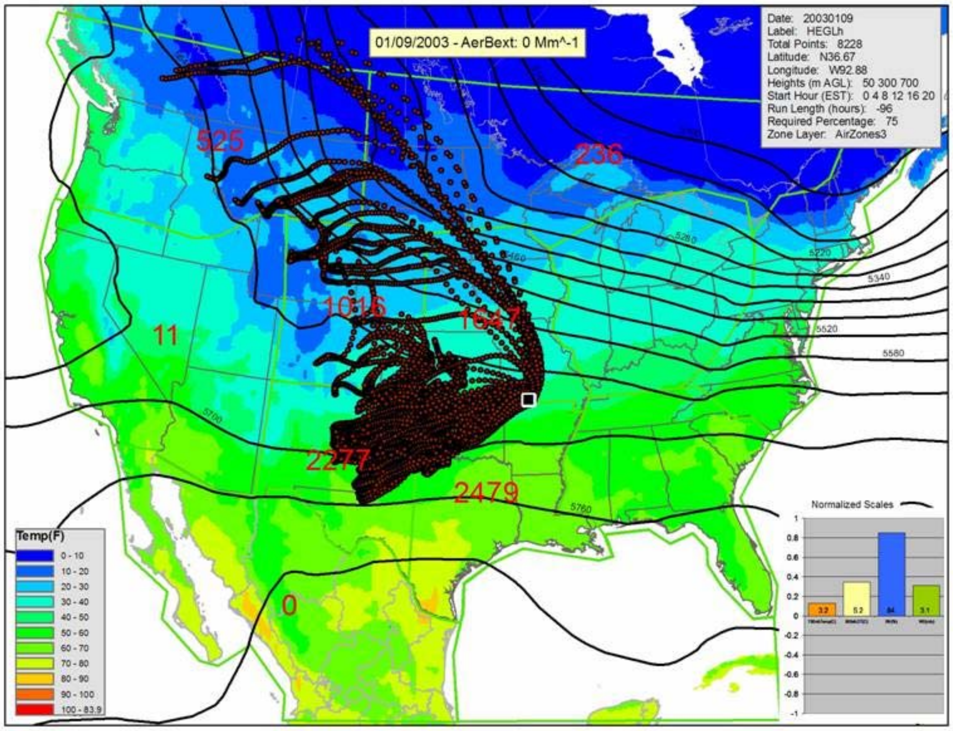


Figure B-35. Cool Season Split Flow – Subgroup B example.

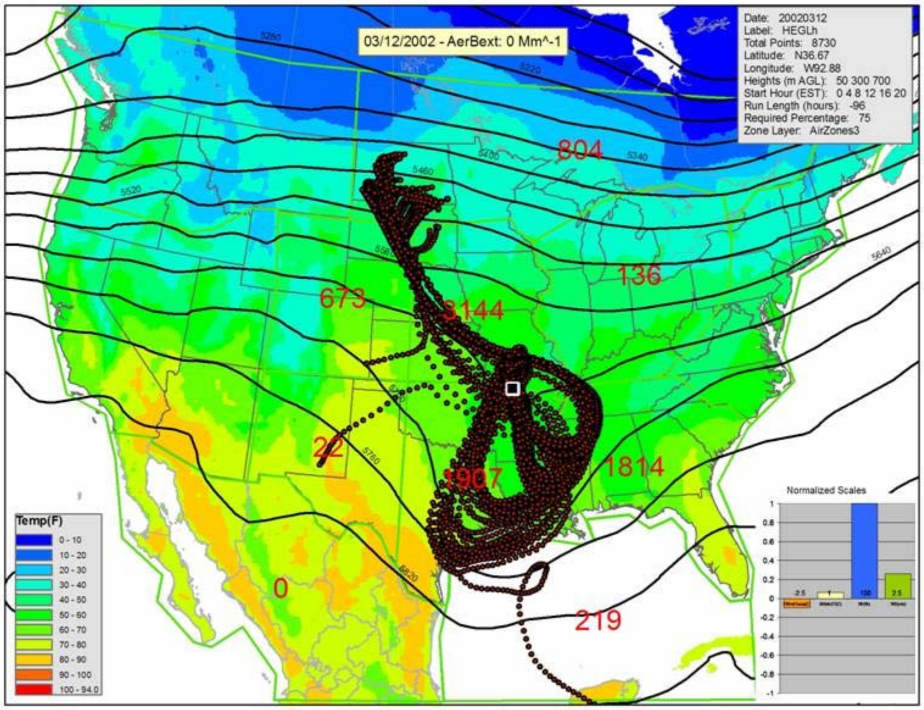


Figure B-36. Spring Season Recirculating Transport example.

B.5 SOUTHEASTERN PLAINS SUBREGION

For the Southeastern Plains subregion (represented by Sikes [SIKE1]), there were four weather/transport day types for the 20%-worst days and four for the 20%-best days. The meteorological and transport characteristics associated with the 20%-worst days are summarized in **Table B-7**; in general, these days were characterized by

- transport from the SE or NE,
- high humidity and light winds, and
- $PM_{2.5}$ consisting primarily of sulfate.

The meteorological and transport characteristics associated with the 20%-best days are summarized in **Table B-8**; in general, these days were characterized by

- transport from the NW and
- cool season temperatures.

The four weather/transport groups associated with the 20%-worst days at Sikes are described below and summarized in Table B-7:

1. Summertime Ridge. This worst visibility group of conditions is the most common and occurred on 29 of 57 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. Within this group are two subgroups. The meteorological pattern for both subgroups is characterized by an upper-level ridge over the central or eastern United States, very warm surface temperatures, light morning winds, and high relative humidity.

   Subgroup A conditions occurred on 16 of the 57 days and are characterized by long-range transport from the east-southeast; the SE and Gulf source areas (Figure B-2) experienced the most parcel residence time. A good example day of this group is August 16, 2003 (see **Figure B-37**).

   Subgroup B conditions occurred on 13 of the 57 days and are characterized by short- to medium-range transport circulating clockwise through the Gulf of Mexico and up to Sikes from the south. The Gulf and TxLa source areas (Figure B-2) experienced the most parcel residence time. A good example day of this group is July 21, 2001 (see **Figure B-38**).

2. Warm Season Northeasterly Transport. This group of conditions is the second most common and occurred on 13 of the 57 days studied. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by long-range transport from the northeast; the ORV and SE source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough or cutoff low over the eastern United States. A good example day of this group is August 10, 2003 (see **Figure B-39**).

3. Warm Season Stagnant. This group of conditions occurred on 9 of the 57 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by short-range transport from numerous directions;

the TxLa and SE source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level ridge over the west-central United States and/or an upper-level trough over the northeastern United States. This group has the highest average morning relative humidity (93%) and the lowest average morning wind speed (1.4 m/s) of all the worst visibility groups. A good example of this group day is June 20, 2003 (see **Figure B-40**).

4. Cool Season Split Flow. This group of conditions is the least common of the worst visibility groups, occurring on only 6 of the 57 days. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate and nitrate with some organic carbon. This group is characterized by transport from split directions, mainly the north-northwest and south; the TxLa source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the Northeast with northwest flow over the Sikes site. This group has the lowest average morning humidity (85%) and highest average morning wind speed (3.5 m/s) of all the worst visibility groups. A good example day of this group is January 9, 2003 (see **Figure B-41**).

The four weather/transport groups associated with the 20%-best days at Sikes are described below and summarized in Table B-8:

1. Wintertime Northwesterly Transport. This best visibility group of conditions is the most common and occurred on 26 of the 57 days studied. $PM_{2.5}$ on the majority of these days was composed of sulfate, organic carbon, and nitrate. This group is characterized by long-range transport from the north-northwest; the Cen and Nor source areas (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level trough over the Northeast and strong northwesterly flow over the Sikes site. This group has the lowest morning humidity of all the best visibility groups (74%). A good example day of this group is January 12, 2003 (see **Figure B-42**).
2. Gulf of Mexico Transport. This group of conditions occurred on 17 of the 57 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. Within this group are two subgroups. Both subgroups are characterized by transport circulating clockwise through the Gulf of Mexico and up to Sikes from the southeast direction. The Gulf and TxLa source areas (Figure B-2) experienced the most parcel residence time.

   Subgroup A conditions occurred on 9 of the 57 days during the late fall and early spring. The meteorological pattern is characterized by a strong upper-level trough over the central United States. A good example day of this group is December 19, 2002 (see **Figure B-43**).

   Subgroup B conditions occurred on 8 of the 57 days during the summer months. The meteorological pattern is characterized by a weak upper-level pattern. The morning average humidity is high (~96%). A good example day of this group is May 31, 2001 (see **Figure B-44**).
3. Wintertime Pre-Trough. This group of conditions occurred on 8 of the 57 days. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by transport from several directions, with recirculation over the Sikes site. The TxLa source area (Figure B-2) experienced the most parcel residence

time for this group. The meteorological pattern is characterized by southwesterly flow aloft over Sikes, with an approaching upper-level trough. A good example day of this group is January 14, 2002 (see **Figure B-45**).

4. Cool Season Cutoff Low. This group of conditions is the least common of the best visibility groups, occurring on only 6 of the 57 days analyzed. $PM_{2.5}$ on the majority of these days was composed mainly of sulfate with some organic carbon. This group is characterized by split long-range transport, from both the north-northwest and south; the TxLa source area (Figure B-2) experienced the most parcel residence time. The meteorological pattern is characterized by an upper-level cutoff low or strong trough over the Midwest. A good example day of this group is May 22, 2001 (see **Figure B-46**).

Table B-7. The four weather/transport day types for the 20%-worst visibility days for the Southern Plains subregion (represented by Sikes [SIKE1]).

		SIKE1 Worst	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1a	12/06/2001	S	long	E,SE	SE	Gulf	ridge over eastern US	Hot summer pattern. 80's - 90's	88.8	-5.8	1.9	7.1
	05/01/2001											
	08/02/2001											
	10/31/2001											
	06/22/2002											
	07/07/2002											
	08/09/2002											
	08/30/2002											
	09/05/2002											
	09/08/2002											
	08/16/2003											
	09/09/2003											
	09/21/2003											
	10/09/2003											
	11/11/2003											
	04/30/2003											
1b	05/16/2001	S,OC	short-medium	S. Trajectories curve clockwise through the Gulf of Mexico, then up from the South.	Gulf	TxLa	ridge over central US	Hot summer pattern. 80's - 90's	89.9	-4.7	2.5	8.6
	05/19/2001											
	07/12/2001											
	07/21/2001											
	04/29/2002											
	05/02/2002											
	07/22/2002											
	01/21/2003											
	05/03/2003											
	05/15/2003											
	08/14/2001											
	08/03/2002											
	08/07/2003											
2	07/15/2001	S,OC	long	N,NE	ORV	SE	trough or cutoff low over the eastern US	mild - cool season. Spring and fall pattern.	86.3	-1.4	1.5	5.7
	10/01/2001											
	05/24/2003											
	05/27/2003											
	11/08/2003											
	09/18/2003											
	11/18/2001											
	09/14/2002											
	03/10/2003											
	06/24/2001											
	11/12/2001											
	08/27/2002											
	08/10/2003											
3	08/13/2003	S,OC	short. local transport	muliple directions	TxLa	SE	ridge over west central US or trough over the Northeast	Warm season (70's)	93.4	-4.3	1.4	6.3
	08/25/2003											
	03/23/2001											
	10/04/2001											
	02/02/2003											
	05/30/2003											
	06/20/2003											
	08/19/2003											
	10/06/2003											
4	11/09/2001	S,N,OC	short-medium	Split N-NW and S	TxLa		NW flow alfot - trough over the Northeast	Cool season (40's-50's)	85.1	1.7	3.5	0.8
	01/09/2003											
	01/15/2003											
	01/27/2003											
	01/30/2003											
	12/08/2003											

Table B-8. The four weather/transport day types for the 20%-best visibility days for the Southern Plains subregion (represented by Sikes [SIKE1]).

		SIKE1 Best	Transport						Avg. Calcuations (12Z)			
Group	Dates	Chemistry	Distance	Directiron	Main Source Region	Secondary Source Region	Upper-Air Pattern	Max Temperature	Relative Humidity (%)	850mb Temp - Surface Temp (deg. C)	Wind Speed (m/s)	700mb Temperature (deg. C)
1	01/12/2003	mixed: S,OC,N	long	N,NW	Cen	Nor	NW flow aloft and/or trough in the eastern US	Cool season, temps in the 50's	74.4	3	2.1	-0.3
	01/24/2003											
	02/08/2003											
	11/21/2001											
	01/18/2003											
	11/14/2003											
	11/29/2003											
	10/07/2001											
	12/30/2001											
	01/26/2002											
	12/25/2002											
	01/03/2003											
	09/30/2003											
	10/15/2003											
	10/27/2003											
	12/26/2003											
	12/11/2003											
	02/05/2003											
	04/26/2002											
	11/20/2003											
	12/20/2003											
	10/16/2001											
	11/30/2001											
	12/21/2001											
	12/27/2001											
	12/17/2003											
2a	10/13/2001	S,OC	long	clockwise circulation from the SE through the Gulf of Mexico	Gulf		strong trough inf the central US	Cool season, temps in the 50's	89.7	-4.1	4.7	2
	11/27/2001											
	03/09/2002											
	03/12/2002											
	04/08/2002											
	12/19/2002											
	12/31/2002											
	11/23/2003											
	12/29/2003											
2b	05/31/2001	S,OC	long	clockwise circulation from the SE through the Gulf of Mexico	Gulf	TxLa	weak upper-level dynamics. Zonal flow or stagnant aloft.	Warm season (70's)	95.9	-5.6	3	7
	06/06/2001											
	08/15/2002											
	06/14/2003											
	07/11/2003											
	06/09/2001											
	06/30/2001											
	09/03/2003											
3	03/19/2003	S,OC	long	multiple directions. Recirculation over SIKE	TxLa		Zonal flow OR trough over the east-central US	Cool season, temps in the 50's	79.2	1.1	3.2	-1.7
	01/14/2002											
	12/24/2001											
	02/10/2002											
	12/22/2002											
	02/11/2003											
	02/20/2003											
	12/02/2003											
4	04/25/2001	S,OC	long	Split: N,NW and S	TxLa		Cufoff low OR trough over the Upper-Midwest.	Mild, Spring/Fall pattern	88.4	-1.6	0.9	3.6
	05/22/2001											
	05/25/2001											
	10/25/2001											
	04/21/2003											
	05/12/2003											

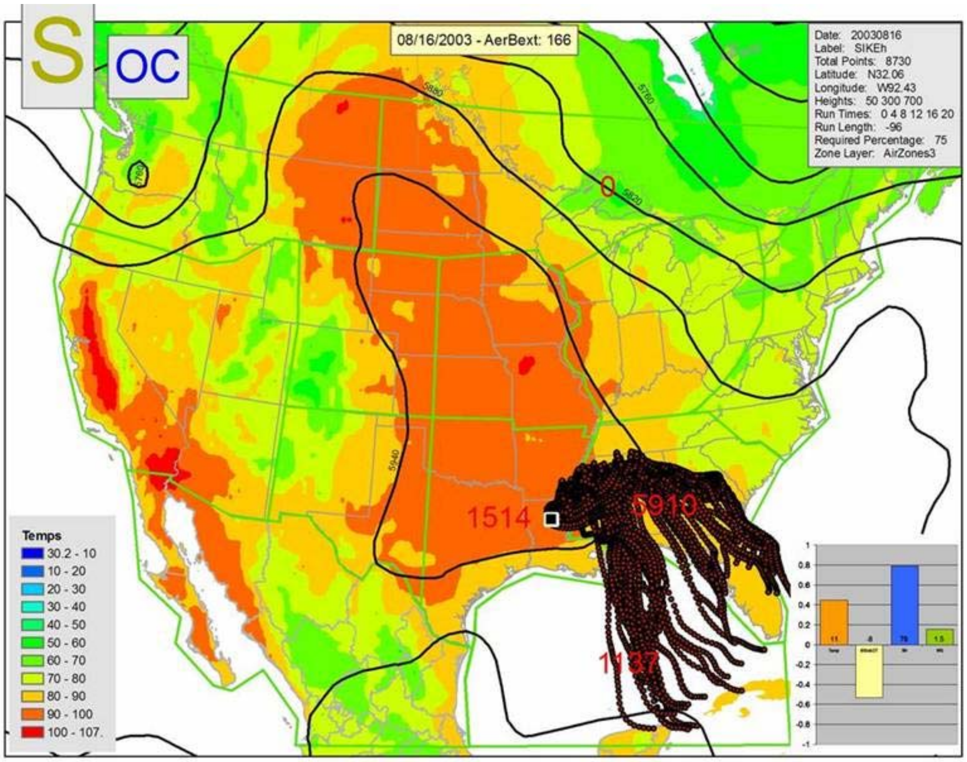


Figure B-37. Summertime Ridge – Subgroup A example.

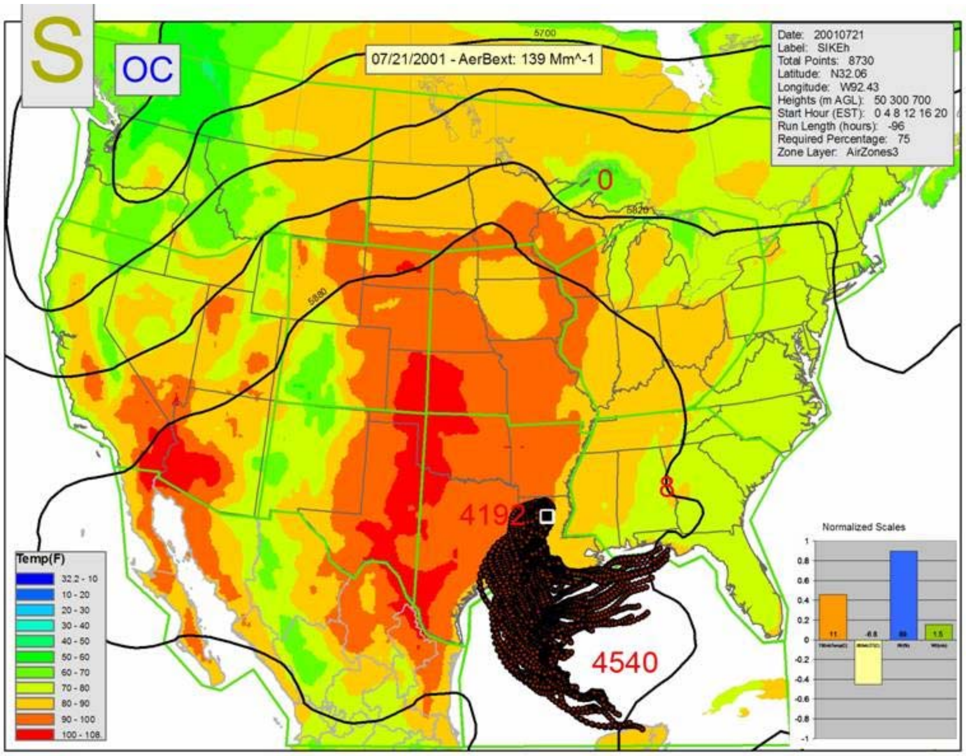


Figure B-38. Summertime Ridge – Subgroup B example.

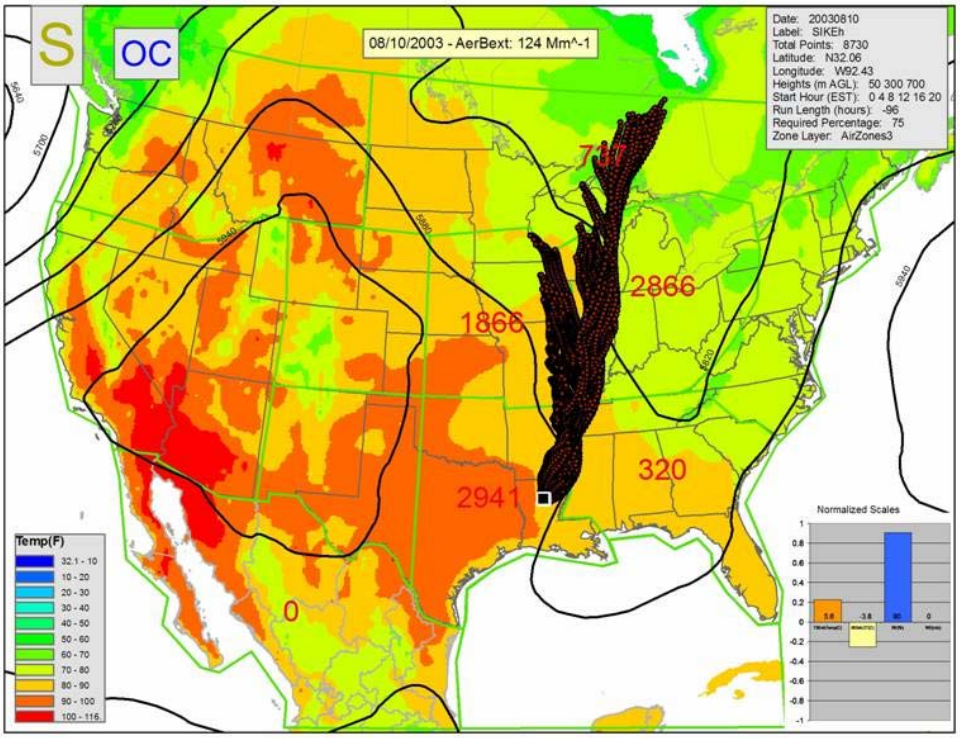


Figure B-39. Warm Season Northeasterly Transport example.

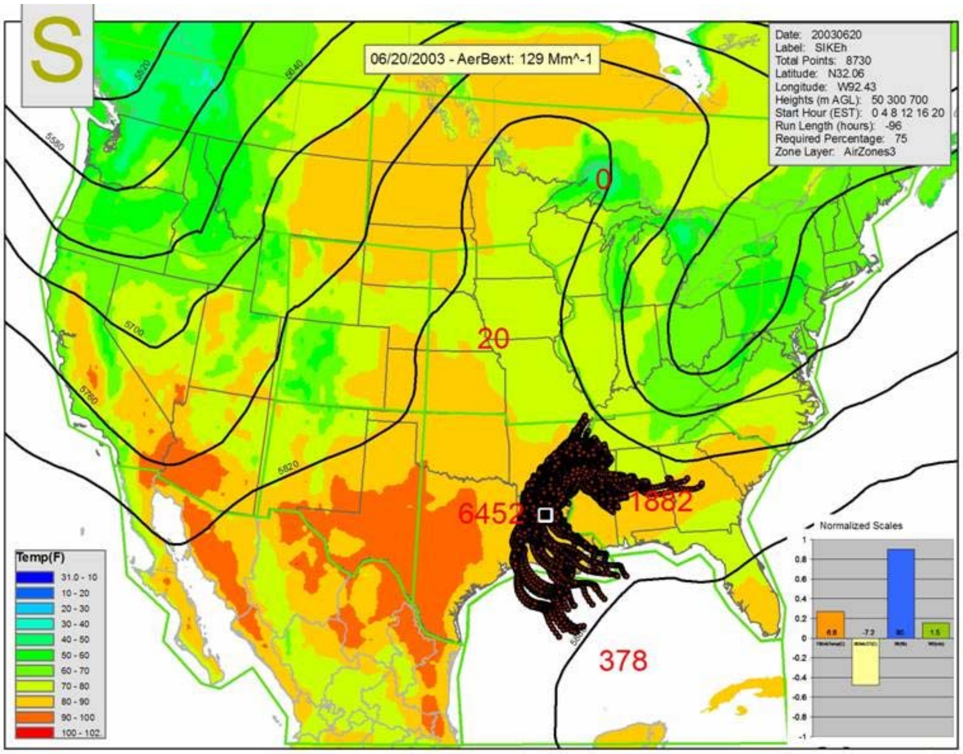


Figure B-40. Warm Season Stagnant example.

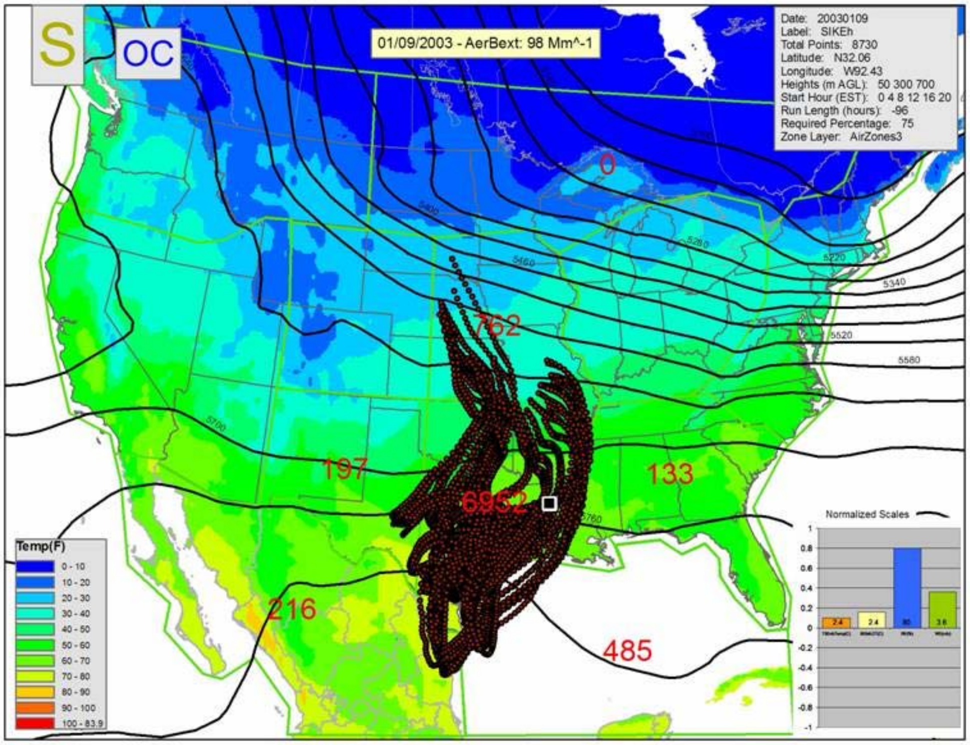


Figure B-41. Cool Season Split Flow example.

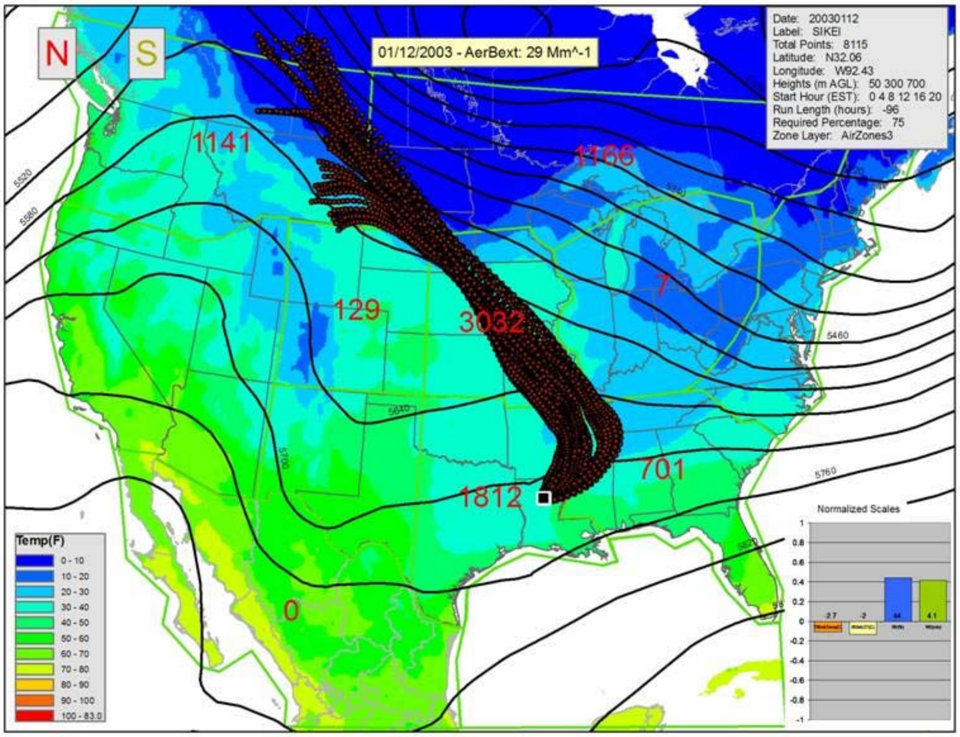


Figure B-42. Wintertime Northwesterly Transport example.

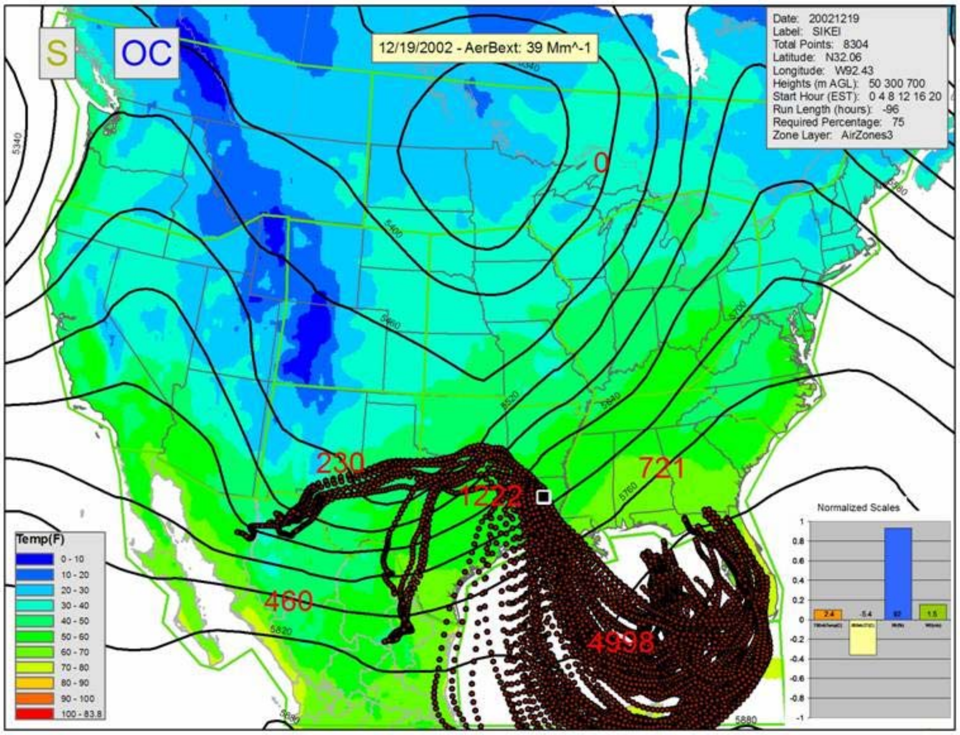


Figure B-43. Gulf of Mexico Transport – Subgroup A example.

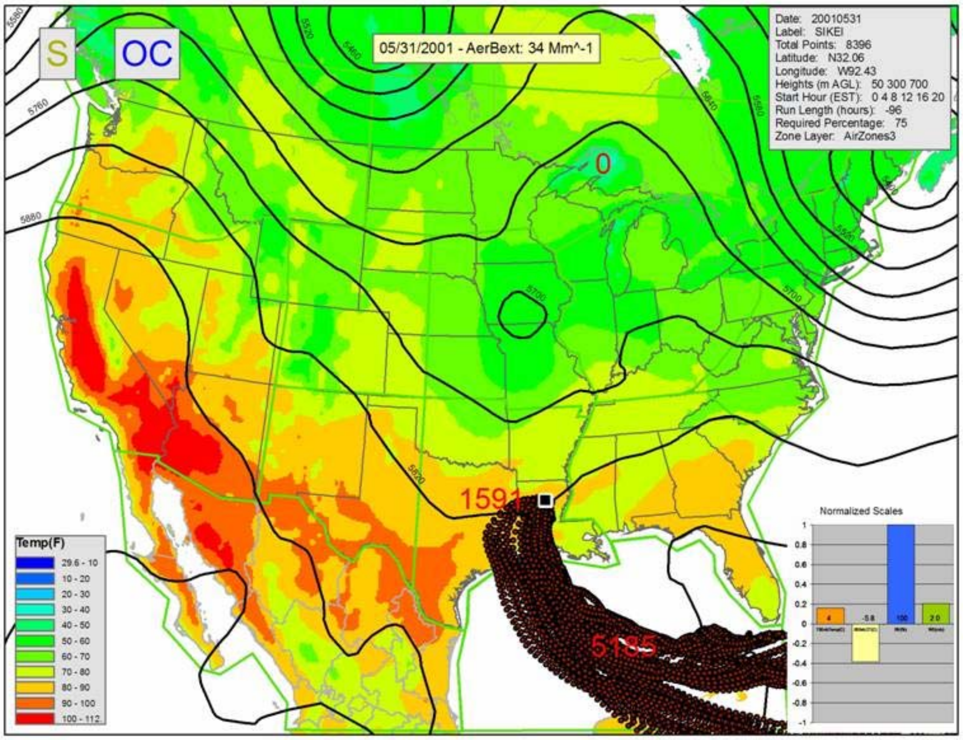


Figure B-44. Gulf of Mexico Transport – Subgroup B example.

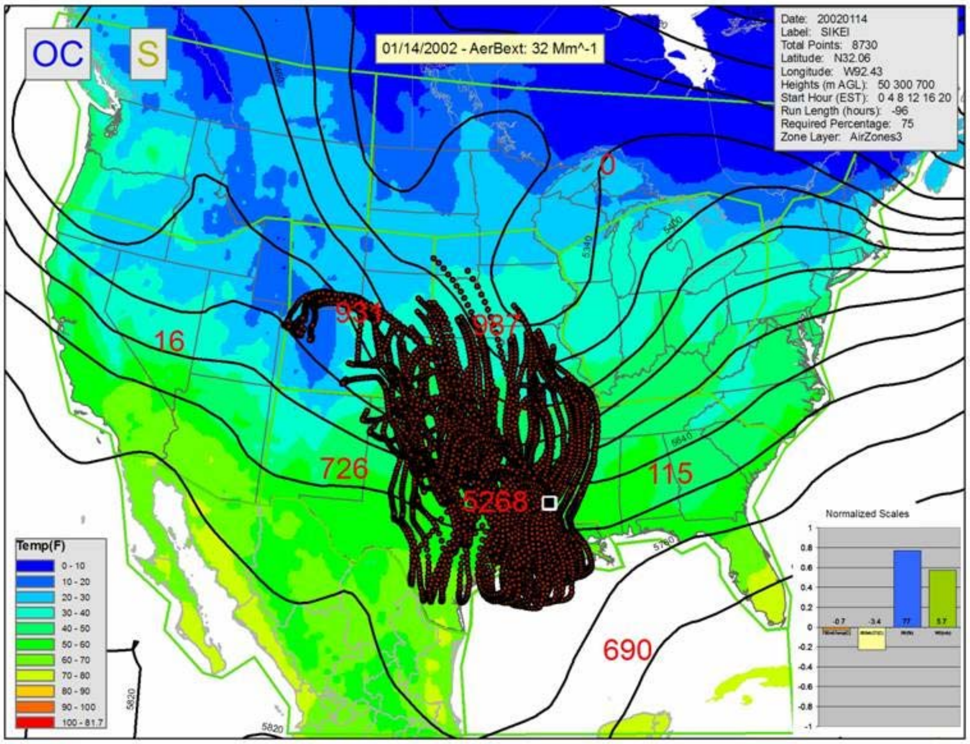


Figure B-45. Wintertime Pre-Trough example.

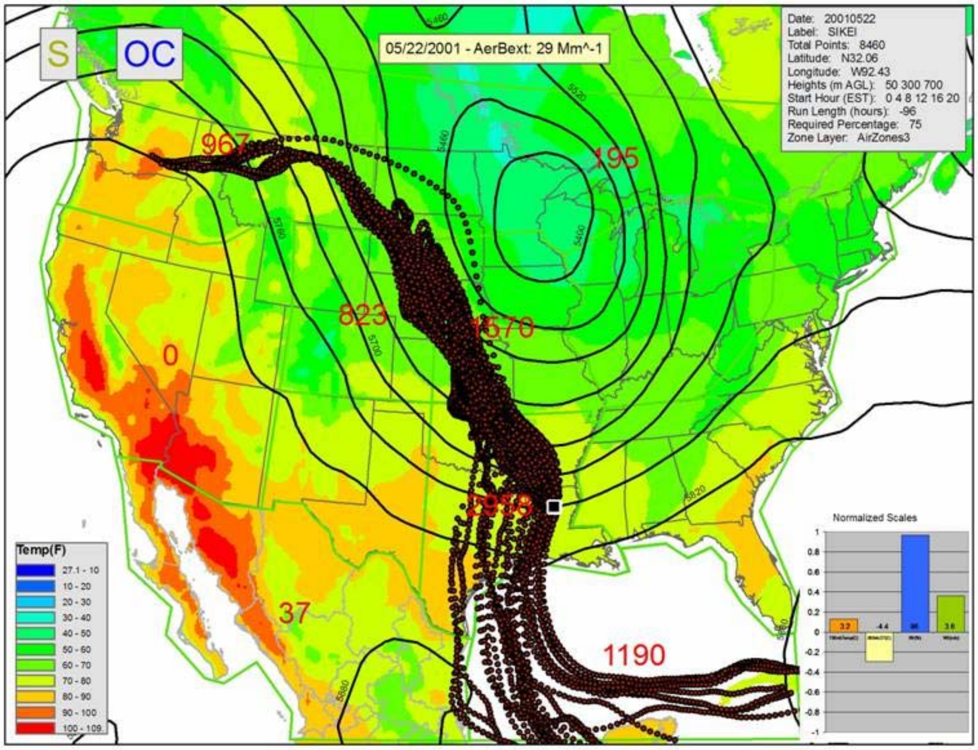


Figure B-46. Cool Season Cutoff Low example.

APPENDIX C

DOCUMENTATION OF METHODS, INFORMATION, RESOURCES, AND GRAPHICAL AND TABULAR SUMMARIES OF DATA FOR (TASK 6)

EMISSIONS ANALYSES

C.1 COMPILATION AND ASSESSMENT OF EMISSION INVENTORIES

The best available emission inventories were compiled from the following sources:

- 2002 inventories prepared by each of the five Regional Planning Organizations (RPOs) were obtained (Central Regional Air Planning Association, 2005; Mid-Atlantic/Northeast Visibility Union, 2002; The Visibility Improvement State and Tribal Association of the Southeast, 2004a, b, c; Western Regional Air Partnership, 2003a, b, c, d, e, f, g).
- The draft 2002 National Emission Inventory (NEI) was consulted for unavailable components of the RPO inventories, including inventories for on-road mobile sources in the WRAP, VISTAS, and MRPO states; and inventories of fugitive dust emissions for the WRAP states (U.S. Environmental Protection Agency, 2005b).
- The preliminary 2002 NEI was consulted for biogenic emissions in the United States (U.S. Environmental Protection Agency, 2005a).
- Environment Canada's 2002 NPRI database was accessed for emissions from Canadian point sources. Emissions were spatially allocated according to facility postal codes (Environment Canada, 2002).
- Environment Canada provided 2002 emission inventories of area, non-road mobile, and on-road mobile sources to EPA. These inventories were acquired from EPA. Province-level data were allocated to postal codes according to population density (Environment Canada, 1995).
- The 2002 Gulfwide emission inventory was consulted for emissions in the Gulf of Mexico (Wilson et al., 2004).
- The emission inventory prepared by (Kuhns et al., 1999) was acquired for emissions in Mexico (Kuhns et al., 2005).

The following information gaps and potential flaws were noted on review of the compiled emission inventories. Because of these potential problems and because the results of other tasks showed that sulfate and nitrate are the primary contributors to visibility impairment in the CENRAP region, Task 6 analyses focused exclusively on SO_2 and NO_x emissions.

- Biogenic emissions contribute substantially to VOC emissions, and we anticipate that the biogenic emissions densities in Mexico and Canada are comparable to those in the United States. However, biogenic emission inventories were unavailable for Canada and Mexico; therefore, assessments of the emission impact potentials of VOC emissions on receptors were seriously limited.
- PM_{10}, $PM_{2.5}$, and NH_3 emissions are inconsistent at state lines and/or RPO boundaries. The differences appear to be partly due to differences in emission estimation methodologies. In addition, the proportion of $PM_{2.5}$ attributed to on-road mobile sources seems too low in many areas. Rural sources of NH_3—which are likely the predominant sources of NH_3—have been omitted from the emission inventories of the WRAP states. These issues greatly limited assessments of the emission impact potentials of PM_{10}, $PM_{2.5}$, and NH_3.

The emission inventories are illustrated in **Figures C-1 through C-7**.

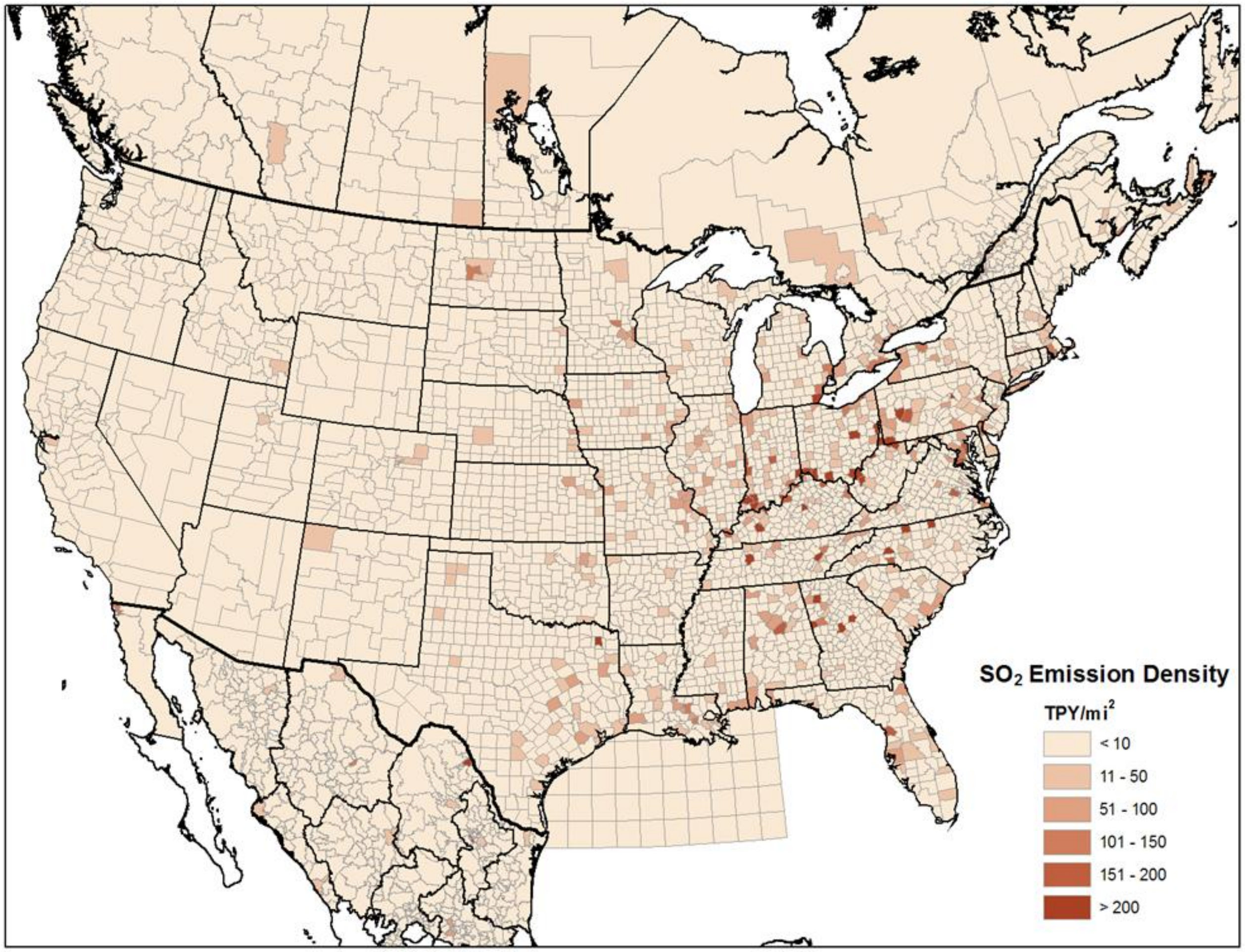


Figure C-1. SO_2 emissions density map for the United States, Canada, and Mexico.

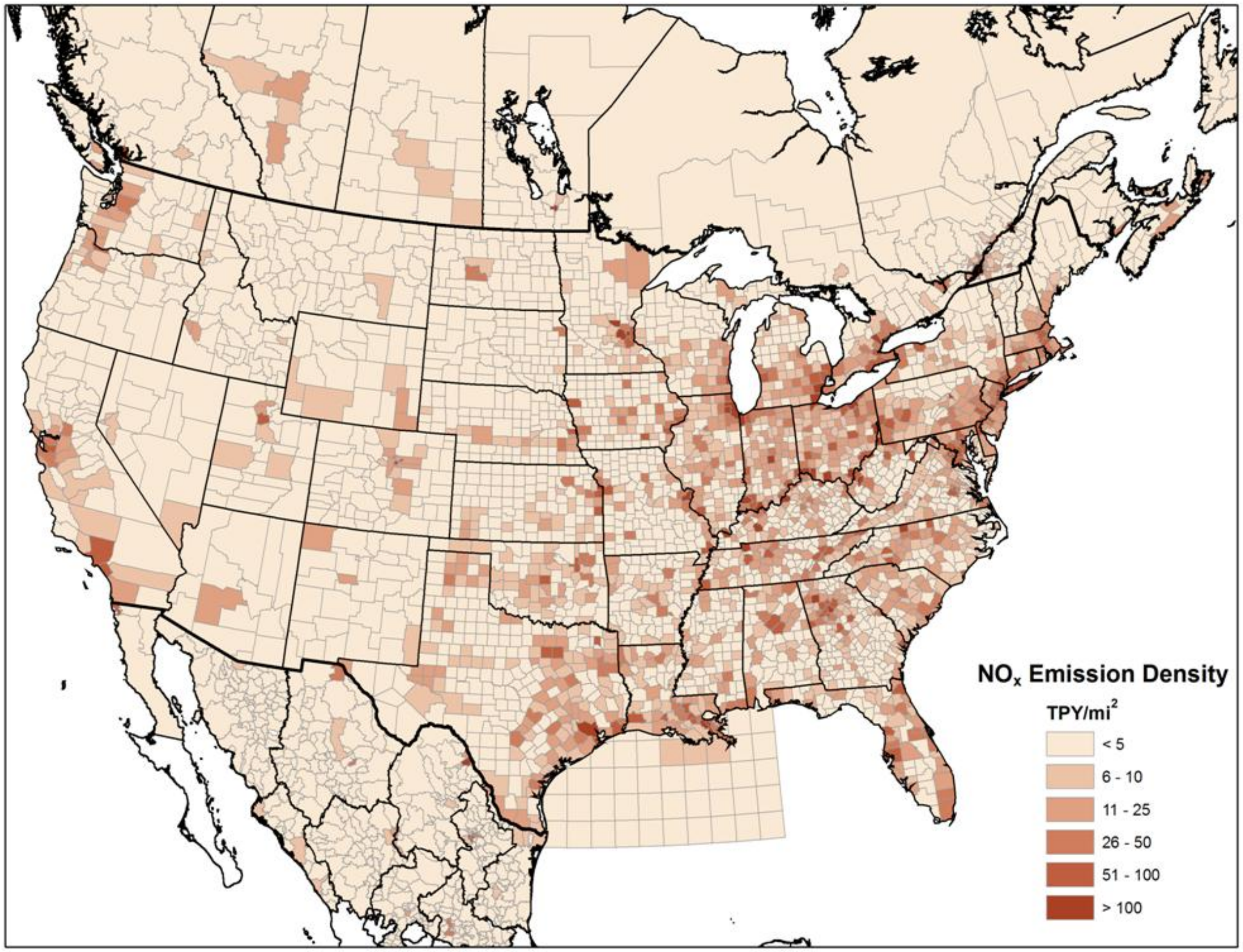


Figure C-2. NO$_x$ emissions density map for the United States, Canada, and Mexico.

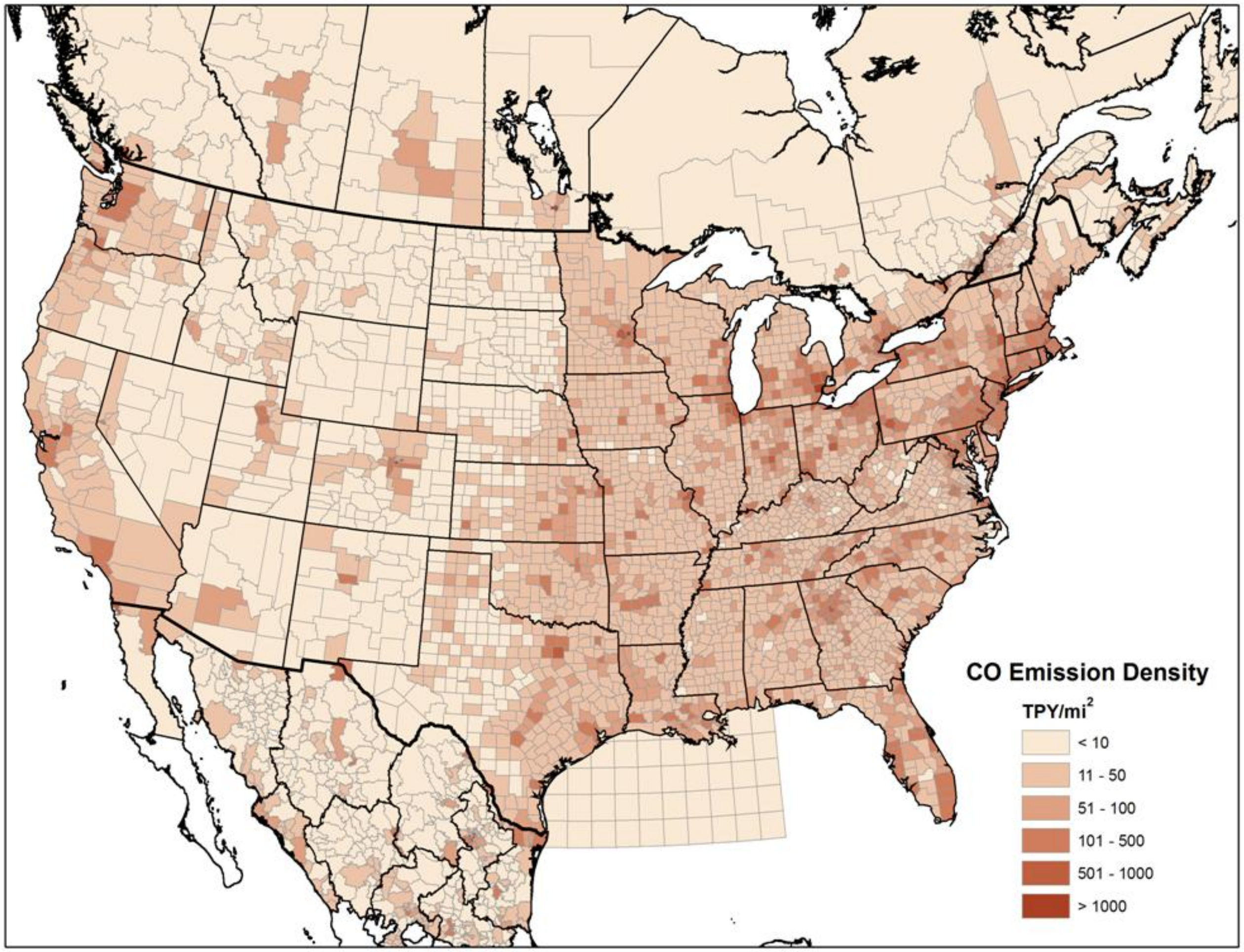
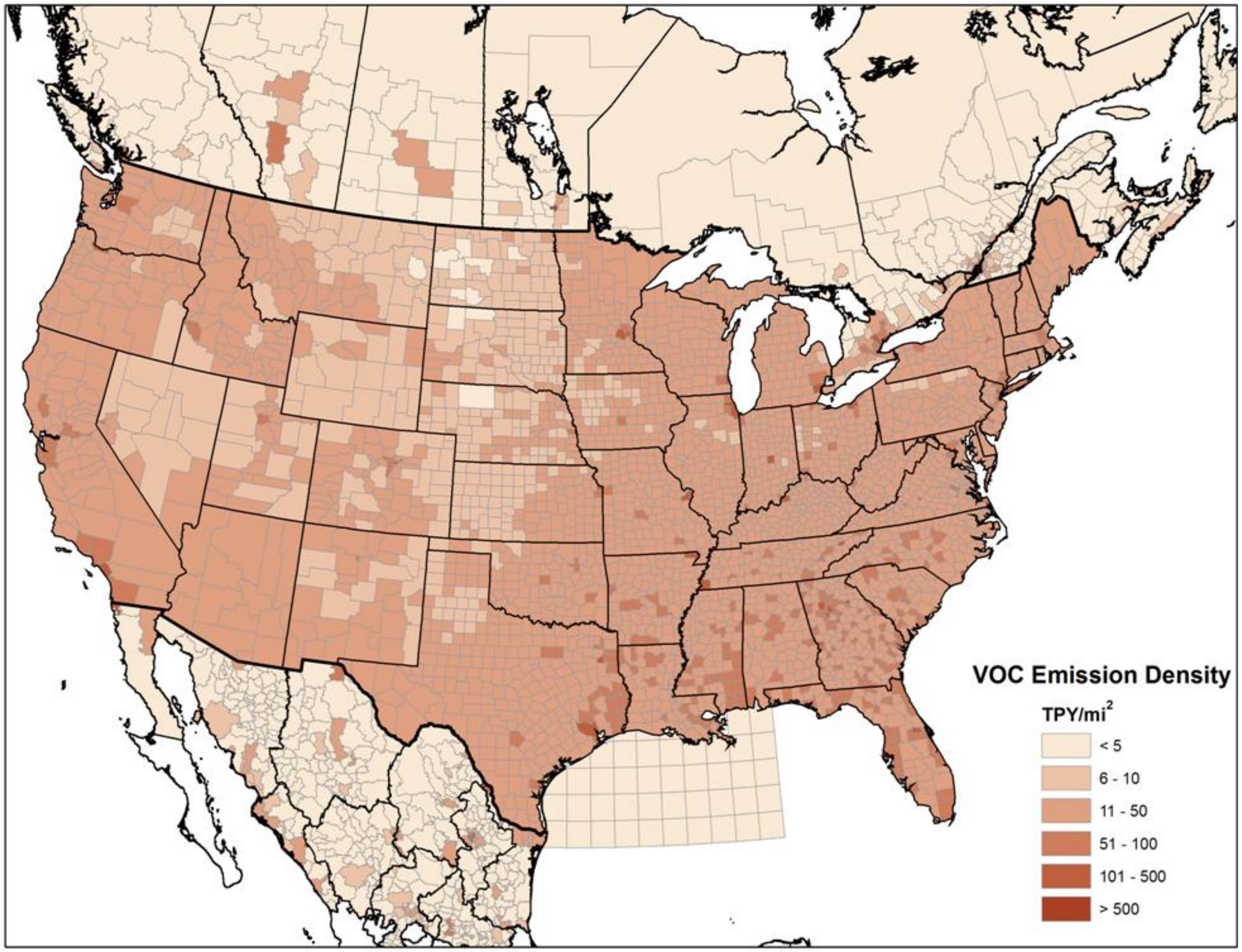
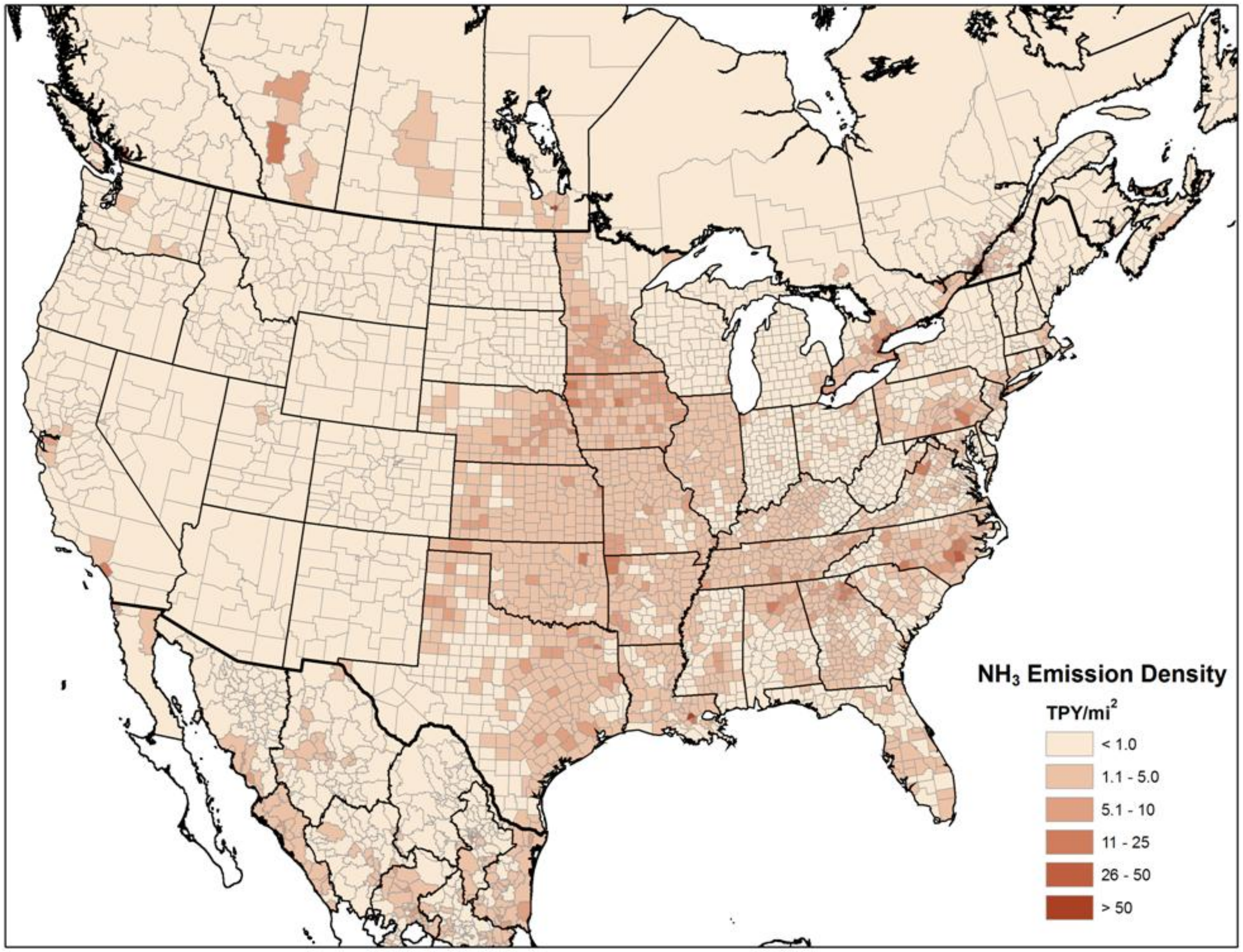


Figure C-3. Carbon monoxide (CO) emissions density map for the United States, Canada, and Mexico.



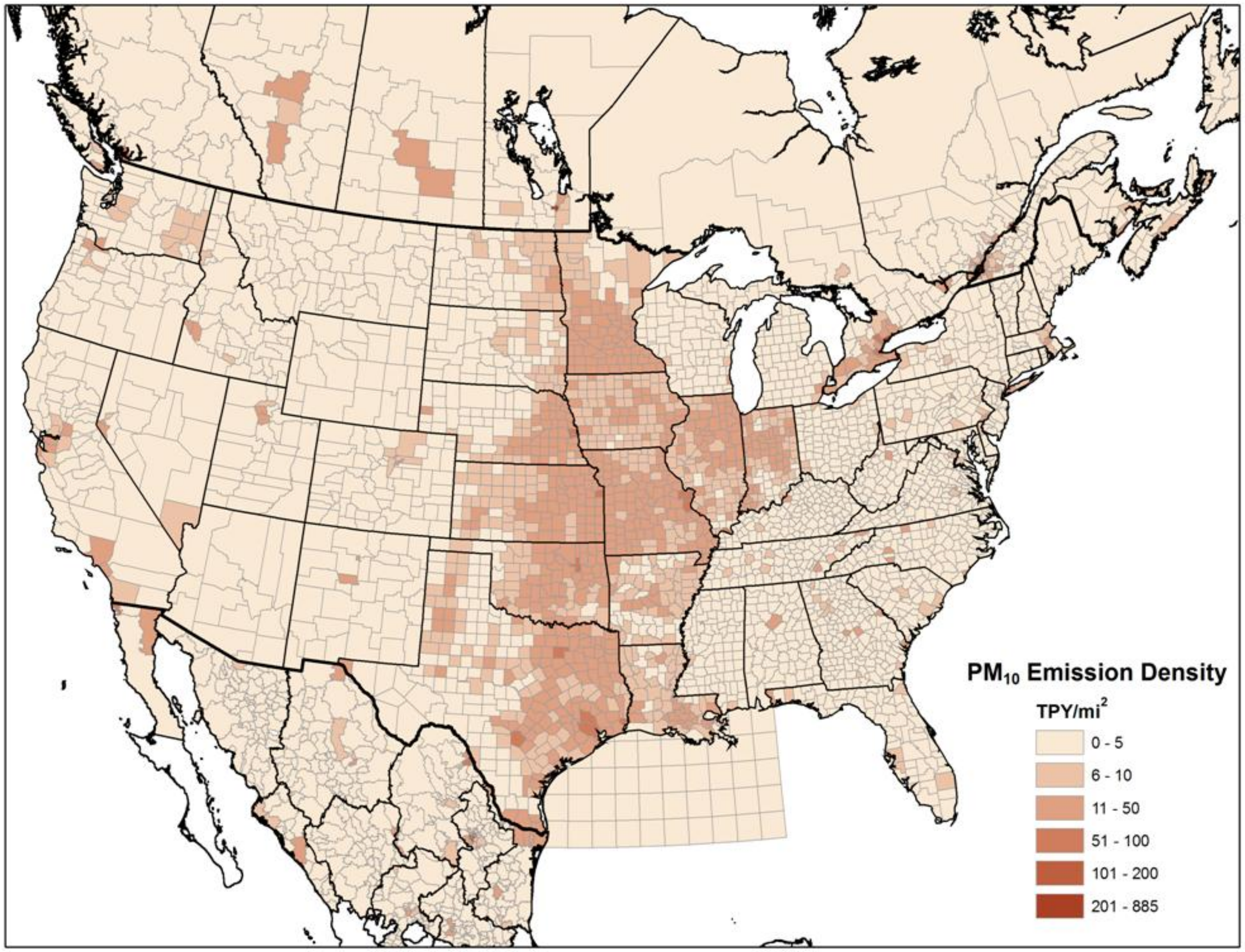
Biogenic emissions are missing for Canada and Mexico, which accounts for large discontinuities across international borders.

Figure C-4. Volatile organic compound (VOC) emissions density map for the United States, Canada, and Mexico.



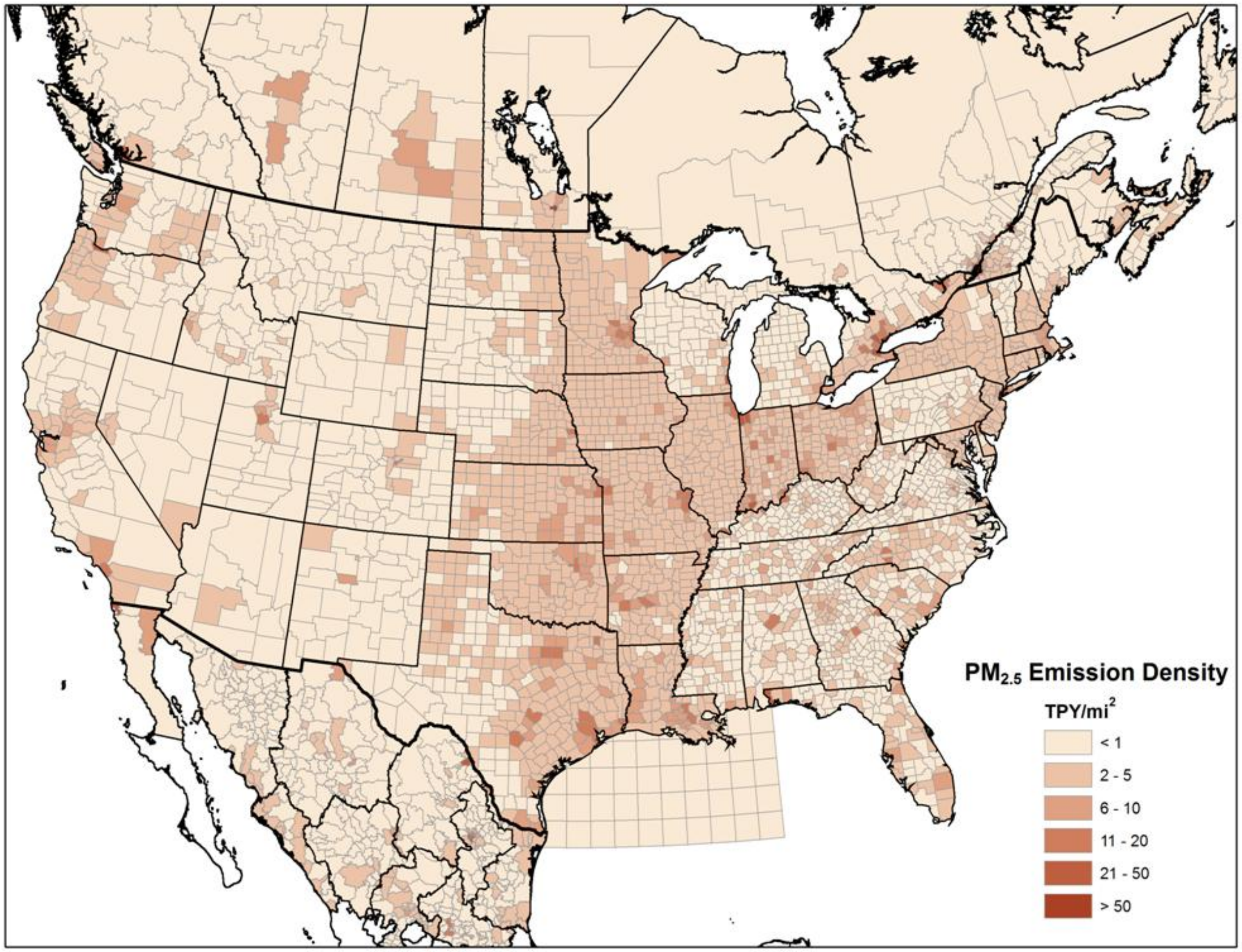
Discontinuities at state boundaries are likely due to differences in emissions estimation methodologies. Rural sources of ammonia are missing from WRAP states.

Figure C-5. Ammonia (NH_3) emissions density map for the United States, Canada, and Mexico.



Discontinuities at state boundaries are likely due to differences in emissions estimation methodologies.

Figure C-6. Coarse particulate matter (PM_{10}) emissions density map for the United States, Canada, and Mexico.



Discontinuities at state boundaries are likely due to differences in emissions estimation methodologies.

Figure C-7. Fine particulate matter (PM$_{2.5}$) emissions density map for the United States, Canada, and Mexico.

C.2 PREPARATION OF BACKWARD WIND TRAJECTORIES

The National Oceanic and Atmospheric Administration (NOAA) HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess, 1997) was used to determine transport patterns to the receptor site. An ensemble of backward trajectory model runs was performed to represent the various possible wind patterns on each day of interest. Days with the 20%-worst and the 20%-best visibility are of most interest. Data from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network for every third day from March 2001 through 2003 were used to determine the dates of best and worst visibility. The parameters used to run the trajectories are shown in **Table C-1**. The trajectories were limited to 72 hours. Six start times were used to cover variations in meteorology during the 24-hr sampling period. Trajectories were initiated at three heights; results for all three heights were combined.

Table C-1. Parameters used to run the NOAA HYSPLIT model.

Parameter Value	
Starting heights	50, 300, 700 m
Run time	72 hours
Minimum valid data points	75%
Starting hours	0, 4, 8, 12, 16, 20
Top of model	10,000 m
Model data	EDAS
Vertical motion	Isobaric (follows height of constant pressure)

The hourly points from all trajectories over all days of interest are combined using the Spatial Probability Density (D0), which is a kernel density of all hourly trajectory points, normalized to a maximum value of one:

$$D_0 = \frac{D_c}{\hat{D}} \quad \textbf{(C-1)}$$

where

D_c = Density at grid cell c

$\hat{D}$ = Maximum density over all grid cells (density at receptor site)

$$D_c = \sum_{i=1}^{n} \kappa_R(r_n) \qquad \textbf{(C-2)}$$

where:

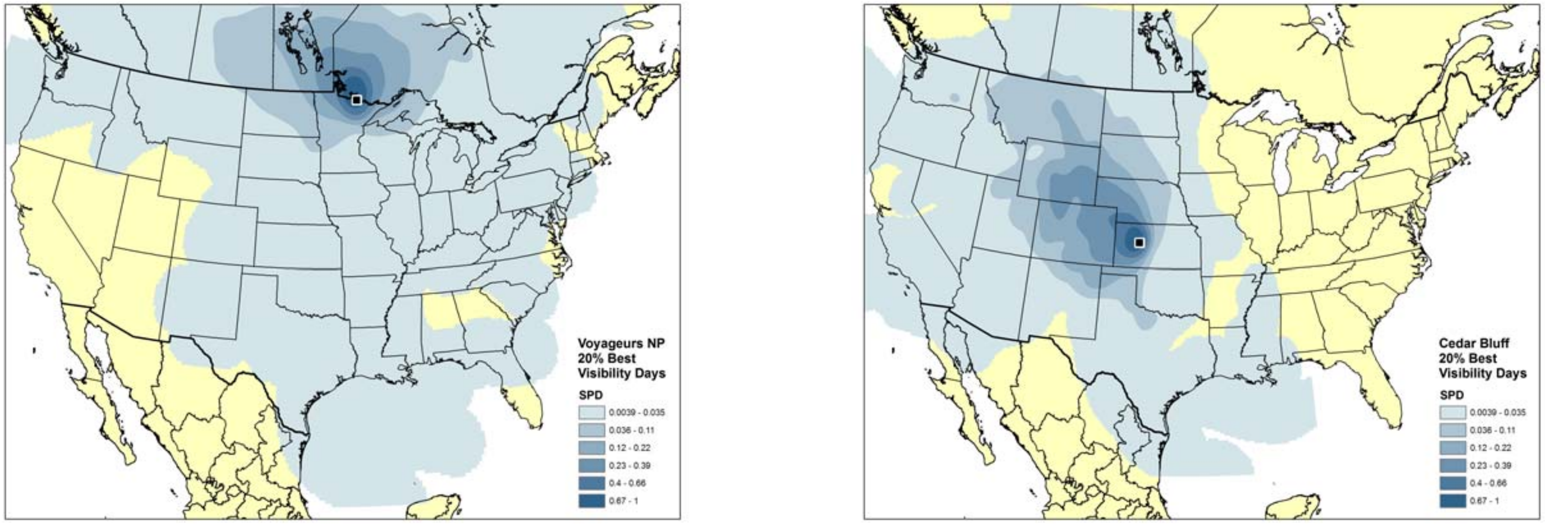
r_n = distance between grid cell center and hourly trajectory point n

$K_R(r)$ = kernel density function = $\begin{cases} \dfrac{3}{\pi R^2}\left[1-\left(\dfrac{r}{R}\right)^2\right]^2 & \text{for } r < R \\ 0 & \text{for } r \geq R \end{cases}$

R = search radius

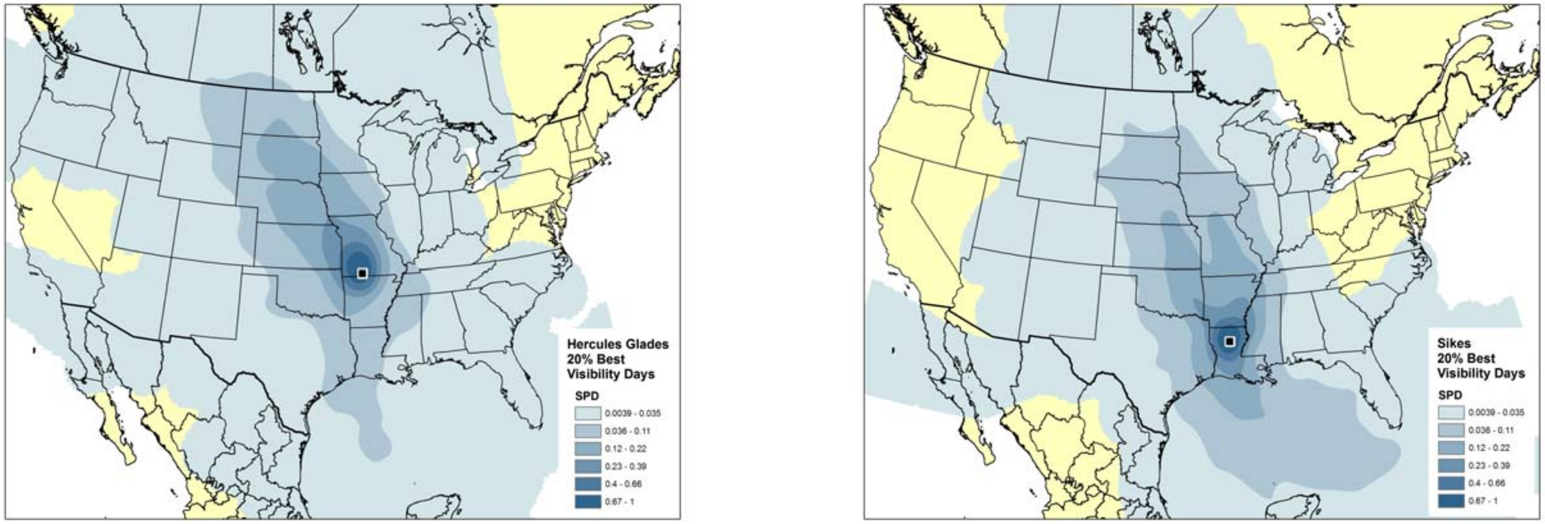
The search radius, R, was determined dynamically by dividing the geographic extent of all hourly trajectory points by 30 (McCoy and Johnston, 2001; Cressie, 1993).

Figure C-8 shows the spatial probability density map for the 20%-best days at the four representative CENRAP sites. **Figure C-9** shows analogous information for the 20%-worst days. A value of one indicates that all trajectories passed near the grid cell, while a value closer to zero denotes an area over which very few trajectories passed.



(a) Voyageurs, Minnesota (Minnesota subregion)*

(b) Cedar Bluff, Kansas (Western Plains subregion)

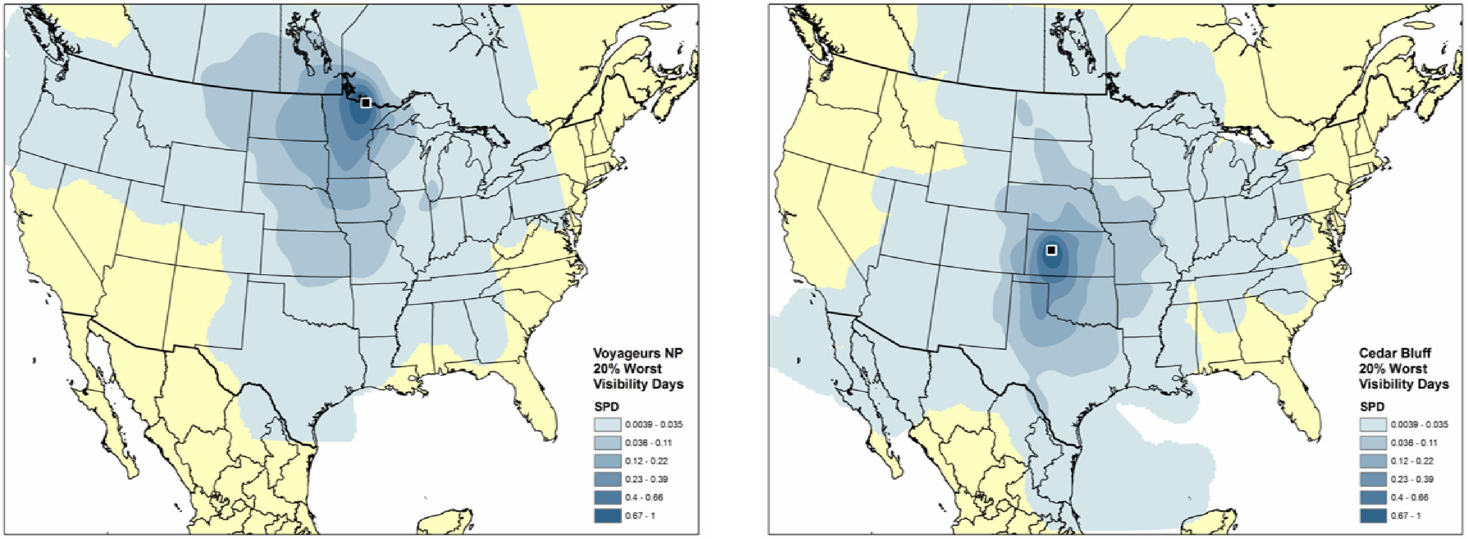


Hercules-Glades, Missouri (Upper Midwest subregion)

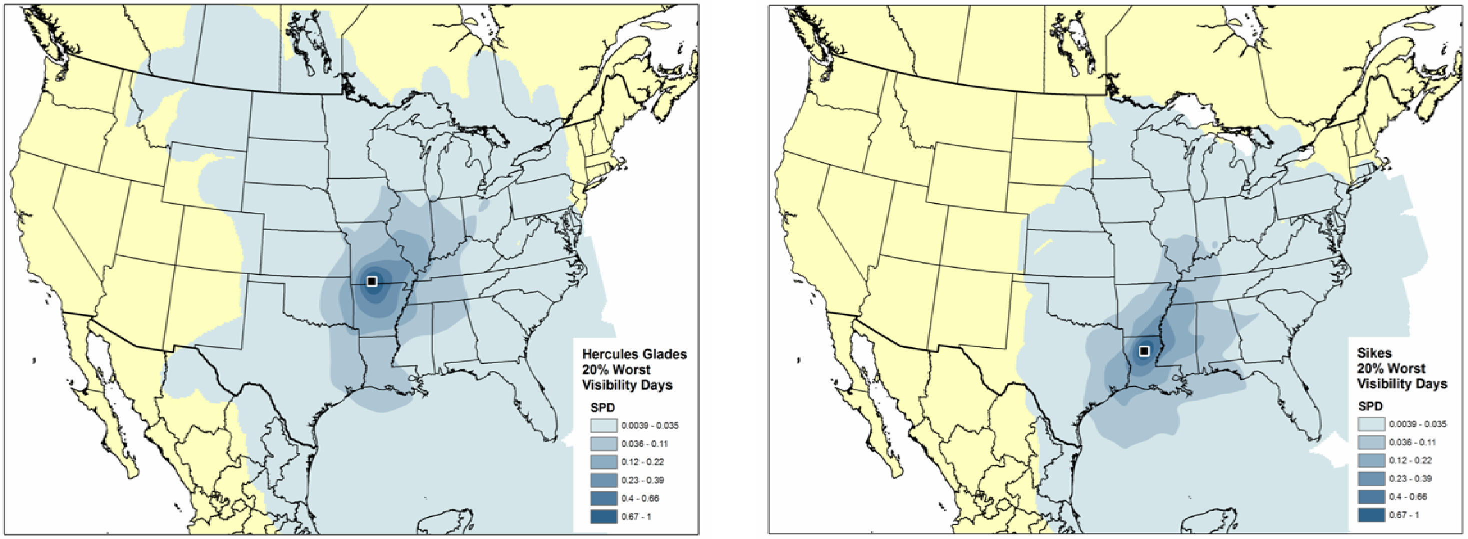
(d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out.

Figure C-8. Geographic distributions of 72-hour backward wind trajectories for the 20%-best visibility days observed at four representative sites.



(a) Voyageurs Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

Figure C-9. Geographic distributions of 72-hour backward wind trajectories for the 20%-worst visibility days observed at four representative sites.

C.3 CALCULATION OF EMISSION IMPACT POTENTIAL (EIP)

The Spatial Probability Density is used to weight the emissions from individual counties and estimate the potential for specific upwind areas to impact the receptor. The EIP of any county is calculated as:

$$EIP = \frac{E_p * D_0}{f(\text{distance})} \tag{C-3}$$

where

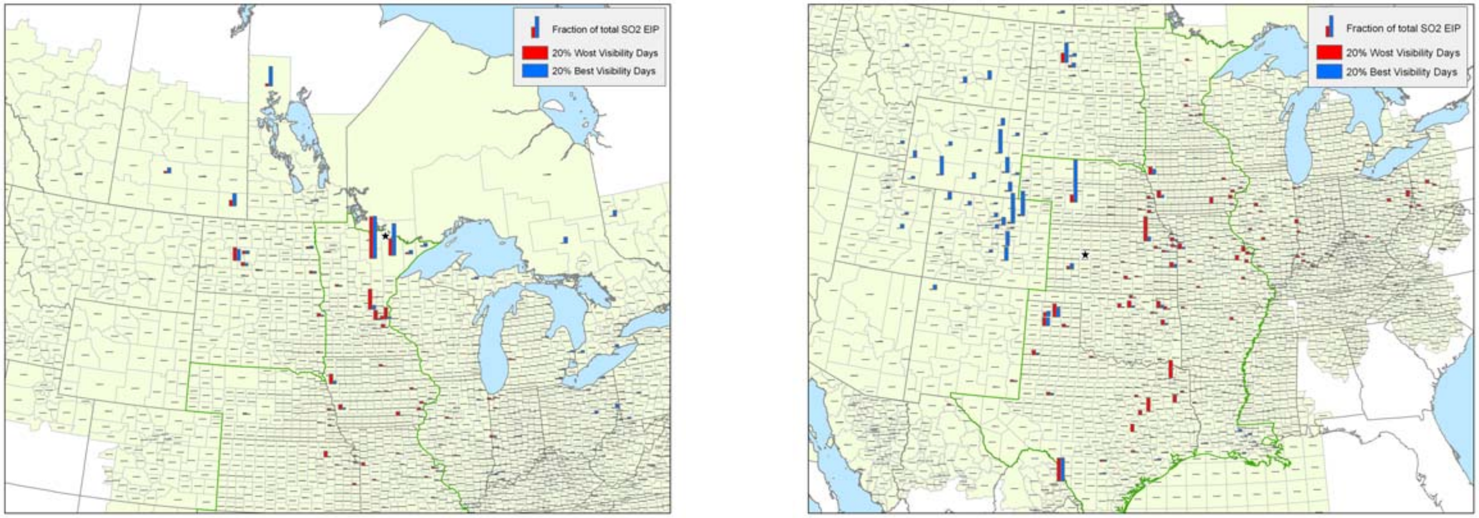
E_p = county total emissions of pollutant p

D_0 = spatial probability density at the county centroid

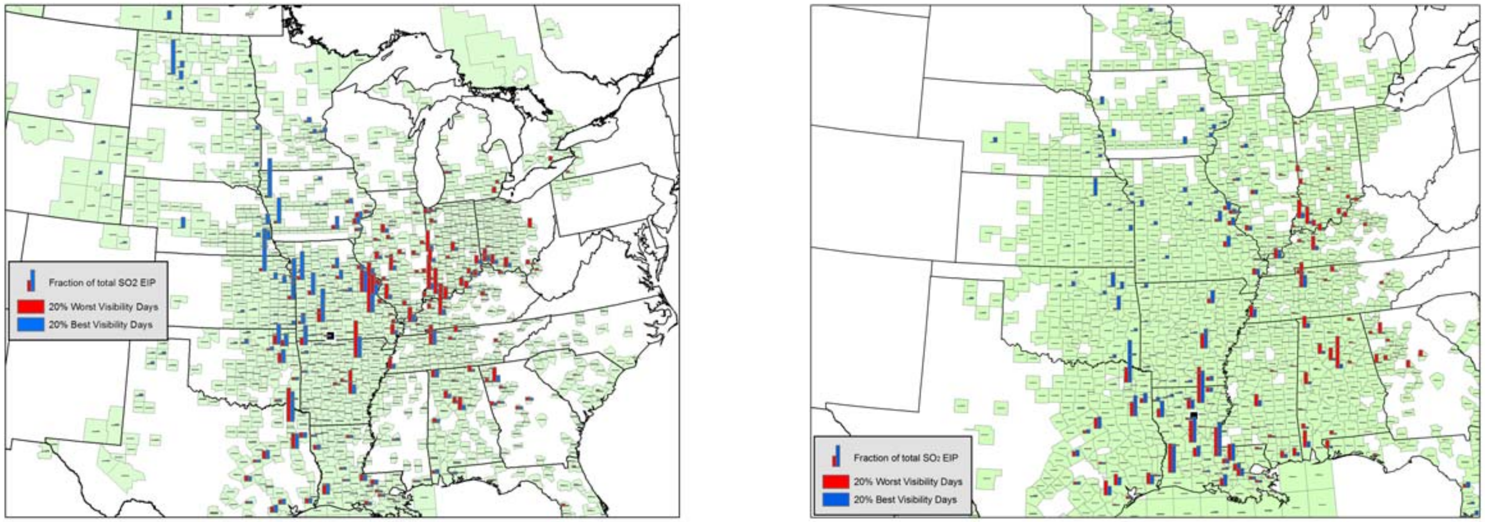
f = function of distance between county and receptor

The EIP may be divided by a distance function to roughly account for dilution and increased uncertainty in model outputs far from the receptor site. However, for this study, $f = 1$. A geographic information system (GIS) tool was developed to calculate EIP values.

Figures C-10 and C-11 show the SO_x and NO_x EIP values by county for the 20%-worst and 20%-best visibility days.



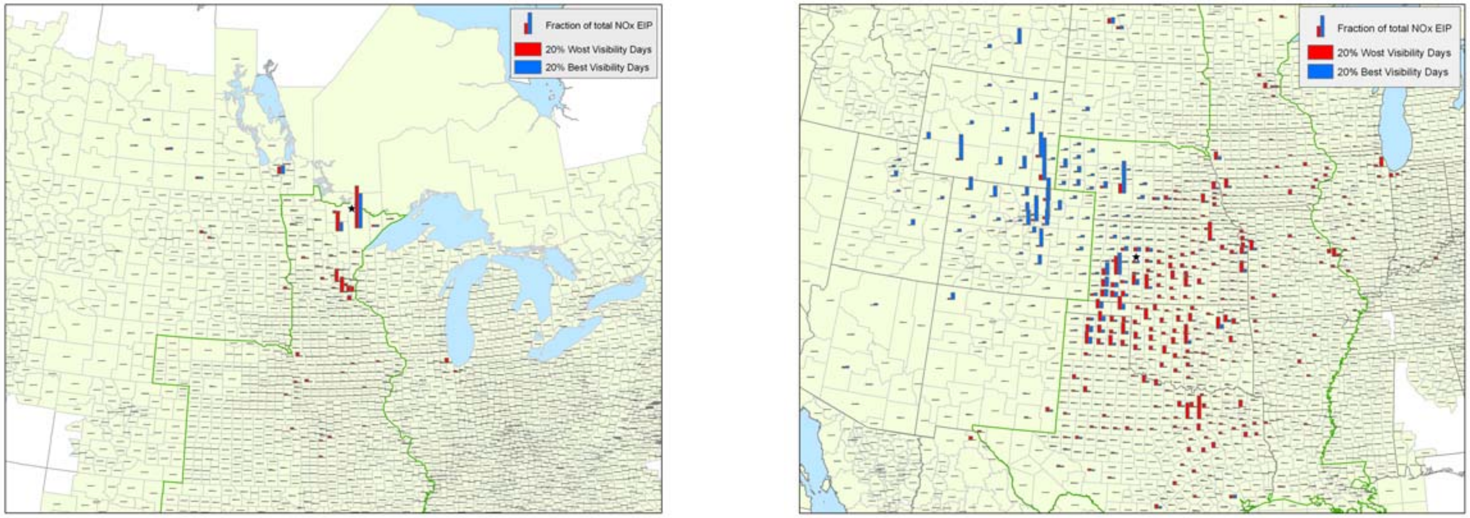
(a) Voyageurs, Minnesota (Minnesota subregion)*   (b) Cedar Bluff, Kansas (Western Plains subregion)



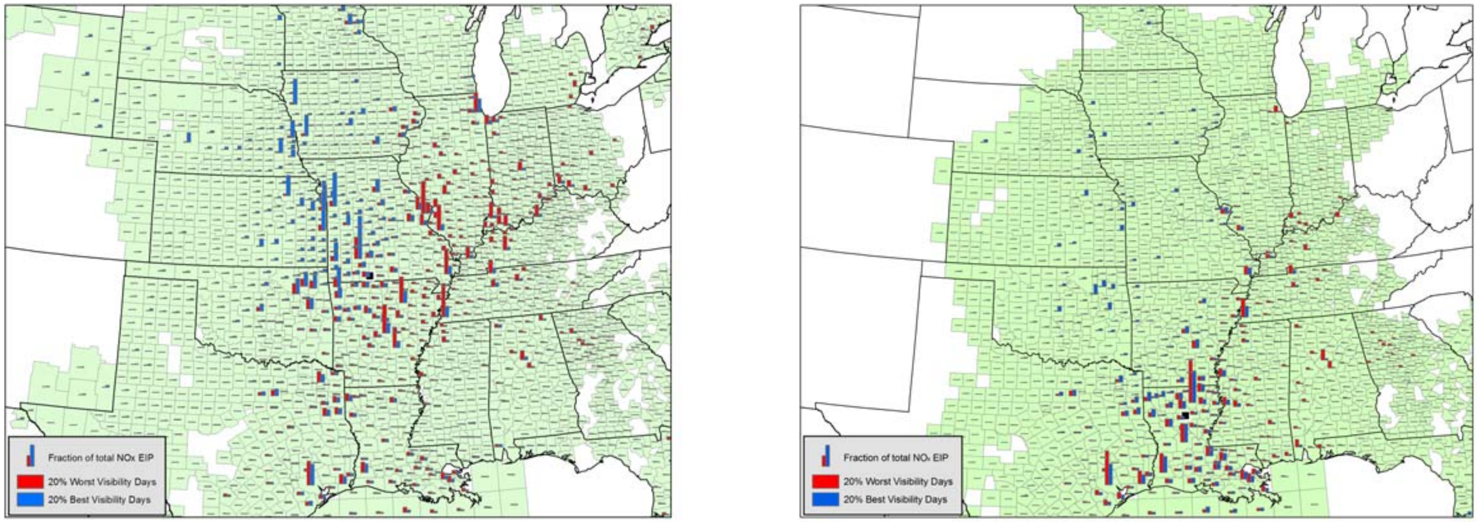
(c) Hercules-Glades, Missouri (Upper Midwest subregion)   (d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory hourly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure C-10. Geographic distributions of SO_2 EIP for the 20%-worst visibility days (red bars) and 20%-best visibility



(a) Voyageurs, Minnesota (Minnesota subregion)* (b) Cedar Bluff, Kansas (Western Plains subregion)



(c) Hercules-Glades, Missouri (Upper Midwest subregion) (d) Sikes, Louisiana (Southeastern Plains subregion)

* Note: Many trajectory houly endpoints for the 20%-best days extended far northward into Canada and therefore dropped out of the analysis.

Figure C-11. Geographic distributions of NO_x EIP for the 20%-worst visibility days (red bars) and 20%-best visibility days (blue bars) observed at four representative sites.

C.4 IDENTIFICATION OF POTENTIALLY BART-ELIGIBLE SOURCES

EPA's National Emissions Inventories (NEI) Draft 2002 point source inventories were compiled including all 50 states plus Washington, D.C. for use in BART Analyses. (U.S. Environmental Protection Agency, 2005b) Stationary point sources located at any of the following 26 types of facilities were identified as *potentially* BART eligible:

1. Fossil fuel-fired steam electric plants of more than 250 million British thermal units (BTU) per hour heat input
2. Coal cleaning plants (thermal dryers)
3. Kraft pulp mills
4. Portland cement plants
5. Primary zinc smelters
6. Iron and steel mill plants
7. Primary aluminum ore reduction plants
8. Primary copper smelters
9. Municipal incinerators capable of charging more than 250 tons of refuse per day
10. Hydrofluoric, sulfuric, and nitric acid plants
11. Petroleum refineries
12. Lime plants
13. Phosphate rock processing plants
14. Coke oven batteries
15. Sulfur recovery plants
16. Carbon black plants (furnace process)
17. Primary lead smelters
18. Fuel conversion plants
19. Sintering plants
20. Secondary metal production facilities
21. Chemical process plants
22. Fossil-fuel boilers of more than 250 million BTUs per hour heat input
23. Petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels
24. Taconite ore processing facilities
25. Glass fiber processing plants
26. Charcoal production facilities

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APPENDIX D

DOCUMENTATION OF METHODS AND GRAPHICAL AND TABULAR SUMMARIES OF DATA FOR TASK 7

SOURCE APPORTIONMENT ANALYSES

Documentation for Task 7 is provided in the form of the attached two draft journal articles, “Source Apportionment of $PM_{2.5}$ at a Rural Site in Louisiana Using Positive Matrix Factorization” and “Source Apportionment of $PM_{2.5}$ at Hercules-Glades, Missouri, Using Positive Matrix Factorization”.

Source Apportionment of $PM_{2.5}$ at a Rural Site in Louisiana Using Positive Matrix Factorization

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ABSTRACT

Speciated $PM_{2.5}$ data collected as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program at Sikes, Louisiana, from March 2001 through February 2004 were analyzed using the multivariate receptor model Positive Matrix Factorization (PMF). Two hundred ninety-six samples and 27 species were utilized, including the organic carbon (OC) and elemental carbon (EC) analytical temperature fractions from the thermal optical reflectance (TOR) method. Eight factors were identified, with good comparison between predicted and measured $PM_{2.5}$ mass (slope = 0.99, $r^2 = 0.97$) and good orthogonality between factors. Bootstrapping over 300 runs was used to determine the concentrations and uncertainties of each species in the factor profiles. A coal combustion factor was the largest contributor to mass (27% of the median mass on all days and 38% on the worst visibility days) and to ammonium sulfate, which is consistent with coal-fired power plant emissions as the main source of SO_2 in the Ohio and Mississippi River Valleys. Southeastern aged aerosol was responsible for 21% of the mass, and an urban carbonaceous aerosol factor accounted for another 23%. Oil combustion and industrial metals factors were minor contributors to the mass (8% and 7%, respectively). Nitrate contributed 5% of the median mass over all days, and less than 1% of the mass on the worst visibility days, which mostly occurred in the spring through fall. Soil and local burning emissions were generally event-driven, and while they were 5% and 4% of the overall mass, they were only 2% and 1% of the mass on the worst visibility days. Conditional Probability Function (CPF) analysis applied to air mass trajectories and trajectories paired with the emission inventory

to find emission impact potential (EIP) both helped better identify the factors and their source regions.

IMPLICATIONS

A relatively new subset of $PM_{2.5}$ data, the analytical carbonaceous fractions, was used to enhance the identification of factors in this source apportionment work. These carbonaceous fractions helped differentiate and quantify carbonaceous aerosol factors that otherwise would not have been separated and apportioned as well. A more realistic treatment of XRF data close to the detection limit was used to better characterize the known analytical uncertainties of, and provide a better fit for, certain species. Bootstrapping was used to better quantify the composition and uncertainties in the factor profiles by compiling results from 300 individual runs. Lastly, emission inventory data were paired with air mass trajectories to better understand the source regions affecting factors with sulfate. All of these techniques were used to improve the confidence in, and to aid policy makers in understanding, the results.

INTRODUCTION

Particles with diameters of less than 2.5 microns ($PM_{2.5}$) impact human health[1-4] and visibility.[5-7] The EPA has identified a number of $PM_{2.5}$ constituents, such as manganese, arsenic, lead, and diesel particulate matter (DPM), which pose a public health risk in urban areas.[8] Visibility regulations are also promulgated by the EPA directing states to reduce the worst-20% visibility days in their Class 1 areas. To better address these issues, it is vital to understand the composition and characteristics of the sources contributing to $PM_{2.5}$. The Sikes site is in a Class 1 area located in rural Louisiana near the Kisatchie National Forest, approximately 100 miles from nearby urban areas such as Shreveport, Louisiana and Jackson, Mississippi. Sikes is generally impacted by transported aerosol from these urban areas and others such as New Orleans, Houston, and St. Louis. This site is also impacted by regional dust events from the Great Plains and local burning in the area.

In previous analyses of $PM_{2.5}$ data using receptor models with only the total organic carbon (OC) and elemental carbon (EC) fractions, it has been difficult to separate different sources of carbonaceous aerosols, such as gasoline-, diesel-fueled vehicles, aged aerosol transport, and fire emissions. Much of the $PM_{2.5}$ emitted from these sources is carbonaceous,[9-13] and a simple ratio of OC to EC is typically insufficient to quantitatively separate various source types. In urban areas, attempts using receptor modeling and data analysis[14-16] to better determine the gasoline-diesel split, for example, have begun to rely on carbon fractions resulting from the Thermal Optical Reflectance (TOR) protocol[17,18] technique. In rural areas, where the aerosol impacting a site is more aged, motor vehicle and diesel emissions will impact the site together, and will be indistinguishable.[19-21] However, the use of the fractions may better apportion the carbonaceous aerosol between the local and aged transported air masses, and possibly better apportion the contribution from burning or other combustion sources.

METHODS

Data

$PM_{2.5}$ data from March 2001 through February 2004 were collected as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program[22] at the Sikes site, shown in Figure 1. These 24-hr samples were collected on Nylon, Teflon, and quartz fiber filters. Teflon filters were analyzed by gravimetric analysis for mass and by x-ray fluorescence (XRF) for elements. The Nylon filter was analyzed by ion chromatography (IC) for sulfate, nitrate, nitrite, and chloride. Ammonium (NH_4^+) was not analyzed, but its mass can be inferred from ionic balance with sulfate and nitrate.[23]

Quartz fiber filters were analyzed by the TOR method[17] to obtain eight thermally resolved fractions of carbonaceous aerosol. OC is volatilized in four steps, all in a helium atmosphere: (1) OC1 consists of the volatilized OC up to 120°C, (2) OC2 from 120° to 250°, (3) OC3 from 250° to 450°, and (4) OC4 from 450° to 550°. After the OC4 section is complete, a 2% O_2/98% He atmosphere is introduced to obtain EC1, and the temperature is then increased to 700°C for EC2 and to 850°C for EC3. A correction for the pyrolysis of OC is made. Pyrolyzed organic carbon (OP) is emitted when the O_2/He atmosphere is first introduced. This amount of OP is defined as the amount detected after the introduction of the O_2/He atmosphere at 550°C until the monitored filter reflectance returns to its original value. As reported, EC1 includes the OP fraction; thus, OP was subtracted from EC1 to achieve the correct EC1 concentration.

Data from the IMPROVE program are routinely validated before being made publicly available; therefore, the overall data quality was very good. Only valid samples from the IMPROVE data were used. Additional quality control (QC) checks performed in this study include comparison of reconstructed fine mass to measured mass and comparison of XRF sulfur to IC sulfate. Only species with good variability (i.e., signal/noise greater than 0.2 when not accounting for seasonal variability) and at least 25% of the data above detection were used. In particular, no sodium or chloride data were used in this analysis; therefore, no sea salt factor could be identified, though the impact of sea salt at this site was expected to be minimal. The final data set contained 296 samples with 27 species (see Table 1).

Source Apportionment With PMF

PMF is a multivariate factor analysis tool applied to a wide range of data, including 24-hr speciated $PM_{2.5}$ data, size-resolved aerosol data, deposition data, air toxics data, and VOC data.[14-16,20,21,24-34] Simply, PMF decomposes a matrix of ambient data into two matrices, which then need to be interpreted by the analyst to discern the source types they represent. The method is considered briefly here and described in greater detail elsewhere.[35,36]

An ambient data set can be viewed as a data matrix X of *i* by *j* dimensions, in which *i* number of samples and *j* chemical species were measured. The goal of multivariate receptor modeling is to identify a number of sources *p* that best characterize the $PM_{2.5}$ at a site, the species profile *f* of each source, and the amount of mass *g* contributed by each source to each individual sample:

$$X_{ij} = \sum_{k=1}^{p} g_{ik} f_{kj} + e_{ij} \qquad (1)$$

One strength of PMF is that results are constrained by a penalty function so that no sample can have a negative source contribution and no species can have a negative concentration in any source profile. Another strength of PMF, compared to other source apportionment tools such as principle component analysis (PCA), is that each data point can be weighed individually. This feature allows the analyst to adjust the influence of each data point, depending on the confidence in the measurement, and retain data that might otherwise be screened out. Data below detection can be retained for use in the model, with the associated uncertainty adjusted so these data points are given less weight in the model solution (i.e., these data have less influence on the solution than measurements above the detection limit). By individually weighing data, samples with some species missing or below detection do not need to be excluded as a whole, rather the analyst can adjust the uncertainty so these data have little or no impact on the final solution. The PMF solution minimizes the object function Q(E), based upon these uncertainties (*u*):

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} f_{kj}}{u_{ij}} \right]^2 \qquad (2)$$

Methods used in analysis for replacing and developing uncertainty values for missing and below-detection-limit data were drawn from previous work with PMF.[20,21,25,26,28,37] Since the solution found by PMF relies on both concentration data and on error estimates, these error estimates must be chosen judiciously so that they reflect the quality and reliability of each data point. The missing and below-detection-limit data are assigned less weight compared to actual measured values, so these data are less important to the solution.[20,21,25,26,28,37] Data below the minimum detection limit (MDL) were substituted with MDL/2; missing data were substituted with the median concentration. Similar to previous studies, the uncertainty for data above detection was calculated as the sum of the analytical uncertainty (UNC) plus one-third the MDL, uncertainty for data below detection was 5/6*MDL, and uncertainty for missing data was four times the median. Additionally, it has shown that XRF data reported above MDL but below approximately 10*MDL are more uncertain[38]; therefore, these data were assigned an uncertainty twice as high as concentrations above this threshold, i.e., 2*(UNC+MDL/3).

The robust mode was used in this analysis to reduce the influence of outliers; between 5 and 13 factors were explored. The uncertainty of the amount of each species in a given factor was determined by bootstrapping 300 runs and calculating the interquartile range of the factor loading over these runs. This was done using multiple starting points and rotations, so that the range of solutions PMF gives can be used as a measure of the confidence in a given factor. Scaled residuals were between -3 and 3 for all species demonstrating a good fit of the modeled results. The factors also showed oblique edges, which has been proposed as an additional check of the quality of the rotation.[39] A multi-linear regression (MLR) was applied to scale the factors back into the original μg/m^3 units by regressing the total measured $PM_{2.5}$ mass against the unscaled factor strength contributions:

$$X_{ij} = \sum_{k=1}^{p} \left(s_k g_{ik} \right) \left(\frac{f_{kj}}{s_k} \right) \qquad (3)$$

The resulting coefficients were then applied to each factor to regain the μg/m^3 units.

Conditional Probability Integrative Analysis

A conditional probability function (CPF) was applied to help interpret the results.[14,16,24,40] The transport patterns of the highest 10% concentration days of a given factor were compared to the climatological transport patterns. This comparison highlights the differences in transport and areas of influence between the general transport pattern (i.e., the climatology) and high concentration days of a given factor. Using the NOAA HYSPLIT model,[41] 96-hr backward trajectories were run for all sample dates, which were then mapped as a spatial probability density (D_0):

$$D_0 = \frac{D_c}{\hat{D}} \qquad (4)$$

D_c = Density at grid cell c

$\hat{D}$ = Maximum density over all grid cells (typically the density at the receptor site)

$$D_c = \sum_{i=1}^{n} \kappa_R(r_n) \qquad (5)$$

r_n = distance between grid cell center and hourly trajectory point n

$$K_R(r) = \text{kernel density function} = \begin{cases} \dfrac{3}{\pi R^2} \left[1 - \left(\dfrac{r}{R} \right)^2 \right]^2 & for\ r < R \\ 0 & for\ r \geq R \end{cases} \qquad (6)$$

R = search radius

The search radius was determined dynamically by dividing the geographic extent of all endpoints by 30.[42,43] The density D_k was then computed using only backward trajectories for the highest 10% concentration days of a given factor k. Areas that have a higher than typical influence on the high concentration days are then highlighted by calculating the conditional probability P_k:

$$P_k = D_k - D_0 \qquad (7)$$

This Conditional Probability Integrative Analysis (CoPIA) is very similar to the CPF analyses employed in other studies;[14,16,24,40] however, CoPIA is adapted to take advantage of tools available in a geographic information system (GIS) framework. Ensemble backward trajectories were run every 6 hours to account for variability over a 24-hr sampling period. Emissions data, such as point source and fire locations, were overlaid on the CoPIA analysis to identify specific emissions sources in likely source areas.

Emission Impact Potential (EIP) Calculations

While trajectory analyses such as CoPIA can help identify transport patterns and likely areas of influence, only a broad conclusion can be reached, such as "the factor showed influence from the Ohio River Valley". However, this analysis only accounts for transport, and not the spatial distribution or magnitude of emissions. For example, a large, distant source and a small nearby source could influence a site in a similar way. To gain a better understanding of the source regions for a given factor, a GIS-tool was used to weight county-level emission inventory data by the trajectory kernel density of the highest 10% concentration days for a given factor. For a given factor, SO_2 emissions were weighted by the frequency and residence time of modeled backward trajectories passing over each county to estimate the potential for emissions from each county to impact the site. This is called the emission impact potential (EIP). This simple analysis technique is useful for characterizing general patterns and developing a preliminary conceptual model of factors affecting visibility conditions, but without the need for, and as an initial step toward, full-scale photochemical modeling efforts.

The EIP of a given county is calculated as:

$$EIP = \frac{E_p * D_0}{f(\text{distance})} \tag{8}$$

where

E_p = county total emissions of pollutant p
D_0 = spatial probability density at the county centroid
f = function of distance between county and receptor

The EIP may be divided by a distance function to roughly account for dilution and increased uncertainty in model outputs far from the receptor site. However, for this study, $f = 1$, assuming vertical dilution is similarly small compared to the horizontal transport distance for all areas and kernel density sufficiently accounts for horizontal dilution and uncertainty. This tool is used for simple analysis only and does not account for atmospheric chemistry, deposition, or other effects, but is expected to qualitatively provide insight into the potential sources affecting mass.

RESULTS AND DISCUSSION

Preliminary Data Analysis

Preliminary data analysis was conducted to gain insight into the trends and relationships among species that would impact later source apportionment with PMF. Inspection of the overall composition, changes in composition by season or on days of poor visibility, species relationships, and day-of-week trends assisted in identifying possible source types.

Annual Median Composition. Figure 2 shows the median $PM_{2.5}$ composition. Ammonium sulfate and nitrate concentrations are calculated from sulfate and nitrate concentrations, assuming full neutralization by ammonium. OC is represented by OC mass (OMC), equal to 1.4 times OC,[44,45] which takes into account the mass of oxygen and hydrogen associated with the carbon, though this factor may actually be higher than 1.4.[44,46] As shown in Figure 2, ammonium sulfate is the dominant component (accounting for 48% of the average mass), followed by OMC (34%). Ammonium nitrate, EC, and soil account for the remaining mass. Dominance of ammonium sulfate is typical of the eastern half of the United States, and the significant portion of mass from OMC demonstrates the importance of determining its source regions.

Seasonal Composition. Changes in $PM_{2.5}$ mass and composition between seasons (Figures 3a and 3b) may reflect differences in transport regimes or source strengths. Mass is highest in spring through fall, with a summer peak, and then drops off significantly in the winter. Ammonium sulfate contributions to mass range between a peak in the spring (54% of the mass) and a low (44%) in the winter. OMC accounts for between 30% of the mass in spring and 38% of the mass in the fall. In spring and summer, soil contributions are between 7% and 9%, while in fall and winter soil contributions are less than 5%. Nitrate accounts for 10% of the mass in winter, but is less than 4% of the mass during the warmer months of spring and summer. While changes in soil concentrations are due to wind-blown dust impacts likely from the arid western plains, the changes in ammonium sulfate and OMC suggest different source influences during these two seasons, even though total mass is similar. These seasonal differences are expected to be observed in PMF analysis and may be because of changes in sources or transport, which will be analyzed further using results from PMF analysis.

Composition on Poor Visibility Days. To investigate which components (i.e., OMC, sulfate, soil, etc.) have the greatest impact on days with severely impaired visibility, the $PM_{2.5}$ composition on the worst-20% visibility days (referred to as the worst visibility days in the remainder of this article) was examined (Figure 4a). Using the IMPROVE equation,[22,23] which likely does not fully account for extinction by OC,[47] the total light extinction (b_{ext}) contribution of each chemical component was calculated. On poor visibility days, which occurred in all months but predominantly in spring and summer, the average $PM_{2.5}$ mass was 16.1 $\mu g/m^3$ with 54% of the mass attributable to ammonium sulfate, 33% to OMC, and the remaining 13% to other components. This composition is actually similar to the median composition during all days, suggesting that the meteorological conditions and total mass are important in determining the visibility degradation on a given day. The analysis of the estimated contributions to light extinction in Figure 4b further shows the importance of ammonium sulfate becuase it dominates the light extinction (71% on average), followed by OMC (17%), ammonium nitrate (6%), and EC (5%). Since ammonium sulfate and OMC account for 88% of the light extinction on the worst visibility days, these components are likely the best candidates for emission reductions to help improve visibility.

Species Relationships. Species relationships were investigated because the degree of covariation among species impacts how species and sources are allocated in source apportionment. It is important to understand these relationships before conducting source apportionment to ensure that PMF results fit within in the context of the data. One example, Figure 5a, shows the fair relationship between ammonium sulfate and selenium ($r^2 = 0.36$), which is typical of coal combustion, although the amount of scatter also suggests other existing sources of these species. Potassium, often used as a tracer for wood smoke,[48,49] had some correlation in a number of samples with EC (Figure 5b) and OC (not shown), which are also emitted by wood combustion.[48,50] The relationship between potassium and OC and EC indicates that a smoke factor may be found by PMF, but that the majority of the carbonaceous aerosol is likely not associated with burning. In addition to the expected good relationships within the OC and EC fractions, the pyrolyzed organic fraction, OP, and the first EC fraction, EC1, showed a fairly good relationship (Figure 5c), especially in the summer and fall. These results may in part be due to analytical bias since these fractions are analyzed sequentially, but they may also suggest that there is a source of OP/EC1 in addition to a source of the other OC fractions.

PMF Results

Eight factors were resolved for the ambient $PM_{2.5}$ at Sikes and identified as (1) coal combustion, (2) southeastern aged aerosol, (3) urban carbonaceous, (4) oil combustion, (5) industrial metals, (6) nitrate, (7) soil, and (8) burning. Factor profiles with the standard deviation over 300 runs graphed as the error bars are shown in Figure 6, and a time series of all samples (every third day) are shown in Figure 7. The PMF solution accounted for the measured mass well, with a slope of 0.99 and r^2 of 0.97 between reconstructed and measured mass (Figure 8). The average compositions over all seasons and on the worst visibility days during the time period are shown in Figure 9. Figure 10 shows CoPIA plots for coal combustion, southeastern aged aerosol, urban carbonaceous, and industrial metals. Figure 11 shows air mass trajectories on days of high soil contributions, demonstrating likely Saharan dust episodes. Figure 12 shows air mass trajectories on days of high burning influence with fire locations from MODIS. Lastly, Figure 13 shows SO_2 EIP analysis results by county and by state for coal combustion, aged aerosol, and oil combustion.

The coal combustion factor was the largest contributor to mass (27% of the median mass on all days and 38% on the worst visibility days), which is consistent with coal emissions as the main source of ammonium sulfate in the region. A southeastern aged aerosol factor was responsible for another 21% of the mass on all days, and 28% of the mass on the worst visibility days. Carbonaceous aerosol from urban areas, most likely mobile sources, accounted for 23% of the mass overall, and 19% on the worst visibility days. Oil combustion and smelter operation factors were minor contributors to the mass (8% and 7%, respectively), and contributed even less on the worst visibility days (6% and 5%, respectively). A nitrate factor was significant only during the winter; while it contributed 5% of the median mass over all days, it accounted for less than 1% of the mass on the worst visibility days, which mostly occurred in the spring through fall, when nitrate concentrations were low. Soil and local burning emissions were both event-driven factors; and while they were 5% and 4% of the overall mass, they were only 2% and 1% of the mass on the worst visibility days, indicating that soil- and burn-events are likely not the key contributors to visibility degradation at Sikes. Overall, and similar to the basic data analysis results, the factor contributions on the worst visibility days were not much different than on average.

A coal combustion factor was identified by typical tracers of coal combustion—sulfate, selenium, and hydrogen.[20,25,26,51] This factor was the largest component of the mass on all days (27%), as well as on the worst visibility days (38%). Since most of the factor's mass derives from ammonium sulfate, this factor is likely more important in terms of visibility extinction. Ammonium sulfate accounted for half the mass at Sikes, and most of the sulfate is found in this factor; the remaining sulfate is found in the oil combustion and secondary transport factors. This factor was highest on days with transport from the Ohio River and Mississippi Valleys, where many coal-fired power plants are located and which have been identified as a significant area for the origin of sulfate transport in other studies in the mid-Atlantic and Northeast.[20,25,26,51] Additionally, EIP analysis using the top 10% concentration days of this factor with the SO_2 emission inventory further shows the high amount of influence from the Indiana-Alabama corridor, as about two-thirds of the EIP comes from these regions. This analysis also shows that the EIP is actually dominated by only a few counties in a given state, where there are major coal combustion facilities. While CoPIA showed possible influence from the State of Mississippi as well, the small amount of EIP indicates that this area likely affects Sikes less than regions located further away.

A southeastern aged aerosol factor was identified by sulfate and carbonaceous aerosol, predominantly the OP and EC1 fractions, consistent with earlier data analysis and demonstrating the usefulness of the carbonaceous fractions. In addition to carbonaceous aerosol, sulfate accounted for about 50% of this factor's mass. This factor was generally highest during the summer, when photochemistry increases, and comprised 21% of the mass over all days, and was the second highest component of the mass on the worst visibility days (28%). The transport regime when this factor was high differed from the coal combustion factor, and was characterized by slow-moving air masses from Louisiana, Mississippi, and Alabama. A combination of various anthropogenic and biogenic sources in these areas is likely for the carbonaceous component. The sulfate component can be further interpreted using EIP analysis, which shows that, unlike the coal combustion factor, SO_2 emissions emanate from a number of counties throughout the southeastern United States and Texas. Fifty-one percent of the SO_2 EIP influence comes from Louisiana, Mississippi, and Alabama, demonstrating the degree of local influence on this factor.

Urban carbonaceous aerosol, most likely from mobile sources, was another identified factor, and contributed 23% of the mass, on average, and 19% of the mass on the worst visibility days. Except for one spike, this factor had very little seasonal variability, which would be consistent with a persistent source, such as mobile emissions. Similar to the secondary transport factor, this factor was characterized by slow-moving air masses, though this factor was predominantly because of influence from urban areas along the Mississippi River in Missouri, Arkansas, Tennessee, and Louisiana.

Oil combustion was identified by its typical markers, nickel and vanadium.[14,20,21,24-26,52,53] This factor originates from the numerous oil refineries and drilling stations in Louisiana, Texas, and in the Gulf of Mexico, as well as the use of oil burning for energy in these areas. A small amount of the ammonium sulfate was also associated with this factor, and the factor contributed 8% of the median mass. On the worst visibility days, the factor had a similar concentration, but since the overall $PM_{2.5}$ mass was higher, the factor contributed only 6% to the total. Sulfate was the main component of the mass of this factor, and nearly 50% of the SO_2 EIP came from Louisiana, as expected. Other contributions came from the southeastern United States, Texas, Florida, and the Gulf of Mexico.

Another industrial factor, associated with copper, lead, zinc, manganese, and arsenic, was also identified. This factor contributed 7% of the median mass, and again was similar in concentration on the worst visibility days, when it was 5% of the mass. This factor comes from a source region different than the oil combustion factor; air masses on the industrial metals factor's highest concentration days come from the north along the Mississippi River, where numerous industrial facilities are located. Figure 10d shows the CoPIA results, indicating potential influence of these facilities.

An ammonium nitrate factor was identified, since it has a very strong seasonal signal that is independent of other components. It is highest in the winter, and is extremely low in the other warmer months, when nitrate production would be limited simply because of the ambient temperature. This factor was 5% of the median mass, but was minimal (< 1%) on the worst visibility days, which mostly occurred in the warmer months. This factor was highest under conditions of slow-moving cool air masses from Arkansas, Missouri, and the Mississippi River area, likely from a combination of on-road mobile sources and stationary sources.

A soil factor was identified by silicon, iron, and titanium and was, in general, an event-driven factor. There were only a few large events when this factor showed high concentrations, including the two biggest events on July 1 and July 31, 2002. These two samples had the highest concentrations of the soil factor, nearing 10 $\mu g/m^3$, while typically the factor averaged only 0.6 $\mu g/m^3$ (5% of the mass). Trajectories on these days (Figure 11) suggest that the high soil factor days in July 2002 may have been Saharan dust episodes; 10-day backward trajectories show fast transport over the Atlantic Ocean. Other days with high concentrations of this factor appear to be caused by transport over the Great Plains. Despite the large spikes in the soil factor concentrations, none of the highest concentration days occurred on the worst visibility days, indicating that while soil contributions to ambient $PM_{2.5}$ are event-driven, this factor is not significant on the worst visibility days.

A wood and biomass burning factor was identified by the presence of potassium[48-50,54] and a small amount of carbonaceous aerosol. This factor also included calcium, which may be caused by entrainment of soil with the smoke.[55,56] The analytical carbonaceous fractions aided in identifying and quantifying this factor, since runs using only a total OC and EC did not effectively resolve this factor. Air mass trajectories were combined with fire location satellite data to better identify this factor, and the combination suggests this factor is significant only when local burning and conducive meteorology occur. On two of the highest concentration days of this factor, August 4, 2003, and April 19, 2001, air mass trajectories show transport from nearby fire locations (Figure 12). Overall, this factor accounted for only 4% of the median mass, and only 2% on the worst visibility days. None of the highest concentration days of this factor were among the worst visibility days, indicating that while burning is episodic, it does not appear to be an important contributor to poor visibility at Sikes.

CONCLUSIONS

PMF was applied to speciated $PM_{2.5}$ data collected as part of the IMPROVE program at Sikes, Louisiana, from March 2001–February 2004. Modeled results accounted for the mass and were consistent with known sources and their locations. The use of the analytical OC/EC fractions, better uncertainty estimates for data near the detection limit, and bootstrapping all helped better apportion and quantify the uncertainties in the identified factors. Eight factors were identified: (1) coal combustion, (2) southeastern aged aerosol, (3) urban carbonaceous, (4) oil combustion, (5) smelter, (6) nitrate, (7) soil, and (8) burning. CPF analysis and emission inventory data were used to confirm the identification of sources. Calculating EIP by combining trajectory density with county-level emission inventory data helped identify the source regions for particular factors. Results showed that a combination of local (such as burning, nitrate, and carbonaceous aerosol) and regional (coal combustion, oil combustion, and industrial metals) impact the site. However, on the worst visibility days, coal combustion, urban carbonaceous, and southeastern aged aerosol factors were the largest contributors to the mass. Event-driven factors such as biomass/wood burning and soil were clearly evident, though their impact was minimal on the worst visibility days.

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Table 1. Summary statistics of species used in PMF analysis (in µg/m^3) for Sikes March 2001–February 2004 (N=296).

Species	Median	Mean	Standard Dev	N Missing	N below 10*MDL and above MDL	N below MDL	% below MDL
AS	0.0004	0.0004	0.0003	28	243	55	18
BR	0.0020	0.0025	0.0016	28	2	0	0
CA	0.0230	0.0354	0.0402	28	1	15	5
CU	0.0004	0.0005	0.0003	28	237	5	2
EC1	0.4548	0.5652	0.3664	50	28	1	0
EC2	0.0704	0.0792	0.0500	50	266	27	9
EC3	0	0.0066	0.0101	50	105	194	65
FE	0.0224	0.0474	0.0795	28	0	0	0
H	0.4256	0.4997	0.2903	28	0	0	0
K	0.0570	0.0731	0.0549	28	1	0	0
MN	0.0007	0.0012	0.0016	28	61	51	17
NI	0.0002	0.0002	0.0003	28	168	112	37
NO3	0.2642	0.4042	0.4566	27	119	2	1
OC1	0.0645	0.1245	0.1944	0	177	94	31
OC2	0.3425	0.4037	0.3150	0	128	6	2
OC3	0.7250	0.8459	0.6227	0	134	1	0
OC4	0.5573	0.6454	0.4269	0	19	1	0
OP	0.2191	0.2679	0.2521	50	155	35	12
PB	0.0011	0.0013	0.0008	28	67	3	1
RB	0.0005	0.0006	0.0003	28	208	85	28
SE	0.1203	0.2004	0.2792	28	122	1	0
SI	2.9655	3.2557	2.1163	28	16	0	0
SO4	0.0003	0.0005	0.0006	27	1	0	0
SR	0.0022	0.0058	0.0099	28	218	46	15
TI	0.0006	0.0011	0.0013	28	33	17	6
V	0.0039	0.0044	0.0023	28	93	73	24
ZN	0.0004	0.0004	0.0003	28	0	0	0

Figure 1. Location of the Sikes, Louisiana, IMPROVE air quality monitoring site (SIKE1).

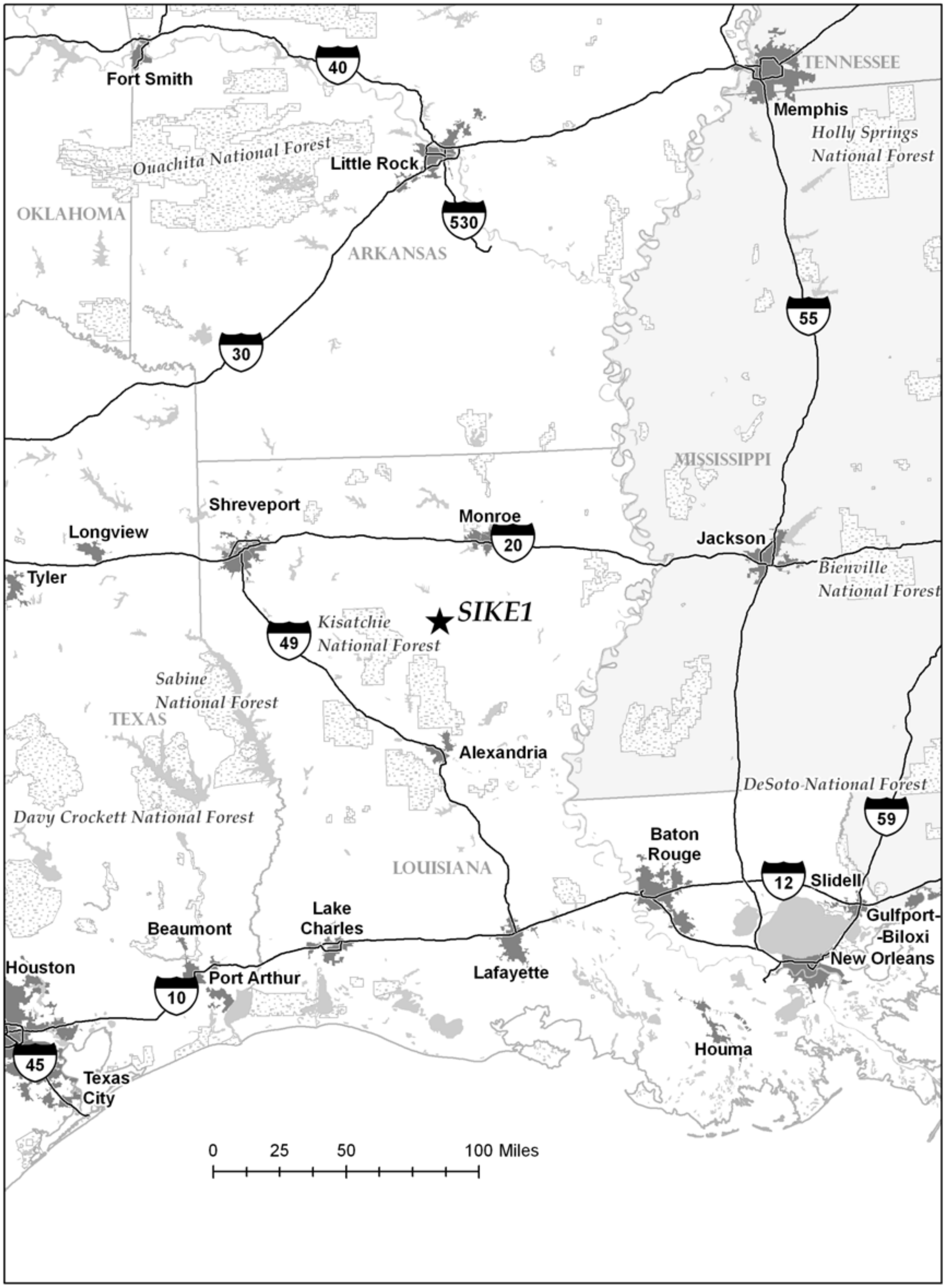


Figure 2. Average $PM_{2.5}$ composition by major component (OMC = 1.4*OC) for all valid data, March 2001–February 2004.

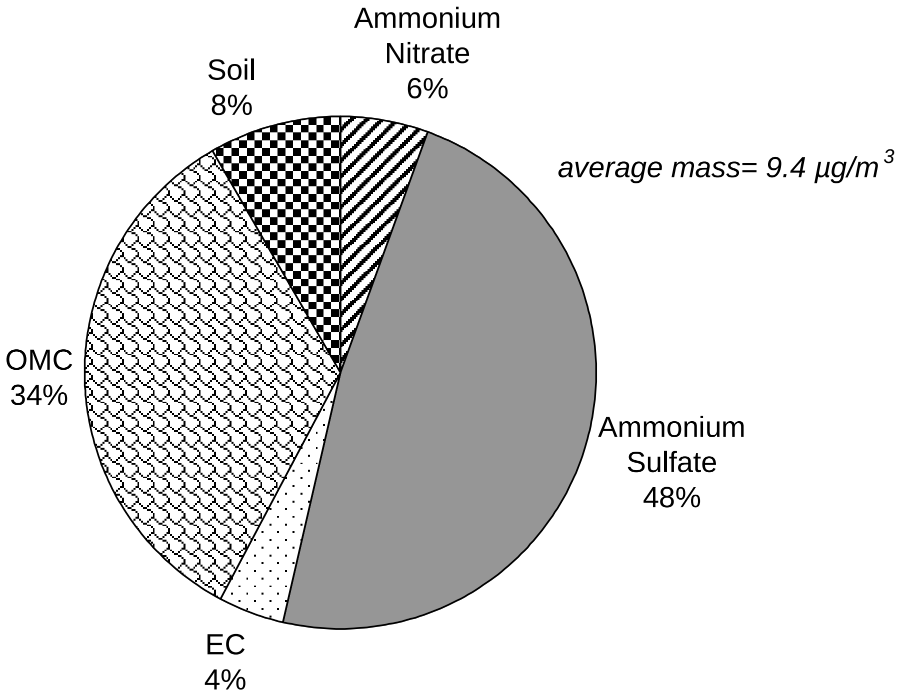


Figure 3a. Average composition ($\mu g/m^3$) by season (spring = March through May, summer = June through August, etc.) at Sikes, March 2001–February 2004.

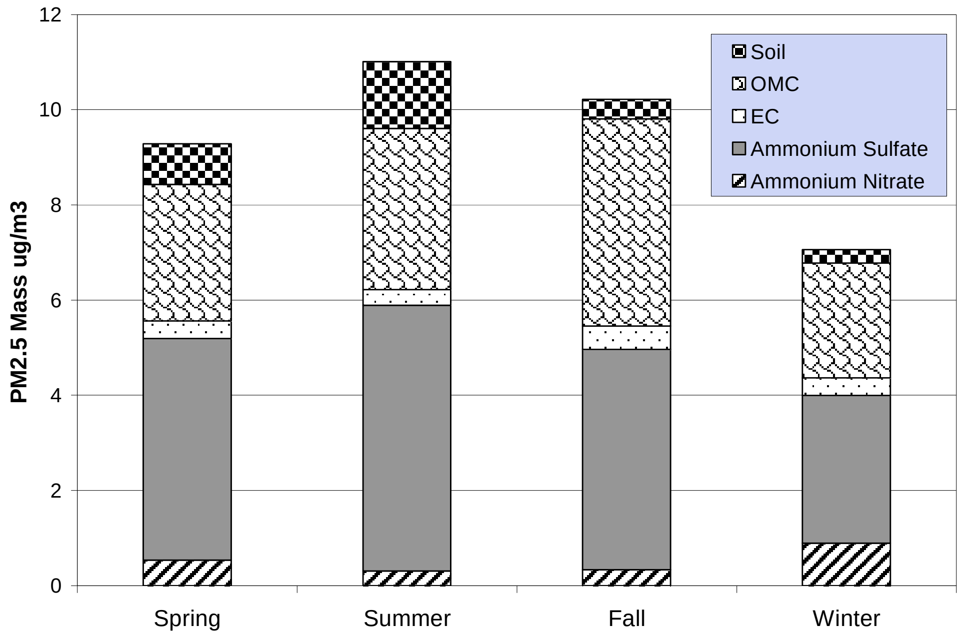


Figure 3b. Average composition (percentage) by season (spring = March through May, summer = June through August, etc.) at Sikes, March 2001–February 2004.

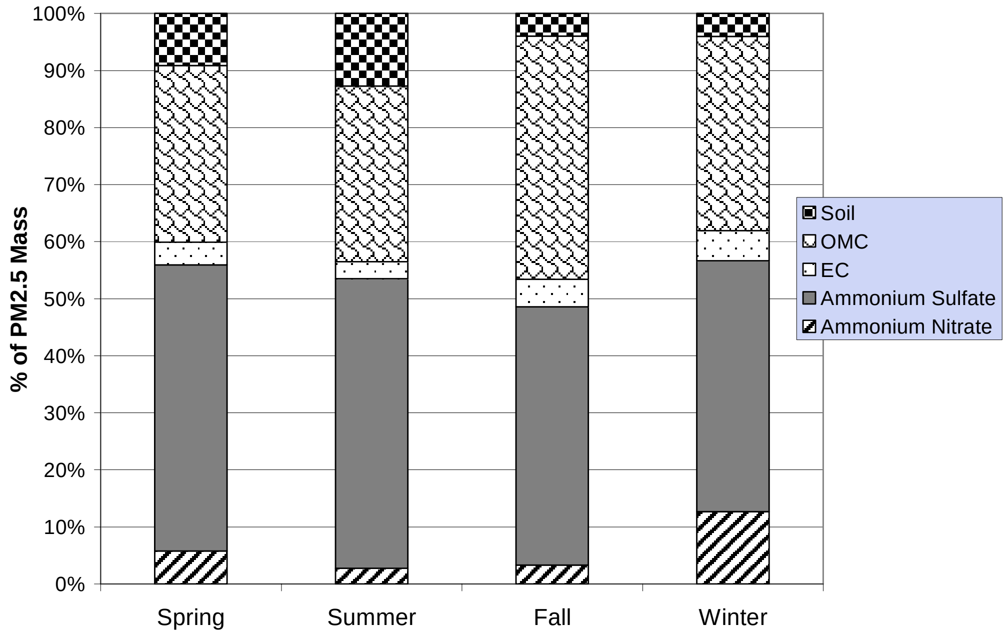


Figure 4a. Average composition on the worst-20% visibility days at Sikes, March 2001-February 2004.

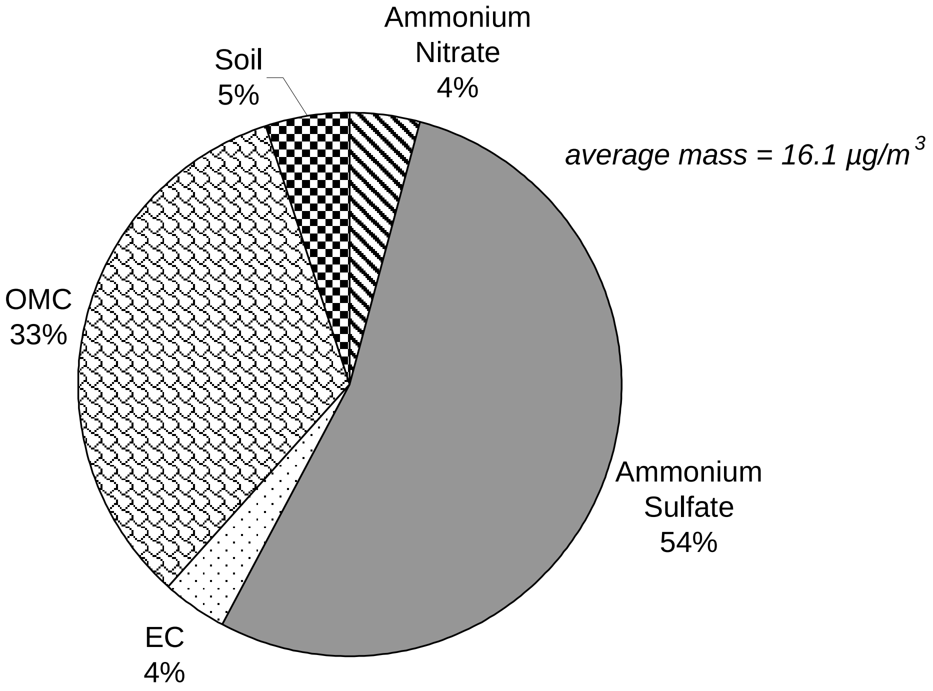


Figure 4b. Average composition of b_{ext} (light extinction by aerosol) based on the IMPROVE visibility equation on the worst-20% visibility days at Sikes, March 2001–February 2004.

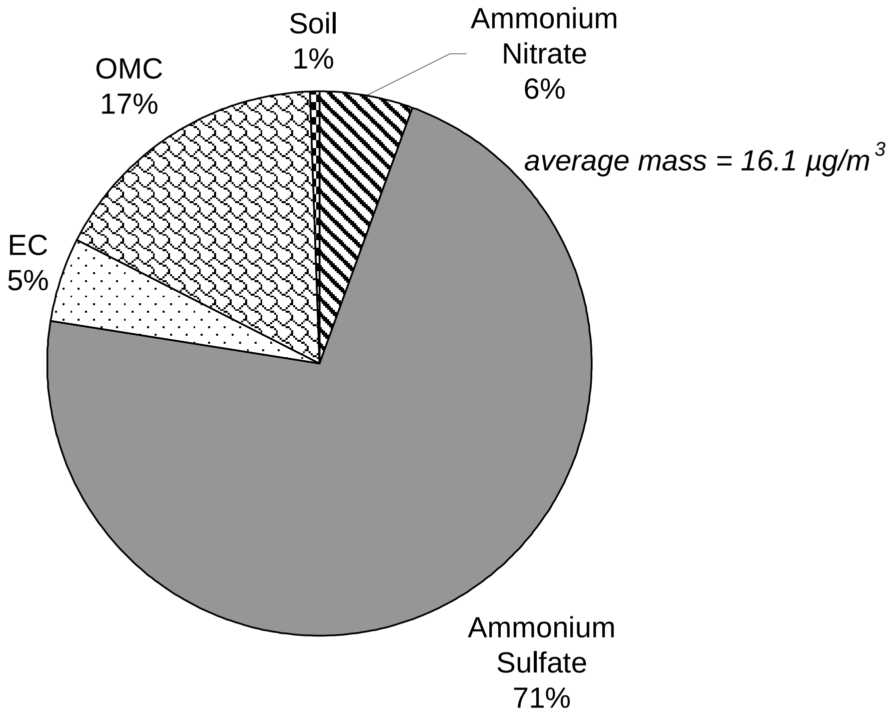


Figure 5a. Scatter plot of ammonium sulfate versus selenium by season (µg/m^3) where 1 = spring, 2 = summer, etc.

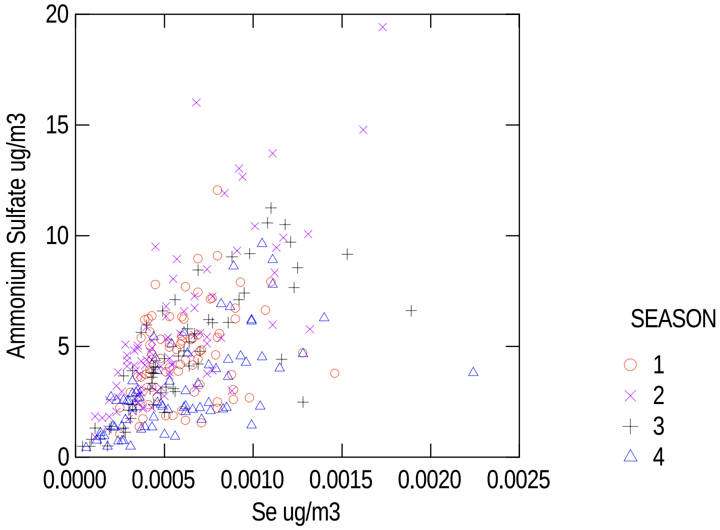


Figure 5b. Scatter plot of potassium (K) versus total EC by season (µg/m^3) where 1 = spring, 2 = summer, etc.

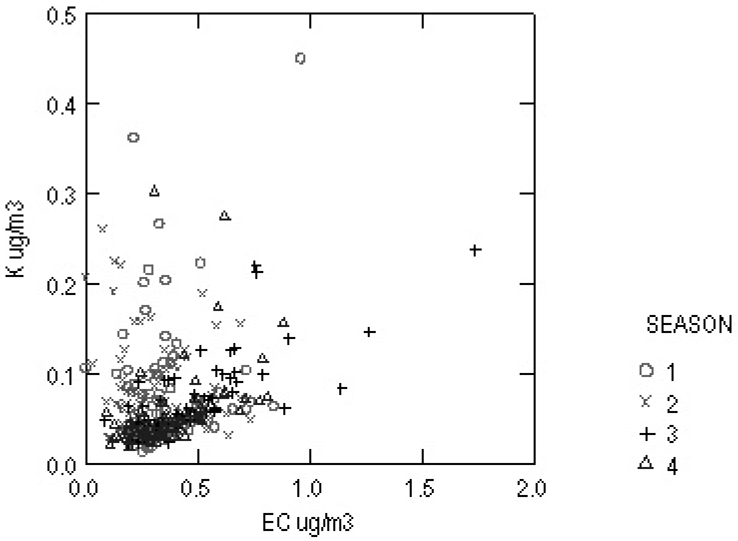


Figure 5c. Scatter plot of EC1 versus OP by season (µg/m^3) where 1 = spring, 2 = summer, etc.

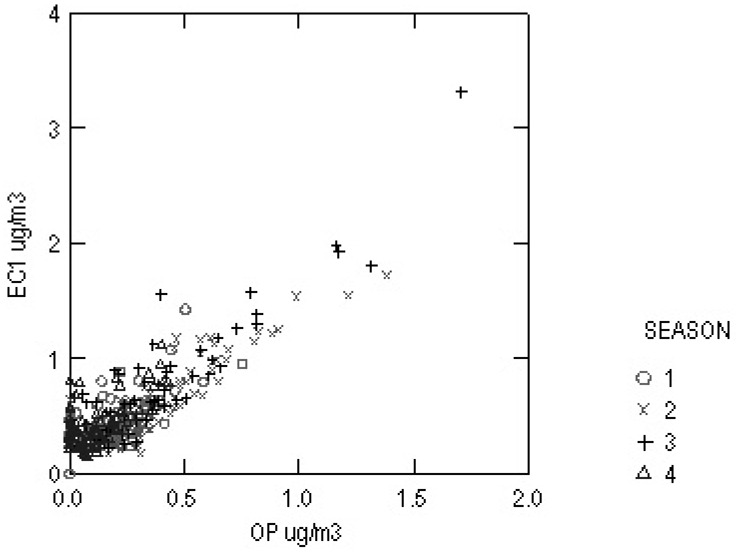


Figure 6. Factor profiles (percent of species in each factor). Error bars indicate the standard deviation from bootstrapping 300 runs.

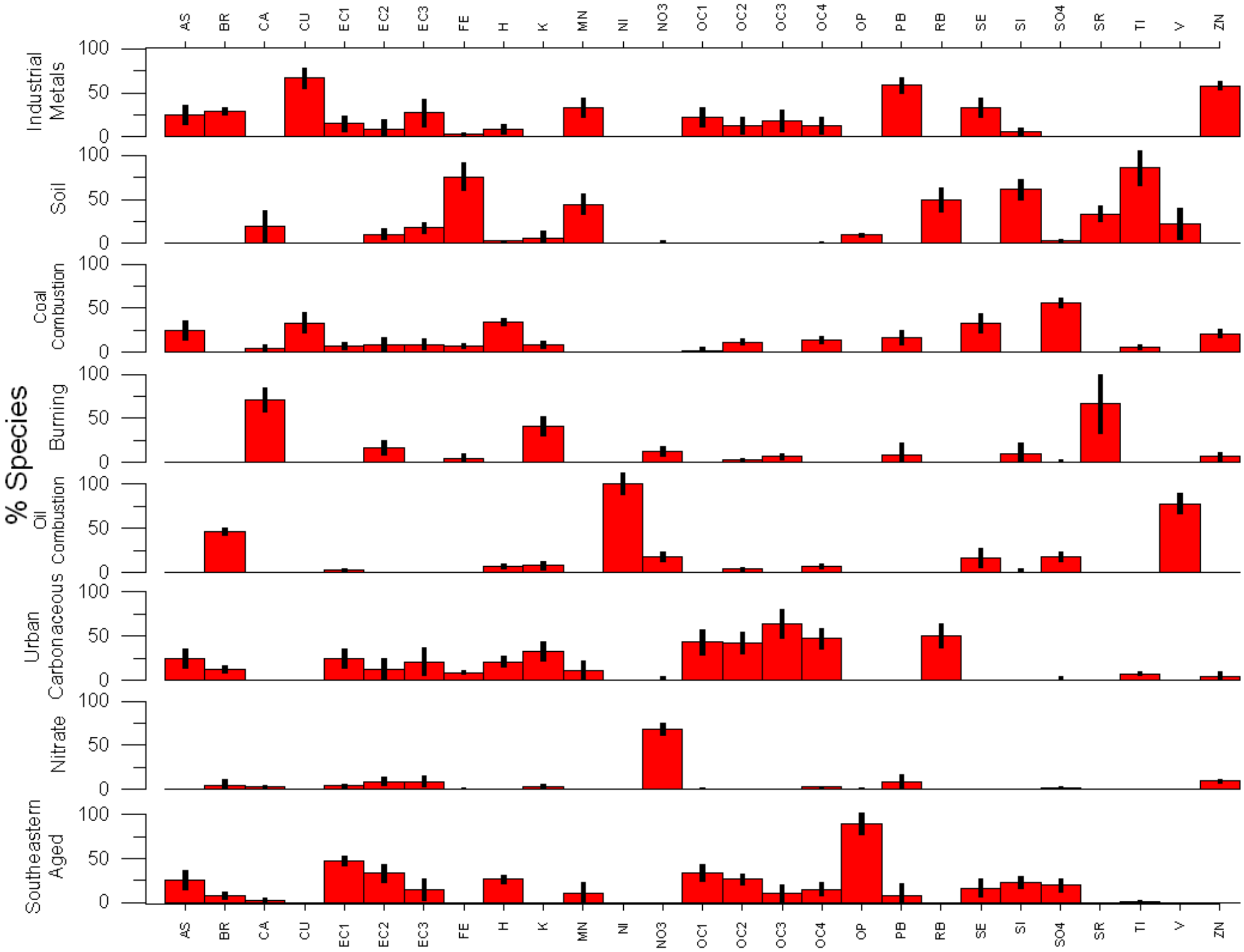


Figure 7. Time series of factor strengths by date (μg/m^3).

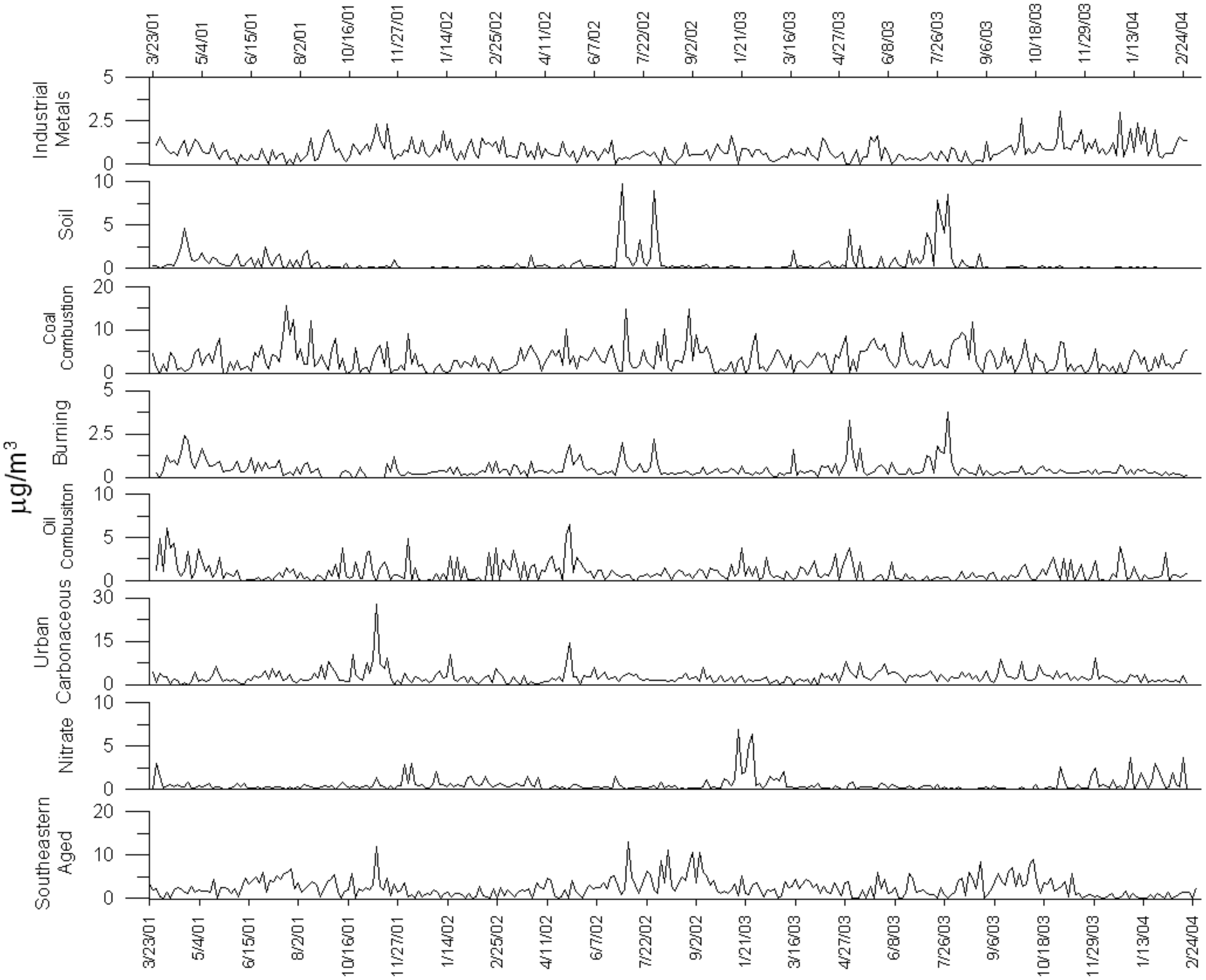


Figure 8. Reconstructed mass versus measured $PM_{2.5}$ mass.

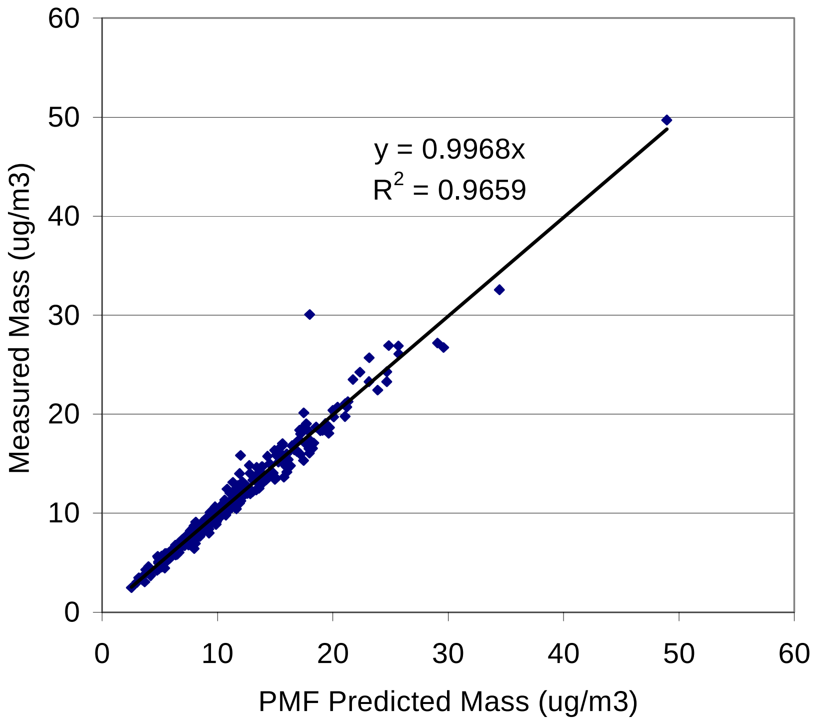


Figure 9. Average factor contribution estimates for (a) all samples and (b) the worst-20% visibility days.

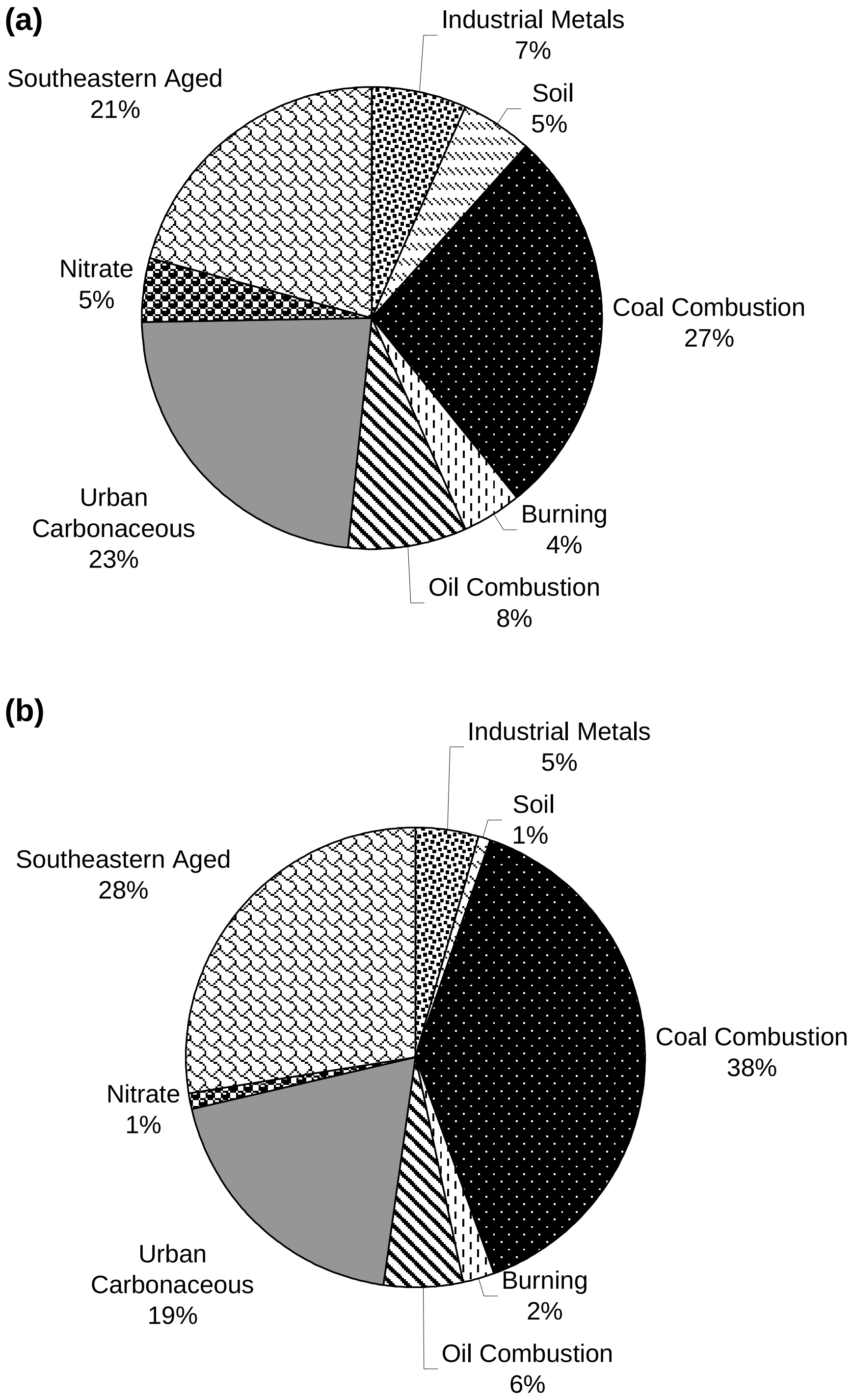


Figure 10. CoPIA plots for (a) coal combustion, (b) urban carbonaceous, (c) southeastern aged aerosol, and (d) industrial metals factors.

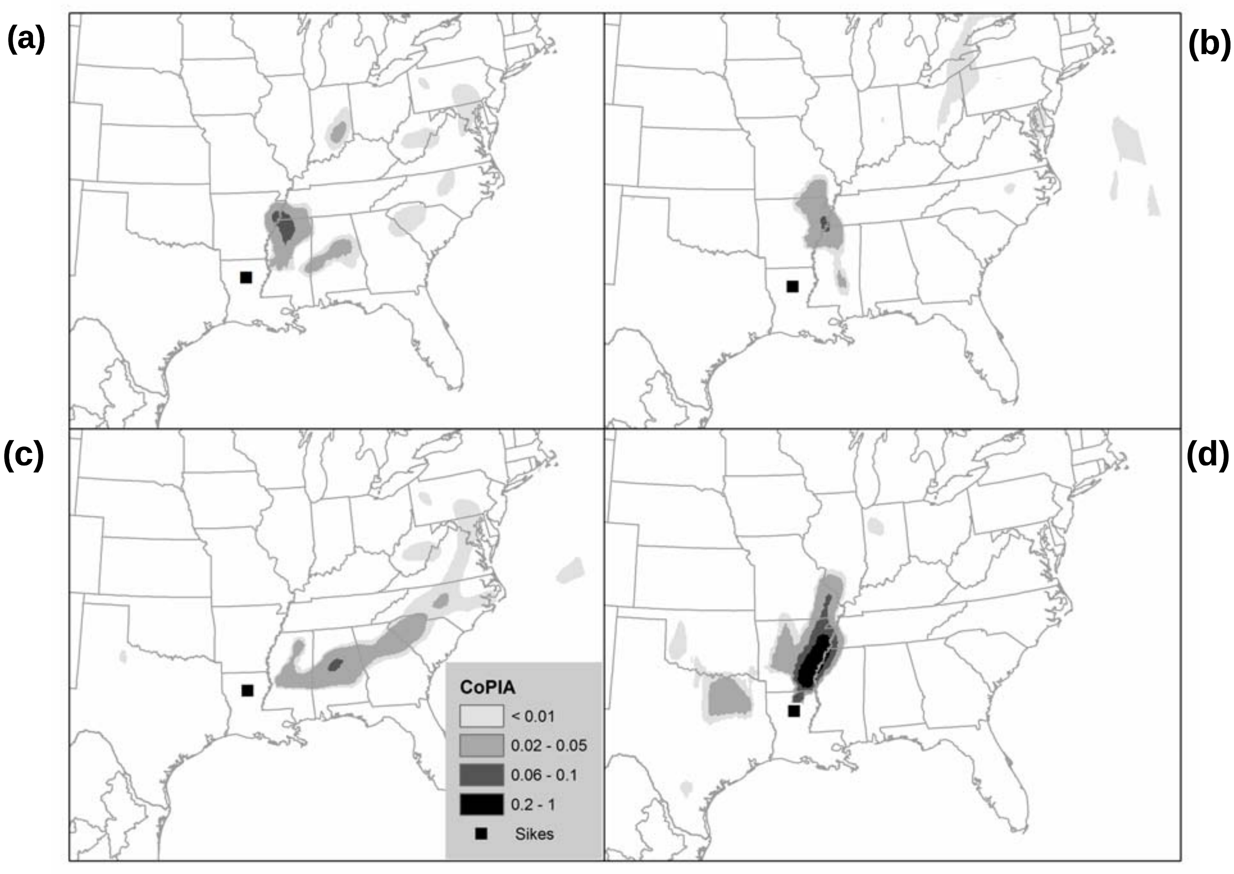


Figure 11. 10-day air mass back trajectories using the NOAA HYSPLIT model with 500 m and 1000 m ending heights on (a) July 1, 2002, and (b) July 31, 2002.

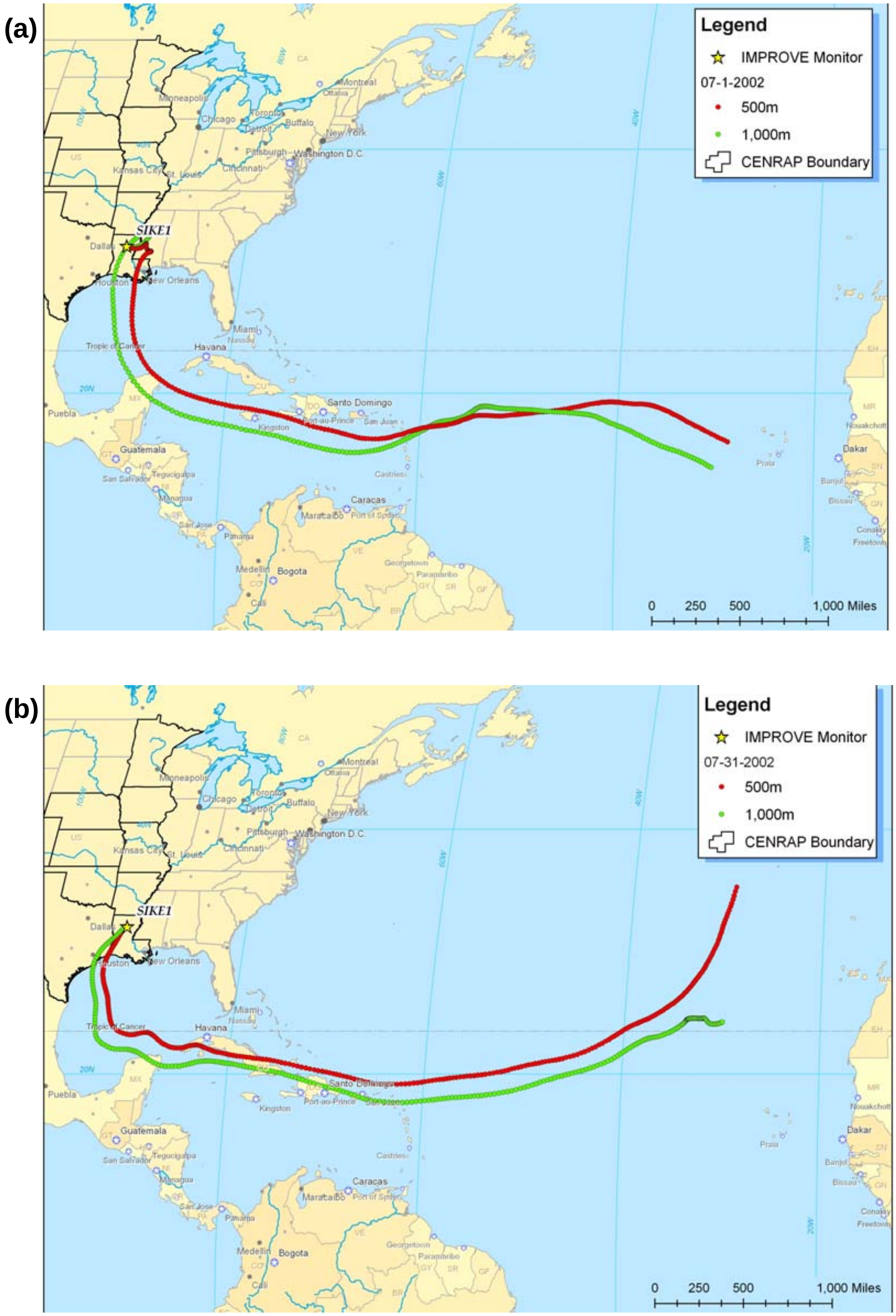


Figure 12. Three-day air mass backward trajectories using the NOAA HYSPLIT model with 250 m, 500 m, and 1000 m ending heights and fire locations on (a) August 4, 2003, and (b) April 19, 2001.

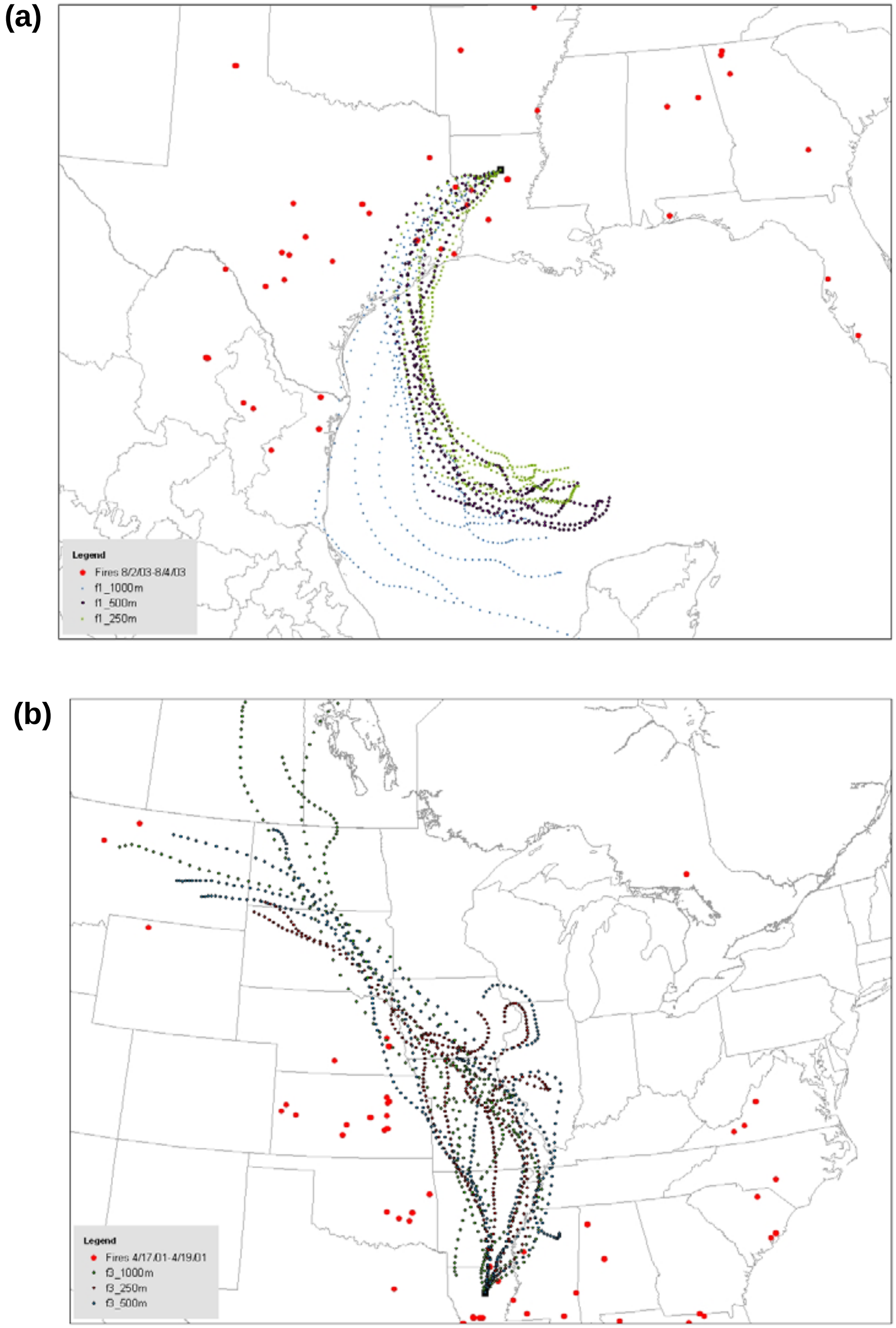
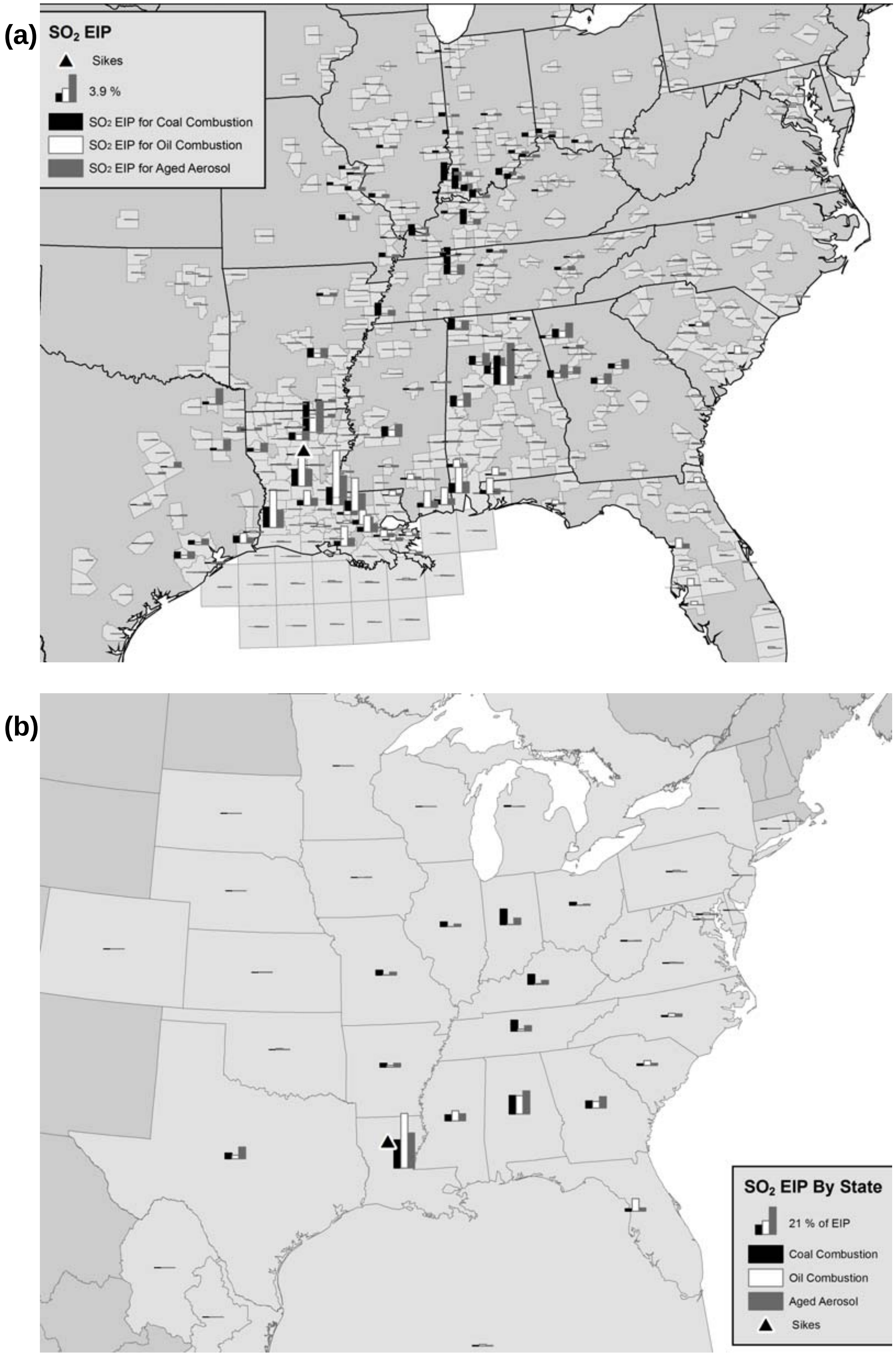


Figure 13. SO_2 EIP analysis for coal combustion, southeastern aged aerosol, and oil combustion factors by (a) county and (b) state.



Source Apportionment of $PM_{2.5}$ at Hercules-Glades, Missouri, Using Positive Matrix Factorization

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ABSTRACT

Speciated $PM_{2.5}$ data collected as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program at Hercules-Glades, Missouri, from March 2001 through February 2004 were analyzed using the multivariate receptor model, Positive Matrix Factorization (PMF). Over 300 samples with 23 species were utilized, including the organic carbon (OC) and elemental carbon (EC) analytical temperature fractions from the thermal optical reflectance (TOR) method. Eight factors were identified, with a good comparison between predicted and measured mass (slope = 0.98, $r^2 = 0.99$). Bootstrapping over 300 runs was used to determine the concentrations and uncertainties of each species in the factor profiles. A coal combustion factor was the largest contributor to mass (34% of the average mass on all days and 49% on the worst visibility days) and to ammonium sulfate, and was predominantly from coal-fired power plant emissions of SO_2 in the Ohio and Mississippi River Valleys. Urban southeastern carbonaceous aerosol was responsible for another 20% of the average mass, and 18%, on average, during the worst visibility days. A background aged aerosol factor was also identified, accounting for 10% of the average mass, and 9% on the worst visibility days. Oil combustion and Mississippi River industrial metals operations factors were minor contributors to the mass (8% and 5%, respectively). Nitrate contributed 11% of the average mass over all days and on the worst visibility days, due to nitrate episodes in the winter. Soil and burning were generally event-driven, and were 5% and 7% of the overall mass, and 4% and 6% of the mass on the worst visibility days, though a few high mass days were dominated by these source types. Conditional Probability Function (CPF) analysis applied to air mass trajectories and trajectories

paired with emission inventory to find emission impact potential (EIP) both helped better identify the factors and their source regions.

IMPLICATIONS

A subset of $PM_{2.5}$ data, the analytical carbonaceous fractions, was used to enhance the identification of factors in this source apportionment work. These carbonaceous fractions helped better differentiate and quantify carbonaceous aerosol factors that otherwise may not have been separated and apportioned as well. A more realistic treatment of x-ray fluorescence (XRF) data close to the detection limit was used to better characterize the known analytical uncertainties of, and provide a better fit for, certain species. Bootstrapping was used to better quantify the composition and uncertainties in the factor profiles by compiling results from 300 individual runs. Lastly, emission inventory data were paired with air mass trajectories to better understand the source regions affecting factors with sulfate. All of these techniques were used to improve the confidence in, and to aid policy makers in understanding, the results.

INTRODUCTION

Particles with diameters of less than 2.5 microns ($PM_{2.5}$) impact human health[1-4] and visibility.[5-7] The EPA has identified a number of $PM_{2.5}$ constituents, such as manganese, arsenic, lead, and diesel particulate matter (DPM), which pose a public health risk in urban areas.[8] There are also visibility regulations promulgated by the EPA directing states to reduce the worst-20% visibility days in their Class 1 areas. To better address these issues, it is vital to understand the composition and characteristics of the sources contributing to $PM_{2.5}$. Hercules-Glades is a Class 1 area located in southern rural Missouri near the border with Arkansas, approximately 50 miles from the closest urban area, Springfield, and less than 150 miles from larger urban centers such as Little Rock, Arkansas and Memphis, Tennessee. Sikes is generally impacted by transported aerosol from these urban areas and others such as St. Louis, Kansas City, and Indianapolis. This site is also impacted by regional dust events from the Great Plains and emissions from agricultural burns and forest fires in the area.

In previous analyses of $PM_{2.5}$ data using receptor models with only the organic carbon (OC) and elemental carbon (EC) values, it has been difficult to separate different sources of carbonaceous aerosols, such as gasoline-, diesel-fueled vehicles, aged aerosol transport, background aerosol, and fire emissions. Much of the $PM_{2.5}$ in these sources is carbonaceous,[9-13] and a simple ratio of OC to EC is typically insufficient to quantitatively separate various source types. In urban areas, attempts using receptor modeling and data analysis[14-16] to better determine the gasoline-diesel split, for example, have begun to rely on the carbon fractions resulting from the Thermal Optical Reflectance (TOR) protocol[17,18] technique. In rural areas, where the aerosol impacting a site is more aged, the motor vehicle and diesel emissions will generally impact the site together, and will be indistinguishable.[19-21] However, the use of the fractions may better apportion the carbonaceous aerosol between the local and aged transported air masses, and possibly better apportion the contribution from burning or other combustion sources.

METHODS

Data

$PM_{2.5}$ data from March 2001 through February 2004 were collected as part of the IMPROVE program[22] at the Hercules-Glades site, shown in Figure 1. These 24-hr samples were collected on Nylon, Teflon, and quartz fiber filters. Teflon filters were analyzed by gravimetric analysis for mass and by x-ray fluorescence (XRF) for elements. The Nylon filter was analyzed by ion chromatography (IC) for sulfate, nitrate, nitrite, and chloride. Ammonium (NH_4^+) was not analyzed, but its mass can be inferred from ionic balance with sulfate and nitrate.[23]

Quartz fiber filters were analyzed by the TOR method[17] to obtain eight thermally resolved fractions of carbonaceous aerosol. OC is volatilized in four steps, all in a helium atmosphere: (1) OC1 consists of the volatilized OC up to 120°C, (2) OC2 from 120° to 250°, (3) OC3 from 250° to 450°, and (4) OC4 from 450° to 550°. After the OC4 section is complete, a 2% O_2/98% He atmosphere is introduced to obtain EC1, and the temperature is then increased to 700°C for EC2 and to 850°C for EC3. A correction for the pyrolysis of OC is made. Pyrolyzed organic carbon (OP) is emitted when the O_2/He atmosphere is first introduced. This amount of OP is defined as the amount detected after the introduction of the O_2/He atmosphere at 550°C until the monitored filter reflectance returns to its original value. As reported, EC1 includes the OP fraction; thus, OP was subtracted from EC1 to get the correct EC1 concentration.

Data from the IMPROVE program are routinely validated before being made publicly available; therefore, the overall data quality was very good. Only valid samples from the IMPROVE data were used. Additional quality control (QC) checks performed in this study include comparison of reconstructed fine mass to measured mass and comparison of XRF sulfur to IC sulfate. Only species with good variability, such as those with a signal/noise ratio greater than 0.2 (not accounting for seasonal variability) and at least 25% of the data above detection, were used. In particular, no sodium or chloride data were used in this analysis; therefore, no sea salt factor could be identified, though the impact of sea salt at this site was expected to be minimal. Also, nickel was not used because more than 50% of the data were below detection, so vanadium will be used as the only marker for oil combustion in the PMF analysis. The final data set contained 328 samples with 23 species (see Table 1).

Source Apportionment With PMF

PMF is a multivariate factor analysis tool that has been applied to a wide range of data, including 24-hr speciated $PM_{2.5}$ data, size-resolved aerosol data, deposition data, air toxics data, and VOC data.[14-16,20,21,24-34] Simply, PMF decomposes a matrix of ambient data into two matrices, which then need to be interpreted by the analyst to discern the source types they represent. The method is considered briefly here and described in greater detail elsewhere.[35,36]

An ambient data set can be viewed as a data matrix X of *i* by *j* dimensions, in which *i* number of samples and *j* chemical species were measured. The goal of multivariate receptor modeling is to identify a number of sources *p* that best characterize the $PM_{2.5}$ at a site, the species profile *f* of each source, and the amount of mass *g* contributed by each source to each individual sample:

$$X_{ij} = \sum_{k=1}^{p} g_{ik} f_{kj} + e_{ij} \tag{1}$$

One strength of PMF is that results are constrained by a penalty function so that no sample can have a negative source contribution and no species can have a negative concentration in any source profile. Another strength of PMF, compared to other source apportionment tools such as principle component analysis (PCA), is that each data point can be weighed individually. This feature allows the analyst to adjust the influence of each data point, depending on the confidence in the measurement. Data below detection can be retained for use in the model, with the associated uncertainty adjusted so these data points are given less weight in the model solution (i.e., these data have less influence on the solution than measurements above the detection limit). By individually weighing data, samples with some species missing or below detection do not need to be excluded as a whole, rather the analyst can adjust the uncertainty so these data also have little or no impact on the final solution. The PMF solution minimizes the object function Q(E), based upon these uncertainties (*u*):

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} f_{kj}}{u_{ij}} \right]^2 \tag{2}$$

Methods used in this analysis for replacing and developing uncertainty values for missing and below-detection-limit data were drawn from previous work with PMF.[20,21,25,26,28,37] Since the solution found by PMF relies on both concentration data and on error estimates, these error estimates must be chosen judiciously so that they reflect the quality and reliability of each data point. The missing and below-detection-limit data are assigned less weight compared to actual measured values, so these data are less important to the solution.[20,21,25,26,28,37] Data below the minimum detection limit (MDL) were substituted with MDL/2; missing data were substituted with the median concentration. Similar to previous studies, the uncertainty for data above detection was calculated as the sum of the analytical uncertainty (UNC) plus one-third the MDL, uncertainty for data below detection was 5/6*MDL, and uncertainty for missing data it was four times the median. Additionally, it has shown that XRF data reported above MDL but below approximately 10*MDL are more uncertain;[38] therefore, these data were assigned an uncertainty twice as high as concentrations above this threshold, i.e., 2*(UNC+MDL/3).

The robust mode was used in this analysis to reduce the influence of outliers; between 5 and 13 factors were explored. The uncertainty of the amount of each species in a given factor was determined by bootstrapping 300 runs and calculating the interquartile range of the factor loading over these runs. This was done using multiple starting points and rotations, so that the range of solutions PMF gives can be used as a measure of the confidence in a given factor. Scaled residuals were inspected and were between -3 and 3 for all species demonstrating a good fit of the modeled results. The factors also showed oblique edges, which has been proposed as an additional check of the quality of the rotation.[39] A multi-linear regression (MLR) was applied to scale the factors back into the original μg/m^3 units by regressing the total measured PM$_{2.5}$ mass against the unscaled factor strength contributions:

$$X_{ij} = \sum_{k=1}^{p} \left(s_k g_{ik}\right)\left(\frac{f_{kj}}{s_k}\right) \tag{3}$$

The resulting coefficients were then applied to each factor to regain the μg/m^3 units.

Conditional Probability Integrative Analysis

A conditional probability function (CPF) was applied to help interpret the results.[14,16,24,40] The transport patterns of the highest 10% concentration days of a given factor were compared to the climatological transport patterns. This comparison highlights the differences in transport and areas of influence between the general transport pattern (i.e., the climatology) and high concentration days of a given factor. Using the NOAA HYSPLIT model,[41] 96-hr backward trajectories were run for all sample dates, which were then mapped as a spatial probability density (D_0):

$$D_0 = \frac{D_c}{\hat{D}} \tag{4}$$

D_c = Density at grid cell c

$\hat{D}$ = Maximum density over all grid cells (typically the density at the receptor site)

$$D_c = \sum_{i=1}^{n} \kappa_R(r_n) \tag{5}$$

r_n = distance between grid cell center and hourly trajectory point n

$$K_R(r) = \text{kernel density function} = \begin{cases} \dfrac{3}{\pi R^2}\left[1-\left(\dfrac{r}{R}\right)^2\right]^2 & for\ r < R \\ 0 & for\ r \geq R \end{cases} \tag{6}$$

R = search radius

The search radius was determined dynamically by dividing the geographic extent of all endpoints by 30.[42,43] The density D_k was then computed using only backward trajectories for the highest 10% concentration days of a given factor k. Areas that have a higher than typical influence on the high concentration days are then highlighted by calculating the conditional probability P_k:

$$P_k = D_k - D_0 \tag{7}$$

This Conditional Probability Integrative Analysis (CoPIA) is very similar to the CPF analyses employed in other studies;[14,16,24,40] however, CoPIA is adapted to take advantage of tools available in a geographic information system (GIS) framework. Ensemble backward trajectories were run every 6 hours to account for variability over a 24-hr sampling period. Emissions data, such as point source and fire locations, were overlaid on the CoPIA analysis to identify specific emissions sources in likely source areas.

Emission Impact Potential (EIP) Calculations

While trajectory analyses such as CoPIA can help identify transport patterns and likely areas of influence, only a broad conclusion can be reached, such as "the factor showed influence from the Ohio River Valley". However, this analysis only accounts for transport, and not the spatial distribution or magnitude of emissions. For example, a large, distant source and a small nearby source could influence a site in a similar way. To gain a better understanding of the source regions for a given factor, a GIS-tool was used to weight county-level emission inventory data by the trajectory kernel density of the highest 10% concentration days for a given factor. For a given factor, SO_2 emissions were weighted by the frequency and residence time of modeled backward trajectories passing over each county to estimate the potential for emissions from each county to impact the site. This is called the emission impact potential (EIP). This simple analysis technique is useful for characterizing general patterns and developing a preliminary conceptual model of factors affecting visibility conditions, but without the need for, and as an initial step toward, full-scale photochemical modeling efforts.

The EIP of a given county is calculated as:

$$EIP = \frac{E_p * D_0}{f(\text{distance})} \tag{8}$$

where

E_p = county total emissions of pollutant p

D_0 = spatial probability density at the county centroid

f = function of distance between county and receptor

The EIP may be divided by a distance function to roughly account for dilution and increased uncertainty in model outputs far from the receptor site. However, for this study, $f = 1$, assuming vertical dilution is similarly small compared to the horizontal transport distance for all areas and the kernel density sufficiently accounts for horizontal dilution and uncertainty. This tool is used for simple analysis only, and does not account for atmospheric chemistry, deposition, or other effects, but is expected to qualitatively provide insight into the potential sources affecting mass.

RESULTS AND DISCUSSION

Preliminary Data Analysis

Preliminary data analysis was conducted to gain insight into the trends and relationships among species that would impact later source apportionment with PMF. Inspection of the overall composition, changes in composition by season or on days of poor visibility, species relationships, and day-of-week trends assisted in identifying possible source types.

Annual Median Composition. Figure 2 shows the median $PM_{2.5}$ composition. Ammonium sulfate and nitrate concentrations are calculated from sulfate and nitrate concentrations, assuming full neutralization by ammonium. OC is represented by OC mass (OMC), equal to 1.4 times OC,[44,45] which takes into account the mass of oxygen and hydrogen associated with the carbon, though this factor may actually be higher than 1.4.[44,46] As shown in Figure 2, ammonium sulfate is the dominant component (accounting for 48% of the average mass), followed by OMC (27%). Ammonium nitrate is 13%, soil is 8%, and EC is 4%. Dominance of ammonium sulfate is typical of the eastern half of the United States, and the significant portion of mass from OMC demonstrates the importance of determining its source regions. Ammonium nitrate concentrations are significant mainly in the winter, and are important to wintertime $PM_{2.5}$ and visibility episodes.

Seasonal Composition. Changes in $PM_{2.5}$ mass and composition between seasons (Figures 3a and 3b) may reflect differences in transport regimes, atmospheric chemistry, or source strengths. Mass is highest in spring through fall, with a summer peak, and then drops off significantly in the winter. Ammonium sulfate contributions to mass range between a peak in the summer (60% of the mass) and a low (30%) in the winter. This large swing in sulfate concentrations is likely caused by meteorology affecting both transport and chemistry. OMC concentrations are similar throughout the year, accounting for between 25% and 30% of the mass. In spring and summer, soil contributions are between 9% and 12%, caused by wind-blown dust impacts likely from the arid western plains, while in fall and winter soil contributions are 5% or less. Nitrate accounts for 35% of the mass in winter, and is at a minimum in summer (4%). These seasonal differences are expected to be observed in PMF analysis and may be because of changes in sources or transport, which will be analyzed further using results from PMF analysis.

Composition on Poor Visibility Days. To investigate which components (i.e., OMC, sulfate, soil, etc.) have the greatest impact on days with severely impaired visibility, the $PM_{2.5}$ composition on the worst-20% visibility days (referred to as the worst visibility days in the remainder of this article) was examined (Figure 4a). Using the IMPROVE equation,[22,23] which likely does not fully account for extinction by OC,[47] the total light extinction (b_{ext}) contribution of each chemical component was calculated. On poor visibility days, which occurred in all months but predominantly in summer, the average $PM_{2.5}$ mass was 17.3 $\mu g/m^3$ with 55% of the mass attributable to ammonium sulfate, 24% to OMC, 12% to ammonium nitrate, and the remaining mass to soil and EC. Sulfate is an even larger part of the mass on these worst visibility days than on average. The analysis of the estimated contributions to light extinction in Figure 4b further shows the importance of ammonium sulfate because it dominates the light extinction (68% on average), followed by ammonium nitrate (14%) and OMC (13%), though the contribution from OMC is likely underestimated. This shows that while sulfate is by far the most important component of visibility extinction, wintertime episodes caused by nitrate and OMC are also important, and both regimes need to be considered when developing control measures.

Species Relationships. Species relationships were investigated because the degree of covariation among species impacts how species and sources are allocated in source apportionment. It is important to understand these relationships before conducting source apportionment to ensure that PMF results fit within in the context of the data. One example, Figure 5a, shows the fair relationship between ammonium sulfate and selenium ($r^2 = 0.63$), which is typical of coal combustion, although the amount of scatter also suggests other existing sources of these species. Potassium, often used as a tracer for wood smoke,[48,49] had some correlation in a number of samples with EC (Figure 5b) and OC (not shown), which are also emitted by wood combustion.[48,50] The relationship between potassium and OC and EC indicates that a smoke factor may be found by PMF, but that the majority of the carbonaceous aerosol is likely not associated with burning. Metals typically emitted from industrial processes, such as smelting, including arsenic, lead, and zinc, showed fairly good correlations, an example of which is shown between zinc and lead in Figure 5c. These relationships will be useful in determining non-coal combustion sources of industrial emissions.

PMF Results

Eight factors were resolved for the ambient $PM_{2.5}$ at Hercules-Glades and identified as (1) coal combustion, (2) urban carbonaceous, (3) background aged aerosol, (4) oil combustion, (5) industrial metals, (6) nitrate, (7) soil, and (8) burning. Factor profiles with the standard deviation over 300 runs graphed as the error bars are shown in Figure 6, and a time series of all samples (every third day) are shown in Figure 7. The PMF solution accounted for the measured mass well, with a slope of 0.98 and r^2 of 0.98 between reconstructed and measured mass (Figure 8). The average compositions over all seasons and on the worst visibility days during the time period are shown in Figure 9. Figure 10 shows CoPIA plots for coal combustion, urban carbonaceous, nitrate, and industrial metals. Figure 11 shows air mass trajectories on a day of high soil, July 1, 2002, demonstrating a likely Saharan dust episode. Figure 12 shows air mass trajectories on days of high burning influence with fire locations from MODIS. Lastly, Figure 13 shows SO_2 EIP analysis results by county and by state for coal combustion, aged aerosol, and oil combustion.

The coal combustion factor was the largest contributor to mass (34% of the median mass on all days and 49% on the worst visibility days), and accounted for most of the ammonium sulfate. Carbonaceous aerosol from urban areas, most likely from mobile sources, accounted for 20% of the mass overall, and 18% on the worst visibility days. A background aged aerosol factor was responsible for another 10% of the mass on all days, and 9% of the mass on the worst visibility days. Oil combustion and industrial metals factors were more minor contributors to the mass (8% and 5%, respectively), and contributed much less on the worst visibility days (2% and 1%, respectively). A nitrate factor was significant only during the winter, and was 11% of the mass, on average, and on the worst visibility days, due to wintertime nitrate episodes. Soil and local burning emissions were both event-driven factors, and while they were 5% and 7% of the overall mass and only 4% and 6% of the mass on the worst visibility days, soil- and burn-events occurred where these factors were likely the largest impact on visibility. Overall, regional coal combustion and urban aerosol accounted for most of the mass on the worst visibility days, with regional coal combustion likely responsible for most of the visibility degradation caused by the high amount of ammonium sulfate.

A coal combustion factor was identified by typical tracers of coal combustion—sulfate, selenium, and hydrogen.[20,25,26,51] This factor was the largest component of the mass on all days (34%), and accounted for half of the mass on the worst visibility days (49%). Since most of the factor's mass is from ammonium sulfate, this factor is likely even more important in terms of visibility extinction. Ammonium sulfate accounted for 65% the mass at Hercules-Glades, and most of the sulfate is found in this factor; the remaining sulfate is found in the urban industrial, oil combustion, and background aged aerosol factors. This factor was highest on days with transport from the Ohio River area, where many coal-fired power plants are located and which has been identified as a significant area for the origin of sulfate transport in other studies in the mid-Atlantic and Northeast.[20,25,26,51] EIP analysis corroborates this, showing more than half of the SO_2 EIP comes from this area. In the county-level map, it is clear that a handful of sources in a few counties are responsible for most of the SO_2 emissions impacting Hercules-Glades.

An urban carbonaceous aerosol factor, mostly likely from mobile sources, accounted for 20% of the mass, and 18% on the worst visibility days. It consisted of all of the analytical carbonaceous fractions except OP, zinc, bromine, and hydrogen. This factor was highest with slow-moving air masses from the south, with influences from the urban areas in Arkansas, Tennessee, Mississippi, and Louisiana. This factor did not show a weekday-weekend difference; because mobile emissions are low close to the site, no weekday-weekend effect is expected. Except for one event, this factor did not show a large seasonal difference, which would be expected from a mobile source/urban signature. On the worst visibility days, the factor's mass was similar to its average contribution, but since the overall mass was higher, this factor contributed less to the worst visibility days on average.

A background aged aerosol factor was composed mostly of carbonaceous aerosol, predominantly the OP and EC1 fractions, consistent with earlier data analysis. The separation of this factor was made possible by the use of the carbonaceous fractions. This factor was higher during the summer, when there would be increased photochemistry, and comprised 10% of the mass over all days, and 9% on the worst visibility days. CPF analysis showed that transport patterns on the highest concentration days of this factor are no different than the average climatology, indicating that this factor is simply a background aged aerosol factor. There is likely a biogenic component to this factor, as it was significantly lower in the winter than in other months, consistent with biogenic emissions. This factor is possibly a combination of various background anthropogenic and biogenic emissions in the region, and is not attributable to any single primary source type.

Oil combustion was identified by its typical marker, vanadium.[14,20,21,24-26,52,53] As expected, this factor is highest on days with transport from the numerous oil refineries and drilling stations in Louisiana, Texas, Florida, and in the Gulf of Mexico. This factor contributed 8% of the mass, and on the worst visibility days, the factor contributed only 2% to the total. Most of the mass of this factor is from sulfate, and SO_2 EIP analysis shows that about half of the influence is from Texas and Louisiana alone, with other areas such as Florida also contributing.

Another industrial factor, consisting of copper, lead, zinc, and arsenic, was also identified. This factor was a minor part of the median mass (5%), but it contained most of the mass of the toxic pollutants lead and arsenic. This factor comes from a source region different than the oil combustion, coal combustion, and urban industrial factors. Similar to coal combustion, EIP analysis showed this factor was influenced by Indiana, Kentucky, Illinois, and Tennessee, but also showed significant influence from Louisiana and Texas. Part of this factor may be coal combustion, but it is likely representative of the variety of smelting and other industrial operations in these areas. Figure 10d shows the CoPIA results combined with point source locations of smelter and ore processing facilities, indicating potential influence of these facilities.

An ammonium nitrate factor was identified because it has a very strong seasonal signal independent of other components. It is highest in the winter, and is extremely low in warmer months, when nitrate production would be limited because of the ambient temperature. This factor was 11% of the mass on average and on the worst visibility days. In the winter, this factor accounted for on average 34% of the mass and was responsible for some visibility extinction episodes. This factor was highest under conditions of slow moving cool air masses from the rural areas of northwest Missouri, Iowa, Nebraska, and Kansas.

A soil factor was identified by silicon, iron, and titanium and was fairly low except during dust events. There were only a few large events when this factor had high concentrations, including the biggest event on July 1 2002, which was also seen at Sikes, Louisiana. This sample had the highest concentration of the soil factor by far, at 19.6 $\mu g/m^3$, while typically the factor averaged only 0.6 $\mu g/m^3$ (5% of the mass). Trajectories (Figure 11) suggest that this high soil factor day may have been Saharan dust episodes; 10-day backward trajectories show fast transport over the Atlantic Ocean. Other days with high concentrations of this factor appear to be caused by transport over the Great Plains. Despite the large spikes in the soil factor concentrations, none of the highest concentration days occurred on the worst visibility days, indicating that while there can be events in which the soil contribution to ambient $PM_{2.5}$ is important, this factor is not as important as others during the worst visibility days.

A wood and biomass burning factor was identified by the presence of potassium[48-50,54] and a small amount of carbonaceous aerosol. The analytical carbonaceous fractions aided in identifying and quantifying this factor, since runs using only a total OC and EC did not effectively resolve this factor. Air mass trajectories were combined with fire location satellite data to better identify this factor, and the combination suggests this factor is significant only when local burning and conducive flow patterns from fire locations occur. On the two highest concentration days of this factor, April 12, 2003, and May 9, 2003, air mass trajectories show transport from nearby fire locations (Figure 12). Samples where this factor showed high concentrations were usually caused by nearby fires, rather than long-range multi-day transport. Overall, this factor accounted for 7% of the median mass, and 6% on the worst visibility days. Some of the days with high burning factor concentrations were episodes of poor visibility, but on average this factor was less important than coal combustion and other factors. However, this is likely a lower limit of burning influence; PMF would not be able to fully quantify a burning factor because the factor profile likely varies with every episode because of source distance, fuel type, and atmospheric chemistry during transport. With sampling every day during the spring and summer, or use of organic molecular markers such as levoglucosan,[48,50,53-58] this factor will likely be better estimated.

CONCLUSIONS

PMF was applied to speciated $PM_{2.5}$ data collected as part of the IMPROVE program at Hercules-Glades, Missouri, from March 2001-February 2004. Modeled results accounted for the mass and were consistent with known sources and their locations. The use of the analytical OC/EC fractions, better uncertainty estimates for data near the detection limit, and bootstrapping all helped better apportion and quantify the uncertainties in the identified factors. Nine factors were identified as: (1) coal combustion, (2) urban carbonaceous, (3) background aged aerosol, (4) oil combustion, (5) industrial metals, (6) nitrate, (7) soil, and (8) burning. CPF analysis and emission inventory data were used to confirm the identification of sources. Calculating EIP by combining trajectory density with county-level emission inventory data helped identify the source regions for particular factors. Results showed that a combination of local (such as burning, nitrate, urban carbonaceous, and industrial metals) and regional (coal combustion, background aerosol, and oil combustion) factors impact the site. However, on the worst visibility days, coal combustion accounted for about half of the mass, with urban carbonaceous aerosol and nitrate during the winter also important. Event-driven factors such as biomass/wood burning and soil were clearly evident, though their impact was important only during their severe events.

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Keywords

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Table 1. Summary statistics of species used in PMF analysis (in $\mu g/m^3$) for Hercules-Glades March 2001–February 2004 (N=328).

Species	Median	Mean	Standard Dev	N Missing	N below 10*MDL and above MDL	N below MDL	% below MDL
AS	0.0003	0.0003	0.0002	1	253	81	24
BR	0.0018	0.0022	0.0014	1	4	0	0
CU	0.0005	0.0005	0.0003	1	213	17	5
EC1	0.43	0.48	0.24	1	47	0	0
EC2	0.084	0.092	0.054	1	294	25	7
EC3	0.0031	0.0076	0.0097	1	145	189	57
FE	0.026	0.045	0.086	1	0	0	0
H	0.42	0.50	0.29	1	0	0	0
K	0.048	0.060	0.049	1	3	0	0
MN	0.0008	0.0012	0.0016	1	81	49	15
NO3	0.41	1.1	1.36	2	91	3	1
OC1	0.063	0.11	0.12	0	200	106	32
OC2	0.28	0.35	0.24	0	175	8	2
OC3	0.54	0.69	0.58	0	201	3	1
OC4	0.44	0.53	0.42	0	64	0	0
OP	0.20	0.22	0.17	1	188	32	10
PB	0.0016	0.0018	0.0011	1	44	0	0
SE	0.0005	0.0006	0.0004	1	130	4	1
SI	0.12	0.20	0.29	1	14	0	0
SO4	2.60	3.29	2.61	2	1	0	0
TI	0.0025	0.0060	0.011	1	26	16	5
V	0.0002	0.0005	0.0008	1	145	124	37
ZN	0.0046	0.0051	0.0027	1	3	0	0

Figure 1. Location of the Hercules-Glade, Missouri, IMPROVE air quality monitoring site.

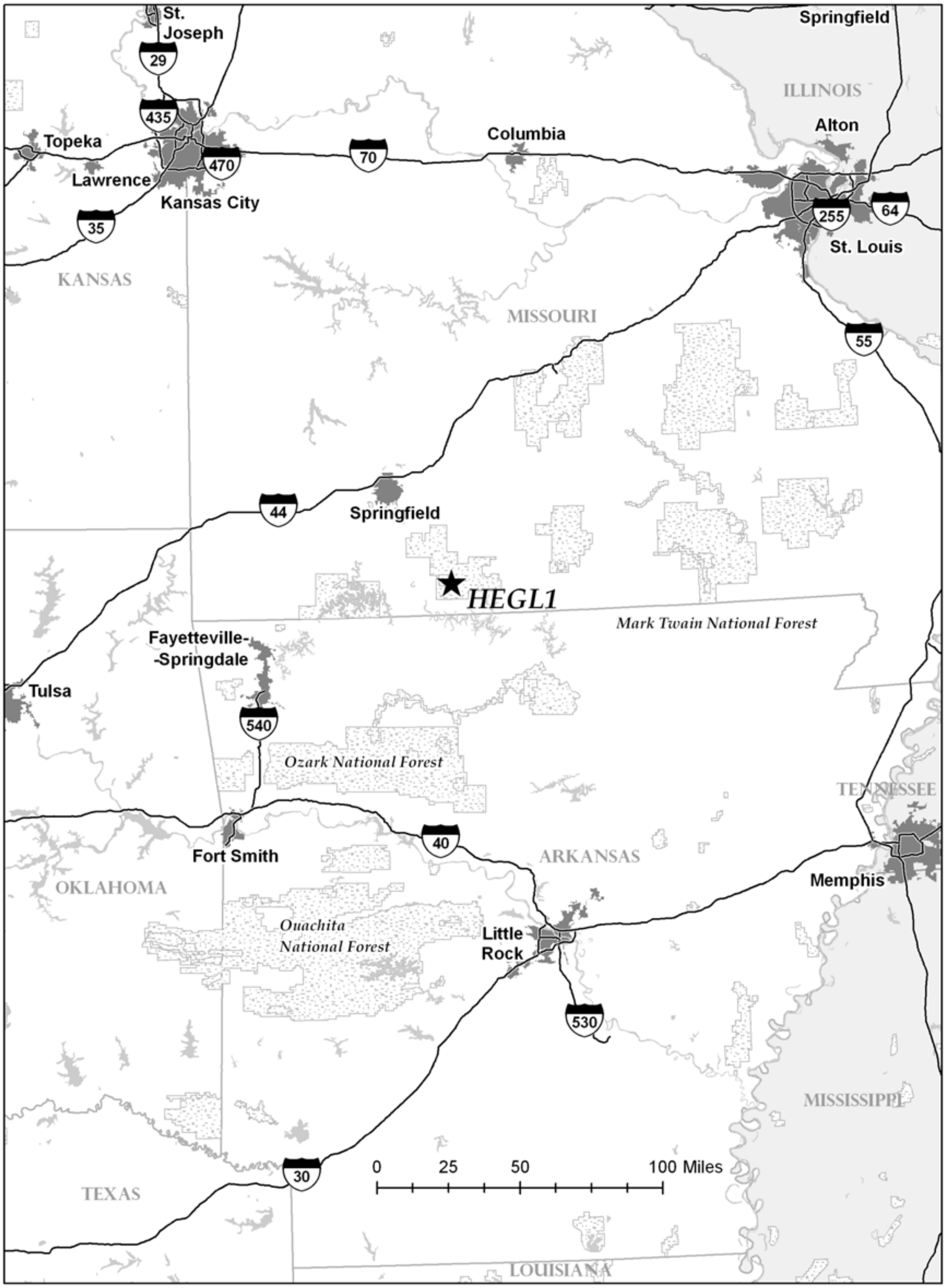


Figure 2. Average $PM_{2.5}$ composition by major component (OMC = 1.4*OC) for all valid data March 2001–February 2004.

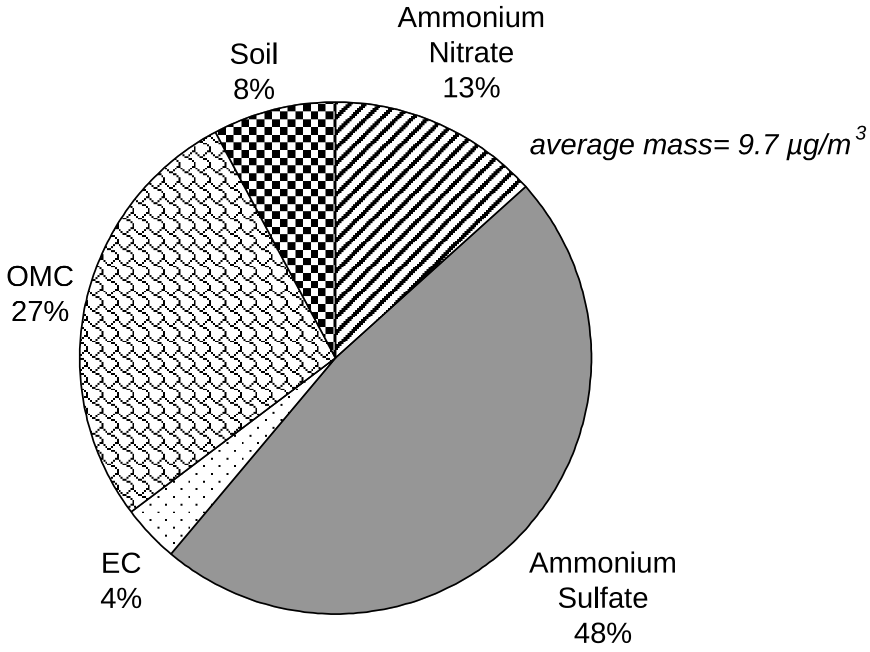


Figure 3a. Average composition ($\mu g/m^3$) by season (spring = March through May, summer = June through August, etc.) at Hercules-Glade, March 2001–February 2004.

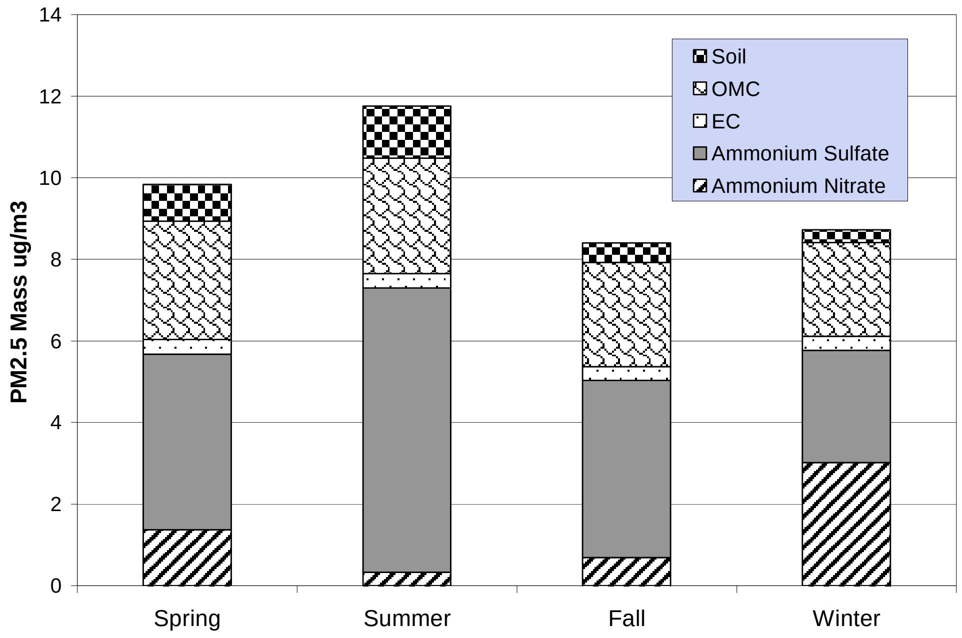


Figure 3b. Average composition (percentage) by season (spring = March through May, summer = June through August, etc.) at Hercules-Glade, March 2001–February 2004.

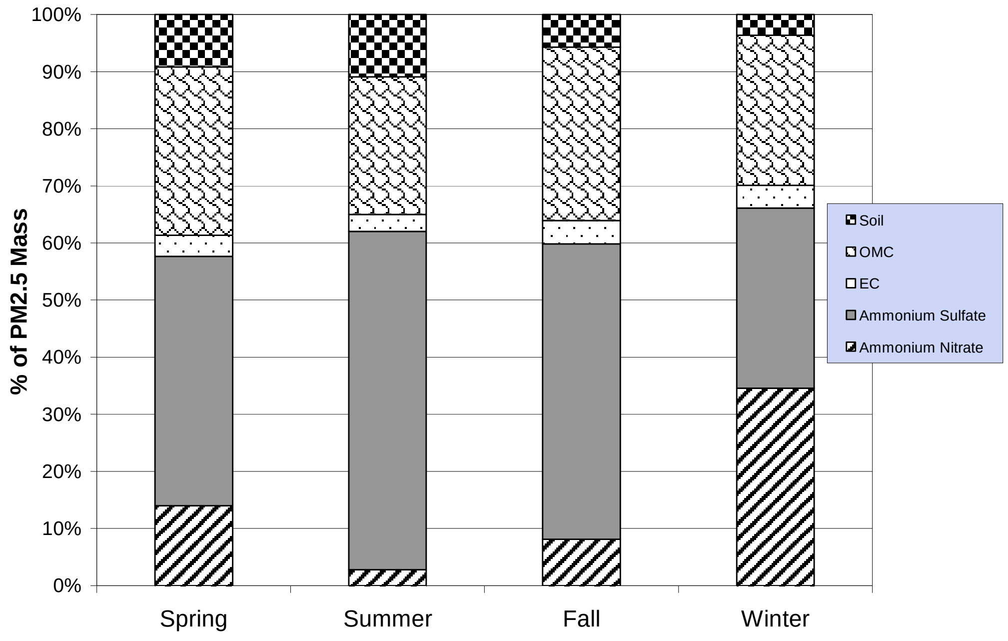


Figure 4a. Median composition on the worst-20% visibility days at Hercules-Glade, March 2001–February 2004.

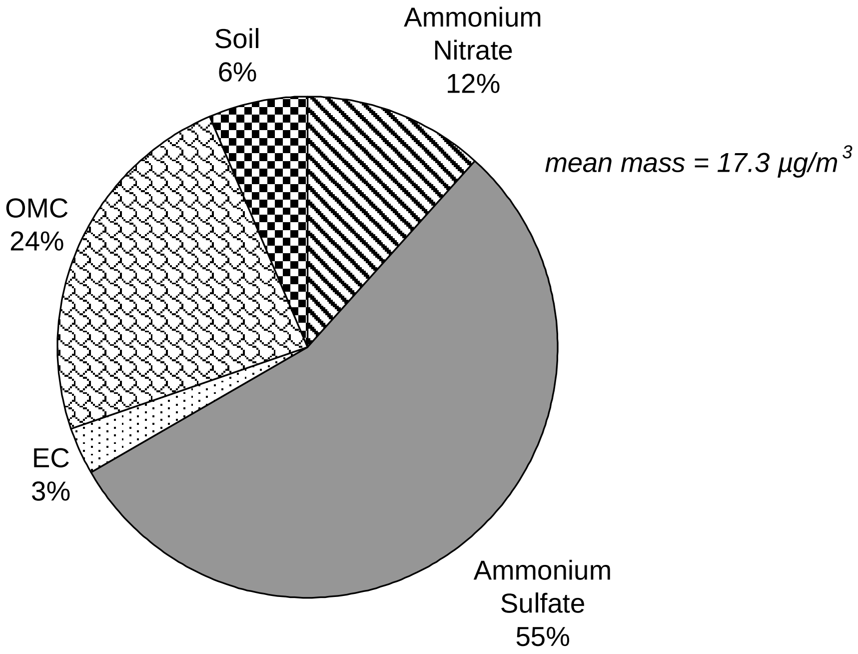


Figure 4b. Median composition of b_{ext} (aerosol extinction) based on the IMPROVE visibility equation on the worst-20% visibility days at Hercules-Glade, March 2001–February 2004.

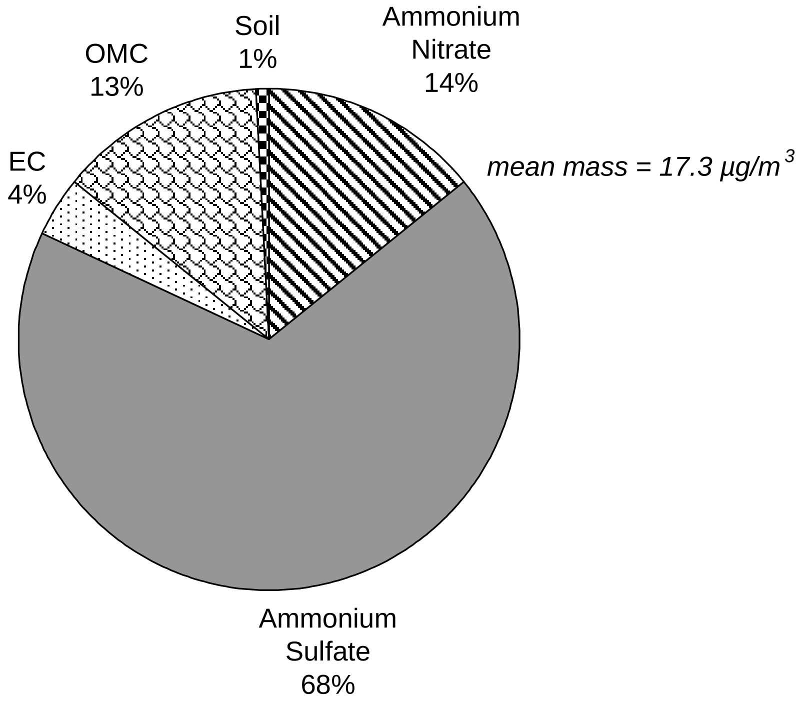


Figure 5a. Scatter plot of ammonium sulfate versus selenium by season (µg/m^3) where 1 = spring, 2 = summer, etc.

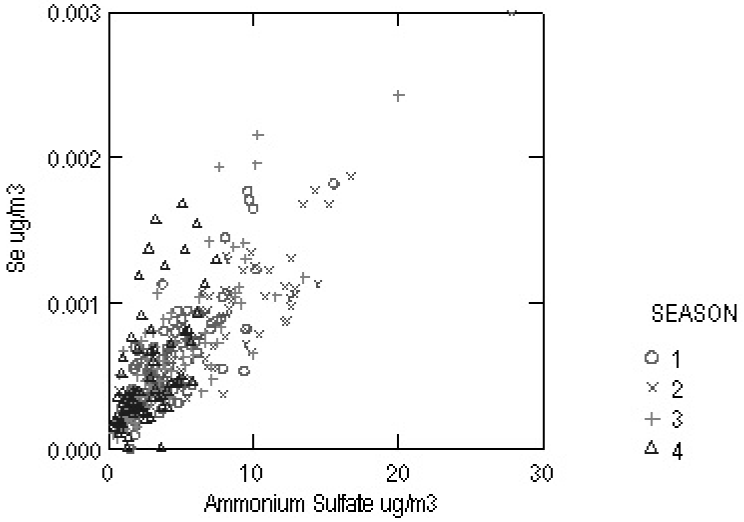


Figure 5b. Scatter plot of potassium versus EC by season (µg/m^3) where 1 = spring, 2 = summer, etc.

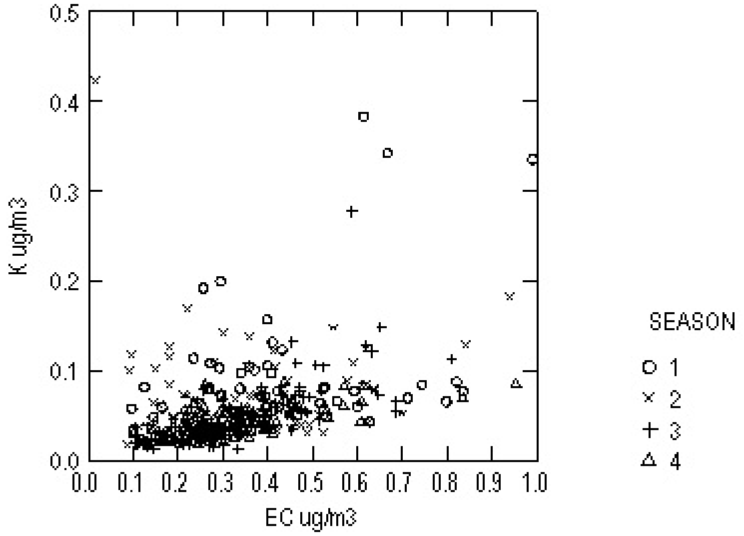


Figure 5c. Scatter plot of lead (PB) versus zinc (ZN) by season ($\mu g/m^3$) where 1 = spring, 2 = summer, etc.

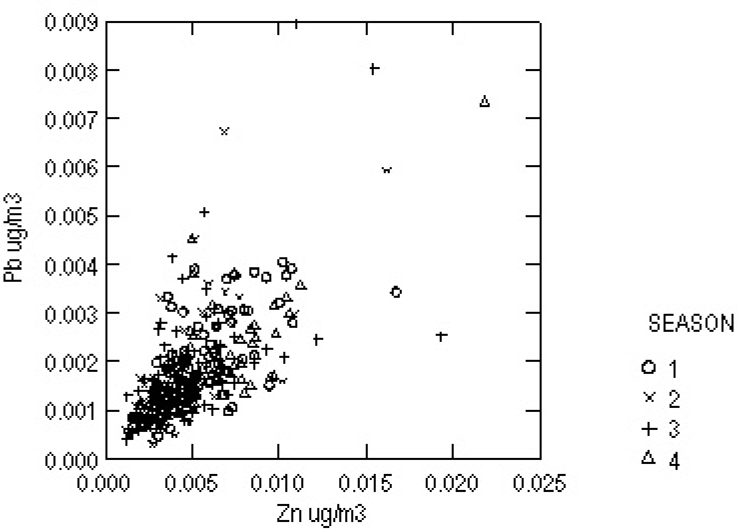


Figure 6. Factor profiles (percent of species in factor). Error bars represent the standard deviation of the factor loading over 300 runs.

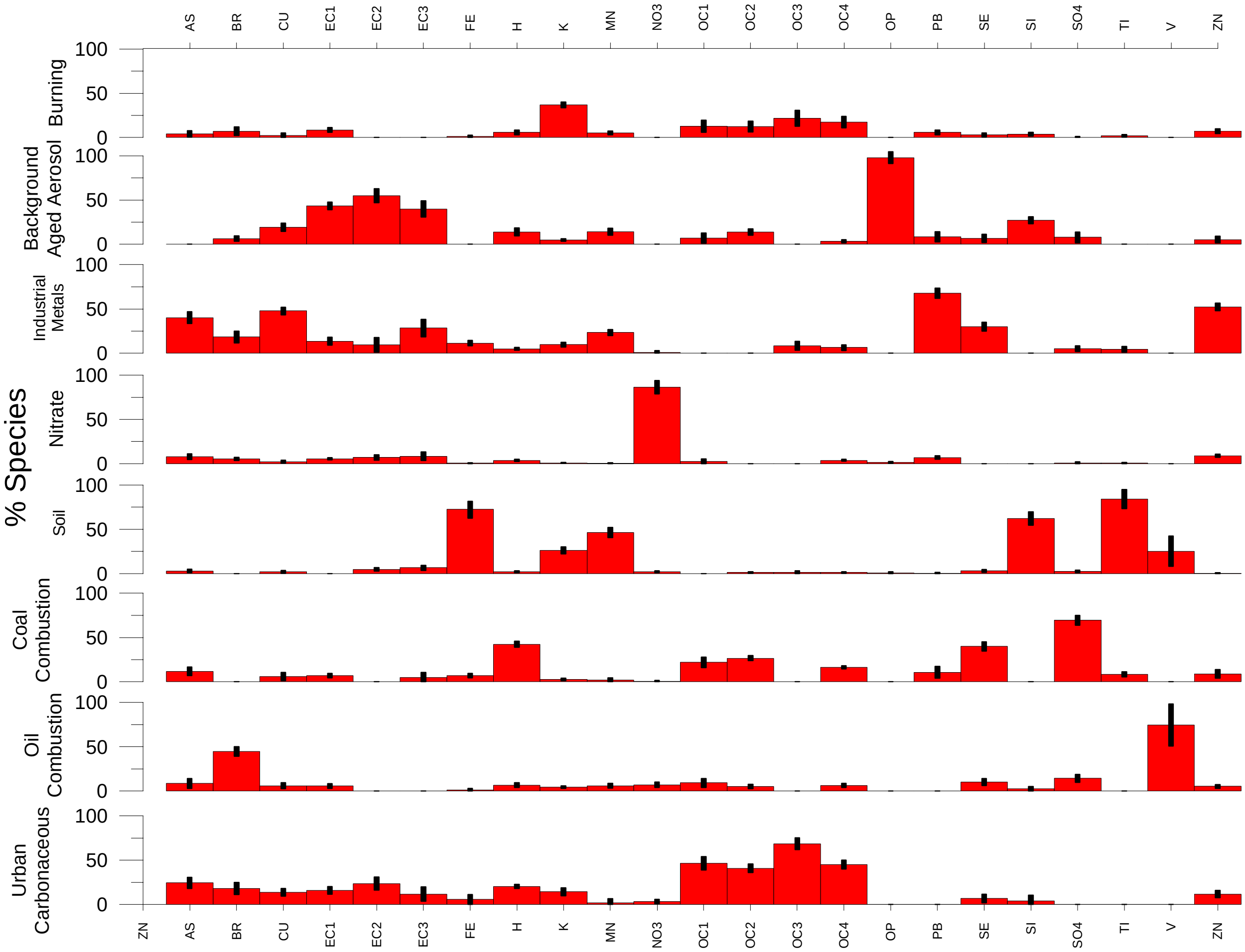


Figure 7. Time series of factor strengths by date (μg/m^3).

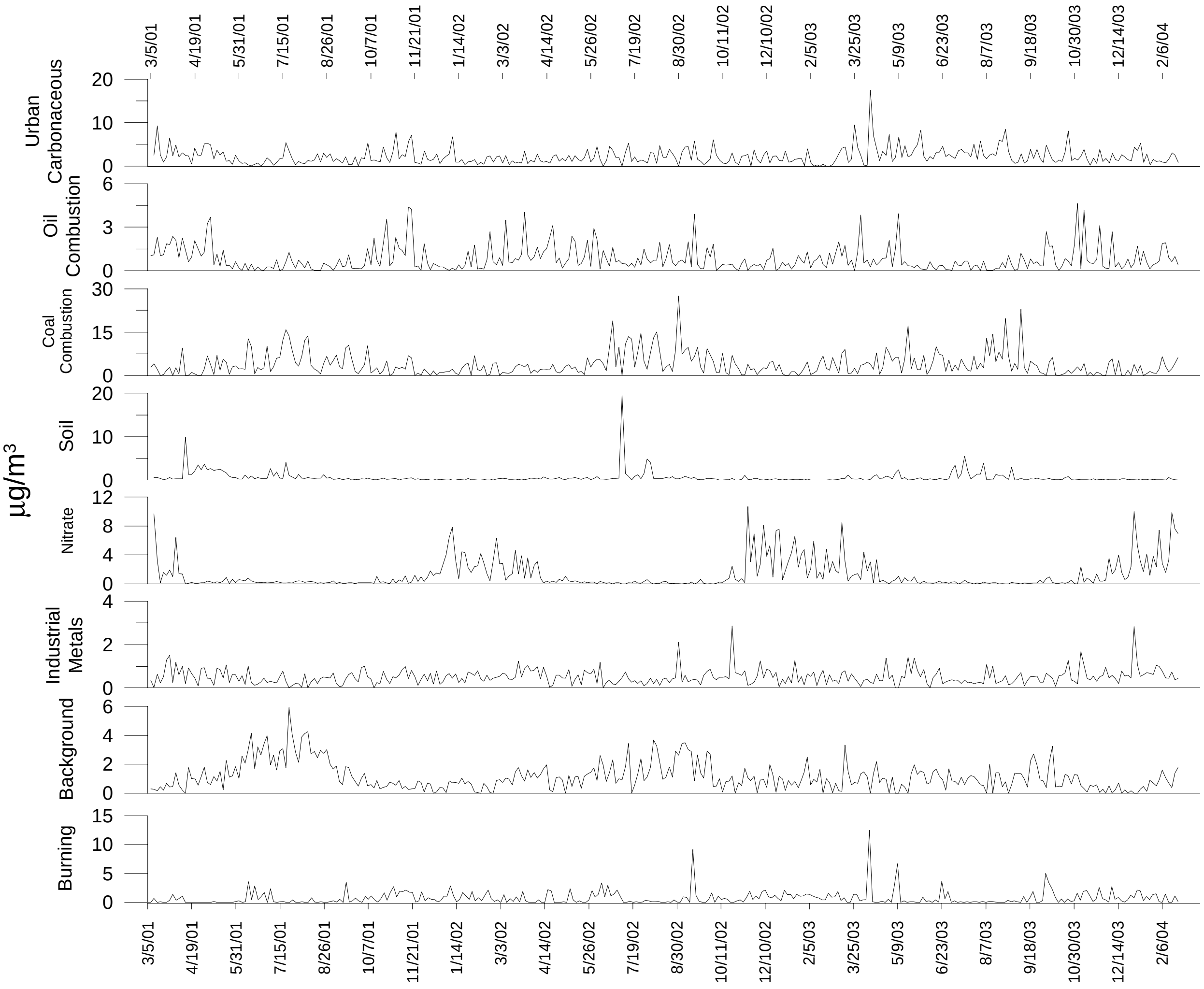


Figure 8. Reconstructed mass versus measured $PM_{2.5}$ mass.

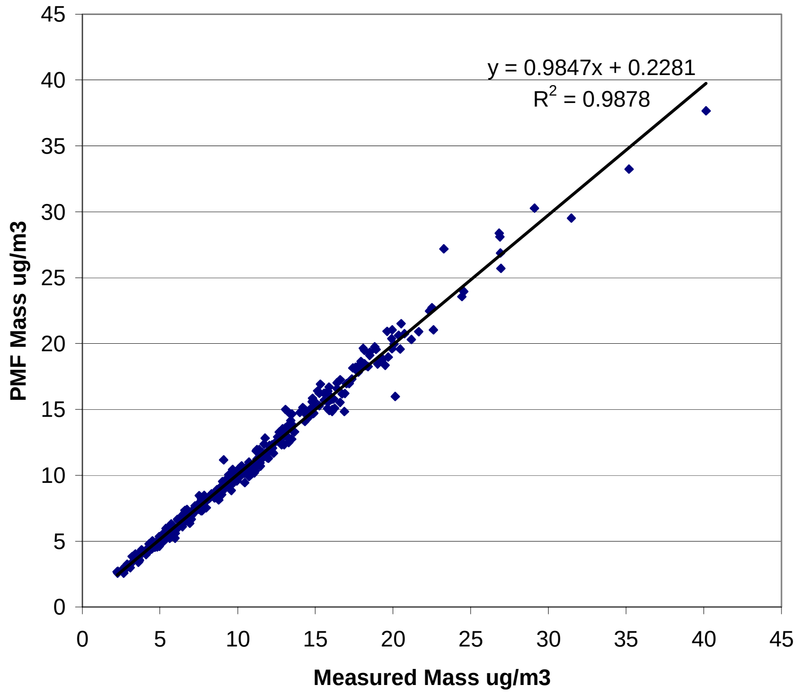


Figure 9. Average factor contribution estimates for (a) all samples and (b) the worst-20% visibility days.

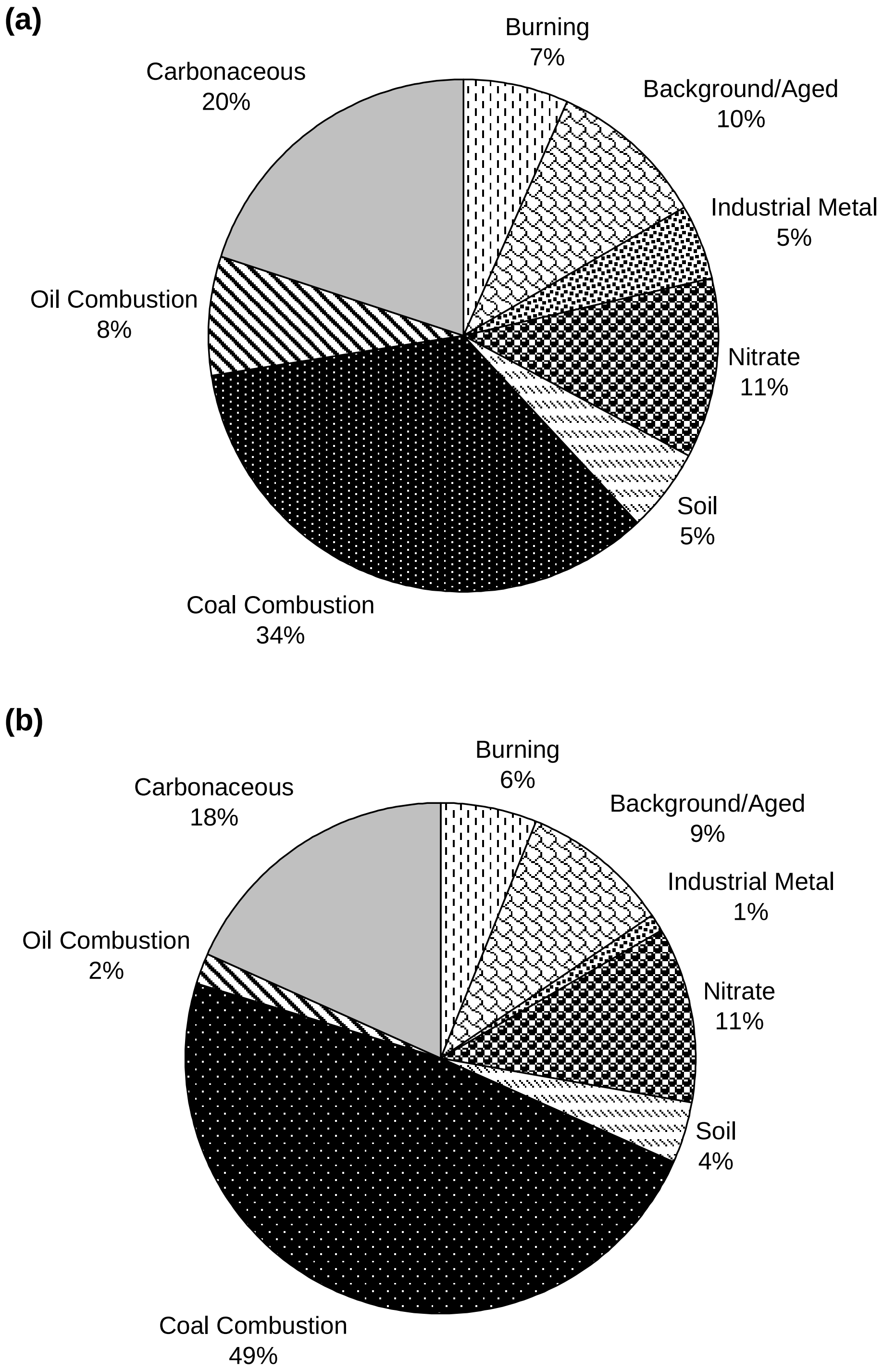


Figure 10. CPF plots for (a) coal combustion, (b) urban carbonaceous, (c) nitrate, and (d) industrial metals.

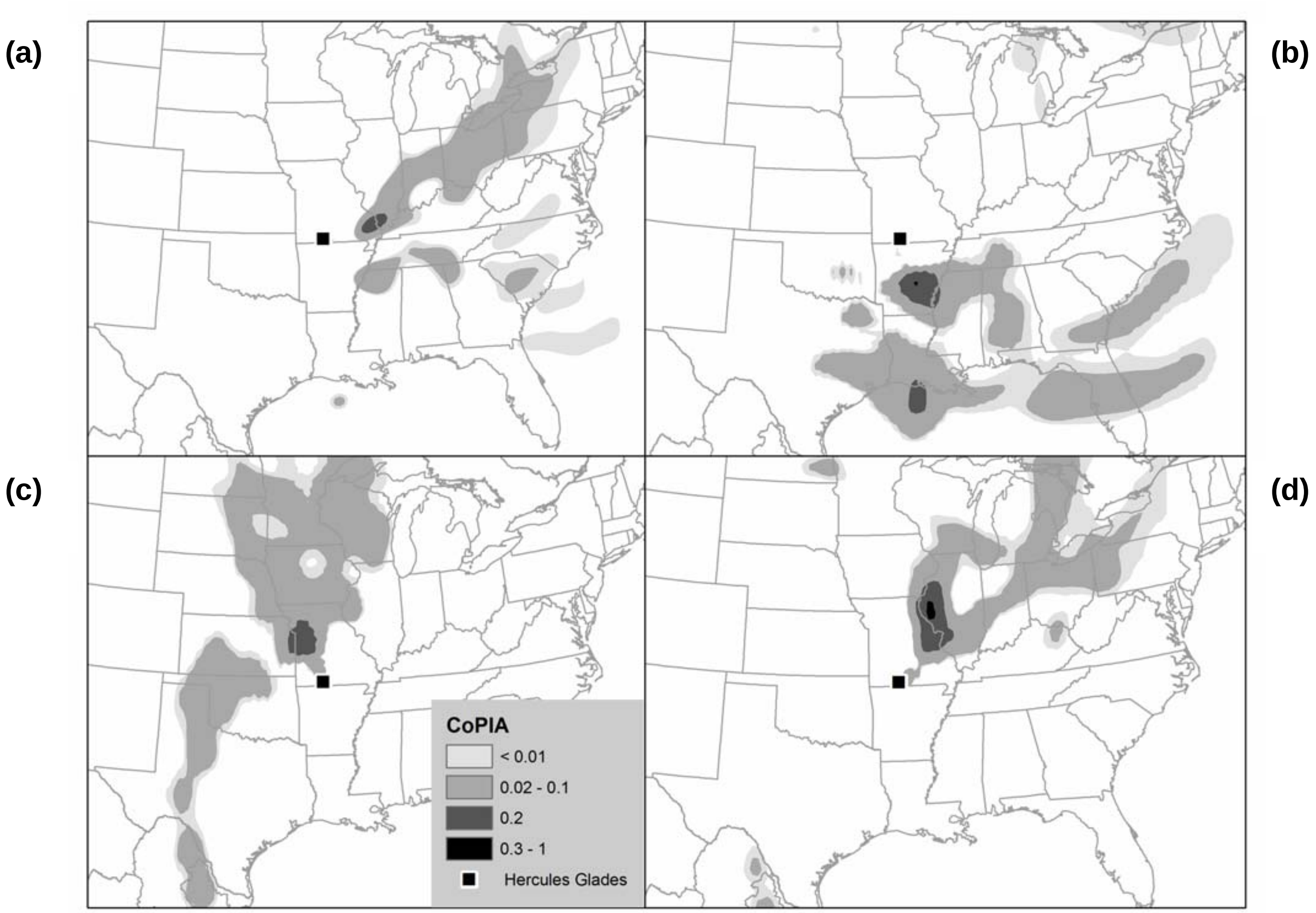


Figure 11. Air mass trajectories on the dust event day of July 1, 2002.

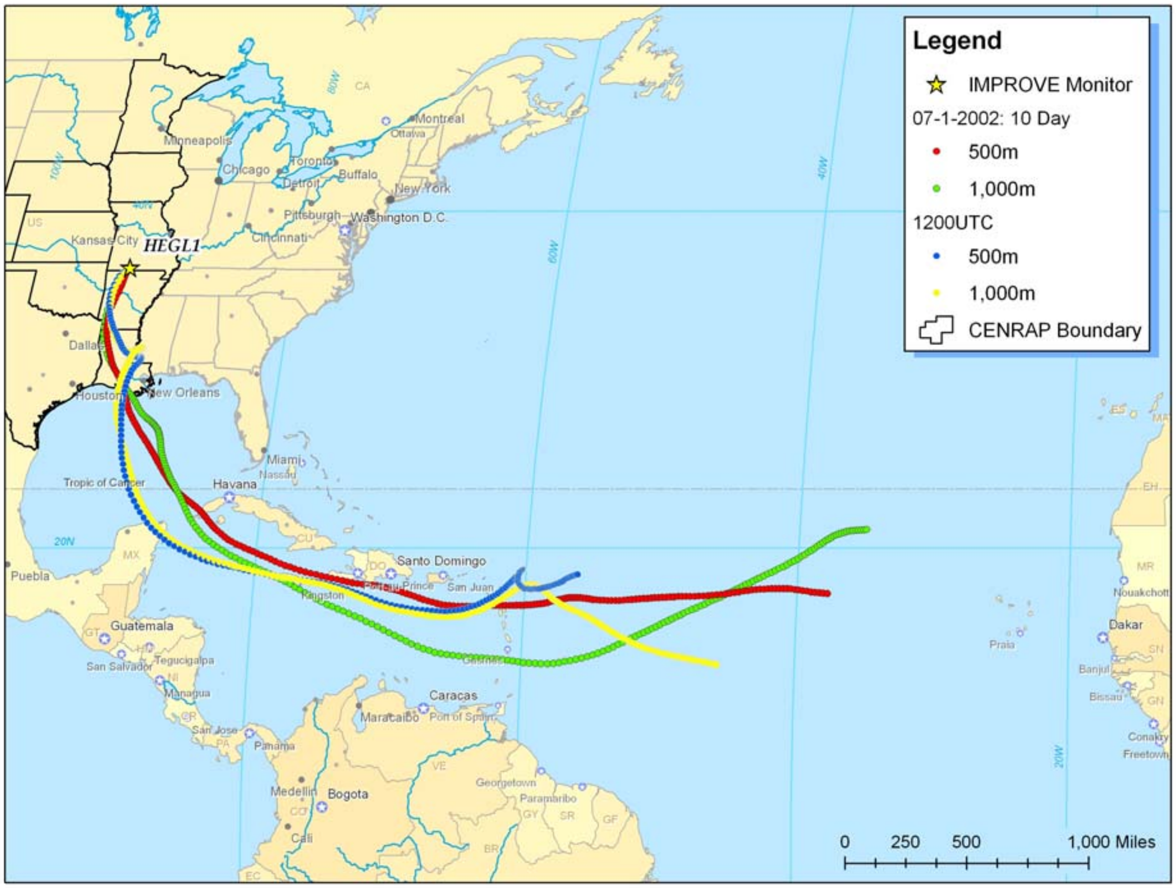
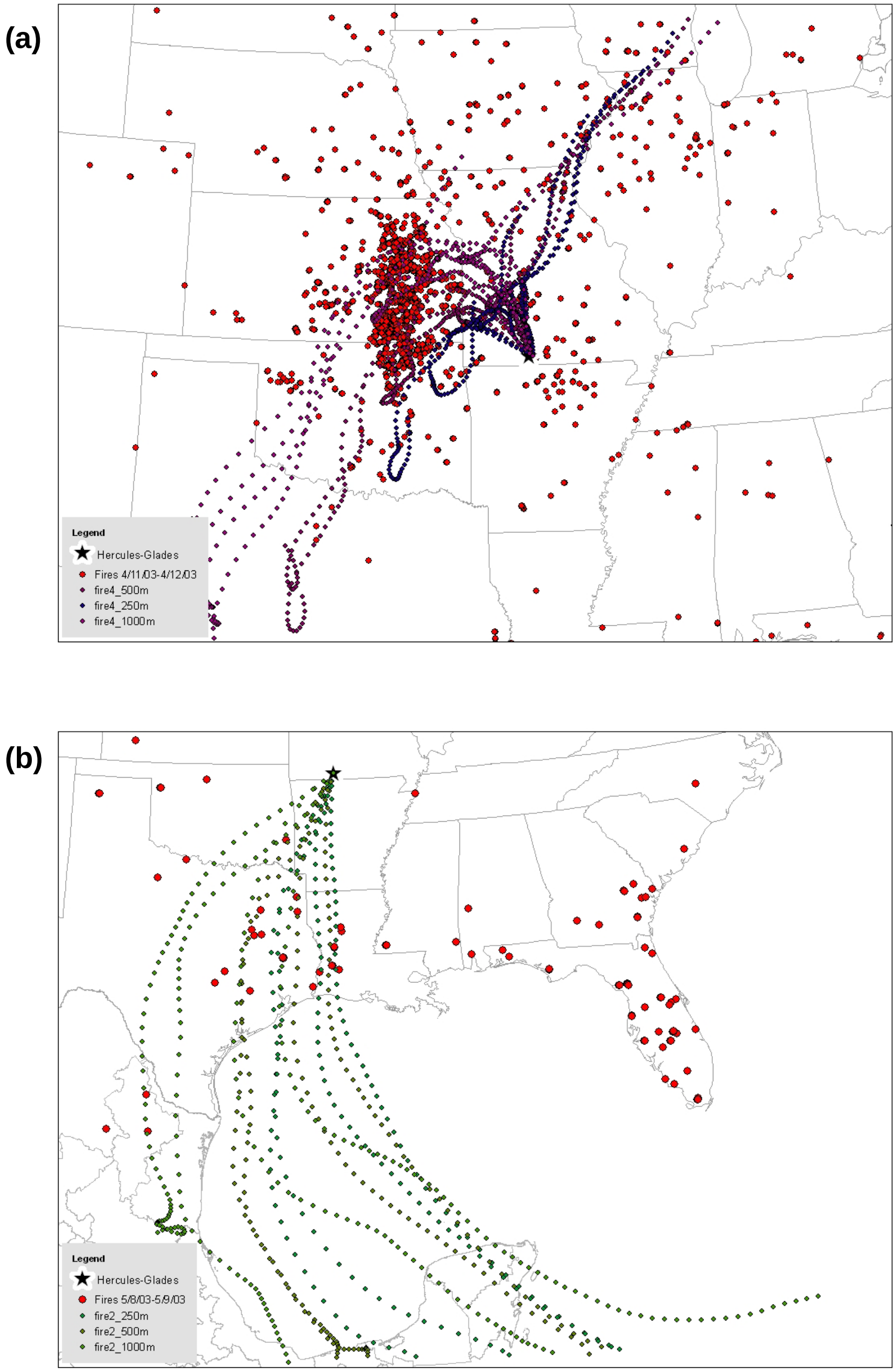


Figure 12. Air mass trajectories with ending heights of 250 m, 500 m, and 1000 m and fire locations on the burning event days of (a) April 12, 2003, and (b) May 9, 2003.



APPENDIX 7

Draft Report

Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans

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ACRONYMS

ACM	Asymmetric Convective Mixing
AIRS	Aerometric Information Retrieval System
Ap	Accuracy of paired peak
AQS	Air Quality System
ASCII	American Standard Code for Information Interchange
BADL	Badlands National Park
BART	Best Available Retrofit Technology
Base02a	2002 Base Case, version a
BCs	Boundary Conditions
BEIS3	Biogenic Emission Inventory System, version 3
BELD	Biogenic Emissions Landcover Database
bext	Extinction coefficient
BF	Bias Factor
BIBE	Big Bend National Park
BOWA	Boundary Waters Canoe Wilderness Area
BRAVO	Big Bend Regional Aerosol and Visibility Observations Study
BRET	Breton Island National Wildlife Refuge
CAAA	Clean Air Act Amendments
CACR	Caney Creek Wilderness Area
CAIR	Clean Air Interstate Rule
CAMx	Comprehensive Air Quality Model with extensions
CARB	California Air Resources Board
CASTNet	Clean Air Status and Trends Network
CB-IV	Carbon Bond IV
CBM-IV	Carbon Bond Mechanism IV
CCRS+CPRM	Coarse matter (coarse crustal & coarse primary)
CEM	Continuous Emissions Monitoring Data
CENRAP	Central Regional Air Planning Association
CFR	Code of Federal Regulations
CHIEF	Clearinghouse for Inventories and Emissions Factors
CM	Coarse Mass
CMAQ	Community Multiscale Air Quality modeling system
CMU	Carnegie Mellon University
CNG	Compressed Natural Gas
CO	Carbon Monoxide
DDM	Decoupled direct method
dv	deciview
EBI	Euler Backward Iterative
EC	Elemental Carbon

EFIG	Emissions Factors and Inventory Group
EGAS	Economic Growth Analysis System
EGUs	Electrical Generating Units
EMFAC	California Air Resources Board mobile source emissions model
EPA	U.S. Environmental Protection Agency
EPM	Emission Production Model
EPRI	Electric Power Research Institute
ERG	Energy Resources Group
Eta	Eta model - a hydrostatic mesoscale model.
FCRS+FPRM	Fine Particulate Matter (fine crustal & fine primary)
FDDA	Four Dimensional Data Assimilation
FE	Fractional Gross Error
FIPS	Federal Implementation Standards
FLM	Federal Land Managers
GA DNR	Georgia Department of Natural Resources
GE	Goddard Earth Observing System
GEOS-CHEM	Goddard Earth Observing Systems – Chemistry model
GIS	Geographic Information System
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GRSA	Great Sands Dunes Wilderness Area
GUMO	Guadalupe Mountains National Park
HEGL1	Hercules-Glades Wilderness Area
HI	Haze index
HNO3	Nitric acid
ICs	Initial concentrations
IDA	Inventory Data Analyzer
IDNR	Iowa Department of Natural Resources
IMPROVE	Interagency Monitoring of Protected Visual Environments
IPM	Integrated Planning Model
ISHALLO=	No Shallow Convection
ISLE	Isle Royale National Park
ISORROPIA	ISORROPIA aerosol equilibrium model.
JPROC	Models 3 Photolysis Rates processors
Kh	Horizontal diffusivity coefficient
km	Kilometer
Kzmin	Minimum vertical diffusivity coefficient
LAC	Light Absorbing Carbon
LITTLE_R	MM5 meteorology processor
LOST	Lostwood Wilderness Area
LPG	Liquefied petroleum gas
LSM	Land-surface model
MACA	Mammoth Cave National Park

MAGE	Mean Absolute Gross Error
MANE-VU	Mid-Atlantic/Northeast Visibility Union
MARAMA	Mid-Atlantic Air Management Association
MATS	EPA's Modeled Attainment Test Software
MB	Mean Bias
MCIP	Meteorological Chemistry Interface Processor
MEGAN	Model of emissions of gases and aerosols from nature
MFB	Mean Fractionalized Bias
MIMS	Multimedia Integrated Modeling System
MING	Mingo Wilderness Area
Mm-1	Inverse megameters
MM5	Mesoscale Meteorological Model
MMS	Minerals Management Service
MNB	Mean Normalized Bias
MNGE	Mean Normalized Gross Error
MOBILE6	EPA's latest computer program for compiling emissions from mobile sources
MPE	Model performance evaluation
MPI	Message passing interface
MRPO	Midwest Regional Planning Organization
MWSS	Monday-weekday-Saturday-Sunday
NAAQS	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NARSTO	North American Research Strategy for Tropospheric Ozone
NCEP	National Centers for Environmental Prediction
NEI	National Emissions Inventory
NH3	Ammonia
NIA	New IMPROVE Algorithm
NIF	National Emission Inventory Input Format
NO3	Nitrate
NMB	Normalized Mean Bias
NME	Normalized Mean Error
NO	Nitrogen Oxide
NO2	Nitrogen dioxide
NOAA	National Oceanic & Atmospheric Administration
NOx	Nitrogen Oxides
O3	Ozone
OAQPS	Office of Air Quality and Planning Standards
OIA	Old IMPROVE Algorithm
OMC	Organic mass carbon
PA	Process Analysis
PBL	Planetary Boundary Layer
PEC	Primary elemental carbon

PinG	Plume-in-Grid
PM	Particulate matter
PM2.5	Particulate matter of 2.5 microns and less
PMC	Particulate Matter Coarse
PNO3	Particulate nitrate
POA	Primary Organic Aerosol
POC	Primary Organic carbon
POG	Policy Oversight Group
PPM	Piecewise Parabolic Method
PSAT	PM Source Apportionment Technology
PSO4	Particulate sulfate
PSU/NCAR	Pennsylvania State University/National Center for Atmospheric Research
P-X	Pleim-Xiu
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
r2	Coefficient of determination
RADM	Regional Acid Deposition Model
RAMS	Regional Atmospheric Modeling System
RHR	Regional Haze Rule
RICE MACT	Reciprocating Internal Combustion Engine Maximum Available Control Technology
RMSE	Root Mean Square Error
ROG	Reactive Organic Gas
ROMO	Rocky Mountain National Park
RPGs	Reasonable Progress Goals
RPOs	Regional Planning Organizations
RRFs	Relative Response Factors
RRTM	Rapid Radiative Transfer Model
SA	Source Apportionment
SACR	Salt Creek Wilderness Area
SCC	Source Classification Code
SEARCH	Southeastern Aerosol Research and Characterization
SECA	Sulphur Emissions Control Area
SIC	Source Industrial Classification
SIPs	State Implementation Plans
SMOKE	Sparse Matrix Operator Kernel Emissions
SOA	Secondary Organic Aerosol
SOAA	Secondary Organic Aerosol from Anthropogenic Sources
SOAB	Secondary organic Aaerosol from biogenic sources
SORGAM	Secondary Organic Aerosol Model
SST	Sea Surface Temperature
STI	Sonoma Technology, Inc.
STN	Speciation Trends Network

SO4	Sulfate
TCEQ	Texas Commission on Environmental Quality
TIPs	Tribal Implementation Plans
TOG	Total Organic Gas
TOMS	Total Ozone Mapping Spectrometer
TPY	Tons Per Year
TSD	Technical Support Document
TSS	Technical Support System
TUV	Tropospheric Ultraviolet and Visible Radiation Model
Typ02G	Base G Typical Version 2
UCR	University of California at Riverside
UH	University of Houston
UPBU	Upper Buffalo Wilderness Area
URP	Uniform Rate of Progress
VIEWS	Visibility Information Exchange Web Site
VISTAS	Visibility Improvements State and Tribal Association of the Southeast
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds
VOYA	Voyageurs National Park
VR	Visual Range
WEPE	Wheeler Peak Wilderness Area
WHIT	White Mountain Wilderness Area
WICA	Wind Cave National Park
WIMO	Wichita Mountains National Park
WRAP	Western Regional Air Partnership
$\mu g/m^3$	Micrograms per cubic meter (concentration)

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1.0 INTRODUCTION

This Technical Support Document (TSD) describes the Central Regional Air Planning Association (CENRAP) regional emissions and air quality modeling to support the central states Regional Haze Rule (RHR) State Implementation Plans (SIPs). The CENRAP 2002 annual emissions and air quality modeling was performed by the contractor team of ENVIRON International Corporation (ENVIRON) and the University of California at Riverside (UCR).

1.1 Background

The 1977 Clean Air Act Amendments (CAAA) added a new Section 169A for the protection of visibility in Federal Class I areas (specific national parks, wilderness areas and wildlife refuges). Section 169A(a)(1) of the CAAA established the national goal for visibility protection: "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution." The CAAA require States to submit SIPs containing emission limits, schedules of compliance and to "promulgate regulations to assure reasonable progress toward meeting the national goal" (Section 169A(a)(4)). In response to these mandates EPA promulgated the Regional Haze Rule (RHR) on July 1, 1999 that requires States to "establish goals (expressed in deciviews) that provide for reasonable progress towards achieving natural visibility conditions" at Class I areas. The States' RHR SIPs are due December 17, 2007 and an important component of the SIP will be the 2018 Reasonable Progress Goals (RPGs) toward achieving natural conditions in 2064. Regional air quality models are used to project visibility to 2018 to determine the level of visibility improvement that is expected to be achieved in 2018. This information, along with other sources, can be used by the states to assist in setting their 2018 RPGs.

CENRAP is one of five Regional Planning Organizations (RPOs) that have responsibility for coordinating development of SIPs and Tribal Implementation Plans (TIPs) in selected areas of the U.S. to address the requirements of the RHR. CENRAP is a regional partnership of states, tribes, federal agencies, stakeholders and citizen groups established to initiate and coordinate activities associated with the management of regional haze and other air quality issues within the CENRAP states. The CENRAP region includes states and tribal lands located within the boundaries of Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, Oklahoma and Texas.

The CENRAP Emissions and Air Quality Modeling Team is composed of staff from ENVIRON and UCR, with assistance and coordination from the CENRAP states, tribes, federal agencies and stakeholders. The ENVIRON/UCR Team performs the emissions and air quality modeling simulations for states and tribes within the CENRAP region, providing analytical results used in developing implementation plans under the RHR. Figure 1-1 shows the states included in each of the five RPOs in the U.S., including CENRAP. Table 1-1 lists the Class I areas within the CENRAP states.

CENRAP is performing emissions and air quality modeling to project visibility to 2018. The modeling results will be used to determine the level of visibility improvement expected in 2018 under various emission scenarios. States will use these results to assist in determining their 2018 RPGs toward achieving natural conditions in 2064.

Figure 1-1. Regional Planning Organizations engaged in Regional Haze Modeling.

Table 1-1. Federal Mandated Class I Areas in the CENRAP States.

Class I Area	Acreage	Federal Land Manager	Public Law
Arkansas			
Caney Creek Wilderness Area	14,460	USDA-FS	93-622
Upper Buffalo Wilderness Area	12,018	USDA-FS	93-622
Louisiana			
Breton Wilderness Area	5,000+	USDI-FWS	93-632
Minnesota			
Boundary Waters Canoe Area Wilderness	810,088	USDA-FS	99-577
Voyageurs National Park	114,964	USDI-NP	99-261
Missouri			
Hercules-Glade Wilderness Area	12,314	USDA-FS	94-557
Mingo Wilderness Area	8,000	USDI-FWS	95-557
Oklahoma			
Wichita Mountains Wilderness	8,900	USDI-FWS	91-504
Texas			
Big Bend National Park	708,118	USDI-NP	74-157
Guadalupe Mountains National Park	76,292	USDI-NP	89-667

1.2 CENRAP Organizational Structure and Work Groups

The governing body of CENRAP is the Policy Oversight Group (POG) that is made up of voting members representing states and tribes within the CENRAP region and non-voting members representing local agencies, the EPA and other federal agencies. The work of CENRAP is accomplished through five standing workgroups:

- Monitoring;
- Emissions Inventory;
- Modeling;
- Communications; and
- Implementation and Control Strategies.

Participation in workgroups is open to all interested parties and the POG may form additional ad hoc workgroups to address specific issues (e.g., a Data Analysis workgroup was formed).

The RHR requires the states, and the tribes that may elect to, submit the first SIPs and TIPs that address progress toward natural conditions at federally mandated Class I areas by December 17, 2007. 40 CFR 51.308 (Section 308) discusses the following four core requirements to be included in SIPs/TIPs and Best Available Retrofit Technology (BART) requirements:

1. Reasonable progress goals;
2. Calculations of baseline and natural visibility conditions;
3. A Long-term strategy for regional haze;
4. A Monitoring strategy and other implementation plan requirements; and
5. BART requirements for regional haze visibility impairment.

One of CENRAP's goals is to provide support to states and tribes to meet each of these requirements of the RHR and to develop scientifically supportable, economical and effective control strategies that the states and tribes may adopt to reduce anthropogenic effects on visibility impairment at Class I areas. One component of CENRAP's support to states and tribes as part of compliance with the RHR is performing emissions and air quality modeling. These activities were implemented to:

- obtain a better understanding of the causes of visibility impairment and to identify potential mitigation measures for visibility impairment at Class I areas;
- to evaluate the effects of alternative control strategies for improving visibility; and
- to project future-year air quality and visibility conditions.

In October 2004, CENRAP selected the team of ENVIRON and UCR to perform their Emissions and Air Quality Modeling.

The CENRAP Emissions and Air Quality Modeling Team performs regional haze analyses by operating regional scale, three-dimensional air quality models that simulate the emissions, chemical transformations, and transport of gaseous and particulate matter (PM) species and consequently the effects on visibility in Class I Areas in the central U.S. A key element of this work includes the integration of emissions inventories and emissions models with regional transport models. The general services provided by the CENRAP Emissions and Air Quality Modeling Team include, but are not limited to:

- Emissions processing and modeling;
- Air quality and visibility modeling simulations;
- Analysis, display, and reporting of modeling results; and
- Storage/quality assurance of the modeling input and output files.

The CENRAP 2002 annual Emissions and Air Quality Modeling Team performs work for the CENRAP Modeling Workgroup through direction from the CENRAP Technical Director and CENRAP Executive Director.

1.3 Overview of 2002 Annual Emissions and Air Quality Modeling Approach

The CENRAP 2002 annual emissions and air quality modeling was initiated on October 16, 2004 and involved the preparation of numerous data bases, model simulations, presentations and reports. Much of the modeling analyses have been posted to the CENRAP modeling website at: http://pah.cert.ucr.edu/aqm/cenrap/index.shtml. There were numerous versions and iterations of the modeling and interim results. The results presented in this TSD focus on the final modeling results and key findings in their development. The reader is referred to the modeling website for interim products.

1.3.1 Modeling Protocol

A Modeling Protocol was prepared at the outset of the study to serve as a road map for performing the CENRAP emissions and air quality modeling and to communicate the modeling plans to the CENRAP participants. The Modeling Protocol was prepared following EPA guidance for preparation at the time it was prepared (EPA, 1991; 1999, 2001) and took into account CENRAP's long-term plan (CENRAP, 2003) and the modeling needs of the RHR SIPs. The first version (Version 1.0) of the Modeling Protocol was dated November 19, 2004. Based on comments received from CENRAP, the Modeling Protocol was updated to the current Version 2.0 (Morris et al., 2004a) that was dated December 8, 2004. This Modeling Protocol can be found on the CENRAP modeling Website at:

http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_Draft2.0_Modeling_Protocol_120804.pdf

1.3.2 Quality Assurance Project Plan (QAPP)

A Quality Assurance Project Plan (QAPP) was prepared for the CENRAP emissions and air quality modeling study that described the quality management functions performed by the modeling team. The QAPP was prepared and was based on the national consensus standards for quality assurance (ANSI/ASQC, 1994), followed EPA's guidelines for quality assurance project plans for modeling (EPA, 2002) and for QAPPs (EPA, 2001) and took into account the recommendations from the North American Research Strategy for Tropospheric Ozone (NARSTO) Quality Handbook for modeling projects (NARSTO, 1998). The EPA and NARSTO guidance documents were developed specifically for modeling projects, which have different quality assurance concerns than environmental monitoring data collection projects. The work performed in this project involves modeling at the basic research level and for regulatory/planning applications. In order to use model outputs for these purposes, it must be established that each model is scientifically sound, robust, and defensible. This is accomplished by following a project planning process that incorporates the following elements as described in the EPA modeling guidance document:

- A systematic planning process including identification of assessments and related performance criteria;
- Peer reviewed theory and equations;
- A carefully designed life-cycle development process that minimizes errors;
- Documentation of any changes from original plans;
- Clear documentation of assumptions, theory, and parameterization that is detailed enough so others can understand the model output;
- Input data and parameters that are accurate and appropriate for the analysis; and
- Output data that can be used to help inform decision makers.

The CENRAP QAPP can be found at:

http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_QAPP_Nov_24_2004.pdf).

A key component of the CENRAP emissions and air quality modeling QAPP was the graphical display of model inputs and outputs and multiple peer-review of each step of the modeling process. This was accomplished through use of the CENRAP modeling website where modelers posted displays of work products (e.g., emissions plots, model outputs, etc.) for review by the CENRAP modeling team, modeling workgroup and others. This website can be found at: http://pah.cert.ucr.edu/aqm/cenrap/index.shtml.

1.3.3 Model Selection

The selection of the meteorological, emissions and air quality models for the CENRAP regional haze modeling was based on a review of previous regional haze modeling studies performed in the CENRAP region (e.g., Pitchford et al., 2004 ; Pun, Chen and Seigneur, 2004; Tonnesen and Morris 2004) as well as elsewhere in the United States (e.g., Morris et al, 2004a; Tonnesen et al., 2003; Baker, 2004). The CENRAP emissions and air quality Modeling Protocol (Morris et al., 2004a) provides details on the justification for model selection and the formulation of the different models. Based on previous work (e.g., CENRAP, WRAP, VISTAS, MRPO, BRAVO and EPA), CENRAP selected the following models for use in modeling PM and regional haze in the central states:

- **MM5:** The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5 Version 3.6 MPP) is a non-hydrostatic, prognostic meteorological model routinely used for urban- and regional-scale photochemical, fine particulate, and regional haze regulatory modeling studies (Anthes and Warner, 1978; Chen and Dudhia, 2001; Stauffer and Seaman, 1990, 1991; Xiu and Pleim, 2000).

- **SMOKE**: The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire and biogenic emission sources for photochemical grid models. (Coats, 1995; Houyoux and Vukovich, 1999). As with most 'emissions models', SMOKE is principally an *emission processing system* and not a true *emissions modeling system* in which emissions estimates are simulated from 'first principles'. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient tool for converting an existing base emissions inventory data into the hourly, gridded, speciated, and formatted emission files required by an air quality model.

- **CMAQ:** EPA's Models-3/Community Multiscale Air Quality (CMAQ) modeling system is a 'One-Atmosphere' photochemical grid model capable of addressing ozone, PM, visibility and acid deposition at a regional scale for extended periods of time (Dennis, et al., 1996; Byun et al., 1998a; Byun and Ching, 1999, Pleim et al., 2003).

- **CAMx:** ENVIRON's Comprehensive Air Quality Model with Extensions (CAMx) modeling system is also a state-of-science 'One-Atmosphere' photochemical grid model capable of addressing ozone, PM, visibility and acid deposition at a regional scale for extended periods of time. (ENVIRON, 2006).

1.3.3.1 MM5 Meteorological Model Configuration for CENRAP Annual Modeling

Application of the MM5 for the 2002 annual modeling on a 36 km grid for the continental US was performed by the Iowa Department of Natural Resources (IDNR; Johnson, 2007). Details of the 2002 36 km MM5 model application and evaluation procedures carried out by IDNR may be found in Johnson, 2007. Application of the MM5 model on a 12 km grid covering the Central States for portions of 2002 was performed by EPA Region VII and the Texas Commission on Environmental Quality (TCEQ).

The MM5 (Version 3.63) configuration used in the generation of the meteorological modeling datasets consists of the following (see Table 1-2 for more details):

- 36 km grid with 34 vertical layers;
- 12 km nested grid for episodic modeling;
- For 12 km runs use two way nesting (without feedback) within the 36 km grid;
- Initialization and boundary conditions from Eta analysis fields;
  - Eta 3D and surface analysis data (ds609.2);
  - Not using NCEP global tropospheric SST data (ds083.0) ;
  - Observational enhancement (LITTLE_R)
    - NCEP ADP surface obs (ds464.0)
    - NCEP ADP upper-air obs (ds353.4)
- Pleim-Xiu (P-X) land-surface model (LSM);
- Pleim-Chang Asymmetric Convective Mixing (ACM) PBL model;
- Kain-Fritsch 2 cumulus parameterization;
- Mixed phase (Reisner 1) cloud microphysics;
- Rapid Radiative Transfer Model (RRTM) radiation;
- No Shallow Convection (ISHALLO=0);
- Standard 3D FDDA analysis nudging outside of PBL; and
- Surface nudging of the winds only.

1.3.3.2 SMOKE Emissions Model Configuration for CENRAP Annual Modeling

SMOKE supports area, mobile, fire and point source emission processing and includes biogenic emissions modeling through a rewrite of the Biogenic Emission Inventory System, version 3 (BEIS3) (see, http://www.epa.gov/ttn/chief/software.html#pcbeis). SMOKE has been available since 1996, and has been used for emissions processing in a number of regional air quality modeling applications. In 1998 and 1999, SMOKE was redesigned and improved with the support of the U.S. Environmental Protection Agency (EPA), for use with EPA's Models-3/CMAQ (http://www.epa.gov/asmdnerl/models3). The primary purposes of the SMOKE redesign were support of: (a) emissions processing with user-selected chemical mechanisms and (b) emissions processing for reactivity assessments.

As an emissions processing system, SMOKE has far fewer 'science configuration' options compared with the MM5 and CMAQ models. Table 1-3 summarizes the version of the SMOKE system that was used and the sources of data that were employed in constructing the required modeling inventories.

1.3.3.3 CMAQ Air Quality Model Configuration for CENRAP Annual Modeling

CENRAP used CMAQ Version 4.5 with the "SOA mods enhancement", described below, and used the model configuration as shown in Table 1-4. The model was set up and exercised on the same 36 km grid that was used by WRAP and VISTAS, the 36 km RPO national grid. CENRAP performed 12 km CMAQ sensitivity tests and found little change in model performance with a large penalty in computation time. Consequently, at the February 7, 2006 CENRAP Modeling

Workgroup Meeting a decision was made to proceed with the CENRAP emissions and air quality modeling using just the 36 km national RPO grid (Morris et al., 2006a).

Initial CMAQ 2002 simulations performed by VISTAS found that the model greatly underestimates organic mass carbon (OMC) concentrations, especially in the summer. A review of the CMAQ formulation found that it failed to treat Secondary Organic Aerosol (SOA) formation from sesquiterpenes and isoprene and also failed to account for the fact that SOA can become polymerized so that it is no longer volatile and stays in the particle form. Thus, VISTAS updated the CMAQ SOA module to include these missing processes and found much improved OMC model performance (Morris et al., 2006c). CENRAP tested the CMAQ Version 4.5 with SOAmods enhancement and found it performed much better for OMC than the standard versions of CMAQ Version 4.5. Therefore, CMAQ Version 4.5, with the enhanced SOAmods (Morris et al., 2006c), was adopted for the CENRAP modeling. CMAQ Version 4.5 is available from the CMAS center (www.cmascenter.org).

1.3.3.4 CAMx Air Quality Model Configuration for CENRAP Annual Modeling

CAMx Version 4.40 was applied using similar options as used by CMAQ. CAMx was used initially in side-by-side comparisons with CMAQ. Comparative model performance results and other factors for CAMx V4 and CMAQ V4.4 with SOAmods were presented at the February 7, 2006 CENRAP modeling workgroup meetings that found (Morris et al., 2006b):

- No one model was consistently performing better than the other over all species and averaging times.
- Both models performed well for sulfate.
- CMAQ's winter nitrate over-prediction tendency not as large as CAMx's.
- CAMx performed slightly better than CMAQ for elemental carbon (EC).
- CMAQ performed much better than CAMx for organic mass carbon (OMC).
- Both models over-predicted Soil and under-predicted coarse mass (CM).
- CMAQ ran faster than CAMx due to MPI multi-processing capability.
- CAMx required much less disk space than CMAQ.

Based on these factors, CMAQ was selected as the lead air quality model for the CENRAP regional haze modeling with CAMx the secondary corroborative model. However, CAMx also contained a PM Source Apportionment Technology (PSAT) capability that was used widely in the CENRAP modeling. Table 1-4 lists the main CAMx configuration used for the CENRAP annual modeling that was selected, in part, to be consistent with the CMAQ model configuration (Table 1-4). One exception to this was that the CAMx PSAT simulations used the Bott advection solver rather than the PPM advection solver. The PPM advection solver is typically used in the standard CAMx and CMAQ runs. Bott, however, is more computationally efficient and the high computational requirements of the CAMx PSAT runs dictated this choice.

Table 1-2. MM5 Meteorological Model Configuration for CENRAP 2002 Annual Modeling (Johnson, 2007).

Science Options	Configuration	Details/Comments
Model Code	MM5 version 3.63	Grell et al., 1994
Horizontal Grid Mesh	36 km	
36 km grid	165 x 129 dot points	RPO MM5 Grid
Vertical Grid Mesh	34 layers	Vertically varying; sigma pressure coordinate system
Grid Interaction	No Feedback	IFEED=0
Initialization	Eta first guess fields/LittleR	
Boundary Conditions	Eta first guess fields/LittleR	
Microphysics	Reisner I Mixed Ice	Look up table
Cumulus Scheme	Kain-Fritsch 2	On 36 and 12 km Grids
Planetary Boundary Layer	ACM PBL	
Radiation RRT	M	
Vegetation Data	USGS	24 Category Scheme
Land Surface Model	Pleim-Xiu Land Surface Model (LSM)	
Shallow Convection	None	
Sea Surface Temperature	Eta Skin	Spatially varying
Thermal Roughness	Garratt	
Snow Cover Effects	None	
4D Data Assimilation	Analysis Nudging on 36 and 12	
Surface Nudging	Wind Field Only	
Integration Time Step	90 seconds	
Simulation Periods	Annual 2002 for 36 km	12 km episodic only
Platform	Linux Cluster	Done at IDNR[1]

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[1] Twelve km episodic modeling completed by EPA Region VII and the Texas Commission on Environmental Quality.

Table 1-3. SMOKE Emissions Model Configuration for CENRAP Annual Modeling.

Emissions Component	Configuration	Details/Comments
Emissions Model	SMOKE Version 2.3	Several versions of SMOKE used during course of the study
Horizontal Grid Mesh	36 km	
36 km grid	148 x 112 cells	RPO National Grid
Area Source Emissions	CENRAP Domain: CENRAP State 2002 EI	Updated '02 developed by CENRAP states (Pechan, 2005d,e)
	Other States: '02 NEI augmented with other 2002	Generated from EPA NEI02 v.1 and RPO interaction (Pechan, 2005c)
On-Road Mobile Sources	CENRAP Domain: CENRAP VMT data	Updated '02 developed by CENRAP states (Reid et al., 2004a)
	Other States: EPA '02 NEI augmented with other 2002	Generated from EPA NEI02 v.1 and RPO interaction (Pechan, 2005c)
Point Sources	CENRAP Domain: CENRAP State 2002 EI	Updated '02 developed by CENRAP states and stakeholders (Pechan, 2005a,b)
	Other States: EPA '02 NEI augmented with other 2002	Generated from EPA NEI02 v.1 and RPO interaction (Pechan, 2005c)
Off-Road Mobile Sources	CENRAP Domain: CENRAP State 2002 EI	Updated '02 developed by CENRAP states (Pechan, 2005d,e)
	Other States: EPA '02 NEI augmented with other 2002	Generated from EPA NEI02 v.1 and RPO interaction (Pechan, 2005c)
Biogenic Sources	SMOKE BEIS-3	BELD3 vegetative database
Mexican Sources	1999 Emissions for 2002 and 2018	http://www.epa.gov/ttn/chief/net/mexico.html; (ERG, 2006)
Canadian Sources	2000 Emissions for 2002 and 2020 Emissions for 2018	http://www.epa.gov/ttn/chief/net/canada.html
Temporal Adjustments	Seasonal, day, hour	Based on latest collected information and CEM-based profiles
Chemical Speciation	Revised CBM-IV Chemical Speciation	Updated January 2004
Gridding	Revised EPA Spatial Surrogates Used	Gridding of surrogates from http://www.epa.gov/ttn/chief/emch/spatial/
Growth and Controls	CENRAP developed	Pechan (2005a,b)
Quality Assurance	QA Tools in SMOKE 2.0	Follow QAPP (Morris and Tonnesen, 2004) and QA refinements (Morris and Tonnesen, 2006)
Simulation Periods	Annual 2002 for 36 km	Episodic periods at 12 km

Table 1-4. CMAQ Air Quality Model Configuration for CENRAP Annual Modeling.

Science Options	Configuration	Details/Comments
Model Code	CMAQ Version 4.5 w/ SOAmods	Secondary Organic Aerosol enhancements as described by Morris et al., (2006c)
Horizontal Grid Mesh	36 km annual	36 km covering continental U.S; some episodic 12 km sensitivity runs were also performed
36 km grid	148 x 112 cells	RPO National Grid
Vertical Grid Mesh	19 Layers	First 17 layers sync'd w/ MM5
Grid Interaction	One-way nesting	
Initial Conditions	~15 days full spin-up	Separately run 4 quarters of 2002
Boundary Conditions	2002 GEOS-CHEM day-specific	2002 GEOS-CHEM day specific 3-hour average data
Emissions		
Baseline Emissions Processing	See SMOKE model configuration	MM5 Meteorology input to SMOKE, CMAQ
Sub-grid-scale Plumes	No Plume-in-Grid (PinG)	
Chemistry		
Gas Phase Chemistry	CBM-IV	
Aerosol Chemistry	AE3/ISORROPIA	
Secondary Organic Aerosols	Secondary Organic Aerosol Model (SORGAM) w/ SOAmods update	Schell et al., (2001); Morris et al., (2006c)
Cloud Chemistry	RADM-type aqueous chemistry	Includes subgrid cloud processes
N2O5 Reaction Probability	0.01 – 0.001	
Meteorological Processor	MCIP Version 2.3	Includes dry deposition and snow cover updates
Horizontal Transport		
Numerical Scheme	PPM advection solver	
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence	Multiscale Smagorinsky (1963) approach
Vertical Transport		
Eddy Diffusivity Scheme	K-theory	
Diffusivity Lower Limit	Kzmin = 0.1 to 1.0	Land use dependent Kzmin
Deposition Scheme	M3dry	Directly linked to Pleim-Xiu Land Surface Model parameters
Numerics		
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver	
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme	
Simulation Periods	Annual 2002 for 36 km	Episodic periods at 12 km
Integration Time Step	Calculated Internally	15 minute coupling time step

Table 1-5. CAMx Air Quality Model Configuration for CENRAP Annual Modeling.

Science Options	Configuration	Details
Model Code	CAMx Version 4.40	Available at: www.camx.com
Horizontal Grid Mesh	36 km annual	36 km covering continental U.S
36 km grid	148 x 112 cells	
Vertical Grid Mesh	19 Layers	17 Layers sync'd w/ MM5
Grid Interaction	Two-way nesting	
Initial Conditions	~15 days full spin-up	Separately run 4 quarters of 2002
Boundary Conditions	2002 GEOS-CHEM day-specific	2002 GEOS-CHEM day specific 3-hour average data
Emissions		
Baseline Emissions Processing	See SMOKE model configuration	MM5 Meteorology input to SMOKE, CAMx
Sub-grid-scale Plumes	No Plume-in-Grid (PinG)	Consistent with CMAQ
Chemistry		
Gas Phase Chemistry	CBM-IV	with Isoprene updates
Aerosol Chemistry	ISORROPIA equilibrium	Dynamic and hybrid also available but not used
Secondary Organic Aerosols	SOAP	
Cloud Chemistry	RADM-type aqueous chemistry	Alternative is CMU multi-section aqueous chemistry
N2O5 Reaction Probability	None	
Meteorological Processor	MM5CAMx	
Horizontal Transport		
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence	
Vertical Transport		
Eddy Diffusivity Scheme	K-Theory	
Diffusivity Lower Limit	Kzmin = 0.1 to 1.0	Land use dependent Kzmin
Planetary Boundary Layer	No Patch	
Deposition Scheme	Wesely	
Numerics		
Gas Phase Chemistry Solver	CMC Fast Solver	
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme. PSAT w/ Bott scheme.	
Simulation Periods	Annual 2002 at 36 km	
Integration Time Step	Wind speed dependent	

1.3.4 Modeling Domains

The CENRAP emissions and air quality modeling was conducted on the 36 km national RPO domain as depicted in Figure 1-2. This domain consists of a 148 by 112 array of 36 km by 36 km grid cells and covers the continental United States. Sensitivity simulations were also performed for episodes on a 12 km modeling domain covering the central states, however the results were very similar to the 36 km results so CENRAP elected to proceed with the 2002 annual modeling using the 36 km domain for computational efficiency (Morris et al., 2006a).

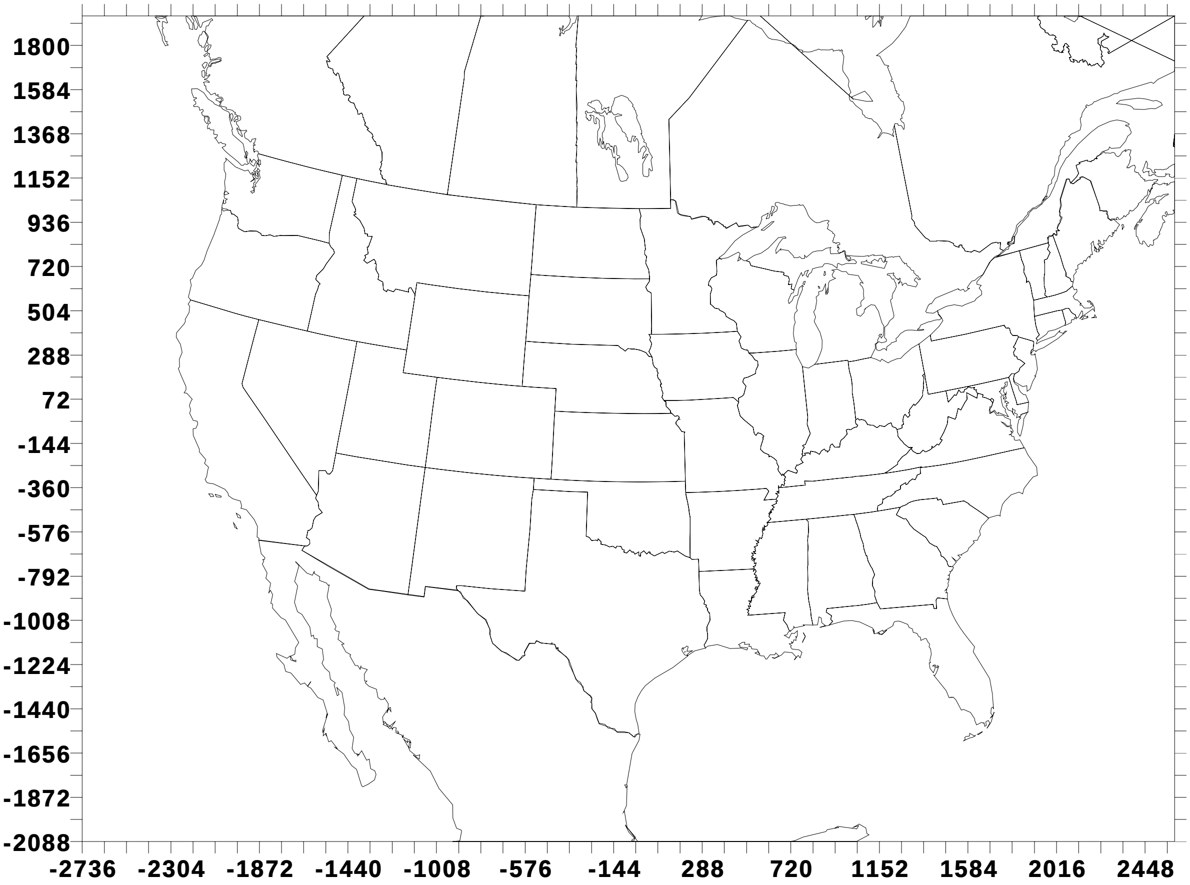

Figure 1-2. National Inter-RPO 36 km modeling domain used for the CENRAP 2002 annual SMOKE, CMAQ and CAMx modeling.

1.3.5 Vertical Structure of Modeling Domain

The MM5 meteorological model was exercised using 34 vertical layers from the surface to a pressure level of 100 mb (approximately 15 km above ground level). Both the CMAQ and CAMx air quality models can employ layer collapsing in which vertical layers in the MM5 are combined in the air quality model, which improves computational efficiency. The sensitivity of the CMAQ model estimates to the number of vertical layers was evaluated by the Western Regional Air Partnership (WRAP) and Visibility Improvements State and Tribal Association of the Southeast (VISTAS) (Tonnesen et al., 2005; 2006; Morris et al., 2004a). CMAQ model simulations were performed with no layer collapsing (i.e., the same 34 layers as used by MM5) and with various levels of layer collapsing. These studies found that using 19 vertical layers up to 100 mb (i.e., same model top as MM5) and matching the eight lowest MM5 vertical layers near the surface produced nearly identical results as with no layer collapsing. They also found that very aggressive layer collapsing (e.g., 34 to 12 layers) produced results with substantial differences compared to no layer collapsing. Therefore, based on the WRAP/VISTAS sensitivity analysis, CENRAP adopted the 19 vertical layer configuration up to the 100 mb model top. Figure 1-3 displays the definition of the 34 MM5 vertical layers and how they were collapsed to 19 vertical layers in the air quality modeling performed by CENRAP.

MM5					**CMAQ**	**19L**			
Layer	Sigma	Pres(mb)	Height(m	Depth(m)	Layer	Sigma	Pres(mb)	Height(m)	Depth(m
34	**0.000**	**100**	**14662**	**1841**	**19**	**0.000**	**100**	**14662**	**6536**
33	0.050	145	12822	1466		0.050	145		
32	0.100	190	11356	1228		0.100	190		
31	0.150	235	10127	1062		0.150	235		
30	0.200	280	9066	939		0.200	280		
29	**0.250**	**325**	**8127**	**843**	**18**	**0.250**	**325**	**8127**	**2966**
28	0.300	370	7284	767		0.300	370		
27	0.350	415	6517	704		0.350	415		
26	0.400	460	5812	652		0.400	460		
25	**0.450**	**505**	**5160**	**607**	**17**	**0.450**	**505**	**5160**	**1712**
24	0.500	550	4553	569		0.500	550		
23	0.550	595	3984	536		0.550	595		
22	**0.600**	**640**	**3448**	**506**	**16**	**0.600**	**640**	**3448**	**986**
21	0.650	685	2942	480		0.650	685		
20	**0.700**	**730**	**2462**	**367**	**15**	**0.700**	**730**	**2462**	**633**
19	0.740	766	2095	266		0.740	766		
18	**0.770**	**793**	**1828**	**259**	**14**	**0.770**	**793**	**1828**	**428**
17	0.800	820	1569	169		0.800	820		
16	**0.820**	**838**	**1400**	**166**	**13**	**0.820**	**838**	**1400**	**329**
15	0.840	856	1235	163		0.840	856		
14	**0.860**	**874**	**1071**	**160**	**12**	**0.860**	**874**	**1071**	**160**
13	0.880	892	911	158	**11**	**0.880**	**892**	**911**	**158**
12	**0.900**	**910**	**753**	**78**	**10**	**0.900**	**910**	**753**	**155**
11	0.910	919	675	77		0.910	919		
10	**0.920**	**928**	**598**	**77**	**9**	**0.920**	**928**	**598**	**153**
9	0.930	937	521	76		0.930	937		
8	**0.940**	**946**	**445**	**76**	**8**	**0.940**	**946**	**445**	**76**
7	**0.950**	**955**	**369**	**75**	**7**	**0.950**	**955**	**369**	**75**
6	**0.960**	**964**	**294**	**74**	**6**	**0.960**	**964**	**294**	**74**
5	**0.970**	**973**	**220**	**74**	**5**	**0.970**	**973**	**220**	**74**
4	**0.980**	**982**	**146**	**37**	**4**	**0.980**	**982**	**146**	**37**
3	**0.985**	**986.5**	**109**	**37**	**3**	**0.985**	**986.5**	**109**	**37**
2	**0.990**	**991**	**73**	**36**	**2**	**0.990**	**991**	**73**	**36**
1	**0.995**	**995.5**	**36**	**36**	**1**	**0.995**	**995.5**	**36**	**36**
0	**1.000**	**1000 0 0**		**0**	**0**	**1.000**	**1000 0 0**		

Figure 1-3. MM5 34 vertical layer definitions and scheme for collapsing the 34 layers down to 19 layers for the CENRAP CMAQ and CAMx 2002 annual modeling.

1.3.6 2002 Calendar Year Selection

The calendar year 2002 was selected for CENRAP regional haze annual modeling as described in the CENRAP Modeling Protocol (Morris et al., 2004a). EPA's applicable guidance on $PM_{2.5}$/Regional Haze modeling at that time (EPA, 2001) identified specific goals to consider when selecting modeling periods for use in demonstrating reasonable progress in attaining the regional haze goals. However, since there is much in common with the goals for selecting episodes for annual and episodic $PM_{2.5}$ attainment demonstrations as well as regional haze, EPA's current guidance addresses all three in a common document. (EPA, 2007) At the time of the modeling period selection EPA had also published an updated summary of $PM_{2.5}$ and Regional Haze Modeling Guidance (Timin, 2002) that served, in some respects, as an interim placeholder until the final guidance was issued as part of the $PM_{2.5}$/regional haze NAAQS implementation process that was ultimately published in April 2007 (EPA, 2007). The interim EPA modeling guidance for episode selection (EPA, 2001; Timin, 2002) was consistent with the final EPA regional haze modeling guidance (EPA, 2007).

EPA recommends that the selection of a modeling period derive from three principal criteria:

- A variety of meteorological conditions should be covered that includes the types of meteorological conditions that produce the worst 20 percent and best 20 percent visibility days at Class I areas in the CENRAP States during the 2000-2004 baseline period;
- To the extent possible, the modeling data base should include days for which enhanced data bases (i.e. beyond routine aerometric and emissions monitoring) are available; and
- Sufficient days should be available such that relative response factors (RRFs) can be based on several (i.e., $\geq$ 15) days.

For regional haze modeling, the guidance goes further by suggesting that the preferred approach is to model a full, *representative* year (EPA, 2001, pg. 188). Moreover, the required RRF values should be based on model results averaged over the 20 percent worst and 20 percent best visibility days determined for each Class I area based on monitoring data from the 2000 – 2004 baseline period. More recent EPA guidance (Timin, 2002) suggests that states should model at least 10 worst and 10 best visibility days at each Class 1 area. EPA also lists several 'other considerations' to bear in mind when choosing potential PM/regional haze episodes including: (a) choose periods which have already been modeled, (b) choose periods which are drawn from the years upon which the current design values are based, (c) include weekend days among those chosen, and (d) choose modeling periods that meet as many episode selection criteria as possible in the maximum number of nonattainment or Class I areas as possible.

Due to limited available resources CENRAP was restricted to modeling a single calendar year. The RHR uses the five-year baseline of 2000-2004 period as the starting point for projecting future-year visibility. Thus, the modeling year should be selected from this five-year baseline period. The 2002 calendar year, which lies in the middle of the 2000-2004 Baseline, was selected for the following reasons:

- Based on available information, 2002 appears to be a fairly typical year in terms of meteorology for the 5-year Baseline period of 2000-2004;

- 2003 and 2004 appeared to be colder and wetter than typical in the eastern US;
- The enhanced IMPROVE and IMPROVE Protocol and Supersites PM monitoring data were fully operational by 2002. Much less IMPROVE monitoring data was available during 2000-2001, especially in the CENRAP region;
- IMPROVE data for 2003 and 2004 were not yet available at the time that the CENRAP modeling was initiated; and
- 2002 was being used by the other RPOs.

1.3.7 Initial Concentrations and Boundary Conditions

The CMAQ and CAMx models were operated separately for each of four quarters of the 2002 year using a ~15 day spin up period (i.e., the models were started approximately 15 days before the first day of interest in each quarter in order to limit the influence of the assumed initial concentrations, e.g., start June 15 for quarter 3 whose first day of interest is July 1). Sensitivity simulations demonstrated that with ~15 initialization days, the influence of initial concentrations (ICs) was minimal using the 36 km Inter-RPO continental U.S. modeling domain. Consequently, clean ICs were specified in the CMAQ and CAMx modeling using a ~15 day spin up period.

Boundary Conditions (BCs) (i.e., the assumed concentrations along the later edges of the 36 km modeling domain, see Figure 1-2) were based on a 2002 simulation by the GEOS-CHEM global circulation/chemistry model. GEOS-CHEM is a three-dimensional global chemistry model driven by assimilated meteorological observations from the Goddard Earth Observing System (GEOS) of the NASA Global Modeling and Assimilation Office. It is applied by research groups around the world to a wide range of atmospheric composition problems, including future climates and planetary atmospheres using general circulation model meteorology to drive the model. Central management and support of the model is provided by the Atmospheric Chemistry Modeling Group at Harvard University.

A joint RPO study was performed, coordinated by VISTAS, in which Harvard University applied the GEOS-CHEM global model for the 2002 calendar year (Jacob, Park and Logan, 2005). The University of Houston (UH) was retained to process the 2002 GEOS-CHEM output into BCs for the CMAQ model (Byun, 2004). The GEOS-CHEM simulations for the RPOs used GEOS meteorological observations for the year 2002. These were obtained from the Global Modeling and Assimilation Office(GMAO) as a 6- hourly archive (3-hour for surface quantities such as mixing depths). The data through August 2002 were from the GEOS-3 assimilation, with horizontal resolution of 1^ox1^o and 55 vertical layers. The data after August 2002 were from the updated GEOS-4 assimilation, with horizontal resolution of 1^ox1.25^o and 48 vertical layers (note 1^o latitude is equal to approximately 110 km). The GEOS-CHEM output was processed by mapping the GEOS-CHEM chemical compounds to the species in the CBM-IV chemical mechanism used by CMAQ/CAMx and mapping the GEOS-CHEM vertical layers to the 19 layer vertical layer structure used by CMAQ/CAMx in the CENRAP modeling (Byun, 2004). The results were day-specific three-hourly BC inputs for the CMAQ model. The CMAQ2CAMx processor was then used to transform the CMAQ day-specific 3-hourly BCs to the format used by CAMx.

There were several quality assurance (QA) checks of the BCs generated from the 2002 GEOS-CHEM output. The first QA/QC check was a range check to assure reasonable values. The BCs were compared against the GEOS-CHEM outputs to assure the mapping and interpolation was performed correctly. The code used to map the GEOS-CHEM output to the CMAQ BC format was obtained from UH, reviewed and the BC generation duplicated for several time periods during 2002.

1.3.8 Emissions Input Preparation

The CENRAP SMOKE emissions modeling was based on an updated 2002 emissions data for the U.S. (Pechan, 2005c,e; Reid et al., 2004a,b), 1999 emissions data for Mexico (ERG, 2006), and 2000 emissions data for Canada. These data were used to generate a final base 2002 Base G Typical (Typ02G) annual emissions database. Numerous iterations of the emissions modeling were conducted using interim databases before arriving at the final Base G emission inventories (e.g., Morris et al., 2005). The 2018 Base G base case emissions (Base18G) for most source categories in the U.S. were based on projections of the 2002 inventory assuming growth and control (Pechan, 2005d). 2018 EGU emissions were based on the run 2.1.9 of the Integrated Planning Model (IPM) updated by the CENRAP states. Canadian emissions for the Base18G scenario were based on a 2020 inventory, whereas the Mexican 1999 inventory was held constant for 2018.

The Typ02G and Base18G emission inventories represent significant improvements to the preliminary emissions modeling performed by CENRAP (Morris et al., 2005). While the preliminary 2002 modeling served its purpose to develop the infrastructure for modeling large emissions data sets and producing annual emissions simulations, much of the input data (both as inventories and ancillary data) were placeholders for actual 2002 data that were being prepared through calendar year 2005. As these actual 2002 data sets became available, they were integrated into the SMOKE modeling and QA system that was developed during the preliminary modeling, to produce a high-quality emissions data set for use in the final CMAQ and CAMx modeling. The addition of entirely new inventory categories, like marine shipping, added complexity to the modeling. By the end of the emissions data collection phase, there were 23 separate emissions processing streams covering a variety of sources categories necessary to general model-ready emission inputs for the 2002 calendar year.

Details on the emissions modeling are provided in Chapter 2 with additional information contained in Appendix B.

1.3.9 Meteorological Input Preparation

The 2002 36 km MM5 meteorological modeling was conducted by the Iowa Department of Natural Resources (IDNR) who also performed a preliminary model performance evaluation (Johnson, 2007). CENRAP performed an additional MM5 evaluation of the CENRAP 2002 36 km MM5 simulation that included a comparative evaluation against the final VISTAS 2002 36 km MM5 and an interim WRAP 2002 36 km simulation (Kemball-Cook et al., 2004). Kemball-Cook and co-workers (2004) found the following in the comparative evaluation of the CENRAP, WRAP and VISTAS 2002 36 km MM5 simulations, (details are provided in Appendix A):

Surface Meteorological Performance within the CENRAP Region

- The three MM5 simulations (CENRAP, VISTAS and WRAP) obtained comparable model performance for winds and humidity that were within model performance benchmarks.
- The WRAP MM5 simulation obtained better temperature model performance than the other two simulations due to the use of surface temperature data assimilation.
    - In the final WRAP MM5 simulation the use of surface temperature assimilation was dropped because it introduced instability in the vertical structure of the atmosphere.
- For all three runs, the Northern CENRAP domain had a cold bias in winter and a warm bias in summer.

Surface Meteorological Performance outside the CENRAP Region

- All three runs had similar surface wind model performance in the western U.S. that was outside the model performance benchmarks
- For temperature, the WRAP MM5 simulation had the best performance overall due to the surface temperature data assimilation that was dropped in the final WRAP run.
- The three runs had comparable humidity performance, although WRAP exhibited a larger wet bias in the summer and the southwestern U.S.

Upper-Air Meteorological Performance

- The VISTAS and CENRAP MM5 simulations were better able to reproduce the deep convective summer boundary layers compared to the WRAP MM5 simulations, which exhibited a smoother decrease in temperature with increase in altitude.
- CENRAP and VISTAS MM5 simulations better simulated the surface temperature inversions than WRAP.
- WRAP was better able to simulate the surface temperature.
- All three models exhibited similar vertical wind profiles.

Precipitation Performance

- In winter, all three MM5 simulations exhibited similar, fairly good, performance in reproducing the spatial distribution and magnitudes of the monthly average observed precipitation.
- In summer, all runs had a wet bias, particularly in the desert southwest where the interim WRAP run had the largest wet bias.

In conclusion, the VISTAS simulation appeared to perform best, the CENRAP MM5 model performance was generally between the VISTAS and WRAP performance, with performance more similar to VISTAS than WRAP. Although the interim WRAP MM5 simulation performed best for surface temperature due to the surface temperature data assimilation, the surface temperature assimilation degraded the MM5 upper-air performance including the ability to assimilate surface inversions and was ultimately dropped from the final WRAP MM5 simulations (Kemball-Cook et al., 2005).

The IDNR 12 km[2] MM5 simulations were also evaluated and compared with the performance of the 36 km MM5 simulation (Johnson et al., 2007). The IDNR 36 km and 12 km MM5 model performance was similar (Johnson, 2007), which supported the findings of the CMAQ and CAMx 36 and 12 km sensitivity simulations that there was little benefit of using a 12 km grid for simulating regional haze at rural Class I areas (Morris et al., 2006a). However, as noted by Tonnesen and co-workers (2005; 2006) and EPA modeling guidance (1991; 1999; 2001; 2007) this finding does not necessarily hold for 8-hour ozone and $PM_{2.5}$ modeling that is characterized by sharper concentration gradients and frequently occurs in the urban environment as compared to the more rural nature of regional haze.

1.3.10 Photolysis Rates Model Inputs

Several chemical reactions in the atmosphere are initiated by the photodissociation of various trace gases. To accurately represent the complex chemical transformations in the atmosphere, accurate estimates of these photodissociation rates must be made. The Models-3/CMAQ system includes the JPROC processor, which calculates a table of clear-sky photolysis rates (or J-values) for a specific date. JPROC uses default values for total aerosol loading and provides the option to use default ozone column data or to use measured total ozone column data. These data come from the Total Ozone Mapping Spectrometer (TOMS) satellite data. TOMS data that is available at 24-hour averages was obtained from http://toms.gsfc.nasa.gov/eptoms/ep.html. Day-specific TOMS data was used in the CMAQ radiation model (JPROC) to calculate photolysis rates. The TOMS data were missing or erroneous for several periods in 2002: August 2-12; June 10; and November 18-19. Thus, the TOMS data for August 1, 2002 was used for August 2-7 and TOMS data for August 13 was used for August 8-12. Similarly, TOMS data for June 9 was used for June 10 and data for August 17 was used for August 18-19. Note that the total column of ozone in the atmosphere is dominated by stratospheric ozone which has very little day-to-day variability so the use of TOMS data within a week or two of an actual day introduces minimal uncertainties in the modeling analysis.

JPROC produces a "look-up" table that provides photolysis rates as a function of latitude, altitude, and time (in terms of the number of hours of deviation from local noon, or hour angle). In the current CMAQ implementation, the J-values are calculated for six latitudinal bands (10º, 20º, 30º, 40º, 50º, and 60º N), seven altitudes (0 km, 1 km, 2 km, 3 km, 4 km, 5 km, and 10 km), and hourly values up to ∀8 hours of deviation from local noon. During model calculations, photolysis rates for each model grid cell are estimated by first interpolating the clear-sky photolysis rates from the look-up table using the grid cell latitude, altitude, and hour angle, followed by applying a cloud correction (attenuation) factor based on the cloud inputs from MM5.

The photolysis rates input file was prepared as separate look-up tables for each simulation day. Photolysis files are ASCII files that were visually checked for selected days to verify that photolysis are within the expected ranges.

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[2] The IDNR twelve 12 km annual simulation domain was not sufficient for CENRAP's needs, thus Bret Anderson with EPA Region 7 in cooperation with Texas completed an episodic 12km simulation on a larger domain.

The Tropospheric Ultraviolet and Visible (TUV) Radiation Model (http://cprm.acd.ucar.edu/Models/TUV/) is used to generate the photolysis rates input file for CAMx. TOMS ozone data and land use data were used to develop the CAMx Albedo/Haze/Ozone input file for 2002. As for CMAQ, the missing TOMS data period in the fall of 2002 was filled-in using observed TOMS data on either side of the missing period using the same procedures as described above for CMAQ. Default land use specific albedo values were used and a constant haze value used, corresponding to rural conditions over North America.

1.3.11 Air Quality Input Preparation

Air quality data used with the CMAQ and CAMx modeling systems include: (1) Initial Concentrations (ICs) that are the assumed initial three-dimensional concentrations throughout the modeling domain.; (2) the Boundary Conditions (BCs) that are the concentrations assumed along the lateral edges of the RPO national 36 km modeling domain; and (3) air quality observations that are used in the model performance evaluation (MPE). The MPE is discussed in Section 3 and Appendix C of this TSD.

As noted in Section 1.3.7, CMAQ default clean Initial Concentrations (ICs) were used along with an approximately 15 day spin up (initialization) period to eliminate any significant influence of the ICs on the modeled concentrations for the days of interest. The same ICs were used with CAMx as well. Both CMAQ and CAMx were run for each quarter of the year. Each quarter's model run was initialized 15 days prior to the first day of interest (e.g., for quarter 3, Jul-Aug-Sep, the model was initialized on June 15, 2002 with the first modeling day of interest July 1, 2002). The CMAQ Boundary Conditions (BCs) for the Inter-RPO 36 km continental U.S. grid (Figure 1-2) were based on day-specific 3-hour averages from the output of the GEOS-CHEM global simulation model of 2002 (Jacob, Park and Logan, 2005). The 2002 GEOS-CHEM output was mapped to the species and vertical layer structure of CMAQ and interpolated to the lateral boundaries of the 36 km grid shown in Figure 1-2 (Byun, 2004).

Table 1-6 summarizes the surface air quality monitoring networks and the number of sites available in the CENRAP region that were used in the model performance evaluation. Data from these monitoring networks were also used to evaluate the CMAQ and CAMx models outside of the CENRAP region.

Table 1-6. Ground-level ambient data monitoring networks and stations available in the CENRAP states for calendar year 2002 used in the model performance evaluation.

Monitoring Network	Chemical Species Measured	Sampling Frequency; Duration	Approximate Number of Monitors
IMPROVE	Speciated $PM_{2.5}$ and PM_{10}	1 in 3 days; 24 hr	11
CASTNET	Speciated $PM_{2.5}$, Ozone	Hourly, Weekly; 1 hr, 1 Week	3
NADP	WSO4, WNO3, WNH4	Weekly	23
EPA-STN	Speciated $PM_{2.5}$ Varies;	Varies	12
AIRS/AQS	CO, NO, NO_2, NO_x, O_3 Hourly;	Hourly	25

1.3.12 2002 Base Case Modeling and Model Performance Evaluation

The CMAQ and CAMx models were evaluated against ambient measurements of PM species, gas-phase species and wet deposition. Table 1-6 summarizes the networks used in the model evaluation, the species measured and the averaging times and frequency of the measurements. Numerous iterations of CMAQ and CAMx 2002 base case simulations and model performance evaluations were conducted during the course of the CENRAP modeling study, most of which have been posted on the CENRAP modeling website (http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml) and presented in previous reports and presentations for CENRAP (e.g., Morris et al., 2005; 2006a,b). Details on the final 2002 Base F 36 km CMAQ base case modeling performance evaluation are provided in Chapter 3 and Appendix C (because of the similarity between 2002 Base F and 2002 Base G and resource constraints the model evaluation was not re-conducted for Base G). In general, the model performance of the CMAQ and CAMx models for sulfate (SO4) and elemental carbon (EC) was good. Model performance for nitrate (NO3) was variable, with a summer underestimation and winter overestimation bias. Performance for organic mass carbon (OMC) was also variable, with the inclusion of the SOAmods enhancement in CMAQ Version 4.5 greatly improving the CMAQ summer OMC model performance (Morris et al., 2006c). Model performance for Soil and coarse mass (CM) was generally poor. Part of the poor performance for Soil and CM is believed to be due to measurement-model incommensurability. The IMPROVE measured values are due, in part, to local fugitive dust sources that are not captured in the model's emission inputs and the 36 km grid resolution is not conducive to modeling localized events.

1.3.13 2018 Modeling and Visibility Projections

Emissions for the 2018 base case were generated following the procedures discussed in Section 1.3.8 and Chapter 2. 2018 emissions for Electrical Generating Units (EGUs) were based on simulations of the Integrated Planning Model (IPM) that took into the account the effects of the Clean Air Interstate Rule (CAIR) on emissions from EGUs in CAIR states using an IPM realization of a CAIR cap-and-trade program. Emissions for on-road and non-road mobile sources were based on activity growth and emissions factors from the EPA MOBILE6 and NONROAD models, respectively. Area sources and non-EGU point sources were grown to 2018 levels (Pechan, 2005d). The Canadian year 2000 emissions inventory was replaced by a Canadian 2020 emissions inventory for the 2018 CMAQ/CAMx simulations. The following sources were assumed to remain constant between the 2002 and 2018 base case simulations:

- Biogenic VOC and NOx emissions from the BEIS3 biogenic emissions model;
- Wind blown dust associated with non-agricultural sources (i.e., natural wind blown fugitive dust);
- Off-shore emissions associated with off-shore marine and oil and gas production activities;
- Emissions from wildfires;
- Emissions from Mexico; and
- Global transport (i.e., emissions due to BCs from the 2002 GEOS-CHEM global chemistry model.

The results from the 2002 and 2018 CMAQ and CAMx simulations were used to project 2018 PM levels from which 2018 visibility estimates were obtained. The 2002 and 2018 modeling results were used in a relative sense to scale the observed PM concentrations from the 2000-2004 Baseline and the IMPROVE monitoring network to obtain the 2018 PM projections. The 2018/2002 modeled scaling factors are called Relative Response Factors (RRFs) and are constructed as the ratio of modeling results for the 2018 model simulation to the 2002 model simulation. Two important regional haze metrics are the average visibility for the worst 20 percent and best 20 percent days from the 2000-2004 five-year Baseline. For the 2018 visibility projections, EPA guidance recommends developing Class I area and PM species specific RRFs using the average modeling results for the worst 20 percent days during the 2002 modeling period and the 2002 and 2018 emission scenarios. The results of the CENRAP 2018 visibility projections following EPA guidance procedures (EPA, 2007a) are provided in Chapter 4 and Appendix D. CENRAP has also developed alternative procedures for visibility projections that are discussed in Chapter 5 and Appendix D. For example, much of the coarse mass (CM) impacts at Class I area IMPROVE monitors is believed to be natural and primarily from local sources that are subgrid-scale to the modeled 36 km grid so are not represented in the modeling. So, one alternative visibility projection approach is to set the RRF for CM to 1.0. That is, the CM impacts in 2018 are assumed to be the same as in the observed 2000-2004 Baseline. Similarly, the Soil impacts at IMPROVE monitors are likely mainly due to local dust sources so another alternative approach is to set the RRFs for both CM and Soil to 1.0.

The 2018 visibility projections for the worst 20 percent days are compared against a 2018 point on the Uniform Rate of Progress (URP) glidepath or the "2018 URP point". The 2018 URP point is obtained by constructing a linear visibility glidepath in deciviews from the observed 2000-2004 Baseline (EPA, 2003a) for the worst 20 percent days to the 2064 Natural Conditions (EPA, 2003b; Pitchford, 2006). Where the linear glidepath crosses the year 2018 is the 2018 URP point. States may use the modeled 2018 visibility to help define their 2018 RPG in their RHR SIPs. The 2018 URP point is used as a benchmark to help judge the 2018 modeled visibility projections and the state's RPG. However, as noted in EPA's RPG guidance "The glidepath is not a presumptive target, and States may establish a RPG that provides for greater, lesser, or equivalent visibility improvement as that described by the glidepath" (EPA, 2007b). Chapter 4 and Appendix D present the 2018 visibility projections for the CENRAP Class I areas and their comparisons with the 2018 URP point using EPA default visibility projection procedures (EPA, 2007a) and EPA default URP glidepaths (EPA, 2003a,b; 2007b).

Various techniques have been developed to display the 2018 visibility modeling results including "DotPlots" that display the 2018 visibility projections as a percentage of meeting the 2018 point on the URP glidepath. A value of 100% on the DotPlot indicates that the Class I area is predicted to meet the 2018 point on the URP glidepath. Over 100% means the 2018 visibility projection obtains more visibility improvements (reductions) than required to meet the 2018 point on the URP glidepath (i.e., projected value is below the glidepath). And less than 100% indicates that fewer visibility improvements are projected than are needed to meet the 2018 point URP on the glidepath (i.e., above the glidepath). Figure 1-4 displays a DotPlot that compares the 2018 visibility projections from the CENRAP 2018 Base G CMAQ simulation with the 2018 URP point using the EPA default RRFs and alternative RRFs that set the CM and Soil RRFs to unity (i.e., assume CM and Soil are natural so remain unchanged from the 2000-2004 Baseline). For these results, the 2018 visibility projections at the Hercules Glade (HEGL1) Class I area meets the 2018 point on the URP glidepath (100%), whereas the 2018 visibility projections at Caney

Creek (CACR), Mingo (MING) and Upper Buffalo (UPBU) achieve more visibility improvements than needed to meet the 2018 URP point so are below the 2018 URP glidepath. However, the 2018 visibility projections at Breton Island comes up slightly short (~5%) of meeting the 2018 point on the URP glidepath and Wichita Mountains (WIMO) comes up approximately 40% short of meeting the 2018 point on the URP glidepath. Class I areas at the northern (e.g., VOYA, BOWA and ISLE) and southern (e.g., BIBE and GUMO) boundaries of the U.S. also fall short of achieving the 2018 URP point. High contributions of international transport and/or natural sources (e.g., wind blown dust) affect the ability of these Class I areas to be on the URP glidepath. These issues are discussed in more detail in Chapters 4 and 5.

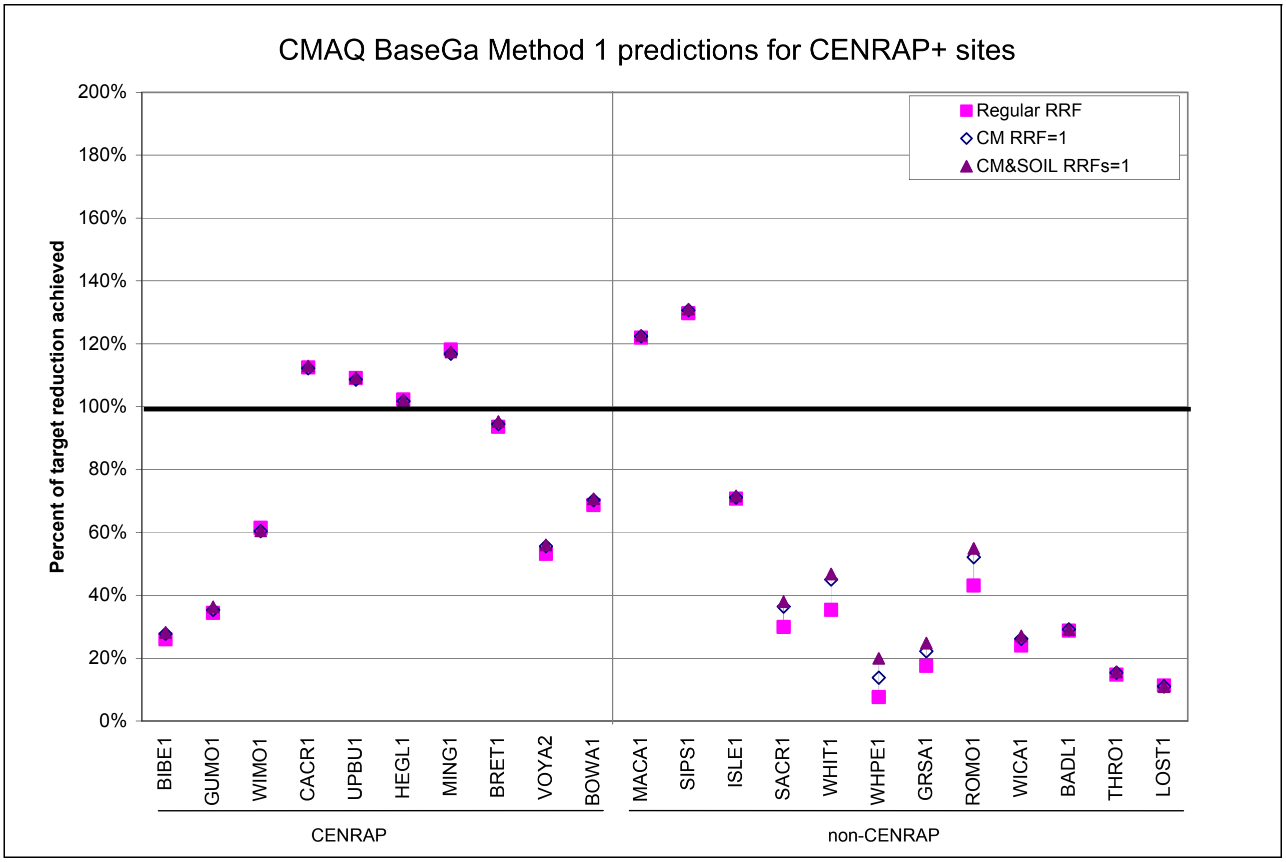

Figure 1-4. 2018 visibility projections expressed as a percent of meeting the 2018 URP point for the 2018 BaseG CMAQ base case simulation using the EPA default (EPA, 2007) Regular RRF and alternative projections procedures that set the RRFs for CM=1.0 and CM&SOIL=1.0.

1.3.14 Additional Supporting Analysis

CENRAP performed numerous supporting analyses of its modeling results including analyzing alternative glidepaths and 2018 projection Approaches and performing confirmatory analysis of the 2018 visibility projections. Details on the additional supporting analysis are contained discussed in Chapter 5, which include:

- The CENRAP 2018 visibility projections were compared with those generated by VISTAS and MRPO. There was close agreement between the CENRAP and VISTAS 2018 visibility projections at almost all common Class I areas. With the only exception being Breton Island where the CENRAP's projections were slightly more optimistic than VISTAS'. The MRPO 2018 visibility projections were less optimistic than CENRAP's at the four Arkansas-Missouri Class I area that may have been due to CENRAP's BART emission controls in CENRAP states not included in the 2018 MRPO inventory.
- Extinction based glidepaths were developed and the CENRAP 2018 visibility projections were shown to produce nearly identical estimates of achieving the 2018 URP point when using total extinction glidepaths as when the linear deciview glidepaths were used. With the extinction based glidepaths the analysis of 2018 URP could be made on a PM species-by-species basis where it was shown that 2018 extinctions due to SO4 and, to a lesser extent, NO3 and EC, achieve the URP, but the other species do not and in fact extinction due to Soil and CM is projected to get worse.
- 2018 visibility projections were made using EPA's new Modeled Attainment Test Software (MATS) program and the CENRAP Typ02G and Base18G modeling results. The CENRAP 2018 visibility projections exactly agreed with those generated by MATS with three exceptions: Breton Island, Boundary Waters and Mingo Class I areas, At these three Class I areas MATS did not produce any 2018 visibility projections due to insufficient data in the raw IMPROVE database to produce a valid observed 2000-2004 Baseline. CENRAP used filled data for these three Class I areas.
- PM Source Apportionment Technology (PSAT) modeling was conducted to estimate the contributions to visibility impairment at Class I areas by source region (e.g., states) and major source category. Source contributions were obtained for a 2002 and 2018 base case and the PSAT modeling results were implemented in a PSAT Visualization Tool that was provided to CENRAP states and others. Major findings from the PSAT source apportionment modeling include the following:
    - Sulfate from elevated point sources was the highest source category contribution to visibility impairment at CENRAP Class I areas for the worst 20 percent days.
    - International transport contributed significantly to visibility impairment at CENRAP Class I areas on the southern (BIBE and GUMO) and northern (BOWA and VOYA) borders of the U.S. and to a lesser extent at WIMO as well.
- Alternative visibility projections were made assuming that coarse mass (CM) alone and CM and Soil were natural in origin that confirmed the original 2018 visibility projections.
- Visibility projections were made using an alternative model (CAMx) that verified the projections made by CMAQ.
- The effects of International Transport were examined several ways and found that the inability of the 2018 visibility projections to achieve the 2018 URP point at the northern and southern border Class I areas was due to high contributions due to International Transport.

- Visibility trends for the worst 20 percent days, best 20 percent days and all monitored days were analyzed at CENRAP Class I areas using the period of record IMPROVE observations. At most Class I areas there was insufficient years of data to produce a discernable trend. In addition, there was significant year-to-year variability in visibility impairment with episodic events (e.g., wildfires and wind blown dust) confounding the analysis.

1.4 Organization of the Report

Chapter 1 of this TSD presents background, an overview of the approach and summary of the results of the CENRAP meteorological, emissions and air quality modeling. Appendix A contains more details on the meteorological model evaluation discussed in Chapter 1. Details on the emissions modeling are provided in Chapter 2 and Appendix B. The model performance evaluation is given in Chapter 3 and Appendix C. The 2018 visibility projections and comparisons with the 2018 URP point are provided in Chapter 4 with more details given in Appendix D. Chapter 5 contains additional supporting analysis with details on the PM source apportionment modeling and alternative projections provided in Appendices E and F, respectively. Chapter 6 lists the references cited in the report.

2.0 EMISSIONS MODELING

2.1 Emissions Modeling Overview

For the emissions modeling work conducted in support of CENRAP air quality modeling, we used updated 2002 emissions data for the U.S., 1999 emissions data for Mexico, and 2000 emissions data for Canada to generate a final base 2002 Base G Typical (Typ02G) annual emissions database. Numerous iterations of the emissions modeling were conducted using interim databases before arriving at the final Base G emission inventories. The 2002 and 2018 emissions inventories and ancillary modeling data were provided by CENRAP emissions inventory contractors (Pechan and CEP, 2005c, e; Reid et al., 2004a,b; Coe and Reid, 2003), other Regional Planning Organizations (RPOs) and EPA. Building from the CENRAP preliminary 2002 database (Pechan and CEP. 2005e) and 2018 projections (Pechan, 2005d), we integrated several updates to the inventories and ancillary data to create final emissions input files; the final simulations are referred to as 2002 Typical and 2018 Base G, or Typ02G and Base18G. We used the Sparse Matrix Operator Kernel Emissions (SMOKE) version 2.1 processing system (CEP, 2004) to prepare the inventories for input to the air quality modeling systems. The SMOKE simulations documented in this report include emissions generated for annual CMAQ and CAMx simulations at a 36-km model grid resolution, and a short-term CMAQ test simulation at a 12-km model grid resolution. We performed the modeling and quality assurance (QA) work based on the CENRAP modeling Quality Assurance Project Plan (QAPP; Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a).

The Typ02G and Base18G emission inventories represent significant improvements to the preliminary emissions modeling performed by CENRAP (Morris et al., 2005). While the preliminary 2002 modeling served its purpose to develop the infrastructure for modeling large emissions data sets and producing annual emissions simulations, much of the input data (both as inventories and ancillary data) were placeholders for actual 2002 data that were being prepared through calendar year 2005. As these actual 2002 data sets became available, they were integrated into the SMOKE modeling and QA system that was developed during the preliminary modeling, to produce a high-quality emissions data set for use in the final CMAQ and CAMx modeling. The addition of entirely new inventory categories, like marine shipping, added complexity to the modeling. By the end of the emissions data collection phase, there were 23 separate emissions processing streams covering a variety of sources categories necessary to general model-ready emission inputs for the 2002 calendar year.

2.1.1 SMOKE Emissions Modeling System Background

The purpose of SMOKE (or any emissions processor) is to process the raw emissions reported by states and EPA into gridded hourly speciated emissions required by the air quality model. Emission inventories are typically available as an annual total emissions value for each emissions source, or perhaps with an average-day emissions value. The air quality models, however, typically require emissions data on an hourly basis, for each model grid cell (and perhaps model layer), and for each model species. Consequently, emissions processing involves (at a minimum) transformation of emission inventory data by temporal allocation, chemical speciation, spatial allocation, and perhaps layer assignment, to achieve the input requirements of the air quality model. For the CENRAP modeling effort, all of these steps were needed. In addition, CENRAP processing requires special MOBILE6 processing and growth and control of emissions for the future-year inventories. Finally, the biogenic emission processing using BEIS2 includes additional processing steps. SMOKE formulates emissions modeling in terms of sparse matrix operations. Figure 2-1 shows an example of how the matrix approach organizes the emissions processing steps for anthropogenic emissions, with the final step that creates the model-ready emissions being the merging of all the different processing streams of emissions into a total emissions input file for the air quality model. Figure 2-1 does not include all the potential processing steps, which can be different for each source category in SMOKE, but does include the major processing steps listed in the previous paragraph, except the layer assignment. Specifically, the inventory emissions are arranged as a vector of emissions, with associated vectors that include characteristics about the sources such as its state and county or source classification code (SCC). SMOKE also creates matrices that will apply the gridding, speciation, and temporal factors to the vector of emissions. In many cases, these matrices are independent from one another, and can therefore be generated in parallel. The processing approach ends with the merge step, which combines the inventory emissions vector (now an hourly inventory file) with the control, speciation, and gridding matrices to create model-ready emissions.

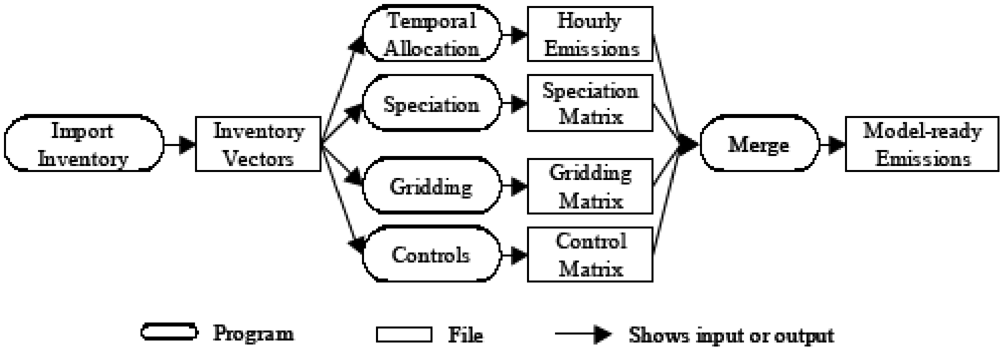

Figure 2-1. Flow diagram of major SMOKE processing steps needed by all source categories.

Temporal processing includes both seasonal or monthly adjustments and day-of-week adjustments. Emissions are known to be quite different for a typical weekday versus a typical Saturday or Sunday. For the day-of-week temporal processing step, emissions may be processed using representative Monday, weekday, Saturday, and Sunday for each month; we refer to this type of processing here as MWSS processing (note that because SMOKE operates in Greenwich Mean Time [GMT] then Monday would include some of local time Sunday so needs to be processed separately from the typical weekday). This approach significantly reduces the number of times the temporal processing step must be run. In the sections below, we have identified the cases in which we have used the MWSS processing approach. Figure 2-2 provides a schematic diagram of SMOKE/BEIS2 processing steps used in this project to generate biogenic emissions rates for Volatile Organic Compounds (VOCs) and oxides of nitrogen (NOx). Because biogenic emissions are temperature sensitive, they are generated for each day of 2002 using day-specific meteorological conditions from the MM5 meteorological model.

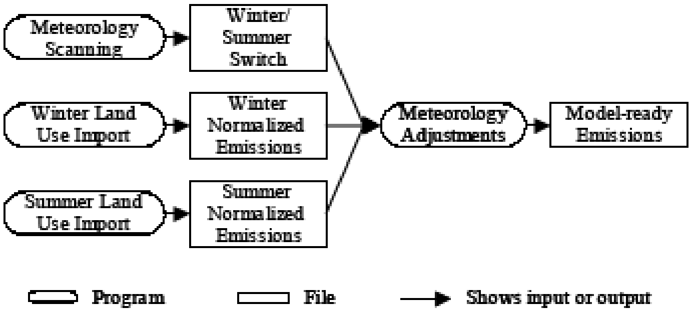

Figure 2-2. Flow diagram of SMOKE/BEIS2 processing steps.

2.1.2 SMOKE Scripts

The scripts are the interface that emissions modelers use to run SMOKE and define the set up and databases used in the emissions modeling so are important for anyone wishing to reproduce the CENRAP SMOKE emissions modeling. Many iterations of the CENRAP SMOKE emissions modeling were performed using updated and corrected emissions data and assumptions resulting in the creation of numerous SMOKE modeling scripts during the course of the study. For the CENRAP annual 2002 SMOKE emissions modeling, the default SMOKE script set up, which is based on source categories, was used to configure the scripts. We made several modifications to the default SMOKE scripts to modularize them, add error checking loops, and break up the report and logs directories by source category. The result is one script for each major source category being modeled that calls all of the SMOKE programs required for simulating that source category. 16 major source categories were modeled by SMOKE for CENRAP. An addition seven SMOKE scripts were also run to set up the emissions modeling. Table 2-1 lists all of the SMOKE scripts used for the 2002 base year modeling and the SMOKE programs called by each script. In addition to the source-specific scripts listed in Table 2-1, we also listed the SMOKE utility scripts that actually call executables, manage the log files, and manage the configuration of the SMOKE simulations.

Table 2-1. Summary of SMOKE scripts.

Source Category	Script Name	SMOKE Programs/Functions
Area	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_ar_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Area fire	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_arf_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Offshore Area	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_ofsar_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Non-road* Mobile	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_nr_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Fugitive dust	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_fd_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Road dust	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_rd_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Ammonia*	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_nh3_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
On-road Mobile (non-VMT-based)	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_mb_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
On-road non-US Mobile (non-VMT-based)	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_nusm_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
On-road Mobile (VMT-based)	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_mbv_base02f.csh	smkinev, mbsetup, grdmat, spcmat, premobl, emisfac, temporal, smkmerge, smkreport
WRAP Oil and Gas	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_wog_base02f.csh	smkinev, grdmat, spcmat, temporal, smkmerge, smkreport
Point	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_pt_base02f.csh	smkinev, grdmat, spcmat, laypoint, temporal, smkmerge, smkreport
Offshore point	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_ofs_base02f.csh	smkinev, grdmat, spcmat, laypoint, temporal, smkmerge, smkreport
Canadian Point fires	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_bsf_base02f.csh	smkinev, grdmat, spcmat, laypoint, temporal, smkmerge, smkreport
All point fires	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_alf_base02f.csh	smkinev, grdmat, spcmat, laypoint, temporal, smkmerge, smkreport
Biogenec	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smk_bg_base02f.csh	Normbies3, tmpbies3, smkmerge
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/make_invdir.csh	builds output file names and directories
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/smk_run.csh	Calls SMOKE executables for everything but projection, controls, and QA
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/qa_run.csh	Calls the SMOKE executables for running QA program & names the input/output directories for reports
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ scripts/run/36km/smoke_calls.csh	Calls smk_run.csh, qa_run.csh, configuration and management
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ Assignes/ASSIGNES.cenrap_base02f.cmaq.cb4p25	Sets up the environment variables for use of SMOKE
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ Assignes/smk_mkdir	Creates the input/output directories
n/a	/home/aqm2/edss2/cenrap02f/subsys/smoke/ Assignes/setmerge_files.scr	Sets up the output environment variables for the smkmerge program

* The nr and nh3 where farther divided to nrm and nry and nh3m and nh3y for the monthly/seasonal and yearly inventories

2.1.3 SMOKE Directory Structures

The SMOKE directories can be divided into three broad categories:

1. Program Directories: These directories contain the model source code, assigns files, scripts and executables needed to run SMOKE.
2. Input Directors : These directories contain the raw emissions inventories, the meteorological data and the ancillary input files.
3. Output Directories: These directories contain all of the output from the model. Also, the output directories contain the MOBILE6 input files.

The directories are described in the Table 2-2. The final pre-merged emission file names and sources of the data re provided in Appendix B.

Table 2-2. Summary of SMOKE directories.

Category	Directory Location	Directory Contents
Program	/home/aqm2/edss2/ cenrap02f/subsys/smoke/src	SMOKE source code
	/home/aqm2/edss2/ cenrap02f/subsys/smoke/assigns	SMOKE assigns files
	/home/aqm2/edss2/ cenrap02f/subsys/smoke/scripts	SMOKE make and run scripts
	/home/aqm2/edss2/ cenrap02f/subsys/smoke/Linux2_x86pg	SMOKE executables
Input	/home/aqm2/edss2/ cenrap02f/data/met	MCIP out metrology files
	/home/aqm2/edss2/ cenrap02f/data/ge_dat	SMOKE ancillary input files
	/home/aqm2/edss2/ cenrap02f/data/inventory/cenrap2002	Raw emissions inventory files
Output	/home/aqm2/edss2/ cenrap02f/data/run_base02f/static	Non-time dependent SMOKE intermediate outputs and MOBILE6 inputs
	/home/aqm2/edss2/ cenrap02f/ data/run_base02f/scenario	Time dependent SMOKE intermediate outputs
	/home/aqm2/edss2/ cenrap02f/data/run_base02f/outputs	Model-ready SMOKE outputs
	/home/aqm2/edss2/ cenrap02f/data/reports	SMOKE QA reports

2.1.4 SMOKE Configuration

SMOKE was configured to generate emissions for all months of 2002 on the 36-km unified RPO modeling domain (Figure 1-2). For the anthropogenic emissions sources that use hourly meteorology and daily or hourly data (i.e., on-road mobile sources, point sources with CEM data, point source fires and biogenic sources) we configured SMOKE to represent the daily emissions explicitly. For the non-meteorology dependent emissions, we used a representative Saturday, Sunday, Monday, and weekday for each month as surrogate days for the entire month's emissions (we refer to this as the MWSS processing approach). For these non-meteorology dependent emissions sources we explicitly represented the holidays as Sundays. Table 2-3 lists the days that we modeled as representative days in the months that we simulated for the 2002 base year modeling. Table 2-4 lists the holidays in 2002 that were modeled as Sundays.

Table 2-3: Representative model days for 2002 base year simulation.

Saturday	Sunday	Monday	Weekday
January 5	January 6	January 7	January 4
February 2	February 3	February 4	February 5
March 2	March 3	March 4	March 5
April 6	April 7	April 8	April 2
May 4	May 5	May 6	May 7
June 8	June 9	June 3	June 4
July 6	July 7	July 8	July 3
August 3	August 4	August 5	August 6
September 7	September 8	September 9	September 10
October 5	October 6	October 7	October 8
November 2	November 3	November 4	November 5
December 7	December 8	December 9	December 10

Table 2-4: 2002 modeled holidays.

Holiday	Date
New Years	January 1, 2002 January 2, 2002
Good Friday	March 29, 2002 March 30, 2002
Memorial Day	May 27, 2002 May 28, 2002
Independence Day	July 4, 2002 July 5, 2002
Labor Day	September 2, 2002 September 3, 2002
Thanksgiving Holiday	November 28-30, 2002
Christmas Holiday	December 24-26, 2002

We used the designations in Table 2-5 to determine which months fell into each season when temporally allocating the seasonal emissions inventories. Some of the inventories for the Electrical Generating Units (EGUs) were received for Winter and Summer. Table 2-6 determines which months fell into each season

Table 2-5. Assignments of months to four seasons for use of seasonal inventory files in SMOKE.

Month	Season
January	Winter
February	Winter
March	Spring
April	Spring
May	Spring
June	Summer
July	Summer
August	Summer
September	Fall
October	Fall
November	Fall
December	Winter

Table 2-6. Assignments of months to two seasons for use of seasonal inventory files in SMOKE.

Month	Season
January Winter	
February Winter	
March Winter	
April Winter	
May Sum	mer
June Summer	
July Summ	er
August Summer	
September Summer	
October Winter	
November Winter	
December Winter	

2.1.5 SMOKE Processing Categories

Emissions inventories are typically divided into area, on-road mobile, non-road mobile, point, and biogenic source categories. These divisions arise from differing methods for preparing the inventories, different characteristics and attributes of the categories, and how the emissions are processed through models. Generally, emissions inventories are divided into the following source categories, which we refer to later as “SMOKE processing categories.”

- Stationary Area Sources: Sources that are treated as being spread over a spatial extent (usually a county or air district) and that are not movable (as compared to non-road mobile and on-road mobile sources). Because it is not possible to collect the emissions at each point of emission, they are estimated over larger regions. Examples of stationary area sources are residential heating and architectural coatings. Numerous sources, such as dry cleaning facilities, may be treated either as stationary area sources or as point sources.

- On-Road Mobile Sources: Vehicular sources that travel on roadways. These sources can be computed either as being spread over a spatial extent or as being assigned to a line location (called a link). Data in on-road inventories can be either emissions or activity data. Activity data consist of vehicle miles traveled (VMT) and, optionally, vehicle speed. Activity data are used when SMOKE will be computing emission factors via another model, such as MOBILE6 (U.S. EPA, 2005). Examples of on-road mobile sources include light-duty gasoline vehicles and heavy-duty diesel vehicles.

- Non-Road Mobile Sources: These sources are engines that do not always travel on roadways. They encompass a wide variety of source types from lawn and garden equipment to locomotives and airplanes. Emission estimates for most non-road sources come from EPA's NONROAD model (OFFROAD in California). The exceptions are emissions for locomotives, airplanes, pleasure craft and commercial marine vessels.

- Point Sources: These are sources that are identified by point locations, typically because they are regulated and their locations are available in regulatory reports. In addition, elevated point sources will have their emissions allocated vertically through the model layers, as opposed to being emitted into only the first model layer. Point sources are often further subdivided into electric generating unit (EGU) sources and non-EGU sources, particularly in criteria inventories in which EGUs are a primary source of NO_x and SO_2. Examples of non-EGU point sources include chemical manufacturers and furniture refinishers. Point sources are included in both criteria and toxics inventories.

- Biogenic Land Use Data: Biogenic land use data characterize the types of vegetation that exist in either county-total or grid cell values. The biogenic land use data in North America are available using two different sets of land use categories: the Biogenic Emissions Landcover Database (BELD) version 2 (BELD2), and the BELD version 3 (BELD3) (CEP, 2004b).

In addition to these standard SMOKE processing categories, we have added other categories either to represent specific emissions processes more accurately or to integrate emissions data that are not compatible with SMOKE. Examples of emissions sectors that fall outside of the SMOKE processing categories include emissions generated from process-based models for representing windblown dust and agricultural ammonia (NH_3) sources. An emissions category with data that are not compatible with SMOKE is one with gridded emissions data sets, such as commercial marine sources. Another nonstandard emissions category that we modeled was emissions from fires. All of the emissions categories that we used to build CENRAP simulations are described in detail in the following sections.

Continuing the enhancement of the emissions source categories that we initiated during the preliminary 2002 modeling, we further refined the categories from the standard definitions listed above to include more explicit emissions sectors. The advantage of using more detailed definitions of the source categories is that it leads to more flexibility in designing control strategies, substituting new inventory or profile data into the modeling, managing the input and output data from SMOKE and conducting QA of the SMOKE outputs. The major drawback to defining more emissions source categories is the increased level of complexity and computational requirements (run times and disk space) that results from having a larger number of input data sets. Another motivation behind separating the various emissions categories is related to the size and flexibility of the input data. Some data sets, like the CENRAP on-road mobile inventory, were so large that we had to process them separately from the rest of the sources in the on-road sector due to computational constraints. We also separated the non-road mobile and ammonia sectors into yearly and monthly inventories to facilitate the application of uniform monthly temporal profiles to the monthly data. Additional details about how we prepared the emissions inventories and ancillary data for modeling are described in Sections 2.2 through 2.16. Table 2-7 summarizes the entire group of source sectors that composed simulation Typ02G. Each emissions sector listed in the table represents an explicit SMOKE simulation. As discussed in Section 2.1.2 below, after finishing all of the source-specific simulations, we used SMOKE to combine all of the data into a single file for each day for input to the air quality modeling systems. Each subsection on the emissions sectors describes each sector in terms of the SMOKE processing category, the year covered by the inventory, and the source(s) of the data.

Additional details about the inventories are also provided, including any modifications that we made to prepare them for input into SMOKE.

Table 2-7. CENRAP Typ02G emissions categories.

Emissions Sector	Abbreviation*
Fires as Point Sources (WRAP, CENRAP, VISTAS)	Alf
Area Sources (All domain)	ar
CENRAP area fires	arf
Area fires, Anthropogenic (All domain, excluding WRAP and CENRAP)	arfa
Area fires, Wild (All domain, excluding WRAP)	arfw
Biogenic b3	
Ontario, Canada, point-source fires	bsf
Fugitive dust	fd
WRAP on-road mobile	mb
CENRAP on-road mobile	mbv_CENRAP
Other US on-road mobile	mbv
Monthly CENRAP/MRPO anthropogenic NH_3 nh3m	
Ammonia from annual inventory (CENRAP)	nh3y
WRAP anthropogenic NH_3 nh3	
Seasonal/Monthly non-road mobile (WRAP, CENRAP, MW)	nrm
Annual non-road mobile	nry
On-road Mobile (Non-US)	nusm
Offshore shipping (Gulf, Atlantic)	ofs
Offshore area (Gulf)	ofsar
Stationary point (All domain, including offshore)	pt
Road dust	rd
Windblown dust (All domain)	wb_dust
WRAP oil and gas	wog

*These abbreviations are used in the file naming of the SMOKE output files for each sector.

Emissions models such as SMOKE are computer programs that convert annual or daily estimates of emissions at the state or county level to hourly emissions fluxes on a uniform spatial grid that are formatted for input to an air quality model. For the Typ02G and Base18G emission inventories we prepared emissions for CMAQ version 4.5 using SMOKE version 2.1 on the UCR Linux computing cluster. SMOKE integrates annual county-level emissions inventories with source-based temporal, spatial, and chemical allocation profiles to create hourly emissions fluxes on a predefined model grid. For elevated sources that require allocation of the emissions to the vertical model layers, SMOKE integrates meteorology data to derive dynamic vertical profiles. In addition to its capacity to represent the standard emissions processing categories, SMOKE is also instrumented with the Biogenic Emissions Inventory System, version 3 (BEIS3) model for estimating biogenic emissions fluxes (U.S. EPA, 2004) and the MOBILE6 model for estimating on-road mobile emissions fluxes from county-level vehicle activity data (U.S. EPA, 2005a).

SMOKE uses C-Shell scripts as user interfaces to set configuration options and call executables. SMOKE is designed with flexible QA capabilities to generate standard and custom reports for checking the emissions modeling process. After modeling all of the source categories individually, including those categories generated outside of SMOKE, we used SMOKE to merge all of the categories together to create a single CMAQ input file per simulation day. Also, for use in the CAMx modeling, we converted the CMAQ-ready emissions estimates to CAMx-ready files using the CMAQ2CAMx converter. Additional technical details about the version of SMOKE used for final simulations are available from CEP (2004b). All scripts, data, and executables used to generate the Typ02G and Base18G emissions for CMAQ and CAMx are archived on the CENRAP computing cluster.

2.1.6 2002 and 2018 Data Sources

This section describes the procedures that the CENRAP followed to collect and prepare all emissions data for Typ02G and Base18G simulations. We discuss the sources of all inventory and ancillary data used for simulations. CENRAP worked with emissions inventory contractors, other RPOs, and EPA to collect all of the data that constitute the simulation. Table 2-8 lists all of the contacts for the various U.S. anthropogenic emission inventories we used. For the CENRAP inventories, this table lists the contacts for the contractors who prepared the inventories; for the non-CENRAP inventories it lists the contacts at the RPOs who provided us inventory data. We obtained the emissions inventories for Canada and Mexico from the U.S. EPA Emissions Factors and Inventory Group (EFIG) via the Clearinghouse for Inventories and Emissions Factors (CHIEF) website (http://www.epa.gov/ttn/chief/index.html).

Table 2-8. CENRAP anthropogenic emissions inventory contacts.

Source Category	Emissions Data Contact
WRAP	
All Tom	Moore, Western Governors' Association Phone: (970) 491-8837 Email: mooret@cira.colostate.edu
CENRAP	
2002 Consolidated Inventory	Randy Strait, E.H. Pechan & Assoc., Inc. Phone: 919-493-3144 Email: rstrait@pechan.com
NH3 Inventory, Prescribed and Agricultural Fires, and On -road mobile emissions	Dana Sullivan, Sonoma Technology, Inc. Phone: 707-665-9900 Email: dana@sonomatech.com
Gulf Off-shore platform and support vessel emissions	Holly Ensz, Minerals Management Service Phone: (504) 736-2536 Email: holli.ensz@mms.gov
VISTAS	
All	Greg Stella, Alpine Geophysics, LLC, Phone: 828-675-9045 Email: gms@alpinegeophysics.com
MANE-VU	
All	Megan Schuster, MARAMA, Baltimore, MD USA Phone: 410-467-0170 Email: mschuster@marama.org
MRPO	
All	Mark Janssen, LADCO, Des Plaines, IL, USA Phone: 847-296-2181 Email:janssen@ladco.org

As mentioned above, the refinement of these inventories involved splitting some of the inventory files in to more specific source sectors. As the stationary-area-source emissions sector has traditionally been a catch-all for many types of sources, this is the inventory sector that required the greatest amount of preparation. Upon receiving all stationary-area- source inventories we extracted fugitive dust, road dust, anthropogenic NH_3, and for the non-WRAP U.S. inventories, stage II refueling sources. We retained the dust sources as separate categories that we would further refine with the application of transport factors (see Section 2.8).

We collected the ancillary data used for SMOKE modeling from several sources. SMOKE ancillary modeling data include:

- Temporal and chemical allocation factors by state, county, and source classification code (SCC);
- Spatial surrogates and cross-reference files for allocating county-level emissions to the model grid;
- Hourly gridded meteorology data;
- Stack defaults for elevated point sources;
- MOBILE6 configuration files;
- A Federal Implementation Standards (FIPS) codes (i.e., country/state/county codes) definition file;

- A Source Category Classification (SCC) codes definition file;
- A pollutant definition file; and
- Biogenic emission factors.

Except for the meteorology data and the MOBILE6 configuration files, we used default data sets provided by EPA as the basis for all of the ancillary data except for temporal profiles used for Electric Generating Units (EGUs). These profiles were developed based on CEM data from 2000 through 2003 (Pechan and CEP, 2005c). CENRAP provided the meteorology data for the simulations at 36-km and 12-km grid resolutions (Johnson, 2007). The inventory contractor who prepared the MOBILE6 inventories provided the MOBILE6 configuration files either directly or via an RPO representative; details about the sources of the MOBILE6 inputs are provided in Section 2.4. We made minor modifications to the chemical allocation, pollutant definition, and country/state/county codes files for new sources, pollutants, or counties contained in the inventories that we had not previously modeled. We made major modifications to the temporal and spatial allocation inputs, as described below.

2.1.7 Temporal Allocation

Temporally allocating annual, daily, or hourly emissions inventories in SMOKE involves combining a temporal cross-reference file and a temporal profiles file.

- Temporal cross-reference files associate monthly, weekly, and diurnal temporal profile codes with specific inventory sources, through a combination of a FIPS (country/state/county) code, an SCC, and sometimes for point sources, facility and unit identification codes.
- Temporal profiles files contain coded monthly, weekly, and diurnal profiles in terms of a percentage of emissions allocated to each temporal unit (e.g., percentage of emissions per month, weekday, or hour).

As a starting point for the temporal allocation data for simulations, we used the files generated by emission inventory contractors (Pechan and CEP, 2005c). Based on guidance from the developers of some of the inventory files, we enhanced the temporal profiles and assignments for some source categories (Pechan, 2005b).

We modified the temporal allocation data for the simulations to improve the representation of temporal emissions patterns for certain source categories. We implemented the adjusted profiles in SMOKE by modifying the temporal cross-reference file for the applicable FIPS and SCC combinations.

Updated temporal profiles for EGUs were made available for MRPO in the MRPO Base K inventory. Since the non-road emissions for IA and MN were monthly emissions developed by MRPO, new temporal profiles were created for all the SCCs in these emissions files for these two states only. The monthly profile was uniform and the weekly and diurnal profiles were kept the same as were modeled for the rest of the country.

An updated temporal profile, profile 485, based on NOAA 1971-2000 population weighted average heating degree days for home heating area source emissions was obtained from

VISTAS. This profile provided state specific updates for home heating emissions and was applied to the full inventory in place of profile 17XX.

Other additions to the Base02G temporal allocation data included updates that made by other RPOs that are applicable to their inventories. These other updates to the temporal allocation files included

- VISTAS continuous emissions monitoring (CEM)-specific profiles for EGUs in the VISTAS states;
- VISTAS agricultural burning profiles;
- Wildfire and prescribed fire profiles developed by VISTAS for the entire U.S.;
- MANE-VU on-road mobile profiles;
- WRAP weekly and diurnal road dust profiles;
- WRAP diurnal wildfire, agricultural fire, and prescribed fire profiles; and
- WRAP on-road mobile weekly and diurnal profiles.

Finally, for all of the monthly and seasonal emissions inventories, we modified the temporal cross-reference files to apply uniform monthly profiles to the sources contained in these inventories. The monthly variability is inherent in monthly and seasonal inventories and does not need to be reapplied through the temporal allocation process in SMOKE. The inventories to which we applied uniform monthly temporal profiles included:

- WRAP, CENRAP, and MRPO non-road mobile sources;
- WRAP on-road mobile sources;
- WRAP road dust; and
- CENRAP anthropogenic ammonia.

2.1.8 Spatial Allocation

SMOKE uses spatial surrogates and SCC cross-reference files to allocate county-level emissions inventories to model grid cells. Geographic information system (GIS)-calculated fractional land use values define the percentage of a grid cell that is covered by standard sets of land use categories. For example, spatial surrogates can define a grid cell as being 50% urban, 10% forest, and 40% agricultural. In addition to land use categories, spatial surrogates can also be defined by demographic or industrial units, such as population or commercial area. Similar to the temporal allocation data, an accompanying spatial cross-reference file associates the spatial surrogates (indexed with a numeric code) to SCCs. Spatial allocation with surrogates is applicable only to area and mobile sources that are provided on a county level basis. Point sources are located in the model grid cells by SMOKE based on the latitude-longitude coordinates of each source. Biogenic emissions are estimated based on 1-km^2 gridded land use information that is mapped to the model grid using a processing program such as the Multimedia Integrated Modeling System (MIMS) Spatial Allocator (CEP, 2004).

We used various sources of spatial surrogate information for the U.S., Canada, and Mexico inventories in the simulations. For the U.S. and Canadian sources, we used the EPA unified surrogates available through the EFIG web site (EPA, 2005c). For the 36-km grid, EPA provides these data already formatted for SMOKE on the RPO Unified 36-km domain that we used for the simulations. We modified the spatial surrogates for Canada on the RPO Unified 36-km domain by adopting several surrogate categories that were enhanced by the WRAP. Table 2-9 provides details about the new Canadian spatial surrogates that were developed by the WRAP and used for CENRAP simulations. For modeling Mexico, we used Shapefiles developed for the Big Bend Regional Aerosol and Visibility Observations Study (BRAVO) modeling to create surrogates for Mexico on the RPO Unified 36-km domain (EPA, 2005c).

Table 2-9. New Canadian spatial surrogates.

Attribute	Base02a Code	Shapefile	Reference
Land area	950	can_land93_land	Natural Resources Canada (1993) AVHRR land cover data
Water area	951	can_land93_water	Natural Resources Canada (1993) AVHRR land cover data
Forest land area	952	can_land93_forest	Natural Resources Canada (1993) AVHRR land cover data
Agricultural land area	953	can_land93_agri	Natural Resources Canada (1993) AVHRR land cover data
Urban land area	954	can_land93_urban	Natural Resources Canada (1993) AVHRR land cover data
Rural land area	955	can_land93_rural	Natural Resources Canada (1993) AVHRR land cover data
Airports 956		can_airport	U.S. DOT Bureau of Transportation Statistics (2005) NORTAD 1:1,000,000 scale data
Ports 957		can_port	U.S. DOT Bureau of Transportation Statistics (2005) NORTAD 1:1,000,000 scale data
Roads 958		can_road1m	Natural Resources Canada (2001) National Scale Frameworks data
Rail 959		can_rail1m	Natural Resources Canada (1999) National Scale Frameworks data

2.2 Stationary Point Source Emissions

Stationary-point-source emissions data for SMOKE consist of (1) Inventory Data Analyzer (IDA)-formatted inventory files; (2) ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx; and (3) meteorology data for calculating plume rise from the elevated point sources. This section describes where CENRAP obtained these data, how we modeled them, and the types of QA that we performed to ensure that SMOKE processed the data as expected.

2.2.1 Data Sources

For the stationary-point-source inventories in Typ02G and Base18G, we used actual 2002 data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and the BRAVO 1999 Mexican inventory. The BRAVO inventory was updated with entirely new inventories for the six northern states of Mexico for stationary area, as well as stationary point, on-road mobile, and off-road mobile sources. Emissions for the southern states of Mexico were included for the first time in CENRAP simulations Typ02G and Base18G. These data were provided by ERG, Inc., who completed an updated 1999 emissions inventory for northern Mexico (ERG, 2006b) and delivered these data to the WRAP. The CENRAP stationary-point inventory consisted of annual county-level and tribal data provided in August of 2005 (Pechan and CEP, 2005e). The WRAP (ERG, 2006a) and VISTAS Base G (MACTEC, 2006) stationary-point inventories consisted of an annual data set and monthly CEM data for selected EGUs. The WRAP and VISTAS provided these data directly to CENRAP. We downloaded the MANE-VU stationary-point inventories from the MANE-VU web sites. MRPO base K data was downloaded and processed for SMOKE modeling by Alpine Geophysics under contract from MARAMA. UCR entered into a nondisclosure agreement with Environment Canada to obtain version 2 of the 2000 Canadian point-source inventory. This inventory represented a major improvement over the version of the data that we had used in the preliminary 2002 modeling.

Reductions anticipated from BART controls for electric generating units (EGU) in Oklahoma, Arkansas, Kansas, and Nebraska were included in projections of 2018 emissions. These anticipated reductions were based on actual operating conditions and estimated control efficiencies from utilities.

Newly permitted coal-fired utilities were included in 2018 projections. Conservatively, no IPM projected new units were removed from the simulation with the addition of the permitted facilities.

Due to missing or clearly erroneous stack parameters, several facilities in CENRAP states were relegated to default stack profiles based on SCC in the NEI QA process. Prioritizing for the largest emissions sources, these default parameters were corrected by CENRAP States and updated files were provided to modeling contractors. Final IDA input files Typ02G and Base18G for point sources reflect State corrections.

For coal-fired point and area sources, The EPA Office of Air Quality and Planning Standards (OAQPS) determined that the organic carbon fraction in the speciation profile code "NCOAL" was not representative of most coal combustion occurring in the U.S. This profile has an organic carbon fraction of 20%, which includes an adjustment factor of 1.2 to account for other atoms (like oxygen) attached to the carbon. OAQPS has reverted back to the profile code "22001" for coal combustion, which has an organic carbon fraction of 1.07% (again including the 1.2 factor adjustment). This is the same profile that EPA used for previous rulemaking efforts including the Heavy Duty Diesel Rule and Non-Road Rule, which were proposed (and publicly reviewed) prior to the introduction of the NCOAL profile.

The consensus in OAQPS is that the NCOAL profile has a high organic carbon percentage because it is based on measurements of combustion of lignite coal. With the exception of Texas, lignite is not widely used in the U.S.. Thus, OAQPS staff stopped relying on this profile as a national default profile. A new coal speciation profile developed based on Eastern bituminous coal combustion (since much of the coal burned in the U.S. is of this type) is being developed by EPA's Office of Research and Development but was not completed for this study.

The profile recently developed for MRPO by Carnegie Mellon was provided to CENRAP and is representative of combustion of eastern bituminous coal. This profile is a more appropriate profile for most facilities in the U.S. than the default NCOAL profile.

Additionally, the "22001" profile has been flagged as problematic because of the apparent inadvertent switching of the organic carbon and elemental carbon fractions, which are 1.07% and 1.83% respectively. The report discovering the discrepancy in the profile did not offer a clear alternative to correct the problem (MACTEC, 2003).

CENRAP has continued to use the NCOAL factor for facilities burning lignite in North Dakota and Texas. For the remainder of the U.S., the MRPO profile, CMU, was used. The NCOAL factor was modified reducing the organic carbon by half and assigning the remainder to $PM_{2.5}$. The modification was at the request of Texas and was reflective of the original study for the NCOAL factor conducted in Texas (Chow, 2005). Table 2-10 summarizes the $PM_{2.5}$ speciation profiles for the NCOAL, 2201 and CMU speciation profiles for coal burning sources.

Table 2-10. PM 2.5 speciation profiles for coal-burning sources.

Profile	POC	PEC	PNO3	PSO4	PM2.5
NCOAL	0.1000	0.0100	0.0050	0.1600	0.7250
22001	0.0107	0.0183	0.0000	0.1190	0.8520
CMU	0.0263	0.0315	0.0036	0.0447	0.8938

Final simulations used improved temporal allocation and speciation information relative to the preliminary 2002 modeling; the rest of the ancillary data for modeling stationary point sources stayed the same (Mansell et al., 2005).

2.2.2 Emissions Processing

For Typ02G and Base18G simulations we configured SMOKE to process the annual inventories for the U.S., Canada, and Mexico and process hourly CEM data for the VISTAS. We configured SMOKE to allocate these emissions up to model layer 15 (approximately 2,500 m AGL), which roughly corresponds to the maximum planetary boundary layer (PBL) heights across the entire domain throughout the year. As coarse particulate matter (PMC) is not an inventory pollutant but is required by the air quality models as input species, we used SMOKE to calculate PMC during the processing as (PM_{10} - $PM_{2.5}$). With the SMOKE option WKDAY_NORMALIZE set to “No,” we treated the annual inventories based on the assumption that they represent average-day data based on a seven-day week, rather than average weekday data. We also assumed that all of the volatile organic compound (VOC) emissions in the inventories are reactive organic gas (ROG), and thus used SMOKE to convert the VOC to total organic gas (TOG) before converting the emissions into CB-IV speciation for the air quality models. To capture the differences in diurnal patterns that are contained in the CEM temporal profiles for VISTAS and CENRAP states (Base02F), we configured SMOKE to generate daily temporal matrices, as opposed to using a Monday-weekday-Saturday-Sunday (MWSS) temporal allocation approach.

To QA the stationary-point emissions, we used the procedures in the CENRAP emissions modeling QA protocol (Morris and Tonnesen, 2004) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for all simulations. These QA graphics are available on the web site at: http://pah.cert.ucr.edu/aqm/cenrap/emissions.shtml

2.2.3 Uncertainties and Recommendations

There were issues with the stationary-point emissions that we left unresolved at the completion of the Typ02G and Base18G emissions modeling either because we did not feel they would have a major impact on the modeling results in CENRAP states or because we did not have alternative approaches and they represented the best available information. Canadian emissions for 2000 were found to have a significant number of missing stack parameters. These stacks when modeled with default parameters frequently resulted in lower plume heights. Stack parameters for 2000 were corrected based on cross referencing sources with the 2005 Canadian inventory for the largest emitting points. Stack parameters for many of the sources with lower emissions remain incorrect, but are assumed to have a less significant impact on CENRAP Class I areas. The 2020 projected emissions for Canada were obtained as air quality model-ready files from EPA. EPA has not confirmed that missing stack parameters were corrected for the projected inventory. It is assumed that they were not corrected and default parameters were used instead. Given confidentiality issues that surround Canadian inventories, EPA processed emissions represent the best available data.

2.3 Stationary Area Sources

Stationary-area-source emissions data for SMOKE consist of IDA-formatted inventory files and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. This section describes where we obtained these data, how we modeled them, and the types of QA that we performed to ensure that SMOKE processed the data as expected.

2.3.1 Data Sources

For the stationary area source inventories in the Typ02G and Base18G simulations, we used actual 2002 data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and the updated Mexican inventory, http://www.epa.gov/ttn/chief/net/mexico.html. The BRAVO inventory was updated with entirely new inventories for the six northern states of Mexico for stationary area, as well as stationary point, on-road mobile, and off-road mobile sources. Emissions for the southern states of Mexico were included for the first time in CENRAP simulations Typ02G and Base18G. The CENRAP stationary-area inventory consisted of annual county-level and tribal data provided by in August of 2005 (Pechan and CEP, 2005e). The WRAP (ERG, 2006a) and VISTAS Base G (MACTEC, 2006) stationary-area inventories consisted of an annual data set. We downloaded the MANE-VU stationary-area inventories from the MANE-VU web sites. MRPO base K data was downloaded and processed for SMOKE modeling by Alpine Geophysics under contract from MARAMA.

To prepare the stationary-area inventories for modeling, we made several modifications to the files by removing selected sources either to model them as separate source categories or to omit them from simulations completely. Using guidance provided by EPA (EPA, 2004b), we extracted fugitive and road dust sources from all stationary-area inventories for adjustment by transport factors and modeling as separate source categories (see Section 2.8). We also extracted and discarded the stage II refueling sources (Table 2-11) from the U.S. inventories; we modeled these sources with MOBILE6 as part of the on-road mobile-source emissions. We left the stage II refueling emissions in the WRAP stationary-area inventory because the on-road mobile inventory that we received for this region did not contain these emissions.

Table 2-11. Refueling SCCs removed from the non-WRAP U.S. stationary-area inventory.

SCC	Description
2501060100	Storage and Transport Petroleum and Petroleum Product Storage Gasoline Service Stations Stage 2: Total
2501060101	Storage and Transport Petroleum and Petroleum Product Storage Gasoline Service Stations Stage 2: Displacement Loss/Uncontrolled
2501060102	Storage and Transport Petroleum and Petroleum Product Storage Gasoline Service Stations Stage 2: Displacement Loss/Controlled
2501060103	Storage and Transport Petroleum and Petroleum Product Storage Gasoline Service Stations Stage 2: Spillage
2501070100	Storage and Transport Petroleum and Petroleum Product Storage Diesel Service Stations Stage 2: Total
2501070101	Storage and Transport Petroleum and Petroleum Product Storage Diesel Service Stations Stage 2: Displacement Loss/Uncontrolled
2501070102	Storage and Transport Petroleum and Petroleum Product Storage Diesel Service Stations Stage 2: Displacement Loss/Controlled
2501070103	Storage and Transport Petroleum and Petroleum Product Storage Diesel Service Stations Stage 2: Spillage

Other steps that we took to prepare the stationary-area inventories included confirming that there is no overlap between the anthropogenic NH_3 inventory (Section 2.9) and stationary area sources, and moving area-source fires in each regional inventory to separate files. In addition to these inventory modifications we made a few changes to the ancillary data files for simulation Typ02G, as described next.

Simulation Typ02G used improved temporal and spatial allocation information relative to the preliminary 2002 modeling; the rest of the ancillary data for modeling stationary area sources stayed the same as in the preliminary 2002 modeling (Mansell et al., 2005). We adopted enhanced spatial allocation data with additional area-based surrogates for Canada (Table 2-9), and added surrogates for a missing county in Colorado (Broomfield) from WRAP modeling and QA work. The WRAP had noticed when looking at the Canadian data for the preliminary 2002 modeling that forest fire emissions from the Canadian area-source inventory, which are relatively large sources of CO, NO_x, and $PM_{2.5}$, were being allocated to a surrogate for logging activities. They found similar discrepancies for other area and non-road SCCs in Canada. To improve the representation of the Canadian emissions, we adopted several land-area-based surrogates developed by the WRAP, such as forested land area, urban land area, and rural land area, and made the accompanying additions to the spatial cross-reference file to associate inventory SCCs with these surrogates. We also added spatial surrogates for Broomfield County, CO; this county was included in the inventory but was not included in the base EPA surrogates (this county was recently created from portions of other counties).

Improvements to the temporal allocation data for simulation Typ02G included the addition of several FIPS-specific profiles provided by VISTAS and CENRAP contractors (Pechan 2005b). These temporal profiles listed in Table 2-12 targeted mainly fire and agricultural NH_3 sources, such as open burning and livestock operations, respectively.

Table 2-12. New Temporal Profile Assignments for CENRAP Area Source SCCs.

SCC	Description	Month	Week	Diurnal	Recommendation Based on Profile Data for SCC	Description of Similar SCC used to Recommend Profiles
2310001000	Industrial Processes; Oil and Gas Production: SIC 13;All Processes : On-shore; Total: All Processes	262	7	26	2310000000	Industrial Processes;Oil and Gas Production: SIC 13;All Processes;Total: All Processes
2310002000	Industrial Processes;Oil and Gas Production: SIC 13;All Processes : Off-shore;Total: All Processes	262	7	26	2310000000	Industrial Processes;Oil and Gas Production: SIC 13;All Processes;Total: All Processes
2461870999	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Pesticide Application: Non-Agricultural;Not Elsewhere Classified	258	7	26	2461800000	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Pesticide Application: All Processes;Total: All Solvent Types
2805009200	Miscellaneous Area Sources;Agriculture Production - Livestock;Poultry production - broilers;Manure handling and storage	1500	7	26	2805009300	Miscellaneous Area Sources;Agriculture Production - Livestock;Poultry production - broilers;Land application of manure
2805021100	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - scrape dairy;Confinement	1500	7	26	2805021300	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - scrape dairy;Land application of manure
2805021200	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - scrape dairy;Manure handling and storage	1500	7	26	2805021300	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - scrape dairy;Land application of manure
2805023100	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - drylot/pasture dairy;Confinement	1500	7	26	2805023300	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - drylot/pasture dairy;Land application of manure
2805023200	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - drylot/pasture dairy;Manure handling and storage	1500	7	26	2805023300	Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle - drylot/pasture dairy;Land application of manure
2810020000	Miscellaneous Area Sources;Other Combustion;Prescribed Burning of Rangeland;Total	3	11	13	2810015000	Miscellaneous Area Sources;Other Combustion;Prescribed Burning for Forest Management;Total

2.3.2 Emissions Processing

For simulations Typ02G and Base18G we configured SMOKE to process the annual stationary-area-source inventories for the U.S., Canada, and Mexico. As PMC is not an inventory pollutant but is required by the air quality models as input species, we used SMOKE to calculate PMC during the processing as (PM_{10} - $PM_{2.5}$). With the SMOKE option WKDAY_NORMALIZE set to "Yes," we treated the annual stationary-area inventories based on the assumption that they represent average weekday data, causing SMOKE to renormalize the data to a seven-day estimate before applying any temporal adjustments. We also assumed that all of the VOC emissions in the inventories are ROG and thus used SMOKE to convert the VOC to TOG before converting the emissions into CB-IV speciation for the air quality models. We configured SMOKE to use a MWSS temporal allocation approach, as opposed to a daily temporal approach.

To QA the stationary-area emissions, we used the procedures in the CENRAP modeling QAPP and Modeling Protocol (Morris and Tonnesen, 2004; Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for all simulations. The graphical QA summaries include, for all emissions output species, daily spatial plots summed across all model layers, daily time-series plots, and annual time-series plots. These QA graphics are available on the UCR/CENRAP web site at http://pah.cert.ucr.edu/aqm/cenrap/emissions.shtml .

2.3.3 Uncertainties and Recommendations

Most of the issues that we encountered with the stationary area sources related to the removal of certain SCCs from the base inventories for inclusion as other source categories or complete omission from simulations. We spent considerable effort on ensuring that we did not have overlap between the area inventory and the other sectors that explicitly represent sources traditionally contained in the area inventory, such as NH_3 and dust.

Both the Canadian and Mexican inventories presented minor problems that we resolved for simulation Typ02G but that can be addressed more thoroughly in future simulations. The Canadian inventory we used contained data only at the province level, essentially equivalent to a statewide rather than county-level inventory. A higher resolution inventory would have allowed us to use higher-resolution and more accurate spatial allocation data. Future modeling that uses Canadian data should move to the newly released municipality-level year 2000 inventories for Canada.

There was a discrepancy between the state and county coding in the Mexican inventory and the SMOKE file that defines acceptable FIPS codes. Differences in the ordering of the Mexican state names between these two data sets led to some of the Mexican inventory sources being mislabeled in the SMOKE QA reports. The state codes in the inventory and spatial surrogate files for two Mexican states were changed to be consistent with the SMOKE country/state/county codes file.

2.4 On-Road Mobile Sources

On-road mobile-source emissions data for SMOKE consist of IDA-formatted emissions and vehicle activity inventory files, and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. This section describes where we obtained these data, how we modeled them, and the types of QA that we performed to ensure that SMOKE processed the data as expected.

2.4.1 Data Sources

The SMOKE processing for CENRAP included two approaches for processing on-road mobile sources depending on the source of the data provided. The first approach was to compute mobile emissions values prior to providing them to SMOKE; we call this the pre-computed emissions approach. The second approach was to provide SMOKE with VMT data, meteorology data, and MOBILE6 inputs, and let the SMOKE/MOBILE6 module compute the mobile emissions based on these data; we call this the VMT approach. These approaches are not mutually exclusive for a single SMOKE run; therefore, we performed single SMOKE runs in which both approaches were used as follows:

- Annual VMT for computing CO, NO_x, VOC, SO2, NH3 and PM using MOBILE6 for all CENRAP States.
- Pre-computed, seasonal MOBILE6-based emissions of all pollutants for the 13 WRAP states that included pre-speciated $PM_{2.5}$ data.
- Annual VMT for computing CO, NO_x, VOC, SO2, NH3 and PM using MOBILE6 for the rest of the United States (VISTAS, MRPO and MANE-VU).
- Pre-computed, annual 1999 emissions of all pollutants for Mexico.
- Pre-computed, annual 2000 emissions of all pollutants for Canada.

For the CENRAP states, STI provided VMT data and MOBILE6 input files for all counties in the CENRAP region (Reid et al., 2004a). MOBILE6 input files were provided only for the months of January and July for 2002. MOBILE6 input files for the remaining months of 2002 had to be generated. These data were then processed with in SMOKE. Using one set of MOBILE6 input files for each county in the CENRAP states resulted in compute memory requirements that were to large to process all CENRAP states together. Therefore the on-road mobile processing for the CENRAP states was split into two groups for SMOKE processing. The resulting gridded emissions data files were then merged together to obtain an on-road mobile source emissions file for the entire CENRAP region.

For the WRAP states we used actual 2002 data split into California and non-California seasonal inventories that were provided by the WRAP (Pollack et al., 2006). In addition to the standard criteria pollutants, these files contained pre-speciated $PM_{2.5}$ emissions. For the rest of the U.S. we used annual county-level activity and speed inventories with monthly, county-level MOBILE6 inputs, and hourly meteorology to estimate the hourly emissions with the SMOKE/MOBILE6 module. For the non-U.S. inventories, we used version 2 of the year 2000 Canadian inventory and the updated 1999 Mexican inventory pre-computed mobile source emissions.

2.4.2 Emissions Processing

For the Typ02G emissions modeling we configured SMOKE to process the annual on-road mobile emissions inventory data for the WRAP, Canada, and Mexico as pre-computed inventories. For the non-WRAP states, we used the SMOKE/MOBILE6 integration to process the annual activity inventories and monthly, county-based roadway information. The WRAP inventories contained pre-computed speciated PM emissions (Pollack et al, 2006) so the SMOKE PM speciation module was not used. The WRAP on-road mobile inventories were developed to represent seven-day (weekly) average emissions (as compared to the area source inventory, which represented average weekday emissions). As actual weekly average emissions, we configured SMOKE to process the WRAP on-road mobile source emissions by setting WKDAY_NORMALIZE to “No” in which case the emissions are adjusted to represent weekday and Saturday and Sunday emissions (as in contrast to the area sources where the emissions are just adjusted for Saturday and Sunday). We also assumed that all of the VOC emissions in the inventories are ROG and used SMOKE to convert the VOC to TOG before converting the emissions into CB-IV speciation for the air quality models. We configured SMOKE to create day-of-week specific rather than MWSS, temporal profiles because the WRAP on-road mobile temporal profiles contain weekly profiles that vary across the weekdays.

As noted previously, the large number of county roadway inputs for MOBILE6 processed for the non-WRAP portion of the U.S. required us to split the states mobile-source processing into three subsets because of computer memory limitations. Separate MOBILE6 input files were used for each separate county for CENRAP states, where as one MOBILE6 input file was used for several counties outside of the CENRAP region. The three subsets consisted of two sets of SMOKE/MOBILE6 simulations for the CENRAP and a simulation that computed on- road mobile emissions for the MRPO, VISTAS, and MANE-VU states. We configured MOBILE6 to use weekly temperature averaging for computing these emissions within SMOKE.

To QA the on-road mobile emissions, we used the CENRAP emissions modeling QA protocol (Morris and Tonnesen, 2004; Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulations Typ02G and Base18G. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/qa_base02b36.shtml#mb

2.4.3 Uncertainties and Recommendations

We approached the on-road mobile emissions preparation for simulation Typ02G from three different directions, which were based on the form of the input inventories and ancillary emissions data for different regions of the modeling domain:

- The WRAP region used emissions estimates pre-computed with EMFAC for California and MOBILE6 for the rest of WRAP states and processed like area sources with SMOKE adjusted from weekly to day-of-week emissions.
- The CENRAP, VISTAS, MRPO, and MANE-VU states used county-level activity data to compute emissions with the SMOKE/MOBILE6 module.

- The non-U.S. parts of the domain also had pre-computer on-road mobile source emissions so used an area-source approach for processing with SMOKE.

Different approaches for modeling a single emissions sector adds complexity and additional sources of error and inconsistencies to the modeling because of the different assumptions that went into the preparation of the input data. For example, refueling emissions from the on-road mobile sector are represented in the WRAP area-source sector but are computed with MOBILE6 for the rest of the U.S. Not using MOBILE6-based emissions for the non-U.S. portion of the domain neglects the effects of the actual 2002 meteorology on these emissions. Applying MOBILE6 outside of the U.S. is currently not possible because MOBILE6 is instrumented only for calculating emissions for the U.S. automotive fleet. The result of using MOBILE6 to calculate U.S. emissions and not using it to calculate the non-U.S. on-road mobile emissions estimates is that the non-U.S. emissions are not specific to this modeling year and the 2002 meteorological conditions, whereas the U.S. emissions are 2002-specific.

While we used the best available information to compute the on-road mobile emissions for the various portions of the modeling domain, inconsistent approaches for representing these emissions may lead to unnatural emissions gradients along political boundaries. We recommend for future work a unified approach for at least the U.S. inventories, where either we use MOBILE6 in SMOKE for the entire domain (or alternative emissions model such as CONCEPT), or we calculate the emissions with MOBILE6 outside of SMOKE and then use the resulting county-based emissions inventories.

2.5 Non-Road Mobile Sources

Non-road mobile source emissions data for SMOKE consist of annual, seasonal, and monthly IDA-formatted emission inventory files and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. This section describes where we obtained these data, how we modeled them, and the types of QA that we performed to ensure that SMOKE processed the data as expected.

2.5.1 Data Sources

The non-road mobile-source inventories in the Typ02G and Base18G emissions modeling used actual 2002 data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory and the improved 1999 Mexican inventory. The U.S. inventories consisted of annual, seasonal, and monthly inventories; the non-U.S. inventories were annual data. Pechan provided the CENRAP inventories divided between annual data for aircraft, locomotive, and commercial marine and annual files for all other non-road sources (Pechan and CEP, 2005e). Minnesota substituted the monthly MRPO Base K non-road inventory for the CENRAP inventory in their state. Iowa substituted the monthly estimates for non-road agricultural sources from the MRPO base K inventory for the CENRAP inventory. Texas provided estimates for 2002 non-road emissions in lieu of the CENRAP prepared inventory. WRAP provided non-road inventories divided between California and non-California seasonal inventories, further subdivided into aircraft, locomotives, shipping, and all other non-road mobile sources (Pollack et al., 2006). Note that the California Air Resources Board uses their own OFFROAD model for California nonroad emissions, whereas the EPA NONROAD model is used for the rest of the states (with the exception of locomotives, aircraft and shipping). With these data WRAP also provided temporal adjustments to apply to the inventories to split them between weekday and weekend emissions. We used these weekday/weekend splits to derive new weekly temporal profiles for the WRAP sources. The MRPO base K monthly non-road inventories were obtained from MRPO in NIF format and were converted to SMOKE format by Wendy Vit of the Missouri DNR. The VISTAS Base G and MANE-VU non-road mobile inventories consisted of annual county-level data (Pechan and CEP, 2005c). We received these inventories directly from the respective RPO inventory representatives. We received the Canadian 2000 inventory version 2 from the U.S. EPA EFIG (EPA, 2005d). For Mexico we used the improved 1999 inventory available at http://www.epa.gov/ttn/chief/net/mexico.html.

Along with adding the WRAP weekday/weekend emissions splits to the temporal allocation files, we also created temporal input files that apply a flat, uniform monthly profile to the monthly and seasonal non-road inventories. With the monthly and seasonal variability inherent in these inventories, we avoided applying redundant monthly profiles by splitting the inventories into seasonal/monthly and annual data. We applied the uniform monthly temporal profiles to the seasonal/monthly inventories and non-uniform monthly temporal profiles to the annual inventories. How the non-road emissions inventory data were split into those with monthly/seasonal emission and those with annual emissions is provided in Table 2-13.

Table 2-13. Non-road mobile-source inventory temporal configuration.

Region	Source	Temporal Coverage
WRAP (non-CA)	Non-road mobile	Seasonal
WRAP (CA)	Non-road mobile	Seasonal
WRAP Airc	raft	Seasonal
WRAP Locomotive		Annual
WRAP	In-port and near-shore shipping	Annual
CENRAP All	non-road	Annual
CENRAP, IA	Non road Ag.	Monthly
VISTAS All	non-road	Annual
MRPO and MN	All non-road	Monthly
MANE-VU All	non-road	Annual
Canada All	non-road	Annual
Mexico All	non-road	Annual

Iowa elected to use the CENRAP-sponsored inventory for all of the non-road categories except for the agricultural equipment categories provided in Table 2-14. For these agricultural equipment categories, Iowa elected to use the Midwest RPO Base K inventory because this inventory provided improvements to the temporal allocation of emissions for the agricultural sector. The Base K inventory includes monthly emissions. The monthly emissions are used in the SMOKE IDA files for modeling.

Table 2-14. Non-road agricultural emissions categories where the MRPO Base K inventory was used instead of the CENRAP inventory in Iowa.

SCC	SCC Description
22600050xx	Off-highway Vehicle Gasoline, 2-Stroke: Agricultural Equipment (2 SCCs);
22650050xx	Off-highway Vehicle Gasoline, 4-Stroke: Agricultural Equipment (11 SCCs);
22670050xx	LPG : Agricultural Equipment (3 SCCs);
22680050xx	CNG : Agricultural Equipment (3 SCCs); and
22700050xx	Off-highway Vehicle Diesel : Agricultural Equipment (11 SCCs).

Texas provided annual and daily emissions for CO, CO_2, NO_x, VOC, SO_2, PM10-FIL, and PM25-FIL for several oil and gas field equipment non-road categories (Table 2-15). Texas provided authorization to change the pollutant codes from PM10-FIL to PM10-PRI and PM25-FIL to PM25-PRI.

Table 2-15. Non-road oil and gas development equipment categories that Texas provided emissions to be used instead of the CENRAP inventory.

SCC	SCC Description
2265010010	Off-highway Vehicle Gasoline, 4-Stroke : Industrial Equipment: Other Oil Field Equipment;
2268010010	CNG : Industrial Equipment : Other Oil Field Equipment; and
2270010010	Off-highway Vehicle Diesel : Industrial Equipment : Other Oil Field Equipment

Lancaster County Nebraska provided its own non-road inventory for SCC 2260000000 (Off-highway Vehicle Gasoline, 2-Stroke : 2-Stroke Gasoline except Rail and Marine: All). The CENRAP-sponsored inventories for SCCs starting with 226 in Lancaster County were removed to correct double-counting of emissions. This adjustment was made by Pechan for Base02b modeling.

2.5.2 Emissions Processing

We configured SMOKE to process all of the non-road mobile emissions inventory data as area-like inventories using spatial surrogates to grid the county-level emissions. As the WRAP inventories contained pre-computed PM emissions, we did not have to use SMOKE to compute coarse mass PM (PMC). The WRAP non-road mobile inventories represented seven-day average emissions (different from the area inventory, which represented weekday average emissions). As actual weekly average emissions, we configured SMOKE to process them by setting WKDAY_NORMALIZE to "No." For the rest of the non-road mobile inventories we processed the data as weekday average data by setting WKDAY_NORMALIZE to "Yes." We also assumed that all of the VOC emissions in the inventories are ROG and used SMOKE to convert the VOC to TOG before converting the emissions into CB-IV speciation for the air quality models. We configured SMOKE to create MWSS temporal intermediates rather than daily temporal files because the non-road mobile sources do not use weekly temporal profiles that vary across the weekdays, but do have very different emissions on weekdays versus weekend days.

We divided the non-road mobile emissions modeling based on whether the data were annual or seasonal/monthly inventories. This split facilitated the application of uniform monthly temporal profiles to the seasonal/monthly inventories. After processing the non-road emissions as two separate categories, non-road yearly and non-road monthly, we combined them with the rest of the emissions sectors to create model-ready emissions for CMAQ and CAMx.
To QA the non-road mobile emissions we used the procedures in the CENRAP emissions modeling QAPP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulations. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/qa_base02f36.shtml#nr

2.5.3 Uncertainties and Recommendations

We prepared non-road mobile emissions using a combination of inventories having different temporal resolutions and various forms of ancillary data. These different combinations of information may lead to inconsistencies in how these emissions are represented across the modeling domain. In addition, the Canadian inventories contain only province-level information and thus have low-resolution spatial and temporal profiles applied to them. The Mexican non-road emissions are deficient in the number of different SCCs contained in the inventory and the availability of spatial surrogates that are applicable to non-road mobile sources. Improvements to the temporal profiles and spatial surrogates could provide a more consistent approach to representing the non-road emissions across the entire modeling domain.

2.6 Biogenic Sources

Biogenic emissions data for SMOKE consist of input files to the BEIS3 model (EPA, 2004a). BEIS3 is a system integrated in to SMOKE for deriving emissions estimates of biogenic gas-phase pollutants from land use information, emissions factors for different plant species, and hourly, gridded meteorology data. The results of BEIS3 modeling are hourly, gridded emissions fluxes formatted for input to CMAQ or CAMx. This section describes the sources of the BEIS3 input data that we used for the Typ02G and Base18G emissions, how we modeled these data and the types of QA that were performed to ensure that SMOKE processed the data as expected.

2.6.1 Data Sources

The BELD3 land use data and biogenic emissions factors that were developed during the WRAP preliminary 2002 modeling were used for the CENRAP biogenic emissions modeling (Tonnesen et al., 2005). These data included BELD3 1-km resolution land use estimates and version 0.98 of the BELD emissions factors. Since the WRAP and CENRAP use the same 36 km Inter-RPO continental U.S. modeling domain, CENRAP was able to leverage of the WRAP work performed previously.

2.6.2 Emissions Processing

We used BEIS3.12 integrated in SMOKE to prepare emissions for the simulations. Most of the preparation for the biogenic emissions processing was completed during the preliminary 2002 modeling (Morris et al., 2005). As the modeling domains did not change from the preliminary 2002 to the final modeling, we re-used the gridded land use data and vegetation emissions factors that we prepared for the preliminary simulations.

To QA the biogenic emissions, we used the CENRAP emissions modeling QAPP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulation Base02b. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/qa_base02b36.shtml#b3

2.6.3 Uncertainties and Recommendations

The use of newer versions of BEIS (BEIS3.13) and the new MEGAN biogenic emissions models should be considered in future modeling.

2.7 Fire Emissions

Fire emissions data for SMOKE have traditionally been represented as county-level area-source inventories that were placed in only the first vertical model layer. We advanced the representation of fire emissions for air quality modeling by preparing portions of the inventory data as point sources with specific latitude-longitude coordinates for each fire centroid and pre-computed plume rise parameters that were derived from individual fire characteristics. These new inventories were based on the fire data products prepared by a CENRAP emission contractor (Reid et al., 2004b) and modified by the project team to be properly modeled as point sources. These data consist of annual, daily, and hourly IDA-formatted emissions inventory files and ancillary data for allocating the inventories in space, time, and to the Carbon Bond-IV chemistry mechanism used in CMAQ and CAMx. This section describes where we obtained these data, how we modeled them, and the types of QA performed to ensure that SMOKE processed the fire emissions data as expected.

2.7.1 Data Sources

The fire inventories in the Typ02G emissions inventory were held constant through Base18G. We used actual 2002 fire data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory fire data, and actual 2002 fire data for Ontario, Canada. The inventories used consisted of both area and point source data for the U.S., Canada, and Mexico. Sonoma Technology, Inc. provided the fire emissions for the CENRAP states (Reid et al., 2004b). Air Sciences provided us with the WRAP inventories divided among six different fire categories: wildfires, agricultural fires, wildland fire use, natural prescribed, anthropogenic prescribed, and non-Federal rangeland fires (Air Sciences, 2007a). These inventories consisted of annual, daily, and hourly IDA-formatted files with information on daily emissions totals and hourly plume characteristics for each fire. We received similar fire emission inventories for the other RPOS (Air Sciences, 2007b). We modeled these sources with the rest of the stationary-area-source sector.

CENRAP received data for 54 fires that occurred in Ontario during the year 2002. Information on the data code abbreviations, data definitions, and data units used in the raw data files was obtained from Mr. Rob Luik (Data Management Specialist) at the Ontario Ministry of Natural Resources (Rob.Luik@MNR.gov.on.ca). Emissions for each fire were estimated using the Emission Production Model (EPM)/CONSUME within the BlueSky framework. A fire identification code is needed to track individual fires throughout the processing. The unique fire identification code was created for each fire by concatenating the FIRE_NUMBER and CUR_DIST fields of the original data. The fire identification code also contains the FIPS code of the fire; this information is not used by BlueSky but is needed by BlueSky2Inv, the utility program that converts the BlueSky output to the SMOKE inventory format. The FIPS code 135000 was used for all fires with longitudes east of –90°, and FIPS code 135059 was used for fires west of –90°. These FIPS codes were used to ensure that the fires would be assigned the correct time zones in later SMOKE processing. Some of the dates provided in the original data included hourly information. In all cases, the hourly information was not used leaving all data at a daily resolution.

2.7.2 Emissions Processing

SMOKE is instrumented to distribute point-source-formatted fire inventories to the vertical model layers either by using a pre-computed plume rise approach or by computing the plume rise dynamically using actual 2002 meteorology. We applied both approaches for modeling point-source fire emissions in simulation Typ02G. For the pre-computed plume rise approach, SMOKE reads an annual inventory file with information on fire locations, a daily inventory file with daily emission totals for each fire, and an hourly inventory file with hourly plume bottom, plume top, and layer 1 fractions for each fire. SMOKE uses this information to locate the fires on the horizontal model grid and to distribute the plume of each fire vertically to the model layers. Because some of these fires have plumes that reach the model top, we set the number of emissions layers for processing these inventories to the full 19 layers of the meteorology. We applied this approach to the point-source fires for the WRAP, CENRAP and VISTAS regions. The alternative plume rise approach uses information on fuel loading and the heat flux of the fires to distribute the fires vertically to the model layers. The data are provided to SMOKE in the form of an annual inventory with information on fire locations and a daily inventory with daily emission totals for each fire, daily heat flux, and daily fuel loading. We applied this approach to the point-source fires for Ontario, Canada.

All of the point-source fires used diurnal temporal profiles and speciation profiles for VOC and $PM_{2.5}$ developed by Air Sciences (2007a) during the preliminary 2002 modeling (Morris et al., 2005).

We modeled the area-source fires for U.S. and Canada as standard stationary area sources. We applied monthly temporal profiles provided by RPOs, flat weekly temporal profiles, and the diurnal profiles developed by Air Sciences for WRAP fires (Air Sciences, 2007a), and for the rest of the RPOs we used diurnal profiles that were provided by them (Air Sciences, 2007b). We used the forestland area surrogate to distribute these emissions from the county or province level in the inventories to the model grid cells.

To QA the fire emissions, we used the procedure in the CENRAP emissions modeling QA protocol (Environ, 2004) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulation Typ02G. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, annual time-series plots, and vertical profiles. These QA graphics are available at: http://pah.cert.ucr.edu/aqm/cenrap/qa_typ02g36.shtml.

2.7.3 Uncertainties and Recommendations

We used forestland spatial surrogates to distribute these county level (province level for Canada) data to the model grid. Using spatial surrogates to locate fires is a crude approach that results in the artificial smearing of the emissions over too large an area. This issue can be remedied by moving to a point-source approach for representing these fires, similar to the approach used by Air Sciences for preparing the WRAP fire inventories.

2.8 Dust Emissions

Dust emissions data for SMOKE have traditionally taken the form of county-level stationary-area-source inventories. As these emissions are correlated to meteorology, land use, and vegetative cover, we made several changes to how dust emissions are simulated by SMOKE to take these parameters into consideration. This section describes where we obtained data for windblown, fugitive, and road dust sources, how we modeled them, and the types of QA performed to ensure that SMOKE processed the data as expected.

2.8.1 Data Sources

For the fugitive dust and road dust inventories in the Typ02G emission scenario, we used actual 2002 data developed by the RPOs for the U.S., version 2 of the year 2000 Canadian inventory, and the BRAVO 1999 Mexican inventory. We extracted the fugitive dust inventories from the stationary-area inventories for each of the RPOs, Mexico, and Canada. Before modeling these data we further divided them into construction/mining sources and agricultural sources. We defined the fugitive dust sources in the Base 02f modeling based on guidance provided by EPA (2004b). WRAP provide road dust emission inventories (Pollack et al., 2006). For the rest of the RPOs and Canada, we extracted the road dust SCCs from the stationary-area-source inventories. The BRAVO 1999 Mexico inventory did not contain any road dust SCCs. Table 2-16 lists the SCCs for the various fugitive and road dust sources that we modeled in the Base02f and Typ02G inventories. We applied near-source capture transport factors that are based on county-level vegetative cover to the fugitive and road dust inventories to prepare them for input to the air quality models.

For windblown dust, we used gridded emissions prepared outside of SMOKE using a land use and meteorology-based model developed under funding from the WRAP by ENVIRON and UC-Riverside (Mansell, 2005; Mansell et al., 2005).

Table 2-16. Fugitive and road dust SCCs.

Dust Category	SCCs
Fugitive dust (construction and mining)	2275085000, 2311000000, 2311010000, 2311010070, 2311020000, 2311030000, 2325000000, 2305070000, 2530000020, 2530000100, 2530000120
Fugitive dust (agricultural)	2801000003, 2801000005, 2801000008, 2805001000
Road dust	2294000000, 2296000000

2.8.2 Emissions Processing

We modeled the fugitive and road dust inventories through SMOKE using an area-source approach. We modeled these data on the assumption that they represented weekday, rather than seven-day week, emissions and thus used the SMOKE setting WKDAY_NORMALIZE to convert the data to a seven-day average. We configured SMOKE to compute PMC during the processing as (PM_{10} - $PM_{2.5}$). Usually the records with dust do not include any other pollutants such as VOC, and NOx. For the few records that did include pollutants other than the PM we

split the records where the PMs processed with dust and the non PMs processed with the area. We configured SMOKE to create MWSS temporal intermediates rather than daily temporal files because the dust sources do not use weekly temporal profiles that vary across the weekdays. As noted above, we used SMOKE to apply near-source transport factors to the raw fugitive and road dust inventories to prepare them for input to the air quality models. We used U.S. transport factors from work done by Pace (2005) and a 2001 land use/land cover database to develop a SMOKE input file of county and SCC-based transport factors for the U.S., Canada, and Mexico. We applied these factors to create a new set of inventories adjusted for these transport factors for all regions except VISTAS; the VISTAS dust sources that we received already had the transport factors applied to them.

We calculated the windblown dust emissions outside of SMOKE using an internally developed, process-based model. By "process-based" we refer to an emissions model that integrates information about the processes that lead to the emissions of interest, in this case windblown dust. The process-based windblown dust model developed by the WRAP considers wind speeds, precipitation history, and soil types to derive gridded dust fluxes resulting from wind disturbances for the modeling domain. More information on this model, its modes of operation, and the configuration used for simulation Base02a are available in Mansell et al. (2005). To QA the fire emissions, we used the procedures in the CENRAP emissions modeling QA PP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for Base02f emissions. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/qa_base02f36.shtml#fd for fugitive dust, http://pah.cert.ucr.edu/aqm/cenrap/qa_base02f36.shtml#rd for road dust, and http://pah.cert.ucr.edu/aqm/cenrap/qa_base02b36.shtml#wbd for windblown dust.

2.8.3 Uncertainties and Recommendations

There are several improvements that should be made to the dust emissions modeling in future simulations. We will expand the list of fugitive dust SCCs that we extract from the stationary-area-source inventories for application of transport factors. This expanded list is based on recent work by EPA (2004b). We will also explore improvements to the assumptions that we used for generating emissions with the WRAP windblown dust model. Areas of improvement in the windblown dust model include refinements to the land use data and soil characteristics, additional information about agricultural activities in the WRAP and CENRAP regions, detailed model evaluation on targeted windblown dust case studies, and the application of snow-cover and vegetative transport factors to these emissions (Mansell et al., 2005).

2.9 Ammonia Emissions

Ammonia (NH_3) emissions from agricultural activities are a major source of ammonia and are dependent on many different environmental parameters, such as meteorology, crop and soil types, and land use. CENRAP developed NH_3 emissions for the CENRAP states (Pechan and CEP, 2005e). Ammonia emissions were estimated for 13 source categories using the Carnegie Mellon University (CMU) model and supplemental technical work; 80% of technical work was dedicated to improving emissions estimates for two source categories—livestock production and fertilizer use. For these two categories, as well as biogenic sources, improvements were made to the activity data and /or emission factors used by the CMU model. For four other source categories (industrial point sources, landfills, ammonia refrigeration, and non-road mobile sources), emissions estimates were prepared independently of the CMU model, and for the remaining six source categories (publicly owned treatment works, wild fires, domestic animals, wild animals, human respiration, and on-road mobile sources), emissions estimates were derived by running the CMU model with no alterations.

CENRAP NH_3 model emissions estimates were combined with data provided by the other RPOs to represent agricultural NH_3 emissions in simulations Typ02G and Base18G.

2.9.1 Data Sources

The WRAP provided NH_3 emissions using the WRAP NH_3 model (Mansell et al, 2005) that generated emissions for the following sectors: domestic sources, wild animals, fertilizers, soils, and livestock. MWRPO provided monthly IDA-formatted inventories reflective of base K to CENRAP that they produced from process-based models of their own, along with temporal profiles and spatial cross-reference information for these sources. Iowa elected to use the MWRPO estimates of NH_3 emissions for fertilizer application, livestock, and wastewater treatment or SCC 28017XXXXX, 28050XXXXX, and 2630020000 respectively. Minnesota reviewed the MWRPO inventory and chose to move forward with the CENRAP developed data set. The rest of the U.S., Canada, and Mexico had agricultural NH_3 emissions contained within their annual stationary-area-source inventories.

2.9.2 Emissions Processing

The WRAP NH_3 emissions were processed outside of SMOKE using the WRAP NH_3 model and provided to CENRAP as gridded, hourly emissions in network common data form (NetCDF) files. CENRAP and MWRPO provided monthly IDA-formatted, county-level NH_3 inventories that were developed separately with process-based models. We modeled these emissions like area sources with SMOKE, applying the temporal profiles and the spatial cross-referencing developed for CENRAP that we received from the MWRPO. The agricultural NH_3 emissions for the rest of the RPOs, Canada, and Mexico are contained within their stationary-area inventories. We applied the SMOKE default temporal profiles and spatial surrogates to all non-process-based NH_3 emissions.

To QA the NH_3 emissions, we used the procedures in the CENRAP modeling QAPP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulations Typ02G and Base18G. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/index.shtml

2.9.3 Uncertainties and Recommendations

Like the other emissions categories that have traditionally been represented as stationary area sources, the agricultural NH_3 emissions sector is affected by interregional inconsistencies in the way these emissions are represented.

During the QA of the Base02a emissions, the WRAP discovered a problem with their soil NH_3 estimates. The emission factor for soil NH_3 that were used in developing these data produced too high an emission estimate from this sector. For simulations Base02B through Typ02G, we therefore removed the soil NH_3 sector completely from the WRAP domain. In future simulations we will include these emissions with a revised emission factor for NH_3 emissions from soils.

2.10 Oil and Gas Emissions

Emissions from oil and gas development activities have been poorly characterized in the past. Simulations These emissions have been sporadically reported by some states in their stationary-area-source inventories, but for the most part were missing from our preliminary modeling. In the Typ02G and Base18G simulations, significant effort was made to better represent oil and gas production emissions explicitly as both area and point sources.

2.10.1 Data Sources

Emissions from oil and gas production activities for the CENRAP states were included with the other CENRAP state emission source categories (Pechan and CEP, 2005e). We received oil and gas production emissions inventories for the WRAP states and for tribal lands in the WRAP region as stationary-area-source and stationary-point-source IDA-formatted inventories. ERG, Inc. provided the point-source inventories with the rest of the stationary-point data (ERG, 2006a). ENVIRON provided the area-source oil and gas inventories for non-CA WRAP states and for tribal lands in the WRAP region, along with spatial surrogates for allocating these data to the model grid (Russell and Pollack. 2005). Oil and gas production emissions data for outside of the WRAP region are contained in the stationary-area inventories.

2.10.2 Emissions Processing

We modeled the WRAP point-source oil and gas production emissions in combination with the rest of the stationary-point-source emissions. We modeled the WRAP area-source oil and gas production emissions explicitly as a separate category that included WRAP and tribal inventories. These data represent weekly average emissions and did not require any renormalization within SMOKE. We used spatial surrogates generated by ENVIRON to allocate these annual county-level emissions to the model grid. For all oil and gas emissions, we applied flat temporal profiles to create hourly inputs to CMAQ and CAMx.

2.10.3 Uncertainties and Recommendations

In future 2002 modeling California oil and gas production emissions should be replaced with revised data provided by the California Air Resources Board (CARB). In addition, WRAP has updated their oil and gas production inventory for the base and future years in a Phase II work effort that substantially improved the emissions inventory estimates (Bar-Ilan et al., 2007).

2.11 MMS Off-shore Gulf of Mexico Emissions

Offshore area point source emissions include emissions in the Gulf of Mexico and off the coast of California that are associated with oil and gas drilling platforms.

2.11.1 Data Sources

We obtained year 2000 IDA-formatted point-source inventories for oil and gas platforms in the Gulf of Mexico from the Minerals Management Service (MMS) web site: http://www.gomr.mms.gov/homepg/regulate/environ/airquality/gulfwide_emission_inventory/2000GulfwideEmissionInventory.html

We combined these with point-source data for coastal California provided to us by CARB during the preliminary 2002 modeling. We also obtained gridded area source emissions for platforms in the Gulf of Mexico from the MMS that we converted to the CENRAP 36-km model grid.

The 2000 MMS Gulfwide Emission Inventory was updated as of June 2006 to account for a change in vessel emissions in the non-point source (non-platform) database file. The point source (platform) emission inventory database file has not changed from the original version. Area source emissions from offshore activities in the Gulf of Mexico were developed from the latest estimates provided by the Minerals Management Service (MMS). The MMS inventory includes both platform and non-platform sources. The non-platform area source emissions estimates are spatially allocated to lease blocks and protraction units throughout the Gulf of Mexico. Temporal and spatial allocation cross-reference data were developed from the MMS inventory data and formatted for input to the SMOKE emissions model by Carolina Environmental Programs. These data were provided to the CENRAP emissions modeling team for implementation within SMOKE. The spatial allocation surrogates were provided for 4-km grid cells. The UCR team used these surrogates and developed surrogates for 36-km grid cells. Because these data are references to lease blocks/protraction units, rather than counties, this source category was processed separately form all other emissions using a customized reference data and SMOKE run scripts.

We modeled the offshore point and area sources as separate categories in the simulations. We used SMOKE to locate the offshore point sources on the model grid and to vertically allocate them into 15 model layers.

To QA the offshore platform emissions, we used the procedures in the CENRAP modeling QAPP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 20042) and a suite of graphical summaries. We used tabulated summaries of the input data and SMOKE script settings to document the data and configuration of SMOKE for simulation Base02a. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/index.shtml for the point and area sources.

2.11.2 Uncertainties and Recommendations

While the MMS data that we used were an improvement over previously modeled Gulf of Mexico platform inventories, the data were developed for a different modeling application that covered only the extreme northwestern portion of the Gulf, so they are missing large areas of the region of the Gulf that contain drilling platforms. The California offshore inventory represents an initial attempt at compiling an emission inventory for this area and contains very few sources. Future simulations will focus on improving these emissions by expanding the coverage of the offshore platform inventories for both the Gulf of Mexico and the Pacific Coast.

2.12 Off-shore Shipping Emissions

Emission inventory development for regional- and continental- scale air quality modeling has historically neglected offshore emissions sources beyond 25 miles offshore. Concern over the environmental effects of commercial shipping emissions in the Pacific on the coastal states in the WRAP region led to the development of a commercial marine shipping inventory for the Pacific. This inventory of off-shore marine vessels emissions made a substantial difference in some of the coastal western PM estimates (e.g., SO4). VISTAS developed an off-shore marine vessels inventory for the entire modeling domain that included the Pacific and Atlantic Oceans and the Gulf Of Mexico. For Typ02G and Base18G emission inventories CENRAP adopted the offshore shipping inventories developed by VISTAS.

2.12.1 Data Sources

Initially we obtained gridded annual commercial marine shipping emissions for the Pacific on the 36-km model grid from WRAP for inclusion in CENRAP simulations in the Base F modeling (Pollack et al., 2006). The commercial marine inventory contains all of the criteria pollutants contained in the non-road mobile-source inventory: CO, NO_x, VOC, NH_3, SO_2, PM_{10}, and $PM_{2.5}$. This inventory was subsequently updated in the Typ02G and Base18G modeling with the VISTAS off-shore commercial marine emissions inventory that covered the Gulf of Mexico and the Atlantic and Pacific Oceans and was based on the EPA/ARB SOx Emissions Control Area (SECA) program. Dr. James Corbett (University of Delaware) analyzed off-shore marine vessel data and worked with ENVIRON/ICF to convert to gridded emissions for the SECA grid. ENVIRON then provided SO_2, NO_X, PM and VOC emissions for the RPO 36-km grid.

2.12.2 Emissions Processing

The commercial marine shipping inventory was not processed through SMOKE. VISTAS provided the data to the as gridded text files on the 36-km model grid. These data were reformatted to the NetCDF CMAQ input format with a utility developed by UCR. The VOC inventory was converted to CB-IV speciation and the NO_x and $PM_{2.5}$ inventory pollutants to CMAQ input species with SMOKE chemical profiles for commercial shipping sources. No temporal adjustments were applied to these emissions; they use uniform monthly, daily, and diurnal profiles. An SCC for commercial marine vessels within the MMS inventory (SCC CM80002200) was accounted for in the commercial marine inventory developed for VISTAS. The duplicate emissions were removed from the MMS inventory prior to processing emissions

for Base G simulations. The duplicated emissions amounted to 19,000 TPY of NO_X and 3,184 TPY of SO_2. For simulation Typ0 2G and Base18G we received binary netCDF file from ENVIRON for one day and that day was used for every day of the year.
To QA the commercial marine shipping emissions, we used the procedures in the CENRAP modeling QAPP (Morris and Tonnesen, 2004) and Modeling Protocol (Morris et al., 2004a) and a suite of graphical summaries. The graphical QA summaries include, for all emissions output species, daily spatial plots, daily time-series plots, and annual time-series plots. These QA graphics are available at http://pah.cert.ucr.edu/aqm/cenrap/index.shtml.

2.12.3 Uncertainties and Recommendations

As a first attempt at representing shipping emissions in the Pacific in international waters, the WRAP and VISTAS 2002 commercial shipping inventory is a breakthrough in a historically neglected emissions category. As the RPOs evaluate the effects of these emissions on the air quality modeling, we anticipate that there will be refinements to the temporal profiles and to the vertical allocation of the emissions. Many of the stacks of large commercial ships contained in this inventory extend vertically above the first model layer. Future versions of this inventory should use higher-resolution temporal adjustments and should allocate the emissions to the appropriate model layers. Off-shore marine shipping activity is projected to increase. However, there are also the potential for emission controls on this source category (e.g., SECA program). Given these two offsetting activities, the 2002 off-shore marine shipping emissions were assumed to be unchanged going from 2002 to 2018. Better estimates of 2018 marine emissions are being developed that should be considered in future modeling activities.

2.13 2018 Growth and Control

Base18G was based on grown inventories assuming on-the-books control strategies. CENRAP contracted with Pechan to deliver growth and control data for CENRAP and to consolidate growth and control information for other RPOs where available (Pechan, 2005d). The data are applicable to all source categories and pollutants included in the CENRAP 2002 emission inventory. This includes the following pollutants: sulfur oxides (SO_x), oxides of nitrogen (NO_x), volatile organic compounds (VOC), carbon monoxide (CO), ammonia (NH_3), and primary PM_{10} and $PM_{2.5}$. Some source categories were held constant between 2002 and 2018 because either stagnant growth was deemed appropriate or insufficient data was available to adequately project future growth or controls. These source categories include the following:

- Wind Blown Dust from non-agricultural land use categories.
- Emissions from wildfires.
- Emissions from Mexico.
- Global transport sources (i.e., the 2002 GEOS-CHEM boundary conditions).

2.13.1 Data Sources

CENRAP contracted with Pechan to provide growth and control factors to be applied with SMOKE for the CENRAP region (Pechan, 2005d). These growth and control parameters were based on growth estimates derived from EGAS 5.0 and control estimates assumed for implementation of federal regulations and on-the-books state and local control programs. Emissions projections for electric generating units were developed for the RPOs with the Integrated Planning Model (IPM). The RPO 2.1.9 IPM results were subsequently modified by VISTAS, MRPO and CENRAP to reflect planned new construction and controls. The WRAP provided 2018 EGU estimates developed in coordination with State and Industry stakeholders. VISTAS, MWRPO and the WRAP provided emissions for 2018, having applied growth and control factors outside of SMOKE processing. EPA provided SMOKE processed emissions, applying both growth and controls, for Canada for the year 2020. These emissions were provided on the RPO 36-km grid. However, emissions were inexplicably processed for an alternative vertical structure. Alpine Geophysics, under contract to VISTAS reallocated the emissions through the vertical layers to more accurately reflect the vertical structure applied uniformly by the RPOs. The modified data was obtained directly from Alpine Geophysics. Emissions from Mexico were held constant between the inventory year 1999 and modeled 2002 and 2018. Improvements to the Mexican inventory have been continuously made between generation of the original BRAVO inventory and the present improved 1999 inventory. However, given the continued uncertainties in the improved inventory, no future year projections where attempted by CENRAP.

2.13.2 Emissions Processing

Growth and control factors developed by Pechan (2005d) for Arkansas did not match the final delivered inventory for Arkansas. Arkansas underwent major revisions to point and facility IDs in mid-2005. These updates were not available by the delivery date of the growth and control parameters. In coordination with Arkansas, a cross-walk was developed to correct the point and facility IDs.

The assumptions that went into the development of controls for engines covered under the RICE MACT were not consistent with the final rule. Rule penetration values for CENRAP states were adjusted to more accurately reflect the impact of the final rule.

The impact of the refinery global settlements was not incorporated into CENRAP modeling until the base G simulations. Control assumptions provided by EPA and referenced in EPA CAIR modeling were applied to the 2018 inventory. These reductions primarily impacted SO_2 emissions; however, NO_X reductions were applied in Oklahoma, Louisiana, and Minnesota.

2.13.3 Uncertainties and Recommendations

The impact of control programs is an area of uncertainty that will need continued review as the programs are implemented. Development of growth and control assumptions for Mexico will be necessary for continued refinement of the impact of international transport. CENRAP obtained estimates of increased prescribed burn activity for the Forest Service after processing of the base G simulations was underway. These estimates of increased activity should be reviewed for inclusion in future simulations. EPA developed 2020 estimates of Canadian emissions are assumed to include erroneous stack parameters previously addressed in the 2000 emissions processing. Further review of this data set is recommended.

2.14 2018 Base G C1 Control Sensitivity

CENRAP conducted a control sensitivity evaluating the impact of point source reductions given a maximum dollar per ton control level. The intent of the control sensitivity was to generate information on the impact of possible control strategies in support of the consultation process. The strategies were grouped together under a common set of criteria and not specifically identified by the states. The results of the modeling were not intended to be prescriptive; instead, they were intended to be a starting point for control discussions that would require much greater refinement.

2.14.1 Data Sources

CENRAP contracted with Alpine Geophysics to provide an evaluation of possible additional controls for the 2018 CENRAP point source inventory. These controls were in addition to on-the-books and BART controls assumed in the development of Base18F and Base18G emission scenarios. Base18F IDA files were enhanced with additional information on base level controls. The enhanced dataset was then linked with the control data contained in the 2006 release of EPA's AirControlNet software. Alpine developed cost curves for NO_X and SO_2 in 2005 dollars for the Base18F CENRAP point source inventory. Staff from Iowa DNR and Kansas DHE worked in conjunction to add area of influence data (Alpine Geophysics, 2006) and distance calculations to each Class I area in CENRAP. A variety of dollar per ton control levels were evaluated. CENRAP elected to base the sensitivity on a maximum control cost of $5,000 per ton. This selection was made with the understanding that the cost data under-represented the true cost of retrofit controls and did not take in to consideration more recent market fluctuations impacting costs of controls and construction. CENRAP refined the selection by applying controls to only those sources that met the criteria that the ratio of their emissions in tons per year to their distance to any Class I area in kilometers be less than 5. This distance weighting criteria allowed the sensitivity to focus on those sources with the greatest impact. Additional controls for other RPOs were not considered in this evaluation.

2.14.2 Emissions Processing

Sources considered for control were removed from the IDA files. Growth and control assumptions were applied outside of SMOKE and delivered to UCR as 2018 emissions. Stack parameter changes as a result of additional controls were not considered in this analysis.

2.14.3 Uncertainties and Recommendations

Given uncertainties in control costs more refined analyses should include an evaluation of retrofit control costs under present values.

2.15 Emissions Summaries

Appendix B provides details on the source of the emission files used in the CENRAP Typ02G and Base18G modeling. Also in Appendix B are sample emission summary plots, additional plots are available on the CENREAP modeling website: http://pah.cert.ucr.edu/aqm/cenrap/emissions.shtml.

CENRAP has contracted with E.H. Pechan and Associates to provide emissions summaries used in the final Typ02G and Base18G modeling in Excel spreadsheets and in an Access database that are available on the CENRAP website (http://www.cenrap.org/projects.asp#). Figures 2- 3 through 2-9 display the, respectively, SO2, NOx, VOC, PM2.5, PM10, NH3 and CO anthropogenic emissions for the CENRAP states and the Typ02G and Base18G emission scenarios. Emissions are broken down by major source sector. For the state of Texas the emissions are broken by three groups, northeast Texas, southeast Texas and remainder of Texas (west Texas).

For most states, EGUs are the largest contributor to SO2 emissions (Figure 2-3). As EGU SO2 emissions are generally projected to be reduced in the future, most states show a reduction in total SO2 emissions from 2002 to 2018. One exception to this is Louisiana for which non-EGU point source SO2 emissions are greater than for EGU and are projected to increase from 2002 to 2018. The reasons for these increases are unclear, but the growth factors for non-EGU points should be examined more carefully.

NOx emissions are fairly evenly distributed across non-EGU point, EGU point, non-road mobile, on-road mobile and area sources for the 2002 Typ02G emissions scenario (Figure 2-4). In 2018, the contributions of on-road mobile source NOx emissions is reduced dramatically, with some states also showing reductions in EGU NOx emissions as well, resulting in all states exhibiting lower NOx emissions in 2018 than 2002.

VOC emissions are dominated by area, non-road mobile, on-road mobile and non-EGU point sources in both 2002 and 2018 (Figure 2-5). VOC emissions from on-road and non-road mobile source are projected to go down in the future, whereas VOC emissions from non-EGU point and, especially, area sources are projected to increase. Thus, whether a state's total VOC emissions increase or decrease depends on the relative contributions of mobile versus area sources and the level of increase in area source VOC emissions. Note that the VOC emissions listed in Figure 2-5 do not include biogenic VOC emissions that would be greater than the anthropogenic VOC emissions shown in Figure 2-5. Note that because biogenic VOC emissions are processed using the SMOKE/BEIS module on the 36 km grid, state-wide biogenic VOC emissions summaries are not readily available.

Primary $PM_{2.5}$ emissions are primarily from road dust and fugitive dust, and for some states fires (Figure 2-6). Kansas, Oklahoma, Louisiana and Texas all have large contributions from fires not seen in the other states. Road dust and fugitive dust are the most dominate source categories for coarse particulate as well (Figure 2-7).

CENRAP developed a separate ammonia emissions for 13 categories using the CMU model including livestock and fertilizer that dominates the ammonia emissions across the CENRAP states (Figure 2-8). Several states also have significant ammonia contributions from non-EGU point sources, whereas others do not.

CO emissions are dominated by the on-road and non-road mobile source sectors (Figure 2-9). However, states with fires also see large CO contributions from them as well. On-road mobile source CO emissions are projected to go down substantially from 2002 to 2018, whereas the other source categories are flat.

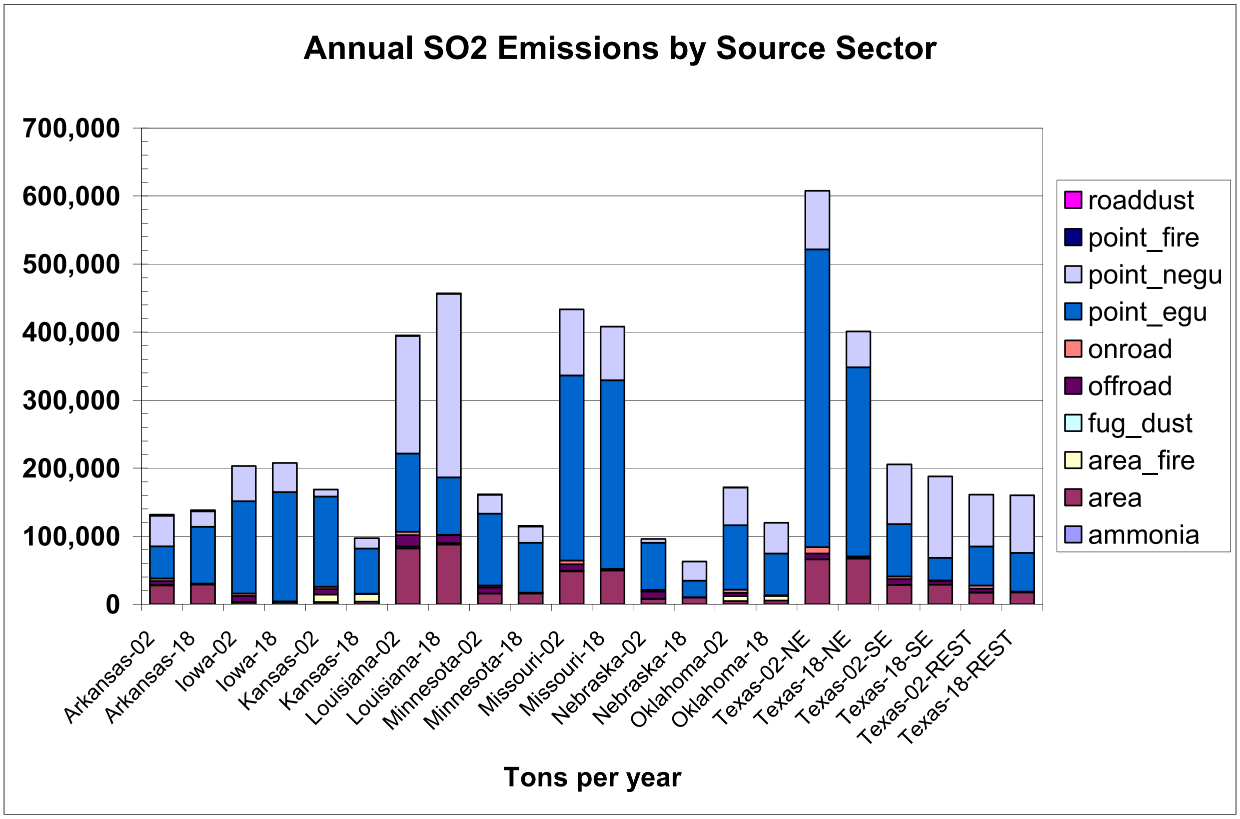

Figure 2-3. Summary of Typ02G and Base18G SO2 emissions by CENRAP state and major source sector (tons per year).

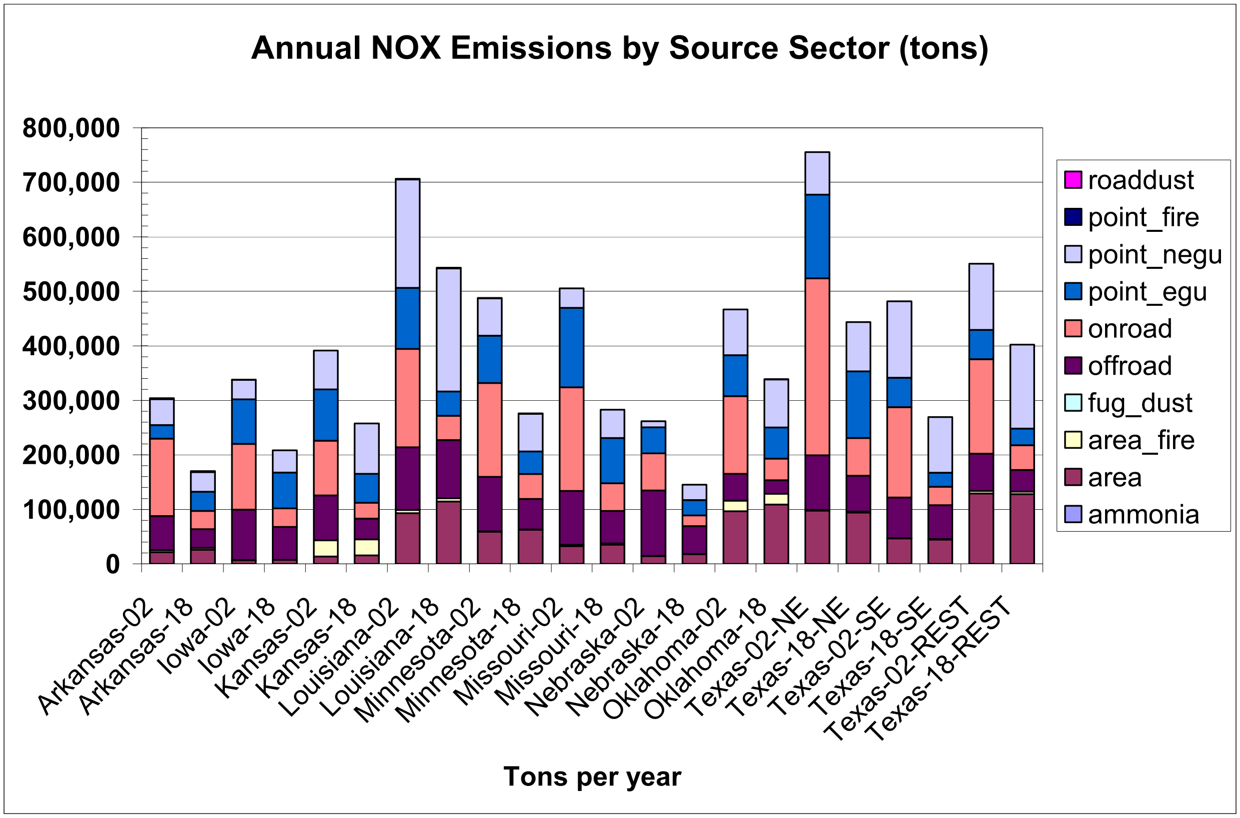

Figure 2-4. Summary of Typ02G and Base18G NOx emissions by CENRAP state and major source sector (tons per year).

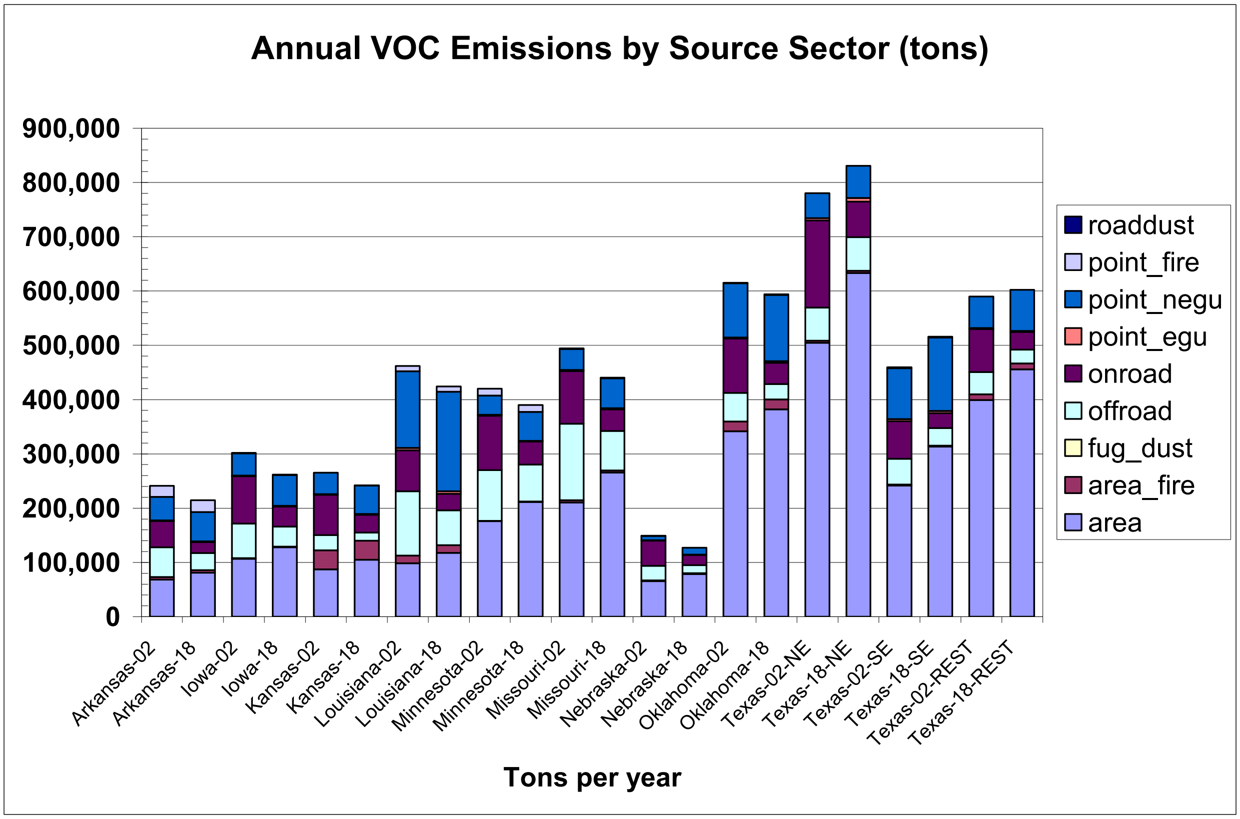

Figure 2-5. Summary of Typ02G and Base18 G VOC emissions by CENRAP state and major source sector (tons per year).

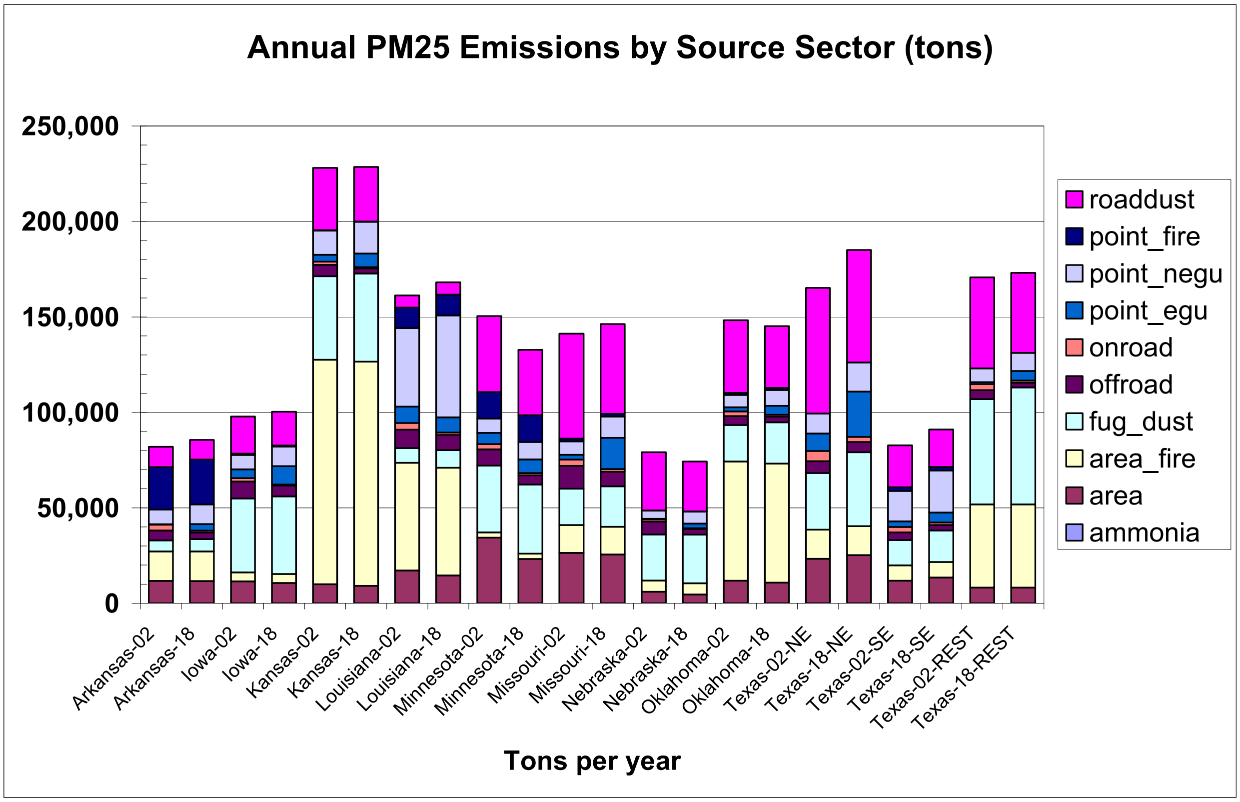

Figure 2-6. Summary of Typ02G and Base18G PM2.5 emissions by CENRAP state and major source sector (tons per year).

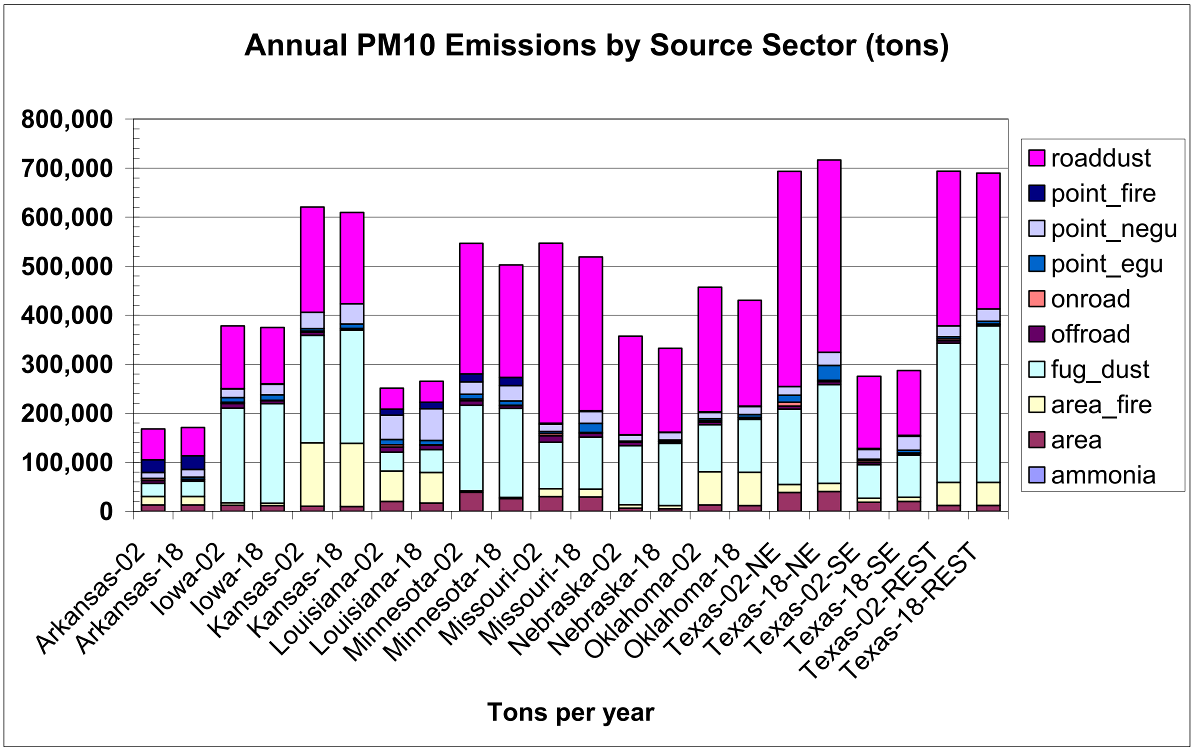

Figure 2-7. Summary of Typ02G and Base18G PM10 emissions by CENRAP state and major source sector (tons per year).

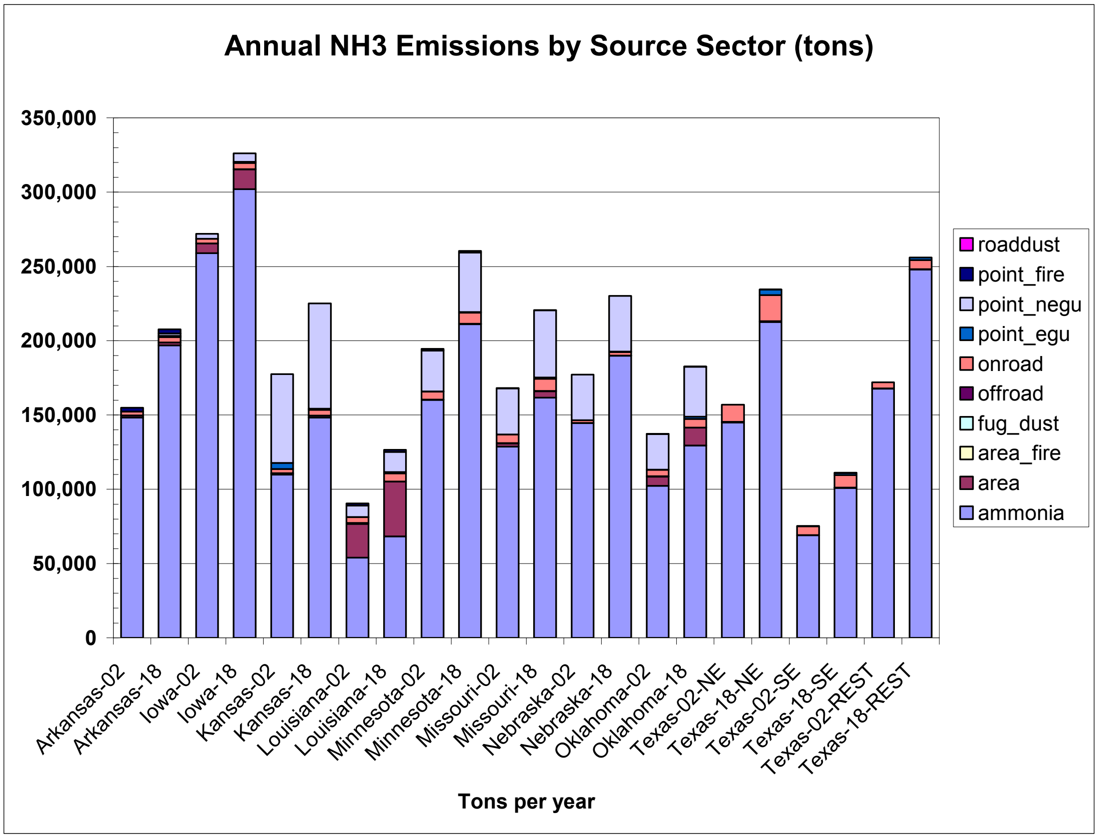

Figure 2-8. Summary of Typ02G and Base18G NH3 emissions by CENRAP state and major source sector (tons per year).

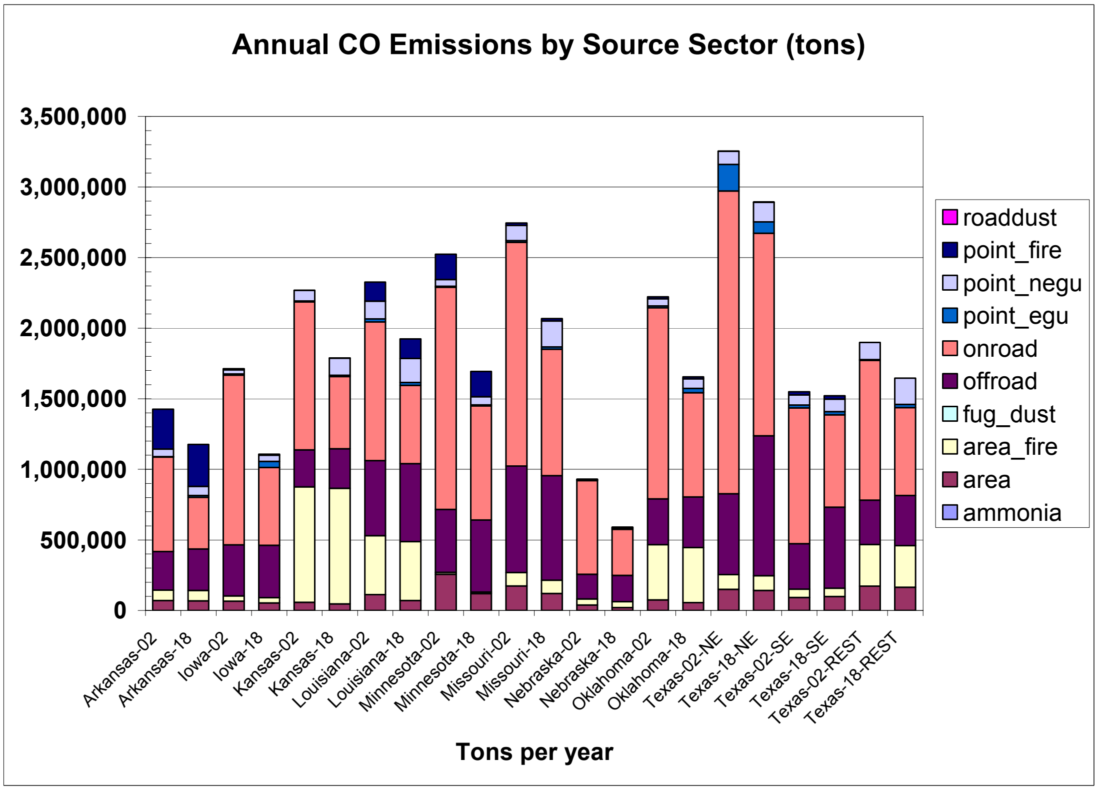

Figure 2-9. Summary of Typ02G and Base18G CO emissions by CENRAP state and major source sector (tons per year).

3.0 MODEL PERFORMANCE EVALUATION

In this Chapter we summarize the CMAQ model performance for the final 2002 36 km Base F base case simulation. Because the 2002 Base F CMAQ simulation produced nearly identical results in the U.S. as the final 2002 Base G simulation and limited resource availability, CENRAP elected not to redo the model evaluation for the 2002 Base G case. This model performance focuses on the ability of the model to predict PM species within the CENRAP region. Details on the model performance are provided in Appendix C. Previously we have documented model performance of interim versions of model base case simulations in reports (Morris et al., 2005) and presentations to the CENRAP Work Groups and POG (e.g., Morris et al., 2006a,b).

3.1 Evaluation Methodology

EPA's integrated ozone, $PM_{2.5}$ and regional haze modeling guidance calls for a comprehensive, multi-layered approach to model performance testing, consisting of the four major components: operational, diagnostic, mechanistic (or scientific) and probabilistic (EPA, 2007). The CMAQ model performance evaluation effort focused on the first two components, namely:

- **Operational Evaluation**: Tests the ability of the model to estimate PM concentrations (both fine and coarse) and the components at PM_{10} and $PM_{2.5}$ including the quantities used to characterize visibility (i.e., sulfate, nitrate, ammonium, organic carbon, elemental carbon, other $PM_{2.5}$, and coarse matter ($PM_{2.5-10}$). This evaluation examines whether the measurements are properly represented by the model predictions but does not necessarily ensure that the model is getting "the right answer for the right reason"; and

- **Diagnostic Evaluation:** Tests the ability of the model to predict visibility and extinction, PM chemical composition including PM precursors (e.g., SOx, NOx, and NH_3) and associated oxidants (e.g., ozone and nitric acid); PM size distribution; temporal variation; spatial variation; mass fluxes; and components of light extinction (i.e., scattering and absorption).

In this final model performance evaluation for the 2002 Typical Base F CMAQ simulation, the operational evaluation has been given the greatest attention since this is the primary thrust of EPA's modeling guidance. However, we have also examined certain diagnostic features dealing with the model's ability to simulate sub-regional, monthly, diurnal, gas phase and aerosol concentration distributions. In the course of the CENRAP air quality modeling and other modeling processes, numerous diagnostic sensitivity tests were performed to investigate and improve model performance. Key diagnostic tests that were performed and the results are discussed on the CENRAP modeling website: http://pah.cert.ucr.edu/aqm/cenrap/index.shtml.

3.2 Ambient Air Quality Data used in the Evaluation

The ground-level model evaluation database for 2002 was compiled by the modeling team using several routine and research-grade databases. The first is the routine gas-phase concentration measurements for ozone, SO_2, NO_2 and CO archived in EPA's Aerometric Information Retrieval System (AIRS) Air Quality System (AQS) database. Other sources of observed information come from the various PM monitoring networks in the U.S. These include the Interagency Monitoring of Protected Visual Environments (IMPROVE); Clean Air Status and Trends Network (CASTNET); EPA Speciation Trends Network (STN) of $PM_{2.5}$ species; and National Acid Deposition Program (NADP). During the course of the CENRAP modeling, the numerous base case simulations were evaluated across the continental U.S. (e.g., Morris et al., 2005). In this section and in Appendix C we focus our evaluation on model performance within the CENRAP region.

3.2 Operational Model Evaluation Approach

The CENRAP modeling databases will be used to develop the visibility State Implementation Plan (SIP) as required by the Regional Haze Rule (RHR). Accordingly, the primary focus of the operational evaluation in this report is on the six components of fine particulate ($PM_{2.5}$) and coarse mass ($PM_{2.5-10}$) within the CENRAP region that are used to characterize visibility at Class I areas:

- Sulfate (SO4);
- Particulate Nitrate (NO3);
- Elemental Carbon (EC);
- Organic Mass Carbon (OMC);
- Other inorganic fine particulate (IP or Soil); and
- Coarse Mass (CM).

The model performance for ozone, precursors, and product species (e.g., SO_4 , NO_3, NH_4 and HNO_3) is also evaluated to build confidence that the modeling system is sufficiently reliable to project future-year visibility.

3.3 Model Performance Goals and Criteria

The issue of model performance goals for PM species is an area of ongoing research and debate. For ozone modeling, EPA has established performance goals for 1-hour ozone: normalized mean bias and gross error of #±15% and #35%, respectively (EPA, 1991). EPA's draft fine particulate modeling guidance notes that performance goals for ozone should be viewed as upper bounds of model performance that PM models may not be able to always achieve and that we should demand better model performance for PM components that make up a larger fraction of the PM mass than those that are minor contributors (EPA, 2001). EPA's final modeling guidance does not list any specific model performance goals for PM and visibility modeling and instead provides a summary of PM model performance across several historical applications that can be used for comparisons, if desired. Measuring PM species is not as precise as ozone monitoring. In fact, the uncertainty in measurement techniques for some PM species is likely to exceed the more stringent model performance goals, such as those for ozone. For example, recent comparisons of the PM species measurements using the IMPROVE and STN measurement technologies found uncertainties of approximately ∀20% (SO4) to ∀50% (EC) (Solomon et al., 2004).

For the CENRAP modeling we have adopted three levels of model performance goals and criteria for bias and gross error as listed in Table 3-1. Note that we are not suggesting that these performance goals be adopted as guidance. Rather, we are just using them to frame and put the PM model performance into context and to facilitate model performance intercomparison across episodes, species, models and sensitivity tests.

Table 3-1. Model performance goals and criteria used to assist in interpreting modeling results.

Fractional Bias	**Fractional Gross Error**	**Comment**
#∀15%	#35%	Ozone model performance goal for which PM model performance would be considered "good" – note that for many PM species measurement uncertainties may exceed this goal.
#∀30%	#50%	Proposed PM model performance goal that we would hope each PM species could meet
#∀60%	#75%	Proposed PM criteria above which indicates potential fundamental problems with the modeling system.

As noted in EPA's PM modeling guidance, less abundant PM species should have less stringent performance goals (EPA, 2001; 2007). Accordingly, we are also using performance goals that are a continuous function of average concentrations, as proposed by Dr. James Boylan at the Georgia Department of Natural Resources (GA DNR), that have the following features (Boylan, 2004):

- Asymptotically approaching proposed performance goals or criteria (i.e., the ∀30%/50% and ∀60%/75% bias/error levels listed in Table 3-1) when the mean of the observed concentrations are greater than 2.5 ug/m^3.
- Approaching 200% error and ∀200% bias when the mean of the observed concentrations are extremely small.

Bias and error are plotted as a function of average concentrations. As the mean concentration approaches zero, the bias performance goal and criteria flare out to ∀200% creating a horn shape, hence the name "Bugle Plots". Dr. Boylan has defined three Zones of model performance: Zone 1 meets the ∀30%/50% bias/error performance goal and is considered "good" model performance; Zone 2 lies between the ∀30%/50% performance goal and ∀60%/75% performance criteria and is an area where concern for model performance is raised; and Zone 3 lies above the ∀60%/75% performance criteria and is an area of questionable model performance.

3.4 Key Measures of Model Performance

Although we have generated numerous statistical performance measures (see Table C-2 in Appendix C) that are available on the CENRAP modeling website, when comparing model performance across months, subdomains, networks, grid resolution, models, studies, etc. it is useful to have a few key measurement statistics to be used to facilitate the comparisons. It is also useful to have a subset of months within the 2002 year that can represent the entire year so that a more focused evaluation can be conducted. We have found that the Mean Fractional Bias and Mean Fractional Gross Error appear to be the most consistent descriptive measure of model performance (Morris et al., 2004b; 2005). The Fractional Bias and Error are normalized by the average of the observed and predicted value (see Table C-2) because it provides descriptive power across different magnitudes of the model and observed concentrations and is bounded by -200% to +200%. This is in contrast to the normalized bias and error (as recommended for ozone performance goals, EPA, 1991) that is normalized by just the observed value so can “blow up” to infinity as the observed value approaches zero. In Appendix C we perform a focused evaluation of model performance for PM and gaseous species and four months of the 2002 year that are used to represent the seasonal variation in performance:

- January
- April
- July
- October

Scatter plots of model predictions and observations for each PM species are presented for each of the four months along with performance statistics and predicted and observed time series plots at each CENRAP Class I area. Summary plots of monthly fractional bias and error are also presented.

3.5 Operational Model Performance Evaluation

A summary of the operational evaluation is presented below. Just the monthly fractional bias performance metrics for each PM species using bar charts and Bugle Plots are presented in this section. The reader is referred to Appendix C for the complete model performance evaluation.

3.5.1 Sulfate (SO4) Model Performance

Figure 3-1 compares the monthly SO4 fractional bias across the CENRAP region for the IMPROVE, STN and CASTNet monitoring networks. An underprediction bias is clearly evident the first 8-10 months of the year. This underestimation bias is greatest across the CASTNet network which persists throughout the year. The SO4 underprediction is not as severe for the STN network and it is minimal by August becoming a slight overprediction in September. For the IMPROVE network, the SO4 fractional bias is < ±20% for the first 2 and last 3 months of the year and ranges from -30% to -50% for the late Spring and Summer months.

Figure 3-1 also includes a Bugle Plot of monthly SO4 fractional bias statistics (for Bugle Plot of fractional gross error see Appendix C) and compares them against the proposed PM model performance goal and criteria (see Table 3-1). For the STN network, SO4 model performance meets the proposed performance goal for all months. For the IMPROVE network, approximately half of the months achieve the proposed PM performance goal with the other half outside of the goal, but within the performance criteria. Across the CASTNet network, most months are outside of the proposed goal but are within the criteria. The CASTNet fractional bias for some months is right at the performance criteria (≤±60%). With the exception of two IMPROVE months, the monthly SO4 fractional bias performance statistics achieve the proposed PM model performance goal.

3.5.2 Nitrate (NO3) Model Performance

Monthly NO3 model performance across the CENRAP region is characterized by a summer underestimation and winter overestimation bias (Figure 3-2). The summer underestimation bias is more severe, exceeding -100%. Whereas, the winter overestimation bias is approximately 50%. So based on statistics alone, it appears the summer underestimation bias is a bigger concern than the winter overestimation bias. However, the Bugle Plots in the bottom part of Figure 3-2 show that the summer underestimation bias occurs when NO3 is very low and is not an important component of PM and visibility impairment. These summer values occur in the flared horn part of the Bugle Plot and the summer NO3 performance, in most cases, achieves the model performance goal and always achieves the performance criteria. Whereas, the winter overstated NO3 performance for the most part doesn't meet the performance goal and there are some months/networks that also don't meet the performance criteria.

3.5.3 Organic Matter Carbon (OMC) Model Performance

The OMC monthly fractional bias across IMPROVE and STN sites in the CENRAP region are shown in Figure 3-3. The fractional bias for OMC at the IMPROVE sites is quite good throughout the year with values generally within ±20%, albeit with a slight winter overestimation and summer underestimation bias. At the urban STN sites, the model exhibits an underestimation bias throughout the year that ranges from -20% to -50%. The urban underestimation of OMC is a fairly common occurrence and suggests there may be missing sources of organic aerosol emissions in the modeling inventory.

The good performance of the model for OMC at the IMPROVE sites is also reflected in the Bugle Plot (Figure 3-3, bottom) with the bias achieving the proposed PM model performance goal for all months of the year. At the STN sites, however, the OMC bias falls between the proposed PM model performance goal and criteria, with error right at the goal for most months.

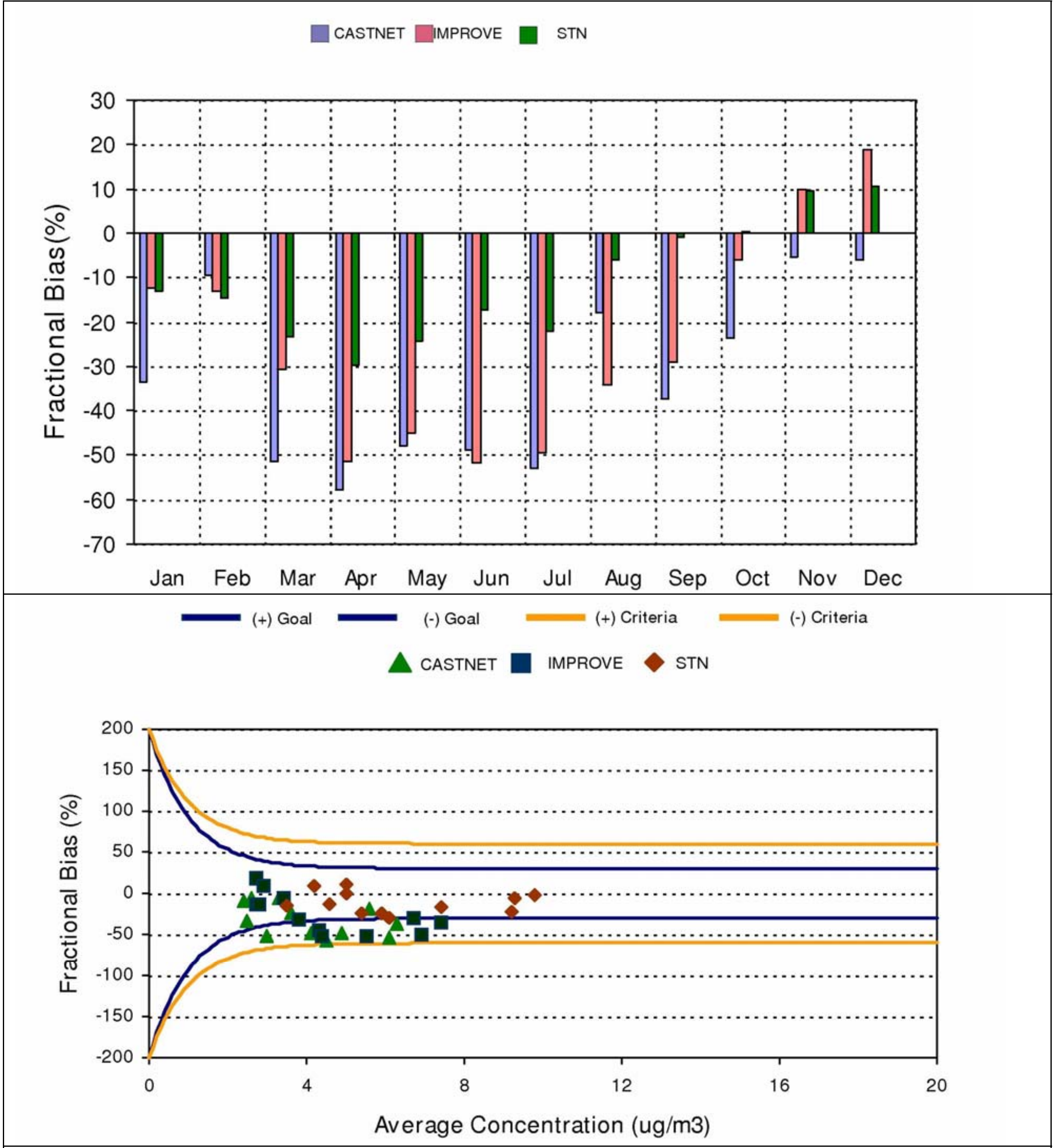

Figure 3-1. Monthly fractional bias (%) for sulfate (SO4) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

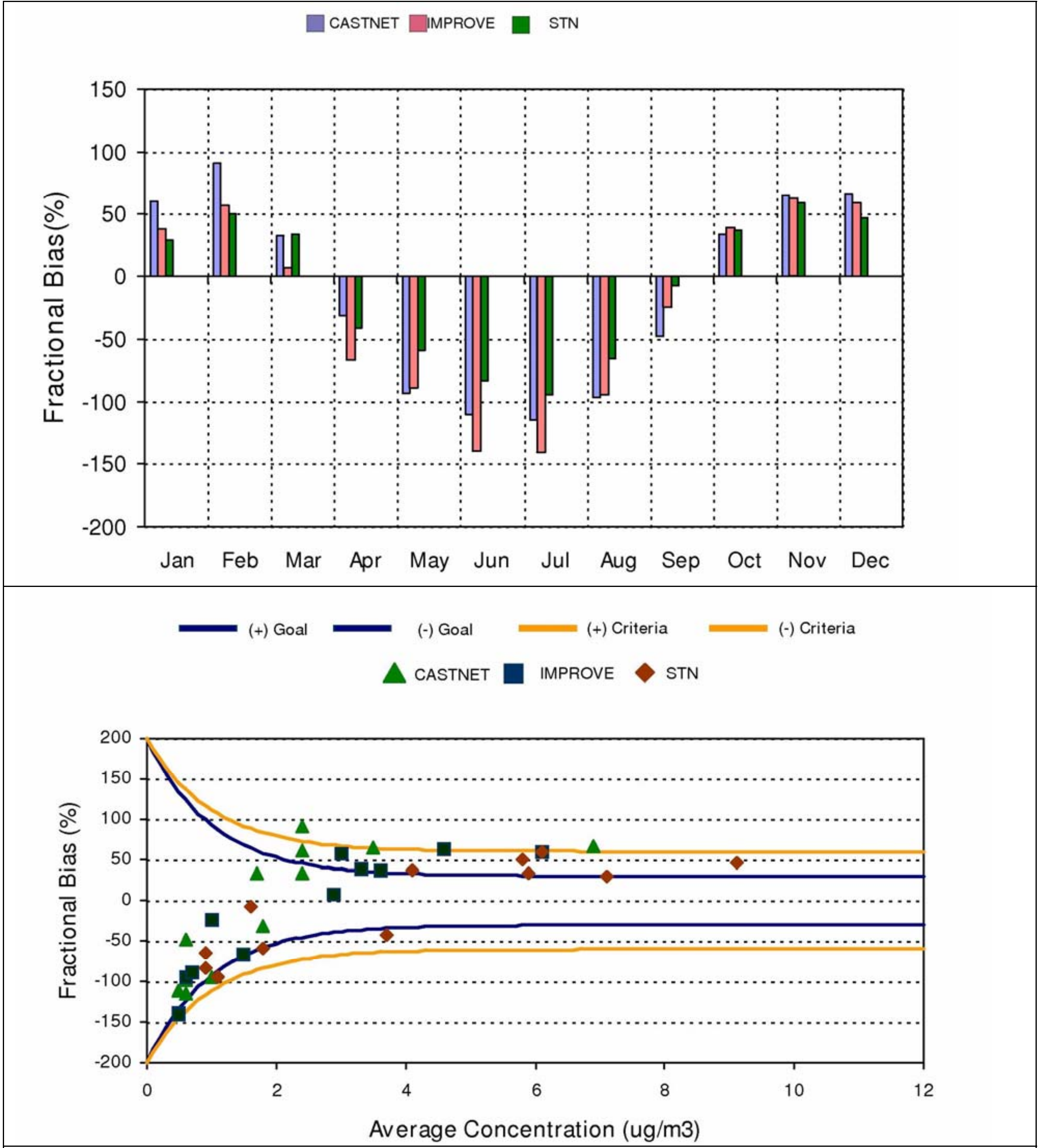

Figure 3-2. Monthly fractional bias (%) for nitrate (NO3) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

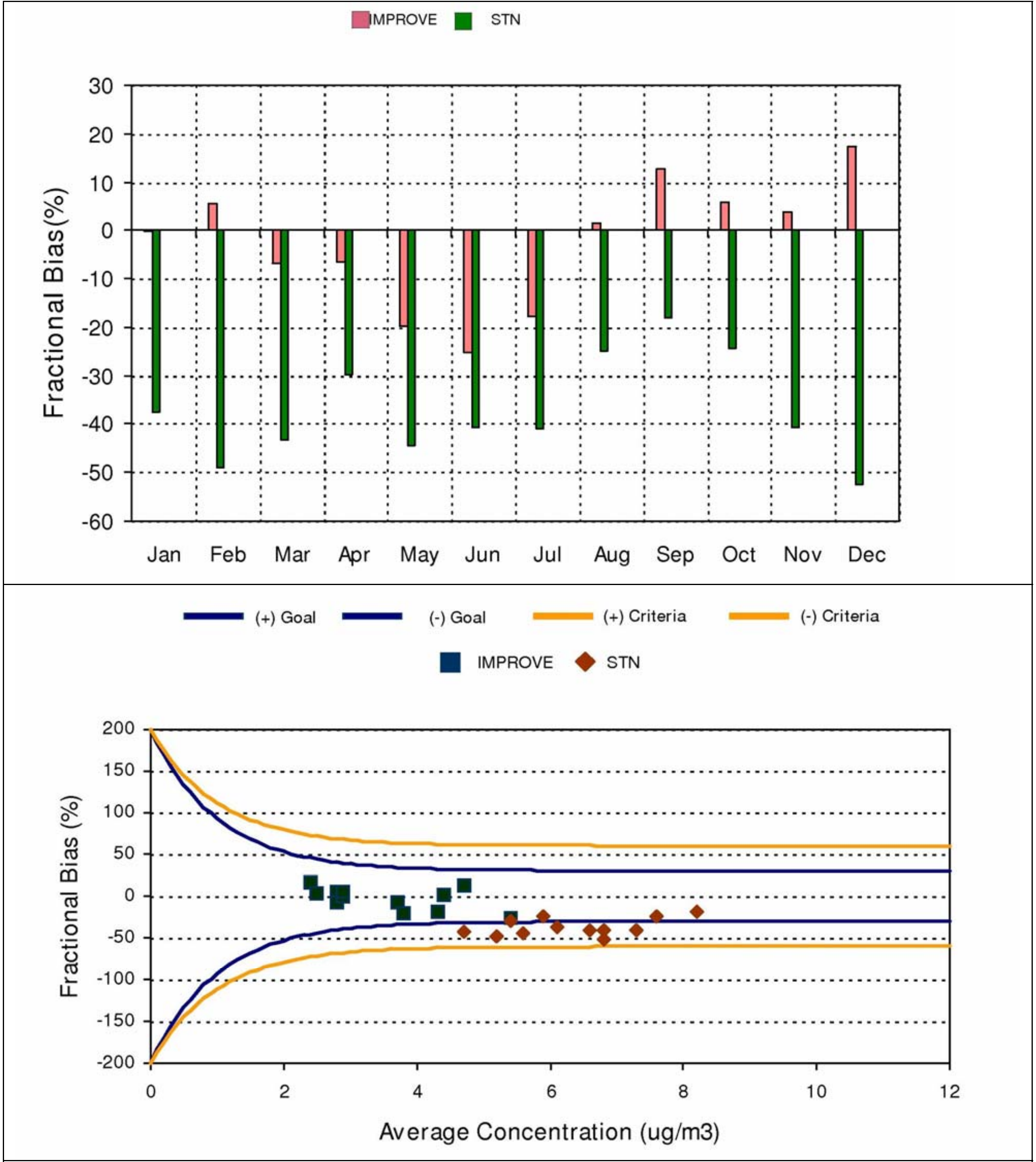

Figure 3-3. Monthly fractional bias (%) for organic matter carbon (OMC) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

3.5.4 Elemental Carbon (EC) Model Performance

The monthly average bias for EC across the IMPROVE and STN monitors in the CENRAP region are shown in Figure 3-4. The STN network exhibits small fractional bias year round, whereas the IMPROVE monitoring network exhibits a large underprediction bias in the summer months (-40% to -70%) and much smaller bias in the winter. The Bugle Plot puts the EC performance in context. The low EC concentrations at the IMPROVE sites results in bias values in the horn of the Bugle Plot. Thus, EC bias achieves the proposed PM performance goal for all months of the year.

3.5.5 Other $PM_{2.5}$ (Soil) Model Performance

Figure 3-5 displays the monthly variation in the Soil fractional bias using IMPROVE measurements in the CENRAP region. During the winter months, the model exhibits a very large (> 100%) overestimation bias. With the exception of July, the summer monthly bias is toward a slight overprediction but generally less than 20%. The July underestimation bias appears to be driven by impacts of high Soil values from wind blown dust events (e.g., see July 2002 discussion in Appendix C). The Bugle Plot indicates that the summer Soil performance achieves the PM performance goal, a few months in the Spring/Fall period fall between the performance goal and criteria and the winter Soil performance exceeds the model performance criteria. Thus, the Soil performance is a cause for concern.

3.5.6 Coarse Mass (CM) Model Performance

The monthly average fractional bias values for CM are shown in Figure 3-6. In the winter the underprediction bias is typically in the -60% to -80% range. In the late Spring and Summer the underprediction bias ranges from -120% to -160%. As this underprediction bias is nearly systematic (i.e., an underprediction almost always occurs), then the fractional errors are the same magnitude as the bias.

The Bugle Plots clearly show that the CM model performance is a problem. The monthly bias exceeds both the performance goal and criteria for almost every month of the year.

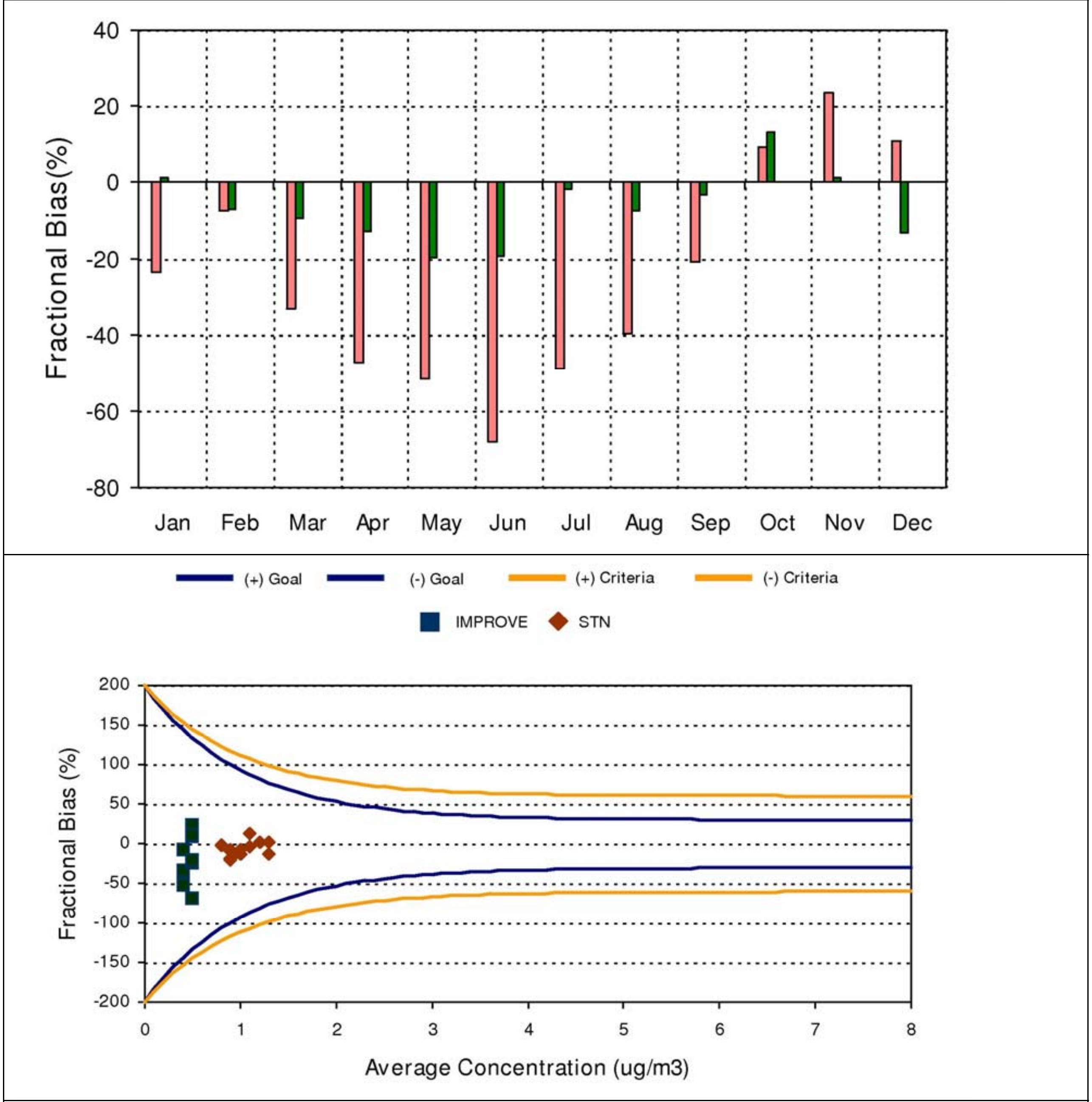

Figure 3-4. Monthly fractional bias (%) for elemental carbon (EC) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

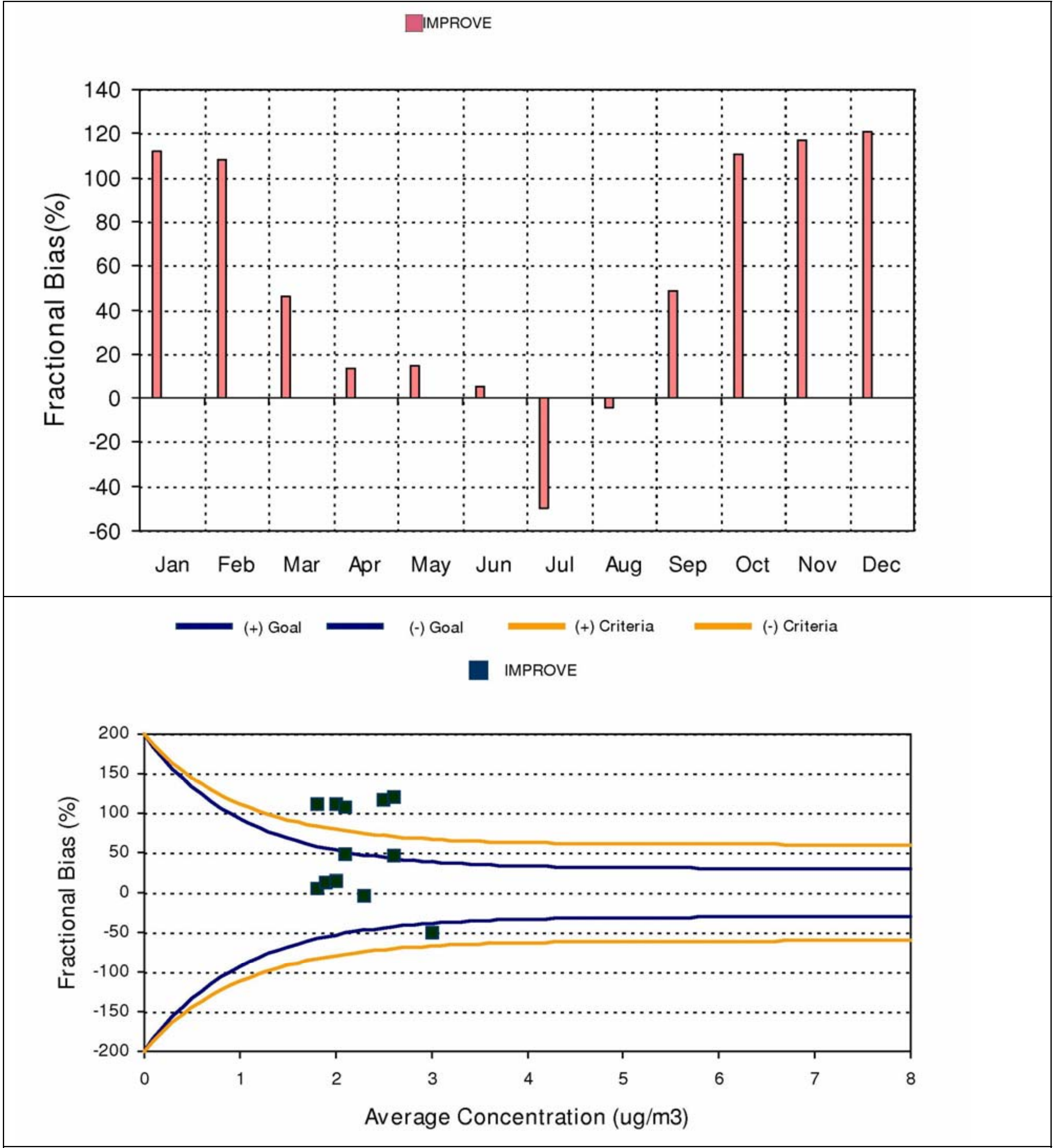

Figure 3-5. Monthly fractional bias (%) for other $PM_{2.5}$ (Soil) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

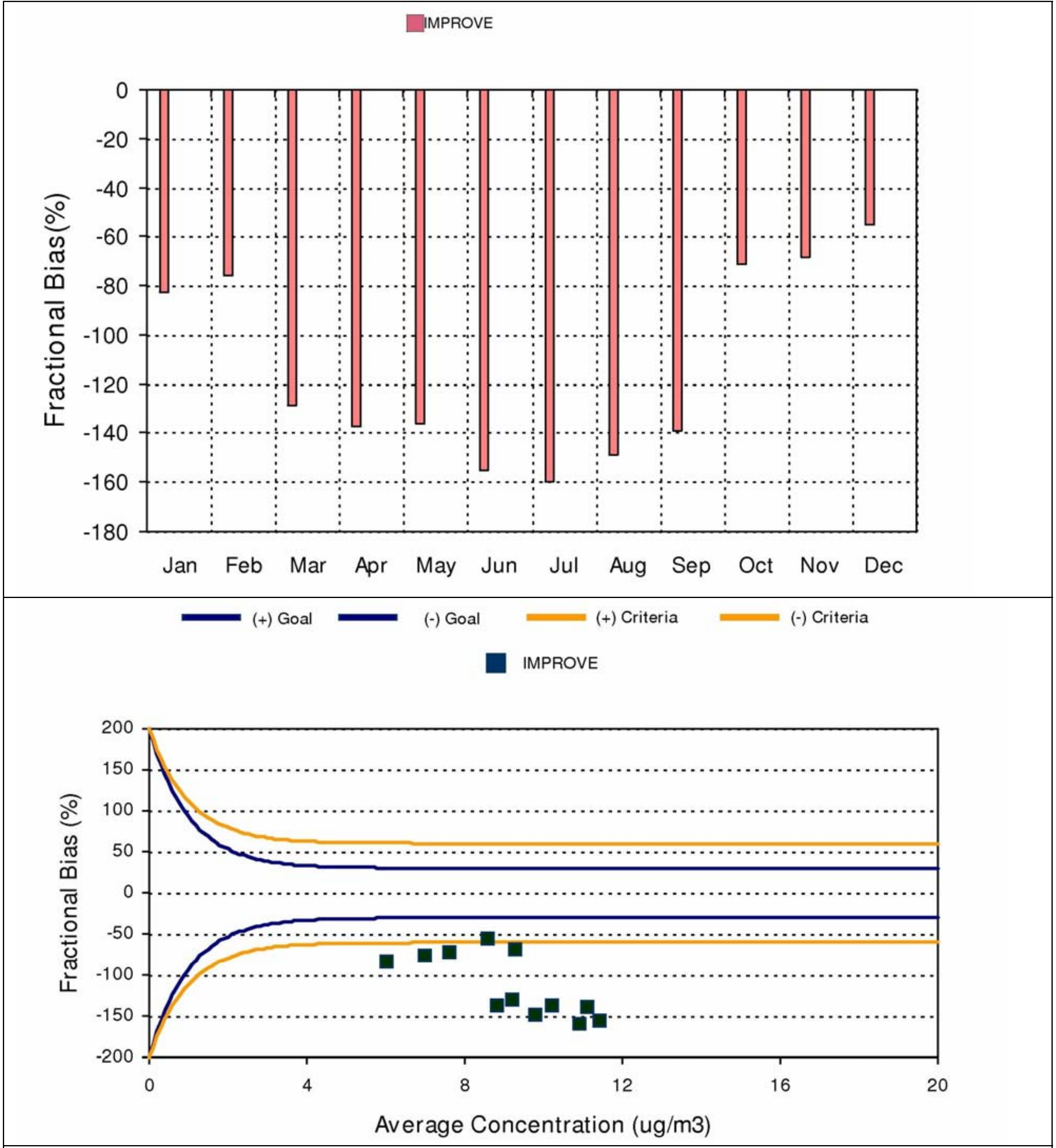

Figure 3-6. Monthly fractional bias (%) for coarse mass (CM) across the CENRAP region for the CMAQ 2002 36 km Base F base case simulation.

3.6 Diagnostic Model Performance Evaluation

The CASTNet and AQS networks also measure gas-phase species that are PM precursor or related species. The diagnostic evaluation of the 2002 36 km Base F CMAQ base case simulation for these compounds and the four seasonal months are presented in Appendix C. The displays for January are provided below as an example; the reader is referred to Appendix C for the rest of the monthly displays.

The CASTNet network measures weekly average samples of SO2, SO4, NO2, HNO3, NO3 and NH4. The AQS network collects hourly measurements of SO2, NO2, O3 and CO. A comparison of the SO2 and SO4 performance provides insight into whether the SO4 formation rate may be too slow or fast. For example, if SO4 is underestimated and SO2 is overestimated that may indicate chemical conversion rates that are too slow. Analyzing the performance for SO4, HNO3, NO3, Total NO3 and NH4 provides insight into the equilibrium of these species. For example, if Total NO3 performs well but HNO3 and NO3 do not, then there may be issues associated with the partitioning between the gaseous and particulate phases of nitrate. Causes for incorrect HNO3/NO3 partitioning could include inadequate ammonia emissions and/or poorly characterized meteorological conditions (e.g., temperature).

3.6.1 Diagnostic Model Performance in January 2002

In January, SO2 is overstated across both the CASTNet and AQS sites with fractional bias values of 38% (Figure 3-7) and 31% (Figure 3-8), respectively. SO4 is understated by -34% across the CASTNet monitors (Figure 3-7) and -12% and -13% for the IMPROVE and STN networks (Figure C-4a). Wet SO4 deposition is also overstated in January (+40%, Figure C-4a). Given that SO2 emissions are well characterized, these results suggest that the January SO4 underestimation may be partly due to understated transformation rates of SO2 to SO4 and overstated wet SO4 deposition.

Total NO3 is overestimated by 35% on average across the CASTNet sites in the CENRAP region in January (Figure 3-7). HNO3 is underestimated (-34%) and particle NO3 is overestimated (+61%) suggesting there are gas/particle equilibrium issues. An analysis of the time series of the four CASTNet stations reveals that NO3, HNO3 and NH4 performance is actually very reasonable at the west Texas site and the HNO3 underestimation and NO3 overestimation bias is coming from the east Kansas, central Arkansas and northern Minnesota CASTNet sites (see Figure C-3 for site locations). One potential contributor for this performance problem could be overstated NH3 emissions. However, the Total NO3 overestimation bias suggests that the model estimated NOx oxidation rate may be too high in January.

The SO2, NO2, O3 and CO performance across the AQS sites in January is shown in Figure 3-8. The AQS monitoring network is primarily an urban-oriented network. So, it is not surprising that the model is underestimating concentrations of primary emissions when a 36 km grid is used. NO2 is underestimated by approximately 5%, and CO by approximately 67%. Ozone is also underestimated on average, especially the maximum values above 60 ppb.

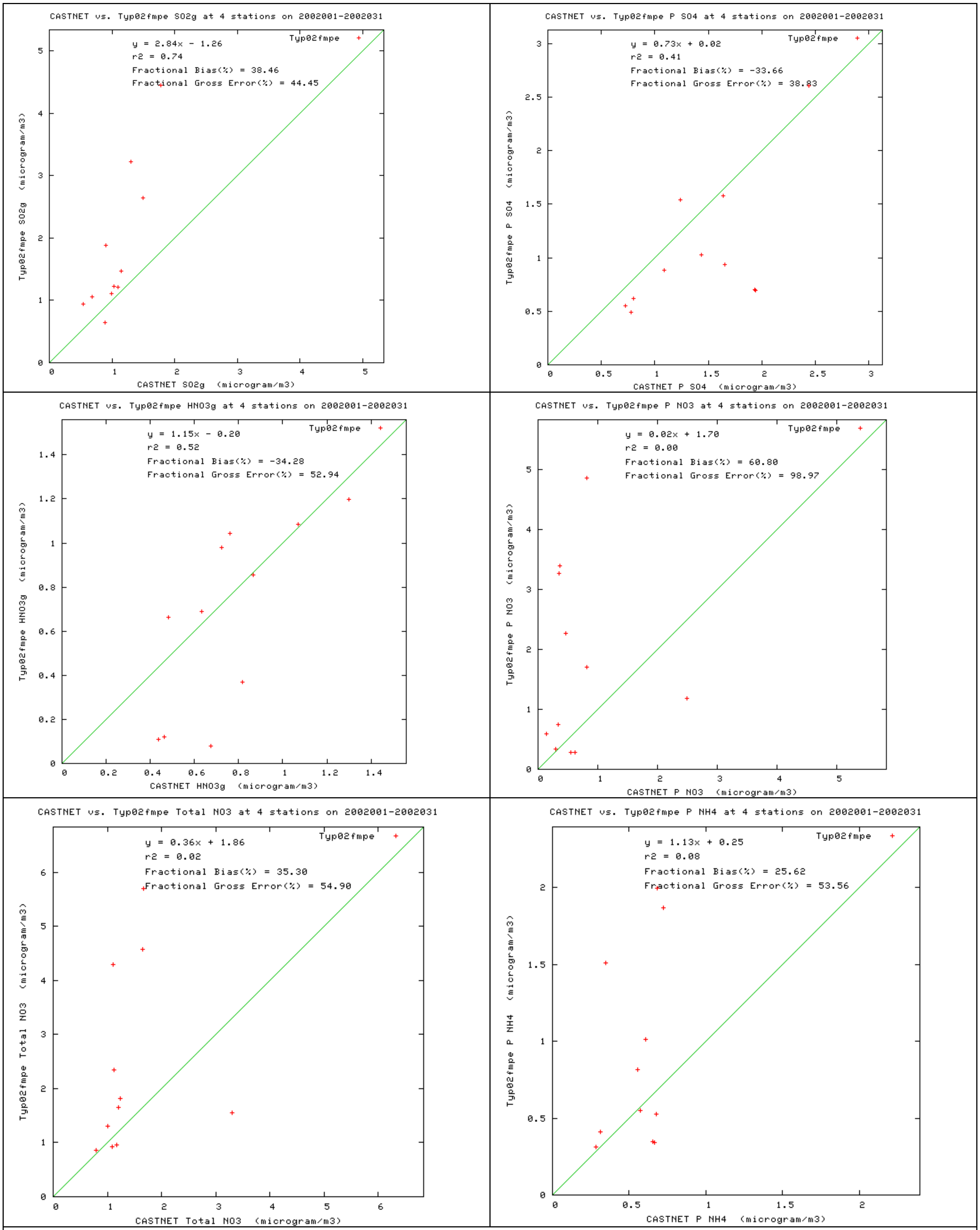

Figure 3-7. January 2002 performance at CENRAP CASTNet sites for SO2 (top left), SO4 (top right), HNO3 (middle left), NO3 (middle right), Total NO3 (bottom left) and NH4 (bottom right).

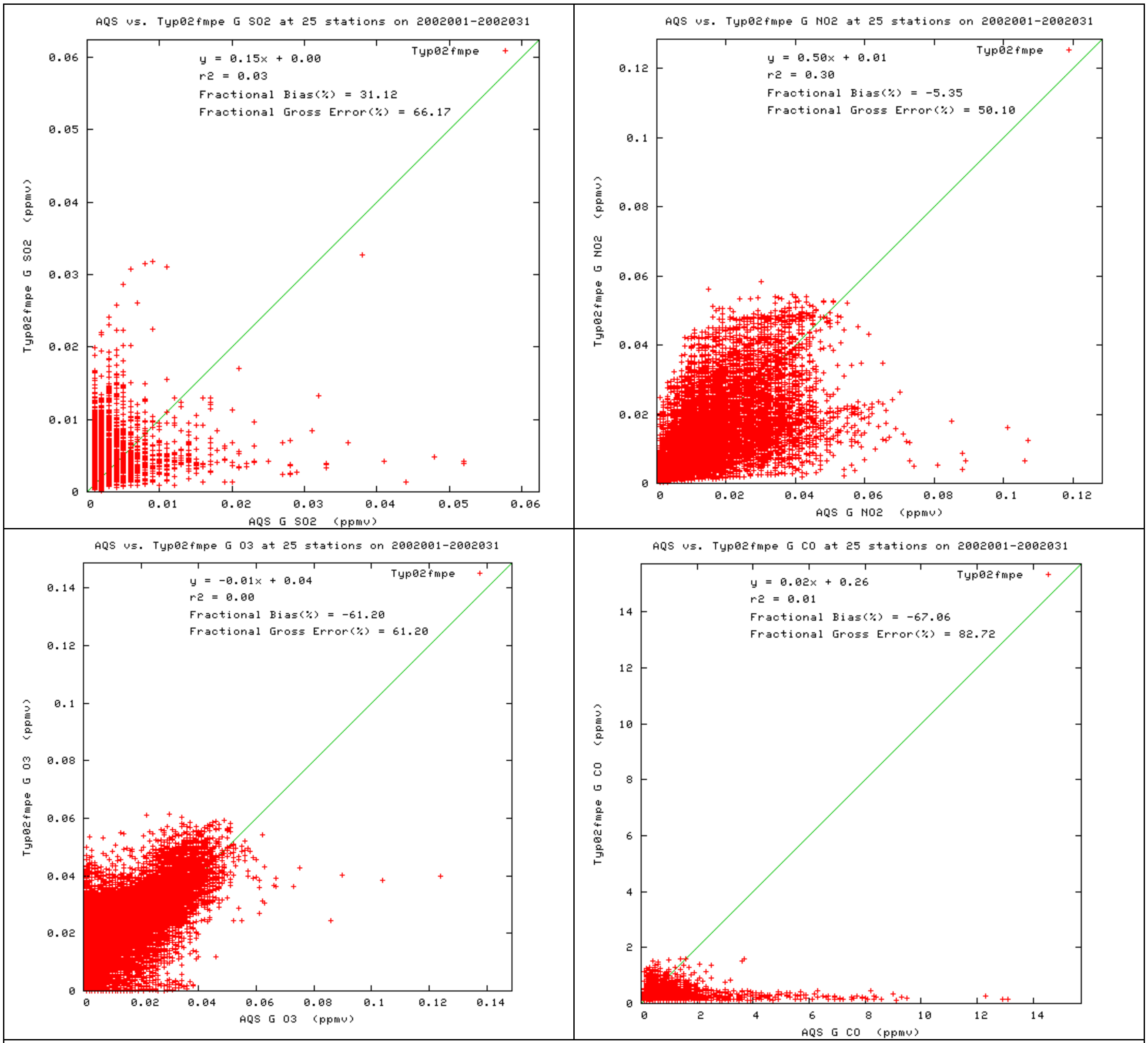

Figure 3-8. January 2002 performance at CENRAP AQS sites for SO2 (top left), NO2 (top right), O3 (bottom left) and CO (bottom right).

3.6.2 Diagnostic Model Performance In April

In April there is an average SO2 overestimation bias across the CASTNet (+15%) and underestimation bias across the AQS (-10%) networks (Figures C-42 and C-43). SO4 is underestimated across all networks by -30% to -58% (Figure C-5a). The wet SO4 deposition bias is near zero. Both SO2 and SO4 are underestimated at the west Texas CASTNet monitor in April suggesting SO2 emissions in Mexico are likely understated.

The HNO3 performance in April is interesting with almost perfect agreement except for 5 modeled-observed comparisons that drives the average underprediction bias of -29% (Figure C-42). On Julian Day 102 there is high HNO3 at the MN, KS and OK CASTNet sites that is not captured by the model. Given that HNO3, NO3 and Total NO3 are all underestimated by about the same amount (-30%), then part of the underestimation bias is likely due to too slow oxidation of NOx.

There is a lot of scatter in the NO2 and O3 performance that is more or less centered on the 1:1 line of perfect agreement with bias values of -8% and -21%, respectively (Figure C-43). CO is underestimated by -72% with the model unable to predict CO concentrations above 1 ppm due to the use of the coarse 36 km grid spacing. Mobile sources produce a vast majority of the CO emissions. So, AQS monitors for CO compliance are located near roadways, which are not simulated well using a 36 km grid.

3.6.3 Diagnostic Model Performance In July

In July SO2 is slightly underestimated across the CASTNet (-5%) and AQS (-12%) networks (Figures C-44 and C-45). SO4 is more significantly underestimated across all networks (-22% to -53%, as shown in Figure C-6a). Since wet deposition SO4 is also underestimated, it is unclear why all sulfur species are underestimated.

The nitrate species are also all underestimated with the Total NO3 bias (-56%) being between the HNO3 bias (-35%) and NO3 bias (-115%). The modeled NO3 values are all near zero with little correlation with the observations, whereas the observed HNO3 and Total NO3 is tracked well with correlation coefficients of 0.74 and 0.76. These results suggest that the July NO3 model performance problem is partly due to insufficient formation of Total NO3, but mainly due to incorrect partitioning of the Total NO3.

Again, there is abundant scatter in the AQS NO2 scatter plot for July (Figure C-45) resulting in a low bias (0%) but high error (65%). Ozone performance also exhibits a low bias (-15%) and error (20%), but the model is incapable of simulating ozone above 100 ppb. Although CO performance in July is better than the previous months, it still has a large underestimation bias of 82%.

3.6.4 Diagnostic Model Performance In October

SO2 is overstated in October across the CASTNet (+28%) and AQS (+33%) sites (Figures C-46 and C-47). Although SO4 is understated across the CASTNet sites (-24%), the bias across the IMPROVE (-6%) and STN (0%) sites are near zero (Figure C-7a).

Performance for HNO3 is fairly good with a low bias (+12%) and error (30%). But NO3 is overstated (+34%) leading to an overstatement of Total NO3 (+37%). The overstatement of NO3 leads to an overstatement of NH4 as well (Figure C-46)

As seen in the other months, NO2 exhibits a lot of scatter resulting in a low correlation (0.22) and high error (61%) but low bias (12%). The model tends to underpredict the high and overpredict the low O3 observations resulting in a -29% bias and low correlation coefficient. CO is also underpredicted (-76%) for the reasons discussed previously.

3.7 Performance at CENRAP Class I Areas for the Worst and Best 20 Percent Days

In this section, and in section C.5 of Appendix C, we present the results of the model performance evaluation at each of the CENRAP Class I areas for the worst and best 20 percent days. Performance on these days is critical since they are the days used in the 2018 visibility projections discussed in Chapter 4. For each Class I area we compared the predicted and observed extinction of the worst and best 20 percent days below. In Appendix C the PM species-specific extinction is also compared for the worst 20 percent days.

3.7.1 Caney Creek (CACR) Arkansas

The ability of the CMAQ model to estimate visibility extinction at the CACR Class I area on the 2002 worst and best 20 percent days is provide in Figures 3-9 and C-48. On most of the worst 20 percent days at CACR total extinction is dominated by SO4 extinction with some extinction due to OMC. On four of the worst 20 percent days extinction is dominated by NO3. The average extinction across the worst 20 percent days is underestimated by -33% (Figure 3-9), which is primarily due to a -51% underestimation of SO4 extinction combined with a 6% overestimation of NO3 extinction (Figure C-48). Performance for OMC extinction at CACR on the worst 20 percent days is pretty good with a -20% bias and 36% error. EC extinction is systematically underestimated. Soil extinction has low bias (-19%) buts lots of scatter and high error (74%), while CM extinction is greatly underestimated (bias of -153%).

On the best 20 percent days at CACR the observed extinction ranges from 20 to 40 Mm^{-1}. Whereas, the modeled extinction has a much larger range from 15 to 120 Mm^{-1}. Much of the modeled overestimation of total extinction on the best 20% days (+44% bias) is due to NO3 overestimation (+94% bias).

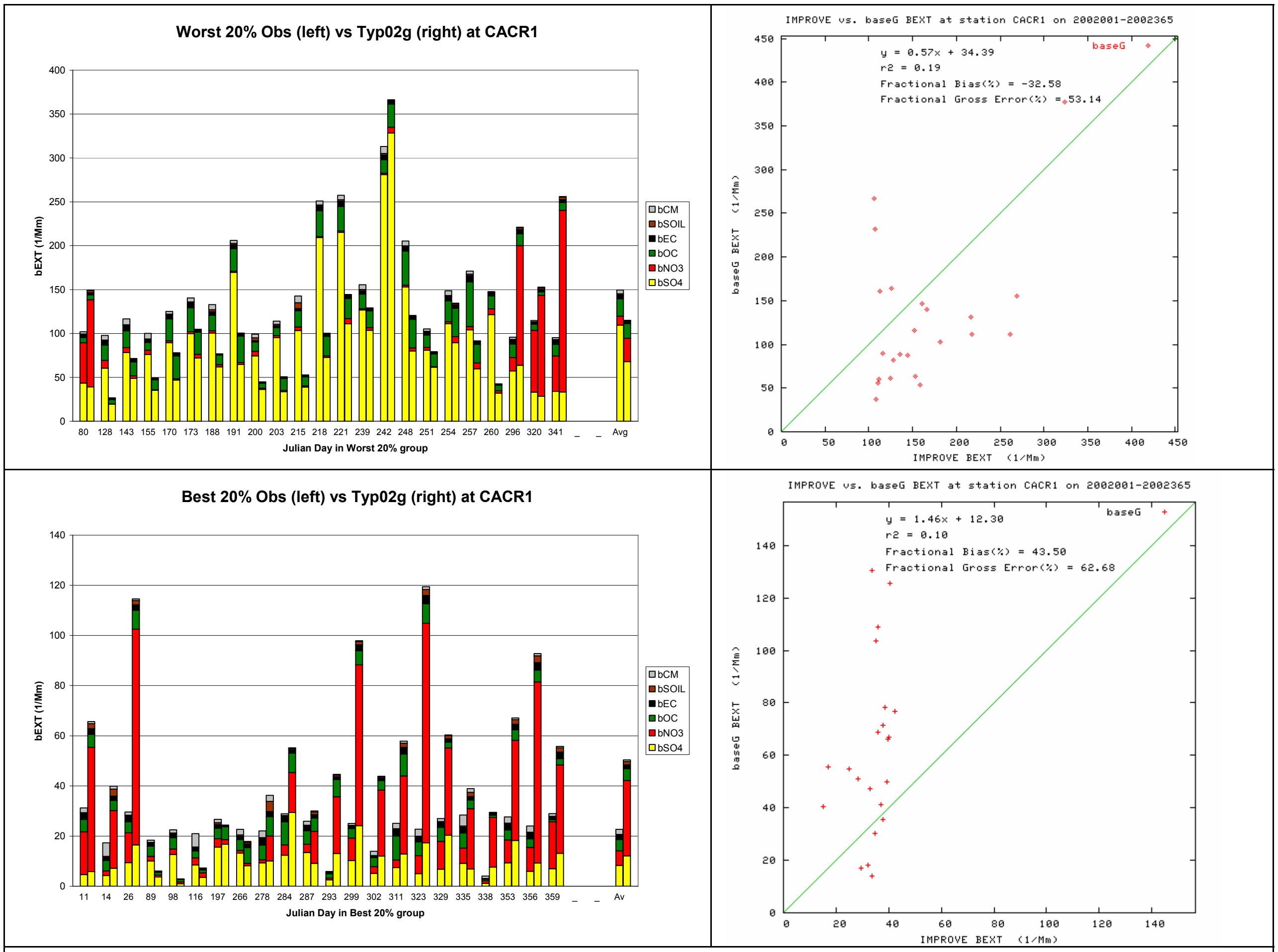

Figure 3-9. Daily extinction model performance at Caney Creek (CACR), Arkansas for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.2 Upper Buffalo (UPBU) Arkansas

Model performance at the UPBU Class I area for the worst and best 20 percent days is shown in Figures 3-10 and C-49. On most of the worst 20 percent days at UPBU, visibility impairment is dominated by SO4, although there are also two high NO3 days. The model underestimates the average of the total extinction on the worst 20 percent days at UPBU by -40% (Figure 3-10), which is due to an underestimation of extinction due to SO4, OMC and CM by -46%, -33% and -179%, respectively.

On the best 20 percent days at UPBU, the model performs reasonably well with a low bias (2%) and error (42%). But again, the model has a much wider range in extinction values across the best 20 percent days (15 to 120 Mm^{-1}) than observed (20 to 45 Mm^{-1}). There are five days in which the modeled NO3 overprediction is quite severe and when those days are removed the range in the modeled and observed extinction on the best 20 percent days is quite similar to the observed, although the model gets much cleaner on the very cleanest modeled days.

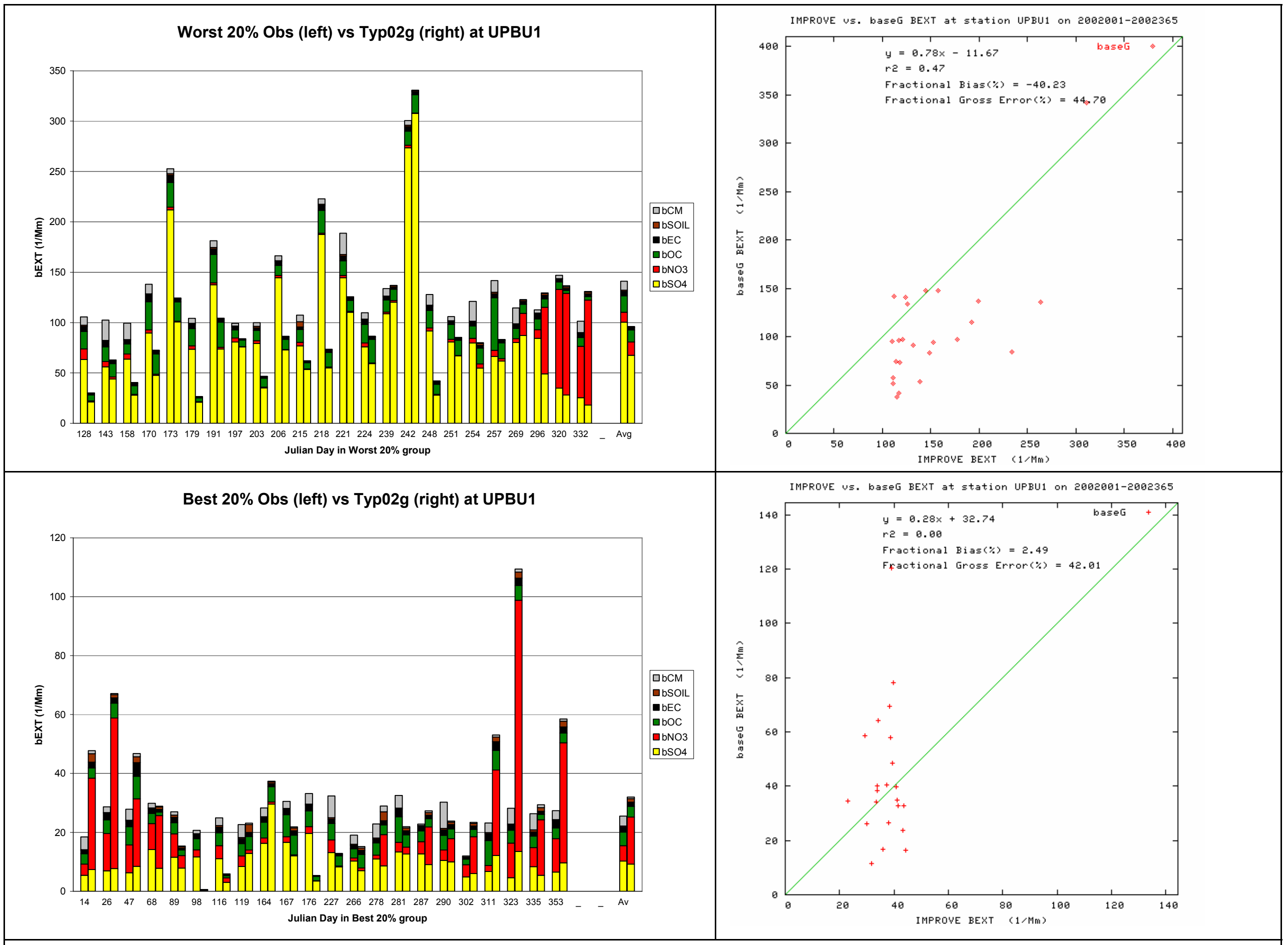

Figure 3-10. Daily extinction model performance at Upper Buffalo (UPBU), Arkansas for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.3 Breton Island (BRET), Louisiana

The observed total extinction on the worst 20 percent days at Breton Island is underestimated by -71% (Figure 3-11), which is due to an underestimation of each component of extinction (Figure C-50) by from -50% to -70% (SO4, OMC and Soil) to over -100% (EC and CM). The observed extinction on the worst 20 percent days ranges from 90 to 170 Mm^{-1}, whereas the modeled values drop down to as low as approximately 15 Mm^{-1}. On the best 20 percent days the range of the observed and modeled extinction is similar (roughly 10 to 50 Mm^{-1}) that results in a reasonably low bias (-22%), but there is little agreement on which days are higher or lower resulting in a lot of scatter and high error (54%).

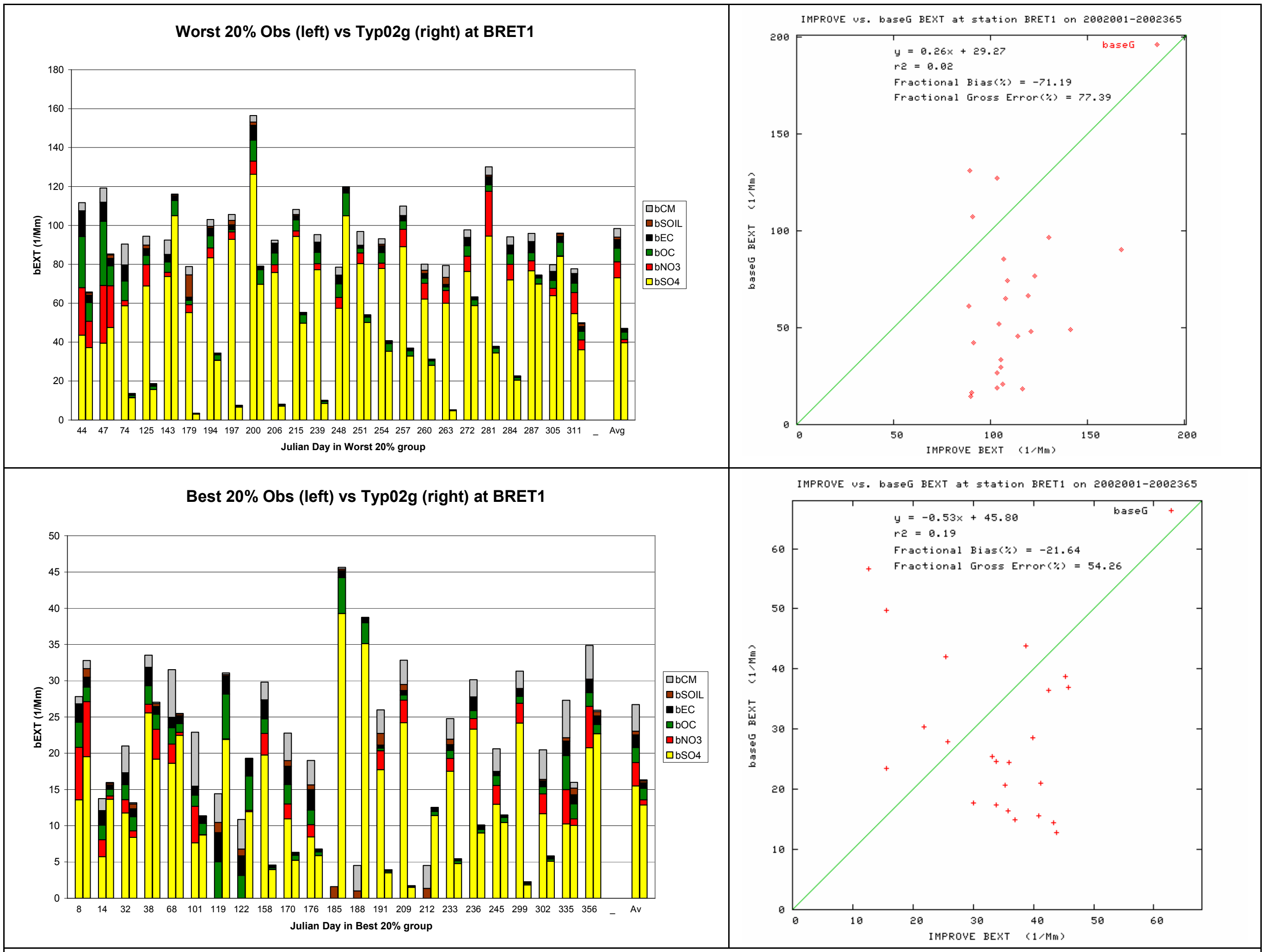

Figure 3-11. Daily extinction model performance at Breton Island (BRET), Louisiana for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.4 Boundary Waters (BOWA), Minnesota

There are three types of days during the worst 20 percent days at BOWA: SO4 days, OMC days and NO3 days (Figure 3-12). The two high OMC days are likely fire impact events that the model captures to some extent on one day and not on the other. On the five high (> 20 Mm^{-1}) NO3 extinction days the model predicts the observed extinction well on three days and overestimates by a factor of 3-4 on the other two high NO3 days. SO4 is underestimated by -43% on average across the worst 20 percent days at BOWA.

With the exception of two days, the model reproduces the total extinction for the best 20 percent days at BOWA quite well with a bias and error value of +14% and 22% (Figure 3-12). Without these two days, the modeled and observed extinction both range between 15 and 25 Mm^{-1}.

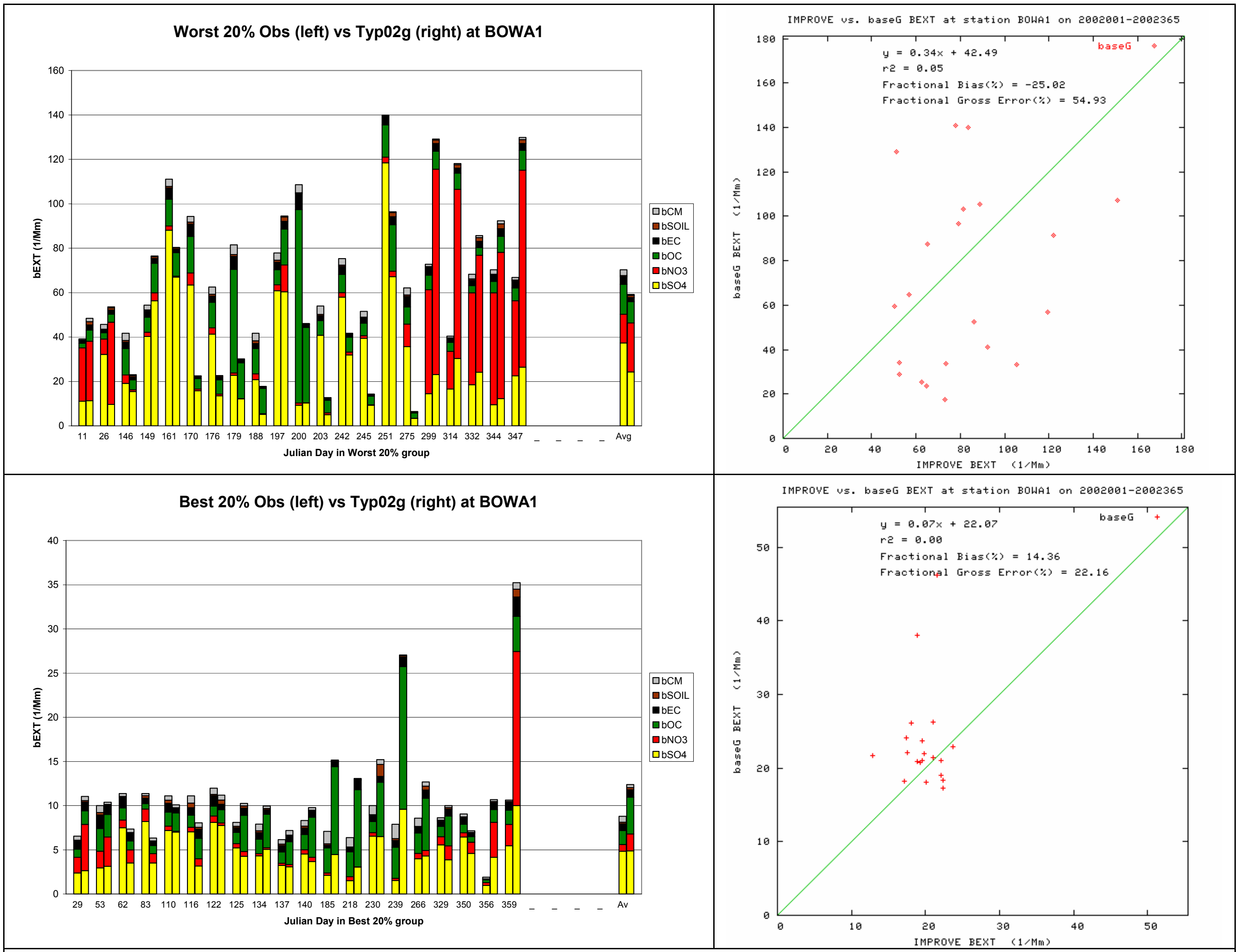

Figure 3-12. Daily extinction model performance at Boundary Waters (BOWA), Minnesota for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.5 Voyageurs (VOYA) Minnesota

VOYA is also characterized by SO4, NO3 and OMC days (Figure 3-13). Julian Days 179 and 200 are high OMC days that were also high OMC days at BOWA again indicating impacts from fires in the area that is not fully captured by the model. SO4 and NO3 performance is fairly good and, without the fire days, OMC performance looks good as well (Figure C-52). On the best 20 percent days there is one day the modeled extinction is much higher than observed and a few others that are somewhat higher, but for most of the best 20 percent days the modeled extinction is comparable to the observed values.

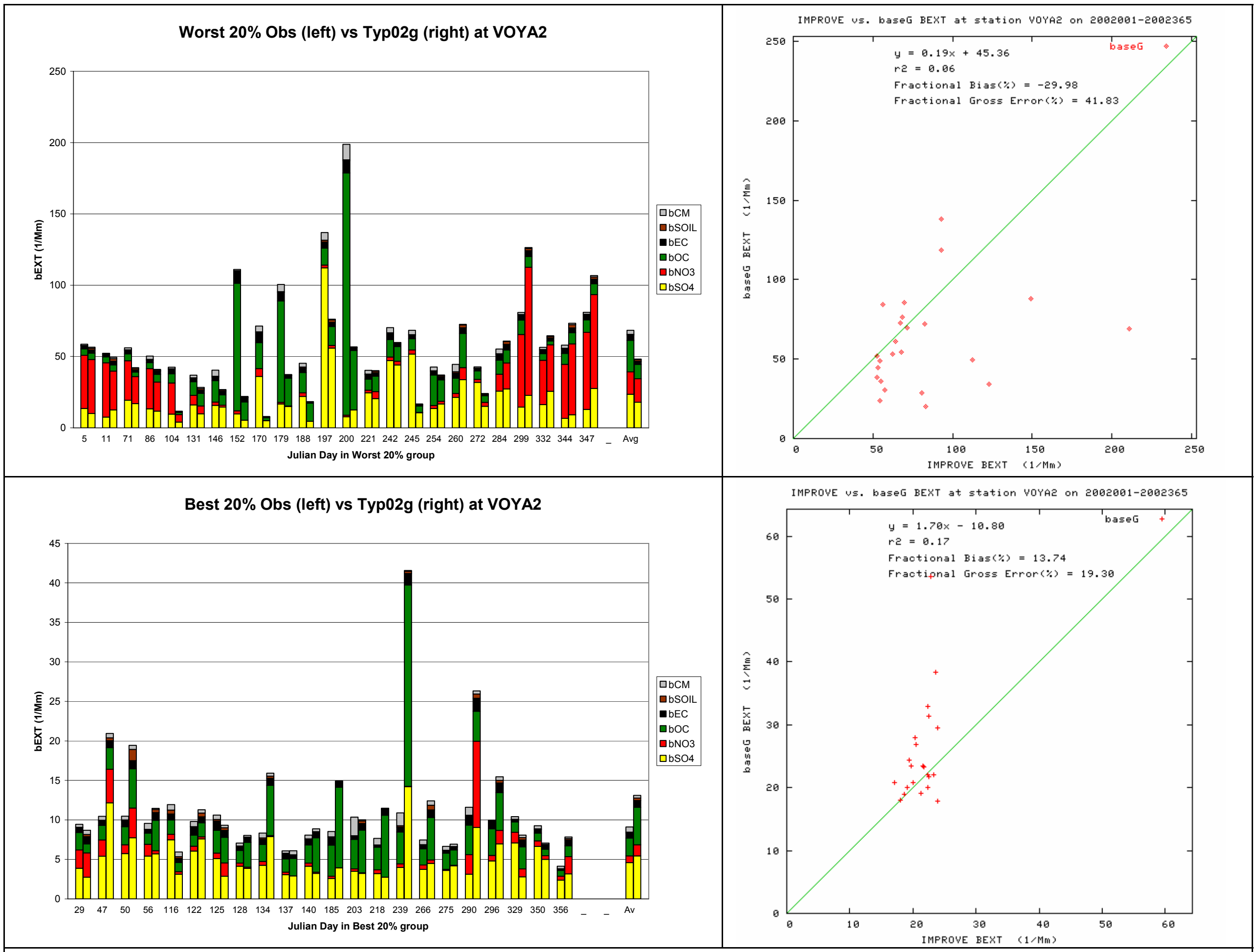

Figure 3-13. Daily extinction model performance at Voyageurs (VOYA), Minnesota for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.6 Hercules Glade (HEGL) Missouri

On most of the worst 20 percent days at HEGL the observed extinction ranges from 120 to 220 Mm^{-1} whereas model extinction ranges from 50 to 170 Mm^{-1} (Figure 3-14). However, there is one extreme day with extinction approaching 400 Mm^{-1} that the model does a very good job in replicating. Over all the days there is a modest underestimation bias in SO4 (-39%) and OMC (-39%) extinction, larger underestimation bias in EC (-62%) and CM (-118%) extinction and overestimation bias in Soil (+30%) extinction (Figure C-53).

On the best 20 percent days there is one day where the model overstates the observed extinction by approximately a factor of four and a handful of other days that the model overstates the extinction by a factor of 2 or so, but most of the days both the model and observed extinction sites are around 40 Mm^{-1} ±10 Mm^{-1}. On the best 20 percent days, when the observed extinction is overstated, it is due to overstatement of the NO3.

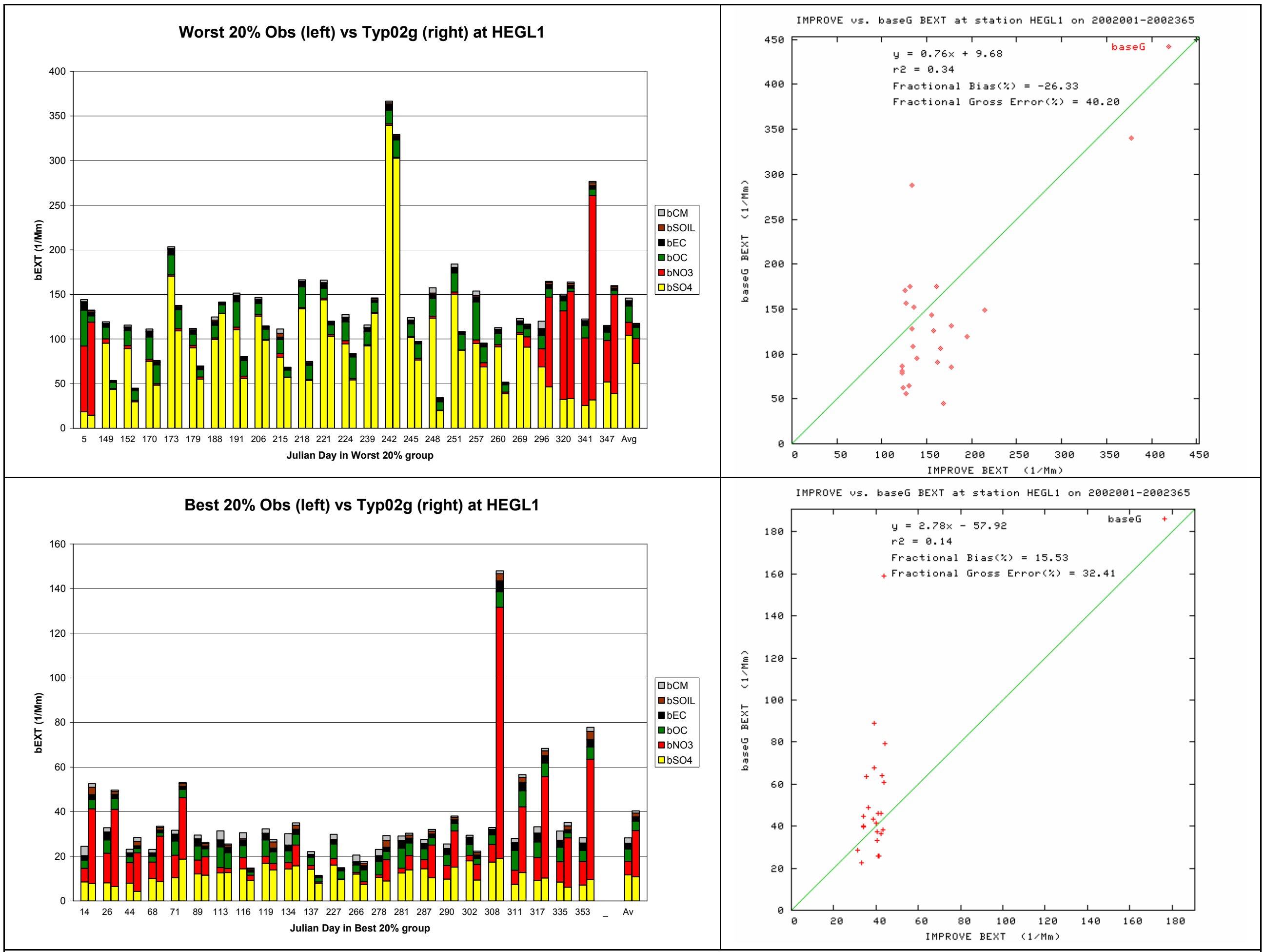

Figure 3-14. Daily extinction model performance at Hercules Glade (HEGL), Missouri for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.7 Mingo (MING) Missouri

The worst 20 percent days at MING are mainly high SO4 days with a few high NO3 days that the model reproduces reasonably well resulting in low bias (+10%) and error (38%) for total extinction (Figure 3-15). The PM species specific performance is fairly good with low bias for SO4 (+4%), good agreement with NO3 on high NO3 days except for one day, low OMC (+23%) and EC (+3%) bias and larger bias in EC (+37%) and CM (-105%) extinction (Figure C-54).

For the best 20 percent days, there is one day the model is way too high due to overstated NO3 extinction and a few other days the model overstates the observed extinction that is usually due to overpredicted NO3, but on most of the best 20 percent days the modeled extinction is comparable to the observed values. This results in low bias (+12%) and error (36%) for total extinction at MING for the best 20 percent days.

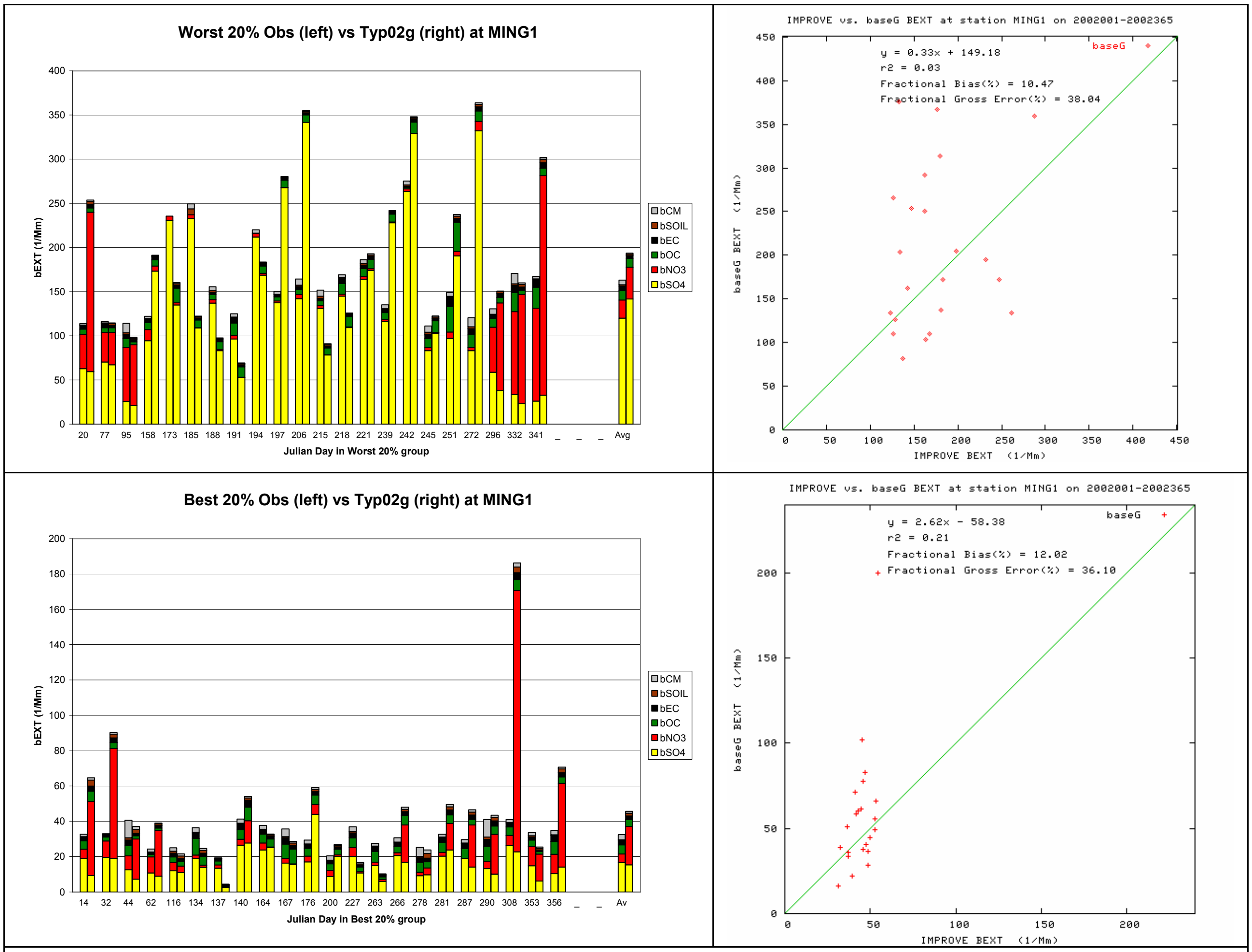

Figure 3-15. Daily extinction model performance at Mingo (MING), Missouri for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.8 Wichita Mountains (WIMO), Oklahoma

With the exception of an overprediction on day 344 due to NO3, observed total extinction on the worst 20 percent days at WIMO is understated with a bias of -42% (Figure 3-16) that is primarily due to an underestimation of extinction due to SO4 (-48%) and OMC (-69%) (Figure C-55).

CMAQ total extinction performance for the average of the best 20 percent days at WIMO is characterized by an overestimation bias (+21%) on most days that is primarily due to NO3 overprediction on several days. Again the modeled range of extinction on the best 20 percent days (12-60 Mm^{-1}) is much greater than observed (20-35 Mm^{-1}).

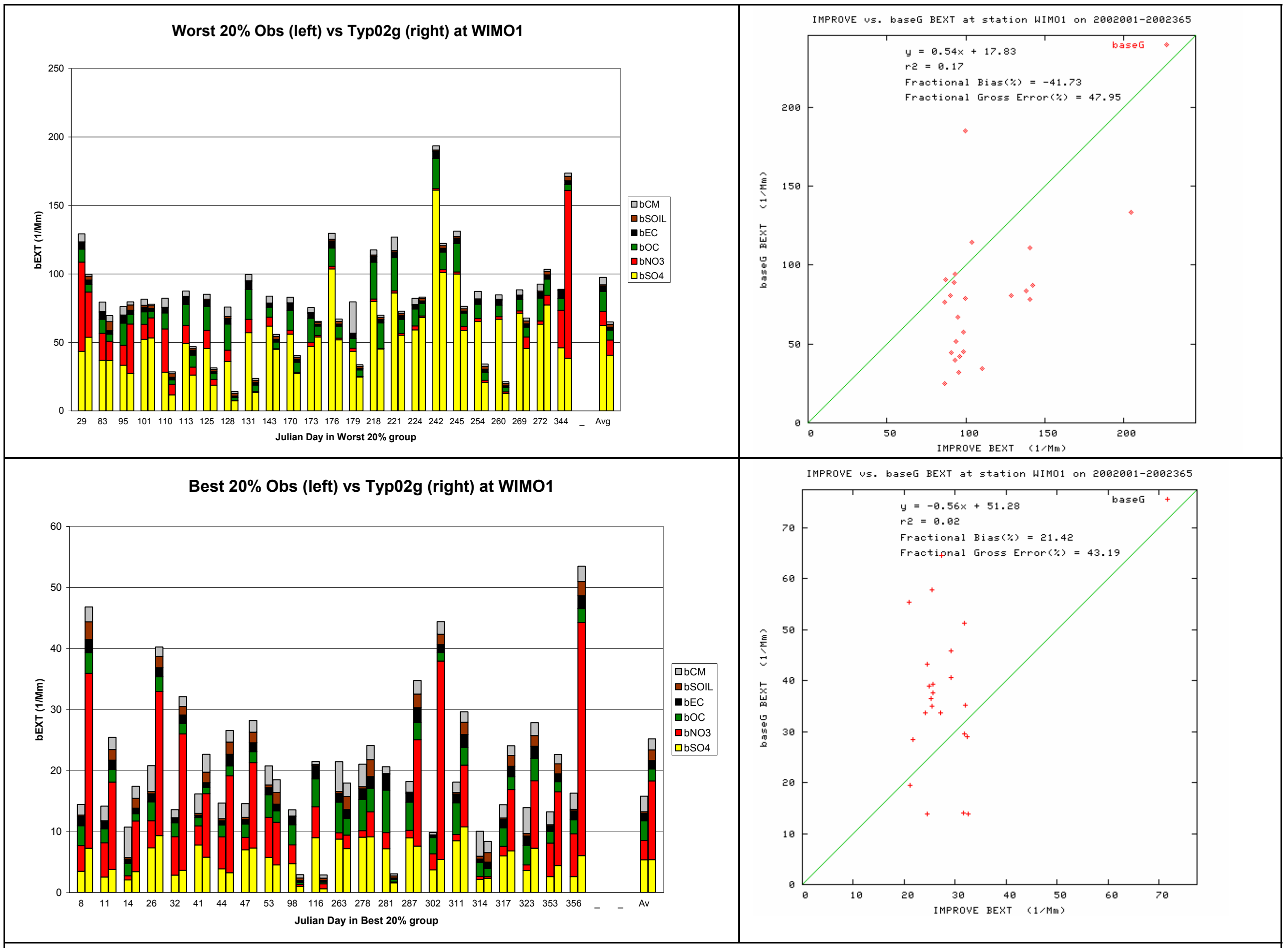

Figure 3-16. Daily extinction model performance at Wichita Mountains (WIMO), Oklahoma for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.9 Big Bend (BIBE) Texas

The observed extinction on the worst 20 percent days at BIBE is underpredicted on almost every day resulting in a fractional bias value of -72% (Figure 3-17). Every component of extinction is underestimated on average for the worst 20 percent days (Figure C-56) with the underestimation bias ranging from -24% (OMC) to -162% (CM). SO4 extinction, that typically represents the largest component of the total extinction is understated by -94%.

The model does a better job in predicting the total extinction at BIBE for the best 20 percent days with average fractional bias and error values of +13% and 19% (Figure 3-17). With the exception of one day that the observed extinction is overestimated by approximately a factor of 2, the modeled and observed extinction on the best 20 percent days at BIBE are both within 12 to 25 Mm^{-1}. However, there are some mismatches with the components of extinction with the model estimating much lower contributions due to Soil and CM.

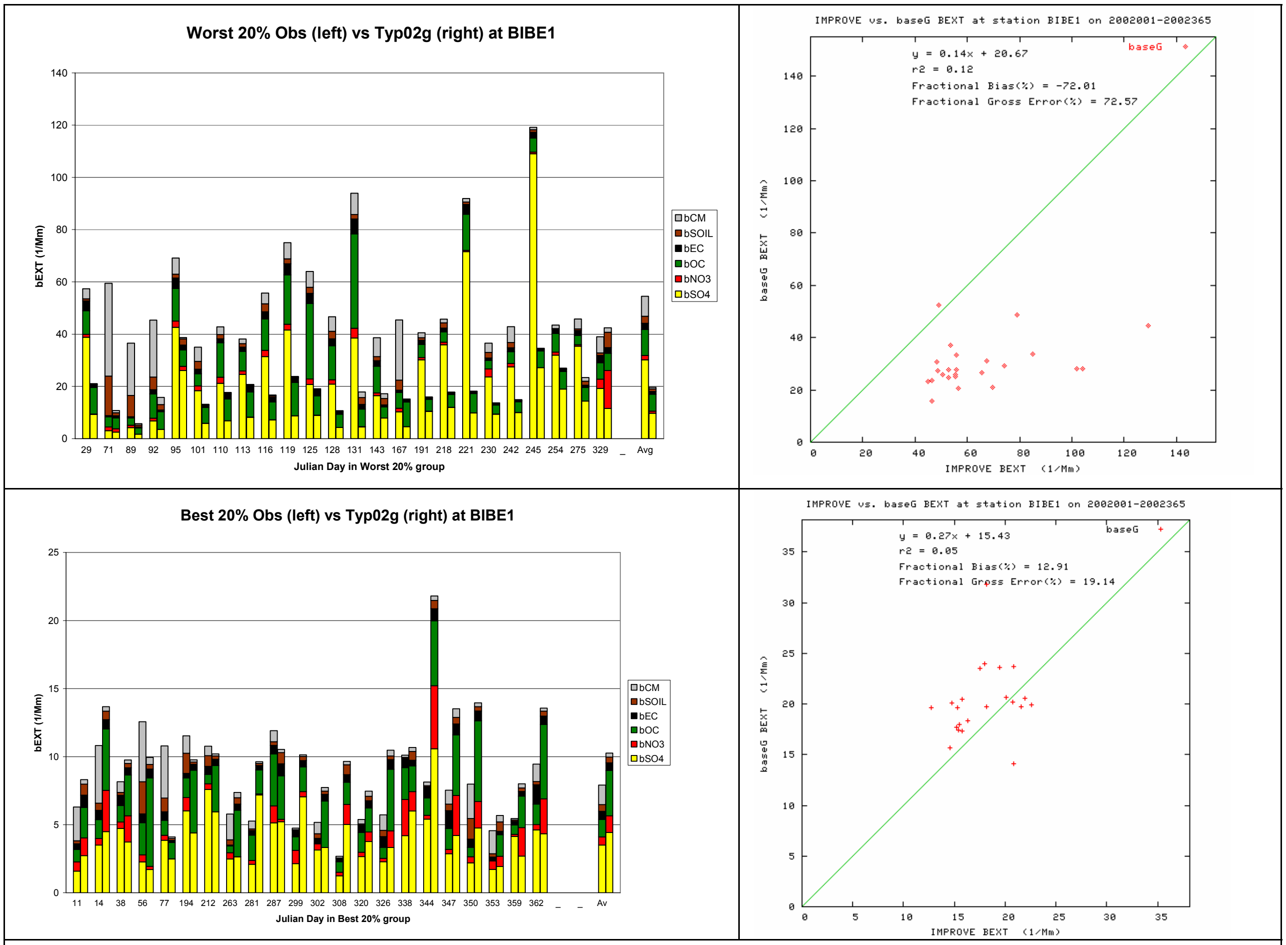

Figure 3-17. Daily extinction model performance at Big Bend (BIBE), Texas for the worst (top) and best (bottom) 20 percent days during 2002.

3.7.10 Guadalupe Mountains (GUMO) Texas

Most of the worst 20 percent days at GUMO are high dust days with high Soil and CM that is not captured by the model (Figure 3-18). Extinction due to Soil and CM on the worst 20 percent days is underestimated by -105% and -191%, respectively (Figure C-57). Better performance is seen on the best 20 percent days with bias and error for total extinction of 8% and 21%, but the model still understates Soil and CM.

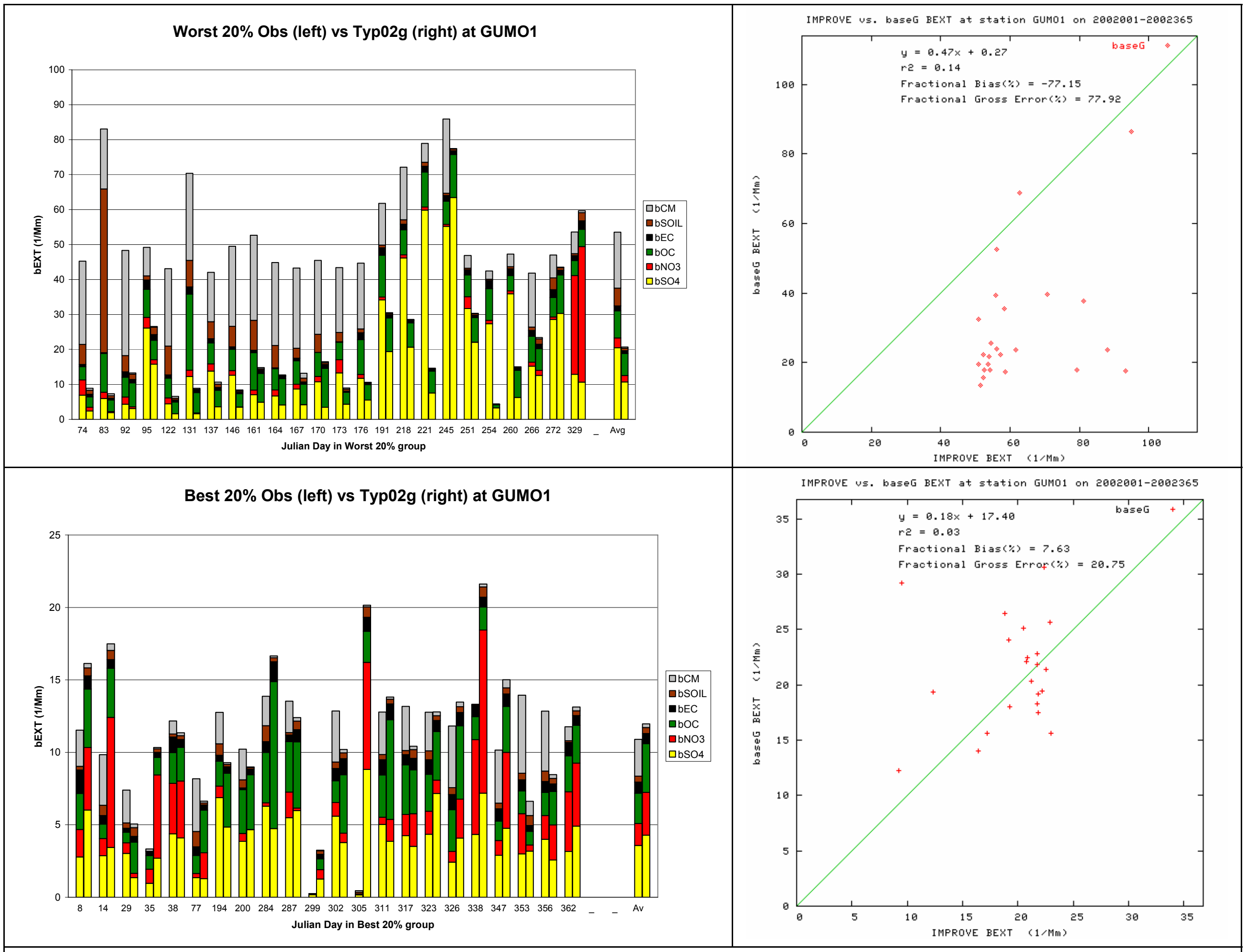

Figure 3-18. Daily extinction model performance at Guadalupe Mountains (GUMO), Texas for the worst (top) and best (bottom) 20 percent days during 2002.

3.8 Model Performance Evaluation Conclusions

The model performance evaluation reveals that the model is performing best for SO4, OMC and EC. Soil performance is mixed with a winter overestimation bias with lower bias and higher error in the summer. CM performance is poor year round. The operational evaluation reveals that SO4 performance usually achieves the PM model performance goal and always achieves the model performance criteria, although it does have an underestimation bias that is greatest in the summer. NO3 performance is characterized by a winter overestimation bias with an even greater summer underestimation bias. However, the summer underestimation bias occurs when NO3 is very low and when it is not an important component of the observed or predicted PM mass concentrations or component of visibility impairment. Performance for OMC meets the model performance goal year round at the IMPROVE sites, but is characterized by an underestimation bias at the more urban STN sites. EC exhibits very low bias at the STN sites and a summer underestimation bias at the IMPROVE sites, but meets the model performance goal throughout the year. Soil has a winter overestimation bias that is outside of the model performance goal and criteria raising questions whether the model should be used for this species. Finally, CM performance is extremely poor with an underprediction bias that is outside of the performance goal and criteria. We suspect that much of the CM concentrations measured at the IMPROVE sites is due to highly localized emissions from fugitive dust sources that are not included in the emissions inventory and would be difficult to simulate using 36 km regional modeling.

Performance for the worst 20 percent days at the CENRAP Class I areas is generally characterized by an underestimation bias. Performance at the BRET, BIBE and GUMO Class I areas for the worst 20 percent days is particularly suspect and care should be taken in the interpretation of the visibility projections at these three Class I areas.

The CMAQ 2002 36 km model appears to be working well enough to reliably make future-year projections for changes in SO4, NO3, EC and OMC at the rural Class I areas. Performance for Soil and especially CM is suspect enough that care should be taken in interpreting these modeling results. The model evaluation focused on the model's ability to predict the components of light extinction mainly at the Class I areas. Additional analysis would have to be undertaken to examine the model's ability to simulate ozone and fine particulate to address 8-hour ozone and $PM_{2.5}$ attainment issues.

4.0 VISIBILITY PROJECTIONS

This section presents the future-year visibility projections for Class I areas within and near the CENRAP states and their comparison with the 2018 Uniform Rate of Progress (URP) point. As noted in Chapter 1, the Regional Haze Rule (RHR) requires states with Class I areas to develop State Implementation Plans (SIPs) that include reasonable progress goals (RPGs) for improving visibility in each Class I area and emission reduction measures to meet those goals. For the initial SIPs due in December 2007, states are required to adopt RPGs for improving visibility from Baseline Conditions. The 2000-2004 five-year period is used to define Baseline Conditions and the first future progress period is 2018. A state is required to set RPGs for each Class I area in the state for two visibility metrics:

- Provide for an improvement in visibility for the most impaired visibility days (i.e., the worst 20 percent days); and
- Ensure no degradation in visibility for the least impaired visibility days (i.e., the best 20 percent days).

The goal of the RPGs is to provide for a rate of improvement sufficient to be on a course to attain "Natural Conditions" by 2064. States are to define controls to meet RPGs every 10 years, starting in 2018, which defines progress periods ending in 2018, 2028, 2038, 2048, 2058 and finally 2064. States will determine whether they are meeting their goals by comparing visibility conditions from one five-year period to another (e.g., 2000-2004 to 2013-2017). As stated in 40 CFR 51.308 (d) (1), baseline visibility conditions, reasonable progress goals, and changes in visibility must be expressed in terms of deciview (dv) units. The haze index (HI) metric of visibility impairment, in deciviews, is derived from light extinction (b_{ext}) as follows:

$$HI = 10 \ln (b_{ext}/10),$$

Where light extinction (b_{ext}) is expressed in terms of inverse megameters ($Mm^{-1} = 10^{-6}\ m^{-1}$). Light extinction ($b_{ext}$) is calculated using the observed fine particulate concentrations from the IMPROVE monitors using either the original or the new IMPROVE aerosol extinction equation. Both equations are discussed below.

4.1 Guidance for Visibility Projections

EPA has published several guidance documents that relate to how modeling results should be used to project future-year visibility and how states should define RPGs:

> "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$ and Regional Haze" (EPA, 2007a).
>
> "Guidance for Tracking Progress Under the Regional Haze Rule" (EPA, 2003a).
>
> "Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule" (EPA, 2003b).

“Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program” (EPA, 2007b).

The first EPA modeling guidance document listed above (EPA, 2007) discusses the use of modeling results to project future-year visibility. The second EPA guidance document (EPA, 2003a) focuses on monitored visibility, how to define the visibility Baseline Conditions and how to track visibility goals. The third EPA guidance document discusses procedures for defining Natural Conditions for a Class I area. Natural Conditions are the visibility goal for 2064. Although states may propose alternative approaches for defining Natural Conditions, in this section we use the default Natural Conditions at Class I areas (EPA, 2003b; Pitchford, 2006). The final EPA guidance document discusses how states should define their RPGs and their relationship to the 2018 URP point.

The EPA documents discussed above are followed for the visibility projections presented in this section with one notable exception. Some of the EPA documents are based on the original IMPROVE equation (e.g., EPA, 2003a, b). The CENRAP visibility projections are based on the new IMPROVE equation, although projections based on the original IMPROVE equation are also presented as an alternative approach in Chapter 5. EPA guidance allows for using either the original or the new IMPROVE equation (EPA, 2007a; Timin, 2007). CENRAP, along with the other RPOs, have elected to use the new IMPROVE equation for their visibility projections.

4.2 Calculation of Visibility and 2018 URP Point from IMPROVE Measurements

EPA guidance recommends using the model in a relative sense to project future-year visibility conditions (EPA, 2007a). This projection is made using Relative Response Factors (RRFs) that are defined as the ratio of the future-year modeling results to the base-year modeling results. The RRFs are applied to the baseline visibility conditions to project future-year visibility. The major features of EPA’s recommended visibility projection approach are as follows (EPA, 2003a,b; 2007a):

- Monitored data are used to define current visibility Baseline Conditions using IMPROVE monitoring data from the 2000-2004 five-year base period.

- Monitored concentrations of PM_{10} are divided into six major components, the first five of which are assumed to be $PM_{2.5}$ and the sixth is coarse mass (CM or $PM_{2.5-10}$).
    - SO4 (sulfate) that is assumed to be ammonium sulfate $[(NH_4)_2SO_4]$;
    - NO3 (particulate nitrate) that is assumed to be ammonium nitrate $[NH_4NO_3]$;
    - OC (organic carbon) that is assumed to be total organic mass carbon (OMC)
    - EC (elemental carbon);
    - IP (other fine inorganic particulate or Soil); and
    - CM (coarse mass).

- Models are used in a relative sense to develop RRFs between baseline and future predicted concentrations of each component.

- PM component-specific RRFs are multiplied by observed Baseline monitored values to estimate future-year PM component concentrations.
- Estimates of future-year component concentrations are consolidated to provide an estimate of future-year air quality and visibility using either the original or new IMPROVE equation.
- Future-year model projected visibility is compared with the 2018 point on the URP glidepath to assist in evaluating the visibility improvements.
- It is assumed that all measured sulfate is in the form of ammonium sulfate [$(NH_4)_2SO_4$] and all particulate nitrate is in the form of ammonium nitrate [NH_4NO_3].

In order to facilitate tracking visibility progress, three important visibility concepts are required for each Class I area:

> Baseline Conditions: Baseline Conditions represent visibility for the 20 percent best (B20%) and 20 percent worst (W20%) visibility days for the initial five-year baseline period of the regional haze program. Baseline Conditions are calculated using IMPROVE monitor data collected during the 2000-2004 five-year period and are the starting point in 2004 for the URP glidepath and 2018 visibility projections.
>
> Natural Conditions: Estimates of natural visibility conditions for the best 20 percent and worst 20 percent days at a Class I area (i.e., visibility conditions that would be experienced in the absence of human-caused impairment). EPA has defined a set of default Natural Conditions for the original IMPROVE equation (EPA, 2003b) that has been updated to the new IMPROVE equation by the Natural Haze Levels II Committee (Pitchford, 2006) that we have used in this Chapter.
>
> 2018 URP Point: The 2018 Uniform Rate of Progress (URP) point is defined by defining a linear glidepath in deciviews starting with the 2000-2004 Baseline Conditions in 2004 and ending at Natural Conditions in 2064. Where the linear glidepath passes through 2018 is the 2018 URP point in deciviews.

4.2.1 Calculation of Visibility from IMPROVE PM Measurements

Baseline Conditions for Class I areas are calculated using the procedures in EPA's guidance document (EPA, 2003a) and fine and coarse particulate matter concentrations measured at IMPROVE monitors (Malm et al, 2000; Debell et al., 2006). Currently, each Class I area in the CENRAP domain has an associated IMPROVE monitor. The IMPROVE monitors do not directly measure visibility, but instead measure speciated fine particulate ($PM_{2.5}$) and total $PM_{2.5}$ and PM_{10} mass concentrations from which visibility is obtained through the IMPROVE equation.

Visibility conditions are estimated starting with the IMPROVE 24-hour average mass measurements for six PM species:

- Sulfate [$(NH_4)_2SO_4$];
- Particulate Nitrate [$(NH_4NO_3$];
- Organic Matter Carbon or Organic Mass by Carbon [OMC];
- Elemental Carbon [EC] or Light Absorbing Carbon [LAC];
- Other fine particulate [Soil]; and
- Coarse Matter or Coarse Mass [CM].

The IMPROVE monitors do not directly measure some of these species so assumptions are made as to how the IMPROVE measurements can be adjusted and combined to obtain these six components of light extinction. For example, in the IMPROVE equation sulfate and particulate nitrate are assumed to be completely neutralized by ammonium. In addition, only the fine mode ($PM_{2.5}$) of PM is speciated by the IMPROVE monitor to obtain sulfate and nitrate measurements (that is, any coarse mode sulfate and nitrate in the real atmosphere may be present in the CM IMPROVE measurement). Concentrations for the above six components of light extinction in the IMPROVE equation are obtained from the IMPROVE measured species using the mappings shown in Table 4-1:

Table 4-1. Definition of IMPROVE PM Components from Measured IMPROVE Species.

IMPROVE Component	IMPROVE Measured Species
Sulfate	1.375 x (3 x S)
Nitrate	1.29 x NO_3^-
OMC	1.4*OC (original IMPROVE) and 1.8*OC (new IMPROVE)
LAC	EC
Soil	2.2*AL + 2.49*SI + 1.63*CA + 2.42*FE + 1.94*TI
CM	MT – MF

Where:

- S is elemental sulfur as determined from proton induced x-ray emissions (PIXE) analysis of the IMPROVE Module A[1]. To estimate the mass of the sulfate ion ($SO_4^=$), S is multiplied by 3 to account the presence of oxygen. If S is missing then the sulfate (SO_4) measured by ion chromatography analysis of the Module B is used to replace (3 x S). For the IMPROVE aerosol extinction calculation, Sulfate is assumed to be completely neutralized by ammonium (1.375 x SO_4).
- NO_3^- is the particulate nitrate measured by ion chromatography analysis of the Module B. For the IMPROVE aerosol extinction calculation, it is assumed to be completely neutralized by ammonium (1.29 x NO_3^-).
- The IMPROVE Organic Carbon (OC) measurements are multiplied by 1.4 to obtain Organic Mass Carbon (OMC) using the original IMPROVE equation and multiplied by 1.8 for the new IMPROVE equation. This adjustment of the measured OC accounts for mass due to other elements in the OMC besides Carbon.
- Elemental Carbon (EC) is also referred to as Light Absorbing Carbon (LAC).

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[1] The IMPROVE sampler consists of four independent modules (A, B, C and D). Each module incorporates a separate inlet, filter pack and pump assembly and are controlled by a common timing mechanism. Module A measures fine PM mass and elements. Module B measures sulfate and nitrate ions. Module C measures EC and OC. Module D measures PM_{10} mass. (see http://vista.cira.colostate.edu/improve/ for more details).

- Soil is determined as a sum of the masses of those elements (measured by PIXE) predominantly associated with soil (Al, Si, Ca, Fe, K and Ti), adjusted to account for oxygen associated with the common oxide forms. Since K and FE are products of the combustion of vegetation, they are both represented in the formula by 0.6 x Fe and K is not shown explicitly.
- MT and MF are total PM_{10} and $PM_{2.5}$ mass, respectively.

4.2.1.1 Original and New IMPROVE Equations

Associated with each PM species is an extinction efficiency that converts concentrations (in $\mu g/m^3$) to light extinction (in inverse megameters, Mm^{-1}). Sulfate and nitrate are hygroscopic which means that they can absorb water from the atmosphere which changes their extinction efficiency. This is accounted for through relative humidity adjustment factors [f(RH)] that increase the particle's extinction efficiency with increasing RH to account for the particles taking on water Note that some OMC may also have hygroscopic properties, but the IMPROVE equations assume OMC is non-hygroscopic.

There are currently two IMPROVE equations that are used to convert the measured PM concentrations to light extinction, the original (or old) and the new IMPROVE equations.

4.2.1.1.1 Original IMPROVE Equation

The original IMPROVE equation that converts PM species concentrations to light extinction is given as follows:

$$
\begin{aligned}
b_{Sulfate} &= 3 \times f(RH) \times [Sulfate] \\
b_{Nitrate} &= 3 \times f(RH) \times [Nitrate] \\
b_{EC} &= 10 \times [EC] \\
b_{OMC} &= 4 \times [OMC] \\
b_{Soil} &= 1 \times [Soil] \\
b_{CM} &= 0.6 \times [CM]
\end{aligned}
$$

Monthly average f(RH) factors are used as recommended in EPA's guidance (EPA, 2003a). These values are available in the final EPA guidance document (EPA, 2003a) and at: ftp://ftp.saic.com/raleigh/RegionalHaze_2002FRHcurve/fRH_analysis/.

The total light extinction (b_{ext}) is assumed to be the sum of the light extinction due to the six PM species listed above plus Rayleigh (blue sky) background (b_{Ray}) that is assumed to be 10 Mm^{-1}.

$$b_{ext} = b_{Ray} + b_{Sulfate} + b_{Nitrate} + b_{EC} + b_{OMC} + b_{Soil} + b_{CM}$$

The total light extinction (b_{ext}) in Mm^{-1} is related to visual range (VR) in km using the following relationship:

$$VR = 3912 / b_{ext},$$

for b_{ext} in Mm^{-1}.

The Regional Haze Rule requires that visibility be expressed in terms of a haze index (HI) in units of deciviews (dv), which is calculated as follows:

$$HI = 10 \ln(b_{ext}/10)$$

4.2.1.1.2 New IMPROVE Equation

The new IMPROVE equation is nonlinear in SO4, NO3 and OMC concentrations accounting for the different light scattering efficiency characteristics as a function of concentrations for these three species. It is expressed as follows:

$$\begin{aligned}
b_{Sulfate} &= 2.2 \times f_S(RH) \times [\text{Small Sulfate}] + 4.8\ f_S(RH) \times [\text{Large Sulfate}] \\
b_{Nitrate} &= 2.4 \times f_S(RH) \times [\text{Small Nitrate}] + 5.1\ f_S(RH) \times [\text{Large Nitrate}] \\
b_{EC} &= 10 \times [\text{Elemental Carbon}] \\
b_{OMC} &= 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\
b_{Soil} &= 1 \times [\text{Fine Soil}] \\
b_{CM} &= 0.6 \times [\text{Coarse Mass}] \\
b_{NaCl} &= 1.7 \times f_{SS}(RH) \times [\text{Sea Salt}] \\
b_{NO2} &= 0.33 \times [NO_2\ (\text{ppb})]
\end{aligned}$$

The total Sulfate, Nitrate and OMC are each split into two fractions, representing small and large size distributions of those components. As noted in Table 4-1, the OMC is 1.8 times the IMPROVE OC measurement in the new IMPROVE algorithm, compared to 1.4 times the IMPROVE OC measurement in the original IMPROVE equation. New terms have been added for Sea Salt (important for coastal areas and possibly other areas)and for light absorption by NO2 (only used where NO2 observations are available). As none of the CENRAP Class I area IMPROVE sites measure NO2 concentrations, then this component of the new IMPROVE equations was not used. Site-specific Rayleigh scattering for each IMPROVE monitoring site is used in the new IMPROVE equation, as compared to a constant 10 Mm^{-1} value assumed in the original IMPROVE equation.

The apportionment of the Small and Large components of Sulfate, Nitrate and Organic Mass is done as follows:

$$[\text{Large Sulfate}] = [\text{Total Sulfate}] / 20 \times [\text{Total Sulfate}], \text{ for } [\text{Total Sulfate}] < 20\ \mu g/m^3$$

$$[\text{Large Sulfate }] = [\text{Total Sulfate}], \text{ for } [\text{Total Sulfate}] \geq 20\ \mu g/m^3$$

$$[\text{Small Sulfate}] = [\text{Total Sulfate}] - [\text{Large Sulfate}]$$

The same equations are used to apportion Total Nitrate and Total OMC among their Large and Small components.

The total extinction (b_{ext}) in the new IMPROVE equations is the sum of all the extinction components associated with each PM species. The new IMPROVE equation adds Sea Salt and

NO_2 as noted above. In addition, site-specific Rayleigh background is used with the new IMPROVE equation:

$$b_{ext} = b_{Ray} + b_{Sulfate} + b_{Nitrate} + b_{EC} + b_{OMC} + b_{Soil} + b_{CM} + b_{NaCl} + b_{NO2}$$

The Haze Index (HI) and Visual Range (VR) are calculated from the total extinction from the new IMPROVE equation using the same formulas as given above for the original IMPROVE equation.

4.2.1.1.3 Justification for Using the New IMPROVE Equation

The new IMPROVE equation was developed using the latest scientific information on PM species extinction properties combined with fitting reconstructed light extinction based on IMPROVE measured PM and NO2 concentrations with actual co-located measured light extinction (e.g., nephelometer measurements). Figure 4-1 displays example comparisons of 24-hour light extinction using the original and new IMPROVE equations compared against 24-hour nephelometer measurements of light extinction at the Great Smoky Mountains Class I area IMPROVE monitor. The original IMPROVE equation has a bias toward understating light extinction at the high end and overstating it at the low end, whereas the new IMPROVE equation does a better job in estimating light extinction from measured PM at all extinction levels. Because the new IMPROVE equation is based on more recent science and fits the observed light extinction values better, the CENRAP states have elected to perform their primary visibility projections using the new IMPROVE equation. Results using the original IMPROVE equation are presented in Section 5 as an alternative approach.

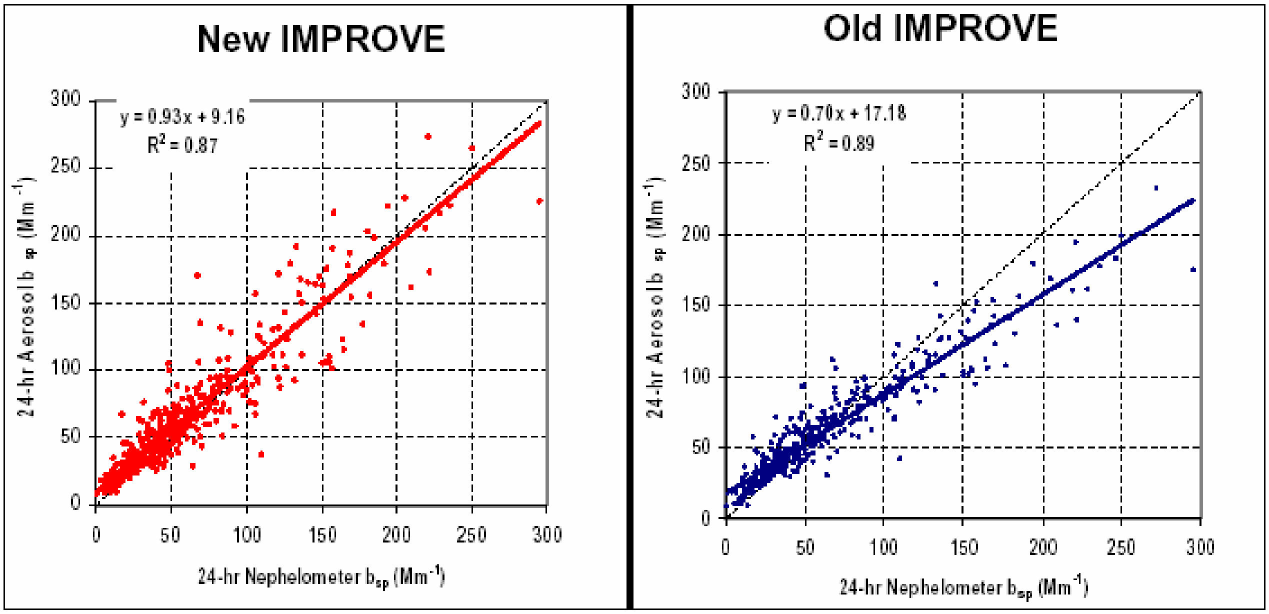


Figure 4-1. Comparisons of observed light extinction with reconstructed light extinction using the new (left) and original (right) IMPROVE equations at the Great Smoky Mountains National Park.

4.2.2 Calculation of the Baseline Conditions

The visibility Baseline Conditions for the worst 20 percent and best 20 percent days is calculated from the IMPROVE observations from the 2000-2004 period for each Class I area following EPA's guidance (EPA, 2003a). The basic procedures for calculating the Baseline Conditions are as follows:

1. Determine whether the observed IMPROVE data for each site and year satisfies EPA's minimal data capture criteria (EPA, 2003a). If there are less than three years with valid data capture for the 2000-2004 Baseline then the Baseline Conditions can not be calculated and data filling is needed.
2. For each year in the 2000-2004 period with sufficient valid data, rank the visibility in terms of extinction or deciview using either the original or new IMPROVE equation and monthly average f(RH) factors (EPA, 2003a).
3. For the worst 20 percent days, extract the 20% most impaired visibility days for each year (similarly for best 20 percent days extract 20% cleanest days). With a complete yearly data capture of IMPROVE 1:3 day sampling frequency this would result in 24 worst 20 percent and 24 best 20 percent days in a year.
4. For each worst 20 percent (or best 20 percent) day in each year, calculate 24-hour average visibility extinction using the IMPROVE measurements and either the original and new IMPROVE equation, convert the daily extinction to daily deciview and then average across each year to get yearly average deciview extinction for the worst 20 percent (or best 20 percent) days for each valid year from the 2000-2004 period.
5. Average the annual average deciview worst 20 percent (or best 20 percent) days deciview across each valid year in the 2000-2004 period (minimum of 3 valid years required) to get the worst 20 percent (or best 20 percent) Baseline Conditions.

4.2.3 Data Filling for Sites with Insufficient Valid Data to Calculate Baseline Conditions

Three CENRAP Class I areas did not contain sufficient IMPROVE observations during the five-year 2000-2004 Baseline to have three valid years of data from which Baseline Conditions could be constructed: Breton Island (BRET), Louisiana; Boundary Waters (BOWA), Minnesota and Mingo (MING), Missouri. For these three Class I areas, data filling was used to obtain sufficient data so that at least three-years of valid data were available from which Baseline Conditions could be calculated. These data filled IMPROVE databases were prepared and made available on the VIEWS website. More information on the data filling procedures can be found at the VIEWS website: (http://vista.cira.colostate.edu/views/).

4.2.4 Natural Conditions

EPA has published default Natural Conditions for Annual Average and the worst 20 percent and best 20 percent days based on the original IMPROVE equation (EPA, 2003b). These default Natural Conditions have been updated to the new IMPROVE equation by the Natural Haze Levels II Committee (Pitchford, 2006). These default Natural Conditions are used as the anchor point for the glidepaths in 2064 and are provided in Appendix D for the CENRAP Class I areas.

4.2.5 2018 URP Point

The 2018 point on the Uniform Rate of Progress (URP) glidepath is constructed by generating a linear glidepath in deciviews from the Baseline Conditions in 2004 to Natural Conditions in 2064. Where the linear glidepath crosses 2018 is the 2018 point on the URP glidepath or the 2018 URP point. Figure 4-2 displays an example linear glidepath for the Caney Creek Class I area in Arkansas. There are three years of sufficient valid IMPROVE data during the 2000-2004 Baseline (2002, 2003 and 2004) with values of 27.21, 26.52 and 25.34 dv resulting in worst 20 percent Baseline Conditions of 26.36 dv that is placed as the starting point in 2004 for the glidepath. The ending point for the glidepath is 11.58 dv which is the default Natural Conditions for the worst 20 percent days (EPA, 2003b; Pitchford, 2006). The linear glidepath crosses 2018 at 22.91 dv which becomes the 2018 URP point.

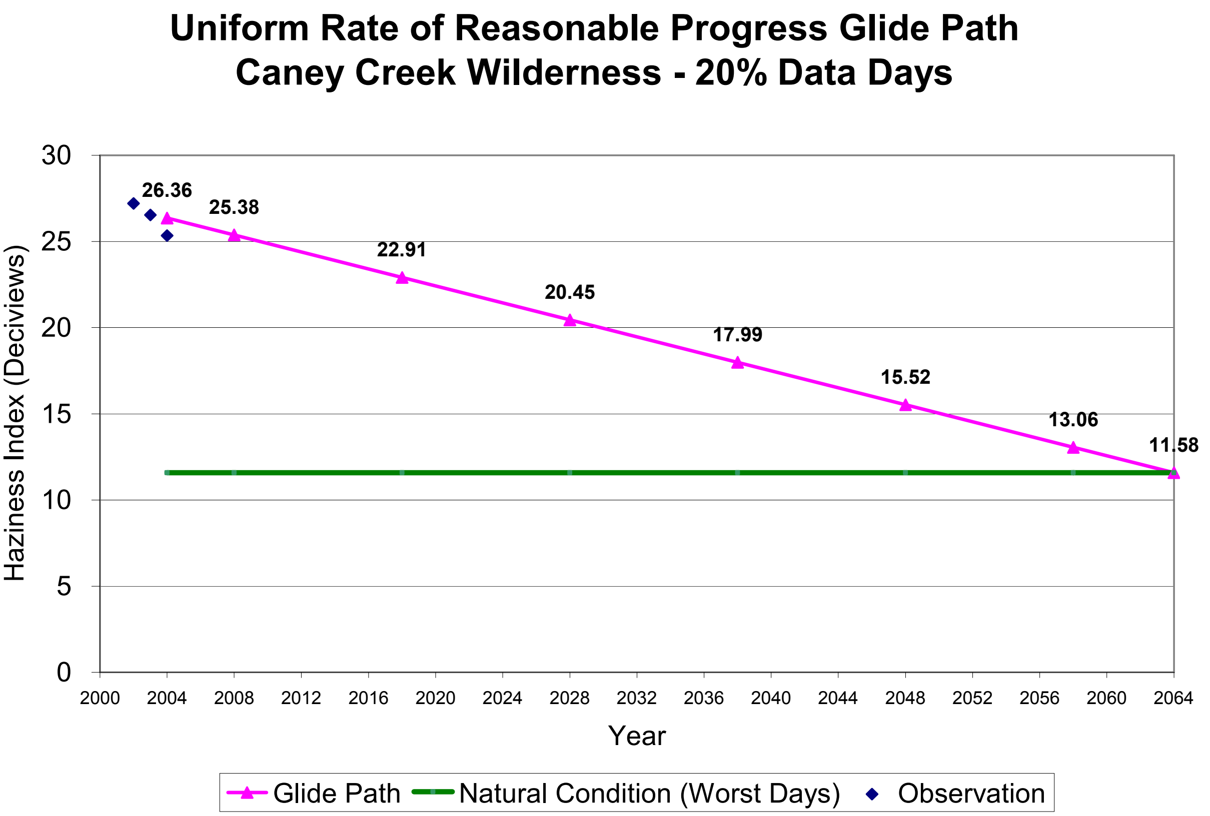


Figure 4-2. Linear Glidepath for Caney Creek (CACR), Arkansas that linearly connects the 26.36 dv Baseline Conditions in 2004 with the 11.58 dv Natural Conditions in 2064 resulting in a 22.91 dv 2018 URP Point.

4.3 EPA Default Approach to Visibility Projections

For CENRAP's model application for a single year (2002), EPA's regional haze modeling guidance recommends developing Class I area-specific and PM species-specific RRFs based on the average concentrations for the worst 20 percent days from 2002 (EPA, 2007). Thus, this is the methodology used to project 2018 visibility estimates in this section. For example, if $SO4(2002)_i$ and $SO4(2018)_i$ are the model estimated sulfate concentrations for the 2002 worst 20 percent days (i=1…N) at a given Class I area for the 2002 and 2018 emission scenarios then the RRF for sulfate and this Class I area is given by:

$$RRF(SO4)_i \quad = \quad \sum SO4(2018)_i \,/\, \sum SO4(2002)_i$$

4.3.1 Mapping of Modeling Results to the IMPROVE Measurements

As noted above, to project future-year visibility at Class I areas the modeling results are used in a relative sense to scale current observed visibility for the worst 20 percent and best 20 percent visibility days using RRFs that are the ratio of modeling results for the future-year to current-year. This scaling is done separately for each of the six components of light extinction in the IMPROVE equations. The CMAQ modeled species do not necessarily exactly match up with the IMPROVE PM species, thus assumptions must be made to map the modeled species to the IMPROVE PM species for the purpose of projecting visibility improvements. For example, CMAQ explicitly simulates ammonium and sulfate may or may not be fully neutralized in the model by ammonium, whereas the IMPROVE equations assume sulfate is fully neutralized by ammonium. For the CMAQ Version 4.5 (September 15, 2005 release) model, the mapping of modeled species to IMPROVE equation PM species is listed in Table 4-2.

Table 4-2. Mapping of CMAQ V4.5 modeled species concentrations to IMPROVE PM components.

IMPROVE Component	CMAQ V4.3 Species
Sulfate	1.375 x (ASO4J + ASO4I)
Nitrate	1.29 x (ANO3J + ANO3I)
LAC	AECJ + AECI
OMC	AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI
Soil A25J	+ A25I
CM	ACORS + ASEAS + ASOIL

For the CENRAP visibility projections using the 2002 Typical and 2018 base case Base G emission scenarios, the secondary organic aerosol (SOA) module in CMAQ V4.5 was modified (SOAmods) to include additional processes related to the generation of SOA from biogenic emissions. In particular, three new species have been added that represent SOA products from biogenic emission compounds that is not included in the standard version of CMAQ V4.5 (Morris et al., 2006c):

- ASOC1 – SOA from biogenic sources (e.g., terpenes and isoprene) that has become polymerized so is no longer volatile.

- ASOC2 – SOA from biogenic sesquiterpene and higher reactivity and higher yield monoterpene emissions.

- ASOC3 – SOA from biogenic isoprene emissions.

Thus, the species mapping for Organic Mass Carbon (OMC) and the CMAQ V4.5 SOAmods version of the model used in CENRAP 2018 visibility projections is as given in Table 4-2 only with the addition of the three new biogenic SOA species to OMC as follows:

OMC = AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI + ASOC1 + ASOC2 + ASOC3

4.3.2 Using Modeling Results to Project Changes in Visibility

Modeling results are used in a relative fashion to project future-year visibility using relative response factors (RRFs). RRFs are expressed as the ratio of the modeling results for the future-year to the results of the base year (2018/2002) and are Class I area and PM species specific. RRFs are applied to the Baseline Condition observed PM species to project future-year PM levels from which visibility can be assessed using the IMPROVE equations listed above. The following six steps are used to project future-year visibility for the worst 20 percent and best 20 percent visibility days (discussion is for worst 20 percent days but also applies to best 20 percent days):

1. For each Class I area and each monitored day, daily visibility is ranked using IMPROVE data and IMPROVE equation (either original or new IMPROVE equation) for each year from the five-year baseline period (2000-2004) to identify the worst 20 percent visibility days for each year from the five-year baseline (see Baseline Conditions discussion above).

2. Use an air quality model to simulate a base year period (ideally the five-year Baseline period of 2000-2004, but for CENRAP just the 2002 annual period was simulated) and a future-year (e.g., 2018) and use the resulting information to develop Class I area-specific RRFs for each of the six components of light extinction in the IMPROVE equation (SO4, NO3, EC, OMC, Soil and CM).

3. Multiply the RRF times the measured 24-hour PM concentration data for each day from the worst 20 percent days in each year from the five-year Baseline period to obtain projected future-year 24-hour PM concentrations for the worst 20 percent days and the five-year Baseline.

4. Compute the future-year daily extinction using the IMPROVE equation and the projected PM concentrations for each of the worst 20 percent days in the five-year baseline from Step 3.

5. For each of the worst 20 percent days within each year of the five-year baseline, convert the future-year daily extinction to deciview and average the daily deciview values within each of the five years separately to obtain five-years (or as many years with valid data in the 2000-2004 Baseline) of average deciview visibility for the worst 20 percent days.

6. Average the five-years of average deciview visibility to obtain the future-year visibility Haze Index estimate that is the future-year estimated visibility.

In calculating the RRFs, EPA draft guidance recommends selecting estimated PM species concentrations "near" the monitor by taking a spatial average of PM concentrations across a grid cell resolution dependent NX by NY array of cells centered on the grid containing the monitor. The NX x NY array of cells is grid resolution specific with EPA recommending that NX=NY=1 for 36 km grids, NX=NY=3 for 12 km grids and NX=NY=7 for 4 km grids (EPA, 2007). For the CENRAP 2002 36 km modeling, just the model estimates for the grid cell containing the monitor was used (i.e., NX=NY=1).

4.4 EPA Default 2018 Visibility at CENRAP and Nearby Class I areas and Comparisons to 2018 URP Goals

Using the EPA default visibility projection procedure described in Section 4.3 and the CENRAP 2002 Typical Base G and 2018 Base Case Base G CMAQ modeling results, 2018 visibility projections were made for CENRAP and nearby Class I areas. Appendix D details the 2018 Base G visibility projections for each Class I area in the CENRAP region using the new IMPROVE equation. Results for the Caney Creek (CACR), Arkansas Class I area are discussed in Section 4.4.1 below Displays for other CENRAP Class I areas are provided in Appendix D and summarized in Section 4.4.2

4.4.1 Example 2018 Base G Visibility Projections for Caney Creek, Arkansas

The 2018 visibility projections for the Caney Creek (CACR), Arkansas Class I area given in Figure D-1 in Appendix D are reproduced in Figure 4-3 and described below.

4.4.1.1 EPA Default 2018 Visibility Projections

The 2018 Base G visibility projection using the EPA default method (EPA, 2007a) and comparison with the 2018 URP point for the worst 20 percent days and the CACR Class I area is shown in Figure 4-3a. The 2000-2004 Baseline Conditions for CACR is 26.36 dv and the 2018 URP point is 22.91 dv so that a 3.45 dv reduction in visibility for the worst 20 percent days is needed to meet the 2018 URP point. The 2018 Base G CMAQ projected visibility is 22.48 dv so that the modeling predicts more visibility improvements (3.88 dv reduction) than required to meet the 2018 URP point (3.45 dv reduction). When looking at visibility projections across several Class I areas, it has been useful to present the 2018 visibility projections as a percentage of meeting the 2018 URP point; where 100% is meeting the point, greater than 100% surpassing the point (i.e., below the glidepath) and less than 100% means that less visibility improvement is achieved than needed to meet the 2018 URP point. For 2018 Base G CMAQ modeling at CACR, we achieve 112% of the visibility reduction needed to meet the 2018 URP point. Note that meeting the 2018 URP point is not a requirement of the RHR SIPs, rather it just serves as a benchmark to compare progress toward Natural Conditions in 2064 and is designed to help states in selecting their 2018 RPGs. As clearly stated in EPA guidance "The glidepath is not a presumptive target, and States may establish a RPG that provides for greater, lesser, or equivalent improvement as that described by the glidepath" (EPA, 2007b).

The 2018 Base G CMAQ visibility projections for the best 20 percent days and CACR is shown in Figure 4-3b. Recall the RHR goal for this visibility metric is no worsening of the visibility for the best 20 percent days. The Baseline Conditions for the best 20 percent days at CACR is 11.24 dv. The 2018 Base G projected visibility for the best 20 percent days is 10.35 dv, which represents a 0.89 dv visibility improvement for the best 20 percent days at CACR and demonstrating no worsening in visibility for the best 20 percent days.

Figure 4-3c displays "StackedBar Chart" plots of observed and model estimated extinction for each of the worst 20 percent days in 2002 and the 2002 Typical Base G CMAQ simulation and the average across the worst 20 percent days. This figure allows a comparison of how well the model is reproducing the observed extinction at CACR for the worst 20 percent days in 2002 and the breakdown of the PM components that are contributing to visibility impairment (more details on model performance were presented in Chapter 3). The 2002 worst 20 percent days at CACR are dominated by SO4 days (yellow), although during the winter there are also three days dominated by NO3 (Julian Days 80, 320 and 341). For most of the worst 20 percent days at CACR, the model reproduces the observed extinction reasonably well, although it does tend to understate SO4 on a few days and overstate NO3 on the four winter days. The observed average extinction across the 2002 worst 20 percent days at CACR is 150 Mm^{-1}, compared to a modeled value that is 23% lower (115 Mm^{-1}).

Figure 4-3d displays "Boxplots" of differences in modeled extinction for the 2002 worst 20 percent days between the 2018 Base G and 2002 Typical Base G CMAQ simulations. On most days SO4 is the largest component of the extinction that is estimated to be reduced at CACR on the worst 20 percent days. The exception to this is for the winter NO3 days where NO3 is the largest component of extinction that is reduced. The modeling results are not used directly in the visibility projections, rather they are used to develop the PM-species specific RRFs. That is, an important attribute in Figures 4-3c and 4-3d is the relative changes in the modeled PM species averaged across the worst 20 percent days that are represented by the last bar in each figure and provide insight into the RRFs used in the visibility projections. These results are summarized in Table 4-3 below. Table 4-3 compares the average extinction across the 2002 worst 20 percent days at CACR from the measured IMPROVE data, the modeled values and the modeled change in extinction between the 2018 and 2002 emissions scenarios. Although the results in Table 4-3 are not RRFs (RRFs are based on ratios of concentrations not extinction) they do show how the RRFs may magnify or deflate the importance of a modeled PM species. For example, the model estimates that approximately 23% (26.66 Mm^{-1}) of the visibility extinction average across the worst 20 percent days is due to NO3, whereas it is only 7% in the observed values (10.22 Mm^{-1}). So the modeled ~40% reduction in NO3 between the 2018 and 2002 scenarios is applied to the smaller observed NO3 value to obtain the 2018 projected NO3 value making NO3 a smaller portion of the 2018 projected visibility than the 2018 modeled visibility. On the other hand, the modeled SO4 extinction is less than observed so that its importance in the 2018 projections is much greater than in the modeled 2018 SO4 values.

Table 4-3. Observed and Modeled Extinction by Species Averaged Across the Worst 20 Percent Days in 2002 at CACR.

	2002 Average Observed W20% (Mm^{-1})	**2002 Average Modeled W20% (Mm^{-1})**	**2018-2002 Reduction (Mm^{-1})**	**2018-2002 Reduction (%)**
bSO4 109.50		67.90	-24.47	-36%
bNO3 10.22		26.66	-10.90	-41%
bOMC 19.65		16.68	-2.12	-13%
bEC 4.38		2.32	-0.67	-29%
bSOIL 1.43		1.04	+0.21	+20%
bCM 4.30		0.37	-0.01	-3%

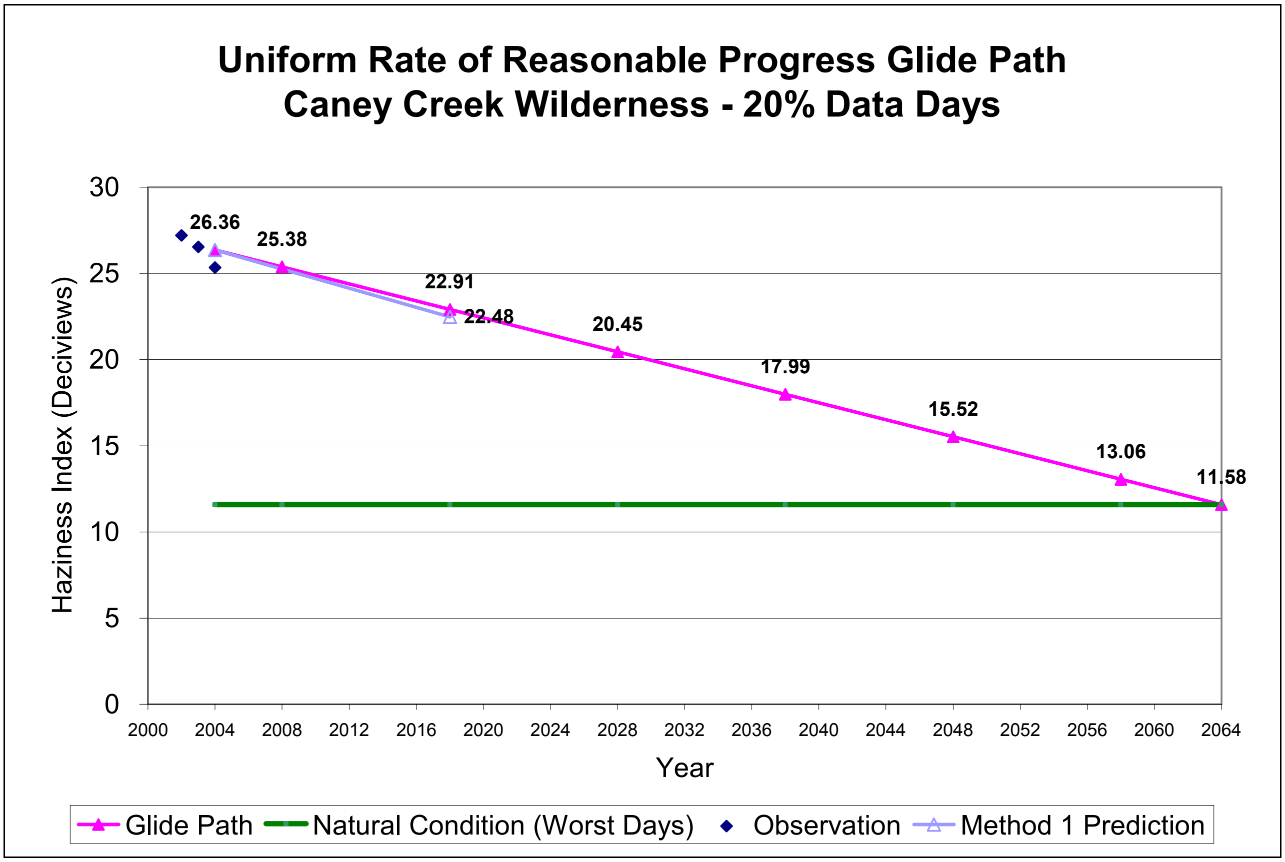


Figure 4-3a. 2018 Visibility Projections and 2018 URP Glidepaths in Deciview for Caney Creek (CACR), Arkansas and Worst 20 Percent (W20%) days Using 2002/2018 Base G CMAQ 36 km Modeling Results.

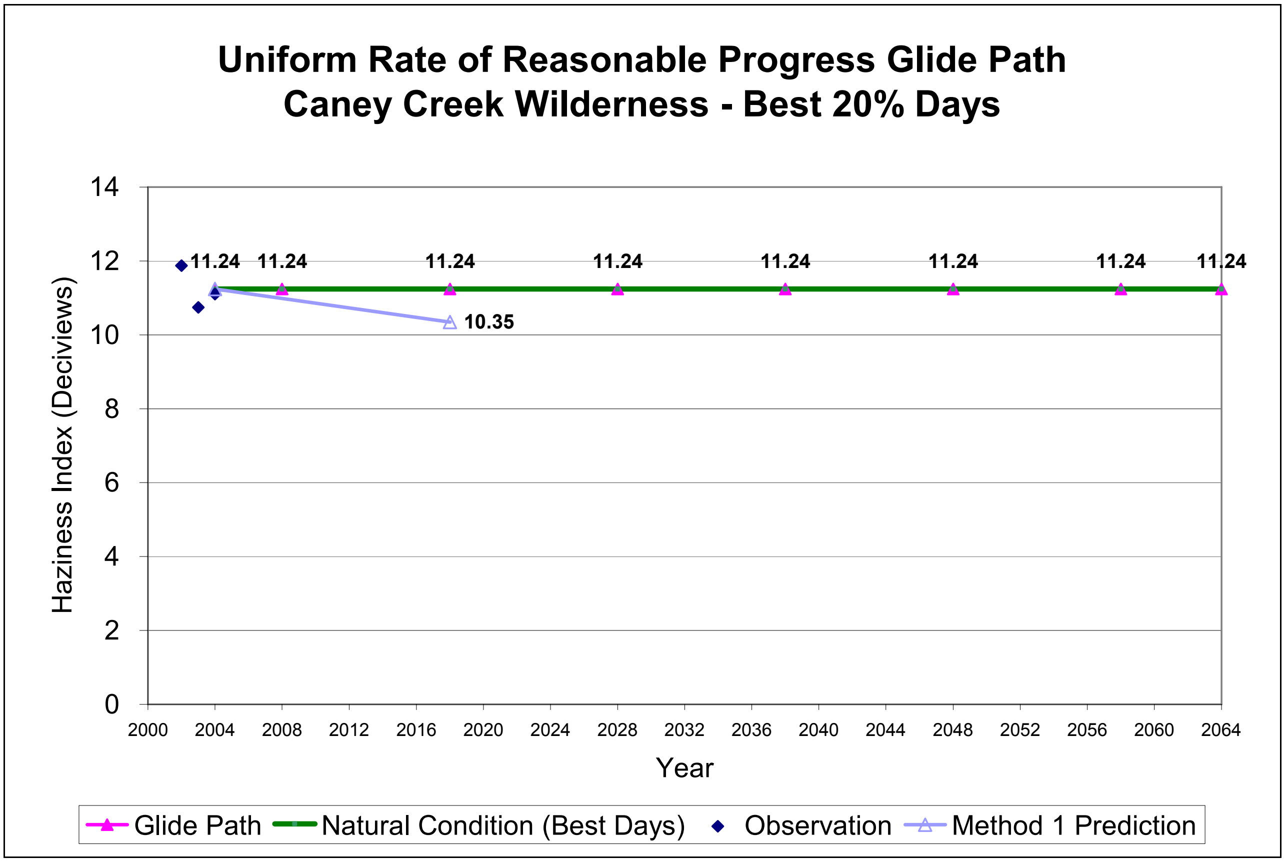


Figure 4-3b. 2018 Visibility Projections and 2018 URP Glidepaths in Deciview for CACR, Arkansas and Best 20 Percent (B20%) days Using 2002/2018 Base G CMAQ 36 m Modeling Results.

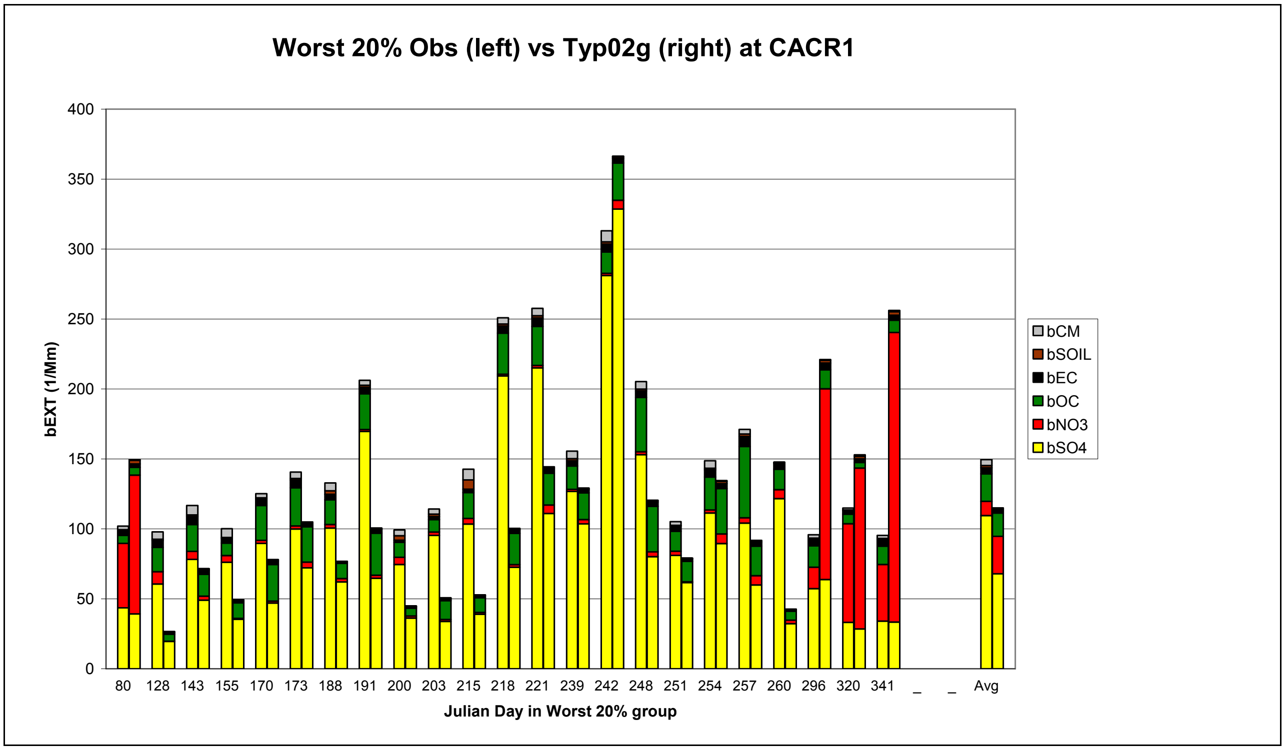


Figure 4-3c. Comparison of Observed (left) and 2002 Base G Modeled (right) Daily Extinction for Caney Creek (CACR), Arkansas and Worst 20 Percent (W20%) days in 2002.

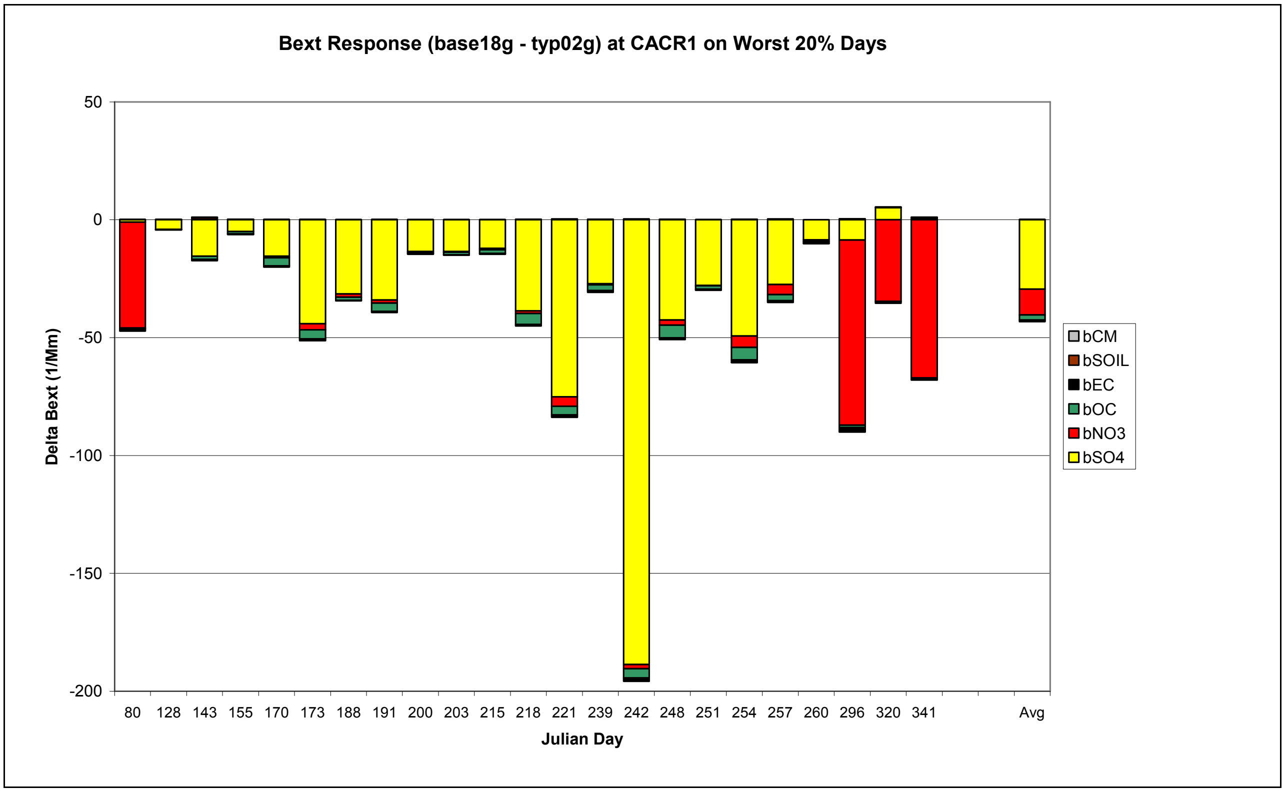


Figure 4-3d. Differences in Modeled 2002 and 2018 Base G CMAQ Results (2018-2002) Daily Extinction for Caney Creek (CACR), Arkansas and Worst 20 Percent (W20%) Days in 2002.

4.4.2 Summary 2018 Visibility Projections Across Class I Areas

Figure 4-4 displays a "DotPlot" of 2018 visibility projections using the 2002 Typical and 2018 base case Base G CMAQ 36 km modeling results. DotPlots present the 2018 visibility projections as a percentage of meeting the 2018 URP point. For example, at CACR the 2018 Base G modeling achieved 112% of the visibility reduction needed to meet the 2018 URP point so the dot under CACR is plotted at 112%. Class I areas' with dots above 100% surpass the 2018 URP point (i.e., are below the glidepath), whereas Class I areas' with dots that are under 100% fail to meet the 2018 URP point. Figure 4-4 summarizes the 2018 visibility projections using the EPA default "Regular RRF" and the two alternatives where CM is assumed to be natural (CM RRF=1) and both CM and Soil are assumed to be natural (CM&SOIL RRF=1). When CM or CM&SOIL are assumed to be natural that means that we assume the same CM or CM&SOIL occurs in the 2018 future-year as in the 2000-2004 Baseline Conditions. For the CENRAP sites, the EPA default and alternative projection, assuming CM alone or CM and Soil are natural, techniques produced similar results.

At the four eastern CENRAP Class I area sites close to the Mississippi River (CACR, UPBU, HEGL and MING), the 2018 visibility projections meet (HEGL) or surpass the 2018 URP point. Breton Island Class I area (BRET) comes up 6% short of meeting the 2018 URP point (i.e., 94% of the URP point). Wichita Mountains Class I area (WIMO) comes up approximately 40% short of the 2018 URP point. The two northern Class I areas (BOWA and VOYA) also come up about 40% short of meeting the 2018 URP point (i.e., achieve 69% and 53% of the visibility improvement needed to meet the 2018 URP point). The two Texas Class I areas only achieve

26% (BIBE) and 34% (GUMO) of the visibility improvement needed to meet the 2018 URP point for the worst 20 percent days. As discussed in more detail in Chapter 5, much of the difficulty for the Texas and some of the other CENRAP Class I areas in meeting the 2018 URP point is due to large contributions due to international transport, much of which (e.g., Mexico and global transport) is assumed to remain unchanged from 2002 to 2018.

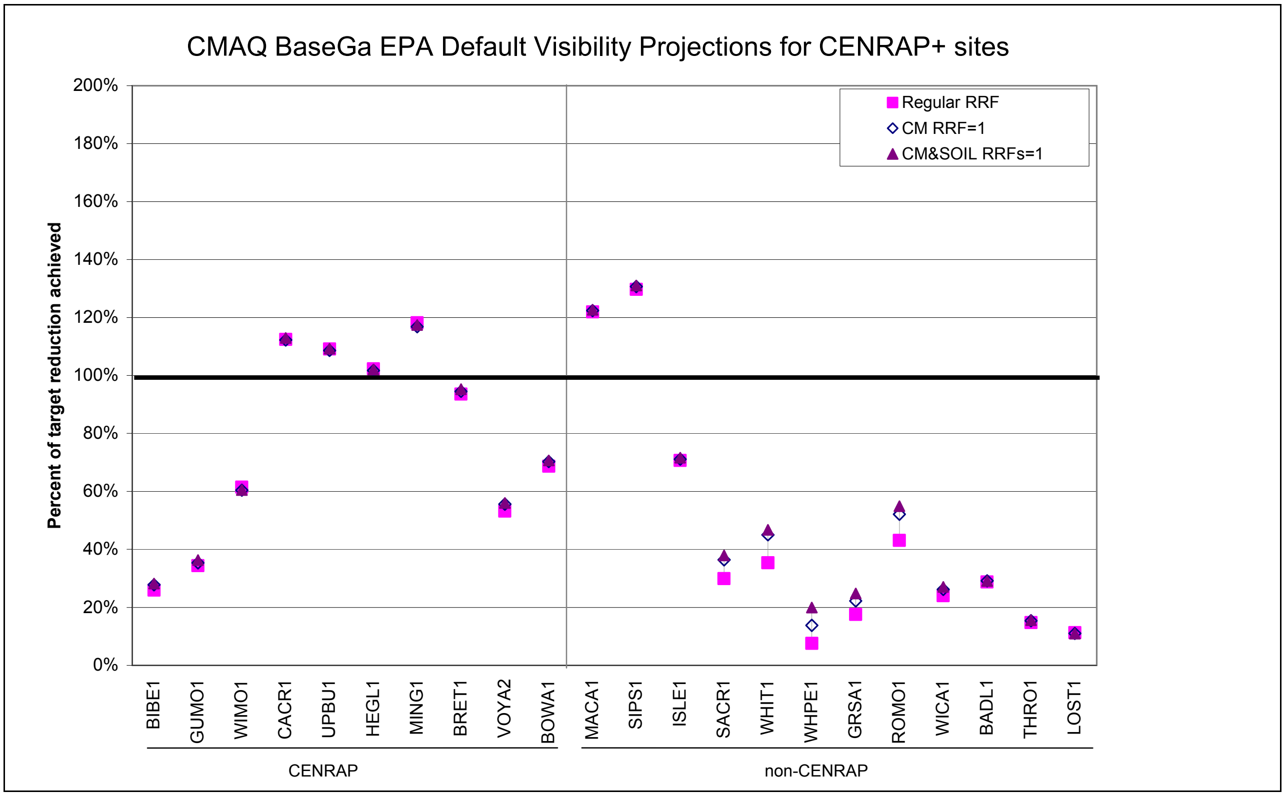


Figure 4-4. 2018 Base G CMAQ Visibility Projections for CENRAP and Nearby Class I areas Using DotPlots that Express 2018 Visibility as a Percentage of Meeting the 2018 URP Point On the Deciview Linear Glidepath.

Figure 4-5 displays the model estimated absolute change in extinction (Mm^{-1}) averaged across the 2002 worst 20 percent days at Class I areas in and near the CENRAP region. The largest modeled reductions are in SO4 extinction. Figure 4-6 displays the percent change in the projected PM extinction by PM species for each CENRAP and nearby Class I area average across the worst 20 percent days (i.e., the relative modeled change). The four CENRAP Class I areas that meet the 2018 URP point (CACR, UPBU, HEGL and MING) are characterized by large SO4, NO3 and EC extinction reductions (30-40%) with small Soil increases. At the other CENRAP Class I areas, however, there are lower levels of SO4, NO3 and EC extinction reductions and even some NO3 increases (BIBE). At the non-CENRAP Class I areas, the two VISTAS Class I areas (MACA and SIPS) have large reductions in SO4 extinction (~50%), whereas the WRAP Class I areas SO4 extinction reductions are much smaller.

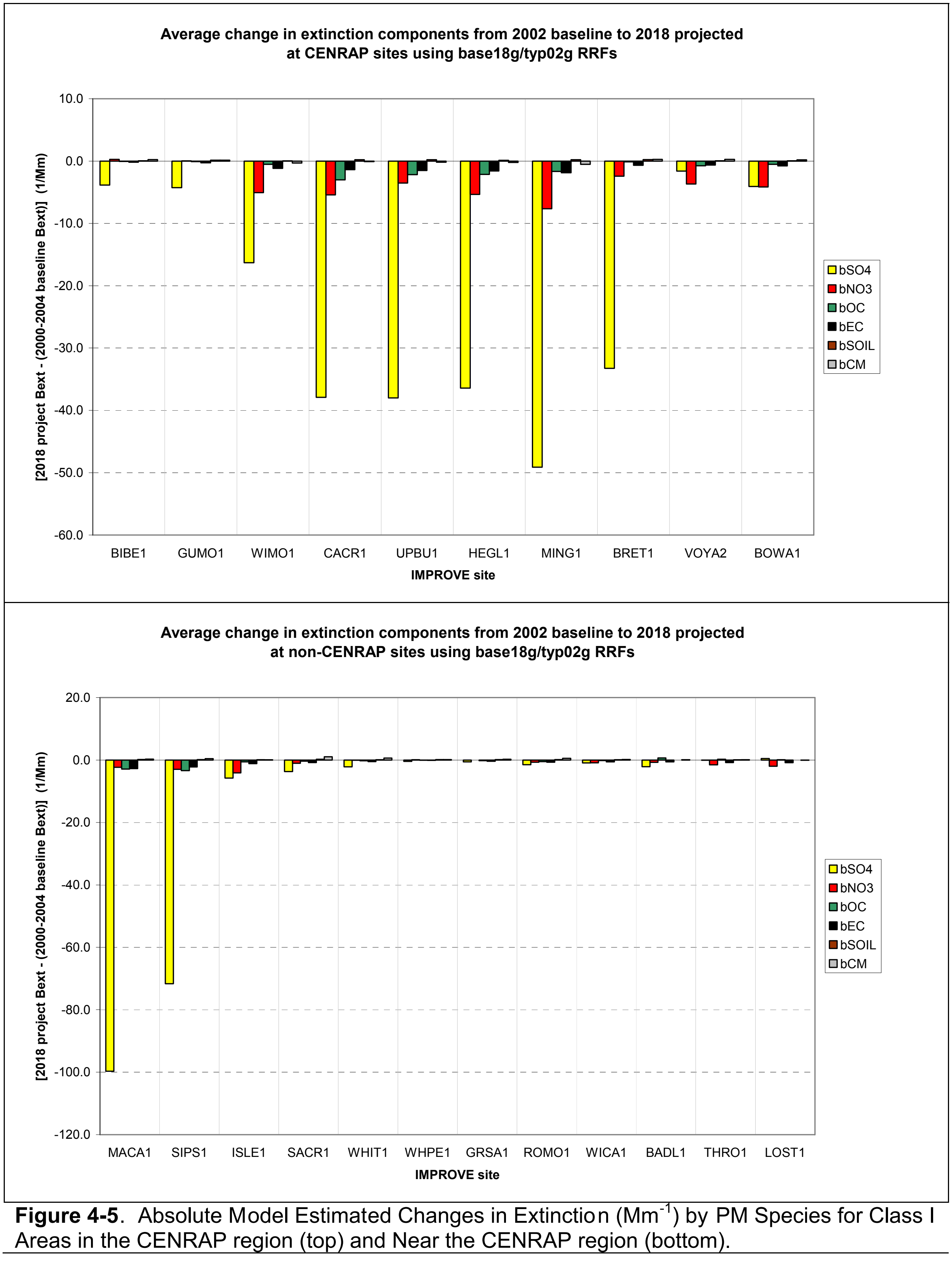
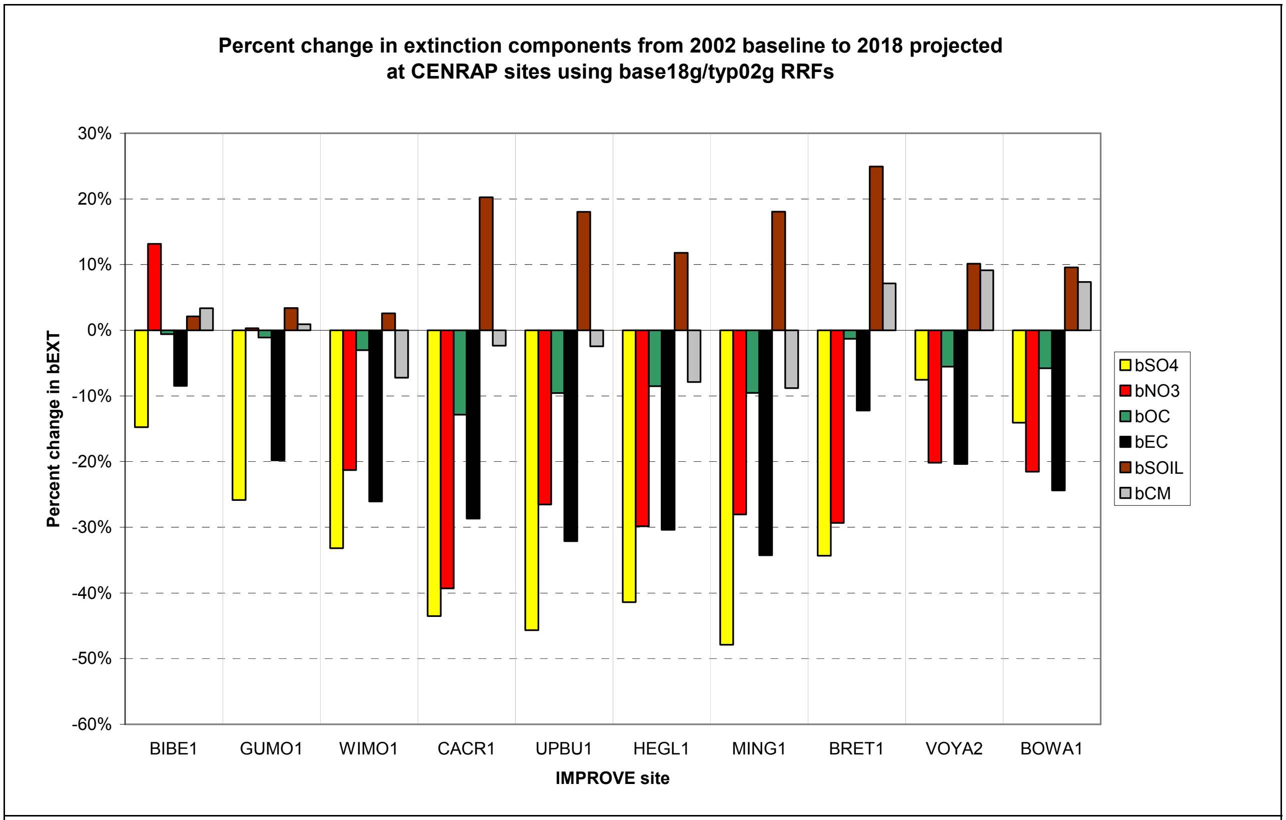


Figure 4-5. Absolute Model Estimated Changes in Extinction (Mm^{-1}) by PM Species for Class I Areas in the CENRAP region (top) and Near the CENRAP region (bottom).



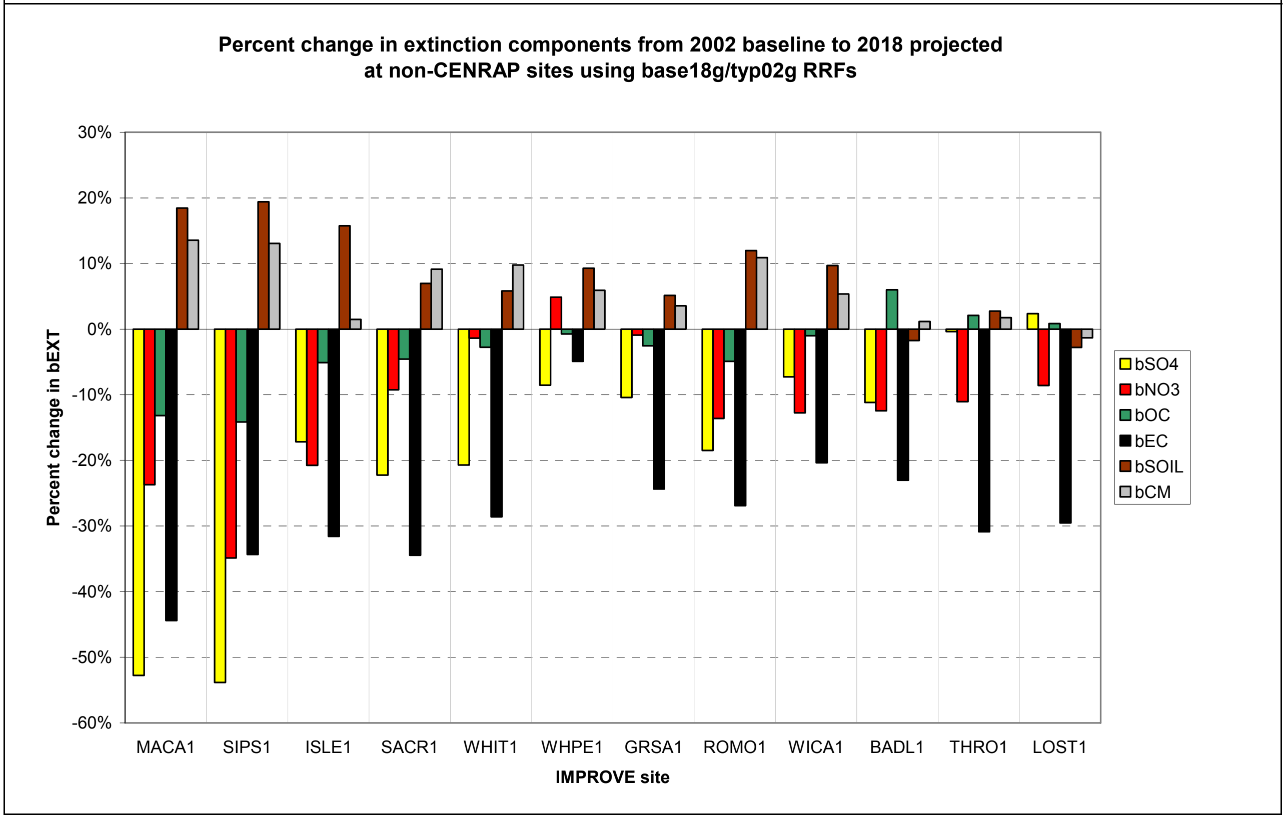


Figure 4-6. Percent Change In Modeled Extinction by PM Species Averaged Across the 2002 Worst 20 Percent Days for Class I areas in the CENRAP region (top) and Near the CENRAP region (bottom).

4.5 2018 Visibility Projections for Base G C1 Control Scenario

The 2018 visibility projections based on the CMAQ simulations for the 2018 Base G C1 Control Strategy simulations are presented in this section. The C1 Control Strategy results in reductions mainly in SO2 and NOx emissions from point sources in the CENRAP states. Consequently, PM improvements are limited to mainly SO4 and NO3 concentration reductions in the CENRAP states. Figure 4-7 displays the differences in CMAQ-estimated annual average SO4 and NO3 concentrations between the 2018 Base G base case and the 2018 Base G C1 Control Strategy case; the differences in all other PM species (with the exception of NH4) were negligible (see: http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml#base18gc1vsbase18g). Annual average SO4 concentration reductions of over a quarter of a µg/m^3 are estimated to occur in northeast Texas, east Oklahoma, Missouri, northeast Arkansas and up into Iowa and Illinois. There are much lower reductions in NO3 that cover a similar area.

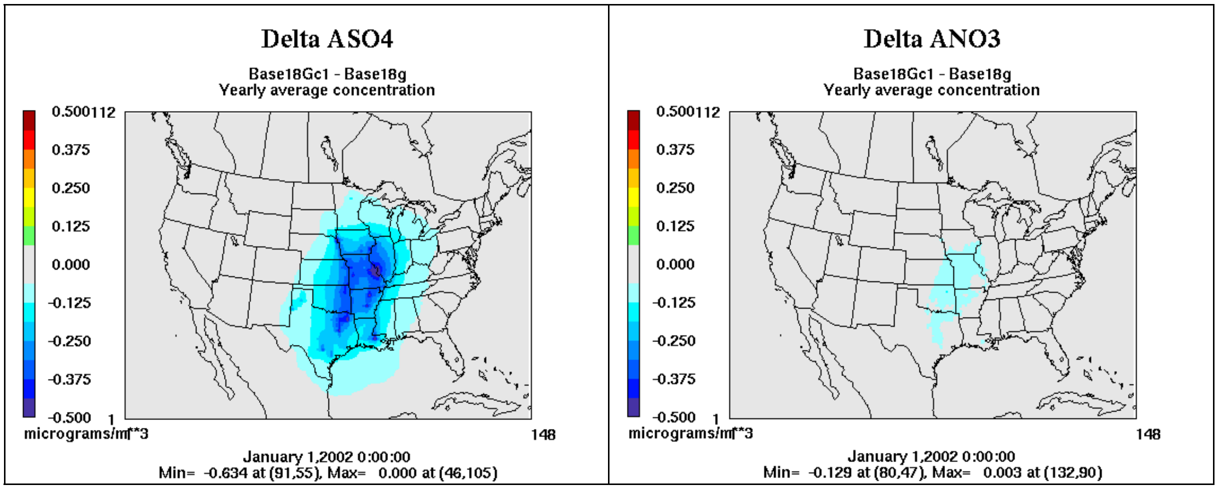


Figure 4-7. CMAQ-Estimated Reductions in Annual Average SO4 (left) and NO3 (right) Fine Particle Concentrations Between the 2018 Base G Base Case and 2018 Base G C1 Control Strategy Case.

Figure 4-8 displays the DotPlot comparisons of the 2018 visibility projections for 2018 Base G and 2018 Base G C1 Control Strategy emission scenarios. The additional controls in the C1 Control Strategy are projected to result in visibility improvements for the worst 20 percent days at Class I areas throughout and near the CENRAP region. Sites are closer to being on the glide path by 10 to 30 percent. For Breton Island this makes a difference of not meeting the 2018 URP point in 2018 Base G (94%) to surpassing the URP point in the C1 Control Strategy (106%).

Table 4-4 presents a tabular summary of the information presented in Figure 4-8, including the Baseline, 2018 URP point, and 2018 projected visibility for the Base G and C1 Control Strategy simulations.

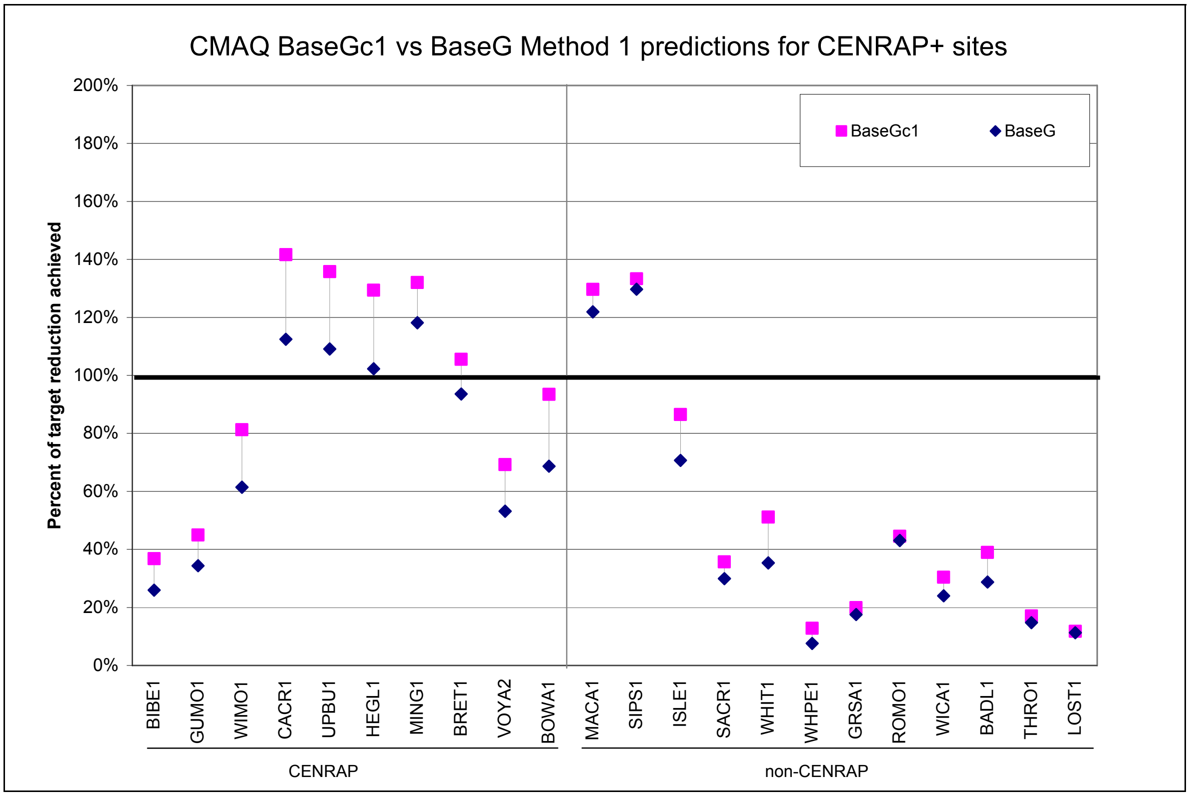


Figure 4-8. 2018 Visibility Projections as a Percentage of Meeting the 2018 URP Point (i.e., DotPlot) for the 2018 Base G and 2018 Base G C1 Control Strategy Emission Scenarios.

Table 4-4. 2000-2004 Baseline, 2018 URP Point, and Projected 2018 Visibility and Percent of Meeting the 2018 URP Point for the 2018 Base G and 2018 C1 Control Strategy CMAQ Simulations.

Class I Area Name	State	ID	Lat.	Lon.	00/04 Baseline Condit.	2018 URP Point	2018 Base G Base Case		2018 Base G C1 Control Strategy	
			(deg)	(deg)	(dv) (dv	)	(dv) (	%)	(dv)	(%)
Badlands NP	SD	BADL1	43.81	-102.36	17.14	15.02	16.53	29%	16.31	39%
Big Bend NP	TX	BIBE1	29.33	-103.31	17.30	14.93	16.69	26%	16.43	37%
Boundary Waters Canoe Area	MN	BOWA1	48.06	-91.43	19.58	17.72	18.30	69%	17.84	93%
Breton LA		BRET1	29.87	-88.82	25.73	22.51	22.72	94%	22.34	106%
Caney Creek Wilderness	AR	CACR1	34.41	-94.08	26.36	22.91	22.48	112%	21.48	142%
Great Sand Dunes NM	CO	GRSA1	37.77	-105.57	12.78	11.35	12.53	18%	12.49	20%
Guadalupe Mountains NP	TX	GUMO1	31.91	-104.85	17.19	14.74	16.35	34%	16.09	45%
Hercules-Glades Wilderness	MO	HEGL1	36.68	-92.9	26.75	23.14	23.06	102%	22.09	129%
Isle Royale NP	MI	ISLE1	48.01	-88.83	20.74	18.78	19.36	71%	19.05	87%
Lostwood ND		LOST1	48.59	-102.46	19.57	16.87	19.27	11%	19.26	12%
Mammoth Cave NP	KY	MACA1	37.20	-86.15	31.37	26.64	25.60	122%	25.23	130%
Mingo MO		MING1	37.00	-90.19	28.02	24.37	23.71	118%	23.21	132%
Rocky Mountain NP	CO	ROMO1	40.35	-105.7	13.83	12.29	13.17	43%	13.14	45%
Salt Creek	NM	SACR1	33.6	-104.41	18.03	15.41	17.25	30%	17.10	36%
Sipsey Wilderness	AL	SIPS1	34.32	-87.44	29.03	24.82	23.57	130%	23.42	133%
Theodore Roosevelt NP	ND	THRO1	46.96	-103.46	17.74	15.42	17.40	15%	17.34	17%
Upper Buffalo Wilderness	AR	UPBU1	36.17	-92.41	26.27	22.84	22.52	109%	21.61	136%
Voyageurs NP	MN	VOYA2	48.47	-92.8	19.27	17.58	18.37	53%	18.10	69%
White Mountain Wilderness	NM	WHIT1	33.48	-105.85	13.70	12.11	13.14	35%	12.89	51%
Wheeler Peak Wilderness	NM	WHPE1	36.57	-105.4	10.41	9.49	10.34	8%	10.30	13%
Wind Cave NP	SD	WICA1	43.58	-103.47	15.84	13.94	15.39	24%	15.26	30%
Wichita Mountains	OK	WIMO1	34.75	-98.65	23.81	20.01	21.47	61%	20.72	81%

5.0 ADDITIONAL SUPPORTING ANALYSIS

This Chapter presents additional supporting analysis to the modeled 2018 visibility projections provided in Chapter 4. This supporting analysis may be used by the states in their RHR SIPs, along with their factor analysis, to assist in setting their 2018 RPGs for the worst 20 percent days and best 20 percent days.

5.1 Comparison of CENRAP 2018 Visibility Projections with Other Groups

2018 visibility projections for CENRAP and nearby Class I area have also been performed by the other RPOs. Thus, it is useful to compare the CENRAP 2018 visibility projections with those from the other RPOs as a quality assurance (QA) check and to foster confidence in the CENRAP modeling results.

5.1.1 Comparison of CENRAP, VISTAS, MRPO and WRAP Visibility Projections

The CENRAP 2018 Base G visibility projections were compared to the following other RPO visibility projections:

- VISTAS 2018 visibility projections based on their CMAQ 12 km 2002 annual modeling results for the 2002 Base G and 2018 Base G2a emissions scenarios.
- MRPO 2018 visibility projections based on their CAMx 36 km 2002 annual modeling for the Run 4 Scenario 1a (R4S1a) emissions scenario.
- WRAP 2018 visibility results based on their Plan02b and Base18b CMAQ 36 km modeling of the 2002 calendar year.

Figure 5-1 displays a DotPlot comparison of the four RPO visibility projections expressed as a percentage of achieving the 2018 URP point at CENRAP and nearby Class I areas. For the four CENRAP Class I areas just west of the Mississippi River in Arkansas and Missouri (CACR, UPBU, HEGL and MING), 2018 visibility projections are available from the CENRAP, VISTAS and MRPO RPOs. At HEGL, the three RPOs 2018 visibility projections are in close agreement with each other (estimated to achieve 99%, 101% and 95% of the 2018 URP point). The CENRAP and VISTAS 2018 visibility projections are also very close at the other three Arkansas-Missouri CENRAP Class I areas: CACR (112% and 116%), UPBU (109% and 112%) and MING (118% and 114%). But the MRPO 2018 visibility projections are approximately 12 to 25 percentage points lower than the CENRAP and VISTAS projections at these three Class I areas, with values of 97% to 100%. The reasons why the MRPO 2018 visibility projections are less optimistic than CENRAP and VISTAS are unclear. However, the MRPO focused on visibility projections at their northern Class I areas and likely did not use the latest CENRAP emission estimates. In addition, the CENRAP 2018 visibility projections included BART controls on several sources in CENRAP states not included in the MRPO projections. Such BART controls are even more important in those states not covered by CAIR.

For the Breton Island (BRET) Class I area, 2018 visibility projections are available from CENRAP and VISTAS. CENRAP estimates that BRET will achieve 94% of the URP point and

VISTAS is slightly less optimistic with an 84% value. One potential contributor to this is that emissions from off-shore marine vessel emissions in the oil and gas production areas of the Gulf of Mexico are double counted in the VISTAS Base G modeling. As these emissions were assumed to remain unchanged between 2002 and 2018, the double counting of their emissions will result in stiffer RRFs than there should be and consequently less visibility benefits in 2018. This double counting also occurred in the CENRAP Base F modeling but was corrected in Base G. The double counting occurred because off-shore marine vessels were present in both the MMS off-shore oil/gas development inventory for the Gulf of Mexico and the VISTAS off-shore marine vessel inventory for the Pacific and Atlanta Oceans and the Gulf of Mexico. VISTAS intends to correct this double counting in their next round of modeling.

At the two northern Minnesota Class I areas (BOWA and VOYA), the MRPO 2018 visibility projections (93% and 92%) exhibit more visibility improvements than CENRAP's (69% and 53%). This is believed to be due to higher contributions to visibility impairment from Canada in the CENRAP modeling. Figure 5-2 displays the CENRAP 2002 Base F total SO2 emissions and their differences with the 2018 Base F SO2 emissions. The SO2 emissions in Alberta Canada appear to be much higher and more wide spread when compared to the other provinces in Canada and emissions in the U.S. states. Also, there is a very large SO2 source in northern Manitoba (> 10^5 tons/year). The Alberta SO2 emissions may be overstated in the CENRAP modeling, which would overstate the Canadian contribution to visibility impairment. The western boundary of the MRPO modeling domain was east of the Rocky Mountains so did not include Alberta. CENRAP confirmed that the Alberta emissions and the source in Manitoba were present in the emissions provided by Canada. Air parcels from Canada are generally associated with clean visibility conditions at the northern Minnesota Class I areas with the worst 20 percent days generally occurring under conditions with a southerly wind component. However, in 2002 some of the worst 20 percent days did occur with transport out of Canada. For example, Figure 5-3 displays back trajectories off of the VIEWS website for two of the worst 20 percent days at Voyageurs National Park (Julian Days 347 and 332). These back trajectories suggest that the potentially overstated emissions in Alberta would have an impact at VOYA during the worst 20 percent days in 2002.

At the VISTAS Mammoth Cave (MACA), Kentucky Class I area, VISTAS, CENRAP and the MRPO estimated that 2018 visibility for the worst 20 percent days will achieve, respectively, 122%, 123% and 102% of the 2018 URP point. The close agreement between the VISTAS (122%) and CENRAP (123%) 2018 visibility projections for MACA is encouraging. Why MRPO is 20 percentage points lower is unclear, but may be due to using earlier versions of the VISTAS and CENRAP emissions. The 2018 visibility projections at Sipsey (SIPS), Alabama estimated by VISTAS (127%) and CENRAP (130%) are also extremely close.

Both the CENRAP and WRAP 2018 visibility projections agree that the WRAP Class I areas fail to achieve the 2018 URP point by a wide margin, with values achieving only ~40% or less of the 2018 URP point. The CENRAP 2018 visibility projections agrees well with the WRAP values at Great Sands (GRSA), Colorado (18% vs. 15%), Badlands (BADL), South Dakota (24% vs. 31%), Theodore Roosevelt, North Dakota (15% vs. 11%) and Lostwood (LOST), Montana (11% vs. 14%). There is also reasonable agreement between CENRAP and WRAP 2018 visibility projections at Salt Creek (SACR), New Mexico (30% vs. 12%), Rocky Mountain (ROMO), Colorado (43% vs. 30%), and Wind Cave (WICA), South Dakota (24% vs. 6%). There are two WRAP Class I areas, White Mountains (WHIT) and Wheeler Peak (WEPE), where the WRAP

2018 visibility projections estimate that visibility will degrade for the worst 20 percent days (i.e., negative percent of achieving the 2018 URP point), whereas CENRAP estimates visibility improvements. The reasons for these differences are unclear.

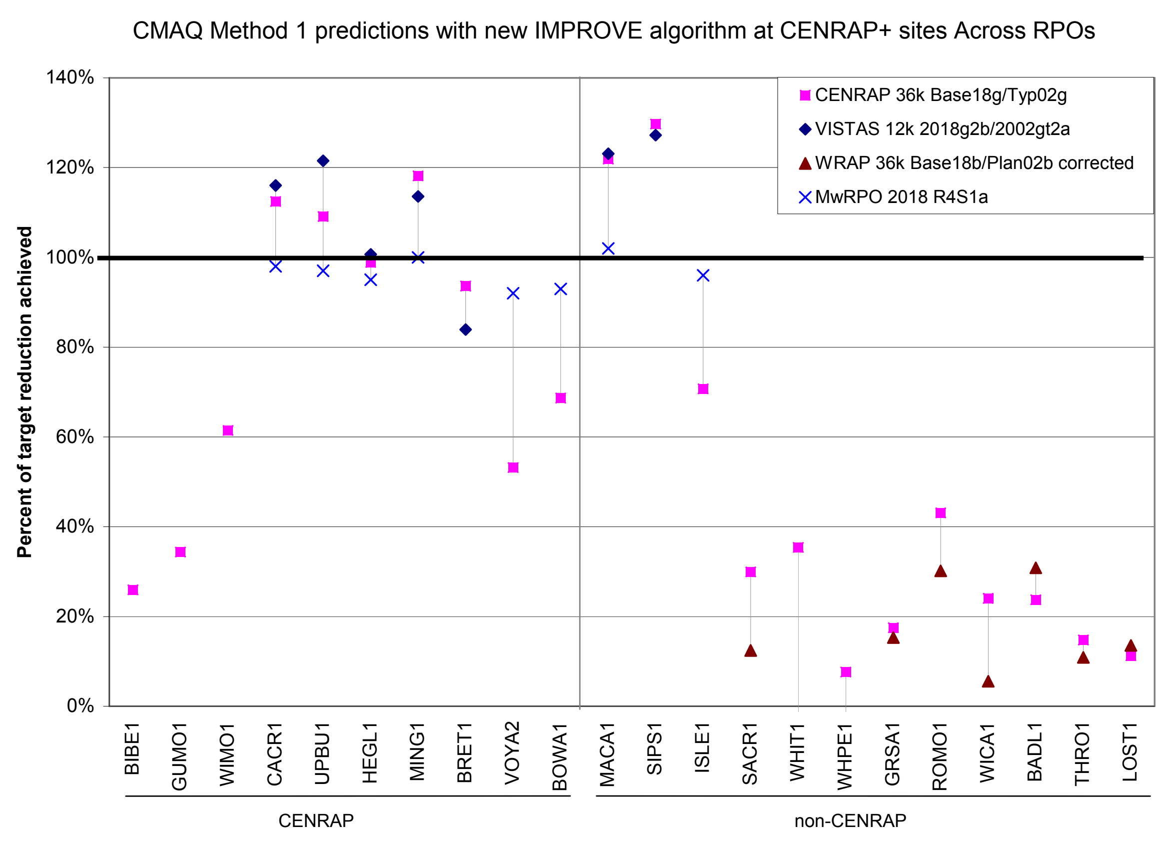


Figure 5-1. DotPlot comparing the CENRAP, VISTAS, MRPO and WRAP 2018 visibility projections expressed as a percentage of achieving the 2018 URP goal.

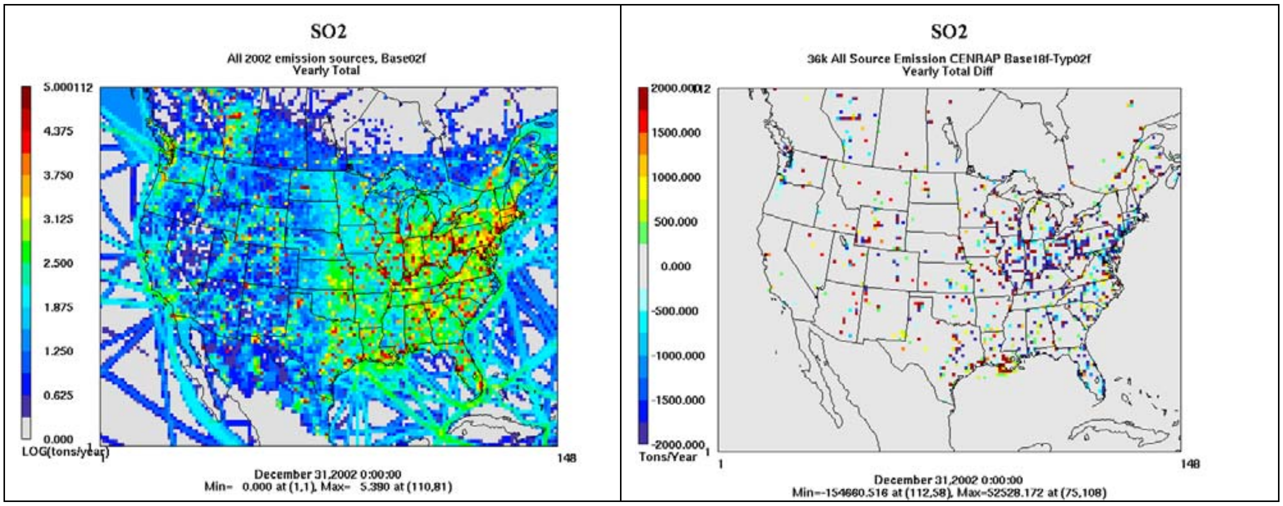


Figure 5-2. 2002 Base F SO2 emissions (left) as LOG10(tons/year) and differences in 2018 and 2002 Base F SO2 emissions (tons/year).

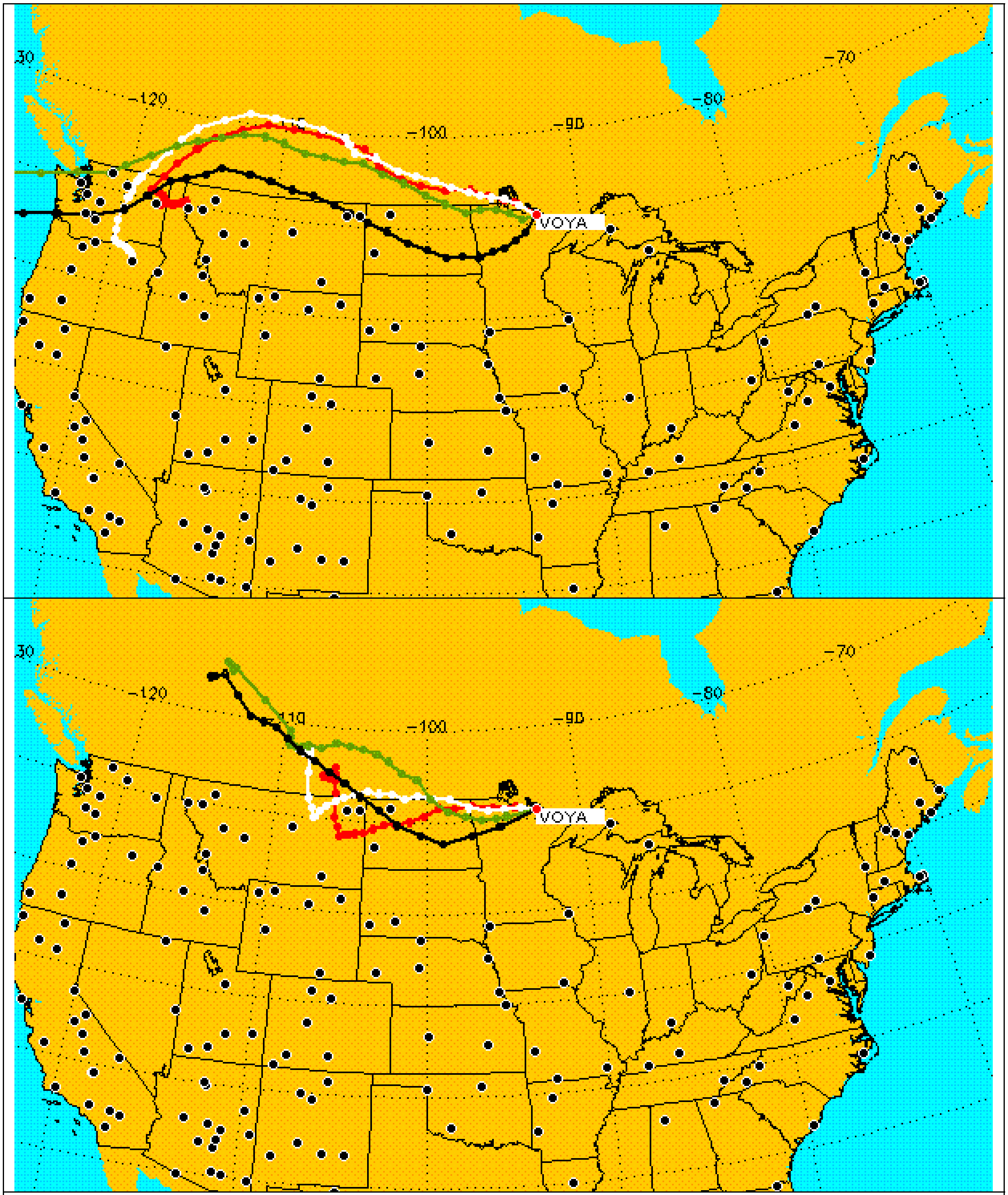


Figure 5-3. Exampled back trajectories to Voyageurs National Park for two of the worst 20 percent days from 2002: December 13, 2002 (Julian Day 347) and November 28, 2002 (Julian Day 332).

5.2 Extinction and PM Species Specific Visibility Projections and Comparisons to 2018 URP Point

It is useful to examine 2018 visibility projections by PM species to determine how each PM component of visibility is changing as both a diagnostic analysis of the visibility projections as well as whether species that are associated more with anthropogenic emissions (e.g., SO4 and NO3) are being reduced substantially compared to those that are less influenced by anthropogenic emissions (e.g., Soil and CM). However, because deciview is the natural logarithm of total extinction, such comparisons can not be made using the deciview scale and must be made using extinction. The linear glidepath from which the 2018 URP points are derived are based on deciview, thus to examine corresponding glidepath using extinction the curvature associated with the logarithmic transformation of the linear deciview glidepath to extinction must be accounted for in the extinction glidepath.

5.2.1 Total Extinction Glidepaths

Figure 5-4 displays a total extinction based glidepath for Caney Creek that is based on the EPA default deciview linear glidepath counterpart shown in Figure 4-3a. That is, the deciview linear glidepath defined by the line connecting the 26.36 dv Baseline Conditions at 2004 to the 11.58 dv Natural Conditions in 2064. The glidepath points in 2008, 2018, 2028, etc. from the linear deciview glidepath (Figure 4-3a) are turned into extinction (Bext) [Bext = 10 exp(dv/10)] to create the curved extinction glidepath that exactly match the linear deciview glidepath points. Note that the 2000-2004 Baseline using the curved extinction glidepath is slightly different than if you just converted the deciview baseline to extinction because the logarithm relationship is performed before the averaging, but they are extremely close. Using the extinction curved glidepath, the 2018 URP point is a reduction of the Baseline 145.10 Mm^{-1} to 98.88 Mm^{-1} (a 46.22 Mm^{-1} reduction). The modeled 2018 visibility projection in extinction is 97.54 Mm^{-1}, a 47.56 Mm^{-1} reduction, which achieves 103% of the reduction needed to achieve the 2018 URP point. Note that this compares with achieving 112% of the 2018 URP reduction point when using the deciview linear glidepath. The percent of achieving the 2018 URP point using the linear deciview and curved extinction glidepaths will rarely be the same due to the logarithmic relationship between the two visibility metrics and the fact that averaging within and across years in the deciview calculations occur after the logarithms have been applied. The greater the difference in extinction across the worst 20 percent days in a year and averaged across the years in the 2000-2004 Baseline and the greater number of years available from the 2000-2004 Baseline may result in greater differences in the 2018 URP points using the linear deciview and the curved extinction glidepaths.

Appendix F contains total extinction curved glidepaths for all the CENRAP Class I areas and Figure 5-5 contains a DotPlot that compares the percent of achieving the 2018 URP point at each CENRAP Class I area using the 2018 Base G modeling results and the linear deciview and curved extinction glidepaths. At most CENRAP Class I areas the ability of the 2018 modeling results to achieve the 2018 URP point is the same using either the deciview or extinction glidepaths. There are some differences at GUMO, BOWA and VOYA Class I areas which are due to these Class I areas having more complete data during the 2000-2004 Baseline period and therefore more years in the Baseline than other Class I areas as well as having variations in extinction across the worst 20 percent days and years (Appendix F). In any event, the closeness of the ability of the model to achieve the 2018 URP point using either the extinction or deciview glidepath verifies the validity of the extinction based glidepaths and allows for the construction of PM species specific glidepaths in extinction to gain insight into how each component of extinction is being reduced to achieve a uniform rate of progress toward natural conditions in 2064.

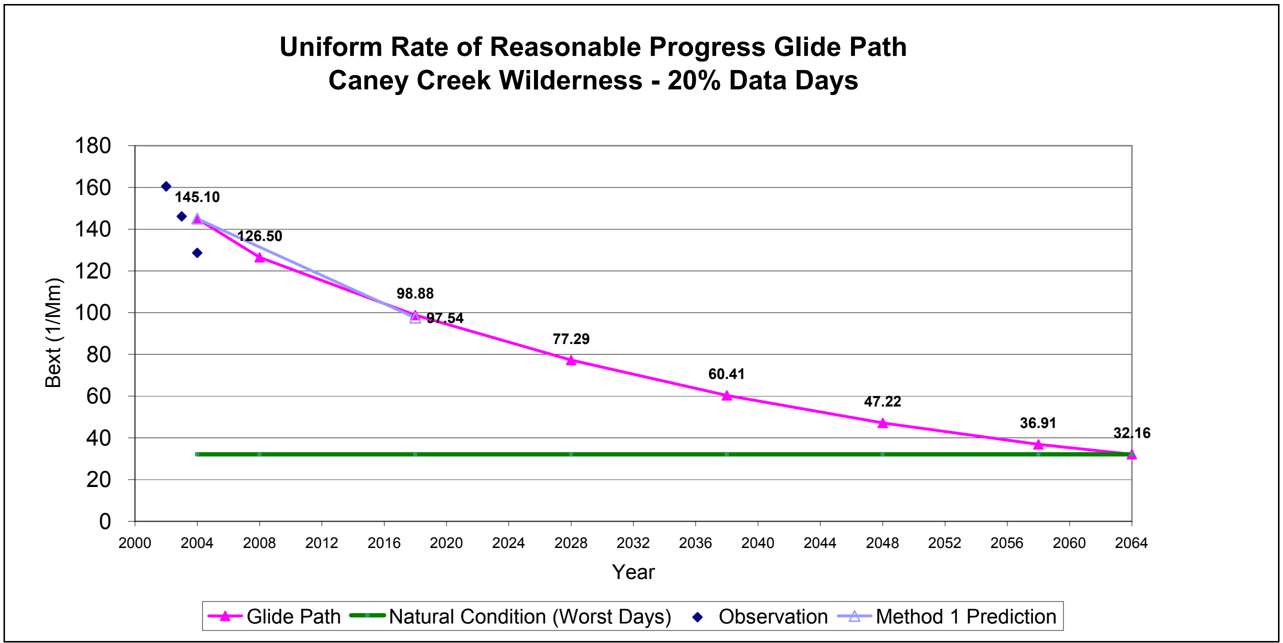


Figure 5-4. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

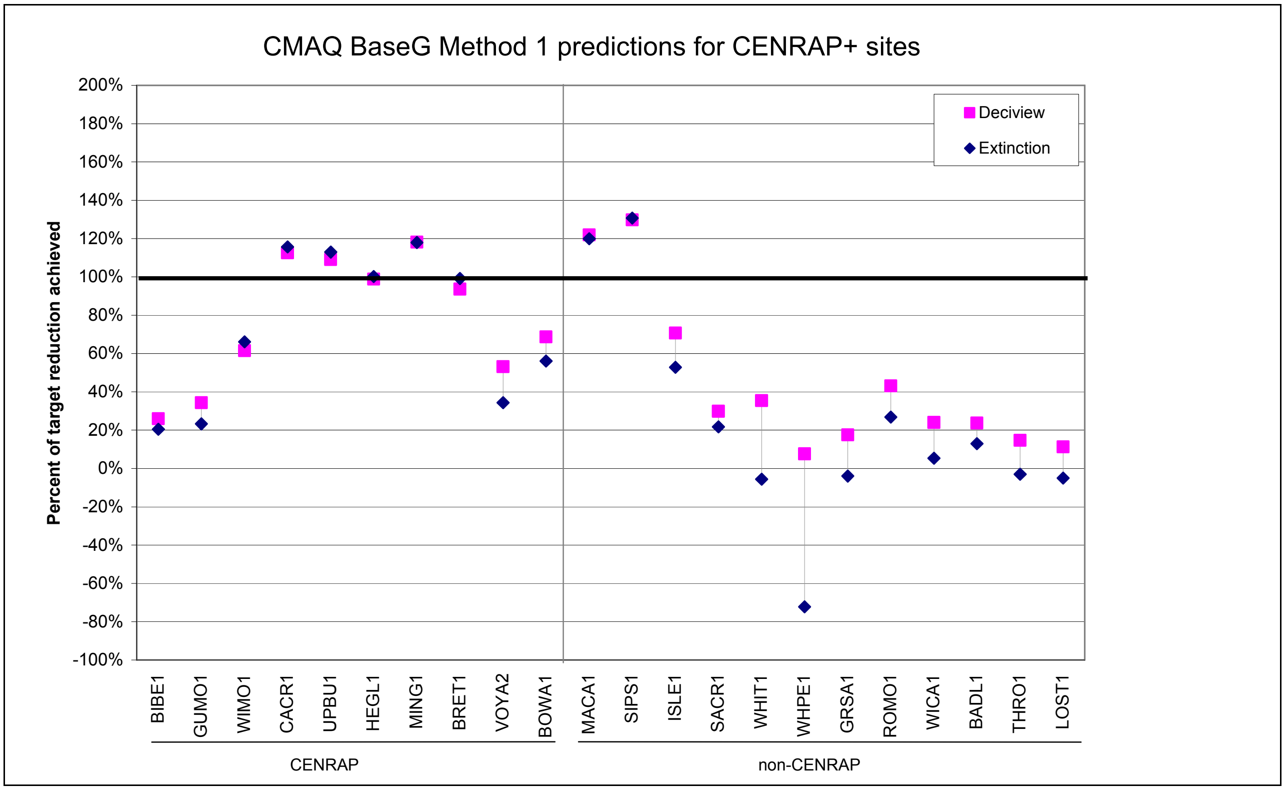


Figure 5-5. CMAQ 2018 Base G visibility projections and comparison of ability to achieve the 2018 URP point using the EPA default deciview and alternative total extinction Glidepaths.

5.2.2 PM Species specific Glidepaths

The VIEWS website (http://vista.cira.colostate.edu/views/) has posted PM species specific Natural Conditions based on the new IMPROVE equation. Using these PM species specific Natural Conditions and the curved extinction glidepaths we can evaluate how well visibility extinction achieves the 2018 URP point on a species-by-species basis. The PM species specific glidepaths are constructing starting with a Baseline at 2004 averaging the extinction for each PM species measured using the 2000-2004 IMPROVE observations and ending with the Natural Conditions in 2064 from the VIEWS website. Points in the glidepath for the years in between 2004 and 2064 are constructed based on the relative differences in the 2004 Baseline and 2064 Natural Conditions PM species extinction such that the total extinction due to all PM species at each interim year adds up to the same as the total extinction on the extinction-based glidepath (e.g., Figure 5-3). For example, for the CACR SO4 extinction glidepath the 2018 URP point is generated from the 2004 and 2064 SO4 extinction (BSO4) and the 2004, 2018 and 2064 total extinction (BTOT) as follows:

$$\begin{aligned} \text{BSO4\_2018} &= \text{BSO4\_2004} - [(\text{BSO4\_2004} - \text{BSO4\_2064})/ \\ &\quad (\text{BTOT\_2004} - \text{BTOT\_2064})] \times (\text{BTOT\_2004} - \text{BTOT\_2018}) \\ &= 87.05 - [(87.05 - 3.20)/(145.10 - 32.16)] \times (145.10 - 98.88) \\ &= 52.73\ \text{Mm}^{-1} \end{aligned}$$

Note that the SO4 2018 URP point in Figure 5-5 and F-1b (52.77 Mm-1) does not exactly match the 52.73 Mm^{-1} calculated due to round off error in the above calculation that only used numbers with precision to the nearest hundredth.

As there are larger differences between the Baseline and Natural PM species extinction for some species, then the rate of improvement to achieve a species specific 2018 URP point will vary across PM species. For example, current Baseline extinction values for Soil and CM tend to be closer to Natural Conditions than extinction due to SO4 and NO3. Consequently the rate of progress to achieve the 2018 URP point for Soil and CM will be less than for SO4 and NO3.

Appendix F contains the PM species specific glidepaths compares them to the modeled 2018 projections for all CENRAP Class I areas. The species specific results for the CACR Class I area in Figure F-1 are reproduced in Figure 5-6. The modeled rate of SO4 and NO3 extinction reduction is greater than the PM species specific glidepaths and both achieve the species specific 2018 URP point by achieving 111% and 104% of the reduction needed to achieve the 2018 URP point. The modeled rate of extinction improvement at CACR for EC and OC is less than the species specific glidepath achieving only 65% and 75% of the reduction needed to achieve the species specific 2018 URP point. The PM species specific glidepath for Soil is flat because the Baseline and Natural Conditions (1.12 Mm^{-1}) are the same. This does not mean that anthropogenic emissions of Soil do not contribute on worst 20 percent days at CACR. It just points to a mismatch between the current set of worst 20 percent days and those in 2064 under Natural Conditions. The worst 20 percent days in 2064 under Natural Conditions will be dominated by wind blown dust days when Soil and CM may be higher than during the current set of worst 20 percent days that are dominated by SO4, NO3 and OMC. Thus, the Soil and CM glidepaths tend to be flatter and in some cases may even have an upward trend for some Class I areas (see Appendix F). Soil is projected to increase at CACR in 2018 so does not achieve its species specific URP point. Little reduction in CM is also seen by 2018. As discussed previously, this is due in part to incompatibilities between the measured Soil and CM values at the IMPROVE monitor and the modeled Soil and CM species. In the model, a large component of the Soil and CM in the inventory is due to paved and unpaved road dust. These emissions are directly related to Vehicles Miles Traveled (VMT). VMT is projected to increase in future-years resulting in increases in road dust emissions. At the IMPROVE monitor, much of the measured Soil and CM is likely due to local dust events that are not simulated by the model using a 36 km grid resolution. Thus, the 2018 projections for Soil and CM are likely applying modeled changes due to road dust to local Soil and CM concentrations that in reality are likely natural and should remain unchanged in the future year. This is why alternative 2018 modeled projection approaches have been developed that assume that CM and CM and Soil are natural so remain unchanged in the future-year (see Section 5.5).

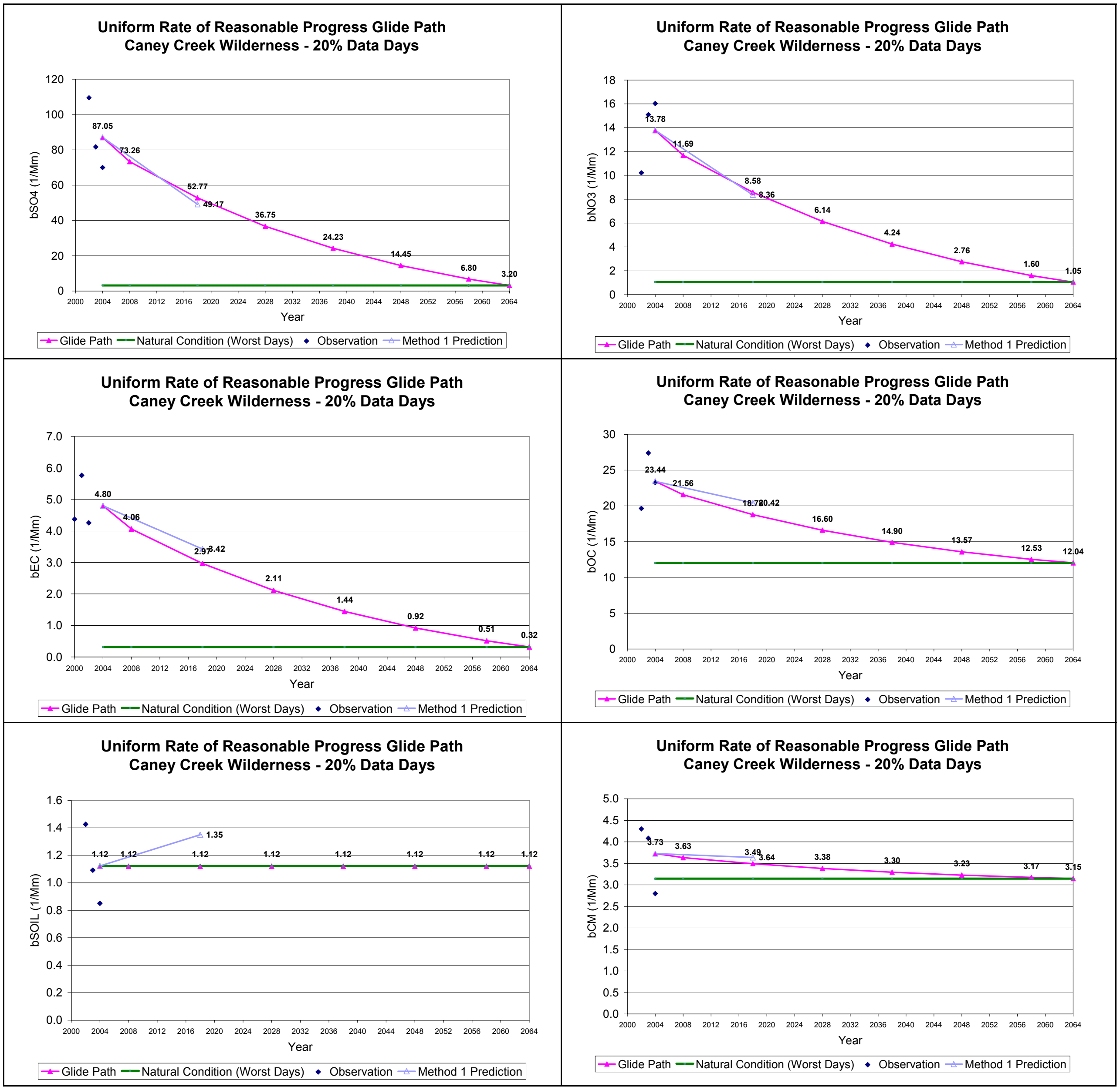


Figure 5-6. 2018 Visibility Projections and 2018 URP Glidepaths for SO4 (top left), NO3 (top right), EC (middle left), OMC (middle right), Soil (bottom left) and CM (bottom right) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20 Percent Days using 2002/ 2018 Base G CMAQ 36 km modeling results.

Figure 5-7 displays a DotPlot that compares the 2018 projected total and PM species specific extinction with the 2018 URP points. These results show that SO4 is most frequently achieving its 2018 URP point at those Class I areas that achieve the deciview URP point. Reductions in NO3 and EC also sometimes achieve their species specific URP point.

There are some anomalies in the species specific projections and glidepaths that bear mention and point to areas where better estimates of emissions growth and Natural Conditions are needed needed. The increase in 2018 Soil projections is not an isolated incident at CACR and occurs at other CENRAP Class I areas. There are three CENRAP Class I areas that "achieve" the Soil specific 2018 URP point (HEGL, BOWA and VOYA). An examination of these glidepaths and visibility projections (Figures F-4f, F-5f and F-6f) reveals that the current Baseline Conditions Soil at these three Class I areas is actually <u>less</u> than the 2064 Natural Conditions so that the glidepath is an accent rather than reduction (Figures F-4g, F-5g and F-6g). In these three cases to "achieve" the 2018 URP point the modeling results must increase the projected Soil extinction, which is why these three Class I areas "achieve" their 2018 URP point for Soil. Clearly, the 2018 URP point for Soil is not very meaningful under these conditions. The current Baseline Conditions for OMC at BRET and BOWA is also less than the Natural Conditions resulting in anomalous glidepaths (Figure F-3e and F-4e).

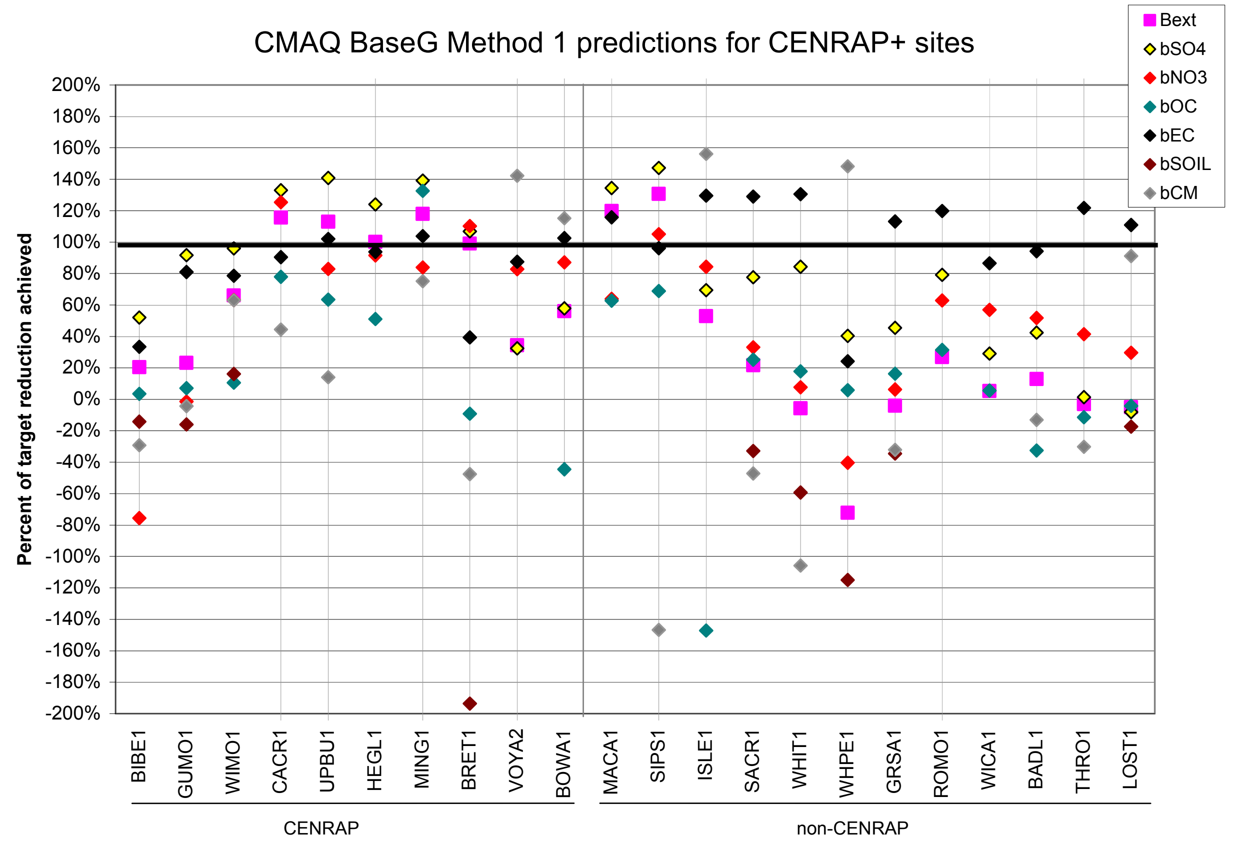


Figure 5-7. Ability of total and species specific 2018 visibility projections to achieve 2018 URP points.

5.3 Alternative 2018 Visibility Projection Software

The CENRAP 2018 visibility projections were made using software developed by the CENRAP modeling team. PM concentrations in the 36 km grid cells containing each of the Class I area IMPROVE monitoring sites were extracted using the UCR Analysis Tool. These modeling data were then ported into Excel spreadsheets that also include the filled RHR IMPROVE database available from the VIEWS website along with the EPA default Natural Conditions (EPA, 2003b). Excel macros are then used to perform the visibility projections using the EPA default procedures described in Chapter 4 and alternative procedures described in this Chapter.

EPA is developing a Modeled Attainment Test Software (MATS) program that codifies the 8-hour ozone, $PM_{2.5}$ and visibility projection procedures given in EPA's latest air quality modeling guidance (EPA, 2007a). The June 2007 release of the beta version of MATS is capable of performing 8-hour ozone and visibility projections; MATS is still under development for making $PM_{2.5}$ projections. The June 2007 beta versions of MATS was applied to the CENRAP 2002 and 2018 Base G 36 km CMAQ results and the resultant 2018 visibility projections were compared with the CENRAP values using the EPA default projection approach (see Chapter 4) at CENRAP and nearby Class I areas. The projected 2018 visibility estimates using the CENRAP and EPA MATS software are shown in Table 5-1. The biggest differences in the two 2018 visibility projections are for the Boundary Waters (BOWA). Breton Island (BRET), and Mingo (MING) Class I areas where MATS produces no 2018 visibility projections. This is because there is insufficient capture of valid IMPROVE PM measurements within the 2000-2004 five-year baseline to generate three years of annual visibility estimates that is the minimum needed to develop the Baseline Conditions following EPA's guidance (EPA, 2003a). For the CENRAP projections, data filling was used to fill out the IMPROVE measurements with sufficient data so that Baseline Conditions could be calculated at these three Class I areas. At 14 of the remaining 17 Class I areas, the CENRAP and MATS 2018 visibility projections agree exactly to within a hundredth of a deciview. At the three sites that are different (BIBE, GUMO and ISLE) the difference is 0.01 dv, which is 0.06 percent or less. These differences are likely due to round off errors in the calculations and are not significant. These results verify the consistency with the CENRAP spreadsheet based and EPA MATS software for projecting future-year visibility estimates.

Table 5-1. Comparison of CENRAP and EPA MATS 2018 visibility projections at CENRAP and nearby Class I areas.

	2018 Visibility Projections		**2000-2004 Baseline Conditions**	
Site	**MATS (dv)**	**CENRAP (dv)**	**MATS (dv)**	**CENRAP (dv)**
BADL	16.53	16.53	17.14	17.14
BIBE	16.70	16.69	17.30	17.30
BOWA	NA	18.30	NA	19.58
BRET	NA	22.72	NA	25.73
CACR	22.48	22.48	26.36	26.36
GRSA	12.53	12.53	12.78	12.78
GUMO	16.36	16.35	17.19	17.19
HEGL	23.06	23.06	26.75	26.75
ISLE	19.35	19.36	20.74	20.74
LOST	19.27	19.27	19.57	19.57
MACA	25.60	25.60	31.37	31.37
MING	NA	23.71	NA	28.02
ROMO	13.17	13.17	13.83	13.83
SACR	17.25	17.25	18.03	18.03
SIPS	23.57	23.57	29.03	29.03
THRO	17.40	17.40	17.74	17.74
UPBU	22.52	22.52	26.27	26.27
VOYA	18.37	18.37	19.27	19.27
WHIT	13.14	13.14	13.70	13.70
WHPE	10.34	10.34	10.41	10.41
WICA	15.39	15.39	15.84	15.84
WIMO	21.47	21.47	23.81	23.81

NA = Not Available

5.4 PM Source Apportionment Modeling

The PM Source Apportionment Technology (PSAT) was used to obtain PM source apportionment by geographic regions and major source category for the CENRAP 2002 and 2018 Base E base case conditions. PSAT uses reactive tracers that operated in parallel to the CAMx host model using the same emissions, transport, chemical transformation and deposition rates as the host model to account for the contributions of user specified source regions and categories to PM concentrations throughout the modeling domain. Details on the formulation of the CAMx PSAT source apportionment can be found in the CAMx user's guidance (ENVIRON, 2006; www.camx.com).

5.4.1 Definition of CENRAP 2002 and 2018 PM Source Apportionment Modeling

PSAT calculated PM source apportionment for user defined source groups. Source groups are usually defined by specifying a source region map of geographic regions where source contributions are desired and providing source categories as input so that source group would consist of a geographic region plus source category (e.g., on-road mobile source emissions from Oklahoma). Although other source group configurations and even individual sources may be specified. For the CENRAP PSAT application, a source region map was used that divided up the modeling domain into 30 geographic source regions as shown in Figure 5-8. The 2002 and 2018 emissions inventories were divided into six source categories. The 30 geographic source regions consisted of CENRAP and nearby states, with Texas divided into 3 regions, remainder of the western and eastern States, Gulf of Mexico, Canada and Mexico. The original intent of the CENRAP PSAT analysis was to obtain separate contributions due to on-road mobile, non-road mobile, area, natural, EGU point and non-EGU point sources. However, the CAMx emissions for the PSAT runs were based on the CMAQ pre-merged 3-D emission files. Since all point sources were contained in a single CMAQ pre-merged emissions file, then the separate source apportionment modeling of EGU and non-EGU point sources was not possible. The six source categories that were separately tracked in the PSAT PM source apportionment modeling were:

- Elevated point sources;
- Low-level point sources (i.e., point source emissions emitted into layer 1 of the model);
- On-Road Mobile Sources;
- Non-Road Mobile Sources;
- Area Sources; and
- Natural Sources.

Natural Sources included biogenic VOC and NOx emissions from the BEIS3 biogenic emissions model, emissions from wildfires and emissions from wind blown dust due to non-agriculture land use types.

PM source apportionment in PSAT is available for five families of PM tracers: (1) Sulfate; (2) Nitrate and Ammonium; (3) Secondary Organic Aerosols (SOA); (4) Primary PM; and (5) mercury. The CENRAP PSAT 2002 and 2018 applications used three of the PSAT families of tracers and did not use the SOA and mercury families. For SOA, the standard CAMx model output was used that partitions SOA into an anthropogenic (SOAA) and biogenic (SOAB) components.

The PSAT results were extracted at the CENRAP and nearby Class I areas and the contributions for the average of the worst 20 percent and best 20 percent days were processed. A PSAT Visualization Tool was developed that can be used by States, Tribes and others to generate displays of the contributions of source regions and categories to visibility impairment for the average of the worst 20 percent and best 20 percent days at each CENRAP and nearby Class I areas.

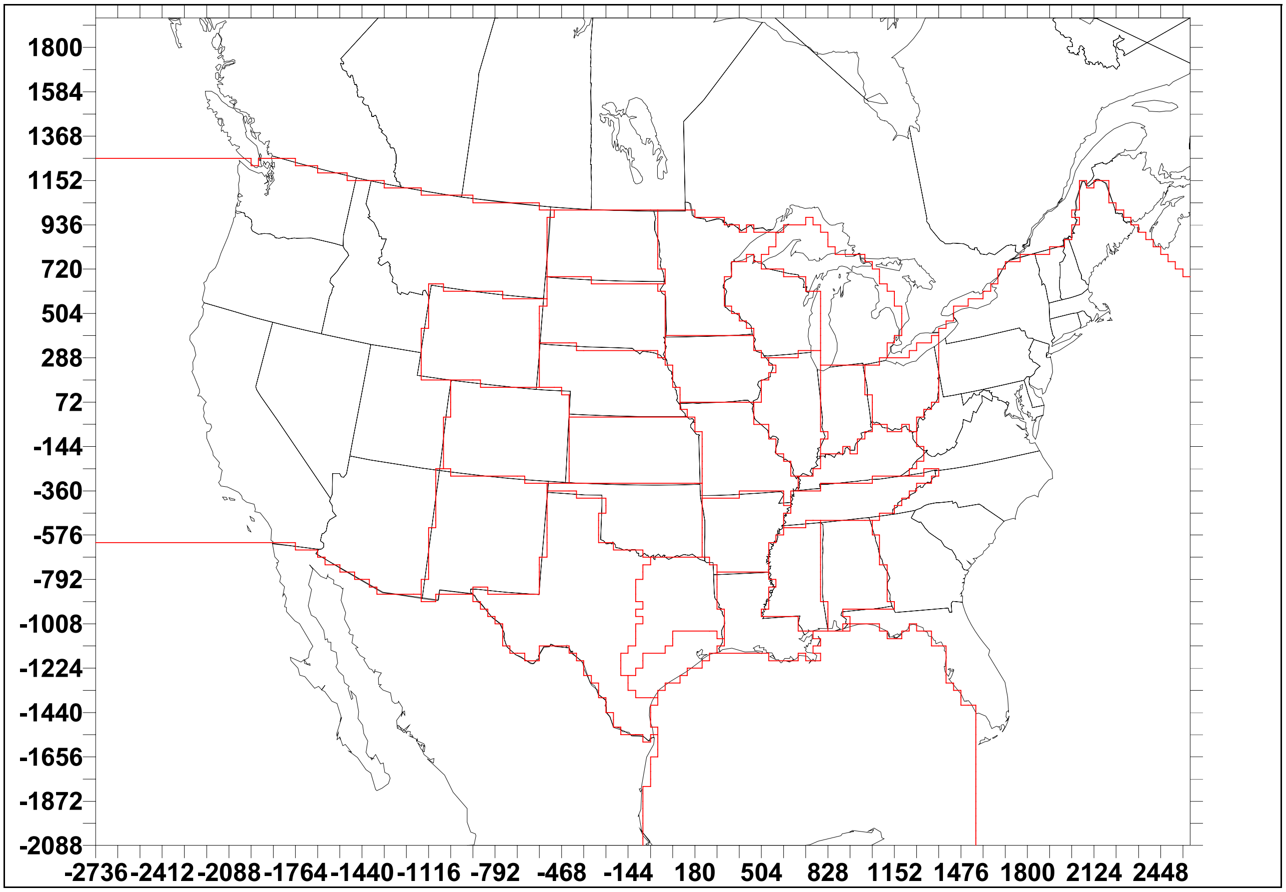


Figure 5-8. 30 source regions used in the CENRAP 2002 and 2018 CAMx PSAT PM source apportionment modeling.

5.4.2 CENRAP PSAT Visualization Tool

The PSAT Visualization Tool allows CENRAP States, Tribes and others to visualize the CENRAP 2002 and 2018 PSAT modeling results and identify which source regions, categories and PM species are contributing to visibility impairment at Class I areas for the average of the worst 20 percent and best 20 percent visibility days. The Visualization Tool is currently available on the CENRAP website (http://www.cenrap.org) under Projects. The Tool can generate bar charts of source contributions at Class I areas. It can be run in a receptor oriented mode where it identifies the contributions of PM species and source regions and categories to visibility impairment on the worst and best 20 percent days. It can also be run in a source oriented mode to examine an individual source region's (State's) contribution to visibility impairment at downwind Class I areas on the worst and best 20% days. The original IMPROVE equation is used to convert the PM species concentrations to extinction.

There are 14 air quality analysis metrics in the Tool:

> W20% Modeled Bext: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area estimated by the model averaged across the worst 20 percent days in 2002.

W20% Projected Bext: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area projected by the model averaged across the worst 20 percent days in the 2000-2004 Baseline.

W20% Modeled USAnthro: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area for just U.S. anthropogenic emission source categories estimated by the model averaged across the worst 20 percent days in 2002.

W20% Projected USAnthro: The source region, source category and PM species contributions to the extinction (Bext) at a Class I area for just U.S. anthropogenic emission source categories projected by the model averaged across the worst 20 percent days in the 2000-2004 Baseline.

Emissions: Emissions by source region, source category and PM precursor. Precursors include SOx, NOx, primary organic aerosol (POA), primary elemental carbon (PEC) other primary fine particulate (FCRS+FPRM) and coarse mass (CCRS+CPRM). Emissions for four days have been extracted and implemented in the Tool.

Control Effectiveness: Control effectiveness is defined as the PM contribution divided by the emissions of the primary precursor. For example the SO4 contribution divided by the SO2 emissions.

Visualization Tool results are available for visibility contributions on both an absolute (Mm^{-1}) and percentage basis. When looking at contributions at a given Class I area, contributions can be examined in terms of PM species, source regions and/or source categories. Results are available for both the current year (2002 modeled or 2000-2004 projected) and future year (2018). The “2002 W20% Project Bext” metric applies the 2002 PSAT modeled source apportionment to the observed 2000-2004 Baseline extinction keeping the relative contributions of source groups to each PM species (e.g., SO4, NO3, etc.) the same averaged across the 2002 worst 20 percent days but scaling their magnitudes up or down based on the ratio of the 2000-2004 Baseline to the 2002 modeling results. Similarly, the “2018 W20% Projected” metric uses the relative contributions of the 2018 PSAT results from each source group and scales them according to the differences in the 2018 projected PM species to the 2018 modeled PM species for the average of the worst 20 percent days. The US Anthropogenic metrics just include source groups associated with U.S. man-made emissions (i.e., non-Natural source categories from states and Gulf of Mexico source regions) so excludes contributions from Canada and Mexico, Boundary Conditions, SOA from biogenic sources and the natural source category (biogenic NOx, wildfires and wind blown dust).

5.4.3 Source Contributions to Visibility Impairment at Class I Areas

Appendix E displays example contributions of PM species, source regions and source categories to visibility impairment for the worst and best 20 percent days at the CENRAP Class I areas. Some of the results from Figure E-1 for the CACR Class I area are reproduced in Figures 5-9, 5-10 and 5-11 below.

5.4.3.1 Caney Creek (CACR) Arkansas

2002 visibility impairment for the worst 20 percent days at CACR is primarily due to SO4 from elevated point sources that contributes over half (66.3 Mm^{-1}) of the total extinction of 118.8 Mm^{-1} (Figure E-1a and 5-8 left). By 2018, the total extinction at CACR for the worst 20 percent days is reduced by approximately one third (38.5 Mm^{-1}) which is primarily due to reductions in SO4 extinction from elevated point sources (from 66.3 to 37.3 Mm^{-1}) as well as reductions in visibility impairment from on-road and non-road mobile sources. Even with such large reductions in SO4 from point sources in 2018, extinction due to elevated point sources is still the highest contributor to visibility impairment on the worst 20 percent days contributing over half (41.8 Mm^{-1}) of the total extinction in 2018 of 80.3 Mm^{-1}, with area sources the next most important source category contributing 16.0 Mm^{-1} (~20%).

The geographic source apportionment for the worst 20 percent says at CACR is shown in Figures 5-10, E-1c and E-1d. Elevated point sources from the eastern source region is the largest contributor in 2002 contributing almost 18 Mm^{-1} that is reduced by over a factor of three in 2018 to approximately 5 Mm^{-1}. By 2018, Arkansas is the largest contributor to extinction at CACR for the 20 percent worst days followed by East Texas, the large Eastern U.S. region and then SOA due to biogenic sources. Figures E-1e ranks the source group contributions to extinction on the worst 20 percent days at CACR with Elevated Point Sources from East Texas being the highest contributor to total extinction, similar results are seen when examining extinction at CACR for the worst 20 percent days due to just SO4 and NO3 (Figure E-1f).

For the best 20 percent days at CACR (Figures 5-11, E-1g-j), SO4 is still a major contributor but no where near as dominate as seen for the worst 20 percent days, but elevated point is still the largest contributing source category Local contributions from within Arkansas contribute the most to the average of extinction across the best 20 percent days at CACR.

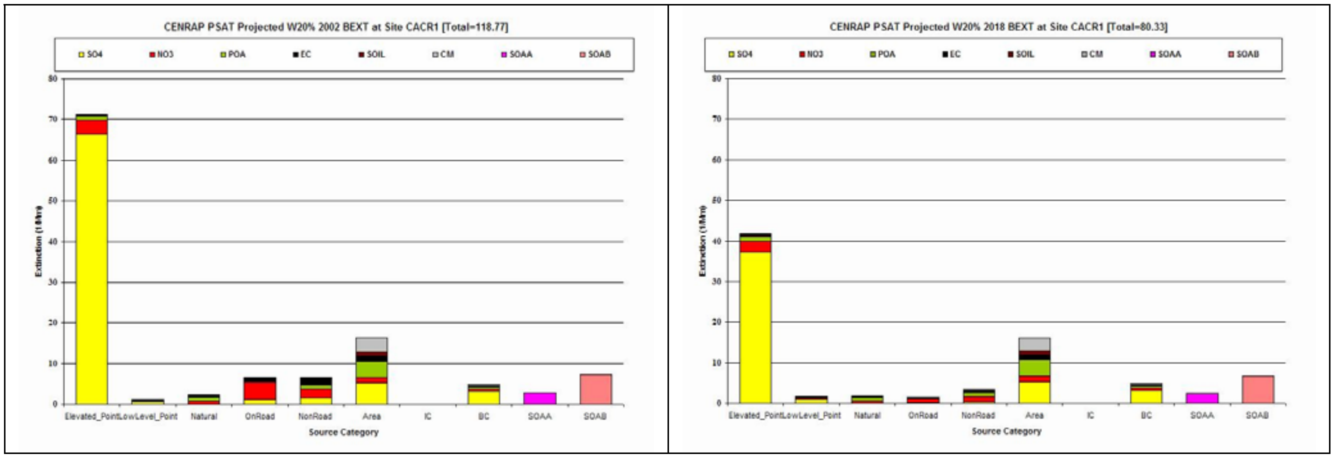


Figure 5-9. PSAT source category by PM species contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the worst 20 percent visibility days at Caney Creek (CACR), Arkansas.

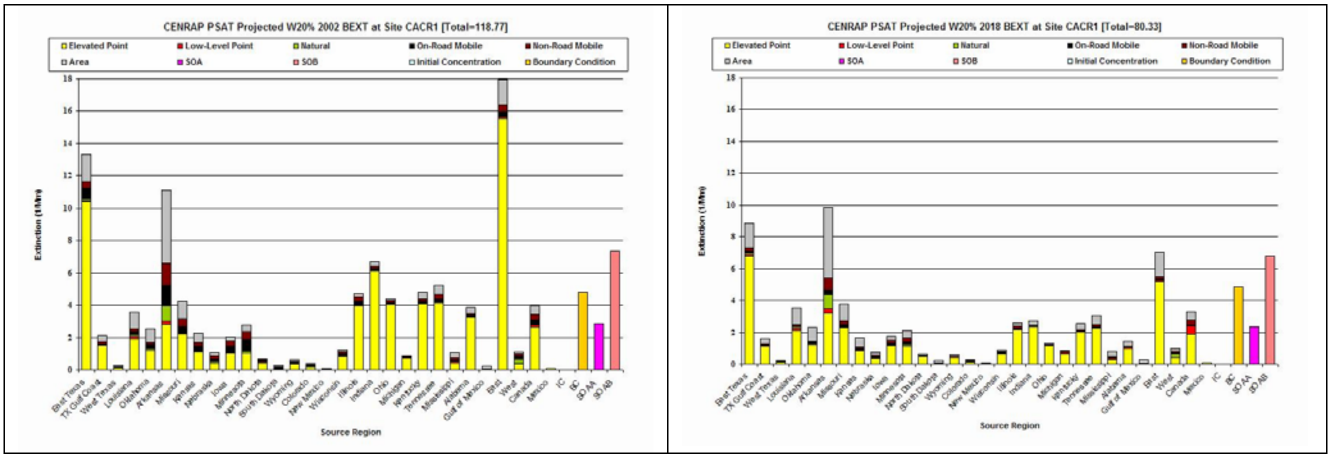


Figure 5-10. PSAT source region by source category contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the worst 20 percent visibility days at Caney Creek (CACR), Arkansas.

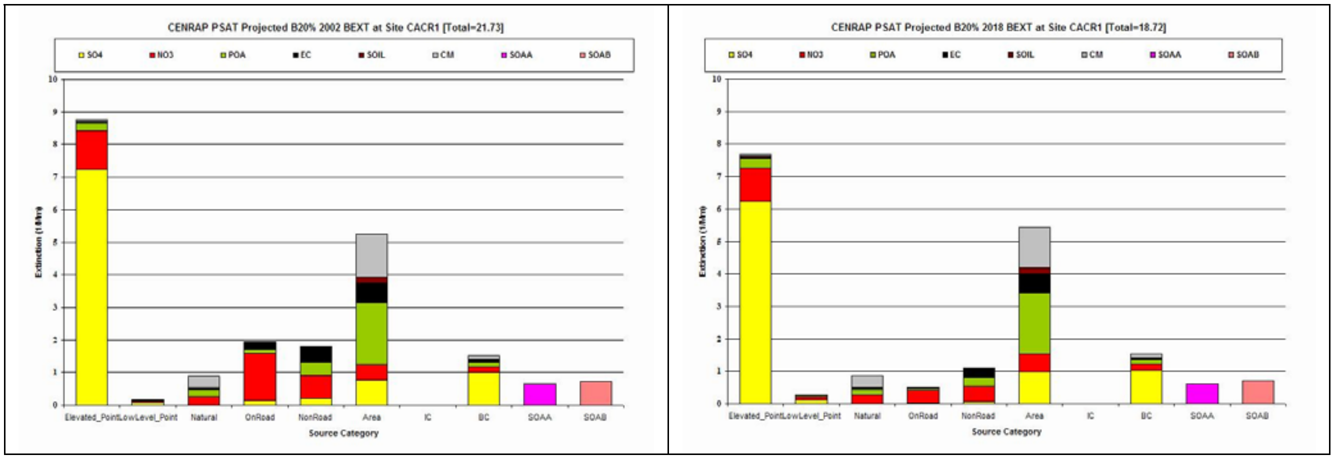


Figure 5-11. PSAT source category by PM species contributions to the average 2000-2004 Baseline and 2018 projected extinction (Mm^{-1}) for the best 20 percent visibility days at Caney Creek (CACR), Arkansas.

5.4.3.2 Upper Buffalo (UPBU) Arkansas

The contributions to extinction on the worst 20 percent days at UPBU (Figure E-2) is similar to CACR only with less contributions from East Texas and more from Missouri, Illinois and Indiana. By 2018, the top five highest contributing source groups to the average extinction on the worst 20 percent days are as follows: Arkansas Elevated Point; SOA from biogenics; Boundary Conditions, East Elevated Points, and Illinois Elevated Points (Figure E-2e). On the best 20 percent days at UPBU visibility impairment is primarily due to Arkansas and adjacent states Oklahoma, Missouri, and Kansas).

5.4.3.3 Breton Island (BRET) Missouri

Visibility impairment for the worst 20 percent days at Breton Island is primarily (69%) due to elevated point sources that contribute 77.7 Mm^{-1} out of a total of 122.2 Mm^{-1} (Figure E-3a). Although the contribution of elevated point sources is reduced substantially by 2018, they still contribute over half of the total extinction (101.1 Mm^{-1}) on the worst 20 percent days at BRET (Figure E-3b). The top five contributing source groups to 2018 visibility impairment at BRET for the worst 20 percent days are: Louisiana Elevated Point Sources; Boundary Conditions; East Elevated Point Sources; Gulf of Mexico Area Sources and Louisiana Area Sources. Gulf of Mexico Area sources includes off shore shipping and oil and gas development emissions; note that for the PSAT simulation the off-shore marine shipping emissions were double counted which was corrected in the Base G emission scenarios used in the 2018 visibility projections discussed in Chapter 4.

5.4.3.4 Boundary Waters (BOWA) Minnesota

As seen for the other Class I areas, elevated point sources contribute the largest amount (47%) to visibility impairment at BOWA for the worst 20 percent days in 2002 (Figure E-4a). However, unlike many of the other Class I areas, there is little reductions (~10%) in the elevated point source contributions going from 2002 (29.0 Mm^{-1}) to 2018 (26.2 Mm^{-1}) (Figures E-4a and E-4b). This is because there is a slight increase in the contributions of elevated point sources in Minnesota from 2002 to 2018 (Figures E-4c and E-4d) that is the highest contributing source group (Figure E-4e). Note that the 2018 emission scenario includes growth and CAIR controls but no BART controls. For the best 20 percent days, the largest contributing source group by far is Boundary Conditions (i.e., global transport) followed by Minnesota and Canada (Figures E-4g-j).

5.4.3.5 Voyageurs (VOYA) Minnesota

Results for VOYA are similar to BOWA with Minnesota, Canada and Boundary Conditions contributing the most to visibility impairment on the worst and best 20 percent days (Figure E-5).

5.4.3.6 Hercules Glade (HEGL) Missouri

Elevated point sources contribute over half to the total extinction for the worst 20 percent days at HEGL in 2002 (Figures E-6a and E-6b). Going from 2002 to 2018 the contributions due to elevated point sources, on-road mobile and non-road mobile are reduced substantially, but the contributions due to the other sources remain unchanged. The largest source group contributing to visibility impairment on the worst 20 percents days is area sources from Missouri in both 2002 and 2018 (Figures E-6c and E-6d). Since area emissions are not reduced much between 2002 and 2018 and Missouri elevated point sources are mostly unchanged because the IPM model assumed Missouri CAIR sources would buy credits, then the Missouri contributions is only reduced a little going from 2002 to 2018 (from ~18 Mm-1 to ~16 Mm-1). However, the contributions due to the Eastern U.S., Illinois and Indiana are reduced substantially. Missouri is by far the largest contribution to visibility impairment at UPBU on the best 20 percent days as well with area sources from Missouri being the largest source category (Figures E-6h through E-6j).

5.4.3.7 Mingo (MING) Missouri

The substantial improvements in visibility impairment at MING for the worst 20 percent days from 2002 (141 Mm^{-1}) to 2018 (96 Mm^{-1}) is primarily due to reductions in SO4 from non-Missouri elevated point sources (Figures E-7a through E-7d). Even so, with the exception of the top contributing Missouri area sources the largest contributing source groups to 2018 visibility impairment for the worst 20 percent days are still elevated point sources from several CAIR states (Illinois, Indiana, Missouri, East; Figure E-7e). Missouri is the largest contributor to visibility on the best 20 percent days followed by Boundary Conditions and Illinois (Figure E-7i-j).

5.4.3.8 Wichita Mountains (WIMO) Oklahoma

Elevated point sources are the largest contributors to visibility impairment on the worst 20 percent days at WIMO in both 2002 and 2018 (Figures E-8a and E-8b). East Texas followed closely by Oklahoma are the largest contributing source regions in 2002, but by 2018 the reverse is true (Figures E-8c and E-8d). By 2018 the largest contributing source group to visibility impairment on the worst 20 percent days at WIMO is global transport (i.e., boundary conditions) followed by Oklahoma Area Sources and East Texas Elevated Point sources (Figure E-8e). Oklahoma Area Sources is the largest contributor to visibility impairment on the best 20 percent days at WIMO (Figures E-8g-j).

5.4.3.9 Big Bend (BIBE) Texas

Elevated point sources (~17 Mm^{-1}) followed by Boundary Conditions (~12 $Mm^{-}1$) are the largest contributions to total extinction (46 Mm^{-1}) on the worst 20 percent days at BIBE in 2002 (Figure E-9a). In 2018 there is very little (~2 Mm^{-1}) reduction in the contributions of elevated point sources and no reductions in global transport resulting in little reductions (~7%) in visibility impairment on the worst 20 percent days from 2002 (46 Mm^{-1}) to 2018 (43 Mm^{-1}). This is due to the extremely large contributions of emissions from Mexico in both 2002 (Figure E-9c) and 2018 (Figure E-9d). In fact, the four highest contributing source groups to visibility impairment at BIBE for the worst 20 percent days are assumed to be unchanged from 2002 to 2018: Boundary Conditions, Mexico Elevated Points, West Texas Natural and Mexico Natural (Figure E-9e). For the best 20 percent days at BIBE, West Texas, Mexico and Boundary Conditions are the highest three contributors to visibility impairment (Figures E-9g-j).

5.4.3.10 Guadalupe Mountains (GUMO) Texas

The large contribution of CM to visibility impairment at GUMO is clearly evident in the source apportionment modeling results (Figures E-10a-b). These sources are about evenly divided in the modeling between natural sources and area sources. Since these source categories are not reduced in the future year then there is little reduction in extinction from 2002 to 2018 (50 to 45

Mm^{-1}) and what reductions there are come from Elevated Point Sources. Sources in West Texas, Mexico, Boundary Conditions and New Mexico are the largest contributing source regions for both the worst 20 percent days (Figure E-10c-e) and best 20 percent days (Figures E-10g-j).

5.5 Alternative Visibility Projection Procedures

In this section we analyze several alternative visibility projection procedures from the EPA's default approach (EPA, 2007a) used in Chapter 4.

5.5.1 Treatment of Coarse Mass and Soil

As noted previously, much of the coarse mass (CM) and, to a lesser extent, Soil measured at the IMPROVE monitor is likely due to local wind blown dust that is natural in origin and not captured by the model. Consequently, even using the modeling results in a relative sense with the RRFs may not be appropriate for projecting CM and Soil. If CM and Soil are in fact local impacts due to wind blown dust from natural lands, then it would be appropriate to assume they are natural and remain unchanged from the 2000-2004 Baseline to 2018. This is probably certainly appropriate for CM because CM is primarily due to fugitive dust and it has a very short transport distance that is subgrid-scale to the model. In fact the model evaluation discussed in Chapter 3 and Appendix C clearly shows a large underprediction bias for CM that is likely due to local fugitive dust impacts at the IMPROVE monitor. For Soil this is less clear as fine particles can be transported over longer distances and is produced by anthropogenic sources, such as combustion and road dust, as well as natural sources. We initially performed two CM and Soil sensitivity tests, the first assumed CM was all natural so remains unchanged from the 2000-2004 Baseline to 2018 (i.e., set the RRF for CM equal to 1.0). The second sensitivity test assumed both CM and Soil were natural so set RRFs for both of them to 1.0. A comment from an FLM noted that we know some of the Soil is likely anthropogenic in origin. So it was suggested to subtract the 2002 base case modeled Soil from the observed values for the 2002 worst 20 percent days and assume that the remainder (if any) was natural so hold the rest of the Soil constant in 2018 and add to the 2018 modeled Soil values.

The results of the CM and Soil visibility projection sensitivity analysis are shown in the DotPlot in Figure 5-12. The CM and Soil visibility projection sensitivity analysis has little effect on the 2018 visibility projections at the CENRAP Class I areas. Even GUMO, which has a large CM and Soil component, shows very little sensitivity. This is probably because the CM at GUMO is likely dominated by wind blown dust that was assumed constant from 2002 to 2018 so the RRF calculated using the default EPA method is near 1.0 anyway. Some larger sensitivity is seen at several WRAP Class I areas. It is encouraging that CENRAP 2018 visibility projections are not sensitive to the CM and Soil components of the modeling which are highly uncertain.

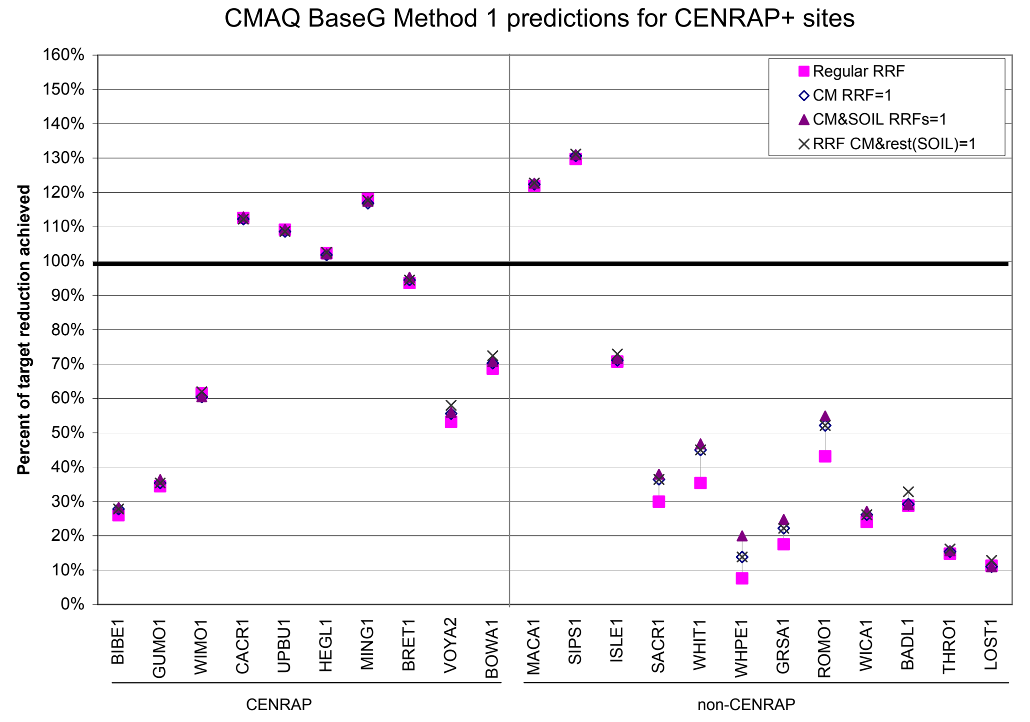


Figure 5-12. Sensitivity of 2018 visibility projections to various methods that assume all CM, all CM and Soil and all CM and part of the Soil is natural.

5.6 Alternative Model

The CAMx model was also run for a 2002 and 2018 base case scenarios with earlier versions of the CENRAP emissions (Base E modified to eliminate double counting of some area fire emissions) than the final CMAQ 2002 Base G modeling. The CAMx 2002 and 2018 output was processed the same way that the CMAQ results were to generate 2018 visibility projections at the CENRAP and nearby Class I areas that were compared with the 2018 URP point. Figure 5-13 summarizes the CAMx 2018 visibility projections using the new IMPROVE algorithm (NIA) in a DotPlot and compares them with the CMAQ 2018 Base G results (from Figure 5-12). The CMAQ and CAMx 2018 visibility projections are remarkably similar. The four Arkansas and Missouri Class I areas are projected to achieve the 2018 URP point by almost the exact same amount by the two models. The two Texas Class I areas are projected to come up short of achieving the 2018 URP point by the same amount by the two models. The largest differences are seen at BRET, and to a lesser extent BOWA and VOYA. At BRET the CAMx 2018 visibility projections are much less optimistic (< 80%) in achieving the 2018 URP point than CMAQ (> 90%). And CMAQ is slightly less optimistic than CAMx in achieving the 2018 URP point for the two northern Minnesota Class I areas. The reasons for these differences are unclear but could be partially due to the emissions updates in the final CMAQ Base G run that included eliminating the double counting of off-shore marine emissions in the Gulf of Mexico that was present in the CAMx simulation, which makes it more difficult to get visibility improvements at BRET since it is influenced by sources in the Gulf. Corrections to stack parameters for Canadian point sources were also made for the final Base G. The general close agreement of the CAMx 2018 visibility projections to the final CMAQ values is encouraging and good QA check.

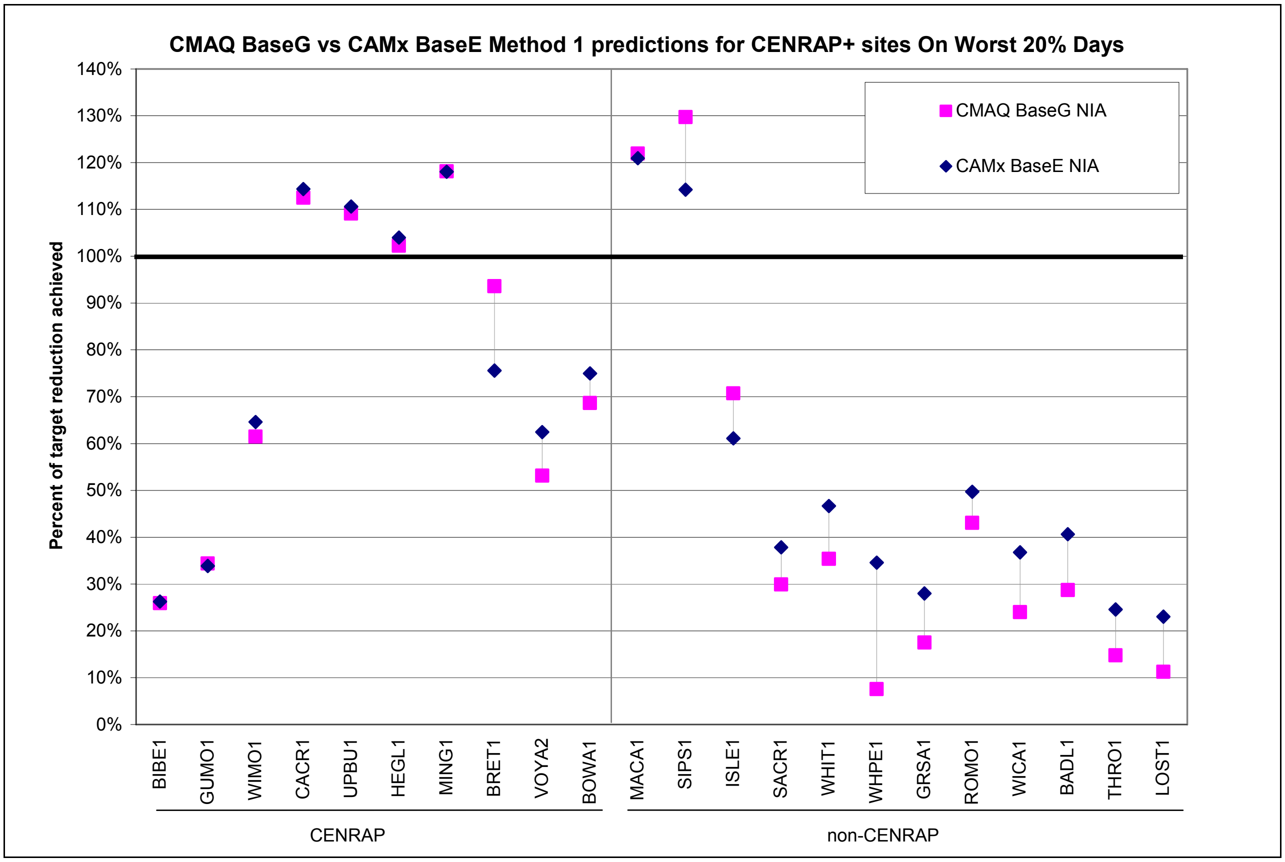


Figure 5-13. Comparison of CAMx 2018 visibility projections with 2018 URP points for CENRAP and nearby Class I areas.

5.7 Effects of International Transport on 2018 Visibility Projections

As seen in the PM source apportionment modeling discussed in Section 5.4, there is significant contributions of international sources to visibility impairment at many CENRAP Class I areas for the worst 20 percent days. With the exception of Canada, where we used a year 2000 inventory for the 2002 base case modeling and a 2020 inventory for the 2018 inventory, international sources were assumed to be constant between 2002 and 2018. Thus, Class I areas that are heavily impacted by contributions of international transport will have a difficult time achieving the 2018 URP point since international sources are assumed to remain constant. The CAMx PSAT runs discussed previously provide a framework for quantitatively assessing the contributions of international transport to the visibility projections and whether reasonable progress toward natural conditions is being achieved in the 2018 modeling.

There are several source regions (Figure 5-8) and source categories in the PSAT modeling that include international sources:

- Mexico Anthropogenic Sources (assumed all international);
- Canada Anthropogenic Sources (assumed all international);
- Gulf of Mexico (assumed all U.S. sources);
- Pacific and Atlanta Ocean (assumed all U.S. sources); and
- Boundary Conditions (assumed half international and half natural sources).

Although it can be argued that Mexico and Canada are not truly international due to the presence of numerous U.S. corporations in Mexico along with free trade among the two countries, states and federal government have no jurisdiction to regulate industry in these two countries so they are considered international in these calculations. The Gulf of Mexico includes off-shore oil and gas production facilities, support vessels and aircraft and off-shore marine shipping. Given that emissions from the oil and gas production can be regulated by the U.S., then the Gulf of Mexico is not considered an international source. Emissions from off-shore shipping in the Pacific and Atlantic Oceans are also currently not regulated by the U.S. government. However, there are current efforts to apply some regulations to these emissions so for these calculations they were not assumed to be international sources. Finally, the Boundary Conditions (BCs) for the CENRAP modeling were generated from a 2002 simulation of the GEOS-CHEM global chemistry model and held constant in 2018. These BCs would include contributions from international sources as well as natural sources, so need to be split. For the sensitivity calculations discussed below we assumed that the BCs were half due to natural and half due to international sources. This results in international sources being defined as follows:

International Contribution = Mexico Anthro + Canada Anthro + ½ BCs

Two methods were examined to see what the effects of international sources on 2018 visibility projections and a Class I areas ability to achieve the 2018 URP point:

> Elimination of International Contributions to 2018 Visibility Projections: In this method the contribution of international emissions is taken out of the 2018 visibility projections and examined to see whether the new visibility projection achieves the URP point. If so, then international sources are hindering a Class I area in achieving the 2018 URP point, which suggests that the 2018 URP point is not a reasonable value for an RPG.
>
> Visibility Projections and Glidepaths Based on Controllable Visibility Impairment: The second method would look at the visibility projections for just the U.S. controllable portion of the visibility impairment. The glidepath end point in 2064 would be to eliminate the U.S. man-made contributions to visibility impairment on the worst 20 percent days.

Note that this analysis is performed solely for providing states and others additional information on which Class I areas the modeling suggest are unduly influenced by International Transport.

5.7.1 Elimination of International Contributions to 2018 Visibility Projections

This method was also discussed in a recent technical brief prepared by the Electric Power Research Institute (EPRI), only in EPRI's analysis they used results from a global chemistry model and VISTAS CMAQ runs with no global anthropogenic emissions (EPRI, 2007). Thus, before discussing our results of this analysis using PSAT, we discuss EPRI's analysis.

5.7.1.1 EPRI's Analysis of Effects of International Contributions

EPRI funded Harvard University to perform annual simulations of the GEOS-Chem global chemistry model (http://www-as.harvard.edu/chemistry/trop/geos/) for annual simulations with and without non-U.S. anthropogenic emissions to determine the contributions of international transport to PM and visibility. The EPRI Harvard GEOS-Chem simulations were performed for 2001. Figure 5-14 and 5-15 compare the annual average ammonium sulfate, ammonium nitrate organic mass carbon (OMC, also called OCM) and elemental carbon (EC) due to the GEOS-Chem global modeling and the CAMx PSAT source apportionment modeling. The similarity of the results for ammonium sulfate is remarkable (Figure 5-14). Both methods estimate that the annual average ammonium sulfate contribution due to international sources ranges from 0.4 to 1.0 µg/m^3 across the Class I areas. There is less agreement between the two methods for ammonium nitrate due in part to a CAMx overestimation issue that is likely due in part to how ammonia emissions were classified as being anthropogenic or not in the no U.S. anthropogenic emissions simulations (Figure 5-15). Better agreement is seen between the two methods international contributions of OMC and EC, although CAMx estimates higher contributions than GEOS-Chem.

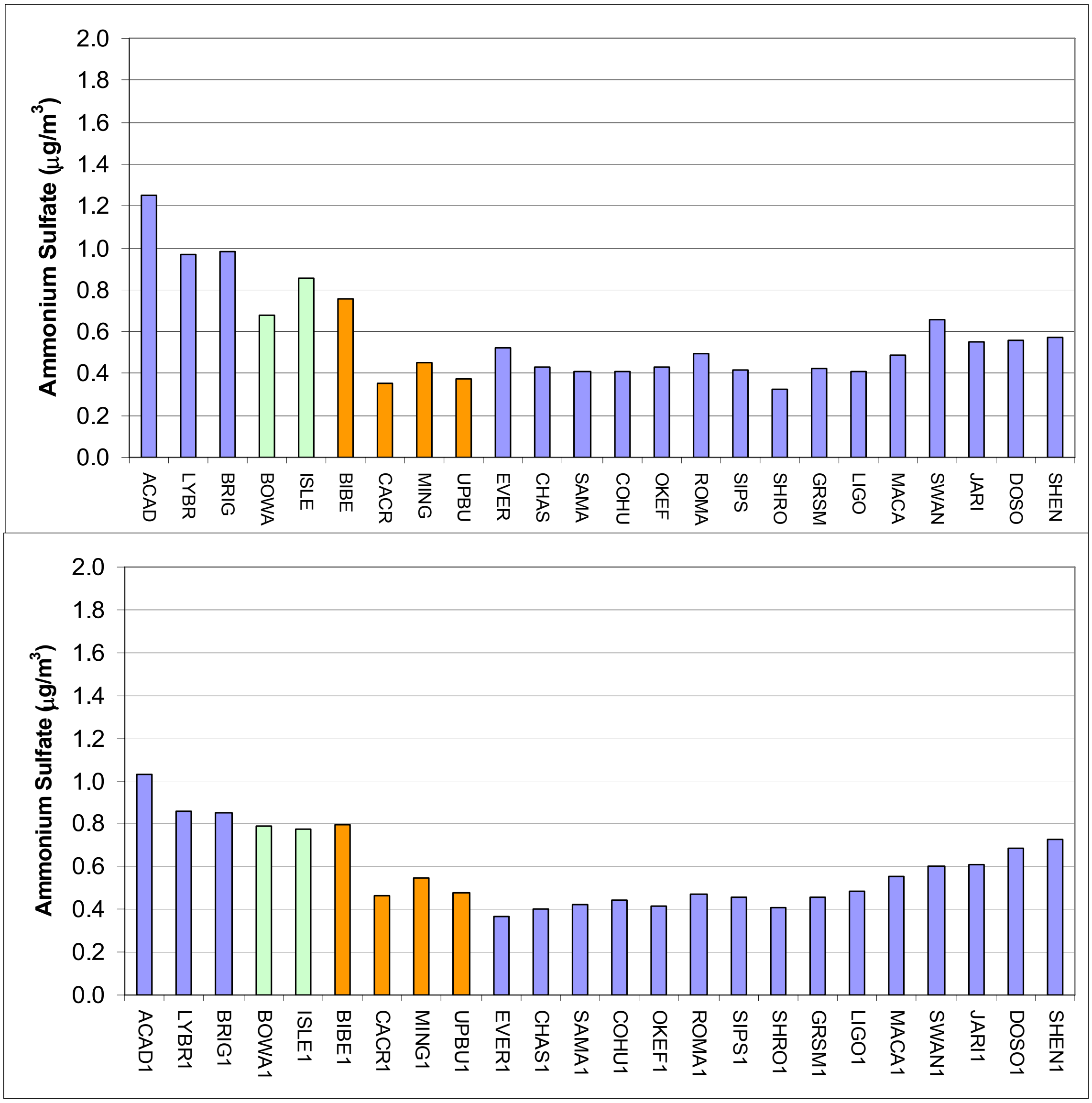


Figure 5-14. Comparison of EPRI Harvard GEOS-Chem global chemistry (top) and CENRAP PSAT (bottom) international source contributions to ammonium sulfate at Class I areas.

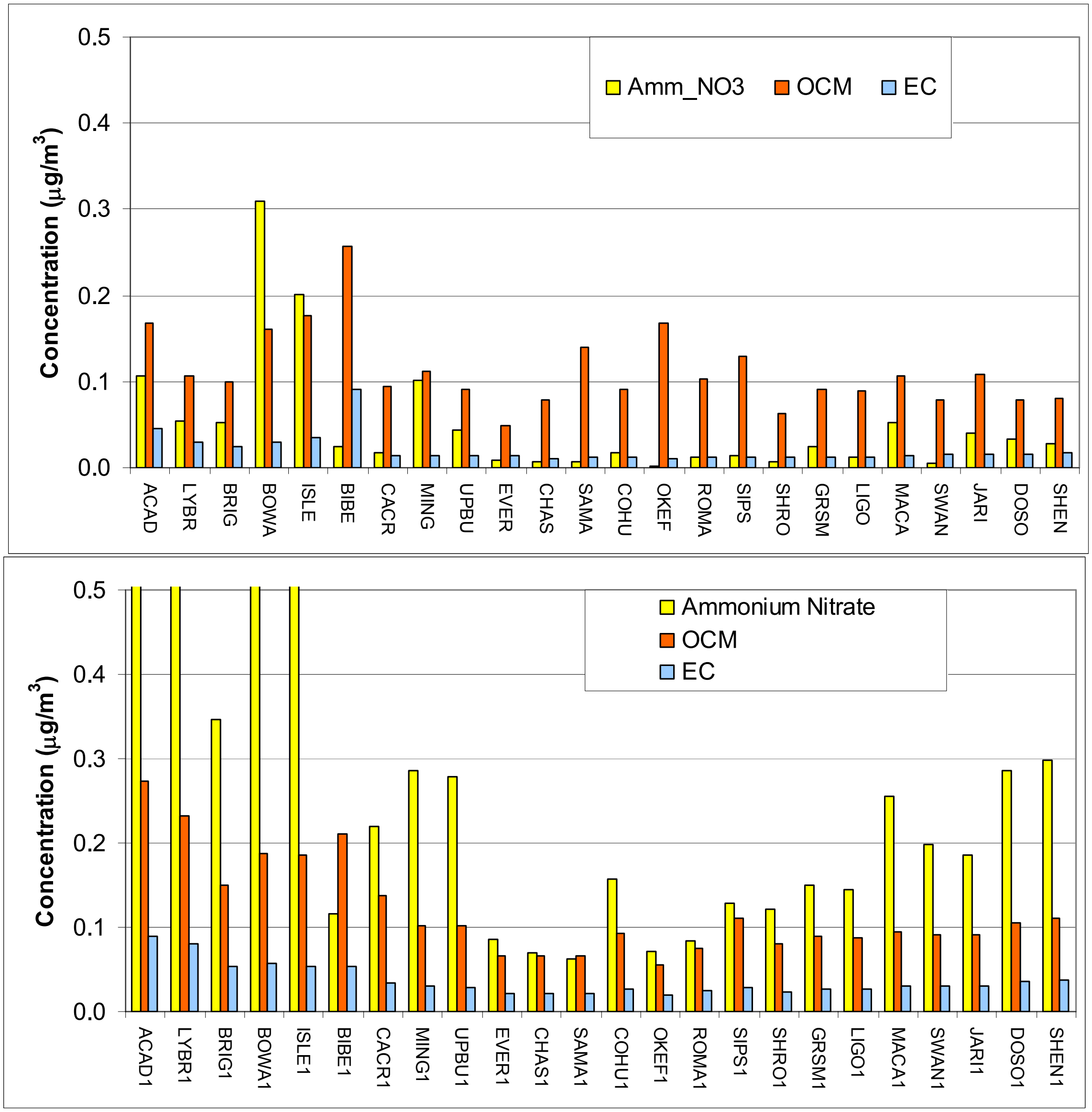


Figure 5-15. Comparison of EPRI Harvard GEOS-Chem global chemistry (top) and CENRAP PSAT (bottom) international source contributions to ammonium nitrate, organic carbon mass (OCM or OMC) and elemental carbon (EC) at Class I areas.

The EPRI technical brief used the VISTAS CMAQ runs to adjust the modeled 2018 visibility projections to eliminate the effect of international transport and compared them to the 2018 URP point. For the Boundary Waters, Voyageurs, Isle Royal and Seney Class I areas the standard 2018 visibility projections did not achieve the 2018 URP point. However, when the effect of transboundary pollutions was removed the 2018 URP point was essentially achieved or more than achieved at all four Class I areas.

5.7.1.2 CENRAP Results From Elimination International Transport

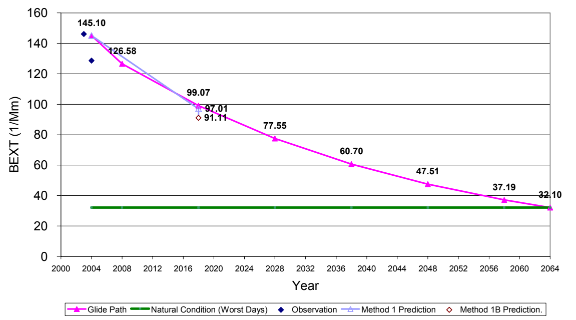
Because the elimination of the international sources from the 2018 visibility projections results in a portion of the total light extinction, then these comparisons with the 2018 URP points were done using extinction glidepaths and projections rather than deciview. In Section 5.2.1 we demonstrated that the level of achieving the 2018 URP point was almost identical at CENRAP Class I areas whether the linear deciview or curved extinction glidepaths were used. The PSAT source apportionment was used to determine the contribution to the projected extinction in 2018 due to international sources. As noted above, international sources were assumed to be due to anthropogenic emissions in Mexico and Canada and half of the Boundary Conditions.

Figure 5-16 shows the standard CAMx extinction glidepaths and 2018 visibility projections and the 2018 visibility projections when the contributions of international sources is eliminated. CACR, which achieved the 2018 URP point by 104%, achieves it by even more when international sources are eliminated (117%). UPBU that barely achieved the 2018 URP point by 102% achieves it by 116% without international emissions.

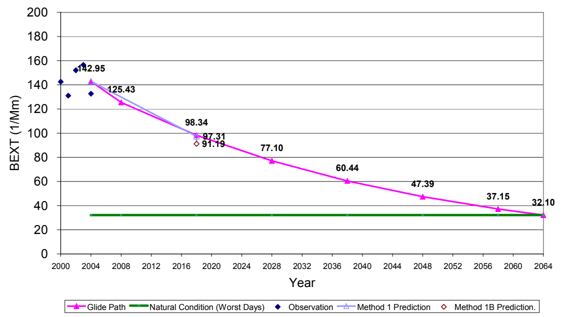
BRET comes up short of achieving the 2018 URP point when international emission are included (76%) as well as when they are eliminated (92%), although it is much closer (recall contributions of Gulf of Mexico to visibility impairment at BRET that is assumed in this analysis to be of U.S. origin). Eliminating international transport emissions makes of difference of meeting the 2018 URP point without them (120%) to not meeting it with them (64%) at BOWA. Similarly at VOYA the standard 2018 visibility projections do not achieve the 2018 URP point (54%), whereas it is achieved by a far margin when international sources are eliminated (132%).

HEGL comes up short achieving the 2018 URP point when international sources are included (95%), but achieves it when they are eliminated (107%). Recall the standard CAMx deciview visibility projections barely achieved the URP point even when international emissions are included (Figure 5-13). MING achieves the 2018 URP point with (106%) and without (116%) international sources. WIMO does not achieve the 2018 URP point when international contributions are eliminated.

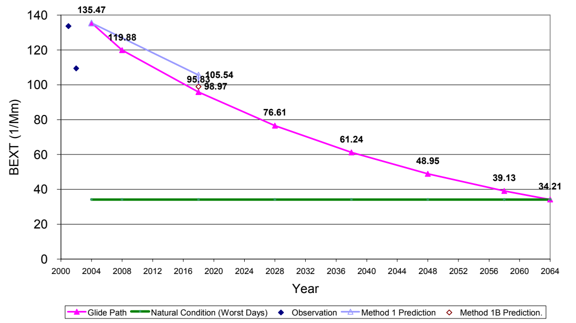
International sources have by far the largest effect at BIBE. Whereas the standard 2018 visibility projections only achieved 27% of the reductions needed to achieve the 2018 URP point, elimination of the international source contributions achieves 172% of the reduction needed. GUMO comes up short in achieving the 2018 URP point when international sources are included (31%), but achieves it when they are not (107%).



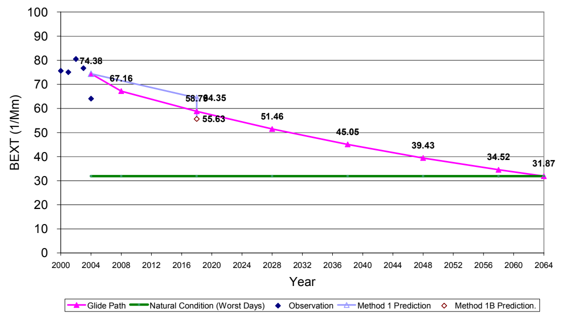
Uniform Rate of Reasonable Progress Glide Path
Caney Creek Wilderness - Worst 20% Days



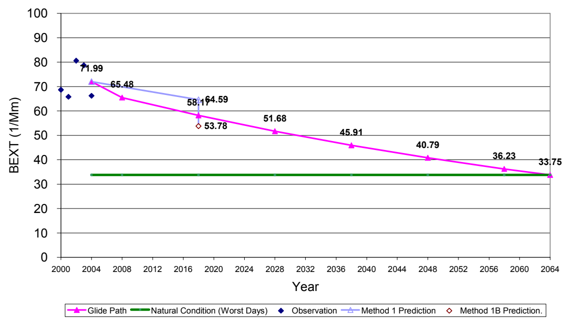
Uniform Rate of Reasonable Progress Glide Path
Upper Buffalo Wilderness - Worst 20% Days



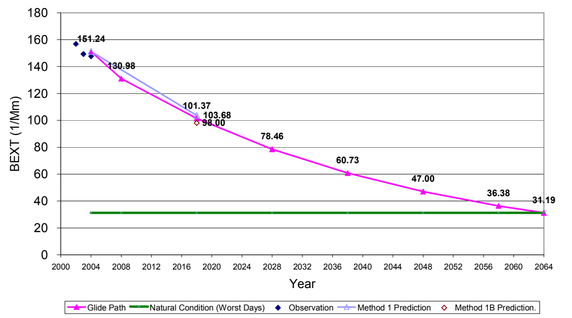
Uniform Rate of Reasonable Progress Glide Path
Breton - Worst 20% Days



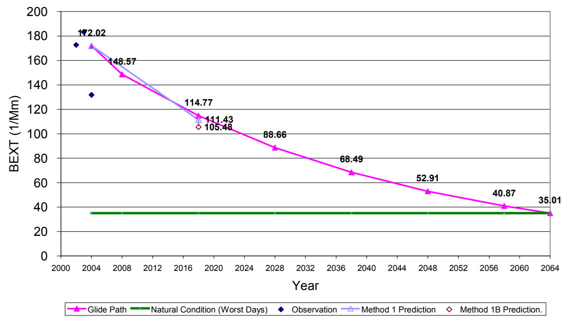
Uniform Rate of Reasonable Progress Glide Path
Boundary Waters - Worst 20% Days



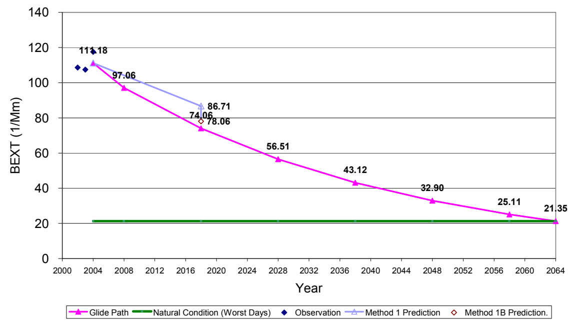
Uniform Rate of Reasonable Progress Glide Path
Voyageurs NP - Worst 20% Days



Uniform Rate of Reasonable Progress Glide Path
Hercules-Glades Wilderness - Worst 20% Days



Uniform Rate of Reasonable Progress Glide Path
Mingo - Worst 20% Days



Uniform Rate of Reasonable Progress Glide Path
Wichita Mountains - Worst 20% Days

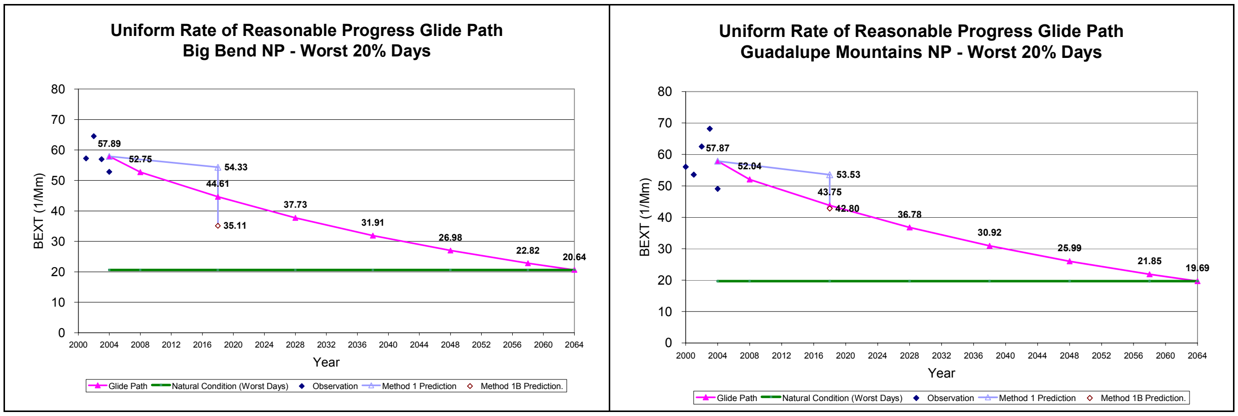


Figure 5-16. Elimination of international sources from 2018 visibility projections and comparison with 2018 URP point at CENRAP Class I areas.

5.7.2 Glidepaths Based on Controllable Extinction

Another alternative glidepath that was examined using the CAMx PSAT source apportionment results was based on the U.S. anthropogenic emissions contributions to visibility impairment on the worst 20 percent days at the CENRAP Class I areas. The RHR strives to achieve "natural visibility conditions" by 2064 and defines natural conditions as conditions that would exist "in the absence of human caused impairment". As shown above, anthropogenic emissions from international sources contribute significantly to visibility impairment at many of the CENRAP Class I areas making the RHR objective not practical if contributions from such sources are not reduced. Given that states and EPA have no jurisdiction over international sources, then we can not assume they will be controlled and have therefore held most of them constant at 2002 levels. For such Class I areas with high contributions from international sources, the comparison with the 2018 URP point is not very meaningful since the 2018 URP assumes such sources will be reduced. A more meaningful comparison would be to focus on the U.S. man-made contributions to visibility impairment at the Class I areas and develop a URP glidepath and 2018 URP point that is aimed at eliminating the U.S. anthropogenic emissions contributions to visibility impairment at Class I areas for the worst 20 percent days in 2064.

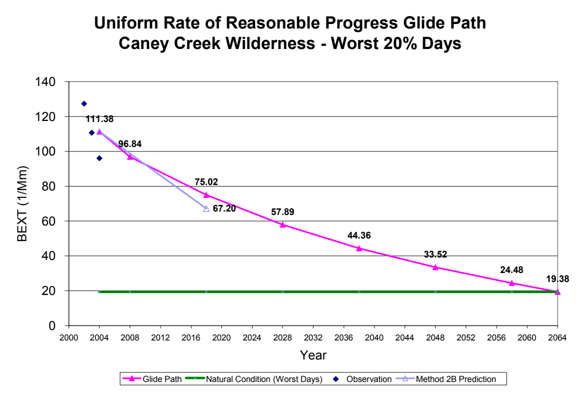
The CAMx 2002 base case PSAT PM source apportionment results were processed to identify the portion of the 2000-2004 Baseline extinction that was due to U.S. anthropogenic emissions (i.e., man-made sources). The contributions of source groups that included on-road mobile, non-road mobile, elevated point sources, low-level point sources and area sources from the PSAT source regions covering the U.S. states and Gulf of Mexico (Figure 5-8) were assumed to make up the U.S. anthropogenic contributions (i.e., excluding the Natural source category, all sources from the Mexico and Canada source regions and boundary conditions). Note that off-shore marine emissions in the Pacific and Atlantic Oceans and Gulf of Mexico were included in the U.S. anthropogenic emissions definition because they were in source regions associated with states or the Gulf of Mexico. As off-shore marine emissions may not be controllable by U.S. agencies and they were assumed to remain unchanged going from 2002 to 2018, then the 2018 visibility projections for the U.S. anthropogenic component are overstated.

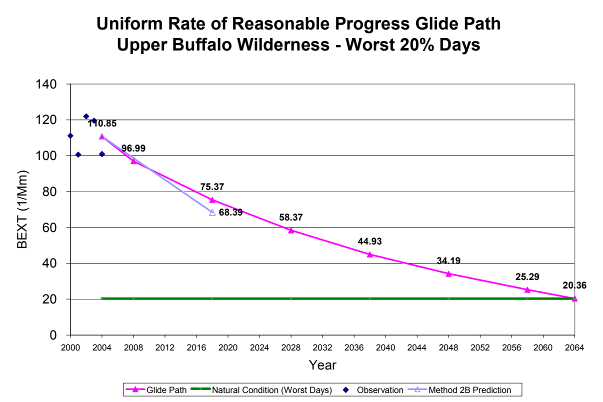
The 2064 objective for the U.S. anthropogenic emissions glidepath would be no contributions on the worst 20 percent days. This does not mean the 2064 U.S. anthropogenic extinction objective is zero, rather the U.S. anthropogenic plus natural background is less than the Natural Conditions for the worst 20 percent days. The PSAT results were used to define the natural background contributions on the current worst 20 percent days which was subtracted from the EPA default Natural Conditions to obtain the 2064 objective for the U.S. anthropogenic emissions contributions. Here the PSAT derived natural background was defined as the sum of the contributions from the Natural source category, secondary organic aerosol from biogenic sources (SOAB) and half of the boundary conditions. For example, Figure 5-17 top left displays the US anthropogenic emissions glidepath for CACR. The PSAT natural sources contribution (=Natural Source Category + SOAB + ½ BC) is approximately 13 Mm^{-1} so that is subtracted from the 2064 Natural Background (~32 Mm^{-1}, see figure 5-16) to obtain a 2064 end point of ~19 Mm^{-1} for the glidepath. The 2002 PSAT results applied to the 2000-2004 Baseline extinction estimates that 111 Mm^{-1} of the extinction is due to U.S. anthropogenic emissions which form the starting point for the glidepath. The curvature in the US anthropogenic glidepath is introduced the same way as for the extinction based glidepath to account for the logarithmic relationship between extinction and deciview.

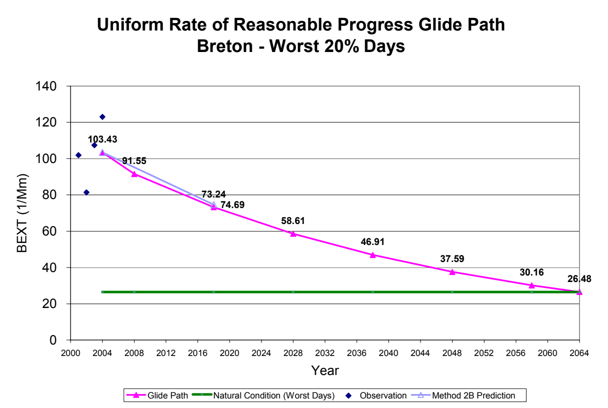
Figure 5-17 displays the U.S. anthropogenic emissions extinction glidepaths and comparison with the 2018 visibility projections for extinction due to U.S. anthropogenic emissions on the worst 20 percent days. As seen by the standard linear deciview glidepaths discussed in Chapter 4, the U.S. anthropogenic emissions 2018 URP point is achieved by a wide margin at the four Class I areas in Arkansas and Missouri (CACR, UPBU, HRGL and MING). BRET that achieved 94% of the 2018 URP point obtains similar results using the U.S. anthropogenic emissions glidepath achieving 96% of the 2018 URP point. As discussed above, the inclusion of the off-shore marine emissions in the U.S. anthropogenic emissions will greatly affect the BRET Class I area so that actual reduction in U.S. anthropogenic emissions extinction would be greater and may even achieve the 2018 URP point if off-shore marine vessels were classified as not being part of the U.S..

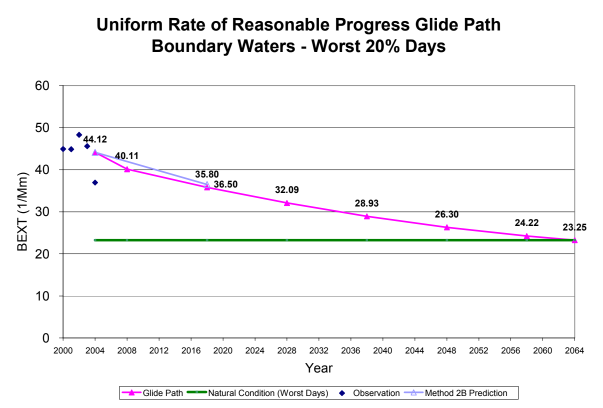
The BOWA and VOYA northern Minnesota Class I areas achieved, respectively, 69% and 53% of the 2018 URP point using the standard EPA default deciview glidepaths and projection techniques (Figure 4-4). Using the U.S. anthropogenic glidepaths BOWA and VOYA achieve 92% and 86% of the 2018 point, respectively (Figure 5-17). WIMO that came up approximately 40% short of achieving the 2018 URP point using the deciview glidepath comes up under 20% short using the U.S. anthropogenic emissions glidepath.

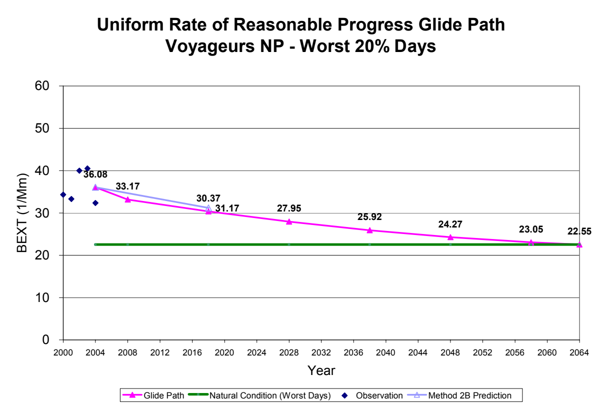
The two Texas Class I areas also come up short in achieving the 2018 URP point using the U.S. anthropogenic emissions glidepaths, but not as short as when the linear deciview glidepaths are used. BIBE increases from 26% to 67% and GUMO increases from 34% to 49%. One reason these two Class I areas fail to achieve the 2018 point for U.S. anthropogenic emissions is because of the high contributions of Soil and CM and little change in precursor emissions of these species between 2002 and 2018.

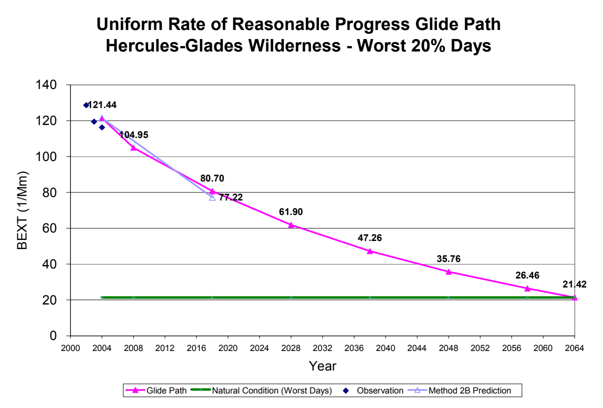

Uniform Rate of Reasonable Progress Glide Path
Caney Creek Wilderness - Worst 20% Days

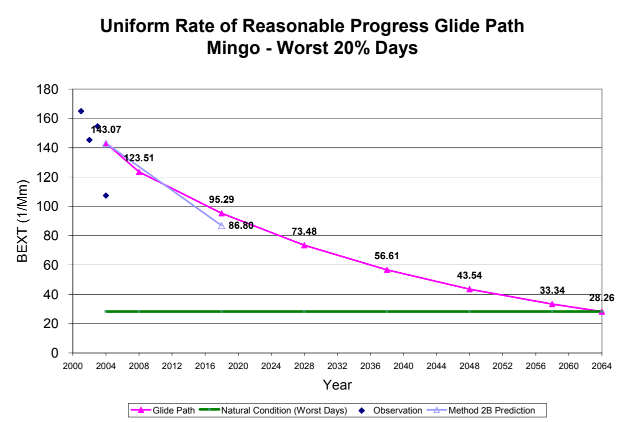

Uniform Rate of Reasonable Progress Glide Path
Upper Buffalo Wilderness - Worst 20% Days

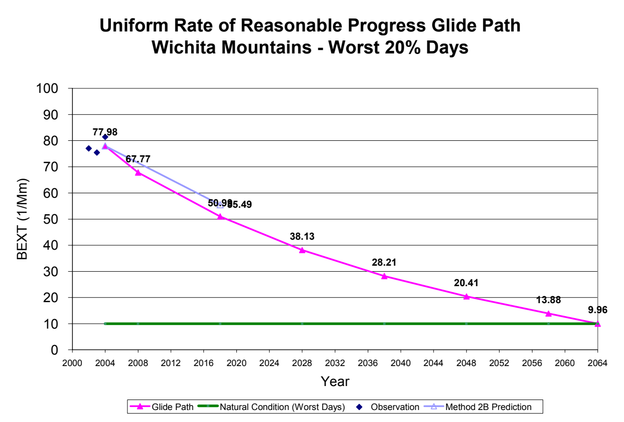

Uniform Rate of Reasonable Progress Glide Path
Breton - Worst 20% Days


Uniform Rate of Reasonable Progress Glide Path
Boundary Waters - Worst 20% Days


Uniform Rate of Reasonable Progress Glide Path
Voyageurs NP - Worst 20% Days


Uniform Rate of Reasonable Progress Glide Path
Hercules-Glades Wilderness - Worst 20% Days


Uniform Rate of Reasonable Progress Glide Path
Mingo - Worst 20% Days


Uniform Rate of Reasonable Progress Glide Path
Wichita Mountains - Worst 20% Days

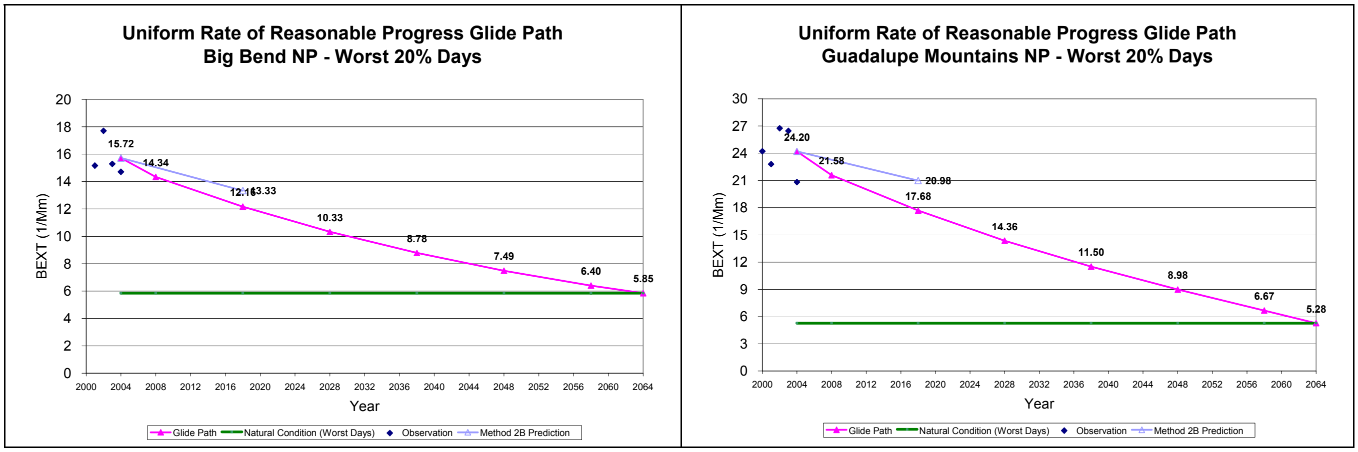


Figure 5-17. Glidepaths and 2018 visibility projections based on visibility due to U.S. anthropogenic emissions at CENRAP Class I areas.

5.8 Use of Original IMPROVE Equation

2018 visibility projections were also made using the CENRAP Typ02g and Base18g CMAQ modeling results and the original (old) IMPROVE equation. Figure 5-18 displays a DotPlot that compares the 2018 Base G visibility projections using the new IMPROVE algorithm (NIA) and the original IMPROVE algorithm (OIA). In general the new IMPROVE equation results in more optimistic 2018 visibility projections than the original IMPROVE equation. For the Texas and WRAP Class I areas, the 2018 visibility projections are nearly identical using the two IMPROVE equations. For the four Class I areas in Arkansas and Missouri the 2018 visibility projections using the new IMPROVE equation are from 7 to 21 percentage points more optimistic than the original IMPROVE equation. In the case of UPBU, HEGL and MING the 2018 visibility projections go from not achieving to achieving the 29018 URP point when switching from the old to new IMPROVE equation.

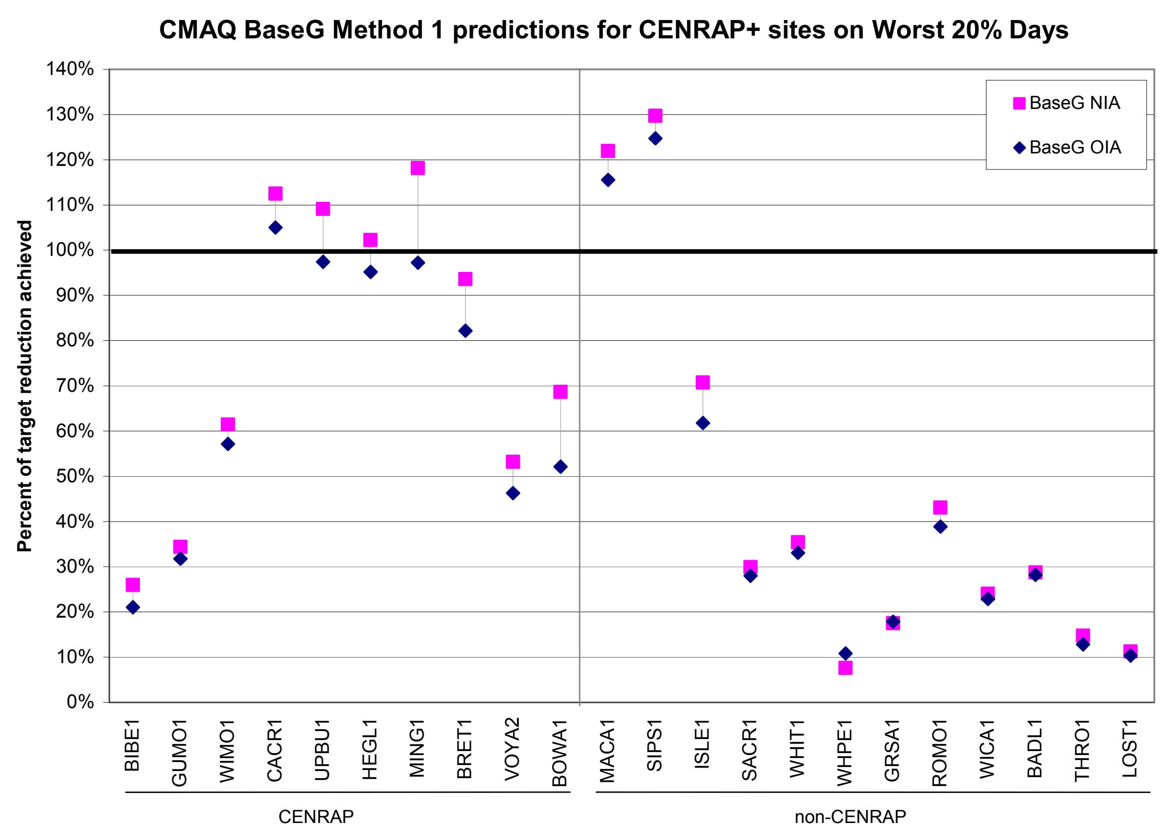


Figure 5-18. Comparison of 2018 Base G visibility projections using the New (NIA) and Old (OIA) IMPROVE algorithms expressed as a percentage of achieving the 2018 URP point visibility improvements.

5.9 Visibility Trends

Figure 5-19 displays trends in visibility impairment at the CENRAP Class I areas using the period of record of measurements at the associated IMPROVE monitor and the new IMPROVE equation. These trends include trends for the worst 20 percent days, the best 20 percent days and all IMPROVE sampled days during a year. The EPA guidance procedures were used to construct the worst and best 20 percent days that includes a minimum data capture requirement (EPA, 2003a), whereas no such minimum data capture was applied when looking at the "annual average" of all IMPROVE sampled days trends. So care must be taken when analyzing trends for the all sampled IMPROVE days trends as there could be large missing periods with high or low extinction that are not being account for. The WRAP Technical Support System (TSS) website was used to calculate the visibility trends at the CENRAP Class I areas that includes IMPROVE data from start of recording through 2004 and includes no data filling (see: http://vista.cira.colostate.edu/TSS/Default.aspx) .

Trends in visibility at CACR has three years of data (2002-2004) for the worst and best 20 percent days and fives years for the IMPROVE sampled days trends. Although it is hard to come to any conclusions regarding trends with just three years of data, there does seem to be a general downward trend, that is also supported by the five year trend in the IMPROVE sampled days.

A much longer trend plot is available for UPBU that includes 12 years of data for the worst and best 20 percent days (Figure 5-19b). Although there is a lot of a year-to-year variation in the visibility trends with cleaner years occurring in 1997, 2001 and 2004, there does appear to be a slight trend toward improved visibility at UPBU.

There is insufficient data to calculate the worst or best 20 percent days visibility for any year at the BRET Class I area so only the IMPROVE sampled days trends are presented (Figure 5-19c). The trends at BRET are inconclusive and given the large amounts of missing data at this site it is difficult to interpret the results.

There is also a lot of missing years in the worst and best 20 percent days for the BOWA Class I area making it difficult to interpret (Figure 5-19d). But visibility appears to be more impaired in the early 1990s than in more current years so improvements have been seen. VOYA has five years of valid data and shows worsening visibility for 2000-2003, and then improved visibility in 2004. It is unclear whether the 2004 improved visibility is a trend or just due to variations in meteorology so no conclusions can be drawn.

Although a downward trend in visibility impairment appears to be occurring at the two Missouri Class I areas (Figure 5-19f-g), given that there are only three years available for HEGL and lots of missing data for MING these trends are inconclusive.

Three years (2002-2004) of visibility trends for the worst and best 20 percent days are available for WIMO (Figure 5-19h). The most impaired year from the three years for the worst 20 percent days is the most recent (2004). Again, the time period is too short to draw any conclusions on trends in visibility at WIMO.

The two Texas Class I areas have a relatively long period of record. There is a lot of year-to-year variability in the visibility measurements that make interpreting the trends difficult. 1998 appears to be an anomalously high visibility impairment year at BIBE and due to the much higher OMC extinction indicates that the year was likely impacted by smoke from fires. GUMO has lots of year to year variability in CM and Soil which are likely due to occurrences of impacts due to wind blown dust. Even taking Soil and CM out of the interpretation it is difficult to interpret ay trend in visibility at the two Texas Class I areas. The higher visibility impairment in 1998 and 1999 suggests a downward trend but that may be just due to more adverse meteorological and natural emissions (e.g., wildfires) in these two years than any real long term trend.

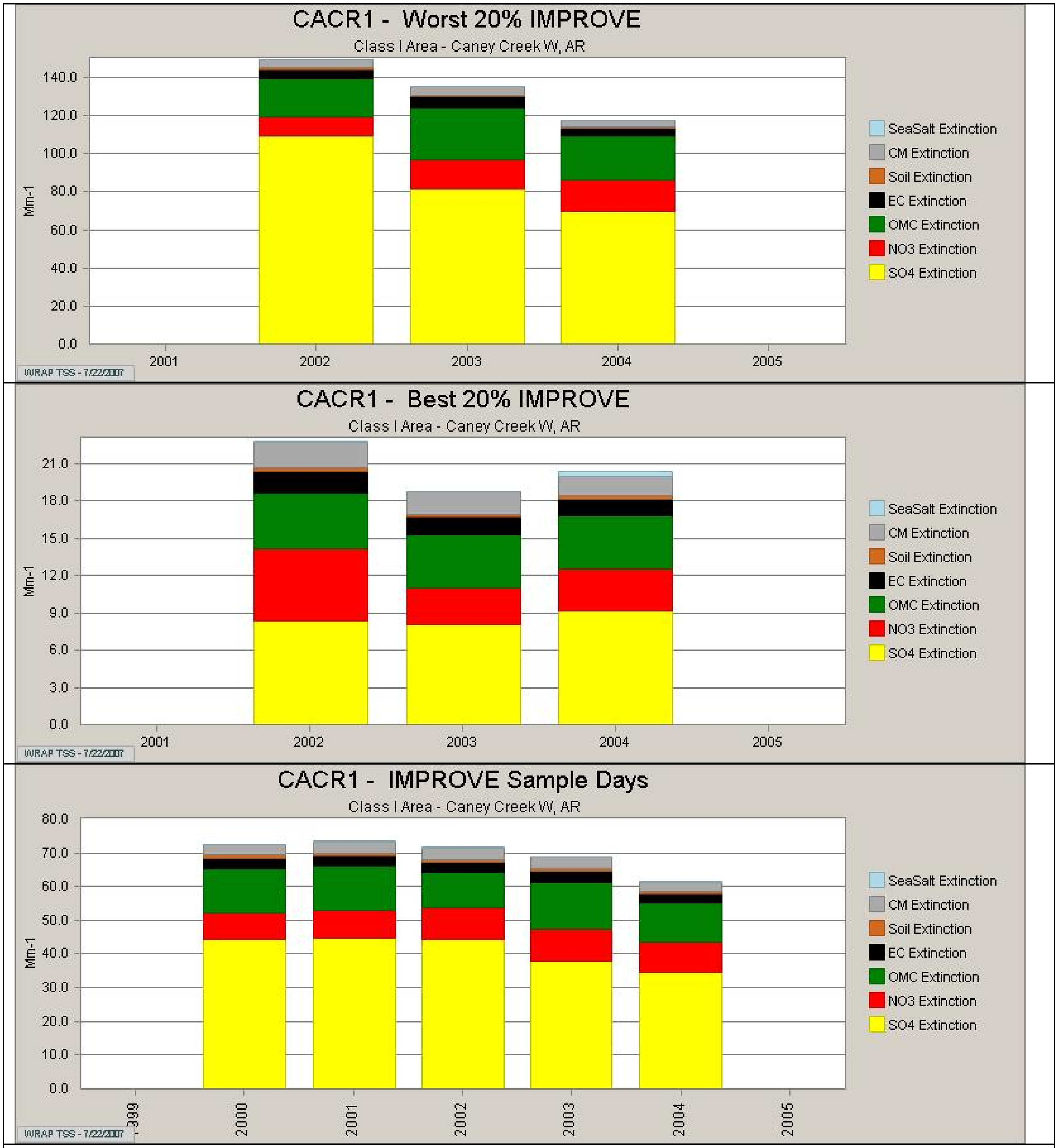


Figure 5-19a. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Caney Creek (CACR), Arkansas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

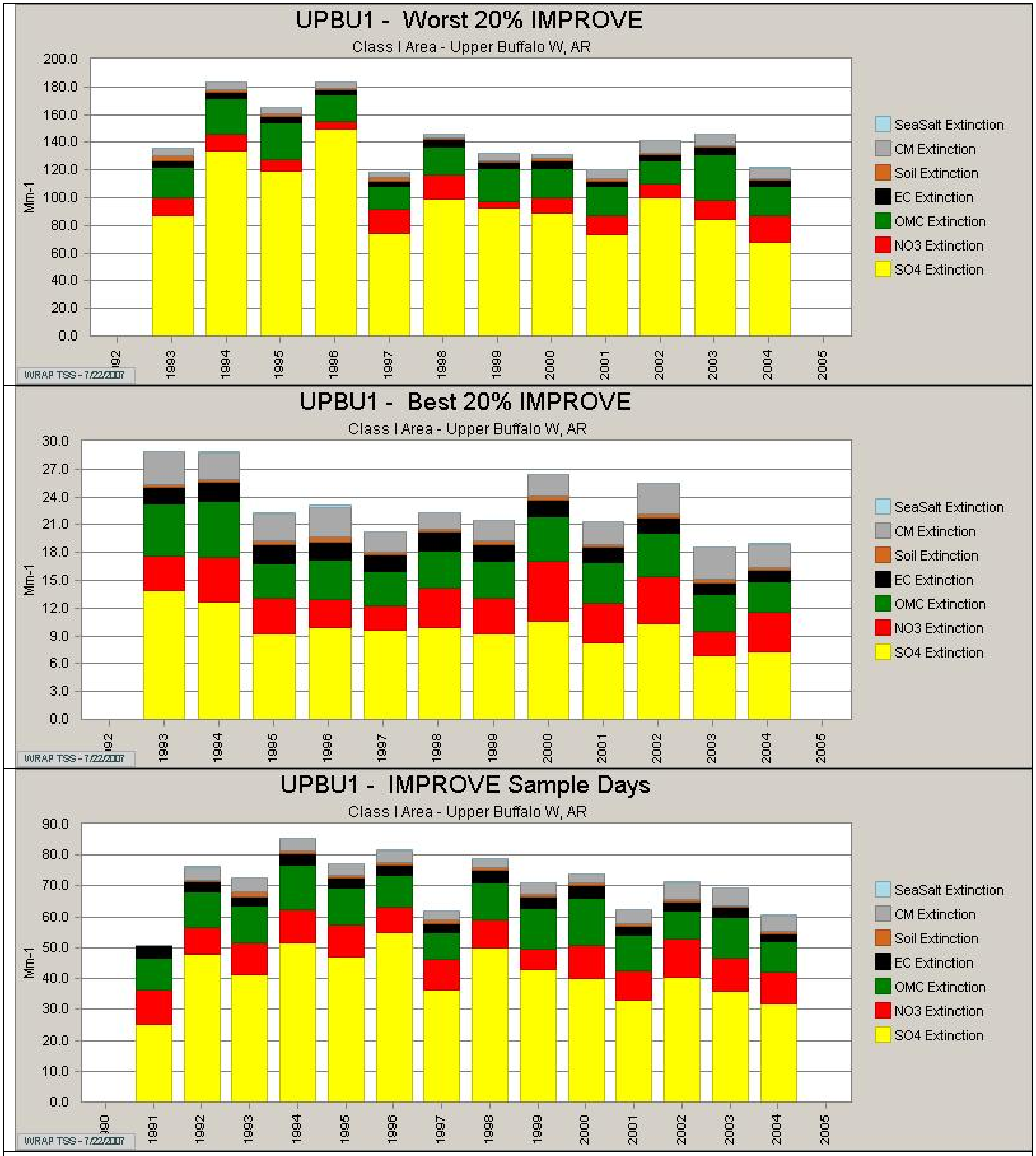


Figure 5-19b. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Upper Buffalo (UPBU), Arkansas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

Insufficient Data to Calculate Best 20 Percent days at BRET

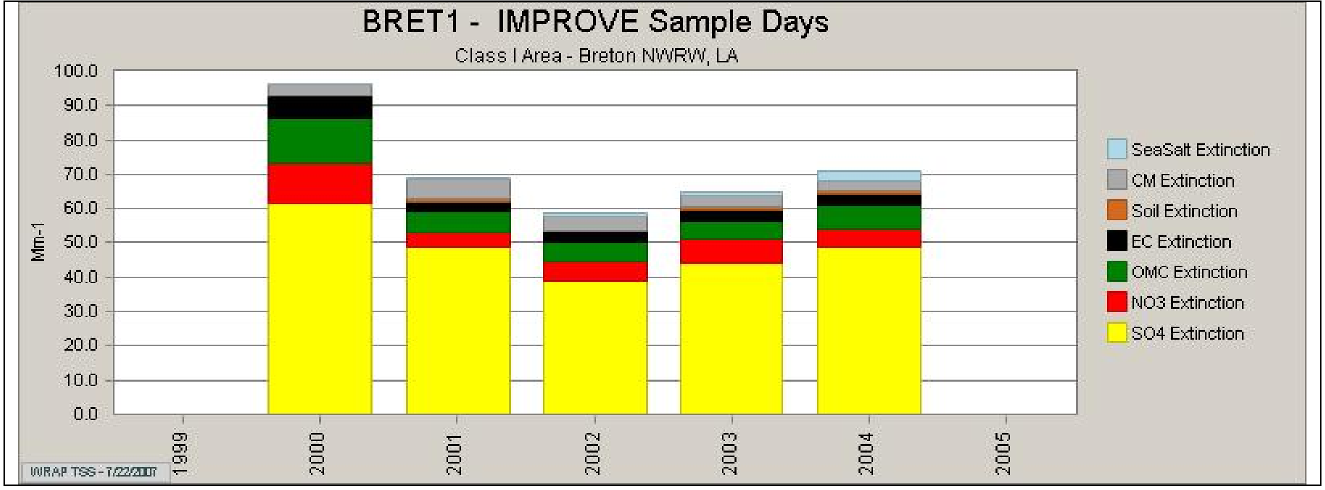


Figure 5-19c. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Breton Island (BRET), Louisiana for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

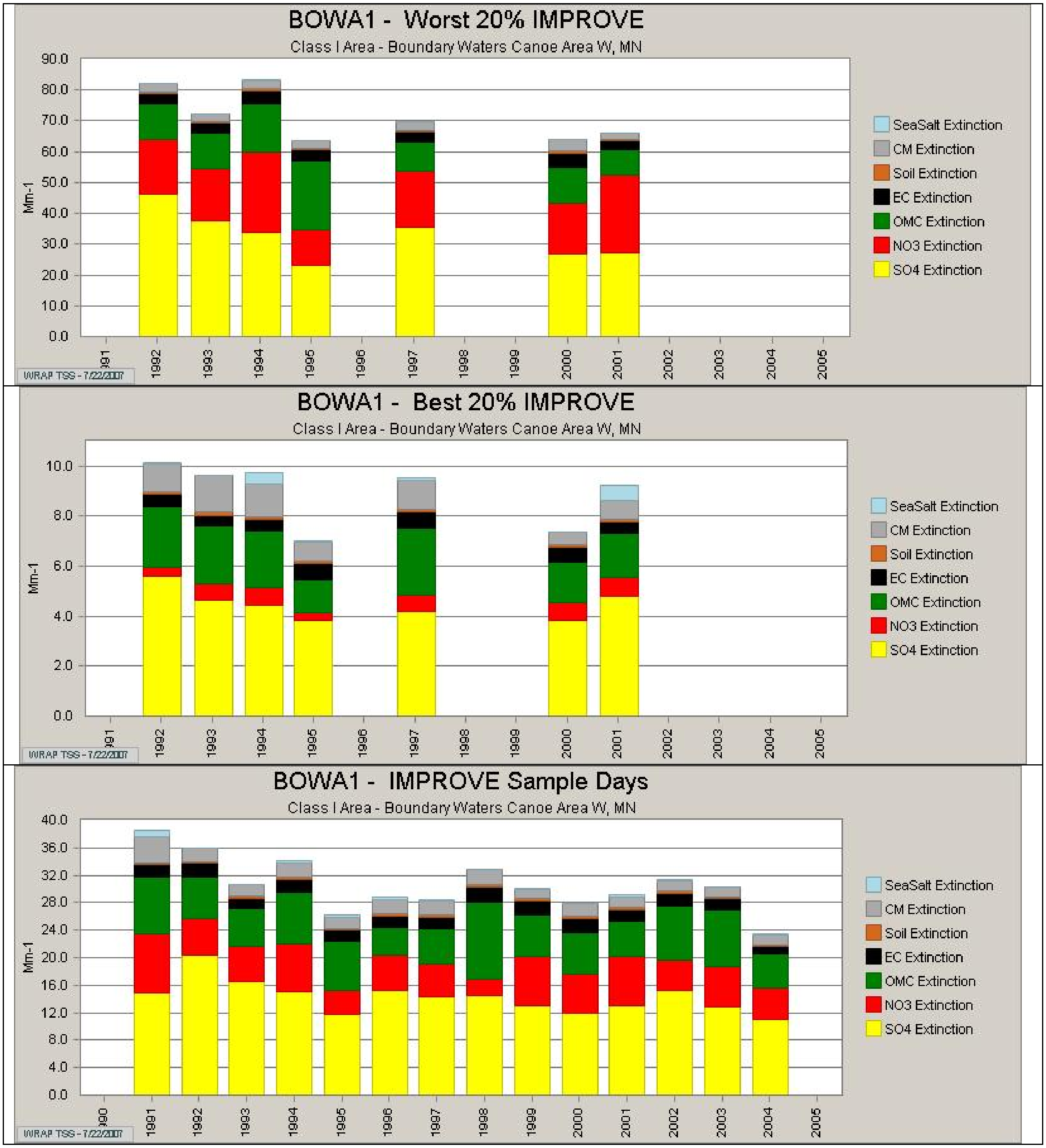


Figure 5-19d. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Boundary Waters (BOWA), Minnesota for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

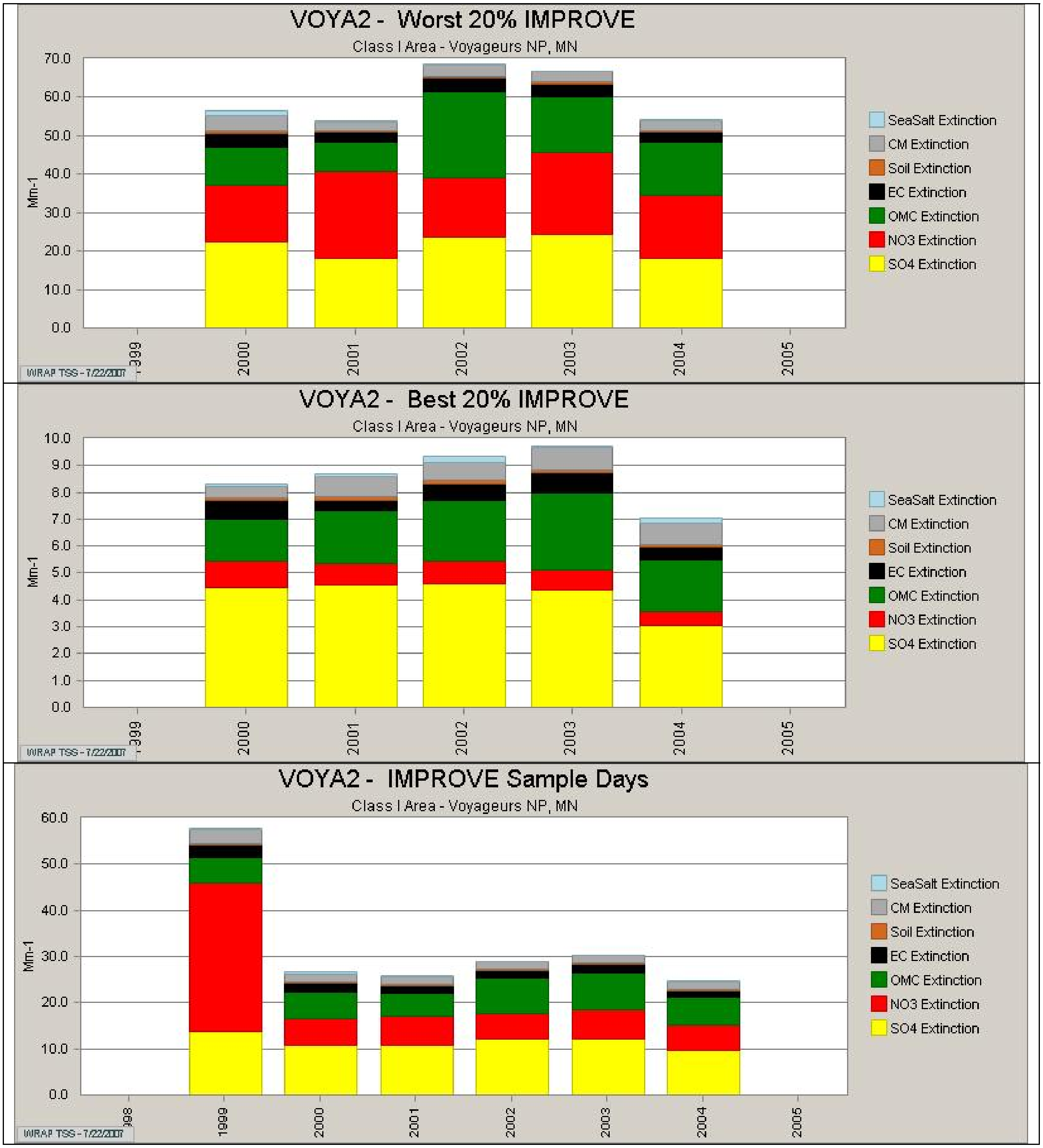


Figure 5-19e. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Voyageurs (VOYA), Minnesota for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

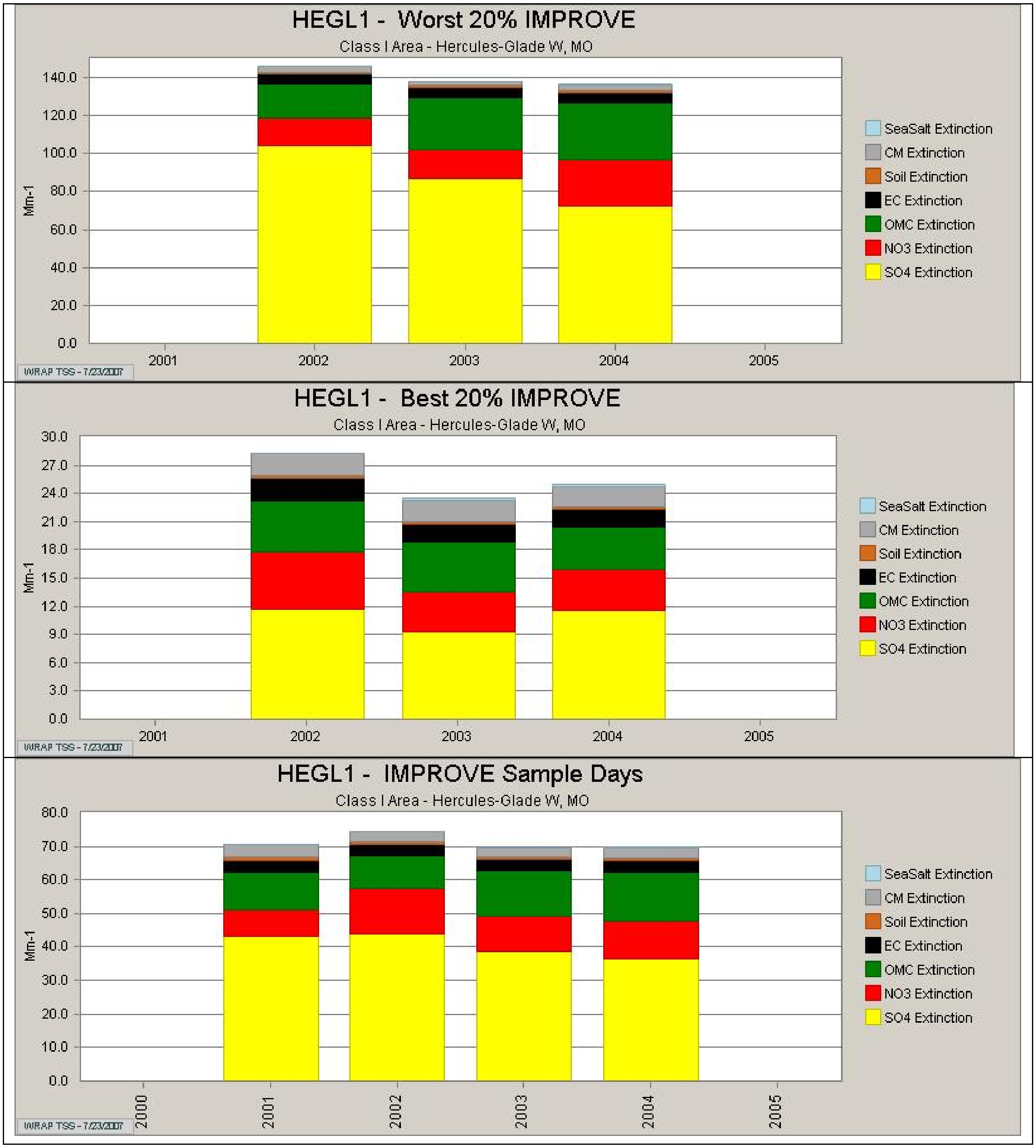


Figure 5-19f. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Hercules Glade (HEGL), Missouri for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

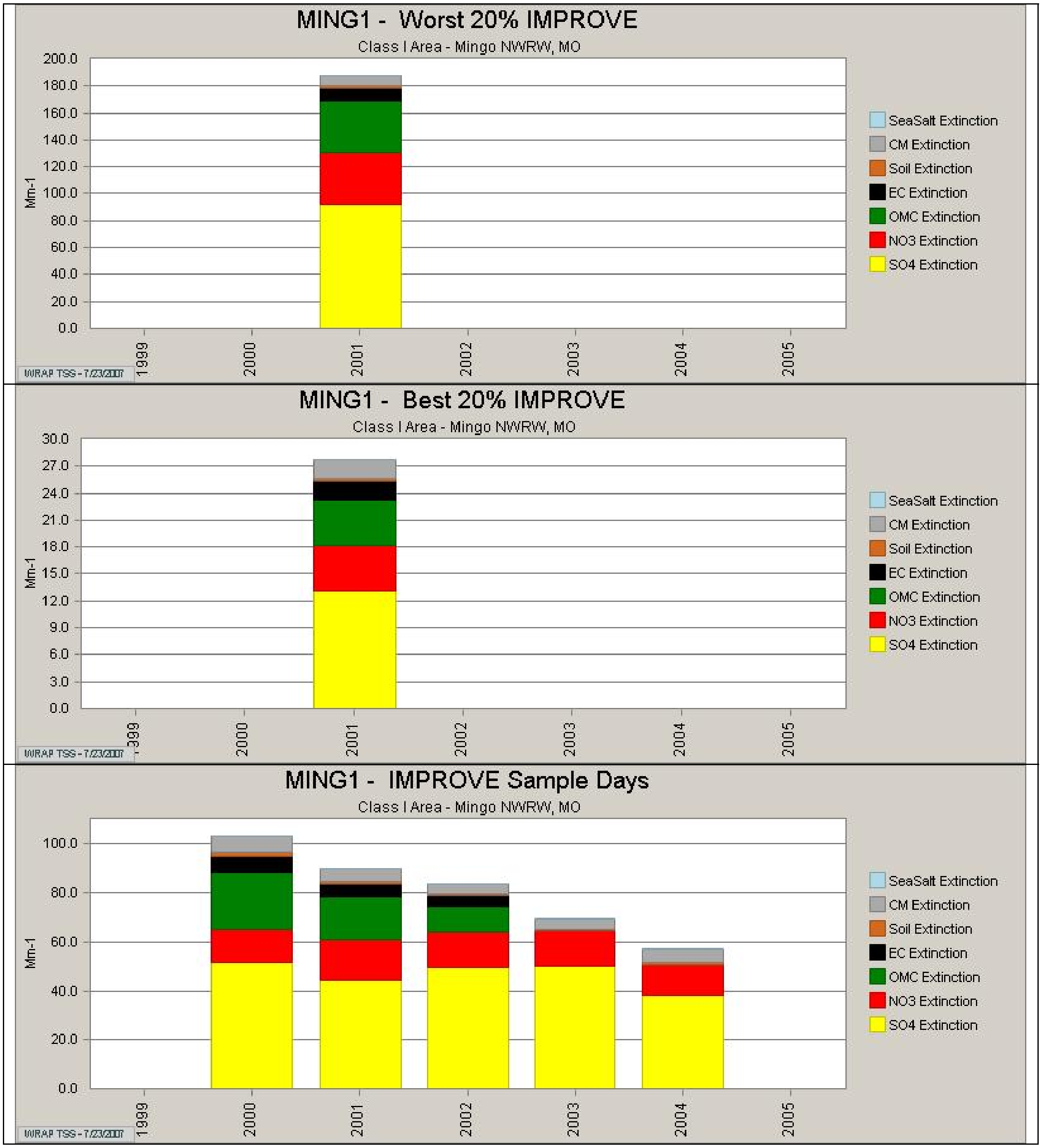


Figure 5-19g. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Mingo (MING), Missouri for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

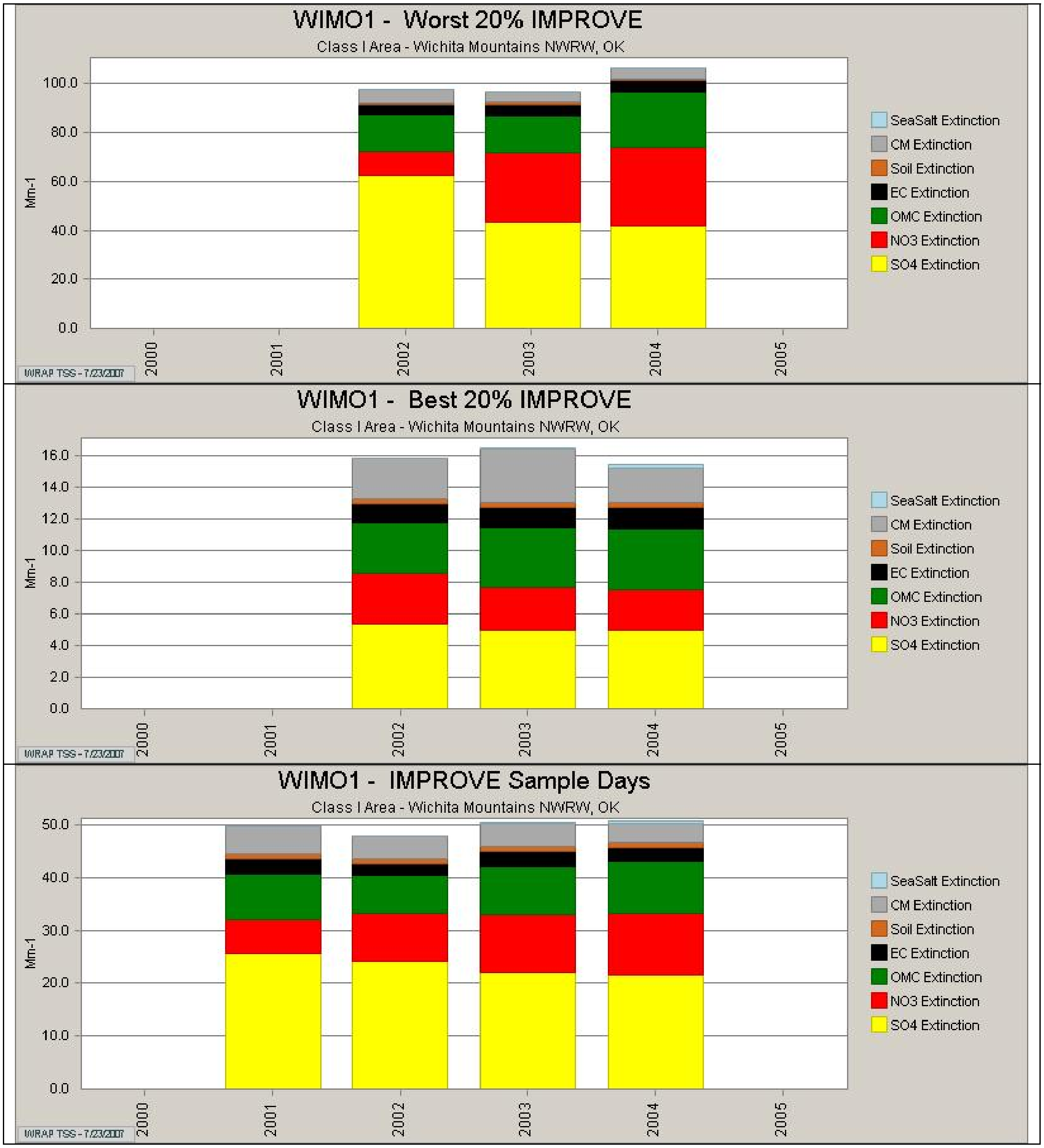


Figure 5-19h. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Wichita Mountains (WIMO), Oklahoma for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

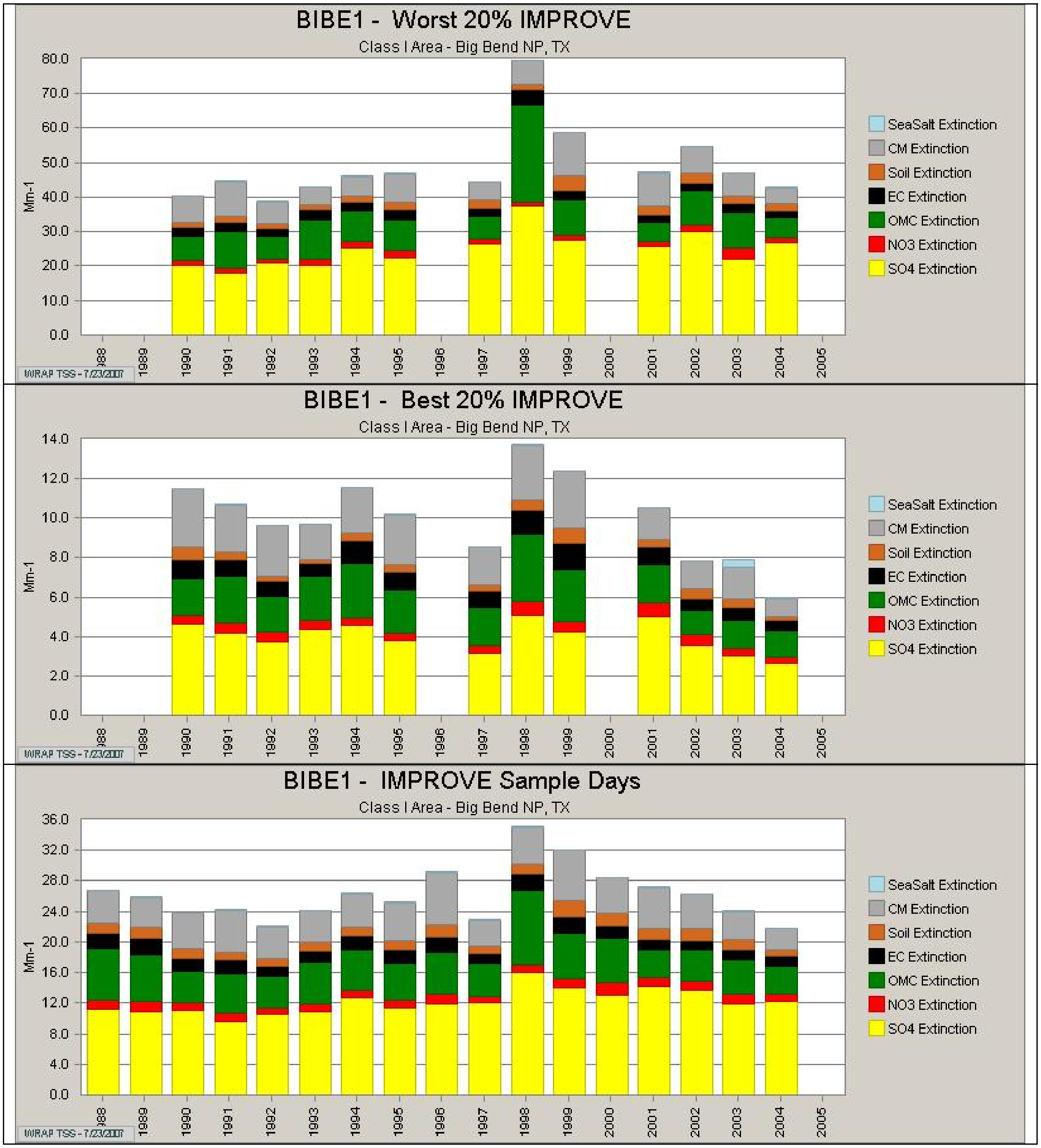
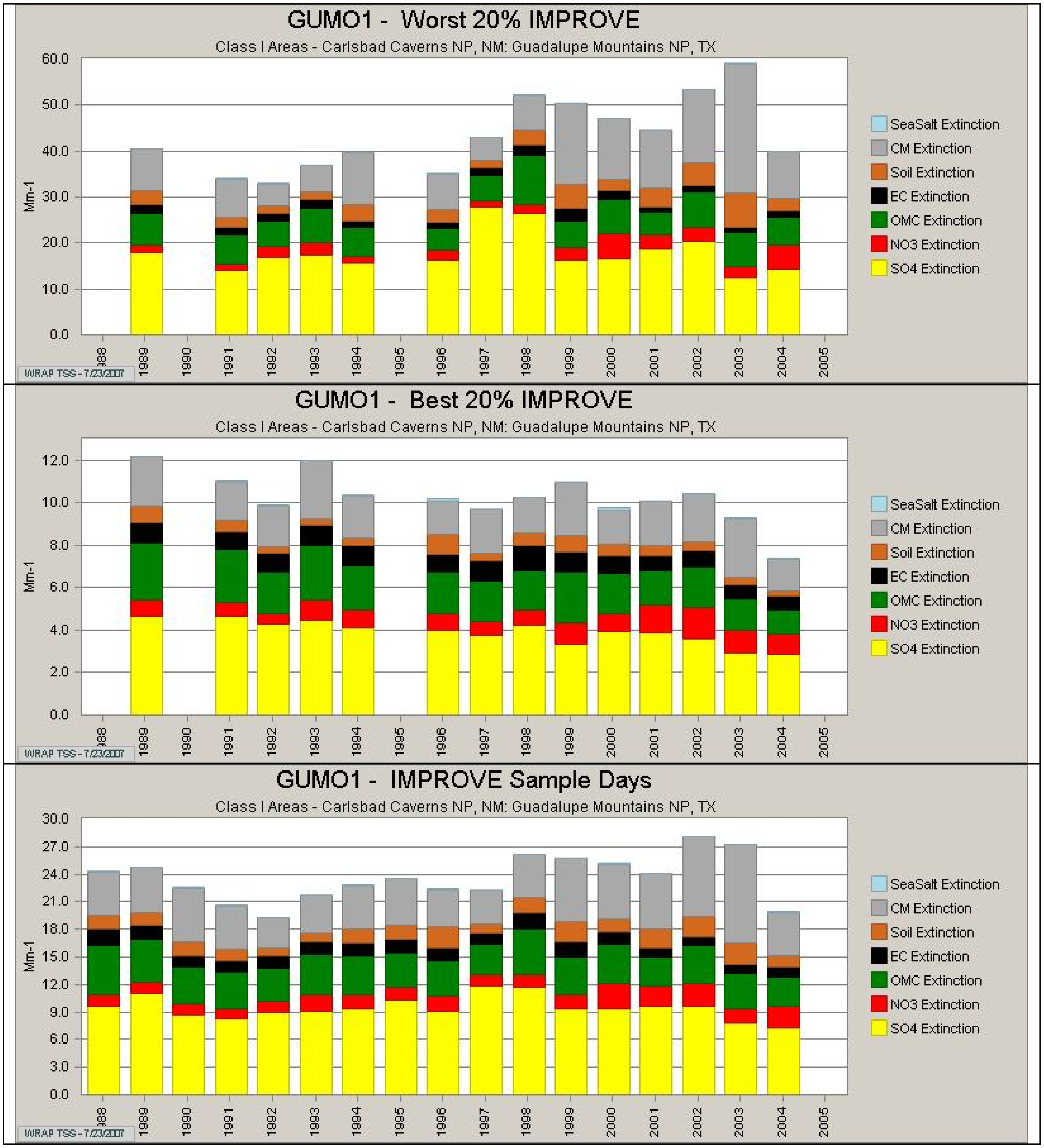


Figure 5-19i. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Big Bend (BIBE), Texas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.



GUMO1 - Worst 20% IMPROVE

Class I Areas - Carlsbad Caverns NP, NM: Guadalupe Mountains NP, TX

GUMO1 - Best 20% IMPROVE

Class I Areas - Carlsbad Caverns NP, NM: Guadalupe Mountains NP, TX

GUMO1 - IMPROVE Sample Days

Class I Areas - Carlsbad Caverns NP, NM: Guadalupe Mountains NP, TX

Figure 5-19j. Time series of observed IMPROVE reconstructed light extinction (New IMPROVE) at Guadalupe Mountains (GUMO), Texas for the average of the Worst 20 Percent days (top), Best 20 Percent days (middle) days and all IMPROVE sampling days during the period of record.

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APPENDIX A

Model Performance Evaluation of the 2002 36 km MM5 Meteorological Model Simulation used in the CENRAP Modeling and Comparison to VISTAS Final 2002 36 km MM5 and WRAP Interim 2002 36 km MM5 Simulations

The CENRAP 2002 36 km MM5 simulation (Johnson, 2007) was evaluated against observed surface and upper-air meteorological observations and observed precipitation amounts and its performance was compared against the VISTAS final and the WRAP interim 2002 36 km MM5 simulations. The CENRAP, VISTAS and WRAP 2002 36 km MM5 simulations used several common science options:

- Lambert Conformal Projection with center at (97°, 40°) and standard parallels at (33°, 45°).
- 164 by 128 36 km by 36 km horizontal grids covering the continental U.S. and adjacent regions.
- 34 vertical layers up to 100 mb (~15 km AGL).
- Pleim-Xiu Land Surface Module (LSM).
- Asymmetric Convective Mixing (ACM) Planetary Boundary Layer (PBL) model.
- RRTM long-wave radiation.
- Dudhia short-wave radiation.
- No Shallow convection.

However, there were some differences in the choice of science options:

- VISTAS and CENRAP MM5 simulations used the Kain Fritsch 2 cumulus parameterization, whereas WRAP MM5 used Kain Fritsch 1.
- VISTAS and CENRAP MM5 simulations used the Reisner 1 moist physics while WRAP MM5 used Reisner 2.
- All three MM5 simulations used Four Dimensional Data Assimilation (FDDA analysis nudging at the surface for winds, but WRAP also used surface analysis nudging to temperature and moisture.
- All three MM5 simulations used analysis nudging FDDA above the PNL to winds, temperature and moisture.

Much of the difference in the model performance for the three MM5 simulations was related to the surface temperature and moisture analysis nudging used in the interim WRAP MM5 simulations that resulted in better surface temperature model performance, but caused instabilities resulting in degradation in meteorological model performance above the surface. The final WRAP 2002 36 km MM5 simulation did not use the surface temperature and moisture FDDA and used the Betts-Miller cumulus scheme instead of Kain Fritsch that resulted in much improved meteorological model performance in the western States (Kemball-Cook et al., 2005).

A.1 Surface Meteorological Model Performance

The performance of the three MM5 simulations at the surface was evaluated through comparisons against observed surface wind, temperature and humidity measurements from the ds472 observational database. The METSTAT program was used to evaluate the MM5 simulations for each month of 2002 and across the 11 subdomains shown in Figure A-1. These subdomains are as follows:

1 = Pacific NW
2 = SW
3 = North
4 = Desert SW
5 = CenrapN
6 = CenrapS
7 = Great Lakes
8 = Ohio Valley
9 = SE
10 = NE
11 = MidAtlantic

Emery and Tai (2001) have developed model performance benchmarks by analyzing over 30 MM5RAMS meteorological model simulations and tabulating the typical level of performance that a good meteorological model achieves. These performance benchmarks are not intended to be pass/fail grades; rather they provide a framework to evaluate the model performance against past applications. Since many of the past MM5/RAMS meteorological model simulations that the benchmarks were developed from were in support of urban ozone modeling that are typically fairly stagnant conditions with little or no precipitation and involved multiple iterations to achieve the final base case simulation. Thus, we may not expect the 2002 annual MM5 simulations to achieve a similar level of performance given the complicating factors of precipitation and complex terrain associate with many Class I areas in the west. Table A-1 lists the meteorological model performance benchmarks for wind speed, wind direction, temperature and humidity.

Table A-1. Meteorological model performance benchmarks (Source: Emery et al., 1999).

Statistic	Wind Speed	Wind Direction	Temperature	Humidity
RMSE	≤ 2 m/s			
Mean Bias	≤ ±0.5 m/s	≤ ±10°	≤ ±0.5 K	≤ ±1.0 g/kg
Index of Agreement	≤ 0.6		≤ 0.8	≤ 0.6
Gross Error		≤ 30°	≤ 2.0 K	≤ 2.0 g/kg

Below we present the evaluation of the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations against surface meteorological observations for the four seasonal months of January, March, July and October and the CENRAP North (CenrapN) and CENRAP South (CenrapS) subdomains (i.e., subdomains 5 and 6 in Figure A-1). The surface evaluation of the three MM5 2002 36 km simulations outside of the CENRAP subdomains can be found in Kemball-Cook et al., (2004).

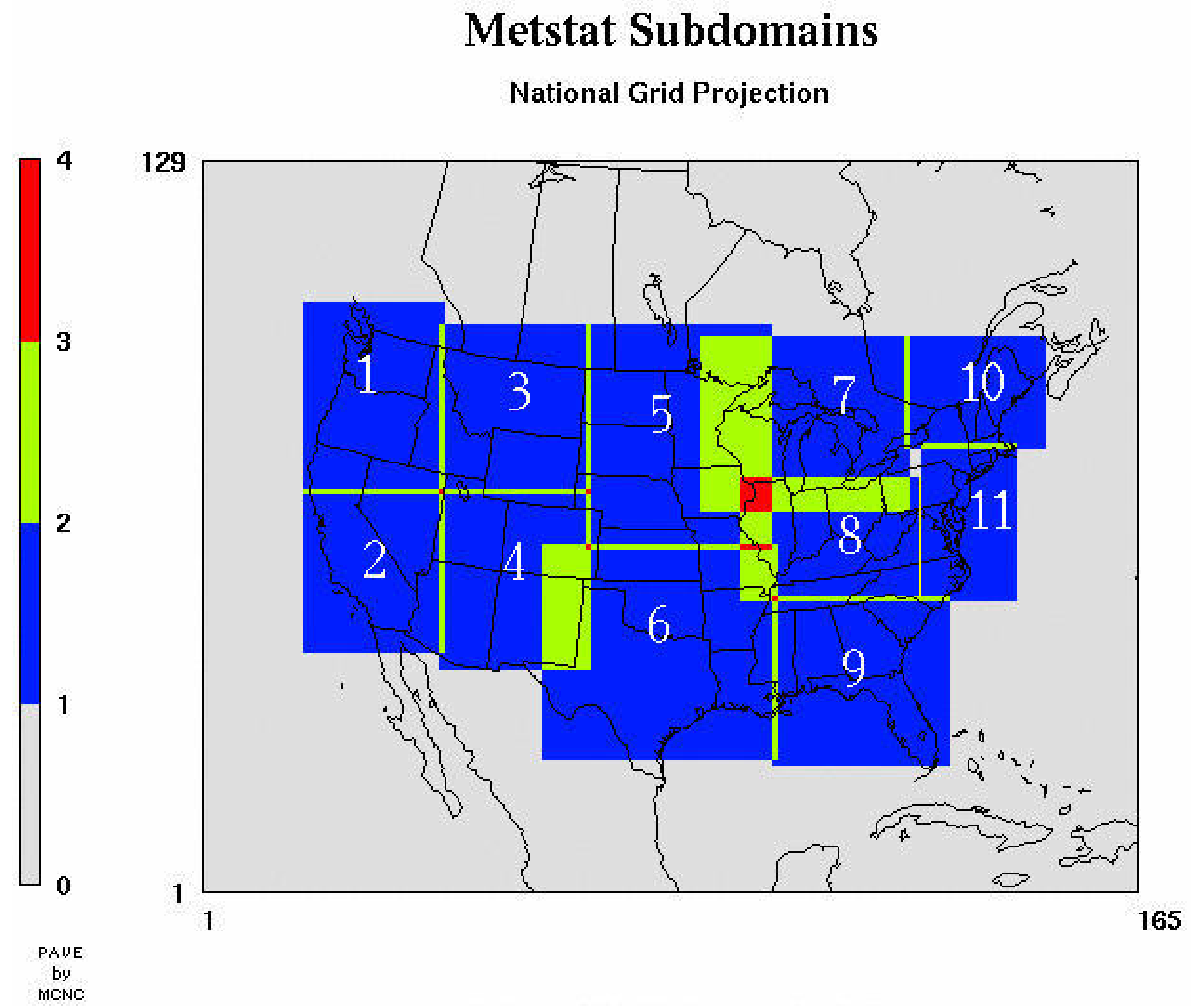


Figure A-1. Eleven subdomains where monthly evaluation of the MM5 simulations surface model performance was evaluated.

A.1.1 Temperature

Figure A-2 displays the surface temperature model performance for the CENRAP, VISTAS and WRAP 2002 36 km MM5 simulations in the CenrapN and CenrapS subdomains and the months of January, March, July and October. The WRAP MM5 simulations are performing best for January temperature in both CENRAP domains exhibiting low bias and the lowest error that are within the benchmark. The VISTAS MM5 rum is performing next best with bias well within the benchmark and error within but close to the error benchmark. The CENRAP MM5 simulation performs well for the CenrapS domain with zero bias and error within, but approaching the benchmark. However, the CENRAP performance for the CenrapN domain does not achieve the performance benchmarks due to a too cold bias.

The temperature performance in March is similar to January with both the VISTAS and WRAP MM5 simulations achieving the benchmark for both CENRAP subdomains. Again the CENRAP MM5 simulation has a near zero bias and achieves the error benchmark in the CenrapS subdomain, but is too cold in the CenrapN domain falling out of the bias benchmark range.

In July the three simulations achieve the temperature benchmark in both CENRAP subdomains, although the WRAP MM5 simulations is cooler with the CenrapS bias right at the -0.5 K lower bound benchmark. The CENRAP MM5 simulation is slightly warmer than the VISTAS MM5 simulation.

In October, all three MM5 simulations achieve the temperature performance benchmarks. The WRAP MM5 simulation performs best with near zero bias and lower error than either the VISTAS or CENRAP simulations. The VISTAS and CENRAP MM5 simulations exhibit nearly identical temperature performance in October with a near zero bias for the CenrapS subdomain and a cool bias for the CenrapN subdomain.

In conclusion, the WRAP MM5 simulation is always performing best for surface temperature with the lowest bias and usually the lowest error. The VISTAS MM5 simulations is performing next best as the CENRAP MM5 simulations exhibits a cool bias for the CenrapN subdomain in January and March that exceed the performance benchmarks.

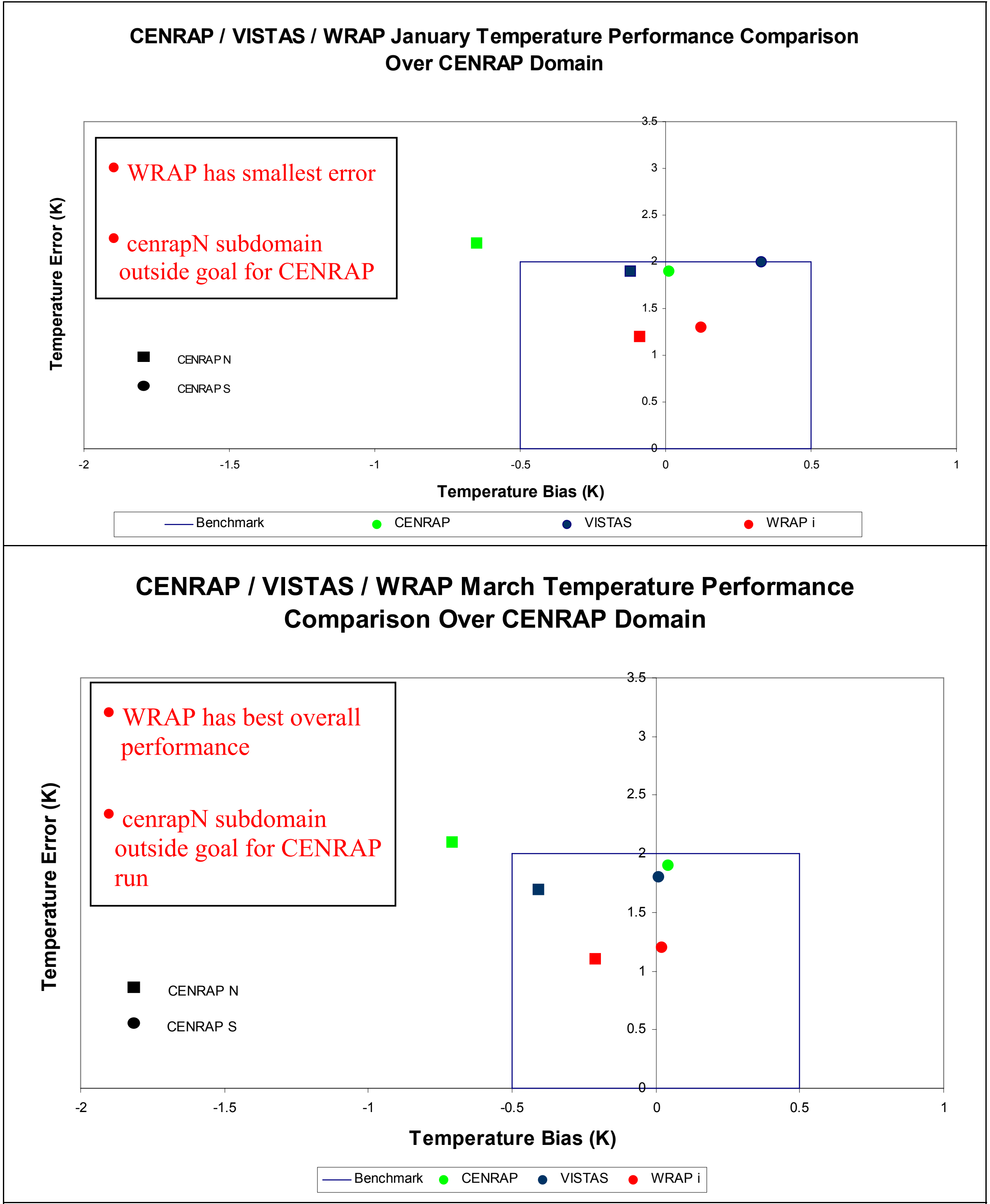
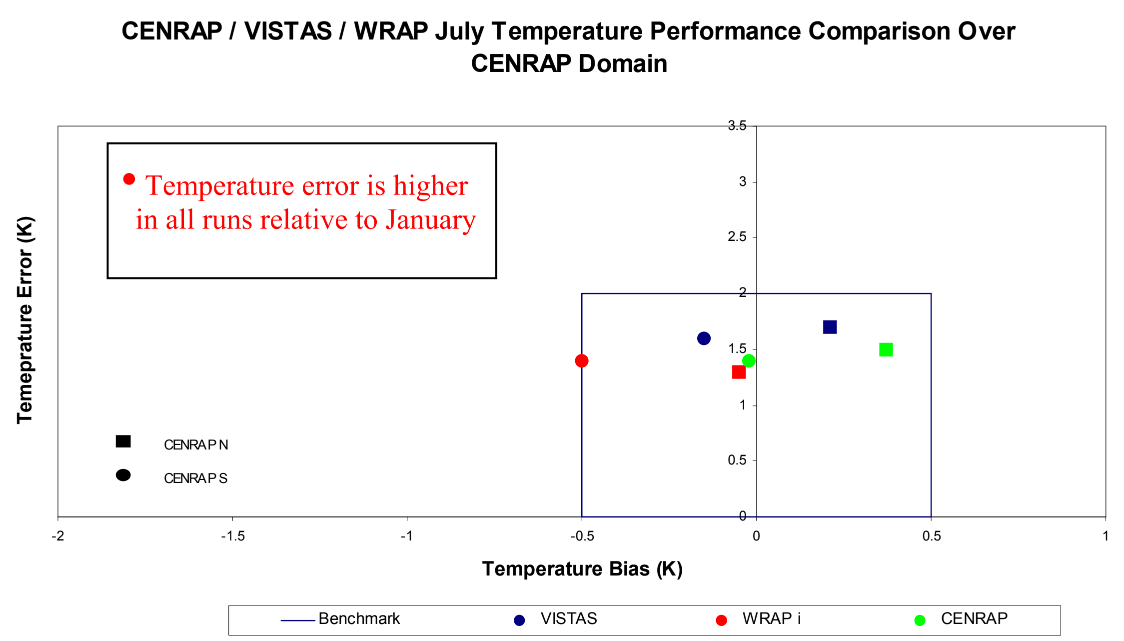


Figure A-2a. Temperature performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and January (top) and March (bottom).



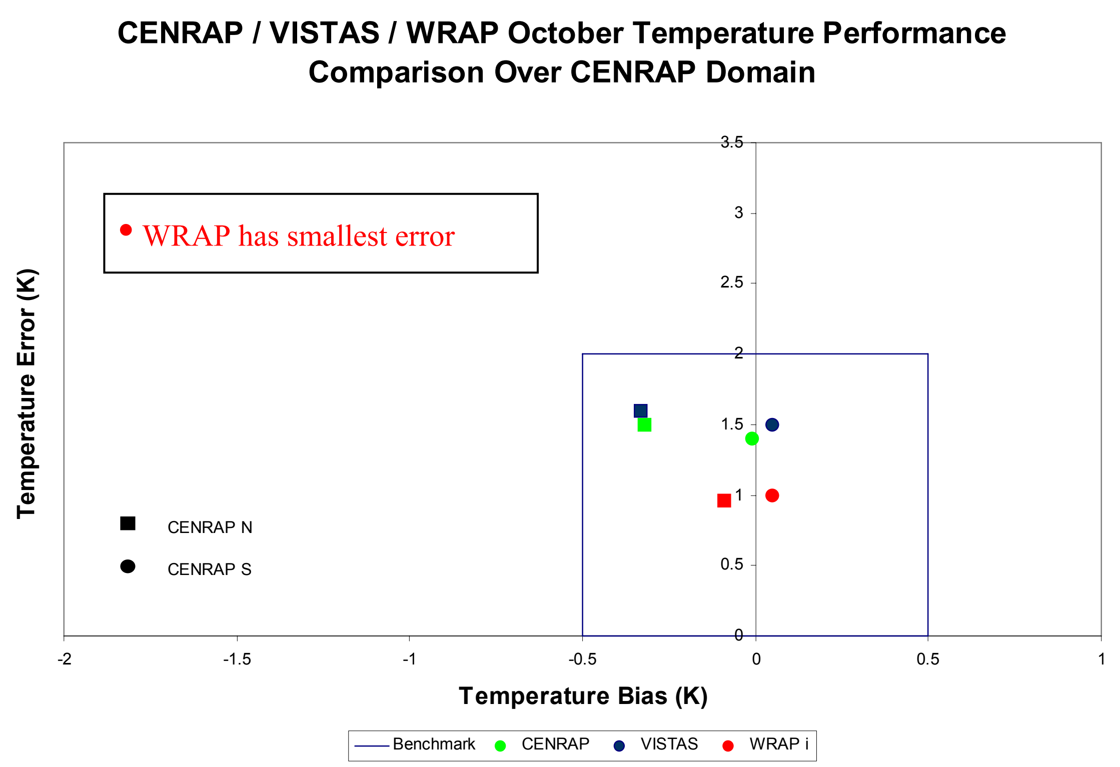


Figure A-2b. Temperature performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and July (top) and October (bottom).

A.1.2 Humidity

The humidity performance for the three MM5 simulations is comparable and always achieves the performance benchmarks. The humidity bias is always near zero for all three runs and four months. In January, March and October the humidity error is at or less than half of the 2.0 g/kg benchmark. However, in July there is more error in the humidity with it within but approaching the benchmark value for all three models.

In conclusion, all three MM5 simulations achieved the humidity benchmark performance goals for all months studied. No model simulation exhibited superior performance over another.

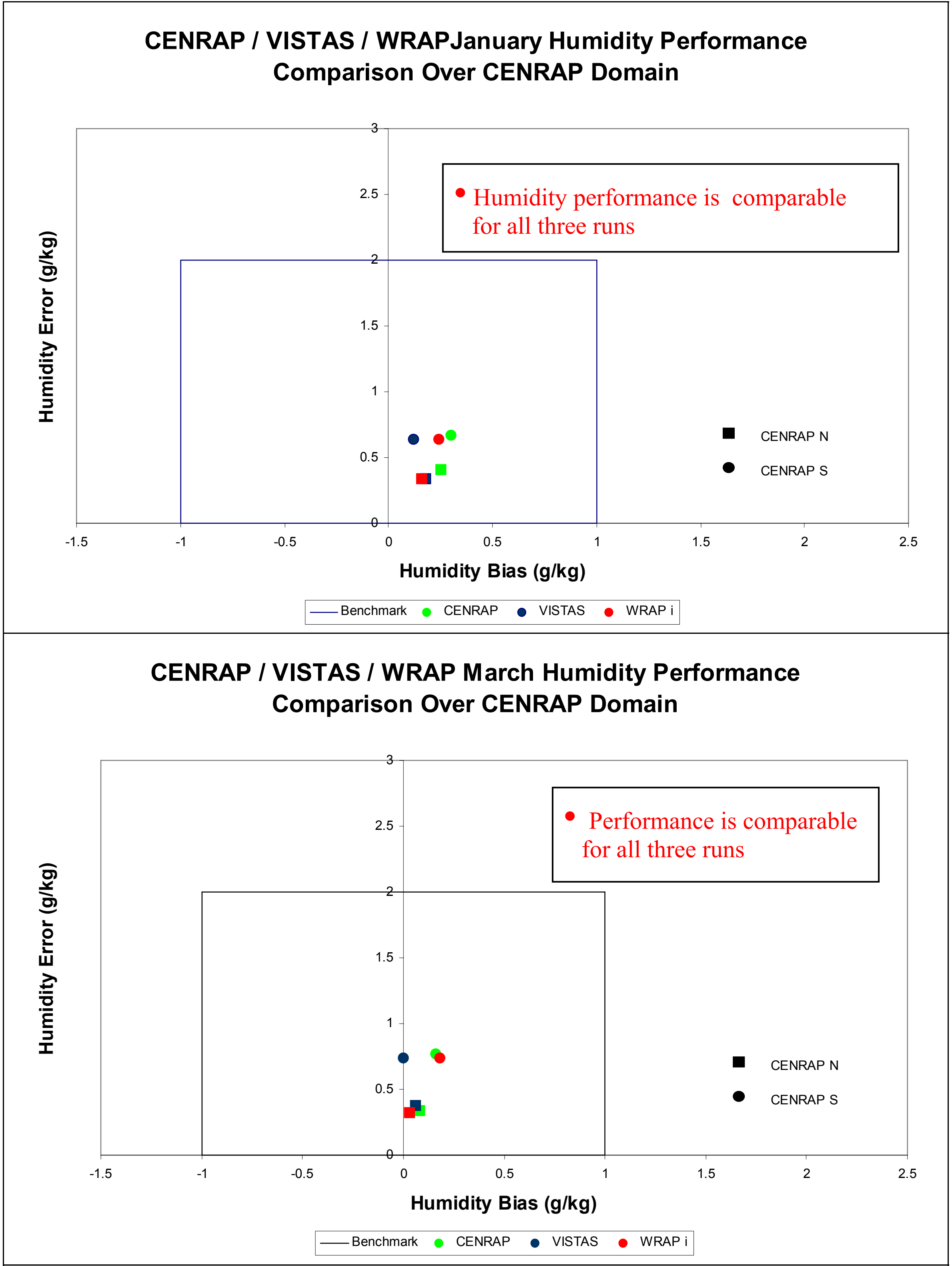
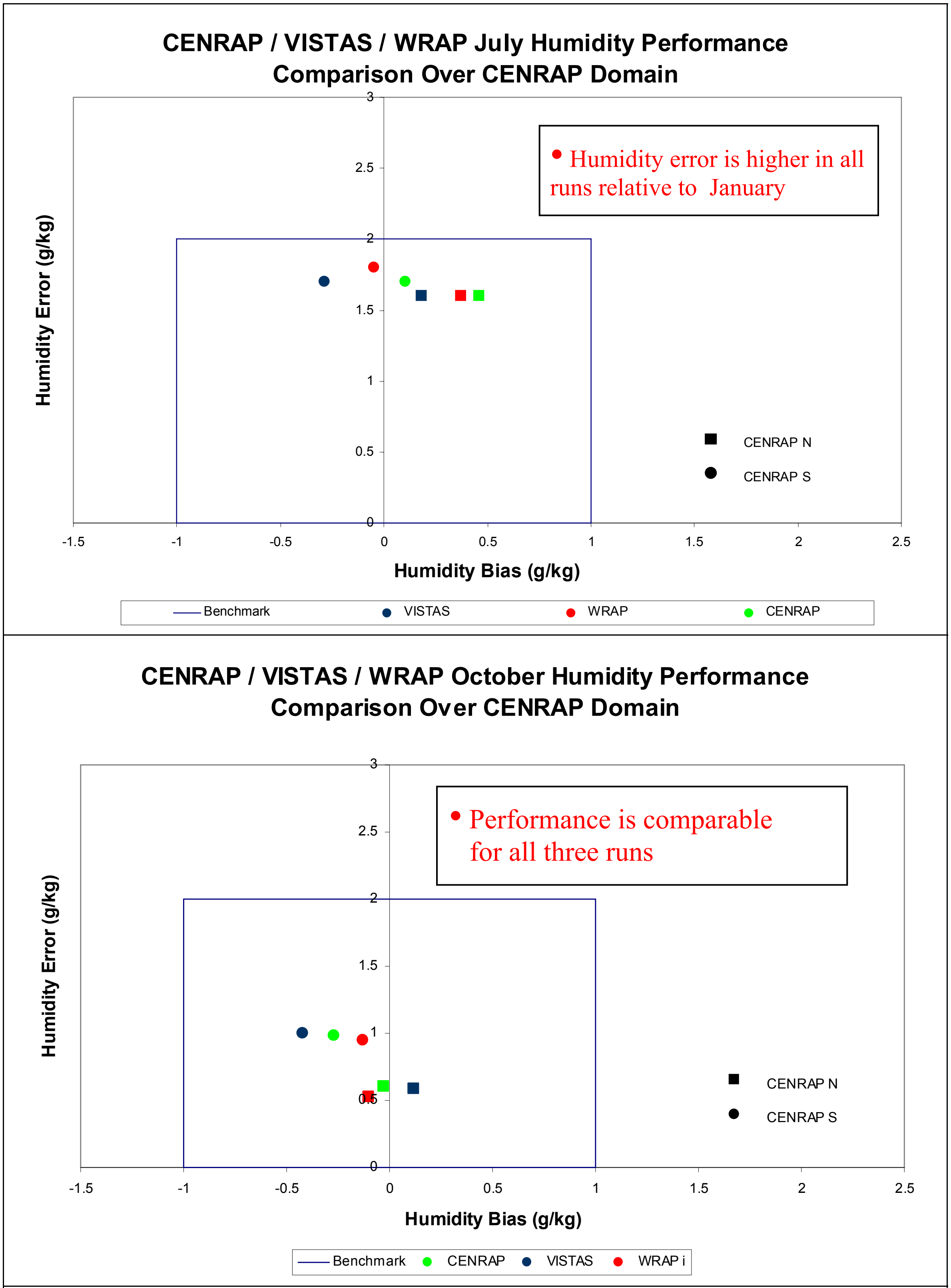


Figure A-3a. Humidity performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and January (top) and March (bottom).



CENRAP / VISTAS / WRAP July Humidity Performance Comparison Over CENRAP Domain

CENRAP / VISTAS / WRAP October Humidity Performance Comparison Over CENRAP Domain

Figure A-3b. Humidity performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and July (top) and October (bottom).

A.1.3 Winds

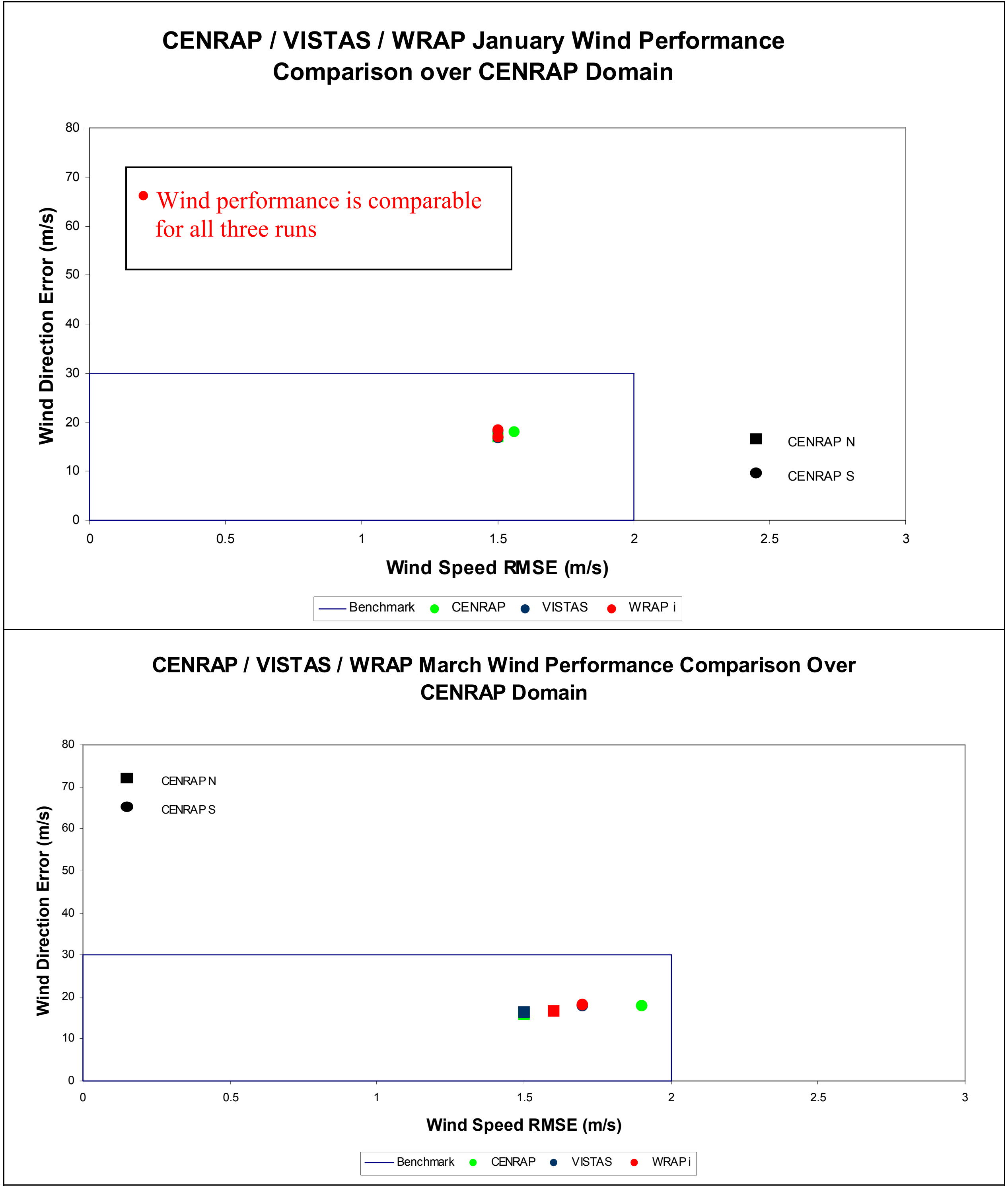
The model performance for wind speed and direction and January is almost identical and within the benchmarks for all three models and both CENRAP subdomains. In fact, the performance is so close the CenrapS symbols are plotted over and obliterate the CenrapN performance symbols.

In March, the wind performance is within the benchmark for all three MM5 simulations, which exhibit similar performance statistics. The wind performance in the CenrapS subdomain is slightly better than CenrapN with the CENRAP MM5 simulations showing the largest wind speed RMSE in the CenrapN subdomain, although still within the benchmarks.

Slight degraded wind direction performance is seen in July with the error increases to just below 20 degrees to just below the 30 degree benchmark value for all three models. Similar wind speed RMSE is seen for all three models.

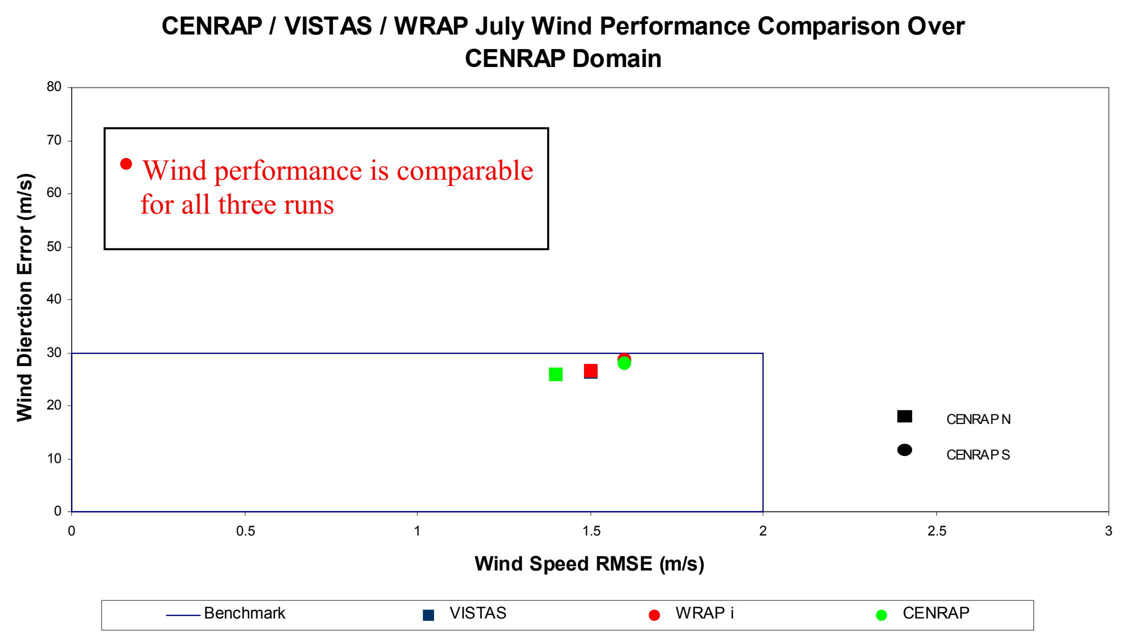
The October wind performance is within the benchmarks for all three models with performance between that seen for January/March and July.

In summary, the models exhibited similar model performance for surface wind speed and direction.



- Wind performance is comparable for all three runs

Figure A-4a. Wind Speed and Wind Direction performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and January (top) and March (bottom).



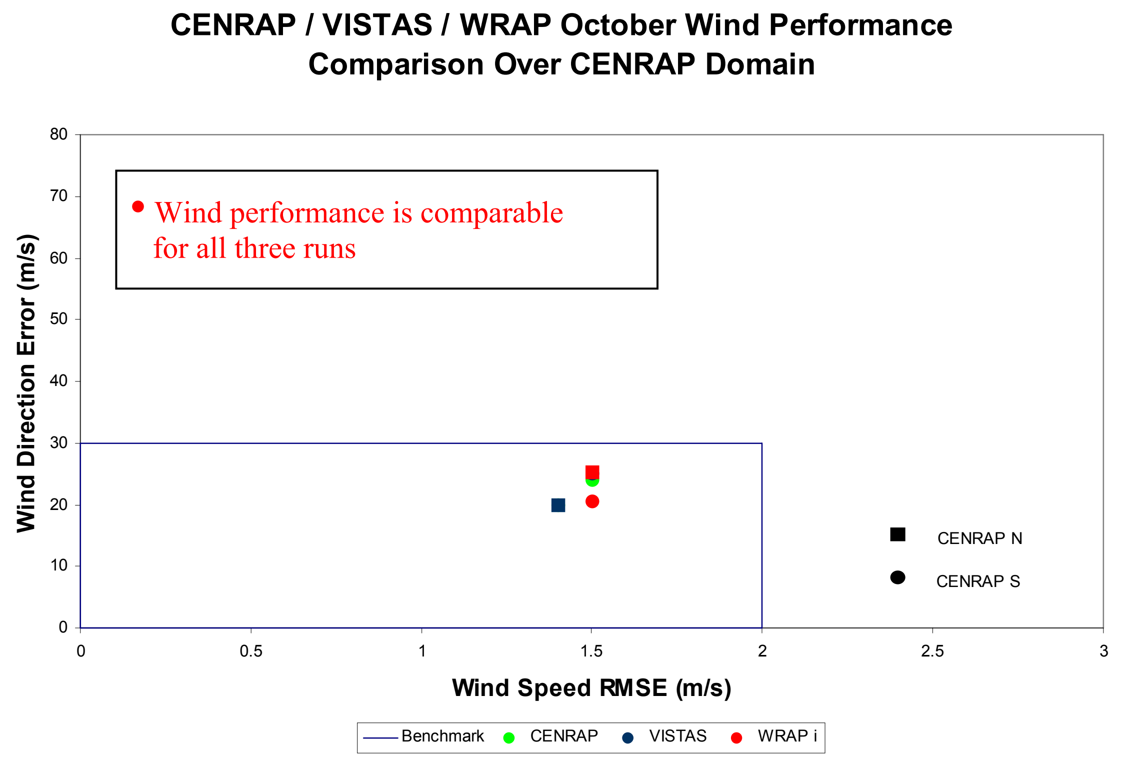


Figure A-4b. Wind Speed and Wind Direction performance for the CENRAP, VISTAS and interim WRAP 2002 36 km MM5 simulations, the CenrapN and CenrapS subdomains and July (top) and October (bottom).

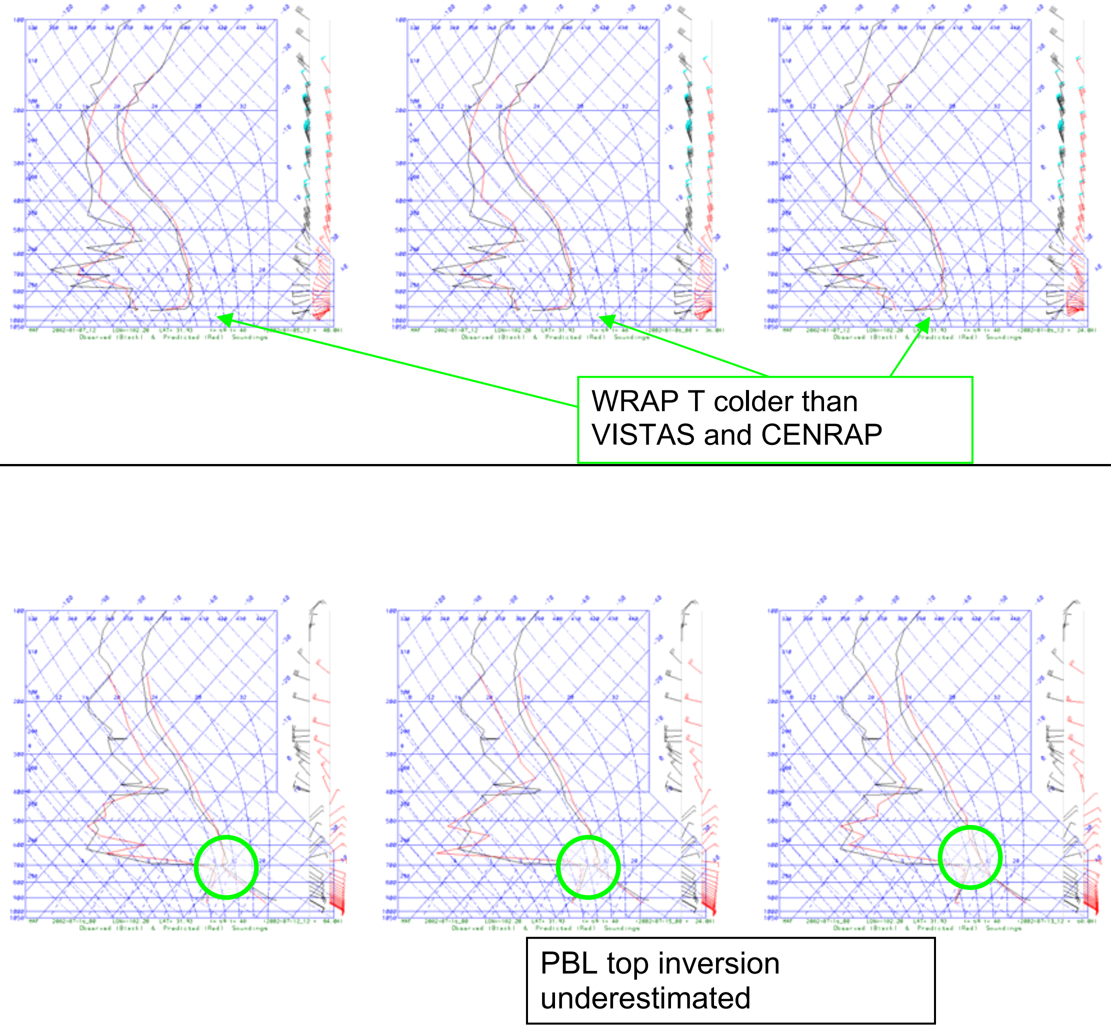
A.2 Upper-Air Meteorological Evaluation

Figure A-5 displays an example comparison of the vertical profile of predicted and observed winds and temperature for Midland, Texas and January 7 2002 at 12 GMT (6am LST) and for July 16, 2002 at 00 GMT (6pm LST). Above the surface, all three models do a good job in replicating the observed temperature, dew point temperature and winds at 6a on January 7, 2002. Although the WRAP MM5 simulation predicts the surface temperature better than the other two simulations, the vertical structure of the temperature and the surface temperature inversion is not reproduced as well.

All three models understate the afternoon PBL depth on July 16, 2002 at Midland Texas. This phenomenon was seen at other sites as well.

The upper-air meteorological model evaluation found that all three models had difficulty reproducing the observed nocturnal inversion. The day time convective mixing depths were also typically underestimated.

Although the WRAP MM5 simulation reproduced the surface temperature the best of the three models, it was worst at reproducing the observed vertical temperature structure and resultant level of mixing. These results are likely due to the surface data assimilation of temperature employed by the WRAP interim MM5 simulation and resulted in WRAP eliminating the surface temperature and humidity FDDA in their final simulation.



WRAP T colder than VISTAS and CENRAP

PBL top inversion underestimated

Figure A-5. Comparison of predicted and observed vertical temperature, dew point and winds profiles for the CENRAP (left), VISTAS (middle) and WRAP (right) at Midland Texas on January 7, 2002 at 12 GMT (top) and July 16, 2002 at 00 GMT (bottom).

A.4 Precipitation Model Performance Evaluation

The three MM5 model simulation precipitation estimates were evaluated by comparing the monthly average spatial distributions and amounts with observed values from the observed CPC 0.25 by 0.25 degree (approximately 28 km by 28 km) gridded analysis fields. The CPC analysis fields are gridded from on U.S. land-based observations, consequently the gridded observed fields are not available over the oceans and Canada and Mexico. The CPC observed monthly average precipitation fields were displayed using the MM5 modeling domain. The MM5 total precipitation estimates were accumulated for a month and plotted. Here total precipitation includes both explicit large scale synoptic precipitation as well as the subgrid-scale convective precipitation from the cumulus parameterization (Kain Fritsch 1 or 2).

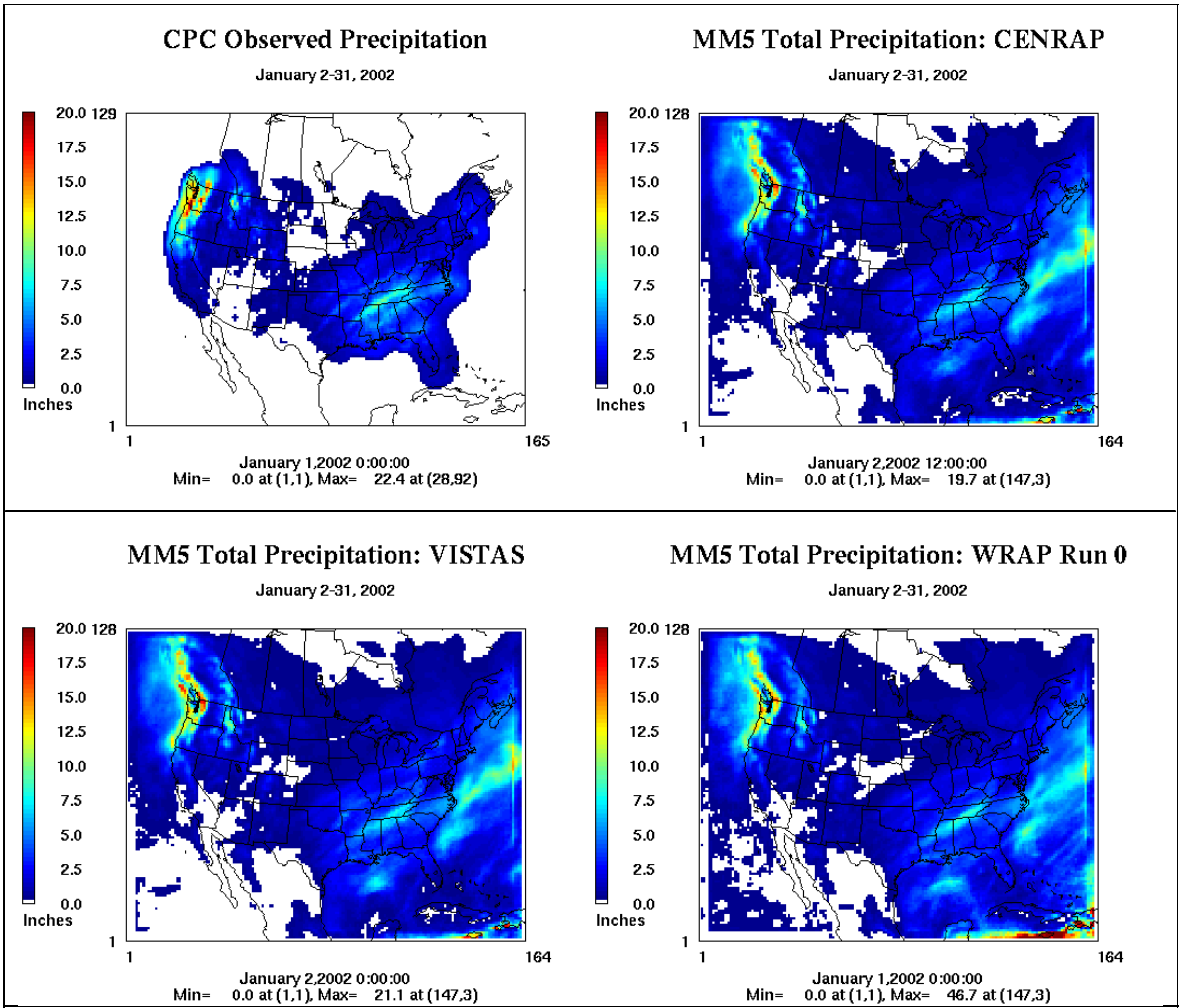
Figures A-6 through A-9 display the monthly average precipitation fields for the months of January, March, July and October and the CPC observed and CENRAP, VISTAS and interim WRAP MM5 simulations. In January (Figure A-6), all three models reproduce the observed monthly average precipitation well with enhanced predicted and observed precipitation over the Pacific Northwest and the Appalachian Mountains. The MM5 simulations also estimated enhanced precipitation in off-shore areas north of Seattle, over the Atlantic Ocean and in the Gulf of Mexico that can not be either confirmed or refuted by the CPC observations. MM5 does overstate the amount of precipitation in January over the northern CENRAP region including over Minnesota, Iowa and Nebraska.

The three models also do a good job in reproducing the observed spatial distribution and amounts of the precipitation in March 2002 (Figure A-7). Elevated precipitation areas in the Pacific Northwest and across the lower Midwest from Arkansas and up into the Ohio River Valley and adjacent areas. The MM5 simulations do understate the highest observed precipitation amounts in Arkansas. The MM5 simulations also overstate the amount of precipitation in the desert southwest (Four Corners) area in March.

The MM5 monthly average precipitation performance is dramatically worse in July 2002 (Figure A-8). Precipitation is overstated by all three MM5 simulations throughout the U.S. and particularly in the southern states, from Arkansas across Texas to the southeastern U.S. particularly Florida South and North Carolina. This over-prediction bias is due to convective precipitation from the cumulus parameterization (either Kain Fritsch 1 or 2). This overactive precipitation is the result of the over-prediction bias I humidity seen in many subdomains (see Table A-3b and Kemball-Cook et al., 2004a).

In October 2002, the three MM5 simulations reproduced the observed monthly average rainfall fairly well across the U.S. (Figure A-9). The models predict the location of the maximum precipitation in southern Louisiana well, but under-predict the magnitude, which may be due to a slight spatial displacement offshore in the Gulf of Mexico. The MM5 simulations understate the precipitation over the CENRAP region, which explains the dry humidity bias in the CenrapS subdomain in October (Figure A-3b).

In conclusion, the three MM5 simulations do a good job in simulating the observed precipitation when it is due to synoptic weather systems. However, when precipitation is due to convective activity as seen in July that is simulated by the MM5 cumulus parameterization, MM5 greatly overstates the precipitation amounts. This is particularly pronounced in the southern states from the Four Corners area to Florida with the interim WRAP simulation exhibiting the largest over-prediction bias. In the final WRAP MM5 simulation the Betts-Miller cumulus parameterization was used that greatly reduced the convective precipitation amounts resulting in better model performance (Kemball-Cook et al., 2005). However, an overestimation bias under convective precipitation conditions still was present.



CPC Observed Precipitation

MM5 Total Precipitation: CENRAP

MM5 Total Precipitation: VISTAS

MM5 Total Precipitation: WRAP Run 0

Figure A-6. Comparison of January 2002 observed monthly average precipitation (top left) with predicted values for the CENRAP (top right), VISTAS (bottom left) and WRAP (bottom right January 2002 simulation (note: observed precipitation not valid over water due to lack of measurements).

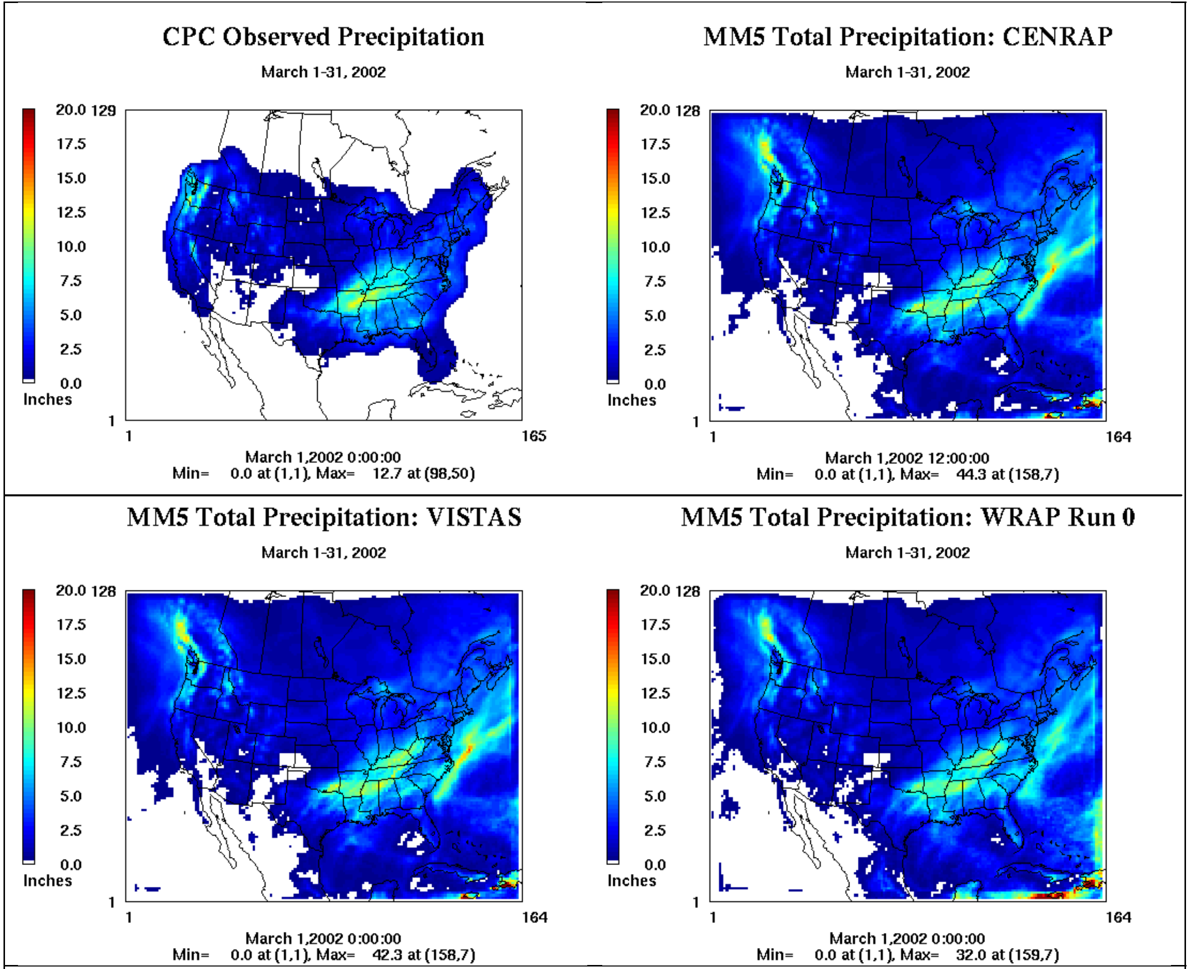
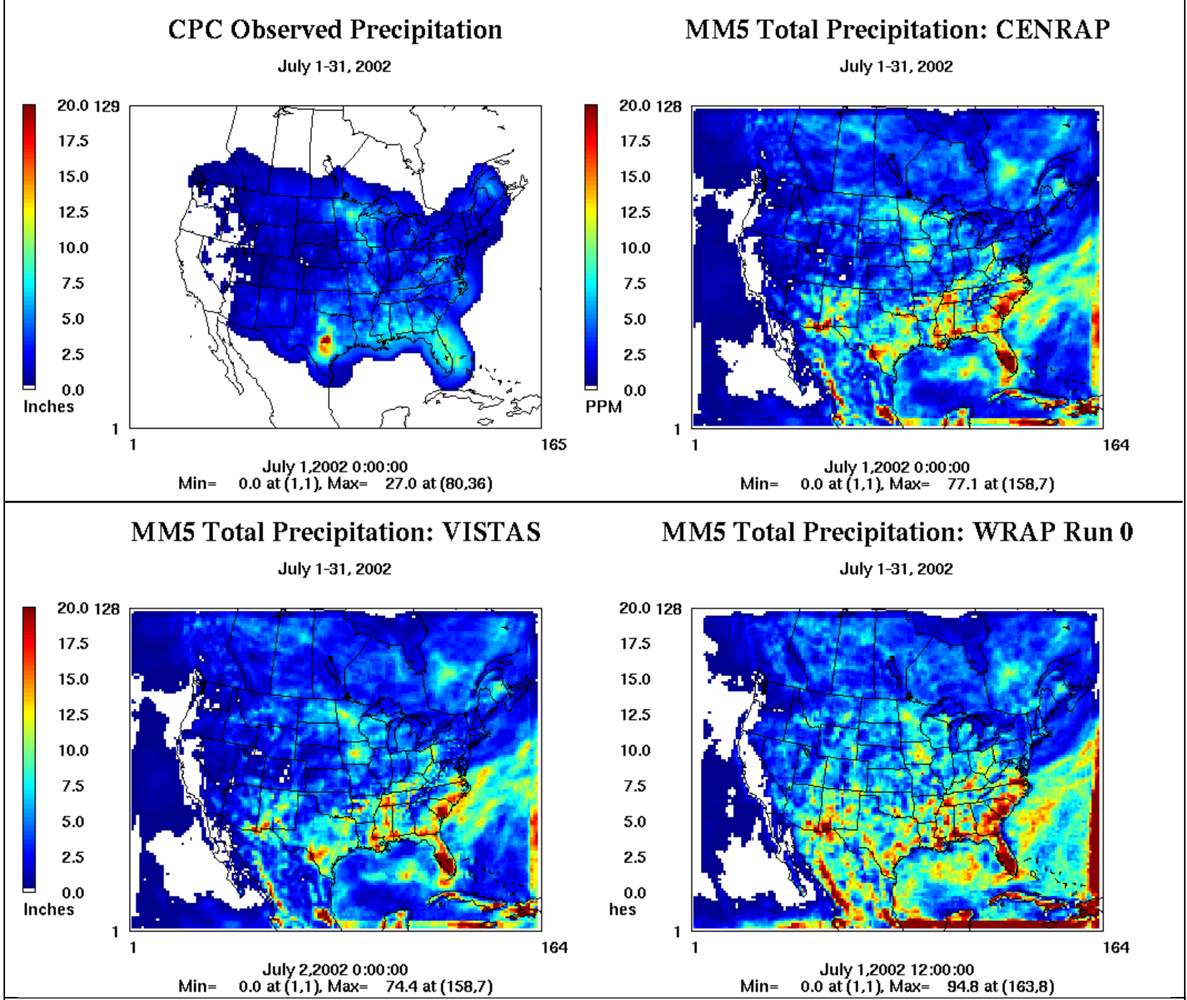


Figure A-7. Comparison of March 2002 observed monthly average precipitation (top left) with predicted values for the CENRAP (top right), VISTAS (bottom left) and WRAP (bottom right January 2002 simulation (note: observed precipitation not valid over water due to lack of measurements).



CPC Observed Precipitation

July 1-31, 2002

MM5 Total Precipitation: CENRAP

July 1-31, 2002

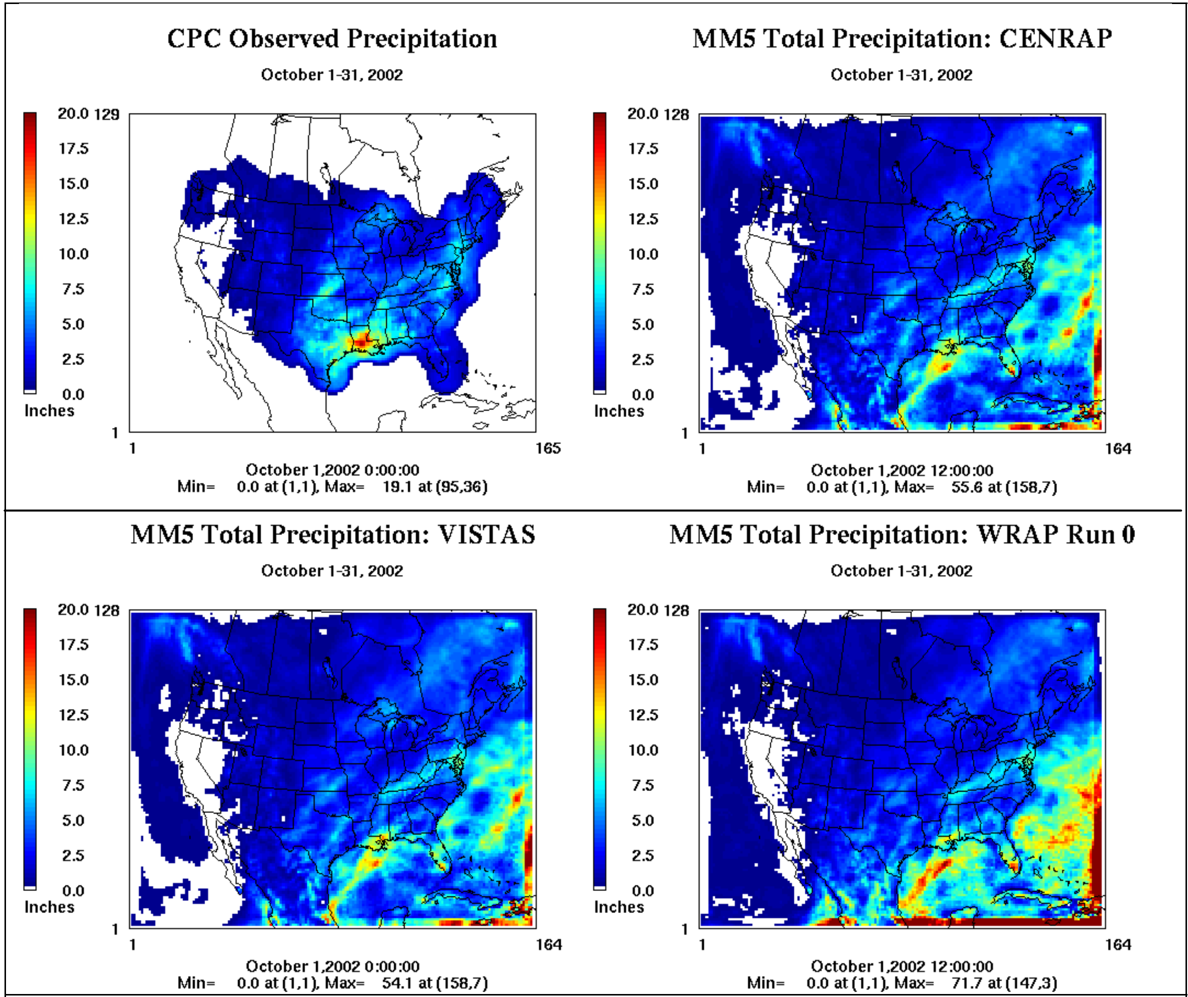
MM5 Total Precipitation: VISTAS

July 1-31, 2002

MM5 Total Precipitation: WRAP Run 0

July 1-31, 2002

Figure A-8. Comparison of July 2002 observed monthly average precipitation (top left) with predicted values for the CENRAP (top right), VISTAS (bottom left) and WRAP (bottom right) (note: observed precipitation not valid over water due to lack of measurements).


CPC Observed Precipitation

October 1-31, 2002

October 1,2002 0:00:00
Min= 0.0 at (1,1), Max= 19.1 at (95,36)

MM5 Total Precipitation: CENRAP

October 1-31, 2002

October 1,2002 12:00:00
Min= 0.0 at (1,1), Max= 55.6 at (158,7)

MM5 Total Precipitation: VISTAS

October 1-31, 2002

October 1,2002 0:00:00
Min= 0.0 at (1,1), Max= 54.1 at (158,7)

MM5 Total Precipitation: WRAP Run 0

October 1-31, 2002

October 1,2002 12:00:00
Min= 0.0 at (1,1), Max= 71.7 at (147,3)

Figure A-9. Comparison of October 2002 observed monthly average precipitation (top left) with predicted values for the CENRAP (top right), VISTAS (bottom left) and WRAP (bottom right) (note: observed precipitation not valid over water due to lack of measurements).

APPENDIX B

File Names, Data Source and Type and Description of Emissions Used in the 2002 Typical and 2018 Base G Emissions Inventories

Table A-1. CENRAP 2002 Typical Base G (Typ02G) emissions inventory.

Filename	Source	Data type	Description
1 Stationary Area Sources			
arinv_Mexico99phase3_border_20051027v4_noDust_noFire.ida	**ERG**	**Text**	**1999 BRAVO Mexico inventory for the six Northern states; annual**
arinv_Mexico99phase3_interior_ERG_Oct06_noDust_noFire.ida	**ERG**	**Text**	**1999 BRAVO Mexico inventory for the Southern states; annual**
arinv_nodust_noOilGas_CA2002_111105.ida	**ERG**	**Test**	**California 2002 inventory; annual**
arinv_noDUST_noREF_vistas_2002g_2453908.ida Alpine	**Geophysics**	**Test**	**VISTAS 2002 inventory; annual**
arinv_nodust_wrap2002_v1_noCAWANDORUT_081205.ida	**ERG**	**Text**	**WRAP 2002 inventory for AZ, CO, ID, MT, NM, NV, SD, and WY ; annual**
arinv_nodust_wrap2002_v2_WANDORUT_102105.ida	**ERG**	**Text**	**WRAP 2002 inventory for ND, OR, UT, and WA; annual**
arinv_NoFire_CANADA2000_v2.ida En	**vironment, Canada 011205**		**2000 Canada inventory; annual**
arinv_NoFire_noDUST_noREF_mrpok_2002_20jun2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 inventory; annual**
arinv_NoFire_nodust_ref_mane-vu2002_011705.ida	**MARAM web site**	**Text**	**MANE_VU 2002 inventory, annual**
arinv_NoFire_nodust_ref_nh3_cenrap2002_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; annual**
arinv_vistas2002_TypicalFires2610000_112704.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory for SCC 2610000500**
2 Fugitive Dust			
fdinv1_CA2002_v2_wfac_111105.ida	**ERG**	**Text**	**CA 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_CANADA2000_v2_wfac.ida En	**vironment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_cenrap2002_wfac_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_manevu2002_wfac_011705.ida	**MARMA web site**	**Text**	**MANE-VU2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_Mexico99phase3_border_20051027v4_wTfac.ida	**MARMA web site**	**Text**	**Mexico Northern states 1999 inventory; extracted from stationary area inventory using initial list of**

Filename	Source	Data type	Description
			SCCs; transport fractions applied; annual
fdinv1_Mexico99phase3_interior_ERG_Oct06_wo_pmfac.ida	**ERG**	**Text**	**Mexico Southern states 1999 inventory; extracted from stationary area inventory using initial list of SCCs; no transport fractions applied; annual**
fdinv1_mrpok_2002_20jun2006_w_tfrac.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_vistas_2002g_2453908_w_pmfac.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_wrap2002_wfac_noCAWANDORUT_081205.ida	**ERG**	**Text**	**WRAP 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_wrap2002_wfac_WANDORUT_102105.ida	**ERG**	**Text**	**WRAP 2002 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv2_CA2002_111105.w_tfrac.ida	**ERG**	**Text**	**CA 2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_CANADA_v2.w_tfrac.ida En	**vironment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_cenrap2002_081705.w_tfrac.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_mane-vu2002_011705.w_tfrac.ida MARAM	**A web site**	**Text**	**MANE-VU2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_vistas_2002g_2453908_w_pmfac.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport**

Filename	Source	Data type	Description
			fractions applied; annual
fdinv2_wrap2002_v1_noCAWANDORUT_081205.w_tfrac.ida	**ERG**	**Text**	**WRAP 2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_wrap2002_v2_WANDORUT_102105.w_tfrac.ida ERG		**Text**	**WRAP 2002 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
3 Road Dust			
rdinv_CA2002_v2_wfac_111105.ida	**Environ**	**Text**	**California 2002 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_CANADA2000_v2_wfac.ida Env	**ironment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_cenrap2002_wfac_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_manevu2002_wfac.ida Alpine	**Geophysics**	**Text**	**MANE-VU 2002 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_vistas_2002g_2453908_w_pmfac.txt Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_wrap2002_wfac_${season}_082205.ida	**ENVIRON**	**Text**	**WRAP 2002 inventory; transport fractions applied; seasonal**
4 Ammonia			
arinv_nh3_2002_mrpok_${month}_3may2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 agricultural ammonia inventory; monthly**
arinv_nh3_cenrap02_082406__${month}.ida	**Pechan**	**Text**	**CENRAP 2002 xxxx inventory; monthly**
CENRAP_AREA_MISC_SMOKE_INPUT_NH3_MONTH_${month}_072805_NoBio.txt	**Pechan**	**Text**	**CENRAP 2002 xxxx inventory; monthly**
NH3_CENRAP_ANN.082506.txt Pechan		**Text**	**CENRAP 2002 xxxx inventory; annual**
CENRAP_AREA_MISC_SMOKE_INPUT_ANN_STATE_071905.txt	**Pechan**	**Text**	**CENRAP 2002 xxxx inventory; annual**
5 WRAP Ammonia			
nh3gts_l.2002###.1.WRAP36.base02b_nosoil.ncf En	**viron**	**Binary, netCDF**	**Includes domestic, livestock, fertilizer, and wild life gridded inventory; daily**
6 Area Anthropogenic Fires			
arfinv_anthro_cenrap2002_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted**

Filename	Source	Data type	Description
			from stationary area inventory; annual
AREA_BURNING_SMOKE_INPUT_ANN_TX_NELI_071905.txt	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_CANADA2000_v2.ida	**Environment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_mane-vu2002_011705.ida	**MARAM web site**	**Text**	**MANE-VU2002 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_Mexico99phase3_border_20051027v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; extracted from stationary area inventory; annual**
arfinv_anthro_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states inventory; extracted from stationary area inventory; annual**
arfinv_anthro_mrpok_2002_20jun2006.ida	**Alpine Geophysics**	**Text**	**MWRPO 2002 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_vistas2002_TypicalFires_No2610000_112704.ida	**Alpine Geophysics**	**Text**	**VISTAS 2002 inventory; annual**
7 Area Wild Fires			
arfinv_wf_CANADA2000_v2.ida	**Environment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory; annual**
arfinv_wf_cenrap2002_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory; annual**
arfinv_wf_mane-vu2002_011705.ida	**MARAM web site**	**Text**	**MANE-VU 2002 inventory; extracted from stationary area inventory; annual**
arfinv_wf_Mexico99phase3_border_20051027v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states inventory; extracted from stationary area inventory; annual**
arfinv_wf_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states inventory; extracted from stationary area inventory; annual**
arfinv_wf_mrpok_2002_20jun2006.ida	**Alpine Geophysics**	**Text**	**MWRPO 2002 inventory; extracted from stationary area inventory; annual**
arfinv_wf_vistas2002_TypicalFires_No2610000_112704.ida	**Alpine**	**Text**	**VISTAS 2002 inventory; annual**

Filename	Source	Data type	Description
	Geophysics		
8 Offshore Area Sources (Gulf of Mexico)			
CO_noCM.txt	**MMS Text**		**Commercial marines records were removed; they are modeled in offshore shipping**
NOX_noCM.txt	**MMS**	**Text**	**Commercial marines records were removed; they are modeled in offshore shipping**
PM_noCM.txt MMS		**Text**	**Commercial marines records were removed; they are modeled in offshore shipping**
SO2_noCM.txt MMS		**Text**	**Commercial marines records were removed; they are modeled in offshore shipping**
VOC_noCM.txt MMS		**Text**	**Commercial marines records were removed; they are modeled in offshore shipping**
9 Non Road (Annual Inventory)			
arinv_marine_mrpok_2002_27apr2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 Marine inventory; annual**
marinv_vistas_2002g_2453972.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 Marine inventory; annual**
nrinv_CANADA2000_v2_aircraft.ida Env	**ironment Canada**	**Text**	**Canada 2000 aircraft inventory; extracted from non-road inventory; annual**
nrinv_CANADA2000_v2.ida Env	**ironment Canada**	**Text**	**Canada 2000 inventory; annual**
nrinv_CANADA2000_v2_locomotive.ida Env	**ironment Canada**	**Text**	**Canada 2000 locomotive inventory; extracted from non-road inventory; annual**
nrinv_CANADA2000_v2_marine.ida Env	**ironment Canada**	**Text**	**Canada 2000 marine inventory; extracted from non-road inventory; annual**
nrinv_cenrap2002_annual_071305.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; annual**
nrinv_mane-vu2002_052505.ida	**MARAM web site**	**Text**	**MANE_VU 2002 inventory; annual**
nrinv_mane-vu2002_aircraft_052505.ida MARAM	**web site**	**Text**	**MANE-VU 2002 aircraft inventory; extracted from non-road inventory; annual**
nrinv_mane-vu2002_locomotive_052505.ida	**MARAM web site**	**Text**	**MANE-VU 2002 locomotive inventory; extracted from non-road inventory; annual**
nrinv_mane-vu2002_shipping_052505.ida	**MARAM web site**	**Text**	**MANE-VU 2002 marine inventory;**

Filename	Source	Data type	Description
			extracted from non-road inventory; annual
nrinv_Mexico1999_ERG_Aircraft_Locomotive_Rec_102705.ida	**ERG**	**Text**	**Mexico 1999 aircraft and locomotive inventory; annual**
nrinv_Mexico99phase3_border_20061025v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; annual**
nrinv_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states; annual**
nrinv_vistas_2002g_2453908.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory; annual**
nrinv_wrap2002_InshoreMarine_annual_tpd_080205.ida	**ENVIRON**	**Text**	**WRAP marine inventory; annual**
nrinv_wrap2002_v2_locomotive_annual_tpd_102705.ida	**ENVIRON**	**Text**	**WRAP locomotive inventory; annual**
11 Non Road (Monthly and Seasonal Inventory)			
nrinv_2002_mrpok_$month_3may2006.ida	**Missouri DNR**	**Text**	**MWRPO 2002 inventory; monthly**
nrinv_CA2002_v2_OffRoad_${season}_103105.ida	**EENVIRON**	**Text**	**California 2002 inventory, seasonal**
nrinv_cenrap2002_$month_082806.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; monthly**
nrinv_wrap2002_nonCA_${season}_060705.ida	**ENVIRON**	**Text**	**WRAP 2002 inventory, monthly**
nrinv_wrap2002_v2_Aircraft_${season}_103105.ida	**ENVIRON**	**Text**	**WRAP 2002 aircraft inventory; seasonal**
12 Stationary Point			
pthour_2002typ_baseg_${month}_28jun2006.ems Alpine	**Geophysics**	**Text**	**VISTAS 2002 hourly inventory for the EGUs; monthly**
egu_ptinv_vistas_2002typ_baseg_2453909.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 EGUs inventory; annual**
negu_ptinv_vistas_2002typ_baseg_2453909.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 non EGUs inventory, annual**
ptinv_CA2002_101405.ida	**ERG**	**Text**	**California 2002 inventory; annual**
ptinv_CA2002_CARBofs_v1.ida	**ARB**	**Text**	**California 2002 offshore inventory; annual**
Ptinv_CANADA2000_v2_032407.ida Env	**ironment Canada**	**Text**	**Canada 2000 inventory; annual**
Ptinv_cenrap2002_033007.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; annual**
ptinv_egu_2002_mrpok_1may2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 EGUs inventory; annual**
ptinv_mane-vu2002_v2_${WINSUM}_041905.ida	**MARAM web site**	**Text**	**MANE-VU 2002 inventory, seasonal; winter summer**
ptinv_Mexico99phase3_border_20061025v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; annual**
ptinv_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states; annual**
ptinv_negu_2002_mrpok_1may2006.ida		**Text**	**MWRPO 2002 non EGUs inventory;**

Filename	Source	Data type	Description
			annual
ptinv_wrap2002_AKAZMTNMORUTWAWY_102405.ida	**ERG**	**Text**	**WRAP 2002 inventory for AK, AZ, MT, NM, OR, UT, WA, and WY; annual**
tinv_wrap2002_v2_NVIDSDNDCO_090805.ida ERG		**Text**	**WRAP 2002 inventory for NV, ID, SD, ND, and CO; annual**
ptinv_WRAPTribes2002_102005.ida	**ERG**	**Text**	**WRAP/Tribes 2002 inventory; annual**
13 Offshore Point (Gulf)			
CO.afs.gwei2000.20000801.latlong.ida	**MMS**	**Text**	
PM10.afs.gwei2000.20000801.latlong.ida	**MMS**	**Text**	
SO2.afs.gwei2000.20000801.latlong.ida MMS		**Text**	
NOX.afs.gwei2000.20000801.latlong.ida MMS		**Text**	
PM2_5.afs.gwei2000.20000801.latlong.ida	**MMS**	**Text**	
VOC.afs.gwei2000.20000801.latlong.ida	**MMS**	**Text**	
14 On Road Mobile (Emissions)			
mbinv_wrap2002_v2_noCA_${season}_101305.ida	**ENVIRON**	**Text**	**WRAP 2002 inventory; seasonal**
mbinv_CA2002_v2_${season}_102705.ida	**ENVIRON**	**Text**	**California 2002 inventory; seasonal**
mbinv_CANADA2000.ida Env	**ironment Canada**	**Text**	**Canada 2000 inventory; annual**
mbinv_Mexico99phase3_border_20051021v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; annual**
mbinv_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states; annual**
15 On Road Mobile (Activities, VMT)			
mbinv#_vmt_cenrap.ida	**STI**	**Text**	**CENRAP 2002 inventory; divided into three files; annual**
mbinv_2002_vmt_mane-vu.ida	**MARAM web site**	**Text**	**MANE-VU 2002 inventory; annual**
mbinv_mrpo_02f_vmt_02may06.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 inventory; annual**
mbinv_vistas_02g_vmt_12jun06.ida Alpine	**Geophysics**	**Text**	**VISTAS 2002 inventory; annual**
16 Point Fires			
ptday_2002CENRAP_ptfires_mon##.ida	**STI**	**Text**	**CENRAP 2002 prescribed fires; daily emissions; monthly**
ptday_agfires_##_vistas.ida Alpine	**Geophysics**	**Text**	**VISTA 2002 all fire sources; daily emissions; monthly**
PTDAY_200504051315_wrap2002_nfr.mon##.ida	**AirSciences**	**Text**	**WRAP 2002 non federal rangeland fires; daily emissions; monthly**
PTDAY_200507011516_wrap2002_agf_base.mon##.ida AirS	**ciences**	**Text**	**WRAP 2002 Ag. Fires; daily emissions; monthly**
PTDAY_200510210936_wrap2002_wild_base.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 wild fires; daily emissions; monthly**

Filename	Source	Data type	Description
PTDAY_200510211022_wrap2002_wfu_base.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 wild fire use; daily emissions; monthly**
PTDAY_200510211029_wrap2002_rx_base.mon##.ida	**AirSciences**	**Text**	**WRAP 2002 prescribed fires; daily emissions; monthly**
pthour_2002CENRAP_ptfires_mon##.ida STI		**Text**	**CENRAP 2002 prescribed fires; hourly plume distribution; monthly**
pthour_agfires_##_vistas.ida Alpine	**Geophysics**	**Text**	**VISTA 2002 all fire sources; hourly plume distribution; monthly**
PTHOUR_200504051315_wrap2002_nfr.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 non federal rangeland; hourly plume distribution; monthly**
PTHOUR_200507011516_wrap2002_agf_base.mon##.ida AirScien	**ces**	**Text**	**WRAP 2002 Ag. Fires; hourly plume distribution; monthly**
PTHOUR_200510210936_wrap2002_wild_base.mon##.ida AirScien	**ces**	**Text**	**WRAP 2002 wild fires; hourly plume distribution; monthly**
PTHOUR_200510211022_wrap2002_wfu_base.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 wild fire use; hourly plume disributution; monthly**
PTHOUR_200510211029_wrap2002_rx_base.mon##.ida AirScien	**ces**	**Text**	**WRAP 2002 prescribed fires; hourly plume distribution; monthly**
ptinv_2002CENRAP_ptfires_mon##.ida STI		**Text**	**CENRAP 2002 prescribed fires; fire location info.; monthly**
ptinv_agfires_##_vistas.ida Alpine	**Geophysics**	**Text**	**VISTA 2002 all fire sourcesfire location info; monthly**
PTINV_200504051315_wrap2002_nfr.mon##.ida	**AirSciences**	**Text**	**WRAP 2002 non federal rangeland fires; fire location info; monthly**
PTINV_200507011516_wrap2002_agf_base.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 Ag. Fires; fire location info.; monthly**
PTINV_200510210936_wrap2002_wild_base.mon##.ida AirScien	**ces**	**Text**	**WRAP 2002 wild fires; fire location info.; monthly**
PTINV_200510211022_wrap2002_wfu_base.mon##.ida AirScienc	**es**	**Text**	**WRAP 2002 wild fire use; fire location info.; monthly**
PTINV_200510211029_wrap2002_rx_base.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 prescribed fires; fire location; monthly**
ptday.ontario_fires.2002.txt.ida En	**vironment Canada**	**Text Onta**	**rio/Canada wild fires; daily emissions and fire info.; monthly**
ptinv.ontario_fires.2002.txt.ida En	**vironment Canada**	**Text Onta**	**rio/Canada wild fires; fire location info.; monthly**
17 Biogenecs			
b3fac.beis3_efac_v0.98.txt EPA		**Text**	**Version 0.98 biogenic emission factors**
b3_a.VISTAS36_148X112.beld3_v2.ncf Alpine	**Geophysics**	**Binary**	**Gridded land use**
b3_b.VISTAS36_148X112.beld3_v2.ncf Al	**pine**	**Binary**	**Gridded land use**

Filename	Source	Data type	Description
	Geophysics		
b3_t.VISTAS36_148X112.beld3_v2.ncf Alpine	**Geophysics**	**Binary**	**Gridded land use**
18 Windblown Dust			
wb_dust_ii_cenrap_cmaq_RPO36_2002###_agadj_tf_b.ncf ENVIRO	**N/UCR**	**Binary; netCDF**	**Domain wide wind blown dust emissions from WRAP wind blown dust model; hourly**
19 WRAP Oil and Gas			
arinv_CA2002_v2_OilGas_111105.ida	**ENVIRON**	**Text**	**California 2002 oil and gas inventory; annual**
arinv_wrap2002_v2_OilGas_annual_082505.ida	**ENVIRON**	**Text**	**WRAP 2002 oil and gas inventory; annual**
20 Offshore Shipping			
ofsgts_l.2002###.1.vista36.baseg_2002.shipping.ncf ENVIRO	**N/VISTAS**	**Binary; netCDF**	**Pacific, Gulf of Mex. and Atlantic 2002 Offshore shipping inventory; daily**

Table A-2. CENRAP 2018 Base G (Base18G) emissions inventory.

Filename	Source	Data type	Description
1 Stationary Area Sources			
arinv_Mexico99phase3_border_20051027v4_noDust_noFire.ida	**ERG**	**Text**	**1999 BRAVO Mexico inventory for the six Northern states; annual**
arinv_Mexico99phase3_interior_ERG_Oct06_noDust_noFire.ida	**ERG**	**Text**	**1999 BRAVO Mexico inventory for the Southern states; annual**
arinv_CA2018_112205.ida	**ERG**	**Text**	**California 2018 inventory; annual**
arinv_NoDust_NoREF_vistas_2018g_2453922.ida Alpine	**Geophysics**	**Test**	**VISTAS 2018 inventory; annual**
arinv_wrap2018.091205.ida	**ERG**	**Text**	**WRAP 2018 inventory; annual**
arinv_canada_2020_noDust_NoFire.ida En	**vironment, Canada**		**Canada 2020 inventory; annual**
arinv_NoFire_NoDust_NoREF_mrpok_2018_22aug2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 inventory; annual**
arinv_mane_vu_2018v3_1_NoDust_NoFire.ida		**Text**	**MANE_VU 2018 inventory, annual**
arinv_NoFire_nodust_ref_nh3_cenrap2002-2018_101606.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 inventory; annual**
arinv_vistas_baseg_2018t_lofire_11feb2007_scc2610000500.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 inventory for SCC 2610000500**
2 Fugitive Dust			
fdinv1.CA2018_wfac.ida	**ERG**	**Text**	**CA 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1.canada_2020.wTfac.ida En	**vironment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1.cenrap2002_2018_wfac.ida	**UCR; grown from 2002**	**Text**	**CENRAP 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1.mane_vu2018_wfac.ida	**MARAM web site**	**Text**	**MANE-VU 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions**

Filename	Source	Data type	Description
			applied; annual
fdinv1_Mexico99phase3_border_20051027v4_wTfac.ida	**ERG**	**Text**	**Mexico Northern states 1999 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_Mexico99phase3_interior_ERG_Oct06_wo_pmfac.ida	**ERG**	**Text**	**Mexico Southern states 1999 inventory; extracted from stationary area inventory using initial list of SCCs; no transport fractions applied; annual**
fdinv1_mrpok_2018_22aug2006_wfac.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1_vistas_2018g_2453922_w_pmfac.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv1.wrap2018_wfac.ida	**ERG**	**Text**	**WRAP 2018 inventory; extracted from stationary area inventory using initial list of SCCs; transport fractions applied; annual**
fdinv2.CA2018_wfac.ida	**ERG**	**Text**	**CA 2018 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2.canada_2020.wTfac.ida En	**vironment Canada**	**Text**	**Canada 2020 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2.cenrap2002_2018_wfac.ida	**UCR; grown from 2002**	**Text**	**CENRAP 2018 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2.mane-vu2018_wfac.ida	**MARAM web site**	**Text**	**MANE-VU 2018 inventory;**

Filename	Source	Data type	Description
			extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual
fdinv2_vistas_2018g_2453922_w_pmfac.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
fdinv2_wrap2018.091205_wfac.ida	**ERG**	**Text**	**WRAP 2018 inventory; extracted from stationary area inventory using extended list of SCCs; transport fractions applied; annual**
3 Road Dust			
rdinv.CA2018_wfac.ida	**Environ**	**Text**	**California 2018 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_canada_2020_wTfac.ida En	**vironment Canada**	**Text**	**Canada 2020 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv.cnrap2002_2018.wfac.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_mane_vu_2018v3_1_wTfac.ida	**MARAM web site**	**Text**	**MANE-VU 2018 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv_vistas_vistas_2018g_2453922_w_pmfac.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 inventory; extracted from stationary area inventory; transport fractions applied; annual**
rdinv.wrap2018_wfac_${season}.ida	**ENVIRON**	**Text**	**WRAP 2018 inventory; transport fractions applied; seasonal**
4 Ammonia			
arinv_nh3_2018_mrpok_${month}_22aug2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 agricultural ammonia inventory; monthly**
nh3minv.cenrap2018gr_18.apr.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 xxxx inventory; monthly**

Filename	Source	Data type	Description
nh3inv.misc.cnrap2002_2018.feb.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 xxxx inventory; monthly**
nh3yinv.annual.cnrap2002_2018.100406.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 xxxx inventory; annual**
nh3inv.misc_annual.cnrap2002_2018.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 xxxx inventory; annual**
5 WRAP Ammonia			
nh3gts_l.2002###.1.WRAP36.base02b_nosoil.ncf En	**viron**	**Binary, netCDF**	**Includes domestic, livestock, fertilizer, and wild life gridded inventory; daily**
6 Area Anthropogenic Fires			
arfinv_anthro_cenrap2002_081705.ida	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory; annual**
AREA_BURNING_SMOKE_INPUT_ANN_TX_NELI_071905.txt	**Pechan**	**Text**	**CENRAP 2002 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_canda2020.ida En	**vironment Canada**	**Text**	**Canada 2000 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_mane_vu_2018v3_1.ida	**MARAM web site**	**Text**	**MANE-VU 2018 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_Mexico99phase3_border_20051027v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; extracted from stationary area inventory; annual**
arfinv_anthro_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states inventory; extracted from stationary area inventory; annual**
arfinv_anthro_mrpok_2018_22aug2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 inventory; extracted from stationary area inventory; annual**
arfinv_anthro_vistas_baseg_2018t_11feb2007_NOscc2610000500.ida	**Alpine Geophysics**	**Text**	**VISTAS 2018 inventory; annual**
7 Area Wild Fires			
arfinv_wf_canada2020.ida En	**vironment Canada**	**Text**	**Canada 2020 inventory; extracted from stationary area inventory; annual**
arfinv_wf_cenrap2002-2018_101606.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 inventory; extracted from stationary area inventory; annual**

Filename	Source	Data type	Description
arfinv_wf_mane_vu_2018v3_1.ida	**MARAM web site**	**Text**	**MANE-VU 2018 inventory; extracted from stationary area inventory; annual**
arfinv_wf_Mexico99phase3_border_20051027v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states inventory; extracted from stationary area inventory; annual**
arfinv_wf_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states inventory; extracted from stationary area inventory; annual**
arfinv_wf_mrpok_2018_22aug2006.ida	**Alpine Geophysics**	**Text**	**MWRPO 2018 inventory; extracted from stationary area inventory; annual**
arfinv_wf_vistas_baseg_2018t_11feb2007_NOscc2610000500.ida	**Alpine Geophysics**	**Text**	**VISTAS 2018 inventory; annual**
8 Offshore Area Sources (Gulf of Mexico)			
ofsarinv.cnrap2002_2018_noCM.ida	**UCR; grown from 2002**	**Text**	**Commercial marines records were removed; they are modeled in offshore shipping; all pollutants; annual**
9 Non Road (Annual Inventory)			
arinv_mar_mrpok_2018_22aug2006.ida		**Text**	**MWRPO 2018 Marine inventory; annual**
marinv_vistas_2018g_2453972.ida	**Alpine Geophysics**	**Text**	**VISTAS 2018 Marine inventory; annual**
NONROAD2020_Canada.ida	**Environment Canada**	**Text**	**Canada 2020 aircraft inventory; extracted from non-road inventory; annual**
CENRAP_2018_Fnl_Nrd_Emissions091506.ida	**Pecahn**	**Text**	**CENRAP 2018 inventory; annual**
nrinv_mane_vu_2018v3_1.ida	**MARAM web site**	**Text**	**MANE_VU 2018 inventory; annual**
nrinv_Mexico1999_ERG_Aircraft_Locomotive_Rec_102705.ida	**ERG**	**Text**	**Mexico 1999 aircraft and locomotive inventory; annual**
nrinv_Mexico99phase3_border_20061025v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; annual**
nrinv_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states; annual**
nrinv_vistas_2018g_2453908.ida	**Alpine Geophysics**	**Text**	**VISTAS 2018 inventory; annual**
nrinv_wrap2018_Locomotive_annual_tpd_111805.ida	**ENVIRON**	**Text**	**WRAP 2018 locomotive inventory; annual**

Filename	Source	Data type	Description
11 Non Road (Monthly and Seasonal Inventory)			
nrinv_2018_mrpok_apr_22aug2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 inventory; monthly**
nrinv_CA2018_win_111805.ida	**EENVIRON**	**Text**	**California 2018 inventory, seasonal**
2018NONROAD_AG_IA_${month}.ida Missouri	**DNR Text**		**CENRAP/IA 2018 inventory; monthly**
nrinv.mrpok.minn.apr_2018.011306.ida	**Missouri DNR**	**Text**	**CENRAP/MN 2018 inventory; monthly**
nrinv_WRAP2018_${season}_102105.ida	**ENVIRON**	**Text**	**WRAP 2018 inventory, monthly**
nrinv_WRAP2018_Aircraft_${season}.111805.ida	**ENVIRON**	**Text**	**WRAP 2018 aircraft inventory; seasonal**
12 Stationary Point			
pthour_2018_baseg_sep_2453993.ems Alpine	**Geophysics**	**Text**	**VISTAS 2018 hourly inventory for the EGUs; monthly**
ptinv_egu_18_vistas_g_2453993.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 EGUs inventory; annual**
ptinv_nonEGU_vistas_2018_baseg_2453957.ida Alpine	**Geophysics**	**Text**	**VISTAS 2018 non EGUs inventory, annual**
pgts3d_l.2002###.1.cmaq.cb4p25.us36b.CANADA_20i01.19L.ncf EPA		**Binary; netCDF**	**Canada 2020 inventory; daily**
Ptinv_cenrap2018_EGU_${WINSUM}_annual_050407.ida	**CENRAP**	**Text**	**CENRAP 2018 EGUs inventory, seasonal; winter summer**
ptinv_o.cenrap2002_2018_nonEGU050307.ida UCR;	**grown from 2002**	**Text**	**CENRAP 2018 non EGUs inventory; annual**
ptinv_cenrapNonegu_2018_050707_refin_new_sources.ida	**CENRAP**	**Text**	**CENRAP 2018 Additional sources; annual**
ptinv_egu_2018_mrpok_11sep006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2002 EGUs inventory; annual**
Ptinv_manevu2018_EGU_${WINSUM}_ANNUAL_080805.ida	**MARAM web site**	**Text**	**MANE-VU 2018 EGUs inventory, seasonal; winter summer**
ptinv_manevu2018_nonEGU_112105.ida		**Text**	**MANE-VU 2018 non EGUs inventory, annual**
ptinv_Mexico99phase3_border_20061025v4.ida	**ERG**	**Text**	**Mexico 1999 inventory for Northern states; annual**
ptinv_Mexico99phase3_interior_ERG_Oct06.ida	**ERG**	**Text**	**Mexico 1999 inventory for Southern states; annual**
ptinv_negu_2018_mrpok_23aug2006.ida Alpine	**Geophysics**	**Text**	**MWRPO 2018 non EGUs inventory; annual**
ptinv_wrap2018_NoOG_050406.ida	**ERG**	**Text**	**WRAP 2018 inventory; no oil and gas; annual**

Filename	Source	Data type	Description
ptinv_wrap2018_OG_091205.ida	ERG	Text	WRAP 2018 inventory; oil and gas; annual
ptinv_WRAPTribes2018_NoOG_091205.ida	ERG	Text	WRAP/Tribes 2018 inventory; no oil and gas annual
ptinv_WRAPTribes2018_OG_091205.ida	ERG		WRAP/Tribes 2018 inventory; oil and gas annual
13 Offshore Point (Gulf)			
ofsinv_o_CO.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
ofsinv_o_NOX.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
ofsinv_o_PM10.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
ofsinv_o_PM2_5.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
ofsinv_o_SO2.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
ofsinv_o_VOC.cnrap2002_2018.ida UCR;	grown from 2002 emissions	Text	
14 On Road Mobile (Emissions)			
mbinv_WRAP2018_aut_102105.ida	ENVIRON	Text	WRAP 2018 inventory; seasonal
mbinv_CA2018_win_111805.ida	ENVIRON	Text	California 2018 inventory; seasonal
mbinv_CANADA2020.ida Env	ironment Canada	Text	Canada 2020 inventory; annual
mbinv_Mexico99phase3_border_20051021v4.ida	ERG	Text	Mexico 1999 inventory for Northern states; annual
mbinv_Mexico99phase3_interior_ERG_Oct06.ida	ERG	Text	Mexico 1999 inventory for Southern states; annual
15 On Road Mobile (Activities, VMT)			
mbinv.mbv#_vmt_cenrap2018_072005.ida	STI	Text	CENRAP 2018 inventory; divided into tow files; annual
mbinv_vmt_manevu2018_update.ida	MARAM web site	Text	MANE-VU 2018 inventory; annual
mbinv_mrpo_18f_vmt_11aug06.ida Alpine	Geophysics	Text	MWRPO 2018 inventory; annual
mbinv_vistas_18g_vmt_12jun06.ida Alpine	Geophysics	Text	VISTAS 2018 inventory; annual
16 Point Fires			
ptday_2002CENRAP_ptfires_mon##.ida	STI	Text	CENRAP 2002 prescribed fires; daily emissions; monthly
ptday.plume.vistasG2_2018.##.ida	Alpine	Text	VISTA 2018 all fire sources; daily

Filename	Source	Data type	Description
	Geophysics emissions;		monthly
PTDAY_200504051315_wrap2002_nfr.mon##.ida	AirSciences	Text	WRAP 2002 non federal rangeland fires; daily emissions; monthly
PTDAY_200604272314_wrap02_04_agf.mon##.ida AirSci	ences	Text	WRAP 2002-4 Ag. Fires; daily emissions; monthly
PTDAY_200510210936_wrap2002_wild_base.mon##.ida AirSci	ences	Text	WRAP 2002 wild fires; daily emissions; monthly
PTDAY_200510211022_wrap2002_wfu_base.mon##.ida AirSci	ences	Text	WRAP 2002 wild fire use; daily emissions; monthly
PTDAY_200604281056_wrap02_04_arx.mon##.ida AirSci	ences	Text	WRAP 2002-4 prescribed fires; daily emissions; monthly
PTDAY_200604281056_wrap02_04_nrx.mon##.ida AirSci	ences	Text	WRAP 2002-4 natural prescribed fires; daily emissions; monthly
pthour_2002CENRAP_ptfires_mon##.ida	STI	Text	CENRAP 2002 anthro. prescribed fires; hourly plume distribution; monthly
pthour.plume.vistasG2_2018.##.ida Alpine	Geophysics	Text	VISTA 2002 all fire sources; hourly plume distribution; monthly
PTHOUR_200504051315_wrap2002_nfr.mon##.ida Ai	rSciences	Text	WRAP 2002 non federal rangeland; hourly plume distribution; monthly
PTHOUR_200604272314_wrap02_04_agf.mon##.ida AirSci	ences	Text	WRAP 2002 Ag. Fires; hourly plume distribution; monthly
PTHOUR_200510210936_wrap2002_wild_base.mon##.ida AirSci	ences	Text	WRAP 2002 wild fires; hourly plume distribution; monthly
PTHOUR_200510211022_wrap2002_wfu_base.mon##.ida AirSci	ences	Text	WRAP 2002 wild fire use; hourly plume disributution; monthly
PTHOUR_200604281056_wrap02_04_arx.mon##.ida AirSci	ences	Text	WRAP 2002 natural prescribed fires; hourly plume distribution; monthly
PTHOUR_200604281056_wrap02_04_nrx.mon##.ida AirSci	ences	Text	WRAP 2002 anthro. prescribed fires; hourly plume distribution; monthly
ptinv_2002CENRAP_ptfires_mon##.ida	STI	Text	CENRAP 2002 prescribed fires; fire location info.; monthly
ptinv.plume.vistasG2_2018.11.ida Alpine	Geophysics	Text	VISTA 2002 all fire sourcesfire location info; monthly
PTINV_200504051315_wrap2002_nfr.mon##.ida	AirSciences	Text	WRAP 2002 non federal rangeland fires; fire location info; monthly

Filename	Source	Data type	Description
PTINV_200507011516_wrap2002_agf_base.mon##.ida Ai	**rSciences**	**Text**	**WRAP 2002 Ag. Fires; fire location info.; monthly**
PTINV_200510210936_wrap2002_wild_base.mon##.ida AirS	**ciences**	**Text**	**WRAP 2002 wild fires; fire location info.; monthly**
PTINV_200604272314_wrap02_04_agf.mon##.ida AirScien	**ces**	**Text**	**WRAP 2002 wild fire use; fire location info.; monthly**
PTINV_200604281056_wrap02_04_arx.mon##.ida AirSci	**ences**	**Text**	**WRAP 2002 anthro. prescribed fires; fire location; monthly**
PTINV_200604281056_wrap02_04_nrx.mon##.ida	**AirSciences**		**WRAP 2002 natural prescribed fires; fire location; monthly**
ptday.ontario_fires.2002.txt.ida En	**vironment Canada**	**Text Onta**	**rio/Canada wild fires; daily emissions and fire info.; monthly**
ptinv.ontario_fires.2002.txt.ida En	**vironment Canada**	**Text Onta**	**rio/Canada wild fires; fire location info.; monthly**
17 Biogenecs			
b3fac.beis3_efac_v0.98.txt EPA		**Text**	**Version 0.98 biogenic emission factors**
b3_a.VISTAS36_148X112.beld3_v2.ncf Alpine	**Geophysics**	**Binary**	**Gridded land use**
b3_b.VISTAS36_148X112.beld3_v2.ncf Alpine	**Geophysics**	**Binary**	**Gridded land use**
b3_t.VISTAS36_148X112.beld3_v2.ncf Alpine	**Geophysics**	**Binary**	**Gridded land use**
18 Windblown Dust			
wb_dust_ii_cenrap_cmaq_RPO36_2002###_agadj_tf_b.ncf ENVIRO	**N/UCR**	**Binary; netCDF**	**Domain wide wind blown dust emissions from WRAP wind blown dust model; hourly**
19 WRAP Oil and Gas			
arinv_CA2018_OilGas_112205.ida	**ENVIRON**	**Text**	**California 2018 oil and gas inventory; annual**
oginv_WRAP2018_annual_tpd_111605.ida EN	**VIRON**	**Text**	**WRAP 2018 oil and gas inventory; annual**
20 Offshore Shipping			
ofsgts_l.2002###.1.vista36.baseg_2002.shipping.ncf ENVIRO	**N/VISTAS**	**Binary; netCDF**	**Pacific, Gulf of Mex. and Atlantic 2002 Offshore shipping inventory; daily**

APPENDIX C

Model Performance Evaluation for the CMAQ 2002 Base F Base Case Simulation in the CENRAP Region

C.1 2002 Typical Base F Model Performance Evaluation Scenario

This Appendix presents the operational evaluation of the CMAQ model for the 2002 36 km Typical Base F emissions scenario. The final CENRAP 2002 and 2018 emissions scenarios used in the 2018 visibility projections was Base G. The main differences between Base G and Base F emissions inventories were updated Mexican emissions in the northern states, addition of Mexican emissions in the southern states that were not included in CENRAP's emission inventories prior to Base G and correction of a few point source stack parameters and emissions in the CENRAP states and Canada (see: http://pah.cert.ucr.edu/aqm/cenrap/QA_typ02g36.plots/log_inv_categ_Typ02g.doc). Figure C-1 displays the differences in annual average $PM_{2.5}$ and ozone concentrations between the 2002 Typical Base G and Base F simulations. Most of the differences in the two simulations are concentrations within Mexico where no monitoring data were available for the model evaluation. Thus, given the very small differences between the 2002 Typical Base F and G base case simulations, the model performance evaluation is presented for just the 2002 Typical Base F simulation (for additional comparisons of Base G and F see: http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml#typ02gvstyp02f_mpe).

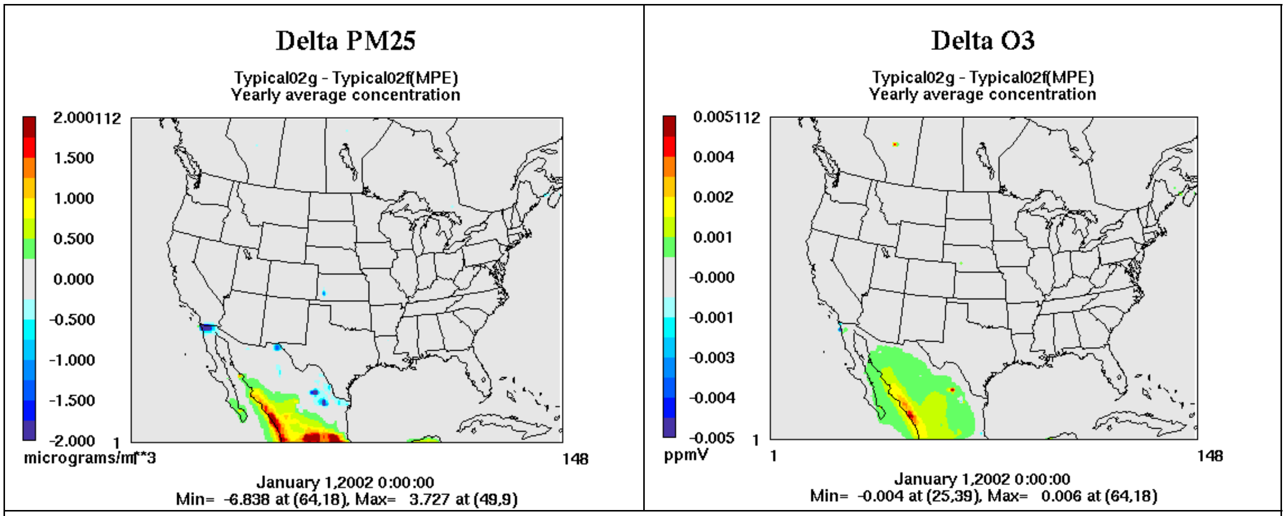


Figure C-1. Comparison of differences in annual average $PM_{2.5}$ (left) and ozone concentrations between 2002 Typical Base G and F (Base G – Base F).

The CENRAP emissions and air quality modeling initially conducted 2002 base case modeling for two 2002 base case emissions scenarios: a 2002 Actual emissions base case; and a 2002 Typical emissions base case. For the 2002 Actual base case, day-specific SO2 and NOx emissions for large stationary point sources were used based on measured continuous emissions monitoring (CEM) data along with actual 2002 fire emissions In the 2002 Typical base case, emissions for large stationary sources and fires were more representative of the 2000-2004 Baseline period. For large stationary sources' typical emissions, 5-years of CEM data were analyzed and typical seasonal and diurnally varying emissions were defined for when the sources where operating For the typical fire emissions, the locations of the 2002 Actual fire emissions were retained, but the intensity was reduced or increased to match the average conditions over the 5-year Baseline. The original intent of the CENRAP modeling of both a 2002 Actual and Typical base cases was to use the 2002 Actual base case for the model performance evaluation and the 2002 Typical base case with the 2018 emission scenario for the 2018 visibility projections.

The need to generate both the 2002 Typical and Actual base case inventories and perform CMAQ model simulations each time an emissions update or correction to the modeling occurred became burdensome and potentially could compromise the CENRAP schedule and available resources. For the Base F vintage emissions database, a model performance evaluation was conducted that compared the model performance of the 2002 Actual and Typical Base F CMAQ base case simulations to determine whether use of the Actual emissions substantially changed the interpretation of the model performance. The maximum change in model performance between the 2002 Actual and Typical base case was for sulfate and occurred during the summer months, when sulfate is the highest. Figure C-2 displays sulfate (SO4), nitrate (NO3), elemental carbon (EC) and organic matter carbon (OMC) performance for July 2002 across IMPROVE sites in the CENRAP region for the 2002 36 km Actual and Typical Base F CMAQ base case simulations. Although differences in predicted 24-hour SO4 concentrations are sometimes discernable in the scatter plot, the basic model performance conclusions remains the same and the difference in fractional bias (-48% vs. -49%) and fraction error (58% vs. 59%) are not significant. Similarly, the difference in NO3 model performance between the Actual and Typical Base F simulations are not significant. The performance of the CMAQ Actual and Typical simulation for EC and OMC is essentially identical. Given the similarity of the 2002 Base F Actual and Typical model performance evaluation, future CENRAP CMAQ model performance analysis were just performed on the Typical simulation.

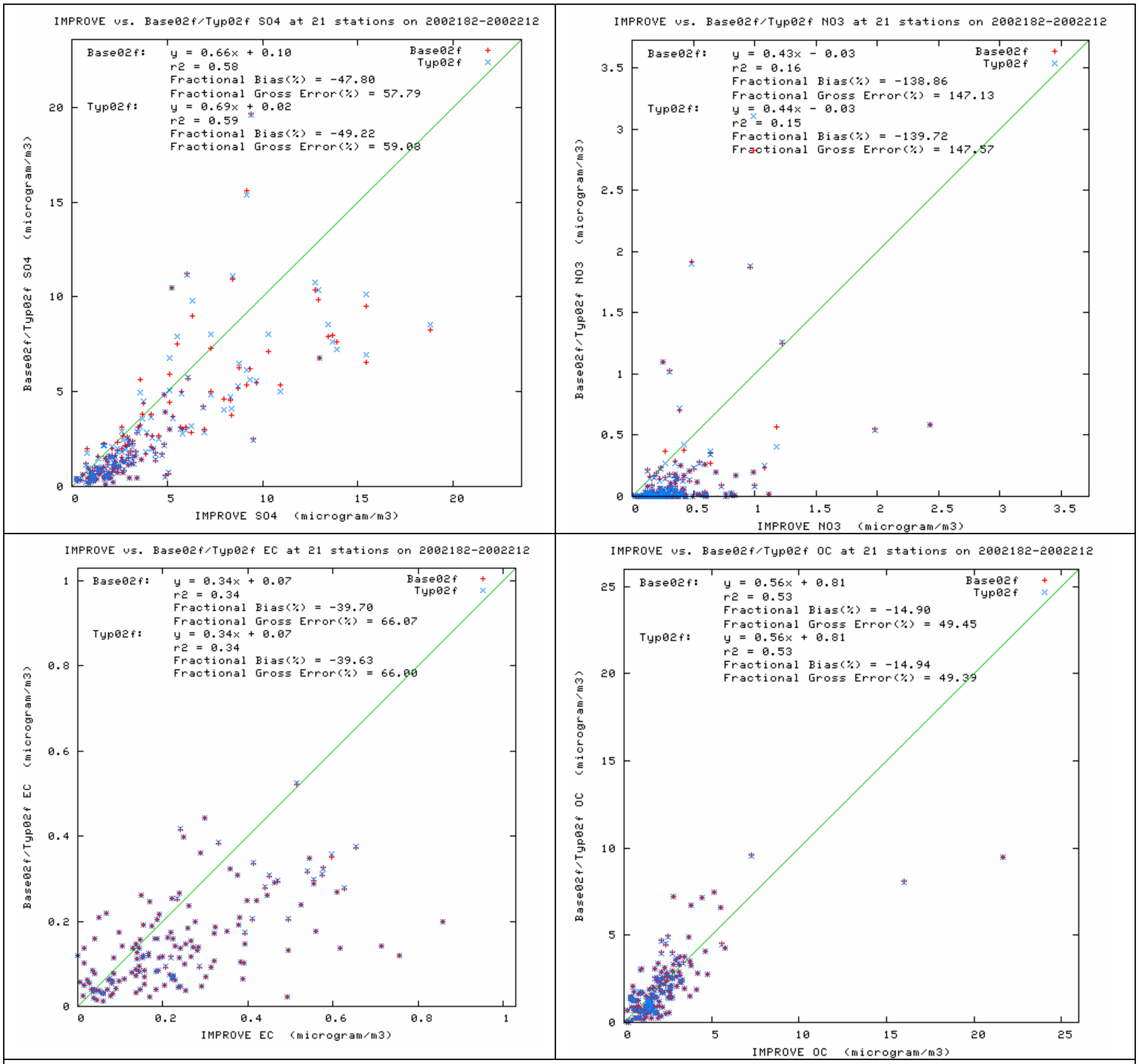


Figure C-2. Comparison of SO4 (top left), NO3 (top right), EC (bottom left) and OMC (bottom right) model performance for July 2002, the CENRAP region and the 2002 36 km Base F Actual (red) and Typical (blue) CMAQ base case simulation.

C.2 CMAQ Evaluation Methodology

EPA's integrated ozone, $PM_{2.5}$ and regional haze modeling guidance calls for a comprehensive, multi-layered approach to model performance testing, consisting of the four major components: operational, diagnostic, mechanistic (or scientific) and probabilistic (EPA, 2007). The CMAQ model performance evaluation effort focused on the first two components, namely:

- **Operational Evaluation**: Tests the ability of the model to estimate PM concentrations (both fine and coarse) and the components at PM_{10} and $PM_{2.5}$ including the quantities used to characterize visibility (i.e., sulfate, nitrate, ammonium, organic carbon, elemental carbon, other $PM_{2.5}$, and coarse matter ($PM_{2.5-10}$). This evaluation examines whether the measurements are properly represented by the model predictions but does not necessarily ensure that the model is getting "the right answer for the right reason"; and

- **Diagnostic Evaluation:** Tests the ability of the model to predict visibility and extinction, PM chemical composition including PM precursors (e.g., SOx, NOx, and NH_3) and associated oxidants (e.g., ozone and nitric acid); PM size distribution; temporal variation; spatial variation; mass fluxes; and components of light extinction (i.e., scattering and absorption).

The diagnostic evaluation also includes the performance of diagnostic tests to better understand model performance and identify potential flaws in the modeling system that can be corrected. The diagnostic evaluation may also includes the use of "probing tools" to understand why the model obtains a given prediction; probing tools include Process Analysis (PA), decoupled direct method (DDM) and source apportionment (SA).

In this final model performance evaluation for the 2002 Typical Base F CMAQ simulation, the operational evaluation has been given the greatest attention since this is the primarily thrust of EPA's modeling guidance. However, we have also examined certain diagnostic features dealing with the model's ability to simulate sub-regional and monthly/diurnal gas phase and aerosol concentration distributions. In the course of the CENRAP and other modeling process numerous diagnostic sensitivity tests were performed to investigate and improve model performance. Key diagnostic tests performed are discussed and the results for the rest are available on the CENRAP modeling website: http://pah.cert.ucr.edu/aqm/cenrap/index.shtml.

C.2.1 Ambient Air Quality Data for CENRAP Model Evaluation

The ground-level model evaluation database for 2002 was compiled by the modeling team using several routine and research-grade databases. The first is the routine gas-phase concentration measurements for ozone, NO, NO_2 and CO archived in EPA's Aerometric Information Retrieval System (AIRS) Air Quality System (AQS) database. Other sources of observed information come from the various PM monitoring networks in the U.S. These include the: (a) Interagency Monitoring of Protected Visual Environments (IMPROVE); (b) Clean Air Status and Trends Network (CASTNET); (c) Southeastern Aerosol Research and Characterization (SEARCH); (d) EPA Federal Reference Method $PM_{2.5}$ and PM_{10} Mass Networks (EPA-FRM); (e) EPA Speciation Trends Network (STN) of $PM_{2.5}$ species; and (f) National Acid Deposition Network (NADP). These PM monitoring networks may also provide ozone and other gas phase precursors and product species, and visibility measurements at some sites. During the course of the CENRAP modeling, the numerous base case simulations were evaluated across the continental U.S. In this section we focus our evaluation on model performance within the CENRAP region. Table C-1 summarizes the observations collected at each monitoring network within the CENRAP region and their sampling frequency with Figure C-3 displaying the locations of the monitors for the various monitoring networks operating in the CENRAP region during 2002.

Table C-1. Ambient monitoring data available in the CENRAP region during 2002.

Monitoring Network	Chemical Species Measured	Sampling Frequency; Duration
IMPROVE	Speciated $PM_{2.5}$ and PM_{10}	1 in 3 days; 24 hr
CASTNET	Speciated $PM_{2.5}$, Ozone	Hourly, Weekly; 1 hr, Week
SEARCH	24-hr PM_{25} (FRM Mass, OC, BC, SO_4, NO_3, NH_4, Elem.); 24-hr PM coarse (SO_4, NO_3, NH_4, elements); Hourly $PM_{2.5}$ (Mass, SO_4, NO_3, NH_4, EC, TC); and Hourly gases (O_3, NO, NO_2, NO_y, HNO_3, SO_2, CO)	Daily, Hourly;
NADP	WSO_4, WNO_3, WNH_4 Weekly	
EPA-FRM	Only total fine mass ($PM_{2.5}$)	1 in 3 days; 24 hr
EPA-STN	Speciated $PM_{2.5}$ Varies;	Varies
AIRS/AQS	CO, NO, NO_2, NO_x, O_3 Hourly;	Hourly

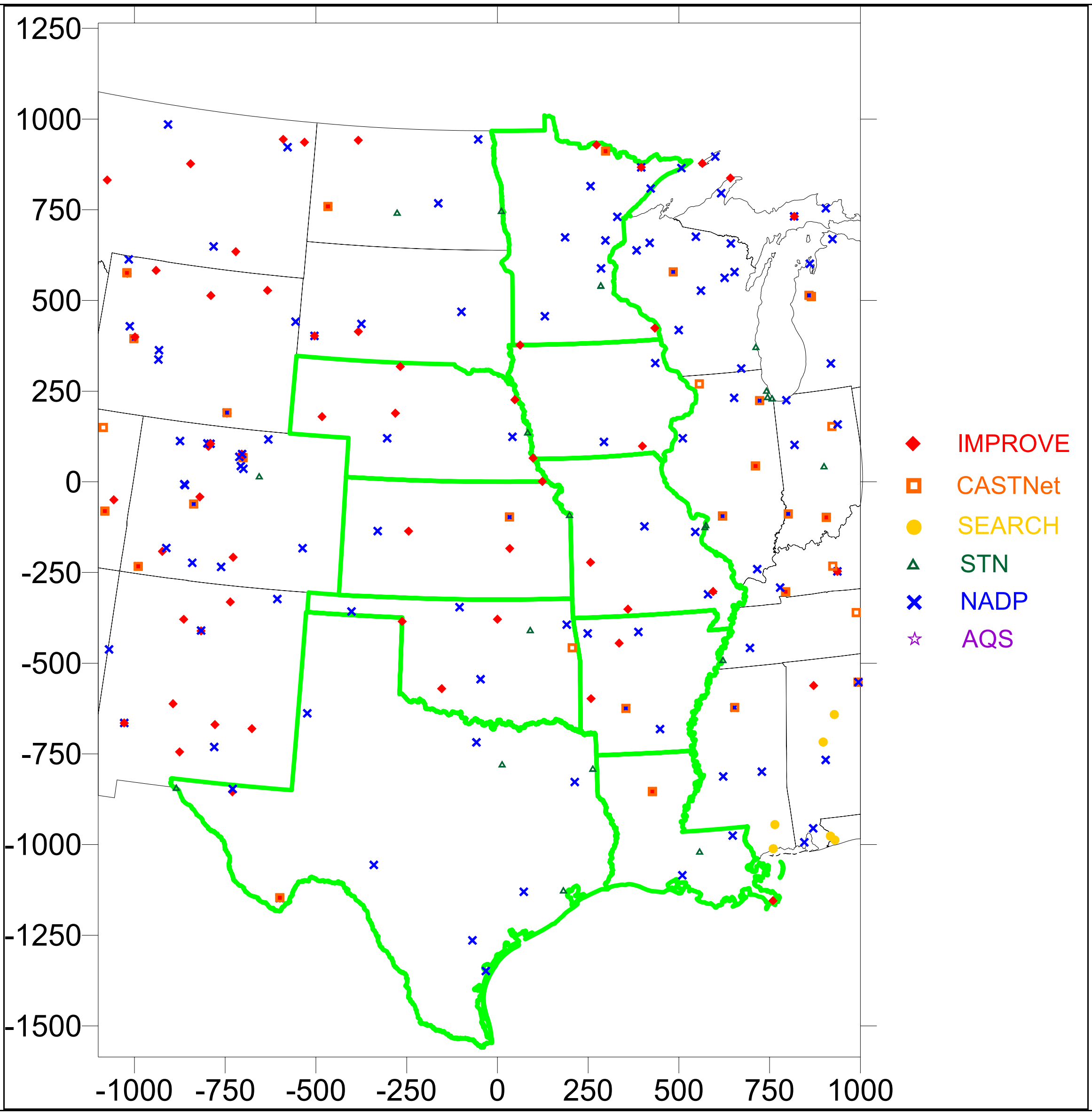


Figure C-3. Locations of surface monitors within the CENRAP states for sites operating during 2002.

C.2.2 Scope of CMAQ Model Performance Evaluation

The primary focus of the CMAQ Base F evaluation is on how well the model is able to replicate observed concentrations gas-phase pollutants and precursors, the various components of $PM_{2.5}$, total observed mass of $PM_{2.5}$, and wet deposition amounts. The CMAQ operational evaluation, model outputs are compared statistically and graphically with observational data obtained from the IMPROVE, CASTNet, STN, NADP and AQS monitoring networks. Because the SEARCH network is located in the southeastern U.S. (VISTAS region) outside of the CENRAP region, it is not a major component of our evaluation. Also, since the EPA-FRM network focuses on just $PM_{2.5}$ mass measurements primarily in $PM_{2.5}$ nonattainment or near nonattainment areas it is not very relevant for simulating regional haze at mainly remote Class I areas so is also not used in our model performance evaluation. The primary focus of the operational evaluation of the CMAQ 2002 Base F simulation is the performance of PM components in the CENRAP region for predicting regional haze at Class I areas.

Many statistical performance measures have been calculated using the different monitoring networks and across the different model performance subdomains (e.g., RPO regions). Table C-2 lists the definitions of the model performance evaluation statistical metrics. These performance metrics are routinely generate by the UCR Analysis Tool and are available on the project website. Many of them are measures of bias and error that are somewhat redundant.

Table C-2. Statistical Measures Used in the CENRAP CMAQ Model Evaluation.

Statistical Measure	**Shorthand Notation**	**Mathematical Expression**	**Notes**
Accuracy of paired peak (***A_p***)	**Paired_Peak**	$\dfrac{P - O_{peak}}{O_{peak}}$	P_{peak} = paired (in both time and space) peak prediction
Coefficient of determination (***r^2***)	**Coef_Determ**	$\dfrac{\left[\sum_{i=1}^{N}(P_i - \overline{P})(O_i - \overline{O})\right]^2}{\sum_{i=1}^{N}(P_i - \overline{P})^2 \sum_{i=1}^{N}(O_i - \overline{O})^2}$	P_i = prediction at time and location i; O_i = observation at time and location i; $\overline{P}$ = arithmetic average of P_i, i=1,2,…, N; $\overline{O}$ = arithmetic average of O_i, i=1,2,…,N
Normalized Mean Error (***NME***)	**Norm_Mean_Err**	$\dfrac{\sum_{i=1}^{N}\lvert P_i - O_i\rvert}{\sum_{i=1}^{N} O_i}$	Reported as %
Root Mean Square Error (***RMSE***)	**Rt_Mean_Sqr_Err**	$\left[\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2\right]^{1/2}$	Reported as %
Fractional Gross Error (***F_E***)	**Frac_Gross_Err**	$\frac{2}{N}\sum_{i=1}^{N}\left\lvert\frac{P_i - O_i}{P_i + O_i}\right\rvert$	Reported as %
Mean Absolute Gross Error (***MAGE***)	**Mean_Abs_G_Err**	$\frac{1}{N}\sum_{i=1}^{N}\lvert P_i - O_i\rvert$	
Mean Normalized Gross Error (***MNGE***)	**Mean_Norm_G_Err**	$\frac{1}{N}\sum_{i=1}^{N}\frac{\lvert P_i - O_i\rvert}{O_i}$	Reported as %
Mean Bias (***MB***)	**Mean_Bias**	$\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)$	Reported as concentration (e.g., μg/m^3)

Statistical Measure	Shorthand Notation	Mathematical Expression	Notes
Mean Normalized Bias (***MNB***)	**Mean_Norm_Bias**	$\frac{1}{N}\sum_{i=1}^{N}\frac{(P_i - O_i)}{O_i}$	Reported as %
Mean Fractionalized Bias (Fractional Bias, ***MFB***)	**Mean_Fract_Bias**	$\frac{2}{N}\sum_{i=1}^{N}\left(\frac{P_i - O_i}{P_i + O_i}\right)$	Reported as %
Normalized Mean Bias (***NMB***)	**Norm_Mean_Bias**	$\frac{\sum_{i=1}^{N}(P_i - O_i)}{\sum_{i=1}^{N}O_i}$	Reported as %
Bias Factor (***BF***)	**Bias Factor**	$\frac{1}{N}\sum_{i=1}^{N}\left(\frac{P_i}{O_i}\right)$	Reported as BF:1 or 1: BF or in fractional notation (BF/1 or 1/BF).

C.2.3 Operational Model Evaluation Approach

The CENRAP modeling databases will be used to develop the visibility State Implementation Plan (SIP) due in December 2007 as required by the Regional Haze Rule (RHR). Accordingly, the primary focus of the operational evaluation is on the six components of fine particulate ($PM_{2.5}$) and Coarse Matter ($PM_{2.5\text{-}10}$) within the CENRAP region that are used to characterize visibility at Class I areas:

- Sulfate (SO4);
- Particulate Nitrate (NO3);
- Elemental Carbon (EC);
- Organic Mass Carbon (OMC);
- Other inorganic fine particulate (IP or Soil); and
- Coarse Matter (CM).

The model performance for ozone and precursor and product species (e.g., SO_2 and HNO_3) is also evaluated to build confidence that the modeling system is sufficiently reliable to project future-year visibility.

C.2.5 Performance Evaluation Tools

One of the many challenges in evaluating an annual PM/ozone model simulation is how to synthesize model performance given the shear volume of output from an annual simulation. The model is run on a 148 x 112 x 19 grid with approximately 30 species producing hourly outputs for each day of the year. This results in approximately 90 trillion concentration estimates that are produced for an annual simulation. Thus, the synthesis and interpretation of numerous graphical and tabular displays of model performance into a few concise and descriptive displays that identify the most salient features of model performance is necessary. As part of the CENRAP modeling, as well as work performed by WRAP, VISTAS, MRPO and MANE-VU, several analysis tools and summary displays have been developed and are used:

> UCR Analysis Tools: The University of California at Riverside (UCR) Analysis Tools have been used extensively to evaluate the CMAQ and CAMx models for CENRAP (e.g., Morris et al., 2005), WRAP (Tonnesen et al., 2004), VISTAS (Morris et al., 2004) as well as other studies and are run on a Linux platform separately for each network. Numerous graphical displays of model performance are automatically generated using gnuplot. The software generates the following summary and graphical displays of model performance:
>
> - Tabular statistical measures (see Table C-2);
> - Time Series Plots for each site and species; and
> - Scatter Plots for each species by allsite_allday, allday_onesite and allsite_oneday.
>
> The UCR Analysis Tool is run for a specific subregion (e.g., by RPO region) and for selected monitoring networks. Because each monitoring network has its own measurement artifacts, the model is evaluated separately for each monitoring network.
>
> Summary Bias/Error Plots: The modeling team has developed additional displays of model performance statistics that elucidate model performance in a concise manner: (1) monthly time series plots of average bias and error; (2) soccer plots that display bias versus error and compares them to model performance goals and criteria; and (3) tools to analyze visibility model performance for the worst and best 20 percent visibility days that are used in visibility projections.
>
> GA DNR Analysis Plots: Dr. James Boylan of the Georgia Department of Natural Resources has extended the concept in EPA's draft PM fine particulate and regional haze modeling guidance that model performance for species that make up a major contribution to visibility impairment be subjected to more stringent goals than species that are minor contributors by developing concentration-dependent performance goals and "Bugle Plots" to display them (Boylan, 2004).

The evaluation of the CENRAP 2002 36 km Base F CMAQ simulation used each of the analysis tools listed above taking advantage of their different descriptive and complimentary nature. The use of these analysis tools generated thousands of statistical measures and graphical displays of model performance that cannot all be displayed in this report. The modeling team has gone through the plots and measures using slide shows to identify those displays that are most descriptive in conveying model performance so should be included in this TSD. The complete set of model performance statistics and graphical performance displays can be found on the CENRAP modeling Website at:

> http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml#cmaq_typ02f_mpe

Note that model performance statistics are calculated separately for each of the monitoring networks. Different PM measurement technology can produce different measurement values even when measuring the same air parcel. Thus, when calculating model performance metrics, measurements in different networks are not mixed.

C.2.4 Subdomains Analyzed

CENRAP has been analyzing model performance in five subdomains corresponding to the states contained in the five RPOs (see Figure 1-1):

- CENRAP
- MRPO
- VISTAS
- MANE-VU
- WRAP

As CENRAP has refined its emissions inventory, the changes in model performance from one 2002 base case to another has diminished to the point where little has changed in the last few iterations. Thus, the CMAQ 2002 36 km Base F evaluation presented in this section was just performed for the CENRAP region and the reader is referred to the modeling Website (http://pah.cert.ucr.edu/aqm/cenrap/cmaq.shtml) and Morris and co-workers (2005) for the evaluation outside of the CENRAP region and the diagnostic model evaluation.

C.2.5 Model Performance Goals and Criteria

The issue of model performance goals for PM species is an area of ongoing research and debate. For ozone modeling, EPA has established performance goals for 1-hour ozone normalized mean bias and gross error of #±15% and #35%, respectively (EPA, 1991). EPA's draft fine particulate modeling guidance notes that performance goals for ozone should be viewed as upper bounds of model performance that PM models may not be able to always achieve and we should demand better model performance for PM components that make up a larger fraction of the PM mass than those that are minor contributors (EPA, 2001). EPA's final modeling guidance does not list any specific model performance goals for PM and visibility modeling and instead provides a summary of PM model performance across several historical applications that can be used for comparisons if desired. Measuring PM species is not as precise as ozone monitoring. In fact, the differences in measurement techniques for some species likely exceed the more stringent performance goals, such as those for ozone. For example, recent comparisons of the PM species measurements using the IMPROVE and STN measurement technologies found differences of approximately ∀20% (SO4) to ∀50% (EC) (Solomon et al., 2004).

For the CENRAP, VISTAS and WRAP modeling we have adopted three levels of model performance goals and criteria for bias and gross error as listed in Table C-3. Note that we are not suggesting that these performance goals be adopted as guidance or that they are the most appropriate goals to use. Rather, we are just using them to frame and put the PM model performance into context and to facilitate model performance intercomparison across episodes, species, models and sensitivity tests.

Table C-3. Model performance goals and criteria used to assist in interpreting modeling results.

Fractional Bias	Fractional Error	Comment
#∀15%	#35%	Ozone model performance goal for which PM model performance would be considered good – note that for many PM species measurement uncertainties may exceed this goal.
#∀30%	#50%	Proposed PM model performance goal that we would hope each PM species could meet
#∀60%	#75%	Proposed PM criteria above which indicates potential fundamental problems with the modeling system.

As noted in EPA's PM modeling guidance, less abundant PM species should have less stringent performance goals (EPA, 2001; 2007). Accordingly, we are also using performance goals that are a continuous function of average concentrations, as proposed by Dr. James Boylan at the Georgia Department of Natural Resources (GA DNR), that have the following features (Boylan, 2004):

- Asymptotically approaching proposed performance goals or criteria (i.e., the ∀30%/50% and ∀60%/75% bias/error levels listed in Table C-1) when the mean of the observed concentrations are greater than 2.5 ug/m^3.
- Approaching 200% error and ∀200% bias when the mean of the observed concentrations are extremely small.

Bias and error are plotted as a function of average concentrations. As the mean concentration approach zero, the bias performance goal and criteria flare out to ∀200% creating a horn shape, hence the name "Bugle Plots". Dr. Boylan has defined three Zones of model performance: Zone 1 meets the ∀30%/50% bias/error performance goal and is considered "good" model performance; Zone 2 lies between the ∀30%/50% performance goal and ∀60%/75% performance criteria and is an area where concern for model performance is raised; and Zone 3 lies above the ∀60%/75% performance criteria and is an area of questionable model performance.

C.2.6 Performance Time Periods

The CMAQ 2002 36 km Base F evaluation, model performance statistics and graphical displays are generated monthly using the native averaging times of each monitoring network (i.e., 24-hour for IMPROVE and STN; weekly for CASTNet and NADP; and hourly for AQS). As the focus of the RHR is on daily average visibility that is calculated from daily average PM species concentrations then the evaluation of the model for 24-hour concentrations is particularly relevant. The RHR places particular emphasis on the Worst 20% (W20%) and Best 20% (B20%) days at Class I areas. Thus, we also place particular emphasis on the model performance for PM species on the W20% and B20% days during 2002 at Class I areas.

C.2.7 Key Measures of Model Performance

Although we have generated numerous statistical performance measures (see Table C-2) that are available on the CENRAP modeling website, when comparing model performance across months, subdomains, networks, grid resolution, models, studies, etc. it is useful to have a few key measurement statistics to be used to facilitate the comparisons. It is also useful to have a subset of the 2002 year that can represent the entire year so that a more focused evaluation can be conducted. We have found that the Mean Fractional Bias and Mean Fractional Gross Error appear to be the most consistent descriptive measure of model performance (Morris et al., 2004b; 2005). The Fractional Bias and Error normalize by the average of the observed and predicted value (see Table C-2) because it provides descriptive power across different magnitudes of the model and observed concentrations and is bounded by -200% to +200%. This is in contrast to the normalized bias and error (as recommended for ozone performance goals, EPA, 1991) that is normalized by just the observed value so can "blow up" to infinity as the observed value approaches zero. Below we perform a focused evaluation of model performance for four months of the 2002 year that are used to represent the seasonal variation in performance:

- January
- April
- July
- October

We also present fractional bias and error for all months of 2002 using time series and bugle plots.

C.3 Operational Model Performance Evaluation in the CENRAP Region

In the following discussions we use selected monthly scatter plots, time series plots and model performance statistical measures from the UCR Analysis Tools application to the 2002 CMAQ Base F base case simulation in an operational evaluation of the model for PM species. We focus on the six main components of PM that are used to project visibility.

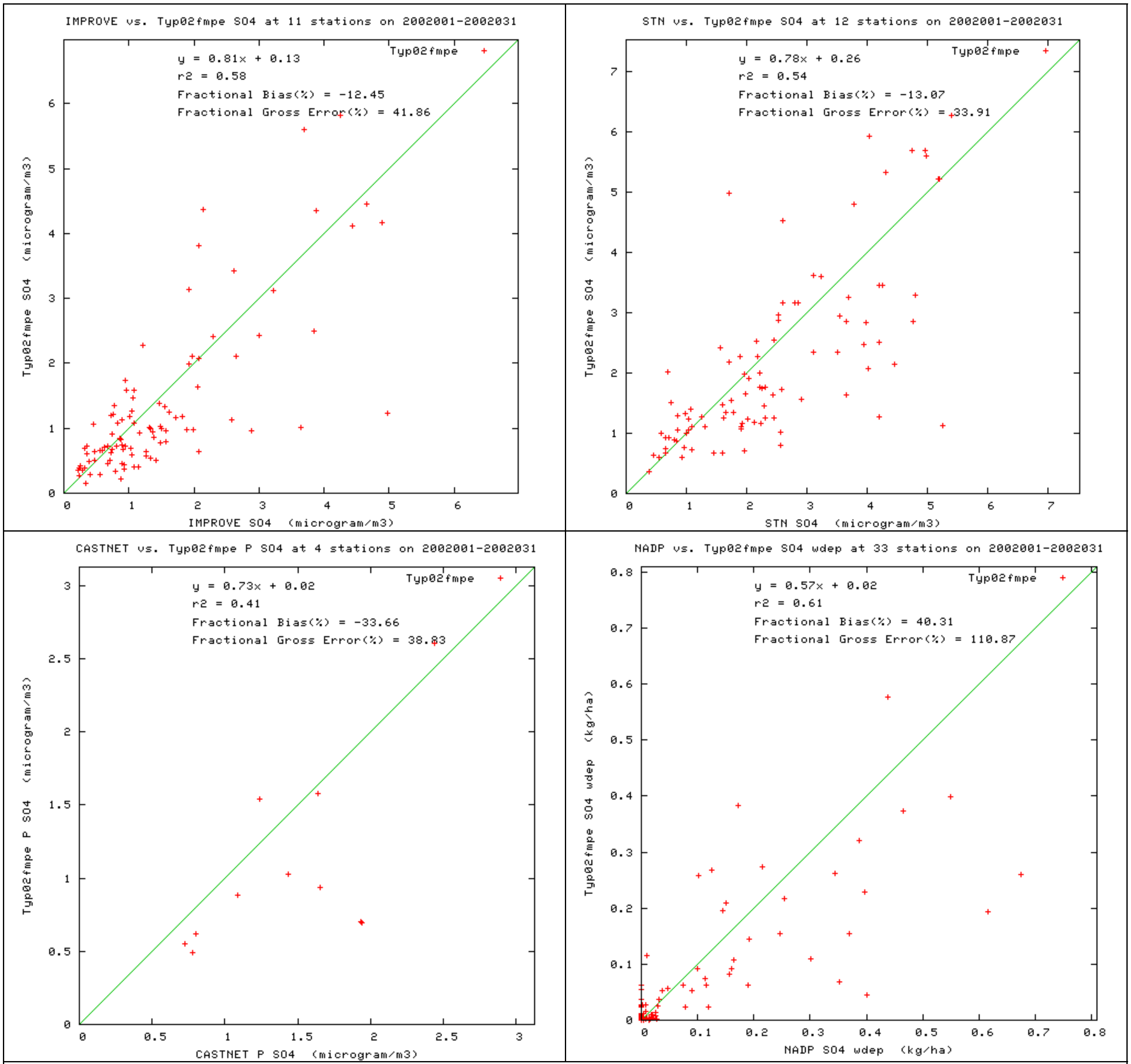
C.3.1 Sulfate (SO4) Monthly Model Performance

C.3.1.1 SO4 in January 2002

Figure C-4a displays scatter plots of predicted and observed SO4 concentrations or wet depositions for sites in the CENRAP regions using observations from the IMPROVE, STN, CASTNet and NADP monitoring networks; the IMPROVE and STN SO4 concentrations are 24-hour averages whereas the CASTNet SO4 concentrations and NADP SO4 wet deposition are weekly averages. The January SO4 performance at the IMPROVE and STN networks in the CENRAP region is quite good with low fractional bias (-12% to -13%) and some scatter (fractional error of 42% and 34%) but centered in the 1:1 line of perfect agreement. There is a net SO4 underestimation bias in January across the CASTNet network (fractional bias of -34%) with wet SO4 deposition overstated on average across the NADP sites in the CENRAP region (+40% fractional bias). Whether the overstated SO4 wet deposition is a contributor to the SO4 concentration underestimation bias is unclear, but it is in the correct direction to account for it.

The time series comparisons of predicted and observed 24-hour SO4 concentrations at CENRAP Class I area IMPROVE sites during January 2002 shown in Figure C-4b are quite encouraging. Although there are some days and sites with mismatches (e.g., January 26 at BOWA and VOYA) and sites with systematic performance problems (SO4 underestimated at BIBE), the time series in generally are quite good with the model tracking the observed temp[oral variation in daily sulfate in January and some sites exhibiting remarkable agreement (e.g., MING).

Figure C-4c displays the spatial variations in the predicted and IMPROVE observed SO4 concentrations for January 20, 23, 26 and 29, 2002, which are four consecutive days of IMPROVE monitoring using its 1:3 day monitoring frequency. On January 20 both the model and observations agree on that an elevated sulfate clouds is entering the CENRAP region across southern Illinois and Missouri. There is a sharp SO4 concentration gradient going east to west with both the model and observations estimating relatively clean SO4 values over Colorado. By January 23 the model and observations agree that elevated SO4 exists along a diagonal orientation from Chicago to East Texas. Although there are some SO4 model/observed spatial mismatches on this day (e.g., northern Louisiana and western Arkansas) the model generally reproduces the areas of elevated and low observed SO4. By January 29 the model and observations agree that SO4 has cleaned out of the CENRAP region. Although there are elevated SO4 observations in western North Dakota and northern Minnesota not reflected in the model. On January 29 there is an elevated tongue of SO3 entering the CENRAP region through southern Illinois stretching to the southwest almost to Big Bend in western Texas. Observed SO4 is measured at Big Bend but the modeled high SO4 is slightly east of there. There is very good agreement on this day between the predicted and observed spatial distribution of SO4.


IMPROVE vs. Typ02fmpe SO4 at 11 stations on 2002001-2002031

y = 0.81x + 0.13
r2 = 0.58
Fractional Bias(%) = -12.45
Fractional Gross Error(%) = 41.86

STN vs. Typ02fmpe SO4 at 12 stations on 2002001-2002031

y = 0.78x + 0.26
r2 = 0.54
Fractional Bias(%) = -13.07
Fractional Gross Error(%) = 33.91

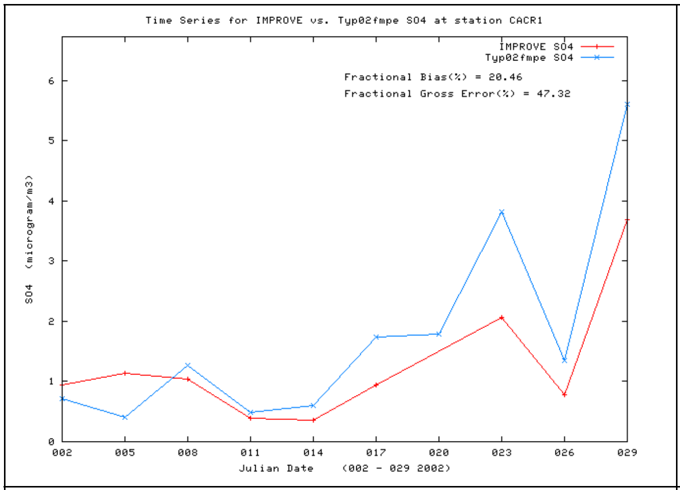
CASTNET vs. Typ02fmpe P SO4 at 4 stations on 2002001-2002031

y = 0.73x + 0.02
r2 = 0.41
Fractional Bias(%) = -33.66
Fractional Gross Error(%) = 38.83

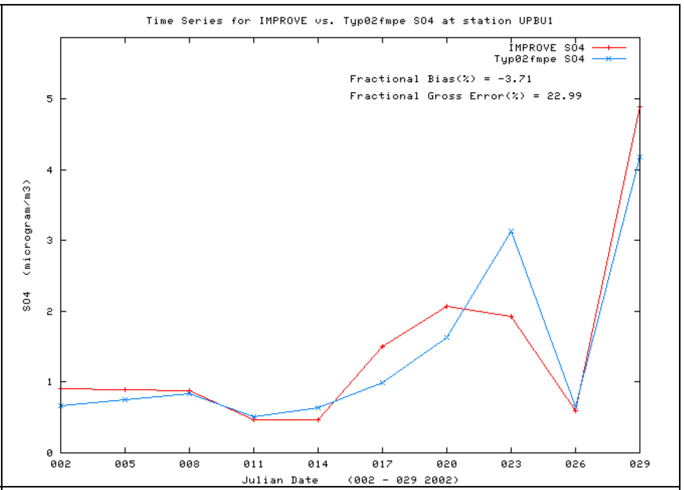
NADP vs. Typ02fmpe SO4 wdep at 33 stations on 2002001-2002031

y = 0.57x + 0.02
r2 = 0.61
Fractional Bias(%) = 40.31
Fractional Gross Error(%) = 110.87

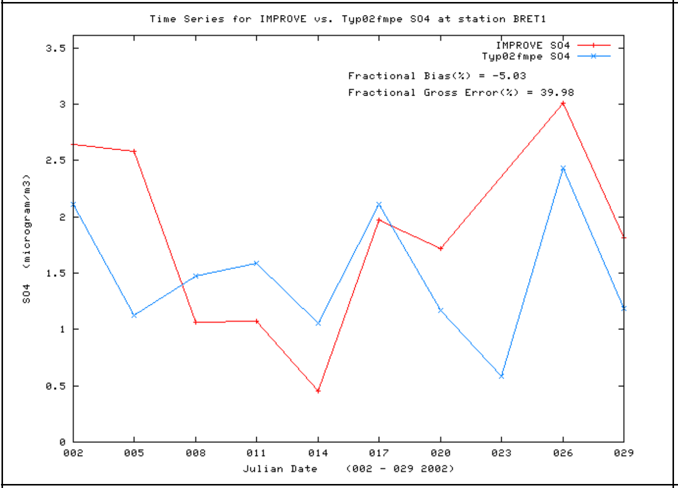
Figure C-4a. Scatter plots of predicted and observed sulfate (SO4) concentrations for January 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.



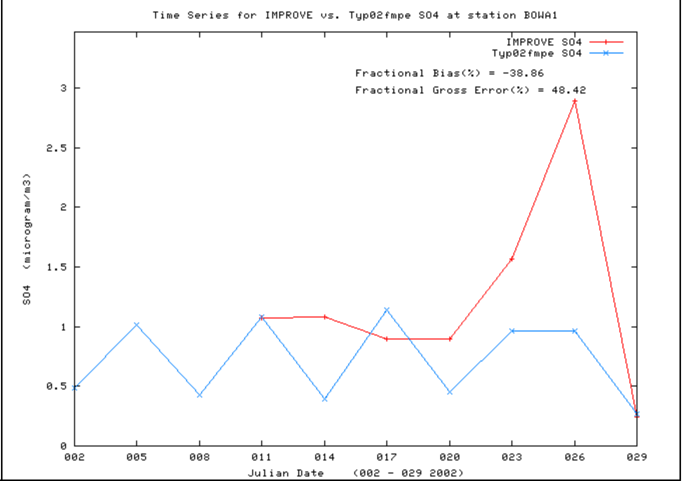
Time Series for IMPROVE vs. Typ02fmpe SO4 at station CACR1



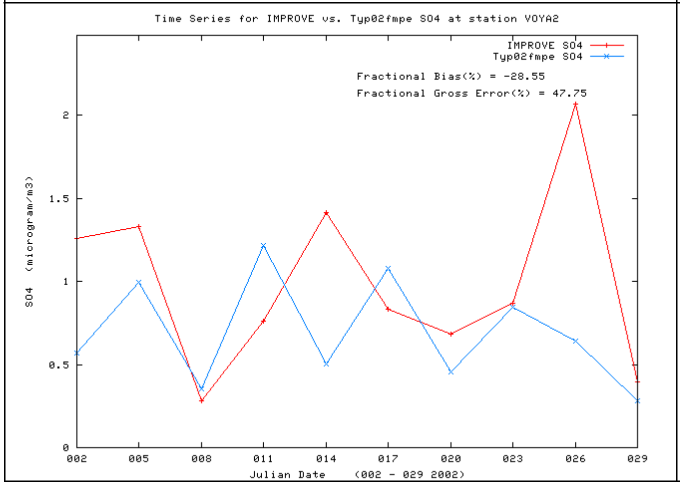
Time Series for IMPROVE vs. Typ02fmpe SO4 at station UPBU1



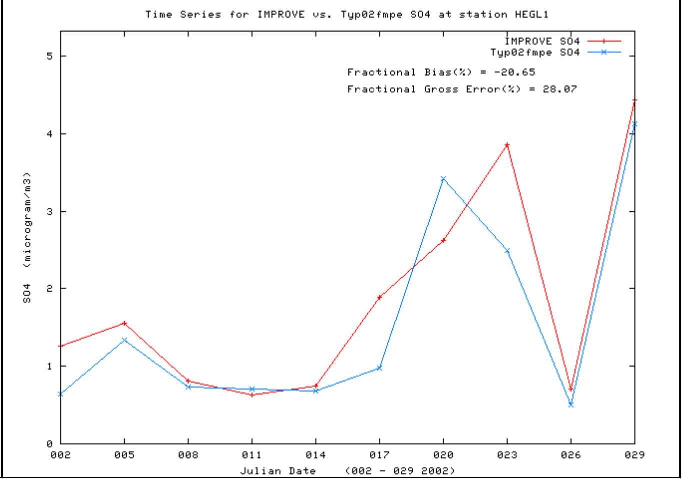
Time Series for IMPROVE vs. Typ02fmpe SO4 at station BRET1



Time Series for IMPROVE vs. Typ02fmpe SO4 at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe SO4 at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe SO4 at station HEGL1

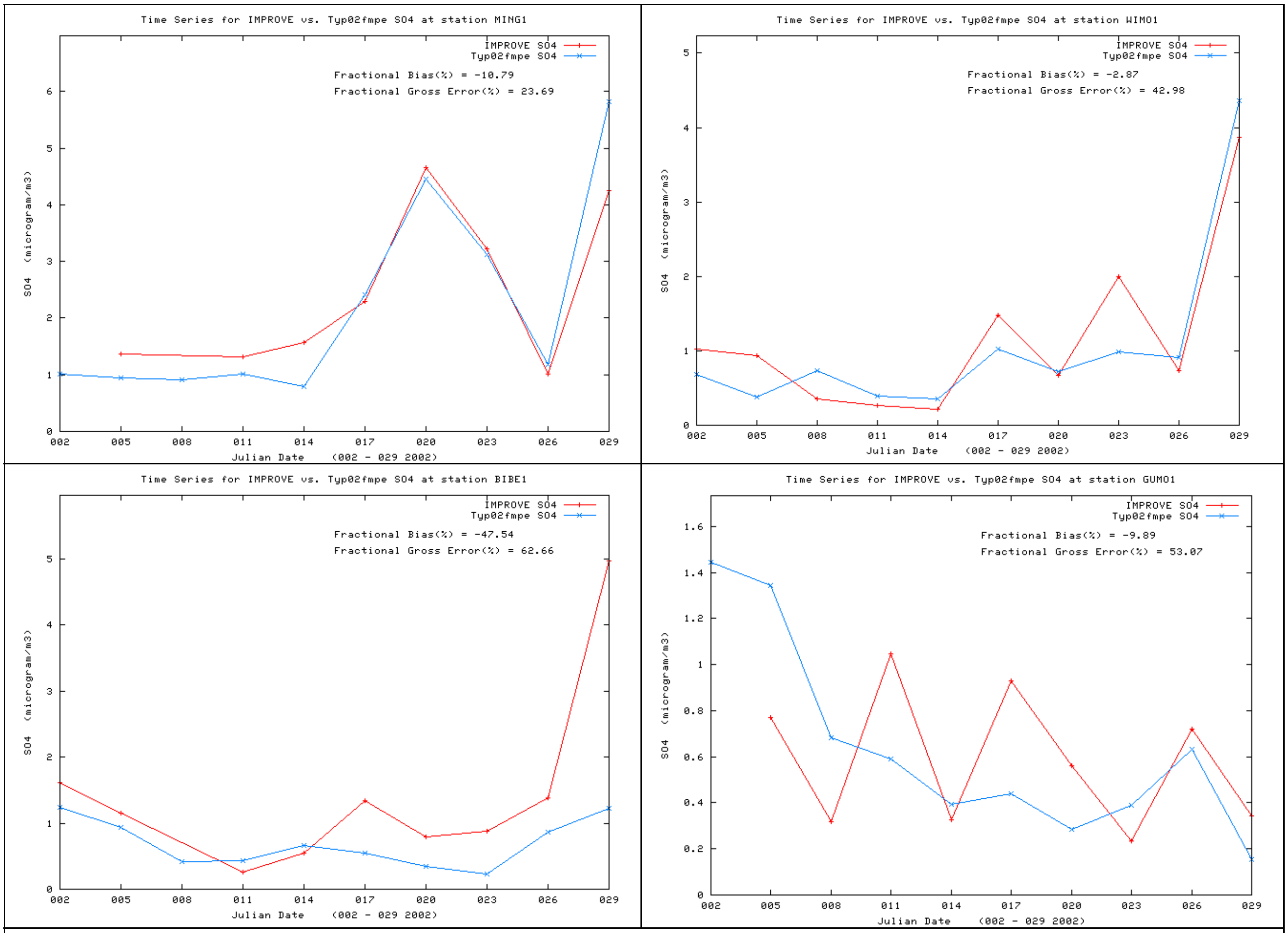


Figure C-4b. Time series of predicted and observed 24-hour sulfate (SO4) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

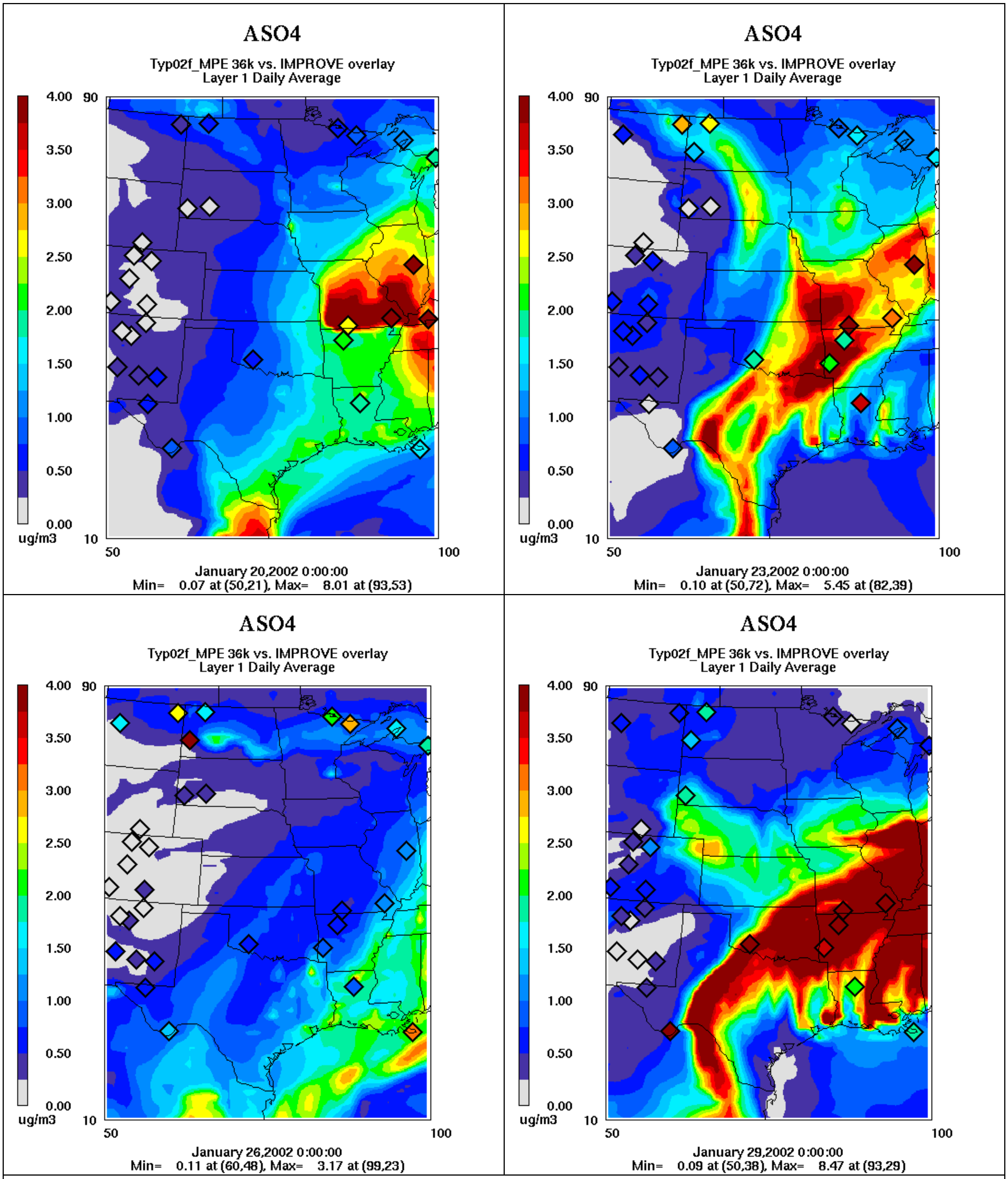


Figure C-4c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour SO4 concentrations for January 20, 23, 26 and 29, 2002.

C.3.1.2 SO4 in April 2002

In April CMAQ underestimates the observed SO4 in the CENRAP region with fractional bias values of -52%, -30% and -58% across the IMPROVE, STN and CASTNet networks (Figure C-5a). The fractional bias for wet SO4 deposition is quite low (3%) albeit with a lot of scatter which is reflected in high fractional error (78%). The ability of the model to reproduce the temporal variability of the April observed SO4 concentrations at the IMPROVE sites is quite variable. The SO4 underprediction bias is clearly present at several sites (e.g., HEGL, BIBE and GUMO), whereas there is quite good agreement at others (UPBU, BRET and VOYA). Comparisons of the spatial distributions of the predicted and observed SO4 concentrations on April 5, 8, 11 and 14 are shown in Figure C-5c. On April 5 the model reproduces the half circle of elevated SO4 across Texas-Louisiana, but appears to not be as large an area as observed coming up short from some of the sites (e.g., BIBE and GUMO). Model and observations agree that April 8 is a relatively low SO4 day in the CENRAP region with just a small intrusion of elevated values across Mississippi. On April 14 the model has two separate clouds of elevated SO4, one over East Texas-Louisiana and one over northeastern Illinois and eastward with a clean area in between in southern Missouri. The observations agree except that it has these two elevated SO4 areas connected with the southern Missouri area not as clean as in the model.

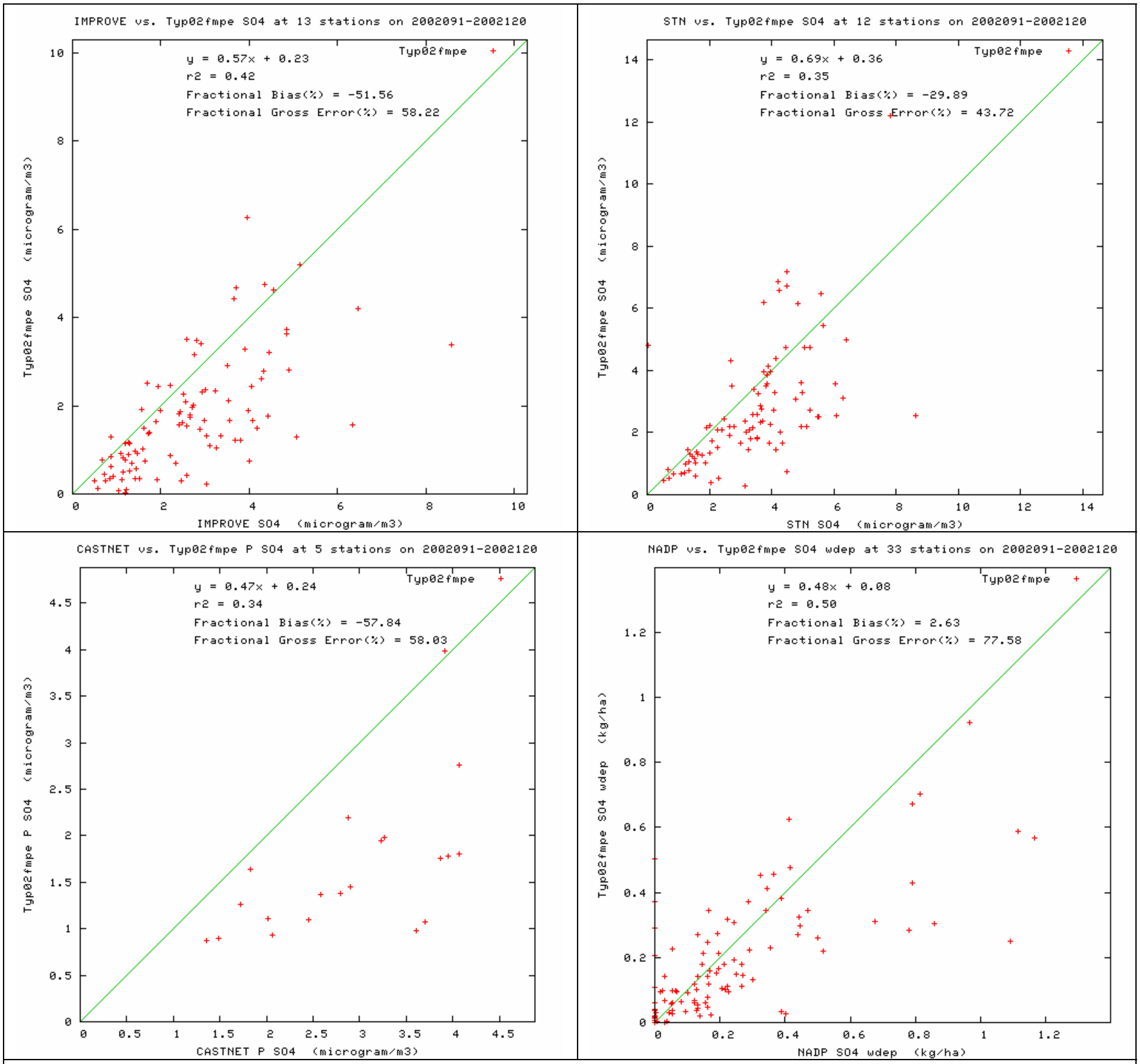
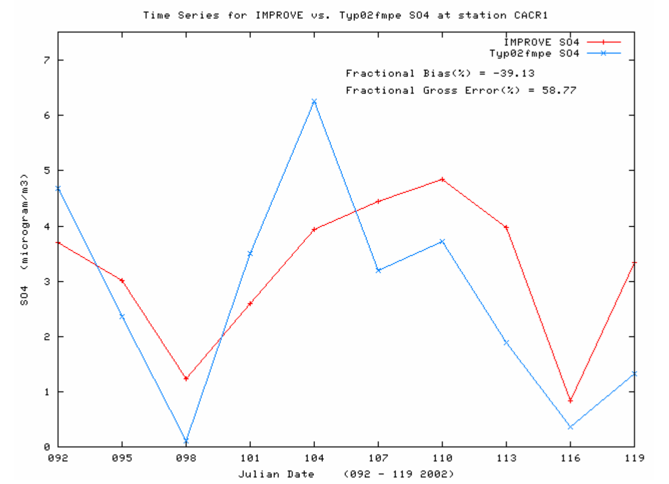
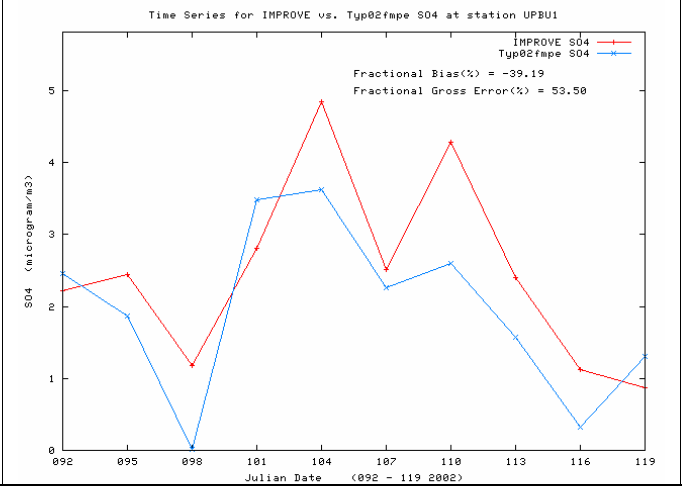
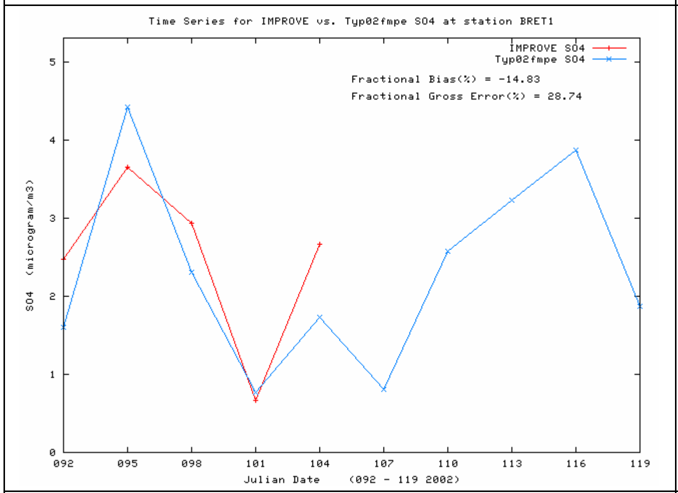
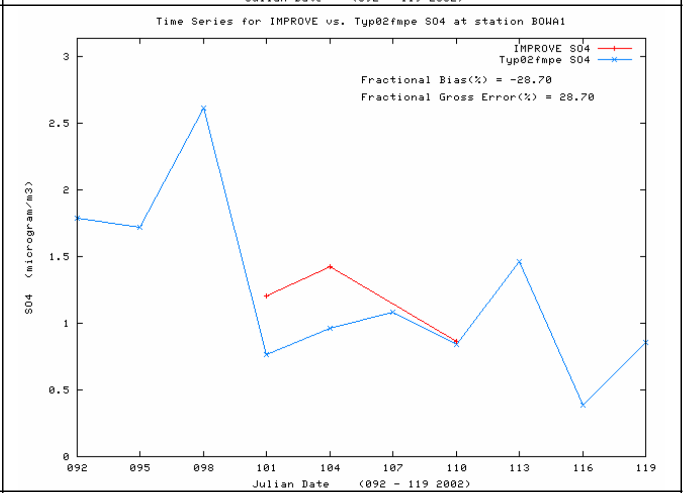


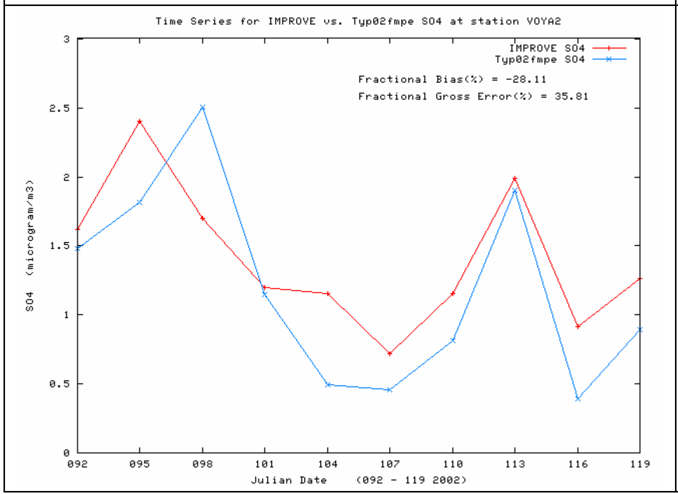
Figure C-5a. Scatter plots of predicted and observed sulfate (SO4) concentrations for April 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

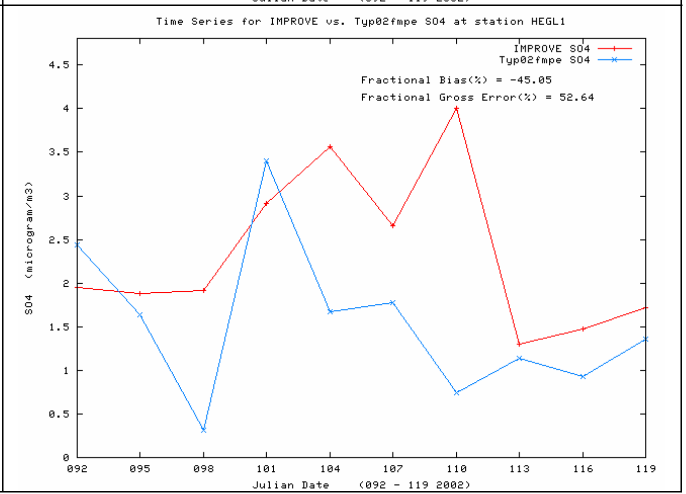

Time Series for IMPROVE vs. Typ02fmpe SO4 at station CACR1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station BRET1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe SO4 at station HEGL1

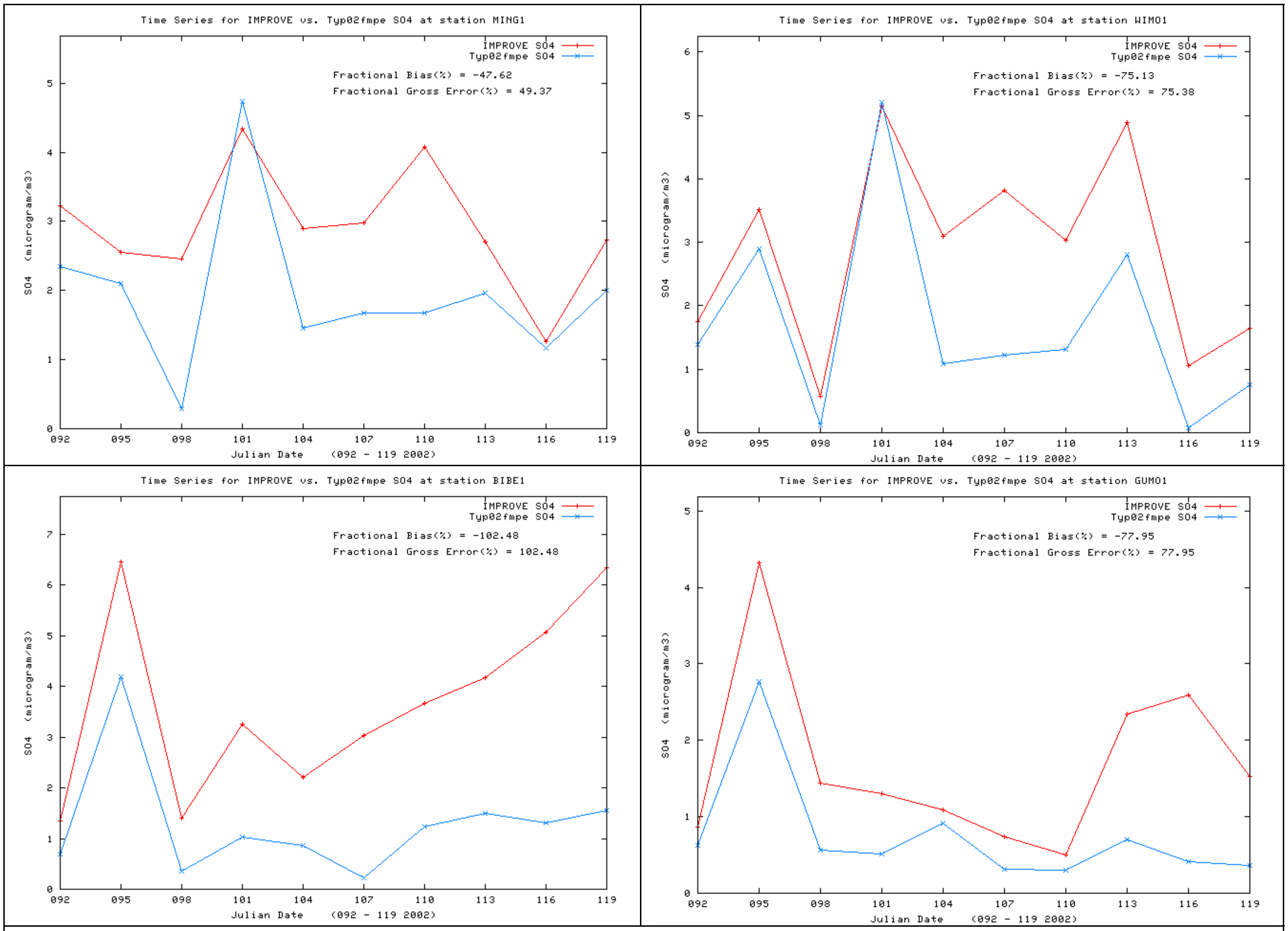


Figure C-5b. Time series of predicted and observed 24-hour sulfate (SO4) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

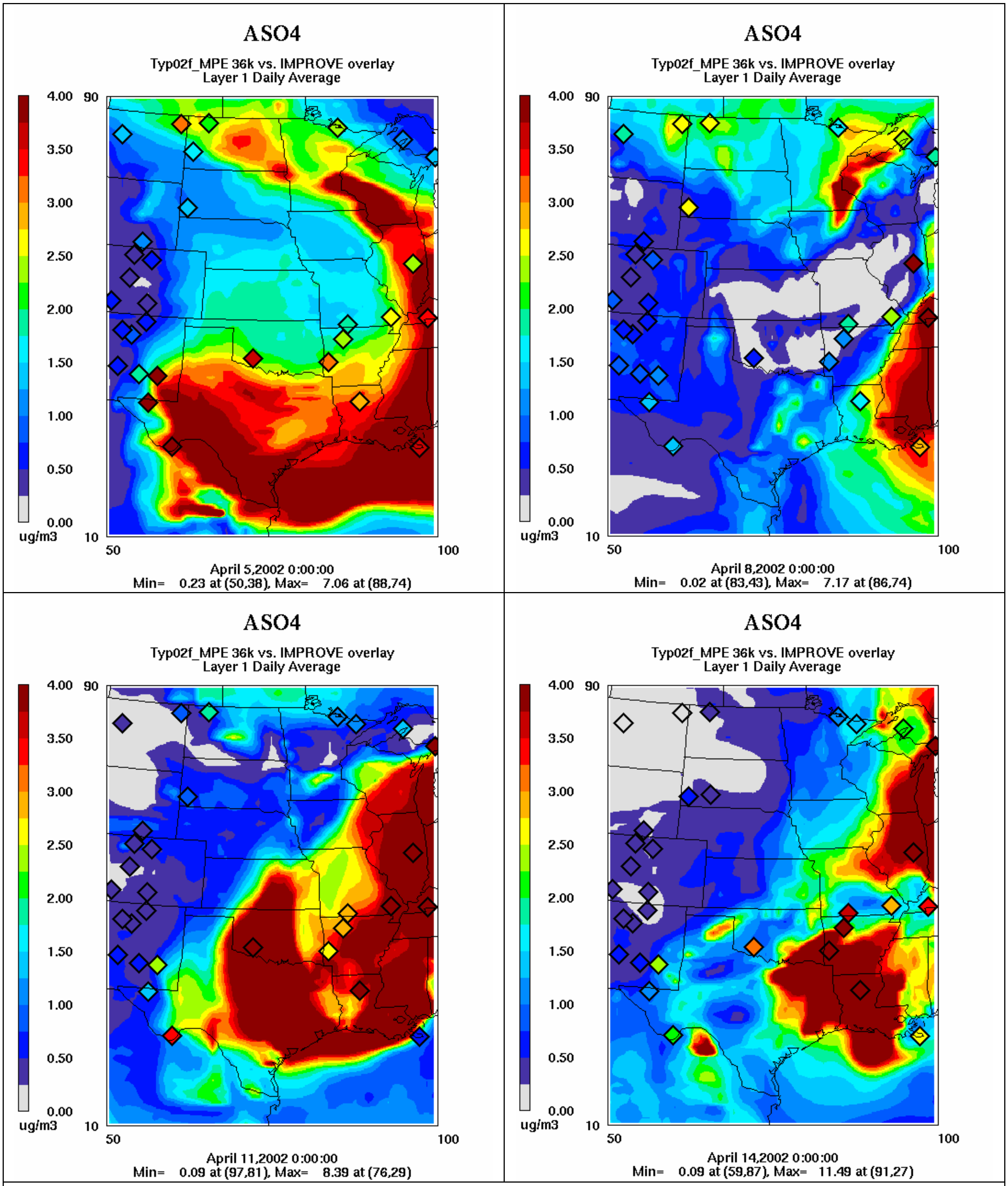


Figure C-5c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour SO4 concentrations for April 5, 8, 11 and 14, 2002.

C.3.1.3 SO4 in July 2002

SO4 concentrations are also underestimated by CMAQ in July (Figure C-6a) with fractional bias value ranging from -22 to -52%. Wet SO4 deposition is slightly overstated (22%) with a lot of scatter (83% error). The July SO4 under-prediction bias is also reflected in the time series plots (Figure C-6b). Comparisons of the predicted and observed spatial distribution of SO4 in the CENRAP region for July 7, 10, 13 and 16, 2002 are shown in Figure C-6c. In general the model and observations agree on the locations of the elevated SO4, except that the observed extent is somewhat larger so that the modeled elevated SO4 fails to impact some of the sites on the edge of the elevated cloud of SO4 (e.g., Big Bend, Guadalupe Mountains and northwestern Oklahoma).

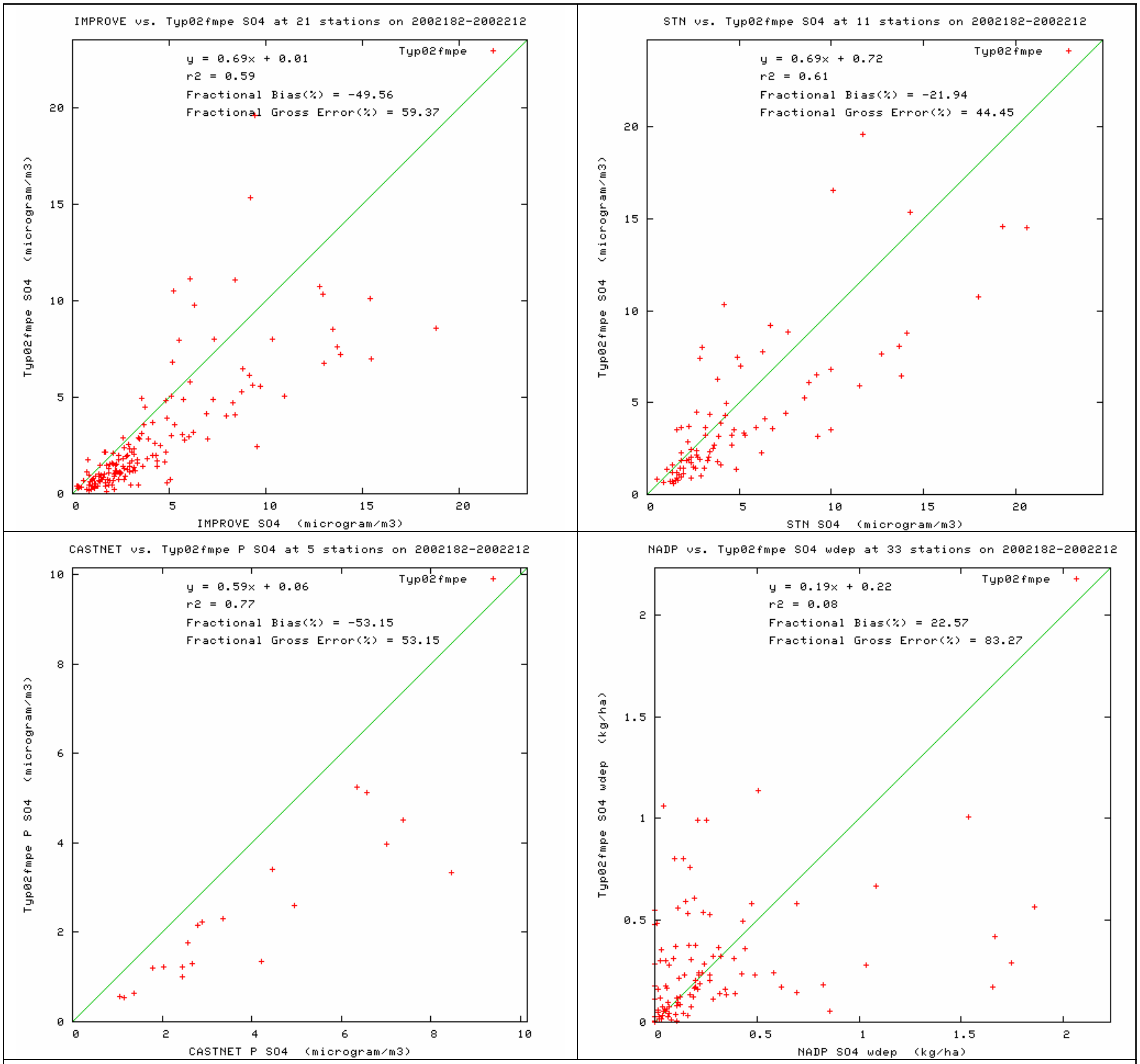
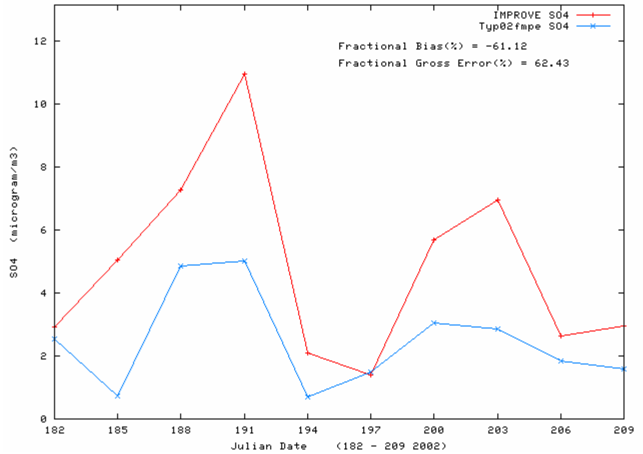
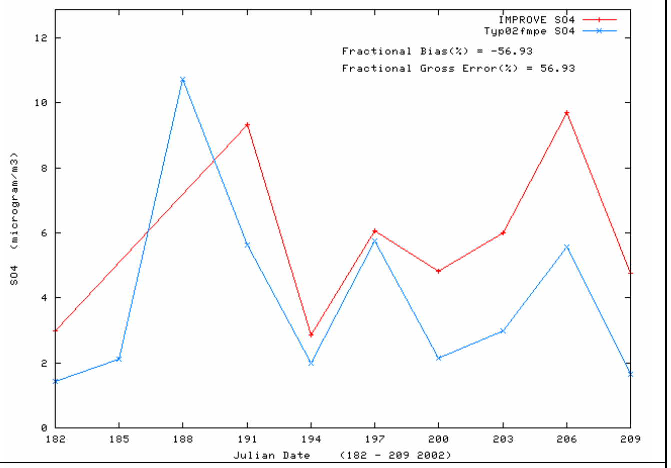


Figure C-6a. Scatter plots of predicted and observed sulfate (SO4) concentrations for July 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

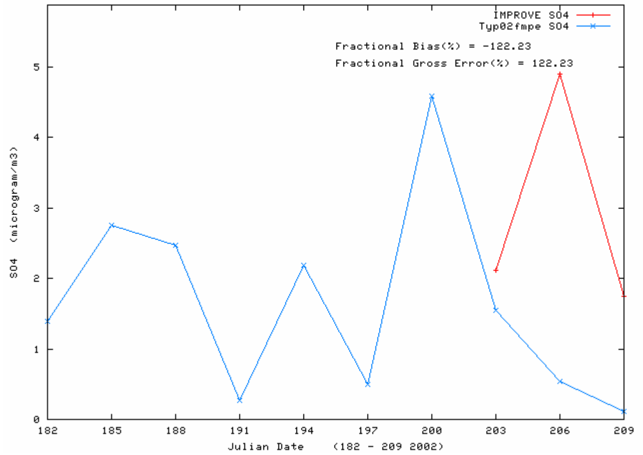
Time Series for IMPROVE vs. Typ02fmpe SO4 at station CACR1



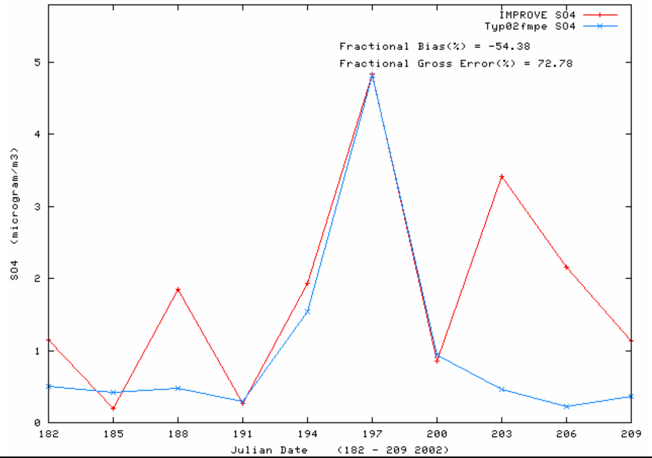
Time Series for IMPROVE vs. Typ02fmpe SO4 at station UPBU1



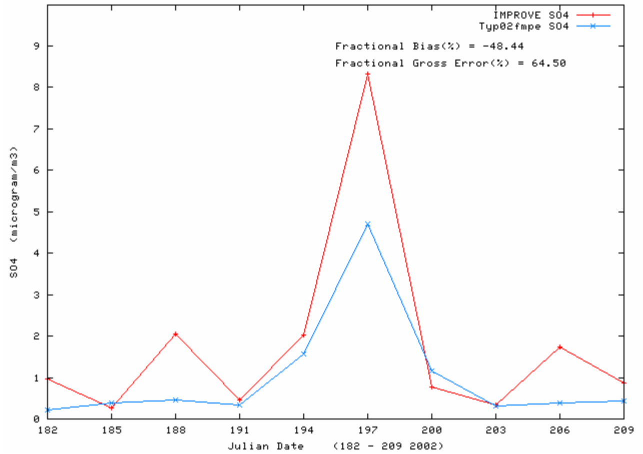
Time Series for IMPROVE vs. Typ02fmpe SO4 at station BRET1



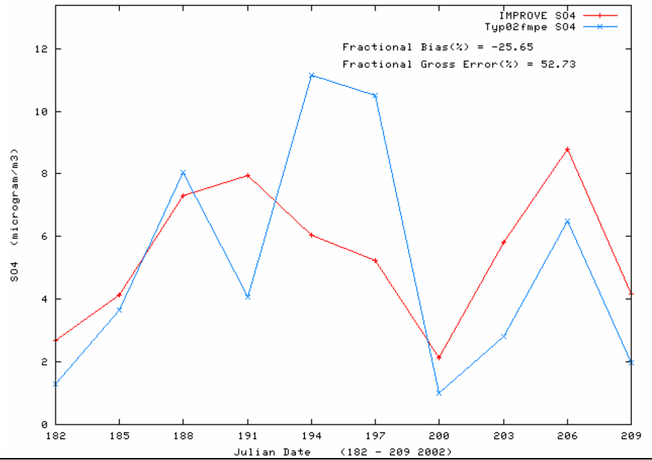
Time Series for IMPROVE vs. Typ02fmpe SO4 at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe SO4 at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe SO4 at station HEGL1



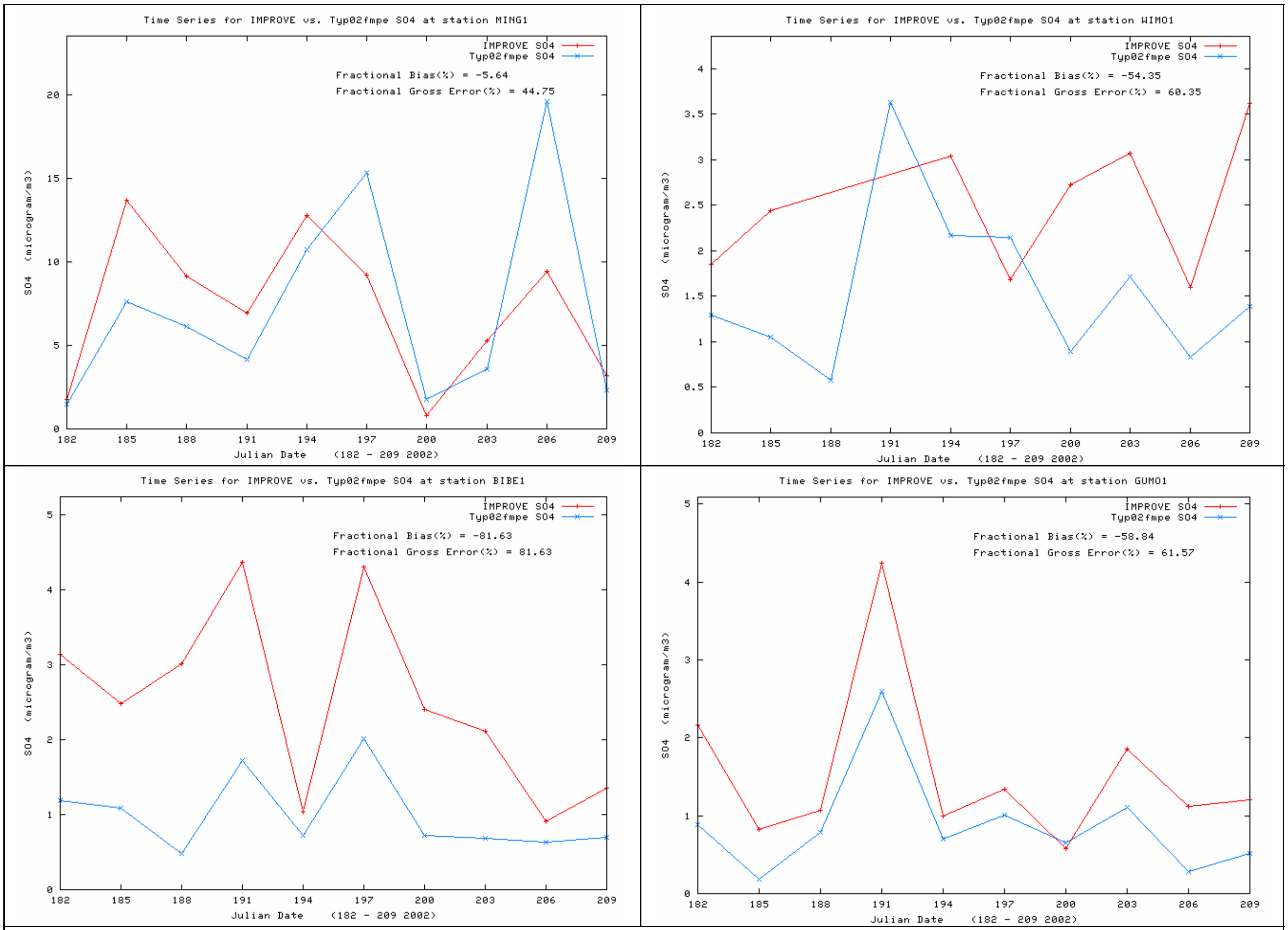


Figure C-6b. Time series of predicted and observed 24-hour sulfate (SO4) concentrations at CENRAP IMPROVE CLASS I AREA sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

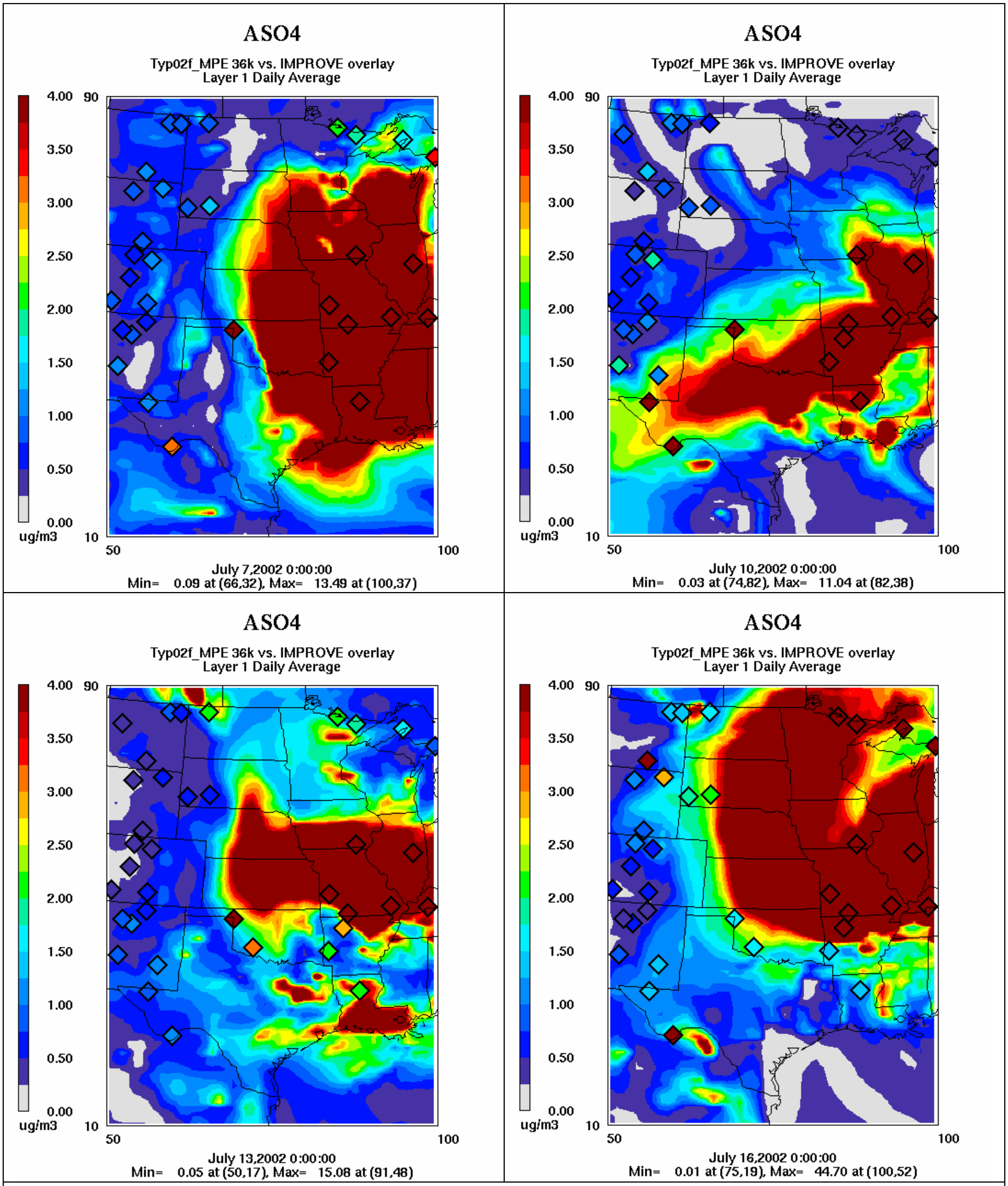


Figure C-6c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour SO4 concentrations for July 7, 10, 13 and 16, 2002.

C.3.1.4 SO4 in October 2002

In October 2002, CMAQ is doing a better job of reproducing the observed SO4 concentrations with much lower fractional bias values (-6%, 0% and -23%) and fractional errors < 40% (Figure C-7a). The observed SO4 time series are also reproduced well by the model, although an under-prediction bias is clearly evident at Big Bend, Guadalupe Mountains and Wichita Mountains. The model also reproduces the observed spatial distribution of SO4 well in October (Figure C-7c).

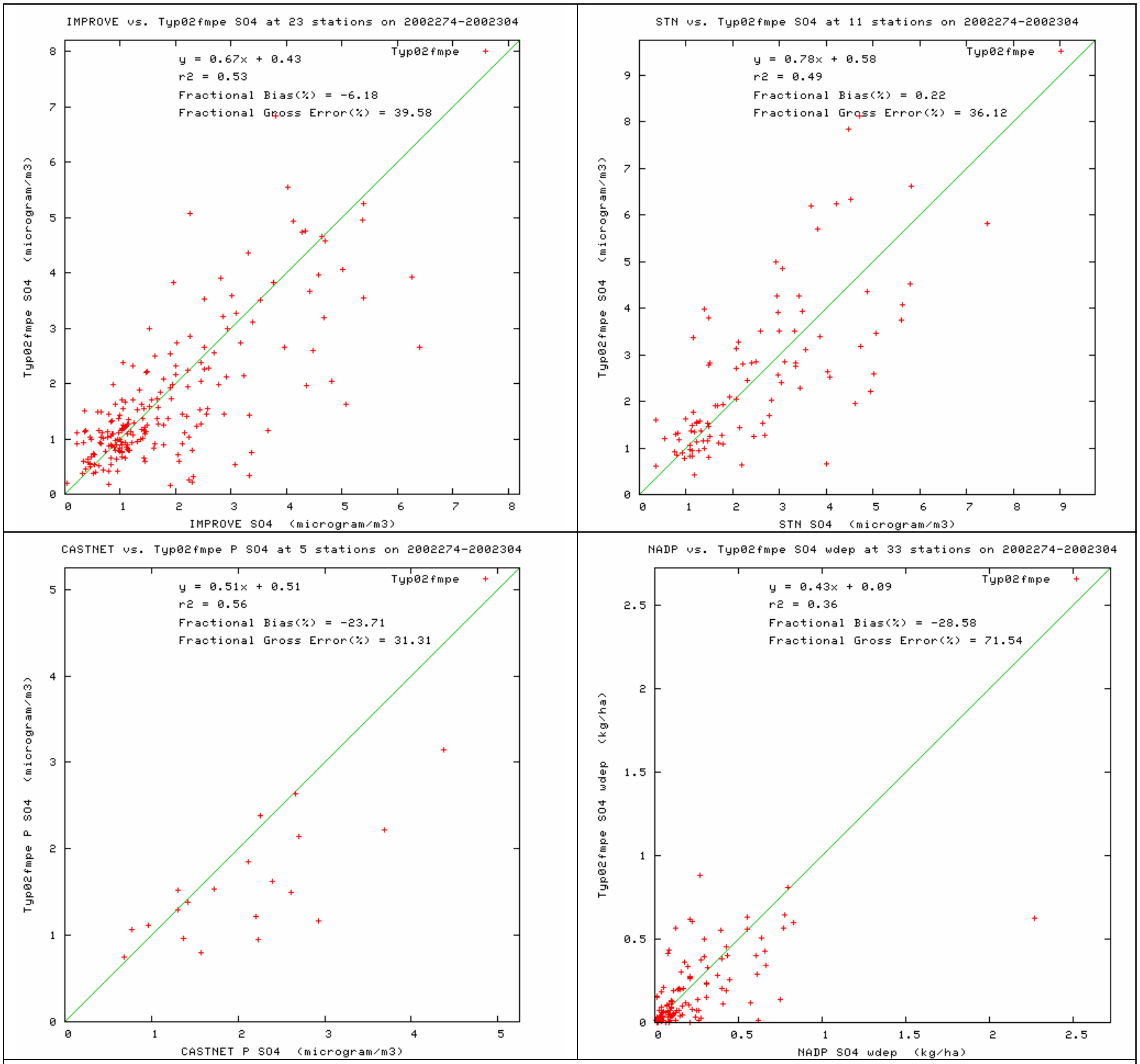
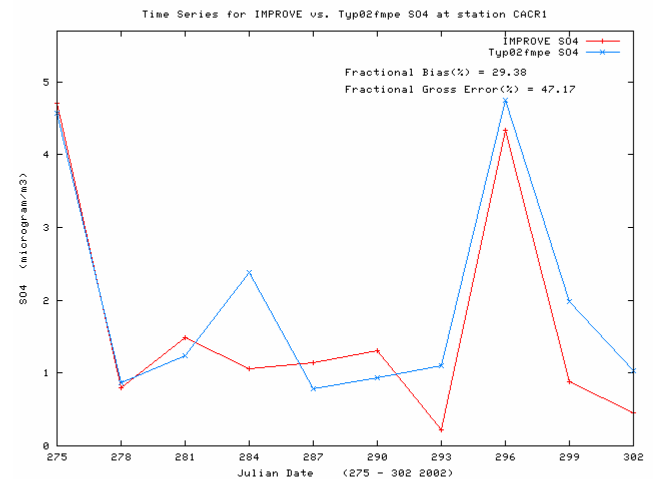
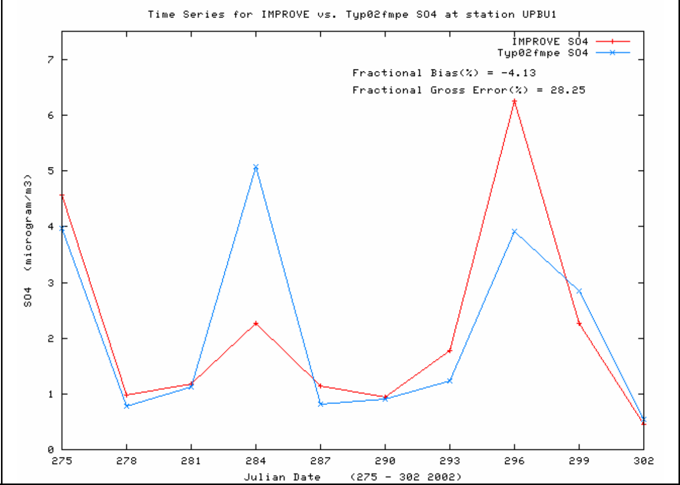
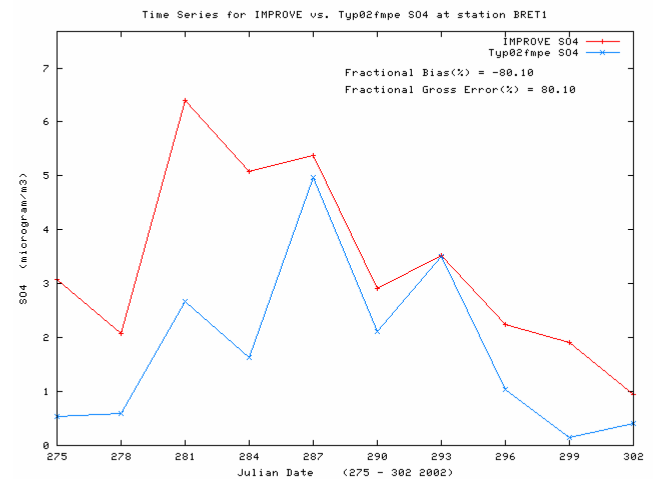
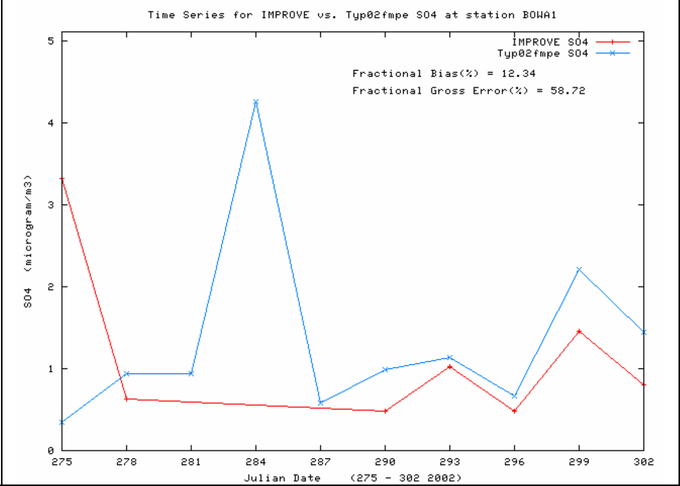


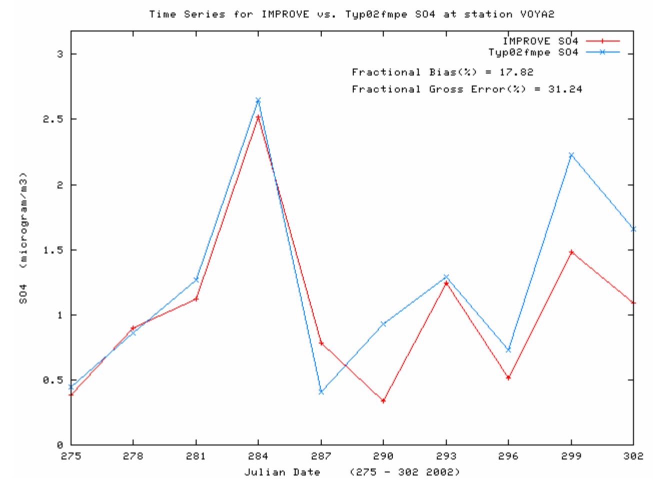
Figure C-7a. Scatter plots of predicted and observed sulfate (SO4) concentrations for October 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

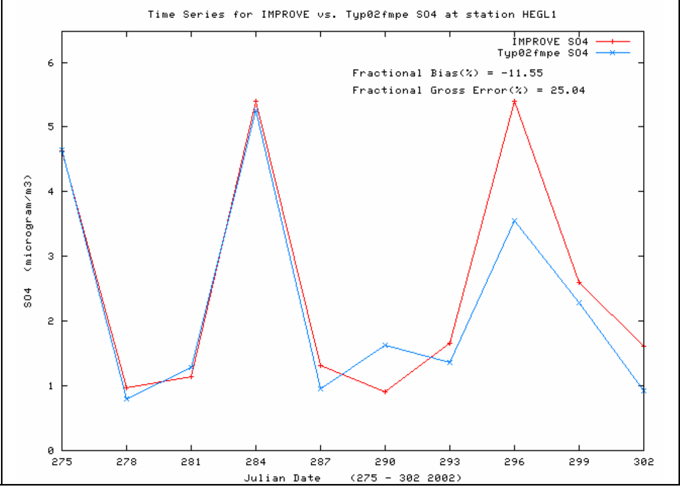

Time Series for IMPROVE vs. Typ02fmpe SO4 at station CACR1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station BRET1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe SO4 at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe SO4 at station HEGL1

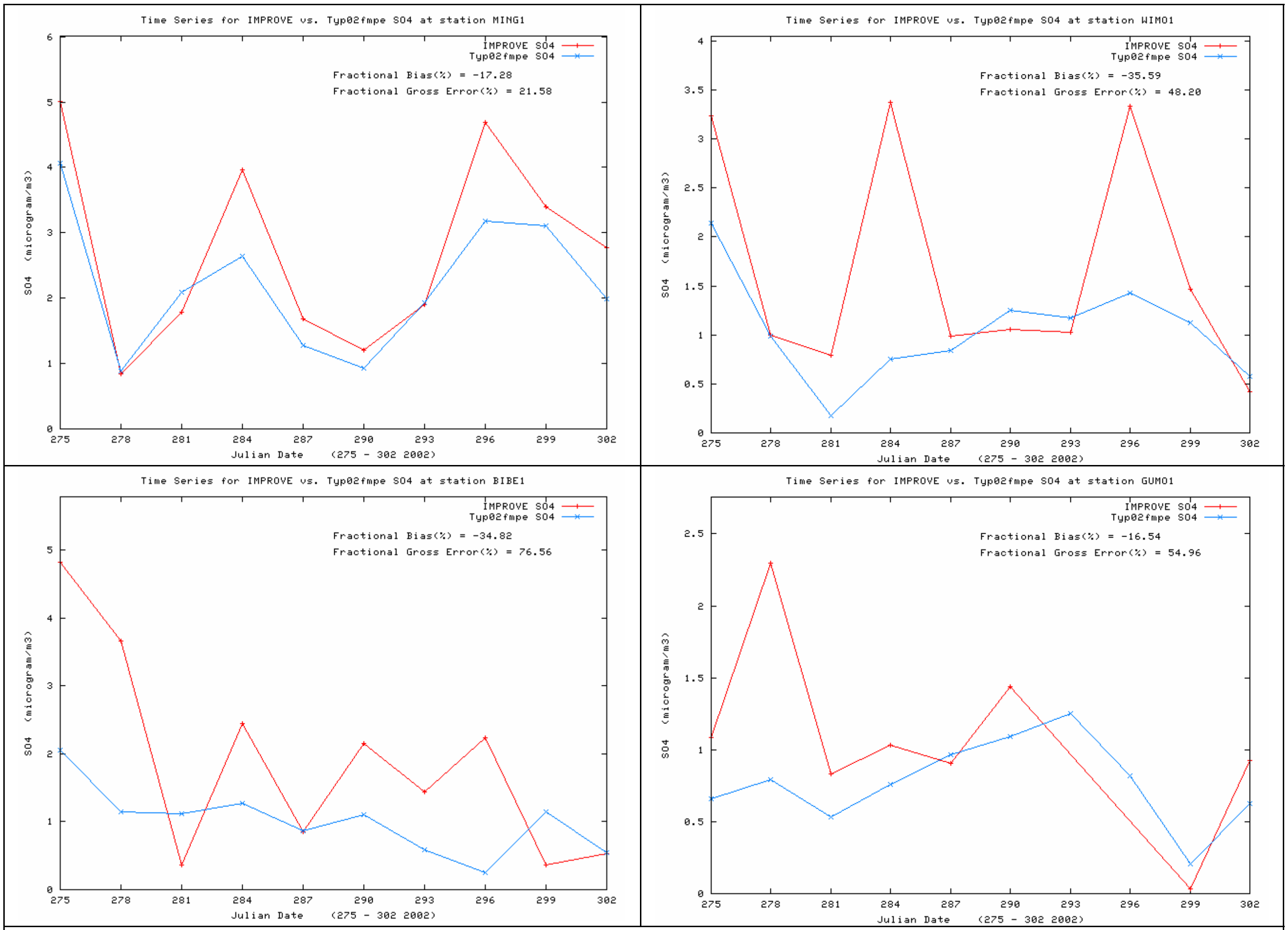


Figure C-7b. Time series of predicted and observed 24-hour sulfate (SO4) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

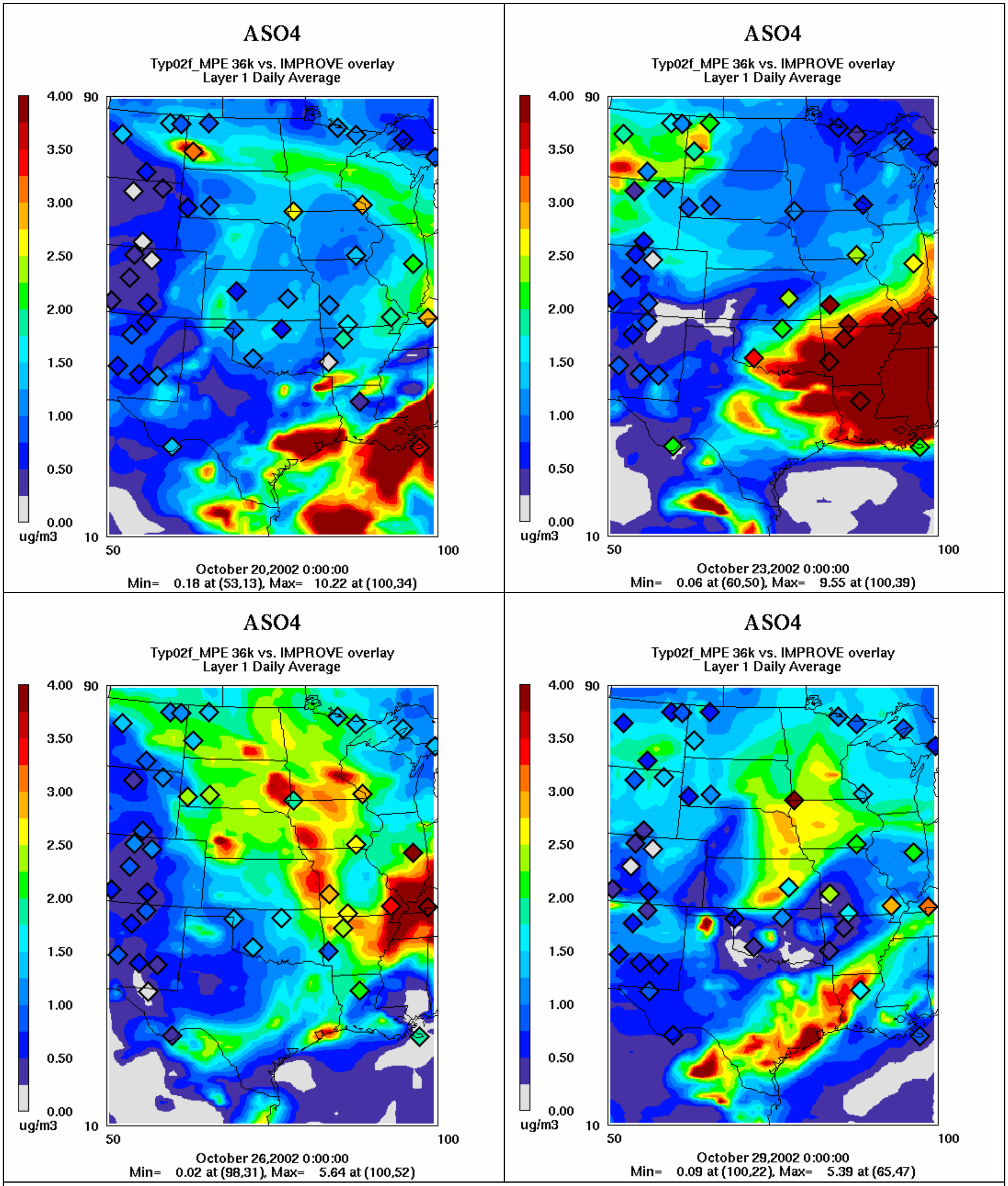


Figure C-7c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour SO4 concentrations for October 20, 23, 26 and 29, 2002.

C.3.1.5 SO4 Monthly Bias and Error

Figure C-8 compares the monthly SO4 fractional bias and error across the CENRAP region for the three monitoring networks. The under-prediction bias is clearly evident the first 8-10 months of the year. This underestimation bias is greatest across the CASTNet network which persists through out the year and is least for the STN network where it disappears by August-September. The monthly SO4 fractional errors are generally between 30% and 60% and are greatest in the summer when SO4 concentrations are the highest.

Figure C-9 presents a Bugle Plot of monthly So4 fractional bias and error statistics and compares them against the proposed PM model performance goal and criteria (see Table C-3). For the STN network, it appears that SO4 performance for all months achieves the proposed PM model performance goal. For the IMPROVE network, approximately half of the months achieve the proposed PM performance goal with the other half exceed the goal but within the performance criteria. Across the CASTNet network most months exceed the proposed goal and are within the criteria. Although the CASTNet fractional bias for some months is right at the criteria (≤±60%). With the exception of two IMPROVE months, all of the monthly SO4 fractional error performance statistics achieve the proposed PM model performance goal.

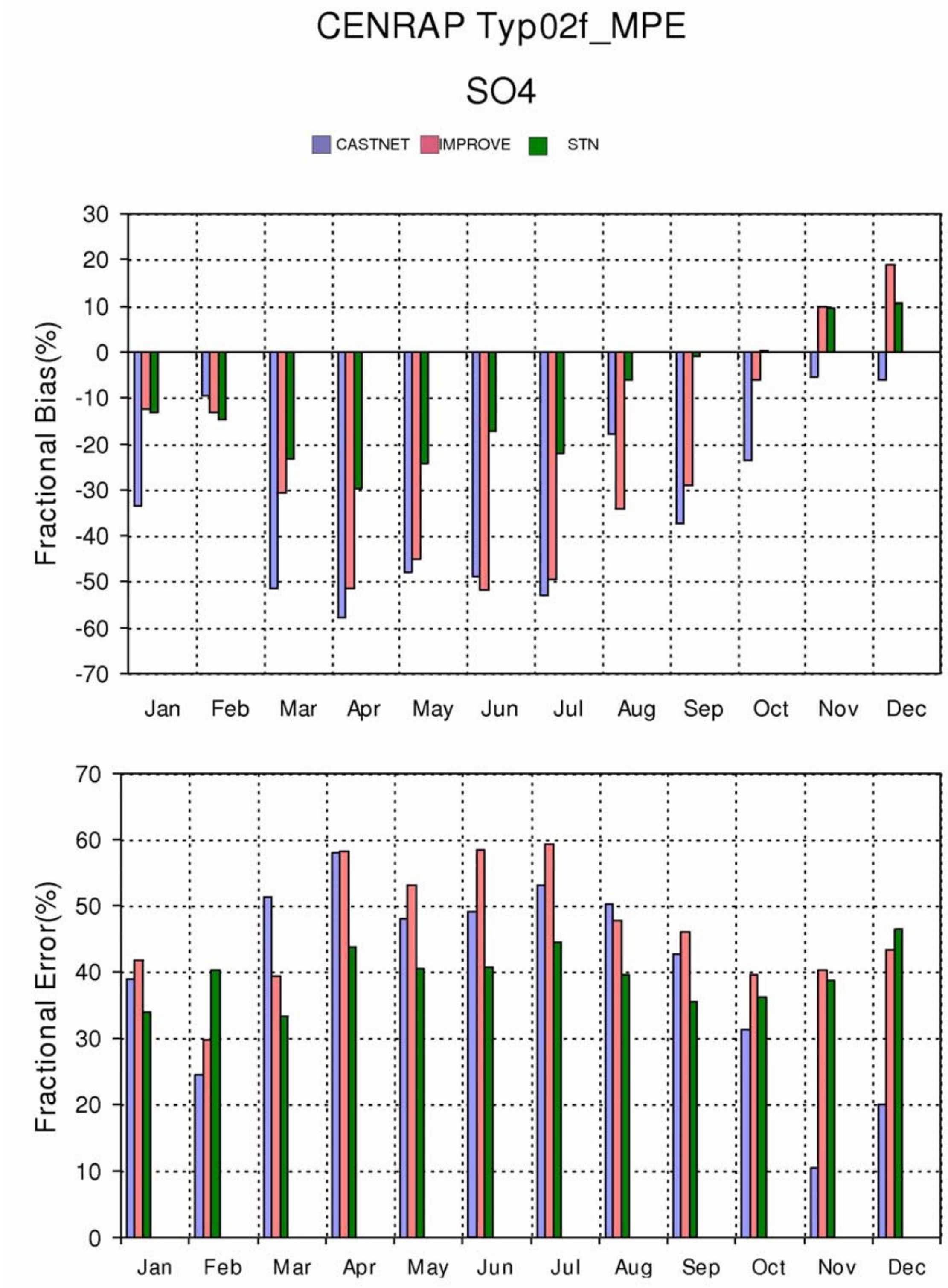


Figure C-8. Monthly SO4 fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

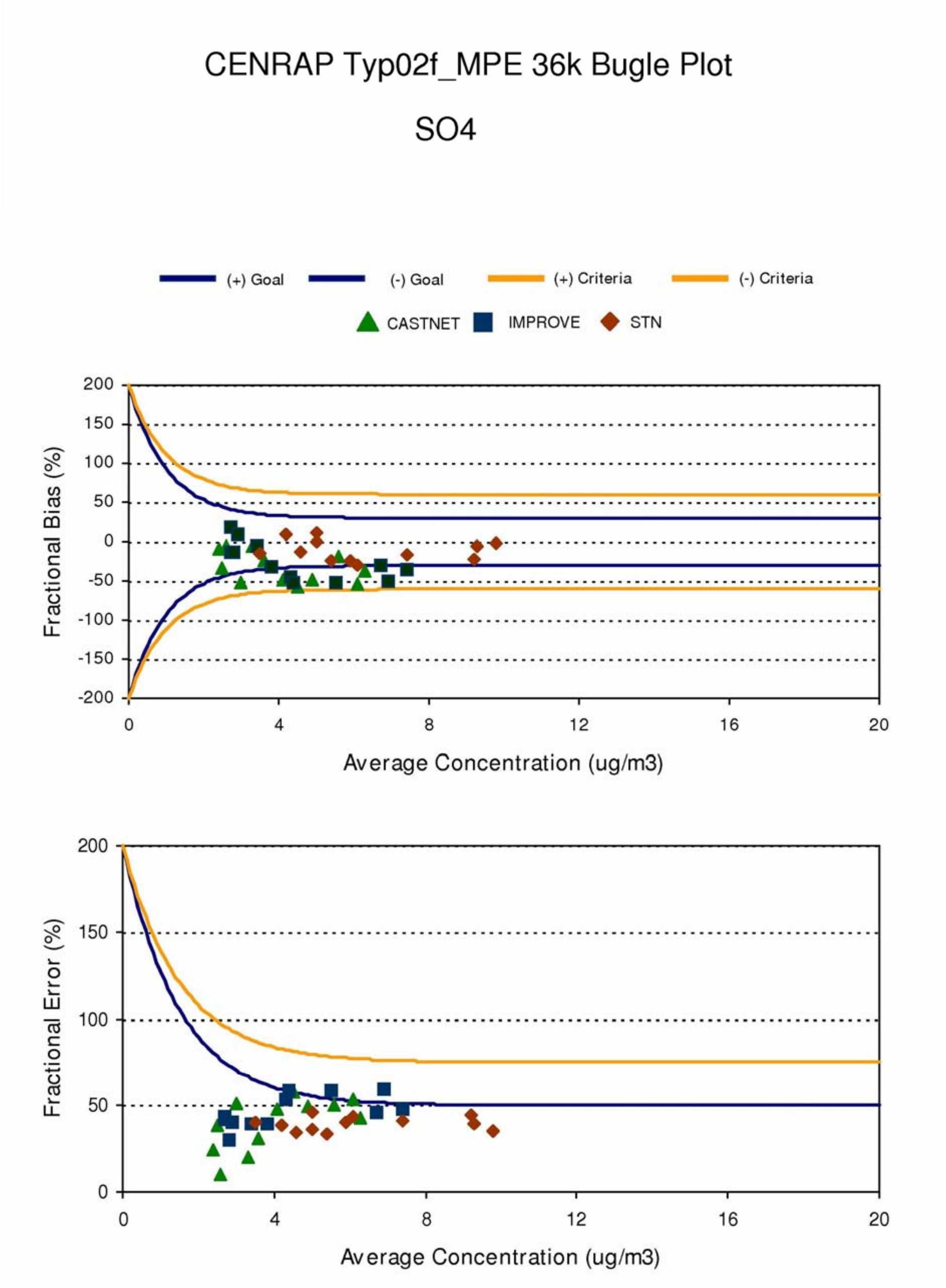


Figure C-9. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for SO4 and IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

C.3.2 Nitrate (NO3) Monthly Model Performance

The following sections discuss the monthly NO3 model performance across the IMPROVE, STN and CASTNet monitoring networks in the CENRAP region.

C.3.2.1 NO3 in January 2002

January NO3 CMAQ model performance is characterized by an overestimation bias across the CENRAP region (Figure C-10a). The fractional bias values for the IMPROVE, STN and CASTNet networks are 38%, 29% and 61%. Unlike SO4, wet deposition of NO3 is also overstated in January (43%). Fractional errors range from 90%-100% for the IMPROVE and CASTNet networks and are lower (54%) for the STN network and higher (114%) for the NADP network.

With the exception of Breton Island and Big Bend, the model NO3 over-prediction bias occurs at the other 8 CENRAP Class I areas (Figure C-10b). The observed time series is reproduced reasonable well at a couple sites, such as Wichita Mountains and the first half of January for Voyageurs. However, for most sites the observed NO3 time series is not reproduced very well and is extremely poorly reproduced for Breton Island, Big Bend and Guadalupe Mountains.

The model typically estimates a larger area of elevated NO3 concentrations than is observed. This is shown for January 20, 23, 26 and 29 in Figure C-10c. Whereas the model exhibits large areas of brown indicated daily average NO3 concentrations of 4 µg/m^3 or higher, the observed values of this high rarely occur and are usually limited to the central Illinois site. On January 20 the model estimates the entire eastern half of the CENRAP region should be covered by elevated NO3 concentrations, whereas the observations indicate much lower values. On January 23 the modeled elevated NO3 concentrations lies between the IMPROVE monitoring sites, although the central Illinois site suggests high NO3 did occur in the region. The observations on January 26 also suggest lower NO3 than the model is predicting. On January 29 the model estimates elevated NO3 from the central Illinois site to Wichita Mountains, Oklahoma that is supported by these two observations. In general, the model is estimating more wide-spread elevated NO3 concentrations than observed, whereas the observations suggest that the elevated NO3 occurrences is less frequent and more spotty.

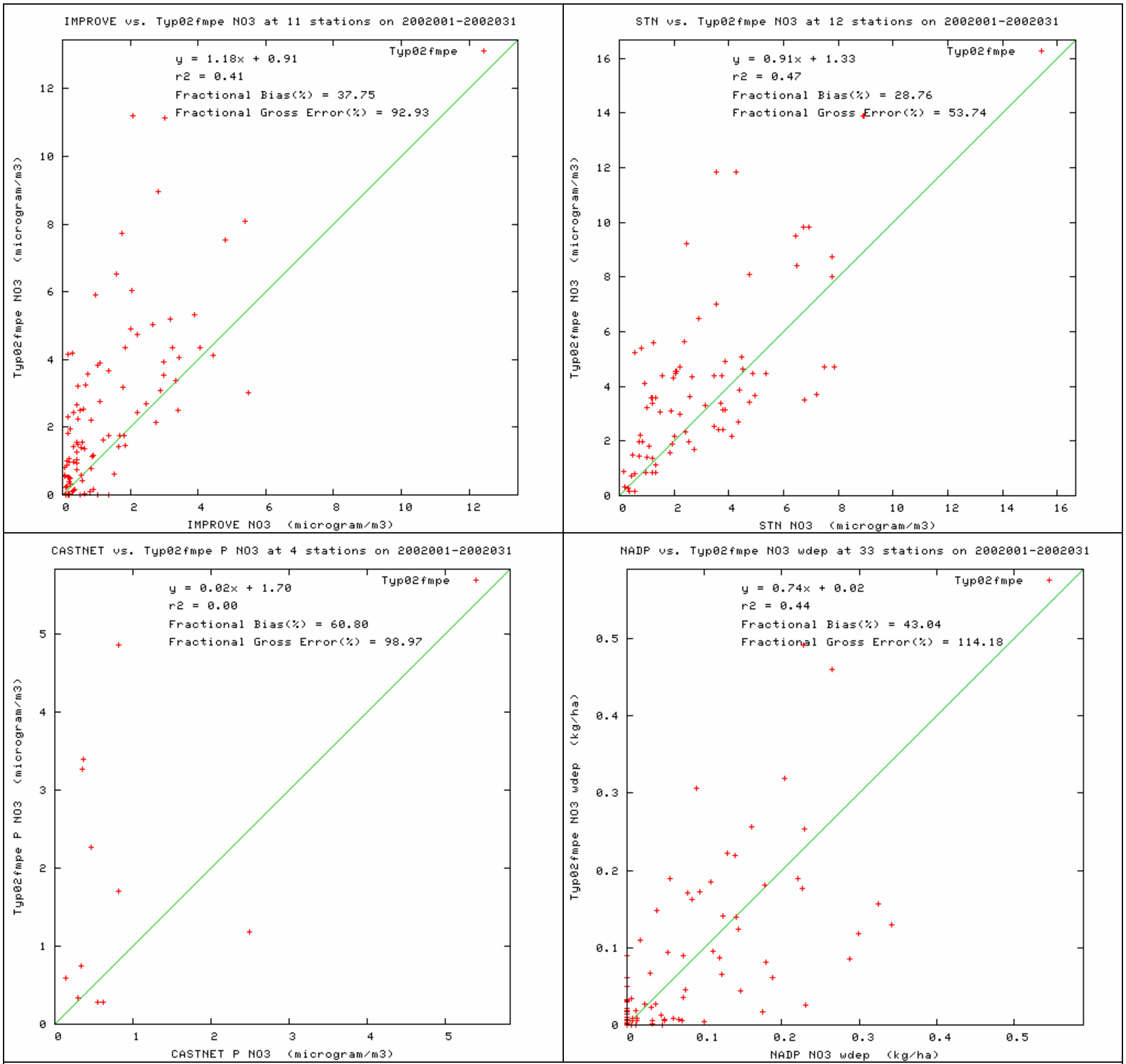
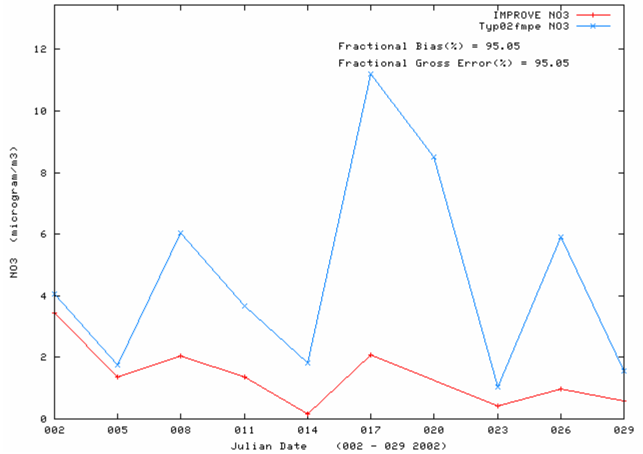
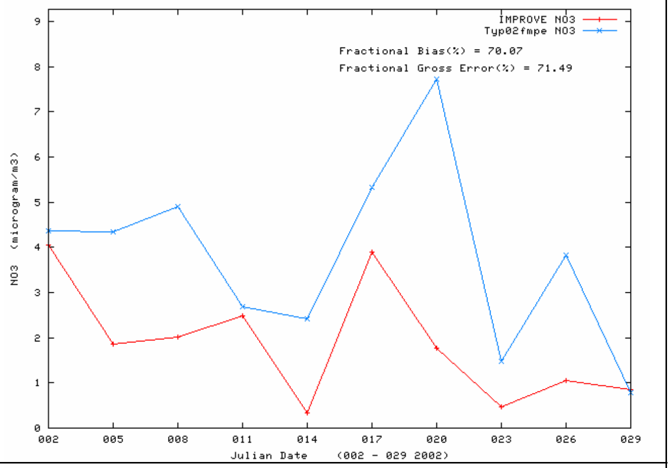


Figure C-10a. Scatter plots of predicted and observed nitrate (NO3) concentrations for January 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

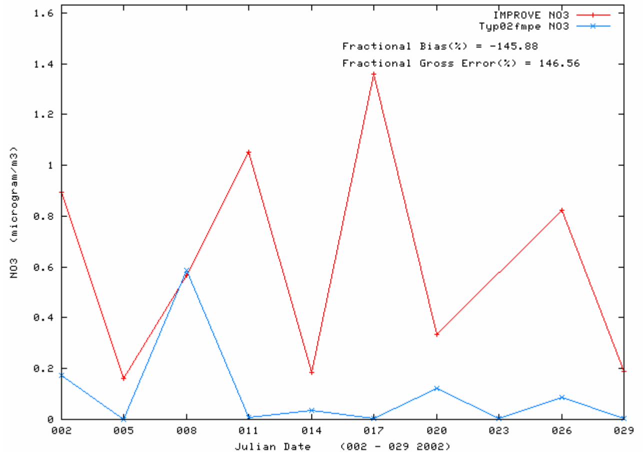
Time Series for IMPROVE vs. Typ02fmpe NO3 at station CACR1



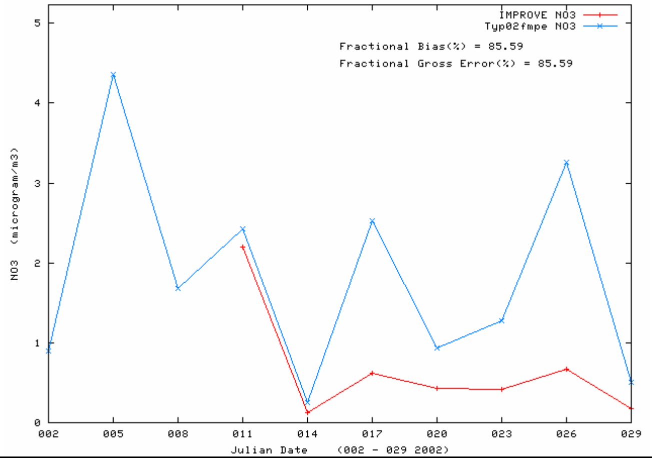
Time Series for IMPROVE vs. Typ02fmpe NO3 at station UPBU1



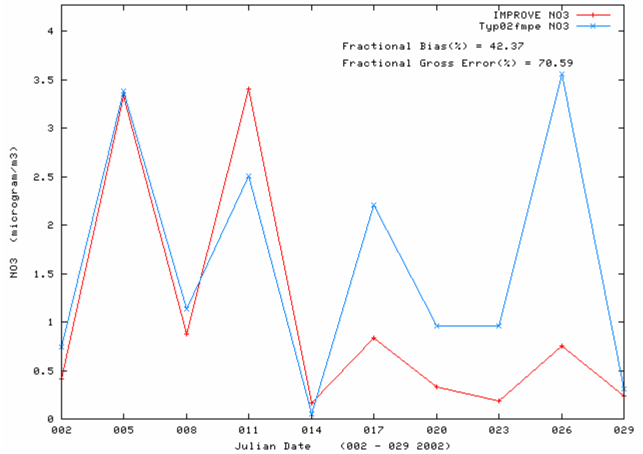
Time Series for IMPROVE vs. Typ02fmpe NO3 at station BRET1



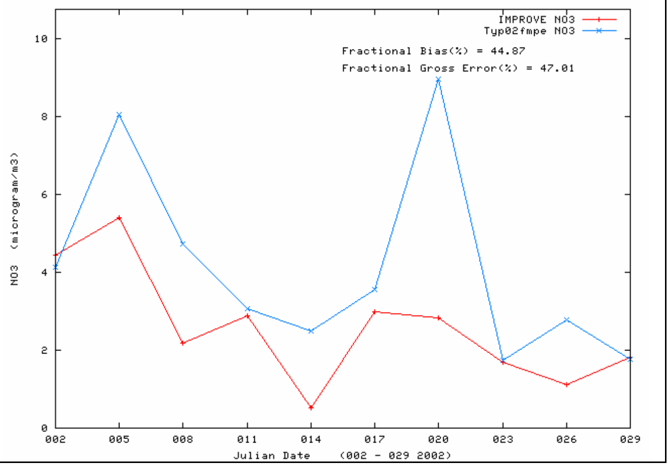
Time Series for IMPROVE vs. Typ02fmpe NO3 at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe NO3 at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe NO3 at station HEGL1



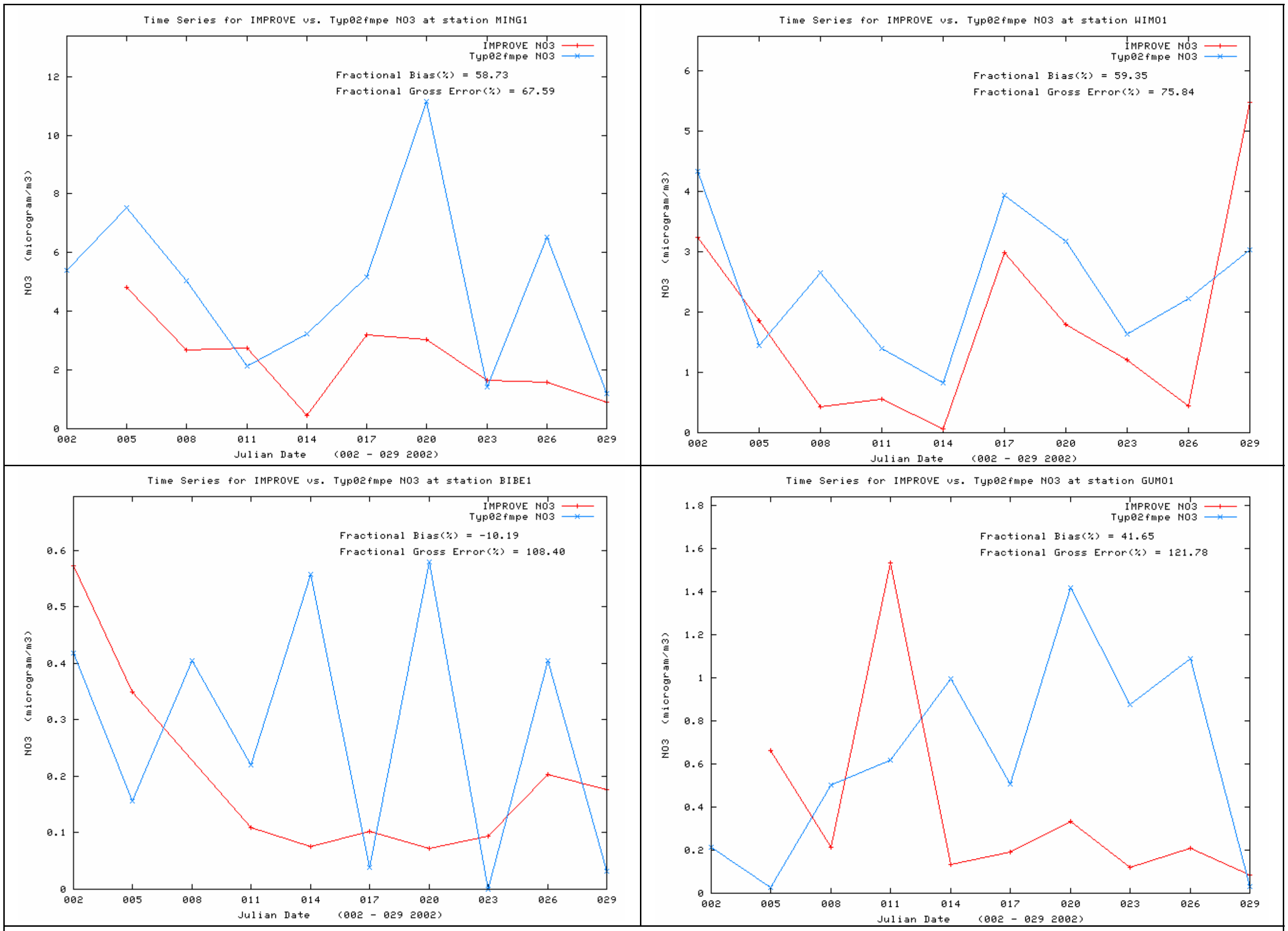


Figure C-10b. Time series of predicted and observed 24-hour nitrate (NO3) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

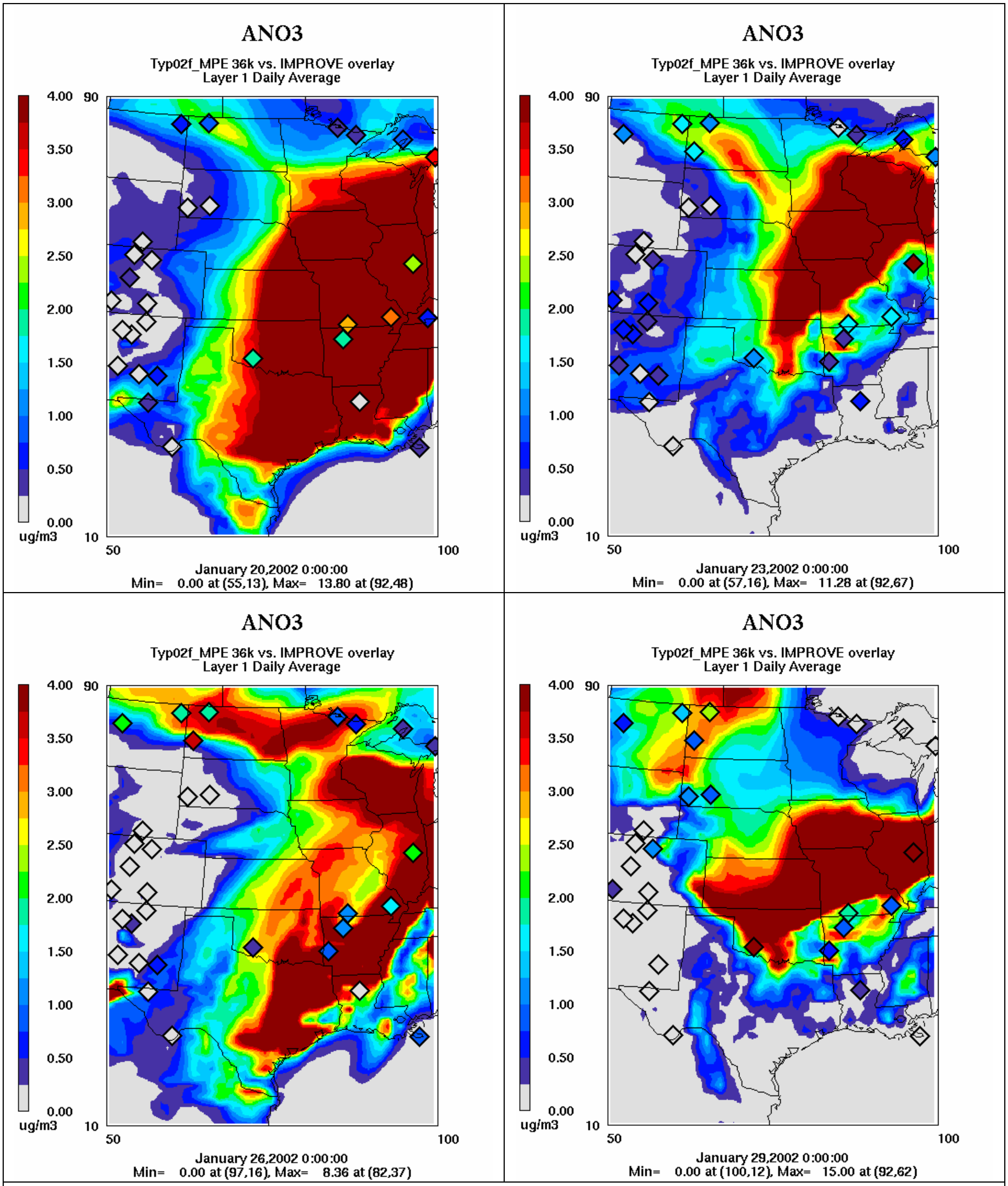


Figure C-10c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour NO3 concentrations for January 20, 23, 26 and 29, 2002.

C.3.2.2 NO3 in April 2002

Unlike the NO3 overestimation bias of January, the April NO3 performance is characterized by an underestimation bias (Figure C-11a). This under-prediction bias appears to be driven by near zero model predictions when the observed values are small (< 1 μg/m^3), but positive. This effect is especially noticeable in the NO3 time series (Figure C-11b) where at several sites the modeled NO3 concentrations foes to zero (e.g., BRET, BIBE, GUMO), whereas the observed values has an approximately 0.2 μg/m3 floor. The spatial maps suggest that the large April NO3 under-prediction bias indicated by the performance statistics is not as bad as they suggest (Figure C-11c). Mostly the model is predicting low NO3 values where low values are observed, just that the model approaches zero which results in a large relative difference with the observe values.

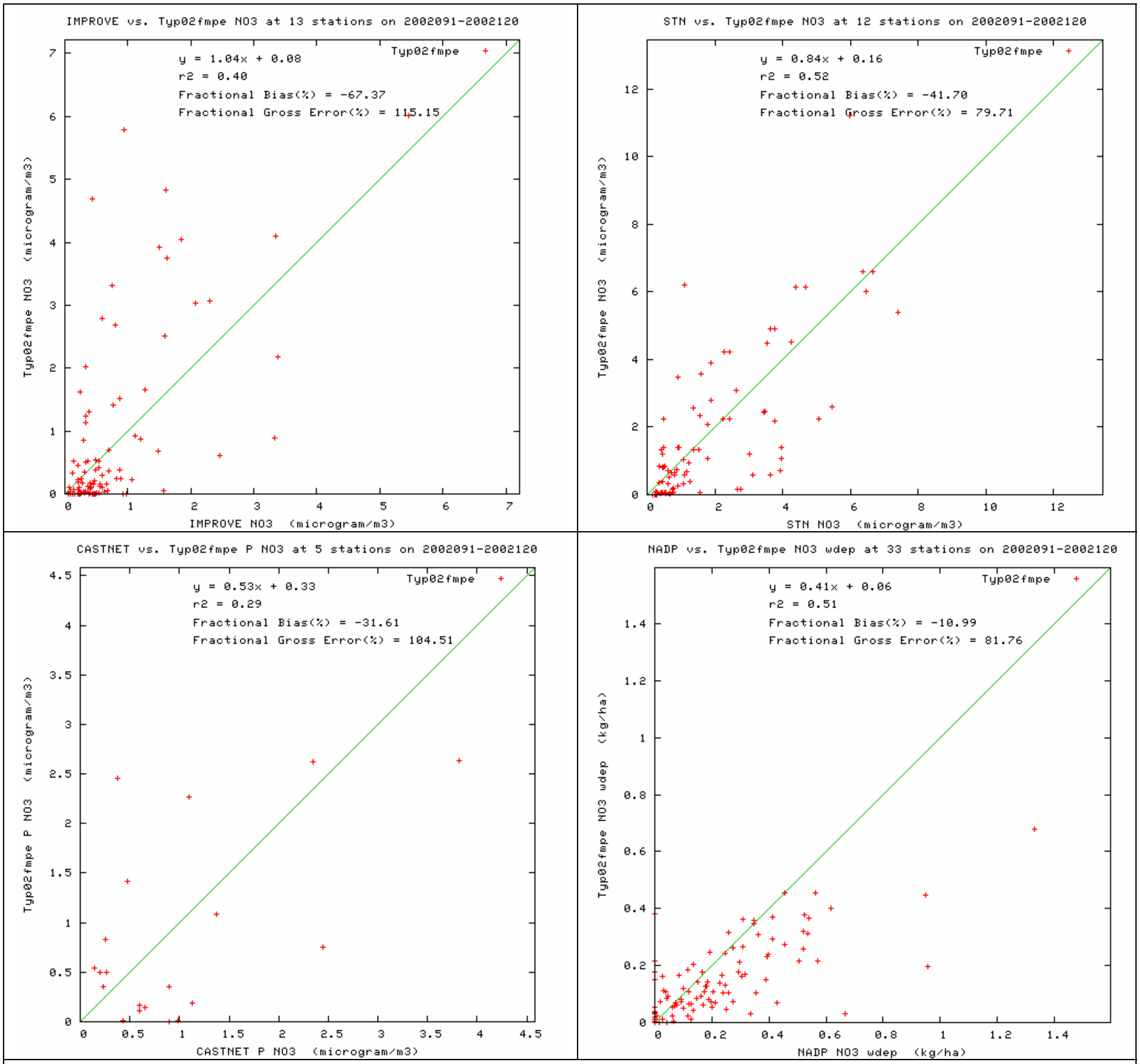
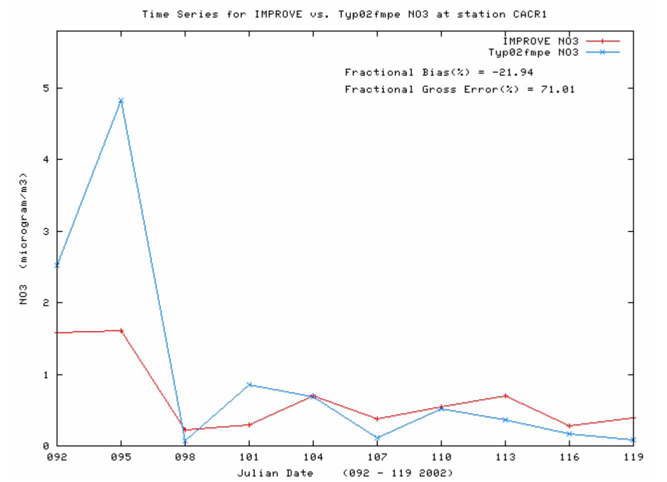
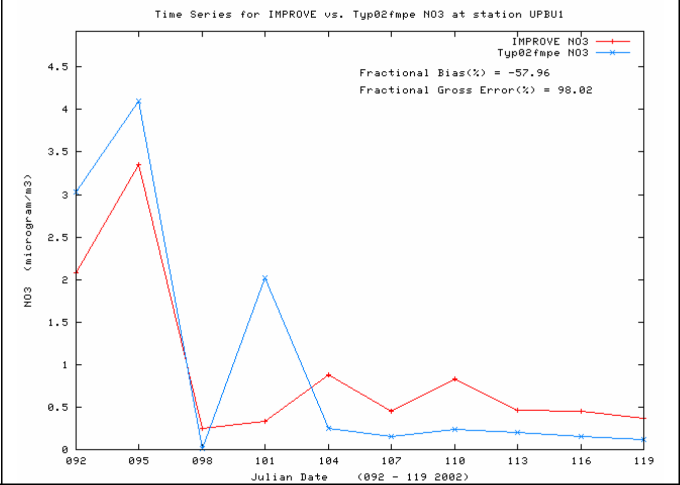
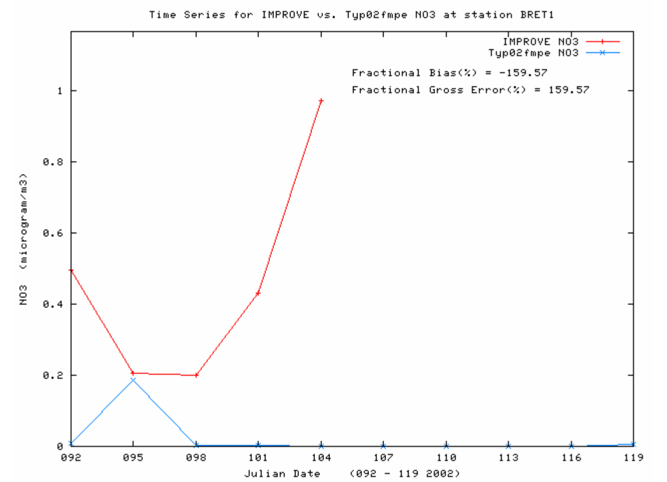
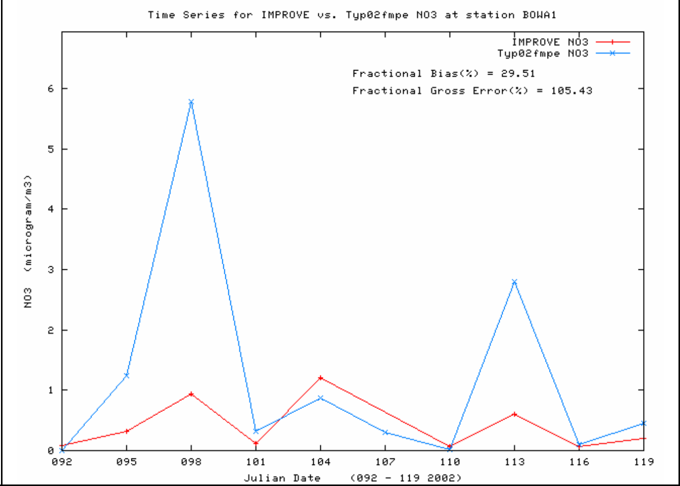


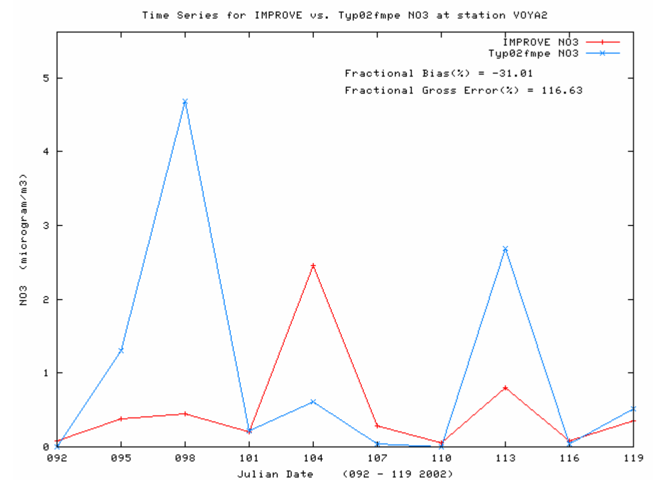
Figure C-11a. Scatter plots of predicted and observed nitrate (NO3) concentrations for April 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

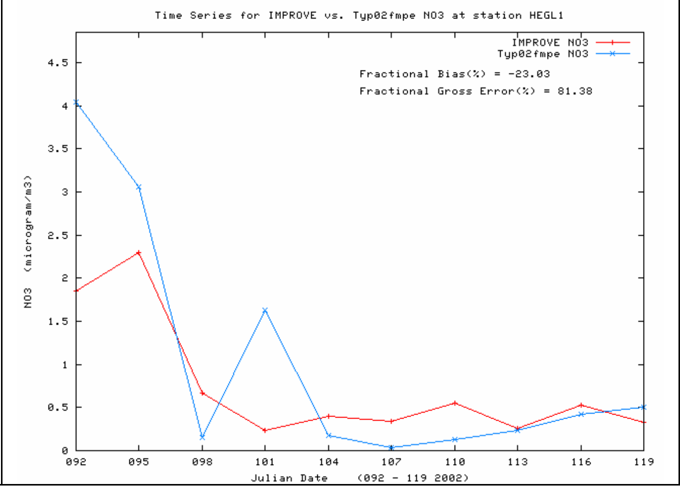

Time Series for IMPROVE vs. Typ02fmpe NO3 at station CACR1
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = -21.94
Fractional Gross Error(%) = 71.01
NO3 (microgram/m3)
0
1
2
3
4
5
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe NO3 at station UPBU1
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = -57.96
Fractional Gross Error(%) = 98.02
NO3 (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe NO3 at station BRET1
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = -159.57
Fractional Gross Error(%) = 159.57
NO3 (microgram/m3)
0
0.2
0.4
0.6
0.8
1
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe NO3 at station BOWA1
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = 29.51
Fractional Gross Error(%) = 105.43
NO3 (microgram/m3)
0
1
2
3
4
5
6
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe NO3 at station VOYA2
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = -31.01
Fractional Gross Error(%) = 116.63
NO3 (microgram/m3)
0
1
2
3
4
5
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe NO3 at station HEGL1
IMPROVE NO3
Typ02fmpe NO3
Fractional Bias(%) = -23.03
Fractional Gross Error(%) = 81.38
NO3 (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
092
095
098
101
104
107
110
113
116
119
Julian Date (092 - 119 2002)

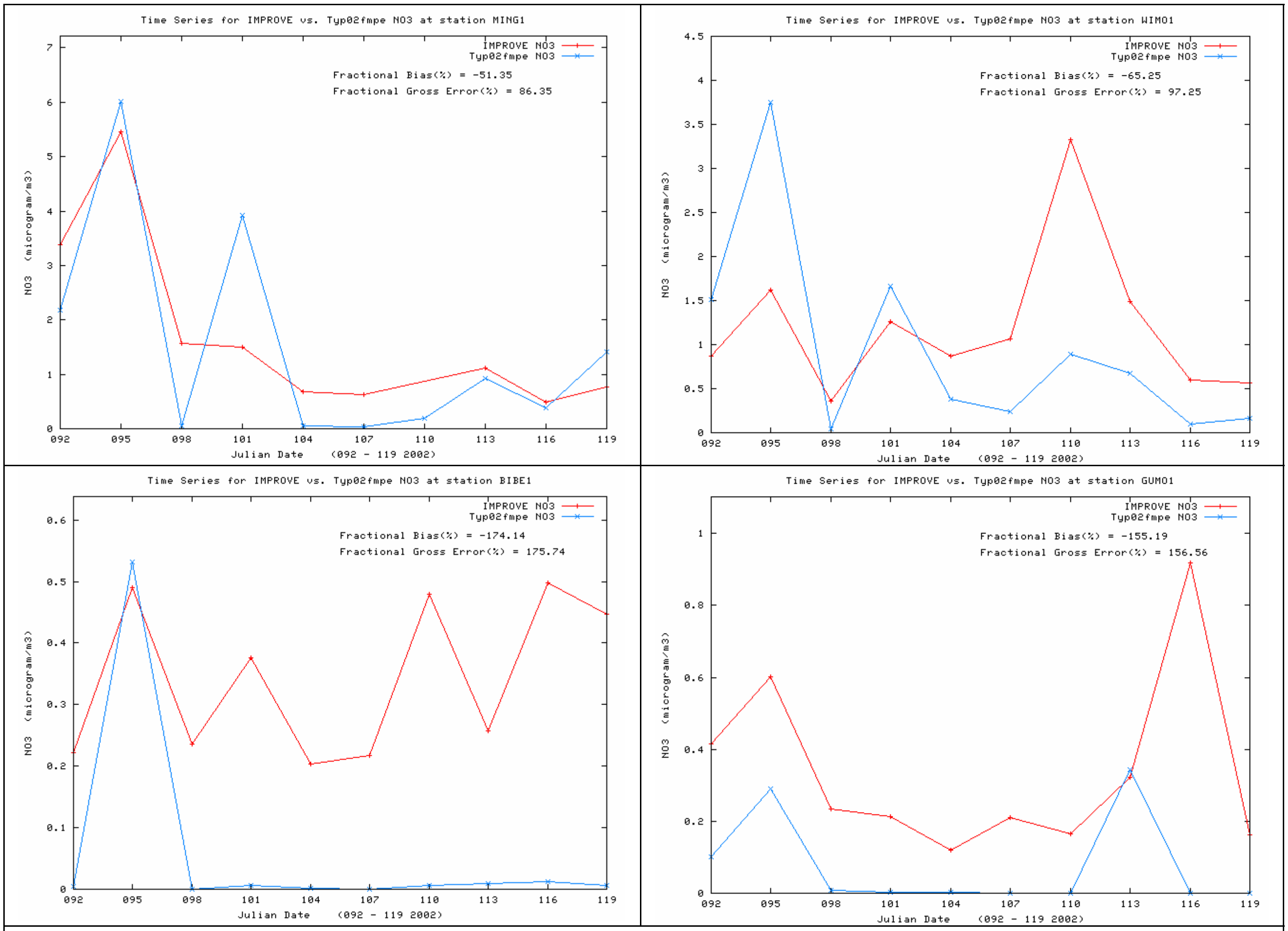


Figure C-11b. Time series of predicted and observed 24-hour nitrate (NO3) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

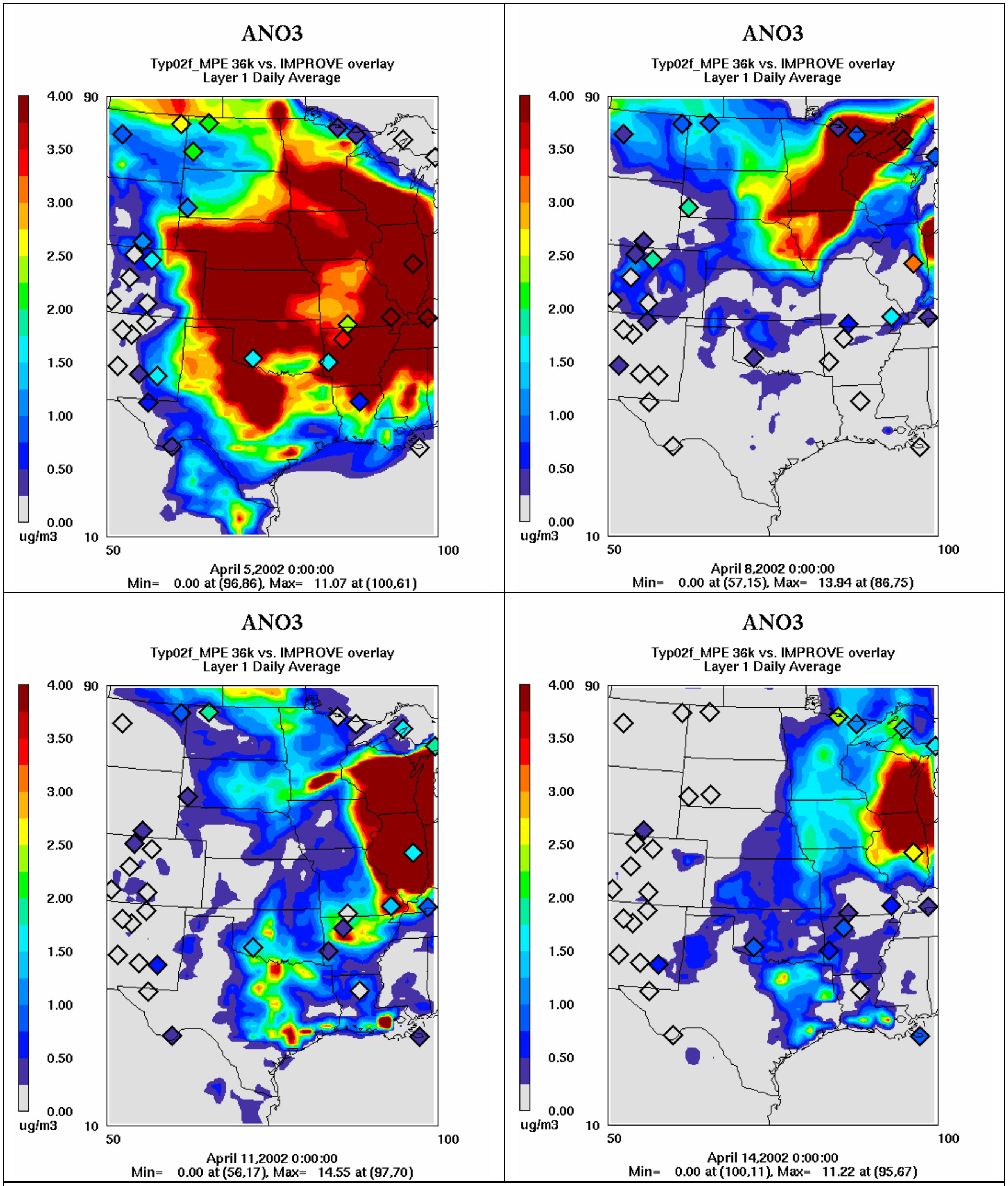


Figure C-11c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour NO3 concentrations for April 5, 8, 11 and 14, 2002.

C.3.2.3 NO3 in July 2002

NO3 performance in July 2002 is also characterized by a large under-prediction bias that is driven by the frequent occurrence of near zero modeled values (Figure C-12). Both the model and observations agree that NO3 is mostly extremely low in July, just the model produces near zero values and resultant poor performance statistics.

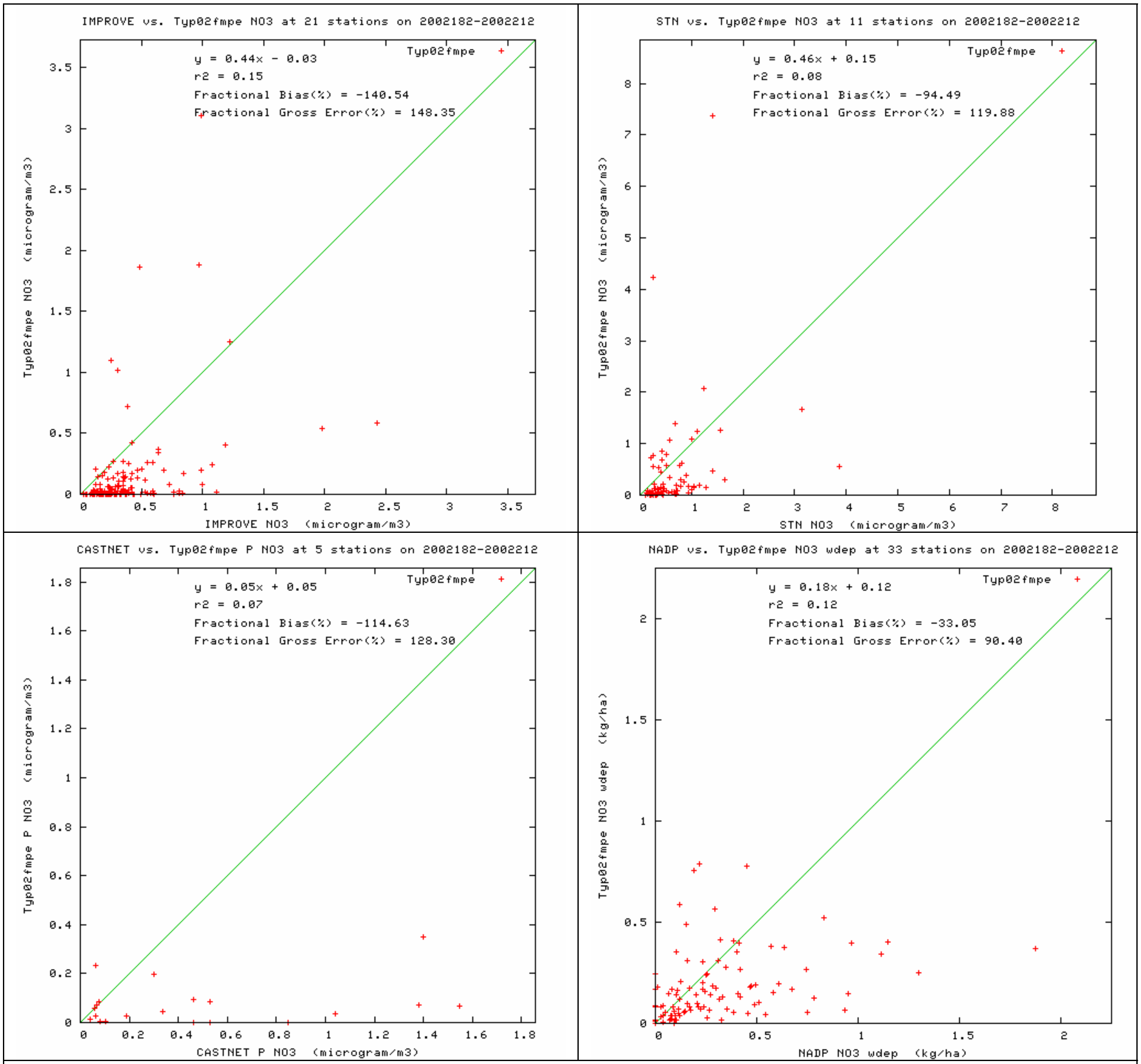
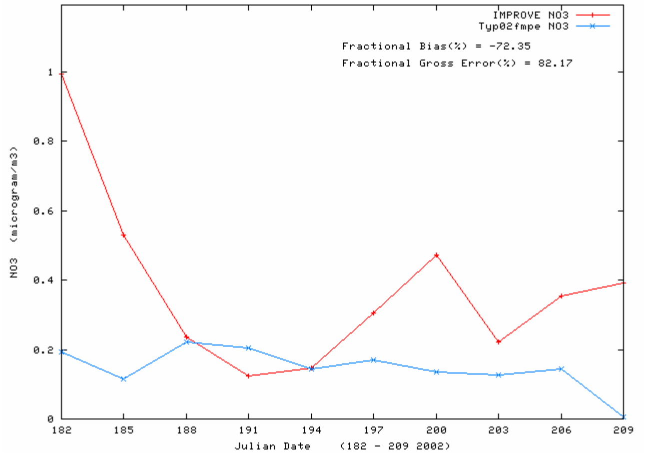
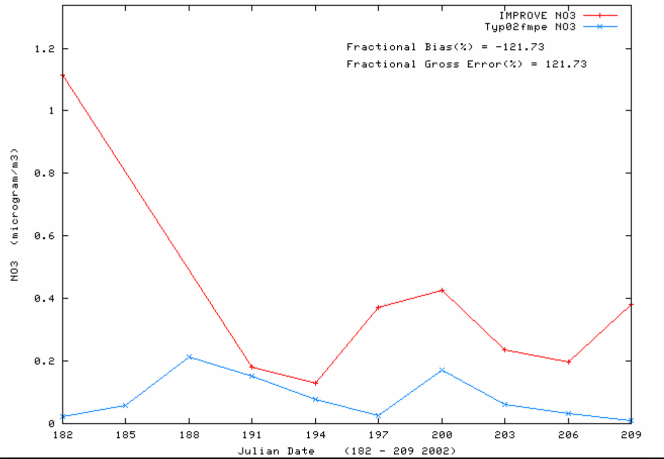


Figure C-12a. Scatter plots of predicted and observed nitrate (NO3) concentrations for July 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

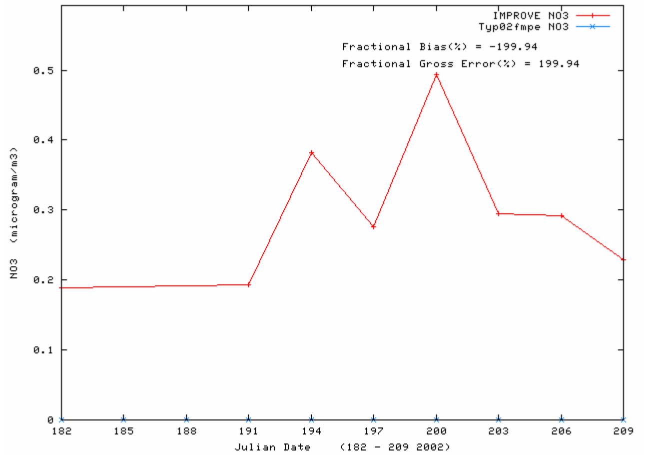
Time Series for IMPROVE vs. Typ02fmpe NO3 at station CACR1



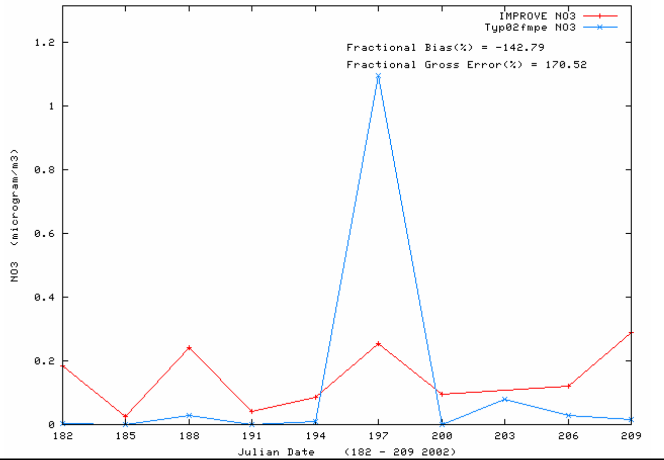
Time Series for IMPROVE vs. Typ02fmpe NO3 at station UPBU1



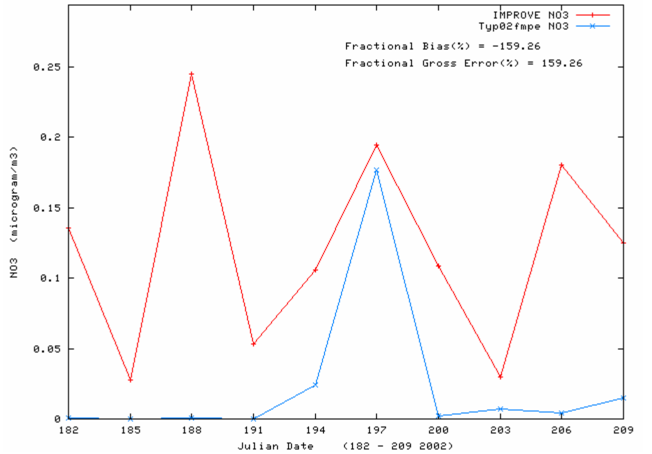
Time Series for IMPROVE vs. Typ02fmpe NO3 at station BRET1



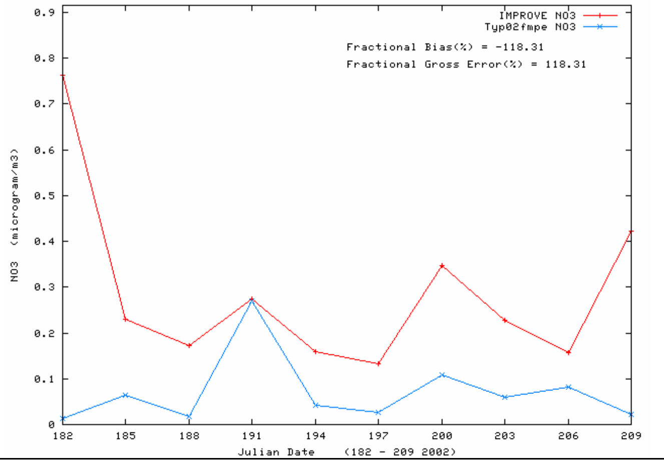
Time Series for IMPROVE vs. Typ02fmpe NO3 at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe NO3 at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe NO3 at station HEGL1



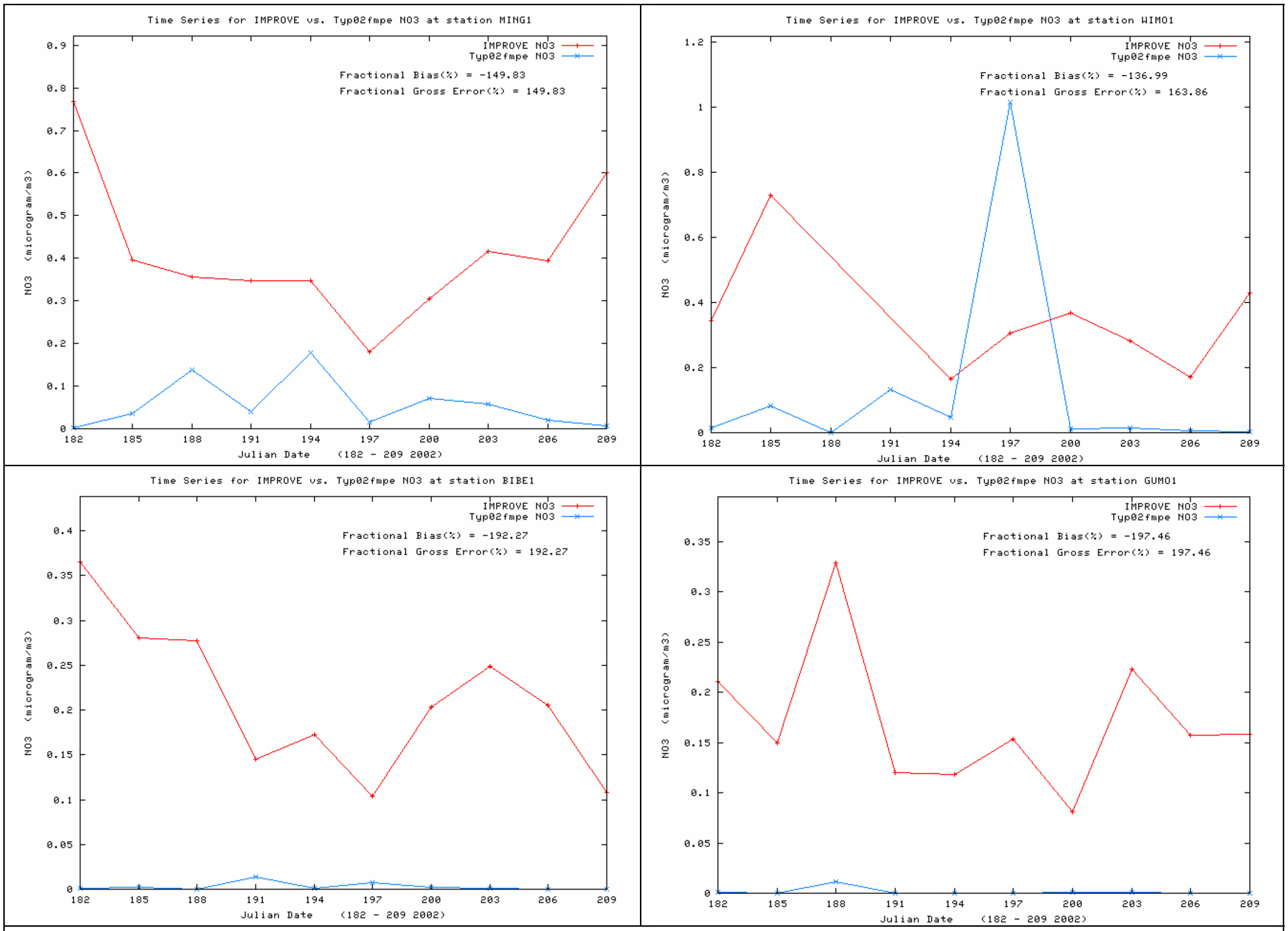


Figure C-12b. Time series of predicted and observed 24-hour nitrate (NO3) concentrations at CENRAP IMPROVE CLASS I AREA sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

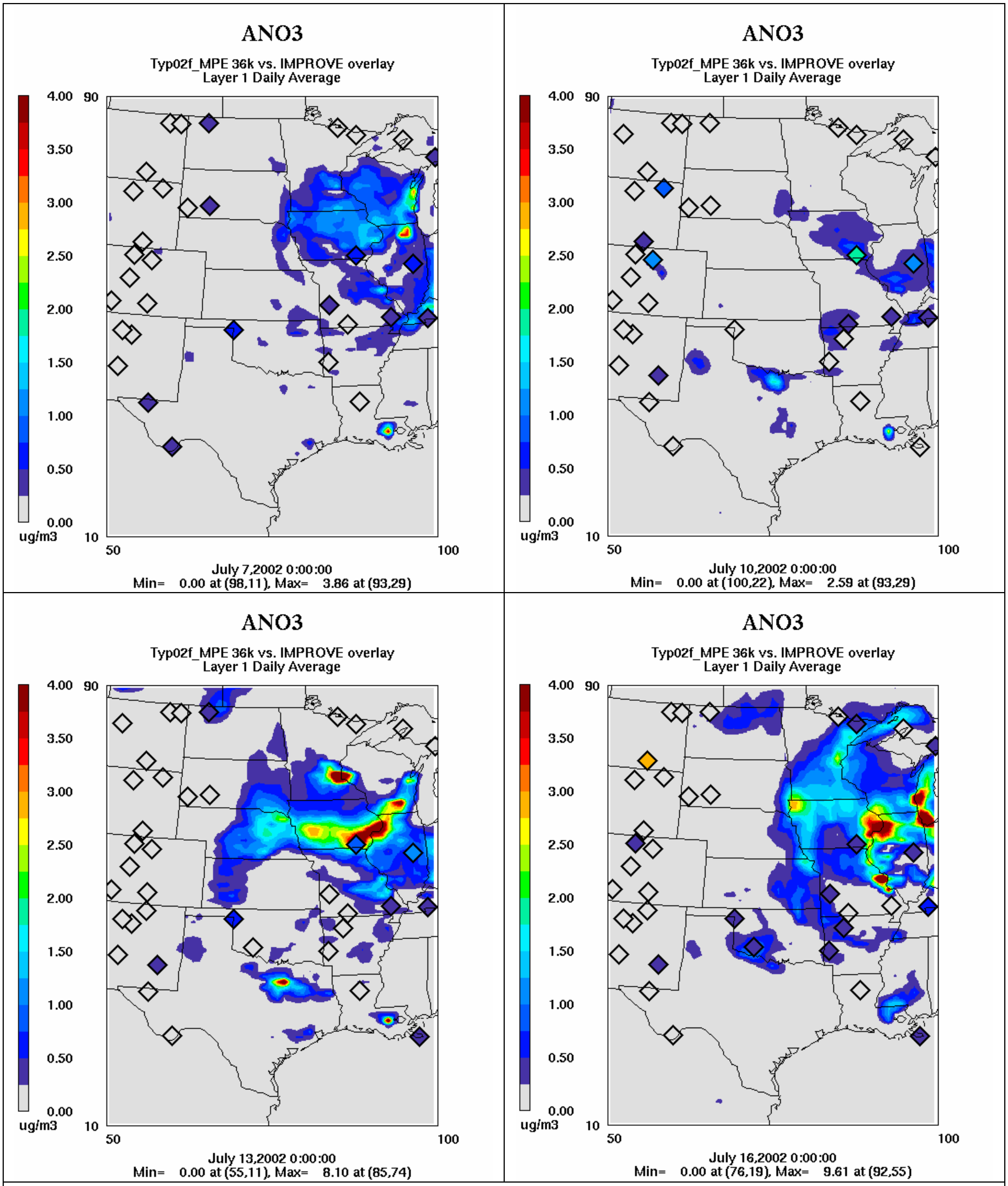


Figure C-12c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour NO3 concentrations for July 7, 10, 13 and 16, 2002.

C.3.2.4 NO3 in October 2002

Like January and unlike April and July, in October the model has a net NO3 overestimation bias of about 30%-40% (Figure C-13a). This overestimation bias occurs at all sites but BRET, BIBE and GUMO that exhibit a NO3 underestimation bias (Figure C-13b). The spatial maps suggest that the modeled elevated NO3 concentrations are more wide-spread and less spotty than observed.

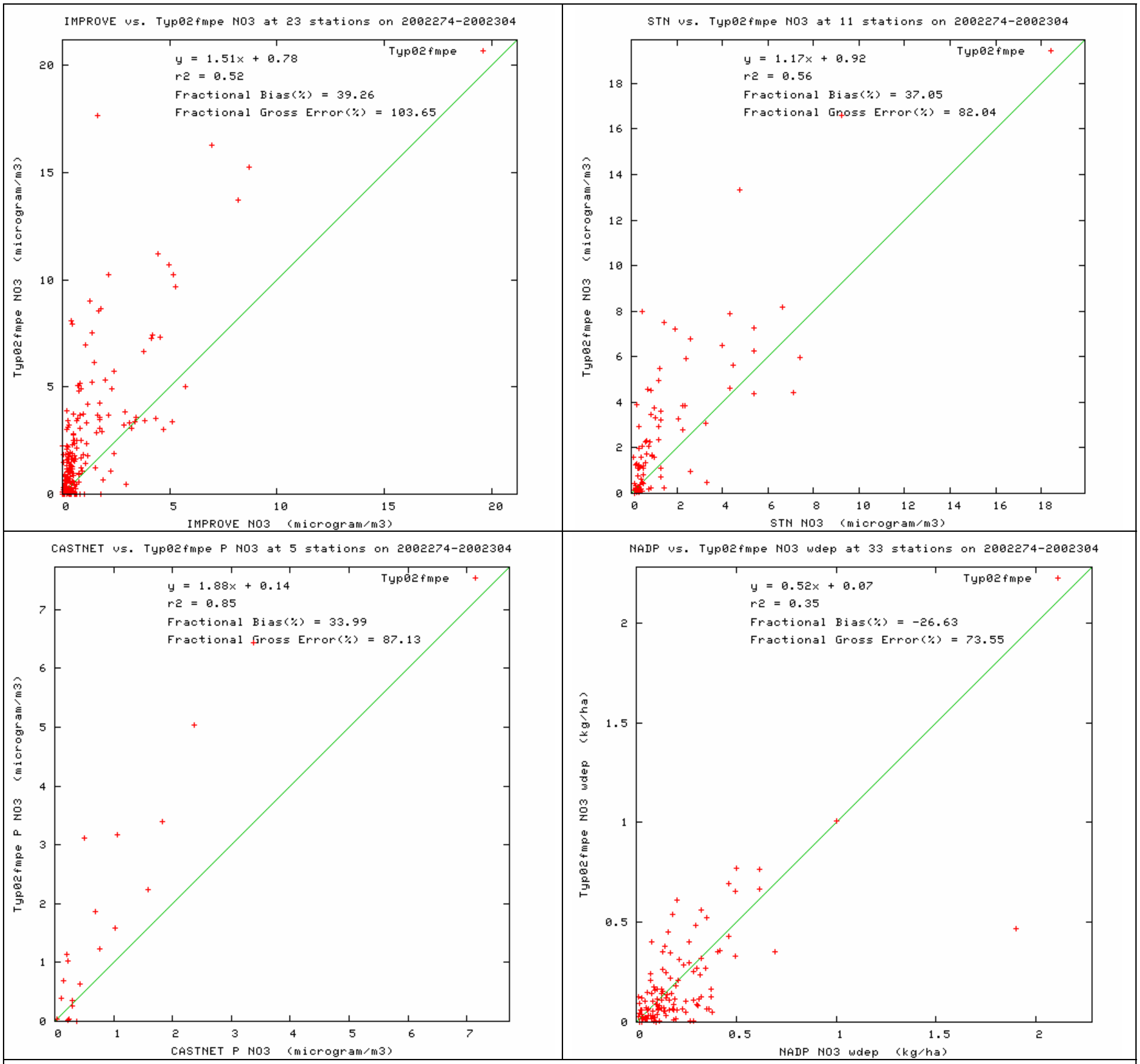
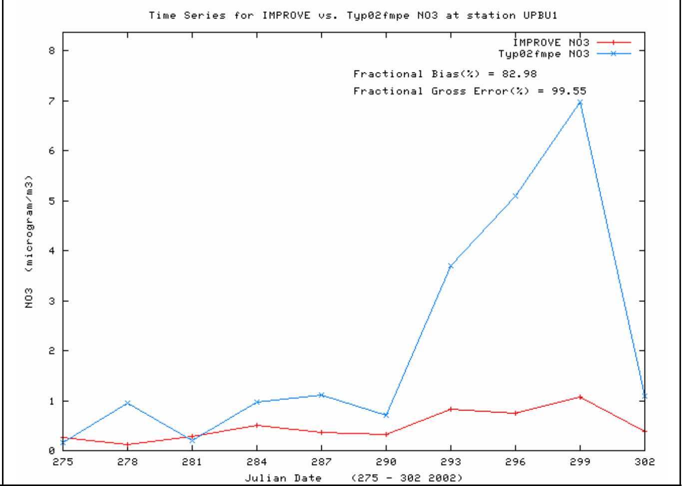
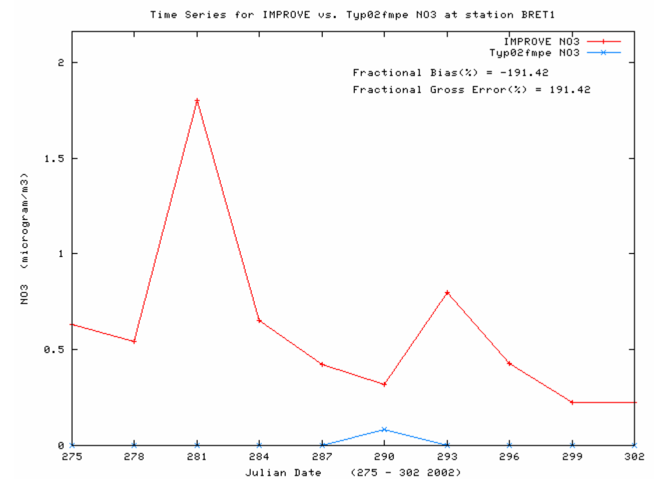
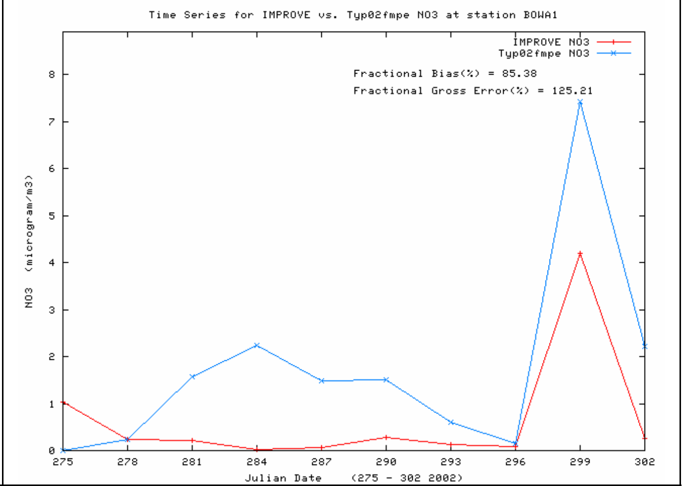


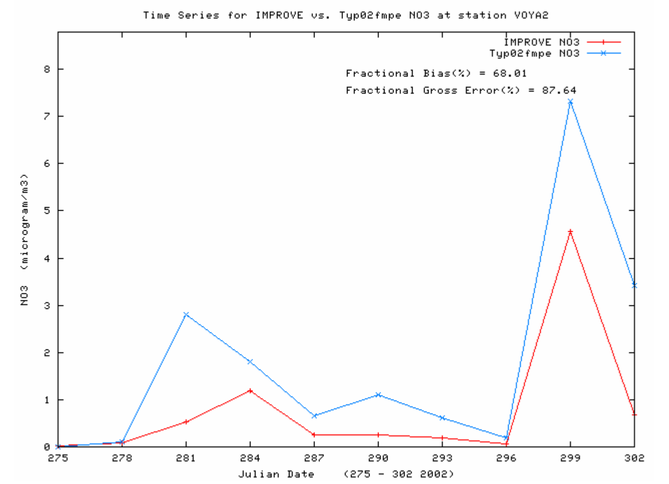
Figure C-13a. Scatter plots of predicted and observed nitrate (NO3) concentrations for October 2002 and sites in the CENRAP region using IMPROVE (top left), STN (top right), CASTNet (bottom left) and NADP monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

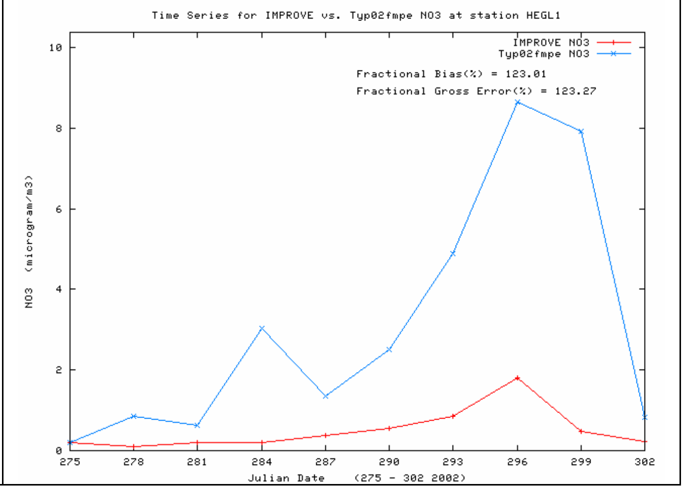

Time Series for IMPROVE vs. Typ02fmpe NO3 at station CACR1


Time Series for IMPROVE vs. Typ02fmpe NO3 at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe NO3 at station BRET1


Time Series for IMPROVE vs. Typ02fmpe NO3 at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe NO3 at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe NO3 at station HEGL1

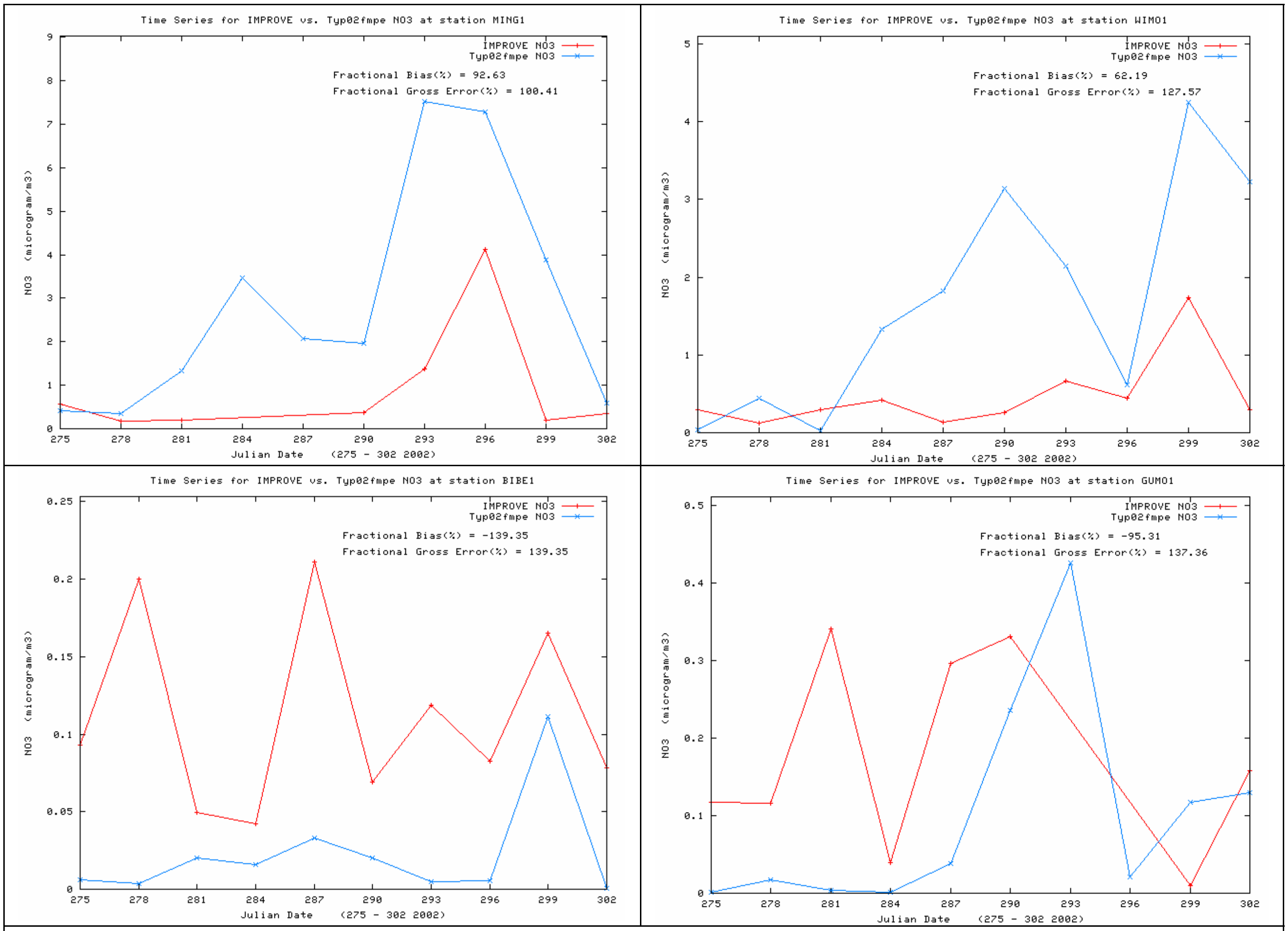
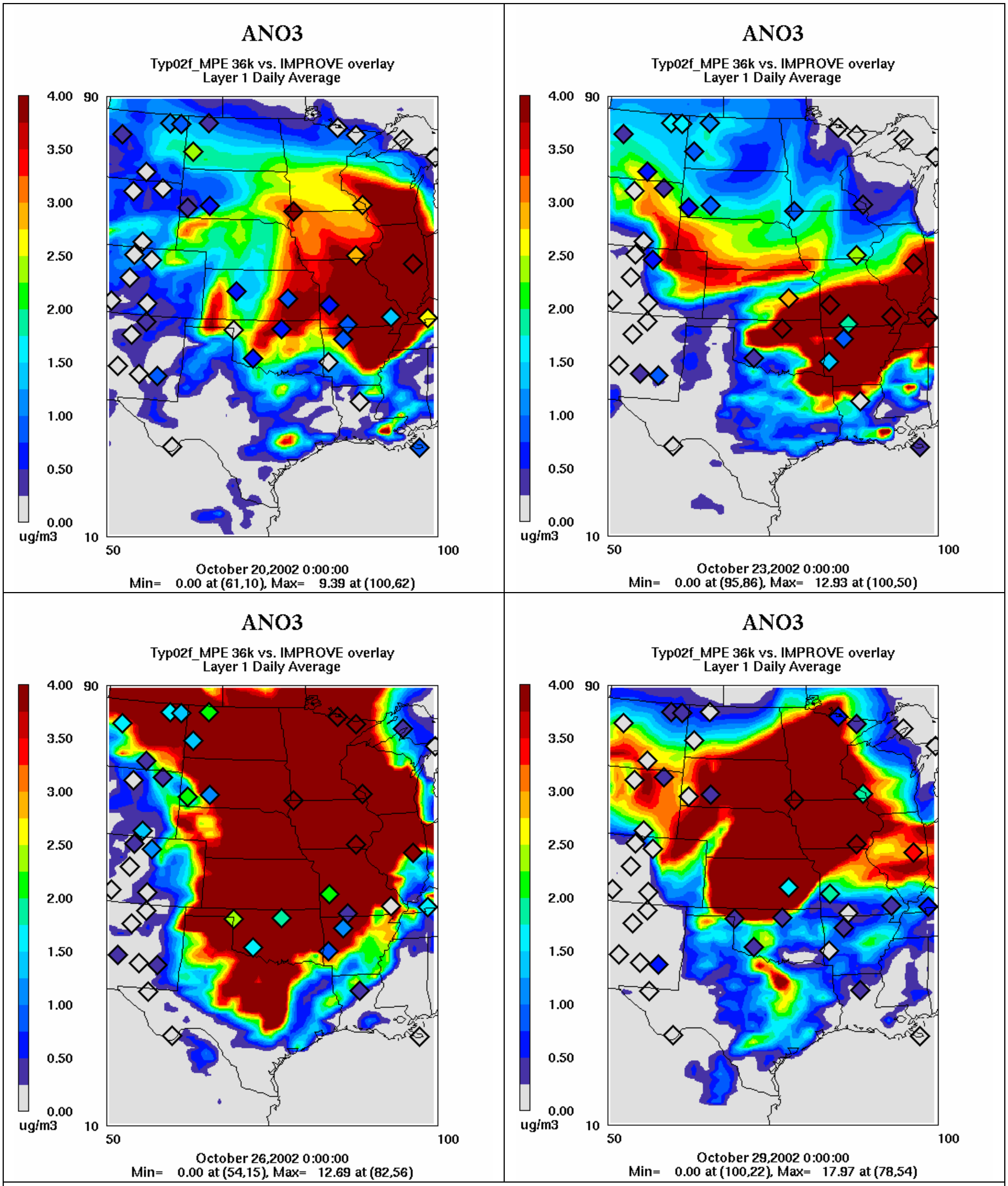


Figure C-13b. Time series of predicted and observed 24-hour nitrate (NO3) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.


ANO3

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

October 20,2002 0:00:00
Min= 0.00 at (61,10), Max= 9.39 at (100,62)

ANO3

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

October 23,2002 0:00:00
Min= 0.00 at (95,86), Max= 12.93 at (100,50)

ANO3

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

October 26,2002 0:00:00
Min= 0.00 at (54,15), Max= 12.69 at (82,56)

ANO3

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

October 29,2002 0:00:00
Min= 0.00 at (100,22), Max= 17.97 at (78,54)

Figure C-13c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour NO3 concentrations for October 20, 23, 26 and 29, 2002.

C.3.2.5 NO3 Monthly Bias and Error

The monthly fractional bias values for NO3 clearly show the summer underestimation and winter overestimation bias (Figure C-14). The summer underestimation bias is more severe exceeding -100%, whereas the winter overestimation is closer to 50%. The fractional errors in the summer are also greater than in the winter with some values exceeding 100%. So based on statistics alone, it appears the summer underestimation bias is a bigger concern than the winter overestimation bias. However, the Bugle Plots in Figure C-15 paint a different picture entirely. The summer underestimation bias occurred when NO3 is low and is not an important component of PM and visibility impairment. These summer values occur in the flared horn part of the Bugle Plot and in fact the summer NO3 performance mostly achieves the model performance goal and always achieves the performance criteria. Whereas the winter overstated NO3 performance mostly doesn’t meet the performance goal and there are even some months/networks that don’t meet the performance criteria.

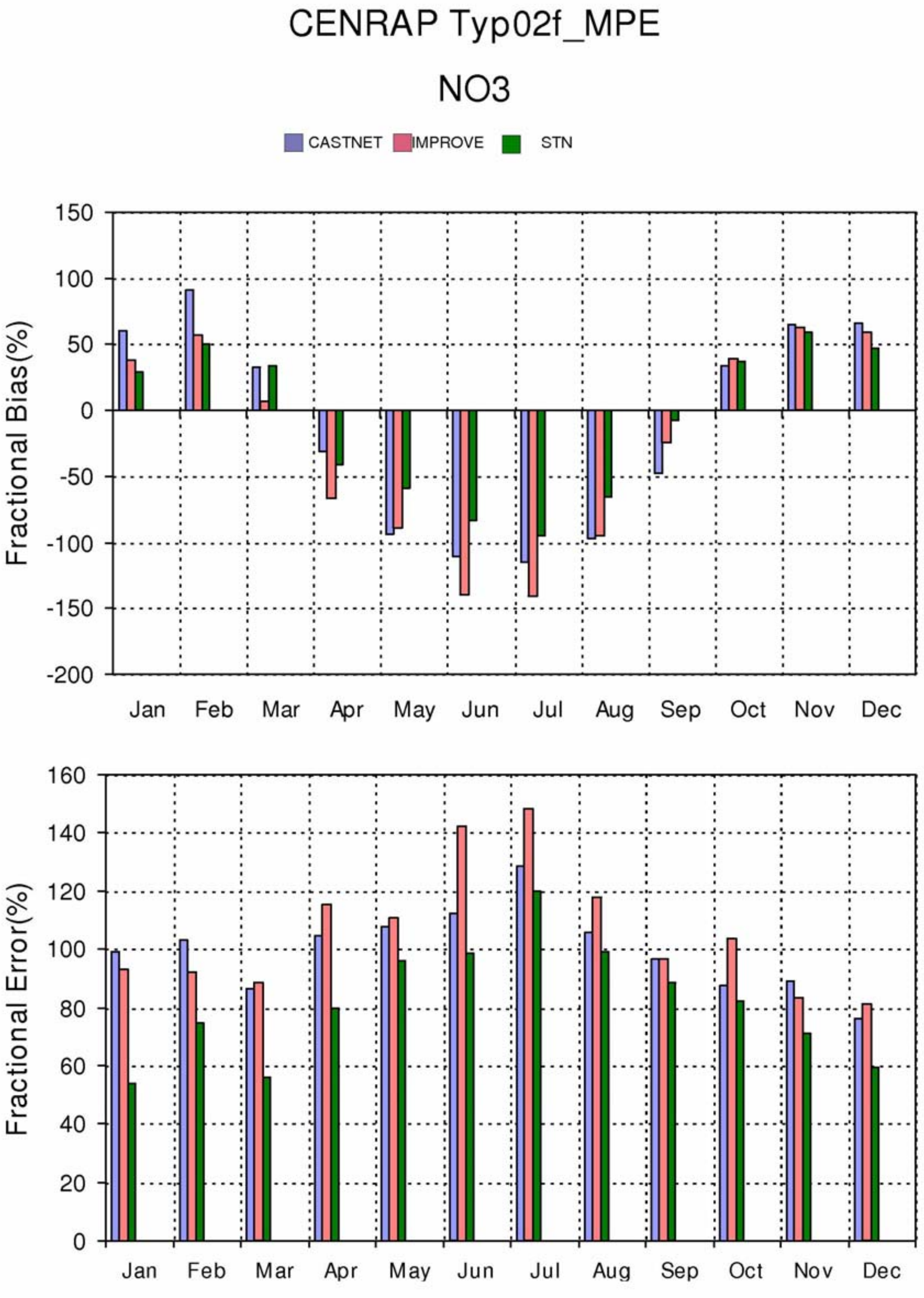


Figure C-14. Monthly NO3 fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

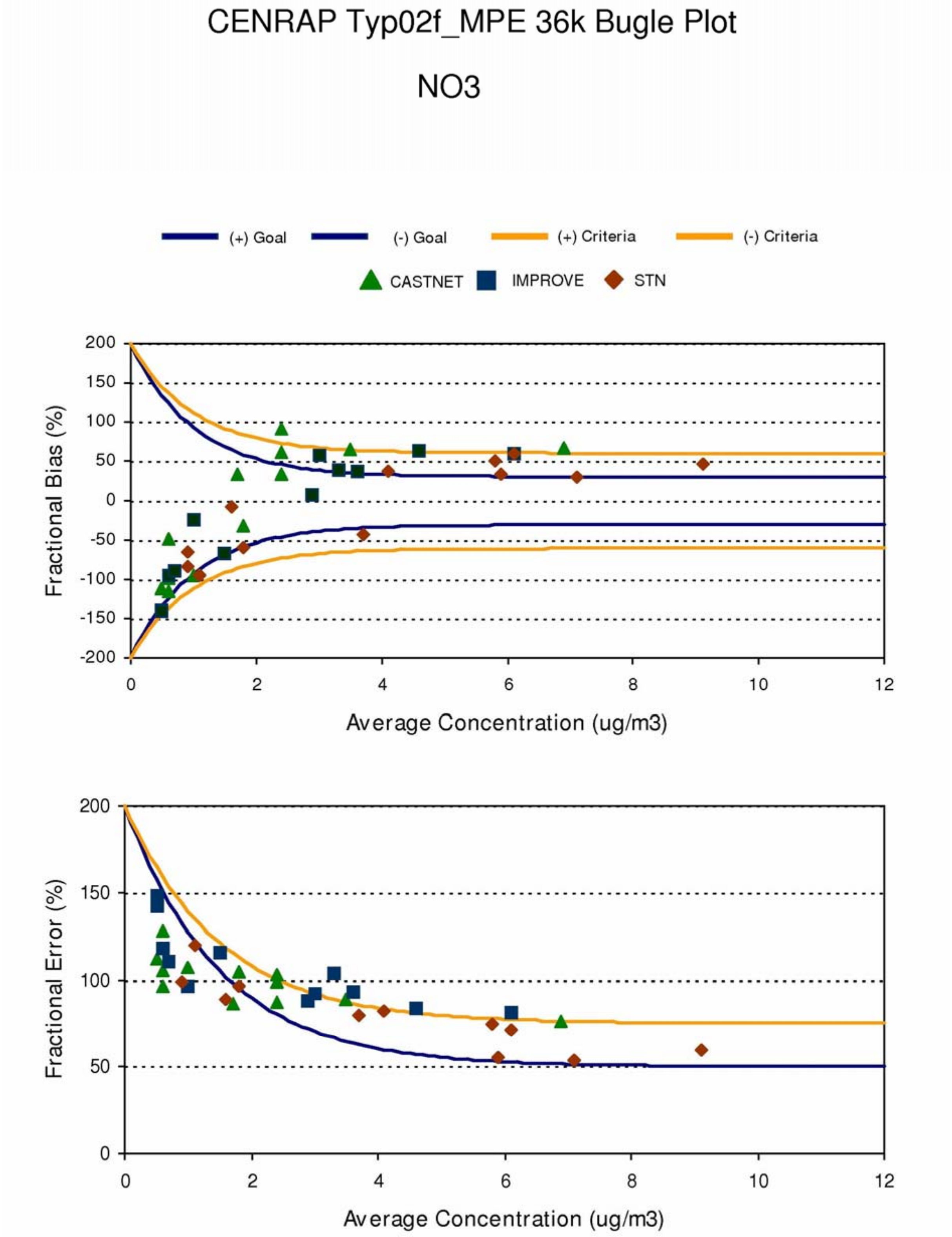


Figure C-15. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for NO3 and IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

C.3.3 Organic Matter Carbon (OMC) Monthly Model Performance

Organic Matter Carbon (OMC) model performance is presented below. There is incommensurability between the observed and modeled OMC, the model provides estimates of OMC that includes Organic Carbon (OC) as well as other elements attached to the OC (e.g., oxygen), whereas the monitoring networks measure just the carbon component of OMC (i.e., OC). Consequently, the measured OC must be adjusted to OMC for comparison with the model to account for the additional elements attached to the carbon. The OMC/OC ratio is not constant and depends in part on the age of the OMC with fresh OMC having lower OMC/OC ratios than aged OMC. The original IMPROVE equation used an OMC/OC ratio of 1.4 based mainly on urban-oriented measurements. The new IMPROVE equation uses an OMC/OC ratio of 1.8 reflecting the fact that OMC at the more rural IMPROVE monitors is more aged than urban OMC. Thus, selecting a single OMC/OC ratio for adjusting the measured OC to OMC for the model evaluation is somewhat problematic when we have both urban (STN) and rural (IMPPROVE) monitors. In addition, measured OC also has substantial uncertainty with different measurement techniques differing by as much as 50% (Solomon et al., 2005). A 1.4 OMC/OC ratio was used to convert the measured OC to OMC for the model performance evaluation.

C.3.3.1 OMC in January 2002

Figure C-16a displays scatter plots and performance statistics for January OMC model performance across the IMPROVE and STN sites in the CENRAP region. OMC model performance is fairly with near zero bias across the IMPROVE sites, -38% underestimation bias across the STN sites and errors of ~50%. The underestimation of OMC at the urban STN sites is a common occurrence in air quality modeling and may indicate a missing source of urban OMC. With the exception of an underestimation bias at Breton Island and an over-prediction bias at the two Texas IMPORVE sites (BIBE and GUMO), the model reproduces the observed OMC time series in January fairly well. The modeled spatial distribution of OMC is in general agreement with the observations although it sometimes captures the elevated values on some days (e.g., January 29, 2002 in central Illinois) and misses it on others (e.g., January 26, 2002 at Mingo).

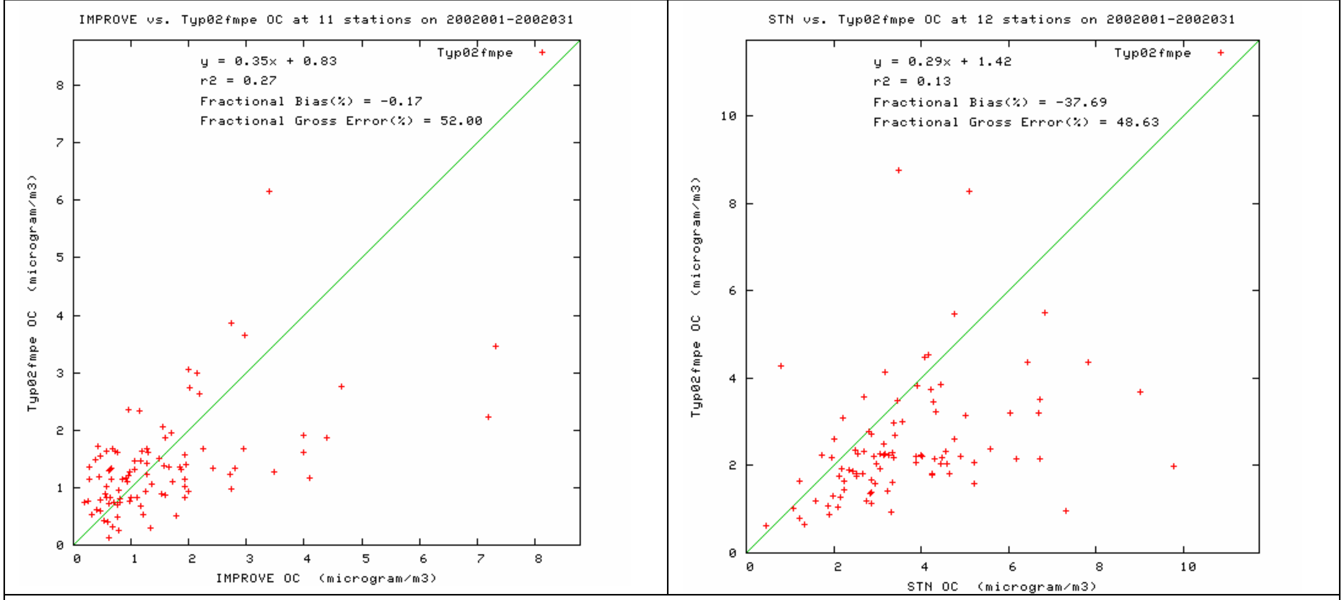
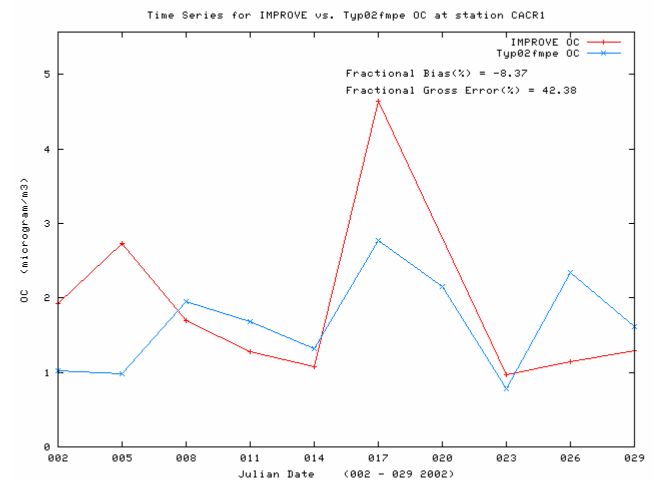
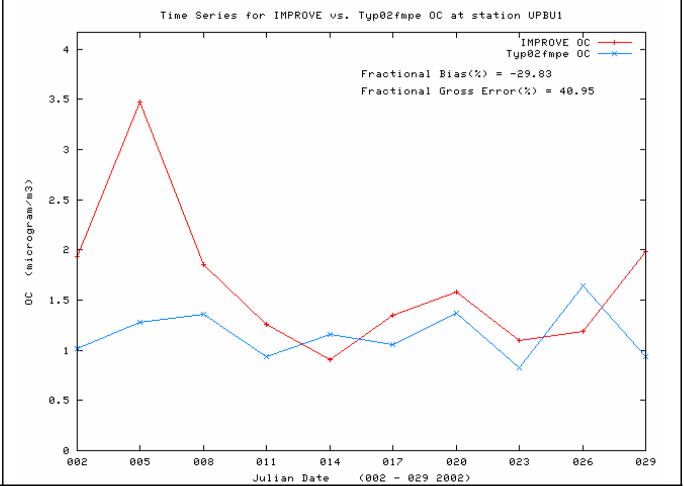
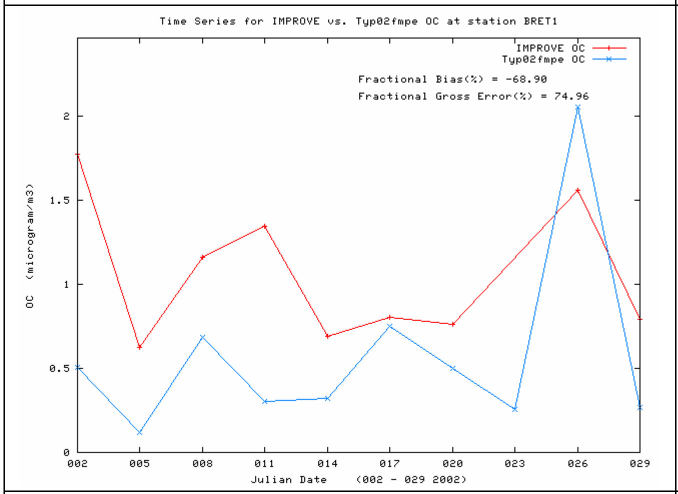
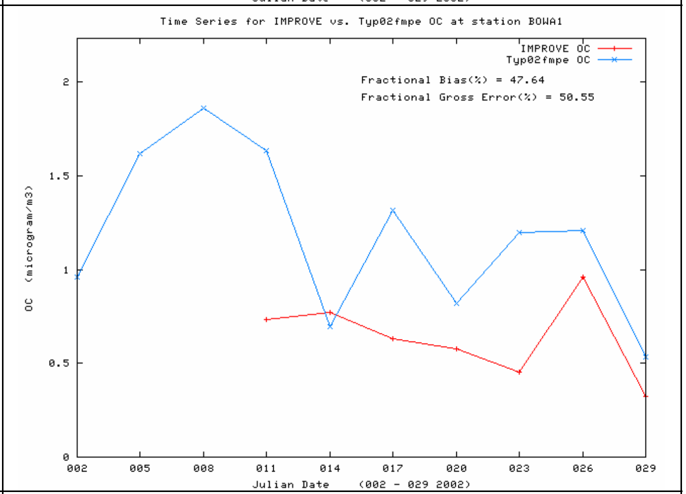


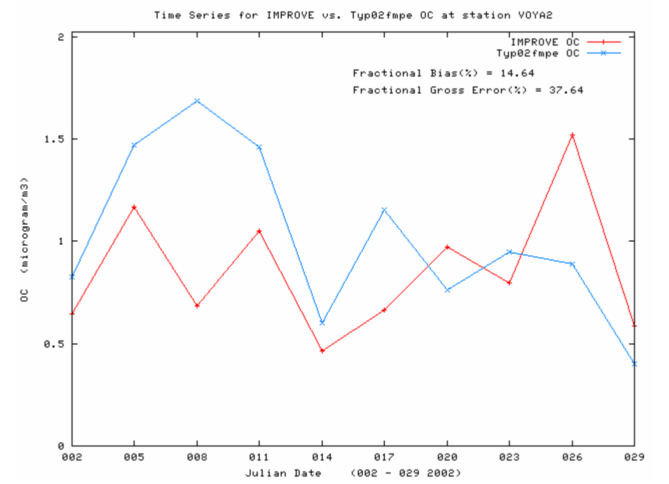
Figure C-16a. Scatter plots of predicted and observed organic matter carbon (OMC) concentrations for January 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.


Time Series for IMPROVE vs. Typ02fmpe OC at station CACR1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -8.37
Fractional Gross Error(%) = 42.38
OC (microgram/m3)
0
1
2
3
4
5
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station UPBU1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -29.83
Fractional Gross Error(%) = 40.95
OC (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
4
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station BRET1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -68.90
Fractional Gross Error(%) = 74.96
OC (microgram/m3)
0
0.5
1
1.5
2
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station BOWA1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = 47.64
Fractional Gross Error(%) = 50.55
OC (microgram/m3)
0
0.5
1
1.5
2
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station VOYA2
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = 14.64
Fractional Gross Error(%) = 37.64
OC (microgram/m3)
0
0.5
1
1.5
2
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station HEGL1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -47.00
Fractional Gross Error(%) = 52.77
OC (microgram/m3)
0
1
2
3
4
5
6
7
8
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)

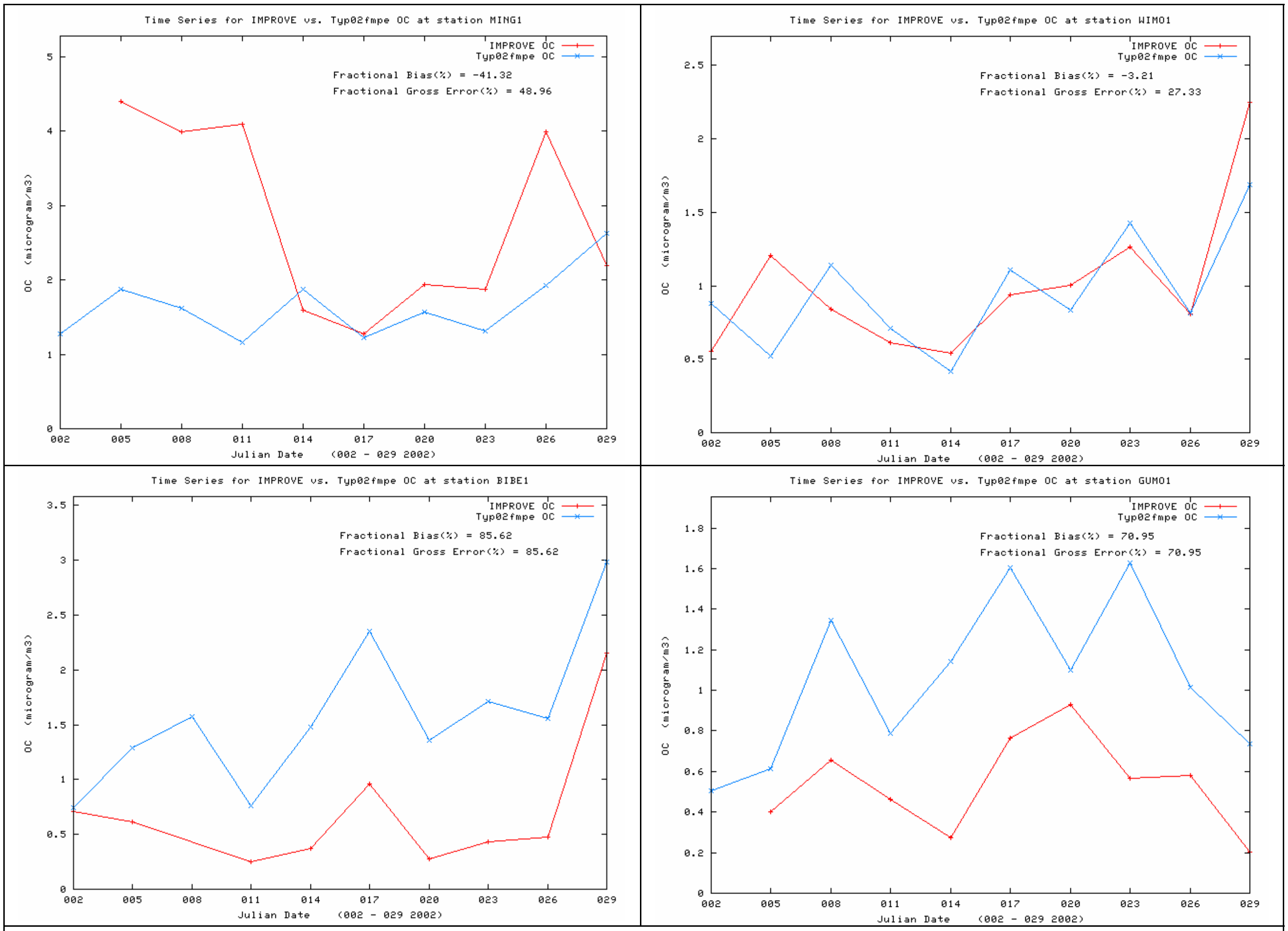


Figure C-16b. Time series of predicted and observed 24-hour organic matter carbon (OMC) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

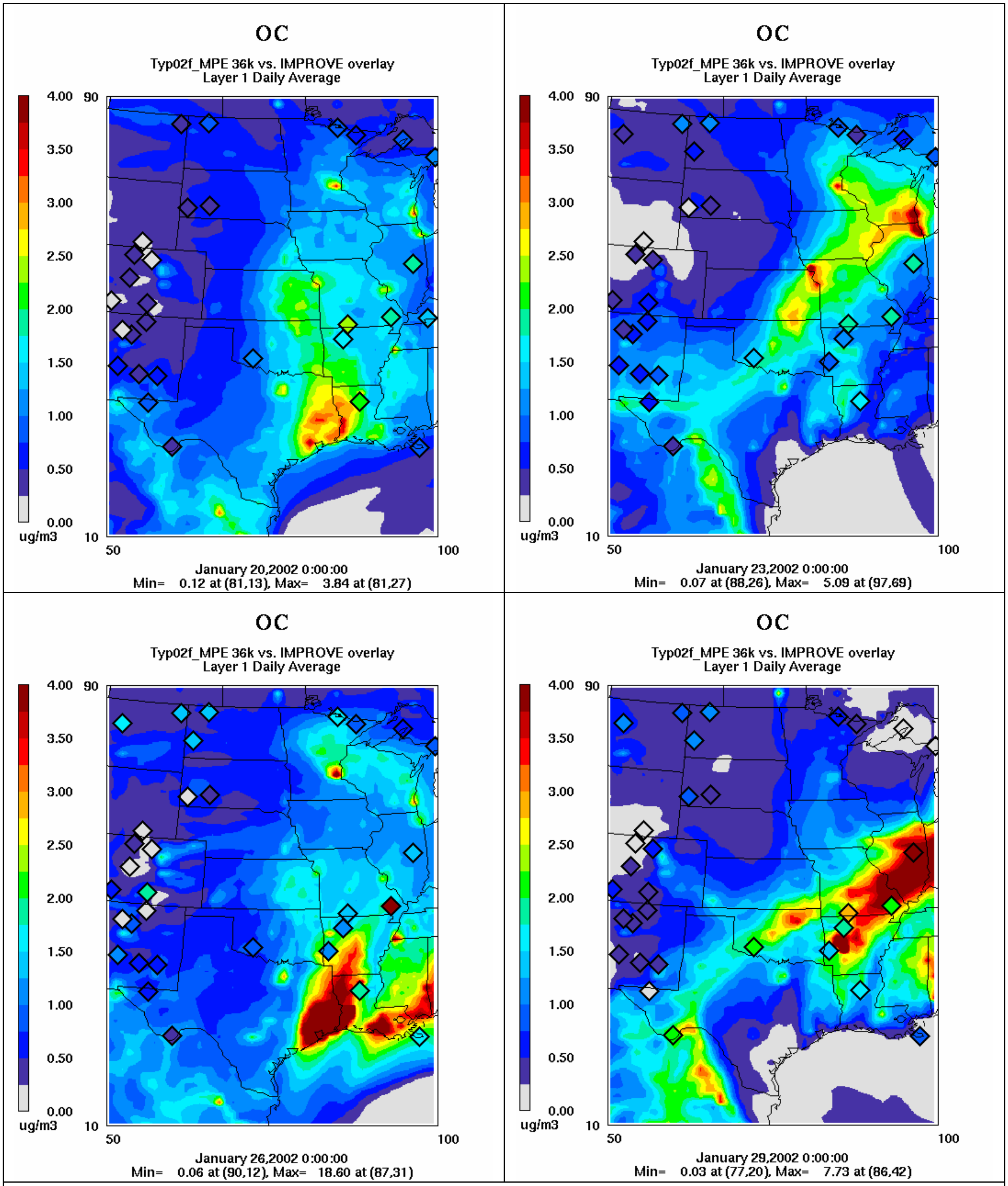


Figure C-16c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour OMC concentrations for January 20, 23, 26 and 29, 2002.

C.3.3.2 OMC in April 2002

The OMC performance in April is also fairly reasonable, again bias across the IMPROVE monitors is near zero (-7%), an underestimation bias exists across the STN sites (-30%) and errors are near 50% (Figure C-17a). The time series comparisons (Figure C-17b) are also reasonable with the model generally agreeing on the magnitudes of the observed OMC, but with an underestimation bias at several sites (e.g., MING and WIMO). The observed spatial distribution of OMCV appears to be much spottier than predicted (Figure C-17c). Thus, when the model reproduces an elevated observed OMC value like at UPBU on April 5th, it overestimates OMC at neighboring sites that have lower values (e.g., HEGL).

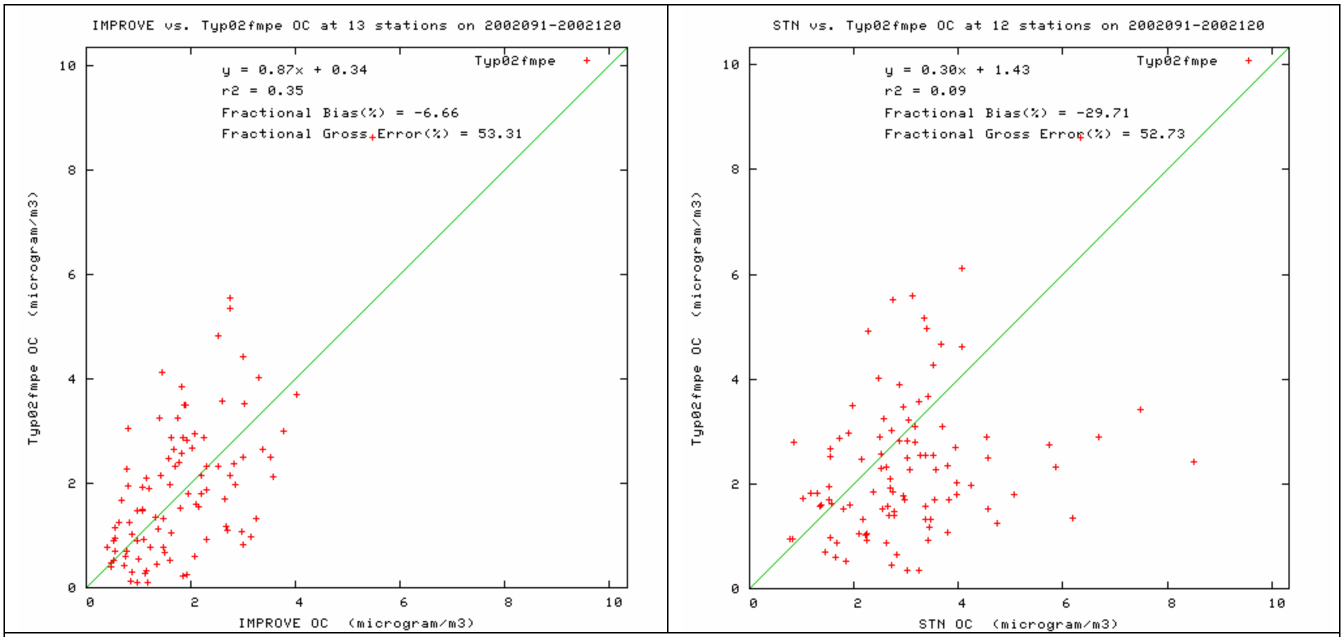
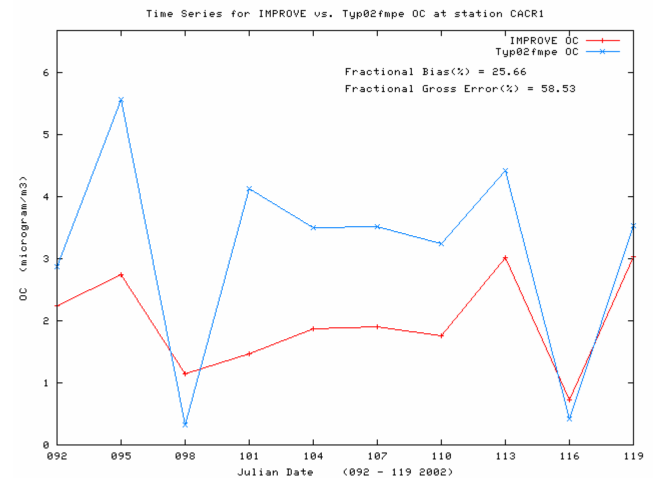
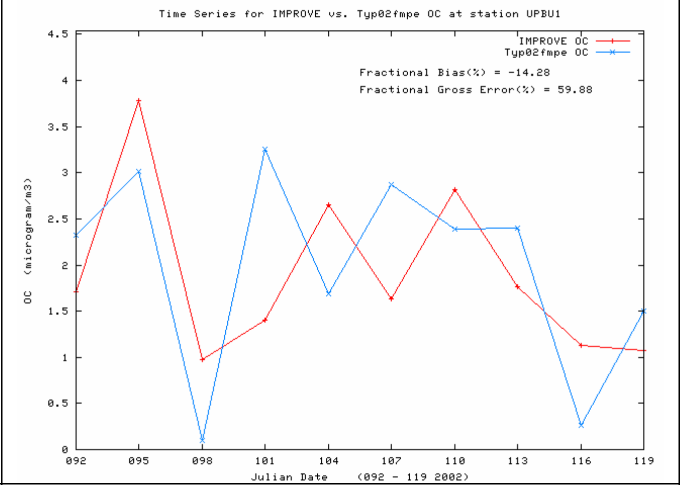
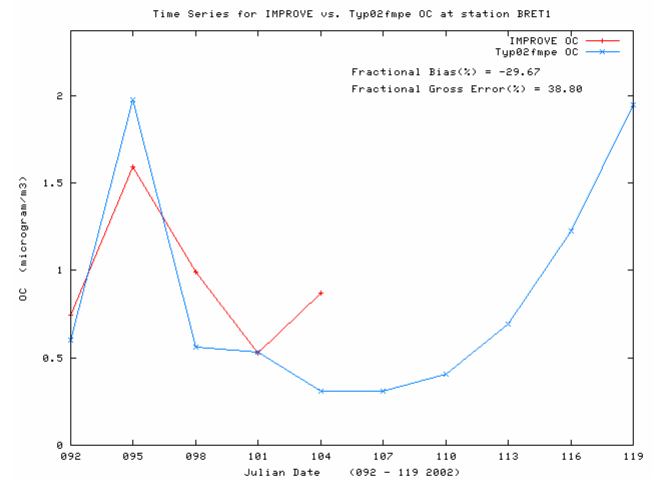
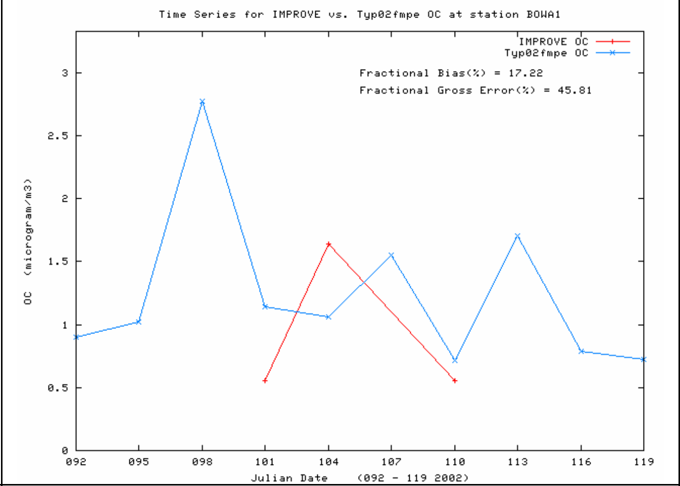


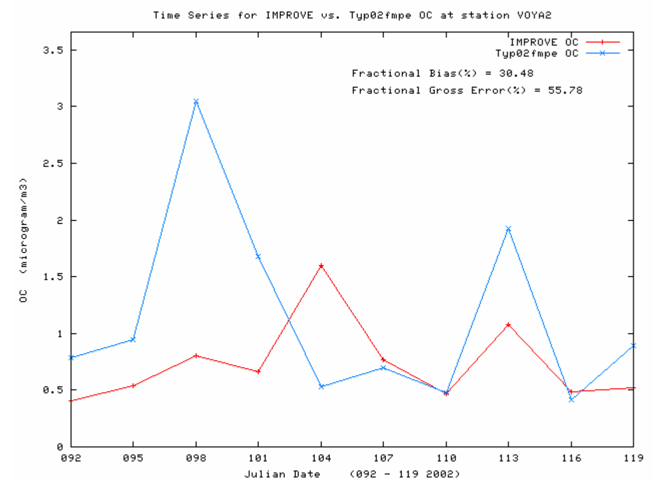
Figure C-17a. Scatter plots of predicted and observed organic matter carbon (OMC) concentrations for April 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

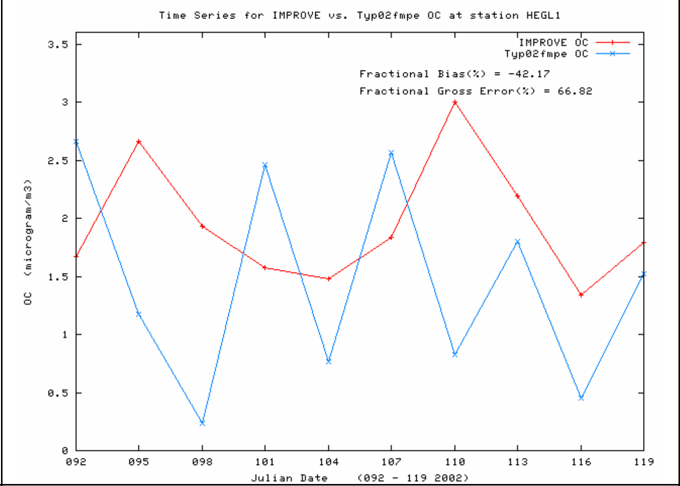

Time Series for IMPROVE vs. Typ02fmpe OC at station CACR1


Time Series for IMPROVE vs. Typ02fmpe OC at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe OC at station BRET1


Time Series for IMPROVE vs. Typ02fmpe OC at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe OC at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe OC at station HEGL1

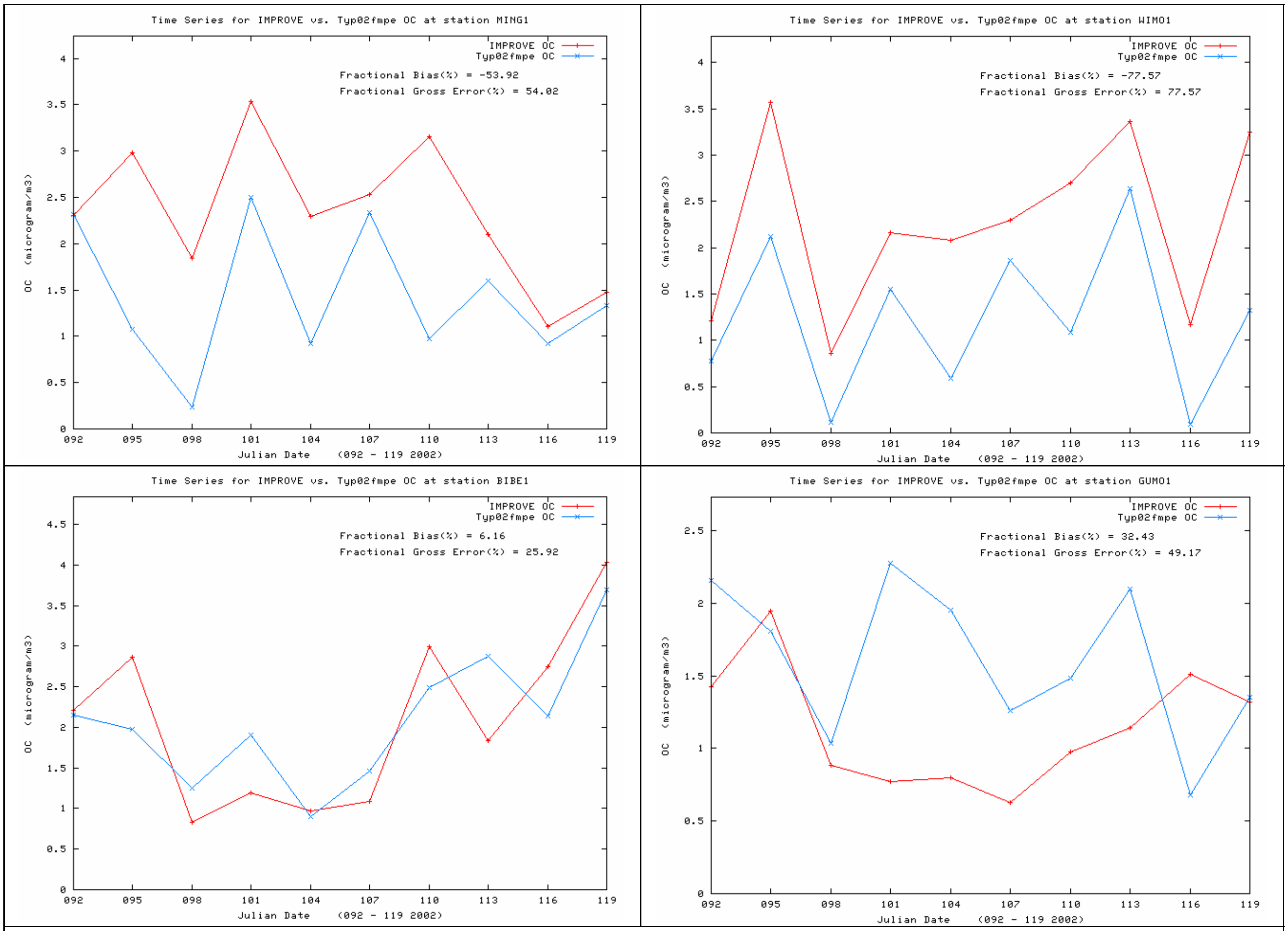


Figure C-17b. Time series of predicted and observed 24-hour organic matter carbon (OMC) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

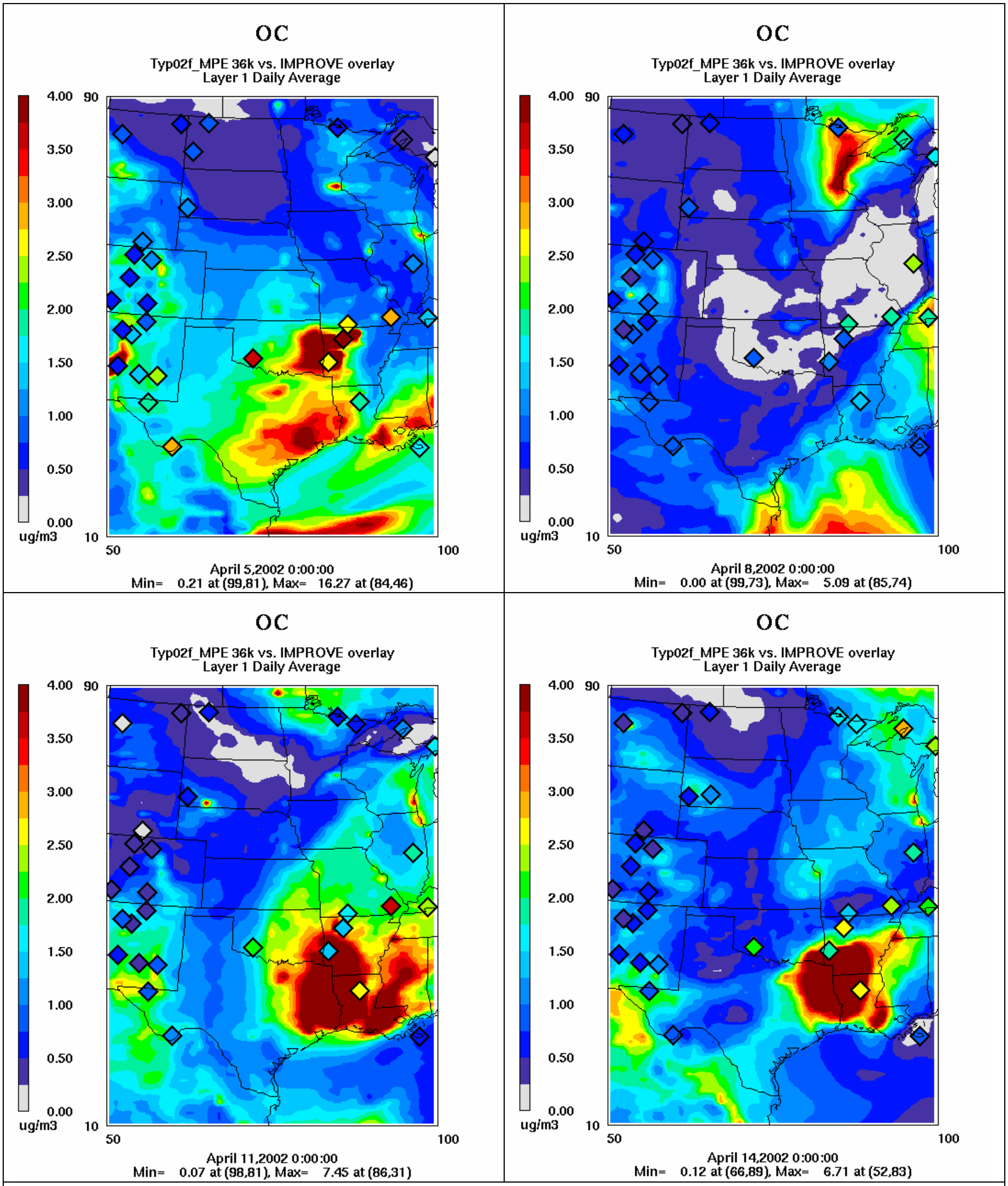


Figure C-17c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour OMC concentrations for April 5, 8, 11 and 14, 2002.

C.3.3.3 OMC in July 2002

Modeled and observed OMC are higher in July due to the impacts of more secondary organic aerosols (SOA) and fires. OMC bias values of -18% and -41% exist across the IMPROVE and STN networks in July (Figure C-18a). Two of the observed OMC values at the IMPROVE sites are very high (> 15 µg/m^3). An examination of the time series plots (Figure C-18b) reveals that these two values occur on Julian Day 200 and the two northern Minnesota sites (VOYA and BOWA) and are likely due to fire impacts. The model is also estimating elevated OMC at these sites on these two days, but not as high as observed. At most sites the model is racking the temporal variation of the observed OMC reasonably well. OMC data for MING were missing in July 2002. The model reproduces the observed high OMC in northern Minnesota and centered on Louisiana and adjacent areas on July 7 and 10 quite well, but also predicts elevated OMC in the Denver area that is not reflected in the observations (Figure C-18c). The model is exhibiting less skill in predicting the spatial distribution of the observed OMC on July 13 and 16.

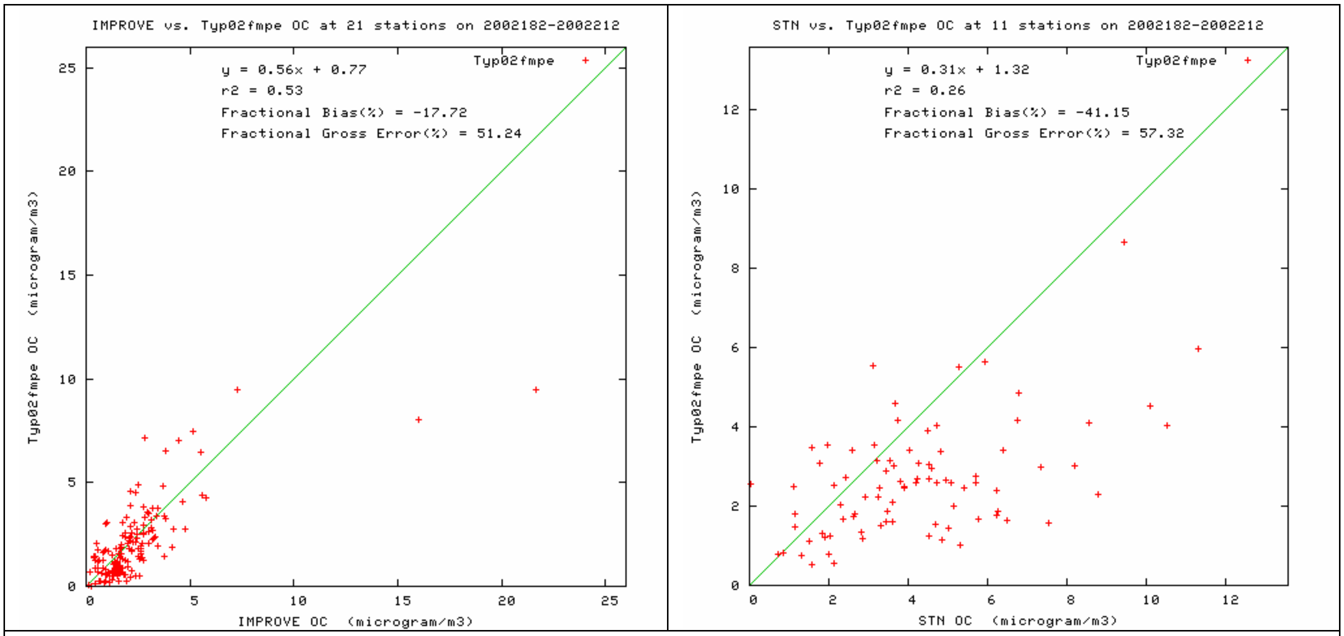
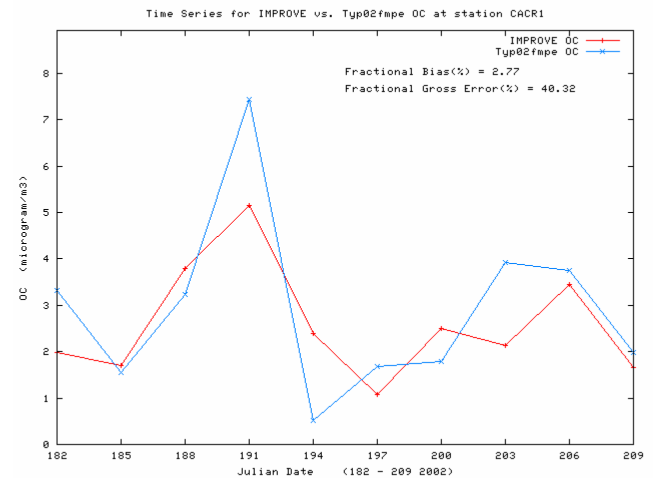
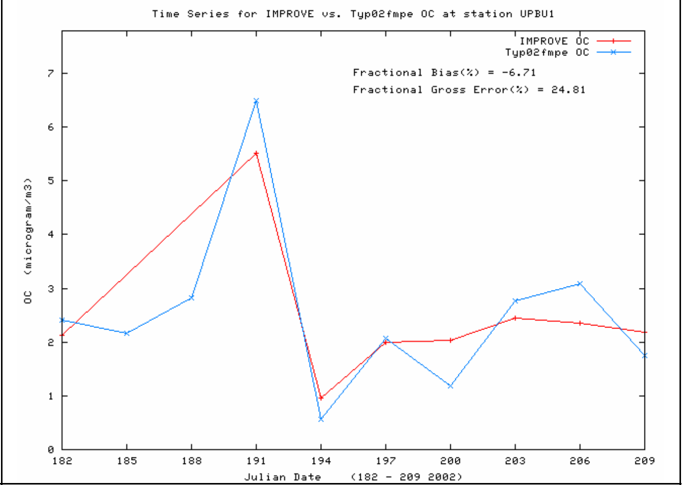
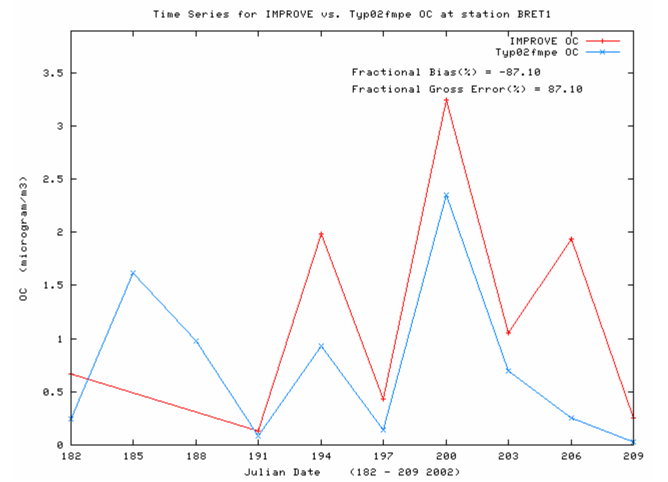
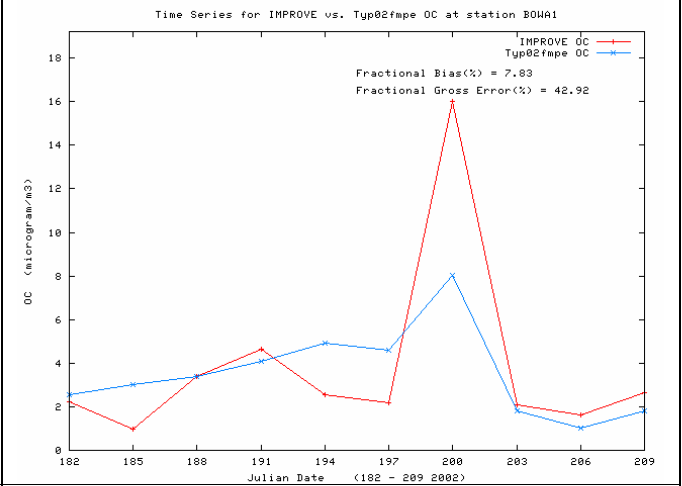


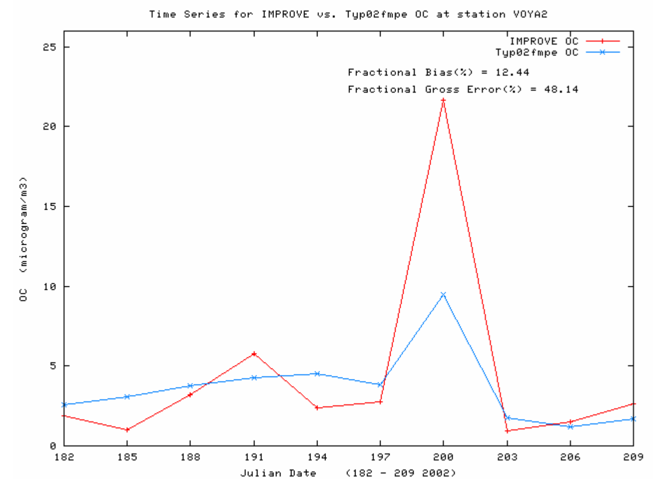
Figure C-18a. Scatter plots of predicted and observed organic matter carbon (OMC) concentrations for July 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

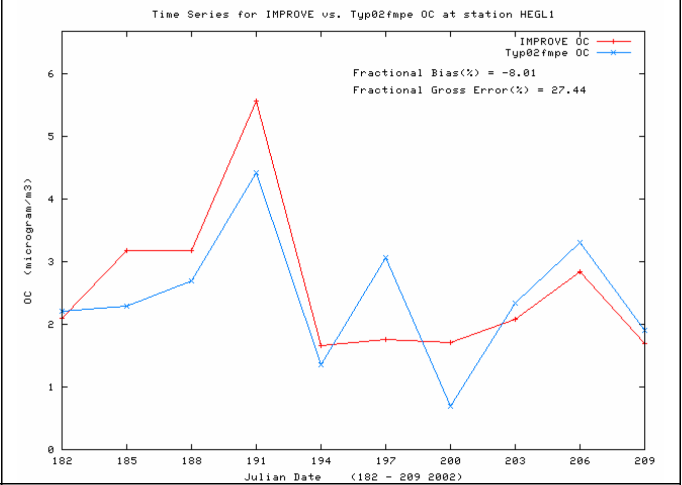

Time Series for IMPROVE vs. Typ02fmpe OC at station CACR1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = 2.77
Fractional Gross Error(%) = 40.32
OC (microgram/m3)
0
1
2
3
4
5
6
7
8
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station UPBU1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -6.71
Fractional Gross Error(%) = 24.81
OC (microgram/m3)
0
1
2
3
4
5
6
7
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)

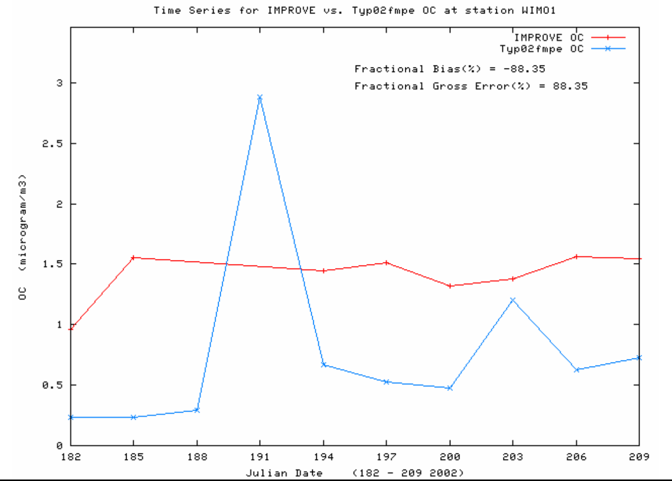

Time Series for IMPROVE vs. Typ02fmpe OC at station BRET1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -87.10
Fractional Gross Error(%) = 87.10
OC (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)

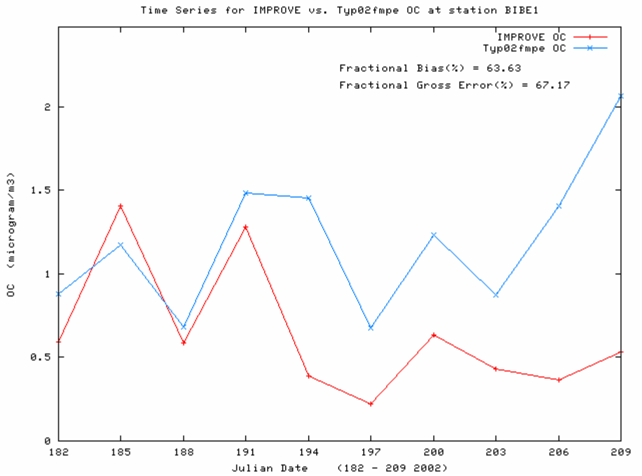

Time Series for IMPROVE vs. Typ02fmpe OC at station BOWA1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = 7.83
Fractional Gross Error(%) = 42.92
OC (microgram/m3)
0
2
4
6
8
10
12
14
16
18
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station VOYA2
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = 12.44
Fractional Gross Error(%) = 48.14
OC (microgram/m3)
0
5
10
15
20
25
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe OC at station HEGL1
IMPROVE OC
Typ02fmpe OC
Fractional Bias(%) = -8.01
Fractional Gross Error(%) = 27.44
OC (microgram/m3)
0
1
2
3
4
5
6
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)

No Data for Mingo (MING)





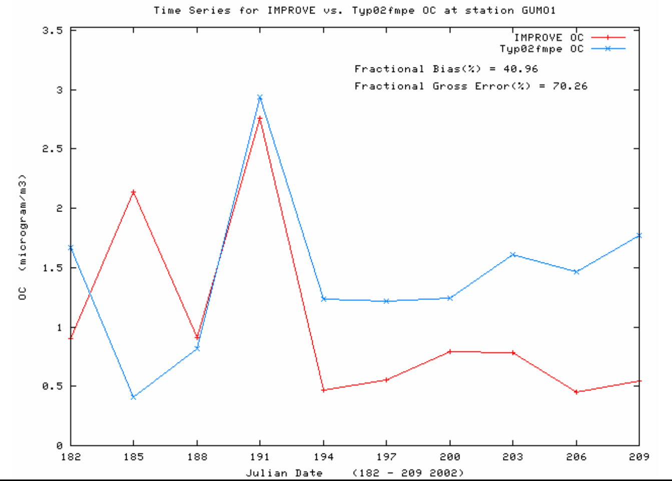


Figure C-18b. Time series of predicted and observed 24-hour organic matter carbon (OMC) concentrations at CENRAP IMPROVE CLASS I AREA sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

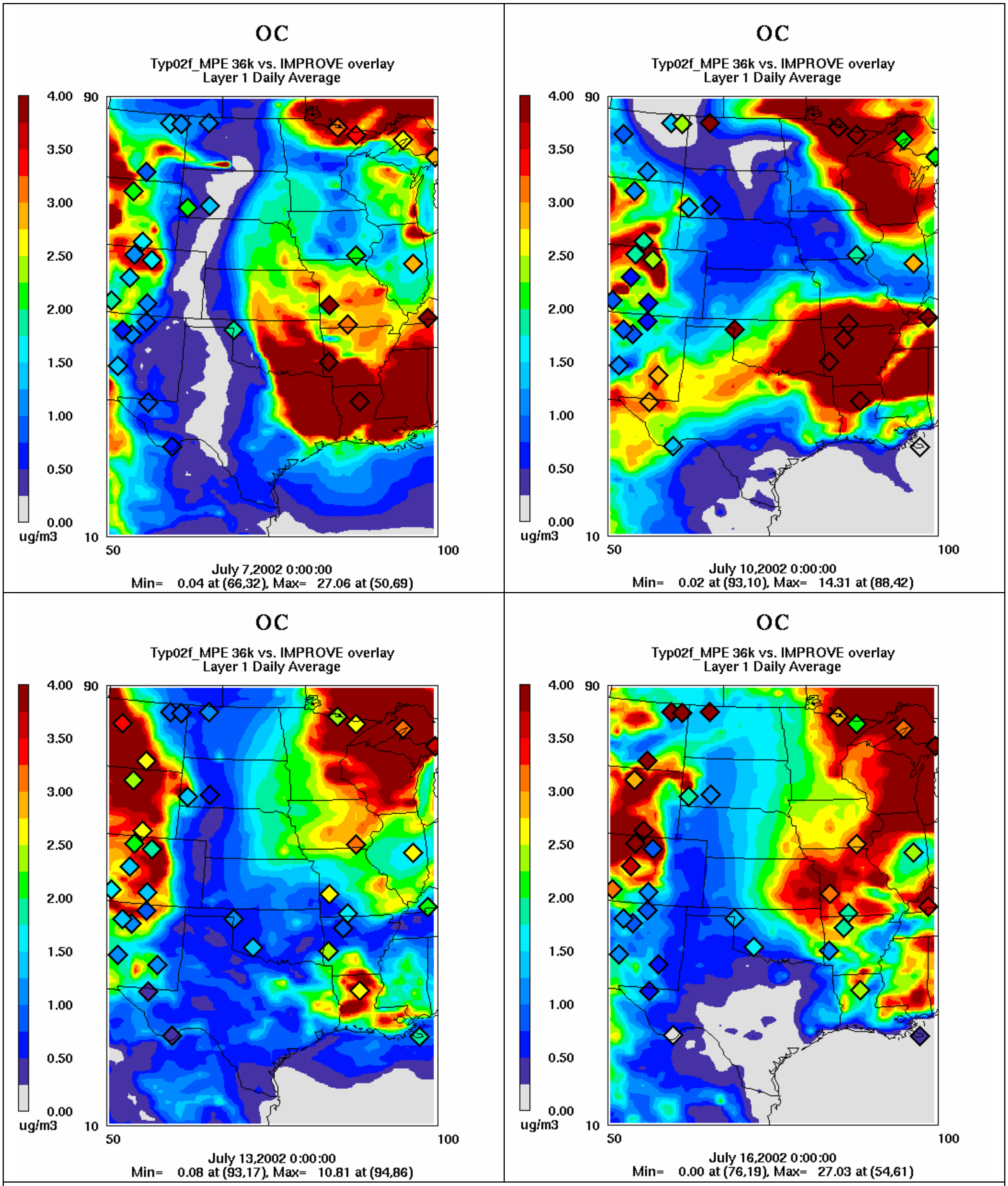


Figure C-18c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour OMC concentrations for July 7, 10, 13 and 16, 2002.

C.3.3.4 OMC in October 2002

OMC model performance in October 2002 is similar to the other months with near zero bias across the IMPROVE sites and an underestimation bias across the STN sites in the CENRAP region (Figure C-19a). Although OMC overestimation bias occurs at the Texas sites (BIBE and GUMO), the model is exhibiting remarkable ability to reproduce the observed temporal variation in OMC at several of the sites (e.g., CACR, UPBU, VOYA and HEGL; Figure C-19b). The model also performs reasonable well in reproducing the day to day and spatial variability in the observed OMC (Figure C-19c).

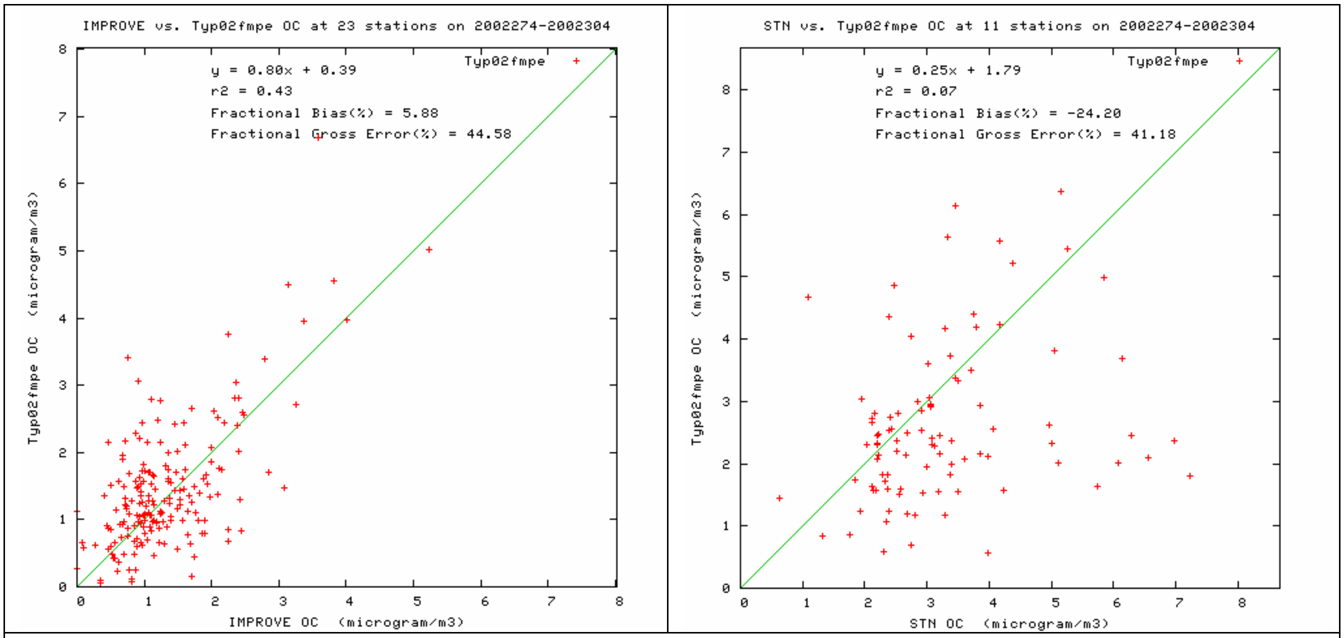
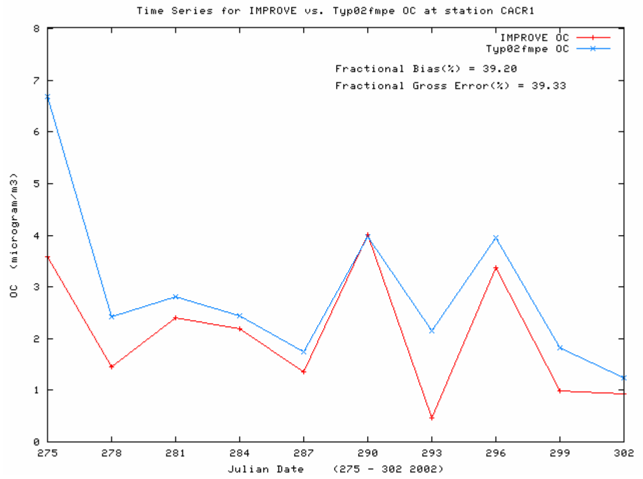
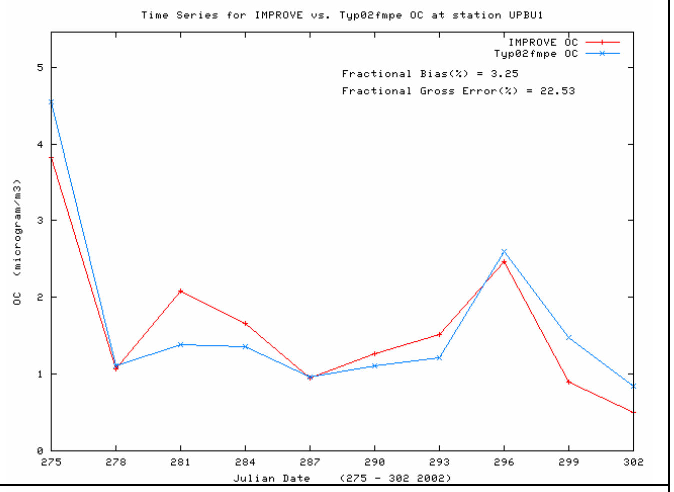
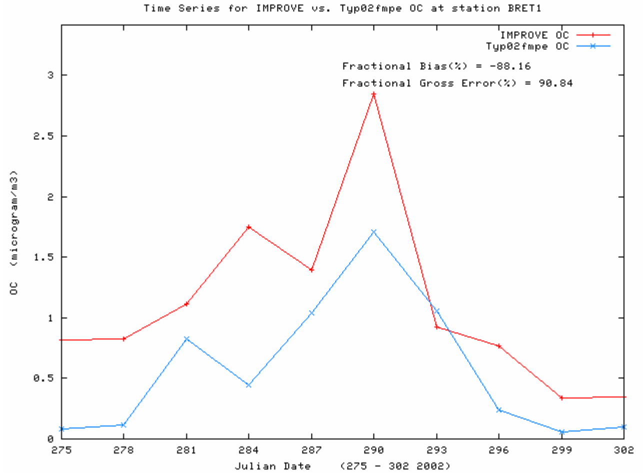
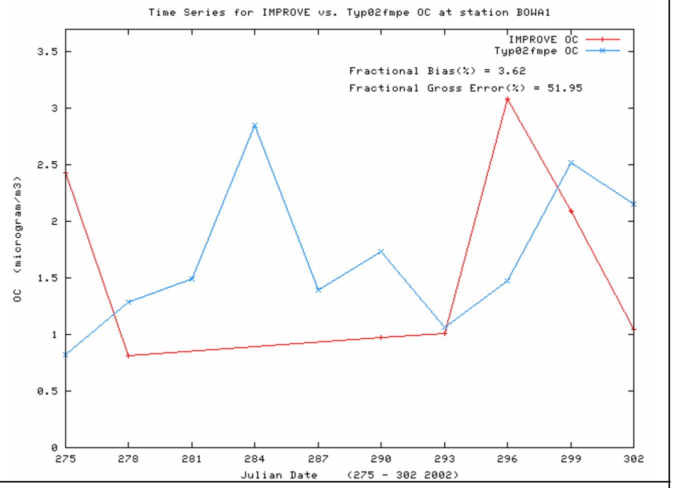


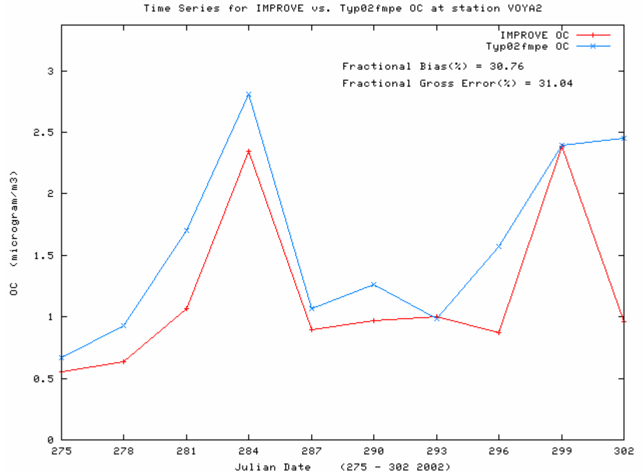
Figure C-19a. Scatter plots of predicted and observed organic matter carbon (OMC) concentrations for October 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

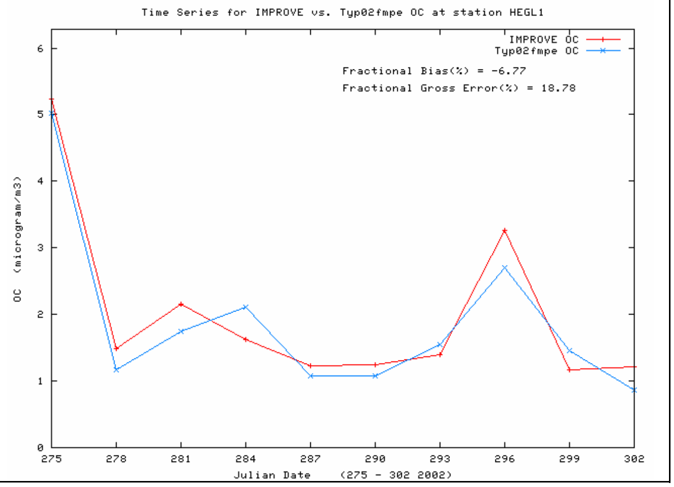

Time Series for IMPROVE vs. Typ02fmpe OC at station CACR1


Time Series for IMPROVE vs. Typ02fmpe OC at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe OC at station BRET1


Time Series for IMPROVE vs. Typ02fmpe OC at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe OC at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe OC at station HEGL1

No Data for Mingo (MING)

Figure C-19b. Time series of predicted and observed 24-hour organic matter carbon (OMC) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

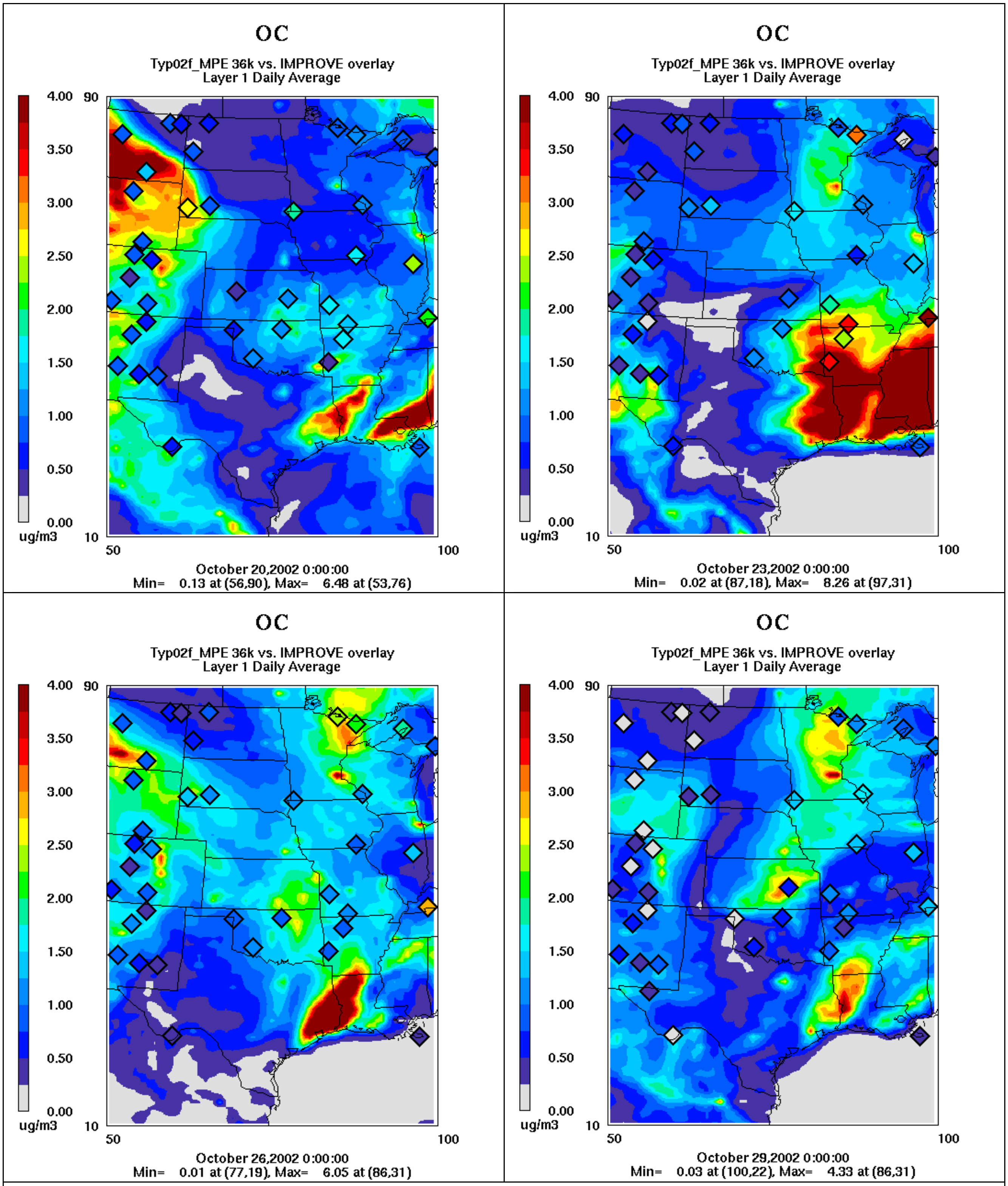


Figure C-19c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour OMC concentrations for October 20, 23, 26 and 29, 2002.

C.3.3.5 OMC Monthly Bias and Error

The OMC monthly bias and error across IMPROVE and STN sites in the CENRAP region are shown in Figure C-20. The bias performance for OMC at the IMPROVE sites are quite good throughout the year with values generally within ±20%, albeit with a slight winter overestimation and summer underestimation bias. At the urban STN sites the model exhibits an underestimation bias throughout the year that ranges from -20% to -50%. Fractional errors are mostly within 40% to 60% with the STN network generally exhibiting more error than IMPROVE.

The good performance of the model for OMC at the IMPROVE sites is also reflected in the Bugle Plot (Figure C-21) with the bias and error achieving the proposed PM model performance goal for all months of the year. At the STN sites, however, the OMC bias falls between the proposed PM model performance goal and criteria, with error right at the goal for most months.

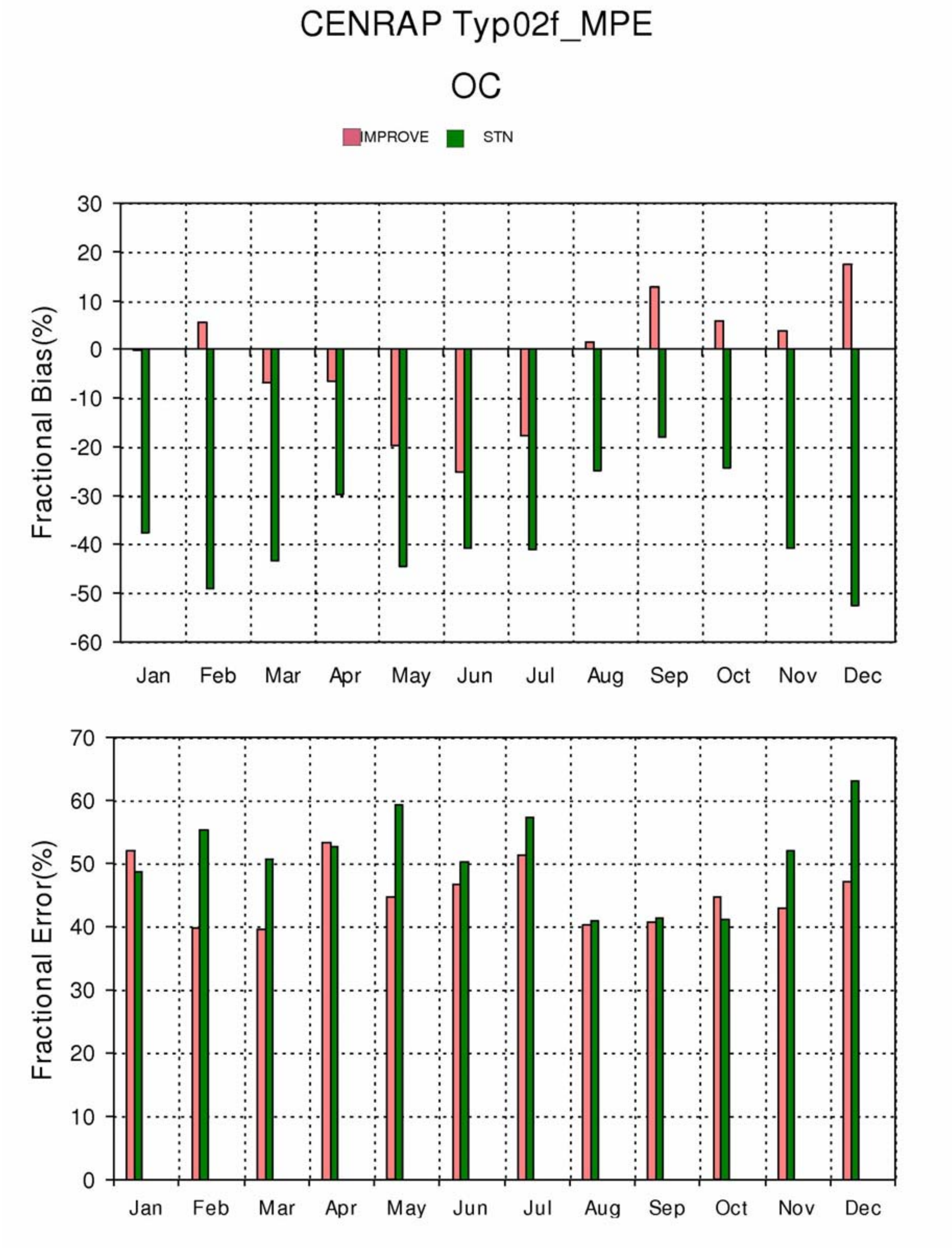


Figure C-20. Monthly OMC fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE and STN monitoring sites in the CENRAP region.

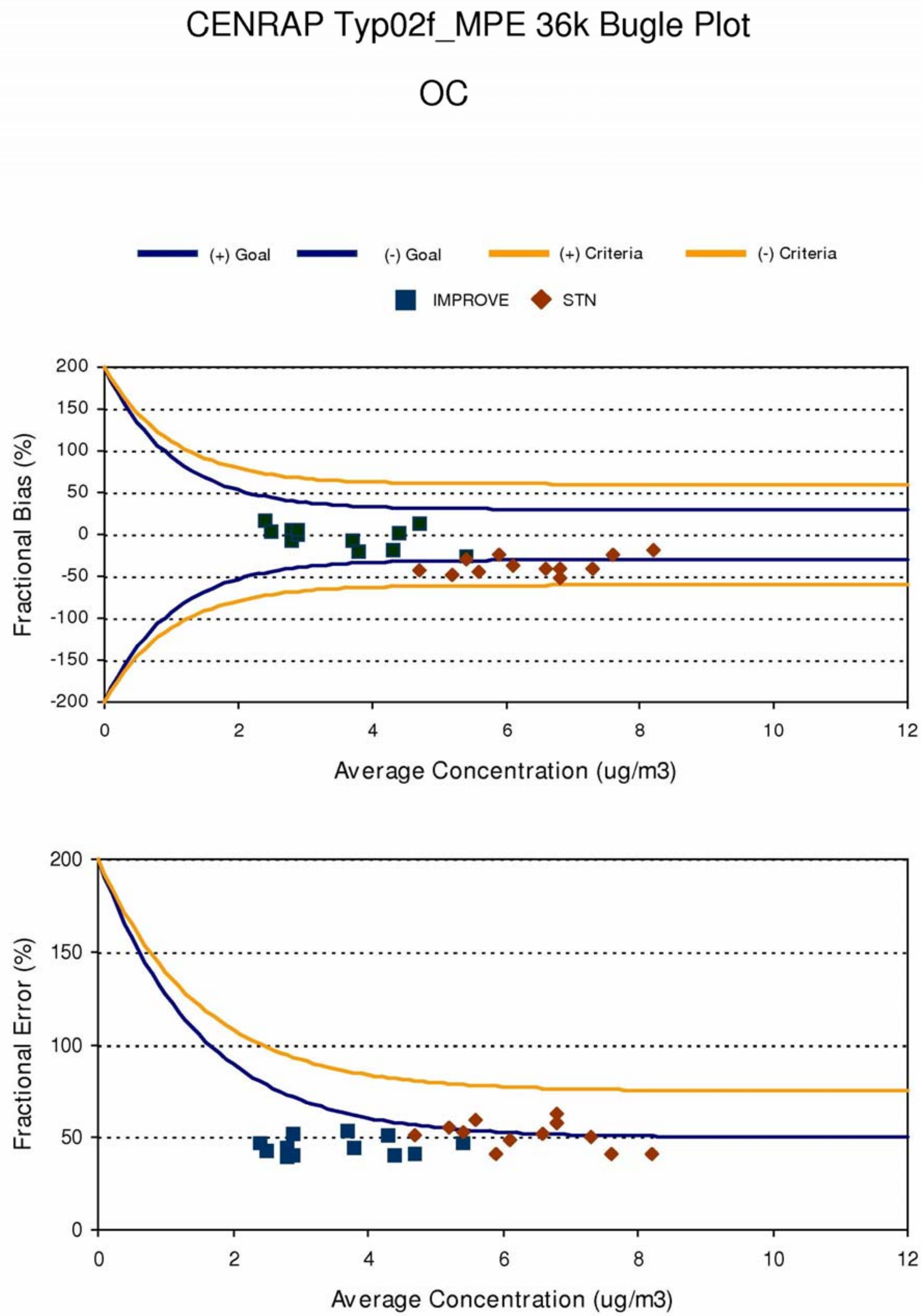


Figure C-21. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for OMC and IMPROVE and STN monitoring sites in the CENRAP region.

C.3.4 Elemental Carbon (EC) Monthly Model Performance

Elemental Carbon (EC) measurements are also uncertain, with the IMPROVE and STN using different measurement technologies with different measurement artifacts.

C.3.4.1 EC in January 2002

Although there is a lot of scatter in the January EC scatter plots at the IMPROVE and STN sites, the bias is fairly low (-24% and 1%) with errors in the 40%-50% range (Figure C-22a). The time series comparisons (Figure C-22b) suggest an EC underestimation bias at BRET and an overestimation bias at the northern Minnesota sites (VOYA and BOWA). The model generally agrees with the observed spatial distribution of EC in January with higher values on the eastern than western portions of the CENRAP region (Figure C-22c).

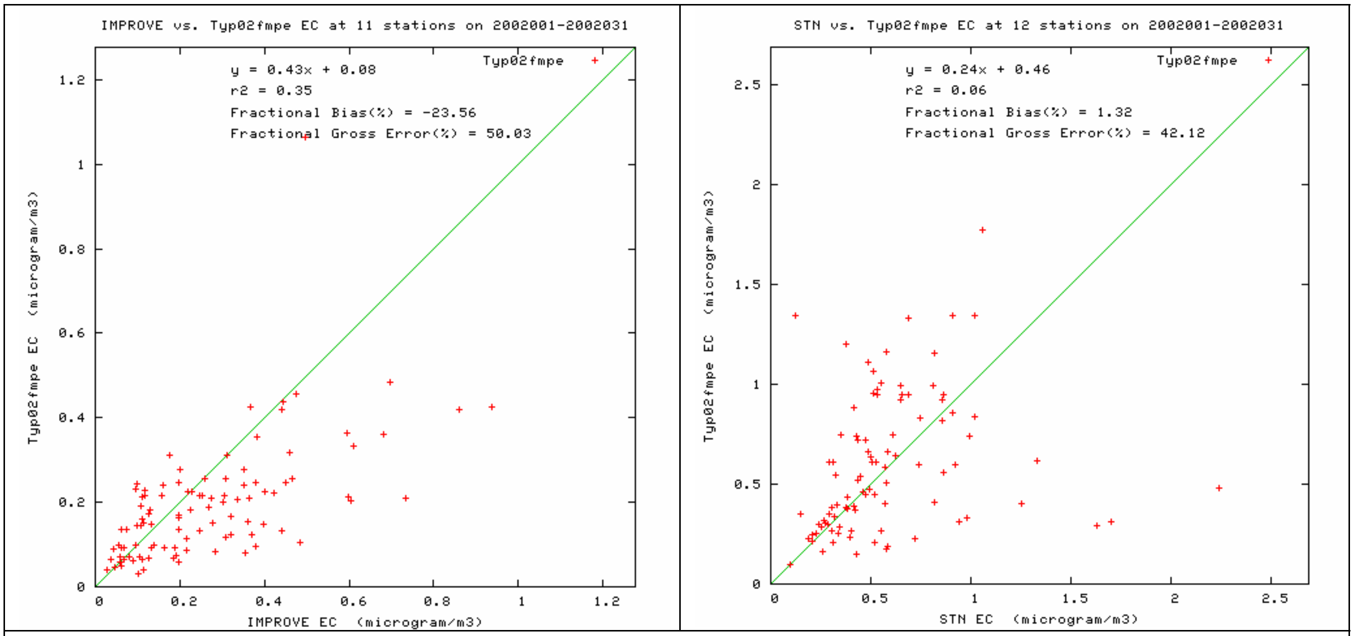
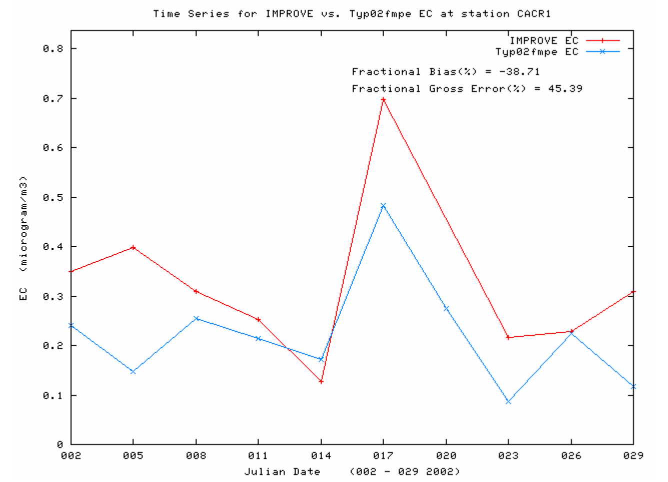
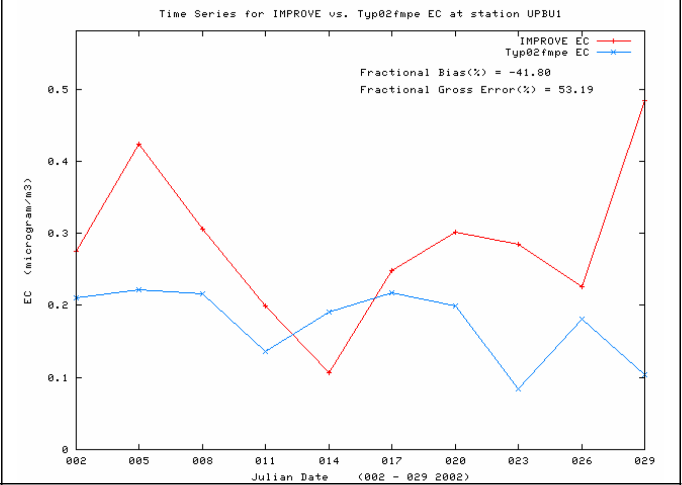
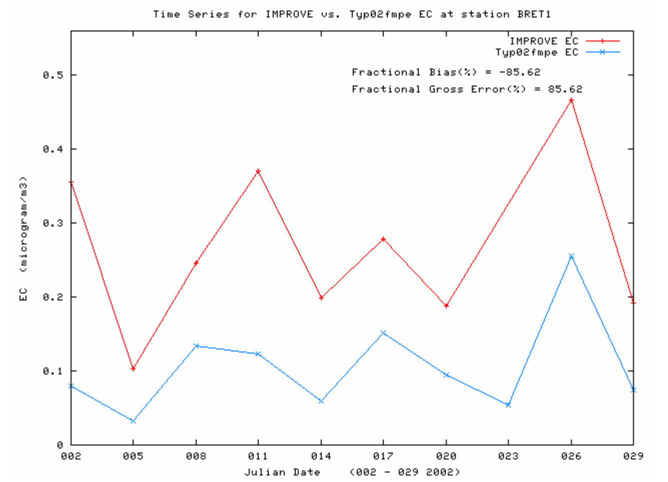
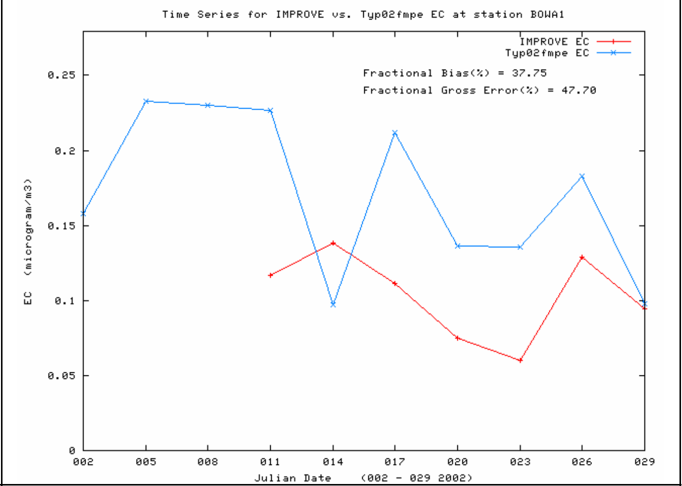


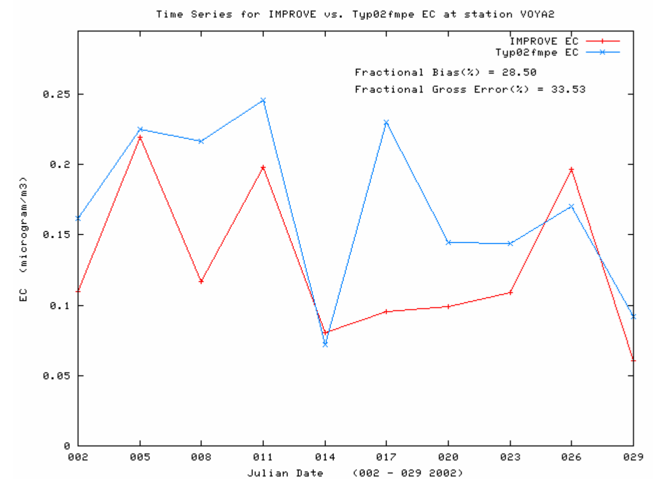
Figure C-22a. Scatter plots of predicted and observed elemental carbon (EC) concentrations for January 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

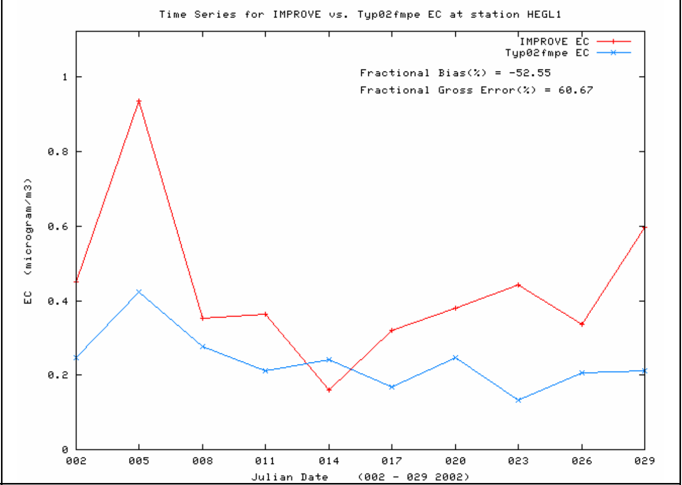

Time Series for IMPROVE vs. Typ02fmpe EC at station CACR1
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = -38.71
Fractional Gross Error(%) = 45.39
EC (microgram/m3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)

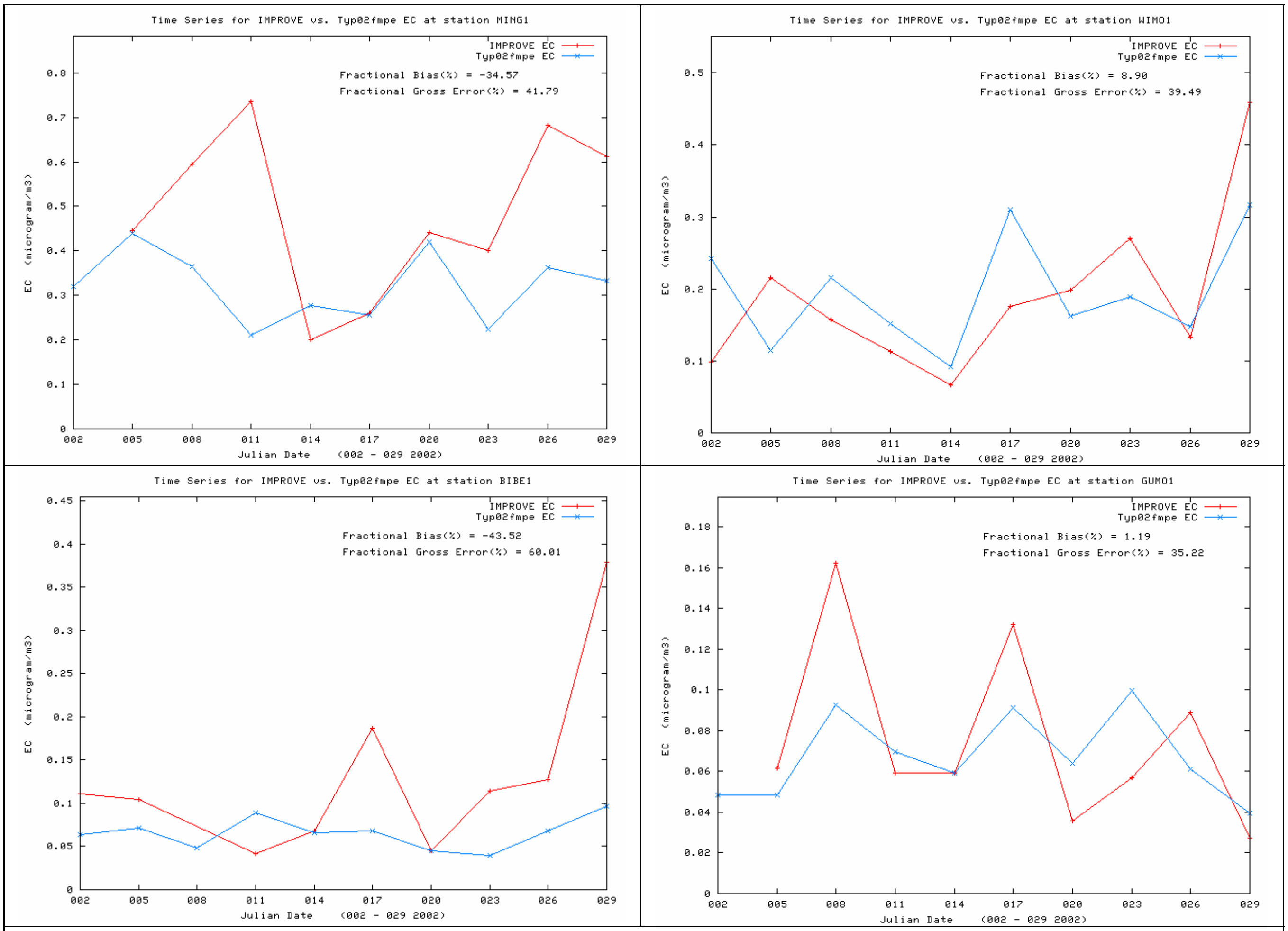

Time Series for IMPROVE vs. Typ02fmpe EC at station UPBU1
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = -41.80
Fractional Gross Error(%) = 53.19
EC (microgram/m3)
0
0.1
0.2
0.3
0.4
0.5
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe EC at station BRET1
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = -85.62
Fractional Gross Error(%) = 85.62
EC (microgram/m3)
0
0.1
0.2
0.3
0.4
0.5
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe EC at station BOWA1
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = 37.75
Fractional Gross Error(%) = 47.70
EC (microgram/m3)
0
0.05
0.1
0.15
0.2
0.25
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe EC at station VOYA2
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = 28.50
Fractional Gross Error(%) = 33.53
EC (microgram/m3)
0
0.05
0.1
0.15
0.2
0.25
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe EC at station HEGL1
IMPROVE EC
Typ02fmpe EC
Fractional Bias(%) = -52.55
Fractional Gross Error(%) = 60.67
EC (microgram/m3)
0
0.2
0.4
0.6
0.8
1
002
005
008
011
014
017
020
023
026
029
Julian Date (002 - 029 2002)



Time Series for IMPROVE vs. Typ02fmpe EC at station MING1

Time Series for IMPROVE vs. Typ02fmpe EC at station WIMO1

Time Series for IMPROVE vs. Typ02fmpe EC at station BIBE1

Time Series for IMPROVE vs. Typ02fmpe EC at station GUMO1

Figure C-22b. Time series of predicted and observed 24-hour elemental carbon (EC) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

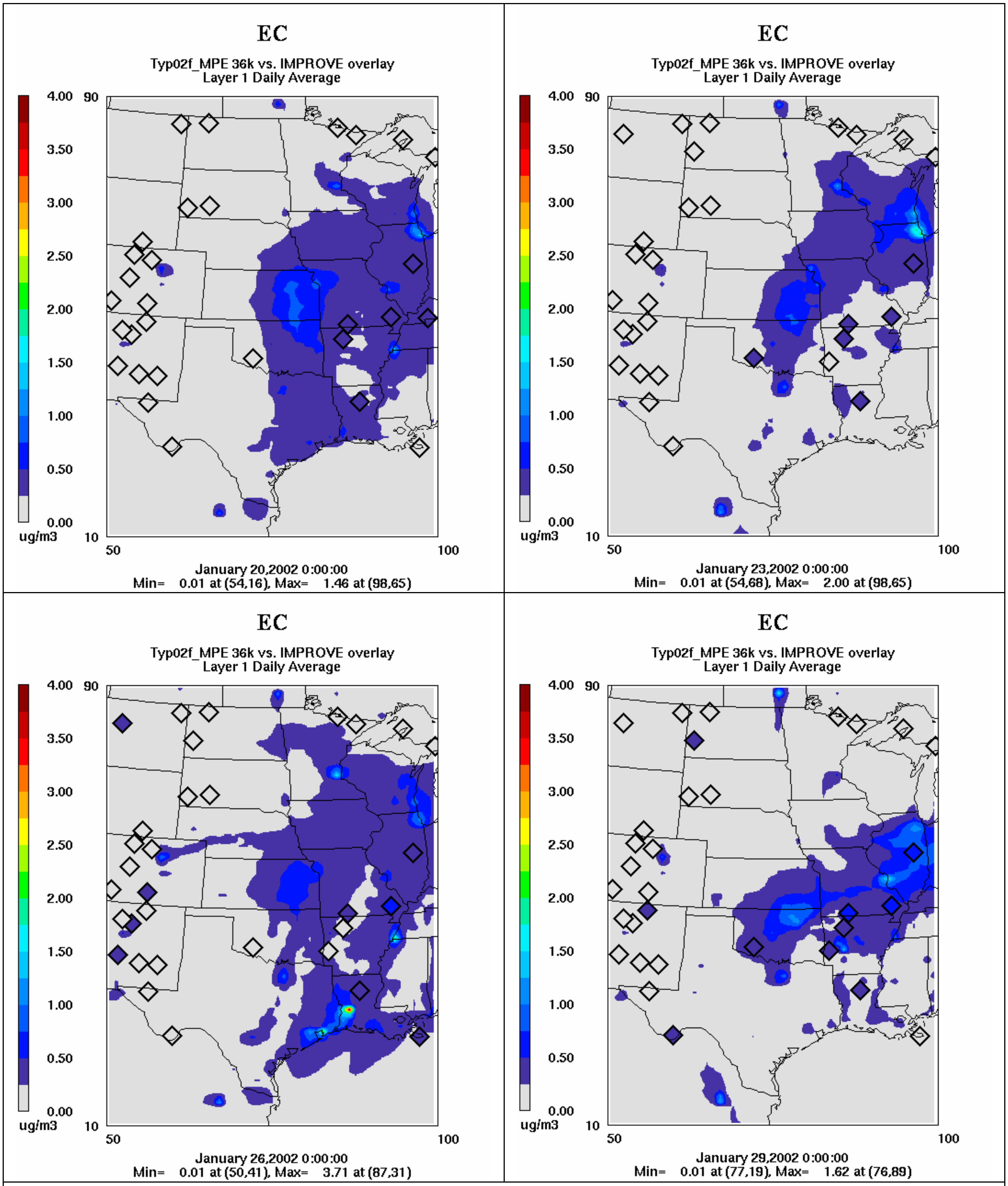


Figure C-22c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour EC concentrations for January 20, 23, 26 and 29, 2002.

C.3.4.2 EC in April 2002

EC is underestimated at the IMPROVE sites in April (bias of -48%), but reproduced well at the STN sites (bias of -13%). Although EC is underestimated at the IMPROVE sites both the model and observations agree that EC concentrations are very small and not a significant component of the PM budget. The model fails to capture the day-to-day variability in the observed EC at the IMPROVE sites and exhibits a systematic under-prediction tendency at some sites (Figure C-23b). On April 5 and 11 the model reproduces the spatial distribution of the observed EC reasonable well with higher values in the eastern than western portion of the CENRAP region. But on April 8 and 14 the model is much to clean in the eastern portion of the CENRAP region (Figure C-23c).

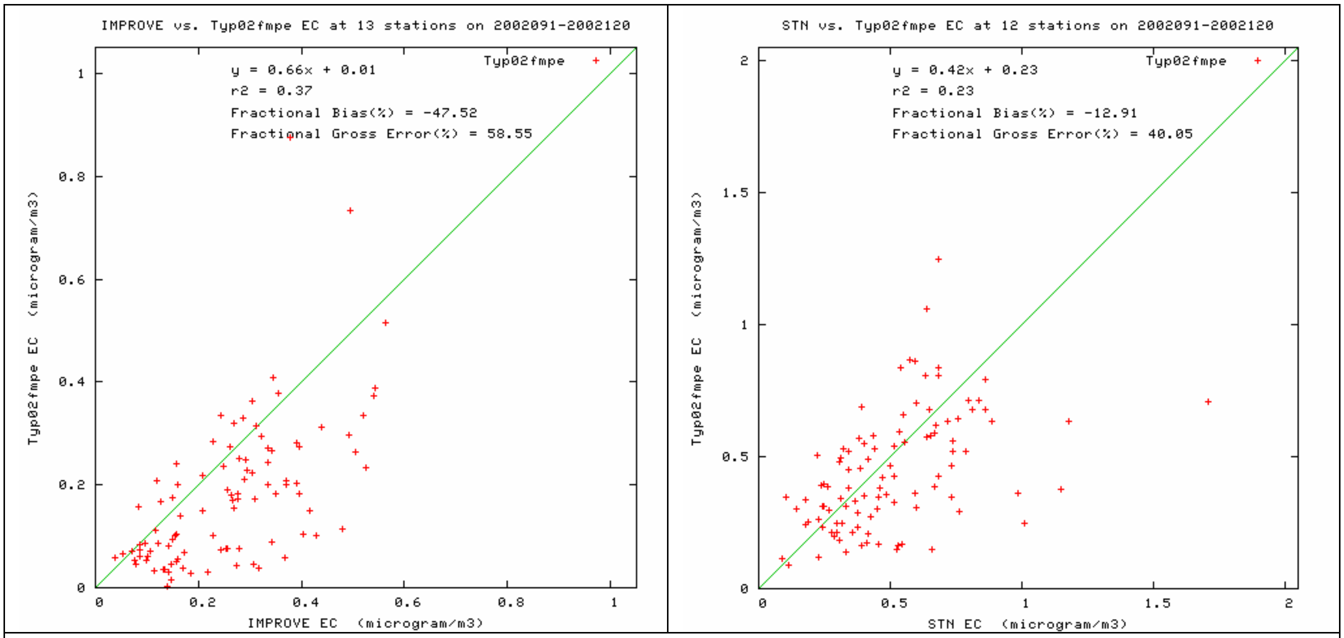
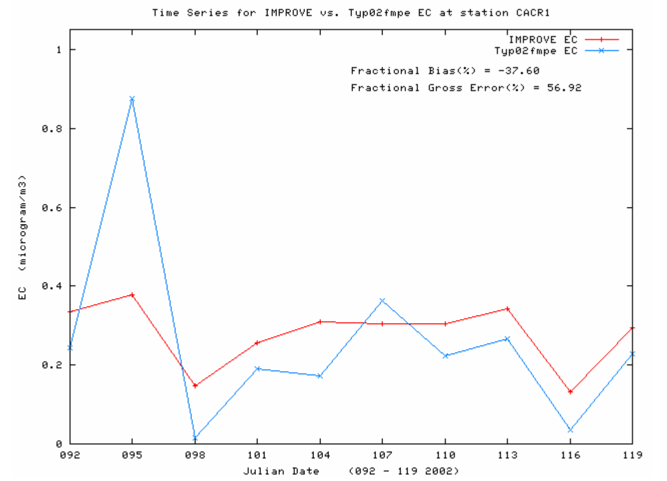
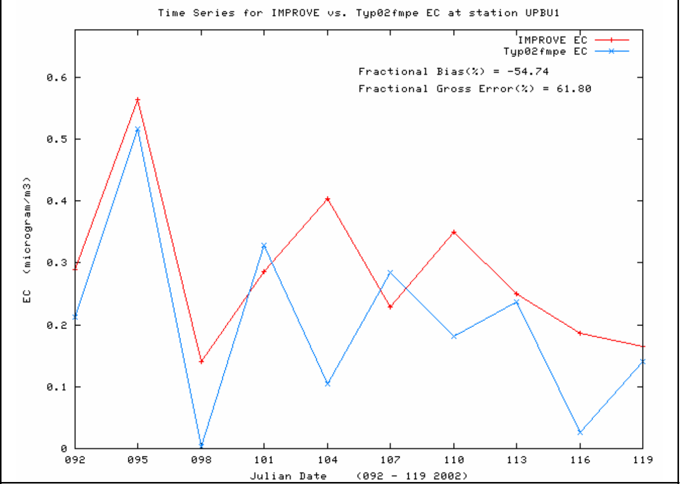
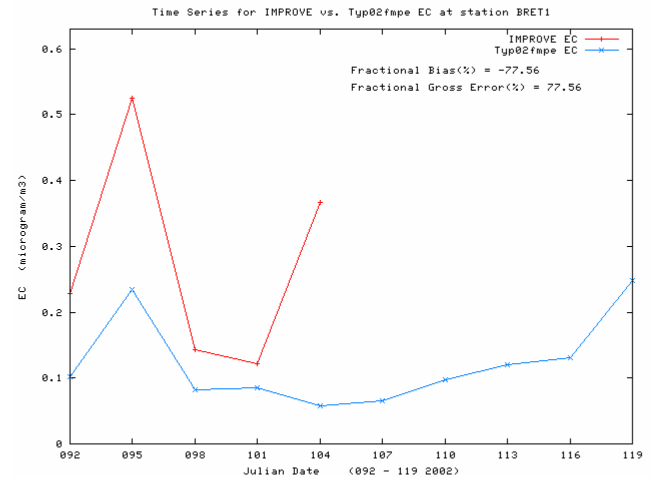
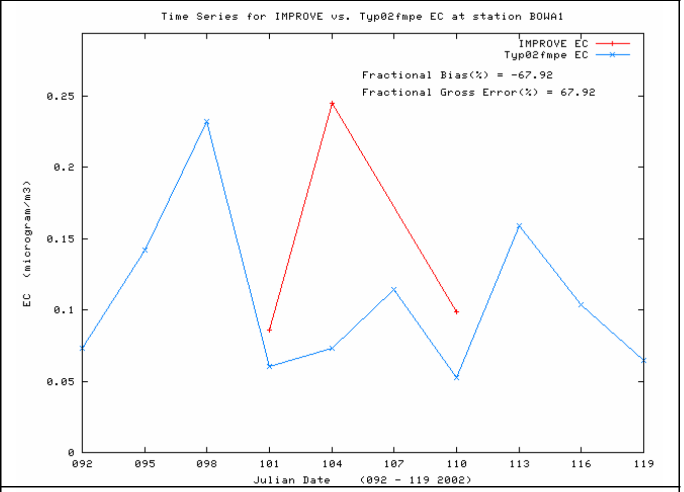


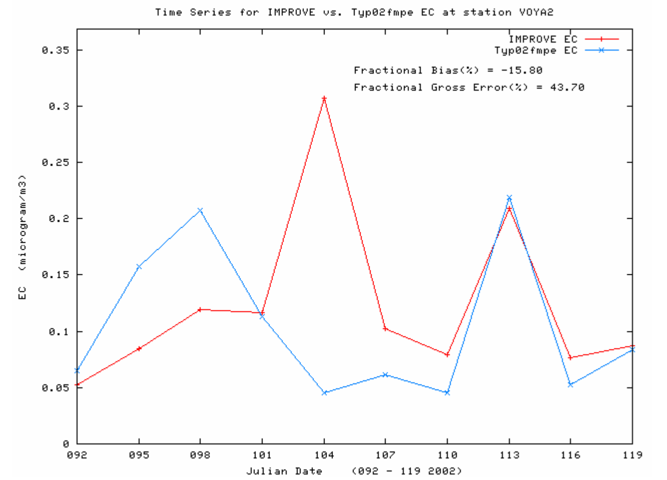
Figure C-23a. Scatter plots of predicted and observed elemental carbon (EC) concentrations for April 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation

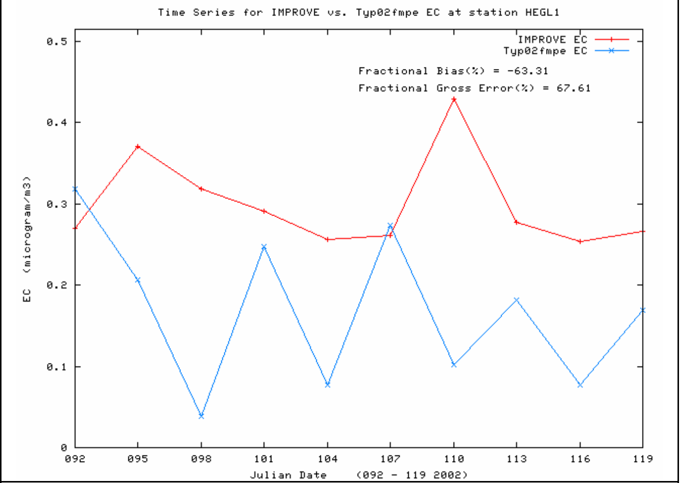

Time Series for IMPROVE vs. Typ02fmpe EC at station CACR1


Time Series for IMPROVE vs. Typ02fmpe EC at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe EC at station BRET1


Time Series for IMPROVE vs. Typ02fmpe EC at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe EC at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe EC at station HEGL1

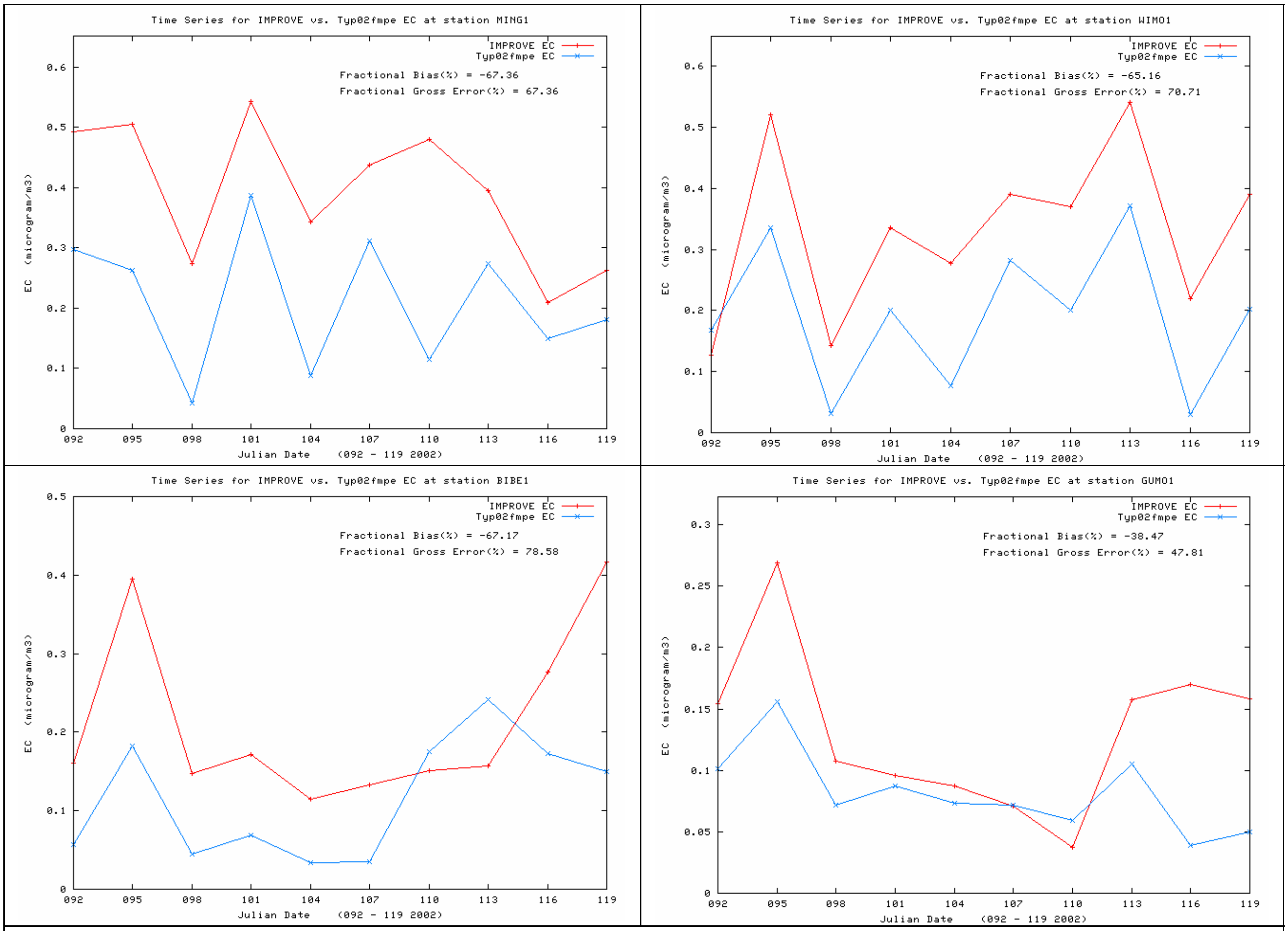


Figure C-23b. Time series of predicted and observed 24-hour elemental carbon (EC) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

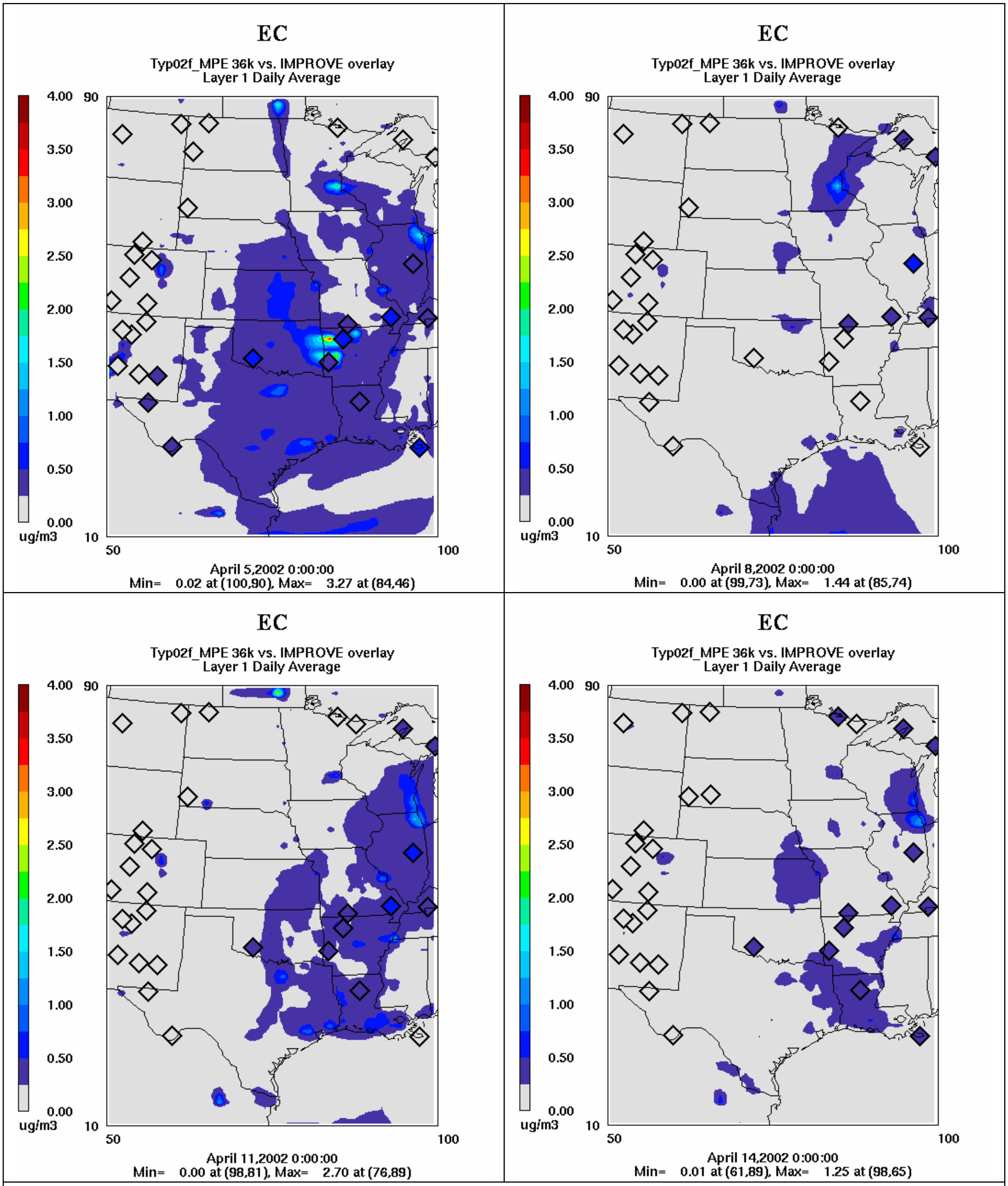


Figure C-23c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour EC concentrations for April 5, 8, 11 and 14, 2002.

C.3.3.3 EC in July 2002

July EC performance is similar to the other months with near zero bias across he STN sites and an underestimation bias across the IMPROVE sites (Figure C-24). Again the model and observations agree that EC is low in July and not a significant component of visibility impairment.

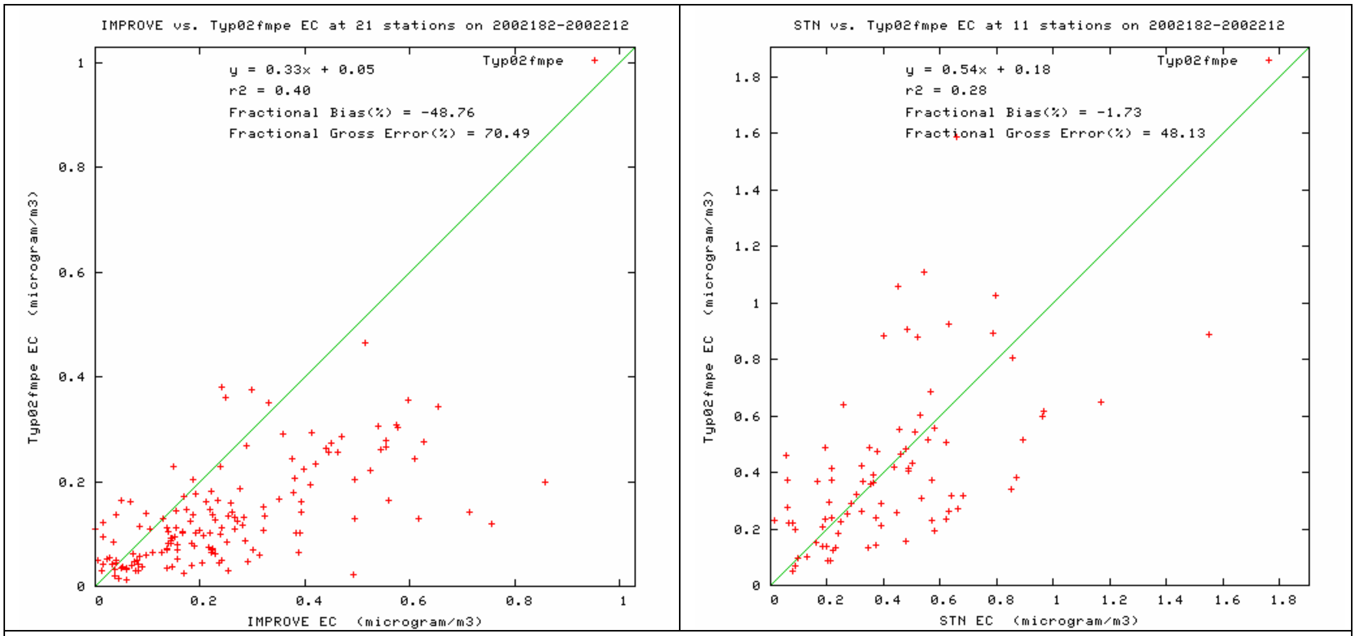
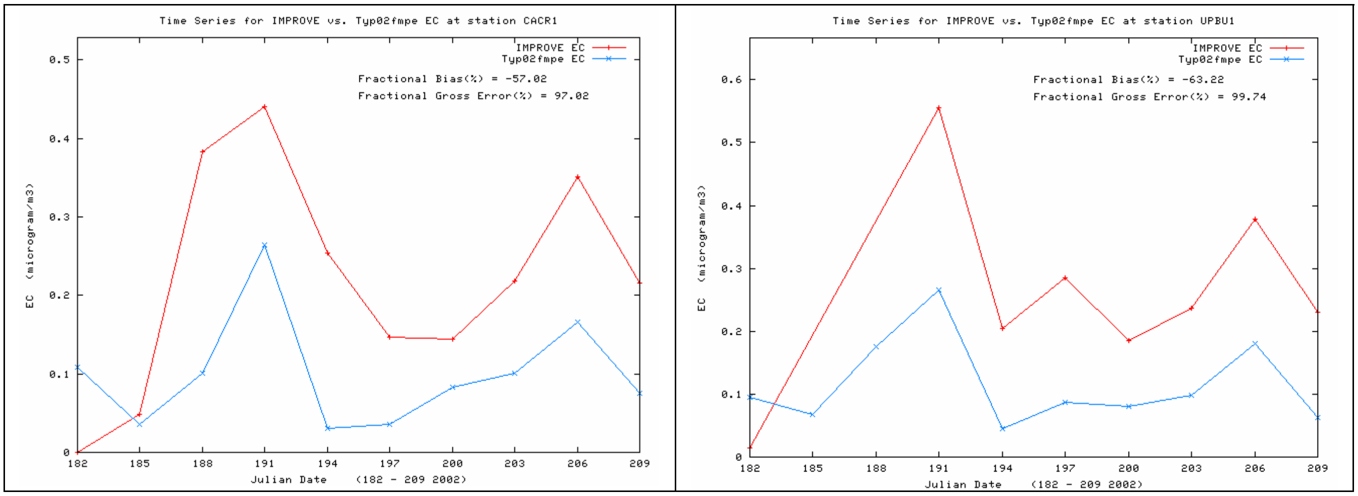
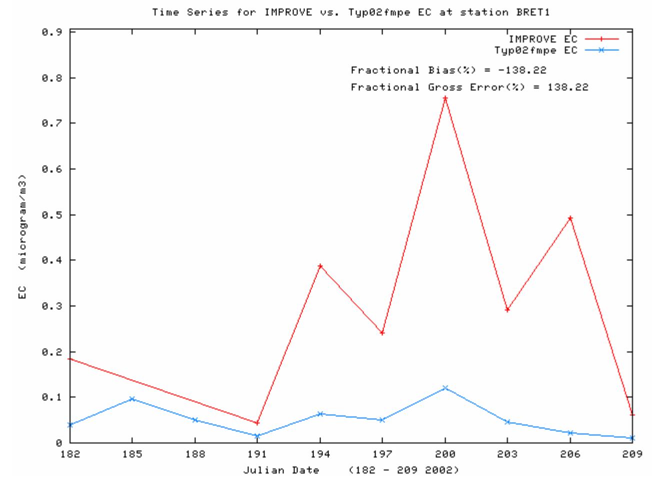
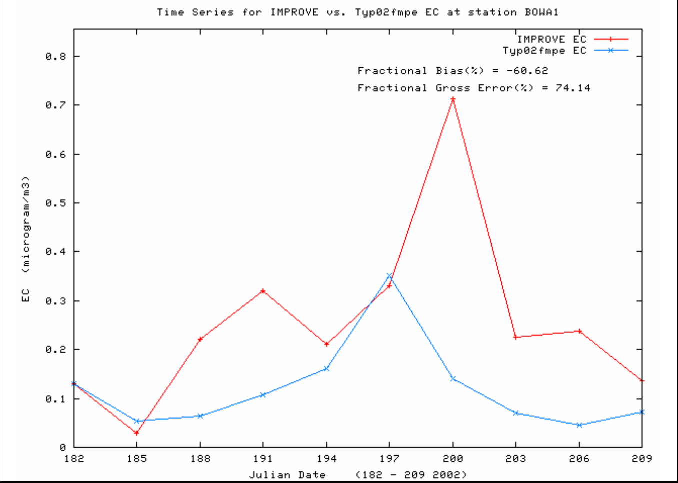
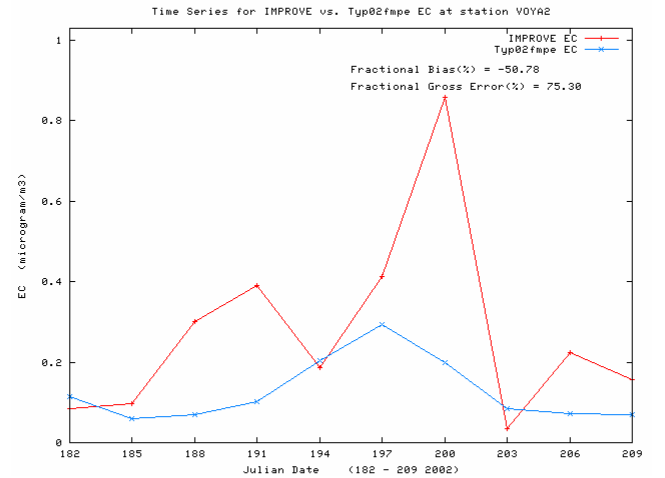


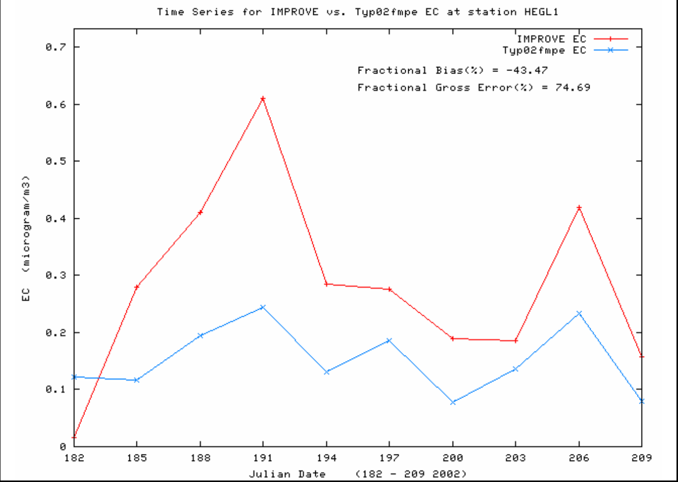
Figure C-24a. Scatter plots of predicted and observed elemental carbon (EC) concentrations for July 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.



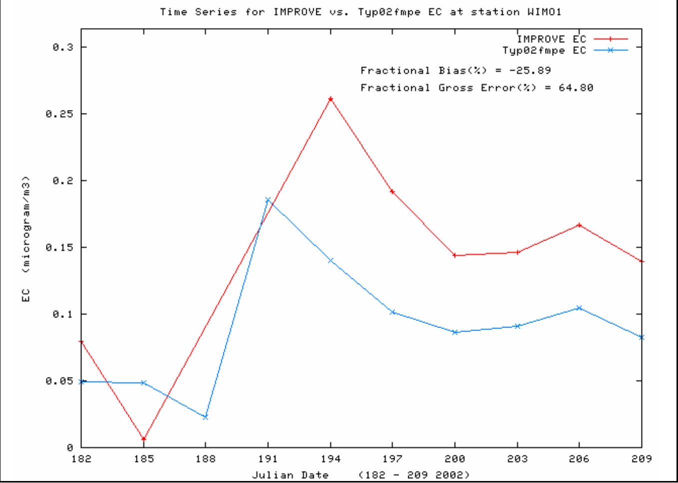








No Data for Mingo (MING)



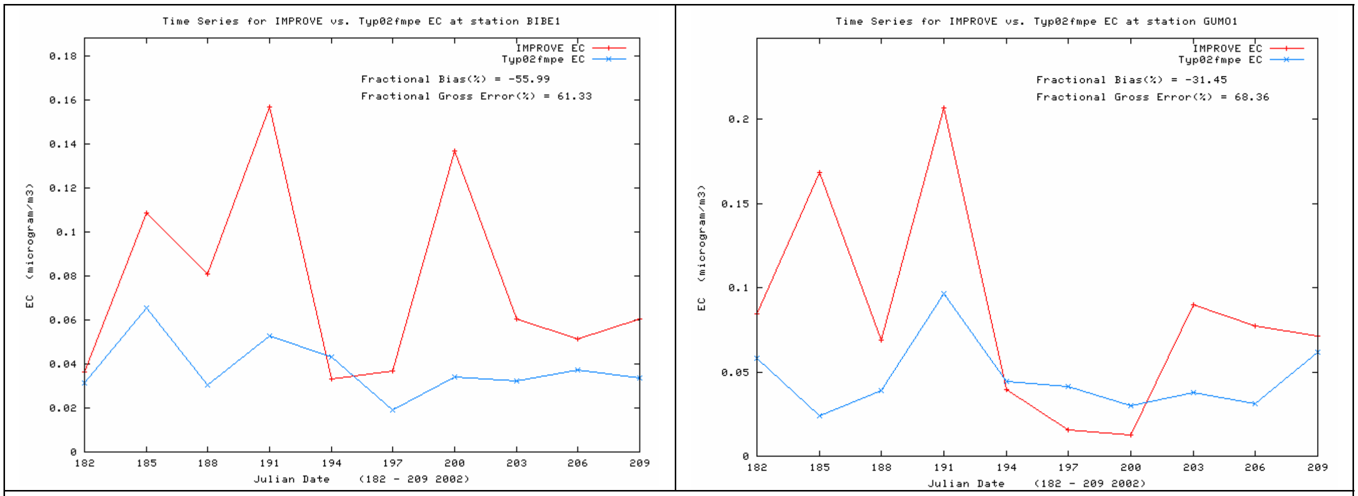
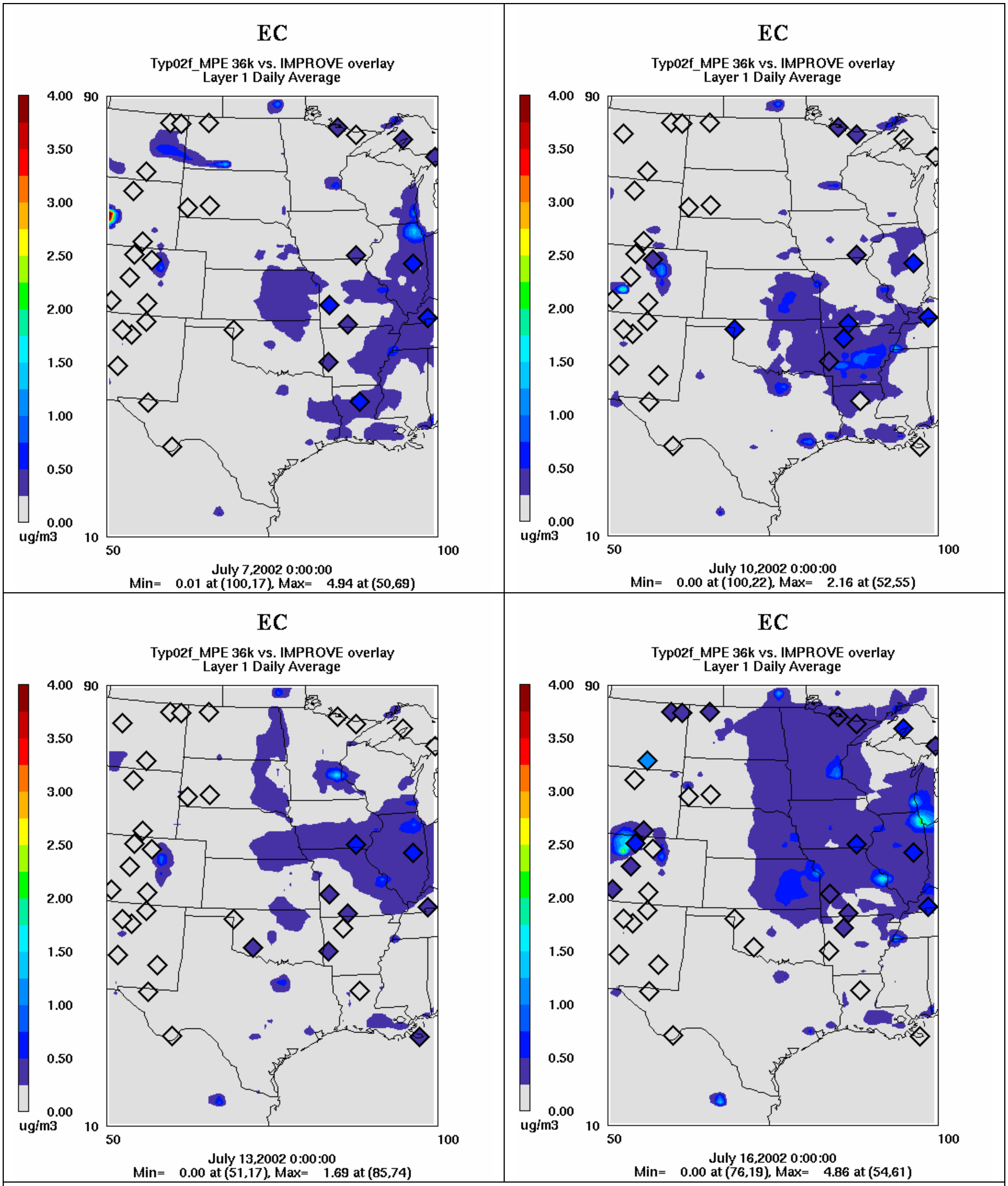


Figure C-24b. Time series of predicted and observed 24-hour elemental carbon (EC) concentrations at CENRAP IMPROVE CLASS I AREA sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.



EC

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

July 7,2002 0:00:00
Min= 0.01 at (100,17), Max= 4.94 at (50,69)

EC

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

July 10,2002 0:00:00
Min= 0.00 at (100,22), Max= 2.16 at (52,55)

EC

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

July 13,2002 0:00:00
Min= 0.00 at (51,17), Max= 1.69 at (85,74)

EC

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

July 16,2002 0:00:00
Min= 0.00 at (76,19), Max= 4.86 at (54,61)

Figure C-24c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour EC concentrations for July 7, 10, 13 and 16, 2002.

C.3.4.4 EC in October 2002

EC performance is improved at the IMPROVE sites in October with lower bias (9%) than the previous months where an under-prediction tendency was seen (Figure C-25a). EC bias is also fairly low at the STN sites with errors across both networks of approximately 50%. Although there is a systematic underestimation of EC at BRET, the agreement between the predicted and observed October time series (Figure C-25b) is remarkable at several sites (e.g., CACR, UPBU, VOYA and HEGL).

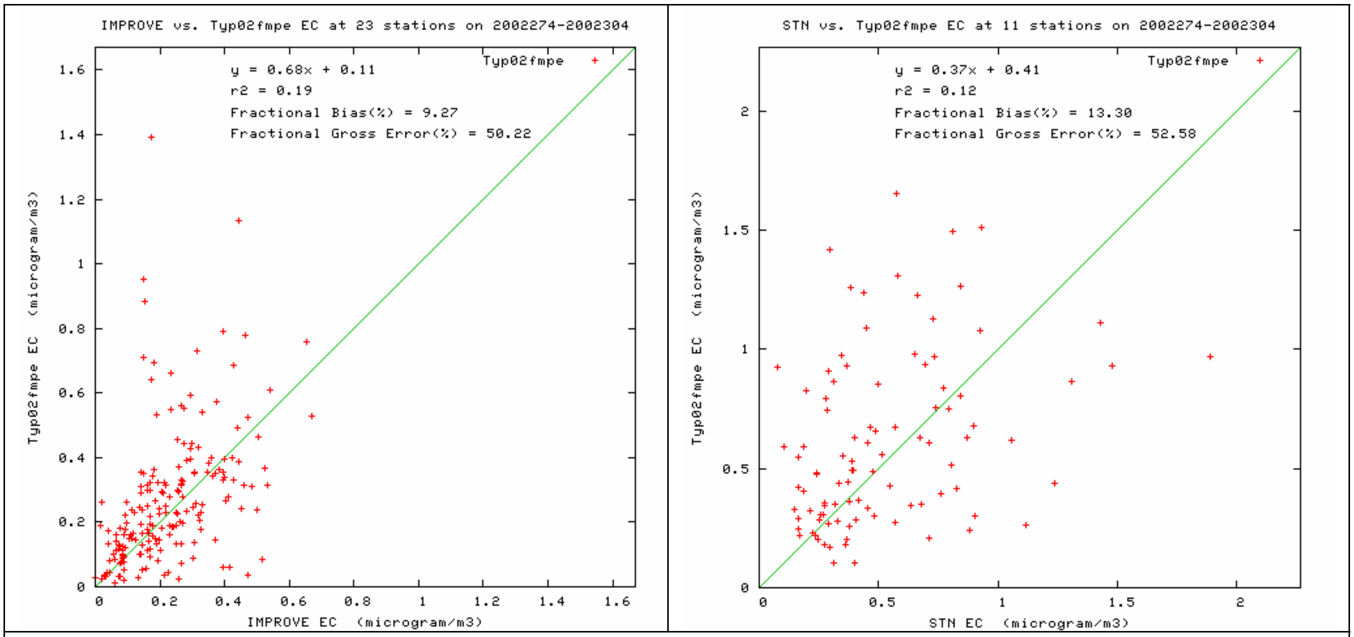
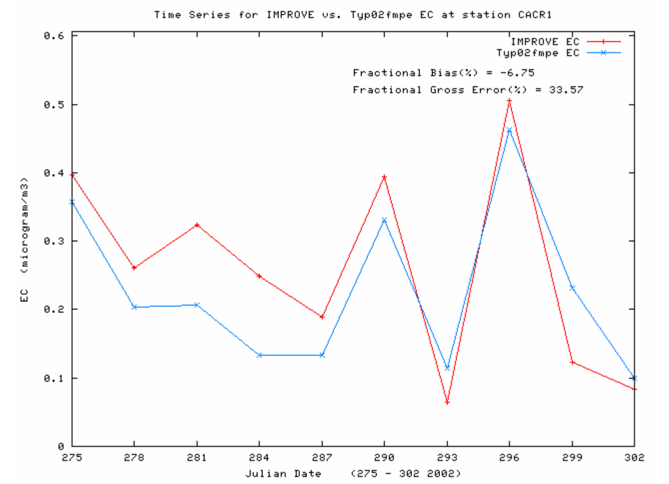
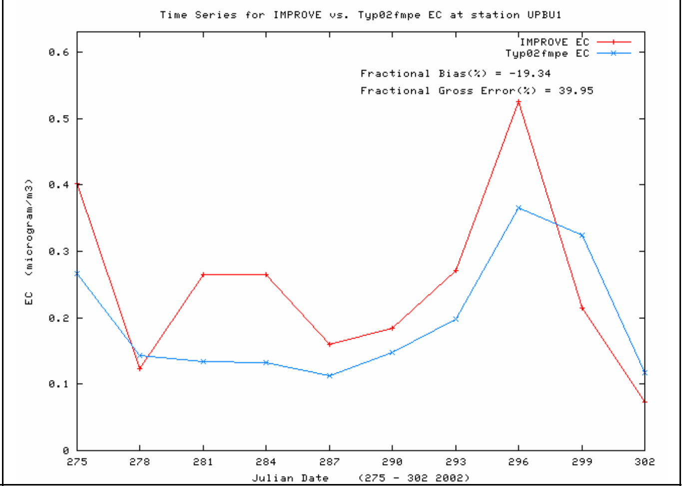


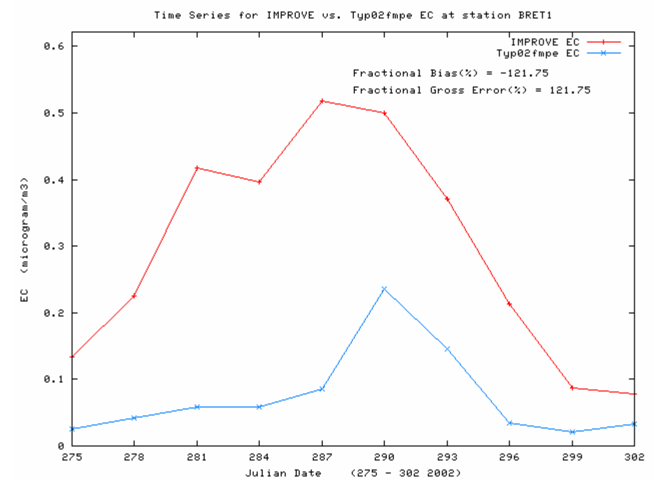
Figure C-25a. Scatter plots of predicted and observed elemental carbon (EC) concentrations for October 2002 and sites in the CENRAP region using IMPROVE (left) and STN (right) monitoring networks using the CMAQ 2002 36 km Base F base case simulation.


Time Series for IMPROVE vs. Typ02fmpe EC at station CACR1

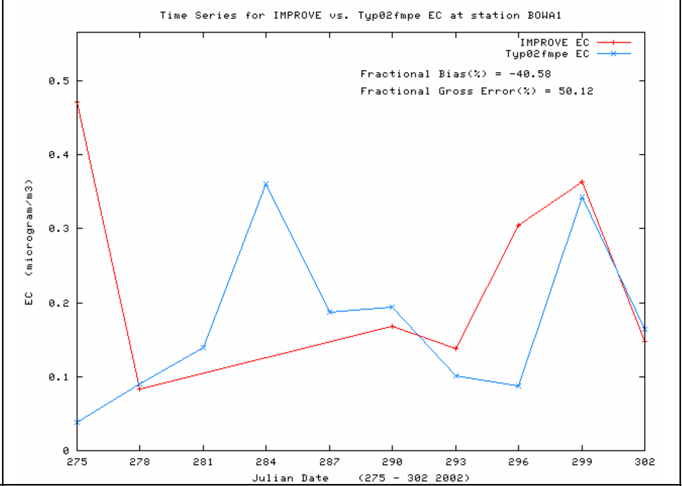
Fractional Bias(%) = -6.75
Fractional Gross Error(%) = 33.57


Time Series for IMPROVE vs. Typ02fmpe EC at station UPBU1

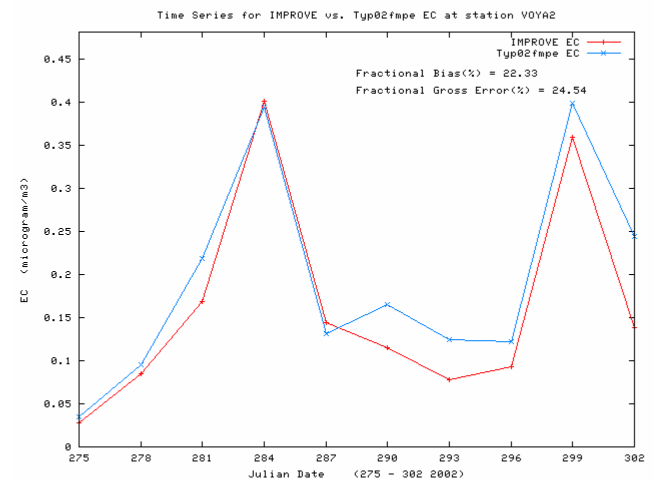
Fractional Bias(%) = -19.34
Fractional Gross Error(%) = 39.95


Time Series for IMPROVE vs. Typ02fmpe EC at station BRET1

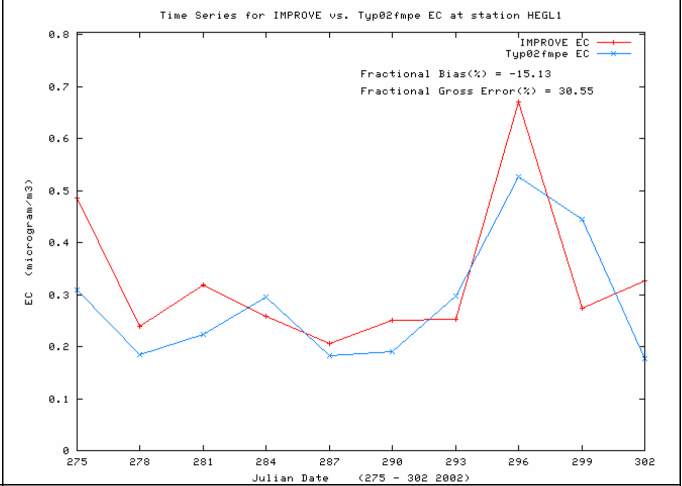
Fractional Bias(%) = -121.75
Fractional Gross Error(%) = 121.75


Time Series for IMPROVE vs. Typ02fmpe EC at station BOWA1

Fractional Bias(%) = -40.58
Fractional Gross Error(%) = 50.12

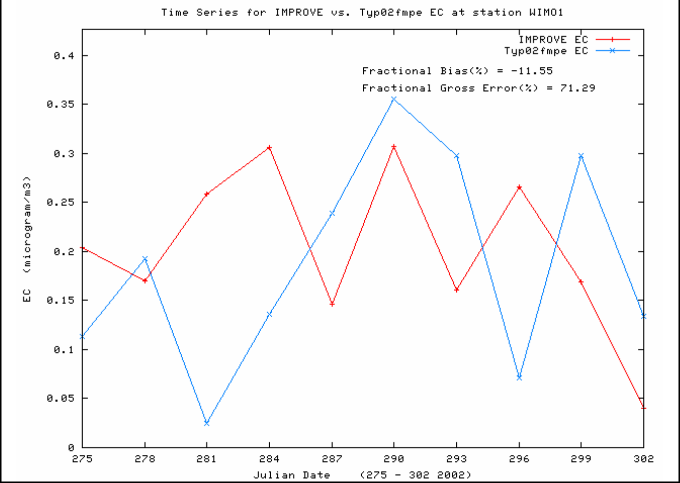

Time Series for IMPROVE vs. Typ02fmpe EC at station VOYA2

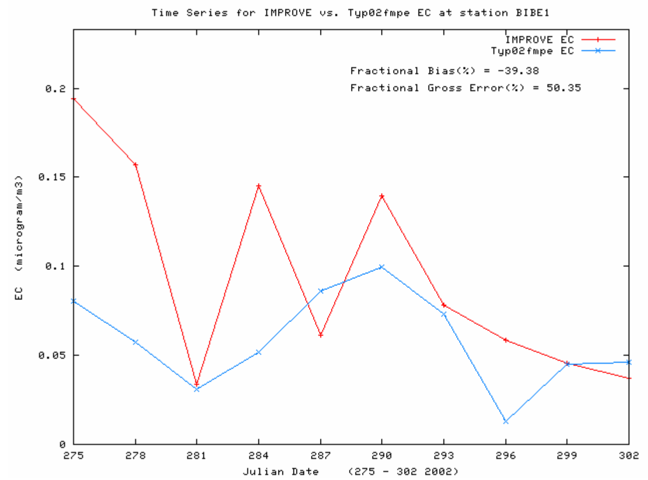
Fractional Bias(%) = 22.33
Fractional Gross Error(%) = 24.54


Time Series for IMPROVE vs. Typ02fmpe EC at station HEGL1

Fractional Bias(%) = -15.13
Fractional Gross Error(%) = 30.55

No Data for Mingo (MING)





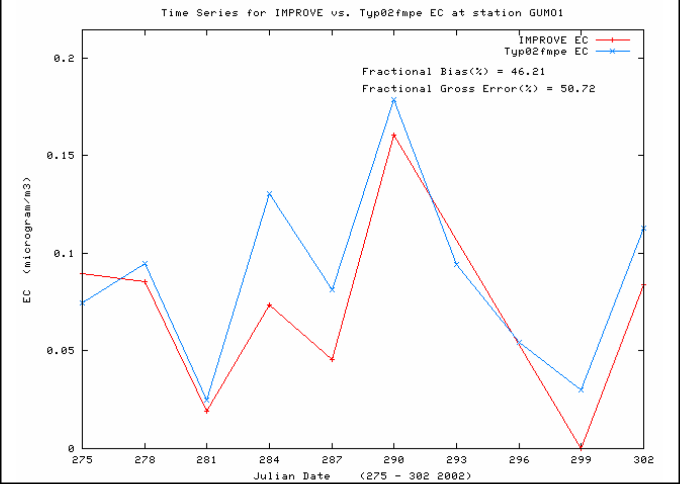


Figure C-25b. Time series of predicted and observed 24-hour elemental carbon (EC) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

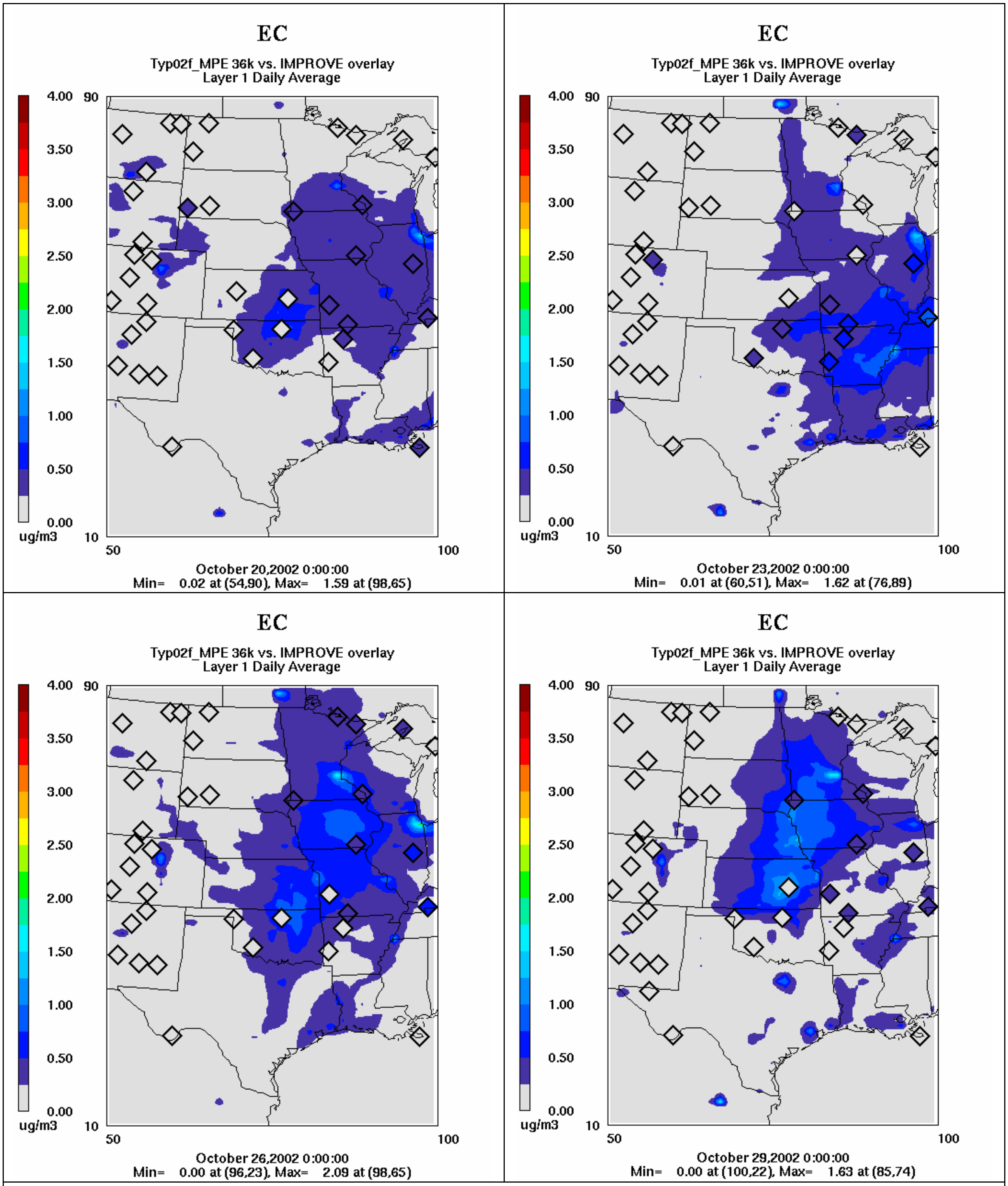


Figure C-25c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour EC concentrations for October 20, 23, 26 and 29, 2002.

C.3.4.5 EC Monthly Bias and Error

The monthly average bias and error for EC across the IMPROVE and STN monitors in the CENRAP region are shown in Figure C-26. The STN network exhibits low bias year round, whereas the IMPROVE monitoring network exhibits a large under-prediction bias in the summer months (-40% to -60%) and much lower EC bias in the winter. The errors in the IMPROVE summer EC performance are also quite high (60% to 80%), whereas during the winter the IMPROVE errors are in the 40% to 50% range which is also where the STN errors reside year round.

The Bugle Plot puts the EC performance in context (Figure C-27). The low EC concentrations put the IMPROVE EC performance in the horn of the Bugle Plot so that it achieves the proposed PM performance goal for all months of the year.

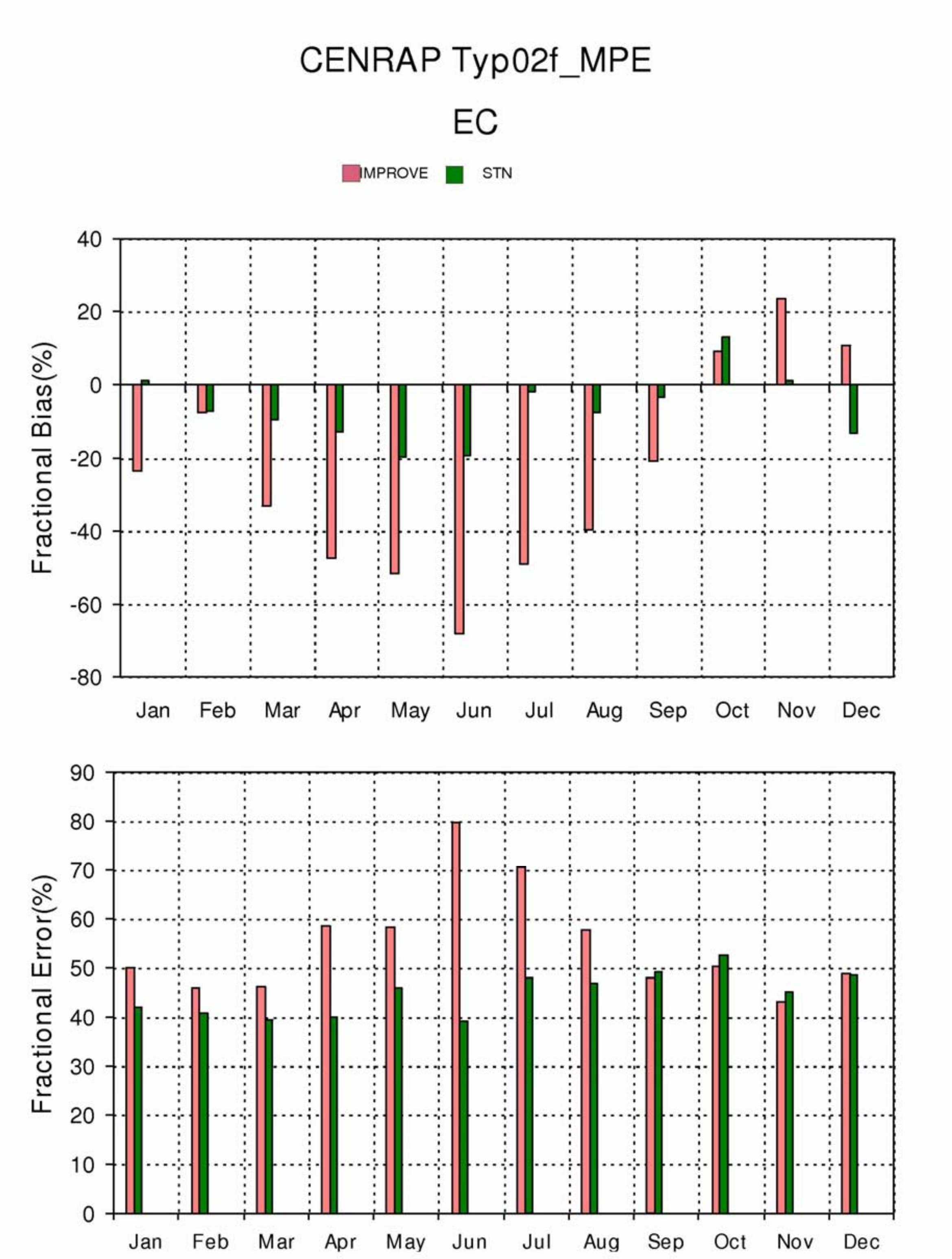


Figure C-26. Monthly EC fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE and STN monitoring sites in the CENRAP region.

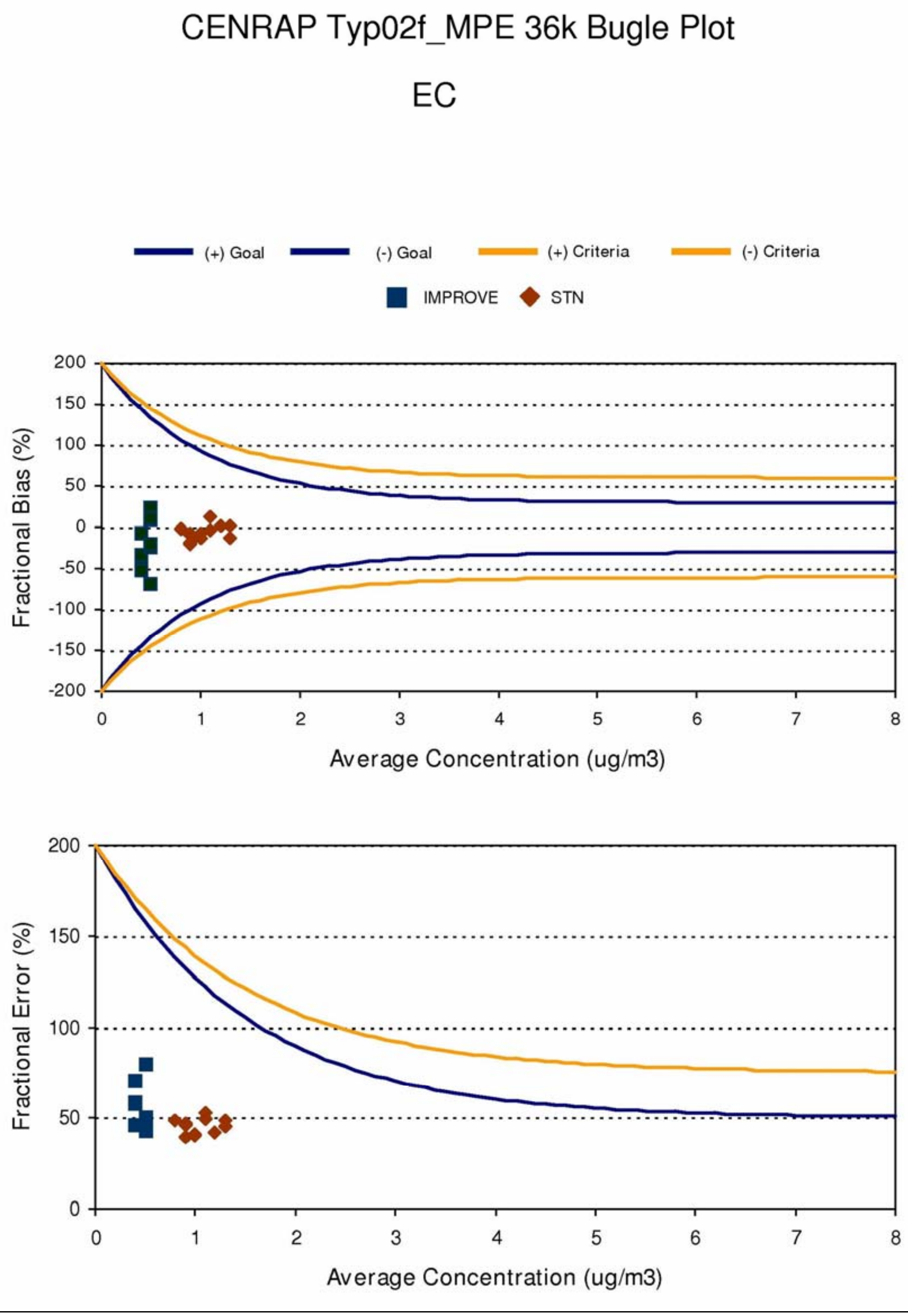


Figure C-27. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for EC and IMPROVE and STN monitoring sites in the CENRAP region.

C.3.5 Other $PM_{2.5}$ (Soil) Monthly Model Performance

There are also model-measurement incommensurability problems with the other $PM_{2.5}$ (Soil) species. Whereas the IMPROVE Soil species is built up from measure elements, the modeled other $PM_{2.5}$ concentrations are based on emissions speciation profiles that likely include other species besides just elements. Soil is only collected at the IMPROVE monitors.

C.3.5.1 Soil in January 2002

The model greatly overestimates the Soil species at IMPORVE sites in January (Figure C-28a). The fractional bias exceeds 100% with errors of almost 130%. With the possible exception of the two Texas sites, the model Soil overestimation bias occurs across all of the CENRAP Class I areas in January (Figure C-28b). The model also does a poor job in reproducing the spatial variability of the observed Soil with a general overestimation tendency except at GUMO where it fails to reproduce the high Soil events.

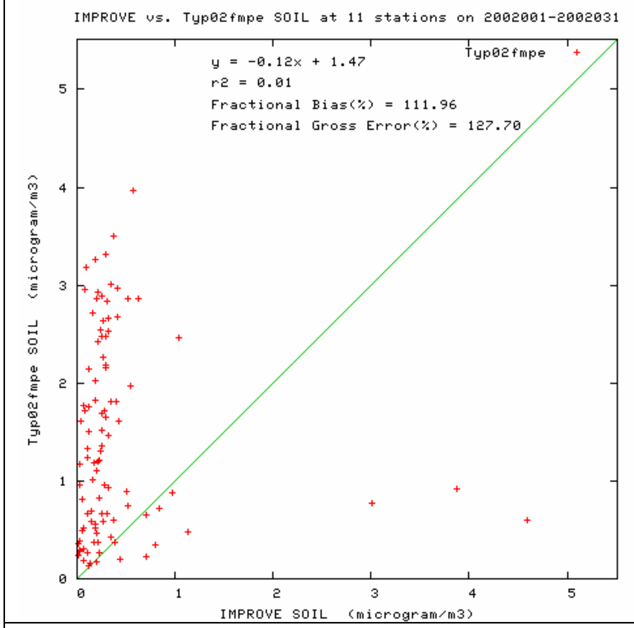
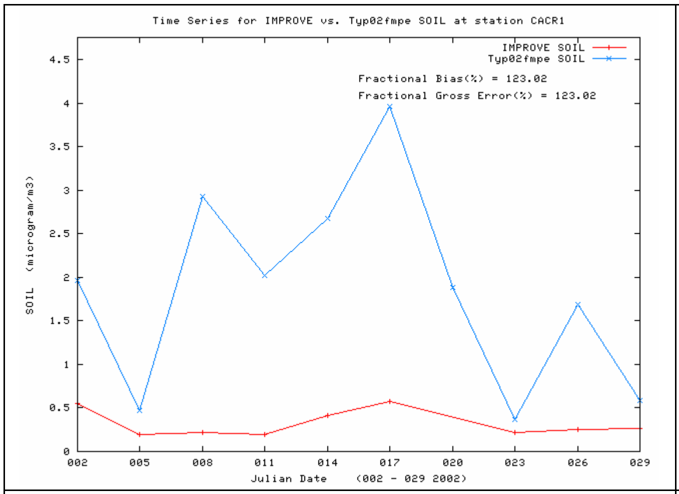
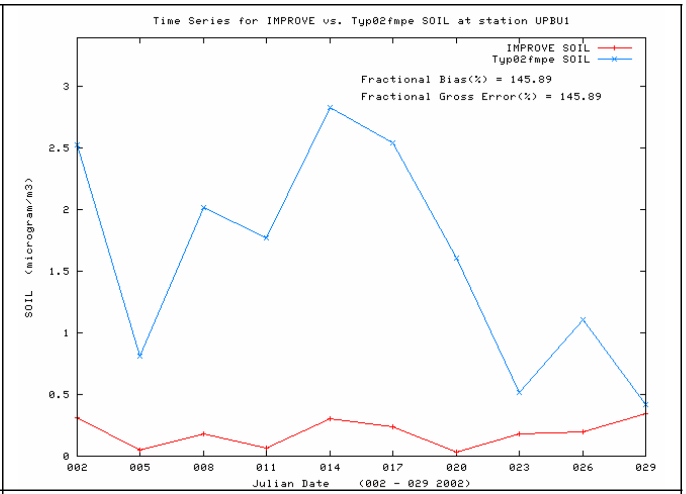


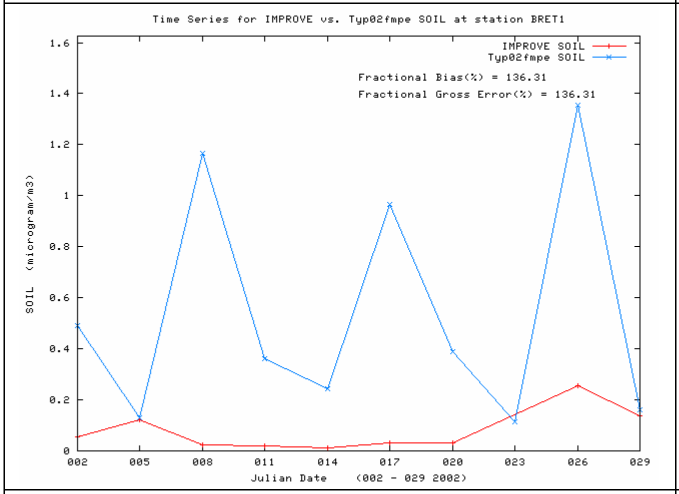
Figure C-28a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for January 2002 and sites in the CENRAP region using IMPROVE monitoring network and the CMAQ 2002 36 km Base F base case simulation.



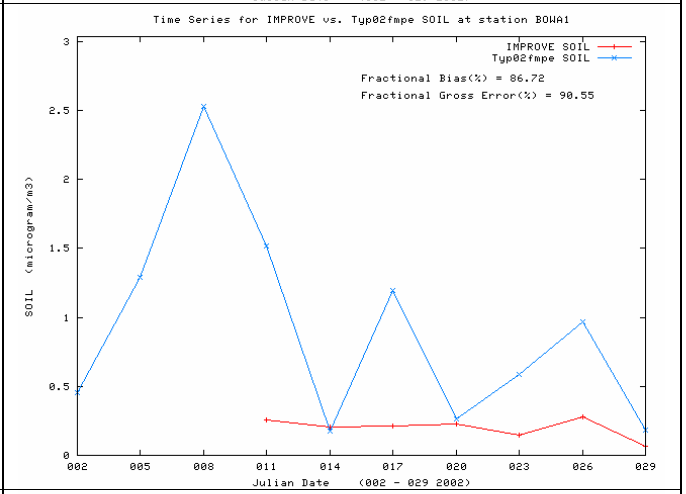
Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1



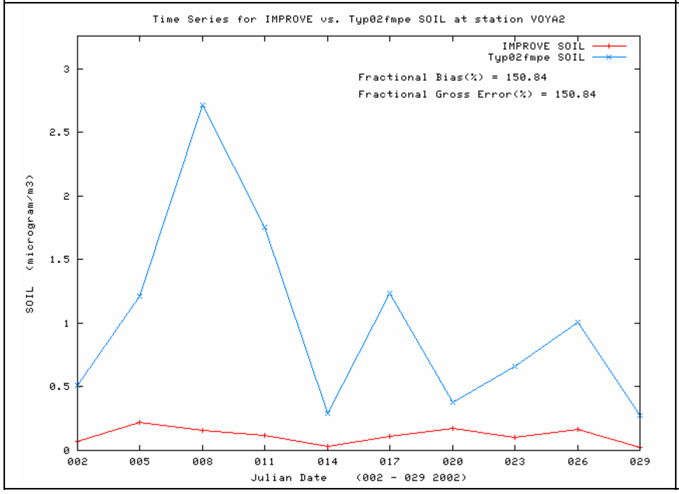
Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1



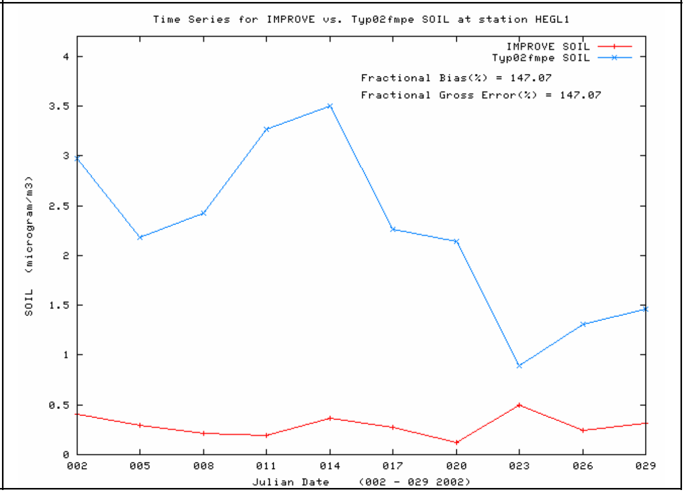
Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1



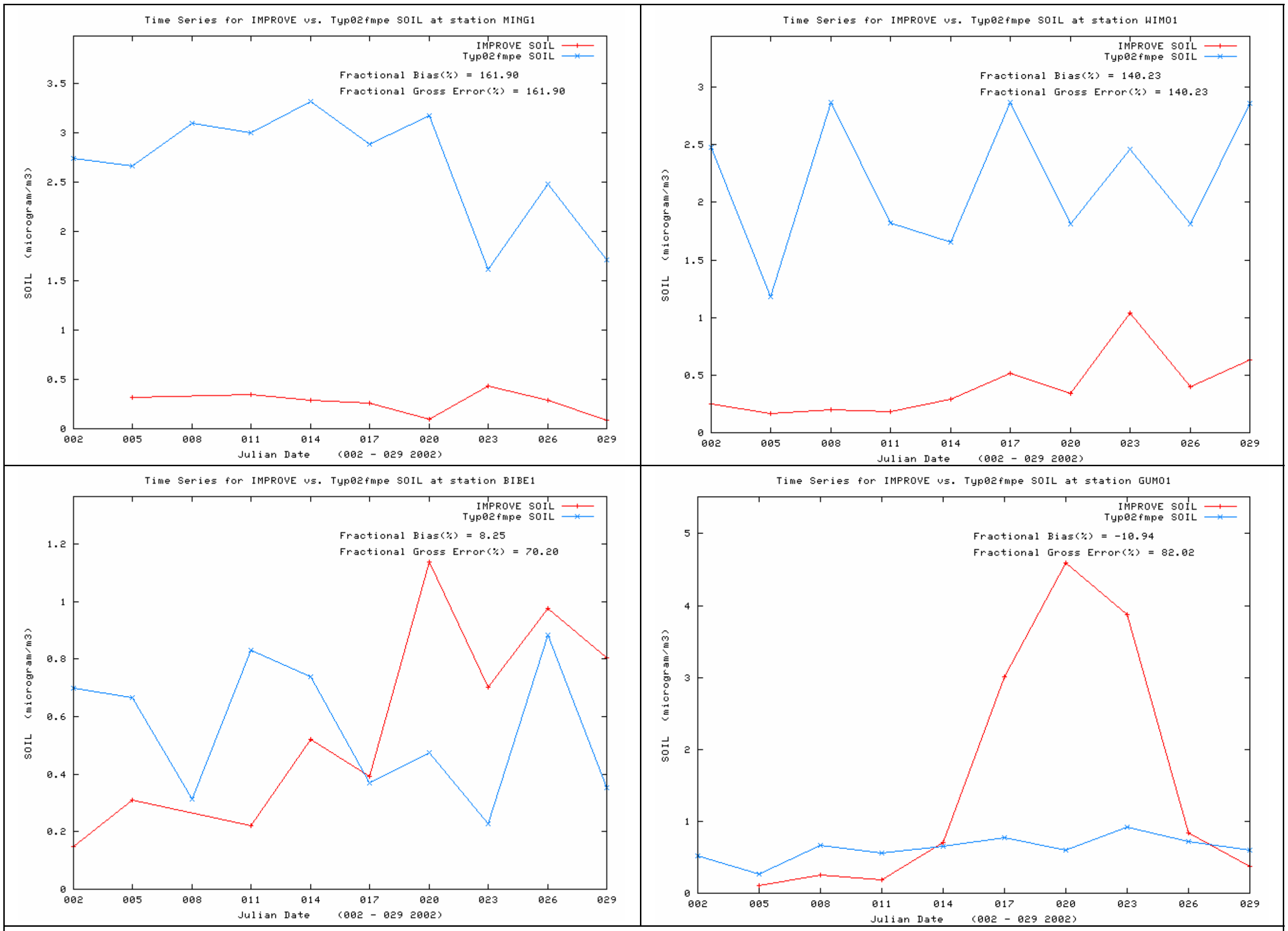
Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1



Time Series for IMPROVE vs. Typ02fmpe SOIL at station MING1

Time Series for IMPROVE vs. Typ02fmpe SOIL at station WIMO1

Time Series for IMPROVE vs. Typ02fmpe SOIL at station BIBE1

Time Series for IMPROVE vs. Typ02fmpe SOIL at station GUMO1

Figure C-28b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

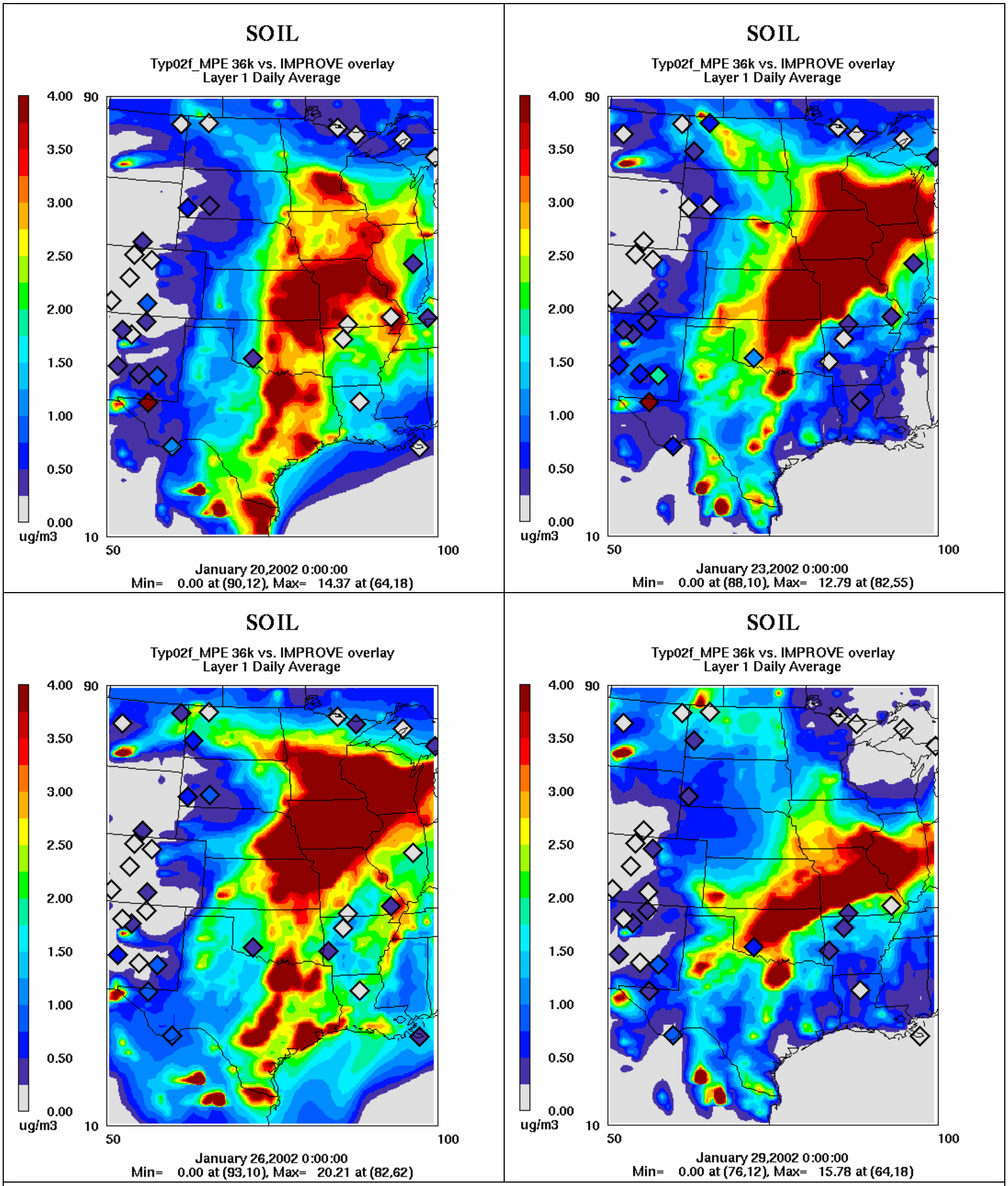


Figure C-28c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for January 20, 23, 26 and 29, 2002.

C.3.5.2 Soil in April 2002

The model does a better job in reproducing the overall magnitude of the Soil measurements in April with a bias of 13% (Figure C-29a). But it exhibits little skill with lots of scatter and an error of 81%. The model is generally exhibiting a lot more day-to-day variability than observed with the observed daily time series much flatter than the modeled values (Figure C-29b). The modeled and observed spatial variability in Soil on April 5, 8, 11 and 14 are shown in Figure C-29c. Although the model exhibits large day-to-day variability, the observations do not reflect what the model predicts.

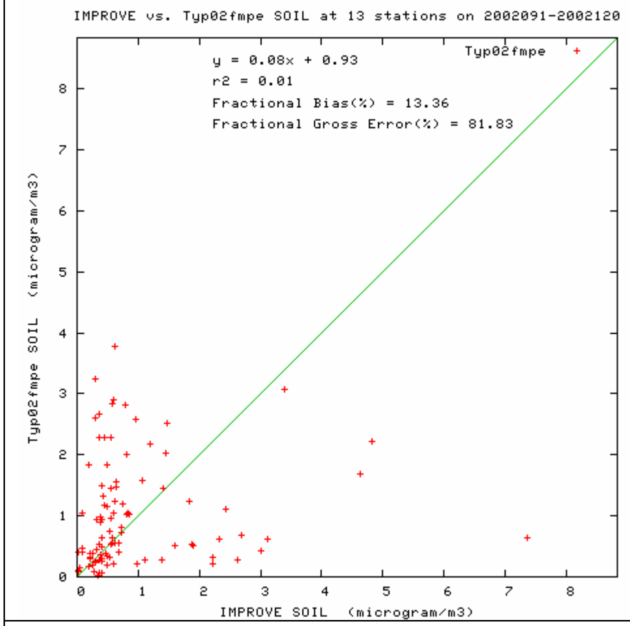
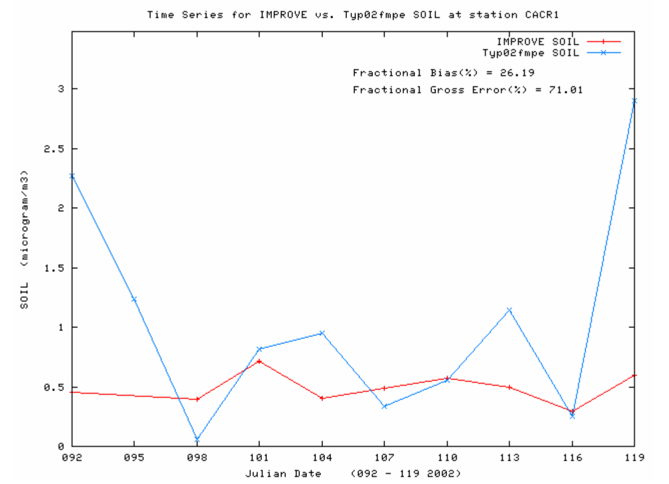
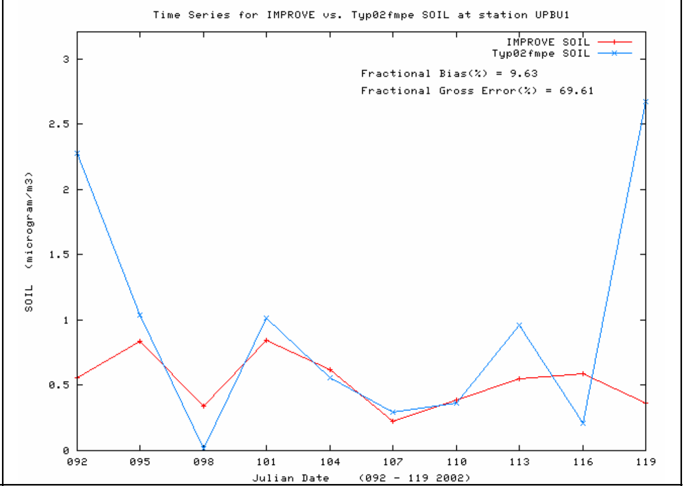
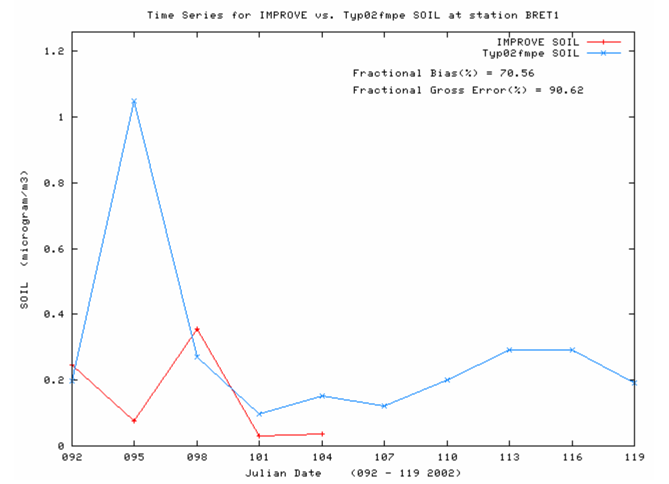
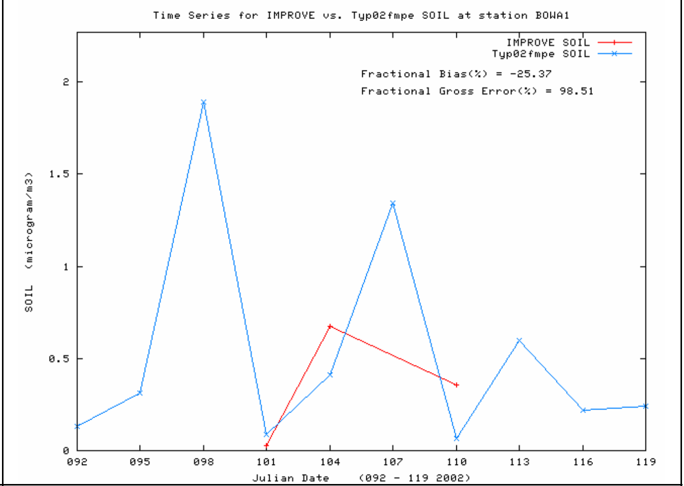


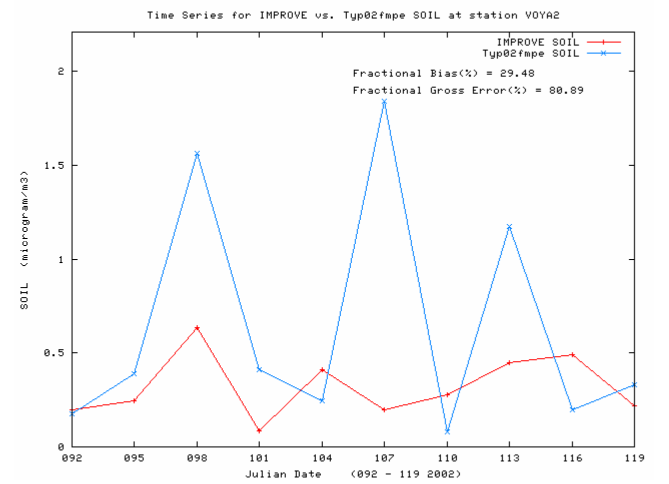
Figure C-29a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for April 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

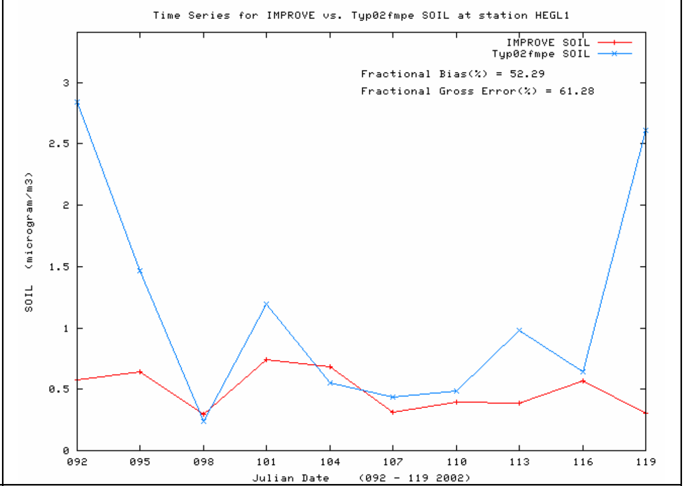

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1

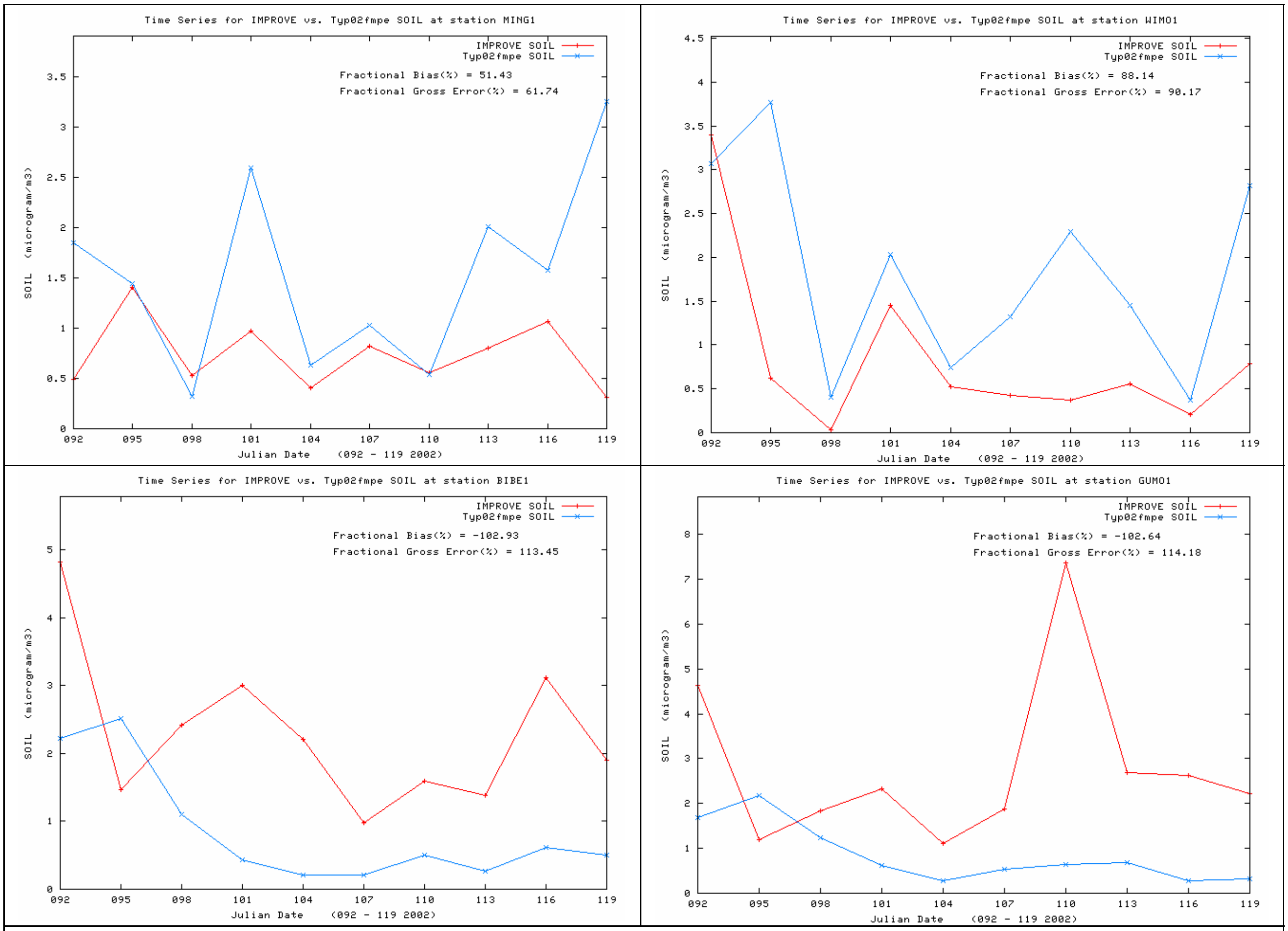
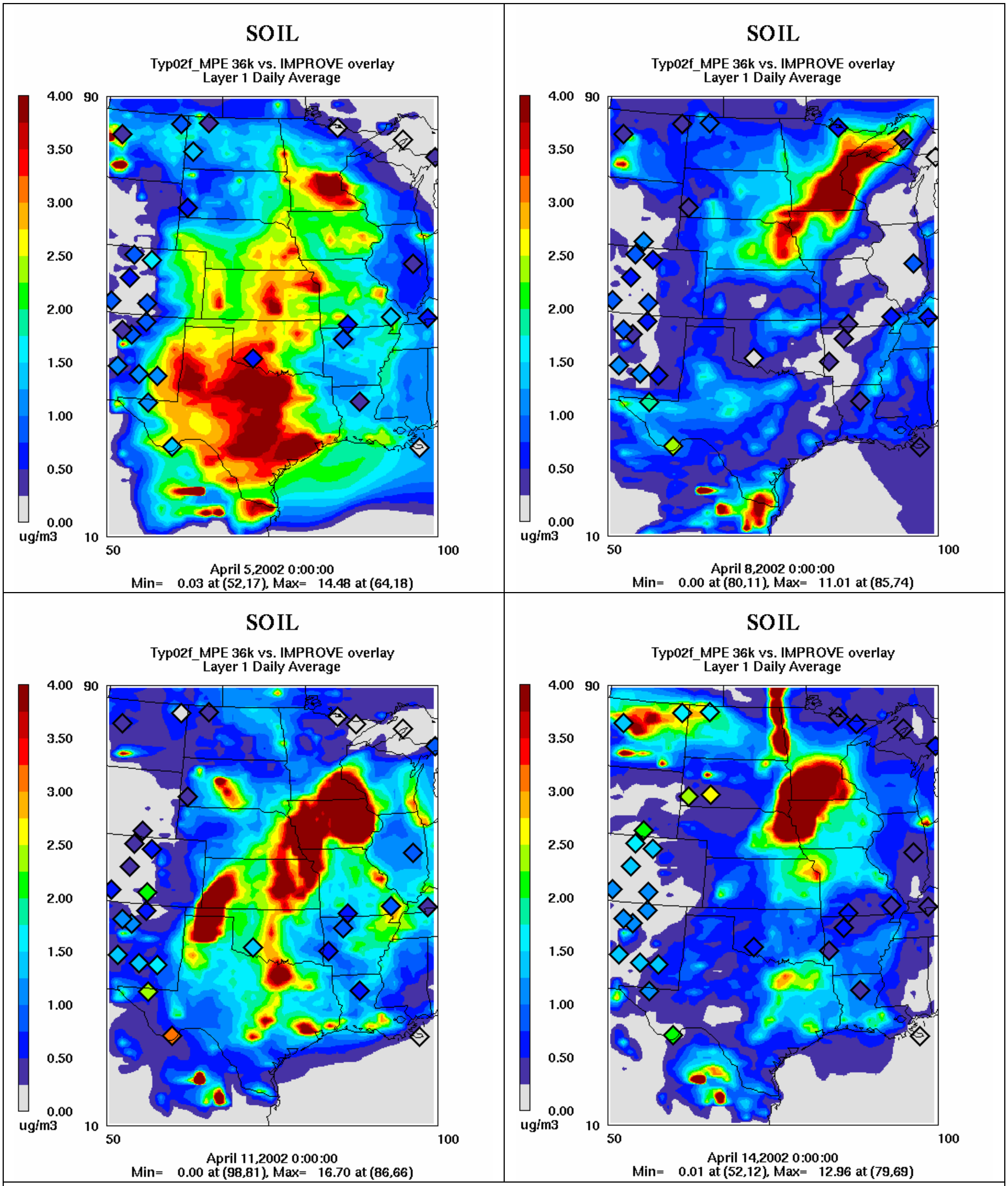


Figure C-29b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.



SOIL

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

April 5,2002 0:00:00
Min= 0.03 at (52,17), Max= 14.48 at (64,18)

SOIL

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

April 8,2002 0:00:00
Min= 0.00 at (80,11), Max= 11.01 at (85,74)

SOIL

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

April 11,2002 0:00:00
Min= 0.00 at (98,81), Max= 16.70 at (86,66)

SOIL

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

April 14,2002 0:00:00
Min= 0.01 at (52,12), Max= 12.96 at (79,69)

Figure C-29c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for April 5, 8, 11 and 14, 2002.

C.3.5.3 Soil in July 2002

The -50% Soil under-prediction bias seen in July appears to be driven to several high Soil measurements (Figure C-30a). An observed high Soil event took place on July 1 (Julian Day 182) across the Arkansas and Missouri Class I areas that all observed Soil values in excess of 15 µg/m^3. This event was not captured by the model. With the exception of a systematic Soil underestimation bias at the two Texas sites and missing these high Soil events, the model generally reproduces the magnitudes of the Soil observations in July.

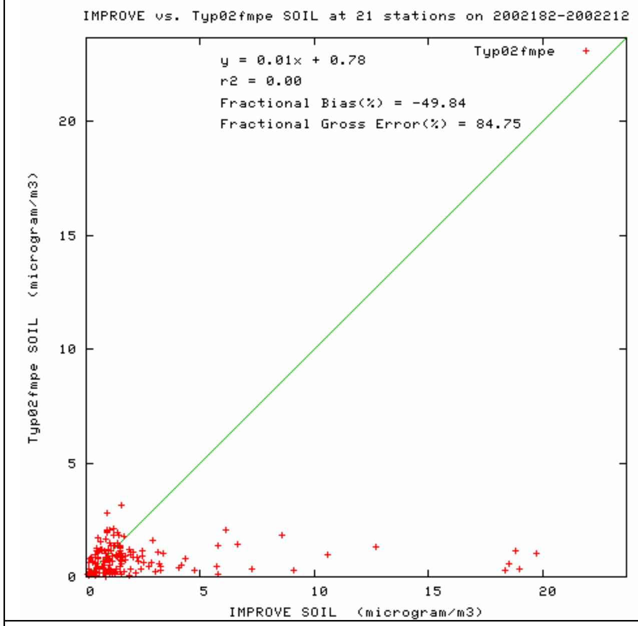
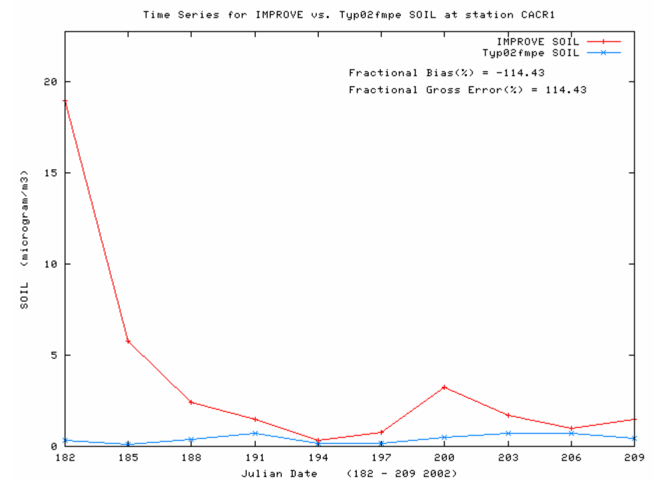
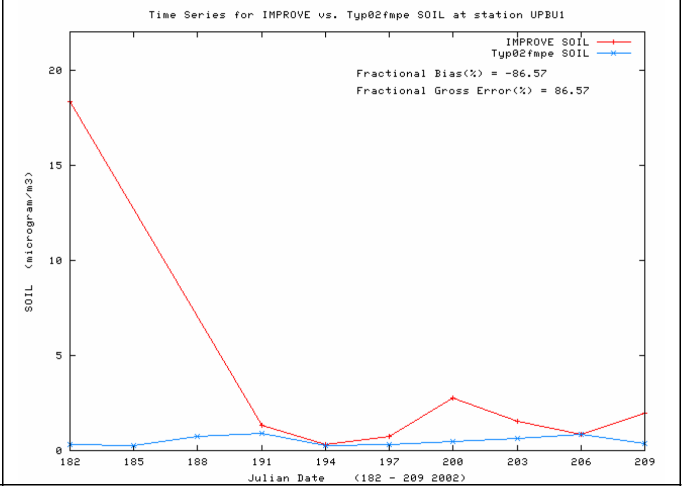
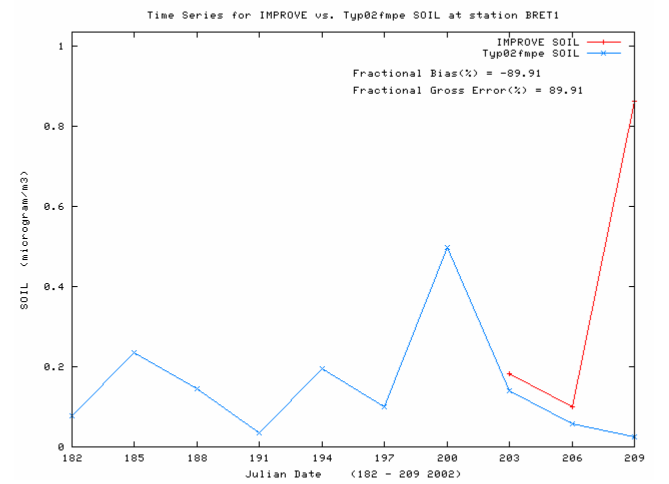
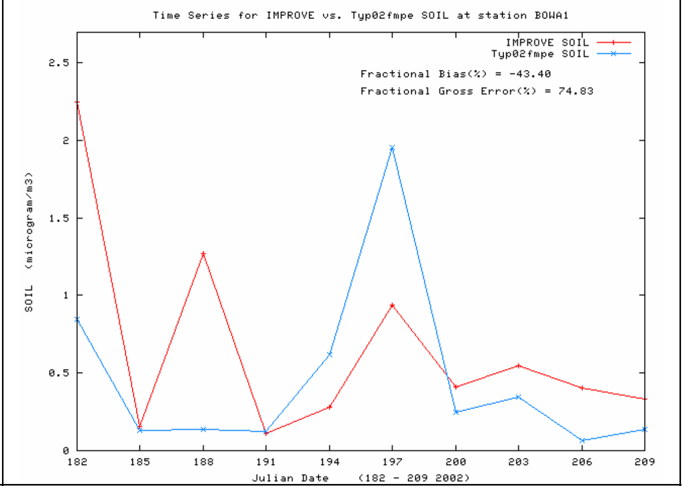


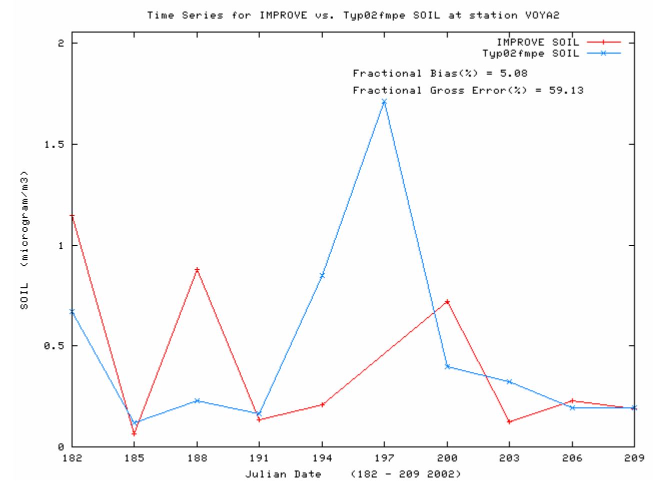
Figure C-30a. Scatter plots of predicted and observed other PM$_{2.5}$ (Soil) concentrations for July 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

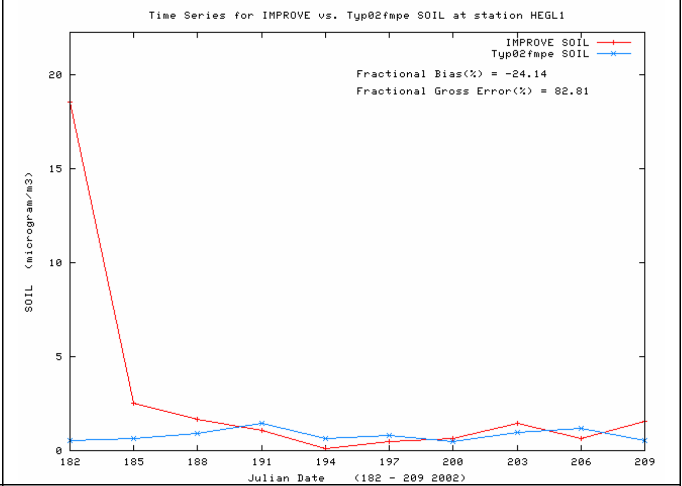

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1

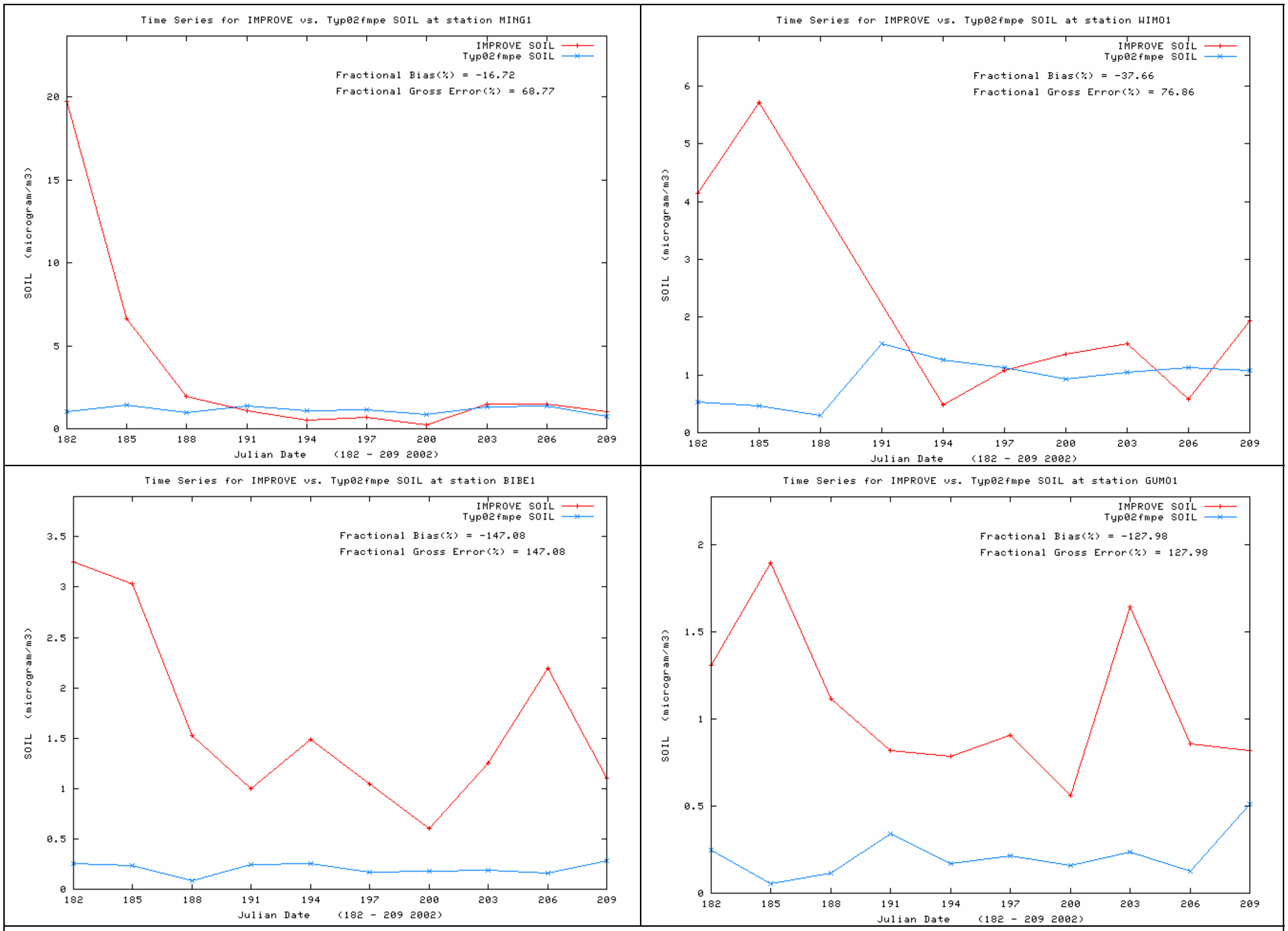


Figure C-30b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

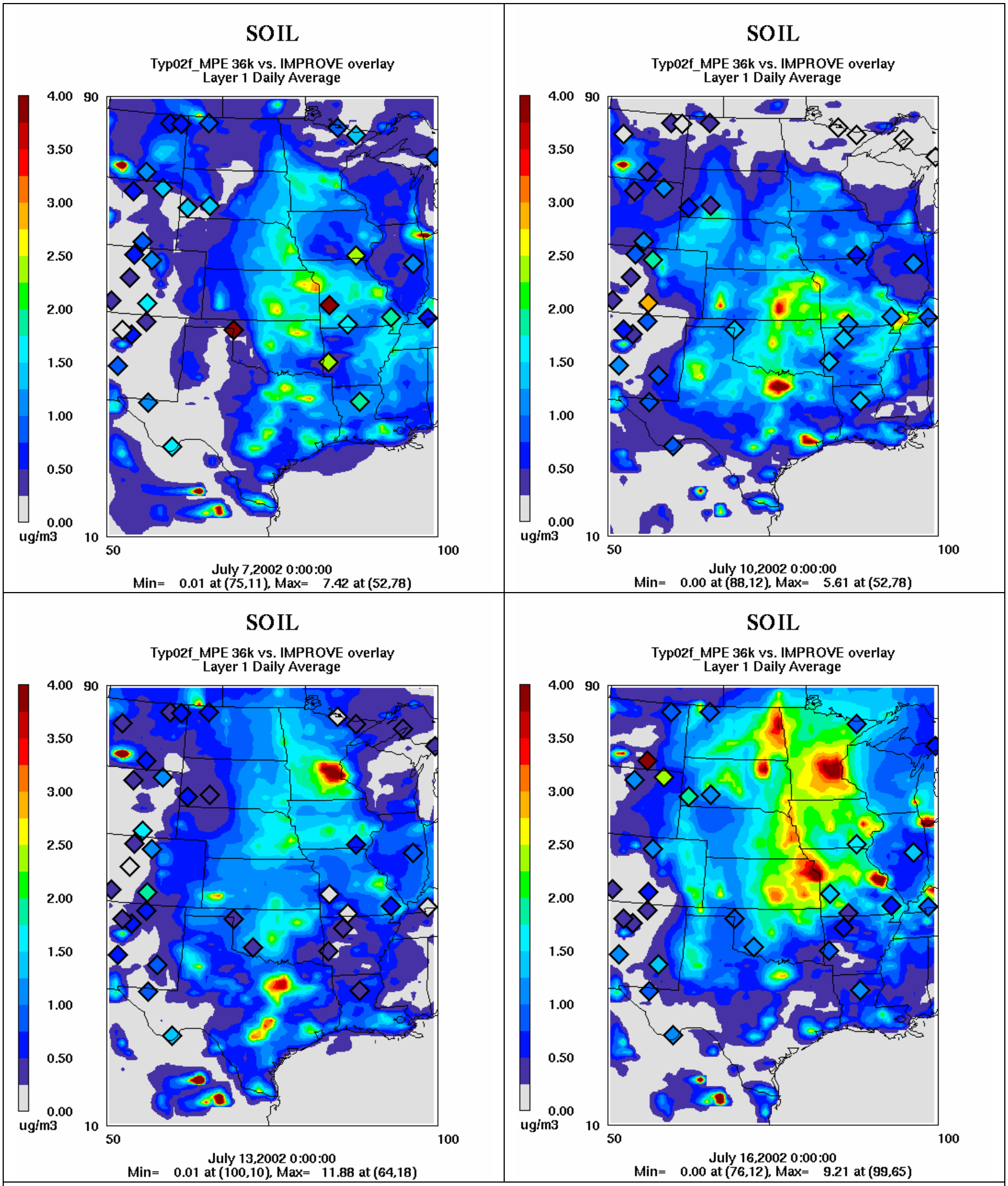


Figure C-30c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for July 7, 10, 13 and 16, 2002.

C.3.5.4 Soil in October 2002

The nearly systematic Soil over-prediction bias seen in January returns in October (Figure C-31a). Except for the two Texas sites, BRET and BOWA, the model overstates the observed Soil during all days of October at the other monitoring sites (Figure C-31b). The model is predicting elevated Soil concentrations in the OK-KS-MO-IA area that is not reflected in the measurements (Figure C-31c).

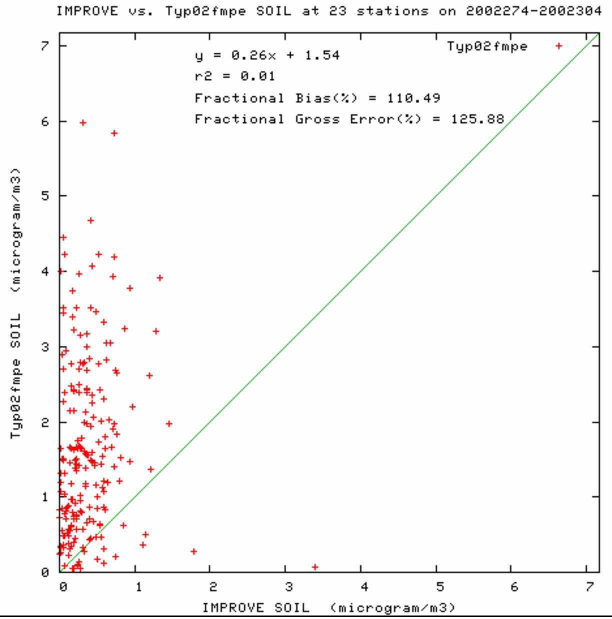
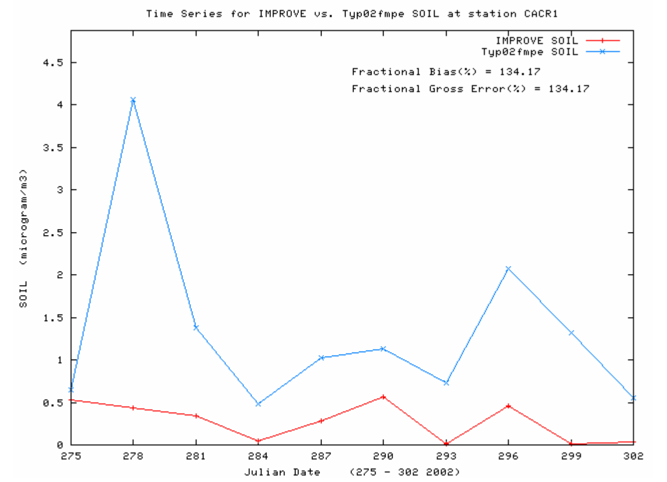
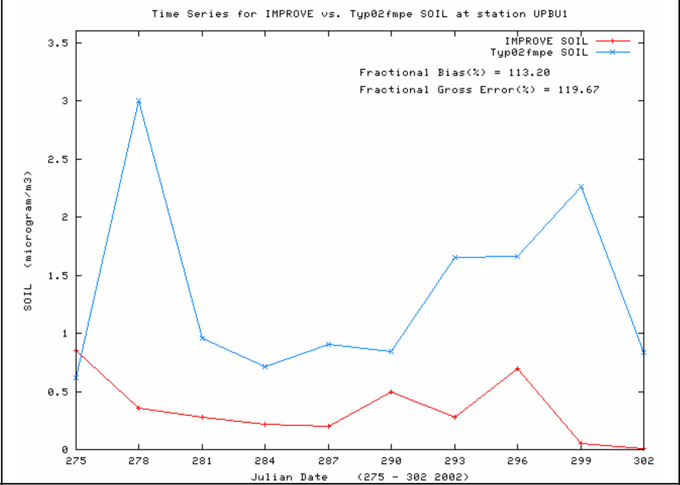
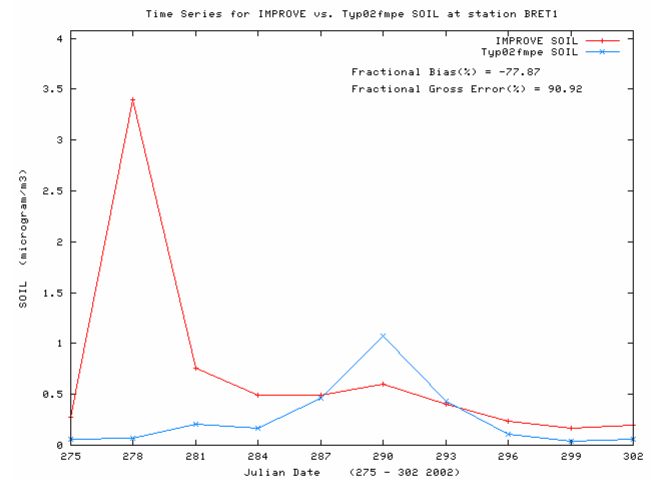
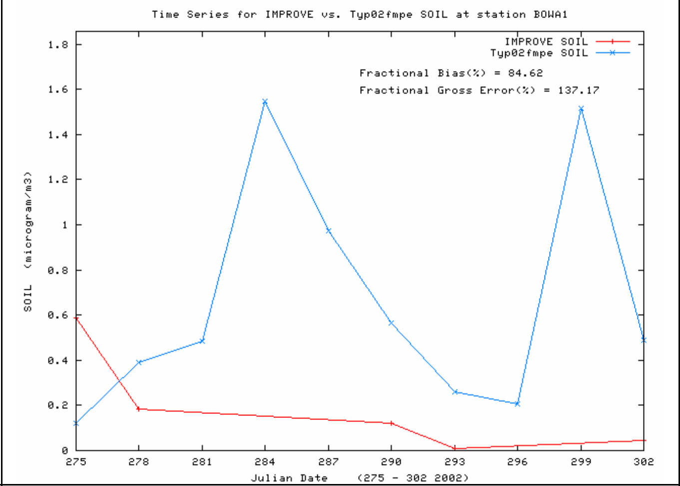


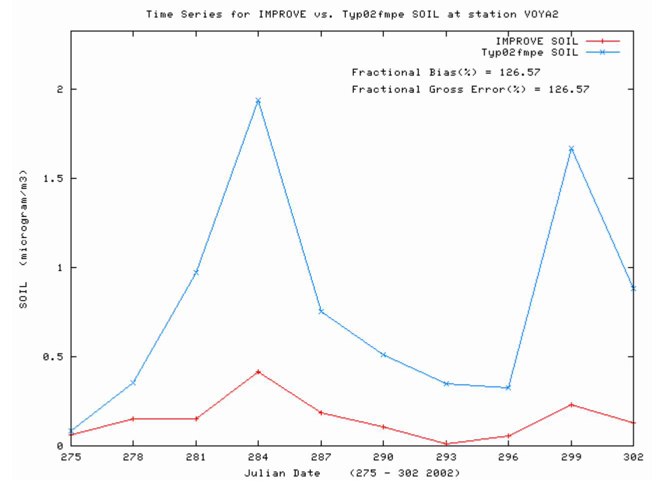
Figure C-31a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for October 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

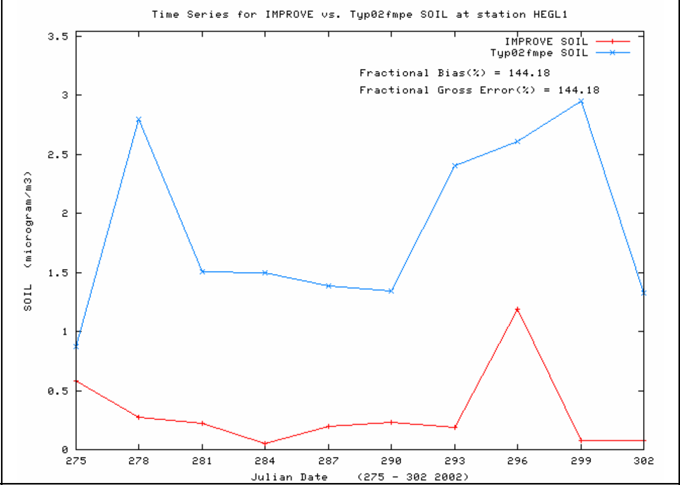

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 134.17
Fractional Gross Error(%) = 134.17
SOIL (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 113.20
Fractional Gross Error(%) = 119.67
SOIL (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -77.87
Fractional Gross Error(%) = 90.92
SOIL (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
4
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 84.62
Fractional Gross Error(%) = 137.17
SOIL (microgram/m3)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 126.57
Fractional Gross Error(%) = 126.57
SOIL (microgram/m3)
0
0.5
1
1.5
2
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 144.18
Fractional Gross Error(%) = 144.18
SOIL (microgram/m3)
0
0.5
1
1.5
2
2.5
3
3.5
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)

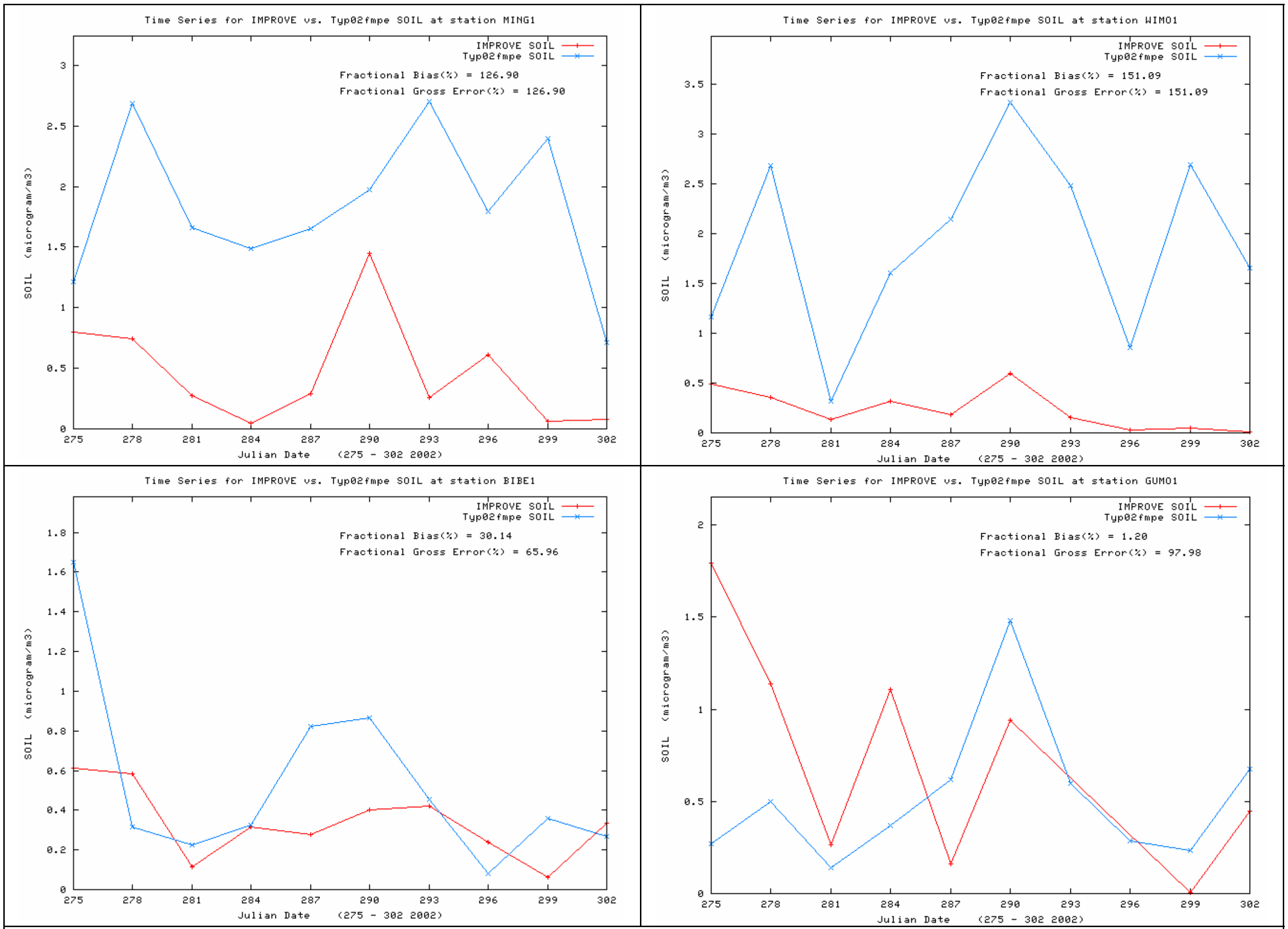


Figure C-31b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

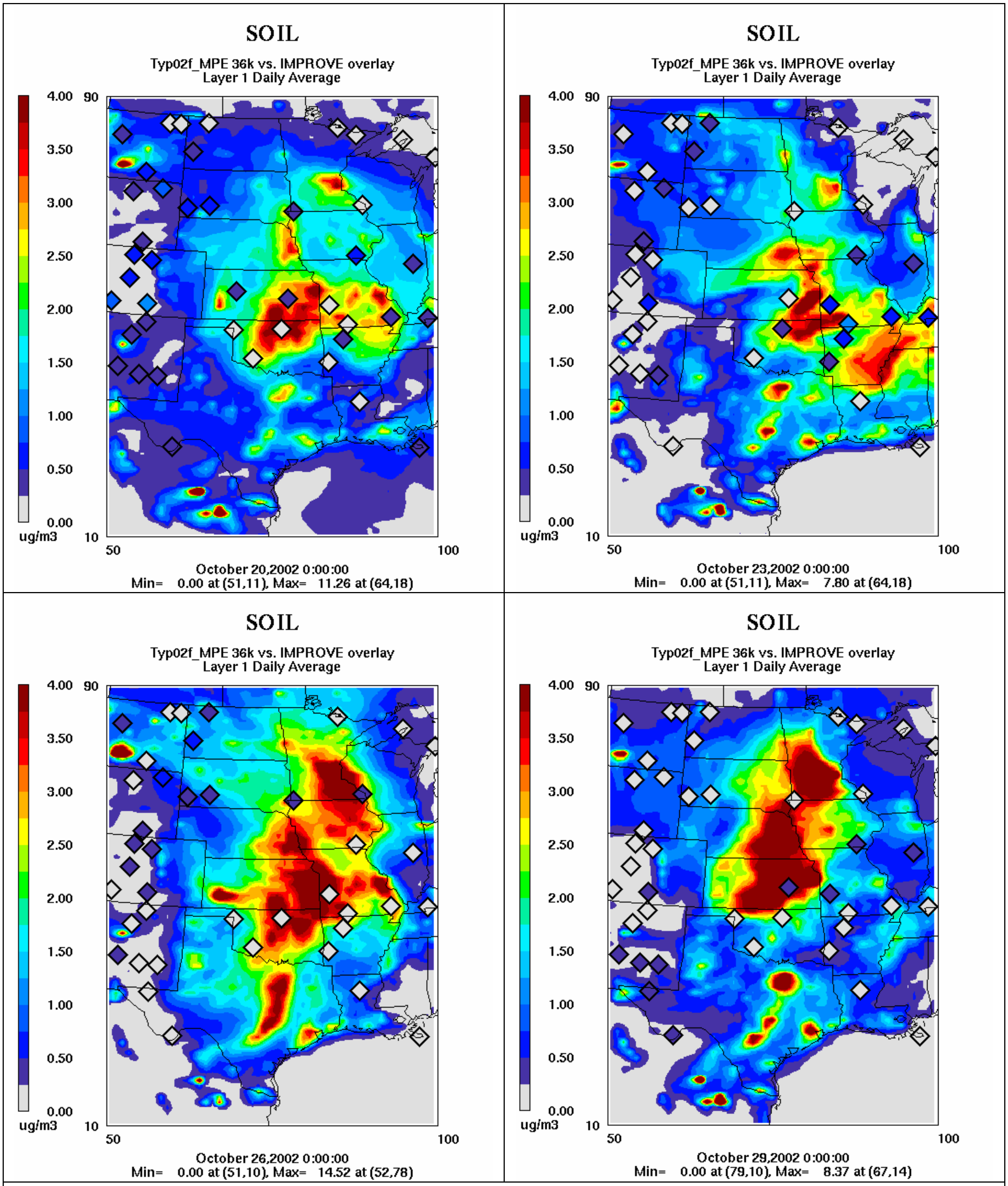


Figure C-31c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for October 20, 23, 26 and 29, 2002.

C.3.5.5 Soil Monthly Bias and Error

Figure C-32 displays the monthly variation in the Soil bias and error. During the winter months the model exhibits a very large (> 100%) overestimation bias with large errors as well. With the exception of July, in the summer the model bias is a slight over-prediction but generally less than 20% with errors of 60% to 80%. The Bugle Plot indicates that the summer Soil performance achieves the PM performance goal, a few months in the Spring/Fall period fall between the performance goal and criteria and the winter Soil performance exceeds the model performance criteria by a far margin. Thus, the Soil performance is a cause for concern.

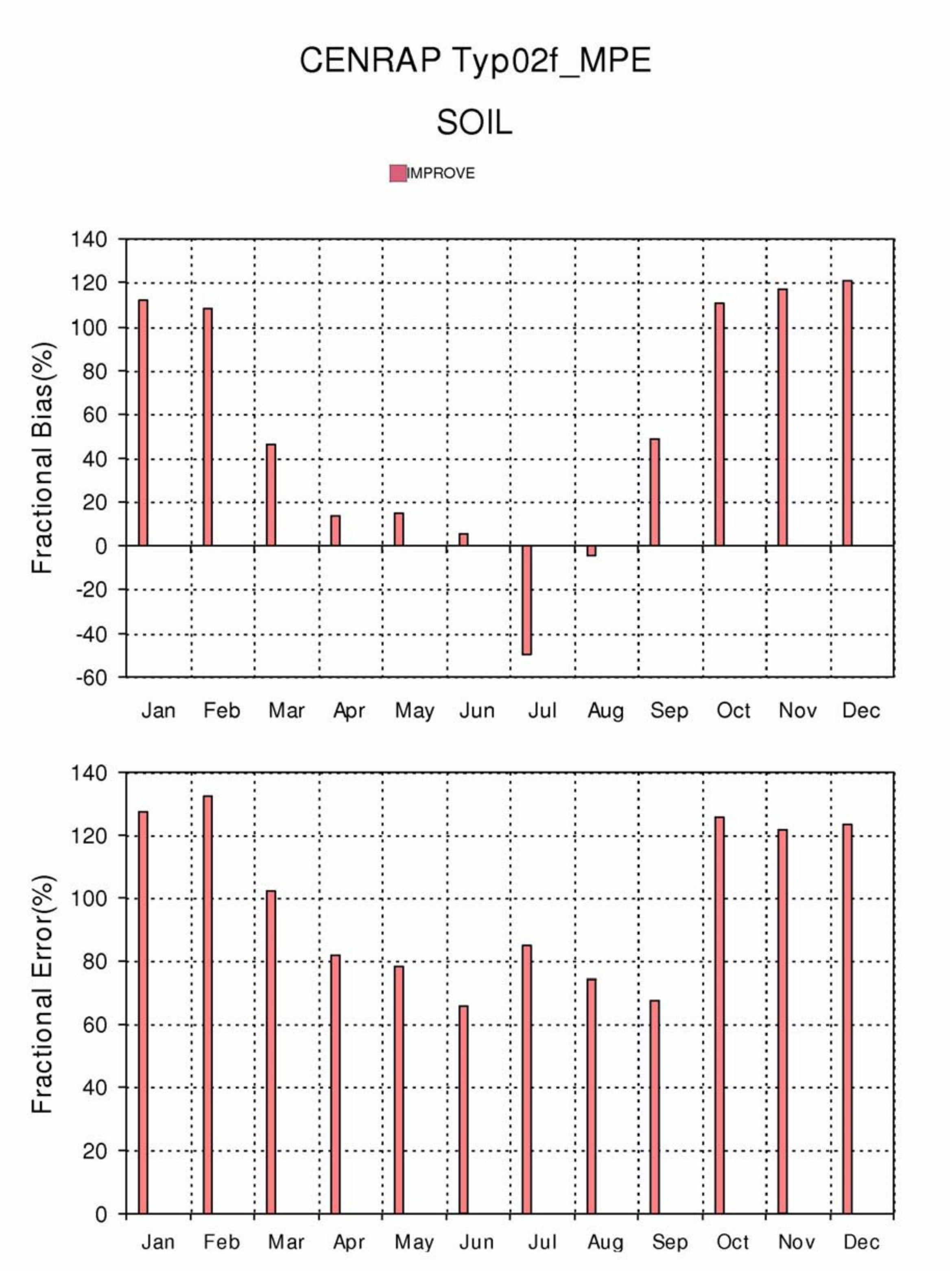


Figure C-32. Monthly Soil fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

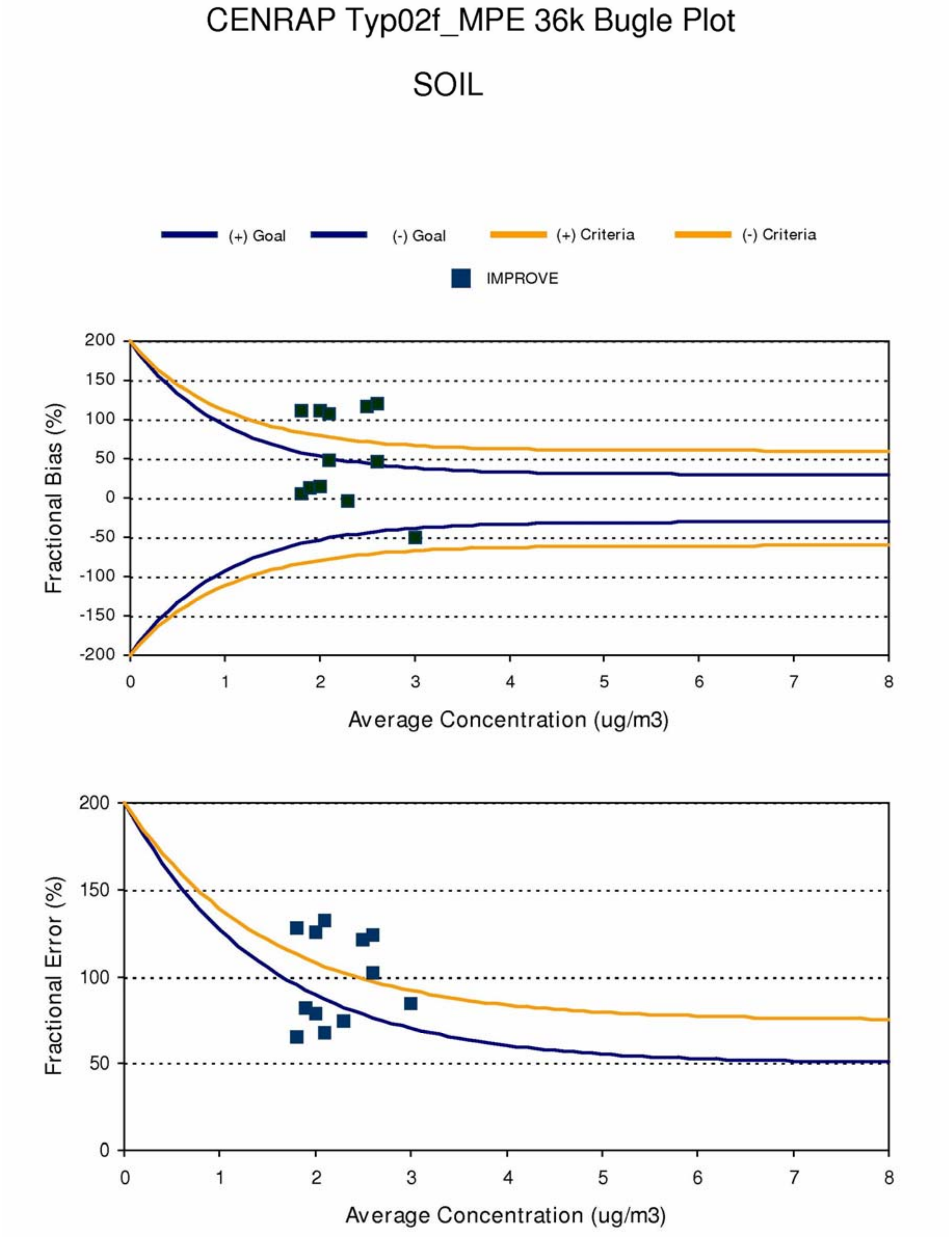


Figure C-33. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for Soil and IMPROVE monitoring sites in the CENRAP region.

C.3.6 Coarse Mass (CM) Monthly Model Performance

The IMPROVE coarse mass (CM) measurement is taken as the difference between the PM_{10} and $PM_{2.5}$ mass measurement. Any SO4 or NO3 in the coarse mode will be in the CM measurement. The model, on the other hand, only includes primary CM. Any coarse SO4 or NO3 will be in the SO4 and NO3 modeled species.

C.3.6.1 CM in January 2002

The model underestimates the observed CM in January with a fractional bias of -83% (Figure C-34a). Although the model appears to reproduce CM at some sites (e.g., VOYA) at the two Texas sites the bias is approximately -150% (Figure C-34b). The observed spatial distribution of CM in January is not reproduced by the model at all (Figure C-34c). Whereas the observations indicate high CM concentrations in the west Texas-New Mexico area, the model estimates elevated CM in northeast Texas, through Oklahoma, Kansas, Iowa and into southern Minnesota. Although the CM measurements at WIMO in this area are also elevated, the rest of the high modeled CM values fall in between the IMPROVE monitors so can not be verified or refuted by the measurements.

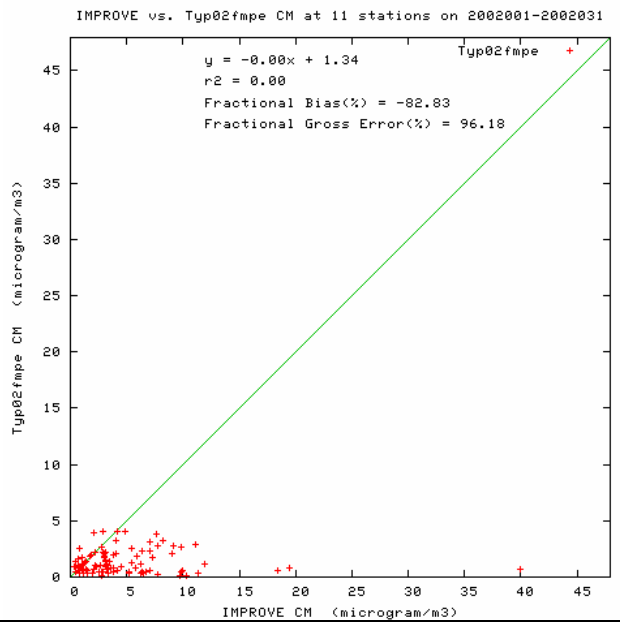
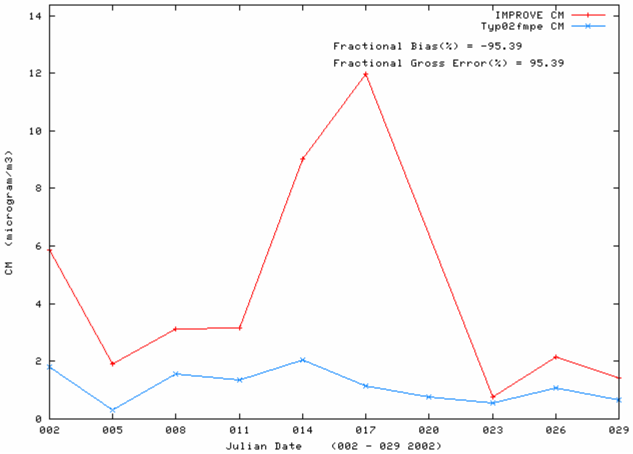
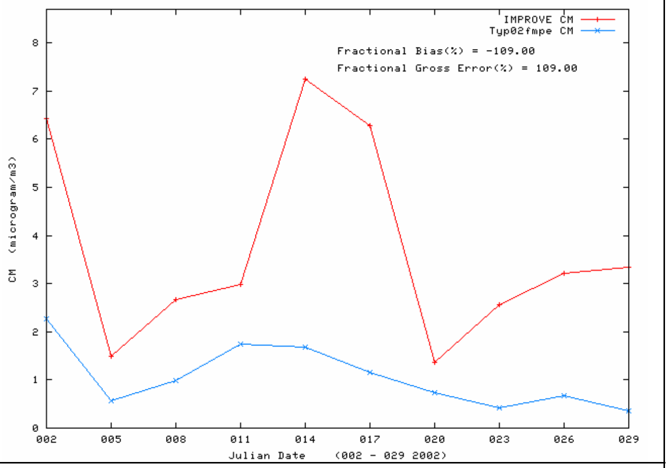


Figure C-34a. Scatter plots of predicted and observed coarse mass (CM) concentrations for January 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

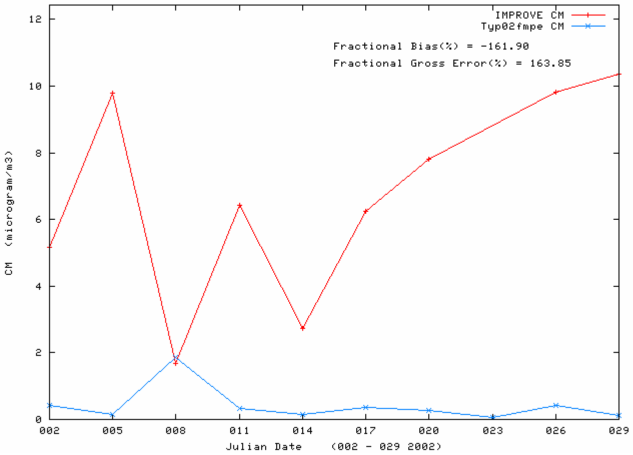
Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1



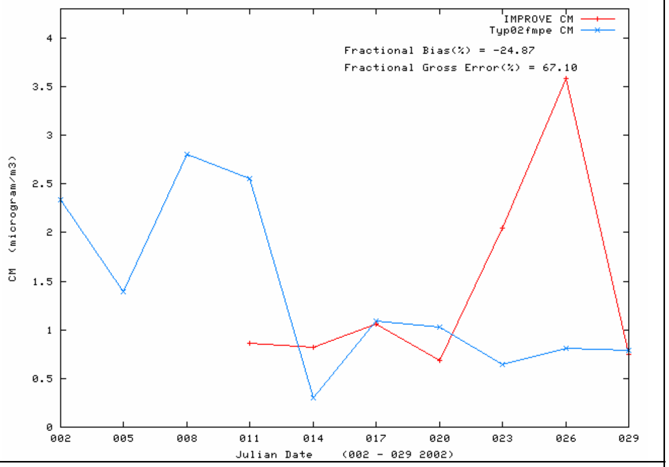
Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1



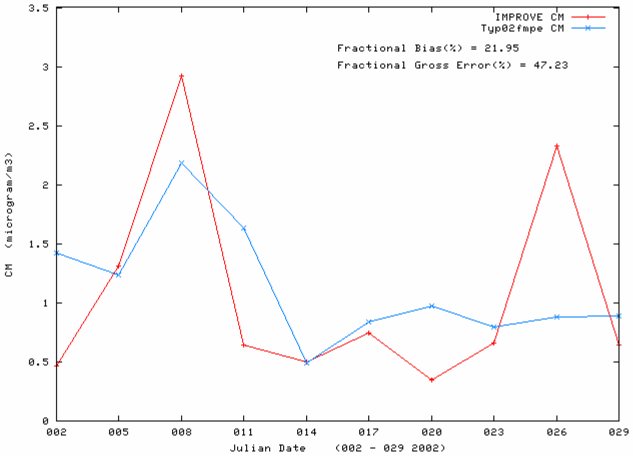
Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1



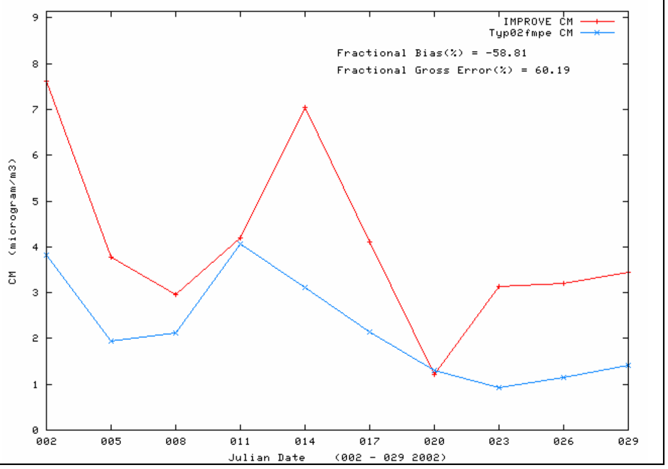
Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1



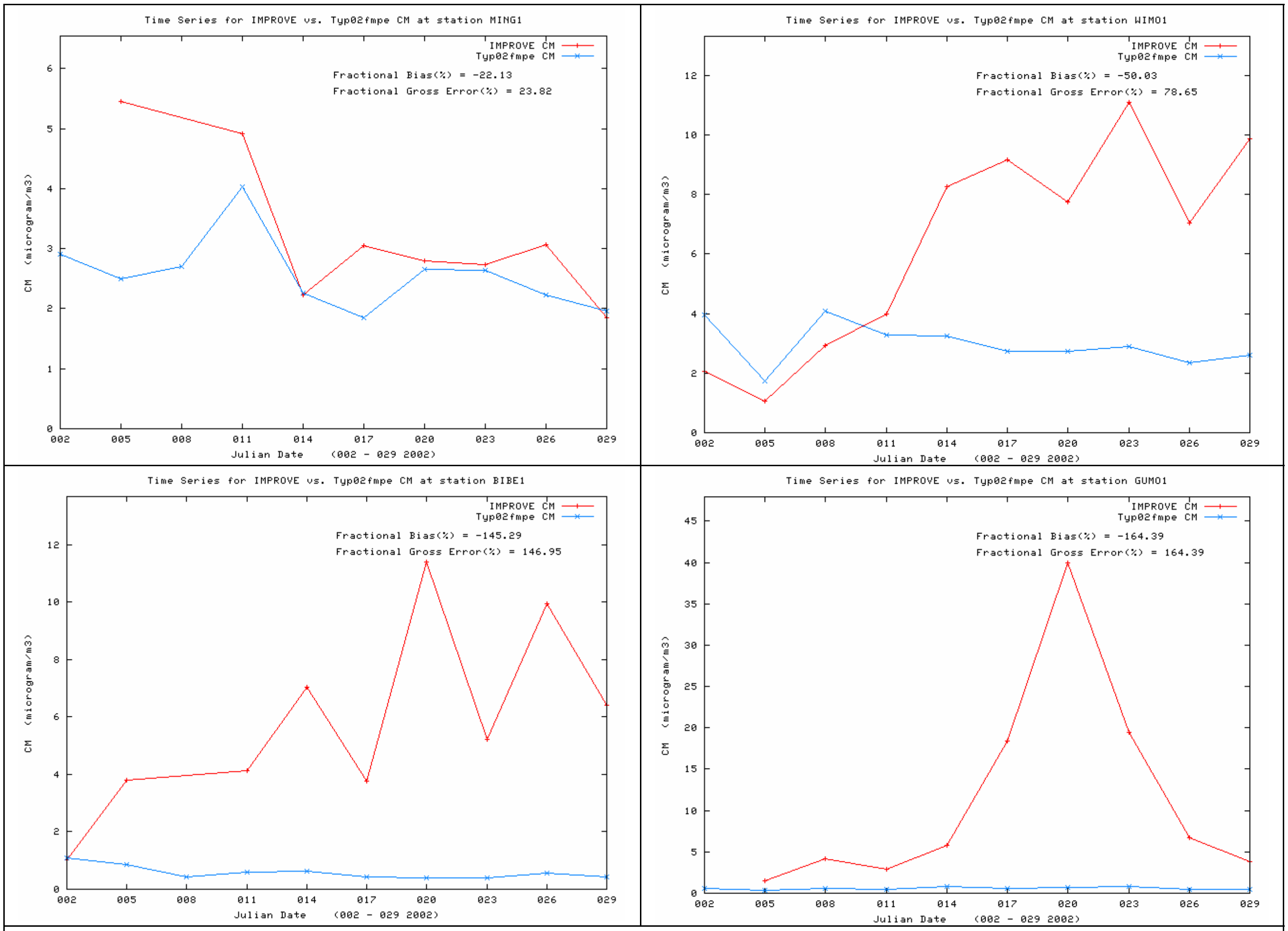
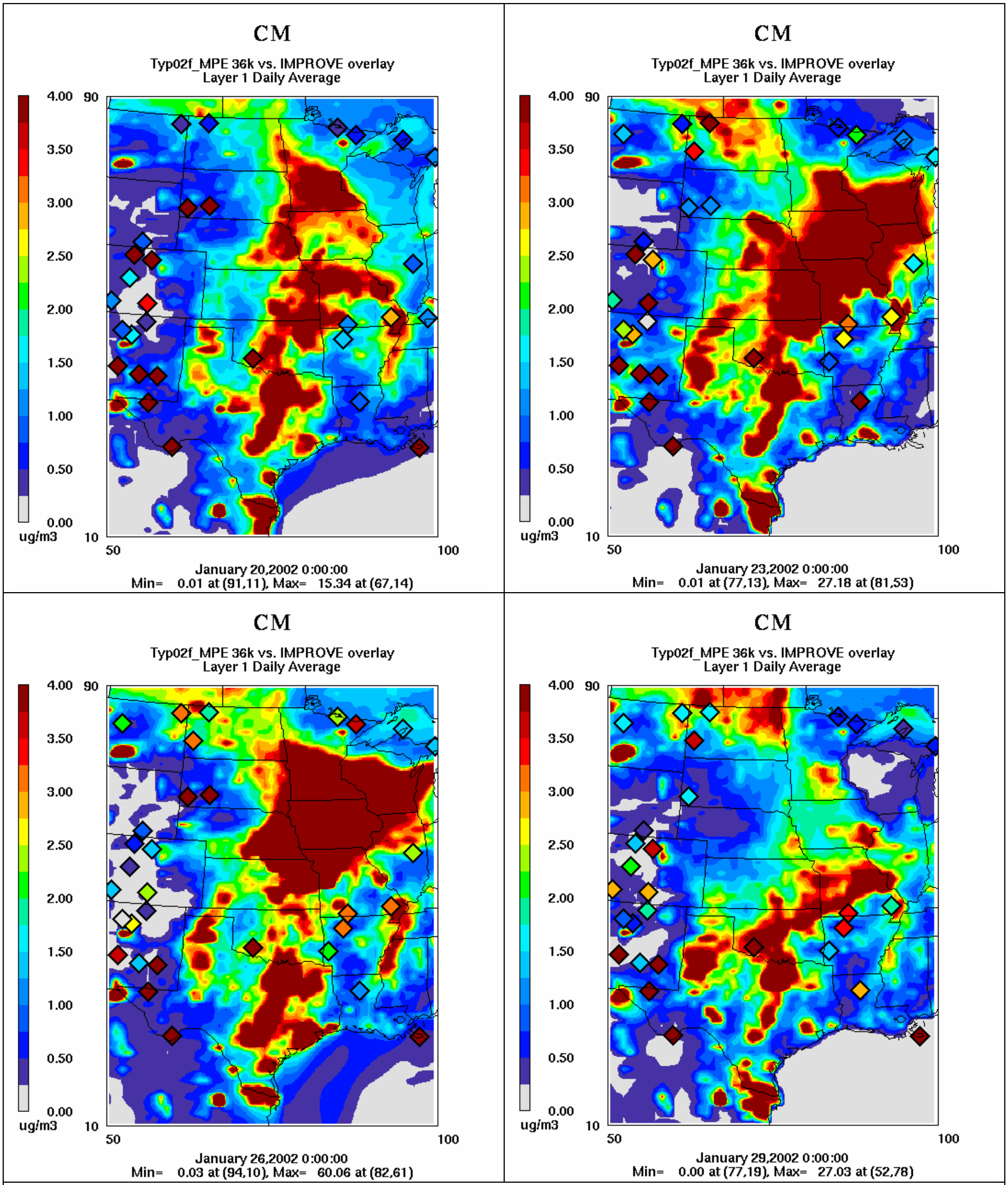


Figure C-34b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.



CM

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

January 20,2002 0:00:00
Min= 0.01 at (91,11), Max= 15.34 at (67,14)

CM

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

January 23,2002 0:00:00
Min= 0.01 at (77,13), Max= 27.18 at (81,53)

CM

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

January 26,2002 0:00:00
Min= 0.03 at (94,10), Max= 60.06 at (82,61)

CM

Typ02f_MPE 36k vs. IMPROVE overlay
Layer 1 Daily Average

January 29,2002 0:00:00
Min= 0.00 at (77,19), Max= 27.03 at (52,78)

Figure C-34c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for January 20, 23, 26 and 29, 2002.

C.3.6.2 CM in April 2002

The CM underestimation bias is even greater in April (-137%) and occurs at all IMPROVE sites (Figure C-35).

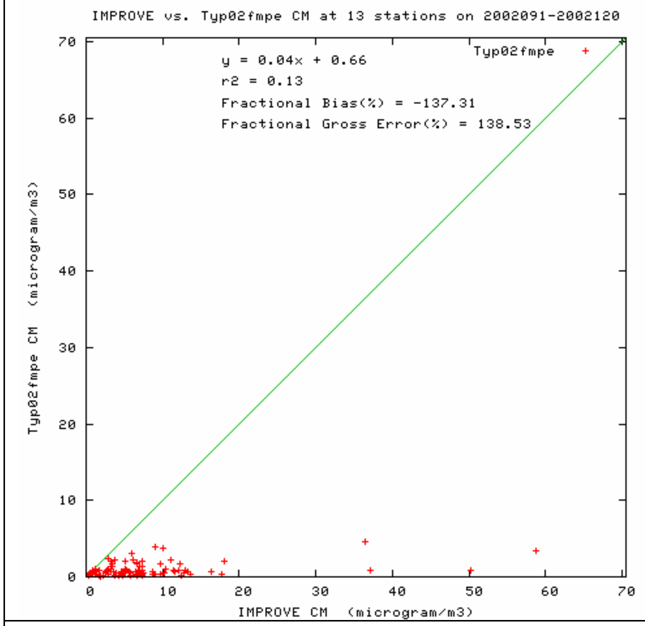
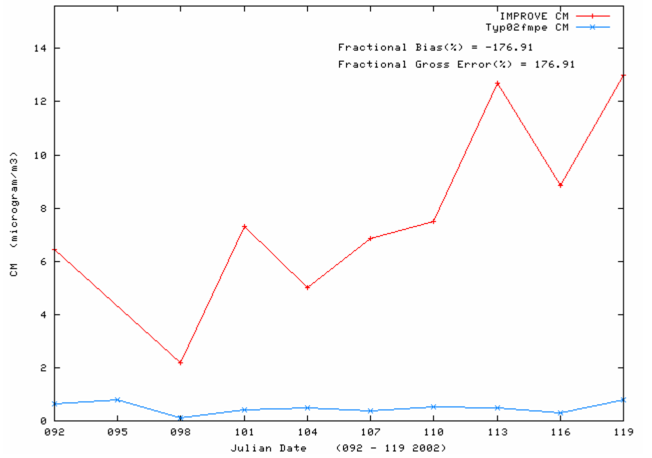
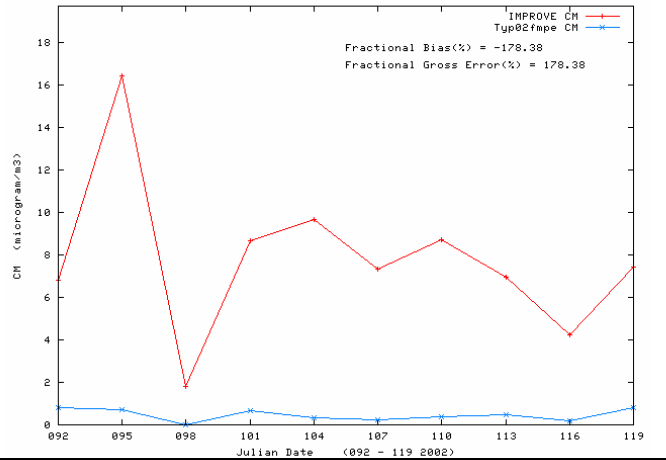


Figure C-35a. Scatter plots of predicted and observed coarse mass (CM) concentrations for April 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

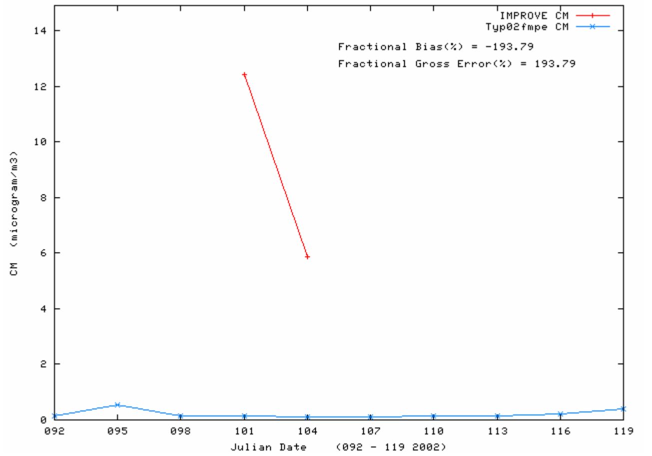
Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1



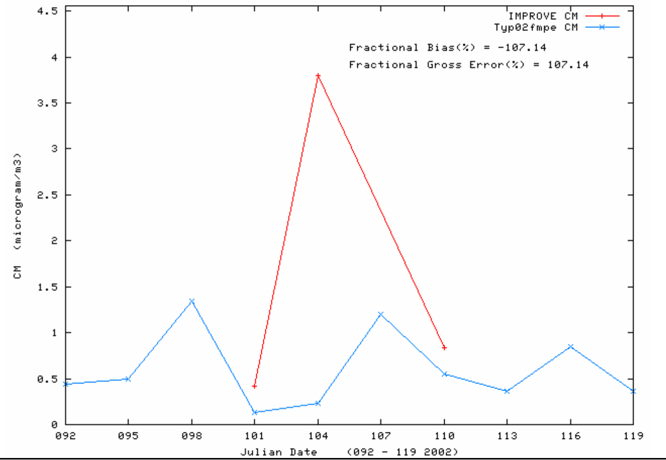
Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1



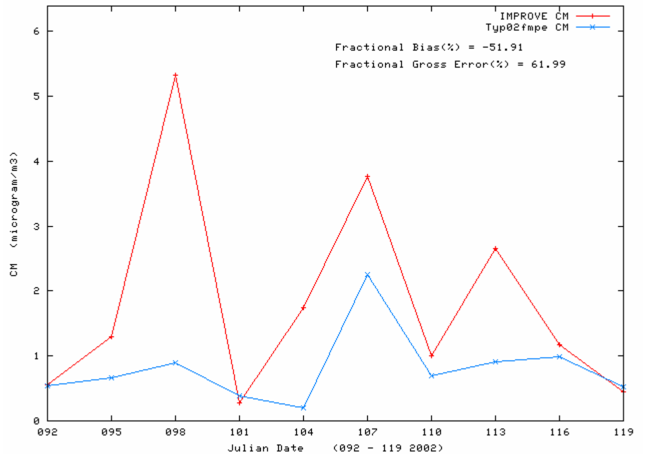
Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1



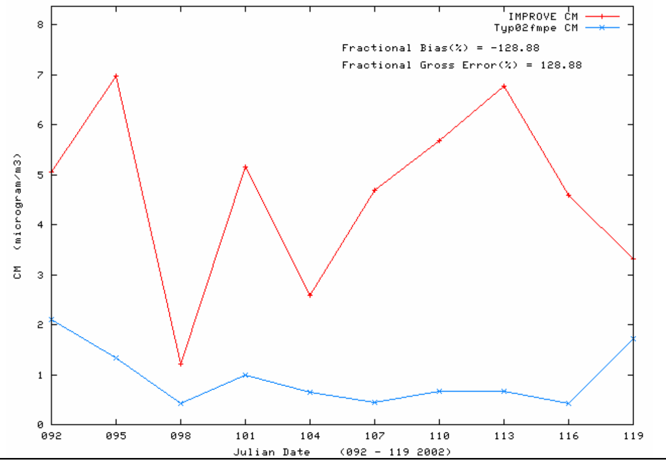
Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1



Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2



Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1



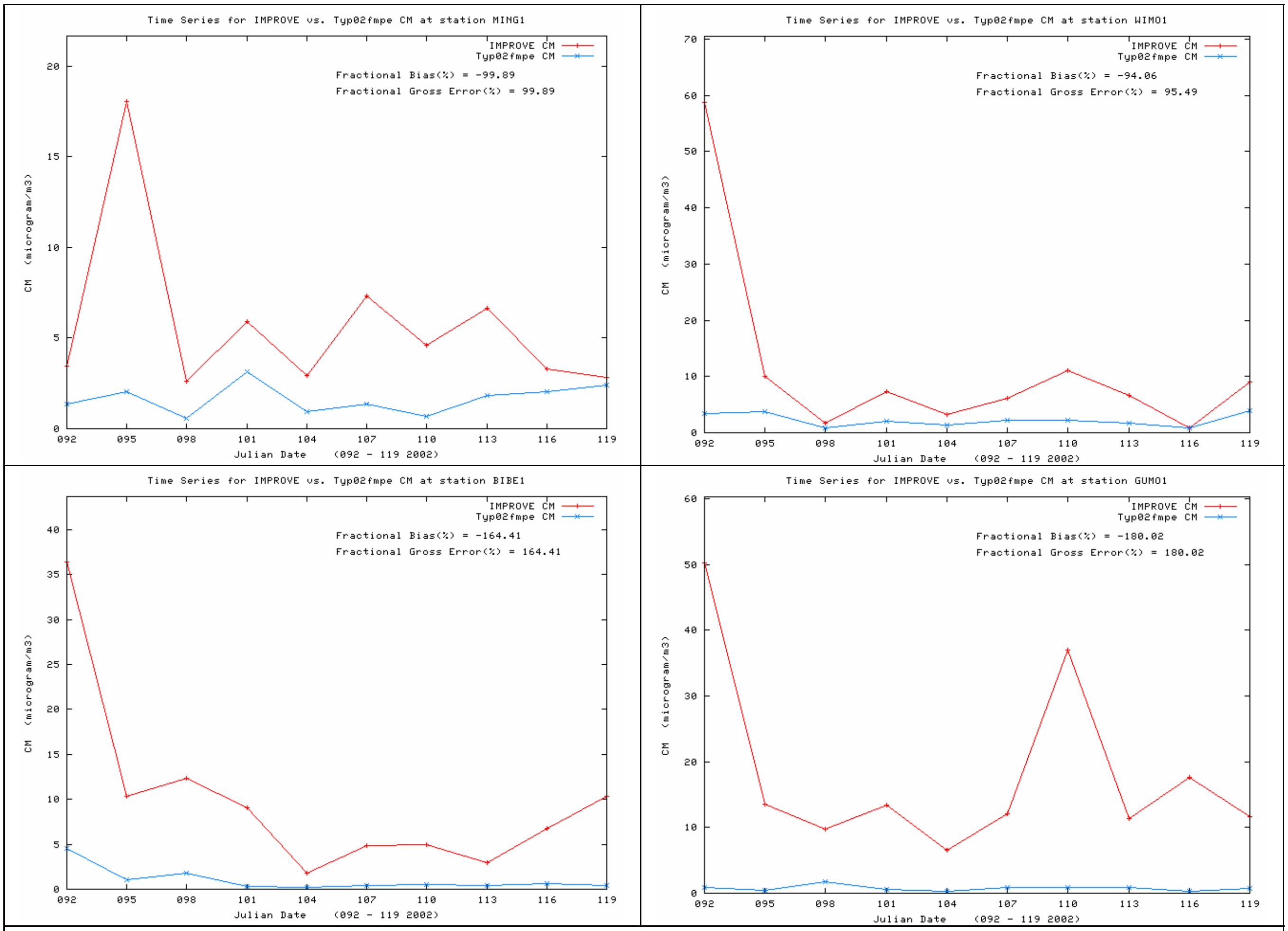


Figure C-35b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

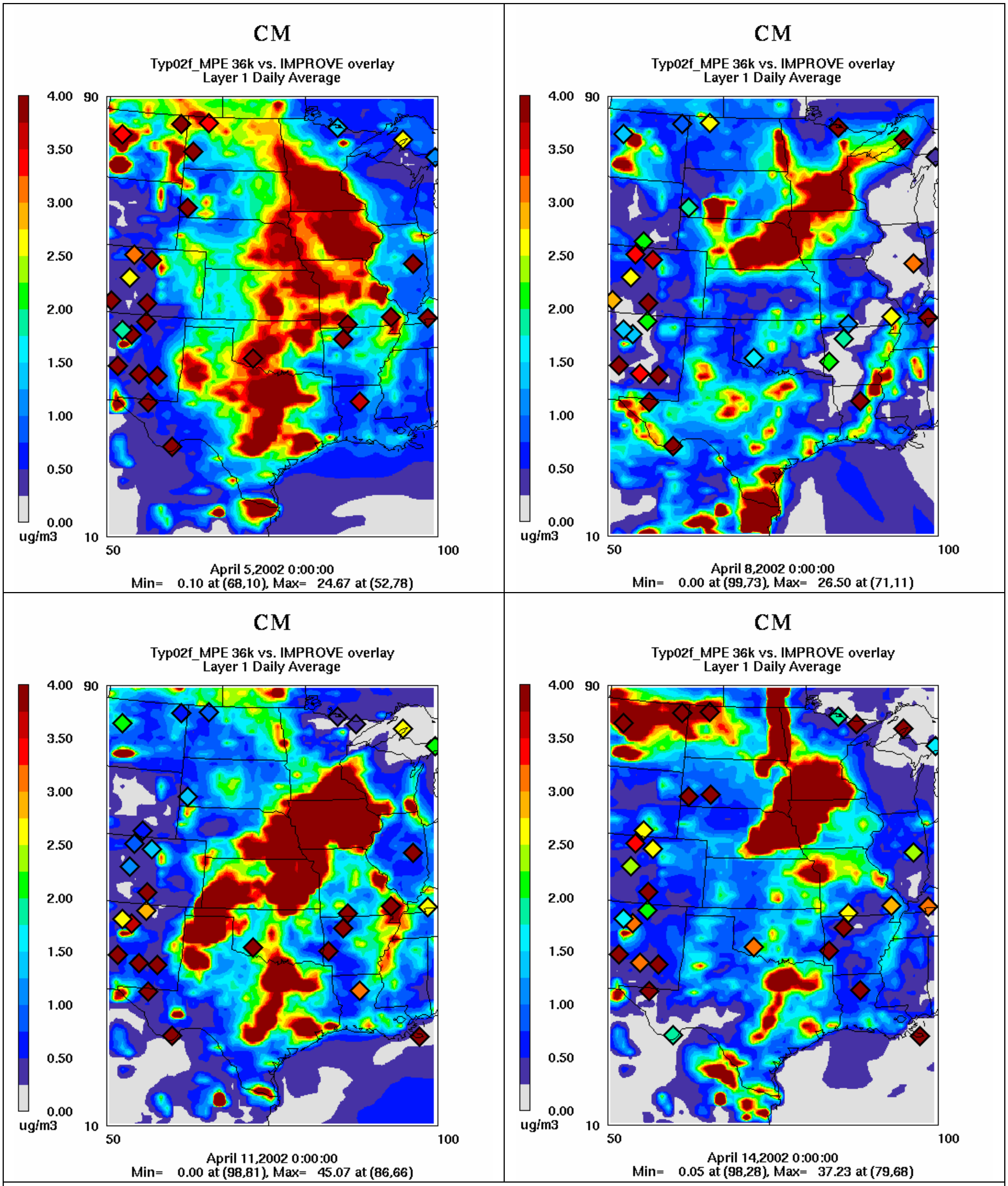


Figure C-35c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for April 5, 8, 11 and 14, 2002.

C.3.6.3 CM in July 2002

CM performance in July is also very poor with a fractional bias value of -160% (Figure C-36).

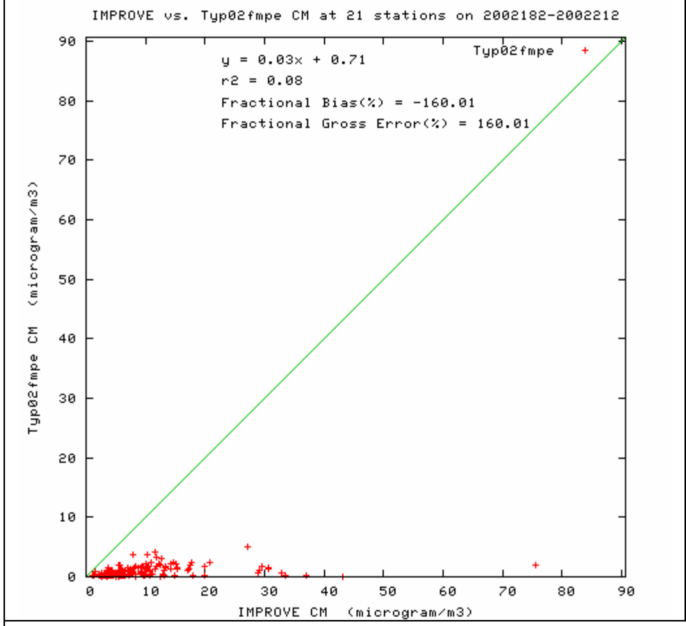
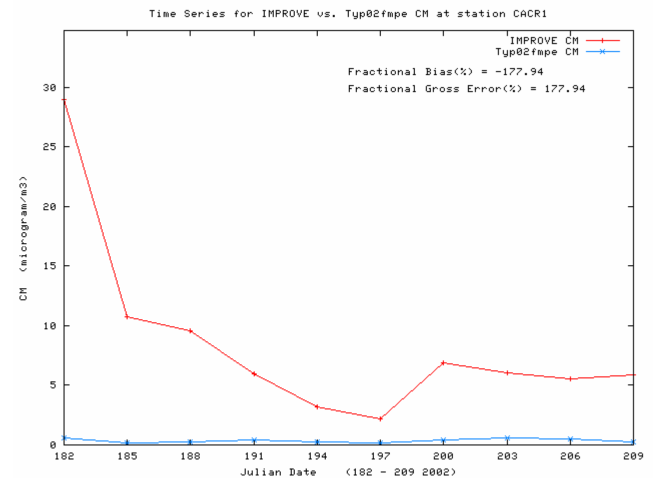
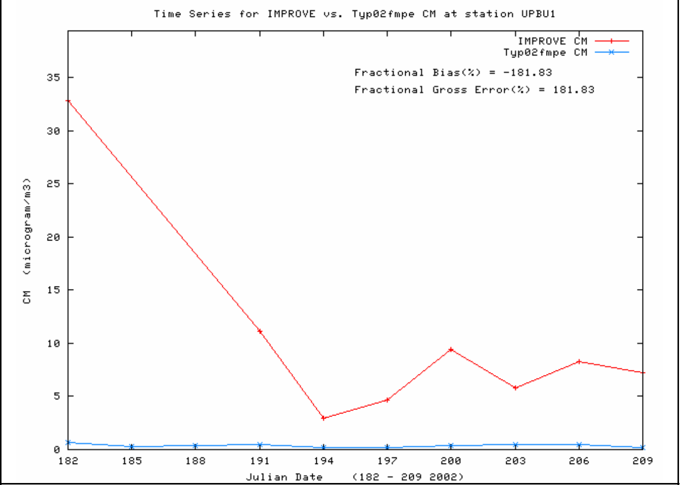
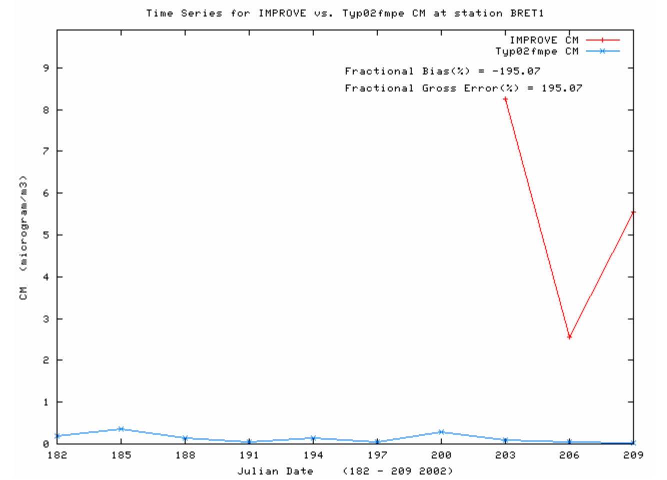
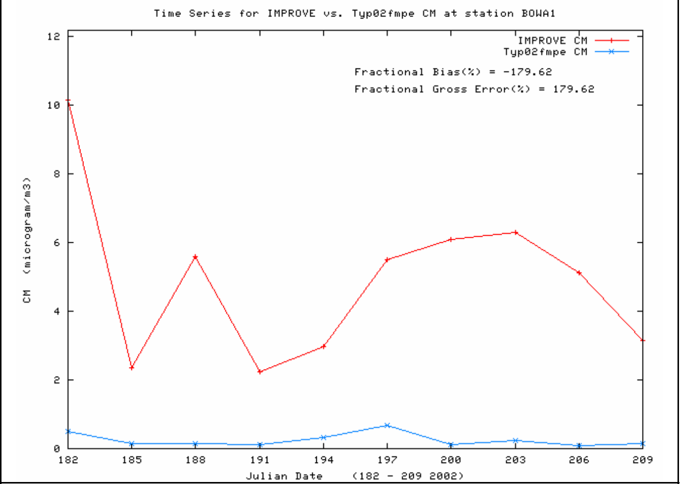


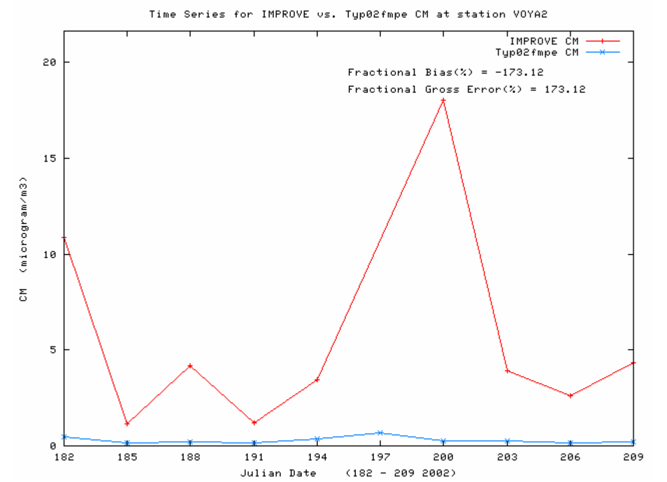
Figure C-36a. Scatter plots of predicted and observed coarse mass (CM) concentrations for July 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

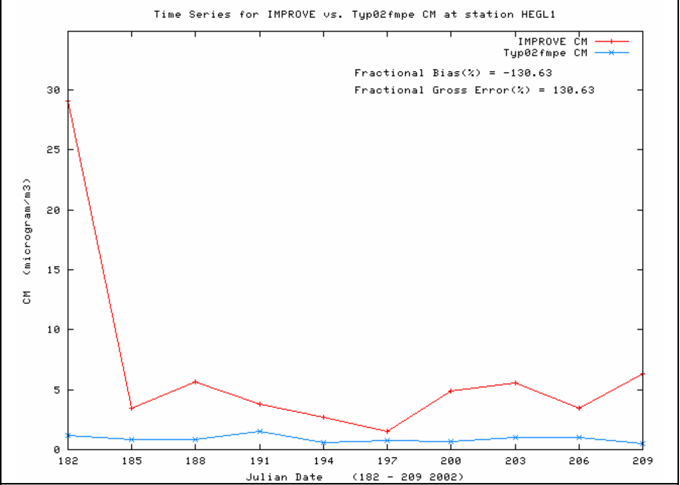

Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -177.94
Fractional Gross Error(%) = 177.94
CM (microgram/m3)
0
5
10
15
20
25
30
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -181.83
Fractional Gross Error(%) = 181.83
CM (microgram/m3)
0
5
10
15
20
25
30
35
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -195.07
Fractional Gross Error(%) = 195.07
CM (microgram/m3)
0
1
2
3
4
5
6
7
8
9
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -179.62
Fractional Gross Error(%) = 179.62
CM (microgram/m3)
0
2
4
6
8
10
12
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -173.12
Fractional Gross Error(%) = 173.12
CM (microgram/m3)
0
5
10
15
20
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -130.63
Fractional Gross Error(%) = 130.63
CM (microgram/m3)
0
5
10
15
20
25
30
182
185
188
191
194
197
200
203
206
209
Julian Date (182 - 209 2002)

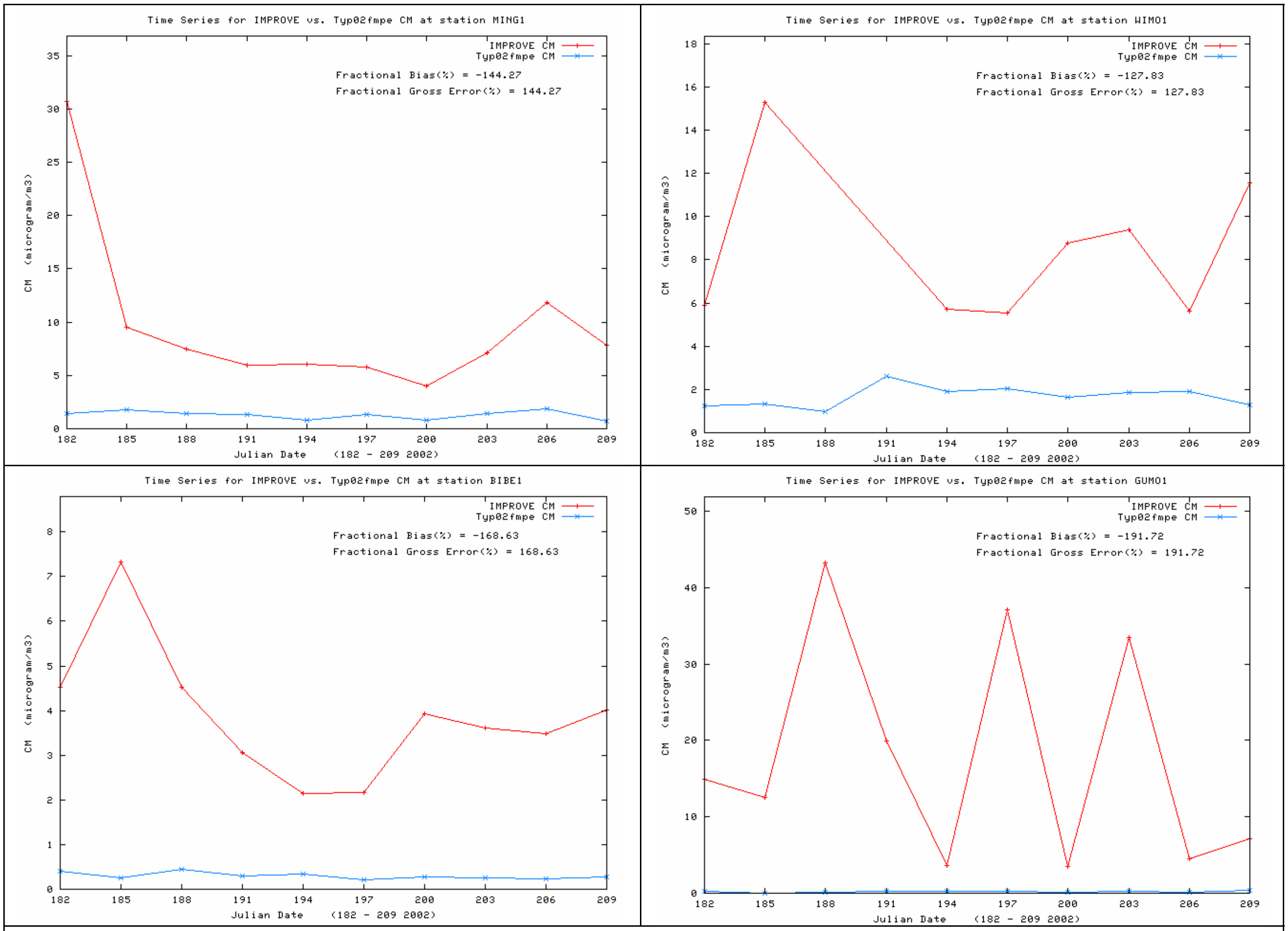


Figure C-36b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

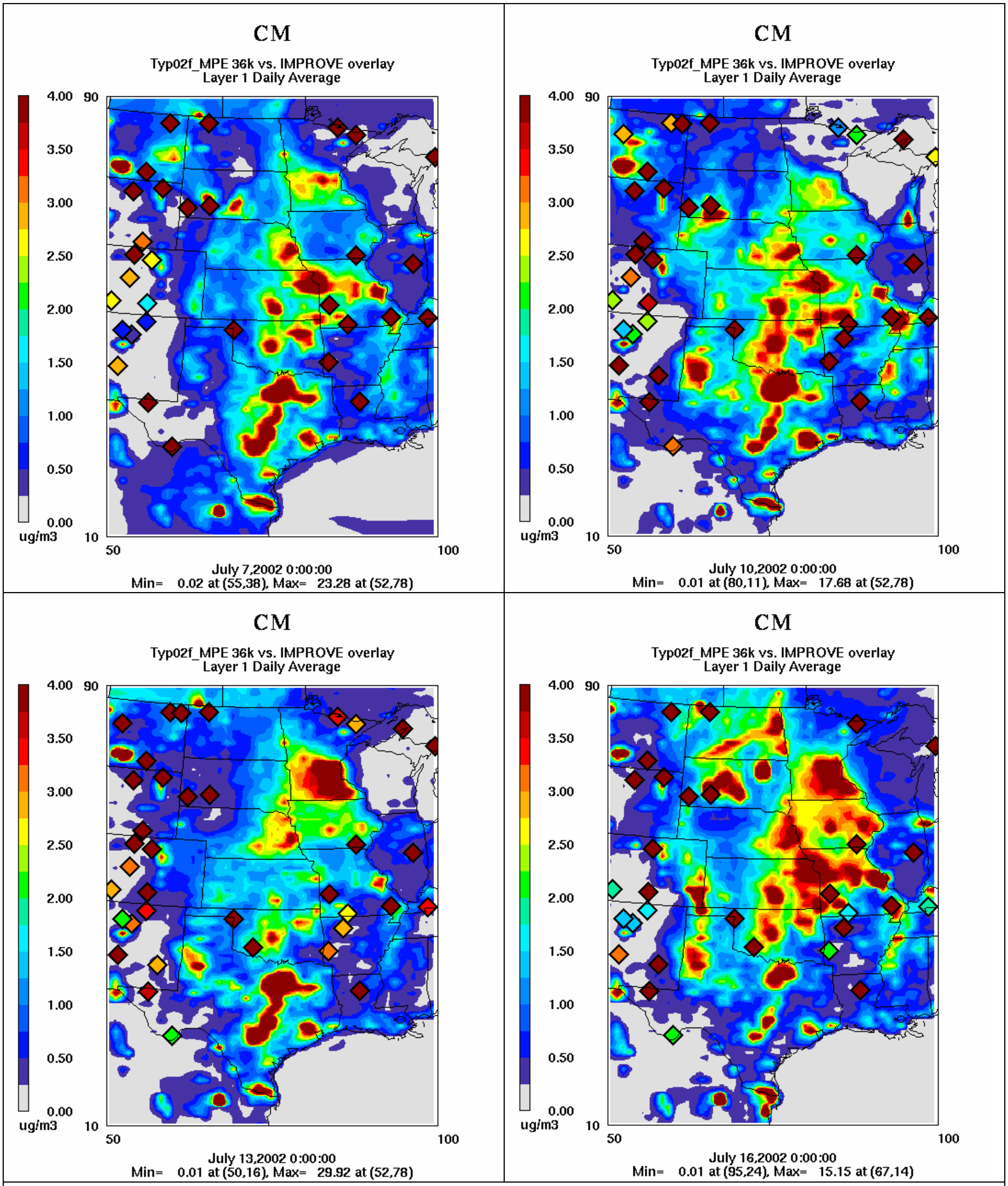


Figure C-36c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for July 7, 10, 13 and 16, 2002.

C.3.6.4 CM in October 2002

CM is also underestimated in October, although the overestimation bias (-72%) is not as great as seen in July (Figure C-37).

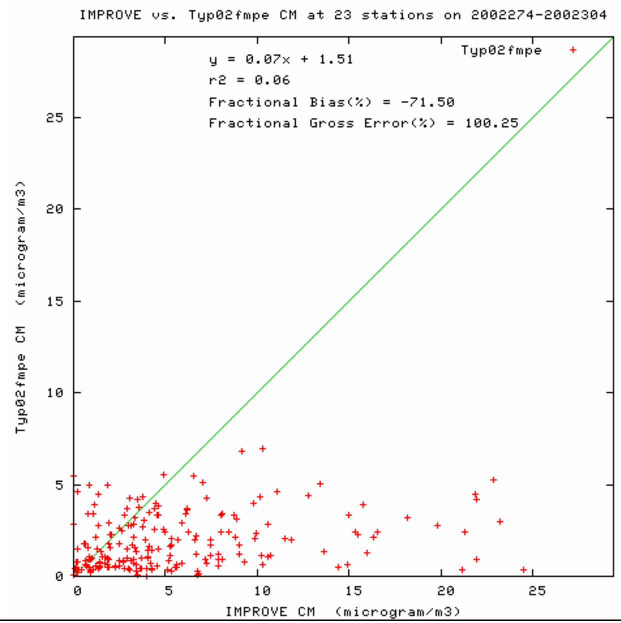
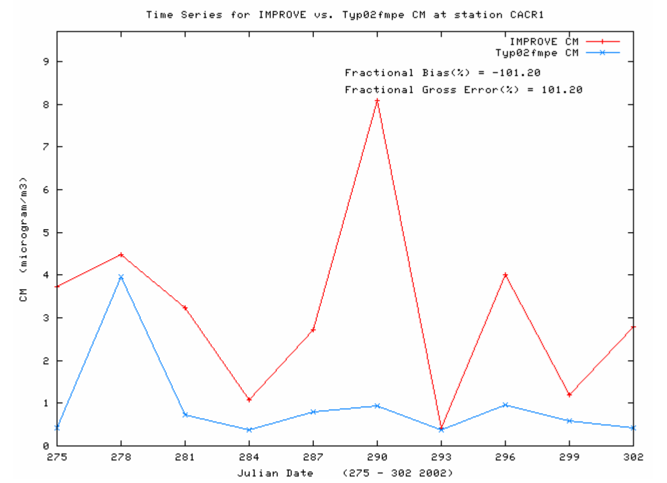
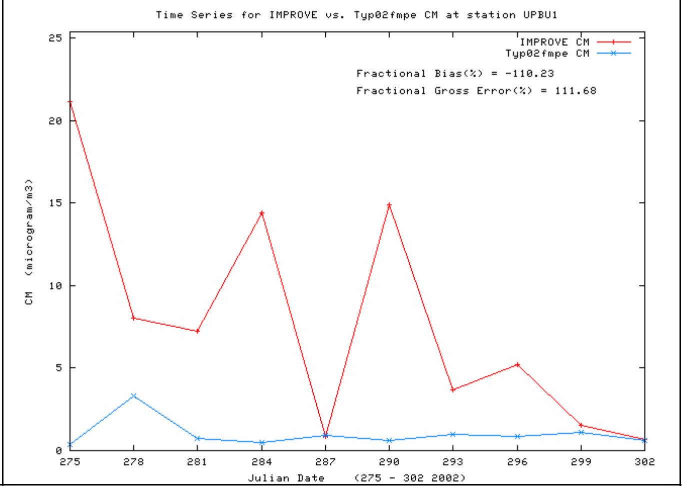


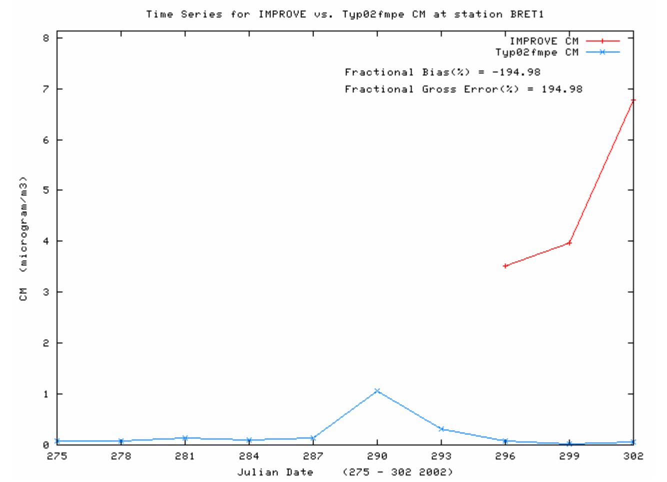
Figure C-37a. Scatter plots of predicted and observed coarse mass (CM) concentrations for October 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.



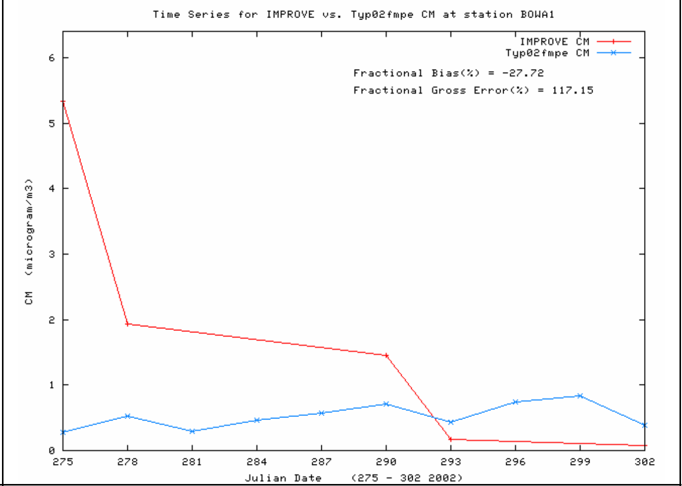
Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -101.20
Fractional Gross Error(%) = 101.20
CM (microgram/m3)
0
1
2
3
4
5
6
7
8
9
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)



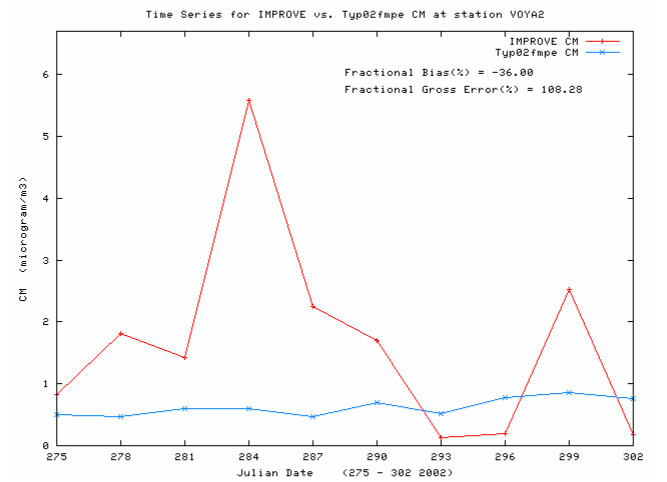
Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -110.23
Fractional Gross Error(%) = 111.68
CM (microgram/m3)
0
5
10
15
20
25
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)



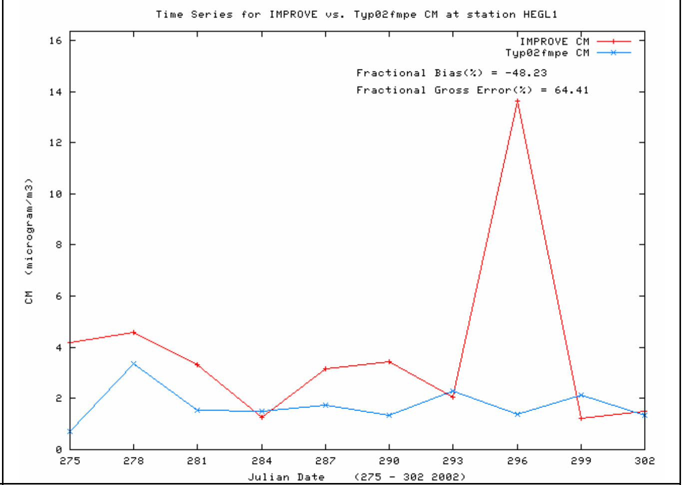
Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -194.98
Fractional Gross Error(%) = 194.98
CM (microgram/m3)
0
1
2
3
4
5
6
7
8
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)



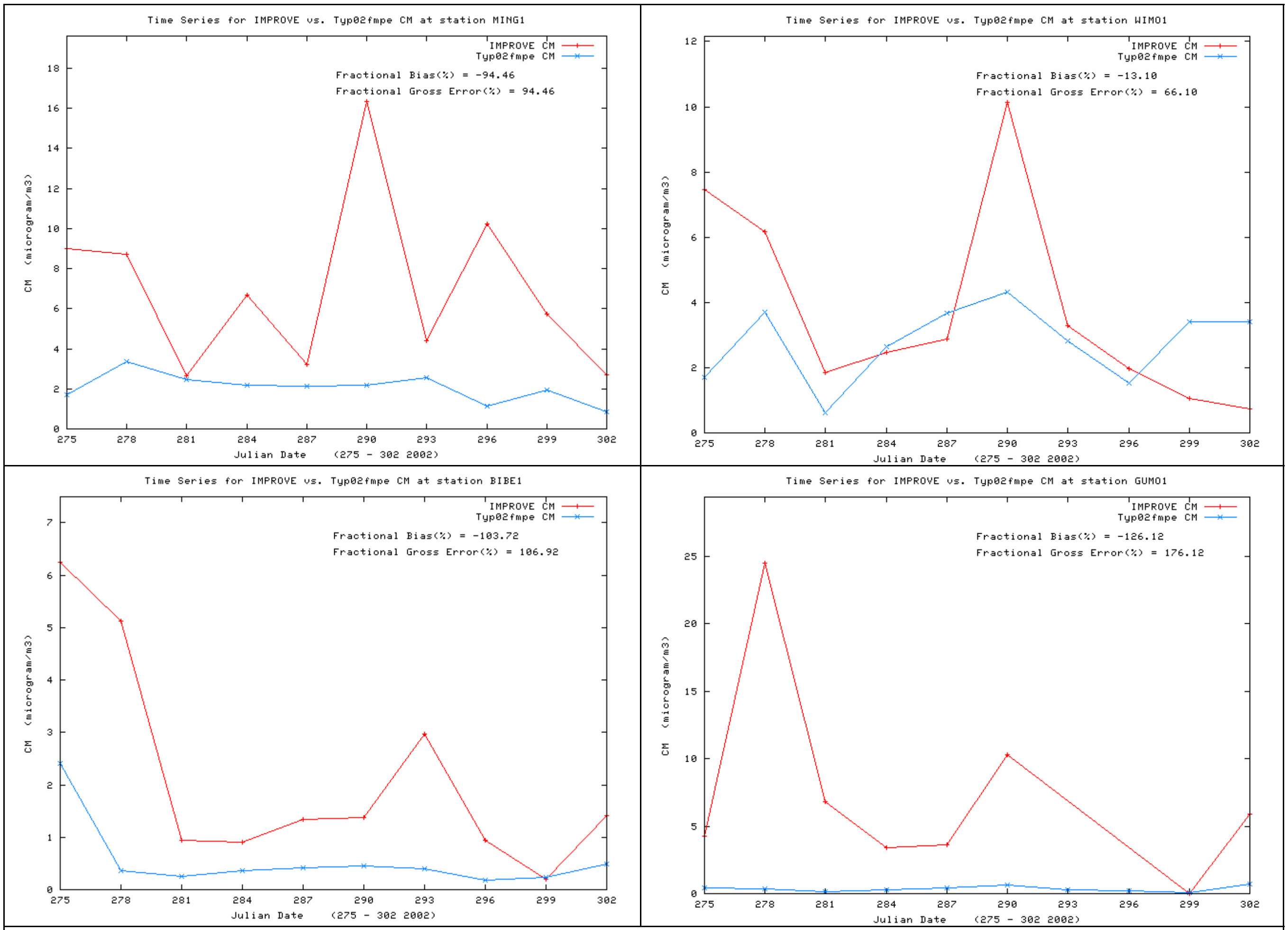
Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -27.72
Fractional Gross Error(%) = 117.15
CM (microgram/m3)
0
1
2
3
4
5
6
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)



Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -36.00
Fractional Gross Error(%) = 108.28
CM (microgram/m3)
0
1
2
3
4
5
6
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)



Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -48.23
Fractional Gross Error(%) = 64.41
CM (microgram/m3)
0
2
4
6
8
10
12
14
16
275
278
281
284
287
290
293
296
299
302
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station MING1

Time Series for IMPROVE vs. Typ02fmpe CM at station WIMO1

Time Series for IMPROVE vs. Typ02fmpe CM at station BIBE1

Time Series for IMPROVE vs. Typ02fmpe CM at station GUMO1

Figure C-37b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

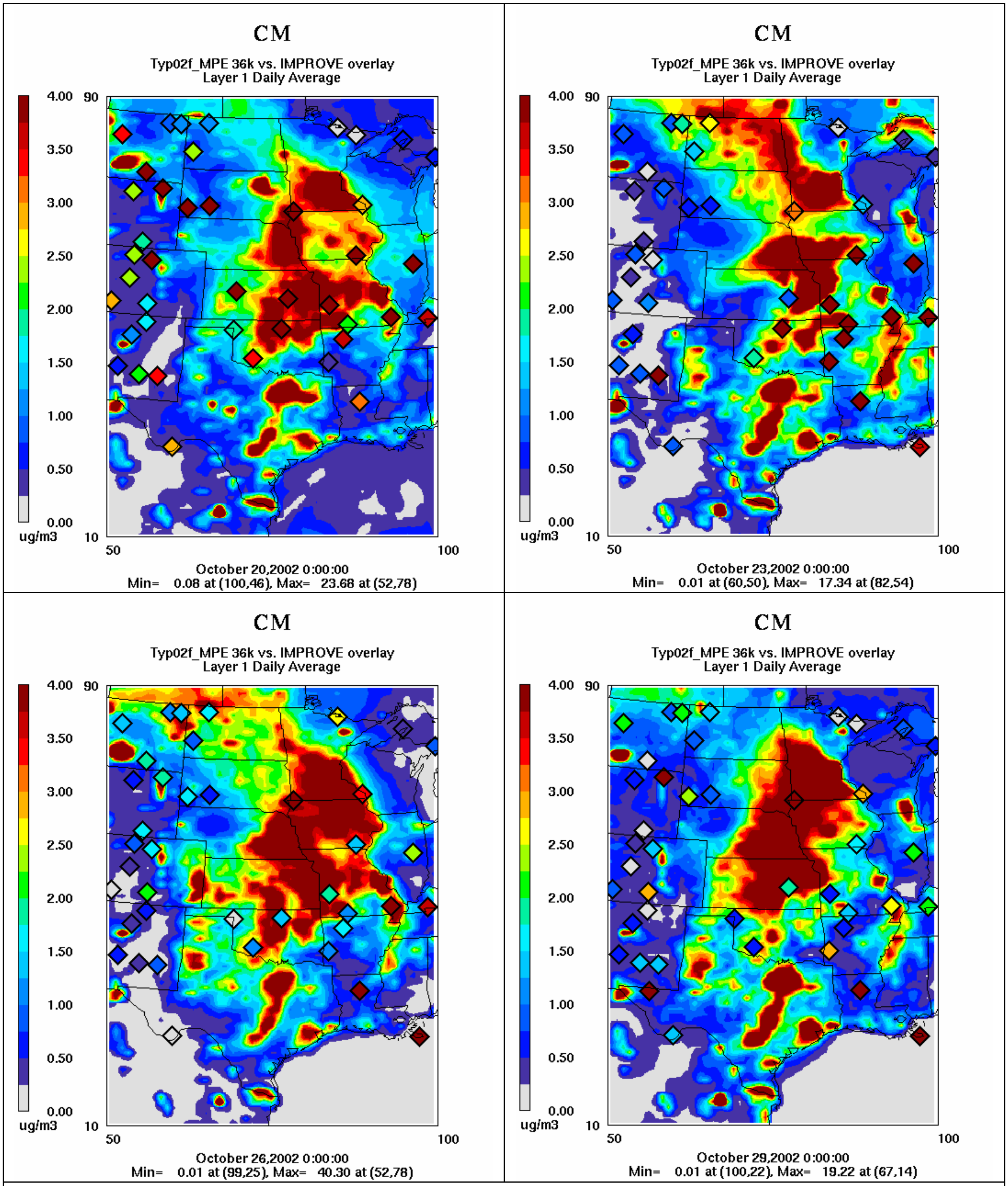


Figure C-37c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for October 20, 23, 26 and 29, 2002.

C.3.6.5 CM Monthly Bias and Error

The monthly average fractional bias and error values for CM are shown in Figure C-38. In the winter the under-prediction bias is typically in the -60% to -80% range. In the late Spring and Summer the under-prediction bias ranges from -120% to -160%. As this under-prediction bias is nearly systematic, then the errors are the same magnitude as the bias.

The Bugle Plots clearly show that the CM model performance is a problem. The monthly bias exceeds both the performance goal and criteria for almost every month of the year. The error criteria are also exceeded for all months of the year.

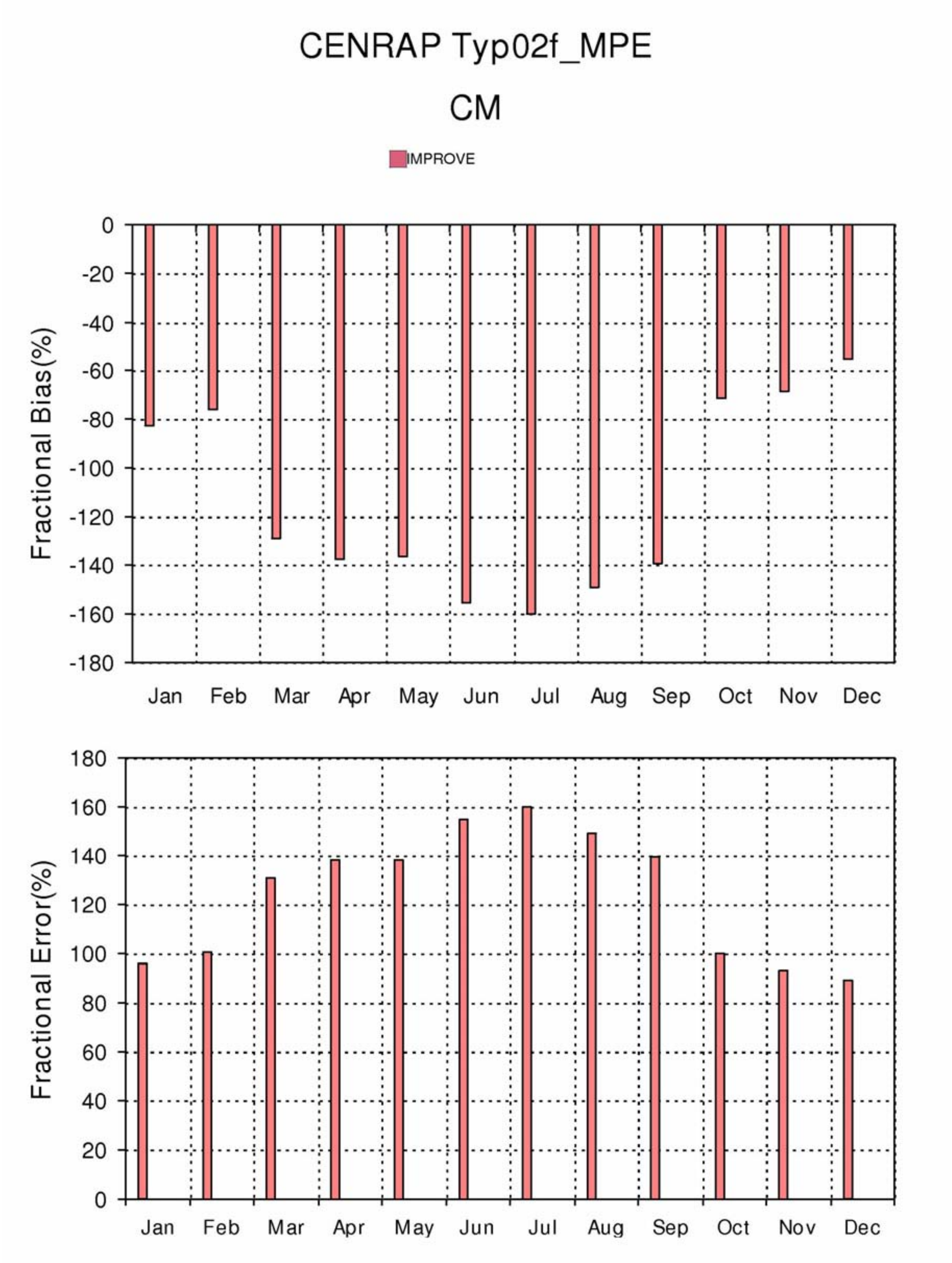


Figure C-38. Monthly CM fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE monitoring sites in the CENRAP region.

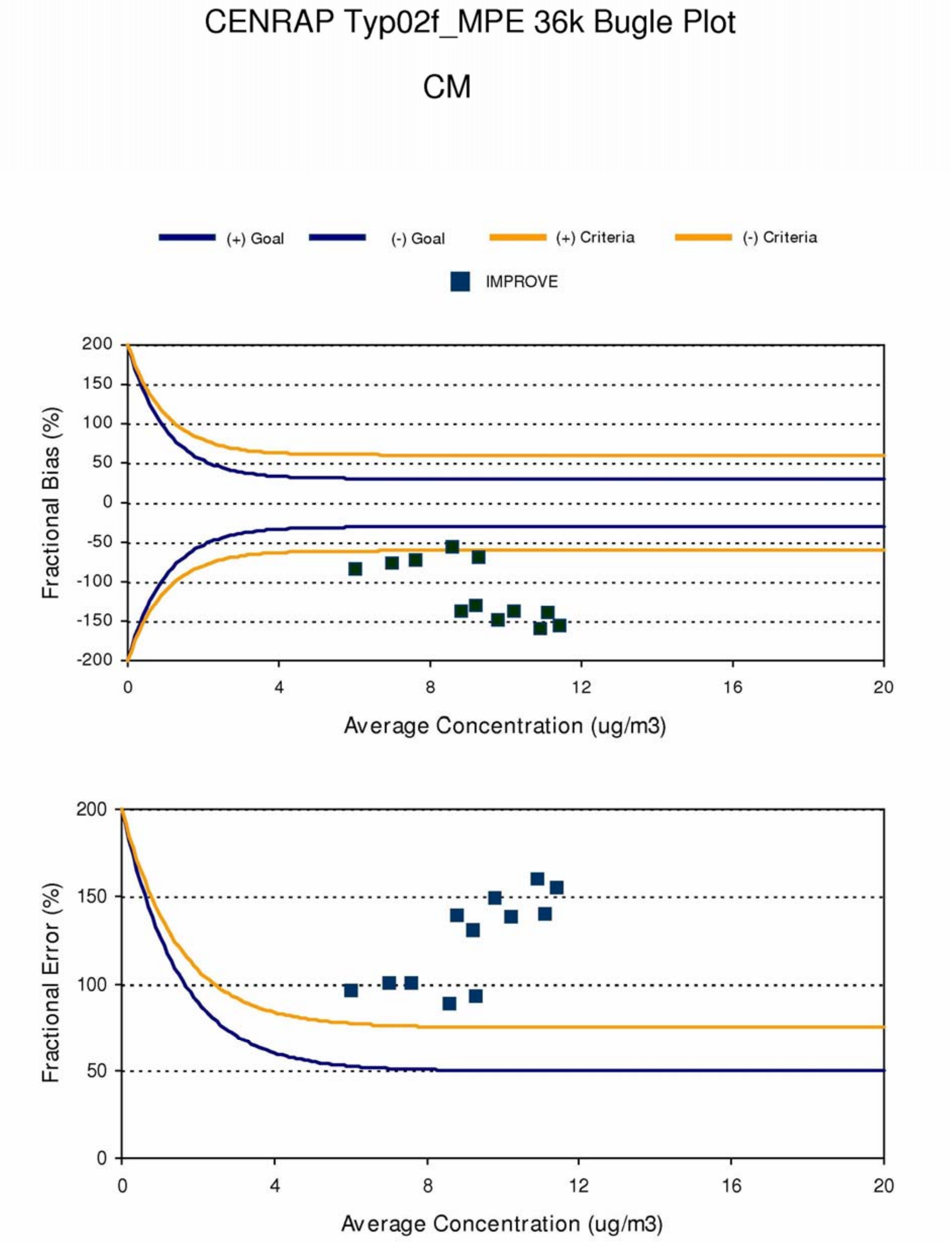


Figure C-39. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for CM and IMPROVE monitoring sites in the CENRAP region.

C.4 Diagnostic Model Evaluation for Gas-Phase and Precursor Species

The CASTNet and AQS networks also measure gas-phase species that are PM precursor or related species. The diagnostic evaluation of the 2002 36 km Base F CMAQ base case simulation for these compounds and the four seasonal months presented previously is provided below.

The CASTNet network measures weekly average samples of SO2, SO4, NO2, HNO3, NO3 and NH4. The AQS network collects hourly measurements of SO2, NO2, O3 and CO. A comparison of the SO2 and SO4 performance provides insight into whether the SO4 formation rate may be too slow or fast. For example, if SO4 is underestimated and SO2 is overestimated that may indicate too slow chemical conversion rate. Analyzing the performance for SO4, HNO3, NO3, Total NO3 and NH4 provides insight into the equilibrium of these species. For example, if Total NO3 performs well but HNO3 and NO3 do not, then there may be issues associated with the partitioning between the gaseous and particle phases of nitrate.

C.4.1 Diagnostic Model Performance in January 2002

In January, SO2 is overstated across both the CASTNet and AQS sites with fractional bias values of 38% (Figure C-40) and 31% (Figure C-41), respectively. SO4 is understated by -34% across the CASTNet monitors (Figure C-40) and -12% and -13% for the IMPROVE and STN networks (Figure C-4a). As noted previously, wet SO4 deposition is also overstated in January (+40%, Figure C-4a). Given that SO2 emissions are well characterized, these results suggest that the January SO4 underestimation may be partly due to understated transformation rates of So2 to SO4 and overstated wet SO4 deposition.

Total NO3 is overestimated by 35% on average across the CASTNet sites in the CENRAP region in January (Figure C-40). HNO3 is underestimated (-34%) and particle NO3 is overestimated (+61%) suggesting there are gas/particle equilibrium issues. An analysis of the time series of the four CASTNet stations reveals that NO3, HNO3 and NH4 performance is actually very reasonable at the west Texas and the HNO3 underestimation and NO3 overestimation bias is coming from the east Kansas, central Arkansas and northern Minnesota CASTNet sites. One potential contributor for this performance problem is overstated NH3 emissions. However the overstated Total NO3 suggests that the model estimated NOx oxidation rate may be too high in January.

The SO2, NO2, O3 and CO performance across the AQS sites in January is shown in Figure C-41. The AQS monitoring network is primarily an urban-oriented network so it is not surprising that the model is underestimating concentrations of primary emissions like NO2 (-5%) and particularly CO (-67%) when a 36 km grid is used. Ozone is also underestimated on average, especially the maximum values above 60 ppb.

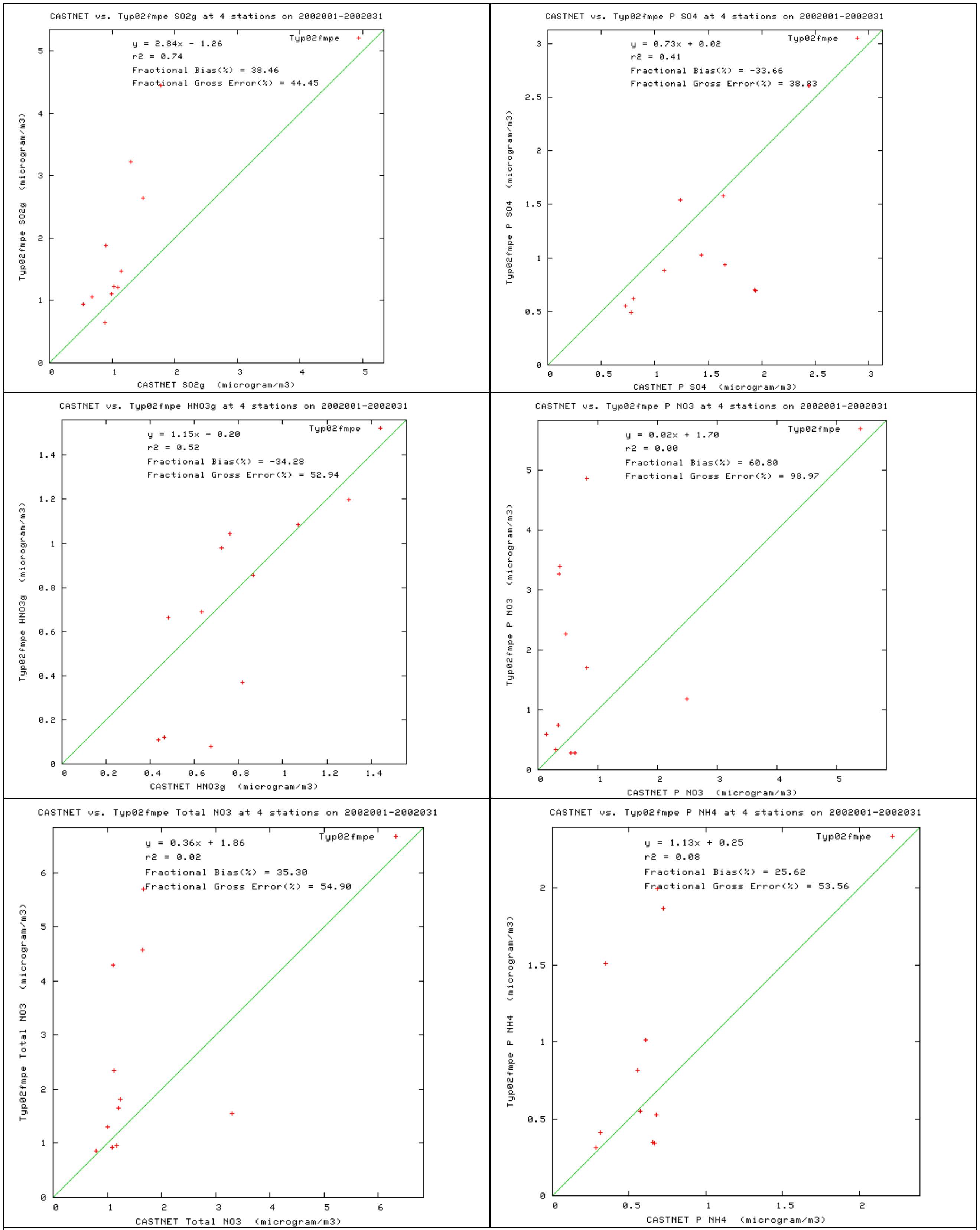


Figure C-40. January 2002 performance at CENRAP CASTNet sites for SO2 (top left), SO4 (top right), HNO3 (middle left), NO3 (middle right), Ttoal NO3 (bottom left) and NH4 (bottom right).

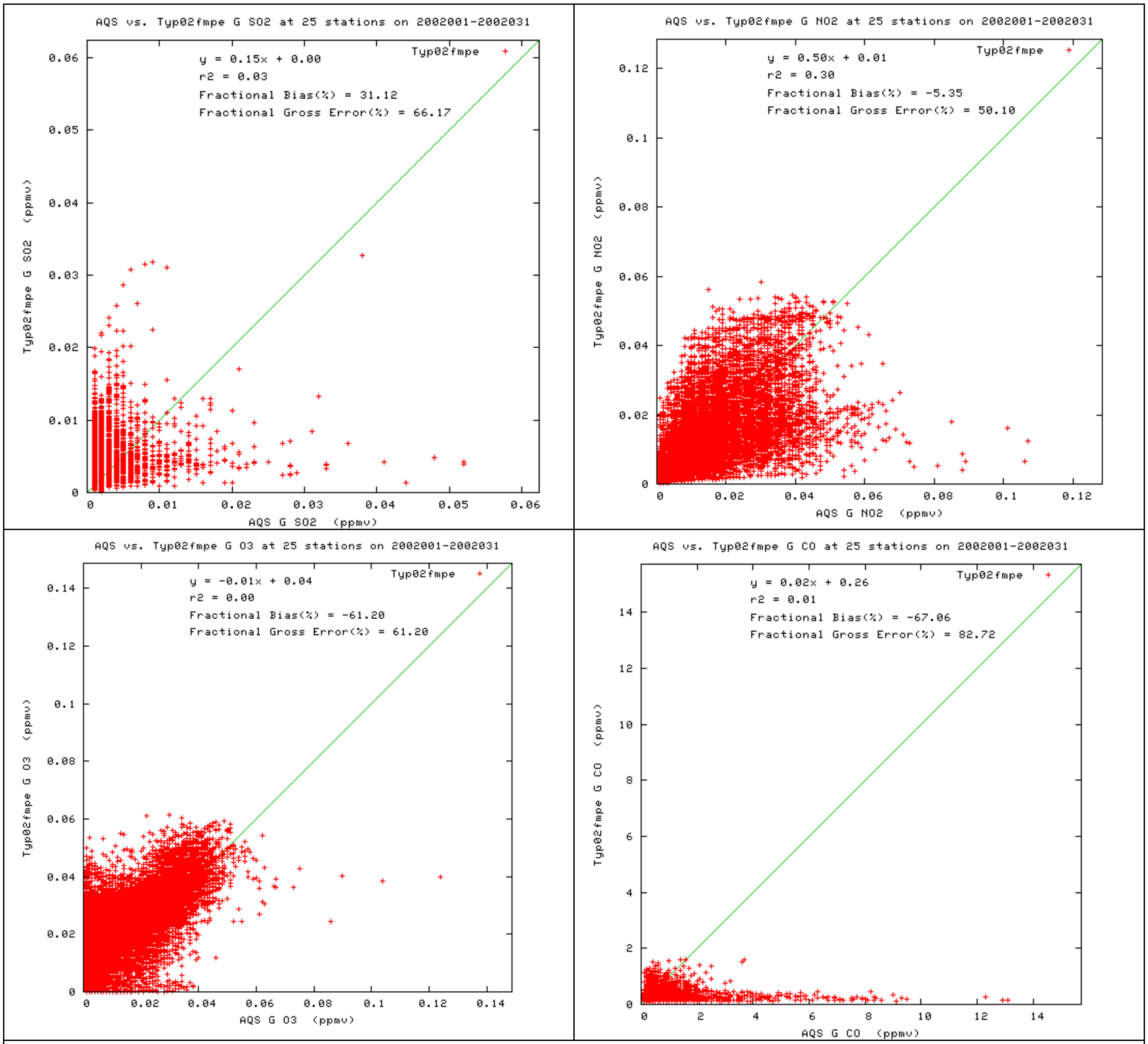


Figure C-41. January 2002 performance at CENRAP AQS sites for SO2 (top left), NO2 (top right), O3 (bottom left) and CO (bottom right).

C.4.2 Diagnostic Model Performance In April

In April there is an average SO2 overestimation bias across the CASTNet (+15%) and underestimation bias across the AQS (-10%) networks (Figures C-42 and C-43). SO4 is underestimated across all networks by -30% to -58% (Figure C-5a). The wet SO4 deposition bias is near zero. Both SO2 and SO4 are underestimated at the west Texas CASTNet monitor in April suggesting SO2 emissions in Mexico are likely understated.

The HNO3 performance in April is interesting with almost perfect agreement except for 5 modeled-observed comparisons that drives the average under-prediction bias of -29%. On Julian Day 102 there is high HNO3 at the MN, KS and OK CASTNet sites that is not captured by the model. Given that HNO3, NO3 and Total NO3 are all underestimated by about the same amount (-30%), then part of the underestimation bias is likely due to too slow oxidation of NOx.

There is a lot of scatter in the NO2 and O3 performance that is more or less centered on the 1:1 line of perfect agreement with bias values of -8% and -21%, respectively (Figure C-43). CO is underestimated by -72% with the model unable to predict CO concentrations above 1 $\mu g/m^3$ due to the use of the coarse 36 km grid spacing. Mobile sources produce a vast majority of the CO emissions so AQS monitors for CO compliance are located near roadways, which are not simulated well using a 36 km grid.

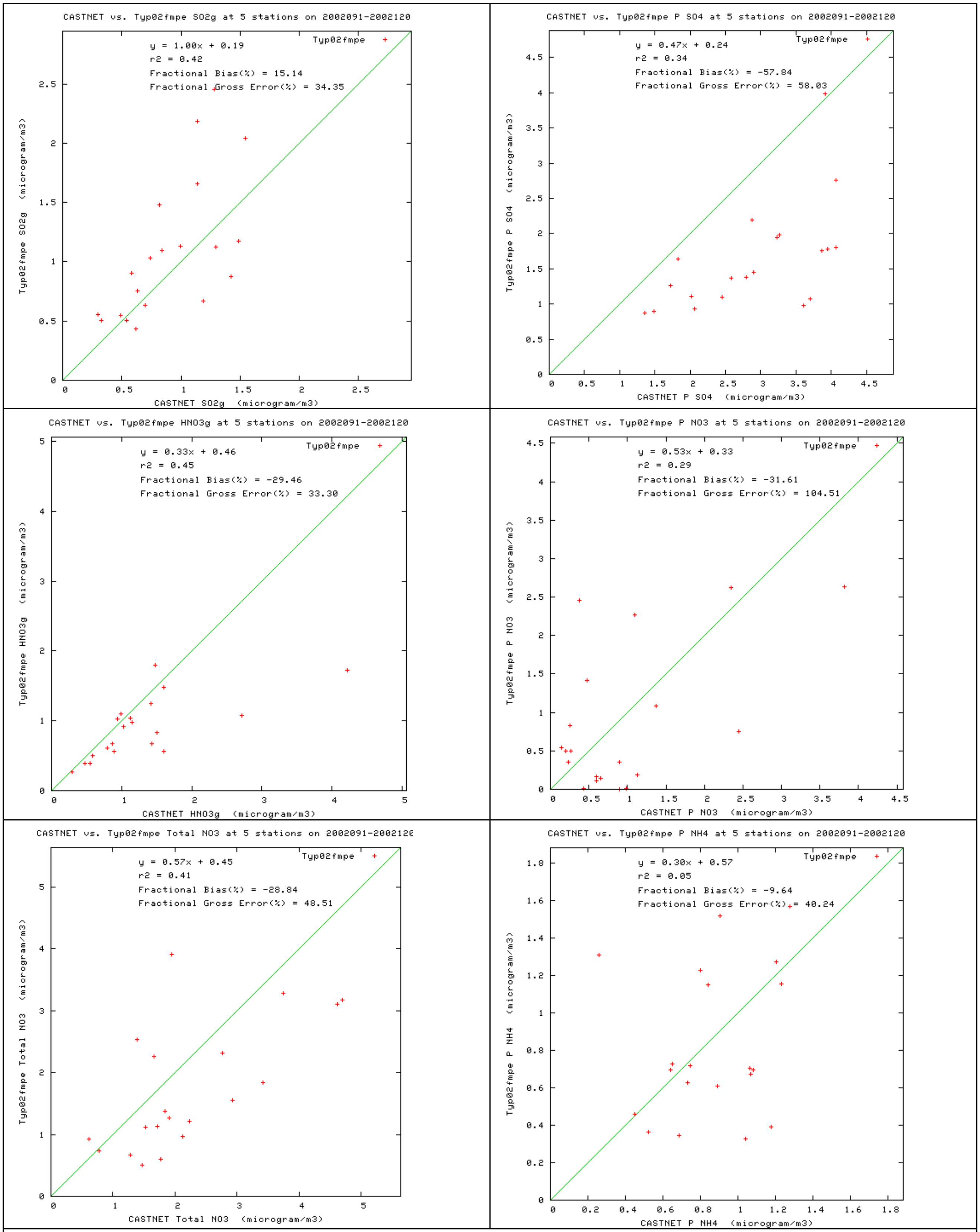


Figure C-42 April 2002 performance at CENRAP CASTNet sites for SO2 (top left), SO4 (top right), HNO3 (middle left), NO3 (middle right), Total NO3 (bottom left) and NH4 (bottom right).

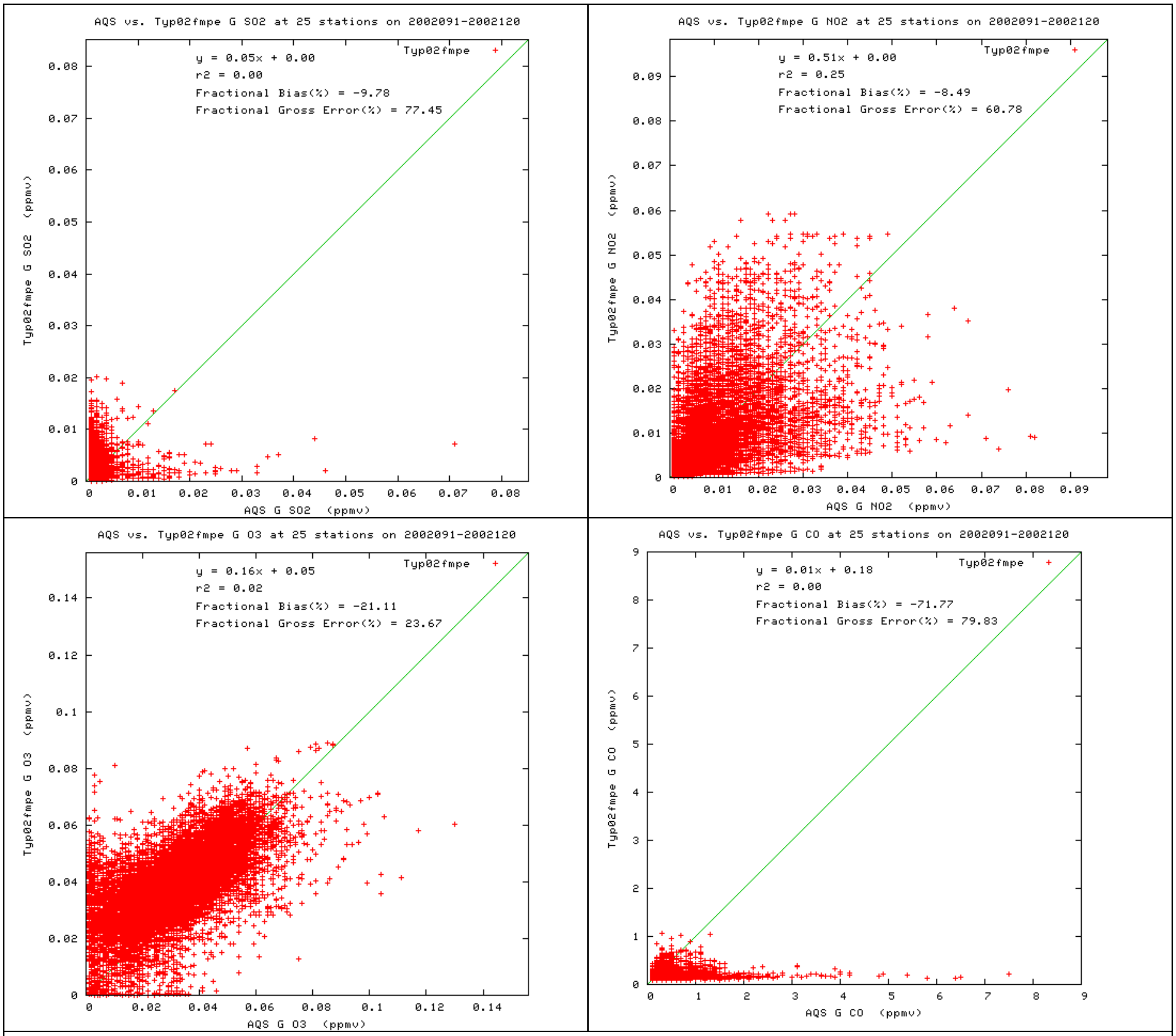


Figure C-43 April 2002 performance at CENRAP AQS sites for SO2 (top left), NO2 (top right), O3 (bottom left) and CO (bottom right).

C.4.3 Diagnostic Model Performance In July

In July SO2 is slightly underestimated across the CASTNet (-5%) and AQS (-12%) networks (Figures C-44 and C-45) and SO4 is more significantly underestimated across all networks (-22% to -53%, Figure C-6a). Since wet SO4 is also underestimated it is unclear the reasons for why all sulfur species are underestimated.

The nitrate species are also all underestimated with the Total NO3 bias (-56%) being between the HNO3 bias (-35%) and NO3 bias (-115%). The modeled NO3 values are all near zero with little correlation with the observations, whereas the observed HNO3 and Total NO3 is tracked well with correlation coefficients of 0.74 and 0.76. These results suggest that the July NO3 model performance problem is partly due to insufficient formation of Total NO3 and mainly due to too little incorrect partitioning of the Total NO3 into the particle NO3.

Again there is lots of scatter in the AQS NO2 scatter plot for July (Figure C-45) resulting in a low bias (0%) but high error (65%). Ozone performance also exhibits a low bias (-15%) and error (20%), but the model is incapable of simulating ozone above 100 ppb. Although CO performance in July is better than the previous months, it still has a large underestimation bias (-82%).

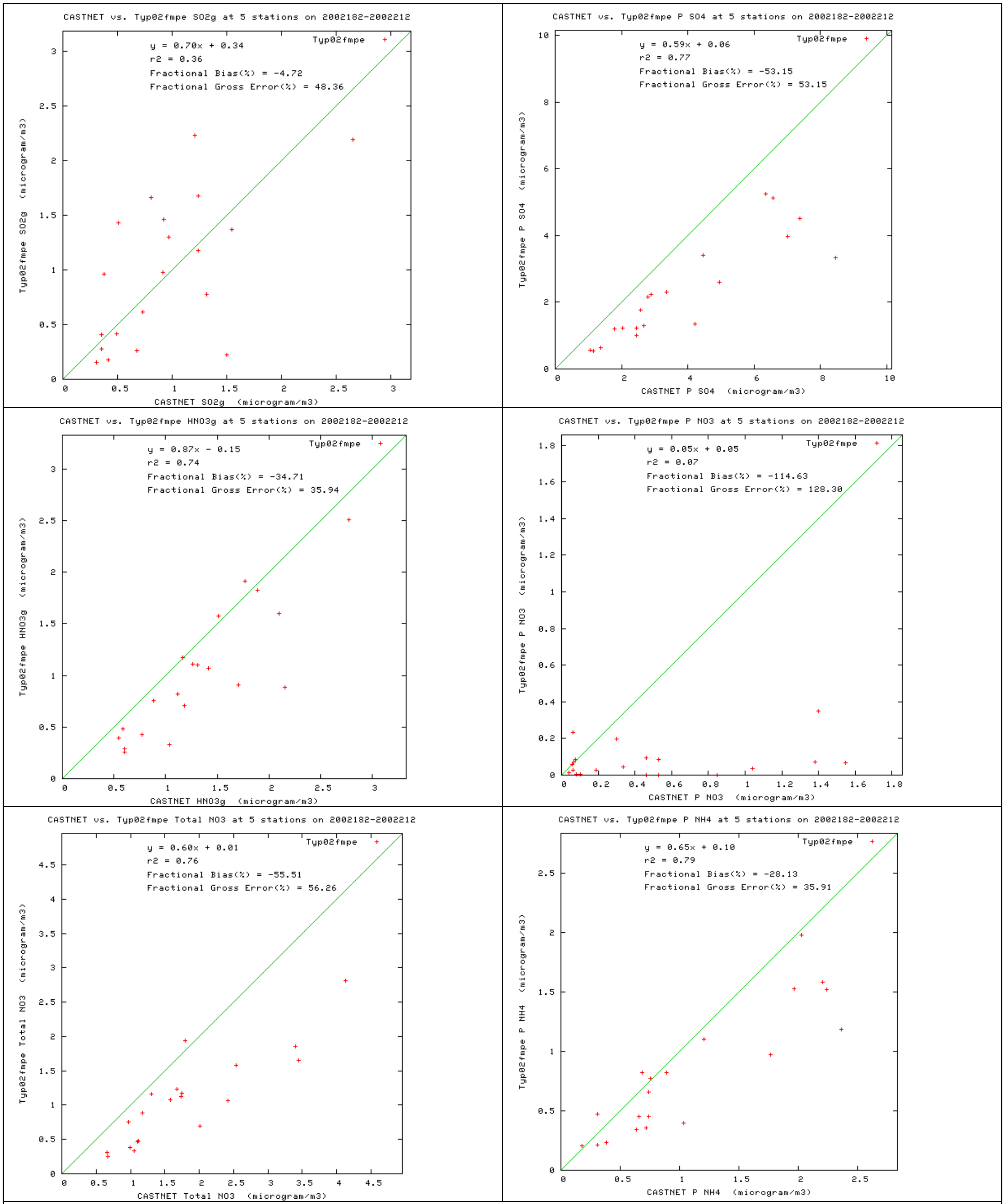


Figure C-44 July 2002 performance at CENRAP CASTNet sites for SO2 (top left), SO4 (top right), HNO3 (middle left), NO3 (middle right), Total NO3 (bottom left) and NH4 (bottom right).

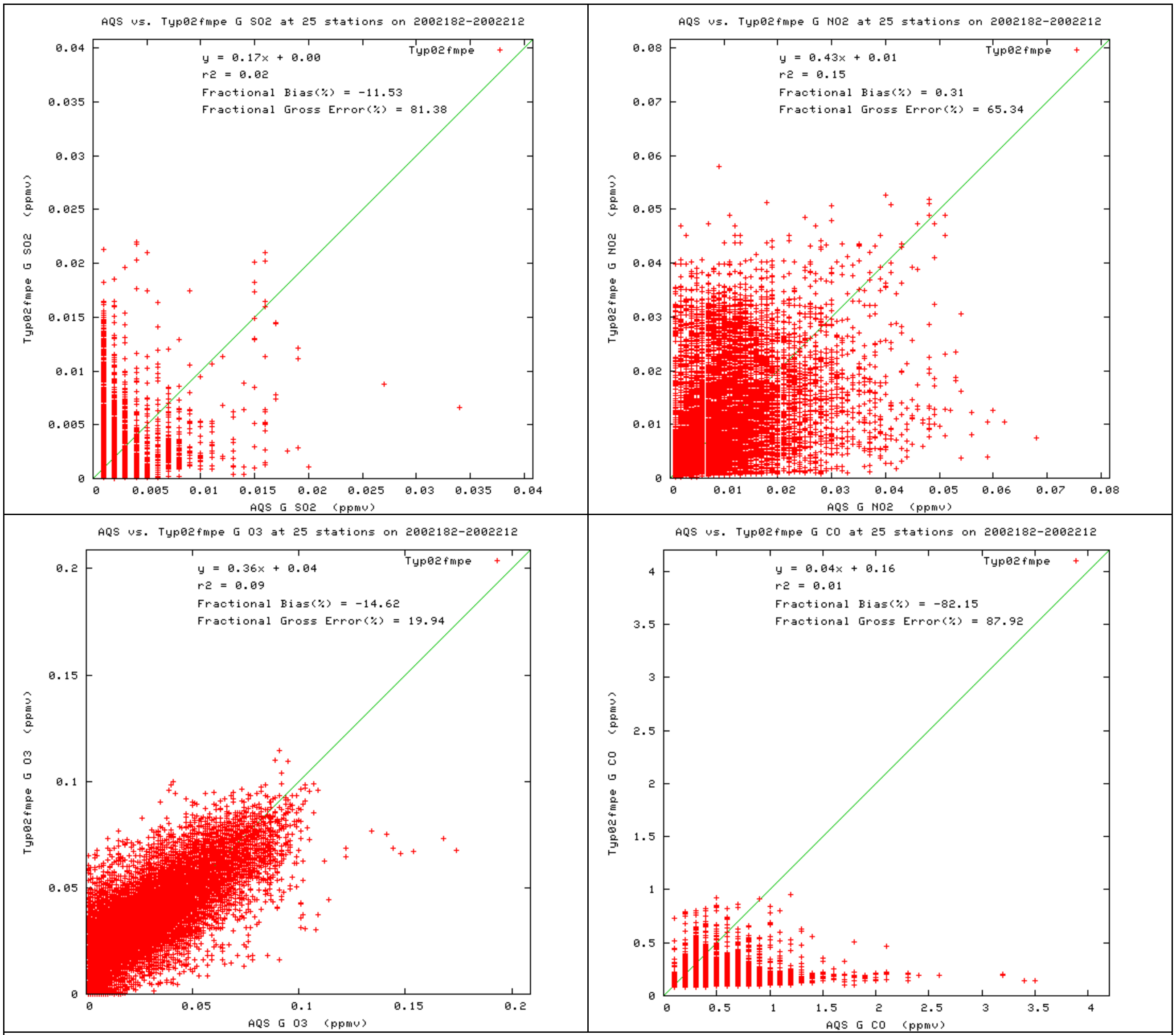


Figure C-45 July 2002 performance at CENRAP AQS sites for SO2 (top left), NO2 (top right), O3 (bottom left) and CO (bottom right).

C.4.4 Diagnostic Model Performance In October

SO2 is overstated in October across the CASTNet (+28%) and AQS (+33%) sites (Figures C-46 and C-47). Although SO4 is understated across the CASTNet sites (-24%), the bias across the IMPROVE (-6%) and STN (0%) sites are near zero (Figure C-7a).

Performance for HNO3 is fairly good with a low bias (+12%) and error (30%). But NO3 is overstated (+34%) leading to an overstatement of Total NO3 (+37%). The overstatement of NO3 leads to an overstatement of NH4 as well (Figure C-46)

As seen in the other months, NO2 exhibits a lot of scatter resulting in a low correlation (0.22) and high error (61%) but low bias (12%). The model tends to under-predict the high and over-predict the low O3 observations resulting in a -29% bias and low correlation coefficient. CO is also under-predicted (-76%) for the reasons discussed previously.

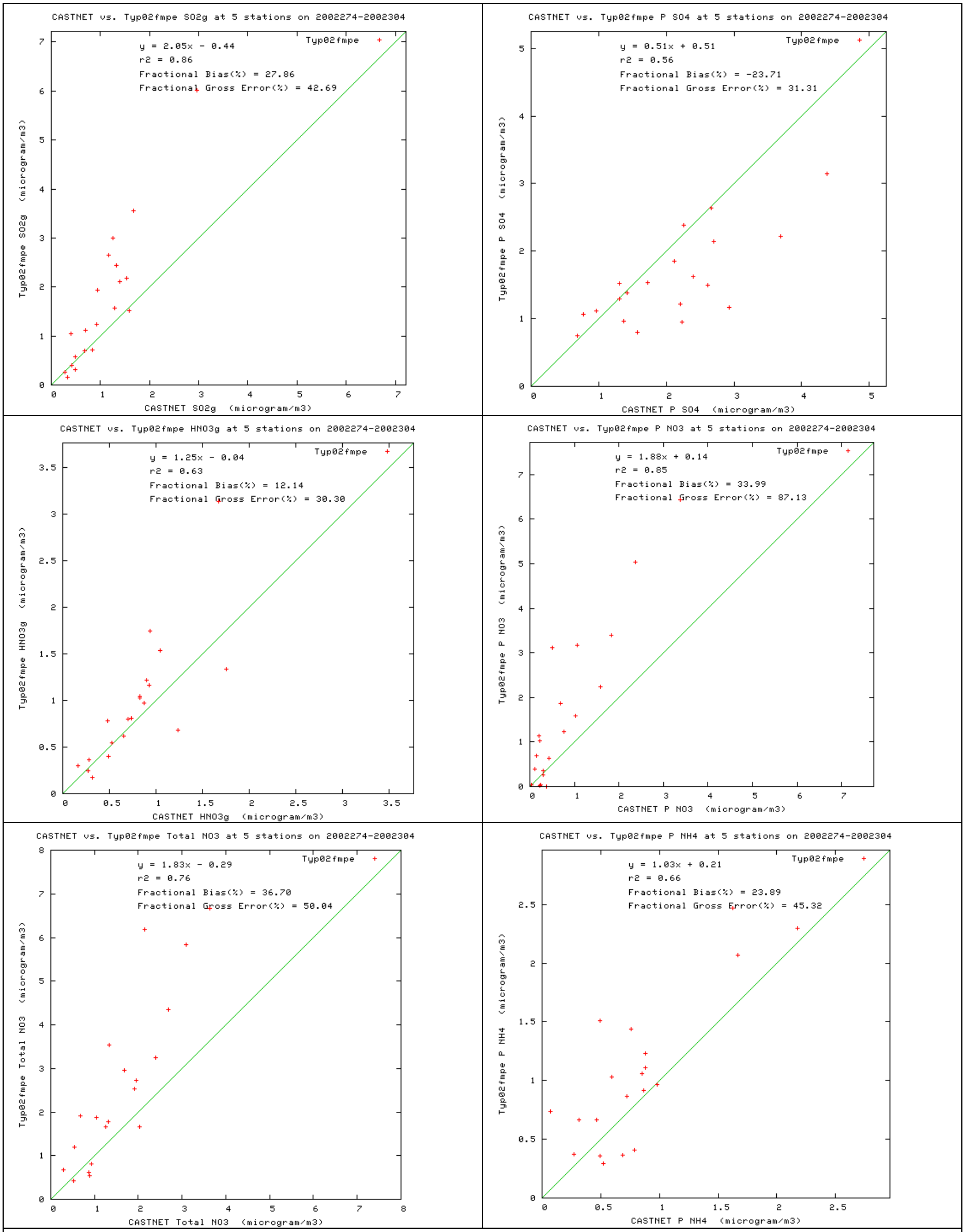


Figure C-46 October 2002 performance at CENRAP CASTNet sites for SO2 (top left), SO4 (top right), HNO3 (middle left), NO3 (middle right), Total NO3 (bottom left) and NH4 (bottom right).

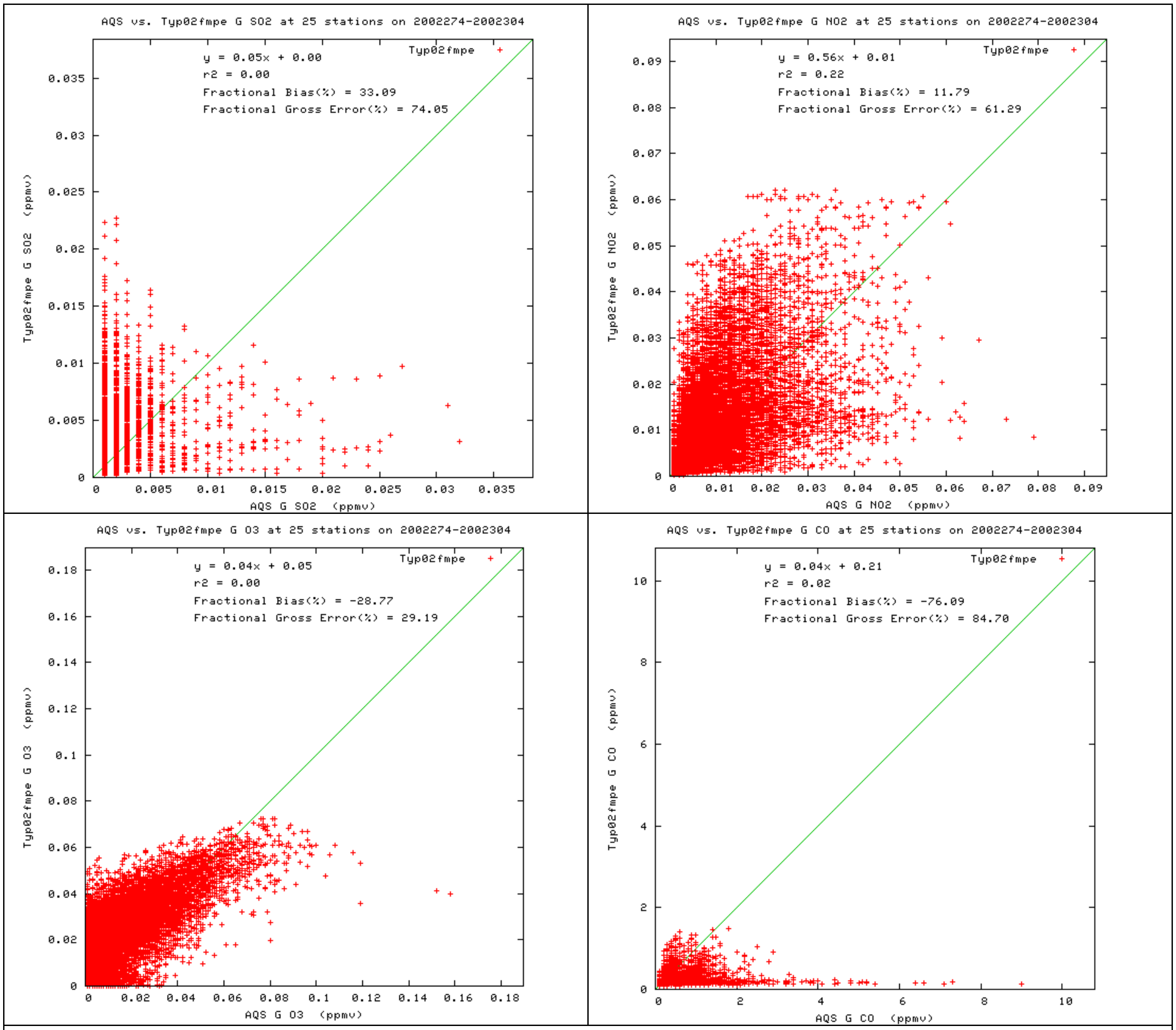


Figure C-47 October 2002 performance at CENRAP AQS sites for SO2 (top left), NO2 (top right), O3 (bottom left) and CO (bottom right).

C.5 Evaluation at Class I Areas for the Worst and Best 20 Percent Days

In this section, and in section C.5 of Appendix C, we present the results of the model performance evaluation at each of the CENRAP Class I areas for the worst and best 20 percent days. Performance on these days is critical since they are the days used in the 2018 visibility projections discussed in Chapter 4. For each Class I area we compared the predicted and observed total extinction (these figures are in Chapter 3) and PM species-specific extinction for the worst and best 20 percent days in 2002.

C.5.1 Caney Creek (CACR) Arkansas

The ability of the CMAQ model to estimate visibility extinction at the CACR Class I area on the 2002 worst and best 20 percent days is provide in Figures 3-9 and C-48. On most of the worst 20 percent days at CACR total extinction is dominated by SO4 extinction with some extinction due to OMC. On four of the worst 20 percent days extinction is dominated by NO3. The average extinction across the worst 20 percent days is underestimated by -33% (Figure 3-9), which is primarily due to a -51% underestimation of SO4 extinction combined with a 6% overestimation of NO3 extinction (Figure C-48). Performance for OMC extinction at CACR on the worst 20 percent days is pretty good with a -20% bias and 36% error, EC extinction is systematically underestimated, Soil extinction has low bias (-19%) buts lots of scatter and high error (74%), while CM extinction is greatly underestimated (bias of -153%).

On the best 20 percent days at CACR the observed extinction ranges from 20 to 40 Mm^{-1}, whereas then modeled extinction has a much larger range from 15 to 120 Mm^{-1}. Much of the modeled overestimation of total extinction on the best 20% days (+44% bias) is due to NO3 overestimation (+94% bias).

C.5.2 Upper Buffalo (UOBU) Arkansas

Model performance at the UPBU Class I area for the worst and best 20 percent days is shown in Figures 3-10 and C-49. On most of the worst 20 percent days at UPBU visibility impairment is dominated by SO4, although there are also two high NO3 days. The model underestimates the average of the total extinction on the worst 20 percent days at UPBU by -40% (Figure 3-10), which is due to an underestimation of extinction due to SO4, OMC and CM by, respectively, -46%, -33% and -179%.

On the best 20 percent days at UPBU, the model performs reasonably well with a low bias (2%) and error (42%). But again the model has a much wider range in extinction values across the best 20 percent days (15 to 120 Mm^{-1}) than observed (20 to 45 Mm^{-1}). There are five days in which the modeled NO3 over-prediction is quite severe and when those days are removed the range in the modeled and observed extinction on the best 20 percent days is quite similar, although the model gets much cleaner on the very cleanest modeled days.

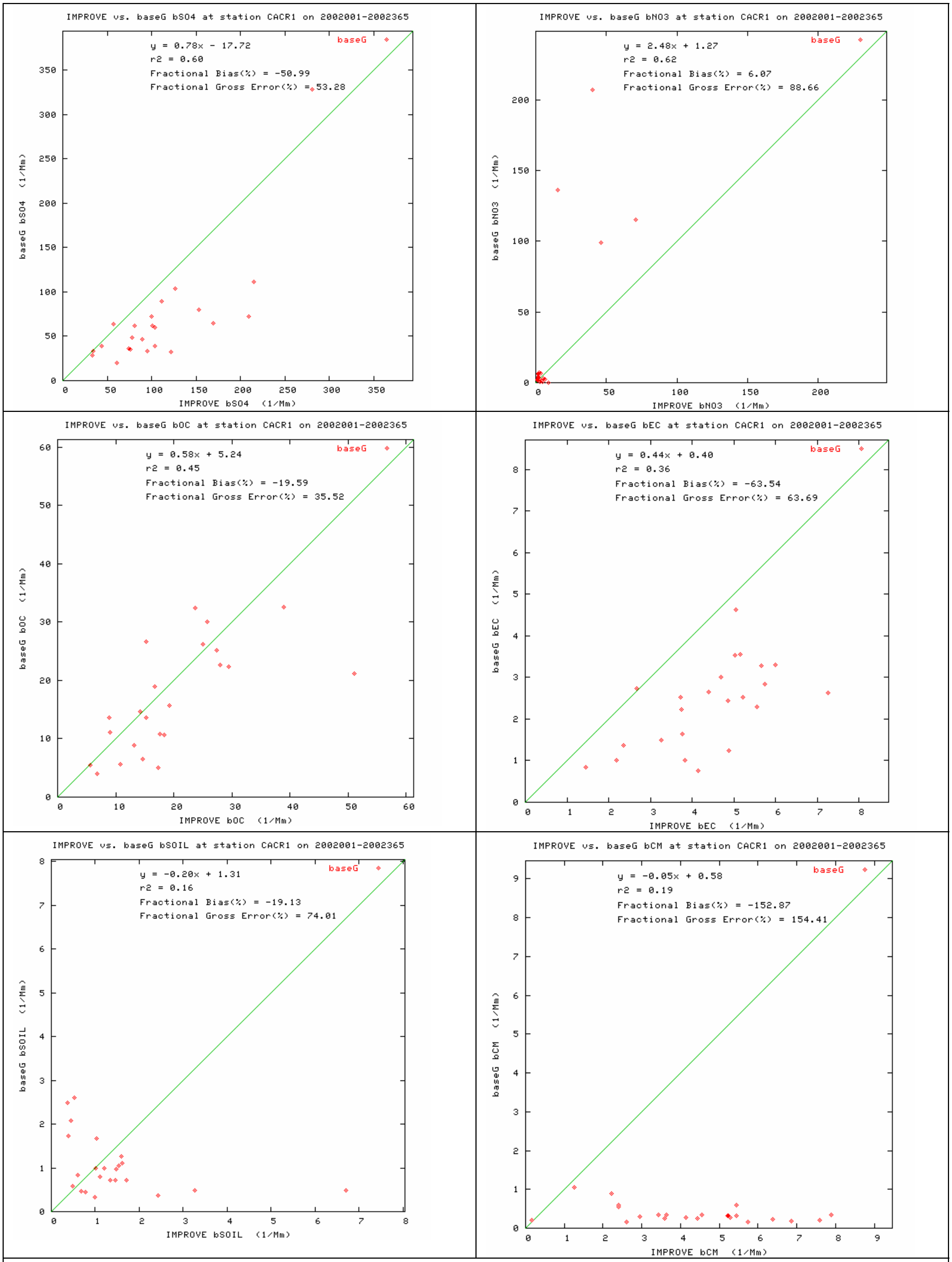


Figure C-48. PM species extinction model performance at Caney Creek (CACR) for the worst 20 percent days during 2002.

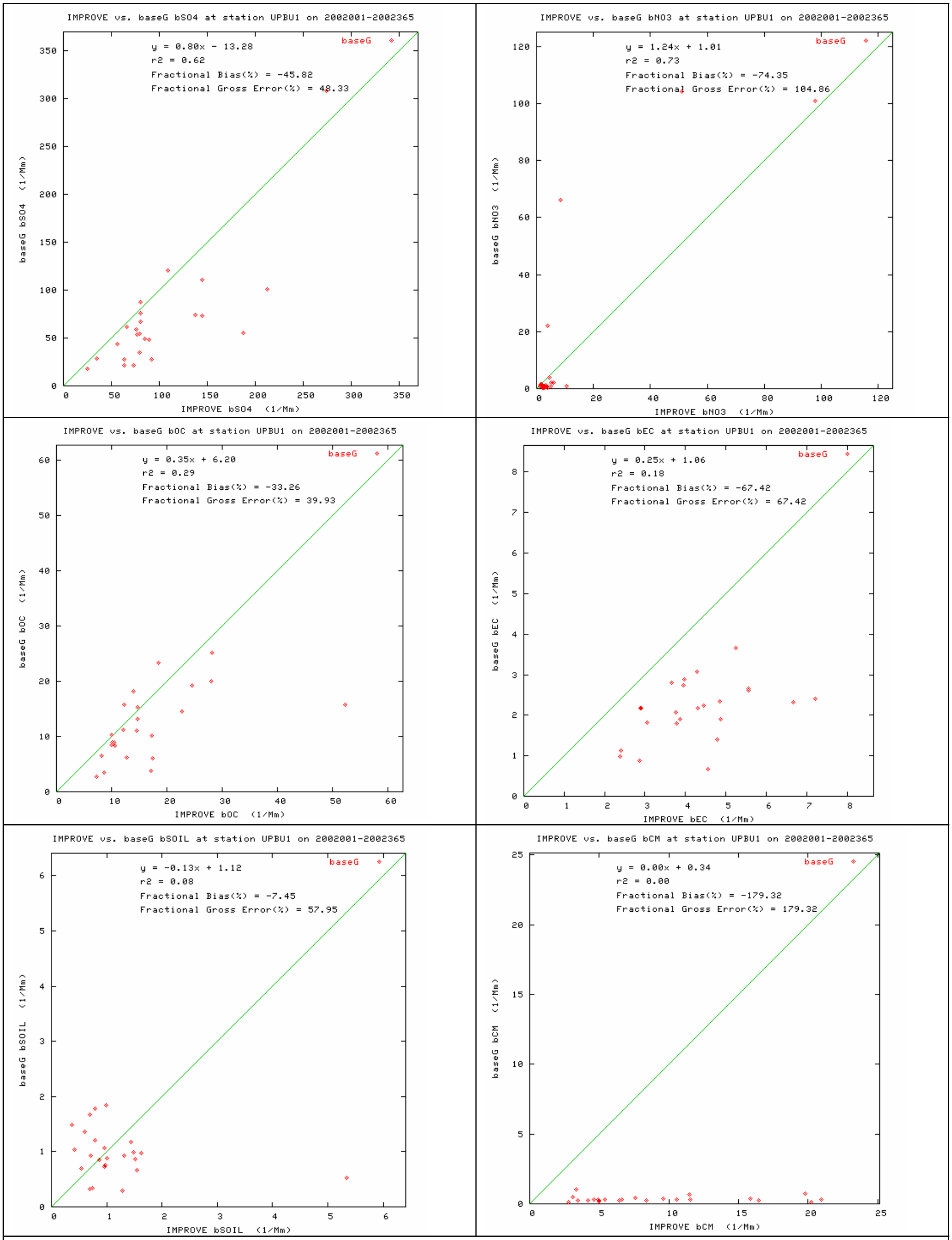


Figure C-49. PM species extinction model performance at Upper Buffalo (UPBU) for the worst 20 percent days during 2002.

C.5.3 Breton Island (BRET), Louisiana

The observed total extinction on the worst 20 percent days at Breton Island is underestimated by -71% (Figure 3-11), which is due to an underestimation of each component of extinction (Figure C-50) by from -50% to -70% (SO4, OMC and Soil) to over -100% (EC and CM). The observed extinction on the worst 20 percent days ranges from 90 to 170 Mm^{-1}, whereas the modeled values drop down to as low as approximately 15 Mm^{-1}. On the best 20 percent days the range of the observed and modeled extinction is similarly (roughly 10 to 50 Mm^{-1}) that results in a reasonably low bias (-22%), but there is little agreement on which days are higher or lower resulting in a lot of scatter and high error (54%).

C.5.4 Boundary Waters (BOWA), Minnesota

There are three types of days during the worst 20 percent days at BOWA, SO4 days, OMC days and NO3 days (Figure 3-12). The two high OMC days are likely fire impact events that the model captures to some extent on one day and not on the other. On the five high (> 20 Mm^{-1}) NO3 extinction days the model predicts the observed extinction well on three days and overestimates by a factor of 3-4 on the other two high NO3 days. SO4 in underestimate by -43% on average across the worst 20 percent days at BOWA.

With the exception of two days, the model reproduces the total extinction for the best 20 percent days at BOWA quite well with a bias and error value of +14% and 22% (Figure 3-12). Without these two days, the modeled and observed extinction both range between 15 and 25 Mm^{-1}.

C.5.5 Voyageurs (VOYA) Minnesota

VOYA is also characterized by SO4, NO3 and OMC days (Figure 3-13). Julian Days 179 and 200 are high OMC days that were also high OMC days at BOWA again indicating impacts from fires in the area that is not fully captured by the model. SO4 and NO3 extinction is fairly good and, without the fire days, OMC performance looks good as well (Figure C-52). On the best 20 percent days there is one day the modeled extinction is much higher than observed and a few others that are somewhat higher, but for most of the best 20 percent days the modeled extinction is comparable to the observed values.

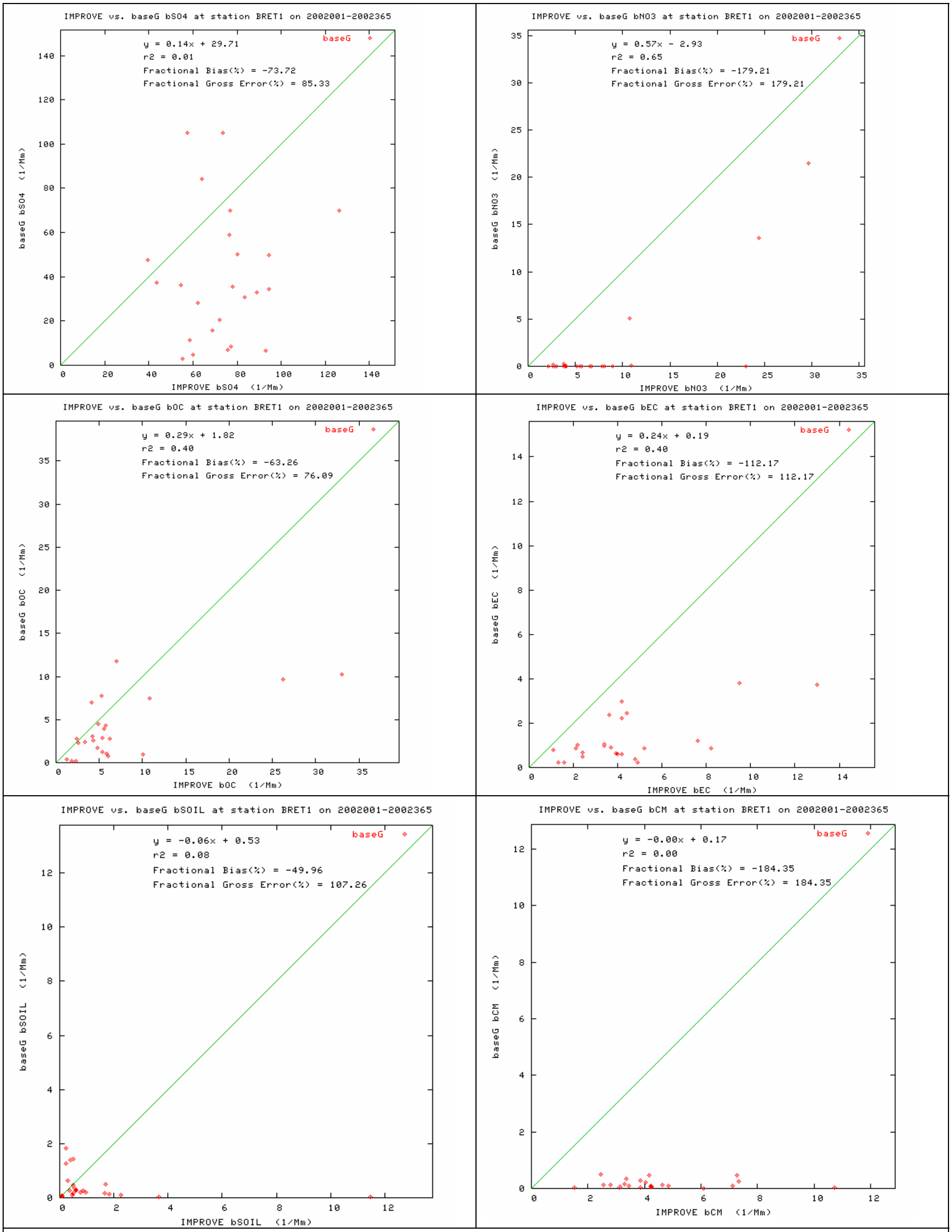


Figure C-50. PM species extinction model performance at Breton Island (BRET) for the worst 20 percent days during 2002.

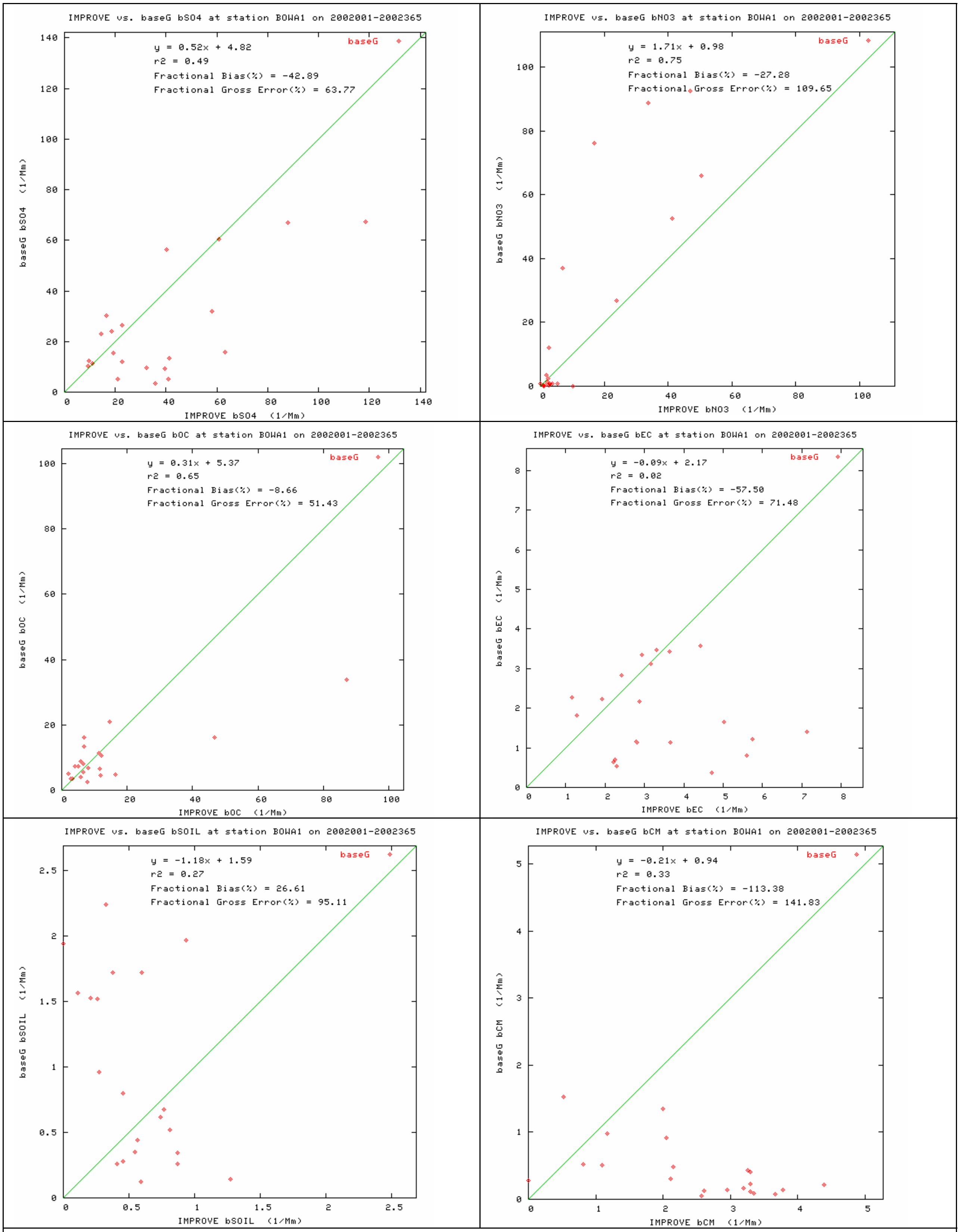


Figure C-51. PM species extinction model performance at Boundary Waters (BOWA) for the worst 20 percent days during 2002.

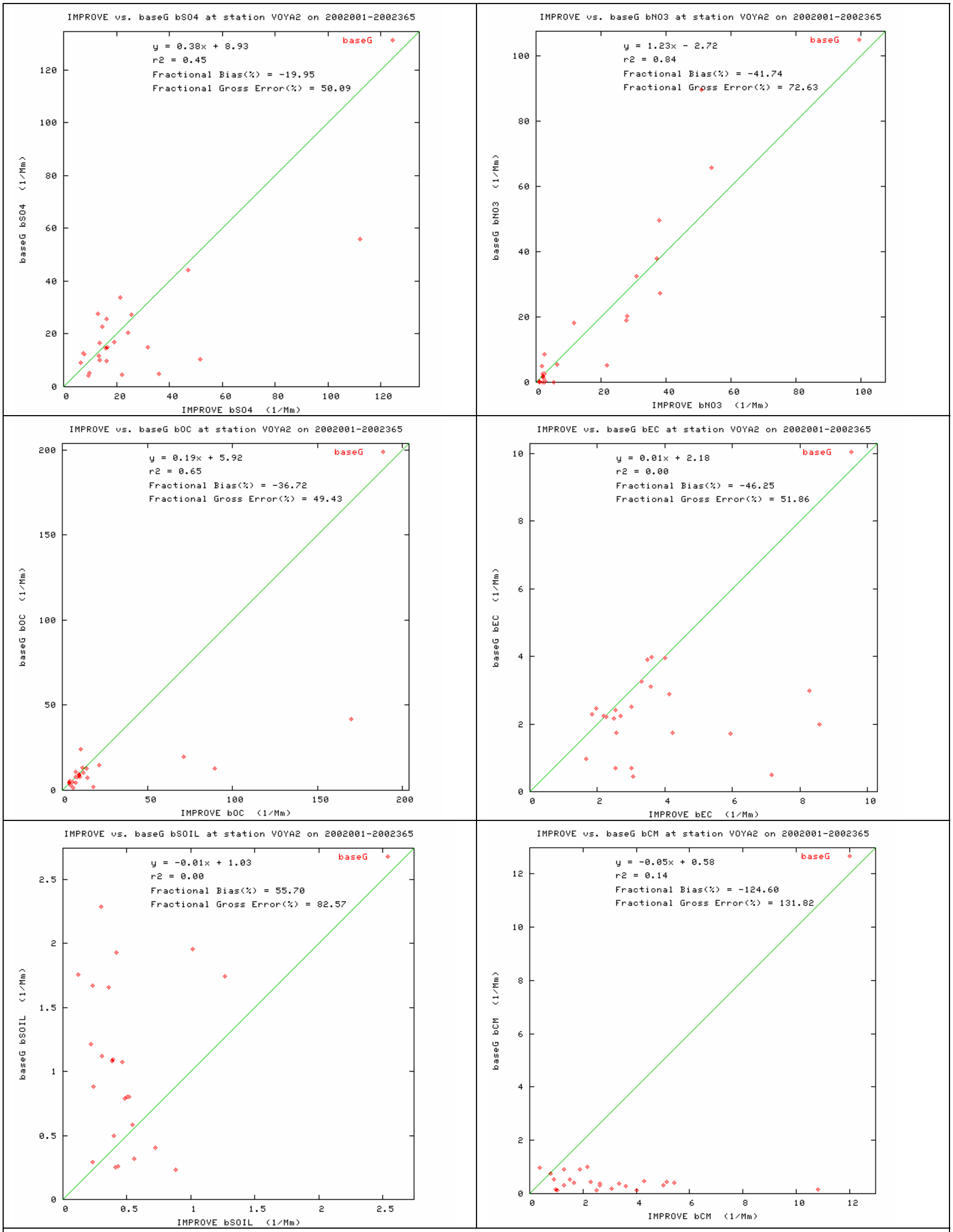


Figure C-52. PM species extinction model performance at Voyageurs (VOYA) for the worst 20 percent days during 2002.

C.5.6 Hercules Glade (HEGL) Missouri

On most of the worst 20 percent days at HEGL the observed extinction ranges from 120 to 220 Mm^{-1} whereas model extinction ranging from 50 to 170 Mm^{-1} (Figure 3-14). However, there is one extreme day with extinction approaching 400 Mm^{-1} that the model does a very good job in replicating. Over all the days there is a modest underestimation bias in SO4 (-39%) and OMC (-39%) extinction, larger underestimation bias in EC (-62%) and CM (-118%) extinction and overestimation bias in Soil (+30%) extinction (Figure C-53).

On the best 20 percent days there is one day where the model overstates the observed extinction by approximately a factor of four and a handful of other days that the model overstates the extinction by a factor of 2 or so, but most of the days both the model and observed extinction sites are around 40 Mm^{-1} plus or minus about 10 Mm^{-1}. On the best 20 percent days when the observed extinction is overstated it is due to overstatement of the NO3.

C.5.7 Mingo (MING) Missouri

The worst 20 percent days at Ming are mainly high SO4 days with a few high NO3 days that the model reproduces reasonably well resulting in low bias (+10%) and error (38%) for total extinction (Figure 3-15). The PM species specific performance is fairly good with low bias for SO4 (+4%), good agreement with NO3 on high NO3 days except for one day, low OMC (+23%) and EC (+3%) bias and larger bias in EC (+37%) and CM (-105%) extinction (Figure C-54).

For the best 20 percent days, there is one day the model is way to high due to overstated NO3 extinction and a few other days the model overstates the observed extinction that is usually due to overrated NO3, but on most of the best 20 percent days the modeled extinction is comparable to the observed values. This results in low bias (+12%) and error (36%) for total extinction at MING for the best 20 percent days.

C.5.8 Wichita Mountains (WIMO), Oklahoma

With the exception of an over-prediction on day 344 due to NO3, observed total extinction on the worst 20 percent days at WIMO is understated with a bias of -42% (Figure 3-16) that is primarily due to an underestimation of extinction due to SO4 (-48%) and OMC (-69%) (Figure C-55).

CMAQ total extinction performance for the average of the best 20 percent days at WIMO is characterized by an overestimation bias (+21%) on most days that is primarily due to NO3 over-prediction on several days. Again the modeled range of extinction on the best 20 percent days (12-60 Mm^{-1}) is much greater than observed (20-35 Mm^{-1}).

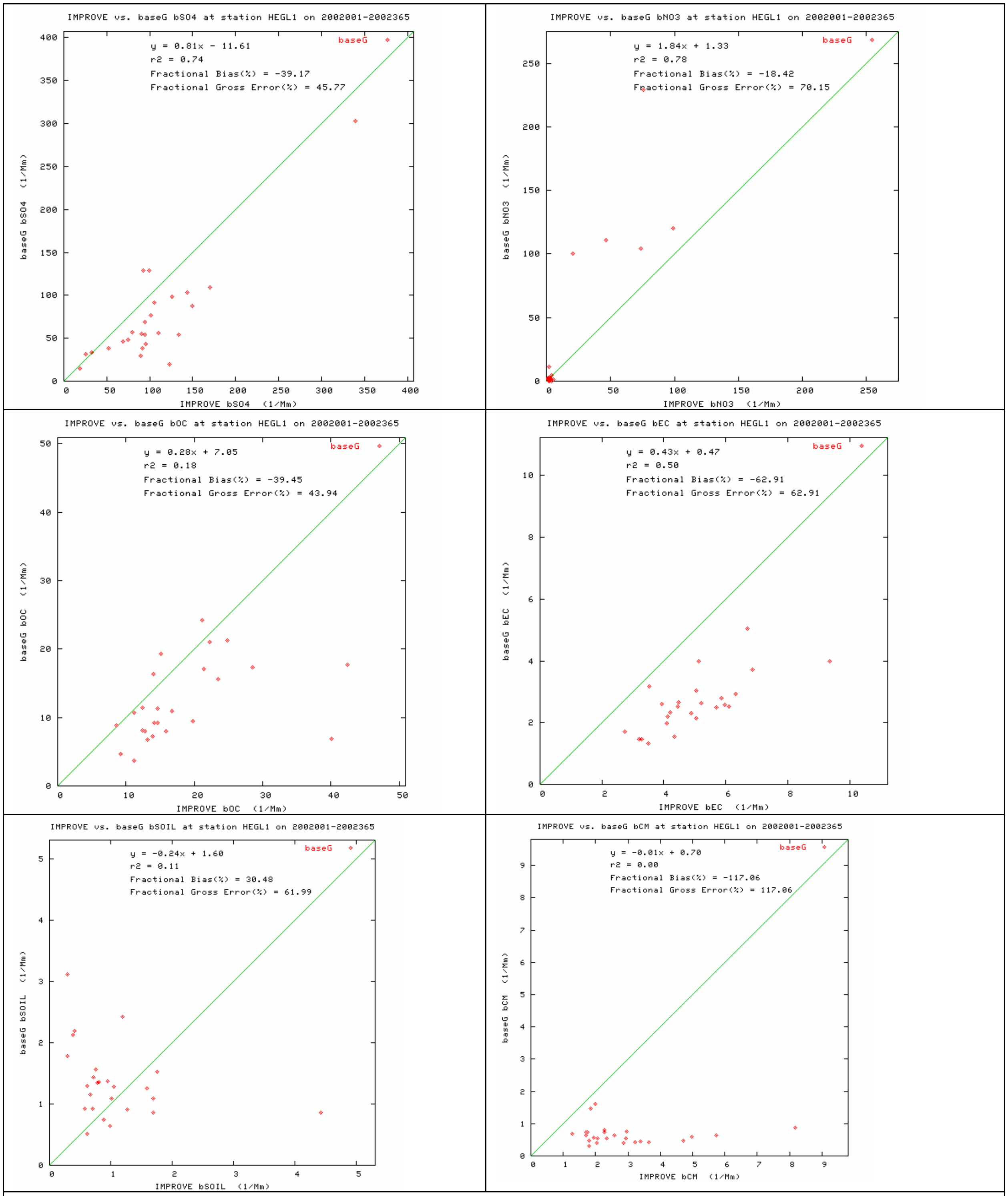


Figure C-53. PM species extinction model performance at Hercules Glade (HEGL) for the worst 20 percent days during 2002.

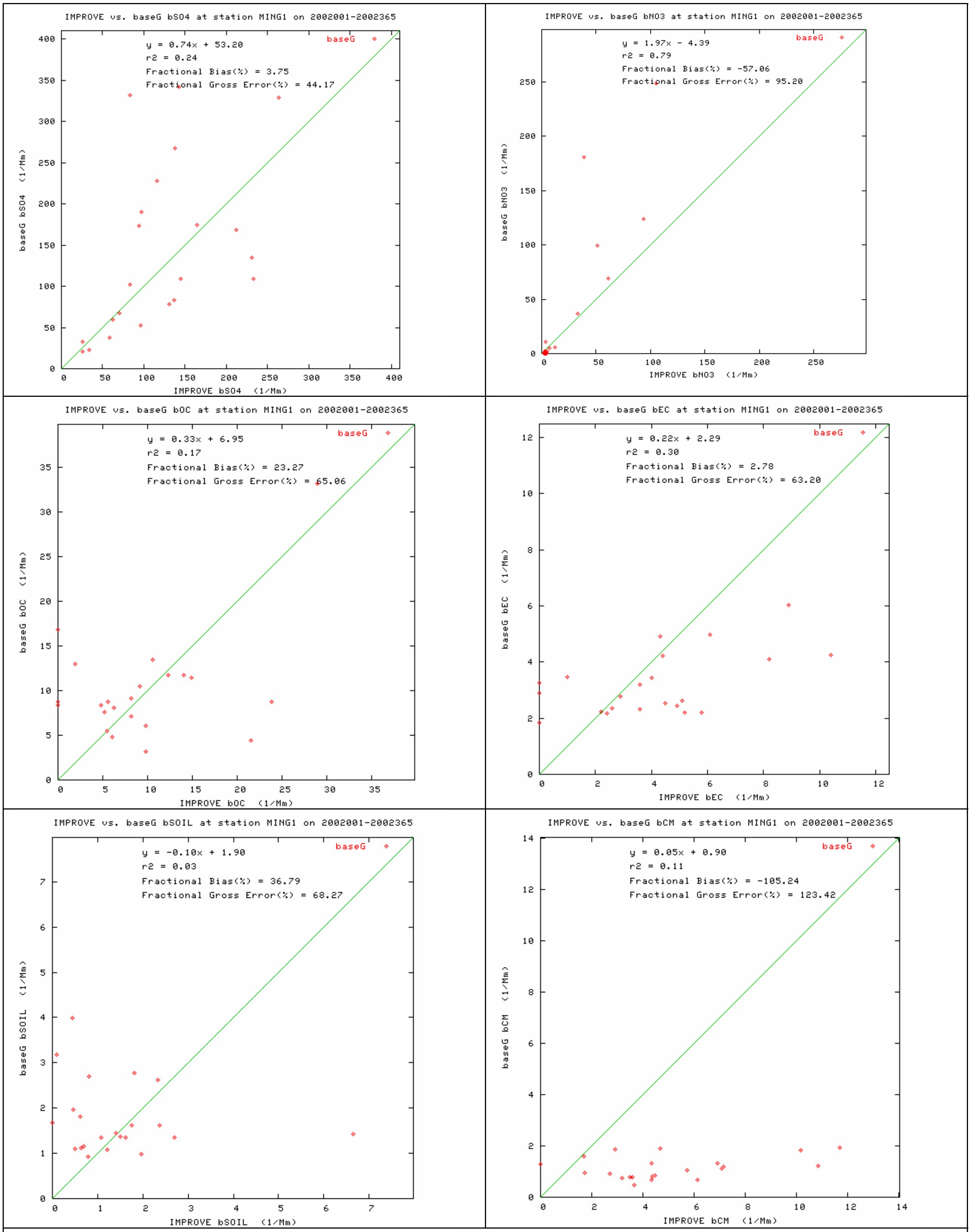


Figure C-54. PM species extinction model performance at Mingo (MING) for the worst 20 percent days during 2002.

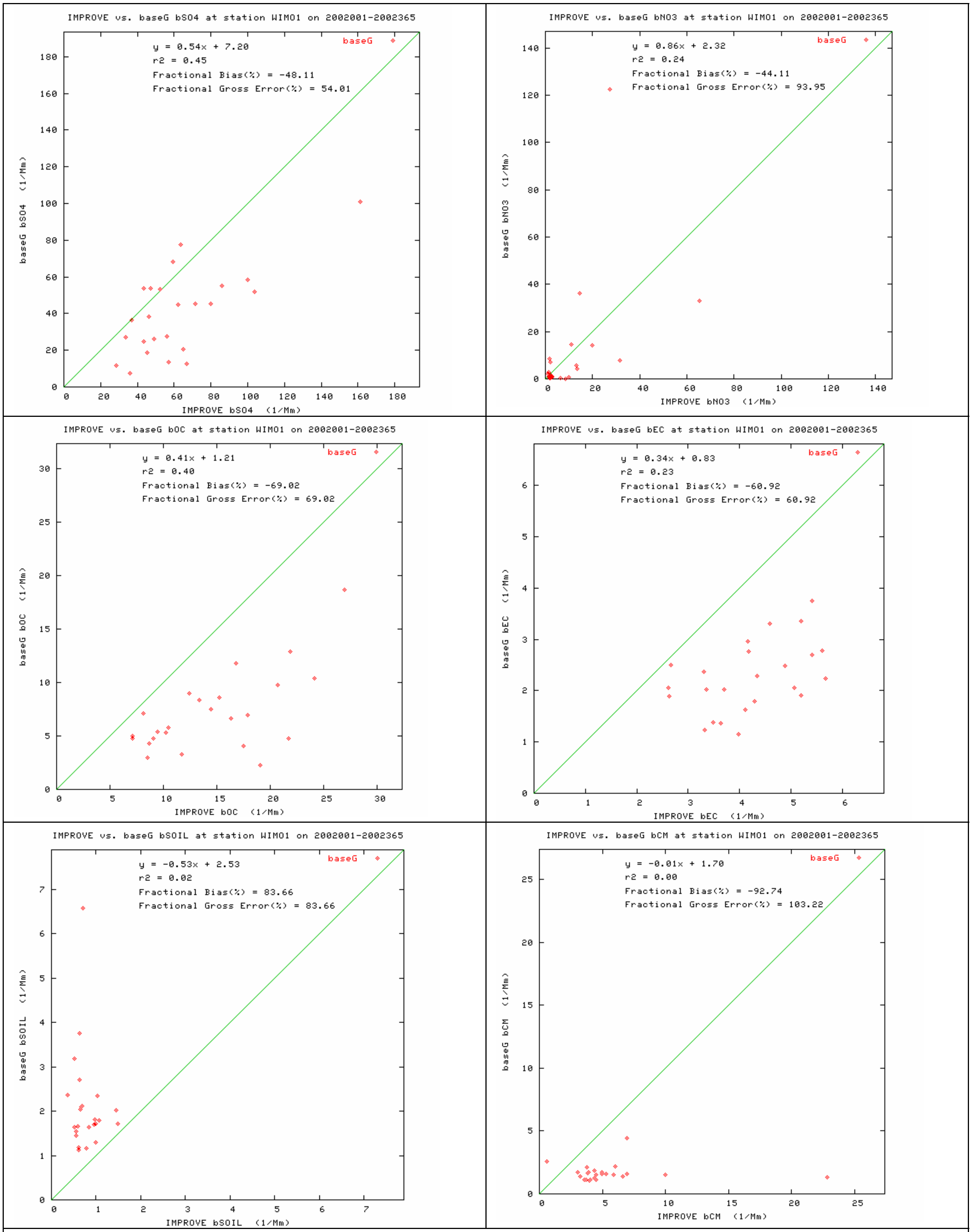


Figure C-55. PM species extinction model performance at Wichita Mountains (WIMO) for the worst 20 percent days during 2002.

C.5.9 Big Bend (BIBE) Texas

The observed extinction on the worst 20 percent days at BIBE is under-predicted on almost every day resulting in a fractional bias value of -72% (Figure 3-17). Every component of extinction is underestimated on average for the worst 20 percent days (Figure C-56) with the underestimation bias ranging from -24% (OMC) to -162% (CM). SO4 extinction, that typically represents the largest component of the total extinction is understated by -94%.

The model does a better job in predicting the total extinction at BIBE for the best 20 percent days with average fractional bias and error values of +13% and 19% (Figure 3-17). With the exception of one day that the observed extinction is overestimated by approximately a factor of 2, the modeled and observed extinction on the best 20 percent days at BIBE are both within 12 to 25 Mm^{-1}. However, there are some mismatches with the components of extinction with the model estimating much lower contributions due to Soil and CM.

C.5.10 Guadalupe Mountains (GUMO) Texas

Most of the worst 30 percent days at GUMO are dust days with high Soil and CM that is not at all captured by the model (Figure 3-18). Extinction due to Soil and CM on the worst 20 percent days is underestimated by -105% and -191%, respectively (Figure C-57). Better performance is seen on the best 20 percent days with bias and error for total extinction of 8% and 21%, but the model still understates Soil and CM.

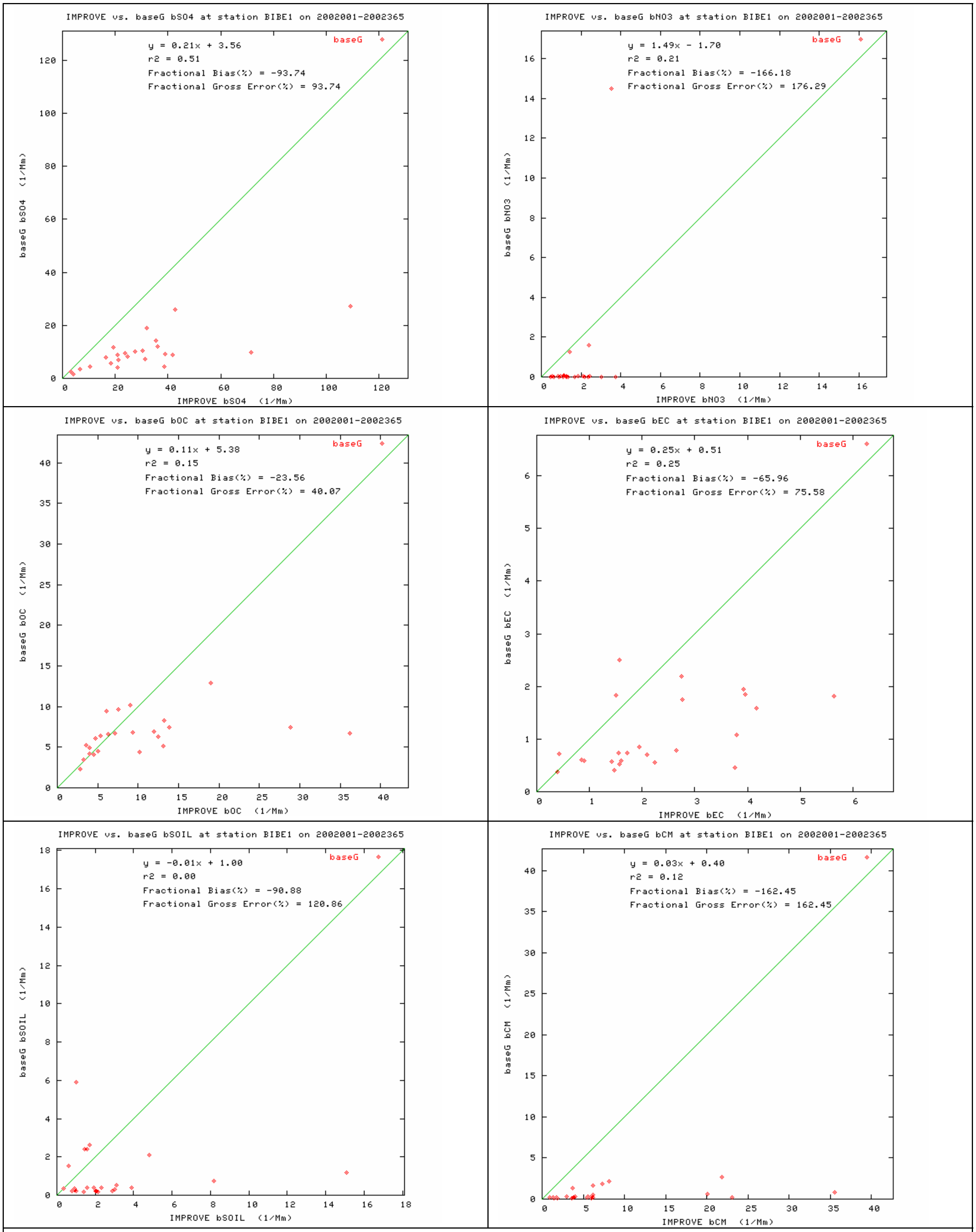


Figure C-56. PM species extinction model performance at Big Bend (BIBE) for the worst 20 percent days during 2002.

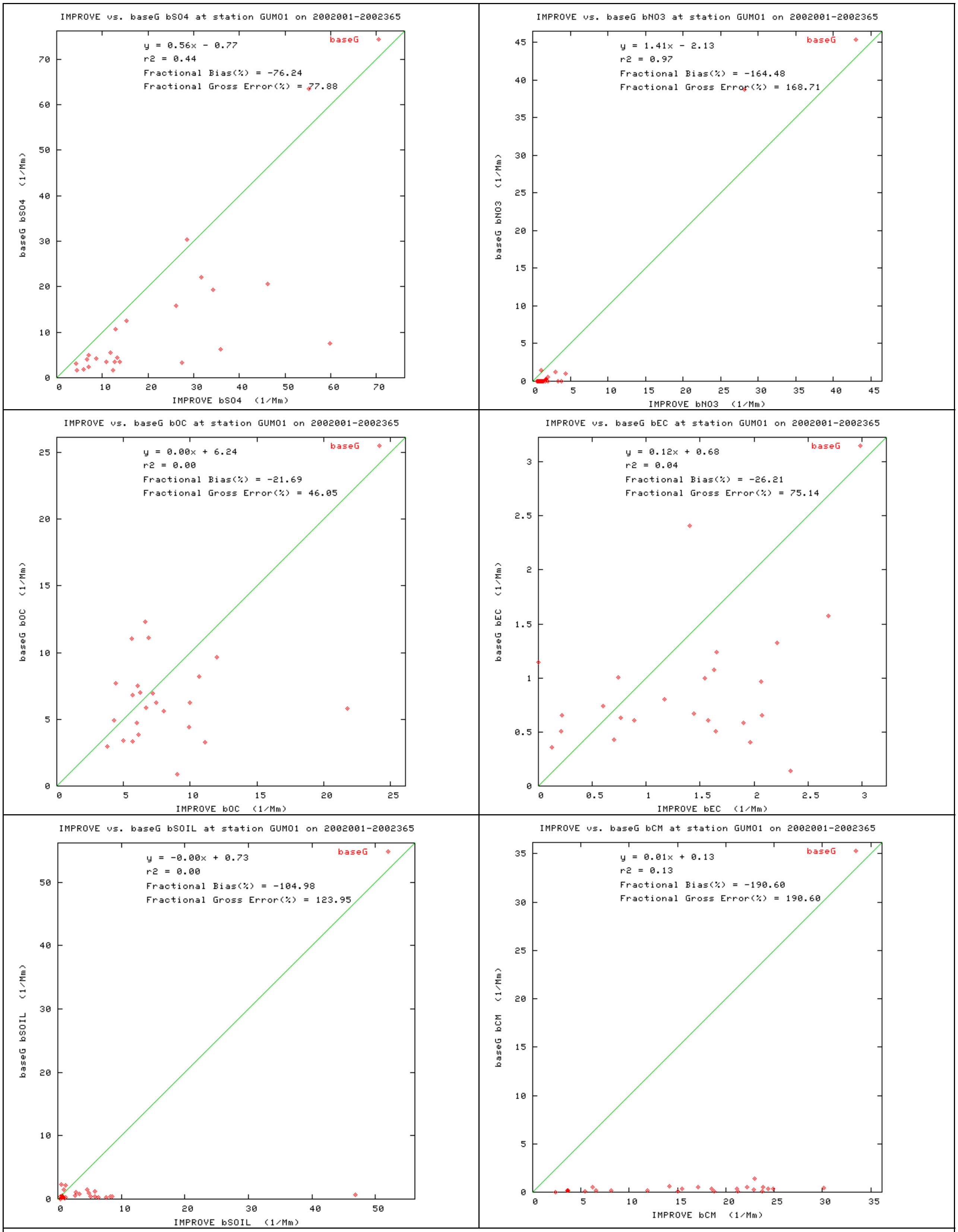


Figure C-57. PM species extinction model performance at Guadalupe Mountains (GUMO) for the worst 20 percent days during 2002.

C.6 Model Performance Evaluation Conclusions

The model performance evaluation reveals that the model is performing best for SO4, OMC and EC. Soil performance is mixed with winter overestimation bias but lower bias but high error in the summer. CM performance is poor year round. The operational evaluation reveals that SO4 performance usually achieves the PM model performance goal and always achieves the model performance criteria, although it does have an underestimation bias that is greatest in the summer. NO3 performance is characterized by a winter overestimation bias with an even greater summer underestimation bias. However, the summer underestimation bias occurs when NO3 is very low and it is not an important component of the observed or predicted PM and visibility impairment. Performance for OMC meets the model performance goal year round at the IMPROVE sites, but is characterized by an underestimation bias at the more urban STN sites. EC exhibits very low bias at the STN sites and a summer underestimation bias at the IMPROVE sites, but meets the model performance goal throughout the year. Soil has a winter overestimation bias that exceeds the model performance goal and criteria raising questions whether the model should be used for this species. Finally, CM performance is extremely poor with an under-prediction bias that exceeds the performance goal and criteria. We suspect that much of the CM concentrations measured at the IMPROVE sites is due to highly localized emissions that can not be simulated with 36 km regional modeling.

Performance for the worst 20 percent days at the CENRAP Class I areas is generally characterized by an underestimation bias. Performance at the BRET, BIBE and GUMO Class I areas for the worst 20 percent days is particularly suspect and care should be taken in the interpretation of the visibility projections at these three Class I areas.

The CMAQ 2002 36 km model appears to be working well enough to reliably make future-year projections for changes in SO4, NO3, EC and OMC at the rural Class I areas. Performance for Soil and especially CM is suspect enough that care should be taken in interpreting these modeling results. The model evaluation focused on the model's ability to predict the components of light extinction mainly at the Class I areas. Additional analysis would have to be undertaken to examine the model's ability to treat ozone and fine particulate to address 8-hour ozone and $PM_{2.5}$ attainment issues.

APPENDIX D

2018 Visibility Projections for CENRAP Class I Areas Using 2002 Typical and 2018 Base Case Base G Emission Scenario CMAQ Results and EPA Default Projection Method and Comparison with 2018 Uniform Rate of Progress (URP) Glidepaths

Figure D-1: Caney Creek Wilderness Area (CACR), Arkansas
Figure D-2: Upper Buffalo Wilderness Area (UPBU), Arkansas
Figure D-3: Breton Island Wilderness Area (BRET), Louisiana
Figure D-4: Boundary Waters Canoe Area Wilderness Area (BOWA), Minnesota
Figure D-5: Voyageurs National Park (VOYA), Minnesota
Figure D-6: Hercules Glade Wilderness Area (HEGL), Missouri
Figure D-7: Mingo Wilderness Area (MING), Missouri
Figure D-8: Wichita Mountains Wilderness Area (WIMO), Oklahoma
Figure D-9: Big Bend National Park (BIBE), Texas
Figure D-10: Guadalupe Mountains National Park (GUMO), Texas

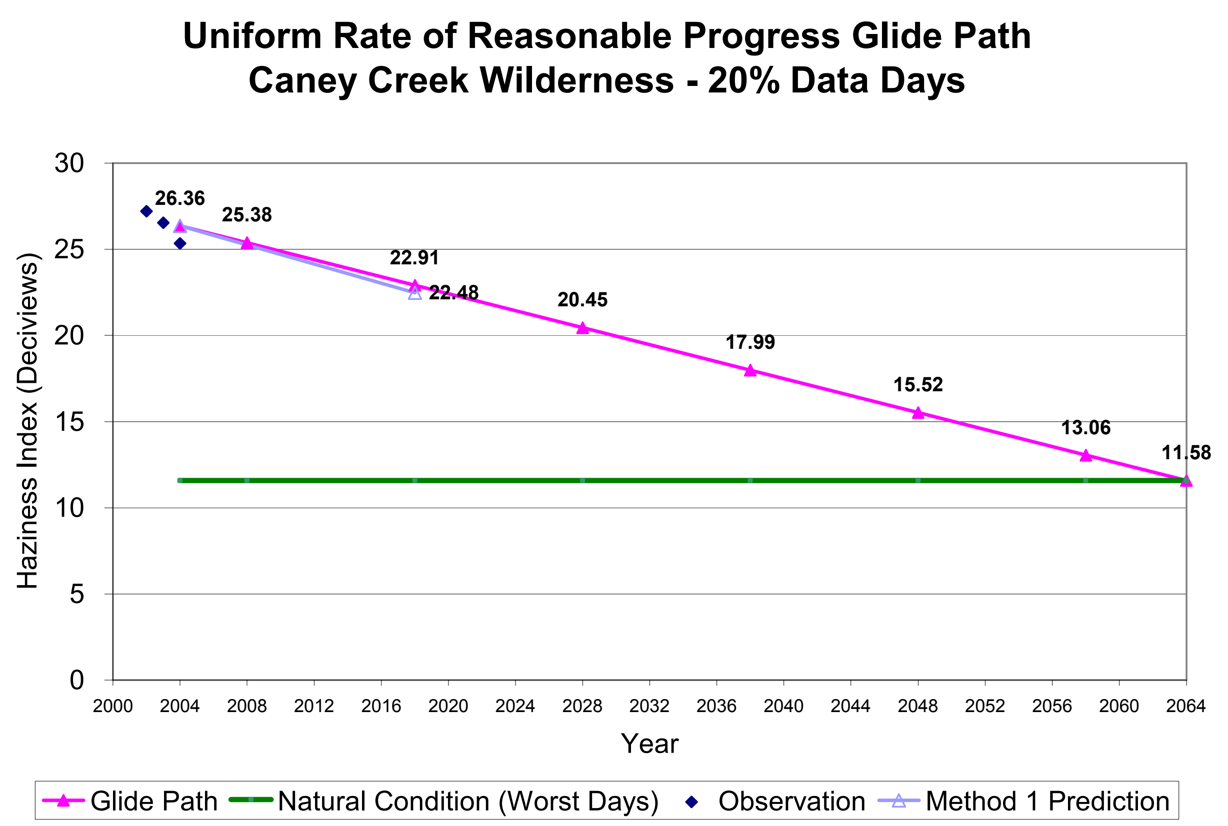


Figure D-1a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

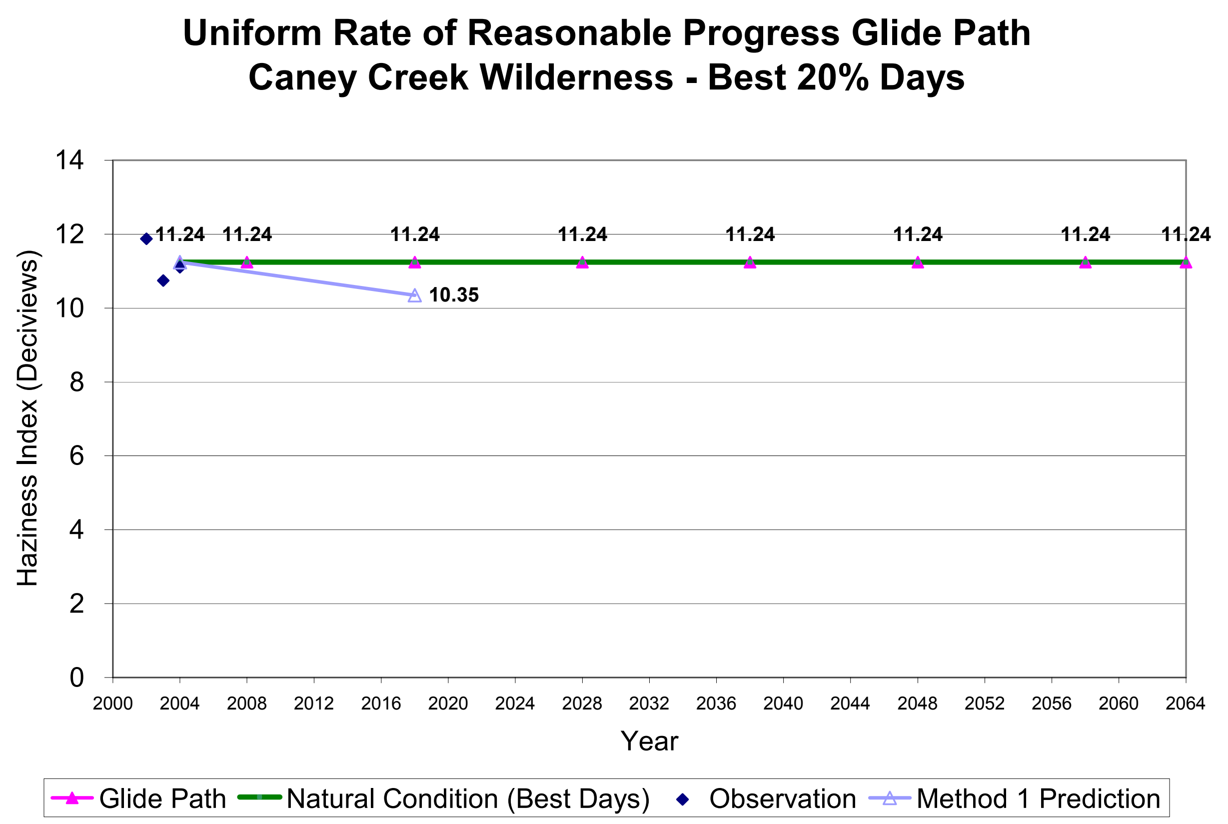


Figure D-1b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Caney Creek (CACR), Arkansas and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

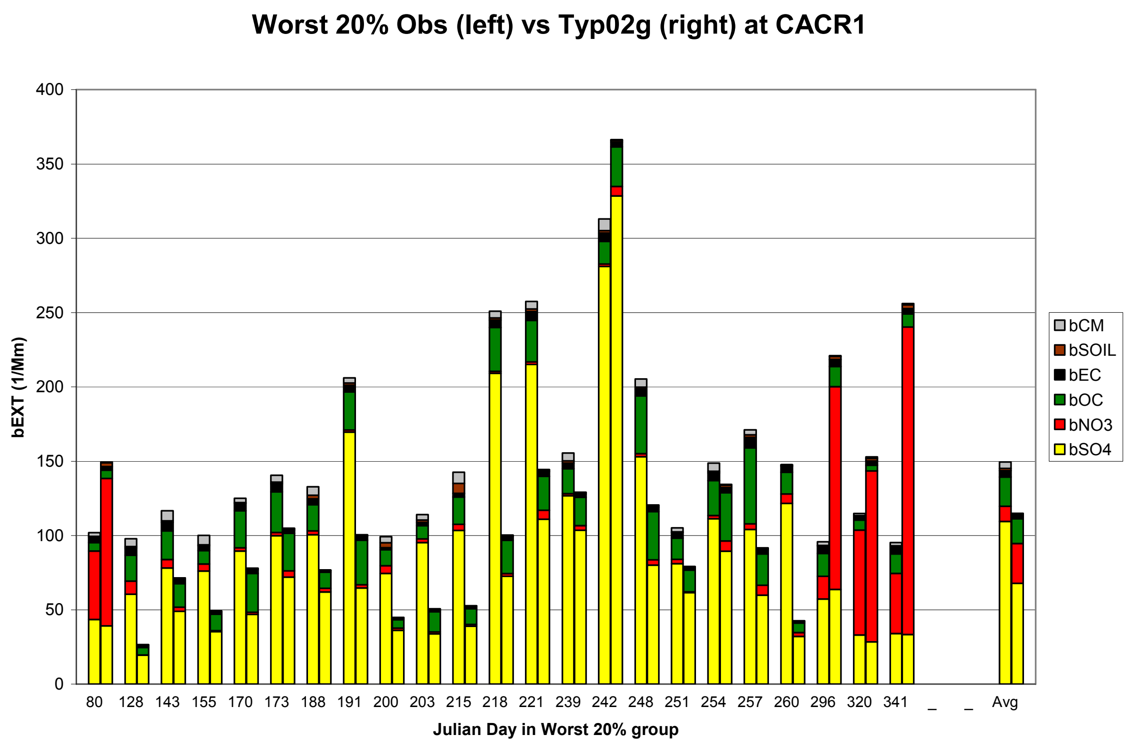


Figure D-1c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days in 2002.

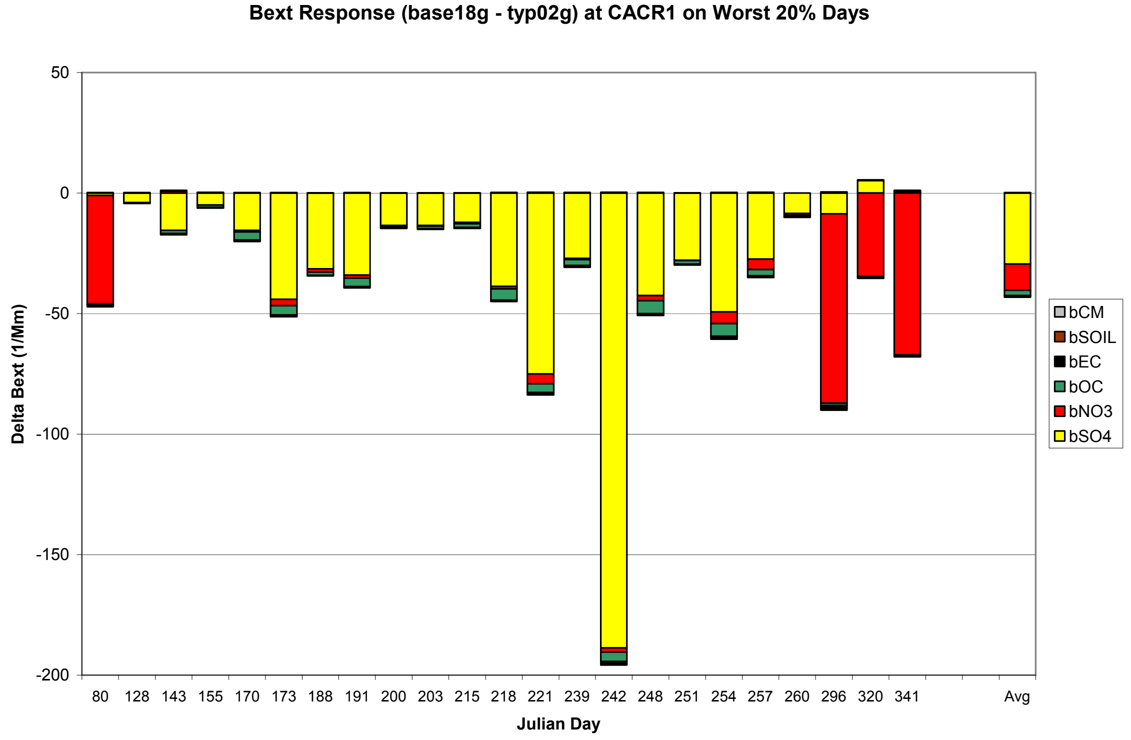


Figure D-1d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days in 2002.

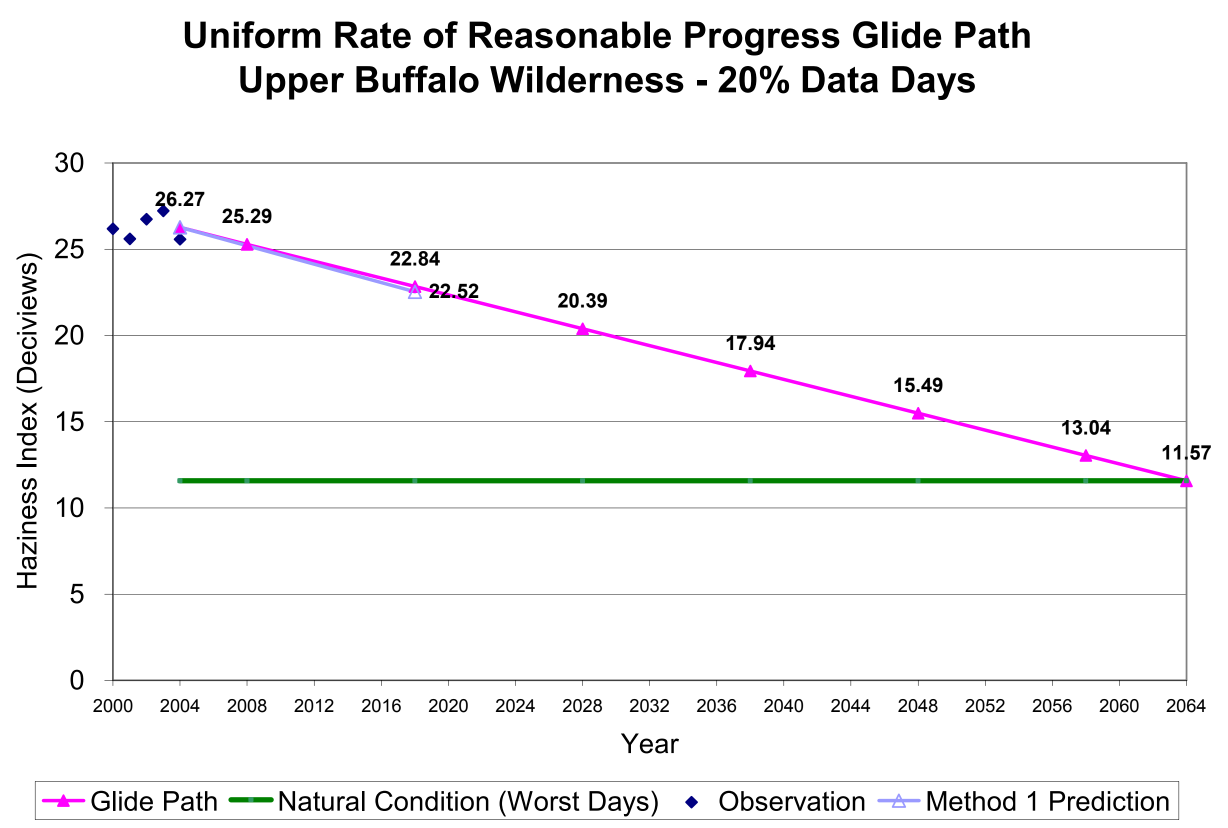


Figure D-2a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

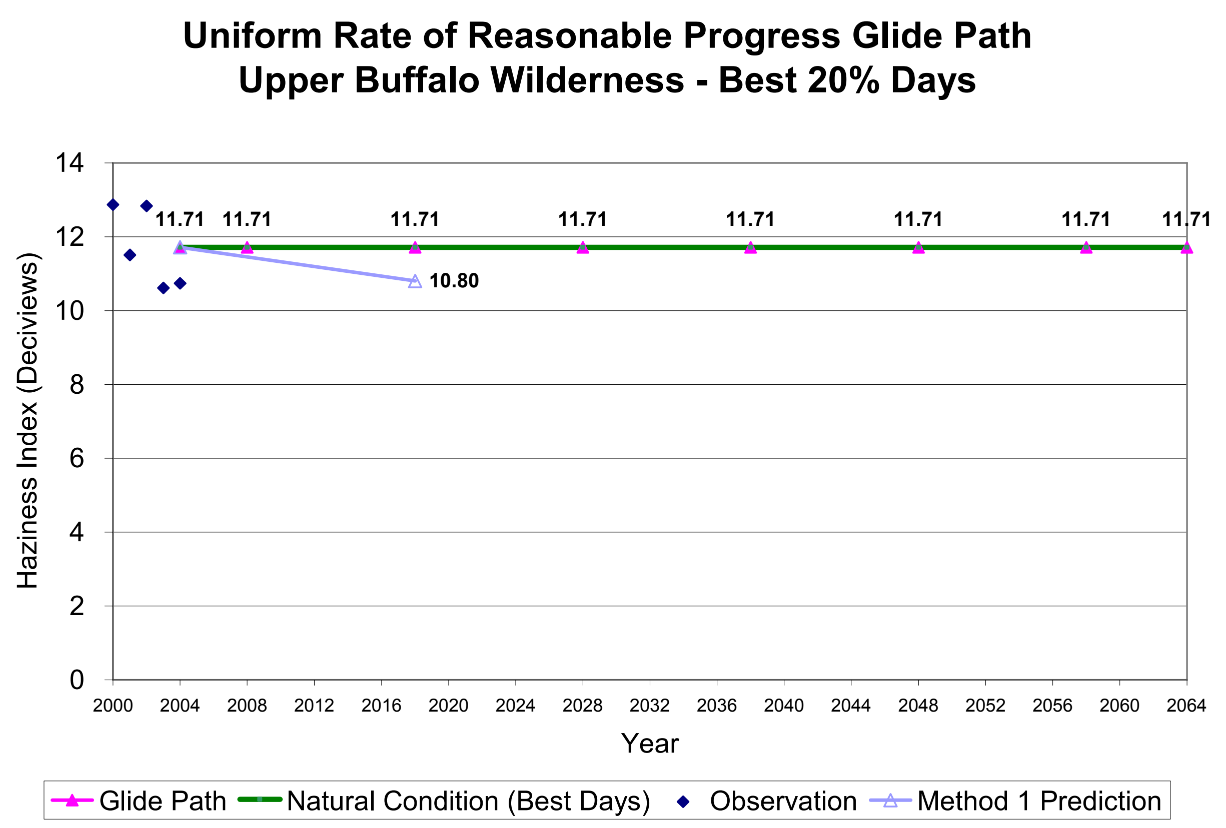


Figure D-2b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Upper Buffalo (UPBU), Arkansas and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

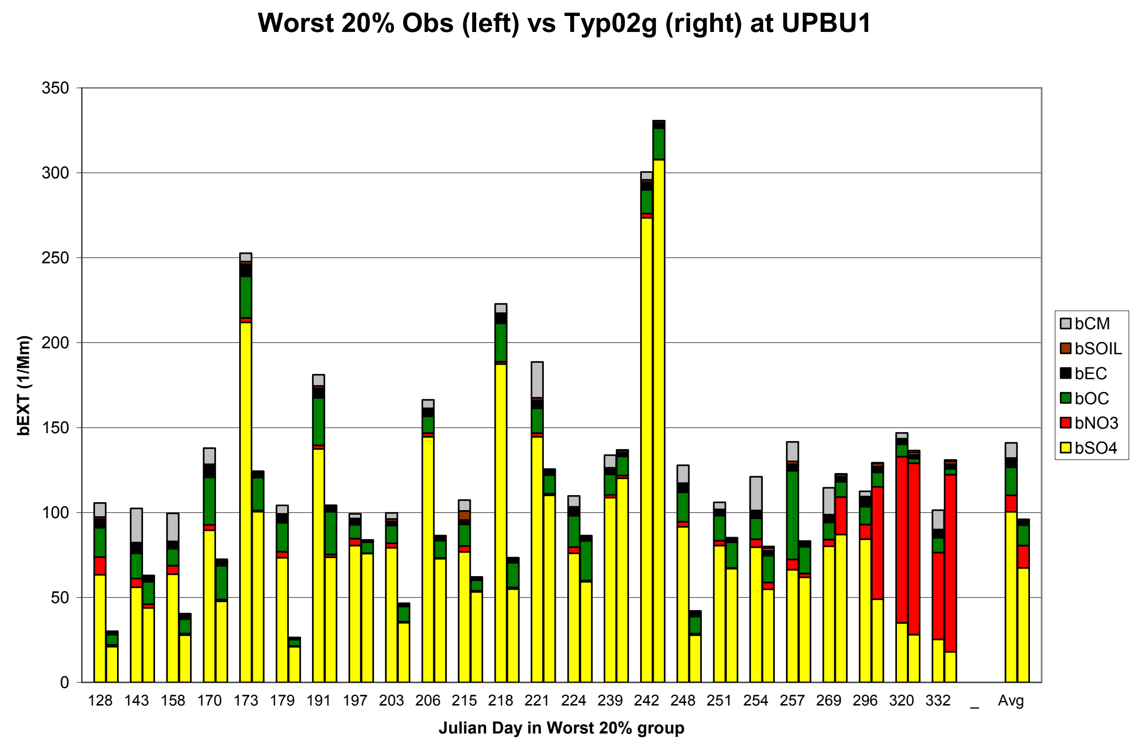


Figure D-2c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days in 2002.

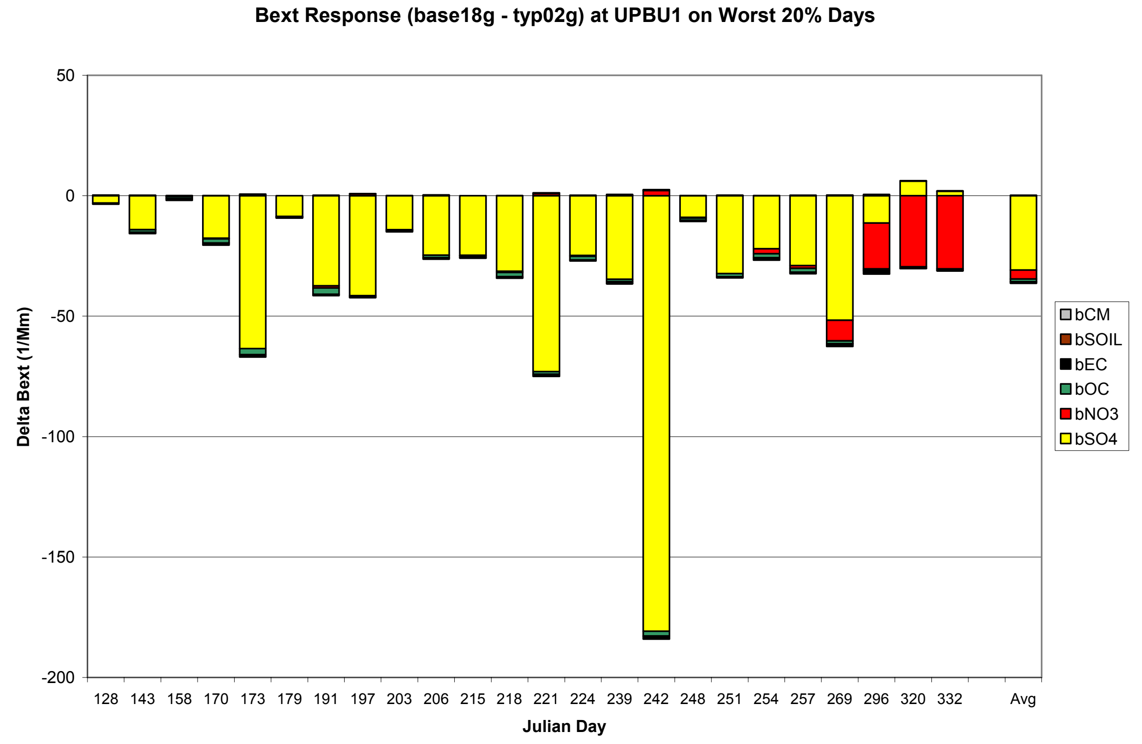


Figure D-2d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days in 2002.

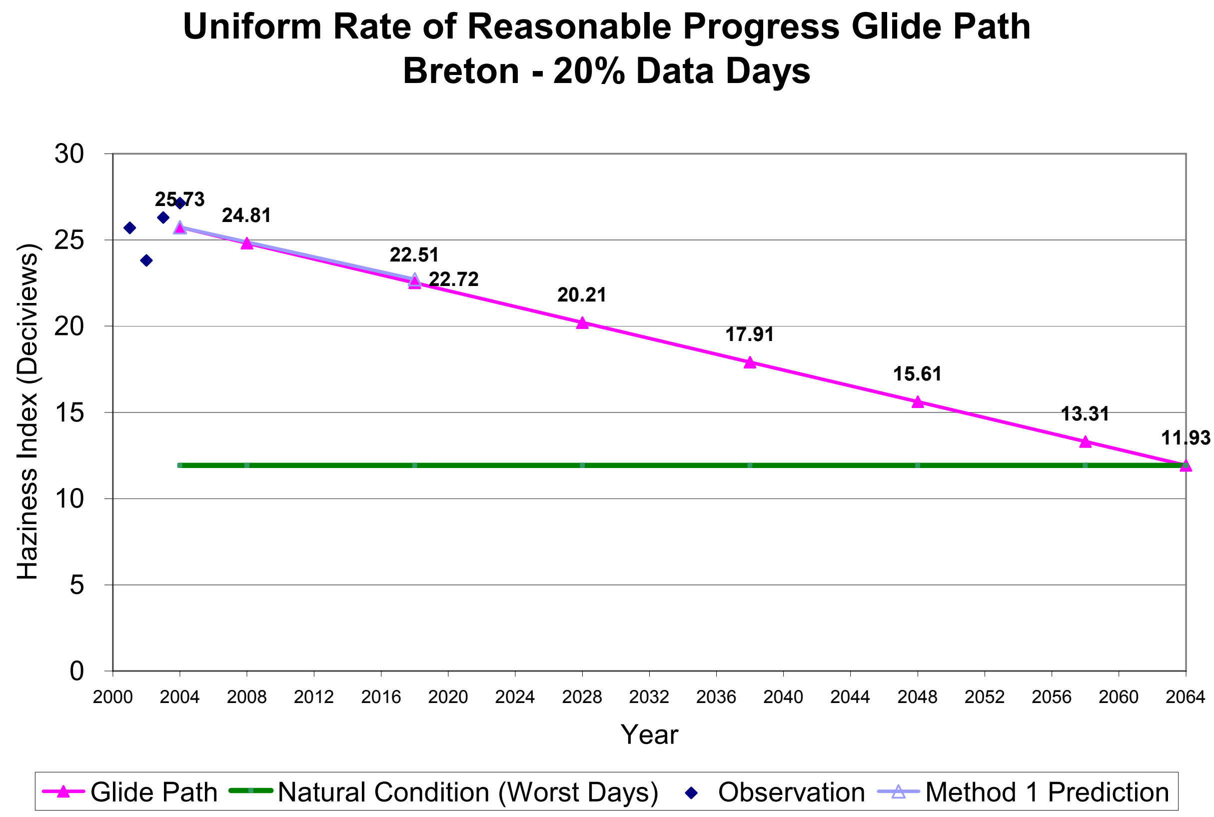


Figure D-3a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

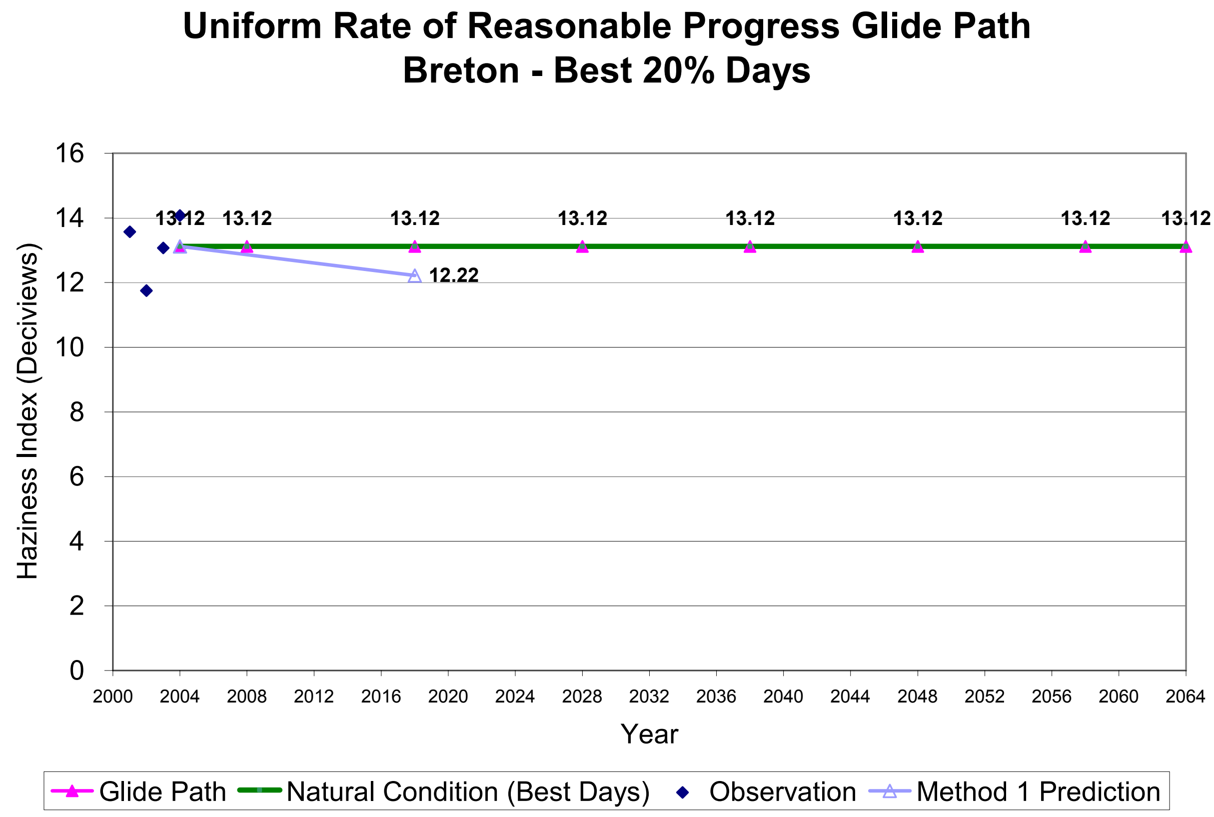


Figure D-3b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Breton Island (BRET), Louisiana and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

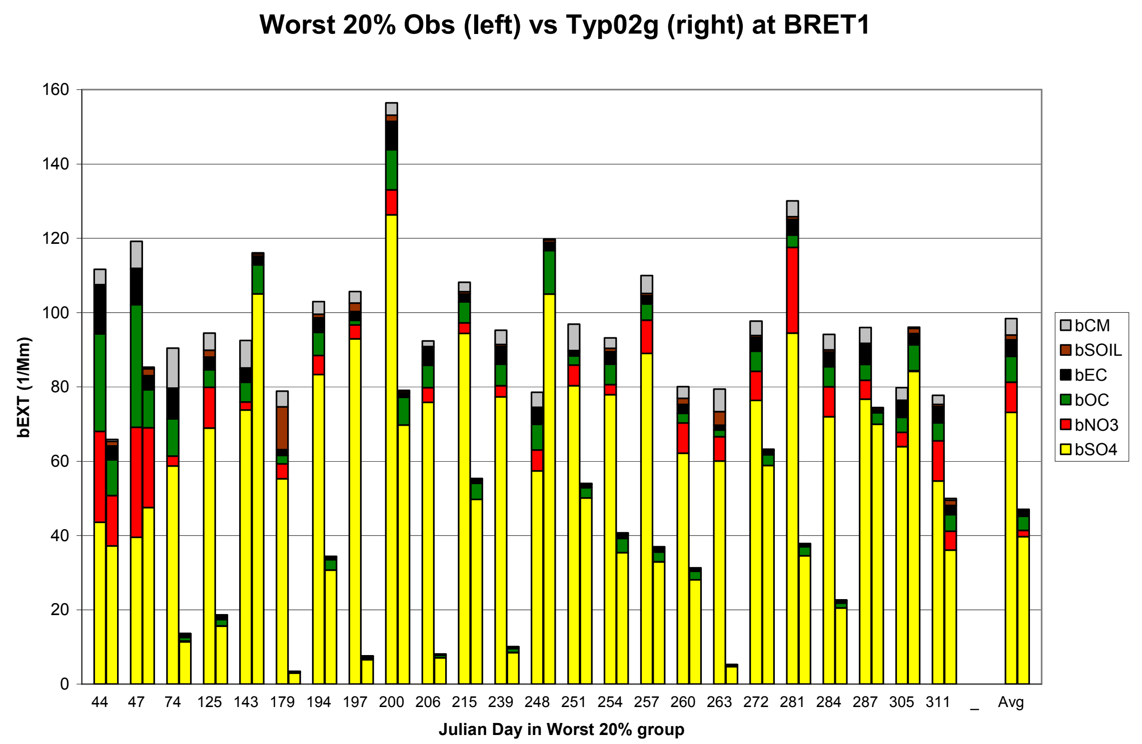


Figure D-3c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Breton Island (BRET), Louisiana and Worst 20% (W20%) days in 2002.

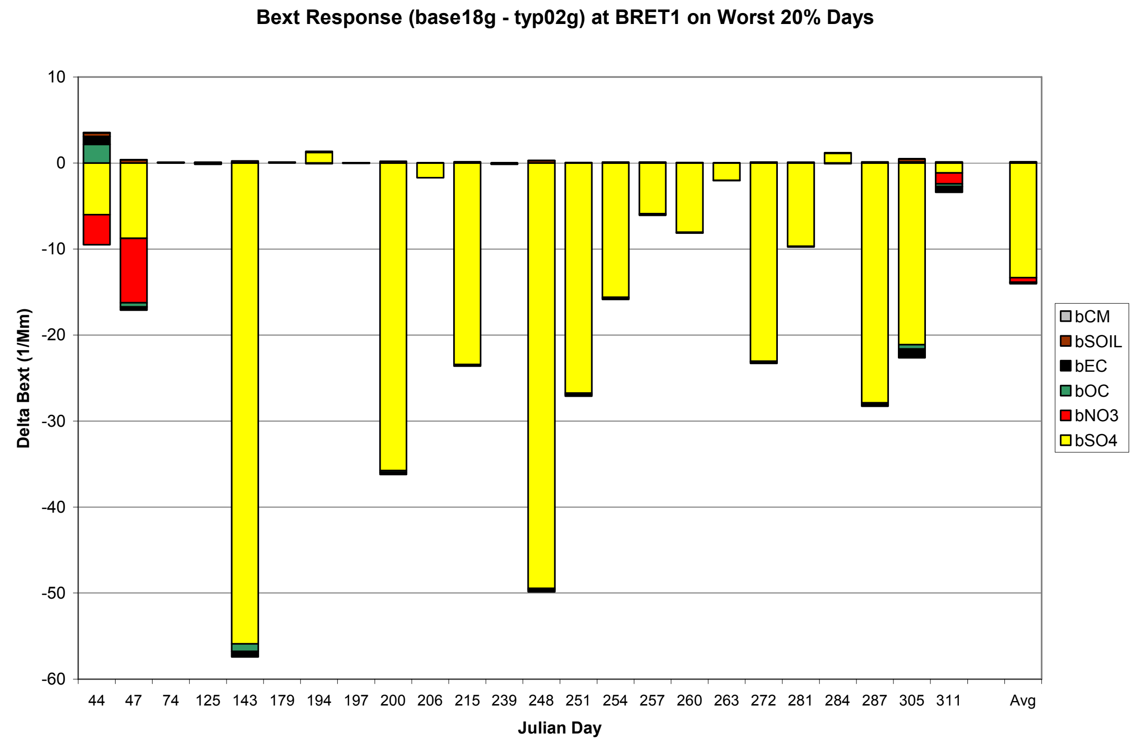


Figure D-3d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Breton Island (BRET), Louisiana and Worst 20% (W20%) days in 2002.

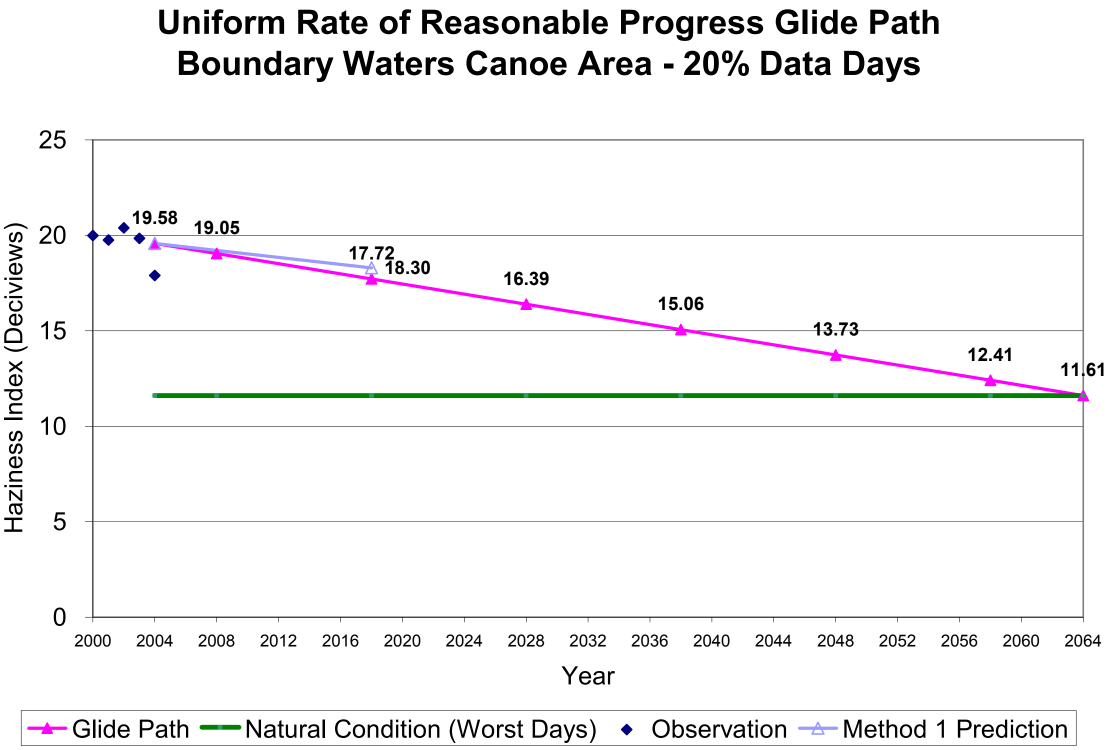


Figure D-4a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

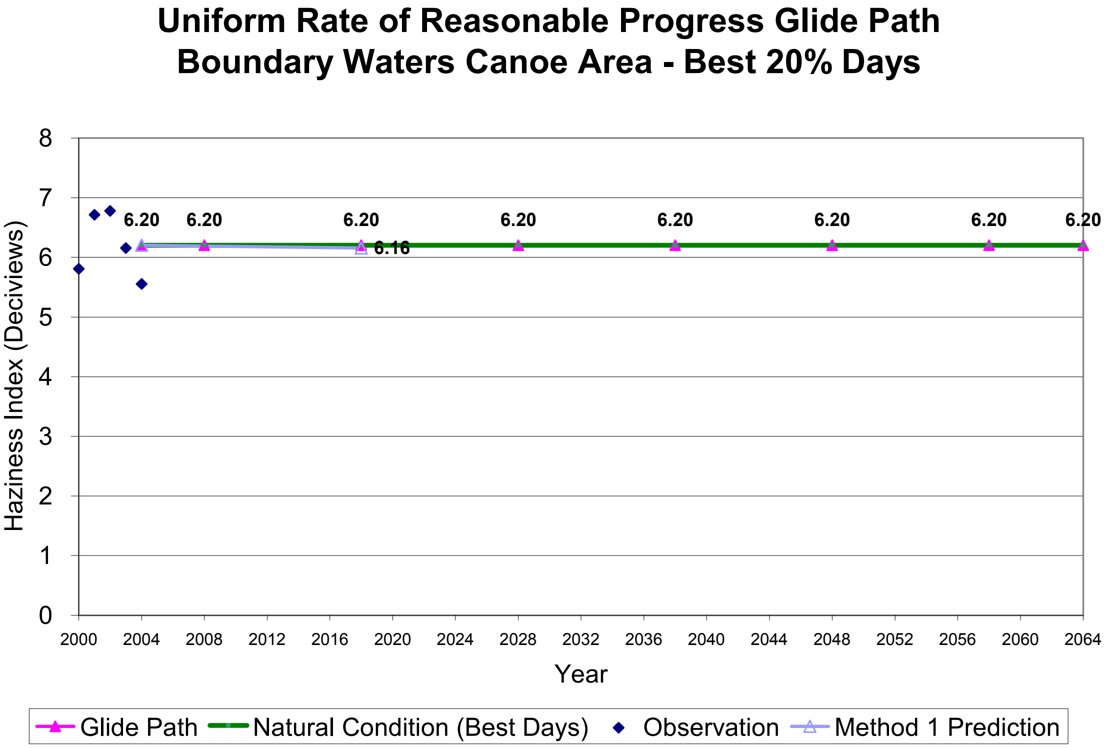


Figure D-4b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Boundary Waters (BOWA), Minnesota and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

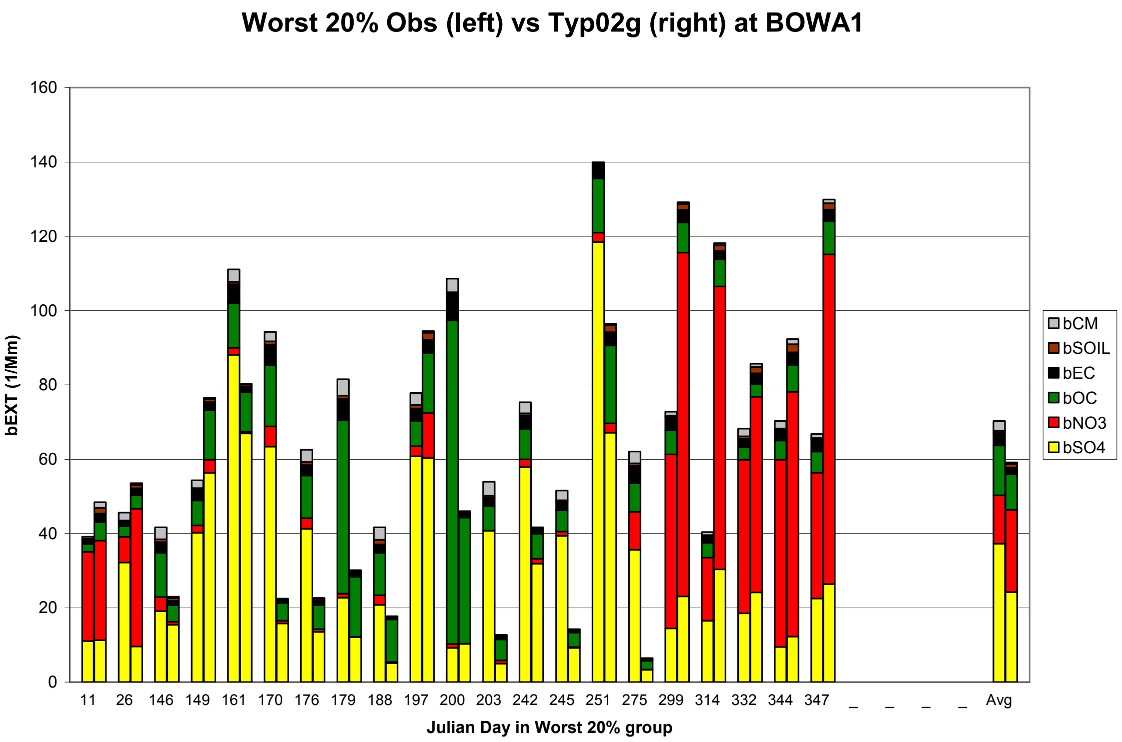


Figure D-4c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days in 2002.

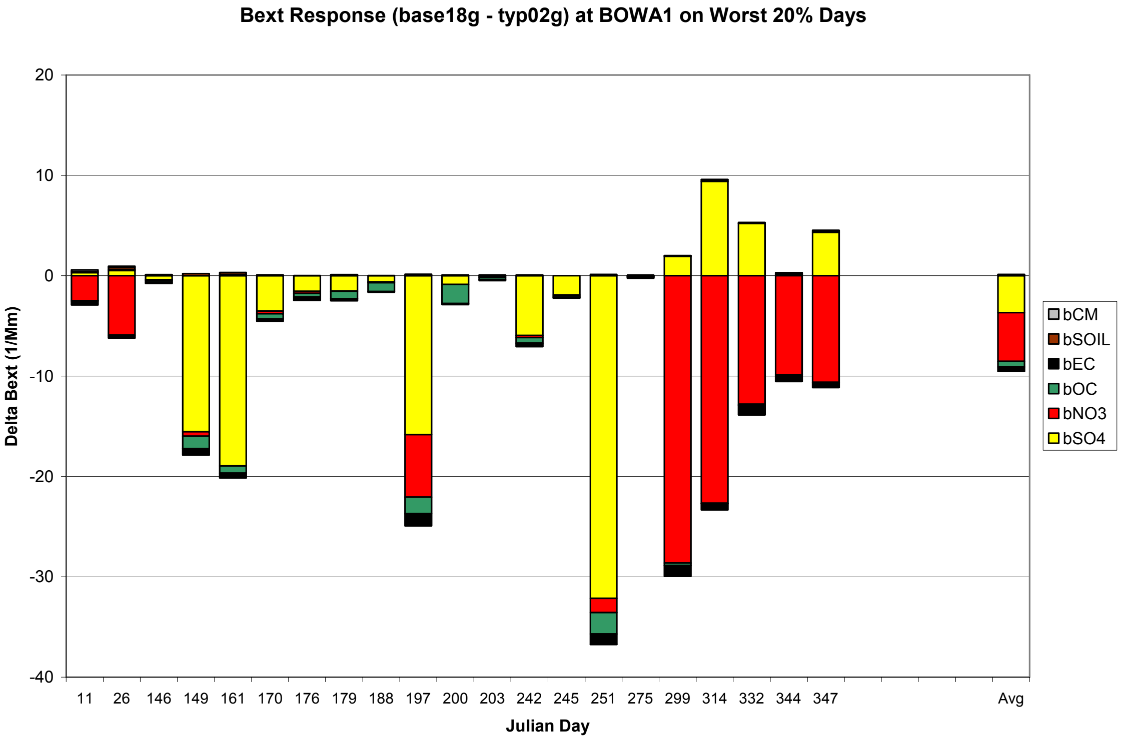


Figure D-4d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days in 2002.

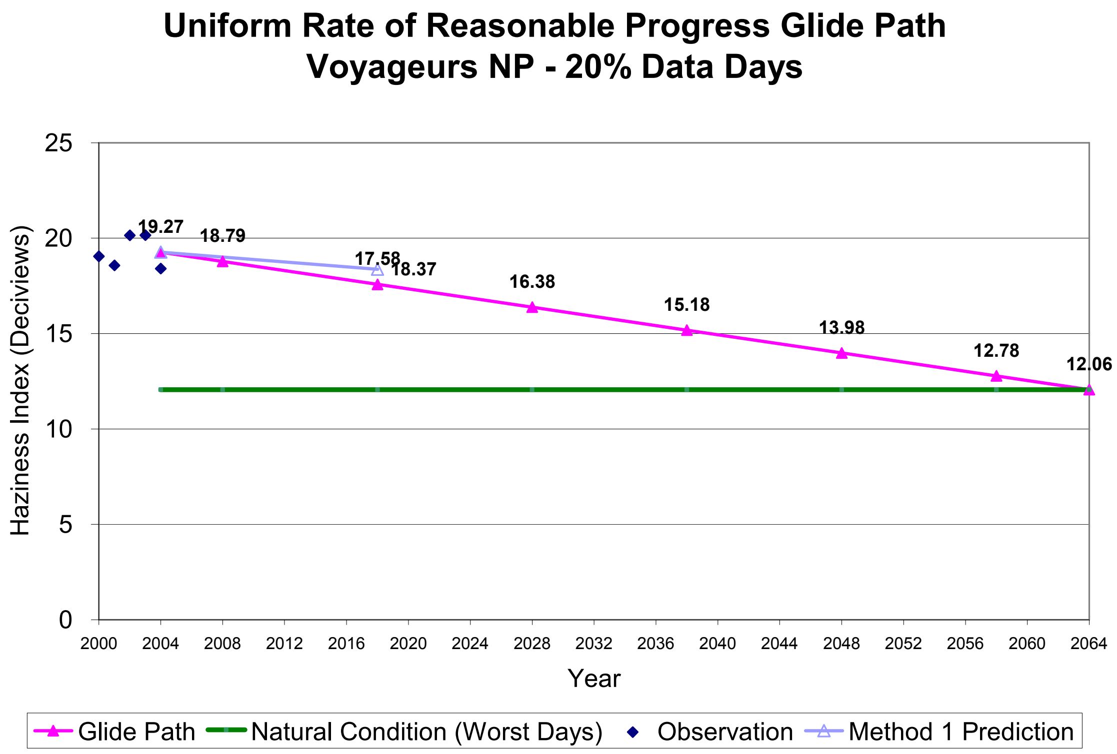


Figure D-5a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

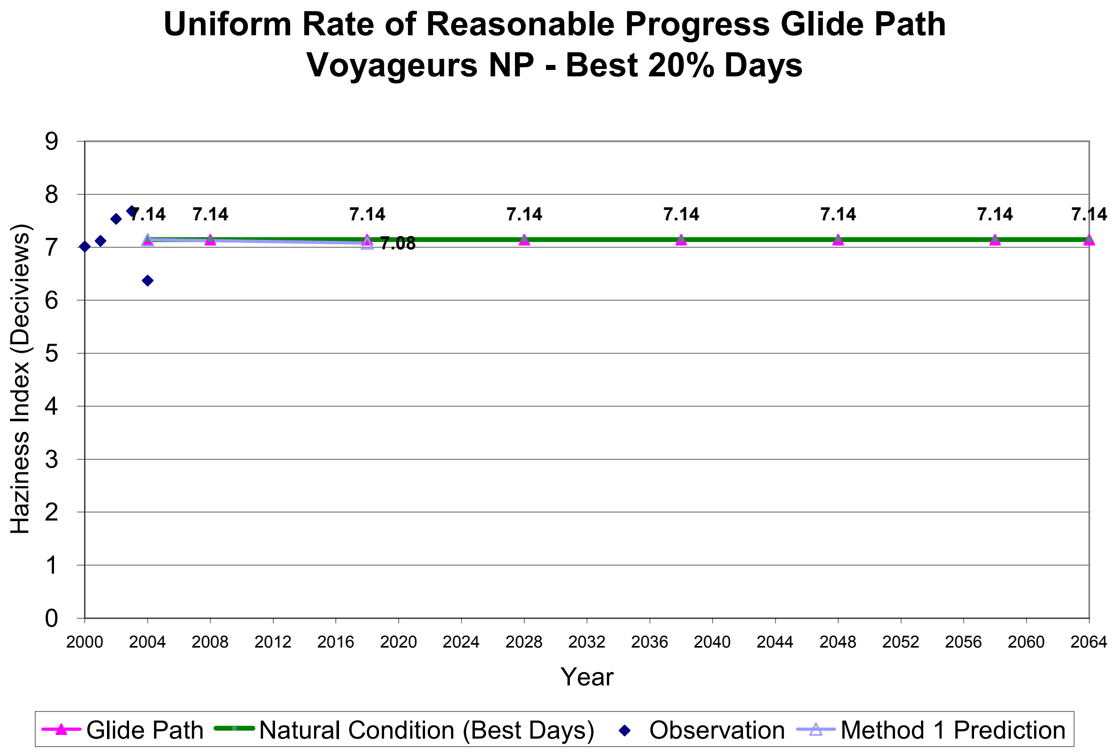


Figure D-5b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Voyageurs (VOYA), Minnesota and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

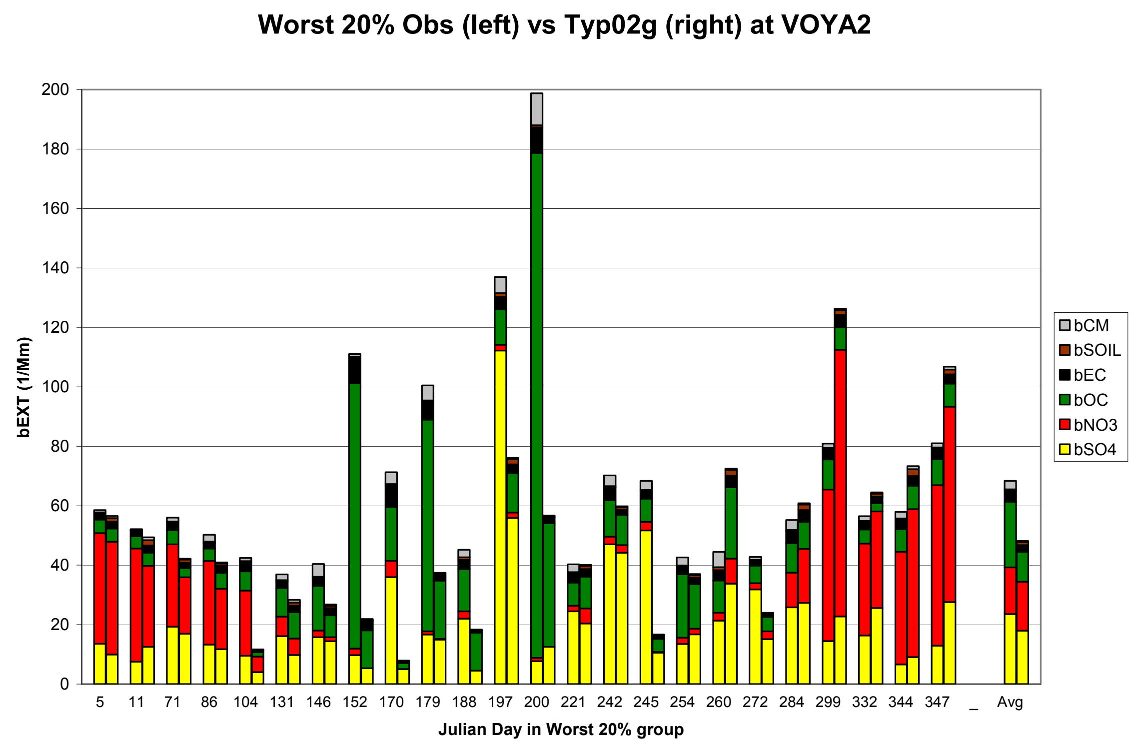


Figure D-5c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days in 2002.

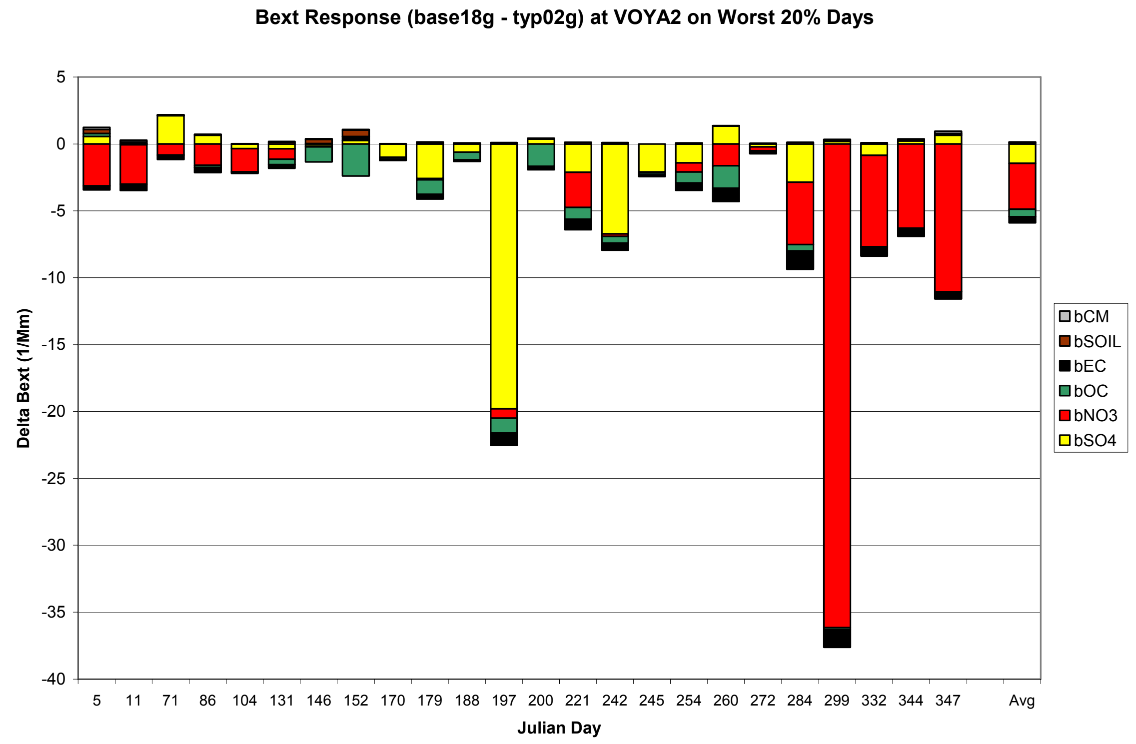


Figure D-5d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days in 2002.

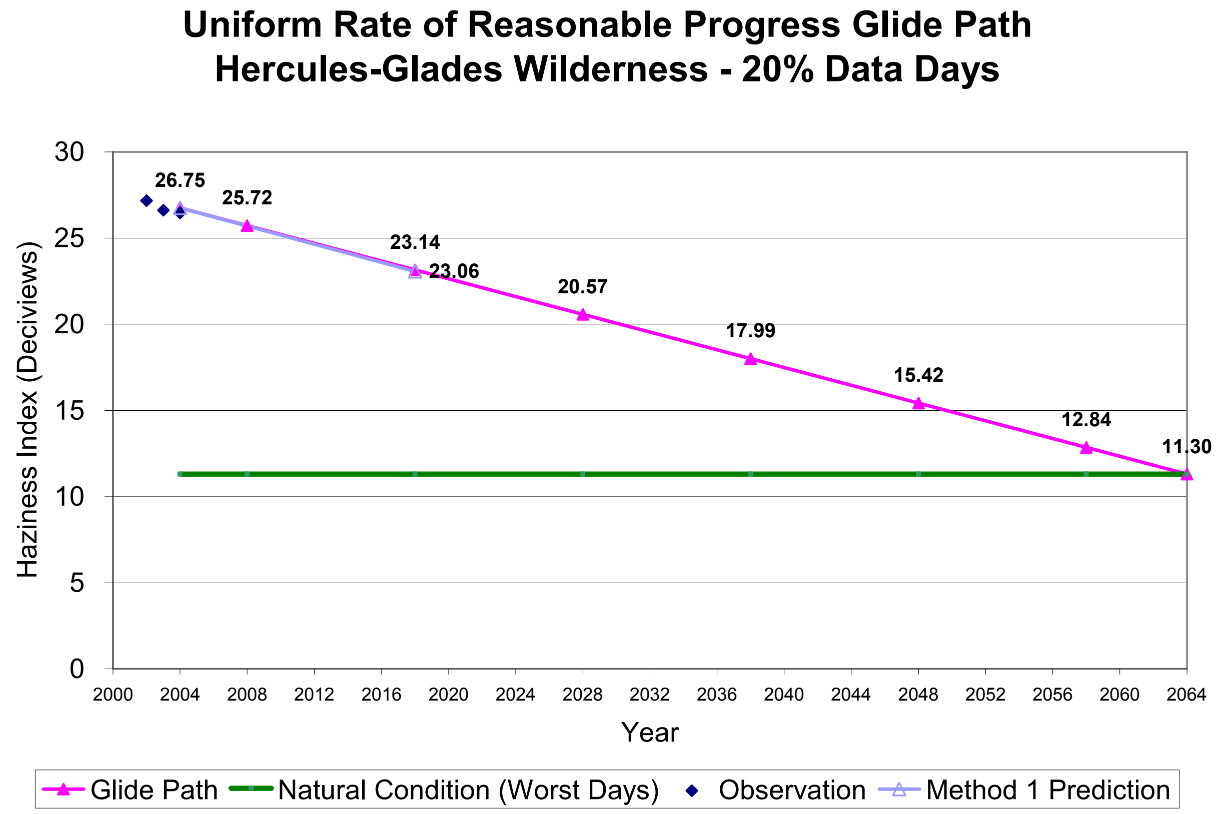


Figure D-6a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

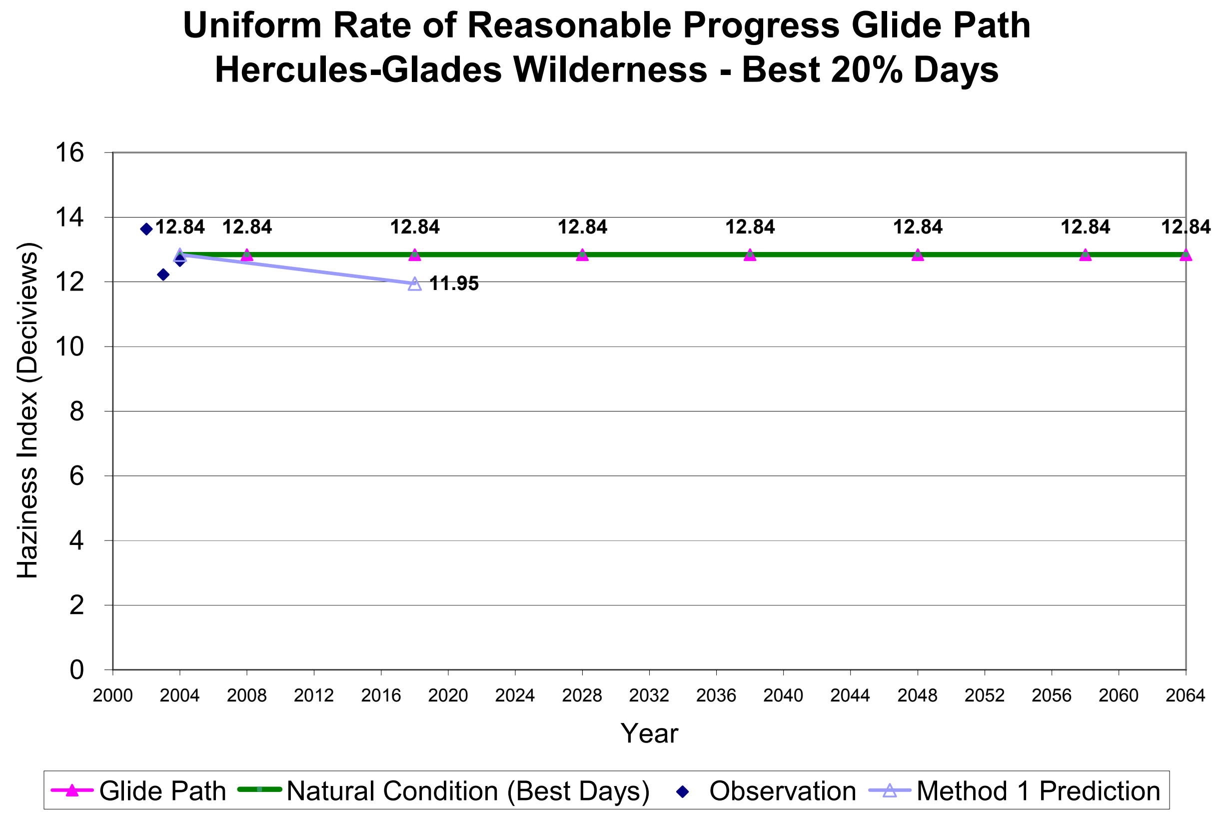


Figure D-6b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Hercules-Glade (HEGL), Missouri and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

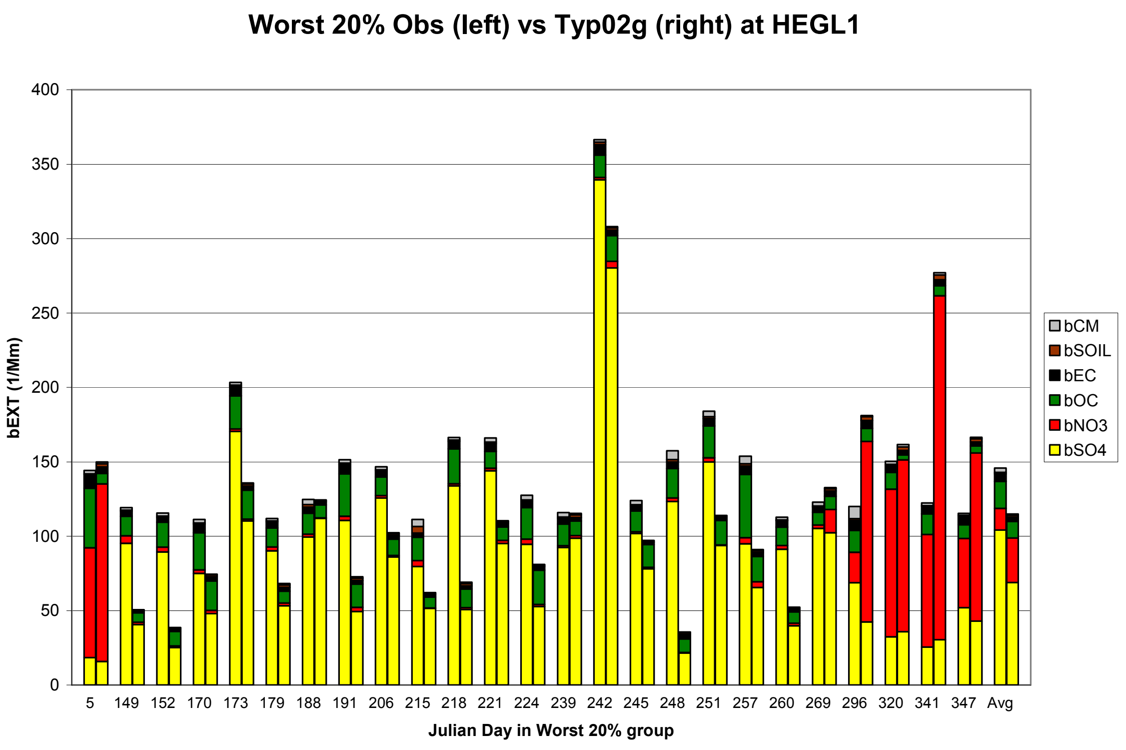


Figure D-6c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days in 2002.

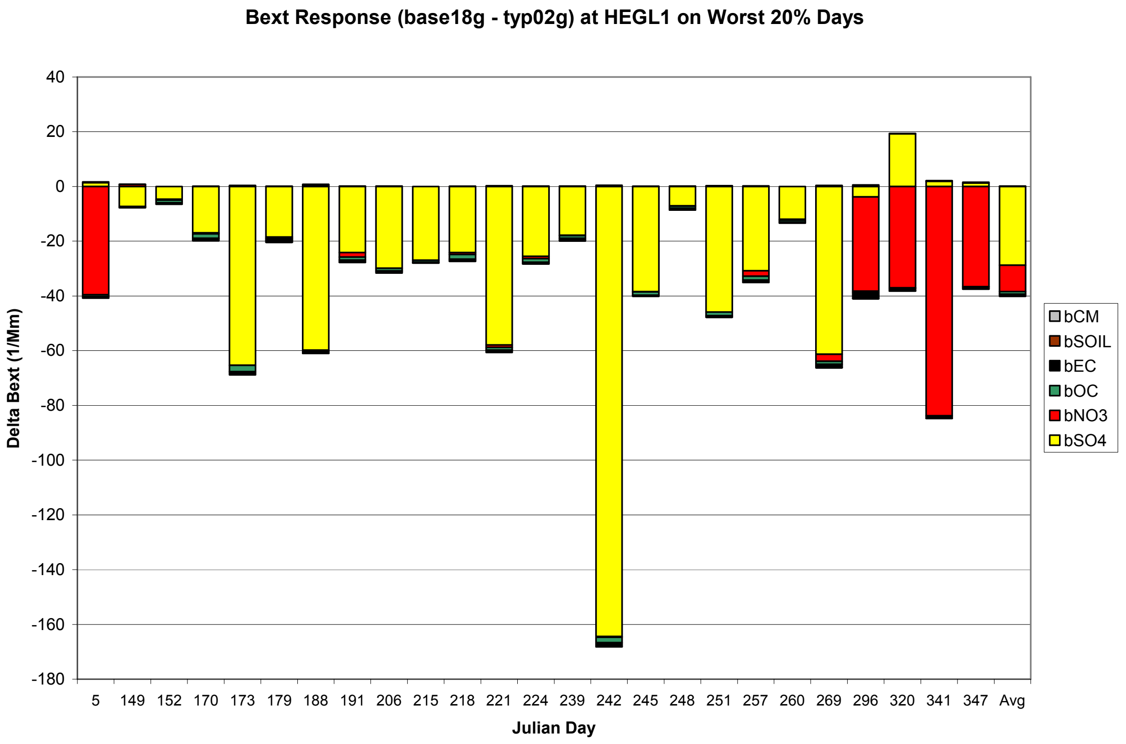


Figure D-6d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days in 2002.

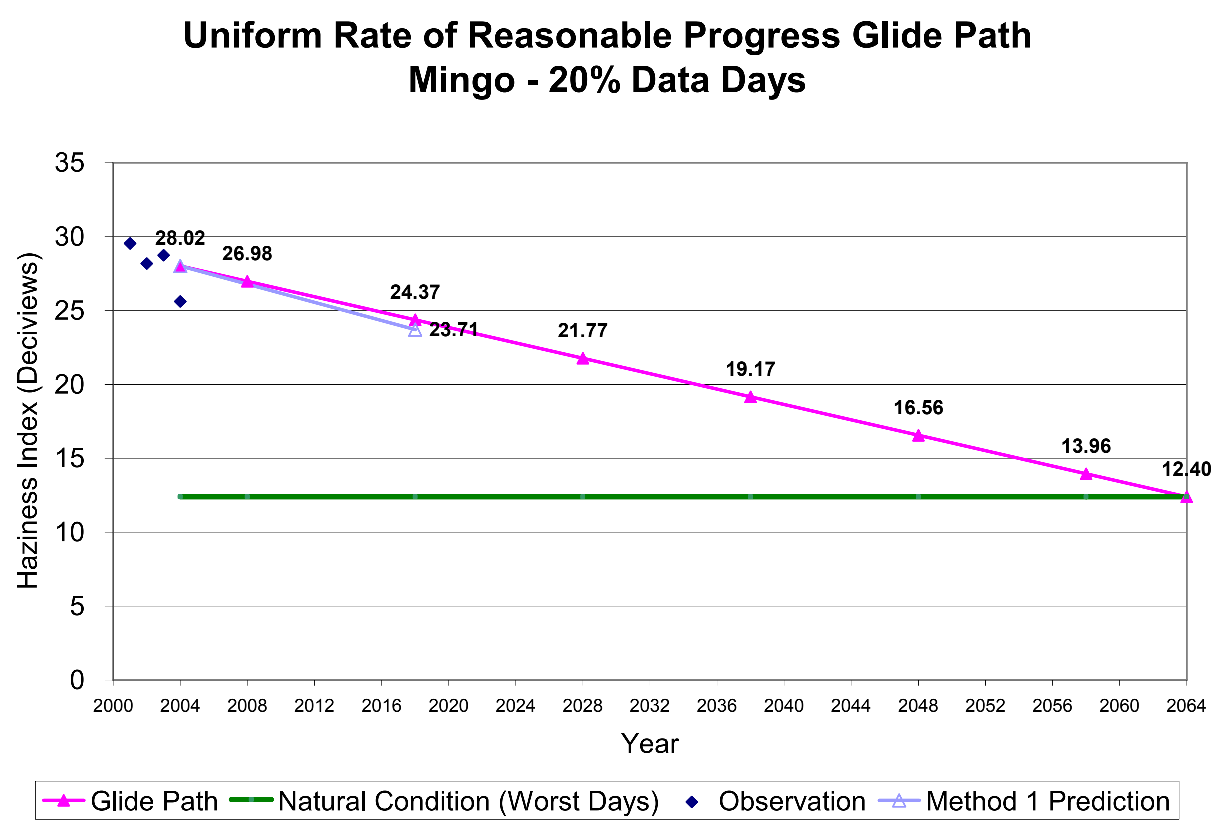


Figure D-7a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

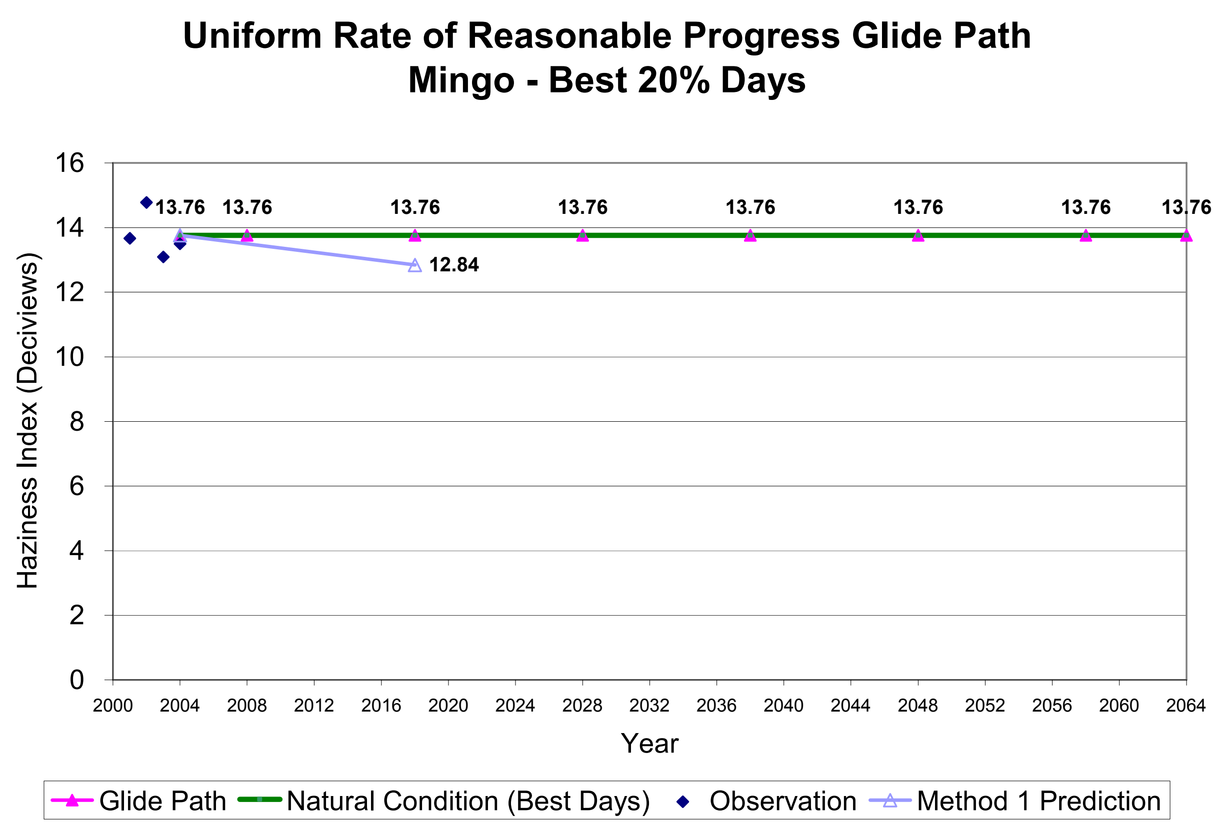


Figure D-7b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Mingo (MING), Missouri and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

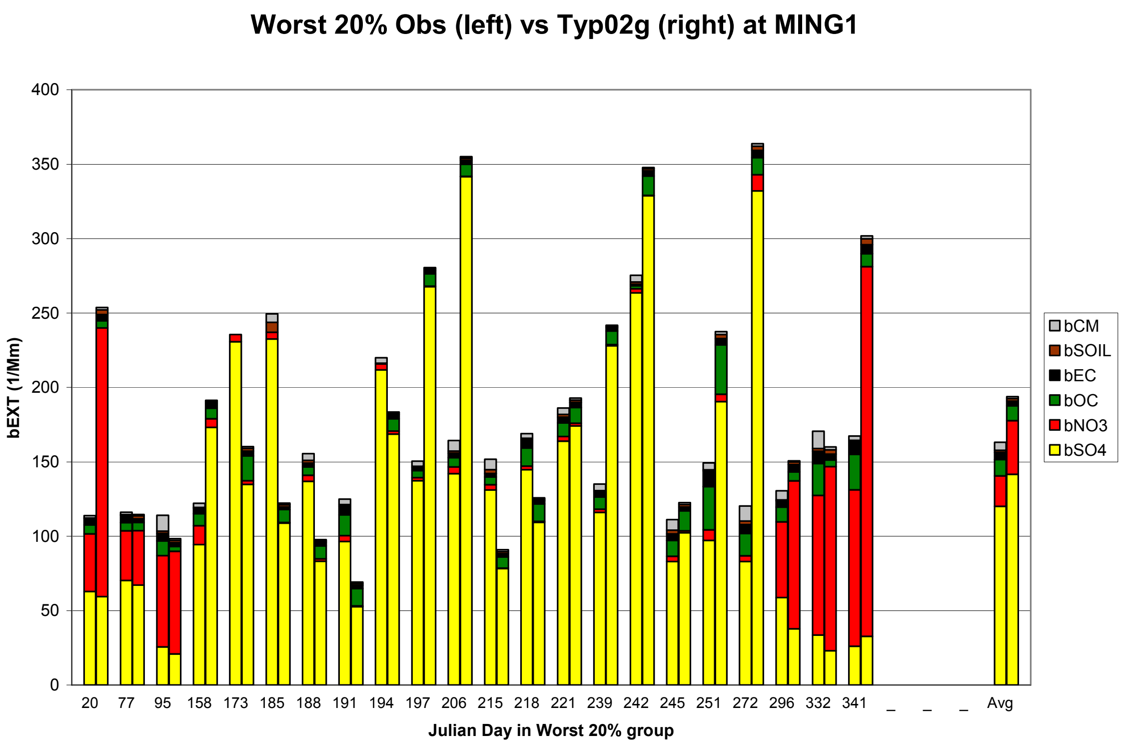


Figure D-7c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Mingo (MING), Missouri and Worst 20% (W20%) days in 2002.

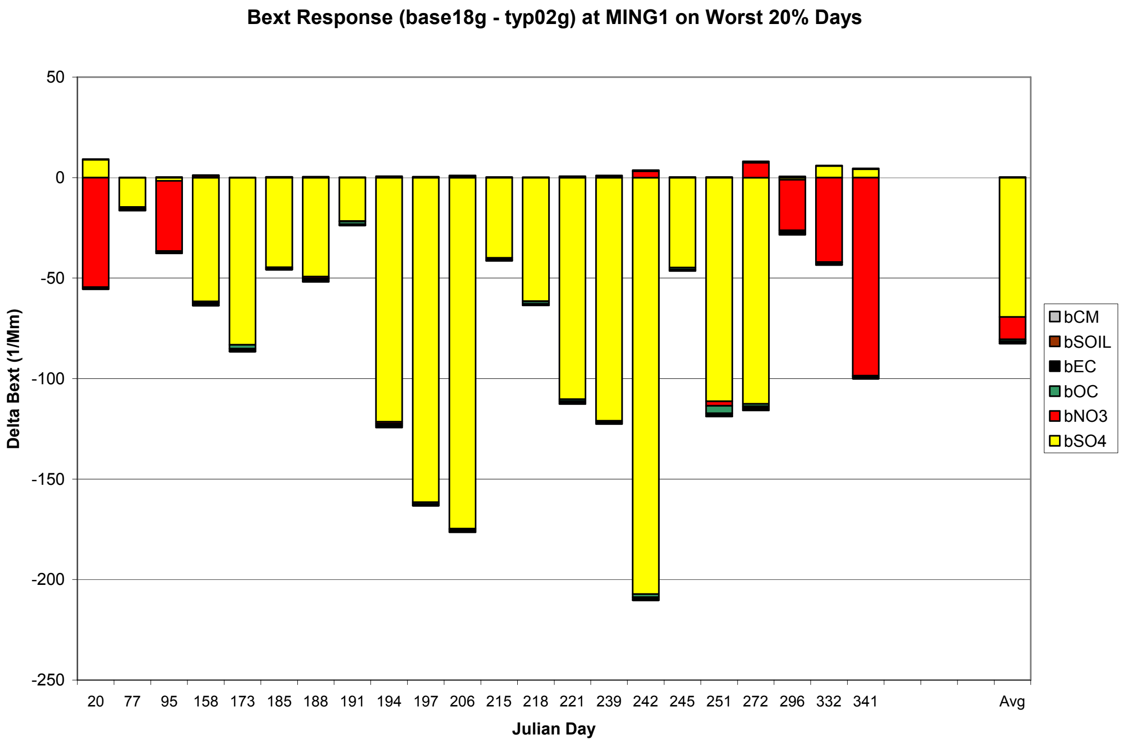


Figure D-7d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Mingo (MING), Missouri and Worst 20% (W20%) days in 2002.

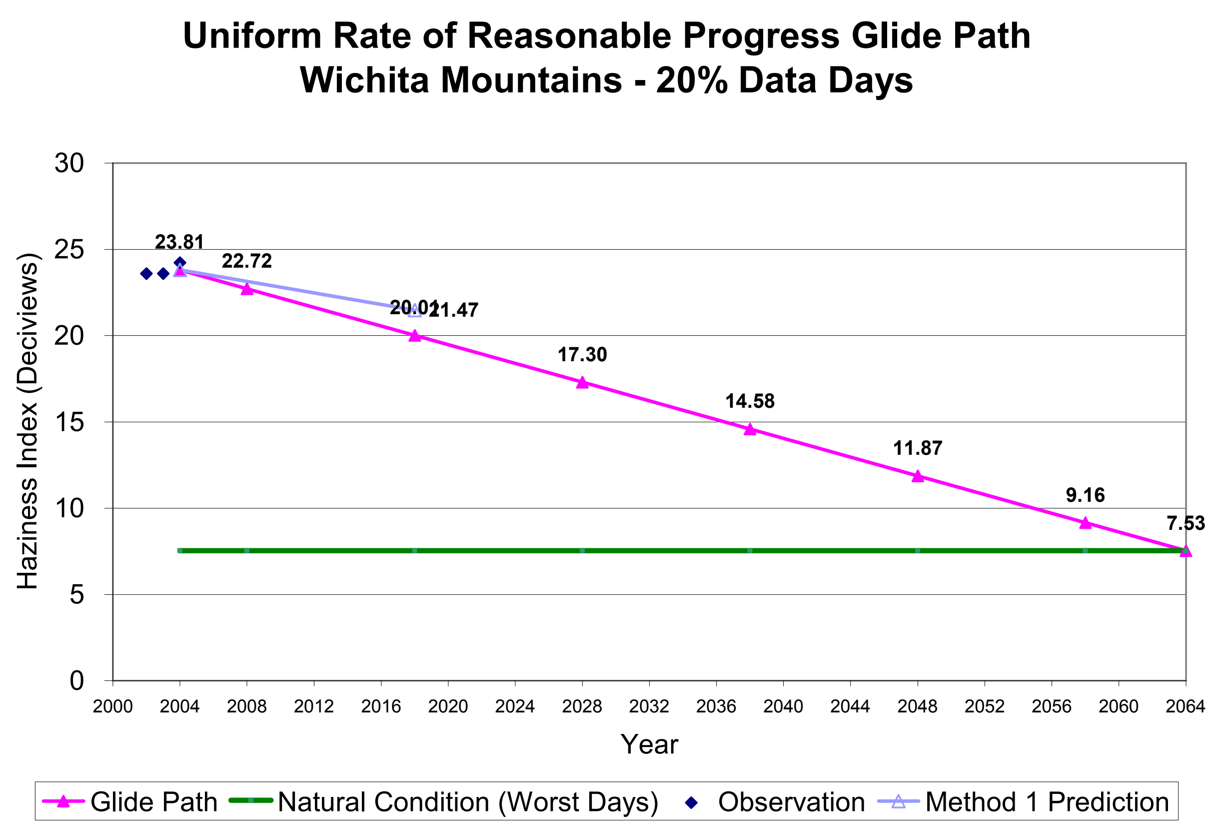


Figure D-8a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

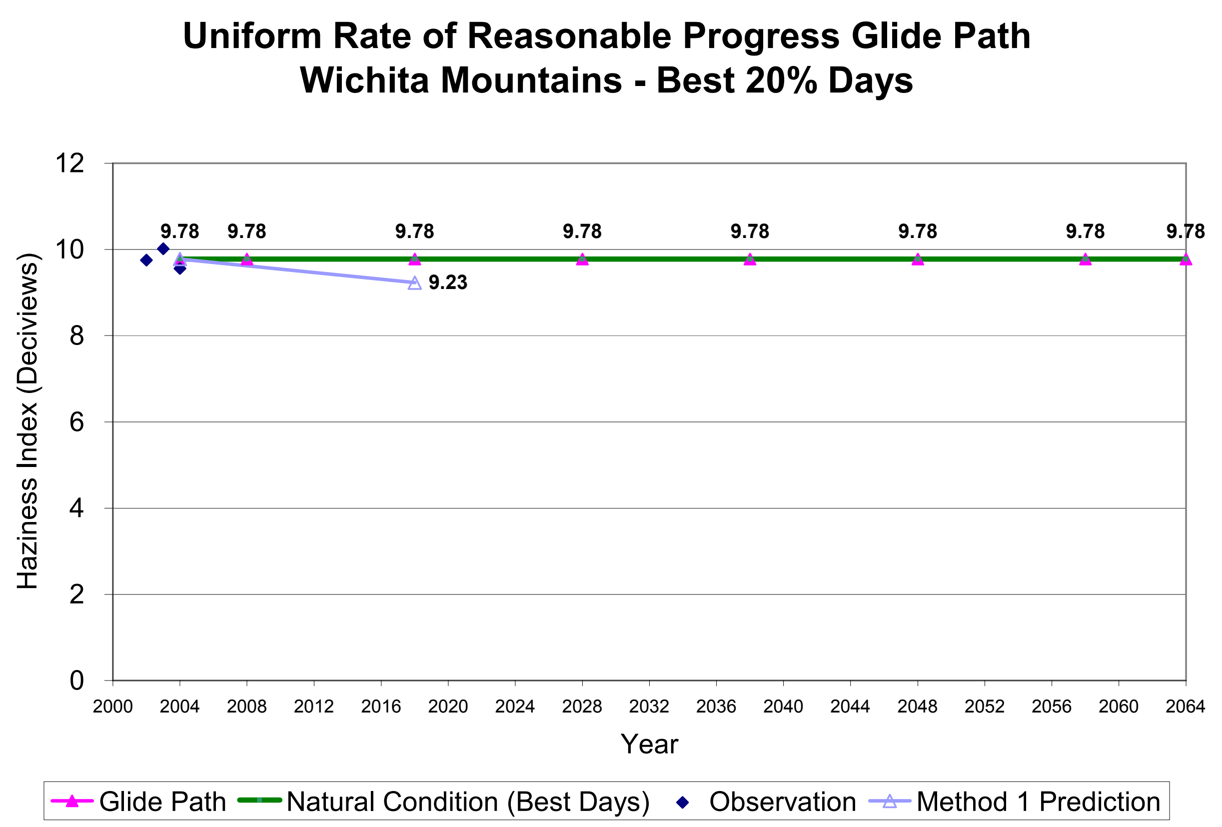


Figure D-8b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Wichita Mountains (WIMO), Oklahoma and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

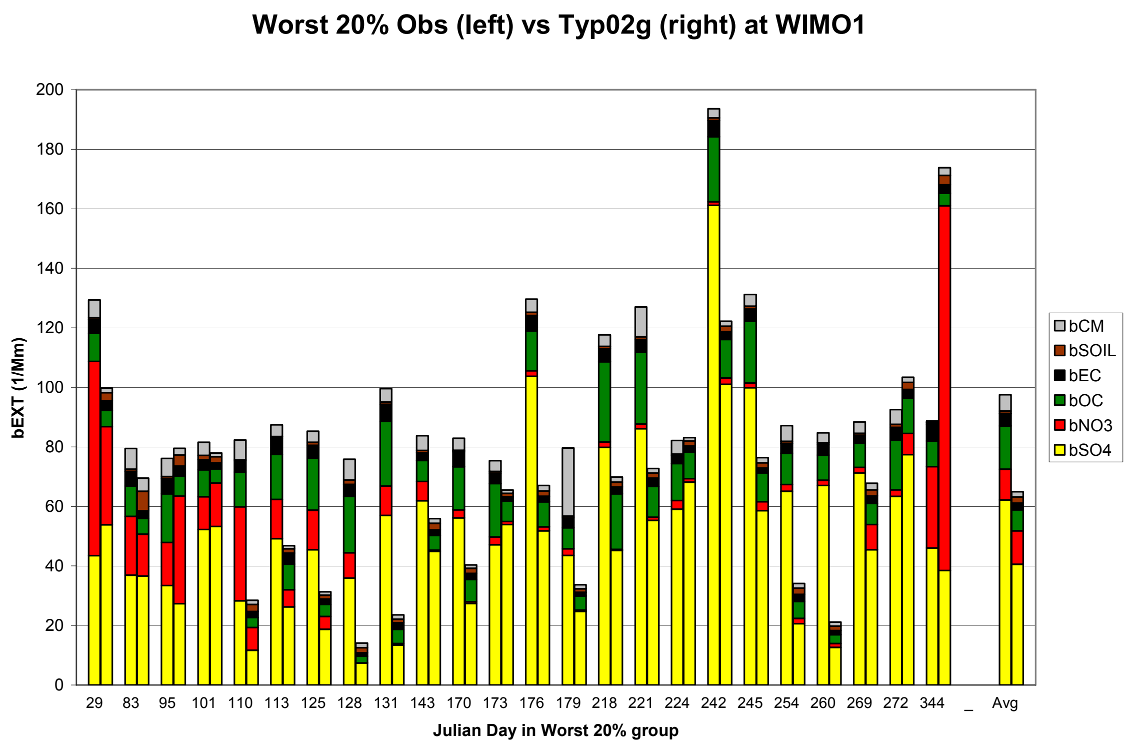


Figure D-8c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days in 2002.

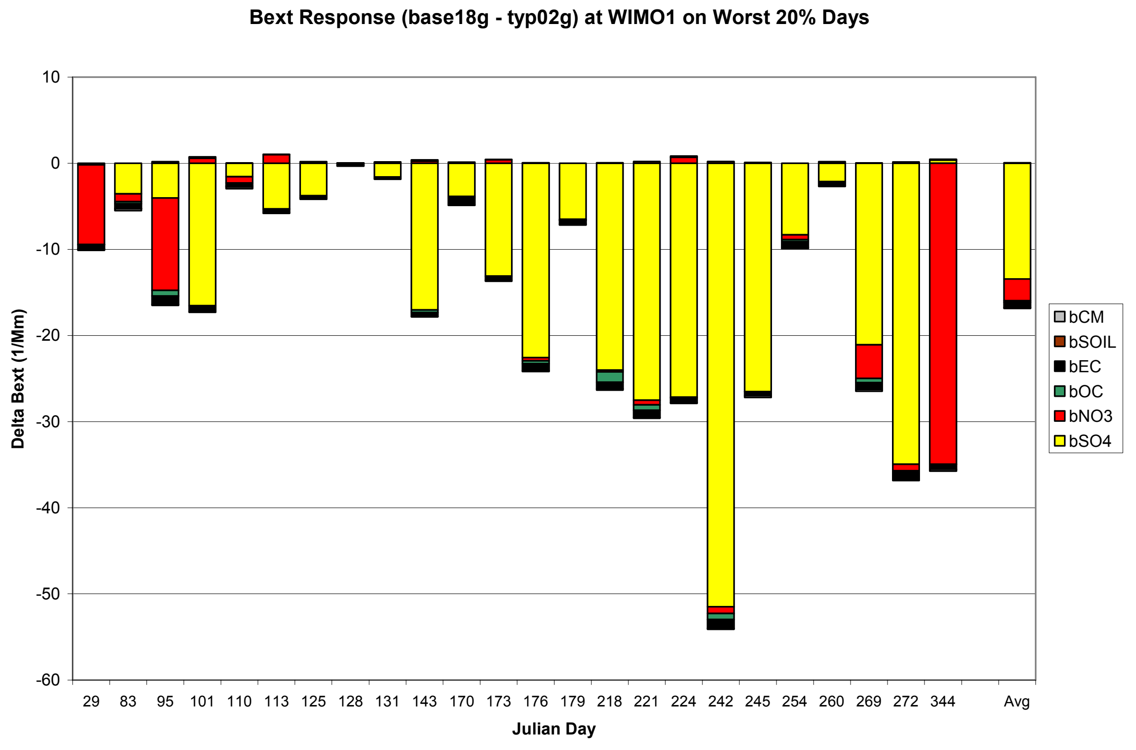


Figure D-8d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days in 2002.

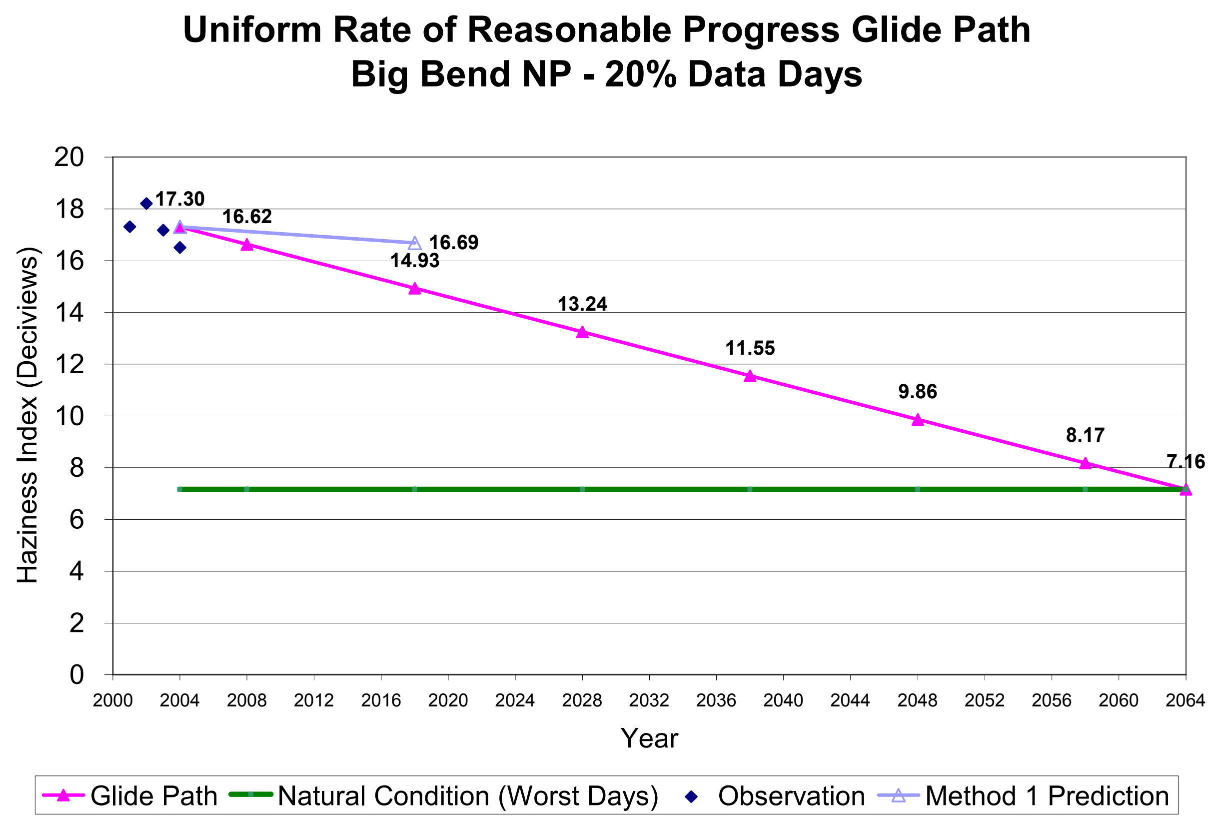


Figure D-9a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

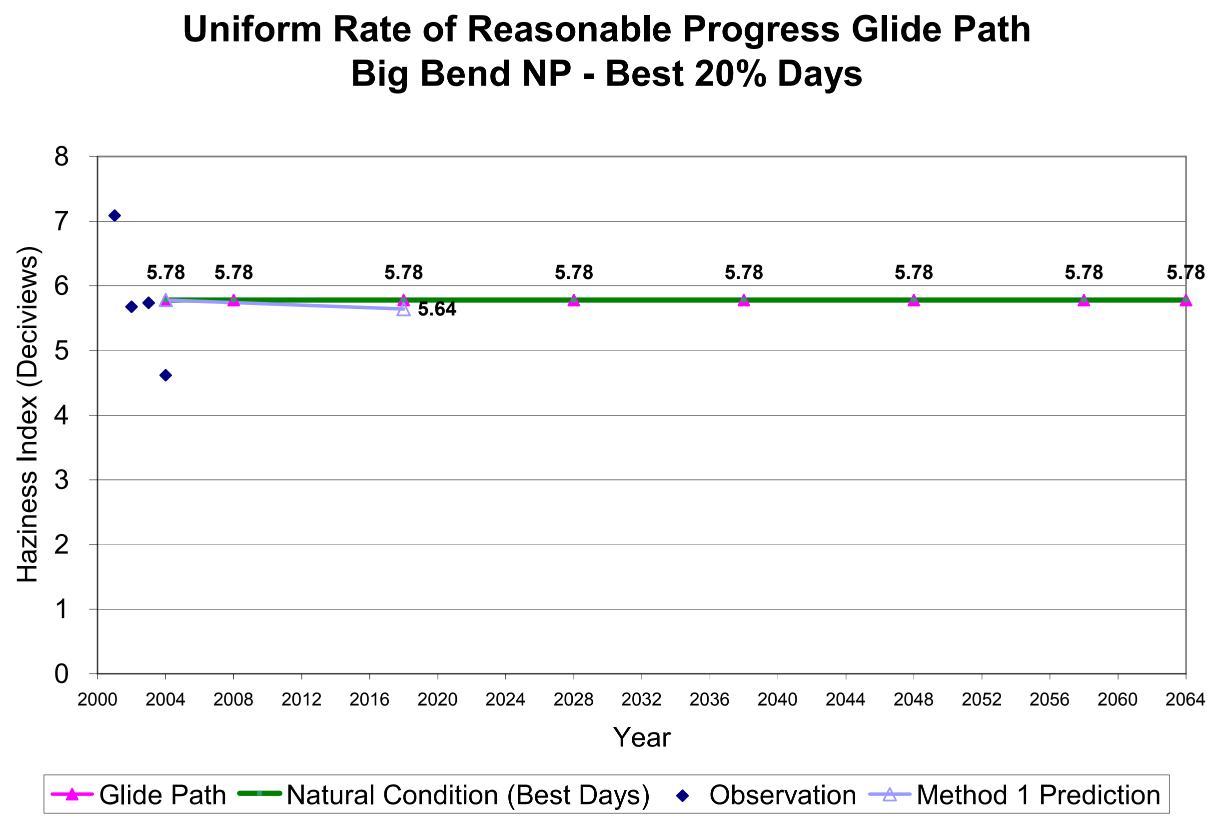


Figure D-9b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Big Bend (BIBE), Texas and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

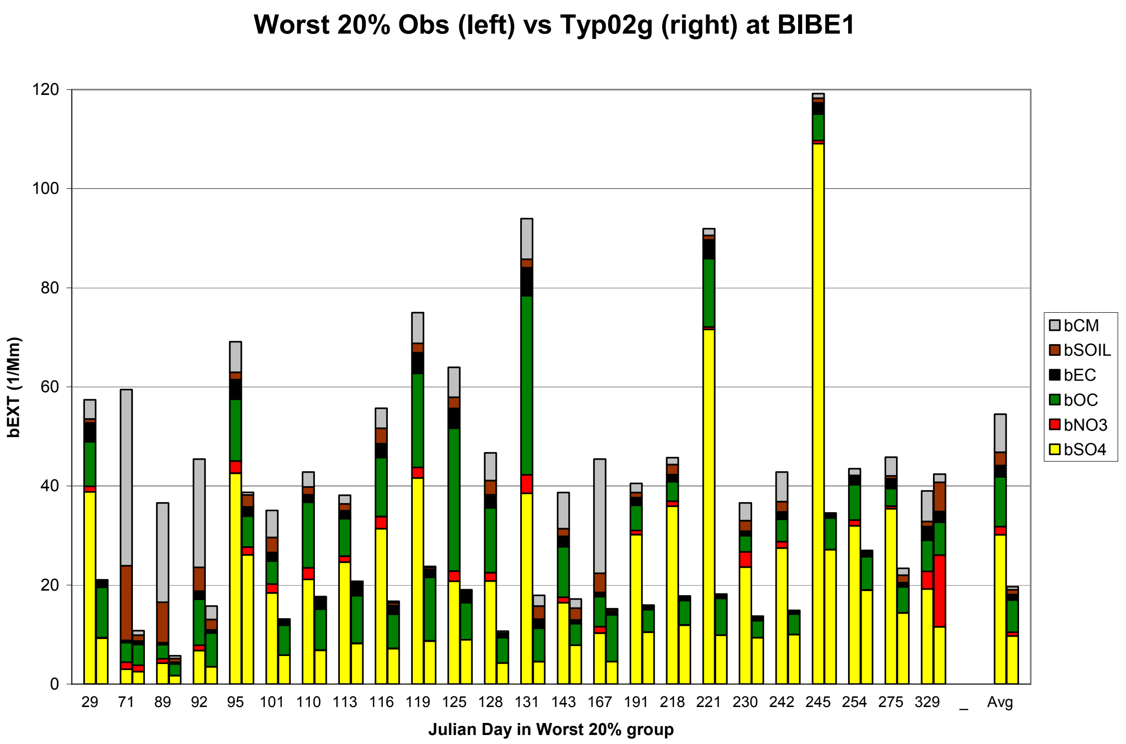


Figure D-9c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Big Bend (BIBE), Texas and Worst 20% (W20%) days in 2002.

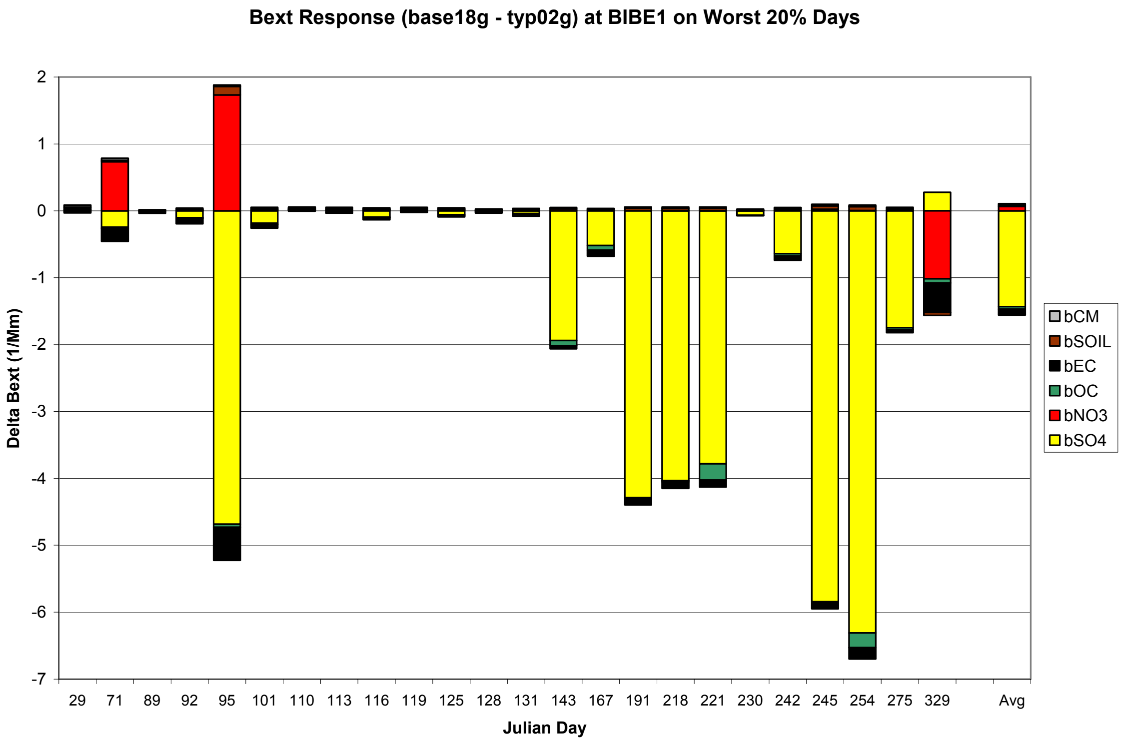


Figure D-9d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Big Bend (BIBE), Texas and Worst 20% (W20%) days in 2002.

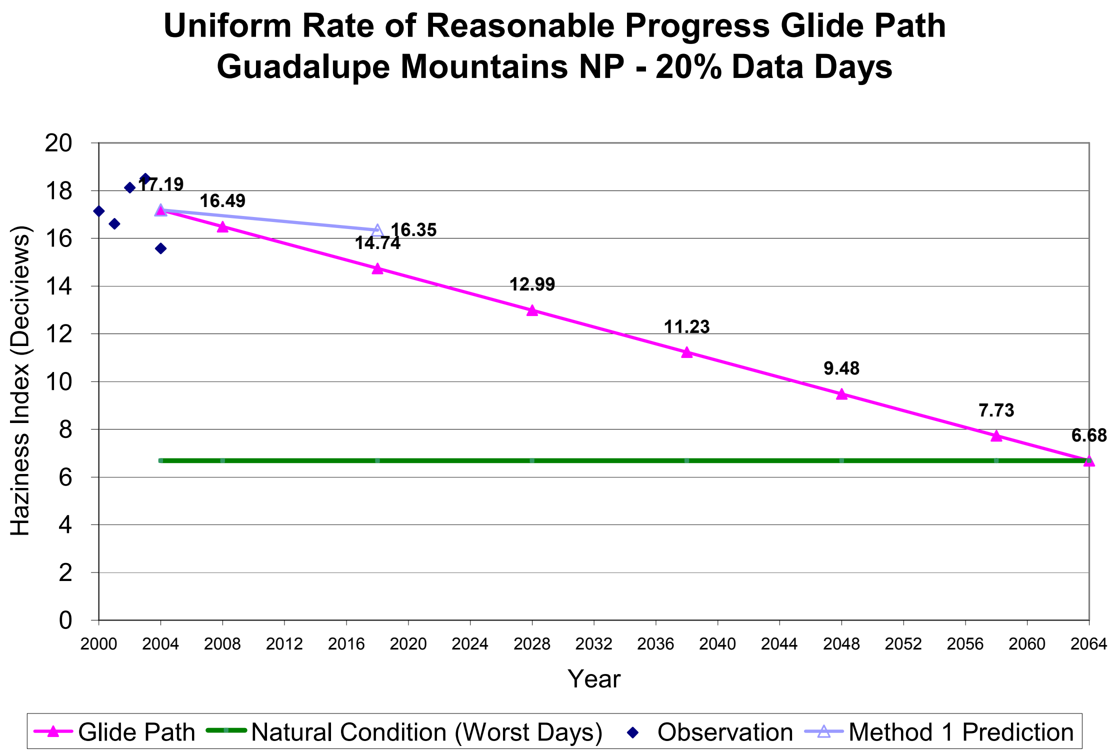


Figure D-10a. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

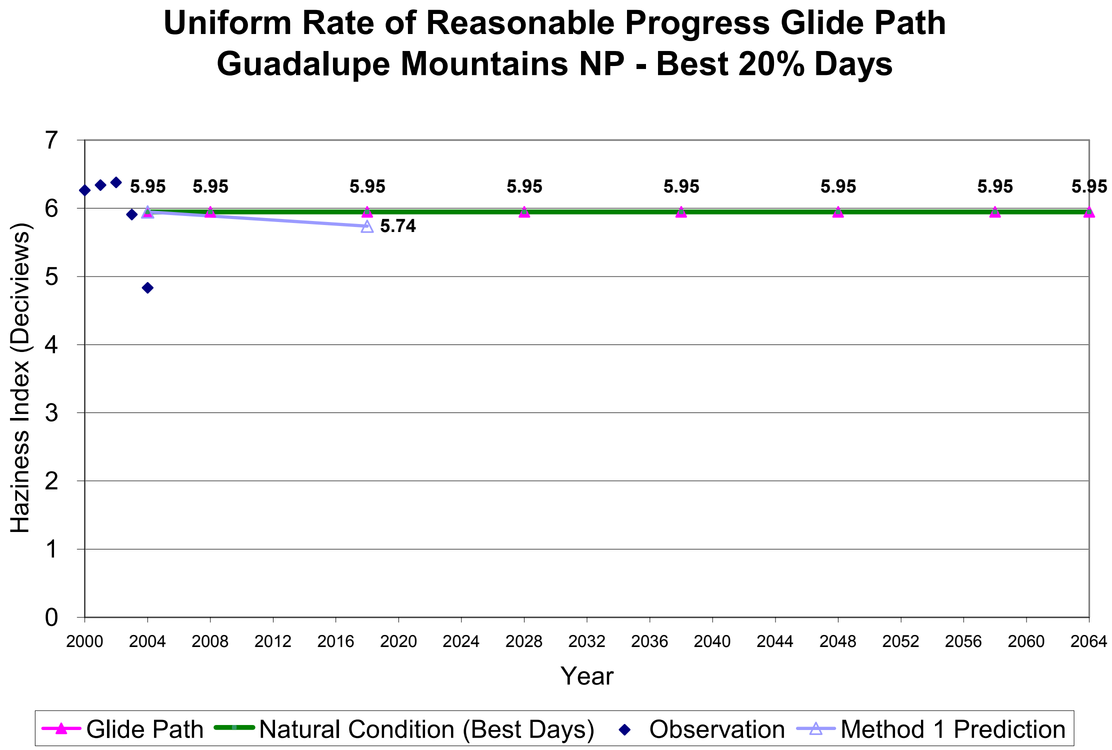


Figure D-10b. 2018 Visibility Projections and 2018 URP Glidepaths in deciview for Guadalupe Mountains (GUMO), Texas and Best 20% (B20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

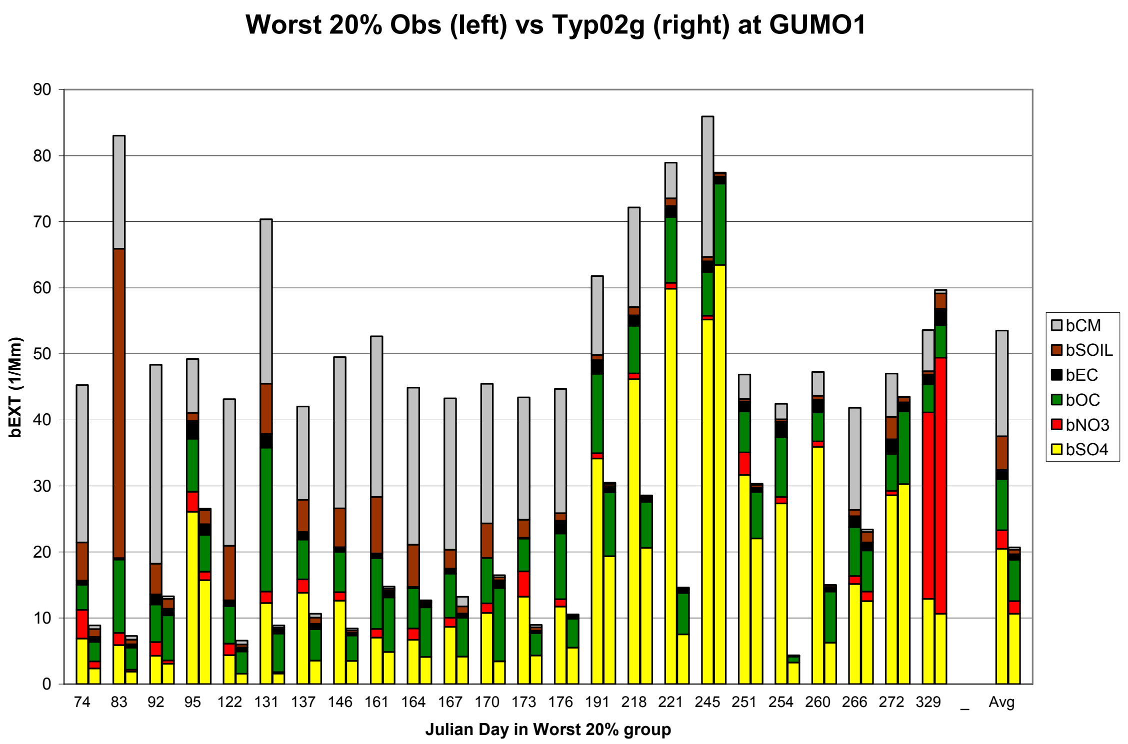


Figure D-10c. Comparison of observed (left) and 2002 Base G modeled (right) daily extinction for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days in 2002.

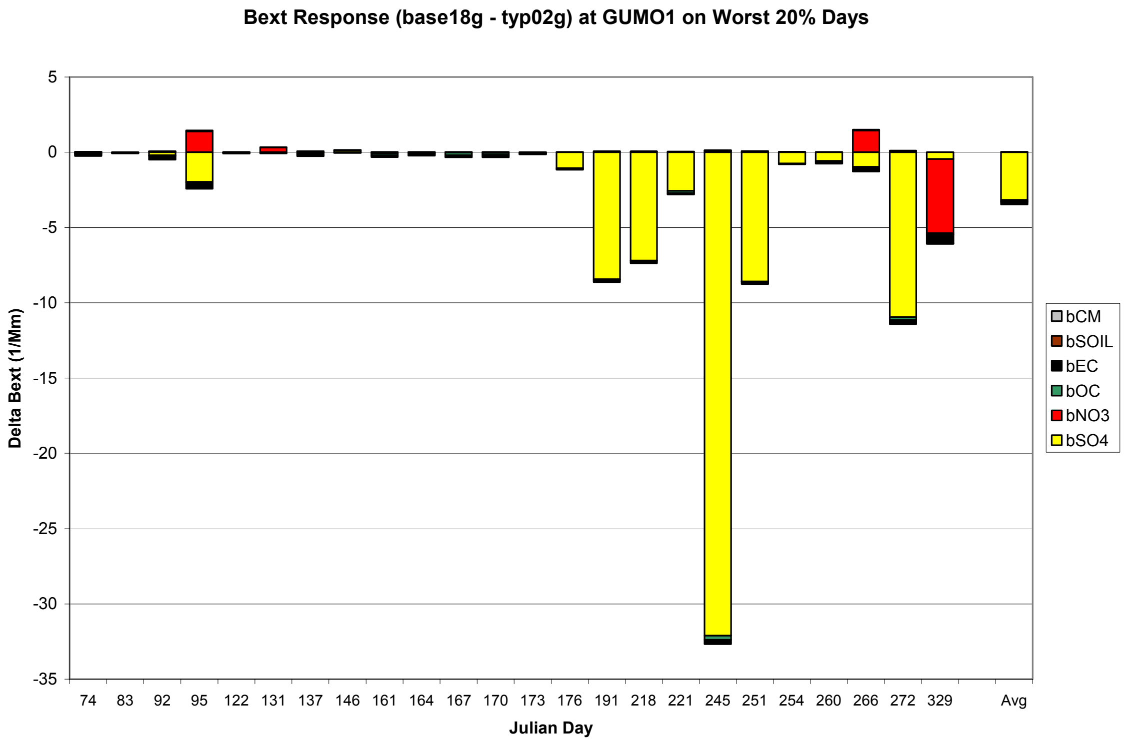


Figure D-10d. Differences in modeled 2002 and 2018 Base G CMAQ results (2018-2002) daily extinction for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days in 2002.

APPENDIX E

CAMx PM Source Apportionment Technology (PSAT) Extinction (Mm^{-1}) Contributions for the 2002 Worst and Best 20 Percent Days at CENRAP Class I Areas

Figure E-1: Caney Creek Wilderness Area (CACR), Arkansas
Figure E-2: Upper Buffalo Wilderness Area (UPBU), Arkansas
Figure E-3: Breton Island Wilderness Area (BRET), Louisiana
Figure E-4: Boundary Waters Canoe Area Wilderness Area (BOWA), Minnesota
Figure E-5: Voyageurs National Park (VOYA), Minnesota
Figure E-6: Hercules Glade Wilderness Area (HEGL), Missouri
Figure E-7: Mingo Wilderness Area (MING), Missouri
Figure E-8: Wichita Mountains Wilderness Area (WIMO), Oklahoma
Figure E-9: Big Bend National Park (BIBE), Texas
Figure E-10: Guadalupe Mountains National Park (GUMO), Texas

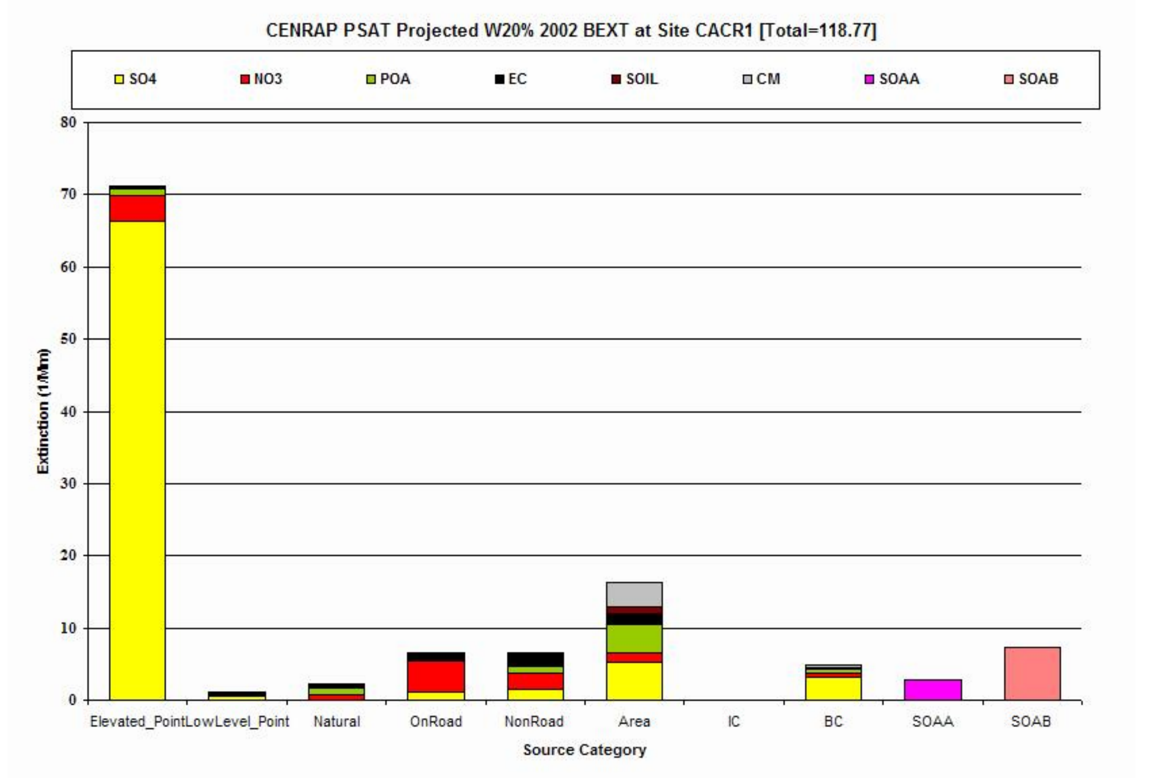

CENRAP PSAT Projected W20% 2002 BEXT at Site CACR1 [Total=118.77]

Figure E-1a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas.

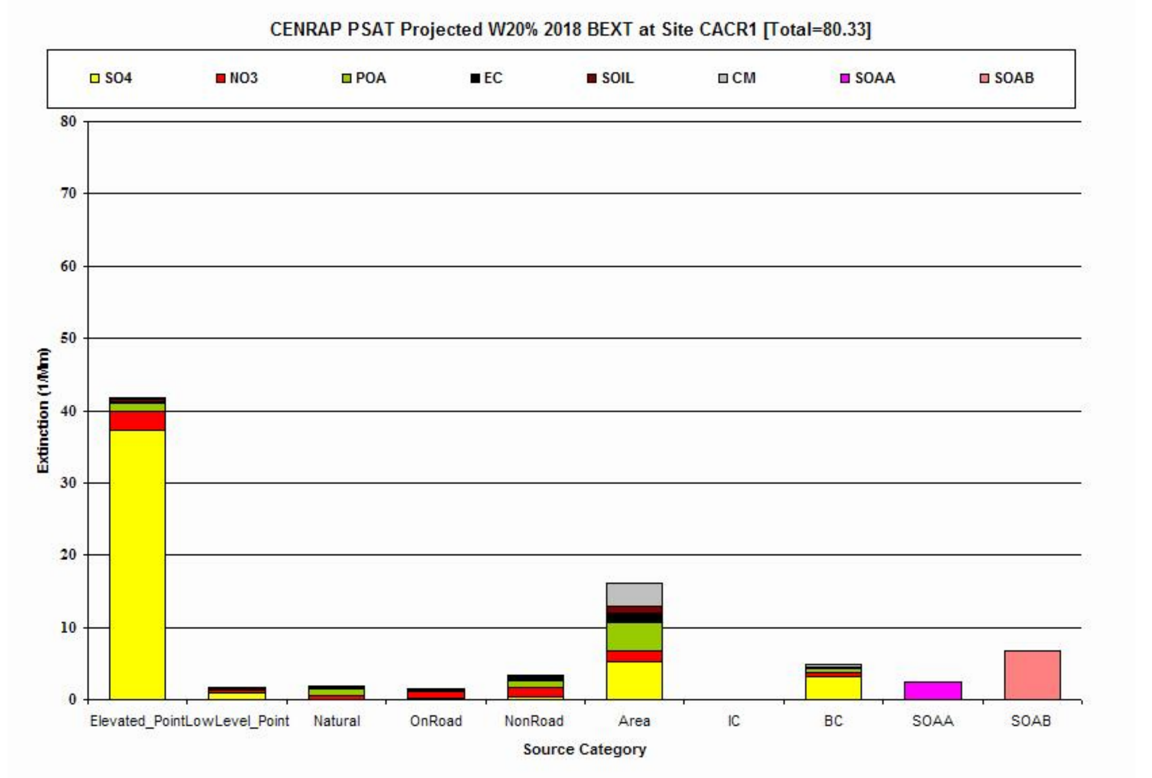

CENRAP PSAT Projected W20% 2018 BEXT at Site CACR1 [Total=80.33]

Figure E-1b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas.

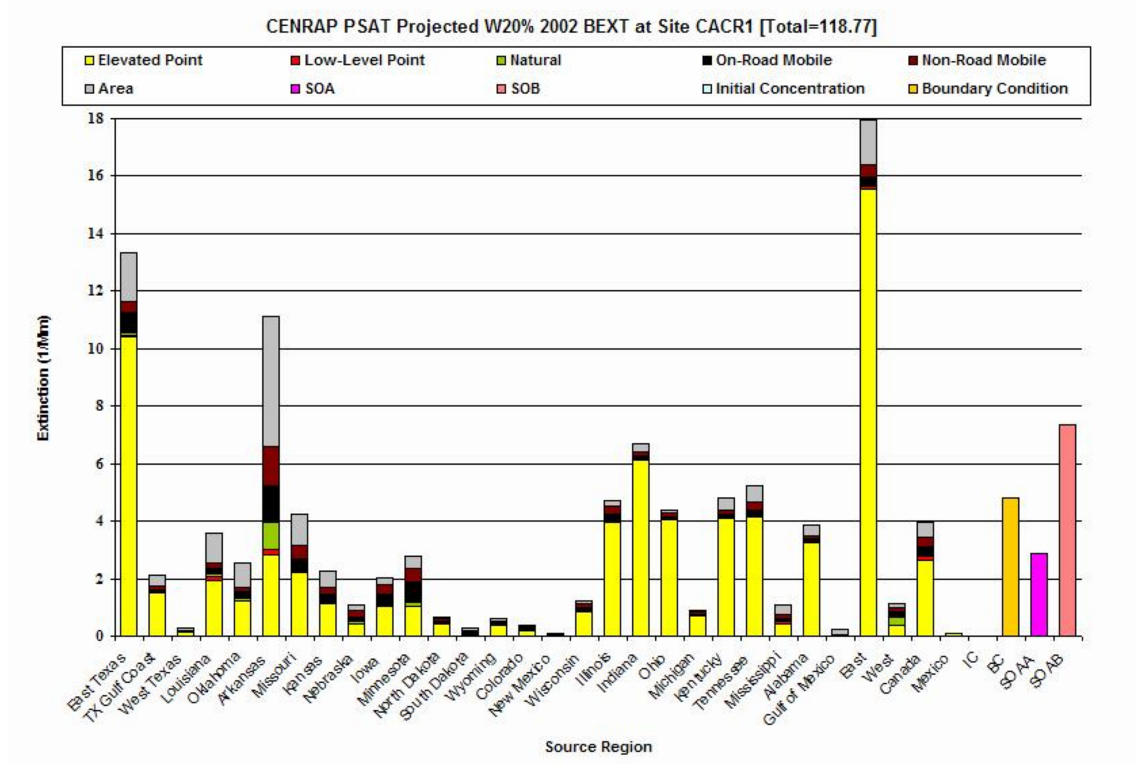


Figure E-1c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas.

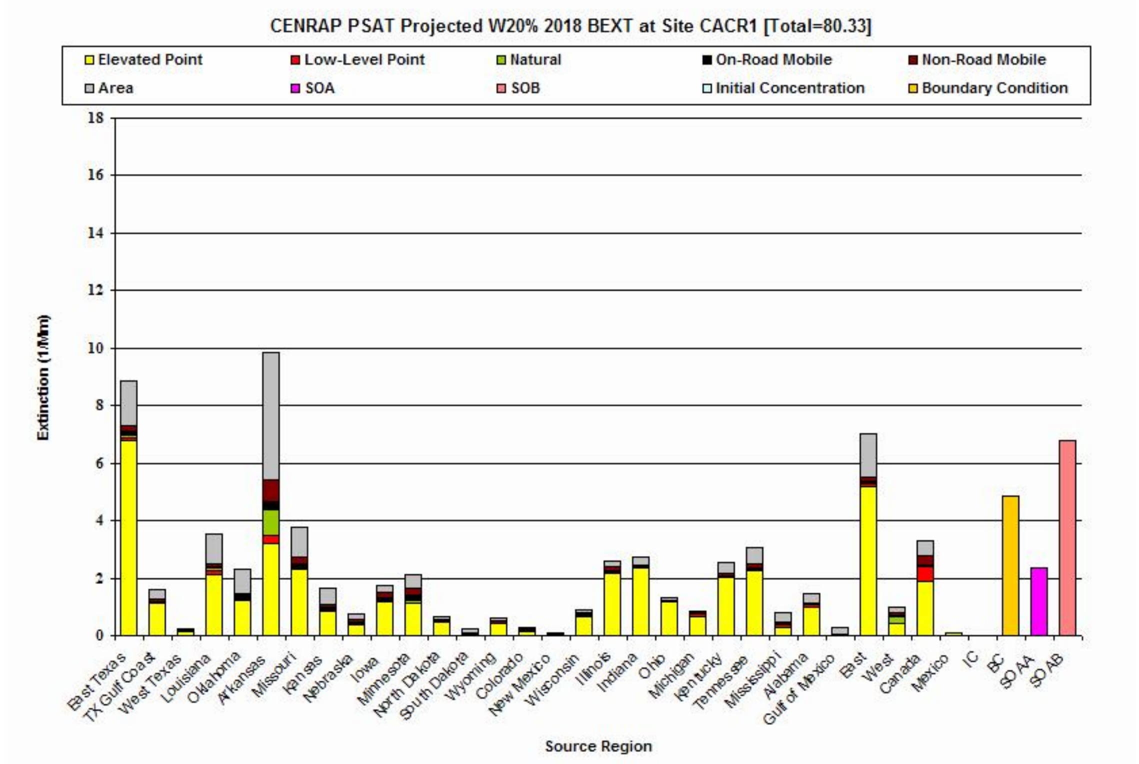


Figure E-1d. PSAT source region by source category contributions to the average 2018 extinction

(Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas.

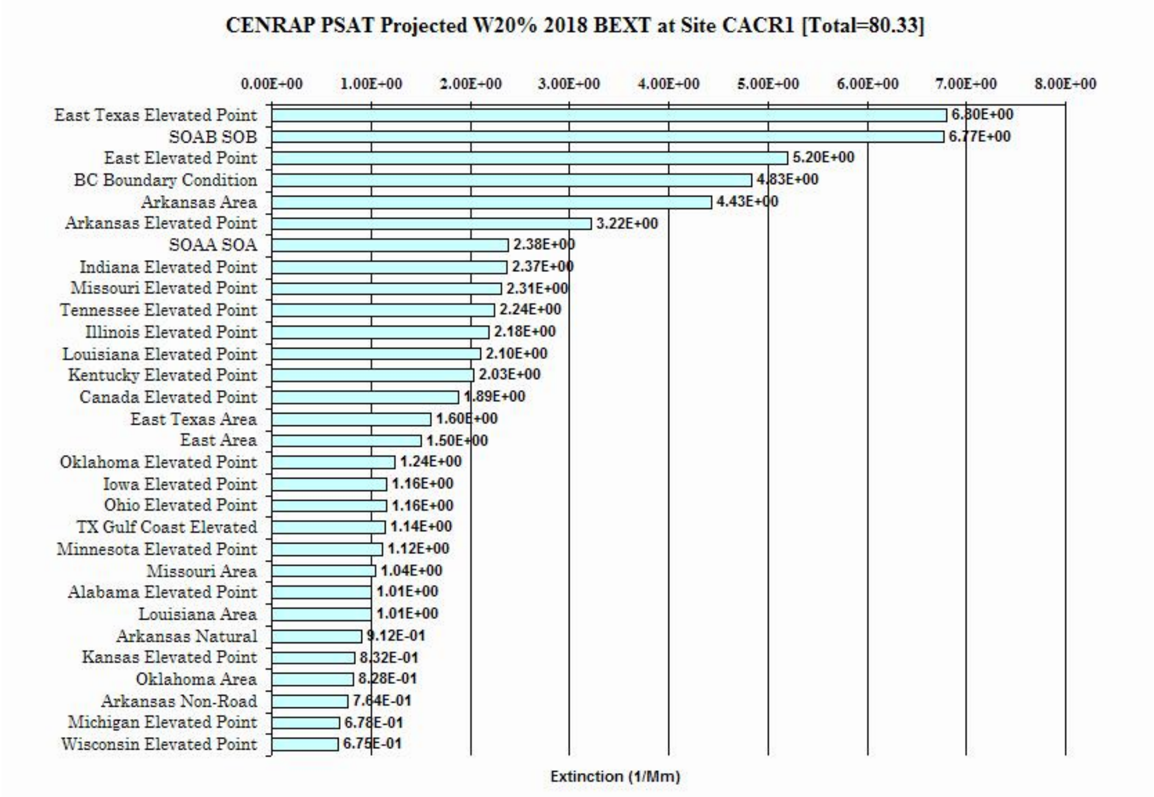


Figure E-1e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas

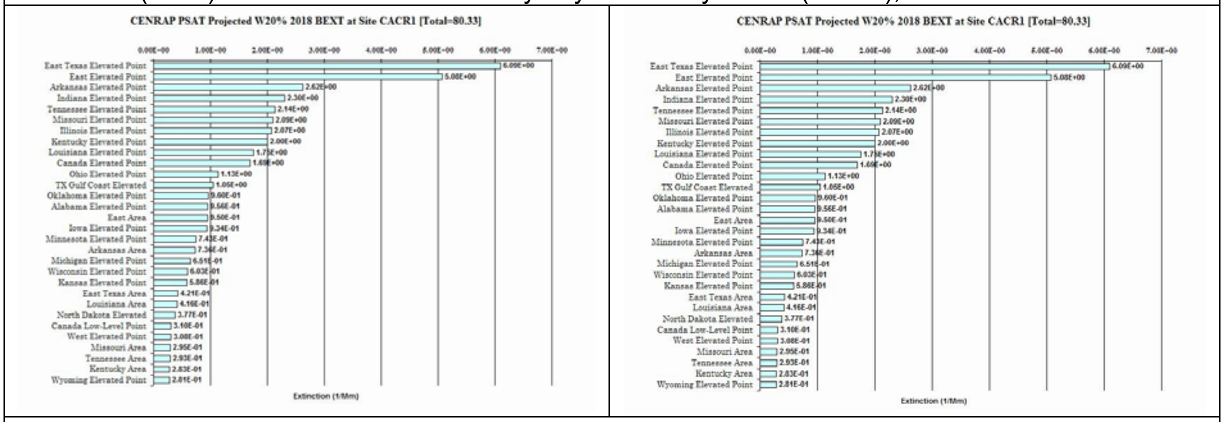


Figure E-1f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Caney Creek (CACR), Arkansas

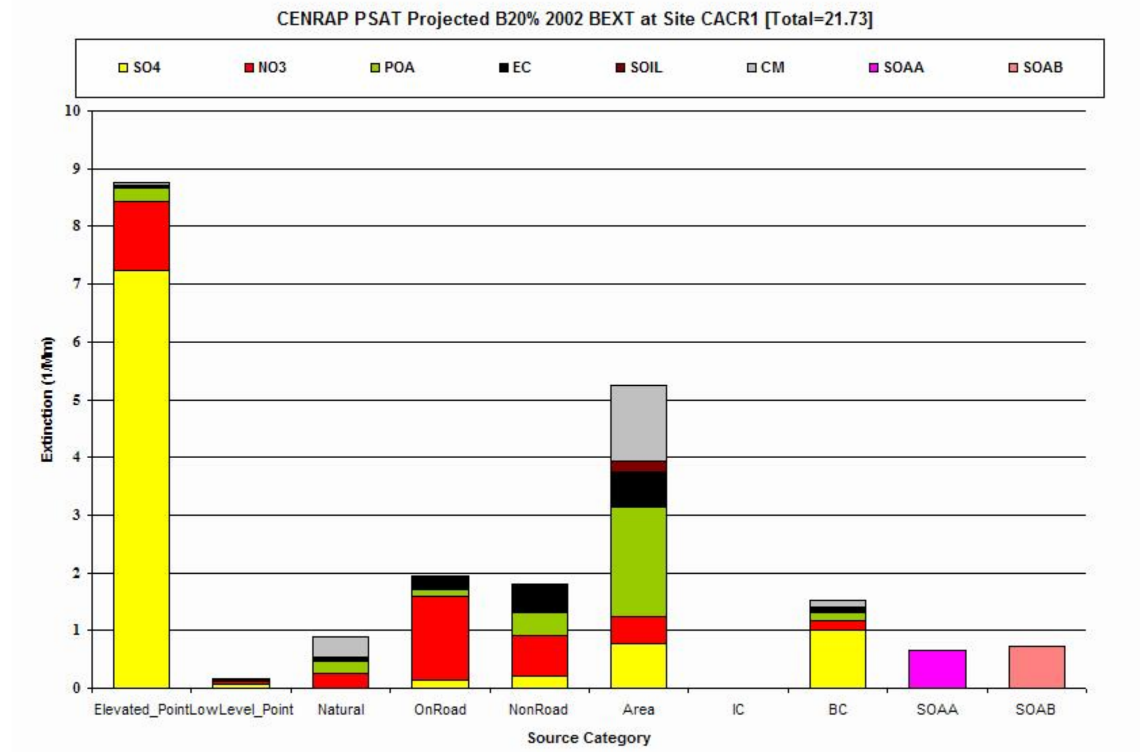


Figure E-1g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Caney Creek (CACR), Arkansas.

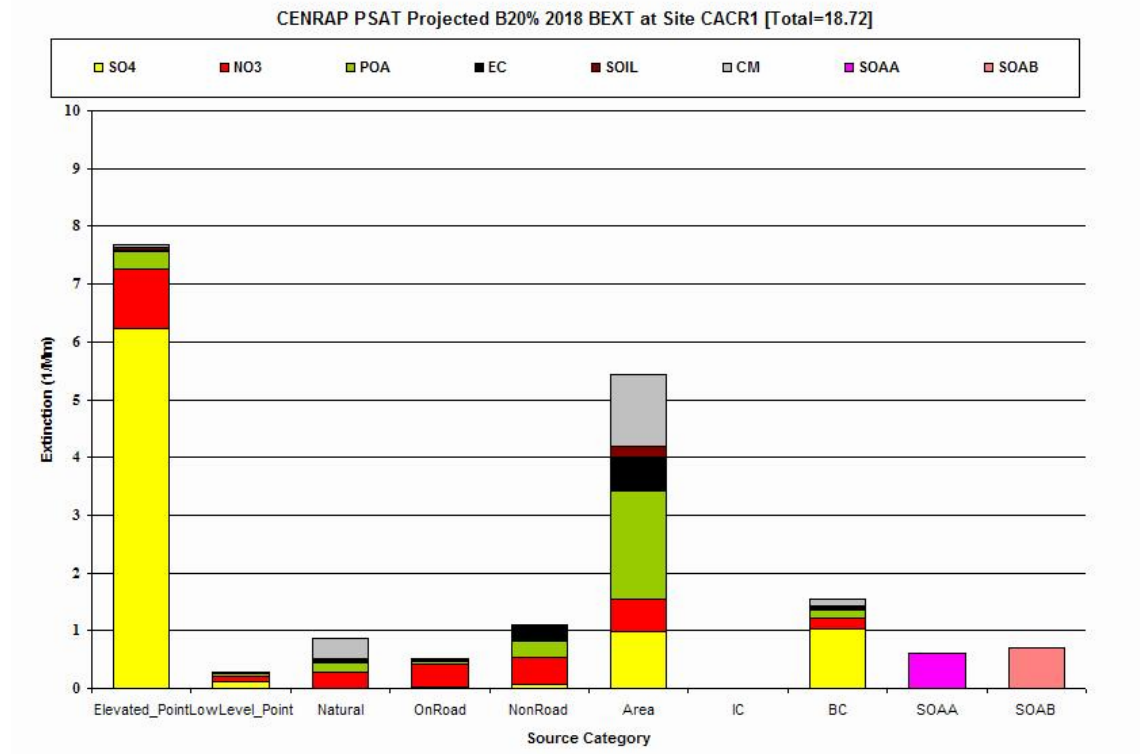


Figure E-1h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Caney Creek (CACR), Arkansas.

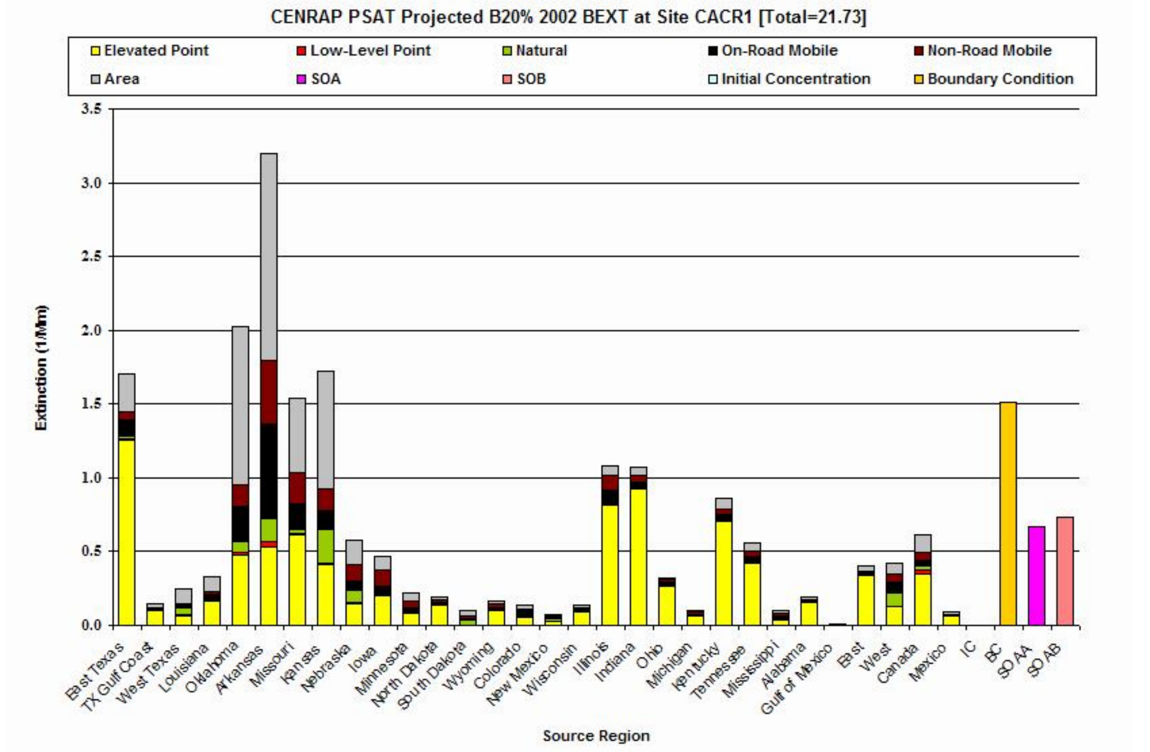


Figure E-1i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Caney Creek (CACR), Arkansas.

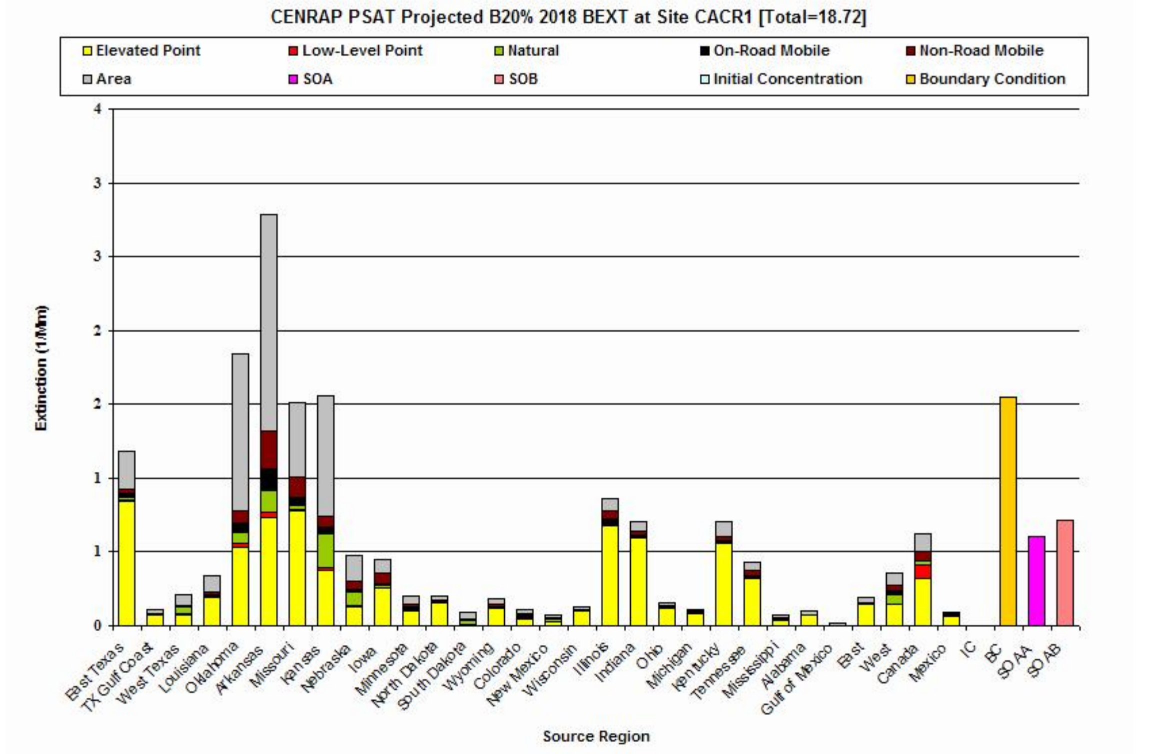


Figure E-1j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Caney Creek (CACR), Arkansas.

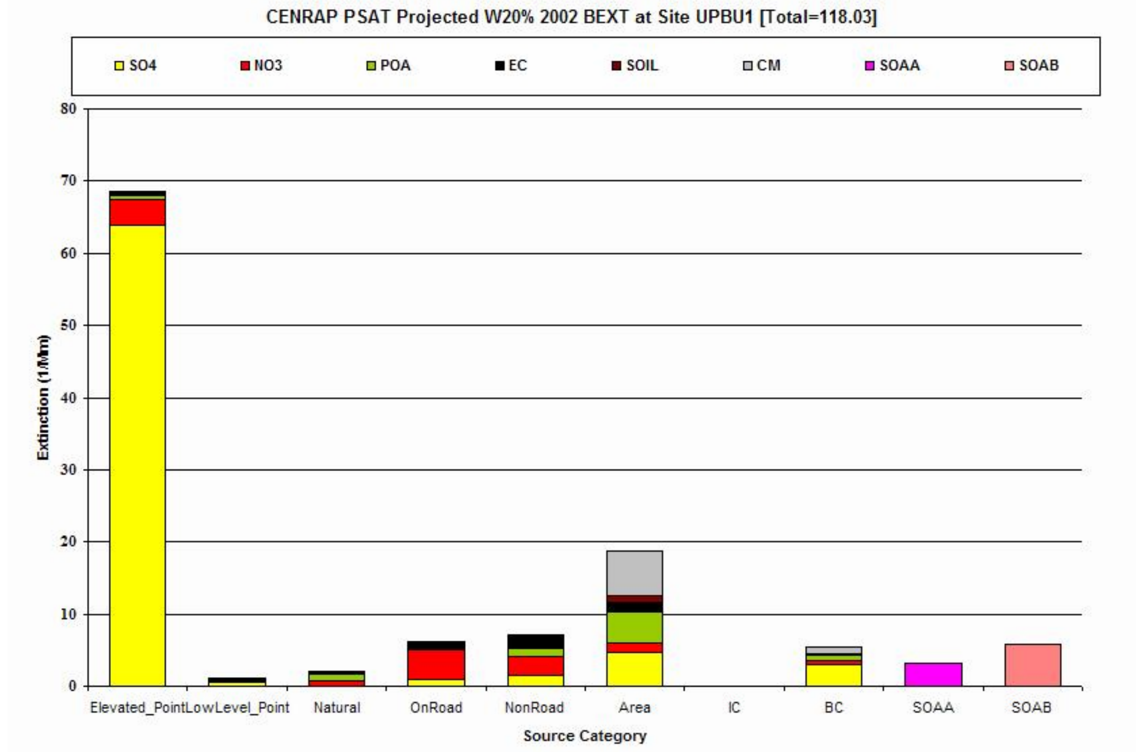


Figure E-2a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

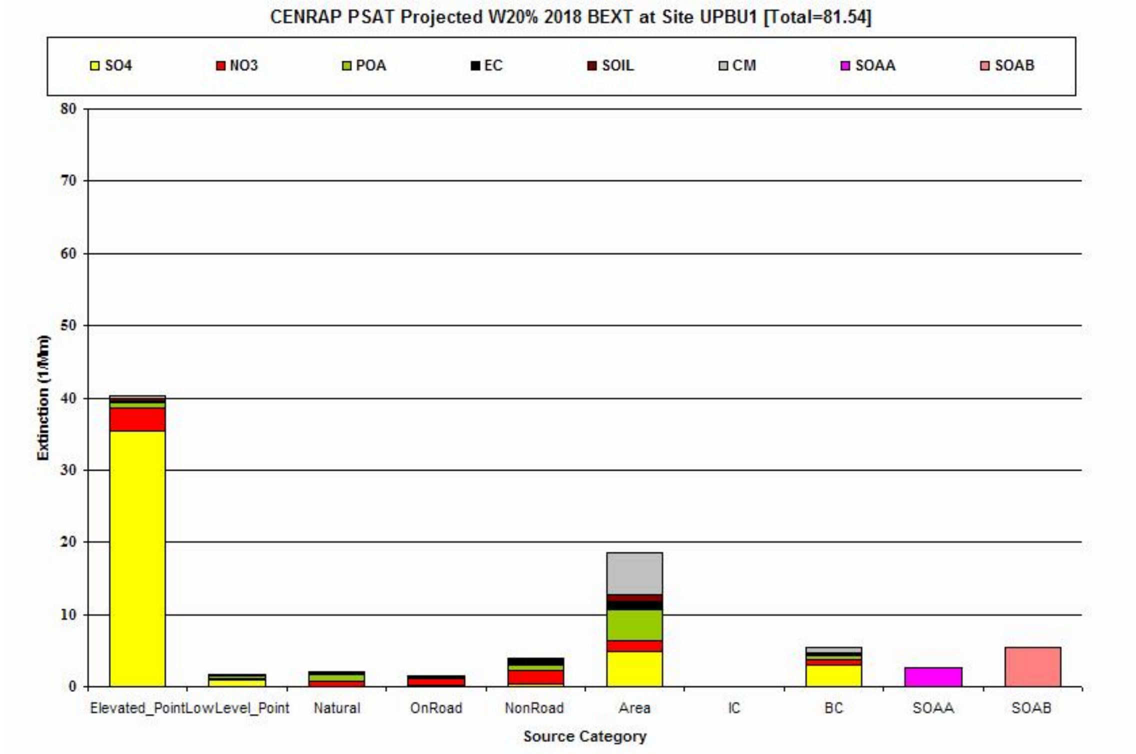


Figure E-2b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

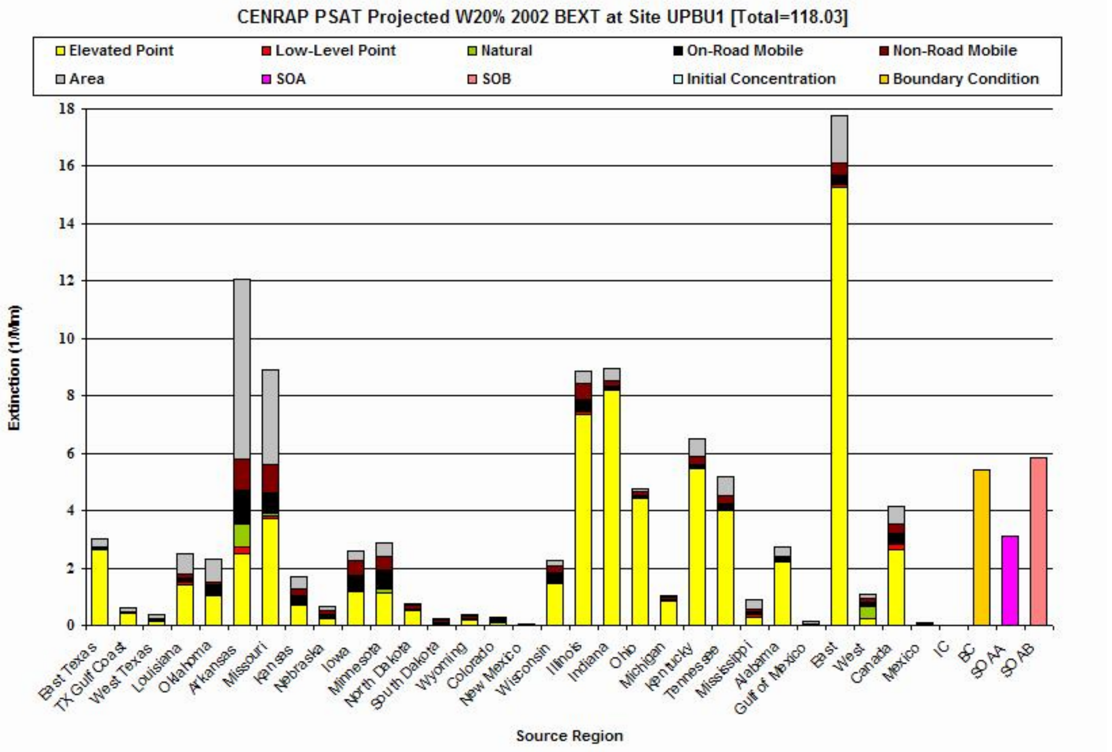


Figure E-2c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

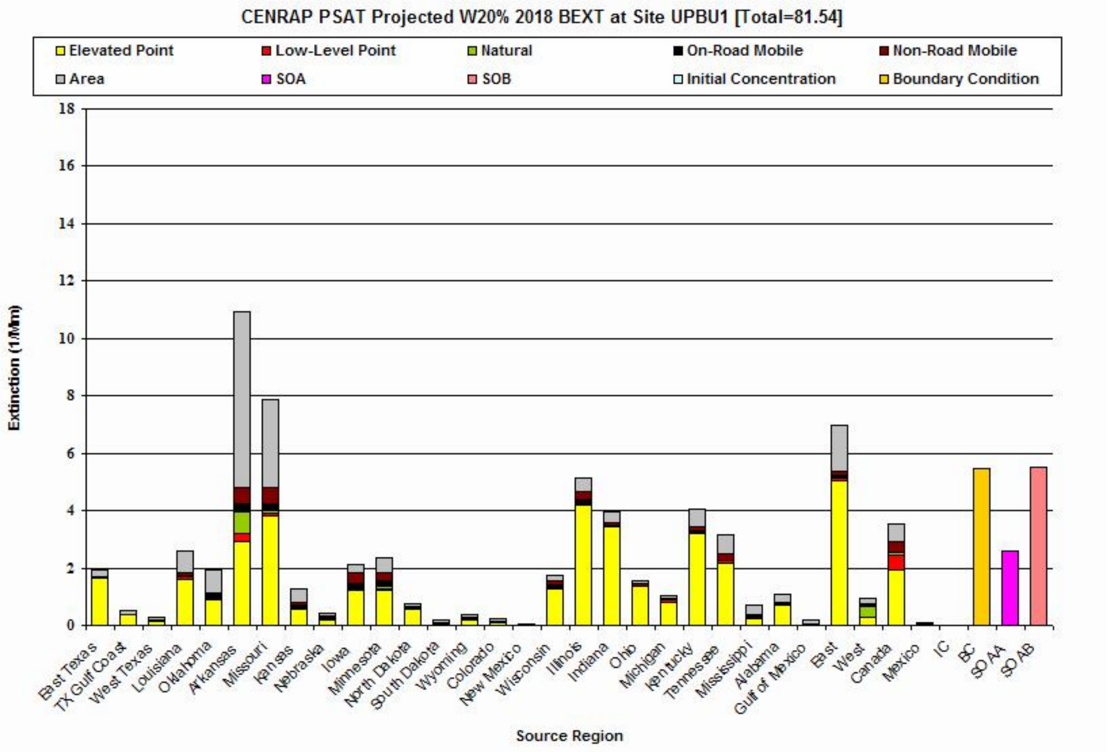


Figure E-2d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

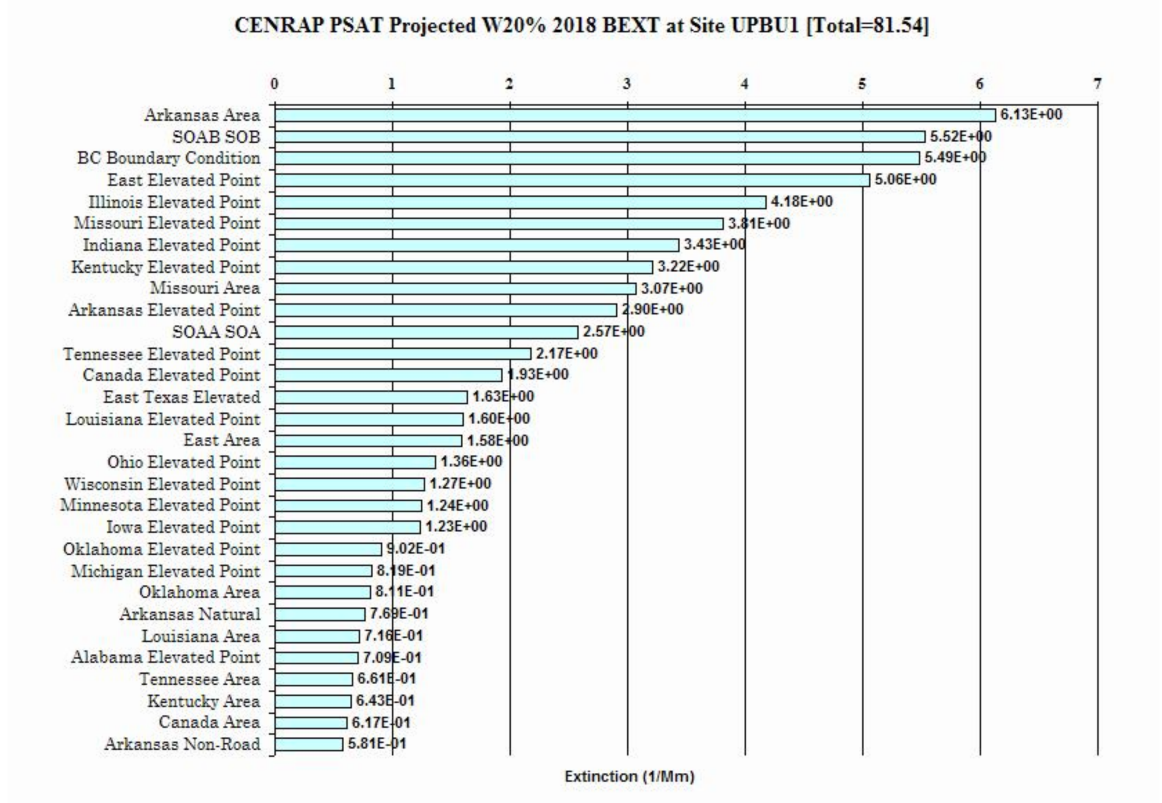


Figure E-2e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

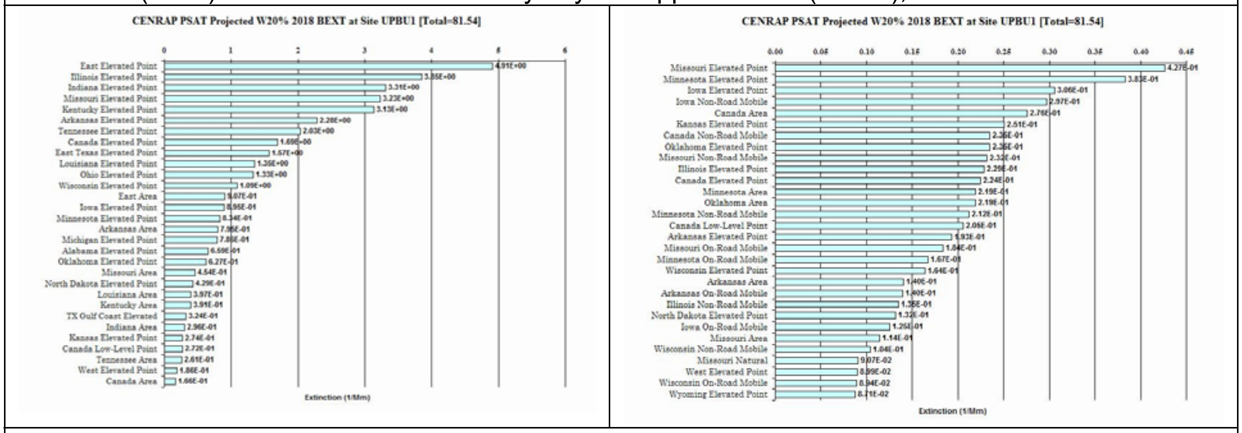


Figure E-2f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Upper Buffalo (UPBU), Arkansas.

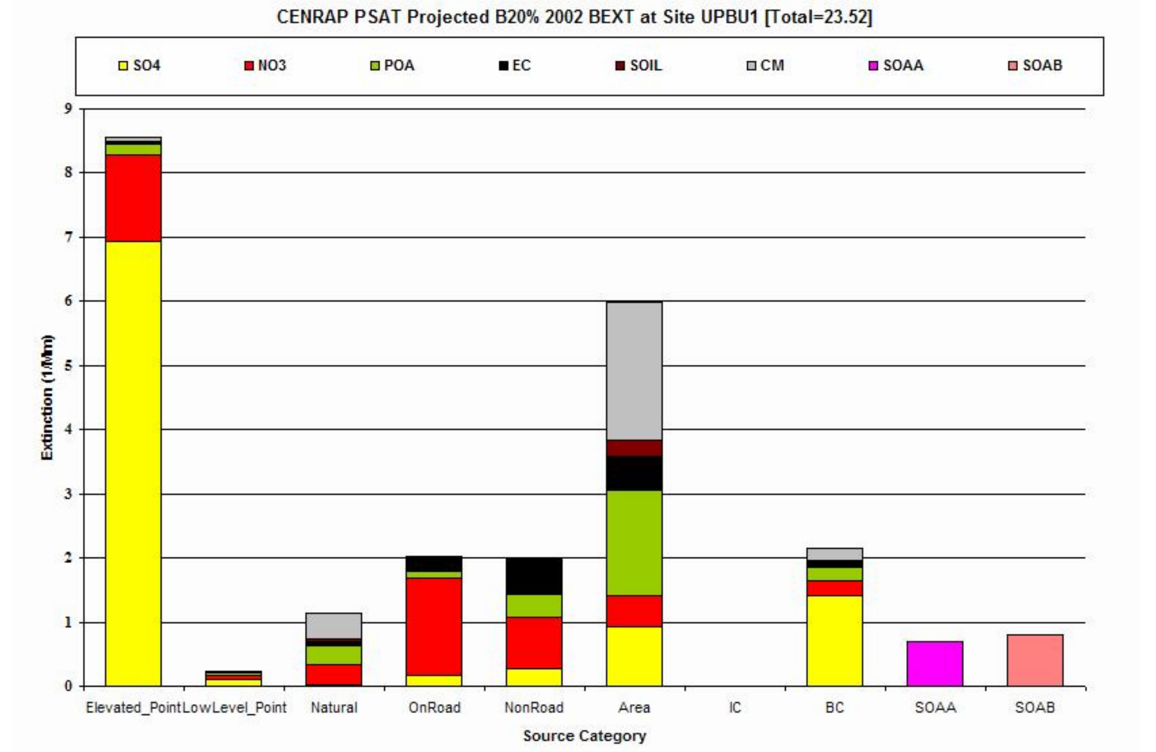


Figure E-2g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Upper Buffalo (UPBU), Arkansas.

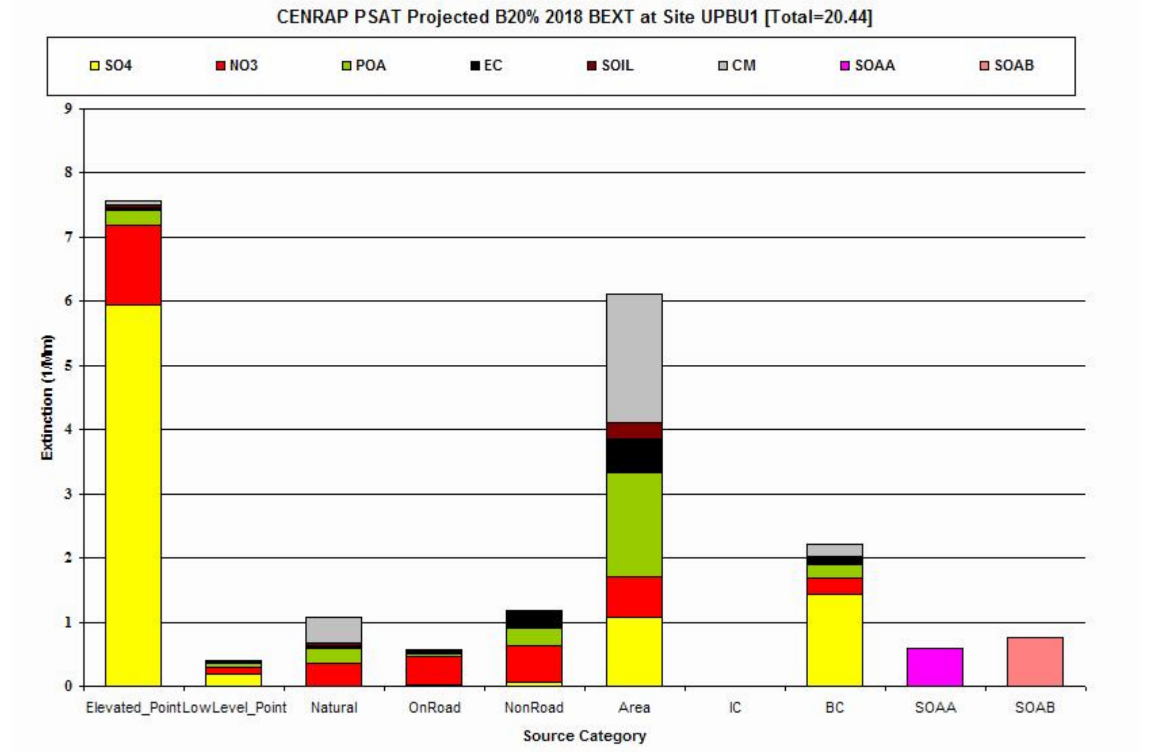


Figure E-2h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Upper Buffalo (UPBU), Arkansas.

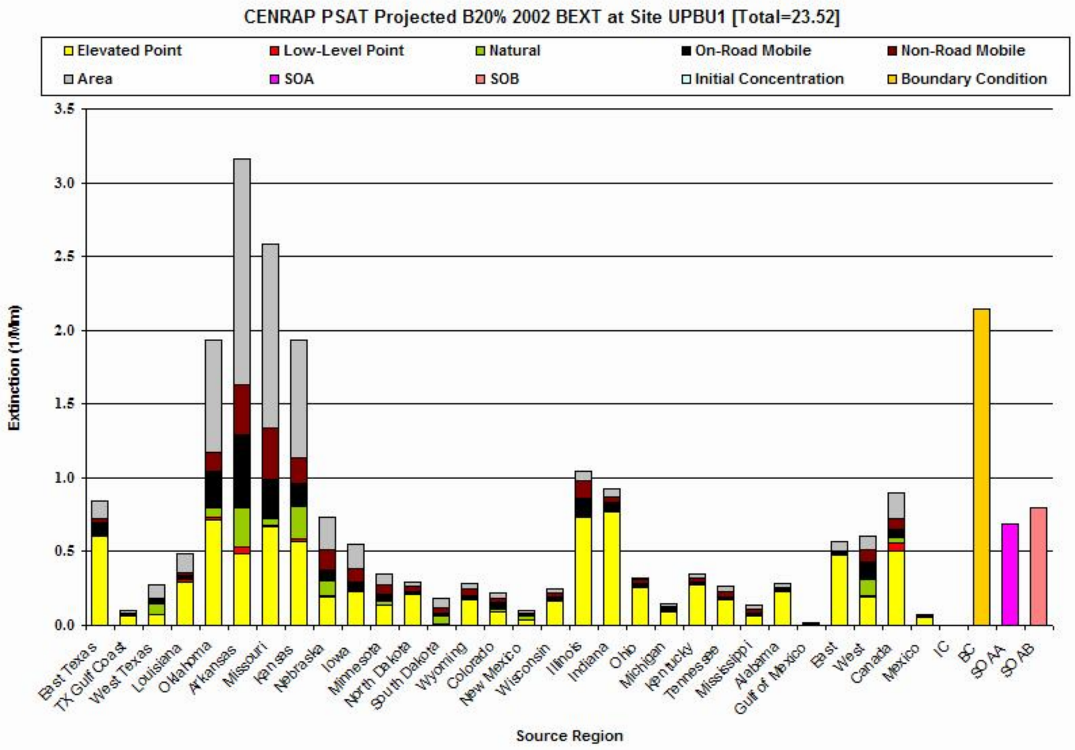


Figure E-2i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Upper Buffalo (UPBU), Arkansas.

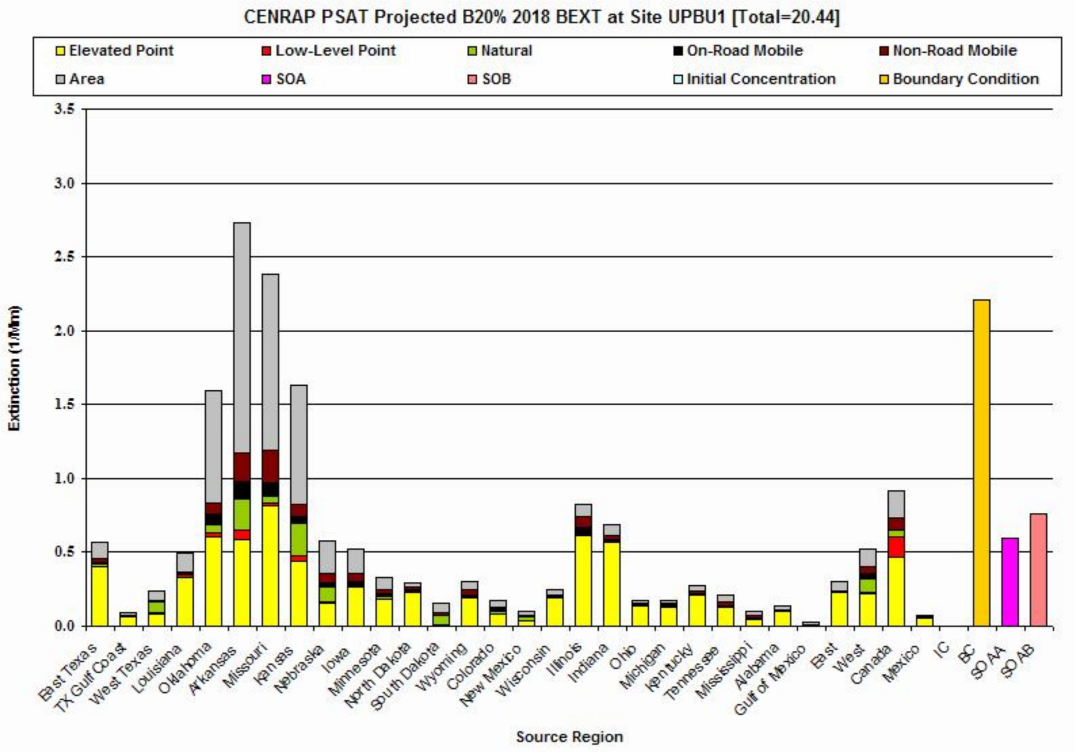


Figure E-2j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Upper Buffalo (UPBU), Arkansas.

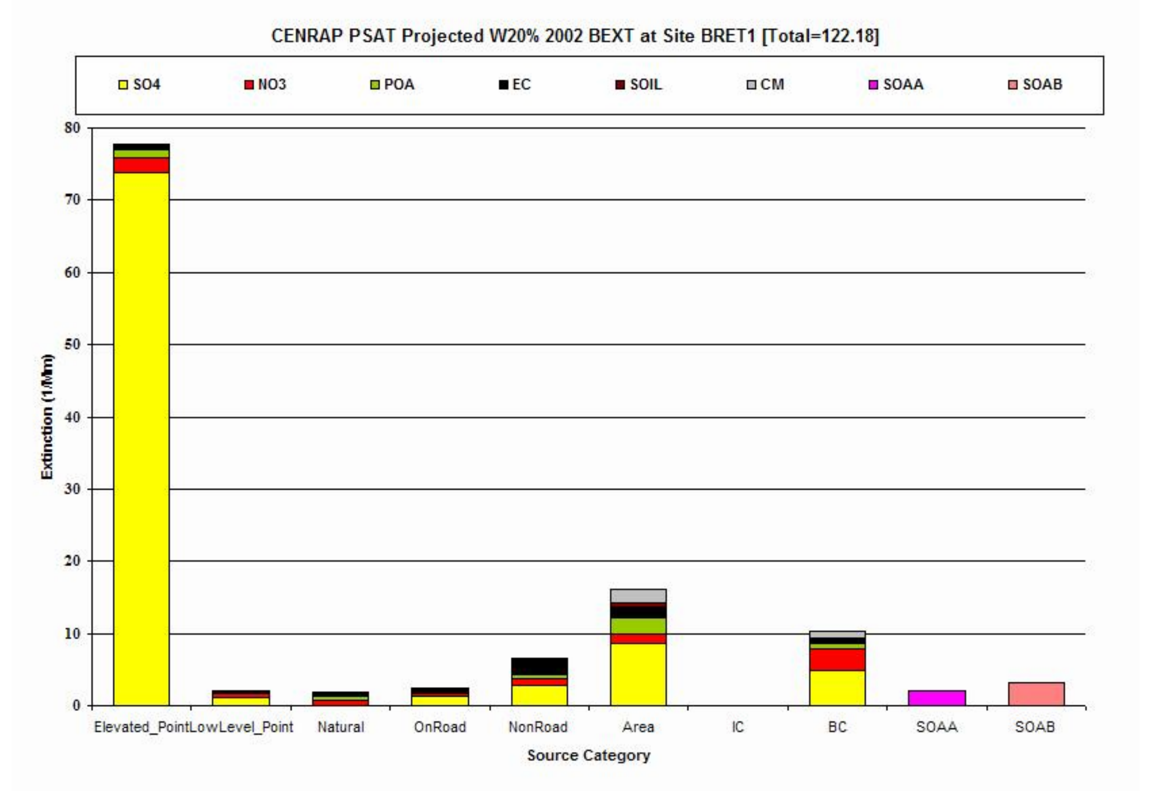


Figure E-3a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

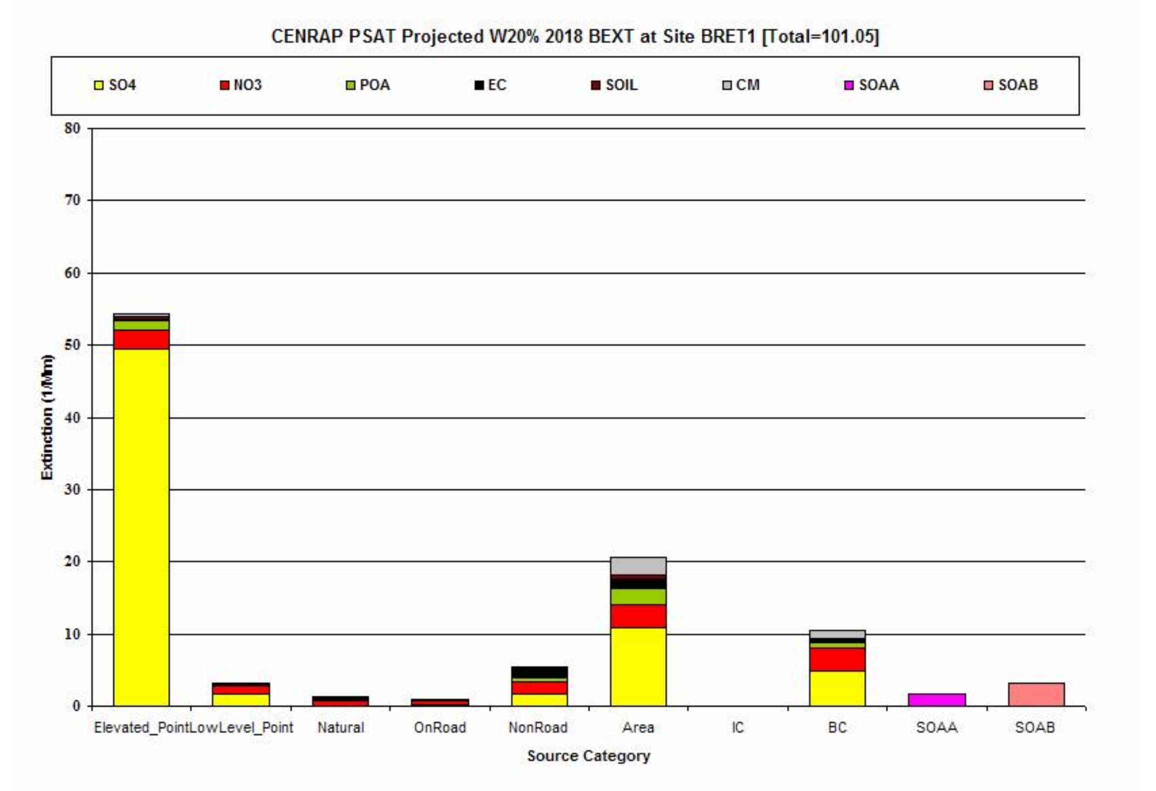


Figure E-3b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

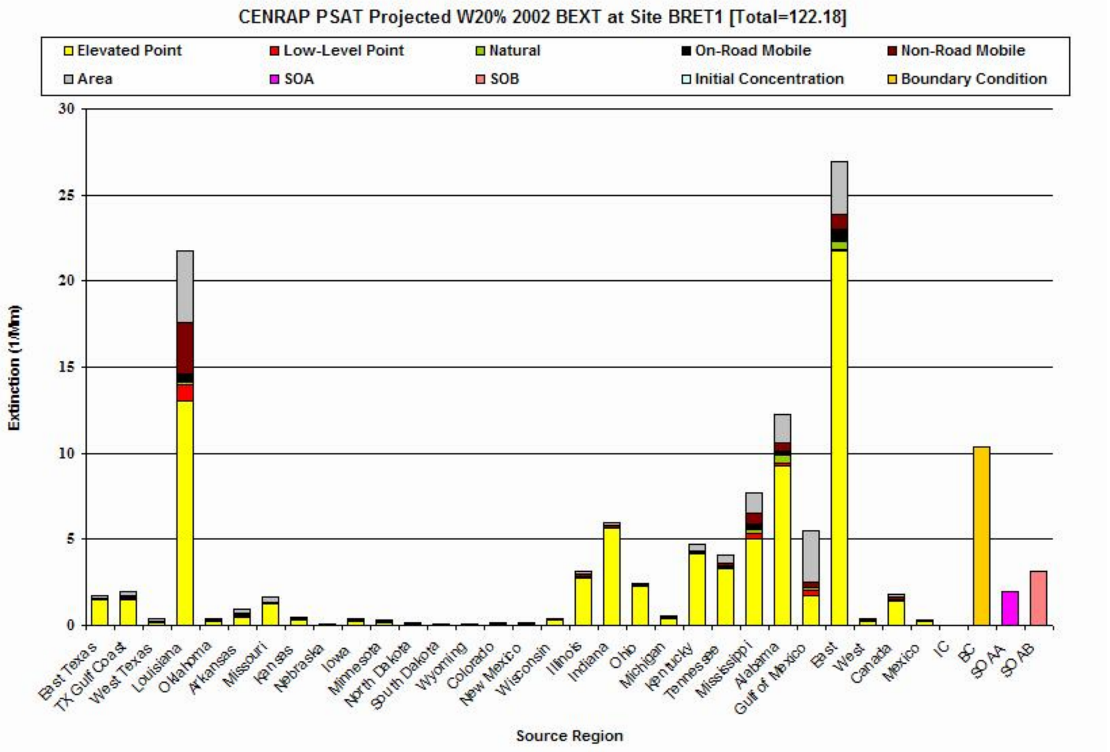


Figure E-3c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

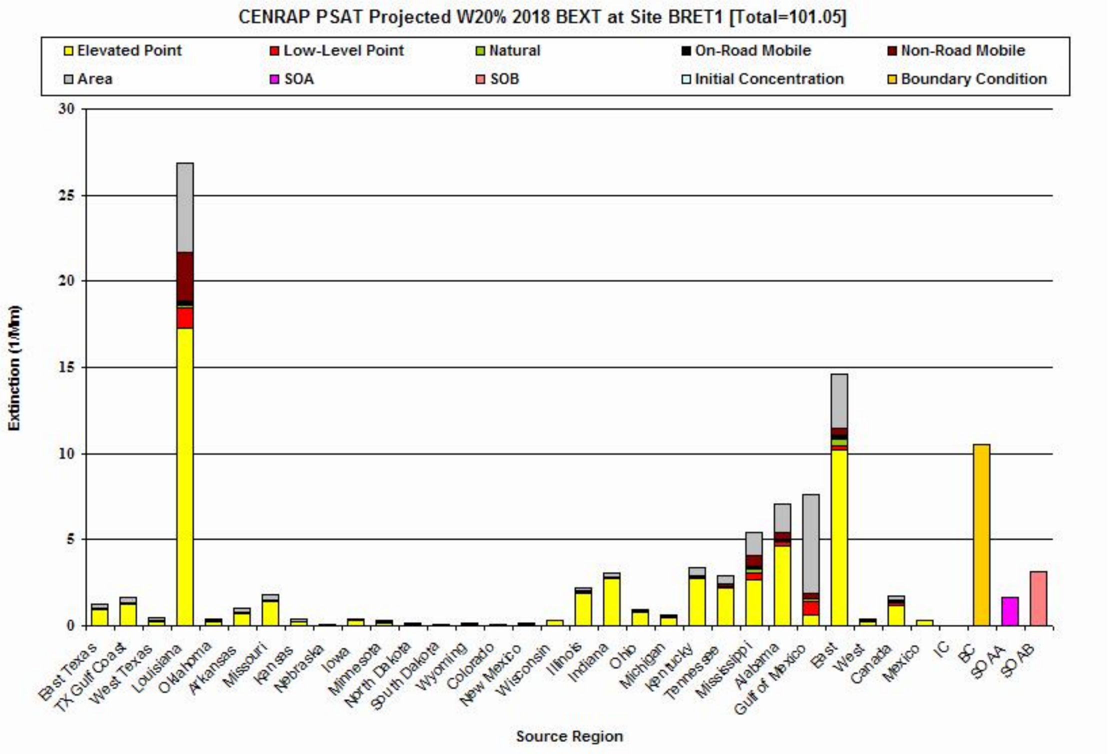


Figure E-3d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

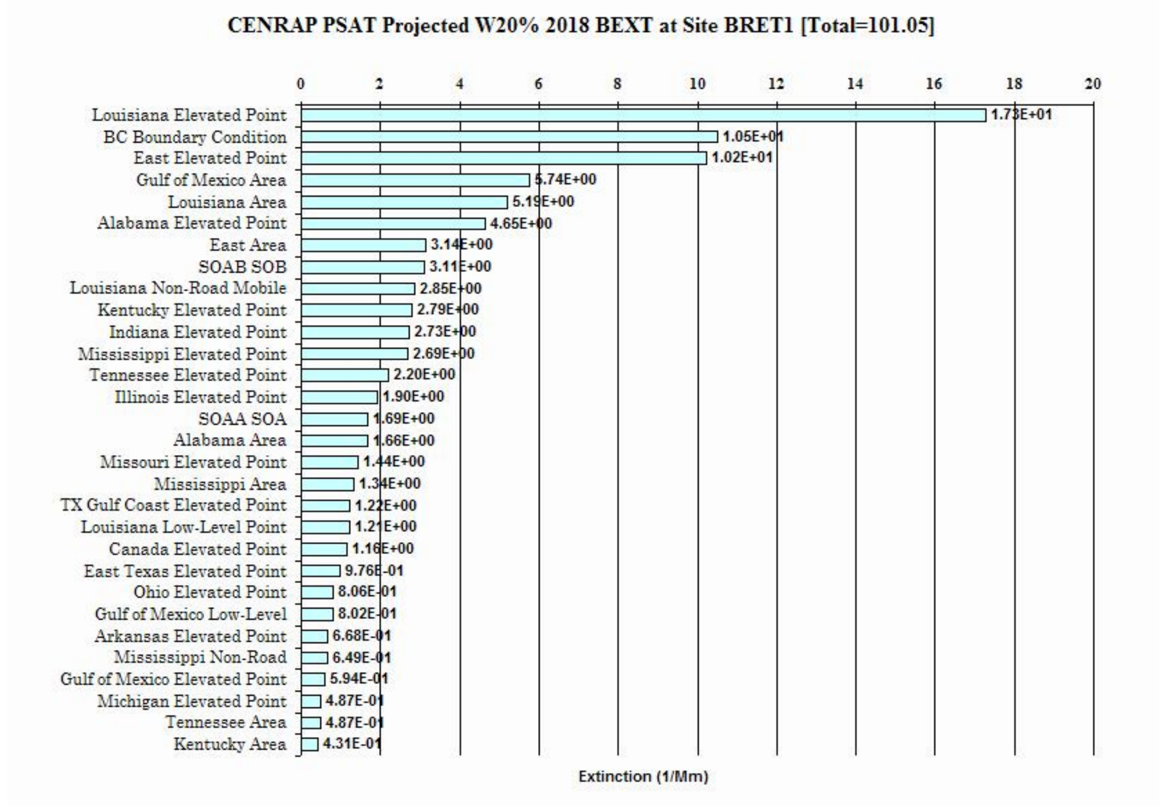


Figure E-3e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

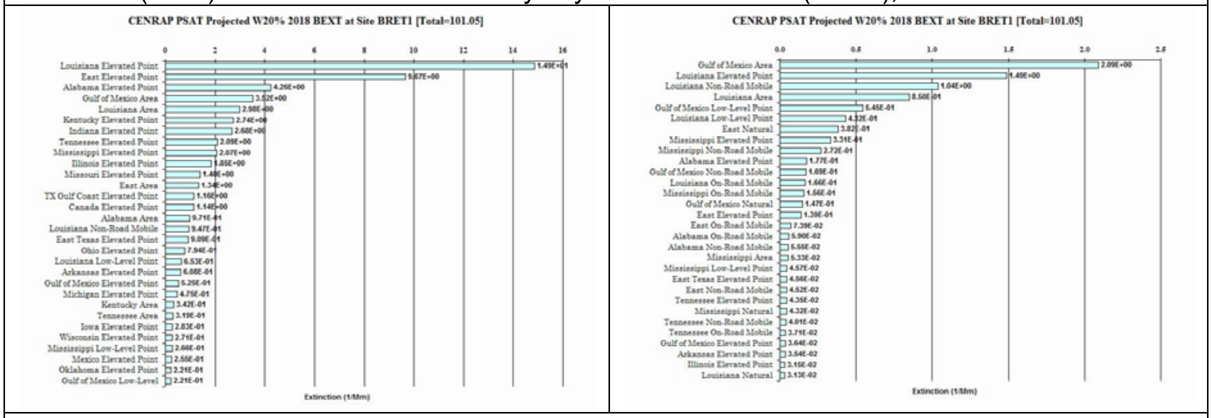


Figure E-3f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Breton Island (BRET), Louisiana.

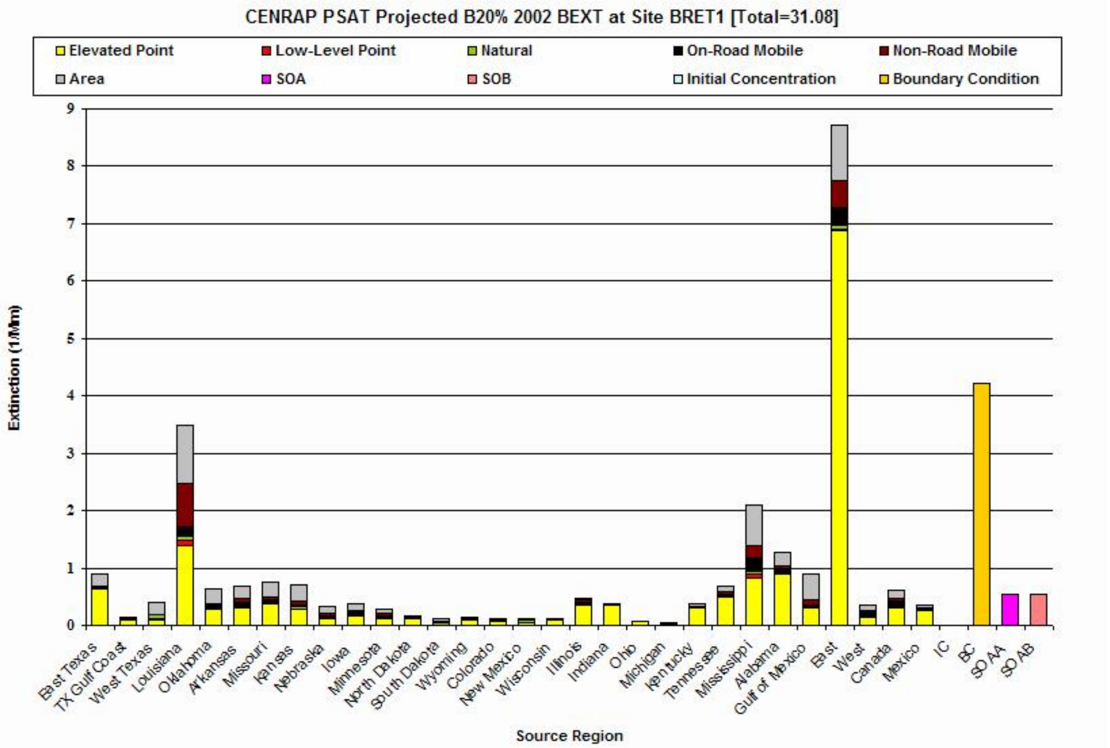


Figure E-3g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Breton Island (BRET), Louisiana.

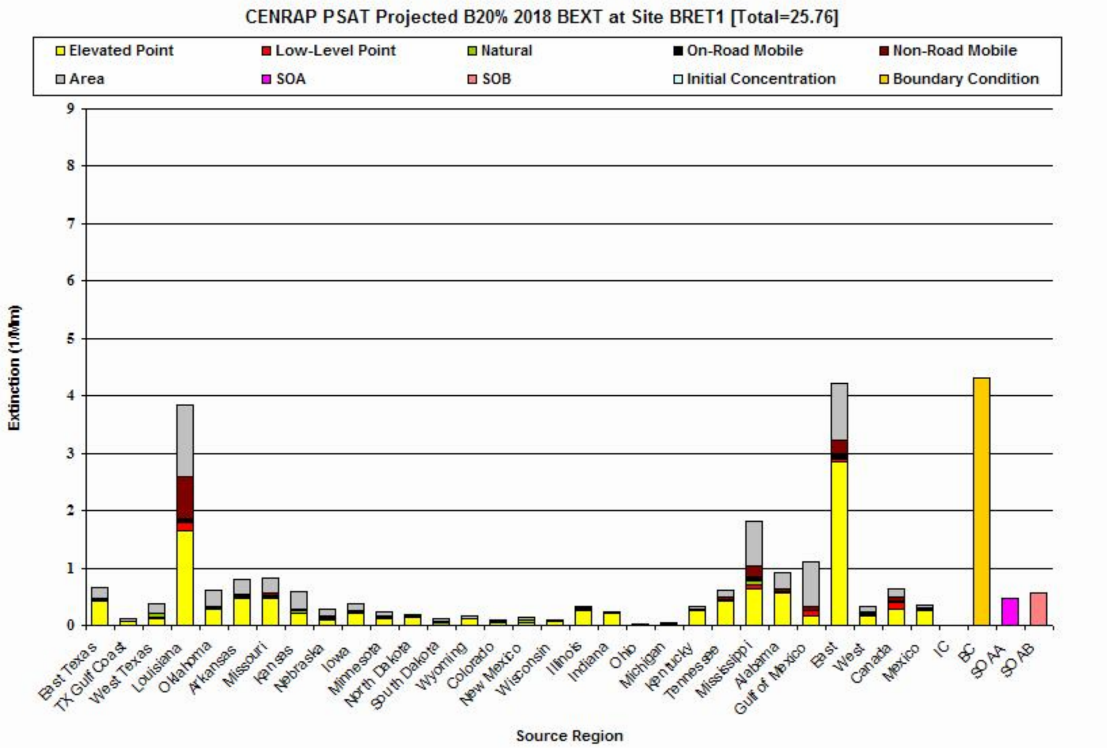


Figure E-3h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Breton Island (BRET), Louisiana.

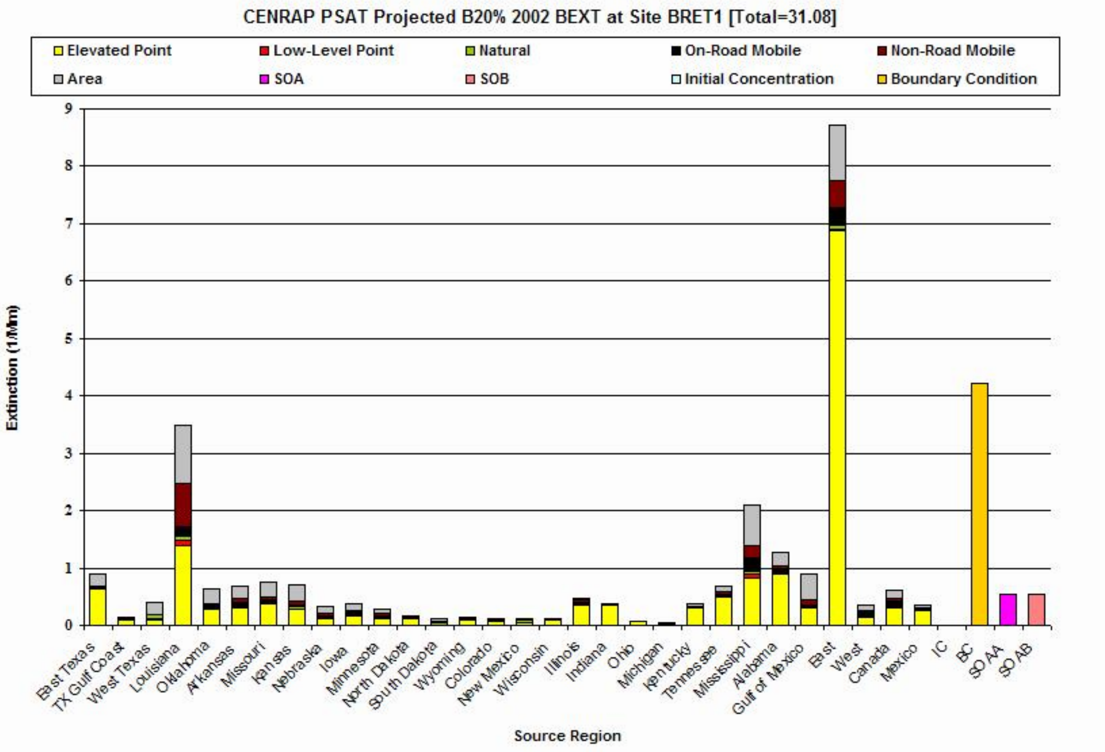


Figure E-3i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Breton Island (BRET), Louisiana.

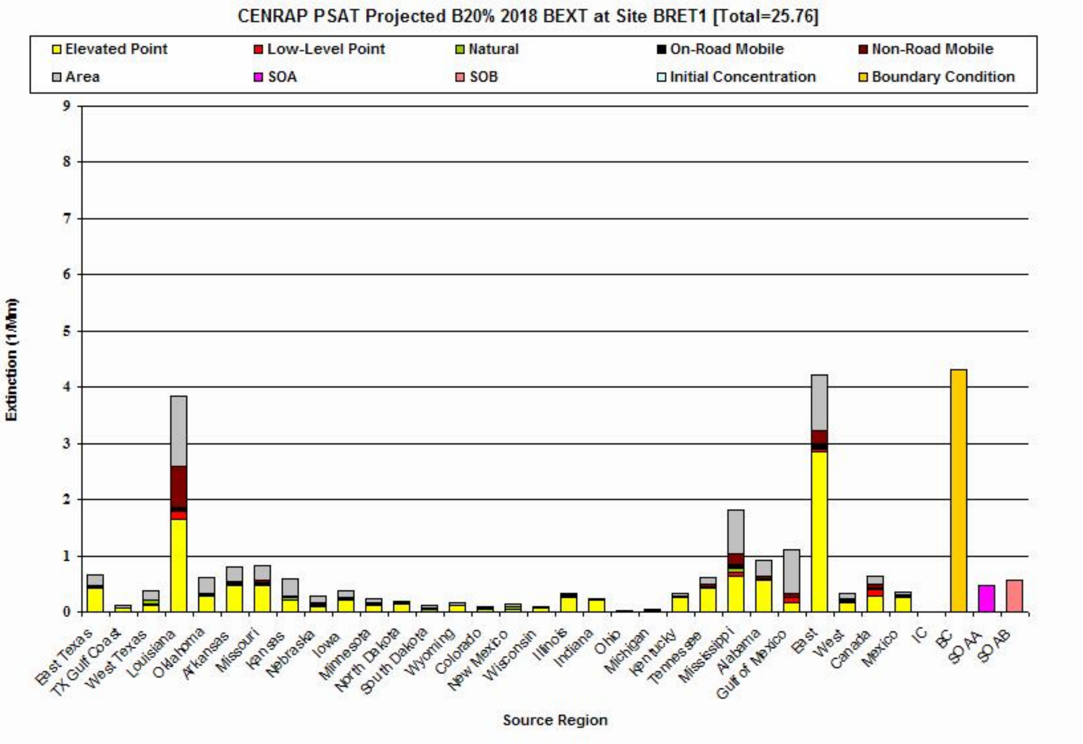


Figure E-3j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Breton Island (BRET), Louisiana.

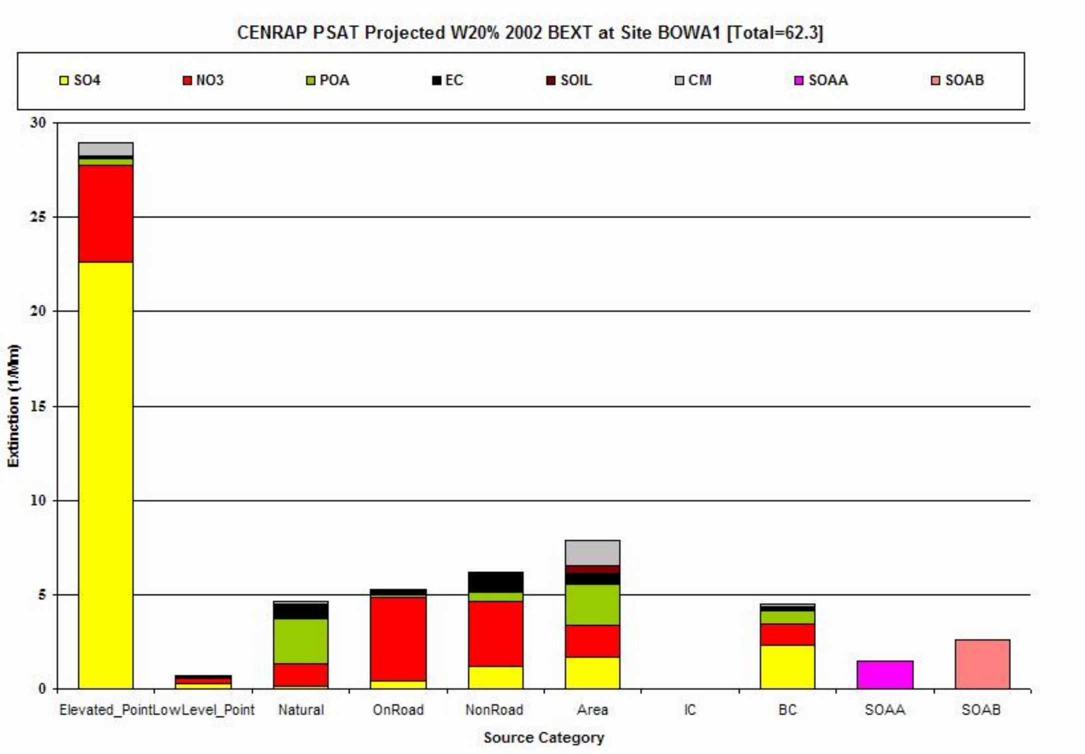


Figure E-4a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.

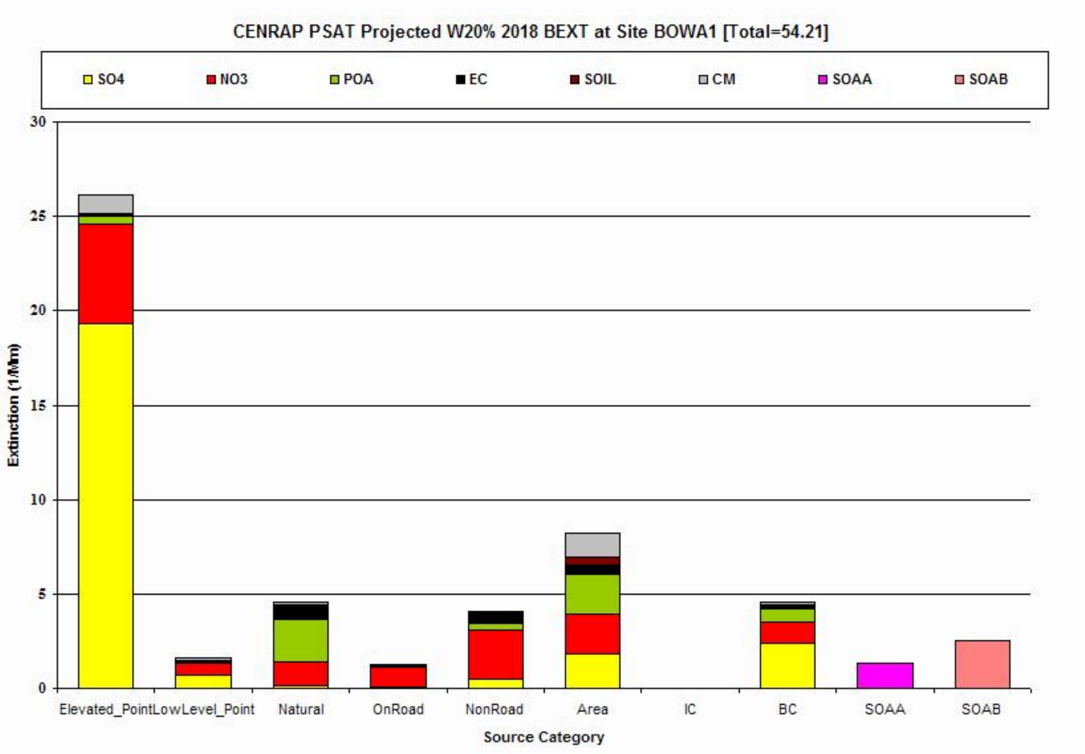


Figure E-4b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.

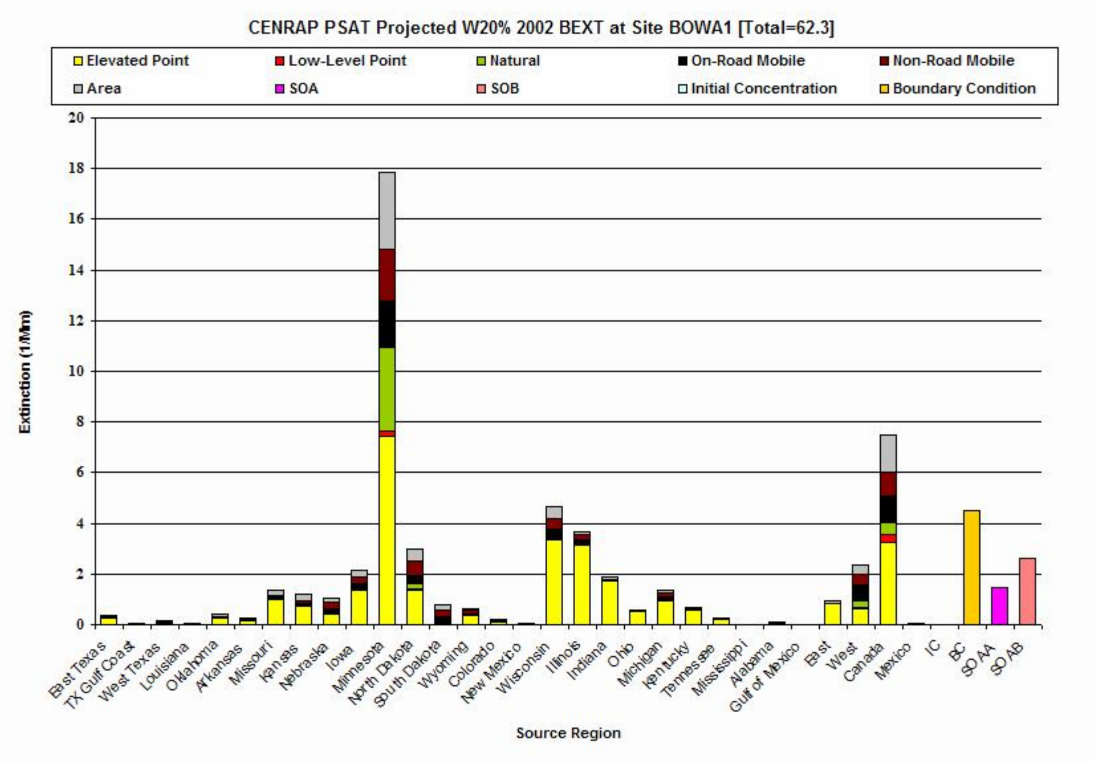


Figure E-4c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.

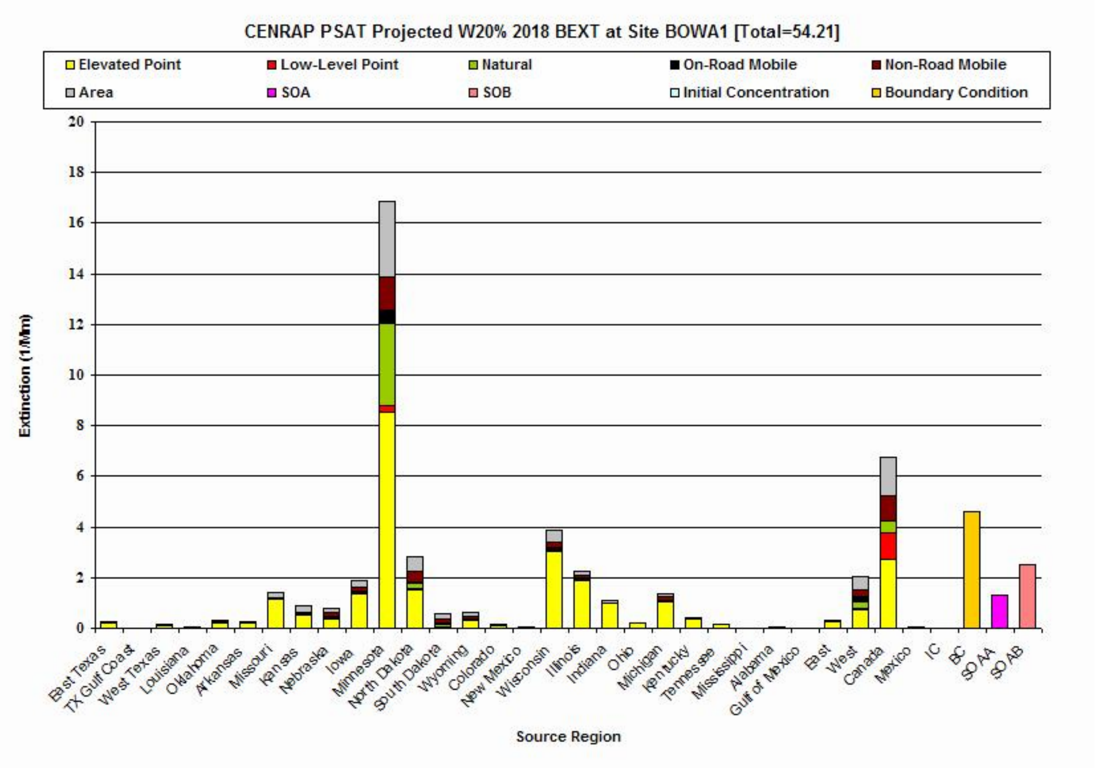
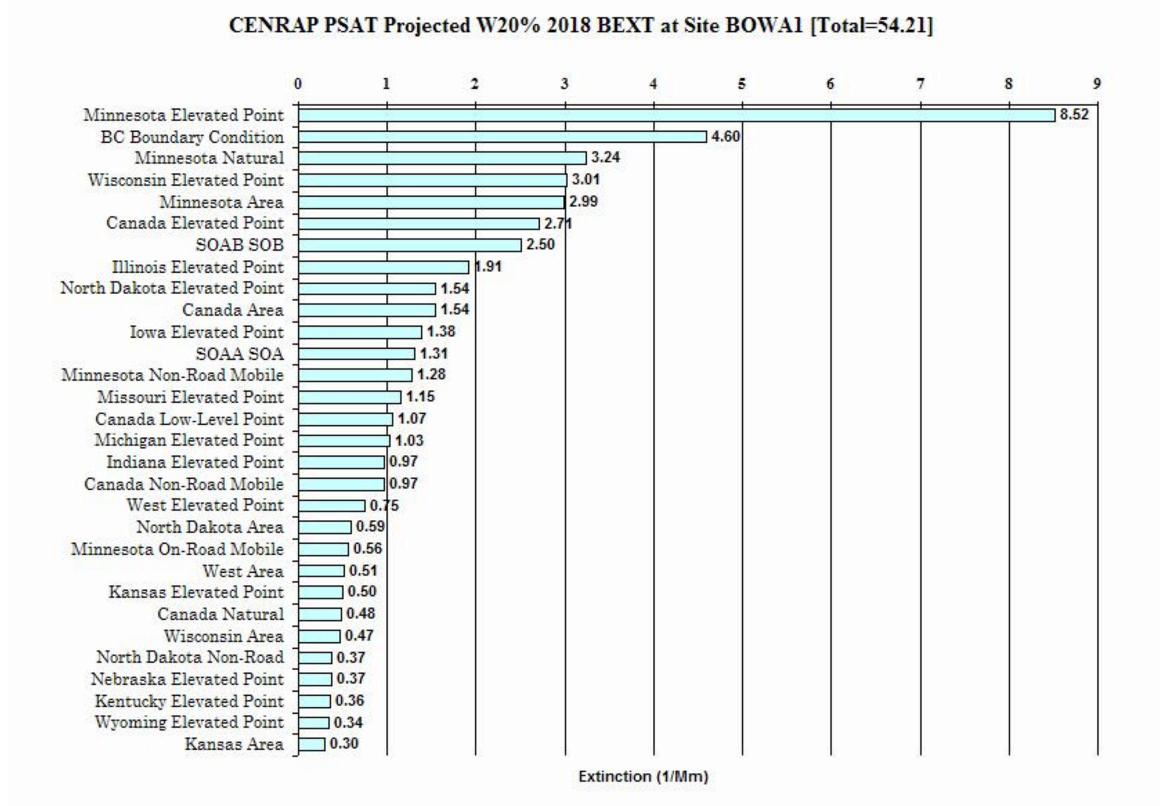
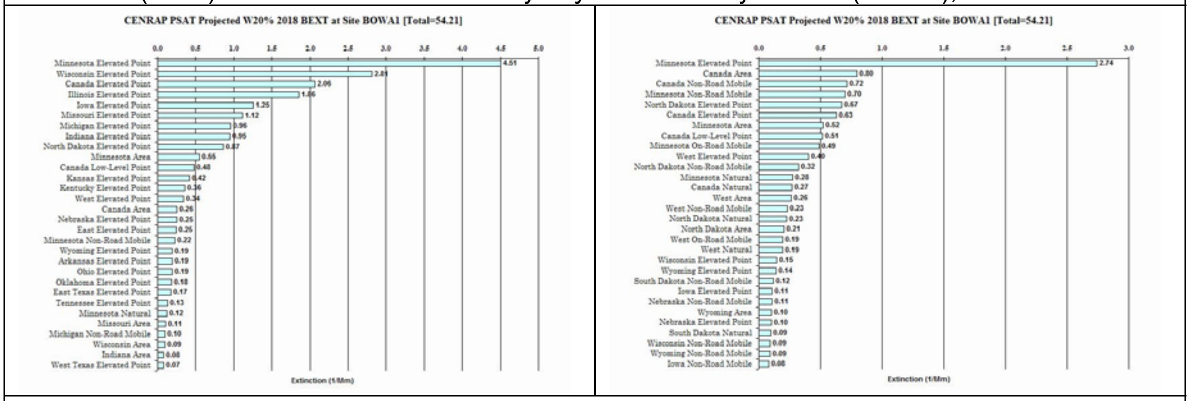


Figure E-4d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.



CENRAP PSAT Projected W20% 2018 BEXT at Site BOWA1 [Total=54.21]

Figure E-4e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.



CENRAP PSAT Projected W20% 2018 BEXT at Site BOWA1 [Total=54.21]

CENRAP PSAT Projected W20% 2018 BEXT at Site BOWA1 [Total=54.21]

Figure E-4f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Boundary Waters (BOWA), Minnesota.

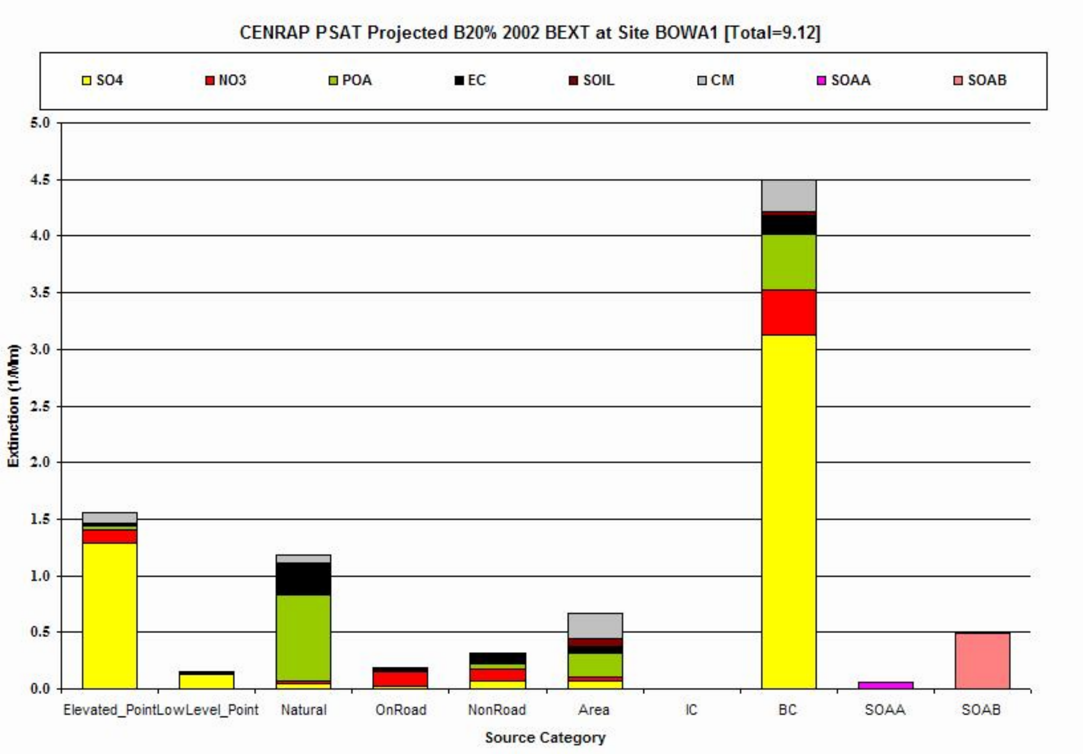


Figure E-4g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Boundary Waters (BOWA), Minnesota.

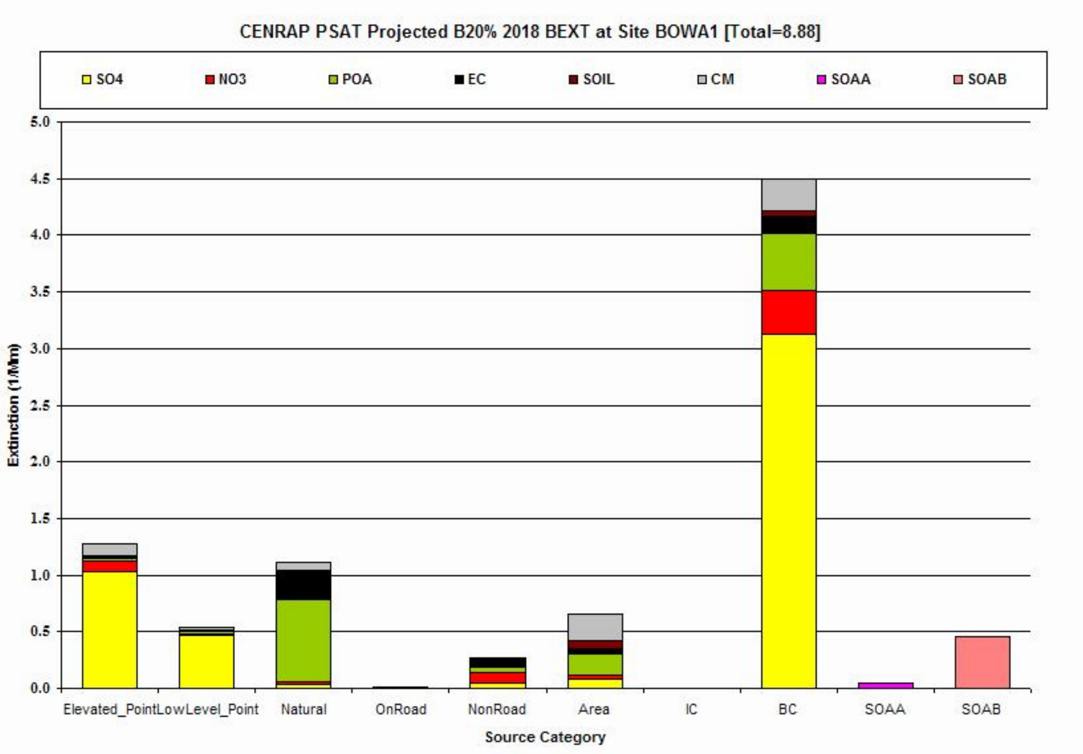


Figure E-4h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Boundary Waters (BOWA), Minnesota.

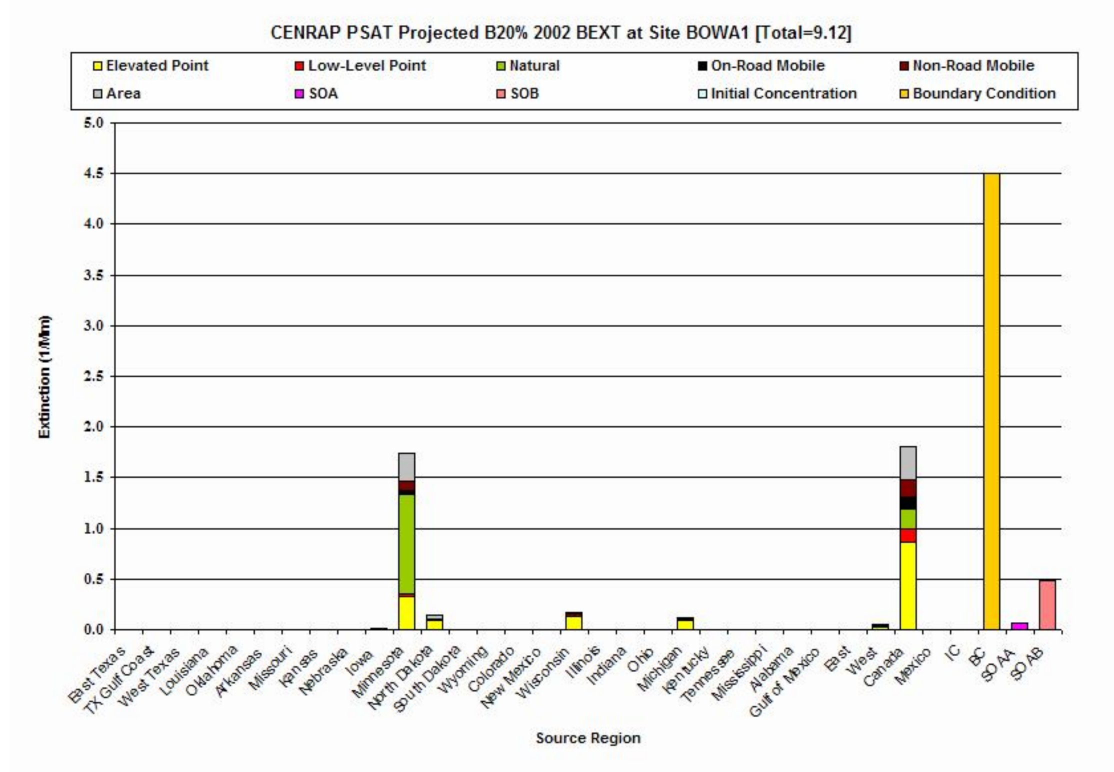


Figure E-4i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Boundary Waters (BOWA), Minnesota.

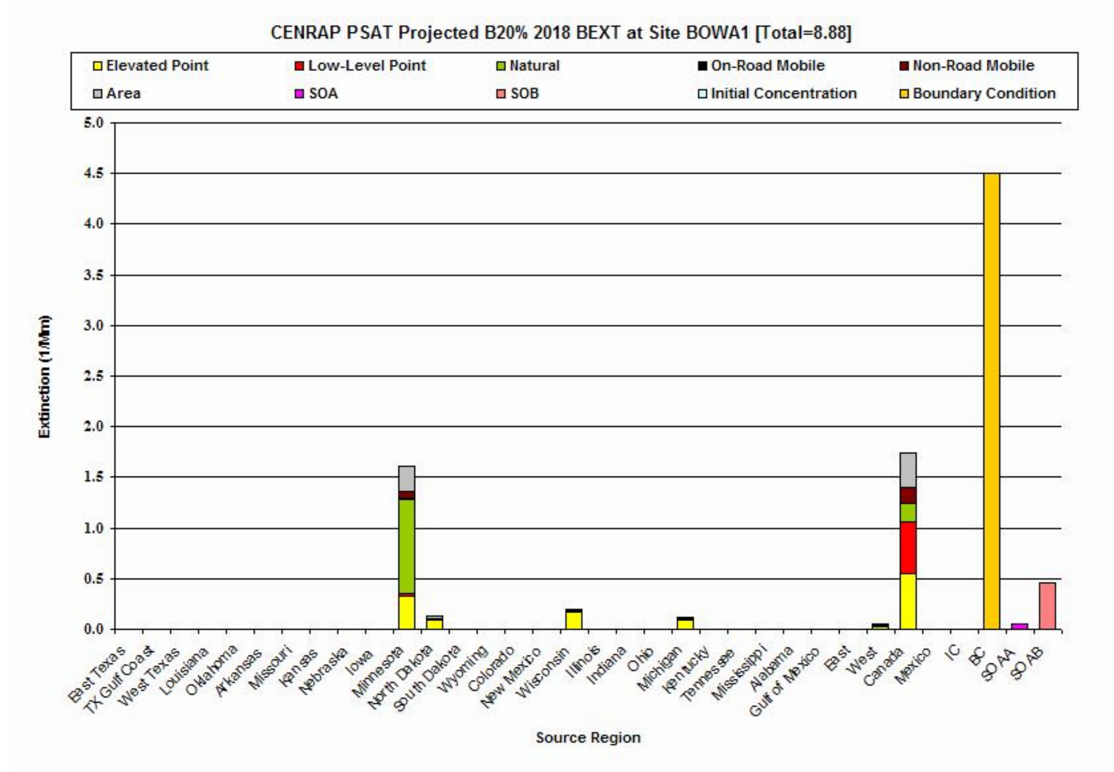


Figure E-4j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Boundary Waters (BOWA), Minnesota.

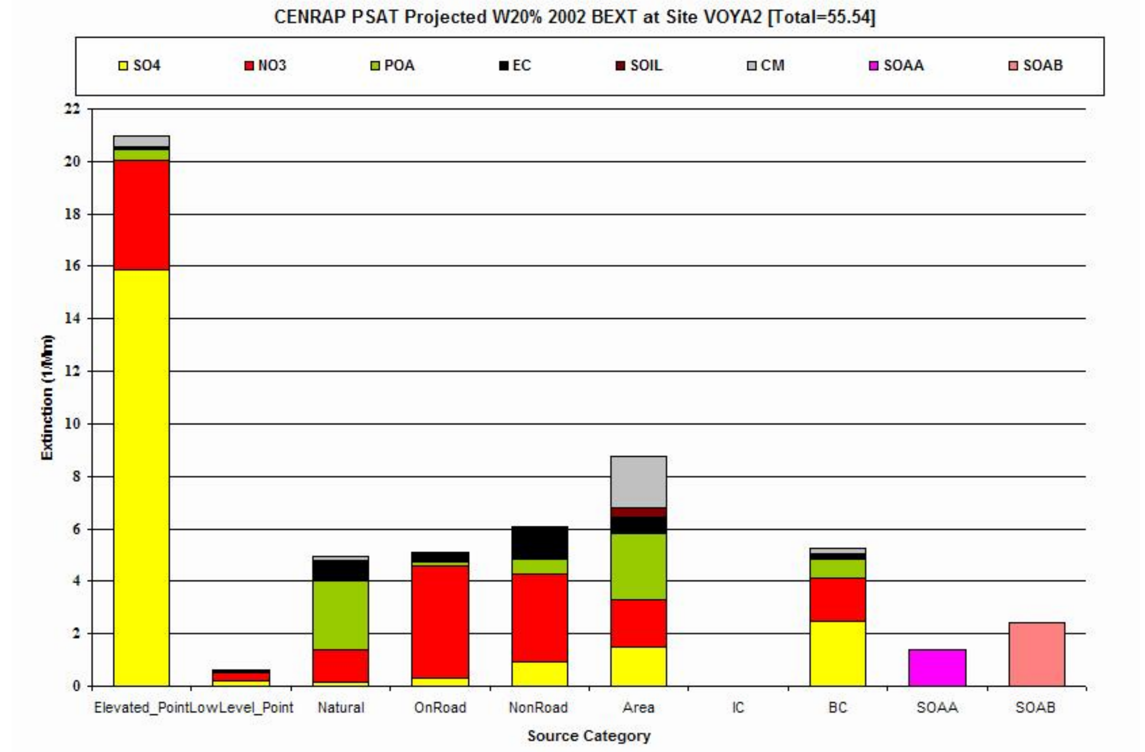


Figure E-5a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.

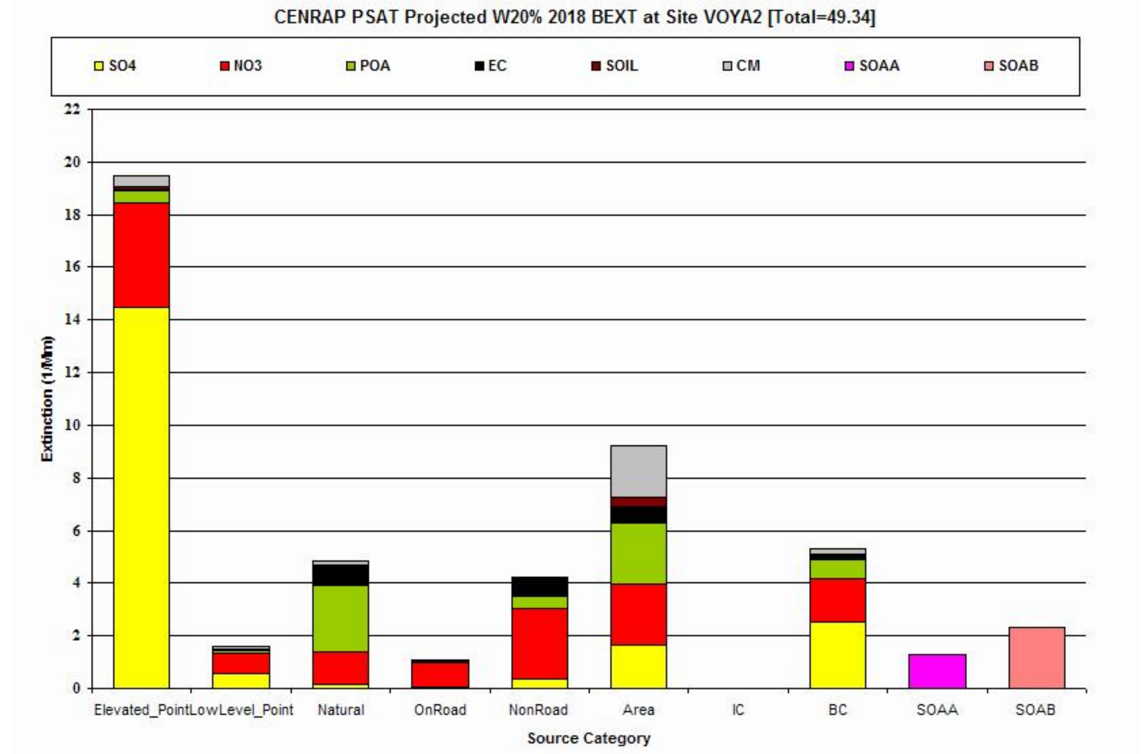


Figure E-5b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.

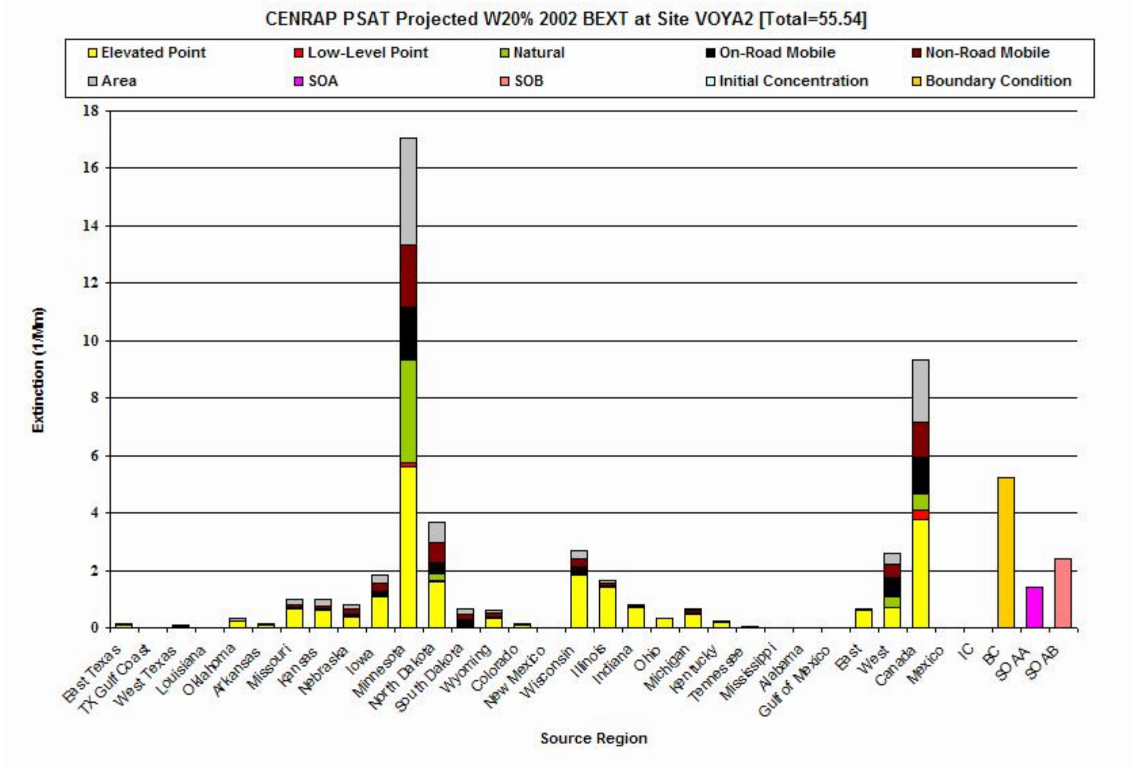


Figure E-5c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.

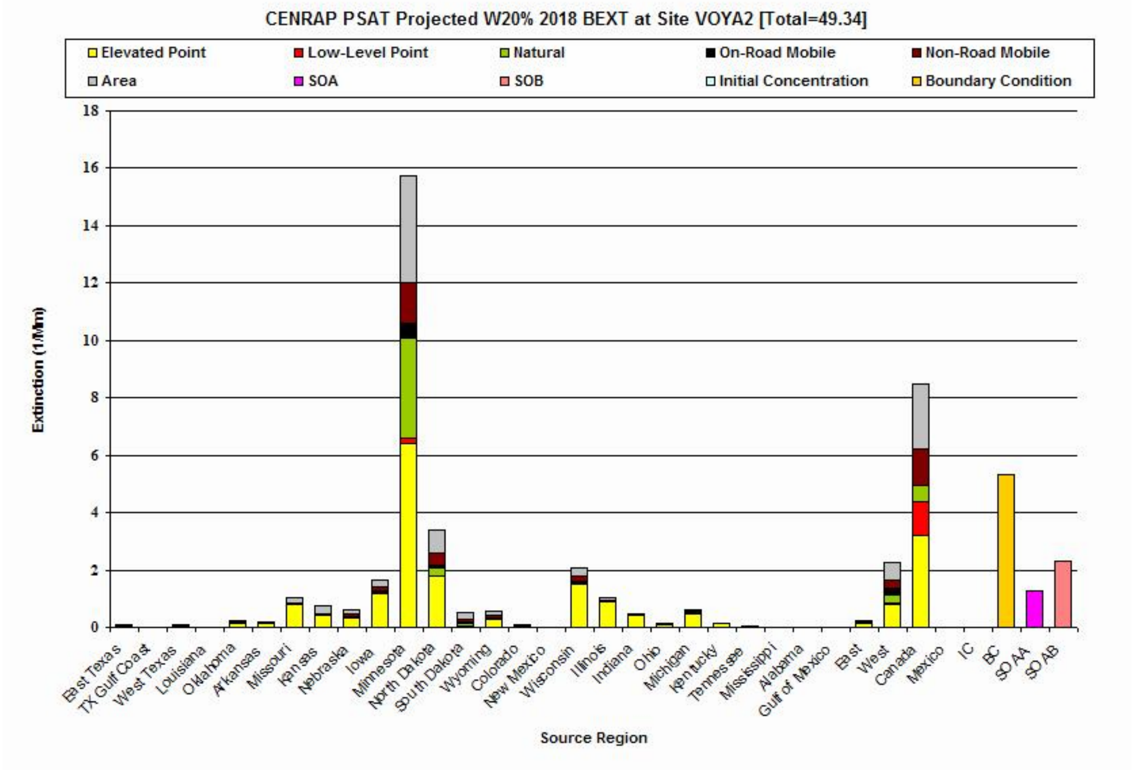
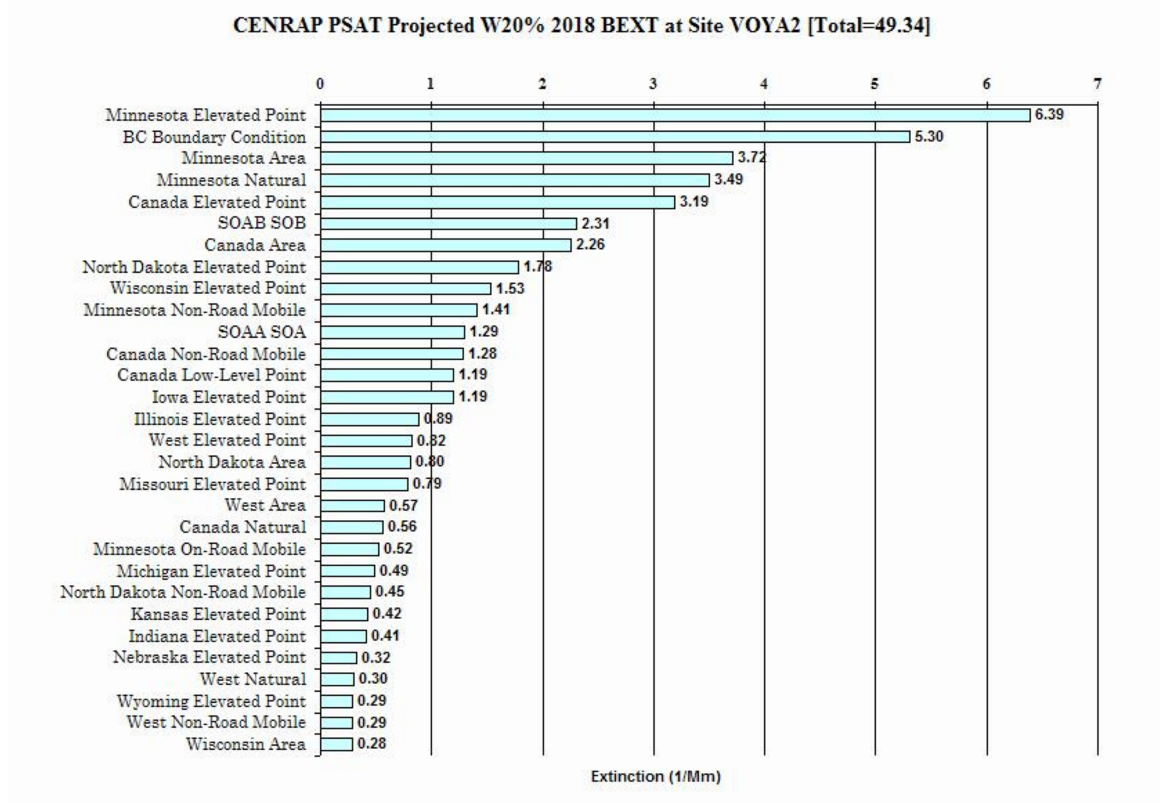
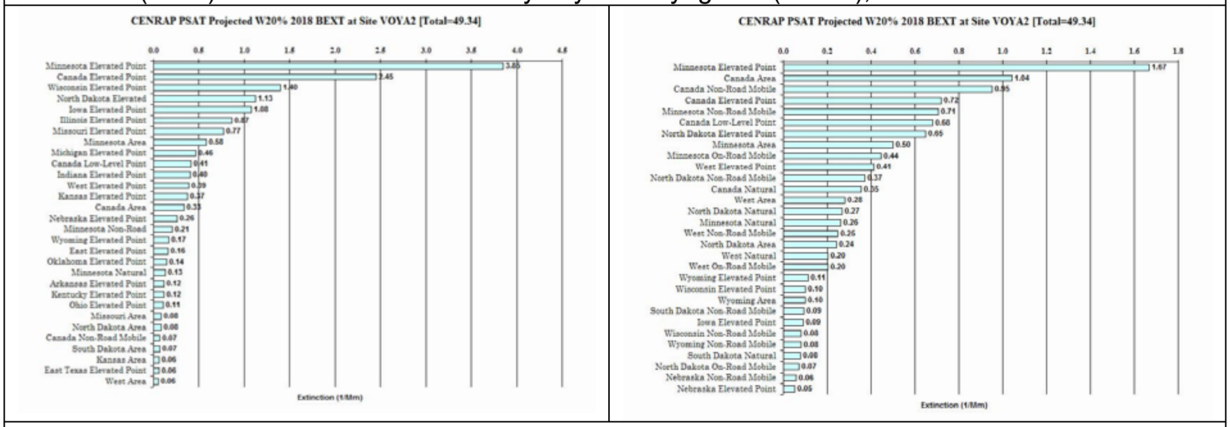


Figure E-5d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.



CENRAP PSAT Projected W20% 2018 BEXT at Site VOYA2 [Total=49.34]

Figure E-5e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.



CENRAP PSAT Projected W20% 2018 BEXT at Site VOYA2 [Total=49.34]

CENRAP PSAT Projected W20% 2018 BEXT at Site VOYA2 [Total=49.34]

Figure E-5f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Voyageurs (VOYA), Minnesota.

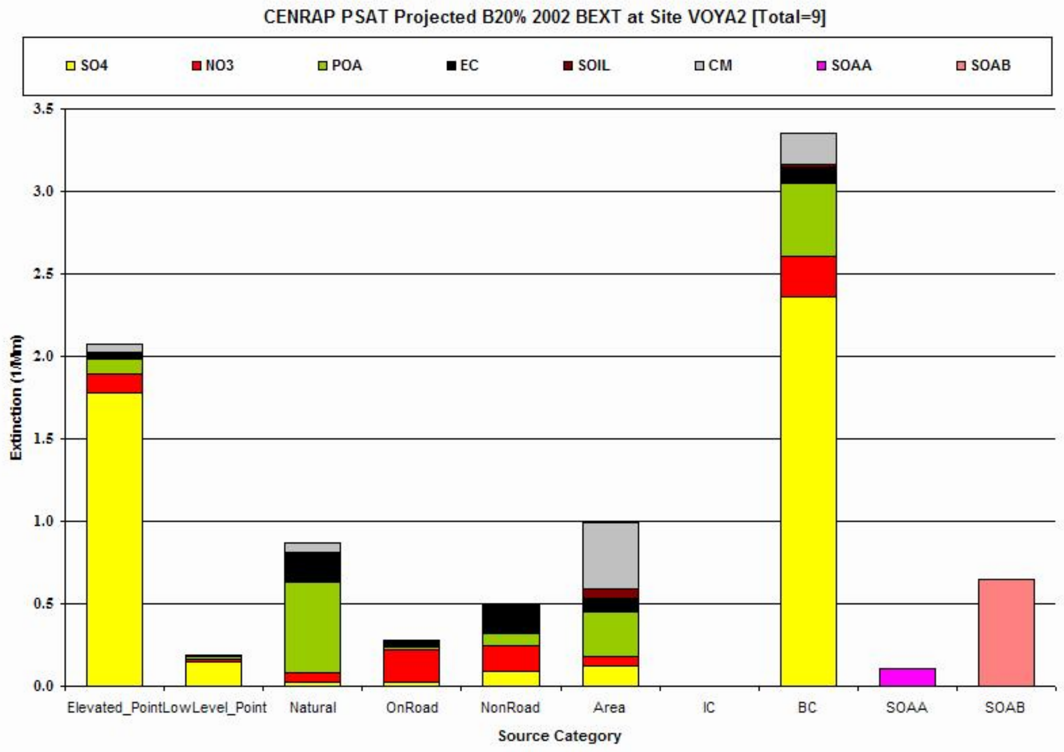


Figure E-5g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Voyageurs (VOYA), Minnesota.

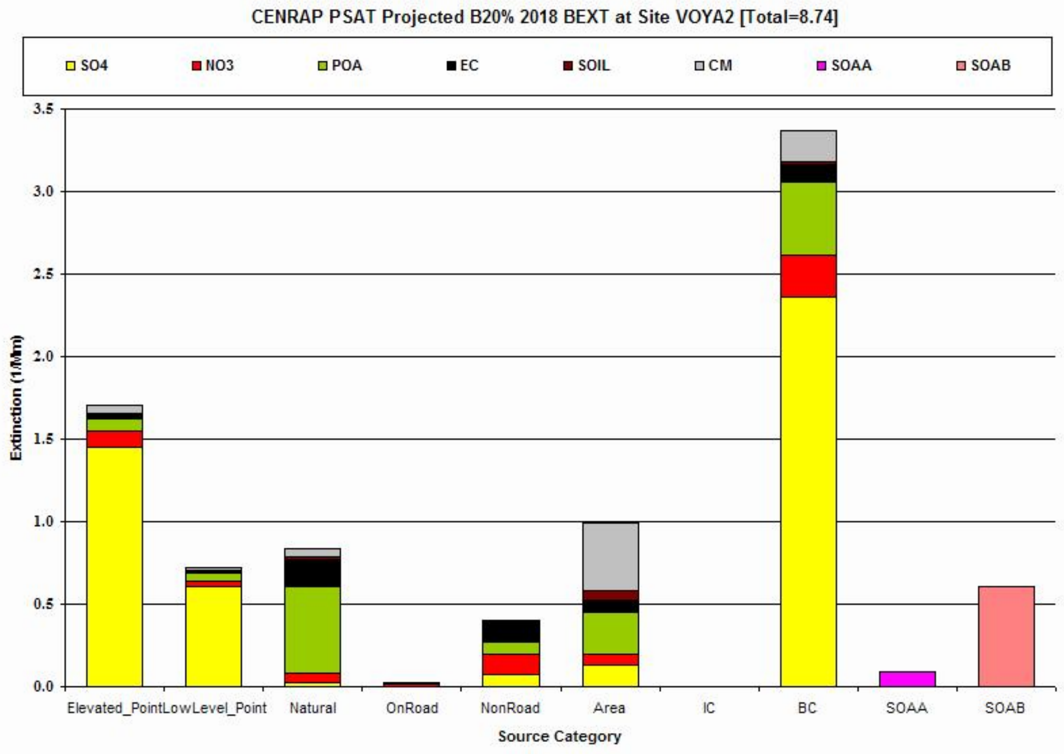


Figure E-5h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Voyageurs (VOYA), Minnesota.

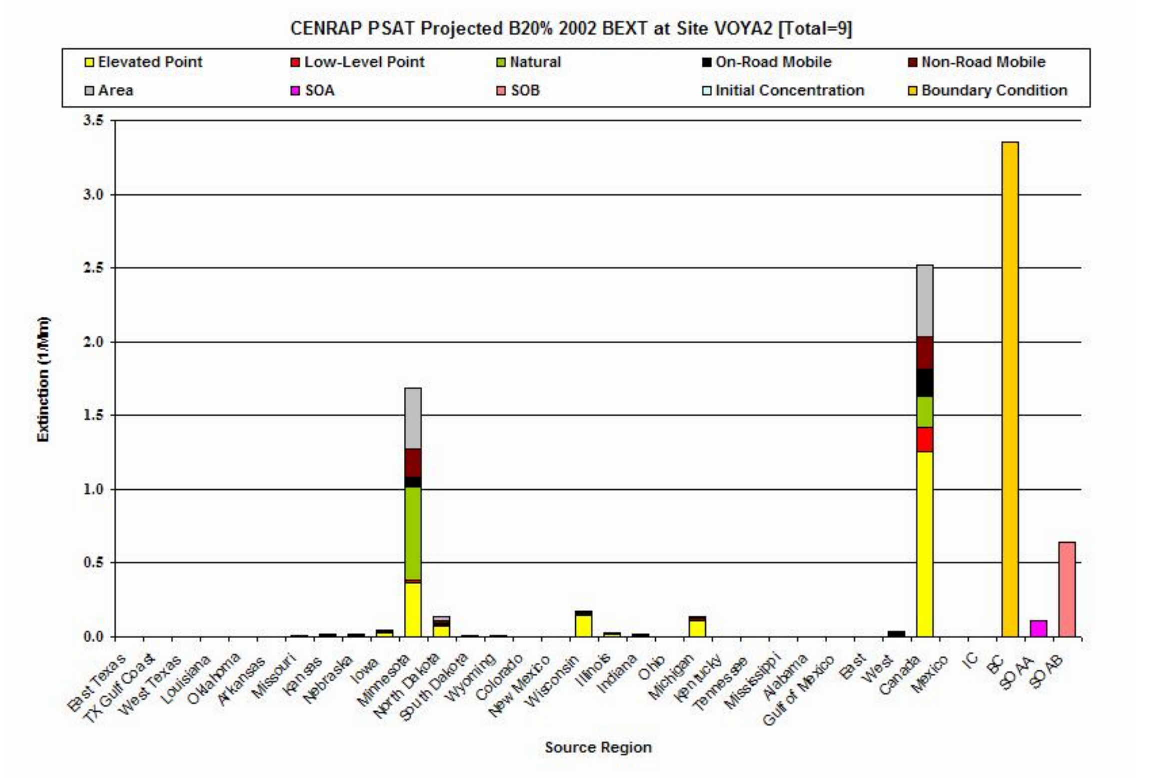


Figure E-5i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Voyageurs (VOYA), Minnesota.

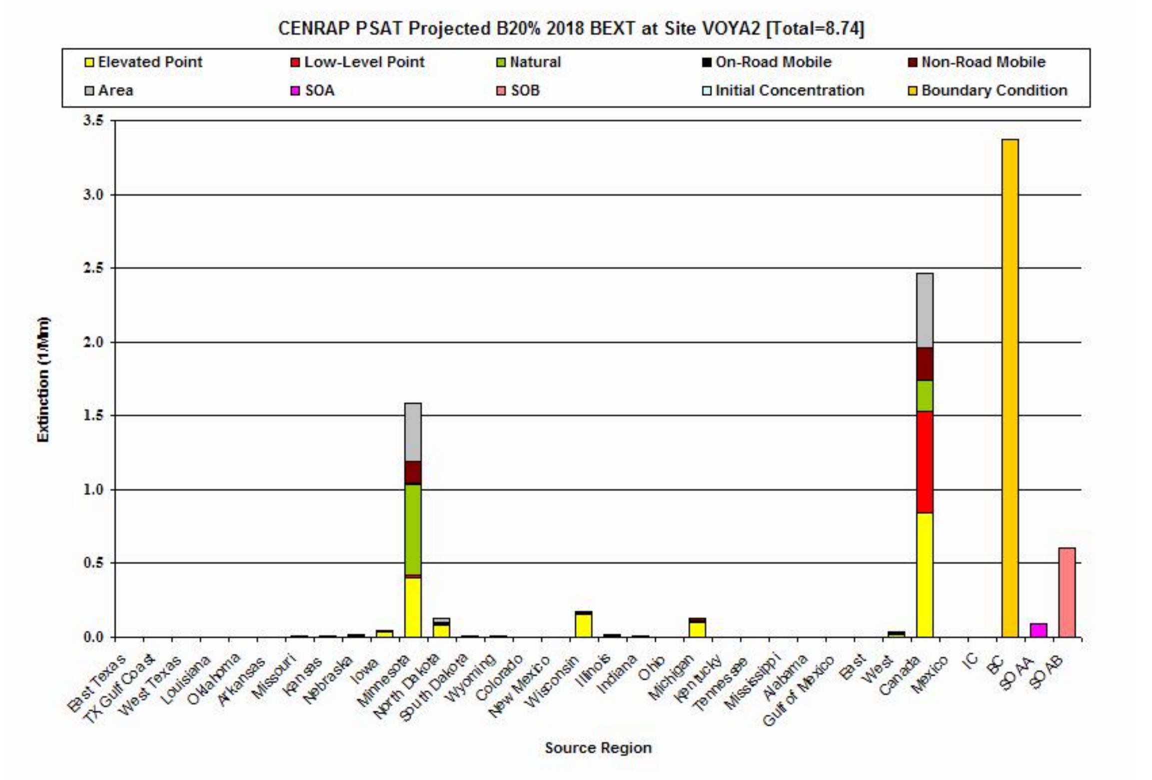


Figure E-5j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Voyageurs (VOYA), Minnesota.

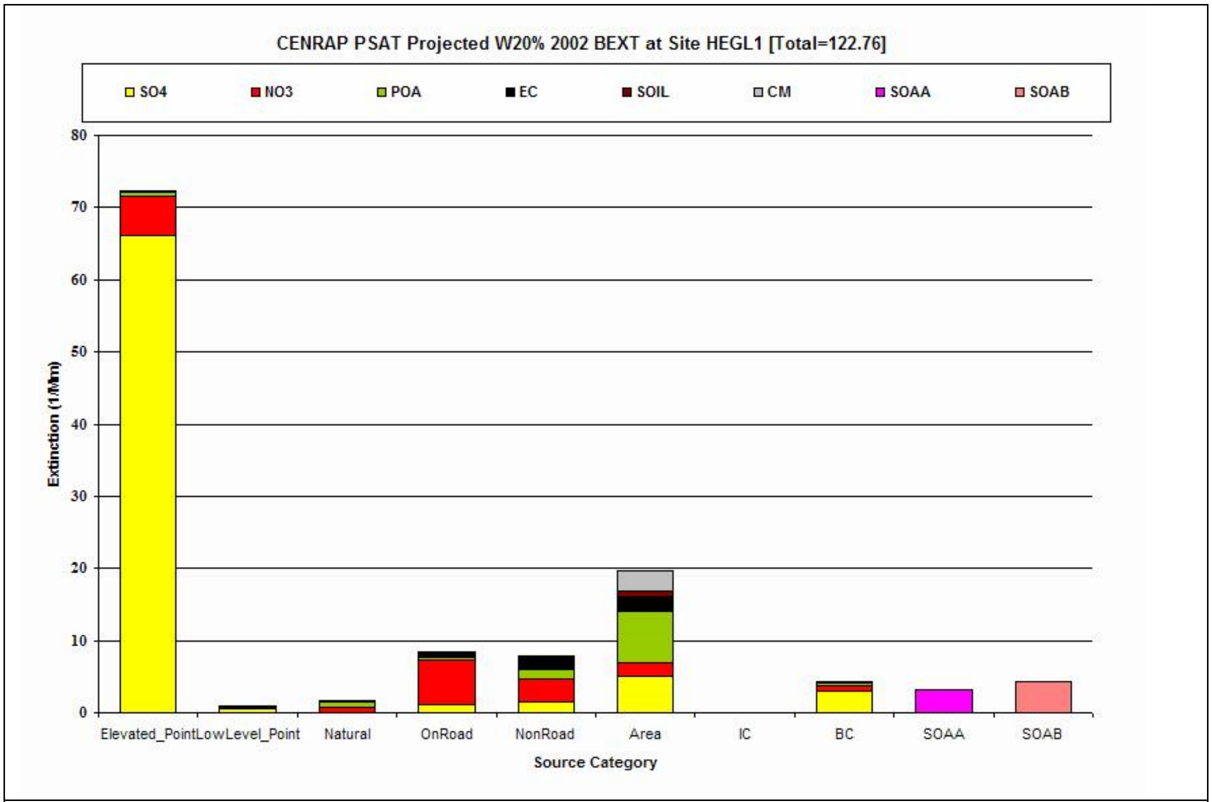


Figure E-6a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

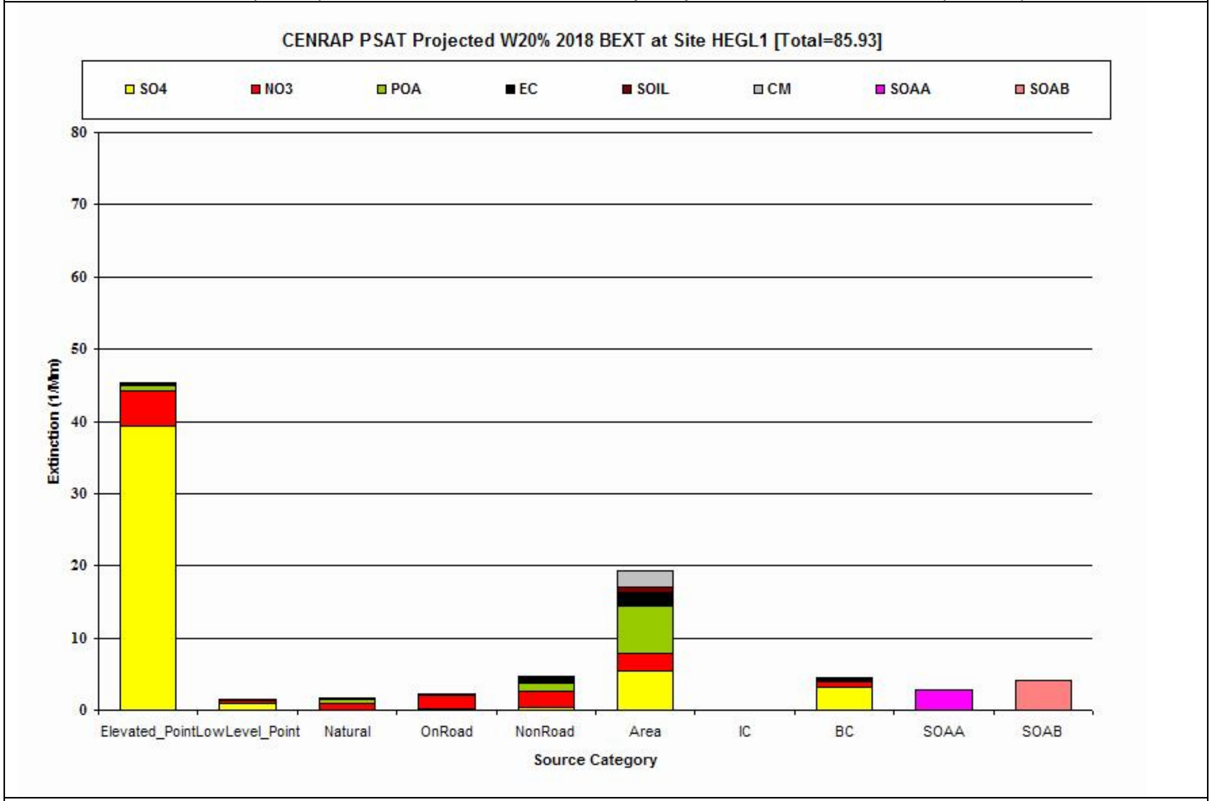


Figure E-6b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

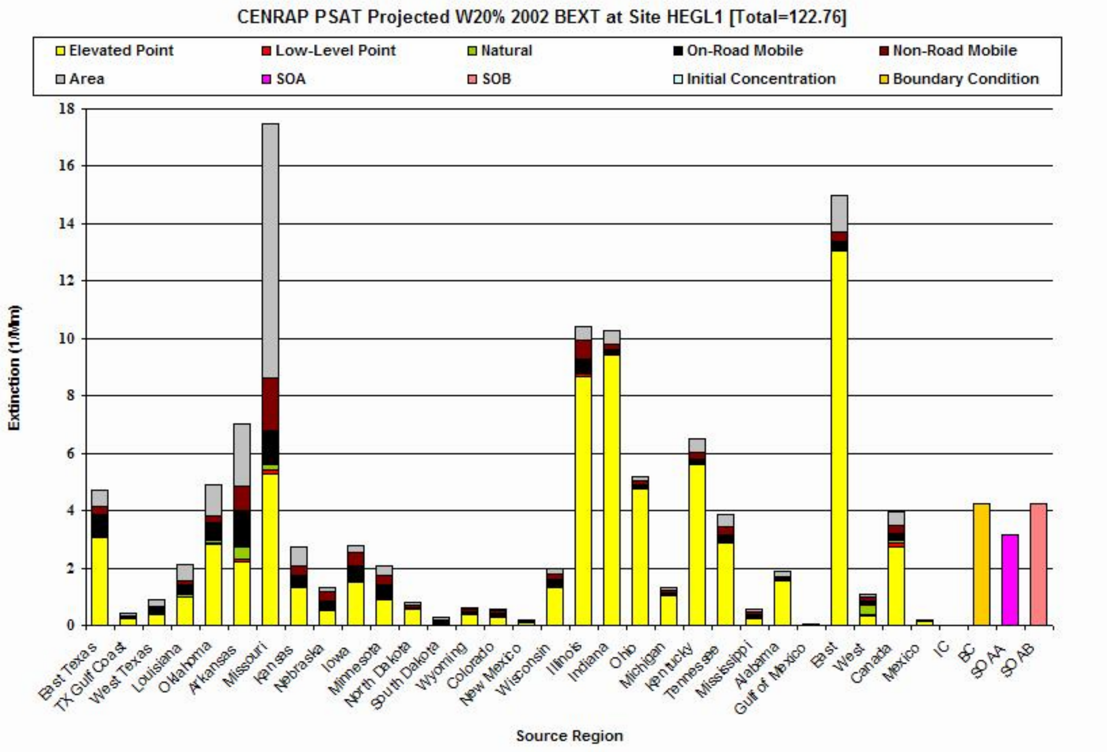


Figure E-6c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

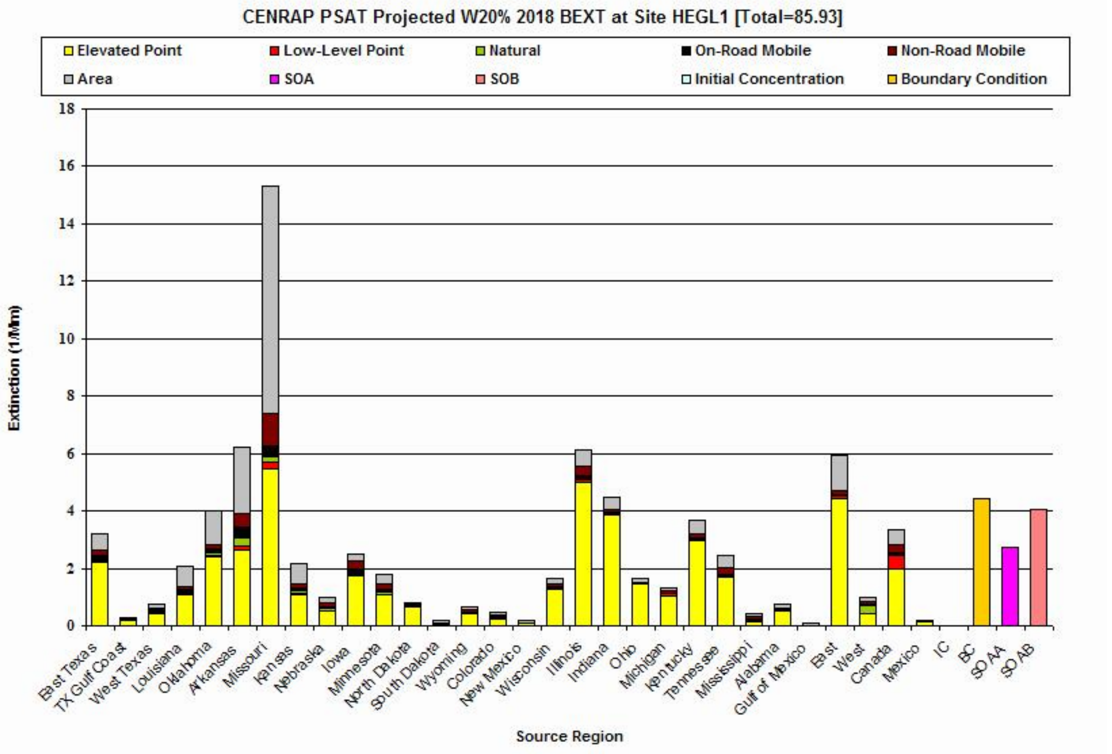


Figure E-6d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

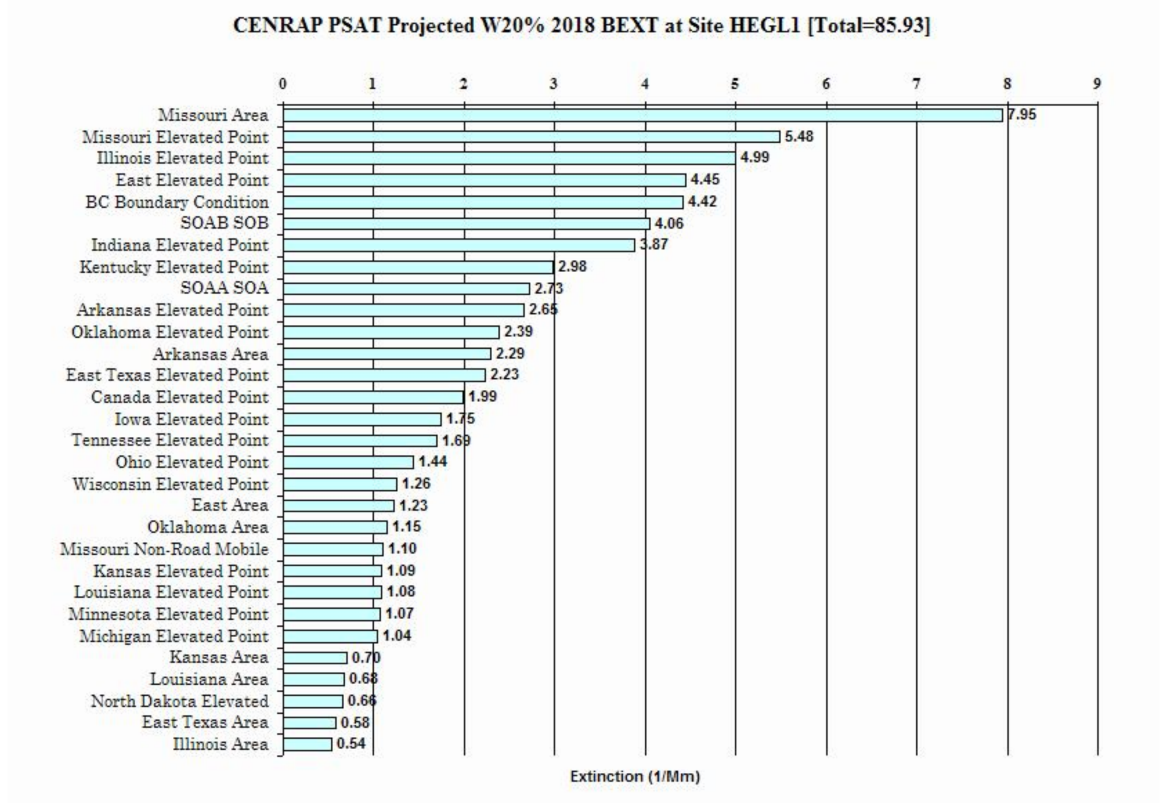


Figure E-6e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

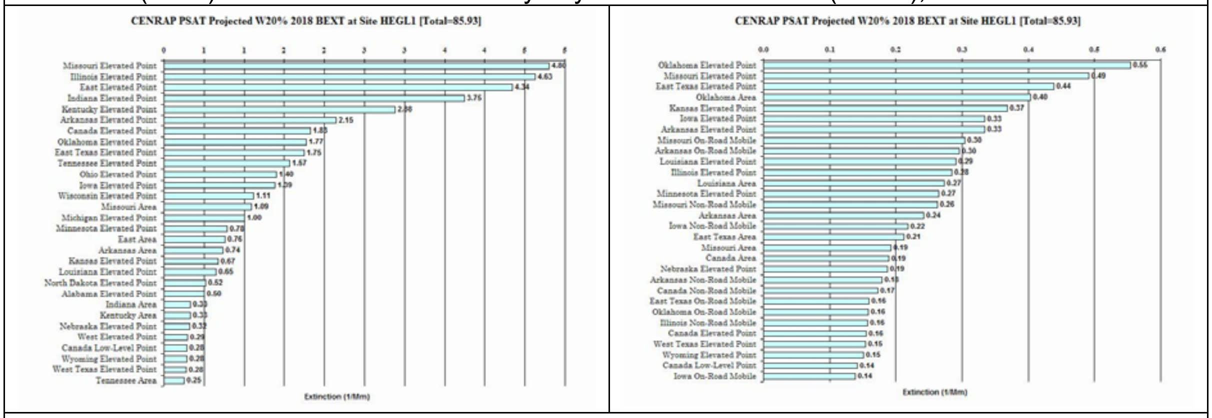


Figure E-6f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Hercules Glade (HEGL), Missouri.

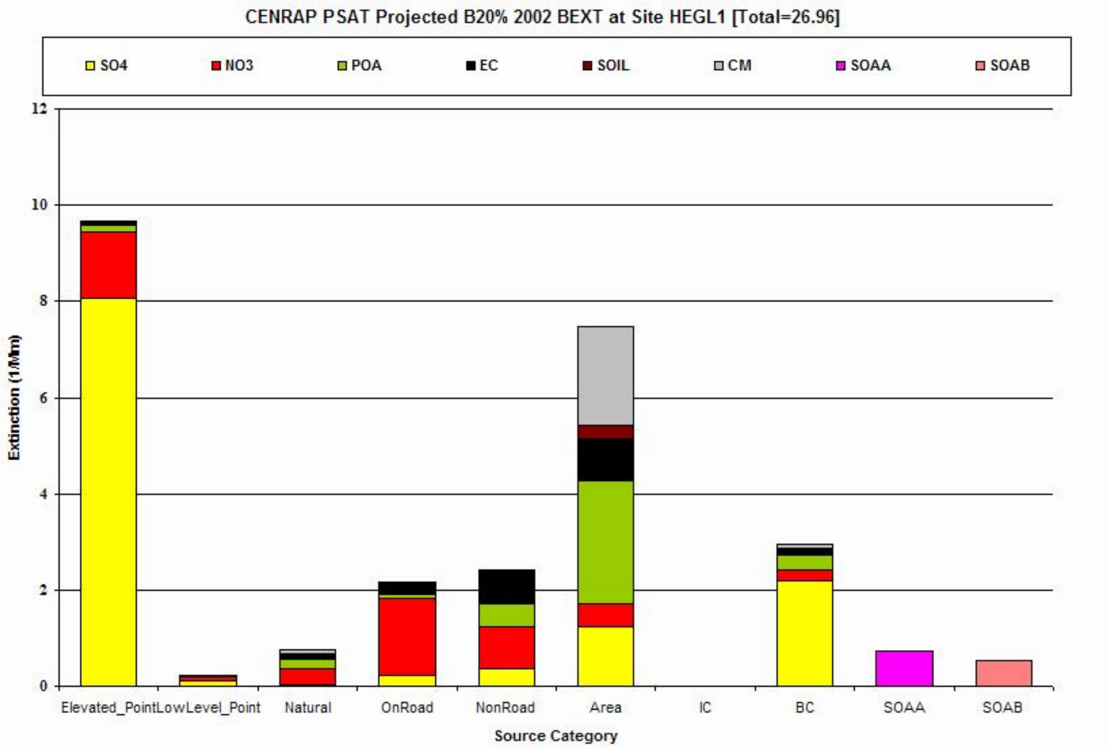


Figure E-6g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Hercules Glade (HEGL), Missouri.

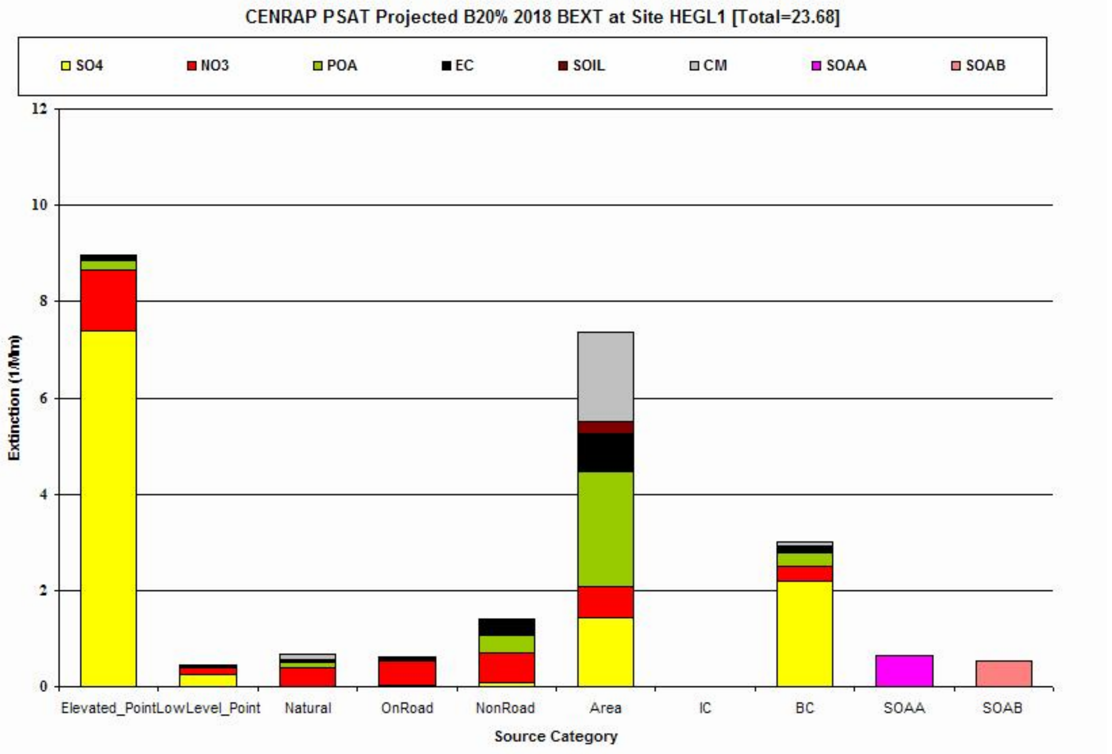


Figure E-6h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Hercules Glade (HEGL), Missouri.

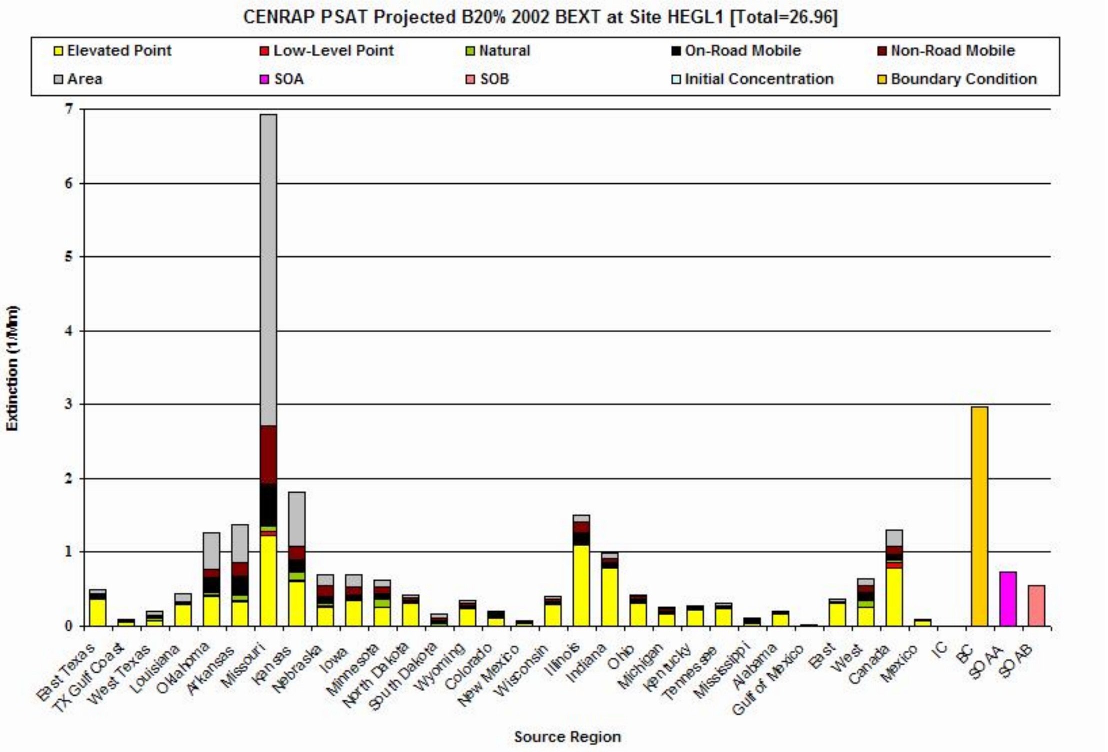


Figure E-6i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Hercules Glade (HEGL), Missouri.

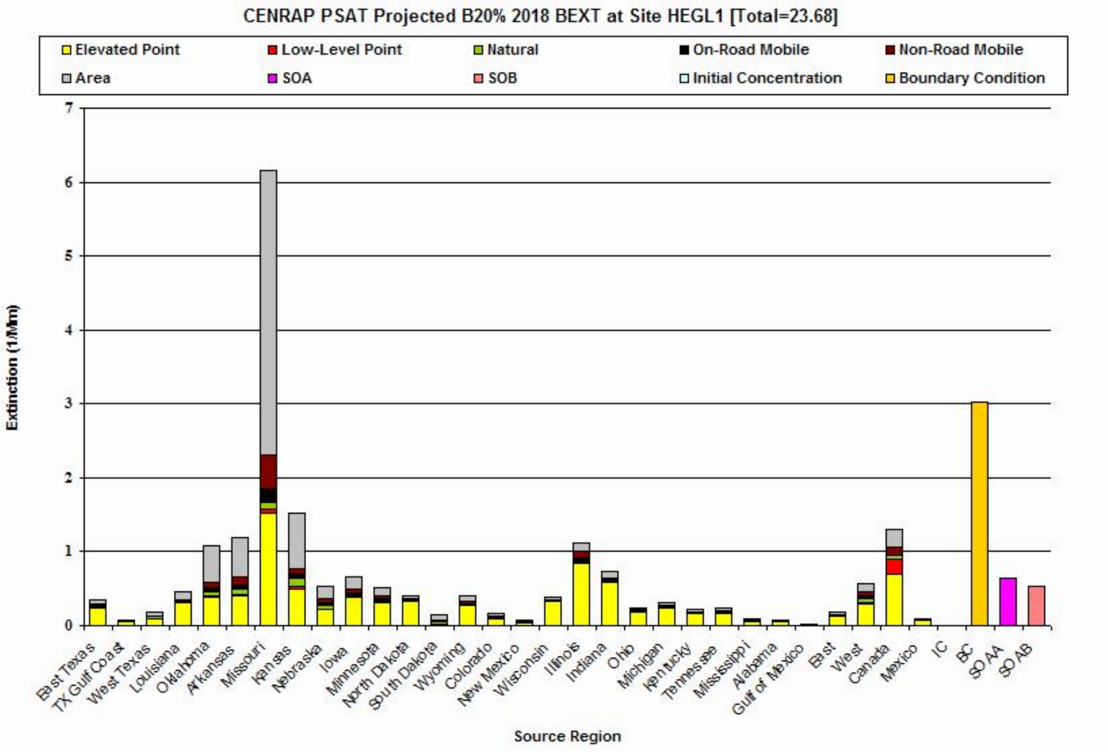


Figure E-6j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Voyageurs Hercules Glade (HEGL), Missouri.

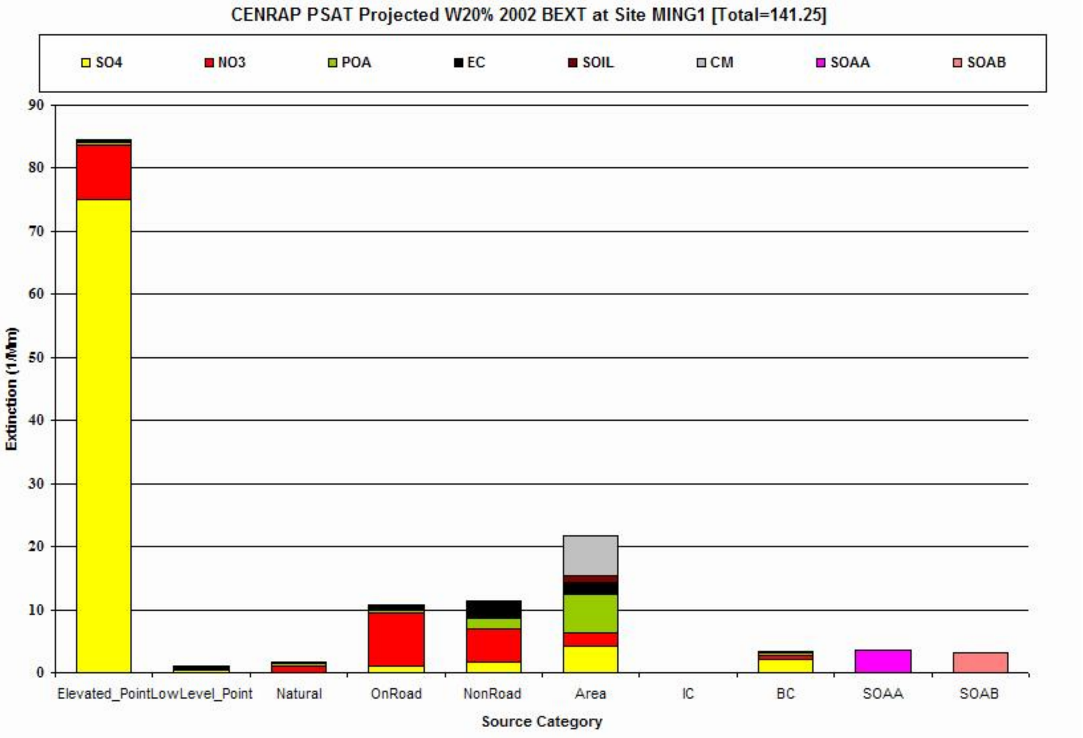


Figure E-7a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

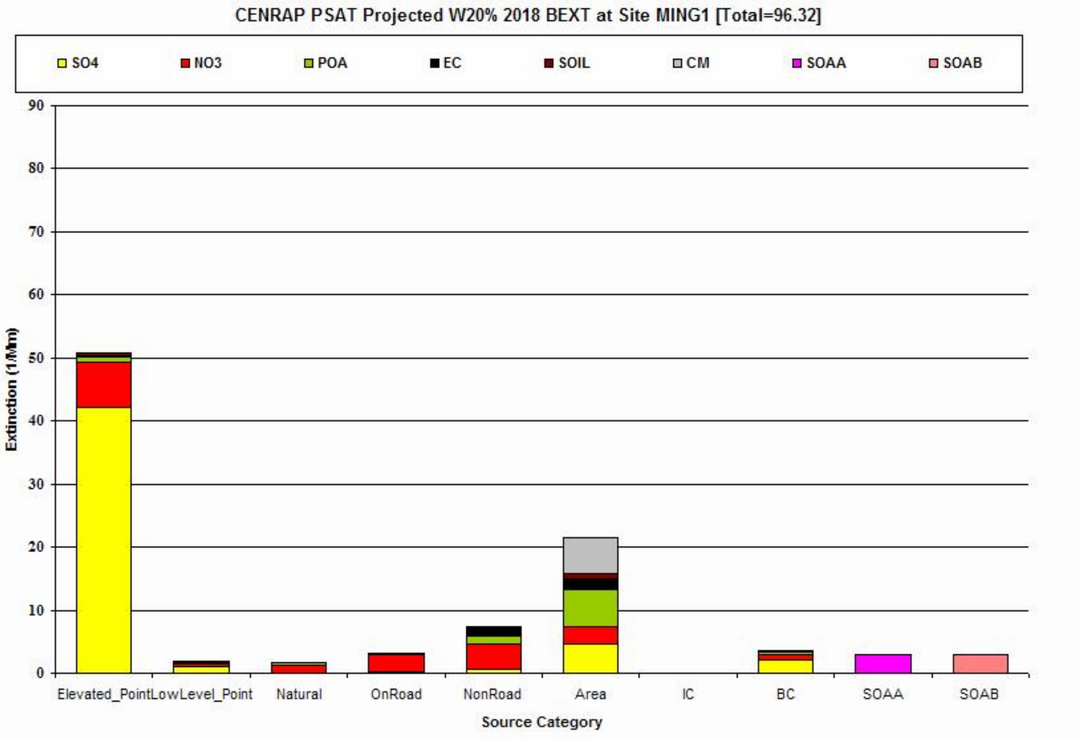


Figure E-7b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

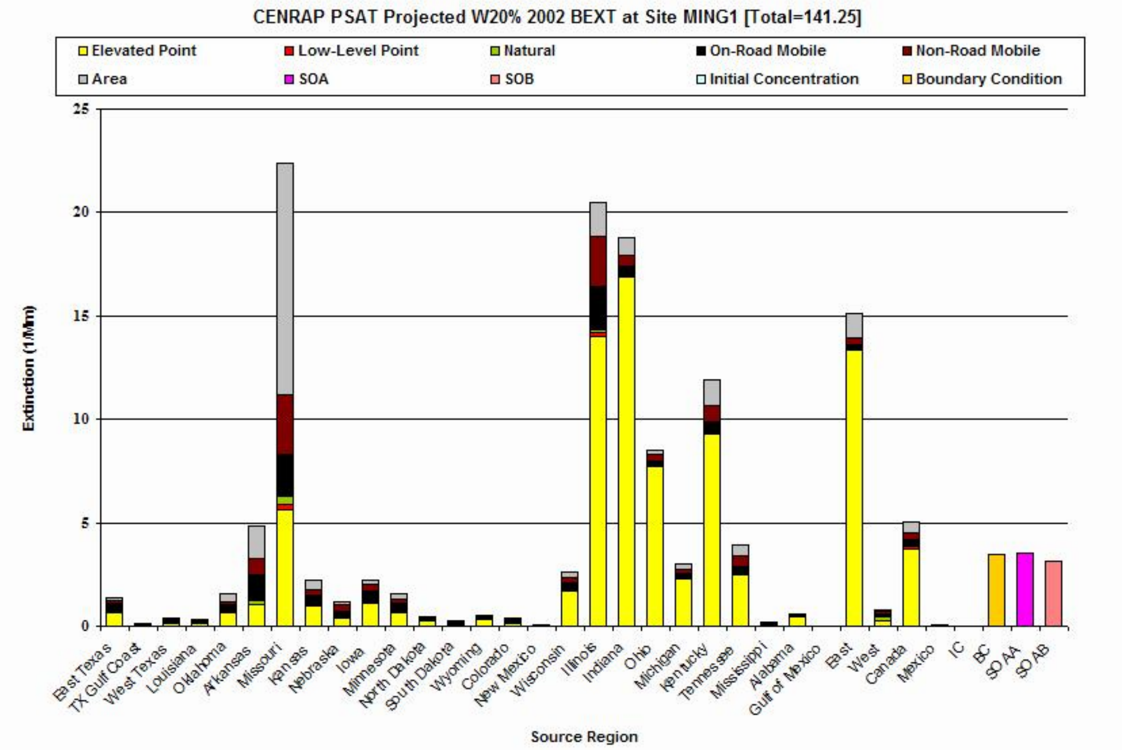


Figure E-7c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

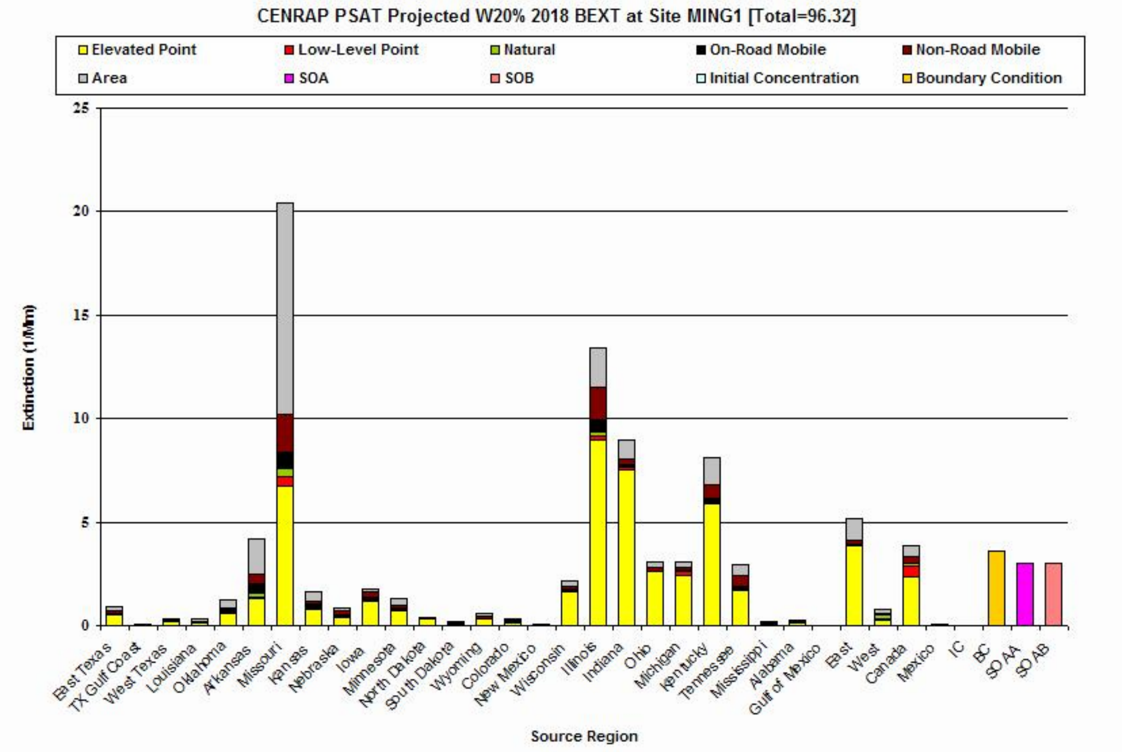


Figure E-7d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

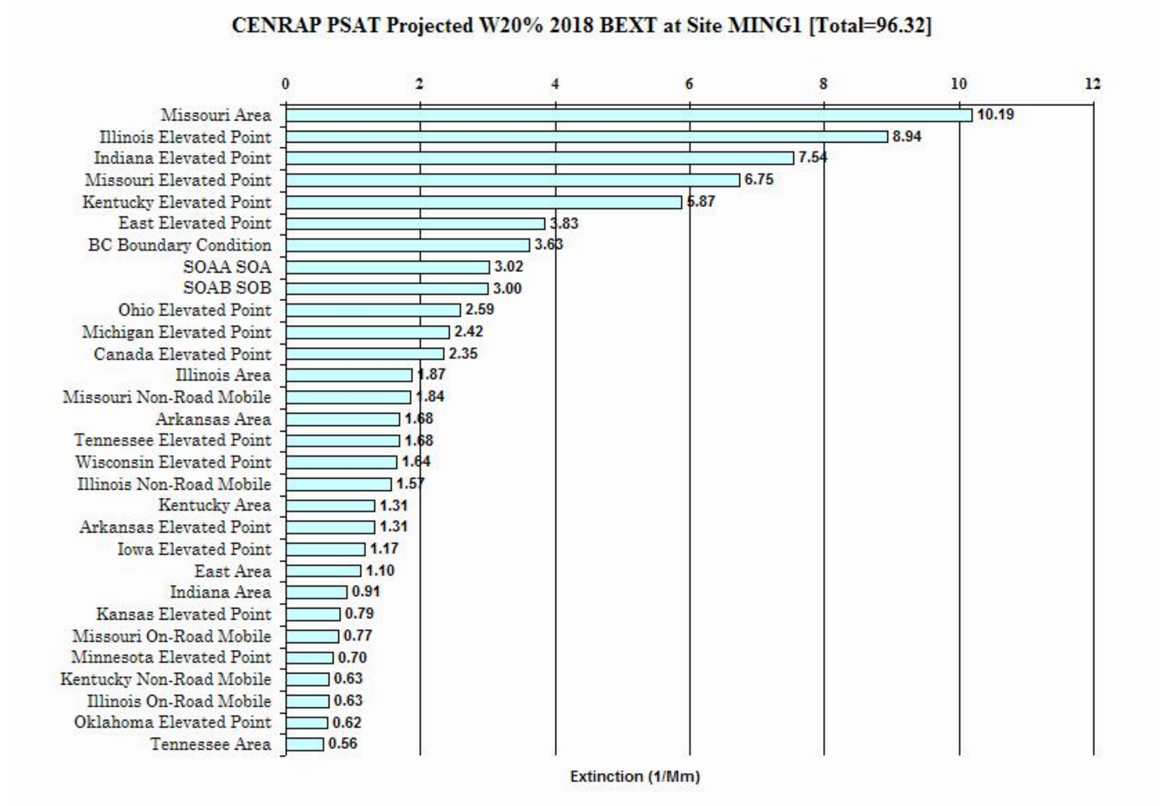


Figure E-7e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

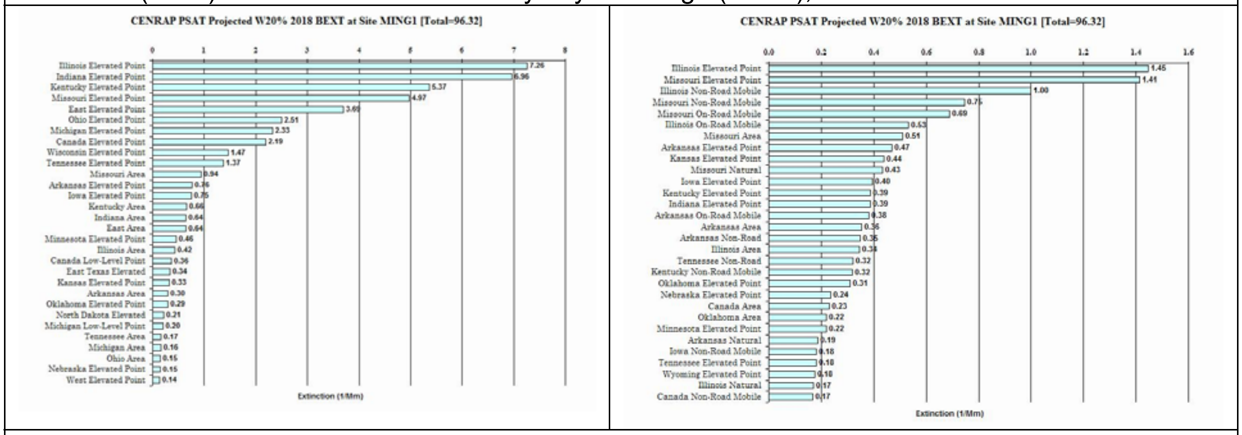


Figure E-7f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Mingo (MING), Missouri.

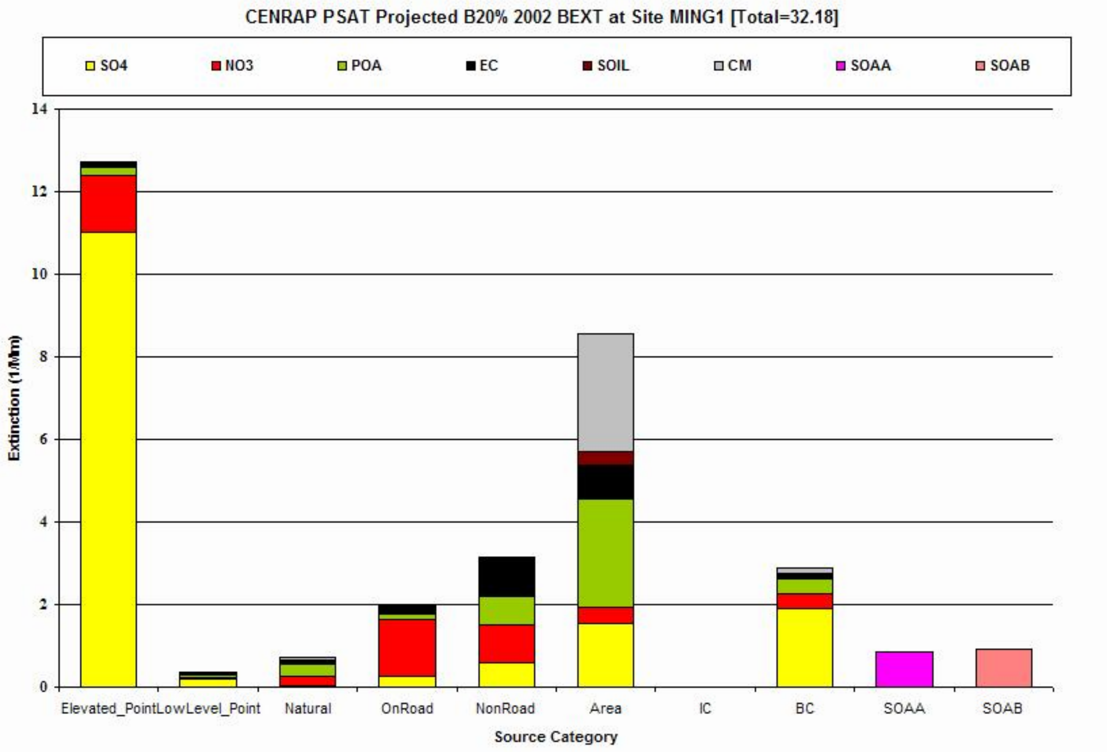


Figure E-7g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Mingo (MING), Missouri.

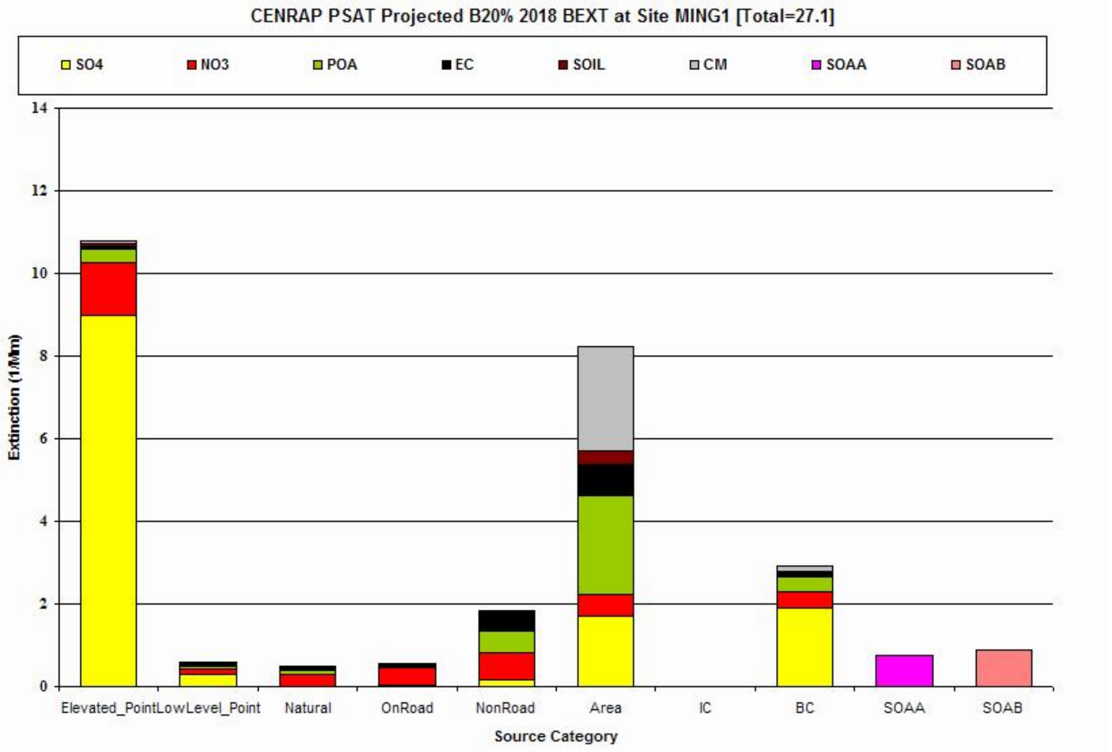


Figure E-7h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Mingo (MING), Missouri.

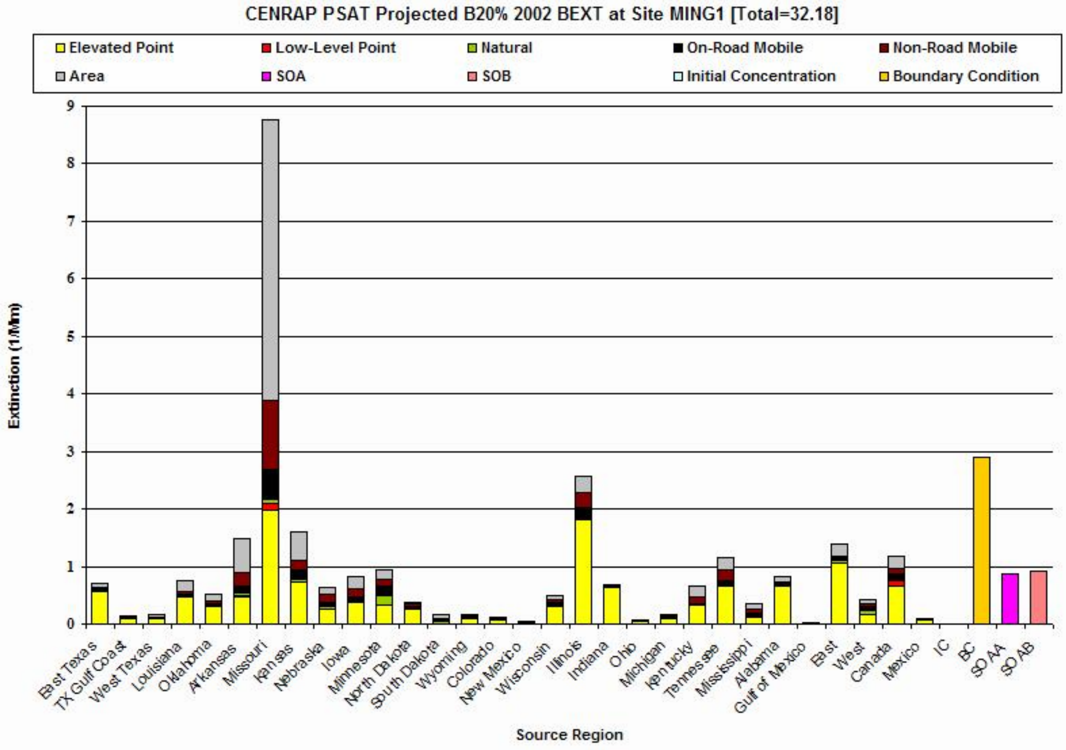


Figure E-7i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Mingo (MING), Missouri.

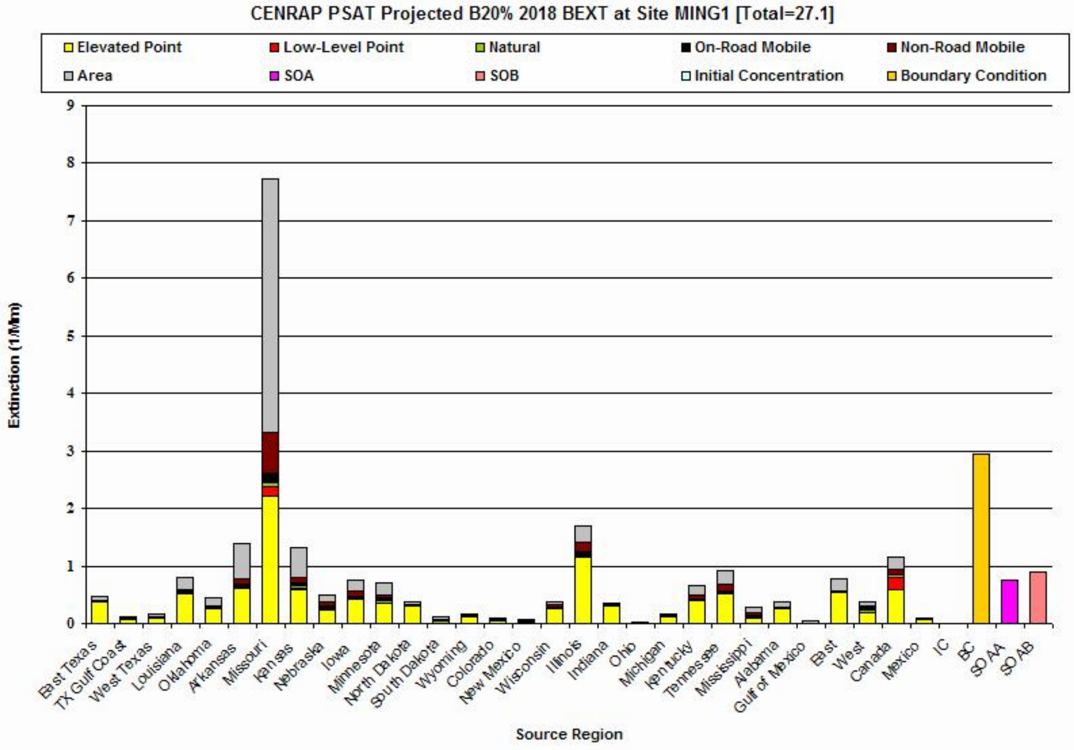


Figure E-7j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Mingo (MING), Missouri.

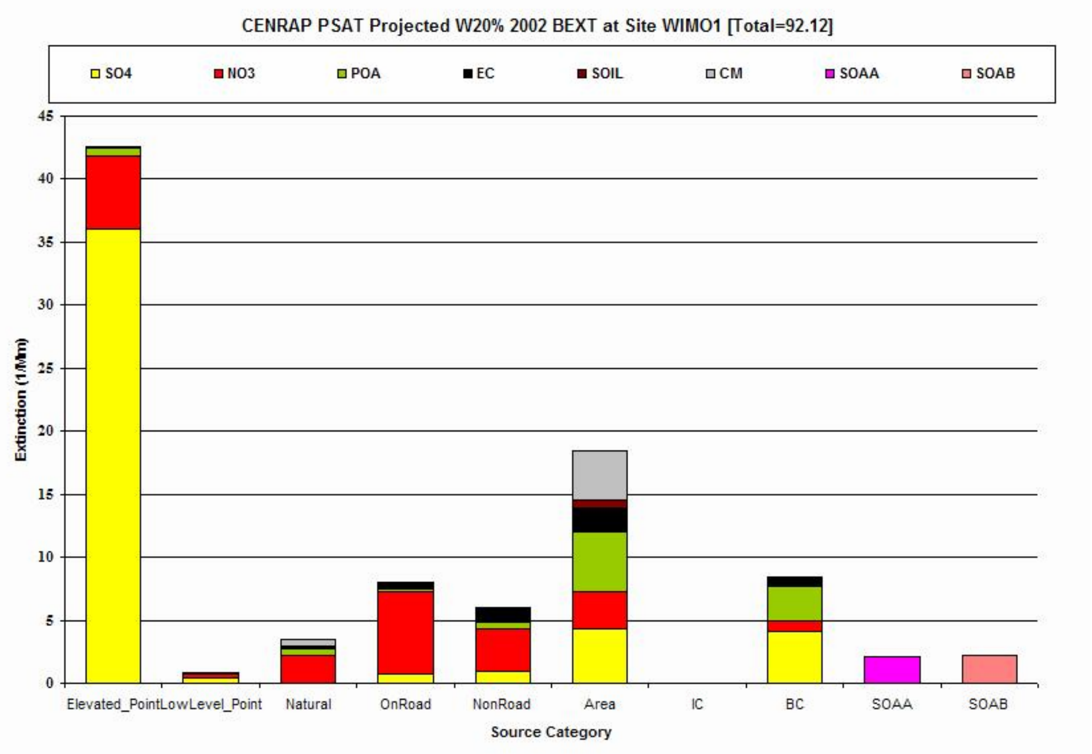


Figure E-8a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

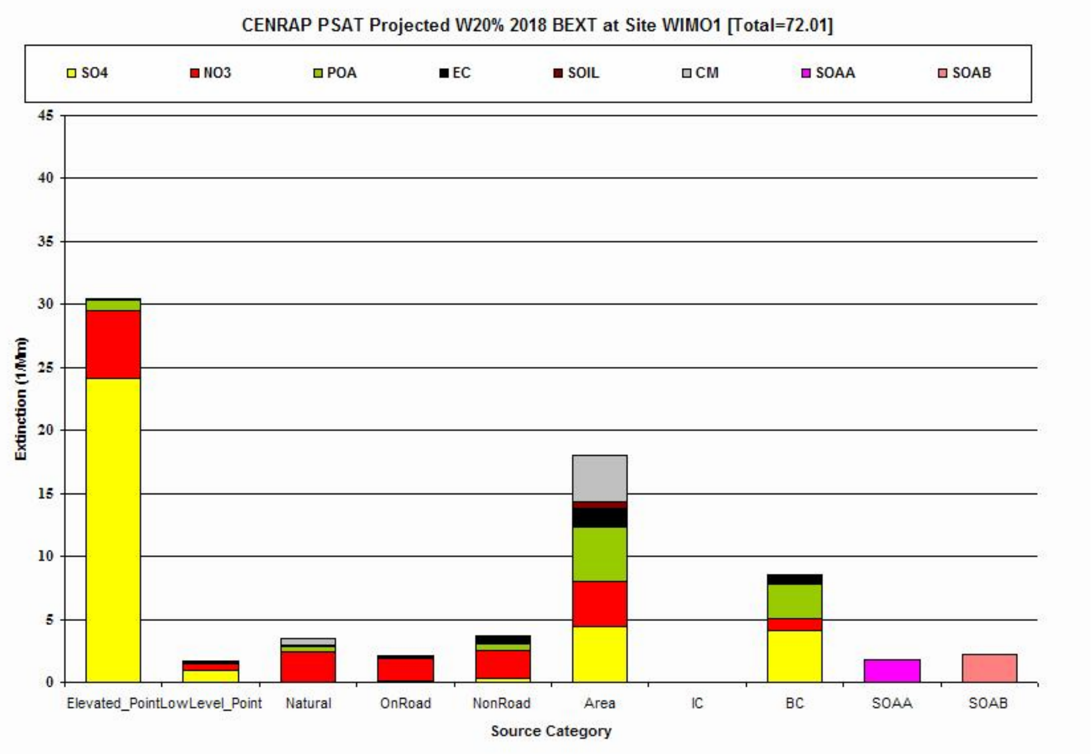


Figure E-8b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

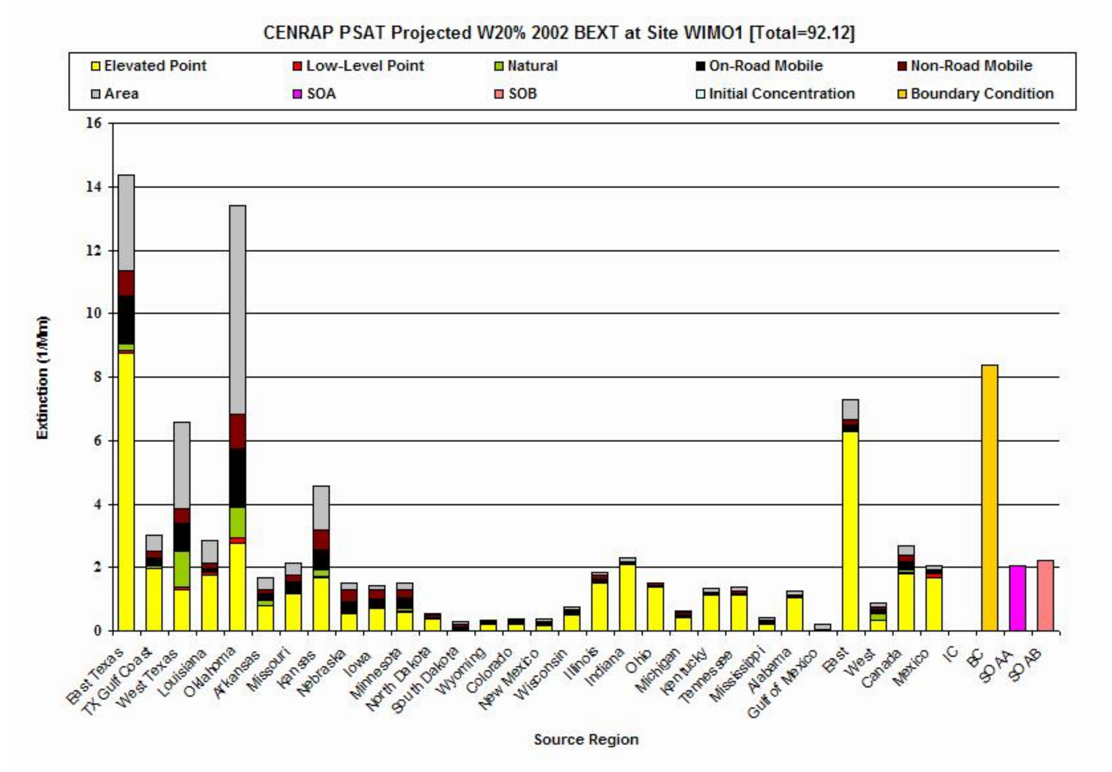


Figure E-8c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

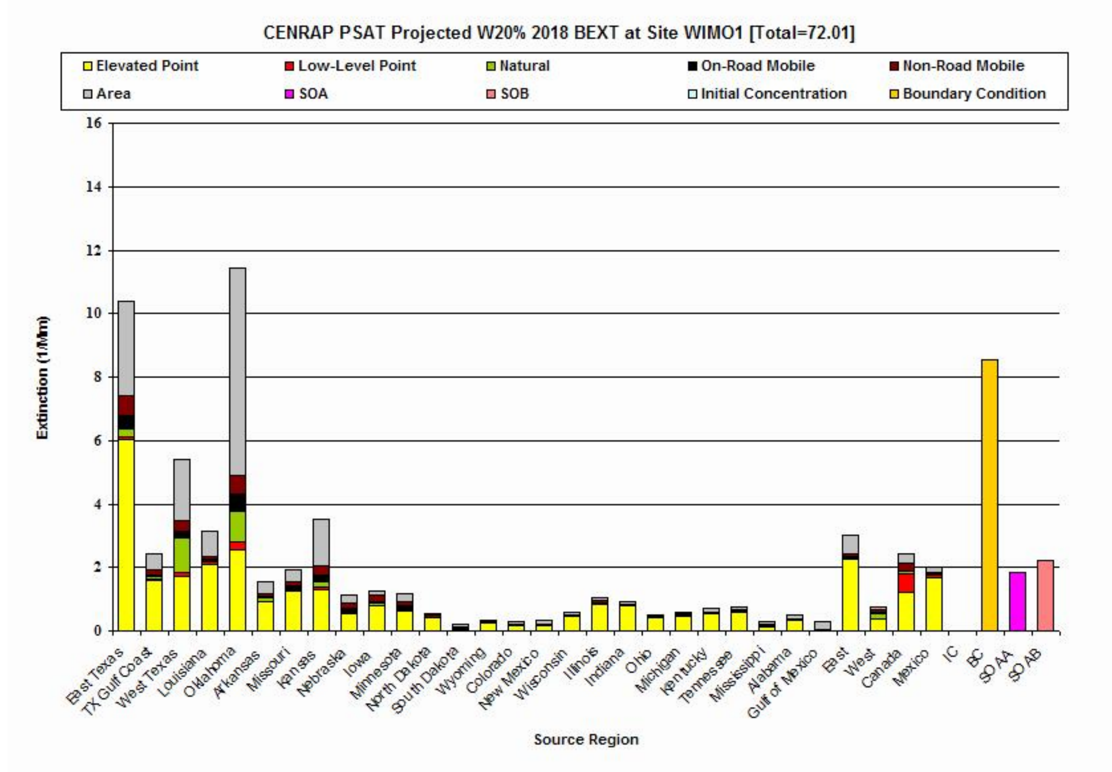


Figure E-8d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

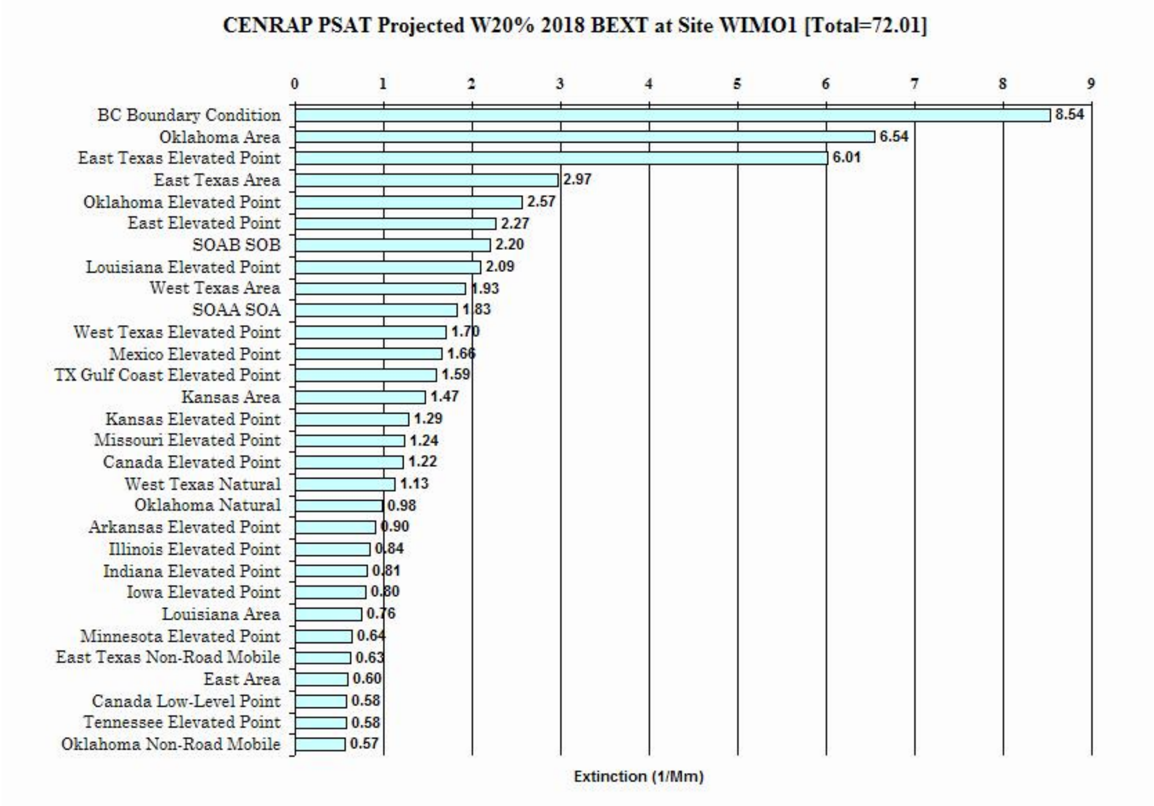


Figure E-8e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

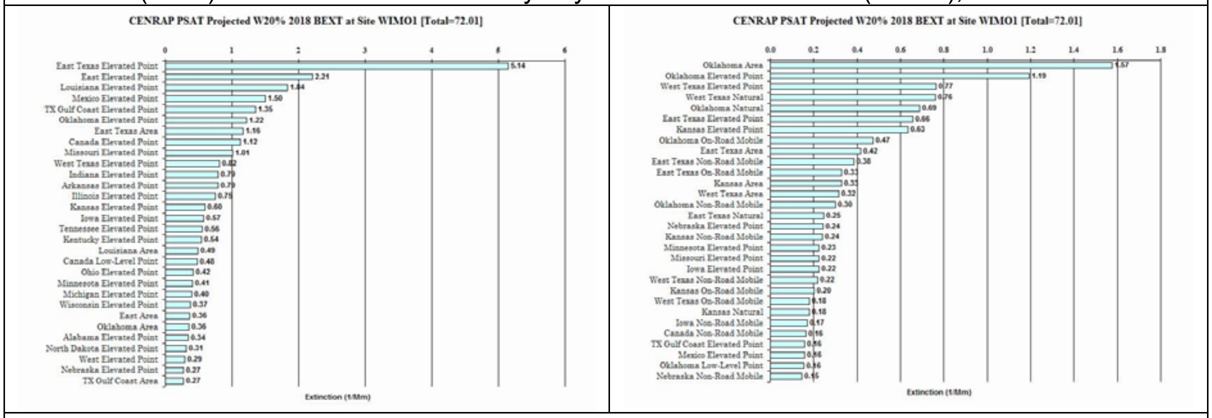


Figure E-8f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

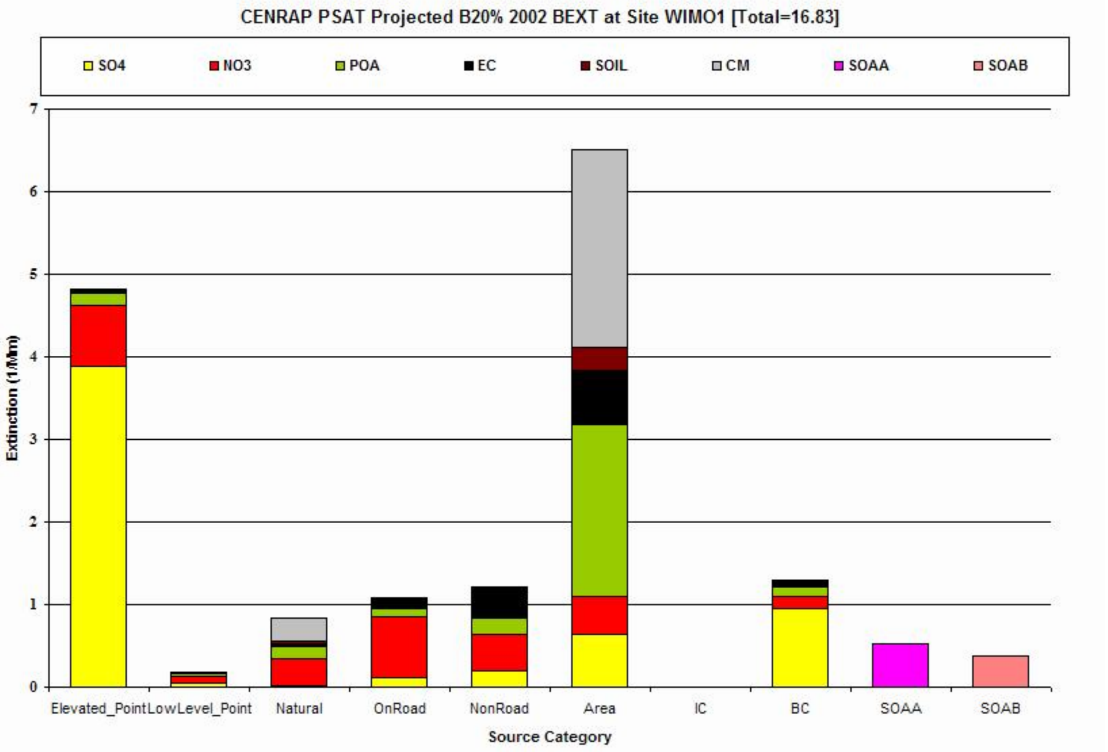


Figure E-8g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

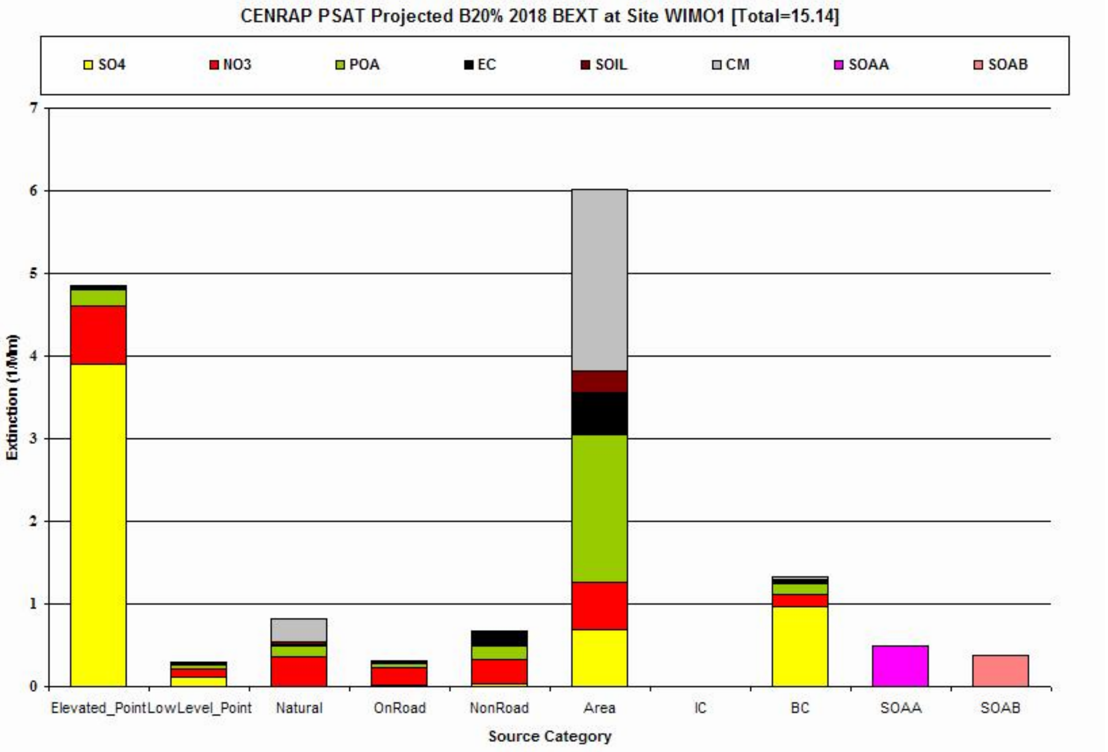


Figure E-8h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

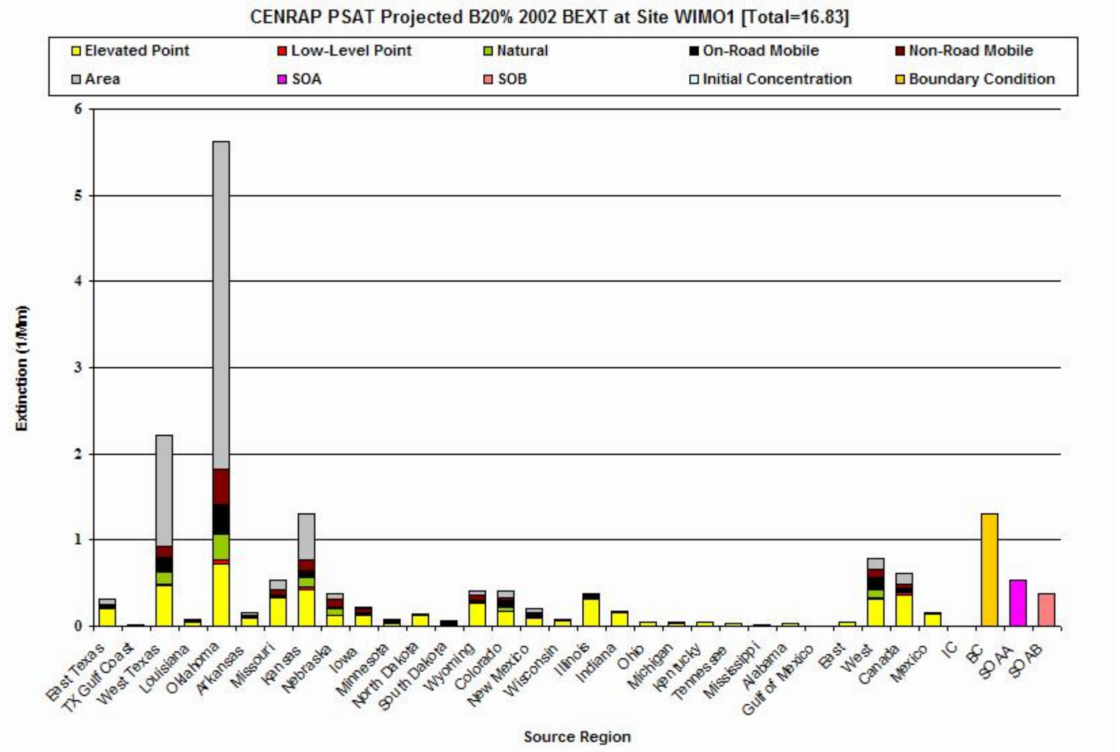


Figure E-8i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

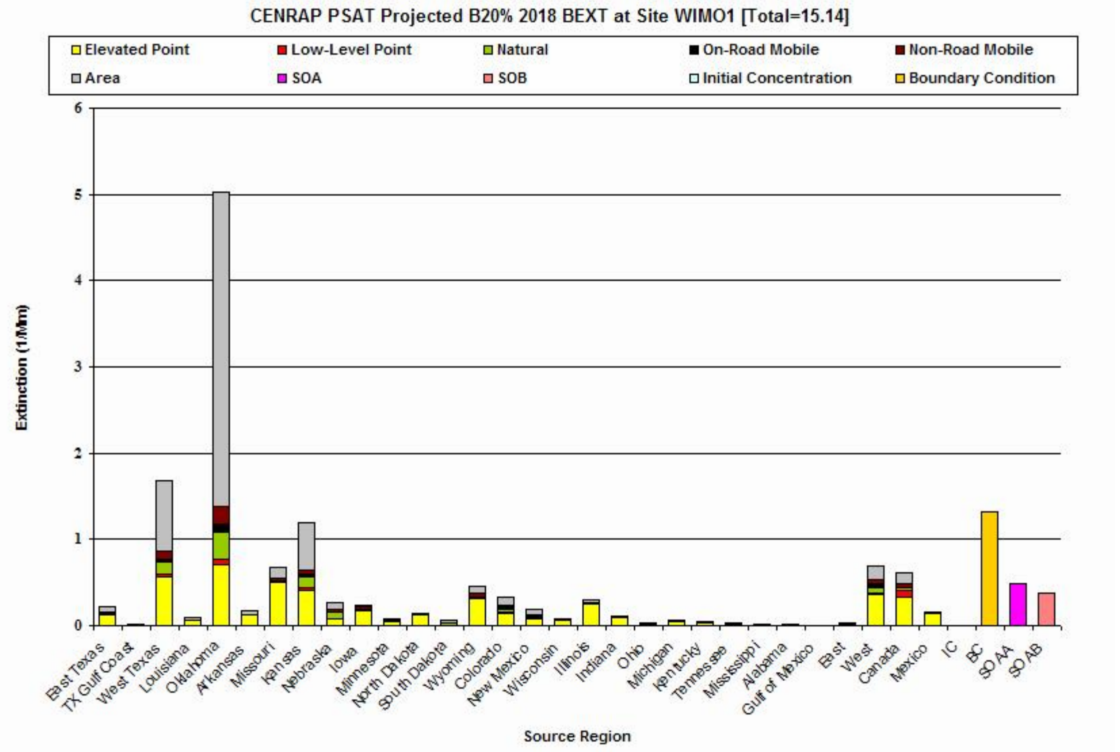


Figure E-8j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Wichita Mountains (WIMO), Oklahoma.

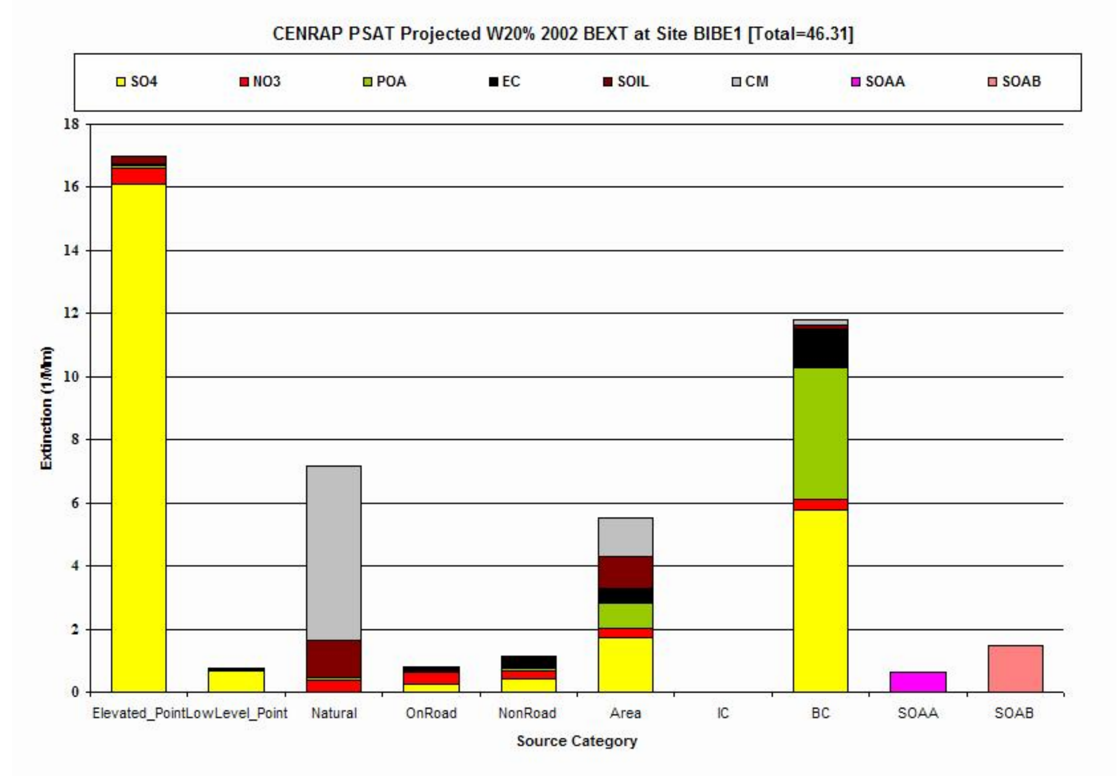


Figure E-9a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

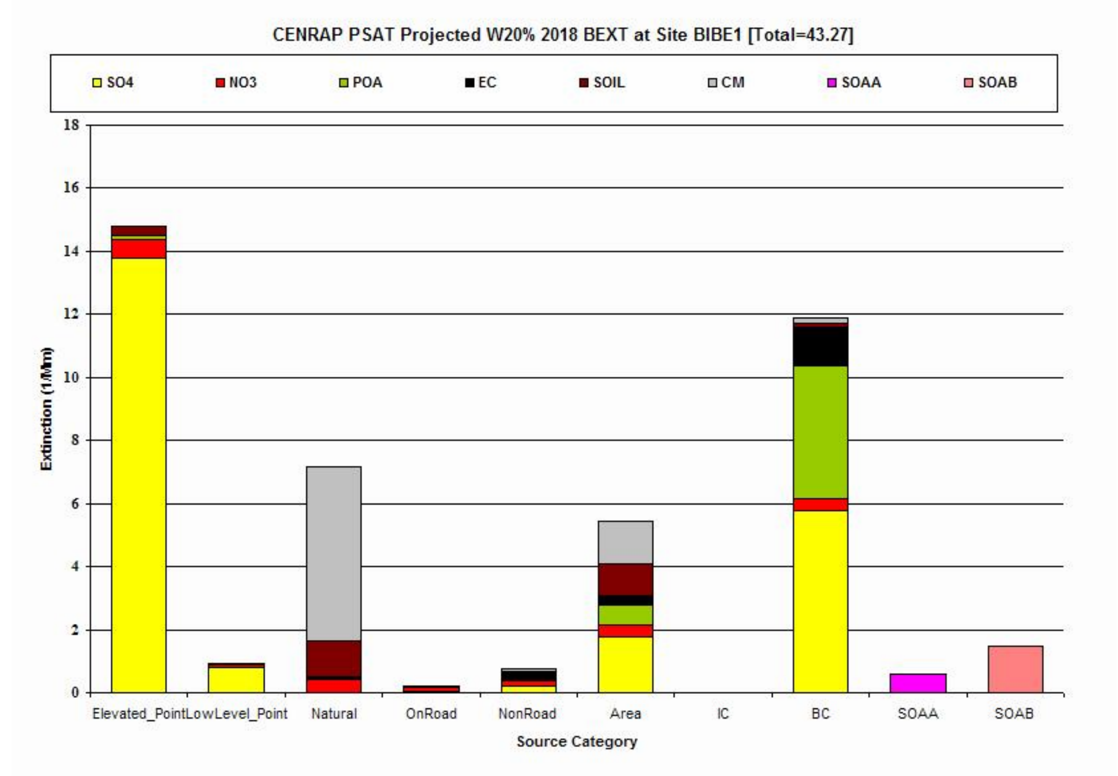


Figure E-9b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

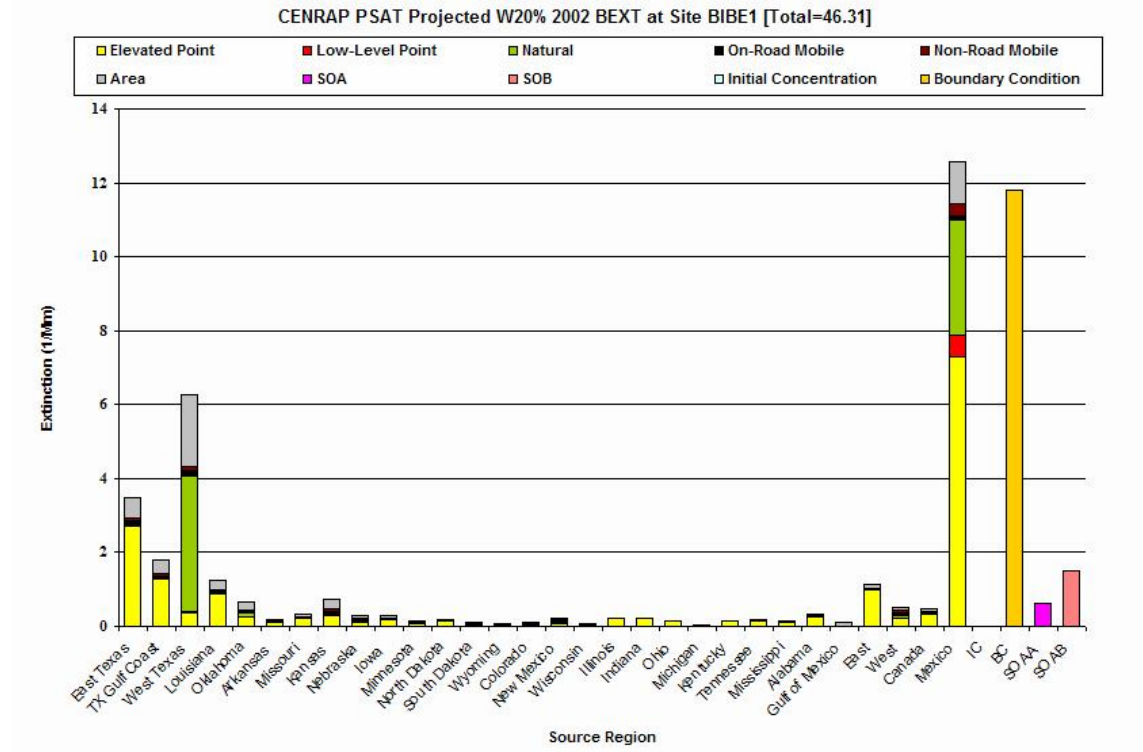


Figure E-9c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

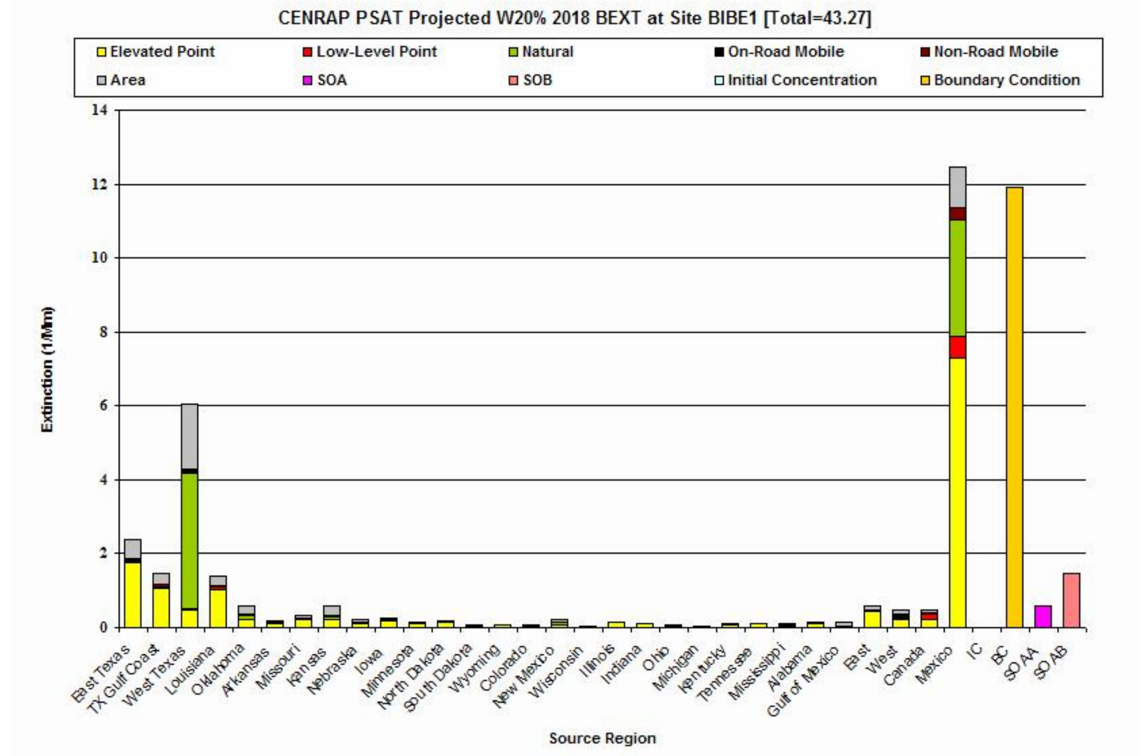


Figure E-9d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

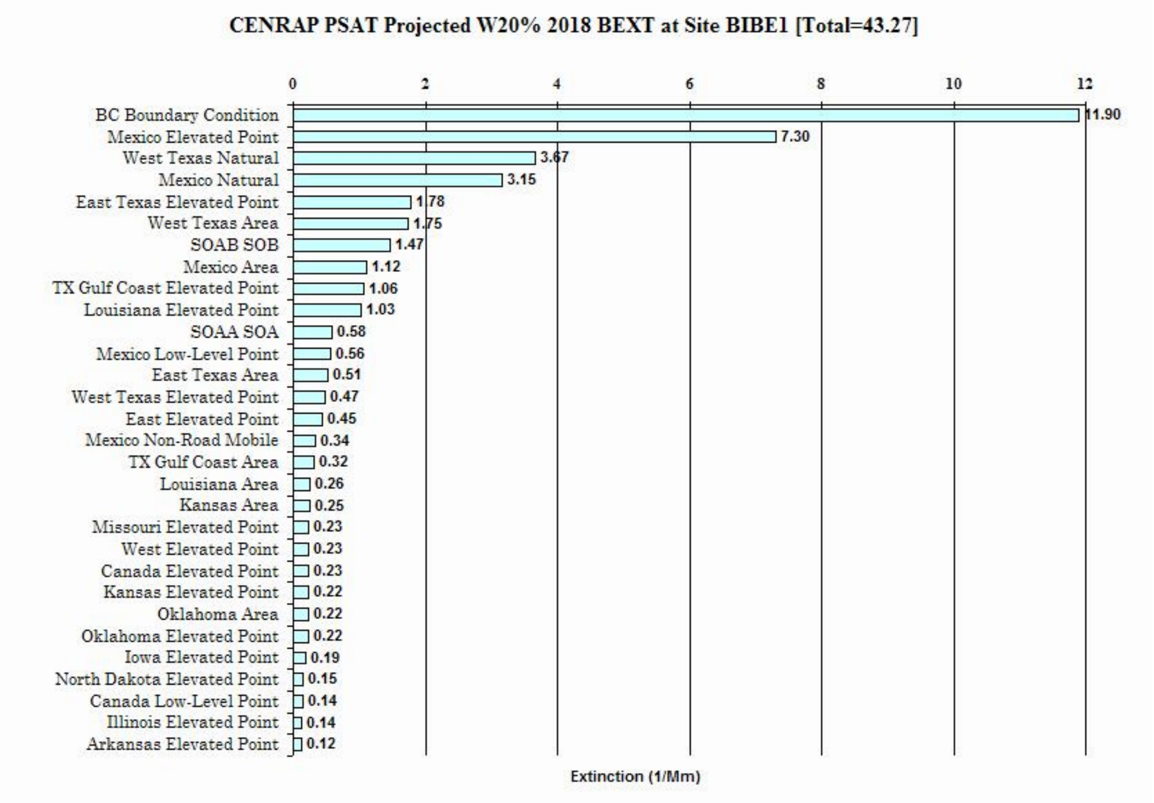


Figure E-9e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

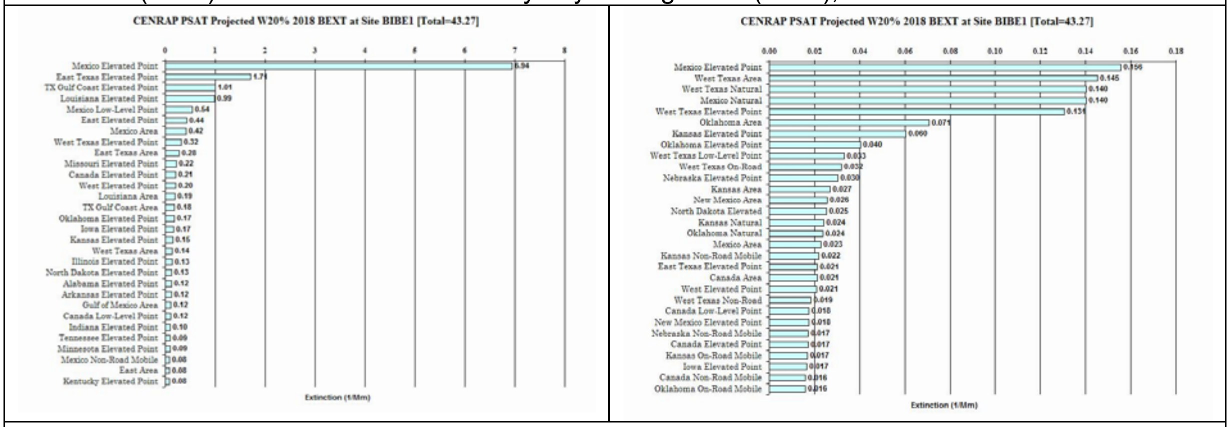


Figure E-9f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

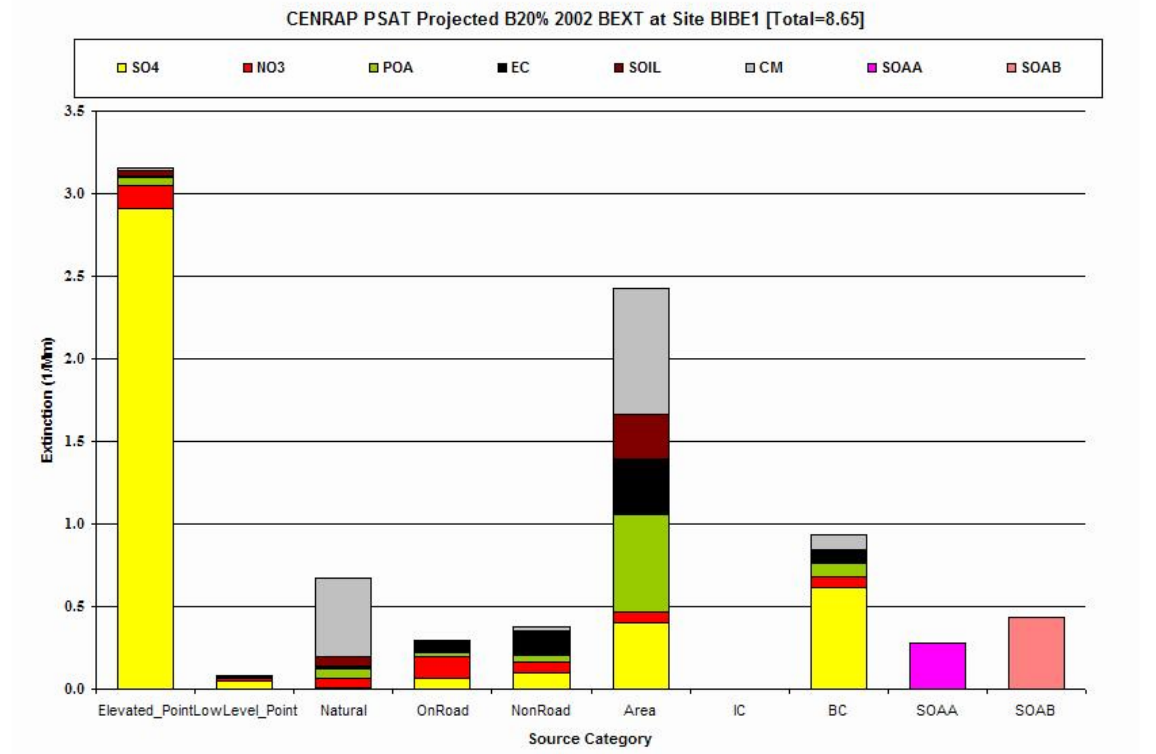


Figure E-9g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

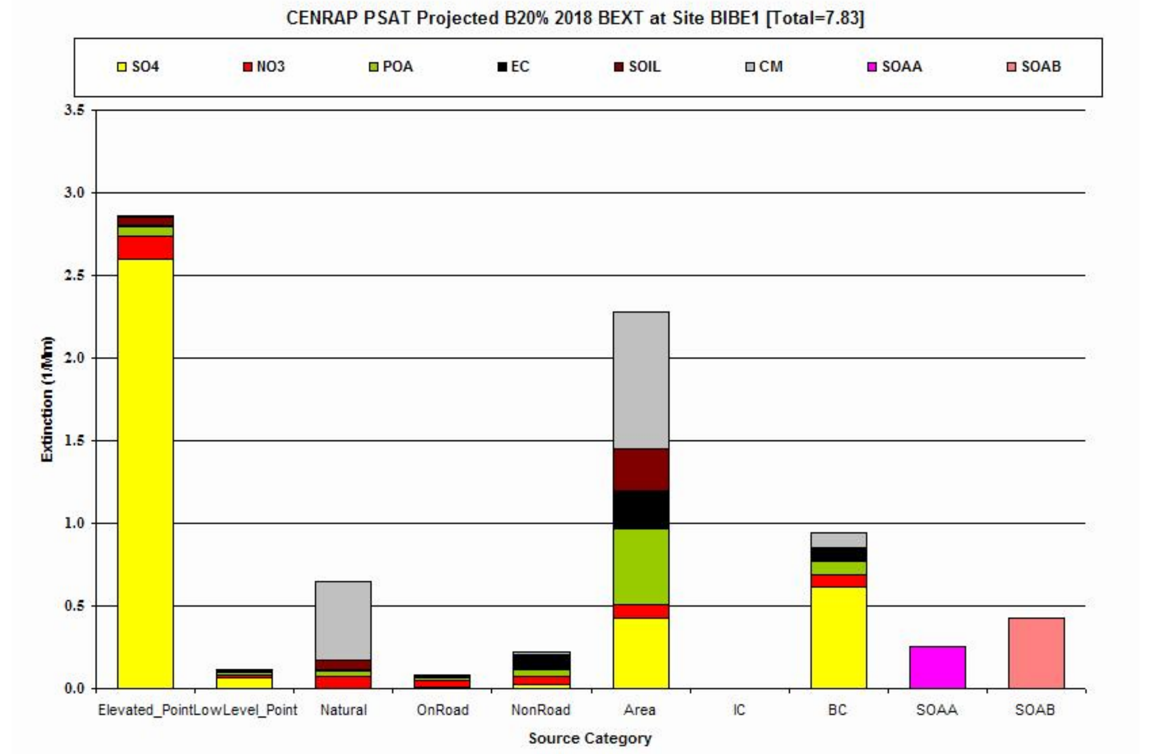


Figure E-9h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

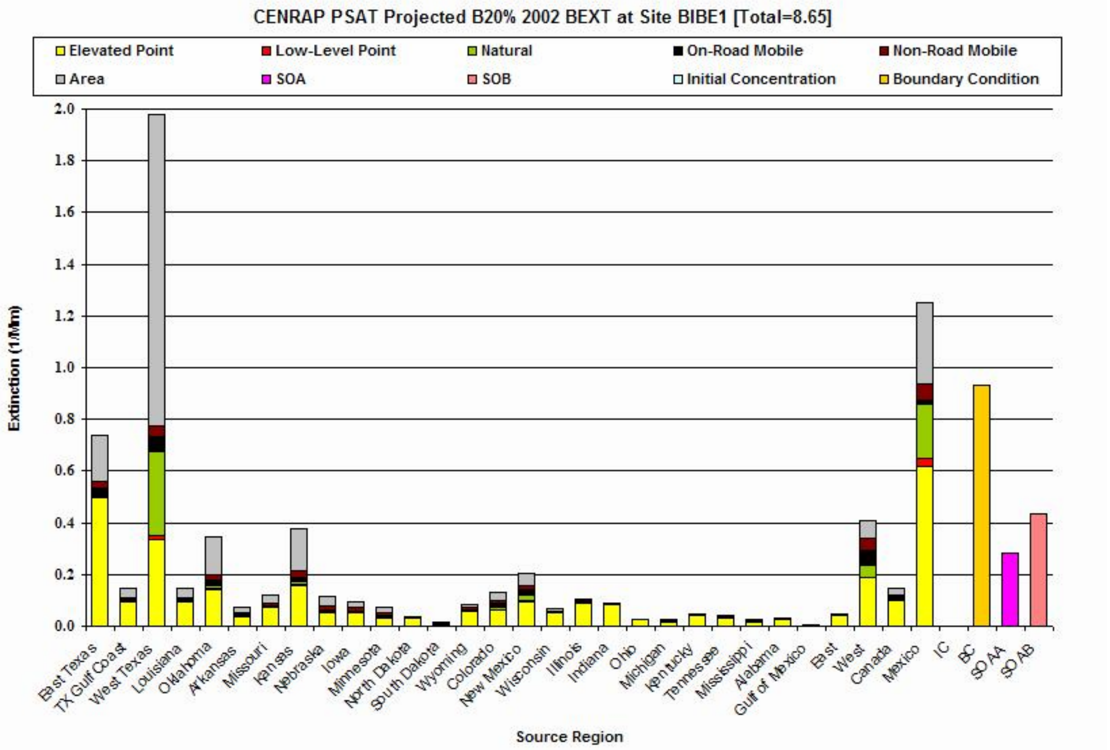


Figure E-9i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days Big Bend (BIBE), Texas.

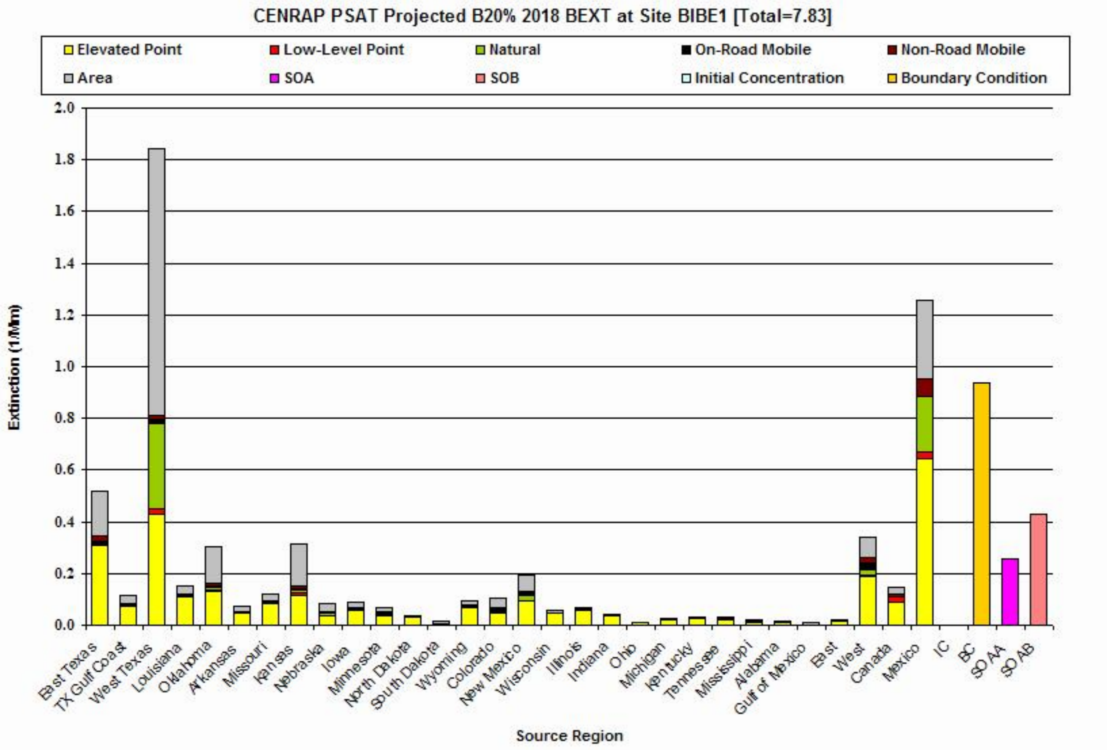


Figure E-9j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

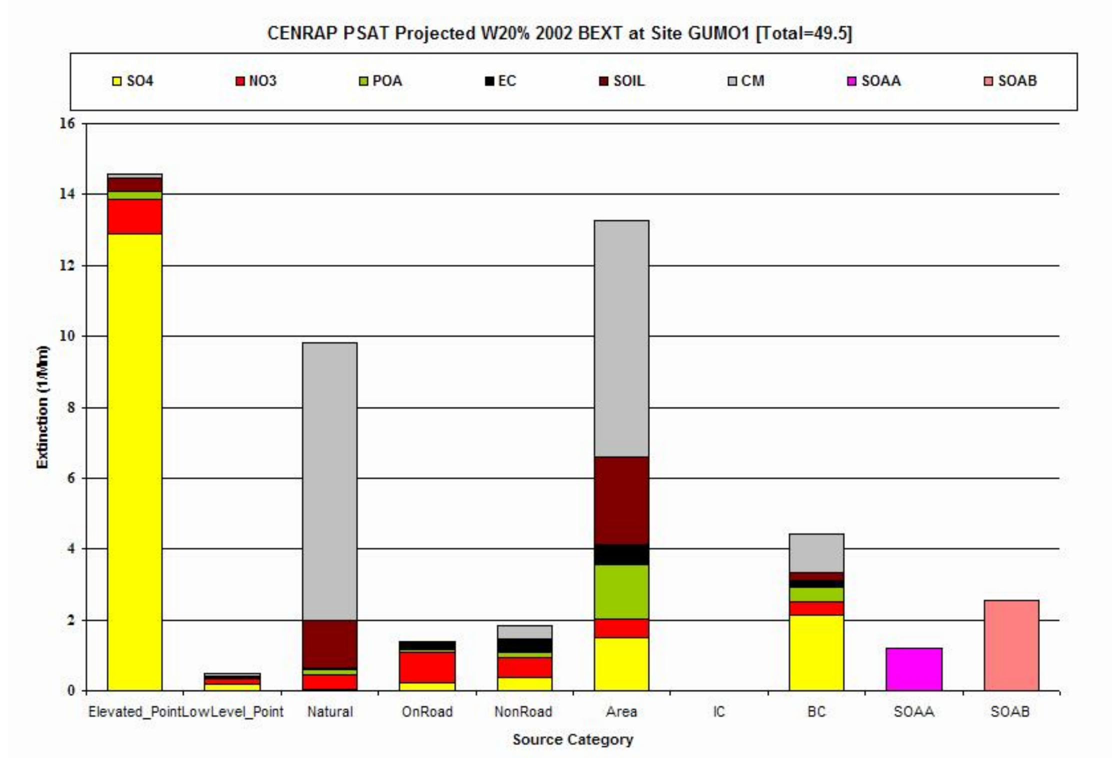


Figure E-10a. PSAT source categories by PM species contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

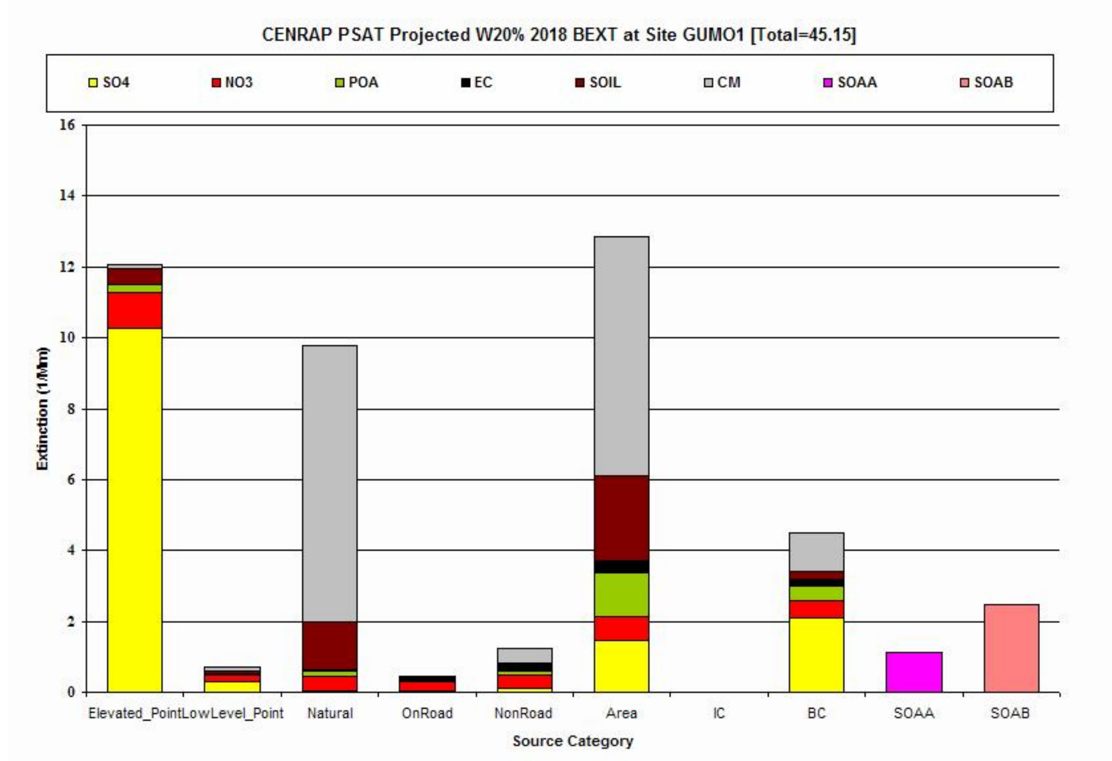


Figure E-10b. PSAT source category by PM species contributions to the average 2018 projected extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

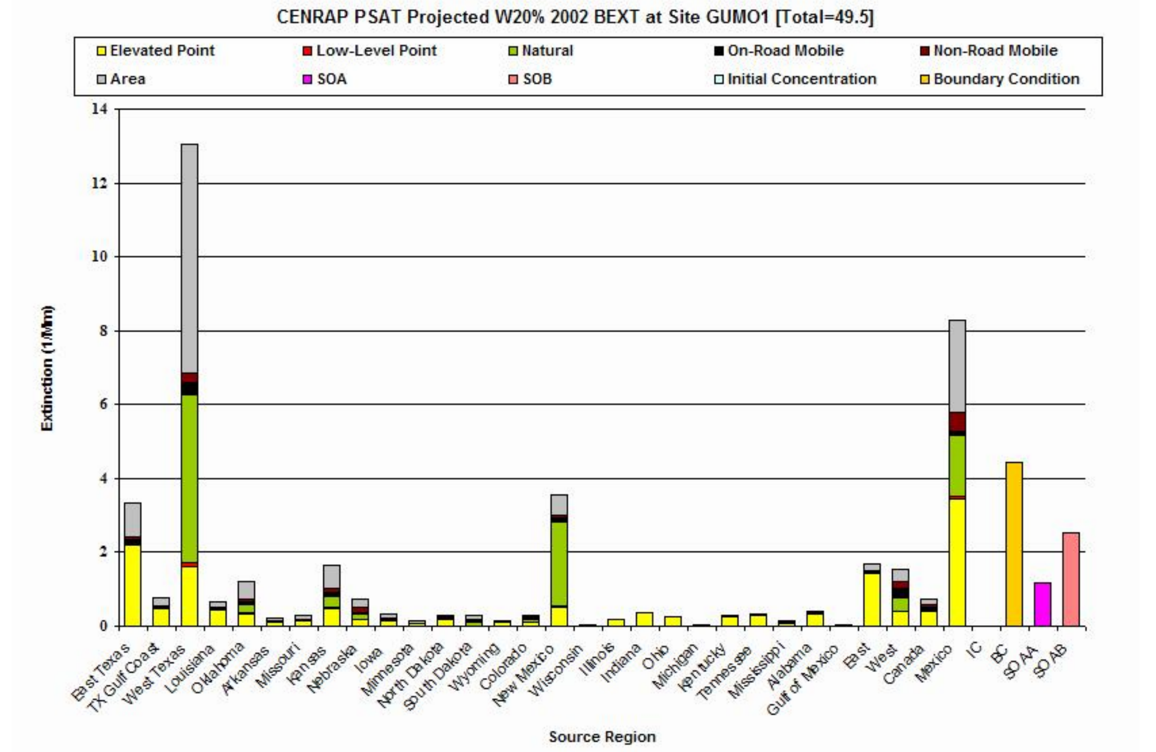


Figure E-10c. PSAT source region by source category contributions to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

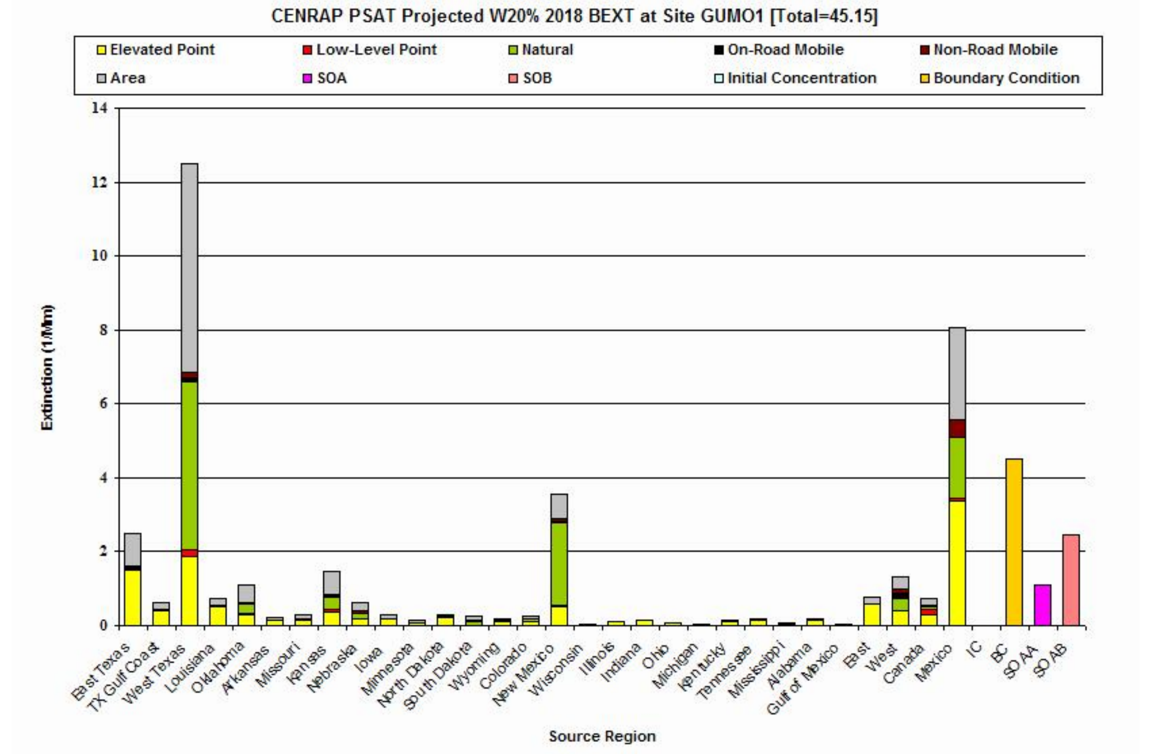


Figure E-10d. PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

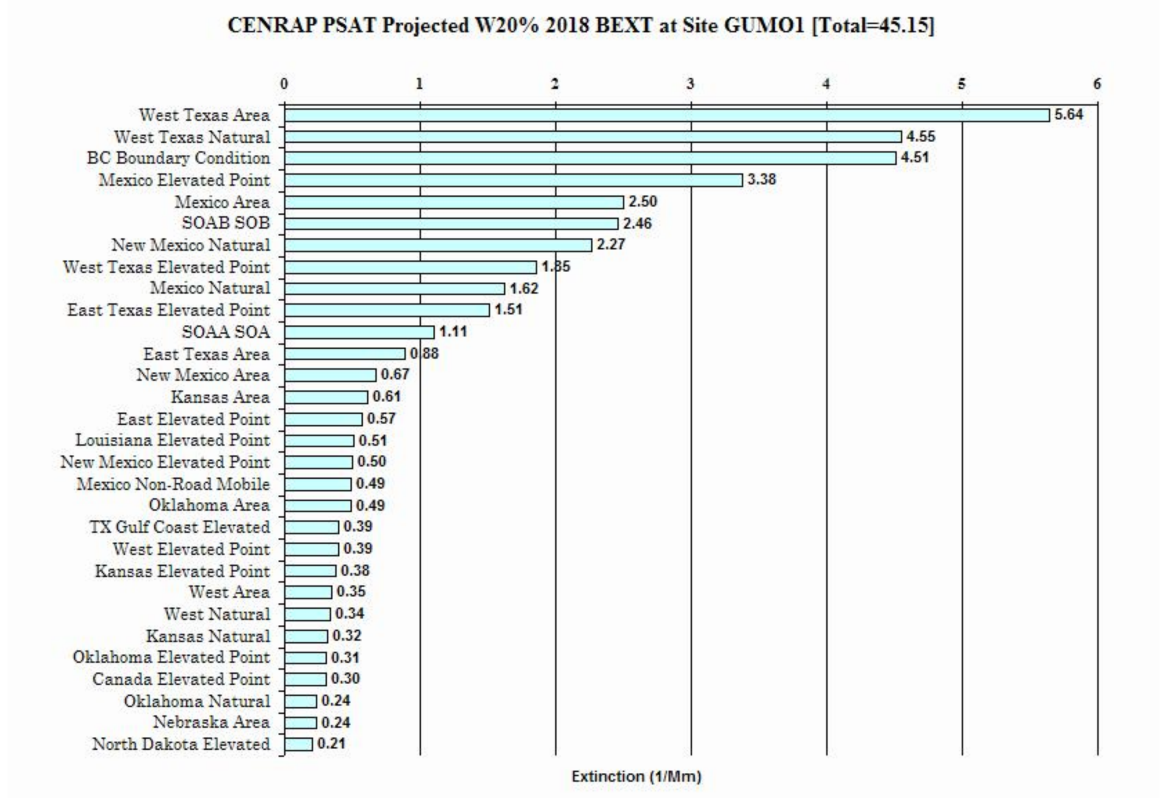


Figure E-10e. Ranked PSAT source region by source category contributions to the average 2018 extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

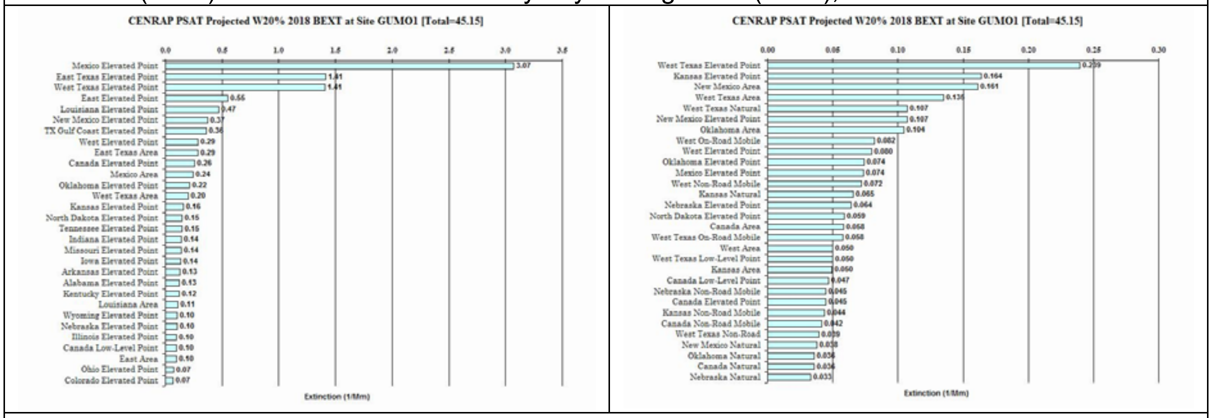


Figure E-10f. Ranked PSAT source region by source category contributions to the average 2018 SO4 (left) and NO3 (right) extinction (Mm^{-1}) for the Worst 20% visibility days at Big Bend (BIBE), Texas.

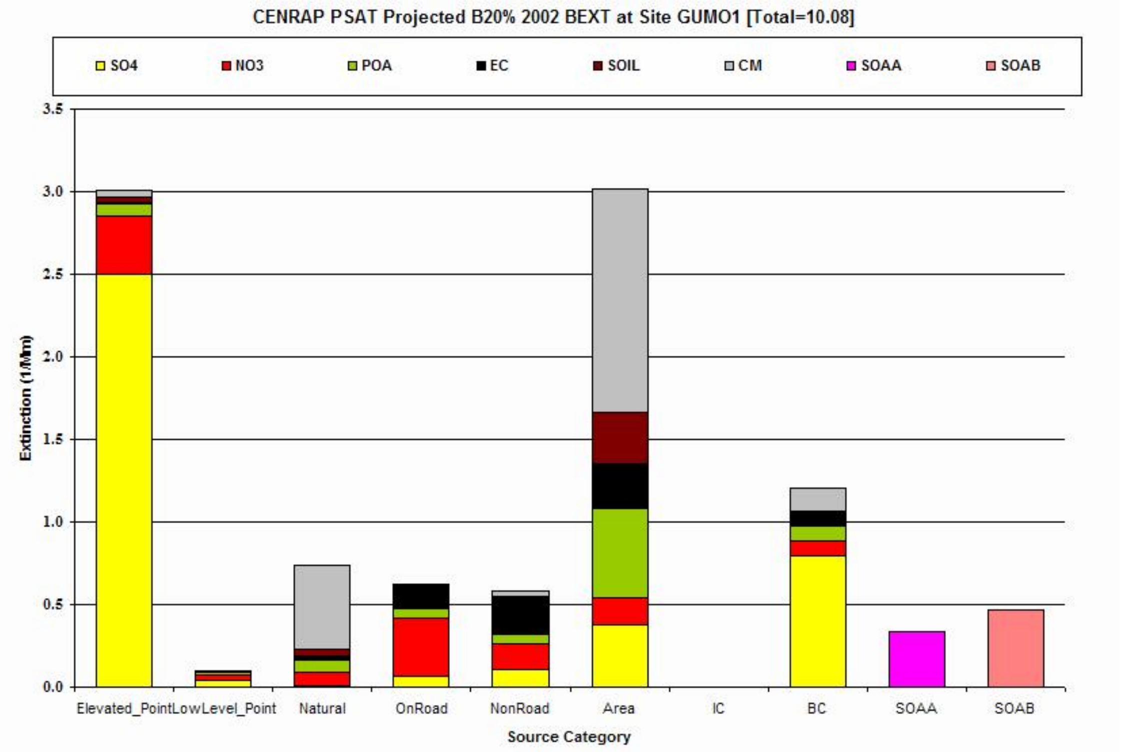


Figure E-10g. PSAT contributions by source category and PM species to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

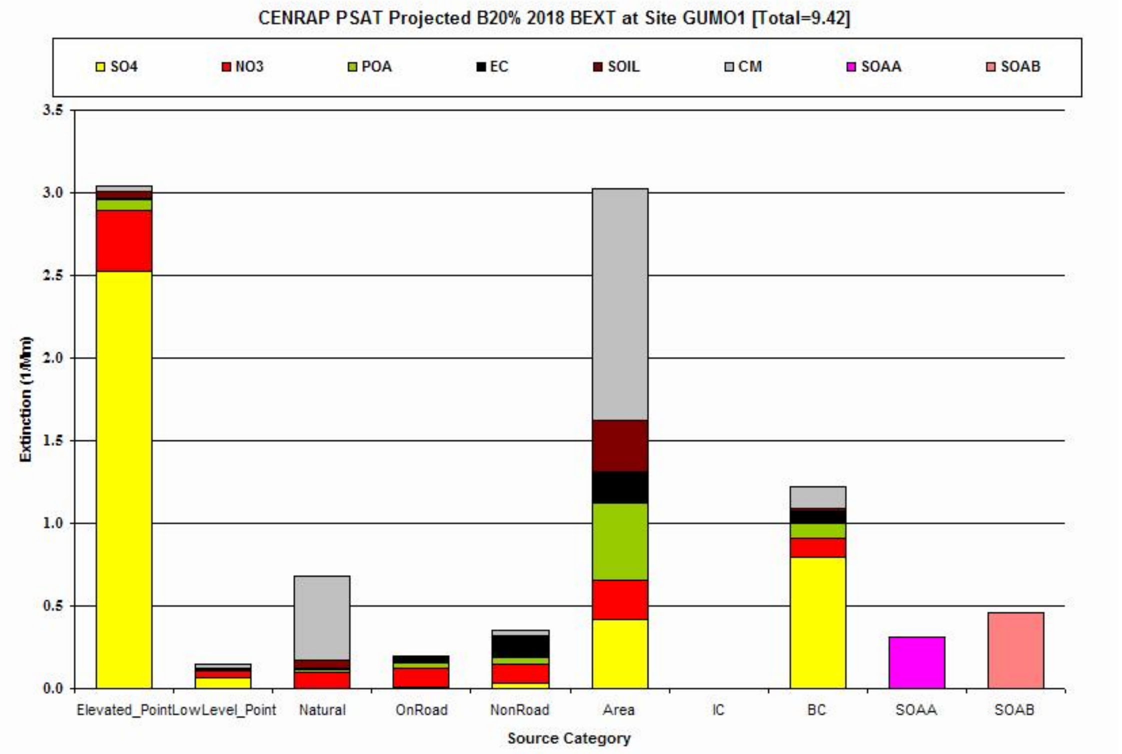


Figure E-10h. PSAT contributions by source category and PM species to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

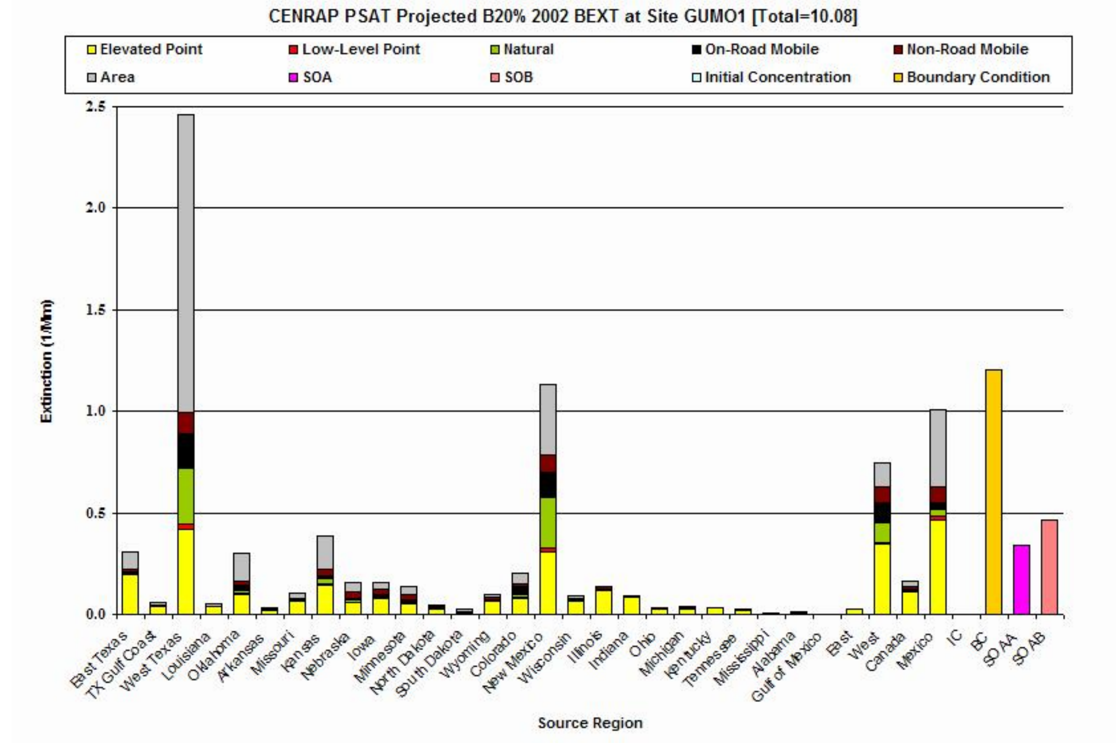


Figure E-10i. PSAT contributions by source region and source category to the average 2000-2004 Baseline extinction (Mm^{-1}) for the Best 20% visibility days Big Bend (BIBE), Texas.

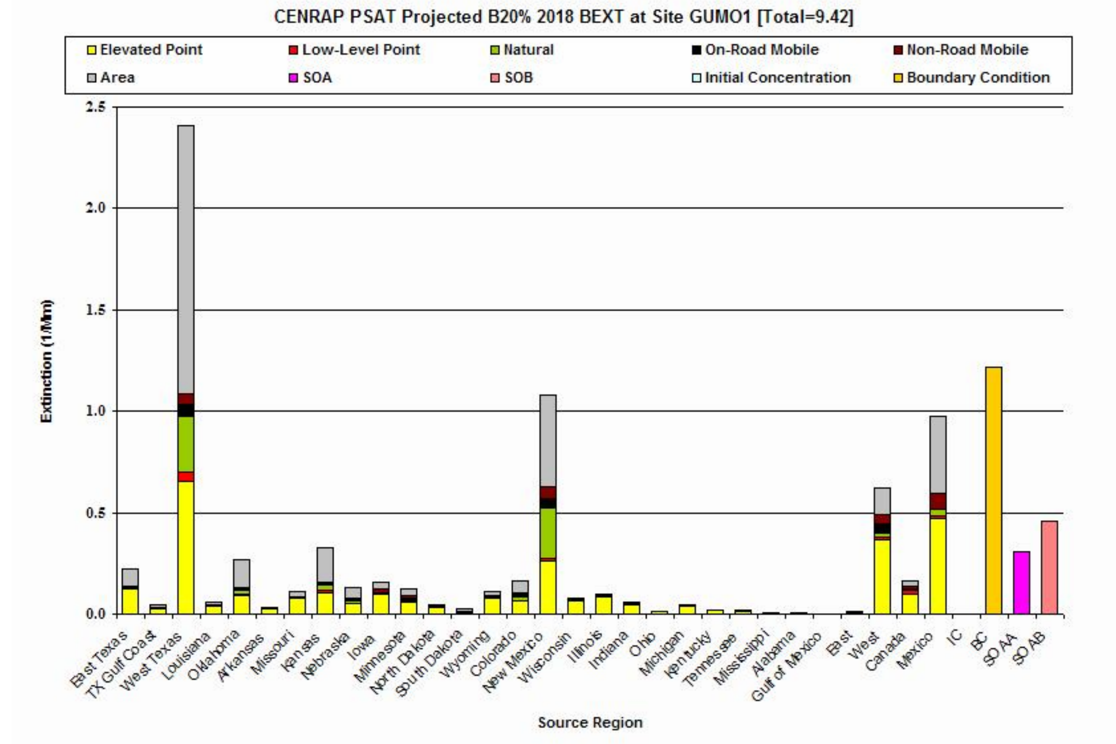


Figure E-10j. PSAT contributions by source region and source category to the average 2018 extinction (Mm^{-1}) for the Best 20% visibility days at Big Bend (BIBE), Texas.

APPENDIX F

Extinction and PM Species-Specific 2018 Visibility Projections and Comparisons with 2018 URP Points

Figure F-1: Caney Creek Wilderness Area (CACR), Arkansas
Figure F-2: Upper Buffalo Wilderness Area (UPBU), Arkansas
Figure F-3: Breton Island Wilderness Area (BRET), Louisiana
Figure F-4: Boundary Waters Canoe Area Wilderness Area (BOWA), Minnesota
Figure F-5: Voyageurs National Park (VOYA), Minnesota
Figure F-6: Hercules Glade Wilderness Area (HEGL), Missouri
Figure F-7: Mingo Wilderness Area (MING), Missouri
Figure F-8: Wichita Mountains Wilderness Area (WIMO), Oklahoma
Figure F-9: Big Bend National Park (BIBE), Texas
Figure F-10: Guadalupe Mountains National Park (GUAD), Texas

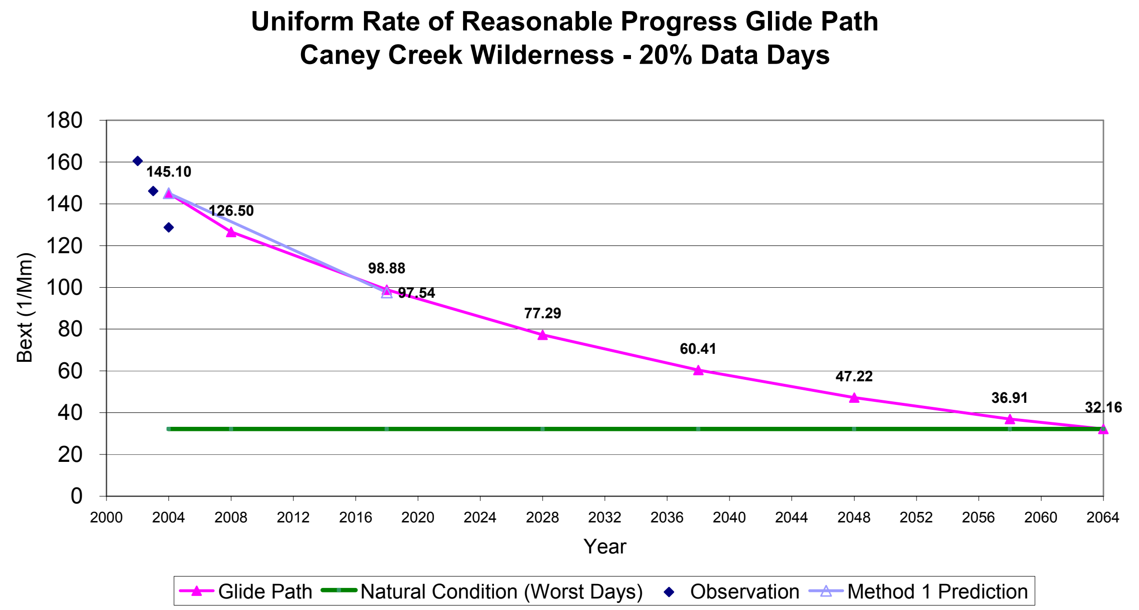


Figure F-1a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

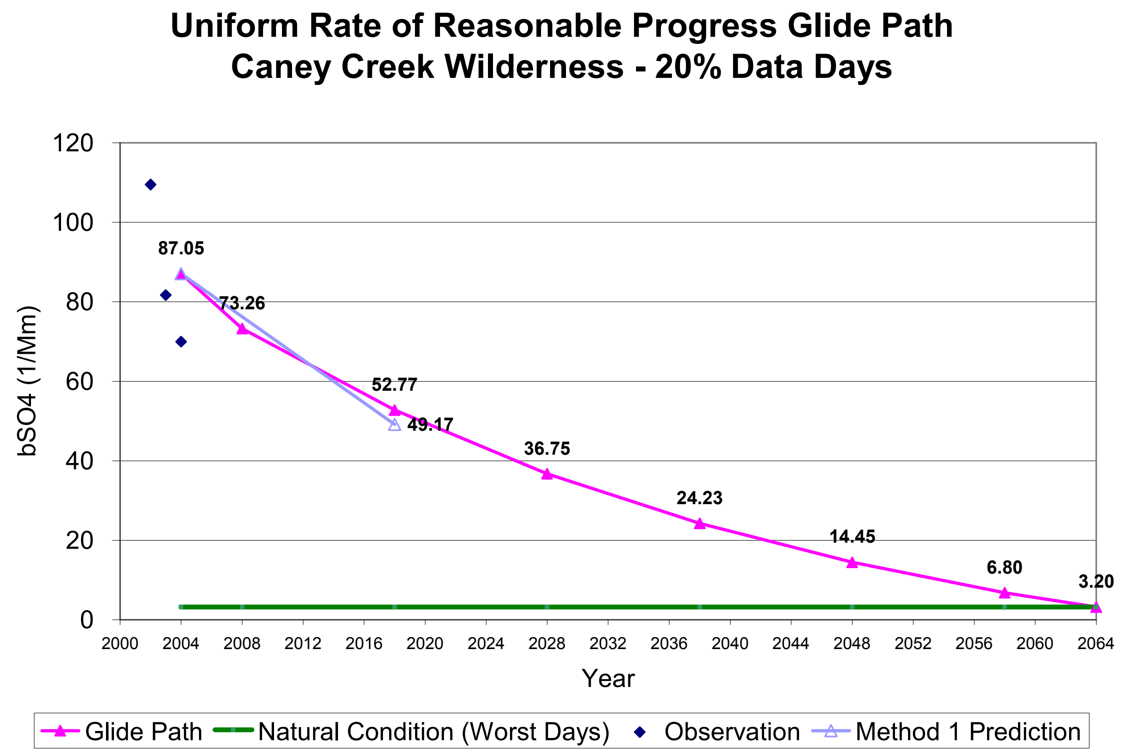


Figure F-1b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

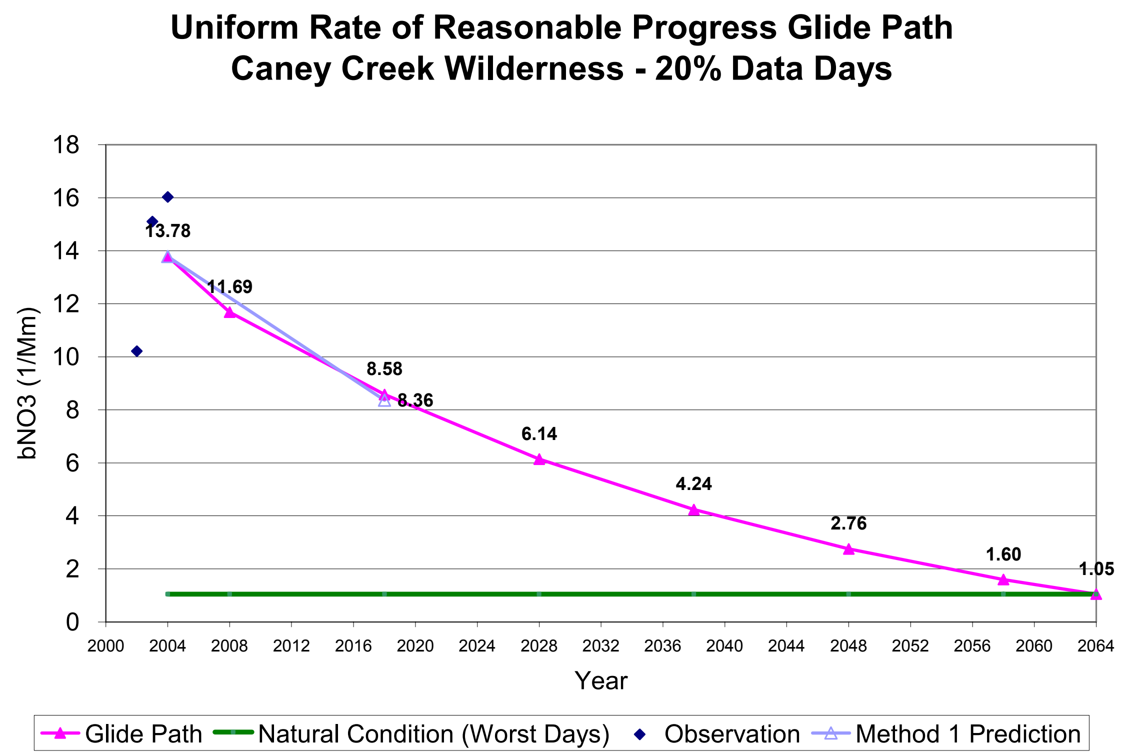


Figure F-1c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

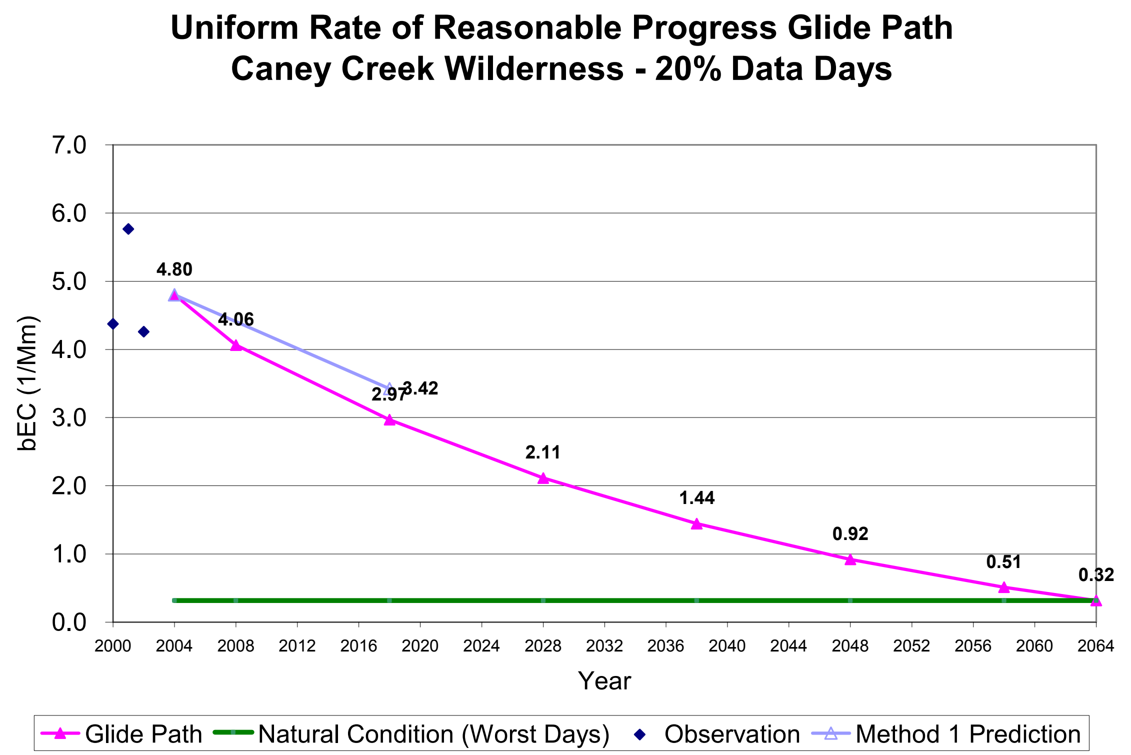


Figure F-1d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

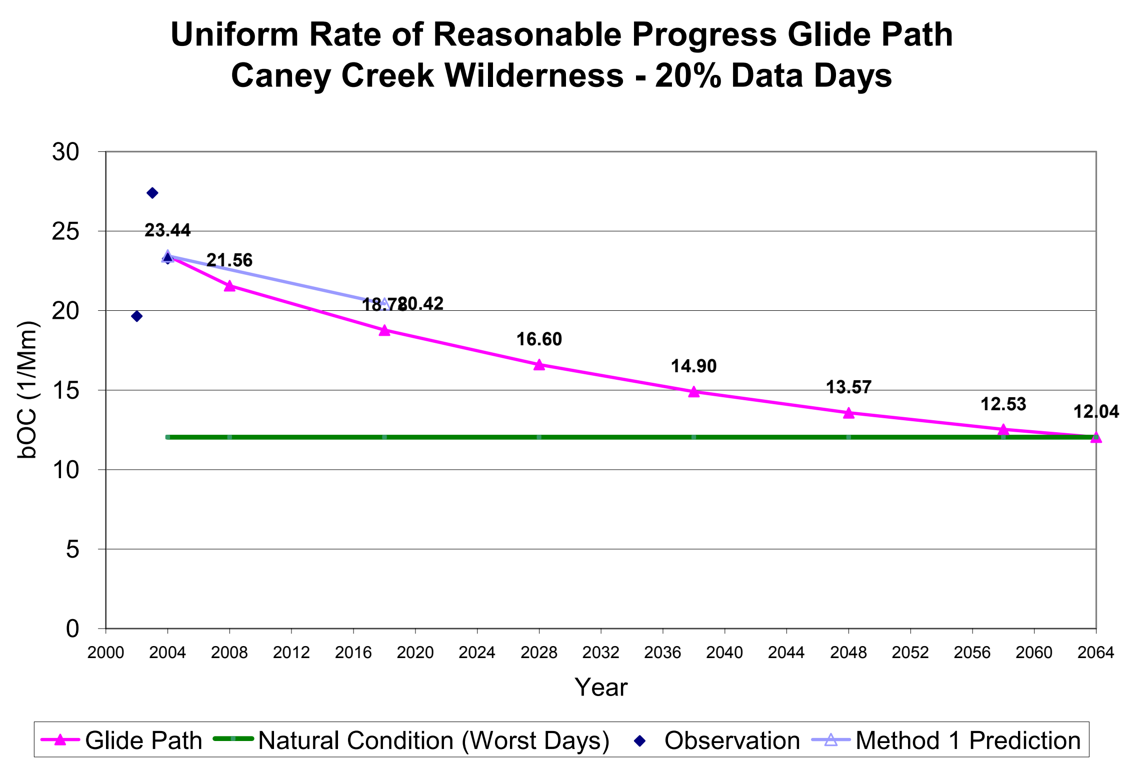


Figure F-1e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

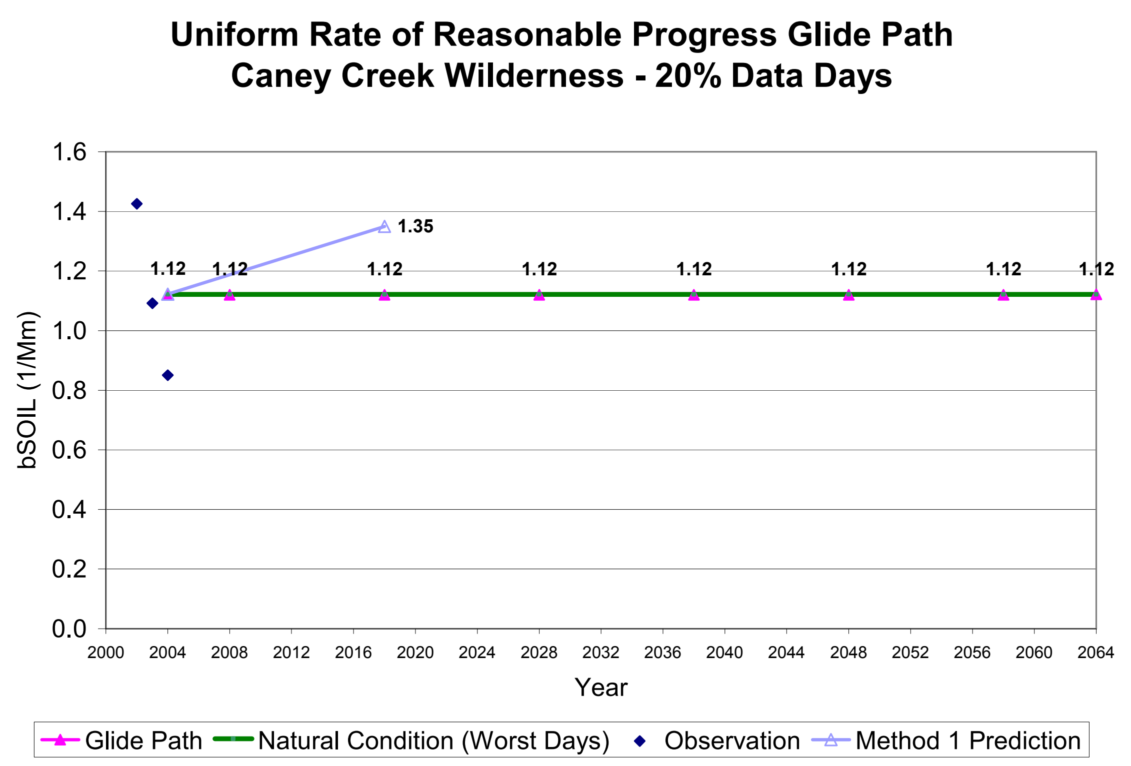


Figure F-1f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

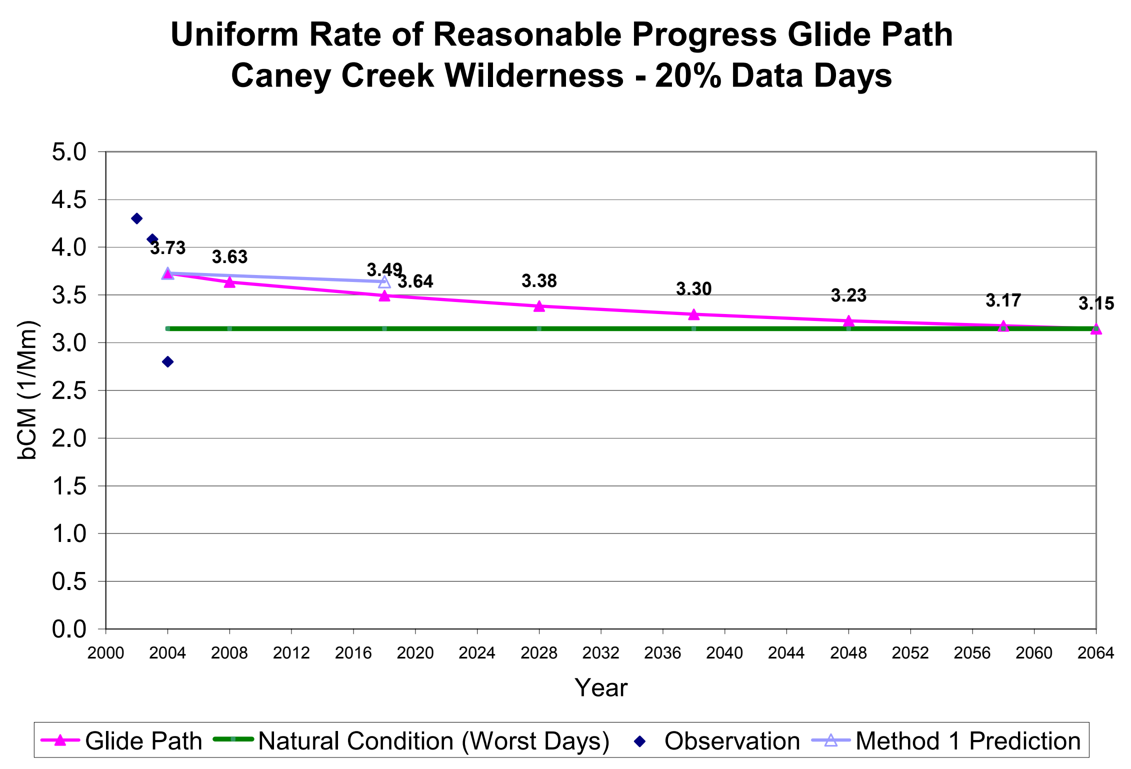


Figure F-1g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Caney Creek (CACR), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

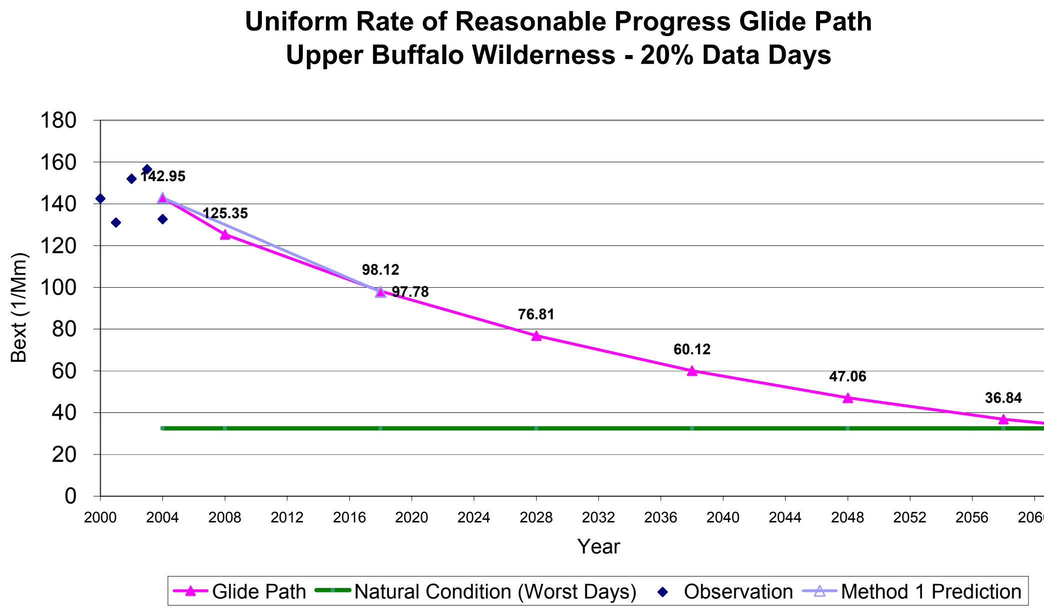


Figure F-2a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

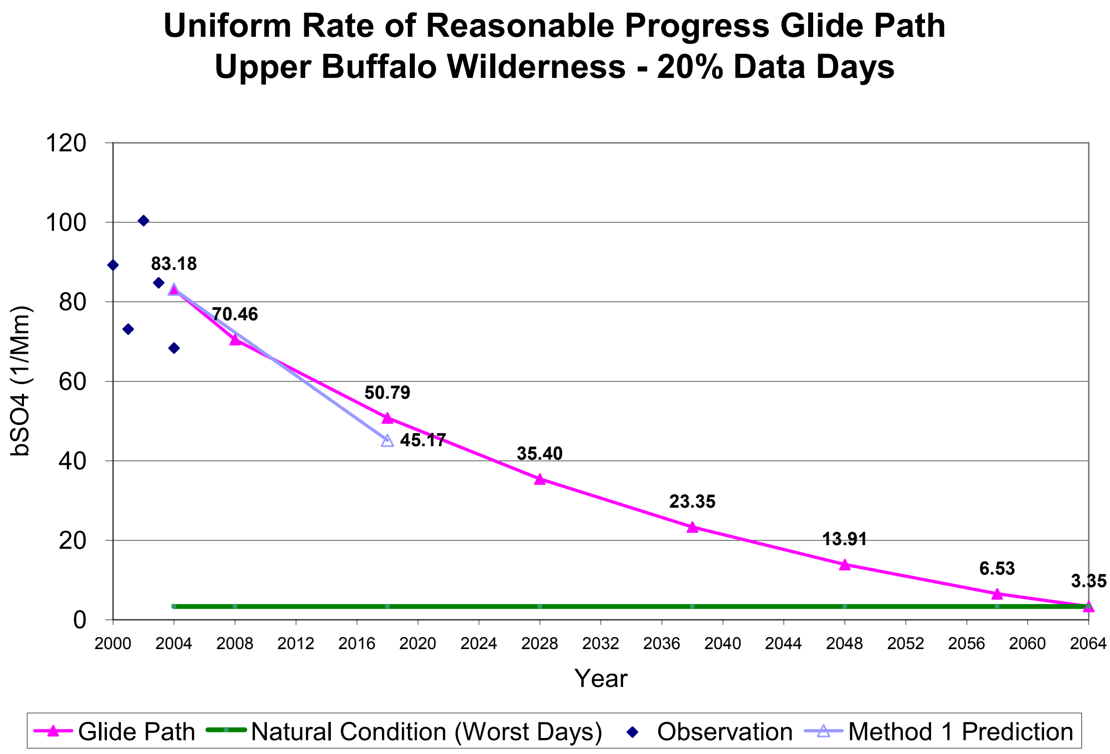


Figure F-2b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

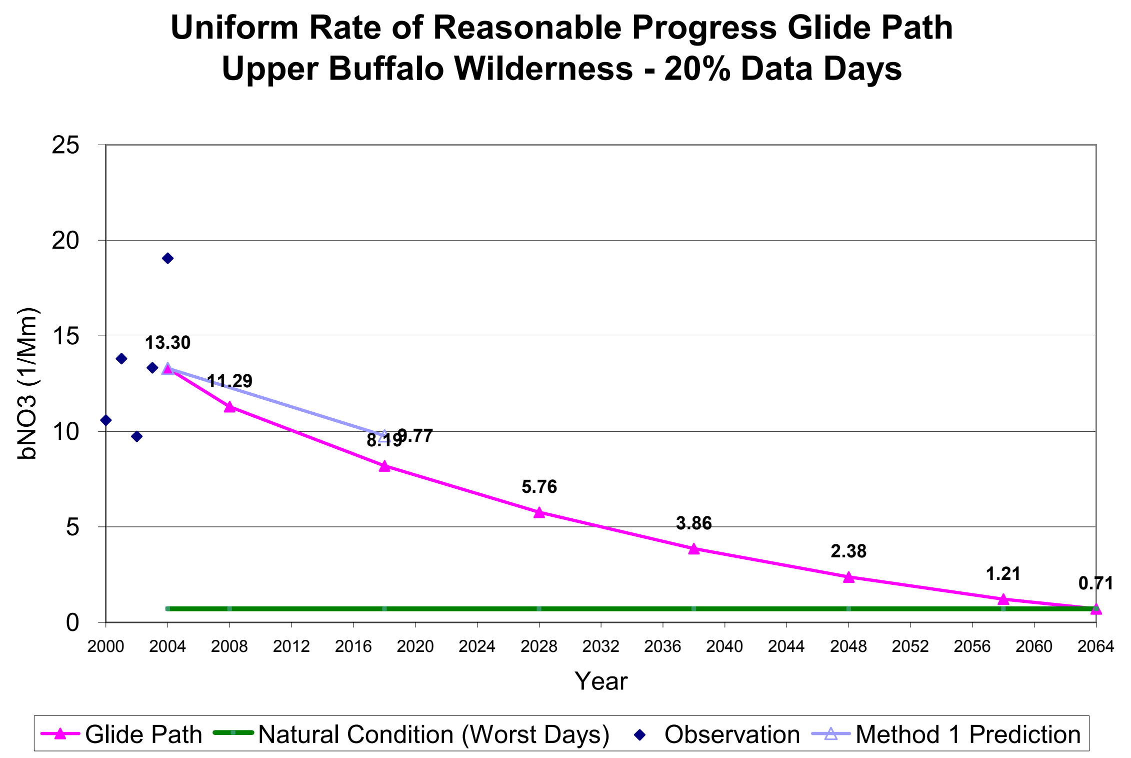


Figure F-2c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

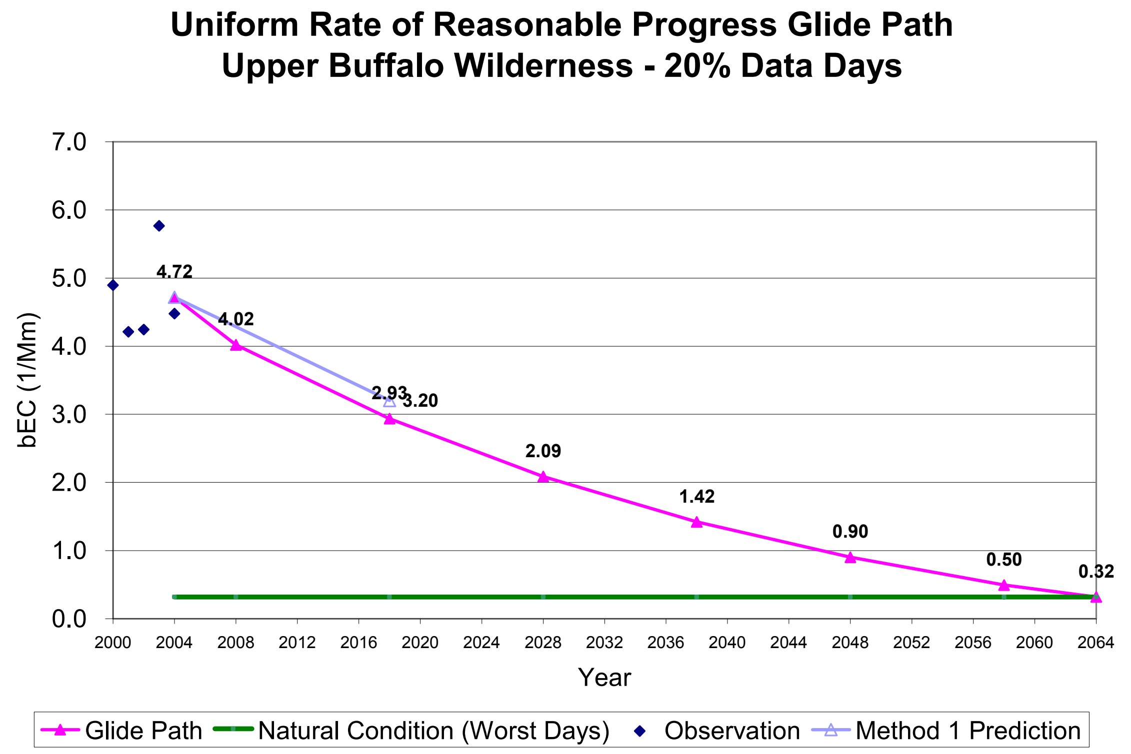


Figure F-2d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

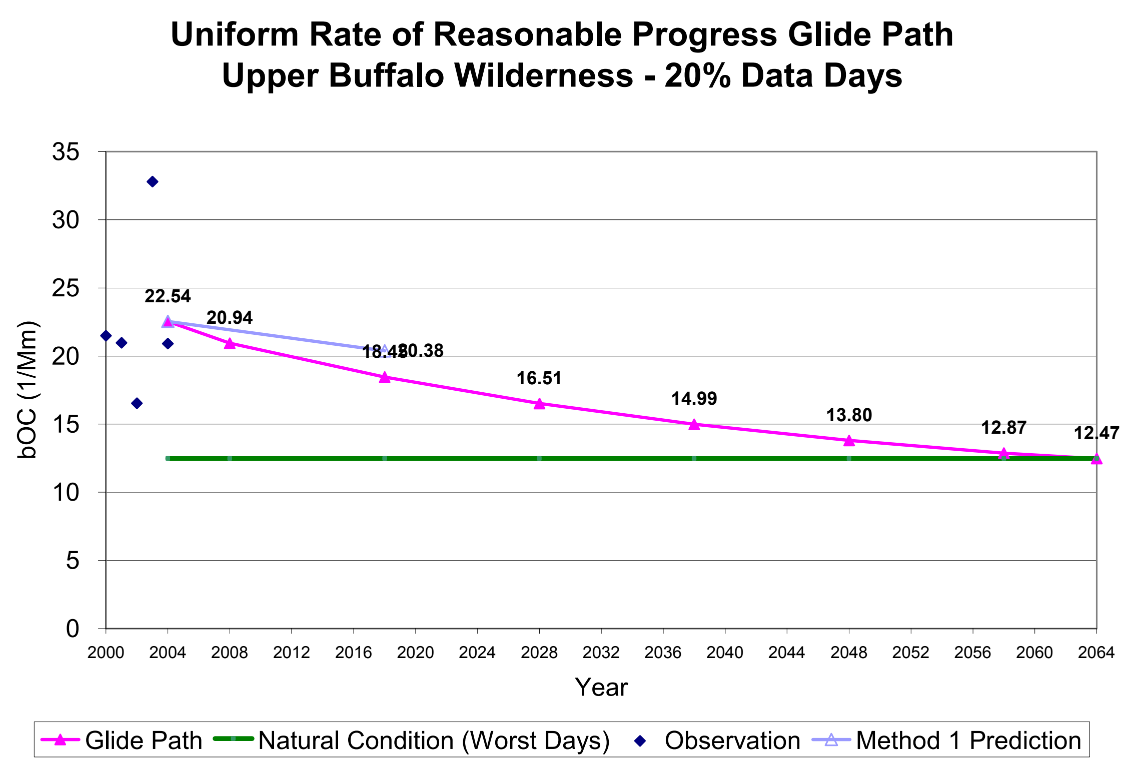


Figure F-2e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

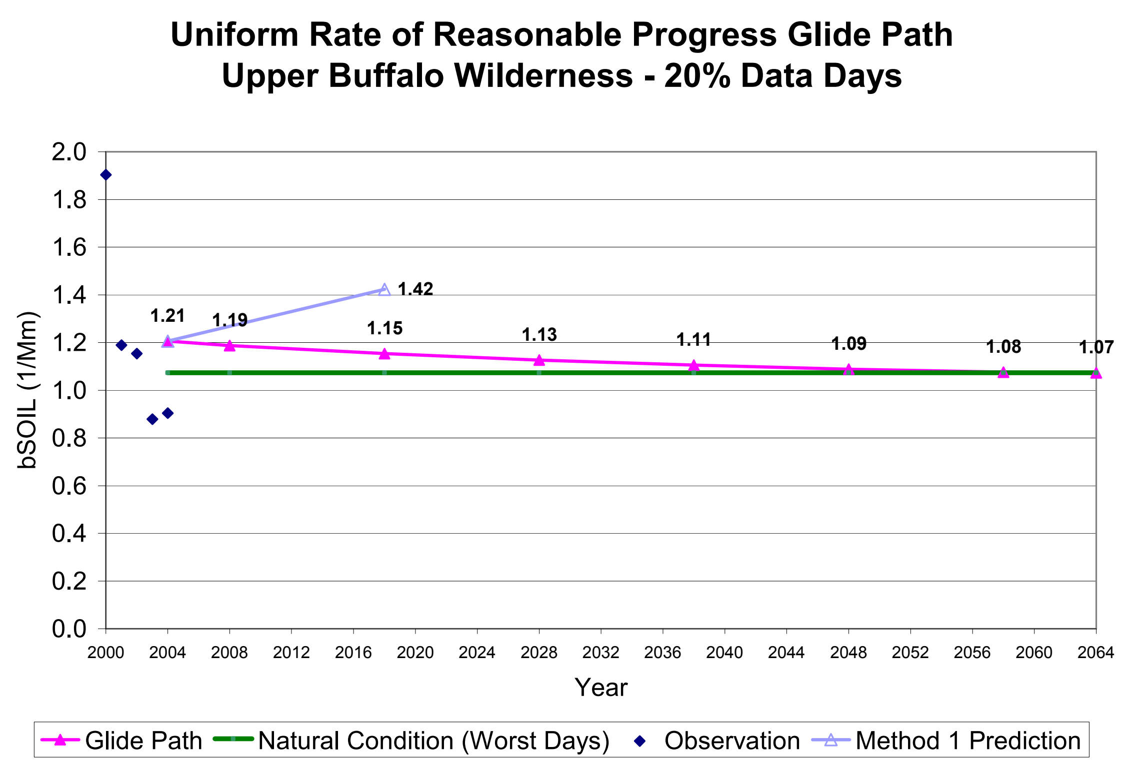


Figure F-2f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

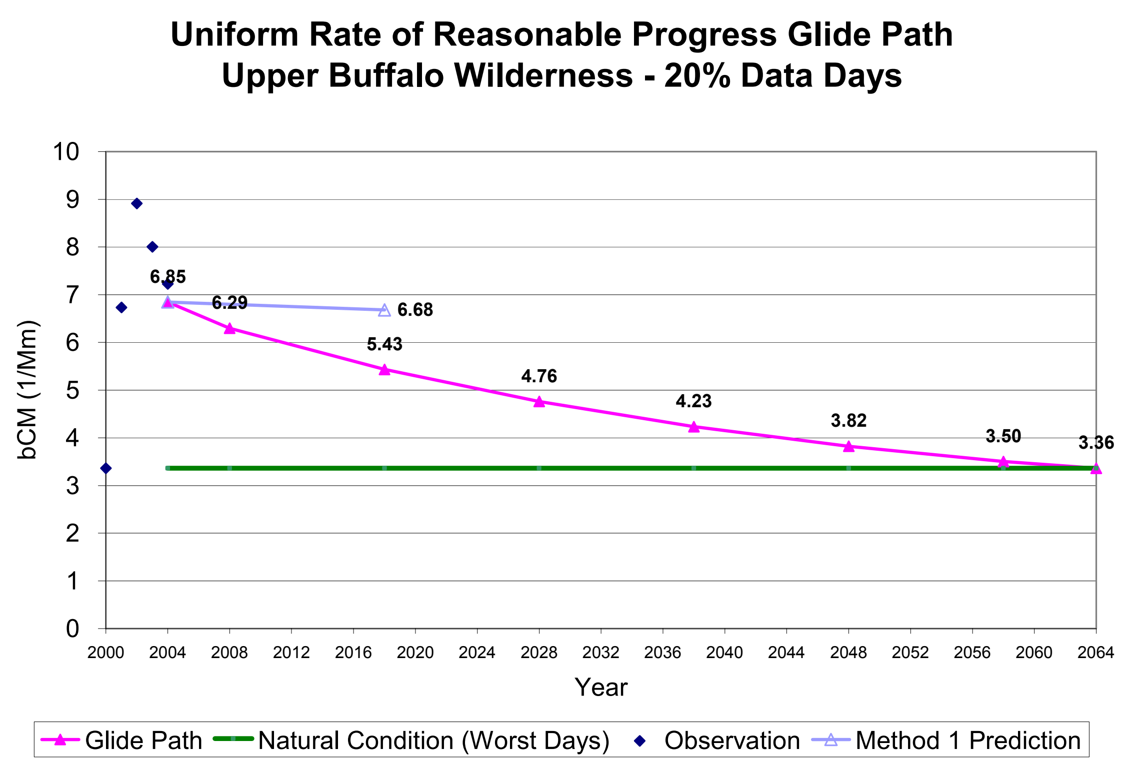


Figure F-2g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Upper Buffalo (UPBU), Arkansas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

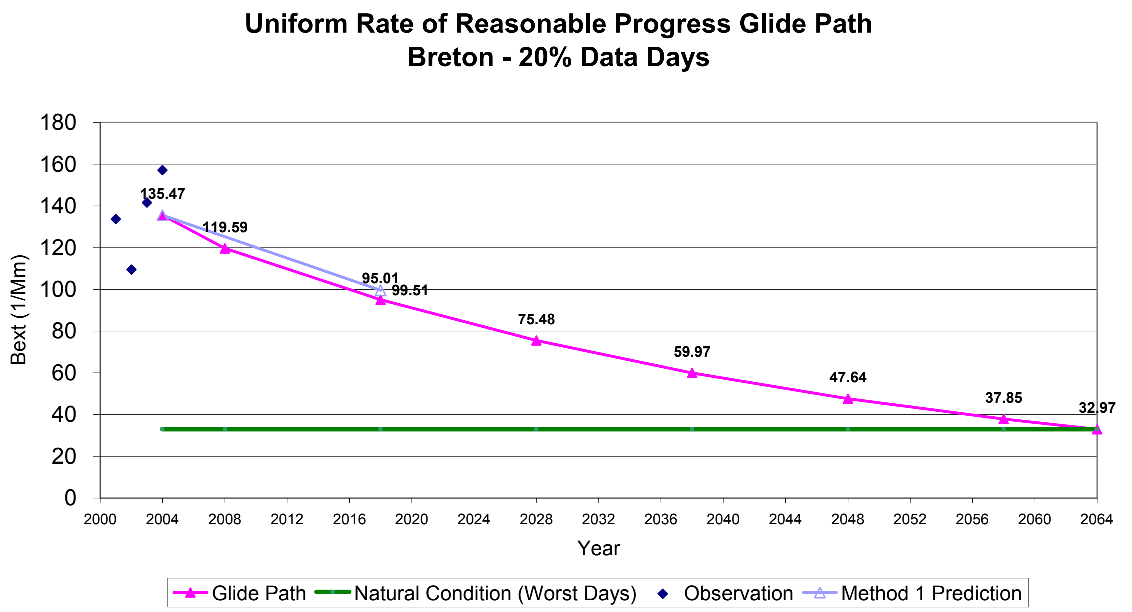


Figure F-3a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

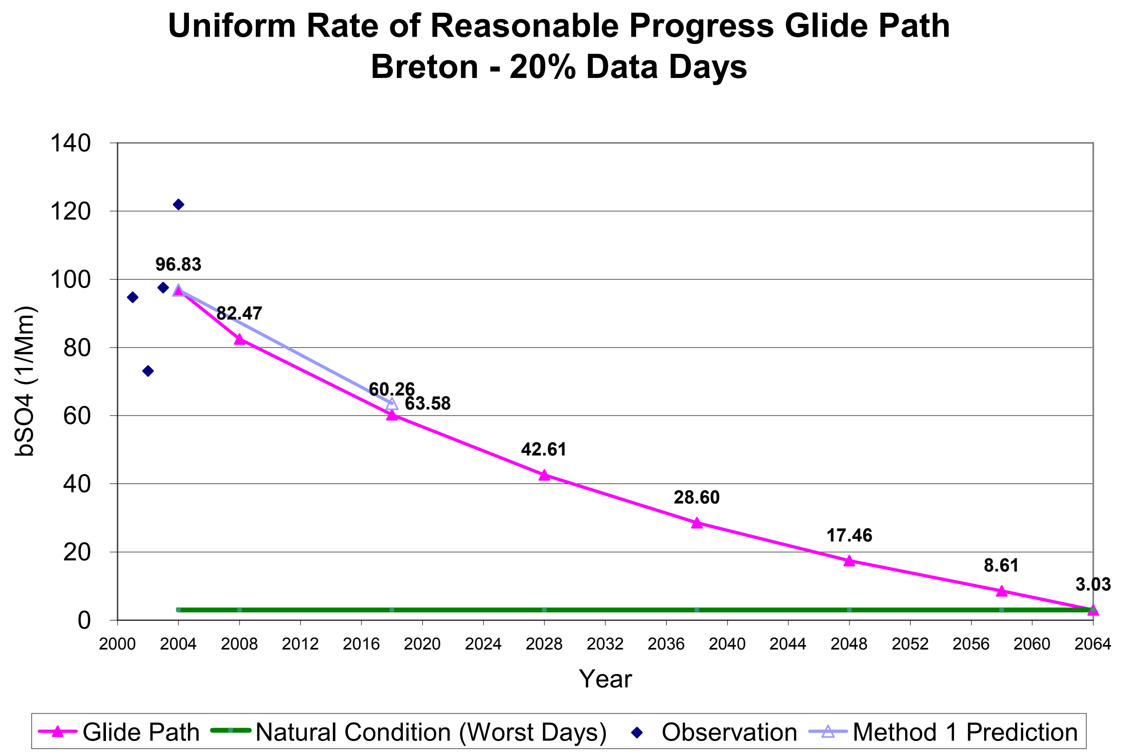


Figure F-3b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

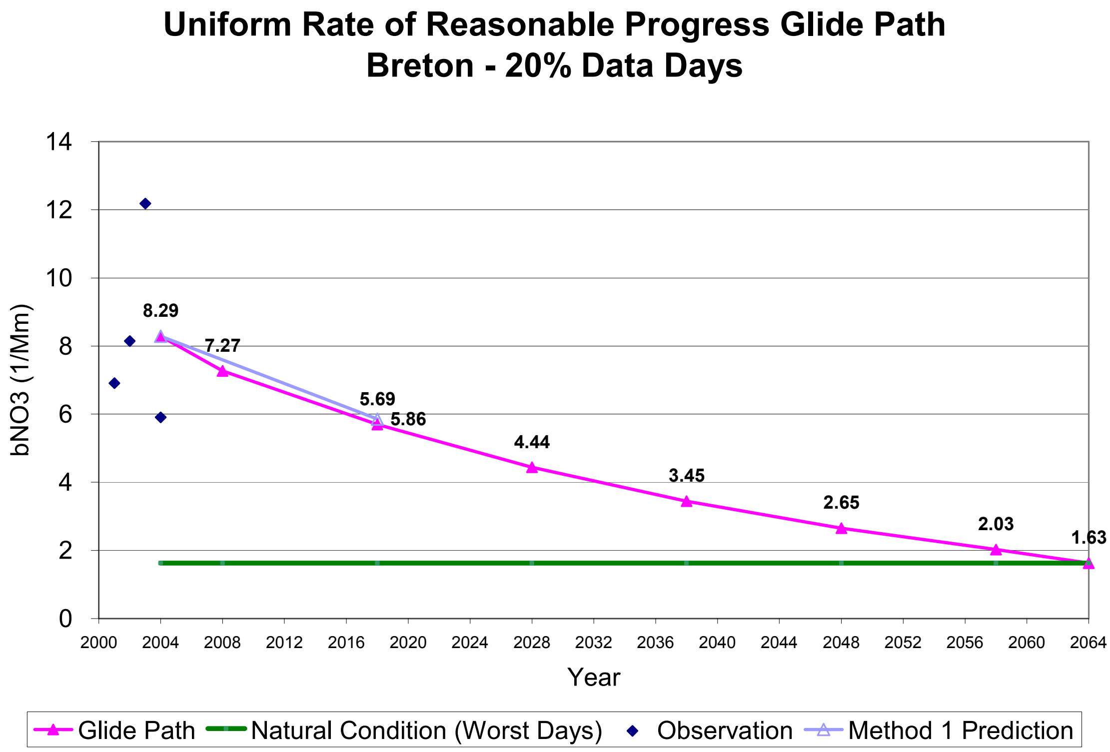


Figure F-3c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

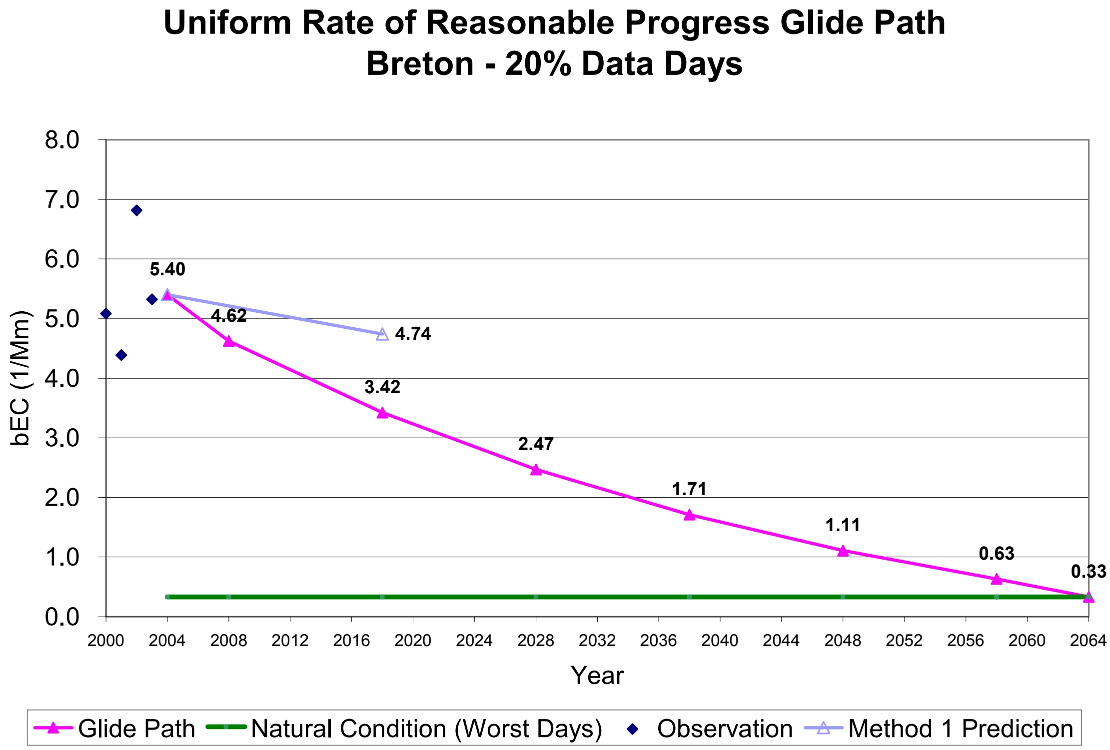


Figure F-3d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

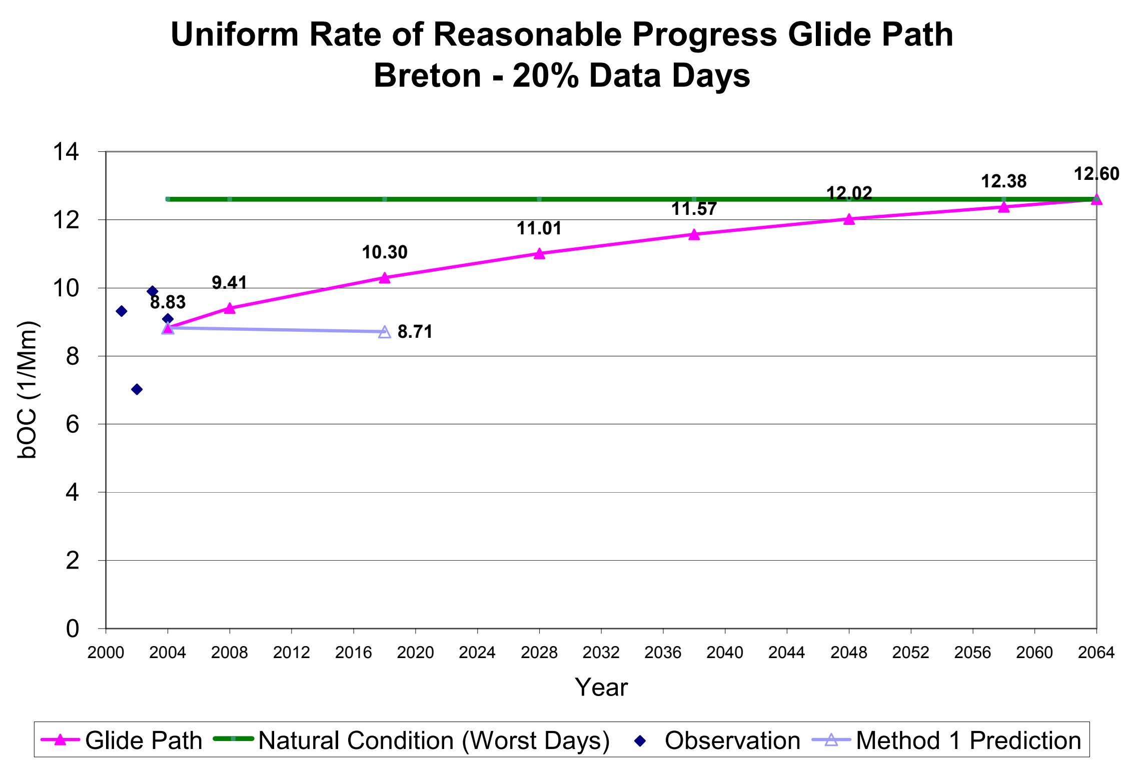


Figure F-3e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

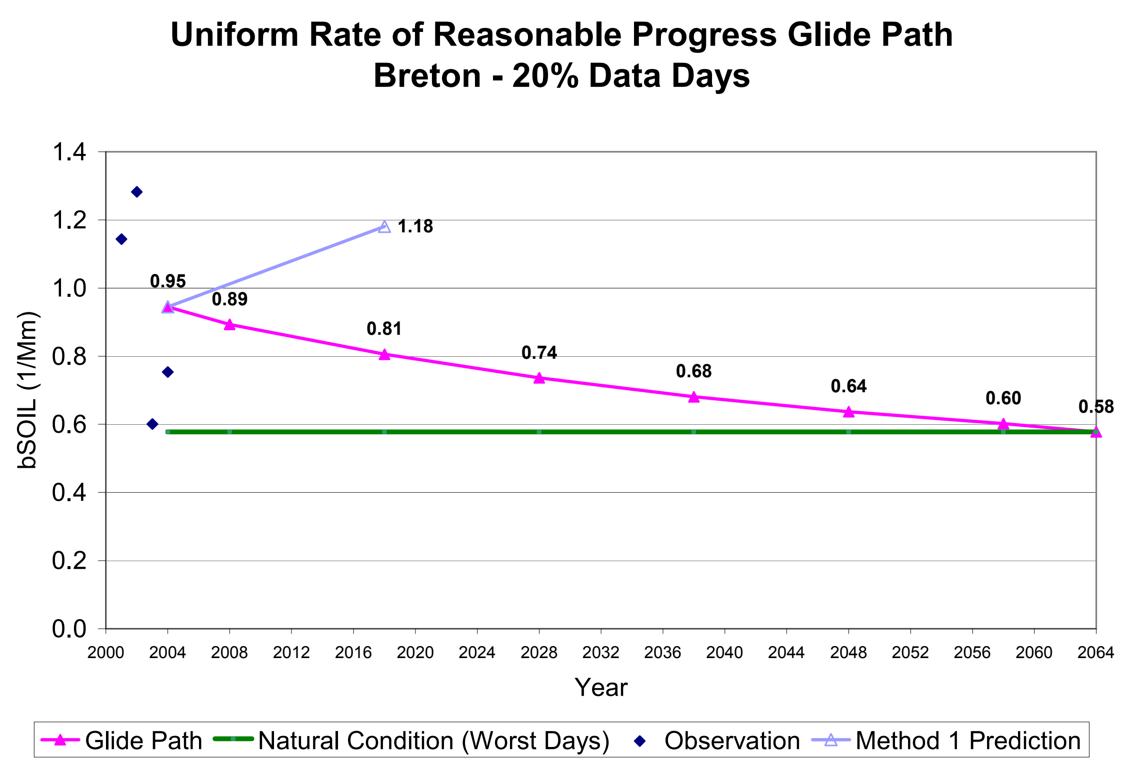


Figure F-3f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

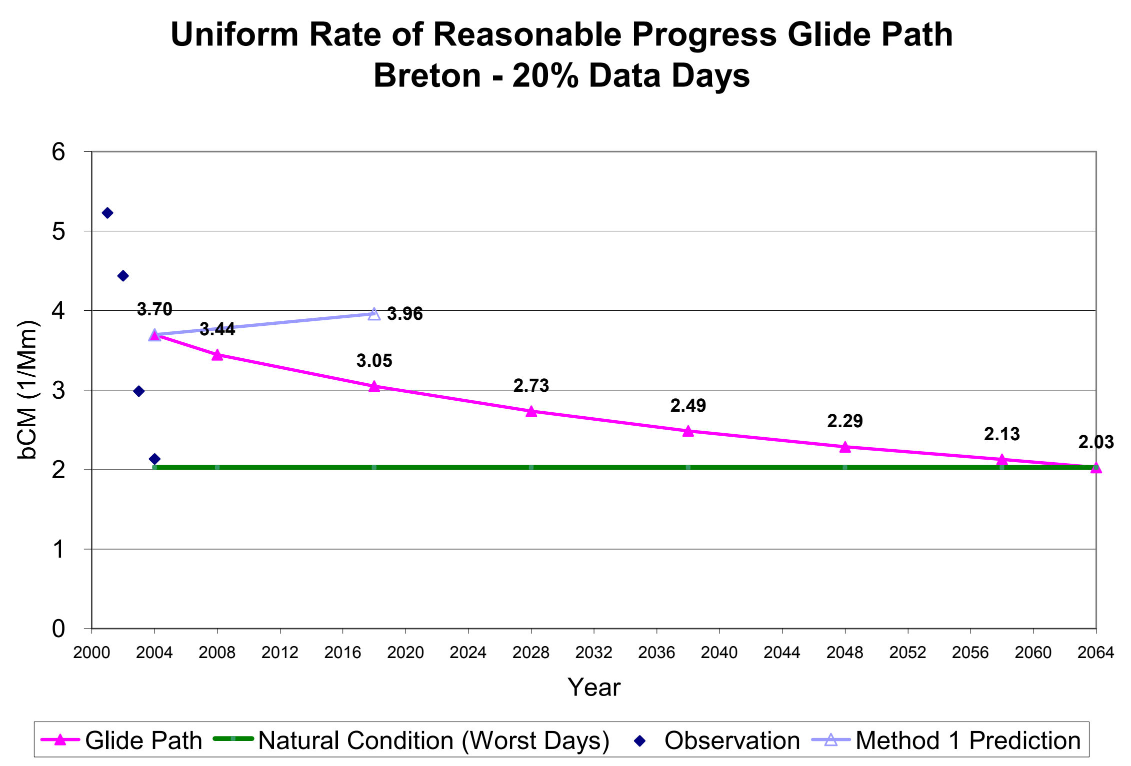


Figure F-3g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Breton Island (BRET), Louisiana and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

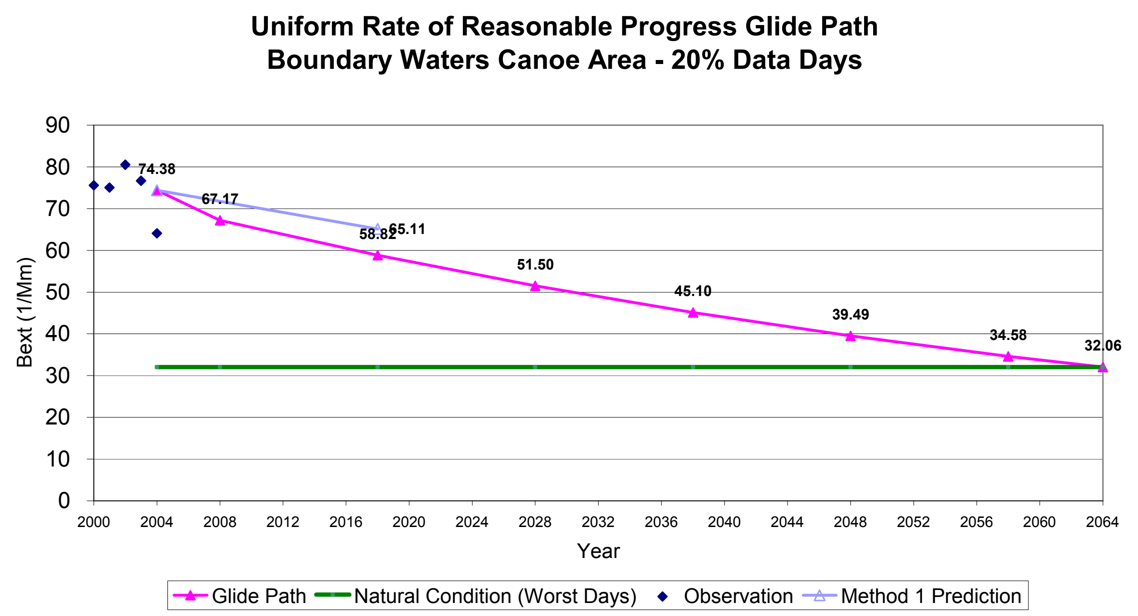


Figure F-4a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

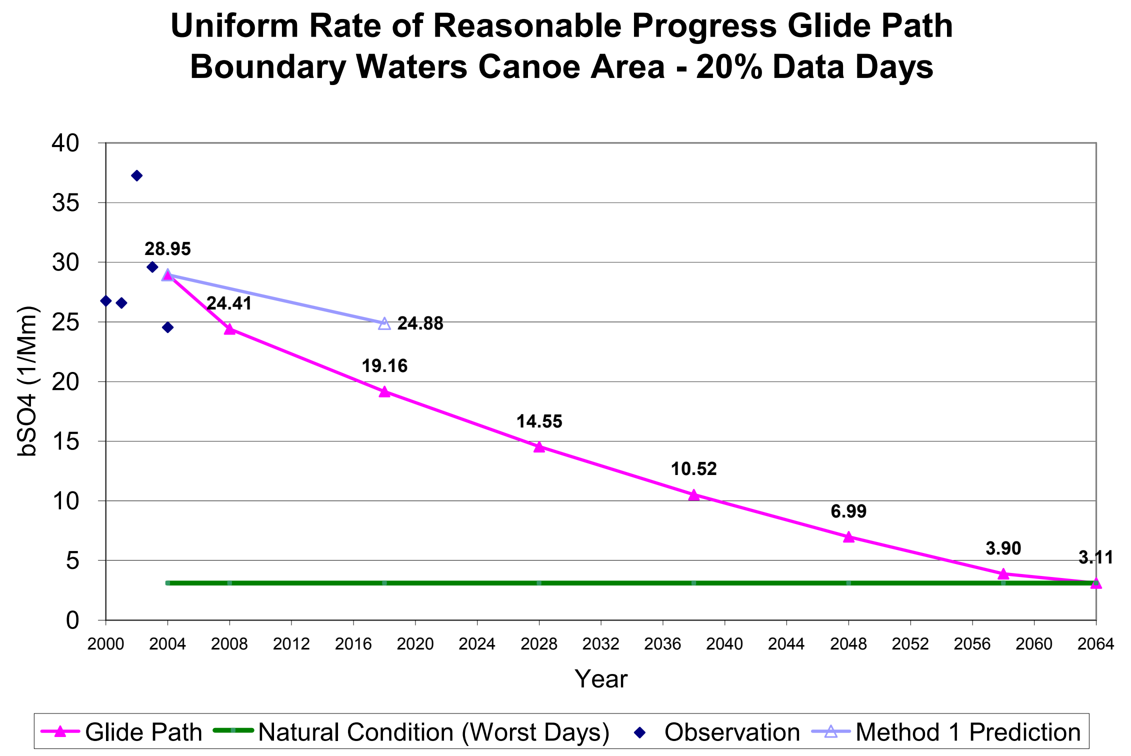


Figure F-4b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

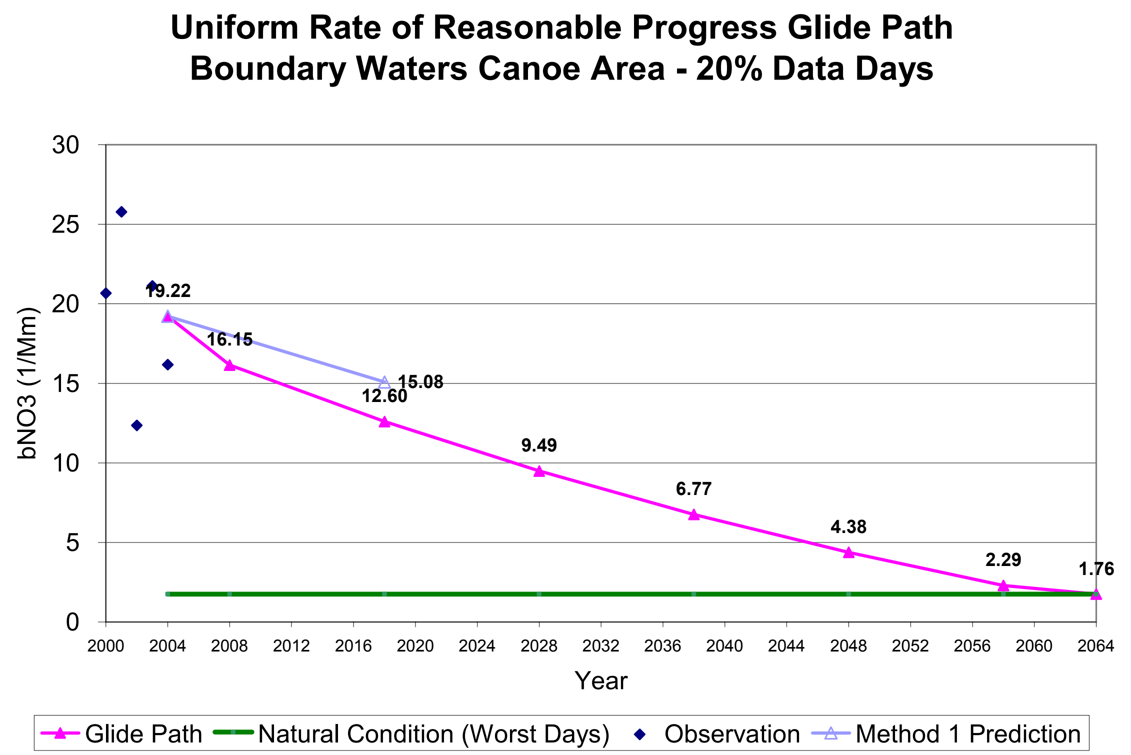


Figure F-4c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

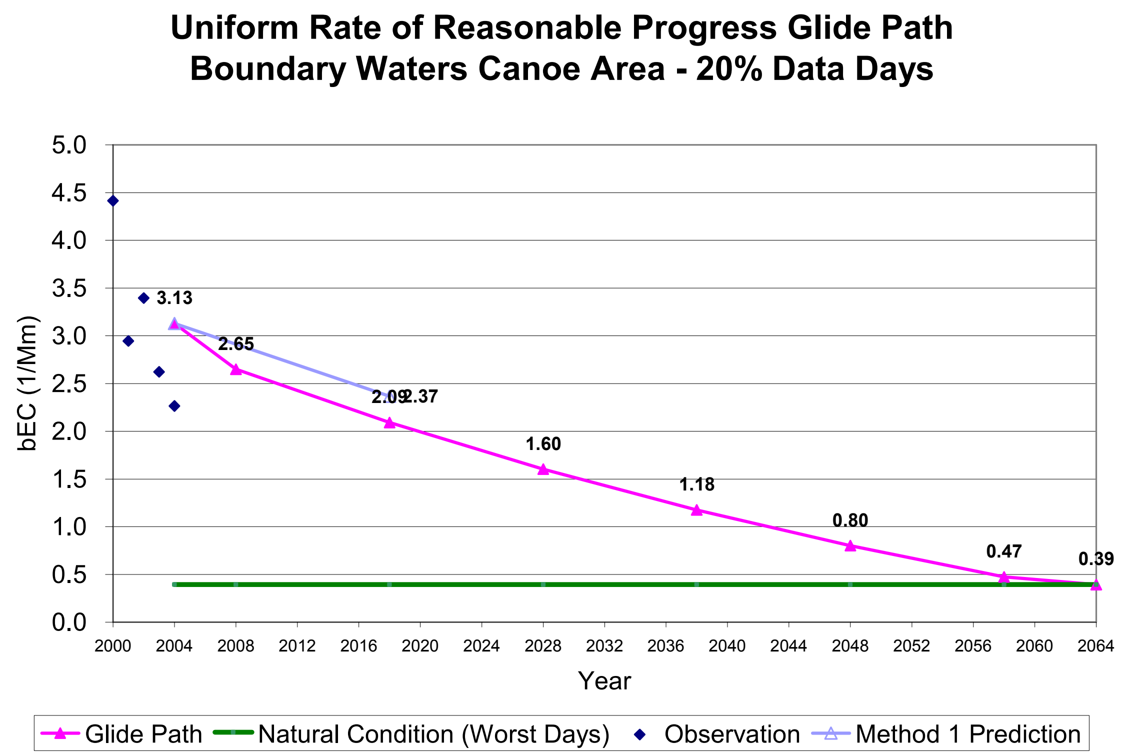


Figure F-4d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

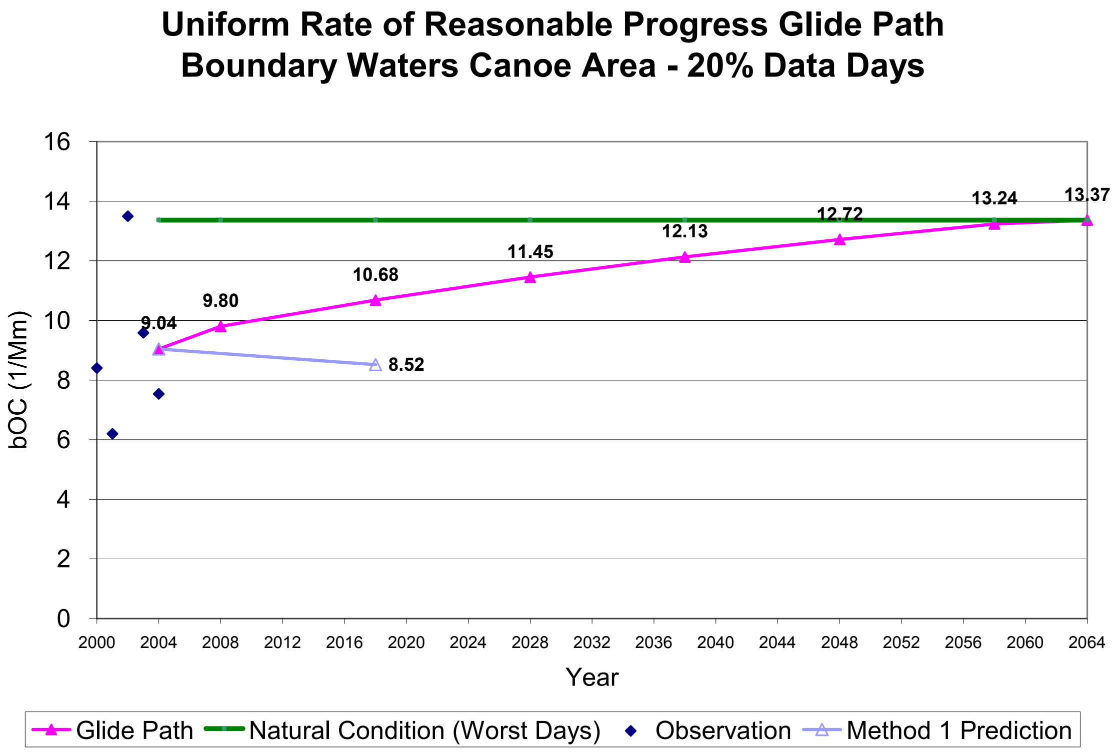


Figure F-4e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

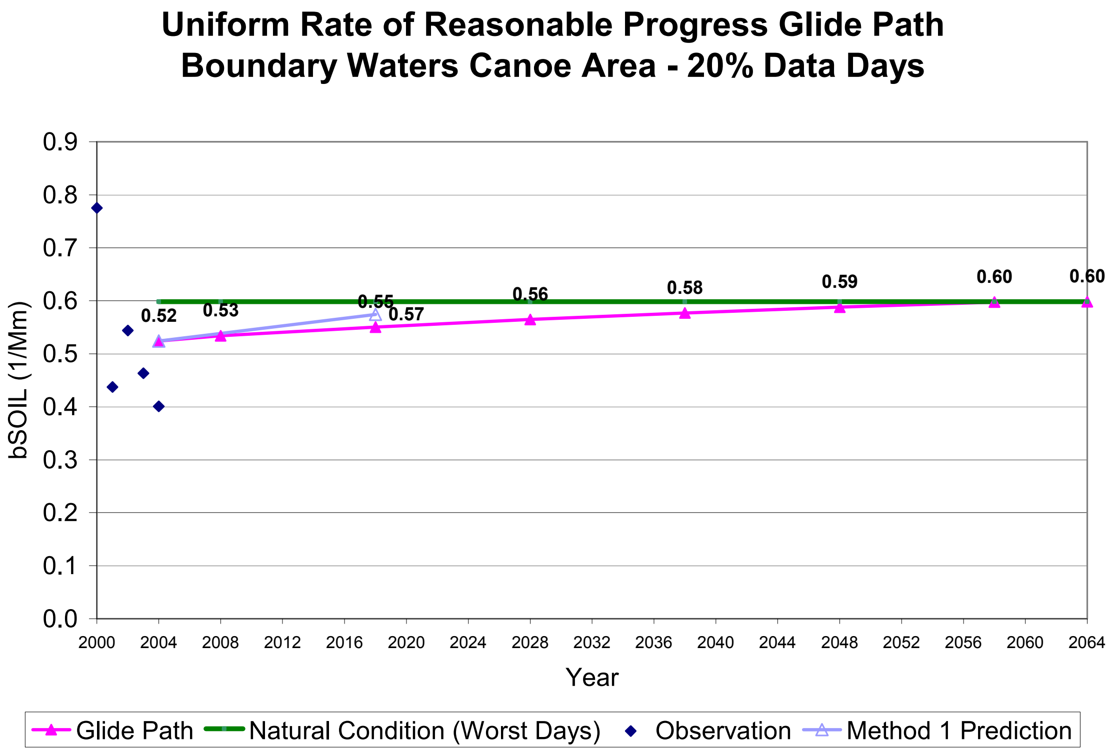


Figure F-4f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

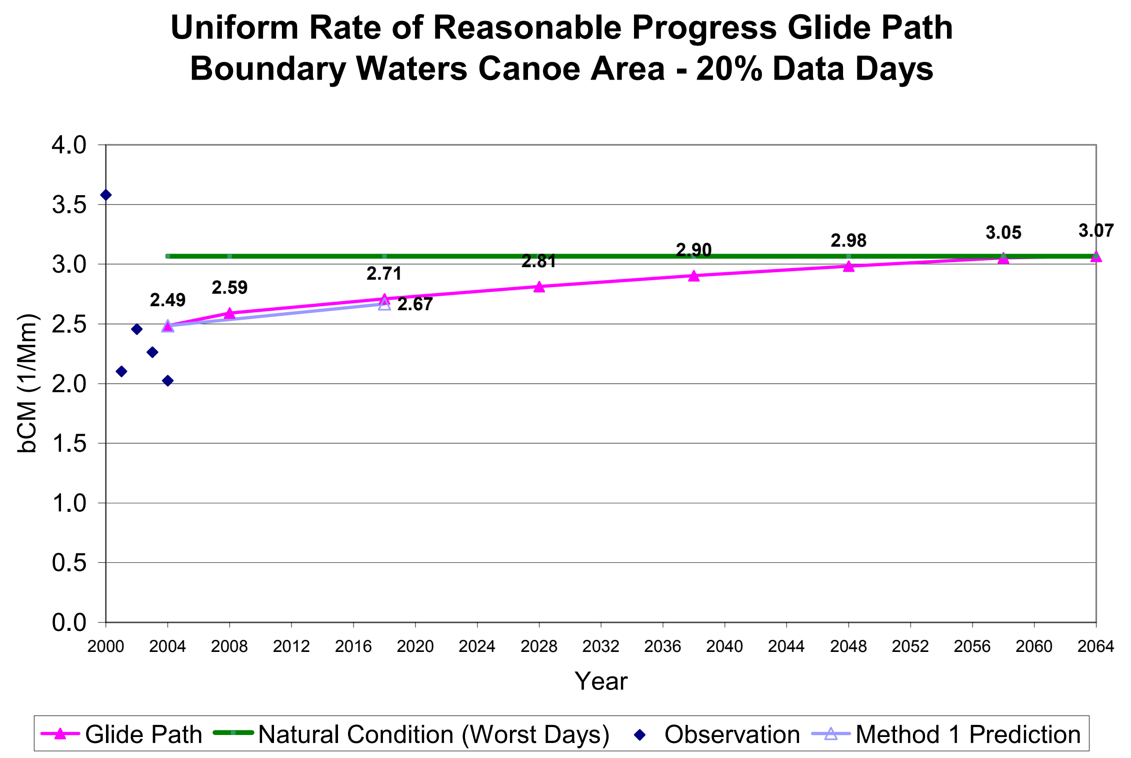


Figure F-4g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Boundary Waters (BOWA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

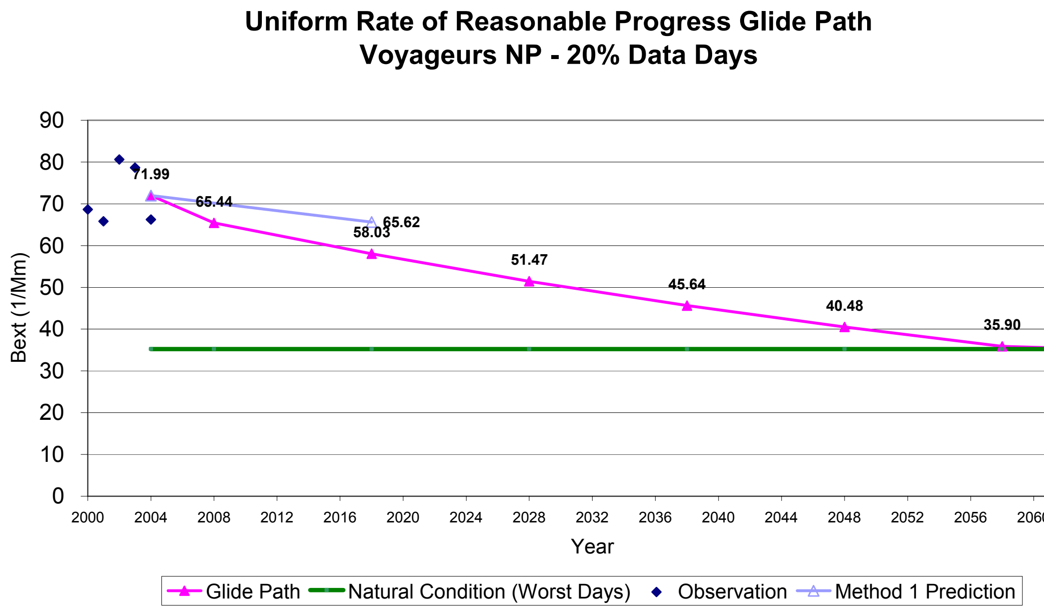


Figure F-5a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

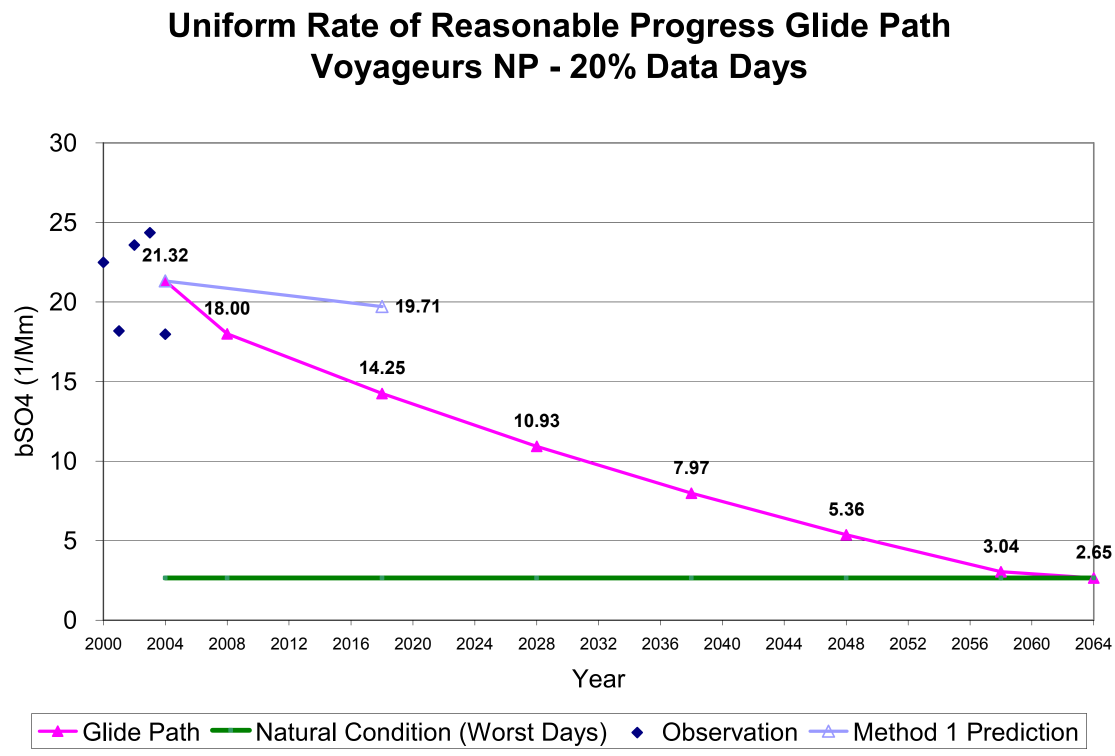


Figure F-5b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

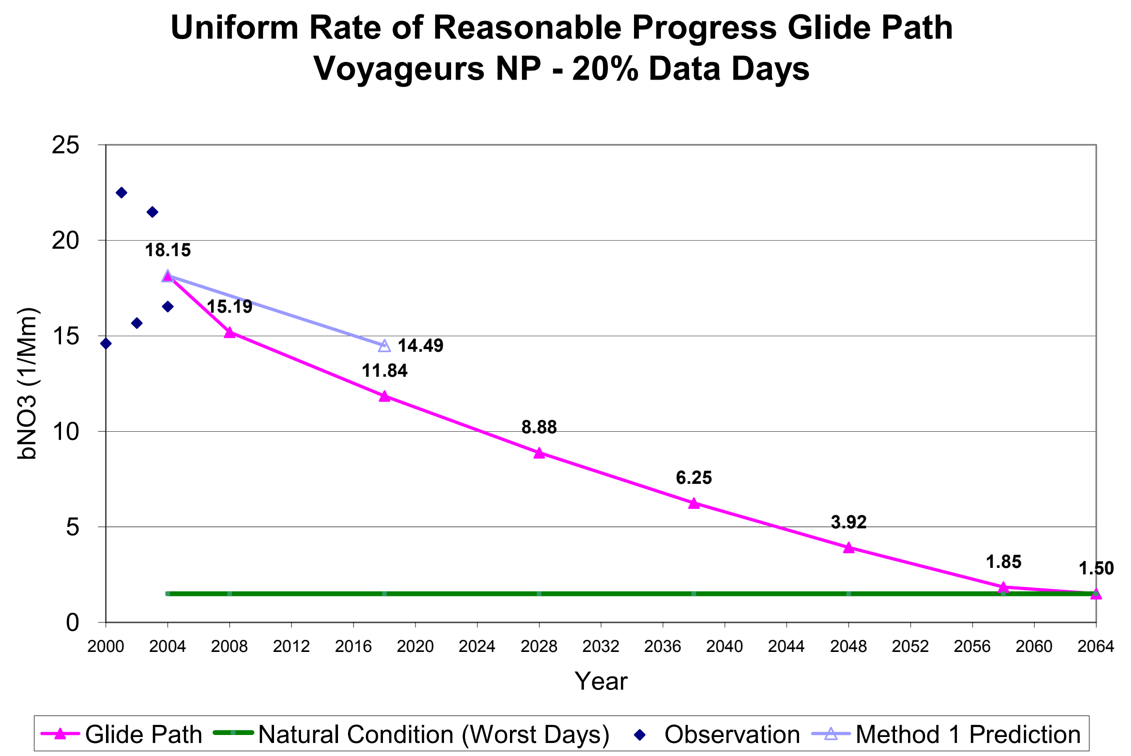


Figure F-5c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

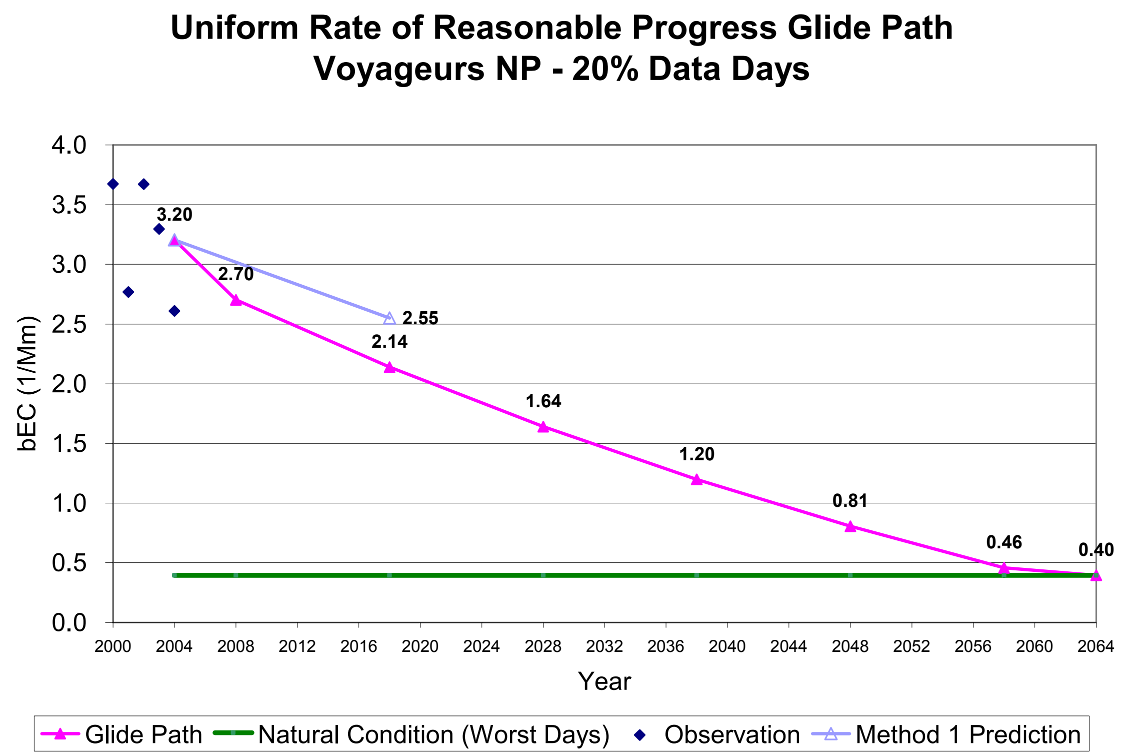


Figure F-5d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

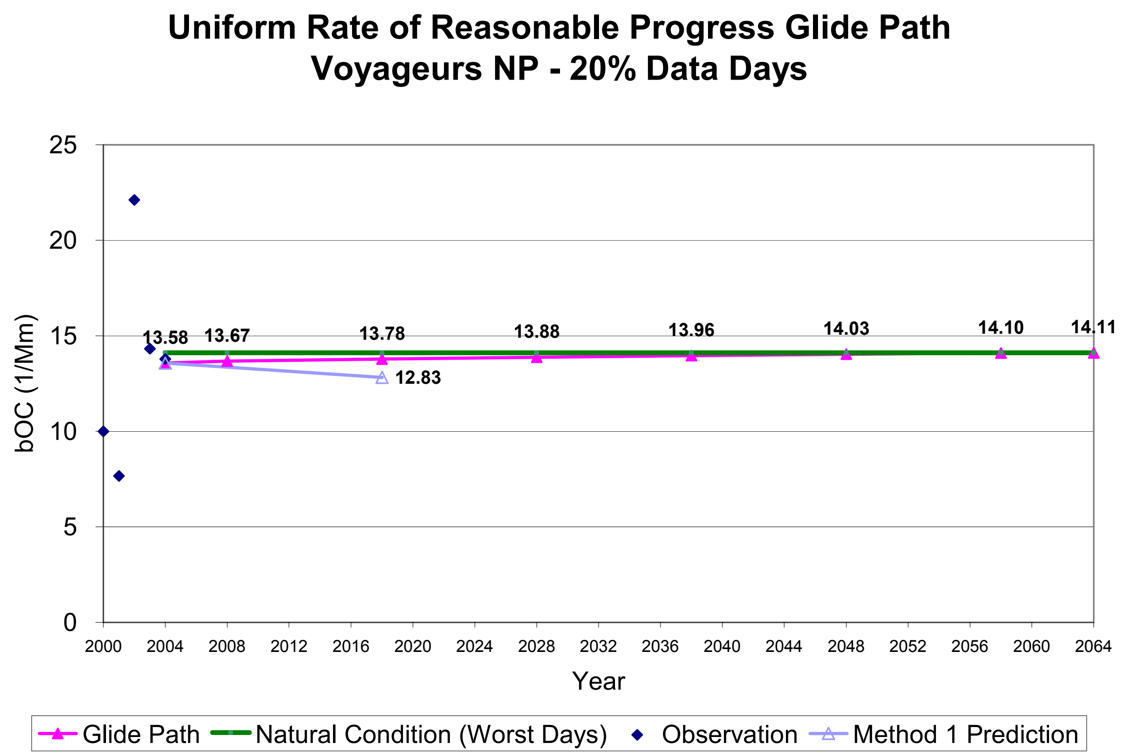


Figure F-5e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

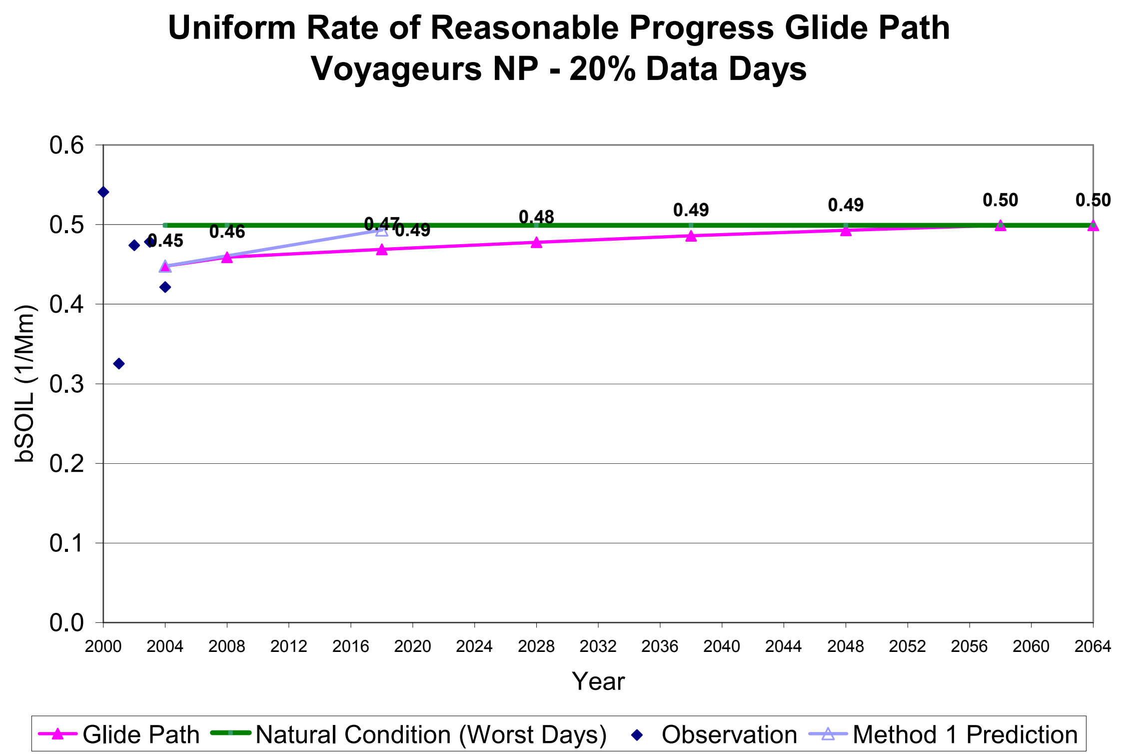


Figure F-5f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

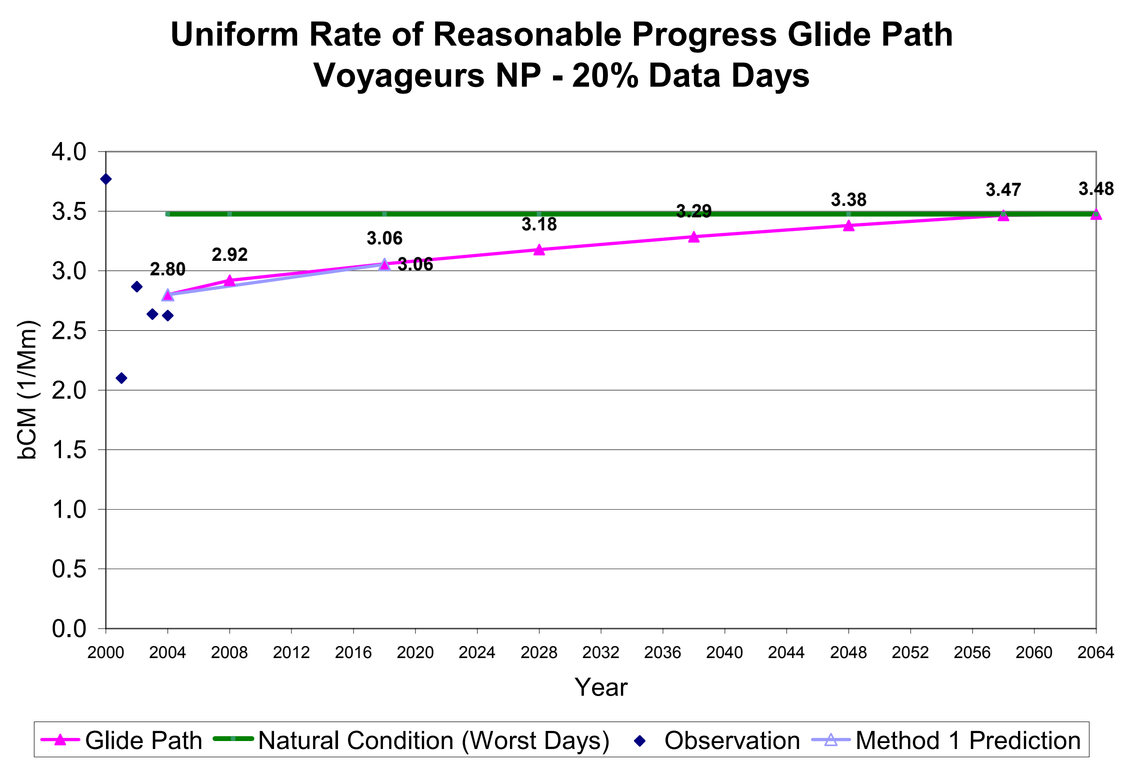


Figure F-5g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Voyageurs (VOYA), Minnesota and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

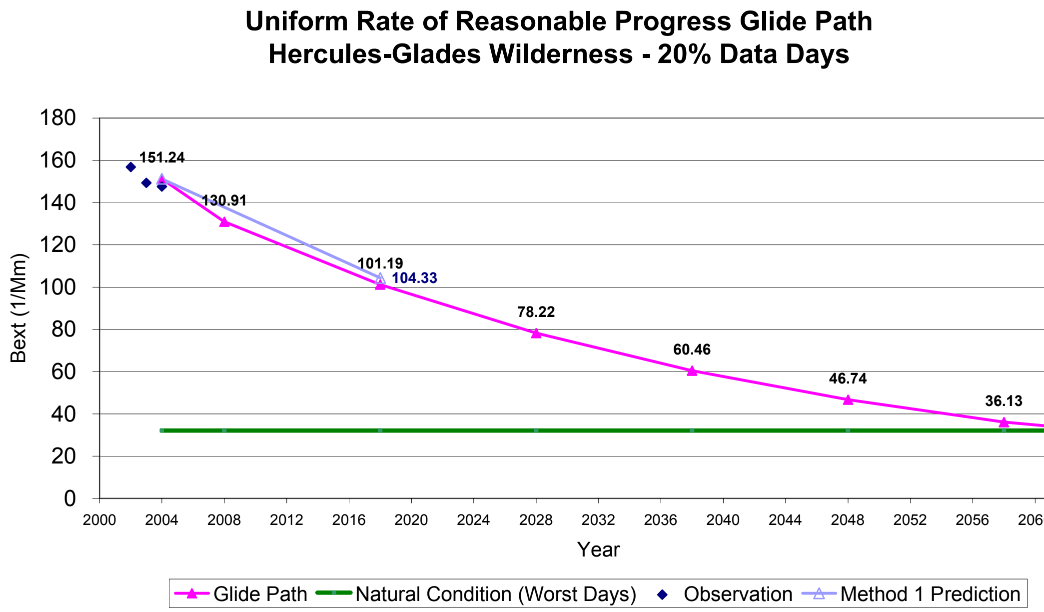


Figure F-6a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

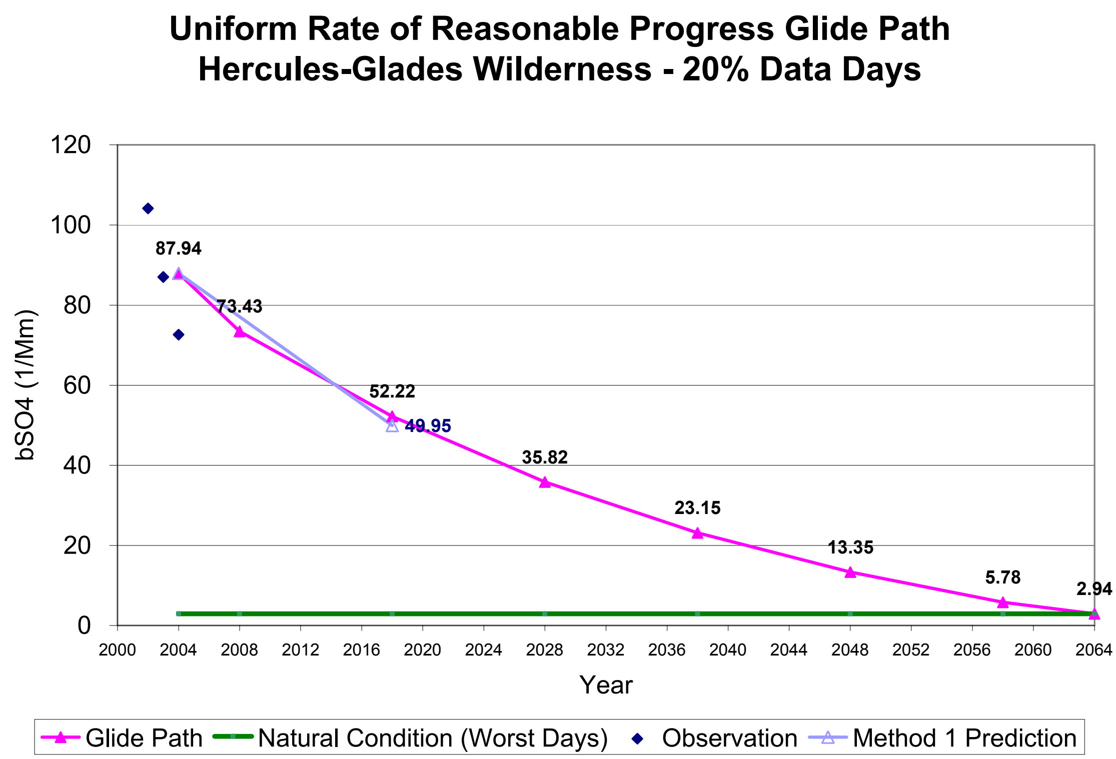


Figure F-6b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

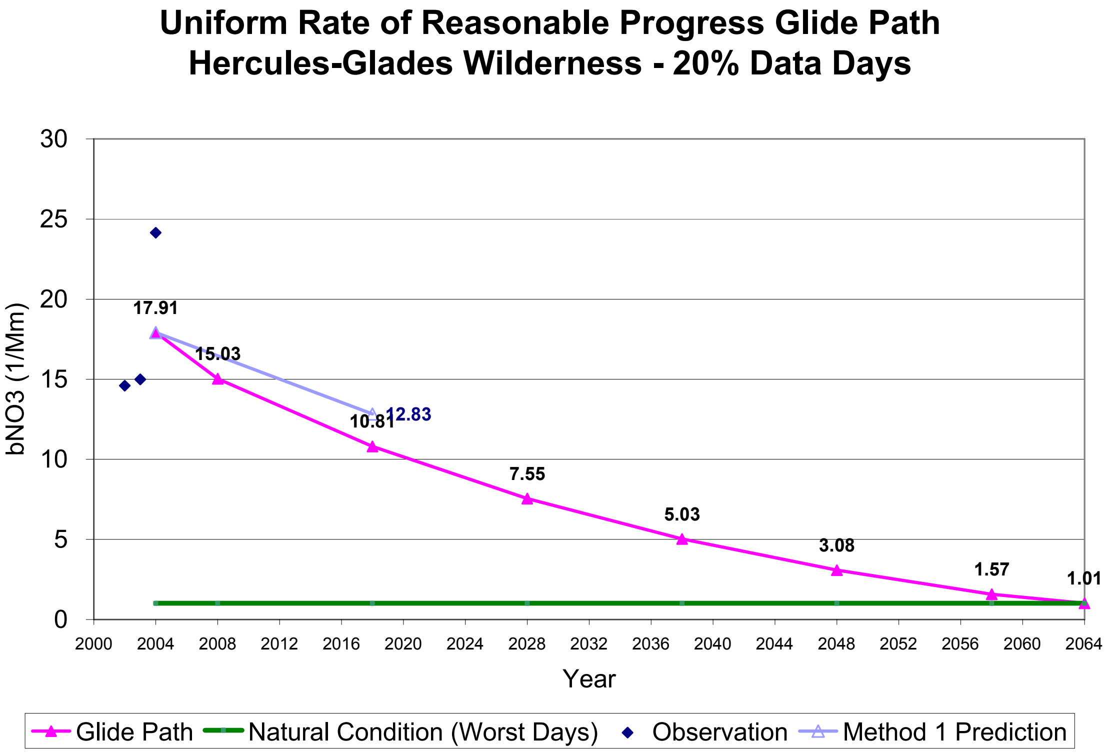


Figure F-6c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

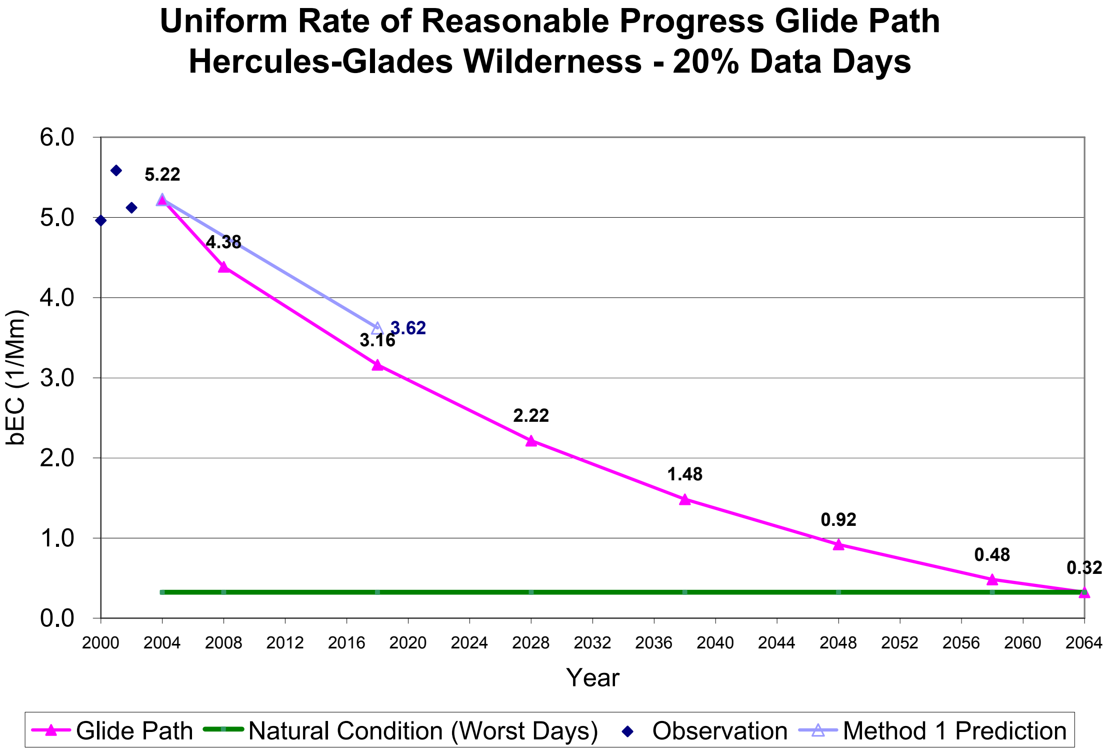


Figure F-6d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

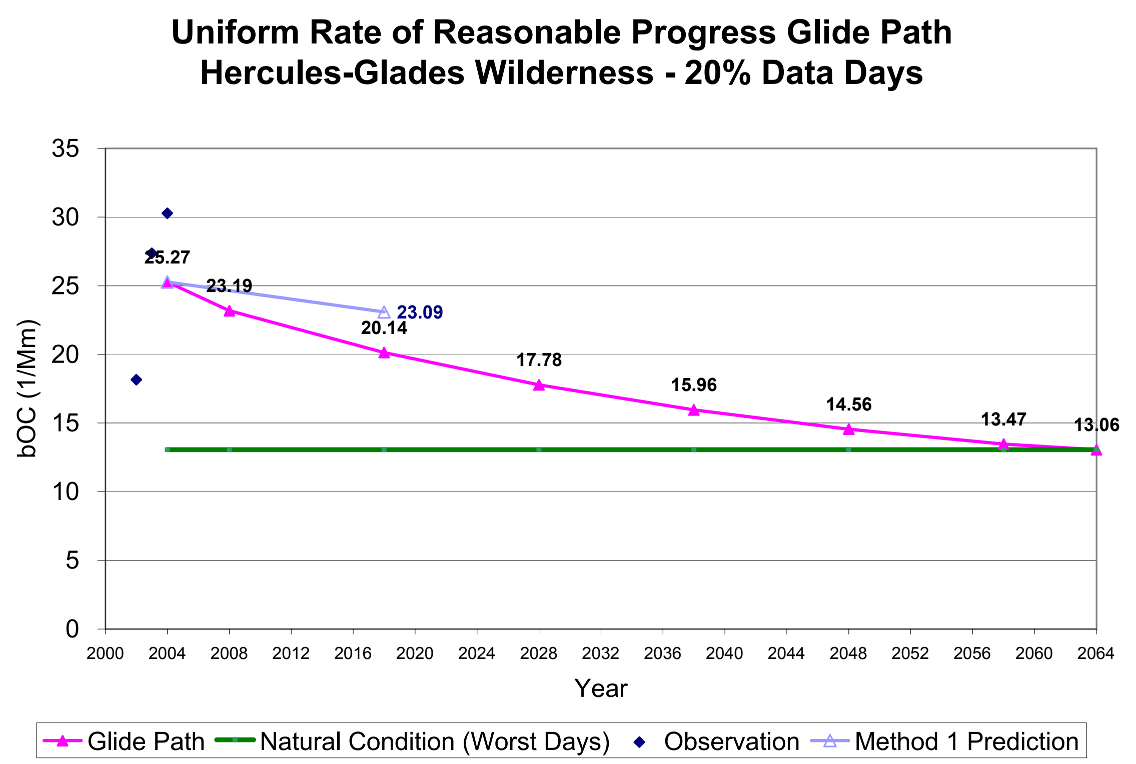


Figure F-6e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

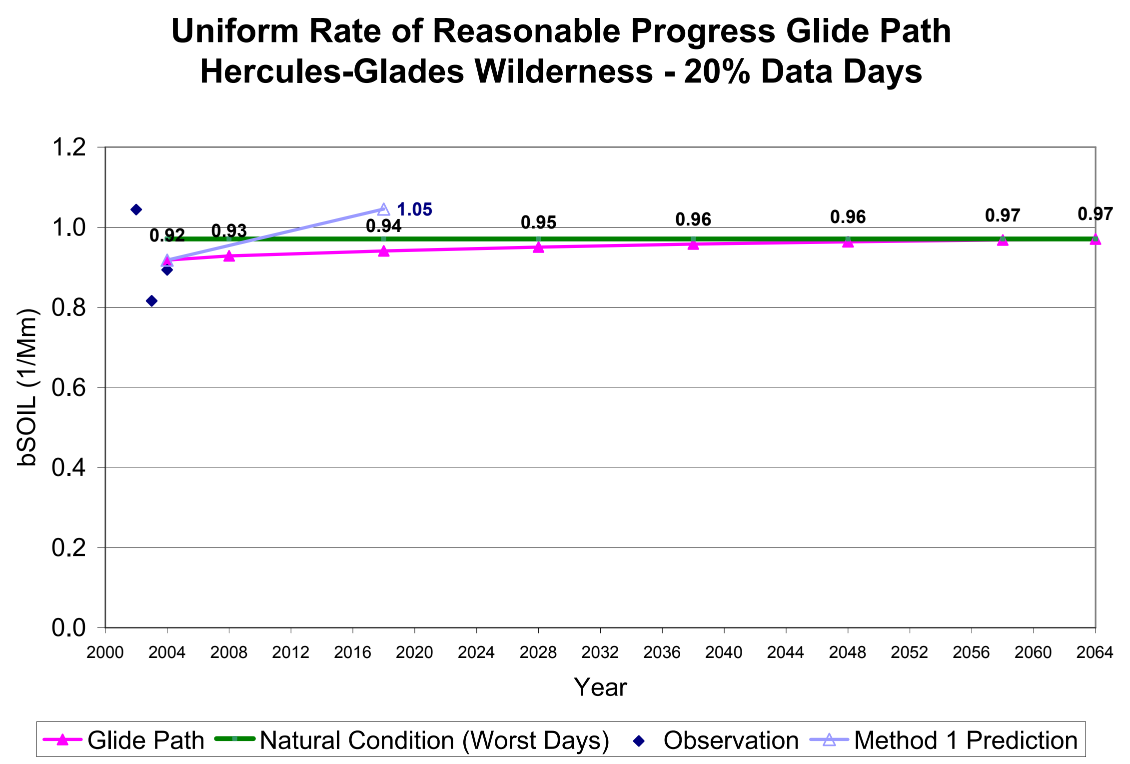


Figure F-6f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

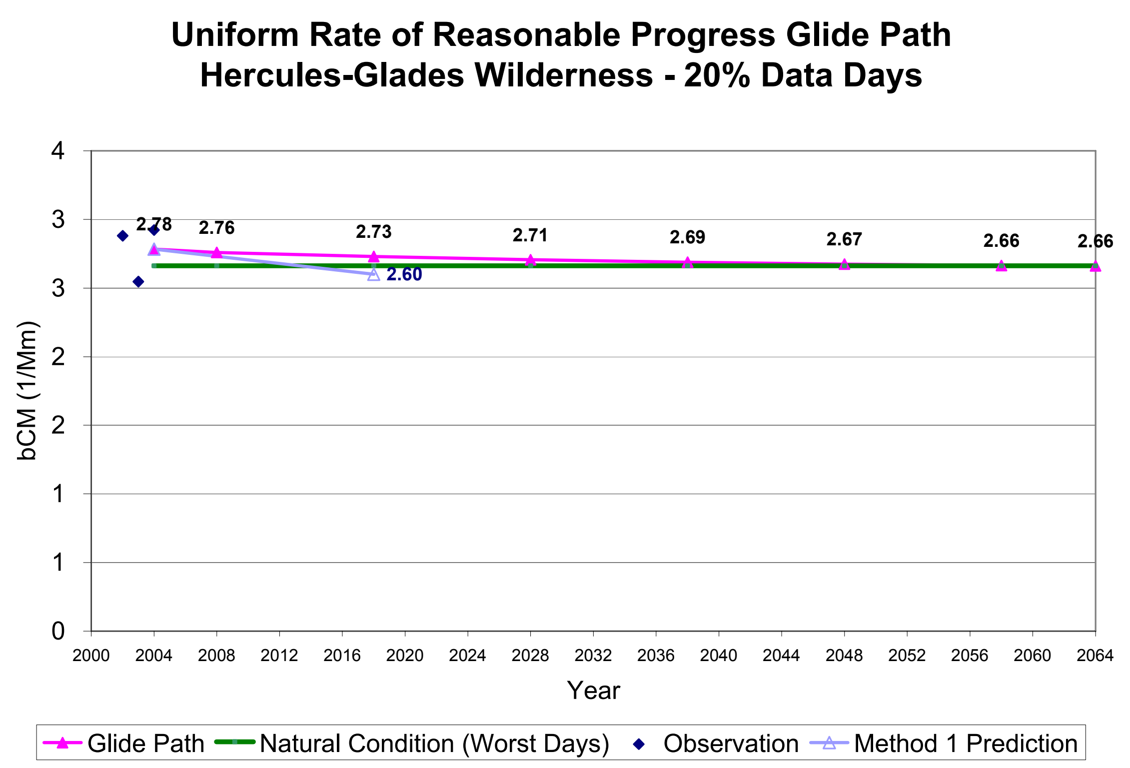


Figure F-6g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Hercules-Glade (HEGL), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

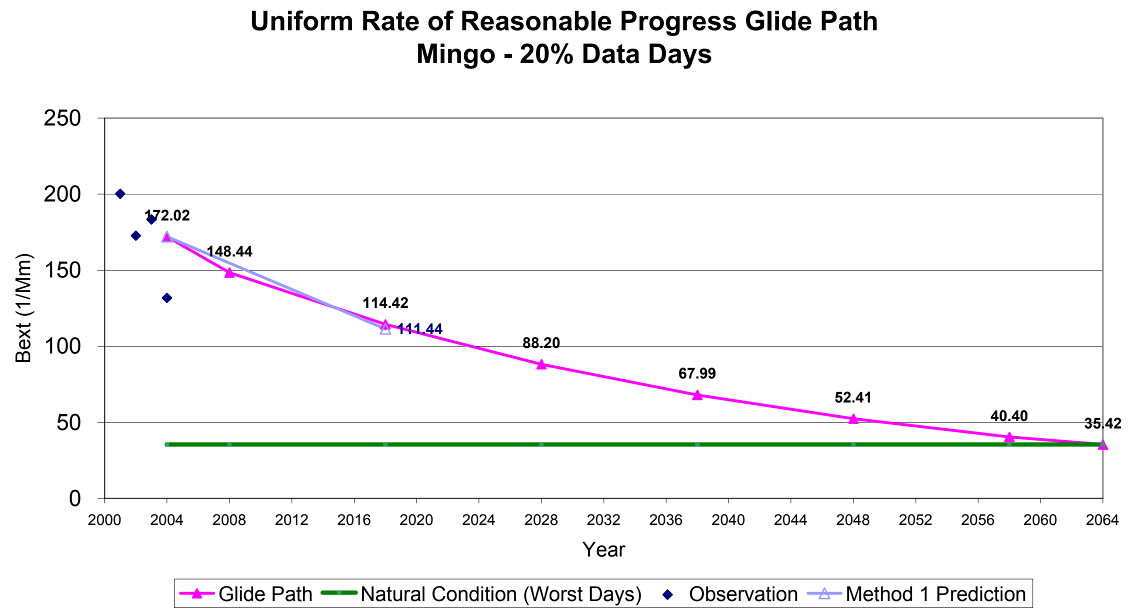


Figure F-7a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

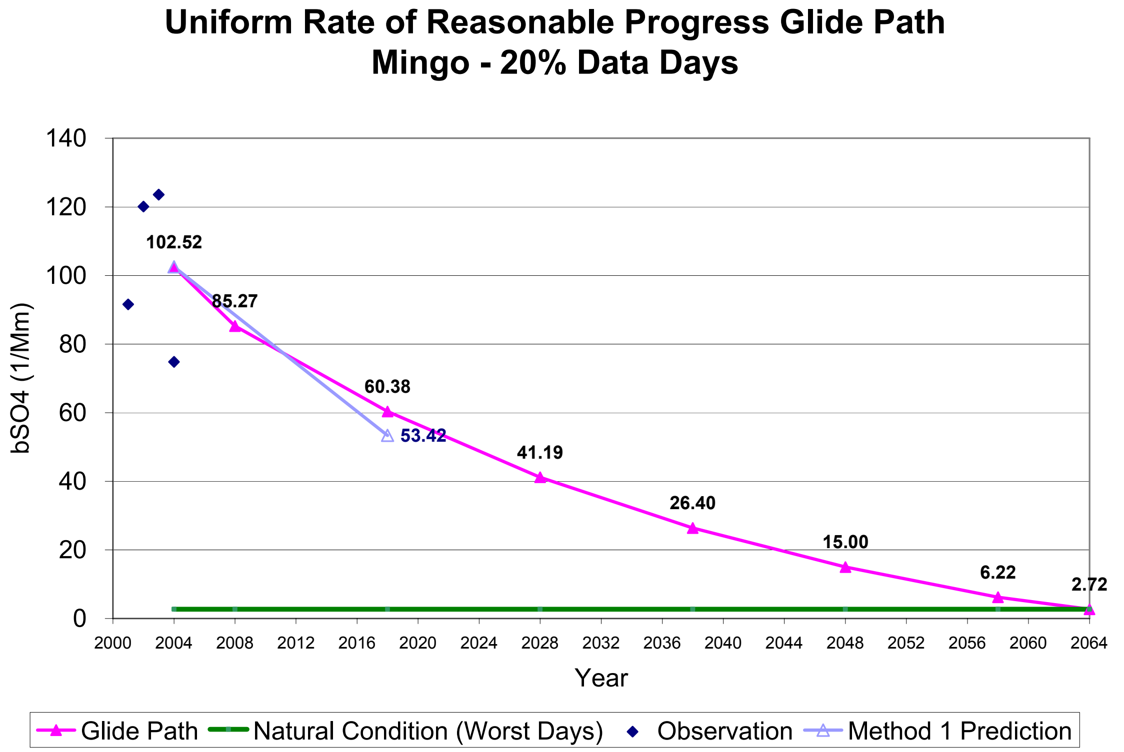


Figure F-7b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

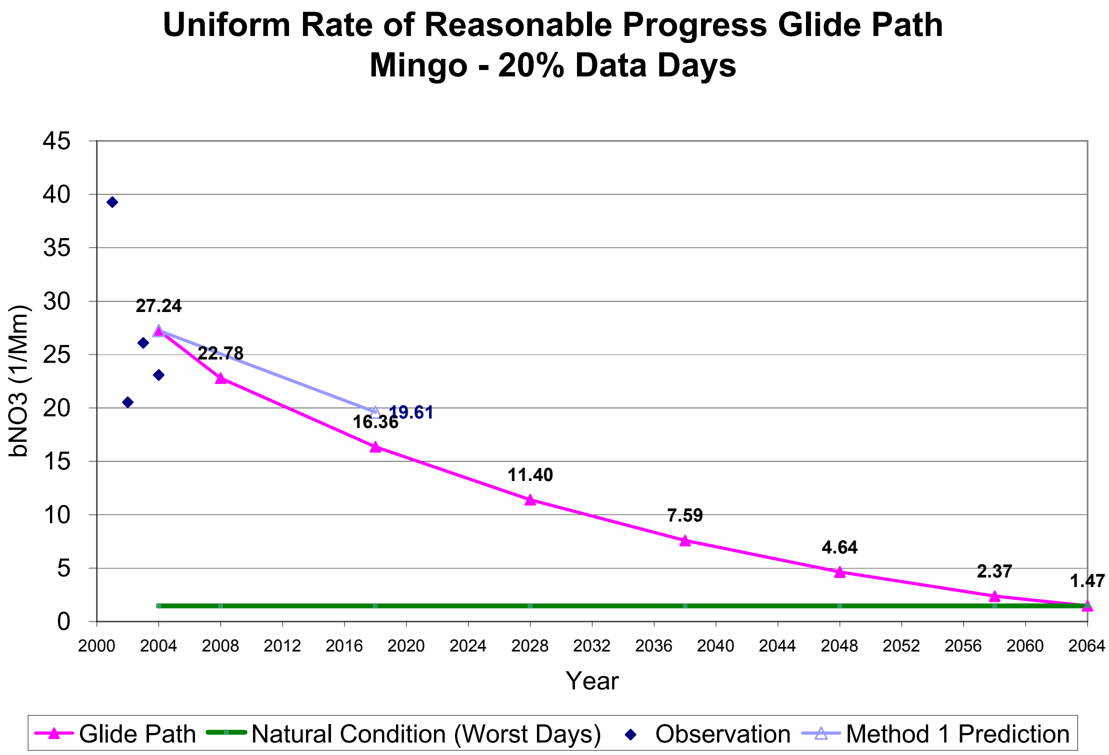


Figure F-7c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

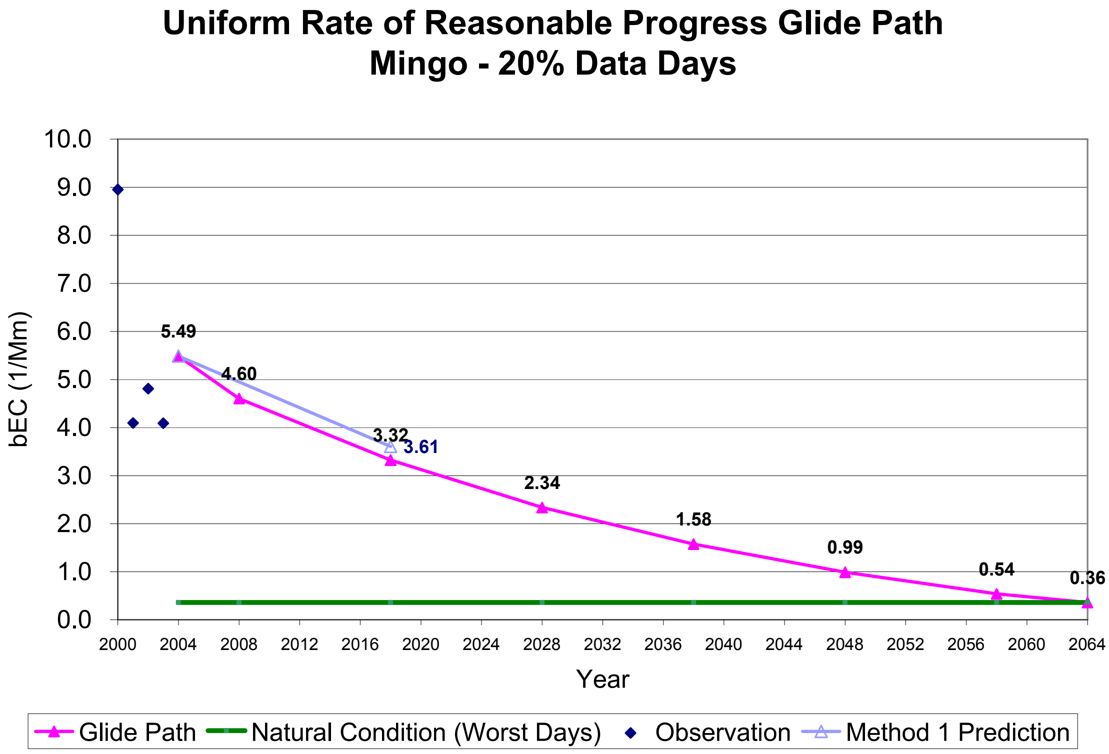


Figure F-7d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

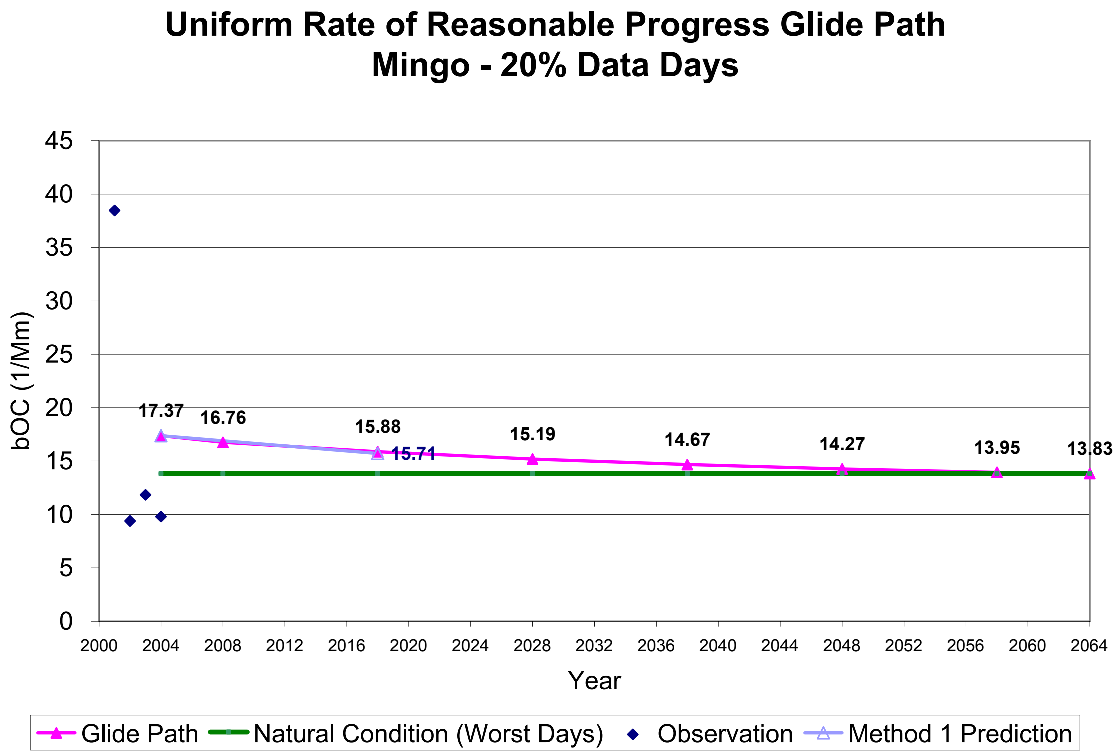


Figure F-7e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

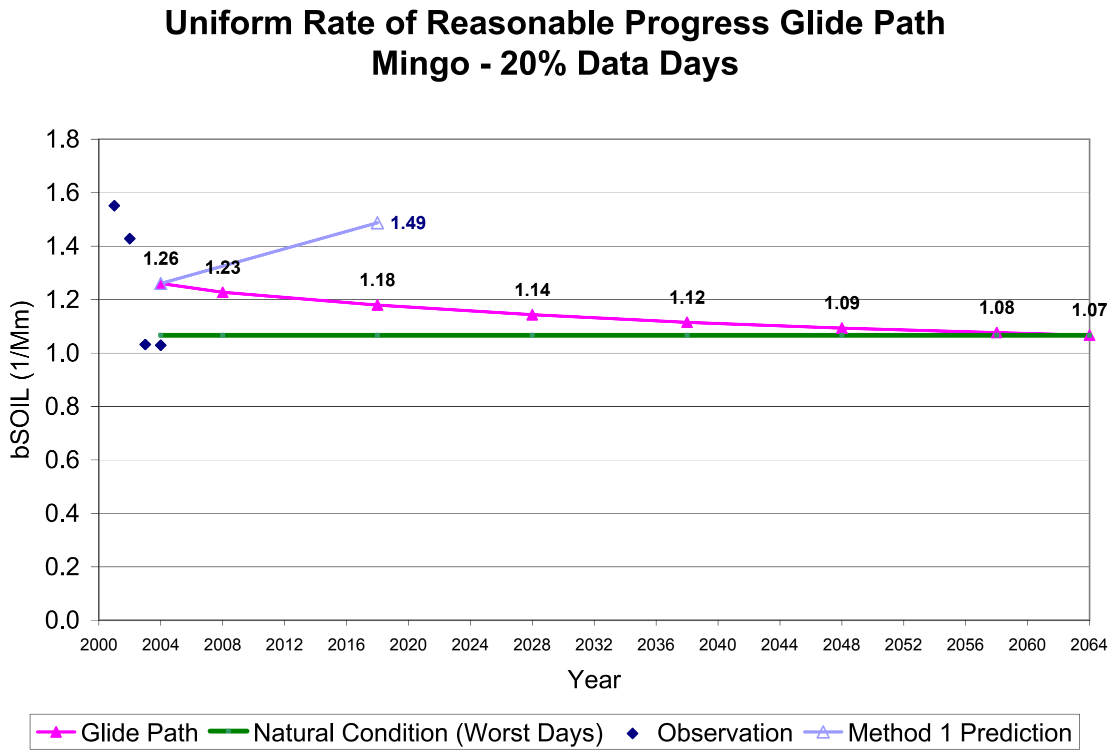


Figure F-7f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

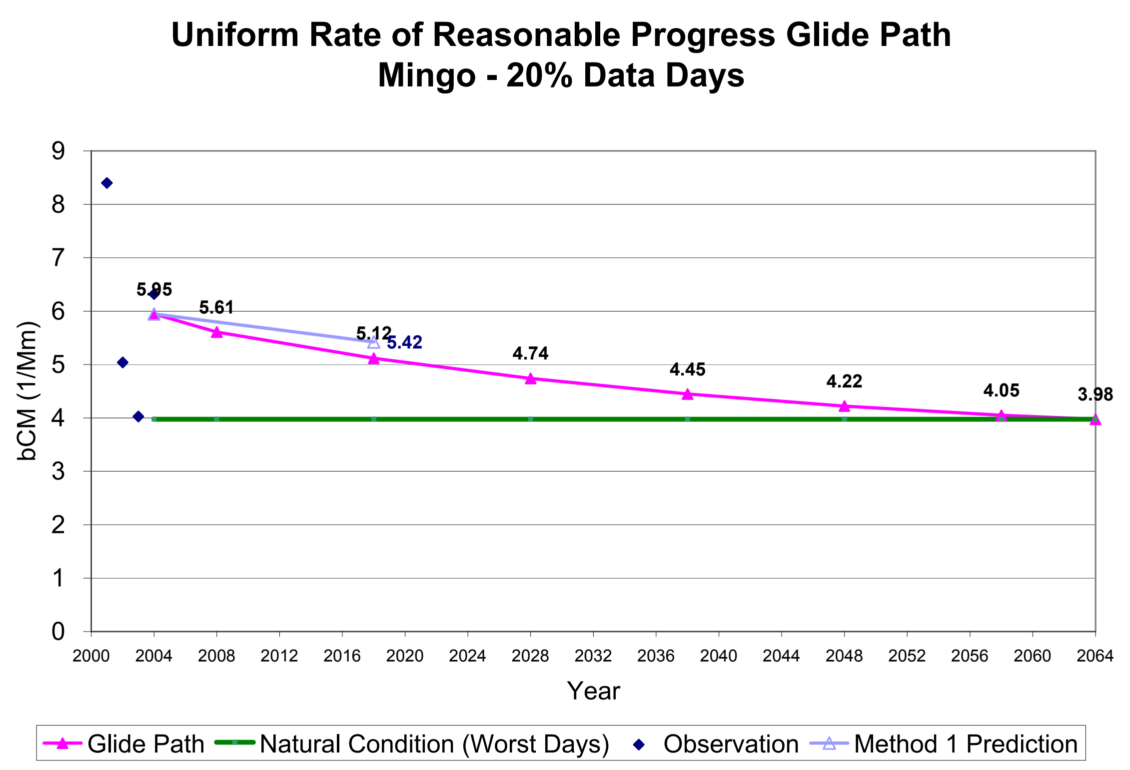


Figure F-7g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Mingo (MING), Missouri and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

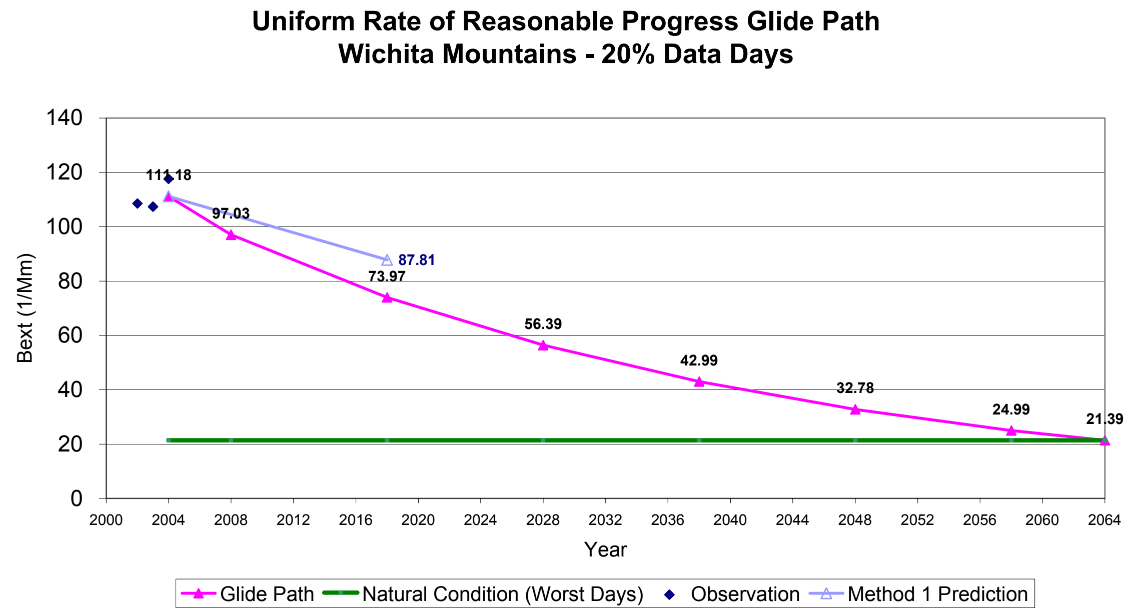


Figure F-8a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

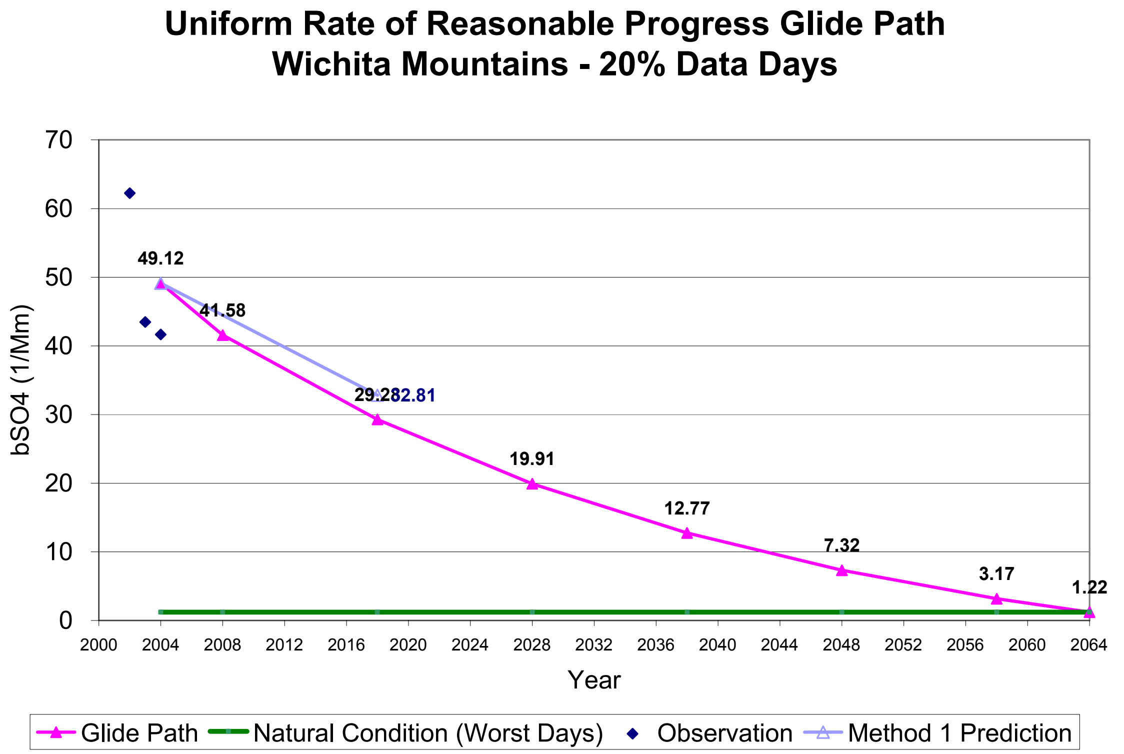


Figure F-8b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

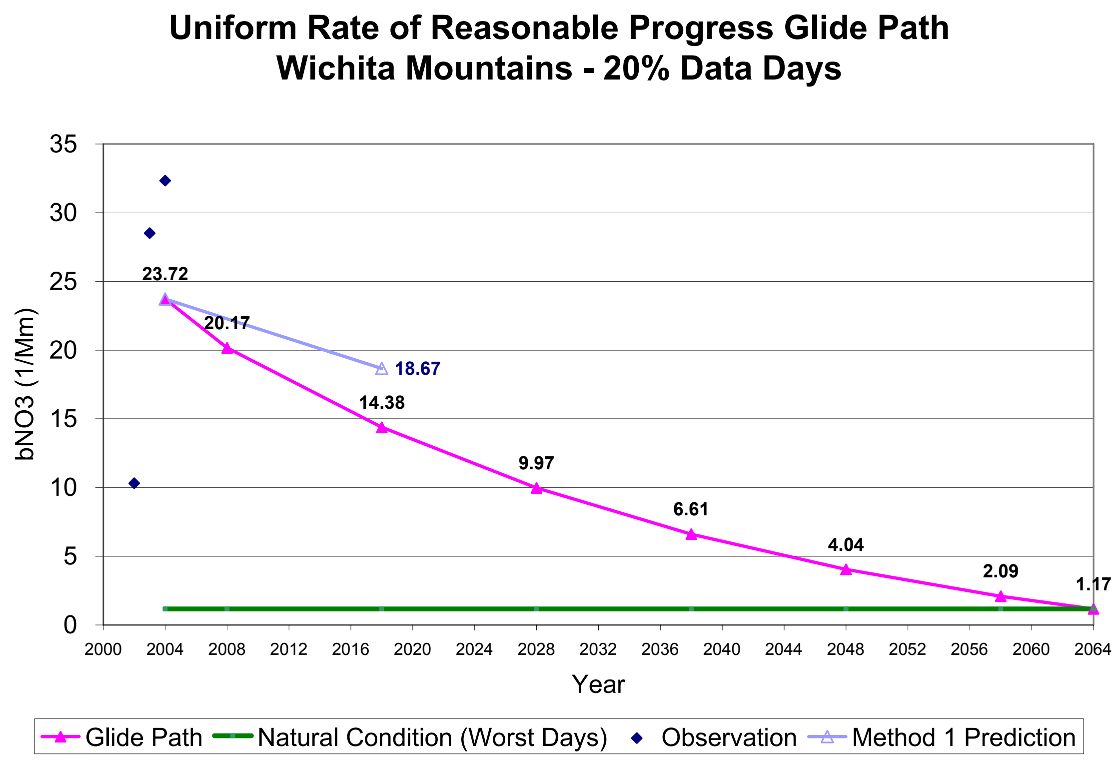


Figure F-8c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

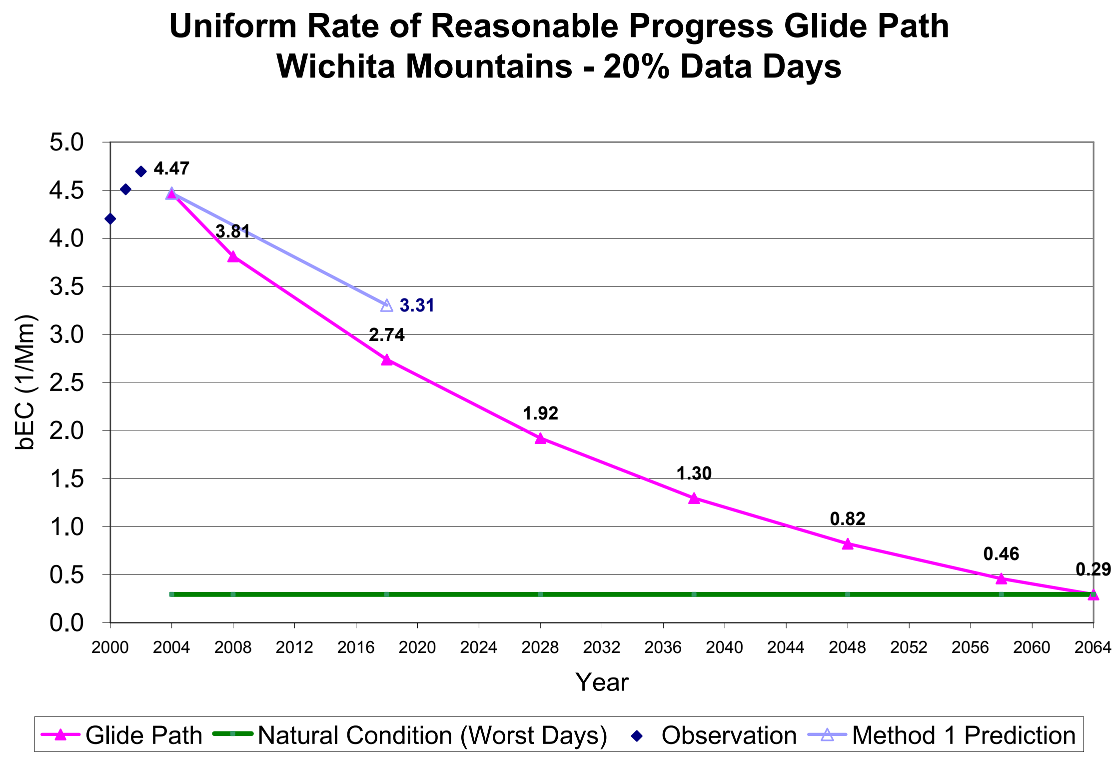


Figure F-8d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

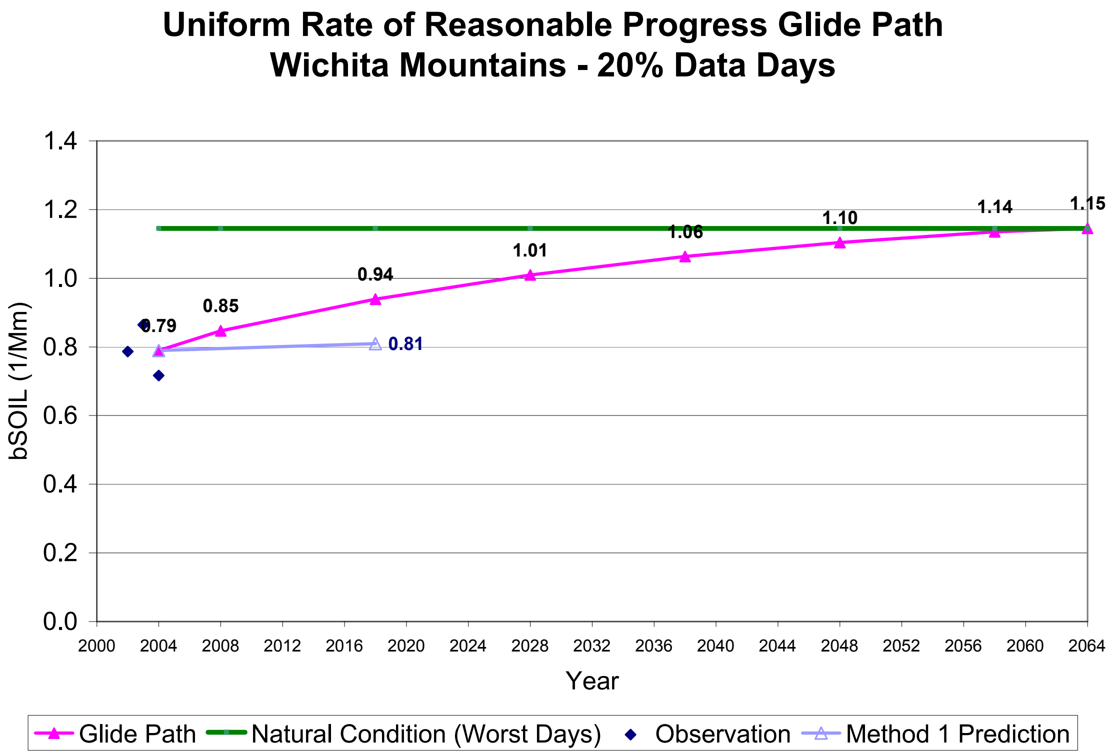


Figure F-8e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

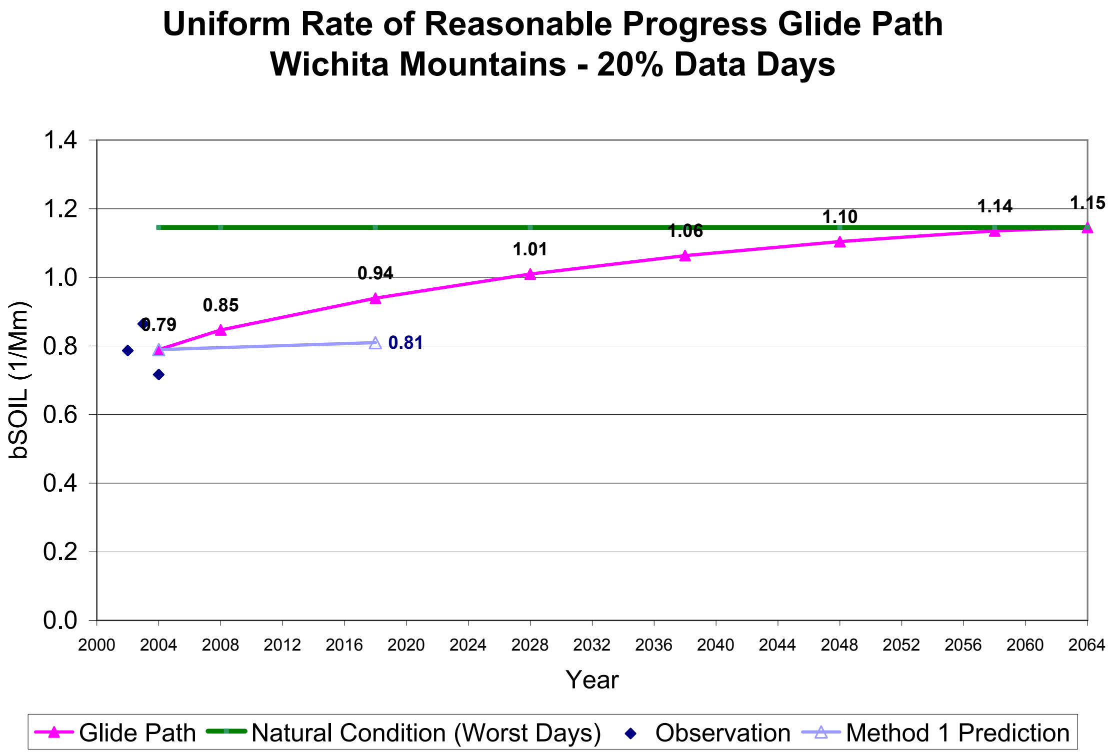


Figure F-8f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

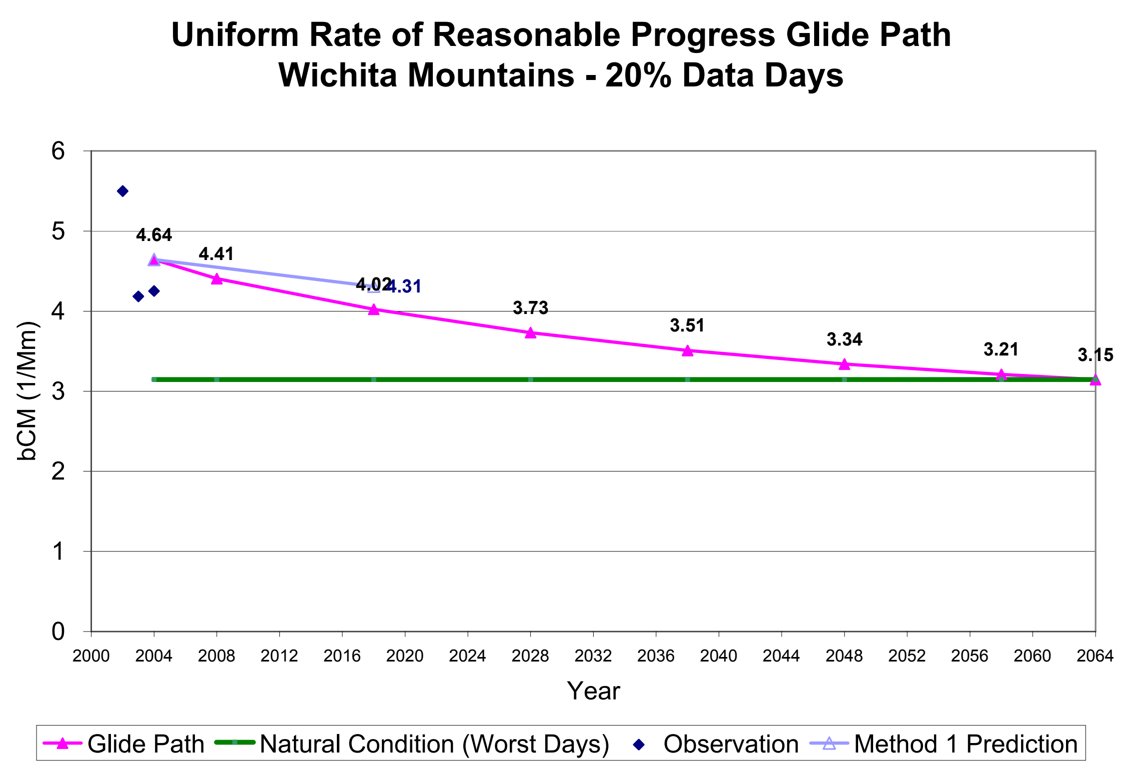


Figure F-8g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Wichita Mountains (WIMO), Oklahoma and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

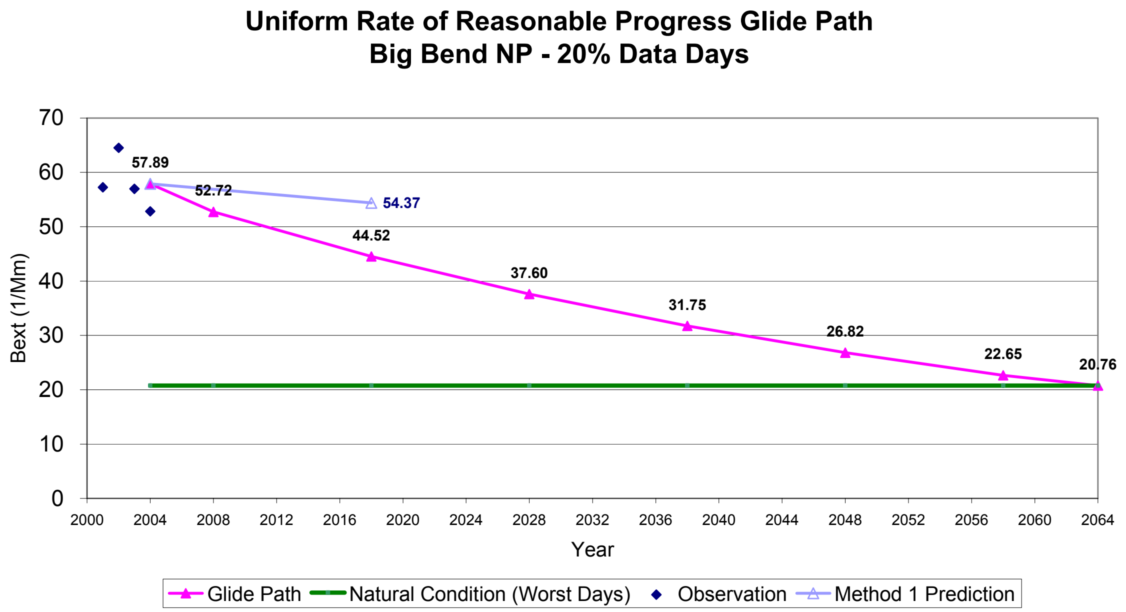


Figure F-9a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

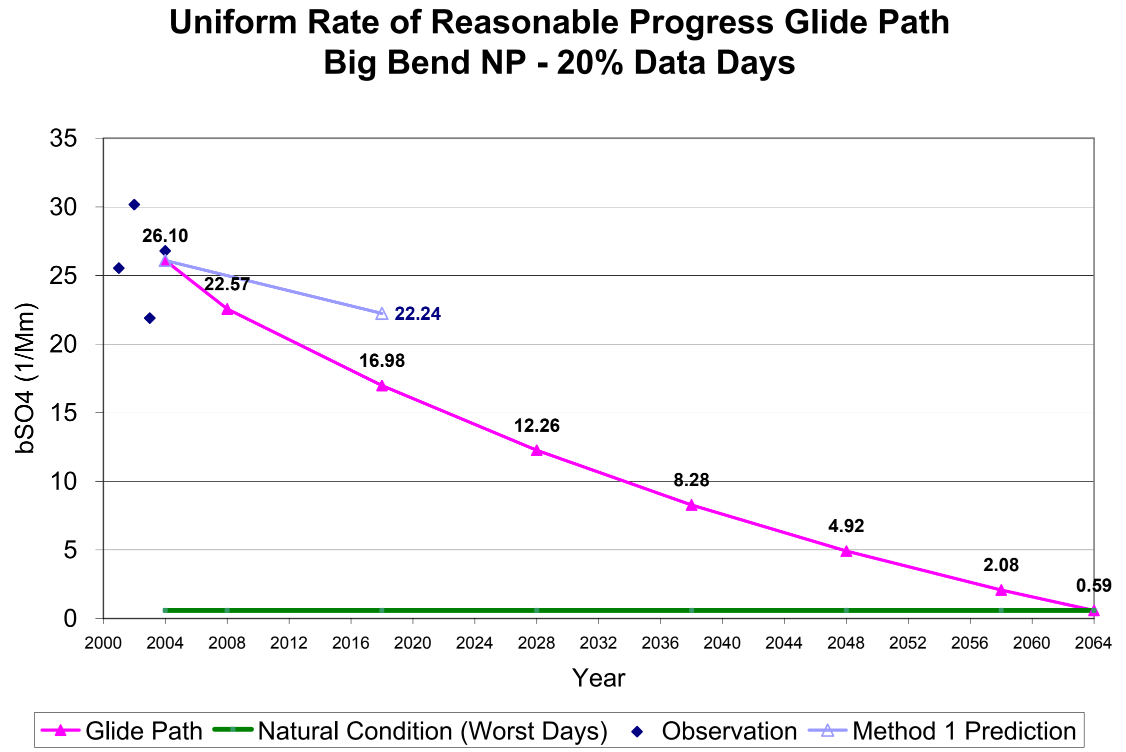


Figure F-9b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

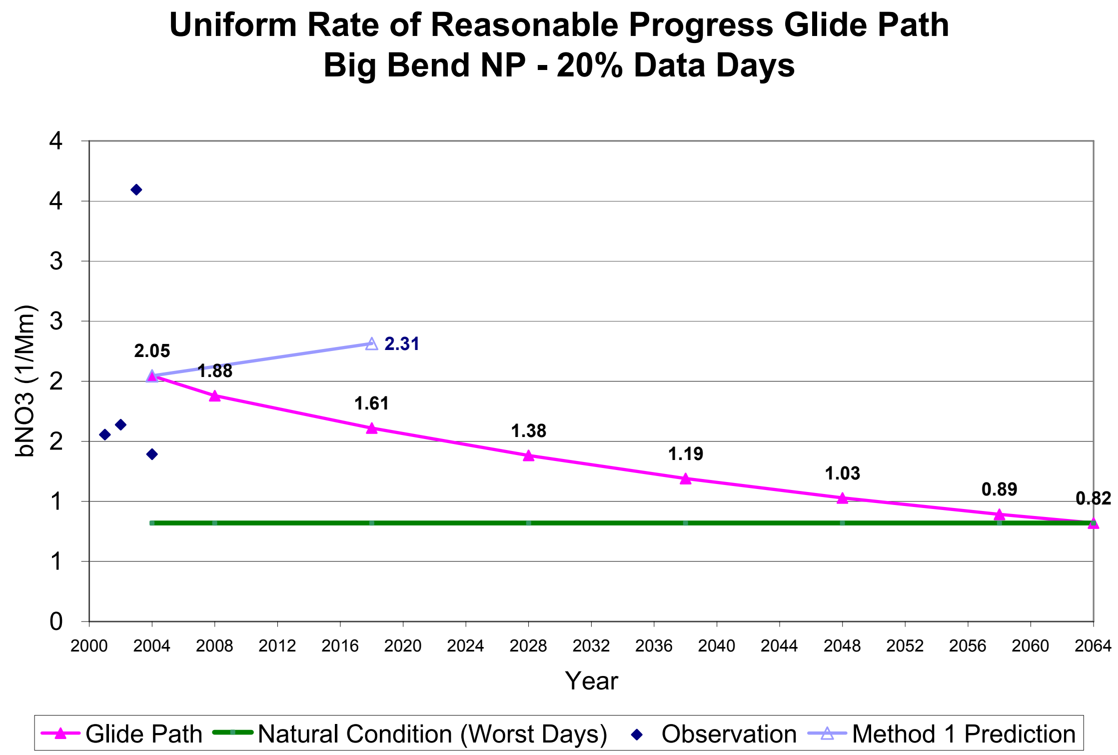


Figure F-9c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

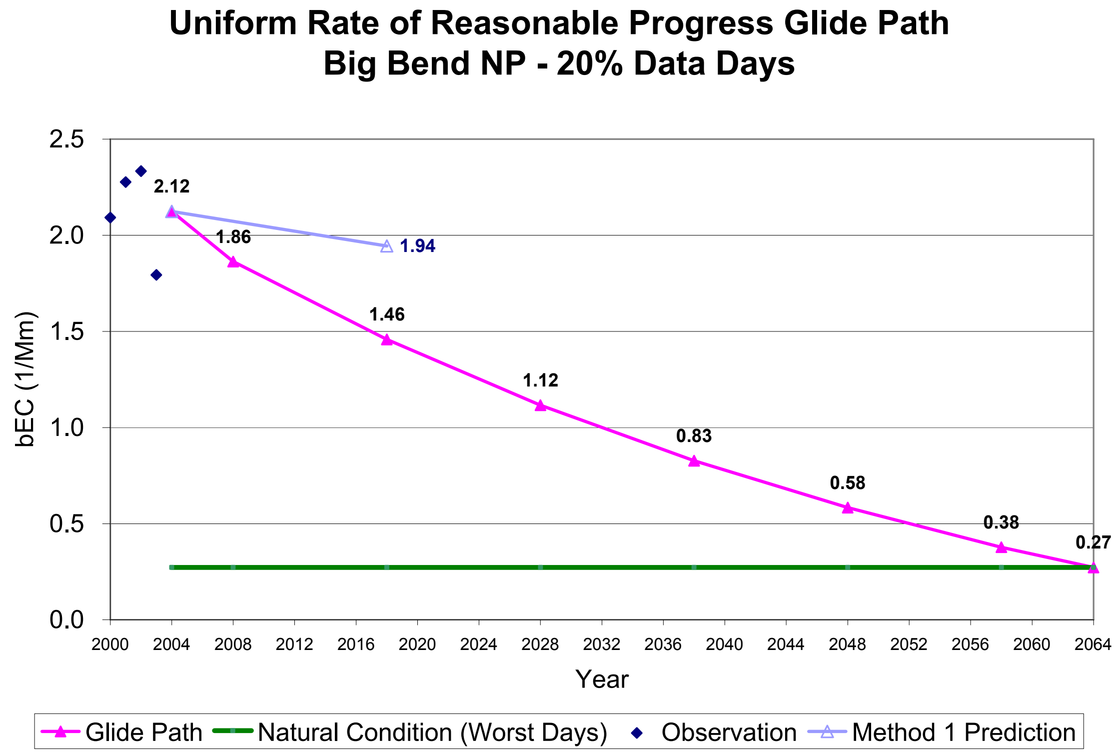


Figure F-9d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

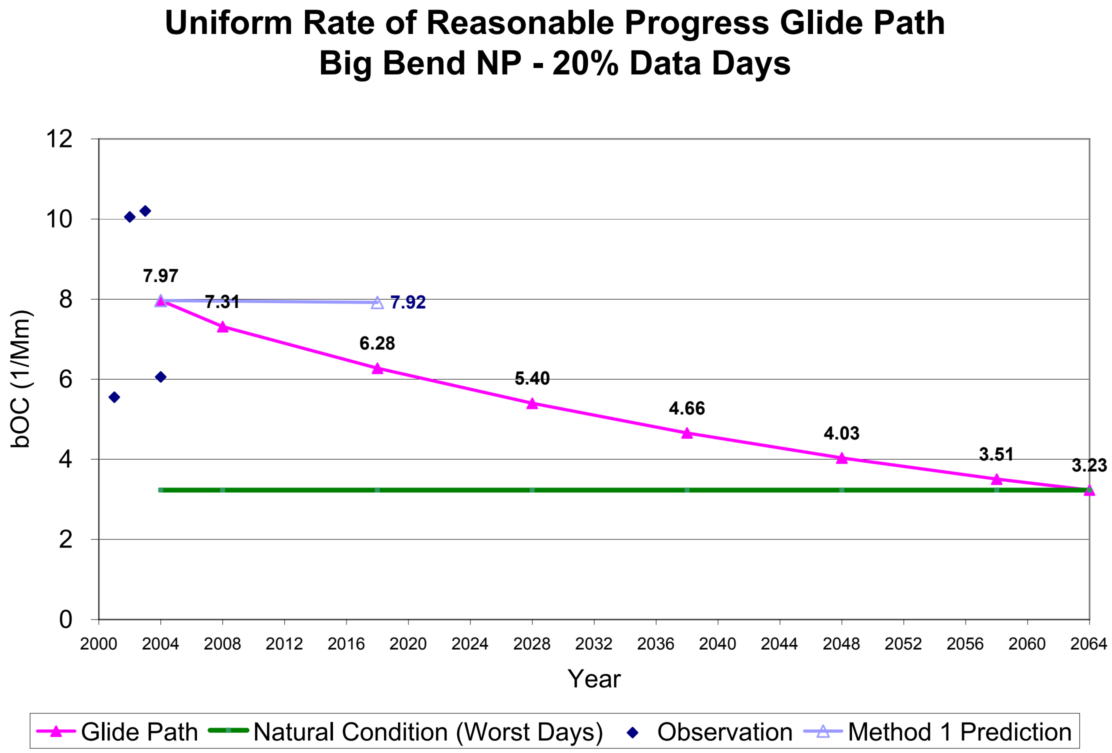


Figure F-9e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

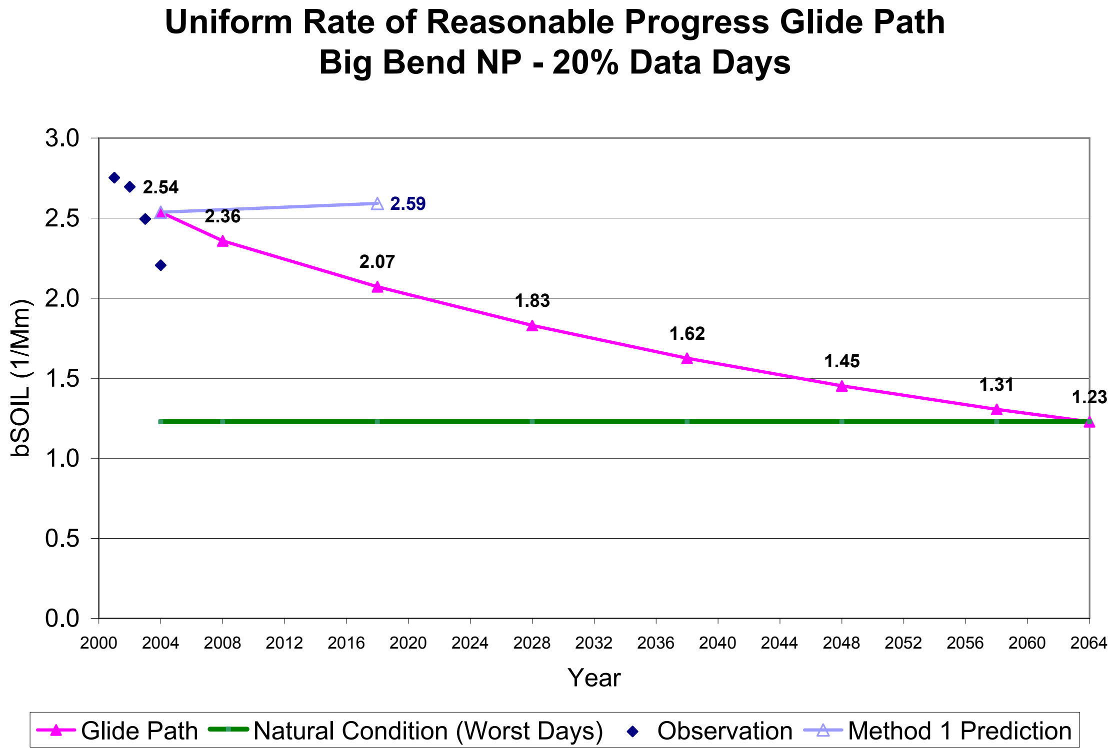


Figure F-9f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

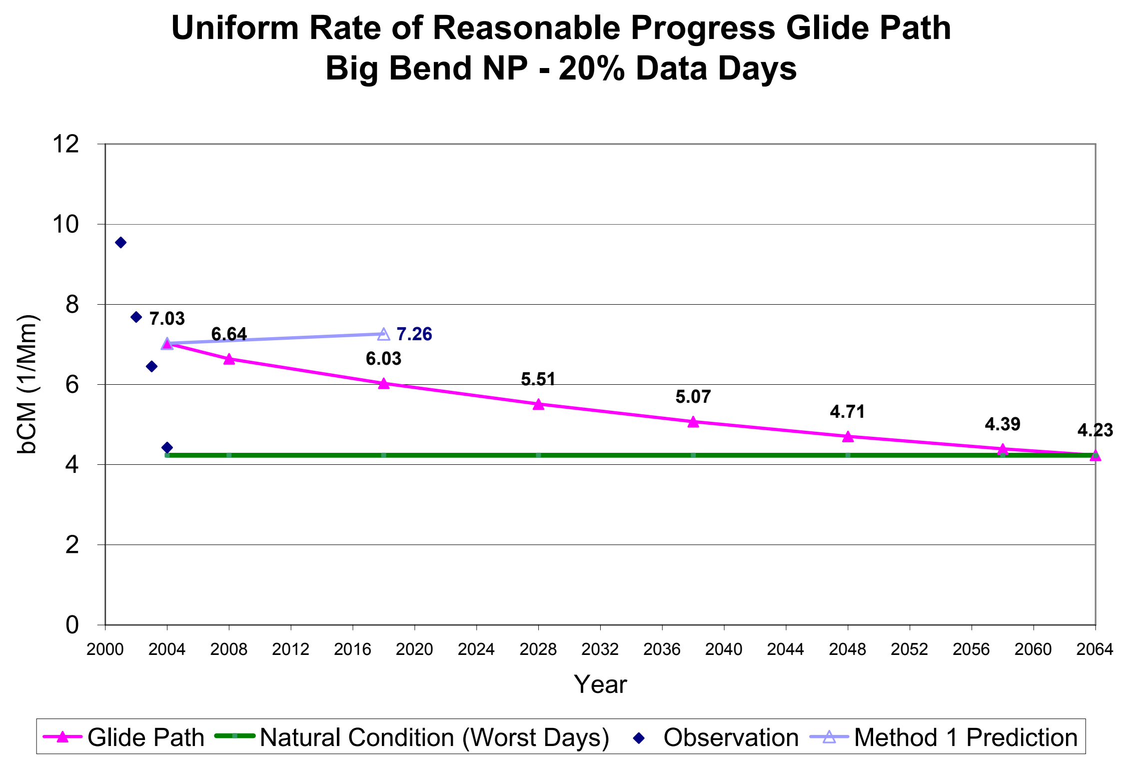


Figure F-9g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Big Bend (BIBE), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

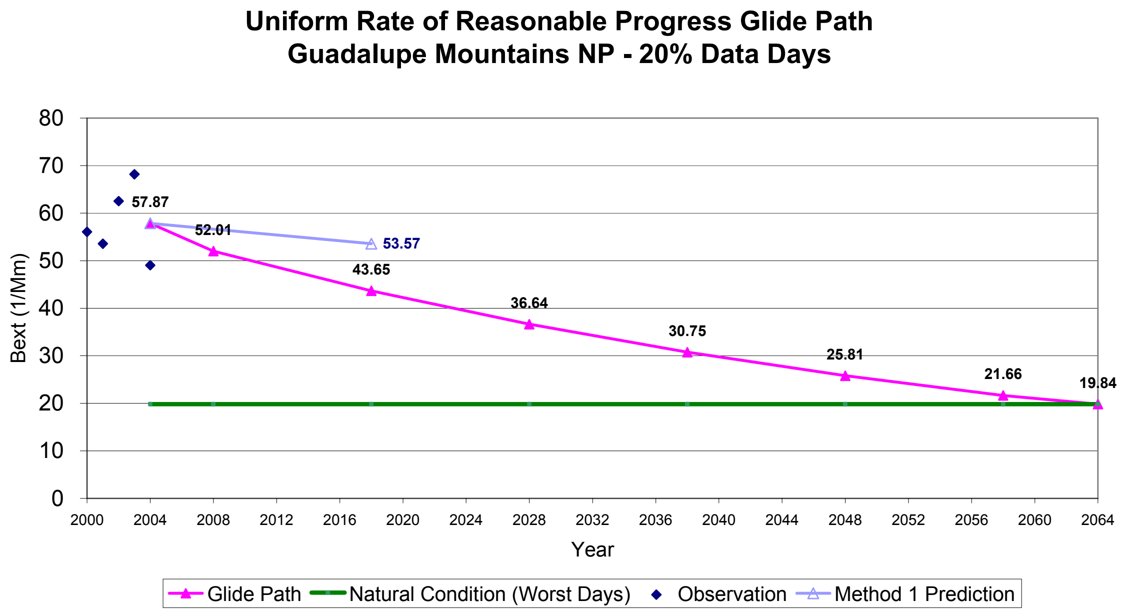


Figure F-10a. 2018 Visibility Projections and 2018 URP Glidepaths in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

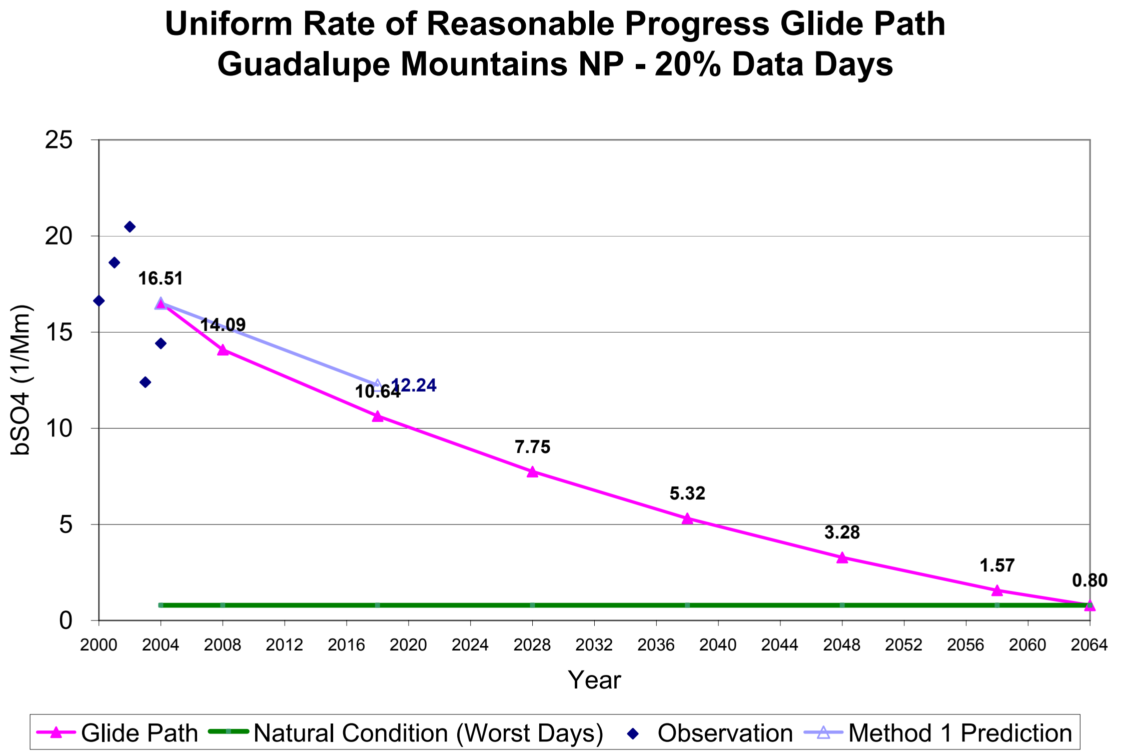


Figure F-10b. 2018 Visibility Projections and 2018 URP Glidepaths for Sulfate (SO4) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

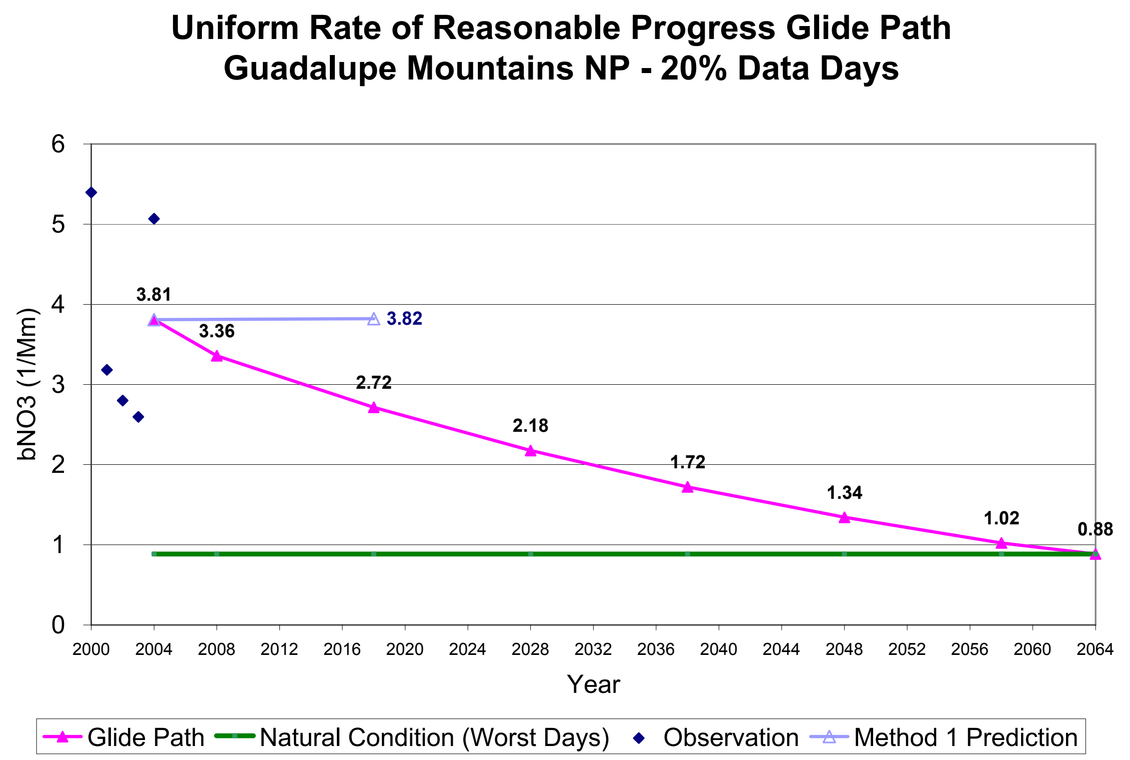


Figure F-10c. 2018 Visibility Projections and 2018 URP Glidepaths for Nitrate (NO3) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

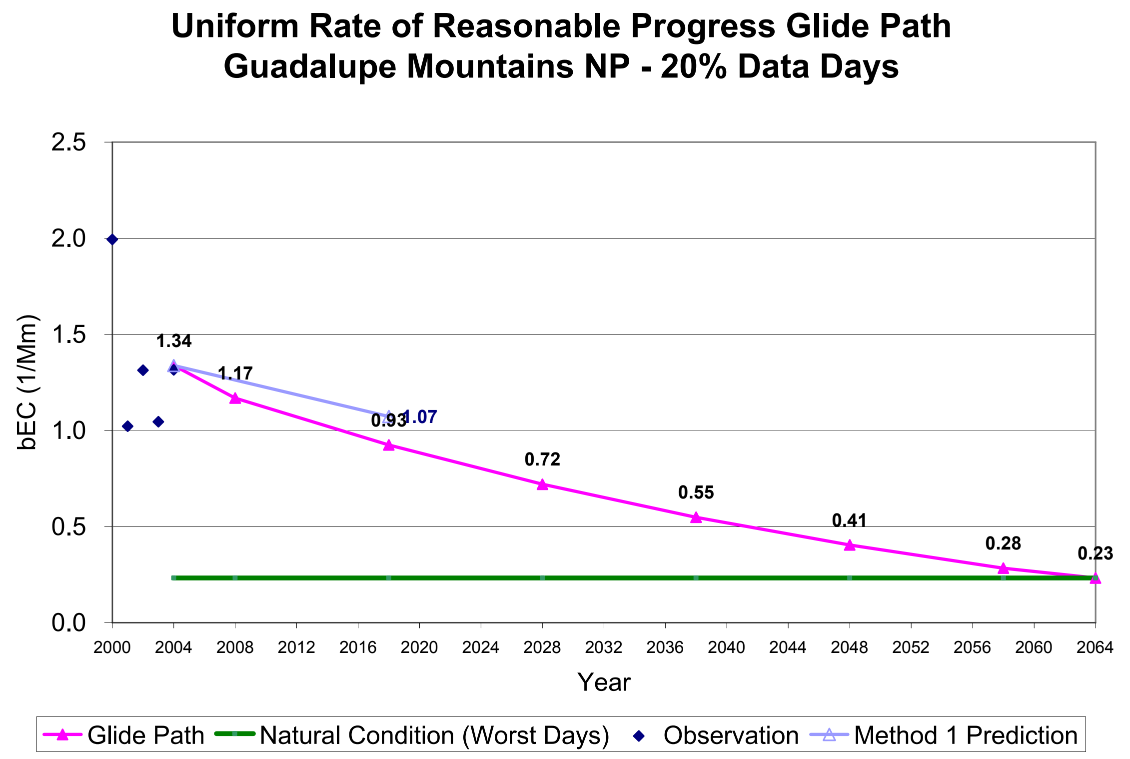
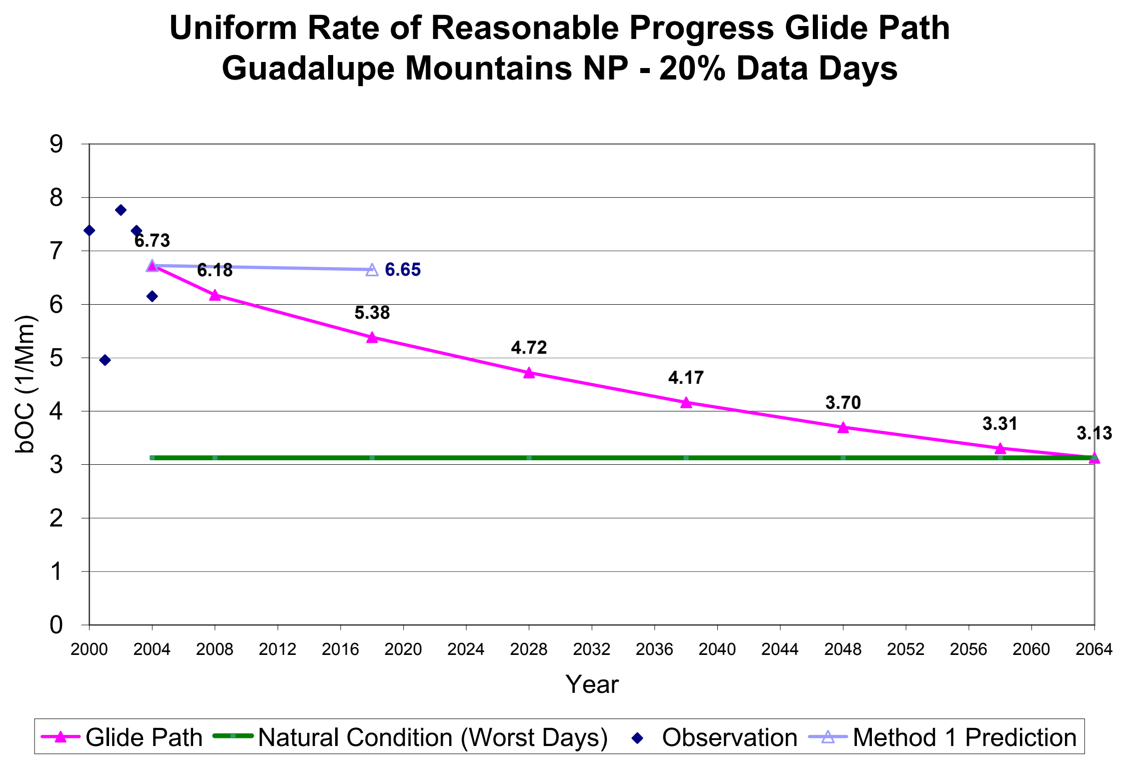
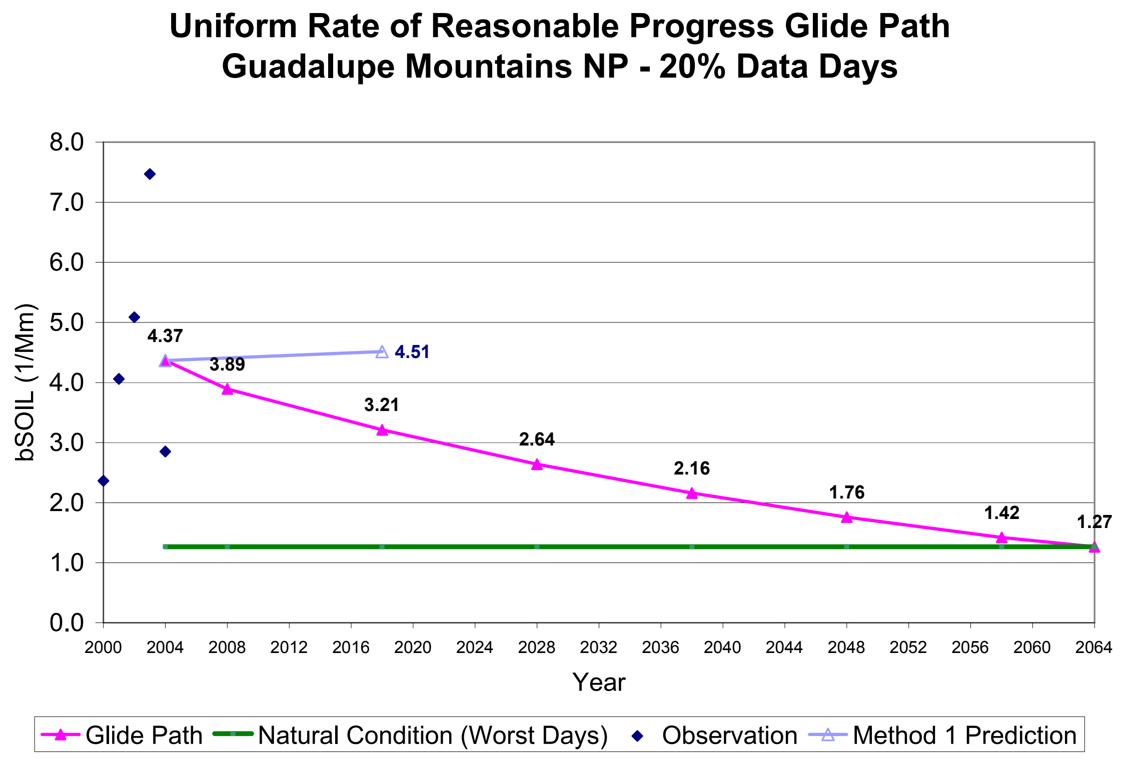


Figure F-10d. 2018 Visibility Projections and 2018 URP Glidepaths for Elemental Carbon (EC) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.



Uniform Rate of Reasonable Progress Glide Path
Guadalupe Mountains NP - 20% Data Days

Figure F-10e. 2018 Visibility Projections and 2018 URP Glidepaths for Organic Mass Carbon (OMC) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.



Uniform Rate of Reasonable Progress Glide Path
Guadalupe Mountains NP - 20% Data Days

Figure F-10f. 2018 Visibility Projections and 2018 URP Glidepaths for Other Fine Particulate (SOIL) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

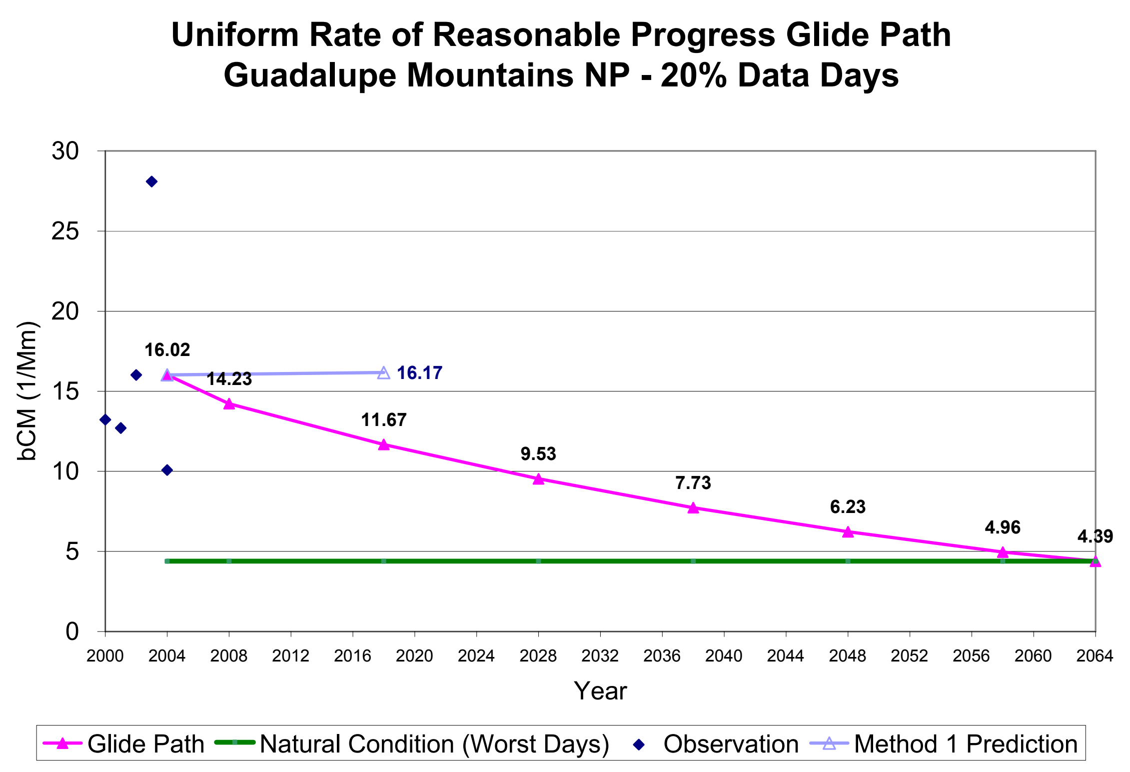


Figure F-10g. 2018 Visibility Projections and 2018 URP Glidepaths for Coarse Mass (CM) in extinction (Mm^{-1}) for Guadalupe Mountains (GUMO), Texas and Worst 20% (W20%) days using 2002/2018 Base G CMAQ 36 km modeling results.

APPENDIX 8

Appendix 8.1

Meteorological Model Performance Evaluation of an Annual 2002 MM5 (version 3.6.3) Simulation

Matthew T. Johnson
Iowa Department of Natural Resources

2004 - 2007

v2.0.4

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1. INTRODUCTION

1.1 BACKGROUND

Projects pursuing PM2.5, 8-hour ozone, and regional haze are generating modeling requirements at spatial and temporal scales only recently confronted within the regulatory air quality community. The scope of recent legislative and executive decisions has created the need to implement sophisticated models developed for regional scale multi-pollutant environments encompassing diverse climatological regimes. Computational limitations have historically bound the modeler's ability to investigate broad and complex scenarios with sufficient resolution. Exponential growth in computational efficiency has partially minimized this hurdle. As scientific theory and model complexity evolve, computational innovations remain moderately offset. Currently, a balance has been achieved which permits the development of large modeling databases such as annual continental scale simulations.

Annual continental scale air quality simulations require the implementation of a triumvirate modeling system composed of meteorological, emissions, and air quality models. Meteorological modeling is the first component addressed as meteorological data supports both the emissions and air quality models. In preparation for regulatory requirements involving regional haze, PM2.5, and ozone, the Iowa Department of Natural Resources (IDNR) developed a continental scale annual meteorological dataset designed for use in air quality applications. This document details the methods employed to create the annual meteorological simulation and provides performance evaluation results.

1.2 MODEL SELECTION

Due to scientific progression, historical application, community support, and availability, the Fifth Generation Penn State University/National Center for Atmospheric Research Mesoscale Model (MM5) was selected for the development of an annual meteorological dataset. Originally formulated in the 1970s at Penn State and first documented by Anthes and Warner (1978), the MM5 modeling system maintains its status as a state-of-the-science[1] model through enhancements provided by a broad user community (*e.g.* Chen and Dudhia, 2001; Dudhia, 1993; Stauffer and Seaman, 1990; Stauffer and Seaman, 1991; Xiu and Pleim, 2000). The MM5 modeling system is routinely employed in operational forecasting frameworks as well as research applications spanning meteorological disciplines from synoptic to mesoscale. Utilization of MM5 within air quality applications is also a conventional practice. The MM5 modeling system was recently selected to generate three continental scale annual simulations: 1996, 2001, and 2002. The 1996 and 2001 simulations were conducted through EPA contracts (Olerud et al., 2000; McNally, 2003). The 2002 simulation was conducted in support of regional haze modeling for the Visibility Improvement – State and Tribal Association of the Southeast (VISTAS) regional planning organization (RPO) (Olerud and Sims, 2004). This list is not exhaustive as both public and private organizations continue to pursue annual meteorological modeling episodes.

Additional information regarding MM5 is available at: http://www.mmm.ucar.edu/mm5/

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[1] True during project implementation. MM5 is no longer regularly updated as the focus has shifted to WRF.

2. SENSITIVITY PROJECTS

The MM5 modeling system consists of several pre-processors, the core prognostic model, and post-processing tools. Each component contains highly configurable control files; together they control the aspects of grid structure, first-guess fields, model physics, temporal operation, and ultimately results visualization. The inherit complexity of the MM5 modeling system complicates the development of a sound model configuration suitable for regional scale annual episode air quality applications. Although the complete matrix of configuration options reduces in size as inappropriate options are eliminated, a large matrix of potentially acceptable model configurations remains with most applications. The first step in developing the annual MM5 dataset was therefore completion of a series of sensitivities studies designed to identify the configuration yielding optimum results.

The first sensitivity study project began in 2002 and involved a collaborative project lead by Kirk Baker with the Lake Michigan Air Directors Consortium (LADCO) and Matthew Johnson (IDNR). Wyat Appel and Mike Abraczinskas with the North Carolina Division of Air Quality participated through the generation of a summary analysis for select sensitivity runs. The project was conducted in coordination with sensitivity work performed by Dennis McNally (with Alpine Geophysics). Components evaluated included, for example, PBL schemes, microphysical schemes, convective parameterizations, land surface parameterizations, and snow models. Two one-month long episodes were selected for evaluation, January and July of 2001. The performance evaluation of each sensitivity run included, but was not limited to, temperatures, wind vectors, cloud cover, precipitation, and mixing ratios.

Following the sensitivity study, the IDNR completed a 2002 annual simulation. This simulation utilized surface moisture and temperature nudging. Within implementation of the Pleim-Xiu (PX) land surface model (LSM), soil moisture and soil temperatures were modeled in continuum from one 5-day episode block to the next. The model performance evaluation revealed an extreme cold bias over the Central U.S. While unrelated to the cold bias, utilization of surface nudging techniques was abandoned following discussion with the modeling community, as this practice has lead to the generation of super-adiabatic lapse rates near the surface. The optimum IDNR/LADCO configuration was thus modified accordingly and this annual simulation was deemed unsuitable for use in air quality modeling projects.

In a similar timeframe, VISTAS contracted with Baron Advanced Meteorological Systems, LLC (BAMS) for the development of an annual MM5 dataset (Olerud and Sims, 2004). The work of VISTAS (through Olerud and Sims, 2004) also included a series of sensitivity studies. Independent results from the VISTAS project yielded findings similar to the conclusions reached by IDNR and LADCO. The compilation of all project results subsequently produced the configuration utilized by the IDNR in development of an annual metrological dataset suitable for regional scale air quality modeling.

3. MODELING SYSTEM CONFIGURATION

3.1 OVERVIEW

Version 3.6.3 of the MM5 modeling system was utilized in the second[1] (and final) 2002 IDNR annual meteorological simulation. The 3.6.3 release represented the most current version available at the time of project inception. Other than the necessary configuration parameters, no modeling system code modifications capable of altering results were rendered.

3.1.1 TERRAIN

The terrain processor is used to define grid structure and assign various surface features. Terrain elevation, the dominant landuse category, and vegetative and soil data were assigned using the 2-minute 24-category USGS data. The horizontal grid structure consists of a 36 km domain conforming to the RPO meteorological grid specifications. A nested 12 km grid was also included. The RPO 36 km meteorological domain consists of a Lambert Conic Conformal projection centered at 90º W longitude, 40º N latitude, with true latitudes of 33 and 45º N. The horizontal extent of the RPO domain was engineered according to the bounds of the Eta 212 grid. Domain development involved the implementation of TERRAIN through a series of sensitivity runs designed to extract the largest domain which remains within the borders of the Eta 212 grid. The 12 km grid was designed to achieve a balance between computational resources while maximizing coverage of Iowa-centric upwind and downwind flows. Both grid structures are described in Table 3.1 and depicted in Figure 3.1.

Table 3.1. Grid data, referencing MM5 terminology specifications refer to dot points.

Grid	Resolution (km)	NX	NY	Nest Location (x,y)	Southwest Coordinate (km offset)
1	36	165	129	1,1	(-2952, -2304)
2	12	193	199	66,30	(-612, -1260)

3.1.2 PREGRID/REGRIDDER

The PREGRID processor prepares archived gridded meteorological data for use within MM5 through conversion to an intermediate data format readable by MM5. REGRIDDER invokes a horizontal interpolation scheme to translate data to the MM5 domain. The 3-hour Eta analysis and surface fields (ds609.2) were used to supply initial and boundary conditions to MM5. As the Eta analysis fields obtained from NCAR are a compressed (tar) file, the data were first uncompressed prior to use within PREGRID. The tar files also include the undesirable 12 hourly cold start files. All cold start files (*.tm12) were deleted prior to running PREGRID.

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[1] The first simulation was deemed unsuitable for use in air quality modeling projects and has been deleted.

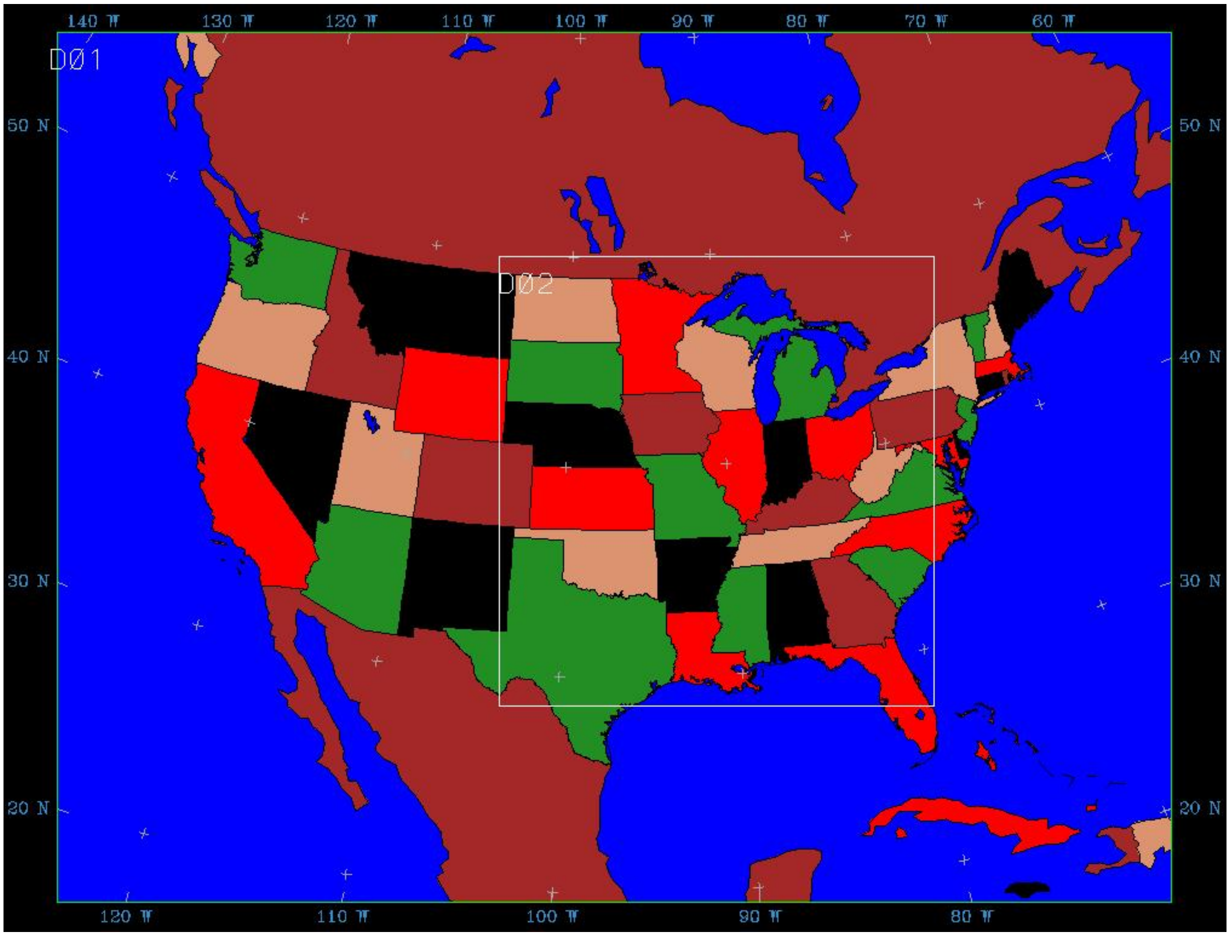

Figure 3.1. Twelve and 36 km domains utilized in the IDNR 2002 MM5v363 annual simulation.

In the first IDNR 2002 MM5 simulation, NCEP data was included in PREGRID to supply time-variant sea-surface temperature (SST) data, as the Eta surface files supply only a time-invariant SST approximation known as skin-temperature. Upon further examination of SST data sources, the temporally variable NCEP SST data was found to lead to unrealistic diurnal temperature profiles over the Great Lakes and near shorelines. Figure 3.2 shows the NCEP-based Great Lakes SSTs for July 4, 2002, at 12 and 18Z. Over this 6-hour span, temperature fluctuations over many areas of the Great Lakes (particularly Lake Erie, and most shorelines) reach 20° F. While some variability is expected along shorelines and other shallow areas, the magnitudes observed through use of the NCEP data are unrealistic. Observed SST data from buoy 45007 (located in the southern end of Lake Michigan yet far removed from the shoreline, see Figure 3.3) for the period July 4 – July 9 are provided in Figure 3.4. The maximum temperature variation throughout July 4 at this site was less than 3° F. Figure 3.5 depicts the 5-day SST timeseries produced using the NCEP SST data within REGRIDDER for the 36 km grid cell corresponding to the location of buoy 45007. The NCEP data yields a diurnal temperature range of approximately 7° F in this cell on July 4. The NCEP data also generates unrealistic diurnal profiles with a net upward trend in SST over this five-day period. In contrast, the observed data show less variability and a downward trend in SST. Utilization of the Eta skin-temperature data produces the constant SST boundary conditions shown in Figure 3.6. The corresponding Eta skin-temperature for the location of buoy 45007 is ~294 K. While this yields warmer surface temperatures than observed throughout the July 4 – July 9 period, no questionable diurnal variability or artificial warming trends are present.

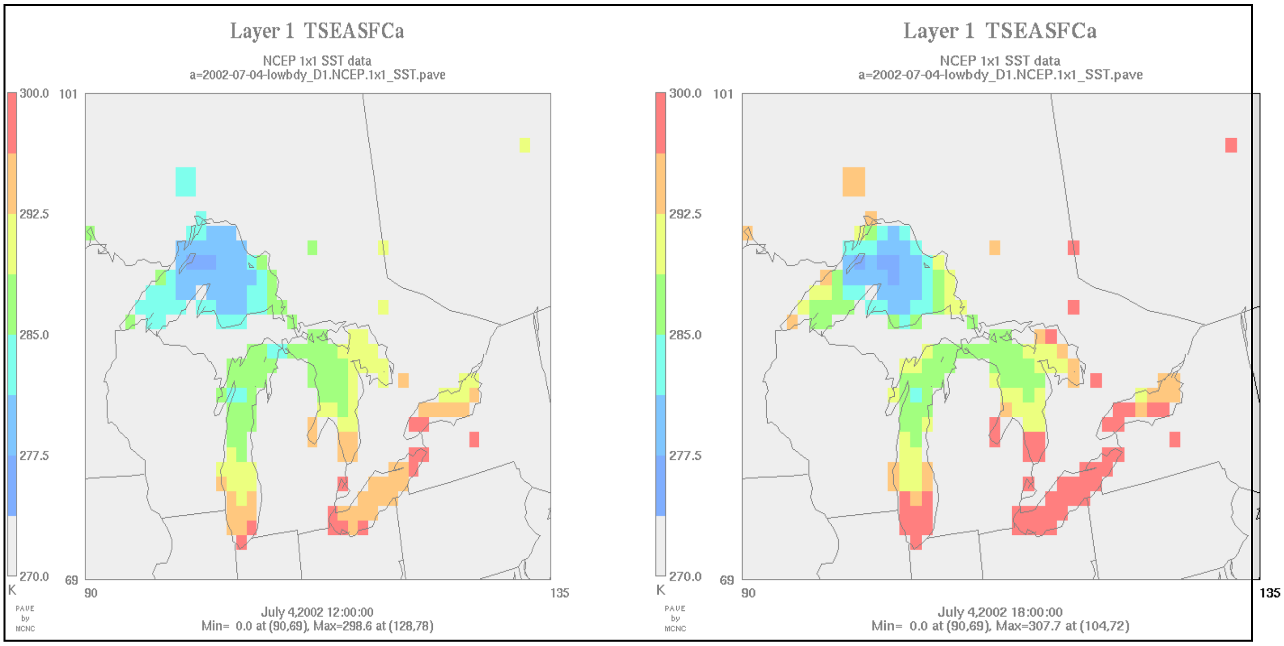

Figure 3.2. Lake temperature variability across a 6 hour span, from 12Z 7/4/2002 to 18Z 7/4/2002, using the NCEP SST data.

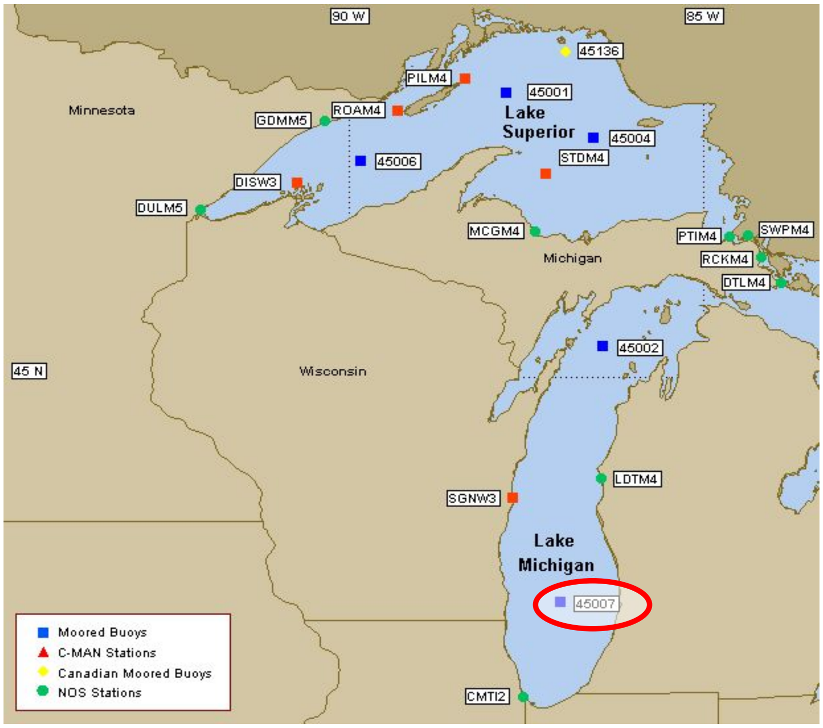

Figure 3.3. Great Lake buoy locations.

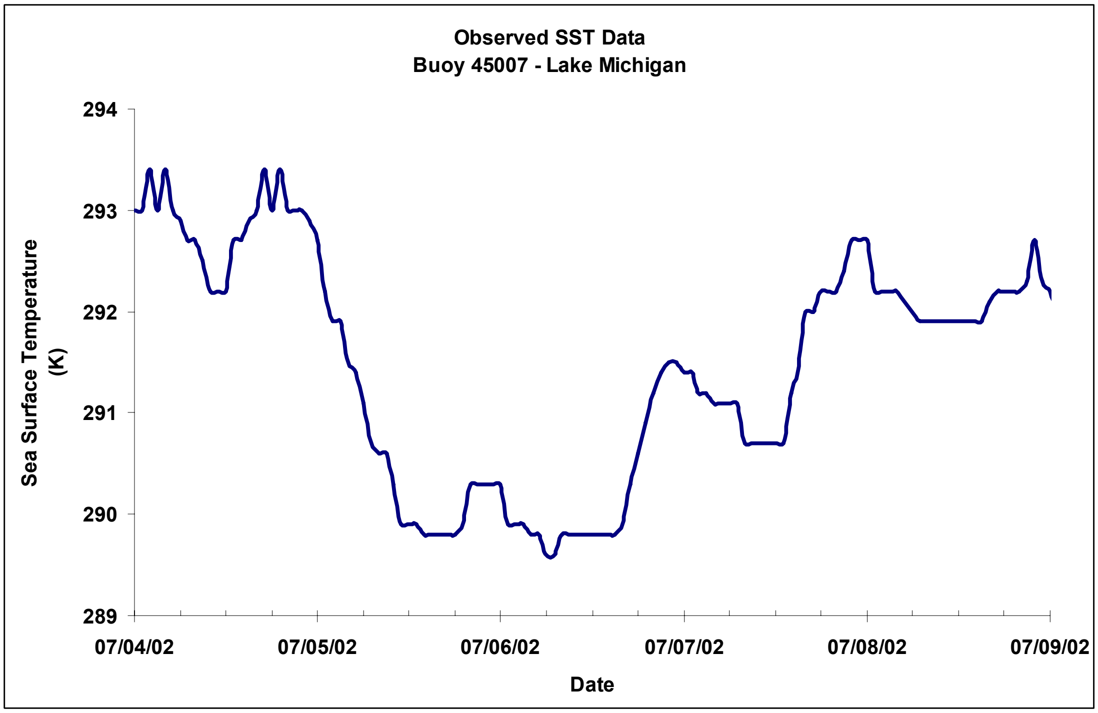

Figure 3.4 Observed SST temperature data for buoy 45007.

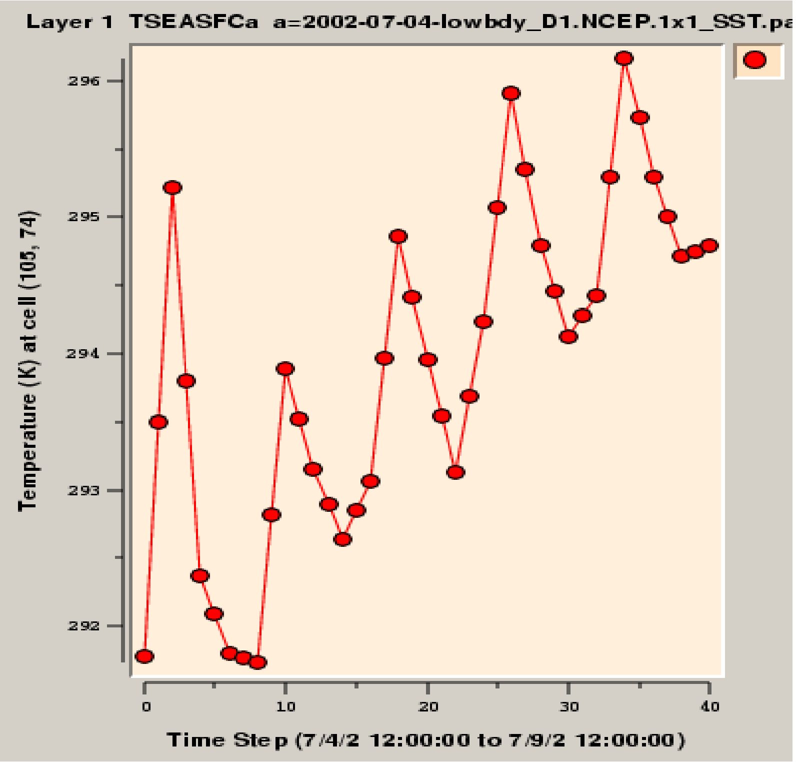

Figure 3.5 NCEP derived SST profile for the grid cell corresponding to the location of buoy 45007.

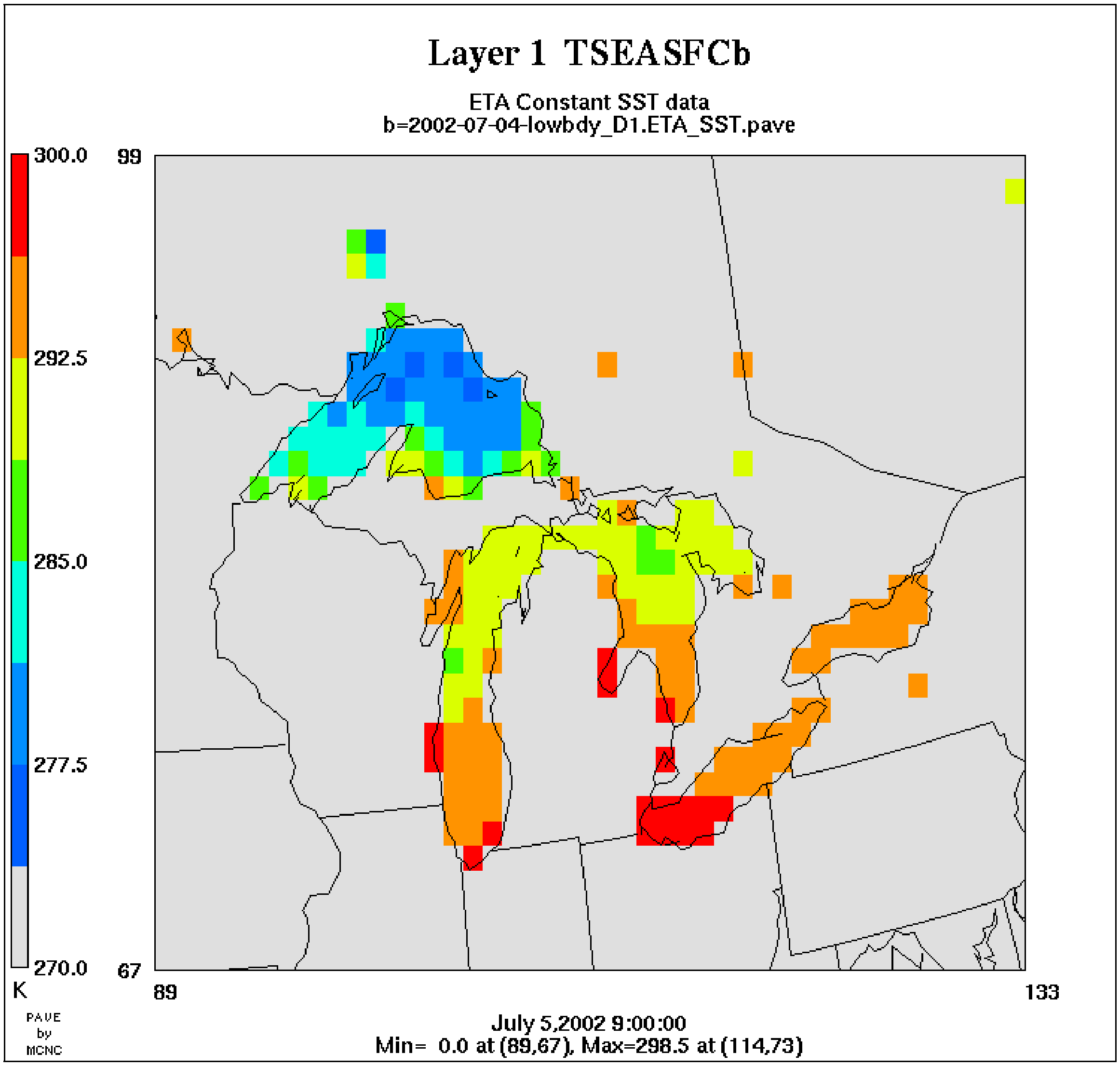

Figure 3.6. Constant SST data derived from Eta skin-temperatures for the period 12Z 7/4/2002 through12Z 7/9/2002.

3.1.3 LIITLE_R

LITTLE_R was originally designed to improve the REGRIDDER output by using objective analysis techniques to blend observational data into the gridded first-guess fields. Following traditional practices, the NWS upper air (ds353.4) and surface (ds464.0) datasets supply the observations. As the Eta fields already contain these NWS datasets, the implementation of LITTLE_R is viewed as partially redundant. However, LITTLE_R also generates the files used in both the four-dimensional data assimilation (FDDA) and Pleim-Xiu soil moisture nudging schemes and therefore must be invoked. The implementation of LITTLE_R does not negatively affect model performance when the Eta surface and analysis data provide the first-guess fields (Baker, 2002).

3.1.4 INTERPF

The IDNR 2002MM5v363 simulation uses a 34 vertical layer structure defined through the INTERPF preprocessor. The layer interfaces, provided in Table 3.2, were designed through coordination with Dennis McNally to parallel the vertical structure in use by EPA. INTERPF interpolates the pressure level data developed in the previous preprocessors to MM5's native vertical system - terrain following sigma coordinates. Sigma levels are defined according to Eq. 3.1, where p_s equals the surface pressure, and p_t equals the pressure at model top. The model top was defined at 100 mb, or approximately 14,662 meters above ground level. Approximate sigma heights are calculated using Eqs. 3.1 – 3.3, with the user-defined variables assigned the following values: $p_s = 1000$ mb; $p_t = 100$ mb; $T_s = 275$ K; A = 50 K. R and g represent the gas and gravitational constants of 287 J/(kg K) and 9.8 m/s^2, respectively.

$$\sigma = \frac{p - p_t}{p_s - p_t} \quad (3.1)$$

$$p = \sigma \cdot (p_s - p_t) + p_t \quad (3.2)$$

$$z = -\left[\frac{R \cdot A}{2g} \cdot \ln\left(\frac{p}{p_s}\right)^2 + \frac{R \cdot T_s}{g} \ln\left(\frac{p}{p_s}\right) \right] \quad (3.3)$$

Table 3.2. Details of the 34-layer vertical structure.

Level	Sigma	Height (m)	p (mb)	Depth (m)
34	0.000	14662	100	1841
33	0.050	12822	145	1466
32	0.100	11356	190	1228
31	0.150	10127	235	1062
30	0.200	9066	280	939
29	0.250	8127	325	843
28	0.300	7284	370	767
27	0.350	6517	415	704
26	0.400	5812	460	652
25	0.450	5160	505	607
24	0.500	4553	550	569
23	0.550	3984	595	536
22	0.600	3448	640	506
21	0.650	2942	685	480
20	0.700	2462	730	367
19	0.740	2095	766	266
18	0.770	1828	793	259
17	0.800	1569	820	169
16	0.820	1400	838	166
15	0.840	1235	856	163
14	0.860	1071	874	160
13	0.880	911	892	158
12	0.900	753	910	78
11	0.910	675	919	77
10	0.920	598	928	77
9	0.930	521	937	76
8	0.940	445	946	76
7	0.950	369	955	75
6	0.960	294	964	74
5	0.970	220	973	74
4	0.980	146	982	37
3	0.985	109	987	37
2	0.990	73	991	36
1	0.995	36	996	36
0	1.000	0	1000	0

3.2 MM5

An overview of the physics parameterization configuration used in the IDNR 2002MM5v363 simulation is provided in Table 3.3. As previously discussed, the configuration emerges from the cumulative efforts of several sensitivity studies, in combination with guidance from the Ad-Hoc Meteorological Modeling community. In comparison with the original IDNR 2002 simulation, the cessation of continuous soil field techniques within the PX LSM is one of the most notable modifications.[1] With the PX LSM no longer restricted to sequential operation, the annual simulation was generated from 95 independent simulations initialized at 12Z and integrated through five days (versus 5-day blocks arranged in quarterly sequential simulations in the original run). This temporal structure allows maximum air quality modeling flexibility as photochemical simulations can be initialized using midnight local time or midnight GMT without the need to split any given 24-hour period across multiple MM5 simulation blocks. While this methodology does increase the number of runs required to complete an annual simulation (versus initialization at 00Z with a 5.5 day run time), the increased computational requirements are not prohibitive. An example of the temporal structure is provided in Appendix A. To allow for approximately a two week photochemical model spin-up period, the simulation started at 12/16/2001 12Z. The completion date occurred at 12Z on 1/1/2003. A 90 second timestep was used with output written every hour. The output files were split every 24 hours to simplify the post-processing (and photochemical pre-processing) stages.

Table 3.3 Description of the options selected within the IDNR 2002 annual MM5v363 run.

Option	Configuration	Details
Microphysics	Mixed-Phase (Reisner I)	
Cumulus Scheme	Kain-Fritsch 2	
PBL	Asymmetric Convective Model *	Required by Pleim-Xiu LSM
Radiation	RRTM	Calculated every 15 minutes
Land Surface Model	Pleim-Xiu	No continuous soil fields
Shallow Convection	Not enabled	
SST Data source	Eta Skin-Temperature	
Snow Cover Effects	Considered	IFSNOW=1
Timestep	90 seconds	(PX uses an internal 40s timestep)

*The Asymmetric Convective Model (ACM) is also referred to as the Pleim-Chang PBL. The ACM parameterization is a derivative of the Blackadar scheme (Pleim and Chang, 1992).

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[1] While discussion of the complete list of configuration variability between the original and 2020MM5v363 simulations is beyond the scope of this document, additional key updates include: the abandonment of NCEP SST data in favor of Eta-Skin temperatures; the addition of the 12 km domain; use of a more recent modeling system release; and a new temporal structure.

Additional configuration details include the following: Sea surface temperatures remained constant during the simulation as Eta skin temperatures were used as surrogate sea surface temperatures. Snow cover effects were considered. Analysis nudging of the temperature, mixing ratio, and wind fields was applied above the PBL. At the surface only the wind field was nudged. The default nudging strengths of 2.5 x 10^{-4} and 1.0 x 10^{-4} were used for the temperature and wind fields at 36 and 12 km, respectively. A nudging coefficient of 1.5 x 10^{-5} was established for the mixing ratios at both 36 and 12 km. The rotational wind field was not nudged, nor were observational nudging techniques applied. Optimal observational nudging methods require a station density not available across a continental scale annual simulation.

Referencing Baker et al. (2004) the following details are provided:

> Vertical moisture and temperature advection are set to use linear interpolation. Other options incorporated include: moist vertical diffusion in clouds, temperature advection using potential temperature, diffusion using perturbation temperature, and an upper radiative boundary condition. The Pleim-Xiu land surface module requires the addition of three variables in the MM5 deck: ISMRD, NUDGE, and IFGROW. ISMRD was set to use soil moisture fields from the ETA analyses. NUDGE was assigned to adjust the soil moisture data to the analyses fields. Finally, IFGROW was set to option 2, which takes vegetative growth into account based on vegetative fraction data from the TERRAIN file.

The configuration of the 12 km grid pictured in Figure 3.1 closely resembles the 36 km grid methodology. The explicit exceptions include a decrease in the wind and temperature nudging strengths. While the terminology is questionable, the nesting technique employed is commonly referred to as "a two-way nested run without feedback". In this method, the 12 km model solution is not feed back to the master domain, but the grids are run simultaneously to allow the fine grid to receive boundary condition updates at every timestep.

3.3 COMPUTATIONAL SUMMARY

Seven dual CPU Linux workstations were acquired to complete the annual simulation. Six machines were equipped with dual 3.06 GHz Intel Pentium Xeon processors, with the final machine a dual 2.0 GHz processor. Each machine[1] was equipped with 2 Gb of RAM, and Ultra 320 SCSI local hard drives for model I/O. Upon completion of each run, output data was transferred via NFS to a SCSI-IDE RAID array. In summation, 41 wall-clock days were required to complete the annual simulation. This represents each machine computing two independent simulations simultaneously (essentially each CPU was tasked with one simulation at any given time). Open MP was not an available option due to the implementation of PX. Approximately 100 wall-clock hours was required for a 3.06 GHz machine to complete two simulations running simultaneously. Storage requirements reached 1.1 terabytes, with the 36 km simulation occupying 400 Gb and the 12 km data using 700 Gb.

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[1] The 2.0 GHz machine had only 1 Gb of onboard RAM.

4. MODEL PERFORMANCE EVALUATION

4.1 BACKGROUND

No rigid guidelines exist for systematically and objectively evaluating the quality of meteorological simulations. However, sound comprehensive philosophies exist. A seven point approach outlined by Tesche (1994) provides the framework for a thorough model performance evaluation. The framework can be classified into two components: an operational evaluation and a scientific evaluation (Emery and Tai, 2001). The scientific evaluation requires rigorous examinations of model formulation and algorithm development, methods beyond the scope of most modeling projects. Historical development and applications of MM5 within the scientific community (including air quality and prognostic projects published through peer-reviewed journal articles) must then serve to support the scientific evaluation. Thus the performance evaluation of the IDNR 2002MM5v363 annual simulation will focus upon operational criteria.

4.2 METHODS

Climatic variability, complex mesoscale meteorological phenomena, and scientific unknowns contribute to meteorological modeling difficulties and force modelers to take a subjective approach to model performance. Objective statistical measures which offer a quantitative model assessment exist, but implementation of the metrics is subjective to a degree. For example, defining the area over which domain averaged metrics are calculated is a subjective decision, buffered only through guidelines. In general, metrics averaged over large meteorological modeling domain are avoided, as error cancellation dilutes relevance. Conversely, splitting the modeling domain into small subdomains renders sample sizes unrepresentative. The logical approach falls well within the bounds of the extremes, leaving optimum subdomain definition open to interpretation. As one means of addressing the issue, a subjective grid decomposition technique was applied, resulting in the twelve rectangular[1] subdomains pictured in Figure 4.1.

Model performance measures must also minimally include a review of upper air features in tandem with surface statistics. Upper air features are key variables in terms of air quality modeling given the importance of fields such as three dimension wind flows and PBL depths. Evaluation of the upper atmosphere also introduces a level of complexity exceeding the difficulty associated with assessing surface features. The sheer volume of upper air model data, in combination with a relatively sparse observing network gathering only twice daily soundings, creates problems in terms of scale. A limited set of data analysis tools also restricts the review process. In an attempt to achieve a balance between available resources and the level of detailed review, the upper air evaluation includes review of PBL features and focuses upon observed versus modeled soundings. To improve the efficiency and simplify the review of soundings, a new software tool was developed in-house: RAOBPLOT. In the final aspect of the upper air evaluation, an independent review of precipitation prediction, conducted by Kirk Baker, is briefly summarized. While technically a surface feature, the precipitation evaluation indirectly enhances the upper air review given the three dimensional nature of precipitation events.

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[1] Processing requirements necessitated that subdomains be simple rectangles defined only through a southwest and northeast grid coordinate.

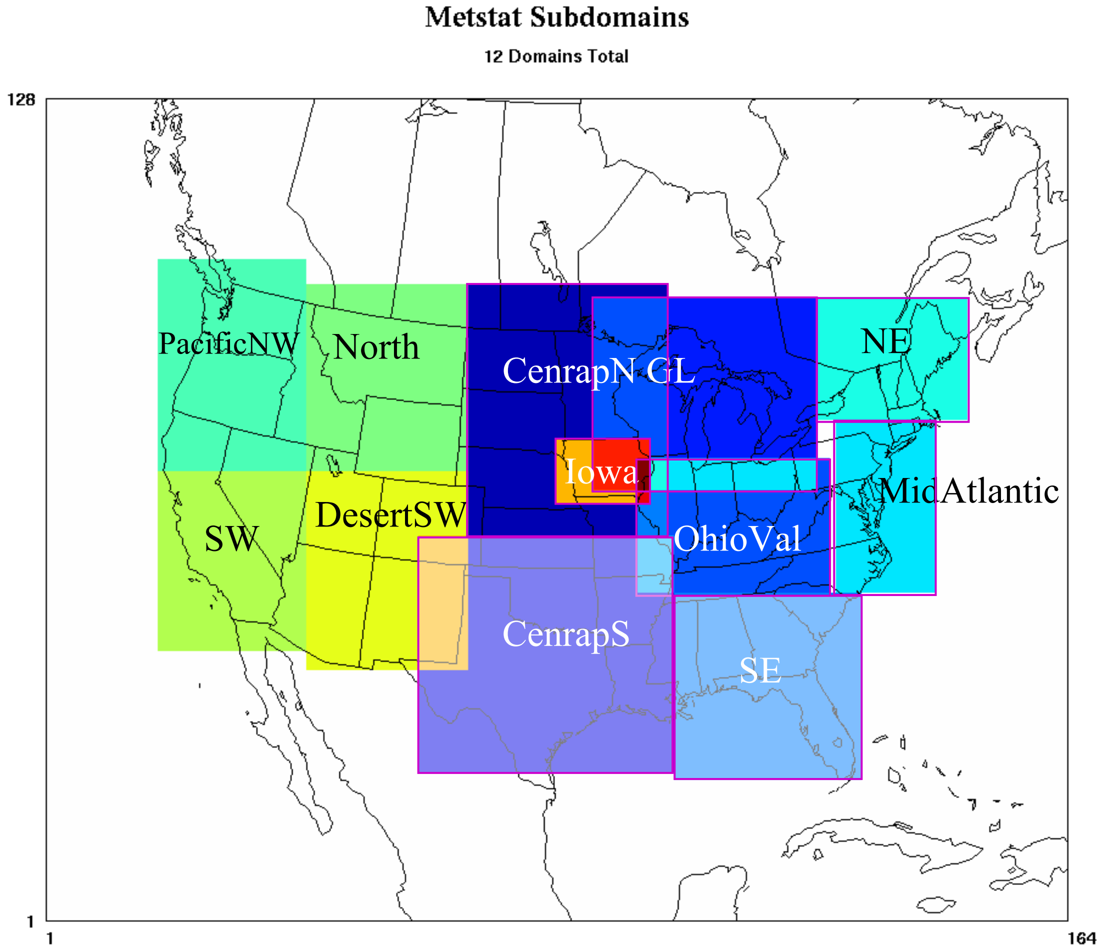

Figure 4.1. Decomposition of the continental scale MM5 domain into simple rectangular subregions designed for targeted model performance evaluation. Areas of overlap are shaded differently and outlines have been added to highlight individual subdomain boundaries.

4.3 STATISTICAL MEASURES

Within the statistical degrees of freedom available to the meteorological modeler, a subset of standard statistical measures has emerged, outlined in Table 4.1. These metrics are calculated based upon data contained within a given subdomain (See Figure 4.1). Metrics are calculated using hourly and daily averages. While no strict criteria establishing acceptable model performance exist, the general guidelines established by Emery and Tai (2001) provide a community adopted frame of reference. A summary of the guidelines is provided in Table 4.2.

Table 4.1. List of statistical measures commonly discussed in meteorological model evaluations. The DH designation represents that both daily and hourly averaged values are calculated for a particular metric. Conversely, D or H indicates that the value is available only on a daily or hourly average, respectively.

Statistical Measure	Wind Speed	Wind Direction	Temperature	Humidity
Obs. vs Predicted Timeline	DH	DH	DH	DH
Bias	DH	DH	DH	DH
Gross Error	D	D	D	D
Total RMSE	DH		DH	DH
Systematic RMSE	DH		DH	DH
Unsystematic RMSE	DH		DH	DH
Index of Agreement	DH		DH	DH

Table 4.2. Guidelines for meteorological model performance. Source: ***Meteorological Modeling and Performance Evaluation of the September 13-20, 1999 Ozone Episode*** *(Emery and Tai, 2001). Data pertain to daily averaged values.*

Wind Speed	Wind Direction	Temperature	Humidity
RMSE ≤ 2 m/s	Gross Error ≤ 30 deg	Gross Error ≤ 2 K	Gross Error ≤ 2 g/kg
Mean Bias ≤ ±0.5 m/s	Mean Bias ≤± 10 deg	Mean Bias ≤ ±0.5 K	Mean Bias ≤ ±1 g/kg
IOA ≥ 0.6		IOA ≥ 0.8	IOA ≥ 0.6

An overview of the significance for each metric is provided by Baker et al. (2004):

> "*Bias error* (bias) is the degree of correspondence between the mean prediction and the mean observation, with lower numbers indicative of better performance. Values less than 0 indicate under-prediction. The *gross error*, or mean absolute error, is the mean of the absolute value of the residuals from a fitted statistical model. Lower numbers indicate better model performance.
>
> *Root Mean Square Error* (RMSE) is a good overall measure of model performance. The weighting of (prediction-observation) by its square tends to inflate RMSE, particularly when extreme values are present. With respect to a good model the root mean square error should approach zero. RMSE can be divided into a systematic and unsystematic component by least-squares regression. Since differences described by systematic RMSE can be described by a linear function, they should be relatively easy to dampen by a new parameterization of the model. Unsystematic RMSE can be interpreted as a measure of potential accuracy or noise level (Emery et al., 2001). With respect to a good model the systematic difference should approach zero while the unsystematic difference approaches RMSE.

> *Index of Agreement* is a relative measure of the degree of which predictions are error-free. The denominator accounts for the model's deviation from the mean of the observations as well as to the observations deviation from their mean. It does not provide information regarding systematic and unsystematic errors. The index of agreement approaches one when model performance is best."

The basis of the statistical analysis if formed through a comparison of the modeled fields with the Techniques Data Laboratory U.S. and Canada surface hourly observations (ds472.0). Hourly and daily averaged bias, error, RMSE (total, systematic, and unsystematic), and index of agreement metrics for wind speed, wind direction, temperature and humidity were generated using the Metstat program and MS Excel post-processing macro developed by Environ. Time series of modeled and observed conditions were also prepared via Metstat. As continental-scale domain averaged statistical measures are susceptible to error cancellation, metrics were calculated over the twelve subdomains illustrated in Fig. 4.1.

The volume of data associated with the annual simulation can quickly overwhelm standard time series displays or similar attempts at numerical data presentation. As a solution Kirk Baker developed and ingenious method of data display. PAVE is used to plot daily metrics, aligned vertically by month, and horizontally by date. This allows for an annual graphical display of daily averaged metrics in a single plot, simplifying the identification of error trends or pervasive biases. Even with this method of simplification, a detailed discussion of all twelve subdomains becomes excessive. The statistical analysis therefore focuses upon those regions encompassing the CENRAP and Midwest RPO states, primarily the regions: CenrapN, CenrapS, GL (Great Lakes), OhioVal (Ohio Valley), and Iowa.

5. SURFACE EVALUATION (36 KM)

The daily averaged metrics described below are provided graphically in the form of a "Bakergram". The Bakergram, developed by Kirk Baker, allows for the meaningful depiction of an annual set of daily averaged statistical values in a single plot. For example, Figure 5.1 consists of a compilation of four Bakergrams, one each for the wind speed bias, wind speed error, wind direction bias, and wind direction error. Focusing on the wind speed bias Bakergram in Figure 5.1 (top left), 365 daily averaged metrics are provided. Twelve columns are provided, which each column containing a monthly dataset. The individual days are provided in rows, with the first of the month displayed at the top, with days descending from top to bottom. The concept is repeated (for example, see Figure 5.2) with temperature and mixing ratio metrics plotted.

5.1 GREAT LAKES

In previous sensitivity studies, the Pleim-Chang/Pleim-Xiu PBL/LSM configuration was found to improve wind vector performance versus the use of alterative PBL parameterizations. Consistent with this discovery, the wind vector performance in the GL region is encouraging. Wind speed metrics are generally favorable, and no clear trends in error or bias are evident (see Figure 5.1). A notable caveat, daily metrics may hide inconsistencies occurring within the diurnal profile.[1] Turning to the wind direction evaluation, again results are satisfactory, with one exception found, an increase in the summertime gross error.

In the Great Lakes region, the problems of greatest concern lie in the winter time cold temperature biases, the warm summertime biases, and the summertime positive moisture biases (See Figure 5.2). Examining the temperature biases from a diurnal[2] perspective, the warm bias is predominantly caused by nighttime temperatures remaining warmer than observed. The cold wintertime temperature bias is often traced to underpredicted high temperatures, evening temperatures falling too rapidly, and nighttime lows often colder than observed. Caution should be exercised when generalizing the wintertime bias trends though, as exceptions are more abundant than with the summertime warm biases. Turning to the mixing ratio (humidity) evaluation (see Figure 5.2), although the gross error metrics are generally within the statistical guidelines, the summertime positive bias is a concerning trend. Only on rare occasions do negative biases occur. The likely culprit is MM5's tendency to overpredict precipitation.

5.2 NORTHERN AND SOUTHERN CENRAP

In general, the statistical evaluation for the CenrapN subdomain (Figures 5.3 - 5.4) yields results similar to the Great Lakes region. A notable exception being the nearly consistently negatively biased wind speeds. Examining the wind speed bias in greater detail (through diurnal profiles), this fault is predominantly influenced by the underprediction in the daily peak wind speeds. Keeping these errors in perspective, the magnitude of the underprediction typically remains below 1 m/s. Examining the mixing ratio performance, the most serious issue remains the abundance of summertime surface moisture. While arguable trivial, CenrapN does differ from the GL subdomain during May, where several surface moisture underpredictions occur.

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[1] Diurnal metrics are examined in Chapter 6.

[2] Ibid.

Turning to the Southern CENRAP subdomain (Figures 5.5 - 5.6), wind direction performance remains encouraging, similar to the performance for the CenrapN and GL regions. As found in CenrapN, wind speeds are generally negatively biased, but more pronounced in this region. The mixing ratio biases reveal excess moisture, although a drier than observed fall was predicted. Examining temperature performance, late winter/early spring temperatures yielded positively biased trends, in contrast to the pervasive cold winter biases found in the CenrapN and GL regions. Examination of the diurnal profiles revealed the biases were attributable to warm nighttime lows.

5.3 OHIO VALLEY

Once again, the wind speeds are generally too low, however, the associated error is well within the acceptable guidelines. Wind directions errors are also generally small, but an increase in error is found in the summer months. Mixing ratios are consistently too moist, except in the mid-October timeframe. As in the Great Lakes regions, a cold winter bias is found, while summer temperatures remain too warm (predominantly over the nighttime hours). The results are depicted in Figures 5.7 - 5.8.

5.4 IOWA

Within the Iowa subdomain wind vector performance is favorable, with wind speed bias and error measures predominantly meeting the statistical goals. Wind directions exhibit greater errors in the late summer/early fall timeframe versus the CenrapN and GL subdomains, but are not cause for severe alarm (see Figure 5.9). As is common, cold winter and warm summer biases are present (Figure 5.10). In terms of the moisture bias, the Iowa domain exhibits greater springtime negative moisture bias versus CenrapN, otherwise similar performance is shown (this result is not unexpected, given the superposition of the Iowa subdomain over CenrapN).

5.5 EASTERN REGIONS

A detailed discussion of model performance for all areas is beyond the scope of this document. Alternatively, summary remarks are provided. Over the MidAtlantic, no serious abnormalities are found beyond the errors identified previously in Central U.S. subdomains. As is common to MM5, a positive moisture bias exists, affecting both the MidAtlantic and SE regions. Examining the NE region, wind speed, and wind direction errors approach the upper extreme of acceptable performance. Again, the moisture bias is positively biased, with errors maximized over the summer months. Given moisture carrying capacity is a non-linear function of temperature, the relatively small mixing ratio gross errors occurring in the wintertime of regions with colder climates should not be interpreted as superior model performance. The daily averaged statistical results are provided in Appendix B for each of the individual Eastern subregions.

5.6 WESTERN REGIONS

The daily averaged statistical results for the western subdomains are also provided in Appendix B. The complex topography found in the Western United States clearly introduces a degree of modeling difficulty not found in other regions. Performance metrics are discouraging when viewed initially, however, the appropriateness of the statistical measures are questionable as model resolution is not designed to capture the topographically induced near-field flows affecting many of the local observations.

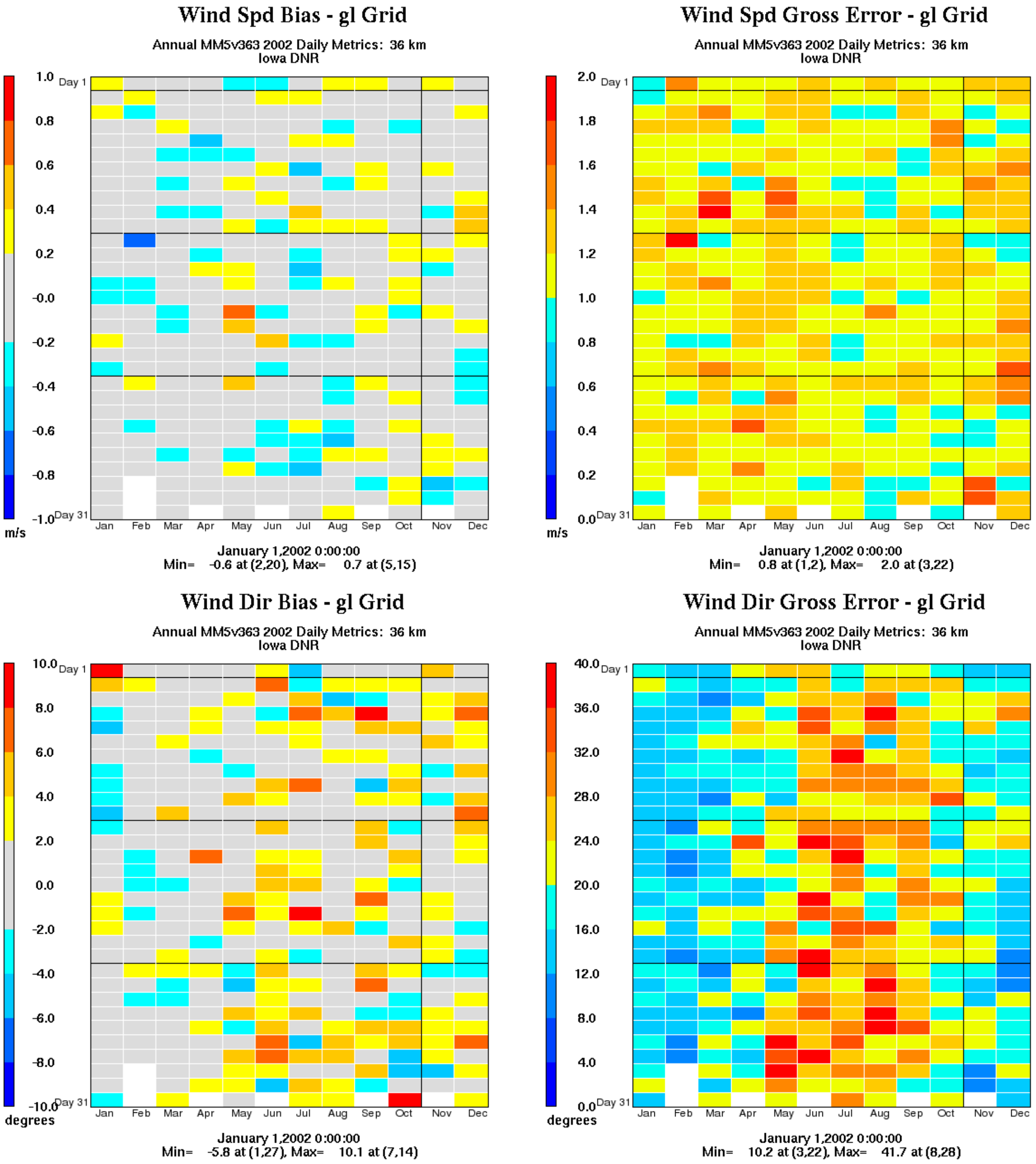


Figure 5.1. Daily averaged wind speed/direction metrics for the Great Lakes (GL) subdomain.

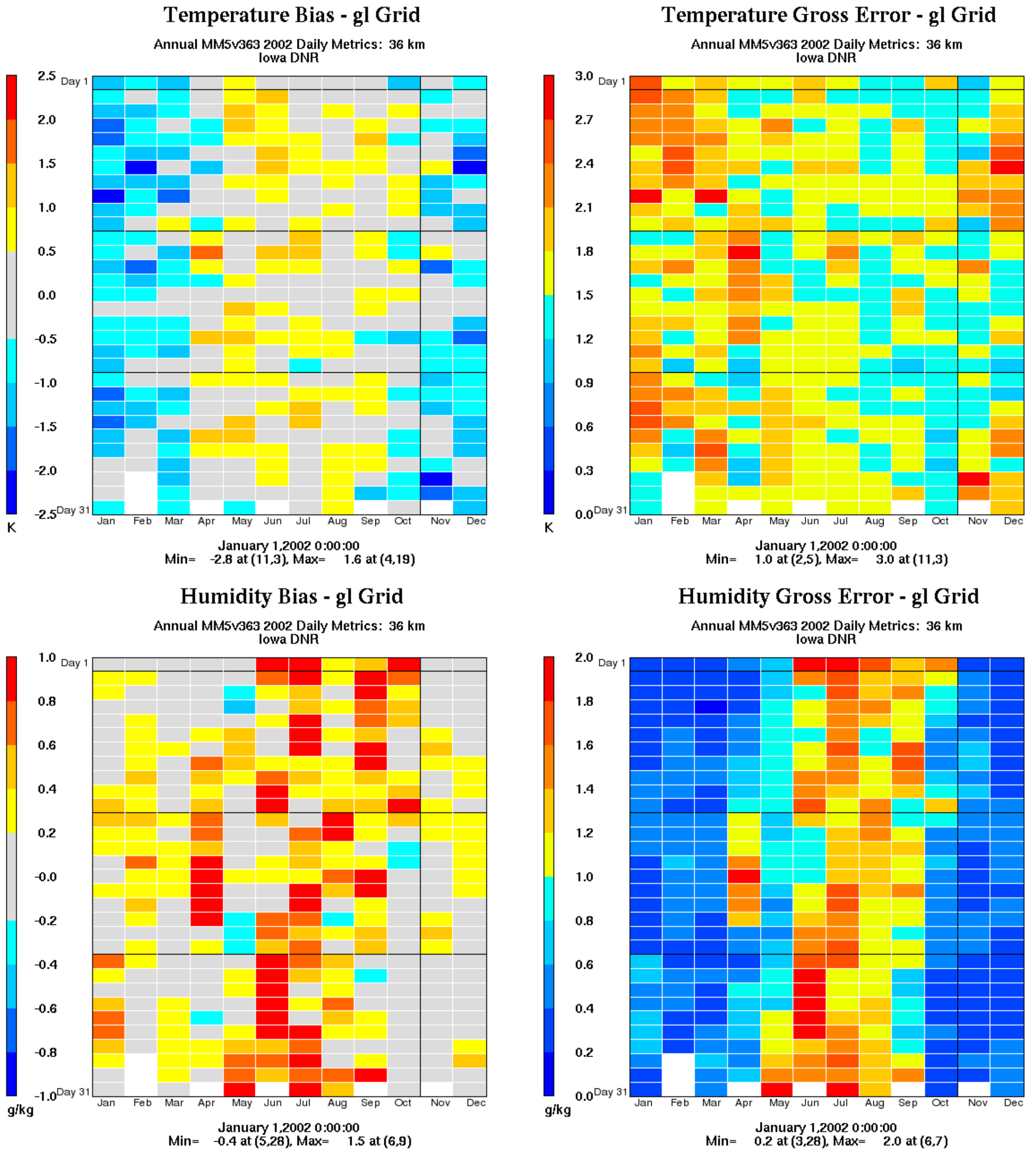
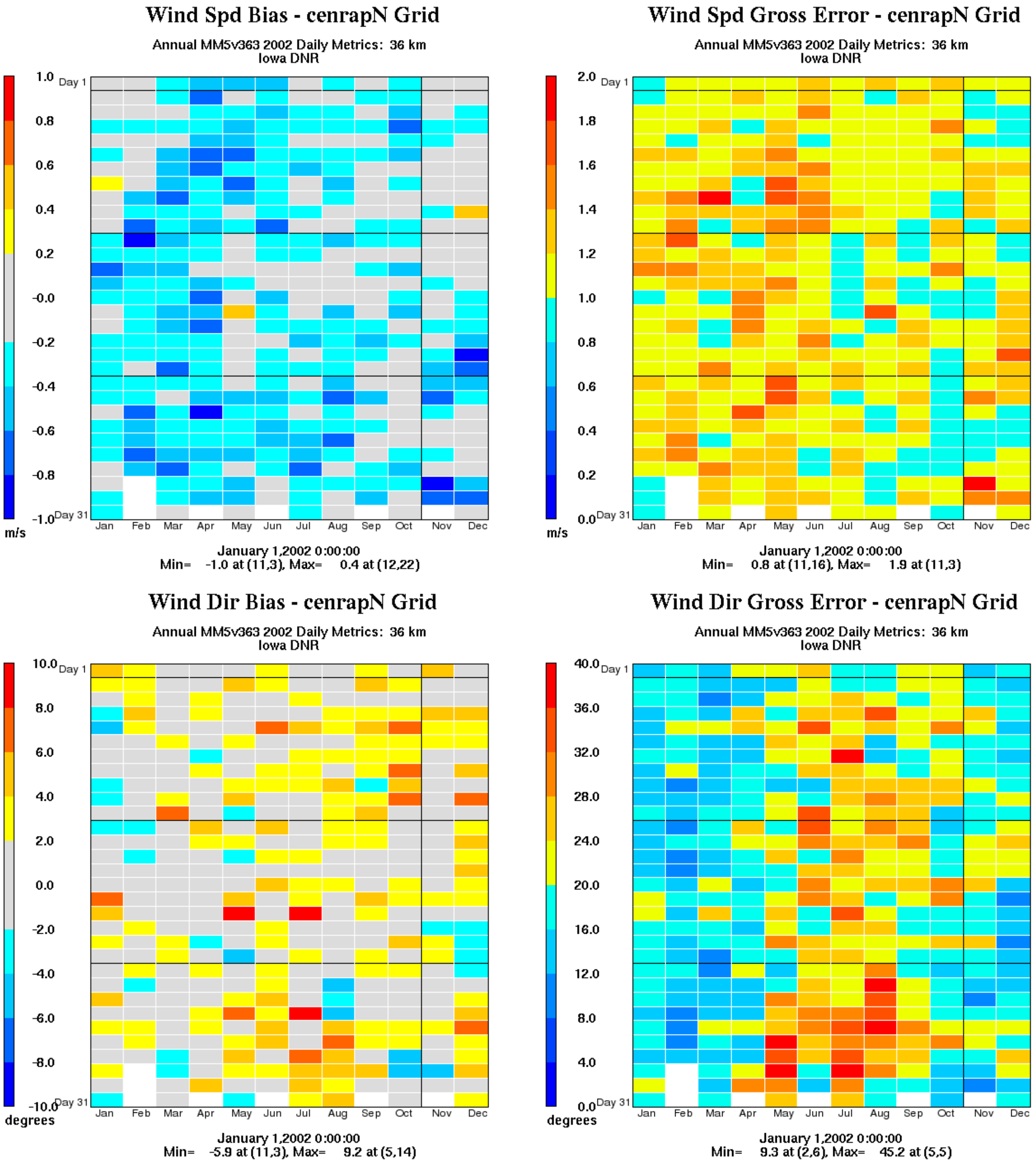


Figure 5.2. Daily averaged temperature and mixing ratio metrics for the Great Lakes (GL) subdomain.



Wind Spd Bias - cenrapN Grid

Wind Spd Gross Error - cenrapN Grid

Wind Dir Bias - cenrapN Grid

Wind Dir Gross Error - cenrapN Grid

Figure 5.3. Daily averaged wind speed/direction metrics for the CenrapN subdomain.

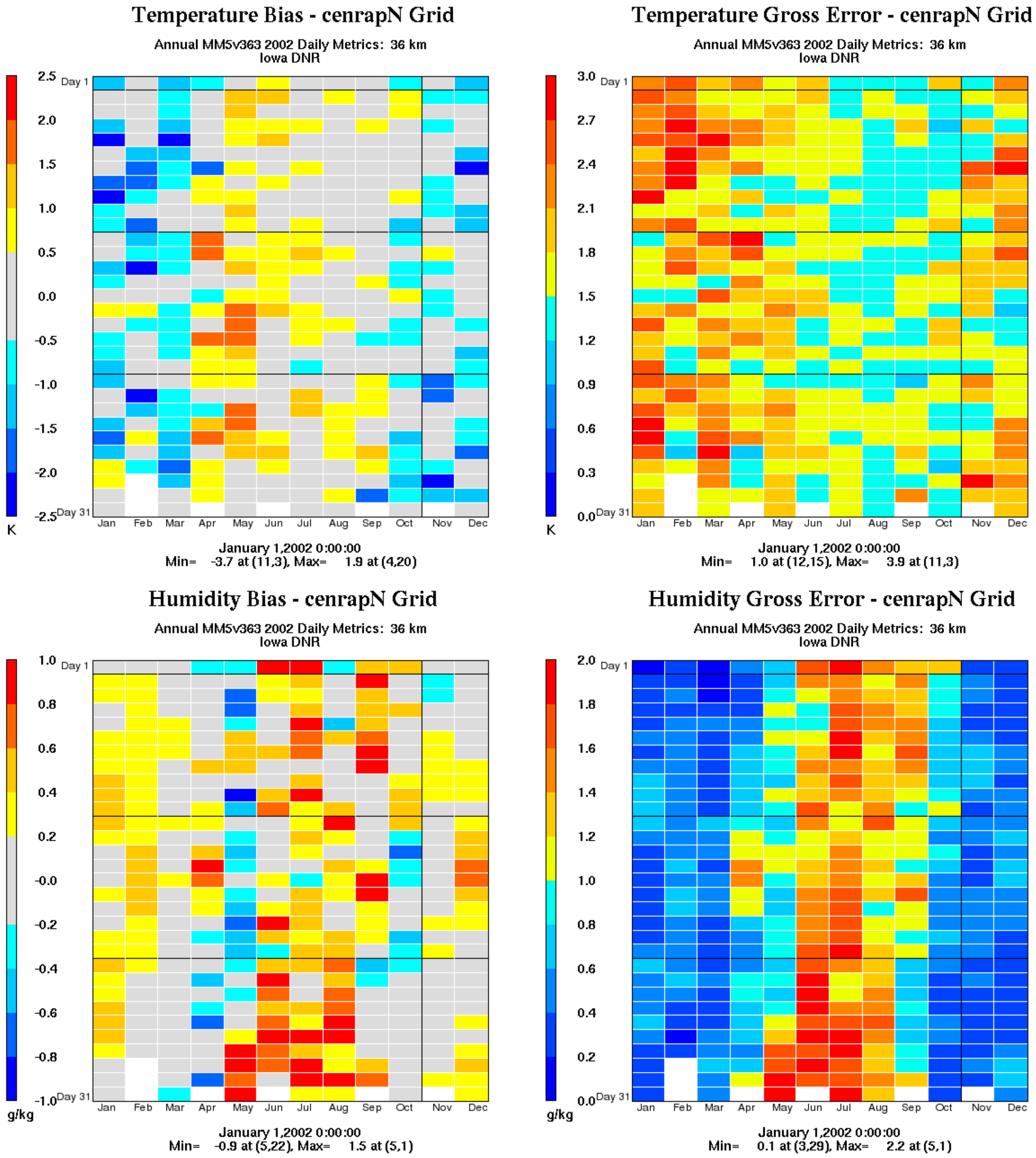


Figure 5.4. Daily averaged temperature and mixing ratio metrics for the CenrapN subdomain.

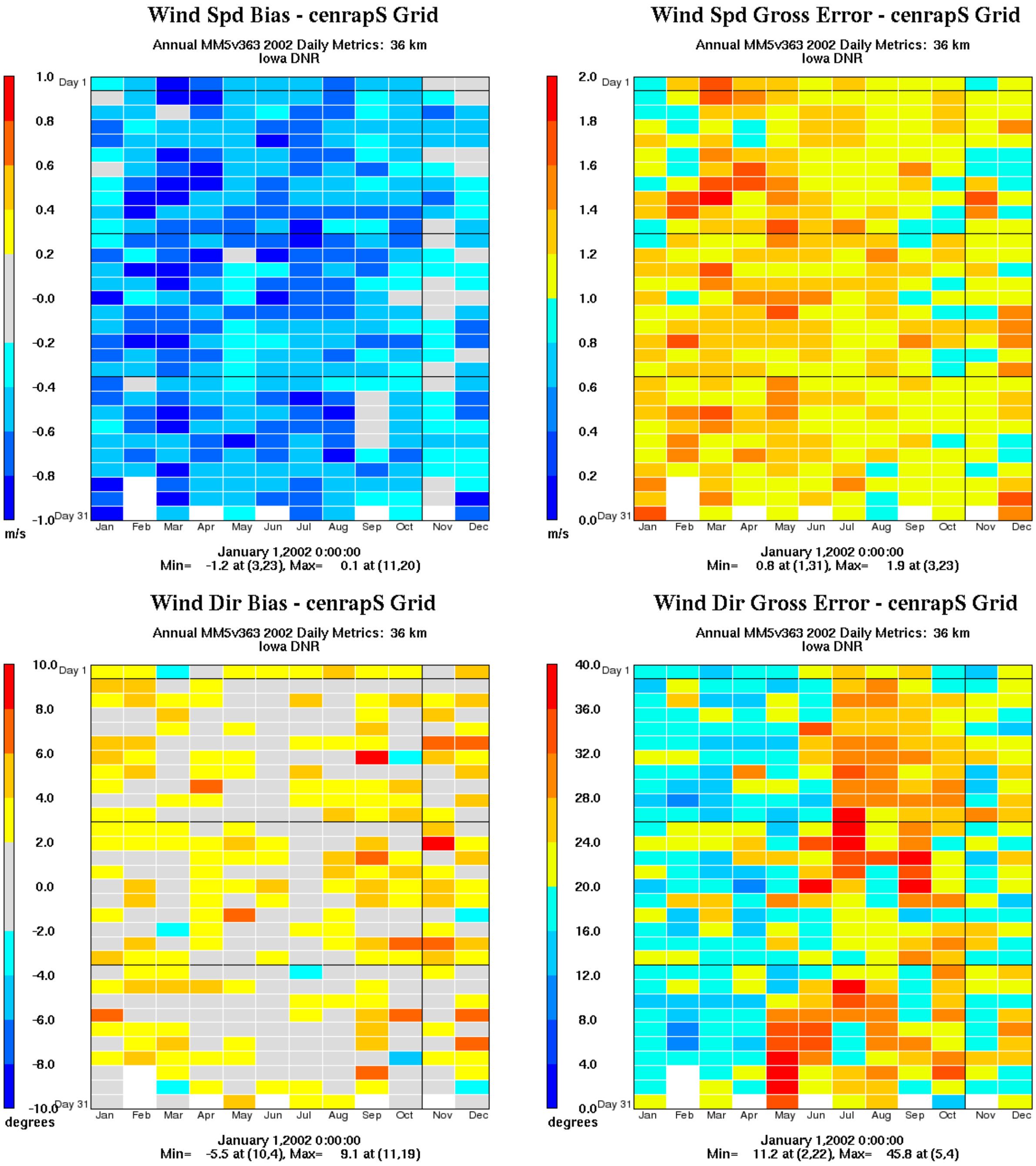
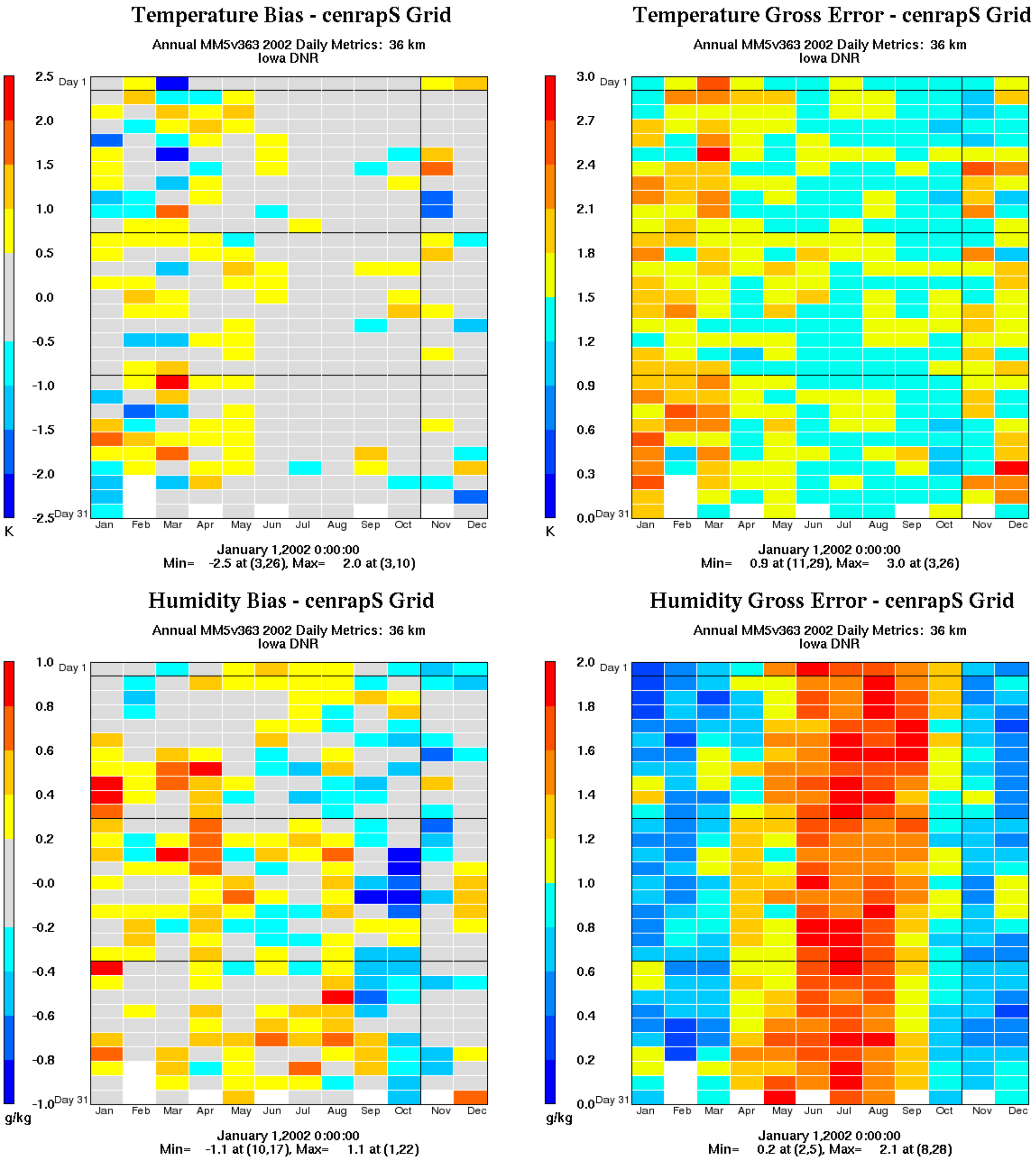


Figure 5.5. Daily averaged wind speed/direction metrics for the CenrapS subdomain



Temperature Bias - cenrapS Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -2.5 at (3,26), Max= 2.0 at (3,10)

Temperature Gross Error - cenrapS Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 0.9 at (11,29), Max= 3.0 at (3,26)

Humidity Bias - cenrapS Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -1.1 at (10,17), Max= 1.1 at (1,22)

Humidity Gross Error - cenrapS Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 0.2 at (2,5), Max= 2.1 at (8,28)

Figure 5.6. Daily averaged temperature and mixing ratio metrics for the CenrapS subdomain.

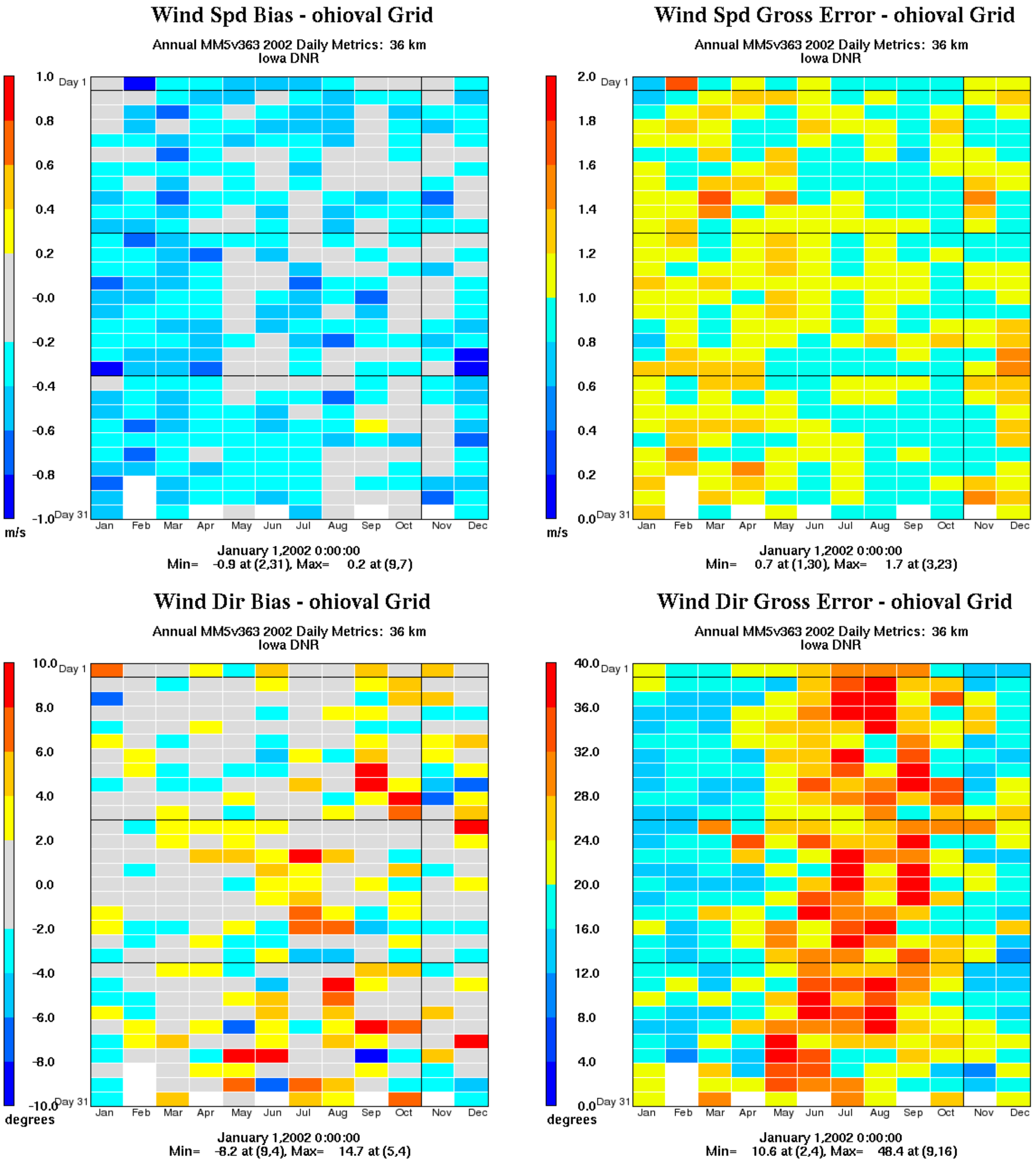
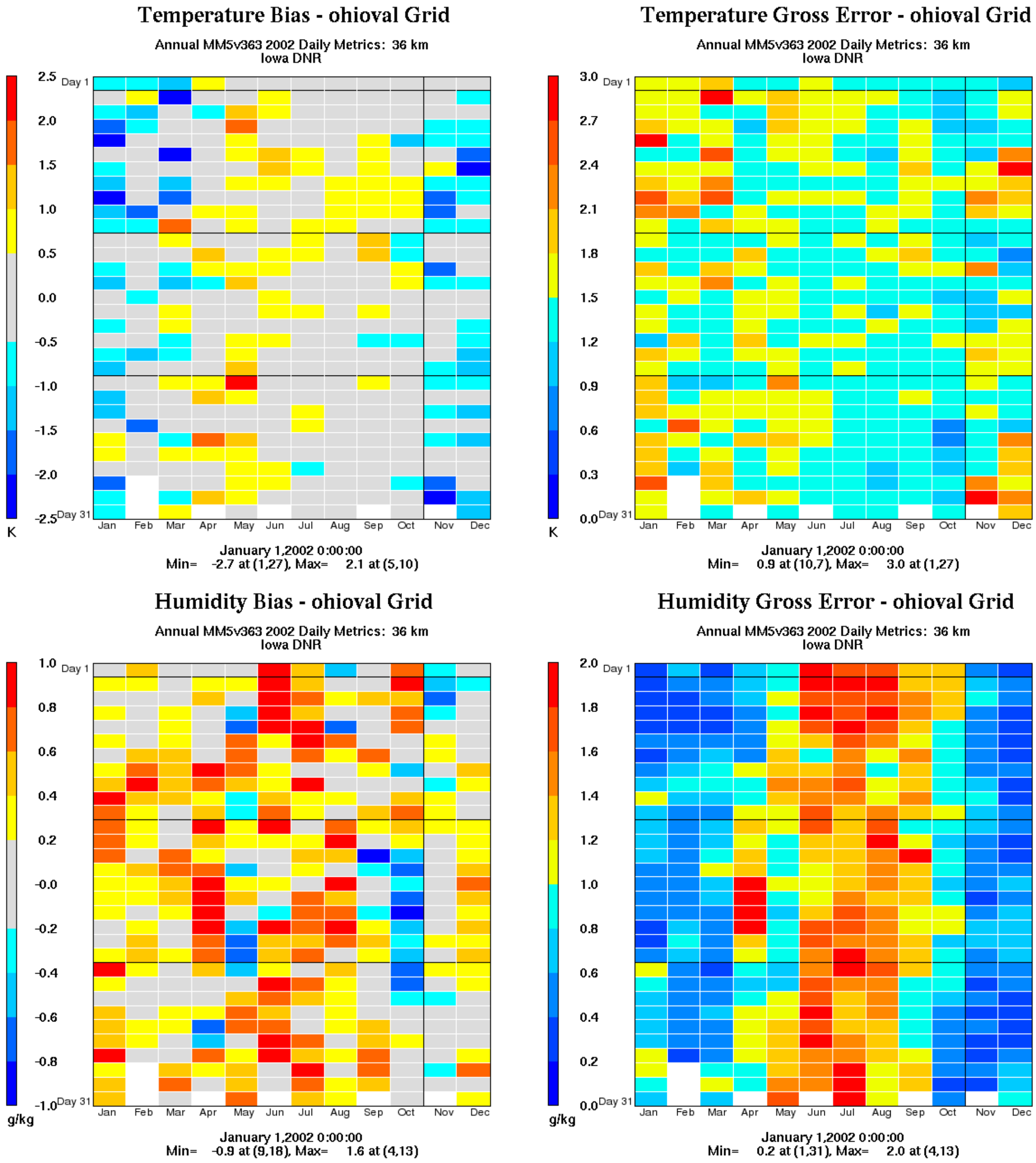


Figure 5.7. Daily averaged wind speed/direction metrics for the OhioVal subdomain.

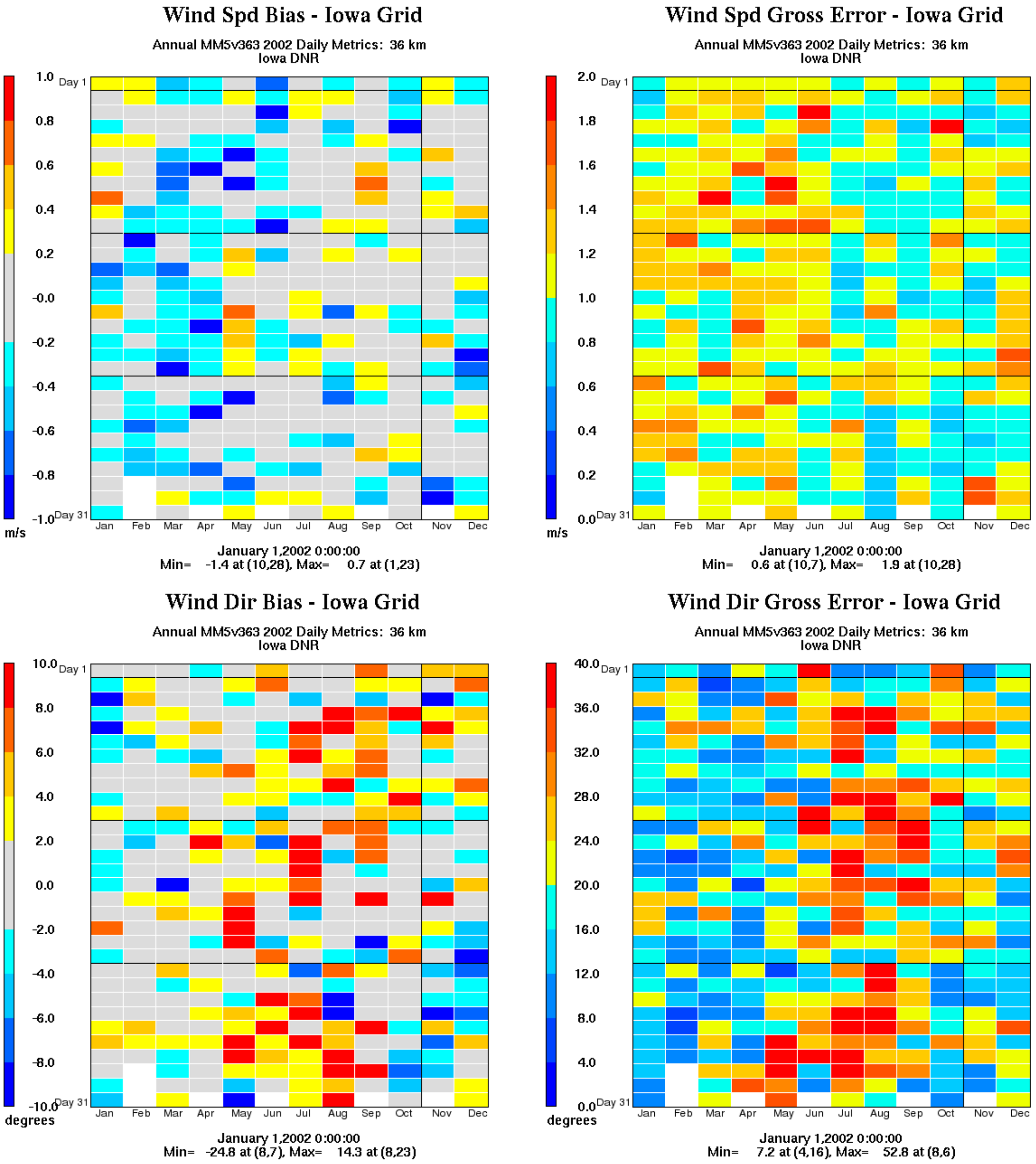

Temperature Bias - ohioval Grid

Temperature Gross Error - ohioval Grid

Humidity Bias - ohioval Grid

Humidity Gross Error - ohioval Grid

Figure 5.8. Daily averaged temperature and mixing ratio metrics for the OhioVal subdomain.



Wind Spd Bias - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -1.4 at (10,28), Max= 0.7 at (1,23)

Wind Spd Gross Error - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 0.6 at (10,7), Max= 1.9 at (10,28)

Wind Dir Bias - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

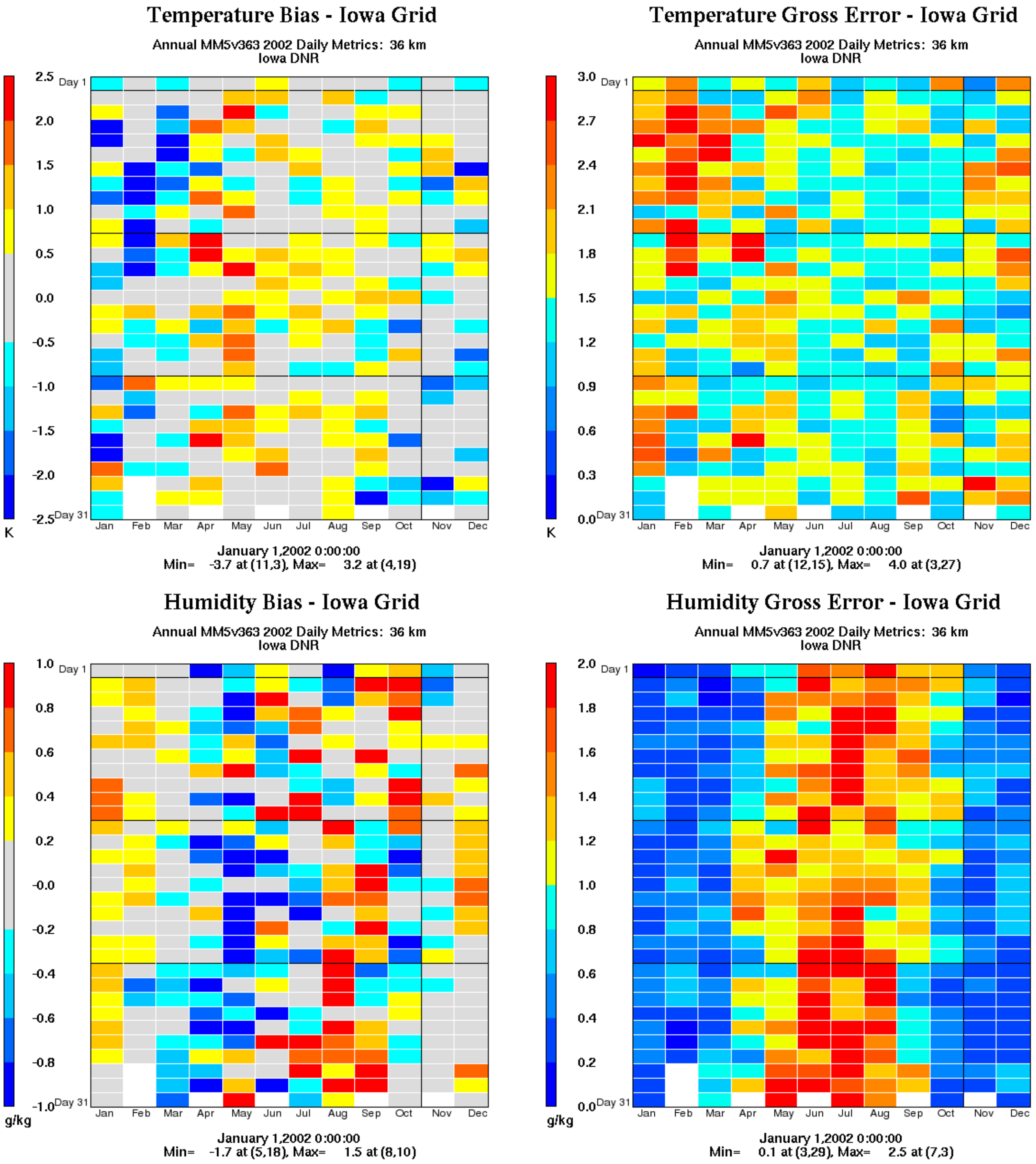
January 1,2002 0:00:00
Min= -24.8 at (8,7), Max= 14.3 at (8,23)

Wind Dir Gross Error - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 7.2 at (4,16), Max= 52.8 at (8,6)

Figure 5.9. Daily averaged wind speed/direction metrics for the Iowa subdomain.



Temperature Bias - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -3.7 at (11,3), Max= 3.2 at (4,19)

Temperature Gross Error - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 0.7 at (12,15), Max= 4.0 at (3,27)

Humidity Bias - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -1.7 at (5,18), Max= 1.5 at (8,10)

Humidity Gross Error - Iowa Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 0.1 at (3,29), Max= 2.5 at (7,3)

Figure 5.10. Daily averaged temperature and mixing ratio metrics for the Iowa subdomain.

6. TWELVE KILOMETER EVALUATION

6.1 DAILY AVERAGED STATISTICS

Generalizing the impacts of the 12 km domain upon the Great Lakes region, in terms of daily averaged metrics, a decrease in simulation accuracy during the winter months is found, while only negligible changes occur across the remainder of the year. This trend is prevalent for wind speed, wind direction[1] and temperature errors. The wintertime temperature cold bias (found at 36 km resolution) is thus even more pronounced in the 12 km domain. Mixing ratio statistics were generally uninfluenced by domain resolution. These results are depicted in Figures 6.1 – 6.2, where the Bakergram concept is maintained, however, the results are presented in terms of the differences between the 36 and 12 km results. The plots were generated by subtracting the 36 km daily averaged statistical values from the 12 km data. As the comparison only involves gross and root mean square error metrics, negative values indicate an improvement in model performance at 12 km resolution. This methodology is maintained for Figures 6.1 - 6.8.

The CenrapN regions shows only minor variations in the temperature fields, with the greatest change concentrated to the cooler months, with slight performance disbenefits. Wind direction metrics produced a drastically different trend, as nearly all days showed poorer performance. Figures 6.3 – 6.4 provide a graphical depiction of the 12 km domain impacts upon the daily averaged metrics for this subdomain.

Over the Ohio Valley, only minor differences were calculated between the 12 and 36 km daily averaged statistical results, in general. A slight improvement in the mixing ratio fields was computed. As in CenrapN, wind direction gross errors encountered widespread performance degradation during the winter and early spring months. Keeping the increasing errors in perspective, additional error remained below 3.5 degrees. See Figures 6.5 - 6.6.

In terms of daily averaged statistical measures, the Iowa subdomain receives few benefits from increased resolution. Wind speeds generally exhibit slightly greater error in the winter, spring, and fall, while demonstrating little variability during the summer. Consistent with nearby subdomains, wind direction performance suffers. While mixing ratios impacts were negligible, most months exhibited days with increased temperature error, particularly in the winter. Fortunately, gross error degradation remained below 0.5 K. The results are depicted in Figures 6.7 - 6.8.

Due to the spatial extent of the 12 km domain, neither the CenrapS domain, nor any other subdomain, is eligible for comparison.

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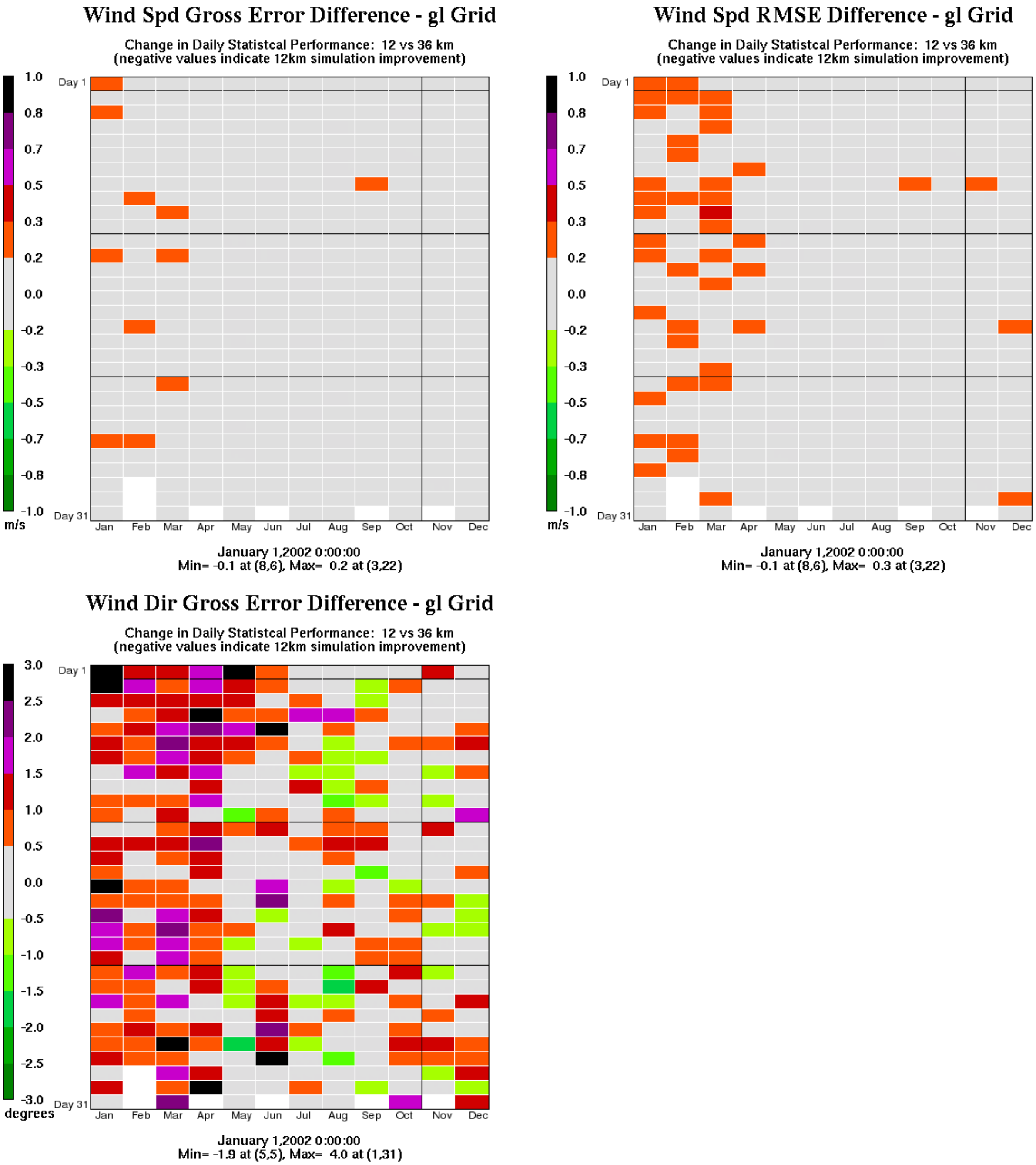
[1] With additional errors occurring into the early spring months.


Wind Spd Gross Error Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.1 at (8,6), Max= 0.2 at (3,22)

Wind Spd RMSE Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

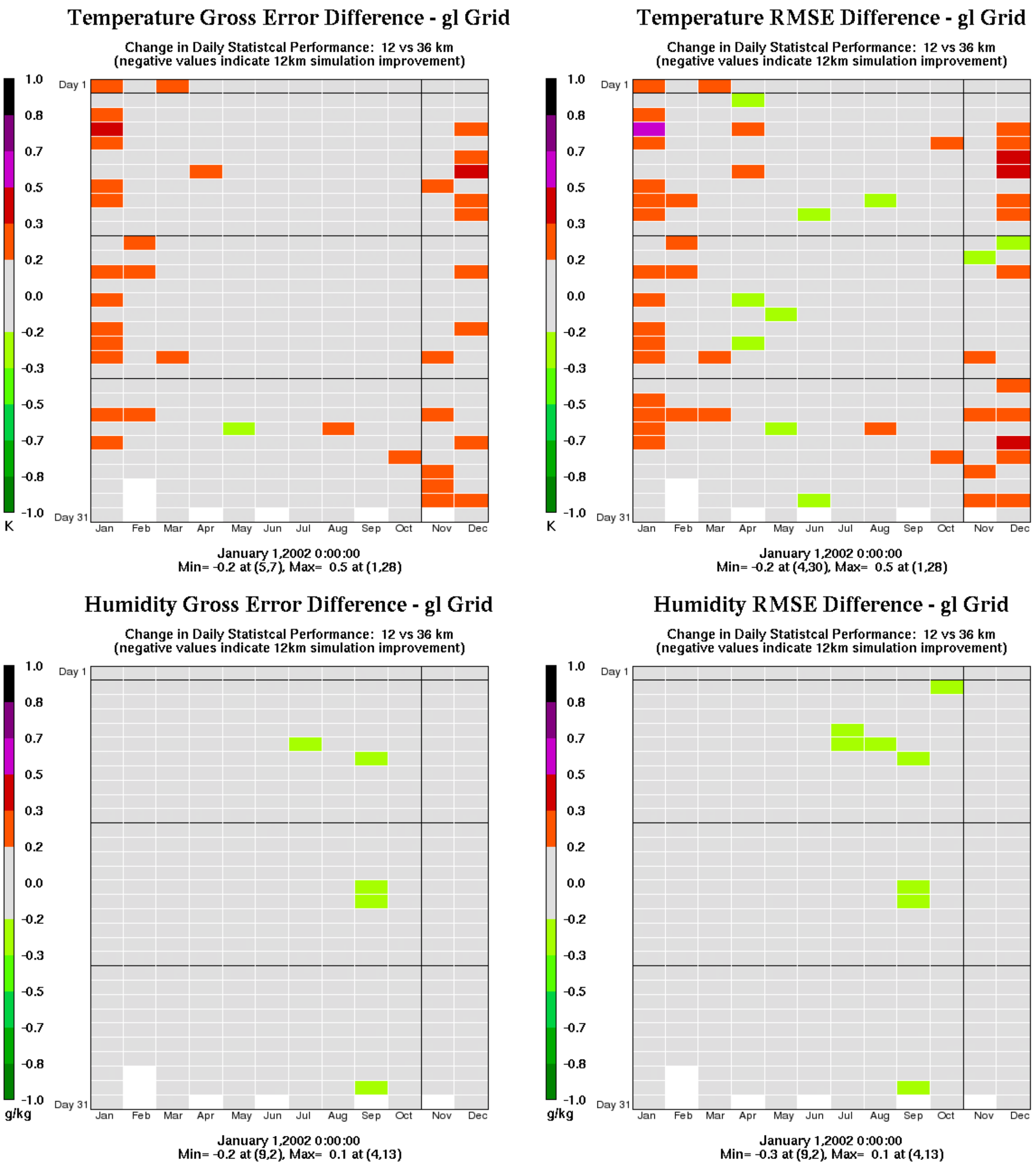
January 1,2002 0:00:00
Min= -0.1 at (8,6), Max= 0.3 at (3,22)

Wind Dir Gross Error Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -1.9 at (5,5), Max= 4.0 at (1,31)

Figure 6.1. Twelve km domain daily averaged statistical performance for selected wind metrics in relation to the 36 km grid for the Great Lakes (GL) subdomain.



Temperature Gross Error Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (5,7), Max= 0.5 at (1,28)

Temperature RMSE Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (4,30), Max= 0.5 at (1,28)

Humidity Gross Error Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (9,2), Max= 0.1 at (4,13)

Humidity RMSE Difference - gl Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.3 at (9,2), Max= 0.1 at (4,13)

Figure 6.2. Twelve km domain daily averaged statistical performance for selected temperature and mixing ratio metrics in relation to the 36 km grid for the Great Lakes (GL) subdomain.

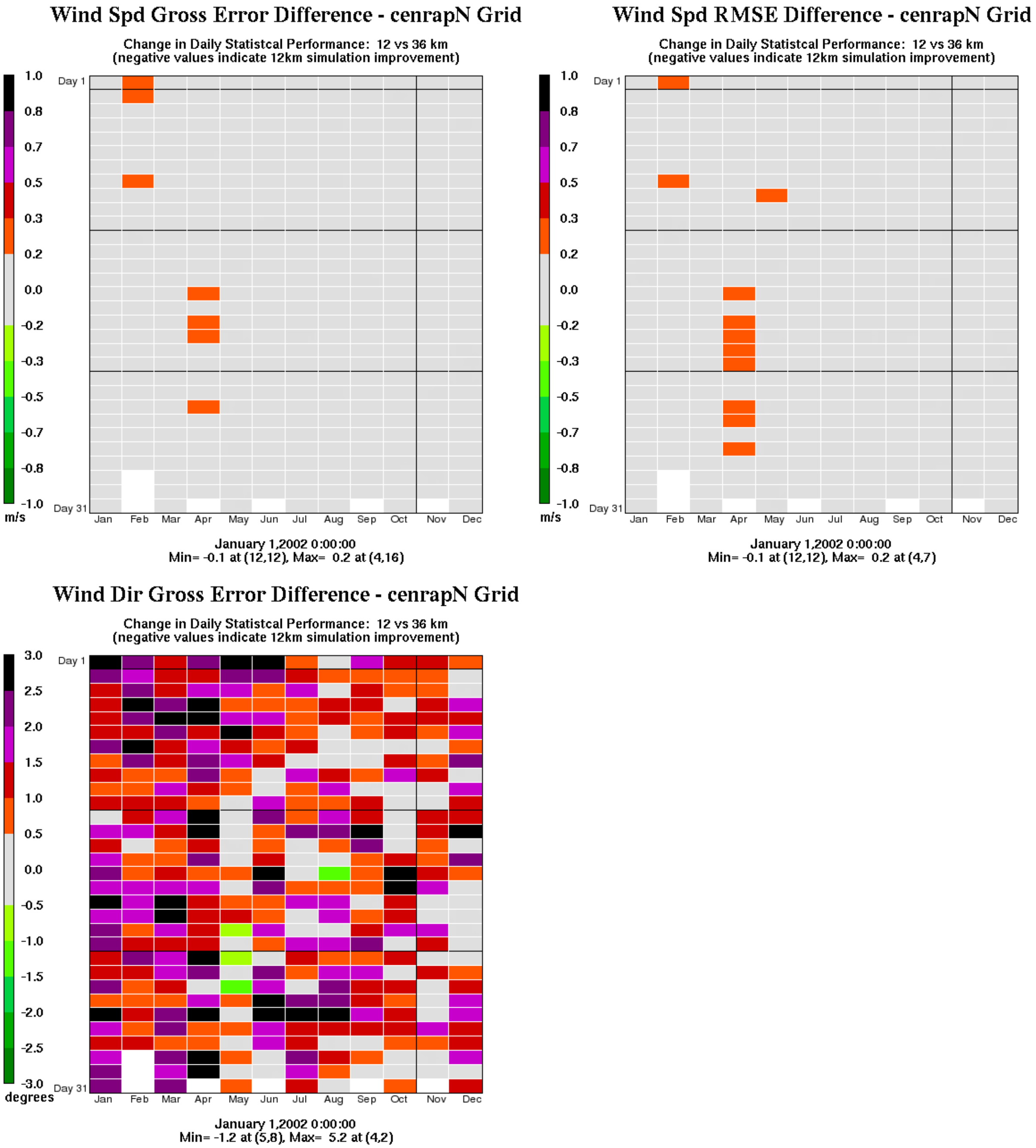
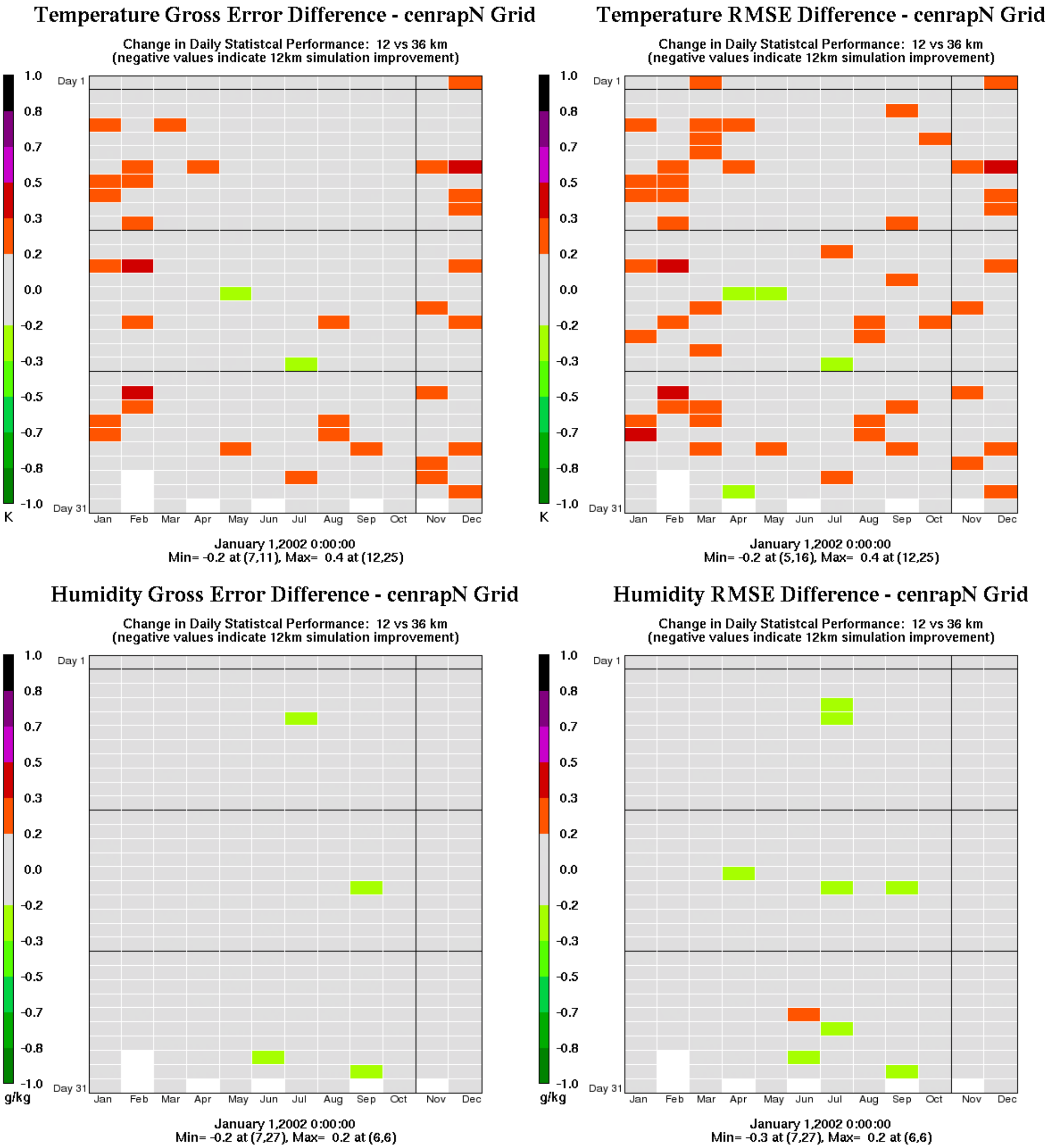


Figure 6.3. Twelve km domain daily averaged statistical performance for selected wind metrics in relation to the 36 km grid for the CenrapN subdomain.



Temperature Gross Error Difference - cenrapN Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (7,11), Max= 0.4 at (12,25)

Temperature RMSE Difference - cenrapN Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (5,16), Max= 0.4 at (12,25)

Humidity Gross Error Difference - cenrapN Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (7,27), Max= 0.2 at (6,6)

Humidity RMSE Difference - cenrapN Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.3 at (7,27), Max= 0.2 at (6,6)

Figure 6.4. Twelve km domain daily averaged statistical performance for selected temperature and mixing ratio metrics in relation to the 36 km grid for the CenrapN subdomain.

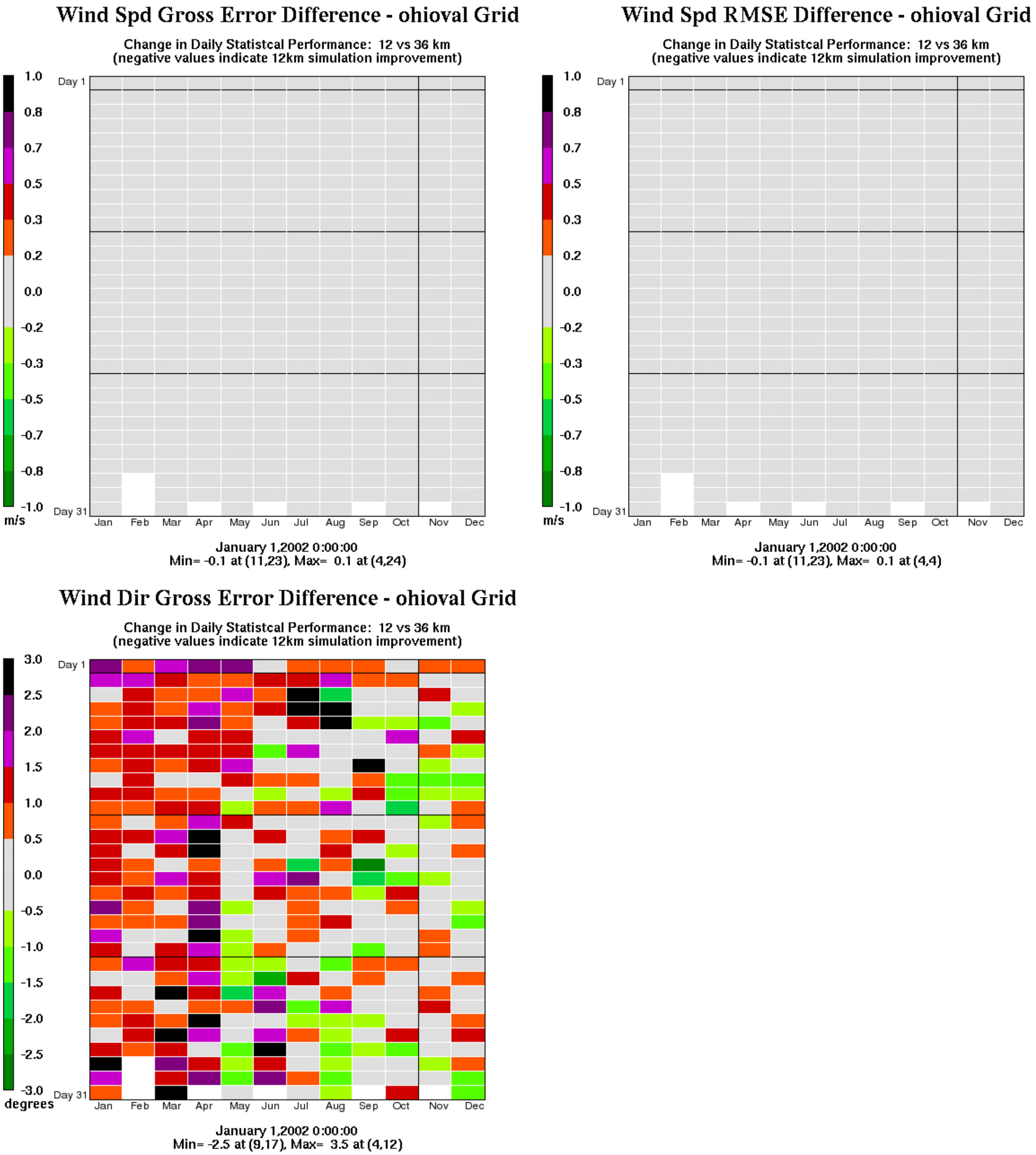
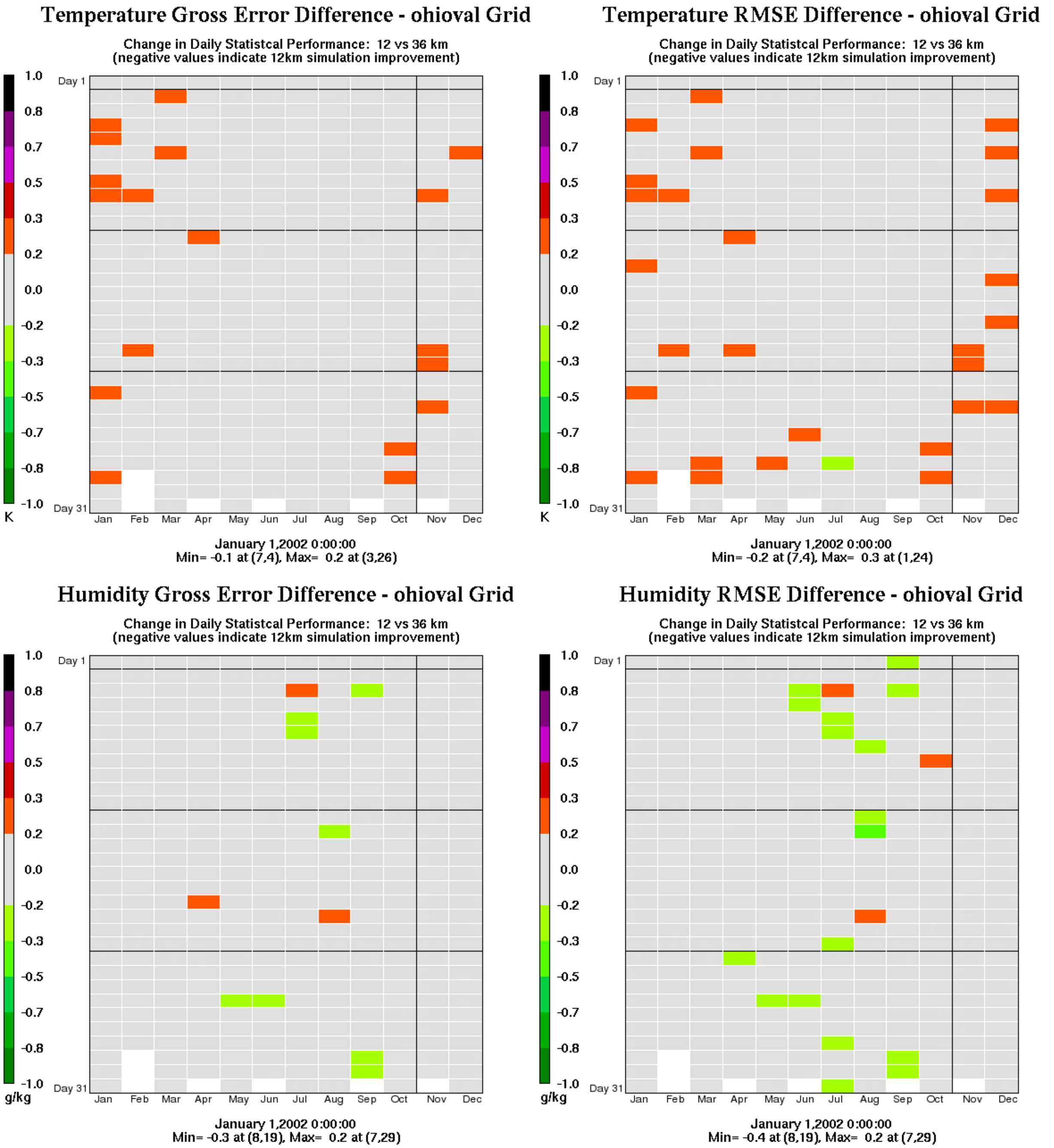


Figure 6.5. Twelve km domain daily averaged statistical performance for selected wind metrics in relation to the 36 km grid for the OhioVal subdomain.


Temperature Gross Error Difference - ohioval Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.1 at (7,4), Max= 0.2 at (3,26)

Temperature RMSE Difference - ohioval Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.2 at (7,4), Max= 0.3 at (1,24)

Humidity Gross Error Difference - ohioval Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

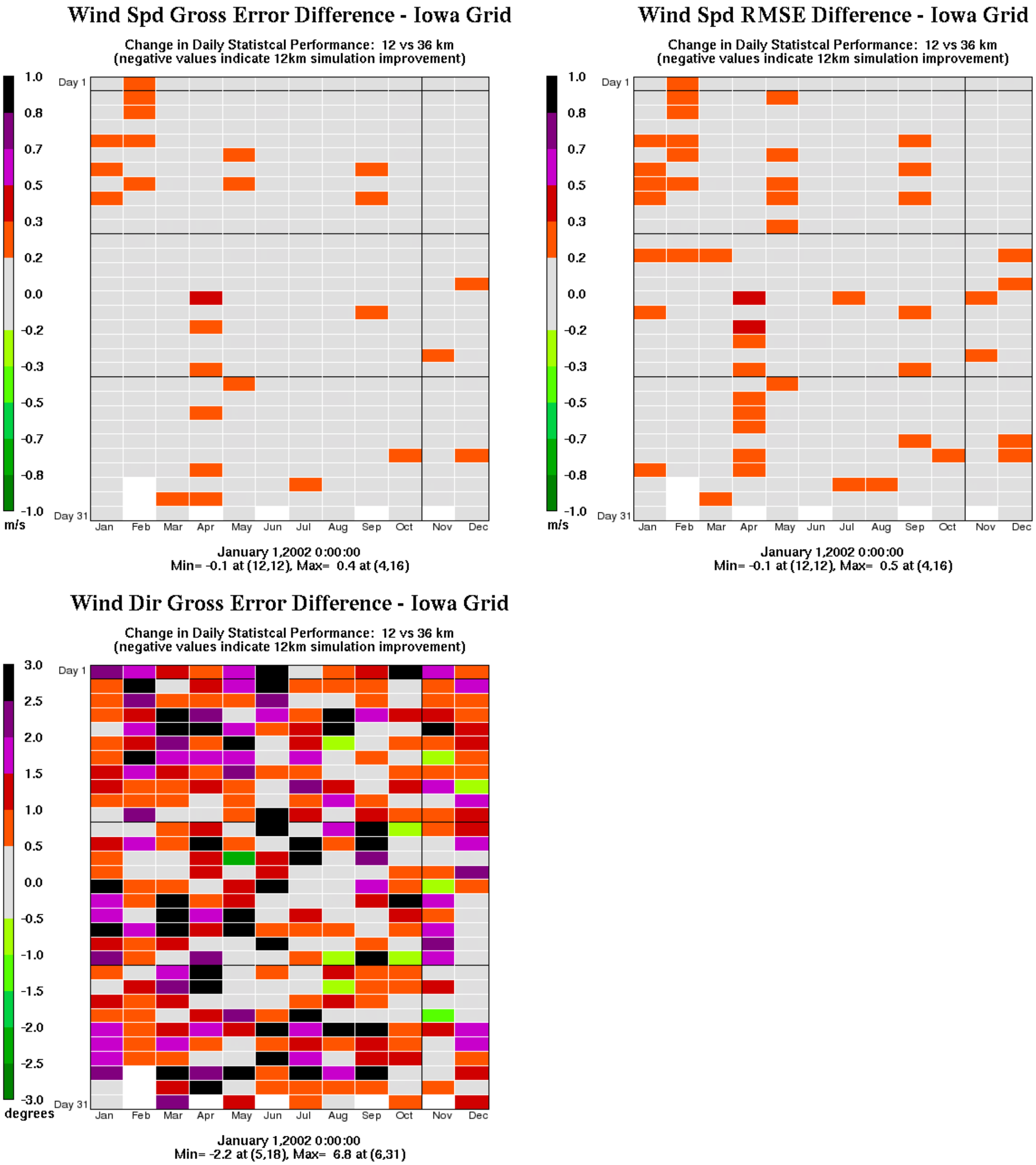
January 1,2002 0:00:00
Min= -0.3 at (8,19), Max= 0.2 at (7,29)

Humidity RMSE Difference - ohioval Grid

Change in Daily Statistcal Performance: 12 vs 36 km
(negative values indicate 12km simulation improvement)

January 1,2002 0:00:00
Min= -0.4 at (8,19), Max= 0.2 at (7,29)

Figure 6.6. Twelve km domain daily averaged statistical performance for selected temperature and mixing ratio metrics in relation to the 36 km grid for the OhioVal subdomain.


Wind Spd Gross Error Difference - Iowa Grid

Wind Spd RMSE Difference - Iowa Grid

Wind Dir Gross Error Difference - Iowa Grid

Figure 6.7. Twelve km domain daily averaged statistical performance for selected wind metrics in relation to the 36 km grid for the Iowa subdomain.

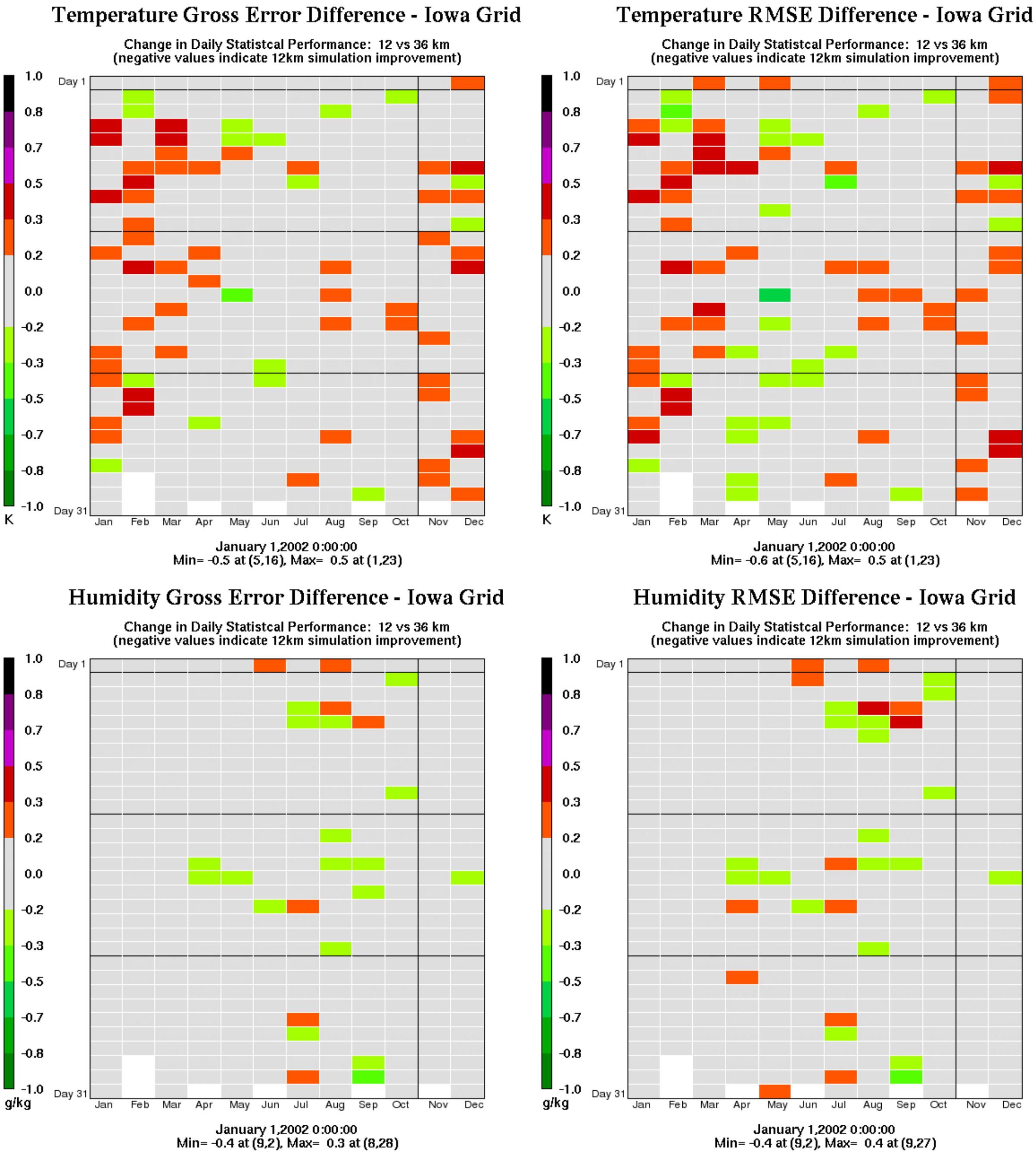


Figure 6.8. Twelve km domain daily averaged statistical performance for selected temperature and mixing ratio metrics in relation to the 36 km grid for the Iowa subdomain.

6.2 HOURLY STATISTICS

Additional comparisons between the 36 and 12 km simulations are provided below through review of hourly time series. Modeled (both 36 and 12 km) versus observed conditions are plotted below, with the associated bias also depicted. The hourly time series evaluation eliminates the statistical smoothing associated with the daily averaging periods. These charts also serve as the diurnal profile data source referenced in previous chapters, however, the discussion below will primarily focus upon differences between the 12 and 36 km simulations.

Assessing the time series from a winter (January) and summer (June) monthly subset of the annual simulation for the Great Lakes region (Figures 6.9 - 6.10) leads to a general conclusion that improvement occurs in the daytime wind speed biases with implementation of the 12 km grid, while nighttime disbenefits are observed. At 12 km resolution, the wintertime cold bias is even more pronounced versus the 36 km domain, as nighttime low temperatures dip further below observed values (Figure 6.11). The ultimate cause for the low temperature bias is unknown, but this is not an uncommon feature of MM5 simulations (Ad-Hoc Meteorological Modelers Meeting group discussion, 2007). For the GL region, no significant differences are found in either temperature or humidity during the summer month of June (Figure 6.12). Appendix C provides additional January and June hourly 12 versus 36 km statistical charts for the Great Lakes, OhioVal, CenrapN, and Iowa subdomains.

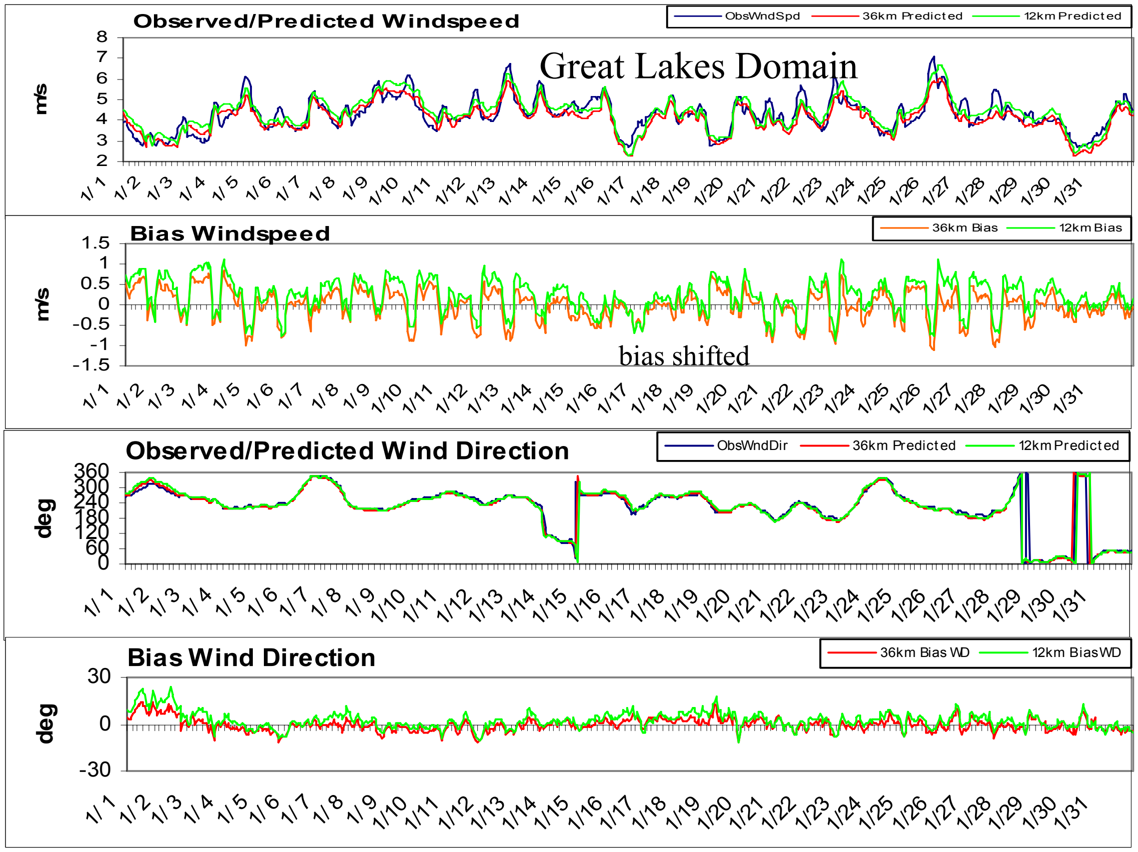


Figure 6.9. Twelve and 36 km hourly wind vector statistics for the Great Lakes subdomain for January, 2002.

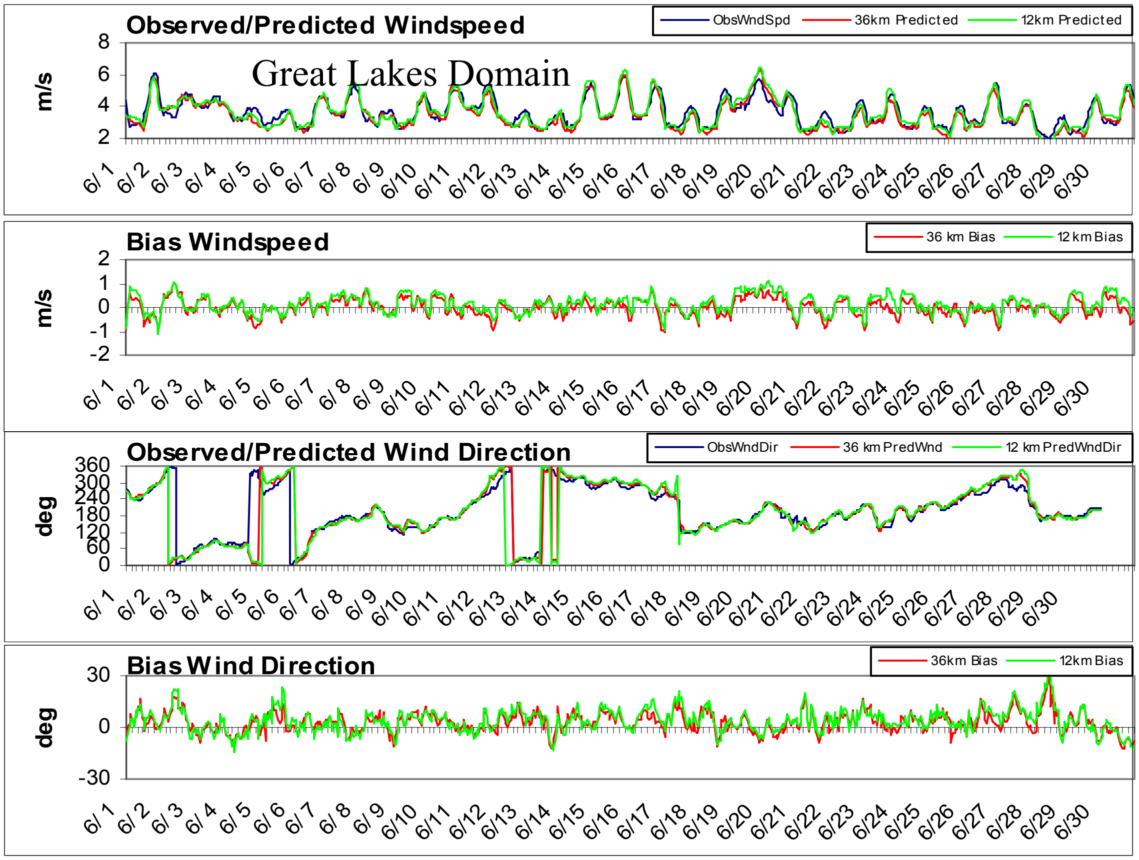


Figure 6.10. Twelve and 36 km hourly wind vector statistics for the Great Lakes subdomain for June, 2002.

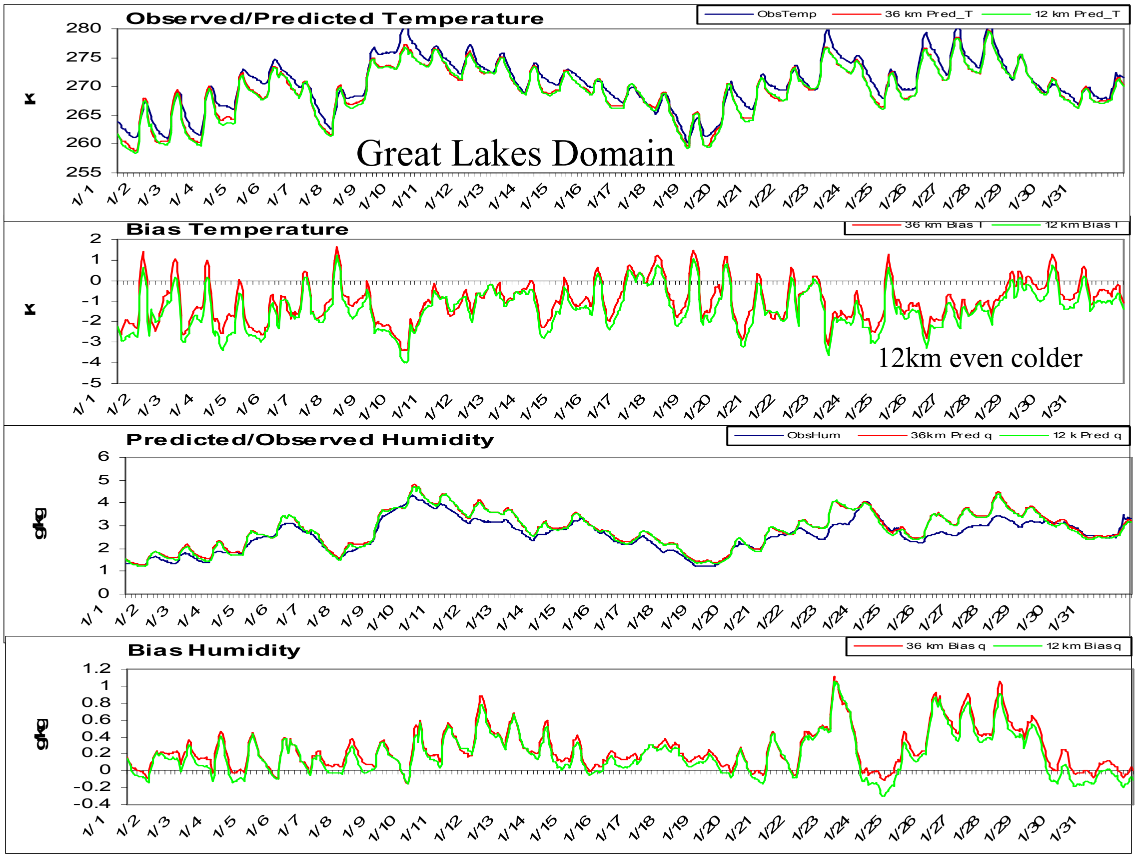


Figure 6.11. Twelve and 36 km hourly temperature and moisture statistics for the Great Lakes subdomain for January, 2002.

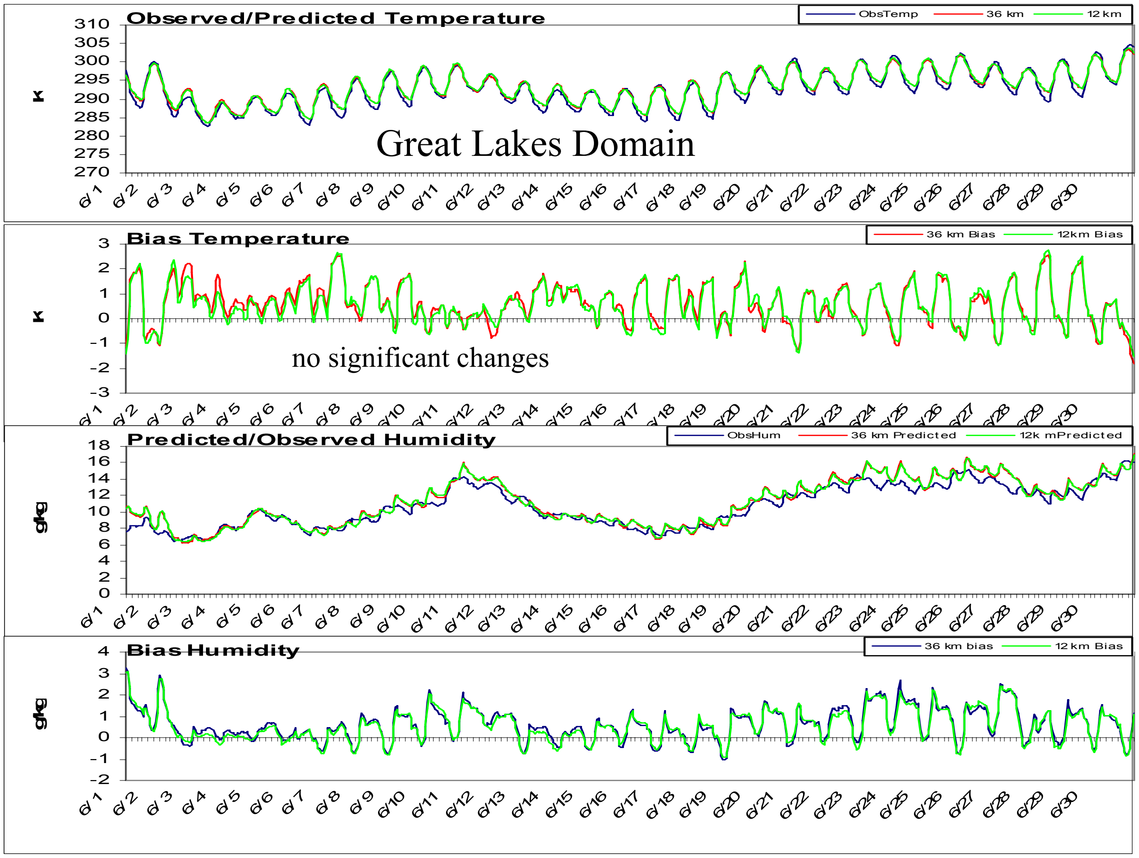


Figure 6.12. Twelve and 36 km hourly temperature and moisture statistics comparison for the Great Lakes subdomain for June, 2002.

7. UPPER AIR EVALUATION

7.1 SOUNDINGS

A comprehensive assessment of model performance cannot be completed through the evaluation of surface statistical measures alone. A rigorous evaluation requires the examination of additional features such as precipitation fields, PBL depths, and vertical profiles of temperature, moisture, and wind vectors. As readily available tools have not been identified which yield objective measures of such parameters, evaluations are typically subjective. A precipitation evaluation of the 36 km dataset has been completed by Kirk Baker (Baker et al., 2004) and is summarized below. In combination with the precipitation evaluation, the most efficient method available for an upper air analysis is to focus upon radiosonde observations. To aid in the review of upper air feature, the IDNR created the RAOBPLOT software tool that efficiently displays modeled versus observed radiosonde upper air measurements. With twice-daily soundings available from approximately 70 observing stations, roughly 51,100 modeled versus observed soundings are available for examination from the 36 km annual simulation alone. Clearly a complete examination is resource prohibitive. The volume of data available, in combination with only inefficient subjective methods for evaluations highlights a current deficiency in annual scale regional modeling applications. While inelegant, the immediately practicable solution requires a targeted review of specific data.

A brief review of the modeled versus observed sounding for many sites in the Central U.S. was conducted, with no terminal deficiencies discovered. A more focused evaluation upon the Davenport, Iowa, station was completed over the simulated summer months, with the following conclusions reached: Upper level wind vectors are well simulated. The temperature fields below approximately 900 mb yielded a tendency toward underprediction at 0Z, while the moisture fields were generally overstated during the same region and time. At 12Z, temperatures were generally underpredicted below 900 mb. In terms of estimated PBL depths, the mixed layer commonly appears shallower than observed. While error is never desired, in terms of modeling air quality (in a conservative sense) a shallow PBL is preferred versus excessive depth. A sample of the observed versus modeled sounding produced by RAOBPLOT is provided in Figure 7.1.

7.2 PRECIPITATION

Kirk Baker with the Lake Michigan Air Directors Consortium was provided a complete copy of the 36 km meteorological dataset and subsequently completed a model performance evaluation examining precipitation fields. In summary, both rainfall totals and precipitation spatial coverage are generally well simulated in the fall, winter, and springtime periods. As is common with many MM5 simulations, summertime precipitation events produce an excess of precipitation. Rainfall patterns also exhibit greater spatial coverage than observed. Additional detail, including graphical representation of predicted and observed rainfall, is available in Baker et al., 2004.

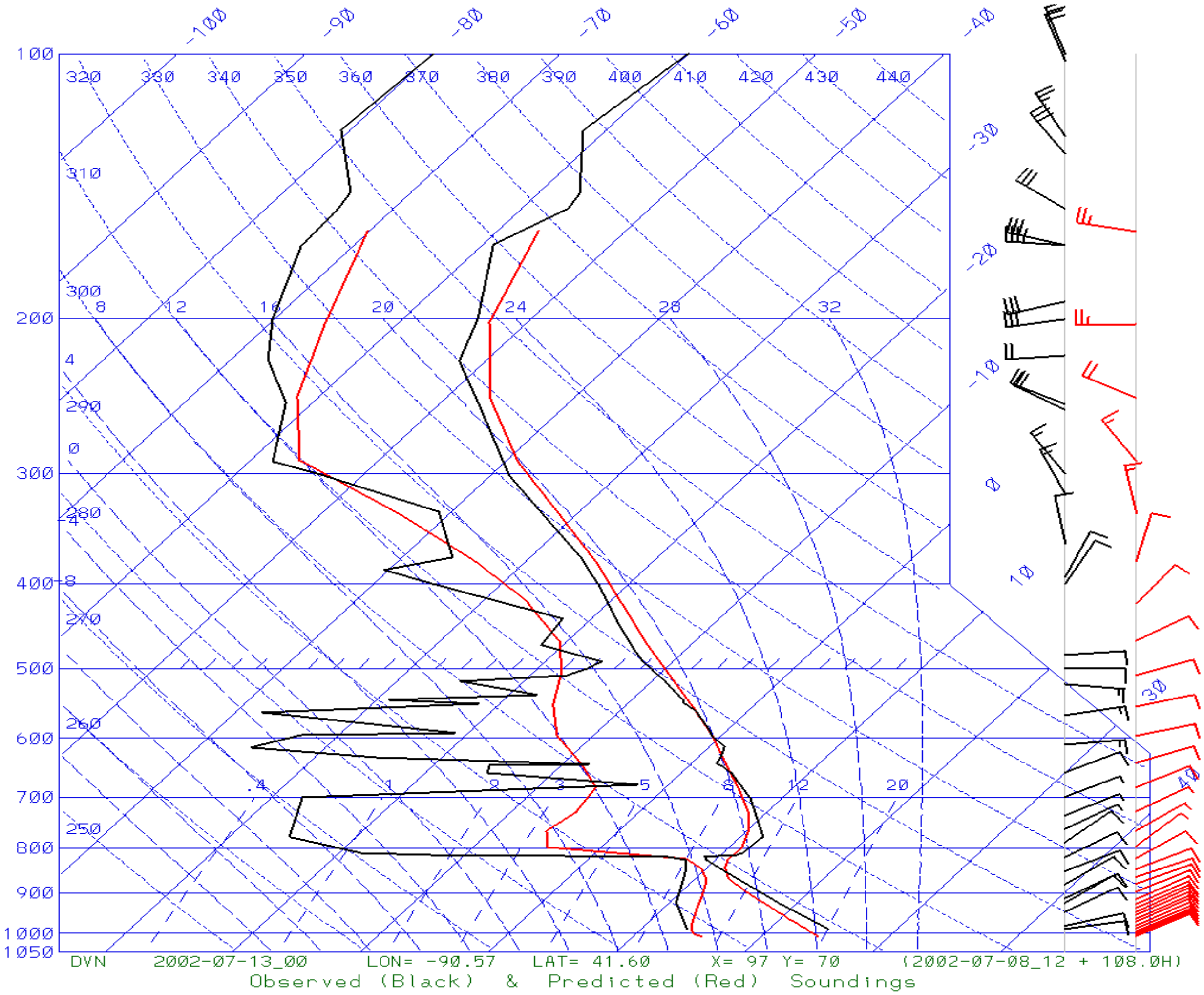


Figure 7.1. Sample ROABPLOT observed versus predicted (36 km domain) sounding for Davenport Iowa, on July 13, 2007, at 0Z. Wind speed and directions are accurately simulated throughout the depth of the sounding. The temperature profile performance is more than adequate. As is common, a positive moisture bias exists at (and above the surface), while the estimated PBL depth remains too shallow.

7.3 PBL DEPTHS

Additional upper air analyses included a limited comparison of the 36 and 12 km predicted PBL heights. Figure 7.2 provides an example comparison. As expected, the degree of agreement between the 36 and 12 km results exceeds variability. Areas in Western Illinois and Eastern Texas (among others) do display deviations. In Eastern Texas, MM5 predicts a precipitation event (which is weakly supported by observations, see Figures 7.3 - 7.4). The reduction in PBL heights in Western Illinois would appear to be precipitation driven as well, but no convective or non-convective rainfall was predicted by MM5 during this time. The observed radar reflectivities also suggests no precipitation occurred during this time. In summary, the 12 km grid yields improved feature detail yet the accuracy of such fields, across a continental scale annual simulation, is difficult to assess within a reasonable timeframe.

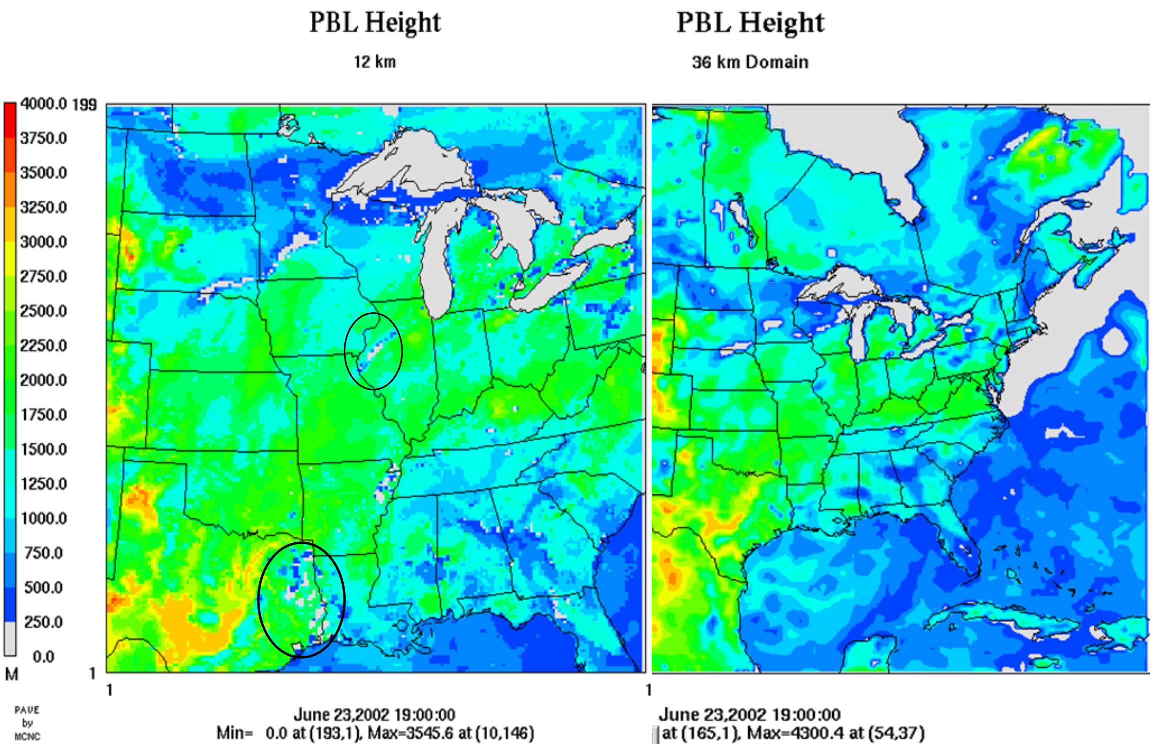


Figure 7.2. PBL heights predicted by MM5 for June 23, 2002, at 19Z. for the 12 and 36 km modeling domains.

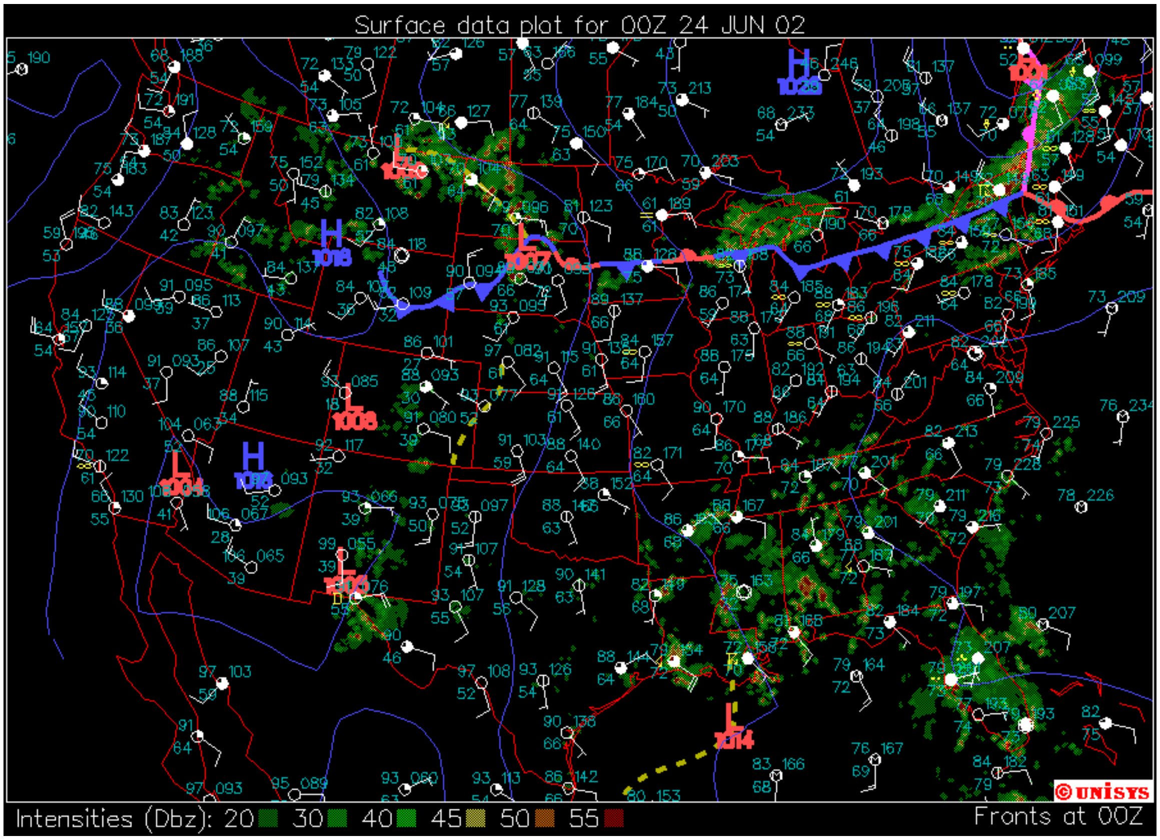


Figure 7.3. Observed conditions on June 24, 0Z.

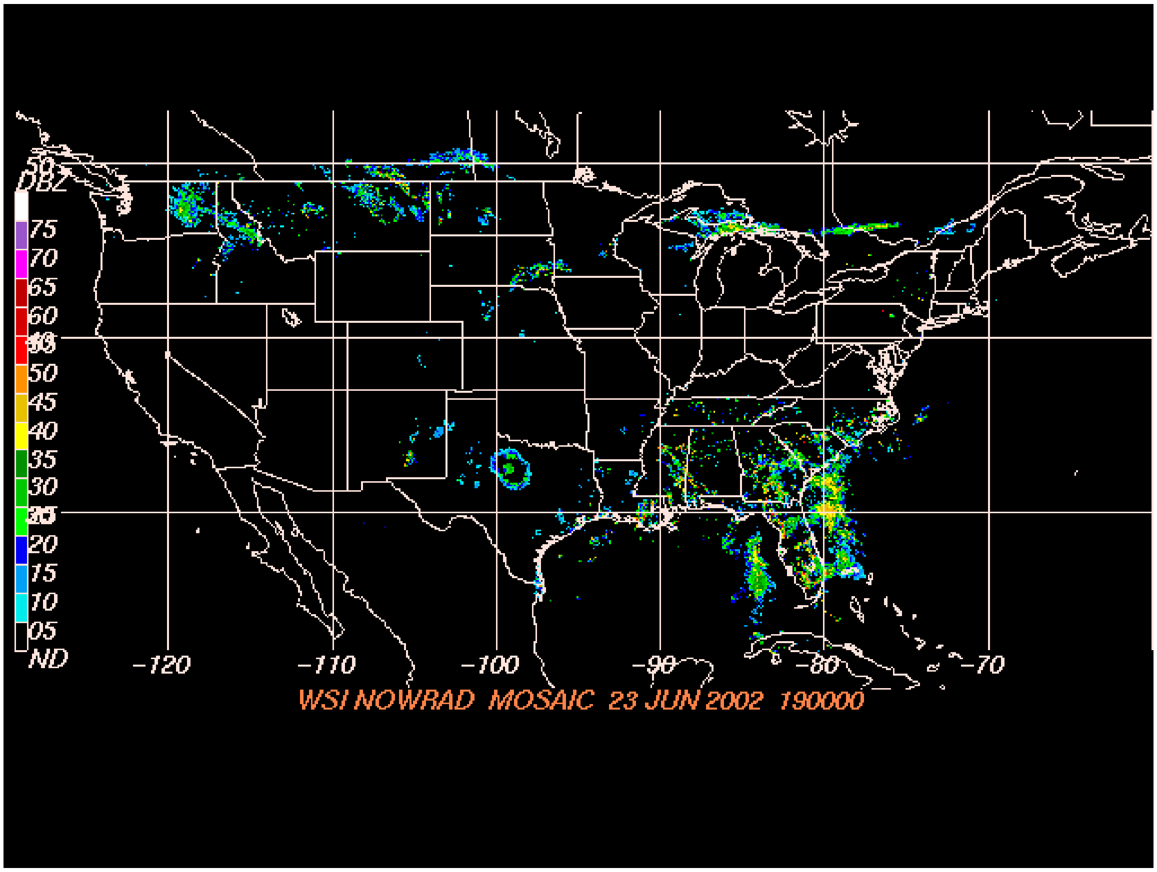


Figure 7.3. Radar reflectivity on June 23, 2002 at 19Z.

8. CONCLUSIONS

In the northern half of the Central U.S. through the Ohio River valley, the surface statistical evaluation reveals a dominant wintertime cold bias, with cool conditions typically present in the evening hours, while overly aggressive nighttime lows and weak high temperatures also contribute to the cold bias. The summer months exhibit a warm bias, attributable to the overprediction of nighttime temperatures. Wind speed and direction predictions over the central and northern Central U.S. exhibit low statistical error and provide for an increase in model confidence. Continuing the evaluation in to the Western U.S. yields a reduction in model confidence, as error measures increase across all fields. As discussed, this result is not completely unexpected given complex Western topography. Regions within the Eastern U.S. demonstrate prediction skill above Western regions, yet statistical accuracy falls below that found in the Midwest.

Expanding the evaluation into upper air features reveals no fundamental flaws jeopardizing the adequacy of the simulation in terms of air quality modeling. A tendency to slightly underpredict summertime PBL depths over Eastern Iowa was discovered. In subjective terms, such error is acceptable as perfect model performance is unattainable. A similar conclusion is reached for the precipitation shortfalls discussed by Baker et al., 2004.

Within the Central U.S, increasing the horizontal resolution from 36 to 12 km yielded no benefits from a surface-feature statistical evaluation perspective. Within the Great Lakes subdomain, the 12 km simulation appears to improve daytime wind speed predictions, however, nighttime predictions suffer. Overall, wind speed error showed little variability between the 36 and 12 km domains. Beyond the statistical evaluation, additional field detail is resolved by the 12 km domain as expected. As in the upper air analysis for the 36 km grid, no fundamental flaws were identified in review of 12 km upper air features.

In summary, the statistical evaluation yields results predominantly within acceptable guidelines for the principal regions of interest (the States near and within LADCO and the northern two-thirds of CENRAP). Concurrently, no major simulation deficiencies were revealed during the upper air review. The 36 and 12 km Iowa DNR 2002MM5v363 datasets are thus judged acceptable for use in regional scale air quality modeling studies focused within the central United States.

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APPENDIX A

Temporal structure example for the 2002 annual simulation.

Start BLOCK	End BLOCK	Start (Z)	End (Z)	Filename	Metstat Usable	
					Start (Z)	End (Z)
12/28/2001 12:00	**1/2/2002 12:00**	12/28/2001 12:00	12/28/2001 12:00	**MMOUT_DOMAIN1_00**		
		12/28/2001 13:00	12/29/2001 12:00	**MMOUT_DOMAIN1_01**	12/29/2001 0:00	12/29/2001 12:00
		12/29/2001 13:00	12/30/2001 12:00	**MMOUT_DOMAIN1_02**	12/29/2001 13:00	12/30/2001 12:00
		12/30/2001 13:00	12/31/2001 12:00	**MMOUT_DOMAIN1_03**	12/30/2001 13:00	12/31/2001 12:00
		12/31/2001 13:00	1/1/2002 12:00	**MMOUT_DOMAIN1_04**	12/31/2001 13:00	1/1/2002 12:00
		1/1/2002 13:00	1/2/2002 12:00	**MMOUT_DOMAIN1_05**	1/1/2002 13:00	1/1/2002 23:00
1/1/2002 12:00	**1/6/2002 12:00**	1/1/2002 12:00	1/1/2002 12:00	**MMOUT_DOMAIN1_00**		
		1/1/2002 13:00	1/2/2002 12:00	**MMOUT_DOMAIN1_01**	1/2/2002 0:00	1/2/2002 12:00
		1/2/2002 13:00	1/3/2002 12:00	**MMOUT_DOMAIN1_02**	1/2/2002 13:00	1/3/2002 12:00
		1/3/2002 13:00	1/4/2002 12:00	**MMOUT_DOMAIN1_03**	1/3/2002 13:00	1/4/2002 12:00
		1/4/2002 13:00	1/5/2002 12:00	**MMOUT_DOMAIN1_04**	1/4/2002 13:00	1/5/2002 12:00
		1/5/2002 13:00	1/6/2002 12:00	**MMOUT_DOMAIN1_05**	1/5/2002 13:00	1/5/2002 23:00
1/5/2002 12:00	**1/10/2002 12:00**	1/5/2002 12:00	1/5/2002 12:00	**MMOUT_DOMAIN1_00**		
		1/5/2002 13:00	1/6/2002 12:00	**MMOUT_DOMAIN1_01**	1/6/2002 0:00	1/6/2002 12:00
		1/6/2002 13:00	1/7/2002 12:00	**MMOUT_DOMAIN1_02**	1/6/2002 13:00	1/7/2002 12:00
		1/7/2002 13:00	1/8/2002 12:00	**MMOUT_DOMAIN1_03**	1/7/2002 13:00	1/8/2002 12:00
		1/8/2002 13:00	1/9/2002 12:00	**MMOUT_DOMAIN1_04**	1/8/2002 13:00	1/9/2002 12:00
		1/9/2002 13:00	1/10/2002 12:00	**MMOUT_DOMAIN1_05**	1/9/2002 13:00	1/9/2002 23:00

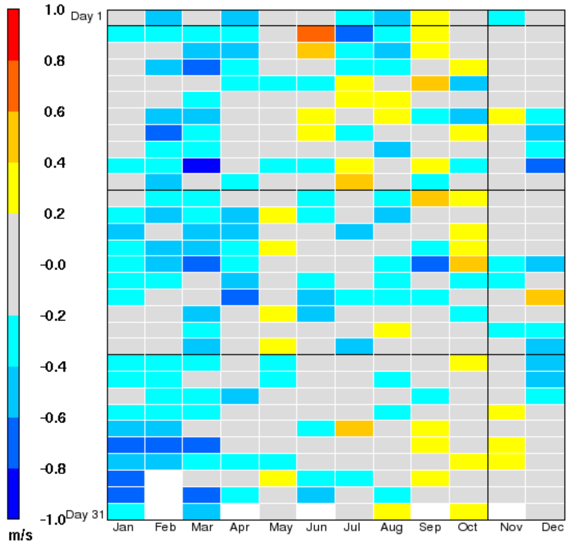
APPENDIX B

Daily averaged metrics from the 36 km simulation.

Eastern Subdomains

Wind Spd Bias - NE Grid

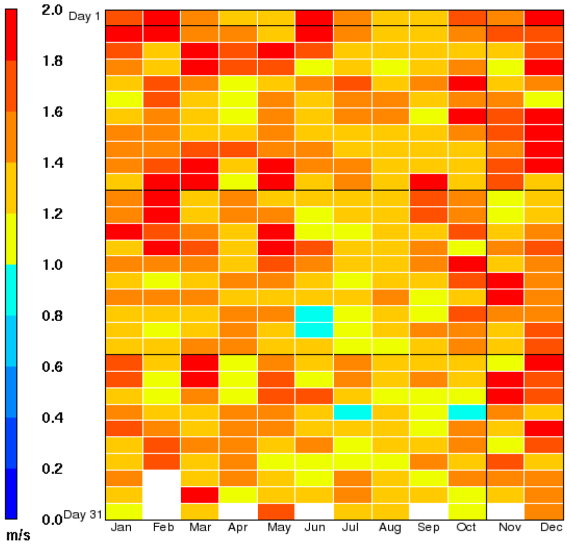
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.1 at (3,22), Max= 0.6 at (6,30)

Wind Spd Gross Error - NE Grid

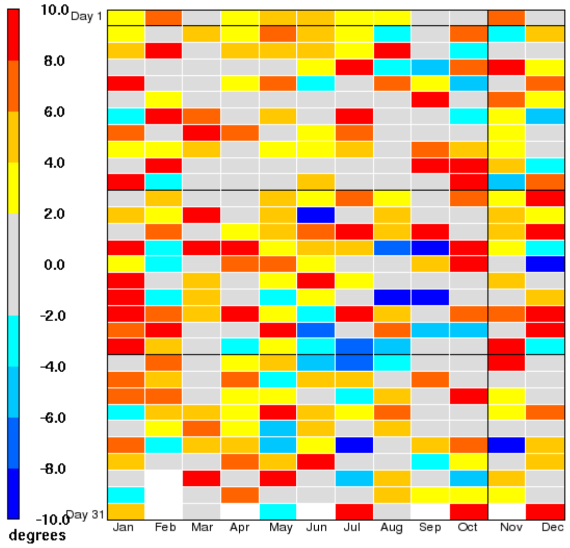
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 0.9 at (6,13), Max= 2.5 at (3,22)

Wind Dir Bias - NE Grid

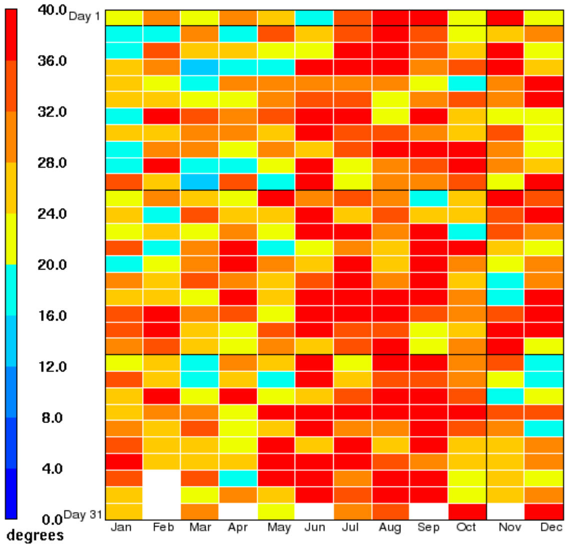
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -10.9 at (11,5), Max= 16.6 at (8,29)

Wind Dir Gross Error - NE Grid

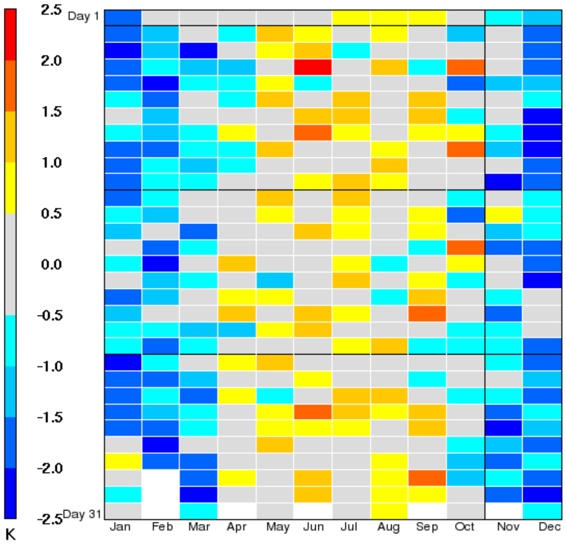
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 13.9 at (3,21), Max= 63.8 at (9,16)

Temperature Bias - NE Grid

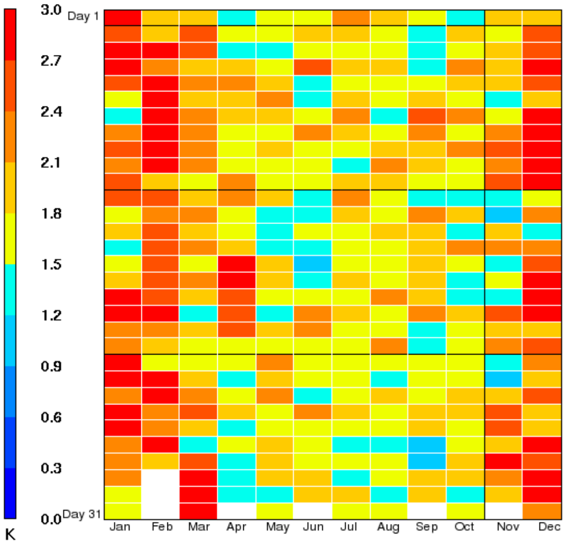
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -2.5 at (2,5), Max= 2.0 at (6,28)

Temperature Gross Error - NE Grid

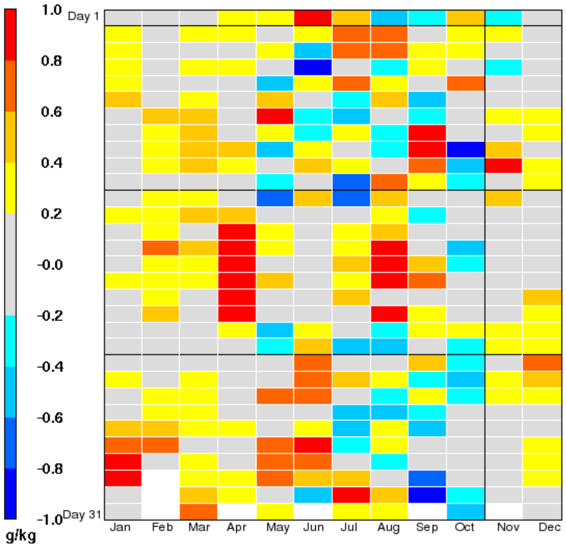
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.0 at (11,19), Max= 3.5 at (1,9)

Humidity Bias - NE Grid

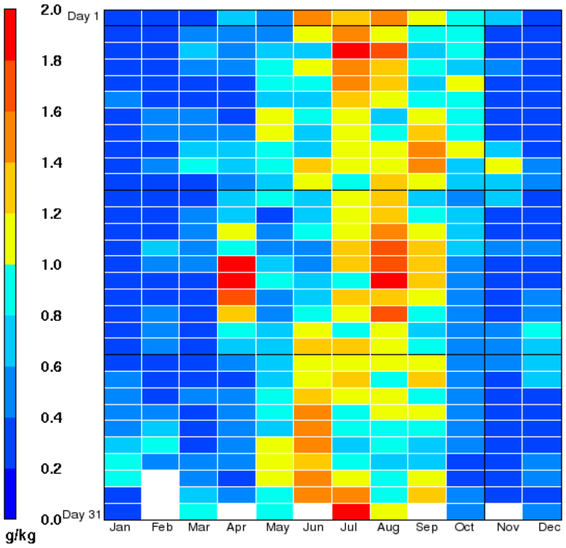
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.2 at (9,2), Max= 2.7 at (4,15)

Humidity Gross Error - NE Grid

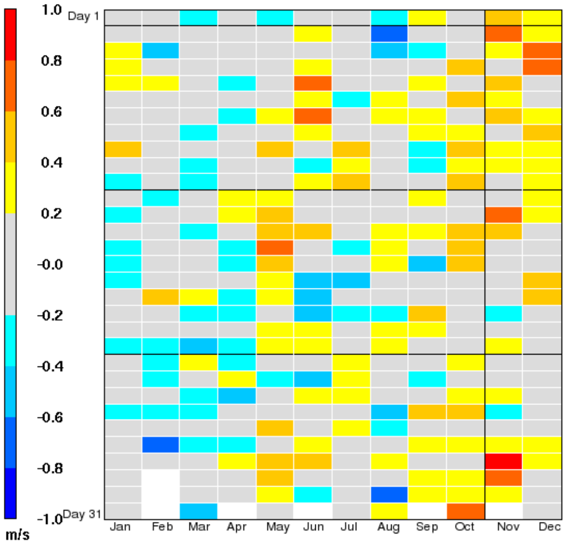
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 0.2 at (1,24), Max= 2.7 at (4,15)

Wind Spd Bias - MidAtlantic Grid

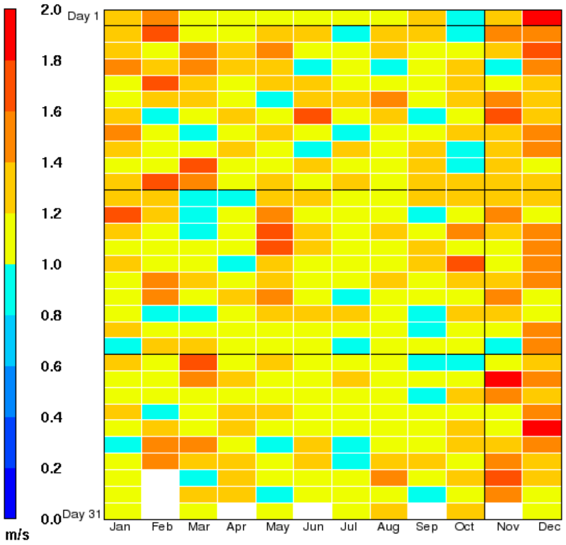
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -0.7 at (2,5), Max= 0.9 at (11,4)

Wind Spd Gross Error - MidAtlantic Grid

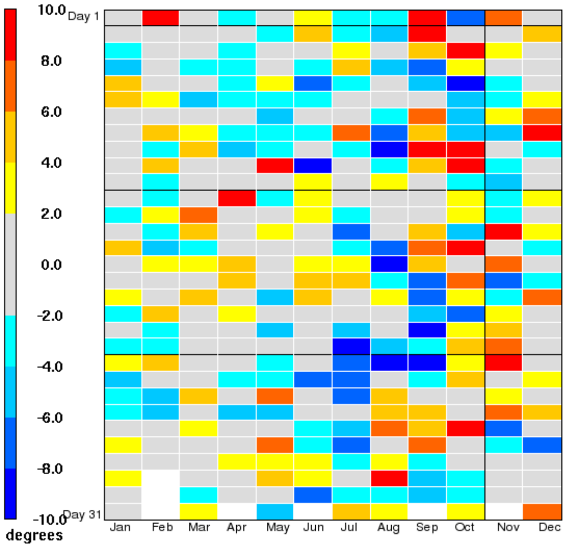
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 0.8 at (11,11), Max= 1.9 at (12,6)

Wind Dir Bias - MidAtlantic Grid

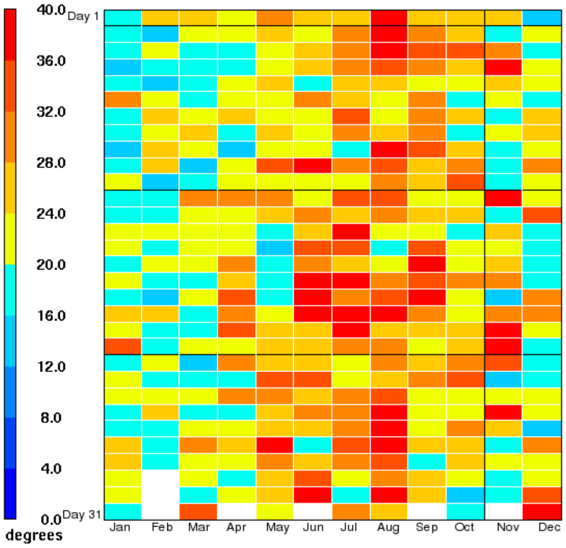
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -11.3 at (10,27), Max= 18.2 at (9,30)

Wind Dir Gross Error - MidAtlantic Grid

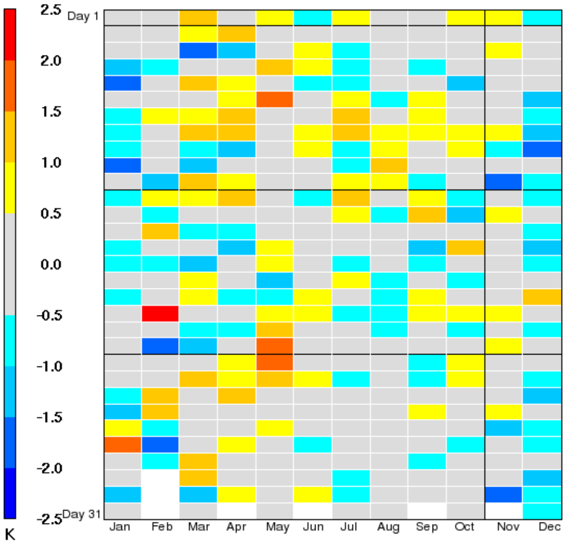
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 12.7 at (2,27), Max= 50.1 at (8,6)

Temperature Bias - MidAtlantic Grid

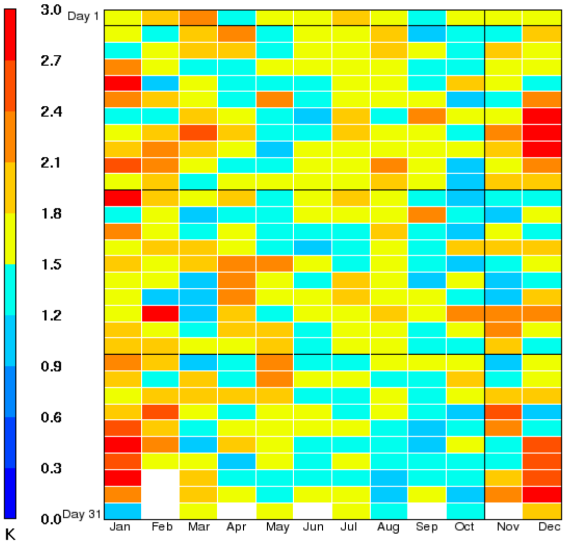
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.9 at (1,27), Max= 2.4 at (2,13)

Temperature Gross Error - MidAtlantic Grid

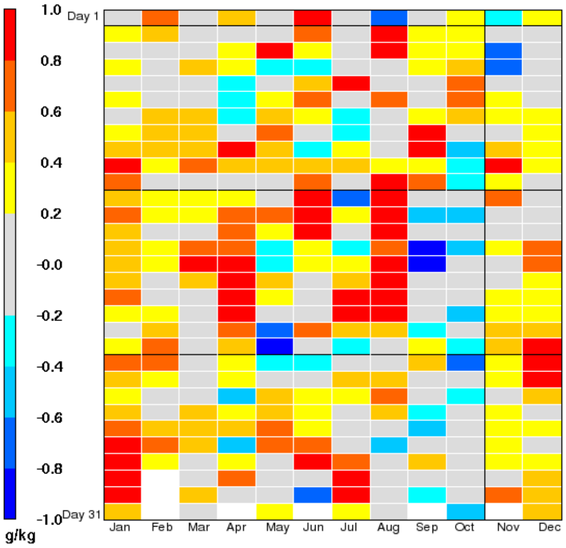
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.0 at (12,7), Max= 3.2 at (1,5)

Humidity Bias - MidAtlantic Grid

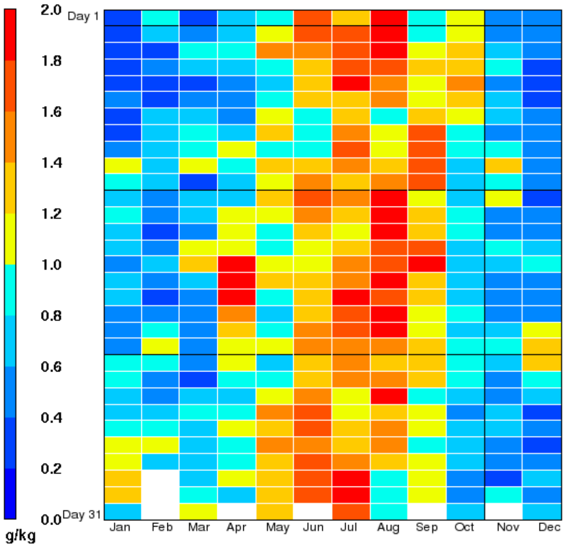
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.3 at (9,16), Max= 2.7 at (4,15)

Humidity Gross Error - MidAtlantic Grid

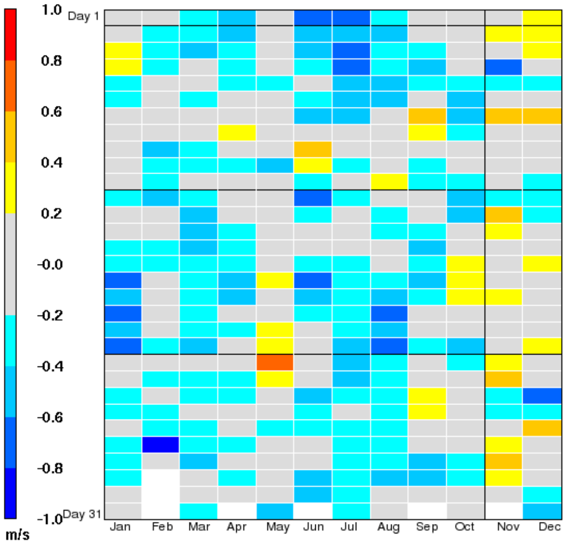
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 0.2 at (3,27), Max= 2.8 at (4,15)

Wind Spd Bias - SE Grid

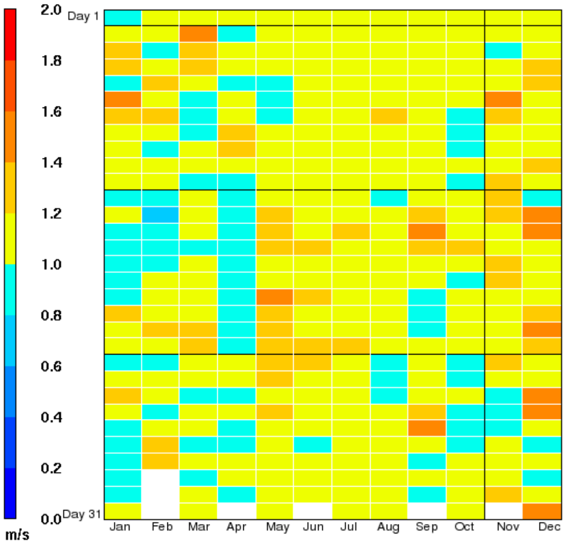
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -0.8 at (2,5), Max= 0.6 at (5,10)

Wind Spd Gross Error - SE Grid

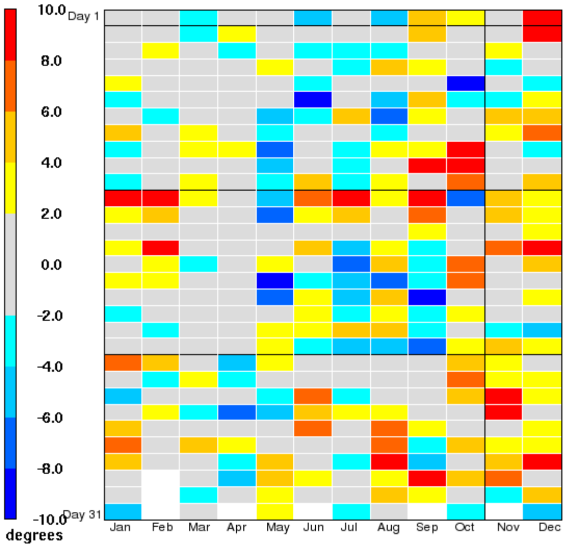
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 0.8 at (2,19), Max= 1.5 at (12,8)

Wind Dir Bias - SE Grid

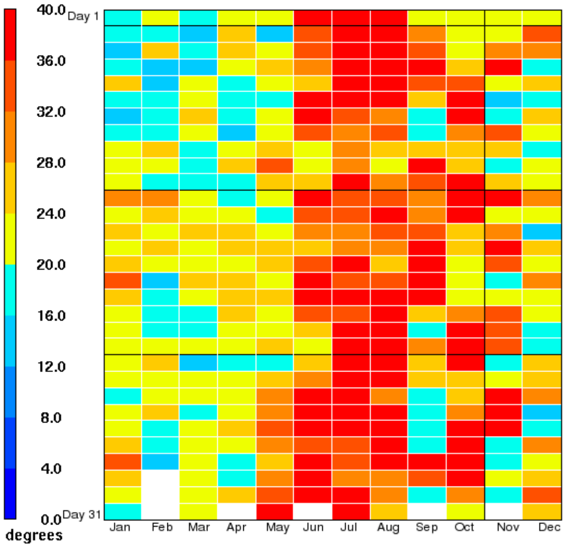
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -9.7 at (5,15), Max= 14.5 at (8,4)

Wind Dir Gross Error - SE Grid

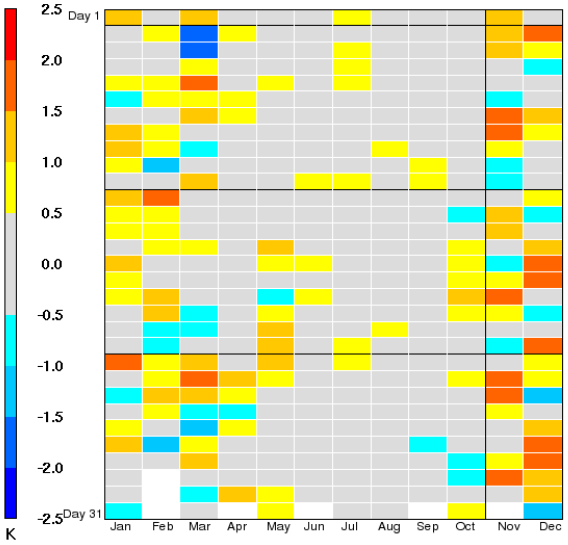
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 12.5 at (4,24), Max= 59.5 at (7,27)

Temperature Bias - SE Grid

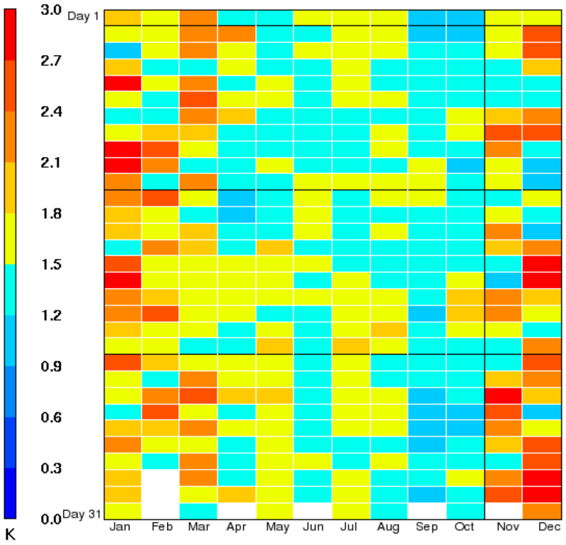
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -2.0 at (3,30), Max= 1.9 at (12,16)

Temperature Gross Error - SE Grid

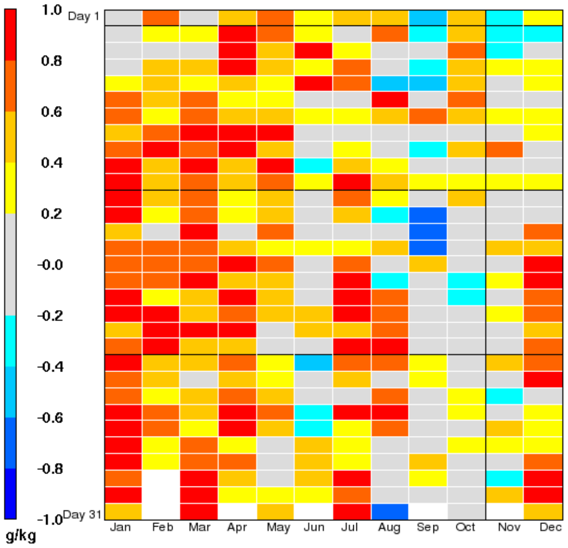
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.0 at (9,7), Max= 3.5 at (12,2)

Humidity Bias - SE Grid

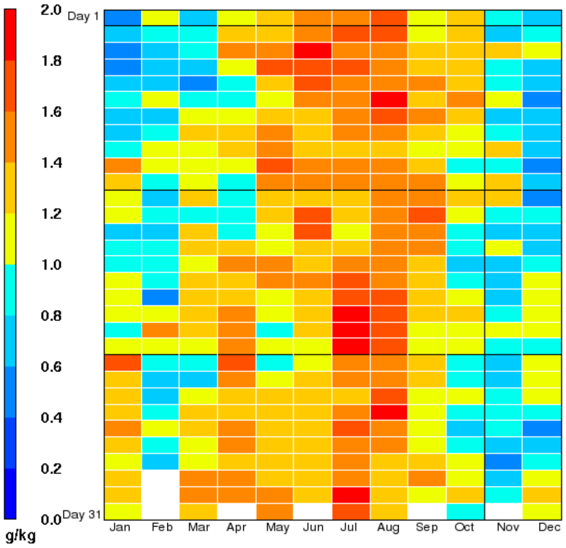
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -0.8 at (8,1), Max= 1.6 at (1,10)

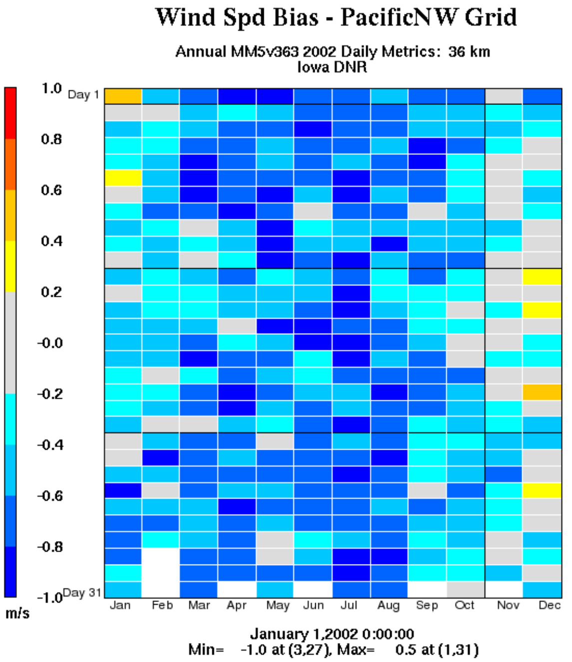
Humidity Gross Error - SE Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



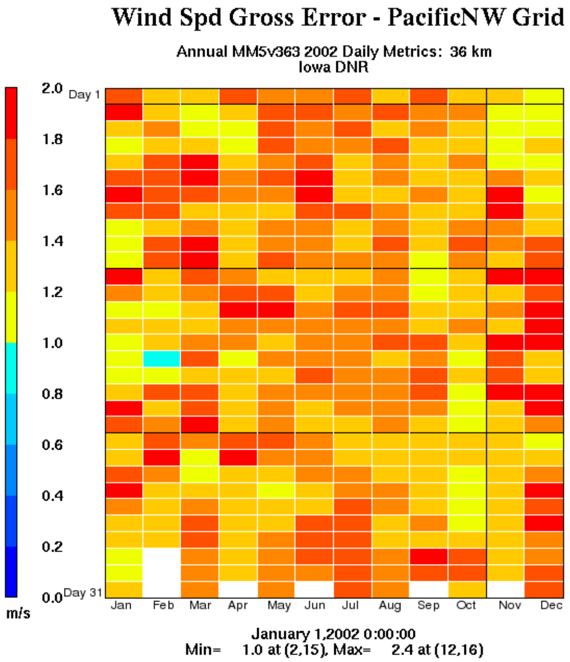
January 1,2002 0:00:00
Min= 0.4 at (1,28), Max= 2.0 at (6,29)

Western Subdomains


Wind Spd Bias - PacificNW Grid

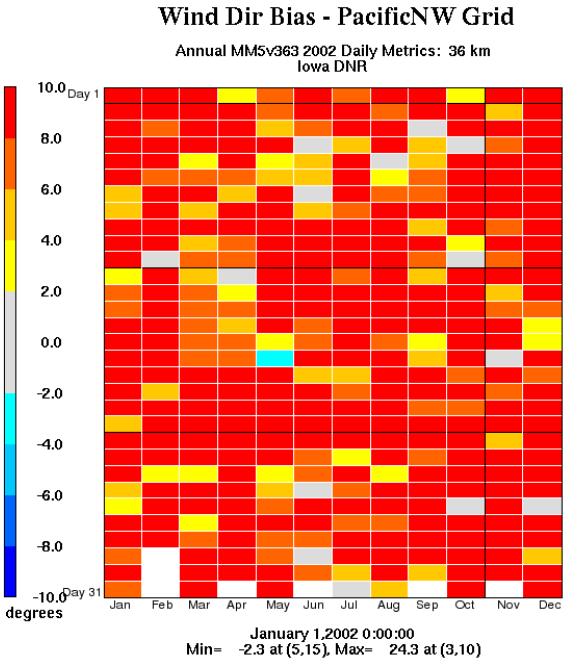
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -1.0 at (3,27), Max= 0.5 at (1,31)


Wind Spd Gross Error - PacificNW Grid

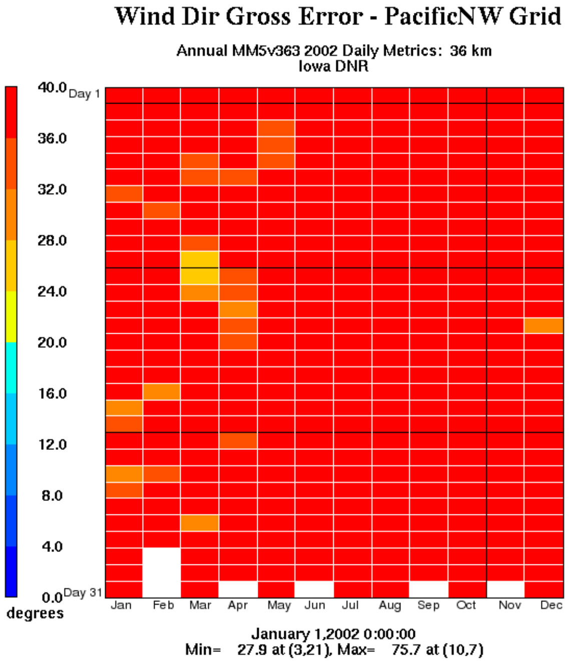
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 1.0 at (2,15), Max= 2.4 at (12,16)


Wind Dir Bias - PacificNW Grid

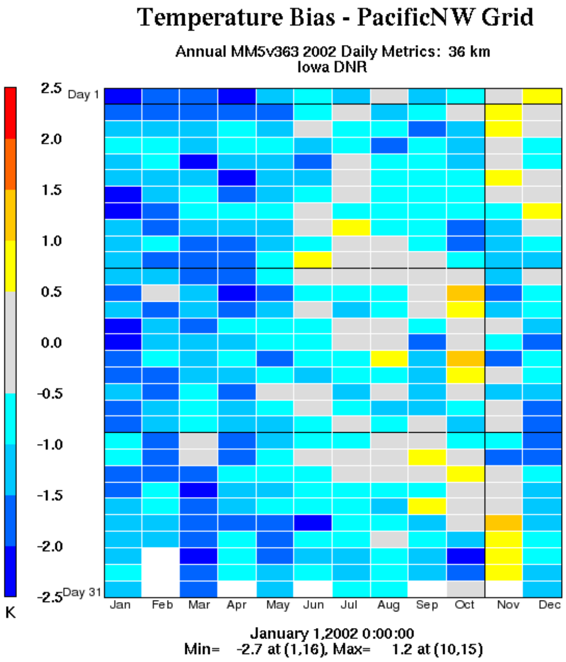
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -2.3 at (5,15), Max= 24.3 at (3,10)

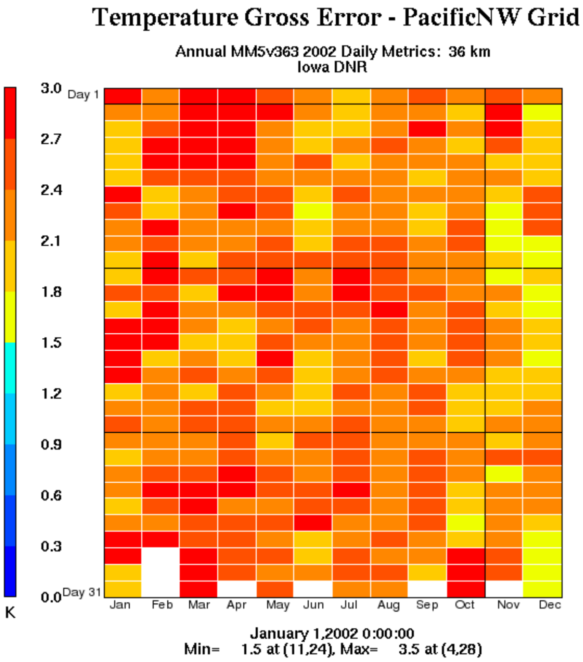

Wind Dir Gross Error - PacificNW Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

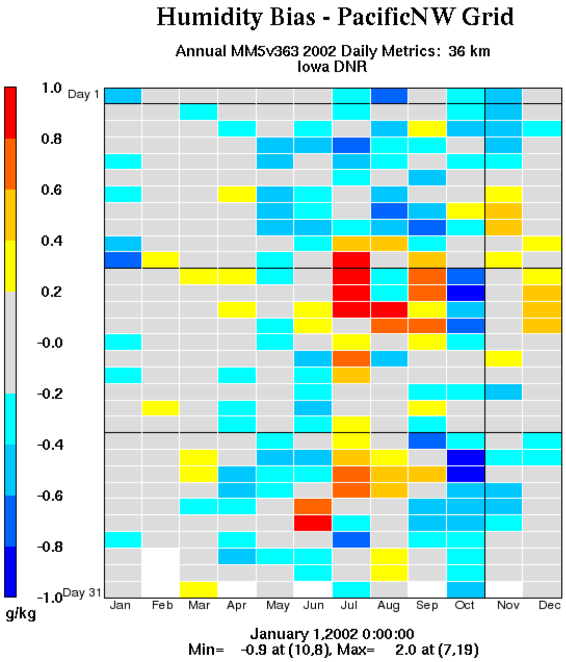
January 1,2002 0:00:00
Min= 27.9 at (3,21), Max= 75.7 at (10,7)



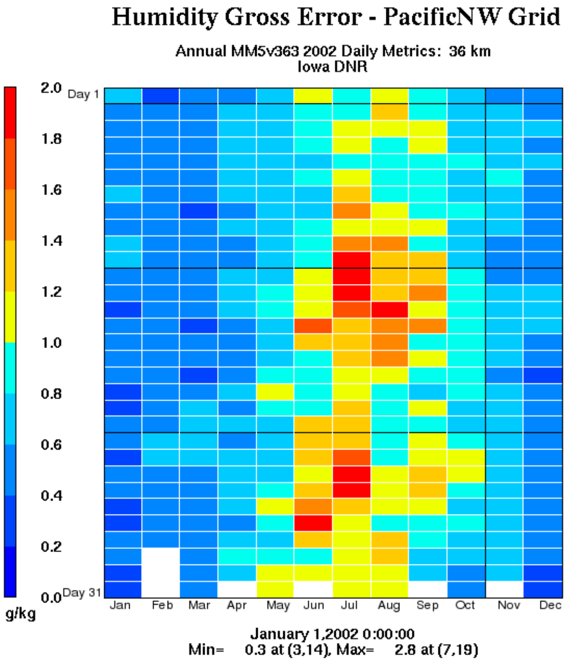
Temperature Bias - PacificNW Grid



Temperature Gross Error - PacificNW Grid



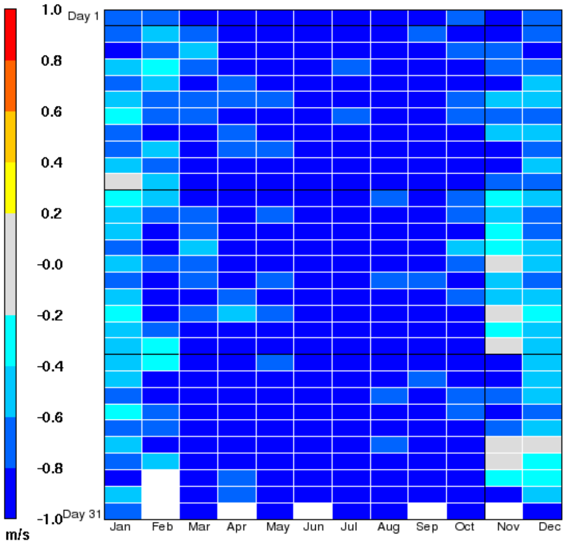
Humidity Bias - PacificNW Grid



Humidity Gross Error - PacificNW Grid

Wind Spd Bias - SW Grid

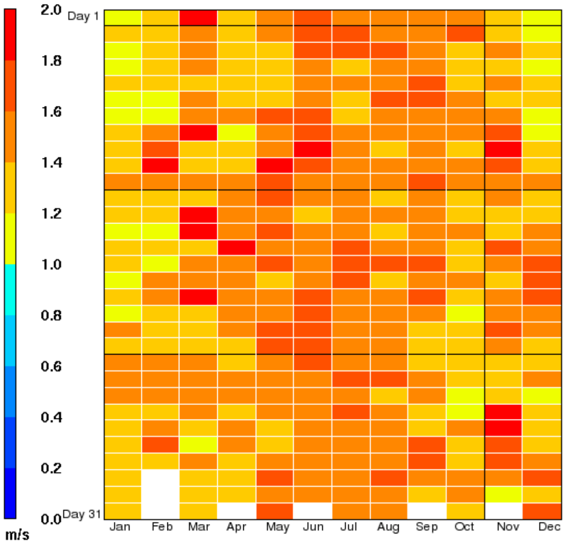
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.5 at (5,22), Max= -0.1 at (11,13)

Wind Spd Gross Error - SW Grid

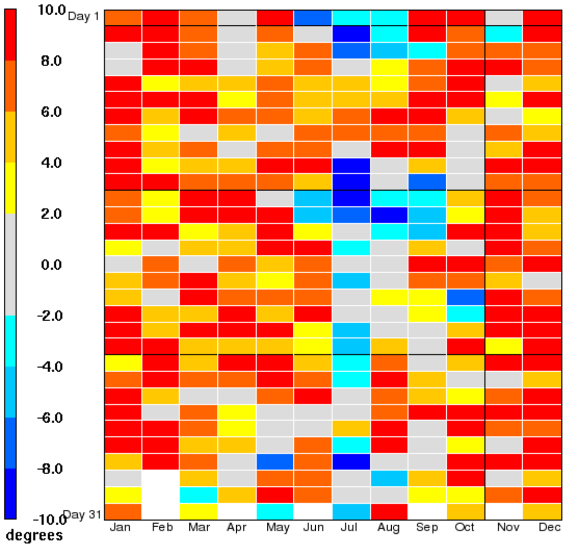
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.0 at (12,25), Max= 2.1 at (4,17)

Wind Dir Bias - SW Grid

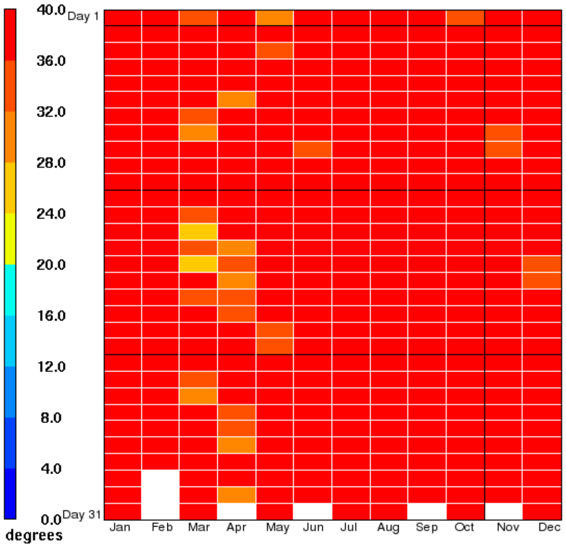
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



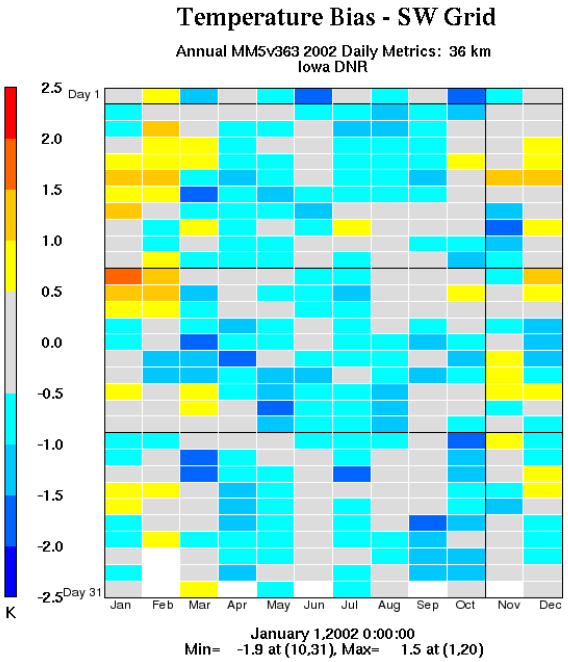
January 1,2002 0:00:00
Min= -11.4 at (7,4), Max= 20.5 at (12,11)

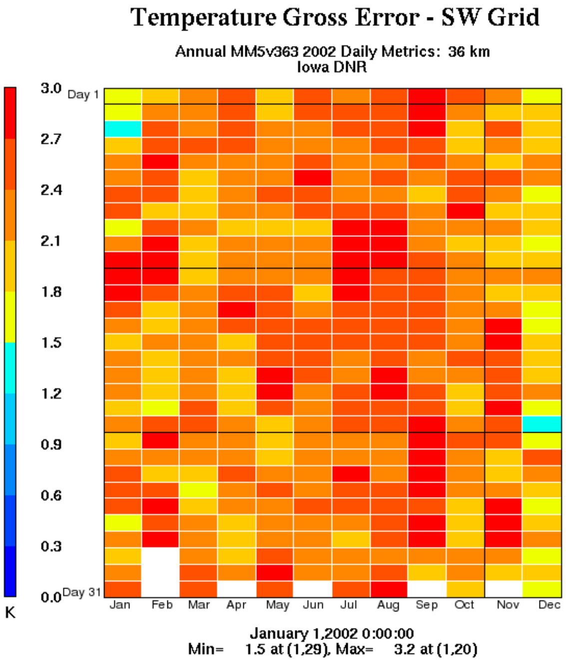
Wind Dir Gross Error - SW Grid

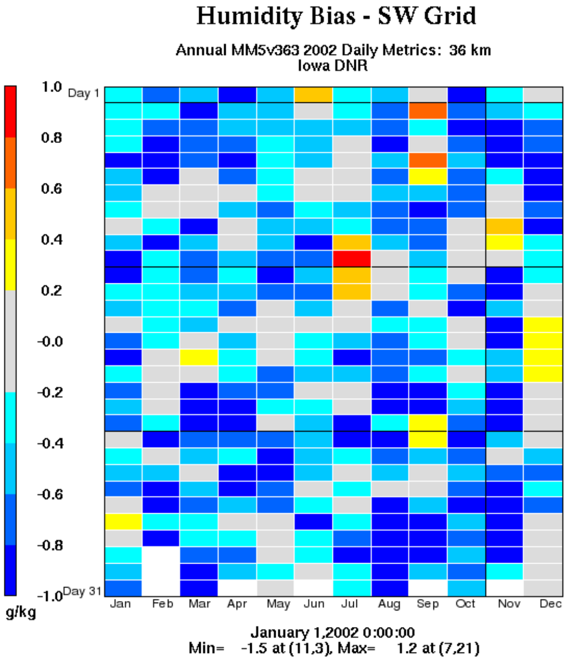
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

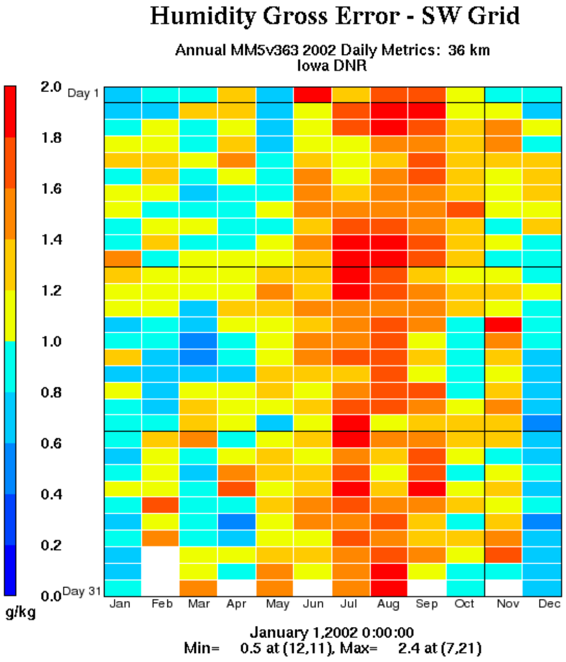


January 1,2002 0:00:00
Min= 25.3 at (3,18), Max= 65.8 at (12,25)


Temperature Bias - SW Grid
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
K
Day 1
Day 31
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
January 1,2002 0:00:00
Min= -1.9 at (10,31), Max= 1.5 at (1,20)

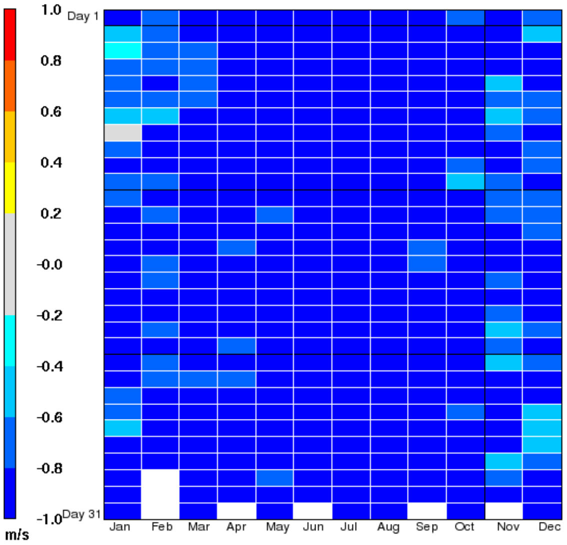

Temperature Gross Error - SW Grid
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
K
Day 1
Day 31
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
January 1,2002 0:00:00
Min= 1.5 at (1,29), Max= 3.2 at (1,20)


Humidity Bias - SW Grid
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR
1.0
0.8
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
g/kg
Day 1
Day 31
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
January 1,2002 0:00:00
Min= -1.5 at (11,3), Max= 1.2 at (7,21)


Humidity Gross Error - SW Grid
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
g/kg
Day 1
Day 31
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
January 1,2002 0:00:00
Min= 0.5 at (12,11), Max= 2.4 at (7,21)

Wind Spd Bias - DessertSW Grid

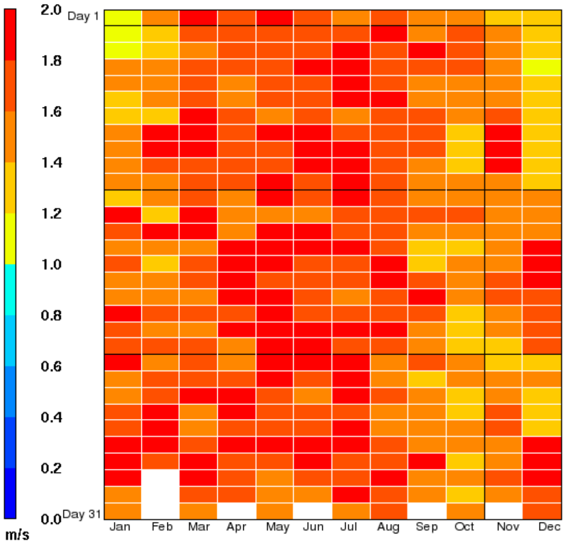
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -1.9 at (8,3), Max= -0.1 at (1,24)

Wind Spd Gross Error - DessertSW Grid

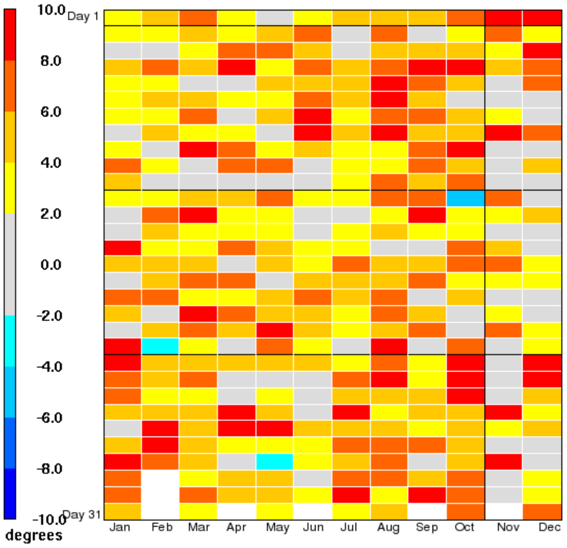
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.0 at (1,30), Max= 2.5 at (4,5)

Wind Dir Bias - DessertSW Grid

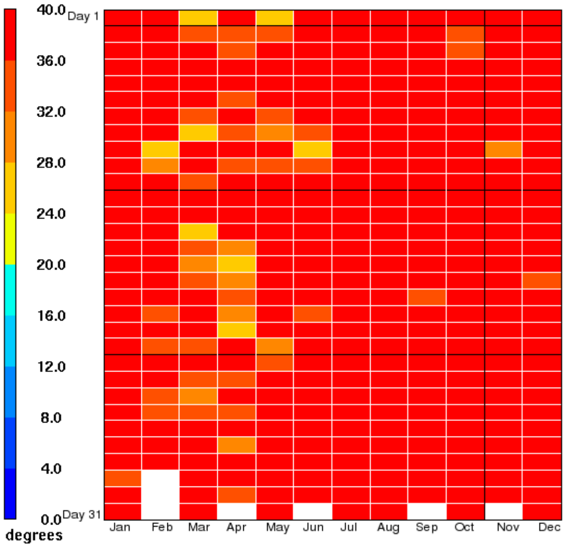
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -5.2 at (10,20), Max= 12.0 at (8,27)

Wind Dir Gross Error - DessertSW Grid

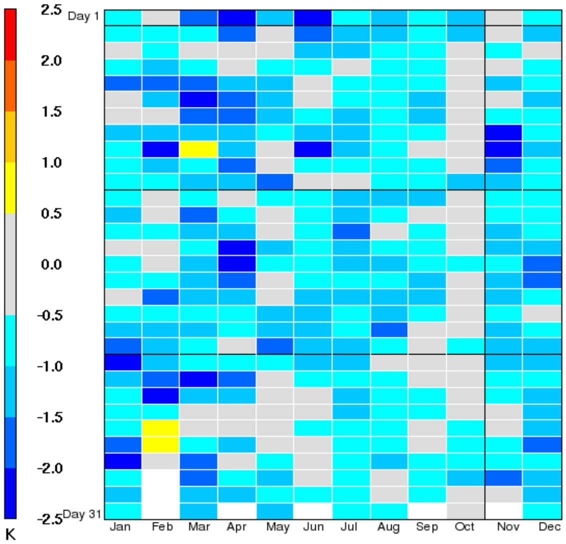
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 24.4 at (4,16), Max= 56.2 at (5,4)

Temperature Bias - DessertSW Grid

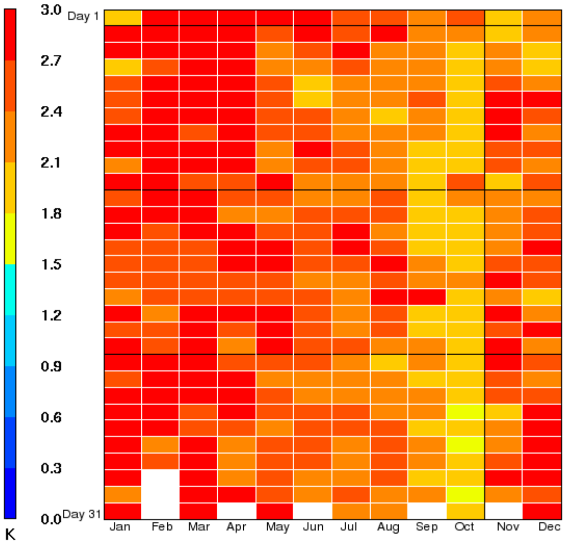
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= -2.8 at (4,17), Max= 0.9 at (3,23)

Temperature Gross Error - DessertSW Grid

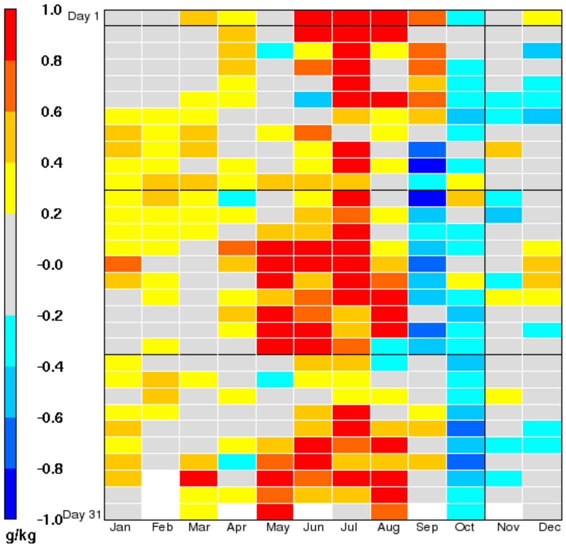
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



January 1,2002 0:00:00
Min= 1.7 at (10,2), Max= 3.8 at (3,11)

Humidity Bias - DessertSW Grid

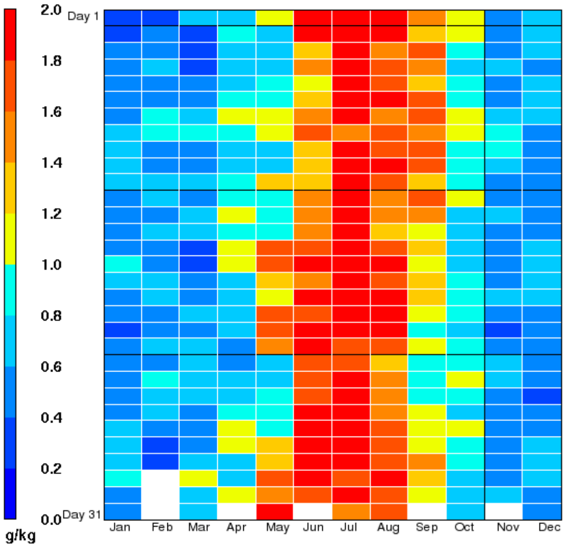
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



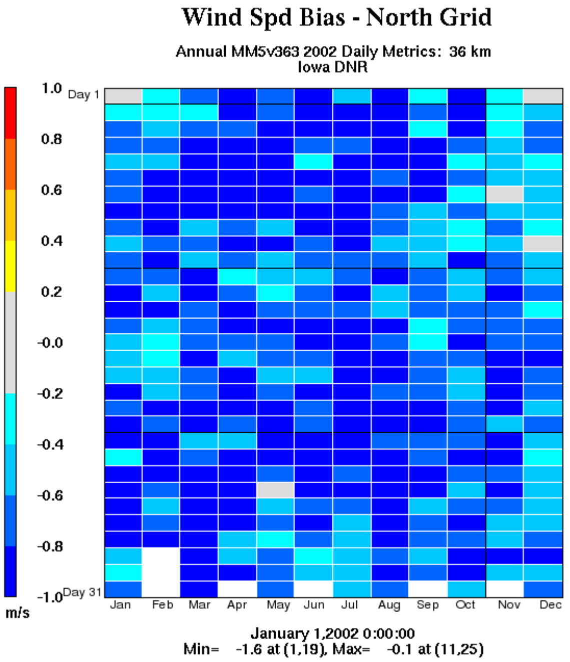
January 1,2002 0:00:00
Min= -0.9 at (9,22), Max= 2.8 at (6,31)

Humidity Gross Error - DessertSW Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR



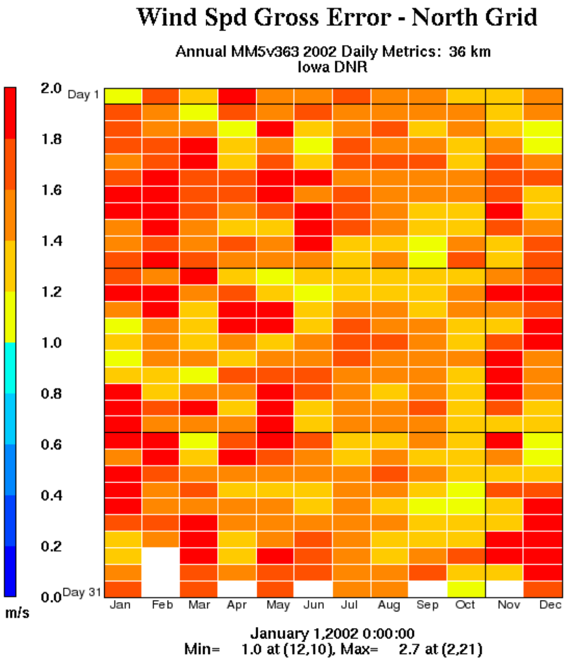
January 1,2002 0:00:00
Min= 0.2 at (3,29), Max= 3.2 at (6,31)



Wind Spd Bias - North Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

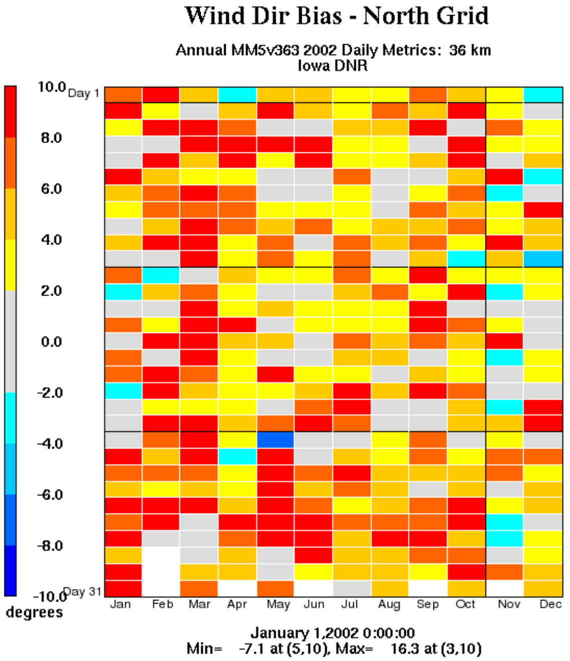
January 1,2002 0:00:00
Min= -1.6 at (1,19), Max= -0.1 at (11,25)



Wind Spd Gross Error - North Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

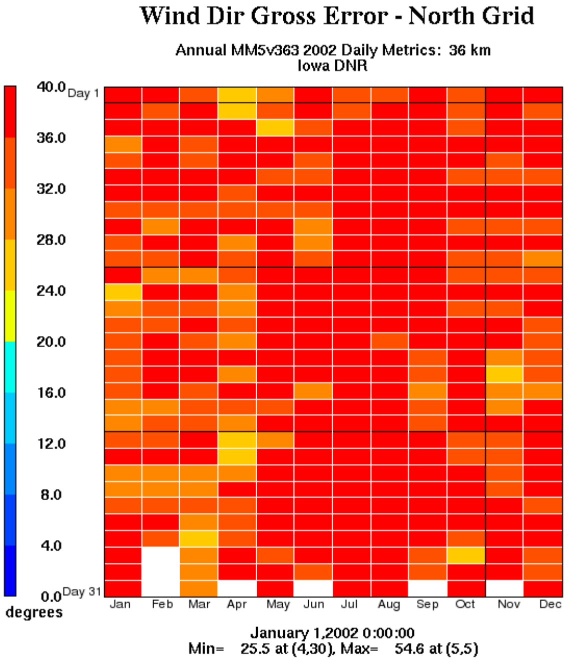
January 1,2002 0:00:00
Min= 1.0 at (12,10), Max= 2.7 at (2,21)



Wind Dir Bias - North Grid

Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= -7.1 at (5,10), Max= 16.3 at (3,10)

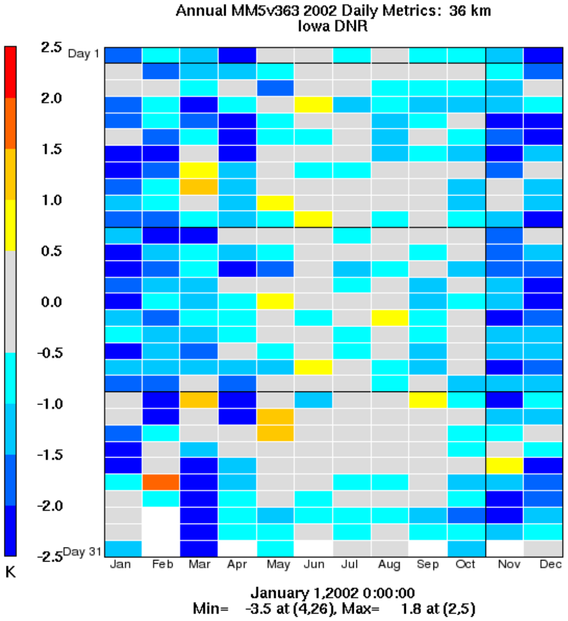


Wind Dir Gross Error - North Grid

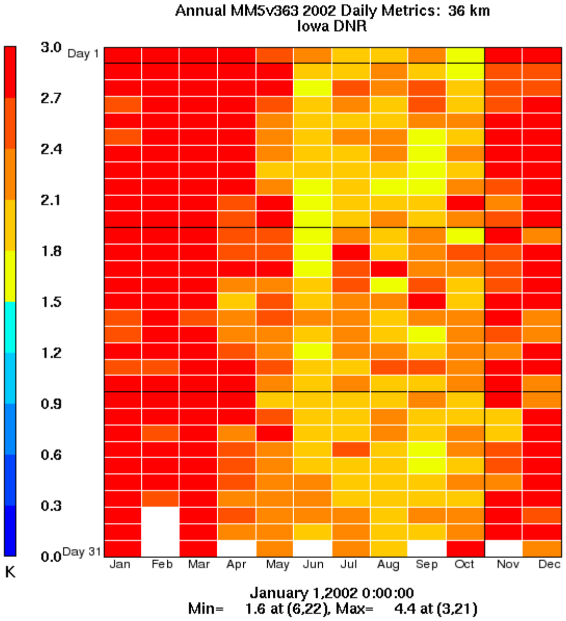
Annual MM5v363 2002 Daily Metrics: 36 km
Iowa DNR

January 1,2002 0:00:00
Min= 25.5 at (4,30), Max= 54.6 at (5,5)

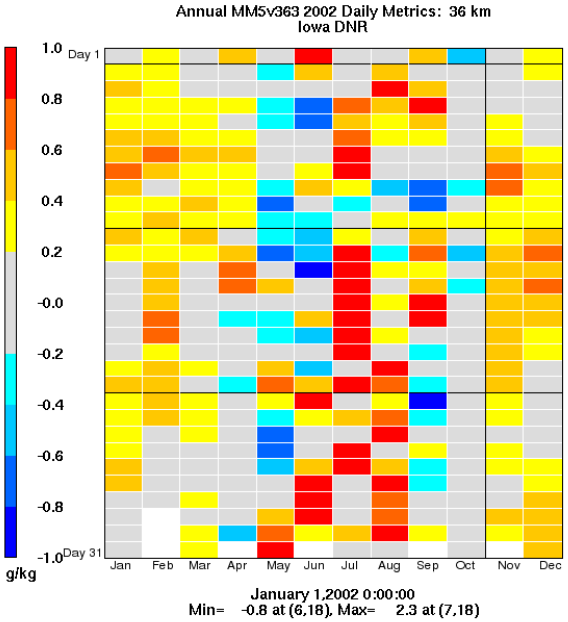
Temperature Bias - North Grid



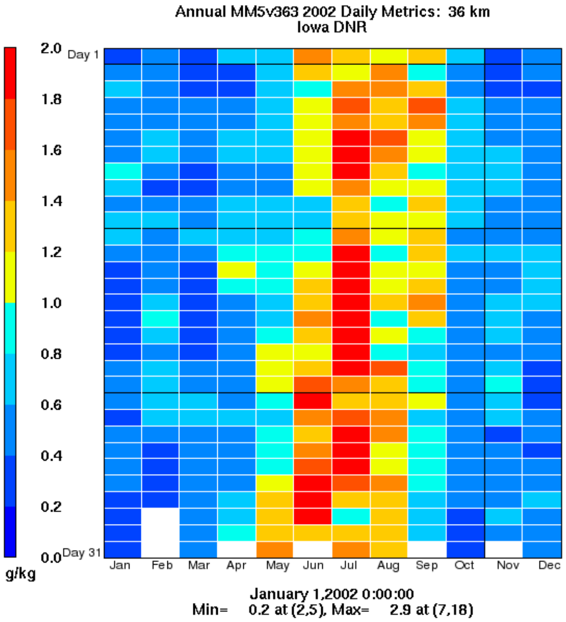
Temperature Gross Error - North Grid



Humidity Bias - North Grid



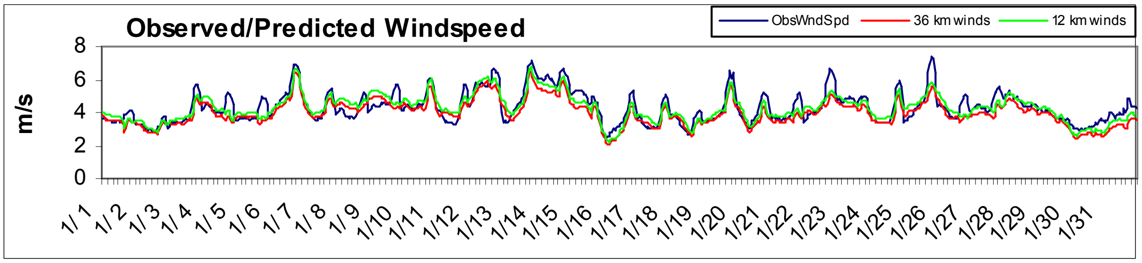
Humidity Gross Error - North Grid

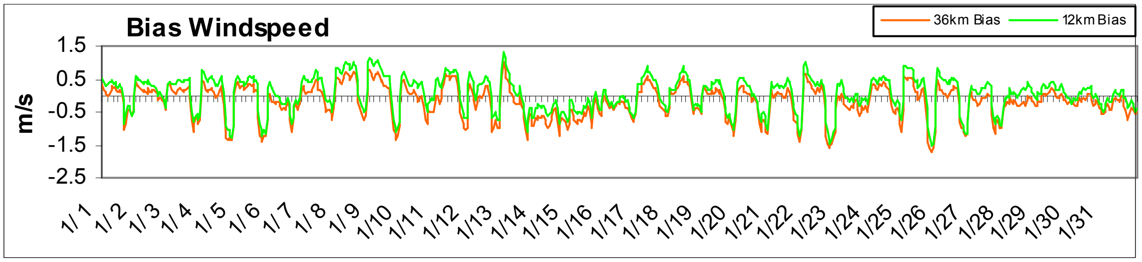


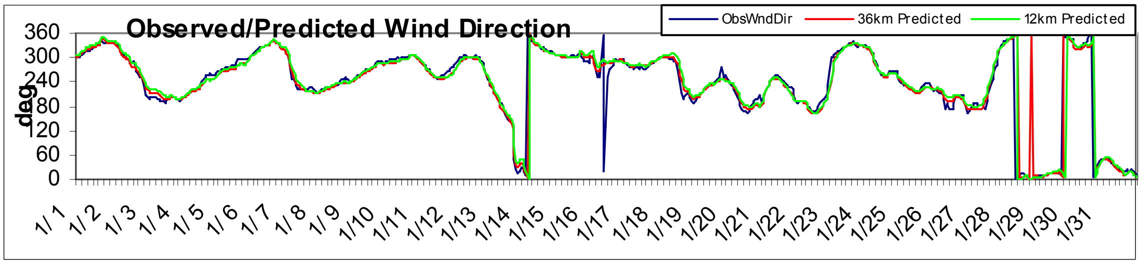
APPENDIX C

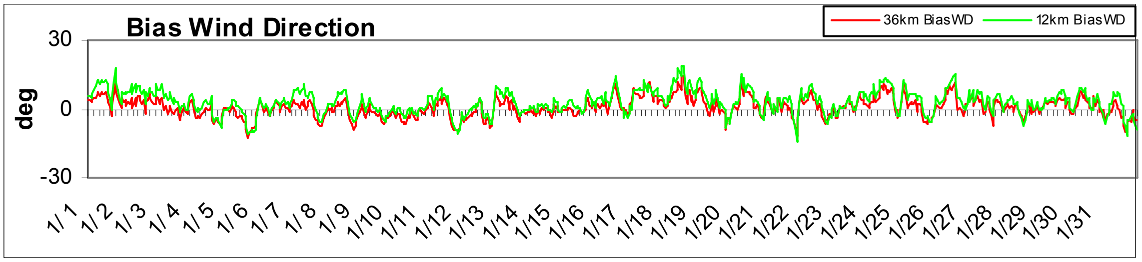
Hourly statistical results for both the 36 and 12 km grids.

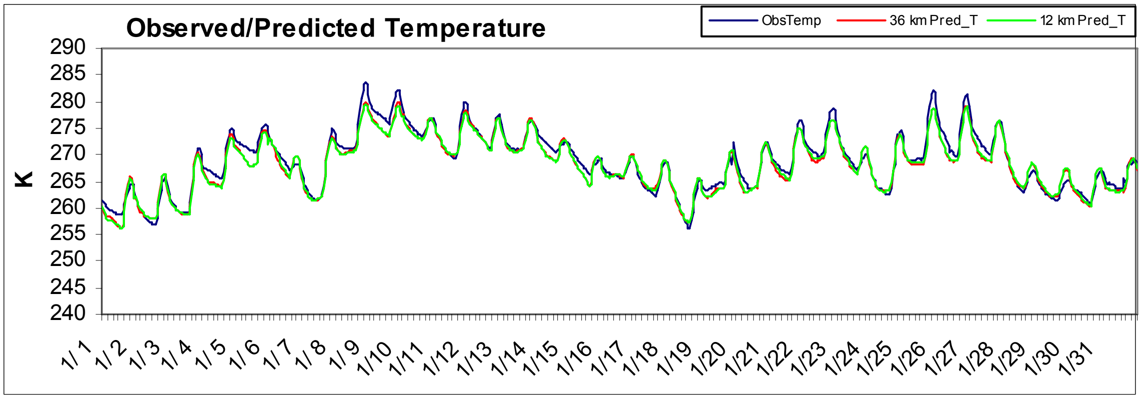
CenrapN: January 2002

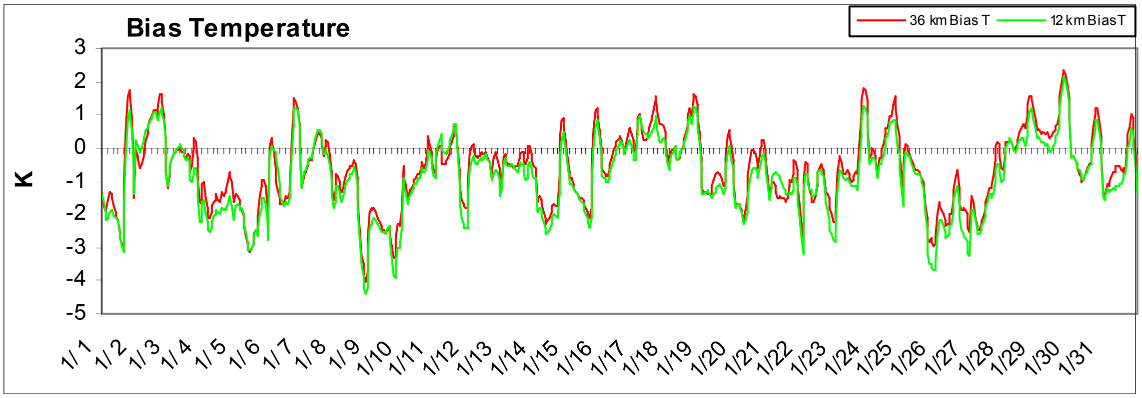


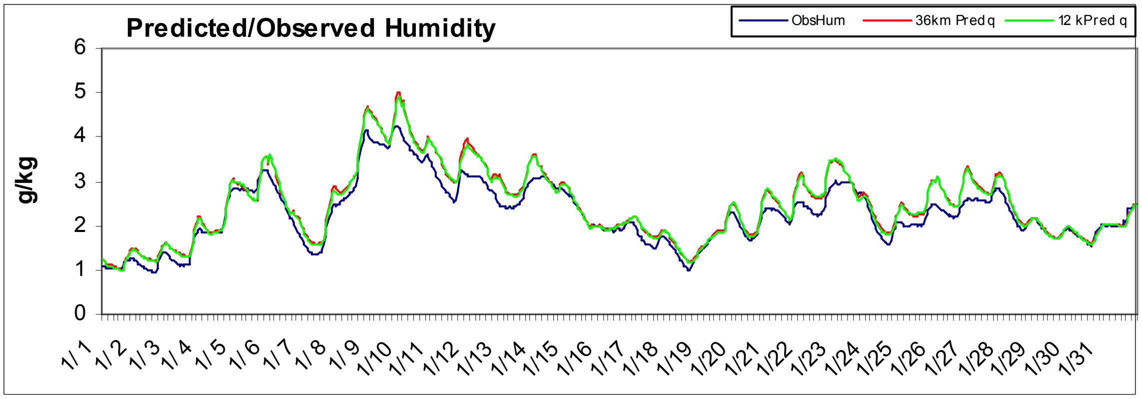


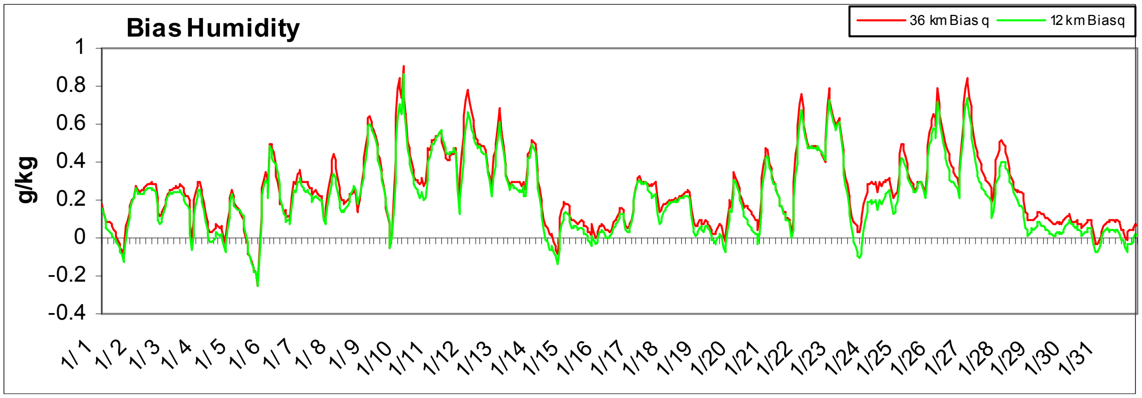




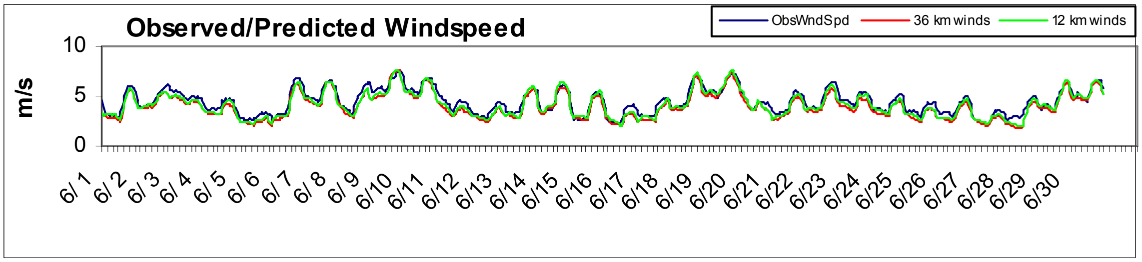

Observed/Predicted Temperature

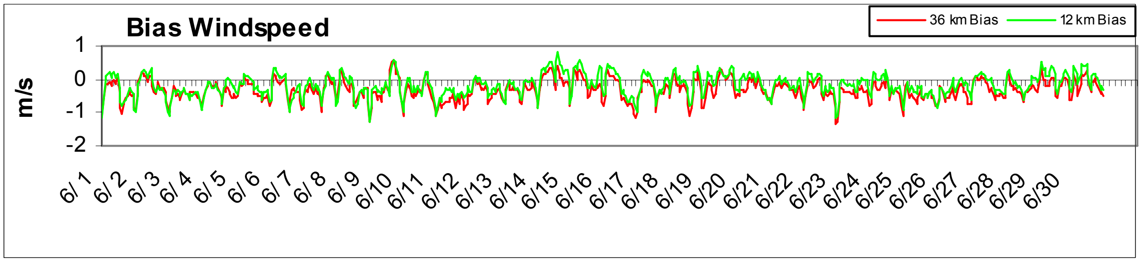

Bias Temperature

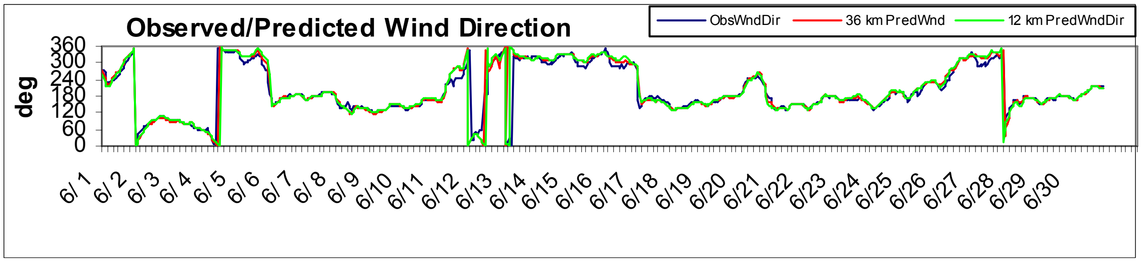

Predicted/Observed Humidity

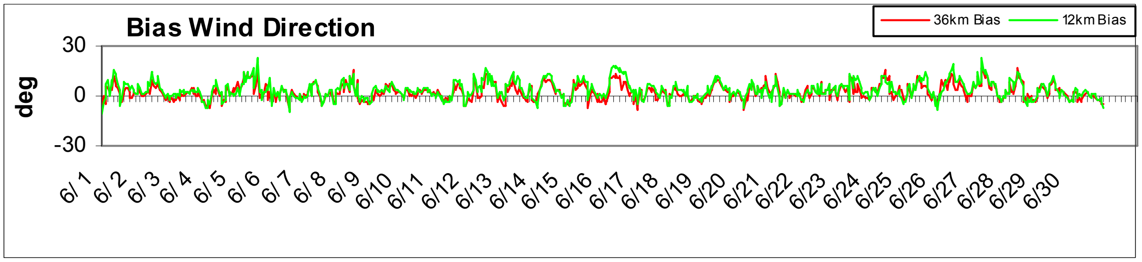

Bias Humidity

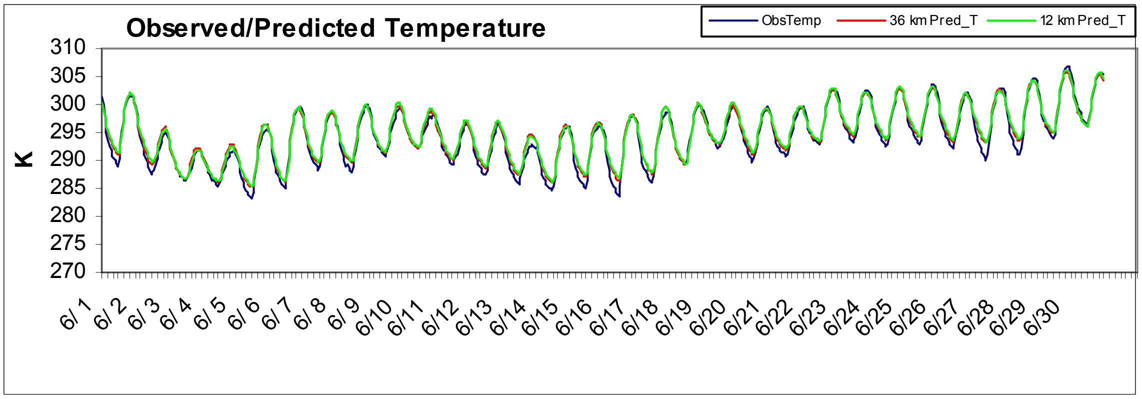
CenrapN: June 2002

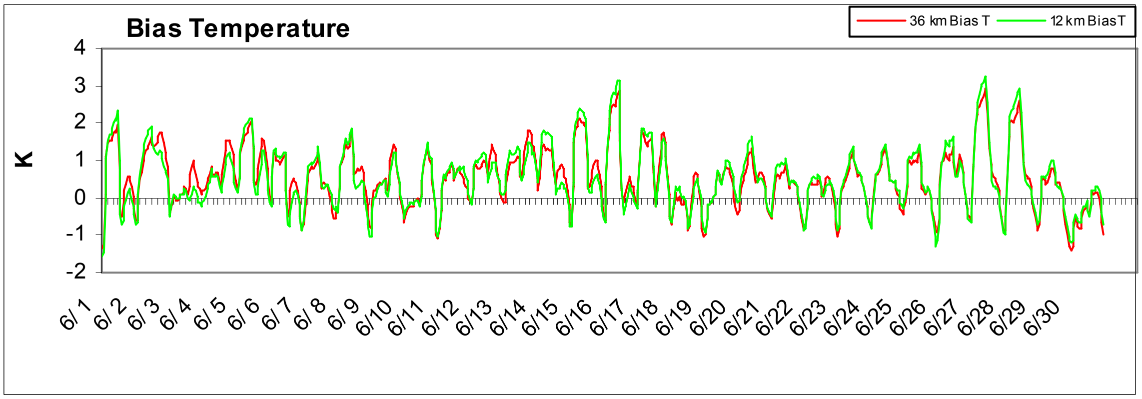


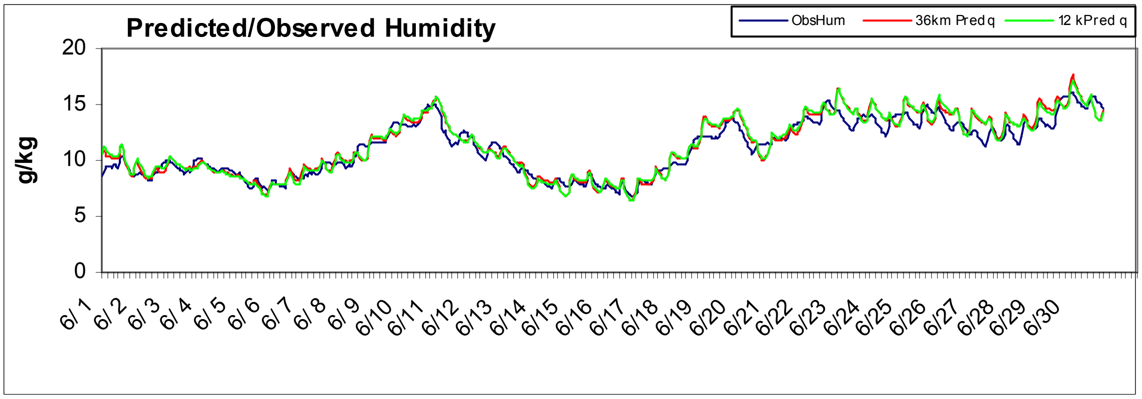


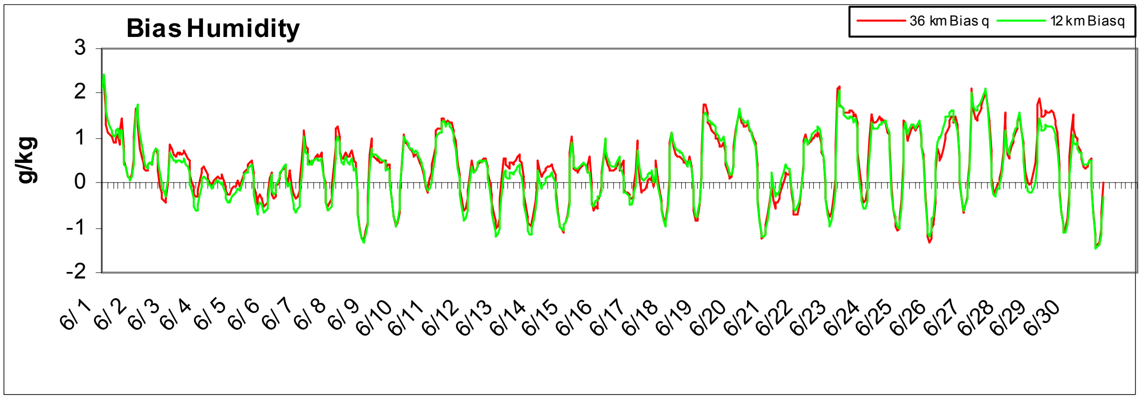




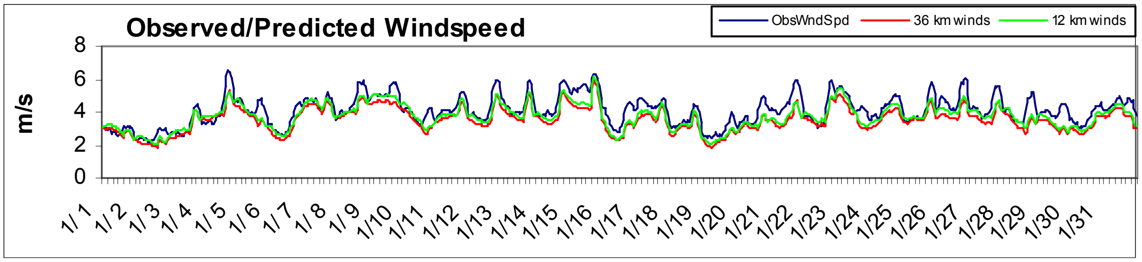

Observed/Predicted Temperature

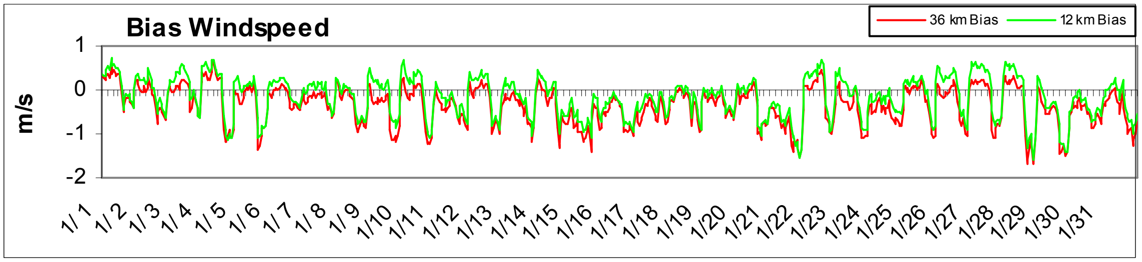

Bias Temperature

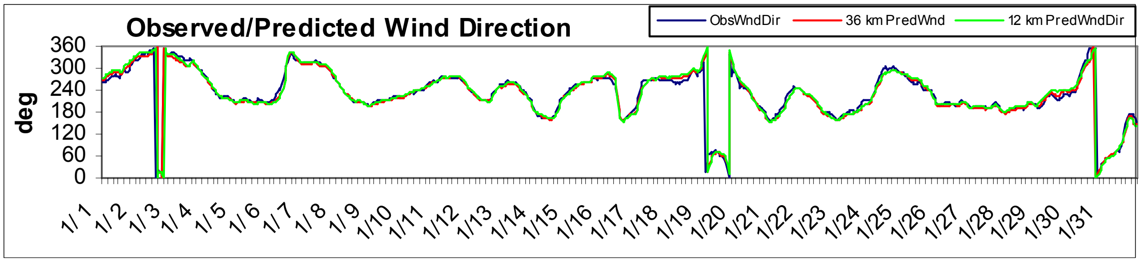

Predicted/Observed Humidity

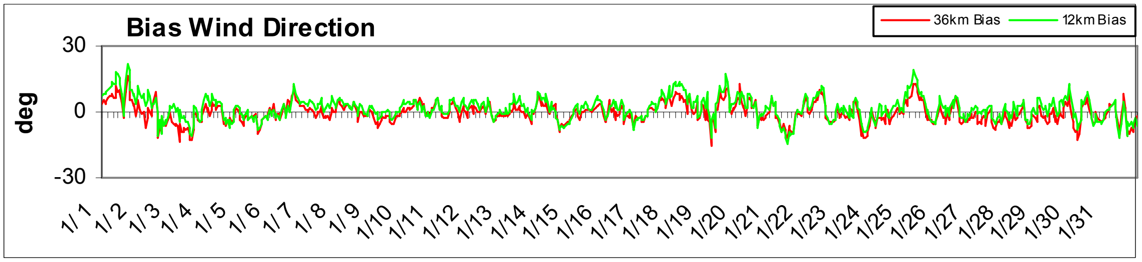

Bias Humidity

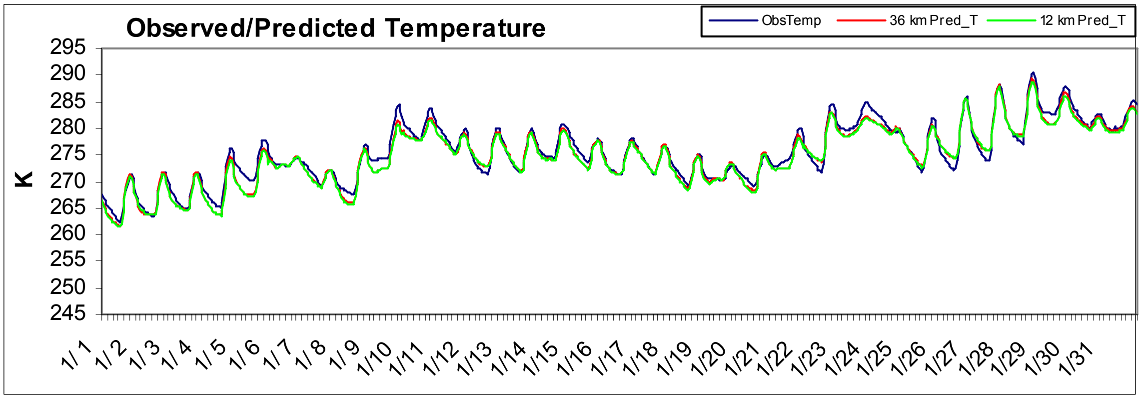
OhioVal: January 2002

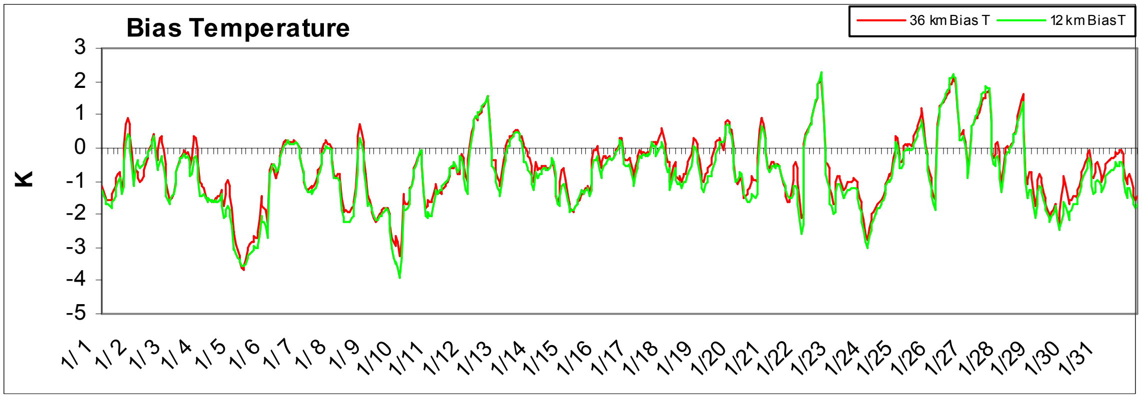


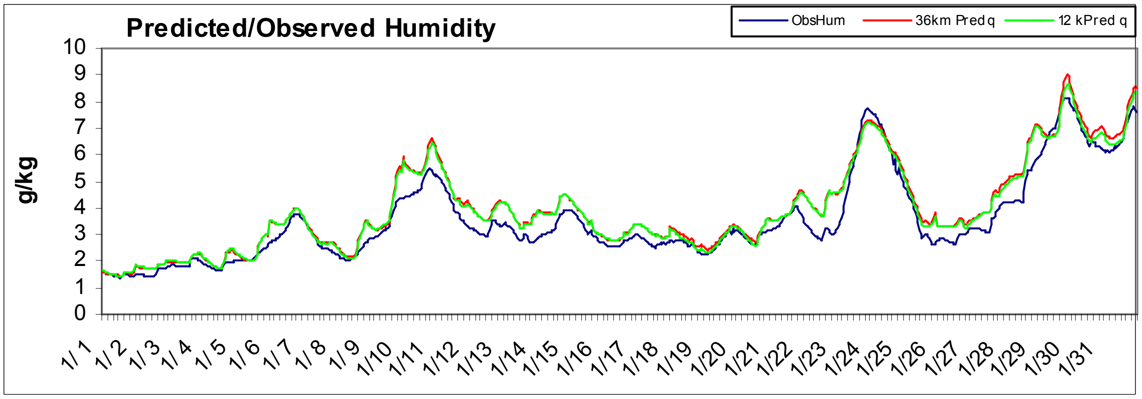


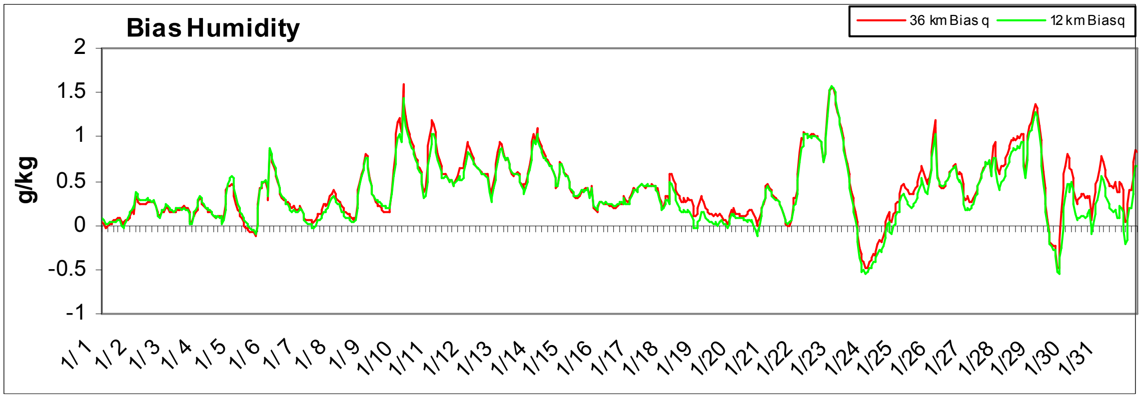




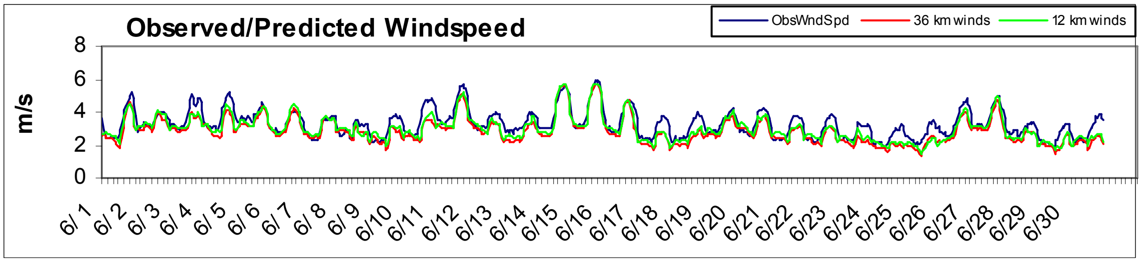

Observed/Predicted Temperature
ObsTemp
36 km Pred_T
12 km Pred_T
K
295
290
285
280
275
270
265
260
255
250
245
1/1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/11 1/12 1/13 1/14 1/15 1/16 1/17 1/18 1/19 1/20 1/21 1/22 1/23 1/24 1/25 1/26 1/27 1/28 1/29 1/30 1/31

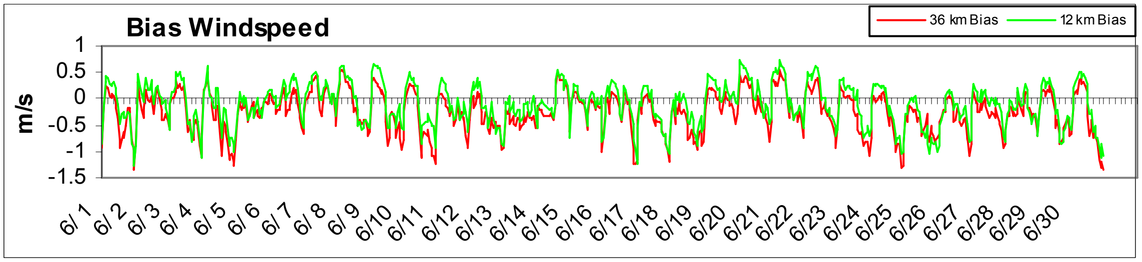

Bias Temperature
36 km Bias T
12 km Bias T
K
3
2
1
0
-1
-2
-3
-4
-5
1/1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/11 1/12 1/13 1/14 1/15 1/16 1/17 1/18 1/19 1/20 1/21 1/22 1/23 1/24 1/25 1/26 1/27 1/28 1/29 1/30 1/31

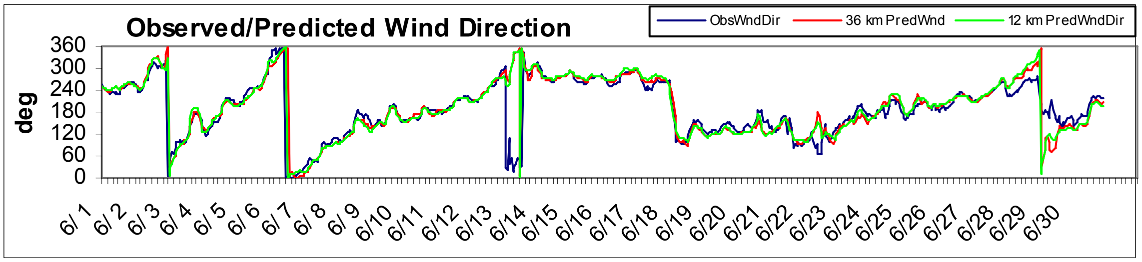

Predicted/Observed Humidity
ObsHum
36km Pred q
12 kPred q
g/kg
10
9
8
7
6
5
4
3
2
1
0
1/1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/11 1/12 1/13 1/14 1/15 1/16 1/17 1/18 1/19 1/20 1/21 1/22 1/23 1/24 1/25 1/26 1/27 1/28 1/29 1/30 1/31

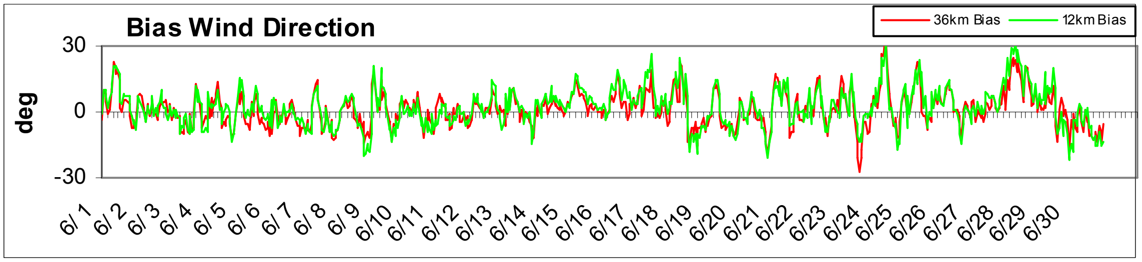

Bias Humidity
36 km Bias q
12 km Biasq
g/kg
2
1.5
1
0.5
0
-0.5
-1
1/1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/11 1/12 1/13 1/14 1/15 1/16 1/17 1/18 1/19 1/20 1/21 1/22 1/23 1/24 1/25 1/26 1/27 1/28 1/29 1/30 1/31

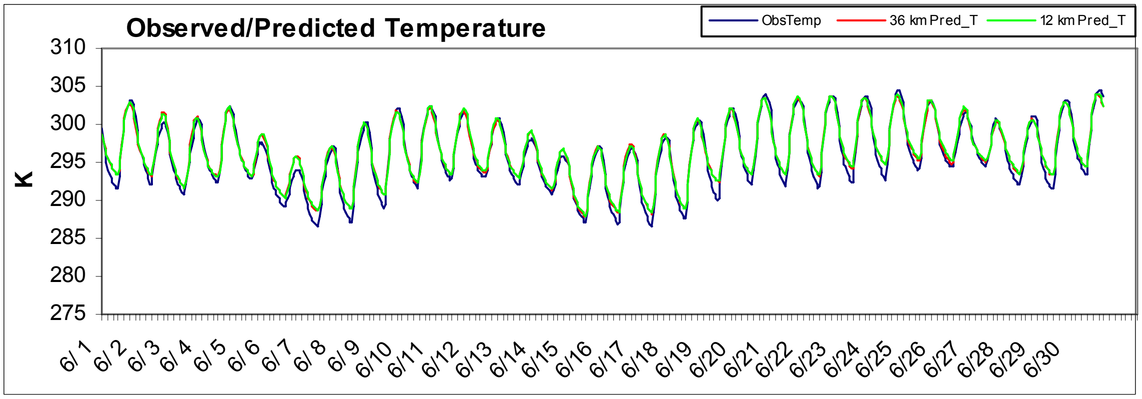
OhioVal: June 2002


Observed/Predicted Windspeed


Bias Windspeed


Observed/Predicted Wind Direction


Bias Wind Direction


Observed/Predicted Temperature
ObsTemp
36 km Pred_T
12 km Pred_T
K
310
305
300
295
290
285
280
275
6/ 1
6/ 2
6/ 3
6/ 4
6/ 5
6/ 6
6/ 7
6/ 8
6/ 9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
6/18
6/19
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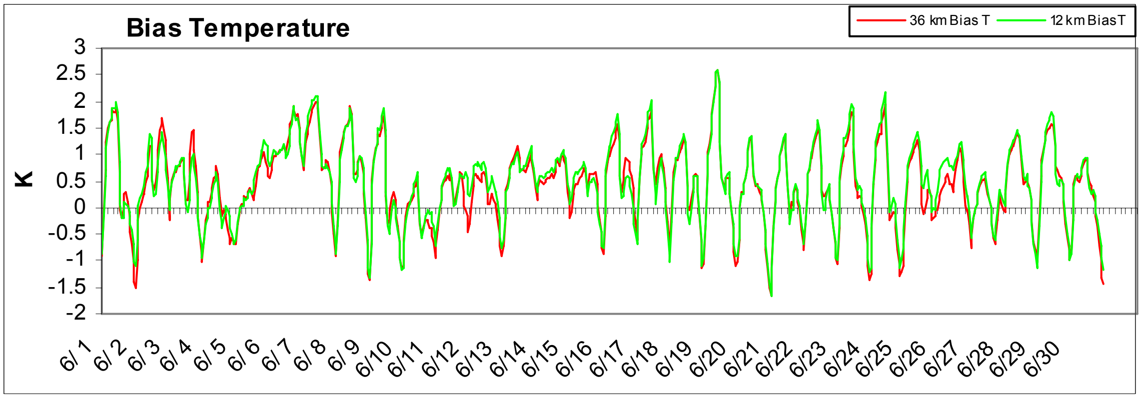
6/23
6/24
6/25
6/26
6/27
6/28
6/29
6/30


Bias Temperature
36 km Bias T
12 km Bias T
K
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
6/ 1
6/ 2
6/ 3
6/ 4
6/ 5
6/ 6
6/ 7
6/ 8
6/ 9
6/10
6/11
6/12
6/13
6/14
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6/17
6/18
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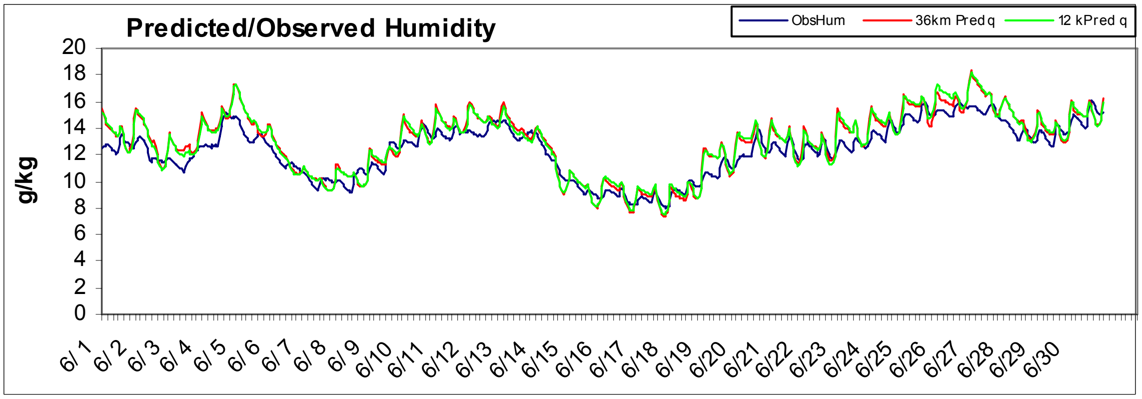
6/28
6/29
6/30


Predicted/Observed Humidity
ObsHum
36km Pred q
12 kPred q
g/kg
20
18
16
14
12
10
8
6
4
2
0
6/ 1
6/ 2
6/ 3
6/ 4
6/ 5
6/ 6
6/ 7
6/ 8
6/ 9
6/10
6/11
6/12
6/13
6/14
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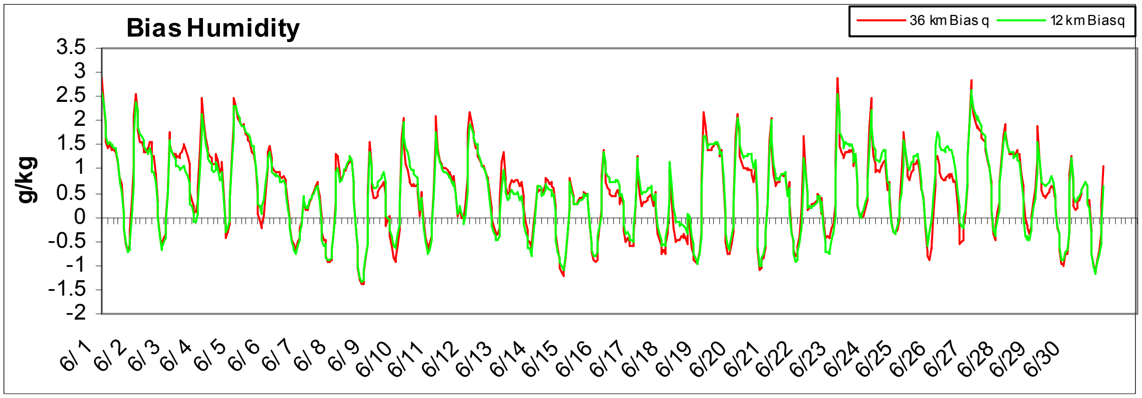
6/30


Bias Humidity
36 km Bias q
12 km Bias q
g/kg
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
6/ 1
6/ 2
6/ 3
6/ 4
6/ 5
6/ 6
6/ 7
6/ 8
6/ 9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
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6/19
6/20
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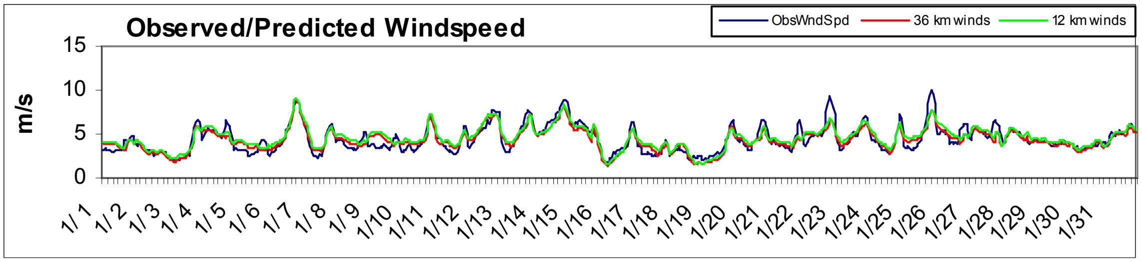
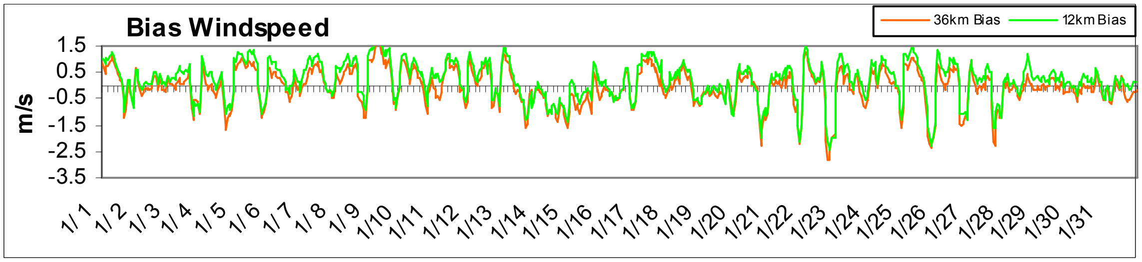
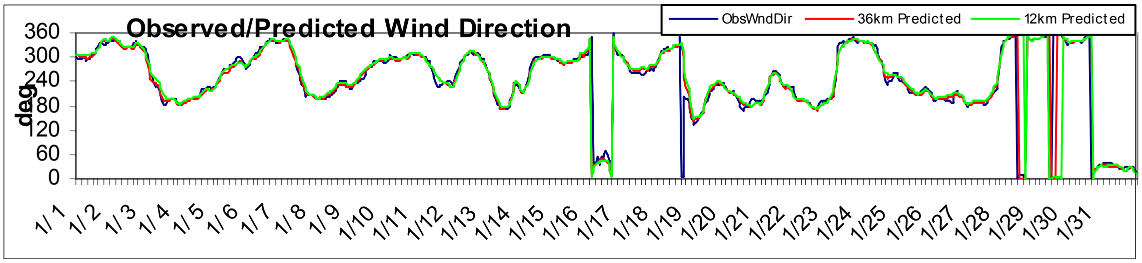
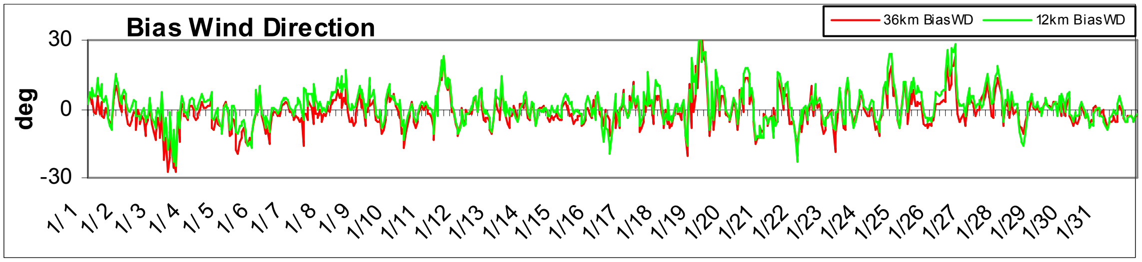
6/26
6/27
6/28
6/29
6/30

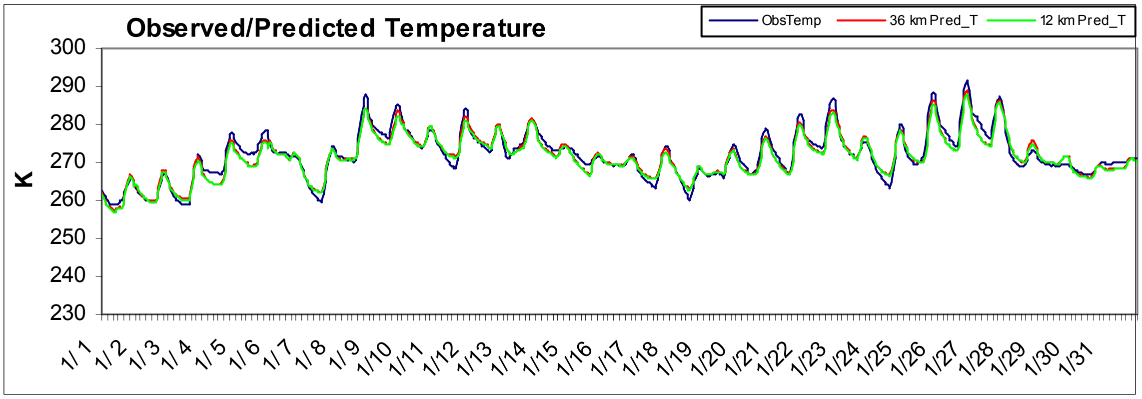
Iowa: January 2002

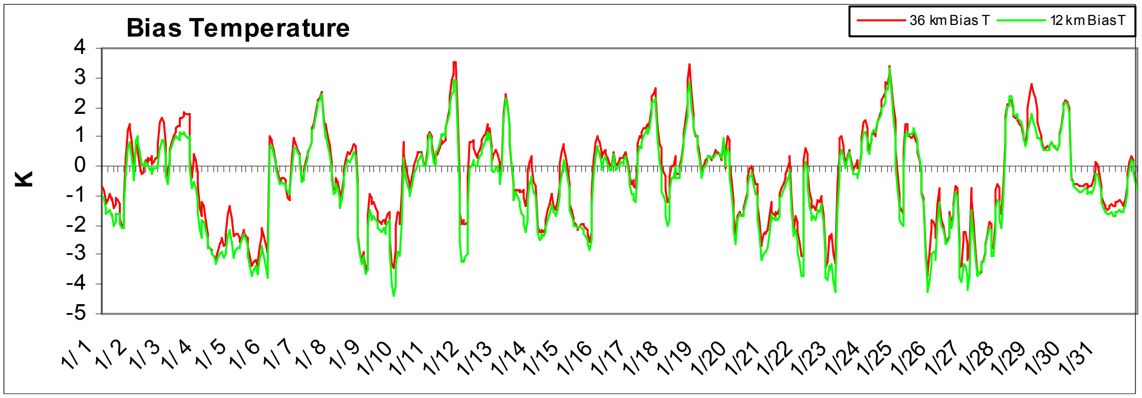


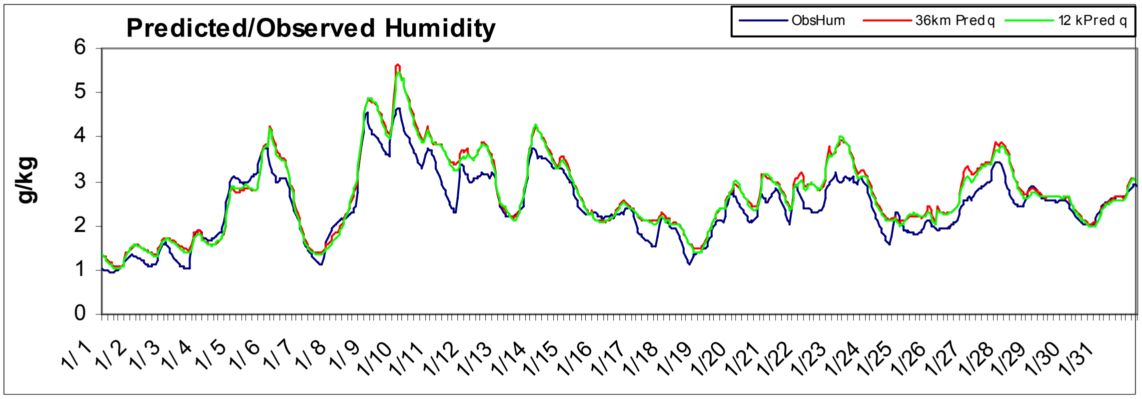


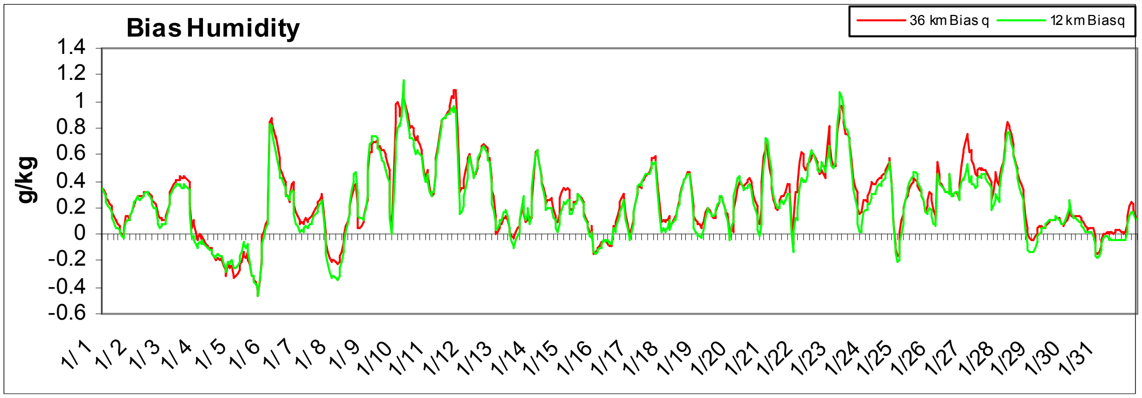




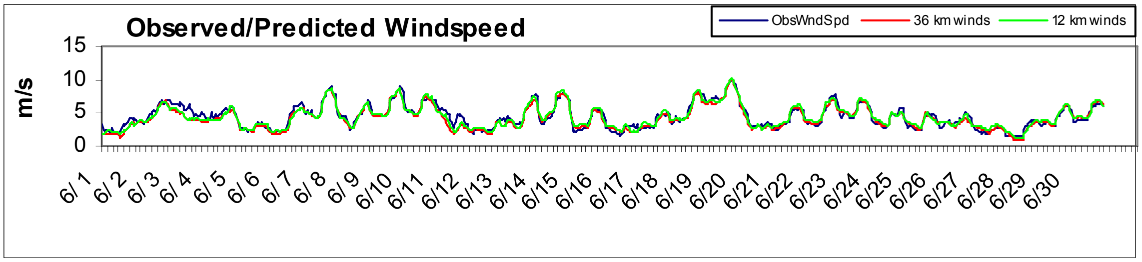

Observed/Predicted Temperature

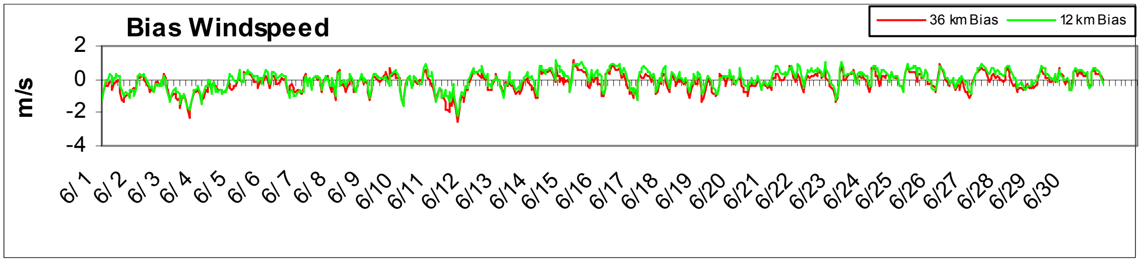

Bias Temperature

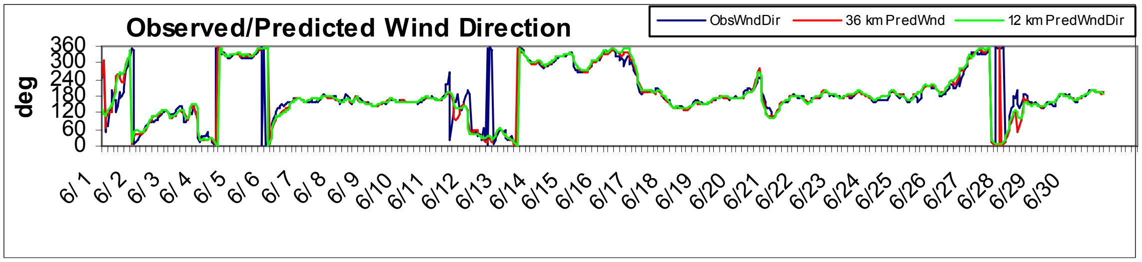

Predicted/Observed Humidity

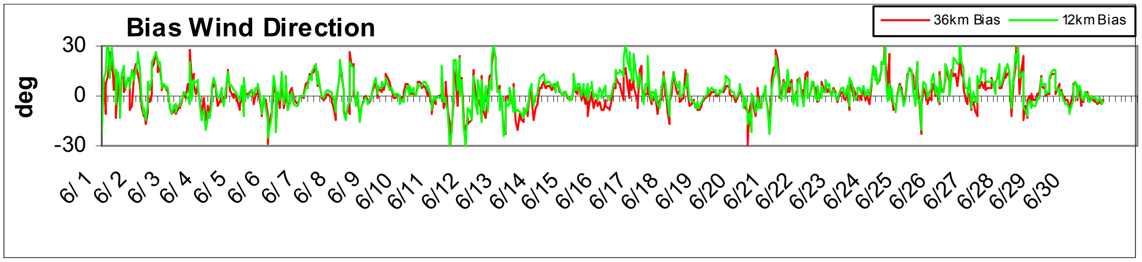

Bias Humidity

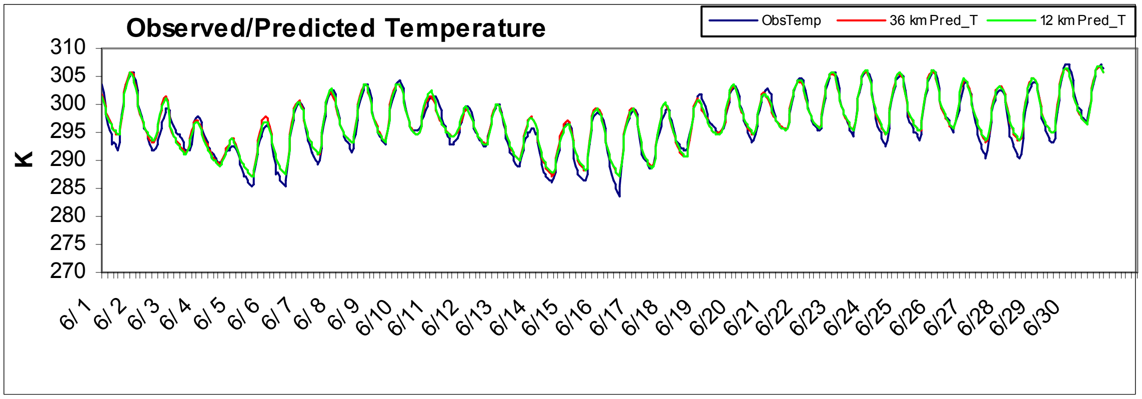
Iowa: June 2002







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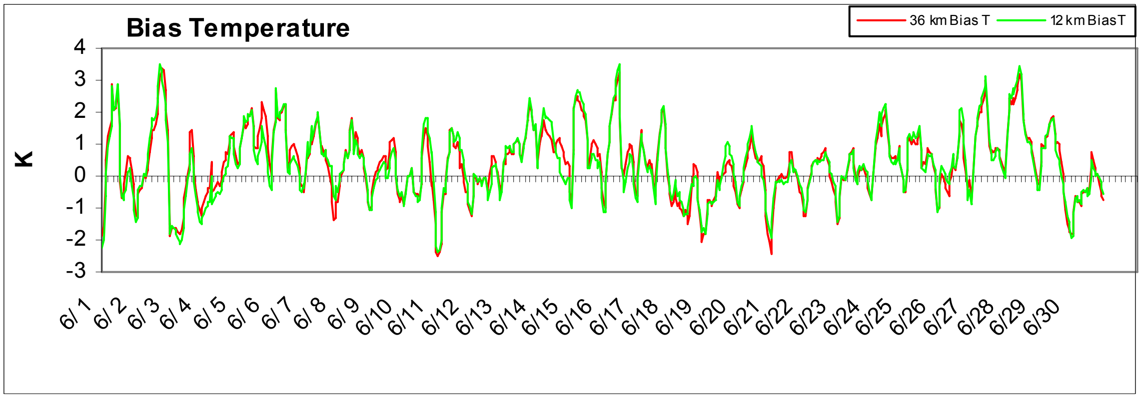
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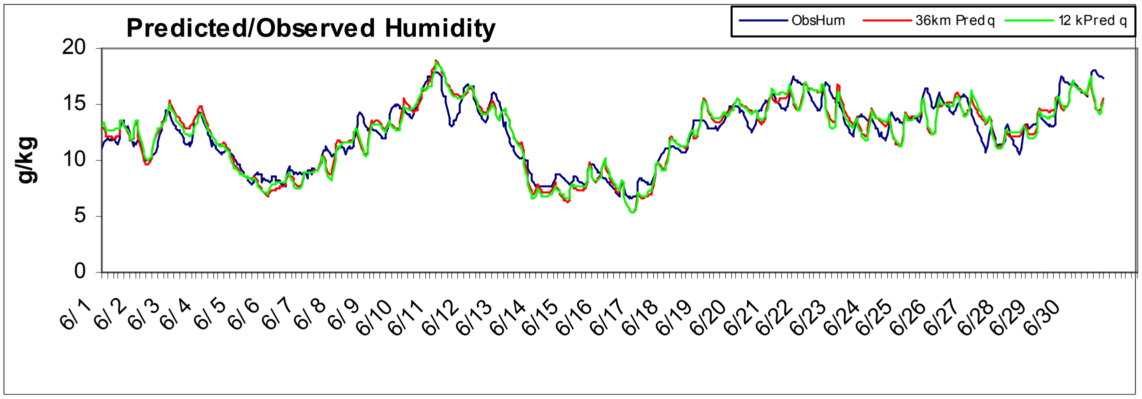
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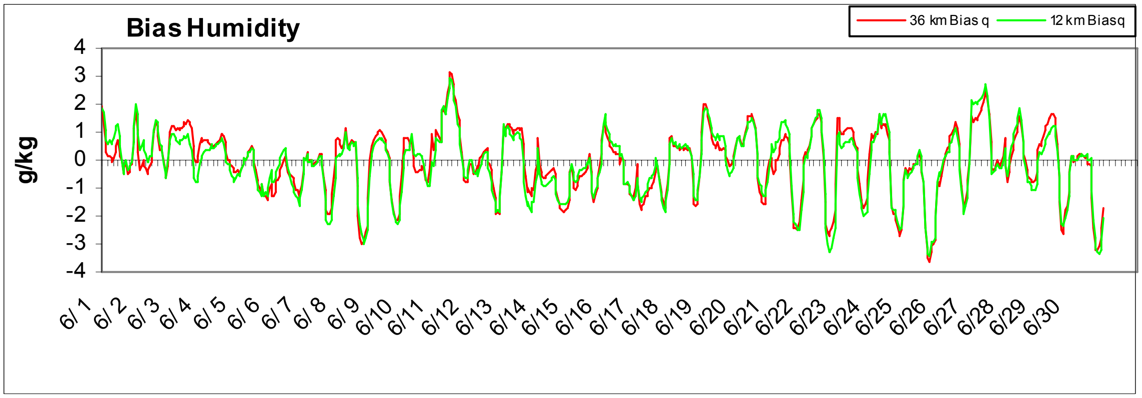
Bias Humidity
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Appendix 8.2

LADCO NONROAD EMISSIONS INVENTORY PROJECT - DEVELOPMENT OF LOCAL DATA FOR CONSTRUCTION AND AGRICULTURAL EQUIPMENT

FINAL REPORT

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September 10, 2004

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ACRONYMS AND ABBREVIATIONS

ANOVA	analysis of variance
CATI	computer assisted telephone interviewing
EMCH	Emission Modeling Clearinghouse
EPA	United States Environmental Protection Agency
FAQs	Frequently Asked Questions
LADCO	Lake Michigan Air Directors Consortium
LPG	liquefied petroleum gas
MSG	Marketing Systems Group
NO_x	oxides of nitrogen
Pechan	E.H. Pechan & Associates, Inc.
PRS	Population Research Systems, LLC
QA	quality assurance
RPO	Regional Planning Organization
SCC	source classification code
SIC	standard industrial classification
VMT	vehicle miles traveled

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CHAPTER I. INTRODUCTION

E.H. Pechan & Associates, Inc. (Pechan) is supporting the Lake Michigan Air Directors Consortium's (LADCO) efforts to develop 2002 nonroad emissions inventories for the Midwest region states. The purpose of this project was to develop local data to improve upon the United States Environmental Protection Agency's (EPA's) default 2002 nonroad construction and agricultural engine emission estimates. The EPA's NONROAD emissions model relies on county allocations of national equipment population and activity data to estimate county-level emissions. Information was collected via survey methods, and from publically available sources of data, to develop local model inputs for equipment populations, engine characteristics, and spatial and temporal activity. This study addressed improvements to the NONROAD model inputs for Indiana, Illinois, Michigan, Ohio, and Wisconsin for construction equipment, and for these five states plus Iowa, Minnesota, and Missouri for agricultural equipment.

To develop local data for the construction category, a telephone survey of construction equipment owners and operators was performed, targeting businesses which are most likely to use these types of equipment. The survey results were used to develop more representative estimates of the types and number of equipment used, as well as information on the use of the equipment (i.e., during the day/week or throughout the year). For the agricultural equipment category, county-level diesel fuel consumption estimates were developed to improve upon the NONROAD model's methods for spatially allocating agricultural equipment activity. Weekly and monthly diesel fuel consumption were also estimated for each state to improve upon the monthly activity profile defaults in the NONROAD model.

CHAPTER II. CONSTRUCTION EQUIPMENT

This section discusses the results of a telephone survey of construction equipment owners and operators, as well as rental equipment companies, to collect local data for the construction category. The survey results were used to develop more representative estimates of the types and number of equipment used, as well as information on the use of the equipment (i.e., during the day/week or throughout the year). The data resulting from this survey are presented and compared to the existing NONROAD model default inputs, where available.

A. SURVEY METHODS

Pechan and its subcontractor, Population Research Systems, LLC (PRS), designed and implemented a survey of construction equipment owners and operators, as well as construction equipment rental companies.

1. Respondents

Pechan first identified the 20 top-emitting construction equipment applications contributing to oxides of nitrogen (NO_x) emissions in the LADCO region to prioritize the equipment types and standard industrial classification (SIC) groups to focus on. Based on this prioritization, Pechan surveyed firms classified under the following SIC groupings:

- Mining (Metals, coal, and nonmetallic): SIC 10, 12, 14
- Heavy Construction Contractors: SIC - 16
- Specialty Trade Contractors, 4-digit SICs:
    - 1771 - Concrete Work
    - 1794 - Excavation Work
    - 1781 & 1795 - Water Well Drilling & Wrecking and Demolition Work
- Landfills: SIC - 4953
- Rental Equipment: SIC – 7353, 7359, 5082

2. Survey Methods and Survey Instrument

The survey instrument was designed to request information on: 1) the types and number of equipment used; 2) frequency of use and time of use (e.g., during the day/week or throughout the year); and 3) engine size. The survey also requested information needed to use in scaling the survey results for the various SIC groups (i.e., number of employees). Please see Appendix A for a detailed description of the sample, the interview, and summaries of response and refusal rates.

3. Processing and Quality Assurance (QA) of Survey Data

Prior to analyzing the data as described in Section III, Pechan performed the following processing steps and quality assurance (QA) on the data. Pechan first converted the survey results from the initial database structure prepared by PRS (with each separate question and associated equipment application as a separate field) to a format more conducive to analysis. For each respondent, equipment type was pulled into a single field, along with the associated variables:

- Number of equipment owned;
- Number of equipment leased;
- Percentage fuel;
- Horsepower;
- Hours of operation per week;
- Weeks of operation per year; and
- Seasonal operation percentages.

All other respondent information (e.g., contact, SIC, employment, etc.) was also included. The fraction of fuel type was then applied to the equipment totals per respondent to assign equipment populations per fuel type. These manipulations were then cross-checked against the original database of responses for accuracy. Additional manipulations prior to analysis included:

- Excluding equipment identified as "electric";
- Excluding responses coded as "Refused" or "Don't Know"; and
- Excluding zero when this was an artifact of the computer-assisted telephone interviewing (CATI) system (i.e., if it was not a response provided as zero, or if not used to fill in values for a question requiring 100 percent).

The responses for the rental companies were included in a separate database. Questions concerning operating schedules were not asked for these respondents, since it was determined prior to the survey that rental companies did not generally keep records for this type of information. Only questions concerning the types and number of equipment leased were asked of the rental SIC codes.

B. RESULTS AND ANALYSIS

Questions concerning weekly and hourly operations were asked in relation to the operation of all equipment by the respondent, and not specific to a certain equipment type. For all activity variables, responses were weighted by the number of pieces of equipment for which respondents were providing information, as well as by a weighting factor of the surveyed to the regional employment of their SIC grouping. Questions on annual and seasonal usage, equipment populations, and equipment horsepower were asked for each of the 26 types of equipment, if a respondent owned/leased this type of equipment.

1. Weekly and Hourly Temporal Profiles

The survey requested information on the operation of equipment during six 4-hour time periods during a typical weekday and a typical weekend day (Q8 and Q9). Table II-1 provides the percentage of operation for the designated 4-hour time periods within a weekday and weekend. Note that these percentages were not required to equal 100 percent for a given day. Based on these percentages, it was estimated that operators were almost 4 times as likely to operate equipment on the weekdays than the weekend days. Table II-2 shows this comparison to the default NONROAD model weekly profile, which assumes that construction equipment is 2 times as likely to be operated during the weekday than a weekend day.

Table II-1. Weekday and Weekend Profiles by 4-Hour Time Periods from Survey Data

Weekday	Weighted % of Operation	Weekend Day	Weighted % of Operation
8 am to 12 Noon	84.3	8 am to 12 Noon	28.0
12 Noon to 4 pm	80.6	12 Noon to 4 pm	19.1
4 pm to 8 pm	33.3	4 pm to 8 pm	2.5
8 pm to 12 am	8.5	8 pm to 12 am	2.2
12 am to 4 am	5.1	12 am to 4 am	0.2
4 am to 8 am	30.0	4 am to 8 am	9.8
Weekday Sum	241.7	Weekend Sum	61.8
		Weekday/Weekend Fraction	3.9

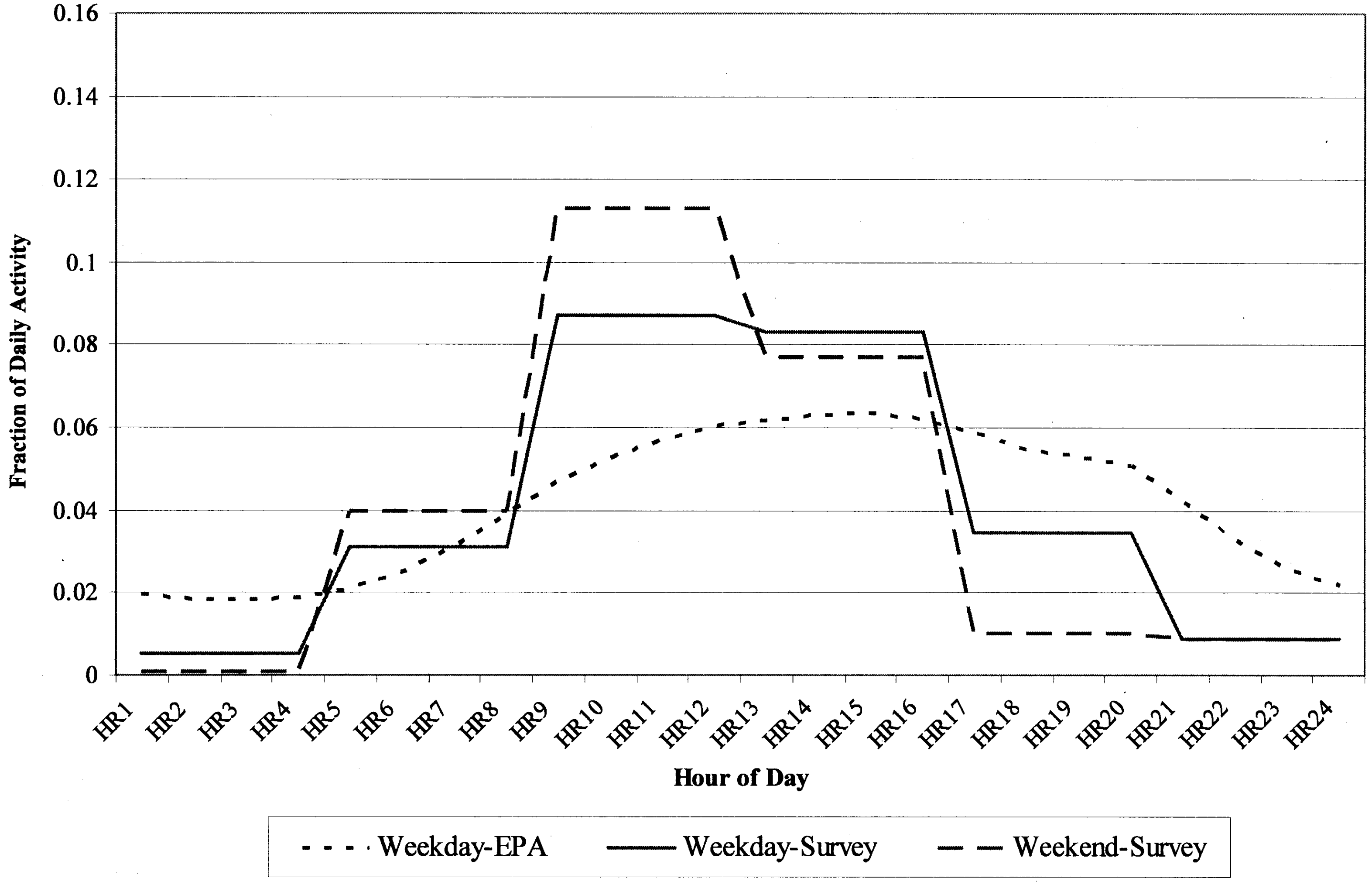
Table II-2. Comparison of Weekday and Weekend Day Profiles from NONROAD and Survey Data

Time Period	NONROAD model	Survey
Monday	0.166667	0.181400
Tuesday	0.166667	0.181400
Wednesday	0.166667	0.181400
Thursday	0.166667	0.181400
Friday	0.166667	0.181400
Saturday	0.083333	0.046500
Sunday	0.083333	0.046500
Weekday Total*	0.833333	0.907000
Weekend Total**	0.166667	0.093000
Weekday/Weekend Fraction	2.0	3.9

*One Weekday multiplied by 5.
**One Weekend day multiplied by 2.

The NONROAD model does not calculate emissions for different periods during a given day. The weekday diurnal profile developed from the survey results is shown in Figure II-1, and compared to EPA's diurnal profile for construction equipment, as listed in EPA's Emission Modeling Clearinghouse (EMCH) at http://www.epa.gov/ttn/chief/emch/temporal/. A weekend day temporal profile was also developed from the survey. Note that the survey does not provide information on how the activity may vary within each 4-hour period, which is reflected in EPA's default profile.

Figure II-1. Weekday and Weekend Diurnal Profiles from EPA and Survey Results



2. Annual and Seasonal Usage

Equipment-specific annual hours of use were estimated by multiplying hours of operation per week, (Q10e) by weeks of operation per year (Q10f). Table II-3 lists the average hours of operation per year across all applications, irrespective of engine/fuel type. The sample obtained per equipment type was not deemed sufficient for replacing the NONROAD defaults by source classification code (SCC). As such, we examined the weighted average annual use for all SCCs combined from the survey, and compared that to annual use across all applications in the NONROAD model. From these averages, we developed a value of 1.2 that represents the ratio of the survey to the NONROAD model annual use. Annual hours of use per year were then adjusted by increasing values 20 percent for all construction SCCs in NONROAD.

Table II-3. Hours of Operation Per Year by Equipment Type

Equipment Description	**Average Hours per Year**
Bore/Drill Rigs	1,293
Cement and Mortar Mixers	479
Concrete/Industrial Saws	282
Cranes	928
Crawler Tractor/Dozers	1,379
Crushing/Processing Equipment	962
Dumpers/Tenders	786
Excavators	1,282
Graders	439
Off-highway Tractors	369
Off-highway Trucks	1,341
Other Construction Equipment	1,177
Pavers	525
Paving Equipment	445
Plate Compactors	381
Rollers	472
Rough Terrain Forklifts	1,231
Rubber Tire Loaders	1,149
Rubber Tire Tractor/Dozers	0
Scrapers	547
Signal Boards/Light Plants	602
Skid Steer Loaders	1,012
Surfacing Equipment	1,028
Tampers/Rammers	327
Tractors/Loaders/Backhoes	778
Trenchers	590
Average Across Applications	**762**
NONROAD Model Average	**632**
Ratio of Survey to NONROAD Model	**1.2**

Based on responses to questions concerning operation during the four seasons of the year, we estimated the average seasonal percentages for each equipment type, shown in Table II-4. The NONROAD model includes a single seasonal allocation for all construction equipment, regardless of engine or application. We evaluated responses for groups of equipment, since, similar to the data obtained for annual hours of use, the sample size obtained per equipment type was not deemed sufficient. We first evaluated the data across all applications, and also examined statistical differences among two groups of equipment. It was expected that paving and surfacing equipment may be operated more frequently in the summer months than other types of construction equipment. To test whether the responses for paving-related equipment were statistically different from all other equipment, we performed an analysis of variance (ANOVA) to compare the responses for these two groups of equipment. The ANOVA resulted in a significance or p-value less than 0.05, which indicates that samples were likely drawn from different populations with different mean values. This supported the development of an average paving and surfacing seasonal profile separate from all other construction. These final aggregate profiles are shown in Figure II-2, as well as the NONROAD model seasonal profile.

3. Equipment Horsepower

Equipment populations are reported by horsepower ranges in NONROAD. The LADCO survey requested the average engine horsepower by SCC. We estimated a weighted average horsepower for each equipment type based on survey responses (Q10d) and then compared these to the NONROAD horsepower values, weighted by equipment populations, shown in Table II-5. To be consistent with the NONROAD inputs, one would obtain equipment population estimates by SCC and horsepower. To use an SCC-level average horsepower value in the model, one needs to make assumptions about distributing the revised populations to the various horsepower bins. Because the average values were relatively comparable and the method to assign revised populations to the horsepower bins to reflect the new average would be arbitrary, we did not make adjustments to the horsepower distribution.

Table II-4. Survey Seasonal Allocation Percentages by Equipment Type

Equipment	**WINTER**	**SPRING**	**SUMMER**	**FALL**
Pavers	9	0	62	29
Tampers/Rammers	16	29	30	25
Plate Compactors	16	30	27	26
Rollers	13	29	27	31
Scrapers	9	35	28	28
Paving Equipment	14	1	56	30
Surfacing Equipment	6	20	39	35
All Paving and Surfacing Equipment	**12**	**21**	**38**	**29**
Trenchers	11	12	14	63
Bore/Drill Rigs	18	49	16	17
Cranes	18	21	29	31
Rough Terrain Forklifts	27	35	19	19
Off-highway Trucks	27	17	24	32
Off-highway Tractors	11	8	19	62
Signal Boards/Light Plants	14	23	49	14
Concrete/Industrial Saws	20	14	27	39
Cement and Mortar Mixers	24	9	43	25
Crushing/Processing Equipment	17	27	22	33
Excavators	18	17	25	39
Graders	20	10	28	42
Tractors/Loaders/Backhoes	21	18	24	36
Crawler Tractor/Dozers	14	14	29	43
Skid Steer Loaders	25	15	26	34
Dumpers/Tenders	23	16	24	38
Other Construction Equipment	21	14	22	44
All Other NONROAD	**20**	**19**	**26**	**36**

Figure II-2. Seasonal Allocation Percentages for All Equipment Types

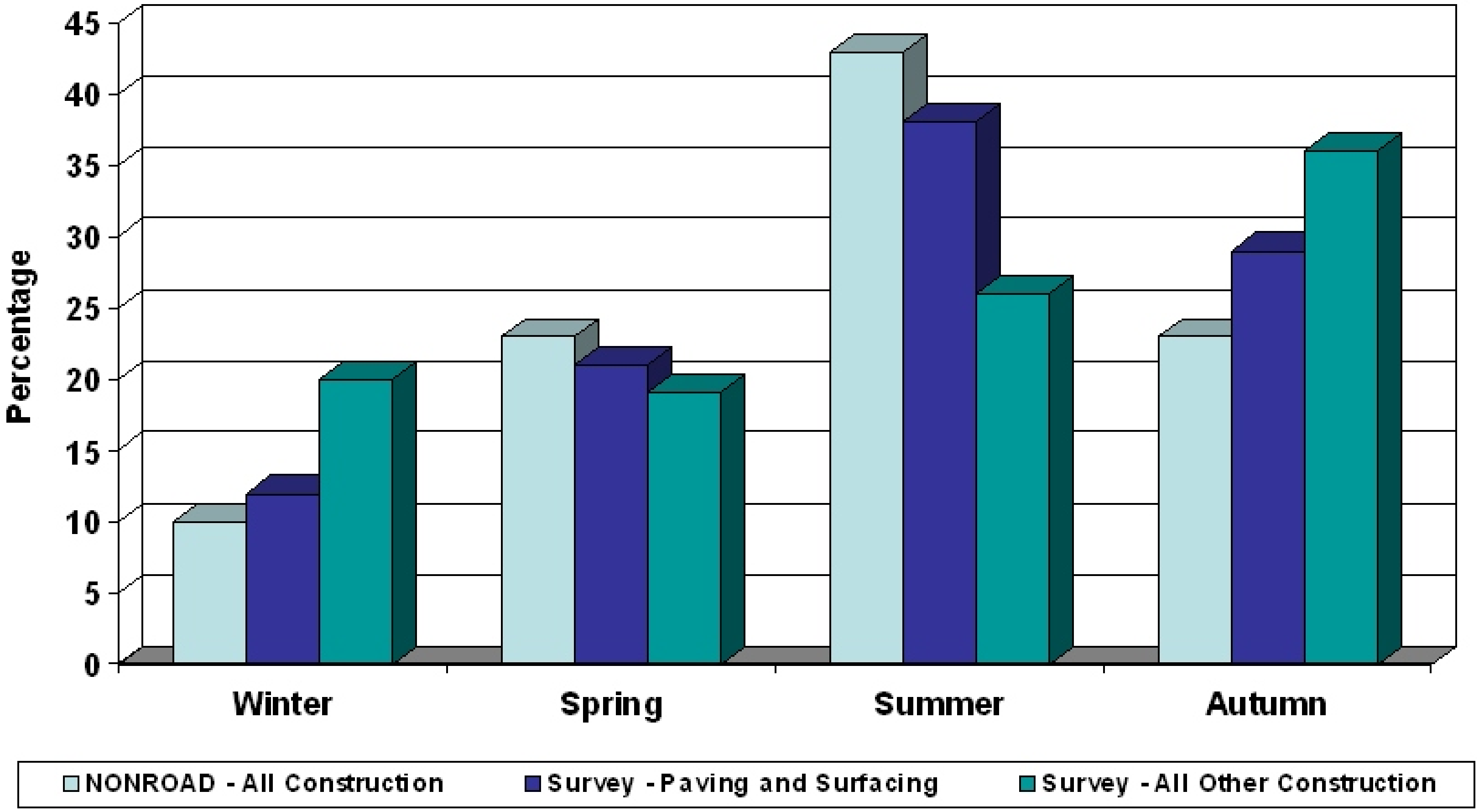


Table II-5. Comparison of NONROAD2002a Average Horsepower and Survey Values, by Equipment Type

SCC	Equipment Description	NONROAD Model	LADCO Survey	Difference
2260002006	2-Str Tampers/Rammers	4	15	11
2260002009	2-Str Plate Compactors	2	33	32
2260002021	2-Str Paving Equipment	2	74	72
2260002027	2-Str Signal Boards/Light Plants	2	74	71
2260002039	2-Str Concrete/Industrial Saws	4	18	14
2260002054	2-Str Crushing/Proc. Equipment	2	184	182
2265002003	4-Str Pavers	14	83	69
2265002006	4-Str Tampers/Rammers	8	15	8
2265002009	4-Str Plate Compactors	6	33	28
2265002015	4-Str Rollers	15	53	38
2265002021	4-Str Paving Equipment	9	74	64
2265002024	4-Str Surfacing Equipment	9	78	68
2265002027	4-Str Signal Boards/Light Plants	7	74	67
2265002030	4-Str Trenchers	12	19	7
2265002033	4-Str Bore/Drill Rigs	4	37	33
2265002039	4-Str Concrete/Industrial Saws	11	18	7
2265002042	4-Str Cement & Mortar Mixers	7	10	2
2265002045	4-Str Cranes	49	127	77
2265002054	4-Str Crushing/Proc. Equipment	9	184	175
2265002057	4-Str Rough Terrain Forklift	65	38	-27
2265002060	4-Str Rubber Tire Loaders	71	120	48
2265002066	4-Str Tractors/Loaders/Backhoes	20	63	43
2265002072	4-Str Skid Steer Loaders	30	221	191
2265002078	4-Str Dumpers/Tenders	10	260	251
2265002081	4-Str Other Construction Equipment	121	70	-52
2267002033	LPG - Bore/Drill Rigs	78	61	-17
2267002039	LPG - Concrete/Industrial Saws	46	30	-16
2267002054	LPG - Crushing/Proc. Equipment	63	30	-33
2267002081	LPG - Other Construction Equipment	125	123	-3
2268002081	CNG - Other Construction Equipment	125	147	22
2270002003	Dsl - Pavers	115	132	17
2270002006	Dsl - Tampers/Rammers	4	132	128
2270002009	Dsl - Plate Compactors	7	42	35
2270002015	Dsl - Rollers	91	111	21
2270002018	Dsl - Scrapers	394	399	5
2270002021	Dsl - Paving Equipment	74	237	163
2270002024	Dsl - Surfacing Equipment	72	204	132
2270002027	Dsl - Signal Boards/Light Plants	20	26	6
2270002030	Dsl - Trenchers	72	58	-14
2270002033	Dsl - Bore/Drill Rigs	186	112	-74
2270002036	Dsl - Excavators	178	162	-16
2270002039	Dsl - Concrete/Industrial Saws	46	29	-17
2270002042	Dsl - Cement & Mortar Mixers	21	46	24
2270002045	Dsl - Cranes	199	131	-69
2270002048	Dsl - Graders	208	188	-20
2270002051	Dsl - Off-highway Trucks	860	253	-607

Table II-5 (continued)

SCC	Equipment Description	NONROAD Model	LADCO Survey	Difference
2270002054	Dsl - Crushing/Proc. Equipment	142	136	-6
2270002057	Dsl - Rough Terrain Forklifts	94	87	-7
2270002060	Dsl - Rubber Tire Loaders	242	163	-79
2270002066	Dsl - Tractors/Loaders/Backhoes	95	119	24
2270002069	Dsl - Crawler Tractor/Dozers	307	165	-142
2270002072	Dsl - Skid Steer Loaders	50	84	34
2270002075	Dsl - Off-Highway Tractors	854	176	-679
2270002078	Dsl - Dumpers/Tenders	36	390	354
2270002081	Dsl - Other Construction Equipment	318	212	-106

▨ For shaded SCCs, the survey did not distinguish between 2-stroke and 4-stroke gasoline engines.

4. Equipment Populations

a. Extrapolation of Survey Results

To scale the results to the entire 5-State LADCO region, equipment populations were estimated based on scaling factors derived from the survey results. For all SICs, Pechan used data on employees as the scaling factor. Scaling factors were developed for each SIC/equipment type combination, shown in Table B-1. The factors were calculated by dividing the number of pieces of owned equipment by the total number of employees. An example calculation for diesel rollers in SIC 1771 follows.

$$SF_{SCC,\ SIC} = Eq_{SCC,\ SIC} \div Emp_{SIC}$$

where: $SF_{SCC,\ SIC}$ = Scaling factor, for SCC/SIC combination
$Eq_{SCC,\ SIC}$ = Equipment count from survey, by SCC and SIC; 8
Emp_{SIC} = Employment for surveyed respondents by SIC; 693

Resulting in:

$$SF_{SCC,\ SIC} = 8 \div 693 = 0.0115$$

State-level employment for SIC 1771, including surveyed and non-surveyed employees, was then multiplied by this scaling factor to yield the following estimate of State-level SCC-level equipment populations:

$$Eq_{SCC,\ ST} = SF_{SCC,\ SIC} * Emp_{ST}$$

where: $Eq_{SCC,\ ST}$ = State equipment count, by SCC
$SF_{SCC,\ SIC}$ = Scaling factor for diesel rollers used in SIC 1771; 0.0115
Emp_{ST} = State employment for SIC 1771; 7,207

Resulting in:

$$Eq_{SCC,\ ST} = 0.0115 * 7{,}207 = 83 \text{ diesel rollers}$$

Scaling factors developed from rental company equipment population data were also developed in a similar manner and applied to employment for the rental firms. Scaling factors were calculated for each SCC by dividing the number of pieces of leased equipment by the total number of employees. It should be noted that within the rental company SICs, especially SIC 7359 - *Equipment Rental and Leasing, Not Elsewhere Classified*, there was a high percentage of non-qualified respondents within the sample for these SIC classifications. This was determined based on the survey disposition report, which tracks and records the outcome of all telephone calls made during the survey. As such, Pechan made an adjustment to the employment data for the rental equipment SICs to account for this relatively higher percentage of non-eligibility. State-level employment for all Midwest Regional Planning Organization (RPO) States was adjusted downward from 29 to 46 percent for SICs 5083, 7353, and 7359. To estimate total equipment in use, we added populations derived from scaling the owned equipment to populations derived from scaling the rental equipment. Scaling factors developed from rental company data are presented in Table B-2. To account for all equipment being used, Pechan added populations derived from the owned equipment to populations derived from the rental equipment.

It should be noted that for landfills, Pechan did request information on daily waste acceptance rates (Q11 and Q12). Pechan then developed factors relating equipment use to the size or daily waste input. Pechan compiled available State data on waste acceptance rates at active landfill sites. The respondents in the survey represented much smaller private waste collection operations than the remaining landfills for which the data were being extrapolated. Total equipment populations scaled using the waste acceptance rate were significantly higher than those populations scaled based on employment. Pechan does not believe that the waste acceptance rates of the surveyed businesses are representative of the remaining landfill population to use this as the scaling factor. As such, Pechan extrapolated equipment data for this SIC using employment.

Appendix C provides comparisons of the scaled equipment populations by equipment type to NONROAD model estimates for the LADCO region, as well as for each LADCO state. Pechan shows the comparison for equipment populations estimated using scaling factors for the owned equipment only, as well as for equipment populations estimated using scaling factors for the owned plus rented equipment. When scaling the owned equipment results, overall equipment populations are lower than the NONROAD model estimates. Once the estimated rental equipment populations were added in, the results are higher for all equipment types combined when compared to the NONROAD model for the states of Illinois and Michigan (about 30 percent). Overall, survey results for Indiana, Ohio and Wisconsin are lower (between 11 and 19 percent). The magnitude of the difference varies by equipment type.

C. REVISIONS TO NONROAD MODEL INPUT FILES

Using data collected from the survey, we prepared revised NONROAD model inputs for weekly and seasonal temporal profiles, annual hours of use, and equipment populations. A summary of the revisions to model inputs, and the names of the files submitted, is shown in Table II-6. SCC-level populations were incorporated into the NONROAD population input files by horsepower bin using NONROAD's distribution of engines by horsepower. Initially, revised population input files were developed and tested to ensure compatibility with NONROAD2002a. Population files were then revised to be compatible with NONROAD2004, which was released by OTAQ in May 2004 (EPA, 2004). Additional horsepower bins for diesel engines were included in these files compared to NONROAD2002a.

We did not replace NONROAD population defaults with results for off-highway tractors, other construction equipment, and off-highway trucks. The estimated populations for these SCCs exceeded the national equipment populations, the number of responses for off-highway tractors was small, and what constitutes "other construction equipment" may be interpreted differently by respondents. Finally, there were concerns that the results for off-highway trucks included engines registered for highway use, which are already accounted for in the onroad mobile inventory.

For a comparison of annual regional construction emissions based on the updated survey inputs relative to emissions based on default inputs, see Table C-7 in Appendix C. These results were based on NONROAD2002a model runs, so results generated using NONROAD2004 will differ.

Table II-6. Summary of Revisions to NONROAD Input Files

File Name	Description of File	Notes
Ladco.sea	Weekday/Weekend Day Allocation and Seasonal Allocation	Added in revised monthly profiles for paving-related equipment and all other construction equipment; adjusted weekday to weekend day fraction for all construction equipment
Ladco02.act	Annual Hours of Use per Year by SCC	Adjusted all construction SCCs equally by 20 percent increase
17000.pop	Illinois Equipment Populations by SCC and HP	Replaced populations for all equipment types included in both NONROAD and survey results, except for Off-Highway Tractors, Off-Highway Trucks, and Other Construction Equipment
18000.pop	Indiana Equipment Populations by SCC and HP	Replaced populations for all equipment types included in both NONROAD and survey results, except for Off-Highway Tractors, Off-Highway Trucks, and Other Construction Equipment
26000.pop	Michigan Equipment Populations by SCC and HP	Replaced populations for all equipment types included in both NONROAD and survey results, except for Off-Highway Tractors, Off-Highway Trucks, and Other Construction Equipment
39000.pop	Ohio Equipment Populations by SCC and HP	Replaced populations for all equipment types included in both NONROAD and survey results, except for Off-Highway Tractors, Off-Highway Trucks, and Other Construction Equipment
55000.pop	Wisconsin Equipment Populations by SCC and HP	Replaced populations for all equipment types included in both NONROAD and survey results, except for Off-Highway Tractors, Off-Highway Trucks, and Other Construction Equipment
lbfsc.emf, lexhco.emf, lexhnox.emf, lexhpm.emf, lexhthc.emf	Emission Factor Files for Brake-specific Fuel Consumption and Exhaust Pollutants	Added emission rate record for equipment type that previously reported zero populations in NONROAD (Diesel tampers/rammers)

CHAPTER III. AGRICULTURAL EQUIPMENT

For the Agricultural sector, Pechan focused on improving the NONROAD default spatial and temporal allocations. The NONROAD default spatial allocations are based on county-level total harvested crop acreage in 1992. These data originated from the 1992 *Census of Agriculture* (DOC, 1994). Although the NONROAD model uses input files containing state-level agricultural equipment populations, these values are summations of the county-level estimates derived from allocating national equipment populations based on harvested acreage in each county. The NONROAD defaults for the Great Lakes/Midwest region, which covers all 8 states included in the scope of the agricultural equipment study, assume that 50 percent, 22 percent, 6 percent, and 22 percent of annual agricultural equipment activity occurs in the summer, fall, winter, and spring months, respectively. Pechan developed improvements to both the spatial and temporal allocations from county and weekly diesel fuel consumption estimates developed in this effort.

A. SPATIAL ALLOCATIONS

The spatial allocation factors compiled from the *Census of Agriculture's* harvested crop acreage data cannot account for any crop- or state-specific differences in agricultural equipment use intensity (e.g., differences in use attributable to higher per acre productivity and/or higher non-till/conservation tillage rates in certain states). Therefore, Pechan compiled two sets of data to assist in improving upon the NONROAD model default spatial allocations. The following section summarizes the state-level nonroad equipment population data that were compiled from the U.S. Department of Agriculture (USDA)'s 2002 *Census of Agriculture* (USDA, 2004a). This section is followed by a discussion of the county-level agricultural diesel fuel consumption estimates developed in this study.

1. USDA Equipment Population Estimates

Every five years, the USDA reports estimates of the equipment population in each State for each of the following five types of agricultural equipment:

- Tractors;
- Grain and Bean Combines;
- Cotton Pickers and Strippers;
- Forage Harvesters; and
- Hay Balers.

With the exception of hay balers, the USDA population estimates are specific to self-propelled equipment. Because the NONROAD model only reflects equipment with engines, the Census' reported number of hay balers is not comparable to the NONROAD model hay baler populations.

Table III-1 presents a comparison of the 2002 equipment populations from the NONROAD model (EPA, 2003) with the same year equipment populations reported by USDA (USDA, 2004a). The USDA equipment population estimates, which are based on a statistical sample survey of farms in 2002, are two to four times higher than the NONROAD model estimates.

The NONROAD model uses the following series of inputs to estimate base year (1996) equipment populations at the State-level:

- National historical equipment sales data;
- Median engine life and attrition rate;
- Engine load factor and annual hours of use; and
- County allocation of national equipment

The first three inputs are used to estimate National equipment; the last input uses acres of crops harvested data to allocate National equipment to counties. To estimate 2002 equipment populations, the NONROAD model projects these county equipment populations based on the average annual national growth rate by equipment type over the 1989-1996 period. Given the level of uncertainty associated with identifying the values for each of these inputs, the NONROAD model estimates are assumed to have a greater level of uncertainty than the USDA estimates.

Because the scope of this study did not include an independent review of each of these NONROAD model variables, it is unclear as to why there are such large discrepancies between the two sets of population estimates. However, some possible explanations for the discrepancies include:

(1) The annual hours of use and/or engine load factor and/or attrition rate is overestimated in 1996 in NONROAD, and/or the median engine life is underestimated in 1996 in NONROAD (these differences could, for example, lead to an underestimate of 1996 equipment populations as the model assumes more pieces of equipment are scrapped than actually occurred); and

(2) Equipment growth is underestimated in model (the 1989-1996 growth rate may not be representative of the actual growth between 1996-2002).

For each of the agricultural equipment types reported in the *Census of Agriculture*, Table III-1 also displays the state-level proportions of national equipment based on both the USDA and the NONROAD model data (note that because each equipment type's allocation is based on harvested crop acreage, the NONROAD model proportions do not differ by type of equipment). Table III-1 indicates much closer agreement between the USDA and NONROAD model proportions. For the most important equipment type (agricultural tractors), the biggest differences occur in Illinois, Iowa, and Wisconsin. In Illinois and Iowa, the USDA indicates a smaller proportion of the national agricultural tractor population compared with that reflected by the NONROAD model (0.048 to 0.074 and 0.058 to 0.077, respectively), while the USDA indicates a larger proportion in Wisconsin (0.048 to 0.030).

Table III-1. Comparison of Estimated 2002 Agricultural Equipment Populations

	NATIONAL				ILLINOIS				INDIANA				IOWA				MICHIGAN			
Source	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled
Number of Equipment																				
NONROAD Model	1,505,390	303,172	-	-	111,441	22,443	-	-	60,309	12,146	-	-	116,323	23,426	-	-	33,551	6,757	-	-
Census of Agriculture	4,592,545	409,442	23,336	67,610	218,511	39,782	-	1,617	143,965	22,958	-	1,398	266,070	44,901	-	2,912	137,474	14,308	-	2,240
Proportion of National Equipment Total																				
NONROAD Model					0.074	0.074	-	-	0.040	0.040	-	-	0.077	0.077	-	-	0.022	0.022	-	-
Census of Agriculture					0.048	0.097	-	0.024	0.031	0.056	-	0.021	0.058	0.110	-	0.043	0.030	0.035	-	0.033

	NATIONAL				MINNESOTA				MISSOURI				OHIO				WISCONSIN			
Source	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled	Tractors	Grain and Bean Combines	Cotton Pickers and Strippers	Forage Harvesters, self-propelled
Number of Equipment																				
NONROAD Model	1,505,390	303,172	-	-	92,744	18,678	-	-	61,961	12,478	-	-	49,891	10,048	-	-	45,067	9,076	-	-
Census of Agriculture	4,592,545	409,442	23,336	67,610	223,138	32,771	-	3,772	207,013	20,976	661	1,454	192,381	24,251	-	1,586	219,442	14,973	-	5,050
Proportion of National Equipment Total																				
NONROAD Model					0.062	0.062	-	-	0.041	0.041	-	-	0.033	0.033	-	-	0.030	0.030	-	-
Census of Agriculture					0.049	0.080	-	0.056	0.045	0.051	0.028	0.022	0.042	0.059	-	0.023	0.048	0.037	-	0.075

2. Agricultural Diesel Fuel Consumption Estimates

Pechan developed county-to-state spatial allocation factors from agricultural sector diesel fuel consumption estimates prepared in this study. These agricultural sector diesel consumption estimates were computed by multiplying USDA estimates of diesel fuel use per planted acre by county-level planted crop acreage data (USDA, 2004b; USDA, 2004c). The USDA reports diesel, gasoline, and liquified petroleum gasoline consumption estimates for major crops. These estimates are provided as an overall average by crop, and, for major crop-producing states, by crop and state. Because diesel fuel consumption factors are more readily available and because diesel is the primary fuel used to operate self-propelled agricultural planting/harvesting equipment (e.g., the NONROAD model estimates that both nationally and in the states of interest, approximately 98 percent of total agricultural equipment fuel consumption is from diesel-fueled equipment), the focus of this study was on developing diesel fuel consumption estimates. Although the USDA developed diesel consumption estimates from surveys of fuel use associated with all crop activities (i.e., pre-planting tillage, planting, cultivation, harvesting, hauling, and post-harvesting), the estimates are expressed on a number of acres planted basis. Table III-2 reports the diesel fuel consumption per planted acre estimates used in this study.

Table III-3 identifies the top 5 crops (based on planted acreage in 2002) for each of the eight states included in this study. Although hay and oats are two of the top five crops on a planted acre basis, the USDA does not report fuel consumption estimates for these crops. Based on consultation with USDA personnel, the diesel fuel consumption estimates for wheat were used for oats. For hay, an average fuel consumption factor was developed using equipment-specific diesel fuel consumption per acre estimates available from Iowa State University and the University of Minnesota (ISU, 2004; UMN, 2004). An example calculation based on equipment-specific diesel fuel consumption estimates is provided in the temporal allocation section below. Unlike other crops, the USDA does not report planted hay acreage. Although the USDA reports the number of acres of hay harvested, these values represent acres harvested for a single cutting. Hay is harvested 3-6 times per year depending on the length of the growing season. Pechan assumed an average of 3 harvests per year due to the shorter growing seasons associated with many of the states included in this study.

Figure III-1 presents the difference between the NONROAD model-based and diesel fuel consumption-based county proportion of each state's total agricultural activity. In this figure, a higher proportion of state activity is allocated to counties in red using the diesel fuel consumption estimates than indicated by the NONROAD model defaults (with the darker red counties indicating the greatest increase in activity). Similarly, less state activity is allocated to the counties in green (with darker green counties indicating the greatest decrease in activity).

Table III-2. Agricultural Diesel Fuel Consumption Factors by Crop and State

Commodity	State	Diesel Use (Gallons/Planted Acre)
Corn	ALL[1]	6.2
Corn	IA	4.6
Corn	IL	3.7
Corn	IN	4.6
Corn	MI	7.2
Corn	OH	4.3
Corn	WI	7.4
Hay[2]	ALL	4.6
Soybeans	ALL	4.5
Soybeans	IA	4.1
Soybeans	IL	3.7
Soybeans	IN	3.2
Soybeans	MI	4.4
Soybeans	OH	2.8
Soybeans	WI	4.5
Sugarbeets	ALL	17.9
Sugarbeets	MI	12.3
Sugarbeets	WI	31.5
Wheat All	ALL	4.4
Wheat All	IL	2
Wheat All	OH	2.3
Oats[3]	ALL	4.4
Oats[3]	IL	2
Oats[3]	OH	2.3

[1] ALL refers to all states that grow and harvest the crop specified.

[2] Pechan estimated hay factors from equipment-specific fuel consumption per acre estimates and assumption of three harvests/year.

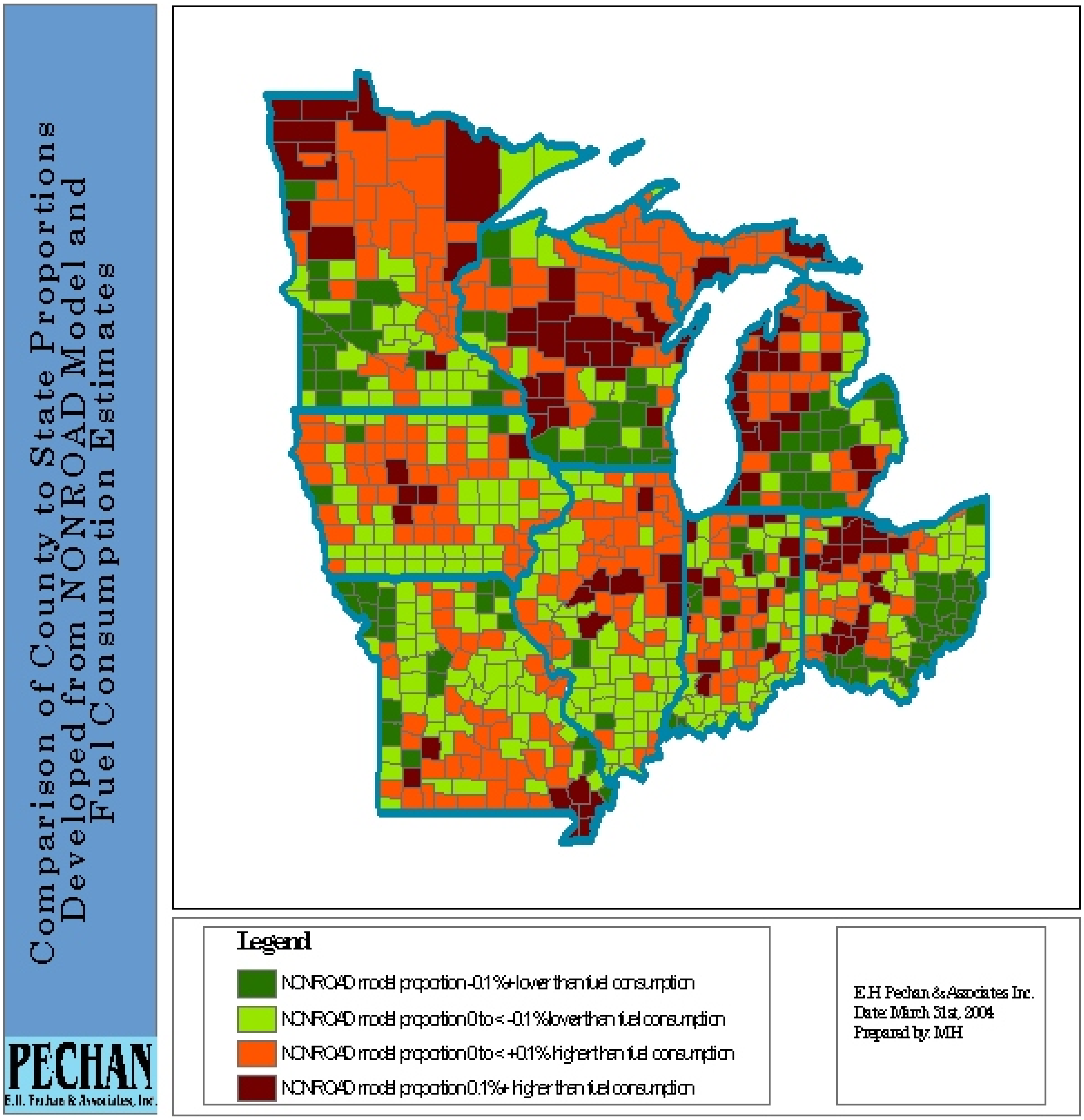
[3] Wheat values were assumed for oats per discussion with USDA.

Table III-3. Top 5 Crops Planted in 2002 by State

State	#1 Crop	#2 Crop	#3 Crop	#4 Crop	#5 Crop	Percent Of State Total Planted Acres[1]
IA	Corn	Soybeans	Hay	Oats	Wheat	100.0
IL	Corn	Soybeans	Hay	Wheat	Sorghum	99.7
IN	Soybeans	Corn	Hay	Wheat	Oats	100.0
MI	Corn	Soybeans	Hay	Wheat	Beans	92.1
MN	Corn	Soybeans	Hay	Wheat	Sugarbeets	93.5
MO	Soybeans	Hay	Corn	Wheat	Cotton	94.5
OH	Soybeans	Corn	Hay	Wheat	Oats	99.9
WI	Corn	Hay	Soybeans	Oats	Wheat	95.6

[1] Represents the proportion of total planted acreage in 2002 for the crops included in the temporal allocation procedure (i.e., corn, soybeans, hay, oats, wheat, and sugarbeets) relative to the total planted acreage in 2002 for all crops in the state.

Figure III-1. Comparison of County Proportions of State Activity (Fuel-Consumption-based Estimates minus NONROAD Model Estimates)



B. TEMPORAL ALLOCATIONS

The following were the steps used to develop temporal allocation factors by state:

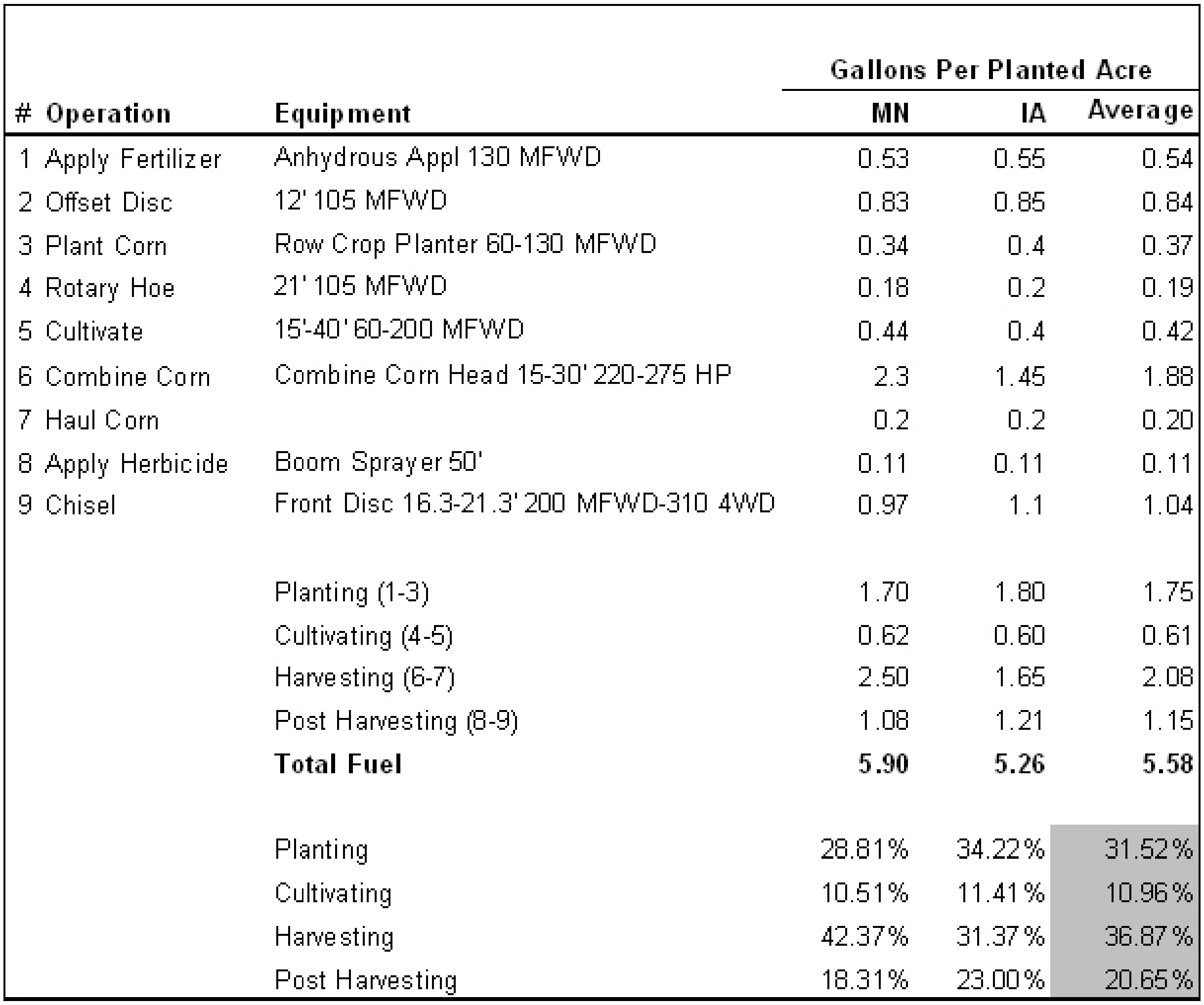
(1) Identify Production Operations By Crop;
(2) Estimate Diesel Consumption By Operation;
(3) Estimate Time-Frame for Operation;
(4) Apportion Acres of Operation By Week;
(5) Calculate Weekly Diesel Consumption;
  (a) Estimate Diesel Consumption by Operation (multiply diesel consumption by state by crop [from spatial allocation] by the proportion of diesel consumption by operation);
  (b) Estimate Diesel Consumption by Operation by Week (multiply diesel consumption by operation by the weekly proportion of annual operation); and
  (c) Estimate Diesel Consumption by State (sum across operations/crops within each state).

Tables III-4 and III-5 provide example calculations of the procedure used to develop weekly temporal allocation factors for corn production in Iowa in year 2002. For corn production, it was assumed that all four potential crop production operations (i.e., planting, cultivation, harvesting, and post-harvesting) are used. Table III-3 shows the calculations performed to estimate the proportion of total diesel fuel consumption for each of these corn production operations. Based on an average of University of Minnesota and Iowa State University diesel fuel consumption per acre estimates for nine corn production machinery operations (ISU, 2004; UMN, 2004), Pechan estimated the following break-down of diesel fuel consumption by corn production operation: Planting - 31.52%; Cultivation - 10.96%, Harvesting - 36.87%, and Post-Harvesting - 20.65%.

To estimate the time-frame for corn planting and harvesting operations in Iowa, and to estimate the acreage associated with these operations in each week, Pechan compiled 2002 year planting and harvesting data from the USDA's Agricultural Statistics' web-site (USDA, 2004d). This web-site reports the weekly cumulative percentage of the total 2002 year planted acreage and harvested acreage by crop and state. Each week's proportion of total planting and total harvesting of corn in Iowa was then calculated from these values. These proportions were then applied to the total acres of year 2002 planted corn in Iowa to estimate the number of acres of crops planted and harvested by week. Because temporal information is not available on cultivation/post-harvesting activities, Pechan made the following simplifying assumptions:

(1) All cultivation takes place between the last three weeks of the planting season and three weeks before the start of the harvesting season;
(2) All post-harvesting activity takes place over the period that includes the last three weeks of the harvesting season and one week after the end of the harvesting season; and
(3) Cultivation and post-harvesting activities occur on an equal basis over each week in which these activities are assumed to occur.

Table III-4. Estimation of Diesel Fuel Use for Corn Operations



#	Operation	Equipment	Gallons Per Planted Acre MN	IA	Average
1	Apply Fertilizer	Anhydrous Appl 130 MFWD	0.53	0.55	0.54
2	Offset Disc	12' 105 MFWD	0.83	0.85	0.84
3	Plant Corn	Row Crop Planter 60-130 MFWD	0.34	0.4	0.37
4	Rotary Hoe	21' 105 MFWD	0.18	0.2	0.19
5	Cultivate	15'-40' 60-200 MFWD	0.44	0.4	0.42
6	Combine Corn	Combine Corn Head 15-30' 220-275 HP	2.3	1.45	1.88
7	Haul Corn		0.2	0.2	0.20
8	Apply Herbicide	Boom Sprayer 50'	0.11	0.11	0.11
9	Chisel	Front Disc 16.3-21.3' 200 MFWD-310 4WD	0.97	1.1	1.04
		Planting (1-3)	1.70	1.80	1.75
		Cultivating (4-5)	0.62	0.60	0.61
		Harvesting (6-7)	2.50	1.65	2.08
		Post Harvesting (8-9)	1.08	1.21	1.15
		Total Fuel	**5.90**	**5.26**	**5.58**
		Planting	28.81%	34.22%	31.52%
		Cultivating	10.51%	11.41%	10.96%
		Harvesting	42.37%	31.37%	36.87%
		Post Harvesting	18.31%	23.00%	20.65%

Notes:

MN figures taken from University of MN Extension Service FO-6696: Farm Machinery Economic Costs for 2004.

IA Figures taken from IA State University Extension PM 709: Fuel Required for Field Operations.

Hauling figures taken from PM 709 and applied to all states.

Table III-5. Calculation of Weekly Corn Production Diesel Fuel Consumption Estimates in Iowa

		Planting	Cultivating	Harvesting	Post Harvesting		State	StFips	Corn Planted	Gal of Diesel per Acre
% of Total		31.52	10.96	36.87	20.65		IA	19	12,300,000	4.6
State	**Week Ending**	**Total Planted (%)**	**Total Harvested (%)**	**Weekly Progress Planted**	**Weekly Progress Harvested**	**Planted Acres**	**Cultivated Acres**	**Harvested Acres**	**Post Harvesting Acres**	**Diesel Fuel (gal)**
IA	Apr 14	1		1	0	123,000				178,340
IA	Apr 21	12		11	0	1,353,000				1,961,742
IA	Apr 28	33		21	0	2,583,000				3,745,143
IA	May 5	53		20	0	2,460,000				3,566,803
IA	May 12	86		33	0	4,059,000				5,885,225
IA	May 19	94		8	0	984,000	878,571			1,869,662
IA	May 26	98		4	0	492,000	878,571			1,156,301
IA	Jun 2	100		2	0	246,000	878,571			799,621
IA	Jun 9			0	0		878,571			442,941
IA	Jun 16			0	0		878,571			442,941
IA	Jun 23			0	0		878,571			442,941
IA	Jun 30			0	0		878,571			442,941
IA	Jul 7			0	0		878,571			442,941
IA	Jul 14			0	0		878,571			442,941
IA	Jul 21			0	0		878,571			442,941
IA	Jul 28			0	0		878,571			442,941
IA	Aug 4			0	0		878,571			442,941
IA	Aug 11			0	0		878,571			442,941
IA	Aug 18			0	0		878,571			442,941
IA	Aug 25			0	0					0
IA	Sep 1			0	0					0
IA	Sep 8			0	0					0
IA	Sep 15		4	0	4			492,000		834,442
IA	Sep 22		6	0	2			246,000		417,221
IA	Sep 29		10	0	4			492,000		834,442
IA	Oct 6		13	0	3			369,000		625,831
IA	Oct 13		21	0	8			984,000		1,668,884
IA	Oct 20		41	0	20			2,460,000		4,172,209
IA	Oct 27		61	0	20			2,460,000		4,172,209
IA	Nov 3		76	0	15			1,845,000		3,129,157
IA	Nov 10		89	0	13			1,599,000		2,711,936
IA	Nov 17		96	0	7			861,000	3,075,000	4,381,216
IA	Nov 24		99	0	3			369,000	3,075,000	3,546,774
IA	Dec 1		100	0	1			123,000	3,075,000	3,129,553
IA	Dec 8			0	0				3,075,000	2,920,943

Diesel fuel consumption by operation is then estimated using the USDA's diesel consumption per planted acre estimates that were used in the spatial allocation procedure (e.g., 4.6 gallons per acre for corn) and the percentage of fuel consumption associated with each production activity. These estimates are then allocated to each week in 2002 based on the estimated weekly number of acres associated with each crop's production activity (i.e., planting, cultivating, harvesting, and post-harvesting). The weekly diesel fuel consumption by operation values are then summed across production operations to yield total weekly diesel consumption. These weekly diesel consumption values for corn are then summed with weekly diesel consumption estimates for soybeans, wheat, hay, and oats (although included in the spatial allocation calculations, sugar beets were not included in the temporal allocation calculations because of a lack of information on fuel consumption by individual sugar beet operation). These state-level weekly totals are then divided by each state's annual diesel fuel consumption to calculate the weekly percentage of 2002 year nonroad agricultural equipment activity by state. Because the NONROAD model does not currently support weekly temporal allocation factors, the weekly fuel consumption values were used to calculate monthly percentages, which the current model supports. See Tables D-1 through D-42 of Appendix D for calculations for the weekly diesel fuel consumption associated with each major crop for all five of the Midwest RPO states.

The agricultural equipment study results in a significant improvement in the ability to characterize nonroad agricultural equipment activity in the eight Midwest region states of interest. Table III-6 displays the estimated proportion of diesel consumption by month for each major crop across the eight states included in this study. Note, for example, that unlike the other major crops, hay and oats are associated with a large proportion of annual activity in the summer months. Table III-7 presents a comparison of the monthly allocations by state from this study with the NONROAD model default monthly allocations. Note, for example, the larger proportion of total activity in November and December in Wisconsin. A review of the USDA crop progress data indicates that the 5-year average Wisconsin planting and harvesting dates for corn and soybeans tend to be later than those for more southern states such as Illinois. In addition, 2002 was associated with later than average planting and harvesting dates, presumably due to weather conditions specific to that year. Although there are some differences in the allocations across states in the region, the proportion of annual activity that is allocated to the summer months is significantly lower than assumed by the NONROAD model defaults. See Table E-1 in Appendix E for summer season agricultural emissions for the State of Michigan based on updated seasonal allocations from the study, compared to emissions generated using NONROAD defaults. It is important to note that the temporal data compiled in this study can also benefit other aspects of inventories (e.g., fugitive dust) in the states of interest.

There were several assumptions used in this study to develop temporal allocation factors. Pechan expects that more representative assumptions for each crop and state may be available from contacts with state agricultural experts in the region. For example, it may be more appropriate to assume that a certain percentage of corn post-harvesting activity takes place in the spring rather than fall. Although further research would provide improvements to these assumptions, it is not anticipated that the refinements would have a significant impact on the major conclusion from this study that the NONROAD model over-allocates agricultural activity to the summer months in the Great Lakes/Midwest region states.

Table III-6. Monthly Proportion of Fuel Consumption by Crop for States of Interest

CROP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corn	0.0	0.0	0.0	6.6	17.1	12.6	3.5	2.8	6.2	17.3	24.1	9.7
Hay	0.0	0.0	0.0	1.0	14.6	26.0	24.2	12.5	16.0	5.6	0.0	0.0
Oats	0.0	0.0	4.7	13.9	8.2	1.9	30.0	30.6	10.7	0.0	0.0	0.0
Soybeans	0.0	0.0	0.0	0.4	12.9	22.9	7.7	7.7	7.3	34.3	6.3	0.5
Wheat	0.0	0.0	0.0	0.4	3.3	13.9	37.0	13.2	9.4	20.8	1.9	0.2

Table III-7. Comparison of Monthly Allocations from Nonroad Model and this Study

STATE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IA	0.0	0.0	0.0	6.4	23.2	8.9	6.0	4.9	5.8	27.1	14.5	3.1
IL	0.0	0.0	0.0	4.1	10.9	20.9	6.6	5.5	6.9	30.1	9.6	5.4
IN	0.0	0.0	0.0	0.7	9.3	25.4	7.4	5.3	5.2	26.6	14.0	6.2
MI	0.0	0.0	0.0	1.2	15.8	16.5	9.4	6.9	6.0	22.5	15.2	6.4
MN	0.0	0.0	0.0	3.9	23.1	8.0	5.9	8.5	10.2	19.5	15.2	5.7
MO	0.0	0.0	0.1	8.3	9.0	22.5	9.1	6.4	13.2	18.2	12.3	0.9
OH	0.0	0.0	0.0	1.0	9.1	24.0	10.8	6.2	5.5	24.6	13.4	5.3
WI	0.0	0.0	0.0	2.1	19.7	12.6	7.0	6.9	4.7	14.7	22.4	10.0
Average	**0.0**	**0.0**	**0.0**	**3.5**	**15.0**	**17.3**	**7.8**	**6.3**	**7.2**	**22.9**	**14.6**	**5.4**
NONROAD	**2**	**2**	**7.3**	**7.3**	**7.3**	**16.7**	**16.7**	**16.7**	**7.3**	**7.3**	**7.3**	**2**

CHAPTER IV. REFERENCES

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APPENDIX A. SURVEY METHOD AND INTERVIEW

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Final Report

Introduction

Population Research Systems (PRS), LLC, a subsidiary of Freeman, Sullivan & Co., launched the Lake Michigan Air Directors Consortium (LADCO) project in August 2003 on behalf of E.H. Pechan & Associates, Inc. The project, which was sponsored by LADCO, was designed to collect construction equipment data from construction companies and construction equipment rental companies located in the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin.

Pechan and PRS collaborated closely on the development of the business telephone interview (Appendix B) used for this project. PRS was responsible for programming the interview for use by the PRS computer-assisted telephone interviewing (CATI) laboratory.

The report is divided into two sections. The first section describes the study methods and the second section contains the report attachments. Attachment A contains the study interview. Attachments B and C contain the Frequently Asked Questions (FAQs) and the construction equipment list respectively, which were used for training the project interviewers. Attachment D contains the sample disposition report. The frequencies and cross-tabs are contained in Attachment E.

Methods

A. Sample

PRS purchased 5,550 commercial sample points from Marketing Systems Group (MSG), a sampling vendor located in Fort Washington, Pennsylvania. Sample was purged by MSG of incorrect and disconnected telephone numbers as well as fax and modem numbers prior to delivery to PRS.

The sample frame consisted of all listed business within the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin corresponding to the following seven categories: heavy construction contractors, concrete work, excavation work, landfill, mining, water well drilling and wrecking and demolition work, and rental equipment.

The selected SIC codes that correspond to the seven categories are displayed in Table 1 on the following page.

While there were no formal quota cells for the study either by category or state, PRS attempted to complete approximately 55 interviews in each of the seven categories shown below. Each record was "flagged" based on SIC code to identify the category from which it was drawn so that a tally by cell could be made at the conclusion of the study. See Table I below.

Table I

Business Classification and SIC codes	**Desired # Interviews**
Heavy Construction Contractors (SIC codes: 1611, 1622, 1623, 1629)	55
Concrete Work (SIC code 1771)	55
Excavation Work (SIC code 1794)	55
Landfills (SIC code 4953)	55
Mining (Metals, coal, and nonmetallic) (SIC codes: 10, 12, 14)	55
Water Well Drilling and Wrecking and Demolition Work (SIC codes: 1781, 1795)	55
Rental Equipment (SIC codes: 7353, 7359, 5082)	55
Total	**385**

B. Screening and Respondent Selection

Eligible respondents for six out of seven categories (heavy construction contractors, concrete work, excavation work, landfills, mining, and water well drilling and wrecking and demolition work) were directors of operations or persons who were most knowledgeable about their company's day-to-day construction activities. For rental equipment companies, PRS interviewers asked to interview directors of operations or persons who were most knowledgeable about their company's equipment rental activities. Only companies that perform construction work or rent construction equipment in the five states of interest, Indiana, Illinois, Michigan, Ohio, and Wisconsin, were eligible to participate in the study.

C. The Interview

If the respondent agreed to participate, they were guided through a series of closed-ended and open-ended questions concerning construction or mining activities, landfill activities, or rental equipment activities in 2002. Respondents were asked particular sets of questions using programmed skip patterns based on their company SIC code.

All companies were asked to specify their number of part-time and full-time employees. Construction and mining companies were then asked questions concerning: 1) the number of heavy-equipment operators or operating engineers they employed, 2) the percent of operating engineers working on a typical weekday and weekend day per shift. They were then asked to indicate in response to the reading of a 25-item heavy equipment construction list: 1) the number of pieces of equipment used in each category in 2002, 2) how the equipment was powered, 3) the average horsepower of the equipment, 4) how many hours per week on average the equipment was used in 2002, 5) how many weeks the equipment was used in 2002, 6) percentage use by equipment per season in 2002.

Landfill companies were asked to indicate the amount of average daily waste their company put into landfill in 2002. Rental equipment companies were read the 25-item equipment list and were asked: 1) how many pieces of equipment they rented in each category in 2002, 2) how the equipment was powered, 3) the average horsepower of the equipment. A copy of the business interview is presented in Attachment A.

D. Interview Period, Times, and Duration

Commercial data collection took place from November 3, 2003 through November 12, 2003. Telephone interviews were conducted using trained PRS CATI laboratory interviewers. Interviews were conducted weekdays between the hours of 6:00 A.M. and 5:00 P.M. Pacific Standard Time. At a respondent's request, PRS also scheduled callback appointments outside of these interviewing hours. Interviews conducted by appointment were typically conducted between the hours of 4:00 AM and 6:00 AM or after 5:00 PM Pacific Standard Time.

A total of four call attempts were made to each business. No refusal conversions were used to convince eligible respondents to participate in the study. The interviews, which were administered in English, took on average 12.9 minutes to complete. Respondents were not paid an incentive for participating in the study.

PRS agreed to deliver 385 completed interviews. PRS completed a total of 390 commercial interviews. Table II on the following page outlines the number and percent of completed interviews per category.

Table II

Business Classification and SIC codes	**Completed Interviews**	**%**
Heavy Construction Contractors (SIC codes: 1611, 1622, 1623, 1629)	57	14.6%
Concrete Work (SIC code 1771)	56	14.4%
Excavation Work (SIC code 1794)	56	14.4%
Landfills (SIC code 4953)	56	14.4%
Mining (Metals, coal, and nonmetallic) (SIC codes: 10, 12, 14)	56	14.4%
Water Well Drilling and Wrecking and Demolition Work (SIC codes: 1781, 1795)	56	14.4%
Rental Equipment SIC codes: 7353, 7359, 5082	53	13.6%
Total	**390**	

E. Staff Training

PRS trained eleven CATI interviewers and three CATI laboratory supervisory staff for the LADCO study. Pechan and PRS jointly conducted the training session. The purpose of the training was to familiarize PRS interviewing and supervisory staff with the project, the research goals, project procedures, and content of the telephone interview. Pechan provided background information concerning the project and a two-page handout detailing the 25 types of heavy equipment being studied (See Attachment C). PRS interviewers were provided both a copy of the telephone interview (see Attachment A) and the project Frequently Asked Questions (FAQs) (See Attachment B).

The training included a question-by-question review of the instrument. Interviewers then role-played to become familiar with the instrument. During the role-play, each interviewer was observed by a supervisor and approved for interviewing only after the supervisor was confident that the questionnaire and study protocol had been mastered.

F. Telephone Contact Outcomes

Of the 5,550 commercial records dialed, 407 telephone numbers (7.4% of the dialed sample) were: disconnected or no longer working; connected to beepers, fax machines, or modems; connected to residences; connected to businesses with a potential respondent who could not participate due to a language barrier or physical impairment, leaving 5,093 records, or 92.6% of the total sample as usable sample (See Attachment D).

G. Response and Refusal Rates

For purposes of this study, two response and two refusal rates have been calculated. The response rates are defined as: the number of completed interviews divided by the total number of sample points (raw response rate) and the total number of completed interviews divided by the total number of usable sample points (adjusted response rate). The response rate for the total sample was 7.1%. The adjusted response rate for usable sample was 7.7%.

The raw refusal rate is defined as the number of refusals divided by the total number of sample points. The adjusted refusal rate is calculated as the number of refusals divided by the amount of usable sample. There were a total of 1,800 commercial refusals, representing 32.7% of the total commercial sample or 35.3% of the usable sample. A final sample disposition report for the commercial records attempted is included in Attachment D.

H. Data Analysis

Frequencies (counts and percentages), which were run for certain variables together with selected cross-tabs, are contained within Attachment E.

ATTACHMENT A

Lake Michigan Air Directors Consortium (LADCO)

Construction Activity Telephone Interview

INTRO1: Hello, my name is _________. I'm calling on behalf of the Lake Michigan Air Directors Consortium or LADCO, a non-profit organization working for the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin. Your business has been randomly selected to participate in an important study about air quality.

<If SIC code Eq 1011, 1041, 1099, 1221, 1222, 1241, 1411, 1422, 1429, 1442, 1446, 1459, 1479, 1499, 1611, 1622, 1623, 1629, 1771, 1781, 1794, 1795, or 4953, go to Q1>

<If SIC code Eq 5082, 7353, or 7359 skip to Q2>

Q1. Our records show that this is a construction or mining business. Is that correct?

[1] Yes	(Go to Q3)
[2] No, neither	(Terminate)
[8] DON'T KNOW	(Terminate)
[9] REFUSED	(Terminate)

Q2. Our records show that this is an equipment rental company. Is that correct?

[1] Yes	(Go to Q4)
[2] No	(Terminate)
[8] DON'T KNOW	(Terminate)
[9] REFUSED	(Terminate)

TERMINATE: Thank you for your time. Goodbye.

Q3. I would like to speak with your director of operations or the person who would be most knowledgeable about your company's day-to-day construction activities.

[1] I am that person	(Go to INTRO3)
[2] I'll get him/her	(Go to INTRO2)
[3] No one is available now	(Go to CALLBACK)
[4] No such person	(Terminate)
[8] DON'T KNOW	(Terminate)
[9] REFUSED	(Terminate)

Q4. I would like to speak with your director of operations or the person who would be most knowledgeable about your company's equipment rental activities.

[1] I am that person	(Go to INTRO3)
[2] I'll get him/her	(Go to INTRO2)
[3] No one is available now	(Go to CALLBACK)
[4] No such person	(Terminate)
[8] DON'T KNOW	(Terminate)
[9] REFUSED	(Terminate)

CALLBACK: When would be a good time to call back?

INTRO2: Hello, my name is _________ and I'm calling on behalf of the Lake Michigan Air Directors Consortium or LADCO, a non-profit organization working for the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin Your business has been randomly selected to participate in an important study about air quality (Go to INTRO3).

INTRO3: The interview will take about 10 minutes. Your responses will be kept confidential and will not be connected to your name. Can I begin the interview?

<If Q1 Eq 1, go to Q5. If Q2 Eq 1, skip to Q7>

Q5. In 2002, how many part-time and full-time employees did your company have? _______

8888888888 = DON'T KNOW
9999999999 = REFUSED

<Go to Q6>

Q6. In 2002, approximately how many people did your company employ as heavy-equipment operators or operating engineers including part-time equipment operators? _______

88888 = DON'T KNOW
99999 = REFUSED

<SKIP TO Q8>

Q7. In 2002, how many part-time and full-time employees did your company have? _______

88888 = DON'T KNOW
99999 = REFUSED

<SKIP TO INTRO5>

CONSTRUCTION AND MINING COMPANY QUESTIONS

Q8. What percent of your operating engineers are working on a typical weekday between the hours of:

a. 8 AM and 12 Noon _____ %
b. 12 Noon and 4 PM _____ %
c. 4 PM and 8 PM _____ %
d. 8 PM and midnight _____ %
e. Midnight and 4 AM _____ %
f. 4 AM and 8 AM _____ %

888 = DON'T KNOW
999 = REFUSED

<Go to Q9>

Q9. What percent of your operating engineers are working on a typical weekend day between the hours of:

a. 8 AM and 12 Noon _____ %
b. 12 Noon and 4 PM _____ %
c. 4 PM and 8 PM _____ %
d. 8 PM and midnight _____ %
e. Midnight and 4 AM _____ %
f. 4 AM and 8 AM _____ %

888 = DON'T KNOW
999 = REFUSED

<Go to INTRO4>

INTRO4: For the rest of the questions, we want you to focus only on construction projects which your company conducted within Indiana, Illinois, Michigan, Ohio, or Wisconsin in 2002 in which fuel-powered construction equipment were used (Go to Q10a)

INTRO5: For the rest of the questions, we want you to focus only on fuel-powered construction equipment you rented for projects in Indiana, Illinois, Michigan, Ohio, or Wisconsin in 2002 (Skip to Q13a)

I will now read you a list of types of construction equipment and will then ask you to tell me: 1) how many pieces of equipment you used in each category in 2002, 2) how the equipment was powered, 3) the average horsepower of the equipment, 4) how many hours per week on average you used the equipment, 5) how many weeks you used the equipment, and 6) your percentage use by season.

Q10a. How many of your own [equipment] did you use in 2002? ______

888888 = DON'T KNOW
999999 = REFUSED

Q10b. How many of the [equipment] you used in 2002 were leased? ______

888888 = DON'T KNOW
999999 = REFUSED

<If Q10a AND Q10b = 0, 888888 OR 999999, then skip to next piece of equipment on Equipment List>

Q10c. What percent of the [equipment] were powered by:

1. Gas? _____%
2. Diesel? _____%
3. LPG? _____%
4. CNG? _____%

888 = DON'T KNOW
999 = REFUSED

<If Q10c1 through Q10c4 ≠ 100%, re-ask>

Q10d. What was the average horsepower of the [equipment]? ______

8888 = DON'T KNOW
9999 = REFUSED

Q10e. On average, how many hours per week did you use [equipment] in 2002? ______

888 = DON'T KNOW
999 = REFUSED

Q10f. About how many weeks did your company use [equipment] in 2002? ______

88 = DON'T KNOW
99 = REFUSED

Q10g. For 2002, what percent of the [equipment] were used each season?

1. Winter? _____%
2. Spring? _____%
3. Summer? _____%
4. Fall? _____%

888 = DON'T KNOW
999 = REFUSED

<If Q10g1 through Q10g4 ≠ 100%, re-ask>

<Skip to next piece of equipment on Equipment List>

Equipment List

1. Pavers
2. Tampers/rammers
3. Plate compactors
4. Rollers
5. Paving equipment
6. Surfacing equipment
7. Scrapers
8. Excavators
9. Graders
10. Rubber tire loaders
11. Tractors/loaders/backhoes
12. Crawler tractor/dozers
13. Skid steer loaders
14. Dumpers/tenders
15. Rubber tire dozers
16. Trenchers
17. Bore/drill rigs
18. Cranes
19. Rough terrain forklifts
20. Off-highway trucks
21. Off-highway tractors
22. Signal boards/light plants
23. Concrete/industrial saws
24. Cement and mortar mixers
25. Crushing/processing equipment <or>
26. Other construction equipment (specify) _________________________

<If SIC code Eq 4953, go to Q11>

<If SIC code Eq 1011, 1041, 1099, 1221, 1222, 1241, 1411, 1422, 1429, 1442, 1446, 1459, 1479, 1499, 1611, 1622, 1623, 1629, 1771, 1781, 1794, 1795, go to THANK YOU>

LANDFILL COMPANY QUESTIONS

Q11. What is the average daily waste your company put into landfill in 2002? ____________________________

8888 = DON'T KNOW
9999 = REFUSED

Q12. Is that:

[1] Cubic feet
[2] Cubic yards
[3] Tons
[8] DON'T KNOW
[9] REFUSED

<Go to THANK YOU>

RENTAL COMPANY QUESTIONS

I will now read you a list of types of construction equipment and will then ask you to tell me: 1) how many pieces of equipment you rented in each category in 2002, 2) how the equipment was powered, 3) the average horsepower of the equipment.

Q13a. How many [equipment] did you rent in 2002? ______

888888 = DON'T KNOW
999999 = REFUSED

<If Q13a = 0, 888888 OR 999999, then skip to next piece of equipment on Equipment List>

Q13b. What percent of the [equipment] were powered by:

1. Gas? _____%
2. Diesel? _____%
3. LPG? _____%
4. CNG? _____%

888 = DON'T KNOW
999 = REFUSED

<If Q13b1 through Q13b4 ≠ 100, re-ask question>

Q13c. What was the average horsepower of the [equipment]? ______

8888 = DON'T KNOW
9999 = REFUSED

<Skip to next equipment on Equipment List>

<Go to THANK YOU>

THANK YOU: Those are all the questions I have for you. Thank you for your time. Goodbye.

ATTACHMENT B

LADCO Construction Activity Interview

Frequently Asked Questions (FAQs)

What is the purpose of the study?

The purpose of the study is to better characterize the contribution of construction equipment to air pollutant emissions in the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin.

Who is conducting this study?

This study is being sponsored by the Lake Michigan Air Directors Consortium and E.H. Pechan & Associates, Inc., a consulting firm specializing in air pollution with offices in Virginia, North Carolina, and Sacramento, California.

How did we get your telephone number/name?

Your business was randomly selected from the Yellow Pages or other similar database.

Who is calling you?

Population Research Systems, a survey research firm located in San Francisco, has been hired by E.H. Pechan & Associates to conduct the interviews.

Why should you participate?

Through your cooperation, the Lake Michigan Air Directors Consortium will be able to better characterize the contribution of construction equipment to air pollutant emissions within the states of Indiana, Illinois, Michigan, Ohio, and Wisconsin.

Do you have to do this?

No, your participation is voluntary and you can choose not to answer any questions that you would like.

How long is the interview?

The interview takes about 10 minutes on the telephone.

How will the results be used?

The results from the study will be used to inform state policymakers about the contribution of construction equipment to air pollutant emissions.

Will you be contacted again?

No. We will contact you just this one time.

Will my information be given to anyone else?

No. Your name and telephone number will not be given out to anyone else and will not be linked to your responses. Only group statistics will be included in the final report.

How can I be sure this is authentic?

I can let you speak to my supervisor and s/he can provide you with additional information about the study. You may also visit the Lake Michigan Air Directors Consortium or LADCO website at http://www.ladco.org/ladco/about.htm

Who is the person managing the study?

The person managing the study is Dr. Katrin Ewald, a researcher at Population Research Systems. I can have her give you a call when she is available.

ATTACHMENT C

Construction Equipment Types, Definition, and General Category Classification

Equipment Type	Definition	General Category
Pavers	Large and small (such as for curbs) primarily self-propelled pavers	Paving/Surfacing
Tampers/ Rammers	Small 'handheld,' walk-behind, or single person sized equipment for compaction such as for sidewalk or other small area compaction	Paving/Surfacing
Plate Compactors	Similar to tamper/rammers with a larger vibrating plate instead of a ram	Paving/Surfacing
Rollers	Rollers include smooth and knobby (such as used in landfills and called "compactors" not to be confused with smaller Plate Compacters) self-propelled rollers	Paving/Surfacing
Scrapers	Special equipment type that is an off-highway tractor with a mid-frame bucket that lowers to scrape loose material (dirt) into the bucket to carry to another part of the job site to dump; sometimes converted to a water-wagon	Earthmoving
Paving Equipment	Various equipment types used to smooth and distributing paving material including vibrators and finishers to support the work of the pavers	Paving/Surfacing
Surfacing Equipment	Other various equipment used to supplement paving activity including paving material mixers, surface profilers (road reclaiming chippers), and seal coating equipment not used to distribute paving material as with paving equipment	Paving/Surfacing
Signal Boards/ Light Plants	Highway boards and light plants used for nighttime lighting	Other Support Equipment
Trenchers	Large and small trenchers typically using a rotating front mounted rotating 'blade' to pull material from trench and distribute it to the side	Trenching/Boring
Bore/Drill Rigs	Self-explanatory drills or boring rigs of all types that are skid mounted, trailer mounted, or self-propelled; not to be confused with highway trucks with drill attachments running off the highway engine, though truck mounted nonroad engines\equipment exist	Trenching/Boring
Excavators	Single purpose wheeled or tracked excavators (backhoe) distinct of multipurpose tractor/backhoe/loaders	Earthmoving
Concrete/ Industrial Saws	Handheld and large engine powered saws for stone cutting.	Other Support
Cement & Mortar Mixers	Small mixers used for small batch mixing	Other Support
Cranes	Self-propelled typically cable hoists; not to be confused with highway trucks with crane attachments running off the highway engine, though truck mounted nonroad engines\equipment exist	Lifting
Graders	Called road or motor graders often used to prepare a site, especially a road, for paving. A blade is mid-frame mounted with equipment having a long wheel base	Earthmoving
Off-highway Trucks	Large off-highway dump trucks not certified for highway use	Off-Road Hauling
Crushing/ Proc. Equipment	Various crushing and screening equipment for bulk material	Other Support
Rough Terrain Forklifts	Rough terrain forklifts (RTF) can be confused with typical forklifts but have larger knobby off-road wheels and can be confused with rubber tire loaders but are specifically designed for handling palettes. RTFs include telescoping lift trucks called telescopic handlers often used in building construction.	Lifting
Rubber Tire Loaders	Bucket loaders or front-end loaders with a front mounted bucket for scooping though other attachments can be used instead of a bucket	Earthmoving

Equipment Type	**Definition**	**General Category**
Tractors/ Loaders/ Backhoes	Common and ubiquitous multipurpose equipment type that is most often referred to as a "backhoe" but include the combined functions of loading and a backhoe in one unit. Agricultural tractors with alternative attachments may used for similar purposes	Earthmoving
Crawler Tractor/Dozers	Tracked (not wheeled) loaders and dozers	Earthmoving
Skid Steer Loaders	Smaller (able to be 'skid' mounted to transport to job site) loaders which may have alternative attachments than a bucket for loading	Earthmoving
Off-Highway Tractors	Large tractors used to primarily drag large buckets or other equipment around a job or mine site, and agricultural tractors have been used for the same purpose	Off-Road Hauling
Dumpers/ Tenders	Small loaders and other trucks for confined space and light loads typically used for small building projects and are typically walk-behind equipment	Earthmoving
Rubber Tire Dozers	Similar to a rubber-tire loader with a vertically mounted blade instead of a bucket	Earthmoving
Other Construction Equipment	Miscellaneous category for equipment not categorized above; only example of this type supplied by PSR are tensioners which are large winches used in construction	Other

ATTACHMENT D

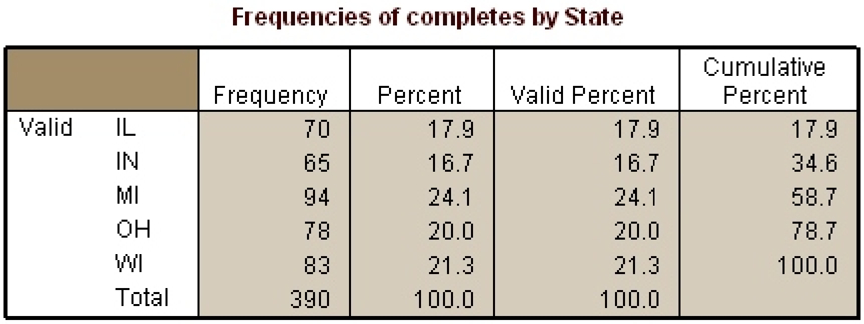
Final Sample Disposition Report

Date of Report: **11/17/03**

	TOTAL SAMPLE		**USABLE SAMPLE**	
DISPOSITION	FREQUENCY	PERCENT OF TOTAL SAMPLE	FREQUENCY	PERCENT OF USABLE SAMPLE
NOT PART OF SURVEY POPULATION	**407**	**7.4%**		
Number not working	129	2.3%		
Beeper/Fax/Modem	73	1.3%		
Language Barrier	3	0.1%		
Residential number	40	0.7%		
Disconnected	157	2.9%		
Ill/Hard of Hearing	5	0.1%		
Eligibility Unknown	**1429**	**26.0%**	**1429**	**28.1%**
No Answer	248	4.5%	248	4.9%
Busy	79	1.4%	79	1.6%
Answering Machine	1102	20.0%	1102	21.6%
REFUSALS	**1800**	**32.7%**	**1800**	**35.3%**
Refusal	645	11.7%	645	12.7%
Unknown Elig. Refusal/No Scrnr	1155	21.0%	1155	22.7%
Eligibility Known	**1474**	**26.8%**	**1474**	**28.9%**
Callback	311	5.7%	311	6.1%
Respondent Never Available	70	1.3%	70	1.4%
No Eligible Respondent	31	0.6%	31	0.6%
Business Not Qualified	977	17.8%	977	19.2%
Quota Full	85	1.5%	85	1.7%
COMPLETES	**390**	**7.1%**	**390**	**7.7%**
Heavy Construction Contractors	**57**	**1.0%**	57	1.1%
Concrete Works	**56**	**1.0%**	56	1.1%
Excavation Work	**56**	**1.0%**	56	1.1%
Landfill Work	**56**	**1.0%**	56	1.1%
Mining	**56**	**1.0%**	56	1.1%
Drilling, Wrecking, Demolition Work	**56**	**1.0%**	56	1.1%
Rental Equipment	**53**	**1.0%**	53	1.0%
SAMPLE TOTAL	**5500**	**100.0%**		
USABLE SAMPLE	**5093**	**92.6%**		
TOTAL SAMPLE ATTEMPTED	**5500**	**100.0%**		
NOT ATTEMPTED	**0**	**0.0%**		

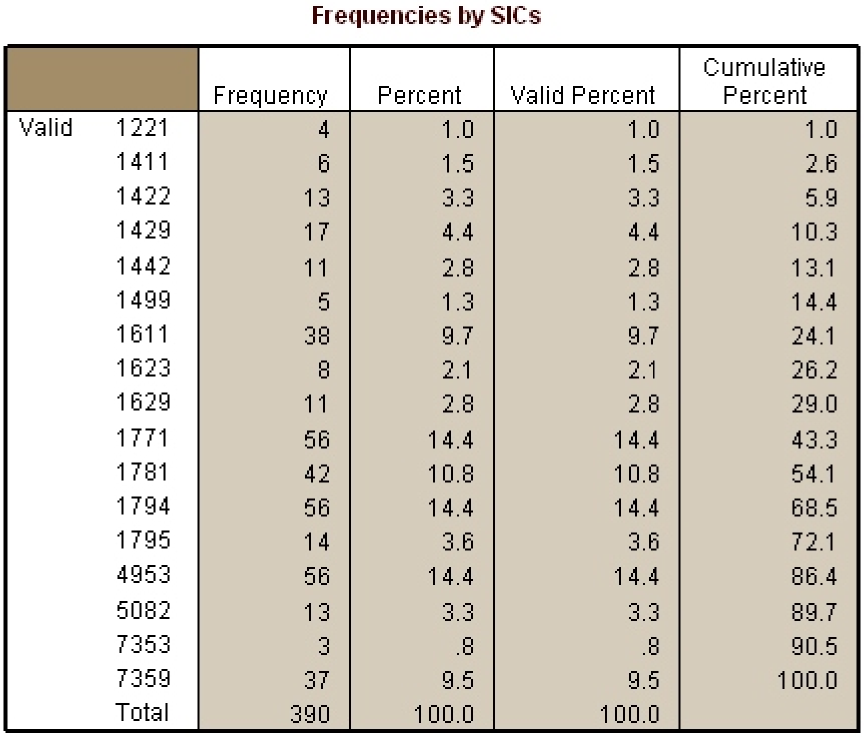
ATTACHMENT E

Frequencies and Crosstabs



Frequencies of completes by State

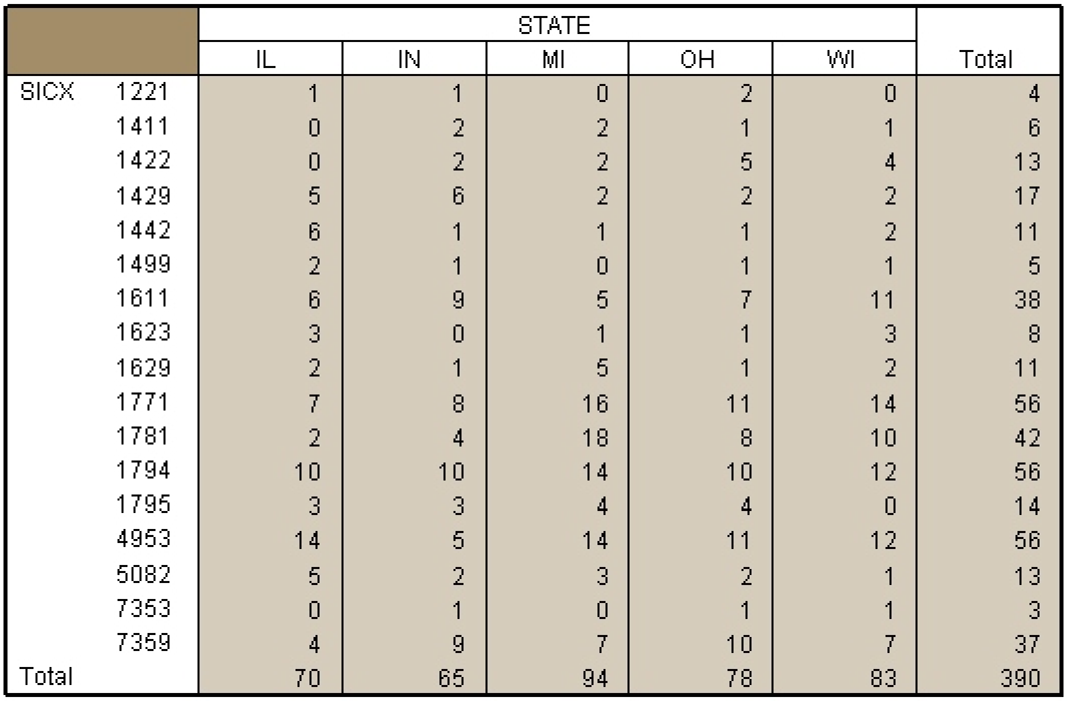
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	IL	70	17.9	17.9	17.9
	IN	65	16.7	16.7	34.6
	MI	94	24.1	24.1	58.7
	OH	78	20.0	20.0	78.7
	WI	83	21.3	21.3	100.0
	Total	390	100.0	100.0	



Frequencies by SICs

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1221	4	1.0	1.0	1.0
	1411	6	1.5	1.5	2.6
	1422	13	3.3	3.3	5.9
	1429	17	4.4	4.4	10.3
	1442	11	2.8	2.8	13.1
	1499	5	1.3	1.3	14.4
	1611	38	9.7	9.7	24.1
	1623	8	2.1	2.1	26.2
	1629	11	2.8	2.8	29.0
	1771	56	14.4	14.4	43.3
	1781	42	10.8	10.8	54.1
	1794	56	14.4	14.4	68.5
	1795	14	3.6	3.6	72.1
	4953	56	14.4	14.4	86.4
	5082	13	3.3	3.3	89.7
	7353	3	.8	.8	90.5
	7359	37	9.5	9.5	100.0
	Total	390	100.0	100.0	

Crosstabulation SICs by State



		STATE					Total
		IL	IN	MI	OH	WI	
SICX	1221	1	1	0	2	0	4
	1411	0	2	2	1	1	6
	1422	0	2	2	5	4	13
	1429	5	6	2	2	2	17
	1442	6	1	1	1	2	11
	1499	2	1	0	1	1	5
	1611	6	9	5	7	11	38
	1623	3	0	1	1	3	8
	1629	2	1	5	1	2	11
	1771	7	8	16	11	14	56
	1781	2	4	18	8	10	42
	1794	10	10	14	10	12	56
	1795	3	3	4	4	0	14
	4953	14	5	14	11	12	56
	5082	5	2	3	2	1	13
	7353	0	1	0	1	1	3
	7359	4	9	7	10	7	37
Total		70	65	94	78	83	390

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APPENDIX B. EQUIPMENT POPULATION SCALING FACTORS

Table B-1. Scaling Factors for Construction and Mining Equipment Owners by SIC and Equipment Type

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1611	2270002003	Pavers	Diesel	9	0.004380
1611	2265002003	Pavers	Gas	2	0.000973
1611	2270002060	Rubber Tire Loaders	Diesel	72	0.035036
1611	2270002066	Tractors/Loaders/Backhoes	Diesel	110	0.053723
1611	2265002066	Tractors/Loaders/Backhoes	Gas	4	0.001752
1611	2270002069	Crawler Tractor/Dozers	Diesel	79	0.038443
1611	2270002072	Skid Steer Loaders	Diesel	23	0.011192
1611	2265002072	Skid Steer Loaders	Gas	2	0.000973
1611	2270002078	Dumpers/Tenders	Diesel	22	0.010706
1611	2265002078	Dumpers/Tenders	Gas	3	0.001460
1611	2270002030	Trenchers	Diesel	10	0.004866
1611	2265002030	Trenchers	Gas	1	0.000487
1611	2270002033	Bore/Drill Rigs	Diesel	51	0.024818
1611	2270002045	Cranes	Diesel	17	0.008273
1611	2270002057	Rough Terrain Forklifts	Diesel	1	0.000487
1611	2265002057	Rough Terrain Forklifts	Gas	1	0.000487
1611	2270002006	Tampers/Rammers	Diesel	9	0.004380
1611	2265002006	Tampers/Rammers	Gas	13	0.006326
1611	2270002051	Off-highway Trucks	Diesel	213	0.103650
1611	2270002075	Off-highway Tractors	Diesel	9	0.004380
1611	2265002075	Off-highway Tractors	Gas	3	0.001460
1611	2270002027	Signal Boards/Light Plants	Diesel	11	0.005109
1611	2265002027	Signal Boards/Light Plants	Gas	5	0.002190
1611	2270002039	Concrete/Industrial Saws	Diesel	3	0.001460
1611	2265002039	Concrete/Industrial Saws	Gas	31	0.015085
1611	2270002042	Cement and Mortar Mixers	Diesel	1	0.000487
1611	2265002042	Cement and Mortar Mixers	Gas	10	0.004866
1611	2270002054	Crushing/Processing Equipment	Diesel	1	0.000487
1611	2265002054	Crushing/Processing Equipment	Gas	1	0.000487
1611	2268002081	Other Construction Equipment	CNG	3	0.001460
1611	2270002081	Other Construction Equipment	Diesel	123	0.059854
1611	2265002081	Other Construction Equipment	Gas	19	0.009246
1611	2270002009	Plate Compactors	Diesel	3	0.001460
1611	2265002009	Plate Compactors	Gas	27	0.013139
1611	2270002015	Rollers	Diesel	35	0.017041
1611	2265002015	Rollers	Gas	17	0.008263
1611	2270002021	Paving Equipment	Diesel	8	0.003893
1611	2265002021	Paving Equipment	Gas	3	0.001460
1611	2270002024	Surfacing Equipment	Diesel	17	0.008273
1611	2265002024	Surfacing Equipment	Gas	4	0.001946
1611	2267002024	Surfacing Equipment	LPG	1	0.000487
1611	2270002018	Scrapers	Diesel	10	0.004866
1611	2270002036	Excavators	Diesel	56	0.027251
1611	2265002036	Excavators	Gas	3	0.001460
1611	2270002048	Graders	Diesel	58	0.028224
1611	2265002048	Graders	Gas	1	0.000487

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1623	2270002003	Pavers	Diesel	9	0.004380
1623	2265002003	Pavers	Gas	2	0.000973
1623	2270002060	Rubber Tire Loaders	Diesel	72	0.035036
1623	2270002066	Tractors/Loaders/Backhoes	Diesel	110	0.053723
1623	2265002066	Tractors/Loaders/Backhoes	Gas	4	0.001752
1623	2270002069	Crawler Tractor/Dozers	Diesel	79	0.038443
1623	2270002072	Skid Steer Loaders	Diesel	23	0.011192
1623	2265002072	Skid Steer Loaders	Gas	2	0.000973
1623	2270002078	Dumpers/Tenders	Diesel	22	0.010706
1623	2265002078	Dumpers/Tenders	Gas	3	0.001460
1623	2270002030	Trenchers	Diesel	10	0.004866
1623	2265002030	Trenchers	Gas	1	0.000487
1623	2270002033	Bore/Drill Rigs	Diesel	51	0.024818
1623	2270002045	Cranes	Diesel	17	0.008273
1623	2270002057	Rough Terrain Forklifts	Diesel	1	0.000487
1623	2265002057	Rough Terrain Forklifts	Gas	1	0.000487
1623	2270002006	Tampers/Rammers	Diesel	9	0.004380
1623	2265002006	Tampers/Rammers	Gas	13	0.006326
1623	2270002051	Off-highway Trucks	Diesel	213	0.103650
1623	2270002075	Off-highway Tractors	Diesel	9	0.004380
1623	2265002075	Off-highway Tractors	Gas	3	0.001460
1623	2270002027	Signal Boards/Light Plants	Diesel	11	0.005109
1623	2265002027	Signal Boards/Light Plants	Gas	5	0.002190
1623	2270002039	Concrete/Industrial Saws	Diesel	3	0.001460
1623	2265002039	Concrete/Industrial Saws	Gas	31	0.015085
1623	2270002042	Cement and Mortar Mixers	Diesel	1	0.000487
1623	2265002042	Cement and Mortar Mixers	Gas	10	0.004866
1623	2270002054	Crushing/Processing Equipment	Diesel	1	0.000487
1623	2265002054	Crushing/Processing Equipment	Gas	1	0.000487
1623	2268002081	Other Construction Equipment	CNG	3	0.001460
1623	2270002081	Other Construction Equipment	Diesel	123	0.059854
1623	2265002081	Other Construction Equipment	Gas	19	0.009246
1623	2270002009	Plate Compactors	Diesel	3	0.001460
1623	2265002009	Plate Compactors	Gas	27	0.013139
1623	2270002015	Rollers	Diesel	35	0.017041
1623	2265002015	Rollers	Gas	17	0.008263
1623	2270002021	Paving Equipment	Diesel	8	0.003893
1623	2265002021	Paving Equipment	Gas	3	0.001460
1623	2270002024	Surfacing Equipment	Diesel	17	0.008273
1623	2265002024	Surfacing Equipment	Gas	4	0.001946
1623	2267002024	Surfacing Equipment	LPG	1	0.000487
1623	2270002018	Scrapers	Diesel	10	0.004866
1623	2270002036	Excavators	Diesel	56	0.027251
1623	2265002036	Excavators	Gas	3	0.001460
1623	2270002048	Graders	Diesel	58	0.028224
1623	2265002048	Graders	Gas	1	0.000487
1629	2270002003	Pavers	Diesel	9	0.004380

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1629	2265002003	Pavers	Gas	2	0.000973
1629	2270002060	Rubber Tire Loaders	Diesel	72	0.035036
1629	2270002066	Tractors/Loaders/Backhoes	Diesel	110	0.053723
1629	2265002066	Tractors/Loaders/Backhoes	Gas	4	0.001752
1629	2270002069	Crawler Tractor/Dozers	Diesel	79	0.038443
1629	2270002072	Skid Steer Loaders	Diesel	23	0.011192
1629	2265002072	Skid Steer Loaders	Gas	2	0.000973
1629	2270002078	Dumpers/Tenders	Diesel	22	0.010706
1629	2265002078	Dumpers/Tenders	Gas	3	0.001460
1629	2270002030	Trenchers	Diesel	10	0.004866
1629	2265002030	Trenchers	Gas	1	0.000487
1629	2270002033	Bore/Drill Rigs	Diesel	51	0.024818
1629	2270002045	Cranes	Diesel	17	0.008273
1629	2270002057	Rough Terrain Forklifts	Diesel	1	0.000487
1629	2265002057	Rough Terrain Forklifts	Gas	1	0.000487
1629	2270002006	Tampers/Rammers	Diesel	9	0.004380
1629	2265002006	Tampers/Rammers	Gas	13	0.006326
1629	2270002051	Off-highway Trucks	Diesel	213	0.103650
1629	2270002075	Off-highway Tractors	Diesel	9	0.004380
1629	2265002075	Off-highway Tractors	Gas	3	0.001460
1629	2270002027	Signal Boards/Light Plants	Diesel	11	0.005109
1629	2265002027	Signal Boards/Light Plants	Gas	5	0.002190
1629	2270002039	Concrete/Industrial Saws	Diesel	3	0.001460
1629	2265002039	Concrete/Industrial Saws	Gas	31	0.015085
1629	2270002042	Cement and Mortar Mixers	Diesel	1	0.000487
1629	2265002042	Cement and Mortar Mixers	Gas	10	0.004866
1629	2270002054	Crushing/Processing Equipment	Diesel	1	0.000487
1629	2265002054	Crushing/Processing Equipment	Gas	1	0.000487
1629	2268002081	Other Construction Equipment	CNG	3	0.001460
1629	2270002081	Other Construction Equipment	Diesel	123	0.059854
1629	2265002081	Other Construction Equipment	Gas	19	0.009246
1629	2270002009	Plate Compactors	Diesel	3	0.001460
1629	2265002009	Plate Compactors	Gas	27	0.013139
1629	2270002015	Rollers	Diesel	35	0.017041
1629	2265002015	Rollers	Gas	17	0.008263
1629	2270002021	Paving Equipment	Diesel	8	0.003893
1629	2265002021	Paving Equipment	Gas	3	0.001460
1629	2270002024	Surfacing Equipment	Diesel	17	0.008273
1629	2265002024	Surfacing Equipment	Gas	4	0.001946
1629	2267002024	Surfacing Equipment	LPG	1	0.000487
1629	2270002018	Scrapers	Diesel	10	0.004866
1629	2270002036	Excavators	Diesel	56	0.027251
1629	2265002036	Excavators	Gas	3	0.001460
1629	2270002048	Graders	Diesel	58	0.028224
1629	2265002048	Graders	Gas	1	0.000487
1771	2270002003	Pavers	Diesel	7	0.009380
1771	2265002003	Pavers	Gas	1	0.000722

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1771	2270002060	Rubber Tire Loaders	Diesel	20	0.028860
1771	2265002060	Rubber Tire Loaders	Gas	1	0.001443
1771	2270002066	Tractors/Loaders/Backhoes	Diesel	26	0.037518
1771	2270002069	Crawler Tractor/Dozers	Diesel	7	0.010101
1771	2270002072	Skid Steer Loaders	Diesel	33	0.047633
1771	2265002072	Skid Steer Loaders	Gas	6	0.008644
1771	2270002078	Dumpers/Tenders	Diesel	6	0.008658
1771	2265002078	Dumpers/Tenders	Gas	6	0.008658
1771	2270002030	Trenchers	Diesel	7	0.010101
1771	2265002030	Trenchers	Gas	1	0.001443
1771	2270002045	Cranes	Diesel	4	0.005772
1771	2270002057	Rough Terrain Forklifts	Diesel	6	0.008658
1771	2265002006	Tampers/Rammers	Gas	42	0.060606
1771	2270002051	Off-highway Trucks	Diesel	2	0.002886
1771	2265002051	Off-highway Trucks	Gas	2	0.002886
1771	2270002075	Off-highway Tractors	Diesel	1	0.001443
1771	2270002027	Signal Boards/Light Plants	Diesel	1	0.001443
1771	2265002027	Signal Boards/Light Plants	Gas	0	0.000000
1771	2265002039	Concrete/Industrial Saws	Gas	79	0.113997
1771	2267002039	Concrete/Industrial Saws	LPG	1	0.001443
1771	2265002042	Cement and Mortar Mixers	Gas	12	0.017316
1771	2270002054	Crushing/Processing Equipment	Diesel	1	0.001443
1771	2270002081	Other Construction Equipment	Diesel	24	0.034632
1771	2265002081	Other Construction Equipment	Gas	27	0.038961
1771	2267002081	Other Construction Equipment	LPG	1	0.001443
1771	2270002009	Plate Compactors	Diesel	5	0.007215
1771	2265002009	Plate Compactors	Gas	42	0.060606
1771	2270002015	Rollers	Diesel	8	0.011544
1771	2265002015	Rollers	Gas	4	0.005772
1771	2267002015	Rollers	LPG	1	0.001443
1771	2270002021	Paving Equipment	Diesel	6	0.008658
1771	2265002021	Paving Equipment	Gas	1	0.001443
1771	2265002024	Surfacing Equipment	Gas	5	0.007215
1771	2270002018	Scrapers	Diesel	1	0.001443
1771	2270002036	Excavators	Diesel	31	0.044733
1771	2270002048	Graders	Diesel	3	0.004329
1794	2270002003	Pavers	Diesel	1	0.000917
1794	2270002060	Rubber Tire Loaders	Diesel	89	0.081577
1794	2265002060	Rubber Tire Loaders	Gas	1	0.000917
1794	2270002066	Tractors/Loaders/Backhoes	Diesel	86	0.078827
1794	2270002069	Crawler Tractor/Dozers	Diesel	168	0.153987
1794	2270002072	Skid Steer Loaders	Diesel	44	0.040330
1794	2270002078	Dumpers/Tenders	Diesel	9	0.008249
1794	2265002078	Dumpers/Tenders	Gas	1	0.000917
1794	2270002030	Trenchers	Diesel	8	0.007333
1794	2270002033	Bore/Drill Rigs	Diesel	12	0.010999
1794	2270002045	Cranes	Diesel	7	0.006416

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1794	2270002057	Rough Terrain Forklifts	Diesel	1	0.000917
1794	2270002006	Tampers/Rammers	Diesel	8	0.006874
1794	2265002006	Tampers/Rammers	Gas	16	0.014207
1794	2270002051	Off-highway Trucks	Diesel	30	0.027498
1794	2265002051	Off-highway Trucks	Gas	1	0.000917
1794	2270002075	Off-highway Tractors	Diesel	5	0.004583
1794	2270002027	Signal Boards/Light Plants	Diesel	2	0.001833
1794	2265002027	Signal Boards/Light Plants	Gas	3	0.002750
1794	2270002039	Concrete/Industrial Saws	Diesel	20	0.018332
1794	2265002039	Concrete/Industrial Saws	Gas	26	0.023831
1794	2270002042	Cement and Mortar Mixers	Diesel	1	0.000917
1794	2265002042	Cement and Mortar Mixers	Gas	4	0.003666
1794	2270002054	Crushing/Processing Equipment	Diesel	4	0.003666
1794	2270002081	Other Construction Equipment	Diesel	10	0.009166
1794	2265002081	Other Construction Equipment	Gas	1	0.000917
1794	2270002009	Plate Compactors	Diesel	31	0.028423
1794	2265002009	Plate Compactors	Gas	33	0.030238
1794	2270002015	Rollers	Diesel	38	0.034830
1794	2265002015	Rollers	Gas	2	0.001833
1794	2270002018	Scrapers	Diesel	83	0.075967
1794	2265002018	Scrapers	Gas	0	0.000110
1794	2270002036	Excavators	Diesel	160	0.146654
1794	2270002048	Graders	Diesel	31	0.028414
4953	2270002060	Rubber Tire Loaders	Diesel	30	0.032609
4953	2270002066	Tractors/Loaders/Backhoes	Diesel	27	0.029348
4953	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.002174
4953	2270002069	Crawler Tractor/Dozers	Diesel	25	0.027174
4953	2270002072	Skid Steer Loaders	Diesel	9	0.009783
4953	2267002072	Skid Steer Loaders	LPG	2	0.002174
4953	2270002078	Dumpers/Tenders	Diesel	14	0.015217
4953	2270002063	Rubber Tire Tractor/Dozers	Diesel	0	0.000000
4953	2270002033	Bore/Drill Rigs	Diesel	0	0.000000
4953	2270002057	Rough Terrain Forklifts	Diesel	1	0.001087
4953	2267002057	Rough Terrain Forklifts	LPG	6	0.006522
4953	2270002006	Tampers/Rammers	Diesel	0	0.000000
4953	2270002051	Off-highway Trucks	Diesel	26	0.027717
4953	2265002051	Off-highway Trucks	Gas	5	0.004891
4953	2270002075	Off-highway Tractors	Diesel	1	0.001087
4953	2270002027	Signal Boards/Light Plants	Diesel	15	0.016304
4953	2265002027	Signal Boards/Light Plants	Gas	1	0.001087
4953	2265002039	Concrete/Industrial Saws	Gas	1	0.001087
4953	2270002054	Crushing/Processing Equipment	Diesel	43	0.046196
4953	2265002054	Crushing/Processing Equipment	Gas	5	0.004891
4953	2270002081	Other Construction Equipment	Diesel	42	0.045870
4953	2265002081	Other Construction Equipment	Gas	4	0.004348
4953	2267002081	Other Construction Equipment	LPG	2	0.001957
4953	2270002009	Plate Compactors	Diesel	6	0.006522

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
4953	2265002009	Plate Compactors	Gas	1	0.001087
4953	2270002015	Rollers	Diesel	1	0.001087
4953	2265002015	Rollers	Gas	0	0.000000
4953	2270002018	Scrapers	Diesel	2	0.002174
4953	2270002036	Excavators	Diesel	23	0.025000
4953	2270002048	Graders	Diesel	7	0.007609
4953	2265002048	Graders	Gas	0	0.000000
1429	2270002003	Pavers	Diesel	3	0.000957
1429	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1429	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734
1429	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1429	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1429	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1429	2265002072	Skid Steer Loaders	Gas	6	0.001914
1429	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1429	2270002030	Trenchers	Diesel	1	0.000319
1429	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1429	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1429	2270002045	Cranes	Diesel	42	0.013397
1429	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319
1429	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1429	2270002006	Tampers/Rammers	Diesel	3	0.000957
1429	2265002006	Tampers/Rammers	Gas	3	0.000957
1429	2270002051	Off-highway Trucks	Diesel	312	0.099522
1429	2265002051	Off-highway Trucks	Gas	2	0.000638
1429	2270002075	Off-highway Tractors	Diesel	14	0.004466
1429	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1429	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1429	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1429	2267002039	Concrete/Industrial Saws	LPG	3	0.000957
1429	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1429	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1429	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1429	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1429	2270002081	Other Construction Equipment	Diesel	128	0.040829
1429	2267002081	Other Construction Equipment	LPG	1	0.000319
1429	2270002009	Plate Compactors	Diesel	1	0.000319
1429	2265002009	Plate Compactors	Gas	2	0.000638
1429	2270002015	Rollers	Diesel	13	0.004147
1429	2270002024	Surfacing Equipment	Diesel	5	0.001595
1429	2270002018	Scrapers	Diesel	6	0.001914
1429	2270002036	Excavators	Diesel	47	0.014992
1429	2265002036	Excavators	Gas	3	0.000957
1429	2270002048	Graders	Diesel	30	0.009569
1442	2270002003	Pavers	Diesel	3	0.000957
1442	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1442	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1442	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1442	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1442	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1442	2265002072	Skid Steer Loaders	Gas	6	0.001914
1442	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1442	2270002030	Trenchers	Diesel	1	0.000319
1442	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1442	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1442	2270002045	Cranes	Diesel	42	0.013397
1442	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319
1442	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1442	2270002006	Tampers/Rammers	Diesel	3	0.000957
1442	2265002006	Tampers/Rammers	Gas	3	0.000957
1442	2270002051	Off-highway Trucks	Diesel	312	0.099522
1442	2265002051	Off-highway Trucks	Gas	2	0.000638
1442	2270002075	Off-highway Tractors	Diesel	14	0.004466
1442	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1442	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1442	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1442	2267002039	Concrete/Industrial Saws	LPG	3	0.000957
1442	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1442	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1442	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1442	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1442	2270002081	Other Construction Equipment	Diesel	128	0.040829
1442	2267002081	Other Construction Equipment	LPG	1	0.000319
1442	2270002009	Plate Compactors	Diesel	1	0.000319
1442	2265002009	Plate Compactors	Gas	2	0.000638
1442	2270002015	Rollers	Diesel	13	0.004147
1442	2270002024	Surfacing Equipment	Diesel	5	0.001595
1442	2270002018	Scrapers	Diesel	6	0.001914
1442	2270002036	Excavators	Diesel	47	0.014992
1442	2265002036	Excavators	Gas	3	0.000957
1442	2270002048	Graders	Diesel	30	0.009569
1499	2270002003	Pavers	Diesel	3	0.000957
1499	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1499	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734
1499	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1499	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1499	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1499	2265002072	Skid Steer Loaders	Gas	6	0.001914
1499	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1499	2270002030	Trenchers	Diesel	1	0.000319
1499	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1499	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1499	2270002045	Cranes	Diesel	42	0.013397
1499	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1499	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1499	2270002006	Tampers/Rammers	Diesel	3	0.000957
1499	2265002006	Tampers/Rammers	Gas	3	0.000957
1499	2270002051	Off-highway Trucks	Diesel	312	0.099522
1499	2265002051	Off-highway Trucks	Gas	2	0.000638
1499	2270002075	Off-highway Tractors	Diesel	14	0.004466
1499	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1499	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1499	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1499	2267002039	Concrete/Industrial Saws	LPG	3	0.000957
1499	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1499	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1499	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1499	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1499	2270002081	Other Construction Equipment	Diesel	128	0.040829
1499	2267002081	Other Construction Equipment	LPG	1	0.000319
1499	2270002009	Plate Compactors	Diesel	1	0.000319
1499	2265002009	Plate Compactors	Gas	2	0.000638
1499	2270002015	Rollers	Diesel	13	0.004147
1499	2270002024	Surfacing Equipment	Diesel	5	0.001595
1499	2270002018	Scrapers	Diesel	6	0.001914
1499	2270002036	Excavators	Diesel	47	0.014992
1499	2265002036	Excavators	Gas	3	0.000957
1499	2270002048	Graders	Diesel	30	0.009569
1221	2270002003	Pavers	Diesel	3	0.000957
1221	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1221	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734
1221	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1221	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1221	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1221	2265002072	Skid Steer Loaders	Gas	6	0.001914
1221	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1221	2270002030	Trenchers	Diesel	1	0.000319
1221	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1221	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1221	2270002045	Cranes	Diesel	42	0.013397
1221	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319
1221	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1221	2270002006	Tampers/Rammers	Diesel	3	0.000957
1221	2265002006	Tampers/Rammers	Gas	3	0.000957
1221	2270002051	Off-highway Trucks	Diesel	312	0.099522
1221	2265002051	Off-highway Trucks	Gas	2	0.000638
1221	2270002075	Off-highway Tractors	Diesel	14	0.004466
1221	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1221	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1221	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1221	2267002039	Concrete/Industrial Saws	LPG	3	0.000957

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1221	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1221	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1221	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1221	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1221	2270002081	Other Construction Equipment	Diesel	128	0.040829
1221	2267002081	Other Construction Equipment	LPG	1	0.000319
1221	2270002009	Plate Compactors	Diesel	1	0.000319
1221	2265002009	Plate Compactors	Gas	2	0.000638
1221	2270002015	Rollers	Diesel	13	0.004147
1221	2270002024	Surfacing Equipment	Diesel	5	0.001595
1221	2270002018	Scrapers	Diesel	6	0.001914
1221	2270002036	Excavators	Diesel	47	0.014992
1221	2265002036	Excavators	Gas	3	0.000957
1221	2270002048	Graders	Diesel	30	0.009569
1422	2270002003	Pavers	Diesel	3	0.000957
1422	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1422	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734
1422	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1422	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1422	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1422	2265002072	Skid Steer Loaders	Gas	6	0.001914
1422	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1422	2270002030	Trenchers	Diesel	1	0.000319
1422	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1422	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1422	2270002045	Cranes	Diesel	42	0.013397
1422	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319
1422	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1422	2270002006	Tampers/Rammers	Diesel	3	0.000957
1422	2265002006	Tampers/Rammers	Gas	3	0.000957
1422	2270002051	Off-highway Trucks	Diesel	312	0.099522
1422	2265002051	Off-highway Trucks	Gas	2	0.000638
1422	2270002075	Off-highway Tractors	Diesel	14	0.004466
1422	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1422	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1422	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1422	2267002039	Concrete/Industrial Saws	LPG	3	0.000957
1422	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1422	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1422	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1422	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1422	2270002081	Other Construction Equipment	Diesel	128	0.040829
1422	2267002081	Other Construction Equipment	LPG	1	0.000319
1422	2270002009	Plate Compactors	Diesel	1	0.000319
1422	2265002009	Plate Compactors	Gas	2	0.000638
1422	2270002015	Rollers	Diesel	13	0.004147
1422	2270002024	Surfacing Equipment	Diesel	5	0.001595

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1422	2270002018	Scrapers	Diesel	6	0.001914
1422	2270002036	Excavators	Diesel	47	0.014992
1422	2265002036	Excavators	Gas	3	0.000957
1422	2270002048	Graders	Diesel	30	0.009569
1411	2270002003	Pavers	Diesel	3	0.000957
1411	2270002060	Rubber Tire Loaders	Diesel	446	0.142265
1411	2270002066	Tractors/Loaders/Backhoes	Diesel	65	0.020734
1411	2265002066	Tractors/Loaders/Backhoes	Gas	2	0.000638
1411	2270002069	Crawler Tractor/Dozers	Diesel	70	0.022329
1411	2270002072	Skid Steer Loaders	Diesel	75	0.023923
1411	2265002072	Skid Steer Loaders	Gas	6	0.001914
1411	2270002078	Dumpers/Tenders	Diesel	38	0.012121
1411	2270002030	Trenchers	Diesel	1	0.000319
1411	2270002033	Bore/Drill Rigs	Diesel	19	0.006061
1411	2265002033	Bore/Drill Rigs	Gas	1	0.000319
1411	2270002045	Cranes	Diesel	42	0.013397
1411	2270002057	Rough Terrain Forklifts	Diesel	1	0.000319
1411	2265002057	Rough Terrain Forklifts	Gas	1	0.000319
1411	2270002006	Tampers/Rammers	Diesel	3	0.000957
1411	2265002006	Tampers/Rammers	Gas	3	0.000957
1411	2270002051	Off-highway Trucks	Diesel	312	0.099522
1411	2265002051	Off-highway Trucks	Gas	2	0.000638
1411	2270002075	Off-highway Tractors	Diesel	14	0.004466
1411	2270002027	Signal Boards/Light Plants	Diesel	20	0.006380
1411	2265002027	Signal Boards/Light Plants	Gas	3	0.000957
1411	2265002039	Concrete/Industrial Saws	Gas	3	0.000957
1411	2267002039	Concrete/Industrial Saws	LPG	3	0.000957
1411	2265002042	Cement and Mortar Mixers	Gas	3	0.000957
1411	2270002054	Crushing/Processing Equipment	Diesel	187	0.059649
1411	2265002054	Crushing/Processing Equipment	Gas	1	0.000319
1411	2267002054	Crushing/Processing Equipment	LPG	1	0.000319
1411	2270002081	Other Construction Equipment	Diesel	128	0.040829
1411	2267002081	Other Construction Equipment	LPG	1	0.000319
1411	2270002009	Plate Compactors	Diesel	1	0.000319
1411	2265002009	Plate Compactors	Gas	2	0.000638
1411	2270002015	Rollers	Diesel	13	0.004147
1411	2270002024	Surfacing Equipment	Diesel	5	0.001595
1411	2270002018	Scrapers	Diesel	6	0.001914
1411	2270002036	Excavators	Diesel	47	0.014992
1411	2265002036	Excavators	Gas	3	0.000957
1411	2270002048	Graders	Diesel	30	0.009569
1781	2270002060	Rubber Tire Loaders	Diesel	16	0.040921
1781	2270002066	Tractors/Loaders/Backhoes	Diesel	34	0.086982
1781	2265002066	Tractors/Loaders/Backhoes	Gas	5	0.012762
1781	2270002069	Crawler Tractor/Dozers	Diesel	7	0.017903
1781	2265002069	Crawler Tractor/Dozers	Gas	0	0.000000
1781	2270002072	Skid Steer Loaders	Diesel	16	0.040921

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1781	2270002078	Dumpers/Tenders	Diesel	3	0.007673
1781	2270002030	Trenchers	Diesel	6	0.014322
1781	2265002030	Trenchers	Gas	7	0.018926
1781	2270002033	Bore/Drill Rigs	Diesel	62	0.158568
1781	2265002033	Bore/Drill Rigs	Gas	23	0.058824
1781	2267002033	Bore/Drill Rigs	LPG	4	0.010230
1781	2270002045	Cranes	Diesel	6	0.015345
1781	2265002045	Cranes	Gas	3	0.007673
1781	2270002057	Rough Terrain Forklifts	Diesel	2	0.005115
1781	2265002057	Rough Terrain Forklifts	Gas	2	0.005115
1781	2265002006	Tampers/Rammers	Gas	2	0.005115
1781	2270002051	Off-highway Trucks	Diesel	3	0.008312
1781	2265002051	Off-highway Trucks	Gas	1	0.001918
1781	2270002039	Concrete/Industrial Saws	Diesel	24	0.060972
1781	2265002039	Concrete/Industrial Saws	Gas	77	0.196061
1781	2267002039	Concrete/Industrial Saws	LPG	4	0.008951
1781	2265002042	Cement and Mortar Mixers	Gas	3	0.007673
1781	2270002054	Crushing/Processing Equipment	Diesel	1	0.002558
1781	2265002054	Crushing/Processing Equipment	Gas	1	0.002558
1781	2270002081	Other Construction Equipment	Diesel	33	0.085141
1781	2265002081	Other Construction Equipment	Gas	30	0.075985
1781	2265002009	Plate Compactors	Gas	4	0.010230
1781	2270002024	Surfacing Equipment	Diesel	2	0.005115
1781	2270002036	Excavators	Diesel	12	0.030716
1781	2265002036	Excavators	Gas	2	0.005090
1795	2270002060	Rubber Tire Loaders	Diesel	16	0.040921
1795	2270002066	Tractors/Loaders/Backhoes	Diesel	34	0.086982
1795	2265002066	Tractors/Loaders/Backhoes	Gas	5	0.012762
1795	2270002069	Crawler Tractor/Dozers	Diesel	7	0.017903
1795	2265002069	Crawler Tractor/Dozers	Gas	0	0.000000
1795	2270002072	Skid Steer Loaders	Diesel	16	0.040921
1795	2270002078	Dumpers/Tenders	Diesel	3	0.007673
1795	2270002030	Trenchers	Diesel	6	0.014322
1795	2265002030	Trenchers	Gas	7	0.018926
1795	2270002033	Bore/Drill Rigs	Diesel	62	0.158568
1795	2265002033	Bore/Drill Rigs	Gas	23	0.058824
1795	2267002033	Bore/Drill Rigs	LPG	4	0.010230
1795	2270002045	Cranes	Diesel	6	0.015345
1795	2265002045	Cranes	Gas	3	0.007673
1795	2270002057	Rough Terrain Forklifts	Diesel	2	0.005115
1795	2265002057	Rough Terrain Forklifts	Gas	2	0.005115
1795	2265002006	Tampers/Rammers	Gas	2	0.005115
1795	2270002051	Off-highway Trucks	Diesel	3	0.008312
1795	2265002051	Off-highway Trucks	Gas	1	0.001918
1795	2270002039	Concrete/Industrial Saws	Diesel	24	0.060972
1795	2265002039	Concrete/Industrial Saws	Gas	77	0.196061
1795	2267002039	Concrete/Industrial Saws	LPG	4	0.008951

Table B-1 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
1795	2265002042	Cement and Mortar Mixers	Gas	3	0.007673
1795	2270002054	Crushing/Processing Equipment	Diesel	1	0.002558
1795	2265002054	Crushing/Processing Equipment	Gas	1	0.002558
1795	2270002081	Other Construction Equipment	Diesel	33	0.085141
1795	2265002081	Other Construction Equipment	Gas	30	0.075985
1795	2265002009	Plate Compactors	Gas	4	0.010230
1795	2270002024	Surfacing Equipment	Diesel	2	0.005115
1795	2270002036	Excavators	Diesel	12	0.030716
1795	2265002036	Excavators	Gas	2	0.00509

Table B-2. Scaling Factors for Rental Equipment Businesses by SIC and Equipment Type

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
5082	2265002039	Concrete/Industrial Saws	Gas	550	0.30623608
5082	2265002027	Signal Boards/Light Plants	Gas	1	0.00055679
5082	2270002036	Excavators	Diesel	424	0.236080178
5082	2265002030	Trenchers	Gas	776.98	0.432616927
5082	2270002006	Tampers/Rammers	Diesel	2.4	0.001336303
5082	2270002030	Trenchers	Diesel	239.02	0.133084633
5082	2270002027	Signal Boards/Light Plants	Diesel	61	0.033964365
5082	2270002045	Cranes	Diesel	49	0.027282851
5082	2270002018	Scrapers	Diesel	23	0.012806236
5082	2270002033	Bore/Drill Rigs	Diesel	135	0.075167038
5082	2270002015	Rollers	Diesel	122.05	0.06795657
5082	2270002009	Plate Compactors	Diesel	9.76	0.005434298
5082	2265002042	Cement and Mortar Mixers	Gas	123	0.068485523
5082	2267002081	Other Construction Equipment	LPG	5.5	0.003062361
5082	2265002066	Tractors/Loaders/Backhoes	Gas	242.8	0.13518931
5082	2265002081	Other Construction Equipment	Gas	235.29	0.131007795
5082	2265002072	Skid Steer Loaders	Gas	24.96	0.01389755
5082	2265002036	Excavators	Gas	206	0.114699332
5082	2270002060	Rubber Tire Loaders	Diesel	423	0.235523385
5082	2270002081	Other Construction Equipment	Diesel	314.21	0.174949889
5082	2270002048	Graders	Diesel	12	0.006681514
5082	2265002006	Tampers/Rammers	Gas	432.6	0.240868597
5082	2270002051	Off-highway Trucks	Diesel	12	0.006681514
5082	2270002057	Rough Terrain Forklifts	Diesel	299	0.166481069
5082	2270002069	Crawler Tractor/Dozers	Diesel	179	0.099665924
5082	2265002009	Plate Compactors	Gas	861.24	0.479532294
5082	2265002015	Rollers	Gas	22.95	0.012778396
5082	2270002066	Tractors/Loaders/Backhoes	Diesel	624.2	0.347550111
5082	2270002072	Skid Steer Loaders	Diesel	798.64	0.44467706
7353	2265002072	Skid Steer Loaders	Gas	24.96	0.01389755
7353	2265002045	Cranes	Gas	5	0.002783964
7353	2270002045	Cranes	Diesel	49	0.027282851
7359	2265002048	Graders	Gas	50	0.027839644
7359	2265002054	Crushing/Processing Equipment	Gas	2	0.001113586
7359	2265002006	Tampers/Rammers	Gas	432.6	0.240868597
7359	2265002066	Tractors/Loaders/Backhoes	Gas	242.8	0.13518931
7359	2265002060	Rubber Tire Loaders	Gas	200	0.111358575
7359	2265002042	Cement and Mortar Mixers	Gas	123	0.068485523
7359	2265002030	Trenchers	Gas	776.98	0.432616927
7359	2265002009	Plate Compactors	Gas	861.24	0.479532294
7359	2265002036	Excavators	Gas	206	0.114699332
7359	2265002015	Rollers	Gas	22.95	0.012778396
7359	2265002033	Bore/Drill Rigs	Gas	1	0.000556793
7359	2265002021	Paving Equipment	Gas	105.3	0.05863029
7359	2265002024	Surfacing Equipment	Gas	153	0.08518931
7359	2265002039	Concrete/Industrial Saws	Gas	550	0.30623608
7359	2270002021	Paving Equipment	Diesel	29.7	0.016536748
7359	2270002075	Off-highway Tractors	Diesel	200	0.111358575

Table B-2 (continued)

SIC	SCC	EquipmentType	Fuel	EquipmentCount	Scaling Factor
7359	2270002072	Skid Steer Loaders	Diesel	798.64	0.44467706
7359	2270002069	Crawler Tractor/Dozers	Diesel	179	0.099665924
7359	2270002066	Tractors/Loaders/Backhoes	Diesel	624.2	0.347550111
7359	2270002060	Rubber Tire Loaders	Diesel	423	0.235523385
7359	2270002057	Rough Terrain Forklifts	Diesel	299	0.166481069
7359	2270002048	Graders	Diesel	12	0.006681514
7359	2270002045	Cranes	Diesel	49	0.027282851
7359	2270002036	Excavators	Diesel	424	0.236080178
7359	2270002033	Bore/Drill Rigs	Diesel	135	0.075167038
7359	2267002081	Other Construction Equipment	LPG	5.5	0.003062361
7359	2270002027	Signal Boards/Light Plants	Diesel	61	0.033964365
7359	2265002072	Skid Steer Loaders	Gas	24.96	0.01389755
7359	2270002018	Scrapers	Diesel	23	0.012806236
7359	2270002015	Rollers	Diesel	122.05	0.06795657
7359	2270002009	Plate Compactors	Diesel	9.76	0.005434298
7359	2270002006	Tampers/Rammers	Diesel	2.4	0.001336303
7359	2270002081	Other Construction Equipment	Diesel	314.21	0.174949889
7359	2270002003	Pavers	Diesel	10	0.005567929
7359	2265002003	Pavers	Gas	7	0.00389755
7359	2267002072	Skid Steer Loaders	LPG	0.4	0.000222717
7359	2267002039	Concrete/Industrial Saws	LPG	90	0.050111359
7359	2267002024	Surfacing Equipment	LPG	1	0.000556793
7359	2265002081	Other Construction Equipment	Gas	235.29	0.131007795
7359	2270002030	Trenchers	Diesel	239.02	0.133084633

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APPENDIX C. MIDWEST RPO EQUIPMENT POPULATION AND EMISSIONS COMPARISONS

Table C-1. Midwest RPO Total Equipment Population Comparison

SCC	Survey Equipment Number	EquipmentType	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	1,300.96	147	-1,153.60	-89%
2265002006	2	Tampers/Rammers	Gas	50.23	4,888	4,837.85	9631%
2265002009	3	Plate Compactors	Gas	15,083.06	6,517	-8,566.11	-57%
2265002015	4	Rollers	Gas	1,478.77	1,320	-158.89	-11%
2265002018	7	Scrapers	Gas	NA	5	NA	NA
2265002021	5	Paving Equipment	Gas	15,802.36	242	-15,560.85	-98%
2265002024	6	Surfacing Equipment	Gas	2,902.29	622	-2,280.05	-79%
2265002027	22	Signal Boards/Light Plants	Gas	208.96	447	237.80	114%
2265002030	16	Trenchers	Gas	4,607.10	333	-4,274.36	-93%
2265002033	17	Bore/Drill Rigs	Gas	15,316.13	619	-14,696.71	-96%
2265002036	8	Excavators	Gas	NA	228	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	5,667.95	11,395	5,726.64	101%
2265002042	24	Cement and Mortar Mixers	Gas	36,356.47	1,788	-34,568.60	-95%
2265002045	18	Cranes	Gas	154.71	80	-74.58	-48%
2265002048	9	Graders	Gas	NA	53	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	502	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	987.52	349	-638.54	-65%
2265002057	19	Rough Terrain Forklifts	Gas	145.67	112	-33.91	-23%
2265002060	10	Rubber Tire Loaders	Gas	232.06	126	-105.76	-46%
2265002066	11	Tractors/Loaders/Backhoes	Gas	1,206.52	452	-754.13	-63%
2265002072	13	Skid Steer Loaders	Gas	1,481.78	628	-854.13	-58%
2265002075	21	Off-highway Tractors	Gas	NA	160	NA	NA
2265002078	14	Dumpers/Tenders	Gas	4,274.57	695	-3,579.24	-84%
2265002081	26	Other Construction Equipment	Gas	96.44	4,294	4,197.86	4353%
2267002015	4	Rollers	LPG	107.65	82	-25.77	-24%
2267002024	6	Surfacing Equipment	LPG	25.01	53	28.20	113%
2267002033	17	Bore/Drill Rigs	LPG	206.60	107	-99.76	-48%
2267002039	23	Concrete/Industrial Saws	LPG	177.24	191	13.51	8%
2267002054	25	Crushing/Processing Equipment	LPG	18.49	5	-13.36	-72%
2267002057	19	Rough Terrain Forklifts	LPG	152.23	352	199.68	131%
2267002072	13	Skid Steer Loaders	LPG	588.26	117	-470.96	-80%
2267002081	26	Other Construction Equipment	LPG	95.69	193	96.89	101%
2268002081	26	Other Construction Equipment	CNG	4.35	160	155.28	3570%
2270002003	1	Pavers	Diesel	3,089.31	1,071	-2,018.38	-65%
2270002006	2	Tampers/Rammers	Diesel	0.00	827	827.46	#DIV/0!

Table C-1. Midwest RPO Total Equipment Population Comparison

SCC	Survey Equipment Number	EquipmentType	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002009	3	Plate Compactors	Diesel	2,931.54	2,304	-627.87	-21%
2270002015	4	Rollers	Diesel	11,487.84	4,332	-7,155.92	-62%
2270002018	7	Scrapers	Diesel	3,137.42	4,444	1,306.53	42%
2270002021	5	Paving Equipment	Diesel	1,370.66	917	-453.70	-33%
2270002024	6	Surfacing Equipment	Diesel	387.14	984	596.49	154%
2270002027	22	Signal Boards/Light Plants	Diesel	7,417.25	1,712	-5,705.47	-77%
2270002030	16	Trenchers	Diesel	7,523.54	1,615	-5,908.19	-79%
2270002033	17	Bore/Drill Rigs	Diesel	5,809.37	5,000	-809.19	-14%
2270002036	8	Excavators	Diesel	17,196.51	14,537	-2,659.75	-15%
2270002039	23	Concrete/Industrial Saws	Diesel	791.07	1,685	893.78	113%
2270002042	24	Cement and Mortar Mixers	Diesel	3,372.39	98	-3,274.76	-97%
2270002045	18	Cranes	Diesel	4,367.10	1,919	-2,448.37	-56%
2270002048	9	Graders	Diesel	5,687.41	5,273	-414.00	-7%
2270002051	20	Off-highway Trucks	Diesel	2,328.45	16,013	13,684.43	588%
2270002054	25	Crushing/Processing Equipment	Diesel	1,327.03	3,791	2,464.24	186%
2270002057	19	Rough Terrain Forklifts	Diesel	15,998.16	706	-15,292.04	-96%
2270002060	10	Rubber Tire Loaders	Diesel	23,813.73	13,897	-9,916.88	-42%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	51,482.11	14,649	-36,833.01	-72%
2270002069	12	Crawler Tractor/Dozers	Diesel	16,604.61	14,252	-2,352.28	-14%
2270002072	13	Skid Steer Loaders	Diesel	69,922.84	7,221	-62,701.61	-90%
2270002075	21	Off-highway Tractors	Diesel	339.03	913	574.32	169%
2270002078	14	Dumpers/Tenders	Diesel	323.36	3,158	2,834.50	877%
2270002081	26	Other Construction Equipment	Diesel	1,996.13	12,975	10,978.79	550%
			Total	**367,433.06**	**171,555.34**	**-195,877.72**	**-53%**

▨ SCCs shaded in gray not included in State-level comparison totals; data provided by respondents but not in NONROAD model.

Gas	107,353.56	36,003.00	**-71,350.56**	**-66%**
LPG	1,371.16	1,099.59	**-271.57**	**-20%**
CNG	4.35	159.63	**155.28**	**3570%**
Diesel	258,703.99	134,293.13	**-124,410.87**	**-48%**

Table C-1. Midwest RPO Total Equipment Population Comparison

SCC	Survey Equipment Number	EquipmentType	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	281	-1,019.92	-78%
2265002006	2	Tampers/Rammers	Gas	16,448	16,397.85	32646%
2265002009	3	Plate Compactors	Gas	29,531	14,448.06	96%
2265002015	4	Rollers	Gas	1,933	454.38	31%
2265002018	7	Scrapers	Gas	5	NA	NA
2265002021	5	Paving Equipment	Gas	2,252	-13,550.03	-86%
2265002024	6	Surfacing Equipment	Gas	3,544	641.65	22%
2265002027	22	Signal Boards/Light Plants	Gas	454	245.43	117%
2265002030	16	Trenchers	Gas	21,095	16,488.20	358%
2265002033	17	Bore/Drill Rigs	Gas	639	-14,677.61	-96%
2265002036	8	Excavators	Gas	5,733	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	26,092	20,423.82	360%
2265002042	24	Cement and Mortar Mixers	Gas	5,075	-31,281.77	-86%
2265002045	18	Cranes	Gas	102	-53.10	-34%
2265002048	9	Graders	Gas	1,008	NA	NA
2265002051	20	Off-highway Trucks	Gas	502	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	387	-600.35	-61%
2265002057	19	Rough Terrain Forklifts	Gas	112	-33.91	-23%
2265002060	10	Rubber Tire Loaders	Gas	3,946	3,713.45	1600%
2265002066	11	Tractors/Loaders/Backhoes	Gas	6,941	5,734.00	475%
2265002072	13	Skid Steer Loaders	Gas	1,402	-79.91	-5%
2265002075	21	Off-highway Tractors	Gas	160	NA	NA
2265002078	14	Dumpers/Tenders	Gas	695	-3,579.24	-84%
2265002081	26	Other Construction Equipment	Gas	10,582	10,485.31	10872%
2267002015	4	Rollers	LPG	82	-25.77	-24%
2267002024	6	Surfacing Equipment	LPG	72	47.30	189%
2267002033	17	Bore/Drill Rigs	LPG	107	-99.76	-48%
2267002039	23	Concrete/Industrial Saws	LPG	1,909	1,732.15	977%
2267002054	25	Crushing/Processing Equipment	LPG	5	-13.36	-72%
2267002057	19	Rough Terrain Forklifts	LPG	352	199.68	131%
2267002072	13	Skid Steer Loaders	LPG	125	-463.32	-79%
2267002081	26	Other Construction Equipment	LPG	340	243.87	255%
2268002081	26	Other Construction Equipment	CNG	160	155.28	3570%
2270002003	1	Pavers	Diesel	1,262	-1,827.42	-59%
2270002006	2	Tampers/Rammers	Diesel	892	891.59	#DIV/0!

Table C-1. Midwest RPO Total Equipment Population Comparison

SCC	Survey Equipment Number	EquipmentType	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002009	3	Plate Compactors	Diesel	2,564	-367.07	-13%
2270002015	4	Rollers	Diesel	7,593	-3,894.48	-34%
2270002018	7	Scrapers	Diesel	5,059	1,921.14	61%
2270002021	5	Paving Equipment	Diesel	1,484	113.45	8%
2270002024	6	Surfacing Equipment	Diesel	984	596.49	154%
2270002027	22	Signal Boards/Light Plants	Diesel	3,342	-4,075.42	-55%
2270002030	16	Trenchers	Diesel	8,002	478.94	6%
2270002033	17	Bore/Drill Rigs	Diesel	8,608	2,798.30	48%
2270002036	8	Excavators	Diesel	25,867	8,670.44	50%
2270002039	23	Concrete/Industrial Saws	Diesel	1,685	893.78	113%
2270002042	24	Cement and Mortar Mixers	Diesel	98	-3,274.76	-97%
2270002045	18	Cranes	Diesel	3,439	-928.46	-21%
2270002048	9	Graders	Diesel	5,594	-93.33	-2%
2270002051	20	Off-highway Trucks	Diesel	16,104	13,775.94	592%
2270002054	25	Crushing/Processing Equipment	Diesel	3,791	2,464.24	186%
2270002057	19	Rough Terrain Forklifts	Diesel	8,696	-7,302.12	-46%
2270002060	10	Rubber Tire Loaders	Diesel	25,200	1,386.59	6%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	31,329	-20,153.05	-39%
2270002069	12	Crawler Tractor/Dozers	Diesel	19,036	2,430.98	15%
2270002072	13	Skid Steer Loaders	Diesel	28,563	-41,360.24	-59%
2270002075	21	Off-highway Tractors	Diesel	4,733	4,393.53	1296%
2270002078	14	Dumpers/Tenders	Diesel	3,158	2,834.50	877%
2270002081	26	Other Construction Equipment	Diesel	21,371	19,375.15	971%
			Total	**380,522**	**13,089.38**	**4%**
▨	SCCs shaded in gray not included in State-level comparison totals; data pr					
			Gas	138,918.16	31,564.60	29%
			LPG	2,991.94	1,620.78	118%
			CNG	159.63	155.28	3570%
			Diesel	238,452.71	-20,251.29	-8%
				380,522.43		

Table C-2. Illinois Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	310.42	38.68	-271.74	-88%
2265002006	2	Tampers/Rammers	Gas	12.06	1,235.75	1,223.69	10151%
2265002009	3	Plate Compactors	Gas	3,601.49	1,609.49	-1,992.00	-55%
2265002015	4	Rollers	Gas	353.62	340.70	-12.91	-4%
2265002018	7	Scrapers	Gas	NA	1.05	NA	NA
2265002021	5	Paving Equipment	Gas	3,774.28	63.37	-3,710.91	-98%
2265002024	6	Surfacing Equipment	Gas	692.17	162.85	-529.32	-76%
2265002027	22	Signal Boards/Light Plants	Gas	49.23	108.42	59.19	120%
2265002030	16	Trenchers	Gas	1,100.04	87.53	-1,012.51	-92%
2265002033	17	Bore/Drill Rigs	Gas	3,656.74	164.27	-3,492.47	-96%
2265002036	8	Excavators	Gas	NA	62.48	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	1,354.20	2,909.27	1,555.07	115%
2265002042	24	Cement and Mortar Mixers	Gas	8,681.75	459.05	-8,222.70	-95%
2265002045	18	Cranes	Gas	36.17	21.15	-15.02	-42%
2265002048	9	Graders	Gas	NA	14.00	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	118.23	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	236.08	80.35	-155.73	-66%
2265002057	19	Rough Terrain Forklifts	Gas	34.16	30.25	-3.91	-11%
2265002060	10	Rubber Tire Loaders	Gas	55.25	30.12	-25.13	-45%
2265002066	11	Tractors/Loaders/Backhoes	Gas	287.32	115.28	-172.04	-60%
2265002072	13	Skid Steer Loaders	Gas	353.62	168.91	-184.71	-52%
2265002075	21	Off-highway Tractors	Gas	NA	42.00	NA	NA
2265002078	14	Dumpers/Tenders	Gas	1,020.67	178.97	-841.70	-82%
2265002081	26	Other Construction Equipment	Gas	23.11	1,111.94	1,088.84	4712%
2267002015	4	Rollers	LPG	26.10	21.37	-4.73	-18%
2267002024	6	Surfacing Equipment	LPG	5.44	14.00	8.56	158%
2267002033	17	Bore/Drill Rigs	LPG	48.93	28.19	-20.74	-42%
2267002039	23	Concrete/Industrial Saws	LPG	42.41	52.49	10.09	24%
2267002054	25	Crushing/Processing Equipment	LPG	4.35	2.15	-2.20	-51%
2267002057	19	Rough Terrain Forklifts	LPG	35.88	76.20	40.32	112%
2267002072	13	Skid Steer Loaders	LPG	140.27	25.40	-114.87	-82%
2267002081	26	Other Construction Equipment	LPG	22.83	46.38	23.55	103%
2268002081	26	Other Construction Equipment	CNG	1.09	42.00	40.91	3763%

Table C-2. Illinois Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	737.36	280.11	-457.25	-62%
2270002006	2	Tampers/Rammers	Diesel	0.00	198.11	198.11	#DIV/0!
2270002009	3	Plate Compactors	Diesel	698.20	498.64	-199.56	-29%
2270002015	4	Rollers	Diesel	2,741.33	1,034.54	-1,706.79	-62%
2270002018	7	Scrapers	Diesel	749.67	925.17	175.50	23%
2270002021	5	Paving Equipment	Diesel	328.96	240.22	-88.74	-27%
2270002024	6	Surfacing Equipment	Diesel	92.87	262.86	169.99	183%
2270002027	22	Signal Boards/Light Plants	Diesel	1,771.23	419.41	-1,351.82	-76%
2270002030	16	Trenchers	Diesel	1,796.97	401.24	-1,395.73	-78%
2270002033	17	Bore/Drill Rigs	Diesel	1,387.45	1,296.94	-90.51	-7%
2270002036	8	Excavators	Diesel	4,107.51	3,324.89	-782.62	-19%
2270002039	23	Concrete/Industrial Saws	Diesel	189.10	385.11	196.01	104%
2270002042	24	Cement and Mortar Mixers	Diesel	805.61	22.75	-782.86	-97%
2270002045	18	Cranes	Diesel	1,041.70	517.42	-524.28	-50%
2270002048	9	Graders	Diesel	1,358.36	1,300.92	-57.44	-4%
2270002051	20	Off-highway Trucks	Diesel	556.10	4,305.47	3,749.37	674%
2270002054	25	Crushing/Processing Equipment	Diesel	316.65	1,019.57	702.92	222%
2270002057	19	Rough Terrain Forklifts	Diesel	3,821.07	179.92	-3,641.15	-95%
2270002060	10	Rubber Tire Loaders	Diesel	5,686.29	3,667.94	-2,018.35	-35%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	12,293.45	3,576.49	-8,716.96	-71%
2270002069	12	Crawler Tractor/Dozers	Diesel	3,964.29	3,243.63	-720.66	-18%
2270002072	13	Skid Steer Loaders	Diesel	16,697.48	1,801.02	-14,896.46	-89%
2270002075	21	Off-highway Tractors	Diesel	81.68	233.96	152.28	186%
2270002078	14	Dumpers/Tenders	Diesel	77.20	795.71	718.51	931%
2270002081	26	Other Construction Equipment	Diesel	476.66	3,368.42	2,891.77	607%
			Total	**87,736.85**	**42,762.77**	**-44,974.08**	**-51%**

Gas	25,632.37	9,154.11	**-16,478.26**	**-64%**
LPG	326.21	266.19	**-60.02**	**-18%**
CNG	1.09	42.00	**40.91**	**3763%**
Diesel	61,777.19	33,300.47	**-28,476.72**	**-46%**

Table C-2. Illinois Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	80.43	-229.99	-74%
2265002006	2	Tampers/Rammers	Gas	5319.66	5,307.60	44028%
2265002009	3	Plate Compactors	Gas	9739.93	6,138.44	170%
2265002015	4	Rollers	Gas	557.36	203.74	58%
2265002018	7	Scrapers	Gas	1.05	NA	NA
2265002021	5	Paving Equipment	Gas	691.29	-3,082.99	-82%
2265002024	6	Surfacing Equipment	Gas	1075.21	383.04	55%
2265002027	22	Signal Boards/Light Plants	Gas	111.89	62.67	127%
2265002030	16	Trenchers	Gas	7422.52	6,322.49	575%
2265002033	17	Bore/Drill Rigs	Gas	170.23	-3,486.51	-95%
2265002036	8	Excavators	Gas	2007.20	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	8101.49	6,747.29	498%
2265002042	24	Cement and Mortar Mixers	Gas	1620.22	-7,061.54	-81%
2265002045	18	Cranes	Gas	26.60	-9.56	-26%
2265002048	9	Graders	Gas	312.16	NA	NA
2265002051	20	Off-highway Trucks	Gas	118.23	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	92.28	-143.80	-61%
2265002057	19	Rough Terrain Forklifts	Gas	30.25	-3.91	-11%
2265002060	10	Rubber Tire Loaders	Gas	1222.75	1,167.50	2113%
2265002066	11	Tractors/Loaders/Backhoes	Gas	2407.40	2,120.09	738%
2265002072	13	Skid Steer Loaders	Gas	431.78	78.16	22%
2265002075	21	Off-highway Tractors	Gas	42.00	NA	NA
2265002078	14	Dumpers/Tenders	Gas	178.97	-841.70	-82%
2265002081	26	Other Construction Equipment	Gas	3333.17	3,310.06	14326%
2267002015	4	Rollers	LPG	21.37	-4.73	-18%
2267002024	6	Surfacing Equipment	LPG	19.96	14.53	267%
2267002033	17	Bore/Drill Rigs	LPG	28.19	-20.74	-42%
2267002039	23	Concrete/Industrial Saws	LPG	589.18	546.77	1289%
2267002054	25	Crushing/Processing Equipment	LPG	2.15	-2.20	-51%
2267002057	19	Rough Terrain Forklifts	LPG	76.20	40.32	112%
2267002072	13	Skid Steer Loaders	LPG	27.79	-112.48	-80%
2267002081	26	Other Construction Equipment	LPG	98.30	75.47	331%
2268002081	26	Other Construction Equipment	CNG	42.00	40.91	3763%

Table C-2. Illinois Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	339.74	-397.62	-54%
2270002006	2	Tampers/Rammers	Diesel	220.76	220.76	#DIV/0!
2270002009	3	Plate Compactors	Diesel	590.78	-107.42	-15%
2270002015	4	Rollers	Diesel	2186.74	-554.59	-20%
2270002018	7	Scrapers	Diesel	1142.29	392.63	52%
2270002021	5	Paving Equipment	Diesel	417.32	88.36	27%
2270002024	6	Surfacing Equipment	Diesel	262.86	169.99	183%
2270002027	22	Signal Boards/Light Plants	Diesel	995.28	-775.96	-44%
2270002030	16	Trenchers	Diesel	2657.68	860.71	48%
2270002033	17	Bore/Drill Rigs	Diesel	2571.39	1,183.94	85%
2270002036	8	Excavators	Diesel	7327.62	3,220.10	78%
2270002039	23	Concrete/Industrial Saws	Diesel	385.11	196.01	104%
2270002042	24	Cement and Mortar Mixers	Diesel	22.75	-782.86	-97%
2270002045	18	Cranes	Diesel	1033.46	-8.24	-1%
2270002048	9	Graders	Diesel	1414.20	55.85	4%
2270002051	20	Off-highway Trucks	Diesel	4347.20	3,791.10	682%
2270002054	25	Crushing/Processing Equipment	Diesel	1019.57	702.92	222%
2270002057	19	Rough Terrain Forklifts	Diesel	3002.60	-818.48	-21%
2270002060	10	Rubber Tire Loaders	Diesel	7661.22	1,974.93	35%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	9469.18	-2,824.27	-23%
2270002069	12	Crawler Tractor/Dozers	Diesel	4933.46	969.17	24%
2270002072	13	Skid Steer Loaders	Diesel	9340.49	-7,356.98	-44%
2270002075	21	Off-highway Tractors	Diesel	1426.59	1,344.91	1647%
2270002078	14	Dumpers/Tenders	Diesel	795.71	718.51	931%
2270002081	26	Other Construction Equipment	Diesel	6334.69	5,858.03	1229%
			Total	**115,897.93**	**28,161.09**	**32%**
			Gas	45,094.07	**19,461.71**	**76%**
			LPG	863.15	**536.94**	**165%**
			CNG	42.00	**40.91**	**3763%**
			Diesel	69,898.71	**8,121.53**	**13%**

Table C-3. Indiana Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	211.97	21.88	-190.0895	-90%
2265002006	2	Tampers/Rammers	Gas	8.04	671.67	663.6344	8257%
2265002009	3	Plate Compactors	Gas	2,451.22	935.73	-1515.495	-62%
2265002015	4	Rollers	Gas	240.10	198.38	-41.71985	-17%
2265002018	7	Scrapers	Gas	NA	0.91	NA	NA
2265002021	5	Paving Equipment	Gas	2,567.76	35.42	-2532.336	-99%
2265002024	6	Surfacing Equipment	Gas	472.16	85.36	-386.8009	-82%
2265002027	22	Signal Boards/Light Plants	Gas	35.16	72.76	37.59825	107%
2265002030	16	Trenchers	Gas	749.43	41.32	-708.1127	-94%
2265002033	17	Bore/Drill Rigs	Gas	2,489.40	71.14	-2418.259	-97%
2265002036	8	Excavators	Gas	NA	33.98	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	920.21	1,523.57	603.3534	66%
2265002042	24	Cement and Mortar Mixers	Gas	5,909.06	250.56	-5658.499	-96%
2265002045	18	Cranes	Gas	26.12	9.15	-16.96615	-65%
2265002048	9	Graders	Gas	NA	8.34	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	75.81	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	160.74	55.57	-105.1669	-65%
2265002057	19	Rough Terrain Forklifts	Gas	24.11	15.41	-8.704785	-36%
2265002060	10	Rubber Tire Loaders	Gas	38.17	17.98	-20.19672	-53%
2265002066	11	Tractors/Loaders/Backhoes	Gas	196.90	66.38	-130.5182	-66%
2265002072	13	Skid Steer Loaders	Gas	241.10	84.75	-156.3524	-65%
2265002075	21	Off-highway Tractors	Gas	NA	25.02	NA	NA
2265002078	14	Dumpers/Tenders	Gas	694.18	95.00	-599.18	-86%
2265002081	26	Other Construction Equipment	Gas	15.07	575.91	560.8363	3722%
2267002015	4	Rollers	LPG	17.40	10.40	-6.997989	-40%
2267002024	6	Surfacing Equipment	LPG	4.35	8.34	3.991208	92%
2267002033	17	Bore/Drill Rigs	LPG	33.71	12.20	-21.50344	-64%
2267002039	23	Concrete/Industrial Saws	LPG	28.27	23.97	-4.304483	-15%
2267002054	25	Crushing/Processing Equipment	LPG	3.26	0.96	-2.299389	-70%
2267002057	19	Rough Terrain Forklifts	LPG	25.01	57.62	32.61037	130%
2267002072	13	Skid Steer Loaders	LPG	95.69	19.21	-76.48082	-80%
2267002081	26	Other Construction Equipment	LPG	15.22	28.65	13.42527	88%
2268002081	26	Other Construction Equipment	CNG	1.09	25.02	23.93454	2201%

Table C-3. Indiana Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	502.39	153.13	-349.2598	-70%
2270002006	2	Tampers/Rammers	Diesel	0.00	134.79	134.7915	#DIV/0!
2270002009	3	Plate Compactors	Diesel	476.66	370.61	-106.0472	-22%
2270002015	4	Rollers	Diesel	1,867.46	685.38	-1182.076	-63%
2270002018	7	Scrapers	Diesel	509.10	746.88	237.7804	47%
2270002021	5	Paving Equipment	Diesel	221.54	129.12	-92.42059	-42%
2270002024	6	Surfacing Equipment	Diesel	62.66	152.71	90.04757	144%
2270002027	22	Signal Boards/Light Plants	Diesel	1,206.18	276.44	-929.7479	-77%
2270002030	16	Trenchers	Diesel	1,224.09	234.88	-989.2057	-81%
2270002033	17	Bore/Drill Rigs	Diesel	945.48	723.77	-221.703	-23%
2270002036	8	Excavators	Diesel	2,795.03	2,304.77	-490.2632	-18%
2270002039	23	Concrete/Industrial Saws	Diesel	127.56	249.33	121.7731	95%
2270002042	24	Cement and Mortar Mixers	Diesel	549.38	15.92	-533.4652	-97%
2270002045	18	Cranes	Diesel	708.27	295.18	-413.0915	-58%
2270002048	9	Graders	Diesel	924.22	845.99	-78.23027	-8%
2270002051	20	Off-highway Trucks	Diesel	377.07	2,579.86	2202.788	584%
2270002054	25	Crushing/Processing Equipment	Diesel	215.95	640.26	424.3152	196%
2270002057	19	Rough Terrain Forklifts	Diesel	2,599.22	94.99	-2504.239	-96%
2270002060	10	Rubber Tire Loaders	Diesel	3,871.42	2,249.27	-1622.158	-42%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	8,366.08	2,268.57	-6097.51	-73%
2270002069	12	Crawler Tractor/Dozers	Diesel	2,698.81	2,333.70	-365.1069	-14%
2270002072	13	Skid Steer Loaders	Diesel	11,362.52	1,076.03	-10286.49	-91%
2270002075	21	Off-highway Tractors	Diesel	54.83	146.44	91.6115	167%
2270002078	14	Dumpers/Tenders	Diesel	51.47	494.28	442.8086	860%
2270002081	26	Other Construction Equipment	Diesel	325.60	1,981.33	1655.726	509%
			Total	**59,717.89**	**26,341.98**	**-33375.91**	**-56%**
			Gas	17,450.91	4,971.99	**-12478.92**	**-72%**
			LPG	222.91	161.35	**-61.55927**	**-28%**
			CNG	1.09	25.02	**23.93454**	**2201%**
			Diesel	42,042.99	21,183.62	**-20859.37**	**-50%**

Table C-3. Indiana Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	35.48	-176.4912	-83%
2265002006	2	Tampers/Rammers	Gas	1899.58	1891.539	23536%
2265002009	3	Plate Compactors	Gas	3380.30	929.0741	38%
2265002015	4	Rollers	Gas	263.52	23.42211	10%
2265002018	7	Scrapers	Gas	0.91	NA	NA
2265002021	5	Paving Equipment	Gas	239.98	-2327.778	-91%
2265002024	6	Surfacing Equipment	Gas	382.58	-89.58051	-19%
2265002027	22	Signal Boards/Light Plants	Gas	73.66	38.49407	109%
2265002030	16	Trenchers	Gas	2246.72	1497.29	200%
2265002033	17	Bore/Drill Rigs	Gas	73.08	-2416.317	-97%
2265002036	8	Excavators	Gas	618.70	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	3084.70	2164.49	235%
2265002042	24	Cement and Mortar Mixers	Gas	599.68	-5309.372	-90%
2265002045	18	Cranes	Gas	12.06	-14.05855	-54%
2265002048	9	Graders	Gas	105.47	NA	NA
2265002051	20	Off-highway Trucks	Gas	75.81	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	59.45	-101.2816	-63%
2265002057	19	Rough Terrain Forklifts	Gas	15.41	-8.704785	-36%
2265002060	10	Rubber Tire Loaders	Gas	406.50	368.3267	965%
2265002066	11	Tractors/Loaders/Backhoes	Gas	755.55	558.6526	284%
2265002072	13	Skid Steer Loaders	Gas	170.11	-70.99042	-29%
2265002075	21	Off-highway Tractors	Gas	25.02	NA	NA
2265002078	14	Dumpers/Tenders	Gas	95.00	-599.18	-86%
2265002081	26	Other Construction Equipment	Gas	1243.76	1228.69	8154%
2267002015	4	Rollers	LPG	10.40	-6.997989	-40%
2267002024	6	Surfacing Equipment	LPG	10.28	5.933825	136%
2267002033	17	Bore/Drill Rigs	LPG	12.20	-21.50344	-64%
2267002039	23	Concrete/Industrial Saws	LPG	198.80	170.531	603%
2267002054	25	Crushing/Processing Equipment	LPG	0.96	-2.299389	-70%
2267002057	19	Rough Terrain Forklifts	LPG	57.62	32.61037	130%
2267002072	13	Skid Steer Loaders	LPG	19.98	-75.70377	-79%
2267002081	26	Other Construction Equipment	LPG	44.26	29.03664	191%
2268002081	26	Other Construction Equipment	CNG	25.02	23.93454	2201%

Table C-3. Indiana Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	172.56	-329.8336	-66%
2270002006	2	Tampers/Rammers	Diesel	141.60	141.6037	#DIV/0!
2270002009	3	Plate Compactors	Diesel	398.31	-78.34414	-16%
2270002015	4	Rollers	Diesel	1031.81	-835.6454	-45%
2270002018	7	Scrapers	Diesel	812.17	303.0643	60%
2270002021	5	Paving Equipment	Diesel	186.82	-34.72486	-16%
2270002024	6	Surfacing Equipment	Diesel	152.71	90.04757	144%
2270002027	22	Signal Boards/Light Plants	Diesel	449.58	-756.6037	-63%
2270002030	16	Trenchers	Diesel	913.32	-310.7642	-25%
2270002033	17	Bore/Drill Rigs	Diesel	1106.96	161.4851	17%
2270002036	8	Excavators	Diesel	3508.26	713.231	26%
2270002039	23	Concrete/Industrial Saws	Diesel	249.33	121.7731	95%
2270002042	24	Cement and Mortar Mixers	Diesel	15.92	-533.4652	-97%
2270002045	18	Cranes	Diesel	462.76	-245.5139	-35%
2270002048	9	Graders	Diesel	880.05	-44.16911	-5%
2270002051	20	Off-highway Trucks	Diesel	2590.61	2213.538	587%
2270002054	25	Crushing/Processing Equipment	Diesel	640.26	424.3152	196%
2270002057	19	Rough Terrain Forklifts	Diesel	943.68	-1655.549	-64%
2270002060	10	Rubber Tire Loaders	Diesel	3449.92	-421.5023	-11%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	4040.32	-4325.762	-52%
2270002069	12	Crawler Tractor/Dozers	Diesel	2841.78	142.9721	5%
2270002072	13	Skid Steer Loaders	Diesel	3342.91	-8019.607	-71%
2270002075	21	Off-highway Tractors	Diesel	534.96	480.1349	876%
2270002078	14	Dumpers/Tenders	Diesel	494.28	442.8086	860%
2270002081	26	Other Construction Equipment	Diesel	2873.19	2547.589	782%
			Total	**48476.64528**	**-11241.25**	**-19%**
			Gas	15863.0378	**-1587.867**	**-9%**
			LPG	354.5153034	**131.6073**	**59%**
			CNG	25.02189781	**23.93454**	**2201%**
			Diesel	32234.07027	**-9808.922**	**-23%**

Table C-4. Michigan Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	233.07	27.14	-205.9228	-0.8835339
2265002006	2	Tampers/Rammers	Gas	9.04	1,071.44	1062.398	117.503665
2265002009	3	Plate Compactors	Gas	2,714.43	1,408.81	-1305.622	-0.4809933
2265002015	4	Rollers	Gas	266.22	246.34	-19.87406	-0.0746531
2265002018	7	Scrapers	Gas	NA	1.23	NA	NA
2265002021	5	Paving Equipment	Gas	2,844.02	45.35	-2798.677	-0.9840558
2265002024	6	Surfacing Equipment	Gas	522.39	128.36	-394.0367	-0.7542932
2265002027	22	Signal Boards/Light Plants	Gas	37.17	88.27	51.10141	1.37479505
2265002030	16	Trenchers	Gas	830.80	93.64	-737.1609	-0.887286
2265002033	17	Bore/Drill Rigs	Gas	2,756.62	206.14	-2550.484	-0.9252205
2265002036	8	Excavators	Gas	NA	45.93	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	1,019.67	2,708.59	1688.922	1.65634396
2265002042	24	Cement and Mortar Mixers	Gas	6,542.96	380.61	-6162.349	-0.9418291
2265002045	18	Cranes	Gas	28.13	26.83	-1.297598	-0.0461306
2265002048	9	Graders	Gas	NA	8.94	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	127.23	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	177.81	90.73	-87.08367	-0.4897453
2265002057	19	Rough Terrain Forklifts	Gas	26.12	27.26	1.143792	0.04379058
2265002060	10	Rubber Tire Loaders	Gas	41.19	28.73	-12.45935	-0.3024952
2265002066	11	Tractors/Loaders/Backhoes	Gas	218.00	109.87	-108.1256	-0.4959931
2265002072	13	Skid Steer Loaders	Gas	266.22	131.40	-134.8213	-0.5064301
2265002075	21	Off-highway Tractors	Gas	NA	26.83	NA	NA
2265002078	14	Dumpers/Tenders	Gas	769.52	148.14	-621.3821	-0.8074894
2265002081	26	Other Construction Equipment	Gas	18.08	1,010.16	992.0797	54.8631781
2267002015	4	Rollers	LPG	19.57	18.52	-1.05582	-0.0539443
2267002024	6	Surfacing Equipment	LPG	4.35	8.94	4.593641	1.05614896
2267002033	17	Bore/Drill Rigs	LPG	36.97	35.77	-1.195172	-0.0323281
2267002039	23	Concrete/Industrial Saws	LPG	31.53	51.12	19.5849	0.62108563
2267002054	25	Crushing/Processing Equipment	LPG	3.26	0.43	-2.829214	-0.8673066
2267002057	19	Rough Terrain Forklifts	LPG	27.18	96.55	69.36392	2.55165373
2267002072	13	Skid Steer Loaders	LPG	105.47	32.18	-73.29094	-0.6948751
2267002081	26	Other Construction Equipment	LPG	17.40	47.91	30.5161	1.75403039
2268002081	26	Other Construction Equipment	CNG	1.09	26.83	25.74184	23.6737864

Table C-4. Michigan Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	557.22	212.36	-344.8599	-0.6188974
2270002006	2	Tampers/Rammers	Diesel	0.00	158.38	158.381	#DIV/0!
2270002009	3	Plate Compactors	Diesel	529.24	533.09	3.84332	0.00726191
2270002015	4	Rollers	Diesel	2,067.74	871.12	-1196.625	-0.5787108
2270002018	7	Scrapers	Diesel	565.05	989.15	424.1024	0.75055885
2270002021	5	Paving Equipment	Diesel	246.16	182.64	-63.51583	-0.2580267
2270002024	6	Surfacing Equipment	Diesel	70.49	172.08	101.5926	1.44120897
2270002027	22	Signal Boards/Light Plants	Diesel	1,334.86	382.87	-951.9873	-0.7131749
2270002030	16	Trenchers	Diesel	1,355.00	351.27	-1003.733	-0.740763
2270002033	17	Bore/Drill Rigs	Diesel	1,046.18	1,141.38	95.2042	0.09100176
2270002036	8	Excavators	Diesel	3,094.90	3,206.71	111.8069	0.03612614
2270002039	23	Concrete/Industrial Saws	Diesel	142.10	444.30	302.1994	2.12664595
2270002042	24	Cement and Mortar Mixers	Diesel	607.57	19.16	-588.4117	-0.9684715
2270002045	18	Cranes	Diesel	787.71	369.43	-418.2823	-0.5310094
2270002048	9	Graders	Diesel	1,023.80	1,016.46	-7.33701	-0.0071664
2270002051	20	Off-highway Trucks	Diesel	419.59	2,822.73	2403.141	5.72734493
2270002054	25	Crushing/Processing Equipment	Diesel	238.33	842.08	603.7507	2.53328155
2270002057	19	Rough Terrain Forklifts	Diesel	2,877.83	164.67	-2713.166	-0.9427809
2270002060	10	Rubber Tire Loaders	Diesel	4,286.54	2,742.05	-1544.488	-0.3603113
2270002066	11	Tractors/Loaders/Backhoes	Diesel	9,265.68	3,113.81	-6151.873	-0.6639416
2270002069	12	Crawler Tractor/Dozers	Diesel	2,988.61	3,047.03	58.42696	0.01954991
2270002072	13	Skid Steer Loaders	Diesel	12,584.37	1,586.67	-10997.7	-0.8739177
2270002075	21	Off-highway Tractors	Diesel	60.42	172.22	111.7976	1.850309
2270002078	14	Dumpers/Tenders	Diesel	59.30	668.32	609.0166	10.2697202
2270002081	26	Other Construction Equipment	Diesel	359.17	2,678.72	2319.548	6.45808225
			Total	**66,136.16**	**36,394.92**	**-29741.24**	**-0.4496971**
			Gas	19,321.47	8,187.97	**-11133.5**	**-0.5762241**
			LPG	245.74	291.43	**45.6874**	**0.18591575**
			CNG	1.09	26.83	**25.74184**	**23.6737864**
			Diesel	46,567.86	27,888.69	**-18679.17**	**-0.4011172**

Table C-4. Michigan Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	62.03	-171.0377	-73%
2265002006	2	Tampers/Rammers	Gas	3690.26	3681.222	40715%
2265002009	3	Plate Compactors	Gas	6622.48	3908.054	144%
2265002015	4	Rollers	Gas	385.28	119.058	45%
2265002018	7	Scrapers	Gas	1.23	NA	NA
2265002021	5	Paving Equipment	Gas	570.12	-2273.906	-80%
2265002024	6	Surfacing Equipment	Gas	890.84	368.4502	71%
2265002027	22	Signal Boards/Light Plants	Gas	89.34	52.17152	140%
2265002030	16	Trenchers	Gas	4797.24	3966.432	477%
2265002033	17	Bore/Drill Rigs	Gas	211.12	-2545.5	-92%
2265002036	8	Excavators	Gas	1292.99	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	6038.12	5018.45	492%
2265002042	24	Cement and Mortar Mixers	Gas	1125.21	-5417.746	-83%
2265002045	18	Cranes	Gas	31.52	3.392908	12%
2265002048	9	Graders	Gas	258.12	NA	NA
2265002051	20	Off-highway Trucks	Gas	127.23	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	100.70	-77.11652	-43%
2265002057	19	Rough Terrain Forklifts	Gas	27.26	1.143792	4%
2265002060	10	Rubber Tire Loaders	Gas	1025.44	984.2556	2390%
2265002066	11	Tractors/Loaders/Backhoes	Gas	1579.71	1361.709	625%
2265002072	13	Skid Steer Loaders	Gas	305.91	39.6937	15%
2265002075	21	Off-highway Tractors	Gas	26.83	NA	NA
2265002078	14	Dumpers/Tenders	Gas	148.14	-621.3821	-81%
2265002081	26	Other Construction Equipment	Gas	2434.53	2416.451	13363%
2267002015	4	Rollers	LPG	18.52	-1.05582	-5%
2267002024	6	Surfacing Equipment	LPG	13.93	9.577215	220%
2267002033	17	Bore/Drill Rigs	LPG	35.77	-1.195172	-3%
2267002039	23	Concrete/Industrial Saws	LPG	499.64	468.1066	1484%
2267002054	25	Crushing/Processing Equipment	LPG	0.43	-2.829214	-87%
2267002057	19	Rough Terrain Forklifts	LPG	96.55	69.36392	255%
2267002072	13	Skid Steer Loaders	LPG	34.18	-71.29751	-68%
2267002081	26	Other Construction Equipment	LPG	81.21	63.81137	367%
2268002081	26	Other Construction Equipment	CNG	26.83	25.74184	2367%

Table C-4. Michigan Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	262.19	-295.0241	-53%
2270002006	2	Tampers/Rammers	Diesel	172.91	172.9099	#DIV/0!
2270002009	3	Plate Compactors	Diesel	592.17	62.9273	12%
2270002015	4	Rollers	Diesel	1609.97	-457.7729	-22%
2270002018	7	Scrapers	Diesel	1128.39	563.3372	100%
2270002021	5	Paving Equipment	Diesel	330.66	84.49634	34%
2270002024	6	Surfacing Equipment	Diesel	172.08	101.5926	144%
2270002027	22	Signal Boards/Light Plants	Diesel	752.15	-582.7124	-44%
2270002030	16	Trenchers	Diesel	1798.22	443.2193	33%
2270002033	17	Bore/Drill Rigs	Diesel	1958.63	912.4518	87%
2270002036	8	Excavators	Diesel	5773.47	2678.57	87%
2270002039	23	Concrete/Industrial Saws	Diesel	444.30	302.1994	213%
2270002042	24	Cement and Mortar Mixers	Diesel	19.16	-588.4117	-97%
2270002045	18	Cranes	Diesel	712.03	-75.68475	-10%
2270002048	9	Graders	Diesel	1089.11	65.30722	6%
2270002051	20	Off-highway Trucks	Diesel	2835.57	2415.982	576%
2270002054	25	Crushing/Processing Equipment	Diesel	842.08	603.7507	253%
2270002057	19	Rough Terrain Forklifts	Diesel	1974.72	-903.114	-31%
2270002060	10	Rubber Tire Loaders	Diesel	5302.76	1016.221	24%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	6892.52	-2373.162	-26%
2270002069	12	Crawler Tractor/Dozers	Diesel	4130.64	1142.037	38%
2270002072	13	Skid Steer Loaders	Diesel	6421.38	-6162.984	-49%
2270002075	21	Off-highway Tractors	Diesel	1168.93	1108.513	1835%
2270002078	14	Dumpers/Tenders	Diesel	668.32	609.0166	1027%
2270002081	26	Other Construction Equipment	Diesel	4580.85	4221.676	1175%
			Total	**84281.91322**	**18145.75**	**27%**
			Gas	31841.6589	**12520.19**	**65%**
			LPG	780.2239035	**534.4814**	**217%**
			CNG	26.82919708	**25.74184**	**2367%**
			Diesel	51633.20122	**5065.341**	**11%**

Table C-5. Ohio Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	391.79	41.71	-350.0887	-89%
2265002006	2	Tampers/Rammers	Gas	15.07	1,303.65	1288.579	8551%
2265002009	3	Plate Compactors	Gas	4,538.78	1,755.81	-2782.97	-61%
2265002015	4	Rollers	Gas	445.04	373.15	-71.89038	-16%
2265002018	7	Scrapers	Gas	NA	1.46	NA	NA
2265002021	5	Paving Equipment	Gas	4,754.77	67.92	-4686.856	-99%
2265002024	6	Surfacing Equipment	Gas	874.00	169.14	-704.8598	-81%
2265002027	22	Signal Boards/Light Plants	Gas	63.29	123.87	60.5805	96%
2265002030	16	Trenchers	Gas	1,385.34	73.34	-1312.003	-95%
2265002033	17	Bore/Drill Rigs	Gas	4,608.10	114.41	-4493.686	-98%
2265002036	8	Excavators	Gas	NA	59.99	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	1,704.81	2,884.58	1179.776	69%
2265002042	24	Cement and Mortar Mixers	Gas	10,940.09	479.25	-10460.84	-96%
2265002045	18	Cranes	Gas	46.21	14.76	-31.44945	-68%
2265002048	9	Graders	Gas	NA	15.49	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	123.98	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	296.36	84.44	-211.9152	-72%
2265002057	19	Rough Terrain Forklifts	Gas	43.20	26.57	-16.62496	-38%
2265002060	10	Rubber Tire Loaders	Gas	69.32	33.59	-35.72409	-52%
2265002066	11	Tractors/Loaders/Backhoes	Gas	362.66	110.71	-251.9458	-69%
2265002072	13	Skid Steer Loaders	Gas	446.04	166.79	-279.2485	-63%
2265002075	21	Off-highway Tractors	Gas	NA	46.48	NA	NA
2265002078	14	Dumpers/Tenders	Gas	1,286.89	187.24	-1099.651	-85%
2265002081	26	Other Construction Equipment	Gas	29.13	1,087.25	1058.117	3632%
2267002015	4	Rollers	LPG	32.62	21.43	-11.18779	-34%
2267002024	6	Surfacing Equipment	LPG	7.61	15.49	7.88291	104%
2267002033	17	Bore/Drill Rigs	LPG	61.98	19.68	-42.29643	-68%
2267002039	23	Concrete/Industrial Saws	LPG	53.28	42.37	-10.91405	-20%
2267002054	25	Crushing/Processing Equipment	LPG	5.44	1.24	-4.19978	-77%
2267002057	19	Rough Terrain Forklifts	LPG	45.67	83.72	38.0506	83%
2267002072	13	Skid Steer Loaders	LPG	177.24	27.91	-149.3326	-84%
2267002081	26	Other Construction Equipment	LPG	29.36	47.79	18.42715	63%
2268002081	26	Other Construction Equipment	CNG	1.09	46.48	45.39586	4175%

Table C-5. Ohio Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	929.81	294.63	-635.1783	-68%
2270002006	2	Tampers/Rammers	Diesel	0.00	234.36	234.3637	#DIV/0!
2270002009	3	Plate Compactors	Diesel	881.70	615.70	-266.0017	-30%
2270002015	4	Rollers	Diesel	3,457.43	1,206.21	-2251.221	-65%
2270002018	7	Scrapers	Diesel	944.36	1,219.56	275.2008	29%
2270002021	5	Paving Equipment	Diesel	412.88	252.55	-160.3247	-39%
2270002024	6	Surfacing Equipment	Diesel	115.25	279.43	164.1837	142%
2270002027	22	Signal Boards/Light Plants	Diesel	2,231.10	442.48	-1788.62	-80%
2270002030	16	Trenchers	Diesel	2,263.55	431.05	-1832.502	-81%
2270002033	17	Bore/Drill Rigs	Diesel	1,746.62	1,264.73	-481.8897	-28%
2270002036	8	Excavators	Diesel	5,173.83	3,915.93	-1257.901	-24%
2270002039	23	Concrete/Industrial Saws	Diesel	238.33	407.00	168.6736	71%
2270002042	24	Cement and Mortar Mixers	Diesel	1,012.61	27.65	-984.9576	-97%
2270002045	18	Cranes	Diesel	1,314.72	515.74	-798.98	-61%
2270002048	9	Graders	Diesel	1,711.93	1,474.73	-237.2009	-14%
2270002051	20	Off-highway Trucks	Diesel	700.44	4,465.73	3765.294	538%
2270002054	25	Crushing/Processing Equipment	Diesel	399.45	914.82	515.3722	129%
2270002057	19	Rough Terrain Forklifts	Diesel	4,814.66	181.28	-4633.38	-96%
2270002060	10	Rubber Tire Loaders	Diesel	7,165.49	3,675.56	-3489.927	-49%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	15,492.41	3,938.13	-11554.28	-75%
2270002069	12	Crawler Tractor/Dozers	Diesel	4,997.05	3,886.90	-1110.144	-22%
2270002072	13	Skid Steer Loaders	Diesel	21,038.84	1,896.02	-19142.82	-91%
2270002075	21	Off-highway Tractors	Diesel	102.94	252.96	150.0163	146%
2270002078	14	Dumpers/Tenders	Diesel	97.35	836.03	738.6867	759%
2270002081	26	Other Construction Equipment	Diesel	599.74	3,452.78	2853.045	476%
			Total	**110,557.66**	**45,733.69**	**-64823.97**	**-59%**
			Gas	32,300.90	9,345.61	**-22955.3**	**-71%**
			LPG	413.20	259.63	**-153.5699**	**-37%**
			CNG	1.09	46.48	**45.39586**	**4175%**
			Diesel	77,842.47	36,081.98	**-41760.5**	**-54%**

Table C-5. Ohio Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	74.69	-317.1042	-81%
2265002006	2	Tampers/Rammers	Gas	3915.63	3900.558	25885%
2265002009	3	Plate Compactors	Gas	6955.86	2417.078	53%
2265002015	4	Rollers	Gas	511.72	66.67855	15%
2265002018	7	Scrapers	Gas	1.46	NA	NA
2265002021	5	Paving Equipment	Gas	564.10	-4190.675	-88%
2265002024	6	Surfacing Equipment	Gas	890.09	16.08707	2%
2265002027	22	Signal Boards/Light Plants	Gas	125.20	61.90629	98%
2265002030	16	Trenchers	Gas	4764.64	3379.295	244%
2265002033	17	Bore/Drill Rigs	Gas	119.13	-4488.974	-97%
2265002036	8	Excavators	Gas	1303.79	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	6205.41	4500.6	264%
2265002042	24	Cement and Mortar Mixers	Gas	1221.91	-9718.182	-89%
2265002045	18	Cranes	Gas	21.35	-24.86535	-54%
2265002048	9	Graders	Gas	251.10	NA	NA
2265002051	20	Off-highway Trucks	Gas	123.98	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	93.87	-202.4911	-68%
2265002057	19	Rough Terrain Forklifts	Gas	26.57	-16.62496	-38%
2265002060	10	Rubber Tire Loaders	Gas	976.01	906.6902	1308%
2265002066	11	Tractors/Loaders/Backhoes	Gas	1576.71	1214.047	335%
2265002072	13	Skid Steer Loaders	Gas	350.37	-95.67562	-21%
2265002075	21	Off-highway Tractors	Gas	46.48	NA	NA
2265002078	14	Dumpers/Tenders	Gas	187.24	-1099.651	-85%
2265002081	26	Other Construction Equipment	Gas	2507.90	2478.765	8508%
2267002015	4	Rollers	LPG	21.43	-11.18779	-34%
2267002024	6	Surfacing Equipment	LPG	20.21	12.59498	165%
2267002033	17	Bore/Drill Rigs	LPG	19.68	-42.29643	-68%
2267002039	23	Concrete/Industrial Saws	LPG	466.45	413.1724	775%
2267002054	25	Crushing/Processing Equipment	LPG	1.24	-4.19978	-77%
2267002057	19	Rough Terrain Forklifts	LPG	83.72	38.0506	83%
2267002072	13	Skid Steer Loaders	LPG	29.79	-147.4477	-83%
2267002081	26	Other Construction Equipment	LPG	80.99	51.63539	176%
2268002081	26	Other Construction Equipment	CNG	46.48	45.39586	4175%

Table C-5. Ohio Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	341.76	-588.0576	-63%
2270002006	2	Tampers/Rammers	Diesel	248.85	248.8545	#DIV/0!
2270002009	3	Plate Compactors	Diesel	674.63	-207.0722	-23%
2270002015	4	Rollers	Diesel	1943.13	-1514.3	-44%
2270002018	7	Scrapers	Diesel	1358.43	414.0716	44%
2270002021	5	Paving Equipment	Diesel	392.50	-20.37615	-5%
2270002024	6	Surfacing Equipment	Diesel	279.43	164.1837	142%
2270002027	22	Signal Boards/Light Plants	Diesel	810.79	-1420.31	-64%
2270002030	16	Trenchers	Diesel	1874.22	-389.3319	-17%
2270002033	17	Bore/Drill Rigs	Diesel	2079.84	333.2216	19%
2270002036	8	Excavators	Diesel	6475.99	1302.153	25%
2270002039	23	Concrete/Industrial Saws	Diesel	407.00	168.6736	71%
2270002042	24	Cement and Mortar Mixers	Diesel	27.65	-984.9576	-97%
2270002045	18	Cranes	Diesel	876.12	-438.6005	-33%
2270002048	9	Graders	Diesel	1547.18	-164.7466	-10%
2270002051	20	Off-highway Trucks	Diesel	4481.64	3781.204	540%
2270002054	25	Crushing/Processing Equipment	Diesel	914.82	515.3722	129%
2270002057	19	Rough Terrain Forklifts	Diesel	1986.60	-2828.059	-59%
2270002060	10	Rubber Tire Loaders	Diesel	6229.58	-935.9118	-13%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	7706.96	-7785.447	-50%
2270002069	12	Crawler Tractor/Dozers	Diesel	4967.68	-29.36635	-1%
2270002072	13	Skid Steer Loaders	Diesel	6718.09	-14320.75	-68%
2270002075	21	Off-highway Tractors	Diesel	1195.37	1092.431	1061%
2270002078	14	Dumpers/Tenders	Diesel	836.03	738.6867	759%
2270002081	26	Other Construction Equipment	Diesel	5349.94	4750.201	792%
			Total	**93309.41465**	**-17248.24**	**-16%**
			Gas	32815.17053	**514.2695**	**2%**
			LPG	723.5169951	**310.3216**	**75%**
			CNG	46.48321168	**45.39586**	**4175%**
			Diesel	59724.24391	**-18118.23**	**-23%**

Table C-6. Wisconsin Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	153.70	17.95	-135.7587	-88%
2265002006	2	Tampers/Rammers	Gas	6.03	605.58	599.5524	9947%
2265002009	3	Plate Compactors	Gas	1,777.14	807.11	-970.026	-55%
2265002015	4	Rollers	Gas	173.80	161.30	-12.49294	-7%
2265002018	7	Scrapers	Gas	NA	0.69	NA	NA
2265002021	5	Paving Equipment	Gas	1,861.52	29.46	-1832.066	-98%
2265002024	6	Surfacing Equipment	Gas	341.56	76.54	-265.0274	-78%
2265002027	22	Signal Boards/Light Plants	Gas	24.11	53.44	29.32945	122%
2265002030	16	Trenchers	Gas	541.48	36.90	-504.5782	-93%
2265002033	17	Bore/Drill Rigs	Gas	1,805.27	63.46	-1741.804	-96%
2265002036	8	Excavators	Gas	NA	25.79	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	669.06	1,368.58	699.518	105%
2265002042	24	Cement and Mortar Mixers	Gas	4,282.61	218.40	-4064.204	-95%
2265002045	18	Cranes	Gas	18.08	8.23	-9.850063	-54%
2265002048	9	Graders	Gas	NA	6.43	NA	NA
2265002051	20	Off-highway Trucks	Gas	NA	57.15	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	116.53	37.89	-78.64806	-67%
2265002057	19	Rough Terrain Forklifts	Gas	18.08	12.27	-5.817695	-32%
2265002060	10	Rubber Tire Loaders	Gas	28.13	15.88	-12.24766	-44%
2265002066	11	Tractors/Loaders/Backhoes	Gas	141.65	50.14	-91.50367	-65%
2265002072	13	Skid Steer Loaders	Gas	174.80	75.80	-99.00109	-57%
2265002075	21	Off-highway Tractors	Gas	NA	19.30	NA	NA
2265002078	14	Dumpers/Tenders	Gas	503.30	85.99	-417.319	-83%
2265002081	26	Other Construction Equipment	Gas	11.05	509.04	497.9874	4506%
2267002015	4	Rollers	LPG	11.96	10.16	-1.799303	-15%
2267002024	6	Surfacing Equipment	LPG	3.26	6.43	3.170048	97%
2267002033	17	Bore/Drill Rigs	LPG	25.01	10.98	-14.03221	-56%
2267002039	23	Concrete/Industrial Saws	LPG	21.75	20.80	-0.947157	-4%
2267002054	25	Crushing/Processing Equipment	LPG	2.17	0.34	-1.830215	-84%
2267002057	19	Rough Terrain Forklifts	LPG	18.49	37.82	19.33451	105%
2267002072	13	Skid Steer Loaders	LPG	69.59	12.61	-56.98428	-82%
2267002081	26	Other Construction Equipment	LPG	10.87	21.85	10.97842	101%
2268002081	26	Other Construction Equipment	CNG	0.00	19.30	19.29635	#DIV/0!

Table C-6. Wisconsin Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	NONROAD Model Population	Population Scaled with Owned Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	362.53	130.69	-231.8339	-64%
2270002006	2	Tampers/Rammers	Diesel	0.00	101.82	101.819	#DIV/0!
2270002009	3	Plate Compactors	Diesel	345.74	285.63	-60.11184	-17%
2270002015	4	Rollers	Diesel	1,353.88	534.67	-819.2102	-61%
2270002018	7	Scrapers	Diesel	369.24	563.19	193.9506	53%
2270002021	5	Paving Equipment	Diesel	161.12	112.43	-48.69622	-30%
2270002024	6	Surfacing Equipment	Diesel	45.88	116.56	70.68171	154%
2270002027	22	Signal Boards/Light Plants	Diesel	873.87	190.58	-683.2909	-78%
2270002030	16	Trenchers	Diesel	883.94	196.92	-687.0169	-78%
2270002033	17	Bore/Drill Rigs	Diesel	683.65	573.36	-110.2923	-16%
2270002036	8	Excavators	Diesel	2,025.22	1,784.46	-240.7677	-12%
2270002039	23	Concrete/Industrial Saws	Diesel	93.99	199.11	105.1213	112%
2270002042	24	Cement and Mortar Mixers	Diesel	397.21	12.15	-385.061	-97%
2270002045	18	Cranes	Diesel	514.70	220.96	-293.7344	-57%
2270002048	9	Graders	Diesel	669.11	635.31	-33.79681	-5%
2270002051	20	Off-highway Trucks	Diesel	275.25	1,839.09	1563.833	568%
2270002054	25	Crushing/Processing Equipment	Diesel	156.65	374.53	217.8785	139%
2270002057	19	Rough Terrain Forklifts	Diesel	1,885.36	85.26	-1800.104	-95%
2270002060	10	Rubber Tire Loaders	Diesel	2,803.98	1,562.03	-1241.951	-44%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	6,064.48	1,752.10	-4312.386	-71%
2270002069	12	Crawler Tractor/Dozers	Diesel	1,955.85	1,741.05	-214.7978	-11%
2270002072	13	Skid Steer Loaders	Diesel	8,239.64	861.51	-7378.137	-90%
2270002075	21	Off-highway Tractors	Diesel	39.16	107.77	68.61271	175%
2270002078	14	Dumpers/Tenders	Diesel	38.04	363.52	325.4784	856%
2270002081	26	Other Construction Equipment	Diesel	234.97	1,493.67	1258.703	536%
			Total	**43,284.49**	**20,321.97**	**-22962.52**	**-53%**
			Gas	12,647.91	4,343.32	**-8304.597**	**-66%**
			LPG	163.10	120.99	**-42.11018**	**-26%**
			CNG	0.00	19.30	**19.29635**	**#DIV/0!**
			Diesel	30,473.48	15,838.37	**-14635.11**	**-48%**

Table C-6. Wisconsin Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2265002003	1	Pavers	Gas	28.41	-125.2964	-82%
2265002006	2	Tampers/Rammers	Gas	1622.96	1616.928	26825%
2265002009	3	Plate Compactors	Gas	2832.55	1055.413	59%
2265002015	4	Rollers	Gas	215.28	41.4802	24%
2265002018	7	Scrapers	Gas	0.69	NA	NA
2265002021	5	Paving Equipment	Gas	186.84	-1674.682	-90%
2265002024	6	Surfacing Equipment	Gas	305.21	-36.35036	-11%
2265002027	22	Signal Boards/Light Plants	Gas	54.30	30.1866	125%
2265002030	16	Trenchers	Gas	1864.18	1322.7	244%
2265002033	17	Bore/Drill Rigs	Gas	64.96	-1740.309	-96%
2265002036	8	Excavators	Gas	510.26	NA	NA
2265002039	23	Concrete/Industrial Saws	Gas	2662.06	1992.992	298%
2265002042	24	Cement and Mortar Mixers	Gas	507.67	-3774.937	-88%
2265002045	18	Cranes	Gas	10.08	-8.005881	-44%
2265002048	9	Graders	Gas	81.16	NA	NA
2265002051	20	Off-highway Trucks	Gas	57.15	NA	NA
2265002054	25	Crushing/Processing Equipment	Gas	40.87	-75.65882	-65%
2265002057	19	Rough Terrain Forklifts	Gas	12.27	-5.817695	-32%
2265002060	10	Rubber Tire Loaders	Gas	314.81	286.6766	1019%
2265002066	11	Tractors/Loaders/Backhoes	Gas	621.15	479.5062	339%
2265002072	13	Skid Steer Loaders	Gas	143.71	-31.09474	-18%
2265002075	21	Off-highway Tractors	Gas	19.30	NA	NA
2265002078	14	Dumpers/Tenders	Gas	85.99	-417.319	-83%
2265002081	26	Other Construction Equipment	Gas	1062.39	1051.335	9514%
2267002015	4	Rollers	LPG	10.16	-1.799303	-15%
2267002024	6	Surfacing Equipment	LPG	7.93	4.664669	143%
2267002033	17	Bore/Drill Rigs	LPG	10.98	-14.03221	-56%
2267002039	23	Concrete/Industrial Saws	LPG	155.32	133.5688	614%
2267002054	25	Crushing/Processing Equipment	LPG	0.34	-1.830215	-84%
2267002057	19	Rough Terrain Forklifts	LPG	37.82	19.33451	105%
2267002072	13	Skid Steer Loaders	LPG	13.20	-56.38643	-81%
2267002081	26	Other Construction Equipment	LPG	34.79	23.91316	220%
2268002081	26	Other Construction Equipment	CNG	19.30	19.29635	#DIV/0!

Table C-6. Wisconsin Equipment Population Comparison

SCC	Survey Equipment Number	Equipment Type	Fuel	Population Scaled with Owned + Rented Equipment	Absolute Difference	Percent Difference
2270002003	1	Pavers	Diesel	145.64	-216.8877	-60%
2270002006	2	Tampers/Rammers	Diesel	107.46	107.4632	#DIV/0!
2270002009	3	Plate Compactors	Diesel	308.58	-37.15856	-11%
2270002015	4	Rollers	Diesel	821.70	-532.1766	-39%
2270002018	7	Scrapers	Diesel	617.28	248.0413	67%
2270002021	5	Paving Equipment	Diesel	156.82	-4.305965	-3%
2270002024	6	Surfacing Equipment	Diesel	116.56	70.68171	154%
2270002027	22	Signal Boards/Light Plants	Diesel	334.03	-539.8329	-62%
2270002030	16	Trenchers	Diesel	759.04	-124.8967	-14%
2270002033	17	Bore/Drill Rigs	Diesel	890.85	207.1967	30%
2270002036	8	Excavators	Diesel	2781.61	756.383	37%
2270002039	23	Concrete/Industrial Saws	Diesel	199.11	105.1213	112%
2270002042	24	Cement and Mortar Mixers	Diesel	12.15	-385.061	-97%
2270002045	18	Cranes	Diesel	354.27	-160.4247	-31%
2270002048	9	Graders	Diesel	663.53	-5.575568	-1%
2270002051	20	Off-highway Trucks	Diesel	1849.37	1574.119	572%
2270002054	25	Crushing/Processing Equipment	Diesel	374.53	217.8785	139%
2270002057	19	Rough Terrain Forklifts	Diesel	788.44	-1096.924	-58%
2270002060	10	Rubber Tire Loaders	Diesel	2556.83	-247.1519	-9%
2270002066	11	Tractors/Loaders/Backhoes	Diesel	3220.07	-2844.411	-47%
2270002069	12	Crawler Tractor/Dozers	Diesel	2162.02	206.1691	11%
2270002072	13	Skid Steer Loaders	Diesel	2739.73	-5499.919	-67%
2270002075	21	Off-highway Tractors	Diesel	406.70	367.537	939%
2270002078	14	Dumpers/Tenders	Diesel	363.52	325.4784	856%
2270002081	26	Other Construction Equipment	Diesel	2232.62	1997.653	850%
			Total	**38556.5247**	**-4727.97**	**-11%**
			Gas	13304.21691	**656.3038**	**5%**
			LPG	270.5363838	**107.4329**	**66%**
			CNG	19.29635036	**19.29635**	**#DIV/0!**
			Diesel	24962.47506	**-5511.003**	**-18%**

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with default inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	1,249.60	1,238.83	1,186.16	1,237.63	76.77	70.62	1,196.94
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	69.32	68.72	65.80	68.66	3.23	2.97	66.40
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	82.06	81.36	77.90	81.28	3.88	3.57	78.60
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	0.65	0.64	0.62	0.64	0.03	0.03	0.62
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	3,432.17	3,402.59	3,257.93	3,399.30	206.59	190.06	3,287.52
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	16.66	16.52	15.81	16.50	0.81	0.74	15.96
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	65.21	58.96	56.27	58.33	0.66	0.61	62.52
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	0.47	0.43	0.41	0.42	0.01	0.00	0.45
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	249.99	226.03	215.72	223.63	1.90	1.75	239.69
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	107.01	96.75	92.34	95.72	1.17	1.07	102.59
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	320.64	289.89	276.68	286.82	2.85	2.62	307.42
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	127.85	115.59	110.32	114.36	1.20	1.10	122.58
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	8.93	8.07	7.70	7.99	0.07	0.07	8.56
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	269.43	243.60	232.49	241.01	2.40	2.21	258.32
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	147.66	133.50	127.41	132.09	1.05	0.96	141.57
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	390.51	353.07	336.97	349.33	4.52	4.15	374.41
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	310.88	281.08	268.26	278.10	2.61	2.40	298.07
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	16.05	14.51	13.85	14.36	0.12	0.11	15.39
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	34.15	30.88	29.47	30.55	0.32	0.30	32.74
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	26.10	23.60	22.52	23.35	0.19	0.17	25.02
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	64.04	57.90	55.26	57.29	0.46	0.42	61.40
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	120.38	108.83	103.87	107.68	1.39	1.28	115.41
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	96.44	87.19	83.22	86.27	0.85	0.78	92.46
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	39.81	35.99	34.35	35.61	0.36	0.33	38.17
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	22.45	20.29	19.37	20.08	0.16	0.15	21.52
2267002003	Construction and Mining Equipment	Pavers	LPG	3.97	3.68	3.32	3.59	0.08	0.08	3.61
2267002015	Construction and Mining Equipment	Rollers	LPG	6.87	6.37	5.75	6.22	0.14	0.14	6.25
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	1.07	0.99	0.90	0.97	0.02	0.02	0.97
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	0.71	0.66	0.60	0.65	0.01	0.01	0.65
2267002030	Construction and Mining Equipment	Trenchers	LPG	12.45	11.54	10.42	11.27	0.26	0.26	11.32
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	4.07	3.77	3.40	3.68	0.08	0.08	3.70
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	11.73	10.88	9.82	10.62	0.24	0.24	10.67
2267002045	Construction and Mining Equipment	Cranes	LPG	4.27	3.96	3.57	3.87	0.09	0.09	3.88
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	0.71	0.66	0.60	0.64	0.01	0.01	0.65
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	7.86	7.29	6.58	7.12	0.16	0.16	7.15
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	19.57	18.15	16.38	17.72	0.41	0.41	17.80
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	2.16	2.00	1.81	1.95	0.04	0.04	1.96

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with default inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	3,429.09	15.34	6,813.26	1.38	76.77	23,216.30	1,080,291.87
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	159.03	0.25	372.57	0.08	3.23	2,181.99	59,380.69
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	190.13	0.31	444.43	0.09	3.88	2,089.57	70,638.53
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	1.52	0.00	3.31	0.00	0.03	6.03	538.71
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	9,219.80	36.77	16,813.94	3.40	206.59	9,935.49	2,774,135.77
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	39.02	0.06	84.93	0.02	0.81	210.97	13,802.28
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	3,284.71	24.18	5,662.47	1.17	0.66	1,300.96	595,643.20
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	23.99	0.15	42.82	0.01	0.01	50.23	4,497.62
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	5,664.68	31.66	9,951.71	2.05	1.90	15,083.06	1,088,911.29
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	6,218.28	42.12	10,039.70	2.07	1.17	1,478.77	1,053,413.49
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	11,144.33	66.22	19,859.87	4.09	2.85	15,802.36	2,117,658.02
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	5,066.54	26.73	8,117.35	1.67	1.20	2,902.29	864,556.37
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	258.71	1.28	408.86	0.08	0.07	208.96	44,319.97
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	10,164.44	73.96	17,330.64	3.57	2.40	4,607.10	1,844,741.60
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	2,994.01	23.59	5,618.47	1.16	1.05	15,316.13	616,796.22
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	24,387.76	130.20	36,123.11	7.44	4.52	5,667.95	3,791,921.29
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	9,753.82	53.25	17,821.15	3.67	2.61	36,356.47	1,907,467.96
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	632.55	11.14	1,423.71	0.29	0.12	154.71	149,655.66
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	1,402.67	8.39	2,305.73	0.47	0.32	987.52	244,904.25
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	960.73	19.39	2,285.60	0.47	0.19	145.67	240,356.75
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	2,339.62	47.87	5,581.35	1.15	0.46	232.06	587,037.63
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	7,395.70	40.99	11,945.02	2.46	1.39	1,206.52	1,251,173.17
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	4,182.80	53.17	8,592.11	1.77	0.85	1,481.78	903,035.79
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	1,531.81	8.62	2,824.24	0.58	0.36	4,274.57	299,350.48
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	820.82	16.79	1,967.13	0.41	0.16	96.44	206,860.53
2267002003	Construction and Mining Equipment	Pavers	LPG	70.44	17.66	987.99	0.02	0.08	106.56	147,951.29
2267002015	Construction and Mining Equipment	Rollers	LPG	122.14	30.52	1,706.58	0.03	0.14	107.65	255,568.06
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	19.00	4.78	267.39	0.01	0.02	88.08	40,040.21
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	12.70	3.18	177.75	0.00	0.01	25.01	26,618.76
2267002030	Construction and Mining Equipment	Trenchers	LPG	221.20	55.44	3,100.89	0.06	0.26	288.15	464,358.41
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	72.18	18.19	1,018.15	0.02	0.08	206.60	152,459.65
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	209.10	51.75	2,890.06	0.06	0.24	177.24	432,838.77
2267002045	Construction and Mining Equipment	Cranes	LPG	75.82	19.07	1,067.24	0.02	0.09	96.77	159,813.86
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	12.64	3.18	177.87	0.00	0.01	18.49	26,635.79
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	139.59	35.05	1,960.79	0.04	0.16	152.23	293,624.04
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	347.93	87.04	4,867.67	0.09	0.41	251.18	728,945.18
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	38.38	9.58	535.56	0.01	0.04	29.36	80,203.61

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with default inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	14.02	13.00	11.73	12.69	0.29	0.29	12.75
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	6.45	5.98	5.40	5.84	0.13	0.13	5.87
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	3.27	0.16	0.16	0.01	0.01	0.01	3.26
2270002003	Construction and Mining Equipment	Pavers	Diesel	109.86	108.21	101.03	108.11	106.27	97.77	102.67
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	6.88	6.78	6.33	6.77	4.80	4.41	6.43
2270002015	Construction and Mining Equipment	Rollers	Diesel	342.75	337.62	315.20	337.30	329.32	302.98	320.32
2270002018	Construction and Mining Equipment	Scrapers	Diesel	320.68	315.89	294.91	315.59	327.84	301.62	299.71
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	29.26	28.82	26.91	28.79	26.81	24.66	27.34
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	8.99	8.85	8.27	8.85	8.23	7.57	8.40
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	50.81	50.05	46.72	50.00	33.94	31.23	47.48
2270002030	Construction and Mining Equipment	Trenchers	Diesel	185.53	182.75	170.62	182.58	173.50	159.62	173.39
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	200.40	197.40	184.29	197.21	179.41	165.06	187.29
2270002036	Construction and Mining Equipment	Excavators	Diesel	959.56	945.21	882.43	944.31	962.21	885.23	896.78
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	13.99	13.78	12.87	13.77	12.42	11.42	13.07
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	11.11	10.94	10.22	10.93	8.82	8.11	10.38
2270002045	Construction and Mining Equipment	Cranes	Diesel	215.37	212.15	198.06	211.95	173.18	159.33	201.28
2270002048	Construction and Mining Equipment	Graders	Diesel	327.29	322.40	300.98	322.09	313.95	288.83	305.88
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	951.75	937.51	875.25	936.62	864.39	795.24	889.48
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	53.61	52.81	49.30	52.76	44.65	41.08	50.10
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	499.51	492.04	459.37	491.58	496.48	456.76	466.83
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	1,540.88	1,517.83	1,417.03	1,516.39	1,501.69	1,381.56	1,440.07
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	2,506.08	2,468.60	2,304.65	2,466.26	1,721.23	1,583.53	2,342.13
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	1,603.21	1,579.24	1,474.36	1,577.74	1,476.01	1,357.93	1,498.33
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	1,979.67	1,950.06	1,820.55	1,948.21	1,185.74	1,090.88	1,850.16
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	104.18	102.62	95.81	102.53	91.40	84.08	97.37
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	4.15	4.08	3.81	4.08	2.83	2.60	3.88
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	161.09	158.68	148.15	158.53	164.05	150.93	150.55
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	58.87	57.99	54.14	57.94	37.95	34.91	55.02
			Gasoline	7,268.46	6,994.81	6,690.70	6,966.99	313.59	288.50	6,964.35
			LPG	95.91	88.94	80.26	86.82	2.00	2.00	87.23
			CNG	3.27	0.16	0.16	0.01	0.01	0.01	3.26
			Diesel	12,245.45	12,062.34	11,261.24	12,050.90	10,247.10	9,427.33	11,444.35
				19,613.09	19,146.25	18,032.35	19,104.72	10,562.70	9,717.84	18,499.19

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with default inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	248.87	62.52	3,498.38	0.07	0.29	588.26	523,869.77
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	114.50	28.82	1,612.91	0.03	0.13	95.69	241,524.18
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	4.34	1.09	45.63	0.00	0.01	4.35	6,759,498.00
2270002003	Construction and Mining Equipment	Pavers	Diesel	573.57	1,162.37	103,944.73	147.66	106.27	3,089.31	9,207,516.06
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	23.69	39.78	2,716.32	3.86	4.80	2,931.54	241,670.11
2270002015	Construction and Mining Equipment	Rollers	Diesel	1,835.53	3,205.24	287,302.45	408.12	329.32	11,487.84	25,459,801.15
2270002018	Construction and Mining Equipment	Scrapers	Diesel	2,095.93	4,684.29	393,059.14	558.36	327.84	3,137.42	34,792,589.53
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	155.49	271.17	22,707.00	32.26	26.81	1,370.66	2,012,790.80
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	49.51	66.68	5,579.78	7.93	8.23	387.14	495,075.90
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	168.94	289.71	22,117.71	31.42	33.94	7,417.25	1,966,427.88
2270002030	Construction and Mining Equipment	Trenchers	Diesel	998.29	1,319.08	120,439.83	171.08	173.50	7,523.54	10,683,999.04
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	851.62	2,105.33	128,085.70	181.94	179.41	5,809.37	11,363,063.49
2270002036	Construction and Mining Equipment	Excavators	Diesel	4,713.58	12,671.38	1,176,337.04	1,671.05	962.21	17,196.51	104,126,295.57
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	72.54	85.24	8,173.62	11.61	12.42	791.07	725,435.39
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	41.88	84.11	5,208.63	7.40	8.82	3,372.39	462,860.52
2270002045	Construction and Mining Equipment	Cranes	Diesel	762.47	2,828.11	217,198.26	308.54	173.18	4,367.10	19,235,880.62
2270002048	Construction and Mining Equipment	Graders	Diesel	1,498.45	4,370.95	396,636.88	563.44	313.95	5,687.41	35,110,252.70
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	5,835.47	13,820.01	1,144,298.85	1,625.54	864.39	2,328.45	101,295,184.01
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	218.93	611.24	46,629.35	66.24	44.65	1,327.03	4,131,608.20
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	2,771.29	4,069.74	368,513.89	523.48	496.48	15,998.16	32,672,255.49
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	8,821.46	19,020.66	1,538,294.17	2,185.21	1,501.69	23,813.73	136,241,103.69
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	10,168.63	10,770.86	850,758.71	1,208.37	1,721.23	51,482.11	75,783,996.21
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	9,030.04	20,271.07	1,666,048.96	2,366.69	1,476.01	16,604.61	147,538,604.10
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	7,130.93	5,488.96	452,051.53	642.01	1,185.74	69,922.84	40,438,514.93
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	640.10	1,169.18	85,475.88	121.42	91.40	339.03	7,575,173.73
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	13.84	13.22	1,024.83	1.46	2.83	323.36	91,586.54
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	1,034.32	1,865.51	135,454.52	192.42	164.05	1,996.13	12,003,403.85
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	234.11	261.23	17,832.25	25.33	37.95	657.85	1,590,133.84
			Gasoline	111,266.57	732.42	192,433.49	39.53	313.59	144,993.91	21,811,089.15
			LPG	1,704.50	426.77	23,869.25	0.46	2.00	2,231.25	3,574,451.57
			CNG	4.34	1.09	45.63	0.00	0.01	4.35	6,759,498.00
			Diesel	59,740.59	110,545.12	9,195,890.03	13,062.82	10,247.10	259,361.84	815,245,223.35
				172,716.00	111,705.40	9,412,238.40	13,102.82	10,562.70	406,591.36	847,390,262.07

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with new inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	1,058.98	1,049.85	1,005.22	1,048.83	65.05	59.85	1,014.35
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	141.09	139.87	133.92	139.74	6.69	6.16	135.14
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	12.54	12.44	11.91	12.42	0.60	0.55	12.02
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	1.43	1.41	1.35	1.41	0.07	0.06	1.37
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	6,886.99	6,827.62	6,537.37	6,821.03	414.54	381.37	6,596.74
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	6.34	6.29	6.02	6.28	0.31	0.28	6.08
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	16.51	14.92	14.24	14.77	0.17	0.16	15.83
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	0.40	0.36	0.35	0.36	0.00	0.00	0.38
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	506.35	457.81	436.93	452.95	3.86	3.55	485.48
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	167.94	151.84	144.91	150.23	1.84	1.69	161.02
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	48.25	43.63	41.64	43.17	0.43	0.40	46.27
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	186.44	168.57	160.88	166.78	1.76	1.62	178.75
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	22.60	20.43	19.50	20.21	0.19	0.17	21.67
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	1,486.24	1,343.74	1,282.47	1,329.49	13.33	12.27	1,424.97
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	7.36	6.66	6.35	6.58	0.05	0.05	7.06
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	786.15	710.77	678.36	703.23	9.09	8.37	753.73
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	50.65	45.80	43.71	45.31	0.43	0.40	48.56
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	12.97	11.72	11.19	11.60	0.10	0.09	12.43
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	13.11	11.85	11.31	11.73	0.12	0.11	12.57
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	23.64	21.37	20.40	21.14	0.17	0.16	22.66
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	1,311.51	1,185.77	1,131.70	1,173.19	9.33	8.58	1,257.44
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	821.78	742.99	709.11	735.11	9.64	8.87	787.90
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	107.72	97.39	92.95	96.36	0.96	0.88	103.28
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	7.59	6.86	6.55	6.79	0.07	0.06	7.27
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	26.84	24.26	23.16	24.01	0.19	0.18	25.73
2267002003	Construction and Mining Equipment	Pavers	LPG	4.76	4.41	3.98	4.31	0.10	0.10	4.33
2267002015	Construction and Mining Equipment	Rollers	LPG	6.47	6.00	5.41	5.86	0.13	0.13	5.88
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	1.29	1.19	1.08	1.16	0.03	0.03	1.17
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	2.46	2.28	2.06	2.23	0.05	0.05	2.24
2267002030	Construction and Mining Equipment	Trenchers	LPG	14.24	13.21	11.92	12.89	0.30	0.30	12.95
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	2.56	2.37	2.14	2.31	0.05	0.05	2.33
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	156.22	144.85	130.72	141.42	3.25	3.25	142.08
2267002045	Construction and Mining Equipment	Cranes	LPG	5.13	4.75	4.29	4.64	0.11	0.11	4.66
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	0.19	0.17	0.15	0.17	0.00	0.00	0.17
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	21.81	20.22	18.25	19.74	0.45	0.45	19.84
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	23.46	21.76	19.63	21.24	0.49	0.49	21.34
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	2.59	2.40	2.17	2.34	0.05	0.05	2.35
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	3.58	3.32	2.99	3.24	0.07	0.07	3.25

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with new inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	2,906.30	13.02	5,782.38	1.17	65.05	16,411.00	916,356.12
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	327.20	0.53	758.03	0.15	6.69	3,732.00	120,830.37
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	29.23	0.05	66.48	0.01	0.60	264.00	10,650.35
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	3.34	0.01	7.27	0.00	0.07	11.00	1,180.98
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	18,500.22	73.77	33,738.96	6.82	414.54	16,615.00	5,566,590.03
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	14.86	0.02	32.34	0.01	0.31	67.00	5,256.47
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	857.51	5.99	1,431.01	0.29	0.17	278.00	150,538.50
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	21.33	0.13	37.46	0.01	0.00	37.00	3,931.21
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	11,619.85	64.47	20,328.10	4.18	3.86	25,799.00	2,222,952.83
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	9,874.69	66.02	15,738.78	3.24	1.84	1,933.00	1,651,448.15
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	1,700.03	9.95	2,973.72	0.61	0.43	1,989.00	317,163.36
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	7,568.42	38.15	11,788.45	2.43	1.76	3,543.00	1,255,795.62
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	666.19	3.20	1,032.08	0.21	0.19	442.00	111,895.53
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	56,953.81	402.94	94,806.40	19.52	13.33	21,097.00	10,095,405.51
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	148.94	1.13	275.84	0.06	0.05	638.00	30,316.48
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	49,164.61	261.76	72,543.17	14.94	9.09	9,479.00	7,615,608.38
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	1,625.61	9.35	2,959.95	0.61	0.43	5,073.00	316,509.84
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	511.65	9.03	1,151.97	0.24	0.10	102.00	121,084.33
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	550.87	3.16	888.01	0.18	0.12	320.00	94,307.66
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	869.30	17.58	2,067.64	0.43	0.17	110.00	217,444.06
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	47,905.71	980.69	114,355.99	23.55	9.33	3,945.00	12,027,583.92
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	52,123.93	275.82	81,754.43	16.84	9.64	6,941.00	8,562,662.34
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	4,766.63	60.10	9,706.16	2.00	0.96	1,401.00	1,019,743.65
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	298.58	1.75	546.95	0.11	0.07	696.00	57,934.84
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	982.07	20.05	2,348.41	0.48	0.19	96.00	246,967.75
2267002003	Construction and Mining Equipment	Pavers	LPG	84.55	21.18	1,184.57	0.02	0.10	106.56	177,390.58
2267002015	Construction and Mining Equipment	Rollers	LPG	115.15	28.62	1,599.59	0.03	0.13	84.00	239,556.97
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	22.83	5.73	320.86	0.01	0.03	88.08	48,048.25
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	43.74	10.90	609.40	0.01	0.05	74.97	91,261.67
2267002030	Construction and Mining Equipment	Trenchers	LPG	253.14	63.37	3,544.35	0.07	0.30	274.70	530,771.87
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	45.37	11.43	639.68	0.01	0.05	108.00	95,787.37
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	2,785.14	688.42	38,443.28	0.75	3.25	1,952.59	5,757,636.56
2267002045	Construction and Mining Equipment	Cranes	LPG	91.02	22.89	1,280.68	0.02	0.11	96.77	191,776.65
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	3.29	0.82	46.16	0.00	0.00	4.00	6,911.71
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	387.40	97.16	5,435.21	0.11	0.45	352.00	813,916.66
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	416.99	104.37	5,837.43	0.11	0.49	251.18	874,164.82
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	46.04	11.49	642.68	0.01	0.05	29.36	96,244.33
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	63.54	15.96	892.87	0.02	0.07	125.00	133,705.22

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with new inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	7.75	7.19	6.49	7.02	0.16	0.16	7.05
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	3.92	0.19	0.19	0.02	0.01	0.01	3.92
2270002003	Construction and Mining Equipment	Pavers	Diesel	48.78	48.05	44.86	48.01	48.84	44.93	45.59
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	1.40	1.38	1.29	1.38	1.04	0.96	1.31
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	7.01	6.91	6.45	6.90	4.90	4.51	6.55
2270002015	Construction and Mining Equipment	Rollers	Diesel	245.84	242.16	226.08	241.93	243.42	223.95	229.75
2270002018	Construction and Mining Equipment	Scrapers	Diesel	546.14	537.97	502.24	537.46	567.55	522.14	510.41
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	34.80	34.28	32.01	34.25	32.40	29.81	32.53
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	25.57	25.19	23.51	25.16	23.57	21.68	23.90
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	25.99	25.61	23.91	25.58	17.32	15.94	24.29
2270002030	Construction and Mining Equipment	Trenchers	Diesel	214.59	211.38	197.35	211.18	207.21	190.63	200.55
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	335.64	330.62	308.66	330.31	293.78	270.28	313.68
2270002036	Construction and Mining Equipment	Excavators	Diesel	1,595.94	1,572.08	1,467.67	1,570.59	1,648.71	1,516.82	1,491.54
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	32.44	31.96	29.84	31.93	29.91	27.51	30.32
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	0.28	0.28	0.26	0.28	0.22	0.20	0.26
2270002045	Construction and Mining Equipment	Cranes	Diesel	183.56	180.82	168.81	180.64	147.26	135.47	171.55
2270002048	Construction and Mining Equipment	Graders	Diesel	344.87	339.71	317.15	339.39	345.88	318.21	322.31
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	1,143.52	1,126.42	1,051.61	1,125.35	1,038.56	955.48	1,068.71
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	164.76	162.29	151.51	162.14	136.31	125.41	153.98
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	300.76	296.26	276.59	295.98	303.90	279.58	281.08
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	1,788.19	1,761.45	1,644.47	1,759.78	1,736.63	1,597.70	1,671.21
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	1,736.90	1,710.93	1,597.30	1,709.31	1,213.12	1,116.07	1,623.28
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	2,000.62	1,970.71	1,839.83	1,968.84	1,895.49	1,743.86	1,869.74
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	913.51	899.85	840.09	899.00	561.13	516.24	853.75
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	99.44	97.95	91.45	97.86	87.17	80.20	92.93
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	48.27	47.54	44.39	47.50	32.50	29.90	45.11
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	151.91	149.64	139.70	149.50	148.21	136.35	141.98
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	58.87	57.99	54.14	57.94	37.95	34.91	55.02
			Gasoline	13,711.41	13,104.22	12,531.49	13,042.73	539.01	495.89	13,138.69
			LPG	252.49	234.12	211.27	228.57	5.26	5.26	229.65
			CNG	3.92	0.19	0.19	0.02	0.01	0.01	3.92
			Diesel	12,049.63	11,869.45	11,081.16	11,858.19	10,802.97	9,938.73	11,261.34
				26,017.47	25,207.99	23,824.12	25,129.50	11,347.24	10,439.88	24,633.59

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Midwest RPO Region 2002 Annual Emissions, tons per year (with new inputs)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	137.63	34.58	1,934.59	0.04	0.16	95.69	289,698.84
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	5.21	1.31	54.72	0.00	0.01	4.35	8,107,753.60
2270002003	Construction and Mining Equipment	Pavers	Diesel	249.19	545.64	50,995.92	72.44	48.84	1,263.00	4,515,917.19
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	5.12	8.67	574.51	0.82	1.04	892.00	51,100.30
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	24.53	40.77	2,852.44	4.05	4.90	2,566.00	253,723.82
2270002015	Construction and Mining Equipment	Rollers	Diesel	1,313.32	2,435.00	228,090.65	324.01	243.42	7,598.00	20,205,728.93
2270002018	Construction and Mining Equipment	Scrapers	Diesel	3,656.00	8,661.92	761,485.25	1,081.74	567.55	5,060.00	67,384,946.35
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	181.72	334.48	29,295.21	41.61	32.40	1,483.00	2,596,007.16
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	142.62	201.35	17,556.91	24.94	23.57	984.00	1,557,053.47
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	86.99	151.73	11,897.64	16.90	17.32	3,343.00	1,057,436.68
2270002030	Construction and Mining Equipment	Trenchers	Diesel	1,176.40	1,629.66	154,337.22	219.24	207.21	8,005.00	13,684,880.37
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	1,407.01	3,596.11	228,640.48	324.78	293.78	8,612.00	20,277,921.23
2270002036	Construction and Mining Equipment	Excavators	Diesel	7,607.11	22,119.48	2,123,267.23	3,016.23	1,648.71	25,871.00	187,910,279.46
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	172.02	209.13	20,815.58	29.57	29.91	1,686.00	1,846,612.17
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	1.02	1.88	124.74	0.18	0.22	95.00	11,088.72
2270002045	Construction and Mining Equipment	Cranes	Diesel	651.07	2,543.26	205,374.03	291.74	147.26	3,436.00	18,183,396.49
2270002048	Construction and Mining Equipment	Graders	Diesel	1,460.63	4,916.80	468,699.65	665.82	345.88	5,593.00	41,478,213.13
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	7,011.31	16,604.74	1,374,875.06	1,953.09	1,038.56	2,328.45	101,295,184.01
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	669.48	1,983.45	159,502.38	226.58	136.31	3,792.00	14,127,857.69
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	1,669.75	2,576.51	240,307.05	341.36	303.90	8,697.00	21,298,927.90
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	10,184.92	23,048.41	1,954,777.00	2,776.85	1,736.63	25,202.00	173,082,751.54
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	7,136.25	7,436.15	621,522.01	882.79	1,213.12	31,329.99	55,339,300.28
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	11,325.98	26,818.80	2,293,178.60	3,257.58	1,895.49	19,036.00	203,020,444.20
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	3,360.02	2,595.13	221,830.78	315.05	561.13	28,562.00	19,828,735.41
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	613.65	1,208.76	91,707.29	130.27	87.17	303.00	8,124,175.27
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	163.51	152.44	12,063.37	17.13	32.50	3,157.00	1,077,934.23
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	964.69	1,879.24	145,293.45	206.39	148.21	1,784.00	12,869,790.00
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	234.11	261.23	17,832.25	25.33	37.95	657.85	1,590,133.84
			Gasoline	269,990.88	2,318.65	477,120.01	98.10	539.01	121,019.00	52,740,158.27
			LPG	4,495.84	1,116.93	62,411.35	1.21	5.26	3,642.89	9,346,871.49
			CNG	5.21	1.31	54.72	0.00	0.01	4.35	8,107,753.60
			Diesel	61,468.43	131,960.75	11,436,896.73	16,246.49	10,802.97	201,336.28	992,669,539.85
				335,960.36	135,397.64	11,976,482.82	16,345.80	11,347.24	326,002.53	1,062,864,323.21

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Difference (Updated - Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	-190.62	-188.98	-180.95	-188.80	-11.71	-10.77	-182.59
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	71.77	71.15	68.12	71.08	3.46	3.19	68.74
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	-69.52	-68.92	-65.99	-68.85	-3.28	-3.02	-66.59
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	0.78	0.77	0.74	0.77	0.04	0.03	0.74
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	3,454.82	3,425.04	3,279.43	3,421.73	207.95	191.31	3,309.22
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	-10.32	-10.23	-9.79	-10.22	-0.50	-0.46	-9.88
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	-48.70	-44.03	-42.03	-43.57	-0.49	-0.45	-46.70
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	-0.07	-0.06	-0.06	-0.06	0.00	0.00	-0.07
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	256.36	231.78	221.21	229.32	1.96	1.80	245.79
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	60.93	55.09	52.58	54.51	0.67	0.62	58.42
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	-272.38	-246.27	-235.04	-243.65	-2.42	-2.22	-261.15
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	58.59	52.98	50.56	52.41	0.56	0.52	56.18
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	13.67	12.36	11.80	12.23	0.11	0.10	13.11
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	1,216.81	1,100.15	1,049.98	1,088.48	10.93	10.06	1,166.65
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	-140.30	-126.85	-121.06	-125.50	-1.00	-0.92	-134.51
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	395.63	357.70	341.39	353.91	4.58	4.21	379.32
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	-260.23	-235.28	-224.55	-232.79	-2.18	-2.01	-249.50
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	-3.09	-2.79	-2.66	-2.76	-0.02	-0.02	-2.96
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	-21.04	-19.02	-18.15	-18.82	-0.20	-0.18	-20.17
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	-2.46	-2.23	-2.13	-2.20	-0.02	-0.02	-2.36
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	1,247.47	1,127.86	1,076.43	1,115.90	8.87	8.16	1,196.04
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	701.41	634.16	605.24	627.43	8.25	7.59	672.49
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	11.28	10.20	9.73	10.09	0.11	0.10	10.82
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	-32.22	-29.14	-27.81	-28.83	-0.29	-0.26	-30.90
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	4.39	3.97	3.79	3.93	0.03	0.03	4.21
2267002003	Construction and Mining Equipment	Pavers	LPG	0.79	0.74	0.66	0.72	0.02	0.02	0.72
2267002015	Construction and Mining Equipment	Rollers	LPG	-0.40	-0.37	-0.34	-0.36	-0.01	-0.01	-0.37
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	0.22	0.20	0.18	0.20	0.00	0.00	0.20
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	1.74	1.62	1.46	1.58	0.04	0.04	1.59
2267002030	Construction and Mining Equipment	Trenchers	LPG	1.79	1.66	1.50	1.62	0.04	0.04	1.63
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	-1.51	-1.40	-1.26	-1.37	-0.03	-0.03	-1.37
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	144.49	133.98	120.90	130.80	3.01	3.01	131.41
2267002045	Construction and Mining Equipment	Cranes	LPG	0.86	0.79	0.72	0.77	0.02	0.02	0.78
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	-0.53	-0.49	-0.44	-0.48	-0.01	-0.01	-0.48
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	13.95	12.93	11.67	12.63	0.29	0.29	12.69
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	3.89	3.61	3.25	3.52	0.08	0.08	3.54
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	0.43	0.40	0.36	0.39	0.01	0.01	0.39
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	-10.44	-9.68	-8.73	-9.45	-0.22	-0.22	-9.49

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Difference (Updated - Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	-522.79	-2.33	-1,030.88	-0.21	-11.71	-6,805.30	-163,935.75
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	168.17	0.28	385.46	0.08	3.46	1,550.01	61,449.68
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	-160.90	-0.26	-377.94	-0.08	-3.28	-1,825.57	-59,988.18
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	1.82	0.00	3.95	0.00	0.04	4.97	642.26
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	9,280.42	37.00	16,925.02	3.42	207.95	6,679.51	2,792,454.26
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	-24.16	-0.04	-52.58	-0.01	-0.50	-143.97	-8,545.81
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	-2,427.21	-18.19	-4,231.46	-0.87	-0.49	-1,022.96	-445,104.70
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	-2.67	-0.02	-5.36	0.00	0.00	-13.23	-566.41
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	5,955.17	32.81	10,376.39	2.13	1.96	10,715.93	1,134,041.54
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	3,656.40	23.90	5,699.08	1.17	0.67	454.23	598,034.66
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	-9,444.30	-56.27	-16,886.16	-3.48	-2.42	-13,813.36	-1,800,494.66
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	2,501.88	11.42	3,671.10	0.76	0.56	640.71	391,239.25
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	407.49	1.92	623.22	0.13	0.11	233.04	67,575.56
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	46,789.37	328.98	77,475.76	15.95	10.93	16,489.90	8,250,663.91
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	-2,845.06	-22.46	-5,342.63	-1.10	-1.00	-14,678.13	-586,479.74
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	24,776.85	131.56	36,420.07	7.50	4.58	3,811.05	3,823,687.09
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	-8,128.21	-43.90	-14,861.20	-3.06	-2.18	-31,283.47	-1,590,958.12
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	-120.90	-2.11	-271.73	-0.06	-0.02	-52.71	-28,571.33
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	-851.80	-5.23	-1,417.72	-0.29	-0.20	-667.52	-150,596.59
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	-91.43	-1.81	-217.96	-0.04	-0.02	-35.67	-22,912.68
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	45,566.09	932.82	108,774.64	22.40	8.87	3,712.94	11,440,546.28
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	44,728.23	234.83	69,809.41	14.38	8.25	5,734.48	7,311,489.17
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	583.83	6.93	1,114.06	0.23	0.11	-80.78	116,707.86
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	-1,233.23	-6.87	-2,277.29	-0.47	-0.29	-3,578.57	-241,415.64
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	161.25	3.26	381.28	0.08	0.03	-0.44	40,107.22
2267002003	Construction and Mining Equipment	Pavers	LPG	14.11	3.52	196.58	0.00	0.02	0.00	29,439.29
2267002015	Construction and Mining Equipment	Rollers	LPG	-6.99	-1.90	-106.99	0.00	-0.01	-23.65	-16,011.08
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	3.84	0.96	53.47	0.00	0.00	0.00	8,008.04
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	31.04	7.72	431.64	0.01	0.04	49.96	64,642.91
2267002030	Construction and Mining Equipment	Trenchers	LPG	31.94	7.94	443.46	0.01	0.04	-13.45	66,413.45
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	-26.82	-6.76	-378.47	-0.01	-0.03	-98.60	-56,672.28
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	2,576.04	636.67	35,553.22	0.69	3.01	1,775.35	5,324,797.79
2267002045	Construction and Mining Equipment	Cranes	LPG	15.20	3.82	213.44	0.00	0.02	0.00	31,962.79
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	-9.35	-2.35	-131.72	0.00	-0.01	-14.49	-19,724.08
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	247.81	62.11	3,474.41	0.07	0.29	199.77	520,292.63
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	69.06	17.33	969.76	0.02	0.08	0.00	145,219.64
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	7.66	1.92	107.11	0.00	0.01	0.00	16,040.72
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	-185.33	-46.56	-2,605.50	-0.05	-0.22	-463.26	-390,164.55

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Difference (Updated - Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	1.30	1.21	1.09	1.18	0.03	0.03	1.18
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	0.66	0.03	0.03	0.00	0.00	0.00	0.66
2270002003	Construction and Mining Equipment	Pavers	Diesel	-61.07	-60.16	-56.17	-60.10	-57.43	-52.83	-57.08
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	1.40	1.38	1.29	1.38	1.04	0.96	1.31
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	0.13	0.13	0.12	0.13	0.11	0.10	0.12
2270002015	Construction and Mining Equipment	Rollers	Diesel	-96.91	-95.46	-89.12	-95.37	-85.90	-79.03	-90.57
2270002018	Construction and Mining Equipment	Scrapers	Diesel	225.45	222.08	207.33	221.87	239.70	220.53	210.70
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	5.55	5.46	5.10	5.46	5.59	5.14	5.18
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	16.58	16.33	15.25	16.32	15.34	14.11	15.50
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	-24.81	-24.44	-22.82	-24.42	-16.62	-15.29	-23.19
2270002030	Construction and Mining Equipment	Trenchers	Diesel	29.06	28.63	26.73	28.60	33.71	31.01	27.16
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	135.24	133.22	124.37	133.09	114.37	105.22	126.40
2270002036	Construction and Mining Equipment	Excavators	Diesel	636.39	626.87	585.24	626.28	686.51	631.59	594.75
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	18.45	18.18	16.97	18.16	17.49	16.09	17.25
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	-10.83	-10.66	-9.96	-10.65	-8.60	-7.91	-10.12
2270002045	Construction and Mining Equipment	Cranes	Diesel	-31.81	-31.33	-29.25	-31.30	-25.93	-23.85	-29.73
2270002048	Construction and Mining Equipment	Graders	Diesel	17.58	17.32	16.17	17.30	31.93	29.37	16.43
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	191.78	188.91	176.36	188.73	174.17	160.24	179.23
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	111.15	109.49	102.21	109.38	91.66	84.33	103.88
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	-198.75	-195.78	-182.78	-195.60	-192.58	-177.18	-185.75
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	247.32	243.62	227.44	243.39	234.94	216.14	231.14
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	-769.17	-757.67	-707.35	-756.95	-508.11	-467.46	-718.85
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	397.41	391.47	365.47	391.10	419.48	385.92	371.41
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	-1,066.15	-1,050.21	-980.46	-1,049.21	-624.61	-574.64	-996.40
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	-4.74	-4.67	-4.36	-4.67	-4.23	-3.89	-4.43
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	44.12	43.46	40.57	43.42	29.67	27.30	41.23
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	-9.18	-9.04	-8.44	-9.03	-15.84	-14.57	-8.58
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Gasoline	6,442.96	6,109.41	5,840.79	6,075.74	225.41	207.38	6,174.34
			LPG	156.58	145.19	131.02	141.74	3.26	3.26	142.41
			CNG	0.66	0.03	0.03	0.00	0.00	0.00	0.66
			Diesel	-195.82	-192.89	-180.08	-192.70	555.87	511.40	-183.00
				6,404.38	6,061.74	5,791.77	6,024.78	784.54	722.04	6,134.40

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Difference (Updated - Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	23.14	5.76	321.68	0.01	0.03	0.00	48,174.65
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	0.88	0.22	9.08	0.00	0.00	0.00	1,348,255.60
2270002003	Construction and Mining Equipment	Pavers	Diesel	-324.38	-616.73	-52,948.81	-75.22	-57.43	-1,826.31	-4,691,598.87
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	5.12	8.67	574.51	0.82	1.04	892.00	51,100.30
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	0.84	0.99	136.12	0.19	0.11	-365.54	12,053.72
2270002015	Construction and Mining Equipment	Rollers	Diesel	-522.21	-770.24	-59,211.80	-84.11	-85.90	-3,889.84	-5,254,072.22
2270002018	Construction and Mining Equipment	Scrapers	Diesel	1,560.07	3,977.63	368,426.12	523.38	239.70	1,922.58	32,592,356.82
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	26.23	63.31	6,588.21	9.36	5.59	112.34	583,216.35
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	93.11	134.67	11,977.13	17.01	15.34	596.86	1,061,977.57
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	-81.95	-137.98	-10,220.07	-14.52	-16.62	-4,074.25	-908,991.20
2270002030	Construction and Mining Equipment	Trenchers	Diesel	178.11	310.58	33,897.39	48.15	33.71	481.46	3,000,881.33
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	555.40	1,490.79	100,554.78	142.84	114.37	2,802.62	8,914,857.74
2270002036	Construction and Mining Equipment	Excavators	Diesel	2,893.53	9,448.10	946,930.19	1,345.18	686.51	8,674.49	83,783,983.89
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	99.49	123.89	12,641.96	17.96	17.49	894.93	1,121,176.78
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	-40.86	-82.23	-5,083.90	-7.22	-8.60	-3,277.39	-451,771.79
2270002045	Construction and Mining Equipment	Cranes	Diesel	-111.40	-284.85	-11,824.23	-16.79	-25.93	-931.10	-1,052,484.13
2270002048	Construction and Mining Equipment	Graders	Diesel	-37.81	545.85	72,062.77	102.37	31.93	-94.41	6,367,960.43
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	1,175.85	2,784.73	230,576.22	327.55	174.17	0.00	0.00
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	450.55	1,372.21	112,873.04	160.34	91.66	2,464.97	9,996,249.49
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	-1,101.53	-1,493.23	-128,206.84	-182.12	-192.58	-7,301.16	-11,373,327.60
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	1,363.46	4,027.76	416,482.83	591.65	234.94	1,388.27	36,841,647.85
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	-3,032.38	-3,334.71	-229,236.69	-325.59	-508.11	-20,152.12	-20,444,695.93
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	2,295.94	6,547.73	627,129.64	890.88	419.48	2,431.39	55,481,840.10
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	-3,770.91	-2,893.83	-230,220.75	-326.96	-624.61	-41,360.84	-20,609,779.52
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	-26.45	39.57	6,231.41	8.85	-4.23	-36.03	549,001.54
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	149.67	139.22	11,038.55	15.68	29.67	2,833.63	986,347.69
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	-69.63	13.73	9,838.93	13.98	-15.84	-212.13	866,386.16
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Gasoline	158,724.31	1,586.22	284,686.52	58.57	225.41	-23,974.91	30,929,069.12
			LPG	2,791.34	690.16	38,542.10	0.75	3.26	1,411.64	5,772,419.92
			CNG	0.88	0.22	9.08	0.00	0.00	0.00	1,348,255.60
			Diesel	1,727.84	21,415.64	2,241,006.71	3,183.67	555.87	-58,025.56	177,424,316.50
				163,244.36	23,692.24	2,564,244.41	3,242.99	784.54	-80,588.83	215,474,061.14

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Percent Difference (Updated - Default/Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	-15.25%	-15.25%	-15.25%	-15.25%	-15.25%	-15.25%	-15.25%
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	103.53%	103.53%	103.53%	103.53%	107.27%	107.27%	103.53%
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	-84.71%	-84.71%	-84.71%	-84.71%	-84.52%	-84.52%	-84.71%
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	119.22%	119.22%	119.22%	119.22%	119.22%	119.22%	119.22%
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	100.66%	100.66%	100.66%	100.66%	100.66%	100.66%	100.66%
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	-61.92%	-61.92%	-61.92%	-61.92%	-61.92%	-61.92%	-61.92%
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	-74.69%	-74.69%	-74.69%	-74.69%	-74.31%	-74.31%	-74.69%
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	-14.80%	-14.80%	-14.80%	-14.80%	-12.76%	-12.76%	-14.80%
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	102.55%	102.55%	102.55%	102.55%	103.26%	103.26%	102.55%
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	56.94%	56.94%	56.94%	56.94%	57.54%	57.54%	56.94%
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	-84.95%	-84.95%	-84.95%	-84.95%	-84.79%	-84.79%	-84.95%
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	45.83%	45.83%	45.83%	45.83%	47.04%	47.04%	45.83%
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	153.11%	153.11%	153.11%	153.11%	154.13%	154.13%	153.11%
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	451.63%	451.63%	451.63%	451.63%	454.98%	454.98%	451.63%
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	-95.01%	-95.01%	-95.01%	-95.01%	-94.99%	-94.99%	-95.01%
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	101.31%	101.31%	101.31%	101.31%	101.38%	101.38%	101.31%
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	-83.71%	-83.71%	-83.71%	-83.71%	-83.53%	-83.53%	-83.71%
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	-19.24%	-19.24%	-19.24%	-19.24%	-19.35%	-19.35%	-19.24%
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	-61.61%	-61.61%	-61.61%	-61.61%	-61.29%	-61.29%	-61.61%
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	-9.44%	-9.44%	-9.44%	-9.44%	-9.59%	-9.59%	-9.44%
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	1947.87%	1947.87%	1947.87%	1947.87%	1947.87%	1947.87%	1947.87%
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	582.68%	582.68%	582.68%	582.68%	592.18%	592.18%	582.68%
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	11.70%	11.70%	11.70%	11.70%	12.57%	12.57%	11.70%
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	-80.94%	-80.94%	-80.94%	-80.94%	-80.52%	-80.52%	-80.94%
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	19.56%	19.56%	19.56%	19.56%	19.57%	19.57%	19.56%
2267002003	Construction and Mining Equipment	Pavers	LPG	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%
2267002015	Construction and Mining Equipment	Rollers	LPG	-5.84%	-5.84%	-5.84%	-5.84%	-5.84%	-5.84%	-5.84%
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	243.98%	243.98%	243.98%	243.98%	243.98%	243.98%	243.98%
2267002030	Construction and Mining Equipment	Trenchers	LPG	14.41%	14.41%	14.41%	14.41%	14.41%	14.41%	14.41%
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	-37.15%	-37.15%	-37.15%	-37.15%	-37.15%	-37.15%	-37.15%
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	1231.55%	1231.55%	1231.55%	1231.55%	1231.55%	1231.55%	1231.55%
2267002045	Construction and Mining Equipment	Cranes	LPG	20.04%	20.04%	20.04%	20.04%	20.04%	20.04%	20.04%
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	-74.01%	-74.01%	-74.01%	-74.01%	-74.01%	-74.01%	-74.01%
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	177.45%	177.45%	177.45%	177.45%	177.45%	177.45%	177.45%
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	19.86%	19.86%	19.86%	19.86%	19.86%	19.86%	19.86%
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	19.96%	19.96%	19.96%	19.96%	19.96%	19.96%	19.96%
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	-74.47%	-74.47%	-74.47%	-74.47%	-74.47%	-74.47%	-74.47%

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Percent Difference (Updated - Default/Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2260002006	Construction and Mining Equipment	Tampers/Rammers	2 Stroke	-15.25%	-15.18%	-15.13%	-15.13%	-15.25%	-29.31%	-15.18%
2260002009	Construction and Mining Equipment	Plate Compactors	2 Stroke	105.75%	111.43%	103.46%	103.46%	107.27%	71.04%	103.48%
2260002021	Construction and Mining Equipment	Paving Equipment	2 Stroke	-84.63%	-84.51%	-85.04%	-85.05%	-84.52%	-87.37%	-84.92%
2260002027	Construction and Mining Equipment	Signal Boards/Light Plants	2 Stroke	119.22%	119.22%	119.22%	119.22%	119.22%	82.49%	119.22%
2260002039	Construction and Mining Equipment	Concrete/Industrial Saws	2 Stroke	100.66%	100.65%	100.66%	100.66%	100.66%	67.23%	100.66%
2260002054	Construction and Mining Equipment	Crushing/Proc. Equipment	2 Stroke	-61.92%	-61.92%	-61.92%	-61.92%	-61.92%	-68.24%	-61.92%
2265002003	Construction and Mining Equipment	Pavers	4 Stroke	-73.89%	-75.22%	-74.73%	-74.73%	-74.31%	-78.63%	-74.73%
2265002006	Construction and Mining Equipment	Tampers/Rammers	4 Stroke	-11.11%	-12.67%	-12.52%	-12.52%	-12.76%	-26.34%	-12.59%
2265002009	Construction and Mining Equipment	Plate Compactors	4 Stroke	105.13%	103.65%	104.27%	104.27%	103.26%	71.05%	104.14%
2265002015	Construction and Mining Equipment	Rollers	4 Stroke	58.80%	56.75%	56.77%	56.77%	57.54%	30.72%	56.77%
2265002021	Construction and Mining Equipment	Paving Equipment	4 Stroke	-84.75%	-84.98%	-85.03%	-85.03%	-84.79%	-87.41%	-85.02%
2265002024	Construction and Mining Equipment	Surfacing Equipment	4 Stroke	49.38%	42.71%	45.23%	45.22%	47.04%	22.08%	45.25%
2265002027	Construction and Mining Equipment	Signal Boards/Light Plants	4 Stroke	157.51%	149.85%	152.43%	152.43%	154.13%	111.53%	152.47%
2265002030	Construction and Mining Equipment	Trenchers	4 Stroke	460.32%	444.83%	447.05%	447.04%	454.98%	357.92%	447.25%
2265002033	Construction and Mining Equipment	Bore/Drill Rigs	4 Stroke	-95.03%	-95.22%	-95.09%	-95.09%	-94.99%	-95.83%	-95.08%
2265002039	Construction and Mining Equipment	Concrete/Industrial Saws	4 Stroke	101.60%	101.04%	100.82%	100.82%	101.38%	67.24%	100.84%
2265002042	Construction and Mining Equipment	Cement & Mortar Mixers	4 Stroke	-83.33%	-82.45%	-83.39%	-83.39%	-83.53%	-86.05%	-83.41%
2265002045	Construction and Mining Equipment	Cranes	4 Stroke	-19.11%	-18.92%	-19.09%	-19.09%	-19.35%	-34.07%	-19.09%
2265002054	Construction and Mining Equipment	Crushing/Proc. Equipment	4 Stroke	-60.73%	-62.30%	-61.49%	-61.49%	-61.29%	-67.60%	-61.49%
2265002057	Construction and Mining Equipment	Rough Terrain Forklifts	4 Stroke	-9.52%	-9.33%	-9.54%	-9.54%	-9.59%	-24.49%	-9.53%
2265002060	Construction and Mining Equipment	Rubber Tire Loaders	4 Stroke	1947.59%	1948.73%	1948.90%	1948.90%	1947.87%	1599.97%	1948.86%
2265002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	4 Stroke	604.79%	572.88%	584.42%	584.42%	592.18%	475.29%	584.37%
2265002072	Construction and Mining Equipment	Skid Steer Loaders	4 Stroke	13.96%	13.03%	12.97%	12.97%	12.57%	-5.45%	12.92%
2265002078	Construction and Mining Equipment	Dumpers/Tenders	4 Stroke	-80.51%	-79.69%	-80.63%	-80.63%	-80.52%	-83.72%	-80.65%
2265002081	Construction and Mining Equipment	Other Construction Equipment	4 Stroke	19.64%	19.42%	19.38%	19.38%	19.57%	-0.46%	19.39%
2267002003	Construction and Mining Equipment	Pavers	LPG	20.03%	19.91%	19.90%	19.90%	20.00%	0.00%	19.90%
2267002015	Construction and Mining Equipment	Rollers	LPG	-5.72%	-6.21%	-6.27%	-6.27%	-5.84%	-21.97%	-6.26%
2267002021	Construction and Mining Equipment	Paving Equipment	LPG	20.19%	20.02%	20.00%	20.00%	20.15%	0.00%	20.00%
2267002024	Construction and Mining Equipment	Surfacing Equipment	LPG	244.31%	242.99%	242.83%	242.83%	243.98%	199.77%	242.85%
2267002030	Construction and Mining Equipment	Trenchers	LPG	14.44%	14.32%	14.30%	14.30%	14.41%	-4.67%	14.30%
2267002033	Construction and Mining Equipment	Bore/Drill Rigs	LPG	-37.15%	-37.17%	-37.17%	-37.17%	-37.15%	-47.72%	-37.17%
2267002039	Construction and Mining Equipment	Concrete/Industrial Saws	LPG	1231.94%	1230.38%	1230.19%	1230.19%	1231.55%	1001.67%	1230.20%
2267002045	Construction and Mining Equipment	Cranes	LPG	20.05%	20.01%	20.00%	20.00%	20.04%	0.00%	20.00%
2267002054	Construction and Mining Equipment	Crushing/Proc. Equipment	LPG	-74.00%	-74.05%	-74.05%	-74.05%	-74.01%	-78.36%	-74.05%
2267002057	Construction and Mining Equipment	Rough Terrain Forklifts	LPG	177.53%	177.23%	177.19%	177.19%	177.45%	131.23%	177.20%
2267002060	Construction and Mining Equipment	Rubber Tire Loaders	LPG	19.85%	19.91%	19.92%	19.92%	19.86%	0.00%	19.92%
2267002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	LPG	19.95%	19.99%	20.00%	20.00%	19.96%	0.00%	20.00%
2267002072	Construction and Mining Equipment	Skid Steer Loaders	LPG	-74.47%	-74.48%	-74.48%	-74.48%	-74.47%	-78.75%	-74.48%

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Percent Difference (Updated - Default/Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%
2270002003	Construction and Mining Equipment	Pavers	Diesel	-55.60%	-55.60%	-55.60%	-55.60%	-54.04%	-54.04%	-55.60%
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	1.88%	1.88%	1.88%	1.88%	2.22%	2.22%	1.88%
2270002015	Construction and Mining Equipment	Rollers	Diesel	-28.27%	-28.27%	-28.27%	-28.27%	-26.08%	-26.08%	-28.27%
2270002018	Construction and Mining Equipment	Scrapers	Diesel	70.30%	70.30%	70.30%	70.30%	73.11%	73.11%	70.30%
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	18.96%	18.96%	18.96%	18.96%	20.85%	20.85%	18.96%
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	184.48%	184.48%	184.48%	184.48%	186.50%	186.50%	184.48%
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	-48.84%	-48.84%	-48.84%	-48.84%	-48.96%	-48.96%	-48.84%
2270002030	Construction and Mining Equipment	Trenchers	Diesel	15.67%	15.67%	15.67%	15.67%	19.43%	19.43%	15.67%
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	67.49%	67.49%	67.49%	67.49%	63.75%	63.75%	67.49%
2270002036	Construction and Mining Equipment	Excavators	Diesel	66.32%	66.32%	66.32%	66.32%	71.35%	71.35%	66.32%
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	131.91%	131.91%	131.91%	131.91%	140.82%	140.82%	131.91%
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	-97.46%	-97.46%	-97.46%	-97.46%	-97.56%	-97.56%	-97.46%
2270002045	Construction and Mining Equipment	Cranes	Diesel	-14.77%	-14.77%	-14.77%	-14.77%	-14.97%	-14.97%	-14.77%
2270002048	Construction and Mining Equipment	Graders	Diesel	5.37%	5.37%	5.37%	5.37%	10.17%	10.17%	5.37%
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	207.33%	207.33%	207.33%	207.33%	205.28%	205.28%	207.33%
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	-39.79%	-39.79%	-39.79%	-39.79%	-38.79%	-38.79%	-39.79%
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	16.05%	16.05%	16.05%	16.05%	15.64%	15.64%	16.05%
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	-30.69%	-30.69%	-30.69%	-30.69%	-29.52%	-29.52%	-30.69%
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	24.79%	24.79%	24.79%	24.79%	28.42%	28.42%	24.79%
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	-53.86%	-53.86%	-53.86%	-53.86%	-52.68%	-52.68%	-53.86%
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	-4.55%	-4.55%	-4.55%	-4.55%	-4.62%	-4.62%	-4.55%
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	1064.05%	1064.05%	1064.05%	1064.05%	1049.47%	1049.47%	1064.05%
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	-5.70%	-5.70%	-5.70%	-5.70%	-9.66%	-9.66%	-5.70%
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Gasoline	88.64%	87.34%	87.30%	87.21%	71.88%	71.88%	88.66%
			LPG	163.25%	163.25%	163.25%	163.25%	163.25%	163.25%	163.25%
			CNG	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%	20.15%
			Diesel	-1.60%	-1.60%	-1.60%	-1.60%	5.42%	5.42%	-1.60%
				32.65%	31.66%	32.12%	31.54%	7.43%	7.43%	33.16%

Table C-7. Comparison of NONROAD Model 2002 Annual Emissions for the Midwest RPO Region

Percent Difference (Updated - Default/Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	TotalPopulation	TotalFuel
2267002081	Construction and Mining Equipment	Other Construction Equipment	LPG	20.21%	19.97%	19.94%	19.94%	20.15%	0.00%	19.95%
2268002081	Construction and Mining Equipment	Other Construction Equipment	CNG	20.21%	19.97%	19.91%	19.91%	20.15%	0.00%	19.95%
2270002003	Construction and Mining Equipment	Pavers	Diesel	-56.55%	-53.06%	-50.94%	-50.94%	-54.04%	-59.12%	-50.95%
2270002006	Construction and Mining Equipment	Tampers/Rammers	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270002009	Construction and Mining Equipment	Plate Compactors	Diesel	3.54%	2.49%	5.01%	5.01%	2.22%	-12.47%	4.99%
2270002015	Construction and Mining Equipment	Rollers	Diesel	-28.45%	-24.03%	-20.61%	-20.61%	-26.08%	-33.86%	-20.64%
2270002018	Construction and Mining Equipment	Scrapers	Diesel	74.43%	84.91%	93.73%	93.73%	73.11%	61.28%	93.68%
2270002021	Construction and Mining Equipment	Paving Equipment	Diesel	16.87%	23.35%	29.01%	29.01%	20.85%	8.20%	28.98%
2270002024	Construction and Mining Equipment	Surfacing Equipment	Diesel	188.06%	201.96%	214.65%	214.66%	186.50%	154.17%	214.51%
2270002027	Construction and Mining Equipment	Signal Boards/Light Plants	Diesel	-48.51%	-47.63%	-46.21%	-46.21%	-48.96%	-54.93%	-46.23%
2270002030	Construction and Mining Equipment	Trenchers	Diesel	17.84%	23.54%	28.14%	28.15%	19.43%	6.40%	28.09%
2270002033	Construction and Mining Equipment	Bore/Drill Rigs	Diesel	65.22%	70.81%	78.51%	78.51%	63.75%	48.24%	78.45%
2270002036	Construction and Mining Equipment	Excavators	Diesel	61.39%	74.56%	80.50%	80.50%	71.35%	50.44%	80.46%
2270002039	Construction and Mining Equipment	Concrete/Industrial Saws	Diesel	137.15%	145.34%	154.67%	154.67%	140.82%	113.13%	154.55%
2270002042	Construction and Mining Equipment	Cement & Mortar Mixers	Diesel	-97.57%	-97.76%	-97.61%	-97.61%	-97.56%	-97.18%	-97.60%
2270002045	Construction and Mining Equipment	Cranes	Diesel	-14.61%	-10.07%	-5.44%	-5.44%	-14.97%	-21.32%	-5.47%
2270002048	Construction and Mining Equipment	Graders	Diesel	-2.52%	12.49%	18.17%	18.17%	10.17%	-1.66%	18.14%
2270002051	Construction and Mining Equipment	Off-highway Trucks	Diesel	20.15%	20.15%	20.15%	20.15%	20.15%	0.00%	0.00%
2270002054	Construction and Mining Equipment	Crushing/Proc. Equipment	Diesel	205.80%	224.50%	242.06%	242.07%	205.28%	185.75%	241.95%
2270002057	Construction and Mining Equipment	Rough Terrain Forklifts	Diesel	-39.75%	-36.69%	-34.79%	-34.79%	-38.79%	-45.64%	-34.81%
2270002060	Construction and Mining Equipment	Rubber Tire Loaders	Diesel	15.46%	21.18%	27.07%	27.08%	15.64%	5.83%	27.04%
2270002066	Construction and Mining Equipment	Tractors/Loaders/Backhoes	Diesel	-29.82%	-30.96%	-26.94%	-26.94%	-29.52%	-39.14%	-26.98%
2270002069	Construction and Mining Equipment	Crawler Tractor/Dozers	Diesel	25.43%	32.30%	37.64%	37.64%	28.42%	14.64%	37.60%
2270002072	Construction and Mining Equipment	Skid Steer Loaders	Diesel	-52.88%	-52.72%	-50.93%	-50.93%	-52.68%	-59.15%	-50.97%
2270002075	Construction and Mining Equipment	Off-Highway Tractors	Diesel	-4.13%	3.38%	7.29%	7.29%	-4.62%	-10.63%	7.25%
2270002078	Construction and Mining Equipment	Dumpers/Tenders	Diesel	1081.55%	1053.26%	1077.11%	1077.12%	1049.47%	876.30%	1076.96%
2270002081	Construction and Mining Equipment	Other Construction Equipment	Diesel	-6.73%	0.74%	7.26%	7.26%	-9.66%	-10.63%	7.22%
2270009010	Construction and Mining Equipment	Other Underground Mining Equipment	Diesel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Gasoline	142.65%	216.57%	147.94%	148.15%	71.88%	-16.54%	141.80%
			LPG	163.76%	161.72%	161.47%	161.47%	163.25%	63.27%	161.49%
			CNG	20.21%	19.97%	19.91%	19.91%	20.15%	0.00%	19.95%
			Diesel	2.89%	19.37%	24.37%	24.37%	5.42%	-22.37%	21.76%
				94.52%	21.21%	27.24%	24.75%	7.43%	-19.82%	25.43%

APPENDIX D. DIESEL FUEL CONSUMPTION ESTIMATES BY CROP AND STATE

Table D-1. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN ILLINOIS

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	IL	17	11,200,000	3.7

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IL	Apr 7			0	0					0
IL	Apr 14	1		1	0	112,000				130,607
IL	Apr 21	18		17	0	1,904,000				2,220,313
IL	Apr 28	25		7	0	784,000				914,246
IL	May 5	30		5	0	560,000				653,033
IL	May 12	51		21	0	2,352,000				2,742,739
IL	May 19	51		0	0	0				0
IL	May 26	74		23	0	2,576,000				3,003,953
IL	Jun 2	91		17	0	1,904,000	933,333			2,598,717
IL	Jun 9	99		8	0	896,000	933,333			1,423,258
IL	Jun 16	100		1	0	112,000	933,333			509,011
IL	Jun 23			0	0		933,333			378,405
IL	Jun 30			0	0		933,333			378,405
IL	Jul 7			0	0		933,333			378,405
IL	Jul 14			0	0		933,333			378,405
IL	Jul 21			0	0		933,333			378,405
IL	Jul 28			0	0		933,333			378,405
IL	Aug 4			0	0		933,333			378,405
IL	Aug 11			0	0		933,333			378,405
IL	Aug 18			0	0		933,333			378,405
IL	Aug 25			0	0					0
IL	Sep 1			0	0					0
IL	Sep 8			0	0					0
IL	Sep 15		4	0	4			448,000		611,171
IL	Sep 22		9	0	5			560,000		763,964
IL	Sep 29		20	0	11			1,232,000		1,680,721
IL	Oct 6		35	0	15			1,680,000		2,291,892
IL	Oct 13		50	0	15			1,680,000		2,291,892
IL	Oct 20		70	0	20			2,240,000		3,055,856
IL	Oct 27		84	0	14			1,568,000		2,139,099
IL	Nov 3		91	0	7			784,000		1,069,550
IL	Nov 10		95	0	4			448,000		611,171
IL	Nov 17		98	0	3			336,000	2,800,000	2,598,179
IL	Nov 24		99	0	1			112,000	2,800,000	2,292,593
IL	Dec 1		100	0	1			112,000	2,800,000	2,292,593
IL	Dec 8			0	0				2,800,000	2,139,800

Table D-2. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN INDIANA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	IN	18	5,400,000	4.6

State	**Week Ending**	**Total Planted (%)**	**Total Harvested (%)**	**Weekly Progress Planted**	**Weekly Progress Harvested**	**Planted Acres**	**Cultivated Acres**	**Harvested Acres**	**Post Harvesting Acres**	**Diesel Fuel (gal)**
IN	Apr 7			0	0					0
IN	Apr 14			0	0					0
IN	Apr 21	2		2	0	108,000				156,577
IN	Apr 28	4		2	0	108,000				156,577
IN	May 5	10		6	0	324,000				469,730
IN	May 12	11		1	0	54,000				78,288
IN	May 19	13		2	0	108,000				156,577
IN	May 26	43		30	0	1,620,000				2,348,650
IN	Jun 2	75		32	0	1,728,000	450,000			2,732,050
IN	Jun 9	92		17	0	918,000	450,000			1,557,725
IN	Jun 16	**100**		8	0	432,000	450,000			853,130
IN	Jun 23			0	0		450,000			226,824
IN	Jun 30			0	0		450,000			226,824
IN	Jul 7			0	0		450,000			226,824
IN	Jul 14			0	0		450,000			226,824
IN	Jul 21			0	0		450,000			226,824
IN	Jul 28			0	0		450,000			226,824
IN	Aug 4			0	0		450,000			226,824
IN	Aug 11			0	0		450,000			226,824
IN	Aug 18			0	0		450,000			226,824
IN	Aug 25			0	0					0
IN	Sep 1			0	0					0
IN	Sep 8			0	0					0
IN	Sep 15		4	0	4			216,000		366,349
IN	Sep 22		8	0	4			216,000		366,349
IN	Sep 29		14	0	6			324,000		549,523
IN	Oct 6		21	0	7			378,000		641,110
IN	Oct 13		31	0	10			540,000		915,872
IN	Oct 20		44	0	13			702,000		1,190,634
IN	Oct 27		66	0	22			1,188,000		2,014,918
IN	Nov 3		78	0	12			648,000		1,099,046
IN	Nov 10		90	0	12			648,000		1,099,046
IN	Nov 17		96	0	6			324,000	1,350,000	1,832,164
IN	Nov 24		98	0	2			108,000	1,350,000	1,465,815
IN	Dec 1		**100**	0	2			108,000	1,350,000	1,465,815
IN	Dec 8			0	0				1,350,000	1,282,641

Table D-3. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN IOWA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	IA	19	12,300,000	4.6

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Apr 7			0	0					0
IA	Apr 14	1		1	0	123,000				178,323
IA	Apr 21	12		11	0	1,353,000				1,961,558
IA	Apr 28	33		21	0	2,583,000				3,744,792
IA	May 5	53		20	0	2,460,000				3,566,469
IA	May 12	86		33	0	4,059,000				5,884,674
IA	May 19	94		8	0	984,000	878,571			1,869,434
IA	May 26	98		4	0	492,000	878,571			1,156,140
IA	Jun 2	100		2	0	246,000	878,571			799,493
IA	Jun 9			0	0		878,571			442,846
IA	Jun 16			0	0		878,571			442,846
IA	Jun 23			0	0		878,571			442,846
IA	Jun 30			0	0		878,571			442,846
IA	Jul 7			0	0		878,571			442,846
IA	Jul 14			0	0		878,571			442,846
IA	Jul 21			0	0		878,571			442,846
IA	Jul 28			0	0		878,571			442,846
IA	Aug 4			0	0		878,571			442,846
IA	Aug 11			0	0		878,571			442,846
IA	Aug 18			0	0		878,571			442,846
IA	Aug 25			0	0					0
IA	Sep 1			0	0					0
IA	Sep 8			0	0					0
IA	Sep 15		4	0	4			492,000		834,461
IA	Sep 22		6	0	2			246,000		417,231
IA	Sep 29		10	0	4			492,000		834,461
IA	Oct 6		13	0	3			369,000		625,846
IA	Oct 13		21	0	8			984,000		1,668,922
IA	Oct 20		41	0	20			2,460,000		4,172,306
IA	Oct 27		61	0	20			2,460,000		4,172,306
IA	Nov 3		76	0	15			1,845,000		3,129,229
IA	Nov 10		89	0	13			1,599,000		2,711,999
IA	Nov 17		96	0	7			861,000	3,075,000	4,381,878
IA	Nov 24		99	0	3			369,000	3,075,000	3,547,417
IA	Dec 1		100	0	1			123,000	3,075,000	3,130,186
IA	Dec 8			0	0				3,075,000	2,921,571

Table D-4. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MICHIGAN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	MI	26	2,250,000	7.2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MI	Apr 7			0	0					0
MI	Apr 14			0	0					0
MI	Apr 21	1		1	0	22,500				51,058
MI	Apr 28	6		5	0	112,500				255,288
MI	May 5	17		11	0	247,500				561,634
MI	May 12	41		24	0	540,000				1,225,383
MI	May 19	51		10	0	225,000				510,576
MI	May 26	72		21	0	472,500				1,072,210
MI	Jun 2	88		16	0	360,000	187,500			964,850
MI	Jun 9	96		8	0	180,000	187,500			556,389
MI	Jun 16	100		4	0	90,000	187,500			352,159
MI	Jun 23			0	0		187,500			147,928
MI	Jun 30			0	0		187,500			147,928
MI	Jul 7			0	0		187,500			147,928
MI	Jul 14			0	0		187,500			147,928
MI	Jul 21			0	0		187,500			147,928
MI	Jul 28			0	0		187,500			147,928
MI	Aug 4			0	0		187,500			147,928
MI	Aug 11			0	0		187,500			147,928
MI	Aug 18			0	0		187,500			147,928
MI	Aug 25			0	0					0
MI	Sep 1			0	0					0
MI	Sep 8			0	0					0
MI	Sep 15		2	0	2			45,000		119,462
MI	Sep 22		4	0	2			45,000		119,462
MI	Sep 29		7	0	3			67,500		179,192
MI	Oct 6		11	0	4			90,000		238,923
MI	Oct 13		27	0	16			360,000		955,692
MI	Oct 20		34	0	7			157,500		418,115
MI	Oct 27		55	0	21			472,500		1,254,346
MI	Nov 3		74	0	19			427,500		1,134,885
MI	Nov 10		89	0	15			337,500		895,962
MI	Nov 17		93	0	4			90,000	562,500	1,075,428
MI	Nov 24		96	0	3			67,500	562,500	1,015,697
MI	Dec 1		100	0	4			90,000	562,500	1,075,428
MI	Dec 8			0	0				562,500	836,505

Table D-5. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	MN	27	7,200,000	6.2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Apr 7			0	0					0
MN	Apr 14			0	0					0
MN	Apr 21	3		3	0	216,000				422,076
MN	Apr 28	22		19	0	1,368,000				2,673,150
MN	May 5	56		34	0	2,448,000				4,783,531
MN	May 12	78		22	0	1,584,000				3,095,226
MN	May 19	90		12	0	864,000				1,688,305
MN	May 26	97		7	0	504,000				984,845
MN	Jun 2	98		1	0	72,000	553,846			516,961
MN	Jun 9	99		1	0	72,000	553,846			516,961
MN	Jun 16	100		1	0	72,000	553,846			516,961
MN	Jun 23			0	0		553,846			376,269
MN	Jun 30			0	0		553,846			376,269
MN	Jul 7			0	0		553,846			376,269
MN	Jul 14			0	0		553,846			376,269
MN	Jul 21			0	0		553,846			376,269
MN	Jul 28			0	0		553,846			376,269
MN	Aug 4			0	0		553,846			376,269
MN	Aug 11			0	0		553,846			376,269
MN	Aug 18			0	0		553,846			376,269
MN	Aug 25			0	0		553,846			376,269
MN	Sep 1			0	0					0
MN	Sep 8			0	0					0
MN	Sep 15			0	0					0
MN	Sep 22		1	0	1			72,000		164,591
MN	Sep 29		4	0	3			216,000		493,774
MN	Oct 6		9	0	5			360,000		822,957
MN	Oct 13		17	0	8			576,000		1,316,732
MN	Oct 20		33	0	16			1,152,000		2,633,464
MN	Oct 27		52	0	19			1,368,000		3,127,238
MN	Nov 3		71	0	19			1,368,000		3,127,238
MN	Nov 10		86	0	15			1,080,000		2,468,872
MN	Nov 17		93	0	7			504,000	1,800,000	3,457,176
MN	Nov 24		97	0	4			288,000	1,800,000	2,963,402
MN	Dec 1		100	0	3			216,000	1,800,000	2,798,810
MN	Dec 8			0	0				1,800,000	2,305,036

Table D-6. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MISSOURI

	Planting	Cultivating	Harvesting	Post Harvesting		State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65		MO	29	2,800,000	6.2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MO	Apr 7	10		10	0	280,000				547,136
MO	Apr 14	26		16	0	448,000				875,417
MO	Apr 21	52		26	0	728,000				1,422,553
MO	Apr 28	62		10	0	280,000				547,136
MO	May 5	74		12	0	336,000				656,563
MO	May 12	77		3	0	84,000				164,141
MO	May 19	78		1	0	28,000				54,714
MO	May 26	83		5	0	140,000				273,568
MO	Jun 2	91		8	0	224,000	233,333			596,230
MO	Jun 9	97		6	0	168,000	233,333			486,802
MO	Jun 16	100		3	0	84,000	233,333			322,662
MO	Jun 23			0	0		233,333			158,521
MO	Jun 30			0	0		233,333			158,521
MO	Jul 7			0	0		233,333			158,521
MO	Jul 14			0	0		233,333			158,521
MO	Jul 21			0	0		233,333			158,521
MO	Jul 28			0	0		233,333			158,521
MO	Aug 4			0	0		233,333			158,521
MO	Aug 11			0	0		233,333			158,521
MO	Aug 18			0	0		233,333			158,521
MO	Aug 25			0	0					0
MO	Sep 1			0	0					0
MO	Sep 8			0	0					0
MO	Sep 15		43	0	43			1,204,000		2,752,335
MO	Sep 22		52	0	9			252,000		576,070
MO	Sep 29		68	0	16			448,000		1,024,125
MO	Oct 6		81	0	13			364,000		832,101
MO	Oct 13		85	0	4			112,000		256,031
MO	Oct 20		91	0	6			168,000		384,047
MO	Oct 27		94	0	3			84,000		192,023
MO	Nov 3		95	0	1			28,000	700,000	960,411
MO	Nov 10		97	0	2			56,000	700,000	1,024,418
MO	Nov 17		100	0	3			84,000	700,000	1,088,426
MO	Nov 24			0	0				700,000	896,403
MO	Dec 1			0	0					0

Table D-7. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN OHIO

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	OH	39	3,200,000	4.3

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
OH	Apr 7	1		1	0	32,000				43,367
OH	Apr 14	2		1	0	32,000				43,367
OH	Apr 21	2		0	0	0				0
OH	Apr 28	5		3	0	96,000				130,102
OH	May 5	11		6	0	192,000				260,205
OH	May 12	17		6	0	192,000				260,205
OH	May 19	22		5	0	160,000				216,837
OH	May 26	45		23	0	736,000				997,451
OH	Jun 2	67		22	0	704,000	266,667			1,079,732
OH	Jun 9	89		22	0	704,000	266,667			1,079,732
OH	Jun 16	100		11	0	352,000	266,667			602,690
OH	Jun 23			0	0		266,667			125,648
OH	Jun 30			0	0		266,667			125,648
OH	Jul 7			0	0		266,667			125,648
OH	Jul 14			0	0		266,667			125,648
OH	Jul 21			0	0		266,667			125,648
OH	Jul 28			0	0		266,667			125,648
OH	Aug 4			0	0		266,667			125,648
OH	Aug 11			0	0		266,667			125,648
OH	Aug 18			0	0		266,667			125,648
OH	Aug 25			0	0					0
OH	Sep 1			0	0					0
OH	Sep 8			0	0					0
OH	Sep 15		1	0	1			32,000		50,734
OH	Sep 22		4	0	3			96,000		152,203
OH	Sep 29		7	0	3			96,000		152,203
OH	Oct 6		15	0	8			256,000		405,874
OH	Oct 13		22	0	7			224,000		355,140
OH	Oct 20		37	0	15			480,000		761,014
OH	Oct 27		57	0	20			640,000		1,014,686
OH	Nov 3		75	0	18			576,000		913,217
OH	Nov 10		85	0	10			320,000		507,343
OH	Nov 17		91	0	6			192,000	800,000	1,014,919
OH	Nov 24		96	0	5			160,000	800,000	964,184
OH	Dec 1		100	0	4			128,000	800,000	913,450
OH	Dec 8			0	0				800,000	710,513

Table D-8. CALCULATION OF WEEKLY CORN PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Corn For Grain Planted	Gal of Diesel per Acre
% of Total	31.52	10.96	36.87	20.65	WI	55	3,650,000	7.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Apr 7			0	0					0
WI	Apr 14			0	0					0
WI	Apr 21			0	0					0
WI	Apr 28	8		8	0	292,000				681,020
WI	May 5	19		11	0	401,500				936,403
WI	May 12	35		16	0	584,000				1,362,041
WI	May 19	56		21	0	766,500				1,787,678
WI	May 26	79		23	0	839,500				1,957,933
WI	Jun 2	92		13	0	474,500	260,714			1,318,063
WI	Jun 9	94		2	0	73,000	260,714			381,660
WI	Jun 16	100		6	0	219,000	260,714			722,170
WI	Jun 23			0	0		260,714			211,405
WI	Jun 30			0	0		260,714			211,405
WI	Jul 7			0	0		260,714			211,405
WI	Jul 14			0	0		260,714			211,405
WI	Jul 21			0	0		260,714			211,405
WI	Jul 28			0	0		260,714			211,405
WI	Aug 4			0	0		260,714			211,405
WI	Aug 11			0	0		260,714			211,405
WI	Aug 18			0	0		260,714			211,405
WI	Aug 25			0	0		260,714			211,405
WI	Sep 1			0	0		260,714			211,405
WI	Sep 8			0	0					0
WI	Sep 15			0	0					0
WI	Sep 22			0	0					0
WI	Sep 29		2	0	2			73,000		199,176
WI	Oct 6		8	0	6			219,000		597,529
WI	Oct 13		14	0	6			219,000		597,529
WI	Oct 20		22	0	8			292,000		796,705
WI	Oct 27		36	0	14			511,000		1,394,234
WI	Nov 3		49	0	13			474,500		1,294,646
WI	Nov 10		58	0	9			328,500		896,294
WI	Nov 17		78	0	20			730,000	912,500	3,386,455
WI	Nov 24		88	0	10			365,000	912,500	2,390,573
WI	Dec 1		100	0	12			438,000	912,500	2,589,749
WI	Dec 8			0	0				912,500	1,394,691

Table D-9. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN ILLINOIS

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	IL	17	800,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Mar 24									0
IA	Mar 31									0
IA	Apr 7									0
IA	Apr 14									0
IA	Apr 21									0
IA	Apr 28									0
IA	May 5									0
IA	May 12									0
IA	May 19		25		25			400,000		224,175
IA	May 26		50		25			400,000		224,175
IA	Jun 2		75		25			400,000		224,175
IA	Jun 9		100		25			400,000		224,175
IA	Jun 16							0		0
IA	Jun 23		5		5			80,000		44,835
IA	Jun 30		25		20			320,000		179,340
IA	Jul 7		45		20			320,000		179,340
IA	Jul 14		65		20			320,000		179,340
IA	Jul 21		85		20			320,000		179,340
IA	Jul 28		100		15			240,000		134,505
IA	Aug 4		5		5			80,000		44,835
IA	Aug 11		15		10			160,000		89,670
IA	Aug 18		25		10			160,000		89,670
IA	Aug 25		35		10			160,000		89,670
IA	Sep 1		45		10			160,000		89,670
IA	Sep 8		55		10			160,000		89,670
IA	Sep 15		65		10			160,000		89,670
IA	Sep 22		75		10			160,000		89,670
IA	Sep 29		85		10			160,000		89,670
IA	Oct 6		95		10			160,000		89,670
IA	Oct 13		100		5			80,000		44,835
IA	Oct 20									0
IA	Oct 27									0
IA	Nov 3									0

Table D-10. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN INDIANA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	IN	18	600,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IN	Mar 24									0
IN	Mar 31									0
IN	Apr 7									0
IN	Apr 14							0		0
IN	Apr 21							0		0
IN	Apr 28							0		0
IN	May 5							0		0
IN	May 12							0		0
IN	May 19		25		25			150,000		84,066
IN	May 26		50		25			150,000		84,066
IN	Jun 2		75		25			150,000		84,066
IN	Jun 9		100		25			150,000		84,066
IN	Jun 16							0		0
IN	Jun 23		5		5			30,000		16,813
IN	Jun 30		25		20			120,000		67,252
IN	Jul 7		45		20			120,000		67,252
IN	Jul 14		65		20			120,000		67,252
IN	Jul 21		85		20			120,000		67,252
IN	Jul 28		100		15			90,000		50,439
IN	Aug 4		5		5			30,000		16,813
IN	Aug 11		15		10			60,000		33,626
IN	Aug 18		25		10			60,000		33,626
IN	Aug 25		35		10			60,000		33,626
IN	Sep 1		45		10			60,000		33,626
IN	Sep 8		55		10			60,000		33,626
IN	Sep 15		65		10			60,000		33,626
IN	Sep 22		75		10			60,000		33,626
IN	Sep 29		85		10			60,000		33,626
IN	Oct 6		95		10			60,000		33,626
IN	Oct 13		100		5			30,000		16,813
IN	Oct 20									0
IN	Oct 27									0
IN	Nov 3									0

Table D-11. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN IOWA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	IA	19	1,600,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Mar 24									0
IA	Mar 31									0
IA	Apr 7									0
IA	Apr 14									0
IA	Apr 21									0
IA	Apr 28									0
IA	May 5									0
IA	May 12									0
IA	May 19		25		25			400,000		224,175
IA	May 26		50		25			400,000		224,175
IA	Jun 2		75		25			400,000		224,175
IA	Jun 9		100		25			400,000		224,175
IA	Jun 16							0		0
IA	Jun 23		5		5			80,000		44,835
IA	Jun 30		25		20			320,000		179,340
IA	Jul 7		45		20			320,000		179,340
IA	Jul 14		65		20			320,000		179,340
IA	Jul 21		85		20			320,000		179,340
IA	Jul 28		100		15			240,000		134,505
IA	Aug 4		5		5			80,000		44,835
IA	Aug 11		15		10			160,000		89,670
IA	Aug 18		25		10			160,000		89,670
IA	Aug 25		35		10			160,000		89,670
IA	Sep 1		45		10			160,000		89,670
IA	Sep 8		55		10			160,000		89,670
IA	Sep 15		65		10			160,000		89,670
IA	Sep 22		75		10			160,000		89,670
IA	Sep 29		85		10			160,000		89,670
IA	Oct 6		95		10			160,000		89,670
IA	Oct 13		100		5			80,000		44,835
IA	Oct 20									0
IA	Oct 27									0
IA	Nov 3									0

Table D-12. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MICHIGAN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	MI	26	1,150,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MI	Mar 24									0
MI	Mar 31									0
MI	Apr 7									0
MI	Apr 14									0
MI	Apr 21							0		0
MI	Apr 28							0		0
MI	May 5							0		0
MI	May 12							0		0
MI	May 19							0		0
MI	May 26		25		25			287,500		161,126
MI	Jun 2		50		25			287,500		161,126
MI	Jun 9		75		25			287,500		161,126
MI	Jun 16		100		25			287,500		161,126
MI	Jun 23							0		0
MI	Jun 30		5		5			57,500		32,225
MI	Jul 7		25		20			230,000		128,900
MI	Jul 14		45		20			230,000		128,900
MI	Jul 21		65		20			230,000		128,900
MI	Jul 28		85		20			230,000		128,900
MI	Aug 4		100		15			172,500		96,675
MI	Aug 11		5		5			57,500		32,225
MI	Aug 18		15		10			115,000		64,450
MI	Aug 25		25		10			115,000		64,450
MI	Sep 1		35		10			115,000		64,450
MI	Sep 8		45		10			115,000		64,450
MI	Sep 15		55		10			115,000		64,450
MI	Sep 22		65		10			115,000		64,450
MI	Sep 29		75		10			115,000		64,450
MI	Oct 6		85		10			115,000		64,450
MI	Oct 13		95		10			115,000		64,450
MI	Oct 20		100		5			57,500		32,225
MI	Oct 27									0
MI	Nov 3									0

Table D-13. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	MN	27	2,300,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Mar 24									0
MN	Mar 31									0
MN	Apr 7									0
MN	Apr 14									0
MN	Apr 21							0		0
MN	Apr 28							0		0
MN	May 5							0		0
MN	May 12							0		0
MN	May 19							0		0
MN	May 26		25		25			575,000		322,251
MN	Jun 2		50		25			575,000		322,251
MN	Jun 9		75		25			575,000		322,251
MN	Jun 16		100		25			575,000		322,251
MN	Jun 23							0		0
MN	Jun 30		5		5			115,000		64,450
MN	Jul 7		25		20			460,000		257,801
MN	Jul 14		45		20			460,000		257,801
MN	Jul 21		65		20			460,000		257,801
MN	Jul 28		85		20			460,000		257,801
MN	Aug 4		100		15			345,000		193,351
MN	Aug 11		5		5			115,000		64,450
MN	Aug 18		15		10			230,000		128,900
MN	Aug 25		25		10			230,000		128,900
MN	Sep 1		35		10			230,000		128,900
MN	Sep 8		45		10			230,000		128,900
MN	Sep 15		55		10			230,000		128,900
MN	Sep 22		65		10			230,000		128,900
MN	Sep 29		75		10			230,000		128,900
MN	Oct 6		85		10			230,000		128,900
MN	Oct 13		95		10			230,000		128,900
MN	Oct 20		100		5			115,000		64,450
MN	Oct 27									0
MN	Nov 3									0

Table D-14. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MISSOURI

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	MO	29	4,260,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MO	Mar 24							0		0
MO	Mar 31							0		0
MO	Apr 7							0		0
MO	Apr 14							0		0
MO	Apr 21							0		0
MO	Apr 28		25		25			1,065,000		596,865
MO	May 5		50		25			1,065,000		596,865
MO	May 12		75		25			1,065,000		596,865
MO	May 19		100		25			1,065,000		596,865
MO	May 26							0		0
MO	Jun 2		5		5			213,000		119,373
MO	Jun 9		25		20			852,000		477,492
MO	Jun 16		45		20			852,000		477,492
MO	Jun 23		65		20			852,000		477,492
MO	Jun 30		85		20			852,000		477,492
MO	Jul 7		100		15			639,000		358,119
MO	Jul 14		5		5			213,000		119,373
MO	Jul 21		15		10			426,000		238,746
MO	Jul 28		25		10			426,000		238,746
MO	Aug 4		35		10			426,000		238,746
MO	Aug 11		45		10			426,000		238,746
MO	Aug 18		55		10			426,000		238,746
MO	Aug 25		65		10			426,000		238,746
MO	Sep 1		75		10			426,000		238,746
MO	Sep 8		85		10			426,000		238,746
MO	Sep 15		95		10			426,000		238,746
MO	Sep 22		100		5			213,000		119,373
MO	Sep 29									0
MO	Oct 6									0
MO	Oct 13									0
MO	Oct 20									0
MO	Oct 27									0
MO	Nov 3									0

Table D-15. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN OHIO

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	OH	39	1,490,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
OH	Mar 24									0
OH	Mar 31									0
OH	Apr 7									0
OH	Apr 14							0		0
OH	Apr 21							0		0
OH	Apr 28							0		0
OH	May 5							0		0
OH	May 12							0		0
OH	May 19		25		25			372,500		208,763
OH	May 26		50		25			372,500		208,763
OH	Jun 2		75		25			372,500		208,763
OH	Jun 9		100		25			372,500		208,763
OH	Jun 16							0		0
OH	Jun 23		5		5			74,500		41,753
OH	Jun 30		25		20			298,000		167,010
OH	Jul 7		45		20			298,000		167,010
OH	Jul 14		65		20			298,000		167,010
OH	Jul 21		85		20			298,000		167,010
OH	Jul 28		100		15			223,500		125,258
OH	Aug 4		5		5			74,500		41,753
OH	Aug 11		15		10			149,000		83,505
OH	Aug 18		25		10			149,000		83,505
OH	Aug 25		35		10			149,000		83,505
OH	Sep 1		45		10			149,000		83,505
OH	Sep 8		55		10			149,000		83,505
OH	Sep 15		65		10			149,000		83,505
OH	Sep 22		75		10			149,000		83,505
OH	Sep 29		85		10			149,000		83,505
OH	Oct 6		95		10			149,000		83,505
OH	Oct 13		100		5			74,500		41,753
OH	Oct 20									0
OH	Oct 27									0
OH	Nov 3									0

Table D-16. CALCULATION OF WEEKLY HAY PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Hay Harvested	Gal of Diesel per Acre
% of Total	0.00	0.00	100.00	0.00	WI	55	2,050,000	1.52

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Mar 24									0
WI	Mar 31									0
WI	Apr 7									0
WI	Apr 14									0
WI	Apr 21							0		0
WI	Apr 28							0		0
WI	May 5							0		0
WI	May 12							0		0
WI	May 19							0		0
WI	May 26		25		25			512,500		287,224
WI	Jun 2		50		25			512,500		287,224
WI	Jun 9		75		25			512,500		287,224
WI	Jun 16		100		25			512,500		287,224
WI	Jun 23							0		0
WI	Jun 30		5		5			102,500		57,445
WI	Jul 7		25		20			410,000		229,779
WI	Jul 14		45		20			410,000		229,779
WI	Jul 21		65		20			410,000		229,779
WI	Jul 28		85		20			410,000		229,779
WI	Aug 4		100		15			307,500		172,334
WI	Aug 11		5		5			102,500		57,445
WI	Aug 18		15		10			205,000		114,890
WI	Aug 25		25		10			205,000		114,890
WI	Sep 1		35		10			205,000		114,890
WI	Sep 8		45		10			205,000		114,890
WI	Sep 15		55		10			205,000		114,890
WI	Sep 22		65		10			205,000		114,890
WI	Sep 29		75		10			205,000		114,890
WI	Oct 6		85		10			205,000		114,890
WI	Oct 13		95		10			205,000		114,890
WI	Oct 20		100		5			102,500		57,445
WI	Oct 27									0
WI	Nov 3									0

Table D-17. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN ILLINOIS

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	IL	17	65,000	2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IL	Mar 31	12		12	0	7,800				4,306
IL	Apr 7	34		22	0	14,300				7,895
IL	Apr 14	61		27	0	17,550				9,689
IL	Apr 21	93		32	0	20,800				11,484
IL	Apr 28	97		4	0	2,600				1,435
IL	May 5	99		2	0	1,300				718
IL	May 12	100		1	0	650				359
IL	May 19									0
IL	May 26									0
IL	Jun 2									0
IL	Jun 9			0	0					0
IL	Jun 16			0	0					0
IL	Jun 23			0	0					0
IL	Jun 30			0	0					0
IL	Jul 7			0	0					0
IL	Jul 14		19	0	19			12,350		11,451
IL	Jul 21		55	0	36			23,400		21,697
IL	Jul 28		84	0	29			18,850	16,250	25,939
IL	Aug 4		98	0	14			9,100	16,250	16,899
IL	Aug 11		100	0	2			1,300	16,250	9,666
IL	Aug 18								16,250	8,461
IL	Aug 25									0
IL	Sep 1									0
IL	Sep 8									0

Table D-18. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN INDIANA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	IN	18	20,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IN	Mar 31	12		12	0	2,400				2,915
IN	Apr 7	34		22	0	4,400				5,344
IN	Apr 14	61		27	0	5,400				6,559
IN	Apr 21	93		32	0	6,400				7,774
IN	Apr 28	97		4	0	800				972
IN	May 5	99		2	0	400				486
IN	May 12	100		1	0	200				243
IN	May 19									0
IN	May 26									0
IN	Jun 2									0
IN	Jun 9			0	0					0
IN	Jun 16			0	0					0
IN	Jun 23			0	0					0
IN	Jun 30			0	0					0
IN	Jul 7			0	0					0
IN	Jul 14		19	0	19			3,800		7,752
IN	Jul 21		55	0	36			7,200		14,687
IN	Jul 28		84	0	29			5,800	5,000	17,559
IN	Aug 4		98	0	14			2,800	5,000	11,439
IN	Aug 11		100	0	2			400	5,000	6,543
IN	Aug 18								5,000	5,727
IN	Aug 25									0
IN	Sep 1									0
IN	Sep 8									0

Table D-19. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN IOWA

	Planting	Cultivating	Harvesting	Post Harvesting		State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03		IA	19	290,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Mar 31	12		12	0	34,800				42,269
IA	Apr 7	34		22	0	63,800				77,493
IA	Apr 14	61		27	0	78,300				95,105
IA	Apr 21	93		32	0	92,800				112,717
IA	Apr 28	97		4	0	11,600				14,090
IA	May 5	99		2	0	5,800				7,045
IA	May 12	100		1	0	2,900				3,522
IA	May 19									0
IA	May 26									0
IA	Jun 2									0
IA	Jun 9			0	0					0
IA	Jun 16			0	0					0
IA	Jun 23			0	0					0
IA	Jun 30			0	0					0
IA	Jul 7			0	0					0
IA	Jul 14		19	0	19			55,100		112,398
IA	Jul 21		55	0	36			104,400		212,965
IA	Jul 28		84	0	29			84,100	72,500	254,603
IA	Aug 4		98	0	14			40,600	72,500	165,867
IA	Aug 11		100	0	2			5,800	72,500	94,879
IA	Aug 18								72,500	83,047
IA	Aug 25									0
IA	Sep 1									0
IA	Sep 8									0

Table D-20. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MICHIGAN

	Planting	Cultivating	Harvesting	Post Harvesting		State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03		MI	26	80,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
M	Mar 31			0	0					0
M	Apr 7			0	0					0
M	Apr 14	2		2	0	1,600				1,943
M	Apr 21	20		18	0	14,400				17,491
M	Apr 28	34		14	0	11,200				13,604
M	May 5	64		30	0	24,000				29,151
M	May 12	76		12	0	9,600				11,660
M	May 19	85		9	0	7,200				8,745
M	May 26	95		10	0	8,000				9,717
M	Jun 2	99		4	0	3,200				3,887
M	Jun 9	100		1	0	800				972
M	Jun 16			0	0					0
M	Jun 23			0	0					0
M	Jun 30			0	0					0
M	Jul 7			0	0					0
M	Jul 14			0	0					0
M	Jul 21		6	0	6			4,800		9,792
M	Jul 28		22	0	16			12,800		26,111
M	Aug 4		37	0	15			12,000		24,479
M	Aug 11		66	0	29			23,200		47,326
M	Aug 18		77	0	11			8,800		17,951
M	Aug 25		88	0	11			8,800	20,000	40,861
M	Sep 1		95	0	7			5,600	20,000	34,333
M	Sep 8		100	0	5			4,000	20,000	31,069
M	Sep 15			0	0				20,000	22,910

Table D-21. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	MN	27	420,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Mar 31			0	0					0
MN	Apr 7			0	0					0
MN	Apr 14	2		2	0	8,400				10,203
MN	Apr 21	20		18	0	75,600				91,825
MN	Apr 28	34		14	0	58,800				71,420
MN	May 5	64		30	0	126,000				153,042
MN	May 12	76		12	0	50,400				61,217
MN	May 19	85		9	0	37,800				45,913
MN	May 26	95		10	0	42,000				51,014
MN	Jun 2	99		4	0	16,800				20,406
MN	Jun 9	100		1	0	4,200				5,101
MN	Jun 16			0	0					0
MN	Jun 23			0	0					0
MN	Jun 30			0	0					0
MN	Jul 7			0	0					0
MN	Jul 14			0	0					0
MN	Jul 21		6	0	6			25,200		51,405
MN	Jul 28		22	0	16			67,200		137,081
MN	Aug 4		37	0	15			63,000		128,513
MN	Aug 11		66	0	29			121,800		248,459
MN	Aug 18		77	0	11			46,200		94,243
MN	Aug 25		88	0	11			46,200	105,000	214,519
MN	Sep 1		95	0	7			29,400	105,000	180,248
MN	Sep 8		100		5			21,000	105,000	163,113
MN	Sep 15								105,000	120,276

Table D-22. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MISSOURI

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	MO	29	65,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MO	Mar 10	12		12	0	7,800				9,474
MO	Mar 17	34		22	0	14,300				17,369
MO	Mar 24	61		27	0	17,550				21,317
MO	Mar 31	93		32	0	20,800				25,264
MO	Apr 7	97		4	0	2,600				3,158
MO	Apr 14	99		2	0	1,300				1,579
MO	Apr 21	100		1	0	650				790
MO	Apr 28									0
MO	May 5									0
MO	May 12									0
MO	May 19			0	0					0
MO	May 26			0	0					0
MO	Jun 2			0	0					0
MO	Jun 9			0	0					0
MO	Jun 16			0	0					0
MO	Jun 23			0	0					0
MO	Jun 30		19	0	19			12,350		25,193
MO	Jul 7		55	0	36			23,400		47,734
MO	Jul 14		84	0	29			18,850	16,250	57,066
MO	Jul 21		98	0	14			9,100	16,250	37,177
MO	Jul 28		100	0	2			1,300	16,250	21,266
MO	Aug 4								16,250	18,614
MO	Aug 11									0
MO	Aug 18									0
MO	Aug 25									0
MO	Sep 1									0
MO	Sep 8									0

Table D-23. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN OHIO

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	OH	39	70,000	2.3

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
OH	Mar 31	6		6	0	4,200				2,667
OH	Apr 7	11		5	0	3,500				2,222
OH	Apr 14	12		1	0	700				444
OH	Apr 21	26		14	0	9,800				6,222
OH	Apr 28	45		19	0	13,300				8,444
OH	May 5	61		16	0	11,200				7,111
OH	May 12	74		13	0	9,100				5,778
OH	May 19	85		11	0	7,700				4,889
OH	May 26	97		12	0	8,400				5,333
OH	Jun 2	99		2	0	1,400				889
OH	Jun 9	100		1	0	700				444
OH	Jun 16			0	0					0
OH	Jun 23			0	0					0
OH	Jun 30			0	0					0
OH	Jul 7			0	0					0
OH	Jul 14		6	0	6			4,200		4,479
OH	Jul 21		19	0	13			9,100		9,703
OH	Jul 28		35	0	16			11,200		11,943
OH	Aug 4		64	0	29			20,300		21,646
OH	Aug 11		87	0	23			16,100		17,168
OH	Aug 18		94	0	7			4,900	17,500	15,703
OH	Aug 25		99	0	5			3,500	17,500	14,211
OH	Sep 1		100	0	1			700	17,500	11,225
OH	Sep 8								17,500	10,479

Table D-24. CALCULATION OF WEEKLY OATS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Oats Planted	Gal of Diesel per Acre
% of Total	27.61	0.00	46.36	26.03	WI	55	430,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Mar 31	1		1	0	4,300				5,223
WI	Apr 7	1		0	0	0				0
WI	Apr 14	6		5	0	21,500				26,114
WI	Apr 21	29		23	0	98,900				120,126
WI	Apr 28	34		5	0	21,500				26,114
WI	May 5	43		9	0	38,700				47,006
WI	May 12	65		22	0	94,600				114,903
WI	May 19	76		11	0	47,300				57,452
WI	May 26	90		14	0	60,200				73,120
WI	Jun 2	100		10	0	43,000				52,229
WI	Jun 9			0	0					0
WI	Jun 16			0	0					0
WI	Jun 23			0	0					0
WI	Jun 30			0	0					0
WI	Jul 7			0	0					0
WI	Jul 14			0	0					0
WI	Jul 21		3	0	3			12,900		26,315
WI	Jul 28		21	0	18			77,400		157,888
WI	Aug 4		41	0	20			86,000		175,431
WI	Aug 11		65	0	24			103,200		210,517
WI	Aug 18		87	0	22			94,600		192,974
WI	Aug 25		94	0	7			30,100	107,500	184,540
WI	Sep 1		96	0	2			8,600	107,500	140,682
WI	Sep 8		100	0	4			17,200	107,500	158,225
WI	Sep 15			0	0				107,500	123,139

Table D-25. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN ILLINOIS

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	IL	17	10,600,000	3.7

State	**Week Ending**	**Total Planted (%)**	**Total Harvested (%)**	**Weekly Progress Planted**	**Weekly Progress Harvested**	**Planted Acres**	**Cultivated Acres**	**Harvested Acres**	**Post Harvesting Acres**	**Diesel Fuel (gal)**
IL	Apr 28	1		1	0	106,000				116,051
IL	May 5	1		0	0	0				0
IL	May 12	10		9	0	954,000				1,044,461
IL	May 19	10		0	0	0				0
IL	May 26	22		12	0	1,272,000				1,392,615
IL	Jun 2	56		34	0	3,604,000				3,945,743
IL	Jun 9	86		30	0	3,180,000				3,481,538
IL	Jun 16	94		8	0	848,000	963,636			1,720,063
IL	Jun 23	97		3	0	318,000	963,636			1,139,807
IL	Jun 30	100		3	0	318,000	963,636			1,139,807
IL	Jul 7			0	0		963,636			791,653
IL	Jul 14			0	0		963,636			791,653
IL	Jul 21			0	0		963,636			791,653
IL	Jul 28			0	0		963,636			791,653
IL	Aug 4			0	0		963,636			791,653
IL	Aug 11			0	0		963,636			791,653
IL	Aug 18			0	0		963,636			791,653
IL	Aug 25			0	0		963,636			791,653
IL	Sep 1			0	0					0
IL	Sep 8			0	0					0
IL	Sep 15			0	0					0
IL	Sep 22		2	0	2			212,000		378,134
IL	Sep 29		13	0	11			1,166,000		2,079,736
IL	Oct 6		35	0	22			2,332,000		4,159,473
IL	Oct 13		65	0	30			3,180,000		5,672,008
IL	Oct 20		84	0	19			2,014,000		3,592,272
IL	Oct 27		92	0	8			848,000		1,512,535
IL	Nov 3		96	0	4			424,000		756,268
IL	Nov 10		97	0	1			106,000		189,067
IL	Nov 17		99	0	2			212,000		378,134
IL	Nov 24		99	0	0			42,400		75,627
IL	Dec 1		100	0	1			63,600		113,440

Table D-26. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN INDIANA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	IN	18	5,800,000	3.2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IN	Apr 28			0	0					0
IN	May 5	2		2	0	116,000				109,837
IN	May 12	3		1	0	58,000				54,919
IN	May 19	4		1	0	58,000				54,919
IN	May 26	19		15	0	870,000				823,780
IN	Jun 2	45		26	0	1,508,000				1,427,886
IN	Jun 9	72		27	0	1,566,000				1,482,805
IN	Jun 16	86		14	0	812,000	527,273			1,143,494
IN	Jun 23	95		9	0	522,000	527,273			868,901
IN	Jun 30	100		5	0	290,000	527,273			649,226
IN	Jul 7			0	0		527,273			374,632
IN	Jul 14			0	0		527,273			374,632
IN	Jul 21			0	0		527,273			374,632
IN	Jul 28			0	0		527,273			374,632
IN	Aug 4			0	0		527,273			374,632
IN	Aug 11			0	0		527,273			374,632
IN	Aug 18			0	0		527,273			374,632
IN	Aug 25			0	0		527,273			374,632
IN	Sep 1			0	0					0
IN	Sep 8			0	0					0
IN	Sep 15			0	0					0
IN	Sep 22		3	0	3			174,000		268,415
IN	Sep 29		10	0	7			406,000		626,302
IN	Oct 6		30	0	20			1,160,000		1,789,435
IN	Oct 13		58	0	28			1,624,000		2,505,209
IN	Oct 20		78	0	20			1,160,000		1,789,435
IN	Oct 27		89	0	11			638,000		984,189
IN	Nov 3		93	0	4			232,000		357,887
IN	Nov 10		96	0	3			174,000		268,415
IN	Nov 17		98	0	2			116,000		178,944
IN	Nov 24		99	0	1			58,000		89,472
IN	Dec 1		100	0	1			58,000		89,472

Table D-27. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN IOWA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	IA	19	10,400,000	4.1

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Apr 28	2		2	0	208,000				252,342
IA	May 5	7		5	0	520,000				630,855
IA	May 12	30		23	0	2,392,000				2,901,932
IA	May 19	54		24	0	2,496,000				3,028,103
IA	May 26	84		30	0	3,120,000				3,785,129
IA	Jun 2	94		10	0	1,040,000	800,000			1,989,982
IA	Jun 9	98		4	0	416,000	800,000			1,232,956
IA	Jun 16	100		2	0	208,000	800,000			980,614
IA	Jun 23			0	0		800,000			728,272
IA	Jun 30			0	0		800,000			728,272
IA	Jul 7			0	0		800,000			728,272
IA	Jul 14			0	0		800,000			728,272
IA	Jul 21			0	0		800,000			728,272
IA	Jul 28			0	0		800,000			728,272
IA	Aug 4			0	0		800,000			728,272
IA	Aug 11			0	0		800,000			728,272
IA	Aug 18			0	0		800,000			728,272
IA	Aug 25			0	0		800,000			728,272
IA	Sep 1			0	0					0
IA	Sep 8			0	0					0
IA	Sep 15			0	0					0
IA	Sep 22		4	0	4			416,000		822,215
IA	Sep 29		16	0	12			1,248,000		2,466,644
IA	Oct 6		26	0	10			1,040,000		2,055,536
IA	Oct 13		63	0	37			3,848,000		7,605,485
IA	Oct 20		88	0	25			2,600,000		5,138,841
IA	Oct 27		96	0	8			832,000		1,644,429
IA	Nov 3		98	0	2			208,000		411,107
IA	Nov 10		99	0	1			104,000		205,554
IA	Nov 17		100	0	1			104,000		205,554
IA	Nov 24									0

Table D-28. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MICHIGAN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	MI	26	2,050,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MI	Apr 28	1		1	0	20,500				26,690
MI	May 5	7		6	0	123,000				160,140
MI	May 12	20		13	0	266,500				346,970
MI	May 19	23		3	0	61,500				80,070
MI	May 26	42		19	0	389,500				507,110
MI	Jun 2	72		30	0	615,000				800,700
MI	Jun 9	87		15	0	307,500	170,833			567,246
MI	Jun 16	96		9	0	184,500	170,833			407,106
MI	Jun 23	100		4	0	82,000	170,833			273,656
MI	Jun 30			0	0		170,833			166,896
MI	Jul 7			0	0		170,833			166,896
MI	Jul 14			0	0		170,833			166,896
MI	Jul 21			0	0		170,833			166,896
MI	Jul 28			0	0		170,833			166,896
MI	Aug 4			0	0		170,833			166,896
MI	Aug 11			0	0		170,833			166,896
MI	Aug 18			0	0		170,833			166,896
MI	Aug 25			0	0		170,833			166,896
MI	Sep 1			0	0					0
MI	Sep 8			0	0					0
MI	Sep 15			0	0					0
MI	Sep 22		5	0	5			102,500		217,413
MI	Sep 29		18	0	13			266,500		565,273
MI	Oct 6		32	0	14			287,000		608,755
MI	Oct 13		55	0	23			471,500		1,000,098
MI	Oct 20		73	0	18			369,000		782,685
MI	Oct 27		91	0	18			369,000		782,685
MI	Nov 3		96	0	5			102,500		217,413
MI	Nov 10		100	0	4			82,000		173,930
MI	Nov 17									0
MI	Nov 24									0

Table D-29. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	MN	27	7,200,000	4.5

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Apr 28	1		1	0	72,000				95,871
MN	May 5	6		5	0	360,000				479,355
MN	May 12	24		18	0	1,296,000				1,725,678
MN	May 19	52		28	0	2,016,000				2,684,388
MN	May 26	82		30	0	2,160,000				2,876,130
MN	Jun 2	95		13	0	936,000				1,246,323
MN	Jun 9	98		3	0	216,000				287,613
MN	Jun 16	99		1	0	72,000	654,545			749,863
MN	Jun 23	99		0	0	28,800	654,545			692,340
MN	Jun 30	100		1	0	43,200	654,545			711,514
MN	Jul 7			0	0		654,545			653,992
MN	Jul 14			0	0		654,545			653,992
MN	Jul 21			0	0		654,545			653,992
MN	Jul 28			0	0		654,545			653,992
MN	Aug 4			0	0		654,545			653,992
MN	Aug 11			0	0		654,545			653,992
MN	Aug 18			0	0		654,545			653,992
MN	Aug 25			0	0		654,545			653,992
MN	Sep 1			0	0					0
MN	Sep 8			0	0					0
MN	Sep 15			0	0					0
MN	Sep 22		9	0	9			648,000		1,405,709
MN	Sep 29		25	0	16			1,152,000		2,499,039
MN	Oct 6		33	0	8			576,000		1,249,519
MN	Oct 13		48	0	15			1,080,000		2,342,849
MN	Oct 20		76	0	28			2,016,000		4,373,318
MN	Oct 27		87	0	11			792,000		1,718,089
MN	Nov 3		91	0	4			288,000		624,760
MN	Nov 10		97	0	6			432,000		937,140
MN	Nov 17		99	0	2			144,000		312,380
MN	Nov 24		99	0	0			28,800		62,476
MN	Dec 1		100	0	1			43,200		93,714

Table D-30. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MISSOURI

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	MO	29	5,050,000	4.5

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MO	Apr 28	4		4	0	202,000				268,971
MO	May 5	11		7	0	353,500				470,700
MO	May 12	13		2	0	101,000				134,486
MO	May 19	18		5	0	252,500				336,214
MO	May 26	29		11	0	555,500				739,671
MO	Jun 2	50		21	0	1,060,500				1,412,100
MO	Jun 9	68		18	0	909,000				1,210,371
MO	Jun 16	81		13	0	656,500	459,091			1,332,860
MO	Jun 23	94		13	0	656,500	459,091			1,332,860
MO	Jun 30	100		6	0	303,000	459,091			862,160
MO	Jul 7			0	0		459,091			458,702
MO	Jul 14			0	0		459,091			458,702
MO	Jul 21			0	0		459,091			458,702
MO	Jul 28			0	0		459,091			458,702
MO	Aug 4			0	0		459,091			458,702
MO	Aug 11			0	0		459,091			458,702
MO	Aug 18			0	0		459,091			458,702
MO	Aug 25			0	0		459,091			458,702
MO	Sep 1			0	0					0
MO	Sep 8			0	0					0
MO	Sep 15			0	0					0
MO	Sep 22		4	0	4			202,000		438,199
MO	Sep 29		14	0	10			505,000		1,095,499
MO	Oct 6		27	0	13			656,500		1,424,148
MO	Oct 13		48	0	21			1,060,500		2,300,547
MO	Oct 20		66	0	18			909,000		1,971,898
MO	Oct 27		77	0	11			555,500		1,205,049
MO	Nov 3		79	0	2			101,000		219,100
MO	Nov 10		87	0	8			404,000		876,399
MO	Nov 17		91	0	4			202,000		438,199
MO	Nov 24		96	0	5			252,500		547,749
MO	Dec 1		100	0	4			202,000		438,199

Table D-31. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN OHIO

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	OH	39	4,750,000	2.8

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
OH	Apr 28	2		2	0	95,000				78,709
OH	May 5	5		3	0	142,500				118,063
OH	May 12	6		1	0	47,500				39,354
OH	May 19	7		1	0	47,500				39,354
OH	May 26	20		13	0	617,500				511,608
OH	Jun 2	36		16	0	760,000				629,671
OH	Jun 9	69		33	0	1,567,500				1,298,697
OH	Jun 16	85		16	0	760,000	431,818			898,131
OH	Jun 23	97		12	0	570,000	431,818			740,713
OH	Jun 30	100		3	0	142,500	431,818			386,523
OH	Jul 7			0	0		431,818			268,460
OH	Jul 14			0	0		431,818			268,460
OH	Jul 21			0	0		431,818			268,460
OH	Jul 28			0	0		431,818			268,460
OH	Aug 4			0	0		431,818			268,460
OH	Aug 11			0	0		431,818			268,460
OH	Aug 18			0	0		431,818			268,460
OH	Aug 25			0	0		431,818			268,460
OH	Sep 1			0	0					0
OH	Sep 8			0	0					0
OH	Sep 15			0	0					0
OH	Sep 22		8	0	8			380,000		512,920
OH	Sep 29		14	0	6			285,000		384,690
OH	Oct 6		33	0	19			902,500		1,218,185
OH	Oct 13		59	0	26			1,235,000		1,666,990
OH	Oct 20		74	0	15			712,500		961,725
OH	Oct 27		86	0	12			570,000		769,380
OH	Nov 3		92	0	6			285,000		384,690
OH	Nov 10		95	0	3			142,500		192,345
OH	Nov 17		96	0	1			47,500		64,115
OH	Nov 24		99	0	3			142,500		192,345
OH	Dec 1		100	0	1			47,500		64,115

Table D-32. CALCULATION OF WEEKLY SOYBEANS PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Soybeans Planted	Gal of Diesel per Acre
% of Total	29.59	22.20	48.21	0.00	WI	55	1,540,000	4.5

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Apr 28			0	0					0
WI	May 5	8		8	0	123,200				164,046
WI	May 12	20		12	0	184,800				246,069
WI	May 19	28		8	0	123,200				164,046
WI	May 26	62		34	0	523,600				697,195
WI	Jun 2	81		19	0	292,600				389,609
WI	Jun 9	88		7	0	107,800	118,462			261,901
WI	Jun 16	95		7	0	107,800	118,462			261,901
WI	Jun 23	100		5	0	77,000	118,462			220,890
WI	Jun 30			0	0		118,462			118,361
WI	Jul 7			0	0		118,462			118,361
WI	Jul 14			0	0		118,462			118,361
WI	Jul 21			0	0		118,462			118,361
WI	Jul 28			0	0		118,462			118,361
WI	Aug 4			0	0		118,462			118,361
WI	Aug 11			0	0		118,462			118,361
WI	Aug 18			0	0		118,462			118,361
WI	Aug 25			0	0		118,462			118,361
WI	Sep 1			0	0		118,462			118,361
WI	Sep 8			0	0					0
WI	Sep 15			0	0					0
WI	Sep 22			0	0					0
WI	Sep 29		8	0	8			123,200		267,258
WI	Oct 6		19	0	11			169,400		367,480
WI	Oct 13		36	0	17			261,800		567,924
WI	Oct 20		53	0	17			261,800		567,924
WI	Oct 27		69	0	16			246,400		534,517
WI	Nov 3		78	0	9			138,600		300,666
WI	Nov 10		89	0	11			169,400		367,480
WI	Nov 17		96	0	7			107,800		233,851
WI	Nov 24		99	0	3			52,360		113,585
WI	Dec 1		100	0	1			9,240		20,044

Table D-33. CALCULATION OF WEEKLY SPRING WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Spring Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	MN	27	2,000,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Mar 31			0	0					0
MN	Apr 7			0	0					0
MN	Apr 14			0	0					0
MN	Apr 21	3		3	0	60,000				81,958
MN	Apr 28	9		6	0	120,000				163,916
MN	May 5	26		17	0	340,000				464,430
MN	May 12	42		16	0	320,000				437,110
MN	May 19	59		17	0	340,000				464,430
MN	May 26	91		32	0	640,000				874,221
MN	Jun 2	98		7	0	140,000				191,236
MN	Jun 9	100		2	0	40,000				54,639
MN	Jun 16			0	0					0
MN	Jun 23			0	0					0
MN	Jun 30			0	0					0
MN	Jul 7			0	0					0
MN	Jul 14			0	0					0
MN	Jul 21			0	0					0
MN	Jul 28			0	0					0
MN	Aug 4		12	0	12			240,000		427,128
MN	Aug 11		31	0	19			380,000		676,287
MN	Aug 18		49	0	18			360,000		640,693
MN	Aug 25		69	0	20			400,000		711,881
MN	Sep 1		78	0	9			180,000		320,346
MN	Sep 8		91	0	13			260,000	500,000	1,089,887
MN	Sep 15		95	0	4			80,000	500,000	769,540
MN	Sep 22		100	0	5			100,000	500,000	805,134
MN	Sep 29			0	0				500,000	627,164

Table D-34. CALCULATION OF WEEKLY SPRING WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Spring Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	WI	55	8,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Mar 31			0	0					0
WI	Apr 7			0	0					0
WI	Apr 14			0	0					0
WI	Apr 21	3		3	0	240				328
WI	Apr 28	9		6	0	480				656
WI	May 5	26		17	0	1,360				1,858
WI	May 12	42		16	0	1,280				1,748
WI	May 19	59		17	0	1,360				1,858
WI	May 26	91		32	0	2,560				3,497
WI	Jun 2	98		7	0	560				765
WI	Jun 9	100		2	0	160				219
WI	Jun 16			0	0					0
WI	Jun 23			0	0					0
WI	Jun 30			0	0					0
WI	Jul 7			0	0					0
WI	Jul 14			0	0					0
WI	Jul 21			0	0					0
WI	Jul 28			0	0					0
WI	Aug 4		12	0	12			960		1,709
WI	Aug 11		31	0	19			1,520		2,705
WI	Aug 18		49	0	18			1,440		2,563
WI	Aug 25		69	0	20			1,600		2,848
WI	Sep 1		78	0	9			720		1,281
WI	Sep 8		91	0	13			1,040	2,000	4,360
WI	Sep 15		95	0	4			320	2,000	3,078
WI	Sep 22		100	0	5			400	2,000	3,221
WI	Sep 29			0	0				2,000	2,509

Table D-35. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN ILLINOIS

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	IL	17	680,000	2

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IL	Mar 31			0	0					0
IL	Apr 7			0	0					0
IL	Apr 14			0	0					0
IL	Apr 21			0	0					0
IL	Apr 28			0	0					0
IL	May 5			0	0					0
IL	May 12			0	0					0
IL	May 19			0	0					0
IL	May 26			0	0					0
IL	Jun 2			0	0					0
IL	Jun 9			0	0					0
IL	Jun 16		3	0	3			20,400		16,503
IL	Jun 23		54	0	51			346,800		280,546
IL	Jun 30		79	0	25			170,000		137,522
IL	Jul 7		90	0	11			74,800		60,510
IL	Jul 14		96	0	6			40,800	170,000	129,931
IL	Jul 21		99	0	3			20,400	170,000	113,428
IL	Jul 28		100	0	1			6,800	170,000	102,426
IL	Aug 4								170,000	96,925
IL	Aug 11									0
IL	Aug 18									0
IL	Aug 25									0
IL	Sep 1									0
IL	Sep 8			0	0					0
IL	Sep 15			0	0					0
IL	Sep 22	1		1	0	6,800				4,222
IL	Sep 29	5		4	0	27,200				16,888
IL	Oct 6	28		23	0	156,400				97,108
IL	Oct 13	65		37	0	251,600				156,217
IL	Oct 20	82		17	0	115,600				71,776
IL	Oct 27	94		12	0	81,600				50,665
IL	Nov 3	97		3	0	20,400				12,666
IL	Nov 10	98		1	0	6,800				4,222
IL	Nov 17	99		1	0	6,800				4,222
IL	Nov 24	100		1	0	6,800				4,222

Table D-36. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN INDIANA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	IN	18	350,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IN	Mar 31			0	0					0
IN	Apr 7			0	0					0
IN	Apr 14			0	0					0
IN	Apr 21			0	0					0
IN	Apr 28			0	0					0
IN	May 5			0	0					0
IN	May 12			0	0					0
IN	May 19			0	0					0
IN	May 26			0	0					0
IN	Jun 2			0	0					0
IN	Jun 9			0	0					0
IN	Jun 16		2	0	2			7,000		12,458
IN	Jun 23		28	0	26			91,000		161,953
IN	Jun 30		42	0	14			49,000		87,205
IN	Jul 7		65	0	23			80,500		143,266
IN	Jul 14		91	0	26			91,000	87,500	271,707
IN	Jul 21		99	0	8			28,000	87,500	159,585
IN	Jul 28		100	0	1			3,500	87,500	115,983
IN	Aug 4								87,500	109,754
IN	Aug 11									0
IN	Aug 18									0
IN	Aug 25									0
IN	Sep 1									0
IN	Sep 8			0	0					0
IN	Sep 15	2		2	0	7,000				9,562
IN	Sep 22	3		1	0	3,500				4,781
IN	Sep 29	8		5	0	17,500				23,904
IN	Oct 6	27		19	0	66,500				90,837
IN	Oct 13	49		22	0	77,000				105,180
IN	Oct 20	74		25	0	87,500				119,522
IN	Oct 27	89		15	0	52,500				71,713
IN	Nov 3	94		5	0	17,500				23,904
IN	Nov 10	98		4	0	14,000				19,124
IN	Nov 17	99		1	0	3,500				4,781
IN	Nov 24	100		1	0	3,500				4,781

Table D-37. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN IOWA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	IA	19	20,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
IA	Mar 31			0	0					0
IA	Apr 7			0	0					0
IA	Apr 14			0	0					0
IA	Apr 21			0	0					0
IA	Apr 28			0	0					0
IA	May 5			0	0					0
IA	May 12			0	0					0
IA	May 19			0	0					0
IA	May 26			0	0					0
IA	Jun 2			0	0					0
IA	Jun 9			0	0					0
IA	Jun 16		2	0	2			400		712
IA	Jun 23		28	0	26			5,200		9,254
IA	Jun 30		42	0	14			2,800		4,983
IA	Jul 7		65	0	23			4,600		8,187
IA	Jul 14		91	0	26			5,200	5,000	15,526
IA	Jul 21		99	0	8			1,600	5,000	9,119
IA	Jul 28		100	0	1			200	5,000	6,628
IA	Aug 4								5,000	6,272
IA	Aug 11									0
IA	Aug 18									0
IA	Aug 25			0	0					0
IA	Sep 1			0	0					0
IA	Sep 8	1		1	0	200				273
IA	Sep 15	9		8	0	1,600				2,186
IA	Sep 22	18		9	0	1,800				2,459
IA	Sep 29	26		8	0	1,600				2,186
IA	Oct 6	51		25	0	5,000				6,830
IA	Oct 13	74		23	0	4,600				6,283
IA	Oct 20	90		16	0	3,200				4,371
IA	Oct 27	98		8	0	1,600				2,186
IA	Nov 3	100		2	0	400				546
IA	Nov 10									0
IA	Nov 17									0
IA	Nov 24									0

Table D-38. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MICHIGAN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	MI	26	500,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MI	Mar 31			0	0					0
MI	Apr 7			0	0					0
MI	Apr 14			0	0					0
MI	Apr 21			0	0					0
MI	Apr 28			0	0					0
MI	May 5			0	0					0
MI	May 12			0	0					0
MI	May 19			0	0					0
MI	May 26			0	0					0
MI	Jun 2			0	0					0
MI	Jun 9			0	0					0
MI	Jun 16			0	0					0
MI	Jun 23			0	0					0
MI	Jun 30			0	0					0
MI	Jul 7			0	0					0
MI	Jul 14		17	0	17			85,000		151,275
MI	Jul 21		75	0	58			290,000		516,113
MI	Jul 28		92	0	17			85,000	125,000	308,066
MI	Aug 4		98	0	6			30,000	125,000	210,182
MI	Aug 11		100	0	2			10,000	125,000	174,588
MI	Aug 18								125,000	156,791
MI	Aug 25									0
MI	Sep 1									0
MI	Sep 8	1		1	0	5,000				6,830
MI	Sep 15	9		8	0	40,000				54,639
MI	Sep 22	18		9	0	45,000				61,469
MI	Sep 29	26		8	0	40,000				54,639
MI	Oct 6	51		25	0	125,000				170,746
MI	Oct 13	74		23	0	115,000				157,087
MI	Oct 20	90		16	0	80,000				109,278
MI	Oct 27	98		8	0	40,000				54,639
MI	Nov 3	100		2	0	10,000				13,660
MI	Nov 10									0
MI	Nov 17									0
MI	Nov 24									0

Table D-39. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MINNESOTA

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	MN	27	35,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MN	Mar 31			0	0					0
MN	Apr 7			0	0					0
MN	Apr 14			0	0					0
MN	Apr 21			0	0					0
MN	Apr 28			0	0					0
MN	May 5			0	0					0
MN	May 12			0	0					0
MN	May 19			0	0					0
MN	May 26			0	0					0
MN	Jun 2			0	0					0
MN	Jun 9			0	0					0
MN	Jun 16			0	0					0
MN	Jun 23			0	0					0
MN	Jun 30			0	0					0
MN	Jul 7			0	0					0
MN	Jul 14		17	0	17			5,950		10,589
MN	Jul 21		75	0	58			20,300		36,128
MN	Jul 28		92	0	17			5,950	8,750	21,565
MN	Aug 4		98	0	6			2,100	8,750	14,713
MN	Aug 11		100	0	2			700	8,750	12,221
MN	Aug 18								8,750	10,975
MN	Aug 25	1		1	0	350				478
MN	Sep 1	9		8	0	2,800				3,825
MN	Sep 8	18		9	0	3,150				4,303
MN	Sep 15	26		8	0	2,800				3,825
MN	Sep 22	51		25	0	8,750				11,952
MN	Sep 29	74		23	0	8,050				10,996
MN	Oct 6	90		16	0	5,600				7,649
MN	Oct 13	98		8	0	2,800				3,825
MN	Oct 20	100		2	0	700				956
MN	Oct 27									0
MN	Nov 3									0
MN	Nov 10									0
MN	Nov 17									0
MN	Nov 24									0

Table D-40. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN MISSOURI

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	MO	29	900,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
MO	Mar 31			0	0					0
MO	Apr 7			0	0					0
MO	Apr 14			0	0					0
MO	Apr 21			0	0					0
MO	Apr 28			0	0					0
MO	May 5			0	0					0
MO	May 12			0	0					0
MO	May 19			0	0					0
MO	May 26			0	0					0
MO	Jun 2			0	0					0
MO	Jun 9		2	0	2			18,000		32,035
MO	Jun 16		12	0	10			90,000		160,173
MO	Jun 23		45	0	33			297,000		528,571
MO	Jun 30		85	0	40			360,000	225,000	922,916
MO	Jul 7		97	0	12			108,000	225,000	474,432
MO	Jul 14		100	0	3			27,000	225,000	330,276
MO	Jul 21								225,000	282,224
MO	Jul 28									0
MO	Aug 4									0
MO	Aug 11									0
MO	Aug 18									0
MO	Aug 25									0
MO	Sep 1									0
MO	Sep 8			0	0					0
MO	Sep 15			0	0					0
MO	Sep 22	3		3	0	27,000				36,881
MO	Sep 29	8		5	0	45,000				61,469
MO	Oct 6	20		12	0	108,000				147,525
MO	Oct 13	41		21	0	189,000				258,168
MO	Oct 20	60		19	0	171,000				233,581
MO	Oct 27	74		14	0	126,000				172,112
MO	Nov 3	78		4	0	36,000				49,175
MO	Nov 10	88		10	0	90,000				122,937
MO	Nov 17	91		3	0	27,000				36,881
MO	Nov 24	96		5	0	45,000				61,469
MO	Dec 1	100		4	0	36,000				49,175

Table D-41. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN OHIO

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips	Winter Wheat Planted	Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	OH	39	860,000	2.3

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
OH	Mar 31			0	0					0
OH	Apr 7			0	0					0
OH	Apr 14			0	0					0
OH	Apr 21			0	0					0
OH	Apr 28			0	0					0
OH	May 5			0	0					0
OH	May 12			0	0					0
OH	May 19			0	0					0
OH	May 26			0	0					0
OH	Jun 2			0	0					0
OH	Jun 9			0	0					0
OH	Jun 16			0	0					0
OH	Jun 23			0	0					0
OH	Jun 30		2	0	2			17,200		16,001
OH	Jul 7		36	0	34			292,400		272,019
OH	Jul 14		90	0	54			464,400	215,000	573,000
OH	Jul 21		99	0	9			77,400	215,000	212,975
OH	Jul 28		100	0	1			8,600	215,000	148,970
OH	Aug 4								215,000	140,969
OH	Aug 11									0
OH	Aug 18									0
OH	Aug 25									0
OH	Sep 1									0
OH	Sep 8			0	0					0
OH	Sep 15	1		1	0	8,600				6,141
OH	Sep 22	2		1	0	8,600				6,141
OH	Sep 29	9		7	0	60,200				42,985
OH	Oct 6	40		31	0	266,600				190,360
OH	Oct 13	72		32	0	275,200				196,501
OH	Oct 20	88		16	0	137,600				98,251
OH	Oct 27	95		7	0	60,200				42,985
OH	Nov 3	98		3	0	25,800				18,422
OH	Nov 10	100		2	0	17,200				12,281
OH	Nov 17									0
OH	Nov 24									0

Table D-42. CALCULATION OF WEEKLY WINTER WHEAT PRODUCTION DIESEL FUEL CONSUMPTION ESTIMATES IN WISCONSIN

	Planting	Cultivating	Harvesting	Post Harvesting	State	StFips		Gal of Diesel per Acre
% of Total	31.04	0.00	40.45	28.51	WI	55	190,000	4.4

State	Week Ending	Total Planted (%)	Total Harvested (%)	Weekly Progress Planted	Weekly Progress Harvested	Planted Acres	Cultivated Acres	Harvested Acres	Post Harvesting Acres	Diesel Fuel (gal)
WI	Mar 31			0	0					0
WI	Apr 7			0	0					0
WI	Apr 14			0	0					0
WI	Apr 21			0	0					0
WI	Apr 28			0	0					0
WI	May 5			0	0					0
WI	May 12			0	0					0
WI	May 19			0	0					0
WI	May 26			0	0					0
WI	Jun 2			0	0					0
WI	Jun 9			0	0					0
WI	Jun 16			0	0					0
WI	Jun 23			0	0					0
WI	Jun 30			0	0					0
WI	Jul 7			0	0					0
WI	Jul 14		17	0	17			32,300		57,484
WI	Jul 21		75	0	58			110,200		196,123
WI	Jul 28		92	0	17			32,300	47,500	117,065
WI	Aug 4		98	0	6			11,400	47,500	79,869
WI	Aug 11		100	0	2			3,800	47,500	66,343
WI	Aug 18								47,500	59,581
WI	Aug 25			0	0					0
WI	Sep 1			0	0					0
WI	Sep 8	1		1	0	1,900				2,595
WI	Sep 15	9		8	0	15,200				20,763
WI	Sep 22	18		9	0	17,100				23,358
WI	Sep 29	26		8	0	15,200				20,763
WI	Oct 6	51		25	0	47,500				64,884
WI	Oct 13	74		23	0	43,700				59,693
WI	Oct 20	90		16	0	30,400				41,525
WI	Oct 27	98		8	0	15,200				20,763
WI	Nov 3	100		2	0	3,800				5,191
WI	Nov 10									0
WI	Nov 17									0
WI	Nov 24									0

APPENDIX E. AGRICULTURAL EMISSIONS COMPARISON

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

2002 Summer Season Emissions, tons per season (all default input files)										
SCC	**CLASSIFICATION**	**EQUIP**	**Engine Type**	**TOG exhaust**	**NMOG exhaust**	**NMHC exhaust**	**VOC exhaust**	**PM10 exhaust**	**PM25 exhaust**	**THC exhaust**
2260005035	Agricultural Equipment	Sprayers	2 Stroke	10.67	10.58	10.13	10.57	0.45	0.41	10.22
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	1.39	1.38	1.32	1.37	0.07	0.06	1.33
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	1.40	1.27	1.21	1.25	0.02	0.02	1.35
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	6.59	5.96	5.69	5.89	0.05	0.05	6.32
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	4.23	3.82	3.65	3.78	0.03	0.03	4.05
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	1.37	1.24	1.18	1.22	0.01	0.01	1.31
2265005035	Agricultural Equipment	Sprayers	4 Stroke	20.90	18.89	18.03	18.69	0.16	0.15	20.04
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	35.74	32.31	30.84	31.97	0.24	0.22	34.26
2265005045	Agricultural Equipment	Swathers	4 Stroke	6.91	6.25	5.97	6.19	0.05	0.05	6.63
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	12.06	10.90	10.40	10.79	0.12	0.11	11.56
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	9.97	9.02	8.60	8.92	0.08	0.07	9.56
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	12.60	11.39	10.87	11.27	0.09	0.08	12.08
2267005050	Agricultural Equipment	Hydro Power Units	LPG	0.06	0.05	0.05	0.05	0.00	0.00	0.05
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	0.03	0.03	0.03	0.03	0.00	0.00	0.03
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	0.32	0.02	0.02	0.00	0.00	0.00	0.31
2268005060	Agricultural Equipment	Irrigation Sets	CNG	37.90	1.85	1.82	0.15	0.06	0.06	37.82
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	621.43	612.13	571.48	611.55	604.50	556.14	580.77
2270005020	Agricultural Equipment	Combines	Diesel	40.30	39.69	37.06	39.66	77.47	71.27	37.66
2270005025	Agricultural Equipment	Balers	Diesel	0.70	0.69	0.65	0.69	0.59	0.54	0.66
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	8.52	8.39	7.84	8.39	7.06	6.49	7.96
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	3.77	3.72	3.47	3.71	6.69	6.15	3.53
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	1.21	1.19	1.11	1.19	0.95	0.87	1.13
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	14.35	14.14	13.20	14.12	15.20	13.98	13.41
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	8.97	8.84	8.25	8.83	7.24	6.66	8.38
			Gasoline	123.82	113.00	107.89	111.92	1.36	1.25	118.71
			LPG	0.09	0.08	0.07	0.08	0.00	0.00	0.08
			CNG	38.22	1.87	1.83	0.15	0.06	0.06	38.14
			Diesel	699.29	688.83	643.08	688.18	719.72	662.14	653.54
				861.42	**803.79**	**752.88**	**800.33**	**721.14**	**663.46**	**810.47**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

2002 Summer Season Emissions, tons per season (all default input files)										
SCC	**CLASSIFICATION**	**EQUIP**	**Engine Type**	**CO exhaust**	**NOx exhaust**	**CO2 exhaust**	**SOx exhaust**	**PM exhaust**	**Total Population**	**TotalFuel**
2260005035	Agricultural Equipment	Sprayers	2 Stroke	23.33	0.03	51.14	0.01	0.45	1,039.03	8,508.98
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	3.25	0.01	7.07	0.00	0.07	29.99	1,149.37
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	86.03	0.45	139.66	0.03	0.02	115.69	14,627.57
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	268.04	4.48	592.27	0.12	0.05	62.13	62,229.82
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	153.82	3.20	373.41	0.08	0.03	430.61	39,256.95
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	66.47	0.39	121.30	0.02	0.01	196.02	12,751.15
2265005035	Agricultural Equipment	Sprayers	4 Stroke	637.76	5.63	1,266.59	0.26	0.16	3,539.14	135,195.68
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	1,482.08	5.69	2,777.01	0.57	0.24	17,208.30	293,284.36
2265005045	Agricultural Equipment	Swathers	4 Stroke	251.63	5.23	611.03	0.13	0.05	277.79	64,237.38
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	520.02	2.78	846.01	0.17	0.12	487.38	89,712.52
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	385.36	6.15	862.98	0.18	0.08	537.73	90,788.47
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	442.46	8.75	1,044.32	0.22	0.09	74.98	110,032.77
2267005050	Agricultural Equipment	Hydro Power Units	LPG	1.00	0.25	13.93	0.00	0.00	3.00	2,085.56
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	0.57	0.14	7.91	0.00	0.00	2.00	1,185.03
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	0.42	0.10	4.20	0.00	0.00	1.49	627,003.25
2268005060	Agricultural Equipment	Irrigation Sets	CNG	50.96	12.20	502.67	0.01	0.06	43.22	75,090,002.30
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	0.18	0.19	13.85	0.02	0.03	16.71	1,231.57
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	3,069.31	5,115.82	385,491.08	547.58	604.50	36,768.60	34,203,481.69
2270005020	Agricultural Equipment	Combines	Diesel	153.60	438.80	24,560.90	34.89	77.47	5,125.84	2,179,400.69
2270005025	Agricultural Equipment	Balers	Diesel	1.99	2.51	202.00	0.29	0.59	141.46	18,021.52
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	23.24	31.92	2,393.35	3.40	7.06	971.26	213,582.95
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	14.78	36.56	2,251.82	3.20	6.69	1,207.39	199,835.25
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	4.09	8.44	737.63	1.05	0.95	116.95	65,453.79
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	62.15	104.39	7,158.97	10.17	15.20	663.84	635,934.60
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	29.62	71.37	5,870.53	8.34	7.24	603.70	520,745.48
			Gasoline	4,320.24	42.77	8,692.80	1.79	1.36	23,998.79	921,775.00
			LPG	1.57	0.39	21.84	0.00	0.00	5.00	3,270.59
			CNG	51.38	12.30	506.87	0.01	0.06	44.71	75,717,005.55
			Diesel	3,358.97	5,809.98	428,680.14	608.93	719.72	45,615.74	38,037,687.54
				7,732.16	**5,865.44**	**437,901.65**	**610.73**	**721.14**	**69,664.23**	**114,679,738.68**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

2002 Summer Season Emissions, tons per season (updated season.dat input file)

SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260005035	Agricultural Equipment	Sprayers	2 Stroke	6.04	5.99	5.73	5.98	0.25	0.23	5.79
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	0.79	0.78	0.75	0.78	0.04	0.04	0.75
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	0.79	0.72	0.69	0.71	0.01	0.01	0.76
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	3.73	3.37	3.22	3.34	0.03	0.03	3.58
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	2.39	2.16	2.07	2.14	0.02	0.02	2.29
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	0.78	0.70	0.67	0.69	0.01	0.01	0.74
2265005035	Agricultural Equipment	Sprayers	4 Stroke	11.83	10.70	10.21	10.59	0.09	0.09	11.35
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	20.24	18.30	17.46	18.10	0.13	0.12	19.40
2265005045	Agricultural Equipment	Swathers	4 Stroke	3.92	3.54	3.38	3.50	0.03	0.03	3.75
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	6.83	6.17	5.89	6.11	0.07	0.06	6.55
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	5.65	5.11	4.87	5.05	0.04	0.04	5.41
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	7.14	6.45	6.16	6.38	0.05	0.05	6.84
2267005050	Agricultural Equipment	Hydro Power Units	LPG	0.03	0.03	0.03	0.03	0.00	0.00	0.03
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	0.02	0.02	0.02	0.02	0.00	0.00	0.02
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	0.18	0.01	0.01	0.00	0.00	0.00	0.18
2268005060	Agricultural Equipment	Irrigation Sets	CNG	21.46	1.05	1.03	0.09	0.03	0.03	21.42
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	351.91	346.65	323.63	346.32	342.33	314.94	328.89
2270005020	Agricultural Equipment	Combines	Diesel	22.82	22.48	20.99	22.46	43.87	40.36	21.33
2270005025	Agricultural Equipment	Balers	Diesel	0.40	0.39	0.37	0.39	0.33	0.31	0.37
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	4.83	4.75	4.44	4.75	4.00	3.68	4.51
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	2.14	2.10	1.96	2.10	3.79	3.48	2.00
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	0.69	0.68	0.63	0.67	0.54	0.49	0.64
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	8.13	8.01	7.47	8.00	8.61	7.92	7.60
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	5.08	5.00	4.67	5.00	4.10	3.77	4.75
			Gasoline	70.12	63.99	61.10	63.38	0.77	0.71	67.22
			LPG	0.05	0.05	0.04	0.05	0.00	0.00	0.05
			CNG	21.64	1.06	1.04	0.09	0.03	0.03	21.60
			Diesel	396.01	390.08	364.18	389.71	407.58	374.97	370.10
				487.82	**455.18**	**426.35**	**453.23**	**408.38**	**375.71**	**458.97**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

2002 Summer Season Emissions, tons per season (updated season.dat input fi										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	Total Population	TotalFuel
2260005035	Agricultural Equipment	Sprayers	2 Stroke	13.21	0.02	28.96	0.01	0.25	1,039.03	4,818.63
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	1.84	0.00	4.00	0.00	0.04	29.99	650.89
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	48.72	0.25	79.09	0.02	0.01	115.69	8,283.59
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	151.79	2.53	335.40	0.07	0.03	62.13	35,240.72
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	87.11	1.81	211.46	0.04	0.02	430.61	22,231.19
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	37.64	0.22	68.69	0.01	0.01	196.02	7,220.97
2265005035	Agricultural Equipment	Sprayers	4 Stroke	361.16	3.19	717.27	0.15	0.09	3,539.14	76,561.24
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	839.30	3.22	1,572.62	0.32	0.13	17,208.30	166,086.84
2265005045	Agricultural Equipment	Swathers	4 Stroke	142.50	2.96	346.03	0.07	0.03	277.79	36,377.60
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	294.49	1.57	479.10	0.10	0.07	487.38	50,804.15
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	218.23	3.48	488.70	0.10	0.04	537.73	51,413.45
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	250.57	4.95	591.40	0.12	0.05	74.98	62,311.50
2267005050	Agricultural Equipment	Hydro Power Units	LPG	0.57	0.14	7.89	0.00	0.00	3.00	1,181.05
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	0.32	0.08	4.48	0.00	0.00	2.00	671.08
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	0.24	0.06	2.38	0.00	0.00	1.49	355,071.53
2268005060	Agricultural Equipment	Irrigation Sets	CNG	28.86	6.91	284.66	0.01	0.03	43.22	42,523,429.14
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	0.10	0.11	7.84	0.01	0.02	16.71	697.44
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	1,738.15	2,897.09	218,303.40	310.10	342.33	36,768.60	19,369,413.54
2270005020	Agricultural Equipment	Combines	Diesel	86.98	248.49	13,908.82	19.76	43.87	5,125.84	1,234,193.89
2270005025	Agricultural Equipment	Balers	Diesel	1.12	1.42	114.39	0.16	0.33	141.46	10,205.59
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	13.16	18.08	1,355.35	1.92	4.00	971.26	120,951.92
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	8.37	20.70	1,275.21	1.81	3.79	1,207.39	113,166.64
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	2.32	4.78	417.72	0.59	0.54	116.95	37,066.45
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	35.20	59.12	4,054.12	5.76	8.61	663.84	360,129.43
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	16.78	40.41	3,324.48	4.72	4.10	603.70	294,897.93
			Gasoline	2,446.55	24.22	4,922.73	1.01	0.77	23,998.79	522,000.76
			LPG	0.89	0.22	12.37	0.00	0.00	5.00	1,852.13
			CNG	29.10	6.96	287.04	0.01	0.03	44.71	42,878,500.67
			Diesel	1,902.18	3,290.19	242,761.34	344.84	407.58	45,615.74	21,540,722.82
				4,378.72	**3,321.60**	**247,983.48**	**345.86**	**408.38**	**69,664.23**	**64,943,076.38**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

Difference (Updated - Default)										
SCC	**CLASSIFICATION**	**EQUIP**	**Engine Type**	**TOG exhaust**	**NMOG exhaust**	**NMHC exhaust**	**VOC exhaust**	**PM10 exhaust**	**PM25 exhaust**	**THC exhaust**
2260005035	Agricultural Equipment	Sprayers	2 Stroke	-4.63	-4.59	-4.39	-4.58	-0.19	-0.18	-4.43
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	-0.60	-0.60	-0.57	-0.60	-0.03	-0.03	-0.58
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	-0.61	-0.55	-0.53	-0.54	-0.01	-0.01	-0.58
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	-2.86	-2.58	-2.47	-2.56	-0.02	-0.02	-2.74
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	-1.83	-1.66	-1.58	-1.64	-0.01	-0.01	-1.76
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	-0.59	-0.54	-0.51	-0.53	-0.01	-0.01	-0.57
2265005035	Agricultural Equipment	Sprayers	4 Stroke	-9.06	-8.19	-7.82	-8.11	-0.07	-0.07	-8.69
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	-15.50	-14.01	-13.37	-13.86	-0.10	-0.09	-14.86
2265005045	Agricultural Equipment	Swathers	4 Stroke	-3.00	-2.71	-2.59	-2.68	-0.02	-0.02	-2.88
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	-5.23	-4.73	-4.51	-4.68	-0.05	-0.05	-5.01
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	-4.32	-3.91	-3.73	-3.87	-0.03	-0.03	-4.15
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	-5.47	-4.94	-4.72	-4.89	-0.04	-0.04	-5.24
2267005050	Agricultural Equipment	Hydro Power Units	LPG	-0.02	-0.02	-0.02	-0.02	0.00	0.00	-0.02
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	-0.01	-0.01	-0.01	-0.01	0.00	0.00	-0.01
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	-0.14	-0.01	-0.01	0.00	0.00	0.00	-0.14
2268005060	Agricultural Equipment	Irrigation Sets	CNG	-16.44	-0.80	-0.79	-0.07	-0.03	-0.03	-16.40
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	-269.51	-265.48	-247.85	-265.23	-262.17	-241.20	-251.88
2270005020	Agricultural Equipment	Combines	Diesel	-17.48	-17.22	-16.07	-17.20	-33.60	-30.91	-16.33
2270005025	Agricultural Equipment	Balers	Diesel	-0.30	-0.30	-0.28	-0.30	-0.26	-0.24	-0.28
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	-3.70	-3.64	-3.40	-3.64	-3.06	-2.82	-3.45
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	-1.64	-1.61	-1.50	-1.61	-2.90	-2.67	-1.53
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	-0.53	-0.52	-0.48	-0.52	-0.41	-0.38	-0.49
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	-6.22	-6.13	-5.72	-6.13	-6.59	-6.06	-5.82
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	-3.89	-3.83	-3.58	-3.83	-3.14	-2.89	-3.64
			Gasoline	-53.70	-49.01	-46.79	-48.54	-0.59	-0.54	-51.48
			LPG	-0.04	-0.04	-0.03	-0.03	0.00	0.00	-0.03
			CNG	-16.57	-0.81	-0.79	-0.07	-0.03	-0.03	-16.54
			Diesel	-303.28	-298.75	-278.91	-298.46	-312.14	-287.17	-283.44
				-373.60	**-348.60**	**-326.52**	**-347.10**	**-312.76**	**-287.74**	**-351.50**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

Difference (Updated - Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	Total Population	TotalFuel
2260005035	Agricultural Equipment	Sprayers	2 Stroke	-10.12	-0.01	-22.18	0.00	-0.19	0.00	-3,690.35
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	-1.41	0.00	-3.07	0.00	-0.03	0.00	-498.48
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	-37.31	-0.19	-60.57	-0.01	-0.01	0.00	-6,343.98
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	-116.25	-1.94	-256.87	-0.05	-0.02	0.00	-26,989.10
2265005020	Agricultural Equipment	Combines	4 Stroke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2265005025	Agricultural Equipment	Balers	4 Stroke	-66.71	-1.39	-161.95	-0.03	-0.01	0.00	-17,025.76
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	-28.83	-0.17	-52.61	-0.01	-0.01	0.00	-5,530.18
2265005035	Agricultural Equipment	Sprayers	4 Stroke	-276.60	-2.44	-549.32	-0.11	-0.07	0.00	-58,634.43
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	-642.78	-2.47	-1,204.39	-0.25	-0.10	0.00	-127,197.52
2265005045	Agricultural Equipment	Swathers	4 Stroke	-109.13	-2.27	-265.00	-0.05	-0.02	0.00	-27,859.78
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	-225.53	-1.21	-366.92	-0.08	-0.05	0.00	-38,908.37
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	-167.13	-2.67	-374.27	-0.08	-0.03	0.00	-39,375.01
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	-191.90	-3.79	-452.92	-0.09	-0.04	0.00	-47,721.27
2267005050	Agricultural Equipment	Hydro Power Units	LPG	-0.44	-0.11	-6.04	0.00	0.00	0.00	-904.51
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	-0.25	-0.06	-3.43	0.00	0.00	0.00	-513.95
2267005060	Agricultural Equipment	Irrigation Sets	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005050	Agricultural Equipment	Hydro Power Units	CNG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	-0.18	-0.04	-1.82	0.00	0.00	0.00	-271,931.72
2268005060	Agricultural Equipment	Irrigation Sets	CNG	-22.10	-5.29	-218.01	0.00	-0.03	0.00	-32,566,573.16
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	-0.08	-0.08	-6.01	-0.01	-0.01	0.00	-534.13
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	-1,331.16	-2,218.73	-167,187.68	-237.49	-262.17	0.00	-14,834,068.15
2270005020	Agricultural Equipment	Combines	Diesel	-66.62	-190.31	-10,652.08	-15.13	-33.60	0.00	-945,206.79
2270005025	Agricultural Equipment	Balers	Diesel	-0.86	-1.09	-87.61	-0.12	-0.26	0.00	-7,815.94
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005035	Agricultural Equipment	Sprayers	Diesel	-10.08	-13.84	-1,038.00	-1.47	-3.06	0.00	-92,631.03
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2270005045	Agricultural Equipment	Swathers	Diesel	-6.41	-15.86	-976.62	-1.39	-2.90	0.00	-86,668.62
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	-1.78	-3.66	-319.91	-0.45	-0.41	0.00	-28,387.35
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	-26.96	-45.27	-3,104.85	-4.41	-6.59	0.00	-275,805.17
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	-12.85	-30.95	-2,546.05	-3.62	-3.14	0.00	-225,847.55
			Gasoline	-1,873.69	-18.55	-3,770.07	-0.78	-0.59	0.00	-399,774.24
			LPG	-0.68	-0.17	-9.47	0.00	0.00	0.00	-1,418.46
			CNG	-22.28	-5.33	-219.83	0.00	-0.03	0.00	-32,838,504.88
			Diesel	-1,456.79	-2,519.79	-185,918.80	-264.09	-312.14	0.00	-16,496,964.72
				-3,353.44	**-2,543.85**	**-189,918.17**	**-264.87**	**-312.76**	**0.00**	**-49,736,662.30**

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

Percent Difference (Updated - Default/Default)

SCC	CLASSIFICATION	EQUIP	Engine Type	TOG exhaust	NMOG exhaust	NMHC exhaust	VOC exhaust	PM10 exhaust	PM25 exhaust	THC exhaust
2260005035	Agricultural Equipment	Sprayers	2 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005020	Agricultural Equipment	Combines	4 Stroke	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2265005025	Agricultural Equipment	Balers	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005035	Agricultural Equipment	Sprayers	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005045	Agricultural Equipment	Swathers	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2267005050	Agricultural Equipment	Hydro Power Units	LPG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2267005060	Agricultural Equipment	Irrigation Sets	LPG	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2268005050	Agricultural Equipment	Hydro Power Units	CNG	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2268005060	Agricultural Equipment	Irrigation Sets	CNG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005020	Agricultural Equipment	Combines	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005025	Agricultural Equipment	Balers	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270005035	Agricultural Equipment	Sprayers	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270005045	Agricultural Equipment	Swathers	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%
			Gasoline	-43%	-43%	-43%	-43%	-43%	-43%	-43%
			LPG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
			CNG	-43%	-43%	-43%	-43%	-43%	-43%	-43%
			Diesel	-43%	-43%	-43%	-43%	-43%	-43%	-43%

Table E-1. Comparison of NONROAD Model 2002 Summer Season Agricultural Emissions for Michigan

Percent Difference (Updated - Default/Default)										
SCC	CLASSIFICATION	EQUIP	Engine Type	CO exhaust	NOx exhaust	CO2 exhaust	SOx exhaust	PM exhaust	Total Population	TotalFuel
2260005035	Agricultural Equipment	Sprayers	2 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2260005050	Agricultural Equipment	Hydro Power Units	2 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005010	Agricultural Equipment	2-Wheel Tractors	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005015	Agricultural Equipment	Agricultural Tractors	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005020	Agricultural Equipment	Combines	4 Stroke	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2265005025	Agricultural Equipment	Balers	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005030	Agricultural Equipment	Agricultural Mowers	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005035	Agricultural Equipment	Sprayers	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005040	Agricultural Equipment	Tillers > 6 HP	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005045	Agricultural Equipment	Swathers	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005050	Agricultural Equipment	Hydro Power Units	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005055	Agricultural Equipment	Other Agricultural Equipment	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2265005060	Agricultural Equipment	Irrigation Sets	4 Stroke	-43%	-43%	-43%	-43%	-43%	0%	-43%
2267005050	Agricultural Equipment	Hydro Power Units	LPG	-43%	-43%	-43%	-43%	-43%	0%	-43%
2267005055	Agricultural Equipment	Other Agricultural Equipment	LPG	-43%	-43%	-43%	-43%	-43%	0%	-43%
2267005060	Agricultural Equipment	Irrigation Sets	LPG	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2268005050	Agricultural Equipment	Hydro Power Units	CNG	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2268005055	Agricultural Equipment	Other Agricultural Equipment	CNG	-43%	-43%	-43%	-43%	-43%	0%	-43%
2268005060	Agricultural Equipment	Irrigation Sets	CNG	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005010	Agricultural Equipment	2-Wheel Tractors	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005015	Agricultural Equipment	Agricultural Tractors	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005020	Agricultural Equipment	Combines	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005025	Agricultural Equipment	Balers	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005030	Agricultural Equipment	Agricultural Mowers	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270005035	Agricultural Equipment	Sprayers	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005040	Agricultural Equipment	Tillers > 6 HP	Diesel	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2270005045	Agricultural Equipment	Swathers	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005050	Agricultural Equipment	Hydro Power Units	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005055	Agricultural Equipment	Other Agricultural Equipment	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
2270005060	Agricultural Equipment	Irrigation Sets	Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%
			Gasoline	-43%	-43%	-43%	-43%	-43%	0%	-43%
			LPG	-43%	-43%	-43%	-43%	-43%	0%	-43%
			CNG	-43%	-43%	-43%	-43%	-43%	0%	-43%
			Diesel	-43%	-43%	-43%	-43%	-43%	0%	-43%

APPENDIX 9

Appendix 9.1:

Identification of BART-Eligible Sources in the State of Iowa

Source Category Name	Company Name	Facility Number	BART Emission Units
Fossil Fuel-fired Steam Electric Plant Individually Greater than 250 MMBtu/hour (Electrical Generating Units or EGUs). **Please note that these units are subject to the Clean Air Interstate Rule.**	Cedar Falls Utilities	07-02-005	Unit #7 (EU10.1A)
	Central Iowa Power Cooperative (CIPCO) - Summit Lake Station	88-01-004	Combustion Turbines (EU 1, EU 1G, EU2, EU2G)
	Central Iowa Power Cooperative (CIPCO) - Fair Station	70-08-003	Unit # 2 (EU 2 & EU 2G)
	City of Ames - Steam Electric Plant	85-01-006	Boiler #7 (EU 2)
	Interstate Power and Light - Burlington	29-01-013	Main Plant Boiler.
	Interstate Power and Light - Lansing	03-03-001	Boiler #4. Sixteen units in total.
	Interstate Power and Light - ML Kapp	23-01-014	Boiler #2. Six units in total.
	Interstate Power and Light - Prairie Creek	57-01-042	Boiler #4. Fourteen units in total.
	MidAmerican Energy Company - Council Bluffs	78-01-026	Boiler #3 (EU003)
	MidAmerican Energy Company - Neal North	97-04-010	Boilers #1-3 (EU001 - EU003)
	MidAmerican Energy Company - Neal South	97-04-011	Boiler #4 (EU003)
	Muscatine Power and Water	70-01-011	Boiler #8
	Pella Municipal Power Plant	63-02-005	Boilers #6-8
Chemical Process Plant	Equistar Chemicals	23-01-004	301 emission units
	Koch Nitrogen Company	94-01-005	Ammonia vapor flares and primary reformer/auxiliary boiler. Eight units in total.
	Monsanto Company Muscatine	70-01-008	Boilers #5-7. Fifty-seven emission units in total.
	Terra Nitrogen Port Neal Comp	97-01-030	Boiler B & Auxillary Boiler
Petroleum Storage and Transfer Units with a Total Storage	BP - Bettendorf Terminal	82-02-024	Truck loading.
	BP - Des Moines Terminal	77-01-158	Truck loading.
Portland Cement Plant	Holcim (US) Inc.	17-01-009	109 emission units
Fossil Fuel-fired Boiler	ADM	23-01-006	No. 7 & 8 Boilers. These boilers will be permanently shut down by 09/13/2008.
Iron and Steel Mills	Bloomfield Foundry, Inc.	26-01-001	18 emission units
	Griffin Pipe Products Co.	78-01-012	10 emission units
	John Deere Foundry Waterloo	07-01-010	37 emission units
	Keokuk Steel Castings, A Matrix Metals Company LLC	56-01-025	67 emission units
	The Dexter Company	51-01-005	Tumblers 5 & 6.
Secondary Metal Production	Alcoa, Inc.	82-01-002	Hot line mill. Eighty-seven emission units in total.

Best Available Retrofit Technology
Technical Support Documentation

Iowa Department of Natural Resources
Air Quality Bureau

May 2007
v1.7.2 (final)

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1. INTRODUCTION

1.1 PURPOSE

The following document details the methods and procedures applied by the Iowa Department of Natural Resources (IDNR) in assessing if a Best Available Retrofit Technology (BART)-eligible source is subject to BART. Specifically addressed are the mechanisms, analyses, and results which determine if a BART-eligible source can reasonably be anticipated to cause or contribute to any visibility impairment in any federally mandated Class I area.

1.2 BACKGROUND

On June 15th, 2005, the *"Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations"* final[1] rule was published in the Federal Register (70 FR 39104), amending 40 CFR Part 51 and creating Appendix Y. In conjunction with the Regional Haze rule (64 FR 35714) and the Clean Air Act, the BART rule[2] defines BART-eligible sources as: "those sources which have the potential to emit 250 tons or more of a visibility-impairing air pollutant, were put in place between August 7, 1962 and August 7, 1977, and whose operations fall within one or more of 26 specifically listed source categories." Following identification, the Clean Air Act (169A) requires a State to determine whether any BART unit "emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility in any [Class I] area." A BART-eligible source which causes or contributes to visibility impairment in any Class I area is subsequently subject to BART. BART is defined as an "emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for each pollutant which is emitted by an existing stationary facility" (40 CFR § 51.301). Following an affirmative subject to BART declaration, establishing BART emission limits requires consideration of five factors: 1) the cost of compliance; 2) energy and non-air quality environmental impacts; 3) existing pollution control technology in use at the source; 4) the remaining useful life of the source; and 5) the degree of improvement in visibility expected from the use of best available retrofit technology controls.

The BART rule provides thresholds defining the terms 'cause' and 'contribute': a single source which imparts a change in visibility of 1.0 (or more) deciviews at any Class I area is considered a cause of visibility impairment; a single source contributes to visibility impairment at (or above) the 0.5 deciview level. States are afforded the opportunity to enact more stringent de-minimus levels should they choose. The IDNR believes these thresholds to be adequate and will not propose alternatives. While States are offered discretion regarding the technical tools utilized in determining a single sources' impact on visibility impairment, the BART Guidelines establish implementation of the CALPUFF air quality modeling system as the preferred method. For BART-eligible sources located within Iowa, the CALPUFF modeling system is shown to be inadequate at reasonably characterizing their visibility impacts upon nearby Class I areas. IDNR is thereby implementing a multivariate system which includes Q/d screening methods, emission inventory scale analyses, CALPUFF model plant analyses, and regional scale one-atmosphere photochemical grid modeling.

---

[1] Minor technical and typographical errors were corrected in a memo published June 24th, 2005.

[2] Note: The final BART rule (70 FR 39104) may also be referred to as the BART Guidelines within this document.

2. BART-ELIGIBLE SOURCES

2.1 IDENTIFICATION

On February 21st, 2005, the Environmental Protection Commission adopted into the Iowa Administrate Code rule 567-22.9 *Special Requirements for Visibility Protection.* Effective as of April 20th, 2005, the rule established BART-eligible source identification procedures. BART-eligible sources were required to self-identify by completing and submitting BART-Eligibility Certification Form #542-8125 no later than September 1st, 2005. Information provided included: source identification, description of processes, potential emissions, emission unit and emission point characteristics, date construction commenced and date of startup. BART-eligible units were thus identified by rule through a source's duty to self-identify. On May 1st, 2007, rule 22.9 was amended[1] to clarify BART-eligible source category definitions. The original rule encompassed fossil–fuel boilers, or combinations thereof, totaling more than 250 million Btu per hour heat input. The rule was modified in accordance with the BART Guidelines to include only fossil–fuel fired boilers with an individual heat rate greater than 250 million Btu per hour. Our rule modification occurred successive to the required submittal date of the BART-Eligibility Certification Form, therefore IDNR staff reviewed all in-house permitting, Title V databases, and BART forms, to eliminate any source incompatible with the modified requirement. After final review of all submitted applications, 27 BART-eligible sources were identified. Table 2-1 lists the facilities operating BART-eligible units. A regional perspective is provided in Figure 2-1 while Figure 2-2 clarifies the individual BART-eligible facility locations.

2.2 CATEGORIZATION

Of the 27 facilities containing BART-eligible units, 13 facilities are classified as electrical generating units (EGUs). Each BART-eligible EGU is subject to the Clean Air Interstate Rule (CAIR) in terms of the annual sulfur dioxide (SO2) trading rules as well as the annual and seasonal oxides of nitrogen (NOx) trading rules. As explained in the BART Guidelines and codified at 40 CFR § 51.308(e)(4), EPA has determined participation in CAIR may serve as a substitute to BART. Specifically, participation in CAIR achieves BART requirements in terms of NOx and SO2 emission limits given participation in SO2 and NOx trading rules. IDNR is utilizing CAIR in lieu of BART respective of BART-eligible EGU NOx and SO2 emissions.

The Clean Air Interstate Rule is limited in terms of a negative subject to BART declaration as CAIR does not address all five[2] visibility impairing pollutants, nor are non-EGU sources addressed. Therefore BART-eligible EGU particulate matter (PM), volatile organic compounds (VOC), and ammonia (NH3) emissions must be evaluated. Additionally, subject to BART determinations for the 14 non-EGU BART-eligible sources require the consideration of all five visibility impairing pollutants. The following chapters thus focus upon the methods and results associated with determining if any emissions of visibility impairing pollutants from a non-EGU BART-eligible source, or if any PM, VOC, or NH3 BART-eligible EGU emissions, may be reasonably anticipated to cause or contribute to visibility impairment at any Class I area.

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[1] Concurrently rule 22.9 was expanded to address regional haze program requirements as in 40 CFR § 51.308.

[2] SO2, NOx, VOC, particulate matter, and NH3

Table 2-1. Iowa's BART-Eligible facilities.

Source Category Name	Facility Number	Facility Name	BART Emission Units	BART Unit Count
Fossil Fuel-fired Steam Electric Plant Individually Greater than 250 MMBtu/hour (Electrical Generating Units or EGUs). **Note: These units are subject to the Clean Air Interstate Rule.**	07-02-005 Cedar	Falls Utilities	Streeter Unit #7 (EU10.1A)	1
	88-01-004	Central Iowa Power Cooperative (CIPCO) - Summit Lake	Combustion Turbines (EU1, EU1G, EU2, EU2G)	4
	70-08-003	Central Iowa Power Cooperative (CIPCO) – Fair Station	Unit # 2 (EU2 & EU2G)	2
	85-01-006	City of Ames - Steam Electric Plant	Boiler #7 (EU2)	1
	29-01-013	Interstate Power and Light - Burlington	Main Plant Boiler. Twenty-one units in total.	21
	03-03-001	Interstate Power and Light - Lansing	Boiler #4. Sixteen units in total.	16
	23-01-014	Interstate Power and Light - ML Kapp	Boiler #2. Six units in total.	6
	57-01-042	Interstate Power and Light - Prairie Creek	Boiler #4. Fourteen units in total.	14
	78-01-026	MidAmerican Energy Company - Council Bluffs	Boiler #3 (EU003)	1
	97-04-010	MidAmerican Energy Company - George Neal North	Boilers #1-3 (EU001 - EU003)	3
	97-04-011	MidAmerican Energy Company - George Neal South	Boiler #4 (EU003)	1
	70-01-011	Muscatine Power and Water	Boiler #8	1
	63-02-005	Pella Municipal Power Plant	Boilers #6-8	3
Chemical Process Plant	23-01-004	Equistar Chemicals	301 emission units	301
	94-01-005	Koch Nitrogen Company	Ammonia vapor flares and primary reformer/auxiliary boiler. Eight units in total.	8
	70-01-008	Monsanto Company Muscatine	Boilers #5-7. Fifty-seven emission units in total.	57
	97-01-030	Terra Nitrogen Port Neal	Boiler B & Auxiliary Boiler	2
Petroleum Storage and Transfer Units[1]	82-02-024	BP - Bettendorf Terminal	Truck loading	1
	77-01-158	BP - Des Moines Terminal	Truck loading	1
Portland Cement Plant	17-01-009	Holcim (US) Inc.	109 emission units	109
Fossil Fuel-fired Boiler	23-01-006	ADM (Clinton)	No. 7 & 8 Boilers. These boilers will be permanently shut down by 09/13/2008.	2
Iron and Steel Mills	26-01-001	Bloomfield Foundry, Inc.	18 emission units	18
	78-01-012	Griffin Pipe Products Co.	10 emission units	10
	07-01-010	John Deere Foundry Waterloo	37 emission units	37
	56-01-025	Keokuk Steel Castings, A Matrix Metals Company LLC	67 emission units	67
	51-01-005	The Dexter Company	Tumblers 5 & 6	1
Secondary Metal Production	82-01-002	Alcoa, Inc.	Hot line mill. Eighty-seven emission units in total.	87

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[1] Total storage capacity exceeding 300,000 barrels.

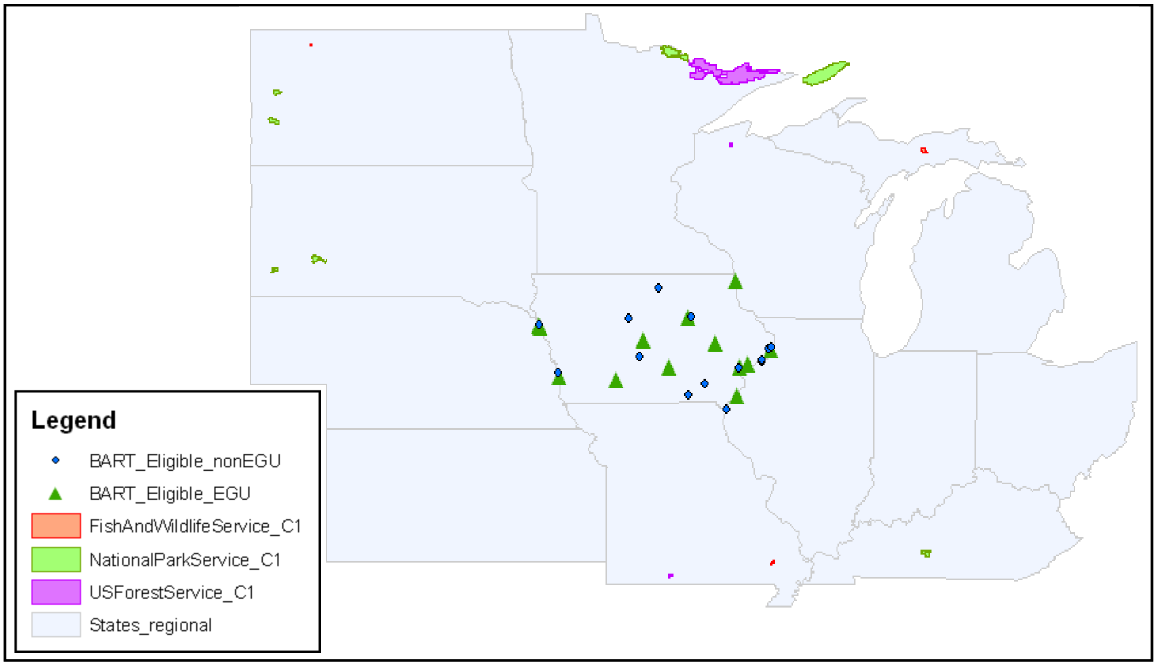

Figure 2-1. Regional overview of BART-eligible facilities within Iowa.

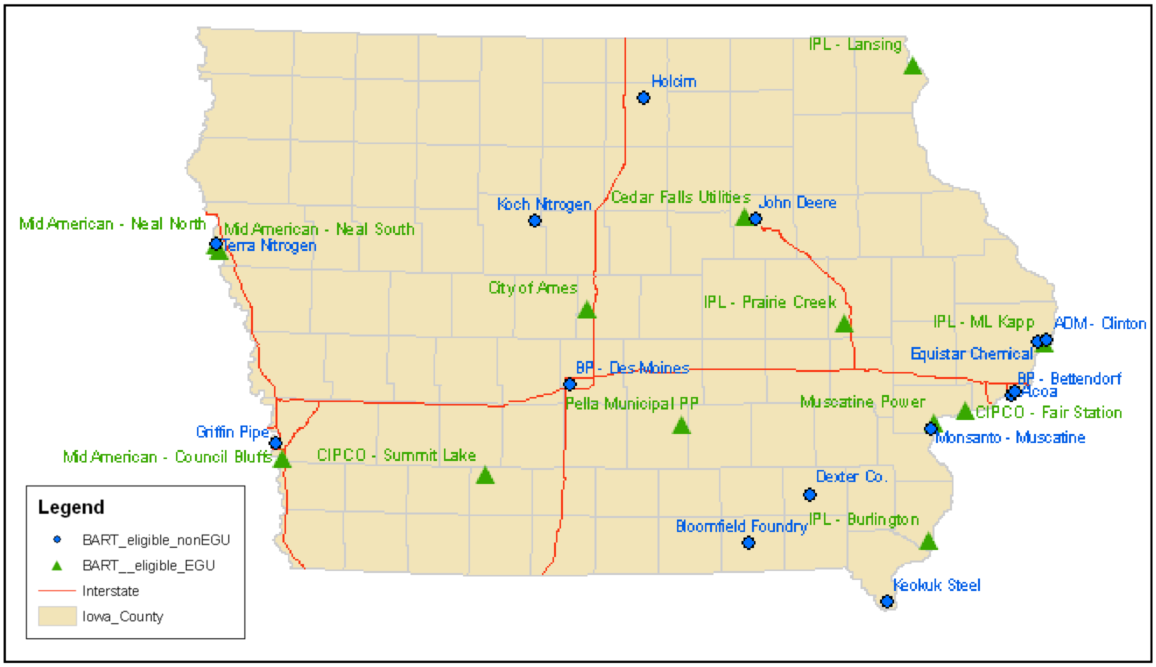

Figure 2-2. Individually labeled and categorized (EGU/non-EGU) BART-eligible facility locations.

3. SUBJECT TO BART METHODOLOGY

3.1 INTRODUCTION

In order to remain consistent with the guidelines established in the BART rule, the IDNR devoted extensive personnel and computational resources toward implementation of the CALPUFF modeling system in development of a scientifically sound modeling protocol for subject to BART determinations. Iterative CALPUFF simulations were investigated to identify a refined configuration capable of accurately characterizing a BART-eligible source's visibility impact upon nearby Class I areas. After considerable study IDNR has concluded that the preferred source-specific/receptor-specific application of the CALPUFF modeling system fails to provide technically defensible results for applications unique to Iowa facilities.

Sources within Iowa's borders share the distinct geographical characteristic where they are assured that the separation distance to the border of their nearest Class I area will exceed 300 kilometers (see Figure 3-1). In reference to Iowa's BART-eligible sources (see Table 2-1), the minimum separation distance is 392 km with an average of approximately 516 km. IDNR acknowledges CALPUFF has been adopted by EPA in the Guideline on Air Quality Models (40 CFR Part 51 Appendix W) as the preferred model for assessing long range transport of pollutants and their impacts on federal Class I areas. IDNR agrees CALPUFF is suited for a variety of single-source impact analyses, however, IDNR has not identified data or studies supporting the appropriateness of CALPUFF in applications with minimum transport distances of nearly 400 km.

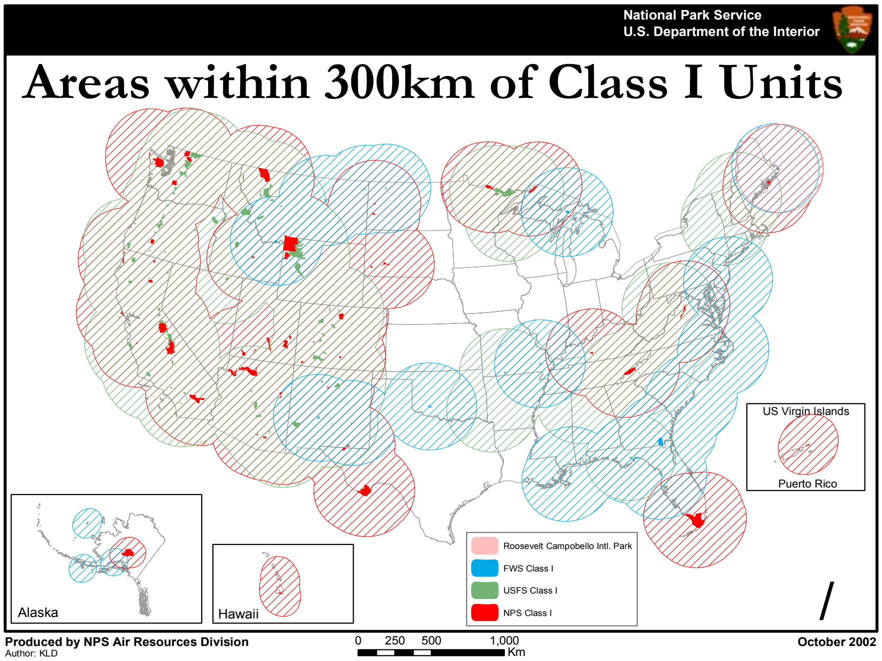

Figure 3-1. Areas within 300 km of a Class I area. Iowa is the only state whose border does not intersect a 300 km buffer zone.

Through design and implementation CALPUFF is typically configured to err conservatively in the prediction of ambient air pollutant concentrations. However, the levels of conservatism encountered by the IDNR are more appropriately described as model bias. As noted in the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 report (EPA, 1998):

> *"...there are serious conceptual concerns with the use of puff dispersion for very long-range transport (300 km and beyond). As the puffs enlarge due to dispersion, it becomes problematic to characterize the transport by a single wind vector, as significant wind direction shear may well exist over the puff dimensions."*

IDNR has implemented puff-splitting in an attempt to alleviate the errors, however, as noted in the CENRAP BART Modeling Guidelines (Alpine Geophysics, 2005):

> *"Detailed guidance on when and how the puff-splitting algorithm should be used and actual verification studies demonstrating that the technique operates as intended are not discussed in the model documentation or presented in the science literature."*

The IDNR chose to investigate puff-splitting as a potential means of justifiably retaining a traditional CALPUFF implementation. The investigation confirmed the hypothesis that puff-splitting would reduce maximum impacts versus an otherwise identical simulation. For example, puff-splitting reduced the twenty-four hour averaged maximum deciview (dv) impacts[1] an average of 0.14 dv. Unfortunately the costs associated with puff-splitting involve a near 60-fold increase in run-time, while serious abnormalities remained in the solutions. Figure 3-2 depicts maximum deciview impacts as a function of distance. These results were generated from ten independent simulations, with each run employing puff splitting. A single theoretical source located in central Iowa was modeled, with emissions of 2500 tons per year (tpy) of NOx and SO2 each and 50 tpy of PM. Discrete concentric receptors separated by one degree were defined. Only one variable, the radius of the receptor ring, was modified between runs. Beyond approximately 450 km, maximum impacts increase monotonically. These results are non-physical given the operational design and chemical mechanisms of the CALPUFF modeling system. As the majority of Iowa BART sources are positioned beyond 450 km from their nearest Class I area, application of CALPUFF will be limited to a model plant approach in which source-receptor distances remain below 450 km. Such constraints minimize the importance of CALPUFF transport mechanisms while simultaneously avoiding interpretation of results which are highly suspect of unacceptable overprediction.

3.2 VARIEGATED ASSESSMENT

Given the concerns associated with application of the CALPUFF modeling system in a setting which may exceed its operational design, the IDNR is utilizing a multivariate approach in the subject to BART determination process as an alternative to sole reliance upon the CALPUFF modeling system. CALPUFF will be used in a model plant approach in order to generate emission rate thresholds which inform subject to BART determination decisions. In the near term, simple screening procedures are conducted using Q/d methodology. A third phase of the multiform approach includes a variety of assessments utilizing the CAMx regional scale one-atmosphere model. The final mechanism completing the weight of evidence approach involves emission inventory scale analyses.

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[1] Generated using the configuration relative to Figure 3-2 with a receptor radius of 425 km. The 0.14 dv reduction represents the average of the seven differences calculated for each Class I area indicated in Figure 3-2.

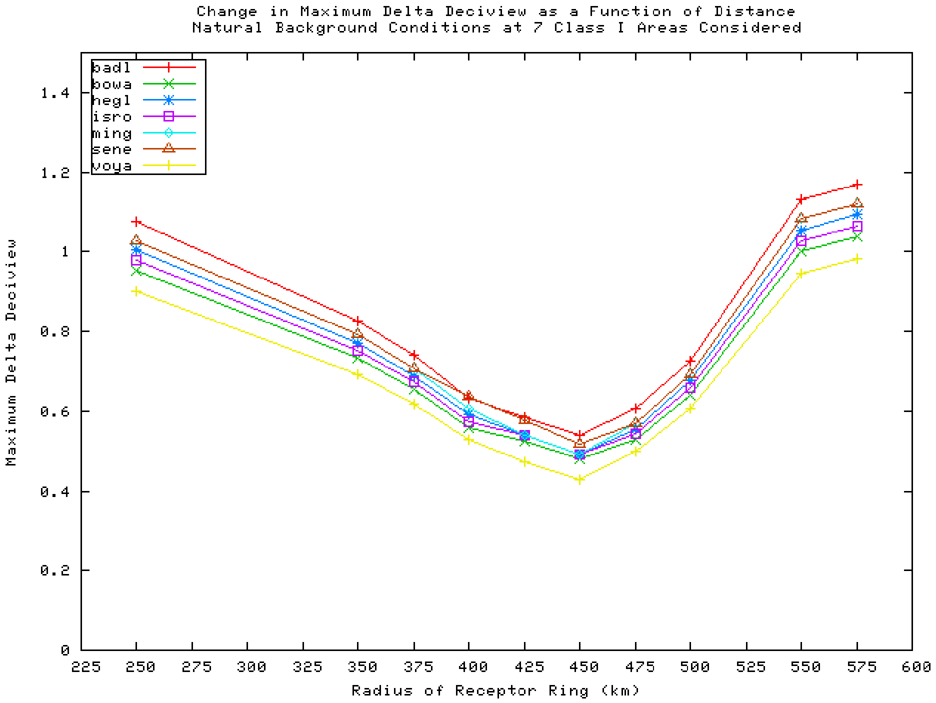

Figure 3-2. Maximum deciview impacts as a function of distance. Generated using the IDNR model plant configuration with 2500 tpy of SO2 and NOx emissions each, and 50 tpy of PM (modeled as PM2.5), for calendar year 2002. Results from seven Class I areas are depicted. (Class I variations reflect site specific f(RH) data only and are not dependent upon actual spatial location. Data evaluated against annually averaged natural background conditions. (The model plant configuration is explained further in Chapter 5.)

4. Q/D METHODOLOGY

4.1 CALCULATION

A Q/d (emissions divided by distance) screening approach is used to determine those sources which are probable candidates for exclusion from BART. Emissions, designated as Q (in tons per year), represent the summation of emissions across all BART-eligible units at a given facility. The value "d" (specified in kilometers) is determined as the distance between the location of the BART source and the nearest Class I area gridded 1 km receptor. The Class I area 1 km receptor database[1] was developed by the National Park Service (NPS) and includes all Class I areas in the contiguous 48 states. An improved approach[2] to spherical trigonometry, as described by Sinnott (1984), was utilized to calculate the separation distance between a BART facility and the nearest Class I area 1 km discrete receptor. The NPS receptor data serve as an accurate proxy to GIS derived border data, and accommodate calculation of Q/d through spreadsheets. An independent check of the distance calculations was conducted through implementation of GIS techniques. The review revealed near perfect agreement (Gail George of the IDNR, personal communication, 2005).

The Q/d values calculated for each of the 14 non-EGU[3] BART-eligible sources are provided in Table 4-1 with the nearest Class I area listed in Table 4-2. Q/d calculations are compiled for both potential and actual emissions. Potential emissions include only BART-eligible units while actual emissions represent facility wide totals, thus in certain cases actual emissions may exceed potentials. Although EPA proposed potential PM2.5 emissions be included in the summation of Q, PM2.5 emission rates are unavailable. PM10 emissions were selected as a surrogate. Q therefore sums NOx, SO2 and PM10 emissions.

4.2 EVALUATION

The Q/d values for three prescribed constants are compared against a significance level of 1. Standard procedures, such as the "Screening Threshold" method for Prevention of Significant Deterioration (PSD) modeling originally developed by the North Carolina Department of Environment and Natural Resources (1985), have typically used a constant of 20. The IDNR has calculated Q/20d as well as the more conservative Q/10d (utilization of Q/10d values is common practice by the NPS in PSD increment consumption analyses). Further conservatism is incorporated through calculation and consideration of Q/5d values. As indicated above, Q/d values are provided for both potential and actual emissions.

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[1] Data available at: http://www2.nature.nps.gov/air/Maps/Receptors/index.cfm

[2] Method available at: http://tchester.org/sgm/analysis/peaks/how_to_get_view_params.html

[3] Due to CAIR, Q/d values for EGUs were not evaluated.

Table 4-1. Q/d values for non-EGU BART-eligible sources.

Facility Number	Facility Name	Distance (km)	BART Units Potential Emissions (tpy)							Facility Wide Actual Emissions (tpy)						
			SO2	NOx	PM 10	VOC	Q/20D	Q/10D	Q/5D	SO2	NOx	PM 10	VOC	Q/20D	Q/10D	Q/5D
23-01-004	Equistar Chemicals	531.2	3,883	3,433	258	17,894	0.71	1.43	2.85	1	728	52	2,310	0.07	0.15	0.29
94-01-005	Koch Nitrogen Company	615.4	40	1,399	23	11	0.12	0.24	0.48	0	442	20	2	0.04	0.08	0.15
70-01-008	Monsanto Company Muscatine	486.8	430	168	81	153	0.07	0.14	0.28	465	192	8	16	0.07	0.14	0.27
97-01-030	Terra Nitrogen Port Neal	487.6	1	916	325	5	0.13	0.25	0.51	1	461	33	19	0.05	0.10	0.20
82-02-024	BP - Bettendorf Terminal	499.9	0	0	0	298	0.00	0.00	0.00	0	0	0	153	0.00	0.00	0.00
77-01-158	BP - Des Moines Terminal	547.0	0	0	0	301	0.00	0.00	0.00	0	0	0	169	0.00	0.00	0.00
17-01-009	Holcim (US) Inc.	527.1	28,715	4,738	1,000	27	3.27	6.54	13.07	3,826	2,813	190	15	0.65	1.30	2.59
23-01-006	ADM (Clinton)	531.9	6,051	2,117	507	8	0.82	1.63	3.26	6,479	5,003	1,272	2,790	1.20	2.40	4.80
26-01-001	Bloomfield Foundry, Inc.	448.8	136	68	605	64	0.09	0.18	0.36	1	0	22	3	0.00	0.01	0.01
78-01-012	Griffin Pipe Products Co.	563.6	190	235	211	586	0.06	0.11	0.23	2	88	111	260	0.02	0.04	0.07
07-01-010	John Deere Foundry Waterloo	588.8	0	0	285	172	0.02	0.05	0.10	9	21	99	115	0.01	0.02	0.04
56-01-025	Keokuk Steel Castings	392.0	11	72	554	406	0.08	0.16	0.32	4	9	67	111	0.01	0.02	0.04
51-01-005	The Dexter Company	468.9	0	0	541	0	0.06	0.12	0.23	29	3	112	11	0.02	0.03	0.06
82-01-002	Alcoa, Inc.	501.8	15	400	1,092	317	0.15	0.30	0.60	2	137	209	296	0.03	0.07	0.14

Table 4-2. Nearest Class I area for non-EGU BART-eligible facilities.

Facility Name	Nearest Class I Area	Distance (km)	Facility Name	Nearest Class I Area	Distance (km)
Equistar Chemicals	Mingo	531.2	ADM (Clinton)	Mingo	531.9
Koch Nitrogen Company	Boundary Waters Canoe Area	615.4	Bloomfield Foundry, Inc.	Hercules-Glades	448.8
Monsanto Company Muscatine	Mingo	486.8	Griffin Pipe Products Co.	Hercules-Glades	563.6
Terra Nitrogen Port Neal	Badlands	487.6	John Deere Foundry Waterloo	Boundary Waters Canoe Area	588.8
BP - Bettendorf Terminal	Mingo	499.9	Keokuk Steel Castings	Mingo	392.0
BP - Des Moines Terminal	Hercules-Glades	547.0	The Dexter Company	Mingo	468.9
Holcim (US) Inc.	Boundary Waters Canoe Area	527.1	Alcoa, Inc.	Mingo	501.8

4.3 RESULTS

The non-EGU BART-eligible sources are easily classified into three groups based upon the Q/d evaluation. Facilities clearly exceeding the 1.0 threshold, sources well below the threshold, and those with mixed results. Holcim and ADM (Clinton) exceed 1 in almost every Q/d calculation and clearly require more refined analyses. Alternatively, the majority of non-EGU facilities remain well below the screening threshold in all six Q/d tests. The eleven facilities listed in Table 4-3 yield Q/d values well below 1.0 at even the most stringent potential to emit Q/5d evaluation and subsequently are unlikely to be considered subject to BART. This conclusion is further supported through evaluation of the Q/d values based upon facility-wide actual emissions. The actual emission Q/5d values average 0.09, with the upper limit established by Monsanto Company Muscatine at only 0.27. These low values suggest any emission reductions would be imperceptible at the nearest Class I area.

Table 4-3. Non-EGU BART-eligible facilities significantly below all Q/d screening thresholds.

Koch Nitrogen Company
Monsanto Company Muscatine
Terra Nitrogen Port Neal
Bloomfield Foundry, Inc. The
BP - Bettendorf Terminal
BP - Des Moines Terminal

Griffin Pipe Products Co.
John Deere Foundry Waterloo
Keokuk Steel Castings
Dexter Company
Alcoa, Inc.

Equistar Chemical initially emerges in a gray area. Considering potential emissions, the Q/20d value is 0.71 with Q/10d and Q/5d exceeding 1.0. Actual emissions reveal a different situation. The most conservative value, Q/5d, remains well below 1 at 0.29. Equistar Chemical reported facility wide SO2 emissions in 2002 at one ton per year, with NOx emissions of 728 tpy. As shown in Table 4-2, the nearest Class I area receptor is located within the Mingo Wilderness Area, at a distance of approximately 531 km. By definition, the great transport distance in combination with low actual emissions produced the low Q/d value. Under these circumstances, Equistar Chemical remains unlikely to be considered subject to BART. Prior to any subject to BART exemption, results from additional analyses will be considered.

5. CALPUFF MODEL PLANT

5.1 INTRODUCTION

Implementation of the CALPUFF modeling system occurs through a 'model plant' assessment for screening sources which are not reasonably anticipated to cause or contribute to visibility impairment at nearby Class I areas. The IDR model plant analyses follow the theory outlined in the technical support documentation (EPA, 2005b) referenced in the BART Guidelines. The IDNR model plant configuration utilizes methods similar to those incorporated in more traditional (refined) BART applications, and follows the IDNR CALPUFF protocol[10] (2005). Primary asymmetries between refined evaluation and the IDNR model plant approach include utilization of a representative plant (*e.g.* idealized stack parameters and centralized location) and a ring of receptors around the model plant versus source specific stack parameters coupled with receptors located within Class I areas. A detailed description of the IDNR model plant configuration is provided within Section 5.2.

5.2 MODELING SYSTEM CONFIGURATION

Application of the CALPUFF modeling system, whether in a model plant framework or a site specific application, requires the completion of four operational tasks:

1) developing a three dimensional modeling domain
2) generation of meteorological fields appropriate for CALPUFF simulations
3) specification of appropriate options within modeling system control files
4) quantitatively (in terms of deciviews) characterizing the visibility impairment attributable to a BART-eligible source upon nearby Class I areas

Successful implementation of the modeling system involves refinement of model configuration parameters and generation of complex meteorological datasets. To assist with the process, EPA recommends following the IWAQM Phase 2 framework. EPA recognizes the IWAQM framework may be unsuitable in certain situations, such as those involving extensive transport distances, thus States are not restricted from making appropriate modifications. As all BART-eligible sources within the State of Iowa share the unique geographical characteristic where the separation distance between a source and the nearest neighboring Class I area exceeds ~390 kilometers, not all IWAQM recommendations are appropriate. Deviations from the IWAQM recommendations deemed necessary to provide a more robust analysis or conserve computational and/or personnel resources, while maintaining technical defensibility, are noted.

5.2.1 VERSION CONTROL

Based upon verbal comments received from EPA Region VII, the IDNR implemented a beta[11] version of the CALPUFF modeling system. Table 5-1 details the version and level uniquely defining each program. Processor arrangement in Table 5-1 corresponds to the order in which the programs are invoked.

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[10] For completeness, the detail of the IDNR 2005 CALPUFF protocol has been incorporated in this document.

[11] Beta at the time of implementation.

Table 5-1. Specification of the version and level of the CALPUFF modeling system processors used by the IDNR.

Processor	Version	Level
TERREL	3.311	030709
CTGCOMP[12]	not used	
CTGPROC	2.42	030709
MAKEGEO	2.22	030709
CALMM5	2.4	050413
CALMET	5.53a	040716
CALPUFF	5.711a	040716
POSTUTIL[13]	1.4	040818
CALPOST	5.51	030709

5.2.2 TERREL

The TERREL processor constructs the basic properties of the gridded domain and subsequently defines the coordinates upon which meteorological data are stored. Key assignments include grid type, location, resolution, and terrain elevation. Grid type is a Lambert Conic Conformal (LCC) projection centered at 97 degrees West longitude, 40 degrees North latitude, with true latitudes of 33 and 45 degrees north. CALMET meteorological processing is computed upon the LCC projection with 171 by 165 horizontal grid cells at 12 km resolution. Computational burden reduction and boundary artifact minimization requires the CALPUFF domain consist of a subset of the CALMET domain. Nine grid cells (108 km) were eliminated along each boundary. Figure 5-1 depicts the horizontal attributes of the CALMET and CALPUFF modeling domains in reference to the 36 km Regional Planning Organizations (RPO) meteorological modeling domain. Table 5-2 provides the LCC specifications for each domain.

Terrain elevation is assigned using 30 second GTOPO data. To ensure comprehensive disclosure of all model configuration options related to TERREL, Appendix 10.1 provides a complete listing of control script variables and their assigned values.

5.2.3 CTGPROC

Land use categories for each grid cell are assigned using CTGPROC. The primary variable adjustment associated with CTGRPOC is selection of an appropriate land use database. Version 1.2 of the North American Land Cover Characteristics database is recommended and a model ready version of this dataset was used.[14] Appendix 10.2 provides further guidance regarding the CTGPROC control file configuration.

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[12] The CTGCOMP processor was not required as the North American landuse file was obtained from the CALPUFF Training Course CD distributed during the CENSARA sponsored CALPUFF training held in Kansas City, November 17-19, 2003.

[13] Obtained from Kirk Baker with the Lake Michigan Air Directors Consortium.

[14] Obtained from the CALPUFF Training Course CD distributed during the CENSARA sponsored CALPUFF training held in Kansas City, November 17-19, 2003.

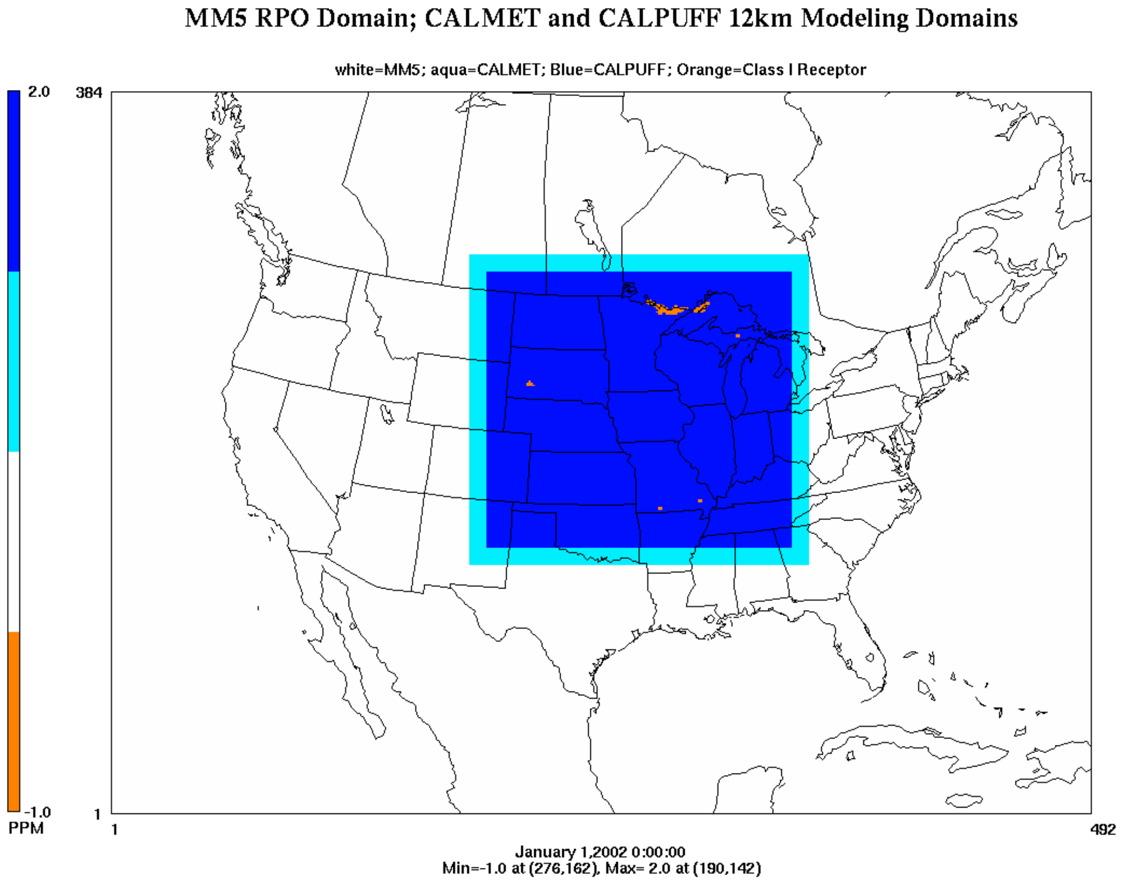

Figure 5-1. The dark blue area depicts the horizontal attributes of the CALPUFF modeling domain. Boundary cells modeled within CALMET and excluded in CALPUFF are indicated in aqua. The background map represents the RPO 36 km MM5 domain. Grid cells which contain a 1 km Class I area receptor (flagged for evaluation) are indicated in orange.

Table 5-2. Lambert Conic Conformal modeling domain specifications. (Referencing MM5 terminology, the coordinate data represent 'dot' points, while the number of grid cells refers to 'cross' points.)

Domain	**Southwest Coordinate**	**Northeast Coordinate**	**Number of X grid cells**	**Number of Y Grid Cells**	**Resolution**
MM5	(-2952.0, -2304.0)	(2952.0, 2304.0)	164	128	36 km
CALMET	(-792.0,-720.0)	(1260.0,1260.0)	171	165	12 km
CALPUFF	(-684.0,-612.0)	(1152.0,1152.0)	153	147	12 km

5.2.4 MAKEGEO

As stated in the control file: "MAKEGEO creates the geophysical data file for CALMET. Using the fractional land use data from CTGPROC, it calculates the dominant land use for each cell and computes weighted surface parameters". Generating the appropriate MAKEGEO.INP control file requires only minimal alteration of the default assignments. Key modifications include specifying domain attributes and ensuring input files are correctly referenced. Appendix 10.3 provides complete detail regarding the IDNR control script configuration.

5.2.5 CALMM5

The meteorological data incorporated within the model plant analyses originates with three annual MM5 mesoscale meteorological simulations, covering the years 2002-2004. The 2002 MM5 data was generated by the IDNR, while years 2003 and 2004 were supplied by Kirk Baker with the Lake Mike Michigan Air Directors Consortium (LADCO). The IDNR 2002 dataset has been evaluated by several reviewers (Johnson, 2007; Baker et al., 2004; Baker, 2005; and Kemball-Cook et al., 2005) and was found appropriate for implementation in regional air quality modeling studies. Through independent evaluation, K. Baker has completed a model evaluation of years 2003 & 2004, and found the meteorology to be of the same quality as other datasets currently employed in regional scale one-atmosphere modeling efforts (Baker, 2005).

CALMM5 prepares the MM5 data for CALMET ingestion. Configuration is intuitive as only a minimal number of variables are available for user modification. Two settings are of primary importance: 1) All vertical layers from MM5 were extracted, providing CALMET configuration flexibility. 2) Of the five fields CALMM5 is capable of extracting, four were obtained: vertical velocity, relative humidity, cloud/rain fields, and ice/snow fields. Graupel was not available in the MM5 datasets. Appendix 10.4 contains a representative control file.

5.2.6 CALMET

CALMET configuration begins with the recommendations published in the IWAQM Phase 2 report. The authors of the IWAQM report and EPA recognize a 'cookbook' approach is rarely proper. When deemed appropriate for reasons of scientific validity or for resource constraint issues, the IDNR CALMET configuration differs from the IWAQM settings. Modifications are discussed below. Appendix 10.5 contains a robust comparison between the IDNR configuration and the recommendations from the IWAQM Phase 2 report.

5.2.6.1 METEOROLOGICAL DATA DISCUSSION

Meteorological data sources are the primary point of disparity between the IWAQM recommendations and the IDNR configuration. The IDNR utilized three annual MM5 simulations (2002, 2003, and 2004) as the sole source for CALMET input meteorological data. Blending MM5 and observational data within CALMET was originally viewed as an unnecessary redundancy considering the numerous mesoscale meteorological modeling advances made since publication of the IWAQM Phase 2 report. The Penn State University/National Center for Atmospheric Research Meteorological Model has evolved from MM4 to MM5. MM5 features new land surface models, new/updated physics parameterizations, bug fixes, and is generally configured with higher model resolution, all of which contribute to improved model performance.

Substantial gains in MM5 initialization data quality and four-dimensional data assimilation (FDDA) techniques, through utilization of Eta objective analyses, also surface as key improvements which would appear to diminish the need for additional CALMET processing of National Weather Service (NWS) data. FDDA was applied in each annual MM5 simulation with surface winds and several state variables above the PBL nudged toward observations. Generation of the FDDA datasets requires incorporating the NWS surface and upper air data with the Eta data, a requirement viewed to be redundant by many meteorological modelers as the complexity, resolution, and accuracy of the Eta data exceeds that of traditional initialization sources such as the ECMWF datasets. The Eta data consists of 3-hourly, 40km objective analysis fields computed using an extensive supply of observational data. In addition to the standard NWS surface and upper air data, data sources include: GOES (satellite) precipitable water; VAD wind profiles from NEXRAD; ACARS aircraft temperature data; SSM/I oceanic surface winds; daily NESDIS 23-km snow cover and sea-ice analysis data; RAOB balloon drift; GOES and TOVS-1B radiance data; 2D-VAR sea surface temperature data from the NCEP Ocean Modeling Branch; radar estimated rainfall; and surface rainfall. Obtaining and preparing the NWS data for blending within CALMET was therefore originally viewed as purely extraneous. These assumptions were shown to be incorrect when CALMET performance as a function of meteorological data was investigated by Bret Anderson. B. Anderson (2006) discovered performance issues exist within the CALMET/CALPUFF system if CALMET digests only MM5 data (the 'No-Obs' approach). The preferred alternative re incorporates the NWS observational data into the MM5 solution within the CALMET processor.

The findings were quickly released once discovered; unfortunately the timing remained well past the completion date of the IDNR model plant analyses. Recognizing that reconstruction of all CALPUFF analyses with the preferred approach was not feasible given time and resource constraints, regeneration of the model-plant results was not required. IDNR acknowledges any subsequent CALPUFF analyses will require avoidance of No-Obs. While the CALMET data utilized by IDNR is not an ideal dataset, the model plant approach may reduce the impacts of the errors, as: 1) specific transport pathways are not considered; and 2) the model-plant approach utilizes results from the receptor reporting the greatest impact, co-location within a Class I area is not required.

5.2.6.2 VERTICAL STRUCTURE

The vertical structure of the IDNR CALMET configuration deviates from the IWAQM recommendation to remain consistent with MM5. The IDNR vertical structure was designed to reduce vertical interpolation while simultaneously improving vertical resolution within the planetary boundary layer (PBL). Table 5-3 specifies the 13 layer interfaces defining the IDNR 12 layer vertical structure. With the exception of the interfaces at 20 and 40 meters, all values correspond to an MM5 interface. The model top in the CALMET simulation is 3448 meters, which also corresponds to the maximum mixing height. Given that PBLs regularly exceed 3000 meters over the Dakotas and arid regions in the western third of the IDNR CALMET domain, the PBL increase is appropriate.

Table 5-3. Vertical resolution as defined through 13 layer interfaces. Heights are in meters.

Layer number	**Layer Height**	**Layer number**	**Layer Height**
0 0.		7 1071.	
1 20.		8 1569.	
2 40.		9 2095.	
3 73.		10 2462.	
4 146.		11 2942.	
5 369.		12 3448.	
6 598.			

5.2.6.3 PARAMETERIZATIONS

Kinematic terrain effects were enabled in response to the interpolation between the 36 km MM5 and 12 km CALMET domains. Higher resolution is not being sought as: 1) the lack of topological features within and near the State of Iowa does not warrant the additional processing; and 2) interpolation of 36 km meteorological fields to a resolution finer than 12 km raises conceptual concerns. While terrain features further downwind and within specific Class I areas may differ from Iowa's relatively flat topology, given extensive transport distances, a realistic expectation of pollutant transport includes sufficient mixing and shear across the plume such that low concentration gradients occur around candidate Class I areas, subsequently reducing the impacts of downwind topology. In addition, application of CALPUFF in the model plant configuration eliminates the evaluation of plume concentrations at specific Class I area receptors. A more conservative approach is taken as the analysis focuses only upon maximum impacts, with no preference to receptor location. This methodology is discussed further under the CALPUFF configuration section (5.2.7).

5.2.6.4 REMAINING ASYMETRIES

The following bullets summarize the residual differences between the IDNR and IWAQM recommended CALMET configurations.

- Gridded cloud data is being inferred from the MM5 relative humidity fields, a process not invoked in IWAQM. As discovered by Anderson (2006), when incorporated with the No-Obs approach, this methodology leads to simulation error. However, EPA Region VII is not requiring regeneration of the CALMET fields to correct this methodology given discovery date and project timelines.
- Given that all state variables are MM5-derived, surface layer winds were not extrapolated to the upper layers (the IDR configuration uses IEXTRP = -1), whereas the IWAQM recommends similarity theory in surface layer wind extrapolation.
- The radius of influence regarding terrain features is equidistant to the resolution of the processed terrain data: 12 km.
- The radius of influence for temperature interpolation is set to 36 km (TRADKM), a value considered appropriate given the 12 km CALMET domain and 36 km MM5 domain.
- The beginning/ending land use categories for temperature interpolation over water are assigned category 55: (JWAT1 = JWAT2 = 55).

- SIGMAP was set to 50 km, while the IWAQM recommendation is 100 km. However, as precipitation rates are incorporated from the MM5 data, a lower radius of influence is deemed appropriate by the IDNR.
- Note, while the BIAS array equals NZ*0 in the IDNR control file, CALMET reassigns BIAS(1) = -1 (i.e. upper air data not used in layer 1); and BIAS(2) = +1 (i.e. the surface data is not extrapolated vertically).
- The MM5 wind fields supply CALMET with the initial guess fields to the diagnostic wind model (IWFCOD =1, IPROG = 14) and observational data are not reintroduced. The following variables therefore have no impact upon the simulation and are provided solely for completeness:
    - The minimum distance for which extrapolation of surface winds should occur is set to -1 (RMIN2 = -1.).
    - RMIN is left at the IWAQM recommendation of 0.1 km.
    - RMAX1 and RMAX2 are each assigned a value of 30 km. RMAX3 is assigned a value of 50 km.
    - R1 and R2 were each assigned the value of 1.0.
    - ISURFT and IUPT are assigned placeholder values of 4 and 2, respectively.

5.2.7 CALPUFF

Unlike traditional CALPUFF implementations which rely upon receptors confined to Class I areas, the model plant analysis evaluates impacts independent from Class I area location. Discrete receptors are located at evenly spaced intervals equidistant from the model plant. Visually, the receptors comprise a ring around the plant. Only two variables are required to define the ring, distance from the stack to the ring (radius) and the spacing of the receptors relative to one another. In defining the IDNR receptors, Figure 3-2 was consulted. A radius of 425 km was selected, as this value maintains some conservatism by avoiding the trough of the curve (where impacts are minimized) while simultaneously avoiding distances (above ~450 km) where impacts are highly suspect. To ensure thorough receptor density at this distance, one degree separation was chosen, yielding 360 receptors per simulation. In terms of the visibility contribution analysis, the model plant configuration assumes each receptor to be located in a Class I area, and the receptor reporting the highest impact is utilized.

The initial CALPUFF configuration resembles the recommendations of the Phase 2 IWAQM report, as related to refined (versus screening) analyses. While Section 2.0 of the IWAQM documentation recommends using time and space varying ozone concentrations, IDNR methods deviate. As the application of CALPUFF is occurring within a model plant framework, receptor location is not critical thus no real advantage is gained through the application of prognostic models to develop spatially dependent pollutant concentration fields. Similarly, retrieval of ozone monitoring network data is not viewed as advantageous as observing stations trend toward urban centers and thus are not representative of the conditions found in the predominantly rural IDNR domain. As an alternative, background ozone concentrations of 40 ppb are prescribed across the modeling domain. An analysis of ozone data collected at Lake Seguma, IA, for the 2003[15] ozone modeling season, supports this conclusion. The monthly averages of the one-hour ozone concentrations at Lake Seguma ranged from 21 to 39 ppb. Forty ppb is selected as an

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[15] 2003 data was analyzed as a complete year of NH3 data was available, and utilizing co-located (time and space) NH3 and ozone data was viewed as advantageous.

accurate, yet slightly conservative value, as the seasonal average was found to be 31 ppb. Analysis of the NH3 data collected at Lake Seguma yielded an annual average concentration of 3 ppb. Incorporation of monthly varying NH3 concentrations was considered; however, as the version of CALPOST utilized does not take such variation into consideration, the default NH3 background concentration was assigned as 3 ppb. Appendix 10.6 contains a robust comparison between the IDNR configuration and the recommendations from the IWAQM Phase 2 report, variations are described below.

Configuration options and notable exceptions are included below:

- Puff splitting was enabled, with NSPLIT=2 (the default NSPLIT value of 3 is computationally prohibitive). Puffs are allowed to split once per day, at hour 17. Puff splitting was enabled for years 2002 and 2004. Puff splitting was excluded from the 2003 simulation as run times approached day per day (real-time) requirements at the mid-point of the simulation (*e.g.* the 2003 annual CALPUFF simulation was estimated to require 160 days[16] to complete).
- No subgrid scale complex terrain options were activated.
- The modeled (and output) species include the following six compounds: SO2, SO4, NOx, HNO3, NO3, primary PM.
- Three species were emitted, NOx, SO2, and primary PM. All primary PM is assumed to be PM2.5. This assumption is prescribed through assignment of geometric mass mean diameter and geometric standard deviation as 0.48 and 2.0 microns, respectively (see Table 5-4 below).
- Building downwash parameters were not applicable, as downwash was not modeled.
- Boundary conditions were not modeled (MBCON = 0) (boundary conditions are not mentioned in the IWAQM report).
- FOG model output was not enabled (MFOG =0) (this parameter was not mentioned in the IWAQM report).
- Output units were in terms of ug/m**3, versus the IWAQM setting of g/m**3.
- New to CALPUFF is an aqueous phase transformation flag, however, this option was not enabled (MAQCHEM=0).
- The IWAQM report provides only one value (0.01) for CDIV (the divergence criterion for dw/dz). The version utilized provides a two dimensional array for CDIV values. Default values were 0.0 & 0.0 and were not altered.
- Model plant stack parameters mirrored the values provided in the *CALPUFF Analysis in support of the June 2005 Changes to the Regional Haze Rule* (EPA, 2005b). Specifically, the following Industrial Boiler stack parameters were defined: stack height of 55 meters, stack diameter of 2.6 meters, exit velocity of 11.4 m/s, and an exit temperature of 414 K. Stack location was defined near the center of Iowa with a base elevation of 333.5 meters. The industrial boiler was selected as Iowa EGU sources satisfy most BART requirements through participation in the CAIR cap and trade program.

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[16] Run times for years 2002 and 2004 were a more reasonable 30 hours per simulation. The cause of the run time disparity was not investigated due to resource constraint issues and a lack of anomalous results when puff-splitting was disabled.

- Tables 5-4 through 5-6 detail the size parameters for the dry deposition of particles, dry deposition parameters for gases, and the wet deposition parameters, respectively. Values were based upon the defaults when available.

Table 5-4. Dry deposition particle size parameters.

Species Name	Geometric Mass Mean Diameter (microns)	Geometric Standard Deviation (microns)
SO4	0.48 2.	0
NO3	0.48 2.	0
Particulate	0.48 2.	0

Table 5-5. Dry deposition parameters.

Species Name	Diffusivity (cm**2/s)	Alpha Star	Reactivity	Mesophyll Resistance (s/cm)	Henry's Law Coefficient
SO2	0.1509	1000.	8.	0.	0.04
NOx	0.1656 1.		8.	5.	3.5
HNO3	0.1628 1.		18.	0.	0.00000008

Table 5-6. Wet deposition parameters.

Species Name	Liquid Precipitation Scavenging Coefficient	Frozen Precipitation Scavenging Coefficient
SO2	3.0E-5 0.	0E0
SO4	1.0E-4 3.	0E-5
NOx	0.00E0 0.	0E0
HNO3	6.0E-4 0.	0E0
NO3	1.0E-4 3.	0E-5
Particulate	1.0E-4 3.	0E-5

5.2.8 POSTUTIL

Generation of an appropriate POSTUTIL configuration file is straightforward. Of critical importance is the version selected for implementation. Neither the Beta nor regulatory versions available through the CALPUFF website are utilized, due to run-time errors encountered. Alternatively, version 1.4 Level 040818 was selected. Establishment of the appropriate control file requires the following modifications:

- The modeled (and output) species list includes the following six species: SO2, SO4, NOx, HNO3, NO3, primary PM.
- Simplification of the modeling process occurs through independent execution of each annual simulation. Subsequently, as in CALPUFF and CALMET, modification of the control file to prescribe either calendar year 2002, 2003, or 2004, is required.

- The background NH3 concentration is set at 3 ppb, in order to remain consistent with the CALPUFF configuration.

Appendix 10.7 provides appropriate definition for all POSTUTIL variables.

5.2.9 CALPOST

The CALPOST processor is capable of producing a variety of analyses and care must be taken to ensure results are consistent with EPA recommendations. Visibility assessment Method 6 most closely mirrors EPA guidelines. A feature of Method 6 is the need for Class I area specific *f(RH)* (relative humidity adjustment factors) and natural background conditions. Selection of Class I area data for evaluation is therefore required, even with the model plant approach. The following Class I areas were flagged for evaluation based upon their distance from Iowa sources:

- Badlands, South Dakota
- Boundary Waters Canoe Area, Minnesota
- Mingo & Hercules-Glades, Missouri

Incremental probability statistical analyses (I DNR, 2002) suggest the need for inclusion of additional sources to the north and northeast of Iowa, hence evaluation of visibility impacts for Isle Royale (MI), Seney (MI), and Voyageurs (MN) is completed. These Class I areas are commonly abbreviated as in Table 5-7.

Table 5-7. Class I area abbreviations.

Class I Area and State	Common Abbreviation
Badlands, SD	BADL
Voyageurs, MN	VOYA
Boundary Waters Canoe Area, MN	BOWA
Isle-Royale, MI	ISRO
Seney, MI	SENE
Mingo, MO	MING
Hercules-Glades, MO	HEGL

Natural background concentration and *f(RH)* data were extracted from EPA's *Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program* (2003). The site specific *f(RH)* values are listed in Table 5-8. Table 5-9 provides the species concentrations representing annual average natural background conditions. Annual average natural background concentrations are not strictly Class I area specific. Alternatively, sites are assigned one of two datasets: Eastern or Western. Of the seven Class I areas examined within the Iowa domain, all are considered Eastern sites with the exception of the Badlands.

Table 5-8. Class I area specific monthly averaged and the annually average f(RH) data. These data are based upon the Class I area centroid. The centroid data are considered more appropriate than IMPROVE monitor data as IMPROVE monitor siting locations may exist outside park boundaries.

Class I Area	Monthly *f(RH)* data: Jan – Dec	Avg.
Badlands, SD	2.6, 2.7, 2.6, 2.4, 2.8, 2.7, 2.5, 2.4, 2.2, 2.3, 2.7, 2.7	2.55
Voyageurs, MN	2.8, 2.4, 2.4, 2.3, 2.3, 3.1, 2.7, 3.0, 3.2, 2.6, 2.9, 2.8	2.71
Boundary Waters Canoe Area, MN	3.0, 2.6, 2.7, 2.4, 2.3, 2.9, 3.1, 3.4, 3.5, 2.8, 3.2, 3.2	2.93
Isle-Royale, MI	3.1, 2.5, 2.7, 2.4, 2.2, 2.6, 3.0, 3.2, 3.8, 2.7, 3.3, 3.3	2.90
Seney, MI	3.3, 2.8, 2.9, 2.7, 2.6, 3.1, 3.6, 4.0, 4.1, 3.4, 3.6, 3.5	3.30
Mingo, MO	3.3, 3.0, 2.8, 2.6, 3.0, 3.2, 3.3, 3.5, 3.5, 3.1, 3.1, 3.3	3.14
Hercules-Glades, MO	3.2, 2.9, 2.7, 2.7, 3.3, 3.3, 3.3, 3.3, 3.4, 3.1, 3.1, 3.3	3.13

Table 5-9. Annual Average natural background concentrations (ug/m3) for Eastern and Western U.S. Class I Sites. Data define annually averaged natural background conditions.

	Eastern	Western
$(NH_4)_2SO_4$	0.23 0.12	
NH_4NO_3	0.10 0.10	
OC	1.40 0.47	
EC	0.02 0.02	
SOIL	0.50 0.50	
CM	3.00 3.00	

Initial evaluation involved natural background as based upon annually averaged conditions. At the request of EPA Region VII, the 20% best natural background conditions are also examined. While results based upon the 20% best natural background conditions will be provided, annual average natural background conditions will also be considered in the subject to BART determination process. These methods are consistent with the UARG Settlement Agreement which provided further clarification regarding natural background conditions, allowing State discretion in selection of natural background conditions in terms of 20% best days or annual averages.

Standard CALPOST configuration requires that natural background conditions be represented as speciated concentration data. No such data exists for the 20 percent best natural background conditions. These conditions are described only through Class I area specific deciview values. The deciview values must therefore be converted into speciated concentrations. Procedures described in the draft North Dakota protocol (North Dakota Department of Public Health, 2005) were followed to scale the annual concentration data to the 20 percent best natural background conditions. An example of the scaling methods follows.

The IMPROVE equation (5.1) is coupled with the following Class I area specific data: the annually averaged natural background concentrations; the annually averaged *f(RH)* value; and the deciview value representing the 20% best natural background visibility conditions. For example, visibility degradation at Boundary Waters Canoe Area (BOWA) for the 20% best natural background conditions is described as 3.53 dv (EPA, 2003). This value is converted to an extinction coefficient, via Eq. 5.2, yielding 14.23 M m^{-1}. Incorporating the annually averaged *f(RH)* value (2.93 for BOWA) from Table 5-8 and the natural background concentrations from Table 5-9 (using Eastern site data), Eq. 5.3 is solved for the BOWA specific scaling factor: [X]. The scaling factor (in this example, 0.385) is then applied equally to the speciated annually averaged natural background concentrations to arrive at the BOWA 20 percent best conditions. Repeating the calculations for each Class I area yields the results provided in Table 5-10.

$$\begin{aligned} B_{ext} &= 3\cdot f(RH)\cdot\left[(NH_4)_2SO_4\right] + 3\cdot f(RH)\cdot\left[NH_4NO_3\right] + 4\cdot[OC] + 10\cdot[EC] \\ &\quad + 1\cdot[SOIL] + 0.6\cdot[CM] + B_{Rayleigh} \end{aligned} \qquad \textit{Eq. 5.1}$$

$$B_{ext} = 10\cdot e^{(dv/10)} \qquad \textit{Eq. 5.2}$$

$$\begin{aligned} 14.23 &= 3\cdot 2.93\cdot[0.12]\cdot[X] + 3\cdot 2.93\cdot\left[0.10\right]\cdot[X] + 4\cdot[1.40]\cdot[X] + 10\cdot[0.02]\cdot[X] \\ &\quad + 1\cdot[0.5]\cdot[X] + 0.6\cdot[3.0]\cdot[X] + 10 \end{aligned} \qquad \textit{Eq. 5.3}$$

Table 5-10. Site specific speciated data associated with calculation of natural background conditions on the 20 percent best days.

			20% Best Natural Background						
			Deciviews (B_{ext})^a	**Scaled Concentrations (ug/m3)**					
Site	***f(RH)***	**Scaling Factor [X]**		**SO_4**	**NO_3**	**OC**	**EC**	**SOIL**	**CM**
BADL	2.55	0.402	2.18 (12.44)	0.048	0.040	0.189	0.008	0.201	1.207
BOWA	2.93	0.385	3.53 (14.23)	0.088	0.038	0.538	0.008	0.192	1.154
HEGL	3.13	0.386	3.59 (14.32)	0.089	0.039	0.540	0.008	0.193	1.157
ISRO	2.90	0.387	3.54 (14.25)	0.089	0.039	0.542	0.008	0.194	1.162
MING	3.14	0.385	3.59 (14.32)	0.089	0.039	0.540	0.008	0.193	1.156
SENE	3.30	0.392	3.69 (14.46)	0.090	0.039	0.549	0.008	0.196	1.177
VOYA	2.71	0.377	3.41 (14.06)	0.087	0.038	0.527	0.008	0.188	1.130

^{a} Deciview values are listed first and the data in parenthesis are the corresponding B_{ext} values calculated using Eq. 5.2.

As CALPOST requires execution for each Class I area, 14 configuration files were produced. Seven assign annually averaged natural background conditions while the remainders assign the 20% best natural background conditions. Control file differences exist only in the site specific *f(RH)* and natural background concentration values. Regarding the calculation of visibility metrics, sulfate, nitrate, and primary PM (modeled in the fine mode) are included. Rayleigh scattering is set to 10 inverse megameters. Appendix 10.8 provides a complete listing of variable assignments.

5.3 RESULTS

Each model plant simulation requires 14 iterations of the CALPOST processor: two natural background scenarios across seven Class I areas. Results for each Class I area assessment are tabulated and ranked individually. Both maximum and 98th percentile values are considered when determining the levels at which emissions may cause (deciview impacts greater than or equal to 1.0) or contribute (deciview impacts greater than or equal to 0.5) to visibility impairment.

Figures 5-2 through 5-4 depict twelve critical model plant analyses. Figure 5-2 data are confined to calendar year 2002. Figure 5-3 and Figure 5-4 summarize years 2003 and 2004, respectively. For each year results are arranged in a four-panel configuration according to the following: the upper figures use the emission scenario where the model plant emits 2500 tpy of SO2, 2500 tpy of NOx, and 50 tpy of PM2.5. The lower figures utilize the model plant configured with emissions of 1500 tpy of SO2 and NOx each, and 50 tpy of PM2.5. In the left hand figures, impacts are compared against annually averaged natural background conditions. The right hand figures compare visibility impacts against the 20 percent best natural background conditions.

Individual plots within the four panel arrangement follow the same template. The bar charts display a count of the number of days in which deciview impacts greater than or equal to 0.5 are produced (labeled on the left hand y-axis). If the 98th percentile is considered, a maximum of 7 days with deciview impacts exceeding 0.5 are permitted, depicted by the solid red line (to remain within the 98th percentile the bar charts must remain at or below this line). Maximum deciview impacts are also reported (labeled on the right hand y-axis and indicated using a character similar to the asterisk). The solid blue line denotes the 0.5 dv impact level. Within each plot, results for each of the seven Class I areas are provided.

The results presented in Figures 5-2 through 5-4 illustrate that the model plant, with 5000 tpy of NOx & SO2 combined (and 50 tpy of PM2.5), does not yield any deciview impacts greater than 0.5 dv at the 98th percentile as compared against annually averaged natural background conditions. In years 2002 and 2003, a maximum of 5 days exceed the 0.5 dv impact threshold, occurring at the Badlands, likely due to utilization of the cleaner Western natural background conditions. During 2004, the count increases to 6. The remaining six Class I area evaluations yield counts less than or equal to 5. Considering individual daily maximum impacts, 2002 values remain near the 0.5 dv level, slightly higher maximum impacts occur in 2003. 2004 shows maximum impacts consistently above 1.0 dv. The situation changes dramatically when compared against the 20 percent best natural background conditions, where in each year, for each site, greater than 7 days are found with maximum impacts exceeding 0.5 dv. As expected, maximum individual daily impacts show a corresponding increase versus annually averaged natural background conditions.

Turning to the model plant scenario with emissions of 3000 tpy SO2+NOx and 50 tpy PM2.5, the 98th percentile is never exceeded, regardless of the natural background scenario. Additionally, at 3000 tpy SO2+NOx, maximum impacts for years 2002 and 2003, as compared against annually averaged natural background conditions, do not exceed 0.5 dv. Year 2004 does produce impacts above 0.5 dv. Two days above 0.5 dv are modeled for the Badlands, and one day above 0.5 dv are shown for the remaining Class I areas.

Consulting the 20% best natural background conditions, maximum daily impacts remain below 0.5 dv for all but Seney in 2002. In 2003, impacts greater than 0.5 dv are found for each site, but occur on no more than 2 days. Again, 2004 stands out as producing the highest impacts, but the impacts do not exceed the 98th percentile.

Based upon the above results, the IDNR concludes that any BART-eligible source which emits less than 3000 tpy of combined NOx, SO2 and PM will likely be exempt from a subject to BART declaration. At the 3000 tpy level, evaluation against the stringent 20% best natural background conditions yields no more than 5 days with deciview impacts exceeding 0.5 dv, thus surpassing the 98th percentile benchmark. Consulting Table 4-1, it can be shown that 11 of the 14 non-EGU BART-eligible sources remain well below the 3000 tpy combined potential to emit. These are the same facilities identified in Table 4-3.

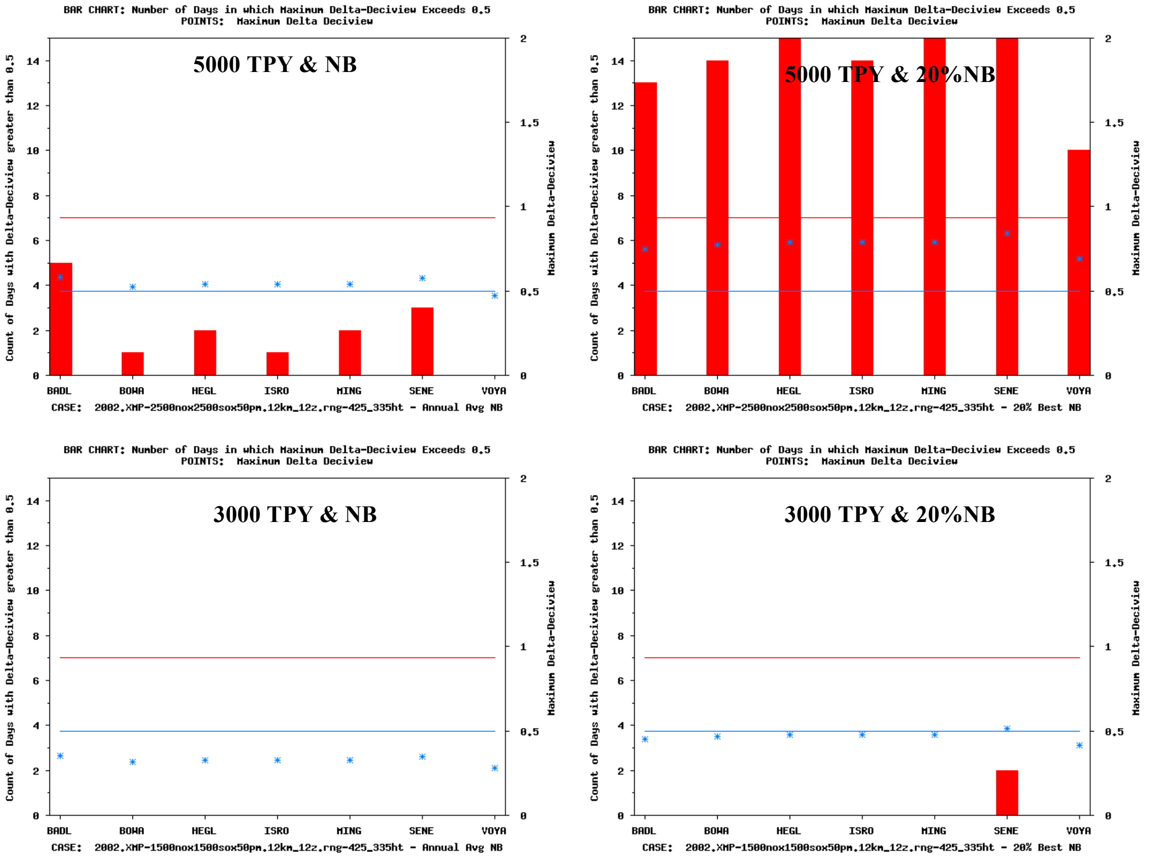

Figure 5-2. Deciview impacts from four Iowa model plant configurations: results for year 2002 with combined SO2 and NOx emissions of 5000 and 3000 tpy, as compared against annually averaged natural background (NB) conditions and 20% best NB conditions.

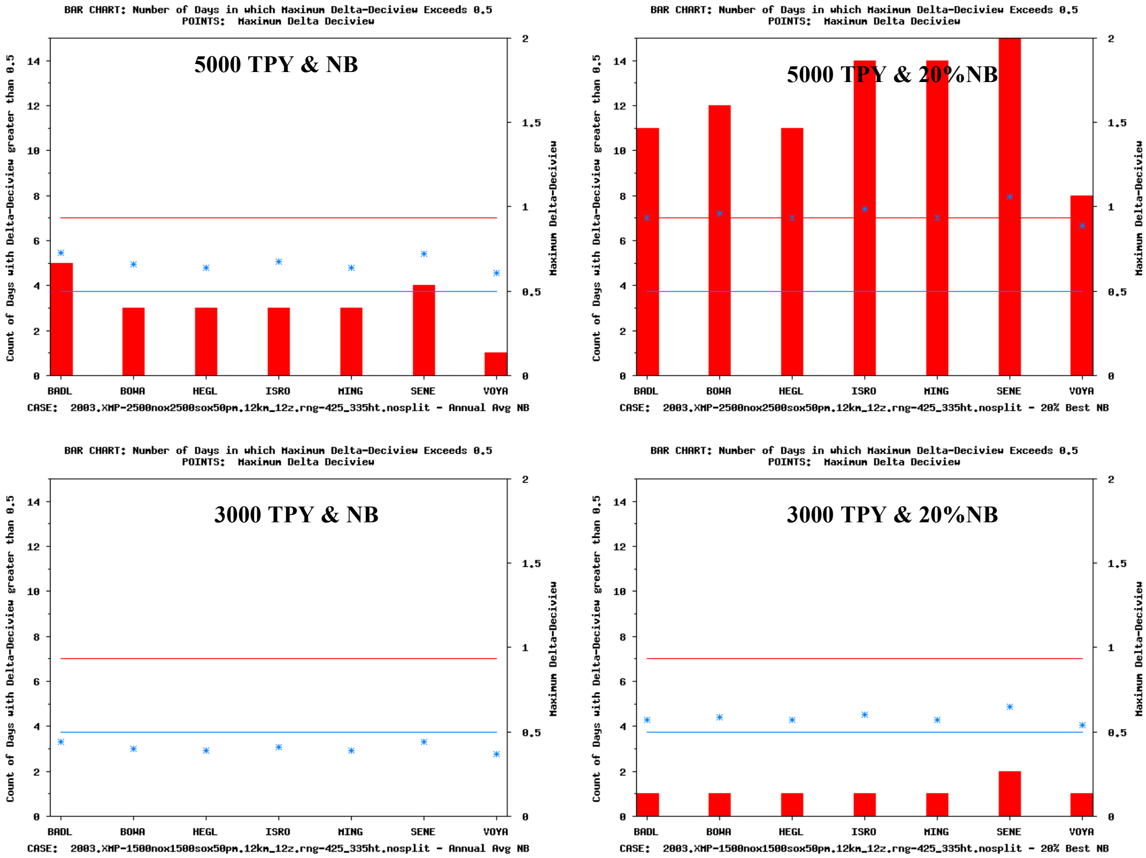

Figure 5-3. Deciview impacts from four Iowa model plant configurations: results for year 2003 with combined SO2 and NOx emissions of 5000 and 3000 tpy, as compared against annually averaged natural background (NB) conditions and 20% best NB conditions. Puff splitting was not enabled for this year, due to computational burden.

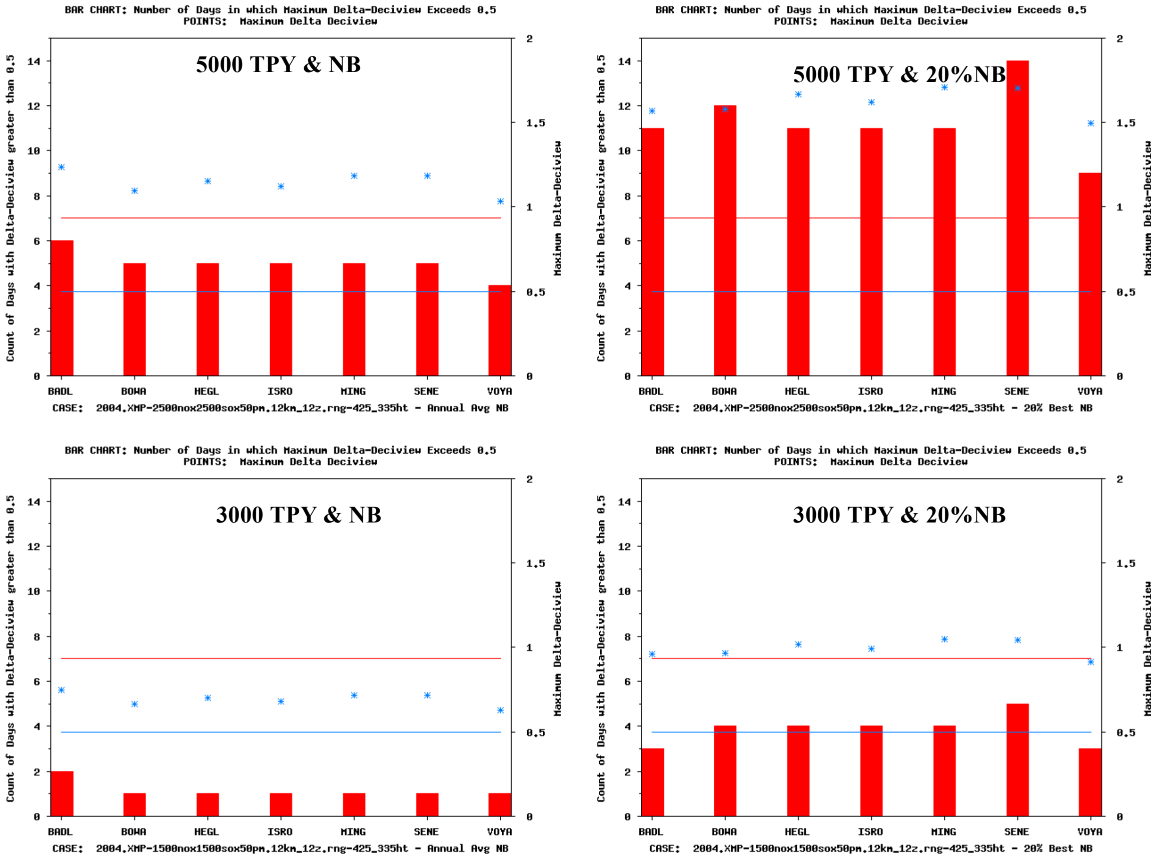

Figure 5-4. Deciview impacts from four Iowa model plant configurations: results for year 2004 with combined SO2 and NOx emissions of 5000 and 3000 tpy, as compared against annually averaged natural background (NB) conditions and 20% best NB conditions.

6. ALTERNATIVE MODELING

6.1 CONFIGURATION

The IDNR is utilizing the Comprehensive Air quality Model with extensions (CAMx) modeling system in a framework for determining which sources may cause or contribute to visibility impairment at nearby Class I areas. The objective is to model cumulative impacts across all BART-eligible sources. Calendar year 2002 serves as the base year due to the availability of model ready emission inventories and the associated baseline established by one-atmosphere modeling efforts under the regional haze rule. The 36 km (LADCO 4_RPO) domain provides the fundamental horizontal structure. The impacts of a finer resolution 12 km grid will also be assessed. Figure 6-1 depicts both the 36 and 12 km air quality modeling domains.

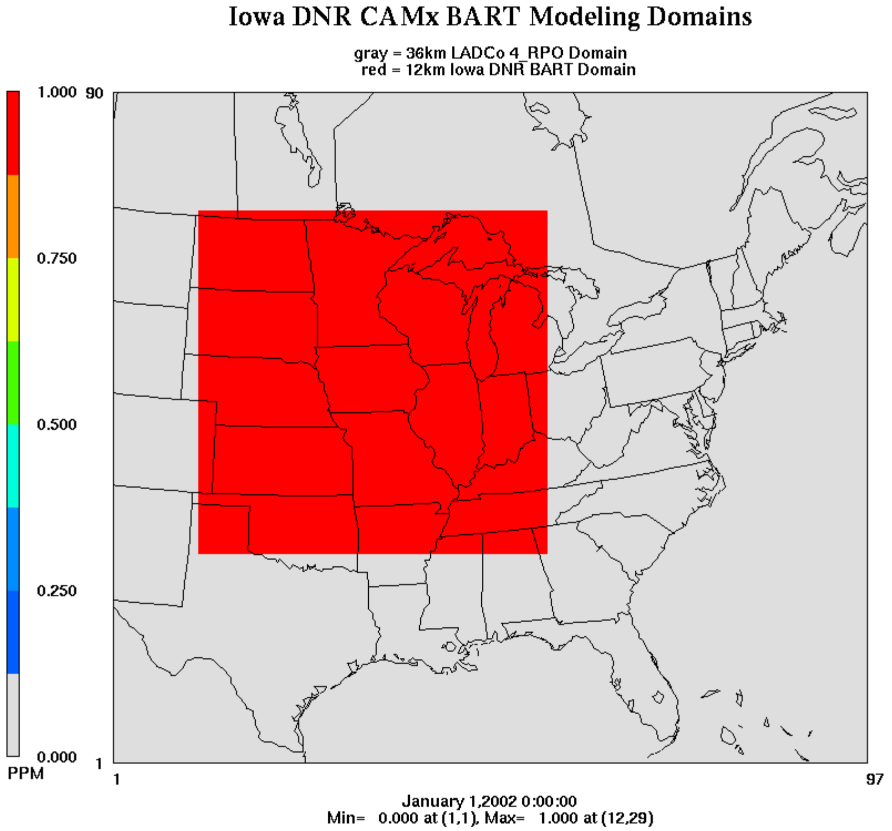

Figure 6-1. The 36 and 12 km modeling domains employed within the CAMx framework for BART modeling.

The meteorological data driving the CAMx system is derived from the IDNR 2002 MM5v363 36/12 km simulation. Performance evaluations of the dataset have been documented by Johnson, 2007; Baker et al., 2004; Baker, 2005; and Kemball-Cook et al., 2005. Reviewers found the dataset well suited to air quality modeling applications. Consequently, the 36 km meteorological dataset is in wide use within the regional modeling community, including use by LADCO, CENRAP, individual states, and private organizations. The 12 km dataset has also been used by

LADCO, IDNR, and the Five-States Modeling Study Project workgroup. Through the results detailed in the referenced reviews, as well as the propensity of the dataset in current studies, IDNR concludes that the meteorological model performance is suitable for use in alternative modeling approaches to BART.

IDNR application of the CAMx modeling system uses the LADCO 2002 BaseJ and BaseK emissions inventories. At project onset BaseJ established the current LADCO inventory, however, during project implementation BaseK was released. Both inventories are the products of multi-year iterative improvement processes and include the most recent 2002 NEI point source inventory. Updates between BaseJ and BaseK emission inventories include motor vehicle emission updates, revised area ammonia and EGU temporal profiles, updated Canadian emissions, and improved non-road emissions (LADCO, 2006). The BaseK modeling system also includes updates to the CAMx source code. Due to the enhancements associated with the BaseK emission inventory and model source code, BaseK is considered technically superior to BaseJ.

Based upon CAMx model performance, in conjunction with review of the emissions inventory and meteorological datasets driving the photochemical grid model, the CAMx (version 4.30) BaseK configuration is viewed to be an appropriate platform for alternative modeling approaches to BART. Initial exploratory cumulative modeling scenarios were completed using BaseJ. Scenarios critical to subject to BART determinations were refined and evaluated using BaseK. BaseK performance evaluations conducted by Kirk Baker (2006) reveal simulation performance commensurate with the current works of other RPOs. In reference to the subject to BART determination, where underprediction may falsely exempt a potential BART source, most species, when biased, were positively biased. Notable exceptions include organic carbon species which were predominantly underpredicted. BaseK results also show a slightly negative bias towards July sulfate concentrations, and late spring/summer nitrate. Mean bias values remained above approximately -0.5 ug/m3. Such error is well within regional modeling expectations and is considered acceptable.

6.2 EVALUATION

Results from the CAMx simulations were evaluated through implementation of IDNR developed software designed to calculate delta-deciview[17] (ddv) metrics. The process begins through calculation of the 24-hour averaged speciated concentrations, followed by conversion into extinction coefficients using the original IMPROVE methods (see Eqs. 6.1 - 6.8). Rayleigh scattering and speciated extinction coefficients are summed to arrive at total extinction (B_{TOT}).

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[17] The delta-deciview terminology is purely semantic and merely reinforces the fact that visibility impacts are measured in terms of a difference, for example, as compared against natural background conditions. The 'delta-deciview' is interchangeable with the 'deciview impact' terminology used in describing the CALPUFF results in Chapter 5.

$$B_{TOT} = b_{SO4} + b_{NO3} + b_{OC} + b_{EC} + b_{soil} + b_{coarse} + b_{ray} \qquad \text{(Eq. 6.1)}$$

$$b_{SO4} = 3 \cdot f(RH) \cdot [(NH_4)_2SO_4] \qquad \text{(Eq. 6.2)}$$
$$b_{NO3} = 3 \cdot f(RH) \cdot [NH_4NO_3] \qquad \text{(Eq. 6.3)}$$
$$b_{OC} = 4 \cdot [OMC] \qquad \text{(Eq. 6.4)}$$
$$b_{EC} = 10 \cdot [EC] \qquad \text{(Eq. 6.5)}$$
$$b_{soil} = 1 \cdot [Soil] \qquad \text{(Eq. 6.6)}$$
$$b_{coarse} = 0.6 \cdot [\text{Coarse Mass}] \qquad \text{(Eq. 6.7)}$$
$$b_{ray} = 10\ Mm^{-1} \qquad \text{(Eq. 6.8)}$$

The mapping of CAMx to IMPROVE species is provided in Eqs. 6.9 - 6.14. CAMx SO4 and NO3 concentrations are ionic and are assumed to be completely neutralized by ammonium (NH4). Full ammonium neutralization is assumed in the IMPROVE methods.

$$[(NH_4)_2SO_4] = 1.375 \text{ x PSO4} \qquad \text{(Eq. 6.9)}$$
$$[NH_4NO_3] = 1.290 \text{ x PNO3} \qquad \text{(Eq. 6.10)}$$
$$[OC] = POA + SOA1 + SOA2 + SOA3 + SOA4 + SOA5 \qquad \text{(Eq. 6.11)}$$
$$[EC] = PEC \qquad \text{(Eq. 6.12)}$$
$$[Soil] = FPRM + FCRS \qquad \text{(Eq. 6.13)}$$
$$[\text{Coarse Mass}] = CPRM + CCRS \qquad \text{(Eq. 6.14)}$$

Two calculation pathways were coded to obtain two delta-deciview metrics. In the first method, Eq. 6.15 (in combination with Eqs. 6.1 - 6.14) is used to calculate a simple delta-deciview between any given scenario and the basecase simulation. Conceptually, this comparison quantitatively describes the visibility impairment, as compared against current (2002) conditions, attributable to those sources whose emissions were modified. This measure is not indicative of a comparison against natural background conditions and was included in the software as a matter of convenience.

$$\Delta dv = 10 \cdot \ln\left(\frac{B_{TOT\_basecase}}{10}\right) - 10 \cdot \ln\left(\frac{B_{TOT\_scenario}}{10}\right) \qquad \text{(Eq. 6.15)}$$

The second metric is designed to mirror the methods established in EPA's BART modeling guidance (EPA, 2005a) and the Federal Land Managers Air Quality Related Values Workgroup report (FLAG, 2000) and therefore calculates the visibility impacts of sources as compared against natural background conditions. The procedure requires calculating the differences in the 24-hour averaged speciated concentrations between the basecase and scenario simulations, and then converting these differences to extinction coefficients (see Eqs. 6.16 – 6.21). The speciated extinction impacts are then summed (Eq. 6.22). The value B_{TOT_diff} thus represents the change in total extinction attributable to those sources modified in a given scenario. Through Equation 6.23, a delta-deciview which assesses visibility impacts against natural background conditions can then be calculated. The natural background total extinction (B_{TOT_NB}) is calculated according to the original IMPROVE equation (referencing Eq. 5.1, $B_{TOT\_NB} = B_{ext}$) using the speciated natural background concentrations from Table 5-9 and the monthly averaged Class I area specific *f(RH)* values in Table 5-8. B_{TOT_NB} can also be calculated in terms of the 20 percent best natural background conditions using the *f(RH)* data from Table 5-8 and the speciated concentration data from Table 5-10.

$$b_{SO4_{diff}} = 3 \cdot f(rh) \cdot 1.375 \cdot \left([SO_4]_{ba\sec ase} - [SO_4]_{scenario}\right) \quad \text{(Eq. 6.16)}$$

$$b_{NO3_{diff}} = 3 \cdot f(rh) \cdot 1.290 \cdot \left([NO_3]_{ba\sec ase} - [NO_3]_{scenario}\right) \quad \text{(Eq. 6.17)}$$

$$b_{OMC_{diff}} = 4 \cdot \left([OMC]_{ba\sec ase} - [OMC]_{scenario}\right) \quad \text{(Eq. 6.18)}$$

$$b_{EC_{diff}} = 10 \cdot \left(EC]_{ba\sec ase} - [EC]_{scenario}\right) \quad \text{(Eq. 6.19)}$$

$$b_{SOIL_{diff}} = 1 \cdot \left([SOIL]_{ba\sec ase} - [SOIL]_{scenario}\right) \quad \text{(Eq. 6.10)}$$

$$b_{CM_{diff}} = 0.6 \cdot \left(CM]_{ba\sec ase} - [CM]_{scenario}\right) \quad \text{(Eq. 6.21)}$$

$$B_{TOT\_diff} = b_{SO4_{diff}} + b_{NO3_{diff}} + b_{OMC_{diff}} + b_{EC_{diff}} + b_{SOIL_{diff}} + b_{CM_{diff}} \quad \text{(Eq. 6.22)}$$

$$\Delta dv = 10 \cdot \ln\left(\frac{B_{TOT\_diff} + B_{TOT\_NB}}{B_{TOT\_NB}}\right) \quad \text{(Eq. 6.23)}$$

The above procedures yield daily (24 hour averaged) delta-deciview impacts calculated in relation to three situations: 1) current conditions; 2) annually averaged natural background conditions; and 3) the 20 percent best natural background conditions. Following compilation of the daily impacts, a simple sorting routine yields the maximum delta-deciview impact, as well as the number of days in which an impact of 0.5 (or greater) delta-deciviews occurs. As these values are available for each grid cell within the CAMx modeling domain, a spatial mask was applied to extract only those values which correspond to a Class I area. Figure 6-2 shows the 36 km and 12 km CAMx grid cells which contain any 1 km Class I area receptor. At 36 km resolution, thirty-four unique grid cells were identified. The 12 km grid yields 116 unique cells. For all Class I areas except Mingo (at 36 km resolution), more than one maximum delta-deciview value is produced as multiple CAMx grid cells are required to ensure complete coverage of a Class I area. The same situation appears in determining the number of days in which an impact greater than or equal to 0.5 delta-deciviews occurs. In terms of summarizing results, the maximum value within those grid cells representing a Class I area is of most importance. Again, a simple sorting function reveals maximum impacts.

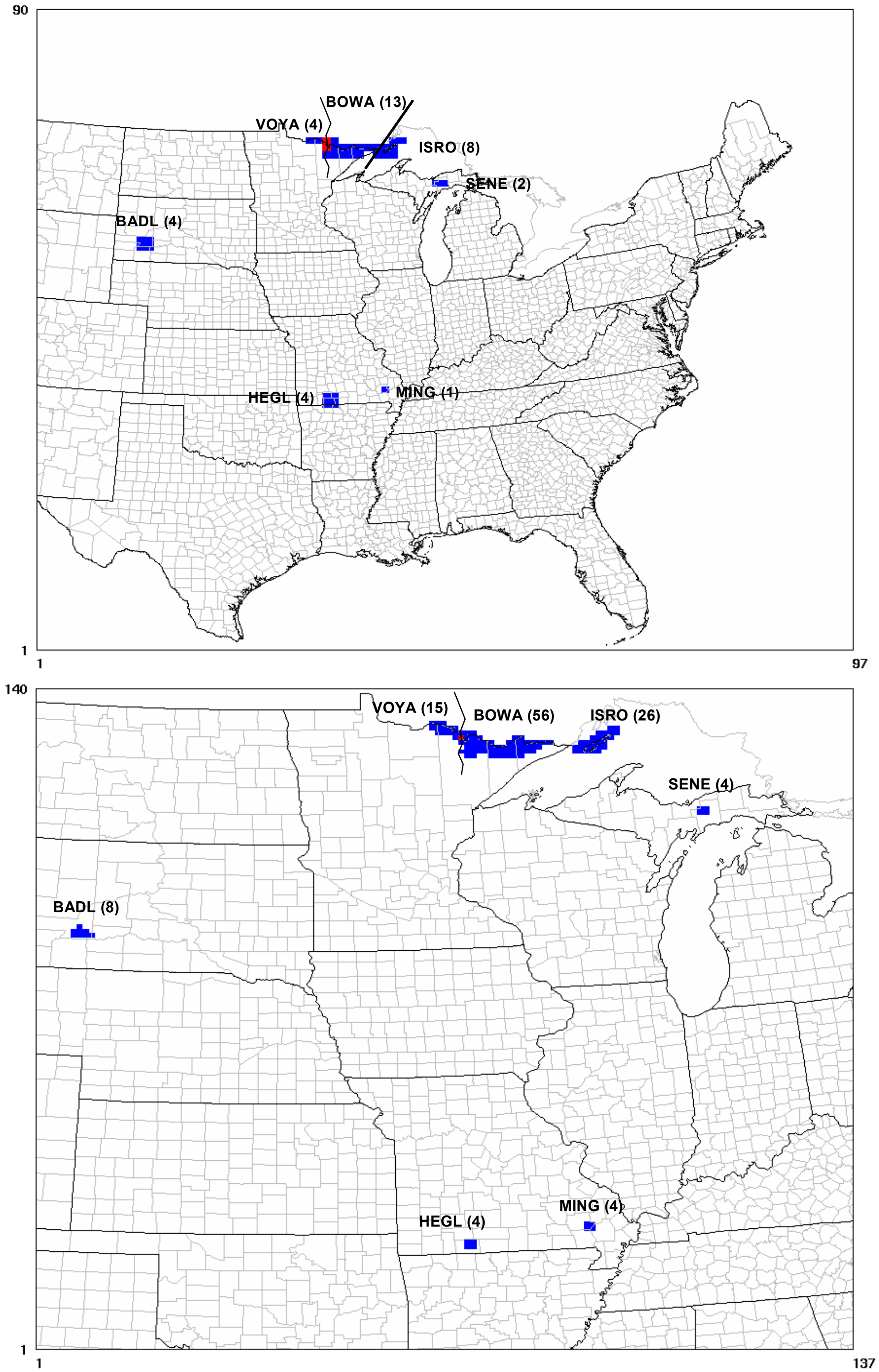

Figure 6-2. CAMx 36 km (top) and 12 km (bottom) grid cells containing a 1 km receptor for the seven Class I areas considered. The value in parentheses indicates the number of CAMx grid cells which contain a 1 km receptor. Grid cells which share areas of BOWA and VOYA are indicated in red.

6.3 MODELING SCENARIOS

Implementation of a scenario (sensitivity) run is completed through variable modification and subsequent comparison with the basecase through the calculations detailed above. Scenario goals are fundamentally driven by examining how visibility impacts change as a function of the BART-eligible source emission rates. For all cumulative CAMx modeling scenarios, fundamental scenario design involves zeroing the actual point source emissions of BART-eligible sources on a facility wide basis. The BART Guidelines prefer emission rates be based upon the maximum 24-hour averaged emission rate. However, continuous emissions monitoring (CEM) data is not available for Iowa's BART-eligible non-EGU facilities, which severely restricts calculation of the preferred emission rates. As a surrogate, emissions were zeroed on a facility wide basis across all pollutants (not just the visibility impairing pollutants). While the efficacy of this method is difficult to determine given a lack of CEM data, the methodology is judged reasonable by the IDNR based upon data availability and the inclusion of all facility emission units regardless of BART status.

In zeroing BART-eligible facility emissions, emphasis was placed upon the elevated point source emissions. Point source emissions are divided between two file types in the LADCO CAMx modeling system: elevated point and low point. Elevated point sources are identified in the emissions modeling stage through implementation of an idealized plume rise calculation. Using each stack's specific characteristics, a representative plume rise calculation is performed. Stacks yielding a plume rise exceeding a user supplied threshold are assigned to the elevated stack file, all other units are placed in the low point file and treated as an area source. Low point source file modification requires complex emissions modeling (while actual low point emission rates are expected to be negligible). Focusing upon the elevated point sources allows a scenario to be constructed using a simple post processor. Scenario construction therefore occurs through implementation of an efficient program capable of zeroing elevated stack emissions. The efficacy of this method is briefly discussed in section 6.4.1.

The unabridged cumulative modeling project consisted of numerous simulations. However, the majority of runs were completed in the project development stage utilizing BaseJ data and preliminary BART-eligible source lists. Due to uncertainty early in the BART identification process, BART-eligibility lists were dynamic and conservative in nature. As BART-eligible unit identification uncertainty minimized, a final BART list emerged. Concurrently the transition from BaseJ to BaseK occurred and pertinent scenarios were identified for implementation in a formal setting. Table 6-1 provides an overview of the three most informative simulations to be discussed in detail. Variability between these runs encompasses two areas:

1) Resolution
2) BART-eligible source lists.

Resolutions investigated included 36 and 12 kilometers. The BART-eligible lists include distinctions for CAIR versus non-CAIR units (in lieu of CAIR as BART). The final BART-eligible list contains only those sources legally identified as BART-eligible (as listed in Table 2-1). A comprehensive list of facilities considered under each scenario is provided in Table 6-2. From a practical perspective, Table 6-2 merely separates the EGU and non-EGU BART-eligible sources.

Table 6-1. Description of the IDNR BaseK cumulative modeling scenarios.

Scenario	Res. (km)	BART Source Emissions Processing Description
k2002ia36b0v2r1	36	All BART source emissions were zeroed out (both EGU and non-EGU facilities). Only elevated point source emissions were zeroed (low point emissions were not modified). Emissions were removed facility wide (not just BART units). The LADCO LAMB (low, area, mobile, biogenic) emission files were not modified.
k2002ia36b0v2r2	36	Similar to k2002ia36b0v2r1, except only non-EGU BART emissions were zeroed. (Again, only elevated point source units were impacted, with emissions zeroed facility-wide.) As above, the LADCO LAMB files were used.
k2002ia12b0v2r2	12	The same emissions scenario as k2002ia36b0v2r2 was implemented within a 12 km grid through flexi-nesting of the emissions data. Twelve km meteorological data was processed independent of the 36 km grid (*i.e.* the meteorological data was not flexi-nested).

Table 6-2. Facilities considered in each cumulative modeling simulation.

Facility Name and ID	k2002ia36b0v2r1	k2002ia36b0v2r2 k2002ia12b0v2r2
IPL - PRAIRIE CREEK GENERATING STATION (57-01-042)	X	
IPL - LANSING GENERATING STATION (03-03-001)	X	
CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/CTS (07-02-005)	X	
IPL - BURLINGTON GENERATING STATION (29-01-013)	X	
IPL - M.L. KAPP GENERATING STATION (23-01-014)	X	
PELLA MUNICIPAL POWER PLANT (63-02-005)	X	
MUSCATINE POWER & WATER (70-01-011)	X	
CENTRAL IOWA POWER COOP. - FAIR STATION (70-08-003)	X	
MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS ENERGY CTR (78-	X	
CITY OF AMES STEAM ELECTRIC PLANT/COMB TURB. (85-01-006)	X	
CENTRAL IOWA POWER COOP. - SUMMIT LAKE (88-01-004)	X	
MIDAMERICAN ENERGY CO. - GEORGE NEAL NORTH (97-04-010)	X	
MIDAMERICAN ENERGY CO. - GEORGE NEAL SOUTH (97-04-011)	X	
BP - DES MOINES TERMINAL (77-01-158)	X	X
BLOOMFIELD FOUNDRY, INC. (26-01-001)	X	X
EQUISTAR CHEMICALS, L.P. (23-01-004)	X	X
ADM CORN PROCESSING – CLINTON (23-01-006)	X	X
HOLCIM (US) INC. - MASON CITY (17-01-009)	X	X
JOHN DEERE FOUNDRY - WATERLOO (07-01-010)	X	X
THE DEXTER COMPANY (51-01-005)	X	X
KEOKUK STEEL CASTING, INC. - HAWKEYE FACILITY (56-01-025)	X	X
MONSANTO COMPANY - MUSCATINE 3670/6908/6909 (70-01-008)	X	X
GRIFFIN PIPE PRODUCTS COMPANY (78-01-012)	X	X
ALCOA INC. (82-01-002)	X	X
BP – BETTENDORF TERMINAL (82-02-024)	X	X
KOCH NITROGEN COMPANY - FORT DODGE (94-01-005)	X	X
TERRA NITROGEN - PORT NEAL COMPLEX (97-01-030)	X	X

6.4 RESULTS

Project initialization occurred through reproduction of the LADCO basecase air quality simulations. IDNR results were compared to the LADCO datasets to ensure the modeling system was configured and implemented correctly. Comparisons revealed agreement between the simulations at the most fundamental level, the binary computer output files.

Numerical evaluation is held for the BaseK/Final-BART-list scenarios in order to focus attention upon the formal results and avoid unnecessary details related to preliminary and subordinate data. No anomalies were found between the BaseJ and BaseK scenario runs, further minimizing the BaseJ scenarios' importance. However, a brief discussion of one preliminary run is informative.

6.4.1 PRELIMINARY DISCUSSION

The decision to focus upon only the elevated point sources was supported by sensitivity runs completed using BaseJ. The Emissions Modeling System (EMS) was used to zero the low point sources and create a new LAMB file. An existing post-processed elevated point source file was utilized to keep variable modification confined to the low point source file. The low point source emissions modeling processing was found to lower emissions rates by less than one ton per day per facility for all pollutants. Summing across all the BART-eligible facilities, NOx and SO2 differences still remained below one ton per day. Considering the low emission rate changes, in combination with considerable transport distances, only minor impacts were expected. Evaluation of the delta deciview impacts attributable to the low point source emissions did yield non-zero impacts. However, in terms of the results discussed below, the low point source delta-deciview impacts were insignificant in relation to any subject to BART determinations. As hypothesized, incurring the additional complexities associated with modification of the low point sources, through implementation of the EMS, is not warranted.

6.4.2 EGU AND NON-EGU: K2002IA36B0V2R1

As outlined in Table 6-1, scenario k2002ia36b0v2R1 eliminates all elevated point source emissions from both EGU and non-EGU BART-eligible sources. The resulting cumulative visibility impacts are depicted in Figure 6-3, arranged in a four panel plot. The upper left panel provides the maximum delta-deciview impacts as compared against annually averaged natural background conditions. The upper right panel depicts the number of days in which delta-deciview impacts greater than or equal to 0.5 dv were calculated. This pattern is repeated in the lower panels, with impacts compared against the 20% best natural back ground conditions. The analysis shows delta-deciview impacts consistently and frequently exceed 0.5 dv. Maximum values are provided in Table 6-3. Impacts range between 2.23 ddv (BADL) and 3.17 ddv (SENE) under annually averaged natural background conditions. The number of days registering an impact greater than or equal to 0.5 ddv ranges between 22 (BADL) and 47 (SENE). As expected, the impacts increase when compared against the 20% best natural background conditions, ranging from 2.79 ddv (BADL) to 4.41 ddv (SENE) with the number of days registering an impact greater than or equal to 0.5 ddv bound between 28 (BADL) and 73 (MING). (For additional perspective, the top ten ranked impacts are provided for each Class I area in Appendix 11.1.) The IDNR can clearly conclude that in the absence of CAIR potential Iowa BART sources would not be eligible for cumulative exclusion from subject to BART analyses.

6.4.3 NON-EGU ONLY: K2002IA36B0V2R2

Graphical and tabular results from scenario k2002ia36b0v2r2 are shown in Figure 6-4 (note the change in scale versus Figure 6-3) and Table 6-4. Modeled impacts decrease sharply versus scenario k2002ia36b0v2r1, as only non-EGU emissions are modified. In contrast to scenario k200ia36b0v2r1, where impacts greater than 0.5 ddv are common and frequent, only three of the seven sites registered impacts above 0.5 ddv: BOWA, ISLE, and SENE. In terms of frequency, BOWA and SENE each registered one impact greater than 0.5 ddv. Isle Royale registered two days with a delta-deciview greater than or equal to 0.5 dv. Additional insight regarding the frequency of impacts is provided in Appendix 11.2, where the individual top ten Class I area impacts are provided. The maximum impacts predicted under annually averaged natural background conditions ranged from 0.15 (BADL) to 0.64 (ISLE) ddv.

The evaluation conducted against the 20 percent best natural background conditions shows that six of the seven Class I areas register impacts greater than 0.5 ddv. Badlands remains the only Class I area under the 0.5 ddv threshold. Isle Royale again exhibits the highest impact, at 0.92 ddv, with the other five Class I areas at or above 0.53 ddv. The Badlands is the only area which does not register an increase in the frequency of ddv impacts greater than 0.5 dv when evaluated against the 20% best natural background conditions, while Isle Royale exhibits the most variability, with a four day increase. All other areas demonstrate only moderate variability, with one or two additional daily impacts greater than 0.5 ddv.

These results establish the cumulative visibility impacts upon nearby Class I areas from all non-EGU BART-eligible sources. If one considers natural background conditions and maximum impacts, a 0.64 ddv is produced. However, a maximum of only two days are of concern. Under the 20% best natural background conditions, the maximum impact increases to 0.92 ddv, with the frequency of impacts increasing to 6 days. As results remain near criteria provided in the BART guidance, increased model resolution is sought to assist in refining the impacts.

6.4.4 12 KM IMPACTS: K2002IA12B0V2R2

The design of scenario k2002ia12b0v2r2 mirrors that of k2002ia36b0v2r2 and implementation differs only in the inclusion of a 12 km domain. To ensure consistency in the emission inventory, emission from the 36 km domain were flexi-nested within the 12 km domain. A readily available 12 km MM5 dataset mitigated the need to flexi-nest the meteorology. While previous model performance evaluation did not demonstrate a statistical advantage to the 12 km MM5 simulation, spatial features and gradients are subject to a greater level of detail, and no disadvantages were identified within the 12 km meteorological fields as compared with 36 km data (Johnson, 2007).

The visibility impacts of the 12 km scenario are shown in Figure 6-5 and Table 6-5. The maximum impacts predicted under annually averaged natural background conditions ranged from 0.24 (BADL) to 0.63 (BOWA) ddv. Compared against the 20% best natural background conditions, impacts range from 0.3 (BADL) to 0.93 (BOWA) ddv. Under the 20% best natural background conditions, a maximum of five days (ISLE) occur in which impacts greater than or equal to 0.5 ddv are calculated. Considering annually averaged natural background conditions, delta deciview impacts greater than or equal to 0.5 dv are found on no more than two days.

Differences between the 12 and 36 km results (provided in Table 6-5 within parentheses; positive values indicate the 12 km grid generated greater visibility impacts) exhibit no pattern. Both increases and decreases in visibility impacts are found among the sites. Assessment of the annually averaged natural background conditions shows the largest change in visibility impacts occurs at VOYA, with impacts increasing 0.17 ddv, from 0.36 to 0.53 ddv. Alternatively, the impacts at SENE are reduced 0.15 dv, from 0.58 to 0.43 dv. The number of days with impacts at or above 0.5 dv fluctuates by no more than one day. As expected, a similar pattern is produced under the 20% best natural background conditions . Under 20% best natural conditions, the 12 km grid increased the visibility impacts at VOYA by 0.25 dv, while impacts at SENE were reduced by 0.21 dv. The number of days in which the 12 km results pushed the impacts above the 0.5 ddv threshold (versus 36 km data) changed by no more than 2 days. Given the increased sensitivity of the 20% best natural background conditions to changes in concentrations, the variability is expected.

In general, the variability encountered through comparison of the 12 km grid is well within expectations. While delta-deciview changes up to 0.25 dv were shown, such a change requires only a modest modification in species concentrations. The number of days in which ddv impacts greater than or equal to 0.5 occurred showed only minor fluctuations (at most 2 days). The results suggest the 12 km simulations leads to more active chemistry, as expected, but major anomalies between the 12 and 36 km results are not created. In summary, considering natural background conditions, the maximum impact modeled is 0.63 ddv with a maximum of only 2 days above the 0.5 ddv threshold. Under the 20% best natural background conditions, the maximum impact increases to 0.93 ddv, while the maximum frequency of impacts increases to 5 days. Appendix 11.3 contains additional detail regarding the frequency and magnitude of impacts above 0.5 ddv.

As mentioned in Section 6.2 the equations coded within the IDNR software, in combination with scenario design, allows calculation of visibility impacts in relation to current conditions. While not a regulatory requirement of subject to BART determinations, an investigation of the current condition visibility impacts attributable to Iowa's non-EGU BART-eligible sources does provide a different perspective and is provided for informational purposes. This analysis is conceptually equivalent to determining the actual (year 2002) visibility improvements expected at nearby Class I areas if all 14 non-EGU BART-eligible sources modeled within scenario k2002ia12b0v2r2 (see Table 6-2) were to cease operations. Results are provided in Figure 6-6 and Table 6-6. Visibility conditions are expected to improve at most 0.19 dv (at ISLE). Averaged over the 7 Class I areas, visibility conditions improve at most 0.12 dv, or approximately one tenth the level detectable by a human observer.

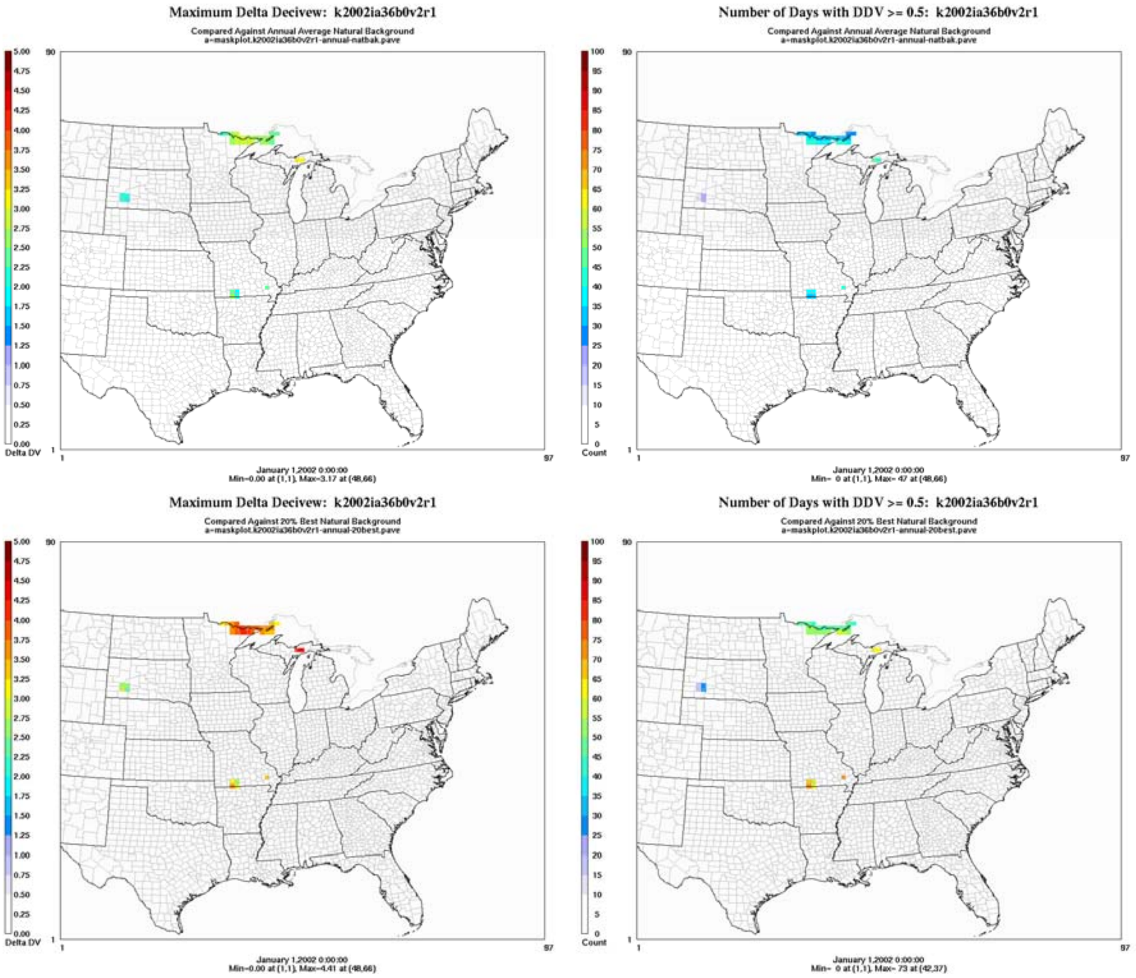

Figure 6-3. Scenario k2002ia36b0v2r1. Four panel plot with maximum delta-deciview impacts as compared against annually averaged natural background conditions (upper left) and the number of days with delta-deciview impacts greater than or equal to 0.5 dv (upper right). Lower panels repeat the calculations referencing the 20% best natural background conditions. Data are depicted at grid cells containing any 1 km Class I area receptor.

Table 6-3. Scenario k2002ia36b0v2r1: Class I area maximum impacts (values extracted from the above figure).

Site	Annual Avg. Natural Background		20% Best Natural Background	
	Maximum DDV	Number of Days DDVs ≥ 0.5	Maximum DDV	Number of Days DDVs ≥ 0.5
BADL	2.23 22		2.79 28	
BOWA	2.97 41		4.16 53	
HEGL	2.65 36		3.72 71	
ISLE	2.70 41		3.72 56	
MING	2.34 40		3.32 73	
SENE	3.17 47		4.41 63	
VOYA	2.40 33		3.41 49	

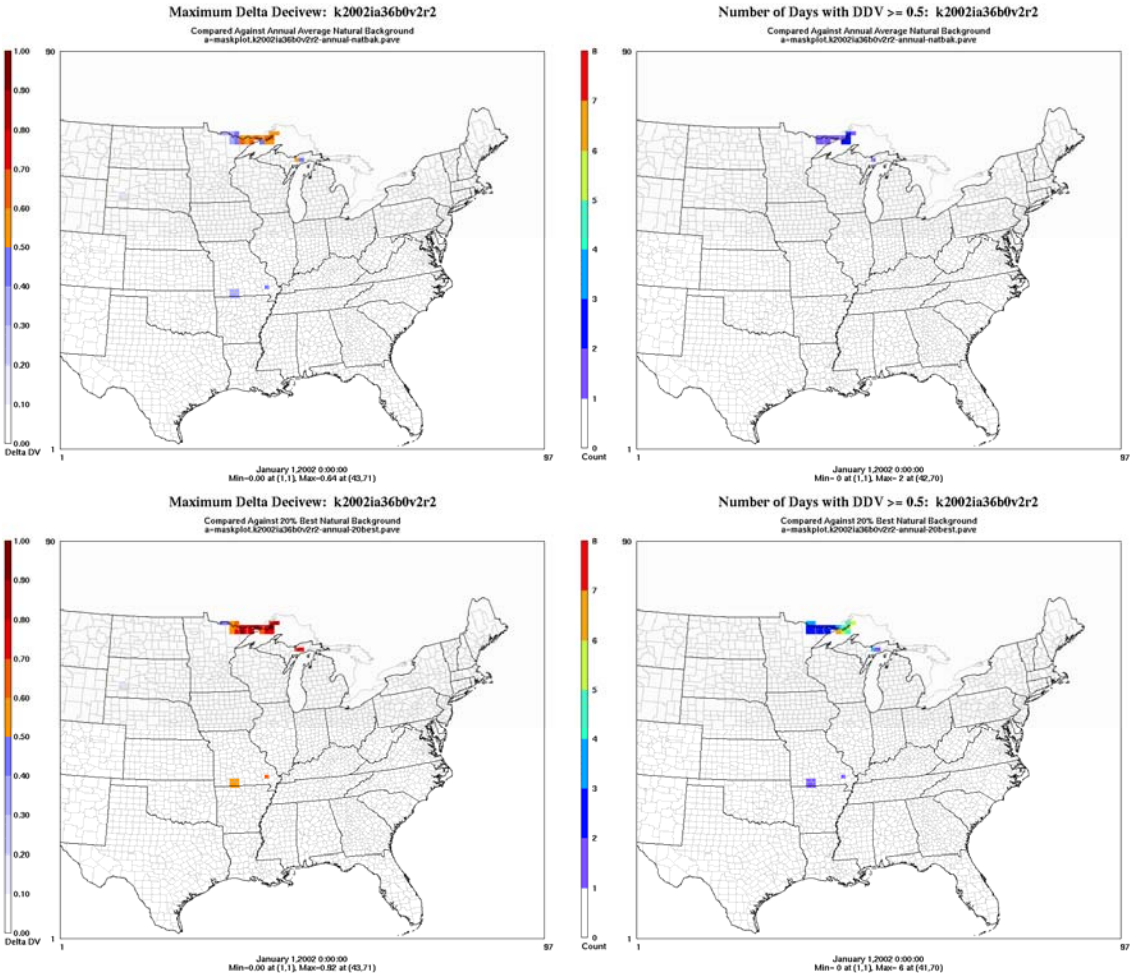

Figure 6-4. Scenario k2002ia36b0v2r2. Four panel plot with maximum delta-deciview impacts as compared against annually averaged natural background conditions (upper left) and the number of days with delta-deciview impacts greater than or equal to 0.5 dv (upper right). Lower panels repeat the calculations referencing the 20% best natural background conditions. Data are depicted at grid cells containing any 1 km Class I area receptor.

Table 6-4. Scenario k2002ia36b0v2r2: Class I area maximum impacts (values extracted from the above figure).

Site	**Annual Avg. Natural Background**		**20% Best Natural Background**	
	Maximum DDV	**Number of Days DDVs ≥ 0.5**	**Maximum DDV**	**Number of Days DDVs ≥ 0.5**
BADL	0.15 0		0.20 0	
BOWA	0.62 1		0.91 3	
HEGL	0.38 0		0.57 1	
ISLE	0.64 2		0.92 6	
MING	0.41 0		0.60 1	
SENE	0.58 1		0.85 3	
VOYA	0.36 0		0.53 2	

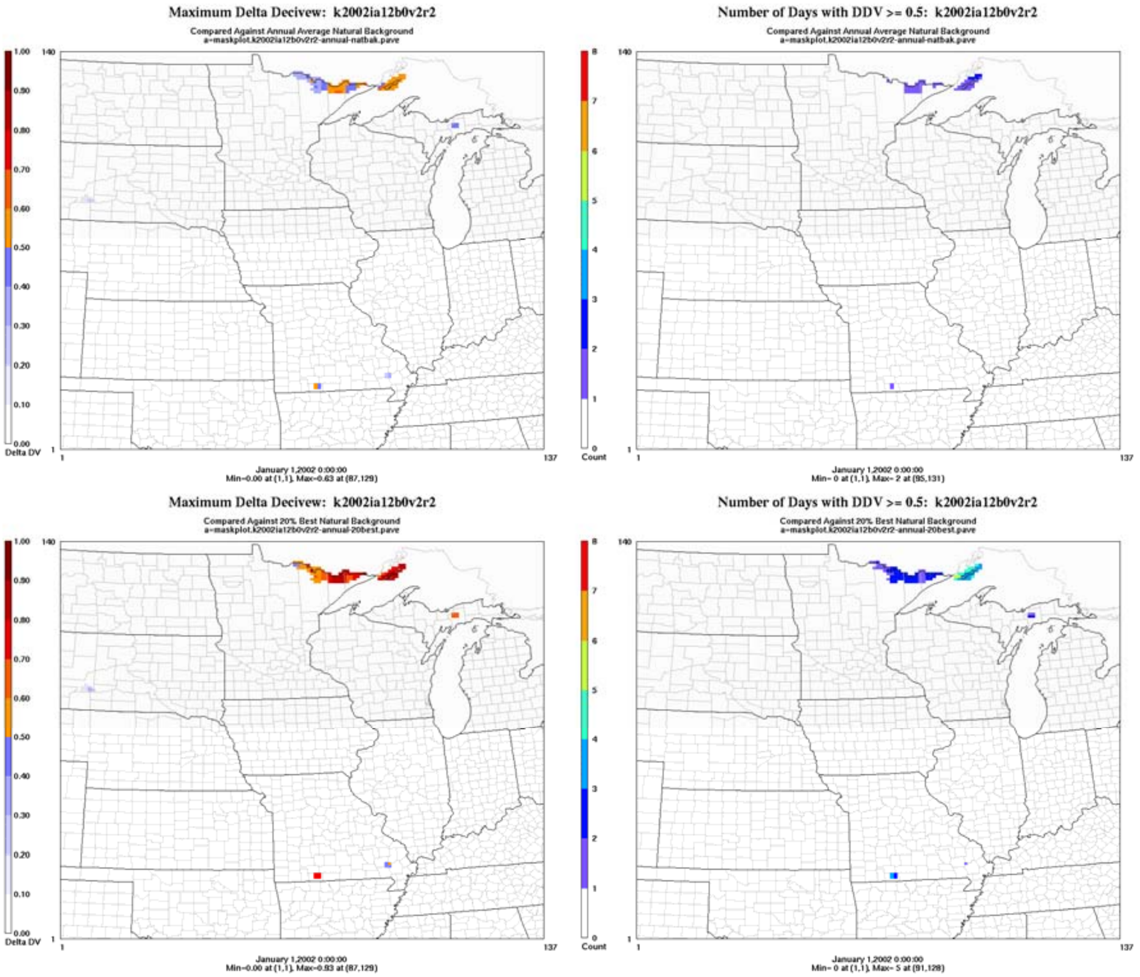

Figure 6-5. Scenario k2002ia12b0v2r2. Four panel plot with maximum delta-deciview impacts as compared against annually averaged natural background conditions (upper left) and the number of days with delta-deciview impacts greater than or equal to 0.5 dv (upper right). Lower panels repeat the calculations referencing the 20% best natural background conditions. Data are depicted at grid cells containing any 1 km Class I area receptor.

Table 6-5. Scenario k2002ia12b0v2r2: Class I area maximum impacts (values extracted from the above figure). Values in parentheses indicate the differences as compared to the 36 km results. Calculated as (k2002ia12b0v2r2 - k2002ia36b0v2r2).

Site	Annual Avg. Natural Background		20% Best Natural Background	
	Maximum DDV	**Number of Days DDVs ≥ 0.5**	**Maximum DDV**	**Number of Days DDVs ≥ 0.5**
BADL	0.24 (0.09)	0 (0)	0.30 (0.10)	0 (0)
BOWA	0.63 (0.01)	1 (0)	0.93 (0.02)	2 (-1)
HEGL	0.52 (0.14)	1 (1)	0.76 (0.19)	3 (2)
ISLE	0.62 (-0.02)	2 (0)	0.90 (-0.02)	5 (-1)
MING	0.34 (-0.07)	0 (0)	0.50 (-0.10)	1 (0)
SENE	0.43 (-0.15)	0 (-1)	0.64 (-0.21)	2 (-1)
VOYA	0.53 (0.17)	1 (1)	0.78 (0.25)	2 (0)

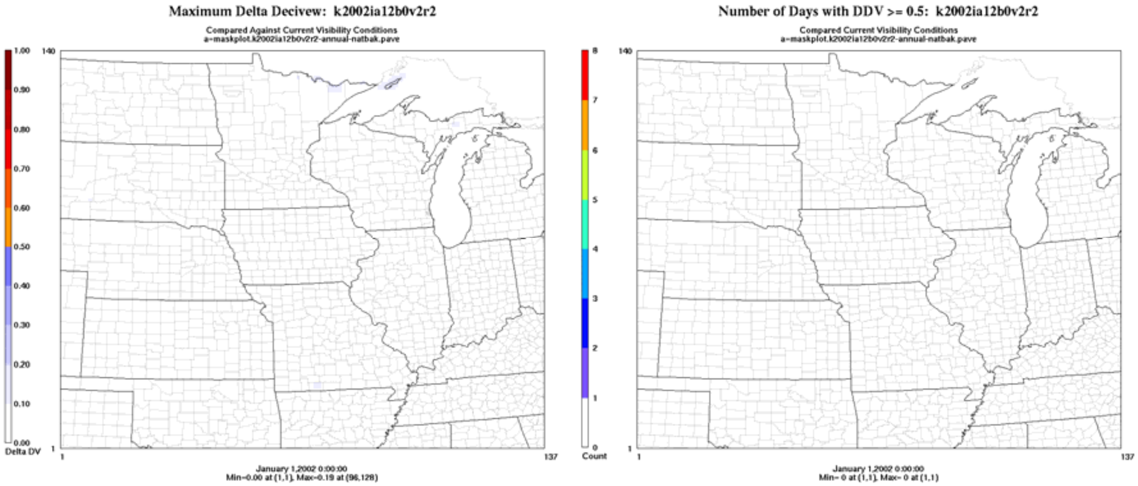

Figure 6-6. Scenario k2002ia12b0v2r2. Two panel plot with maximum delta-deciview impacts as compared against current (year 2002) conditions (left) and the number of days with delta-deciview impacts greater than or equal to 0.5 dv (right). Data are depicted at grid cells containing any 1 km Class I area receptor.

Table 6-6. Scenario k2002ia12b0v2r2: Class I area maximum impacts (values extracted from the above figure). Visibility impacts are in terms of current (year 2002) visibility condition.

Site	Current (2002) Visibility Impacts	
	Maximum DDV	Number of Days DDVs ≥ 0.5
BADL	0.12 0	
BOWA	0.11 0	
HEGL	0.11 0	
ISLE	0.19 0	
MING	0.08 0	
SENE	0.13 0	
VOYA	0.1 0	

7. PM, VOC, AND NH3

7.1 OVERVIEW

The BART Guidelines list five species as visibility impairing pollutants: SO2, NOx, PM, VOC, and NH3. Any visibility impairment attributable to SO2 or NOx emissions is explicitly addressed in all above methods, however, only within the cumulative modeling (CAMx) framework are the visibility impacts attributable to VOC quantified. While NH3 emissions are modeled in CAMx the predicted particulate ammonium concentrations must be neglected in order to remain consistent with the IMPROVE method which assumes full neutralization of sulfates and nitrates. Source specific NH3 emissions are not considered in either Q/d or CALPUFF. PM emissions are included in all the above methods, however, PM impacts from electrical generating units have not been quantified. The following discussions address these deficiencies.

7.2 PM

While CAIR satisfies BART for EGU SO2 and NOx emissions, PM emissions require consideration. A return to the CALPUFF model plant analysis offers a solution for efficiently analyzing EGU PM emissions. Model year 2004 was selected in order to generate maximum[18] impacts. Two scenarios were completed, using emission rates of 10,000 and 5000 tpy of PM (conservatively modeled as PM2.5). No NOx or SO2 emissions were modeled. The model plant configuration was modified to reflect idealized EGU stack parameters, obtained from EPA's *CALPUFF Analysis in Support of the June 2005 Changes to the Regional Haze Rule* (2005).

Results are depicted in Figure 7-1. No impacts above 0.5 dv are observed at any site under annually averaged natural background conditions with PM emissions of 10,000 tpy. Under the 20% best natural background conditions no impacts exceeding the 98th percentile occur. Reducing the emissions to 5000 tpy, no impacts above 0.5 dv are produced under either natural background condition. In terms of scale, Iowa's largest PM10 source (an EGU (not BART-eligible)) emits 3174 tpy[19], a value approximately 36.5% below the level which yields no visibility impacts. Based upon these results the IDNR concludes that EGU PM emissions from Iowa BART sources will not cause or contribute to visibility impairment at any nearby Class I area. As PM emission rates from non-EGU BART-eligible sources remain below those of the EGU's, the aforementioned conclusion is also applicable to Iowa's non-EGU BART-eligible units.

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[18] Previous analysis of the model plant results showed 2004 impacts exceeded 2002 and 2003 values.

[19] Facility wide total.

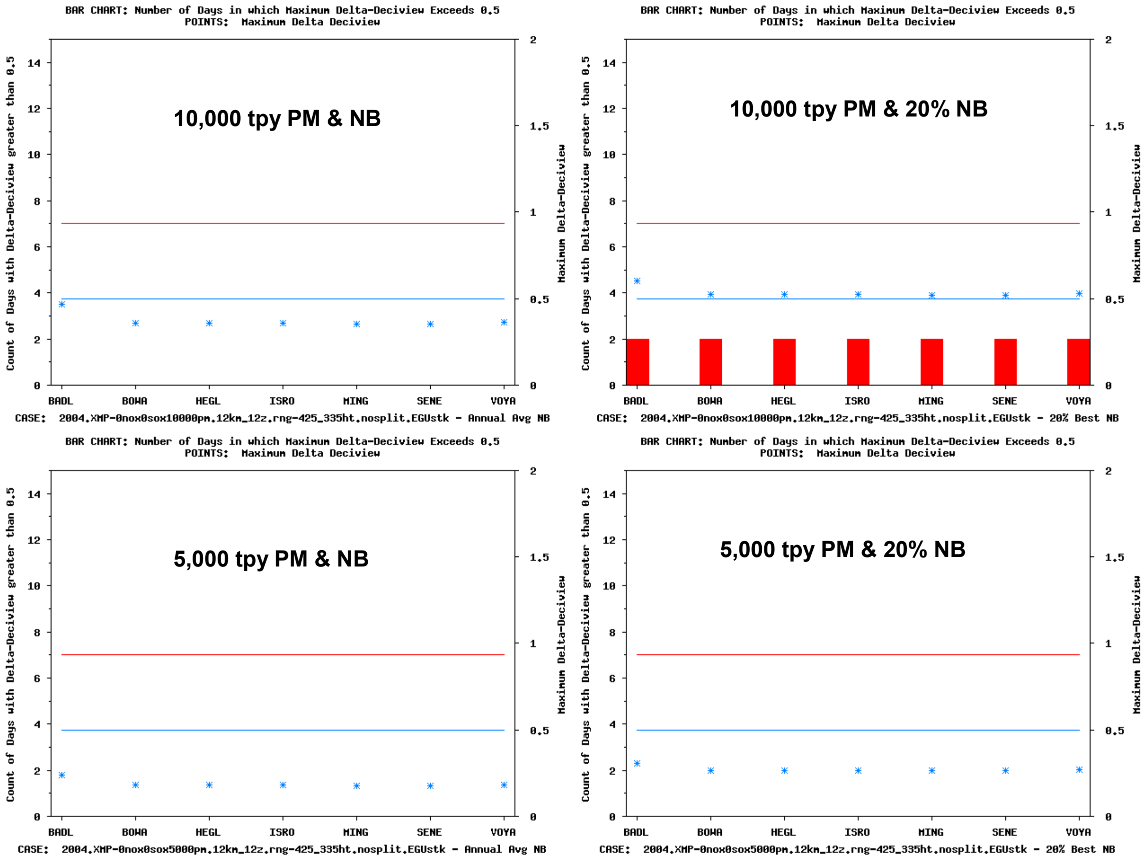

Figure 7-1. PM deciview impacts from four Iowa model plant configurations: results for year 2004 with total PM emissions of 10,000 and 5000 tpy (no NOx or SO2 emissions), as compared against annually averaged natural background (NB) conditions and 20% best NB conditions. Puff splitting was not enabled for simplicity. Idealized stack parameters represent EGU values.

7.3 VOC AND NH3

The BART Guidelines (70 FR 39160) provides that: "[States] should use [their] best judgment in deciding whether VOC or NH3 emissions from a source are likely to have an impact on visibility in an area." The guidelines go on to stress that a formal showing is not required in determining that an individual source is subject to BART review due to VOC or NH3 emissions. Conversely, a subject to BART determination made through VOC or NH3 emissions requires complete documentation and justification of the assessment. As VOC and NH3 emissions are clearly of a different focus than SO2, NOx, or PM emissions, the IDNR concludes that quantitative analyses of emissions inventory data provides sufficient evidence to confirm that Iowa point source NH3 and VOC emissions do not cause or contribute to any visibility impairment in any Class I area.

A simple scale analysis demonstrates that point source emissions of NH3 and VOC are insignificant in comparison to other sources and source types. Summing *all* (not just BART-eligible sources) 2002 Iowa point source NH3 emissions yields and emission rate of 3366 tpy. Area source emissions are approximately seventy-seven times higher, at ~260,000 tpy (Figure 7-2). VOC emissions from Iowa's BART-eligible sources comprise only 4% of the total (anthropogenic plus biogenic) 2002 VOC inventory (Figure 7-3) and are considered insignificant in terms of visibility impacts. Therefore point source NH3 and VOC emissions will not be evaluated for visibility impacts.

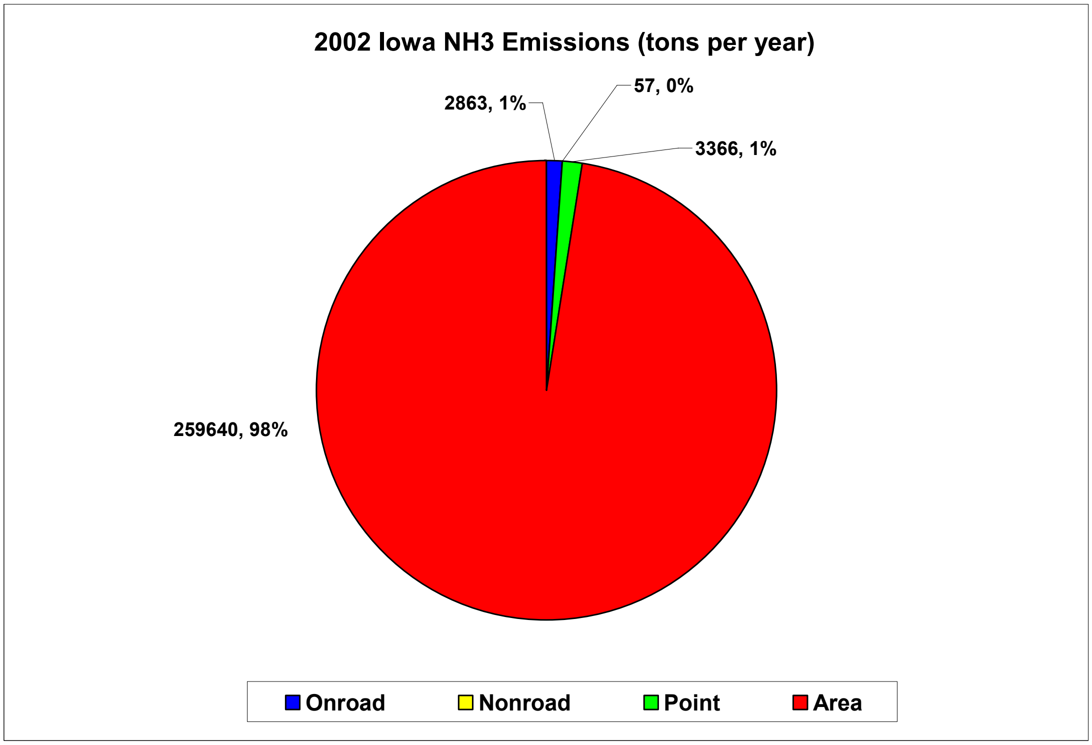

Figure 7-2. Distribution of the 2002 Iowa NH3 emission inventory by source category. Point sources include all Iowa facilities, BART and non-BART.

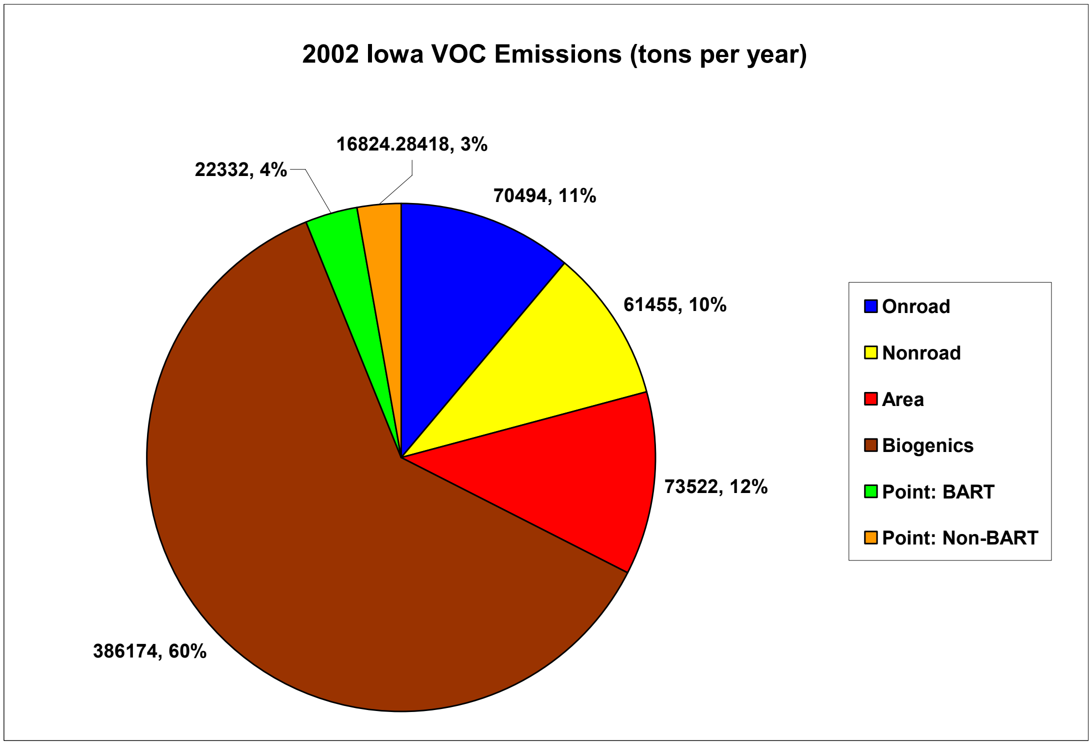

Figure 7-3. Distribution of the 2002 Iowa VOC emission inventory by source category.

8. SUBJECT TO BART DETERMINATIONS

8.1 EGU

The IDNR is utilizing the EPA determination that CAIR is better than BART. As codified in 40 CFR §51.308(e)(4): "A State that chooses to meet the emission reduction requirements of the Clean Air Interstate Rule (CAIR) by participating in one or more of the EPA-administered CAIR trading programs for SO2 and NOx need not require BART-eligible EGUs subject to such trading programs in the State to install, operate, and maintain BART for the pollutants covered by such trading programs in the State." All BART-eligible EGU units are subject to the CAIR SO2 and NOx trading rules, however, the CAIR does not address EGU PM emissions. CALPUFF model plant methods were used to investigate PM emissions. Section 7.2 discussed EGU PM emissions and concluded that no Iowa EGU PM emissions are reasonably anticipated to cause or contribute to any visibility impairment in any Class I area. Chapter 7 also addressed VOC and NH3 emissions and reached a similar conclusion. These findings yield the determination that no Iowa BART-eligible EGUs are subject to BART.

8.2 NON-EGU

Turning to the fourteen non-EGU BART-eligible sources, consideration of several analytical methods is required to complete the subject to BART determinations. Reviewing the Q/d results enables a straightforward classification of facilities. At the most conservative level of Q/5d, with Q based upon potential emission rates, eleven facilities fall below the 1.0 threshold:

- Koch Nitrogen Company
- Monsanto Company Muscatine
- Terra Nitrogen Port Neal
- BP - Bettendorf Terminal
- BP - Des Moines Terminal
- Bloomfield Foundry, Inc.
- Griffin Pipe Products Co.
- John Deere Foundry Waterloo
- Keokuk Steel Castings
- The Dexter Company
- Alcoa, Inc.

By ranking the above facilities in terms of potential to emit (summing SO2, NOx, and PM emissions across all BART-eligible units), Alcoa Inc. tops the list at 1507 tpy. The CALPUF model plant analyses established 3000 tpy as the threshold below which a BART-eligible source would not cause or contribute to visibility impairment. Potential emissions from these facilities are at most approximately half the proposed threshold. The Q/d evaluation, in tandem with the CALPUFF model plant evaluation leads the IDNR to conclude that these facilities will not cause or contribute to any visibility impairment in any Class I area, and are therefore not subject to BART.

This decision is supported by the cumulative modeling impacts. Actual facility emissions (summed over SO2, NOx, PM, VOC and the 11 facilities listed above) totaled 3700 tpy. Inclusion of the remaining non-EGU facilities, Equistar Chemicals, Holcim, Inc., and ADM (Clinton) brings the total to 29,178 tpy. Under scenario k2002ia12b0v2r2, the maximum impact generated (in comparison to the 20% best natural background conditions) was found to be 0.93 deciviews. Impacts above 0.5 dv were recorded on a maximum of 5 days at nearby Class I areas. The 11 facilities listed above are unlikely to have played a significant role in the cumulative modeling visibility impacts when their total emissions account for only 12.7% of the total. Of the three remaining non-EGU BART-eligible sources, Equistar Chemical is an outlier in comparison to ADM (Clinton) and Holcim. Equistar Chemical's potential and actual emissions are dominated by VOC [20] and not SO2 and NOx. While potential emissions of SO2 and NOx exceed the 5000 tpy scenario examined within the CALPUFF model plant framework, actual emission rates are insignificant in reference to the CALPUFF model plant and Q/5d results. IDNR therefore concludes that Equistar Chemical could not reasonably cause or contribute to visibility impairment at any Class I area.

Holcim and ADM (Clinton) emerge as the sources which fail both screening methods. Almost all Q/d metrics exceed the 1.0 significance level, while SO2+NOx emissions (potentials and actuals) exceed both the 3000 and 5000 tpy scenarios examined with CALPUFF. As neither Q/d nor CALPUFF utilize the most accurate science available in terms of transport or chemistry, the CAMx cumulative modeling analyses remain the best method available for assessing the visibility impacts from these sources. Scenario k2002ia12b0v2r2 does yield visibility impacts above 0.5 deciviews at nearby Class I areas. Referencing annual average natural background conditions, four of the seven sites registered impacts above 0.5 dv. The maximum impact of 0.63 delta-deciviews occurred at Boundary Waters Canoe Area. Considering all Class I areas, at most two days with a visibility impact greater than or equal to 0.5 ddv were found under natural background conditions. This value increases to 5 under the more conservative approach involving the 20% best natural background conditions. Based on these considerations, the cumulative CAMx modeling results are inconclusive regarding the individual subject to BART determinations for ADM (Clinton) and Holcim. Additional information will therefore be analyzed.

The absence of an accurate method for determining single source visibility impacts from sources far removed from Class I areas complicates Iowa's subject to BART determination process. Lacking a sophisticated method, an alternative exists through scaling the cumulative modeling impacts according to emission rates. Utilizing the maximum deciview impacts from the most relevant scenario (k2002ia12b0v2r2), at the stringent 20% best natural background conditions, a value of 0.93 dv is produced. Considering the actual SO2, NOx and PM emissions zeroed out in this scenario, Holcim accounts for 6828 tpy of the 22,909 tpy total, or 30%. ADM (Clinton) emits 12,755 tpy, or 56%. The resultant scaled visibility impact attributable to Holcim would thus be 0.28 dv, well below the 0.5 dv threshold. ADM's contribution would be 0.52 dv. This additional information supports the determination that Holcim does not cause or contribute to visibility impairment at any Class I area. The same determination for ADM (Clinton) would be more difficult to justify.

Recent PSD permitting activities related to ADM (Clinton) dramatically alter the situation. ADM (Clinton) will be replacing all fourteen boilers[21] currently in operation at their facility, including both BART-eligible boilers, No. 7 and No. 8, and replacing them with two natural gas and three coal fired boilers. The coal fired boilers require installation and operation of a baghouse, selective non-catalytic reduction, and limestone injection flue gas desulfurization. Construction permit limits establish an annual cap applicable across all 5 new units. SO2

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[20] In terms of visibility impairment, VOC emissions were addressed in Chapter 7.3 and found to be negligible.

[21] These boilers account for all facility SO2 emissions and a great majority of the NOx emissions.

emissions are not to exceed 3629 tpy, NOx emissions are not to exceed 1445 tpy. These limits represent best available control technology (BACT) emission rates as required under the new source review PSD program. The applicable IDNR permit numbers are 05-A-313-P, 05-A-314-P, 05-A-315-P for the coal-fired boilers, and 05-A-316-P, 05-A-317-P for the natural gas fired boilers. As the BART-eligible boilers must be permanently shut down by 09/13/2008 and the replacement boilers satisfy BACT, the IDNR concludes ADM (Clinton) is not subject to BART.

8.3 SUMMARY

The absence of a single tool capable of accurately assessing single source visibility impacts over transport distances in the 500 km range required the use of a variety of technical tools and analyses to complete subject to BART determinations. Implementation of Q/d, CALPUFF, CAMx, and emission inventory scale analysis methods provided the IDNR with the analytical data necessary to make informed decisions. Recent permitting activities involving the removal of BART-eligible units, and EPA's determination that CAIR constitutes BART for NOx and SO2 emissions from EGUs provided additional perspective and resolution. In consideration of all data, the IDNR concludes that BART-eligible sources located in Iowa are not reasonably anticipated to cause or contribute to any impairment of visibility in any Class I area and are therefore not subject to BART.

9. REFERENCES

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10. CALPUFF APPENDICIES

10.1 APPENDIX: TERREL

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the TERREL preprocessor.

Variable	IDNR Value
NTDF 4	
OUTFIL terr1	2k m.dat
LSTFIL terr1	2km.lst
PLTFIL qatr1	2k m.grd
SAVEFIL terr	.sav
LCFILES T	
GTOPO30 W	14 0N90.DEM
GTOPO30 W	10 0N90.DEM
GTOPO30 W	14 0N40.DEM
GTOPO30 W	10 0N40.DEM
DUSGS90 W	GS-G
DUSGS30 N	AS-C
DARM3 NAS	-C
D3CD WGS-	G
DDMDF NAS	-C
DGTOPO30	WGS-G
DUSGSLA E	SR-S
DNZGEN W	GS-G
DGEN WGS-	G
LPREV F	
LXY F	
NXYCOL 2	

Variable	IDNR Value
XYRADKM	0.1
IMODEL	1
ITHRES	75
PMAP	LCC
FEAST	0
FNORTH	0
IUTMZN	19
UTMHEM	N
RLAT0	40.0N
RLON0	97.0W
RLAT1	33.0N
RLAT2	45.0N
DATUM	WGS-G
IGRID	1
XREFKM	-792
YREFKM	-720
NX	171
NY	165
DGRIDKM	12
NRING	0
NRAYS	0
IPROC	2

10.2 APPENDIX: CTGPROC

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the CTGPOROC preprocessor.

Variable	IDNR Value
LUINDAT	noame ric.lu
LUDAT	lulc12km.dat
RUNLST	lulc1 2km.lst
LCFILES	T
LFINAL	T
LPREV	F
LULC	2
IGLAZR	1
DCTG	NAS-C
DUSGSLA	ESR-S
DNZGEN	WGS- G
ITHRESH	75
PMAP	LCC
FEAST	0
FNORTH	0
IUTMZN	19
UTMHEM	N
RLAT0	40.0N
RLON0	97.0W
RLAT1	33.0N
RLAT2	45.0N
DATUM	WGS- G
XREFKM	-792
YREFKM	-720
NX	171
NY	165
DGRIDKM	12

10.3 Appendix: MAKEGEO

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the MAKEGEO preprocessor.

Variable	IDNR Value
LUDAT lulc1	2km.dat
TERRDAT terr1	2km.dat
GEODAT	geo12.dat
RUNLST	makegeo.lst
LCFILES	T
LTERR	T
IXQA	75
IYQA	75
PMAP	LCC
FEAST	0
FNORTH	0
IUTMZN	19
UTMHEM	N
RLAT0	40.0N
RLON0	97.0W
RLAT1	33.0N
RLAT2	45.0N
DATUM	WGS-G
XREFKM	-792
YREFKM	-720
NX	171
NY	165
DGRIDKM	12
NOUTCAT	14
IWAT1	50
IWAT2	55
OUTCAT	10, 20, -20, 30, 40, 51, 54, 55
OUTCAT	60, 61, 62, 70, 80, 90
NINCAT	38
NUMWAT	5
NSPLIT	0
CFRACT	0.5
IMISS	55
IWAT	51
IWAT	52
IWAT	53
IWAT	54
IWAT	55

Landuse Properties
11, 0.5, 0.18, 1.0, 0.20, 0.0, 1.0, 10
12, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
13, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
14, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
15, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
16, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
17, 1.0, 0.18, 1.5, 0.25, 0.0, 0.2, 10
21, 0.25, 0.15, 1.0, 0.15, 0.0, 3.0, 20
22, 0.25, 0.15, 1.0, 0.15, 0.0, 3.0, 20
23, 0.25, 0.15, 1.0, 0.15, 0.0, 3.0, 20
24, 0.25, 0.15, 1.0, 0.15, 0.0, 3.0, 20
31, 0.05, 0.25, 1.0, 0.15, 0.0, 0.5, 30
32, 0.05, 0.25, 1.0, 0.15, 0.0, 0.5, 30
33, 0.05, 0.25, 1.0, 0.15, 0.0, 0.5, 30
41, 1.0, 0.1, 1.0, 0.15, 0.0, 7.0, 40
42, 1.0, 0.1, 1.0, 0.15, 0.0, 7.0, 40
43, 1.0, 0.1, 1.0, 0.15, 0.0, 7.0, 40
51, 0.001, 0.1, 0.0, 1.0, 0.0, 0.0, 51
52, 0.001, 0.1, 0.0, 1.0, 0.0, 0.0, 51
53, 0.001, 0.1, 0.0, 1.0, 0.0, 0.0, 51
54, 0.001, 0.1, 0.0, 1.0, 0.0, 0.0, 54
55, 0.001, 0.1, 0.0, 1.0, 0.0, 0.0, 55
61, 1.0, 0.1, 0.5, 0.25, 0.0, 2.0, 61
62, 0.2, 0.1, 0.1, 0.25, 0.0, 1.0, 62
71, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
72, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
73, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
74, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
75, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
76, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
77, 0.05, 0.3, 1.0, 0.15, 0.0, 0.05, 70
81, 0.2, 0.3, 0.5, 0.15, 0.0, 0.0, 80
82, 0.2, 0.3, 0.5, 0.15, 0.0, 0.0, 80
83, 0.2, 0.3, 0.5, 0.15, 0.0, 0.0, 80
84, 0.2, 0.3, 0.5, 0.15, 0.0, 0.0, 80
85, 0.2, 0.3, 0.5, 0.15, 0.0, 0.0, 80
91, 0.05, 0.7, 0.5, 0.15, 0.0, 0.0, 90
92, 0.05, 0.7, 0.5, 0.15, 0.0, 0.0, 90

10.4 APPENDIX: CALMM5

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the CALMM5 preprocessor.

Variable	**IDNR Value**
Heading	Iowa DNR CALMM5v2.4 run2 36km 2002mm5v363-Iowa
Number of MM5 Output files (0 for auto)	2
MM5 input file name	mmout_a
MM5 input file name	mmout_b
CALMM5 output file name	20021231.m3d *(an example)*
CALMM5 list file name	20021231.lst *(an example)*
Options for selecting a region	2
Southernmost Grid Cell	45
Northernmost Grid Cell	99
Westernmost longitude Grid Cell	61
Easternmost longitude Grid Cell	117
Starting date	2002123107 *(an example)*
Ending date	2003010106 *(an example)*
Output format	1
	Keep this line -
Output W, RH, cloud and rain, ice and snow, graupel	1 1 1 1 0
Flag for 2-D variables output	0
Lowest extraction level in MM5	1
Highest extraction level in MM5	34

10.5 APPENDIX: CALMET

The following table provides a listing of the variab les and subsequent values utilized in the IDNR CALPUFF model plant conf iguration for the CALMET preprocessor. The default values recommended by the IWAQM wor kgroup are provided for com parison. A value of "#N/A" indicates a default setting was not provided in the IWAQM Appendices.

Variable	IDNR Value	IWAQM Default
GEODAT ../input/geo12km.dat		#N/A
MM4DAT OUTFILE.m3	d	#N/A
METLST c	met.OUTFILE.lst	#N/A
METDAT cmet.O	UTFILE.dat	#N/A
LCFILES T		#N/A
NUSTA 0		User Defines
NOWSTA 0		#N/A
IBYR IYEAR		User Defines
IBMO IMONTH		User Defines
IBDY IDAY		User Defines
IBHR 1		User Defines
IBTZ 6		User Defines
IRLG 24		User Defines
IRTYPE 1		1
LCALGRD T		T
ITEST 2		#N/A
PMAP LCC		#N/A
FEAST 0		#N/A
FNORTH 0		#N/A
IUTMZN 19		User Defines
UTMHEM N		#N/A
RLAT0 40N		40
RLON0 97W		90
XLAT1 33N		30
XLAT2 45N		60
DATUM WGS-	G	#N/A
NX 171		User Defines
NY 165		User Defines
DGRIDKM 12		User Defines
XORIGKM -792		User Defines
YORIGKM -720		User Defines
NZ 12		User Defines
ZFACE	0., 20., 40., 73., 146., 369., 598., 1071., 1569., 2095., 2462., 2942., 3448.	User Defines
LSAVE T		T
IFORMO 1		1
LPRINT F		#N/A
IPRINF 1		#N/A
IUVOUT	0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0	#N/A
IWOUT	0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0	#N/A

Variable	IDNR Value	IWAQM Default
ITOUT	0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0	#N/A
STABILITY 0		#N/A
USTAR 0		#N/A
MONIN 0		#N/A
MIXHT 0		#N/A
WSTAR 0		#N/A
PRECIP 0		#N/A
SENSHEAT 0		#N/A
CONVZI 0		#N/A
LDB F		#N/A
NN1 1		#N/A
NN2 1		#N/A
IOUTD 0		#N/A
NZPRN2 0		#N/A
IPR0 0		#N/A
IPR1 0		#N/A
IPR2 0		#N/A
IPR3 0		#N/A
IPR4 0		#N/A
IPR5 0		#N/A
IPR6 0		#N/A
IPR7 0		#N/A
IPR8 0		#N/A
NOOBS 2		#N/A
NSSTA 0		User Defines
NPSTA -1		User Defines
ICLOUD 3		0
IFORMS 2		2
IFORMP 2		2
IFORMC 2		2
IWFCOD 1		1
IFRADJ 1		1
IKINE 1		0
IOBR 0		0
ISLOPE 1		1
IEXTRP -1		-4
ICALM 0		0
BIAS	0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0	NZ*0
RMIN2 -1		4
IPROG 14		0
ISTEPPG 1		#N/A
LVARY F		F
RMAX1 30		User Defines
RMAX2 30		User Defines
RMAX3 50		User Defines
RMIN 0.1		0.1
TERRAD 12		User Defines

Variable	IDNR Value	IWAQM Default
R1 1		User Defines
R2 1		User Defines
RPROG 0.1		#N/A
DIVLIM 0.0000	05	0.000005
NITER 50		50
NSMTH	2 , 4 , 4 , 4 , 4 , 4 , 4 , 4 , 4 , 4 , 4 , 4	2, 4*(NZ-1)
NINTR2	99, 99, 99, 99, 99, 99, 99, 99, 99, 99, 99, 99	99
CRITFN 1		1
ALPHA 0.1		0.1
FEXTR2	0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.	#N/A
NBAR 0		#N/A
XBBAR 0		#N/A
YBBAR 0		#N/A
XEBAR 0		#N/A
YEBAR 0		#N/A
IDIOPT1 0		0
ISURFT 4		User Defines
IDIOPT2 0		0
IUPT 2		User Defines
ZUPT 200		200
IDIOPT3 0		0
IUPWND -1		-1
ZUPWND	1., 1000.	1, 1000
IDIOPT4 0		0
IDIOPT5 0		0
LLBREZE F		#N/A
NBOX 0		#N/A
XG1 0		#N/A
XG2 0		#N/A
YG1 0		#N/A
YG2 0		#N/A
XBCST 0		#N/A
YBCST 0		#N/A
XECST 0		#N/A
YECST 0		#N/A
NLB 0		#N/A
METBXID 0		#N/A
CONSTB 1.41		1.41
CONSTE 0.15		0.15
CONSTN 2400		2400
CONSTW 0.16		0.16
FCORIOL 0.0001		0.0001
IAVEZI 1		#N/A
MNMDAV 1		1
HAFANG 30		30
ILEVZI 1		1
DPTMIN 0.001		0.001

Variable	IDNR Value	IWAQM Default
DZZI 200		200
ZIMIN 50		50
ZIMAX 3448		3000
ZIMINW 50		50
ZIMAXW 3448		3000
ITPROG 2		#N/A
IRAD 1		1
TRADKM 36		500
NUMTS 5		5
IAVET 1		1
TGDEFB -0.009	8	-0.0098
TGDEFA -0.004	5	-0.0045
JWAT1 55		999
JWAT2 55		999
NFLAGP 2		2
SIGMAP 50		100
CUTP 0.01		0.01

10.6 APPENDIX: CALPUFF

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the CALPUFF model. The default values recommended by the IWAQM workgroup are provided for comparison. A value of "#N/A" indicates a default setting was not provided in the IWAQM Appendices.

Variable	IDNR Value	IWAQM Default
PUFLST	cpuf.lst	CALPUFF.LST
CONDAT	cpuf.c on	CONC.DAT
LCFILES	T	#N/A
NMETDAT	365	#N/A
NPTDAT	0	#N/A
NARDAT	0	#N/A
NVOLDAT	0	#N/A
METDAT	inndir/ cmet.20020101.dat *(an example)*	CALMET.DA T
METRUN	0	0
IBYR	2002	User Defined
IBMO	1	User Defined
IBDY	1	User Defined
IBHR	1	User Defined
XBTZ	6	#N/A
IRLG	8760	User Defined
NSPEC	6	5
NSE	3	3
ITEST	2	#N/A
MRESTART	0	0
NRESPD	0	#N/A
METFM	1	1
AVET	60	60
PGTIME	60	#N/A
MGAUSS	1	1
MCTADJ	3	3
MCTSG	0	0
MSLUG	0	0
MTRANS	1	1
MTIP	1	1
MBDW	2	#N/A
MSHEAR	0	0
MSPLIT	1	0
MCHEM	1	1
MAQCHEM	0	#N/A
MWET	1	1
MDRY	1	1
MDISP	3	3
MTURBVW	3	3
MDISP2	3	3
MROUGH	0	0

Variable	IDNR Value	IWAQM Default
MPARTL 1		1
MTINV 0		0
MPDF 0		0
MSGTIBL 0		0
MBCON 0		#N/A
MFOG 0		#N/A
MREG 1		1
CSPEC SO2		#N/A
CSPEC SO4		#N/A
CSPEC NOX		#N/A
CSPEC HNO3		#N/A
CSPEC NO3		#N/A
CSPEC PM10		#N/A
SO2	1, 1, 1, 0	#N/A
SO4	1, 0, 2, 0	#N/A
NOX	1, 1, 1, 0	#N/A
HNO3	1, 0, 1, 0	#N/A
NO3	1, 0, 2, 0	#N/A
PM10	1, 1, 2, 0	#N/A
PMAP LCC		#N/A
FEAST 0		#N/A
FNORTH 0		#N/A
IUTMZN 19		User Defined
UTMHEM N		#N/A
RLAT0 40N		#N/A
RLON0 97W		#N/A
XLAT1 33N		#N/A
XLAT2 45N		#N/A
DATUM WGS-	G	#N/A
NX 171		User Defined
NY 165		User Defined
NZ 12		User Defined
DGRIDKM 12		User Defined
ZFACE	0., 20., 40., 73., 146., 369., 598., 1071., 1569., 2095., 2462., 2942., 3448.	User Defined
XORIGKM -792		User Defined
YORIGKM -720		#N/A
IBCOMP 10		User Defined
JBCOMP 10		User Defined
IECOMP 162		User Defined
JECOMP 156		User Defined
LSAMP F		F
IBSAMP 10		User Defined
JBSAMP 10		User Defined
IESAMP 162		User Defined
JESAMP 156		User Defined
MESHDN 1		1

Variable	IDNR Value	IWAQM Default
ICON 1		1
IDRY 1		1
IWET 1		1
IVIS 1		1
LCOMPRS T		T
IMFLX 0		#N/A
IMBAL 0		#N/A
ICPRT 0		0
IDPRT 0		0
IWPRT 0		0
ICFRQ 1		1
IDFRQ 1		1
IWFRQ 1		1
IPRTU 3		1
IMESG 2		1
SO2	0, 1, 0, 1, 0, 1, 0	#N/A
SO4	0, 1, 0, 1, 0, 1, 0	#N/A
NOX	0, 1, 0, 1, 0, 1, 0	#N/A
HNO3	0, 1, 0, 1, 0, 1, 0	#N/A
NO3	0, 1, 0, 1, 0, 1, 0	#N/A
PM10	0, 1, 0, 1, 0, 1, 0	#N/A
LDEBUG F		F
IPFDEB 1		#N/A
NPFDEB 1		#N/A
NN1 1		#N/A
NN2 10		#N/A
NHILL 0		#N/A
NCTREC 0		#N/A
MHILL 2		#N/A
XHILL2M 1		#N/A
ZHILL2M 1		#N/A
XCTDMKM 0		#N/A
YCTDMKM 0		#N/A
SO2	0.1509, 1000., 8., 0., 0.04	#N/A
NOX	0.1656, 1., 8., 5., 3.5	#N/A
HNO3	0.1628, 1., 18., 0., 0.00000008	#N/A
SO4 0.48,	2.	#N/A
NO3 0.48,	2.	#N/A
PM10 0.48,	2.	#N/A
RCUTR 30		30
RGR 10		10
REACTR 8		8
NINT 9		9
IVEG 1		1
SO2 3.0E-05,	0.0E00	#N/A
SO4 1.0E-04,	3.0E-05	#N/A
NOX 0.0E00,	0.0E00	#N/A

Variable	IDNR Value	IWAQM Default
HNO3 6.0E-05,	0.0E00	#N/A
NO3 1.0E-04,	3.0E-05	#N/A
PM10 1.0E-04,	3.0E-05	#N/A
MOZ 0		1
BCKO3	40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00	80
BCKNH3	3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00, 3.00	10
RNITE1 0.2		0.2
RNITE2 2		2
RNITE3 2		2
MH2O2 1		#N/A
BCKH2O2	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00	#N/A
BCKPMF	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00	#N/A
OFRAC	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15	#N/A
VCNX	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00	#N/A
SYTDEP 550		550
MHFTSZ 0		#N/A
JSUP 5		5
CONK1 0.01		0.01
CONK2 0.1		0.1
TBD 0.5		0.5
IURB1 10		10
IURB2 19		19
ILANDUIN 20		20
Z0IN 0.25		#N/A
XLAIIN 3		3
ELEVIN 0		0
XLATIN 0		User Defined
XLONIN 0		User Defined
ANEMHT 10		10
ISIGMAV 1		1
IMIXCTDM 0		0
XMXLEN 1		1
XSAMLEN 1		1
MXNEW 99		99
MXSAM 99		99
NCOUNT 2		#N/A
SYMIN 1		1
SZMIN 1		1
SVMIN 0.500,	0.500, 0.500, 0.500, 0.500, 0.500	6*0.50
SWMIN 0.200,	0.120, 0.080, 0.060, 0.030, 0.016	0.20, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV .0,	.0	0.01
WSCALM 0.5		0.5

Variable	IDNR Value	IWAQM Default
XMAXZI 3448		3000
XMINZI 50		50
WSCAT	1.54, 3.09, 5.14, 8.23, 10.80 1.54,3.09,5.1	4,8. 23.10.8
PLX0	0.07, 0.07, 0.10, 0.15, 0.35, 0.55	0.07,0.07,0.10,0. 15,0.35,0.55
PTG0 0.020,	0.035	#N/A
PPC	0.50, 0.50, 0.50, 0.50, 0.35, 0.35	0.5,0.5,0.5,0.5,0. 35,0.35
SL2PF 10		10
NSPLIT 2		3
IRESPLIT 0,0,0,0,0,0,0,0,	0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0	User Defined
ZISPLIT 100		100
ROLDMAX 0.25		0.25
NSPLITH 5		#N/A
SYSPLITH 1		#N/A
SHSPLITH 2		#N/A
CNSPLITH 0.0000	001	#N/A
EPSSLUG 0.0001		0.0001
EPSAREA 0.000001		#N/A
DSRISE 1		#N/A
HTMINBC 500		#N/A
RSAMPBC 10		#N/A
MDEPBC 1		#N/A
NPT1 1		User Defined
IPTU 4		1
NSPT1 0		0
NPT2 0		0
SRCNAM STK1		#N/A
X	294.0, 246.0, 55.0, 333.5, 2.6, 11.4, 414, .0, 2.5E3, 0.0E00, 2.5E3, 0.0E00, 0.0E00, 5.0E01	#N/A
FMFAC 1		#N/A
NAR1 0		#N/A
IARU 1		#N/A
NSAR1 0		#N/A
NAR2 0		#N/A
NLN2 0		#N/A
NLINES 0		#N/A
ILNU 1		#N/A
NSLN1 0		#N/A
MXNSEG 7		#N/A
NLRISE 6		#N/A
XL 0		#N/A
HBL 0		#N/A
WBL 0		#N/A
WML 0		#N/A
DXL 0		#N/A
FPRIMEL 0		#N/A
NVL1 0		#N/A
IVLU 1		#N/A

Variable	IDNR Value	IWAQM Default
NSVL1 0		#N/A
NVL2 0		#N/A
NREC 360		User Defined

10.7 APPENDIX: POSTUTIL

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the POSTUTIL postprocessor.

Variable	IDNR Value
UTLLST pstu.lst	
UTLDAT pstu.con	
NMET 365	
NFILES 1	
LCFILES T	
UTLMET	/r1/calpuff/calmet/12km_12z/2002/cmet.20021230.dat *(an example)*
MODDAT cpuf.con	
ISYR 2002	
ISMO 1	
ISDY 1	
ISHR 1	
NPER 8760	
NSPECINP 6	
NSPECOUT 6	
NSPECCMP 0	
MDUPLCT 1	
NSCALED 0	
MNITRATE 1	
BCKNH3 3	
ASPECI SO2	
ASPECI SO4	
ASPECI NOX	
ASPECI HNO3	
ASPECI NO3	
ASPECI PM10	
ASPECO SO2	
ASPECO SO4	
ASPECO NOX	
ASPECO HNO3	
ASPECO NO3	
ASPECO PM10	

10.8 APPENDIX: CALPOST

The following table provides a listing of the variables and subsequent values utilized in the IDNR CALPUFF model plant configuration for the CALPOST postprocessor.

Variable	IDNR Value
MODDAT	input-pstu.con
PSTLST	cp st.lst
VUNAM	v is
LCFILES	T
METRUN	0
ISYR	2002
ISMO	1
ISDY	1
ISHR	1
NHRS	8760
NREP	1
ASPEC	VISIB
ILAYER	1
A	0
B	0
LBACK	F
LG	F
LD	T
LCT	F
LDRING	F
NDRECP	-1
IBGRID	-1
JBGRID	-1
IEGRID	-1
JEGRID	-1
NGONOFF	0

Variable	IDNR Value
RHMAX	95
LVSO4	T
LVNO3	T
LVOC	F
LVPMC	F
LVPMF	T
LVEC	F
LVBK	T
SPECPMC	PMC
SPECPMF	PM10
EEPMC	0.6
EEPMF	1
EEPMCBK	0.6
EESO4	3
EENO3	3
EEOC	4
EESOIL	1
EEEC	10
MVISBK	6
RHFAC	see: Table 5-8, Table 5-9, Table 5-10
BKSO4	see: Table 5-8, Table 5-9, Table 5-10
BKNO3	see: Table 5-8, Table 5-9, Table 5-10
BKPMC	see: Table 5-8, Table 5-9, Table 5-10
BKOC	see: Table 5-8, Table 5-9, Table 5-10
BKSOIL	see: Table 5-8, Table 5-9, Table 5-10
BKEC	see: Table 5-8, Table 5-9, Table 5-10

Variable	IDNR Value
BEXTRAY	10
LDOC	F
IPRTU	3
L1HR	F
L3HR	F
L24HR	T
LRUNL	F
NAVG	0
LT50	F
LTOPN	F
NTOP	4
ITOP	1,2,3,4
LEXCD	F
THRESH1	-1
THRESH3	-1
THRESH24	-1
THRESHN	-1
NDAY	0
NCOUNT	1
LECHO	F
LTIME	F
IECHO	366*0
LPLT	F
LGRD	F
LDEBUG	F

11. CAMX APPENDICES

Analyses pertaining to the CAMx cumulative modeling scenarios focused primarily upon the maximum impacts and the frequency of impacts above 0.5 dv. The investigation of maximum impacts is informative but provides little context regarding relational magnitudes of the immediate subordinate data. The following tables are therefore provided to supply additional detail. For each scenario modeled, the Class I area specific top ten delta deciview impacts are listed, along with the corresponding date of occurrence. Ranked data for both the annual average and the 20% best natural background conditions are provided. The ranked impacts, in relation to current (2002) visibility conditions, are provided for the 12km simulation to compliment Table 6-6.

The data show atmospheric conditions in August and September generally yield the highest impacts at nearby Class I areas. In review of all ranked impacts, greater temporal variability is encountered and the importance of annual episodes becomes clear. A final feature of the datasets is a tendency for a disproportionate increase in visibility impacts when comparing the highest and second highest impacts, versus other rankings. For example, in scenario k2002ia36b0v2r2 under annual average natural background conditions the maximum impact at MING is 0.41 dv while the second high is 0.20 dv, a difference of 0.21 dv. The next largest step decrease is roughly 1/7th this range, at 0.03 dv (and occurs between the 5th and 6th highest values). These tendencies are only moderate in prevalence, as exceptions are easily found (e.g. BADL in scenario k2002ia36b0v2r1). The transition to a 12km grid also eases this gradient. In summary, while not critical in subject to BART determinations, expanding the visibility impact analysis beyond maximum impacts to include the top ten values provides additional insight and perspective.

11.1 Appendix: k2002ia36b0v2r1 Ranked Visibility Impacts

k2002ia36b0v2r1: Annual Average Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	2.23	8/20/2002	2.97	9/18/2002	2.65	12/14/2002	2.70	4/15/2002	2.34	8/25/2002	3.17	11/29/2002	2.40	9/18/2002
2	2.02	8/27/2002	2.72	9/6/2002	2.29	9/16/2002	2.60	9/18/2002	1.53	4/22/2002	1.99	11/28/2002	1.92	10/1/2002
3	1.61	8/21/2002	2.14	10/1/2002	2.27	12/6/2002	2.27	9/17/2002	1.41	9/16/2002	1.94	9/18/2002	1.88	9/30/2002
4	1.22	8/26/2002	2.10	9/17/2002	1.47	4/22/2002	2.21	9/6/2002	1.27	8/26/2002	1.93	7/17/2002	1.85	9/6/2002
5	1.08	8/4/2002	1.97	9/30/2002	1.32	4/2/2002	2.14	6/30/2002	1.11	5/26/2002	1.86	7/27/2002	1.78	12/11/2002
6	0.99	8/6/2002	1.84	6/30/2002	1.31	5/26/2002	1.89	9/2/2002	0.98	6/6/2002	1.62	9/17/2002	1.74	9/1/2002
7	0.98	8/5/2002	1.76	4/15/2002	1.14	9/17/2002	1.86	4/14/2002	0.87	11/19/2002	1.49	9/14/2002	1.46	1/4/2002
8	0.94	7/14/2002	1.60	9/7/2002	0.96	11/17/2002	1.74	10/1/2002	0.82	2/4/2002	1.45	8/12/2002	1.43	8/30/2002
9	0.88	9/29/2002	1.58	8/30/2002	0.92	11/27/2002	1.52	7/16/2002	0.79	9/17/2002	1.25	12/13/2002	1.39	9/17/2002
10	0.76	5/11/2002	1.55	1/4/2002	0.92	9/11/2002	1.51	9/30/2002	0.78	4/23/2002	1.23	12/10/2002	1.35	9/7/2002

k2002ia36b0v2r1: 20% Best Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	2.79	8/20/2002	4.16	9/18/2002	3.72	12/14/2002	3.72	4/15/2002	3.32	8/25/2002	4.41	11/29/2002	3.41	9/18/2002
2	2.53	8/27/2002	3.83	9/6/2002	3.24	9/16/2002	3.68	9/18/2002	2.16	4/22/2002	2.83	11/28/2002	2.72	10/1/2002
3	2.03	8/21/2002	3.01	10/1/2002	3.21	12/6/2002	3.23	9/17/2002	2.03	9/16/2002	2.79	9/18/2002	2.69	9/30/2002
4	1.55	8/26/2002	3.00	9/17/2002	2.08	4/22/2002	3.15	9/6/2002	1.84	8/26/2002	2.74	7/17/2002	2.65	9/6/2002
5	1.38	8/4/2002	2.82	9/30/2002	1.89	5/26/2002	3.00	6/30/2002	1.60	5/26/2002	2.66	7/27/2002	2.53	12/11/2002
6	1.26	8/6/2002	2.61	6/30/2002	1.88	4/2/2002	2.71	9/2/2002	1.43	6/6/2002	2.34	9/17/2002	2.50	9/1/2002
7	1.25	8/5/2002	2.48	4/15/2002	1.66	9/17/2002	2.61	4/14/2002	1.26	11/19/2002	2.16	9/14/2002	2.10	1/4/2002
8	1.20	7/14/2002	2.30	9/7/2002	1.39	11/17/2002	2.46	10/1/2002	1.19	2/4/2002	2.10	8/12/2002	2.06	8/30/2002
9	1.11	9/29/2002	2.28	8/30/2002	1.33	9/11/2002	2.18	9/30/2002	1.16	9/17/2002	1.80	12/13/2002	2.01	9/17/2002
10	0.97	5/11/2002	2.21	1/4/2002	1.33	11/27/2002	2.17	7/16/2002	1.12	4/23/2002	1.78	12/10/2002	1.95	9/7/2002

11.2 Appendix: k2002ia36b0v2r2 Ranked Visibility Impacts

k2002ia36b0v2r2: Annual Average Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	0.15	8/20/2002	0.62	9/6/2002	0.38	12/14/2002	0.64	4/15/2002	0.41	8/25/2002	0.58	9/18/2002	0.36	9/6/2002
2	0.15	2/16/2002	0.42	9/18/2002	0.34	4/2/2002	0.51	9/6/2002	0.20	9/16/2002	0.40	9/17/2002	0.34	9/18/2002
3	0.12	10/15/2002	0.36	1/4/2002	0.29	10/26/2002	0.51	4/14/2002	0.18	6/6/2002	0.38	9/14/2002	0.33	1/4/2002
4	0.11	5/30/2002	0.32	4/15/2002	0.27	4/9/2002	0.50	6/30/2002	0.18	8/26/2002	0.30	2/6/2002	0.28	8/30/2002
5	0.11	8/5/2002	0.30	9/30/2002	0.27	12/6/2002	0.42	9/18/2002	0.18	4/2/2002	0.29	7/17/2002	0.25	12/11/2002
6	0.10	11/5/2002	0.27	12/11/2002	0.25	2/24/2002	0.40	7/16/2002	0.15	11/28/2002	0.26	7/27/2002	0.24	9/30/2002
7	0.10	7/13/2002	0.27	6/30/2002	0.22	8/26/2002	0.31	1/4/2002	0.14	4/5/2002	0.26	1/4/2002	0.22	4/14/2002
8	0.09	3/19/2002	0.26	9/7/2002	0.20	11/27/2002	0.27	9/17/2002	0.14	12/25/2002	0.26	12/10/2002	0.21	1/3/2002
9	0.09	8/22/2002	0.25	1/3/2002	0.20	10/27/2002	0.25	12/10/2002	0.14	2/1/2002	0.24	12/19/2002	0.19	8/29/2002
10	0.08	4/28/2002	0.24	4/14/2002	0.19	12/10/2002	0.25	9/19/2002	0.13	11/25/2002	0.24	4/14/2002	0.19	7/21/2002

k2002ia36b0v2r2: 20% Best Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	0.20	8/20/2002	0.91	9/6/2002	0.57	12/14/2002	0.92	4/15/2002	0.60	8/25/2002	0.85	9/18/2002	0.53	9/6/2002
2	0.19	2/16/2002	0.62	9/18/2002	0.49	4/2/2002	0.76	9/6/2002	0.29	9/16/2002	0.60	9/17/2002	0.51	9/18/2002
3	0.16	10/15/2002	0.52	1/4/2002	0.43	10/26/2002	0.73	4/14/2002	0.27	6/6/2002	0.56	9/14/2002	0.49	1/4/2002
4	0.14	5/30/2002	0.46	4/15/2002	0.39	12/6/2002	0.73	6/30/2002	0.26	8/26/2002	0.44	2/6/2002	0.42	8/30/2002
5	0.14	8/5/2002	0.45	9/30/2002	0.39	4/9/2002	0.62	9/18/2002	0.26	4/2/2002	0.43	7/17/2002	0.36	12/11/2002
6	0.13	11/5/2002	0.41	12/11/2002	0.36	2/24/2002	0.59	7/16/2002	0.22	11/28/2002	0.39	7/27/2002	0.36	9/30/2002
7	0.13	7/13/2002	0.39	6/30/2002	0.33	8/26/2002	0.46	1/4/2002	0.21	12/25/2002	0.38	1/4/2002	0.32	4/14/2002
8	0.12	3/19/2002	0.39	9/7/2002	0.29	11/27/2002	0.40	9/17/2002	0.21	4/5/2002	0.38	12/10/2002	0.31	1/3/2002
9	0.11	8/22/2002	0.37	1/3/2002	0.29	10/27/2002	0.36	9/19/2002	0.21	2/1/2002	0.36	12/19/2002	0.28	8/29/2002
10	0.11	4/28/2002	0.36	8/30/2002	0.28	12/10/2002	0.36	12/10/2002	0.20	11/25/2002	0.35	4/14/2002	0.28	6/19/2002

11.3 Appendix: k2002ia12b0v2r2 Ranked Visibility Impacts

k2002ia12b0v2r2: Annual Average Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	0.24	9/28/2002	0.63	9/6/2002	0.52	12/14/2002	0.62	7/16/2002	0.34	8/25/2002	0.43	9/18/2002	0.53	9/18/2002
2	0.17	8/20/2002	0.57	9/18/2002	0.49	4/9/2002	0.54	6/30/2002	0.26	11/6/2002	0.34	9/14/2002	0.36	9/6/2002
3	0.12	7/13/2002	0.29	9/7/2002	0.38	4/2/2002	0.49	4/15/2002	0.26	9/16/2002	0.27	12/19/2002	0.27	8/30/2002
4	0.11	4/28/2002	0.28	12/11/2002	0.28	11/15/2002	0.39	9/17/2002	0.23	5/26/2002	0.26	7/17/2002	0.24	12/11/2002
5	0.11	7/12/2002	0.28	7/21/2002	0.28	8/27/2002	0.37	9/18/2002	0.22	8/26/2002	0.23	7/27/2002	0.24	6/29/2002
6	0.10	3/7/2002	0.27	10/1/2002	0.25	8/26/2002	0.34	9/2/2002	0.21	6/6/2002	0.22	7/21/2002	0.24	9/30/2002
7	0.09	8/5/2002	0.25	9/2/2002	0.25	9/16/2002	0.33	9/6/2002	0.21	8/27/2002	0.21	2/6/2002	0.23	7/21/2002
8	0.09	9/10/2002	0.24	9/30/2002	0.24	10/26/2002	0.28	4/14/2002	0.20	4/5/2002	0.20	7/1/2002	0.23	5/29/2002
9	0.08	8/27/2002	0.24	4/15/2002	0.22	11/27/2002	0.26	9/7/2002	0.18	12/14/2002	0.19	12/10/2002	0.22	4/15/2002
10	0.08	8/23/2002	0.22	8/9/2002	0.19	10/27/2002	0.21	8/10/2002	0.16	4/10/2002	0.18	6/25/2002	0.22	8/9/2002

k2002ia12b0v2r2: 20% Best Natural Background

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	0.30	9/28/2002	0.93	9/6/2002	0.76	12/14/2002	0.90	7/16/2002	0.50	8/25/2002	0.64	9/18/2002	0.78	9/18/2002
2	0.21	8/20/2002	0.84	9/18/2002	0.70	4/9/2002	0.78	6/30/2002	0.39	11/6/2002	0.51	9/14/2002	0.53	9/6/2002
3	0.15	7/13/2002	0.43	9/7/2002	0.55	4/2/2002	0.71	4/15/2002	0.38	9/16/2002	0.40	12/19/2002	0.41	8/30/2002
4	0.14	4/28/2002	0.41	12/11/2002	0.42	11/15/2002	0.57	9/17/2002	0.34	5/26/2002	0.39	7/17/2002	0.36	12/11/2002
5	0.14	7/12/2002	0.41	7/21/2002	0.42	8/27/2002	0.55	9/18/2002	0.33	8/26/2002	0.34	7/27/2002	0.36	6/29/2002
6	0.13	3/7/2002	0.39	10/1/2002	0.37	8/26/2002	0.50	9/2/2002	0.32	8/27/2002	0.32	7/21/2002	0.36	9/30/2002
7	0.12	8/5/2002	0.37	9/2/2002	0.36	9/16/2002	0.49	9/6/2002	0.32	6/6/2002	0.31	2/6/2002	0.34	7/21/2002
8	0.11	9/10/2002	0.35	9/30/2002	0.36	10/26/2002	0.40	4/14/2002	0.29	4/5/2002	0.30	7/1/2002	0.33	5/29/2002
9	0.10	8/27/2002	0.34	4/15/2002	0.33	11/27/2002	0.39	9/7/2002	0.27	12/14/2002	0.28	12/10/2002	0.33	8/9/2002
10	0.10	8/23/2002	0.32	8/9/2002	0.27	10/27/2002	0.30	8/10/2002	0.24	10/14/2002	0.27	9/17/2002	0.33	4/15/2002

k2002ia12b0v2r2: Current Conditions

RANK	BADL	Date	BOWA	Date	HEGL	Date	ISLE	Date	MING	Date	SENE	Date	VOYA	Date
1	0.12	9/28/2002	0.11	9/6/2002	0.11	4/9/2002	0.19	7/16/2002	0.08	10/14/2002	0.13	9/14/2002	0.10	6/29/2002
2	0.08	9/10/2002	0.11	7/21/2002	0.11	8/26/2002	0.13	6/30/2002	0.08	1/15/2002	0.08	12/7/2002	0.10	7/21/2002
3	0.06	7/12/2002	0.10	9/18/2002	0.10	4/2/2002	0.12	2/14/2002	0.06	10/7/2002	0.08	9/18/2002	0.10	9/18/2002
4	0.06	8/20/2002	0.08	6/29/2002	0.08	1/17/2002	0.11	9/17/2002	0.06	5/26/2002	0.08	9/17/2002	0.09	8/9/2002
5	0.06	2/26/2002	0.08	9/5/2002	0.08	12/14/2002	0.09	9/18/2002	0.06	4/22/2002	0.07	2/14/2002	0.08	4/15/2002
6	0.05	7/13/2002	0.08	8/9/2002	0.07	8/27/2002	0.08	4/15/2002	0.06	8/25/2002	0.06	2/7/2002	0.07	9/6/2002
7	0.05	5/12/2002	0.08	8/15/2002	0.07	2/1/2002	0.06	11/7/2002	0.06	6/6/2002	0.06	7/16/2002	0.07	4/14/2002
8	0.05	5/9/2002	0.07	10/10/2002	0.06	8/25/2002	0.06	8/10/2002	0.05	11/6/2002	0.05	7/17/2002	0.07	5/21/2002
9	0.05	8/22/2002	0.07	5/21/2002	0.06	11/15/2002	0.06	6/7/2002	0.05	5/3/2002	0.05	1/4/2002	0.06	5/29/2002
10	0.04	5/25/2002	0.06	5/28/2002	0.05	2/10/2002	0.06	4/14/2002	0.04	4/5/2002	0.05	2/6/2002	0.06	9/5/2002

APPENDIX 10

Appendix 10.1

Consultation for Regional Haze Planning in Northern Class I Areas

2004-2005 Discussions

During 2004 and 2005, a number of discussions were held between state and tribal representatives in the upper Midwest concerning air quality planning to address regional haze in the four class I areas in northern MI and northern MN. A summary of these calls and meetings is provided below.

July 8, September 16, December 1, 2004 and March 15, 2005 Conference Calls: Midwest RPO (MRPO) staff and MN and IA representatives held several initial calls to review a draft protocol ("Meeting Reasonable Progress Goals for Haze in the Upper Midwest", July 29, 2004), and discuss the progress of the MRPO's air quality modeling.

May 24, 200: Meeting in Madison, WI (see "Meeting Summary, Regional Haze in Northern Class I Areas (Boundary Waters, Voyageurs, Isle Royale and Seney)")

July 6, 2005 Conference Call: Representatives from ND, MN, WI, MI, WRAP, CENRAP, and MRPO participated in a conference call to continue the coordination effort concerning regional haze requirements for the four northern class I areas.

Larry Bruss (WI) asked what MN would do if expected controls (e.g., CAIR) are not enough to meet the reasonable progress goals for their class I areas? What are the options for dealing with interstate impacts? What does EPA expect us to do in terms of "consultation" and working together to address the reasonable progress goals in these class I areas?

It was agreed that we should invite EPA to the next call to discuss SIP approvability and consultation requirements. It was also noted that one objective of this inter-state/inter-RPO coordination effort is to develop a mutually agreeable solution for meeting the reasonable progress goals in these class I areas. To this end, MRPO, CENRAP, and WRAP will share modeling results and, as necessary, collaborate on any possible control strategies.

Mike Koerber (MRPO) reviewed the action items from the May 24 meeting in Madison, WI. First, a copy of the MRPO's latest schedule, with policy and technical activities was distributed via e-mail along with the agenda for this call. Chuck Layman said that CENRAP's schedule will be distributed shortly. Tom Moore said that he just sent out via e-mail the WRAP's current modeling schedule.

Second, new composite back trajectories (prepared by Donna Kenski, LADCO) were distributed via e-mail on June 6. These new trajectories indicate where the air is most likely to have come from on poor air quality/visibility days and on good air quality/visibility days. Chuck Layman said that CENRAP also prepared trajectories for Boundary Waters as part of their Causes of Haze study. The LADCO and CENRAP trajectories are qualitatively similar.

Third, summaries of the updated MRPO modeling was distributed via e-mail along with the agenda for this call. Mike Koerber reviewed the results for Boundary Waters, which indicated that only one scenario (EGU1 reductions applied throughout the 13-state Midwest Governors Association region - see http://www.midwestgovernors.org/states/) would meet the uniform rate of progress goal in 2018. (For more information on the EGU1 and EGU2 controls, see http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/WP_EGU_Version_31.pdf).

Finally, there was a short discussion on the steps being taken to address BART. MRPO is working with their states to finalize the list of BART-eligible sources, conducting modeling to determine which of these sources are subject to BART, and then conduct source-specific engineering analyses to set BART emission limitations. A policy decision is needed on whether to accept EPA's position that CAIR satisfies the BART requirement for EGUs. The CENRAP States are responsible for their own BART work. MN and IA, in particular, have done a lot of work, which could be used to approximate BART emission reductions in a future modeling run, if necessary.

August 9, 2005 Conference Call: Representatives from ND, MN, IA, WI, MI, NPS, USFS, WRAP, CENRAP, and MRPO participated in a conference call to continue the coordination effort concerning regional haze requirements for the four northern class I areas. (EPA was asked to participate to discuss SIP approvability, but they were not ready to do so.)

Larry Bruss suggested that in the absence of EPA guidance, we develop our own SIP approach, which includes the reasonable progress goal for these four class I areas. Example goals include: (1) a uniform rate of progress, and (2) limiting the visibility impact (measured in deciviews) of each state. Prior to the next call, Larry (and Mike Koerber) will prepare a preliminary list of options for the reasonable progress goal. Also, CENRAP will share its table identifying various rule requirements and its draft SIP format. This information may form the basis for our SIP approach.

Chuck Layman noted that CENRAP's Causes of Haze Study is almost done and will be released shortly. He also said that CENRAP will be conducting further analysis of its class I areas, and will do work to identify source/state contributions and candidate control measures. CENRAP's strategy modeling will begin in a couple months. Mike Koerber said that MRPO's Round 3 strategy results will be available in mid-September and will be discussed on the next call.

There was a discussion on BART. It seems that most states will be identifying BART-eligible sources and determining which of these sources are subject BART, and then will be asking those "subject to BART" to conduct a source-specific engineering analysis. The "model plant" work done by MACTEC should be helpful in these source-specific analyses - see

Technical Memo:
http://www.ladco.org/reports/rpo/MWRPOprojects/Strategies/Technical_Memo_LADCO-2.pdf

ICI Boilers:
http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/Boiler_BART_Engineering%20Analysis%20%2B%20Appendix%20A.pdf

Refineries:
http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/Initial%20draft%20BART%20-%20Refineries%20%20%2B%20Appendix%20A.pdf

Cement Plants:
http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/Cement_BART_Engineering%20Analysis%20%2B%20Appendix%20A1.pdf

Iron and Steel Mills:
http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/Iron%20&%20Steel%20Mills%20BART%20Engineering%20Analysis%20%2B%20Appendix%20A.pdf

None of the states on the call have yet taken a position of EPA's statement that CAIR satisfies the BART requirement for EGUs.

Also, MN will work with MRPO on a modeling analysis to estimate the impact of BART controls on the northern class I areas.

Finally, Mike Koerber provided a brief update on what's happening with the Midwest Governors Association on IL's emission reduction initiative. Henry Henderson has been hired to prepare a scoping report identifying options and stakeholder comments. His report is expected later this month. Illinois is hoping to schedule a series of workshops this fall and have a policy summit for state commissioners in November. Also, there was a short discussion in Des Moines on July 16 with the Midwest Governors Association, as part of the U.S. Governors Association meeting.

September 26 Conference Call (Notes prepared by Annette Sharp, CENRAP): Representatives from ND, MN, IA, MI, WI, Leech Lake Band of Ojibwe, CENRAP, MRPO, WRAP, FLM, EPA (Region 5 and OAQPS) participated in a conference call to review BART activities, and to discuss a draft paper prepared by WI on meeting reasonable progress goals. A point was made that MO should be participating in the call as a potential contributor.

I. Update on BART Work

A. MRPO

Mike Koerber presented MRPO's work. The MRPO's BART Determination Process Includes:

- Step 1: Identify BART-eligible sources
- Step 2: Determine which BART-eligible sources are subject to BART (Sources which are *reasonably anticipated to cause or contribute to visibility impairment in any class I area*)
- Step 3: For sources subject to BART, conduct engineering analysis of emissions control alternatives
- Step 4: Perform cumulative air quality analysis (assess degree of visibility improvement due to emission reductions from all sources subject to BART)
- Step 5: Based on engineering analysis and air quality analysis, establish BART emission limitations. (Note, as an alternative to source-specific BART, states may implement an emissions trading program if it achieves greater reasonable progress.)

How MRPO determines which BART-eligible sources are subject to BART?

- EGUs (no action at this time)
    - USEPA BART Rulemaking (July 6, 2005): *"CAIR achieves greater progress than BART and may be used by States as a BART substitute."*
- Non-EGUs (handful of facilities under review)
    - Individual Source Attribution Approach (CALPUFF Modeling): Prioritize modeling for those non-EGU sources with Q/d > 5 (i.e., initial CALPUFF

modeling indicated that < 0.5 dV impacts associated with Q/d combinations < 5)

MRPO BART Work Products

Phase I

- Best Available Retrofit Technology Engineering Analysis (March 30, 2005):
  - Boilers
  - Petroleum refineries
  - Cement plants
  - Iron and steel mils
- "Best Available Retrofit Technology Engineering Analysis for Non-EGU Sources – Summary and Recommendations for Next Steps", March 30, 2005, MACTEC

Phase II

- Workshop – February/March 2006(?)
- State BART guideline – builds off EPA guideline and suggests default control technology and emission limitations

B. CENRAP

Chuck Layman presented CENRAP's work with additional information provided by Chad Daniel (IA)

The CENRAP's BART Determination Process Includes:

- Step 1: Identify BART-eligible sources– Texas is still working on their list and Louisiana has had to concentrate on immediate environmental impacts from Hurricanes Katrina and Rita
- Step 2: Determine which BART-eligible sources are subject to BART
  - Causes of Haze Work presented at RPO Directors Meeting and to POG in October. QA Work Order let to check work done.
- Step 3: For sources subject to BART, conduct engineering analysis of emissions control alternatives
- Step 4: Perform cumulative air quality analysis (assess degree of visibility improvement due to emission reductions from all sources subject to BART)
- Step 5: Based on engineering analysis and air quality analysis, establish BART emission limitations. (Note, as an alternative to source-specific BART, states may implement an emissions trading program if it achieves greater reasonable progress.)

How CENRAP determines which BART-eligible sources are subject to BART?

- CENRAP focused on non-EGUs and without Texas has 81 sources and with EGUs and without Texas has 109 sources. CENRAP used 2002 Base B emissions for the Q/d > 10 calculation. Individual analyses are left up to each state. The first draft of these facilities is due at the end of the week.

CENRAP Next Steps: (1) estimate BART emissions; (2) develop control strategies; and (3) support emissions Trading Committee

Bruce Polkowsky, NPS, asked if CENRAP or MRPO were looking at any IPM modeling similar to the work in VISTAS. Neither CENRAP nor MRPO were considering that option.

II. Meeting Reasonable Progress Discussion

Bob Lopez (WI) discussed the draft Meeting Reasonable Progress Paper developed by Larry Bruss (WI). Kathy Kaufman stated that EPA staff had some reservations about the assumption that meeting the uniform rate of progress equated with meeting reasonable progress. Much discussion ensued.

Folks agreed that the paper was a good starting point for discussion. Bruce Polkowsky agreed to develop the issue of “the slope of the line” for the next call. He stated that the Regional Haze Rule looked at the uniform rate of progress as a “guide.” Bruce intends to modify the WI paper to reflect his proposal by the end of the week which would then be made available to the group for discussion at the next conference call.

October 7, 2005 Conference Call: Representatives from ND, MN, WI, MI, NPS, USFS, WRAP, CENRAP, LADCO, USEPA, and the Fond du Lac and Mille Lacs Tribes participated in a conference call to discuss a proposed approach for determining reasonable progress (see “Approaches for Meeting Reasonable Progress for Visibility at Northern Class I Areas”, Draft, September 29, 2005). After the discussion on the draft paper, a suggestion was made to perform a test case. Here is an outline of the proposed test case:

1. Identify and Prioritize Sources - focus on power plant SO2 emissions

2. Identify Control Options for Priority Sources - consider five scenarios: CAIR based on IPM (with trading), CAIR based on IPM (no interstate trading), BART for EGUs in a 6-state region (ND, SC, MN, IA, WI, MI), EGU1 in 6-state region, and EGU2 in 6-state region

3. Assess Effect of Existing Programs for Priority Sources - summarize 2018 SO2 emissions for five scenarios

4. Evaluate Control Options for Priority Sources - conduct cursory examination of the four statutory factors (costs of compliance, time necessary for compliance, energy and non-air quality environmental impacts of compliance, and remaining useful life of any potentially affected sources)

5. Compare Control Strategies with URP - conduct air quality modeling for the five scenarios and present results on graphic with URP line

November 2, 2005 Conference Call: A brief conference call was held on November 2 to discuss how to address the four statutory factors for the proposed test case. Larry Bruss said that his staff would conduct an analysis for WI sources by the end of the month. This analysis will be reviewed on the next call.

December 5, 2005 Conference Call: Representatives from ND, MN, WI, MI, NPS, CENRAP, LADCO, USEPA, and the Fond du Lac Tribe participated in a conference call to discuss WI’s draft analysis of the four factors. Farrokh Ghoreishi (WI) presented the analysis, as summarized in “Preliminary cost and impact analysis for SO2 control on EGUs in Wisconsin”, December 1, 2005. Similar analyses are needed by other states, but no commitments were made to do so at this time.

Meeting Summary
Regional Haze in Northern Class I Areas (Boundary Waters, Voyageurs, Isle Royale and Seney)

On Tuesday, May 24, 2005, representatives from the States of Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin, and from CENRAP, WRAP, and Midwest RPO met in Madison, Wisconsin to begin the coordination effort on addressing regional haze requirements for the four northern Class I areas: Boundary Waters Canoe Area and Voyageurs National Park in Minnesota, and Isle Royale National Park and Seney National Wildlife Refuge in Michigan.[1]

Lloyd Eagan (Wisconsin) opened the meeting by welcoming everyone to Madison and reviewing the purpose of the meeting.

Mike Koerber (LADCO) provided a little background on regional haze and summarized the results of the Midwest RPO's monitoring and modeling work. Key findings from this technical work include:

- Sulfate is the dominant PM2.5 species affecting visibility in these Class I areas. Nitrate and organic carbon also affect visibility, but to a lesser degree. Back trajectories provide possible information on the location of sources of these species.

- Preliminary modeling indicates that existing and new (e.g., CAIR) controls will improve visibility, but may not be enough to meet the 2018 reasonable progress goals. (Note, this modeling does not reflect BART.)

A draft technical summary report was prepared based on this work. The report will be updated based on additional analyses (e.g., CENRAP's causes of haze study, more back trajectories, and new RPO modeling).

An important policy question that needs to be answered is whether existing ("on the books") controls plus CAIR will be enough to meet the reasonable progress goals for these Class I areas. The Midwest RPO's modeling is being updated to reflect BART and to include all known existing controls (e.g., consent decrees for EGUs in Minnesota and Wisconsin). The new modeling will be available in September.

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[1] This is not the first time that representatives from some of these states have gotten together to discuss regional haze in these northern Class I areas. Five conference calls have been held with technical contacts: July 8, 2004, September 16, 2004, December 1, 2004, March 15, 2004, and May 9, 2005. The purpose of these calls were to review a draft technical analysis protocol (July 8), discuss the progress of the modeling (September 16, December 1, and March 15), and review a draft technical summary report (May 9).

There was agreement to continue sharing technical information between states and RPOs and to continue working together. The RPOs will exchange their schedules of technical activities for the next year, and there will be further discussion on coordination of work products. Also, policy-level discussions need to continue. Given that states are facing tight deadlines for submitting SIPs for regional haze (and ozone and PM2.5), a decision should be made on what controls are needed by spring 2006 in order to give states enough time to conduct their rulemaking.

Finally, it was also noted that Illinois is promoting a Regional Emissions Reduction Initiative, which considers beyond-CAIR reductions for EGUs, through the Midwest Governors Association. (The 13-state Midwest Governors Association includes Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.) Coordination of this Initiative with the inter-state efforts to address regional haze is desirable.

Action Items:

(1) Midwest RPO, CENRAP, and WRAP will exchange their schedules of technical activities for the next year.

(2) The draft technical summary report will be updated based on additional trajectory analyses, the Midwest RPO's latest modeling results, and information from CENRAP's causes of haze study.

(3) A conference call with technical contacts will be held in late June/early July to discuss the RPO schedules, any new analyses (e.g., CENRAP's causes of haze study), updates to the draft technical summary report, and EPA's final BART rule, which is expected to be issued on June 15.

(4) A conference call with Air Directors will be held in late September to review the new modeling and discuss next steps. Tribes, Federal Land Managers, and EPA should be invited to future calls and meetings.

Northern Class I Areas Consultation

Draft Minutes

July 25, 2006
1:30 – 2:30 pm CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Catherine Neuschler, David Thornton
	Michigan	Cindy Hodges, Bob Irvine, Assad Khan, Teresa Walker
	Iowa	Matthew Johnson, Wendy Walker
	North Dakota	Tom Bachman, Dana Mount, Terry O'Clare, Steve Weber, Rob White
	Wisconsin	Larry Bruss, Bob Lopez, Farrokh Ghoreishi
	Tribes	Charlie Lippert – Mille Lacs (MN) Brandy Toft – Leech Lake (MN)
	FLMs	Meredith Bond – USFWS Trent Wickman – USFS – Superior
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP Brandon Krogh – CENRAP/Minnesota Power
	EPA	Matt Rau – EPA Region V

Agenda Items

General Overview and Future Direction

We discussed that the group will have to decide who wants to and should participate in future consultation. We also need to decide how to further move ahead with future consultation, whether that should be formal or informal at this point. Minnesota discussed some of the pollutants of concern and the contributions of other areas. It is clear that all four Northern Class I areas (Voyageurs, BWCA, Isle Royale, and Seney) will be above the uniform rate of progress, even with the implementation of CAIR.

Northern Class I Areas

The group asked whether the four Northern Class I areas should be approached as one group or two separate groups. It was deiced that for efficiency it makes sense to consult on all four areas together, though this will widen the number of participants. Therefore, Minnesota and Michigan will share responsibility for directing these calls and the consultation process. John Seltz. Bob Irvine, and Mike Koerber will work together on this.

Future Consultation

Minnesota raised the question of how frequently we need to be meeting, every two weeks and once a month were suggested. It was suggested that we first need to have a better definition of what our consultation process will entail, and that we need to have some technical work and analyses done to determine what we know and what we need to figure out. Eventually, the group envisions the technical work being done to back up a meeting of policy makers to address these questions:

How effective will existing controls be in reaching uniform rate of progress?

How effective will additional upcoming control strategies (BART, controls for ozone nonattainment, etc.) be?

What other controls are needed to meet reasonable progress goals?

To answer these questions, the group agreed that the consultation process should include discussions of:

- BART implementation
- Visibility conditions (baseline, natural visibility, how we evaluate improvement)
- Addressing international emissions
- Culpability of states in Class I areas
- Actions states taking to reduce emissions
- Control strategy analyses
- Reasonable progress goal
- Long term strategy

It was suggested that we should aim for November have these informal discussions completed via conference call in preparation for a potential face-to-face meeting of higher-level policy makers.

Other Parties to Include

Other parties that the group thought should be invited to participate in the consultation process include the states of Missouri, and Illinois and Indiana (though they are smaller contributors to poor visibility in MI's Class I areas), the Ontario Ministry of Environment, Manitoba and Saskatchewan's environmental ministries, as well as the Tribes located within the borders of Wisconsin and Michigan as well as two Canadian First Nations in Ontario. John Seltz will work to get a distribution list set-up. **Participants in today's call should send email addresses to John Seltz (john.seltz@pca.state.mn.us) of those they feel should be invited to participate in the calls.** Charlie and Brandi said that they would forward e-mail addresses of tribes to invite.

Status Update

The states gave a status update.

ND: Has received draft BART analyses from 5 of 7 EGUs, which had to be sent back to the facilities for further corrections. These should be fixed in the next few weeks. The other two are being held up by a consent decree for NSR. The BART rule should be finalized by the end of the year. After modeling with BART is done, they will consider more control strategies.

IA: Modeling to determine BART applicability showed one source subject-to-BART, which is now slated for retirement. All EGUs are subject to CAIR, and at least one has indicated they will add controls to comply with CAIR . Waiting for PSAT run.

WI: Is in the BART rulemaking process and expects a final rule in January. Facilities will be notified if they are subject-to-BART by March 2007. Currently working on 3 stationary source rules: BART, CAIR, and NOx RACT. They are proposing that BART-eligible EGUs will need to implement BART, as IPM modeling is showing many utilities buying allowances rather than adding controls to comply with CAIR. Evaluating control measures for ozone in the east, and want to address SO2 for EGUs and papermills.

MI: Starting to collect information from facilities for engineering analyses. They started with non-EGU facilities, and found 6 affected facilities. These have been called about their selection as BART facilities and will be asked to do an outline of BART implementation. Due to EPA concerns, BART screening is being gone over and more facilities might be drawn in. BART engineering analyses done by end of year. Currently no CAIR enhancements.

MN: BART will apply to 6 taconite plants; BART engineering analyses are due in September. ND and MN will both do a 30-day comment period for external stakeholders on the BART analyses received from facilities. Have not yet decided if CAIR = BART or not, but have asked potentially subject-to-BART EGUs to do a BART analysis. Have not yet looked at control strategies beyond CENRAP-wide analyses, but will start to do so soon.

Next Up

Next call is currently set for Monday, August 14 at 10 am CDT. Bob, John, and Mike will work to set that up and finalize agenda. Items proposed for the agenda are:

- Review how we are calculating visibility conditions for 4 Class I areas (natural visibility, baseline conditions, status of meeting 2018 uniform rate of progress goal)
- Review analyses on culpability for Class I areas haze – who is contributing what pollutants

Technical Issues:

After the call, Larry Bruss suggested the following list of technical items that should be considered before we tackle the policy questions.

1. What do we know about haze in the Northern Class I Areas?
    a. What are the chemical constituents that cause visibility impairment in the Northern Class I Areas?
    b. What are the geographic areas and sources that contribute to haze in the Northern Class I Areas?
    c. What are the meteorological conditions that are associated with good visibility and poor visibility at the Northern Class I Areas? Is there a seasonal effect to visibility impairment in those areas?
2. Do we agree on the technical basis for visibility related analyses?
    a. What are the present visibility conditions and how did we calculate those values?
    b. What are natural conditions and how did we calculate those values?
    c. How did we determine the twenty percent best and worst days?
    d. Have we appropriately corrected (compensated) for relative humidity in the calculations?
    e. Are we using the most appropriate equation to calculate light extinction?

3. How do we test control measure effectiveness?
    a. What are the control measures that are most likely to improve visibility in the Northern Class I Areas?
    b. Do we have a single modeling platform that we can use to test control measures or strategies? If not, how do we compensate for the differences in the modeling between the various RPOs?
    c. Do we address ammonia control measures?

Northern Class I Area Conference Call Minutes
August 14, 2006

Participants on the call
- Minnesota: John Seltz, Mary Jean Fenske, Margaret McCourtney, Catherine Neuschler, Gordon Andersson
- Michigan: Bob Irvine, Cindy Hodges
- Wisconsin: Larry Bruss, Bob Lopez
- Iowa: Matt Johnson, Wendy Walker
- North Dakota: Tom Bachman, Dana Mount
- Tribes: Charlie Lippert, Joy Wiecks, Shannon Judd, Scott Anderson
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowky, Chris Holbeck
- FS: Trent Wickman
- EPA: Matt Rau

Minutes from last meetings
- Minutes from last meetings will be posted on Midwest RPO and CENRAP websites.
- Iowa requested that currently all findings are unofficial and preliminary.
- All attachments from today's call and future calls will also be posted unless specially requested to not post an attachment. Minutes will include the list of attachments that will be posted on the website. Both CENRAP and MRPO should post the same documents.

Participation on calls
- MN and MI will alternate leading the calls and taking minutes. Current call was lead by MN and minutes taken by MI.
- Industries should not currently be invited to the calls, but can be updated by information on websites and through meetings with the RPOs.
- Currently there are no tribal representatives from MI, WI or Canada. Mike Koerber will attempt to reach the tribes and invite them to the next call.
- Ontario, Canada would also like to be included in the calls.
- Based on culpability, IL (Rob Kaleel) will be invited to the calls by Mike Koerber.

Technical basis for visibility-related conditions
- Mike Koerber reviewed pages 6-7 of "Technical Questions on Haze: MRPO Responses."
- The baseline and natural conditions were calculated using the IMPROVE equation.
- The IMPROVE equation has been modified and results of both equations are reported. There is little difference between the two results, but we agreed that the modified IMPROVE equation should be used to make air quality decisions.

- Data from Boundary Waters was incomplete and Trent Wickman will forward the complete data to the group.

Who is contributing what pollutants to the Northern Class I areas?

- Mike Koerber reviewed page 1-5 of "Technical Questions on Haze: MRPO Responses."
  - Sulfates, Nitrates and OC contribute most to visibility impairment. Sulfate and OC are higher during the summer and nitrates are higher during the winter.
  - There appears to be no seasonal affect, since high days occur throughout the year.
  - High days seem to be coming more from states south of the class I area.
  - Receptor modeling has been done, but is not very helpful identifying sources of secondary sulfates, nitrates and OC.
- Margaret McCourtney reviewed draft work on Minnesota's analysis using CAMX with PSAT on a 36km grid for 2002.
  - Nitrates are more from local sources and sulfates are from sources further away.
  - MN is the greatest contributor to MN class I areas, followed by WI and IL. Canada has little impact.
  - Future work will be to include ammonia and use a smaller grid size (12km).
- Gordon Andersson reviewed slides compiled from various contract work.
  - Nearby sites have greater effect on class I area.
  - Corrected EGU data for 2018 emissions indicate CENRAP sites are below the line of further progress

Next steps

- MN should add to MRPOs "Technical Questions on Haze" document so there is one agreed upon document representing the 4 class I areas.
- How do we determine rate of progress? Evaluate the four factors. Mike Koerber has provided a draft scope of work for hiring a contractor to investigate this issue. CENRAP may be able to contribute to this effort.
- Continue to work on technical questions, Mike Koerber and others

Attachments to include on website:

- MRPO analysis. (M. Koerber) Technical Questions on Haze: MRPO Responses.
- CENRAP analysis. (G. Andersson) Natural Haze Levels II:
  Application of the New IMPROVE Algorithm to Natural Species Concentrations Estimates and CENRAP RHaze NorthClass I 08-10-06_1 slides.

Next Meeting: September 6, 2006, 8am CT, (9am ET, 7am MT)

Northern Class I Areas Consultation

Minutes

September 6, 2006
8:00 – 9:30 am CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Catherine Neuschler, John Seltz
	Michigan	Cindy Hodges, Bob Irvine, Jim Haywood
	Iowa	Matthew Johnson, Wendy Walker
	North Dakota	Tom Bachman, Dana Mount, Terry O'Clair
	Wisconsin Larry	Bruss
	Ontario	Mary Kirby, Peter Wong
	Tribes	Charlie Lippert – Mille Lacs Joy Wiecks – Fond du Lac David Jones – Huron Potawatomi Shannon Judd – Grand Portage
	FLMs	Bruce Polkowsky - NPS Trent Wickman – USFS – Superior
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP
	EPA	Matt Rau – EPA Region V

Agenda Items

Tribal Participation

Mike is going to get agenda time on the September 21st call between EPA and the tribal representatives, and will explain our consultation process and ask the tribes to participate.

Status of Technical Questions

The Technical Questions document will be worked on by Mike Koerber and Minnesota. Minnesota will especially work to integrate CENRAP technical work. Several pieces need to be updated, such as trajectories, and a new version of this document is expected in the next few weeks. It was requested that an executive summary be added to the document, this will be done.

Update on BOWA Patched Data

As of last week, the VIEWS website has all the substituted BOWA data posted. Gordon sent out graphics of annual concentrations and components of light extinction, which would replace those graphics in the Technical Questions document. The 20% best and worst days in deciviews for BOWA 2002-2004 and the 5-year averages were also copied. The natural conditions estimates using the Natural Haze Levels II calculation and the new algorithm should soon be posted on the VIEWS website. (These were provided in the Tech Questions document Table 2 from the July 2006 Natl Haze II ppt presention.)

Technical Questions – Control Measure Effect

Discussed 3rd question in Technical Questions document. The modeling results shown are from the most recent MRPO control strategy runs. Mike will add definitions of the control strategies on the right hand of the table and recalculate with the new IMPROVE equation. The memo needs to incorporate CENRAP control strategy runs. The main question raised was about an ammonia strategy, and the technical concerns raised in the document. Largely the group feels ammonia control strategies are more likely to be a policy than a technical question. The impact of ammonia control strategies depends on geographic area; in the ammonia rich west, controlling ammonia will have less impact.

MPRO has resolved several of the technical questions listed, namely the process-based model, understanding of deposition, model performance, and monitoring data. The technical question that remains is the impact of ammonia in multi-pollutant analysis, and the fate of other pollutants when there is less ammonia in the atmosphere; i.e. do the models address the full chemistry of ammonia? CENRAP did an ammonia scoping study, which will be reviewed and send to the group if relevant; ammonia monitoring has been cut back. The agricultural/ammonia control strategy will stay in the RFP as a suggested area of analysis; knowing something about ammonia control strategies will help us explain why we choose (or not) to propose an ammonia strategy.

Control Strategy Scope of Work
LADCO has drafted a Request for Proposal for a contractor to conduct a four factor analysis to assess reasonable progress in the northern Class I areas. While the contractor is doing technical work to assist with the assessment, it is the state's responsibility to determine reasonable progress in the first implementation period (2018). The RFP includes both source category and source-specific strategies. The RFP should be issued by end of the week, with the contract starting in October. The contractor would deliver a methodology for doing the four factor analysis, and then use that methodology. MANE-VU and VISTAS are interested in the methodology. The analysis should take a targeted look at sources. The contractor will not analyze sources that will be conducting a more detailed BART analysis; however, completed BART analyses will be given to the contractor for those sources. Some source apportionment work from MRPO, MN and MI should be available when the contract starts, and this will also be given to contractor. Contractor will share draft work products with the group on future calls. **Comments on the RFP should be sent to Mike by Friday, Sept 8.**

BART Status Update

MI: Has 6 affected facilities, scheduled to have analyses by the end of the year. MI shared data from their CALPUFF modeling with the facilities. The draft rule is in progress. No materials posted on web yet.

MN: BART engineering analyses are due September 8 from taconite facilities and end of Sept from EGUs. MN will do a completeness review and will then make analyses available for stakeholders and impacted parties.

ND: Has received draft BART analyses from 5 of 7 EGUs, and expect 2 in the next few weeks. All will be posted on the web and available for comment. Their rule is in the final stages and should be effective January 1. Plan to submit BART section of SIP early.

IA: No major updates. Working through rule process, but rule won't go to Board until November. BART determinations will be made after the rule is finished. Currently no BART sources.

WI: BART rule has been pulled from September Board meeting; may go to October meeting for hearing authorization or may be delayed until after election. The final rule probably won't be done until spring. BART facilities will include 10 EGUs and 6 pulp and paper mills. Sources will do BART analyses.

Control Strategy Work
LADCO has posted work on regional air quality planning page at http://www.ladco.org/Regional_Air_Quality.html This includes white papers on stationary and mobile source candidate control measures. Contractor cost-benefit analysis on EGU control strategies is in house and will be posted soon. Modeling is also posted, such as MacTech BART modeling. Can be a starting point for contractor
CENRAP has posted all control strategy work on the webpage http://www.cenrap.org/imp_document.asp. Mostly work on ICI boilers and natural gas compressor stations, including general cost curves. No modeling of control strategies done as yet; eventually it is planned to model gas compressor and boiler strategies.
WRAP is working on area sources from oil and gas production. Expecting Attribution of Haze report 2 in October.

Administrative and Next Up

- Minutes from last meeting are approved and can be posted.
- The RTI scoping study done for CENRAP and mentioned on the call, "Ammonia Monitoring Recommendations" can be found on the CENRAP website *on page 2* of "reports & presentations" (there are no dates or authors listed for the reports & presentations) It includes a comprehensive literature review and some info on NH_3 role in particle formation and sources of NH_3. http://cenrap.org/reports_presentation.asp#
- Next call is currently set for Thursday, September 28 at 1 pm CDT.
    - Should be able to talk about contractor responses to RFP

Northern Class I Area Conference Call Minutes
Sept. 28, 2006

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Margaret McCourtney, Catherine Neuschler, Gordon Andersson
- Michigan: Bob Irvine, Teresa Walker, Jim Haywood
- Wisconsin: Larry Bruss, Bob Lopez
- Iowa: Matt Johnson, Wendy Walker, Jim McGraw
- North Dakota: Tom Bachman, Dana Mount
- Illinois: Rob Kaleel
- Tribes: Charlie Lippert (Mille Lacs), Joy Wiecks (Fond du Lac), Shannon Judd (Grand Portage)
- Ontario: Mary Kirby
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowky
- FS: Trent Wickman, Chuck Sams
- EPA: Julie Henning

1. Follow-ups from last call and news

Tribal involvement – Mike Koerber was on the agenda for the Region V tribal call to discuss this, but the call was canceled. He had sent an email to the tribes in August but did not hear from anyone.

WRAP RFP plan – Dana Mount reported that the reasonable progress assessment will be done on a species basis. Updated versions of the assessment will be out in the future.

2. Update on technical memo

Revisions to the document include adding of an executive summary, data added to the appendix, Boundary Waters '02-'04 data included, and modeling results from MRPO based on new equation.

Additional suggestions include adding Missouri and Indiana, re-reviewing Boundary Waters data, comparing PSAT and back trajectory information, and reviewing discrepancies in Canada data.

Mike Koerber would like to receive any additional comments and questions in the next couple weeks.

3. BART status from each state

Minnesota – the taconite process engineering analysis were submitted and are available now.

North Dakota – 5 BART analysis have been posted for review with comments due by November 1.

Wisconsin – nothing new to report

Michigan – Jim Haywood continues to provide data to several facilities who are doing their own modeling; nothing new on the engineering analysis front.

4. Progress on Request for Proposal

Mike Koerber reported that only one proposal came in, probably because of a problem with others receiving his original email. A new date of October 11 for others to provide proposals was agreed upon by the group. Mike will distribute the Requests for Proposals to the group electronically.

Minnesota noted that they should have approval to spend their contribution to the contractor work in a month or so.

5. Should base year be 2002 or 2005 for RH modeling?

Mike Koerber explained that the LADCO states and some stakeholders are pursing this change for ozone because of the lowered ozone design values based on more recent years monitoring data. It seems reasonable to be consistent for PM2.5 and haze modeling and also use the 2005 base year. Baseline haze values won't change much (i.e. 2002-2004 values and 2005 values are similar.) Existing modeling will continue to be used as weight of evidence. LADCO will revise non-LADCO state inventory info with contractor work. Mike has discussed this with other RPO directors recently. The group asks Mike to keep the group apprised of the status of the project.

6. Messages from the RPO directors meeting of 9/20-21

The '07 allocation for RPOs likely to be 2.5-5 million nationally; EPA won't know for sure until '07. The '08 allocation may be zero funds, and the RPOs will need to determine what forum will exist for continued multi-state collaboration.

Mike discussed this groups activities (i.e. consultation with northern Class I areas) and encouraged other RPOs to initiate their consultation process as soon as possible.

The status of the IMPROVE and VIEWS monitoring networks were also discussed.

7. Next steps/next call

The IMPROVE Steering Committee (chaired by Mark Pitchford) has analyzed the IMP network looking at redundancy between monitors in case of cuts in the EPA monitoring budget. A cut may be recommended for a monitor in the Minnesota or Michigan Class I areas. This should be discussed by the group.

Discuss the scope and scale of the September 26 Technical Memo on the next call.

Discuss and agree on contractor on next call.

Discuss other questions/issues that arise on next call.

Northern Class I Areas Consultation

Minutes

October 19, 2006

2 - 3 pm CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Heather Magee-Hill, Margaret McCourtney, Catherine Neuschler, John Seltz
	Michigan	Jim Haywood, Cindy Hodges, Teresa Walker
	Indiana	Lawrence Brown, Ken Ritter, Mark ?
	Iowa	Matthew Johnson
	North Dakota	Tom Bachman, Dana Mount
	Wisconsin	Larry Bruss, Bob Lopez
	Tribes	Brandy Toft – Leech Lake
	FLMs	Bruce Polkowsky - NPS Trent Wickman – USFS – Superior Ann Mebane, Chuck Sams – USFS
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP

Agenda Items

Tribal and Other State Participation

Mike was on the EPA tribal call, and there was some interest among the tribes in being involved in the process. Mike is going to continue to be on the EPA call and keep the tribes apprised of what we are doing and how they can participate. Indiana was a new and welcome addition to this call. We need to get someone from Missouri (Calvin) on future calls.

Status of Technical Questions Document

People seem to generally be comfortable with the Technical Questions document. Mike expects some LADCO source apportionment work to be done next week and added. EPA has released some new modeling guidance that will slightly change some of the visibility metric numbers. A few more questions must be addressed, such as which states should be specifically identified as contributors to visibility impairment in the four Class I areas.

The group thought of other information that might be added if this is to be a document for policymakers at the state level– these include some context from the CAA, the uncertainty inherent in modeling and control strategies, and the ancillary benefits of visibility improvement. From a more technical side, there are questions about how we are going to deal with fire and international (Canadian) emissions that affect visibility in the N Class I areas. It was suggested that a position or method be agreed upon in this white paper for the Class I areas.

There was some disagreement about how much the document needs to expand, and whether it is an agreed on technical base or a pitch to upper level policy makers. It was generally agreed that some notes about uncertainty and the technical questions on fire and international emissions should be added. The executive summary could be followed with a summary of the regulatory/CAA requirements, and some mention of health benefits could be added to the document or as an appendix.

RFP Response and Contractor Work

Three proposals were received in response to the RFP for contractor work on control strategies. Two of the three were rated very highly by the eight reviewers and were essentially a tie. Both have done good work for LADCO in the past. After discussion, a contractor was chosen. Mike will notify the contractor and the kick-off call will hopefully happen next week.

IMPROVE Monitoring Cuts

The VIEWS staff have done a number of analyses looking at redundancy between IMP monitors in view of proposed EPA monitoring budget reductions. The last tests were used to develop “replaceable” and “non-replaceable” sites. Although the different tests have somewhat contradictory results for the N Class I areas, Voyageurs is listed as one of three “replaceable” monitors. This latest ranking was approved by the IMPROVE Steering Cmte. We should work towards having a comment letter ready to go to EPA when funding is officially proposed.

Administrative and Next Up

- Minutes from last meeting are approved and can be posted.
- Next call is currently set for Thursday, November 16 at 2 pm CST.

Northern Class I Area Conference Call Minutes
November 16, 2006

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Catherine Neuschler, Gordon Andersson
- Michigan: Bob Irvine, Teresa Walker, Jim Haywood, Cindy Hodges
- Wisconsin: Bob Lopez, Farrokh Ghoreishi
- Iowa: Matt Johnson, Wendy Walker, Jim McGraw
- North Dakota: Tom Bachman
- Missouri: Calvin Ku?, Wayne?
- Tribes: Brandy Toft (Leech Lake)
- Ontario: Mary Kirby
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowsky, Chris Holbeck
- FS: Chuck Sams
- EPA: Matthew Rau

1. Follow-ups from last call and news.

- Minutes from October 19, 2006 call were approved and can be posted.
- Minutes from September 28, 2006 need to be updated on websites with the corrected version.

2. Update on technical memo and suggestion for “policy” memo.

- The technical document will be a "living document", but we should bring closure to this version by the end of the year and focus on the policy questions.
- Catherine Neuschler and Mary Jean Fenske proposed separating the technical memo into a technical paper and a policy paper. They provided a rough draft of both, and a few paragraphs on the scope of the technical document, which Mike Koerber will incorporate into the technical document. Larry Bruss e-mailed several questions that should be addressed in the policy document. The states agreed that we should pursue separate technical and policy documents.
- Mike Koerber thought the appendix on benefits in the technical document should be reduced to a bullet within the document.
- Mary Jean Fenske and Catherine Neuschler also developed a tracking grid with the states decision points to make clear what is agreed upon and what areas need further discussion. On the next call, we should walk through the decision points table and see if there is agreement on the status of each point. We should forward comments to Minnesota on additions, revisions, etc prior to the next call. They will keep the list up to date.

3. Update on EC/R reasonable progress contract.

- EC/R is expected to have a draft memo of methodology ready and a preliminary list of source to evaluate by mid-December.

- The work plan has many references to EPA's draft RFP document, but should focus more attention on strategy work such as LADCO's September 29 document and other work done by LADCO, STI, DRI and others.
- We need to make sure EC/R focuses their efforts to our specific needs and focus on specific source categories and strategies where we can achieve measurable emissions reductions as opposed to reductions that are not clearly measurable (i.e. voluntary measures).
- How much time and effort should we spend on "perfecting" the work plan? We may want one more draft of the work plan to better reflect our purpose, but we should have EC/R focus their time on the other 4 tasks and incorporate our comments as they progress.

4. BART status changes

- Minnesota –All EGU BART analyses were received and posted on their website.
- North Dakota – Received comments back for 7 EGU BART analyses and are working on addressing the comments.
- Wisconsin – Beginning their rule making.
- Iowa – Beginning their rule making.
- Michigan – no changes.

5. Next steps/next call

- Policy meetings with Air Directors: Should have an informational call in February and meet with them at the NACAA conference meeting April 29-May 1 to give our recommendations (after we have results from EC/R).
- Discuss 2018 modeling and new IPM runs on future calls.
- Walk through the decision points table and see if there is agreement on the status of each point.

Next call: December 15, 2006, 1 PM (central), 2 PM (Eastern).

Northern Class I Areas Consultation

Minutes

December 15, 2006
1 - 2 pm CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Margaret McCourtney, Catherine Neuschler, John Seltz
	Michigan	Bob Irvine
	Iowa	Matthew Johnson
	North Dakota	Dana Mount, Terry O'Clair
	Wisconsin	Larry Bruss, Bob Lopez
	Ontario	Mary Kirby
	FLMs	Bruce Polkowsky - NPS Trent Wickman – USFS – Superior Ann Mebane – USFS Chris Holbeck - Voyageurs
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP

Agenda Items

Agenda, Minutes from Previous Call

The minutes from the last call (November 19) are approved and can be posted. The revised technical document (version 5a) will go on the web when approved; it includes new modeling. Mike will also post the PowerPoint of PSAT results that was presented on December 11 once corrections are made to a slide depicting locations of Minnesota sources.

Status of Technical Questions Document

The Technical Questions document has been reformatted and had information from the Minnesota and MRPO PSAT model run included. Mike would like to finalize the document soon, so any concerns should be brought up. It was mentioned that a note should be added where information is not documented for all four Class I (such as Table 1) areas that the information shown is representative and the rest is not included for conciseness. On page two, Figure 1on the chemical composition of light extinction should be presented in absolute, rather than percentage, amounts. The PSAT results added as an appendix confirm the selection of source categories given to the contractor. More description of the 2018 baseline is needed – it is based on an RPO IPM model run and does not include BART projections. It was suggested that at the beginning of section 3, page 8, information on what is expected in 2018 should be presented, and the baseline defined before information is presented on the results of control strategies. It was agreed that more information on the 2018 baseline and projections with on-the-books controls would be added. Also related to the 2018 projections, some work needs to be done to understand and explain how new sources were included (or not) when emissions were grown from 2002 to 2018.

Decision Points Document

Items from the decision points document were discussed. Item 2.1, to use the new IMPROVE equation, was decided on August 14. For Item 2.2, it was agreed that VIEWS data would be used for visibility conditions, with a note that one very high extinction day was not included in the VIEWS data – reincluding that data will slightly impact the numbers on baseline and current conditions. For item 1.1 it was agreed that sulfate, nitrate, and organic carbon (largely biogenic) are the key components of visibility impairment. For item 1.2, it was agreed that at least Minnesota, Michigan, Wisconsin, North Dakota, Iowa and Illinois should be named as states that contribute to visibility impairment. We are leaving open the possibility that more contributing states might be added depending on the results of the CENRAP PSAT analysis, due in January or February. Questions were raised about the impact of South Dakota and if they should be invited to the calls.

Other Items, Next Calls

Items on Canadian emissions and BART update were deferred.

A memo from the control strategy contractor is due today, and a call will be held with them on Monday at 1 CST.

Many meetings on regional haze are upcoming. MN is having a stakeholder meeting January 31, LADCO meeting in March, and Wisconsin is briefing their paper council on Dec. 21

Haze discussion will be added to LADCO air directors call on January 4 at 1 pm CST. MN, IA, ND, and Jeff Peltola will be added to that call.

Next states call is January 9 at 1 pm CST.

Northern Class I Areas Consultation

Minutes
February 15, 2007
1 - 2 pm CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Anne Jackson, Margaret McCourtney, Catherine Neuschler, John Seltz
	Michigan	Cindy Hodges, Teresa Walker
	Iowa	Matthew Johnson, Wendy Walker
	North Dakota	Tom Bachman, Dana Mount
	Wisconsin	Larry Bruss, Bob Lopez
	Missouri	Terry Rowles
	Tribes	Brandy Toft, Leech Lake
	FLMs	Chris Holbeck - Voyageurs Bruce Polkowsky - NPS Chuck Sams Trent Wickman – USFS – Superior
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP
	EPA	Matt Rau

Agenda Items

Agenda, Minutes from Previous Call

The minutes from the last call (January 9) are approved and can be posted.

Review of Minnesota's January 31 Stakeholder Meeting

Thanks to all who presented or attended. The meeting went well. Presentations from the meeting are available online at http://www.pca.state.mn.us/air/regionalhaze.html. The meeting was focused on technical information sharing, but Minnesota did state that they were leaning towards deciding that CAIR=BART for EGUs, and no concerns about that decision have been raised.

Decision Points Document

Items from the decision points document were discussed. Item 1.4 was discussed in January, and cannot be completed until we have information from the CENRAP PSAT modeling. Item 1.5, on the meteorological conditions was discussed. It was agreed that, as noted in the Technical Summary on page 3, the worst visibility days are associated with transport from the south, while good visibility days are associated with more northerly transport. Bad visibility days occur throughout the year.

Item 2.2 will be discussed on the next call. Some monitoring days with poor visibility were thrown out, despite having monitored data for the pollutants we are most concerned about. Adding these days back changes baseline visibility conditions. Similar missing data or data substitution issues are occurring in WRAP and VISTAS. Information on this change will be distributed and 2.2 will be discussed on the next call.

Accuracy of IPM Runs

If EPA's IPM runs for 2018 do not account for all known projects and emission reductions, we need to decide what information on future emissions will be used. Information from IPM runs could be adjusted, new IPM runs could be done, or a completely different inventory could be used. MN in particular believes that the IPM data (from IPM-VISTAS run) will have to be adjusted, as it does not include some known projects. MN is going through and adjusting some emissions to account for known projects or areas where projections seem unrealistic (e.g. A tripling of emissions from a plant operating near capacity) and is offering the other states (particularly IL, IA, ND, and WI) the chance to adjust their future inventories to be used in developing the adjusted IPM scenario. MN intends to apply control strategies to the adjusted scenario WI raised concerns about which projects are included, since announcements of emission reductions are not enforceable. Iowa noted that they have units that have applied for permits for pollution reduction projects that are not included in IPM, as well as some plants that show strange emission rates. Mike Koerber states that alternate scenarios are probably a better solution than just tweaking an IPM run, because emissions lowered in one area are likely to pop up in another. WI suggested that we need multiple future scenarios: including an IPM scenario and a hopeful/best guess. CENRAP is going to do something similar with a high, low, best guess, and IPM scenario. Although it is difficult for some states and MRPO to support Minnesota's schedule due to the timing of haze and attainment SIPs, it was agreed that Minnesota would prepare a report that other states could check. This group could further discuss what are appropriate future scenarios.

ECR Update

ECR has submitted some plans – documented in their methodology document and list of chosen sectors on the LADCO website, and in the document listing individual sources that has been sent to the states. Yesterday they presented a summary of the four factor analysis for ORB controls, and then the four factor analysis for one strategy for one sector as an example analysis. These analyses were not complete. A call will be held on March 5, at which time it will hopefully be more clear what results can be obtained from the four factor analysis. Bill Battye of ECR will speak at the LADCO meeting in March, focusing on results from EGU and ICI boiler sectors. Now expecting full report by end of April.
Upcoming Meetings/Next Call LADCO is having a meeting on March 21 and 22. The 22nd is focused on haze. Next call is Monday, March 12 at 1 central/2 eastern. (Remember Daylight Savings Time starts March 11 this year, so check electronic calendars carefully!)

Northern Class I Area Conference Call Minutes
March 12, 2007

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Catherine Neuschler, Gordon Andersson, Margaret McCourtney
- Michigan: Bob Irvine, Teresa Walker, Cindy Hodges
- Wisconsin: Larry Bruss, Farrokh Ghoreishi, Bob Lopez
- Iowa: Matt Johnson, Wendy Walker
- North Dakota: Tom Bachman
- Missouri: Terry Rowles
- Tribes: Brandy Toft (Leech Lake), Joy Wiecks (Fond du Lac)
- Ontario: Dave McLaughlin
- LADCO: Mike Koerber, Donna Kenski
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowsky, Chris Holbeck
- FS: Chuck Sams, Trent Wickman
- EPA: Matthew Rau

1. Follow-ups from last call and news.
   - Minutes from February 15, 2007 call were approved and can be posted.

2. Restoration of IMPROVE sample days.
   - Several days were excluded from the IMPROVE samples days used to determine baseline conditions because they were lacking the complete set of data for that day. However, many of these dates are lacking the coarse and soil fractions which only make up a small portion of visibility impairment. The sulfate and nitrate portions on these days are generally large contributions and of interest since they are man-made pollutants. The average for the 20% worst days would increase only slightly.
   - If we include these days in our data set and analyses, we would add Donna Kenski's table and summary to the technical paper and do some small modifications to the modeling.
   - Minnesota still needs to obtain approval to include the extra dates from the division director. Michigan is fine with the change.

3. Inclusion of Northern Consultation states in CENRAP control strategy runs.
   - CENRAP is designing control strategy runs that they would like finished by April. They would like neighboring states to review assumptions for their states.

4. Update on IPM 3.0 runs/timing
   - States were requested to review runs and make any comments (due March 19). Also comments addressing "will do" changes and "may do" changes that are possible were specifically requested. LADCO hopes to have the new inventory complete by June with 2-3 alternate scenarios.

- Midwest Ozone Group (MOG) is going to pay the contractor Alpine Geophysics to do some updates on this IPM run; however, the specifics have not been determined, yet. **Update (4/17/07):** LADCO has decided to do the updates on the IPM runs instead of Alpine Geophysics.

5. International Emissions
   - CENRAP modeling has higher emissions from Canada than LADCO modeling. M. McCourtney is investigating why there are differences in the results. One possibility is that CENRAP included Alberta, Canada, which has large emissions, in their modeling. LADCO is in contact with Canada to get their most recent inventory. Minnesota and LADCO will continue to investigate the discrepancies between the two models.

6. Update on EC/R analysis
   - EC/R is working on populating the Master Factor Analysis Summary sheet. They have nearly finished "On the books" controls and EGU controls.
   - The due date for their report has been changed until the end of April.

7. Plans for March 21-22 LADCO/MRPO workshop
   - March 21 focuses on PM2.5 and Ozone with policy discussions in the morning sessions and technical evaluations in the afternoon.
   - March 22 focuses on Haze and EC/R will discuss some of their work in the afternoon.

Next call: Tuesday, April 17, 2007, 1 PM (central), 2 PM (Eastern).

Northern Class I Area Conference Call Minutes DRAFT DRAFT DRAFT
April 17, 2007

Participants on the call

- Minnesota: John Seltz, Gordon Andersson, Margaret McCourtney
- Michigan: Teresa Walker, Cindy Hodges, Jim Heywood
- Wisconsin: Bob Lopez, Farrokh Ghoreishi
- Iowa: Matt Johnson, Wendy Walker
- North Dakota: Tom Bachman, Terry O'Clair
- Indiana: Kim Ritter, Chris Pedersen, Scott Deloney
- Missouri: NA
- Tribes: NA
- Ontario: NA
- LADCO: Mike Koerber
- CENRAP: NA
- NPS: NA
- USFS: Chuck Sams, Trent Wickman
- EPA: NA

1) follow-ups from last call and updates to agenda
    - Minutes from March 12, 2007 call were corrected:
      1) re. participation --Bob Lopez (WI) attended the call
      2) re. IPM 3.0 runs -- LADCo will do the updates on IPM instead of Alpine Geophysics
      These minutes (corrected) can now be posted by Michigan.

2) final decision on restoration of IMPROVE sample days (GAndersson)
    - MPCA Asst Commissioner for Air Policy (JDThornton) agreed the addition of selected deleted days from 20% worst baseline years (Donna Kenski review/analysis) on March 13. A draft letter from JDavid Thornton (MPCA) and Vinson Hellwig (MIDEQ) to CIRA staff will request the revised datasets be posted on the VIEWS website. The letter will cc. JPeltola (CenRAP) and MKoerber (MRPO). (This follows the procedure suggested by MPitchford, chair of IMPROVE Steering Committee and moderator of national RPO Monitoring/DataAnalysis monthly conference calls.)
    - The DKenski data and changes to baseline and extinction will be incorporated in the next version of the technical summary paper with revisions due to additional work on OC, NOx, and Canada emissions (see item 6).

3) update on RPO calculations of international (Canada) emissions (MMcCourtney)
    - CenRAP SMOKE default stack parameters for Canada emissions caused overprediction. LADCo modeling of "lst layer" emissions resulted in under prediction. Scott Edick (MIDEQ) has proposed methodology for Canadian review and will redo LADCo modeling. CenRAP & LADCo modeling will then be recompared and outcomes discussed.
    - This issue will be updated in agenda item next month.

4) report on LADCo/MRPO workshops March 21 & 22, 2007 (MKoerber)
    - 100+ attended O3 & PM2.5 mtg on 03/21; ~80 attended RHaze mtg on 03/22; all 5 RPO states, local agencies, many EPA staff; enviro group representatives attended 03/21
    - RHaze agenda (03/22): a) FLM/EPA perspectives, regulations, consultation b) technical document review c) state reports on BART d) Bill Battye presented EC/R 4-factor analysis (presentations are on LADCo website)

5) update EC/R progress (MKoerber)
    - Schedule: partial draft report discussed in core group review 04/10/07; complete draft due next week (04/27/07 next core group call); final report due in May

- Three kinds analyses: 1) ‘on the books’ (existing regs) 4 factors 2) candidate controls for sectors + NH3, including off- & on-road 3) individual facility assessment to complement sector assessment (e.g. refineries, cement kilns)
- A summary will be provided as agenda item next month.

6) discussion of LADCo preliminary work on---- (MKoerber)

- OC light extinction
  - examination of role of biogenic emissions and wildfires and effect on glidepaths (follows discussions with BPolkowsky/NPS & DKenski/MRPO)
  - long-term sampling (6wks summer/ 6wks winter) & analysis (of C14, levoglucosan, soluble K, EC/OC) to distinguish fossil & biogenic C in BWCA & Midwest cities
- assessment of NOx emissions on AQ in N Class I Areas
  - modeling underpredicts NO3+
  - nitrates important for N Class I visibility and NOx control strategies
  - use PSAT, back trajectories, ambient monitor data with sensitivity runs
  - draft available soon
- new modeling
  - meeting necessary mid-August with policymakers to present 4-factor analysis <u>with</u> control strategies
  - 2018 runs to be completed and results available by mid August
- Completed and in-process work will be addressed in future revision of technical document (with item 2).

7) upcoming meetings

- FLM/RPO meeting Denver CO on RHaze implementation (April 25-26) (CSams)
  - agenda includes FLM coord review of RHaze SIPs and definition of reasonable progress & control strategies
  - MKoerber (MRPO), LWarden (OKDEQ for CenRAP), CPeterson (IN), BLopez (WI) to attend
- USFS national annual meeting Duluth MN (May 2-4) (TWickman)
  - May 02 a.m. discussion RHaze rule
  - meeting open to everyone
- MPCA RHaze stakeholder meeting (No. 3) St Paul (May 15) (JSeltz)
  - agenda include NE MN concept plan & EC/R (draft) report on 4-factor analysis
  - conservation orgs and industry reps may give perspectives on RHaze implementation
- LADCo States meeting on O3 & PM2.5 & RHaze (August 14-15 or 15-16 (TBD))
  - central issues are O3, PM2.5, and RHaze SIPs
  - day 1: project team, modeling , 4-factor work
  - day 2 : Air Directors mtg (MKoerber would like DThornton to attend or listen by phone)

8) EPA checklist for RHaze SIPs (MKoerber & others)

  - no EPAV reps on call ---little discussion of checklist components
- MRPO states experienced in SIP dev’t; MRPO conf call with JSummerhays May 01
- CenRAP (with staff of several states) developed a draft SIP template in 2005
- JSummerhays “draft” checklist 07/13/06 provided for this call; Matt Rau provided “final” checklist dated 08/04/06 to MPCA RHaze staff on 08/08/06 (any changes?)

9) draft NE Minnesota Concept Plan (JSeltz---with questions&comments MKoerber/KGhoreishi/BLopez) (draft plan provided 04/16 to N Class I discussion group)

- purpose to allow existing and new industry (primarily taconite) and protect visibility in NE MN
- MPCA and FLMs (USFS & NPS) developed plan
- suggest emissions target of 20% reduction in SO2 & NOx by 2012 and 30% reduction by 2018 for new & existing major sources (> 100 tons actual/yr)
- present plan by conf call with tribes (04/12/07), meeting with taconite industry (04/17/07), MN Power utility (04/19/07), enviro organizations (04/23/07)
- discussion include non-linear relation of emissions & visibility (Scott Copeland/USFS address visibility metrics & components in plan)

Next call: Thursday, May 17, 2007, 1:00 PM (CDT), 2:00 PM (EDT).
MN do agenda. MI transcribe notes and post corrected copy.

Northern Class I Area Conference Call Minutes
May 17, 2007

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Catherine Neuschler, Margaret McCourtney
- Michigan: Bob Irvine, Teresa Walker, Cindy Hodges
- Wisconsin: Larry Bruss, Farrokh Ghoreishi, Bob Lopez
- Iowa: Matt Johnson
- North Dakota: Tom Bachman, Dana Mount
- Ontario: Mary Kirby
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowsky, Chris Holbeck
- FS: Chuck Sams, Trent Wickman, Pam Evans
- EPA: Matthew Rau, Julie Henning

1. Follow-ups from last call and news.

- Minutes from April 17, 2007 call were approved and can be posted.

2. Brief status reports (1-2 minutes each)

- Update on restoring IMPROVE sample days: Letters have been signed and issued. We are waiting for the data to be uploaded to the VIEWS website. The baseline values have been recalculated but natural values are not affected by the substitutions.
- Update on efforts to resolve differences in RPO calculations of international emissions: Both RPOs are making efforts to improve their Canadian inventory. MRPO is using the 2005 Canadian inventory which has better stack data. Results seem similar to previous modeling runs for Canada. CENRAP is applying Canada's 2005 stack parameters to the 2000 data. MN in looking into wether EPA is using stack parameters for the 2018 modeling they are doing for the Canadian Inventory.
- ECR five factor contract report: They are close to their final draft version which will likely be open for public comment. It should be out in the next few days.
- Air quality modeling: MRPO has finished it 2005 base K inventory and started future year inventories. They are working on alternative "will do" and "may do" scenarios. CENRAP is nearly finishing their 2002 and 2018 base G runs.

3. Report on April 15 Minnesota stakeholder meeting and status of NE Minnesota plan.

- All presentations will be posted on their website shortly.
- Had talks about modeling, update on ECR, value of the Class I areas,
- For taconite mines, MN proposed a 30% cap, but will further study the problem by enforcing CEMS to monitor emissions, then the companies will do research based on the CEMS data and finally perform a BART-like analysis to determine what more can be done.
- WI was concerned that MN proposal would not allow WI to get the reductions they needed in their state.

4. Continuation of decision points discussion – How do we agree on reasonable progress?

- Each state discussed their present status on RFP:
    - MI: Still working on BART. Have not determined whether CAIR=BART.
    - WI: Likes the $/dv, but doesn't like the fact that it diminishes NOx effects. Suggested we need a straw proposal which would involve doing a RACM type

    - evaluation. The first metric would be to see what is technically feasible, then consider costs per sector as a secondary metric.
    - WRAP states: Doing a different approach. Most states are doing BART and nothing further because of lack of legal authority or time.
    - ND: Weighed the $/ton values more than the $/dv values. May be doing more in 2013.
    - IA: EGUs are leaning towards going with CAIR.
- Others like the $/dv value, but are concerned that different models give different values and that it is harder to grasp the meaning of the number.
- Decided we needed to have a call to discuss MN Northeast plan and other straw proposal ideas.

Next call: Monday, June 18th, 2007 9 AM CST, 10 AM EST

Northern Class I Area Conference Call Minutes
July 30, 2007

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Catherine Neuschler
- Michigan: Teresa Walker, Cindy Hodges
- Wisconsin: Larry Bruss, Farrokh Ghoreishi, Bob Lopez
- Iowa: Matt Johnson, Wendy Walker
- North Dakota: Tom Bachman, Dana Mount, Terry O'Clair
- Indiana: Chris Pederson, Jay Koch, Shri Harsha
- Ontario: Andrea Wrappel
- Tribes: Joy Wiecks
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- NPS: Bruce Polkowsky, Chris Holbeck
- EPA: Matthew Rau

1. Follow-ups from last call and news.
   - Minutes from April 17, 2007 call were approved with some small edits and can be posted.
   - Update from CENRAP meeting:
     - Updated CENRAP emissions summary nearly completed, and posted on website
     - Technical support document on how and why of modeling and emissions inventory, completed portion is posted on website.
     - Modeling progress-completed control sensitivity runs, showed improvements in central region, but still does not get northern Class I areas below the glide path. MRPO modeling however, gets MN closer to the line than CENRAP modeling.
     - CENRAP probably won't use IPM3.0 modifications for this haze SIP, since it is too late for their SIP planning.
     - Several CENRAP states plan to have SIP drafts ready in August.
   - LADCO sent the letter to EPRI on their paper about transboundary pollution.
   - Meeting with Northeast states and Ontario. NE states believe Ontario is impacting their class I areas. MRPO does not have impacts from Ontario.
   - Meeting with Northeast States:
     - Meeting on Monday, Aug 6 to discuss policy issues with MRPO states
     - NE class I areas expected to be below glide path by 2018.
     - MW contributes 10-15% to NE, NE identified about 90% of emissions from 167 smoke stakes and about 50 are located in the MRPO states.
     - NE wants support for a regional control strategy for EGUs and ICI boilers. They want EPA and states to pursue some regional controls.

2. ECR draft final report
   - Report is posted on LADCO's website.
   - $/deciview for additional controls was within the range of OTB controls. Costs for EGUs and ICI boilers may be slightly higher, but they have a larger impact on visibility than other measures. Cost effectiveness and visibility impacts were the most important factors of the five factor analysis. EGU measures may provide enough reductions to meet the glide path.

3. Draft of MN Reasonable Progress determination.
   - Plan on submitting SIP end of 2007 or early 2008.
   - Includes: 30% reduction plan for NE MN, voluntary reductions by utilities, no particular emissions limit for any source category, no proposed rules or regulations.
   - Other states contributing 5% are Wisconsin, Illinois, North Dakota, Iowa and Missouri. Will do/may do modeling show significant reductions from WI and IL, however, predictions for WI may be incorrect.

- WI would like MN to consider setting actual emissions limits in their requests for reductions from other states. ND will send corrections for the emissions inventory.
- A letter from the class I state to the states contributing to a class I area should be sent requesting the contributing state to make reductions needed for the class I state to meet RFP. This should be a high level letter from the governor or commissioner.
- The 5 year update is due 5 years from submittal, thus December 2012.

4. Upcoming meetings.
    - MRPO is having a meeting for project team members on August 20 and for air directors on August 21.

Next call: Thursday, August 23rd, 2007 1:30 PM CDT, 2:30 PM EDT

Meeting Summary
Consultation for Regional Haze Planning in Northern Class I Areas

On August 20-21, 2007, the Midwest RPO met with its member states and the State of Minnesota to review the results of new modeling and determine next steps in control strategy planning. Part of this meeting included a discussion on regional haze in the northern Class I areas. A summary of this discussion is provided below.

August 20, Project Team Meeting

Participants included the States of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, North Dakota, Ohio, and Wisconsin, along with USEPA, U.S. Forest Service, and LADCO staff.

Kirk Baker (LADCO) began the regional haze session with a review of LADCO's new (Base M/Round 5) modeling results. It was noted that these results are preliminary. Further review and analysis are needed before the results are finalized

Mike Koerber (LADCO) reviewed the recent report by EC/R on the five factors to be considered in setting reasonable progress goals:

- costs of compliance,
- time required for compliance,
- energy and non air quality environmental impacts,
- remaining useful life, and
- uniform rate of visibility improvement.

Key findings of the report include the following:

- cost per deciview values for most candidate measures are within the range of values for "on the books" controls,
- visibility impacts for EGU and ICI boiler controls are higher than those for other controls, and
- examination of the other factors suggests that they are either manageable or not likely to affect selection of control measures.

John Seltz (Minnesota) discussed Minnesota's approach for their regional haze SIP. Elements of the SIP include:

- 30% reduction in combined SO2 and NOx emissions for sources in the 6-county area adjacent to Voyageurs and Boundary Waters
- voluntary EGU reductions of about 50% for SO2 and NOx,
- analysis and possible regulation of large ICI boilers, and
- analysis and possible regulation of large turbines and IC engines for NOx.

Minnesota will also be asking contributing states (i.e., those shown to have $\geq$ 5% contribution to Voyageurs or Boundary Waters) to do at least what Minnesota will commit to in its SIP. Specifically, Minnesota will ask the States of Illinois, Iowa, Missouri, North Dakota, and Wisconsin to do the following:

- attain an EGU emission rate of less than 0.25 lb/MMBTU for both SO2 and NOx,
- review large ICI boilers and adopt emission limitations, if there are significant cost effective reductions,
- review large turbines and IC engines for NOx control and adopt emission limitations, if there are significant cost effective reductions, and
- report on progress in 2012/2013 SIP assessment.

The "ask" will be formalized in a letter that will be sent from the Commissioner in Minnesota to the Commissioners in the contributing states.

Bob Irvine (Michigan) discussed Michigan's approach for their regional haze SIP. He noted that Michigan is currently reviewing the EC/R report and has not made a final decision on additional control requirements for haze. Also, Michigan expects to make a decision soon on whether CAIR equals BART for EGUs. Michigan will not ask other states to do more than it commits to in its haze SIP.

Mike Koerber (LADCO) presented a summary of the MANE-VU "ask", which was the subject of a meeting on August 6. Specifically, MANE-VU has asked the Midwest RPO and VISTAS' states for reductions in SO2 emissions from certain EGUs and from non-EGU sources. Discussions with MANE-VU are on-going and it was noted that the Midwest RPO will need to consider (and respond) to both the Minnesota and MANE-VU "asks".

August 21, Air Directors Meeting

Participants included the States of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin, along with USEPA, National Park Service, and LADCO staff.

Mike Koerber (LADCO) began the meeting with an overview of LADCO's new (Base M/Round 5) modeling results, including the regional haze results, and a summary of EC/R report. (In particular, it was noted that the visibility impacts predicted by the modeling are just one of five factors that need to be considered in setting reasonable progress goals.) The modeling results are preliminary, and further review and analysis are needed before the results are finalized

John Seltz (Minnesota) discussed Minnesota's approach for their regional haze SIP (see summary above). He said that a letter would be forthcoming from the Minnesota Commissioner to the Commissioners in the contributing states outlining their "ask" for emission reductions. He noted that the new LADCO modeling will not affect the "ask", given that other modeling analyses (e.g., CENRAP modeling and previous LADCO modeling) shows that the Minnesota Class I areas are projected to be above the glide path in 2018, and the requirement to consider four other factors in setting reasonable progress goals.

Northern Class I Areas Consultation

DRAFT Minutes
August 23, 2007
1:30 – 2:30 pm CDT

Attendees	Minnesota	Gordon Andersson, Catherine Neuschler, John Seltz
	Michigan	Bob Irvine, Jim Heywood, Cindy Hodges, Teresa Walker
	North Dakota	Tom Bachman, Dana Mount
	Ontario	Andrea Wappel
	FLM	Bruce Polkowsky, Chris Holbeck – NPS Trent Wickman, Chuck Sams - USFS
	RPOs	Mike Koerber – LADCO/MRPO Jeff Peltola – CENRAP
	EPA	Matt Rau

Agenda Items

Minutes from Previous Call

No comments were made on the previous minutes, so they are approved to be posted.

Minnesota Consultation Letter Draft

Minnesota sent out a Powerpoint and the attachments that are likely to go with the consultation letter. Minnesota also had presented this information at the LADCO Project Team meeting on August 20. No comments were made.

LADCO/MRPO Air Directors Meetings

At the meeting, the results of new modeling with the 2005 base year and new haze results for 2018 were presented. These results are extremely preliminary, and cased a lot of questions and comments. We should not be distributing any model results until all questions/comments are resolved. This should happen by the time of the stakeholder meeting on October 10. The meeting also covered the Minnesota and MANE-VU asks of the MRPO states. Some decisions were made on how to proceed on the MANE-VU ask, but no policy decisions were made. MANE-VU made a similar ask of the VISTAS states, and MRPO and VISTAS may have some commonality in boiler populations. Mike is going to work on a table of how emissions changed between Base K and Base M. Switching to the 2005 base year means they are now projecting from 05 rather than 02, and are now drawing "the line" from 2004. There were also questions about the decrease in model performance for sulfate; MRPO will go back and put in specific day CEMS data, but remember that this is just another model run, not necessarily the "best" run. WRAP is also working on some new model runs, which hopefully will include Minnesota. ND is not meeting the URP; doing modeling of CALPUFF nestled in CMAQ.

Where do we go from here?

- Report back when LADCO modeling questions answered
- Michigan is starting to draft a SIP
- Missouri expecting to start FLM 60 day review
- Colorado and South Carolina have also submitted SIPs to FLMs – CO did not address RPG, leading to the question of whether the 60 days starts with an incomplete draft SIP. Remember that any comments provided by FLM before the public meeting must be addressed during the meeting.
- MRPO will model the Minnesota ask
- Discussion of looking at grid cells beyond the monitor site for Isle Royale and Boundary Waters

Upcoming Meetings/Next Call

Next Call: October 4 at 2:30 central

LADCO Stakeholder Meeting October 10

Minnesota Pollution Control Agency
520 Lafayette Road North | St. Paul, MN 55155-4194 | 651-296-6300 | 800-657-3864 | 651-282-5332 TTY | www.pca.state.mn.us

September 19, 2007

RECEIVED
SEP 24 2007
Director's Office

TO: Participants in the Northern Class I Areas Consultation Process

RE: Northern Class I Areas Consultation Conclusion

As you are aware, Minnesota is home to two federal Class I areas, Voyageurs National Park (VNP) and the Boundary Waters Canoe Area Wilderness (BWCAW), located in the northern portion of the state. Under the federal Regional Haze Rule (40 CFR 51.300-309), the State of Minnesota is required to work to improve visibility in these two areas, with a goal of no man-made visibility impairment by 2064.

Under the portion of the Regional Haze regulations at 40 CFR 51.308(d)(1)(iv), states with Class I areas are required to develop reasonable progress goals (RPG) for visibility improvement at their Class I areas and associated measures to meet those goals, in consultation with any other State or Tribe that may reasonably cause or contribute to visibility impairment in those areas. This letter provides information on how Minnesota intends to address the reasonable progress goals, identification of the states that cause or contribute to visibility impairment in Minnesota's Class I areas, and our expectations for continued coordination with those states on haze-reducing strategies.

Beginning in 2004 and 2005, a number of discussions were held between state and tribal representatives in the upper Midwest concerning air quality planning to address regional haze in the four Class I areas in Michigan and Minnesota. Formal discussions geared toward the State Implementation Plans (SIP) consultation requirements began in July 2006, in a conference call among representatives from Iowa, Michigan, Minnesota, North Dakota, Wisconsin, the Mille Lacs and Leech Lake bands of Ojibwe, and Federal Land Managers (FLM), Regional Planning Organization (RPO) and U.S. Environmental Protection Agency (EPA) personnel. It was decided that other potentially contributing states should be asked to participate in the consultation process, and that consultation should continue through ongoing conference calls during the development of the regional haze SIP. Minutes of the conference calls and other documentation can be found on the Lake Michigan Air Directors Consortium/Midwest Regional Planning Organization (LADCO/MRPO) Web site.[1]

The group consulted on technical information, producing a document entitled *Regional Haze in the Upper Midwest: Summary of Technical Information*, which lays out the basic sources that cause and contribute to haze in the four Northern Class I areas, as agreed to by all the participating states.[2]

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[1] http://www.ladco.org/Regional_haze_consultation.htm

[2] http://www.ladco.org/Final%20Technical%20Memo%20-%20Version%205d1.pdf

Based on the technical information contained in this document and other supporting analyses, Minnesota has determined that, in addition to Minnesota, Illinois, Iowa, Missouri, North Dakota, and Wisconsin are significant contributors to visibility impairment in VNP and the BWCAW. Attachment 1 to this letter provides a summary of how Minnesota reached this conclusion.[3]

The Minnesota Pollution Control Agency (MPCA) has not yet completed modeling to determine the RPG for these two Class I Areas. However, because of the varying timelines and different non-attainment issues impacting Minnesota and other contributing states, Minnesota intends to submit a RPG resulting from implementation of the minimum interim control measures Minnesota would consider to be reasonable. This decision reflects the need for more in-depth analysis before additional control measures can be determined to be reasonable. The RPG would be revised in the Five Year SIP Assessment to reflect final control measures.

In addition to on-the-books controls, such as the Clean Air Interstate Rule (CAIR), Minnesota expects the RPG to reflect Best Available Retrofit Technology (BART) determinations in Minnesota and surrounding states (where known), the plan for a 30 percent reduction in combined sulfur dioxide (SO_2) and nitrogen oxides (NO_X) emissions in Northeastern Minnesota, voluntary emission reductions planned by Minnesota utilities beyond those predicted from CAIR, and, where known, any additional control measures undertaken in other states for regional haze or attainment purposes. The MPCA expects that the modeling information needed to set the RPG would be available by October 2007.

Minnesota commits to evaluating additional control measures and implementing those that are reasonable under the four factors listed in 40 CFR 51.308(d)(1)(i)(A) in the 2008 SIP. Minnesota expects that additional control measures may be found to be reasonable, and commits to including a plan for implementation of those additional reasonable measures in the Five Year SIP Assessment. Minnesota asks the five other significantly contributing states to make these same commitments for further evaluation and implementation of reasonable control measures.

In particular, Minnesota asks Iowa, Missouri, North Dakota, and Wisconsin to evaluate further reductions of SO_2 from electric generating units (EGU) in order to reduce SO_2 emissions by 2018 to a rate that is more comparable to the rate projected in 2018 for Minnesota, approximately 0.25 lbs/mmBtu. Minnesota believes that Illinois is already in the process of meeting this goal. Emission reductions in Wisconsin are particularly important, as Wisconsin is the highest contributor outside Minnesota to visibility impairment in Minnesota's Class I areas.

Minnesota also asks North Dakota to evaluate the potential for reductions of NO_X from EGUs due to predicted higher NO_X emission rates compared with Minnesota and other contributing states. Illinois, Missouri, and Wisconsin are in the process of evaluating NO_X emission

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[3] Minnesota is relying primarily on data analysis and technical work done by MRPO and CENRAP.

reductions for their ozone SIPs. Minnesota would expect these three states to share information on the NO_X controls being undertaken as part of those ozone SIPs.

Minnesota acknowledges that each state is in a unique position; for example, North Dakota has a different regulatory background and a different fuel mix than other contributing states. Minnesota's use of emission rates to point towards areas where additional emission control strategies should be investigated does not mean that Minnesota expects all the contributing states to achieve the same emission rates. However, the contributing states with higher emission rates should evaluate potential control measures, and should, in their initial SIPs or Five Year SIP Assessments, show either enforceable plans to reduce emissions or a rationale for why such emission reductions are not reasonable (e.g., an overly high cost in $/ton or $/deciview, or lack of visibility improvement).

Minnesota, in turn, also commits to a more detailed review of potential emission reductions from large Industrial, Commercial, and Institutional (ICI) Boilers and other point sources (such as reciprocating engines and turbines) with regulations or permit limits developed by 2013 and included in the Five Year SIP Assessment if control measures on these source categories appear to be reasonable. Minnesota asks the five contributing states to make a similar commitment.

It is the intent of Minnesota to proceed with the development and submittal of a Regional Haze Plan which includes the aforementioned RPG and expectations for contributing states. Minnesota commits to continuing work with the other states to review and analyze potential region-wide control strategies and emission reductions plans and to continue on-going assessments of progress towards visibility improvement goals.

Minnesota asks that any additional control measures found to be reasonable will be included in each state's SIP or Five Year SIP Assessment in an enforceable form. This will ensure that the control measures are on track to be implemented by the 2018 deadline for submittal of SIPs covering the second phase of the Regional Haze process.

Minnesota believes that the consultations conducted to date satisfy the consultation process requirements, providing for consistency between state SIPs and allowing each state to move forward with SIP preparation and submittal. As necessary, Minnesota will engage in future consultation to address any issues identified in the review of the Regional Haze SIPs, any additional technical information, and to ensure continued coordinated efforts among the Midwestern states.

Attached to this letter is an outline of the reasonable progress discussion to appear in our SIP and additional supporting tables and graphs.

In order to document the consultation process, the MPCA is asking that the State and Tribal recipients of this letter respond within 30 days with a letter documenting that these consultations have taken place to the satisfaction of your State or Tribe, or detailing areas where additional consultation should occur. Those states that Minnesota has identified as additional contributing states should respond with your agreement or disagreement with the determination of contributing states and the additional controls strategies that will be evaluated.

Thank you for your participation and contributions in this consultation process. Your time and efforts are appreciated. If you require additional information regarding this matter, please contact John Seltz at 651-296-7801 or john.seltz@pca.state.mn.us.

Sincerely,

Brad Moore
Commissioner

BM/CN:ld:tgr

Attachments

Attachment 1: Supporting Technical Information – Determination of Contributing States

Minnesota used the LADCO 2002 – 2003 Trajectory Analyses and the LADCO 2018 PSAT analysis, using a 5% threshold of contribution from either analysis to either of Minnesota's Class I areas, to define a contributing state. Based on this information, the States identified as contributing to visibility impairment in Minnesota's Class I Areas are: Minnesota, Wisconsin, Illinois, Iowa, Missouri, and North Dakota.

The table below documents the percent contribution to visibility impairment by the States that have participated in the Northern Class I consultation process, estimated from 2000 – 2003 LADCO trajectory analysis, with supporting information from the CENRAP 2002 PSAT model of the 20% worst days.[1]

State Impacts on Minnesota's Class I Areas – Baseline Period

	LADCO Trajectory Analyses (2000-2003)		CENRAP PSAT Modeling (2002)	
	BWCAW	VNP	BWCAW	VNP
Michigan	0.7%	1.6%	2.3 (2.6)%	1.4%
Minnesota	37.6%	36.9%	25.4%	27.6
Wisconsin	11.1%	9.7%	7.8 (8.6)%	5.6%
Illinois	2.7%	1.2%	7.0 (7.3)%	3.7%
Indiana	1.2%		4.5 (3.8)%	1.8%
Iowa	7.4%	10.2%	3.5 (3.9)%	3.8%
Missouri	3.3%	0.3%	2.9 (2.7)%	2.1%
N. Dakota	5.9%	7.1%	4.8%	7.1%
TOTAL	69.9%	67.0%	58.2 (59.2)%	53.1%

The following table documents the percent contribution from these same states projected for the future based on LADCO's 2018 Particulate Matter Source Apportionment Technology (PSAT) analysis, with supporting information from the CENRAP 2018 PSAT model of the 20% worst days.[2] Although in some cases the percentage impacts predicted by CENRAP are lower than those predicted by the MRPO PSAT analysis (Iowa, Missouri), the identified states remain the higher contributors. The relative order of contributing states does not change much between 2002 and 2018.

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[1] Environ. (2007, July 18). *CENRAP PSAT Visualization Tool*. (Corrected Version). Available on the CENRAP Projects webpage

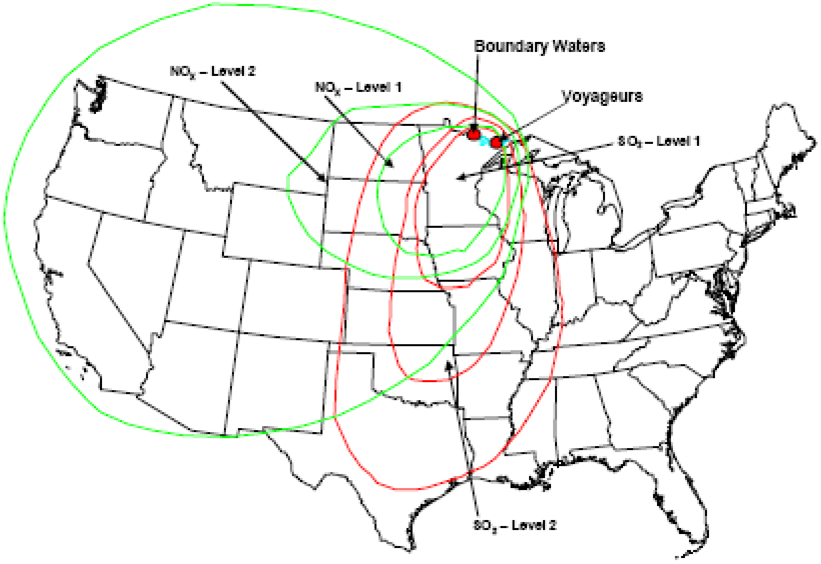
[2] Ibid.

State Impacts on Minnesota's Class I Areas – Future Year (2018 PSAT)

	LADCO PSAT Modeling (2018)		CENRAP PSAT Modeling (2018)	
	BWCAW	VNP	BWCAW	VNP
Michigan	2.6%	1.3%	2.6 (2.2)%	1.5 (1)%
Minnesota	30.5%	35.0%	28 (19.8)%	30 (18.0)%
Wisconsin	10.4%	6.3%	8.0 (6.0)%	5.0 (3.1)%
Illinois	5.2%	3.0%	4.8 (3.7)%	2.5 (1.6)%
Indiana	2.9%	1.6%	2.7 (1.8)%	1.2 (0.8)%
Iowa	7.6%	7.4%	3.8 (2.9)%	4.0 (2.5)%
Missouri	5.2%	4.3%	3.5 (2.3)%	2.5 (1.6)%
N. Dakota	5.7%	10.3%	5.3 (3.7)%	7.5 (4.7)%
TOTAL	70.1%	69.2%	58.7 (42.5)%	54.2 (33.3)%

The states with contributions over 5% to the Class I areas in these analyses generally match well with the impacting states shown in the Area of Influence (AOI) analysis done by Alpine Geophysics for CENRAP.

AOIs for Minnesota's Class I Areas[3]



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[3] Stella, G.M et al. (2006, May 9). *CENRAP Regional Haze Control Strategy Analysis Plan.* Prepared by Alpine Geophysics. Available on the CENRAP Projects webpage http://www.cenrap.org/projects.asp

Attachment 2: Outline of an Approach to Defining Reasonable Progress for Minnesota Class I Areas in the Minnesota Regional Haze SIP

Under EPA rules, Minnesota has a responsibility to set a Reasonable Progress Goal (RPG) for visibility in the Boundary Waters and Voyageurs Park. Because the states that contribute to our Class I areas will submit their SIPs at different times, Minnesota sets forth the following proposal for setting a RPG for our two Class I areas. This document lays out the elements that we plan to include.

Minnesota's Long Term Strategy section will include those control strategies which we plan to undertake and which we consider to be reasonable. It will also include any known controls that are being undertaken in the nearby states, particularly the five states (IL, WI, ND, IA, and MO) that have been identified as contributors to BWCAW and VNP.

- Minnesota's LTS Contains
    - BART
        - For Minnesota: Minimal emission reductions
        - As known for other states
    - CAIR and resulting EGU reductions
        - For Minnesota
        - As known for other states
    - Control strategies for $PM_{2.5}$ and Ozone attainment SIPs
        - As known for other states
    - Other federal on-the-books (OTB) controls:
        - Tier II for on-highway mobile sources
        - Heavy-duty diesel (2007) engine standards
        - Low sulfur fuel standards
        - Federal control programs for nonroad mobile sources
    - Additional Emission Limitations
        - NE Minnesota Plan (30% reduction in combined SO_2/NO_X as a fair share)
        - Additional voluntary reductions as a result of MN Statutes 216B.1692 (emission reduction rider)
        - Anything known for other states
    - Other long term strategy (LTS) Components (without specific emission reductions)
        - Measures to mitigate emissions from construction
        - Source retirement and replacement
        - Smoke management for prescribed burns in Minnesota

After documenting all the components of the LTS, Minnesota will lay out the RPG determined for the best and worst days at VNP and BWCAW.

Reasonable Progress Goals

Once determined, the RPG submitted in Minnesota's SIP will represent an **interim**, **minimum** visibility improvement Minnesota would consider to be reasonable, and contain emission reductions resulting from the elements of the long term strategy.

At this time, Minnesota believes that this is an appropriate goal because other impacting states are working on a multi-SIP approach and have yet to determine what reductions are reasonable in their states for both haze and attainment purposes. Although we cannot compel the states to undertake reductions, Minnesota would expect further emissions reductions than are documented here, resulting in larger visibility improvement. Minnesota intends to revise the RPG for 2018 in the Five Year SIP Assessment, in order to reflect the additional control strategies found to be reasonable.

Steps in Reviewing Control Strategies and Revising RPG

In reviewing additional control strategies to determine those that are reasonable under the Regional Haze rule, Minnesota will focus on strategies that will result in emission reductions in those states that are significant contributors to visibility impairment in either BWCAW or VNP: Minnesota, Wisconsin, Iowa, N. Dakota, Missouri and Illinois.

The MPCA commits to further evaluation of reasonable control strategies that are possible within Minnesota. Minnesota will work with the other contributing states through their submittals of the first haze SIP and through 2013 to develop reasonable control strategies.

In the Five Year SIP Assessment, the MPCA would submit enforceable documents for any additional control measures found to be reasonable within Minnesota. In addition, that report would contain a listing of the additional control measures to be implemented by the other contributing states. Minnesota would then submit modeling that includes all these enforceable measures and would revise the 2018 RPG to reflect the larger degree of visibility improvement expected from the chosen control strategies.

Specific Control Strategies to Be Reviewed

Minnesota will use the EC/R five factor analysis report, the control cost analysis carried out by Alpine Geophysics for CENRAP and the CENRAP Control Sensitivity Model run to identify reasonable region-wide emission reduction strategies. (*See Attachment 3*).

The specific strategies that at this time appear to potentially be reasonable, and Minnesota's expectation for each of these strategies for other states, are outlined below.

EGU SO_2 Reductions

Minnesota will ask the contributing states to look at their EGU emissions of SO_2; Minnesota will particularly focus on possible reductions in states with emission rates that appear to be higher than the average among the Midwestern states. Since contributor states face a variety of regulatory demands and fuel types, it may not be possible to attain uniform emission performance. An emission rate of about 0.25 lb/mmBTU should be achievable in a cost-effective manner; this is the level being achieved in Minnesota and Illinois, and the EC/R report shows that the "EGU1" scenario, a 0.15 lb/mmBTU emission rate, is generally achievable in the Midwest at a reasonable $/ton figure. (See Attachment 3).

Minnesota asks the identified states to demonstrate that reductions are occurring or being undertaken that will allow the state to reach at least the 0.25 lb/mmBTU emission rate, or to describe in their SIPs or Five-Year SIP Assessments why further reductions of SO_2 from EGU are not reasonable. Further reductions may not be reasonable due to the cost of implementation in $/ton or $/deciview or lack of impact on visibility impairment, but they should be evaluated.

At present, it appears as though Illinois has planned or proposed reductions that appear reasonable. It appears that more cost effective reductions are possible in Iowa, Missouri, North Dakota, and Wisconsin. Since Wisconsin is the largest non-Minnesota contributor to Minnesota's Class I areas, their efforts to reduce EGU SO_2 emissions are particularly important.

EGU NO_X Reductions

Wisconsin, Missouri, and Illinois have already reduced NO_X emissions to alleviate ozone standard violations, and Iowa appears to already have relatively low EGU NO_X emissions.

Minnesota will ask North Dakota to look at their EGU emissions of NO_X and to describe in their SIP or Five-Year SIP Assessment why further reductions of NO_X from EGU are not reasonable. Again, an emission rate of approximately 0.25 lb/mmBTU appears to be a reasonable benchmark. Further reductions may not be reasonable due to the cost of implementation in $/ton or $/deciview or lack of impact on visibility impairment, but they should be evaluated.

ICI Boiler Emission Reductions

Minnesota will commit to a more detailed review of potential NO_X and SO_2 reductions from large ICI boilers. Regulations or permit limits will be developed by 2013 if significant cost effective reductions prove feasible from this sector. Minnesota will expect the five contributing states to make at least this level of commitment.

Other Point Source Emission Reductions

Reciprocating engines and turbines appear to be a sector with potential cost effective NO_X controls. Minnesota commits to review this sector in more detail and if, after consideration of planned federal control programs, cost effective reductions appear feasible, Minnesota commits to develop regulations or permit limits for major sources by 2013. Minnesota will expect the five contributing states to make a similar commitment.

Mobile Source Emission Reductions

There appear to be relatively few cost effective NO_X controls for transportation available to states. Minnesota commits to work with LADCO states to implement appropriate cost effective NO_X controls to improve visibility and lower ozone levels in non-attainment areas.

NO_X Modeling, Ammonia, Agricultural Sources

It is not appropriate to commit to control of ammonia sources at this time. However, there is a clear need to improve 1) our understanding of the role of ammonia in haze formation, 2) our understanding of potential ammonia controls, and 3) the accuracy of particulate nitrate predictions. Minnesota does not consider it our responsibility to conduct such research. Minnesota therefore encourages EPA and the regional planning organizations to continue work in these areas and commits to work with EPA and the RPOs to these ends.

Timeline for Reviewing Control Strategies

Minnesota commits to reviewing these control strategies on such a timeline that the 2013 SIP Report will include the four factor analysis for these control strategies, and that any control strategies deemed to be reasonable will be in place with an enforceable document (state rule, order, or permit conditions). Although any control measures ultimately deemed to be reasonable may not be fully implemented by 2013, they will be clearly "on the way" and the SIP Report will include estimates of emission reductions and projected 2018 visibility conditions.

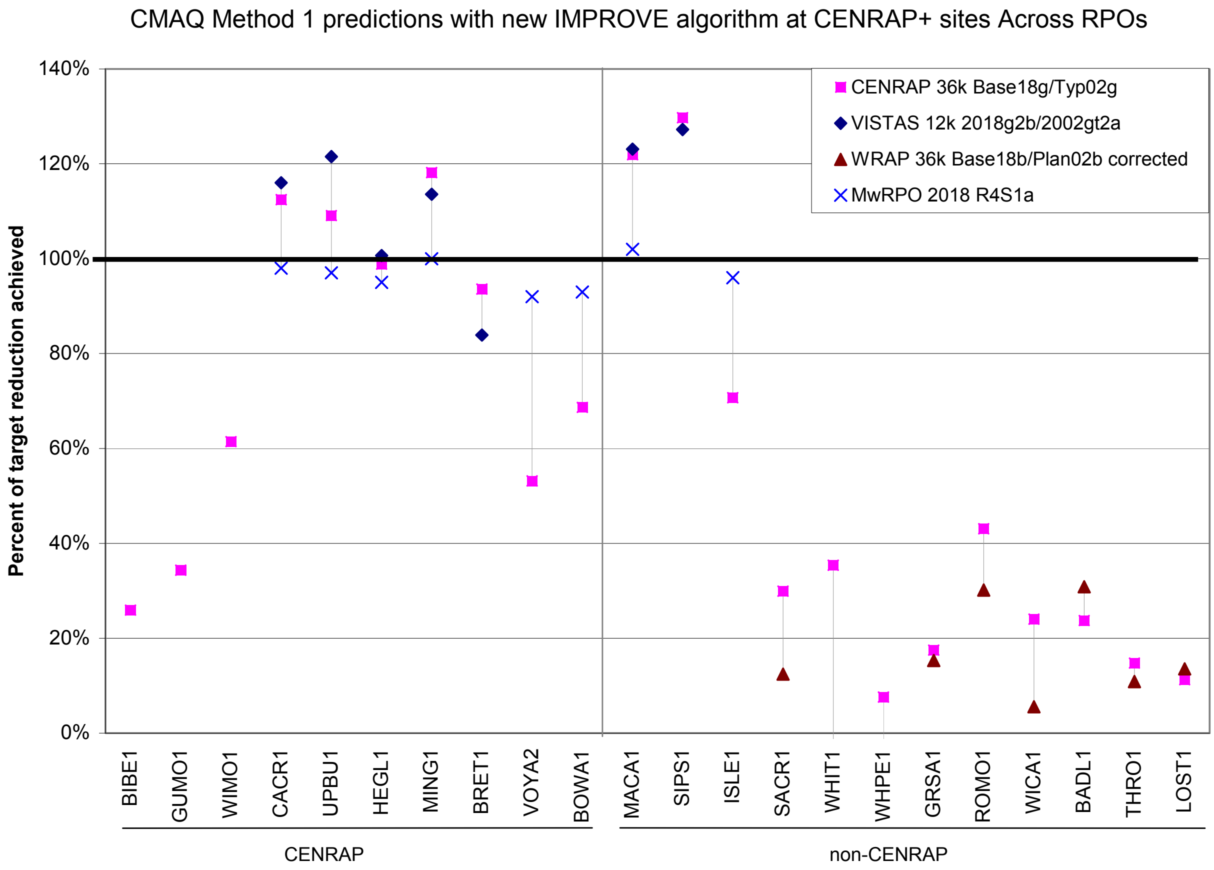
Acknowledging that most states are far along in the process of writing their Regional Haze SIPs, Minnesota would expect that all other contributing states would commit to a timeline that would allow reasonable predictions of the emission reductions and visibility improvement by 2018 from those states in the 2013 SIP Report.

Attachment 3: Supporting Technical Information – Need for Additional Control Strategies

Although there are some fairly major differences in the degree of visibility improvement expected at VNP and BWCAW due to on- the- books controls, projections by both CENRAP and Midwest RPO show that Minnesota's Class I areas are not yet projected to meet the Uniform Rate of Progress, as shown in the graph below.[7] In this graph, the URP is the "target reduction."

EPA's recent guidance on determining the reasonable progress goal (RPG) indicates that states may set a RPG that provides for more, less, or equivalent improvement as the URP. However, the guidance continues to emphasize that an analysis of control strategies with the four factors is necessary; Minnesota believes this is particularly true in light of the lesser degree of visibility improvement shown from on- the- books controls in Minnesota's Class I Areas.

The EGU 2018 Summary table, following, shows projected 2018 EGU SO2 and NOX emissions. Highlighted cells indicate specific states and pollutants of concerns, where Minnesota has requested evaluation of potential reasonable control measures.[8]



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[7] Morris, R. (2007, July 24). *CENRAP Emissions and Modeling Technical Support Document,* Prepared by Environ. Presentation Given at CENRAP Workgroup/POG Meeting.

[8] Provided by Midwest RPO from the IPM 3.0 base run and edits made by certain states.

EGU Summary for 2018

	Heat Input (MMBTU/year)	Scenario	SO2 (tons/year)	SO2 % Reduction (From 2001 - 03 Average)	SO2 (lb/MMBTU)	NOx (tons/year)	NOx % Reduction (From 2001 - 03 Average)	NOx (lb/MMBTU)
IL	**980,197,198**	**2001 - 2003 (average)**	**362,417**		**0.74**	**173,296**		**0.35**
	1,310,188,544	IPM3.0 (base)	277,337	23.5	0.423	70,378	59.4	0.107
		IPM3.0 - will do	140,296	61.3	0.214	62,990	63.7	0.096
		IPM3.0 - may do	140,296	61.3	0.214	62,990	63.7	0.096
IA	**390,791,671**	**2001 - 2003 (average)**	**131,080**		**0.67**	**77,935**		**0.40**
	534,824,314	IPM3.0 (base)	115,938	11.6	0.434	59,994	23.0	0.224
		IPM3.0 - will do	115,938	11.6	0.434	59,994	23.0	0.224
		IPM3.0 - may do	100,762	23.1	0.377	58,748	24.6	0.220
MN	**401,344,495**	**2001 - 2003 (average)**	**101,605**		**0.50**	**85,955**		**0.42**
	447,645,758	IPM3.0 (base)	61,739	39.2	0.276	41,550	51.7	0.186
		IPM3.0 - will do	54,315	46.5	0.243	49,488	42.4	0.221
		IPM3.0 - may do	51,290	49.5	0.229	39,085	54.5	0.175
MO	**759,902,542**	**2001 - 2003 (average)**	**241,375**		**0.63**	**143,116**		**0.37**
	893,454,905	IPM3.0 (base)	243,684	(1.0)	0.545	72,950	49.0	0.163
		IPM3.0 - will do	237,600	1.6	0.532	72,950	49.0	0.163
		IPM3.0 - may do	237,600	1.6	0.532	72,950	49.0	0.163
ND	**339,952,821**	**2001 - 2003 (average)**	**145,096**		**0.85**	**76,788**		**0.45**
	342,685,501	IPM3.0 (base)	41,149	71.6	0.240	44,164	42.5	0.258
		IPM3.0 - will do	56,175	61.3	0.328	58,850	23.4	0.343
		IPM3.0 - may do	56,175	61.3	0.328	58,850	23.4	0.343
WI	**495,475,007**	**2001 - 2003 (average)**	**191,137**		**0.77**	**90,703**		**0.36**
	675,863,447	IPM3.0 (base)	127,930	33.1	0.379	56,526	37.7	0.167
		IPM3.0 - will do	150,340	21.3	0.445	55,019	39.3	0.163
		IPM3.0 - may do	62,439	67.3	0.185	46,154	49.1	0.137

Minnesota also used the cost-curve analysis performed for CENRAP by Alpine Geophysics, originally included in the *CENRAP Regional Haze Control Strategy Analysis Plan* and updated in March 2007, to determine which states might have additional reasonable control strategies. The cost curves were used to perform a modeling run (the "Control Sensitivity Run") in order to determine the visibility improvement that could result from implementing certain control strategies.[9]

The following tables show which point sources are controlled in the CENRAP states that the MPCA has identified as contributing to visibility impairment in BWCAW and VNP (Iowa, Minnesota, Missouri) under the following assumptions: 1) a cost less than $5000/ton, and 2) facility emissions divided by the facility's distance from any Class I area, is greater than or equal to five (often called the Q/5D criteria). The tables include sources that are within Q/5D of either VNP or BWCAW.

The report prepared for the MPCA and Midwest RPO by EC/R, entitled "Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis," also provides documentation that the various control strategies mentioned in Attachment 2 are likely to be reasonable, at least for some states. A summary table follows the tables of units controlled in the CENRAP control sensitivity run.[10]

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[9] Information on the Control Sensitivity run is available on CENRAP's Project website, http://www.cenrap.org/projects.asp, under the link entitled *Results from Control Sensitivity Run, Base18Gc1 - Cost Curve Criteria of 5k per ton, Q over 5D*

[10] Battye, W. et al (2007, July 18). Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis. Prepared for MPCA and MRPO by EC/R. http://www.ladco.org/MRPO%20Report_071807.pdf. See Table 6.5-3, page 110.

NO_X Controls, Q/5D for BWCAW and VNP

State	County	Plant Name	Point ID	Source Type for Control	Control Measure	Tons Reduced	Annualized Cost ($2005)	Cost Per Ton Reduced
Iowa	Woodbury	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148766	Utility Boiler - Coal/Wall	SCR	3739	$5,252,502	$1,405
Iowa	Woodbury	MIDAMERICAN ENERGY CO. - GEORGE NEAL SOU	147140	Utility Boiler - Coal/Wall - Other Coal	LNBO	1191	$2,900,440	$2,435
Iowa	Wapello	IPL - OTTUMWA GENERATING STATION	143977	Utility Boiler - Coal/Tangential	SCR	4708	$13,000,038	$2,761
Iowa	Pottawattamie	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	143798	Utility Boiler - Coal/Wall - Other Coal	LNBO	671	$2,960,866	$4,413
Minnesota	Cook	MINNESOTA POWER - TACONITE HARBOR ENERGY	EU001	Utility Boiler - Coal/Tangential	SCR	411	$1,536,959	$3,737
Minnesota	Cook	MINNESOTA POWER - TACONITE HARBOR ENERGY	EU002	Utility Boiler - Coal/Tangential	SCR	411	$1,574,337	$3,828
Minnesota	Cook	MINNESOTA POWER - TACONITE HARBOR ENERGY	EU003	Utility Boiler - Coal/Tangential	SCR	411	$1,592,948	$3,873
Minnesota	Itasca	MINNESOTA POWER INC - BOSWELL ENERGY CTR	EU004	Utility Boiler - Coal/Tangential - POD10	LNC3	806	$1,413,275	$1,753
Minnesota	Itasca	MINNESOTA POWER INC - BOSWELL ENERGY CTR	EU003	Utility Boiler - Coal/Tangential - POD10	LNC3	600	$884,162	$1,474
Minnesota	Koochiching	Boise Cascade Corp - International Falls	EU320	Sulfate Pulping - Recovery Furnaces	SCR	361	$939,170	$2,603
Minnesota	St. Louis	MINNESOTA POWER INC - LASKIN ENERGY CTR	EU001	Utility Boiler - Coal/Tangential	SCR	1064	$1,346,571	$1,265
Minnesota	St. Louis	MINNESOTA POWER INC - LASKIN ENERGY CTR	EU002	Utility Boiler - Coal/Tangential	SCR	1063	$1,346,571	$1,267
Minnesota	St. Louis	EVTAC Mining - Fairlane Plant	EU042	ICI Boilers - Coke	SCR	1365	$3,142,325	$2,302
Minnesota	Sherburne	NSP - SHERBURNE GENERATING PLANT	EU002	Utility Boiler - Coal/Tangential - POD10	LNC3	998	$1,873,316	$1,877
Minnesota	Sherburne	NSP - SHERBURNE GENERATING PLANT	EU001	Utility Boiler - Coal/Tangential - POD10	LNC3	701	$1,880,449	$2,682
Missouri	Pike	HOLCIM (US) INC-CLARKSVILLE	16745	Cement Manufacturing - Wet	Mid-Kiln Firing	1808	$149,510	$83
Missouri	Randolph	ASSOCIATED ELECTRIC COOPERATIVE INC-THOM	17575	Utility Boiler - Coal/Wall - Other Coal	LNBO	682	$3,114,256	$4,563

SO_2 Controls, Q/5D for BWCAW or VNP

State	County	Plant Name	Point ID	Source Type for Control	Control Measure	Tons Reduced	Annualized Cost ($2005)	Cost Per Ton Reduced
Iowa	Muscatine	CENTRAL IOWA POWER COOP. - FAIR STATION	100125	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	4504	$5,854,468	$1,300
Iowa	Woodbury	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148766	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	11440	$20,886,351	$1,826
Iowa	Woodbury	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148765	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	7020	$13,365,237	$1,904
Iowa	Woodbury	MIDAMERICAN ENERGY CO. - GEORGE NEAL SOU	147140	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14255	$35,558,570	$2,494
Iowa	Wapello	IPL - OTTUMWA GENERATING STATION	143977	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	15894	$40,687,209	$2,560
Iowa	Louisa	MIDAMERICAN ENERGY CO. - LOUISA STATION	147281	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	12964	$36,698,267	$2,831
Iowa	Pottawattamie	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	143798	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	12141	$36,299,373	$2,990
Iowa	Des Moines	IPL - BURLINGTON GENERATING STATION	145381	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	5384	$17,059,783	$3,169
Iowa	Allamakee	IPL - LANSING GENERATING STATION	145136	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	5926	$19,213,055	$3,242
Iowa	Clinton	IPL - M.L. KAPP GENERATING STATION	144559	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	5036	$17,331,069	$3,441
Iowa	Linn	IPL - PRAIRIE CREEK GENERATING STATION	144096	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	3753	$13,730,673	$3,658
Minnesota	Itasca	MINNESOTA POWER INC - BOSWELL ENERGY CTR	EU001	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	2329	$9,472,980	$4,068
Minnesota	Itasca	MINNESOTA POWER INC - BOSWELL ENERGY CTR	EU002	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	2315	$9,472,980	$4,092
Minnesota	Itasca	MINNESOTA POWER INC - BOSWELL ENERGY CTR	EU004	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	7403	$30,486,914	$4,118
Missouri	Clay	INDEPENDENCE POWER AND LIGHT-MISSOURI CI	5430	Utility Boilers - Very High Sulfur Content	FGD Wet Scrubber	8058	$6,232,581	$774
Missouri	Franklin	AMERENUE-LABADIE PLANT	6964	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14741	$34,190,931	$2,319

State	County	Plant Name	Point ID	Source Type for Control	Control Measure	Tons Reduced	Annualized Cost ($2005)	Cost Per Ton Reduced
Missouri	Franklin	AMERENUE-LABADIE PLANT	7408	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14988	$34,874,750	$2,327
Missouri	Franklin	AMERENUE-LABADIE PLANT	7262	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14912	$34,874,750	$2,339
Missouri	Jefferson	AMERENUE-RUSH ISLAND PLANT	11565	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	13979	$32,994,250	$2,360
Missouri	Franklin	AMERENUE-LABADIE PLANT	7087	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14285	$34,019,977	$2,382
Missouri	Henry	KANSAS CITY POWER & LIGHT CO-MONTROSE GE	7847	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	6362	$15,425,097	$2,425
Missouri	Henry	KANSAS CITY POWER & LIGHT CO-MONTROSE GE	7849	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	6191	$15,134,675	$2,445
Missouri	Jefferson	AMERENUE-RUSH ISLAND PLANT	11563	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	13276	$32,994,250	$2,485
Missouri	Henry	KANSAS CITY POWER & LIGHT CO-MONTROSE GE	7848	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	5928	$14,840,835	$2,504
Missouri	St. Louis	AMERENUE-MERAMEC PLANT	21421	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	8494	$21,733,761	$2,559
Missouri	St. Louis	ANHEUSER-BUSCH INC-ST. LOUIS	20274	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	1996	$5,303,934	$2,658
Missouri	Platte	KANSAS CITY POWER & LIGHT CO-IATAN GENER	16912	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	14332	$38,179,875	$2,664
Missouri	Jackson	AQUILA INC-SIBLEY GENERATING STATION	9953	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	9166	$24,430,935	$2,665
Missouri	St. Louis	AMERENUE-MERAMEC PLANT	21423	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	7081	$19,721,240	$2,785
Missouri	Randolph	ASSOCIATED ELECTRIC COOPERATIVE INC-THOM	17575	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	9469	$38,179,875	$4,032
Missouri	New Madrid	ASSOCIATED ELECTRIC COOPERATIVE INC-NEW	14944	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	8132	$33,051,234	$4,064
Missouri	New Madrid	ASSOCIATED ELECTRIC COOPERATIVE INC-NEW	14942	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	8026	$33,051,234	$4,118
Missouri	Jefferson	DOE RUN COMPANY-HERCULANEUM SMELTER	11722	Primary Metals Industry	Sulfuric Acid Plant	10653	$46,396,391	$4,355

Table 6.5-3. Summary of Visibility Impactes and Cost Effectiveness of Potential Control Measures

Emission category	Control strategy	Region	Pollutant	Average estimated visibility improvement for the four Midwest Class I areas (deciviews)	Cost effectiveness ($/ton)	Cost effectiveness per visibility improvement ($million/ deciview)
EGU	EGU1	3-State	SO2	0.32	1,540	2,249
			NOX	0.06	2,037	2,585
		9-State	SO2	0.74	1,743	2,994
			NOX	0.17	1,782	2,332
	EGU2	3-State	SO2	0.41	1,775	2,281
			NOX	0.09	3,016	3,604
		9-State	SO2	0.85	1,952	3,336
			NOX	0.24	2,984	4,045
ICI boilers	ICI1	3-State	SO2	0.055	2,992	1,776
			NOX	0.043	2,537	1,327
		9-State	SO2	0.084	2,275	2,825
			NOX	0.068	1,899	2,034
	ICI Workgroup	3-State	SO2	0.089	2,731	1,618
			NOX	0.055	3,814	1,993
		9-State	SO2	0.136	2,743	3,397
			NOX	0.080	2,311	2,473
Reciprocating engines and turbines	Reciprocating engines emitting 100 tons/year or more	3-State	NOX	0.015	538	282
		9-State	NOX	0.052	506	542
	Turbines emitting 100 tons/year or more	3-State	NOX	0.008	754	395
		9-State	NOX	0.007	754	810
	Reciprocating engines emitting 10 tons/year or more	3-State	NOX	0.037	1,286	673
		9-State	NOX	0.073	1,023	1,095
	Turbines emitting 10 tons/year or more	3-State	NOX	0.011	800	419
		9-State	NOX	0.012	819	880
Agricultural sources	10% reduction	3-State	NH3	0.10	31 - 2,700	8 - 750
		9-State	NH3	0.16	31 - 2,700	18 - 1,500
	15% reduction	3-State	NH3	0.15	31 - 2,700	8 - 750
		9-State	NH3	0.25	31 - 2,700	18 - 1,500
Mobile sources	Low-NOX Reflash	3-State	NOX	0.007	241	516
		9-State	NOX	0.010	241	616
	MCDI	3-State	NOX	0.015	10,697	7,595
		9-State	NOX	0.015	2,408	4,146
	Anti-Idling	3-State	NOX	0.009	(430) - 1,700	(410) - 1,600
		9-State	NOX	0.006	(430) - 1,700	(410) - 1,600
	Cetane Additive Program	3-State	NOX	0.009	4,119	3,155
		9-State	NOX	0.008	4,119	10,553

Attachment 4: Organizations Participating in Northern Class I Consultation Process

States and Provinces
Illinois Environmental Protection Agency
Indiana Department of Environmental Management
Iowa Department of Natural Resources
Michigan Department of Environmental Quality
Minnesota Pollution Control Agency
Missouri Department of Natural Resources
North Dakota Department of Health
Wisconsin Department of Natural Resources
Ontario Ministry of the Environment

Tribes
Leech Lake Band of Ojibwe
Fond du Lac Band of Lake Superior Chippewa
Mille Lacs Band of Ojibwe
Upper and Lower Sioux Community
Red Lake Band of Chippewa
Grand Portage Band of Chippewa
Nottawaseppi Huron Band of Potawatomi

Regional Planning Organizations
Midwest Regional Planning Organization
Central Regional Air Planning Association

Federal Government
USDA Forest Service
U.S. Fish and Wildlife Service
National Park Service
USDA Forest Service
Environmental Protection Agency, Region 5

Northern Class I Area Conference Call Minutes
October 4, 2007

Participants on the call

- Minnesota: John Seltz, Mary Jean Fenske, Gordon Andersson
- Michigan: Bob Irvine, Teresa Walker, Cindy Hodges
- Wisconsin: Larry Bruss, Farrokh Ghoreishi, Bob Lopez
- Iowa: Matt Johnson, Wendy Walker, Jim McGraw
- North Dakota: Tom Bachman
- Missouri: Calvin Ku
- Ontario: Mary Kirby
- Tribes: Joy Wiecks
- LADCO: Mike Koerber
- CENRAP: Jeff Peltola
- FS: Ann Mebane, Chuck Sams, Trent Wickman, Scott Copeland
- EPA: Matthew Rau

1. Follow-ups from last call and news.
    - Minutes from August 23, 2007 call were approved and can be posted.

2. Minnesota's Sept 18 Letter
    - Letter was sent to states and requested a response in 30 days.
    - .

3. Summary of 'ask' by Northeast States.
    - Actions MANE-VU wants MRPO states to take. No impacts from CENRAP states.
    - 'Ask' includes BART, 90% SO2 reduction on 167 EGU stacks (~50 in Midwest), 28% reductions in SO2 from non-EGU sources, continued evaluation of other sources, and the federal beyond-CAIR 'ask'.
    - LADCO plans on doing modeling for MANE-VUs and Minnesota's 'asks."

4. LADCO's latest haze modeling.
    - Uses 2005 base year and new IPM modeling. One alternative scenario corrects for added or removed controls assumed by IPM.
    - Modeled worst days for 2009, 2012 and 2018. Michigan's Class I areas are above the glide path, Minnesota's are on the glide path and other areas are mixed, some above and some below.
    - Both 2002 and 2005 inventories are SIP quality and can be used in weight-of-evidence.
    - LADCO did not change the baseline, still using 2000-2004 to calculate it.
    - EPA has not determined if base year 2005 will be accepted in the Haze SIPS.

5. Comments received on ECR report.
    - Comments from CEED claim retrofit cost are too low.
    - Comments from the American Forest and Paper Association claim modeling and screening methods should not be used and photochemical should be done.
    - Don't need to respond to comments, but post them on website with a disclaimer that we do not necessarily agree with the comments.

6. State progress reports on SIP writing.
    - Minnesota-having public comment in November and final SIP to EPA by January or February.
    - Michigan-sending to FLMs in October, public comments end of November, to EPA by due date. BART will not be complete but will send it later.
    - Wisconsin-BART rules have been stopped by the board. Need to have a scope statement before Wisconsin can proceed with rules. Likely will be submitted a year late.

- Iowa-sending to FLMs end of October, and to EPA in February or March. BART analysis is complete.
- North Dakota-finalizing BART portion and will get that portion only to EPA in January. The rest of the SIP will not be finalized until summer of 2008.
- Missouri-draft SIP to FLMs on August 23, 2007. Public hearing on December 6th and to EPA in February. FLMs are questioning when the 60 days start because they do not have the full SIP.

7. Need to update January 2007 Technical Summary.
    - Have new modeling from LADCO and CENRAP and other new information.
    - Summary should be updated. Mike will work on this for our next call.

8. International contribution guidance from Scott Copeland.
    - Guidance shows better way of calculating transboundary contributions than EPRI report.
    - States should not do this type of analysis. Haze rule is only concerned with man-made pollution not where it comes from.

9. October 10 LADCO workshop and other events.
    - Stakeholders meeting to discuss 2005 modeling and Minnesota's and MANE-VU's 'asks'.
    - Minnesota is having board meeting on October 23 to finalize SIP.

Next call: Thursday, November 29th, 2007 10:30 PM CST, 11:30 PM EST

Iowa
Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

November 1, 2007

Brad Moore
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155-4194

RE: Northern Class I Areas Consultation Process

Dear Commissioner Moore:

I am writing in response to your recent letter concerning the consultation process undertaken in the context of the Regional Haze Rule (40 § CFR 51.308). Current conclusions identify Iowa as a state which reasonably contributes to visibility impairment in the two Class I areas in Minnesota, Voyageurs National Park and the Boundary Waters Canoe Area Wilderness.

Your correspondence requests that Iowa evaluate additional control measures and implement those that are reasonable under the four factors listed in 40 § CFR 51.308(d)(1)(i)(A). In particular, your letter asks Iowa to consider additional control measures for electric generating units (EGU) for SO_2 to meet approximately a 0.25 lbs/mmBtu average emission rate. The letter also requests that Iowa commit to a more detailed review of potential emission reductions from large Industrial, Commercial, and Institutional (ICI) boilers and other point sources such as reciprocating engines and turbines.

Iowa cannot commit at this time to requiring additional controls to units already in the Clean Air Interstate Rule (CAIR) program. The CAIR program permanently caps emissions from SO2 and NOx through a federal trading program. Iowa participates in CAIR in both the ozone season and the annual program. CAIR needs the opportunity to succeed without additional impediments that would hinder its implementation. Within the context of the four factor analysis, this decision is based upon the costs associated with additional EGU SO2 controls.

The LADCO/Minnesota Four-Factor analysis of cost of EGU controls, in terms of dollars per ton, provides a limited view of overall effectiveness. A more rigorous review also requires the consideration of control costs commensurate with their potential for visibility improvement. Such a measure is achieved by coupling the modeled visibility impacts of control projects with their associated costs to arrive at a dollar per deciview metric. While not available for all individual states, the report does quantify dollar per deciview costs in the nine-state region. Examining the EGU1 and EGU2 scenarios, the cost

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effectiveness for SO2 ranges $2,994,000,000/dv - $3,336,000,000/dv and NOx ranges $2,332,000,000/dv - $4,045,000,000/dv for the nine-state region. Expanding this analysis beyond EGU controls, the cost effectiveness of ICI boiler controls is nearly as expensive, ranging from $2,825,000,000/dv - $3,397,000,000/dv for SO2 and $2,034,000,000/dv – 2,473,000,000/dv for NOx. In terms of dollars per ton, one estimate (EC/R's) of Iowa EGU SO2 average control costs totals $1,900/ton, a value which may be underestimated given the assumptions used by EC/R.[1] This cost is well above the estimated costs of CAIR, at $700-1200/ton.[2] Iowa does not find theses costs to be cost effective for visibility improvement.

Iowa has concluded that additional review of our ICI boilers is unwarranted. Costs across the nine-state region, in terms of dollars per deciview, exceed two billion dollars. While state specific dollar per deciview figures are not available, Iowa's projected 2018 ICI SO2 and NOx emissions represent 8.2% and 6.4%, respectively, of the total emissions within the nine-state region.[3] The combination of a low percentage of contributing emissions compounded by the necessary transport distances suggests the above ICI cost estimates would be conservative if calculated for Iowa sources alone. Such costs, in combination with a low potential for discernable visibility improvement, are unreasonable for Iowa sources to incur. Similar arguments apply to other point sources, such as reciprocating engines and combustion turbines.

The vacature of the NESHAP for ICI boilers leaves many unanswered questions. It is unproductive to work on a standard for these sources at the same time that EPA will be working on the standard. The revised NESHAP may expand the standard to include more sources. The likely co-benefits of the revised standard will also assist States with their regional haze goals.

Attachment 1 of your correspondence shows state impacts from a LADCO trajectory analysis and CENRAP PSAT modeling results. Iowa questions the numerical accuracy of a trajectory analysis due to the numerous uncertainties. A trajectory analysis is based upon theoretical air flow and does not account for chemical reactions in the atmosphere. The 2002 CENRAP PSAT[4] modeling indicates that Iowa contributes 3.7% and 3.8% to the Boundary Waters Canoe Area and Voyageurs National Park, respectively, with the majority of this visibility impairment attributable to elevated point source SO2 emissions (predominantly EGUs). In 2018 the modeled percentage contributions increase slightly to 3.9 and 4.0 percent, however, results are based upon outdated emissions forecasts. Based upon the most recent EGU forecasts[5], Iowa EGU SO2 emissions are projected to decline by approximately 15% between 2002 and 2018. Iowa finds this reduction reasonable considering the level of contribution, the distance to the Class I areas, and the timeline to achieve natural background visibility.

---

[1] Battye, W. et al (2007, July 18). Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis. Prepared for MPCA and MRPO by EC/R. See Table 5.1-3 and discussion on page 27.
[2] Ibid. See Table 6.1-2, page 101.
[3] Ibid. See Tables 5.2-1 and 5.2-2, page 40
[4] Results from Environ's August 27th, 2007 source apportionment tool
[5] IPM3.0 results for year 2018

In closing, I would like to reiterate that Iowa has concluded its evaluation of the feasibility of requiring additional controls for EGUs and other boilers, and has determined that no further reductions are reasonable at this time.

If you have any questions regarding this submittal, please contact Wendy Rains at (515) 281-6061 or wendy.rains@dnr.iowa.gov.

Sincerely,

Catharine Fitzsimmons

Catharine Fitzsimmons
Chief, Air Quality Bureau

cc: John Seltz, Minnesota Pollution Control Agency

Northern Class I Areas Consultation

DRAFT Minutes

November 29, 2007
10:30 – 11:30 am CDT

Attendees	Minnesota	Gordon Andersson, Mary Jean Fenske, Catherine Neuschler, John Seltz
	Michigan	Cindy Hodges
	North Dakota	Dana Mount
	Wisconsin	Bob Lopez, Larry Bruss, Farrokh Ghoreishi
	Iowa	Wendy Walker, Matthew Johnson
	FLM	Tim Allen - FWS Trent Wickman, Ann Mebane - USFS
	RPOs	Mike Koerber – LADCO/MRPO
	EPA	Matt Rau

Agenda Items

Minutes from Previous Call

Cindy will send out the minutes after this call for approval, and would like comments by 12/5.

MRPO Analysis of Minnesota and MANE-VU Asks

MRPO did an analysis of the Minnesota and MANE-VU asks. Lots of interpretation was required for the MANE-VU asks, and assumptions about which EGUs would be controlled by the MN ask. The two asks were modeled together, so they show combined emission reductions and visibility improvement. The modeling shows a 0.2 – 0.4 dv improvement in the Northern Class I areas, and a larger (1 dv +) improvement in Eastern Class I areas.

MRPO Updated PSAT Analysis

MRPO has a new PSAT analysis with the 2005 data. Although new meteorology is included, the results overall are not qualitatively too different from the previous results. The 2005 and 2002 analyses are both SIP quality, and States can use them as weight of evidence. Wisconsin and Michigan are likely to submit both model runs in their SIP. However, Wisconsin did note some concerns with the Round 5 modeling, as Wisconsin's non-EGU impacts show very much reduced sulfate impacts and Wisconsin can only account for about half the emission changes.

Haze SIP Updates

- Michigan sent a draft of their SIP to the FLMs, who had significant concerns. FLMs asked them to postpone submitting their SIP, which they are doing. The PM2.5 SIP is taking significant time, which makes the haze timeline somewhat unclear, but hope to have a submittal to EPA by April.
- Iowa sent the SIP to the FLMs on Monday 11/26. Their public hearing is scheduled for January 30. The draft should be up on their website soon, and Wendy will let the group know when it is posted.
- Minnesota is having some BART implementation questions that may create a schedule delay.

Upcoming Meetings/Next Call

Next Call: February 7th at 10:30 CST

ADEQ
ARKANSAS
Department of Environmental Quality

July 23, 2007

To: Participants in the Central Class I Areas Consultation Process

Re: Central Class I Areas Consultation Conclusion

On Feb. 26, 2007, an invitation letter was sent to 12 states and tribes from the states of Missouri and Arkansas. The invitation included a consultation plan, which detailed the procedures and timelines for identifying possible contributors to regional haze in Arkansas and Missouri Class I Areas (Caney Creek, Upper Buffalo, Hercules Glade and Mingo). This process was initiated because the federal Regional Haze Rule requires states to consult with other states and tribes that may be causing or contributing to visibility impairments in federal Class I areas.

These consultations have been accomplished through a series of conference calls. The calls were held on April 3, May 11 and June 7, 2007. Participants included states and tribes, Environmental Protection Agency personnel, regional office staff, Federal Land Managers, and other Regional Planning Organizations. A summary of these conference calls can be found on the CENRAP Web site.

A Uniform Rate of Progress was developed for each of the Class I Areas in Arkansas and Missouri. Regional modeling and other findings indicate that these Class I Areas will meet the established Rate of Progress goals by 2018 based on the existing and proposed controls through both state and federal requirements. Therefore, it is the intent of Arkansas and Missouri to proceed with the development and submittal of a Regional Haze Plan.

Both Missouri and Arkansas believe that the consultations conducted to date have satisfied the consultation process requirements described in the rule. These consultations were completed so that the each state's plan can be submitted for separate review with the Federal Land Managers and Environmental Protection Agency. If necessary, future consultations will be conducted to address any issues that are identified in the review of those draft plans or if changes occur in the contributions associated with regional haze transport.

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Arkansas and Missouri are committed to continue on-going assessments of progress in meeting visibility improvement goals. However, the ability to conduct

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any substantive future planning activities of this nature are made difficult by the lack of federal funding for these efforts. The next review is scheduled for completion in 2013, as dictated by Long Term Strategy Planning on a five-year cycle.

Furthermore, to document that these initial consultations have been made, we are asking that recipients of this letter respond to provide a record that these consultations have taken place to the satisfaction of your state or tribe. Since federal recipients of this letter have a separate administrative process for review, we are not asking for your reply at this time.

Thank you for your participation and contributions in this consultation process. Your time and efforts are appreciated. If you require additional information regarding this matter, please contact Mr. Calvin Ku, Missouri Department of Natural Resources at (573) 751-8406 or, Mr. Mark McCorkle, Arkansas Department of Environmental Quality at (501) 682-0736.

Sincerely,

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

Mike Bates

Mike Bates, Chief
Air Division
Arkansas Department of Environmental Quality

MISSOURI DEPARTMENT OF NATURAL RESOURCES

James L. Kavanaugh, Director
Air Pollution Control Program
Missouri Department of Natural Resources

JM ✓ WR ✓
MJ ✓
File —

Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's
environment for the benefit of current and future generations.

Dave Freudenthal, Governor

John Corra, Director

May 8, 2007

Ms. Catharine Fitzsimmons, Chief
Iowa Department of Natural Resources
Air Quality Bureau
7900 Hickman Road, Suite 1
Urbandale, IA 50322

Dear Ms. Fitzsimmons:

The State of Wyoming, Department of Environmental Quality, will be preparing a State Implementation Plan (SIP) to meet the requirements of 40 CFR 51.308, as well as amending our 309 SIP submittal to protect visibility in Class I areas across the country. While we believe that the Western Regional Air Partnership (WRAP) serves as the coordinating body for all consultation during this process, we would like you to know that we welcome Iowa's participation in our state SIP process. As Chief of the Air Quality Bureau of the Iowa Department of Natural Resources, we hope that you will share this letter with all appropriate personnel that you feel would like to consult with Wyoming on regional haze goals.

I have enclosed a list of contacts within the Air Quality Division who are involved in the SIP process. The Division maintains a web site for regional haze matters at http://deq.state.wy.us/aqd/regionalhaze.asp, and all future public information will be posted there. Technical support information can also be found on the WRAP site at http://vista.cira.colostate.edu/tss/. At this point, the earliest we are anticipating a draft of the SIP will be the summer of 2007. If you have any questions regarding the SIP preparation or schedule, please feel free to contact Christine Anderson of my staff at 307-673-9337.

Sincerely,

Finley

David A. Finley
Administrator
Air Quality Division

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MAY 14 2007

cc: Christine Anderson, Air Quality Division

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FAX 777-3610	FAX 777-6462	FAX 777-5616	FAX 777-6937	FAX 777-5864	FAX 777-5973	FAX 777-5973

Contacts for Wyoming Department of Environmental Quality Regional Haze Effort

Department Director
John V. Corra
307-777-7391
jcorra@state.wy.us

Air Quality Division Administrator
David A. Finley
307-777-7391
dfinle@state.wy.us

SIP Coordination
Christine (Tina) Anderson
307-673-9337
tander@state.wy.us

Smoke Management
Darla Potter
307-777-7346
dpotte@state.wy.us

Air Quality Resource Management
Lori Bocchino
lbocch@state.wy.us

Emission Inventory/Regional Haze
Brian Bohlmann
307-777-6993
bbohlm@state.wy.us

Monitoring
Cara Keslar
307-777-8684
ckesla@state.wy.us

Permitting
Chad Schlichtemeier
307-777-5924
cschli@state.wy.us

South Dakota
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**DEPARTMENT of ENVIRONMENT
and NATURAL RESOURCES**
PMB 2020
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523 EAST CAPITOL
PIERRE, SOUTH DAKOTA 57501-3182
www.state.sd.us/denr

May 31, 2007

Catharine Fitzsimmons
Iowa Department of Natural Resources
7900 Hickman, Suite 1
Urbandale, Iowa 50322

RE: State Consultation for Regional Haze

Dear Ms. Fitzsimmons:

South Dakota is in the process of developing its Regional Haze State Implementation Plan. As you may know, South Dakota has two Class I areas. They are Badlands National Park and Wind Cave National Park. Under the Federal Regional Haze Rule we are required to consult with other states that may impact our Class I areas and also with states whom we may have an impact on.

The Western Regional Air Partnership (WRAP) conducted modeling for South Dakota, which indicated visibility impacts on our Class I areas from states associated with the Central States Regional Air Planning Association (CENRAP). We are interested in knowing if CENRAP or the State of Iowa has conducted a similar analysis to determine what impacts, if any, sources in Iowa might have on the Badlands and/or Wind Cave National Park.

If an analysis has been conducted, we would be interested in reviewing the analysis and any associated modeling. Please contact Rick Boddicker, of my staff, with any information you might have on your states Regional Haze analysis. Rick may be contacted at 605-773-3151 or by email at rick.boddicker@state.sd.us.

I want to thank you in advance for your time.

Sincerely,

Brian Gustafson, P.E.
Administrator
Air Quality Program

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R. SERIES / Initials ________/______
FACILITY ID ______________
WK ACT / Doc Code ________/______

Iowa
Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

June 18, 2007

Rick Boddicker
South Dakota DENR
PMB 2020
Joe Foss Building
523 East Capitol
Pierre, South Dakota 57501

RE: State Consultation for Regional Haze

Dear Mr. Boddicker,

Iowa is participating in the development of technical analyses to support the regional haze State Implementation Plan submission through involvement in the Central States Regional Air Planning Association (CENRAP). CENRAP has completed technical work products which are capable of assessing individual state contributions upon the two Class I areas located in South Dakota.

The contribution assessments are based upon source apportionment techniques available in regional scale one-atmosphere photochemical models. Post processing tools have been created which allow any end user to customize the selection and display of the numerical source-apportionment data. The tool is freely available for download at: http://cenrap.org/projects.asp (PSAT Viz Tool 27 April 2007 - 25MB zip).

Based upon this tool, our analyses of Iowa's impact upon South Dakota Class I areas indicate a state-wide contribution of 1.6 percent to the total visibility extinction on the 20% worst days in 2018, at the Badlands National Park. A similar analysis for Wind Cave National Park yields a contribution of approximately 1.2%. Details regarding the modeling system configuration will be published as CENRAP develops technical support documents. Please contact Matthew Johnson at 515-242-5164 or by email at matthew.johnson@dnr.state.ia.us if you have any additional questions.

Sincerely,

Catharine Fitzsimmons

Catharine Fitzsimmons
Bureau Chief
Air Quality Bureau

cc: SD Board of Minerals and Environment

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515-242-5100 FAX 515-242-5094 HTTP://www.iowacleanair.com7900 Hickman Road, Suite 1 / Urbandale, Iowa 50322
515-242-5100 FAX 515-242-5094 http://www.iowacleanair.com/

JM ✓
WR ✓
M-f ✓
File —

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

STEVEN A THOMPSON
Executive Director

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

BRAD HENRY
Governor

August 2, 2007

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Ms Catharine Fitzsimmons Director
Iowa Department of Natural Resources
Air Quality Bureau
7900 Hickman, Suite 1
Urbandale, IA 50322

Dear Ms. Fitzsimmons:

As you know, the U.S. Environmental Protection Agency (EPA) promulgated the federal Regional Haze Rule on July 1, 1999. The federal Regional Haze Rule and the Clean Air Act require consultation between the States and the Federal Land Managers (FLMs) responsible for managing federal Class I areas. This consultation process provides an opportunity for us to work together to achieve a common goal of protecting the visibility of Class I areas.

The Oklahoma Department of Environmental Quality Air Quality Division would like to officially begin our consultation process for the Wichita Mountains Wilderness Area (WIMO) on Thursday, August 16, 2007 at 10 a.m. We are planning three consultation sessions:

Thursday, August 16, 2007 at 10 a.m.
Thursday, August 30, 2007 at 10 a.m.
Thursday, September 13, 2007 at 10 a.m.

The consultations will take the form of telephone conference calls arranged through the Central Regional Air Planning Association (CENRAP). The access number is 1-800-504-4496. The pass code is 3937085#.

Materials more specific to the consultation will be conveyed electronically via email or by posting on the Oklahoma DEQ web page: http://www.deq.state.ok.us/aqdnew. If you or your staff have questions, please contact Cheryl Bradley at cheryl.bradley@deq.state.ok.us.

Sincerely,

Eddie Terrill
Division Director
Air Quality Division

Attachments: Agenda
Consultation Plan

707 NORTH ROBINSON, P.O. BOX 1677, OKLAHOMA CITY, OKLAHOMA 73101-1677

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

STEVEN A. THOMPSON
Executive Director

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

BRAD HENRY
Governor

February 25, 2008

Catharine Fitzsimmons, Chief
Air Quality Bureau
Iowa Department of Natural Resources
7900 Hickman, Suite I
Urbandale, IA 50322

Dear Ms. ~~F~~itzsimmons: Catharine

Thank you for participating in Oklahoma's Wichita Mountains Regional Haze Consultations conducted pursuant to the requirements in 40 CFR 51.308(d)(3)(i). The Oklahoma Department of Environmental Quality (DEQ) invited states, that were projected in 2018 to contribute greater than 1 inverse megameter (Mm^{-1}) of light extinction in the Wichita Mountains Wilderness Area (WIMO), to participate in Oklahoma's consultations. Iowa sources were projected to contribute approximately 1.5 inverse Mm^{-1}. After evaluating 2018 modeling projections for the 20% worst days, the DEQ determined that Iowa's anthropogenic sources are not reasonably anticipated to contribute to visibility impairment in the WIMO. Therefore, DEQ is not requesting that Iowa consider any additional emission reductions from sources in Iowa.

I hope your Regional Haze SIP development process is proceeding well. Please let me know if you require additional information.

Sincerely,

Ed Terrill

Eddie Terrill, Director
Air Quality Division
Oklahoma Department of Environmental Quality

c: Matt Paque, DEQ Legal

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STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M GRANHOLM
GOVERNOR

DEQ

STEVEN E CHESTER
DIRECTOR

October 26, 2007

TO: Northern Class I Area Consultation Participants Listed on Attachment

We are writing this letter to those parties that have participated in the Regional Haze consultation process with the Michigan Department of Environmental Quality (MDEQ), Air Quality Division (AQD), over the last several months. This letter explains the AQD's response to the Regional Haze Rule.

As you know, the federal rule requires states with Class I areas to consult with other states that may be contributing to visibility impairment within the Class I areas Michigan's two haze Class I areas are Isle Royale National Park and the Seney Wilderness Area. The dialog over the last few months with you and the other participants (see attached list) has helped the AQD decide on the best approach for complying with the reasonable progress requirements of the rule.

The AQD is relying primarily on the study by EC/R, Inc. to evaluate the costs and impacts on visibility through additional controls in the region. A key finding of the report is that "beyond CAIR" reductions from EGUs in a three-state (Michigan, Wisconsin and Minnesota) or nine-state (Michigan, Wisconsin, Minnesota, Indiana, Illinois, Missouri, Iowa, North Dakota and South Dakota) region would provide the most significant visibility improvement in Michigan's Class I areas. While the AQD would likely support a federal "beyond CAIR" program, we do not intend to promulgate a state rule for the purpose of improving visibility.

Additional measures were analyzed in the EC/R report focusing on ICI boilers, reciprocating engines and turbines, agricultural sources and mobile sources. While controls for ICI boilers and reciprocating engines may be cost-effective, they appear to have little effect on visibility. Agricultural (ammonia) sources appear to have a larger impact and may be cost-effective, but the ammonia inventory is still inaccurate. Mobile source controls are generally expensive and have very little impact on visibility. Due to the small effects on visibility from these sources, the AQD does not intend to pursue such category-specific controls for regional haze.

The AQD is completing its Best Available Retrofit Technology (BART) analysis of the six facilities that have been shown to impact one or more of Michigan's Class I areas and will develop consent orders or rules to implement BART controls on these facilities. The AQD is also developing a state implementation plan for PM2.5 and expects there will be additional areas of nonattainment resulting from the new PM2.5 24-hour standard and possibly for the revised National Ambient Air Quality Standard for ozone.

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Additional controls will probably be needed in order to meet these standards, and such controls are likely to contribute to a reduction in regional haze in the 2018 time frame.

Since the AQD is not planning new controls at this time, specifically for the regional haze program, we are not asking other states to reduce emissions for the regional haze rule. However, we do support Minnesota's plan to reduce emissions to improve visibility at their two Class I areas and their request to impacting states to do likewise. Any such emission reductions will have some beneficial impacts on Michigan's Class I areas.

We would like to thank you for your participation in the consultation process. It was an opportunity for a fruitful discussion and sharing of data relative to Michigan's regional haze areas. If you have any questions regarding this letter or the consultation process, please contact Ms. Cindy Hodges, AQD, at 517-335-1059, or you may contact me.

Sincerely,

Lynn Fiedler

ACTING

G. Vinson Hellwig, Chief
Air Quality Division
517-373-7069

Attachment
cc: Mr. Jim Sygo, Deputy Director, MDEQ
Mr. Robert Irvine, MDEQ
Ms. Cindy Hodges, MDEQ

Participants in the Northern Class I Consultation

States and Provinces

Illinois Environmental Protection Agency
Indiana Department of Environmental Management
Iowa Department of Natural Resources
Michigan Department of Environmental Quality
Minnesota Pollution Control Agency
Missouri Department of Natural Resources
North Dakota Department of Health
Wisconsin Department of Natural Resources
Ontario Ministry of the Environment

Tribes

Leech Lake Band of Ojibwe
Fond du Lac Band of Lake Superior Chippewa
Mille Lacs Band of Ojibwe
Upper and Lower Sioux Community
Red Lake Band of Chippewa
Grand Portage Band of Chippewa
Nottawaseppi Huron Band of Potawatomi

Regional Planning Organizations

Midwest Regional Planning Organization
Central Regional Air Planning Association

Federal Government

USDA Forest Service
U S. Fish and Wildlife Service
National Park Service
USDA Forest Service
Environmental Protection Agency, Region 5

Appendix 10.2: LADCO'S Four Factor Report Summaries

Estimated Visibility Impacts of Potential Control Strategies & Summary of Visibility Impacts and Cost Effectiveness of Potential Control Measures

Nine-states region - Estimated visibility improvement on the 20% worst-visibility days in 2018 (deciviews)

Emission Category	Control Strategy	Description	Pollutant	BWCA	VOYA	ISLE	SENEY	Average	Cost effectiveness per visibility improvement ($/deciview)	Cost Effectivness ($/ton)
EGU	EGU1	SO2 limited to 0.15 lb/MM-BTU	SO2	0.77	0.35	0.84	1.01	0.74	2,994,000,000	1,743
		NOX limited to 0.10 lb/MM-BTU	NOx	0.18	0.24	0.15	0.12	0.17	2,332,000,000	1,782
	EGU2	SO2 limited to 0.10 lb/MM-BTU	SO2	0.87	0.40	0.96	1.18	0.85	3,336,000,000	1,952
		NOX limited to 0.07 lb/MM-BTU	NOx	0.26	0.30	0.23	0.19	0.24	4,045,000,000	2,984
ICI Boilers	ICI1	40% SO2 reduction from 2018 baseline emissions	SO2	0.090	0.047	0.092	0.109	0.084	2,825,000,000	2,275
		60% NOX reduction from 2018 baseline emissions	NOx	0.098	0.070	0.048	0.058	0.068	2,034,000,000	1,899
	ICI Workgroup	77% SO2 reduction from 2018 baseline emissions	SO2	0.145	0.075	0.148	0.176	0.136	3,397,000,000	2,743
		70% NOX reduction from 2018 baseline emissions	NOx	0.114	0.082	0.056	0.067	0.080	2,473,000,000	2,311
Reciprocating engines and turbines	Reciprocating engine emissions of 100/tons/yr or more	89% NOX reduction from 2018 baseline emissions	NOx	0.074	0.053	0.036	0.044	0.052	542,000,000	506
	Turbine emissions of 100/tons/year or more	84% NOX reduction from 2018 baseline emissions	NOx	0.010	0.007	0.005	0.006	0.007	810,000,000	754
	Reciprocating engine emissions of 10/tons/year or more	89% NOX reduction from 2018 baseline emissions	NOx	0.105	0.075	0.051	0.062	0.073	1,095,000,000	1,023
	Turbine emissions of 10/tons/year or more	84% NOX reduction from 2018 baseline emissions	NOx	0.017	0.012	0.008	0.010	0.012	880,000,000	819
Agricultural Sources	10% reduction	Achieve a 10-15% NH3 reduction through the use of a variety of best management practices.	NH3	0.15	0.18	0.15	0.17	0.16	18,000,000 - 1,500,000,000	31 - 2,700
	15% reduction		NH3	0.23	0.27	0.23	0.26	0.25	18,000,000 - 1,500,000,000	31 - 2,700
Mobile Sources	Low-NOX Reflash	Install low-NOX software to counteract advanced computer controls installed on MY 1993-1998 HDDV that increase NOX emissions.	NOx	0.008	0.009	0.012	0.012	0.010	616,000,000	241
	MCDI	A collaborative organization between federal, state, and local agencies funding projects that will reduce diesel emissions through operational changes, technological improvements, and cleaner fuels.	NOx	0.014	0.018	0.013	0.013	0.015	4,146,000,000	2,408
	Anti-Idling	Strategies to reduce NOX emissions that take the form of enforced shutdown policies, auxiliary power units (APUs), automatic engine shut-off technology, and truck stop electrification (TSE).	NOx	0.005	0.007	0.006	0.006	0.006	(410,000,000) - 1,600,000,000	(430) - 1,700
	Cetane Additive	Introduces additives to diesel fuel at the distribution source to increase the cetane number to approximately 50.	NOx	0.006	0.007	0.009	0.010	0.008	10,553,000,000	4,119

Tables 6.1, 6.5.2, and 6.5.3

Appendix 10.2: LADCO'S Four Factor Report Summaries

Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures for the Nine-State Region

Emission Category	Control Strategy	Pollutant	Emission Reduction (tons/year)	Additional electricity requirements (GW-hrs/year)	Additional diesel fuel requirements (gal/year)	Steam requirement (tons/year)	Solid Waste Produced (tons/year)	Wastewater Produced (gallons/year)	Additional CO2 emitted (tons/year)
EGU	EGU1	SO2	1,279,000	2,649	0	3,462,000	0	1,128,000	3,651,000
		NOX	224,000	110	0	46,000	0	0	115,000
	EGU2	SO2	1,455,000	3,504	0	5,439,000	0	1,919,000	4,666,000
		NOX	328,000	608	0	255,000	0	0	636,000
ICI Boilers	ICI1	SO2	105,000	37	0	0	346,000	0	102,000
		NOX	73,000	214	0	12,000	1,000	0	217,000
	ICI Workgroup	SO2	169,000	58	0	0	537,000	0	158,000
		NOX	85,000	235	0	14,000	1,000	0	239,000
Reciprocating engines and turbines	Reciprocating engine emissions of 100/tons/yr or more	NOX	Not significant, the most cost effective control technology consists of low-NOx combustion technologies.						
	Turbine emissions of 100/tons/year or more	NOX	Not significant, the most cost effective control technology consists of low-NOx combustion technologies.						
	Reciprocating engine emissions of 10/tons/year or more	NOX	Not significant, the most cost effective control technology consists of low-NOx combustion technologies.						
	Turbine emissions of 10/tons/year or more	NOX	Not significant, the most cost effective control technology consists of low-NOx combustion technologies.						
Agricultural Sources	10% reduction	NH3	91,000	0	19,000 - 42,000	0	0	0	183,000 - 392,000
	15% reduction	NH3	137,000	0	29,000 - 63,000	0	0	0	274,000 - 589,000
Mobile Sources	Low-NOX Reflash	NOX	No other environmental impacts.						
	MCDI	NOX	Anti-idling strategies have no quantifiable environmental impacts. Biodiesel productions results in a 79% reduction in wastewater and a 96% reduction in solid waste.						
	Anti-Idling	NOX	No other environmental impacts.						
	Cetane Additive	NOX	No other environmental impacts.						

Table 6.3.1 (estimated energy & non-air impacts)

Appendix 10.2 CENRAP Control Cost for SO2

Plant ID	Plant Name	Point ID	ORIS ID	BLRID	NETDC (MW)	SIC	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case SO2 -- Tons	2018 Base Case SO2-- CE (%)	Controls -- Tons Reduced	Controls -- CE (%)	Controls -- Annualized Cost ($2005)	Controls -- Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(SO2 Tons Reduced) / 5d	Latitude	Longitude
90-07-001	IPL - OTTUMWA GENERATING STATION	143977	6254	1	714	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	17,659	0	6,181	35	$2,973,763	$481	6,181	$2,973,763	$481	Hercules-Glades Wilderness	487	2.54	41.0987	-92.5616
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148766	1091	2	300	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	12,711	0	4,449	35	$2,140,462	$481	4,449	$2,140,462	$481	Badlands	488	1.82	42.3252	-96.3792
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148765	1091	1	135	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	7,800	0	2,730	35	$1,313,477	$481	2,730	$1,313,477	$481	Badlands	488	1.12	42.3252	-96.3792
03-03-001	IPL - LANSING GENERATING STATION	145136	1047	4	260	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	6,585	0	2,305	35	$1,108,849	$481	2,305	$1,108,849	$481	Boundary Waters Canoe Area	493	0.93	43.3378	-91.1667
29-01-013	IPL - BURLINGTON GENERATING STATION	145381	1104	1	211	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	5,982	0	2,094	35	$1,007,345	$481	2,094	$1,007,345	$481	Mingo	422	0.99	40.7547	-91.1237
23-01-014	IPL - M.L. KAPP GENERATING STATION	144559	1048	2	217	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	5,596	0	1,959	35	$942,292	$481	1,959	$942,292	$481	Mingo	531	0.74	41.8133	-90.2322
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100125	1218	1	25	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	5,004	0	1,752	35	$842,729	$481	1,752	$842,729	$481	Mingo	495	0.71	41.4587	-90.8224
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144096	1073	4	142	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	4,170	0	1,460	35	$702,264	$481	1,460	$702,264	$481	Mingo	561	0.52	41.9442	-91.7013
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172728	1081	9	130	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	3,061	0	1,071	35	$515,382	$481	1,071	$515,382	$481	Mingo	502	0.43	41.5401	-90.4478
64-01-012	IPL - SUTHERLAND GENERATING STATION	145470	1077	3	80	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,625	0	569	35	$273,572	$481	569	$273,572	$481	Hercules-Glades Wilderness	591	0.19	42.0469	-92.8627
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100127	1218	2	38	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,503	0	526	35	$253,165	$481	526	$253,165	$481	Mingo	495	0.21	41.4587	-90.8224
21-01-003	CORNBELT POWER - WISDOM GENERATING STATI	154485	1217	1	38	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,445	0	506	35	$243,405	$481	506	$243,405	$481	Badlands	552	0.18	43.1599	-95.2568
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144016	1073	3	49	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,379	0	483	35	$232,296	$481	483	$232,296	$481	Mingo	561	0.17	41.9442	-91.7013
07-02-005	CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/C	146687	1131	7	37	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,340	0	469	35	$225,628	$481	469	$225,628	$481	Boundary Waters Canoe Area	589	0.16	42.5115	-92.4759
31-01-017	IPL - DUBUQUE GENERATING STATION	146403	1046	1	35	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,162	0	407	35	$195,732	$481	407	$195,732	$481	Seney	542	0.15	42.5108	-90.6533
03-03-001	IPL - LANSING GENERATING STATION	145135	1047	3	34	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	1,063	0	372	35	$178,943	$481	372	$178,943	$481	Boundary Waters Canoe Area	493	0.15	43.3378	-91.1667
70-01-011	MUSCATINE POWER & WATER	163419	1167	8	35	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	962	0	337	35	$162,062	$481	337	$162,062	$481	Mingo	491	0.14	41.3933	-91.056
31-01-017	IPL - DUBUQUE GENERATING STATION	146404	1046	5	30	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	845	0	296	35	$142,223	$481	296	$142,223	$481	Seney	542	0.11	42.5108	-90.6533
64-01-012	IPL - SUTHERLAND GENERATING STATION	145469	1077	2	31	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	744	0	260	35	$125,301	$481	260	$125,301	$481	Hercules-Glades Wilderness	591	0.09	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	145468	1077	1	31	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	723	0	253	35	$121,700	$481	253	$121,700	$481	Hercules-Glades Wilderness	591	0.09	42.0469	-92.8627
57-01-040	IPL - SIXTH STREET GENERATING STATION	143628	1058	4	19	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	625	0	219	35	$105,322	$481	219	$105,322	$481	Mingo	565	0.08	41.9839	-91.6687
03-03-001	IPL - LANSING GENERATING STATION	145133	1047	1	16	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	615	0	215	35	$103,554	$481	215	$103,554	$481	Boundary Waters Canoe Area	493	0.09	43.3378	-91.1667
57-01-040	IPL - SIXTH STREET GENERATING STATION	143616	1058	2	19	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	546	0	191	35	$91,865	$481	191	$91,865	$481	Mingo	565	0.07	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143627	1058	3	19	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	546	0	191	35	$91,865	$481	191	$91,865	$481	Mingo	565	0.07	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143629	1058	5	19	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	546	0	191	35	$91,865	$481	191	$91,865	$481	Mingo	565	0.07	41.9839	-91.6687
03-03-001	IPL - LANSING GENERATING STATION	145134	1047	2	11	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	514	0	180	35	$86,534	$481	180	$86,534	$481	Boundary Waters Canoe Area	493	0.07	43.3378	-91.1667
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172726	1081	7	2	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	75	0	26	35	$12,550	$481	26	$12,550	$481	Mingo	502	0.01	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172727	1081	8	2	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	75	0	26	35	$12,550	$481	26	$12,550	$481	Mingo	502	0.01	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172725	1081	6	1	4911	Electric Services	Utility Boilers - Coal-Fired	Coal Washing	62	0	22	35	$10,457	$481	22	$10,457	$481	Mingo	502	0.01	41.5401	-90.4478
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100125	1218	1	25	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	5,004	0	4,504	90	$5,854,468	$1,300	2,752	$5,011,739	$1,821	Mingo	495	1.82	41.4587	-90.8224
97-04-011	MIDAMERICAN ENERGY CO. - GEORGE NEAL SOU	147140	7343	4	624	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	15,839	0	14,255	90	$35,558,570	$2,494	14,255	$35,558,570	$2,494	Badlands	490	5.82	42.3035	-96.3581
70-01-004	GRAIN PROCESSING CORPORATION	150847	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	1,336	0	1,203	90	$3,197,016	$2,658	1,203	$3,197,016	$2,658	Mingo	491	0.49	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	150849	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	1,336	0	1,203	90	$3,197,016	$2,658	1,203	$3,197,016	$2,658	Mingo	491	0.49	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	150851	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	1,164	0	1,048	90	$2,785,192	$2,658	1,048	$2,785,192	$2,658	Mingo	491	0.43	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	150853	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	1,164	0	1,048	90	$2,785,192	$2,658	1,048	$2,785,192	$2,658	Mingo	491	0.43	41.3997	-91.0605
31-01-009	JOHN DEERE - DUBUQUE WORKS	129074	0	0	0	3531	Construction Machinery and Equipment	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	765	0	689	90	$1,831,056	$2,658	689	$1,831,056	$2,658	Seney	540	0.26	42.5648	-90.6932
68-09-001	CARGILL, INC. - EDDYVILLE	146940	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	614	0	553	90	$1,469,765	$2,658	553	$1,469,765	$2,658	Hercules-Glades Wilderness	491	0.23	41.1409	-92.6461
68-09-001	CARGILL, INC. - EDDYVILLE	146941	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	614	0	553	90	$1,469,765	$2,658	553	$1,469,765	$2,658	Hercules-Glades Wilderness	491	0.23	41.1409	-92.6461
68-09-001	CARGILL, INC. - EDDYVILLE	146942	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	614	0	553	90	$1,469,765	$2,658	553	$1,469,765	$2,658	Hercules-Glades Wilderness	491	0.23	41.1409	-92.6461
70-01-008	MONSANTO COMPANY - MUSCATINE 3670/6908/6	165088	0	0	0	2879	Pesticides and Agricultural Chemicals, NEC	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	427	0	384	90	$1,020,467	$2,658	384	$1,020,467	$2,658	Mingo	487	0.16	41.354	-91.0887
31-01-009	JOHN DEERE - DUBUQUE WORKS	129070	0	0	0	3531	Construction Machinery and Equipment	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	397	0	357	90	$948,557	$2,658	357	$948,557	$2,658	Seney	540	0.13	42.5648	-90.6932
31-01-009	JOHN DEERE - DUBUQUE WORKS	129049	0	0	0	3531	Construction Machinery and Equipment	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	356	0	320	90	$851,817	$2,658	320	$851,817	$2,658	Seney	540	0.12	42.5648	-90.6932
31-01-009	JOHN DEERE - DUBUQUE WORKS	129060	0	0	0	3531	Construction Machinery and Equipment	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	234	0	211	90	$560,282	$2,658	211	$560,282	$2,658	Seney	540	0.08	42.5648	-90.6932
82-01-018	KRAFT FOODS, INC. - DAVENPORT	146828	0	0	0	2013	Sausages and Other Prepared Meats	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	204	0	183	90	$487,122	$2,658	183	$487,122	$2,658	Mingo	500	0.07	41.5208	-90.5934
99-01-001	AG PROCESSING, INC. - EAGLE GROVE	143567	0	0	0	2075	Soybean Oil Mills	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	145	0	130	90	$345,695	$2,658	130	$345,695	$2,658	Boundary Waters Canoe Area	594	0.04	42.6756	-93.9031
99-01-001	AG PROCESSING, INC. - EAGLE GROVE	143568	0	0	0	2075	Soybean Oil Mills	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	145	0	130	90	$345,695	$2,658	130	$345,695	$2,658	Boundary Waters Canoe Area	594	0.04	42.6756	-93.9031
82-01-018	KRAFT FOODS, INC. - DAVENPORT	146827	0	0	0	2013	Sausages and Other Prepared Meats	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	115	0	104	90	$275,208	$2,658	104	$275,208	$2,658	Mingo	500	0.04	41.5208	-90.5934
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148766	1091	2	300	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	12,711	0	11,440	90	$20,886,351	$1,826	6,991	$18,745,889	$2,681	Badlands	488	4.69	42.3252	-96.3792
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148765	1091	1	135	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	7,800	0	7,020	90	$13,365,237	$1,904	4,290	$12,051,760	$2,809	Badlands	488	2.88	42.3252	-96.3792
58-07-001	MIDAMERICAN ENERGY CO. - LOUISA STATION	147281	6664	101	644	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	14,405	0	12,964	90	$36,698,267	$2,831	12,964	$36,698,267	$2,831	Mingo	483	5.37	41.3169	-91.0936
70-01-004	GRAIN PROCESSING CORPORATION	150856	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	IDIS	2,562	0	1,025	40	$2,908,257	$2,838	1,025	$2,908,257	$2,838	Mingo	491	0.42	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	150859	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	IDIS	2,562	0	1,025	40	$2,908,257	$2,838	1,025	$2,908,257	$2,838	Mingo	491	0.42	41.3997	-91.0605
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	143798	1082	3	637	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	13,490	0	12,141	90	$36,299,373	$2,990	12,141	$36,299,373	$2,990	Hercules-Glades Wilderness	554	4.38	41.1792	-95.8406
90-07-001	IPL - OTTUMWA GENERATING STATION	143977	6254	1	714	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	17,659	0	15,894	90	$40,687,209	$2,560	9,713	$37,713,446	$3,883	Hercules-Glades Wilderness	487	6.53	41.0987	-92.5616
70-01-004	GRAIN PROCESSING CORPORATION	150856	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	FGD	2,562	0	2,305	90	$9,068,406	$3,934	1,281	$6,160,149	$4,810	Mingo	491	0.94	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	150859	0	0	0	2046	Wet Corn Milling	Bituminous/Subbituminous Coal (Industrial Boilers)	FGD	2,562	0	2,305	90	$9,068,406	$3,934	1,281	$6,160,149	$4,810	Mingo	491	0.94	41.3997	-91.0605
29-01-013	IPL - BURLINGTON GENERATING STATION	145381	1104	1	211	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	5,982	0	5,384	90	$17,059,783	$3,169	3,290	$16,052,438	$4,879	Mingo	422	2.55	40.7547	-91.1237
03-03-001	IPL - LANSING GENERATING STATION	145136	1047	4	260	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	6,585	0	5,926	90	$19,213,055	$3,242	3,622	$18,104,206	$4,999	Boundary Waters Canoe Area	493	2.40	43.3378	-91.1667
23-01-014	IPL - M.L. KAPP GENERATING STATION	144559	1048	2	217	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	5,596	0	5,036	90	$17,331,069	$3,441	3,078	$16,388,777	$5,325	Mingo	531	1.90	41.8133	-90.2322
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144096	1073	4	142	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	4,170	0	3,753	90	$13,730,673	$3,658	2,294	$13,028,409	$5,680	Mingo	561	1.34	41.9442	-91.7013
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	143797	1082	2	88	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	2,075	0	1,867	90	$10,701,289	$5,731	1,867	$10,701,289	$5,731	Hercules-Glades Wilderness	554	0.67	41.1792	-95.8406
14-02-003	AG PROCESSING INC A COOPERATIVE - MANNIN	142146	0	0	0	2075	Soybean Oil Mills	Residual Oil (Industrial Boilers)	Wet FGD	76	0	69	90	$419,247	$6,094	69	$419,247	$6,094	Badlands	604	0.02	41.9198	-95.0699
17-01-027	AG PROCESSING, INC. - MASON CITY	151524	0	0	0	2075	Soybean Oil Mills	Residual Oil (Industrial Boilers)	Wet FGD	62	0	56	90	$340,106	$6,094	56	$340,106	$6,094	Boundary Waters Canoe Area	532	0.02	43.1332	-93.2261
77-01-022	FIRESTONE AG TIRE COMPANY	149388	0	0	0	3011	Tires and Inner Tubes	Residual Oil (Industrial Boilers)	Wet FGD	33	0	30	90	$182,545	$6,094	30	$182,545	$6,094	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	143796	1082	1	43	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,262	0	1,136	90	$7,532,964	$6,633	1,136	$7,532,964	$6,633	Hercules-Glades Wilderness	554	0.41	41.1792	-95.8406
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	149233	0	0	0	8221	Colleges, Universities, and Professional Schoo	Bituminous/Subbituminous Coal (Commercial/Institutional Boilers)	FGD	931	0	838	90	$6,215,071	$7,414	838	$6,215,071	$7,414	Hercules-Glades Wilderness	593	0.28	42.0275	-93.6391
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172728	1081	9	130	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	3,061	0	2,755	90	$13,100,122	$4,756	1,683	$12,584,740	$7,476	Mingo	502	1.10	41.5401	-90.4478
17-01-009	HOLCIM (US) INC. - MASON CITY	39	0	0	0	3241	Cement, Hydraulic	Mineral Products Industry	FGD	3,521	0	1,760	50	$13,925,864	$7,911	1,760	$13,925,864	$7,911	Boundary Waters Canoe Area	527	0.67	43.173	-93.2018
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100127	1218	2	38	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,503	0	1,353	90	$7,105,814	$5,252	827	$6,852,649	$8,287	Mingo	495	0.55	41.4587	-90.8224
21-01-003	CORNBELT POWER - WISDOM GENERATING STATI	154485	1217	1	38	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,445	0	1,301	90	$7,105,814	$5,462	795	$6,862,409	$8,632	Badlands	552	0.47	43.1599	-95.2568
52-01-005	UNIVERSITY OF IOWA MAIN POWER PLANT/MAIN	06	0	0	0	8221	Colleges, Universities, and Professional Schoo	Bituminous/Subbituminous Coal (Commercial/Institutional Boilers)	FGD	1,535	0	1,381	90	$12,080,267	$8,747	1,381	$12,080,267	$8,747	Mingo	528	0.52	41.663	-91.5357
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	149231	0	0	0	8221	Colleges, Universities, and Professional Schoo	Bituminous/Subbituminous Coal (Commercial/Institutional Boilers)	FGD	769	0	692	90	$6,215,071	$8,980	692	$6,215,071	$8,980	Hercules-Glades Wilderness	593	0.23	42.0275	-93.6391
07-02-005	CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/C	146687	1131	7	37	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,340	0	1,206	90	$7,017,413	$5,819	737	$6,791,785	$9,216	Boundary Waters Canoe Area	589	0.41	42.5115	-92.4759
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144016	1073	3	49	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,379	0	1,242	90	$8,017,482	$6,458	759	$7,785,186	$10,261	Mingo	561	0.44	41.9442	-91.7013
31-01-017	IPL - DUBUQUE GENERATING STATION	146403	1046	1	35	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,162	0	1,046	90	$6,837,299	$6,536	639	$6,641,567	$10,389	Seney	542	0.39	42.5108	-90.6533
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	151090	1122	8	65	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	968	0	871	90	$9,197,712	$10,560	871	$9,197,712	$10,560	Hercules-Glades Wilderness	592	0.29	42.0245	-93.6112
64-01-012	IPL - SUTHERLAND GENERATING STATION	145470	1077	3	80	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,625	0	1,462	90	$10,198,414	$6,975	894	$9,924,842	$11,108	Hercules-Glades Wilderness	591	0.49	42.0469	-92.8627
63-02-005	PELLA MUNICIPAL POWER PLANT	148087	1175	6	15	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	465	0	418	90	$4,670,378	$11,165	418	$4,670,378	$11,165	Hercules-Glades Wilderness	519	0.16	41.3981	-92.9129
03-03-001	IPL - LANSING GENERATING STATION	145135	1047	3	34	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	1,063	0	956	90	$6,745,482	$7,053	584	$6,566,539	$11,235	Boundary Waters Canoe Area	493	0.39	43.3378	-91.1667
17-01-009	HOLCIM (US) INC. - MASON CITY	42	0	0	0	3241	Cement, Hydraulic	Mineral Products Industry	FGD	2,420	0	1,210	50	$13,925,864	$11,511	1,210	$13,925,864	$11,511	Boundary Waters Canoe Area	527	0.46	43.173	-93.2018
63-02-005	PELLA MUNICIPAL POWER PLANT	148088	1175	7	13	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	397	0	357	90	$4,354,665	$12,200	357	$4,354,665	$12,200	Hercules-Glades Wilderness	519	0.14	41.3981	-92.9129
70-01-011	MUSCATINE POWER & WATER	163419	1167	8	35	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	962	0	866	90	$6,837,299	$7,894	529	$6,675,237	$12,611	Mingo	491	0.35	41.3933	-91.056
31-01-017	IPL - DUBUQUE GENERATING STATION	146404	1046	5	30	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	845	0	760	90	$6,365,108	$8,374	465	$6,222,885	$13,396	Seney	542	0.28	42.5108	-90.6533
03-03-001	IPL - LANSING GENERATING STATION	145133	1047	1	16	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	615	0	553	90	$4,751,599	$8,585	338	$4,648,045	$13,743	Boundary Waters Canoe Area	493	0.22	43.3378	-91.1667
03-03-001	IPL - LANSING GENERATING STATION	145134	1047	2	11	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	514	0	462	90	$4,063,138	$8,785	283	$3,976,604	$14,070	Boundary Waters Canoe Area	493	0.19	43.3378	-91.1667
57-01-040	IPL - SIXTH STREET GENERATING STATION	143628	1058	4	19	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	625	0	563	90	$5,206,953	$9,250	344	$5,101,631	$14,830	Mingo	565	0.20	41.9839	-91.6687
64-01-012	IPL - SUTHERLAND GENERATING STATION	145469	1077	2	31	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	744	0	670	90	$6,462,300	$9,650	409	$6,336,999	$15,484	Hercules-Glades Wilderness	591	0.23	42.0469	-92.8627
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	151091	1122	7	30	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	452	0	407	90	$6,365,108	$15,640	407	$6,365,108	$15,640	Hercules-Glades Wilderness	592	0.14	42.0245	-93.6112
64-01-012	IPL - SUTHERLAND GENERATING STATION	145468	1077	1	31	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	723	0	650	90	$6,462,300	$9,935	397	$6,340,600	$15,952	Hercules-Glades Wilderness	591	0.22	42.0469	-92.8627
57-01-040	IPL - SIXTH STREET GENERATING STATION	143616	1058	2	19	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	546	0	491	90	$5,171,719	$10,533	300	$5,079,854	$16,930	Mingo	565	0.17	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143627	1058	3	19	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	546	0	491	90	$5,171,719	$10,533	300	$5,079,854	$16,930	Mingo	565	0.17	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143629	1058	5	19	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	546	0	491	90	$5,171,719	$10,533	300	$5,079,854	$16,930	Mingo	565	0.17	41.9839	-91.6687
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172726	1081	7	2	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	75	0	67	90	$1,875,336	$27,960	41	$1,862,786	$45,447	Mingo	502	0.03	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172727	1081	8	2	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	75	0	67	90	$1,875,336	$27,960	41	$1,862,786	$45,447	Mingo	502	0.03	41.5401	-90.4478
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	149237	0	0	0	8221	Colleges, Universities, and Professional Schoo	Bituminous/Subbituminous Coal (Commercial/Institutional Boilers)	FGD	144	0	129	90	$6,215,071	$48,050	129	$6,215,071	$48,050	Hercules-Glades Wilderness	593	0.04	42.0275	-93.6391
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172725	1081	6	1	4911	Electric Services	Utility Boilers - Medium Sulfur Content	FGD Wet Scr	62	0	56	90	$1,741,369	$31,156	34	$1,730,912	$50,677	Mingo	502	0.02	41.5401	-90.4478
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100125	1218	1	25	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	5,004	0	4,954	99	$49,411,032	$9,973	450	$43,556,564	$96,706	Mingo	495	2.00	41.4587	-90.8224
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148766	1091	2	300	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	12,711	0	12,584	99	$146,538,607	$11,645	1,144	$125,652,256	$109,837	Badlands	488	5.16	42.3252	-96.3792
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	148765	1091	1	135	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	7,800	0	7,722	99	$101,812,263	$13,185	702	$88,447,026	$125,993	Badlands	488	3.17	42.3252	-96.3792
90-07-001	IPL - OTTUMWA GENERATING STATION	143977	6254	1	714	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	17,659	0	17,483	99	$267,211,983	$15,284	1,589	$226,524,774	$142,527	Hercules-Glades Wilderness	487	7.18	41.0987	-92.5616
70-03-003	NORTH STAR STEEL COMPANY	138282	0	0	0	3312	Steel Works, Blast Furnaces (Including Coke C	Primary Metals Industry	Sulfuric Acid F	102	0	71	70	$13,167,401	$184,803	71	$13,167,401	$184,803	Mingo	512	0.03	41.5902	-91.0382
03-03-001	IPL - LANSING GENERATING STATION	145136	1047	4	260	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	6,585	0	6,519	99	$137,061,810	$21,025	593	$117,848,755	$198,856	Boundary Waters Canoe Area	493	2.64	43.3378	-91.1667
29-01-013	IPL - BURLINGTON GENERATING STATION	145381	1104	1	211	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	5,982	0	5,922	99	$124,501,491	$21,023	538	$107,441,708	$199,563	Mingo	422	2.81	40.7547	-91.1237
70-01-011	MUSCATINE POWER & WATER	163415	1167	9	147	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	547	90	492	99	$105,749,971	$214,978	492	$105,749,971	$214,978	Mingo	491	0.20	41.3933	-91.056
23-01-014	IPL - M.L. KAPP GENERATING STATION	144559	1048	2	217	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	5,596	0	5,540	99	$126,108,388	$22,764	504	$108,777,319	$215,992	Mingo	531	2.09	41.8133	-90.2322

Plant ID	Plant Name	Point ID	ORIS ID	BLRID	NETDC (MW)	SIC	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case SO2 -- Tons	2018 Base Case SO2-- CE (%)	Controls -- Tons Reduced	Controls -- CE (%)	Controls -- Annualized Cost ($2005)	Controls -- Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(SO2 Tons Reduced) / 5d	Latitude	Longitude
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144096	1073	4	142	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	4,170	0	4,129	99	$104,129,458	$25,221	375	$90,398,785	$240,851	Mingo	561	1.47	41.9442	-91.7013
71-01-001	AG PROCESSING, INC. - SHELDON	146725	0	0	0	2075	Soybean Oil Mills	Residual Oil (Commercial/Institutional Boilers)	FGD	22	0	20	90	$4,928,072	$250,487	20	$4,928,072	$250,487	Badlands	504	0.01	43.1824	-95.8575
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172728	1081	9	130	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	3,061	0	3,030	99	$100,120,156	$33,043	275	$87,020,034	$315,920	Mingo	502	1.21	41.5401	-90.4478
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	100127	1218	2	38	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,503	0	1,488	99	$58,892,573	$39,568	135	$51,786,759	$382,735	Mingo	495	0.60	41.4587	-90.8224
21-01-003	CORNBELT POWER - WISDOM GENERATING STATI	154485	1217	1	38	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,445	0	1,431	99	$58,892,573	$41,155	130	$51,786,759	$398,084	Badlands	552	0.52	43.1599	-95.2568
07-02-005	CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/C	146687	1131	7	37	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,340	0	1,326	99	$58,234,277	$43,902	121	$51,216,864	$424,726	Boundary Waters Canoe Area	589	0.45	42.5115	-92.4759
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	144016	1073	3	49	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,379	0	1,366	99	$65,584,777	$48,024	124	$57,567,295	$463,684	Mingo	561	0.49	41.9442	-91.7013
31-01-017	IPL - DUBUQUE GENERATING STATION	146403	1046	1	35	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,162	0	1,151	99	$56,887,697	$49,437	105	$50,050,398	$478,448	Seney	542	0.42	42.5108	-90.6533
64-01-012	IPL - SUTHERLAND GENERATING STATION	145470	1077	3	80	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,625	0	1,608	99	$80,933,458	$50,321	146	$70,735,044	$483,781	Hercules-Glades Wilderness	591	0.54	42.0469	-92.8627
03-03-001	IPL - LANSING GENERATING STATION	145135	1047	3	34	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	1,063	0	1,052	99	$56,198,498	$53,420	96	$49,453,016	$517,085	Boundary Waters Canoe Area	493	0.43	43.3378	-91.1667
70-01-011	MUSCATINE POWER & WATER	163419	1167	8	35	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	962	0	953	99	$56,887,697	$59,708	87	$50,050,398	$577,842	Mingo	491	0.39	41.3933	-91.056
31-01-017	IPL - DUBUQUE GENERATING STATION	146404	1046	5	30	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	845	0	836	99	$53,323,194	$63,774	76	$46,958,086	$617,772	Seney	542	0.31	42.5108	-90.6533
03-03-001	IPL - LANSING GENERATING STATION	145133	1047	1	16	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	615	0	609	99	$40,748,861	$66,933	55	$35,997,262	$650,404	Boundary Waters Canoe Area	493	0.25	43.3378	-91.1667
03-03-001	IPL - LANSING GENERATING STATION	145134	1047	2	11	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	514	0	509	99	$35,187,929	$69,167	46	$31,124,791	$672,983	Boundary Waters Canoe Area	493	0.21	43.3378	-91.1667
57-01-040	IPL - SIXTH STREET GENERATING STATION	143628	1058	4	19	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	625	0	619	99	$44,361,360	$71,644	56	$39,154,407	$695,571	Mingo	565	0.22	41.9839	-91.6687
64-01-012	IPL - SUTHERLAND GENERATING STATION	145469	1077	2	31	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	744	0	737	99	$54,060,994	$73,388	67	$47,598,694	$710,768	Hercules-Glades Wilderness	591	0.25	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	145468	1077	1	31	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	723	0	715	99	$54,060,994	$75,559	65	$47,598,694	$731,803	Hercules-Glades Wilderness	591	0.24	42.0469	-92.8627
57-01-040	IPL - SIXTH STREET GENERATING STATION	143616	1058	2	19	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	546	0	540	99	$44,083,669	$81,624	49	$38,911,950	$792,536	Mingo	565	0.19	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143627	1058	3	19	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	546	0	540	99	$44,083,669	$81,624	49	$38,911,950	$792,536	Mingo	565	0.19	41.9839	-91.6687
57-01-040	IPL - SIXTH STREET GENERATING STATION	143629	1058	5	19	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	546	0	540	99	$44,083,669	$81,624	49	$38,911,950	$792,536	Mingo	565	0.19	41.9839	-91.6687
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172726	1081	7	2	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	75	0	74	99	$16,708,696	$226,473	7	$14,833,360	$2,211,624	Mingo	502	0.03	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172727	1081	8	2	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	75	0	74	99	$16,708,696	$226,473	7	$14,833,360	$2,211,624	Mingo	502	0.03	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	172725	1081	6	1	4911	Electric Services	Utility Boilers - Coal-Fired	Repowering	62	0	61	99	$15,538,250	$252,728	6	$13,796,881	$2,468,136	Mingo	502	0.02	41.5401	-90.4478

Appendix 10.2 CENRAP Control Cost for NOx

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx - Tons	2018 Base Case NOx -- CE (%)	Controls - Tons Reduced	Controls - CE (%)	Controls -- Annualized Cost ($2005)	Controls - Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Coal-fired Plants with Production Capacities>100MW	Combustion Optimization	2,169	0	434	20	$29,216	$67	434	$29,216	$67	Boundary Waters Canoe Area	493	0.18	43.3378	-91.1667
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	Mid-Kiln Firing	2,575	0	772	30	$63,873	$83	772	$63,873	$83	Boundary Waters Canoe Area	527	0.29	43.173	-93.2018
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	Mid-Kiln Firing	1,784	0	535	30	$44,249	$83	535	$44,249	$83	Boundary Waters Canoe Area	527	0.20	43.173	-93.2018
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	745	5.43	193	30	$62,442	$323	193	$62,442	$323	Mingo	507	0.08	41.3571	-92.0532
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	447	5.43	116	30	$37,510	$323	116	$37,510	$323	Mingo	507	0.05	41.3571	-92.0532
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	446	5.43	116	30	$37,424	$323	116	$37,424	$323	Hercules-Glades Wilderness	528	0.04	41.0602	-95.4486
70-01-011	MUSCATINE POWER & WATER	Electric Services	Utility Boiler - Cyclone	NGR	1,373	0	686	50	$382,799	$558	686	$382,799	$558	Mingo	491	0.28	41.3933	-91.056
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	335	5.43	87	30	$50,574	$581	87	$50,574	$581	Hercules-Glades Wilderness	528	0.03	41.0602	-95.4486
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	333	5.43	86	30	$50,237	$581	86	$50,237	$581	Mingo	458	0.04	40.9047	-91.9656
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	316	5.43	82	30	$47,653	$581	82	$47,653	$581	Hercules-Glades Wilderness	528	0.03	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	295	5.43	77	30	$44,462	$581	77	$44,462	$581	Hercules-Glades Wilderness	506	0.03	41.2246	-93.7805
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	244	5.43	63	30	$36,880	$581	63	$36,880	$581	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	238	5.43	62	30	$35,946	$581	62	$35,946	$581	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	238	5.43	62	30	$35,909	$581	62	$35,909	$581	Hercules-Glades Wilderness	506	0.02	41.2246	-93.7805
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	231	5.43	60	30	$34,935	$581	60	$34,935	$581	Hercules-Glades Wilderness	506	0.02	41.2246	-93.7805
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	212	5.43	55	30	$31,953	$581	55	$31,953	$581	Mingo	479	0.02	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	203	5.43	53	30	$30,647	$581	53	$30,647	$581	Mingo	479	0.02	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	203	5.43	53	30	$30,625	$581	53	$30,625	$581	Mingo	479	0.02	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	196	5.43	51	30	$29,603	$581	51	$29,603	$581	Mingo	479	0.02	41.246	-91.3514
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	193	5.43	50	30	$29,192	$581	50	$29,192	$581	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	163	5.43	42	30	$24,640	$581	42	$24,640	$581	Hercules-Glades Wilderness	432	0.02	40.5806	-93.5181
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	132	5.43	34	30	$19,964	$581	34	$19,964	$581	Hercules-Glades Wilderness	506	0.01	41.2246	-93.7805
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	128	5.43	33	30	$19,392	$581	33	$19,392	$581	Mingo	479	0.01	41.246	-91.3514
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	117	5.43	30	30	$17,690	$581	30	$17,690	$581	Hercules-Glades Wilderness	506	0.01	41.2246	-93.7805
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	104	5.43	27	30	$15,687	$581	27	$15,687	$581	Mingo	458	0.01	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	101	5.43	26	30	$15,289	$581	26	$15,289	$581	Mingo	458	0.01	40.9047	-91.9656
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	91	5.43	24	30	$13,779	$581	24	$13,779	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	78	5.43	20	30	$11,737	$581	20	$11,737	$581	Mingo	507	0.01	41.3571	-92.0532
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	77	5.43	20	30	$11,687	$581	20	$11,687	$581	Mingo	458	0.01	40.9047	-91.9656
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	74	5.43	19	30	$11,156	$581	19	$11,156	$581	Mingo	507	0.01	41.3571	-92.0532
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	73	5.43	19	30	$11,091	$581	19	$11,091	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	71	5.43	18	30	$10,663	$581	18	$10,663	$581	Mingo	507	0.01	41.3571	-92.0532
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	70	5.43	18	30	$10,493	$581	18	$10,493	$581	Mingo	458	0.01	40.9047	-91.9656
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	68	5.43	18	30	$10,297	$581	18	$10,297	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	64	5.43	17	30	$9,615	$581	17	$9,615	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	61	5.43	16	30	$9,230	$581	16	$9,230	$581	Mingo	505	0.01	41.3682	-91.9408
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	55	5.43	14	30	$8,258	$581	14	$8,258	$581	Hercules-Glades Wilderness	528	0.01	41.0602	-95.4486
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	51	5.43	13	30	$7,767	$581	13	$7,767	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	51	5.43	13	30	$7,696	$581	13	$7,696	$581	Mingo	505	0.01	41.3682	-91.9408
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	50	5.43	13	30	$7,606	$581	13	$7,606	$581	Mingo	458	0.01	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	49	5.43	13	30	$7,453	$581	13	$7,453	$581	Mingo	458	0.01	40.9047	-91.9656
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	48	5.43	12	30	$7,201	$581	12	$7,201	$581	Mingo	479	0.01	41.246	-91.3514
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	43	5.43	11	30	$6,435	$581	11	$6,435	$581	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	39	5.43	10	30	$5,876	$581	10	$5,876	$581	Mingo	479	0.00	41.246	-91.3514
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	39	5.43	10	30	$5,861	$581	10	$5,861	$581	Mingo	505	0.00	41.3682	-91.9408
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	51	17	8	30	$4,654	$581	8	$4,654	$581	Hercules-Glades Wilderness	528	0.00	41.0602	-95.4486
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	30	5.43	8	30	$4,484	$581	8	$4,484	$581	Mingo	505	0.00	41.3682	-91.9408
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	28	5.43	7	30	$4,196	$581	7	$4,196	$581	Hercules-Glades Wilderness	432	0.00	40.5806	-93.5181
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	23	5.43	6	30	$3,421	$581	6	$3,421	$581	Mingo	458	0.00	40.9047	-91.9656
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	28	17	4	30	$2,541	$581	4	$2,541	$581	Hercules-Glades Wilderness	528	0.00	41.0602	-95.4486
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	AF + IR	14	5.43	4	30	$2,177	$581	4	$2,177	$581	Mingo	507	0.00	41.3571	-92.0532
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Internal Combustion Engines - Gas	AF + IR	11	17	2	30	$1,020	$581	2	$1,020	$581	Mingo	498	0.00	41.5006	-90.6418
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Internal Combustion Engines - Gas	AF + IR	11	17	2	30	$1,016	$581	2	$1,016	$581	Mingo	498	0.00	41.5006	-90.6418
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	514	0	334	65	$229,836	$688	334	$229,836	$688	Badlands	488	0.14	42.3301	-96.3778
94-01-005	KOCH NITROGEN COMPANY - FORT DODGE	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	699	0	454	65	$312,731	$689	454	$312,731	$689	Boundary Waters Canoe Area	615	0.15	42.5	-94.0183
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	503	0	281	55.9	$199,636	$710	281	$199,636	$710	Mingo	565	0.10	41.9839	-91.6687
97-01-118	MAGELLAN PIPELINE CO., LLC. - SIOUX CITY	Refined Petroleum Pipelines	Rich Burn IC Engines - Gas, Diesel, LPG	NSCR	21	0	19	90	$14,215	$736	19	$14,215	$736	Badlands	481	0.01	42.5582	-96.3531
97-01-118	MAGELLAN PIPELINE CO., LLC. - SIOUX CITY	Refined Petroleum Pipelines	Rich Burn IC Engines - Gas, Diesel, LPG	NSCR	17	0	15	90	$11,382	$736	15	$11,382	$736	Badlands	481	0.01	42.5582	-96.3531
97-01-118	MAGELLAN PIPELINE CO., LLC. - SIOUX CITY	Refined Petroleum Pipelines	Rich Burn IC Engines - Gas, Diesel, LPG	NSCR	15	0	13	90	$9,716	$736	13	$9,716	$736	Badlands	481	0.01	42.5582	-96.3531
63-02-004	VERMEER MANUFACTURING COMPANY	Construction Machinery and Equipment	Rich Burn IC Engines - Gas, Diesel, LPG	NSCR	14	0	13	90	$9,577	$736	13	$9,577	$736	Hercules-Glades Wilderness	521	0.00	41.4096	-92.8885
94-01-010	GEORGIA PACIFIC - FORT DODGE	Gypsum Products	Rich Burn IC Engines - Gas, Diesel, LPG	NSCR	13	0	12	90	$8,871	$736	12	$8,871	$736	Boundary Waters Canoe Area	621	0.00	42.4711	-94.1436
49-01-024	GENERAC POWER SYSTEMS, INC.	Motors and Generators	Rich Burn Internal Combustion Engines - Oil	NSCR	10	17	9	90	$6,614	$736	9	$6,614	$736	Mingo	558	0.00	42.0427	-90.6644
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	431	0	241	55.9	$199,636	$829	241	$199,636	$829	Mingo	565	0.09	41.9839	-91.6687
71-01-001	AG PROCESSING, INC. - SHELDON	Soybean Oil Mills	ICI Boilers - Residual Oil	LNB	204	0	102	50	$87,949	$861	102	$87,949	$861	Badlands	504	0.04	43.1824	-95.8575
86-01-001	TAMA PAPERBOARD	Paperboard Mills	ICI Boilers - Residual Oil	LNB	88	0	44	50	$38,046	$861	44	$38,046	$861	Hercules-Glades Wilderness	582	0.02	41.9551	-92.5815
14-02-003	AG PROCESSING INC A COOPERATIVE - MANNIN	Soybean Oil Mills	ICI Boilers - Residual Oil	LNB	45	0	22	50	$19,332	$861	22	$19,332	$861	Badlands	604	0.01	41.9198	-95.0699
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Residual Oil	LNB	29	0	15	50	$12,490	$861	15	$12,490	$861	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Residual Oil	LNB	23	0	11	50	$9,833	$861	11	$9,833	$861	Hercules-Glades Wilderness	550	0.00	41.6443	-93.6205
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	28	17	24	87	$19,252	$818	19	$16,711	$871	Hercules-Glades Wilderness	528	0.01	41.0602	-95.4486
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Internal Combustion Engines - Gas	L-E (Medium Speed)	11	17	9	87	$7,696	$818	8	$6,680	$871	Mingo	498	0.00	41.5006	-90.6418
70-01-011	MUSCATINE POWER & WATER	Electric Services	Utility Boiler - Cyclone	SCR	1,373	0	1,235	90	$861,538	$697	549	$478,739	$872	Mingo	491	0.50	41.3933	-91.056
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	51	17	43	87	$35,270	$818	35	$30,616	$872	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Internal Combustion Engines - Gas	L-E (Medium Speed)	11	17	9	87	$7,733	$818	8	$6,713	$872	Mingo	498	0.00	41.5006	-90.6418
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Rich Burn IC Engines - Gas	NSCR	745	5.43	666	90	$490,079	$736	473	$427,637	$905	Mingo	507	0.26	41.3571	-92.0532
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Rich Burn IC Engines - Gas	NSCR	447	5.43	400	90	$294,398	$736	284	$256,888	$905	Mingo	507	0.16	41.3571	-92.0532
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Rich Burn IC Engines - Gas	NSCR	446	5.43	399	90	$293,735	$736	283	$256,311	$905	Hercules-Glades Wilderness	528	0.15	41.0602	-95.4486
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	335	5.43	289	87	$236,331	$818	202	$185,757	$920	Hercules-Glades Wilderness	528	0.11	41.0602	-95.4486
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	333	5.43	287	87	$234,754	$818	201	$184,517	$920	Mingo	458	0.13	40.9047	-91.9656
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	316	5.43	272	87	$222,680	$818	190	$175,027	$920	Hercules-Glades Wilderness	528	0.10	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	295	5.43	254	87	$207,765	$818	178	$163,303	$920	Hercules-Glades Wilderness	506	0.10	41.2246	-93.7805
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	244	5.43	211	87	$172,338	$818	147	$135,458	$920	Hercules-Glades Wilderness	528	0.08	41.0602	-95.4486
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	238	5.43	205	87	$167,974	$818	144	$132,028	$920	Hercules-Glades Wilderness	528	0.08	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	238	5.43	205	87	$167,806	$818	143	$131,897	$920	Hercules-Glades Wilderness	506	0.08	41.2246	-93.7805
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	231	5.43	200	87	$163,252	$818	140	$128,317	$920	Hercules-Glades Wilderness	506	0.08	41.2246	-93.7805

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx - - Tons	2018 Base Case NOx -- CE (%)	Controls - - Tons Reduced	Controls - - CE (%)	Controls -- Annualized Cost ($2005)	Controls - - Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	212	5.43	183	87	$149,318	$818	128	$117,365	$920	Mingo	479	0.08	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	203	5.43	175	87	$143,210	$818	122	$112,563	$920	Mingo	479	0.07	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	203	5.43	175	87	$143,113	$818	122	$112,488	$920	Mingo	479	0.07	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	196	5.43	169	87	$138,339	$818	118	$108,736	$920	Mingo	479	0.07	41.246	-91.3514
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	193	5.43	167	87	$136,419	$818	117	$107,227	$920	Hercules-Glades Wilderness	528	0.06	41.0602	-95.4486
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	163	5.43	141	87	$115,143	$818	98	$90,503	$920	Hercules-Glades Wilderness	432	0.07	40.5806	-93.5181
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	132	5.43	114	87	$93,289	$818	80	$73,325	$920	Hercules-Glades Wilderness	506	0.05	41.2246	-93.7805
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	128	5.43	111	87	$90,615	$818	77	$71,223	$920	Mingo	479	0.05	41.246	-91.3514
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	117	5.43	101	87	$82,667	$818	71	$64,977	$920	Hercules-Glades Wilderness	506	0.04	41.2246	-93.7805
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	104	5.43	90	87	$73,310	$818	63	$57,623	$920	Mingo	458	0.04	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	101	5.43	87	87	$71,447	$818	61	$56,158	$920	Mingo	458	0.04	40.9047	-91.9656
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	91	5.43	79	87	$64,390	$818	55	$50,611	$920	Hercules-Glades Wilderness	432	0.04	40.5806	-93.5181
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	78	5.43	67	87	$54,845	$818	47	$43,108	$920	Mingo	507	0.03	41.3571	-92.0532
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	77	5.43	67	87	$54,619	$818	47	$42,932	$920	Mingo	458	0.03	40.9047	-91.9656
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	74	5.43	64	87	$52,130	$818	45	$40,974	$920	Mingo	507	0.03	41.3571	-92.0532
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	73	5.43	63	87	$51,831	$818	44	$40,740	$920	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	71	5.43	61	87	$49,826	$818	43	$39,163	$920	Mingo	507	0.02	41.3571	-92.0532
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	70	5.43	60	87	$49,036	$818	42	$38,543	$920	Mingo	458	0.03	40.9047	-91.9656
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	68	5.43	59	87	$48,117	$818	41	$37,820	$920	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	64	5.43	55	87	$44,935	$818	38	$35,320	$920	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	61	5.43	53	87	$43,130	$818	37	$33,900	$920	Mingo	505	0.02	41.3682	-91.9408
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	55	5.43	47	87	$38,590	$818	33	$30,332	$920	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	51	5.43	44	87	$36,295	$818	31	$28,528	$920	Hercules-Glades Wilderness	432	0.02	40.5806	-93.5181
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	51	5.43	44	87	$35,963	$818	31	$28,267	$920	Mingo	505	0.02	41.3682	-91.9408
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	50	5.43	43	87	$35,542	$818	30	$27,936	$920	Mingo	458	0.02	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	49	5.43	43	87	$34,823	$818	30	$27,370	$920	Mingo	458	0.02	40.9047	-91.9656
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	48	5.43	41	87	$33,648	$818	29	$26,447	$920	Mingo	479	0.02	41.246	-91.3514
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	43	5.43	37	87	$30,074	$818	26	$23,639	$920	Hercules-Glades Wilderness	432	0.02	40.5806	-93.5181
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	39	5.43	34	87	$27,462	$818	23	$21,586	$920	Mingo	479	0.01	41.246	-91.3514
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	39	5.43	34	87	$27,391	$818	23	$21,530	$920	Mingo	505	0.01	41.3682	-91.9408
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	30	5.43	26	87	$20,952	$818	18	$16,468	$920	Mingo	505	0.01	41.3682	-91.9408
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	28	5.43	24	87	$19,603	$818	17	$15,407	$920	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	23	5.43	20	87	$15,984	$818	14	$12,563	$920	Mingo	458	0.01	40.9047	-91.9656
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Internal Combustion Engines - Gas	L-E (Medium Speed)	14	5.43	12	87	$10,173	$818	9	$7,996	$920	Mingo	507	0.00	41.3571	-92.0532
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Cyclone	NGR	1,452	0	726	50	$672,871	$927	726	$672,871	$927	Hercules-Glades Wilderness	591	0.25	42.0469	-92.8627
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	451	0	252	55.9	$240,818	$954	252	$240,818	$954	Mingo	495	0.10	41.4587	-90.8224
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	Electric Services	Utility Boiler - Coal/Tangential - POD10	LNC1	482	0	209	43.3	$200,560	$960	209	$200,560	$960	Hercules-Glades Wilderness	554	0.08	41.1792	-95.8406
82-01-015	LINWOOD MINING & MINERAL CORPORATION	Crushed and Broken Limestone	Lime Kilns	Mid-Kiln Firing	394	0	118	30	$116,972	$990	118	$116,972	$990	Mingo	494	0.05	41.4625	-90.6836
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	349	0	195	55.9	$199,636	$1,023	195	$199,636	$1,023	Mingo	565	0.07	41.9839	-91.6687
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	506	0	283	55.9	$297,502	$1,052	283	$297,502	$1,052	Boundary Waters Canoe Area	493	0.11	43.3378	-91.1667
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	321	0	219	68	$230,367	$1,054	219	$230,367	$1,054	Boundary Waters Canoe Area	538	0.08	43.0816	-93.2607
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	321	0	219	68	$230,367	$1,054	219	$230,367	$1,054	Boundary Waters Canoe Area	538	0.08	43.0816	-93.2607
28-01-026	ALLIANCE PIPELINE L.P. - MANCHESTER	Natural Gas Transmission	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	46	0	32	68	$33,216	$1,054	32	$33,216	$1,054	Seney	589	0.01	42.4721	-91.4663
58-04-002	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	39	0	27	68	$28,119	$1,054	27	$28,119	$1,054	Mingo	491	0.01	41.3805	-91.1929
ORIS1123	ANITA	Electric Services	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	27	0	19	68	$19,609	$1,054	19	$19,609	$1,054	Hercules-Glades Wilderness	540	0.01	41.3312	-94.9274
85-01-017	USDA, NATIONAL ANIMAL DISEASE CENTER	Noncommercial Research Organizations	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	20	0	14	68	$14,542	$1,054	14	$14,542	$1,054	Hercules-Glades Wilderness	594	0.00	42.0495	-93.5796
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	17	0	12	68	$12,126	$1,054	12	$12,126	$1,054	Mingo	520	0.00	41.6153	-91.4092
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	Dry Low NOx Combustor	12	0	8	68	$8,634	$1,054	8	$8,634	$1,054	Mingo	520	0.00	41.6153	-91.4092
07-02-005	CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/C	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	501	0	280	55.9	$315,385	$1,126	280	$315,385	$1,126	Boundary Waters Canoe Area	589	0.10	42.5115	-92.4759
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	Nitric Acid Manufacturing	SNCR	129	0	127	98	$149,806	$1,183	127	$149,806	$1,183	Badlands	488	0.05	42.3301	-96.3778
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	Nitric Acid Manufacturing	SNCR	82	0	80	98	$94,537	$1,183	80	$94,537	$1,183	Badlands	488	0.03	42.3301	-96.3778
94-01-005	KOCH NITROGEN COMPANY - FORT DODGE	Nitrogenous Fertilizers	Nitric Acid Manufacturing	SNCR	66	0	65	98	$76,658	$1,183	65	$76,658	$1,183	Boundary Waters Canoe Area	615	0.02	42.5	-94.0183
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	260	0	146	55.9	$175,412	$1,205	146	$175,412	$1,205	Boundary Waters Canoe Area	493	0.06	43.3378	-91.1667
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Sec Alum Prod; Smelting Furn	LNB	19	0	10	50	$11,724	$1,226	10	$11,724	$1,226	Mingo	498	0.00	41.5006	-90.6418
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Sec Alum Prod; Smelting Furn	LNB	17	0	8	50	$10,181	$1,226	8	$10,181	$1,226	Mingo	498	0.00	41.5006	-90.6418
07-01-077	JOHN DEERE - WATERLOO WORKS	Farm Machinery and Equipment	Fuel Fired Equip; Furnaces; Natural Gas	LNB	12	0	6	50	$7,522	$1,226	6	$7,522	$1,226	Boundary Waters Canoe Area	589	0.00	42.5012	-92.3526
82-01-017	NICHOLS ALUMINUM - DAVENPORT	Aluminum Sheet, Plate, and Foil	Fuel Fired Equip; Furnaces; Natural Gas	LNB	11	0	5	50	$6,599	$1,226	5	$6,599	$1,226	Mingo	499	0.00	41.512	-90.6236
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	Sec Alum Prod; Smelting Furn	LNB	15	0	7	50	$8,912	$1,227	7	$8,912	$1,227	Mingo	498	0.00	41.5006	-90.6418
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	285	0	159	55.9	$201,709	$1,265	159	$201,709	$1,265	Mingo	565	0.06	41.9839	-91.6687
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	181	0	101	55.9	$137,804	$1,363	101	$137,804	$1,363	Boundary Waters Canoe Area	493	0.04	43.3378	-91.1667
97-04-010	MIDAMERICAN ENERGY CO. - GEORGE NEAL NOR	Electric Services	Utility Boiler - Coal/Wall	SCR	4,673	50	3,739	90	$5,252,502	$1,405	3,739	$5,252,502	$1,405	Badlands	488	1.53	42.3252	-96.3792
31-01-017	IPL - DUBUQUE GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	382	0	214	55.9	$303,511	$1,421	214	$303,511	$1,421	Seney	542	0.08	42.5108	-90.6533
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	443	0	245	55.3	$349,959	$1,429	245	$349,959	$1,429	Hercules-Glades Wilderness	554	0.09	41.1792	-95.8406
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	OT + WI	234	0	152	65	$222,404	$1,463	152	$222,404	$1,463	Mingo	531	0.06	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	OT + WI	208	0	135	65	$197,786	$1,463	135	$197,786	$1,463	Mingo	531	0.05	41.8111	-90.2897
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	115	0	75	65	$109,602	$1,463	75	$109,602	$1,463	Mingo	532	0.03	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	115	0	75	65	$109,514	$1,463	75	$109,514	$1,463	Mingo	532	0.03	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	98	0	64	65	$93,158	$1,463	64	$93,158	$1,463	Mingo	532	0.02	41.8185	-90.2156
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	92	0	60	65	$87,792	$1,463	60	$87,792	$1,463	Hercules-Glades Wilderness	504	0.02	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	92	0	60	65	$87,792	$1,463	60	$87,792	$1,463	Hercules-Glades Wilderness	504	0.02	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	92	0	60	65	$87,792	$1,463	60	$87,792	$1,463	Hercules-Glades Wilderness	504	0.02	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	OT + WI	92	0	60	65	$87,792	$1,463	60	$87,792	$1,463	Hercules-Glades Wilderness	504	0.02	41.1167	-94.3549
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	72	0	47	65	$68,402	$1,463	47	$68,402	$1,463	Mingo	532	0.02	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	72	0	47	65	$68,402	$1,463	47	$68,402	$1,463	Mingo	532	0.02	41.8185	-90.2156
74-01-012	AG PROCESSING, INC. - EMMETSBURG	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	43	0	28	65	$41,105	$1,463	28	$41,105	$1,463	Boundary Waters Canoe Area	565	0.01	43.0994	-94.6532
97-01-001	CARGILL, INC. - SIOUX CITY	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	42	0	27	65	$40,000	$1,463	27	$40,000	$1,463	Badlands	480	0.01	42.5008	-96.3914
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	39	0	25	65	$37,297	$1,463	25	$37,297	$1,463	Mingo	491	0.01	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	38	0	25	65	$36,301	$1,463	25	$36,301	$1,463	Mingo	491	0.01	41.3997	-91.0605
29-06-001	UNITED STATES GYPSUM CO. - SPERRY	Gypsum Products	ICI Boilers - Natural Gas	OT + WI	38	0	25	65	$36,114	$1,463	25	$36,114	$1,463	Mingo	448	0.01	40.9846	-91.1897
14-02-003	AG PROCESSING INC A COOPERATIVE - MANNIN	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	38	0	24	65	$35,789	$1,463	24	$35,789	$1,463	Badlands	604	0.01	41.9198	-95.0699
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	35	0	23	65	$33,642	$1,463	23	$33,642	$1,463	Mingo	491	0.01	41.3997	-91.0605
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	35	0	23	65	$32,951	$1,463	23	$32,951	$1,463	Hercules-Glades Wilderness	491	0.01	41.1409	-92.6461
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	34	0	22	65	$31,914	$1,463	22	$31,914	$1,463	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	34	0	22	65	$31,914	$1,463	22	$31,914	$1,463	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	34	0	22	65	$31,914	$1,463	22	$31,914	$1,463	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx - Tons	2018 Base Case NOx -- CE (%)	Controls - Tons Reduced	Controls - CE (%)	Controls -- Annualized Cost ($2005)	Controls - Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	34	0	22	65	$31,914	$1,463	22	$31,914	$1,463	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	OT + WI	31	0	20	65	$29,661	$1,463	20	$29,661	$1,463	Hercules-Glades Wilderness	555	0.01	41.7175	-93.0432
77-01-010	CARGILL, INC. - DES MOINES	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	31	0	20	65	$29,182	$1,463	20	$29,182	$1,463	Hercules-Glades Wilderness	542	0.01	41.574	-93.5577
78-01-085	BUNGE NORTH AMERICA, INC. - BUNGE AVENUE	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	29	0	19	65	$27,516	$1,463	19	$27,516	$1,463	Hercules-Glades Wilderness	551	0.01	41.1541	-95.8081
78-01-085	BUNGE NORTH AMERICA, INC. - BUNGE AVENUE	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	27	0	18	65	$25,905	$1,463	18	$25,905	$1,463	Hercules-Glades Wilderness	551	0.01	41.1541	-95.8081
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	25	0	17	65	$24,164	$1,463	17	$24,164	$1,463	Mingo	491	0.01	41.3997	-91.0605
77-01-003	TITAN TIRE CORPORATION	Tires and Inner Tubes	ICI Boilers - Natural Gas	OT + WI	23	0	15	65	$22,041	$1,463	15	$22,041	$1,463	Hercules-Glades Wilderness	543	0.01	41.5866	-93.5715
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	23	0	15	65	$21,993	$1,463	15	$21,993	$1,463	Mingo	491	0.01	41.3997	-91.0605
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Natural Gas	OT + WI	23	0	15	65	$21,668	$1,463	15	$21,668	$1,463	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
77-01-045	ADM - DES MOINES SOYBEAN	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	22	0	14	65	$21,122	$1,463	14	$21,122	$1,463	Hercules-Glades Wilderness	548	0.01	41.6244	-93.6175
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	OT + WI	22	0	14	65	$20,902	$1,463	14	$20,902	$1,463	Hercules-Glades Wilderness	555	0.01	41.7175	-93.0432
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	20	0	13	65	$18,820	$1,463	13	$18,820	$1,463	Hercules-Glades Wilderness	491	0.01	41.1409	-92.6461
57-01-095	PMX INDUSTRIES, INC.	Rolling, Drawing, and Extruding of Copper	ICI Boilers - Natural Gas	OT + WI	19	0	12	65	$17,944	$1,463	12	$17,944	$1,463	Mingo	559	0.00	41.9289	-91.6863
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	19	0	12	65	$17,645	$1,463	12	$17,645	$1,463	Hercules-Glades Wilderness	491	0.00	41.1409	-92.6461
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	OT + WI	18	0	12	65	$17,488	$1,463	12	$17,488	$1,463	Mingo	502	0.00	41.5415	-90.4632
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Natural Gas	OT + WI	17	0	11	65	$16,257	$1,463	11	$16,257	$1,463	Hercules-Glades Wilderness	550	0.00	41.6443	-93.6205
57-01-080	ADM CORN PROCESSING - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	17	0	11	65	$15,775	$1,463	11	$15,775	$1,463	Mingo	559	0.00	41.9245	-91.6874
57-01-080	ADM CORN PROCESSING - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	17	0	11	65	$15,775	$1,463	11	$15,775	$1,463	Mingo	559	0.00	41.9245	-91.6874
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	OT + WI	16	0	11	65	$15,530	$1,463	11	$15,530	$1,463	Mingo	502	0.00	41.5415	-90.4632
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	ICI Boilers - Natural Gas	OT + WI	16	0	10	65	$15,171	$1,463	10	$15,171	$1,463	Badlands	488	0.00	42.3301	-96.3778
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	OT + WI	16	0	10	65	$15,082	$1,463	10	$15,082	$1,463	Hercules-Glades Wilderness	555	0.00	41.7175	-93.0432
29-06-001	UNITED STATES GYPSUM CO. - SPERRY	Gypsum Products	ICI Boilers - Natural Gas	OT + WI	15	0	10	65	$14,534	$1,463	10	$14,534	$1,463	Mingo	448	0.00	40.9846	-91.1897
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	ICI Boilers - Natural Gas	OT + WI	15	0	10	65	$13,921	$1,463	10	$13,921	$1,463	Badlands	488	0.00	42.3301	-96.3778
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	OT + WI	14	0	9	65	$13,497	$1,463	9	$13,497	$1,463	Mingo	502	0.00	41.5415	-90.4632
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	14	0	9	65	$13,445	$1,463	9	$13,445	$1,463	Hercules-Glades Wilderness	487	0.00	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	OT + WI	14	0	9	65	$13,445	$1,463	9	$13,445	$1,463	Hercules-Glades Wilderness	487	0.00	41.1024	-92.6547
77-01-003	TITAN TIRE CORPORATION	Tires and Inner Tubes	ICI Boilers - Natural Gas	OT + WI	14	0	9	65	$13,327	$1,463	9	$13,327	$1,463	Hercules-Glades Wilderness	543	0.00	41.5866	-93.5715
42-01-003	CARGILL, INC. - IOWA FALLS	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	13	0	9	65	$12,511	$1,463	9	$12,511	$1,463	Boundary Waters Canoe Area	600	0.00	42.5087	-93.2689
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	OT + WI	13	0	8	65	$12,266	$1,463	8	$12,266	$1,463	Hercules-Glades Wilderness	555	0.00	41.7175	-93.0432
57-01-025	PENFORD PRODUCTS CO.	Wet Corn Milling	ICI Boilers - Natural Gas	OT + WI	12	0	8	65	$11,083	$1,463	8	$11,083	$1,463	Mingo	563	0.00	41.9699	-91.6676
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	Electric Services	ICI Boilers - Natural Gas	OT + WI	11	0	7	65	$10,508	$1,463	7	$10,508	$1,463	Mingo	561	0.00	41.9442	-91.7013
44-01-010	BLUE BIRD MIDWEST	Truck and Bus Bodies	Space Heaters - Natural Gas	OT + WI	11	0	7	65	$10,360	$1,463	7	$10,360	$1,463	Mingo	454	0.00	40.9682	-91.5647
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	OT + WI	11	0	7	65	$10,358	$1,463	7	$10,358	$1,463	Mingo	531	0.00	41.8111	-90.2897
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	OT + WI	11	0	7	65	$10,192	$1,463	7	$10,192	$1,463	Mingo	502	0.00	41.5415	-90.4632
78-01-012	GRIFFIN PIPE PRODUCTS COMPANY	Gray and Ductile Iron Foundries	Space Heaters - Natural Gas	OT + WI	11	0	7	65	$10,084	$1,463	7	$10,084	$1,463	Hercules-Glades Wilderness	564	0.00	41.2548	-95.8861
57-01-095	PMX INDUSTRIES, INC.	Rolling, Drawing, and Extruding of Copper	ICI Boilers - Natural Gas	OT + WI	10	0	7	65	$9,697	$1,463	7	$9,697	$1,463	Mingo	559	0.00	41.9289	-91.6863
17-01-027	AG PROCESSING, INC. - MASON CITY	Soybean Oil Mills	ICI Boilers - Natural Gas	OT + WI	10	0	7	65	$9,587	$1,463	7	$9,587	$1,463	Boundary Waters Canoe Area	532	0.00	43.1332	-93.2261
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Cyclone	SCR	1,452	0	1,307	90	$1,545,874	$1,183	581	$873,003	$1,503	Hercules-Glades Wilderness	591	0.44	42.0469	-92.8627
23-02-013	GUARDIAN INDUSTRIES CORPORATION	Flat Glass	Glass Manufacturing - Flat	LNB	1,970	0	788	40	$1,186,878	$1,506	788	$1,186,878	$1,506	Mingo	532	0.30	41.8126	-90.5299
23-02-013	GUARDIAN INDUSTRIES CORPORATION	Flat Glass	Glass Manufacturing - Flat	SCR	1,970	0	1,478	75	$2,257,188	$1,528	690	$1,070,310	$1,552	Mingo	532	0.56	41.8126	-90.5299
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	2,169	0	1,212	55.9	$1,255,954	$1,036	779	$1,226,738	$1,576	Boundary Waters Canoe Area	493	0.49	43.3378	-91.1667
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	314	0	176	55.9	$279,157	$1,591	176	$279,157	$1,591	Hercules-Glades Wilderness	591	0.06	42.0469	-92.8627
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	2,232	50	1,786	90	$2,867,307	$1,606	1,786	$2,867,307	$1,606	Mingo	561	0.64	41.9442	-91.7013
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	311	0	174	55.9	$279,157	$1,606	174	$279,157	$1,606	Hercules-Glades Wilderness	591	0.06	42.0469	-92.8627
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	426	0	238	55.9	$383,186	$1,610	238	$383,186	$1,610	Mingo	561	0.08	41.9442	-91.7013
31-01-017	IPL - DUBUQUE GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	301	0	168	55.9	$272,929	$1,623	168	$272,929	$1,623	Seney	542	0.06	42.5108	-90.6533
57-01-004	CARGILL, INC. - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Coal/Wall	SNCR	604	0	242	40	$436,652	$1,807	242	$436,652	$1,807	Mingo	563	0.09	41.9713	-91.6473
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	Electric Services	Utility Boiler - Coal/Tangential - POD10	LNC3	482	0	281	58.3	$336,862	$1,198	72	$136,302	$1,884	Hercules-Glades Wilderness	554	0.10	41.1792	-95.8406
77-01-045	ADM - DES MOINES SOYBEAN	Soybean Oil Mills	ICI Boilers - Coal/FBC	SNCR - Urea Based	233	0	175	75	$338,711	$1,936	175	$338,711	$1,936	Hercules-Glades Wilderness	548	0.06	41.6244	-93.6175
52-01-005	UNIVERSITY OF IOWA MAIN POWER PLANT/MAIN	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/FBC	SNCR - Urea Based	182	0	137	75	$264,710	$1,936	137	$264,710	$1,936	Mingo	528	0.05	41.663	-91.5357
07-02-006	UNIVERSITY OF NORTHERN IOWA - POWER PLAN	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/FBC	SNCR - Urea Based	20	0	15	75	$28,441	$1,936	15	$28,441	$1,936	Boundary Waters Canoe Area	589	0.00	42.51	-92.4695
07-02-006	UNIVERSITY OF NORTHERN IOWA - POWER PLAN	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/FBC	SNCR - Urea Based	20	0	15	75	$28,441	$1,936	15	$28,441	$1,936	Boundary Waters Canoe Area	589	0.00	42.51	-92.4695
21-01-003	CORNBELT POWER - WISDOM GENERATING STATI	Electric Services	Utility Boiler - Coal/Wall	SCR	604	50	483	90	$1,006,124	$2,082	483	$1,006,124	$2,082	Badlands	552	0.18	43.1599	-95.2568
52-01-005	UNIVERSITY OF IOWA MAIN POWER PLANT/MAIN	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/Stoker	SNCR	315	0	126	40	$274,874	$2,184	126	$274,874	$2,184	Mingo	528	0.05	41.663	-91.5357
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	253	0	101	40	$221,245	$2,184	101	$221,245	$2,184	Mingo	491	0.04	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	253	0	101	40	$221,245	$2,184	101	$221,245	$2,184	Mingo	491	0.04	41.3997	-91.0605
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	243	0	97	40	$212,070	$2,184	97	$212,070	$2,184	Hercules-Glades Wilderness	491	0.04	41.1409	-92.6461
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	243	0	97	40	$212,070	$2,184	97	$212,070	$2,184	Hercules-Glades Wilderness	491	0.04	41.1409	-92.6461
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	243	0	97	40	$212,070	$2,184	97	$212,070	$2,184	Hercules-Glades Wilderness	491	0.04	41.1409	-92.6461
31-01-009	JOHN DEERE - DUBUQUE WORKS	Construction Machinery and Equipment	ICI Boilers - Coal/Stoker	SNCR	234	0	93	40	$204,103	$2,184	93	$204,103	$2,184	Seney	540	0.03	42.5648	-90.6932
99-01-001	AG PROCESSING, INC. - EAGLE GROVE	Soybean Oil Mills	ICI Boilers - Coal/Stoker	SNCR	208	0	83	40	$181,785	$2,184	83	$181,785	$2,184	Boundary Waters Canoe Area	594	0.03	42.6756	-93.9031
99-01-001	AG PROCESSING, INC. - EAGLE GROVE	Soybean Oil Mills	ICI Boilers - Coal/Stoker	SNCR	208	0	83	40	$181,785	$2,184	83	$181,785	$2,184	Boundary Waters Canoe Area	594	0.03	42.6756	-93.9031
70-01-008	MONSANTO COMPANY - MUSCATINE 3670/6908/6	Pesticides and Agricultural Chemicals, NEC	ICI Boilers - Coal/Stoker	SNCR	161	0	64	40	$140,779	$2,184	64	$140,779	$2,184	Mingo	487	0.03	41.354	-91.0887
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/Stoker	SNCR	142	0	57	40	$123,968	$2,184	57	$123,968	$2,184	Hercules-Glades Wilderness	593	0.02	42.0275	-93.6391
31-01-009	JOHN DEERE - DUBUQUE WORKS	Construction Machinery and Equipment	ICI Boilers - Coal/Stoker	SNCR	121	0	48	40	$105,734	$2,184	48	$105,734	$2,184	Seney	540	0.02	42.5648	-90.6932
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/Stoker	SNCR	117	0	47	40	$102,343	$2,184	47	$102,343	$2,184	Hercules-Glades Wilderness	593	0.02	42.0275	-93.6391
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	113	0	45	40	$98,382	$2,184	45	$98,382	$2,184	Mingo	491	0.02	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	113	0	45	40	$98,382	$2,184	45	$98,382	$2,184	Mingo	491	0.02	41.3997	-91.0605
31-01-009	JOHN DEERE - DUBUQUE WORKS	Construction Machinery and Equipment	ICI Boilers - Coal/Stoker	SNCR	109	0	43	40	$94,950	$2,184	43	$94,950	$2,184	Seney	540	0.02	42.5648	-90.6932
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	98	0	39	40	$85,709	$2,184	39	$85,709	$2,184	Mingo	491	0.02	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Coal/Stoker	SNCR	98	0	39	40	$85,709	$2,184	39	$85,709	$2,184	Mingo	491	0.02	41.3997	-91.0605
31-01-009	JOHN DEERE - DUBUQUE WORKS	Construction Machinery and Equipment	ICI Boilers - Coal/Stoker	SNCR	71	0	29	40	$62,453	$2,184	29	$62,453	$2,184	Seney	540	0.01	42.5648	-90.6932
82-01-018	KRAFT FOODS, INC. - DAVENPORT	Sausages and Other Prepared Meats	ICI Boilers - Coal/Stoker	SNCR	71	0	29	40	$62,305	$2,184	29	$62,305	$2,184	Mingo	500	0.01	41.5208	-90.5934
82-01-018	KRAFT FOODS, INC. - DAVENPORT	Sausages and Other Prepared Meats	ICI Boilers - Coal/Stoker	SNCR	40	0	16	40	$34,649	$2,184	16	$34,649	$2,184	Mingo	500	0.01	41.5208	-90.5934
85-01-007	IOWA STATE UNIVERSITY/ ISU HEATING PLANT	Colleges, Universities, and Professional Schools	ICI Boilers - Coal/Stoker	SNCR	15	0	6	40	$13,041	$2,184	6	$13,041	$2,184	Hercules-Glades Wilderness	593	0.00	42.0275	-93.6391
63-02-005	PELLA MUNICIPAL POWER PLANT	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	303	40	77	55.3	$170,834	$2,209	77	$170,834	$2,209	Hercules-Glades Wilderness	519	0.03	41.3981	-92.9129
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	503	0	453	90	$585,123	$1,293	171	$385,487	$2,248	Mingo	565	0.16	41.9839	-91.6687
63-02-005	PELLA MUNICIPAL POWER PLANT	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	259	40	66	55.3	$153,392	$2,324	66	$153,392	$2,324	Hercules-Glades Wilderness	519	0.03	41.3981	-92.9129
31-01-035	DUBUQUE WATER POLLUTION CONTROL PLANT	Sewerage Systems	Solid Waste Disp;Gov;Other Inc	SNCR	29	0	13	45	$31,959	$2,431	13	$31,959	$2,431	Seney	546	0.00	42.4721	-90.6529
31-01-035	DUBUQUE WATER POLLUTION CONTROL PLANT	Sewerage Systems	Solid Waste Disp;Gov;Other Inc	SNCR	15	0	7	45	$16,920	$2,431	7	$16,920	$2,431	Seney	546	0.00	42.4721	-90.6529
63-02-003	PELLA CORPORATION - PELLA DIVISION	Millwork	Indust. Incinerators	SNCR	12	0	5	45	$12,961	$2,431	5	$12,961	$2,431	Hercules-Glades Wilderness	519	0.00	41.395	-92.914
97-04-011	MIDAMERICAN ENERGY CO. - GEORGE NEAL SOU	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	4,670	40	1,191	55.3	$2,900,440	$2,435	1,191	$2,900,440	$2,435	Badlands	490	0.49	42.3035	-96.3581
88-01-021	CF PROCESSING, LLC	Soybean Oil Mills	ICI Boilers - Distillate Oil	LNB	14	0	7	50	$17,466	$2,539	7	$17,466	$2,539	Hercules-Glades Wilderness	496	0.00	41.0536	-94.3376
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	481	50	385	90	$1,006,124	$2,614	385	$1,006,124	$2,614	Mingo	495	0.16	41.4587	-90.8224
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	431	0	388	90	$585,123	$1,508	147	$385,487	$2,623	Mingo	565	0.14	41.9839	-91.6687

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx - Tons	2018 Base Case NOx -- CE (%)	Controls - Tons Reduced	Controls - CE (%)	Controls -- Annualized Cost ($2005)	Controls - Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
57-01-004	CARGILL, INC. - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Coal/Wall	SCR	604	0	544	90	$1,251,475	$2,302	302	$814,823	$2,698	Mingo	563	0.19	41.9713	-91.6473
90-07-001	IPL - OTTUMWA GENERATING STATION	Electric Services	Utility Boiler - Coal/Tangential	SCR	5,885	50	4,708	90	$13,000,038	$2,761	4,708	$13,000,038	$2,761	Hercules-Glades Wilderness	487	1.93	41.0987	-92.5616
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	33	0	23	68	$62,640	$2,775	23	$62,640	$2,775	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	33	0	23	68	$62,640	$2,775	23	$62,640	$2,775	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	21	0	14	68	$39,234	$2,775	14	$39,234	$2,775	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	21	0	14	68	$39,234	$2,775	14	$39,234	$2,775	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
04-01-003	IPL - CENTERVILLE COMBUSTION TURBINES AN	Electric Services	Combustion Turbines - Oil	Water Injection	11	0	8	68	$21,337	$2,775	8	$21,337	$2,775	Hercules-Glades Wilderness	447	0.00	40.7476	-92.8728
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	Electric Services	Combustion Turbines - Oil	Water Injection	11	0	7	68	$20,272	$2,775	7	$20,272	$2,775	Hercules-Glades Wilderness	592	0.00	42.0245	-93.6112
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	33	0	23	68	$62,742	$2,776	23	$62,742	$2,776	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	33	0	23	68	$62,742	$2,776	23	$62,742	$2,776	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	21	0	14	68	$39,894	$2,776	14	$39,894	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	21	0	14	68	$39,894	$2,776	14	$39,894	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	12	0	8	68	$22,127	$2,776	8	$22,127	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	12	0	8	68	$22,127	$2,776	8	$22,127	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	11	0	8	68	$21,167	$2,776	8	$21,167	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	Water Injection	11	0	8	68	$21,167	$2,776	8	$21,167	$2,776	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
04-01-003	IPL - CENTERVILLE COMBUSTION TURBINES AN	Electric Services	Combustion Turbines - Oil	Water Injection	11	0	7	68	$20,068	$2,776	7	$20,068	$2,776	Hercules-Glades Wilderness	447	0.00	40.7476	-92.8728
70-01-011	MUSCATINE POWER & WATER	Electric Services	Utility Boiler - Coal/Tangential - POD02	LNC3	764	40	167	53.1	$480,338	$2,880	167	$480,338	$2,880	Mingo	491	0.07	41.3933	-91.056
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	Electric Services	Utility Boiler - Coal/Tangential - POD10	LNC3	156	35	56	58.3	$161,964	$2,890	56	$161,964	$2,890	Hercules-Glades Wilderness	592	0.02	42.0245	-93.6112
31-01-021	JELD-WEN, INC.,DBA JELD-WEN - DUBUQUE	Reconstituted Wood Products	ICI Boilers - Wood/Bark/Stoker - Large	SNCR - Urea Based	19	0	10	55	$31,600	$3,098	10	$31,600	$3,098	Seney	543	0.00	42.5014	-90.6624
70-08-003	CENTRAL IOWA POWER COOP. - FAIR STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	451	0	406	90	$724,717	$1,784	154	$483,899	$3,144	Mingo	495	0.16	41.4587	-90.8224
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	69	0	52	75	$166,380	$3,227	52	$166,380	$3,227	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	60	0	45	75	$144,598	$3,227	45	$144,598	$3,227	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	37	0	27	75	$88,722	$3,227	27	$88,722	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	28	0	21	75	$68,542	$3,227	21	$68,542	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	27	0	20	75	$65,130	$3,227	20	$65,130	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	25	0	18	75	$59,602	$3,227	18	$59,602	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	25	0	18	75	$59,400	$3,227	18	$59,400	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	24	0	18	75	$58,303	$3,227	18	$58,303	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	23	0	17	75	$54,891	$3,227	17	$54,891	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	23	0	17	75	$54,891	$3,227	17	$54,891	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	21	0	16	75	$51,194	$3,227	16	$51,194	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	21	0	16	75	$50,170	$3,227	16	$50,170	$3,227	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	ULNB	19	0	14	75	$46,155	$3,227	14	$46,155	$3,227	Mingo	531	0.01	41.8111	-90.2897
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	349	0	314	90	$585,123	$1,863	119	$385,487	$3,240	Mingo	565	0.11	41.9839	-91.6687
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Tangential	SCR	1,022	50	818	90	$2,671,106	$3,267	818	$2,671,106	$3,267	Mingo	502	0.33	41.5401	-90.4478
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	527	40	134	55.3	$466,717	$3,471	134	$466,717	$3,471	Hercules-Glades Wilderness	592	0.05	42.0245	-93.6112
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	506	0	455	90	$921,969	$2,025	173	$624,467	$3,620	Boundary Waters Canoe Area	493	0.18	43.3378	-91.1667
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	20	0	11	55.9	$40,625	$3,665	11	$40,625	$3,665	Mingo	502	0.00	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	20	0	11	55.9	$40,625	$3,665	11	$40,625	$3,665	Mingo	502	0.00	41.5401	-90.4478
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	260	0	234	90	$504,745	$2,154	89	$329,333	$3,709	Boundary Waters Canoe Area	493	0.10	43.3378	-91.1667
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall - Bituminous Coal	LNBO	17	0	9	55.9	$36,080	$3,906	9	$36,080	$3,906	Mingo	502	0.00	41.5401	-90.4478
07-02-005	CEDAR FALLS MUNICIPAL ELECTRIC UTILITY/C	Electric Services	Utility Boiler - Coal/Wall	SCR	501	0	451	90	$985,258	$2,185	171	$669,873	$3,921	Boundary Waters Canoe Area	589	0.15	42.5115	-92.4759
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	181	0	163	90	$383,016	$2,353	62	$245,212	$3,976	Boundary Waters Canoe Area	493	0.07	43.3378	-91.1667
57-01-040	IPL - SIXTH STREET GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	285	0	257	90	$592,062	$2,307	97	$390,353	$4,014	Mingo	565	0.09	41.9839	-91.6687
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	SNCR - Urea Based	2,575	0	1,287	50	$2,132,718	$1,657	515	$2,068,845	$4,018	Boundary Waters Canoe Area	527	0.49	43.173	-93.2018
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	SNCR - Urea Based	1,784	0	892	50	$1,477,485	$1,657	357	$1,433,236	$4,018	Boundary Waters Canoe Area	527	0.34	43.173	-93.2018
29-01-013	IPL - BURLINGTON GENERATING STATION	Electric Services	Utility Boiler - Coal/Tangential	SCR	1,149	50	919	90	$3,946,014	$4,294	919	$3,946,014	$4,294	Mingo	422	0.44	40.7547	-91.1237
78-01-026	MIDAMERICAN ENERGY CO. - COUNCIL BLUFFS	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	6,329	50	671	55.3	$2,960,866	$4,413	671	$2,960,866	$4,413	Hercules-Glades Wilderness	554	0.24	41.1792	-95.8406
03-03-001	IPL - LANSING GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	2,169	0	1,952	90	$4,674,094	$2,395	740	$3,418,140	$4,622	Boundary Waters Canoe Area	493	0.79	43.3378	-91.1667
23-01-014	IPL - M.L. KAPP GENERATING STATION	Electric Services	Utility Boiler - Coal/Tangential	SCR	1,088	50	871	90	$4,036,603	$4,636	871	$4,036,603	$4,636	Mingo	531	0.33	41.8133	-90.2322
70-03-003	NORTH STAR STEEL COMPANY	Steel Works, Blast Furnaces (Including Coke Ovens), and Rolling M	In-Process Fuel Use; Natural Gas	LNB	128	0	64	50	$303,989	$4,733	64	$303,989	$4,733	Mingo	512	0.03	41.5902	-91.0382
31-01-017	IPL - DUBUQUE GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	382	0	344	90	$943,185	$2,743	130	$639,674	$4,910	Seney	542	0.13	42.5108	-90.6533
70-01-011	MUSCATINE POWER & WATER	Electric Services	Utility Boiler - Coal/Tangential	SCR	764	40	637	90	$2,948,171	$4,631	470	$2,467,833	$5,252	Mingo	491	0.26	41.3933	-91.056
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	314	0	283	90	$857,548	$3,035	107	$578,391	$5,402	Hercules-Glades Wilderness	591	0.10	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	311	0	280	90	$857,548	$3,065	106	$578,391	$5,456	Hercules-Glades Wilderness	591	0.09	42.0469	-92.8627
31-01-017	IPL - DUBUQUE GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	301	0	271	90	$835,800	$3,087	103	$562,871	$5,488	Seney	542	0.10	42.5108	-90.6533
58-07-001	MIDAMERICAN ENERGY CO. - LOUISA STATION	Electric Services	Utility Boiler - Coal/Wall - Other Coal	LNBO	5,002	50	530	55.3	$2,993,404	$5,646	530	$2,993,404	$5,646	Mingo	483	0.22	41.3169	-91.0936
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	Electric Services	Utility Boiler - Coal/Wall	SCR	426	0	383	90	$1,229,153	$3,208	145	$845,967	$5,827	Mingo	561	0.14	41.9442	-91.7013
71-01-001	AG PROCESSING, INC. - SHELDON	Soybean Oil Mills	ICI Boilers - Residual Oil	SCR	204	0	164	80	$520,662	$3,184	61	$432,713	$7,057	Badlands	504	0.06	43.1824	-95.8575
86-01-001	TAMA PAPERBOARD	Paperboard Mills	ICI Boilers - Residual Oil	SCR	88	0	71	80	$225,236	$3,184	27	$187,190	$7,057	Hercules-Glades Wilderness	582	0.02	41.9551	-92.5815
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Residual Oil	SCR	29	0	23	80	$73,938	$3,184	9	$61,448	$7,057	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
14-02-003	AG PROCESSING INC A COOPERATIVE - MANNIN	Soybean Oil Mills	ICI Boilers - Residual Oil	SCR	45	0	36	80	$114,439	$3,184	13	$95,107	$7,058	Badlands	604	0.01	41.9198	-95.0699
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Residual Oil	SCR	23	0	18	80	$58,213	$3,184	7	$48,380	$7,058	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall	SCR	20	0	18	90	$94,326	$5,285	7	$53,701	$7,942	Mingo	502	0.01	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall	SCR	20	0	18	90	$94,326	$5,285	7	$53,701	$7,942	Mingo	502	0.01	41.5401	-90.4478
82-02-006	MIDAMERICAN ENERGY CO. - RIVERSIDE STATI	Electric Services	Utility Boiler - Coal/Wall	SCR	17	0	15	90	$82,307	$5,534	6	$46,227	$8,204	Mingo	502	0.01	41.5401	-90.4478
85-01-017	USDA, NATIONAL ANIMAL DISEASE CENTER	Noncommercial Research Organizations	Combustion Turbines - Natural Gas	Steam Injection	20	0	16	80	$36,314	$2,238	2	$21,772	$8,941	Hercules-Glades Wilderness	594	0.01	42.0495	-93.5796
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	Steam Injection	321	0	257	80	$575,227	$2,238	39	$344,860	$8,943	Boundary Waters Canoe Area	538	0.10	43.0816	-93.2607
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	Steam Injection	321	0	257	80	$575,227	$2,238	39	$344,860	$8,943	Boundary Waters Canoe Area	538	0.10	43.0816	-93.2607
28-01-026	ALLIANCE PIPELINE L.P. - MANCHESTER	Natural Gas Transmission	Combustion Turbines - Natural Gas	Steam Injection	46	0	37	80	$82,940	$2,238	6	$49,724	$8,943	Seney	589	0.01	42.4721	-91.4663
58-04-002	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Combustion Turbines - Natural Gas	Steam Injection	39	0	31	80	$70,212	$2,238	5	$42,093	$8,945	Mingo	491	0.01	41.3805	-91.1929
ORIS1123	ANITA	Electric Services	Combustion Turbines - Natural Gas	Steam Injection	27	0	22	80	$48,965	$2,238	3	$29,356	$8,945	Hercules-Glades Wilderness	540	0.01	41.3312	-94.9274
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	Steam Injection	12	0	10	80	$21,561	$2,238	1	$12,927	$8,946	Mingo	520	0.00	41.6153	-91.4092
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	Steam Injection	17	0	14	80	$30,279	$2,238	2	$18,153	$8,947	Mingo	520	0.01	41.6153	-91.4092
94-01-005	KOCH NITROGEN COMPANY - FORT DODGE	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	699	0	559	80	$1,455,399	$2,603	105	$1,142,668	$10,901	Boundary Waters Canoe Area	615	0.18	42.5	-94.0183
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	514	0	411	80	$1,069,623	$2,603	77	$839,787	$10,901	Badlands	488	0.17	42.3301	-96.3778
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	12	0	11	90	$52,216	$4,948	3	$30,089	$11,662	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	12	0	11	90	$52,216	$4,948	3	$30,089	$11,662	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	11	0	10	90	$49,948	$4,948	2	$28,781	$11,662	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	11	0	10	90	$49,948	$4,948	2	$28,781	$11,662	Hercules-Glades Wilderness	591	0.00	42.0469	-92.8627
04-01-003	IPL - CENTERVILLE COMBUSTION TURBINES AN	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	11	0	10	90	$47,356	$4,948	2	$27,288	$11,662	Hercules-Glades Wilderness	447	0.00	40.7476	-92.8728
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	21	0	19	90	$94,139	$4,948	5	$54,245	$11,663	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	21	0	19	90	$94,139	$4,948	5	$54,245	$11,663	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	33	0	30	90	$148,055	$4,949	7	$85,313	$11,664	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx -- Tons	2018 Base Case NOx -- CE (%)	Controls -- Tons Reduced	Controls -- CE (%)	Controls -- Annualized Cost ($2005)	Controls -- Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	33	0	30	90	$148,055	$4,949	7	$85,313	$11,664	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	33	0	30	90	$147,818	$4,949	7	$85,178	$11,665	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	33	0	30	90	$147,818	$4,949	7	$85,178	$11,665	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	21	0	19	90	$92,581	$4,948	5	$53,347	$11,666	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
64-01-012	IPL - SUTHERLAND GENERATING STATION	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	21	0	19	90	$92,581	$4,948	5	$53,347	$11,666	Hercules-Glades Wilderness	591	0.01	42.0469	-92.8627
04-01-003	IPL - CENTERVILLE COMBUSTION TURBINES AN	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	11	0	10	90	$50,353	$4,949	2	$29,016	$11,667	Hercules-Glades Wilderness	447	0.00	40.7476	-92.8728
85-01-006	CITY OF AMES STEAM ELECTRIC PLANT/COMBUS	Electric Services	Combustion Turbines - Oil	SCR + Water Injection	11	0	10	90	$47,840	$4,949	2	$27,568	$11,667	Hercules-Glades Wilderness	592	0.00	42.0245	-93.6112
88-01-021	CF PROCESSING, LLC	Soybean Oil Mills	ICI Boilers - Distillate Oil	SCR	14	0	11	80	$65,840	$5,981	4	$48,374	$11,719	Hercules-Glades Wilderness	496	0.00	41.0536	-94.3376
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	SCR + Steam Injection	17	0	16	95	$69,491	$4,325	3	$39,212	$15,450	Mingo	520	0.01	41.6153	-91.4092
52-01-032	ENTERPRISE NGL PIPELINE, LLC. - IOWA CIT	Pipelines, NEC	Combustion Turbines - Natural Gas	SCR + Steam Injection	12	0	11	95	$49,482	$4,325	2	$27,921	$15,452	Mingo	520	0.00	41.6153	-91.4092
58-04-002	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	Combustion Turbines - Natural Gas	SCR + Steam Injection	39	0	37	95	$161,143	$4,325	6	$90,931	$15,454	Mingo	491	0.02	41.3805	-91.1929
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	SCR + Steam Injection	321	0	305	95	$1,320,187	$4,325	48	$744,960	$15,455	Boundary Waters Canoe Area	538	0.11	43.0816	-93.2607
ORIS8031	EMERY STATION	Electric Services	Combustion Turbines - Natural Gas	SCR + Steam Injection	321	0	305	95	$1,320,187	$4,325	48	$744,960	$15,455	Boundary Waters Canoe Area	538	0.11	43.0816	-93.2607
28-01-026	ALLIANCE PIPELINE L.P. - MANCHESTER	Natural Gas Transmission	Combustion Turbines - Natural Gas	SCR + Steam Injection	46	0	44	95	$190,355	$4,325	7	$107,415	$15,455	Seney	589	0.01	42.4721	-91.4663
85-01-017	USDA, NATIONAL ANIMAL DISEASE CENTER	Noncommercial Research Organizations	Combustion Turbines - Natural Gas	SCR + Steam Injection	20	0	19	95	$83,343	$4,325	3	$47,029	$15,455	Hercules-Glades Wilderness	594	0.01	42.0495	-93.5796
ORIS1123	ANITA	Electric Services	Combustion Turbines - Natural Gas	SCR + Steam Injection	27	0	26	95	$112,380	$4,325	4	$63,415	$15,456	Hercules-Glades Wilderness	540	0.01	41.3312	-94.9274
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	SCR	2,575	0	2,060	80	$14,934,566	$7,251	772	$12,801,848	$16,574	Boundary Waters Canoe Area	527	0.78	43.173	-93.2018
17-01-009	HOLCIM (US) INC. - MASON CITY	Cement, Hydraulic	Cement Manufacturing - Dry	SCR	1,784	0	1,427	80	$10,346,235	$7,251	535	$8,868,750	$16,574	Boundary Waters Canoe Area	527	0.54	43.173	-93.2018
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	SCR	16	0	13	80	$62,679	$4,798	2	$47,149	$19,244	Mingo	502	0.01	41.5415	-90.4632
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	SCR	11	0	9	80	$41,136	$4,798	2	$30,944	$19,244	Mingo	502	0.00	41.5415	-90.4632
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	SCR	18	0	15	80	$70,586	$4,798	3	$53,098	$19,245	Mingo	502	0.01	41.5415	-90.4632
77-01-003	TITAN TIRE CORPORATION	Tires and Inner Tubes	ICI Boilers - Natural Gas	SCR	23	0	19	80	$88,958	$4,798	3	$66,917	$19,246	Hercules-Glades Wilderness	543	0.01	41.5866	-93.5715
82-01-002	ALCOA INC.	Aluminum Sheet, Plate, and Foil	ICI Boilers - Natural Gas	SCR	14	0	11	80	$54,471	$4,798	2	$40,974	$19,246	Mingo	502	0.00	41.5415	-90.4632
57-01-042	IPL - PRAIRIE CREEK GENERATING STATION	Electric Services	ICI Boilers - Natural Gas	SCR	11	0	9	80	$42,418	$4,798	2	$31,910	$19,246	Mingo	561	0.00	41.9442	-91.7013
29-06-001	UNITED STATES GYPSUM CO. - SPERRY	Gypsum Products	ICI Boilers - Natural Gas	SCR	38	0	30	80	$145,762	$4,798	6	$109,648	$19,247	Mingo	448	0.01	40.9846	-91.1897
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	25	0	20	80	$97,532	$4,798	4	$73,368	$19,247	Mingo	491	0.01	41.3997	-91.0605
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	ICI Boilers - Natural Gas	SCR	16	0	13	80	$61,229	$4,798	2	$46,058	$19,247	Badlands	488	0.01	42.3301	-96.3778
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	SCR	13	0	10	80	$49,509	$4,798	2	$37,243	$19,247	Hercules-Glades Wilderness	555	0.00	41.7175	-93.0432
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	92	0	74	80	$354,342	$4,798	14	$266,550	$19,248	Hercules-Glades Wilderness	504	0.03	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	92	0	74	80	$354,342	$4,798	14	$266,550	$19,248	Hercules-Glades Wilderness	504	0.03	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	92	0	74	80	$354,342	$4,798	14	$266,550	$19,248	Hercules-Glades Wilderness	504	0.03	41.1167	-94.3549
88-01-017	GREEN VALLEY CHEMICAL CORPORATION	Nitrogenous Fertilizers	Ammonia - NG-Fired Reformers	SCR	92	0	74	80	$354,342	$4,798	14	$266,550	$19,248	Hercules-Glades Wilderness	504	0.03	41.1167	-94.3549
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	72	0	58	80	$276,088	$4,798	11	$207,686	$19,248	Mingo	532	0.02	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	72	0	58	80	$276,088	$4,798	11	$207,686	$19,248	Mingo	532	0.02	41.8185	-90.2156
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Natural Gas	SCR	23	0	18	80	$87,456	$4,798	3	$65,788	$19,248	Hercules-Glades Wilderness	550	0.01	41.6443	-93.6205
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	14	0	11	80	$54,269	$4,798	2	$40,824	$19,248	Hercules-Glades Wilderness	487	0.00	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	14	0	11	80	$54,269	$4,798	2	$40,824	$19,248	Hercules-Glades Wilderness	487	0.00	41.1024	-92.6547
44-01-010	BLUE BIRD MIDWEST	Truck and Bus Bodies	Space Heaters - Natural Gas	SCR	11	0	9	80	$41,811	$4,798	2	$31,451	$19,248	Mingo	454	0.00	40.9682	-91.5647
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	SCR	11	0	9	80	$41,809	$4,798	2	$31,451	$19,248	Mingo	531	0.00	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	SCR	234	0	187	80	$897,673	$4,798	35	$675,269	$19,249	Mingo	531	0.07	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	ICI Boilers - Process Gas	SCR	208	0	166	80	$798,303	$4,798	31	$600,517	$19,249	Mingo	531	0.06	41.8111	-90.2897
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	115	0	92	80	$442,377	$4,798	17	$332,775	$19,249	Mingo	532	0.03	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	115	0	92	80	$442,024	$4,798	17	$332,510	$19,249	Mingo	532	0.03	41.8185	-90.2156
23-01-006	ADM CORN PROCESSING - CLINTON	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	98	0	78	80	$376,002	$4,798	15	$282,844	$19,249	Mingo	532	0.03	41.8185	-90.2156
14-02-003	AG PROCESSING INC A COOPERATIVE - MANNIN	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	38	0	30	80	$144,449	$4,798	6	$108,660	$19,249	Badlands	604	0.01	41.9198	-95.0699
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	34	0	27	80	$128,814	$4,798	5	$96,900	$19,249	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	34	0	27	80	$128,814	$4,798	5	$96,900	$19,249	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	34	0	27	80	$128,814	$4,798	5	$96,900	$19,249	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
68-09-002	AJINOMOTO HEARTLAND LLC.	Prepared Feed and Feed Ingredients for Animals and Fowls, Except	ICI Boilers - Natural Gas	SCR	34	0	27	80	$128,814	$4,798	5	$96,900	$19,249	Hercules-Glades Wilderness	487	0.01	41.1024	-92.6547
77-01-010	CARGILL, INC. - DES MOINES	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	31	0	25	80	$117,785	$4,798	5	$88,603	$19,249	Hercules-Glades Wilderness	542	0.01	41.574	-93.5577
78-01-085	BUNGE NORTH AMERICA, INC. - BUNGE AVENUE	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	27	0	22	80	$104,555	$4,798	4	$78,650	$19,249	Hercules-Glades Wilderness	551	0.01	41.1541	-95.8081
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	23	0	19	80	$88,767	$4,798	3	$66,774	$19,249	Mingo	491	0.01	41.3997	-91.0605
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	SCR	22	0	18	80	$84,365	$4,798	3	$63,463	$19,249	Hercules-Glades Wilderness	555	0.01	41.7175	-93.0432
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	SCR	16	0	13	80	$60,876	$4,798	2	$45,794	$19,249	Hercules-Glades Wilderness	555	0.00	41.7175	-93.0432
97-01-001	CARGILL, INC. - SIOUX CITY	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	42	0	34	80	$161,446	$4,798	6	$121,446	$19,250	Badlands	480	0.01	42.5008	-96.3914
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	39	0	31	80	$150,542	$4,798	6	$113,245	$19,250	Mingo	491	0.01	41.3997	-91.0605
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	35	0	28	80	$135,785	$4,798	5	$102,143	$19,250	Mingo	491	0.01	41.3997	-91.0605
78-01-085	BUNGE NORTH AMERICA, INC. - BUNGE AVENUE	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	29	0	23	80	$111,061	$4,798	4	$83,545	$19,250	Hercules-Glades Wilderness	551	0.01	41.1541	-95.8081
57-01-095	PMX INDUSTRIES, INC.	Rolling, Drawing, and Extruding of Copper	ICI Boilers - Natural Gas	SCR	19	0	15	80	$72,421	$4,798	3	$54,477	$19,250	Mingo	559	0.01	41.9289	-91.6863
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	19	0	15	80	$71,217	$4,798	3	$53,572	$19,250	Hercules-Glades Wilderness	491	0.01	41.1409	-92.6461
57-01-080	ADM CORN PROCESSING - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	17	0	13	80	$63,669	$4,798	2	$47,894	$19,250	Mingo	559	0.00	41.9245	-91.6874
57-01-080	ADM CORN PROCESSING - CEDAR RAPIDS	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	17	0	13	80	$63,669	$4,798	2	$47,894	$19,250	Mingo	559	0.00	41.9245	-91.6874
77-01-003	TITAN TIRE CORPORATION	Tires and Inner Tubes	ICI Boilers - Natural Gas	SCR	14	0	11	80	$53,791	$4,798	2	$40,464	$19,250	Hercules-Glades Wilderness	543	0.00	41.5866	-93.5715
74-01-012	AG PROCESSING, INC. - EMMETSBURG	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	43	0	35	80	$165,909	$4,798	6	$124,804	$19,251	Boundary Waters Canoe Area	565	0.01	43.0994	-94.6532
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	35	0	28	80	$133,001	$4,798	5	$100,050	$19,251	Hercules-Glades Wilderness	491	0.01	41.1409	-92.6461
68-09-001	CARGILL, INC. - EDDYVILLE	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	20	0	16	80	$75,956	$4,798	3	$57,136	$19,251	Hercules-Glades Wilderness	491	0.01	41.1409	-92.6461
29-06-001	UNITED STATES GYPSUM CO. - SPERRY	Gypsum Products	ICI Boilers - Natural Gas	SCR	15	0	12	80	$58,658	$4,798	2	$44,124	$19,251	Mingo	448	0.01	40.9846	-91.1897
57-01-025	PENFORD PRODUCTS CO.	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	12	0	9	80	$44,733	$4,798	2	$33,650	$19,251	Mingo	563	0.00	41.9699	-91.6676
70-01-004	GRAIN PROCESSING CORPORATION	Wet Corn Milling	ICI Boilers - Natural Gas	SCR	38	0	31	80	$146,517	$4,798	6	$110,216	$19,252	Mingo	491	0.01	41.3997	-91.0605
50-01-002	MAYTAG - NEWTON LAUNDRY PRODUCTS - PLANT	Household Laundry Equipment	ICI Boilers - Natural Gas	SCR	31	0	25	80	$119,721	$4,798	5	$90,060	$19,252	Hercules-Glades Wilderness	555	0.01	41.7175	-93.0432
77-01-022	FIRESTONE AG TIRE COMPANY	Tires and Inner Tubes	ICI Boilers - Natural Gas	SCR	17	0	14	80	$65,618	$4,798	3	$49,361	$19,252	Hercules-Glades Wilderness	550	0.00	41.6443	-93.6205
42-01-003	CARGILL, INC. - IOWA FALLS	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	13	0	11	80	$50,495	$4,798	2	$37,984	$19,252	Boundary Waters Canoe Area	600	0.00	42.5087	-93.2689
17-01-027	AG PROCESSING, INC. - MASON CITY	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	10	0	8	80	$38,696	$4,798	2	$29,109	$19,252	Boundary Waters Canoe Area	532	0.00	43.1332	-93.2261
77-01-045	ADM - DES MOINES SOYBEAN	Soybean Oil Mills	ICI Boilers - Natural Gas	SCR	22	0	18	80	$85,253	$4,798	3	$64,131	$19,253	Hercules-Glades Wilderness	548	0.01	41.6244	-93.6175
97-01-030	TERRA NITROGEN - PORT NEAL COMPLEX	Nitrogenous Fertilizers	ICI Boilers - Natural Gas	SCR	15	0	12	80	$56,186	$4,798	2	$42,265	$19,255	Badlands	488	0.00	42.3301	-96.3778
57-01-095	PMX INDUSTRIES, INC.	Rolling, Drawing, and Extruding of Copper	ICI Boilers - Natural Gas	SCR	10	0	8	80	$39,139	$4,798	2	$29,442	$19,256	Mingo	559	0.00	41.9289	-91.6863
78-01-012	GRIFFIN PIPE PRODUCTS COMPANY	Gray and Ductile Iron Foundries	Space Heaters - Natural Gas	SCR	11	0	8	80	$40,703	$4,798	2	$30,619	$19,257	Hercules-Glades Wilderness	564	0.00	41.2548	-95.8861
23-02-013	GUARDIAN INDUSTRIES CORPORATION	Flat Glass	Glass Manufacturing - Flat	OXY-Firing	1,970	0	1,675	85	$6,845,746	$4,088	197	$4,588,558	$23,291	Mingo	532	0.63	41.8126	-90.5299
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	21	0	17	80	$125,580	$7,573	1	$75,410	$72,719	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	23	0	18	80	$137,398	$7,573	1	$82,507	$72,757	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	23	0	18	80	$137,398	$7,573	1	$82,507	$72,757	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	28	0	23	80	$171,569	$7,573	1	$103,027	$72,759	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	69	0	55	80	$416,466	$7,573	3	$250,086	$72,763	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	60	0	48	80	$361,941	$7,573	3	$217,343	$72,763	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	25	0	20	80	$148,688	$7,573	1	$89,288	$72,769	Mingo	531	0.01	41.8111	-90.2897

Plant ID	Plant Name	Industrial Code Description	Source Type for Control	Control Measure	2018 Base Case NOx - Tons	2018 Base Case NOx -- CE (%)	Controls - Tons Reduced	Controls - CE (%)	Controls -- Annualized Cost ($2005)	Controls - Cost Per Ton Reduced	Incremental Tons Reduced	Incremenal Cost	Incremental Marginal Cost Per Ton	Nearest Class I Area	Distance (km)	(NOx Tons Reduced) / 5d	Latitude	Longitude
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	25	0	20	80	$149,189	$7,573	1	$89,587	$72,776	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	27	0	22	80	$163,028	$7,574	1	$97,898	$72,787	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	24	0	19	80	$145,940	$7,573	1	$87,637	$72,788	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	37	0	29	80	$222,079	$7,574	2	$133,357	$72,793	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	21	0	17	80	$128,142	$7,573	1	$76,948	$72,798	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SNCR	19	0	15	80	$115,534	$7,574	1	$69,379	$72,801	Mingo	531	0.01	41.8111	-90.2897
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	IC Engines - Gas	SCR	11	17	10	90	$58,484	$5,957	0	$50,788	$125,713	Mingo	498	0.00	41.5006	-90.6418
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	51	17	45	90	$268,017	$5,958	2	$232,747	$125,877	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	28	17	25	90	$146,304	$5,958	1	$127,052	$125,919	Hercules-Glades Wilderness	528	0.01	41.0602	-95.4486
82-01-089	NICHOLS ALUMINUM CASTING	Aluminum Sheet, Plate, and Foil	IC Engines - Gas	SCR	11	17	10	90	$58,768	$5,958	0	$51,035	$126,012	Mingo	498	0.00	41.5006	-90.6418
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	14	5.43	13	90	$76,860	$5,958	0	$66,687	$145,605	Mingo	507	0.01	41.3571	-92.0532
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	30	5.43	27	90	$158,288	$5,958	1	$137,336	$145,637	Mingo	505	0.01	41.3682	-91.9408
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	71	5.43	63	90	$376,421	$5,958	2	$326,595	$145,671	Mingo	507	0.02	41.3571	-92.0532
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	68	5.43	61	90	$363,512	$5,958	2	$315,395	$145,679	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	28	5.43	25	90	$148,094	$5,958	1	$128,491	$145,681	Hercules-Glades Wilderness	432	0.01	40.5806	-93.5181
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	48	5.43	43	90	$254,213	$5,958	2	$220,565	$145,684	Mingo	479	0.02	41.246	-91.3514
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	91	5.43	82	90	$486,450	$5,958	3	$422,060	$145,689	Hercules-Glades Wilderness	432	0.04	40.5806	-93.5181
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	51	5.43	46	90	$274,207	$5,958	2	$237,912	$145,690	Hercules-Glades Wilderness	432	0.02	40.5806	-93.5181
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	212	5.43	189	90	$1,128,074	$5,958	7	$978,756	$145,692	Mingo	479	0.08	41.246	-91.3514
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	51	5.43	46	90	$271,692	$5,958	2	$235,729	$145,692	Mingo	505	0.02	41.3682	-91.9408
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	43	5.43	38	90	$227,204	$5,958	1	$197,130	$145,698	Hercules-Glades Wilderness	432	0.02	40.5806	-93.5181
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	50	5.43	45	90	$268,514	$5,958	2	$232,972	$145,699	Mingo	458	0.02	40.9047	-91.9656
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	295	5.43	263	90	$1,569,638	$5,958	9	$1,361,873	$145,702	Hercules-Glades Wilderness	506	0.10	41.2246	-93.7805
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	163	5.43	146	90	$869,887	$5,958	5	$754,744	$145,703	Hercules-Glades Wilderness	432	0.07	40.5806	-93.5181
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	335	5.43	300	90	$1,785,454	$5,958	11	$1,549,123	$145,704	Hercules-Glades Wilderness	528	0.11	41.0602	-95.4486
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	333	5.43	298	90	$1,773,539	$5,958	11	$1,538,785	$145,704	Mingo	458	0.13	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	104	5.43	93	90	$553,843	$5,958	3	$480,533	$145,704	Mingo	458	0.04	40.9047	-91.9656
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	244	5.43	219	90	$1,301,987	$5,958	8	$1,129,649	$145,705	Hercules-Glades Wilderness	528	0.08	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	117	5.43	105	90	$624,545	$5,958	4	$541,878	$145,705	Hercules-Glades Wilderness	506	0.04	41.2246	-93.7805
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	70	5.43	62	90	$370,464	$5,958	2	$321,428	$145,706	Mingo	458	0.03	40.9047	-91.9656
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	231	5.43	207	90	$1,233,335	$5,958	7	$1,070,083	$145,708	Hercules-Glades Wilderness	506	0.08	41.2246	-93.7805
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	193	5.43	173	90	$1,030,626	$5,958	6	$894,207	$145,708	Hercules-Glades Wilderness	528	0.07	41.0602	-95.4486
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	238	5.43	213	90	$1,267,760	$5,958	8	$1,099,954	$145,709	Hercules-Glades Wilderness	506	0.08	41.2246	-93.7805
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	203	5.43	181	90	$1,081,203	$5,958	6	$938,090	$145,711	Mingo	479	0.08	41.246	-91.3514
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	77	5.43	69	90	$412,634	$5,958	2	$358,015	$145,712	Mingo	458	0.03	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	101	5.43	91	90	$539,770	$5,958	3	$468,323	$145,713	Mingo	458	0.04	40.9047	-91.9656
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	23	5.43	20	90	$120,752	$5,958	1	$104,768	$145,713	Mingo	458	0.01	40.9047	-91.9656
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	196	5.43	175	90	$1,045,123	$5,958	6	$906,784	$145,715	Mingo	479	0.07	41.246	-91.3514
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	55	5.43	49	90	$291,551	$5,958	2	$252,961	$145,715	Hercules-Glades Wilderness	528	0.02	41.0602	-95.4486
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	316	5.43	282	90	$1,682,313	$5,958	10	$1,459,633	$145,716	Hercules-Glades Wilderness	528	0.11	41.0602	-95.4486
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	74	5.43	66	90	$393,834	$5,958	2	$341,704	$145,716	Mingo	507	0.03	41.3571	-92.0532
65-04-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	238	5.43	213	90	$1,269,016	$5,958	8	$1,101,042	$145,718	Hercules-Glades Wilderness	528	0.08	41.0602	-95.4486
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	203	5.43	182	90	$1,081,932	$5,958	6	$938,722	$145,719	Mingo	479	0.08	41.246	-91.3514
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	128	5.43	115	90	$684,591	$5,958	4	$593,976	$145,725	Mingo	479	0.05	41.246	-91.3514
54-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	78	5.43	70	90	$414,355	$5,958	2	$359,510	$145,728	Mingo	507	0.03	41.3571	-92.0532
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	61	5.43	55	90	$325,845	$5,958	2	$282,715	$145,729	Mingo	505	0.02	41.3682	-91.9408
91-06-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	132	5.43	118	90	$704,781	$5,958	4	$611,492	$145,732	Hercules-Glades Wilderness	506	0.05	41.2246	-93.7805
92-10-001	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	39	5.43	35	90	$206,945	$5,958	1	$179,554	$145,742	Mingo	505	0.01	41.3682	-91.9408
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	64	5.43	57	90	$339,481	$5,958	2	$294,546	$145,743	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
93-05-001	ANR PIPELINE CO. - LINEVILLE COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	73	5.43	66	90	$391,581	$5,958	2	$339,750	$145,753	Hercules-Glades Wilderness	432	0.03	40.5806	-93.5181
58-02-007	NATURAL GAS PIPELINE CO. OF AMERICA - ST	Natural Gas Transmission	IC Engines - Gas	SCR	39	5.43	35	90	$207,475	$5,958	1	$180,013	$145,760	Mingo	479	0.01	41.246	-91.3514
51-03-001	ANR PIPELINE CO. - BIRMINGHAM COMPRESSOR	Natural Gas Transmission	IC Engines - Gas	SCR	49	5.43	44	90	$263,086	$5,958	2	$228,263	$145,762	Mingo	458	0.02	40.9047	-91.9656
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	19	0	17	88	$417,365	$24,871	2	$301,831	$197,792	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	37	0	32	88	$802,260	$24,872	3	$580,181	$197,811	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	27	0	24	88	$588,935	$24,872	2	$425,907	$197,820	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	25	0	22	88	$538,946	$24,872	2	$389,757	$197,846	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	69	0	60	88	$1,504,483	$24,872	5	$1,088,017	$197,857	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	24	0	21	88	$527,211	$24,872	2	$381,271	$197,857	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	21	0	19	88	$462,918	$24,872	2	$334,776	$197,858	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	60	0	53	88	$1,307,516	$24,872	5	$945,575	$197,860	Mingo	531	0.02	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	21	0	18	88	$453,660	$24,872	2	$328,080	$197,877	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	23	0	20	88	$496,351	$24,872	2	$358,953	$197,879	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	23	0	20	88	$496,351	$24,872	2	$358,953	$197,879	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	25	0	22	88	$537,134	$24,872	2	$388,446	$197,884	Mingo	531	0.01	41.8111	-90.2897
23-01-004	EQUISTAR CHEMICALS, L.P.	Industrial Organic Chemicals, NEC	Process Heaters - Natural Gas	LNB + SCR	28	0	25	88	$619,795	$24,872	2	$448,226	$197,892	Mingo	531	0.01	41.8111	-90.2897

APPENDIX 11

Appendix 11.1

Regional Air Quality Analyses for Ozone, $PM_{2.5}$, and Regional Haze:

Technical Support Document

February 15, 2008

States of Illinois, Indiana, Michigan, Ohio, and Wisconsin

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EXECUTIVE SUMMARY

States in the upper Midwest face a number of air quality challenges. More than 50 counties are currently classified as nonattainment for the 8-hour ozone standard and 60 for the fine particle ($PM_{2.5}$) standard (1997 versions). A map of these nonattainment areas is provided in the figure below. In addition, visibility impairment due to regional haze is a problem in the larger national parks and wilderness areas (i.e., Class I areas). There are 156 Class I areas in the U.S., including two in northern Michigan.

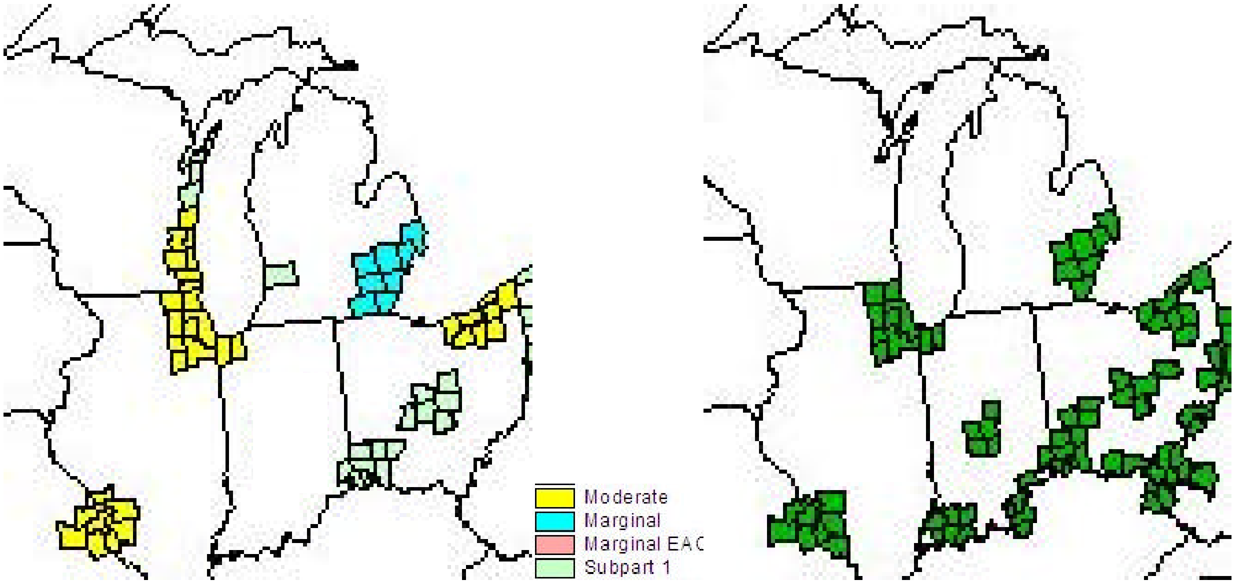

Figure i. Current nonattainment counties for ozone (left) and $PM_{2.5}$ (right)

To support the development of State Implementation Plans (SIPs) for ozone, $PM_{2.5}$, and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, technical analyses were conducted by the Lake Michigan Air Directors Consortium (LADCO), its member states, and various contractors. The analyses include preparation of regional emissions inventories and meteorological data, evaluation and application of regional chemical transport models, and collection and analysis of ambient monitoring data.

Monitoring data were analyzed to produce a conceptual understanding of the air quality problems. Key findings of the analyses include:

Ozone

- Current monitoring data (2005-2007) show about 20 sites in violation of the 8-hour ozone standard of 85 parts per billion (ppb). Historical ozone data show a steady downward trend over the past 15 years, especially since 2001-2003, due likely to federal and state emission control programs.

- Ozone concentrations are strongly influenced by meteorological conditions, with more high ozone days and higher ozone levels during summers with above normal temperatures.

- Inter- and intra-regional transport of ozone and ozone precursors affects many portions of the five states, and is the principal cause of nonattainment in some areas far from population or industrial centers.

$PM_{2.5}$

- Current monitoring data (2004-2006) show about 40 sites in violation of the annual $PM_{2.5}$ standard of 15 ug/m^3. Nonattainment sites are characterized by an elevated regional background (about 12 – 14 ug/m^3) and a significant local (urban) increment (about 2 – 3 ug/m^3). Historical $PM_{2.5}$ data show a slight downward trend since deployment of the $PM_{2.5}$ monitoring network in 1999.

- $PM_{2.5}$ concentrations are less influenced by meteorology (compared to ozone), but, nevertheless, are affected by atmospheric conditions (e.g., stagnation events, especially during the winter) and transport patterns.

- On an annual average basis, $PM_{2.5}$ chemical composition consists mostly of sulfate, nitrate, and organic carbon in similar proportions.

Haze

- Current monitoring data (2000-2004) show visibility levels in the Class I areas in northern Michigan are on the order of 22 – 24 deciviews. The goal of USEPA's visibility program is to achieve natural conditions, which is about 12 deciviews for these Class I areas, by the year 2064.

- Visibility impairment is dominated by sulfate and nitrate.

Air quality models were applied to support the regional planning efforts. Two base years were used in the modeling analyses: 2002 and 2005. Basecase modeling was conducted to evaluate model performance (i.e., assess the model's ability to reproduce observed concentrations). This exercise was intended to build confidence in the model prior to its use in examining control strategies. Model performance for ozone and $PM_{2.5}$ was found to be generally acceptable.

Future year strategy modeling was conducted to determine whether existing ("on the books") controls would be sufficient to provide for attainment of the standards for ozone and $PM_{2.5}$ and if not, then what additional emission reductions would be necessary for attainment. Based on the modeling and other supplemental analyses, the following general conclusions can be made:

- Existing controls are expected to produce significant improvement in ozone and $PM_{2.5}$ concentrations and visibility levels.

- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. 2002 was more ozone conducive than 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).

- Modeling suggests that most sites are expected to meet the current 8-hour ozone standard by the applicable attainment date, except for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.

- Modeling suggests that most sites are expected to meet the current $PM_{2.5}$ standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City.

  The regional modeling for $PM_{2.5}$ does not include air quality benefits expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for $PM_{2.5}$.

- These findings of residual nonattainment for ozone and $PM_{2.5}$ are supported by current (2005 – 2007) monitoring data which show significant nonattainment in the region (e.g., peak ozone design values on the order of 90 – 93 ppb, and peak $PM_{2.5}$ design values on the order of 16 - 17 ug/m^3). It is unlikely that sufficient emission reductions will occur in the next couple of years to provide for attainment at all sites.

- Attainment at most sites by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). If either of these conditions is not met, then attainment may be less likely.

- Modeling suggests that the new $PM_{2.5}$ 24-hour standard (and, probably, a new lower ozone standard) will not be met at many sites, even by 2018, with existing controls.

- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018 based on existing controls, including those in northern Michigan and some in the northeastern U.S. Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018. These results, along with information on the costs of compliance, time necessary for compliance, energy and non air quality environmental impacts of compliance, and remaining useful life of existing sources, should be considered by the states in setting reasonable progress goals for regional haze.

Section 1.0 Introduction

This Technical Support Document summarizes the final air quality analyses conducted by the Lake Michigan Directors Consortium (LADCO)[1] and its contractors to support the development of State Implementation Plans (SIPs) for ozone, fine particles ($PM_{2.5}$), and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin. The analyses include preparation of regional emissions inventories and meteorological modeling data for two base years (2002 and 2005), evaluation and application of regional chemical transport models, and analysis of ambient monitoring data.

Two aspects of the analyses should be emphasized. First, a regional, multi-pollutant approach was taken in addressing ozone, $PM_{2.5}$, and haze for technical reasons (e.g., commonality in precursors, emission sources, atmospheric processes, transport influences, and geographic areas of concern), and practical reasons (e.g., more efficient use of program resources). Furthermore, USEPA has consistently encouraged multi-pollutant planning in its rule for the haze program (64 FR 35719), and its implementation guidance for ozone (70 FR 71663) and $PM_{2.5}$ (72 FR 20609). Second, a weight-of-evidence approach was taken in considering the results of the various analyses (i.e., two sets of modeling results -- one for a 2002 base year and one for a 2005 base year -- and ambient data analyses) in order to provide a more robust assessment of expected future year air quality.

The report is organized in the following sections. This Introduction provides an overview of regulatory requirements and background information on regional planning. Section 2 reviews the ambient monitoring data and presents a conceptual model of ozone, $PM_{2.5}$, and haze for the region. Section 3 discusses the air quality modeling analyses, including development of the key model inputs (emissions inventory and meteorological data), and basecase model performance evaluation. A modeled attainment demonstration for ozone and $PM_{2.5}$ is presented in Section 4, along with relevant data analyses considered as part of the weight-of-evidence determination. Section 5 documents the reasonable progress assessment for regional haze, along with relevant data analyses considered as part of the weight-of-evidence determination. Finally, key study findings are reviewed and summarized in Section 6.

1.1 SIP Requirements

For ozone, USEPA promulgated designations on April 15, 2004 (69 FR 23858, April 30, 2004). In the 5-state region, more than 100 counties were designated as nonattainment.[2] The designations became effective on June 15, 2004. SIPs for ozone were due no later than three years from the effective date of the nonattainment designations (i.e., by June 2007). The attainment date for ozone varies as a function of nonattainment classification. For the region, the attainment dates are either June 2007 (marginal nonattainment areas), June 2009 (basic nonattainment areas), or June 2010 (moderate nonattainment areas).

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[1] A sub-entity of LADCO, known as the Midwest Regional Planning Organization (MRPO), is responsible for the regional haze activities of the multi-state organization.

[2] Based on more recent air quality data, many counties in Indiana, Michigan, and Ohio were subsequently redesignated as attainment. As of December 31, 2007, there are 53 counties designated as nonattainment in the region.

For $PM_{2.5}$, USEPA promulgated designations on December 17, 2004 (70 FR 944, January 5, 2005). In the 5-state region, 70 counties were designated as nonattainment.[3] The designations became effective on April 5, 2005. SIPs for $PM_{2.5}$ are due no later than three years from the effective date of the nonattainment designations (per section 172(b) of the Clean Air Act) (i.e., by April 2008) and for haze no later than three years after the date on which the Administrator promulgated the $PM_{2.5}$ designations (per the Omnibus Appropriations Act of 2004) (i.e., by December 2007). The applicable attainment date for $PM_{2.5}$ nonattainment areas is five years from the date of the nonattainment designation (i.e., by April 2010).

For haze, the Clean Air Act sets "as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in Class I areas which impairment results from manmade air pollution." There are 156 Class I areas, including two in northern Michigan: Isle Royale National Park and Seney National Wildlife Refuge[4]. USEPA's visibility rule (64 FR 35714, July 1, 1999) requires reasonable progress in achieving "natural conditions" by the year 2064. As noted above, the first regional haze SIP was due in December 2007 and must address the initial 10-year implementation period (i.e., reasonable progress by the year 2018). SIP requirements (pursuant to 40 CFR 51.308(d)) include setting reasonable progress goals, determining baseline conditions, determining natural conditions, providing a long-term control strategy, providing a monitoring strategy (air quality and emissions), and establishing BART emissions limitations and associated compliance schedule.

1.2 Organization

LADCO was established by the States of Illinois, Indiana, Michigan, and Wisconsin in 1989. The four states and USEPA signed a Memorandum of Agreement (MOA) that initiated the Lake Michigan Ozone Study (LMOS) and identified LADCO as the organization to oversee the study. Additional MOAs were signed by the States in 1991 (to establish the Lake Michigan Ozone Control Program), January 2000 (to broaden LADCO's responsibilities), and June 2004 (to update LADCO's mission and reaffirm the commitment to regional planning). In March 2004, Ohio joined LADCO. LADCO consists of a Board of Directors (i.e., the State Air Directors), a technical staff, and various workgroups. The main purposes of LADCO are to provide technical assessments for and assistance to its member states, and to provide a forum for its member states to discuss regional air quality issues.

MRPO is a similar entity led by the five LADCO States and involves the federally recognized tribes in Michigan and Wisconsin, USEPA, and Federal Land Managers (i.e., National Park Service, U.S. Fish & Wildlife Agency, and U.S. Forest Service). In October 2000, the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin signed an MOA that established the MRPO. An operating principles document for MRPO, which describe the roles and responsibilities of states, tribes, federal agencies, and stakeholders, was issued in March 2001. MRPO has a similar purpose as LADCO, but is focused on visibility impairment due to regional haze in the Federal Class I areas located inside the borders of the five states, and the impact of emissions from the five states on visibility impairment due to regional haze in the Federal Class I areas located outside the borders of the five states. MRPO works cooperatively with the Regional Planning Organizations (RPOs) representing other parts of the country. The RPOs sponsored several

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[3] Based on more recent air quality data, a few counties in Indiana and Ohio were subsequently redesignated as attainment. As of December 31, 2007, there are 64 counties designated as nonattainment in the region.

[4] Although Rainbow Lake in northern Wisconsin is also a Class I area, the visibility rule does not apply because the Federal Land Manager determined that visibility is not an air quality related value there.

joint projects and, with assistance by USEPA, maintain regular contact on technical and policy matters.

1.3 Technical Work: Overview

To ensure the reliability and effectiveness of its planning process, LADCO has made data collection and analysis a priority. More than $7M in RPO grant funds were used for special purpose monitoring, preparing and improving emissions inventories, and conducting air quality analyses[5]. An overview of the technical work is provided below.

Monitoring: Numerous monitoring projects were conducted to supplement on-going state and local air pollution monitoring. These projects include rural monitoring (e.g., comprehensive sampling in the Seney National Wildlife Refuge and in Bondville, IL); urban monitoring (e.g., continuation of the St. Louis Supersite); aloft (aircraft) measurements; regional ammonia monitoring; and organic speciation sampling in Seney, Bondville, and five urban areas.

Emissions: Baseyear emissions inventories were prepared for 2002 and 2005. States provided point source and area source emissions data, and MOBILE6 input files and mobile source activity data. LADCO and its contractors developed the emissions data for other source categories (e.g., select nonroad sources, ammonia, fires, and biogenics) and processed the data for input into an air quality model. To support control strategy modeling, future year inventories were prepared. The future years of interest include 2008 (planning year to address the 2009 attainment year for basic ozone nonattainment ares), 2009 (planning year to address the 2010 attainment year for $PM_{2.5}$ and moderate ozone nonattainment areas), 2012 (planning to address a 2013 alternative attainment date), and 2018 (first milestone year for regional haze).

Air Quality Analyses: The weight-of-evidence approach relies on data analysis and modeling. Air quality data analyses were used to provide both a conceptual model (i.e., a qualitative description of the ozone, $PM_{2.5}$, and regional haze problems) and supplemental information for the attainment demonstration. Given uncertainties in emissions inventories and modeling, especially for $PM_{2.5}$, these data analyses are a necessary part of the overall technical support.

Modeling includes baseyear analyses for 2002 and 2005 to evaluate model performance and future year strategy analyses to assess candidate control strategies. The analyses were conducted in accordance with USEPA's modeling guidelines (USEPA, 2007a). The PM/haze modeling covers the full calendar year (2002 and 2005) for an eastern U.S. 36 km domain, while the ozone modeling focuses on the summer period (2002 and 2005) for a Midwest 12 km subdomain. The same model (CAMx) was used for ozone, $PM_{2.5}$, and regional haze.

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[5] Since 1999, MRPO has received almost $10M in RPO grant funds from USEPA.

Section 2.0 Ambient Data Analyses

An extensive network of air quality monitors in the 5-state region provides data for ozone (and its precursors), $PM_{2.5}$ (both total mass and individual chemical species), and visibility. These data are used to determine attainment/nonattainment designations, support SIP development, and provide air quality information to public (see, for example, www.airnow.gov).

Analyses of the data were conducted to produce a conceptual model, which is a qualitative summary of the physical, chemical, and meteorological processes that control the formation and distribution of pollutants in a given region. This section reviews the relevant data analyses and describes our understanding of ozone, $PM_{2.5,}$ and regional haze with respect to current conditions, data variability (spatial, temporal, and chemical), influence of meteorology (including transport patterns), precursor sensitivity, and source culpability.

2.1 Ozone

In 1979, USEPA adopted an ozone standard of 0.12 ppm, averaged over a 1-hour period. This standard is attained when the number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.0, averaged over a 3-year period. An alternative means of judging attainment is to take the 4th highest daily 1-hour value over a 3-year period (i.e., the design value). An exceedance is defined as a peak 1-hour ozone concentration equal to or greater than 0.12 ppm and a violation is defined as a design value equal to or greater than 0.12 ppm.

In 1997, USEPA tightened the ozone standard to 0.08 ppm, averaged over an 8-hour period[6]. The standard is attained if the 3-year average of the 4th-highest daily maximum 8-hour average ozone concentrations (i.e., the design value) measured at each monitor within an area is less than 0.08 ppm (or 85 ppb).

Current Conditions: A map of the 8-hour ozone design values at each monitoring site in the region for the 3-year period 2005-2007 is shown in Figure 1. The “hotter” colors represent higher concentrations, where yellow and orange dots represent sites with design values above the standard. Currently, there are 19 sites in violation of the 8-hour ozone NAAQS in the 5-state region, including sites in the Lake Michigan area, Detroit, Cleveland, Cincinnati, and Columbus.

Table 1 provides the 4th-highest daily 8-hour ozone values and the associated design values since 2001 for several high monitoring sites throughout the region.

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[6] On June 20, 2007, USEPA proposed to tighten further the 8-hour ozone standard to increase public health protection and prevent environmental damage from ground-level ozone. USEPA proposed to set the primary (health) standard to a level within the range of 0.070-0.075 ppm (70-75 ppb), averaged over an 8-hour period, and proposed two options for the secondary (welfare) standard: establish a cumulative standard (daily ozone concentrations over a 3-month period) or make the secondary standard identical to the proposed primary standard.

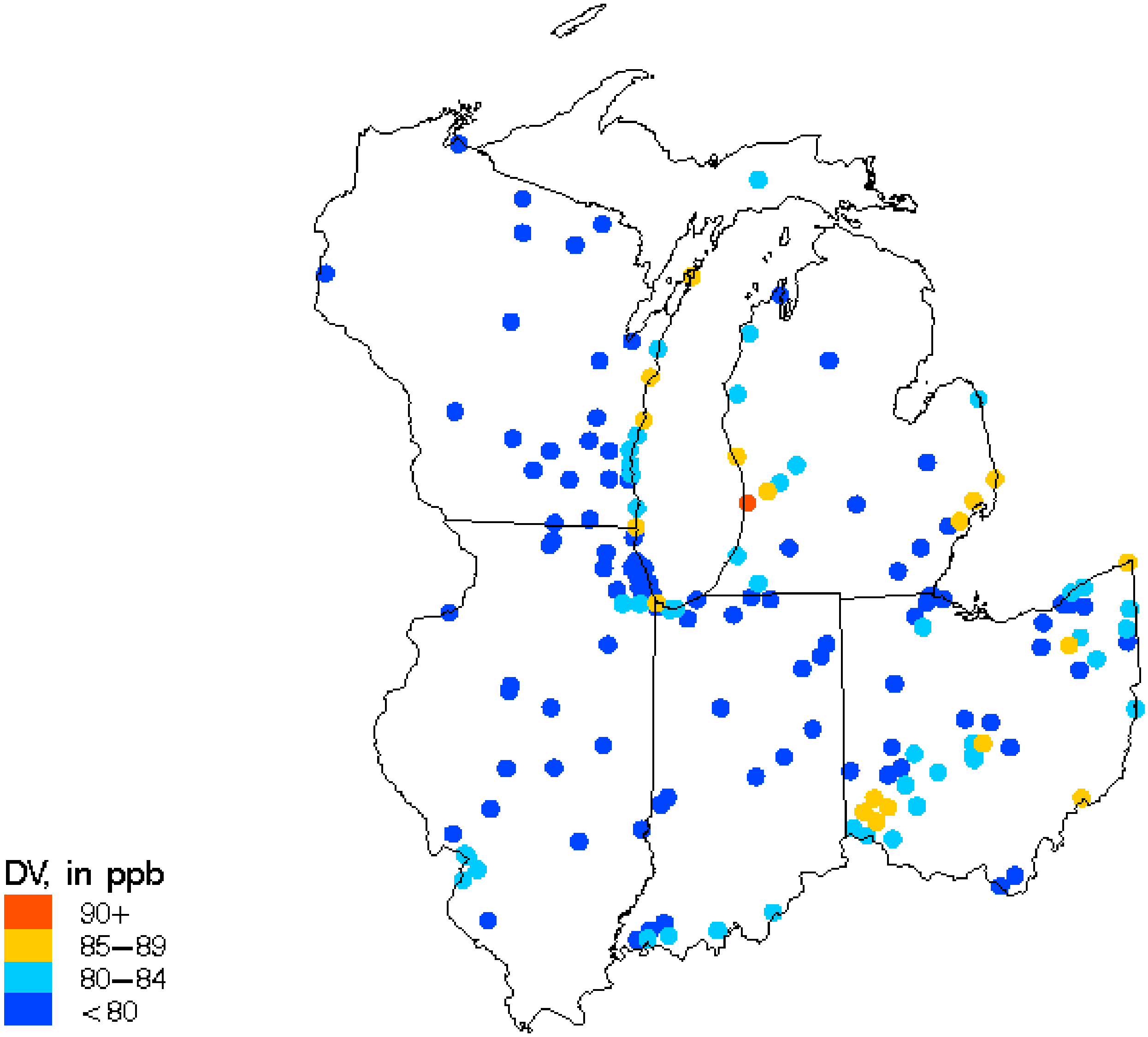


Figure 1. 8-hour ozone design values (2005-2007)

Ozone Data for Select Sites in 5-State Region

Final 2007 data (preliminary)

Key Sites	**4th High 8-hour Value**								**Design Values**				
	'01	**'02**	**'03**	**'04**	**'05**	**'06**	**'07**		**'01-'03**	**'02-'04**	**'03-'05**	**'04-'06**	**'05-'07**
Lake Michigan Area													
Chiwaukee	99	116	88	78	93	79	85		**101**	**94**	**86**	83	**85**
Racine	92	111	82	69	95	71	77		**95**	**87**	82	78	81
Milwaukee-Bayside	93	99	92	73	93	73	83		**94**	**88**	**86**	79	83
Harrington Beach	102	93	99	72	94	72	84		**98**	**88**	**88**	79	83
Manitowoc	97	83	92	74	95	78	84		**90**	83	**87**	82	**85**
Sheboygan	102	105	93	78	97	83	88		**100**	**92**	**89**	**86**	**89**
Kewaunee	90	92	97	73	88	76	85		**93**	**87**	**86**	*79*	83
Door County	95	95	93	78	101	79	92		**94**	**88**	**90**	**86**	**90**
Hammond	90	101	81	67	87	75	77		**90**	83	78	76	79
Whiting				64	88	81	88					77	**85**
Michigan City	90	107	82	70	84	75	72		**93**	**86**	78	76	77
Ogden Dunes	85	101	77	69	90	70	84		**87**	82	78	76	81
Holland	92	105	95	79	94	91	95		**97**	**93**	**89**	**88**	**93**
Jenison	86	93	91	69	86	83	89		**90**	84	82	79	**86**
Muskegon	95	96	94	70	90	91	88		**95**	**86**	84	83	**89**
Indianapolis Area													
Noblesville	88	101	101	75	87	79	84		**96**	**92**	**87**	80	83
Fortville	89	101	92	72	80	76	81		**94**	**88**	81	76	79
Fort B. Harrison	87	100	91	73	80	76	83		**92**	**88**	81	76	79
Detroit Area													
New Haven	95	95	102	81	88	79	92		**97**	**92**	**90**	82	**86**
Warren	94	92	101	71	89	78	90		**95**	**88**	**87**	79	**85**
Port Huron	84	100	86	74	88	78	89		**90**	**86**	82	80	**85**
Cleveland Area													
Ashtabula (Conneaut)	97	103	99	81	93	86	92		**99**	**94**	**91**	**86**	**90**
Notre Dame (Geauga)	99	115	97	75	88	70	68		**103**	**95**	**86**	77	75
Eastlake (Lake)	89	104	92	79	97	83	74		**95**	**91**	**89**	**86**	84
Akron (Summit)	98	103	89	77	89	77	91		**96**	**89**	**85**	81	**85**
Cincinnati Area													
Wilmington (Clinton)	93	99	96	78	83	81	82		**96**	**91**	**85**	80	82
Sycamore (Hamilton)	88	100	93	76	89	80	90		**93**	**89**	**86**	81	**86**
Hamilton (Butler)	83	100	94	75	86	79	91		**92**	**89**	**85**	80	**85**
Middleton (Butler)	87	98	83	76	88	76	91		**89**	**85**	82	80	**85**
Lebanon (Warren)	85	98	95	81	92	86	88		**92**	**91**	**89**	**86**	**88**
Columbus Area													
London (Madison)	84	97	90	75	81	76	83		**90**	**87**	82	77	80
New Albany (Franklin)	90	103	94	78	92	82	87		**95**	**91**	**88**	84	**87**
Franklin (Franklin)	83	99	84	73	86	79	79		**88**	**85**	81	79	81
Ohio Other Areas													
Marietta (Washington)	85	95	80	77	88	81	86		**86**	84	81	82	**85**
St. Louis Area													
W. Alton (MO)	85	99	91	77	89	91	89		**91**	**89**	**85**	**85**	**89**
Orchard (MO)	88	98	90	76	92	92	83		**92**	**88**	**86**	**86**	**89**
Sunset Hills (MO)	88	98	88	70	89	80	89		**91**	**85**	82	79	**86**
Arnold (MO)	86	93	82	70	92	79	87		**87**	81	81	80	**86**
Margaretta (MO)	80	98	90	72	91	76	91		**89**	**86**	84	79	**86**
Maryland Heights (MO)					88	84	94						**88**

Meteorology and Transport: Most pollutants exhibit some dependence on meteorological factors, especially wind direction, because that governs which sources are upwind and thus most influential on a given sample. Ozone is even more dependent, since its production is driven by high temperatures and sunlight, as well as precursor concentrations (see, for example, Figure 2).

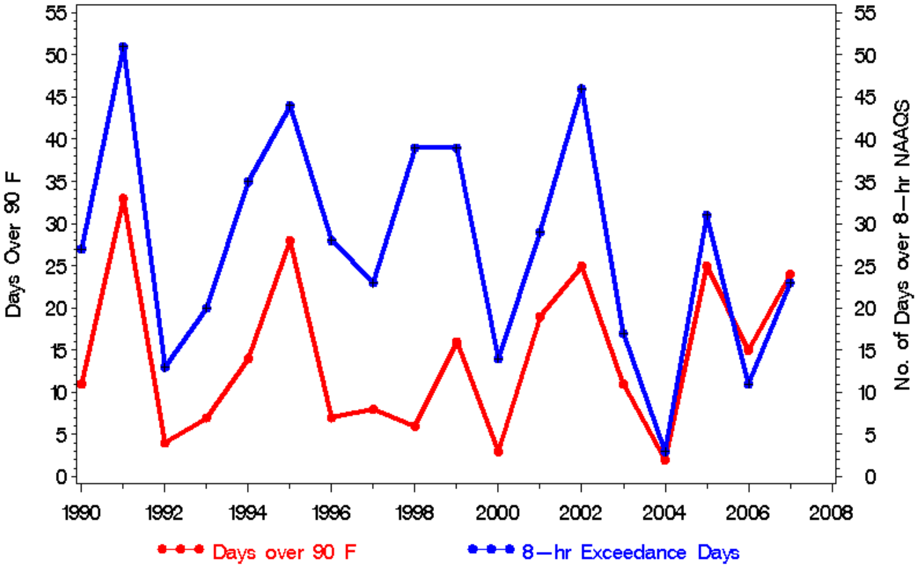
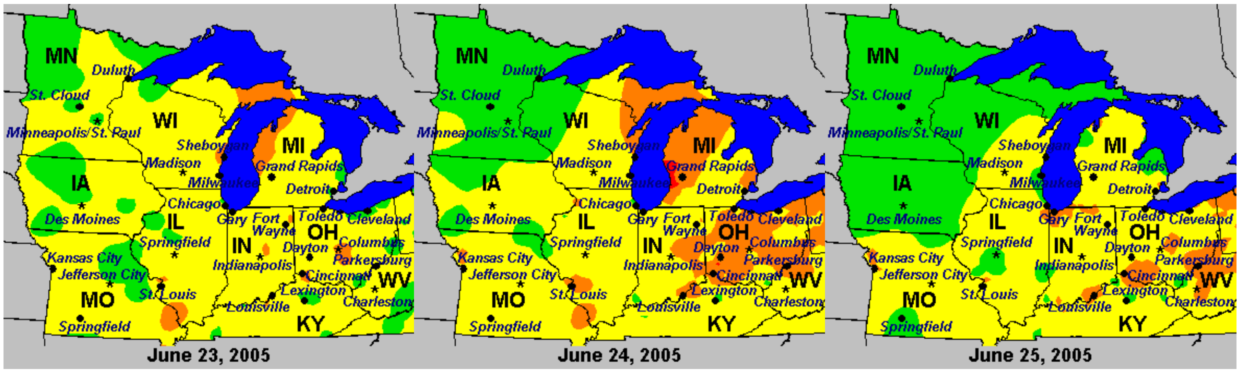


Figure 2. Number of hot days and 8-hour "exceedance" days in 5-state region

Qualitatively, ozone episodes in the region are associated with hot weather, clear skies (sometimes hazy), low wind speeds, high solar radiation, and southerly to southwesterly winds. These conditions are often a result of a slow-moving high pressure system to the east of the region. The relative importance of various meteorological factors is discussed later in this section.

Transport of ozone (and its precursors) is a significant factor and occurs on several spatial scales. Regionally, over a multi-day period, somewhat stagnant summertime conditions can lead to the build-up in ozone and ozone precursor concentrations over a large spatial area. This pollutant air mass can be advected long distances, resulting in elevated ozone levels in locations far downwind. An example of such an episode is shown in Figure 3.

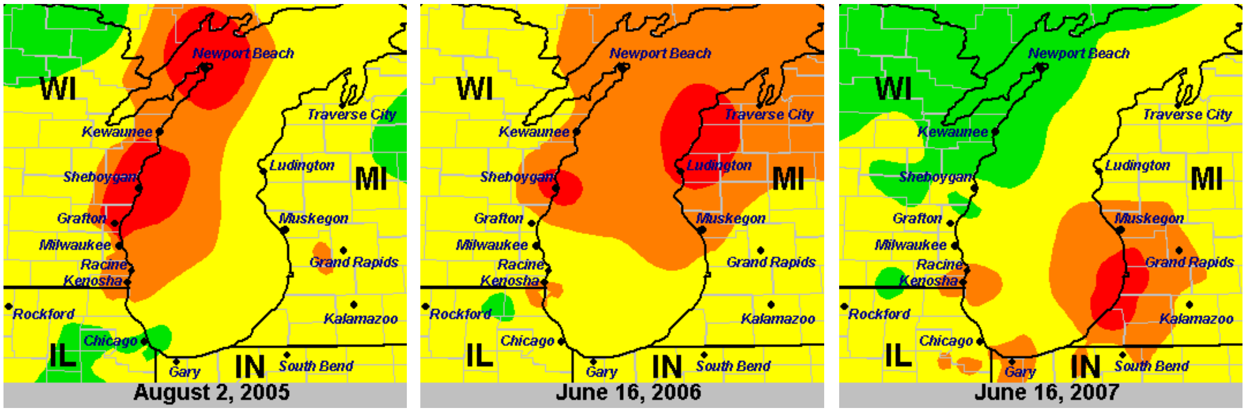


June 23, 2005 June 24, 2005 June 25, 2005

Figure 3. Example of elevated regional ozone concentrations (June 23 – 25, 2005)

Note: hotter colors represent higher concentrations, with orange representing concentrations above the 8-hour standard

Locally, emissions from urban areas add to the regional background leading to ozone concentration hot spots downwind. Depending on the synoptic wind patterns (and local land-lake breezes), different downwind areas are affected (see, for example, Figure 4).



August 2, 2005 June 16, 2006 June 16, 2007

Figure 4. Examples of recent high ozone days in the Lake Michigan area

Note: hotter colors represent higher concentrations, with orange representing concentrations above the 8-hour standard

Aloft (aircraft) measurements in the Lake Michigan area also provide evidence of elevated regional background concentrations and "plumes" from urban areas. For one example summer day (August 20, 2003 – see Figure 5), the incoming background ozone levels were on the order of 80 – 100 ppb and the downwind ozone levels over Lake Michigan were on the order of 100-150 ppb (STI, 2004).

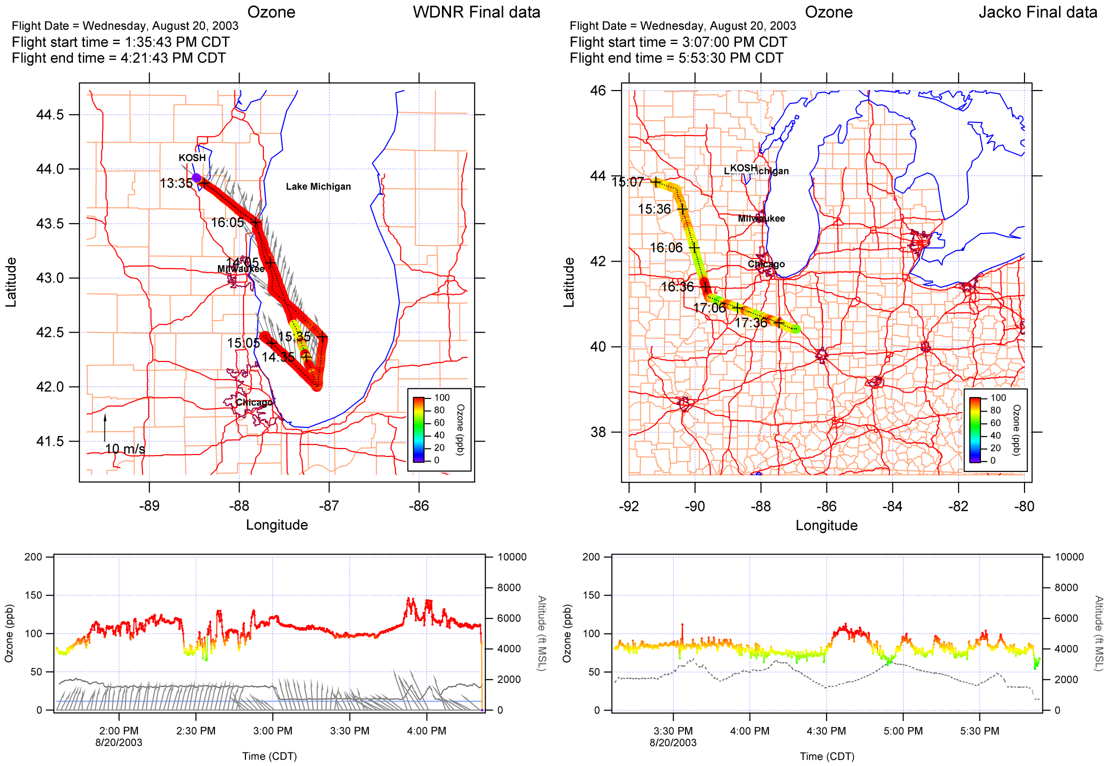


Figure 5. Aircraft ozone measurements over Lake Michigan (left) and along upwind boundary (right) – August 20, 2003 (Note: aircraft measurements reflect instantaneous values)

As discussed in Section 4, residual nonattainment is projected in at least one area in the 5-state region –i.e., western Michigan. To understand the source regions likely impacting high ozone concentrations in western Michigan and estimate the impact of these source regions, two simple transport-related analyses were performed.

First, back trajectories were constructed using the HYSPLIT model for high ozone days (8 -hour peak > 80 ppb) during the period 2002 -2006 in western Michigan to characterize general transport patterns. Composite trajectory plots for all high ozone days based on data from three sites (Cass County, Holland, and Muskegon) are provided in Figure 6. The plots point back to areas located to the south-southwest (especially, northeastern Illinois and northwestern Indiana) as being upwind on these high ozone days.

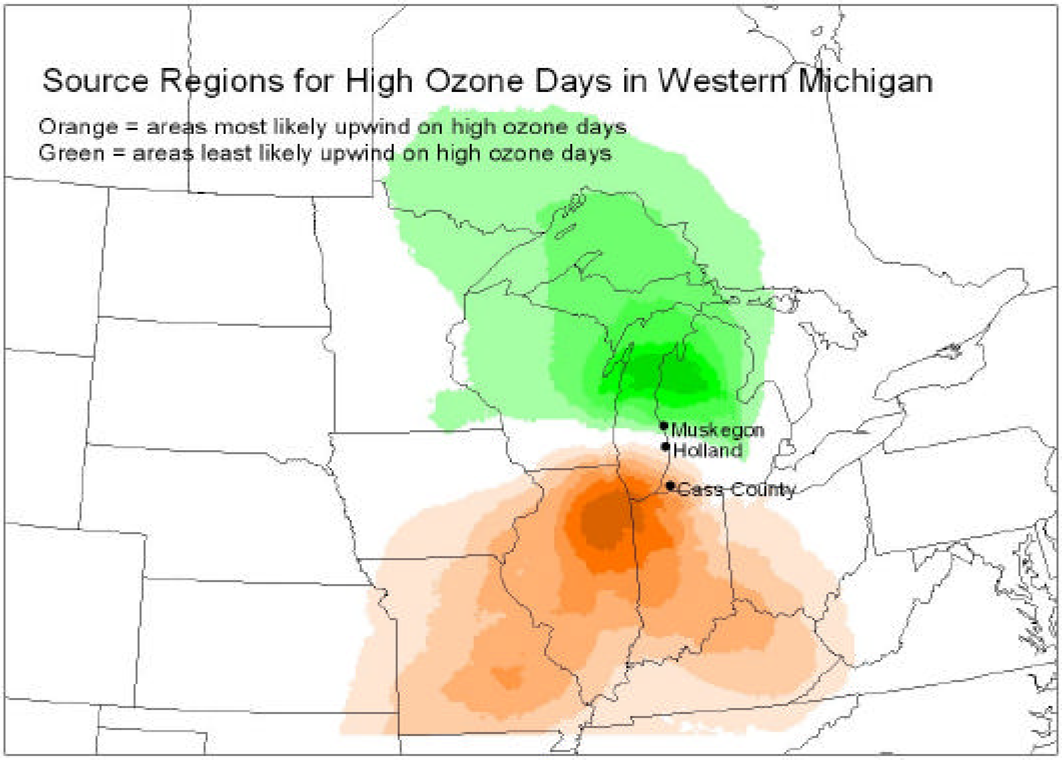


Figure 6 Back trajectory analysis showing upwind areas associated with high ozone concentrations

Second, to assess the impact from Chicago/NW Indiana, Blanchard (2005a) compared ozone concentrations upwind (Braidwood, IL), within Chicago (ten sites in the City), and downwind (Holland and Muskegon) for days in 1999 – 2002 with southwesterly winds - i.e., transport towards western Michigan. Figure 7 shows the distribution of daily peak 8-hour ozone concentrations by day-of-week, with a line connecting the mean values. The difference between day-of-week mean values at downwind and upwind sites indicates that Chicago/NW Indiana contributes about 10-15 ppb to downwind ozone levels.

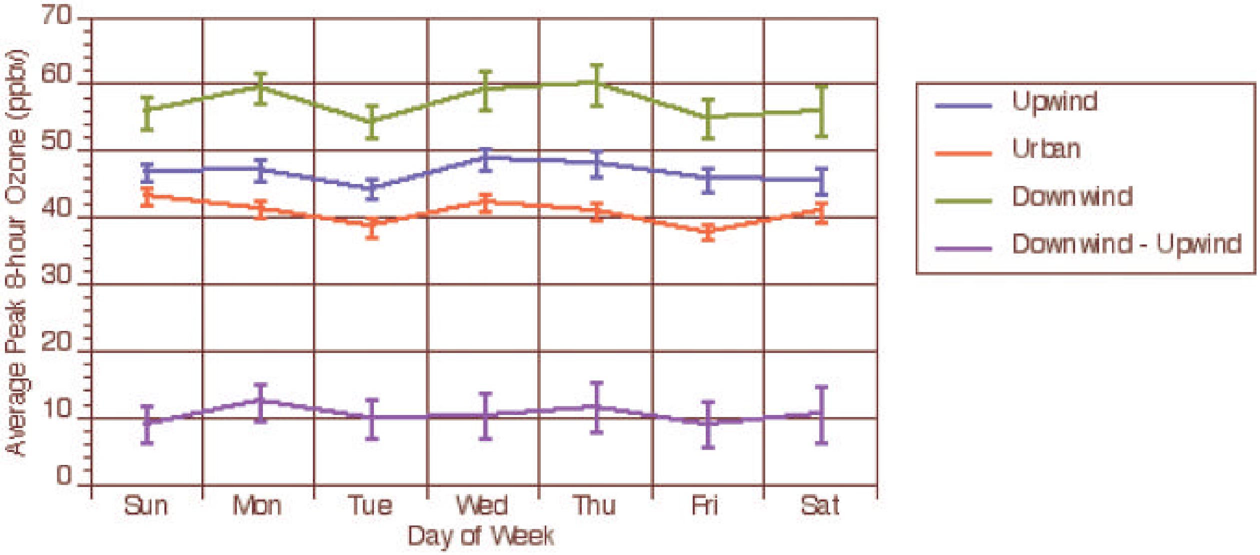


Figure 7. Mean day-of-week peak 8-hour ozone concentrations at sites upwind, within, and downwind of Chicago, 1999 – 2002 (southwesterly wind days)

Based on this information, the following key findings related to transport can be made:

- Ozone transport is a problem affecting many portions of the eastern U.S. The Lake Michigan area (and other areas in the LADCO region) both receive high levels of incoming (transported) ozone and ozone precursors from upwind source areas on many hot summer days, and contribute to the high levels of ozone and ozone precursors affecting downwind receptor areas.

- The presence of a large body of water (i.e., Lake Michigan) influences for the formation and transport of ozone in the Lake Michigan area. Depending on large-scale synoptic winds and local-scale lake breezes, different parts of the area experience high ozone concentrations. For example, under southerly flow, high ozone can occur in eastern Wisconsin, and under southwesterly flow, high ozone can occur in western Michigan.

- Downwind shoreline areas around Lake Michigan are affected by both regional transport of ozone and subregional transport from major cities in the Lake Michigan area. Counties along the western shore of Michigan (from Benton Harbor to Traverse City, and even as far north as the Upper Peninsula) are impacted by high levels of incoming (transported) ozone.

Data Variability: Since 1980, considerable progress has been made to meet the previous 1-hour ozone standard. Figure 8 shows the decline in both the 1-hour and 8-hour design values for the 5-state LADCO region over the last 25 years.

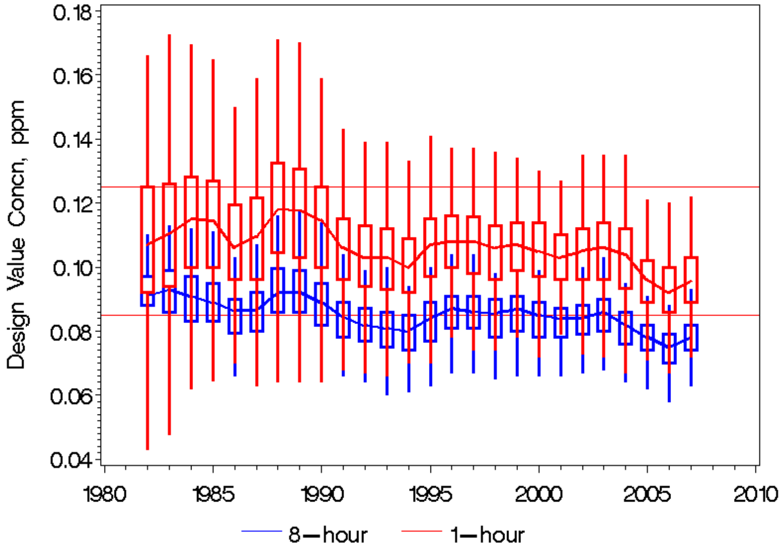


Figure 8 Ozone design value trends in 5-State region

The trend is more dramatic for the higher ozone sites in the 5-state region (see Figure 9). This plot shows a pronounced downward trend in the design value since the 2001-2003 period, due, in part, to the very low 4th high values in 2004.

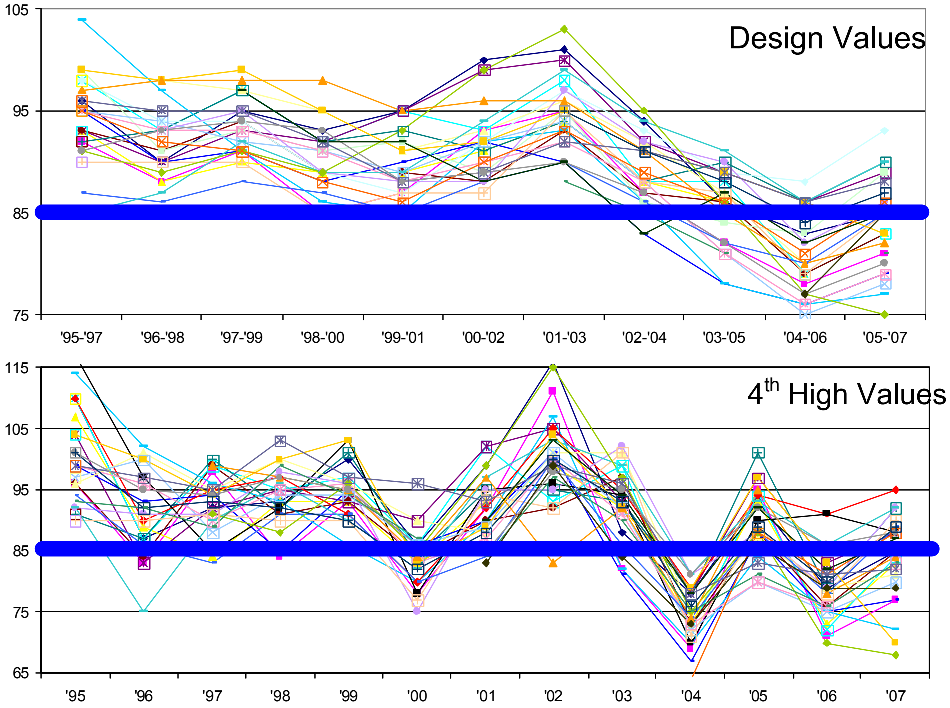


Figure 9. Trend in ozone design values and 4th high values for higher ozone sites in region

The improvement in ozone concentrations is also seen in the decrease in the number of sites measuring nonattainment over the past 15 years in the Lake Michigan area (see Figure 10).

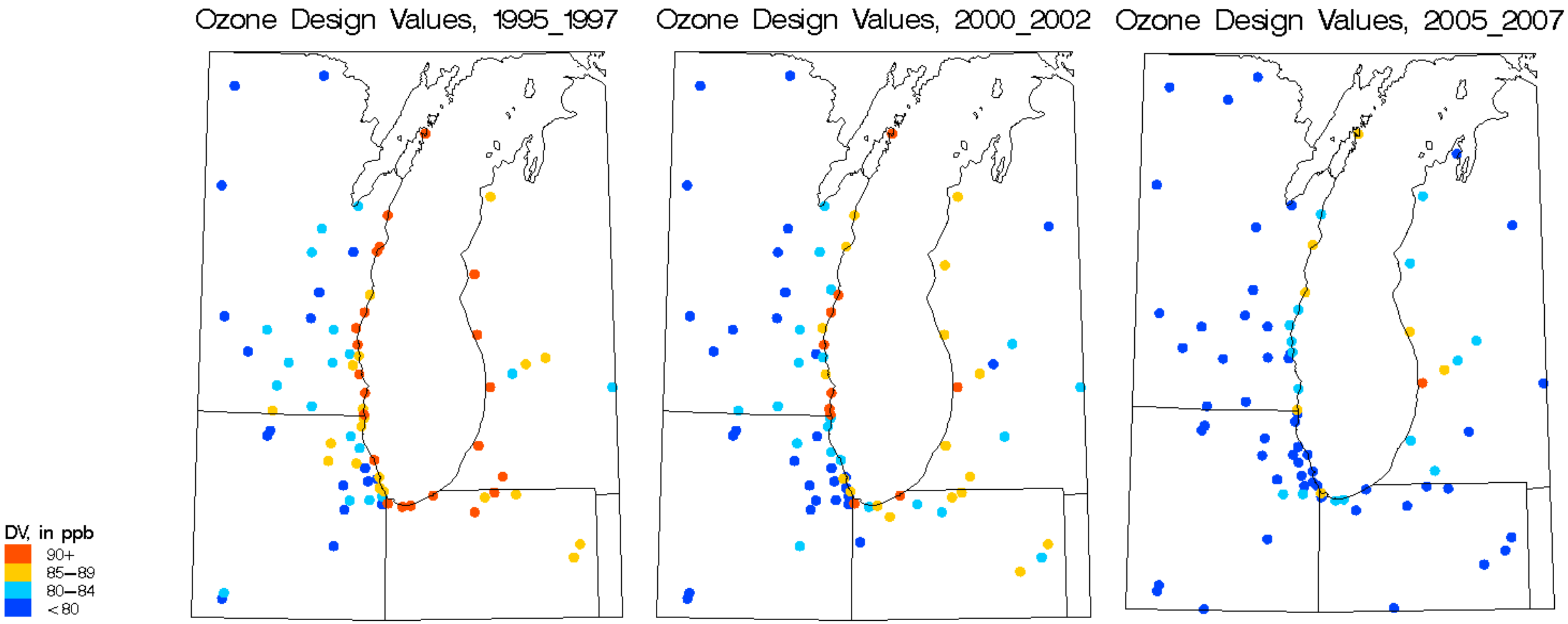


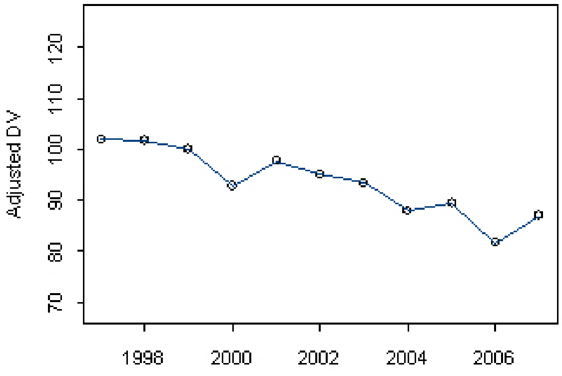
Figure 10. Ozone design value maps for 1995-1997, 2000-2002, and 2005-2007

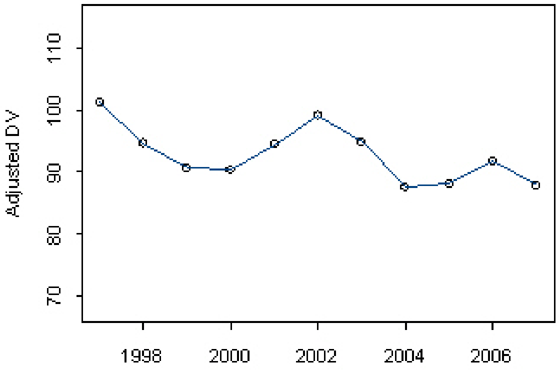
Given the effect of meteorology on ambient ozone levels, year-to-year variations in meteorology can make it difficult to assess trends in ozone air quality. Two approaches were considered to adjust ozone trends for meteorological influences: an air quality-meteorology statistical model developed by USEPA (i.e., Cox method), and statistical grouping of meteorological variables performed by LADCO (i.e., Classification and Regression Trees, or CART).

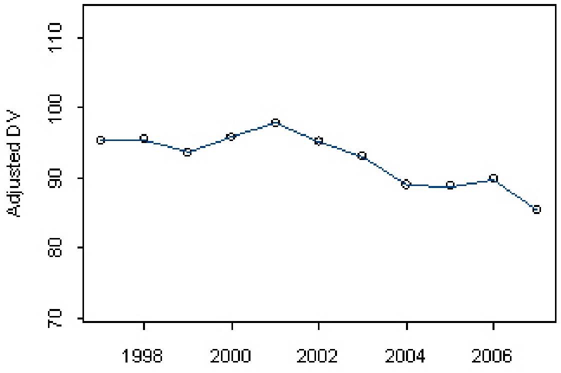
Cox Method: This method uses a statistical model to 'remove' the annual effect of meteorology on ozone (Cox and Chu, 1993). A regression model was fit to the 1997-2007 data to relate daily peak 8-hour ozone concentrations to six daily meteorological variables plus seasonal and annual factors (Kenski, 2008a). Meteorological variables included were daily maximum temperature, mid-day average relative humidity, morning and afternoon wind speed and wind direction. The model is then used to predict 4th high ozone values. By holding the meteorological effects constant, the long term trend can be examined independently of meteorology. Presumably, any trend reflects changes in emissions of ozone precursors.

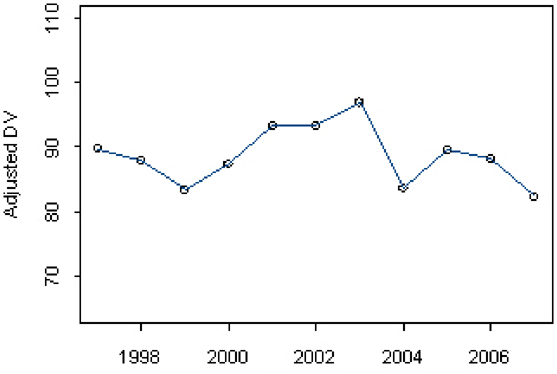
Figure 11a shows the meteorologically-adjusted 4th high ozone concentrations for several monitors near major urban areas in the region. The plots indicate a general downward trend since the late 1990s for most cities, indicating that recent emission reductions have had a positive effect in improving ozone air quality.

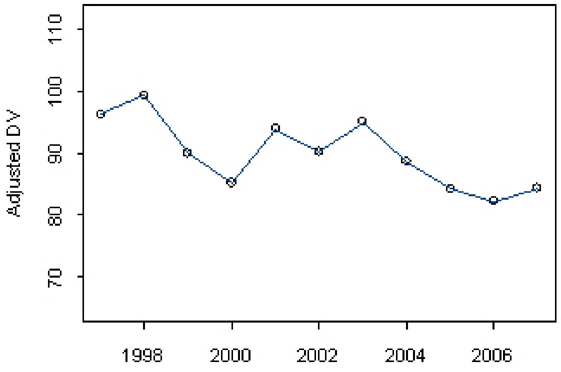
A similar model was run to examine meteorologically adjusted trends in seasonal average ozone. This model incorporates more meteorological variables, including rain and long-distance transport (direction and distance). Model development was documented in Camalier et al., 2007. The seasonal average trends are shown in Figure 11b. Trends determined by seasonal model for the same set of sites examined above are consistent with those developed by the 4th high model.

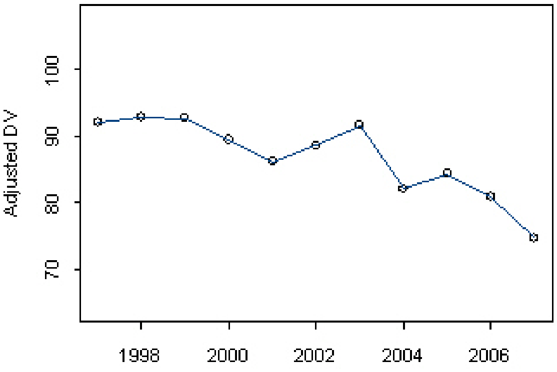

Chiwaukee, WI


Sheboygan, WI


Cleveland (Ashtabula), OH


Cincinnati (Sycamore), OH


Detroit (New Haven), MI


St. Louis, MO

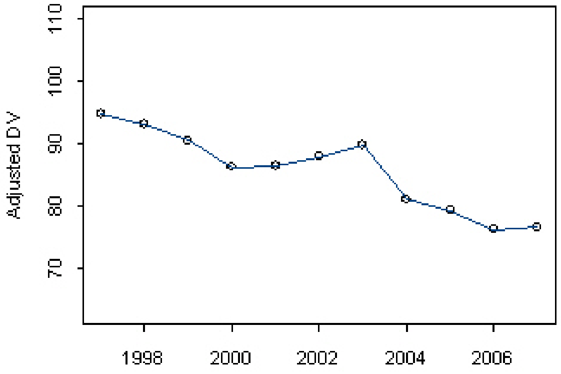

Indianapolis, IN

Figure 11a. Trends in meteorologically adjusted 4th high 8-hour ozone concentrations for seven Midwestern sites (1997 – 2007)

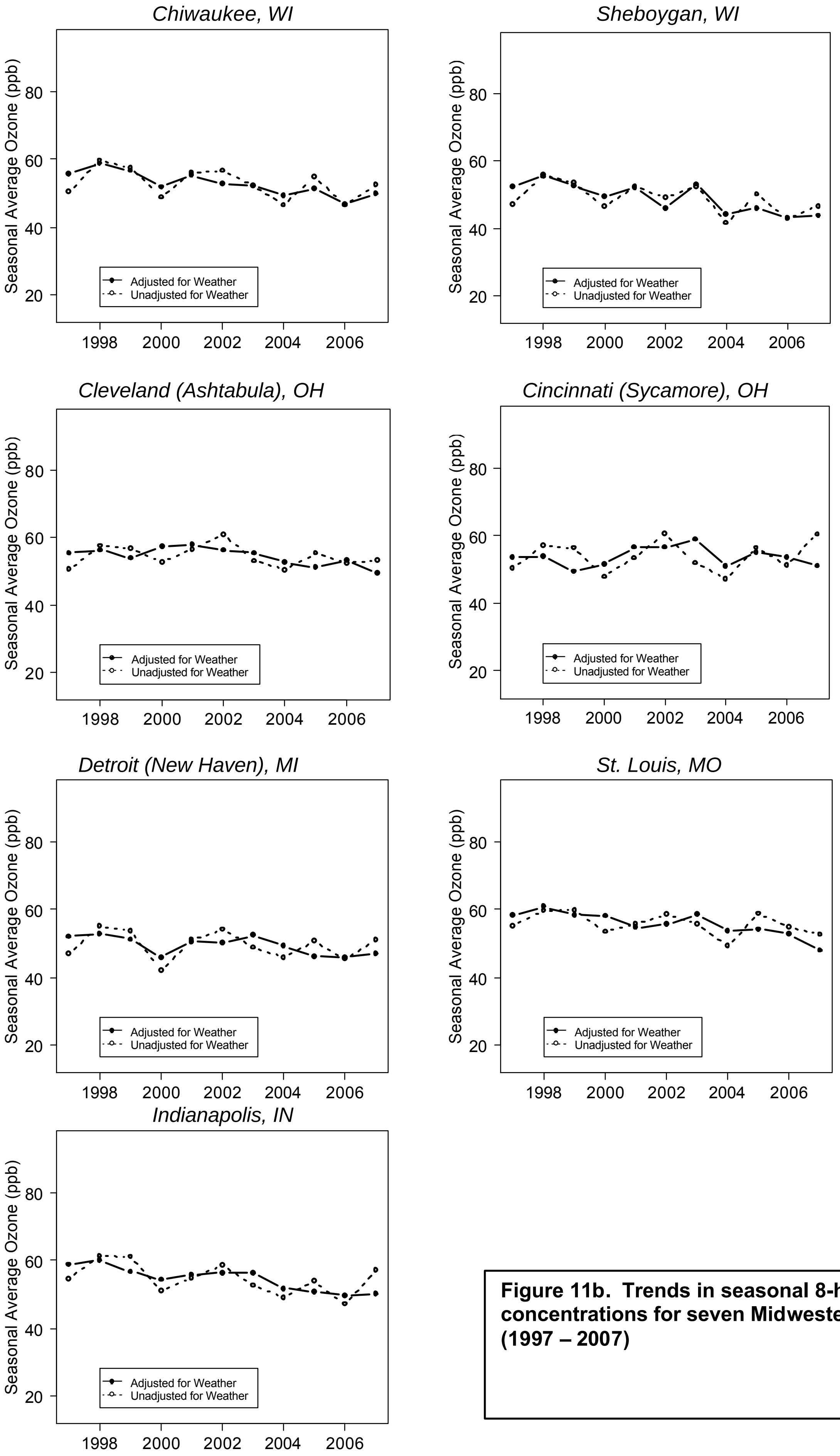


Figure 11b. Trends in seasonal 8-hour ozone concentrations for seven Midwestern sites (1997 – 2007)

CART: Classification and Regression Tree (CART) analysis is another statistical technique which partitions data sets into similar groups (Breiman et al., 1984). CART analysis was performed using data for the period 1995-2007 for 22 selected ozone monitors with current 8-hour design values close to or above the standard (Kenski, 2008b). The CART model searches through 60 meteorological variables to determine which are most efficient in predicting ozone. Although the exact selection of predictive variables changes from site to site, the most common predictors were temperature, wind direction, and relative humidity. Only occasionally were upper air variables, transport time or distance, lake breeze, or other variables significant. (Note, the ozone and meteorological data for the CART analysis are the same as used in the USEPA/Cox analysis.)

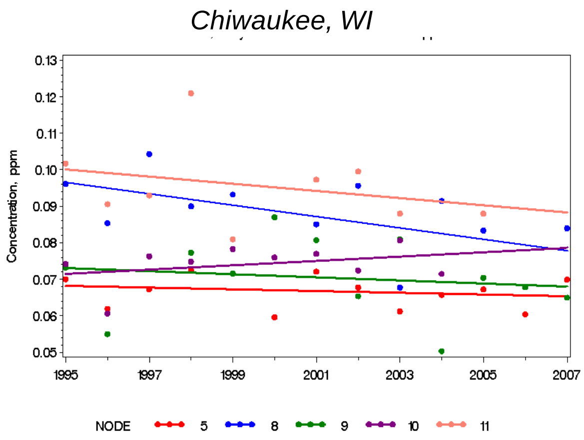
For each monitor, regression trees were developed that classify each summer day (May-September) by its meteorological conditions. Similar days are assigned to nodes, which are equivalent to branches of the regression tree. Ozone time series for the higher concentration nodes are plotted for select sites in Figure 12. By grouping days with similar meteorology, the influence of meteorological variability on the trend in ozone concentrations is partially removed; the remaining trend is presumed to be due to trends in precursor emissions or other non-meteorological influences. Trends over the 13-year period at most sites were found to be declining, with the exception of Detroit which showed fairly flat trends. Comparison of the average of the high concentration node values for 2001-2003 v. 2005-2007 showed an improvement of about 5 ppb across all sites (even Detroit).

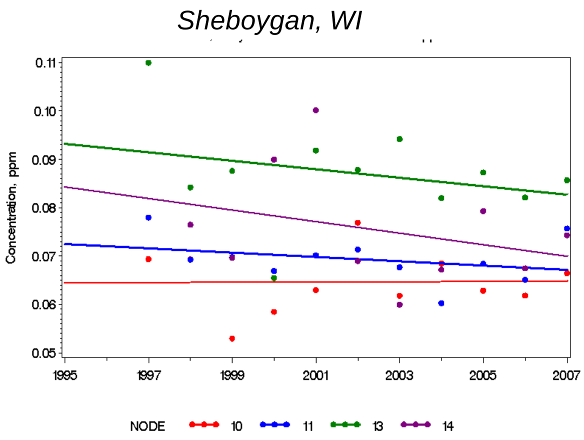
The effect of meteorology was further examined by using an ozone conduciveness index (Kenski, 2008b). This metric reflects the variability from the 13-year average in the number of days in the higher ozone concentration nodes (see Figure 13). Examination of these plots indicates:

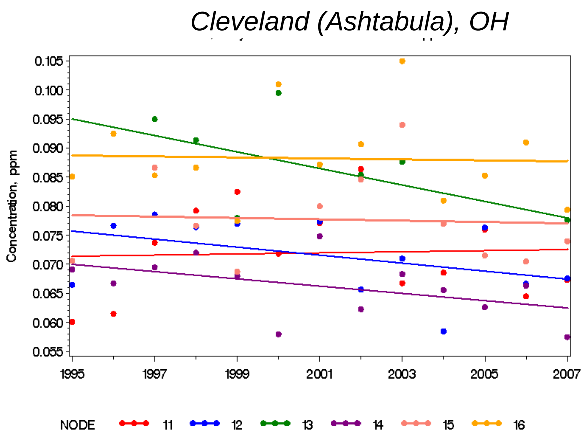
- 2002 and 2005 were both above normal, with 2002 tending to be more severe; and
- 2001-2003 and 2005-2007 were both above normal, with no clear pattern in which period was more severe (i.e., ozone conduciveness values were similar at most sites, 2001-2003 values were higher at a few sites, and 2005-2007 values were higher at a few sites).

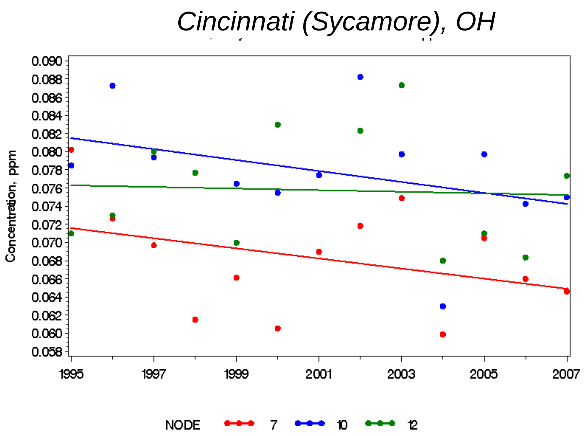
Given the similarity in ozone conduciveness between 2001-2003 and 2005-2007, the improvement in ozone levels noted above is presumed to be due to non-meteorological factors (i.e., emission reductions).

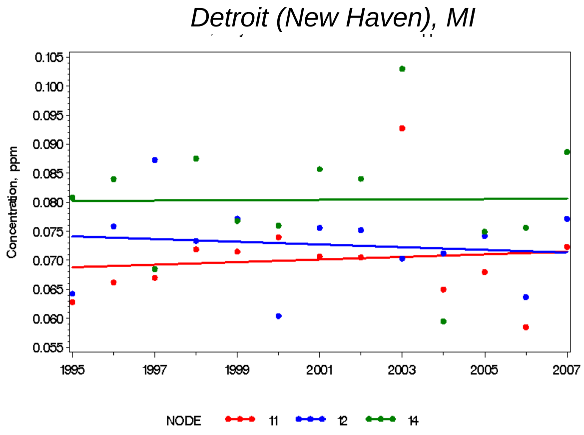
In conclusion, all three statistical approaches (CART and the two nonlinear regression models) show a similar result; ozone in the urban areas of the LADCO region has declined during the 1997-2007 period, even when meteorological variability is accounted for. The decreases are present whether seasonal average ozone, peak values (annual 4th highs), or a subset of high days with similar meteorology are considered. The consistency in results across models is a good indication that these trends reflect impacts of emission control programs.

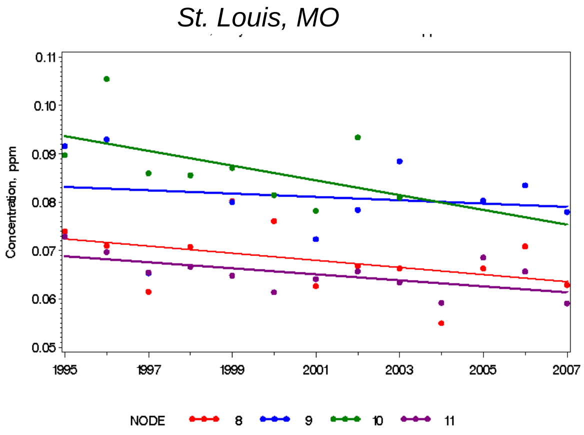












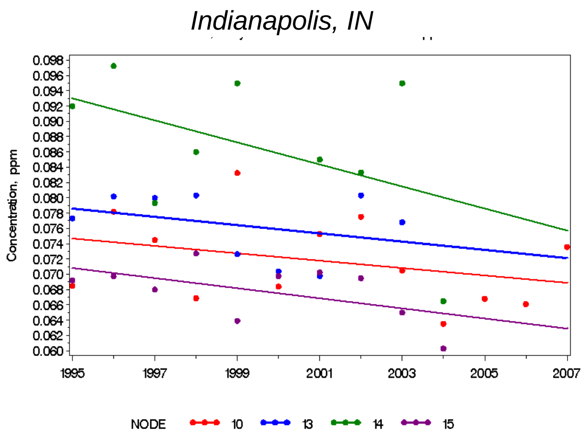
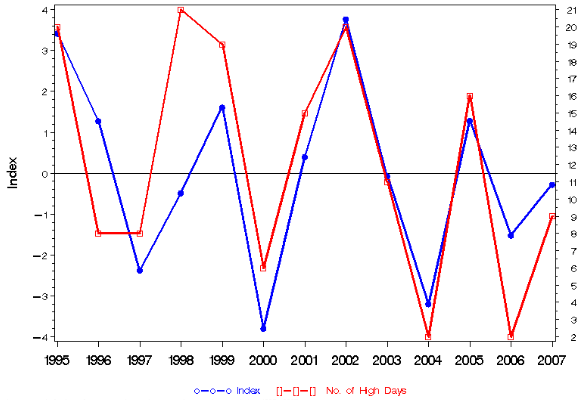


Figure 12. Trends for higher ozone CART groups (average ozone > 65 ppb) for seven Midwestern sites (1995 – 2007)

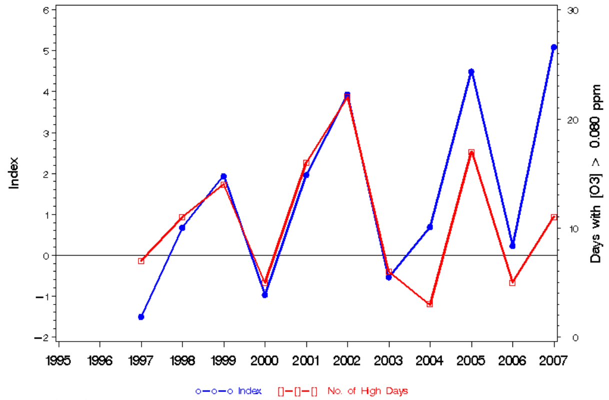
Note: line represents linear best fit

CART Index of Ozone Conduciveness, Wisconsin——Chiwaukee



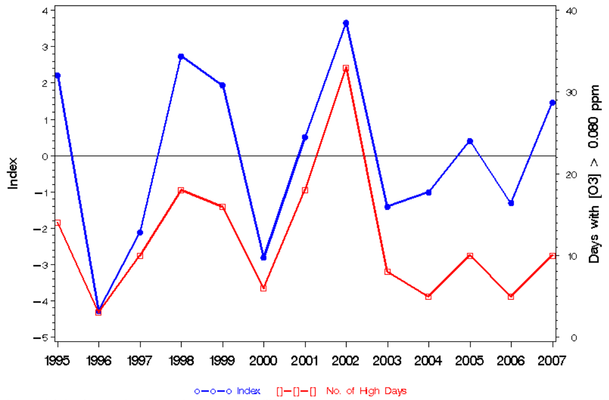
Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, Wisconsin——Sheboygan



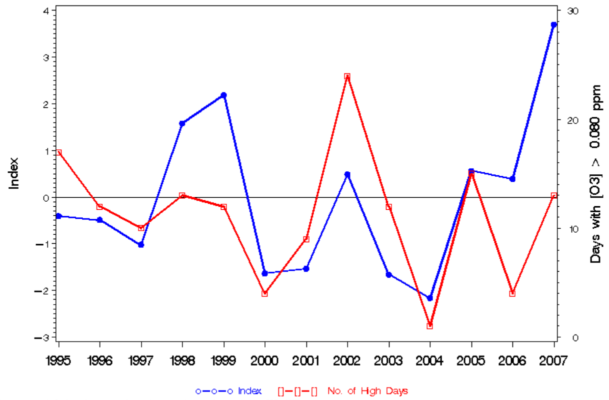
Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, Cleveland—Ashtabula



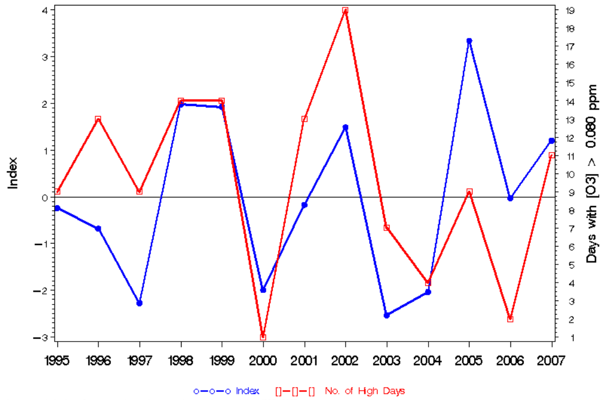
Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, Cincinnati—Sycamore



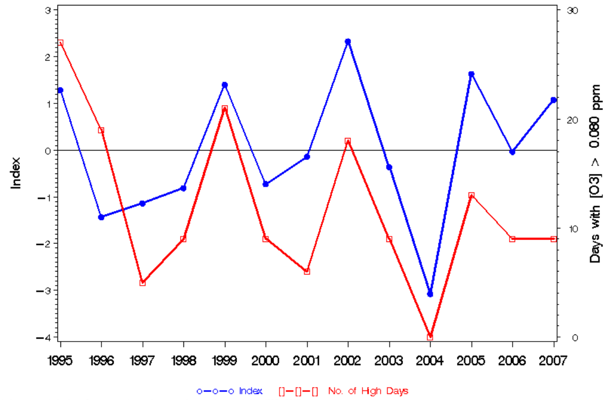
Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, Detroit——New Haven



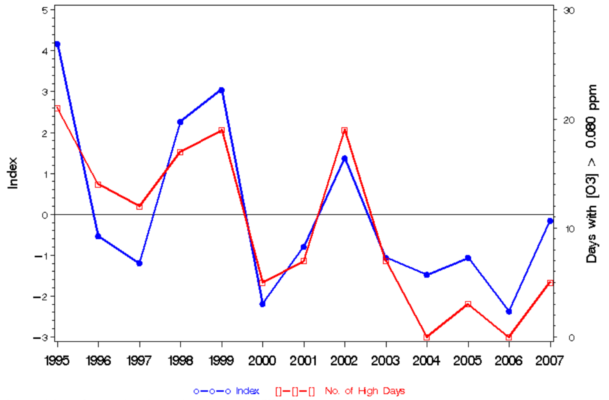
Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, St.Louis——Orchard



Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

CART Index of Ozone Conduciveness, Indianapolis—Ft. Harrison



Index represents fraction of ozone conducive days in each year, above or below 1995—2007 average
1=twice as many days as average year; —1=half as many days as average year

Figure 13. Ozone conduciveness index (and number of high ozone days) for seven Midwestern site (1995 – 2007)

Precursor Sensitivity: Ozone is formed from the reactions of hydrocarbons and nitrogen oxides under meteorological conditions that are conducive to such reactions (i.e., warm temperatures and strong sunlight). In areas with high VOC/NOx ratios, typical of rural environments (with low NOx), ozone tends to be more responsive to reductions in NOx. Conversely, in areas with low VOC/NOx ratios, typical of urban environments (with high NOx), ozone tends to be more responsive to VOC reductions.

An analysis of VOC and NO_x-limitation was conducted with the ozone MAPPER program, which is based on the Smog Production (SP) algorithm (Blanchard, et al., 2004a). The "Extent of Reaction" parameter in the SP algorithm provides an indication of VOC and NOx sensitivity:

Extent Range	**Precursor Sensitivity**
< 0.6	VOC-sensitive
0.6 – 0.8	Transitional
> 0.8	NOx-sensitive

A map of the Extent of Reaction values for high ozone days is provided in Figure 14. As can be seen, ozone is usually VOC-limited in cities and NOx-limited in rural areas. (Data from aircraft measurements suggest that ozone is usually NO_x-limited over Lake Michigan and away from urban centers on days when ozone in the urban centers is VOC-limited.) The highest ozone days were found to be NO_x-limited. This analysis suggests that a NOx reduction strategy would be effective in reducing ozone levels. Examination of day-of-week concentrations, however, raises some question about the effectiveness of NOx reductions.

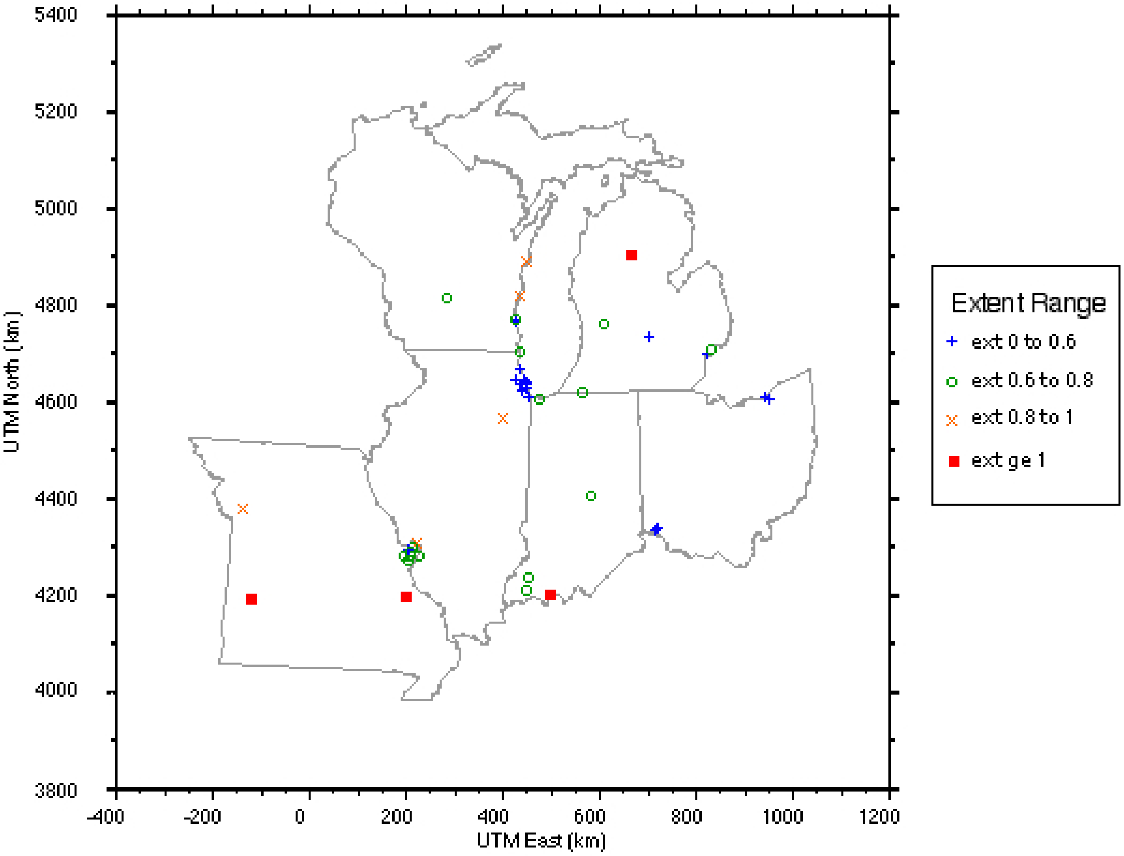


Figure 14. Mean afternoon extent of reaction (1998 – 2002)

Blanchard (2004a and 2005a) examined weekend-weekday differences in ozone and NO_x in the Midwest. All urban areas in these two studies exhibited substantially lower (40-60%) weekend concentrations of NO_x compared to weekday concentrations. Despite lower weekend NO_x concentrations, weekend ozone concentrations were not lower; in fact, most urban sites had higher concentrations of ozone, although the increase was generally not statistically significant (see Figure 15). This small but counterproductive change in **local** ozone concentrations suggests that **local** urban-scale NO_x reductions alone may not be very effective.

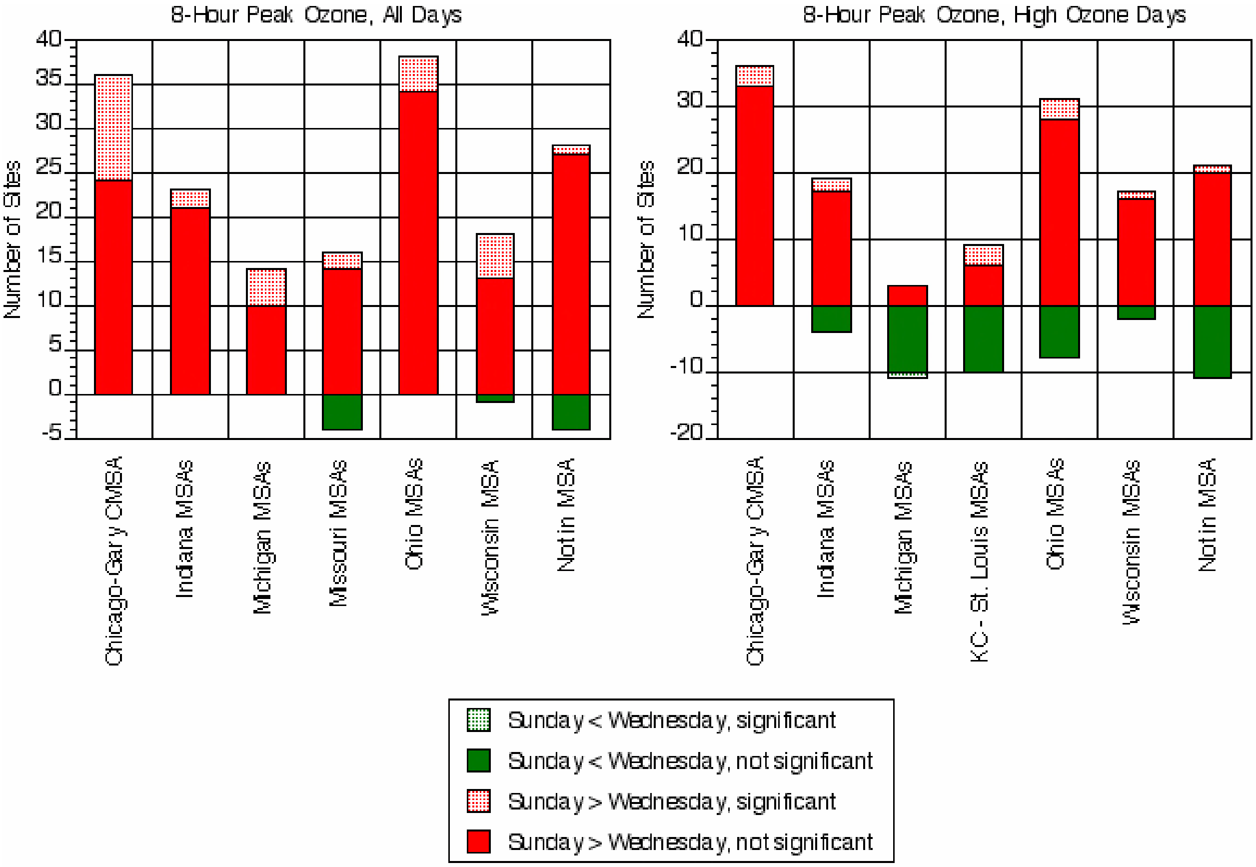


Figure 15. Weekday/weekend differences in 8-hour ozone – number of sites with weekend increase (positive values) v. number of sites with weekend decreases (negative values)

Two additional analyses, however, demonstrate the positive effect of NOx emission reductions on downwind ozone concentrations. First, Blanchard (2005a) looked at the effect of changes in precursor emissions in Chicago on downwind ozone levels in western Michigan. For the transport days of interest (i.e., southwesterly flow during the summers of 1999 – 2002), mean NOx concentrations in Chicago are about 50% lower and mean ozone concentrations at the (downwind) western Michigan sites are about 1.5 – 5.2 ppb (3 – 8 %) lower on Sunday compared to Wednesday. This degree of change in downwind ozone levels suggests a positive, albeit non-linear response to urban area emission reductions.

Second, Environ (2007a) examined the effect of differences in day-of-week emissions in southeastern Michigan on downwind ozone levels. This modeling study found that weekend changes in ozone precursor emissions cause both increases and decreases in Southeast Michigan ozone, depending upon location and time:

- Weekend increases in 8-hour maximum ozone occur in and immediately downwind of the Detroit urban area (i.e., in VOC-sensitive areas).
- Weekend decreases in 8-hour maximum ozone occur outside and downwind of the Detroit urban area (i.e., in NOx-sensitive areas).
- At the location of the peak 8-hour ozone downwind of Detroit, ozone was lower on weekends than weekdays.
- Ozone benefits (reductions) due to weekend emission changes in Southeast Michigan can be transported downwind for hundreds of miles.
- Southeast Michigan benefits from lower ozone transported into the region on Saturday through Monday because of weekend emission changes in upwind areas.

In summary, these analyses suggest that urban VOC reductions and regional (urban and rural) NOx reductions will be effective in lowering ozone concentrations. Local NOx reductions can lead to local ozone increases (i.e., NOx disbenefits), but this effect does not appear to pose a problem with respect to attainment of the standard. It should also be noted that urban VOC and regional NOx reductions are likely to have multi-pollutant benefits (e.g., both lower ozone and $PM_{2.5}$ impacts).

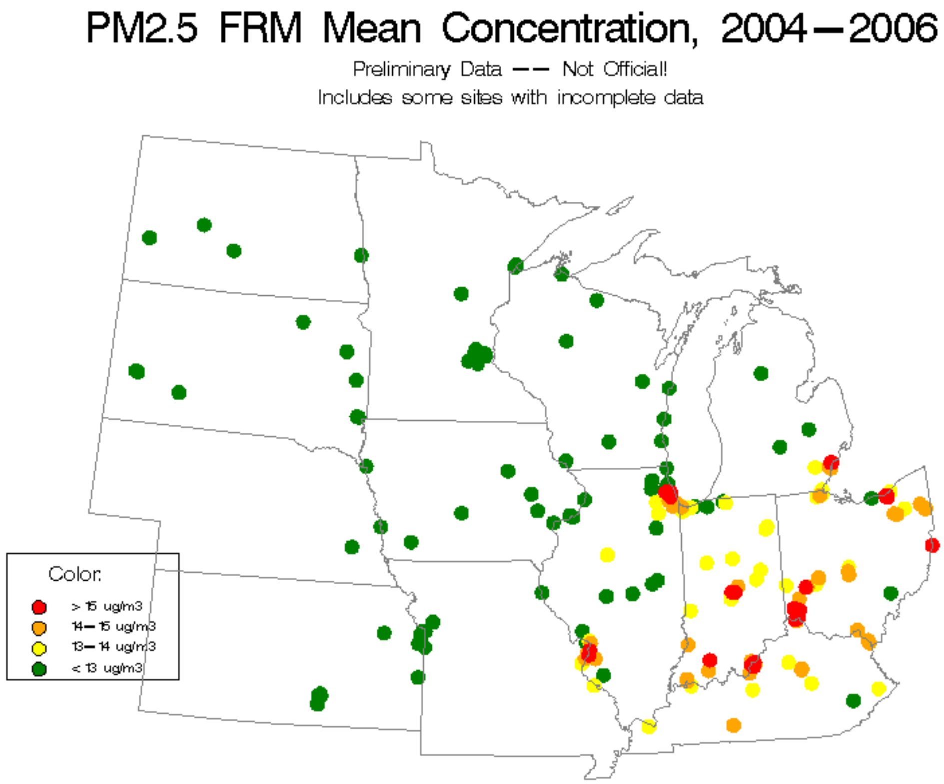
2.2 $PM_{2.5}$

In 1997, USEPA adopted the $PM_{2.5}$ standards of 15 ug/m^3 (annual average) and 65 ug/m3 (24-hour average). The annual standard is attained if the 3-year average of the annual average $PM_{2.5}$ concentration is less than or equal to the level of the standard. The daily standard is attained if the 98th percentile of 24-hour $PM_{2.5}$ concentrations in a year, averaged over three years, is less than or equal to the level of the standard.

In 2006, USEPA revised the $PM_{2.5}$ standards to 15 ug/m^3 (annual average) and 35 ug/m^3 (24-hour average).

Current Conditions: Maps of annual and 24-hour $PM_{2.5}$ design values for the 3-year period 2004-2006 are shown in Figure 16. The "hotter" colors represent higher concentrations, where red dots represent sites with design values above the annual standard. Currently, there are 38 sites in violation of the annual $PM_{2.5}$ standard.

Table 2 provides the annual $PM_{2.5}$ concentrations and the associated design values since 2003 for several high monitoring sites throughout the region.



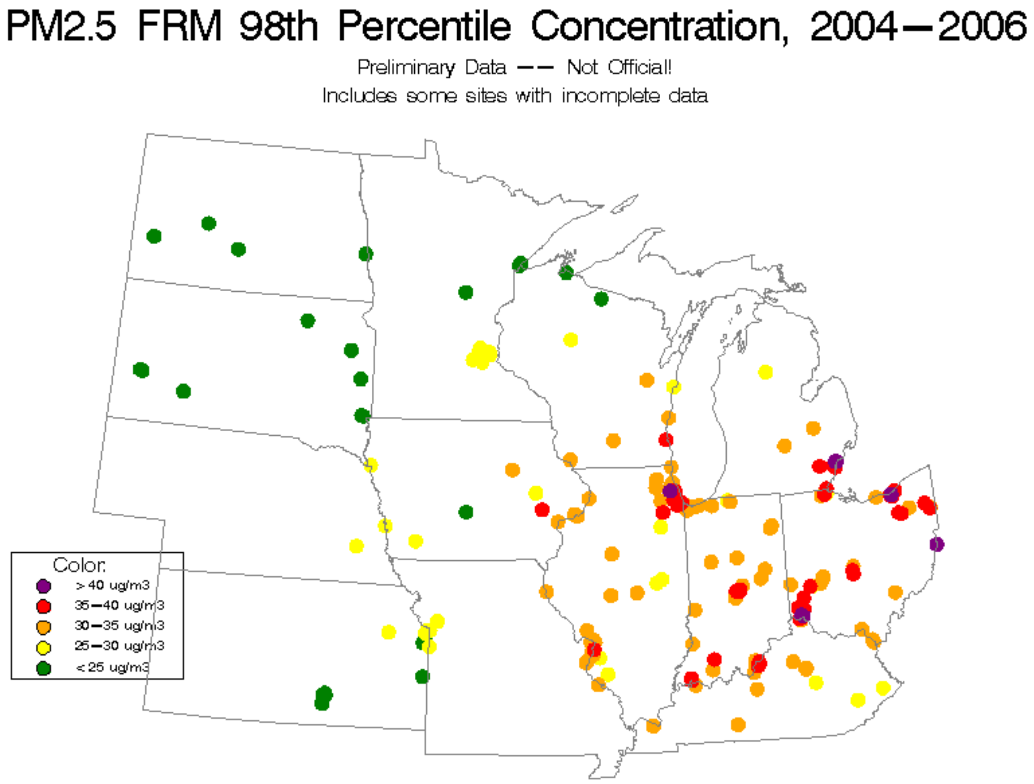


Figure 16. PM$_{2.5}$ design values - annual average (top) and 24-hour average (bottom)– 2004-2006

			Annual Average Conc.						Design Values				2005 BY	2002 BY
Key Site	**County**	**Site ID**	**'03**	**'04**	**'05**	**'06**	**'07**		**'03 - '05**	**'04 - '06**	**'05 - '07**		**Average w/o 2007**	**Average**
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2			15.6	14.8	15.1		**15.1**	**15.9**
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5			16.1	15.6	15.8		**15.8**	**17.1**
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5			15.4	14.7	15.1		**15.0**	**15.6**
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5			15.2	14.8	15.1		**15.0**	**15.6**
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2			15.1	14.6	14.8		14.8	**15.6**
Schiller Park	Cook	170313103		16.0	17.6	14.8			16.8	16.1	16.2		16.4	
Summit	Cook	170313301	15.6	14.2	16.9	13.8			15.6	15.0	15.4		**15.3**	**16.0**
Maywood	Cook	170316005	16.8	15.2	16.3	14.3			16.1	15.3	15.3		**15.6**	**16.4**
Granite City	Madison	171191007	17.5	15.4	18.2	16.3			17.0	16.6	17.3		**17.0**	**17.3**
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5			15.6	15.4	15.8		**15.6**	**16.2**
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0			16.5	16.2	16.8		**16.5**	**16.3**
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5			15.7	14.9	15.2		**15.3**	**16.1**
Gary	Lake	180890031			16.8	13.3			16.8	15.1	15.1		**15.6**	
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1			15.4	14.9	15.3		**15.2**	**16.2**
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1			16.3	15.5	15.8		**15.9**	**16.4**
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2			15.1	14.4	14.6		14.7	**15.8**
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7			16.4	15.8	16.0		**16.0**	**17.3**
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0			15.2	14.2	14.5		14.6	**15.5**
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1			18.2	17.2	17.4		**17.6**	**19.3**
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9			15.5	14.3	14.7		14.8	**16.6**
Middleton	Butler	390170003	17.2	14.1	19.0	14.1			16.8	15.7	16.6		**16.4**	**16.5**
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0			16.1	15.5	16.0		**15.9**	**15.9**
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0			16.1	15.3	15.2		**15.5**	**16.5**
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9			18.1	17.2	17.1		**17.5**	**18.4**
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1			17.0	16.2	16.7		**16.6**	**16.7**
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0			17.7	16.9	17.2		**17.3**	**17.6**
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1			16.5	15.6	15.9		**16.0**	**16.2**
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6			15.9	15.0	15.0		**15.3**	**16.5**
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8			15.5	15.0	15.2		**15.2**	**16.0**
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9			14.4	13.7	13.8		13.9	**16.0**
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5			17.6	17.1	17.7		**17.4**	**17.7**
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6			15.9	15.2	15.6		**15.6**	**15.7**
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9			17.3	16.7	17.0		**17.0**	**17.3**
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5			15.8	15.4	15.7		**15.7**	**16.0**
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4			16.6	16.0	16.4		**16.3**	**16.3**
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9			17.9	17.4	18.0		**17.8**	**17.3**
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8			16.7	15.4	15.1		**15.7**	**17.7**
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6			17.2	16.3	16.4		**16.6**	**17.5**
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4			15.0	15.0	15.7		**15.2**	**15.7**
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6			15.9	15.2	15.5		**15.5**	**15.9**
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3			14.6	14.5	15.3		14.8	**17.1**
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6			16.7	16.0	16.2		**16.3**	**17.3**
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9			15.2	14.2	14.3		14.6	**15.7**
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5			15.6	15.0	15.0		**15.2**	**16.4**
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8			14.6	14.1	14.3		14.3	**15.6**

When USEPA initially set the 24-hour standard at 65 µg/m^3, it also adopted the following concentration ranges for its Air Quality Index (AQI) scale:

Good	< 15 ug/m^3
Moderate	15-40 µg/m^3
Unhealthy for Sensitive Groups (USG)	40-65 µg/m^3
Unhealthy	65-150 µg/m^3

Figure 17 shows the frequency of these AQI categories for major metropolitan areas in the region. Daily average concentrations are often in the moderate range and occasionally in the USG range. Moderate and USG levels can occur any time of the year.

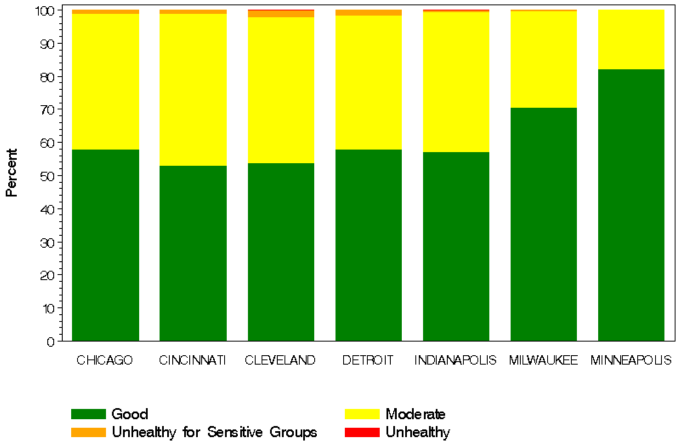


Figure 17. Percent of days in AQI categories for PM$_{2.5}$ (2002-2004)

Data Variability: PM$_{2.5}$ concentrations vary spatially, temporally, and chemically in the region. This variability is discussed further below.

On an annual basis, PM$_{2.5}$ exhibits a distinct and consistent spatial pattern. As seen in Figure 16, across the Midwest, annual concentrations follow a gradient from low values (5-6 µg/m^3) in northern and western areas (Minnesota and northern Wisconsin) to high values (17-18 µg/m^3) in Ohio and along the Ohio River. In addition, concentrations in urban areas are higher than in upwind rural areas, indicating that local urban sources add a significant increment of 2-3 µg/m^3 to the regional background of 12 - 14 µg/m^3 (see Figure 18).

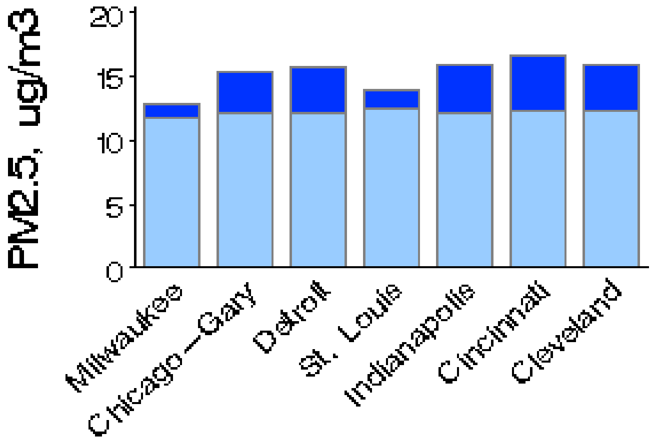


Figure 18. Local (lighter shading) v. regional components (darker shading) of annual average PM$_{2.5}$ concentrations

Because monitoring for $PM_{2.5}$ only began in earnest in 1999, after promulgation of the $PM_{2.5}$ standard, limited data are available to assess trends. Time series based on federal reference method (FRM) $PM_{2.5}$-mass data show a downward trend in each state (see Figure 19)[7].

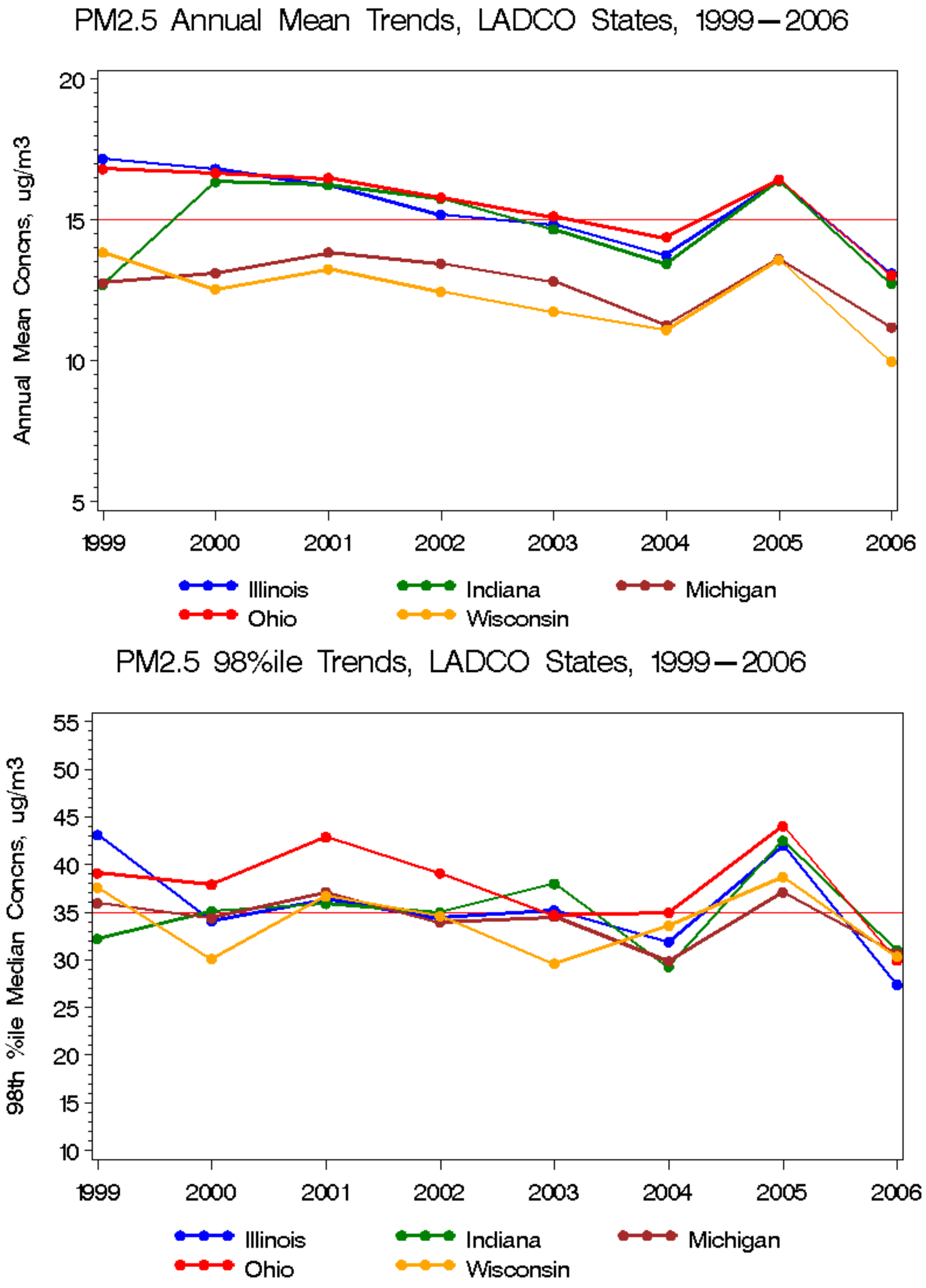


Figure 19. $PM_{2.5}$ trends in annual average (top) and daily concentrations (bottom)

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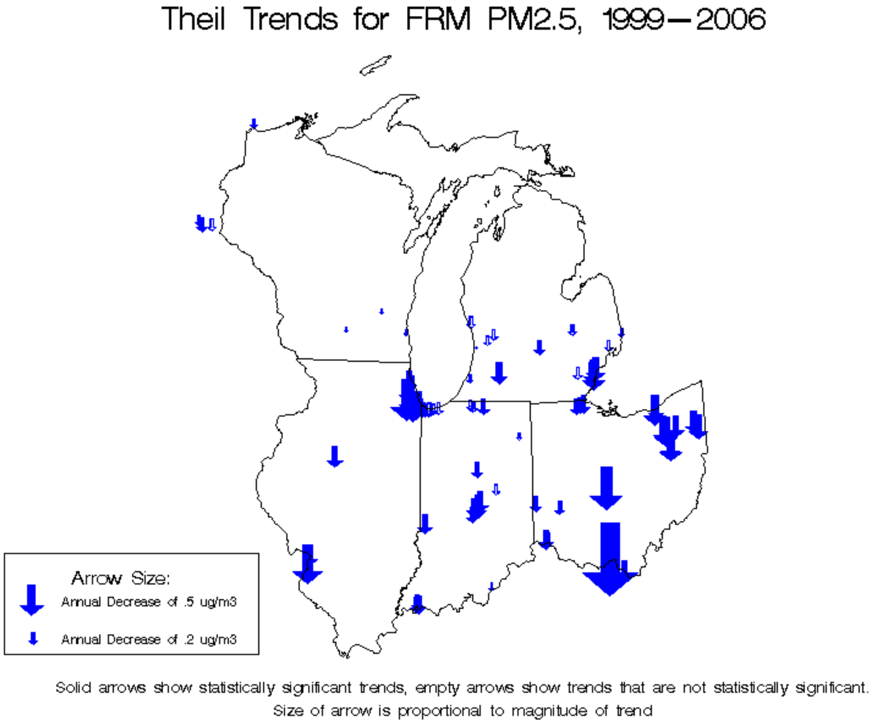
[7] Despite the general downward trend since 1999, all states experienced an increase during 2005. Further analyses are underway to understand this increase (e.g., examination of meteorological and emissions effects).

A statistical analysis of $PM_{2.5}$ trends was performed using the nonparametric Theil test for slope (Hollander and Wolfe, 1973). Trends were generally consistent around the region, for both PM mass and for the individual components of mass. Figure 20 shows trends for $PM_{2.5}$ based on FRM data at sites with six or more years of data since 1999. The size and direction of each arrow shows the size and direction of the trend for each site; solid arrows show statistically significant trends and open arrows show trends that are not significant. Region-wide decreases are widespread and consistent; all sites had decreasing concentration trends (13 of the 38 were statistically significant). The average decrease for this set of sites is -0.24 ug/m^3/year.



Solid arrows show statistically significant trends, empty arrows show trends that are not statistically significant.
Size of arrow is proportional to magnitude of trend

Figure 20. Annual trends in $PM_{2.5}$ mass (1999 – 2006)

Seasonal trends show mostly similar patterns (Figure 21). Trends were downward at most sites and seasons, with overall seasonal averages varying between -0.15 to -0.56 ug/m^3/year. The strongest and most significant decreases took place during the winter quarter (January - March). No statistically significant increasing trends were observed.

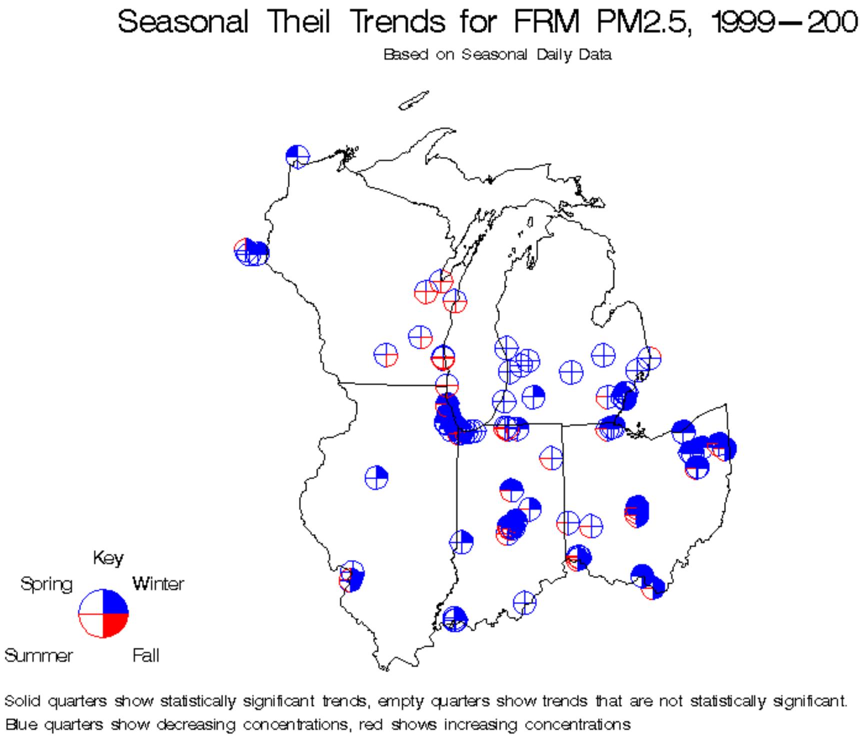


Figure 21. Seasonal trends in $PM_{2.5}$ mass (1999 – 2006)

$PM_{2.5}$ shows a slight variation from weekday to weekend, as seen in Figure 22. Although most cities have slightly lower concentrations on the weekend, the difference is usually less than 1 µg/m^3. There is a more pronounced weekday/weekend difference at monitoring sites that are strongly source-influenced. Rural monitors tend to show less of a weekday/weekend pattern than urban monitors.

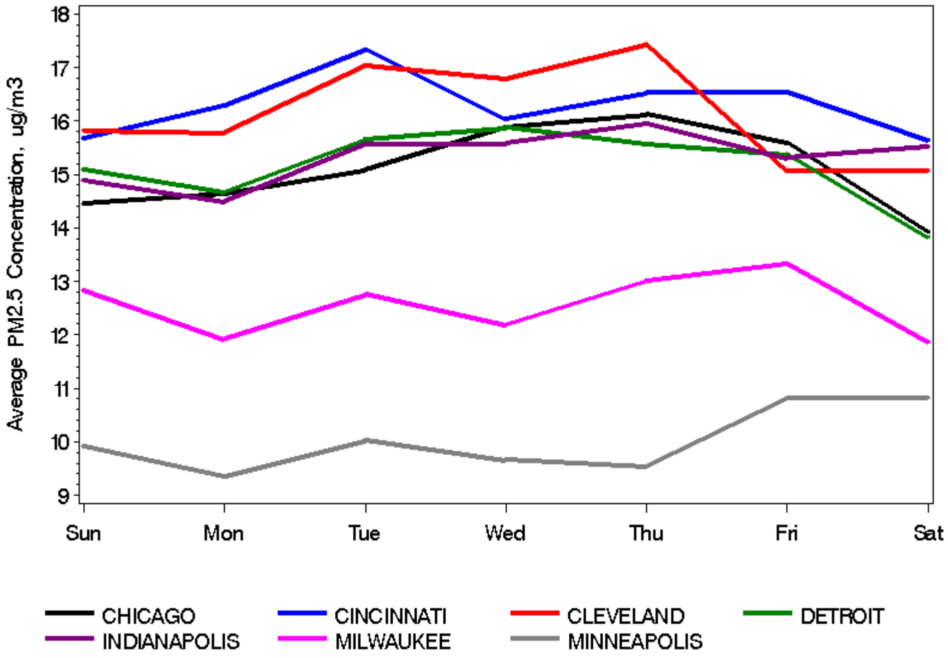


Figure 22 Day-of-week variability in $PM_{2.5}$ (2002-2004)

In the Midwest, $PM_{2.5}$ is made up of mostly ammonium sulfate, ammonium nitrate, and organic carbon in approximately equal proportions on an annual average basis. Elemental carbon and crustal matter (also referred to as soil) contribute less than 5% each.

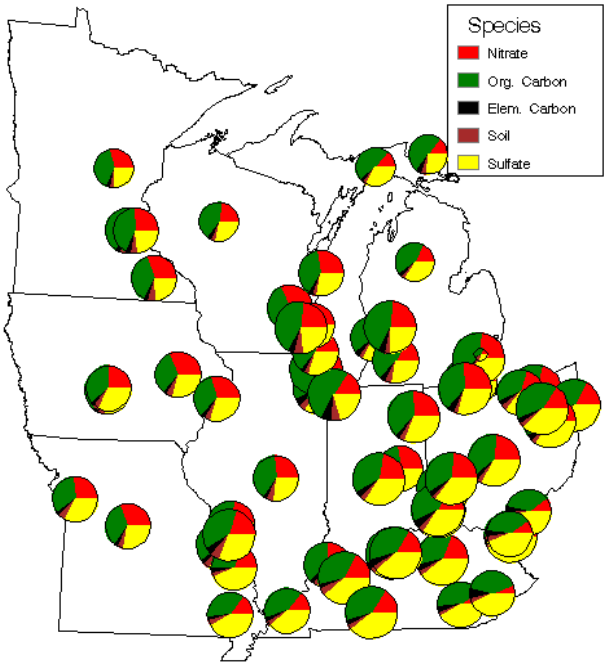


Figure 23. Spatial map of $PM_{2.5}$ chemical composition in the Midwest (2002-2003)

The three major components vary spatially (Figure 23), including notable urban and rural differences (Figure 24). The components also vary seasonally (Figure 25). These patterns account for much of the annual variability in $PM_{2.5}$ mass noted above.

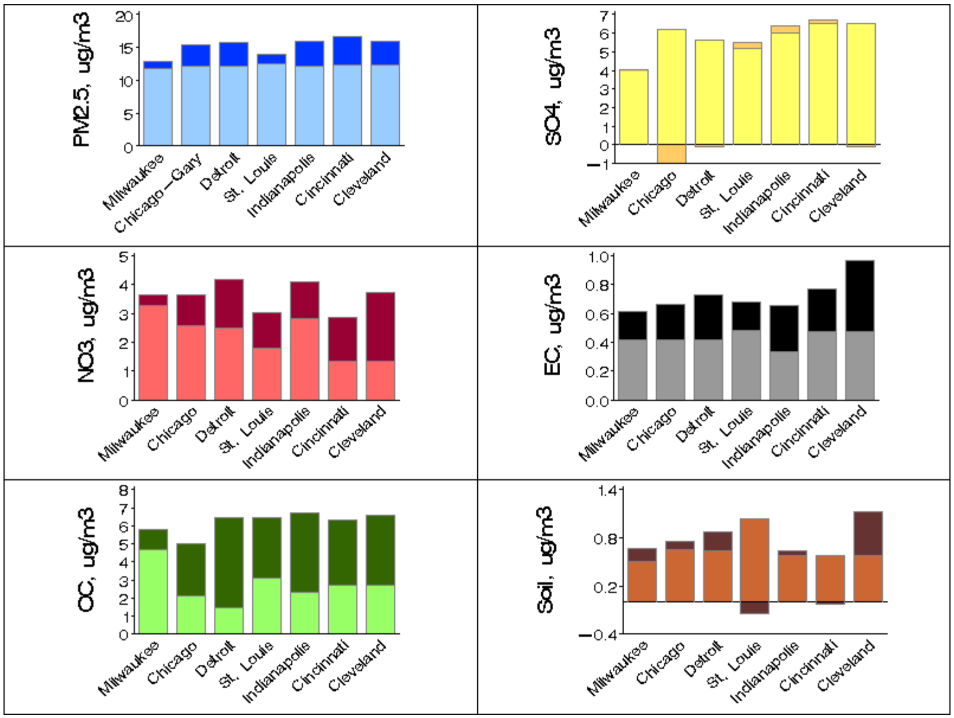
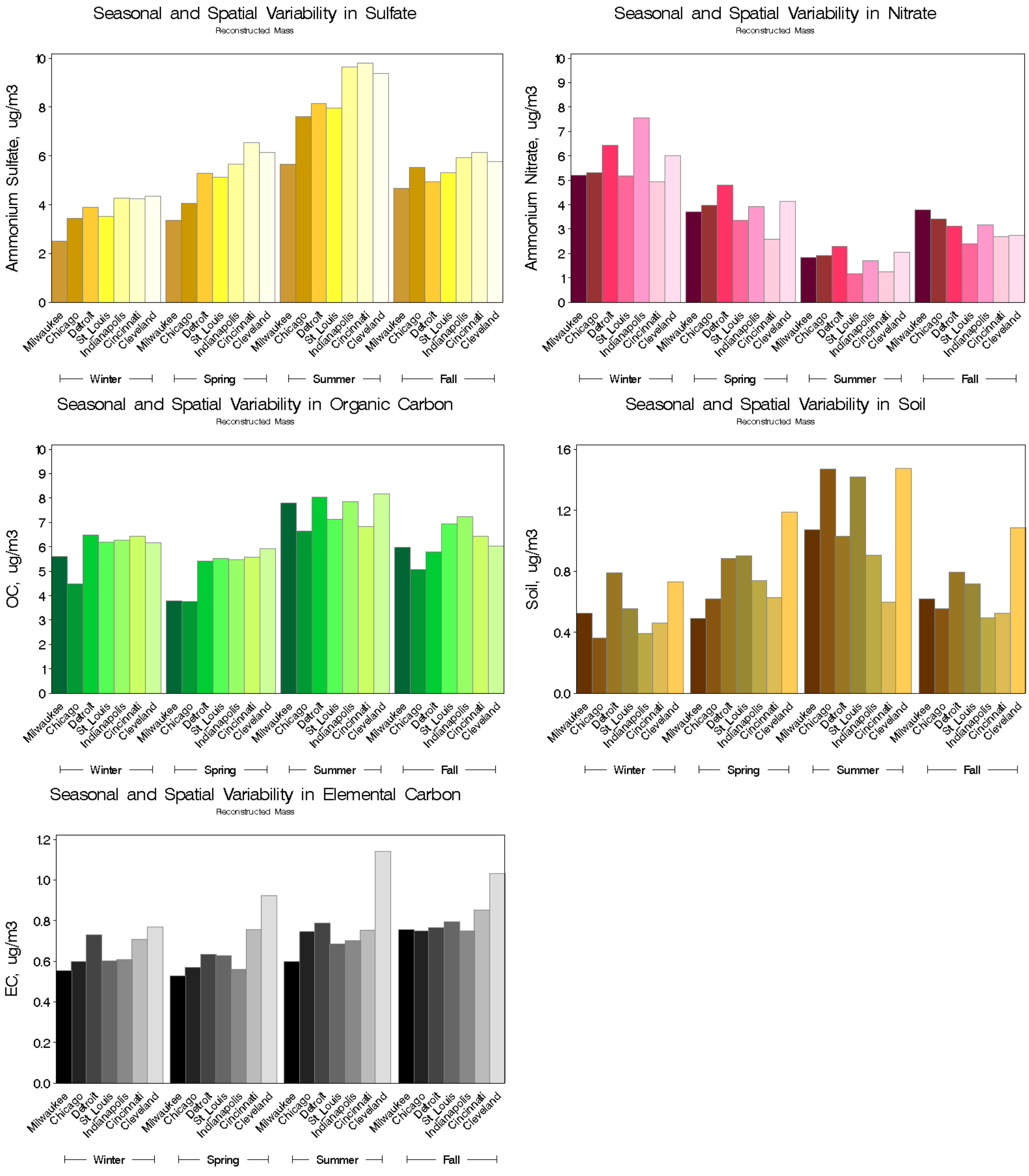


Figure 24. Average local (lighter shading) v. regional (darker shading) of $PM_{2.5}$ chemical species



Seasonal and Spatial Variability in Sulfate

Reconstructed Mass

Seasonal and Spatial Variability in Nitrate

Reconstructed Mass

Seasonal and Spatial Variability in Organic Carbon

Reconstructed Mass

Seasonal and Spatial Variability in Soil

Reconstructed Mass

Seasonal and Spatial Variability in Elemental Carbon

Reconstructed Mass

Figure 25 Seasonal and spatial variability in $PM_{2.5}$ components

Ammonium sulfate peaks in the summer and is highest in the southern and eastern parts of the Midwest, closest to the Ohio River Valley. Sulfate is primarily a regional pollutant; concentrations are similar in rural and urban areas and highly correlated over large distances. It is formed when sulfuric acid (an oxidation product of sulfur dioxide) and ammonia react in the atmosphere, especially in cloud droplets. Coal combustion is the primary source of sulfur dioxide; ammonia is emitted primarily from animal husbandry operations and fertilizer use.

Ammonium nitrate has almost the opposite spatial and seasonal pattern, with the highest concentrations occurring in the winter and in the northern parts of the region. Nitrate seems to have both regional and local sources, because urban concentrations are higher than rural upwind concentrations. Ammonium nitrate forms when nitric acid reacts with ammonia, a process that is enhanced when temperatures are low and humidity is high. Nitric acid is a product of the oxidation of nitric oxide, a pollutant that is emitted by combustion processes.

Organic carbon is more consistent from season to season and city to city, although concentrations are generally slightly higher in the summer. Like nitrate, organic carbon has both regional and local components. Particulate organic carbon can be emitted directly from cars and other fuel combustion sources or formed in a secondary process as volatile organic gases react and condense. In rural areas, summer organic carbon has significant contributions from biogenic sources.

Precursor Sensitivity: Data from the Midwest ammonia monitoring network were analyzed with thermodynamic equilibrium models to assess the effect of changes in precursor gas concentrations on $PM_{2.5}$ concentrations (Blanchard, 2005b). These analyses indicate that particle formation responds in varying degrees to reductions in sulfate, nitric acid, and ammonia. Based on Figure 26, which shows $PM_{2.5}$ concentrations as a function of sulfate, nitric acid (HNO3), and ammonia (NH3), several key findings should be noted:

- $PM_{2.5}$ mass is sensitive to reductions in sulfate at all times of the year and all parts of the region. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that $PM_{2.5}$ mass decreases.

- $PM_{2.5}$ mass is also sensitive to reductions in nitric acid and ammonia. The greatest $PM_{2.5}$ decrease in response to nitric acid reductions occurs during the winter, when nitrate is a significant fraction of $PM_{2.5}$.

- Under conditions with lower sulfate levels (i.e., proxy of future year conditions), $PM_{2.5}$ is more sensitive to reductions in nitric acid compared to reductions in ammonia.

- Ammonia becomes more limiting as one moves from west to east across the region.

Examination of weekend/weekday difference in PM-nitrate and NOx concentrations in the Midwest demonstrate that reductions in local (urban) NOx lead to reductions, albeit non-proportional reductions, in PM-nitrate (Blanchard, 2004b). This result is consistent with analyses of continuous PM-nitrate from several US cities, including St. Louis (Millstein, et al, 2007).

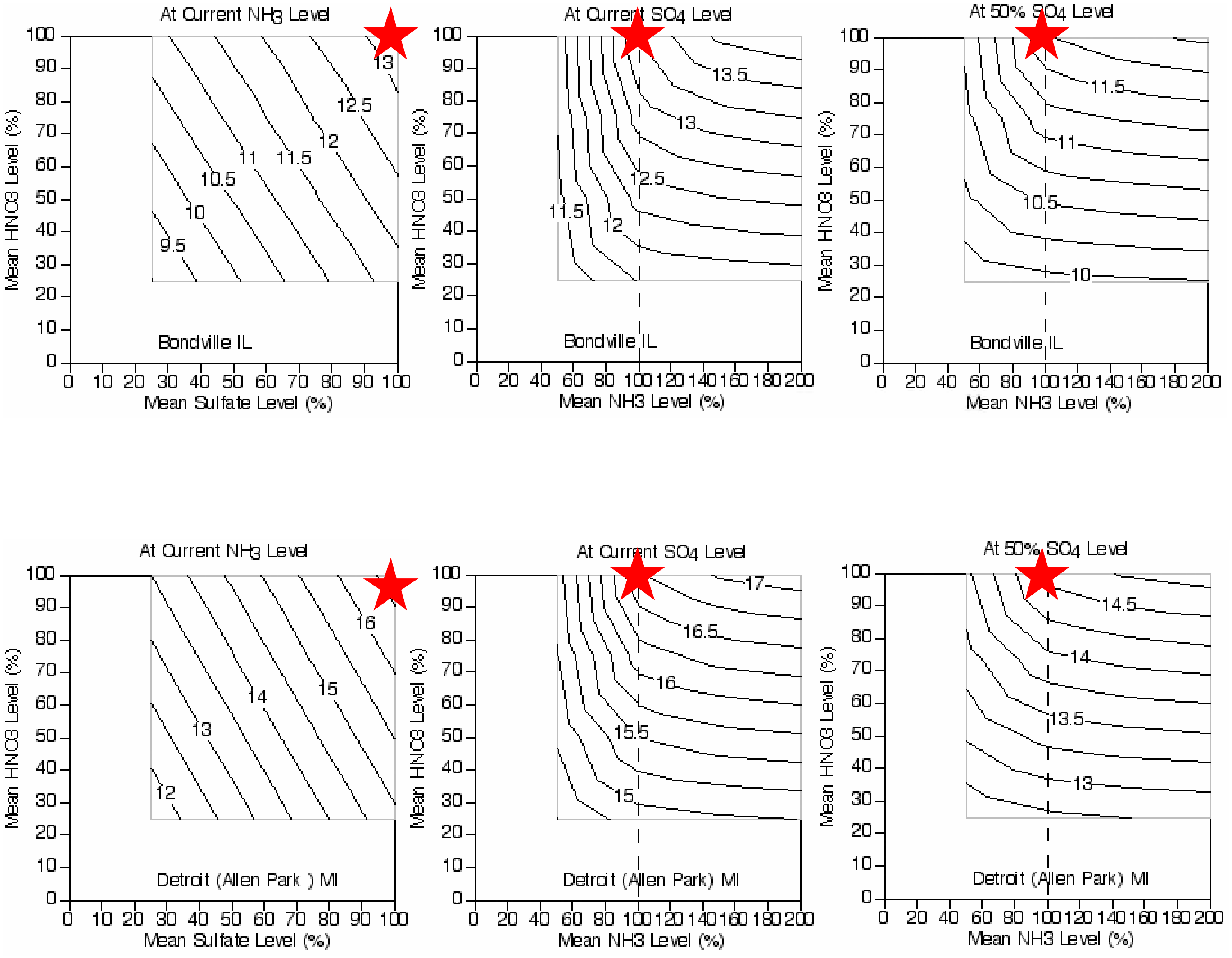


Figure 26. Predicted mean PM fine mass concentrations at Bondville, IL (top) and Detroit (Allen Park), MI (bottom) as functions of changes in sulfate, nitric acid (HNO3), and ammonia (NH3)

Note: starting at the baseline values (represented by the red star), either moving downward (reductions in nitric acid) or moving leftward (reductions in sulfate or ammonia) results in lower $PM_{2.5}$ values

Meteorology: $PM_{2.5}$ concentrations are not as strongly influenced by meteorology as ozone, but the two pollutants share some similar meteorological dependencies. In the summer, conditions that are conducive to ozone (hot temperatures, stagnant air masses, and low wind speeds due to stationary high pressure systems) also frequently give rise to high $PM_{2.5}$. In the case of PM, the reason is two-fold: (1) stagnation and limited mixing under these conditions cause $PM_{2.5}$ to build up, usually over several days, and (2) these conditions generally promote higher conversion of important precursors (SO_2 to SO_4) and higher emissions of some precursors, especially biogenic carbon. Wind direction is another strong determinant of $PM_{2.5}$; air transported from polluted source regions has higher concentrations.

Unlike ozone, $PM_{2.5}$ has occasional winter episodes. Conditions are similar to those for summer episodes, in that stationary high pressure and (relatively) warm temperatures are usually factors. Winter episodes are also fueled by high humidity and low mixing heights.

$PM_{2.5}$ chemical species show noticeable transport influences. Trajectory analyses have demonstrated that high PM-sulfate is associated with air masses that traveled through the sulfate-rich Ohio River Valley (Poirot, et al, 2002 and Kenski, 2004). Likewise, high PM-nitrate is associated with air masses that traveled through the ammonia-rich Midwest. Figure 27 shows results from an ensemble trajectory analysis of 17 rural eastern IMPROVE sites.

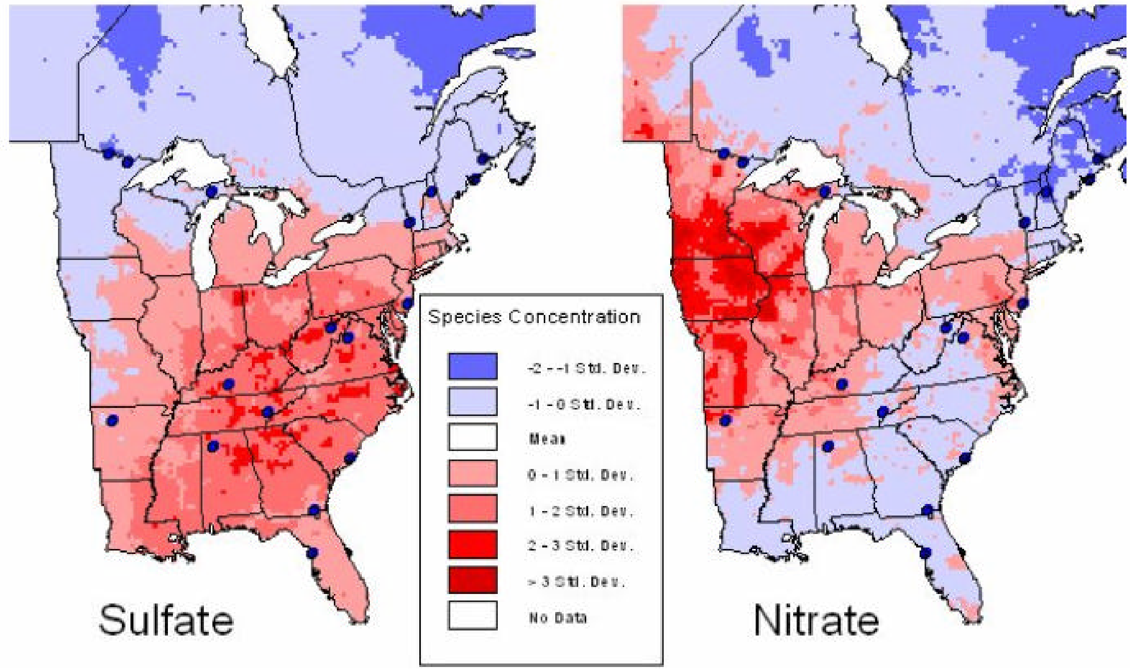


Figure 27. Sulfate and nitrate source regions based on ensemble trajectory analysis

When these results are considered together with analyses of precursor sensitivity (e.g., Figure 26), one possible conclusion is that ammonia control in the Midwest could be effective at reducing nitrate concentrations. The thermodynamic equilibrium modeling shows that ammonia reductions would reduce PM concentrations in the Midwest, but that nitric acid reductions are more effective when the probable reductions in future sulfate levels are considered.

Source Culpability: Three source apportionment studies were performed using speciated $PM_{2.5}$ monitoring data and statistical analysis methods (Hopke, 2005, STI, 2006, and STI, 2008). Figure 28 summarizes the source contributions from these studies. The studies show that a large portion of $PM_{2.5}$ mass consists of secondary, regional impacts, which cannot be attributed to individual facilities or sources (e.g., secondary sulfate, secondary nitrate, and secondary organic aerosols). Nevertheless, wind analyses (e.g., Figure 27) provide information on likely source regions. Regional- or national-scale control programs may be the most effective way to deal with these impacts. USEPA's CAIR, for example, will provide for substantial reductions in SO2 emissions over the eastern half of the U.S., which will reduce sulfate (and $PM_{2.5}$) concentrations and improve visibility levels.

The studies also show that a smaller, yet significant portion of $PM_{2.5}$ mass is due to emissions from nearby (local) sources. Local (urban) excesses occur in many urban areas for organic and elemental carbon, crustal matter, and, in some cases, sulfate. The statistical analysis methods help to identify local sources and quantify their impact. This information is valuable to states wishing to develop control programs to address local impacts. A combination of national/regional-scale and local-scale emission reductions may be necessary to provide for attainment.

The carbon sources are not easily identified in complex urban environments. LADCO's Urban Organics Study (STI, 2006) identified four major sources of organic carbon: mobile sources, burning, industrial sources, and secondary organic aerosols. Additional sampling and analysis is underway in Cleveland and Detroit to provide further information on sources of organic carbon.

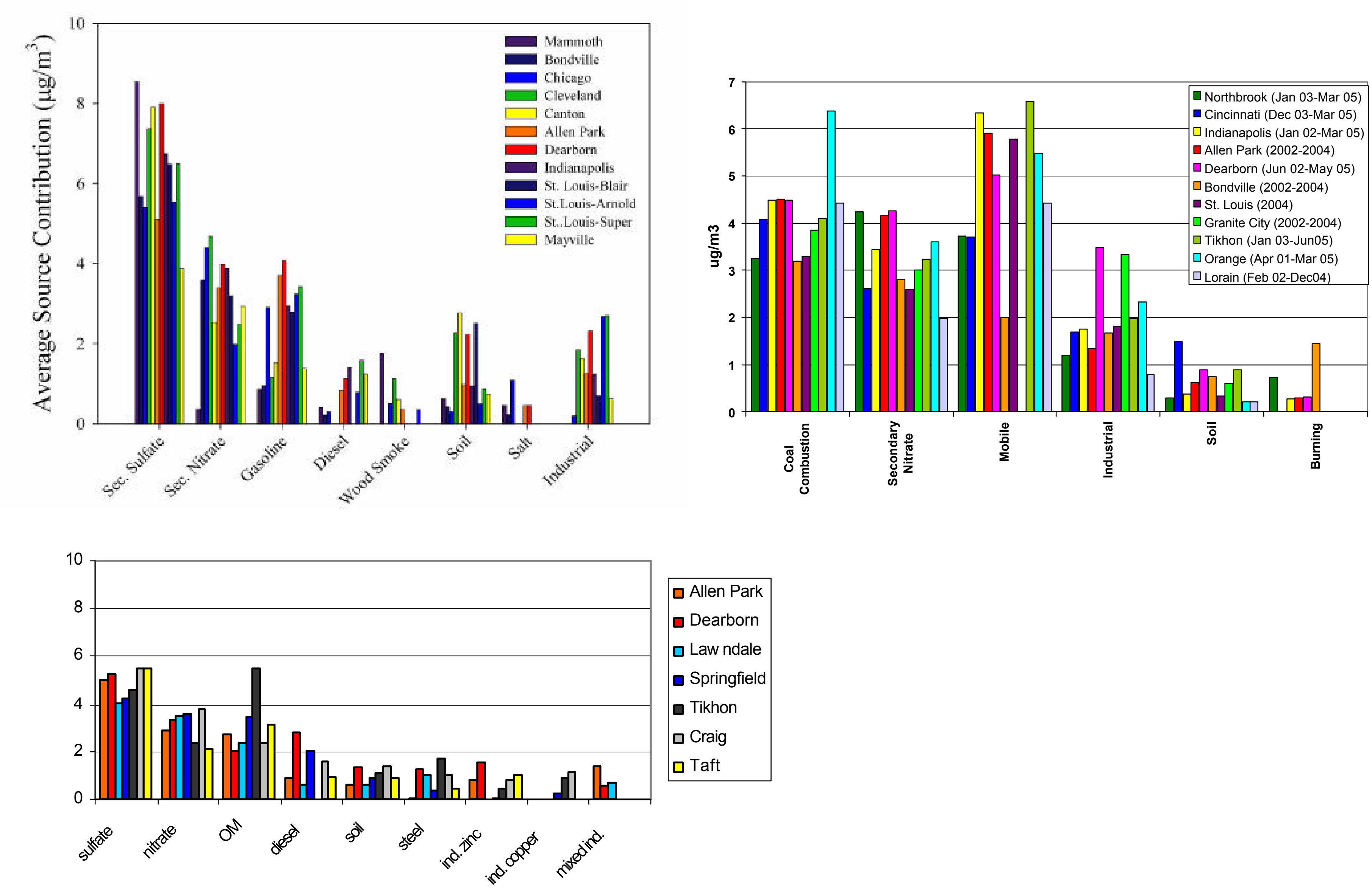


Figure 28. Major Source Contributions in the Midwest based on Hopke 2005 (upper left), STI, 2006 (upper right), and STI, 2008 (lower left)

2.3 Haze

Section 169A of the Clean Air Act sets as a national goal “the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution”. To implement this provision, in 1999, USEPA adopted regulations to address regional haze visibility impairment (USEPA, 1999). USEPA’s rule requires states to “make reasonable progress toward meeting the national goal”. Specifically, states must establish reasonable progress goals, which provide for improved visibility on the most impaired (20% worst) days sufficient to achieve natural conditions by the year 2064, and for no degradation on the least impaired (20% best) days.

The primary cause of impaired visibility in the Class I areas is pollution by fine particles that scatter light. The degree of impairment, which is expressed in terms of visual range, light extinction (1/Mm), or deciviews (dv), depends not just on the total $PM_{2.5}$ mass concentration, but also on the chemical composition of the particles and meteorological conditions.

Current Conditions: A map of the average light extinction values for the most impaired (20% worst) visibility days for the 5-year baseline period (2000-2004) is shown in Figure 29.

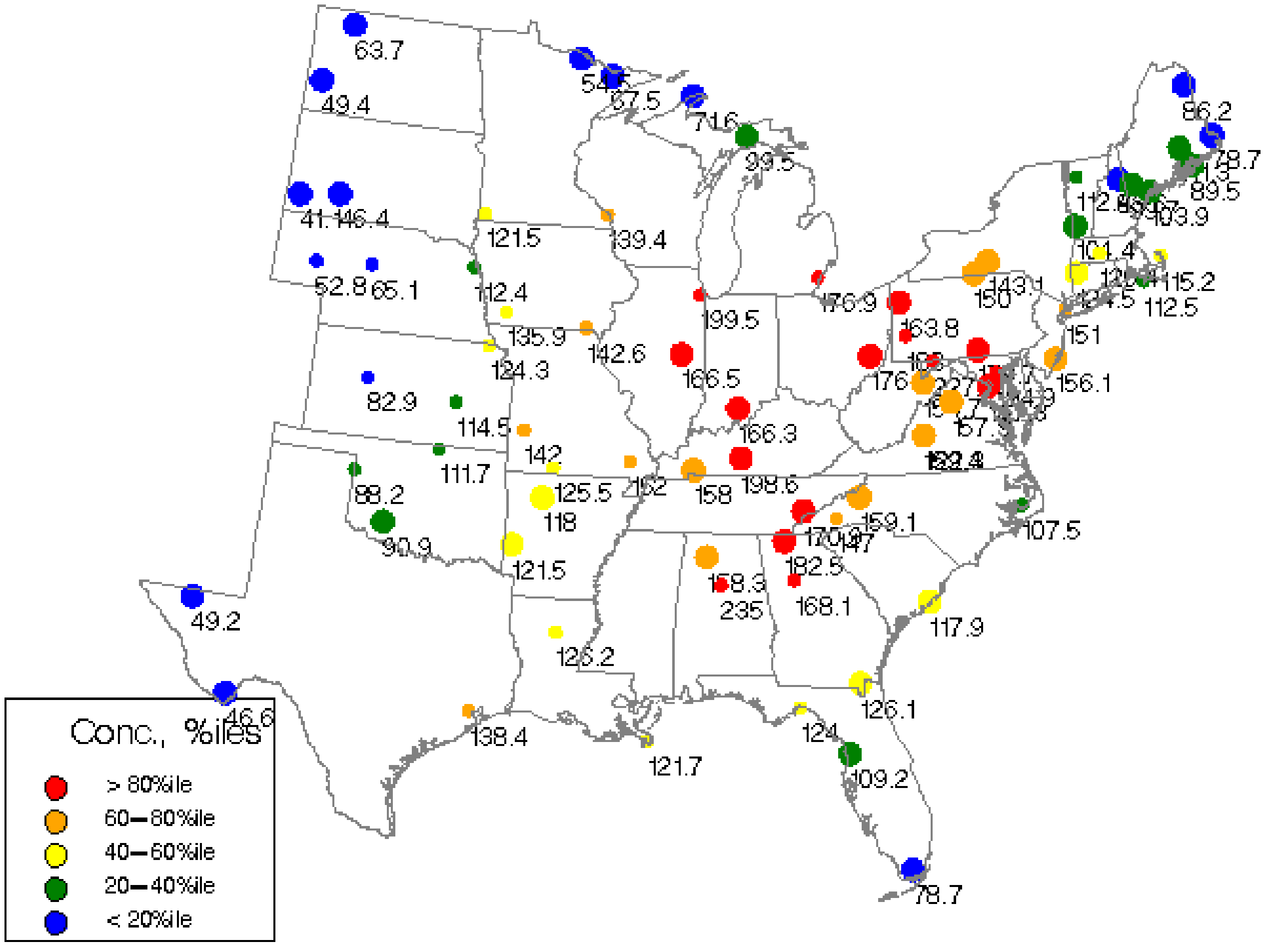


Figure 29. Baseline Visibility Levels for 20% Worst Days (2000 – 2004), units: Mm^{-1}

Initially, the baseline (2000 – 2004) visibility condition values were derived using the average for the 20% worst and 20% best days for each year, as reported on the VIEWS website: http://vista.cira.colostate.edu/views/Web/IMPROVE/SummaryData.aspx . These values were calculated using the original IMPROVE equation for reconstructed light extinction.

Three changes were made to the baseline calculations to produce a new set of values. First, the reconstructed light extinction equation was revised by the IMPROVE Steering Committee in 2005. The new IMPROVE equation was used to calculate updated baseline values.

Second, due to sampler problems, the 2002-2004 data for Boundary Waters were invalid for certain chemical species. (Note, sulfate and nitrate data were valid.) A "substituted" data set was developed by using values from Voyageurs for the invalid species.

Third, LADCO identified a number of days during 2000-2004 where data capture at the Class I monitors was incomplete (Kenski, 2007b). The missing data cause these days to be excluded from the baseline calculations. However, the light extinction due to the remaining measured species is significant (i.e., above the 80th percentile). It makes sense to include these days in the baseline calculations, because they are largely dominated by anthropogenic sources. (Only one of these days is driven by high organic carbon, which might indicate non-anthropogenic aerosol from wildfires.) As seen in Table 3, inclusion of these days in the baseline calculation results in a small, but measurable, effect on the baseline values (i.e., values increase from 0.2 to 0.8 dv).

Table 3. Average of 20% worst days, with and without missing data days

	Average Worst Day DV, per RHR	Average Worst Day DV, with Missing Data Days	Difference
BOWA	19.59	19.86	0.27
ISLE	20.74	21.59	0.85
SENE	24.16	24.38	0.22
VOYA	19.27	19.48	0.21

A summary of the initial and updated baseline values for the Class I areas in northern Michigan and northern Minnesota are presented in Table 4. The updated baseline values reflect the most current, complete understanding of visibility impairing effects and, as such, will be used for SIP planning purposes.

Table 4. Summary of visibility metrics (deciviews) for northern Class I areas

Old IMPROVE Equation (Cite: VIEWS, November 2005)									
		20% Worst Days							
		2000	**2001**	**2002**	**2003**	**2004**	**Baseline Value**	**2018 URI Value**	**Natural Conditions**
Voyageurs		18.50	18.00	19.00	19.20	17.60	18.46	16.74	11.09
BWCA		19.85	19.99	19.68	19.73	17.65	19.38	17.47	11.21
Isle Royale		20.00	22.00	20.80	19.50	19.10	20.28	18.17	11.22
Seney		22.60	24.90	24.00	23.80	22.60	23.58	20.73	11.37
		20% Best Days							
		2000	**2001**	**2002**	**2003**	**2004**	**Baseline Value**		**Natural Conditions**
Voyageurs		6.30	6.20	6.70	7.00	5.40	6.32		3.41
BWCA		5.90	6.52	6.93	6.67	5.61	6.33		3.53
Isle Royale		5.70	6.40	6.40	6.30	5.30	6.02		3.54
Seney		5.80	6.10	7.30	7.50	5.80	6.50		3.69
New IMPROVE Equation (Cite: VIEWS, March 2006)									
		20% Worst Days							
		2000	**2001**	**2002**	**2003**	**2004**	**Baseline Value**	**2018 URI Value**	**Natural Conditions**
Voyageurs		19.55	18.57	20.14	20.25	18.87	19.48	17.74	12.05
BWCA		20.20	20.04	20.76	20.13	18.18	19.86	17.94	11.61
Isle Royale		20.53	23.07	21.97	22.35	20.02	21.59	19.43	12.36
Seney		22.94	25.91	25.38	24.48	23.15	24.37	21.64	12.65
		20% Best Days							
		2000	**2001**	**2002**	**2003**	**2004**	**Baseline Value**		**Natural Conditions**
Voyageurs		7.01	7.12	7.53	7.68	6.37	7.14		4.26
BWCA		6.00	6.92	7.00	6.45	5.77	6.43		3.42
Isle Royale		6.49	7.16	7.07	6.99	6.12	6.77		3.72
Seney		6.50	6.78	7.82	8.01	6.58	7.14		3.73

Notes: (1) BWCA values for 2002 - 2004 reflect "substituted" data.
(2) New IMPROVE equation values include Kenski, 2007 adjustment for missing days

URI = uniform rate of improvement

As noted above, the goal of the visibility program is to achieve natural conditions. Initially, the natural conditions values for each Class I area were taken directly from USEPA guidance (USEPA, 2003). These values were calculated using the original IMPROVE equation. This equation was revised by the IMPROVE Steering Committee in 2005, and the new IMPROVE equation was used to calculate updated natural conditions values. The updated values are reported on the VIEWS website.

A summary of the initial and updated natural conditions values are presented in Table 4. The updated natural conditions values (based on the new IMPROVE equation) will be used for SIP planning purposes.

Data Variability: For the four northern Class I areas, the most important $PM_{2.5}$ chemical species are ammonium sulfate, ammonium nitrate, and organic carbon. The contribution of these species on the 20% best and 20% worst visibility days (based on 2000 – 2004 data) is provided in Figure 30. For the 20% worst visibility days, the contributions are: sulfate = 35-55%, nitrate = 25-30%, and organic carbon = 12-22%. Although the chemical composition is similar, sulfate increases in importance from west to east and concentrations are highest at Seney (the easternmost site). It should also be noted that sulfate and nitrate contribute more to light extinction than to $PM_{2.5}$ mass because of their hygroscopic properties.

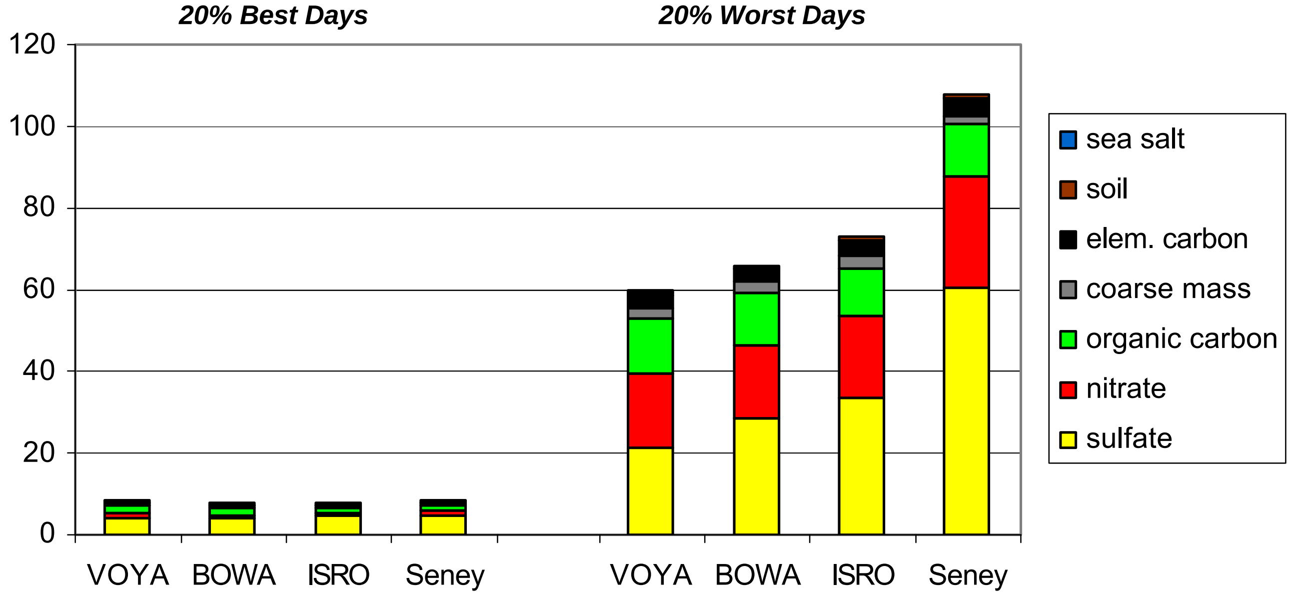


Figure 30. Chemical composition of light extinction for 20% best visibility days (left) and 20% worst visibility days (right) in terms of Mm^{-1}

Analysis of $PM_{2.5}$ mass and chemical species for rural IMPROVE (and IMPROVE-protocol) sites in the eastern U.S. showed a high degree of correlation between $PM_{2.5}$-mass, sulfate, and nitrate levels (see Figure 31). The Class I sites in northern Michigan and northern Minnesota, in particular, are highly correlated for $PM_{2.5}$ mass, sulfates, and organic carbon mass (AER, 2004).

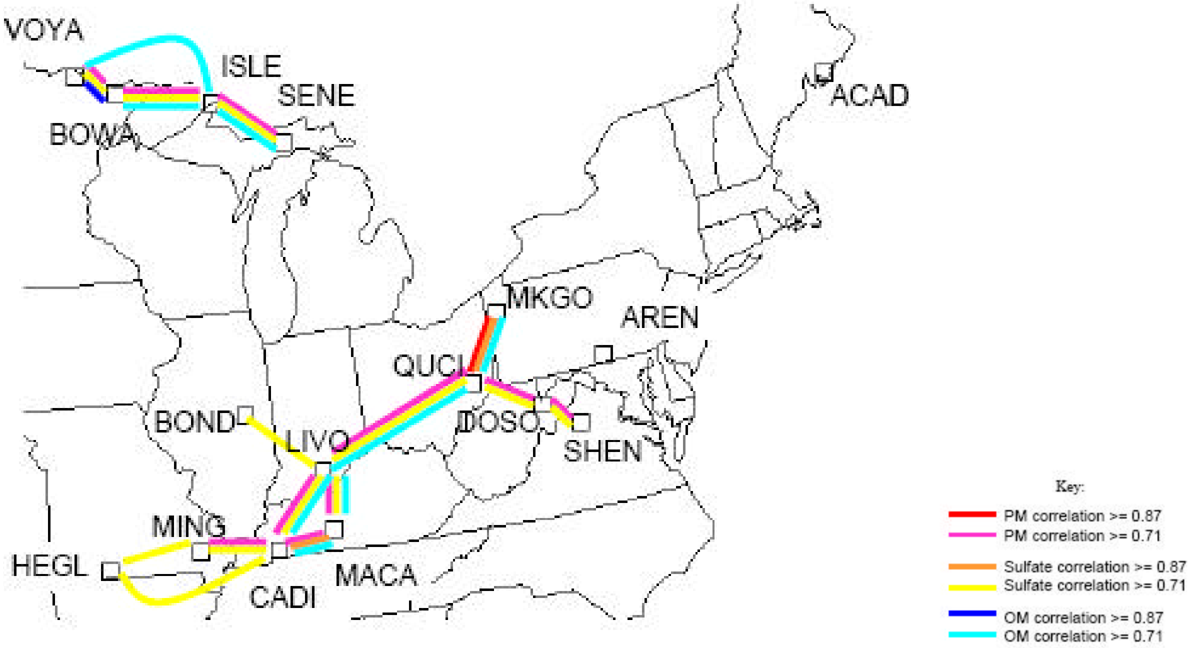
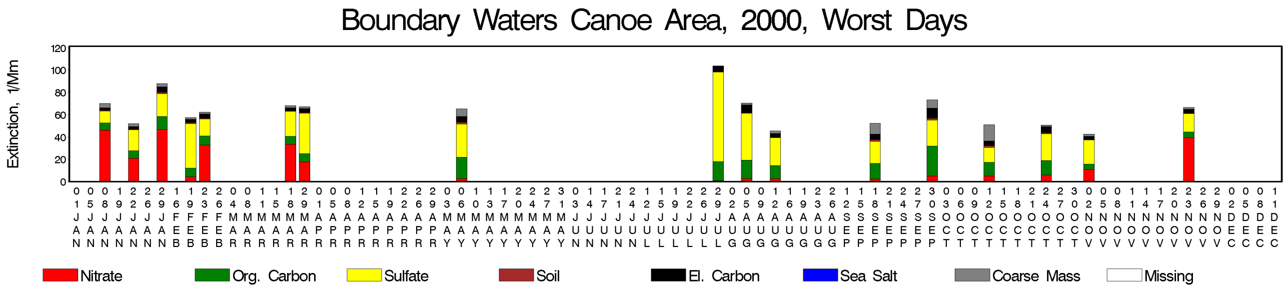
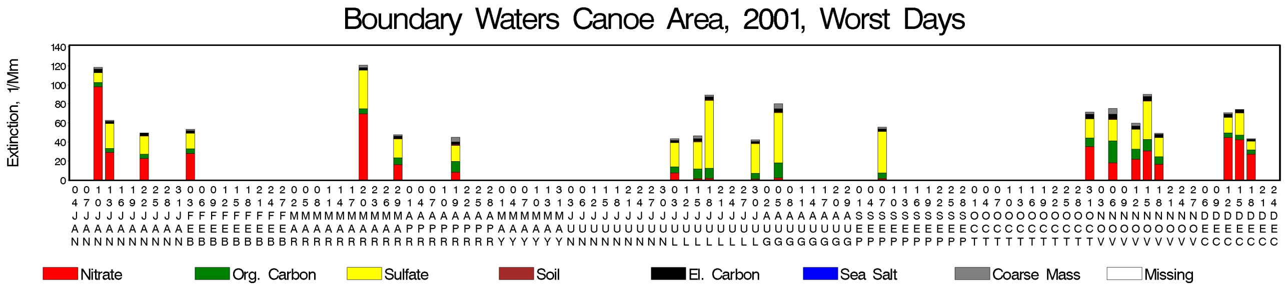


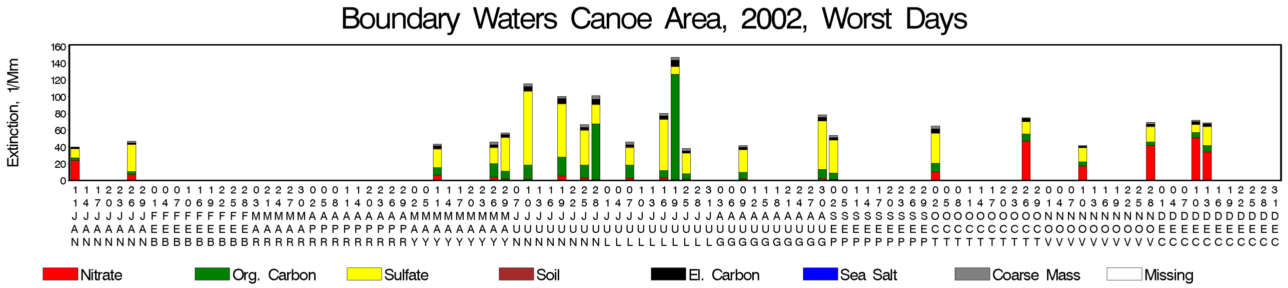
Figure 31. Correlations among IMPROVE (and IMPROVE-protocol) monitoring sites in Eastern U.S.

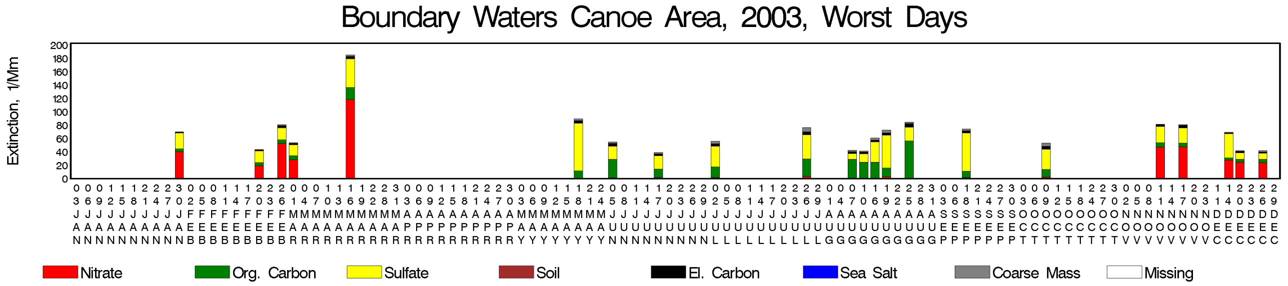
Long-term trends at Boundary Waters (the only regional site with a sufficient data record) show significant decreases in total $PM_{2.5}$ (-0.005 ug/year) and SO4 (-0.04 ug/year) and an increase in NO3 (+0.01 ug/year). These $PM_{2.5}$ and SO4 trends are generally consistent with long-term trends at other IMPROVE sites in the eastern U.S., which have shown widespread decreases in SO4 and $PM_{2.5}$ (DeBell, et al, 2006). Detecting changes in nitrate has been hampered by uncertainties in the IMPROVE data for particular years and, thus, this estimate should be considered tentative.

Haze in the Midwest Class I areas has no strong seasonal pattern. Poor visibility days occur throughout the year, as indicated in Figure 32. (Note, in contrast, other parts of the country, such as Shenandoah National Park in Virginia, show a strong tendency for the worst air quality days to occur in the summer months.) This figure and Figure 33 (which presents the monthly average light extinction values based on all sampling days) also show that sulfate and organic carbon concentrations are higher in the summer, and nitrate concentrations are higher in the winter, suggesting the importance of different sources and meteorological conditions at different times of the year.


Boundary Waters Canoe Area, 2000, Worst Days


Boundary Waters Canoe Area, 2001, Worst Days


Boundary Waters Canoe Area, 2002, Worst Days


Boundary Waters Canoe Area, 2003, Worst Days

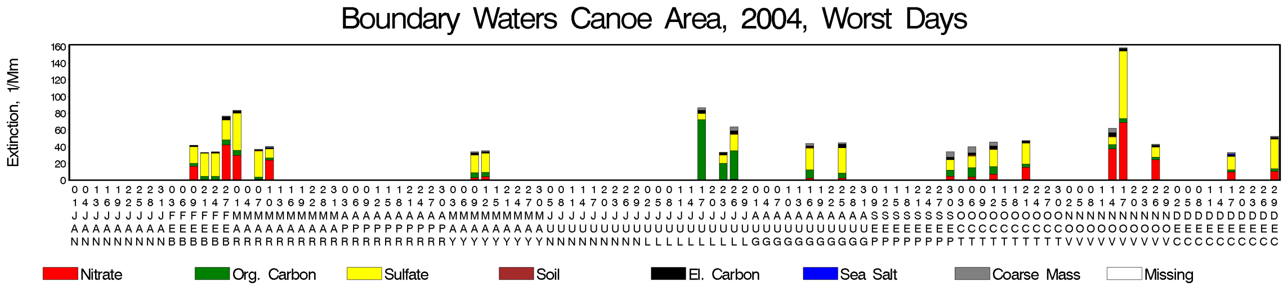

Boundary Waters Canoe Area, 2004, Worst Days

Figure 32. Daily light extinction values for 20% worst days at Boundary Waters (2000 – 2004)

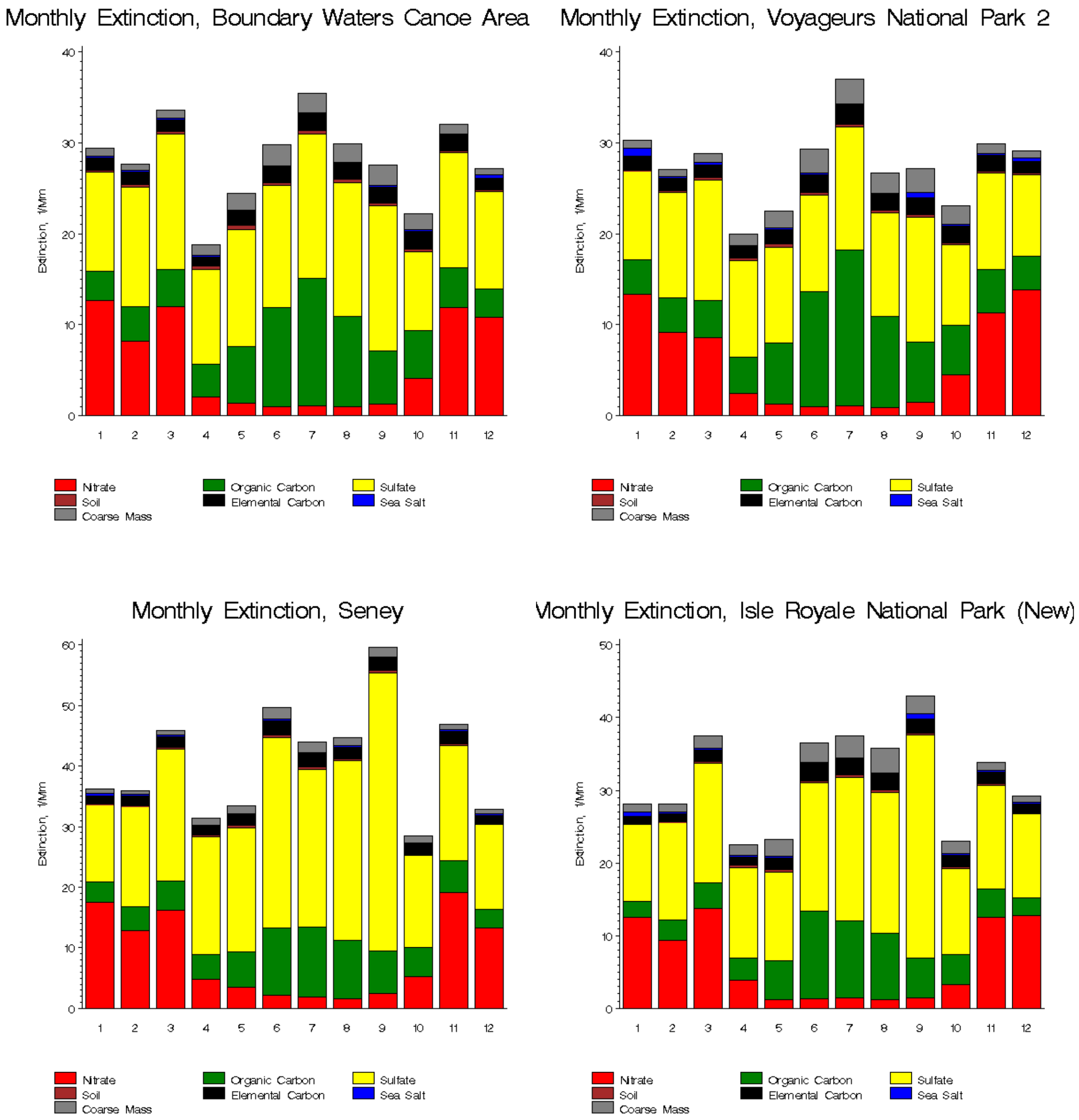


Figure 33. Monthly average light extinction values for northern Class I areas

Precursor Sensitivity: Results from two analyses using thermodynamic equilibrium models provide information on the effect of changes in precursor concentrations on $PM_{2.5}$ concentrations (and, in turn, visibility levels) in the northern Class I areas. First, a preliminary analysis using data collected at Seney indicated that $PM_{2.5}$ there is most sensitive to reductions in sulfate, but is also sensitive to reductions in nitric acid (Blanchard 2004b).

Second, an analysis was performed using data from the Midwest ammonia monitoring network for a site in Minnesota -- Great River Bluffs, which is the closest ammonia monitoring site to the northern Class I areas (Blanchard, 2005b). Figure 34 shows $PM_{2.5}$ concentrations as a function of sulfate, nitric acid (HNO3), and ammonia (NH3). Reductions in sulfate (i.e., movement to the left of baseline value [represented by the red star]), as well as reductions in nitric acid (i.e., movement downward) and NH3 (i.e., movement to the left), result in lower $PM_{2.5}$ concentrations. Thus, reductions in sulfate, nitric acid, and ammonia will lower $PM_{2.5}$ concentrations and improve visibility in the northern Class I areas.

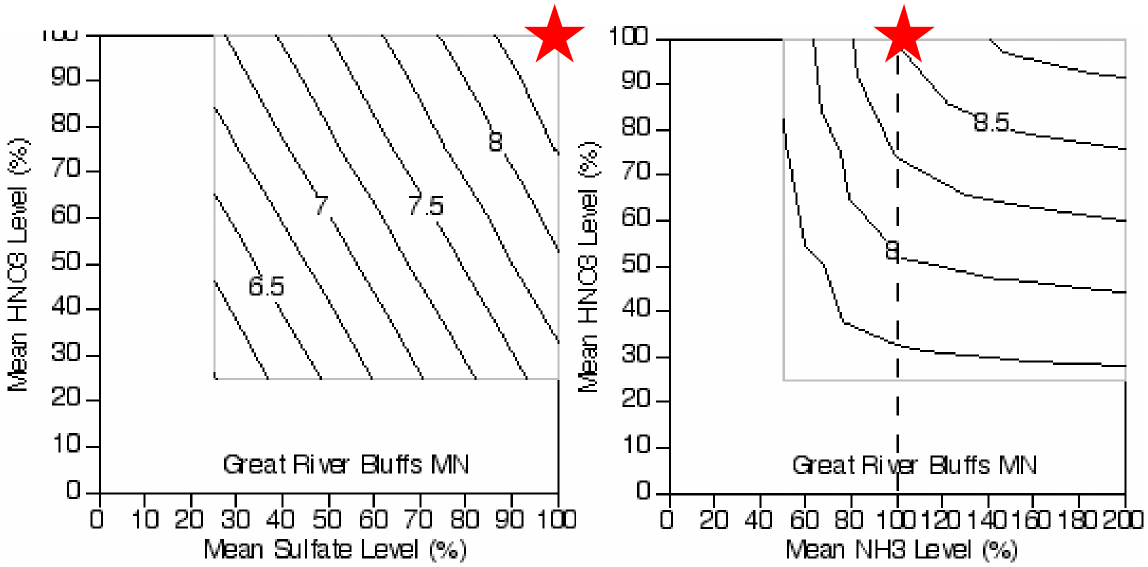


Figure 34. Predicted $PM_{2.5}$ mass concentrations at Great River Bluffs, MN as functions of changes in sulfate, nitric acid, and ammonia

Meteorology and Transport: The role of meteorology in haze is complex. Wind speed and wind direction govern the movement of air masses from polluted areas to the cleaner wilderness areas. As noted above, increasing humidity increases the efficiency with which sulfate and nitrate aerosols scatter light. Temperature and humidity together govern whether ammonium nitrate can form from its precursor gases, nitric acid and ammonia. Temperature and sunlight also play an indirect role in emissions of biogenic organic species that condense to form particulate organic matter; emissions increase in the summer daylight hours.

Trajectory analyses were performed to understand transport patterns for the 20% worst and 20% best visibility days. The composite results for the four northern Class I areas are provided in Figure 35. The orange areas are where the air is most likely to come from, and the green areas are where the air is least likely to come from. As can be seen, bad air days are generally associated with transport from regions located to the south, and good air days with transport from Canada.

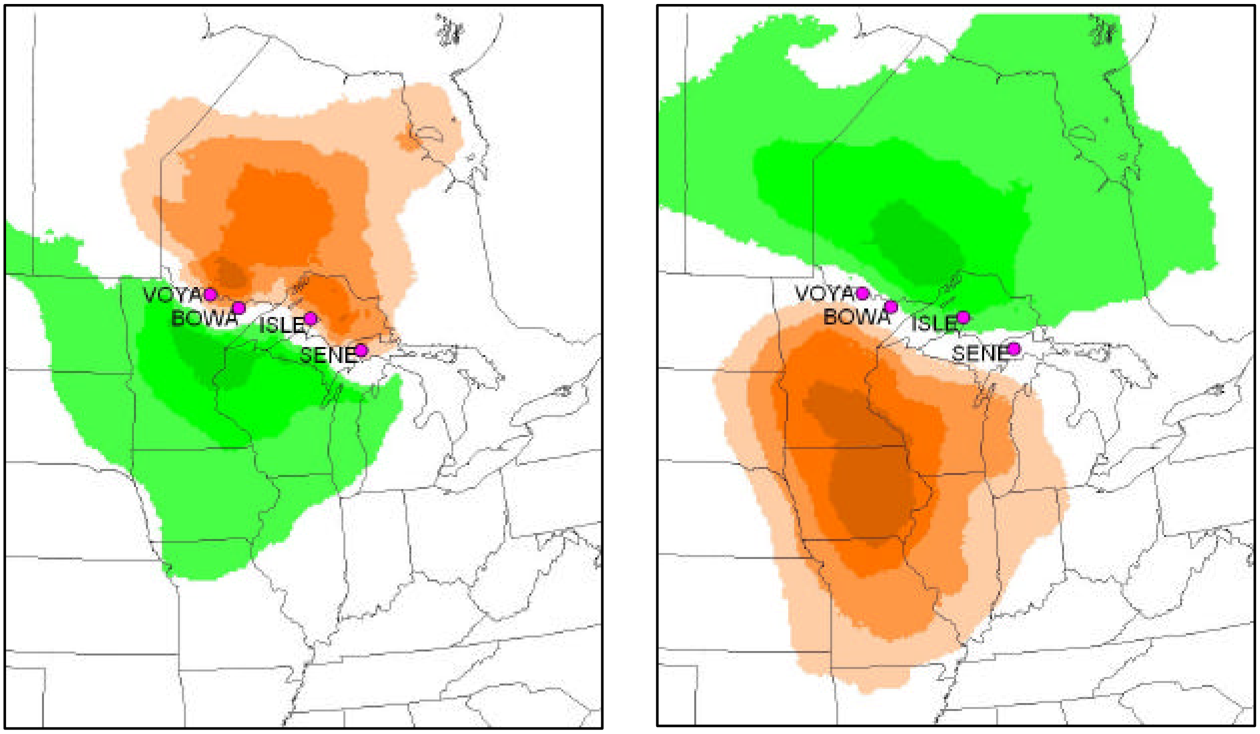


Figure 35. Composite back trajectories for light extinction- 20% best visibility days (left) and 20% worst visibility days (right) (2000 – 2005)

Source Culpability: Air quality data analyses (including the trajectory analyses above) and dispersion modeling were used to provide information on source region and source sector contributions to regional haze in the northern Class I areas (see MRPO, 2007). Based on this information, the most important contributing states are Michigan, Minnesota, and Wisconsin, as well as Missouri, North Dakota, Iowa, Indiana and Illinois (see, for example, Figure 35 above). The most important contributing pollutants and source sectors are SO2 emissions from electrical generating units (EGUs) and certain non-EGUs, which lead to sulfate formation, and NOx emissions from a variety of source types (e.g., motor vehicles), which lead to nitrate formation. Ammonia emissions from livestock waste and fertilizer applications are also important, especially for nitrate formation.

A source apportionment study was performed using monitoring data from Boundary Waters and statistical analysis methods (DRI, 2005). The study shows that a large portion of $PM_{2.5}$ mass consists of secondary, regional impacts, which cannot be attributed to individual facilities or sources (e.g., secondary sulfate, secondary nitrate, and secondary organic aerosols). Industrial sources contribute about 3-4% and mobile sources about 4-7% to $PM_{2.5}$ mass.

A special study was performed in Seney to identify sources of organic carbon (Sheesley, et al, 2004). As seen in Figure 36, the highest $PM_{2.5}$ concentrations occurred during the summer, with organic carbon being the dominant species. The higher summer organic carbon concentrations were attributed mostly to secondary organic aerosols of biogenic origin because of the lack of primary emission markers, and concentrations of know biogenic-related species (e.g., pinonic acid – see Figure 36) were also high during the summer.

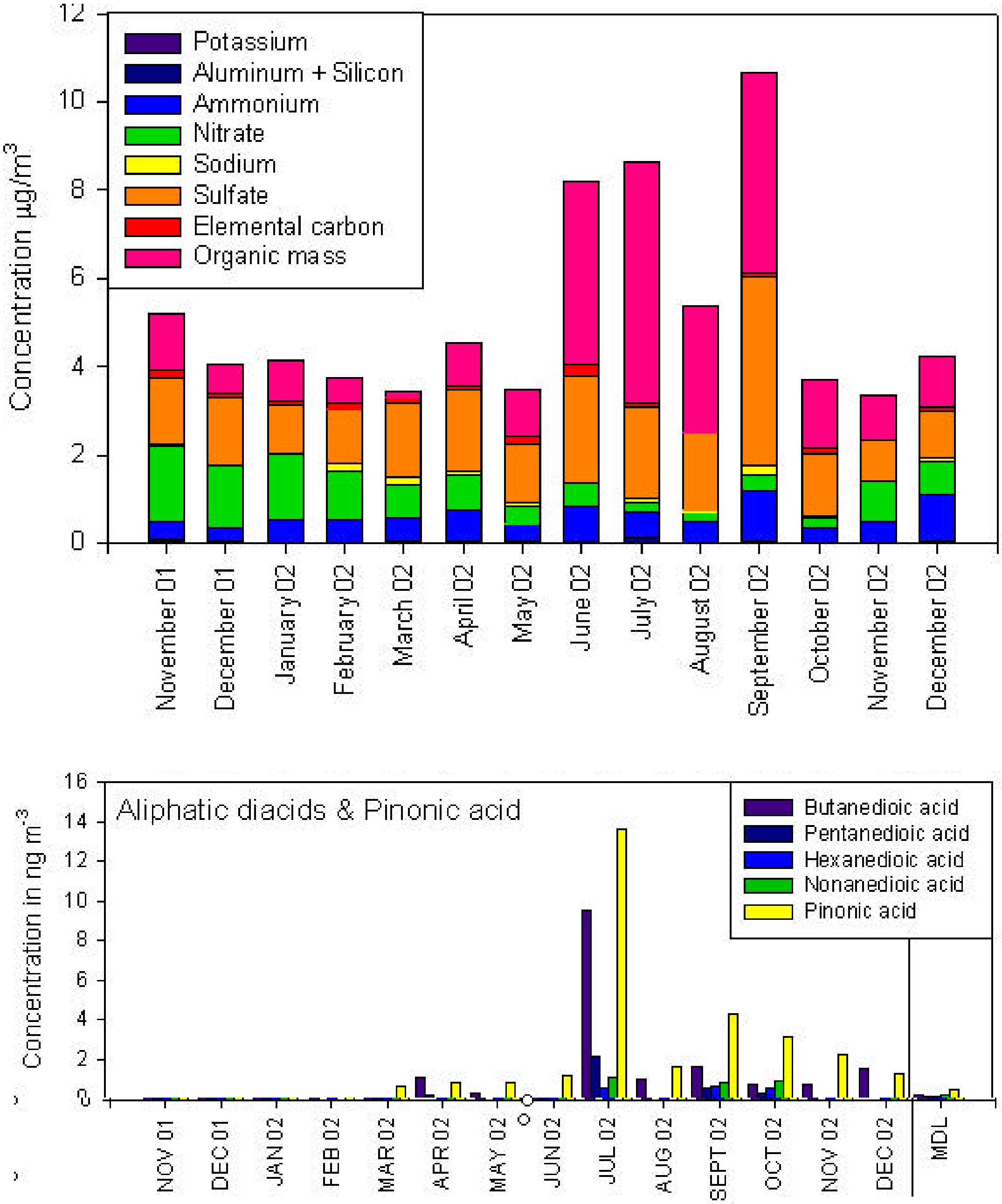


Figure 36. Monthly concentrations of $PM_{2.5}$ species (top), and secondary and biogenic-related organic carbon species in Seney (bottom)

Although the Seney study showed that biomass burning was a relatively small contributor to organic carbon on an annual average basis, episodic impacts area apparent (see, for example, high organic carbon days in Figure 32). To assess further whether burning is a significant contributor to visibility impairment in the northern Class I areas, the $PM_{2.5}$ chemical speciation data were examined for days with high organic carbon and elemental carbon concentrations, which are indicative of biomass burning impacts. Only a handful of such days were identified:

Table 5. Days with high OC/EC concentrations in northern Class I areas

Site	2000	2001	2002	2003	2004
Voyageurs	---	---	Jun 1	Aug 25	Jul 17
			Jun 28		
			Jul 19		
Boundary Waters	---	---	Jun 28	Aug 25	Jul 17
			Jul 19		
Isle Royale	---	---	Jun 1	Aug 25	---
			Jun 28		
Seney	---	---	Jun 28	---	---

Back trajectories on these days point mostly to wildfires in Canada. Elimination of these high organic carbon concentration days has a small effect in lowering the baseline visibility levels in the northern Class I areas (i.e., Minnesota Class I areas change by about 0.3 deciviews and Michigan Class I areas change by less than 0.2 deciviews). This suggests that fire activity, although significant on a few days, is on average a relatively small contributor to visibility impairment in the northern Class I areas.

In summary, these analyses that organic carbon in the northern Class I is largely uncontrollable.

Section 3.0 Air Quality Modeling

Air quality models are relied on by federal and state regulatory agencies to support their planning efforts. Used properly, models can assist policy makers in deciding which control programs are most effective in improving air quality, and meeting specific goals and objectives. For example, models can be used to conduct “what if” analyses, which provide information for policy makers on the effectiveness of candidate control programs.

The modeling analyses were conducted in accordance with USEPA’s modeling guidelines (USEPA, 2007a). Further details of the modeling are provided in two protocol documents: LADCO, 2007a and LADCO, 2007b.

This section reviews the development and evaluation of the modeling system used for the multi-pollutant analyses. Application of the modeling system (i.e., attainment demonstration for ozone and $PM_{2.5}$, and reasonable progress assessment for haze) is covered in the following sections.

3.1 Selection of Base Year

Two base years were used in the modeling analyses: 2002 and 2005. USEPA’s modeling guidance recommends using 2002 as the baseline inventory year, but also allows for use of an alternative baseline inventory year, especially a more recent year. Initially, LADCO conducted modeling with a 2002 base year (i.e., Base K/Round 4 modeling, which was completed in 2006). A decision was subsequently made to conduct modeling with a 2005 base year (i.e., Base M/Round 5, which was completed in 2007). As discussed in the previous section, 2002 and 2005 both had above normal ozone conducive conditions, although 2002 was more severe compared to 2005. Examination of multiple base years provides for a more complete technical assessment. Both sets of model runs are discussed in this document.

3.2 Future Years of Interest

To address the multiple attainment requirements for ozone and $PM_{2.5}$, and reasonable progress goals for regional haze, several future years are of interest:

2008	Planning year for ozone basic nonattainment areas (attainment date 2009)[8]
2009	Planning year for ozone moderate nonattainment areas and $PM_{2.5}$ nonattainment areas (attainment date 2010)
2012	Planning year for ozone moderate nonattainment areas and $PM_{2.5}$ nonattainment areas, with 3-year extension (attainment date 2013)
2018	First milestone year for regional haze planning

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[8] According to USEPA’s ozone implementation rule (USEPA, 2005), emission reductions needed for attainment must be implemented by the beginning of the ozone season immediately preceding the area’s attainment date. The PM2.5 implementation rule contains similar provisions – i.e., emission reductions should be in place by the beginning of the year preceding the attainment date (USEPA, 2007c). The logic for requiring emissions reductions by the year (or season) immediately preceding the attainment year follows from language in the Clean Air Act, and the ability for an area to receive up to two 1-year extensions. Therefore, emissions in the year preceding the attainment year should be at a level that is consistent with attainment. It also follows that the year preceding the attainment year should be modeled for attainment planning purposes.

Detailed emissions inventories were developed for 2009 and 2018. To support modeling for other future years, less rigorous emissions processing was conducted (e.g., 2012 emissions were estimated for several source sectors by interpolating between 2009 and 2018 emissions).

3.3 Modeling System

The air quality analyses were conducted with the CAMx model, with emissions and meteorology generated using EMS (and CONCEPT) and MM5, respectively. The selection of CAMx as the primary model is based on several factors: performance, operator considerations (e.g., ease of application and resource requirements), technical support and documentation, model extensions (e.g., 2-way nested grids, process analysis, source apportionment, and plume-in-grid), and model science. CAMx model set-up for Base M and Base K is summarized below:

Base M (2005)	**Base K (2002)**
• CAMx v4.50	* CAMx 4.30
• CB05 gas phase chemistry	* CB-IV with updated gas-phase chemistry
• SOA chemistry updates	* No SOA chemistry updates
• AERMOD dry deposition scheme	* Wesley-based dry deposition
• ISORROPIA inorganic chemistry	• ISORROPIA inorganic chemistry
• SOAP organic chemistry	• SOAP organic chemistry
• RADM aqueous phase chemistry	• RADM aqueous phase chemistry
• PPM horizontal transport	• PPM horizontal transport

3.4 Domain/Grid Resolution

The National RPO grid projection was used for this modeling. A subset of the RPO domain was used for the LADCO modeling. For PM$_{2.5}$ and haze, the large eastern U.S. grid at 36 km (see box on right side of Figure 36) was used. A PM$_{2.5}$ sensitivity run was also performed for this domain at 12 km. For ozone, the smaller grid at 12 km (see shaded portion of the box on the right side of Figure 37) was used for most model runs. An ozone sensitivity run was also performed with a 4km sub-grid over the Lake Michigan area and Detroit/Cleveland.

The vertical resolution in the air quality model consists of 16 layers extending up to 15 km, with higher resolution in the boundary layer.

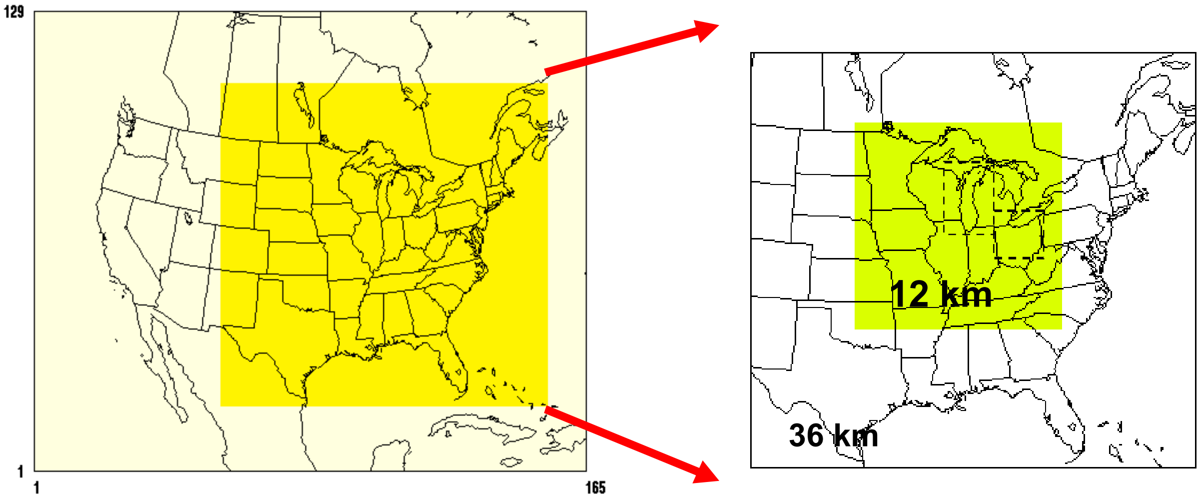

Figure 37. Modeling grids – RPO domain (left) and LADCO modeling domain (right)

3.5 Model Inputs: Meteorology

Meteorological inputs were derived using the Fifth-Generation NCAR/Penn State Meteorological Model (MM5) – version 3.6.3 for the years 2001–2003, and version 3.7 for the year 2005. The MM5 modeling domains are consistent with the National RPO grid projections (see Figure 38).

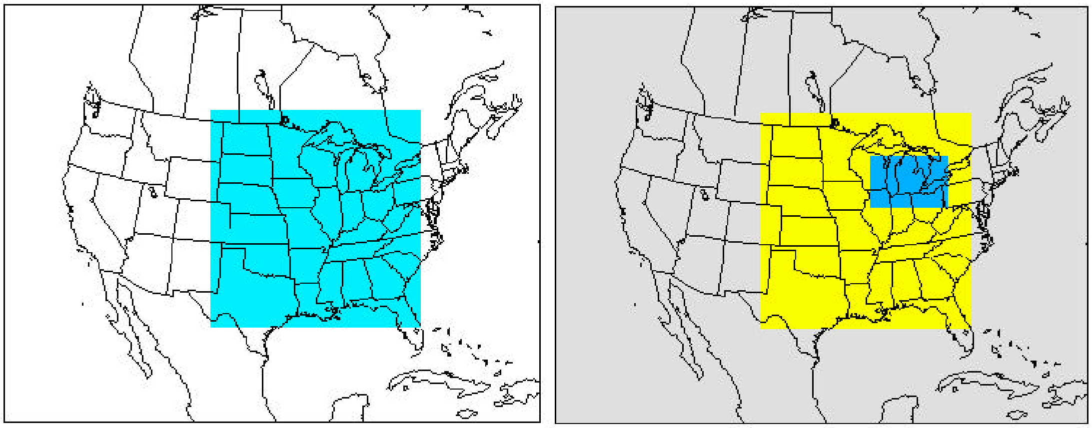

Figure 38. MM5 modeling domain for 2001-2003 (left) and 2005 (right)

The annual 2002 36 km MM5 simulation was completed by Iowa DNR. The 36/12 km 2-way nested simulation for the summers of 2001, 2002, and 2003 were conducted jointly by Illinois EPA and LADCO. The 36 km non-summer portion of the annual 2003 simulation was conducted by Wisconsin DNR. The annual 2005 36/12 km (and summer season 4 km) MM5 modeling was completed by Alpine Geophysics. Wisconsin DNR also completed 36/12 km MM5 runs for the summer season of 2005.

Model performance was assessed quantitatively with the METSTAT tool from Environ. The metrics used to quantify model performance include mean observation, mean prediction, bias, gross error, root mean square error, and index of agreement. Model performance metrics were calculated for several sub-regions of the modeling domain (Figure 39) and represent hourly spatial averages of multiple monitor locations. Additional analysis of rainfall is done on a monthly basis.

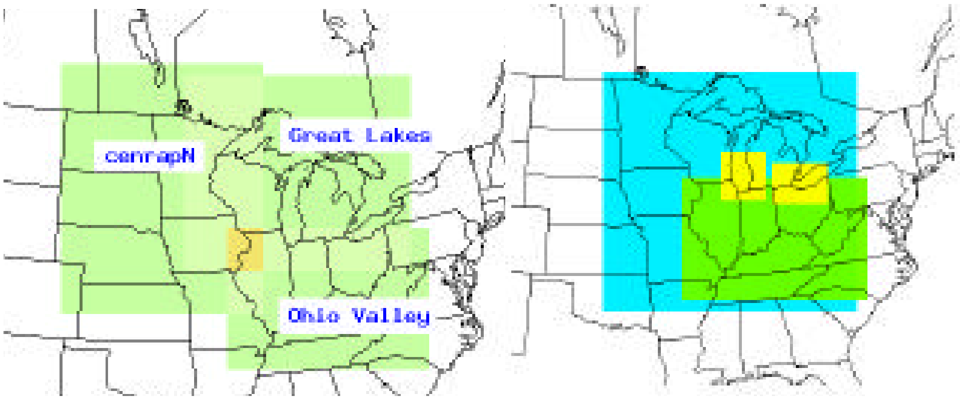

Figure 39. Sub-domains used for model performance for 2001-2003 (left) and 2005 (right)

A summary of the performance evaluation results for the meteorological modeling is provided below. Further details are provided in two summary reports (LADCO, 2005 and LADCO, 2007c).

Temperature: The biggest issue with the performance in the upper Midwest is the existence of a cool diurnal temperature bias in the winter and warm temperature bias over night during the summer (see Figure 40). These features are common to other annual MM5 simulations for the central United States and do not appear to adversely affect model performance.

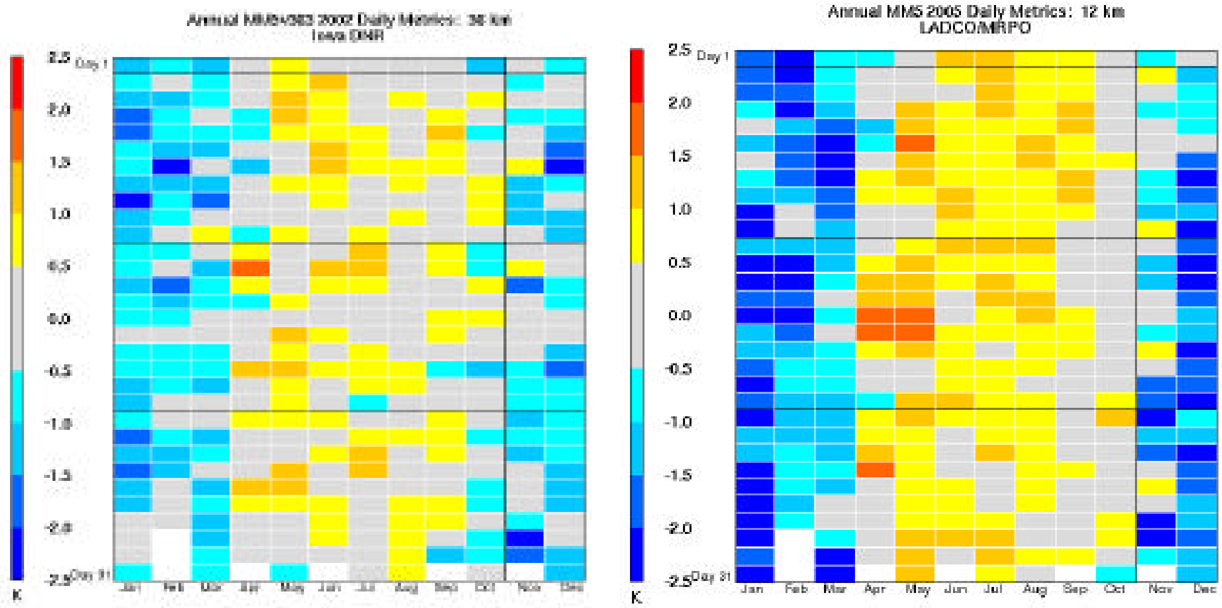

Figure 40. Daily temperature bias for 2002 (left) and 2005 (right) with hotter colors (yellow/orange/red) representing overestimates and cooler colors (blues) representing underestimates

Note: months are represented from left to right (January to December) and days are represented from top to bottom (1 to 30(31) – i.e., upper left hand corner is January 1 and lower right hand corner is December 31

Wind Fields: The wind fields are generally good. Wind speed bias is less than 0.5 m/sec and wind speed error is consistently between 1.0 and 1.5 m/sec. Wind direction error is generally within 15-30 degrees.

Mixing Ratio: The mixing ratio (a measure of humidity) is over-predicted in the late spring and summer months, and mixing ratio error is highest during this period. There is little bias and error during the cooler months when there is less moisture in the air.

Rainfall: The modeled and observed rainfall totals show good agreement spatially and in terms of magnitude in the winter, fall, and early spring months. There are, however, large over-predictions of rainfall in the late spring and summer months (see Figure 41). These over-predictions are seen spatially and in magnitude over the entire domain, particularly in the Southeast United States, and are likely due to excessive convective rainfall being predicted in MM5. This over-prediction of rainfall in MM5 does not necessarily translate into over-prediction of wet deposition in the photochemical model (Baker and Scheff, 2006). CAMx does not explicitly use the convective and non-convective rainfall output by MM5, but estimates wet scavenging by hydrometers using cloud, ice, snow, and rain water mixing ratios output by MM5. Nevertheless, this could have an effect on model performance for $PM_{2.5}$, as discussed in Section 3.7, and may warrant further attention.

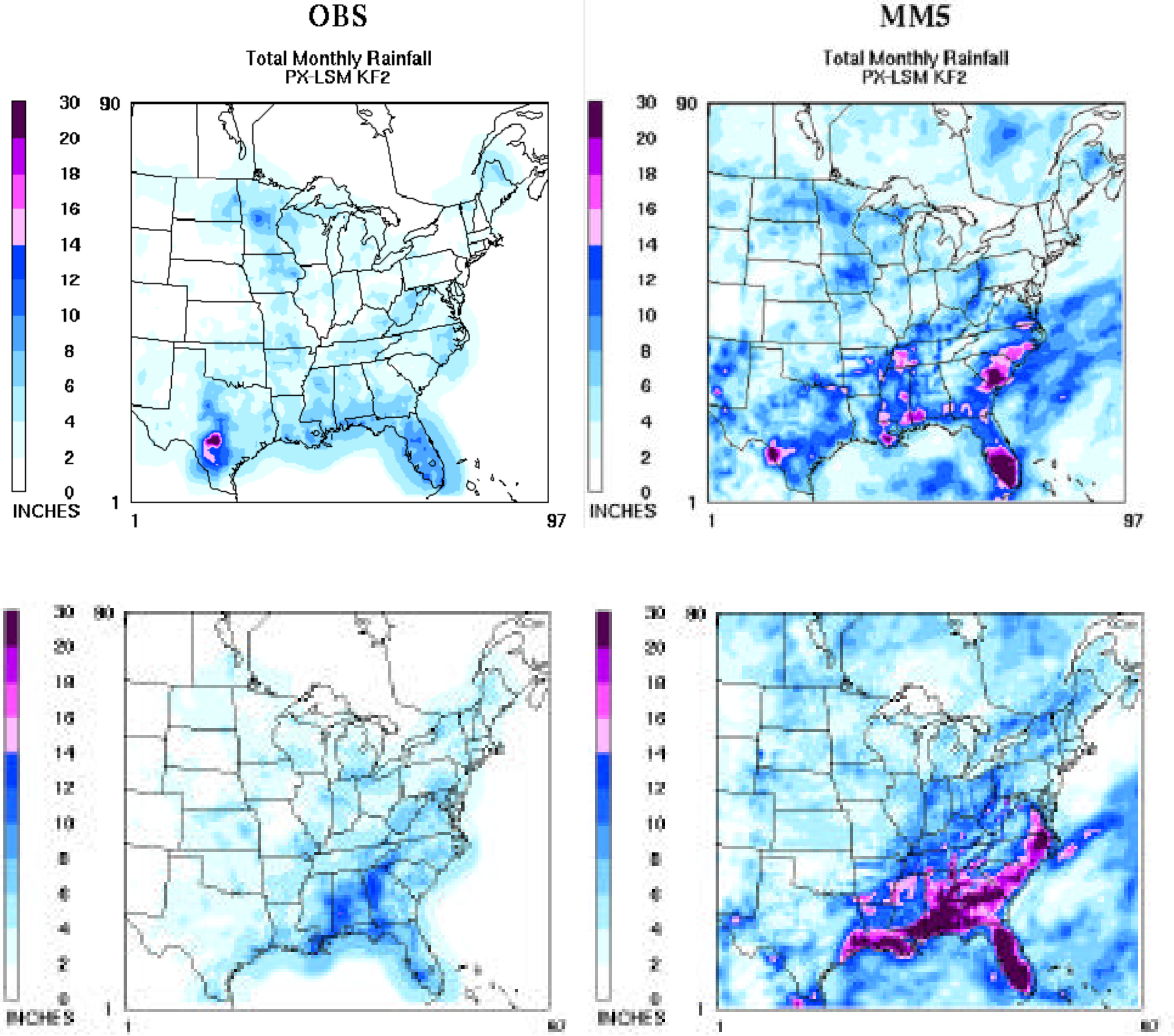

Figure 41. Comparison of observed (left column) and modeled (right column) monthly rainfall for July 2002 (top) and July 2005 (bottom)

3.6 Model Inputs: Emissions

Emission inventories were prepared for two base years: 2002 (Base K) and 2005 (Base M), and several future years: 2008, 2009, 2012, and 2018. Further details of the emission inventories are provided in two summary reports (LADCO, 2006a and LADCO, 2007d) and the following pages of the LADCO web site:

http://www.ladco.org/tech/emis/basek/BaseK_Reports.htm
http://www.ladco.org/tech/emis/r5/round5_reports.htm

For on-road, nonroad, ammonia, and biogenic sources, emissions were estimated by models. For the other sectors (point sources, area sources, and MAR [commercial marine, aircraft, and railroads]), emissions were prepared using data supplied by the LADCO States and other RPOs.

Base Year Emissions: State and source sector emission summaries for 2002 (Base K) and 2005 (Base M) are compared in Figure 42. Additional detail is provided in Table 6.

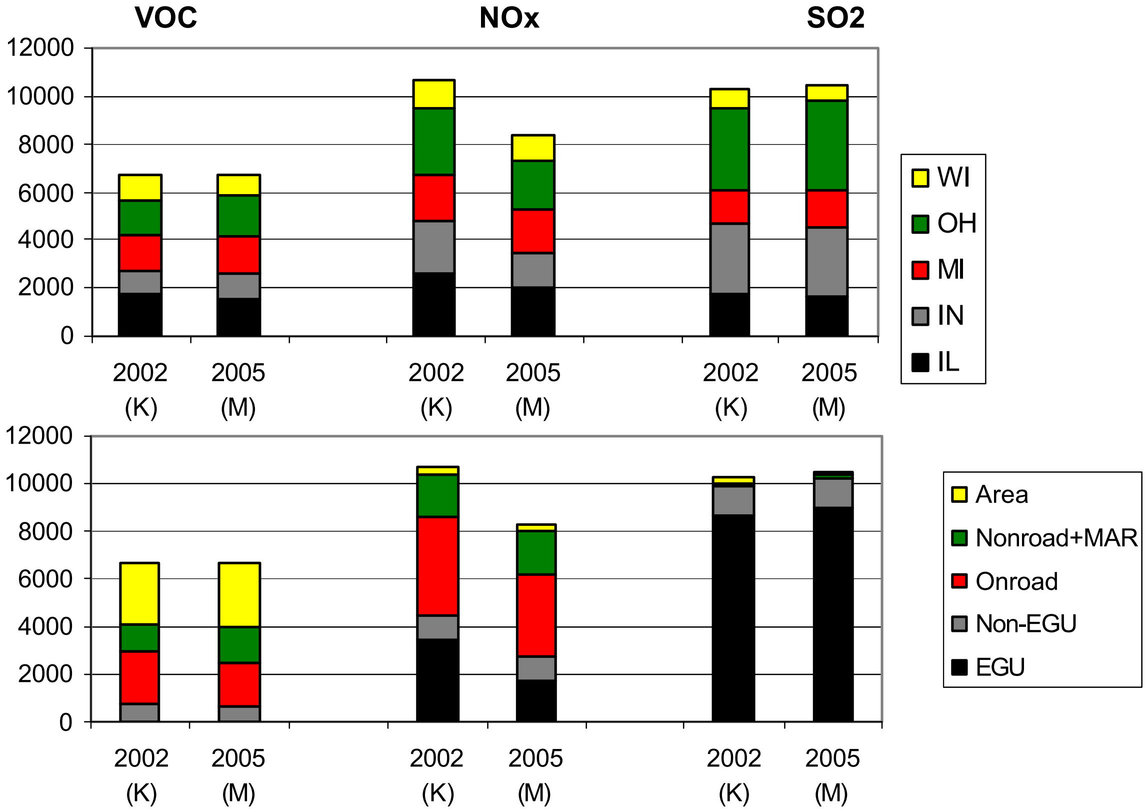

Figure 42. Base K and Base M emissions for 5-state LADCO region by state (top) and source sector (bottom), units: tons per summer weekday

A summary of the base year emissions by sector for the LADCO States is provided below.

On-road Sources: For 2002, EMS was run by LADCO using VMT and MOBILE6 inputs supplied by the LADCO States. EMS was run to generate 36 days (weekday, Saturday, Sunday for each month) at 36 km, and 9 days (weekday, Saturday, Sunday for June – August) at 12 km.

	VOC	Base M	BaseK	Base M	BaseK	BaseK	Base M		NOx	Base M	BaseK	Base M	BaseK	BaseK	Base M		SOX	Base M	BaseK	Base M	BaseK	BaseK	Base M		PM2.5	Base M	BaseK	Base M	BaseK	BaseK	Base M
July	2002	2005	2009	2009	2012	2018	2018		2002	2005	2009	2009	2012	2018	2018		2002	2005	2009	2009	2012	2018	2018		2002	2005	2009	2009	2012	2018	2018
Nonroad																															
IL	224	321	164	257	149	130	213		324	333	263	275	224	154	155		31	33	5	5	0.6	0.4	0.4			30		24			14
IN	125	195	94	160	95	95	128		178	191	142	158	141	141	89		17	19	3	3	3	0.3	0.2			17		13			7
MI	348	414	307	350	276	222	271		205	239	159	197	133	93	112		19	22	3	3	0.5	0.3	0.3			22		18			11
OH	222	356	161	294	145	126	238		253	304	195	246	162	109	135		23	29	4	5	0.5	0.3	0.4			27		22			13
WI	214	238	194	203	175	140	157		145	157	114	129	97	69	77		13	15	2	2	0.3	0.2	0.2			14		12			7
5-State Total	1133	1524	920	1264	840	713	1007		1105	1224	873	1005	757	566	568		103	118	17	18	4.9	1.5	1.5			110		89			52
U.S. Total	8463	9815	5442	8448		5244	6581		6041	9060	6057	8120		5832	5100		505	654	117	153		104	13			573		750			475
MAR																															
IL	10	11	10	10	10	10	6		277	246	201	228	195	186	165		0	22	0	19	0	0	17			7		6			4
IN	5	5	5	5	5	5	3		123	93	89	87	87	84	65		0.2	8	0.2	7	0.2	0.2	6			2		2			2
MI	7	7	7	7	7	8	7		114	87	112	82	111	110	65		0.6	21	0.7	14	0.7	0.8	8			3		3			2
OH	8	7	8	7	8	8	5		177	134	128	126	126	122	94		0.4	14	0.3	12	0.3	0.3	10			4		4			2
WI	4	4	4	4	4	4	3		79	58	59	54	59	57	41		12.7	8	9.5	6	9.5	8.7	5			2		2			1
5-State Total	34	34	34	33	34	35	24		770	618	589	577	578	559	430		13.9	73	10.7	58	10.7	10	46			18		17			11
U.S. Total	307	317	321	157	329	346	334		4968	4515	4002	1813	3964	3919	3812		620	512	509	122	509	503	290			147		57			165
OtherArea																															
IL	679	675	688	594	700	738	582		62	48	68	48	70	73	49		11	11	12	16	12	13	16			40		64			69
IN	354	391	365	358	373	398	384		62	56	65	58	67	69	59		158	32	150	32	151	153	32			2		2			2
MI	518	652	516	562	520	541	549		49	49	52	50	53	54	51		71	29	68	29	68	68	28			111		114			120
OH	546	604	550	506	558	593	487		50	93	59	108	60	62	108		22	6	34	15	35	35	14			19		35			34
WI	458	315	467	290	474	506	293		32	37	34	37	34	35	37		9	17	9	13	10	10	13			11		12			12
5-State Total	2555	2637	2586	2310	2625	2776	2295		255	283	278	301	284	293	304		271	95	273	105	276	279	103			183		227			237
U.S. Total	17876	21093	18638	18683		20512	24300		3856	4899	4100	4220		4418	5357		2075	2947	2062	2559		2189	2709			2735		2621			2570
On-Road																															
IL	446	341	314	268	260	197	151		890	748	578	528	474	300	201			9		4			3			13		10			6
IN	405	282	237	235	193	150	138		703	541	425	402	313	187	173			11		3			2			9		7			2
MI	522	351	335	269	303	217	163		926	722	680	501	619	385	204			14		4			3			12		9			3
OH	574	680	365	424	340	238	242		1035	934	609	693	512	270	274			18		4			4			16		12			4
WI	238	175	144	119	117	88	68		481	457	303	322	226	118	138			9		2			2			8		6			2
5-State Total	2185	1829	1395	1315	1213	890	762		4035	3402	2595	2446	2144	1260	990			61		17			14			58		44			17
U.S. Total	14263				7825				23499				13170																		
EGU																															
IL	9	7	8	6	8	9	7		712	305	227	275	244	231	224		1310	1158	944	958	789	810	869			13		34			77
IN	6	6	6	6	7	6	6		830	393	406	370	424	283	255		2499	2614	1267	1033	1263	1048	1036			16		73			74
MI	12	6	11	4	11	12	4		448	393	218	242	219	247	243		1103	1251	1022	667	1031	1058	725			15		25			29
OH	5	4	6	5	7	7	6		1139	408	330	280	322	271	285		3131	3405	1463	1326	994	701	983			28		94			80
WI	3	5	3	2	4	4	3		293	213	146	165	139	147	177		602	545	512	460	492	500	435			0		22			25
5-State Total	35	28	34	23	37	38	26		3422	1712	1327	1332	1348	1179	1184		8645	8973	5208	4444	4569	4117	4048			72		248			285
U.S. Total	214	140	195	124	197	215	138		14371	10316	7746	7274	7721	7007	6095		31839	34545	20163	16903	17629	14727	14133			685		1131			1571
Non-EGU																															
IL	313	221	286	218	305	350	258		356	330	334	218	338	343	235		373	423	251	335	257	249	346			16		17			19
IN	150	130	160	137	170	199	167		238	179	212	175	216	225	178		292	218	270	216	274	290	180			35		36			44
MI	123	116	115	119	122	139	140		216	240	208	242	214	229	271		162	158	166	148	171	185	163			20		21			25
OH	77	84	75	87	79	90	104		177	175	157	166	160	167	178		240	289	231	288	210	216	293			27		28			33
WI	88	84	97	87	104	120	106		98	97	91	93	92	94	81		163	156	154	152	155	156	85			0		0.1			0.1
5-State Total	751	635	733	648	780	898	775		1085	1021	1002	894	1020	1058	943		1230	1244	1072	1139	1067	1096	1067			98		102			121
U.S. Total	4087	3877	4409		4700	5378			6446	6730	6129		6435	6952			5759	5630	6093		6340	6970						1444			1777
IL	1681	1576	1470	1353	1432	1434	1217		2621	2010	1671	1572	1545	1287	1029		1725	1656	1212	1337	1059	1072	1251			119		155			189
IN	1045	1009	867	901	843	853	826		2134	1453	1339	1250	1248	989	819		2966	2902	1690	1294	1691	1492	1256			81		133			131
MI	1530	1546	1291	1311	1239	1139	1134		1958	1730	1429	1314	1349	1118	946		1356	1495	1260	865	1271	1312	927			183		190			190
OH	1432	1735	1165	1323	1137	1062	1082		2831	2048	1478	1619	1342	1001	1074		3416	3761	1732	1650	1240	953	1304			121		195			166
WI	1005	821	909	705	878	862	630		1128	1019	747	800	647	520	551		800	750	687	635	667	675	540			35		54			47
5-State Total	6693	6687	5702	5593	5529	5350	4889		10672	8260	6664	6555	6131	4915	4419		10263	10564	6581	5781	5928	5504	5280			539		727			723

For 2005, CONCEPT was run by a contractor (Environ) using transportation data (e.g., VMT and vehicle speeds) supplied by the state and local planning agencies in the LADCO States and Minnesota for 24 networks. These data were first processed with T3 (Travel Demand Modeling [TDM] Transformation Tool) to provide input files for CONCEPT to calculate link-specific, hourly emission estimates (Environ, 2007d). CONCEPT was run with meteorological data for a July and January weekday, Saturday, and Sunday (July 15 – 17 and January 16 – 18). A spatial plot of emissions is provided in Figure 43.

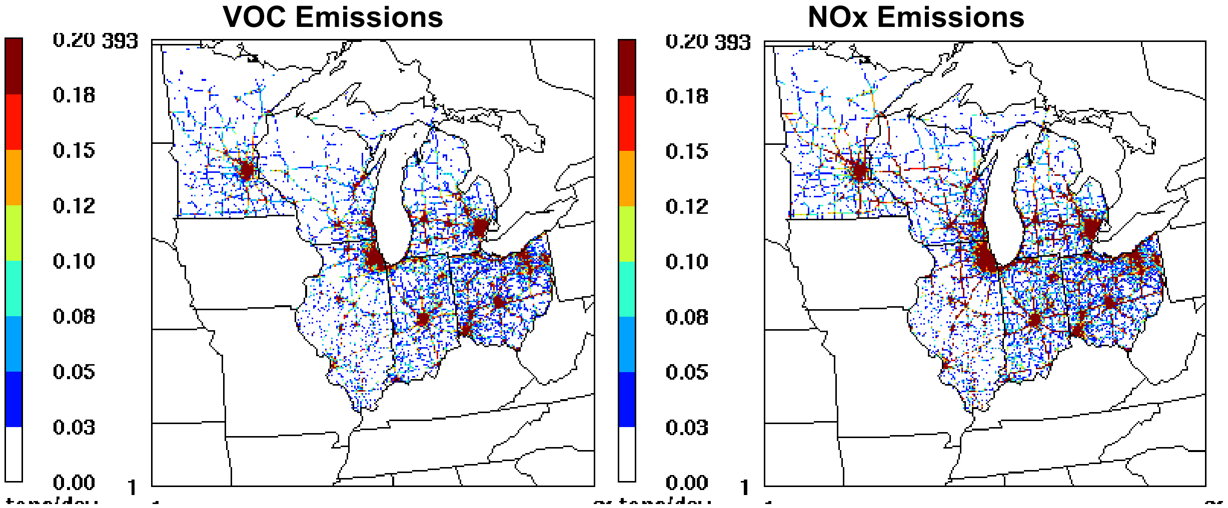

Figure 43. Motor vehicle emissions for VOC (left) and NOx (right) for a July weekday (2005)

Off-road Sources: For 2002 and 2005, NMIM and NMIM2005, respectively, were run by Wisconsin DNR. Additional off-road sectors (i.e., commercial marine, aircraft, and railroads [MAR]) were handled separately. Local data for agricultural equipment, construction equipment, commercial marine, recreational marine, and railroads were prepared by contractors (Environ, 2004, and E.H. Pechan, 2004). For Base M, updated local data for railroads and commercial marine were prepared by a contractor (Environ, 2007b, 2007c). Table 7 compares the Base M 2005 and Base K 2002 emissions. Compared to 2002, the new 2005 emissions reflect substantially lower commercial marine emissions and lower locomotive NOx emissions.

Table 7. Locomotive and commercial marine emissions for the five LADCO States (2002 v. 2005)

	Railroads (TPY)			**Commercial Marine (TPY)**	
	2002	**2005**		**2002**	**2005**
VOC	7,890	7,625		1,562	828
CO	20,121	20,017		8,823	6,727
NOx	182,226	145,132		64,441	42,336
PM	5,049	4,845		3,113	1,413
SO2	12,274	12,173		25,929	8,637
NH3	86	85		----	----

Area Sources: For 2002 and 2005, EMS was run by LADCO using data supplied by the LADCO States to produce weekday, Saturday, and Sunday emissions for each month. For 2005, special attention was given to two source categories: industrial adhesive and sealant solvents (which were dropped from the inventory to avoid double-counting) and outdoor wood boilers (which were added to the inventory).

Point Sources: For 2002 and 2005, EMS was run by LADCO using data supplied by the LADCO States to produce weekday, Saturday, and Sunday emissions for each month. For EGUs, the annual and summer season emissions were temporalized for modeling purposes using profiles prepared by Scott Edick (Michigan DEQ) based on CEM data.

Biogenics: For Base M, a contractor (Alpine) provided an updated version of the CONCEPT/MEGAN biogenics model. Compared to the previous (EMS/BIOME) emissions, there is more regional isoprene using MEGAN compared to the BIOME estimates used for Base K (see Figure 44). Also, with the secondary organic aerosol updates to the CAMx air quality model, Base M includes emissions for monoterpenes and sesquiterpenes, which are precursors of secondary $PM_{2.5}$ organic carbon mass.

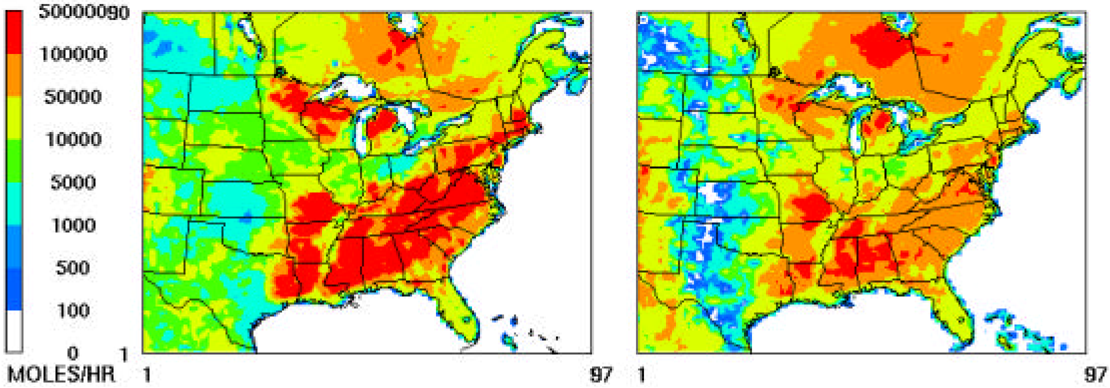

Figure 44. Isoprene emissions for Base M (left) v. Base K (right)

Ammonia: For Base M, the CMU-based 2002 (Base K) ammonia emissions were projected to 2005 using growth factors from the Round 4 emissions modeling. These emissions were then adjusted by applying temporal factors by month based on the process-based ammonia emissions model (Zhang, et al, 2005, and Mansell, et al, 2005). A plot of average daily emissions by state and month is provided in Figure 45. A spatial of emissions is provided in Figure 46.

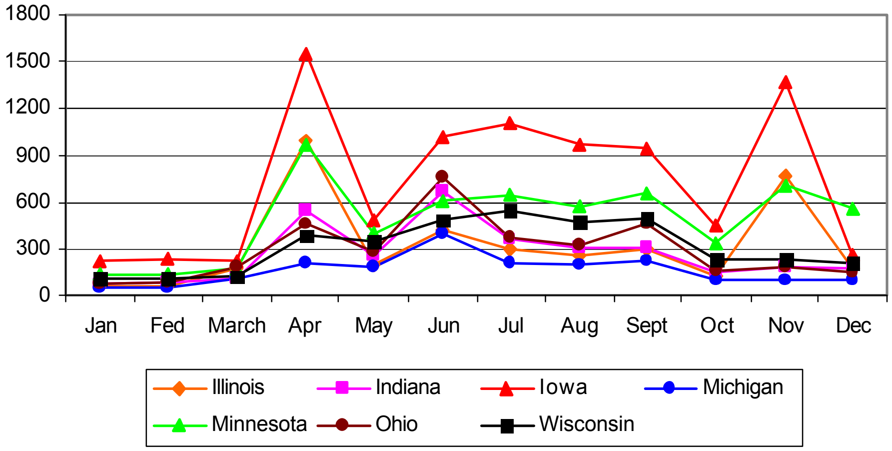

Figure 45. Average daily ammonia emissions for Midwest States by month (2005)

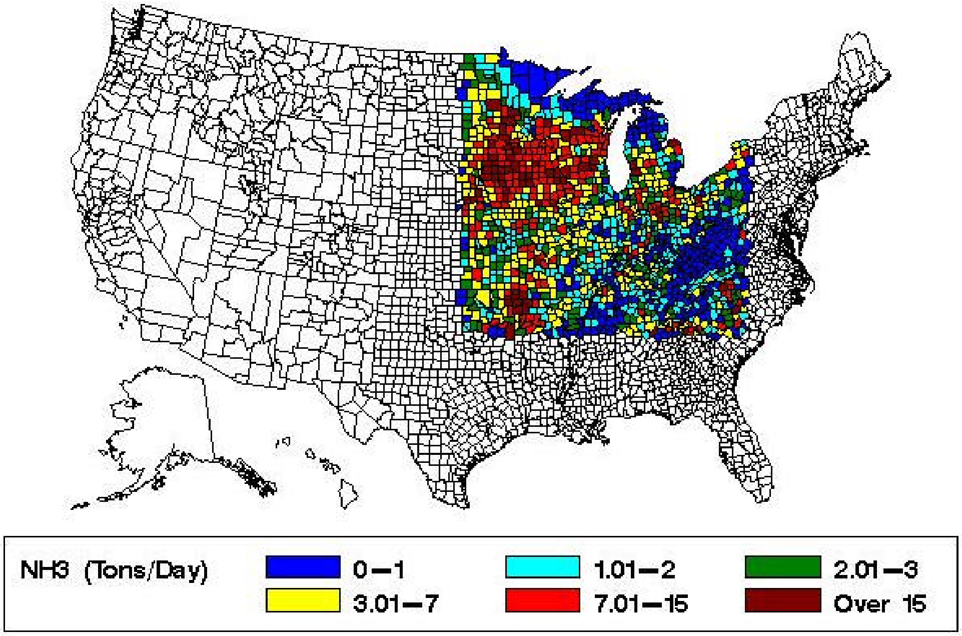

Figure 46. Ammonia emissions for a July weekday (2005) – 12 km modeling domain

Canadian Emissions: For Base M, Scott Edick (Michigan DEQ) processed the 2005 Canadian National Pollutant Release Inventory, Version 1.0 (NPRI). Specifically, a subset of the NPRI data (emissions and stack parameters) relevant to the air quality modeling were reformatted. The resulting emissions represent a significant improvement in the base year emissions.

A spatial plot of point source SO2 and NOx emissions is provided in Figure 47. Additional plots and emission reports are available on the LADCO website (http://www.ladco.org/tech/emis/basem/canada/index.htm).

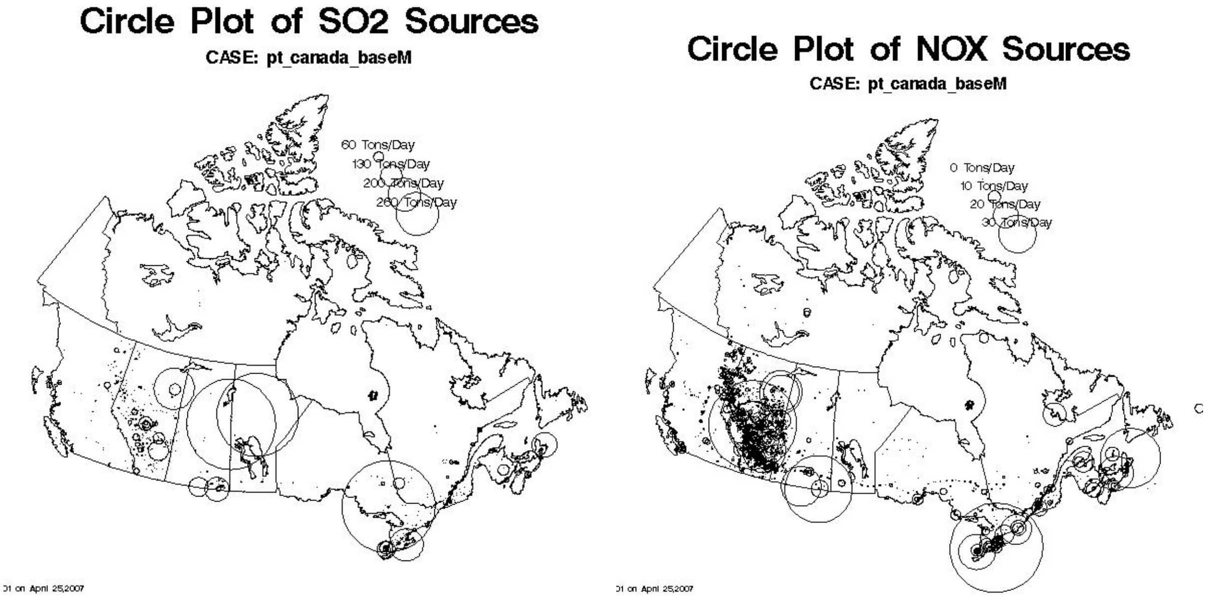

Figure 47. Canadian point source emissions for SO2 (left) and NOx (right)

Fires: For Base K, a contractor (EC/R, 2004) developed a 2001, 2002, and 2003 fire emissions inventory for eight Midwest States (five LADCO states plus Iowa, Minnesota, and Missouri), including emissions from wild fires, prescribed fires, and agricultural burns. Projected emissions were also developed for 2010 and 2018 assuming "no smoke management" and "optimal smoke management" scenarios. An early model sensitivity run showed very little difference in modeled $PM_{2.5}$ concentrations. Consequently, the fire emissions were not included in subsequent modeling runs (i.e., they were not in the Base K or Base M modeling inventories).

Future Year Emissions: Complete emission inventories were developed for several future years: Base K – 2009, 2012, and 2018, and Base M – 2009 and 2018. In addition, 2008 (Base K and Base M) and 2012 (Base M) proxy inventories were estimated based on the 2009 and 2018 data.

Source sector emission summaries for the base years and future years are shown in Figure 48. Additional detail is provided in Table 6.

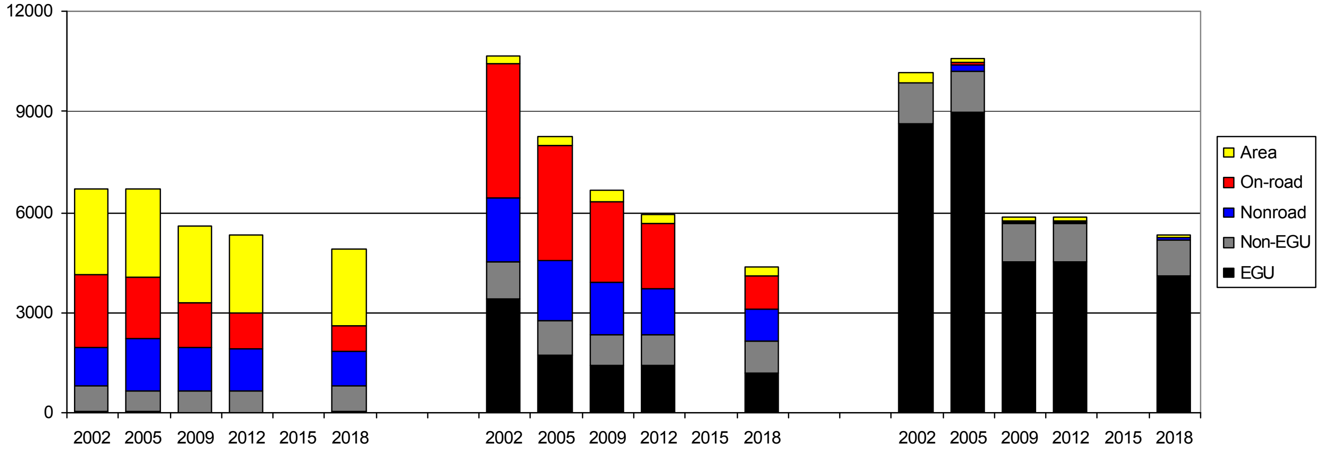

Figure 48. Base year and future year emissions for 5-State LADCO Region (TPD, July weekday)

For on-road, and nonroad, the future year emissions were estimated by models (i.e., EMS/CONCEPT and NMIM, respectively). One adjustment was made to the 2009 and 2018 motor vehicle emission files prepared by Environ with CONCEPT. To reflect newer transportation modeling conducted by CATS for the Chicago area, emissions were increased by 9% in 2009 and 2018. The 2005 base year and adjusted 2009 and 2018 motor vehicle emissions are provided in Table 8.

Table 8. Motor Vehicle Emissions Produced by CONCEPT Modeling (July weekday – tons per day)

Year	State	Sum of CO	Sum of TOG	Sum of NOx	Sum of PM2.5	Sum of SO2	Sum of NH3	Sum of VMT
2005	IL	3,684.3	341.5	748.2	12.9	9.6	35.9	344,087,819.6
	IN	3,384.9	282.0	541.1	8.9	11.1	25.7	245,537,231.9
	MI	4,210.3	351.9	722.0	12.4	13.9	35.3	340,834,025.9
	MN	2,569.1	218.7	380.5	6.3	7.6	17.7	170,024,599.7
	OH	6,113.4	679.8	933.6	16.2	18.8	36.5	360,521,068.6
	WI	2,206.0	175.1	457.5	7.8	9.2	19.7	189,123,964.3
Total		22,168.0	2,049.0	3,782.9	64.5	70.2	170.8	1,650,128,709.9
2009	IL	2,824.4	268.0	527.8	10.1	4.2	38.9	372,132,591.1
	IN	2,839.5	234.9	401.9	6.7	2.8	26.1	249,817,026.3
	MI	3,172.0	269.2	500.9	9.2	4.0	37.1	356,347,010.5
	MN	2,256.8	206.3	307.5	5.1	2.3	21.5	204,443,017.8
	OH	4,619.2	423.7	693.5	11.8	4.7	39.5	387,428,127.2
	WI	1,673.4	119.4	322.1	5.7	2.3	20.6	197,729,964.9
Total		17,385.3	1,521.5	2,753.6	48.7	20.3	183.6	1,767,897,737.8
2018	IL	2,084.7	151.5	200.7	6.3	3.7	43.1	413,887,887.3
	IN	2,217.3	138.4	173.0	4.4	2.6	30.2	288,042,232.1
	MI	2,434.3	163.5	204.1	5.9	3.6	40.5	388,128,431.8
	MN	1,799.6	123.1	137.1	3.6	2.2	24.9	237,022,213.7
	OH	3,361.5	242.5	274.1	6.8	4.0	43.1	421,694,093.4
	WI	1,255.5	68.4	138.5	3.9	2.0	22.2	218,277,167.5
Total		13,152.9	887.5	1,127.5	30.8	18.1	203.9	1,967,052,025.8

For EGUs, future year emissions were based on IPM2.1.9 modeling completed by the RPOs in July 2005 Base K and IPM3.0 completed by EPA in February 2007 for Base M. Several CAIR scenarios were assumed:

Base K
1a: IPM2.1.9, with full trading and banking
1b: IPM2.1.9, with restricted trading (compliance with state-specific emission budgets) and full trading
1d: IPM2.1.9, with restricted trading (compliance with state-specific emission budgets)

Base M
5a: EPA's IPM3.0 was assumed as the future year base for EGUs.
5b: EPA's IPM3.0, with several "will do" adjustments identified by the States. These adjustments should reflect a legally binding commitment (e.g., signed contract, consent decree, or operating permit).
5c: EPA's IPM3.0, with several "may do" adjustments identified by the States. These adjustments reflect less rigorous criteria, but should still be some type of public reality (e.g., BART determination or press announcement).

For other sectors (area, MAR, and non-EGU point sources), the future year emissions for the LADCO States were derived by applying growth and control factors to the base year inventory. These factors were developed by a contractor (E.H. Pechan, 2005 and E.H. Pechan, 2007). For the non-LADCO States, future year emission files were based on data from other RPOs.

Growth factors were based initially on EGAS (version 5.0), and were subsequently modified (for select, priority categories) by examining emissions activity data. Due to a lack of information on future year conditions, the biogenic VOC and NOx emissions, and all Canadian emissions were assumed to remain the constant between the base year and future years.

A "base" control scenario was prepared for each future year based on the following "on the books" controls:

On-Highway Mobile Sources
- Federal Motor Vehicle Emission Control Program, low-sulfur gasoline and ultra-low sulfur diesel fuel
- Inspection/Maintenance programs (nonattainment areas)
- Reformulated gasoline (nonattainment areas)

Off-Highway Mobile Sources
- Federal control programs incorporated into NONROAD model (e.g., nonroad diesel rule), plus the evaporative Large Spark Ignition and Recreational Vehicle standards
- Heavy-duty diesel (2007) engine standard/Low sulfur fuel
- Federal railroad/locomotive standards
- Federal commercial marine vessel engine standards

Area Sources (Base M only)
- Consumer solvents
- AIM coatings
- Aerosol coatings
- Portable fuel containers

Power Plants
- Title IV (Phases I and II)
- NOx SIP Call
- Clean Air Interstate Rule
- Clean Air Mercury Rule

Other Point Sources
- VOC 2-, 4-, 7-, and 10-year MACT standards
- Combustion turbine MACT

Other controls included in the modeling include: consent decrees (refineries, ethanol plants, and ALCOA)[9], NOx RACT in Illinois and Ohio[10], and BART for a few non-EGU sources in Indiana and Wisconsin[11].

For Base K, several additional control scenarios were considered:

> Scenario 2 – "base" controls plus additional SO2 and NOx candidate control measures identified in the White Paper for EGUs
>
> Scenario 3 – Scenario 2 plus additional White Papers for stationary and mobile sources
>
> Scenario 4 – "base" controls plus additional candidate control measures under discussion by State Commissioners
>
> Scenario 5 – "base" controls plus additional candidate control measures identified by the LADCO Project Team

3.7 Basecase Modeling Results

The purpose of the basecase modeling is to evaluate model performance (i.e., assess the model's ability to reproduce the observed concentrations). The model performance evaluation focused on the magnitude, spatial pattern, and temporal of modeled and measured concentrations. This exercise was intended to build confidence in the model prior to its use in examining candidate control strategies. Increased confidence in the model increases the role of the modeling results in the design and establishment of control strategies.

Model performance was assessed by comparing modeled and monitored concentrations. Graphical (e.g., side-by-side spatial plots, time series plots, and scatter plots) and statistical analyses were conducted. No rigid acceptance/rejection criteria were used for this study. Instead, the statistical guidelines recommended by USEPA and other modeling studies (e.g., modeling by the other RPOs) were used to assess the reasonableness of the results. The model performance results presented here describe how well the model replicates observed ozone and $PM_{2.5}$ concentrations after a series of iterative improvements to model inputs.

Ozone: Spatial plots are provided for high ozone periods in June 2002 and June 2005 (see Figures 49a and 49b). The plots show that the model is doing a reasonable job of reproducing the magnitude, day-to-day variation, and spatial pattern of ozone concentrations. There is a tendency, however, to underestimate the magnitude of regional ozone levels. This is more apparent with the 2002 modeling; the regional concentrations in the 2005 modeling agree better with observations due to model and inventory improvements.

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[9] E.H. Pechan's original control file included control factors for three sources in Wayne County, MI. These control factors were not applied in the regional-scale modeling to avoid double-counting with the State's local-scale analysis for PM2.5

[10] NOx RACT in Wisconsin is included in the 2005 basecase (and EGU "will do" scenario). NOx RACT in Indiana was not included in the modeling inventory.

[11] BART assumptions will need to be revisited when the States have completed their BART analyses.

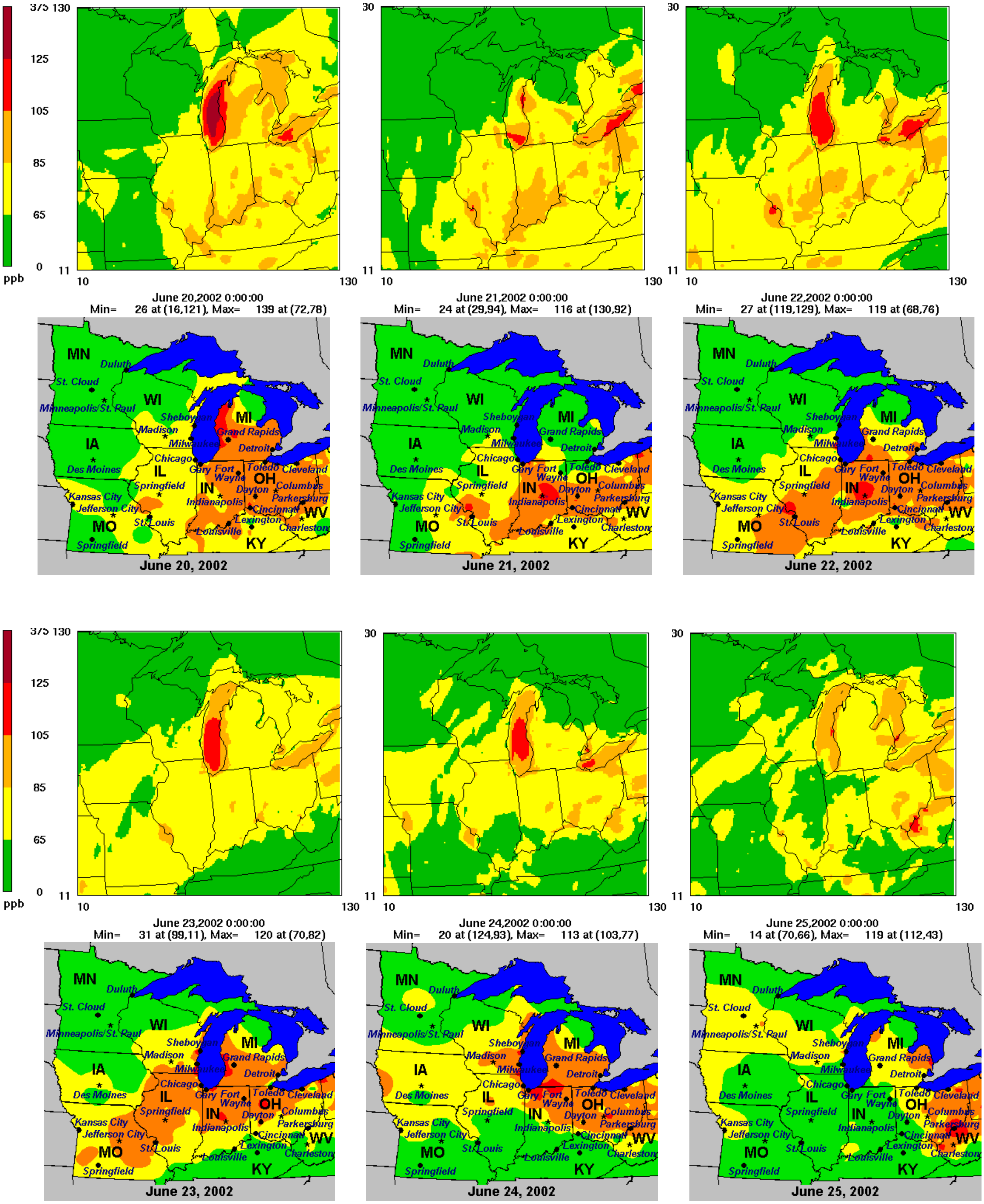


Figure 49a. Modeled (top) v. monitored (bottom) 8-hour ozone concentrations: June 20 – 25, 2002

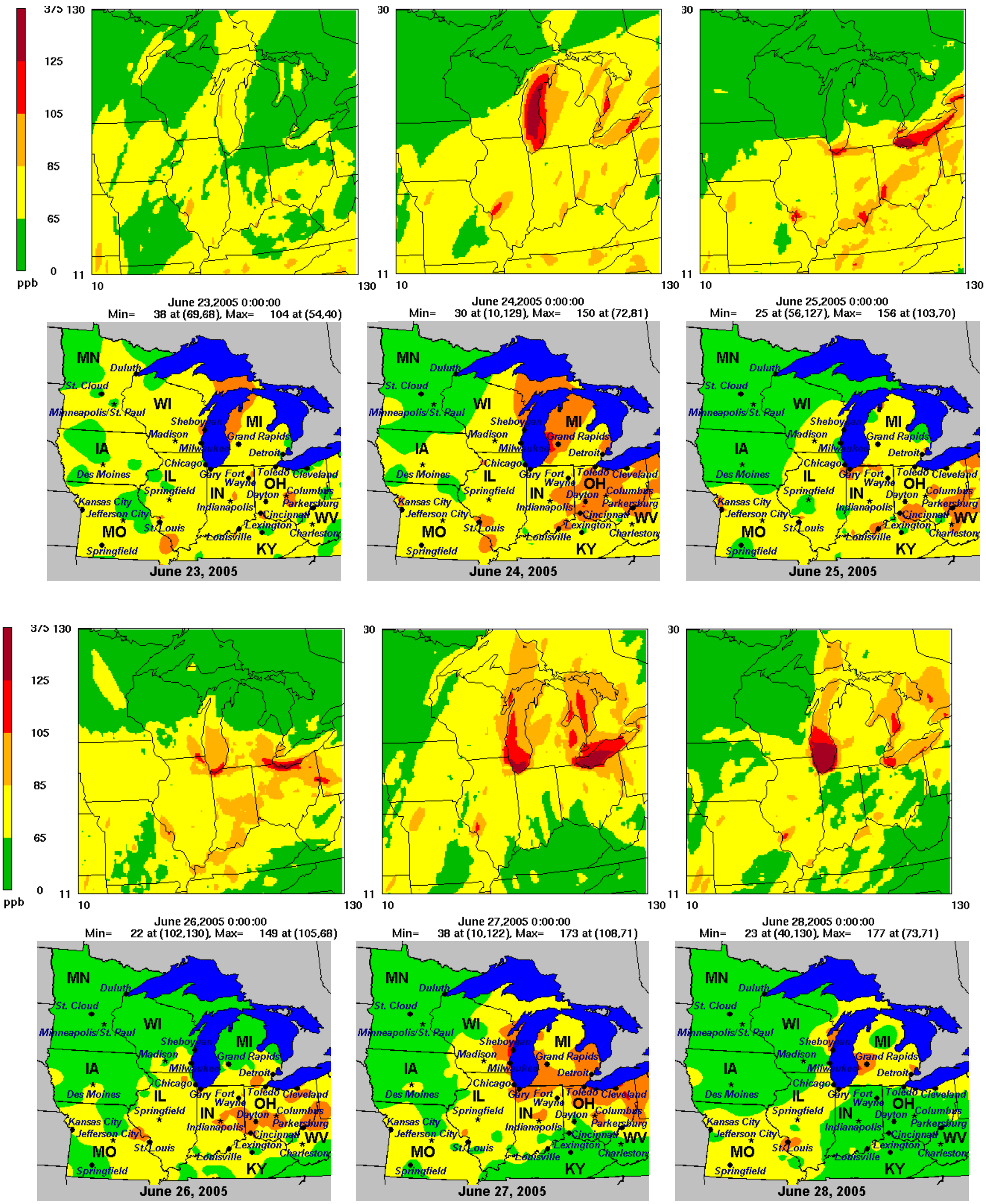


Figure 49b Modeled (top) v. monitored (bottom) 8-hour ozone concentrations: June 23– 28 2005

Standard model performance statistics were generated for the entire 12 km domain, and by day and by monitoring site. The domain-wide mean normalized bias for the 2005 base year is similar to that for the 2002 base year and is generally within 30% (see Figure 50).

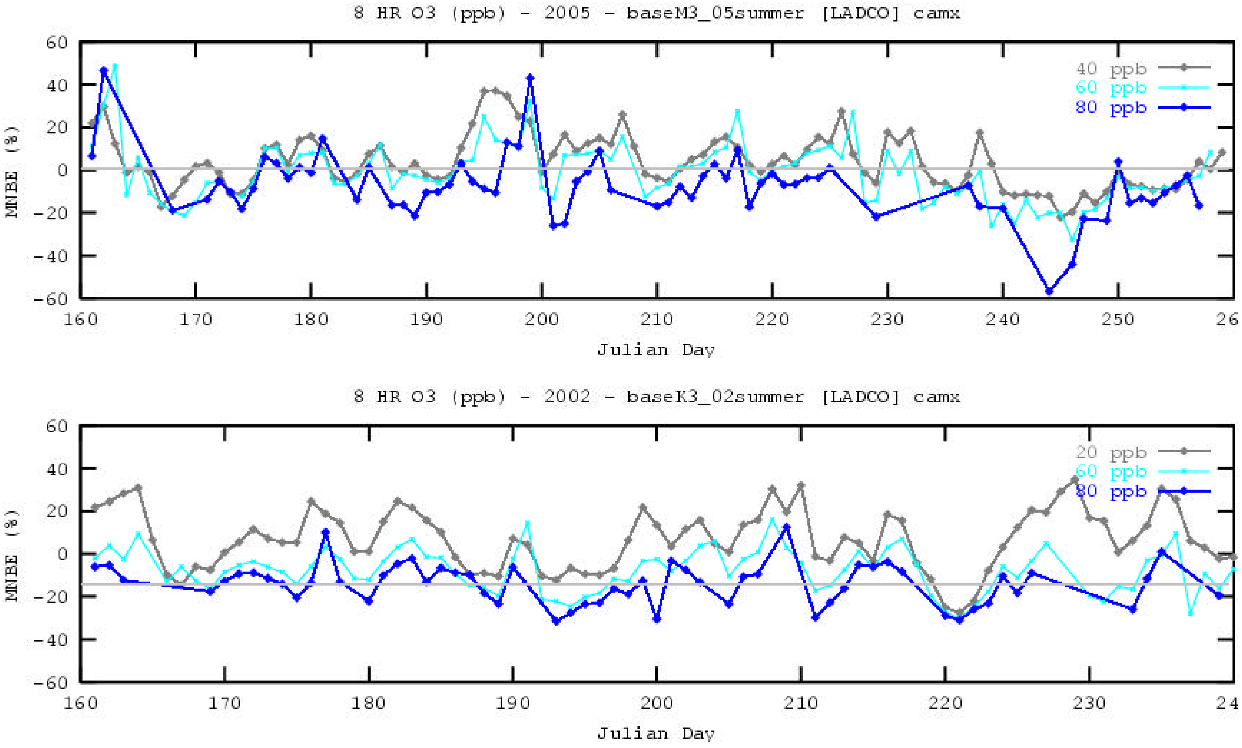


Figure 50. Mean bias for summer 2005 (Base M) and summer 2002 (Base K)

Station-average metrics (over the entire summer) are shown in Figure 51. The bias results further demonstrate the model's tendency to underestimate absolute ozone concentrations.

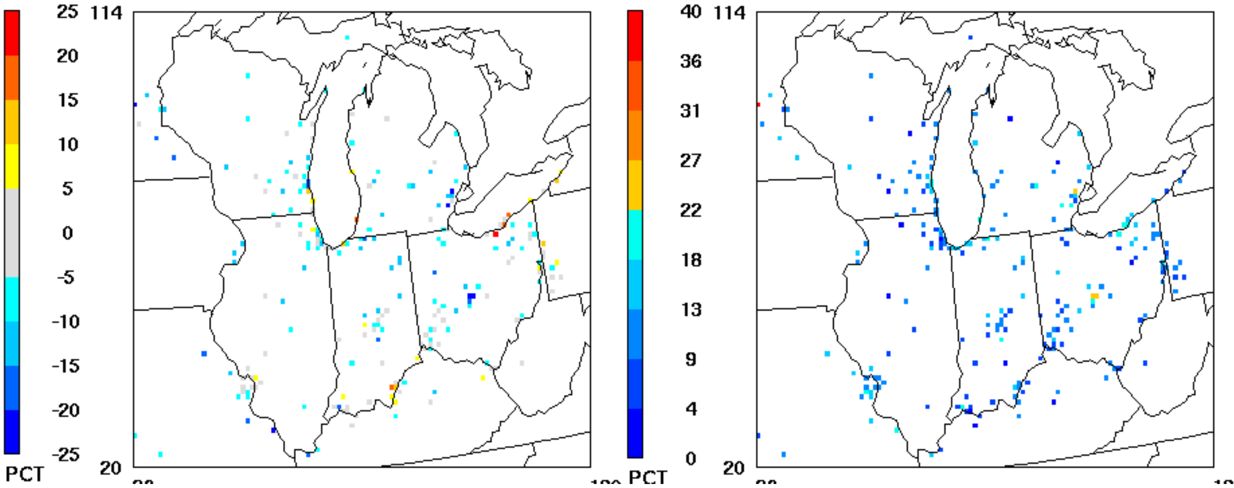


Figure 51. Mean bias (left) and gross error (right) for summer 2005

A limited 4 km ozone analysis was performed by LADCO to address the effect of grid spacing. For this modeling, 4 km grids were placed over Lake Michigan and the Detroit-Cleveland area (see Figure 52). Model inputs included 4 km emissions developed by LADCO (consistent with Base K/Round 4) and the 4 km meteorology developed by Alpine Geophysics.

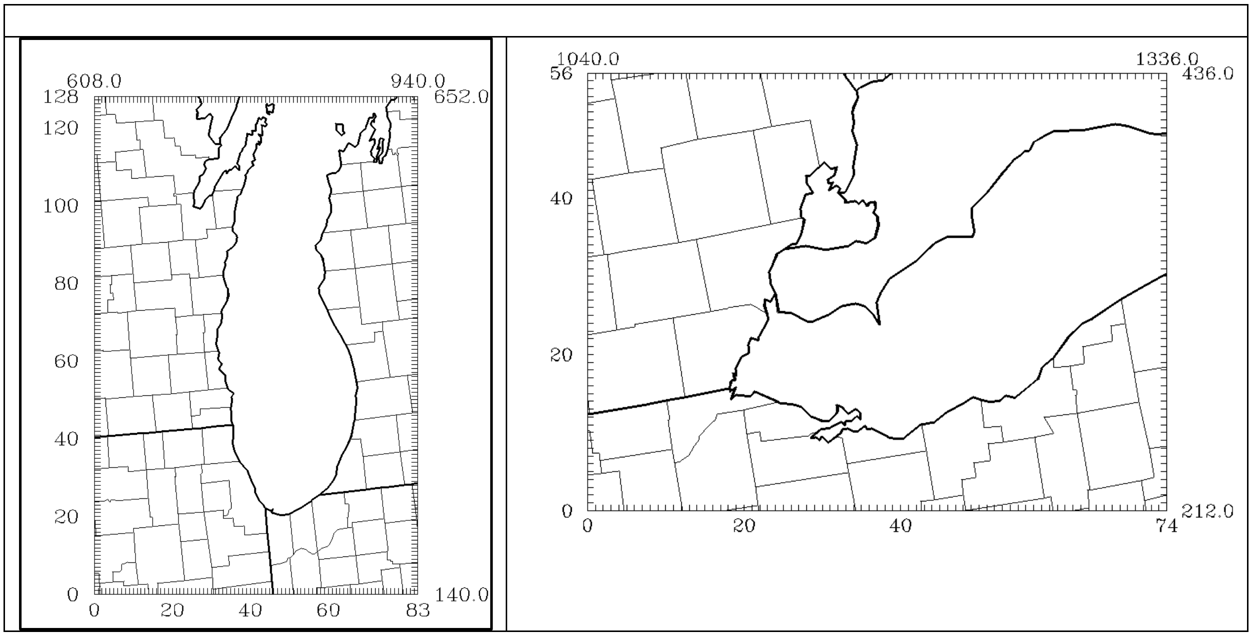


Figure 52. 4 km grids for Lake Michigan region and Detroit-Cleveland region

Hourly time series plots were prepared for several monitors (see Figure 53). The results are similar at 12 km and 4 km, with some site-by-site and day-by-day differences.

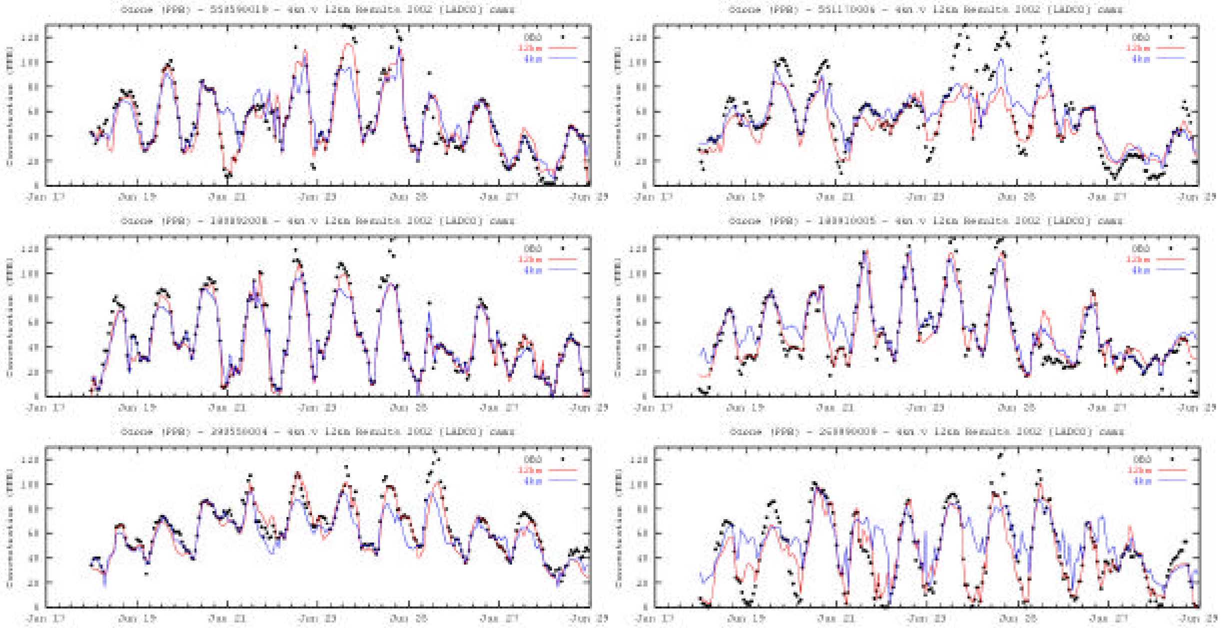
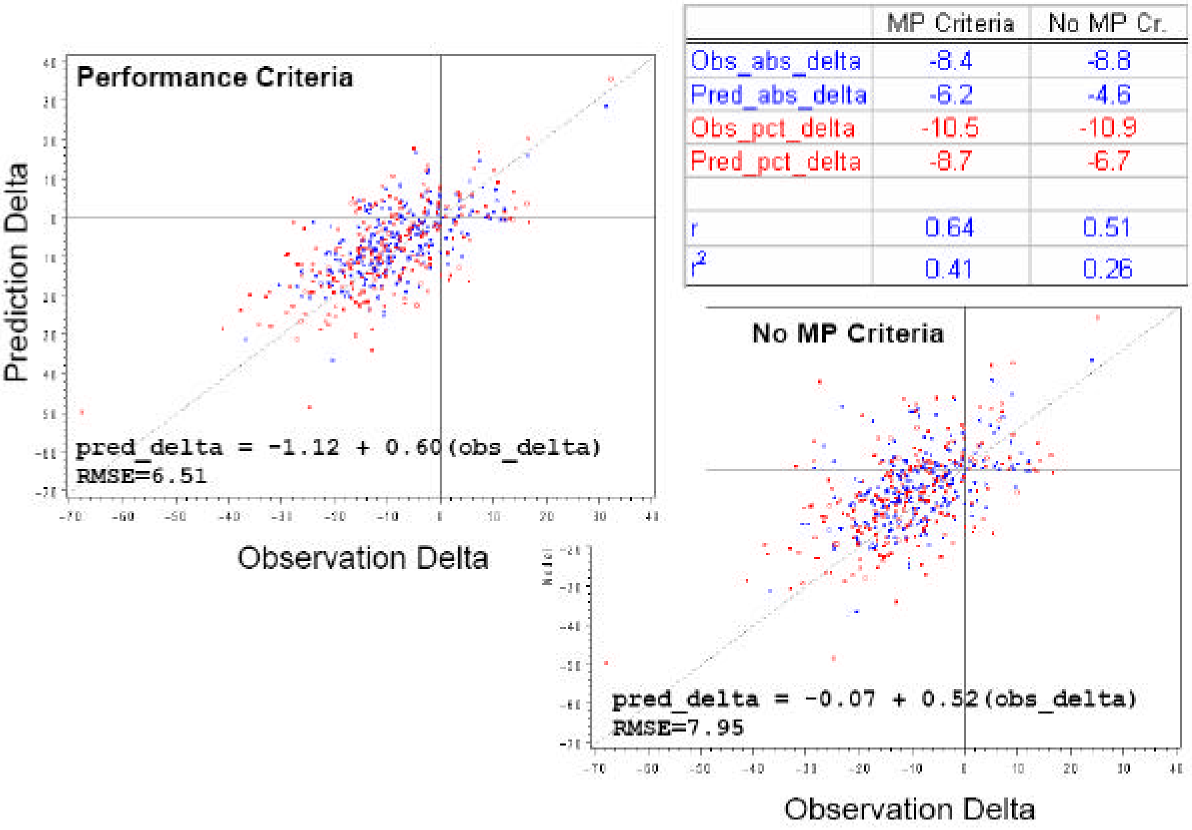


Figure 53. Ozone time series plots for 12 km and 4 km modeling (June 17-29, 2002)

An additional diagnostic analysis was performed to assess the response of the modeling system to changes in emissions (Baker and Kenski, 2007). Specifically, the 2002-to-2005 change in observed ozone concentrations was compared to the change in modeled ozone concentrations based on the 95th percentile (and above) concentration values for each monitor. This analysis was also done with the inclusion of model performance criteria which eliminated poorly performing days (i.e., error > 35%). The results show good agreement in the modeled and monitored ozone concentration changes (e.g., ozone improves by about 9-10 ppb between 2002 and 2005 according to the model and the measurements) – see Figure 54. This provides further support for using the model to develop ozone control strategies.



	MP Criteria	No MP Cr.
Obs_abs_delta	-8.4	-8.8
Pred_abs_delta	-6.2	-4.6
Obs_pct_delta	-10.5	-10.9
Pred_pct_delta	-8.7	-6.7
r	0.64	0.51
r^2	0.41	0.26

Figure 54. Comparison of change in predicted and observed ozone concentrations (2002 v. 2005)

$PM_{2.5}$: Time series plots of the monthly average mean bias and annual fractional bias for Base M and Base K are shown in Figure 55. As can be seen, the Base M model performance results for most species are fairly good (i.e., close to “no bias” throughout most of the year), with two main exceptions. First, the Base M and Base K results for organic carbon are poor, suggesting the need for more work on primary organic carbon emissions. Second, the Base M results for sulfate, while acceptable (i.e., bias values are within 35%), are not as good as the Base K results (e.g., noticeable underprediction during the summer months).

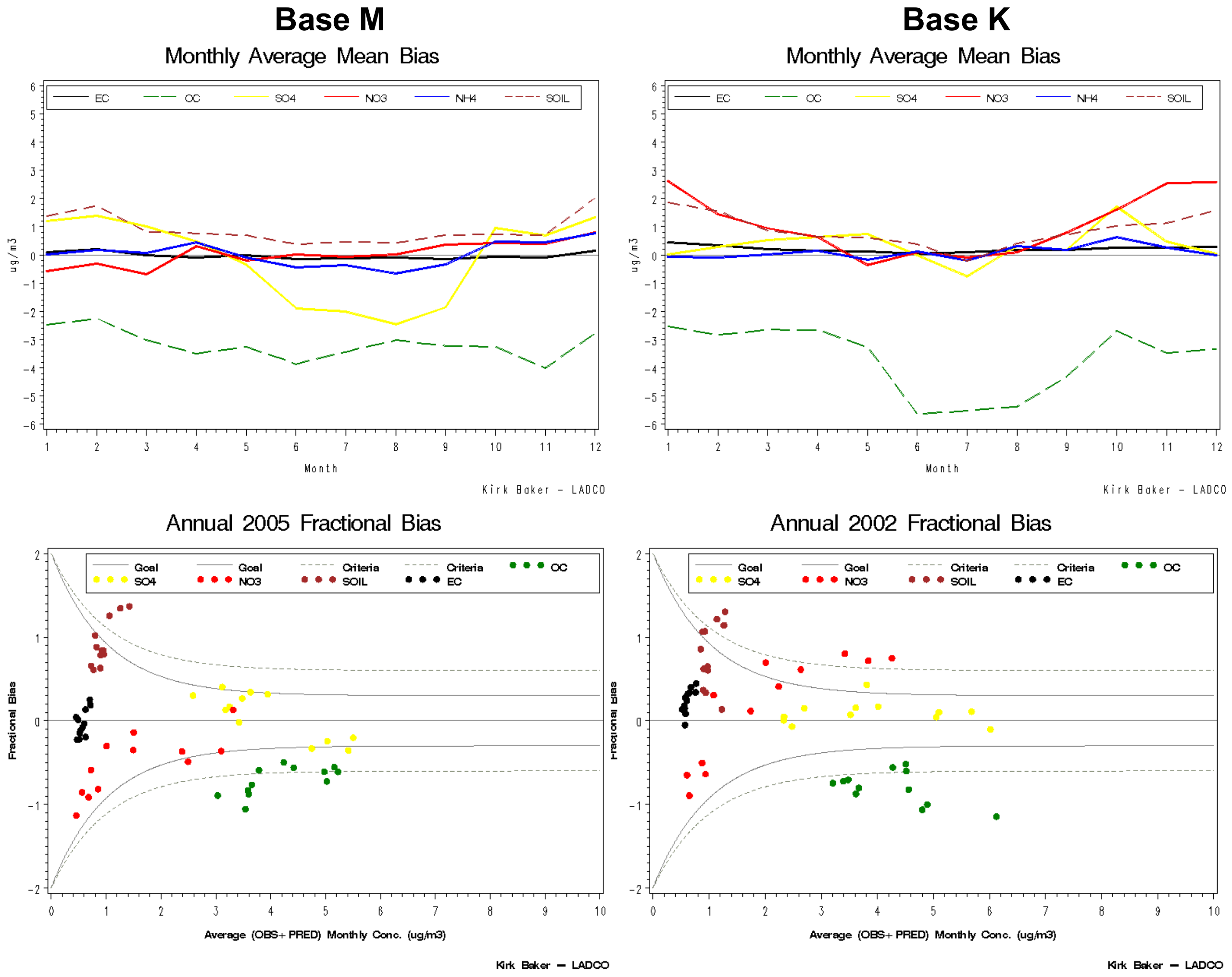


Figure 55. $PM_{2.5}$ Model performance - monthly average mean bias and annual fractional bias for Base M (left column) and Base K (right column)

Two analyses were undertaken to understand sulfate model performance for 2005:

- Assess Meteorological Influences: The MM5 model performance evaluation showed that rainfall is over-predicted by MM5 over most of the domain during the summer months (LADCO, 2007c). Because CAMx does not explicitly use the rainfall output by MM5, this may or may not result in over-prediction sulfate wet deposition (and under-prediction of sulfate concentrations). A sensitivity run was performed with no wet deposition for July, August, and September. The resulting model performance (see green line in Figure 56) showed a noticeable difference from the basecase (i.e., higher sulfate concentrations), and suggests that further evaluation of MM5 precipitation fields may be warranted.

- Assess Emissions Influences: The major contributor to sulfate concentrations in the region is SO2 emitted from EGUs. The basecase modeling inventory for EGUs is based on annual emissions, which were allocated to a typical weekday, Saturday, and Sunday by month using CEM-based temporal profiles. A second sensitivity run was performed using day-specific emissions. The resulting model performance (see purple line in Figure 56) showed little difference from the basecase.

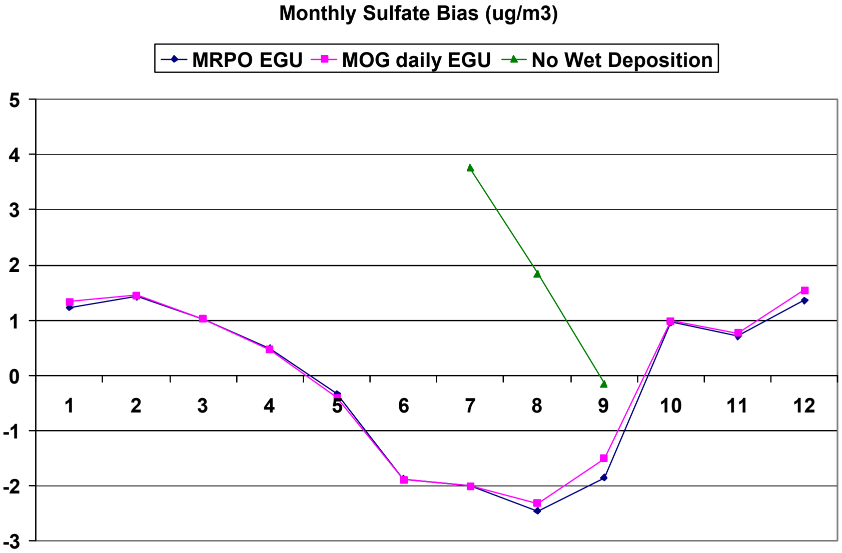


Figure 56. Monthly sulfate bias for Base M (MRPO EGU) v. two sensitivity analyses (Note: positive values indicate over-prediction, negative values indicate under-prediction)

These results indicate that while sulfate model performance is currently acceptable, improvements may be possible through further analysis of MM5 precipitation fields. Regardless, another model sensitivity run showed that this issue should not affect the model projected future year design values.[12] Consequently, even with an improved wet deposition treatment, the Base M strategy results are not expected to change.

Time series plots of daily sulfate, nitrate, elemental carbon, and organic carbon concentrations for three Midwestern locations are presented in Figures 57 (2002) and 58 (2005). These results are consistent with the model performance statistics (i.e., good agreement for sulfates and nitrates and poor agreement [large underprediction] for organic carbon).

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[12] A sensitivity run was conducted with no wet deposition in Quarters 2-3 for the base year (2005) and 2018. The resulting future year design values were consistent with those from the current strategy run – i.e., less than a 0.2 ug/m^3 difference.

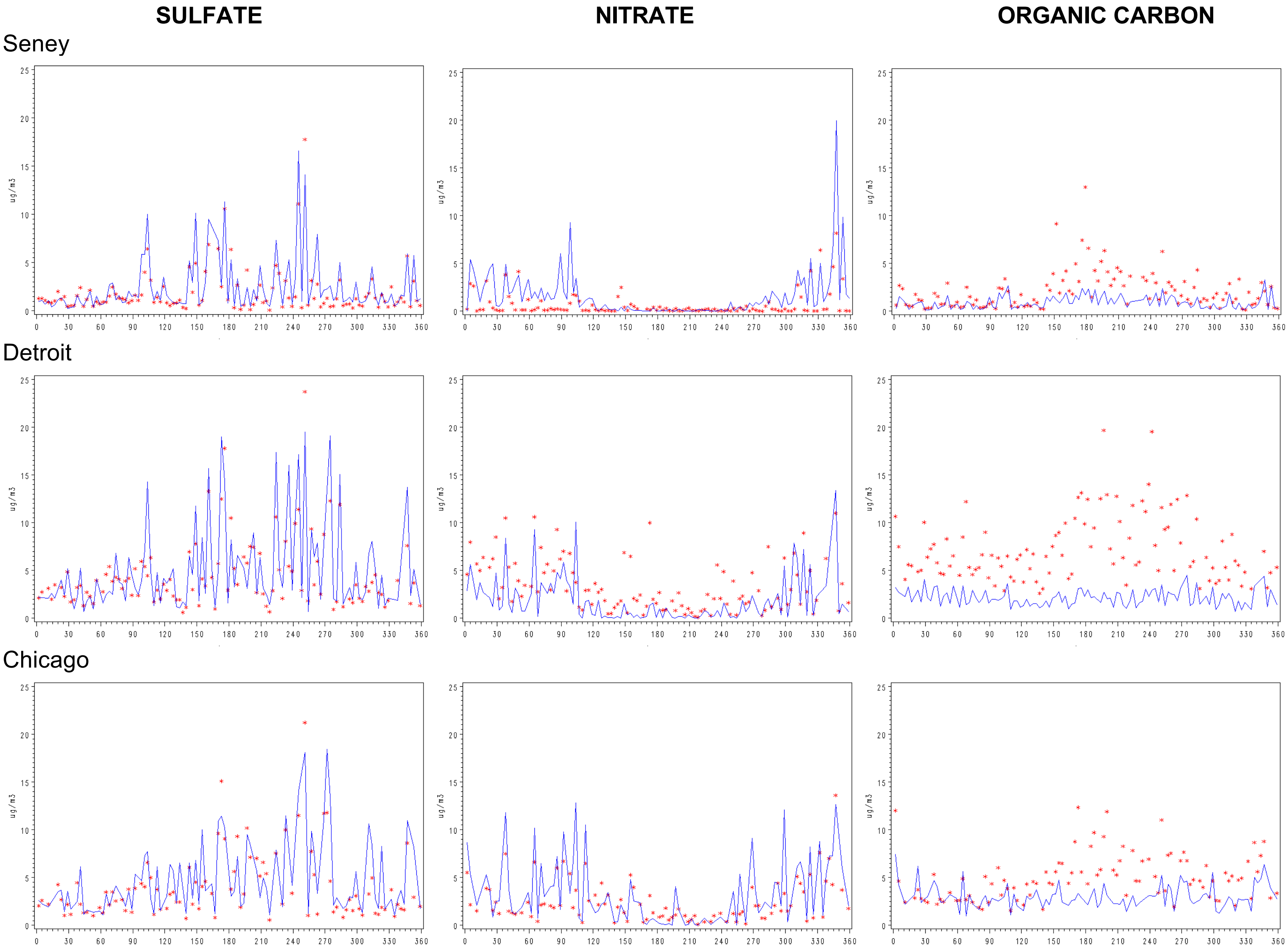

Figure 57. Time series of sulfate, nitrate, and organic carbon at three Midwest sites for 2005

Figure 58. Time series of sulfate, nitrate, and organic carbon at three Midwest sites for 2005

In summary, model performance for ozone and $PM_{2.5}$ is generally acceptable and can be characterized as follows:

Ozone

- Good agreement between modeled and monitored concentration for higher concentration levels (> 60 ppb) – i.e., bias within 30%
- Regional modeled concentrations appear to be underestimated in the 2002 base year, but show better agreement (with monitored data) in the 2005 base year due to model and inventory improvements.
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data
- Model accurately simulates the change in monitored ozone concentrations due to reductions in precursor emissions.

$PM_{2.5}$

- Good agreement in the magnitude of fine particle mass, but some species are overestimated and some are underestimated
    - Sulfates: good agreement in the 2002 base year, but underestimated in the 2005 base year due probably to meteorological factors
    - Nitrates: slightly overestimated in the winter in the 2002 base year, but good agreement in the 2005 base year as a result of model and inventory improvements
    - Organic Carbon: grossly underestimated in the 2002 and 2005 base years due likely to missing primary organic carbon emissions
- Temporal variation and spatial patterns of modeled concentrations are consistent with monitored data

Section 4.0 Attainment Demonstration for Ozone and $PM_{2./5}$

Air quality modeling and other information were used to determine whether existing ("on the books") controls would be sufficient to provide for attainment of the NAAQS for ozone and $PM_{2.5}$ and if not, then what additional emission reductions would be necessary for attainment. Traditionally, attainment demonstrations involved a "bright line" test in which a single modeled value was compared to the ambient standard. To provide a more robust assessment of expected future year air quality, USEPA's modeling guidelines call for consideration of supplemental information. This section summarizes the results of the primary (guideline) modeling analysis and a weight of evidence determination based on the modeling results and other supplemental analyses.

4.1 Future Year Modeling Results

The purpose of the future year modeling is to assess the effectiveness of existing and possible additional control programs. The model was used in a relative sense to project future year design values, which are then compared to the standard to determine attainment/nonattainment. Specifically, the modeling test consists of the following steps:

(1) Calculate base year design values: For ozone and $PM_{2.5}$, the base year design values were derived by averaging the three 3-year periods centered on the emissions base year:

2002 base year: 2000-2002, 2001-2003, and 2002-2004
2005 base year: 2003-2005, 2004-2006, and 2005-2007[13]

(2) Estimate the expected change in air quality: For each grid cell, a relative reduction factor (RRF) is calculated by taking the ratio of the future year and baseline modeling results.

(3) Calculate future year design values: For each grid cell (with a monitor), the RRFs are multiplied by the base year design values to project the future year design values

(4) Assess attainment: Future year design values are compared to the NAAQS to assess attainment or nonattainment.

A comparison of the 2002 and 2005 base year design values for ozone and $PM_{2.5}$ is provided in Figure 59. In general, the figure shows that the 2005 base year design values are much lower than the 2002 base year design values, especially for ozone.

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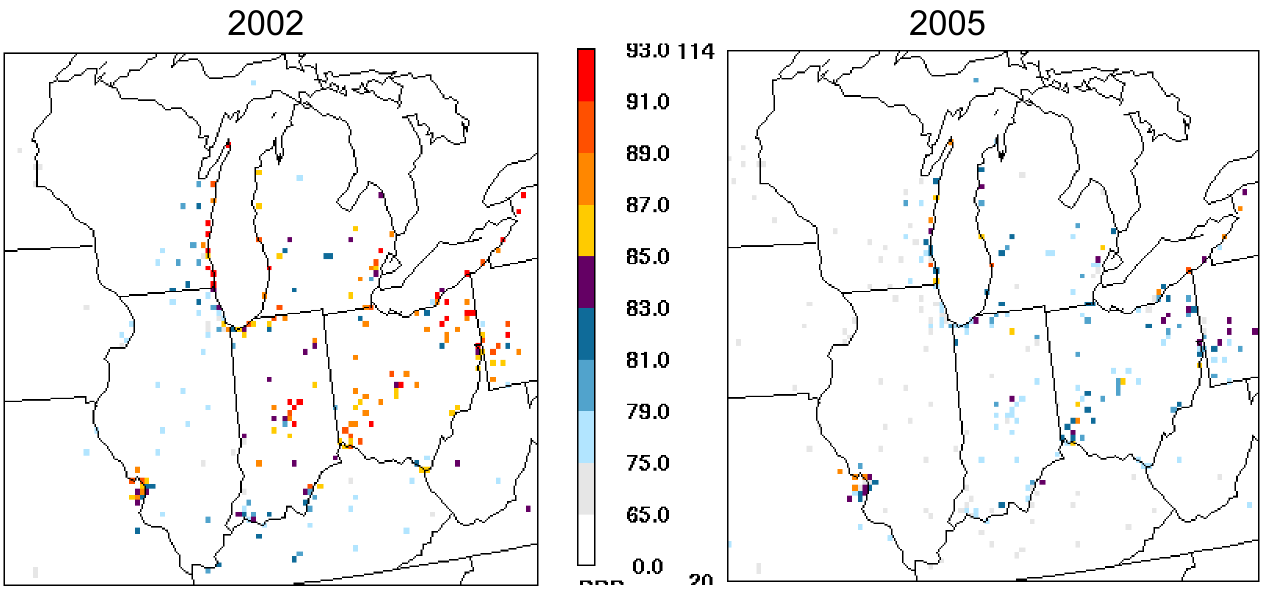
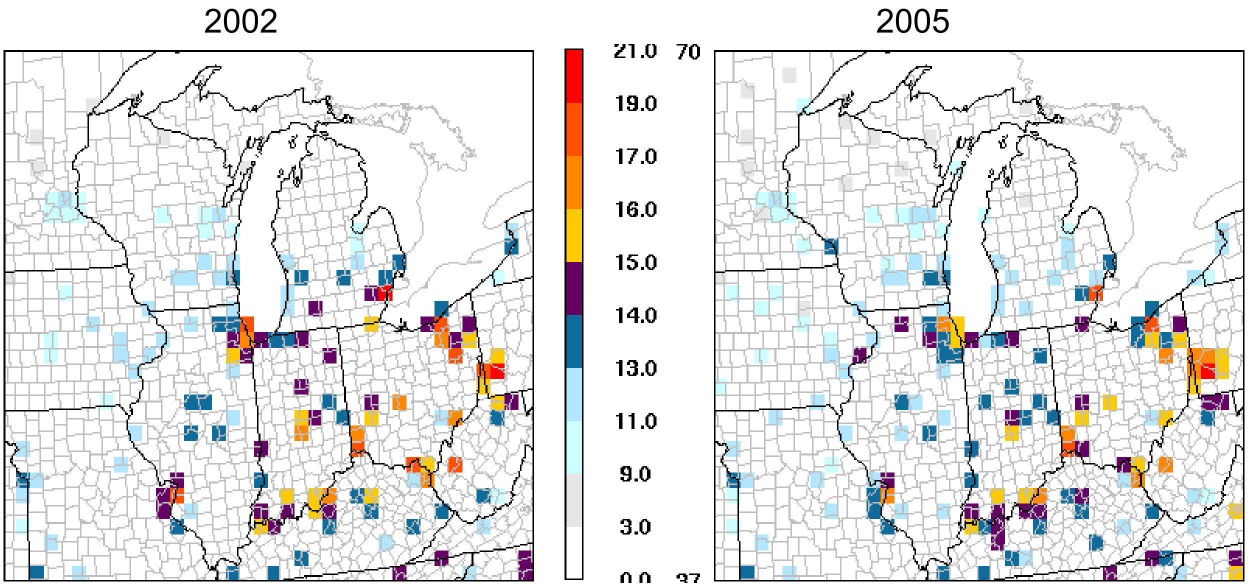
[13] For PM2.5, 2007 data were not available, so the 2005-2007period was represented by the 2005-2006 average. Also, a handful of source-oriented PM2.5 monitors in Illinois and Indiana were excluded from the annual attainment test, because these monitors are not to be used to judging attainment of the annual standard.



Statistical Summary		
# Sites > NAAQS	93	9
Peak Value	99.0 ppb	90.0 ppb
Ave Exceedance Amount	7 ppb	2 ppb



Statistical Summary		
# Sites > NAAQS	58	43
Peak Value	19.3 ug/m^3	17.7 ug/m^3
Ave Exceedance Amount	1.2 ug/m^3	0.9 ug/m^3

Figure 59. 2002 v. 2005 base year design values for ozone (top) and PM$_{2.5}$ (bottom)

Ozone results are provided for those grid cells with ozone monitors. The RRF calculation considers all nearby grid cells (i.e., 3x3 for 12 km modeling) and a threshold of 85 ppb. (If there were less than 10 days above this value, then the threshold was lowered until either there were 10 days or the threshold reached 70 ppb.) $PM_{2.5}$ results are provided for those grid cells with FRM ($PM_{2.5}$-mass) monitors. Spatial mapping was performed to extrapolate $PM_{2.5}$-speciation data from STN and IMPROVE sites to FRM sites.

Additional, hot-spot modeling will be performed by the states for certain $PM_{2.5}$ nonattainment areas (e.g., Detroit, Cleveland, and Granite City) to address primary emissions from local point sources which may not be adequately accounted for by the regional grid modeling. This modeling will consist of Gaussian dispersion modeling (e.g., AERMOD) performed in accordance with USEPA's modeling guidance (see Section 5.3 of the April 2007 guidance document).

The ozone and $PM_{2.5}$ modeling results are provided in Appendix I for select monitors (high concentration sites) in the 5-state region for the following future years of interest: 2008 (ozone only), 2009, 2012, and 2018. A summary of the modeling results is provided in Table 9 (ozone) and Table 10 ($PM_{2.5}$), and spatial maps of the Base M future year concentrations are provided in Figures 60-62.

The number of monitors with design values above the standard are as follows:

Table 11. Number of sites above standard

					Ozone						
State	2002	2005		2009			2012			2018	
	BaseK	Base M		BaseK	Base M		BaseK	Base M		BaseK	Base M
IL	3	0		0	0		0	0		0	0
IN	22	0		0	0		0	0		0	0
MI	15	3		1	1		0	0		0	0
OH	40	4		1	0		1	0		0	0
WI	13	2		4	0		3	0		1	0
Total	93	9		6	1		4	0		1	0
					PM2.5						
State	2002	2005		2009			2012			2018	
	BaseK	Base M		BaseK	Base M		BaseK	Base M		BaseK	Base M
IL	11	9		3	1		3	1		2	0
IN	10	7		1	0		1	0		0	0
MI	6	2		3	1		2	1		0	0
OH	31	25		7	1		4	0		1	1
WI	0	0		0	0		0	0		2	0
Total	58	43		14	3		10	2		5	1

Key Sites		**2008**			**2009**			**2012**			**2018**
		Round 5	Round 4		Round 5	Round 4		Round 5	Round 4		Round 5
Lake Michigan Area											
Chiwaukee	550590019	82.0	**93.0**		82.3	**92.0**		80.9	**90.3**		76.2
Racine	551010017	77.6	**85.9**		77.5	84.9		76.1	82.9		71.2
Milwaukee-Bayside	550190085	79.6	**85.4**		79.8	84.9		78.1	82.3		72.7
Harrington Beach	550890009	80.0	**86.7**		80.1	**85.4**		78.3	82.9		72.5
Manitowoc	550710007	81.0	80.3		80.5	78.9		78.3	76.3		72.2
Sheboygan	551170006	84.4	**90.0**		84.0	**88.9**		81.9	**86.4**		75.4
Kewaunee	550610002	78.9	82.5		78.1	81.0		76.0	79.1		69.9
Door County	550290004	84.8	83.6		83.9	81.8		81.6	79.3		74.7
Hammond	180892008	75.4	**86.9**		75.4	**86.6**		74.6	**86.3**		71.6
Whiting	180890030	77.0			77.0			76.2			73.1
Michigan City	180910005	74.2	**87.4**		73.9	**86.5**		72.5	**85.4**		68.1
Ogden Dunes	181270020	75.7	82.3		75.6	82.8		74.4	82.0		70.8
Holland	260050003	**85.6**	84.9		**85.3**	83.4		82.9	81.0		76.1
Jenison	261390005	78.2	78.7		77.4	77.6		75.2	75.5		69.0
Muskegon	261210039	81.2	82.7		80.8	81.5		78.6	79.4		72.2
Indianapolis Area											
Noblesville	189571001	78.7	**85.2**		78.8	83.7		76.3	82.0		69.3
Fortville	180590003	74.6	**85.1**		74.5	83.8		72.2	82.1		65.7
Fort B. Harrison	180970050	74.8	84.8		75.1	83.7		73.4	82.4		69.1
Detroit Area											
New Haven	260990009	82.7	**86.3**		81.4	**85.3**		80.2	83.5		76.1
Warren	260991003	82.2	84.3		81.0	83.3		80.4	81.9		77.3
Port Huron	261470005	78.7	80.5		77.1	79.1		75.3	77.0		70.6
Cleveland Area											
Ashtabula	390071001	84.9	84.7		83.4	82.7		81.0	80.2		75.1
Geauga	390550004	75.7	**90.3**		74.7	**88.8**		72.7	**86.2**		67.3
Eastlake	390850003	82.8	84.2		81.9	82.8		80.5	80.6		76.2
Akron	391530020	79.3	83.0		78.1	81.4		75.6	78.5		68.7
Cincinnati Area											
Wilmington	390271002	77.8	84.8		77.5	83.5		75.1	81.1		68.3
Sycamore	390610006	81.4	**85.4**		81.6	84.7		80.0	82.9		74.3
Lebanon	391650007	83.6	80.1		83.0	79.0		80.8	77.0		74.2
Columbus Area											
London	390970007	75.4	79.9		75.0	78.4		72.7	76.5		66.3
New Albany	390490029	82.4	84.1		81.8	82.6		79.6	80.2		73.0
Franklin	290490028	77.0	77.7		75.9	76.5		74.2	74.7		69.0
St. Louis Area											
W. Alton (MO)	291831002	82.4	**86.1**		81.0	**85.2**		79.5	84.0		74.9
Orchard (MO)	291831004	83.3	83.3		82.0	82.2		80.4	80.4		76.2
Sunset Hills (MO)	291890004	79.5	82.8		78.7	81.9		77.4	80.6		73.9
Arnold (MO)	290990012	78.7	78.4		77.2	77.4		75.8	75.8		72.0
Margaretta (MO)	295100086	79.8	84.0		79.3	83.4		77.9	82.5		74.4
Maryland Heights (MO)	291890014	84.5			83.4			81.9			78.1

			2009			2012			2018	
County	**Site ID**		**Round 5**	**Round4**		**Round 5**	**Round4**		**Round 5**	**Round4**
Cook	170310022		13.9	14.8		13.8	14.6		13.6	14.4
Cook	170310052		14.2	**15.8**		14.2	**15.5**		13.8	**15.0**
Cook	170310057		13.7	14.5		13.7	14.3		13.5	14.1
Cook	170310076		13.7	14.5		13.7	14.3		13.5	14.1
Cook	170312001		13.6	14.5		13.5	14.3		13.5	14.1
Cook	170313103		14.9			14.8			14.3	
Cook	170313301		14.1	14.8		14.0	14.6		13.8	14.4
Cook	170316005		14.4	**15.3**		14.3	**15.1**		14.1	14.9
Madison	171191007		**15.2**	**16.0**		**15.1**	**15.8**		14.5	**15.5**
St. Clair	171630010		14.0	14.9		13.8	14.7		13.2	14.5
Clark	180190005		13.6	**15.5**		13.6	**15.0**		13.2	14.4
Dubois	180372001		12.4	13.8		12.3	13.5		11.7	13.0
Lake	180890031		12.9			12.7			12.3	
Marion	180970078		12.7	14.5		12.5	14.2		11.9	13.7
Marion	180970083		13.2	14.8		13.0	14.9		12.4	14.0
Wayne	261630001		13.0	14.5		12.9	14.1		12.4	13.3
Wayne	261630015		14.2	**15.8**		14.0	**15.3**		13.5	14.4
Wayne	261630016		13.0	14.1		12.9	13.7		12.4	13.0
Wayne	261630033		**15.7**	**17.7**		**15.5**	**17.1**		**15.0**	**16.1**
Wayne	261630036		13.0	**15.1**		12.9	14.7		12.4	13.9
Butler	390170003		13.3	14.2		13.2	13.7		12.6	13.1
Butler	390170016		13.0	13.5		13.0	12.9		12.4	12.2
Cuyahoga	390350027		13.4	14.4		13.2	13.8		12.6	12.9
Cuyahoga	390350038		**15.1**	**16.1**		14.8	**15.4**		14.2	14.4
Cuyahoga	390350045		14.2	14.6		14.0	14.0		13.4	13.1
Cuyahoga	390350060		14.8	**15.3**		14.6	14.7		14.0	13.7
Cuyahoga	390350065		13.7	14.1		13.5	13.5		12.9	12.6
Franklin	390490024		12.8	14.6		12.6	14.0		11.9	13.0
Franklin	390490025		12.6	14.1		12.4	13.5		11.8	12.5
Franklin	390490081		11.7	14.0		11.5	13.4		10.9	12.5
Hamilton	390610014		14.4	**15.5**		14.3	14.8		13.7	14.0
Hamilton	390610040		12.7	13.6		12.6	13.0		12.1	12.3
Hamilton	390610042		13.9	14.6		13.8	14.0		13.2	13.2
Hamilton	390610043		12.9	13.6		12.8	13.0		12.3	12.2
Hamilton	390617001		13.3	14.2		13.2	13.6		12.7	12.8
Hamilton	390618001		14.6	**15.2**		14.5	14.6		13.9	13.8
Jefferson	390810016		12.5	**16.3**		12.5	**15.9**		12.5	**16.2**
Jefferson	390811001		13.4	**15.5**		13.3	**15.0**		13.3	**15.3**
Lawrence	390870010		12.7	14.2		12.7	13.7		12.2	13.2
Montgomery	391130032		13.0	13.7		12.8	13.2		12.2	12.3
Scioto	391450013		12.2	**15.4**		12.1	14.8		11.6	14.2
Stark	391510017		13.9	**15.0**		13.7	14.3		13.1	13.6
Stark	391510020		12.4	13.6		12.2	13.0		11.7	12.2
Summit	391530017		12.9	14.4		12.8	13.6		12.2	12.9
Summit	391530023		12.1	13.6		12.0	13.0		11.4	12.2

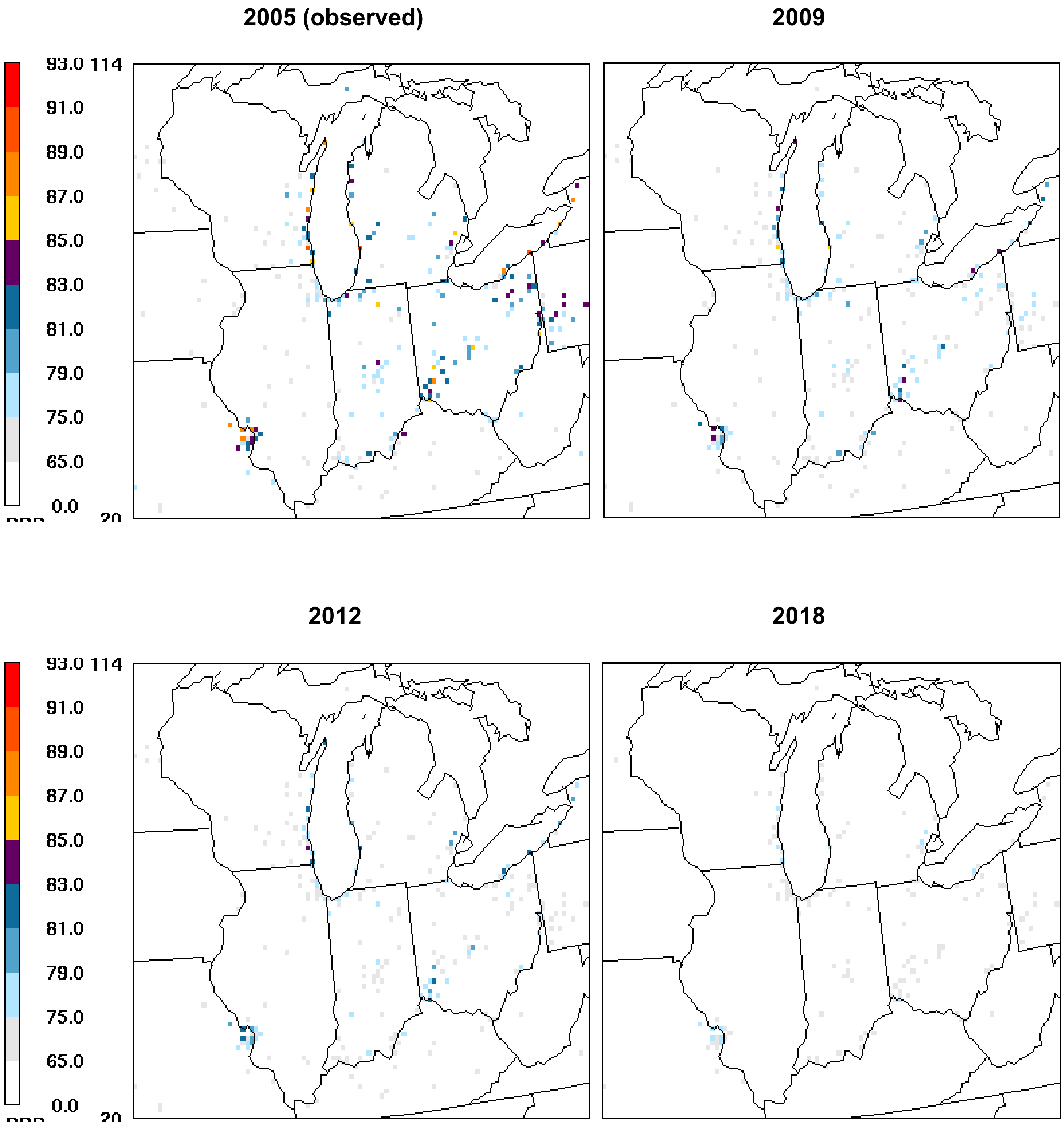


Figure 60. Observed base year and projected future year design values for ozone – Base M

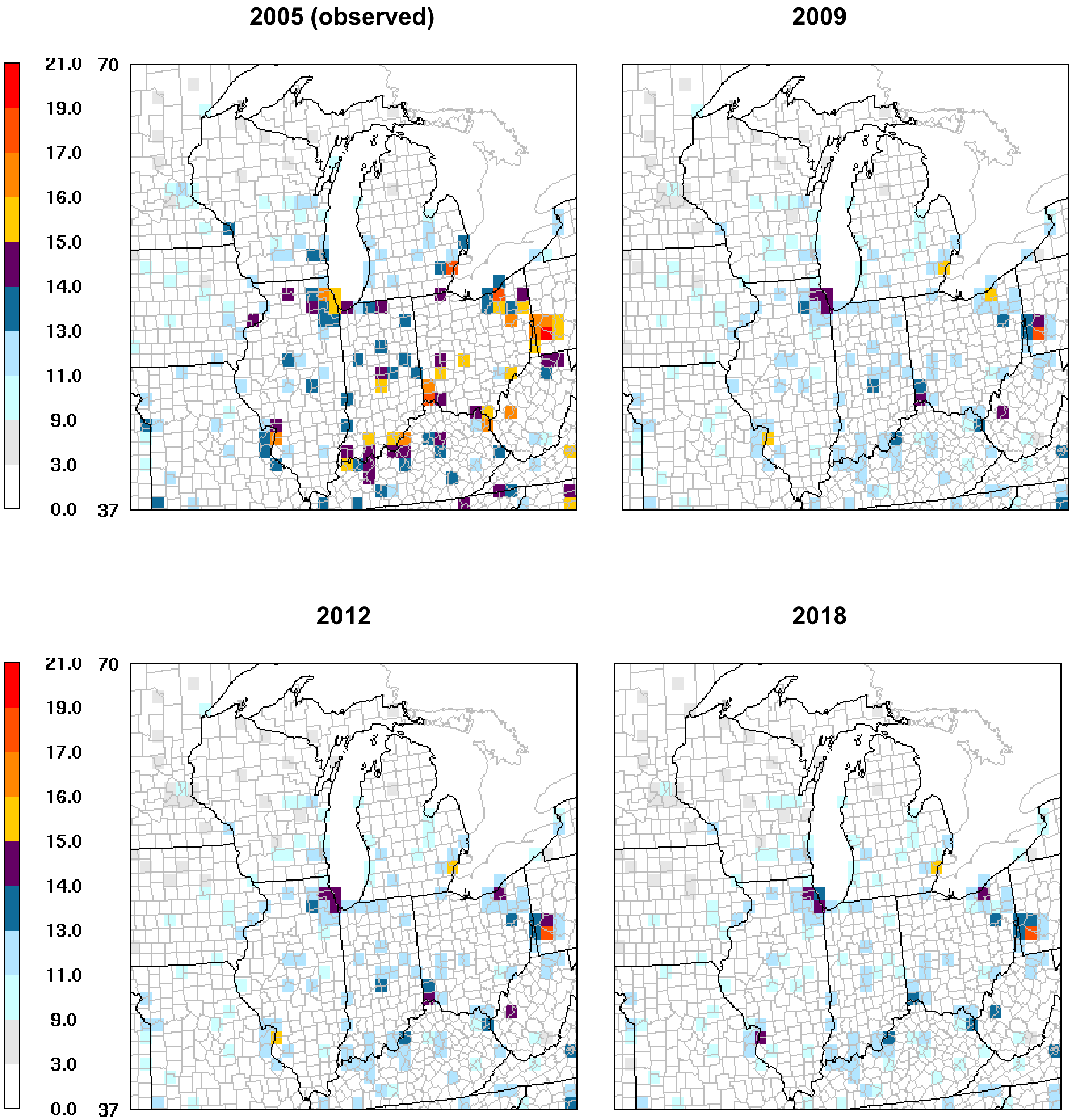


Figure 61. Observed base year and projected future year design values for $PM_{2.5}$ (annual average)–Base M

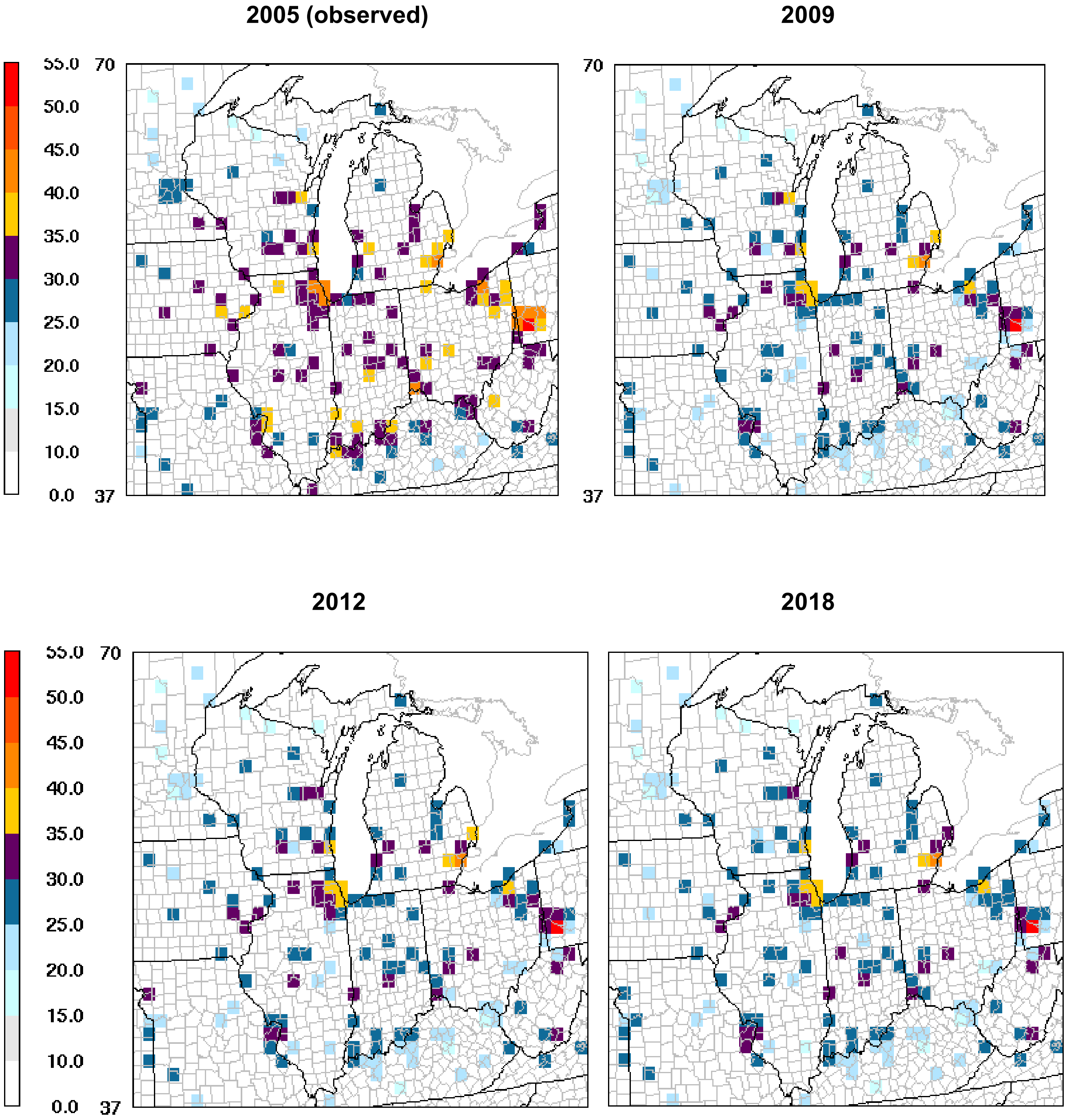
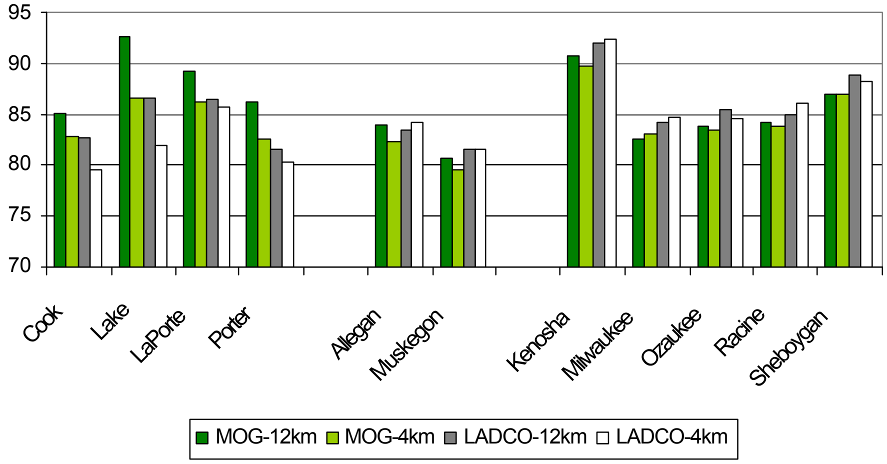


Figure 62. Observed base year and projected future year design values for $PM_{2.5}$ (24-hr average)-Base M

The limited 4 km ozone modeling performed by LADCO included a future year analysis for 2009. The figure below shows the 2009 design values with 12 km and 4 km grid spacing for the LADCO modeling and similar modeling conducted by a stakeholder group (MOG).



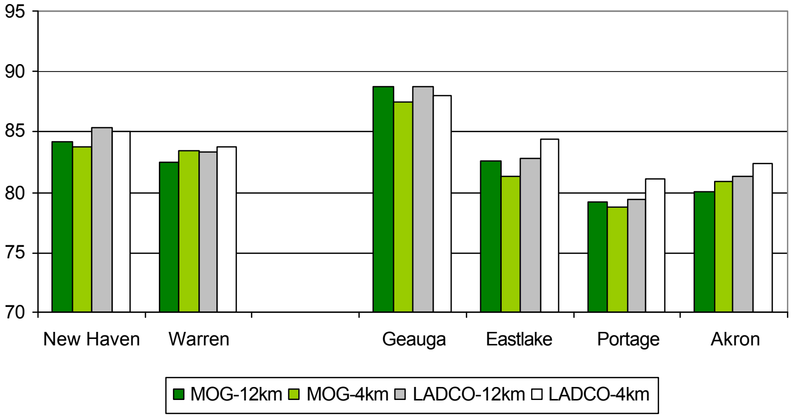


Figure 63. Future year (2009) design values for Lake Michigan area (top) and Detroit-Cleveland region (bottom)

These results show that the 12 km and 4 km design values are similar, with the most notable changes in northwestern Indiana and northeastern Illinois (e.g., 4 km values are as much as 4 ppb lower than 12 km values). The differences in the southern part of the Lake Michigan area are plausible, given the tight emissions gradient there (i.e., finer grid resolution appears to provide more appropriate representation).

In light of these findings, 12 km grid spacing can continue to be used for ozone modeling, but the Base K/Round 4 results for northwestern Indiana/northeastern Illinois should be viewed with caution (i.e., probably 1 – 4 ppb too high).

In summary, the ozone modeling provide s the following information for the nonattainment areas in the region (see Table 12):

Table 12. Ozone Nonattainment Areas in the LADCO Region (as of October 10, 2007)

Area Name	Category	Number of Counties	Attainment Date
Detroit-Ann Arbor, MI	Marginal	8	2007
Chicago-Gary-Lake County, IL-IN	Moderate	10	2010
Cleveland-Akron-Lorain, OH	Moderate	8	2010
Milwaukee-Racine, WI	Moderate	6	2010
Sheboygan, WI	Moderate	1	2010
St Louis, MO-IL	Moderate	4	2010
Allegan Co, MI	Subpart 1	1	2009
Cincinnati-Hamilton, OH-KY-IN	Subpart 1	6	2009
Columbus, OH	Subpart 1	6	2009
Door Co, WI	Subpart 1	1	2009
Kewaunee Co, WI	Subpart 1	1	2009
Manitowoc Co, WI	Subpart 1	1	2009
		53	

Marginal Areas (2007 attainment date): No modeling was conducted for the 2006 SIP planning year. Rather, 2005 – 2007 air quality data are available to determine attainment.

Basic (Subpart 1) Areas (2009 attainment date): The modeling results for the 2008 SIP planning year show:

- Base K: all areas in attainment, except Cincinnati and Indianapolis
- Base M: all areas in attainment, except Holland (Allegan County)

Moderate Areas (2010 attainment date): The modeling results for the 2009 SIP planning year show:

- Base K: all areas still in nonattainment
- Base M: all areas in attainment

The $PM_{2.5}$ modeling results show:

- Base K: all areas in attainment, except for Chicago, Cincinnati, Cleveland, Detroit, Granite City (IL), Louisville, Portsmouth (OH), and Steubenville
- Base M: all areas in attainment, except for Cleveland, Detroit, and Granite City (IL)

With respect to the proposed, lower 8-hour ozone standard, the modeling shows more than 110 sites in 2012 and more than 40 sites in 2018 with design values greater than 70 ppb. With respect to the new, lower 24-hour $PM_{2.5}$ standard, the modeling shows about 20 sites in 2012 and 2018 with design values greater than 35 ug/m^3.

4.2 Supplemental Analyses

USEPA's modeling guidelines recommend that attainment demonstrations consist of a primary (guideline) modeling analysis and supplemental analyses. Three basic types of supplemental analyses are recommended:

- additional modeling
- analyses of trends in ambient air quality and emissions, and
- observational models and diagnostic analyses

Furthermore, according to USEPA's guidelines, if the future year modeled design values are "close" to the standard (i.e., 82 – 87 ppb for ozone and 14.5 – 15.5 ug/m^3 for $PM_{2.5}$), then the results of the primary modeling should be reviewed along with the supplemental information in a "weight of evidence" assessment of whether each area is likely to achieve timely attainment.

A WOE determination for ozone and $PM_{2.5}$ is provided in the following sections. Special attention is given to the following areas with future year modeled design values that exceed or are "close" to the ambient standard (see Appendix I):

Ozone	**PM2.5**
Lake Michigan area	Chicago, IL
Cleveland, OH	Cleveland, OH
Cincinnati, OH	Cincinnati, OH
	Granite City, IL
	Detroit, MI

4.3 Weight-of-Evidence Determination for Ozone

The WOE determination for ozone consists of the primary modeling and other supplemental analyses (some of which were discussed in Section 2). A summary of this information is provided below.

Primary (Guideline) Modeling: The guideline modeling is presented in Section 4.1. Key findings from this modeling include:

- Base M regional modeling shows attainment by 2008 and 2009 at all sites, except Holland (MI), and attainment at all sites by 2012.

- Base K modeling results reflect generally higher future year design values, and show more sites in nonattainment compared to the Base M modeling. The difference in the two modeling analyses is due mostly to lower base year design values in Base M.

- Base K and Base M modeling analyses are considered "SIP quality", so the attainment demonstration for ozone should reflect a weight-of-evidence approach, with consideration of monitoring based information.

- Base M modeling also shows that the proposed lower 8-hour standard will not be met at many sites, even by 2018, with existing controls.

Additional Modeling: Four additional modeling analyses were considered: (1) re-examination of the primary modeling to estimate attainment probabilities, (2) remodeling with different assumptions, (3) an unmonitored area analysis, and (4) USEPA's latest regional ozone modeling. Each of these analyses is described below.

First, the primary modeling results (which were initially processed using USEPA's attainment test) were re-examined to estimate the probability of attaining the ozone standard. Seven estimates of future year ozone concentrations were calculated based on model-based RRFs and appropriate monitor-based concentrations for each year between 2001 and 2007. (Note, RRF values for 2001, 2003, 2004, 2006, and 2007 were derived based on the 2002 and 2005 modeling results, and monitor-based concentrations reflect 4th high values, design values, or average of three design values centered on the year in question.) The probability of attainment was determined as the percentage of these seven estimates below the standard. The results indicate that sites in the Lake Michigan (Chiwaukee, Sheboygan, Holland, Muskegon), Cleveland area (Ashtabula), and St. Louis (W Alton) have a fairly low probability of attainment by 2009 (i.e., about 50% or less).

Second, the primary modeling analysis was redone with different types of assumptions for calculating base year design values (i.e., using the 3-year period centered on base year, and using the highest 3-year period that includes the base year), and for calculating RRFs (i.e., using all days with base year modeled value > 70 ppb, and using all days with base year modeled value > 85 ppb, with at least 10 days and "acceptable" model performance). The results for several high concentration sites are presented in Tables 13a and 13b for 2009. The different modeling assumptions produce eight estimates of future year ozone concentrations. The highest estimates are associated with base year design values representing the 3-year average for 2001-2003, and the lowest estimates are associated with base year design values representing the 3-year average 2004-2006. The different RRF approaches produce little change in future year ozone concentrations. This suggests that future year concentration estimates are most sensitive to the choice of the base year and the methodology used to derive the base year design values.

Third, USEPA's modeling guidelines recommend that an "unmonitored area analysis" be included as a supplemental analysis, particularly in nonattainment areas where the monitoring network just meets or minimally exceeds the size of the network required to report data to USEPA's Air Quality System. The purpose of this analysis is to identify areas where future year design values are predicted to be greater than the NAAQS.

Based on examination of the spatial plots in Figures 49a and 49b, the most notable areas of high modeled concentrations ozone concentrations are over the Great Lakes. Over-water monitoring, however, is not required by USEPA[14]. A cursory analysis of unmonitored areas for ozone was performed by LADCO using an earlier version of the 2002 base year modeling (i.e, Base I) (Baker, 2005). Base year and future year "observed" values were derived for unmonitored grid cells using the absolute modeled concentrations (in all grid cells) and the observed values (in monitored grid cells). A spatial map of the estimated 2009 values is provided in Figure 64. As can be seen, there are very few (over land) grid cells where additional monitors may be desirable. This indicates that the current modeling analysis, which focuses on monitored locations, is addressing areas of high ozone throughout the region.

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[14] Air quality measurements over Lake Michigan were collected by LADCO previously to understand ozone transport in the area (see, for example, Figure 5). Due to cut-backs in USEPA funding, however, these measurements were discontinued in 2003.

Table 13a. Primary and Additional Ozone Modeling Results – Lake Michigan and Cleveland Areas (2009)

2009 Modeling Results		**Lake Michigan Area**								**Cleveland Area**		
		Chiwaukee	Harr.Beach	Sheboygan	DoorCounty	Holland	Hammond	MichiganCity		Ashtabula	Geauga	Eastlake
		550590019	550890009	551170006	550290004	260050003	180892008	180910005		390071001	390550004	390850003
Attainment Test (based on EPA guidance-2002 baseyear)												
Base Year Design Value (average of three 3-year periods)		*98.3*	*93.0*	*97.0*	*91.0*	*94.0*	*88.3*	*90.3*		*95.7*	*99.0*	*92.7*
RRF (all days > 85 ppb, or at least 10 days)		0.935	0.918	0.916	0.899	0.888	0.980	0.958		0.865	0.897	0.894
Future Year Design Value		**91.9**	**85.4**	**88.9**	**81.8**	83.5	**86.5**	**86.5**		82.8	**88.8**	82.9
Attainment Test (based on EPA guidance-2005 baseyear)												
Base Year Design Value (average of three 3-year periods)		*84.7*	*83.3*	*88.0*	*88.7*	*90.0*	*77.7*	*77.0*		*89.0*	*79.3*	*86.3*
RRF (all days > 85 ppb, or at least 10 days)		0.972	0.961	0.955	0.946	0.948	0.971	0.960		0.937	0.942	0.949
Future Year Design Value		82.3	80.1	84.0	83.9	**85.3**	75.4	73.9		83.4	74.7	81.9
Weight of Evidence (alternative approaches-2002baseyear)												
Alt 1 - Base Year Des. Value (3-year period centered on 2002)		*101.0*	*98.0*	*100.0*	*94.0*	*97.0*	*90.0*	*93.0*		*99.0*	*103.0*	*95.0*
Alt 2 - Base Year Des. Value (Highest 3-year period including 2002)		*101.0*	*98.0*	*100.0*	*94.0*	*97.0*	*92.0*	*93.0*		*99.0*	*103*	*95.0*
RRF (all days > 85 ppb, or at least 10 days)		0.935	0.918	0.916	0.899	0.888	0.980	0.958		0.865	0.897	0.894
Alt 1 - Future Year Projected Value		**94.4**	**90.0**	**91.6**	84.5	**86.1**	**88.2**	**89.1**		**85.6**	**92.4**	84.9
Alt 2 - Future Year Projected Value		**94.4**	**90.0**	**91.6**	84.5	**86.1**	**90.2**	**89.1**		**85.6**	**92.4**	84.9
Alt 1 - RRF (all days > 70 ppb)		0.933	0.918	0.912	0.907	0.893	0.969	0.947		0.876	0.907	0.900
Alt 1 - Future Year Projected Value		**94.2**	**90.0**	**91.2**	**85.3**	**86.6**	**87.2**	**88.1**		**86.7**	**93.4**	**85.5**
Alt 2 - Future Year Projected Value		**94.2**	**90.0**	**91.2**	**85.3**	**86.6**	**89.1**	**88.1**		**86.7**	**93.4**	**85.5**
Alt 2 - RRF (all days > 85 ppb, or at least 10 days; with acceptable model performance)		0.945	0.904	0.910	0.904	0.887	0.976	0.964		0.866	0.896	0.894
Alt 1 - Future Year Projected Value		**95.4**	**88.6**	**91.0**	**85.0**	**86.0**	**87.8**	**89.7**		**85.7**	**92.3**	84.9
Alt 2 - Future Year Projected Value		**95.4**	**88.6**	**91.0**	**85.0**	**86.0**	**89.8**	**89.7**		**85.7**	**92.3**	84.9
Weight of Evidence (alternative approaches-2005baseyear)												
Alt 1 - Base Year Des. Value (3-year period centered on 2005)		*83.0*	*79.0*	*86.0*	*86.0*	*88.0*	*76.0*	*76.0*		*86.0*	*77.0*	*86.0*
Alt 2 - Base Year Des. Value (Highest 3-year period including 2005)		*86.0*	*88.0*	*89.0*	*90.0*	*93.0*	*79.0*	*78.0*		*91.0*	*86.0*	*89.0*
Alt 1 - Future Year Projected Value		80.7	75.9	82.1	81.4	83.4	73.8	73.0		80.6	72.5	81.6
Alt 2 - Future Year Projected Value		83.6	84.6	**85.0**	**85.1**	**88.2**	76.7	74.9		**85.3**	81.0	84.5

Table 13b. Primary and Additional Ozone Modeling Results – Cincinnati, Columbus, St. Louis, Indianapolis, and Detroit (2009)

2009 Modeling Results		**Cincinnati Area**				**Columbus**		**St. Louis Area**			**Indianapolis Area**			**Detroit Area**
		Wilmington	Lebanon	Sycamore		NewAlbany		W. Alton	OrchardFarm		Noblesville	Fortville		New Haven
		390271002	39165007	390610006		390490029		291831002	291831004		180571001	18059003		260990009
Attainment Test (based on EPA guidance-2002 baseyear)														
Base Year Design Value (average of three 3-year periods)		*94.3*	*90.7*	*90.7*		*94.0*		*90.0*	*90.0*		*93.7*	*91.3*		*92.3*
RRF (all days > 85 ppb, or at least 10 days)		0.885	0.908	0.938		0.888		0.947	0.914		0.894	0.918		0.924
Future Year Design Value		83.5	82.4	**85.1**		83.5		**85.2**	82.3		83.8	83.8		**85.3**
Attainment Test (based on EPA guidance-2005 baseyear)														
Base Year Design Value (average of three 3-year periods)		*82.3*	*87.7*	*84.3*		*86.3*		*86.3*	*87.0*		*83.3*	*78.7*		*86.0*
RRF (all days > 85 ppb, or at least 10 days)		0.941	0.947	0.967		0.947		0.938	0.942		0.945	0.947		0.947
Future Year Design Value		77.4	83.1	81.5		81.7		80.9	82.0		78.7	74.5		81.4
Weight of Evidence (alternative approaches-2002baseyear)														
Alt 1 - Base Year Des. Value (3-year period centered on 2002)		*96.0*	*92.0*	*93.0*		*95.0*		*91.0*	*92.0*		*96.0*	*94.0*		*97.0*
Alt 2 - Base Year Des. Value (Highest 3-year period including 2002)		*96.0*	*92.0*	*93.0*		*96.0*		*91.0*	*92.0*		*96.0*	*94.0*		*97.0*
RRF (all days > 85 ppb, or at least 10 days)		0.885	0.908	0.938		0.888		0.947	0.914		0.894	0.918		0.924
Alt 1 - Future Year Projected Value		**85.0**	83.5	**87.2**		84.4		**86.2**	84.1		**85.8**	**86.3**		**89.6**
Alt 2 - Future Year Projected Value		**85.0**	83.5	**87.2**		**85.2**		**86.2**	84.1		**85.8**	**86.3**		**89.6**
Alt 1 - RRF (all days > 70 ppb)		0.885	0.914	0.940		0.901		0.945	0.911		0.912	0.907		0.918
Alt 1 - Future Year Projected Value		**85.0**	84.1	**87.4**		**85.6**		**86.0**	83.8		**87.6**	**85.3**		**89.0**
Alt 2 - Future Year Projected Value		**85.0**	84.1	**87.4**		**86.5**		**86.0**	83.8		**87.6**	**85.3**		**89.0**
Alt 2 - RRF (all days > 85 ppb, or at least 10 days; with acceptable model performance)		0.880	0.911	0.940		0.886		0.951	0.913		0.894	0.916		0.935
Alt 1 - Future Year Projected Value		84.5	83.8	**87.4**		84.2		**86.5**	84.0		**85.8**	**86.1**		**90.7**
Alt 2 - Future Year Projected Value		84.5	83.8	**87.4**		**85.1**		**86.5**	84.0		**85.8**	**86.1**		**90.7**
Weight of Evidence (alternative approaches-2005baseyear)														
Alt 1 - Base Year Des. Value (3-year period centered on 2005)		*80.0*	*86.0*	*81.0*		*84.0*		*85.0*	*86.0*		*80.0*	*76.0*		*82.0*
Alt 2 - Base Year Des. Value (Highest 3-year period including 2005)		*85.0*	*89.0*	*86.0*		*88.0*		*89.0*	*89.0*		*87.0*	*81.0*		*90.0*
Alt 1 - Future Year Projected Value		75.3	81.4	78.3		79.5		79.7	81.0		75.6	72.0		77.7
Alt 2 - Future Year Projected Value		80.0	84.3	83.2		83.3		83.5	83.8		82.2	76.7		**85.2**

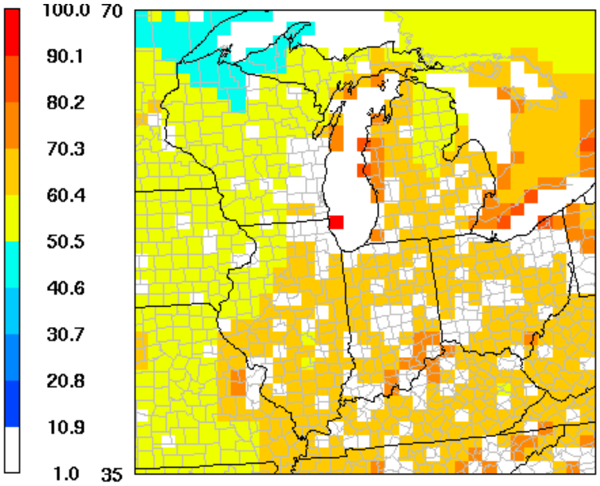


Figure 64. Estimated Future Year Design Values (unmonitored grid cells)

Finally, USEPA's latest regional ozone modeling was considered as corroborative information. This modeling was performed as part of the June 2007 proposal to revise the ozone standard (USEPA, 2007b). USEPA applied the CMAQ model with 2001 meteorology to first estimate ozone levels in 2020 based on the current standard and national rules in effect or proposed (i.e., the baseline), and then to evaluate strategies for attaining a more stringent (70 ppb) primary standard. Baseline (2020) ozone levels were predicted to be below the current standard in 481 of the 491 counties with ozone monitors. Of the 10 counties predicted to be above the standard, there is one county in the LADCO region (i.e., Kenosha County, WI at 86 ppb). This result is consistent with LADCO's Base K modeling for 2018 (i.e., Kenosha County, WI at 86.7 ppb), which is not surprising given that USEPA's modeling and LADCO's Base K modeling have a similar base year (2001 v. 2002).

Analysis of Trends: USEPA's modeling guidelines note that while air quality models are generally the most appropriate tools for assessing the expected impacts of a change in emissions, it may also be possible to extrapolate future trends based on measured historical trends of air quality and emissions. To do so, USEPA's guidance suggests that ambient trends should first be normalized to account for year-to-year variations in meteorological conditions (USEPA, 2002). Meterologically-adjusted 4th high 8-hour ozone concentrations were derived using the air quality – meteorological regression model developed by USEPA (i.e., Cox method – see Section 2.1).

The historical trend in these met-adjusted ozone concentrations were extrapolated to estimate future year ozone concentrations based on historical and projected trends in precursor emissions. Both VOC and NOx emissions affect ozone concentrations. Given that observation-based methods show that urban areas in the region are generally VOC-limited and rural areas in the region are NOx-limited (see Section 2.1), urban VOC emissions and regional NOx emissions are considered important. The trends in urban VOC and regional NOx emissions were calculated to produce appropriate weighting factors.

The resulting 2009 and 2012 ozone values are provided in Figure 65, along with the primary and alternative modeling ozone values for key sites in the Lake Michigan, Cleveland, and Cincinnati areas. The results reflect a fairly wide scatter, but, on balance, the supplemental information is supportive of the primary modeling results (i.e., sites in the Lake Michigan area and Cleveland are expected to be close to the standard).

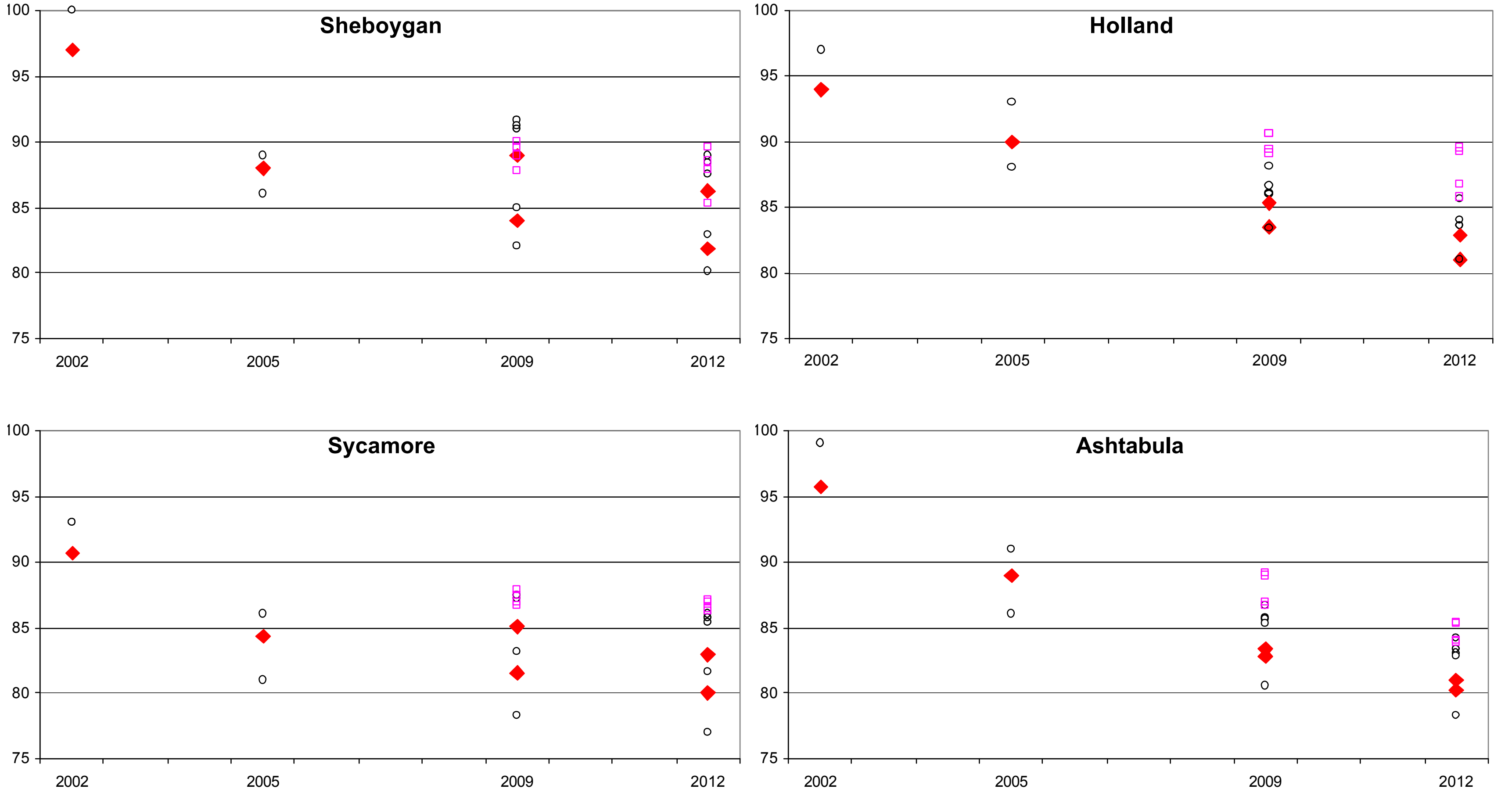


Figure 65. Estimates of Future Year Ozone Concentrations – Lake Michigan Area (Sheboygan and Holland), Cincinnati (Sycamore), and Cleveland (Ashtabula)

Note: Primary (guideline) modeling values (Base K and Base M results) are represented by large red diamonds, additional modeling values by small black circles, and trends-based values by small pink squares

Observational Models and Diagnostic Analyses: The observation-based modeling (i.e., MAPPER) is presented in Section 3. The key findings from this modeling are that most urban areas are VOC-limited and rural areas are NOx-limited.

The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts (Baker, 2007a). Specifically, the model estimated the impact of 18 geographic source regions (which are identified in Figure 66) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and biogenic sources) at ozone monitoring sites in the region.

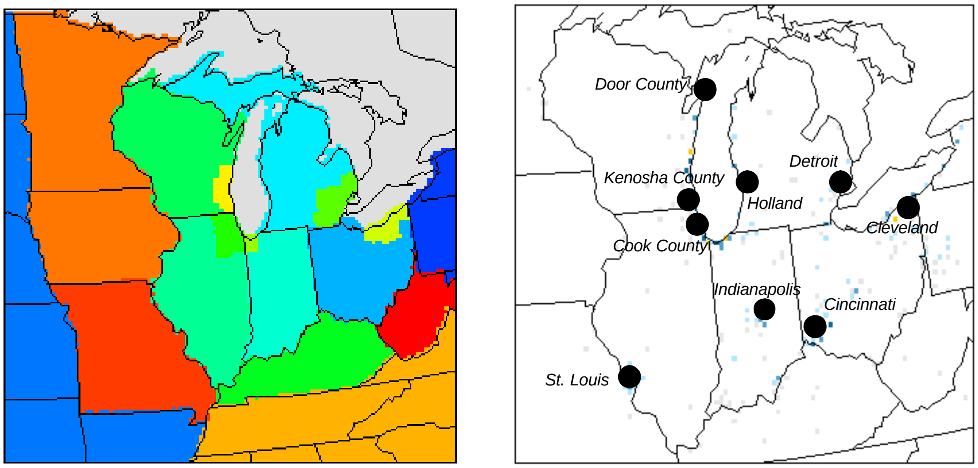


Figure 66. Source regions (left) and key monitoring sites (right) for ozone modeling analysis

Modeling results for 2009 (Base M) and 2012 (Base K) are provided in Appendix II for several key monitoring sites. For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of percentages. (Note, in the sector-level graph, the contributions from NOx emissions are shown in blue, and from VOC emissions in green.)

The sector-level results (see, for example, Figure 67) show that on-road and nonroad NOx emissions generally have the largest contributions at the key monitor locations (> 15% each). EGU and non-EGU NOx emissions are also important contributors (> 10% each). The source group contributions vary by receptor location due to emissions inventory differences.

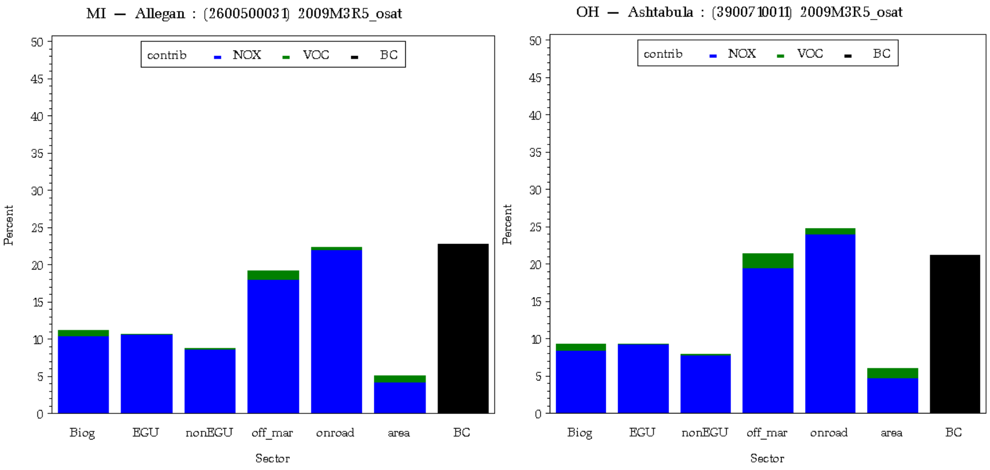


Figure 67. Source-sector results for Holland (left) and Ashtabula (right) monitors – 2009 (Base M)

The source region results (see, for example, Figure 68) show that while nearby areas generally have the highest impacts (e.g., the northeastern IL/northwestern IN/southeastern WI nonattainment area contributes 25-35% to high sites in the Lake Michigan area, and Cleveland nonattainment counties contribute 20-25% to high sites in northeastern Ohio), there is an even larger regional impact (i.e., contribution from other states).

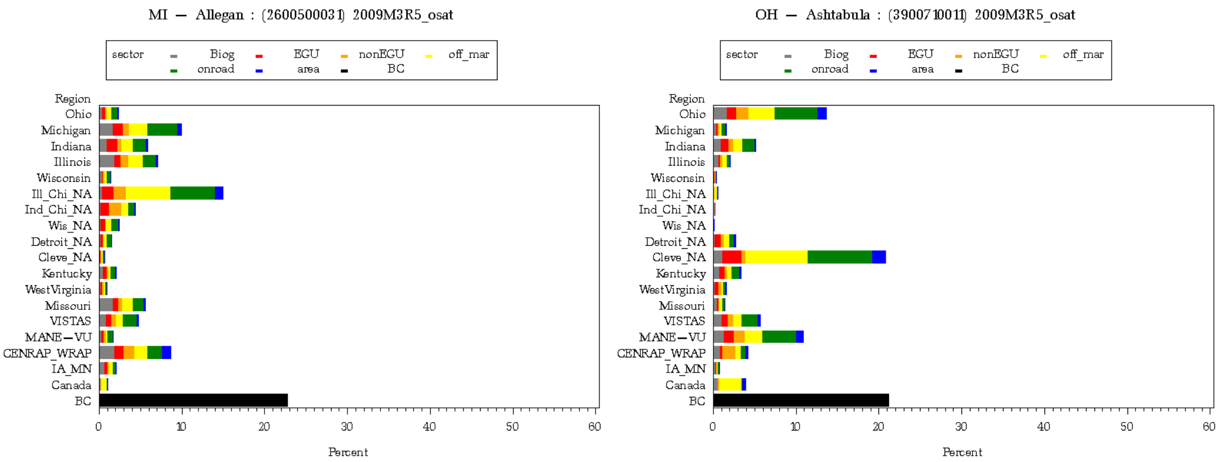


Figure 68. Source-region results for Holland (left) and Ashtabula (right) monitors – 2009 (Base M)

Summary: Air quality modeling and other supplemental analyses were performed to estimate future year ozone concentrations. Based on this information, the following general conclusions can be made:

- Existing ("on the books") controls are expected to produce significant improvement in ozone air quality.

- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. As noted above, 2002 was more ozone conducive than 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).

- Most sites are expected to meet the current 8-hour standard by the applicable attainment date, except, for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.

- Current monitoring data show significant nonattainment in these areas (e.g., peak design values on the order of 90 – 93 ppb). It is not clear whether sufficient emission reductions will occur in the next couple of years to provide for attainment.

- Attainment by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met, then attainment may be less likely.

4.3 Weight-of-Evidence Determination for $PM_{2.5}$

The WOE determination for $PM_{2.5}$ consists of the primary modeling and other supplemental analyses. A summary of this information is provided below.

Primary (Guideline) Modeling: The results of the guideline modeling are presented in Section 4.1. Key findings from this modeling include:

- Base M regional modeling shows attainment by 2009 at all sites, except Detroit, Cleveland, and Granite City, and attainment at all sites by 2012, except for Detroit and Granite City.

  The regional modeling for $PM_{2.5}$ does not reflect any air quality benefit expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for $PM_{2.5}$

- Base K modeling results reflect generally higher future year design values, and show more sites in nonattainment in 2009 and 2012 compared to the Base M modeling. The difference in the two modeling analyses is due mostly to lower base year design values in Base M.

- Base K and Base M modeling analyses are considered “SIP quality”, so the attainment demonstration for $PM_{2.5}$ should reflect a weight-of-evidence approach, with consideration of monitoring based information.

- Base M modeling also shows that the new $PM_{2.5}$ 24-hour standard will not be met at many sites, even by 2018, with existing controls.

Additional Modeling: USEPA’s latest regional $PM_{2.5}$ modeling was considered as corroborative information. This modeling was performed as part of the September 2006 revision to the $PM_{2.5}$ standard (USEPA, 2006). USEPA applied the CMAQ model with 2001 meteorology to estimate $PM_{2.5}$ levels in 2015 and 2020 first with national rules in effect or proposed, and then with additional controls to attain the current standard (15 ug/m^3 annual/65 ug/m^3 daily). Additional analyses were performed to evaluate strategies for attaining more stringent standards in 2020 (15/35, and 14/35). Baseline (2015) $PM_{2.5}$ levels were predicted to be above the current standard in four counties in the LADCO region: Madison County, IL at 15.2 ug/m^3, Wayne County, MI at 17.4, Cuyahoga County, OH at 15.4, and Scioto County, OH at 15.6. These results are consistent with LADCO’s Base K modeling for 2012/2018, which is not surprising given that USEPA’s modeling and LADCO’s Base K modeling have a similar base year (2001 v. 2002).

Observational Models and Diagnostic Analyses: The observation-based modeling (i.e., application of thermodynamic equilibrium models) is presented in Section 3. The key findings from this modeling are that $PM_{2.5}$ mass is sensitive to reductions in sulfate, nitric acid, and ammonia concentrations. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that $PM_{2.5}$ mass decreases. Under conditions with lower sulfate levels (i.e., proxy of future year conditions), $PM_{2.5}$ is more sensitive to reductions in nitric acid compared to reductions in ammonia.

The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts (Baker, 2007b). Specifically, the model estimated the impact of 18 geographic source regions (which are identified in Figure 69) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and biogenic sources) at $PM_{2.5}$ monitoring sites in the region.

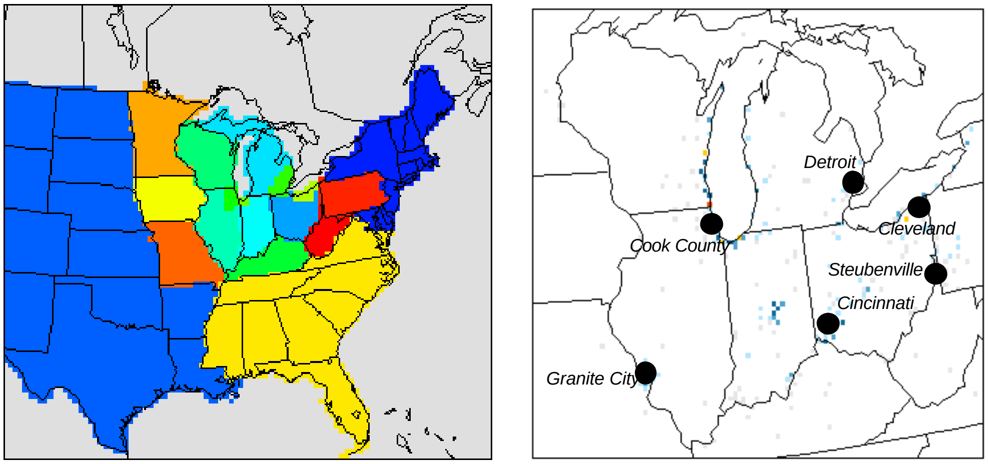


Figure 69. Source regions (left) and key monitoring sites (right) for $PM_{2.5}$ modeling analysis

Modeling results for 2012 (Base K) and 2018 (Base M) are provided in Appendix III for several key monitoring sites. For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of absolute modeled values.

The sector-level results (see, for example, Figure 70) show that EGU sulfate, non-EGU-sulfate, and area organic carbon emissions generally have the largest contributions at the key monitor locations (> 15% each). Ammonia emissions are also important contributors (> 10%). The source group contributions vary by receptor location due to emissions inventory differences.

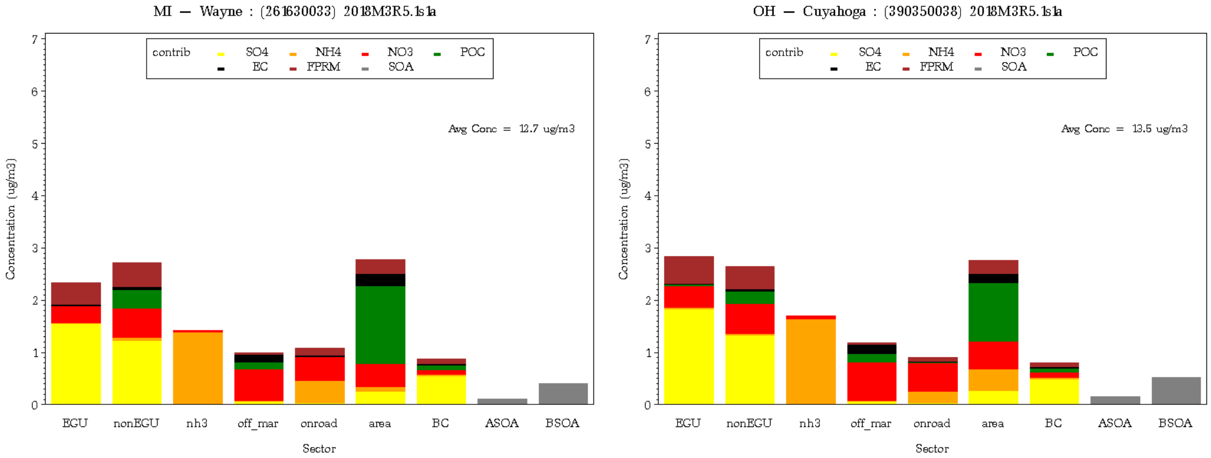


Figure 70. Source-sector results for Detroit (left) and Cleveland (right) monitors – 2018 (Base M)

The source region results (see, for example, Figure 71) show that while nearby areas generally have the highest impacts (e.g., Detroit nonattainment counties contribute 40% to high sites in southeastern Michigan, and Cleveland nonattainment counties contribute 35% to high sites in northeastern Ohio), there is an even larger regional impact (i.e., contribution from other states).

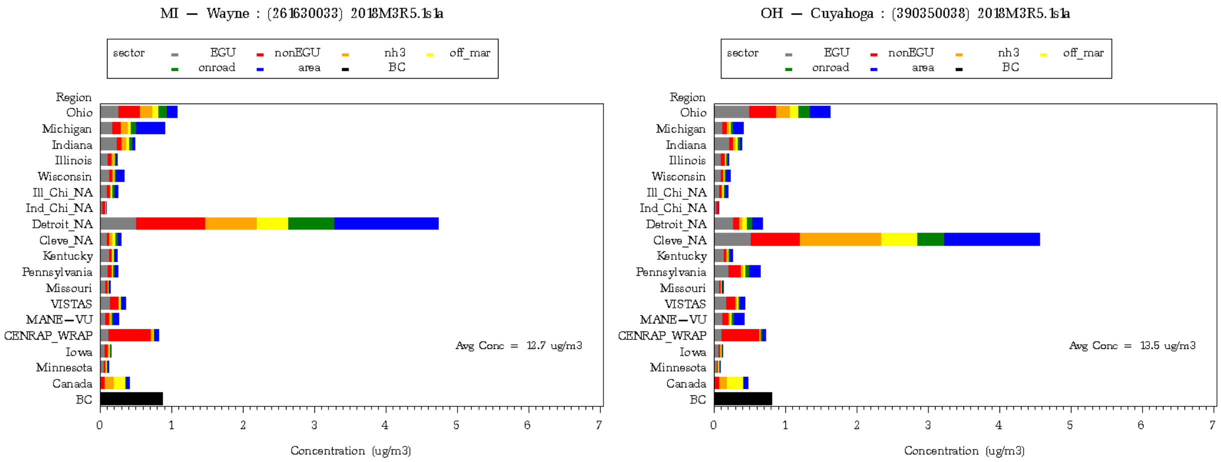


Figure 71. Source-region results for Detroit (left) and Cleveland (right) monitors – 2018 (Base M)

Summary: Air quality modeling and other supplemental analyses were performed to estimate future year $PM_{2.5}$ concentrations. Based on this information, the following general conclusions can be made:

- Existing ("on the books") controls are expected to produce significant improvement in $PM_{2.5}$ air quality.

- The choice of the base year affects the future year model projections. It is not clear how much of this is attributable to differences in meteorology, because, as noted in Section 3, $PM_{2.5}$ concentrations are not as strongly influenced by meteorology as ozone.

- Most sites are expected to meet the current $PM_{2.5}$ standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City.

- Current monitoring data show significant nonattainment in these areas (e.g., peak design values on the order of 16 – 17 ug/m^3). It is not clear whether sufficient emission reductions will occur in the next couple of years to provide for attainment. States are conducting local-scale analyses for Detroit, Cleveland, and Granite City, in particular, to identify appropriate additional local controls.

- Attainment by the applicable attainment date is dependent (possibly) on actual future year meteorology and (more likely) on actual future year emissions (e.g., if the emission reductions associated with the "on the books" controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met (especially, with respect to emissions), then attainment may be less likely.

Section 5. Reasonable Progress Assessment for Regional Haze

Air quality modeling and other information were used to assess the improvement in visibility that would be provided by existing ("on the books") controls and possible additional control programs. In determining reasonable progress for regional haze, Section 169A of the Clean Air Act and USEPA's visibility rule requires states to consider five factors:

- costs of compliance
- time necessary for compliance
- energy and non-air quality environmental impacts of compliance
- remaining useful life of any existing source subject to such requirements
- uniform rate of visibility improvement needed to attain natural visibility conditions by 2064

The uniform rate of visibility improvement requirement can be depicted graphically in the form of a "glide path" (see Figure 72).

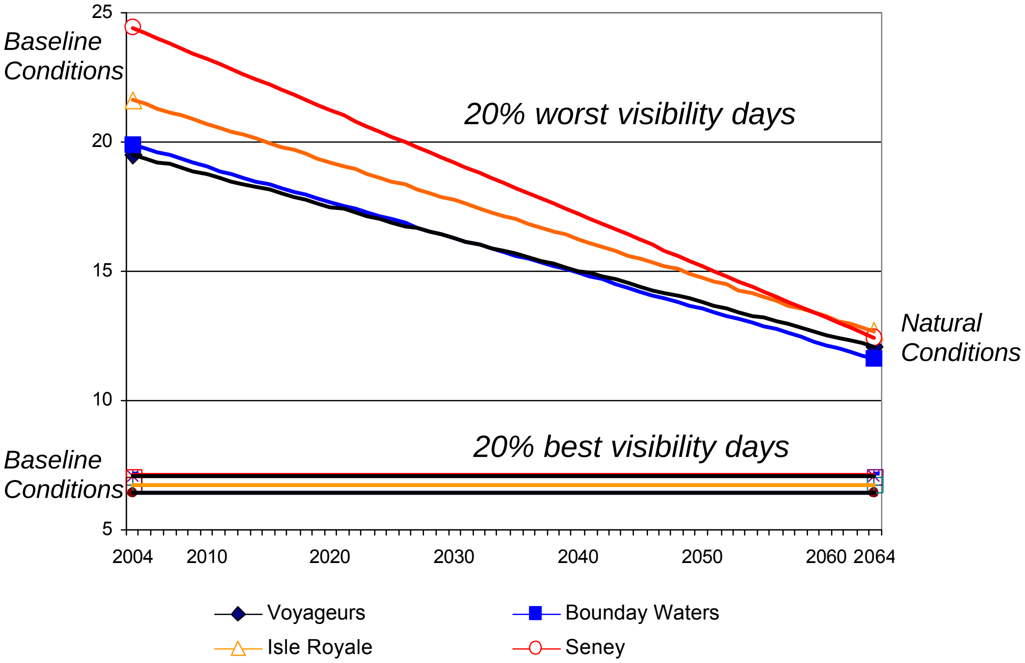


Figure 72. Visibility "glide paths" for northern Class I areas

5.1 Future Year Modeling Results

For regional haze, the calculation of future year conditions assumed:

- baseline concentrations based on 2000-2004 IMPROVE data, with updated (subsitituted) data for Mingo, Boundary Waters, Voyageurs, Isle Royale, and Seney (see Section 2.3);

- use of the new IMPROVE light extinction equation; and

- use of USEPA default values for natural conditions, based on the new IMPROVE light extinction equation.

The uniform rate of visibility improvement values for the 2018 planning year were derived (for the 20% worst visibility days) based on a straight line between baseline concentration value (plotted in the year 2004 -- end year of the 5-year baseline period) and natural condition value (plotted in the year 2064 -- date for achieving natural conditions). Plots of these “glide paths” with the Base M modeling results are presented in Figure 73 for Class I areas in the eastern U.S. A tabular summary of measured baseline and modeled future year deciview values for these Class I areas are provided in Table 14 (2002 base year) and Table 15 (2005 base year)[15].

The haze results show that several Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values (in 2018), including those in northern Michigan and several in the northeastern U.S. Many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values (in 2018). As noted above, states should consider these results, along with information on the other four factors, in setting reasonable progress goals.

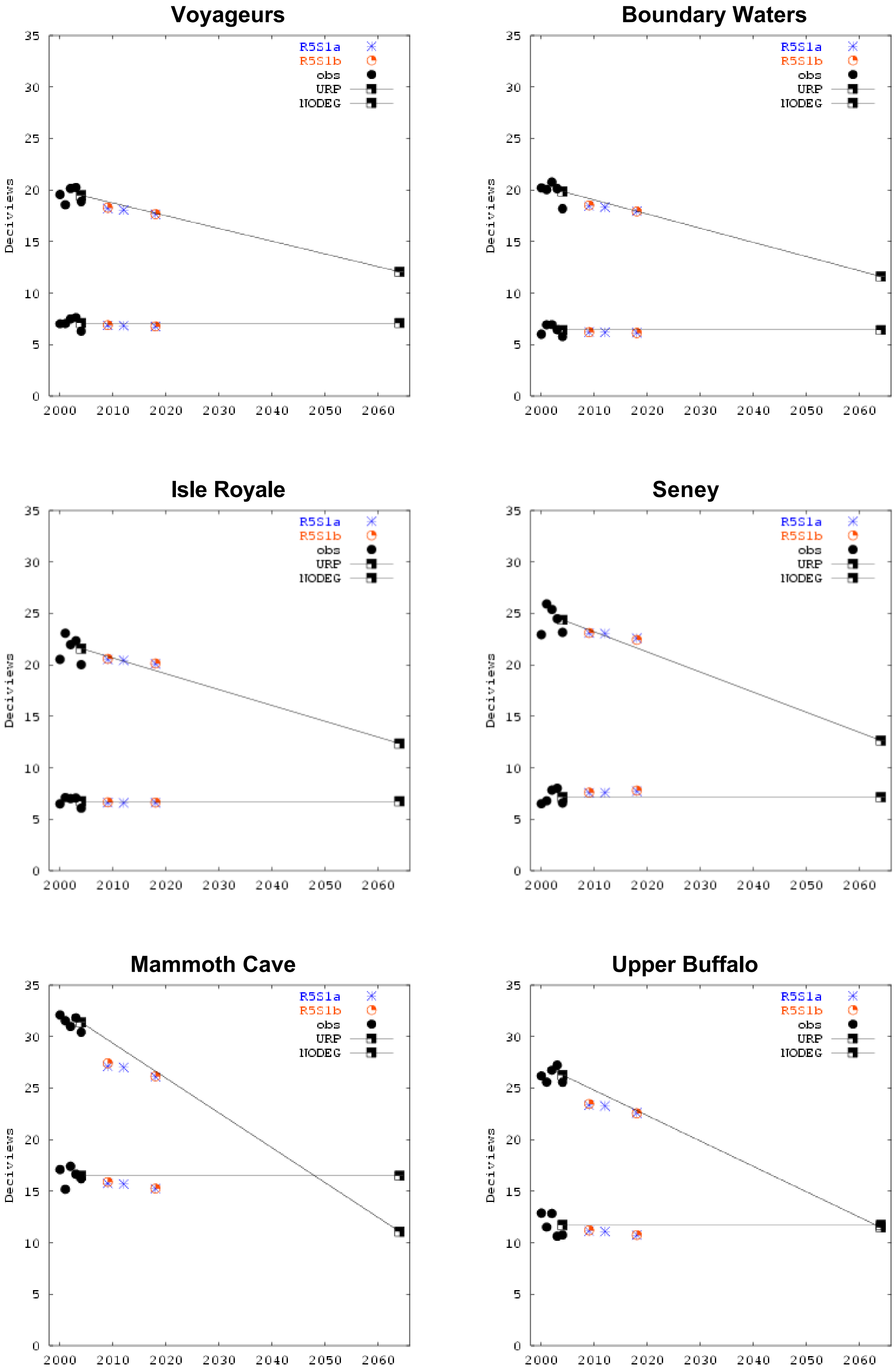
An assessment of the five factors was performed for LADCO and the State of Minnesota by a contractor (EC/R, 2007). Specifically, ECR examined reductions in SO2 and NOx emissions from EGUs and industrial, commercial and institutional (ICI) boilers; NOx emissions from mobile sources and reciprocating engines and turbines; and ammonia emissions from agricultural operations. The impacts of “on the books” controls were also examined to provide a frame of reference for assessing the impacts of the additional control measures.

The results of ECR’s analysis of the five factors are summarized below:

> Factor 1 (Cost of Compliance): The average cost effectiveness values (in terms of $M per ton) are provided in Table 16. For comparison, cost-effectiveness estimates previously provided for “on the books” controls include:
>
> CAIR SO2: $700 - $1,200, NOx: $1,400 – $2.600 ($/T)
>
> BART SO2: $300 - $963, NOx: $248 - $1,770
>
> MACT SO2: $1,500, NOx: $7,600
>
> Most of the cost-effectiveness values for the additional controls are within the range of cost-effectiveness values for “on the books” controls.
>
> Factor 2 (Time Necessary for Compliance): All of the control measures can be implemented by 2018. Thus, this factor can be easily addressed.

---

[15] Model results reflect the grid cell where the IMPROVE monitor is located.


Voyageurs

Boundary Waters

Isle Royale

Seney

Mammoth Cave

Upper Buffalo

Figure 73. Visibility modeling results for Class I areas in eastern U.S.

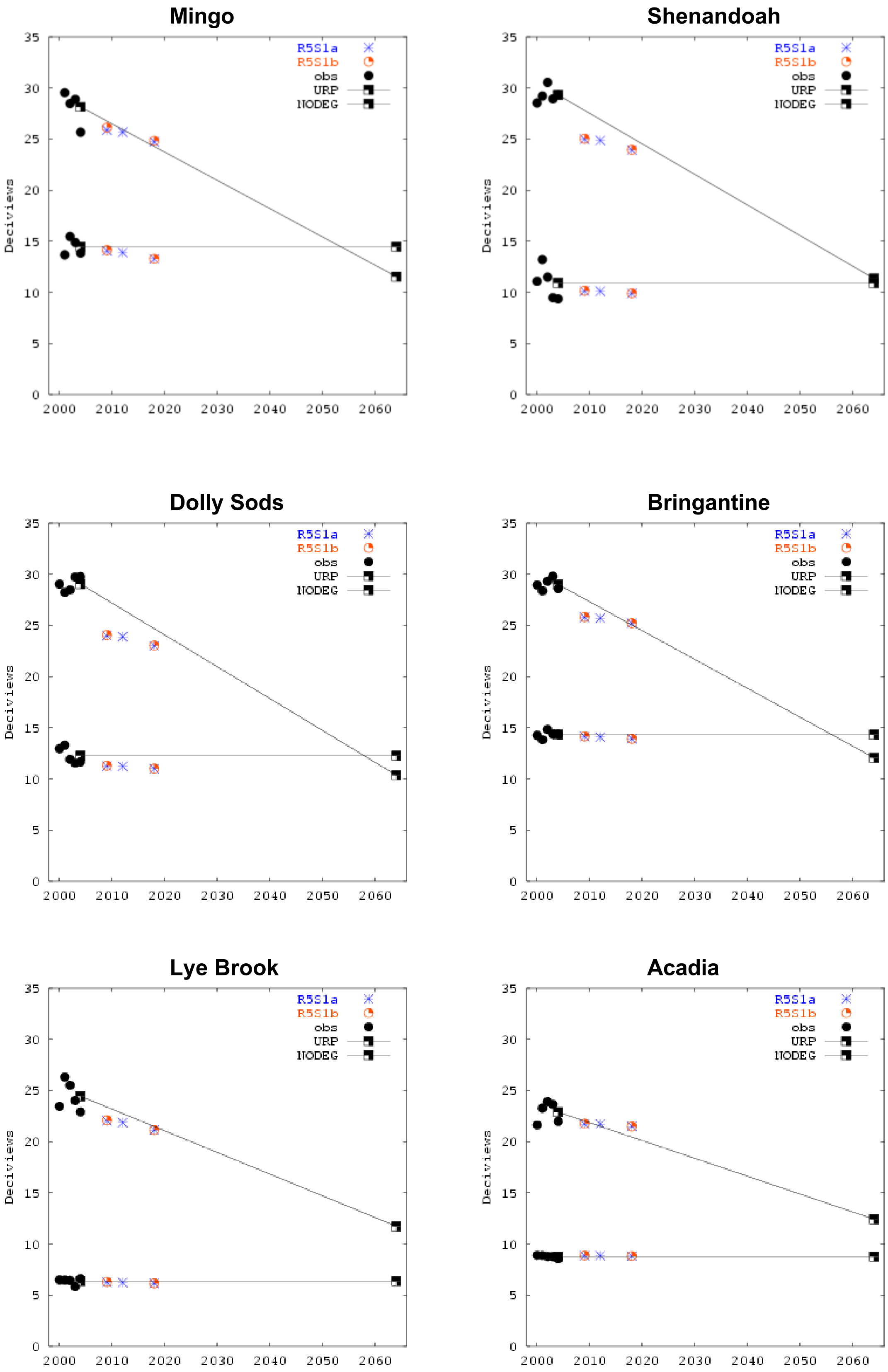


Figure 73 (cont.) Visibility modeling results for Class I areas in eastern U.S.

Haze Results - Round 4 (Based on 2000-2004)

Worst 20%		**2018**	**2009**	**2012**	**2018**	**2018**	**2018**
Site	**Baseline**	**URP**	**OTB**	**OTB**	**OTB**	**EGU2 (5-state region)**	**EGU2 (12-state region)**
BOWA1	19.86	17.70	19.05	19.01	**18.94**	**18.40**	17.72
VOYA2	19.48	17.56	19.14	19.19	**19.18**	**18.94**	**18.38**
SENE1	24.38	21.35	22.98	22.71	**22.38**	21.26	20.63
ISLE1	21.59	19.21	20.46	20.28	**20.04**	19.09	18.64
HEGL1	26.75	22.76	24.73	24.34	**23.85**	**23.01**	22.04
MING1	28.15	24.08	25.18	24.67	24.01	22.53	21.45
CACR1	26.36	22.55	24.01	23.55	**22.99**	22.43	21.57
UPBU1	26.27	22.47	24.02	23.58	**23.06**	22.31	21.38
MACA1	31.37	26.14	28.06	27.03	25.52	24.27	22.57
DOSO1	29.04	24.23	24.86	23.59	22.42	21.60	20.15
SHEN1	29.31	24.67	24.06	22.79	21.57	20.43	19.42
JARI1	29.12	24.48	24.81	23.79	22.42	21.59	20.88
BRIG1	29.01	24.68	25.87	25.25	24.39	23.91	23.45
LYBR1	24.45	21.16	21.80	21.32	20.69	20.18	19.79
Best 20%		**2018**	**2009**	**2012**	**2018**	**2018**	**2018**
Site	**Baseline**	**URP**	**OTB**	**OTB**	**OTB**	**EGU2 (5-state region)**	**EGU2 (12-state region)**
BOWA1	6.42	6.42	6.71	6.73	6.87	6.83	6.81
VOYA2	7.09	7.09	7.21	7.25	7.34	7.31	7.26
SENE1	7.14	7.14	7.19	7.19	7.23	7.06	6.91
ISLE1	6.75	6.75	6.57	6.51	6.47	6.20	6.06
HEGL1	12.84	12.84	12.61	12.62	12.61	12.43	12.02
MING1	14.46	14.46	13.96	13.93	13.94	13.74	13.33
CACR1	11.24	11.24	10.91	10.92	10.90	10.75	10.42
UPBU1	11.71	11.71	11.47	11.46	11.42	11.28	11.01
MACA1	16.51	16.51	16.06	15.91	15.54	15.18	14.75
DOSO1	12.28	12.28	11.72	11.45	11.19	10.93	10.67
SHEN1	10.93	10.93	9.73	9.53	9.17	9.05	8.90
JARI1	14.21	14.21	13.56	13.33	12.97	12.65	12.46
BRIG1	14.33	14.33	13.74	13.69	13.47	13.32	13.21
LYBR1	6.36	6.36	6.12	6.05	5.96	5.88	5.82

Haze Results - Round 5.1 (Based on 2000-2004)

Worst 20%		**2018**	**2009**	**2009**	**2012**	**2018**	**2018**
Site	**Baseline**	**URP**	**OTB**	**OTB+Will DO**	**OTB**	**OTB**	**OTB+Will DO**
BOWA1	19.86	17.94	18.45	18.51	18.33	17.94	17.92
VOYA2	19.48	17.75	18.20	18.28	18.07	17.63	17.66
SENE1	24.38	21.64	23.10	23.10	23.04	**22.59**	**22.42**
ISLE1	21.59	19.43	20.52	20.58	20.43	**20.09**	**20.13**
ISLE9	21.59	19.43	20.33	20.37	20.22	**19.84**	**19.82**
HEGL1	26.75	23.13	24.72	24.82	24.69	**24.22**	**24.17**
MING1	28.15	24.27	25.88	26.13	25.68	**24.74**	**24.83**
CACR1	26.36	22.91	23.39	23.55	23.29	22.44	22.40
UPBU1	26.27	22.82	23.34	23.47	23.27	22.59	22.55
MACA1	31.37	26.64	27.11	27.41	27.01	26.10	26.15
DOSO1	29.05	24.69	24.00	24.06	23.90	23.00	23.04
SHEN1	29.31	25.12	24.99	25.04	24.87	23.92	23.95
JARI1	29.12	24.91	25.17	25.25	25.01	24.06	24.12
BRIG1	29.01	25.05	25.79	25.83	25.72	**25.21**	**25.22**
LYBR1	24.45	21.48	22.04	22.08	21.86	21.14	21.14
ACAD1	22.89	20.45	21.72	21.75	21.72	**21.49**	**21.49**
Best 20%		**2018**	**2009**	**2009**	**2012**	**2018**	**2018**
Site	**Baseline**	**Max**	**OTB**	**OTB+Will DO**	**OTB**	**OTB**	**OTB+Will DO**
BOWA1	6.42	6.42	6.21	6.20	6.19	6.14	6.12
VOYA2	7.09	7.09	6.86	6.89	6.83	6.75	6.76
SENE1	7.14	7.14	7.57	7.59	7.58	7.71	7.78
ISLE1	6.75	6.75	6.62	6.64	6.59	6.60	6.62
ISLE9	6.75	6.75	6.56	6.57	6.55	6.52	6.50
HEGL1	12.84	12.84	12.51	12.56	12.32	11.66	11.64
MING1	14.46	14.46	14.07	14.13	13.89	13.28	13.29
CACR1	11.24	11.24	10.88	10.95	10.85	10.52	10.52
UPBU1	11.71	11.71	11.13	11.19	11.08	10.73	10.74
MACA1	16.51	16.51	15.76	15.88	15.69	15.25	15.25
DOSO1	12.28	12.28	11.25	11.29	11.23	11.00	11.01
SHEN1	10.93	10.93	10.13	10.16	10.11	9.91	9.91
JARI1	14.21	14.21	13.38	13.43	13.38	13.14	13.14
BRIG1	14.33	14.33	14.15	14.16	14.08	13.92	13.92
LYBR1	6.37	6.37	6.25	6.28	6.23	6.14	6.15
ACAD1	8.78	8.78	8.86	8.88	8.86	8.82	8.82

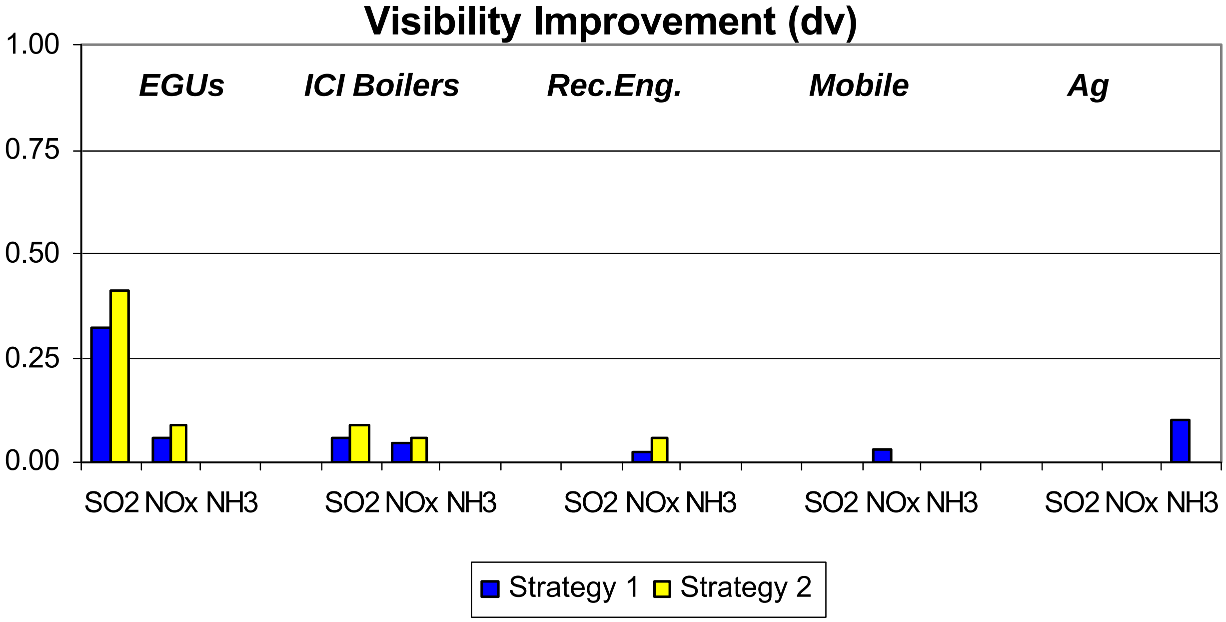
Table 16. Estimated Cost Effectiveness for Potential Control Measures

			Average Cost effectiveness ($/ton)		
Emission category	Control strategy	Region	SO2	NOX	NH3
EGU	EGU1	3-State	1,540	2,037	
		9-State	1,743	1,782	
	EGU2	3-State	1,775	3,016	
		9-State	1,952	2,984	
ICI boilers	ICI1	3-State	2,992	2,537	
		9-State	2,275	1,899	
	ICI Workgroup	3-State	2,731	3,814	
		9-State	2,743	2,311	
Reciprocating engines and turbines	Reciprocating engines emitting 100 tons/year or more	3-State		538	
		9-State		506	
	Turbines emitting 100 tons/year or more	3-State		754	
		9-State		754	
	Reciprocating engines emitting 10 tons/year or more	3-State		1,286	
		9-State		1,023	
	Turbines emitting 10 tons/year or more	3-State		800	
		9-State		819	
Agricultural sources	10% reduction	3-State			31 - 2,700
		9-State			31 - 2,700
	15% reduction	3-State			31 - 2,700
		9-State			31 - 2,700
Mobile sources	Low-NOX Reflash	3-State		241	
		9-State		241	
	MCDI	3-State		10,697	
		9-State		2,408	
	Anti-Idling	3-State		(430) - 1,700	
		9-State		(430) - 1,700	
	Cetane Additive Program	3-State		4,119	
		9-State		4,119	
Cement Plants	Process Modification	Michigan		-	
	Conversion to dry kiln	Michigan		9,848	
	LoTox™	Michigan		1,399	
Glass Manufacturing	LNB	Wisconsin		1,041	
	Oxy-firing	Wisconsin		2,833	
	Electric boost	Wisconsin		3,426	
	SCR	Wisconsin		1,054	
	SNCR	Wisconsin		1,094	
Lime Manufacturing	Mid-kiln firing	Wisconsin		688	
	LNB	Wisconsin		837	
	SNCR	Wisconsin		1,210	
	SCR	Wisconsin		5,037	
	FGD	Wisconsin		128 - 4,828	
Oil Refinery	LNB	Wisconsin		3,288	
	SNCR	Wisconsin		4,260	
	SCR	Wisconsin		17,997	
	LNB+FGR	Wisconsin		4,768	
	ULNB	Wisconsin		2,242	
	FGD	Wisconsin		1,078	

Factor 3 (Energy and Non-Air Quality Environmental Impacts): The energy and other environmental impacts are believed to be manageable. For example, the increased energy demand from add-on control equipment is less than 1% of the total electricity and steam production in the region, and solid waste disposal and wastewater treatment costs are less than 5% of the total operating costs of the pollution control equipment. It should also be noted that the SO2 and NOx controls would have beneficial environmental impacts (e.g., reduced acid deposition and nitrogen deposition).

Factor 4 (Remaining Useful Life): The additional control measures are intended to be market-based strategies applied over a broad geographic region. It is not expected that the control requirements will be applied to units that will be retired prior to the amortization period for the control equipment. Thus, this factor can be easily addressed.

Factor 5 (Visibility Impacts): The estimated incremental improvement in 2018 visibility levels for the additional measures is shown in Figure 74, along with the cost-effectiveness expressed in $M per deciview improvement). These results show that although EGU and ICI boiler controls have higher cost-per-deciview values (compared to some of the other measures), their visibility impacts are larger.



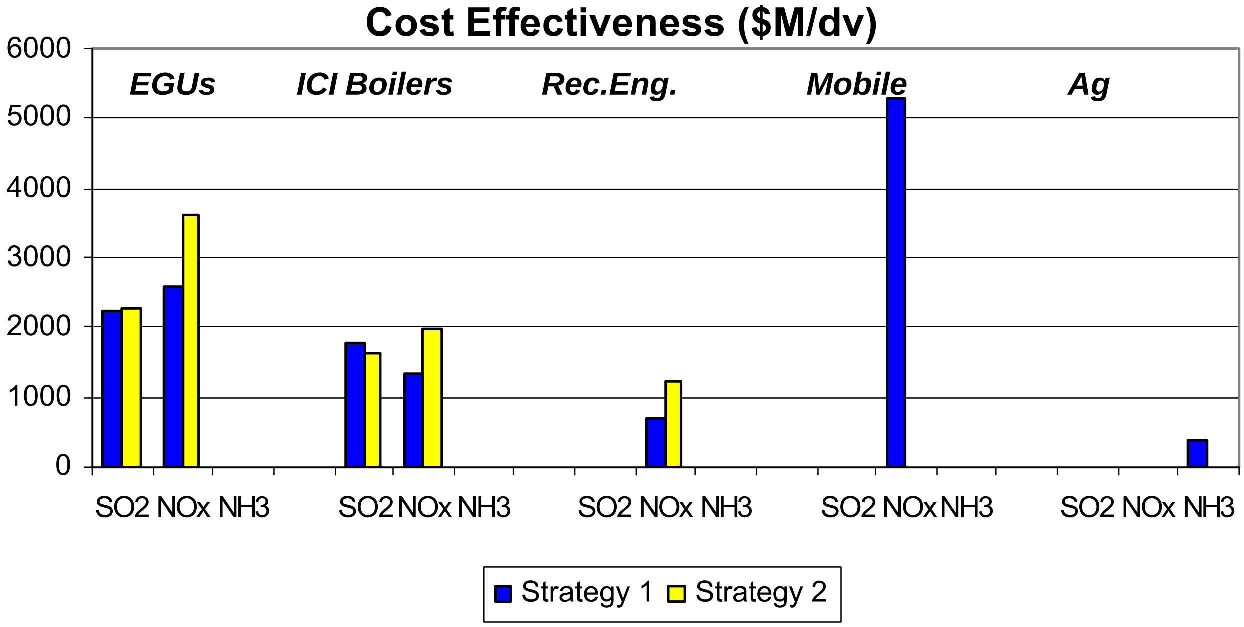


Figure 74. Results of ECR analysis of reasonable progress factors – visibility improvement (Factor 5) is on top, and cost effectiveness (Factor 1) is on bottom

5.2 Weight-of-Evidence Determination for Haze

The WOE determination for haze consists of the primary modeling and other supplemental analyses. A summary of this information is provided below.

Primary (Guideline) Modeling: The results of the guideline modeling are presented in Section 4.1. Key findings from this modeling include:

- Base M modeling results show that the northern Minnesota Class I areas are close to the glide path, whereas the northern Michigan Class I areas are above the glide path in 2018. Other sites in the eastern U.S. are close to (or below) the glide path, except for Mingo (MO), Brigantine (NJ), and Acadia (ME).

- Base K modeling results show that the northern Minnesota and northern Michigan Class I areas are above the glide path in 2018. Other sites in the eastern U.S. are close to (or below) the glide path.

- The difference in the two modeling analyses is due mostly to differences in future year emission projections, especially for EGUs (e.g., use of IPM2.1.9 v. IPM3.0).

- Base K and Base M modeling analyses are considered "SIP quality", so the attainment demonstration for haze should reflect a weight-of-evidence approach, with consideration of monitoring based information.

Additional Modeling: Two additional modeling analyses were considered: (1) the primary modeling redone with different baseline values, and (2) modeling by the State of Minnesota which looked at different receptor locations in the northern Class I areas (MPCA, 2008). Each of these analyses is described below.

First, the primary modeling analysis (Base M) was revised using an alternative baseline value. Specifically, the data for the period 2000-2005 were used to calculate the baseline, given that the Base M modeling reflects a 2005 base year. The results of this alternative analysis (see Table 17) are generally consistent with the primary modeling (see Table 15).

Second, Minnesota's modeling reflects a 2002 base year and much of the data developed by LADCO for its modeling. (Note, Minnesota conducted modeling for LADCO's domain at 36 km, and for a statewide domain at 12 km.) The purpose of the 12 km modeling was to address local scale impacts on the northern Class I areas at several locations, not just the location of the IMPROVE monitor. Results for the Boundary Waters on the 20% worst days range from 18.3 – 19.0 dv, with an average value of 18.7 dv, which is consistent with Minnesota's 36 km modeling results at the IMPROVE monitor. This variability in visibility levels should be kept in mind when reviewing the values presented in Tables 14, 15, and 17, which reflect results at the IMPROVE monitor locations.

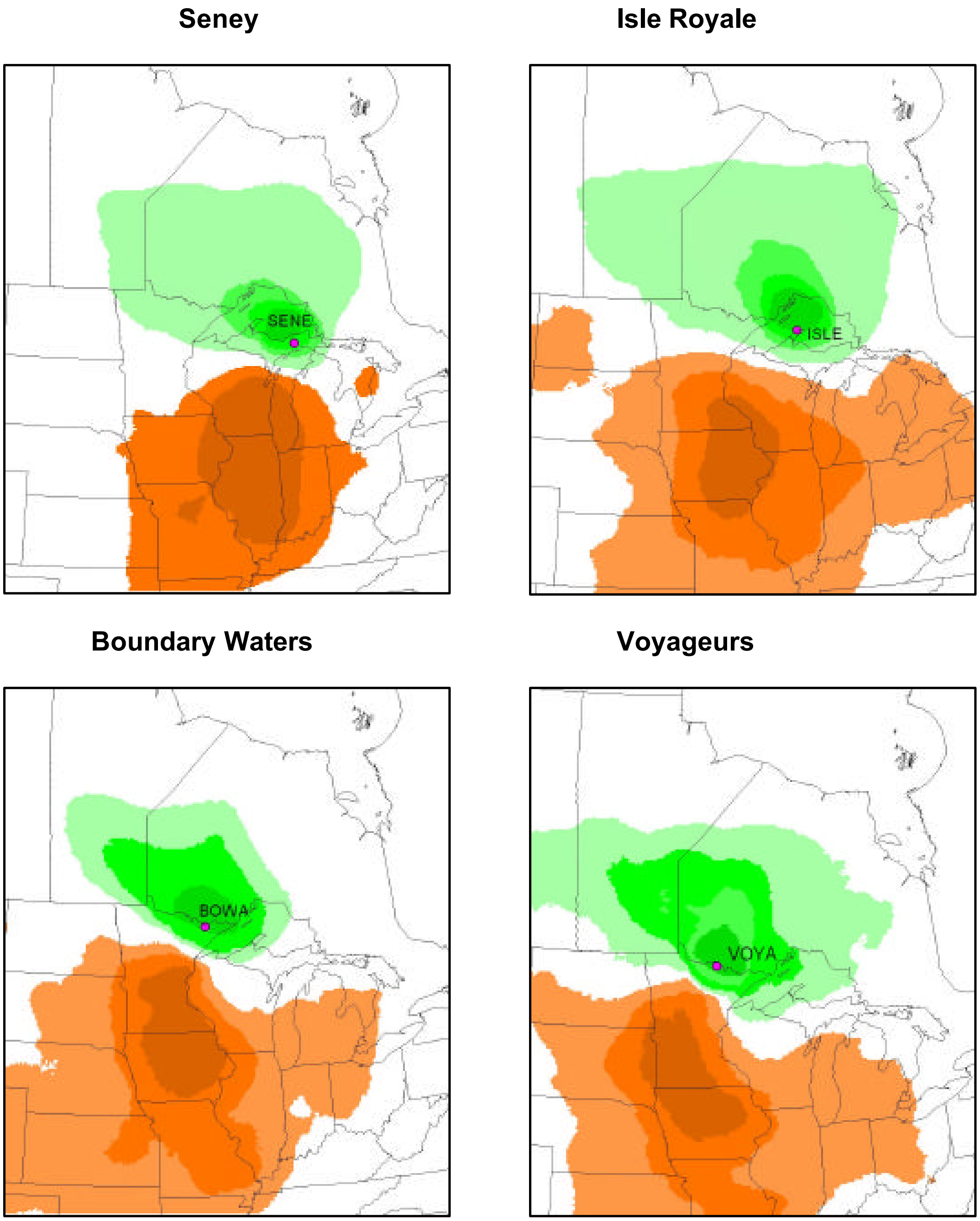
Haze Results - Round 5.1 (Based on 2000-2005)

Worst 20%			**2009**	**2009**	**2012**	**2018**	**2018**
Site	**Baseline**	**URP**	**OTB**	**OTB+Will DO**	**OTB**	**OTB**	**OTB+Will DO**
BOWA1	20.10	18.12	18.63	18.70	18.51	18.12	18.09
VOYA2	19.62	17.86	18.27	18.36	18.15	17.70	17.72
SENE1	24.77	21.94	23.44	23.45	23.39	**22.94**	**22.77**
ISLE1	21.95	19.71	20.84	20.91	20.76	**20.41**	**20.44**
ISLE9	21.95	19.71	20.65	20.70	20.55	**20.15**	**20.13**
HEGL1	27.45	23.67	25.30	25.41	25.27	**24.79**	**24.73**
MING1	28.92	24.86	25.88	26.13	25.68	24.74	24.83
CACR1	27.05	23.44	23.88	24.04	23.78	22.92	22.86
UPBU1	26.97	23.36	23.92	24.05	23.85	23.14	23.09
MACA1	31.76	26.93	27.42	27.72	27.32	26.39	26.44
DOSO1	29.36	24.92	24.20	24.27	24.11	23.19	23.23
SHEN1	29.45	25.23	25.06	25.11	24.94	23.98	24.01
JARI1	29.40	25.13	25.32	25.40	25.17	24.22	24.28
BRIG1	29.12	25.14	25.84	25.88	25.77	**25.26**	**25.26**
LYBR1	24.71	21.69	22.22	22.26	22.06	21.36	21.36
ACAD1	22.91	20.47	21.72	21.75	21.72	**21.49**	**21.49**
Best 20%			**2009**	**2009**	**2012**	**2018**	**2018**
Site	**Baseline**	**URP**	**OTB**	**OTB+Will DO**	**OTB**	**OTB**	**OTB+Will DO**
BOWA1	6.40	6.40	6.20	6.19	6.17	6.13	6.10
VOYA2	7.05	7.05	6.82	6.84	6.78	6.71	6.71
SENE1	7.20	7.20	7.60	7.62	7.61	7.73	7.80
ISLE1	6.80	6.80	6.67	6.69	6.64	6.65	6.66
ISLE9	6.80	6.80	6.62	6.62	6.61	6.57	6.55
HEGL1	13.04	13.04	12.71	12.75	12.51	11.85	11.82
MING1	14.68	14.68	14.07	14.13	13.89	13.28	13.29
CACR1	11.62	11.62	11.24	11.31	11.20	10.86	10.86
UPBU1	11.99	11.99	11.41	11.47	11.36	11.01	11.02
MACA1	16.64	16.64	15.88	16.01	15.82	15.37	15.38
DOSO1	12.24	12.24	11.21	11.25	11.19	10.96	10.97
SHEN1	10.85	10.85	10.04	10.07	10.02	9.82	9.83
JARI1	14.35	14.35	13.51	13.56	13.51	13.27	13.27
BRIG1	14.36	14.36	14.17	14.18	14.10	13.94	13.94
LYBR1	6.21	6.21	6.11	6.14	6.09	6.01	6.01
ACAD1	8.57	8.57	8.67	8.68	8.66	8.62	8.62

Observational Models and Diagnostic Analyses: The observation-based modeling (i.e., application of thermodynamic equilibrium models) is presented in Section 3. The key findings from this modeling are that $PM_{2.5}$ mass is sensitive to reductions in sulfate, nitric acid, and ammonia concentrations. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that $PM_{2.5}$ mass decreases. Under conditions with lower sulfate levels (i.e., proxy of future year conditions), $PM_{2.5}$ is more sensitive to reductions in nitric acid compared to reductions in ammonia.

As discussed in Section 2, thermodynamic equilibrium modeling based on data collected at Seney indicates that $PM_{2.5}$ there is most sensitive to reductions in sulfate, but also responsive to reductions in nitric acid (Blanchard 2004b). An analysis using data from the Midwest ammonia monitoring network for a site in Minnesota (i.e., Great River Bluffs, which is the closest ammonia monitoring site to the northern Class I areas) suggested that reductions in sulfate, nitric acid, and ammonia concentrations will lower $PM_{2.5}$ concentrations and improve visibility levels in the northern Class I areas.

Trajectory analyses for the 20% worst visibility days for the four northern Class I areas are provided in Figure 75. (Note, this figure is similar to Figure 34, but the trajectory results for each Class I area are displayed separately here.) The orange areas are where the air is most likely to come from, and the green areas are where the air is least likely to come from. Darker shading represents higher frequency. As can be seen, bad air days are generally associated with transport from regions located to the south, and good air days with transport from Canada.


Seney

Isle Royale

Boundary Waters

Voyageurs

Figure 75. Trajectory analysis results for northern Class I areas on 20% worst visibility days

The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts (Baker, 2007b). Specifically, the CAMx model was applied to provide source contribution information. Specifically, the model estimated the impact of 18 geographic source regions (which are identified in Figure 76) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and ammonia sources) at visibility/haze monitoring sites in the eastern U.S.

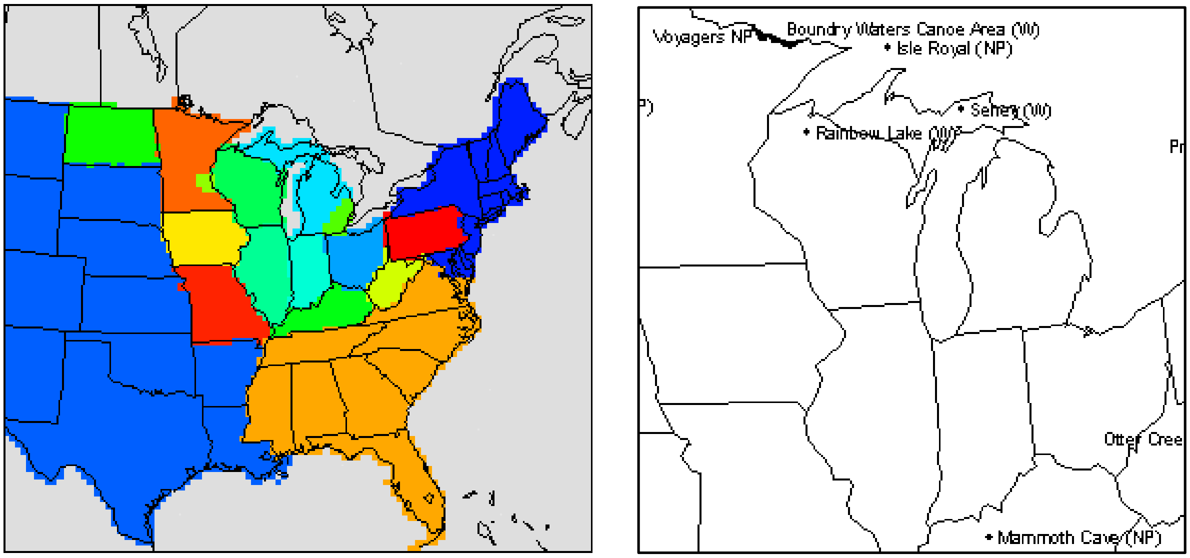


Figure 76. Source regions (left) and key monitoring sites (right) for haze modeling analysis

Modeling results for 2018 (Base K and Base M) are provided in Appendix V for several key monitoring sites (Class I areas). For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of absolute modeled values.

The sector-level results (see, for example, Figure 77) show that EGU sulfate, non-EGU-sulfate, and ammonia emissions generally have the largest contributions at the key monitor locations. The source group contributions vary by receptor location due to emissions inventory differences.

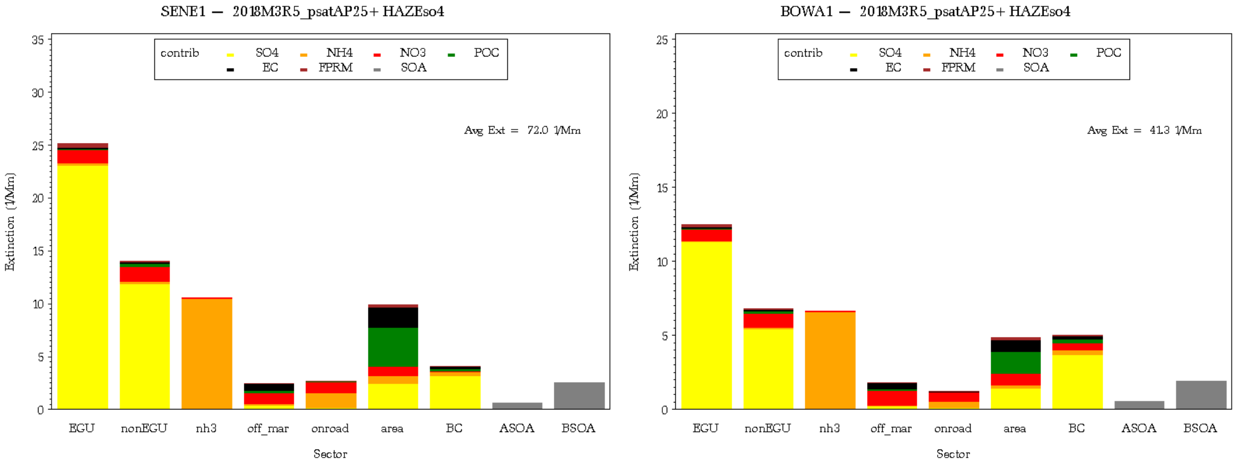


Figure 77. Source-sector results for Seney (left) and Boundary Waters (right) – 2018 (Base M)

The source region results (see, for example, Figure 78) show that emissions from a number of nearby states contribute to regional haze levels.

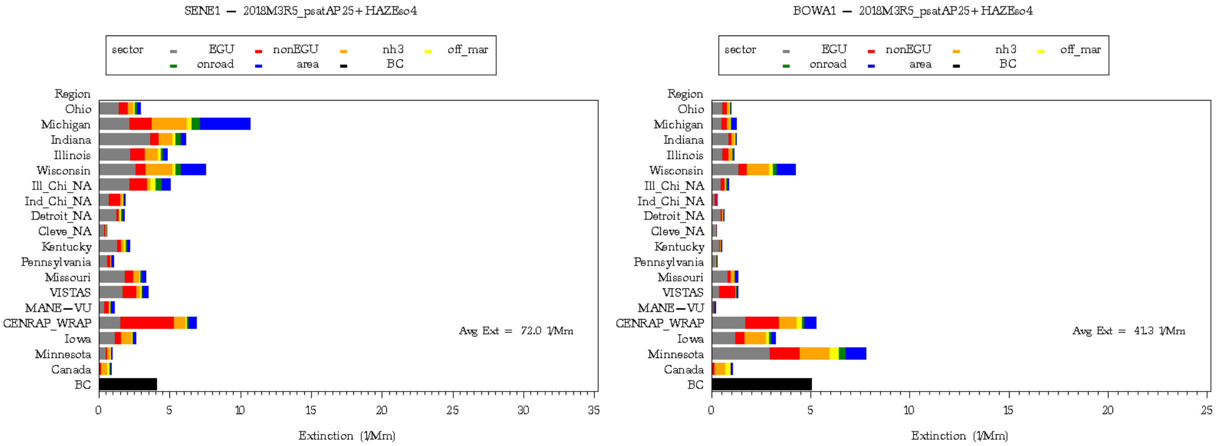


Figure 78. Source-region results for Seney (left) and Boundary Waters (right) – 2018 (Base M)

Summary: Air quality modeling and other supplemental analyses were performed to estimate future year visibility levels. Based on this information, the following general conclusions can be made:

- Existing (“on the books”) controls are expected to improve visibility levels in the northern Class I areas.

- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018, including those in northern Michigan and some in the northeastern U.S.

- Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018.

Section 6. Summary

To support the development of SIPs for ozone, $PM_{2.5}$, and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, technical analyses were conducted by LADCO, its member states, and various contractors. The analyses include preparation of regional emissions inventories and meteorological modeling data for two base years, evaluation and application of regional chemical transport models, and review of ambient monitoring data.

Analyses of monitoring data were conducted to produce a conceptual model, which is a qualitative summary of the physical, chemical, and meteorological processes that control the formation and distribution of pollutants in a given region. Key findings of the analyses include:

Ozone

- Current monitoring data show about 20 sites in violation of the 8-hour ozone standard of 85 ppb. Historical ozone data show a steady downward trend over the past 15 years, especially since 2001-2003, due likely to federal and state emission control programs.
- Ozone concentrations are strongly influenced by meteorological conditions, with more high ozone days and higher ozone levels during summers with above normal temperatures.
- Inter- and intra-regional transport of ozone and ozone precursors affects many portions of the five states, and is the principal cause of nonattainment in some areas far from population or industrial centers

$PM_{2.5}$

- Current monitoring data show about 40 sites in violation of the annual $PM_{2.5}$ standard of 15 ug/m^3. Nonattainment sites are characterized by an elevated regional background (about 12 – 14 ug/m^3) and a significant local (urban) increment (about 2 – 3 ug/m^3). Historical $PM_{2.5}$ data show a slight downward trend since deployment of the $PM_{2.5}$ monitoring network in 1999.
- $PM_{2.5}$ concentrations are less influenced by meteorology (compared to ozone), but, nevertheless, are affected by atmospheric conditions (e.g., stagnation events, especially during the winter) and transport patterns.
- On an annual average basis, $PM_{2.5}$ chemical composition consists of mostly sulfate, nitrate, and organic carbon in similar proportions.

Haze

- Current monitoring data show visibility levels in the Class I areas in northern Michigan are on the order of 22 – 24 deciviews. The goal of USEPA's visibility program is to achieve natural conditions, which is on the order of 12 deciviews for these Class I areas, by the year 2064.
- Visibility impairment is dominated by sulfate and nitrate.

Air quality models were applied to support the regional planning efforts. Two base years were used in the modeling analyses: 2002 and 2005. USEPA's modeling guidance recommends using 2002 as the baseline inventory year, but also allows for use of an alternative baseline inventory year, especially a more recent year. Initially, LADCO conducted modeling with a 2002 base year (i.e., Base K modeling, which was completed in 2006). A decision was subsequently made to conduct modeling with a 2005 base year (i.e., Base M, which was completed in 2007). Statistical analyses showed that 2002 and 2005 both had above normal ozone-conducive conditions, although 2002 was more severe compared to 2005. Examination of multiple base years provides for a more complete technical assessment. Both sets of model runs are discussed in this document.

Basecase modeling was conducted to evaluate model performance (i.e., assess the model's ability to reproduce the observed concentrations). This exercise was intended to build confidence in the model prior to its use in examining candidate control strategies. Model performance for ozone and $PM_{2.5}$ was generally acceptable and can be characterized as follows:

Ozone

- Good agreement between modeled and monitored concentration for higher concentration levels (> 60 ppb) – i.e., bias within 30%
- Regional modeled concentrations appear to be underestimated in the 2002 base year, but show better agreement (with monitored data) in the 2005 base year due to model and inventory improvements.
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data
- Model accurately simulates the change in monitored ozone concentrations due to reductions in precursor emissions.

$PM_{2.5}$

- Good agreement in the magnitude of fine particle mass, but some species are overestimated and some are underestimated
  - Sulfates: good agreement in the 2002 base year, but underestimated in the 2005 base year due probably to meteorological factors
  - Nitrates: slightly overestimated in the winter in the 2002 base year, but good agreement in the 2005 base year as a result of model and inventory improvements
  - Organic Carbon: grossly underestimated in the 2002 and 2005 base years due likely to missing primary organic carbon emissions
- Temporal variation and spatial patterns of modeled concentrations are consistent with monitored data

Future year strategy modeling was conducted to determine whether existing ("on the books") controls would be sufficient to provide for attainment of the standards for ozone and $PM_{2.5}$ and if not, then what additional emission reductions would be necessary for attainment. Traditionally, attainment demonstrations involved a "bright line" test in which a single modeled value (based on USEPA guidance) was compared to the ambient standard. To provide a more robust assessment of expected future year air quality, other information was considered. Furthermore, according to USEPA's modeling guidance, if the future year modeled design values are "close" to the standard (i.e., 82 – 87 ppb for ozone and 14.5 – 15.5 ug/m^3 for PM$_{2.5}$), then the results of the primary modeling should be reviewed along with the supplemental information in a "weight of evidence" (WOE) assessment of whether each area is likely to achieve timely attainment. Key findings of the WOE determination include:

- Existing controls are expected to produce significant improvement in ozone and PM$_{2.5}$ concentrations and visibility levels.

- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. 2002 was more ozone conducive than 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).

- Most sites are expected to meet the current 8-hour standard by the applicable attainment date, except for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.

- Most sites are expected to meet the current PM$_{2.5}$ standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City.

  The regional modeling for PM$_{2.5}$ does not reflect air quality benefits expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for PM$_{2.5}$.

- These findings of residual nonattainment for ozone and PM$_{2.5}$ are supported by current (2005 – 2007) monitoring data which show significant nonattainment in the region (e.g., peak ozone design values on the order of 90 – 93 ppb, and peak PM$_{2.5}$ design values on the order of 16 - 17 ug/m^3). It is unlikely that sufficient emission reductions will occur in the next few of years to provide for attainment at all sites.

- Attainment at most sites by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). If either of these conditions is not met, then attainment may be less likely.

- The new PM$_{2.5}$ 24-hour standard (and, probably, a new lower ozone standard) will not be met at many sites, even by 2018, with existing controls.

- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018 based on existing controls, including those in northern Michigan and some in the northeastern U.S. Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018.

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APPENDIX I

Ozone and $PM_{2.5}$ Modeling Results

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2009 - OTB			2009 - Will Do		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	Round 4	RRF	Round 5	
Lake Michigan Area																	***Lake Michigan Area***
Chiwaukee	550590019	88	78	93	79	85	**86**	83	**85**	84.7	**98.3**	0.972	82.3	**92.0**	0.971	82.2	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	**91.7**	0.965	77.5	84.9	0.964	77.4	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	**86**	79	83	82.7	**91.0**	0.965	79.8	84.9	0.964	79.7	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	**88**	79	83	83.3	**93.0**	0.961	80.1	**85.4**	0.960	80.0	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	**87**	82	**85**	84.7	**87.0**	0.951	80.5	78.9	0.949	80.3	Manitowoc
Sheboygan	551170006	93	78	97	83	88	**89**	**86**	**89**	**88.0**	**97.0**	0.955	84.0	**88.9**	0.953	83.9	Sheboygan
Kewaunee	550610002	97	73	88	76	85	**86**	79	83	82.7	**89.3**	0.945	78.1	81.0	0.943	78.0	Kewaunee
Door County	550290004	93	78	101	79	92	**90**	**86**	**90**	**88.7**	**91.0**	0.946	83.9	81.8	0.945	83.8	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	**88.3**	0.971	75.4	**86.6**	0.970	75.3	Hammond
Whiting	180890030		64	88	81	88	76	77	**85**	79.3		0.971	77.0		0.970	77.0	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	**90.3**	0.960	73.9	**86.5**	0.959	73.8	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	**86.3**	0.965	75.6	82.8	0.964	75.5	Ogden Dunes
Holland	260050003	95	79	94	91	95	**89**	**88**	**93**	**90.0**	**94.0**	0.948	**85.3**	83.4	0.947	**85.2**	Holland
Jenison	261390005	91	69	86	83	89	82	79	**86**	82.3	**86.0**	0.940	77.4	77.6	0.939	77.3	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	**89**	**85.3**	**90.0**	0.947	80.8	81.5	0.945	80.6	Muskegon
Indianapolis Area																	***Indianapolis Area***
Noblesville	189571001	101	75	87	79	84	**87**	80	83	83.3	**93.7**	0.945	78.8	83.7	0.946	78.8	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	**91.3**	0.947	74.5	83.8	0.948	74.6	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	**90.0**	0.955	75.1	83.7	0.956	75.2	Fort B. Harrison
Detroit Area																	***Detroit Area***
New Haven	260990009	102	81	88	79	92	**90**	82	**86**	**86.0**	**92.3**	0.947	81.4	85.3	0.947	81.4	New Haven
Warren	260991003	101	71	89	78	90	**87**	79	**85**	83.7	**90.0**	0.968	81.0	83.3	0.969	81.1	Warren
Port Huron	261470005	86	74	88	78	89	82	80	**85**	82.3	**88.0**	0.937	77.1	79.1	0.938	77.2	Port Huron
Cleveland Area																	***Cleveland Area***
Ashtabula	390071001	99	81	93	86	92	**91**	**86**	**90**	**89.0**	**95.7**	0.937	83.4	82.7	0.941	83.7	Ashtabula
Geauga	390550004	97	75	88	70	68	**86**	77	75	79.3	**99.0**	0.942	74.7	**88.8**	0.945	75.0	Geauga
Eastlake	390850003	92	79	97	83	74	**89**	**86**	84	**86.3**	**92.7**	0.949	81.9	82.8	0.954	82.4	Eastlake
Akron	391530020	89	77	89	77	91	**85**	81	**85**	83.7	**93.3**	0.934	78.1	81.4	0.935	78.2	
Cincinnati Area																	***Cincinnati Area***
Wilmington	390271002	96	78	83	81	82	**85**	80	82	82.3	**94.3**	0.941	77.5	83.5	0.942	77.6	Wilmington
Sycamore	390610006	93	76	89	80	90	**86**	81	**86**	84.3	**90.3**	0.967	81.6	84.7	0.968	81.6	Sycamore
Lebanon	391650007	95	81	92	86	88	**89**	**86**	**88**	**87.7**	**87.0**	0.947	83.0	79.0	0.948	83.1	Lebanon
Columbus Area																	***Columbus Area***
London	390970007	90	75	81	76	83	82	77	80	79.7	**88.7**	0.941	75.0	78.4	0.942	75.0	London
New Albany	390490029	94	78	92	82	87	**88**	84	**87**	**86.3**	**93.0**	0.947	81.8	82.6	0.948	81.8	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	**86.0**	0.945	75.9	76.5	0.948	76.2	Franklin
St. Louis Area																	***St. Louis Area***
W. Alton (MO)	291831002	91	77	89	91	89	**85**	**85**	**89**	**86.3**	**90.0**	0.938	81.0	**85.2**	0.932	80.5	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	**86**	**86**	**89**	**87.0**	**90.0**	0.942	82.0	82.2	0.939	81.7	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	**86**	82.3	**88.3**	0.956	78.7	81.9	0.954	78.5	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	**86**	82.3	84.7	0.938	77.2	77.4	0.937	77.1	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	**86**	83.0	**87.7**	0.955	79.3	83.4	0.955	79.3	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	**88**	**86**	**88**	**87.3**		0.955	83.4		0.954	83.3	Maryland Heights (MO)

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2012 - OTB			2018 - OTB		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	Round 4	RRF	Round 5	
Lake Michigan Area																	***Lake Michigan Area***
Chiwaukee	550590019	88	78	93	79	85	**86**	83	**85**	84.7	**98.3**	0.956	80.9	**90.3**	0.900	76.2	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	**91.7**	0.947	76.1	**82.9**	0.886	71.2	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	**86**	79	83	82.7	**91.0**	0.945	78.1	**82.3**	0.880	72.7	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	**88**	79	83	83.3	**93.0**	0.939	78.3	**82.9**	0.870	72.5	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	**87**	82	**85**	84.7	**87.0**	0.925	78.3	76.3	0.853	72.2	Manitowoc
Sheboygan	551170006	93	78	97	83	88	**89**	**86**	**89**	**88.0**	**97.0**	0.931	81.9	**86.4**	0.857	75.4	Sheboygan
Kewaunee	550610002	97	73	88	76	85	**86**	79	83	82.7	**89.3**	0.919	76.0	79.1	0.845	69.9	Kewaunee
Door County	550290004	93	78	101	79	92	**90**	**86**	**90**	**88.7**	**91.0**	0.920	81.6	79.3	0.843	74.7	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	**88.3**	0.961	74.6	**86.3**	0.922	71.6	Hammond
Whiting	180890030		64	88	81	88	76	77	**85**	79.3		0.961	76.2		0.922	73.1	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	**90.3**	0.941	72.5	**85.4**	0.884	68.1	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	**86.3**	0.950	74.4	**82.0**	0.904	70.8	Ogden Dunes
Holland	260050003	95	79	94	91	95	**89**	**88**	**93**	**90.0**	**94.0**	0.921	**82.9**	81.0	0.846	76.1	Holland
Jenison	261390005	91	69	86	83	89	82	79	**86**	82.3	**86.0**	0.913	75.2	75.5	0.838	69.0	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	**89**	**85.3**	**90.0**	0.921	78.6	79.4	0.846	72.2	Muskegon
Indianapolis Area																	***Indianapolis Area***
Noblesville	189571001	101	75	87	79	84	**87**	80	83	83.3	**93.7**	0.915	76.3	**82.0**	0.831	69.3	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	**91.3**	0.918	72.2	**82.1**	0.835	65.7	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	**90.0**	0.933	73.4	**82.4**	0.879	69.1	Fort B. Harrison
Detroit Area																	***Detroit Area***
New Haven	260990009	102	81	88	79	92	**90**	82	**86**	**86.0**	**92.3**	0.932	80.2	**83.5**	0.885	76.1	New Haven
Warren	260991003	101	71	89	78	90	**87**	79	**85**	83.7	**90.0**	0.961	80.4	81.9	0.924	77.3	Warren
Port Huron	261470005	86	74	88	78	89	82	80	**85**	82.3	**88.0**	0.914	75.3	77.0	0.858	70.6	Port Huron
Cleveland Area																	***Cleveland Area***
Ashtabula	390071001	99	81	93	86	92	**91**	**86**	**90**	**89.0**	**95.7**	0.910	81.0	80.2	0.844	75.1	Ashtabula
Geauga	390550004	97	75	88	70	68	**86**	77	75	79.3	**99.0**	0.916	72.7	**86.2**	0.848	67.3	Geauga
Eastlake	390850003	92	79	97	83	74	**89**	**86**	84	**86.3**	**92.7**	0.932	80.5	80.6	0.883	76.2	Eastlake
Akron	391530020	89	77	89	77	91	**85**	81	**85**	83.7	**93.3**	0.904	75.6	78.5	0.821	68.7	Akron
Cincinnati Area																	***Cincinnati Area***
Wilmington	390271002	96	78	83	81	82	**85**	80	82	82.3	**94.3**	0.912	75.1	81.1	0.830	68.3	Wilmington
Sycamore	390610006	93	76	89	80	90	**86**	81	**86**	84.3	**90.3**	0.949	80.0	**82.9**	0.881	74.3	Sycamore
Lebanon	391650007	95	81	92	86	88	**89**	**86**	**88**	**87.7**	**87.0**	0.922	80.8	77.0	0.846	74.2	Lebanon
Columbus Area																	***Columbus Area***
London	390970007	90	75	81	76	83	82	77	80	79.7	**88.7**	0.912	72.7	76.5	0.832	66.3	London
New Albany	390490029	94	78	92	82	87	**88**	84	**87**	**86.3**	**93.0**	0.922	79.6	80.2	0.845	73.0	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	**86.0**	0.924	74.2	74.7	0.859	69.0	Franklin
St. Louis Area																	***St. Louis Area***
W. Alton (MO)	291831002	91	77	89	91	89	**85**	**85**	**89**	**86.3**	**90.0**	0.921	79.5	**84.0**	0.868	74.9	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	**86**	**86**	**89**	**87.0**	**90.0**	0.924	80.4	80.4	0.876	76.2	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	**86**	82.3	**88.3**	0.940	77.4	80.6	0.897	73.9	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	**86**	82.3	84.7	0.921	75.8	75.8	0.874	72.0	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	**86**	83.0	**87.7**	0.939	77.9	**82.5**	0.896	74.4	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	**88**	**86**	**88**	**87.3**		0.938	81.9		0.894	78.1	Maryland Heights (MO)

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2008 - OTB		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	
Lake Michigan Area														***Lake Michigan Area***
Chiwaukee	550590019	88	78	93	79	85	**86**	83	**85**	84.7	**98.3**	0.968	**82.0**	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	**91.7**	0.966	77.6	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	**86**	79	83	82.7	**91.0**	0.963	79.6	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	**88**	79	83	83.3	**93.0**	0.960	80.0	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	**87**	82	**85**	84.7	**87.0**	0.957	81.0	Manitowoc
Sheboygan	551170006	93	78	97	83	88	**89**	**86**	**89**	**88.0**	**97.0**	0.959	**84.4**	Sheboygan
Kewaunee	550610002	97	73	88	76	85	**86**	79	83	82.7	**89.3**	0.954	78.9	Kewaunee
Door County	550290004	93	78	101	79	92	**90**	**86**	**90**	**88.7**	**91.0**	0.956	**84.8**	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	**88.3**	0.971	75.4	Hammond
Whiting	180890030		64	88	81	88	76	77	**85**	79.3		0.971	77.0	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	**90.3**	0.964	74.2	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	**86.3**	0.967	75.7	Ogden Dunes
Holland	260050003	95	79	94	91	95	**89**	**88**	**93**	**90.0**	**94.0**	0.951	**85.6**	Holland
Jenison	261390005	91	69	86	83	89	82	79	**86**	82.3	**86.0**	0.950	78.2	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	**89**	**85.3**	**90.0**	0.951	81.2	Muskegon
Indianapolis Area														***Indianapolis Area***
Noblesville	189571001	101	75	87	79	84	**87**	80	83	83.3	**93.7**	0.944	78.7	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	**91.3**	0.948	74.6	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	**90.0**	0.951	74.8	Fort B. Harrison
Detroit Area														***Detroit Area***
New Haven	260990009	102	81	88	79	92	**90**	82	**86**	**86.0**	**92.3**	0.962	**82.7**	New Haven
Warren	260991003	101	71	89	78	90	**87**	79	**85**	83.7	**90.0**	0.982	**82.2**	Warren
Port Huron	261470005	86	74	88	78	89	82	80	**85**	82.3	**88.0**	0.956	78.7	Port Huron
Cleveland Area														***Cleveland Area***
Ashtabula	390071001	99	81	93	86	92	**91**	**86**	**90**	**89.0**	**95.7**	0.954	**84.9**	Ashtabula
Geauga	390550004	97	75	88	70	68	**86**	77	75	79.3	**99.0**	0.954	75.7	Geauga
Eastlake	390850003	92	79	97	83	74	**89**	**86**	84	**86.3**	**92.7**	0.959	**82.8**	Eastlake
Akron	391530020	89	77	89	77	91	**85**	81	**85**	83.7	**93.3**	0.948	79.3	
Cincinnati Area														***Cincinnati Area***
Wilmington	390271002	96	78	83	81	82	**85**	80	82	82.3	**94.3**	0.945	77.8	Wilmington
Sycamore	390610006	93	76	89	80	90	**86**	81	**86**	84.3	**90.3**	0.965	81.4	Sycamore
Lebanon	391650007	95	81	92	86	88	**89**	**86**	**88**	**87.7**	**87.0**	0.954	**83.6**	Lebanon
Columbus Area														***Columbus Area***
London	390970007	90	75	81	76	83	82	77	80	79.7	**88.7**	0.946	75.4	London
New Albany	390490029	94	78	92	82	87	**88**	84	**87**	**86.3**	**93.0**	0.954	**82.4**	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	**86.0**	0.958	77.0	Franklin
St. Louis Area														***St. Louis Area***
W. Alton (MO)	291831002	91	77	89	91	89	**85**	**85**	**89**	**86.3**	**90.0**	0.954	**82.4**	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	**86**	**86**	**89**	**87.0**	**90.0**	0.958	**83.3**	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	**86**	82.3	**88.3**	0.966	79.5	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	**86**	82.3	84.7	0.956	78.7	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	**86**	83.0	**87.7**	0.962	79.8	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	**88**	**86**	**88**	**87.3**		0.967	**84.5**	Maryland Heights (MO)

			Annual Average Conc.					Design Values			2005 BY	2002 BY	2009 Modeling Results			
Key Site	**County**	**Site ID**	**'03**	**'04**	**'05**	**'06**	**'07**	**'03 - '05**	**'04 - '06**	**'05 - '07**	**Average w/o 2007**	**Average**	**Round 5 OTB**	**Round 5 Will Do**	**Round4**	**Key Site**
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2		15.6	14.8	15.1	**15.1**	**15.9**	13.9	13.9	**14.8**	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5		16.1	15.6	15.8	**15.8**	**17.1**	**14.2**	**14.3**	**15.8**	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5		15.4	14.7	15.1	**15.0**	**15.6**	13.7	13.8	**14.5**	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5		15.2	14.8	15.1	**15.0**	**15.6**	13.7	13.8	**14.5**	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2		15.1	14.6	14.8	14.8	**15.6**	13.6	13.6	**14.5**	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8		16.8	16.1	16.2	16.4		**14.9**	**15.0**		Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8		15.6	15.0	15.4	**15.3**	**16.0**	**14.1**	**14.1**	**14.8**	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3		16.1	15.3	15.3	**15.6**	**16.4**	**14.4**	**14.4**	**15.3**	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3		17.0	16.6	17.3	**17.0**	**17.3**	**15.2**	**15.3**	**16.0**	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5		15.6	15.4	15.8	**15.6**	**16.2**	**14.0**	**14.1**	**14.9**	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0		16.5	16.2	16.8	**16.5**	**16.3**	13.6	13.9	**15.5**	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5		15.7	14.9	15.2	**15.3**	**16.1**	12.4	12.6	13.8	Jasper
Gary	Lake	180890031			16.8	13.3		16.8	15.1	15.1	**15.6**		12.9	13.0		Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1		15.4	14.9	15.3	**15.2**	**16.2**	12.7	12.8	**14.5**	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1		16.3	15.5	15.8	**15.9**	**16.4**	13.2	13.4	**14.8**	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2		15.1	14.4	14.6	14.7	**15.8**	13.0	13.1	**14.5**	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7		16.4	15.8	16.0	**16.0**	**17.3**	**14.2**	**14.3**	**15.8**	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0		15.2	14.2	14.5	14.6	**15.5**	13.0	13.1	**14.1**	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1		18.2	17.2	17.4	**17.6**	**19.3**	**15.7**	**15.8**	**17.7**	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9		15.5	14.3	14.7	14.8	**16.6**	13.0	13.1	**15.1**	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1		16.8	15.7	16.6	**16.4**	**16.5**	13.3	13.5	**14.2**	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0		16.1	15.5	16.0	**15.9**	**15.9**	13.0	13.2	13.5	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0		16.1	15.3	15.2	**15.5**	**16.5**	13.4	13.5	**14.4**	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9		18.1	17.2	17.1	**17.5**	**18.4**	**15.1**	**15.3**	**16.1**	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1		17.0	16.2	16.7	**16.6**	**16.7**	**14.2**	**14.4**	**14.6**	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0		17.7	16.9	17.2	**17.3**	**17.6**	**14.8**	**15.0**	**15.3**	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1		16.5	15.6	15.9	**16.0**	**16.2**	13.7	13.9	**14.1**	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6		15.9	15.0	15.0	**15.3**	**16.5**	12.8	13.0	**14.6**	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8		15.5	15.0	15.2	**15.2**	**16.0**	12.6	12.8	**14.1**	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9		14.4	13.7	13.8	13.9	**16.0**	11.7	11.8	**14.0**	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5		17.6	17.1	17.7	**17.4**	**17.7**	**14.4**	**14.6**	**15.5**	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6		15.9	15.2	15.6	**15.6**	**15.7**	12.7	12.9	13.6	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9		17.3	16.7	17.0	**17.0**	**17.3**	13.9	**14.1**	**14.6**	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5		15.8	15.4	15.7	**15.7**	**16.0**	12.9	13.1	13.6	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4		16.6	16.0	16.4	**16.3**	**16.3**	13.3	13.5	**14.2**	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9		17.9	17.4	18.0	**17.8**	**17.3**	**14.6**	**14.8**	**15.2**	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8		16.7	15.4	15.1	**15.7**	**17.7**	12.5	12.6	**16.3**	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6		17.2	16.3	16.4	**16.6**	**17.5**	13.4	13.4	**15.5**	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4		15.0	15.0	15.7	**15.2**	**15.7**	12.7	12.8	**14.2**	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6		15.9	15.2	15.5	**15.5**	**15.9**	13.0	13.2	13.7	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3		14.6	14.5	15.3	14.8	**17.1**	12.2	12.3	**15.4**	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6		16.7	16.0	16.2	**16.3**	**17.3**	13.9	**14.0**	**15.0**	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9		15.2	14.2	14.3	14.6	**15.7**	12.4	12.5	13.6	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5		15.6	15.0	15.0	**15.2**	**16.4**	12.9	13.1	**14.4**	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8		14.6	14.1	14.3	14.3	**15.6**	12.1	12.3	13.6	Akron - W. Exchange

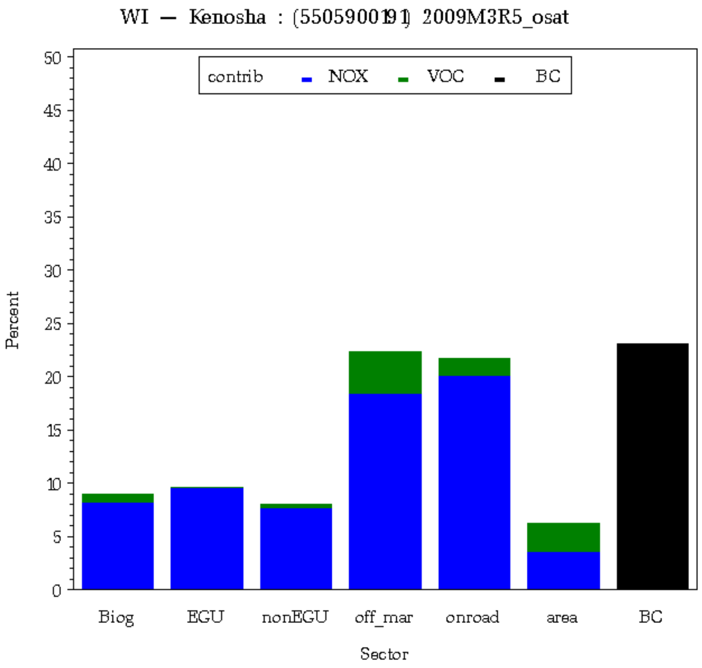
			Annual Average Conc.						Design Values				2005 BY	2002 BY		2012 Modeling Results			
Key Site	**County**	**Site ID**	**'03**	**'04**	**'05**	**'06**	**'07**		**'03 - '05**	**'04 - '06**	**'05 - '07**		**Average w/o 2007**	**Average**		**Round 5 OTB**	**Round 5 Will Do**	**Round4**	**Key Site**
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2			15.6	14.8	15.1		**15.1**	**15.9**		13.8		**14.6**	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5			16.1	15.6	15.8		**15.8**	**17.1**		**14.2**		**15.5**	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5			15.4	14.7	15.1		**15.0**	**15.6**		13.7		**14.3**	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5			15.2	14.8	15.1		**15.0**	**15.6**		13.7		**14.3**	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2			15.1	14.6	14.8		14.8	**15.6**		13.5		**14.3**	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8			16.8	16.1	16.2		16.4			**14.8**			Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8			15.6	15.0	15.4		**15.3**	**16.0**		**14.0**		**14.6**	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3			16.1	15.3	15.3		**15.6**	**16.4**		**14.3**		**15.1**	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3			17.0	16.6	17.3		**17.0**	**17.3**		**15.1**		**15.8**	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5			15.6	15.4	15.8		**15.6**	**16.2**		13.8		**14.7**	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0			16.5	16.2	16.8		**16.5**	**16.3**		13.6		**15.0**	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5			15.7	14.9	15.2		**15.3**	**16.1**		12.3		13.5	Jasper
Gary	Lake	180890031			16.8	13.3			16.8	15.1	15.1		**15.6**			12.7			Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1			15.4	14.9	15.3		**15.2**	**16.2**		12.5		**14.2**	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1			16.3	15.5	15.8		**15.9**	**16.4**		13.0		**14.9**	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2			15.1	14.4	14.6		14.7	**15.8**		12.9		**14.1**	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7			16.4	15.8	16.0		**16.0**	**17.3**		**14.0**		**15.3**	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0			15.2	14.2	14.5		14.6	**15.5**		12.9		13.7	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1			18.2	17.2	17.4		**17.6**	**19.3**		**15.5**		**17.1**	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9			15.5	14.3	14.7		14.8	**16.6**		12.9		**14.7**	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1			16.8	15.7	16.6		**16.4**	**16.5**		13.2		13.7	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0			16.1	15.5	16.0		**15.9**	**15.9**		13.0		12.9	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0			16.1	15.3	15.2		**15.5**	**16.5**		13.2		13.8	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9			18.1	17.2	17.1		**17.5**	**18.4**		**14.8**		**15.4**	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1			17.0	16.2	16.7		**16.6**	**16.7**		**14.0**		**14.0**	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0			17.7	16.9	17.2		**17.3**	**17.6**		**14.6**		**14.7**	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1			16.5	15.6	15.9		**16.0**	**16.2**		13.5		13.5	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6			15.9	15.0	15.0		**15.3**	**16.5**		12.6		**14.0**	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8			15.5	15.0	15.2		**15.2**	**16.0**		12.4		13.5	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9			14.4	13.7	13.8		13.9	**16.0**		11.5		13.4	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5			17.6	17.1	17.7		**17.4**	**17.7**		**14.3**		**14.8**	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6			15.9	15.2	15.6		**15.6**	**15.7**		12.6		13.0	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9			17.3	16.7	17.0		**17.0**	**17.3**		13.8		**14.0**	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5			15.8	15.4	15.7		**15.7**	**16.0**		12.8		13.0	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4			16.6	16.0	16.4		**16.3**	**16.3**		13.2		13.6	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9			17.9	17.4	18.0		**17.8**	**17.3**		**14.5**		**14.6**	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8			16.7	15.4	15.1		**15.7**	**17.7**		12.5		**15.9**	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6			17.2	16.3	16.4		**16.6**	**17.5**		13.3		**15.0**	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4			15.0	15.0	15.7		**15.2**	**15.7**		12.7		13.7	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6			15.9	15.2	15.5		**15.5**	**15.9**		12.8		13.2	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3			14.6	14.5	15.3		14.8	**17.1**		12.1		**14.8**	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6			16.7	16.0	16.2		**16.3**	**17.3**		13.7		**14.3**	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9			15.2	14.2	14.3		14.6	**15.7**		12.2		13.0	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5			15.6	15.0	15.0		**15.2**	**16.4**		12.8		13.6	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8			14.6	14.1	14.3		14.3	**15.6**		12.0		13.0	Akron - W. Exchange

			Annual Average Conc.					**Design Values**			**2005 BY**	**2002 BY**	**2018 Modeling Results**			
Key Site	**County**	**Site ID**	**'03**	**'04**	**'05**	**'06**	**'07**	**'03 - '05**	**'04 - '06**	**'05 - '07**	**Average w/o 2007**	**Average**	**Round 5 OTB**	**Round 5 Will Do**	**Round4**	**Key Site**
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2		15.6	14.8	15.1	**15.1**	**15.9**	13.6	13.5	**14.4**	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5		16.1	15.6	15.8	**15.8**	**17.1**	13.8	13.7	**15.0**	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5		15.4	14.7	15.1	**15.0**	**15.6**	13.5	13.3	**14.1**	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5		15.2	14.8	15.1	**15.0**	**15.6**	13.5	13.3	**14.1**	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2		15.1	14.6	14.8	14.8	**15.6**	13.5	13.2	**14.1**	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8		16.8	16.1	16.2	16.4		**14.3**	**14.2**		Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8		15.6	15.0	15.4	**15.3**	**16.0**	13.8	13.7	**14.4**	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3		16.1	15.3	15.3	**15.6**	**16.4**	**14.1**	**14.0**	**14.9**	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3		17.0	16.6	17.3	**17.0**	**17.3**	**14.5**	**14.4**	**15.5**	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5		15.6	15.4	15.8	**15.6**	**16.2**	13.2	13.2	**14.5**	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0		16.5	16.2	16.8	**16.5**	**16.3**	13.2	13.3	**14.4**	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5		15.7	14.9	15.2	**15.3**	**16.1**	11.7	11.8	13.0	Jasper
Gary	Lake	180890031			16.8	13.3		16.8	15.1	15.1	**15.6**		12.3	12.2		Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1		15.4	14.9	15.3	**15.2**	**16.2**	11.9	11.9	13.7	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1		16.3	15.5	15.8	**15.9**	**16.4**	12.4	12.5	**14.0**	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2		15.1	14.4	14.6	14.7	**15.8**	12.4	12.5	13.3	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7		16.4	15.8	16.0	**16.0**	**17.3**	13.5	13.5	**14.4**	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0		15.2	14.2	14.5	14.6	**15.5**	12.4	12.4	13.0	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1		18.2	17.2	17.4	**17.6**	**19.3**	**15.0**	**15.0**	**16.1**	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9		15.5	14.3	14.7	14.8	**16.6**	12.4	12.4	13.9	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1		16.8	15.7	16.6	**16.4**	**16.5**	12.6	12.7	13.1	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0		16.1	15.5	16.0	**15.9**	**15.9**	12.4	12.5	12.2	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0		16.1	15.3	15.2	**15.5**	**16.5**	12.6	12.7	12.9	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9		18.1	17.2	17.1	**17.5**	**18.4**	**14.2**	**14.3**	**14.4**	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1		17.0	16.2	16.7	**16.6**	**16.7**	13.4	13.5	13.1	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0		17.7	16.9	17.2	**17.3**	**17.6**	**14.0**	**14.1**	13.7	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1		16.5	15.6	15.9	**16.0**	**16.2**	12.9	13.0	12.6	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6		15.9	15.0	15.0	**15.3**	**16.5**	11.9	12.0	13.0	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8		15.5	15.0	15.2	**15.2**	**16.0**	11.8	11.8	12.5	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9		14.4	13.7	13.8	13.9	**16.0**	10.9	11.0	12.5	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5		17.6	17.1	17.7	**17.4**	**17.7**	13.7	13.8	**14.0**	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6		15.9	15.2	15.6	**15.6**	**15.7**	12.1	12.2	12.3	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9		17.3	16.7	17.0	**17.0**	**17.3**	13.2	13.3	13.2	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5		15.8	15.4	15.7	**15.7**	**16.0**	12.3	12.3	12.2	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4		16.6	16.0	16.4	**16.3**	**16.3**	12.7	12.8	12.8	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9		17.9	17.4	18.0	**17.8**	**17.3**	13.9	**14.0**	13.8	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8		16.7	15.4	15.1	**15.7**	**17.7**	12.5	12.5	**16.2**	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6		17.2	16.3	16.4	**16.6**	**17.5**	13.3	13.3	**15.3**	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4		15.0	15.0	15.7	**15.2**	**15.7**	12.2	12.3	13.2	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6		15.9	15.2	15.5	**15.5**	**15.9**	12.2	12.3	12.3	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3		14.6	14.5	15.3	14.8	**17.1**	11.6	11.7	**14.2**	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6		16.7	16.0	16.2	**16.3**	**17.3**	13.1	13.2	13.6	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9		15.2	14.2	14.3	14.6	**15.7**	11.7	11.7	12.2	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5		15.6	15.0	15.0	**15.2**	**16.4**	12.2	12.3	12.9	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8		14.6	14.1	14.3	14.3	**15.6**	11.4	11.5	12.2	Akron - W. Exchange

24-Hour PM$_{2.5}$			98th Percentile (24-hour)					Design Values			Base Year	Round 5 Modeling Results			
Key Site	**County**	**Site ID**	**'03**	**'04**	**'05**	**'06**	**'07**	**'03-'05**	**'04-'06**	**'05-'07**	**Average w/o 2007**	**2009**	**2012**	**2018**	**Key Site**
Chicago - Washington HS	Cook	170310022	37.7	32.5	45.7	27.0		38.6	35.1	36.4	36.7	**36**	**36**	**35**	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	37.3	38.8	48.3	31.6		41.5	39.6	40.0	40.3	**36**	**36**	**35**	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	36.4	33.1	46.5	27.7		38.7	35.8	37.1	37.2	31	31	30	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	32.6	39.7	45.1	29.0		39.1	37.9	37.1	38.0	**35**	34	34	Chicago - Lawndale
McCook	Cook	170311016										**40**	**40**	**39**	McCook
Blue Island	Cook	170312001	39.6	38.5	43.8	28.1		40.6	36.8	36.0	37.8	34	34	34	Blue Island
Schiller Park	Cook	170313103		40.7	50.3	30.0		45.5	40.3	40.2	42.0	**39**	**40**	**39**	Schiller Park
Summit	Cook	170313301	38.4	42.4	49.1	27.4		43.3	39.6	38.3	40.4	**38**	**38**	**37**	Summit
Maywood	Cook	170316005	38.5	42.5	44.6	29.2		41.9	38.8	36.9	39.2	**38**	**38**	**37**	Maywood
Granite City	Madison	171191007	40.8	35.4	44.1	36.3		40.1	38.6	40.2	39.6	33	34	33	Granite City
E. St. Louis	St. Clair	171630010	32.6	30.2	39.6	29.2		34.1	33.0	34.4	33.8	29	29	29	E. St. Louis
Jeffersonville	Clark	180190005		28.4	45.5	35.9		37.0	36.6	40.7	38.1	27	28	28	Jeffersonville
Jasper	Dubois	180372001	39.5	30.0	41.2	31.6		36.9	34.3	36.4	35.9	28	28	28	Jasper
Gary - IITRI	Lake	180890022										34	34	**35**	Gary - IITRI
Gary - Burr School	Lake	180890026										33	34	32	Gary - Burr School
Gary	Lake	180890031			38.7	27.1		38.7	32.9	32.9	34.8	24	24	26	Gary
Indy-West Street	Marion	180970043										34	34	34	Indy-West Street
Indy-English Avenue	Marion	180970066										32	32	33	Indy-English Avenue
Indy-Washington Park	Marion	180970078	39.3	31.0	42.5	31.7		37.6	35.1	37.1	36.6	32	32	32	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	36.7	31.3	40.3	33.5		36.1	35.0	36.9	36.0	28	28	29	Indy- Michigan Street
Luna Pier	Monroe	261150005	34.7	35.0	49.3	32.6		39.7	39.0	41.0	39.9	33	33	32	Luna Pier
Oak Park	Oakland	261250001	36.6	32.5	52.2	33.0		40.4	39.2	42.6	40.8	**38**	**38**	**36**	Oak Park
Port Huron	St. Clair	261470005	37.2	32.2	47.6	37.9		39.0	39.2	42.8	40.3	**36**	**35**	34	Port Huron
Ypsilanti	Washtenaw	261610008	38.8	31.5	52.1	31.3		40.8	38.3	41.7	40.3	**36**	**36**	**36**	Ypsilanti
Allen Park	Wayne	261630001	40.5	36.9	43.0	34.1		40.1	38.0	38.6	38.9	**35**	**35**	33	Allen Park
Southwest HS	Wayne	261630015	33.6	36.0	49.7	36.2		39.8	40.6	43.0	41.1	**36**	**36**	**35**	Southwest HS
Linwood	Wayne	261630016	46.2	38.3	51.8	36,9		45.4	45.1	51.8	47.4	**41**	**40**	**39**	Linwood
E 7 Mile	Wayne	261630019	37.1	35.0	52.3	36.2		41.5	41.2	44.3	42.3	**40**	**40**	**39**	E 7 Mile
Dearborn	Wayne	261630033	42.8	39.4	50.2	43.1		44.1	44.2	46.7	45.0	**42**	**41**	**40**	Dearborn
Wyandotte	Wayne	261630036	34.8	32.3	46.7	33.2		37.9	37.4	40.0	38.4	**36**	**36**	**35**	Wyandotte
Newberry	Wayne	261630038		36.8	57.5	28.6			41.0	41.0	43.7	**39**	**39**	**37**	Newberry
FIA	Wayne	261630039			43.9	32.4				38.2	40.1	34	34	33	FIA
Middleton	Butler	390170003	38.6	37.2	47.6	30.2		41.1	38.3	38.9	39.5	28	28	27	Middleton
Fairfield	Butler	390170016	34.8	32.2	43.4	35.2		36.8	36.9	39.3	37.7	27	27	27	Fairfield
	Butler	390170017	34.6	34.3	44.9			37.9	39.6		40.8	29	29	28	
Cleveland-28th Street	Cuyahoga	390350027	41.3	40.9	35.7	31.5		39.3	36.0	33.6	36.3	33	32	31	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	47.3	42.5	51.2	36.1		44.9	47.0	43.3	46.3	**36**	**36**	**35**	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	42.2	36.1	46.2	29.5		41.5	37.3	37.9	38.9	31	30	29	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	45.5	42.2	49.5	31.0		45.7	40.9	40.3	42.3	**38**	**38**	**36**	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	39.1	36.1	47.9	27.8		41.0	37.3	37.9	38.7	31	31	30	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	39.2	35.1	45.0	34.0		39.8	38.0	39.5	39.1	34	33	32	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	37.0	35.5	44.9	34.0		39.1	38.1	39.5	38.9	32	31	30	Columbus - Ann Street
Cincinnait	Hamilton	390610006			45.0	33.3				39.2	41.1	28	28	28	Cincinnait
Cincinnati - Seymour	Hamilton	390610014	37.8	42.0	38.5	35.2		39.4	38.6	36.9	38.3	25	25	23	Cincinnati - Seymour
Norwood	Hamilton	390617001	37.1	34.6	47.1	34.0		39.6	38.6	40.6	39.6	31	30	29	Norwood
St. Bernard	Hamilton	390618001	35.8	33.9	51.4	36.1		40.4	40.5	43.8	41.5	31	31	30	St. Bernard
Steubenville	Jefferson	390810016	39.6	43.8	43.8	32.1		42.4	39.9	38.0	40.1	29	29	29	Steubenville
Mingo Junction	Jefferson	390811001	40.9	51.5	44.2	32.9		45.5	42.9	38.6	42.3	30	30	30	Mingo Junction
Dayton	Montgomery	391130032	42.7	32.5	45.0	30.3		40.1	35.9	37.7	37.9	31	31	30	Dayton
Canton - Dueber	Stark	391510017	34.2	36.3	47.6	33.1		39.4	39.0	40.4	39.6	29	29	28	Canton - Dueber
Akron - Brittain	Summit	391530017	36.9	36.9	45.2	31.5		39.7	37.9	38.4	38.6	31	31	29	Akron - Brittain
Green Bay - Est High	Brown	550090005	33.5	32.3	41.5	36.9		35.8	36.9	39.2	37.3	**35**	34	32	Green Bay - Est High
Madison	Dane	550250047	32.0	31.9	40.1	33.4		34.7	35.1	36.8	35.5	31	30	28	Madison
Milwaukee-Health Center	Milwaukee	550790010	33.2	38.4	38.7	40.7		36.8	39.3	39.7	38.6	34	34	33	Milwaukee-Health Center
Milwaukee-SER Hdqs	Milwaukee	550790026	29.6	28.7	41.5	42.6		33.3	37.6	42.1	37.6	34	34	34	Milwaukee-SER Hdqs
Milwaukee-Virginia FS	Milwaukee	550790043	39.2	41.4	37.1	44.0		39.2	40.8	40.6	40.2	**36**	**36**	**36**	Milwaukee-Virginia FS
Milwaukee- Fire Dept Hdqs	Milwaukee	550790099	33.7	38.9	37.1	38.3		36.6	38.1	37.7	37.5	32	32	32	Milwaukee- Fire Dept Hdqs
Waukesha	Waukesha	551330027	29.1	38.4	41.1	28.2		36.2	35.9	34.7	35.6	31	31	29	Waukesha

APPENDIX II

Ozone Source Apportionment Modeling Results



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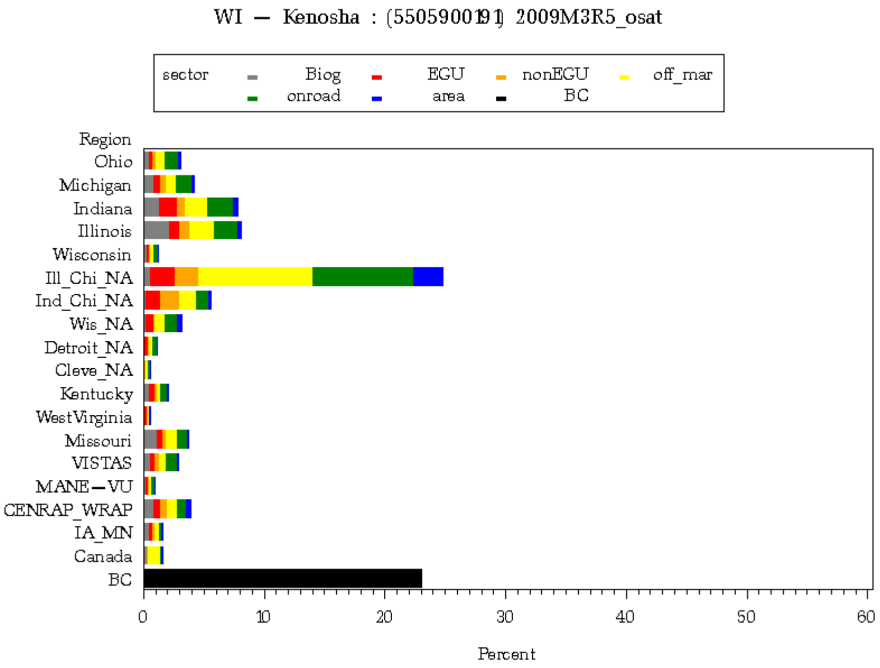

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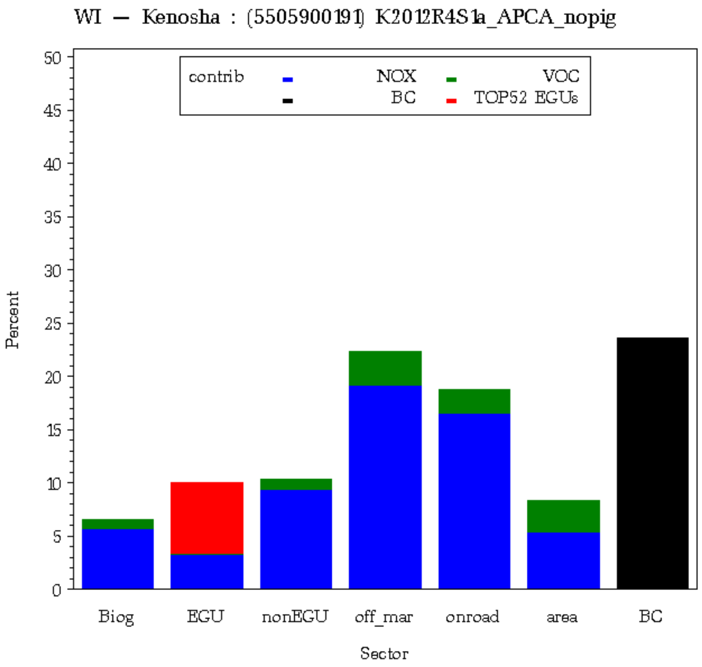

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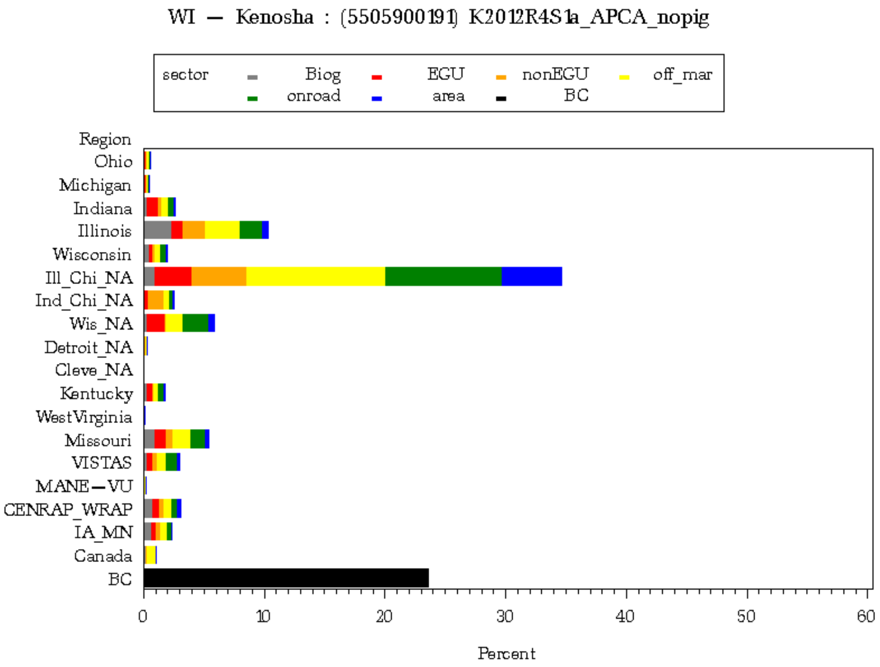

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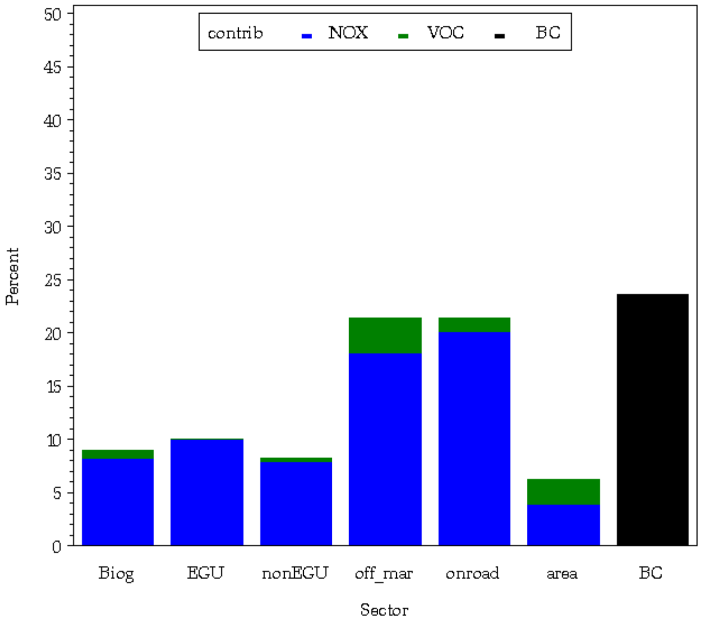

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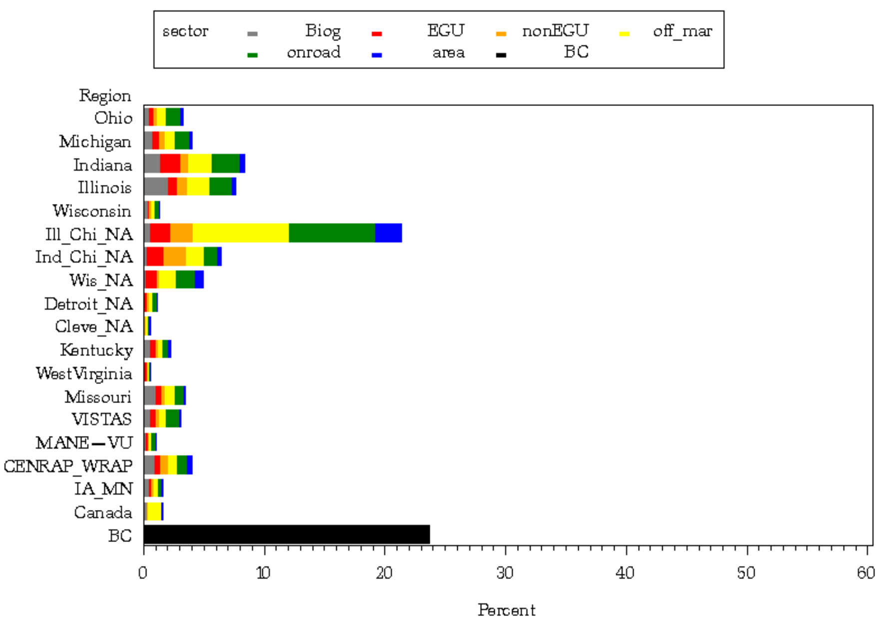

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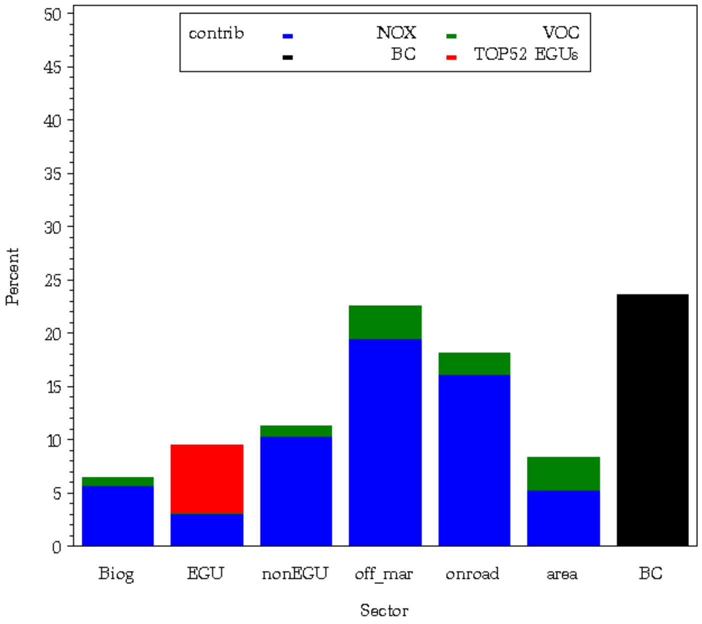

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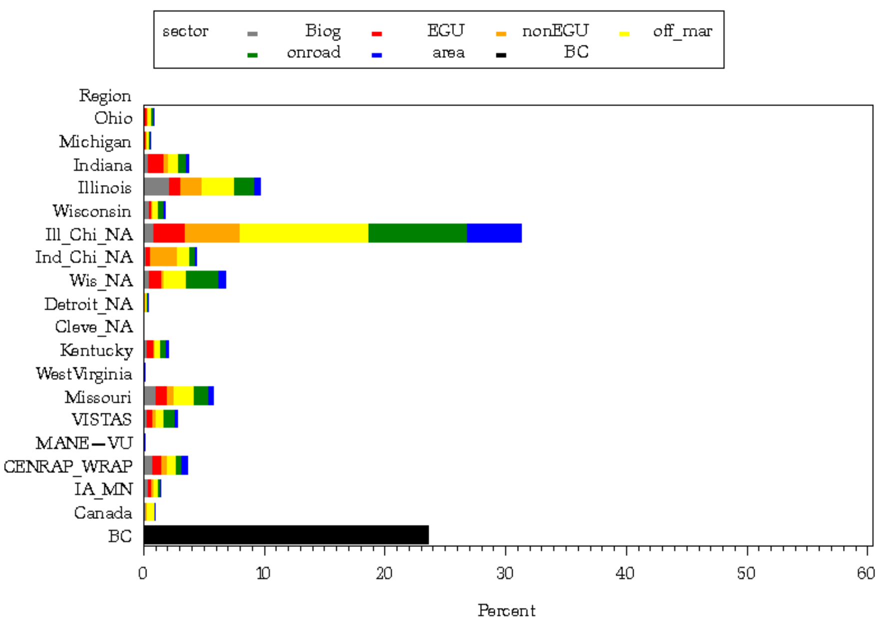

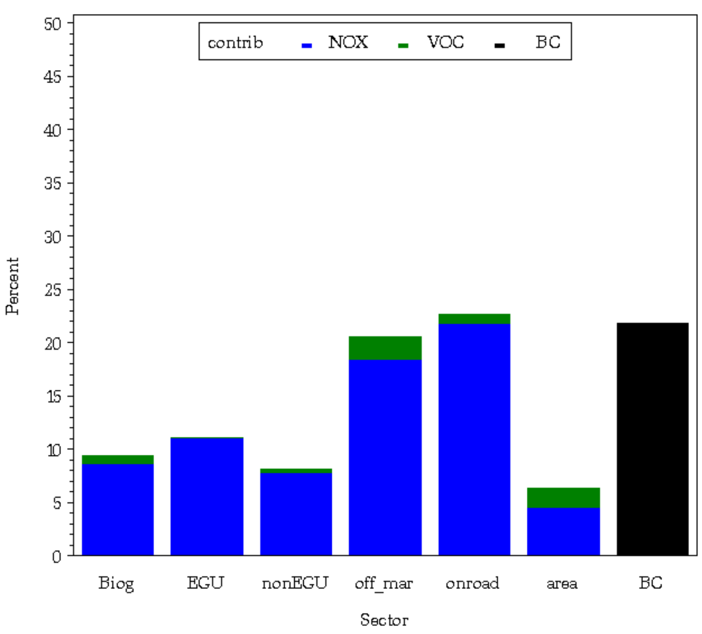
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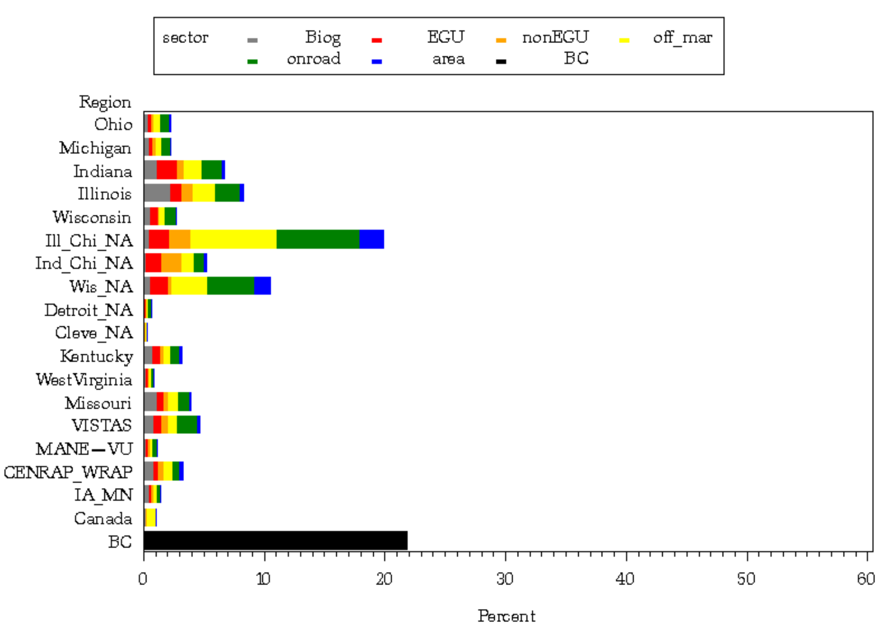
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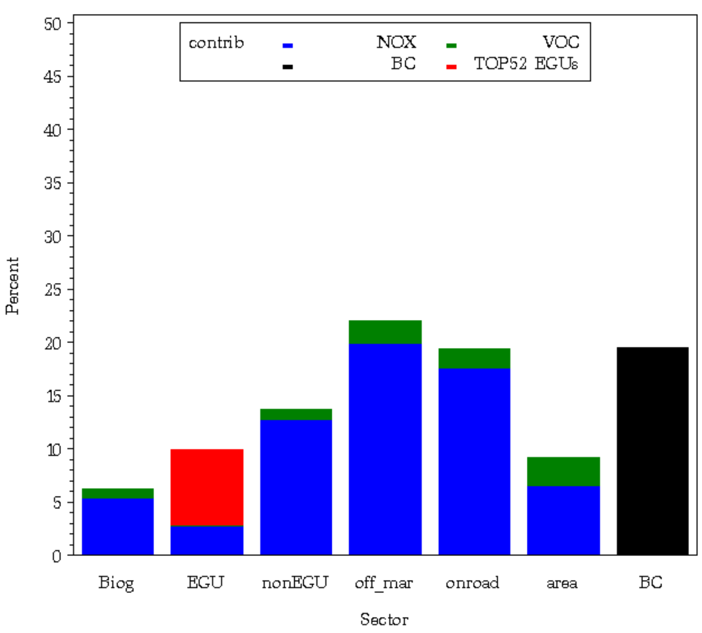
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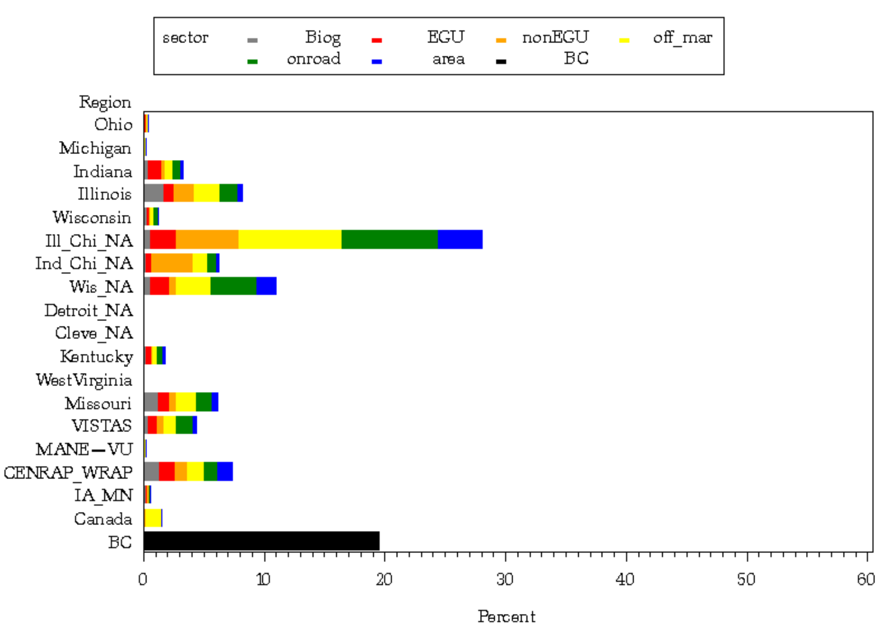
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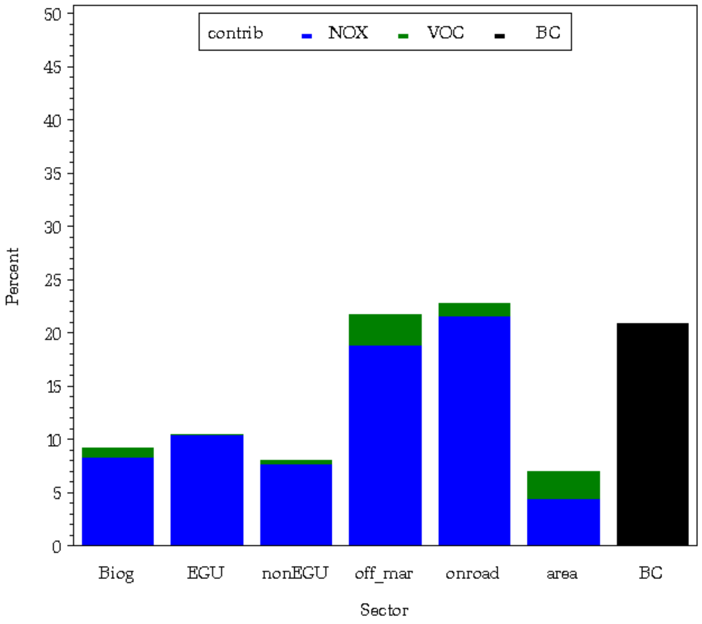

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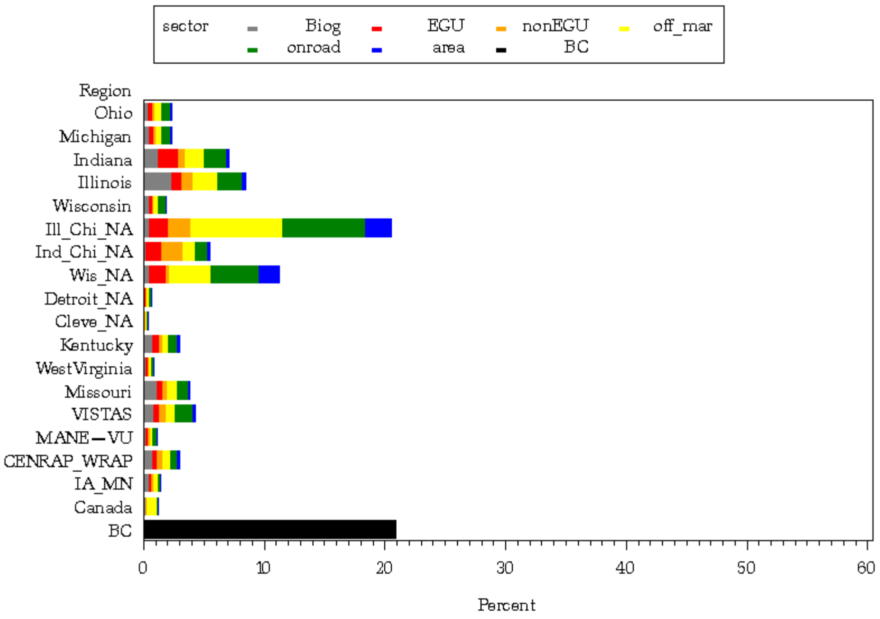

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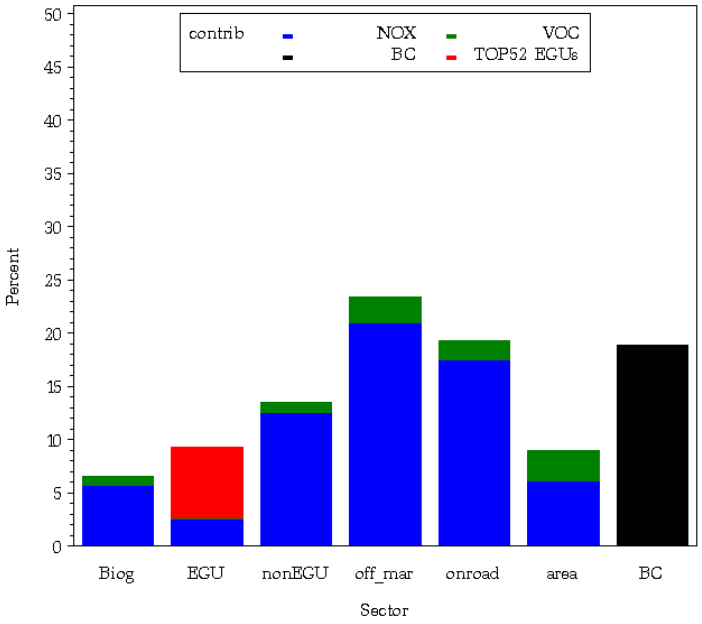

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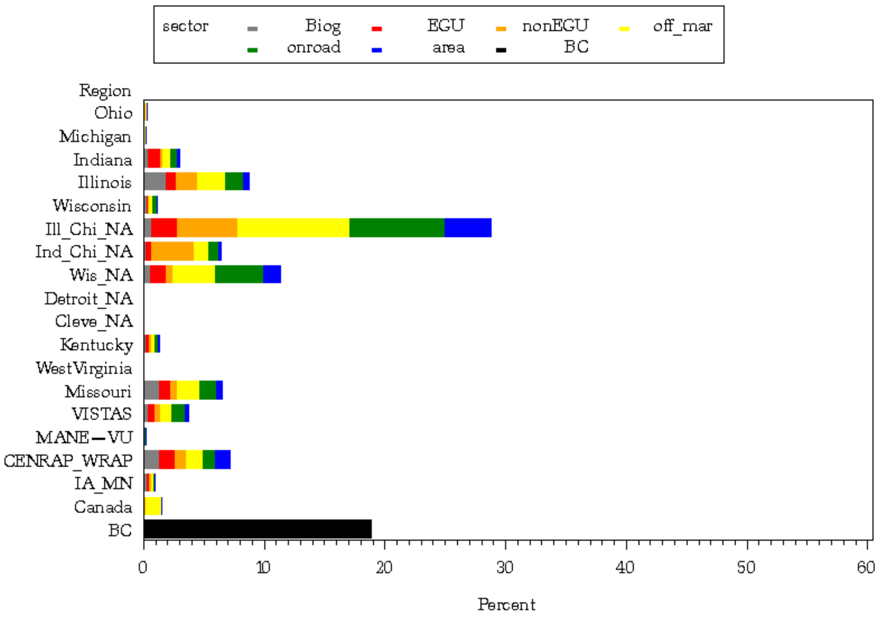

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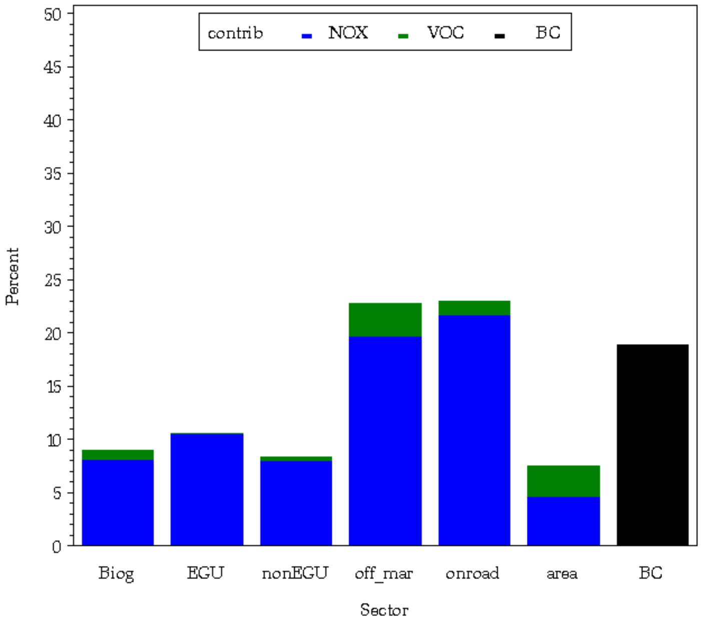

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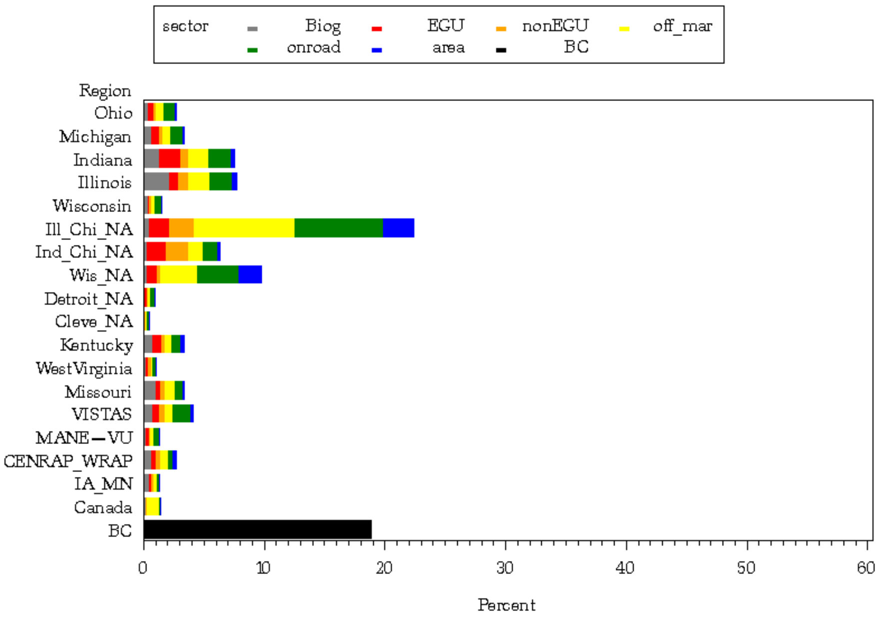

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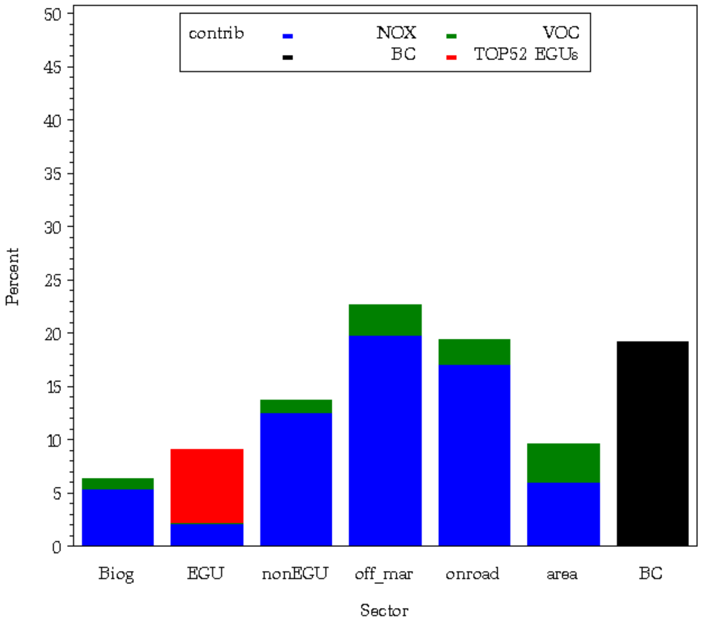

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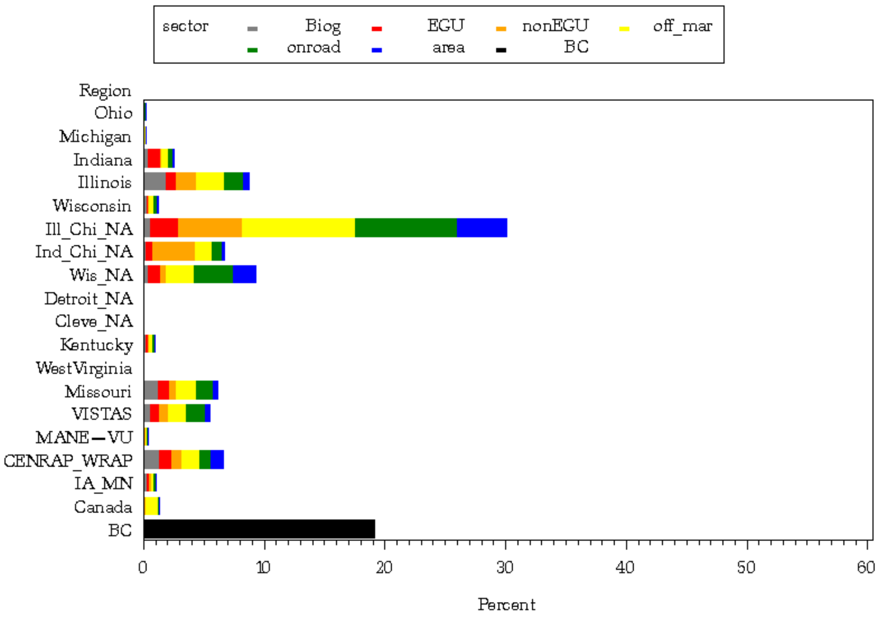

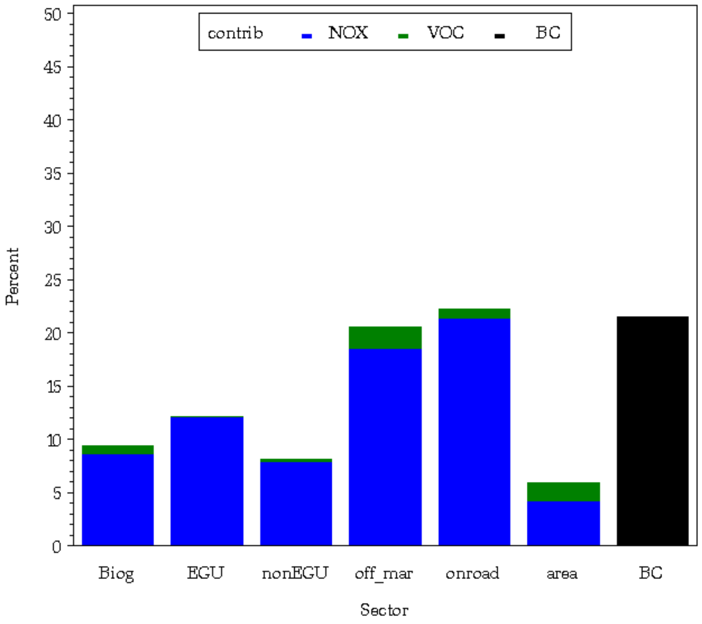
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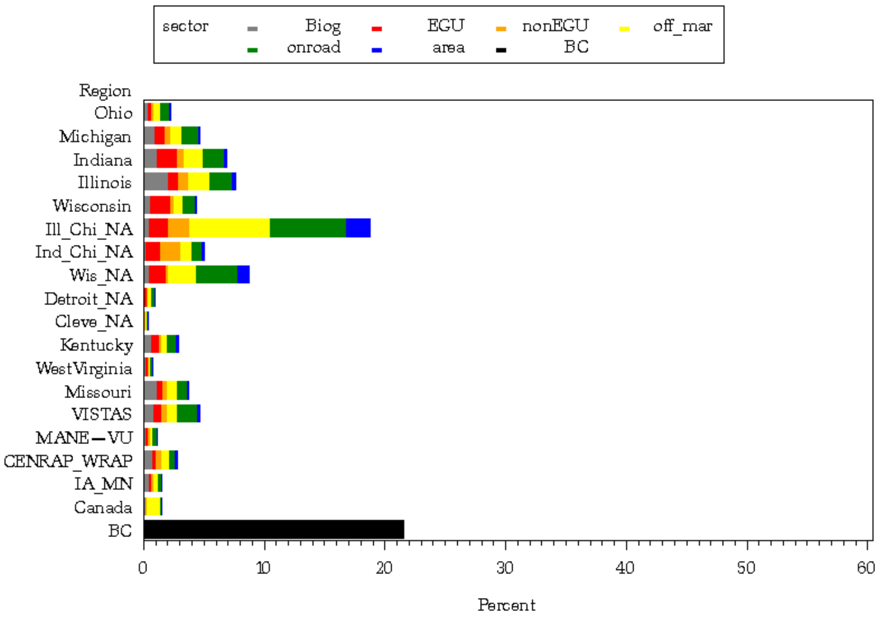
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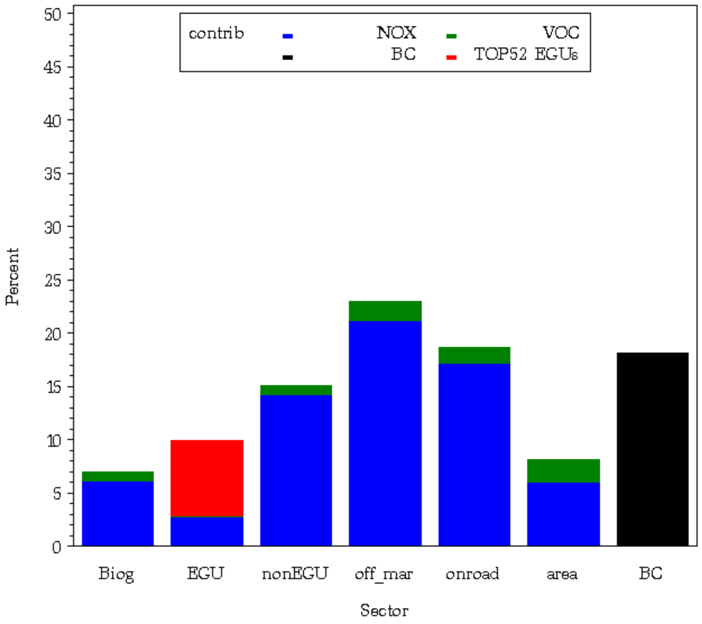
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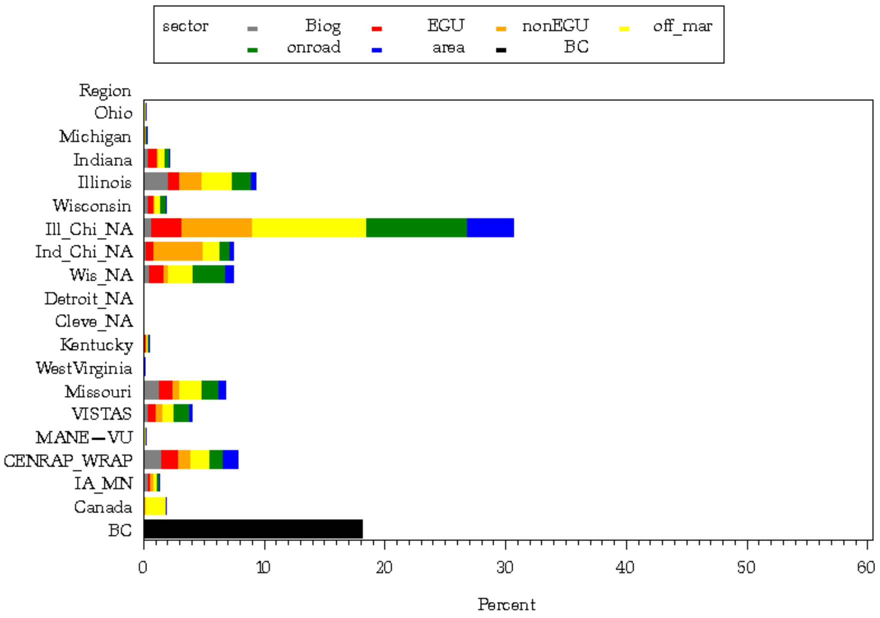
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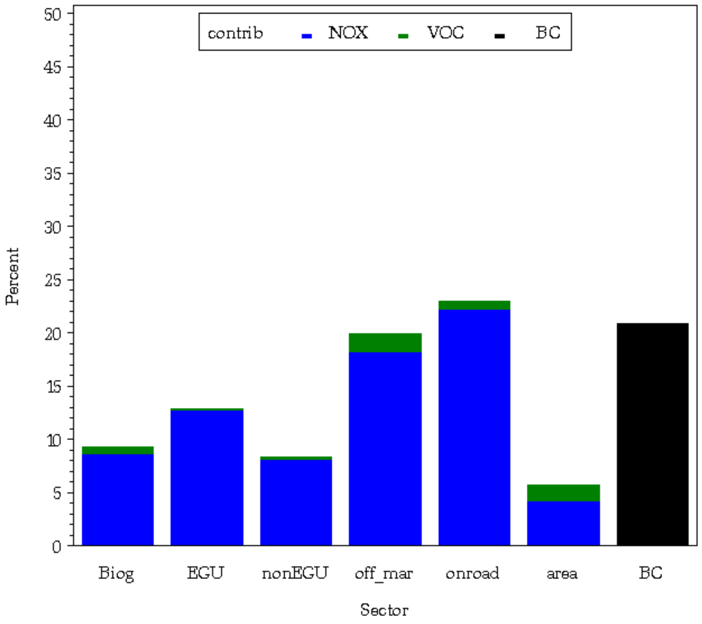
WI — Kewaunee : (550610002l) 2009M3R5_osat



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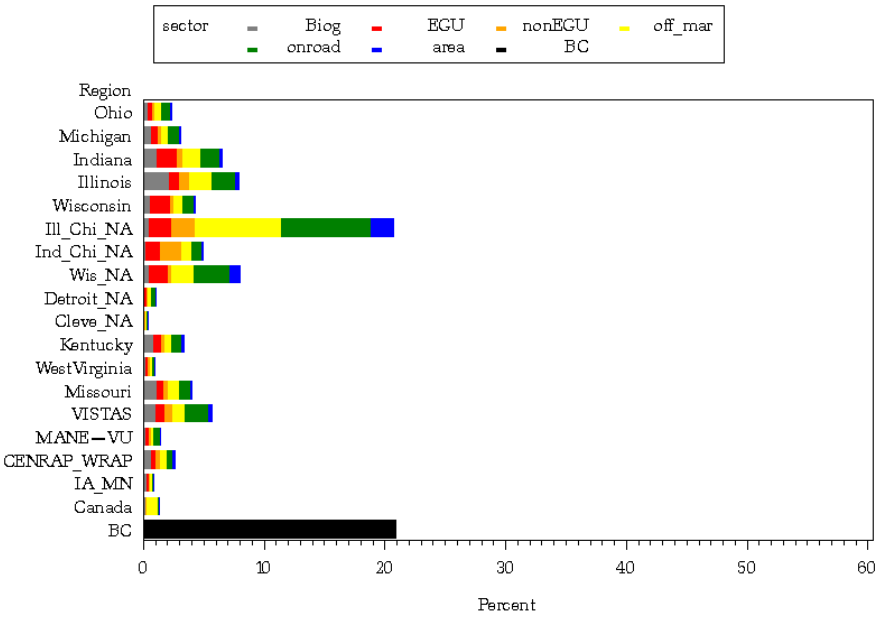

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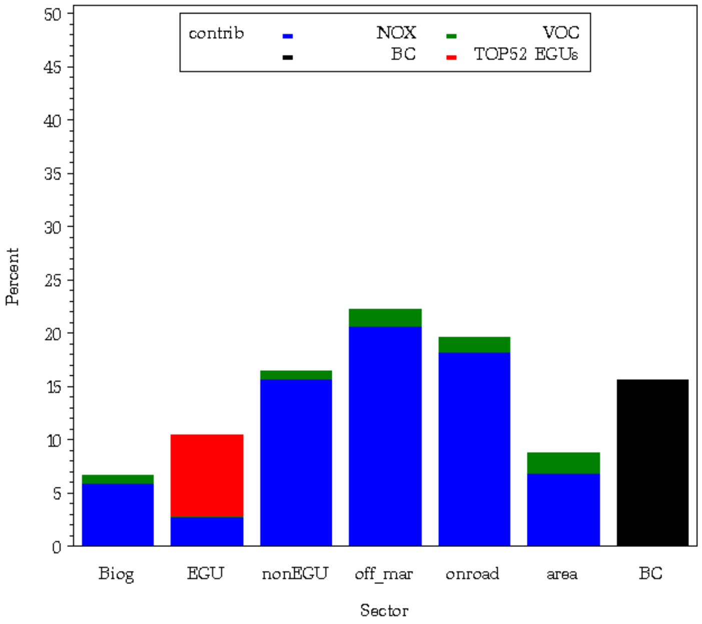

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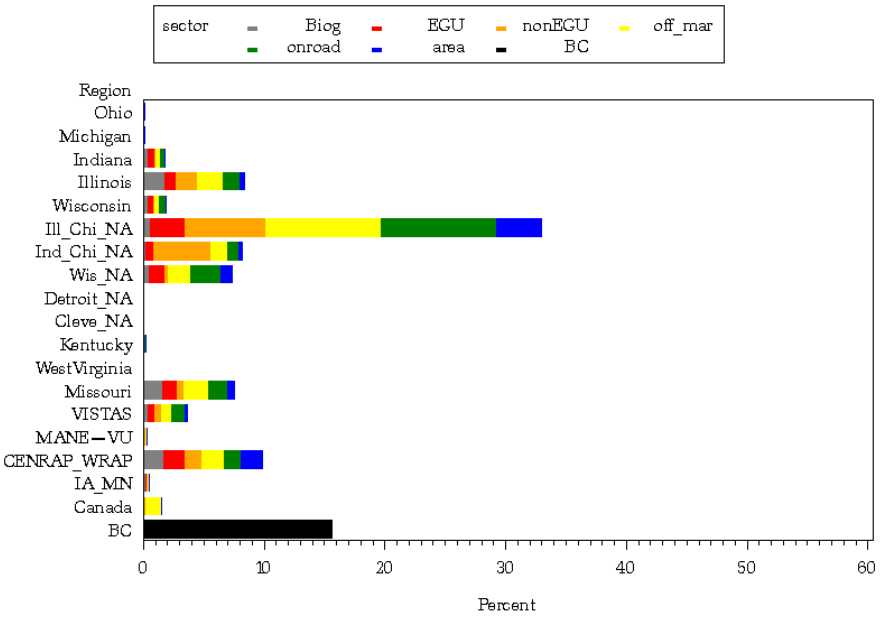

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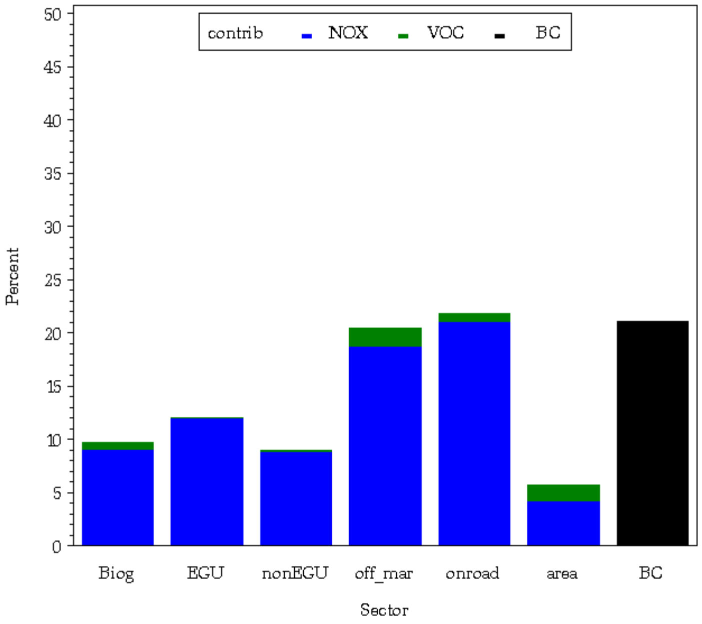

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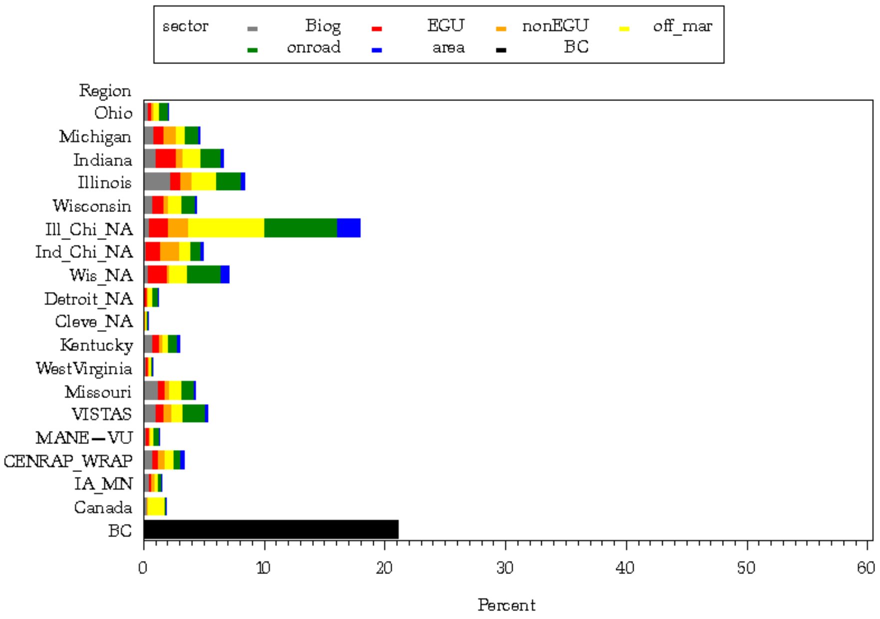

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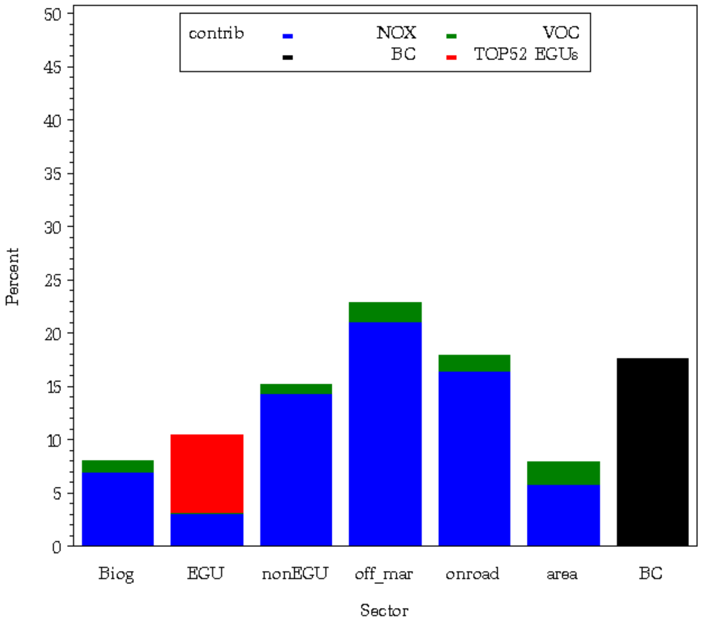

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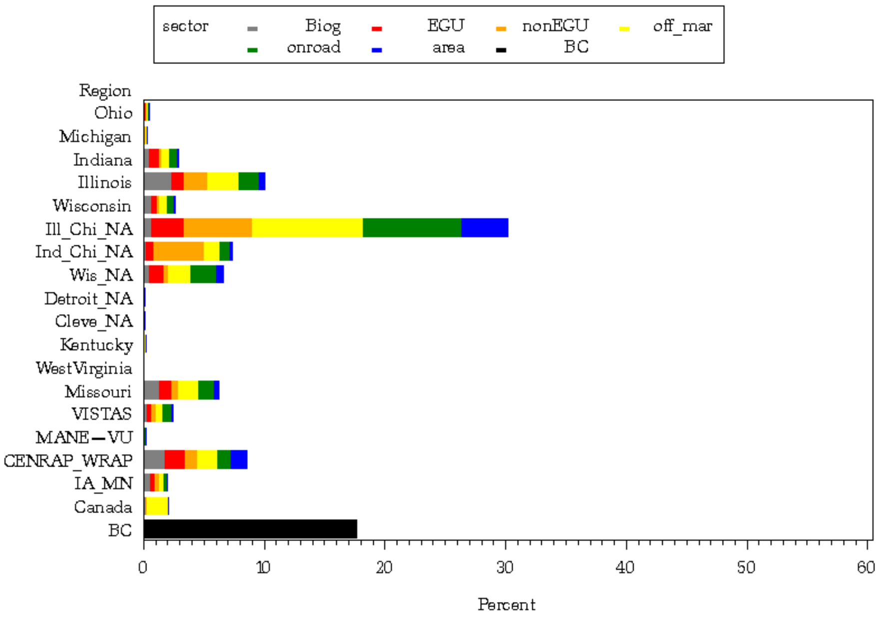
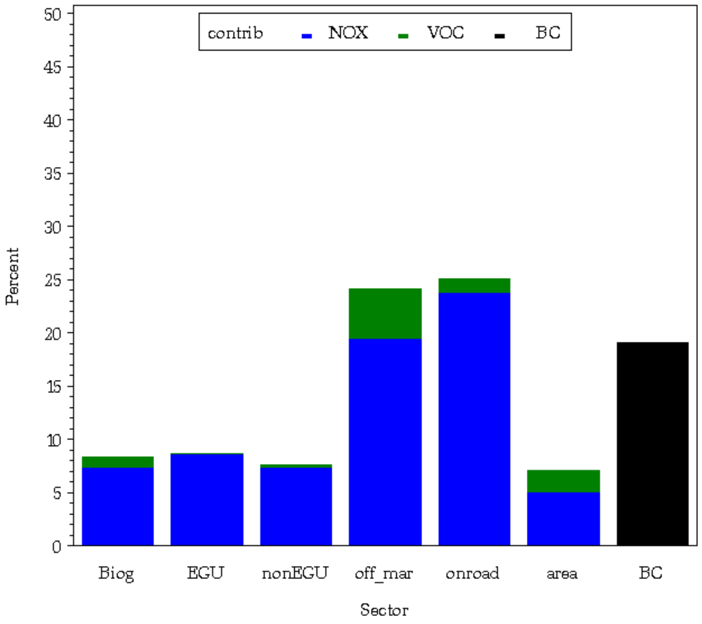
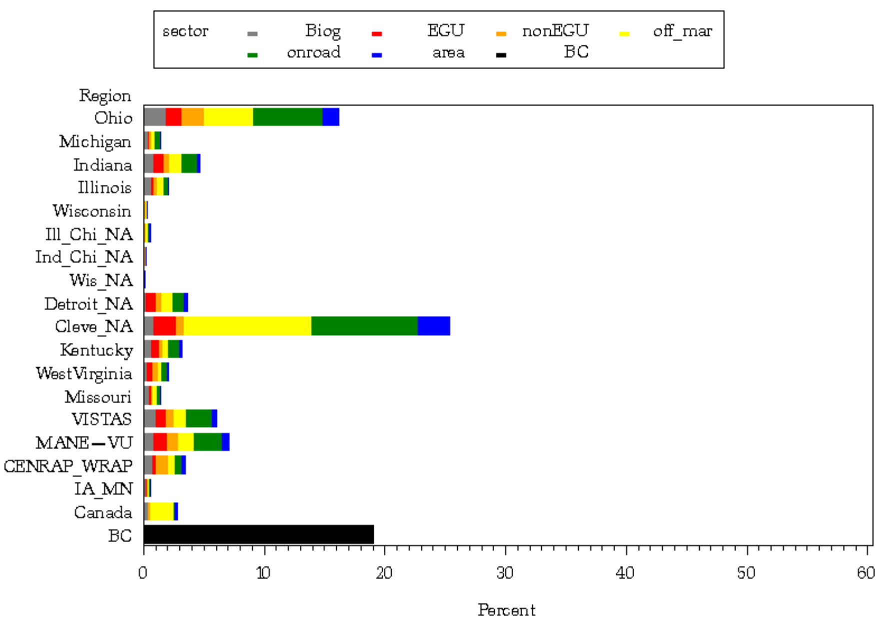



OH — Lake : (390850003 1) 2009M3R5_osat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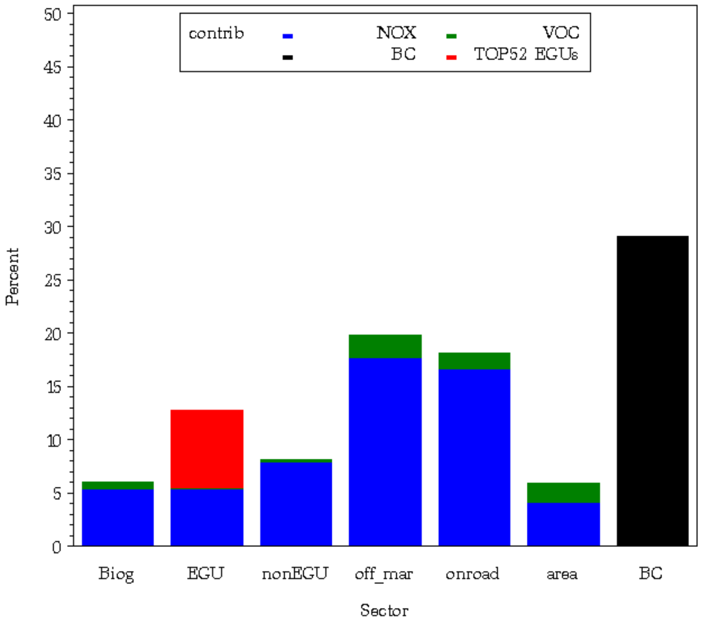
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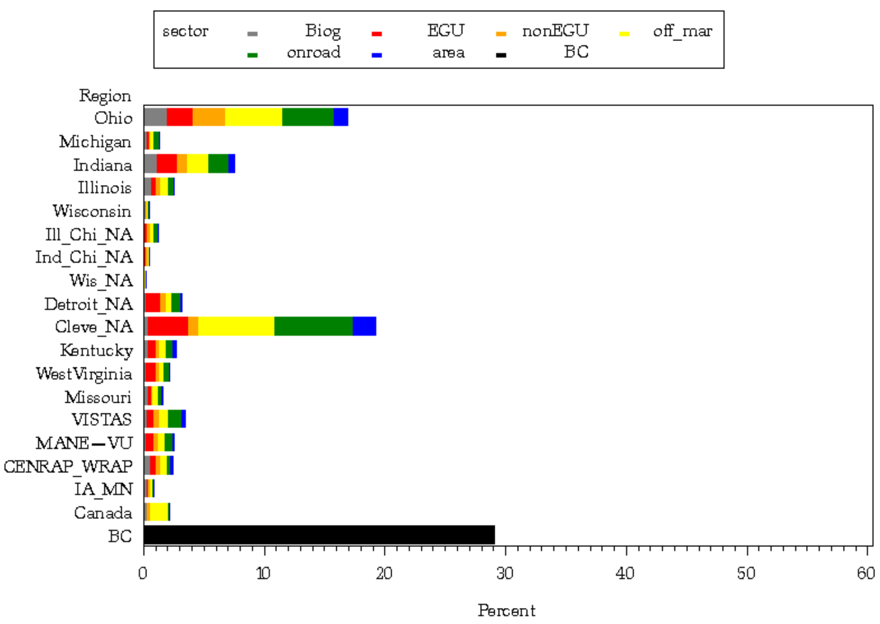
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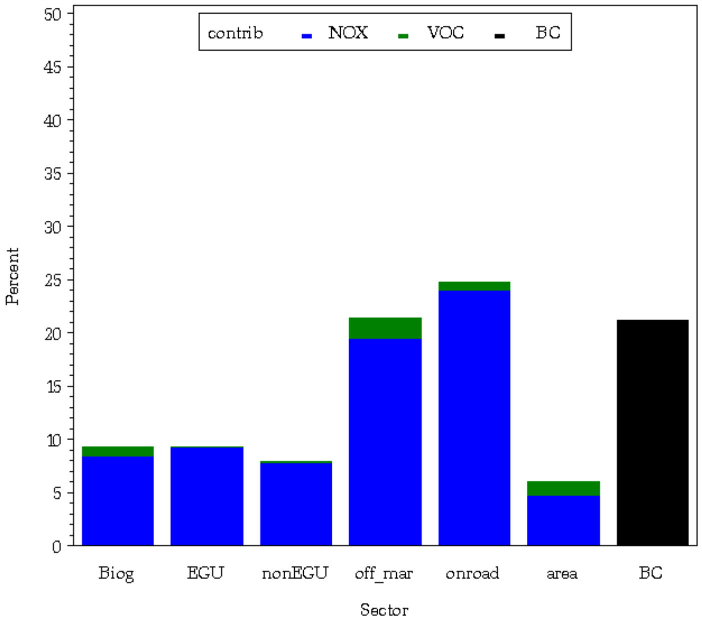
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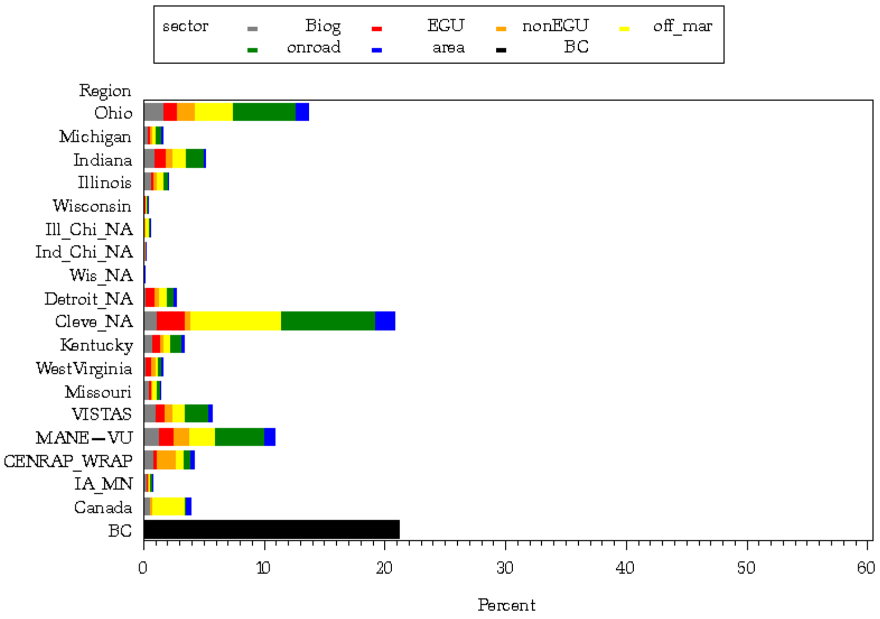
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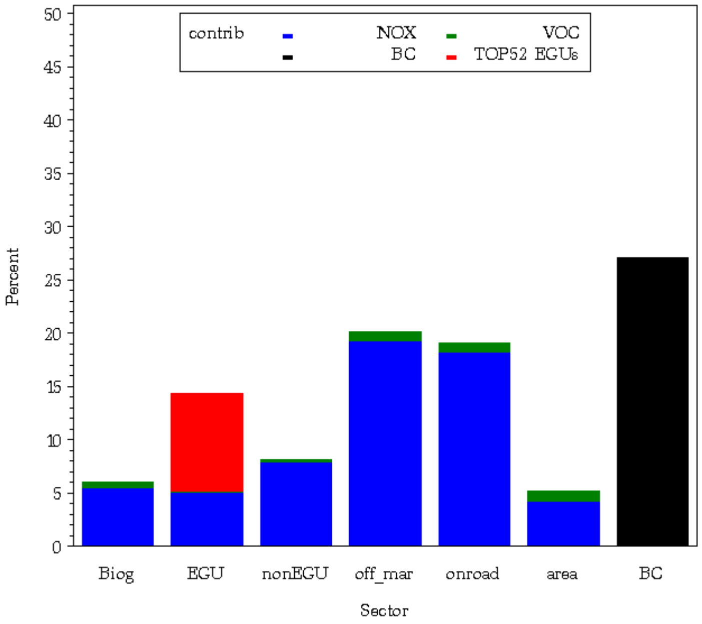
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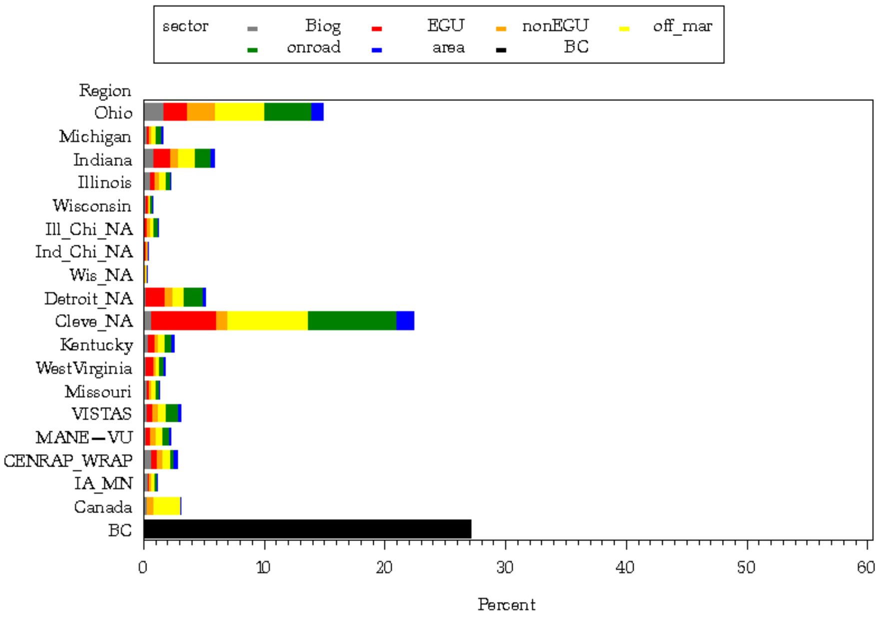
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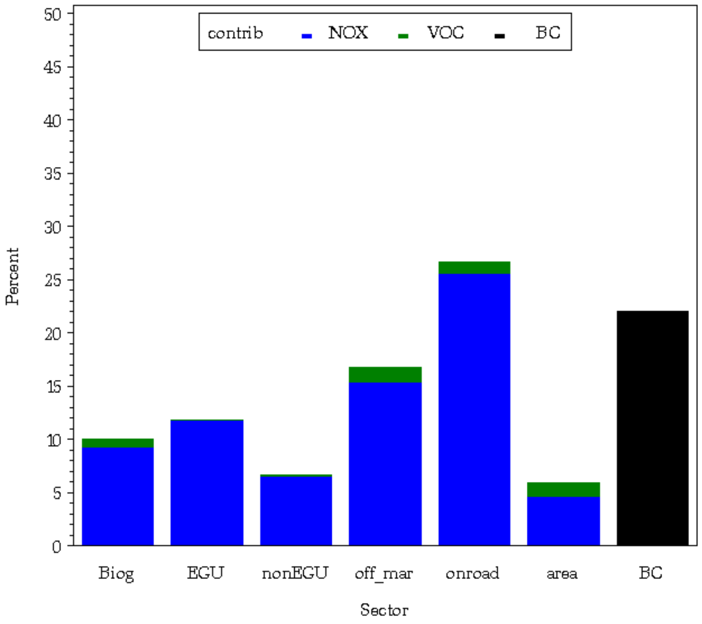
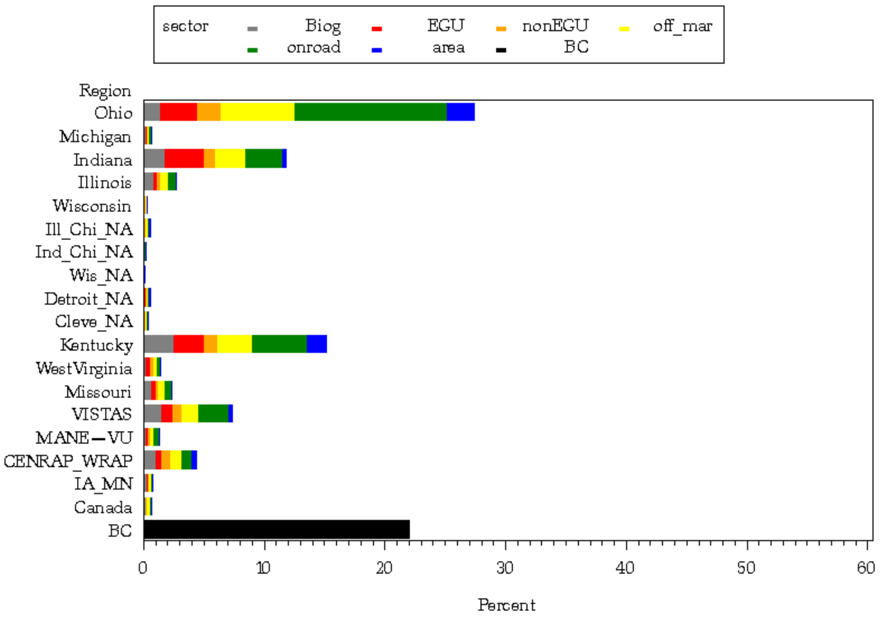

OH — Hamilton : (390610006l) 2009M3R5_osat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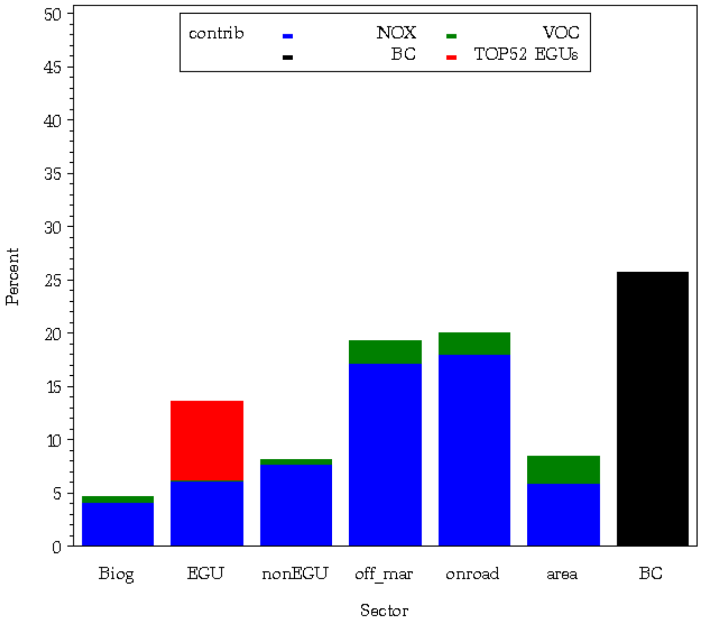
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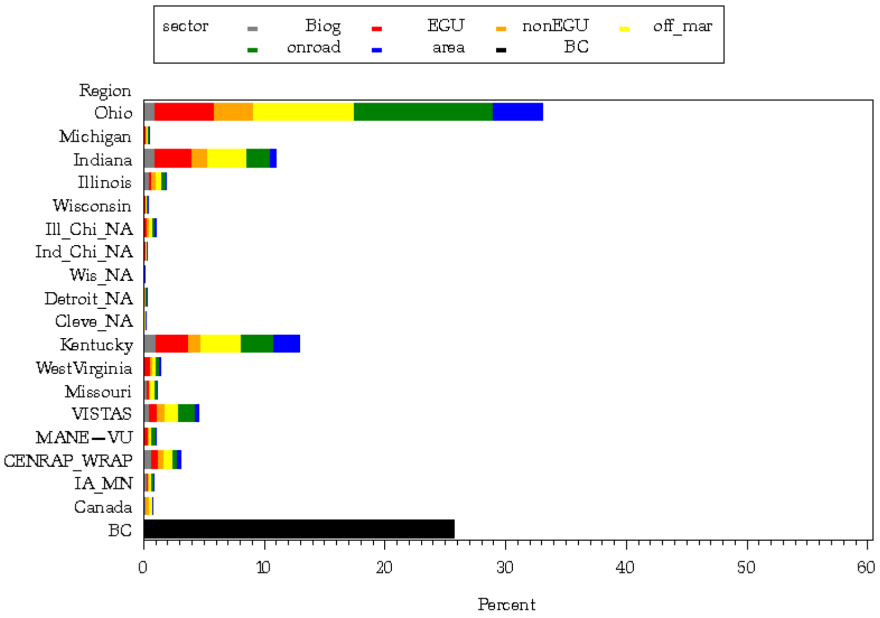
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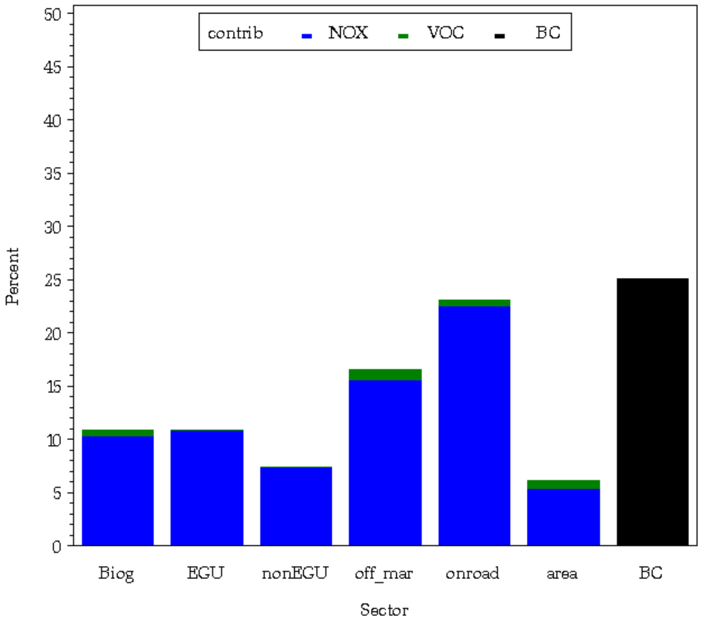
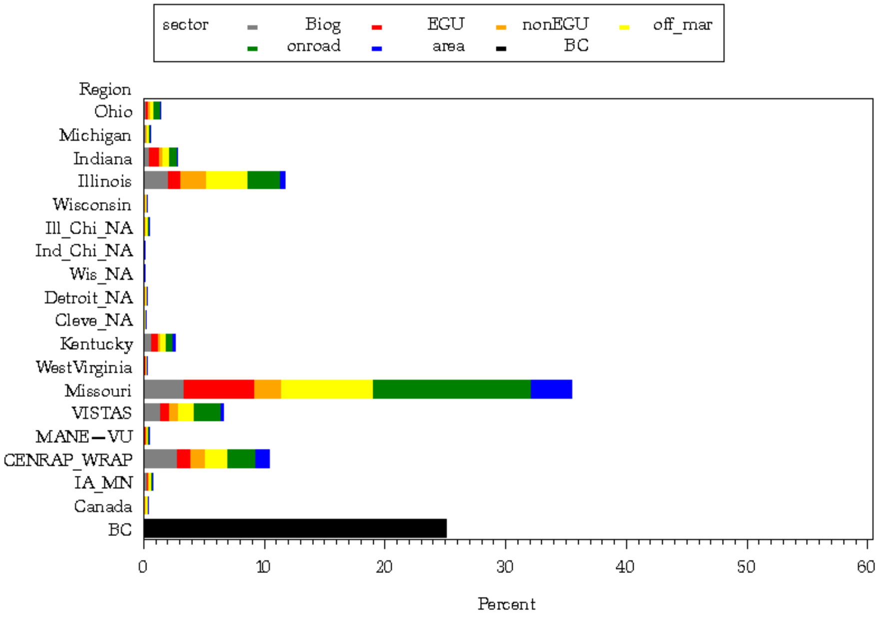
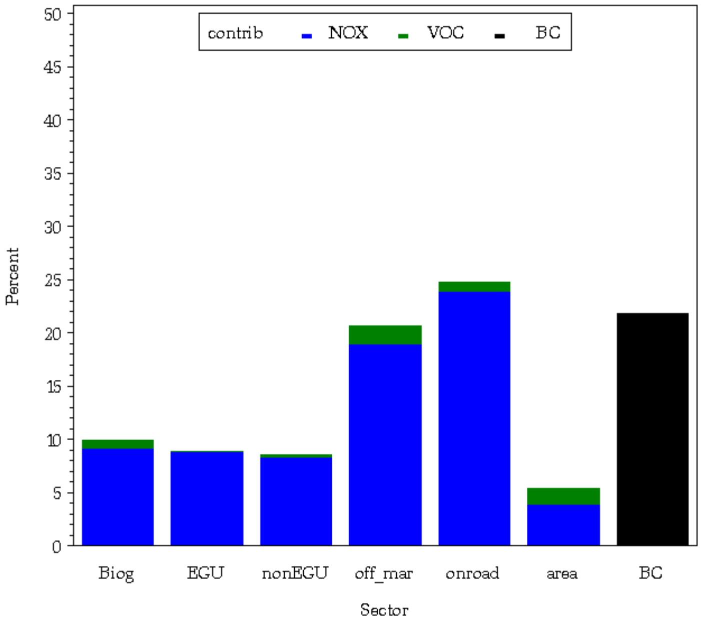
MO — St.Charles : (291831002 1) 2009M3R5_osat



MO — St.Charles : (291831002 1) 2009M3R5_osat



MI — Macomb : (260990009l) 2009M3R5_osat



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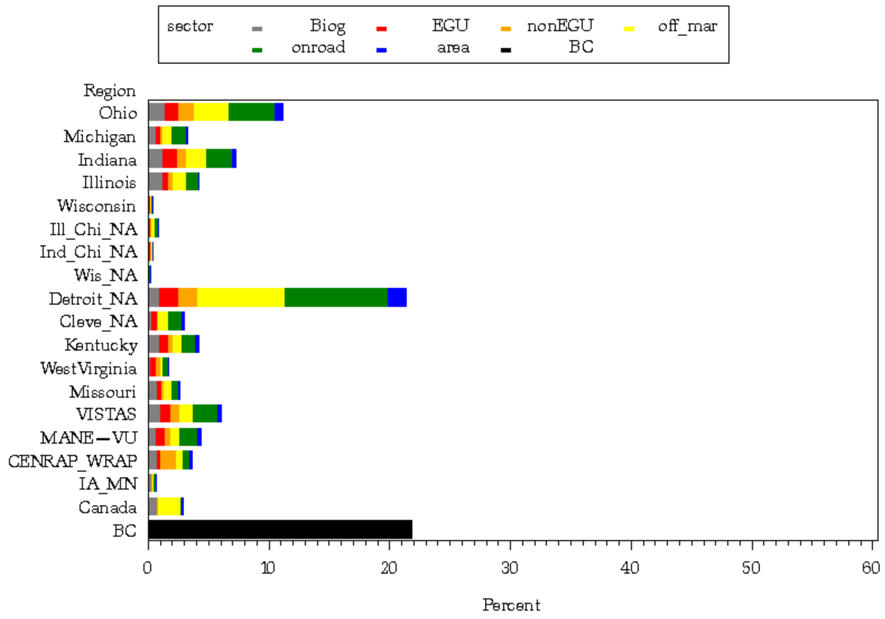

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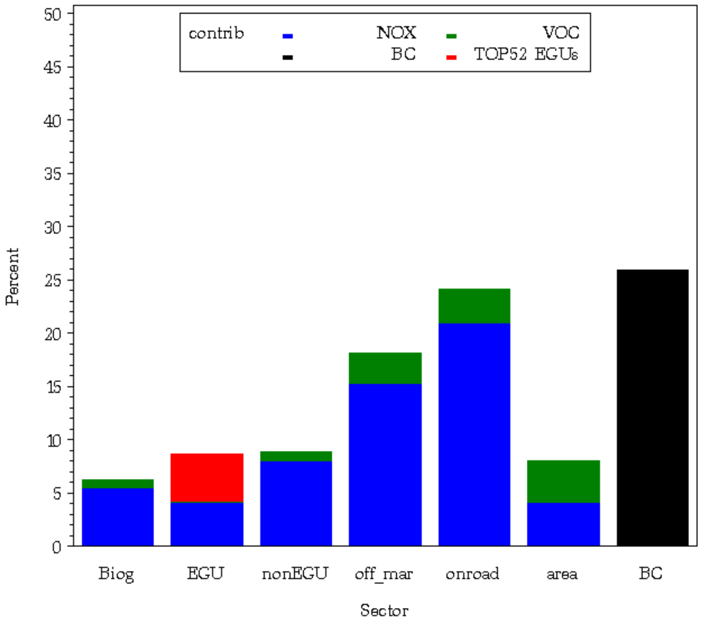

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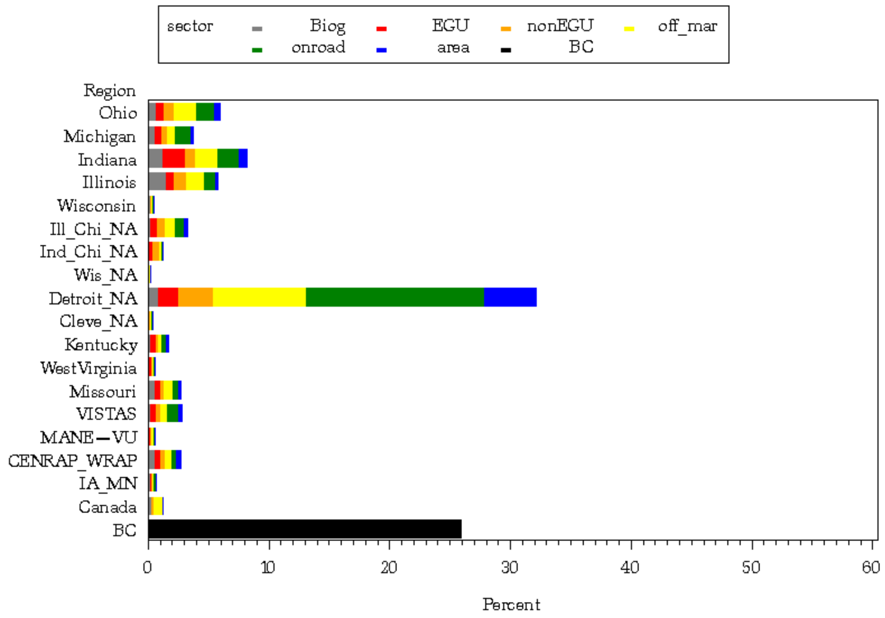
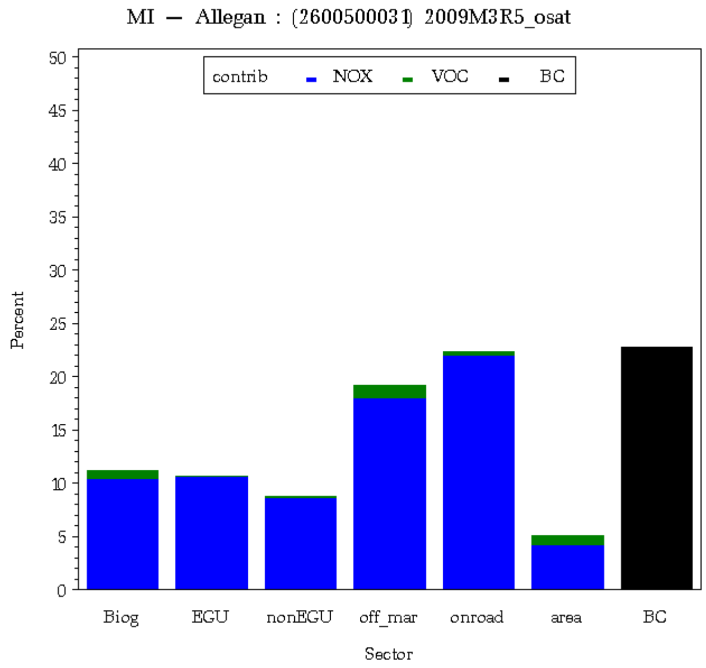
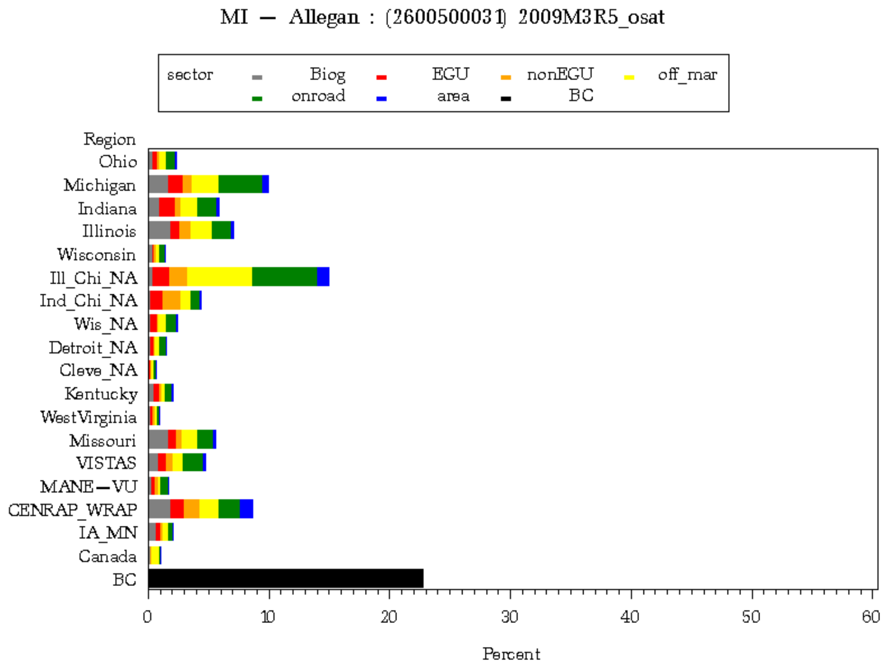
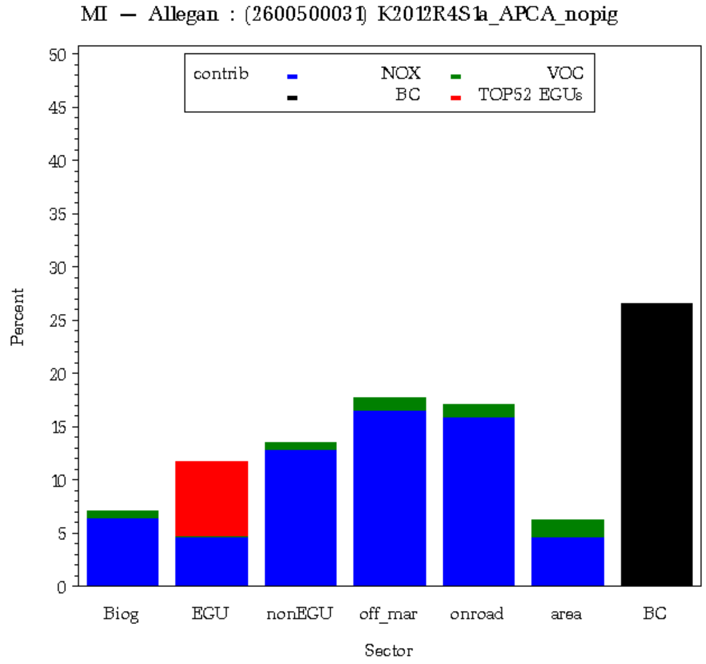
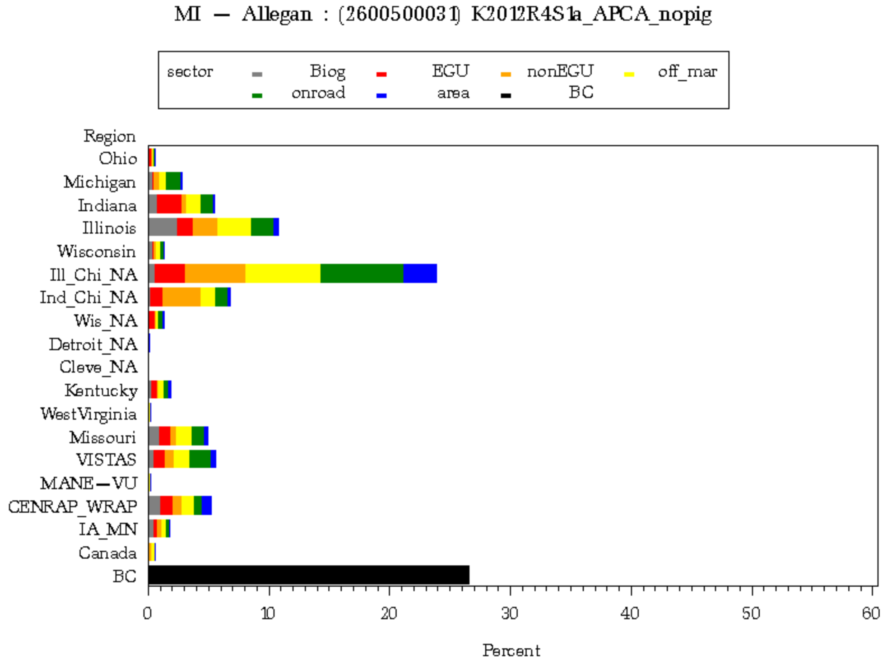


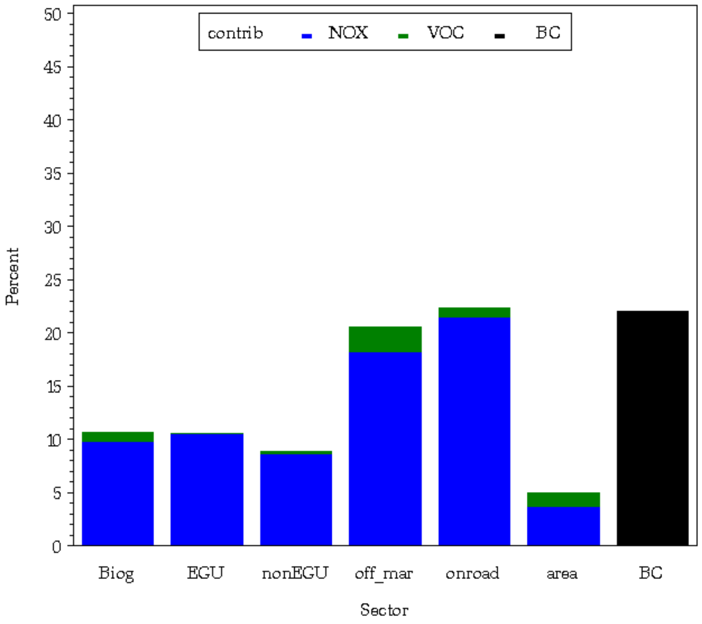

MI — Allegan : (260050031) 2009M3R5_osat
contrib NOX VOC BC
Percent
50
45
40
35
30
25
20
15
10
5
0
Biog
EGU
nonEGU
off_mar
onroad
area
BC
Sector


MI — Allegan : (260050031) 2009M3R5_osat
sector Biog EGU nonEGU off_mar onroad area BC
Region
Ohio
Michigan
Indiana
Illinois
Wisconsin
Ill_Chi_NA
Ind_Chi_NA
Wis_NA
Detroit_NA
Cleve_NA
Kentucky
WestVirginia
Missouri
VISTAS
MANE—VU
CENRAP_WRAP
IA_MN
Canada
BC
0
10
20
30
40
50
60
Percent


MI — Allegan : (260050031) K2012R4S1a_APCA_nopig
contrib NOX VOC BC TOP52 EGUs
Percent
50
45
40
35
30
25
20
15
10
5
0
Biog
EGU
nonEGU
off_mar
onroad
area
BC
Sector


MI — Allegan : (260050031) K2012R4S1a_APCA_nopig
sector Biog EGU nonEGU off_mar onroad area BC
Region
Ohio
Michigan
Indiana
Illinois
Wisconsin
Ill_Chi_NA
Ind_Chi_NA
Wis_NA
Detroit_NA
Cleve_NA
Kentucky
WestVirginia
Missouri
VISTAS
MANE—VU
CENRAP_WRAP
IA_MN
Canada
BC
0
10
20
30
40
50
60
Percent

IN — LaPorte : (180910005 1) 2009M3R5_osat



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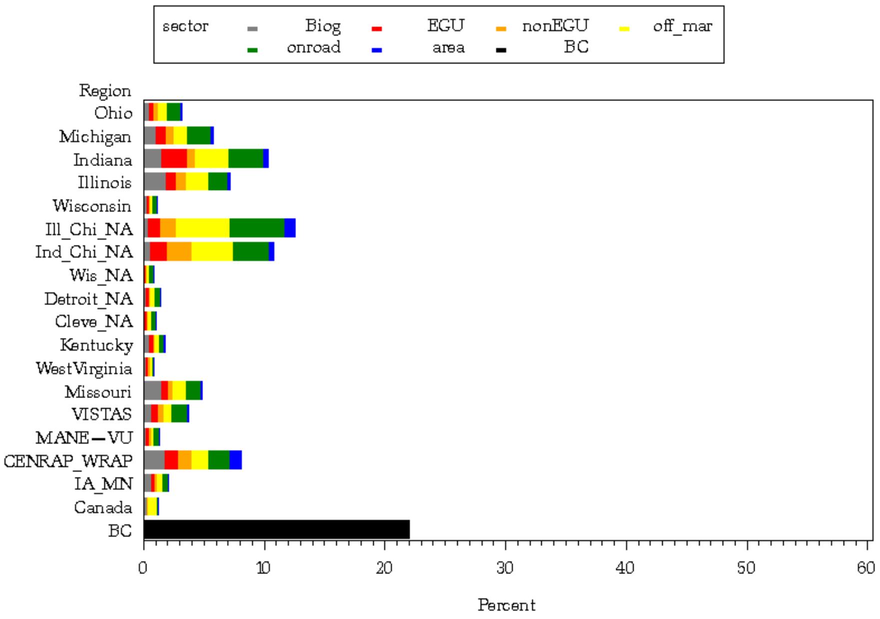

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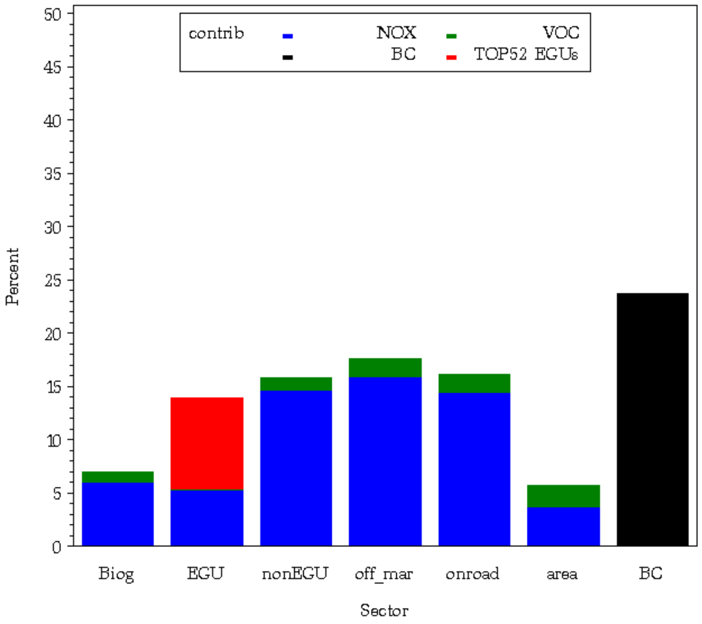

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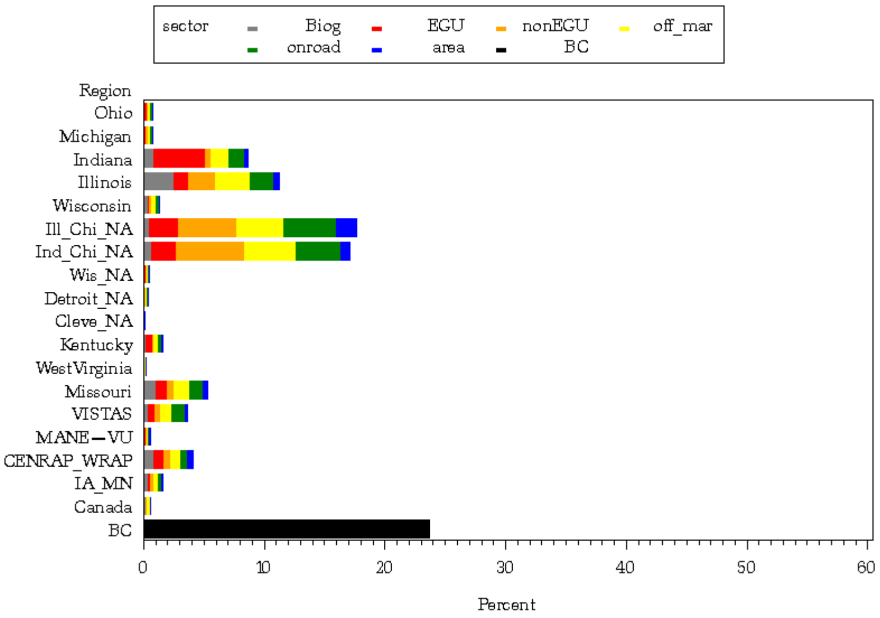

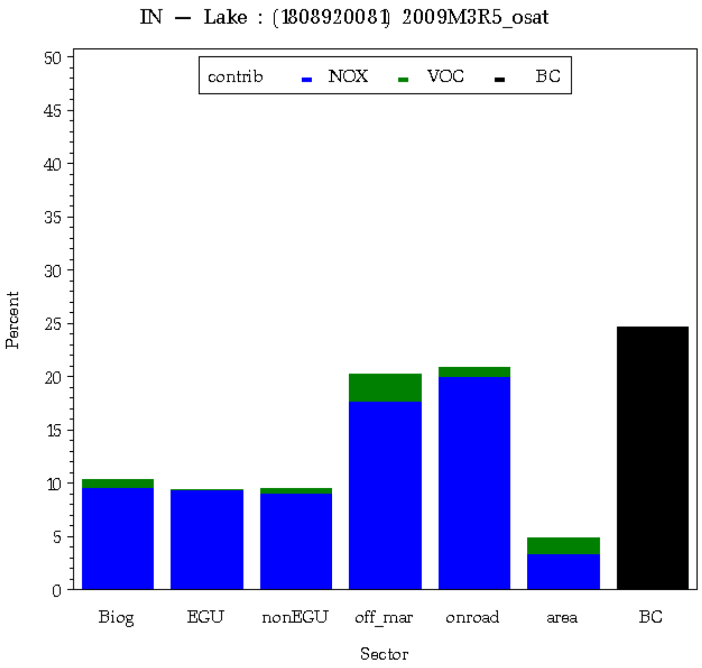
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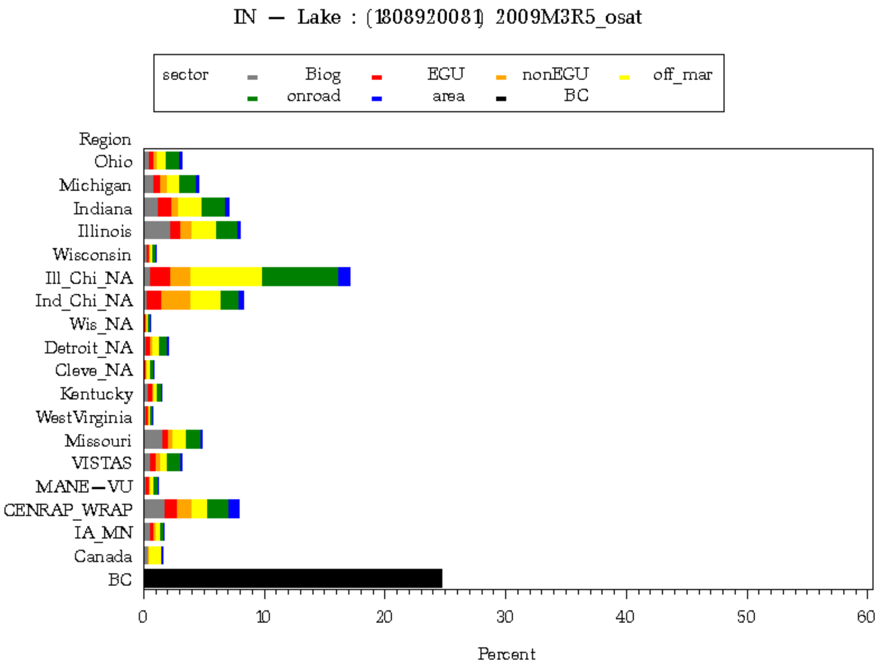
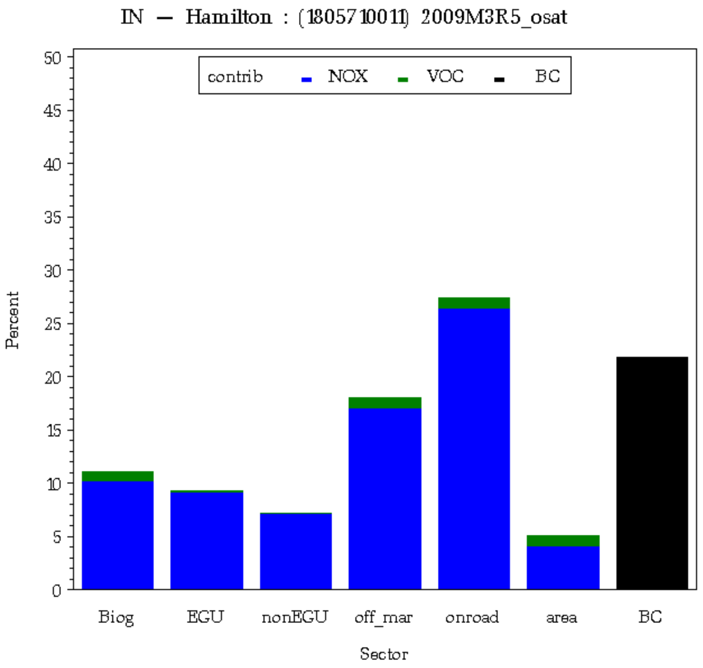
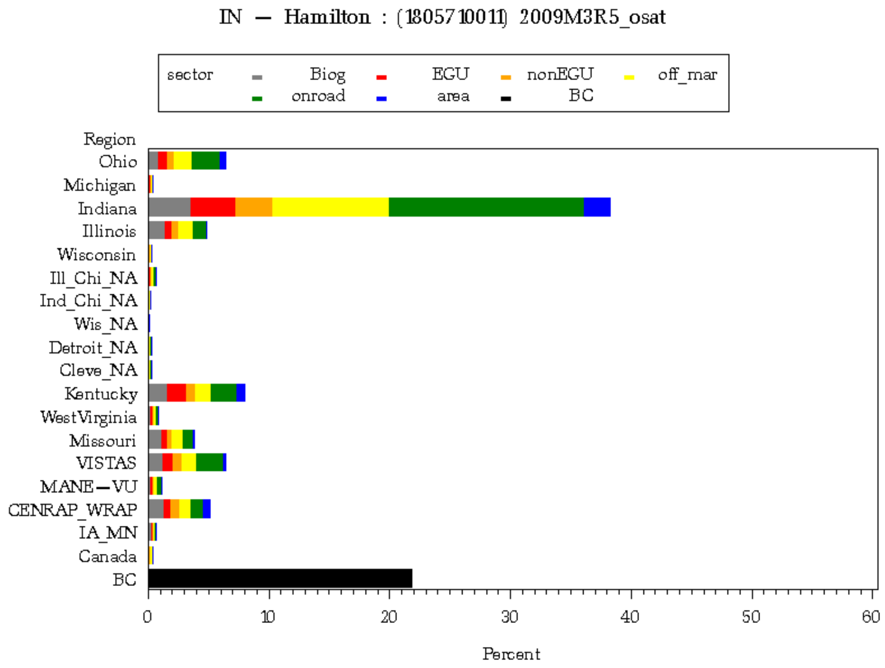
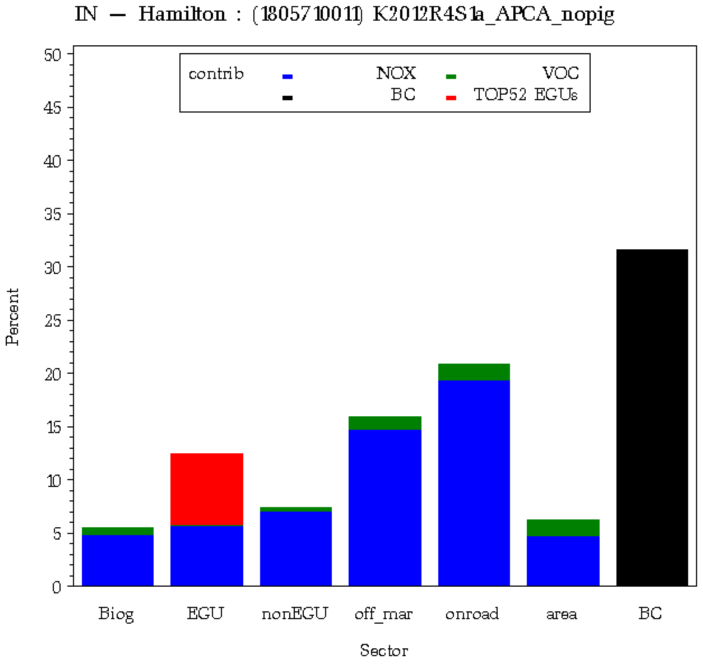

IN — Lake : (180892008l) 2009M3R5_osat


IN — Hamilton : (1805710011) 2009M3R5_osat


IN — Hamilton : (1805710011) 2009M3R5_osat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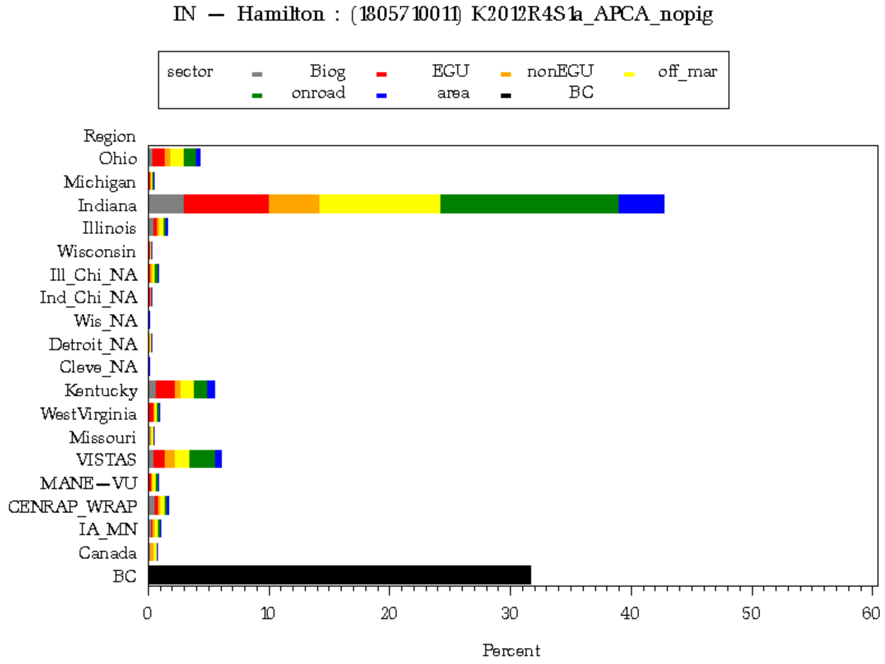
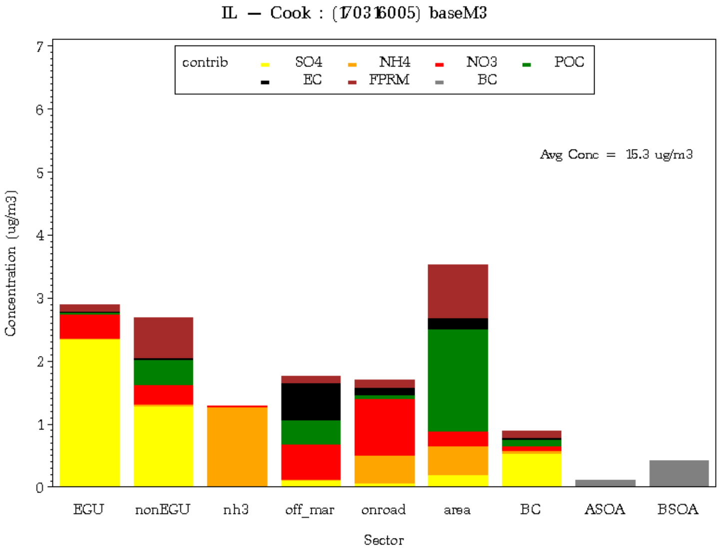

IN — Hamilton : (1805710011) K2012R4S1a_APCA_nopig

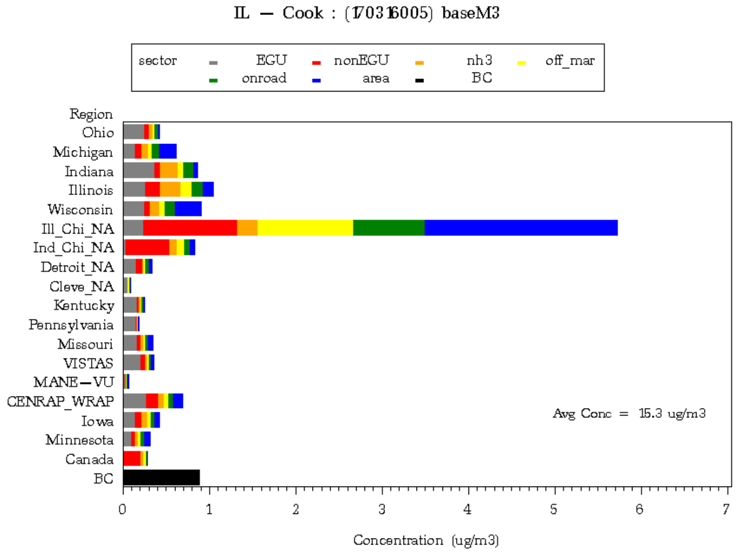
APPENDIX III

PM$_{2.5}$ Source Apportionment Modeling Results

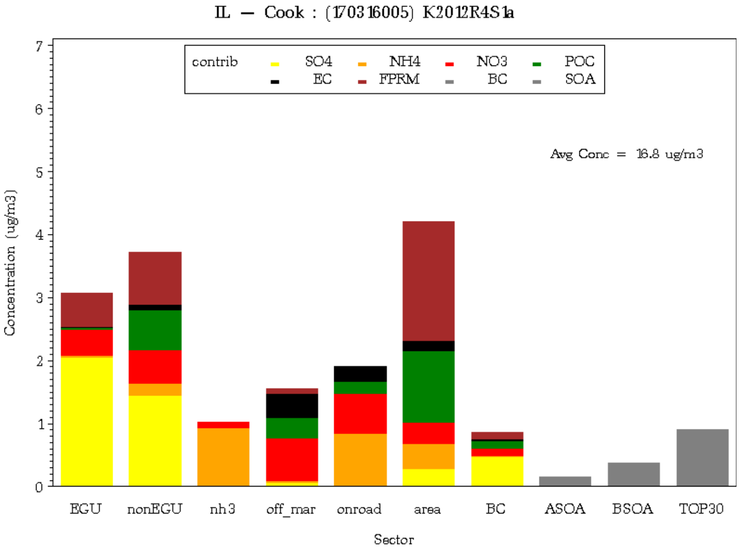
Chicago (Maywood), Illinois

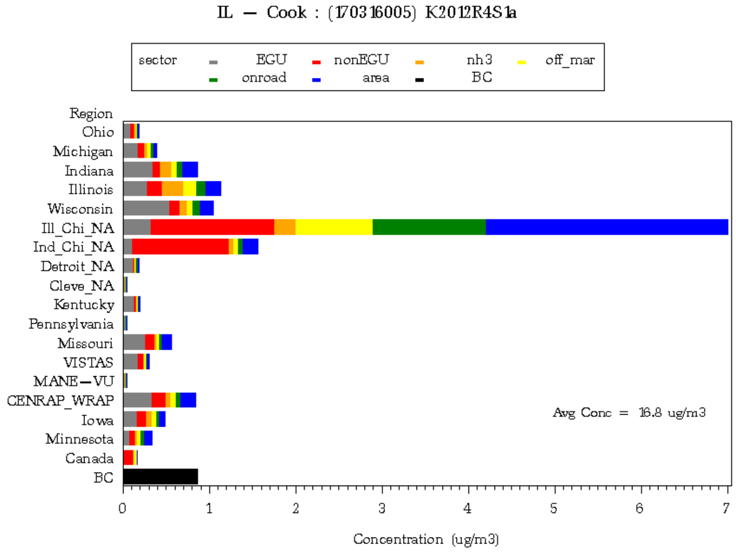
2005 (Round 5)



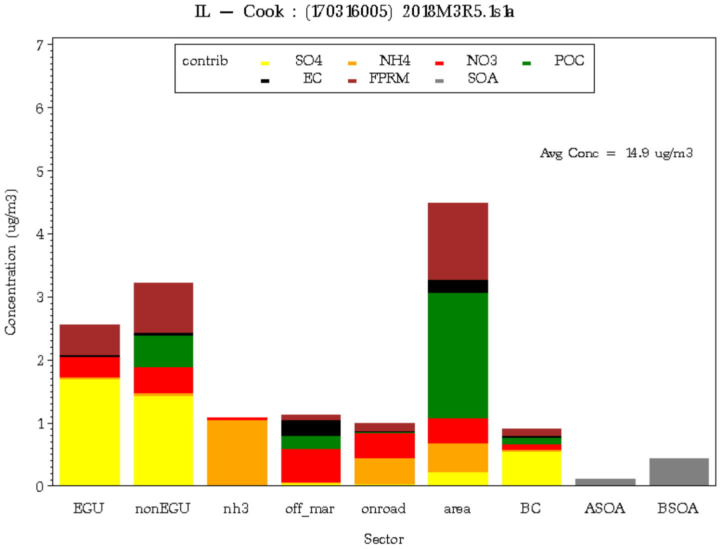


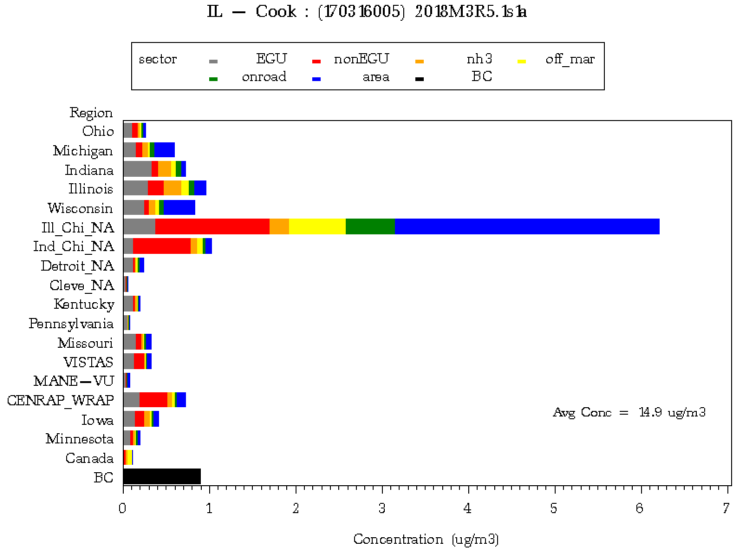
2012 (Round 4)





2018 (Round 5)

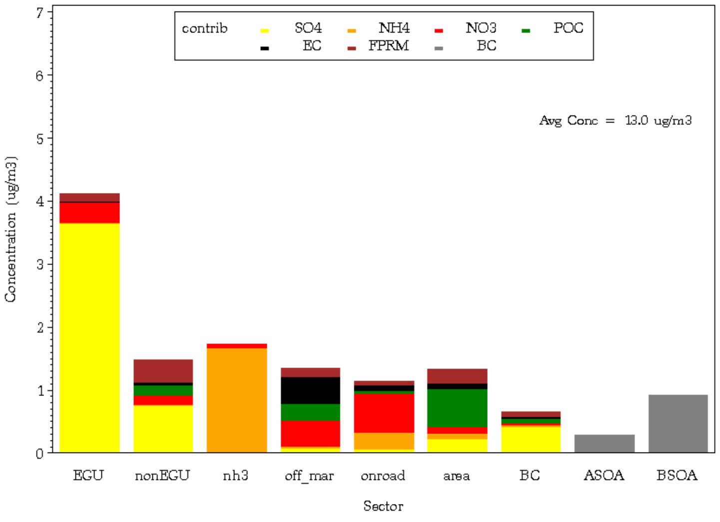




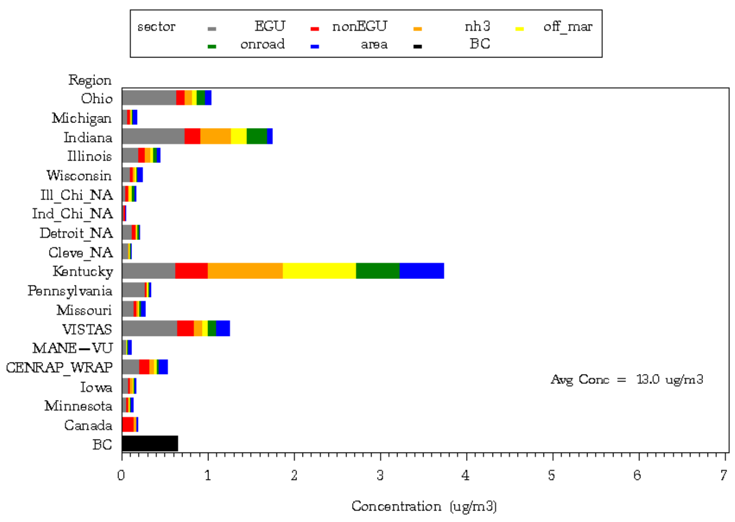
Clark County, Indiana

2005 (Round 5)

IN — Clark : (180190005) baseM3

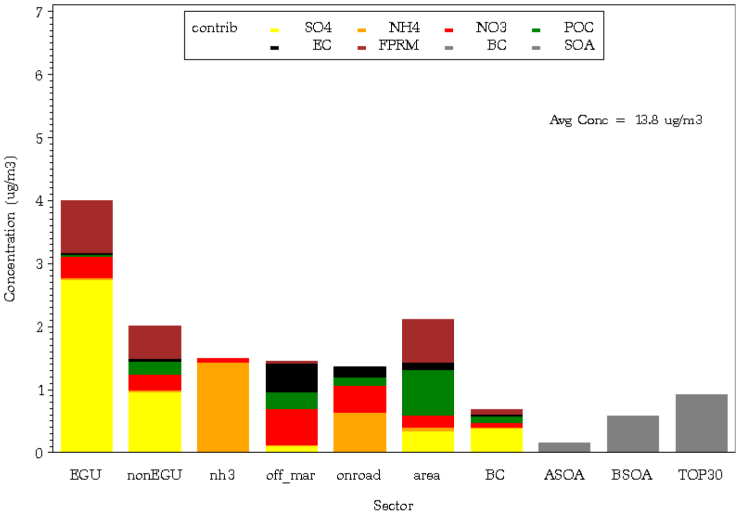


IN — Clark : (180190005) baseM3



2012 (Round 4)

IN — Clark : (180190005) K2012R4S1a



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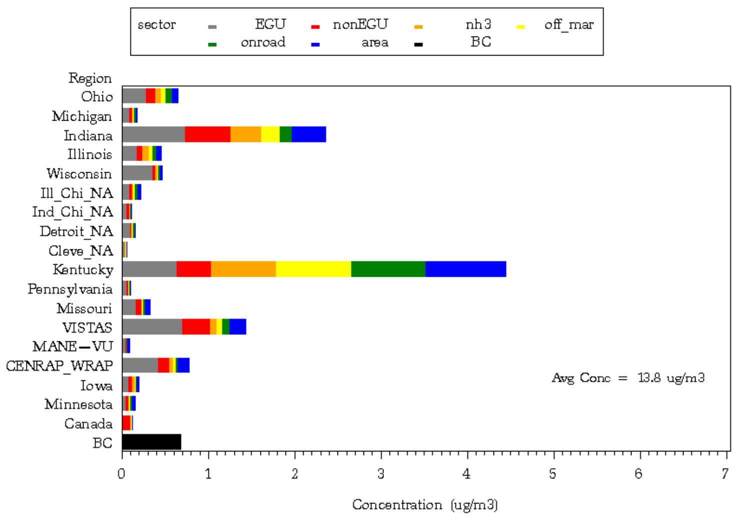
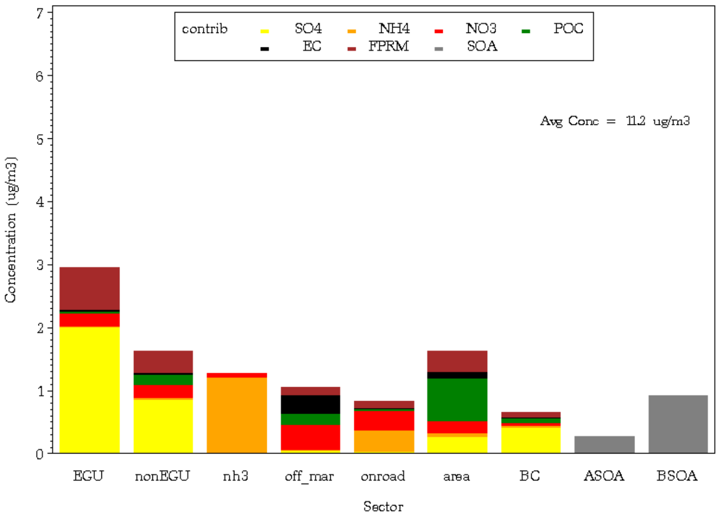


2018 (Round 5)

IN — Clark : (180190005) 2018M3R5.1s1a



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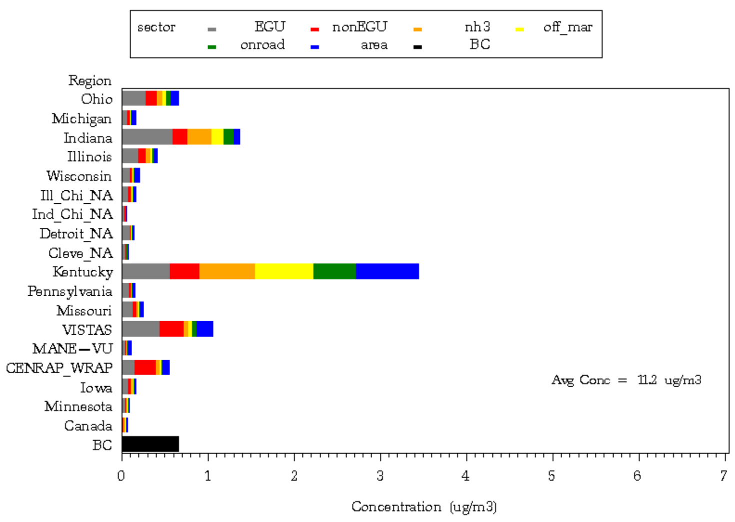
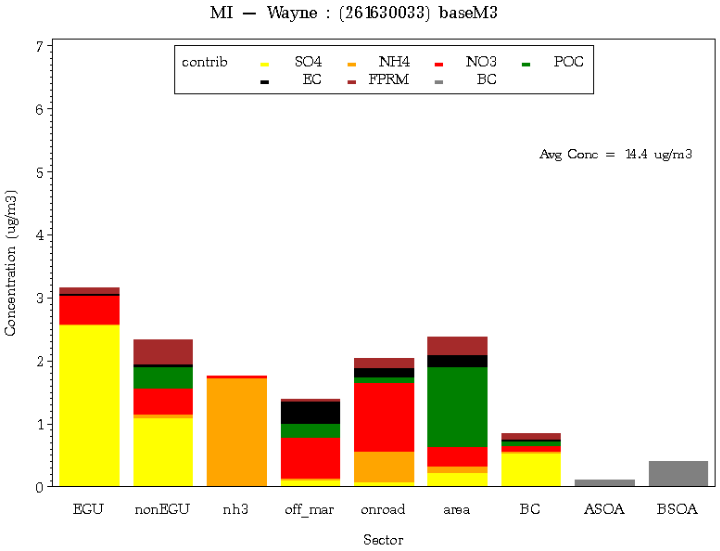
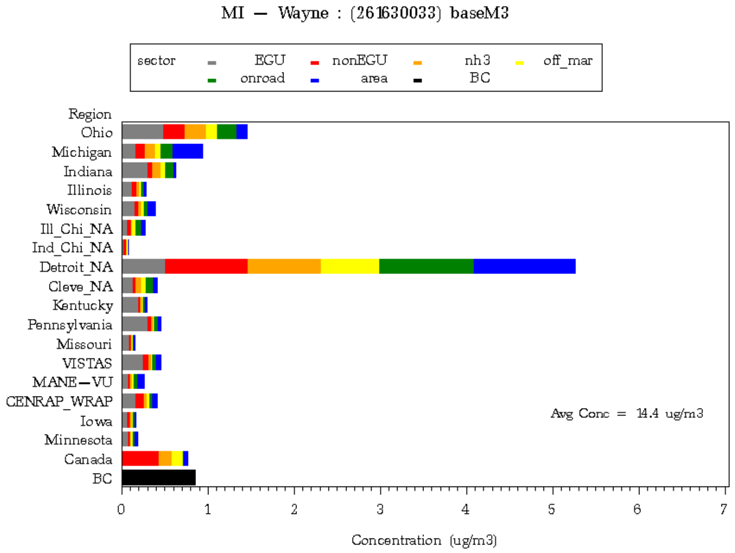


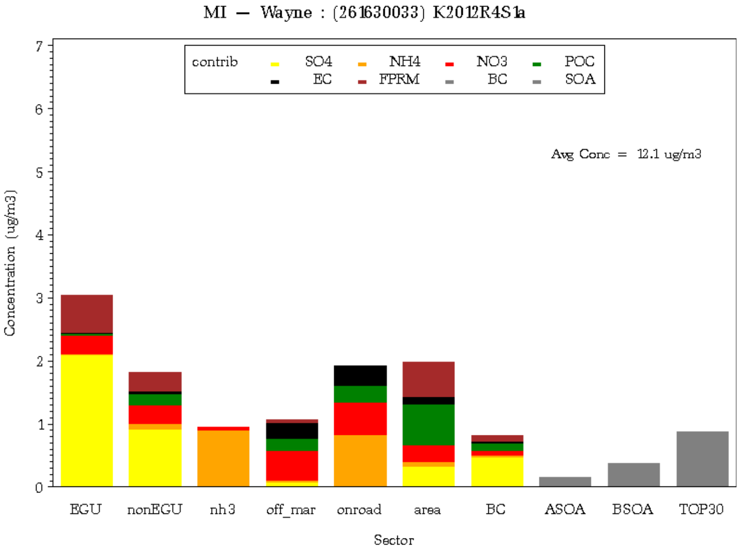
Dearborn, Michigan

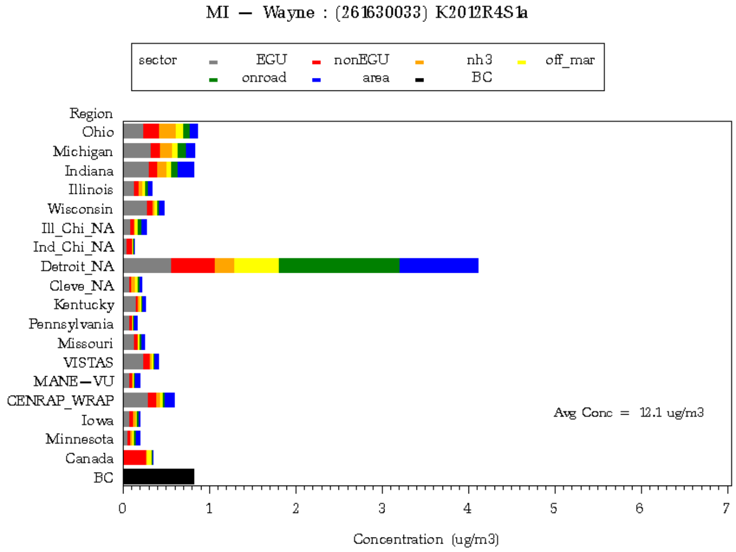
2005 (Round 5)



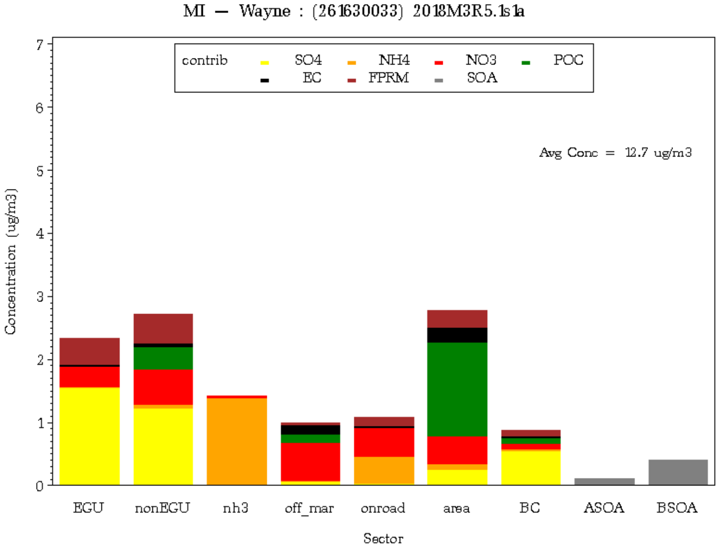


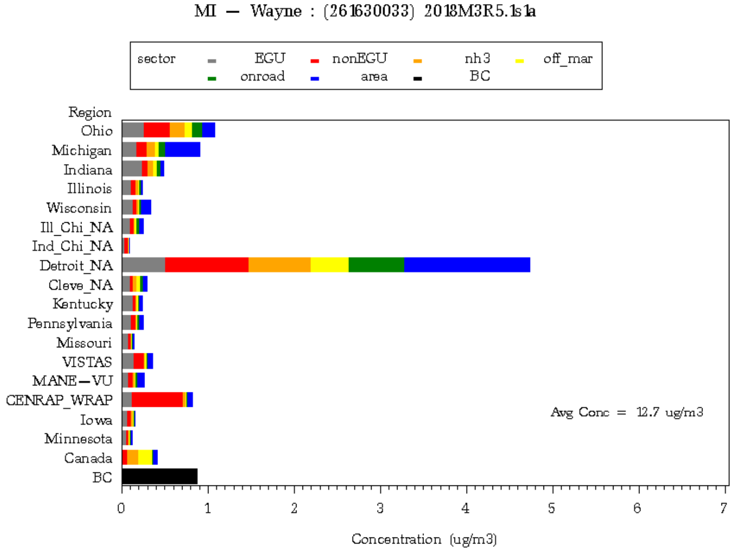
2012 (Round 4)





2018 (Round 5)

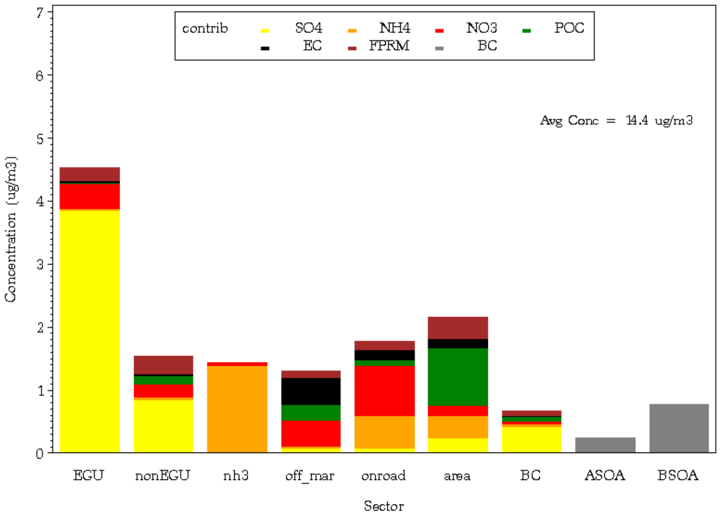




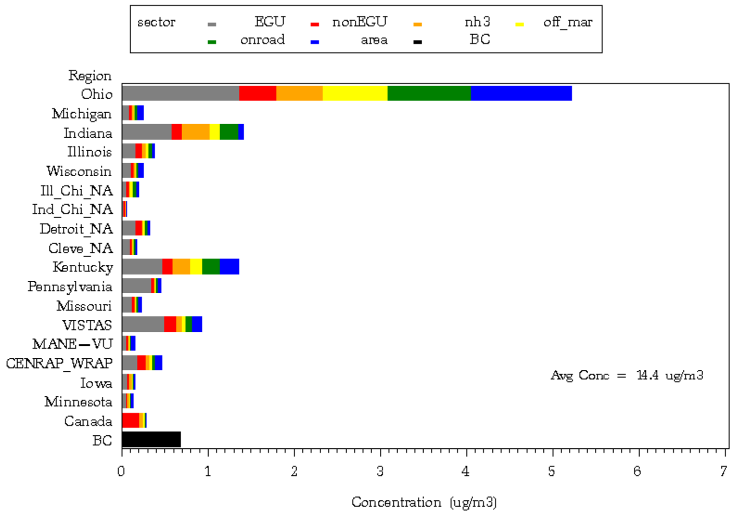
Cincinnati, Ohio

2005 (Round 5)

OH — Hamilton : (390618001) baseM3

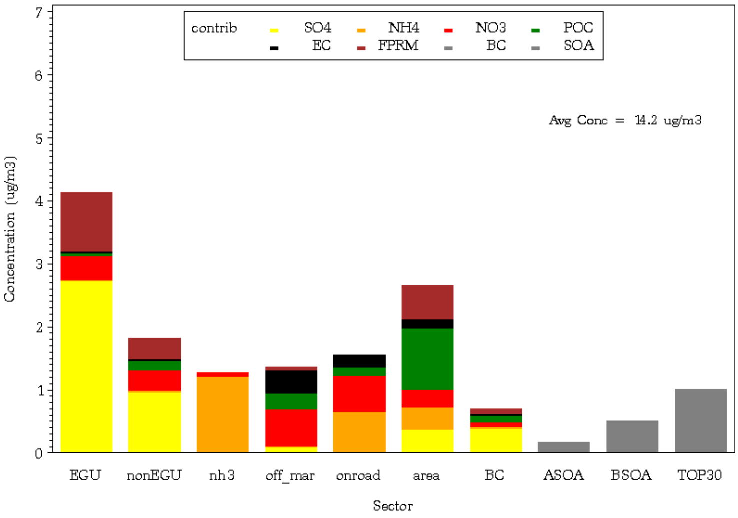


OH — Hamilton : (390618001) baseM3

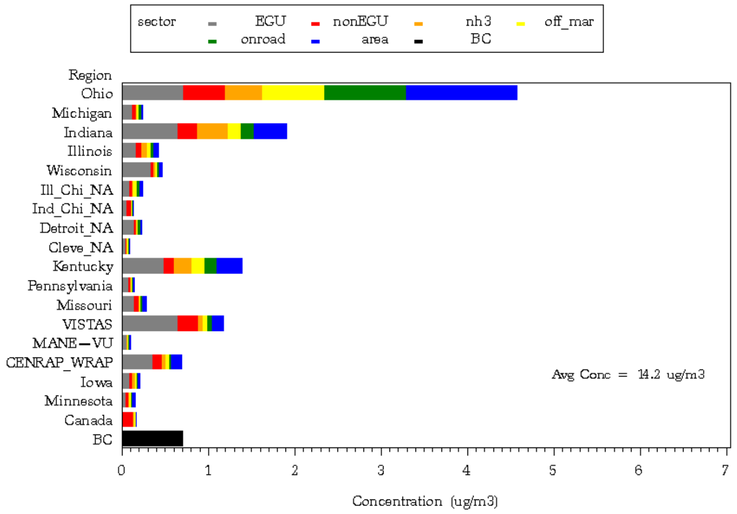


2012 (Round 4)

OH — Hamilton : (390618001) K2012R4S1a

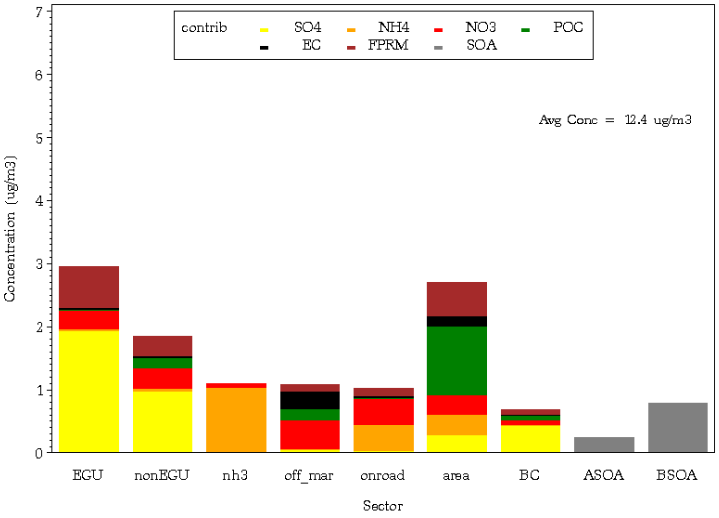


OH — Hamilton : (390618001) K2012R4S1a

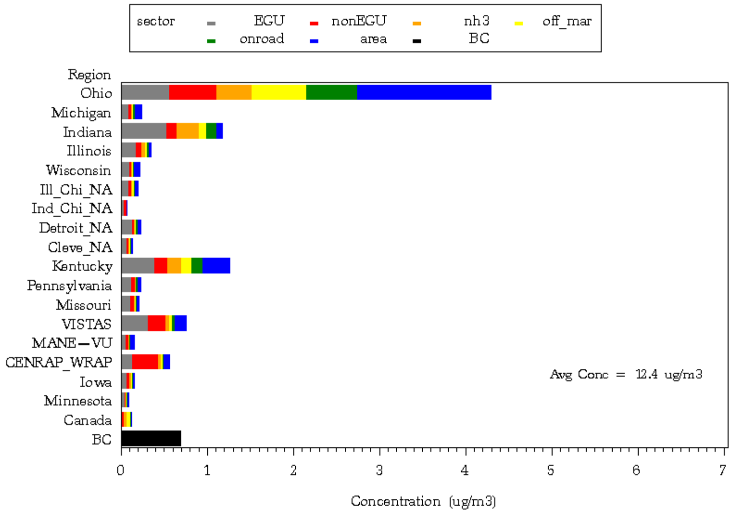


2018 (Round 5)

OH — Hamilton : (390610014) 2018M3R5.1s1a

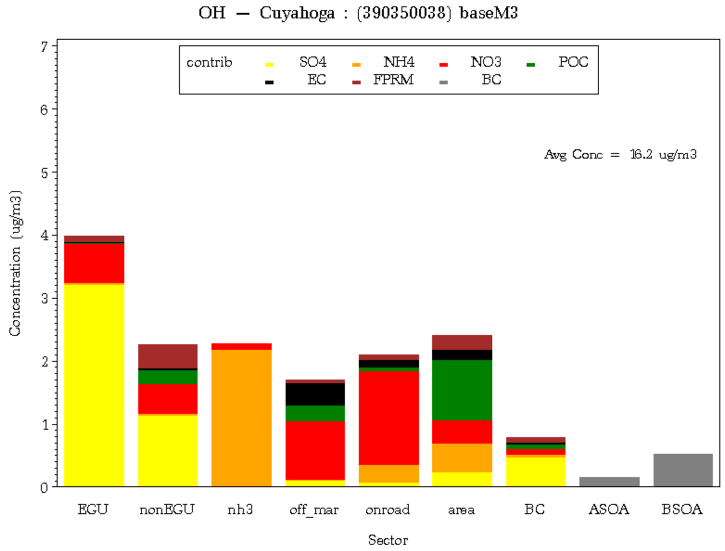


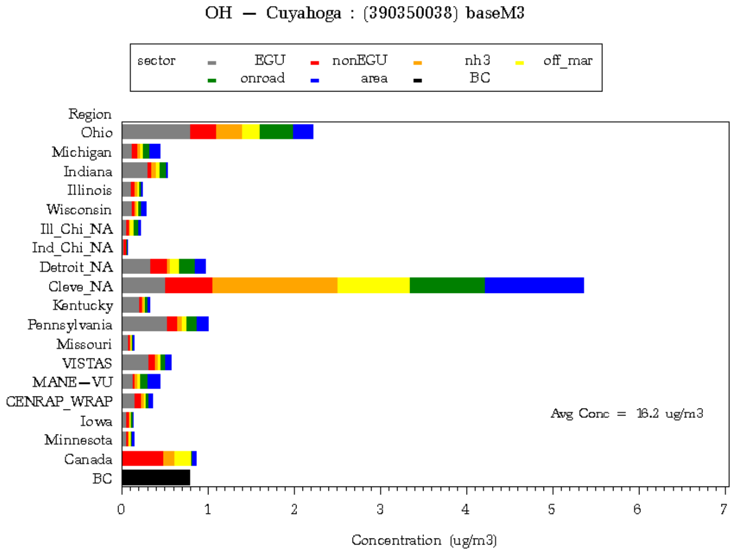
OH — Hamilton : (390610014) 2018M3R5.1s1a



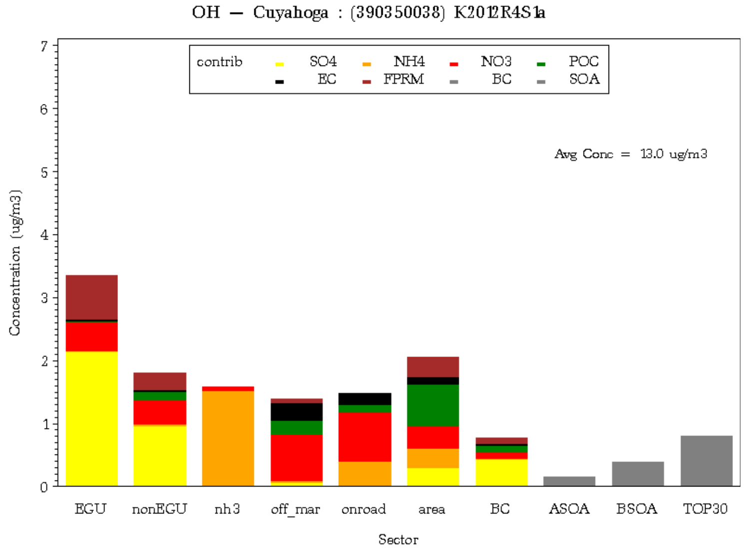
Cleveland, Ohio

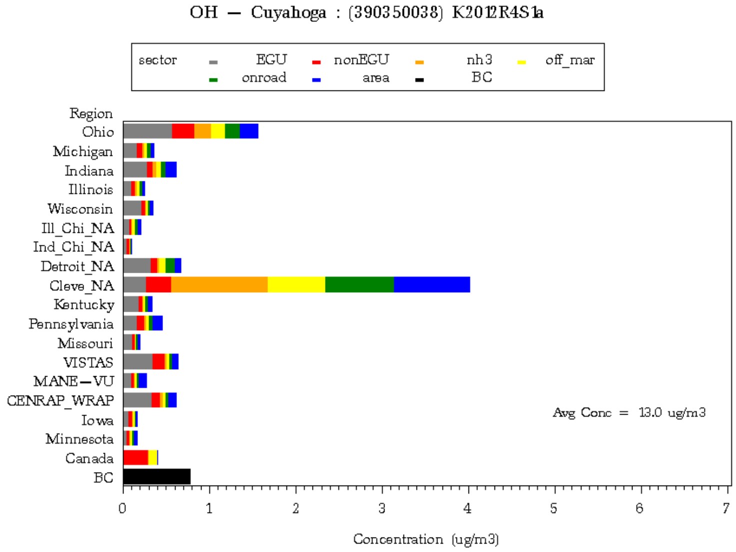
2005 (Round 5)



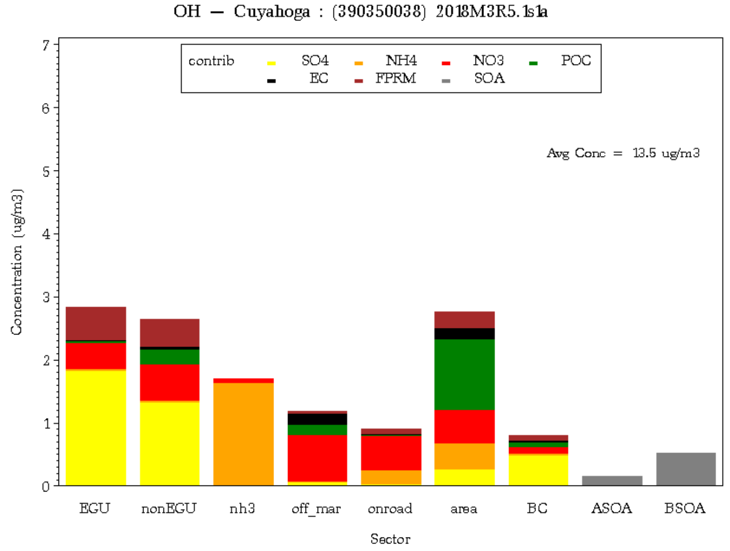


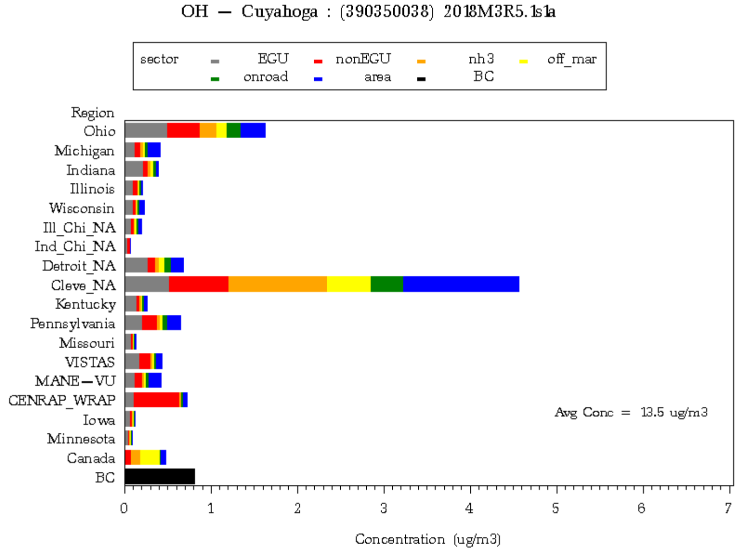
2012 (Round 4)





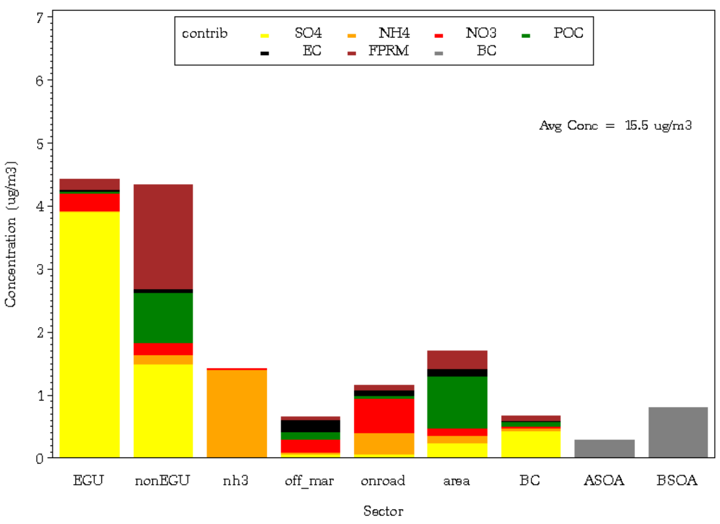
2018 (Round 5)

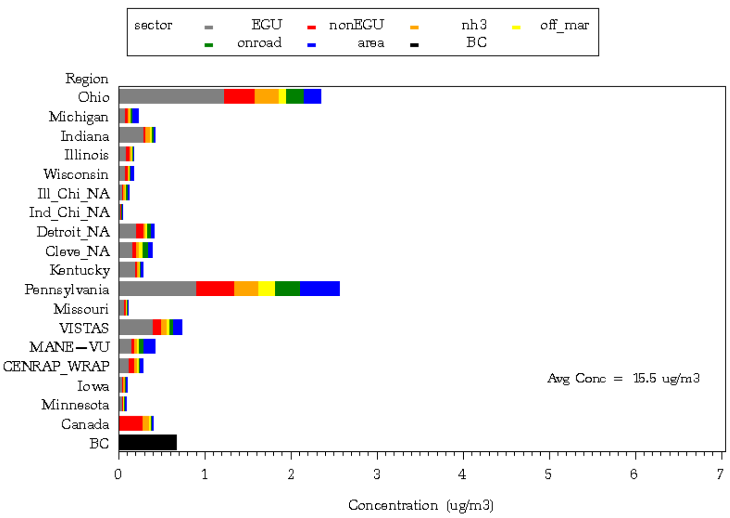




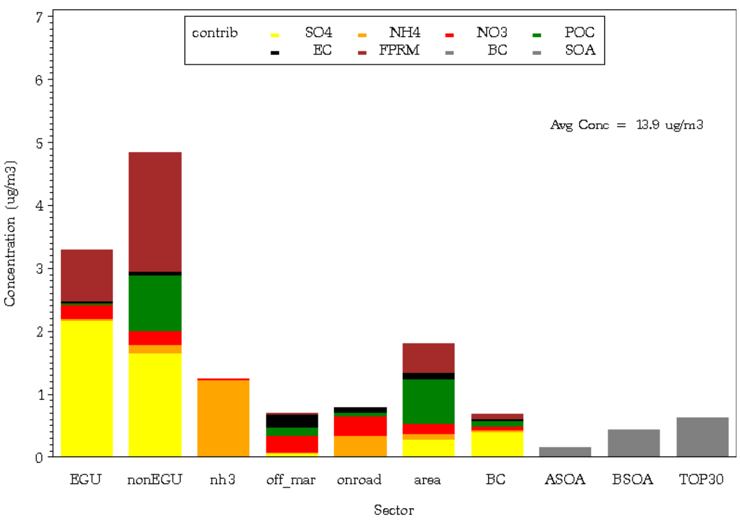
Steubenville, Ohio

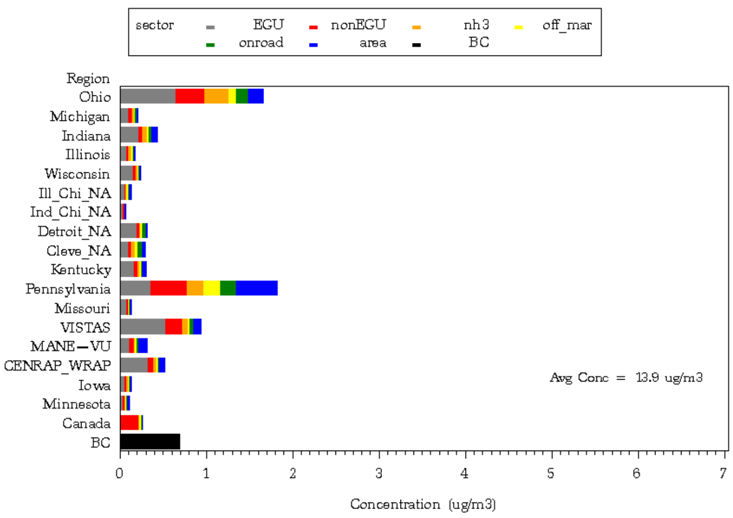
2005 (Round 5)


OH — Jefferson : (390810016) baseM3

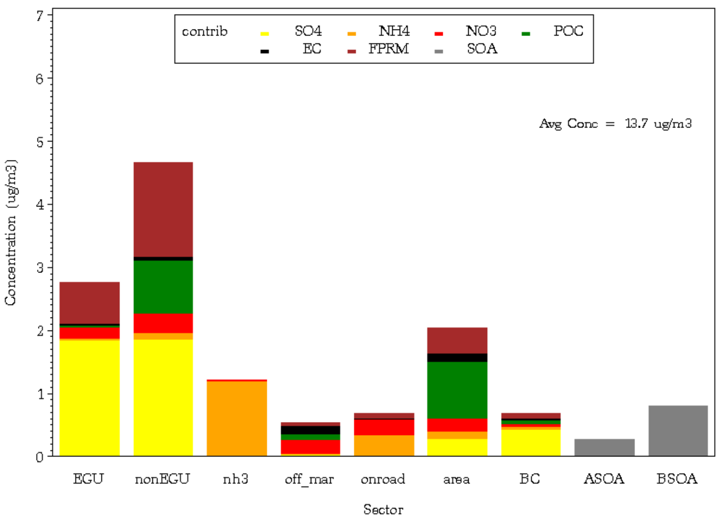

OH — Jefferson : (390810016) baseM3

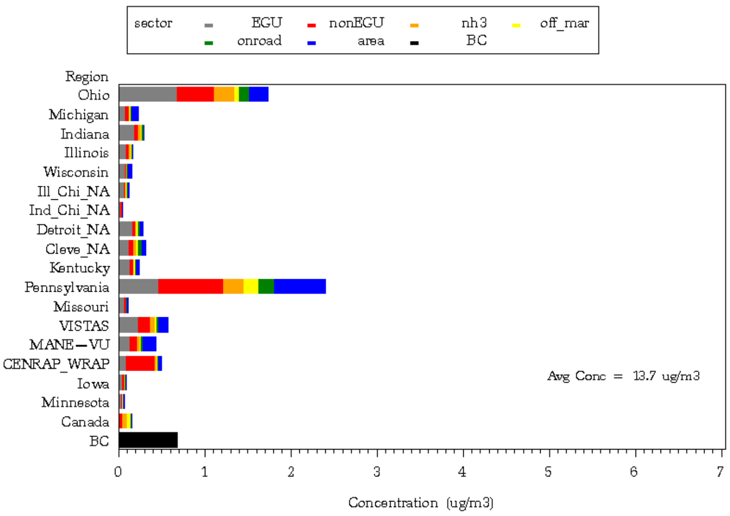
2012 (Round 4)


OH — Jefferson : (390810016) K2012R4S1a


OH — Jefferson : (390810016) K2012R4S1a

2018 (Round 5)


OH — Jefferson : (390810016) 2018M3R5.1s1a

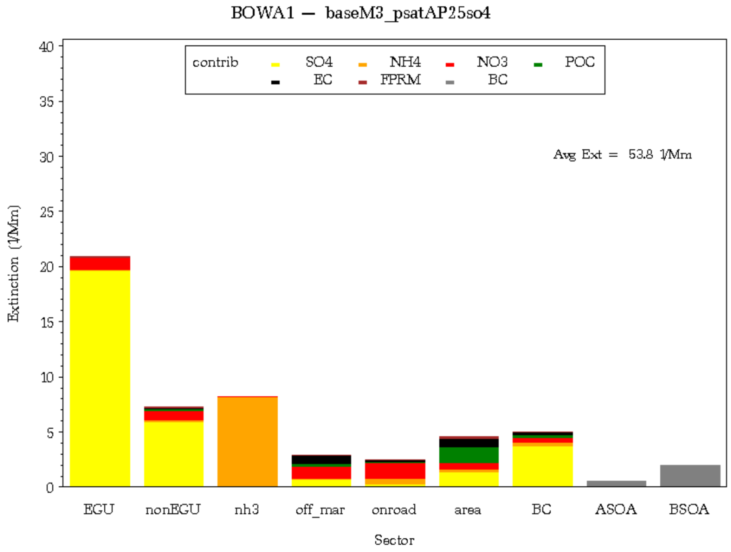

OH — Jefferson : (390810016) 2018M3R5.1s1a

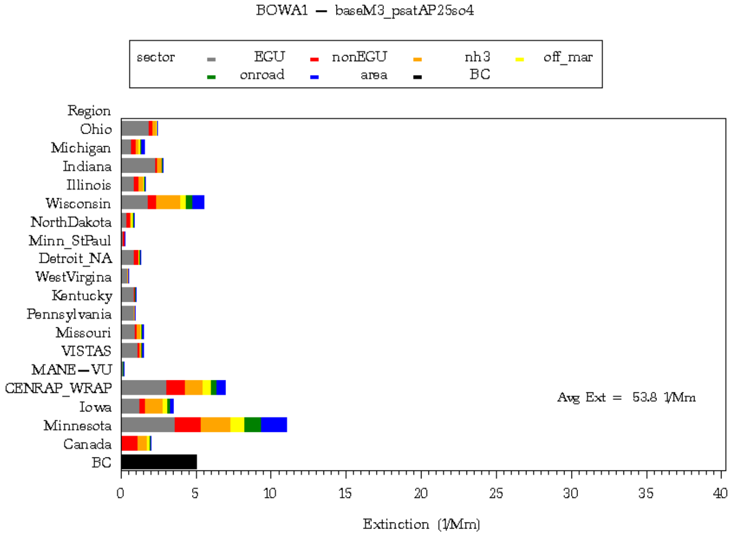
APPENDIX IV

Haze Source Apportionment Modeling Results

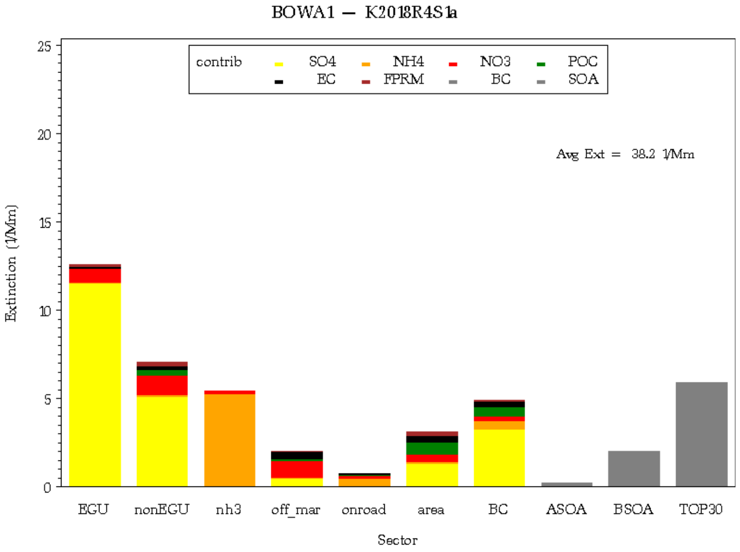
Boundary Waters, Minnesota

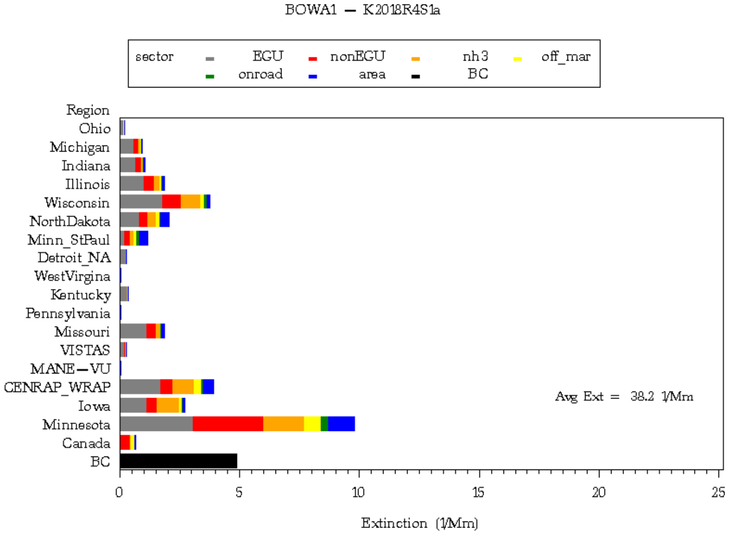
2005 (Round 5)



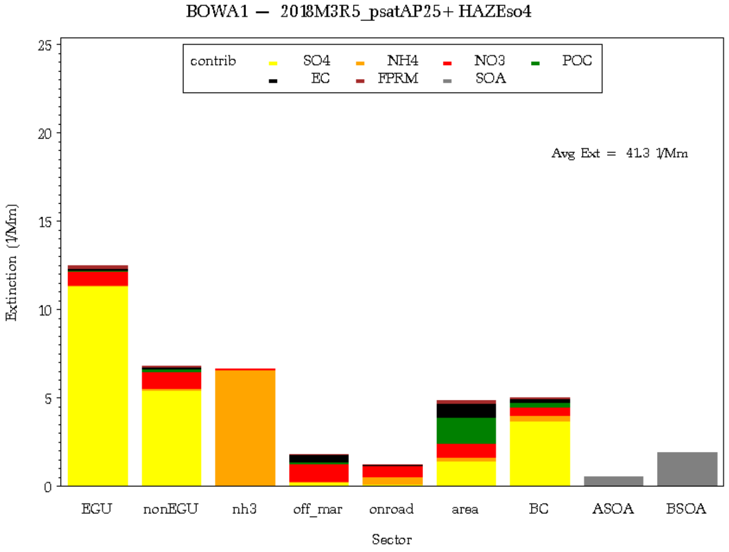


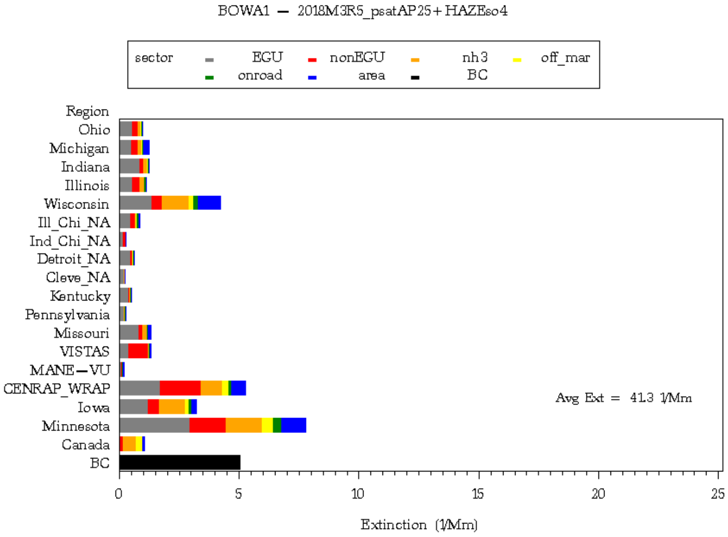
2018 (Round 4)





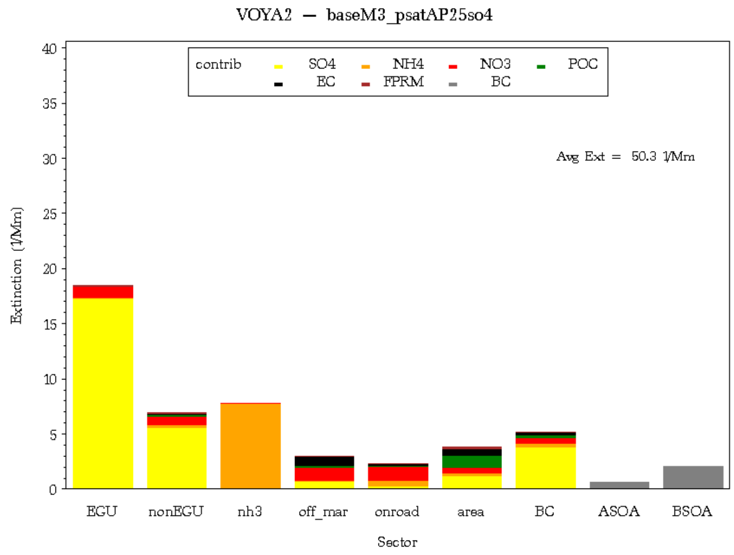
2018 (Round 5)

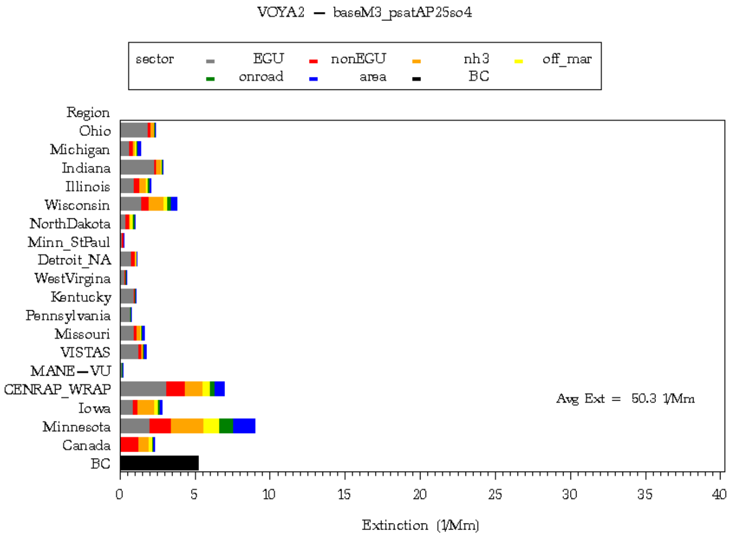




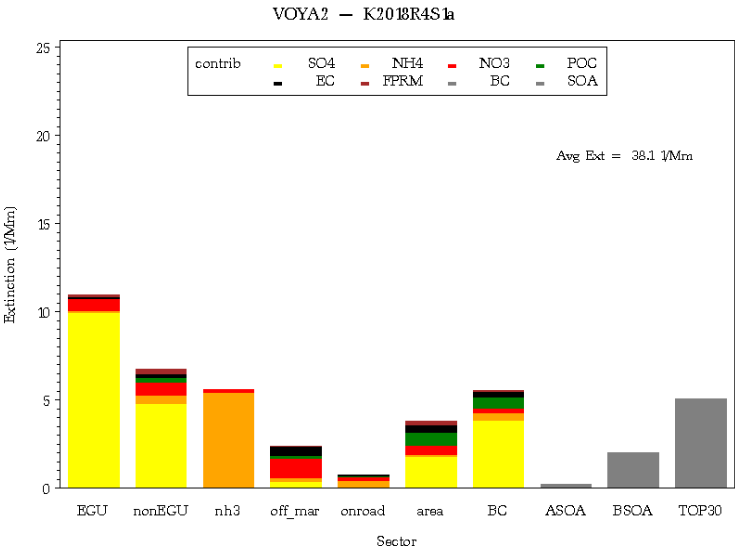
Voyageurs, Minnesota

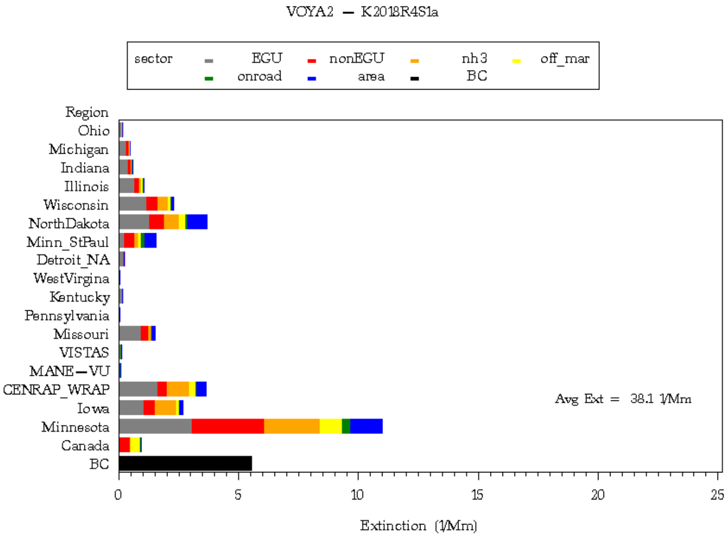
2005 (Round 5)



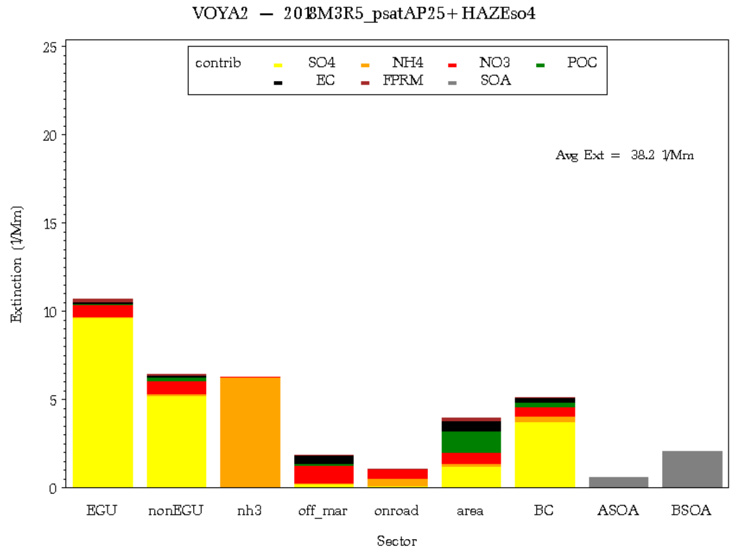


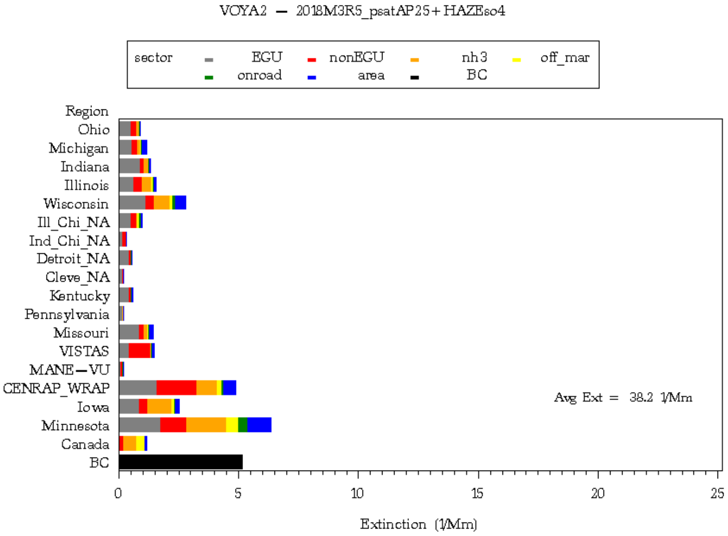
2018 (Round 4)





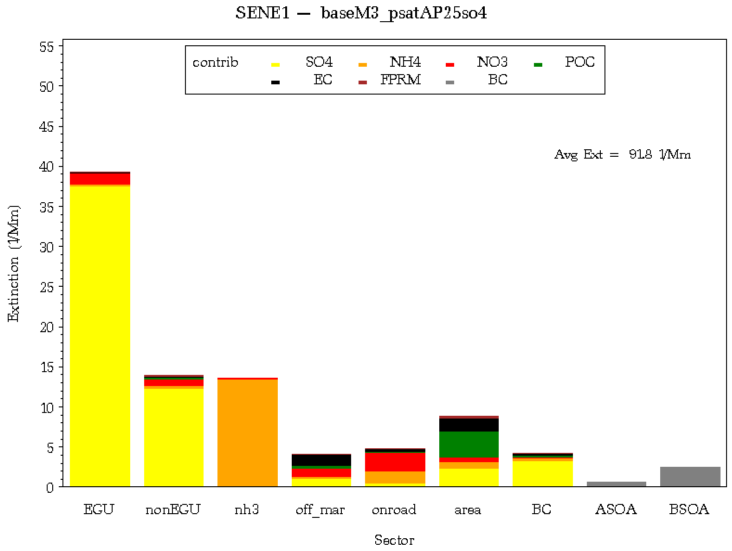
2018 (Round 5)

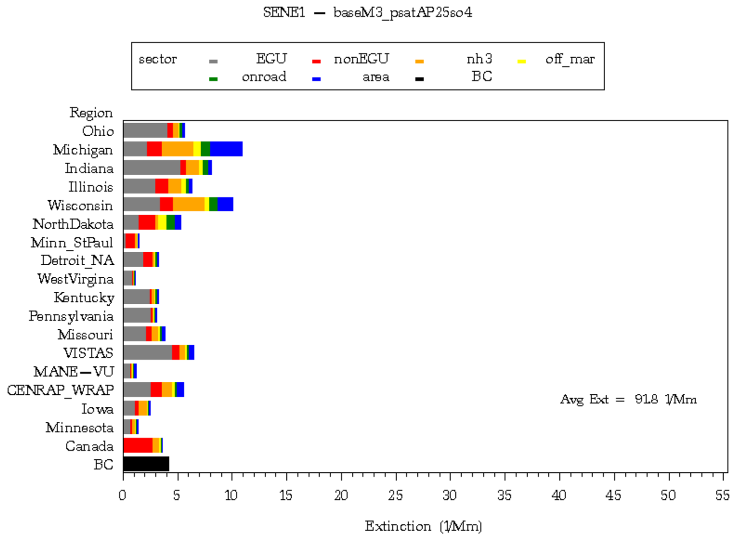




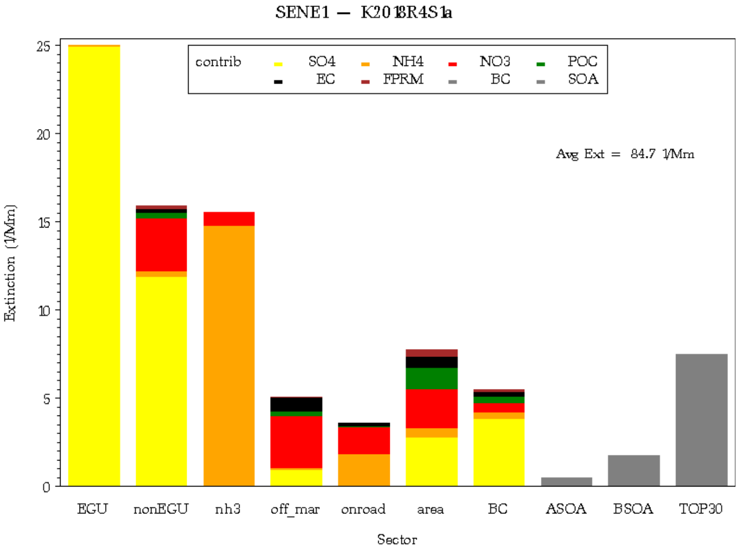
Seney, Michigan

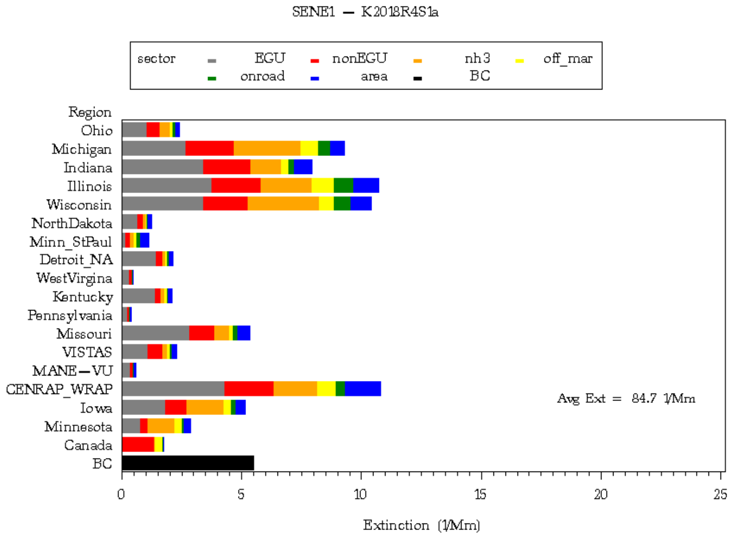
2005 (Round 5)



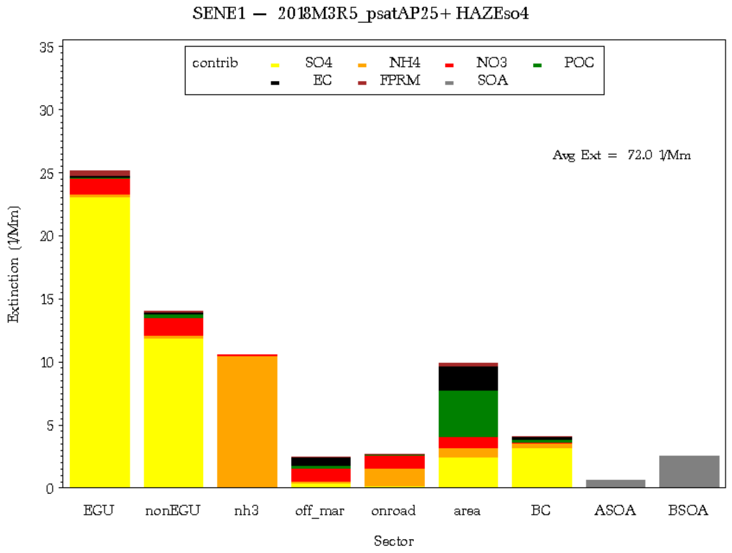


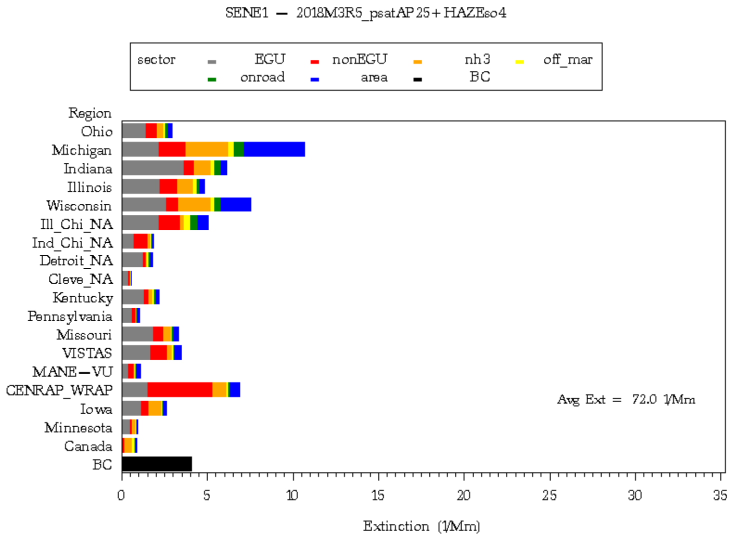
2018 (Round 4)





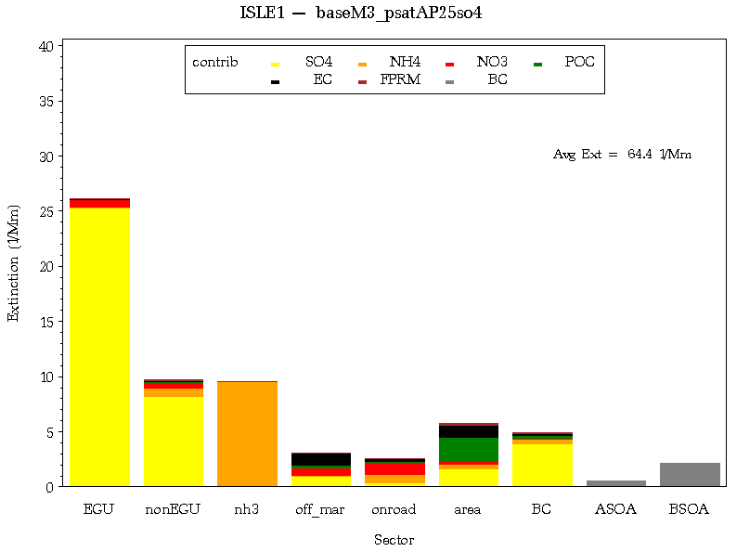
2018 (Round 5)

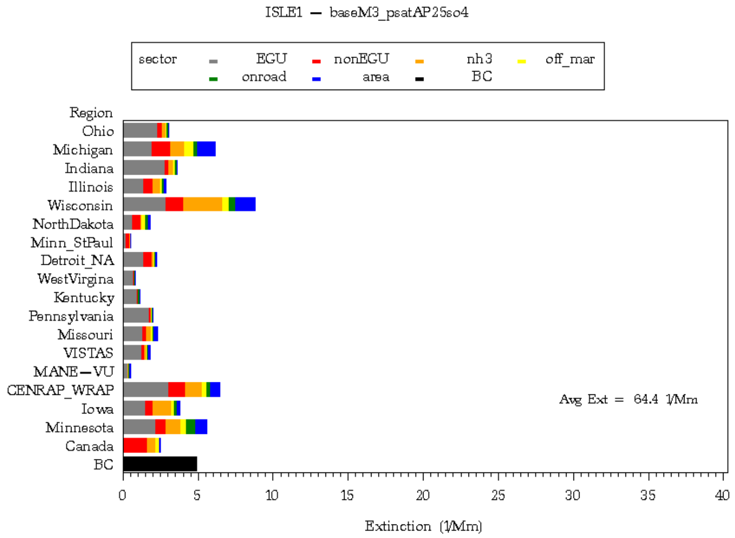




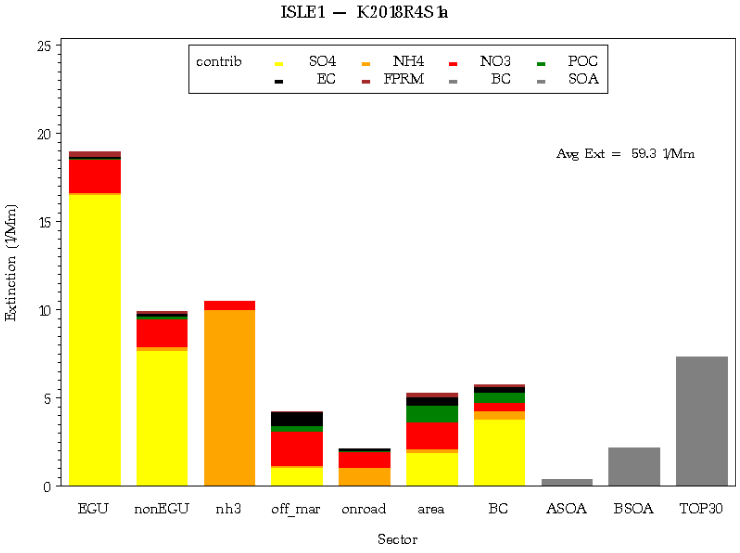
Isle Royale, Michigan

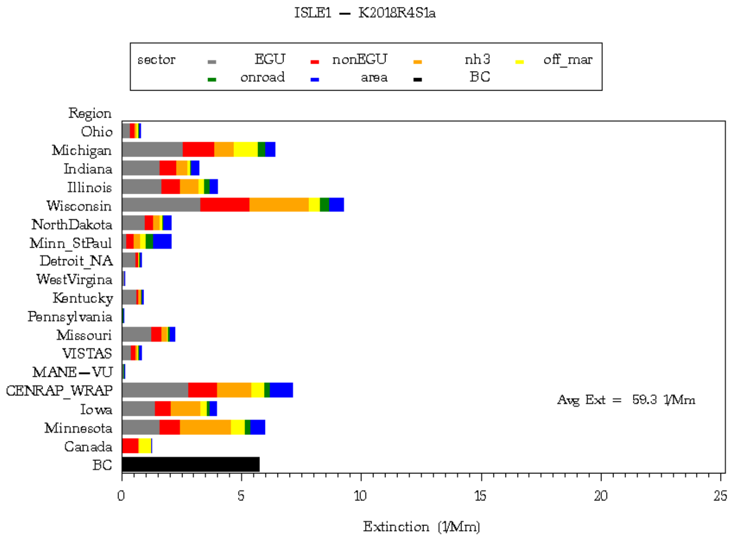
2005 (Round 5)



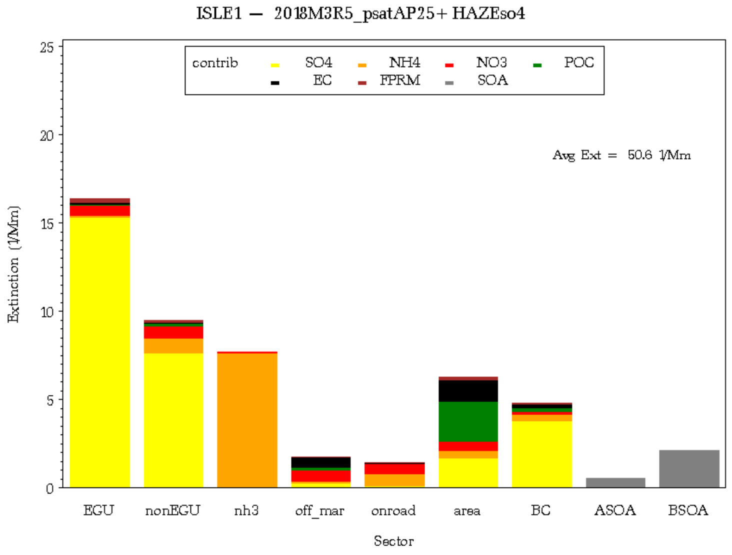


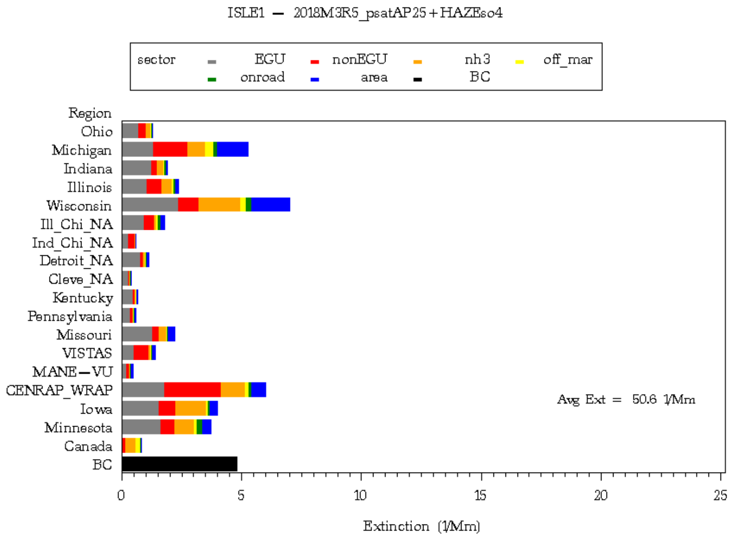
2018 (Round 4)





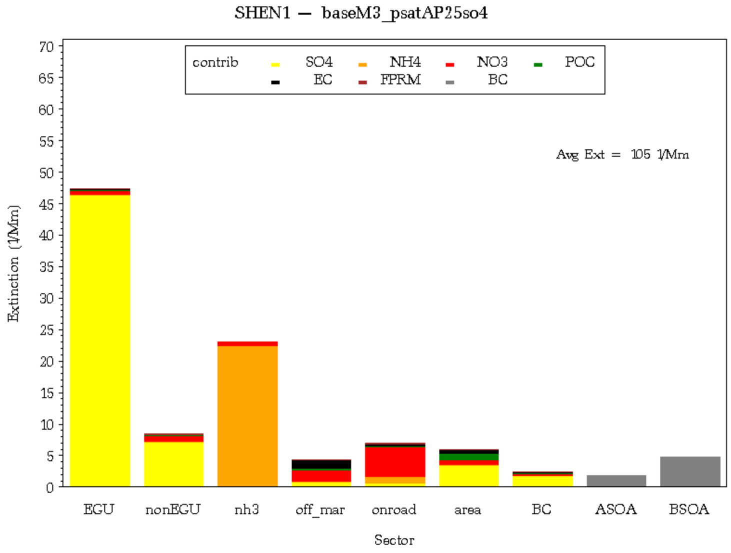
2018 (Round 5)

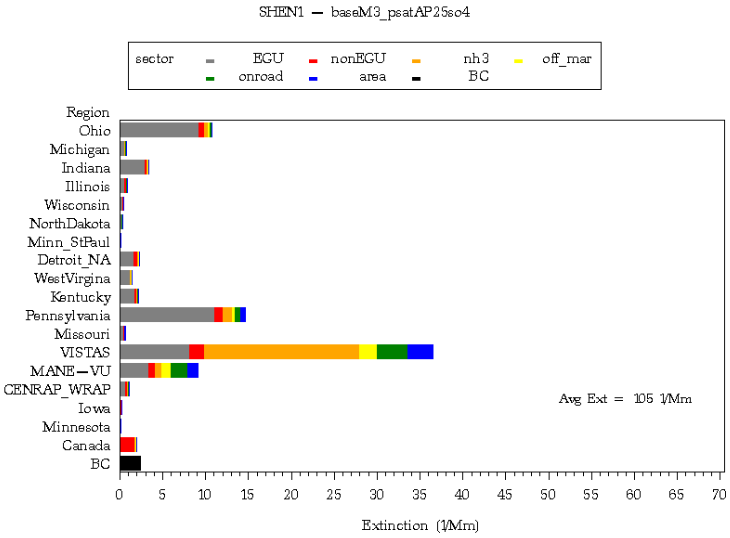




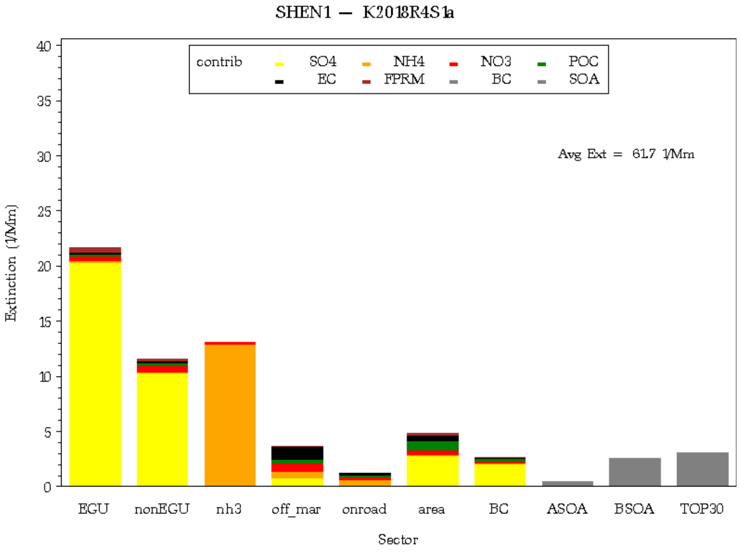
Shenandoah, Virginia

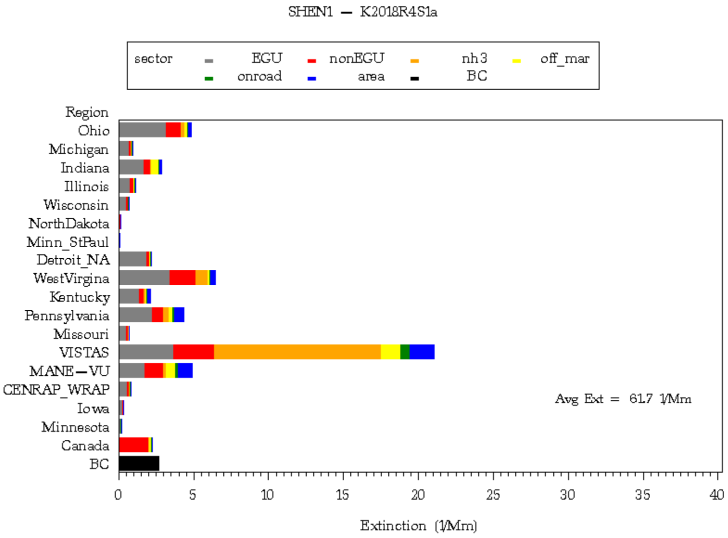
2005 (Round 5)



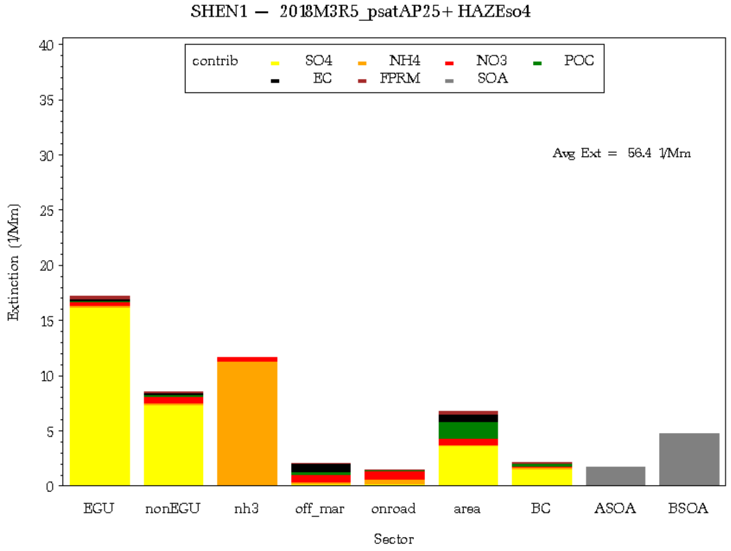


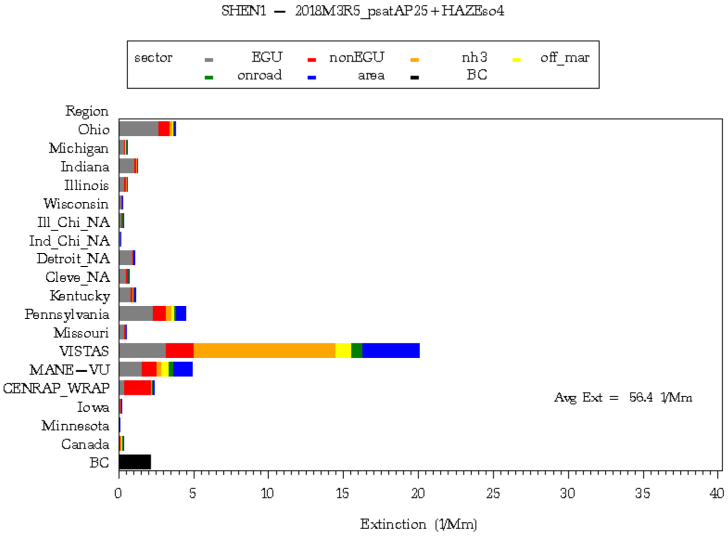
2018 (Round 4)





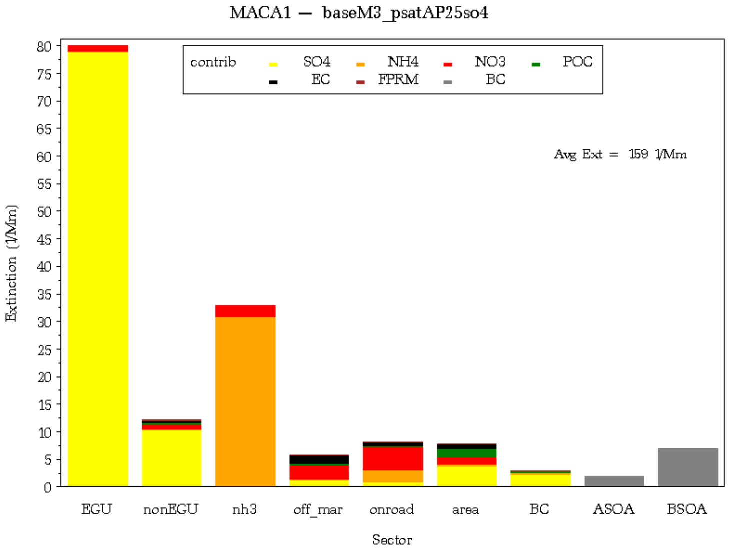
2018 (Round 5)

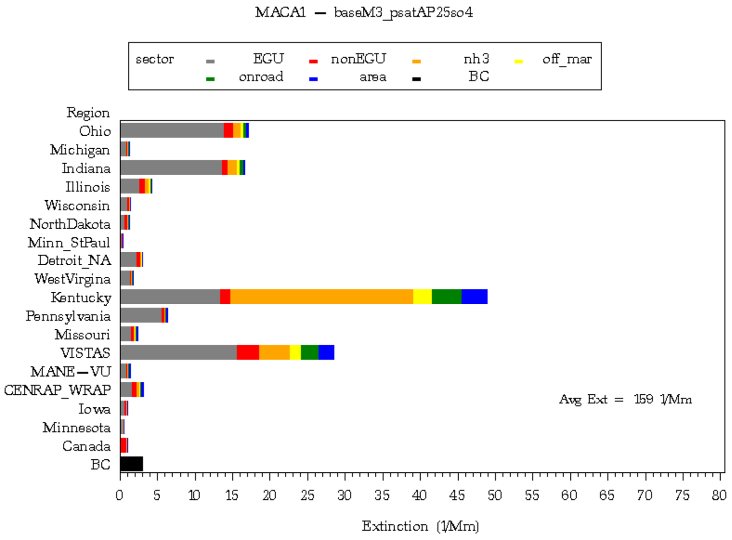




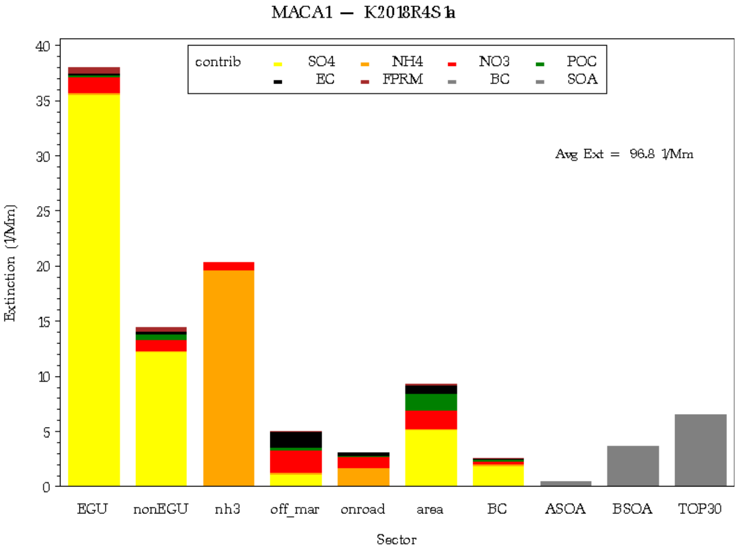
Mammoth Cave, Kentucky

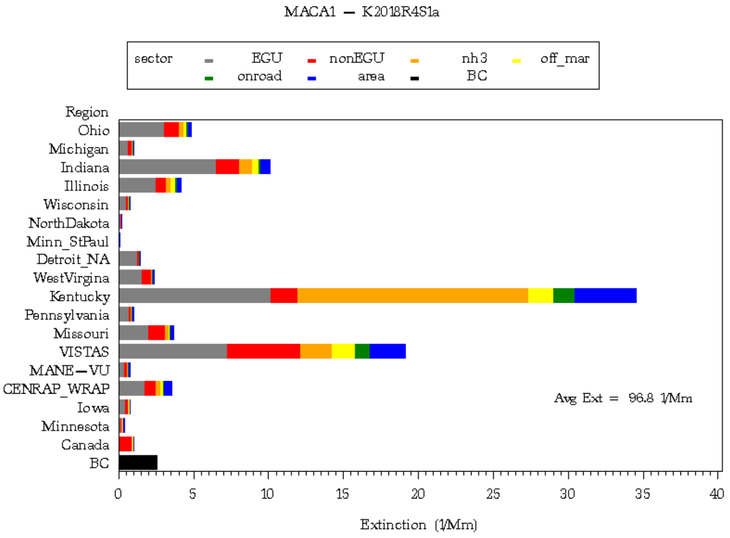
2005 (Round 5)



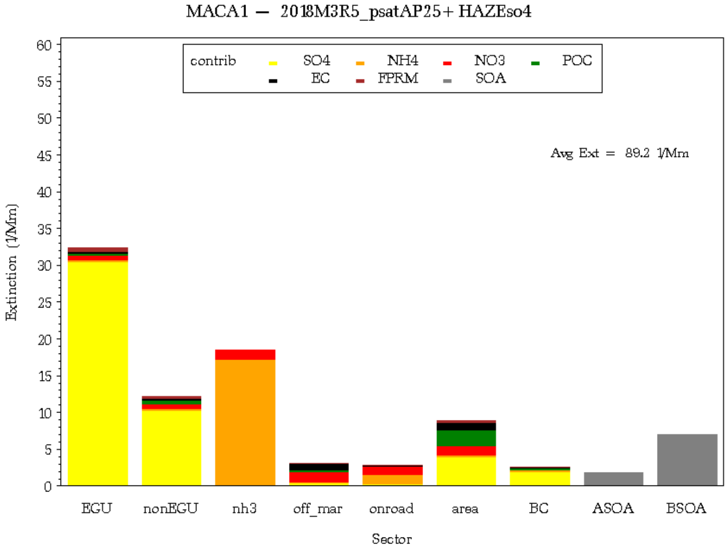


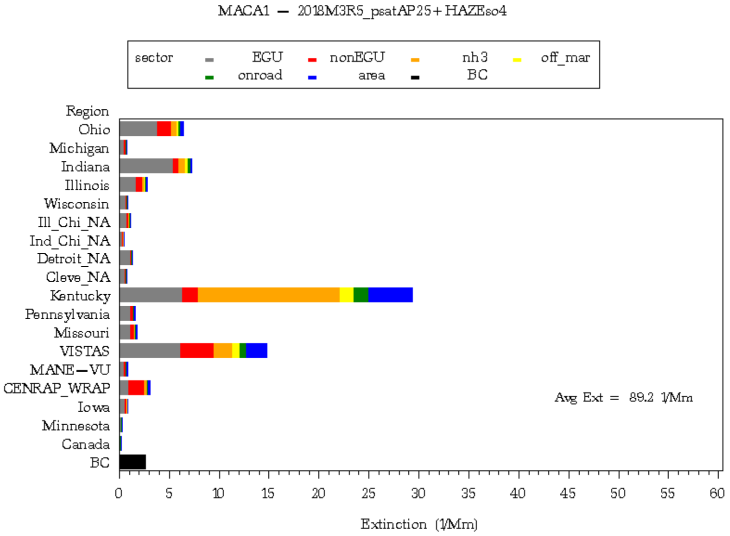
2018 (Round 4)





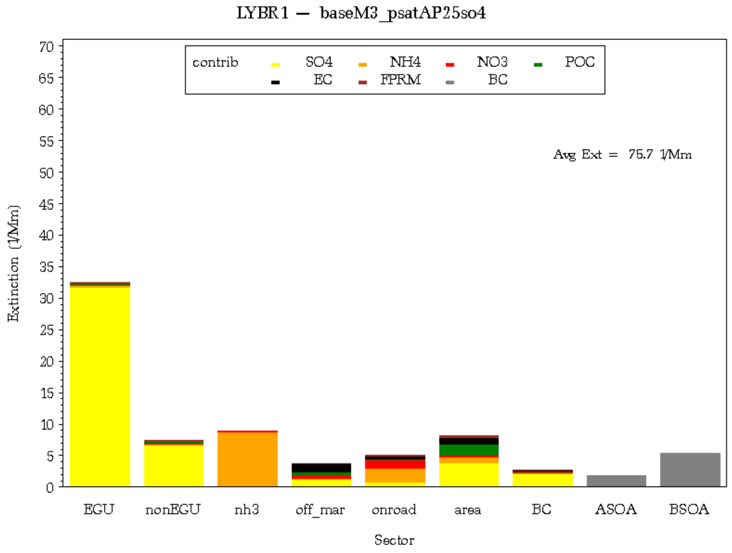
2018 (Round 5)

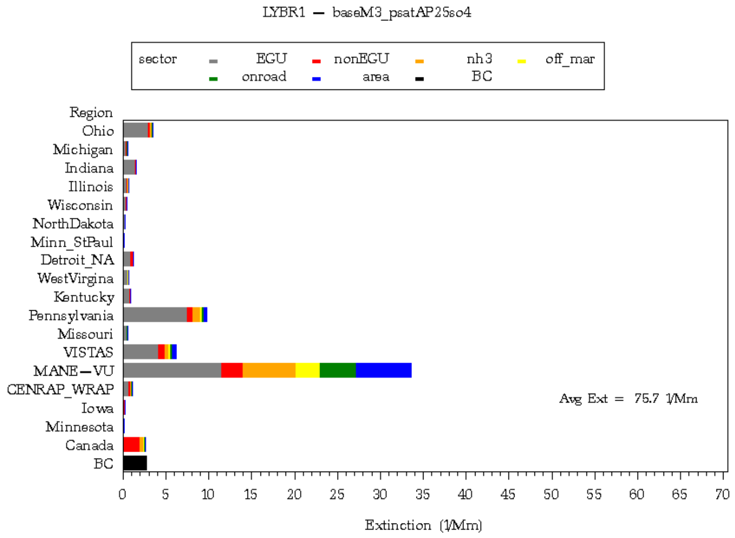




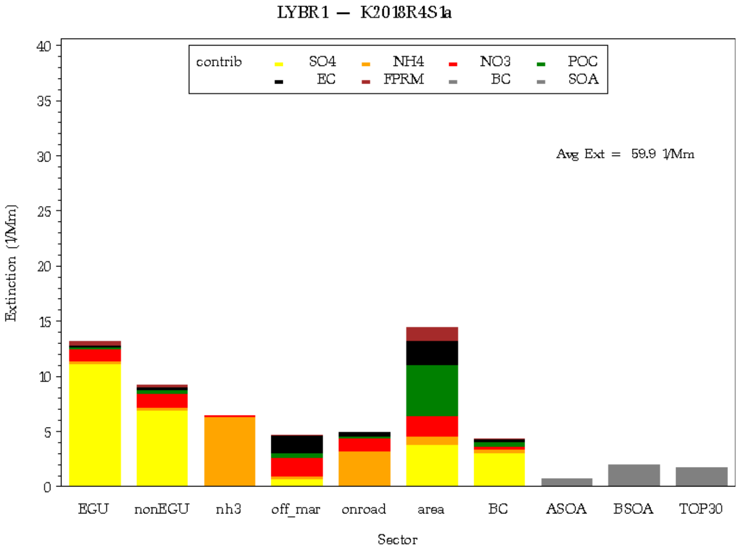
Lye Brook, Vermont

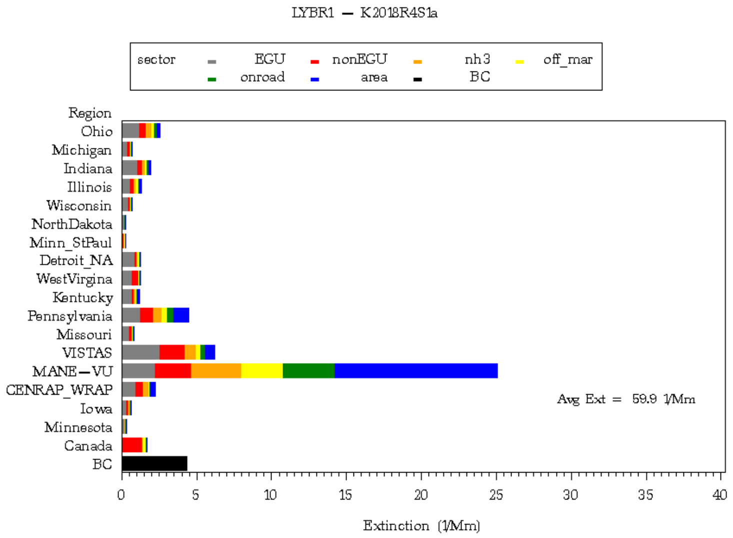
2005 (Round 5)





2018 (Round 4)





2018 (Round 5)