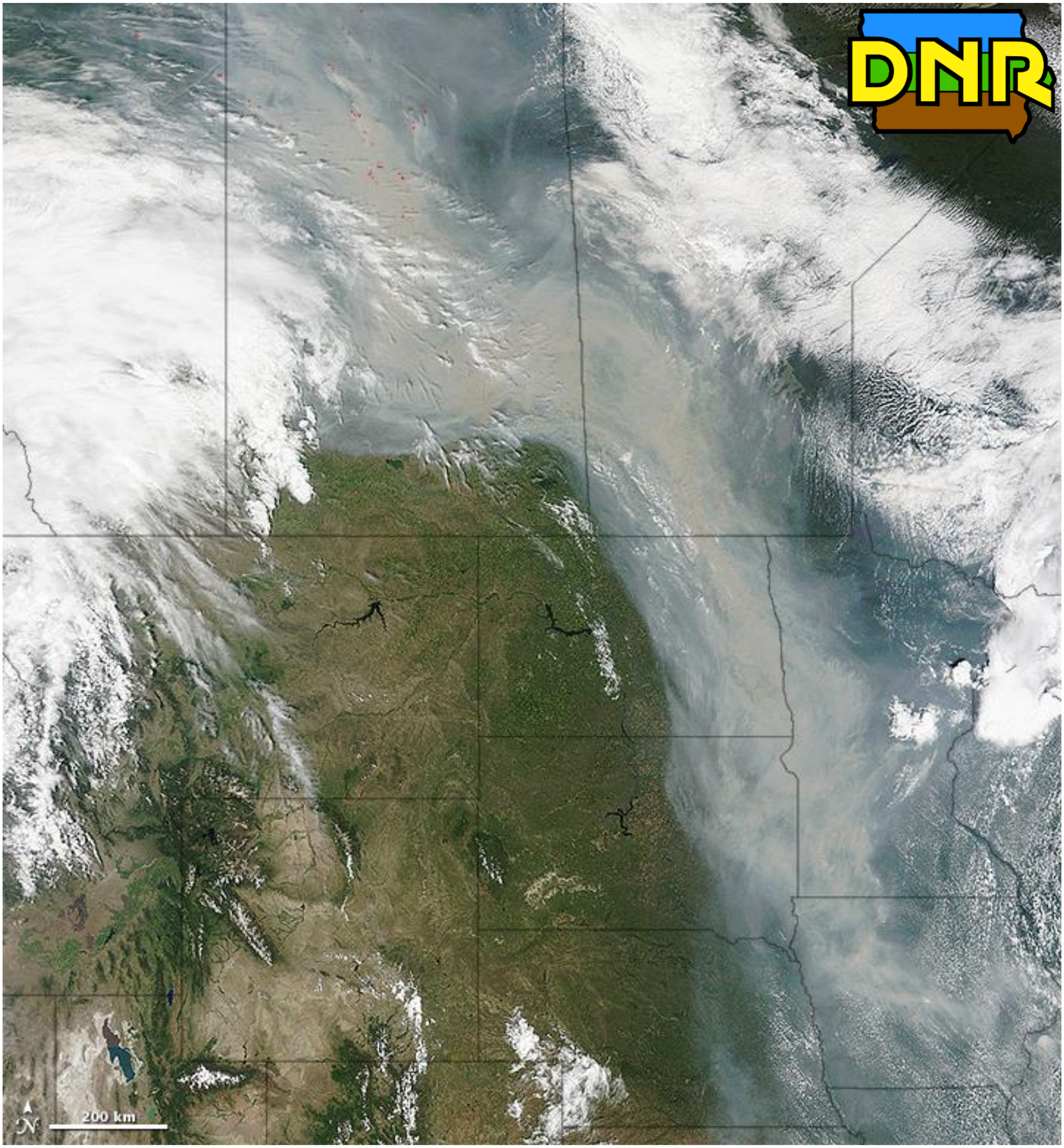
The Summer 2015 Canadian Wildfires and Smoke Transport into Iowa

Iowa Department of Natural Resources – Air Quality Bureau



MODIS imagery courtesy of NASA's Earth Observatory from June 29, 2015.

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I. Introduction

In late June and early July of 2015 smoke from a Canadian wildfire was transported into Iowa. This caused a series of days with hazy skies and copious amounts of smoke at the surface. Smoke can cause an assortment of health conditions depending on the amount and duration of exposure.

EPA has established health standards to limit ambient levels of seven common air pollutants—carbon monoxide (CO), nitrogen dioxide (NO_2), ozone, sulfur dioxide (SO_2), airborne lead, pariculate matter with an aerodynamic diameter of 10 microns or less (PM_{10}) and fine pariculate with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$). EPA regularly reviews these National Ambient Air Quality Standards (NAAQS) to incorporate the latest information from public health studies. Monitors that are accurate enough to implement the standards are designated as federal reference method (FRM) or federal equivalent method (FEM) monitors by EPA. Adverse health effects will be experienced by the public whenever pollutant levels exceed the thresholds established in the NAAQS.

Iowa operates a network of FRM $PM_{2.5}$ samplers that is complimented by a network of continuous beta-attenuation monitors (BAMs). Iowa's BAMs are not currently configured to exact FEM specifications, but they are accurate enough for hourly reporting of the Air Quality Index (AQI). While 24-hour average concentrations on the BAMs that are greater than or equal to 35.5 µg/m^3 signfies that the AQI has degraded to the point where sensitive groups can be negatively affected, it does not necessarily directly correlate to an exceedance on the FRM samplers[1]. Iowa also operates three CO monitors in the cities of Cedar Rapids, Des Moines and Davenport (Figure 1a-c). These monitors sampled a prolonged wildfire smoke episode over Iowa in late-June and early July.

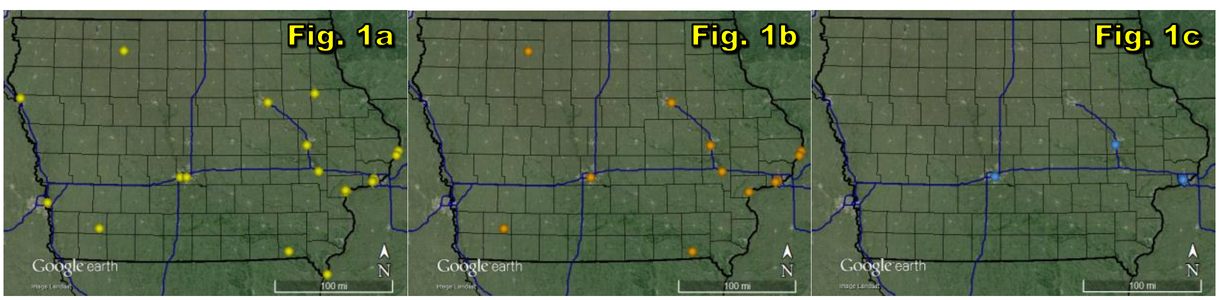

Figure 1a-c. Maps depicting the location of FRM samplers (1a), BAMs (1b) and CO (1c) monitoring sites.

II. Wildfire Smoke and Health Effects

Smoke generated from wildfires is comprised of a complex assortment of carbon dioxide, water vapor, carbon monoxide, particulates, hydrocarbons, nitrogen oxides, trace minerals and other organic compounds. The exact composition of the smoke depends on the type of material being burned and local meteorogical conditions.

Smoke is lofted high into the air by the heat produced. It can then be transported by winds to different locations. Depending on the current weather conditions, the smoke will cool and may rapidly descend or remain aloft. If it descends and reaches the surface, air quality will be negatively impacted even though it has dispersed as it traveled from its source.

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[1] A comparison of various BAMs and their collocated FRM samplers can be found at http://www.shl.uiowa.edu/env/ambient/bamfrm.xml

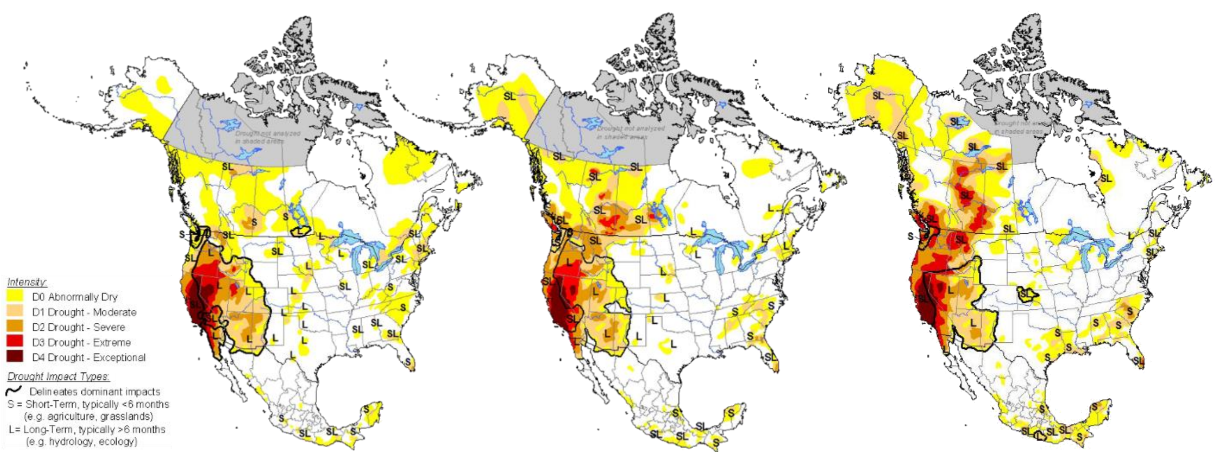
Transported smoke particles are typically very small and reside completely with the categorization of $PM_{2.5}$ and comprise much of the health concerns. Gaseous pollutants like CO tend to only pose concerns for those close to the fires. However, some elevated levels of CO may be observed at long distances from the fire. People can inhale these particles deeply into their respiratory systems. Effects of inhaling the smoke include respiratory tract irritation, reduced lung function, bronchitis, asthma attacks, persistent coughing, wheezing, dificulty breathing and premature death.

While the negative effects of the smoke is of greatest concern to small children, the elderly and those with pre-existing respiratory conditions, $PM_{2.5}$ in smoke can affect healthy people as well. Effects from the $PM_{2.5}$ in smoke can cause transient reductions in lung function, pulmonary inflammation, negative effects on the body's immune system and negatively affect the body's physiological processes to remove foreign material from the lungs such as pollen and bacteria. In addition to respiratory problems, smoke can also cause eye irritation.

The effects of wildfire smoke tend to fall within short-term exposure conditions and are unlikely to greatly increase the risk to chronic health conditions or cancer. Most healthy adults and children will recover quickly, but sensitive populations may see effects from wildfire smoke exposure that include more severe symptoms that persist longer. [2,3]

III. Meteorological Synopsis and Background

Spring 2015 in northern Canada saw below normal rainfall. The lack of rainfall was enough for areas of moderate to extreme drought to develop from May through July 2015 (Figure 2).[4] This caused many of the local forests to begin to dry out. The wildfire forecasts for the Northern Territories, Saskatchewan, British Columbia and Alberta called for an above-average fire danger in May and June.



May 2015 June 2015 July 2015

Figure 2. Monthly Drought Outlooks from the North American Drought Monitor.

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[2] Wildfire Smoke; A Guide for Public Health Officials. http://www.arb.ca.gov/carpa/toolkit/data-to-mes/wildfire-smoke-guide.pdf

[3] Fires and Your Health. http://airnow.gov/index.cfm?action=topics.smoke_events

[4] North American Drought Monitor. http://www.drought.gov/nadm/

Some early fires were spawned by abandoned campfires, grass burning, and lightning. NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) detected fires in Canada's Northwest Territories on May 28, 2015.[5] For the early fires, lightning strikes were responsible for nearly half of the 44 fires identified in Alberta.[6] Two days later more fires developed, and a few reached an intensity great enough to potentially generate up to five pyrocumulonimbus events (thunderstorms produced by heat from fires).[7] By July the dry conditions allowed fires in Saskatchewan to spread and one blaze had grown to five times the area of Saskatchwan's largest city of Saskatoon. Thousands of residents had to evaculate.[8]

Smoke from these fires first appeared in Midwest and eastern skies in early June (Figure 3). It is a relatively rare phenomenon to observe thick Canadian smoke over much of the Midwest and Ohio Valley.[9] A large closed low formed over the southern sections of the Hudson Bay. The location of the low coupled with an area of high pressure over the Rocky Mountains produced northwesterly wind flow from the Canadian wildfires into the Great Lakes (Figures 4a-4b). The smoke plume remained primary between altitudes of 7,000 to 16,000 feet. It had very little impact on surface air quality, but produced haze and vivid sunsets for many residents from Minnesota through the Great Lakes region. MODIS images were able to capture the smoke being transported from the fires in Canada to the Upper Midwest and Great Lakes. The fires continued to grow and intensify.

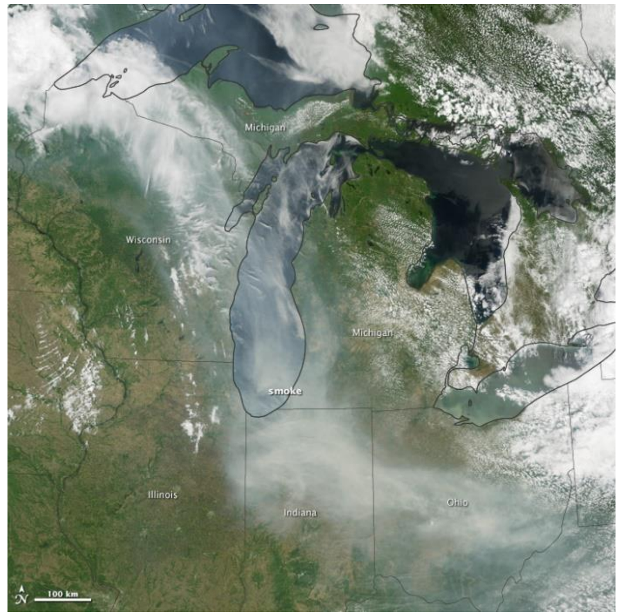


Figure 3. Smoke plume as is travels through the Great Lakes Region on June 9, 2015 as observed via MODIS.

[5] Intense Fires in Northern Canada. http://earthobservatory.nasa.gov/IOTD/view.php?id=85972
[6] Fires in Northern Canada. http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=85953&eocn=home&eoci=nh
[7] Multiple pyroCb events in Canada's Northwest Territories. http://pyrocb.ssec.wisc.edu/archives/518
[8] Wildfires raging in western Canada, with 1 larger than Saskatchewan's largest city. Minneapolis Star Tribune. http://www.startribune.com/wildfires-continue-to-rage-in-western-canada/313340461/
[9] Canadian Fires Send Smoke over the U.S. http://www.earthobservatory.nasa.gov/IOTD/view.php?id=86011

By the end of June, the prevailing meteorological pattern had shifted westward. This brought the smoke plume over Iowa. At 00 UTC on June 28, 2015 (Figure 5a) the mid and upper-level wind patterns had begun to line up over the regions of Canada experiencing robust wildfires so that smoke began to advect into the state from 850 mb up. By 00 UTC on June 29, 2015 (Figure 5b), the low-level winds lined up

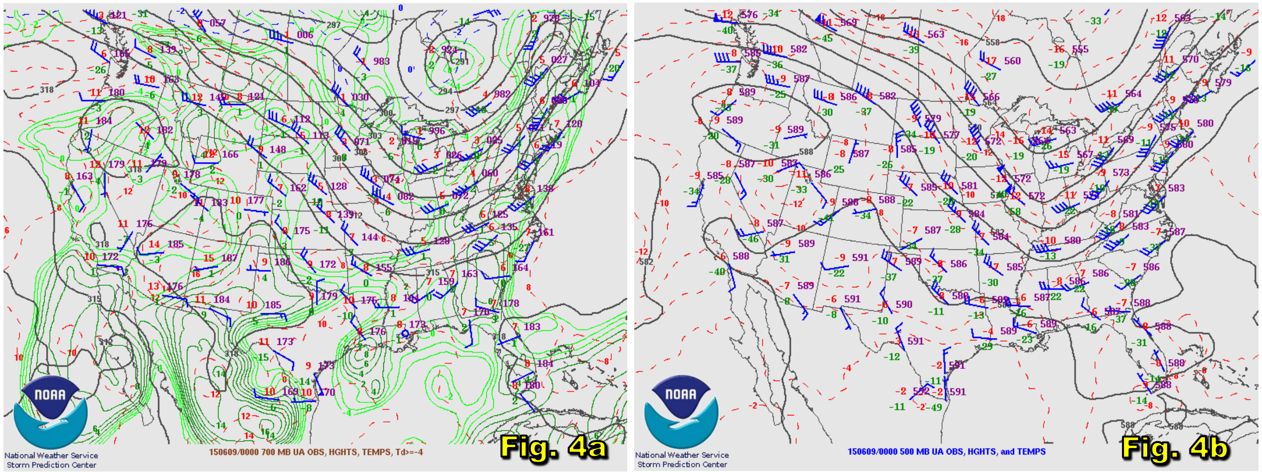


Figure 4a-b. 700 mb and 500 mb maps depicting winds and geopotential heights at 00 UTC on June 9, 2015.

coincident with the mid and upper-level winds. This produced a deep laminar northwesterly flow that began to transport smoke into Iowa.[10] This first wave of smoke continued to flow into Iowa through July 1, 2015. This was the first time period in which air quality levels in Iowa declined due to the smoke content in the air.

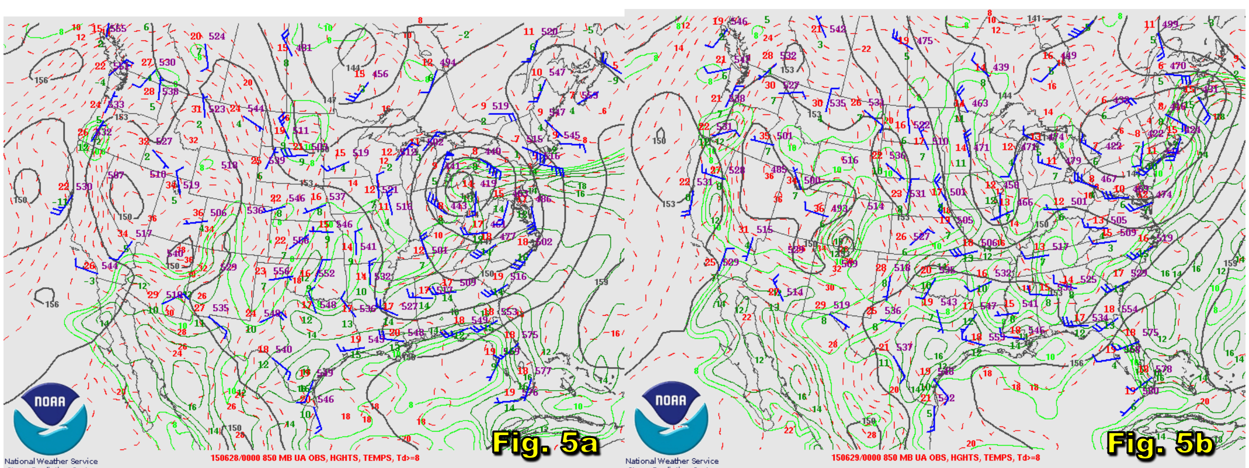


Figure 5a-b. 850 mb maps depicting wind, temperature and geopotential height at 00 UTC on June 28-29, 2015.

[10] Canadian Wildfires Produce River of Smoke. http://www.earthobservatory.nasa.gov/IOTD/view.php?id=86151

Smoke from the Canadian wildfires began to flow back into Iowa on July 3rd and remained in the state through July 7th as northwesterly flow re-established over the upper-Midwest. During this time $PM_{2.5}$ concentrations began to rise. The elevated levels of $PM_{2.5}$ coupled with smoke from Independence Day fireworks displays produced exceedances in two continuous $PM_{2.5}$ BAMs and one $PM_{2.5}$ filter sampler in the Davenport metropolitan area on July 4, 2015.

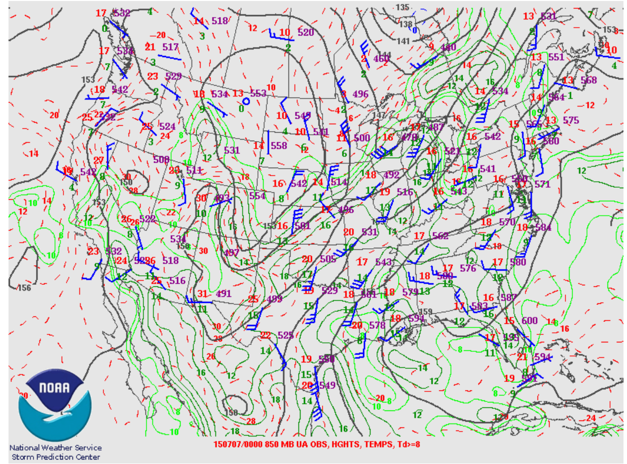


Figure 6. 850 mb map of winds, temperature and geopotential height at 00 UTC on July 7, 2015.

By 00 UTC July 7, 2015 (Figure 6) the passage of a cold front allowed the flow from 850 mb to the surface to return to a northwesterly pattern and more smoke began to advect into Iowa. Following the cold front a surface high settled into Iowa and greatly calmed the winds. This period of tranquil weather allowed the smoke particles to remain over Iowa. This decline in air quality was such that every $PM_{2.5}$ FRM filter sampler in Iowa recorded an exceedance on July 7, 2015, and ten of twelve BAMs recorded at least one exceedance of the $PM_{2.5}$ NAAQS on July 6th or July 7th.

The departure of the surface area high pressure and return of southerly and southwesterly flow pushed the smoke out of Iowa on July 8th. Ambient levels of $PM_{2.5}$ dropped as a result.

IV. Typical Iowa $PM_{2.5}$ and CO Values for June-July

$PM_{2.5}$ concentrations in Iowa have typically been lower in the summer months with no monitored exceedances of the 24-Hour NAAQS with the exception of smoke plumes from fireworks displays. The June-July period in 2015 (Figure 7) saw higher levels in late June and exceedances of the $PM_{2.5}$ 24-Hour NAAQS measured by the FRMs on July 7 with a network average concentration of 46.4 µg/m³. That is more than double the previous daily maximum network average concentration during June-July in 2012 through 2014.

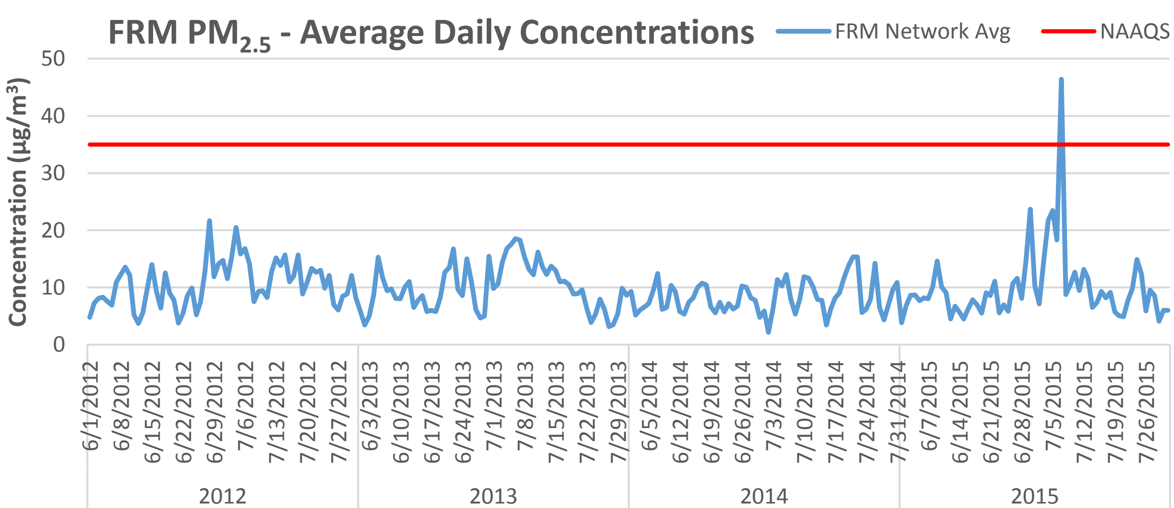


Figure 7. Daily $PM_{2.5}$ network averages in Iowa for June-July from 2012 through 2015.

Typical CO concentrations in Iowa also tend to be very lowCO has two NAAQS. The one-hour limit is 35,000 ppb,and the eight hour average limit is 9,000 ppb, and the maximum one-hour concentration for monitoring sites in Cedar Rapids, Des Moines and Davenport was 580 ppb with an overall average concentration for each site ranging from 191-196 ppb (Table 1).

Site Name	Maximum 1-Hour Concentration (ppb)	Average Concentration (ppb)
Cedar Rapids, Public Health	578.0	192.9
Des Moines, Health Dept.	532.0	196.1
Davenport, Jefferson School.	579.6	191.1

Table 1. CO concentrations for various Iowa sites for the time period of June – July 2015 (omitting the window between June 27 - July 8).

V. Elevated $PM_{2.5}$ and CO Levels From Canadian Wildfire Smoke

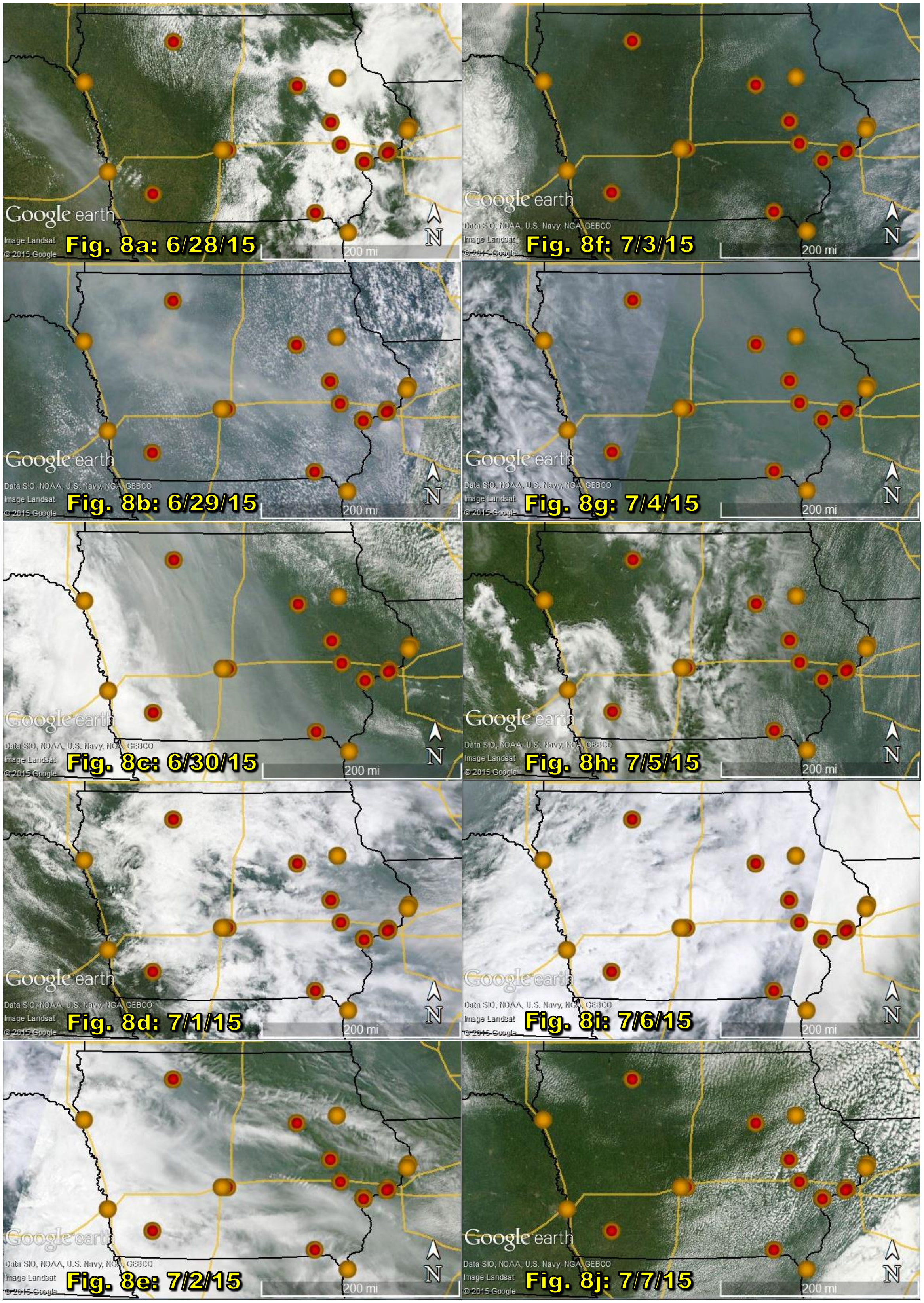
The dense smoke plume arrived in Iowa on June 29 from the northwest. It then spread across the state affecting monitors in northwestern Iowa first. No exceedances of the 24-hour $PM_{2.5}$ NAAQS (of 35 ug/m^3) due to wildfire smoke were recorded until July 6, 2015 when the wildfire smoke was again advected into Iowa. All the July 6, 2015 exceedances were recorded on the continuous BAM network. Both BAMs and FRM samplers recorded exceedances of the 24-hour $PM_{2.5}$ NAAQS on July 7, 2015 (Table 2). No exceedances of the one-hour or eight hour CO NAAQS were recorded on any day during the smoke's intrusion into Iowa. However, elevated levels of CO were observed that coincided with the rise in $PM_{2.5}$ concentrations.

Site Name	July 6, 2015		July 7, 2015	
	FRM (µg/m^3)	BAM (µg/m^3)	FRM (µg/m^3)	BAM (µg/m^3)
Waterloo, Water Tower	-	39.7	-	22.0
Clinton, Chancy Park	19.6	20.0	45.8	50.5
Clinton, Rainbow Park	16.2	15.7	46.3	53.5
Iowa City, Hoover School	18.8	18.7	45.3	47.1
Cedar Rapids, Public Health	23.0	22.0	36.3	40.1
Viking Lake State Park	-	28.7	-	9.5
Muscatine, High School E. Campus	16.0	14.1	50.3	52.1
Emmetsburg, Iowa Lakes CC	-	36.0	-	8.1
Des Moines, Heath Dept.	Missing	24.4	Missing	12.0
Davenport, Jefferson School	17.6	11.5	49.2	54.7
Davenport, Hayes School	16.8	14.7	51.8	58.0
Lake Sugema	-	13.8	-	61.8

Table 2. Daily concentrations for $PM_{2.5}$ monitors in Iowa on July 6-7, 2015.

Figures 8a through 8j show the progression of the smoke through Iowa along with relative locations of FRM (orange dots) and BAM (red dots) $PM_{2.5}$ monitoring sites from June 28, 2015 through July 7, 2015 via MODIS images that are overlayed in Google Earth. Many of these sites have collocated FRM and BAMs.

Generally the dense smoke appears as a gray color over the green surface. It is important to remember that even though the smoke looks dense on the satellite image, the surface $PM_{2.5}$ readings may not be elevated due to the smoke being trapped at an elevated altitude over a monitoring site. The satellite images convey how much smoke is present in a column of air over a point on the surface. Meteorological conditions also affect the ability to depict smoke from satellite images. Any smoke on July 1-2 and 5-7 is obscured by clouds.



Figures 8a-8j. Daily MODIS smoke imagerly displayed in Google Earth with $PM_{2.5}$ monitoring locations. Orange dots correspond to FRM sites. Red dots correspond to BAM sites.

Figure 9 shows the network average hourly concentration from BAM sites from June 26 through July 7, 2015. Smoke that was measureable at the surface first arrived on June 29th. Concentrations rose until July 1 and subsequently fell due to a change in wind direction. Levels began to rise again on July 4th through July 7th except for periods of rain observed on July 6th. Spikes in concentrations on July 3rd and July 4th are likely from fireworks displays. Thick smoke concentrations were prominent across Iowa from late in the afternoon on July 6th through July 7th.

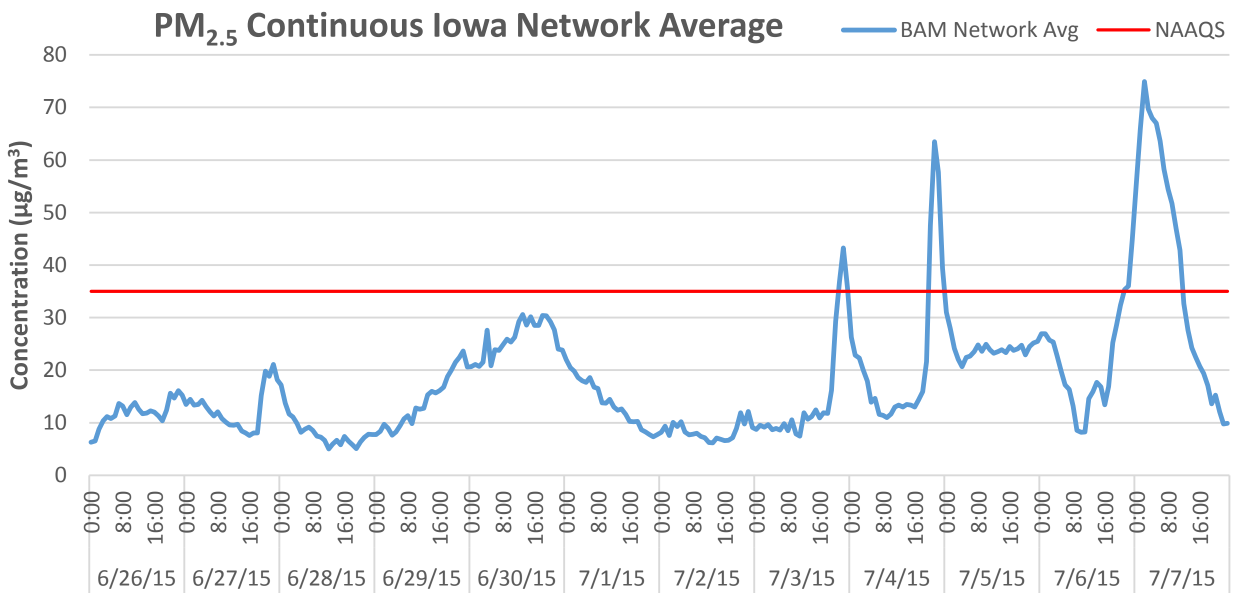


Figure 9. Hourly network average $PM_{2.5}$ concentrations recorded by BAM sites in Iowa.

Maps of the exceedances recorded by the $PM_{2.5}$ monitoring networks in Iowa are show in Figures 10a-10b and Figure 11. The maps with BAM concentrations (Figures 10a and 10b) show the thick surface smoke's southeasterly progression through Iowa with exceedances recorded in the northwestern and southwestern portions of the state on July 6 and July 7 respectively. The FRM map (Figure 11) has does not have concentrations for all locations. This is a result of the sampling schedules (one sample every three days) associated with each site.

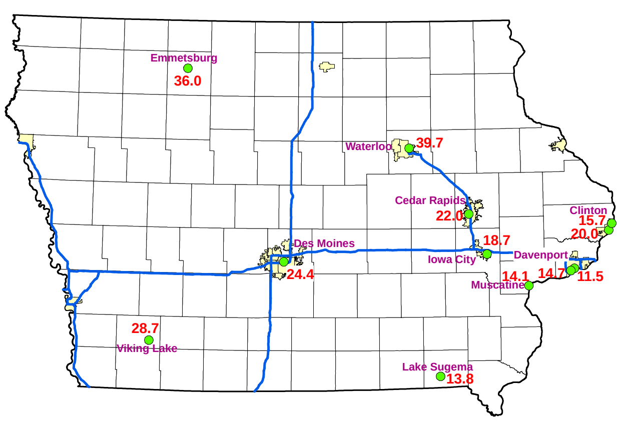


Figure 10a – July 6, 2015

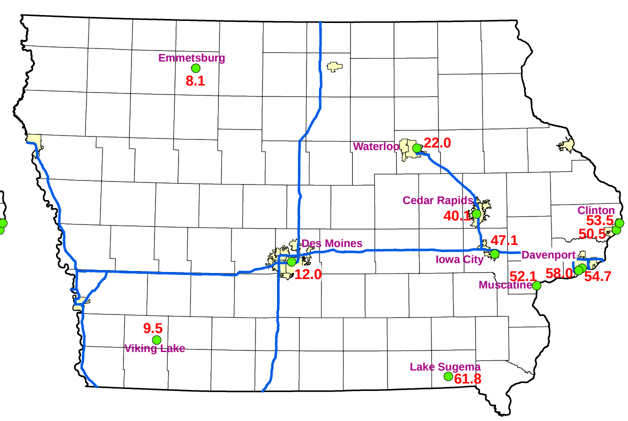


Figure 10b – July 7, 2015

Figures 10a-b. Daily average BAM concentrations (µg/m³). Exceedances are noted on both days.

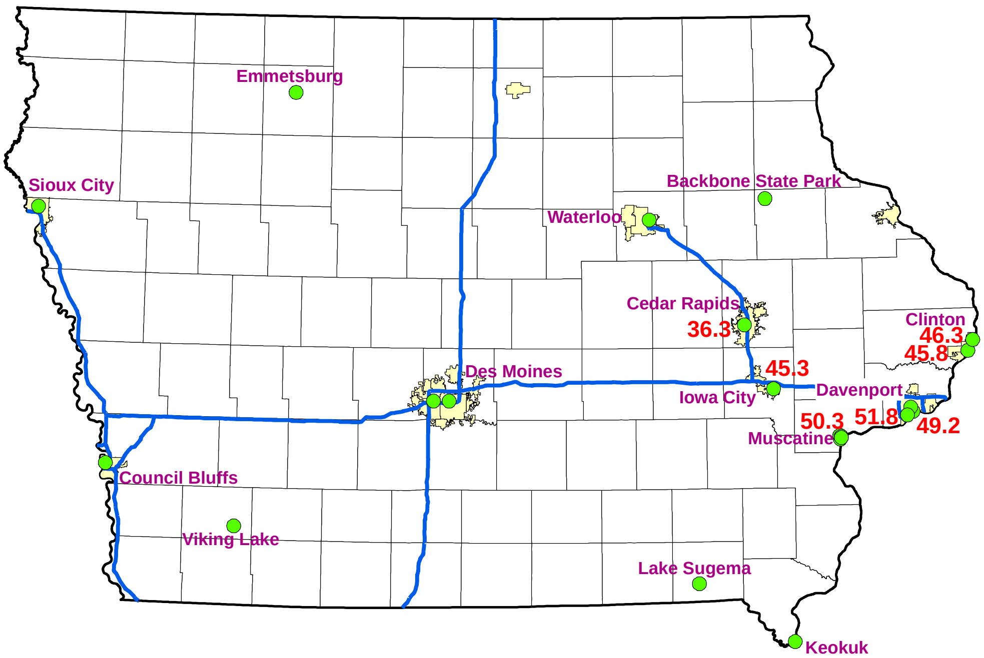


Figure 11. $PM_{2.5}$ concentrations measured by the FRM samplers on July 7, 2015. Not all sites have concentrations. This is typically due to the sampling schedule (e.g. blank sites take a sample once every three days). One daily sampling site in Des Moines did not report on July 7th due a collection error.

While no exceedances of any of the CO NAAQS were observed during the smoke's presence in Iowa, elevated levels of CO were detected by the analyzers in Cedar Rapids, Davenport and Des Moines. Maximum one-hour concentrations while the wildfire smoke was in Iowa were 820 ppb, 862 ppb and 748 ppb respectively. The elevated CO concentrations (one-hour network average) also tracked with the hourly $PM_{2.5}$ concentrations reported by BAMs (Figure 12). In the figure several spikes are noted in both $PM_{2.5}$ and CO that coincide with the smokes arrival in late June, fireworks on July 3rd and 4th and the smoke's return on July 6th.

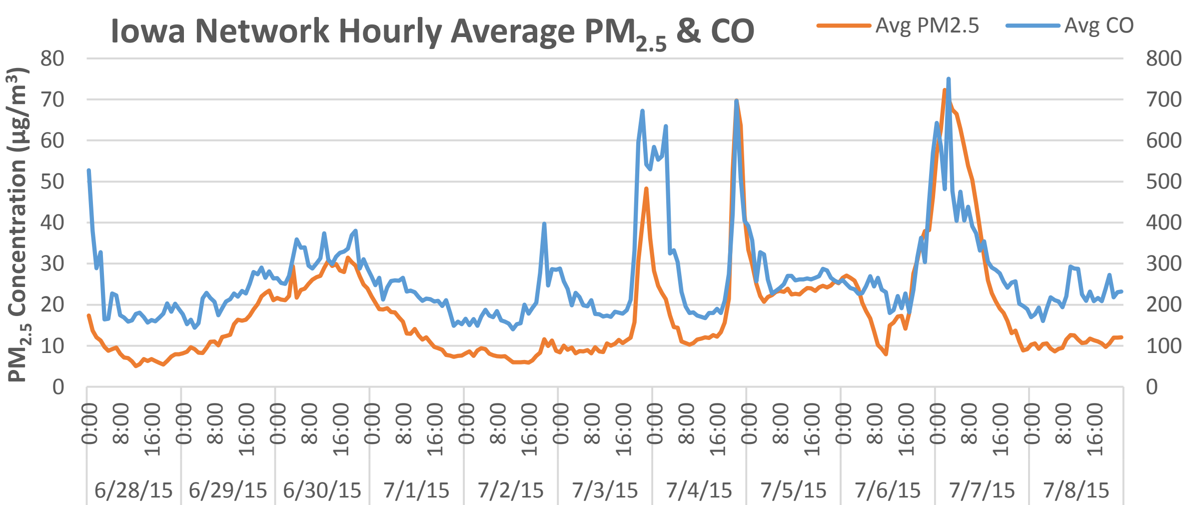


Figure 12. Hourly network average of continuous PM2.5 and CO. Spikes in both data are noted with the arrival of the wildfire smoke (June 29th, July 5th and July 6th) and fireworks (July 3rd and 4th).

VI. Conclusions

Thick smoke from wildfires in northern Canadian provinces and territories was carried south into the Great Lakes and Upper-Midwest in June and July. This negatively affected the air quality in Iowa as the smoke passed. Exceedances of the 24-Hour $PM_{2.5}$ NAAQS were noted at several sites across Iowa during this period. It is important to note that a daily exceedance does not constitute a violation of the 24-Hour $PM_{2.5}$ NAAQS.

VII. References

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North American Drought Monitor. http://www.drought.gov/nadm/