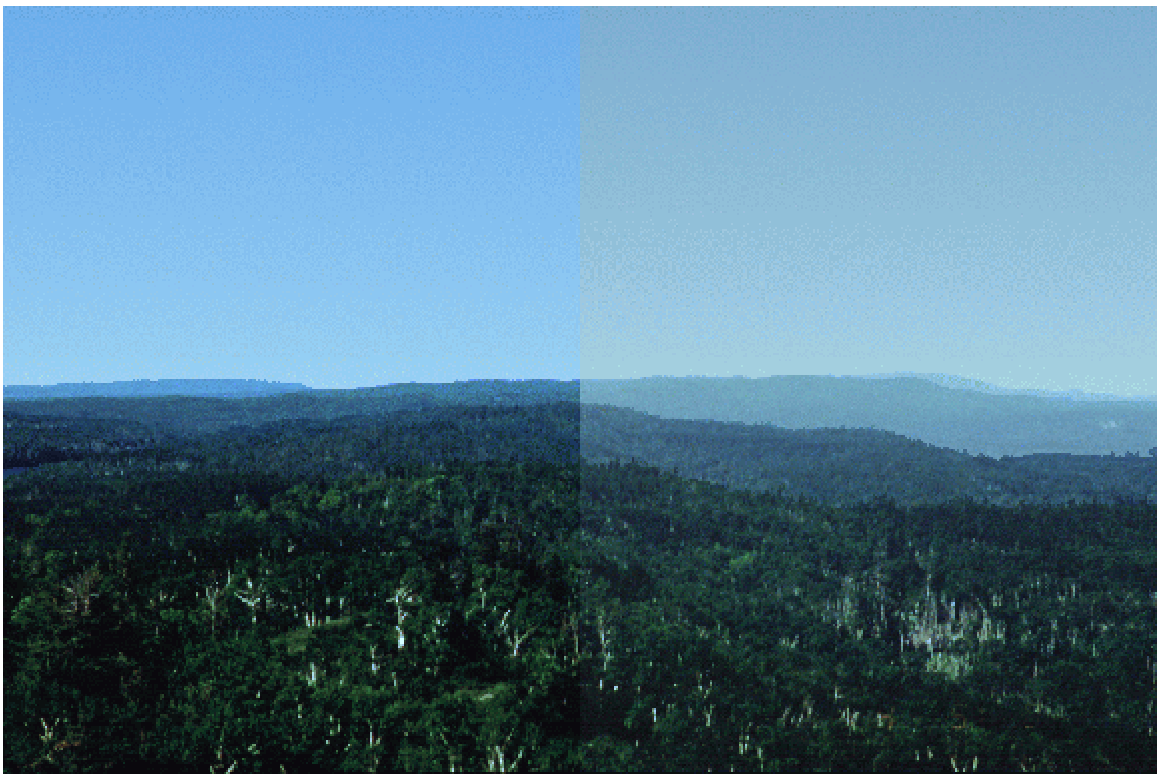
Regional Haze and Visibility in the Upper Midwest

Isle Royale National Park, MI

Visual Range = 194 km (deciviews = 7)

Visual Range = 53 km (deciviews = 20)



Midwest Regional Planning Organization
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Executive Summary

Visibility impairment due to regional haze is a problem affecting many areas throughout the United States (U.S.), especially national parks and wilderness areas. Average visual range in the eastern half of the U.S. is about 30 km (18 miles) as compared to estimated natural conditions of about 160 km (96 miles). Surveys have shown that visitors to national parks and wilderness areas consistently rank visibility and clear scenic vistas as one of the most important aspects of their experience.

To address this problem, section 169A of the Clean Air Act requires 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 mandatory Federal Class I areas across the country, including many well-known parks and wilderness areas, such as the Grand Canyon, Great Smokies, Shendandoah, Yellowstone, and Yosemite.

Given the effect of regional pollutant transport in contributing to haze in Class I areas, multi-state coordination is important. Several regional planning organizations have been formed, including the Midwest Regional Planning Organization (RPO), which is led by the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, and the tribes located in these five states. There are two Class I areas in the Midwest RPO region: Seney National Wildlife Refuge and Isle Royale National Park in northern Michigan.

An initial assessment of the regional haze problem in the upper Midwest (i.e., the five-state region covered by the Midwest RPO) was performed by reviewing existing reports and analyzing available air quality data. A major shortcoming of this assessment is the sparsity of visibility-related measurements in this region. In view of this deficiency, the findings reported here are considered to be preliminary. Further data collection and analyses are recommended to provide a more complete and detailed understanding of the regional haze problem in the upper Midwest.

The key findings of this initial assessment are as follows:

- Visibility impairment exists in the two Class I areas in the upper Midwest, in downwind Class I areas in the eastern half of the U.S., and in other areas (e.g., major urban areas in the five-state region). Although current conditions in the upper Midwest Class I areas approach "natural conditions" on the 20% best visibility days, they are significantly worse on the 20% worst visibility days. Fine particles, which play a major role in visibility impairment, also reach unhealthy levels across a large portion of the eastern U.S.

- Visibility levels and $PM_{2.5}$ concentrations vary...

- spatially, with better visibility and lower $PM_{2.5}$ occurring to the north (near Class I areas in the upper Midwest); and poorer visibility and higher $PM_{2.5}$ to south (near Ohio River Valley)

- seasonally, with the worst and best visibility days occurring throughout the year in the Class I areas in the upper Midwest; and the worst visibility days occurring during summer and best visibility during winter elsewhere in eastern U.S.

- chemically, with sulfates dominating on the worst visibility days during summer (note, organics are a distant second); and nitrates being important on worst visibility days during winter/fall (note, sulfates are also important and organics are a distant third)

(Note: these points suggest that the air quality situation in the Class I areas in the upper Midwest differs from that in other Class I areas in the eastern U.S.)

- Worst visibility days are associated with southerly-westerly flow for many sites in the eastern U.S., and the best visibility days with northerly flow.

- Poor visibility is related to elevated concentrations of fine particles and (during the summer) ozone.

- Visibility levels deteriorated during the last half century, but appear to be improving in recent years due to SO_2 emission reductions.

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Section 1
Introduction

For many years, visibility impairment has been considered the ‘‘best understood and most easily measured effect of air pollution.’’ (CEQ, 1978) Visibility impairment due to regional haze is a problem affecting many areas throughout the U.S., especially national parks and wilderness areas. In the eastern half of the U.S., the average visual range is only about 30 kilometers, which is about 1/5 of the visual range that would exist without manmade air pollution. While in the western U.S., the average visual range is 100–150 kilometers, or about 1/2 - 2/3 of the visual range that would exist under natural conditions.

The picture below shows Isle Royale National Park in northern Michigan on a good visibility day (left) and poor visibility day (right) (Air Resource Specialists, 1998). The milky-white discoloring seen in the image on the right is typical of regional haze. Surveys have shown that visitors to national parks and wilderness areas consistently rank visibility and clear scenic vistas as one of the most important aspects of their experience (NPS, 1988; NPS, 2000).

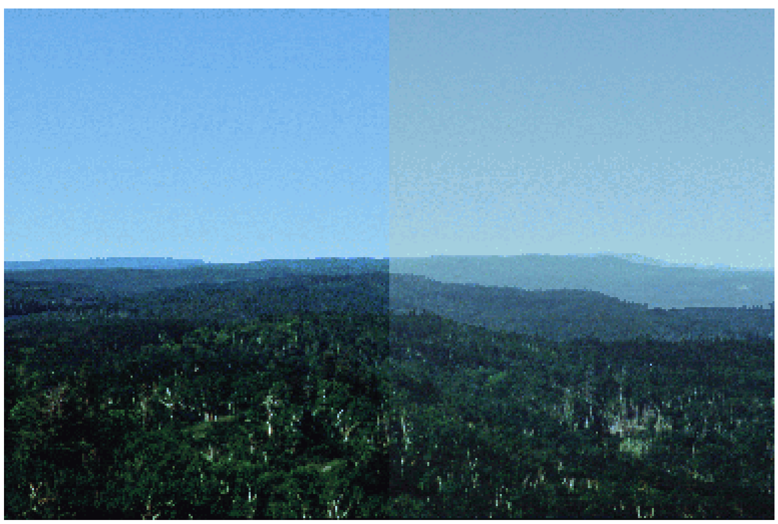

Figure 1. Isle Royale National Park on a Good (left) and Poor (right) Visibility Day

To address this problem, section 169A of the Clean Air Act requires 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 mandatory Federal Class I areas across the country (see Figure 2), including many well-known parks and wilderness areas, such as the Grand Canyon, Great Smokies, Shendandoah, Yellowstone, and Yosemite. There are two Class I areas in the upper Midwest: Seney National Wildlife Refuge (Wilderness Area) and Isle Royale National Park in northern Michigan. (Note: although Rainbow Lake in northern Wisconsin is also a Class I area, the Federal Land Manager [i.e., the U.S. Forest Service] has determined that visibility is not an air quality related value there.)

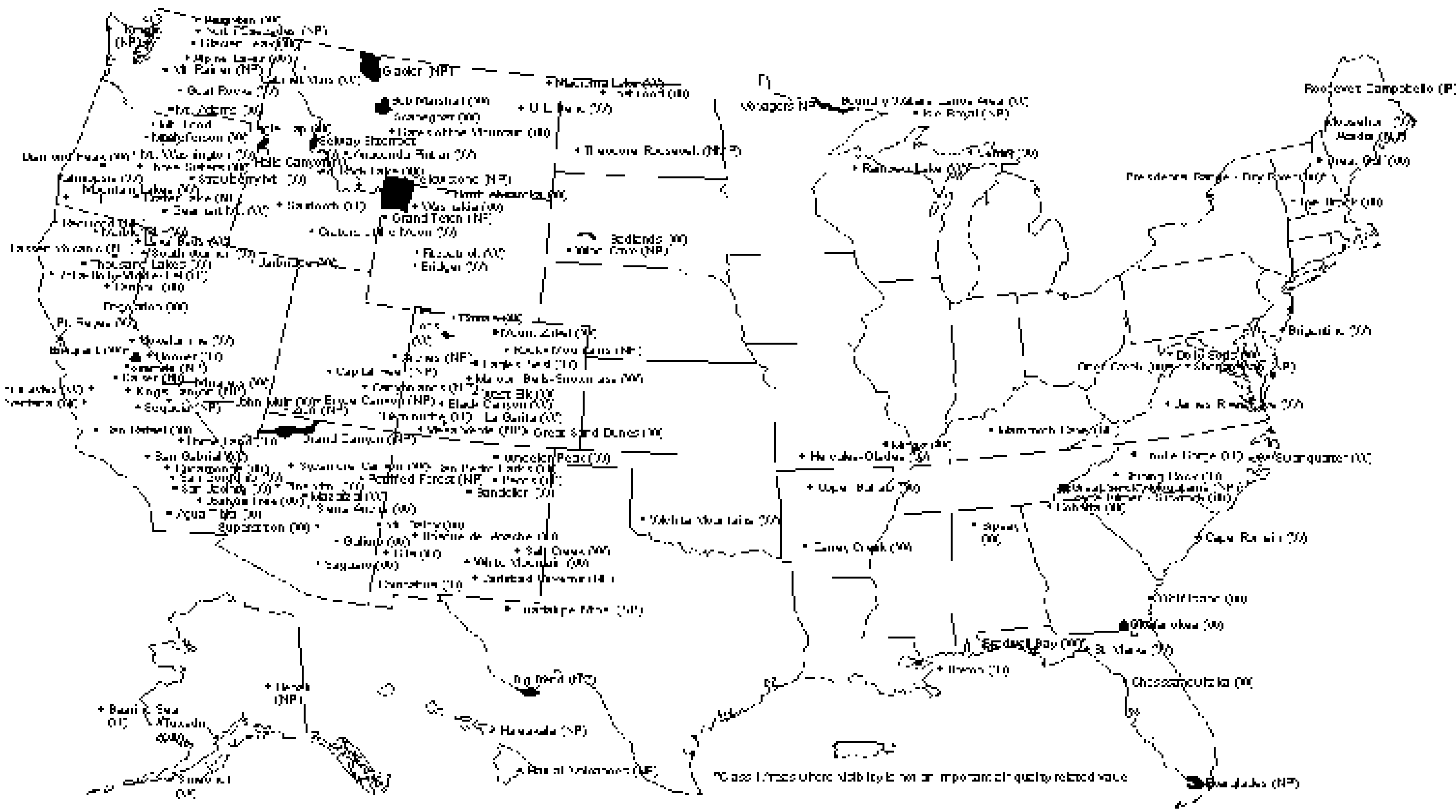

Figure 2. Map of 156 National Park and Wilderness Areas Protected by EPA's Regional Haze Rule

In 1980, the U.S. Environmental Protection Agency (USEPA) promulgated regulations to address visibility impairment that is ''reasonably attributable'' to one or a small group of sources (i.e., plume blight), but deferred action on regional haze regulations until monitoring, modeling, and scientific knowledge about the relationship between pollutants and visibility effects improved (45 FR 80086). 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.'' (NRC, 1993). As such, in 1999, USEPA promulgated regulations to address visibility impairment due to regional haze (64 FR 35714). Regional haze is visibility impairment caused by the cumulative air pollutant emissions from numerous sources over a wide geographic area.

Satellite imagery shows that hazy air masses (see, for example, Figure 3) can cover large portions of the eastern half of the U.S.

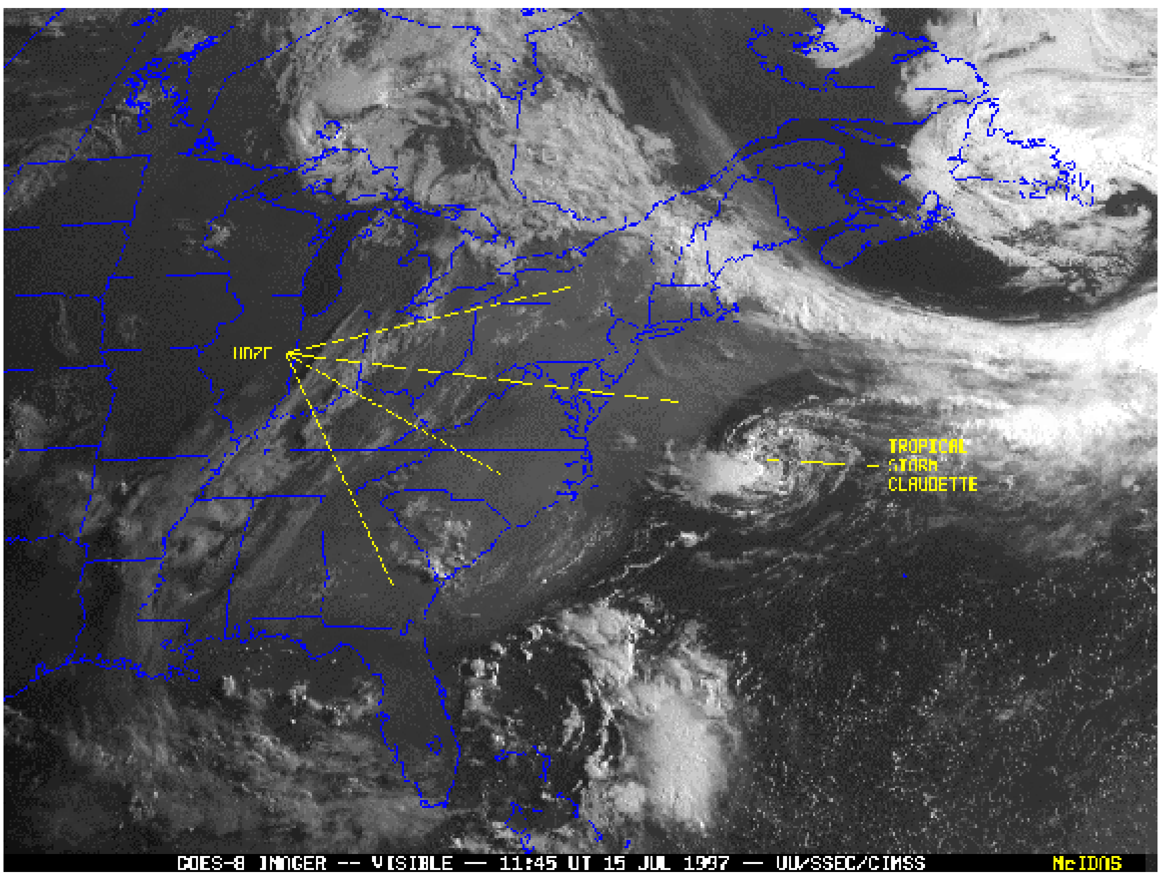

Figure 3. Satellite Imagery of Eastern U.S. Showing Widespread Regional Haze

Given the effect of regional pollutant transport in contributing to haze in Class I areas, multi-state coordination is important. Five regional planning organizations were identified by USEPA to receive grant funds to implement these regulations (see Figure 4). The Midwest Regional Planning Organization (RPO) is led by the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, and the tribes located in these states. Federal Land Managers (FLMs), USEPA, and stakeholders also participate in the regional planning process. The Lake Michigan Air Directors Consortium (LADCO) coordinates the activities of the Midwest RPO.

Figure 4. Regional Planning Organizations for Regional Haze

The purpose of this report is to provide an initial assessment of the regional haze problem in the upper Midwest (i.e., the five-state region covered by the Midwest RPO). A major shortcoming of this assessment is the sparsity of visibility-related measurements in this region. In view of this deficiency, the results reported here are considered to be preliminary. (Note, as discussed later, efforts are currently underway to establish a sufficient monitoring network.)

Section 2 provides an overview of regional haze, including an explanation of what is regional haze and how it impairs visibility, and a summary of the metrics and parameters used to assess visibility impairment. Section 3 describes the regional haze problem in the upper Midwest, including the spatial and temporal pattern of fine particle concentrations and visibility levels. Section 4 presents information about how visibility levels have changed over time. Finally, Section 5 summarizes the key findings based on this initial assessment.

Section 2
Regional Haze Overview

Visibility impairment comes in a variety of forms:

- Plume blight caused by local smokestacks

Figure 5. Visible Plume from Mohave Power Plant near Laughlin, Nevada

- A dirty low-lying inversion layer

Figure 6. "Brown Cloud" over Boston (January 21, 1999)

C A milky or brown regional haze blanketing the view in all directions

Figure 7. Hazy Conditions in Great Smoky Mountains National Park in Tennessee/North Carolina

Each of these forms of visibility impairment is a function of the nature and source of emissions, and the prevailing meteorological conditions. With stable atmospheric conditions and large, local emission sources, plumes and layered hazes are likely to occur. Regional haze occurs under meteorological conditions favorable for regional transport. It should be noted that plumes, layered haze, and regional haze differ from the clouds and fog on a rainy day, and instead are manmade impediments to visibility. For regulatory purposes, USEPA distinguishes between visibility impairment due to plume blight and due to regional haze, because emissions over a wide region are more diffuse and less easy to attribute to specific sources.

Visibility Impairment

Visibility impairment occurs as a result of the scattering and absorption of light by air pollution, including particles and gases. In addition to limiting the distance that we can see, the scattering and absorption of light caused by air pollution can also degrade the color, clarity, and contrast of scenes.

To understand visibility impairment, it is important to understand the nature of light and how the human eye functions. The human eye recognizes a spectrum of colors from blues with a wavelength of about 0.4 micrometers (um) to reds with a wavelength of 0.7 um. We perceive a rose to be red because it absorbs all of the wavelengths in the visible spectrum except for those around 0.7 um, and we perceive a (blue) butterfly to be blue because it absorbs most of the visible spectrum except for those wavelengths around 0.4 um. The same process of *differential absorption and reflection of light* occurs with visibility impairment:

- A low-lying brownish layered haze caused by nitrogen dioxide emissions appears brown because nitrogen dioxide absorbs blue light and reflects back to us the remainder of the spectrum.

- A dark plume coming from a smokestack appears black because the carbon soot and other emissions absorb all of the visible spectrum.

- A white plume of water vapor coming from a power plant's cooling tower appears white because it absorbs none of the incoming light and simply scatters and reflects back the full spectrum to the eye.

Particles about the same size as the visible spectrum (0.4 - 0.7 um) are the most efficient at scattering light. Both primary emissions and secondary formation of particles contribute to visibility impairment. "Primary" particles, such as dust from roads or elemental carbon (soot) from wood combustion and diesel exhaust, are emitted directly into the atmosphere. Elemental carbon is black because it absorbs light. "Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfate, formed from sulfur dioxide (SO_2) emissions from power plants and other industrial facilities; and nitrates, formed from nitrogen oxides (NO_x) emissions from power plants, automobiles, and other types of combustion sources. Humidity can significantly increase the effect of pollution on visibility. Some particles, such as sulfates, accumulate water and grow in size, becoming more efficient at scattering light and causing visibility impairment.

A key factor in the formation of secondary particles is ammonia, which is emitted by livestock waste, fertilizer application, and soils. Across the Midwest, there is an abundance of ammonia emissions from these sources. Sulfate and nitrate compete for the available ammonia, with ammonia preferentially reacting with sulfate to form ammonium sulfate particles. Given the large amount of SO_2 emissions in the eastern half of the U.S., it is, therefore, not surprising that sulfate particles dominate the inorganic aerosol in this part of the country.[1]

Visibility Metrics

Visibility conditions are expressed in terms of three mathematically related metrics: visual range, light extinction, and deciviews.

Visual range is the metric best known by the general public. It is the maximum distance at which one can identify a black object against the horizon, and is typically described in

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[1] Note, as SO_2 emissions are reduced and the concentration of sulfate aerosol decreases, the available ammonia may react with gas-phase nitric acid to form ammonium nitrate particles. It is, therefore, possible that in some areas under certain conditions the net effect of SO_2 emissions reductions is an increase in $PM_{2.5}$ concentrations (West, et al, 1999).

miles or kilometers. Higher visual range estimates mean better visibility. While the theoretical maximum is 391 kilometers on a perfectly clear day, this is never achieved due to the natural scattering of light by gases in the atmosphere, so-called Rayleigh scattering[2]. While visual range is a simple measure that can be easily used to characterize visual conditions, it is somewhat imprecise and cannot be used to effectively determine the relative importance of the contributors to reduced visibility.

Light extinction is a somewhat better alternative than visual range because it allows one to express the relative contribution of particulate matter constituents to overall visibility impairment. Light extinction is the sum of the light scattering and light absorption by particles and gases in the atmosphere (including Rayleigh scattering), and is measured in inverse megameters (Mm^{-1}), which relate how much light is extinguished per megameter. Higher extinction values mean worse visibility. For example, in Shendandoah National Park, a relatively clear day has an extinction of 33 Mm^{-1} and a visual range of 118 kilometers, and a hazy day has an extinction of about 177 Mm^{-1} and a visual range of 22 kilometers.

The following equation is used to estimate "reconstructed" light extinction:

$$b_{ext}\ (Mm^{-1}) = b_{so4} + b_{no3} + b_{OC} + b_{soil} + b_{coarse} + b_{EC} + b_{Ray}$$

b_{so4} = 3 [$(NH_4)_2SO_4$] x f(RH)
b_{no3} = 3 [$(NH_4NO_3$] x f(RH)
b_{OC} = 4 [OC]
b_{soil} = 1 [soil]
b_{coarse} = 0.6 [coarse mass]
b_{EC} = 10 [EC]
b_{Ray} = 10 Mm^{-1}
f(RH) = relative humidity scattering enhancement factor (Tang, 1996)
[ ] = concentration in ug/m^3

Light extinction is related to visual range (VR) by the following equation:

$$b_{ext}\ (Mm^{-1}) = 3912 / VR(km)$$

Deciview index, which USEPA selected as the standard metric for tracking progress in the regional haze program, provides a linear scale for perceived visual changes over the entire range of conditions. For each 10 percent increase in light extinction, the deciview index goes up by one. Higher deciview values mean worse visibility. Under many scenic conditions, a change of one deciview is considered to be just perceptible

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2 Rayleigh scattering is light scattering by individual air molecules. Scattering by these "small" air molecules is greater for shorter (blue) light wavelengths than longer (red) light wavelengths. This greater scattering of blue light explains why the sky is blue.

by the average person. The deciview index in Shenandoah National Park on a relatively clear day is about 12 and on a relatively hazy day is about 29.

The following equation is used to calculate deciviews based on light extinction:

$$dv = 10\ \ln(b_{ext}/10\ Mm^{-1})$$

The plot below compares the three visibility metrics (Malm, 1999):

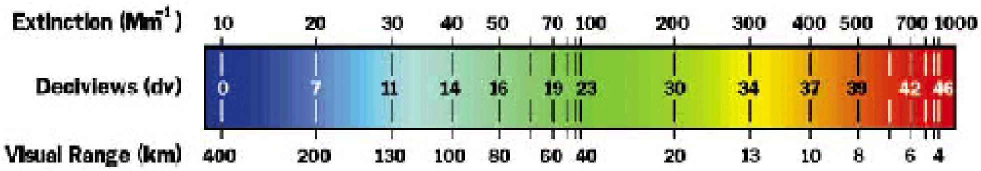

Figure 8. Scale Showing Visibility Metrics

It is worth noting that the same amount of pollution can have dramatically different effects on visibility depending on existing conditions. Most importantly, visibility in cleaner environments is more sensitive to increases in particle concentrations than visibility in more polluted areas. As a result, more emission reductions are needed in dirty areas than in clean areas to achieve a given level of improvement.

Tracking Visibility

To facilitate tracking progress toward the national visibility goal, three visibility parameters must be considered:

> Baseline Conditions - Baseline conditions represent visibility expressed in deciviews for the “least impaired days” (20% of monitored days with the lowest light extinction values)[3] and the “most impaired days” (20% of monitored days with the highest light extinction values) for the 5-year period 2000 - 2004,

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[3] To calculate the visibility metrics for these days, it is necessary first to sort the days into the appropriate subgroups (e.g., top 20%), and then to calculate average values for each subgroup. This sorting should be based on reconstructed light extinction. For both the sorting and the calculation of average values, missing values must be dealt with. At the time this analysis was performed, the draft USEPA guidance for tracking progress and calculating baseline conditions recommended calculating light extinction for a day with missing values by substituting first the 10th percentile value for the missing species (in assessing most impaired conditions) and then the 90th percentile (in assessing least impaired conditions. If the day with the substituted value makes either of these subgroups (20% most impaired or 20% least impaired), then the resulting light extinction value for that day is used in calculating the average values for the subgroup. Although a somewhat different approach for dealing with missing values is included in the latest version of this draft guidance (USEPA, 2001a), this should not significantly alter the findings reported here.

according to the regional haze regulations. The baseline value is determined by calculating the average deciview values for the 20% most (or least) impaired days for each of the five years (2000 - 2004), and then averaging those five values.

Natural Conditions - Natural conditions, or the visibility conditions that would be experienced in the absence of human-caused impairment, constitute the ultimate goal of the regional haze program. Natural conditions need to be estimated for the 20% best and 20% worst days. Draft USEPA guidance suggests that, as a starting point, it is appropriate to derive **regional** estimates of natural visibility conditions by using annual average estimates of natural levels of visibility-impairing pollutants (sulfate, nitrate, organic carbon, elemental carbon, and crustal material) and annual average relative humidity (USEPA, 2001b):

$$b_{ext}\ (Mm^{-1}) = b_{so4} + b_{no3} + b_{OC} + b_{soil} + b_{coarse} + b_{EC} + b_{Ray}$$

b_{so4} = 3 $[(NH_4)_2SO_4]$ x f(RH) = 3 [0.2 ug/m^3] x f(RH)
b_{no3} = 3 $[(NH_4NO_3]$ x f(RH) = 3 [0.1] x f(RH)
b_{OC} = 4 [OC] = 4 [1.5]
b_{soil} = 1 [soil] = 1 [0.5]
b_{coarse} = 0.6 [Coarse Mass] = 0.6 [3.0]
b_{EC} = 10 [EC] = 10 [0.02]
b_{Ray} = 10 Mm^{-1}
f(RH) = 2.89 (Isle Royale) and 3.31 (Seney) - based on SAIC (2001)

b_{ext} = 22.1 (Isle Royale) and 21.5 (Seney) Mm^{-1}
VR = 177 (Isle Royale) and 182 (Seney) km
dv = 7.47 (Isle Royale) and 7.64 (Seney)

Based on this "simple" approach, annual average natural conditions are about 7.5 deciviews. Analyses by Ames and Malm (2000) showed that natural background visibility can be characterized by a normal distribution with a standard deviation of about 3 in the eastern half of the U.S. Thus, the 90th (10th) percentile value can be estimated adding (subtracting) 1.28 x standard deviation to the annual average. Consequently, regional estimates of natural visibility conditions for the 20% worst and 20% best days for the two Class I areas in the upper Midwest are about 11.3 and 3.7 deciviews, respectively.

Because current conditions at most Class I areas exceed the above estimates by several deciviews, USEPA does not believe that refined **site-specific** estimates are necessary for the initial regional haze planning. As the difference between current and natural conditions for a particular Class I area becomes smaller, it will be important to develop more precise techniques for estimating natural conditions.

Current Conditions - Current conditions for the 20% best and 20% worst days are calculated from a multi-year average, based on the most recent years of monitored data. These values would be revised at the time of each periodic SIP revision, and would be used to illustrate: (1) the amount of progress made since the last SIP revision, and (2) the amount of progress made from the baseline period of the program. Similar to the determination of baseline conditions, current conditions are to be estimated by calculating the average of the 20% least impaired days and the 20% most impaired days for each of the five most recent years for which quality-assured data are available, then by averaging those five values.

Measuring Visibility

Ambient air quality measurements, which are used to assess baseline and current conditions, are available from the IMPROVE and CASTNet monitoring networks.

In 1987, the Interagency Monitoring of Protected Visual Environments (IMPROVE) network for national parks and wilderness areas was established as a cooperative effort between USEPA, states, National Park Service, U.S. Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service (CSU, 2000). The network is designed to establish current visibility and aerosol conditions; identify chemical species causing visibility impairment; and document long-term trends for assessing progress toward the national visibility goal. The network is the largest in the country devoted to fully characterizing visibility. The network includes three types of measurements:

- aerosol - a four-module sampler to provide species concentrations of sulfates, nitrates, organic carbon, elemental carbon, crustal material, fine particle ($PM_{2.5}$) mass, and PM_{10} mass for a 24-hour period on a 1-in-3 day schedule

- optical - transmissometer (or nephelometer) to provide continuous data on light extinction (or scattering) (note: relative humidity is also measured continuously at the optical measurement sites)

- scene - cameras to document visual characteristics

In 1999, there were 33 sites in the IMPROVE network, plus 40 additional sites. (Note, these additional sites are referred to as IMPROVE-protocol sites because even though they are not located in a Class I areas, they are operated with the same instrumentation and procedures as the IMPROVE sites.) USEPA is currently expanding the network to include 110 IMPROVE sites, plus 33 IMPROVE-protocol sites (see Figure 9).

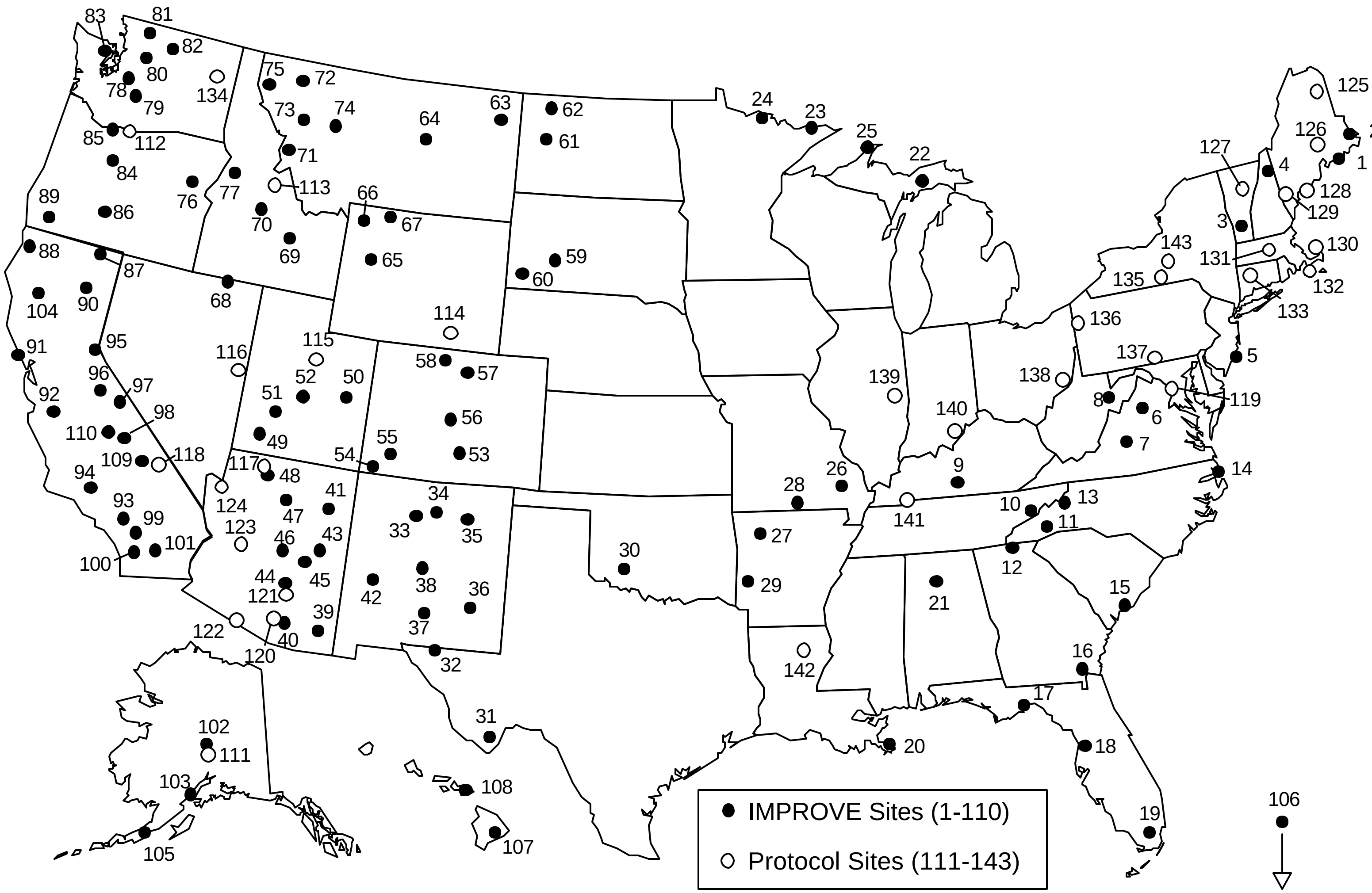

Figure 9. Expanded IMPROVE Network (2000)

Pursuant to the Clean Air Act Amendments of 1990, USEPA established the Clean Air Status and Trends Network (CASTNet) to determine relationships between emissions, air quality, deposition, and ecological effects (USEPA, 2001c). This network became operational in mid-1991. In October 1993, speciated aerosol measurements were added at eight sites (see Figure 10). Aerosol sampling started out on a 1-in-3 day schedule, but converted to a 1-in-6 day schedule in August 1994. All sampling was discontinued in November 1995, but resumed in July 1996. Optical measurements are also available at two sites since October 1996, but there is no scene (camera) monitoring since operations resumed in 1996. Aerosol sampling at these CASTNet sites is conducted using similar procedures as those at IMPROVE sites, except for the lack of coarse particle measurements.

Figure 10. CASTNet Aerosol Sites

An obvious limitation of the IMPROVE and CASTNet networks is the sparsity of sites across the upper Midwest. It is, therefore, important to consider additional information from two recent measurement programs. First, the MARCH-Midwest study collected speciated aerosol data at several sites in the Midwest for the periods August - September 1999 and January - February 2000 (see Figure 11) (EPRI, 2000).

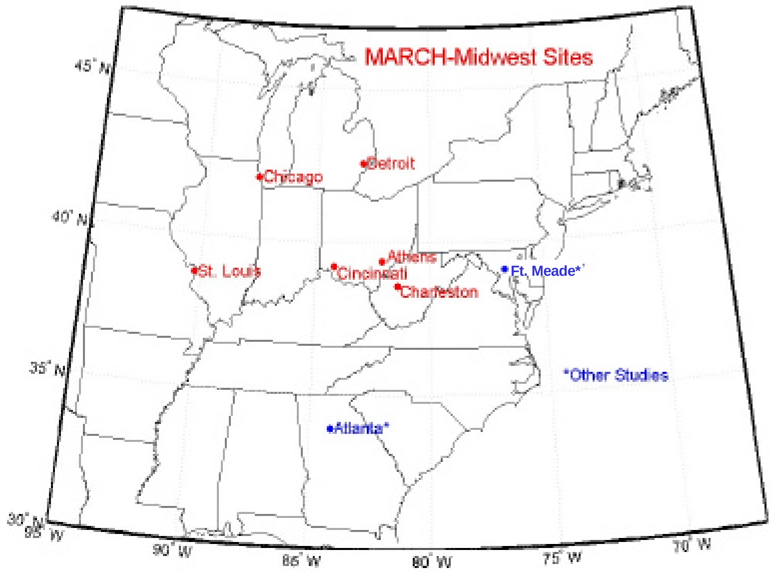

Figure 11. MARCH-Midwest Sampling Sites

This measurement program consisted of the following 24-h integrated sampling:

- •FRM $PM_{2.5}$ mass
- •PM_{10} mass
- •HEADS (Harvard-EPA Annular Denuder Sampler)
- •SO_4^{2-}, NO_3^-, NH_4^+, and acidity from filters
- •SO_2, HNO_3, NH_3, HONO from denuders
- •Undenuded quartz filter carbon sampler
- •Analyzed by TOR (Thermal-Optical Reflectance
- •Elemental and organic carbon
- •Organic compounds estimated as OC x 1.4
- •PM_{10} and $PM_{2.5}$ elements (by XRF)
- •Upper air meteorology at Cincinnati in summer

Second, the filters for 12 $PM_{2.5}$ monitors (7 urban and 5 rural) located throughout the Midwest RPO States (see Figure 12) were analyzed for 24 high, medium, and low concentration days for the period April 1999 - March 2000 (RTI, 2000).

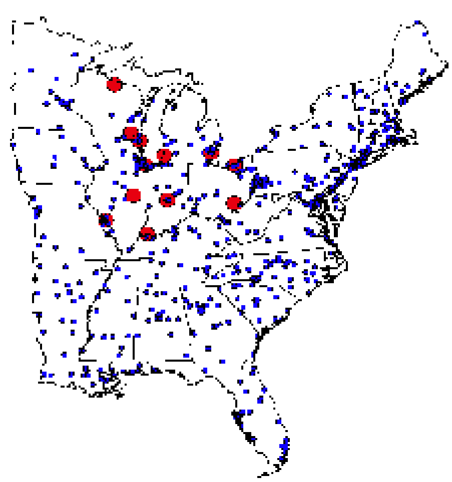

Figure 12. FRM Monitor Locations

The 12 sites are as follows:

IL:	Chicago, SE Police (170310050)	Urban (U)
	Granite City (171191007)	U
	Bondville (170191001)	Rural (R)
IN:	Indianapolis, School #90 (180970081)	U
	Evansville (181630016)	U
MI:	Detroit, Allen Park (261630001)	U
	Coloma (260210014)	R
OH:	Cleveland, St. Tikhon St. (390350038)	U
	Gifford St. Forest (390090003)	R
WI:	Milwaukee, 16th&Greenfield (550790010)	U
	Mayville (550270007)	R
	Boulder Junction (551250001)	R

The sampling days selected for analysis are as follows:

			High Conc	Med. Conc	Low Conc
1999	Quarter 2:	April			
		May		3,15	24
		June	11,23		17
	Quarter 3:	July		5	11
		Aug	28	22	
		Sept	3		21
	Quarter 4:	Oct	30	9	
		Nov			2
		Dec		2, 8	5
2000	Quarter 1	Jan	1 *(extra)*	31	4
		Feb	9		27
		Mar	22	7	

(Note: the results of the filter analyses will be reported in a separate document.)

To fill the void in the visibility monitoring network across the upper Midwest, the following monitoring activities will be undertaken:

- USEPA' s Clean Air Markets Division, which operates the CASTNet network, converted the eight aerosol CASTNet sites to IMPROVE sites in 2001. (Note, these sites are identified as IMPROVE protocol sites in Figure 9.) A special study will be conducted to compare the CASTNet and IMPROVE measurements.

- Three new IMPROVE sites will be established in MN.

- The Region V States' $PM_{2.5}$-speciation monitoring networks will include several rural/transport sites: Luna Pier, MI; Houghton Lake,MI; and Mayville, WI; and Perkinstown, WI. A special study will be conducted to compare the speciation and IMPROVE measurements.

- Two "supersites" will be established (one by the State of Wisconsin in Mayville, WI, and one by the State of Michigan in the Seney National Wildlife Refuge) with the following measurements: light extinction coefficient (nephelometer), filter-based and/or continuous $PM_{2.5}$ mass, speciated $PM_{2.5}$, and meteorology.

- A visibility camera network will be established in the upper Midwest to provide qualitative information about visibility (www.mwhazecam.net).

Collectively, these measurements (see Figure 13) provide improved coverage across the upper Midwest, which will help to establish baseline conditions and current conditions in this part of the country. (Note, although Minnesota is not part of the 5-state Midwest RPO region, it is shown below because of its proximity to the Class I areas in the region.)

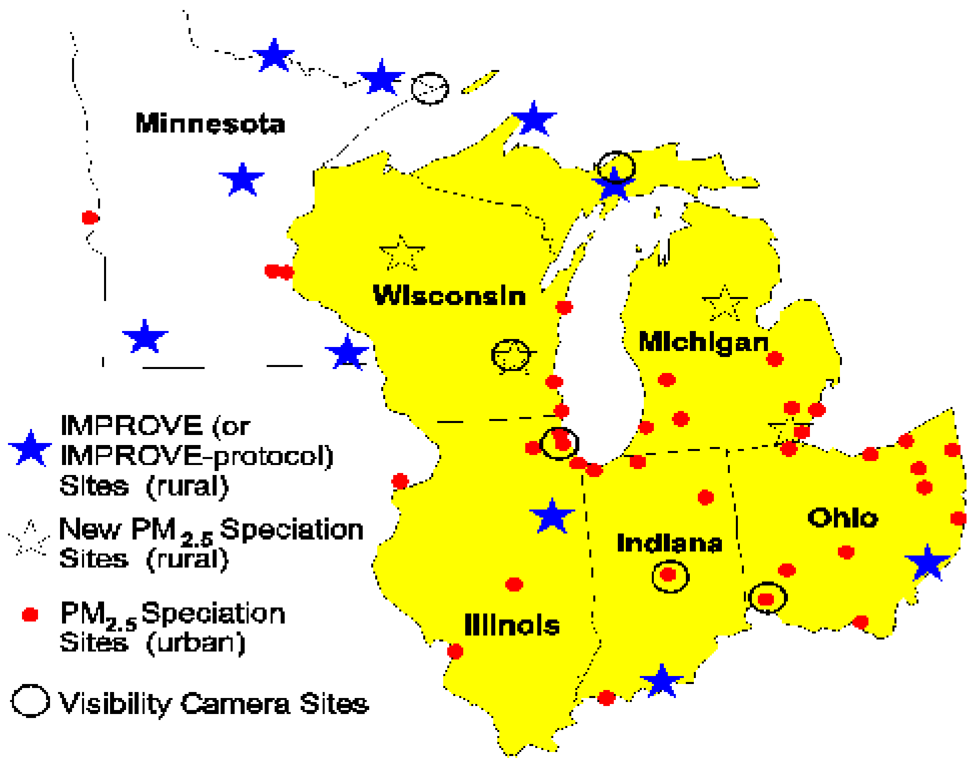

Figure 13. Regional Monitoring Network - $PM_{2.5}$ Speciation, IMPROVE, and Camera Sites

Section 3
Regional Haze in the Upper Midwest

Visibility impairment due to regional haze is a problem in the federal Class I areas in the five-state region:

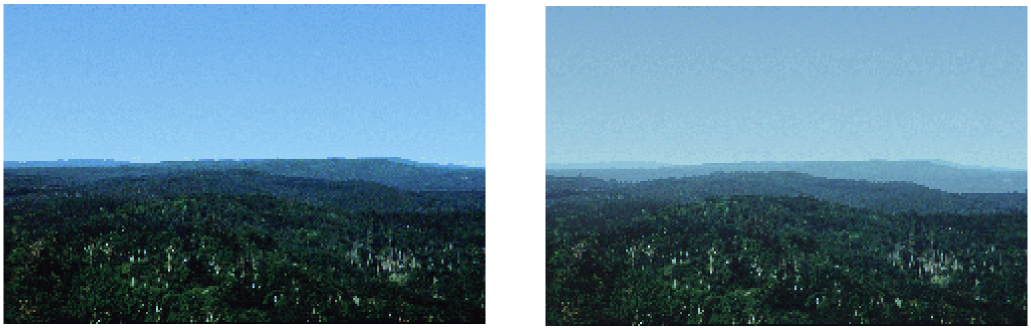

Figure 14. Isle Royale National Park, Michigan on a Good (left) and Poor (right) Visibility Day

and other, downwind Class I areas in the eastern half of the U.S.:

Figure 15. Shenandoah National Park, Virginia on a Good (left) and Poor (right) Visibility Day

Figure 16. Acadia National Park, Maine on a Good (left) and Poor (right) Visibility Day

Visibility impairment due to regional haze is also a problem in other areas in the five-state region:

$PM_{2.5}$ < 10.0 ug/m3 8/16/2000

$PM_{2.5}$ = 15.0 ug/m3 8/7/2000

$PM_{2.5}$ = 20.0 ug/m3 8/24/2000

$PM_{2.5}$ = 25.0 ug/m3 8/25/2000

$PM_{2.5}$ = 30.0 ug/m3 8/15/2000

$PM_{2.5}$ = 35.0 ug/m3 8/26/2000

Figure 17. Chicago, Illinois for Days with a Range of Visibility Conditions and $PM_{2.5}$ Concentrations

Fine particles not only play a major role in visibility impairment, but also can pose a threat to public health. In 1997, USEPA adopted a new ambient air quality standard for fine particles (62 FR 38652, July 18, 1997).[4] Figure 18 shows the estimated annual average fine particle ($PM_{2.5}$) concentrations for 1999 - 2000. Although three full years of data are needed to determine attainment or nonattainment of the ambient standard, the available data show a large portion of the eastern half of the U.S. with annual average concentrations above the ambient standard.

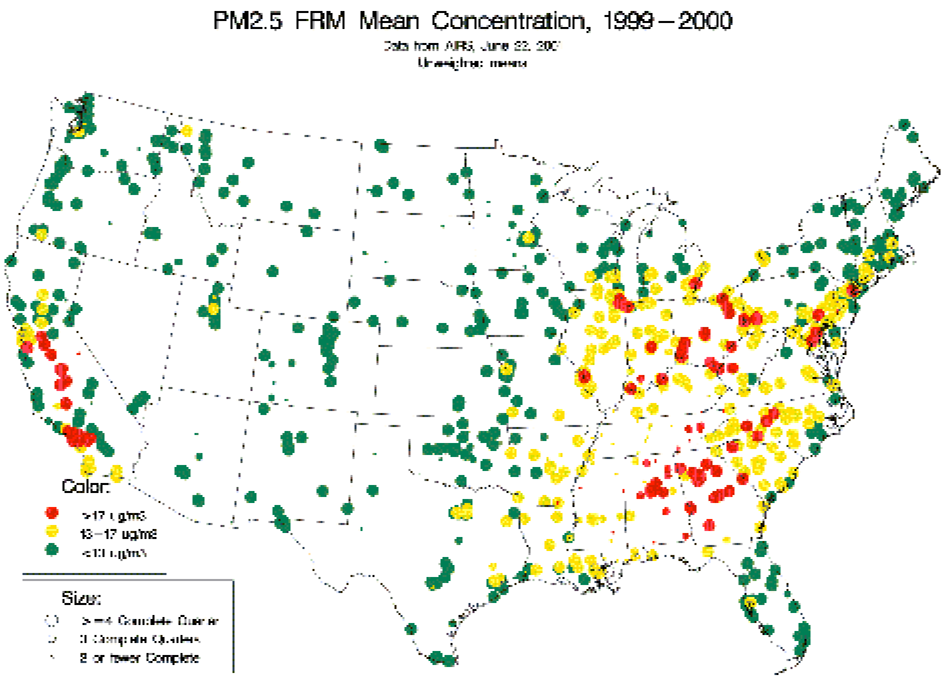

Figure 18. 1999 - 2000 Annual Average Fine Particle Concentrations

Thus, the visibility-related concerns of the Midwest RPO include:

- visibility impairment in the Class I areas in the five-state region;
- visibility impairment in downwind Class I areas in the eastern half of the U.S.;

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4 On May 14, 1999, a panel of the Court of Appeals for the D.C. Circuit remanded the ozone and $PM_{2.5}$ NAAQS to USEPA. In response to USEPA's petition for review of this decision, on February 27, 2001, the U.S. Supreme Court upheld USEPA's authority to set air quality standards under the Clean Air Act and USEPA's position that the Act requires that these standards to be based solely on public health considerations. The Court, however, also found USEPA's implementation policy for ozone to be unlawful and on remand they directed the Circuit Court to dispose of any other preserved challenges to the NAAQS.

- visibility impairment in major urban areas in the five-state region; and

- unhealthy levels of fine particle concentrations across a large portion of the five-state region.

Further information about the nature of the regional haze problem in the upper Midwest is provided below.

A Regional Haze Episode

An example of a significant haze event in the upper Midwest occurred in early September 1999[5]. For several days, especially September 3 and 4, airports across the region reported visibility at less than 10 miles along with haze.

Fine particle concentrations across the region were on the order of 30 - 40 ug/m^3 for several days during the episode (see Figure 19). Fine particle data from the MARCH-Midwest study show elevated $PM_{2.5}$ mass concentrations, especially in St. Louis, Chicago, and Detroit (see Figure 20a). The associated light extinction values for these data are shown in Figure 20b. The dominant species is sulfate, which contributes about 40% of the $PM_{2.5}$ mass and about 60% of the light extinction. The days with higher $PM_{2.5}$ mass tend to reflect an increase in sulfate concentrations.

Elevated 8-hour ozone concentrations occurred throughout much of the upper Midwest during the episode, with values exceeding 85 ppb in many states from September 1 - 5 (see Figure 21). Back trajectories (see Figure 22) show southerly - southwesterly flow during much of the episode (September 1 - 4), and northerly - northwesterly flow at the end of the episode (September 5 - 6).

In summary, this episode exemplifies that:

- hazy conditions are associated with elevated concentrations of fine particles and ozone over a large, multi-state area (note, further analysis of the relationships between visibility, fine particles, and ozone are provided later in this section.);

- sulfates are important contributors to elevated fine particle concentrations and light extinction; and

- synoptic scale transport indicates southerly - southwesterly flow on the days leading up to and including the high pollution/poor visibility days and northerly - northwesterly flow on the low pollution/good visibility days.

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[5] The representativeness of this episode is subject to further data analysis.

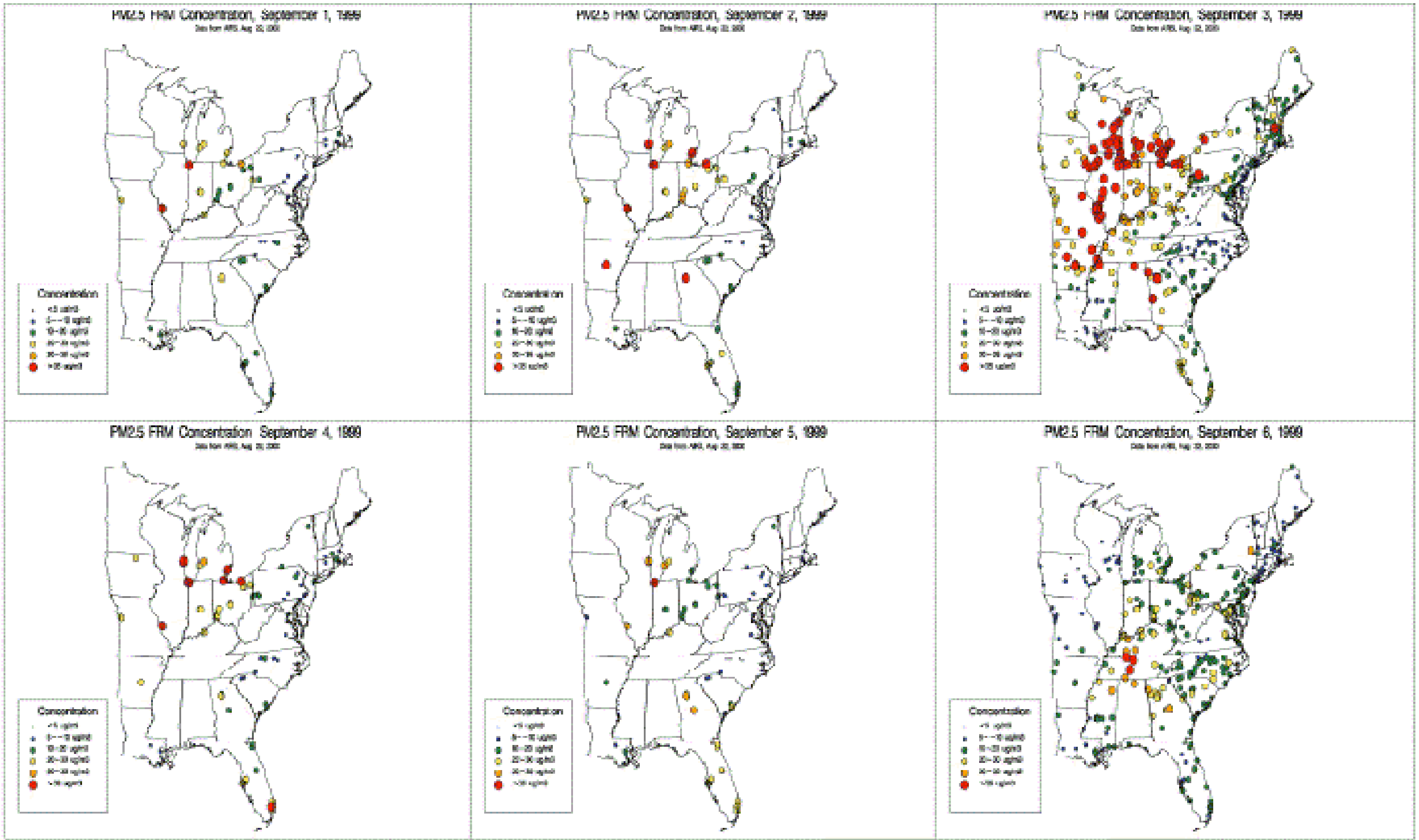

Figure 19. 24-Hour PM2.5 Concentrations (September 1 - 6, 1999)

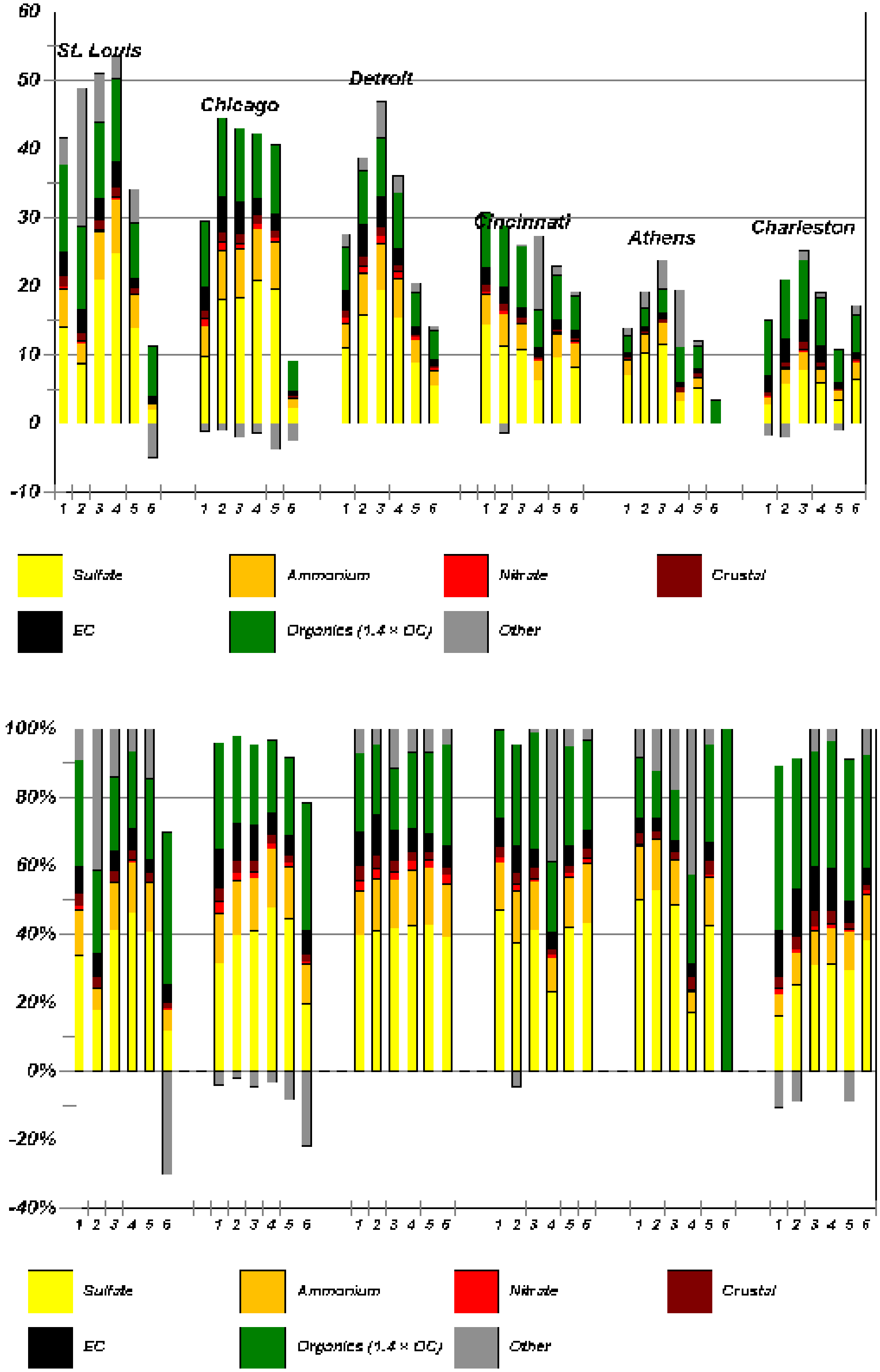

Figure 20a. $PM_{2.5}$ Chemical Composition from MARCH-Midwest Study (Sept 1 – 6, 1999)

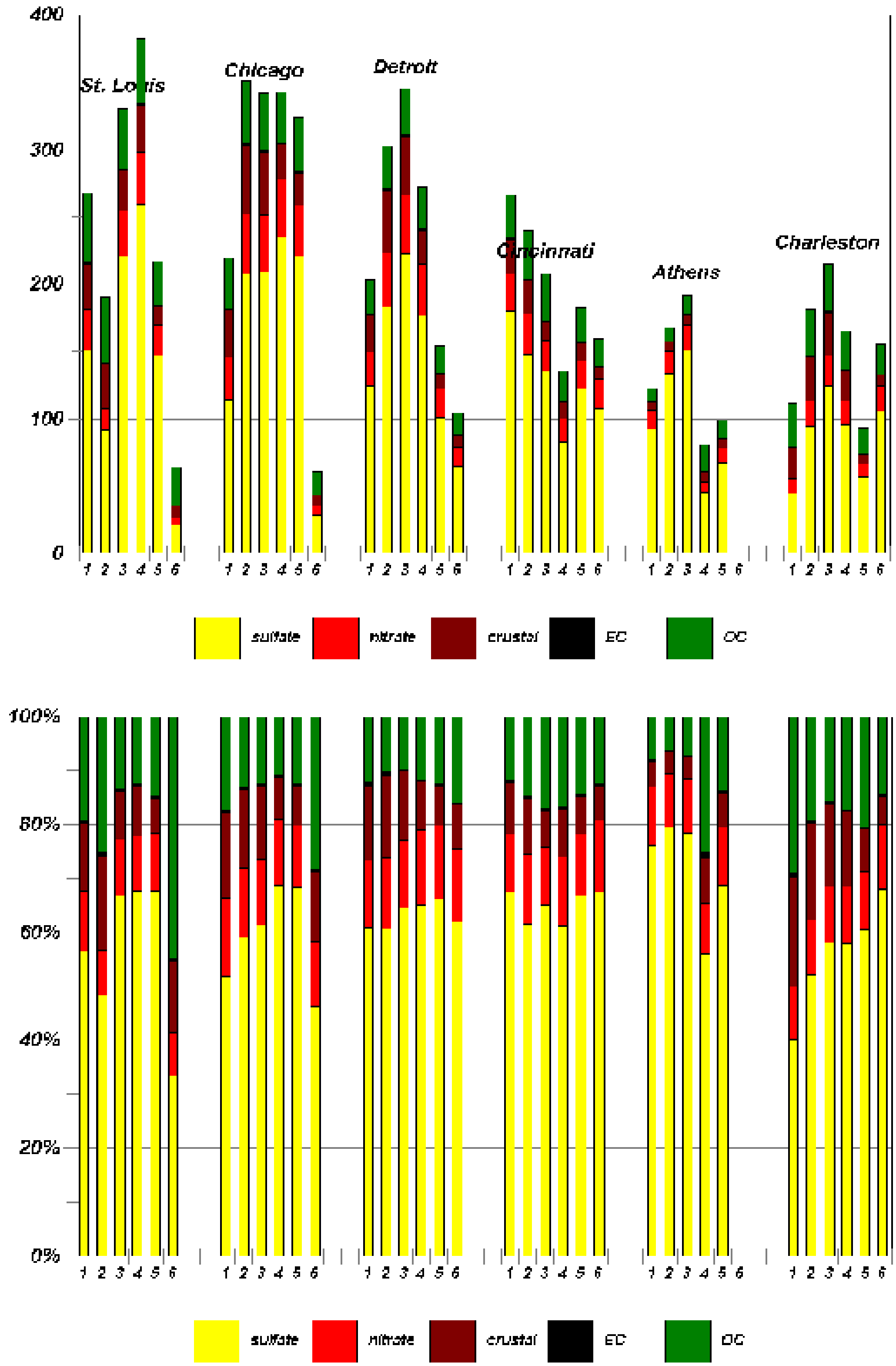

Figure 20b. Light Extinction Chemical Composition from MARCH-Midwest Study (Sept 1 – 6, 1999)

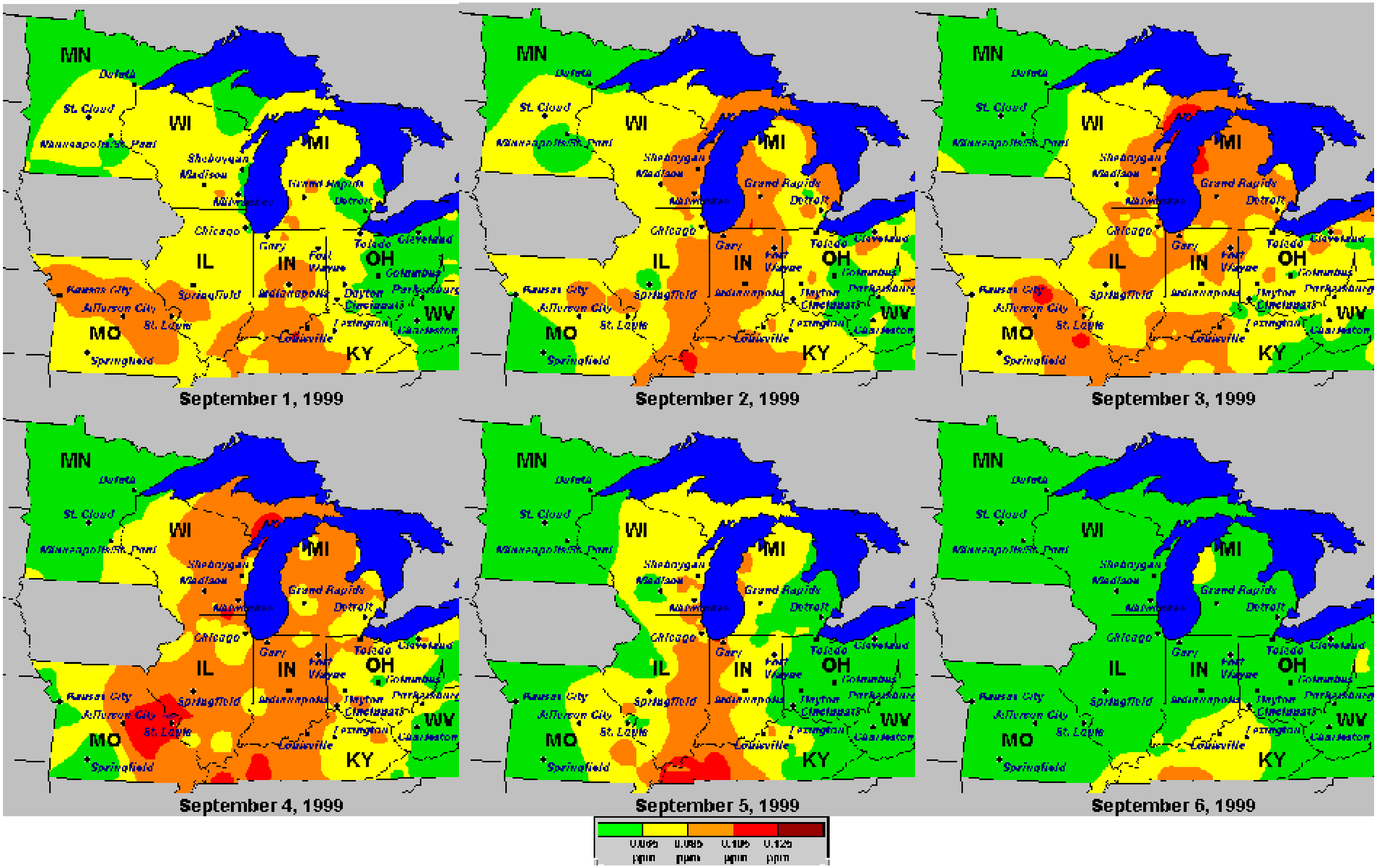

Figure 21. Daily Peak 8-Hour Ozone Levels (September 1 – 6, 1999)

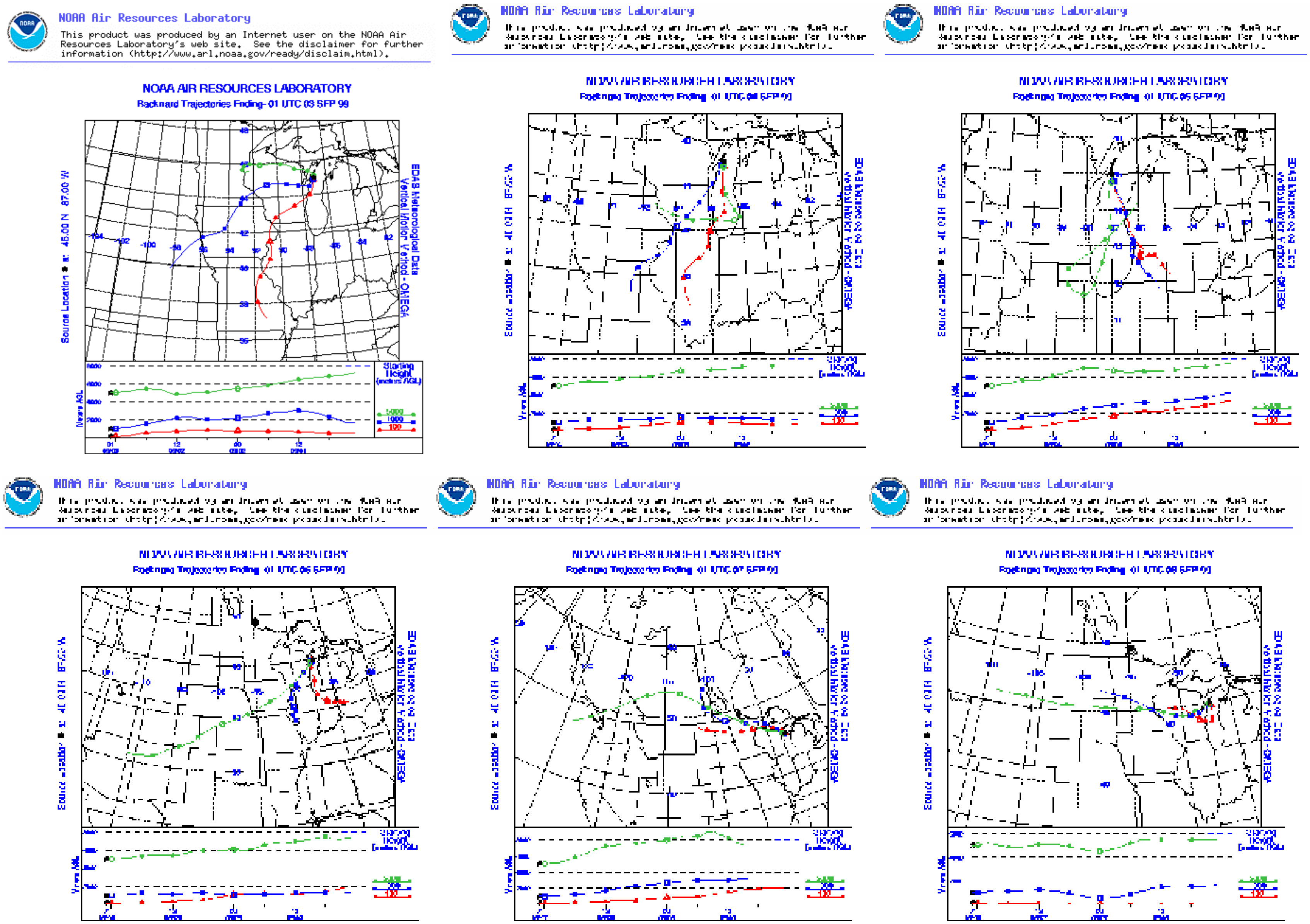

Figure 22. Back Trajectories from HYSPLIT Model (September 1 – 6, 1999)

Variation of Fine Particle Concentrations and Visibility Levels
The spatial distribution of average fine particle concentrations for the 20% best, 20% median, and 20% worst days based on IMPROVE and CASTNet monitors for 1997 - 1999 is shown in Figure 23. In the upper Midwest, lower $PM_{2.5}$ concentrations occur to the north, and higher concentrations to the south. The concentrations in the southern part of the region are generally consistent with those across a broad area in the eastern half of the U.S.

The spatial distribution of annual average fine particle concentrations based on FRM monitors in the Region V States for 1999 - 2000 is shown in Figure 24. As noted above, lower $PM_{2.5}$ concentrations (less than 13 ug/m^3) occur in the northern part of the region (i.e., MN, central/northern WI, and central/northern MI) and higher concentrations occur in the in the southern part of the region (i.e., IL, IN, OH, southern WI, and southern MI). Note also that the concentrations in urban areas are about 3 - 5 ug/m^3 higher than concentrations in rural areas. This urban "excess" is consistent with that reported by Schichtel (1999).

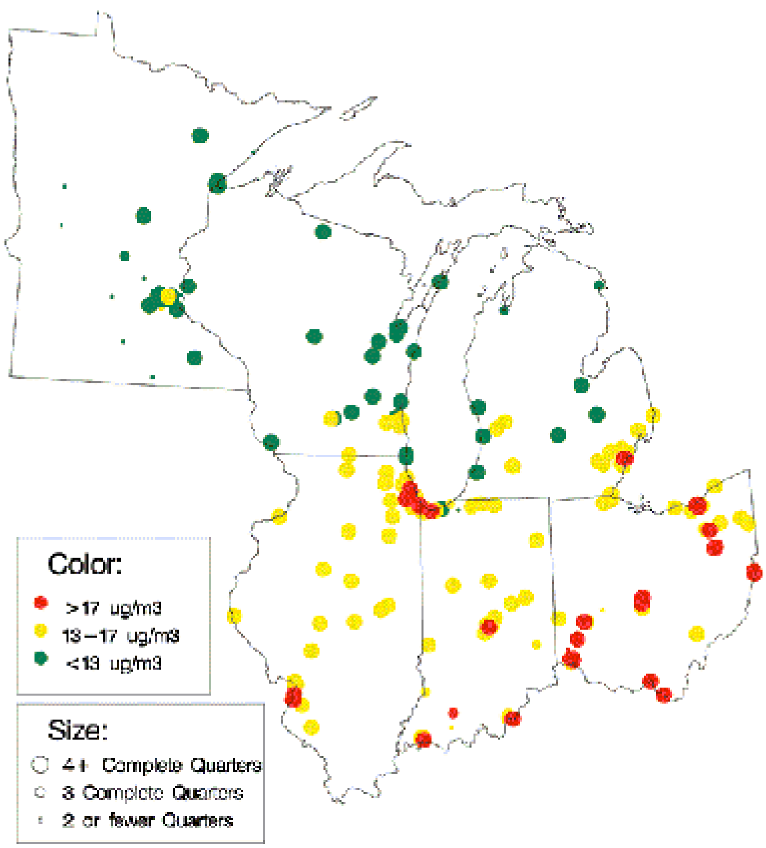

Figure 24. 1999 - 2000 Annual Average Fine Particle Concentrations for Region V States

Figure 23. Average PM2.5 Concentrations for 20% Best, 20% Median, and 20% Worst Days, 1997 - 1999

Examination of the spatial variability of fine particle concentrations at IMPROVE sites in the eastern half of the U.S. found that: (1) the sites in northern MI and MN are highly correlated with each other, slightly less correlated with sites in the Appalachians, and poorly correlated with sites in the Northeast; and (2) correlations between fine particle and sulfate concentrations are strongest in the Appalachians and Northeast, and somewhat weaker in northern MI and MN (AER, 2001). The implications of these findings are as follows. First, the correlation between sites in the upper Midwest (as exemplified in Figure 25 below), suggest that in the absence of recent data from Isle Royale and Seney, data from Boundary Waters Canoe Area can be used to represent conditions in the northern Michigan Class I areas. Second, the differences between sites in the upper Midwest and those in the Appalachians and Northeast suggest conditions are not uniform throughout the eastern half of the U.S. and that there are differences in meteorological and source-receptor relationships which will need to be considered across this region.

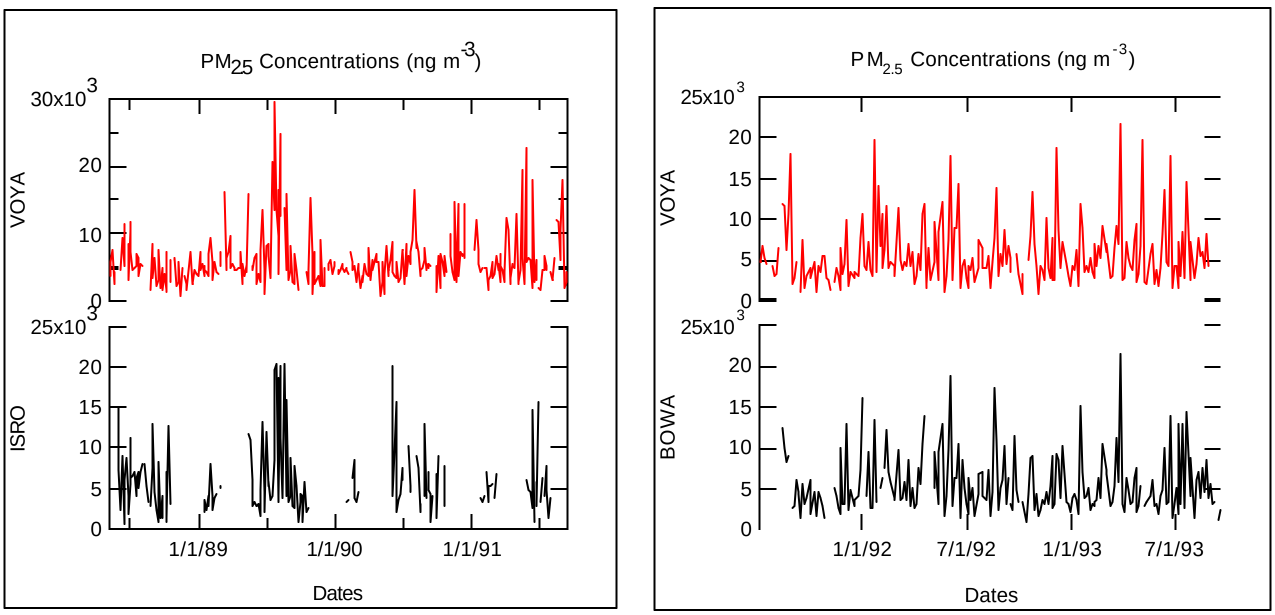

Figure 25. $PM_{2.5}$ Time Series for Voyageurs National Park (VOYA), Isle Royale National Park (ISRO), and Boundary Waters Canoe Area (BOWA) for Overlapping Monitoring Periods

The spatial distribution of average visibility levels for the 20% best, 20% median, and 20% worst days (expressed as deciviews) based on IMPROVE and CASTNet monitors for 1997-1999 is shown in Figure 26[6].

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[6] The calculated deciviews and light extinction values are based on the average fine mass concentrations and monthly average relative humidity. Rayleigh scattering and coarse mass concentrations, which are not available at CASTNet sites, were not included.

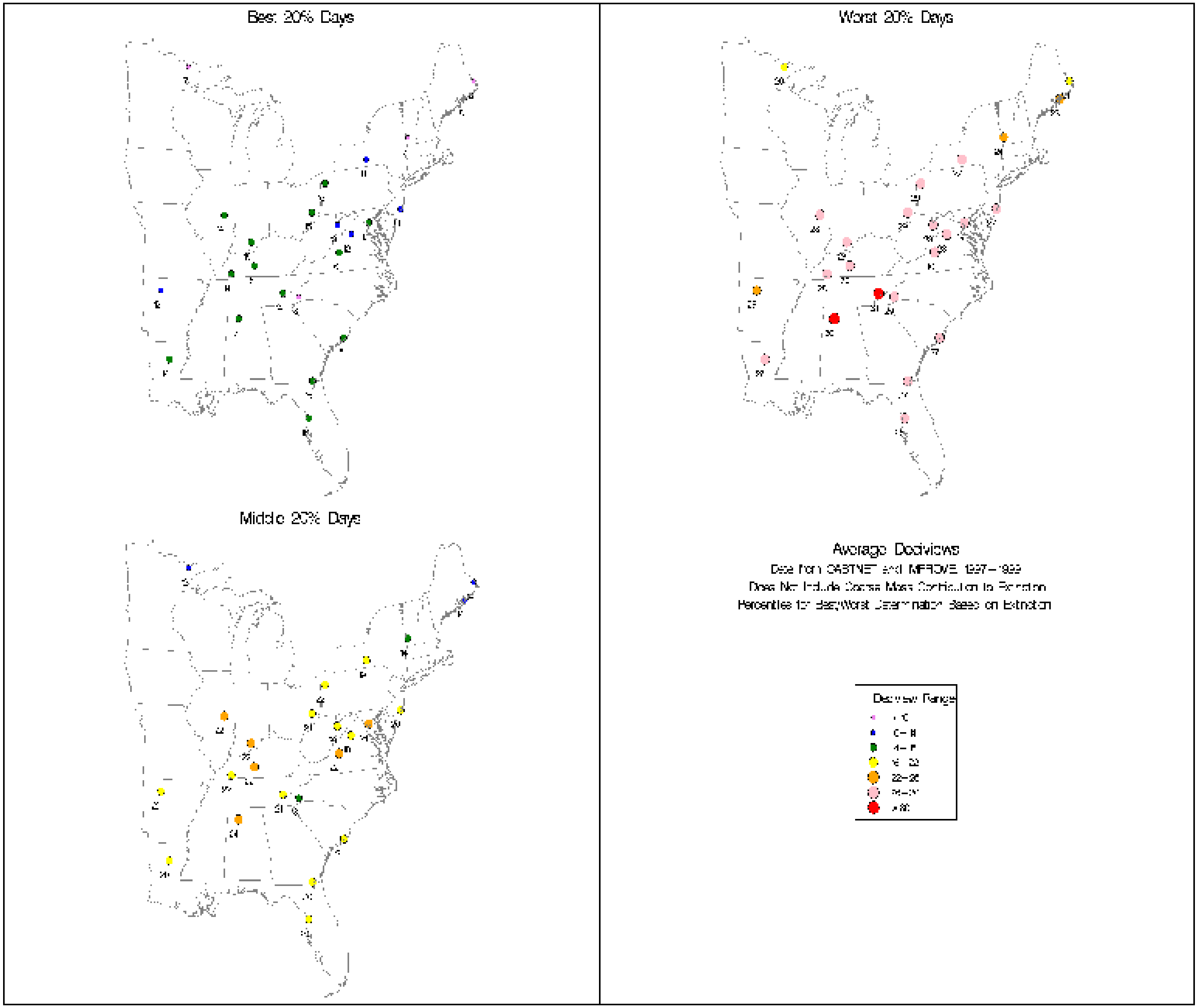


Figure 26. Average Visibility for 20% Best, 20% Median, and 20% Worst Days, 1997 - 1999

In the upper Midwest, the best visibility levels occur to the north, and the worst visibility levels occur to the south. The visibility levels on the 20% worst days in the northern MN and northern MI Class I areas (i.e., about 20 deciviews) are significantly less than those in the other Class I areas in the eastern U.S. and are comparable to some western Class I areas, such as Mt. Ranier National Park in Washington, Glacier National Park in Montana, and Yosemite National Park in California.

The spatial distribution of average chemical composition (i.e., relative amounts of individual species concentrations) for the 20% best, 20% median, and 20% worst days based on IMPROVE and CASTNet monitors for 1997-1999 is shown in Figure 27. This figure also shows the light extinction values (expressed as Mm^{-1}). The dominant species across the eastern half of the U.S. is clearly sulfate, contributing about 2/3 to more than 3/4 to light extinction. Other species of note at these rural sites are organics and nitrates. In Boundary Waters Canoe Area, there is a lower percentage of sulfates and higher percentage of organics and nitrates, compared to other sites in the eastern half of the U.S.

The chemical composition for each of the 20% worst and 20% best days for 1997-1999 for Boundary Waters Canoe Area and Shenandoah is shown in Figures 28 (a) - (d). (Similar plots for other sites are provided in Appendix II.) These figures show that:

- The worst 20% days occur throughout the year in the upper Midwest (as represented by Boundary Waters Canoe Area), whereas they occur mostly in the summer in the eastern U.S. (as represented by Shenandoah National Park).

- The best 20% days occur throughout the year in the upper Midwest, whereas they occur mostly in the winter in the eastern U.S.

- There are differences in the chemical composition between the upper Midwest and the eastern U.S., with sulfates, nitrates, and organics being important in the upper Midwest, while sulfates are the major contributor to visibility impairment in the eastern U.S.

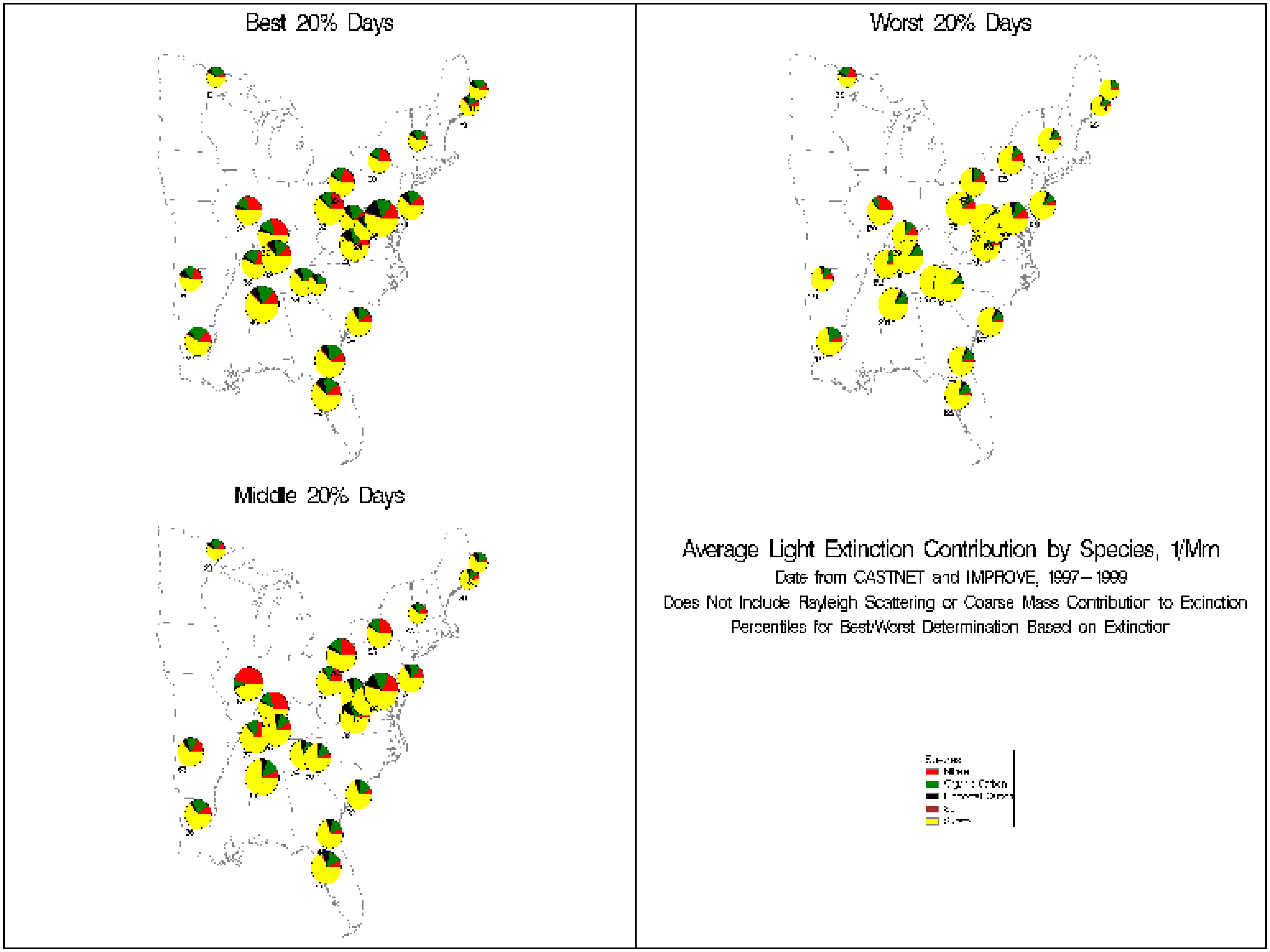


Figure 27. Average Light Extinction Chemical Composition for 20% Best, 20% Median, and 20% Worst Days, 1997 - 1999

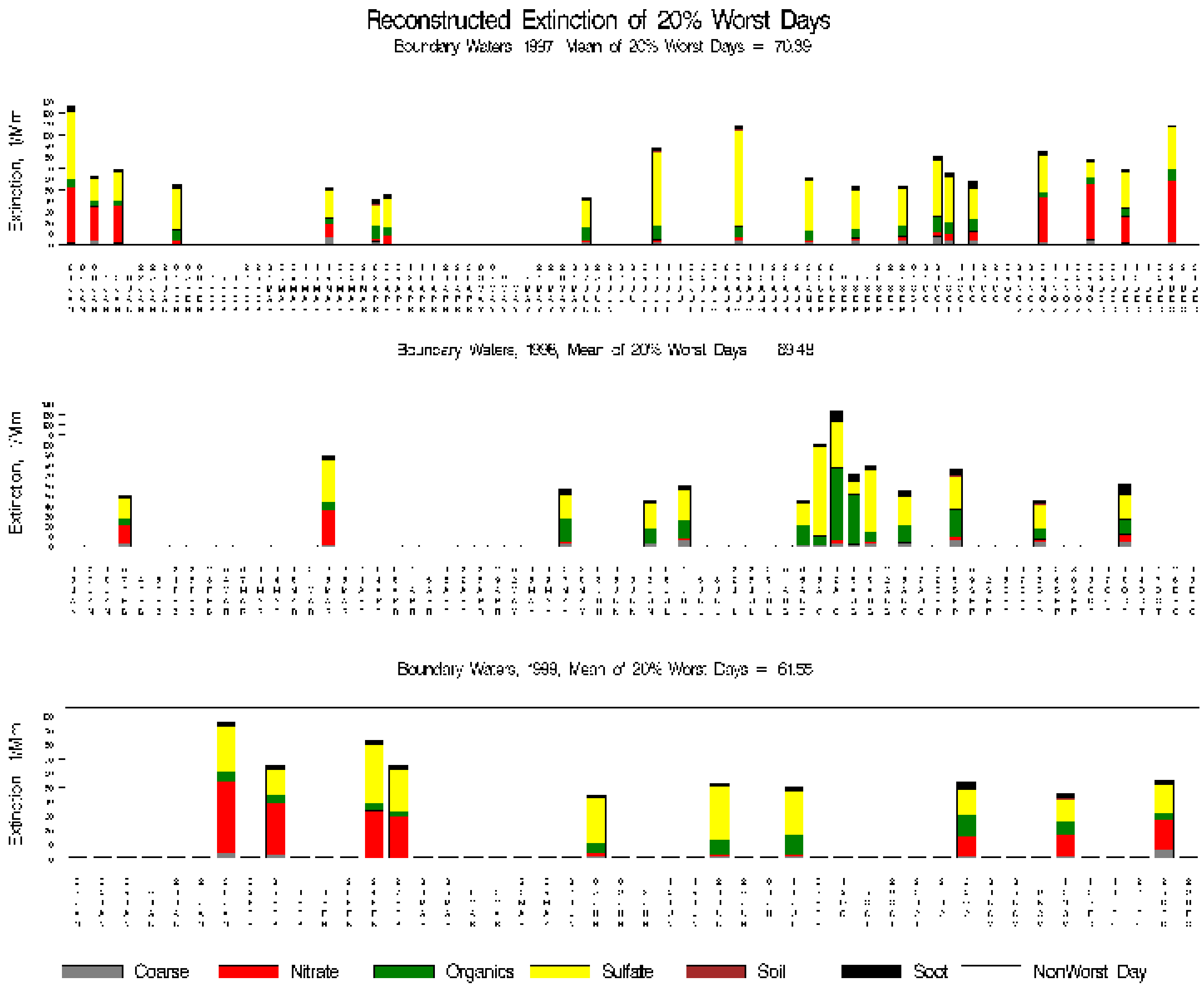


Figure 28(a). Daily Light Extinction and Chemical Composition for 20% Worst Days at Boundary Waters Canoe Area

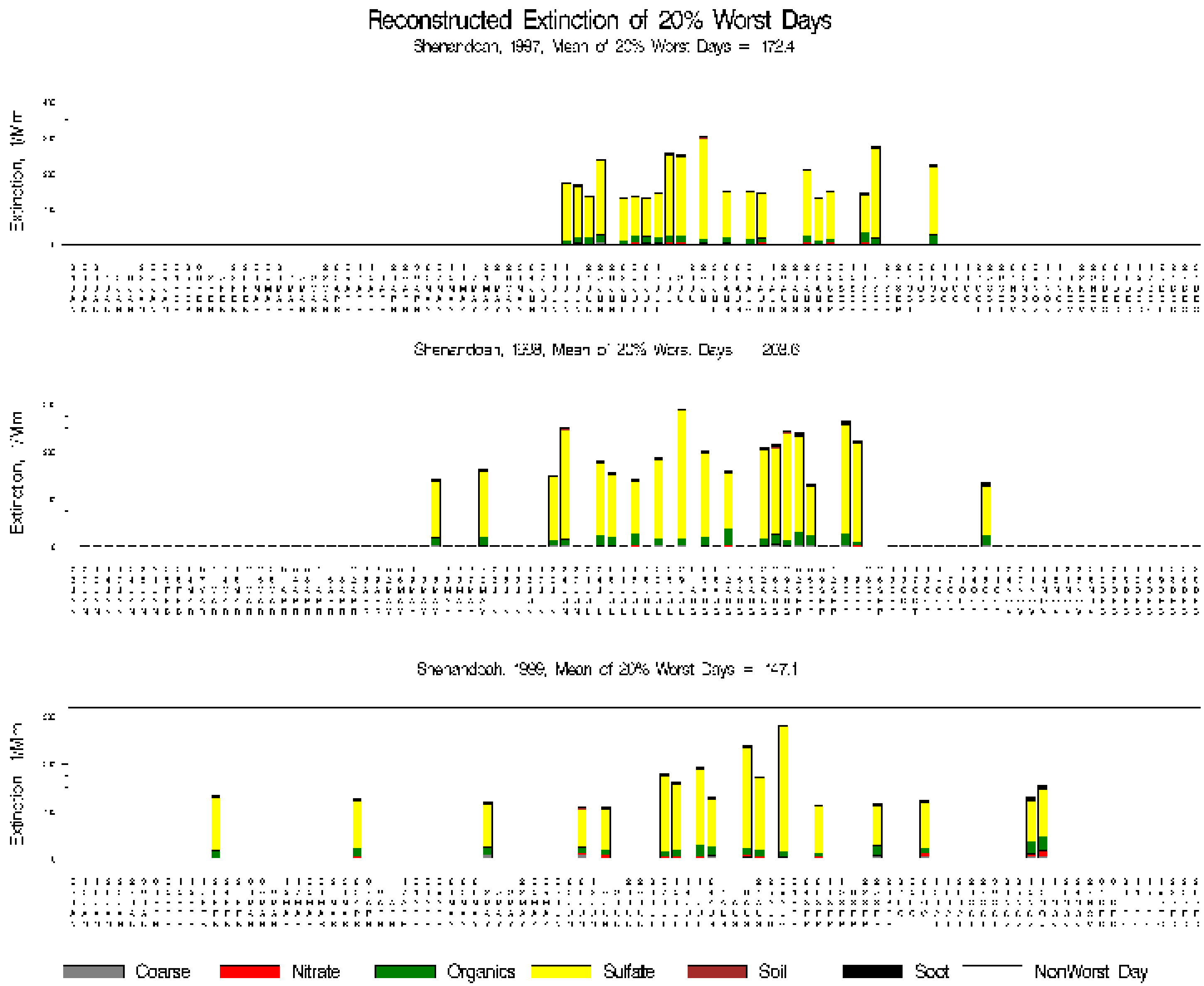


Figure 28(b). Daily Light Extinction and Chemical Composition for 20% Worst Days at Shenandoah National Park

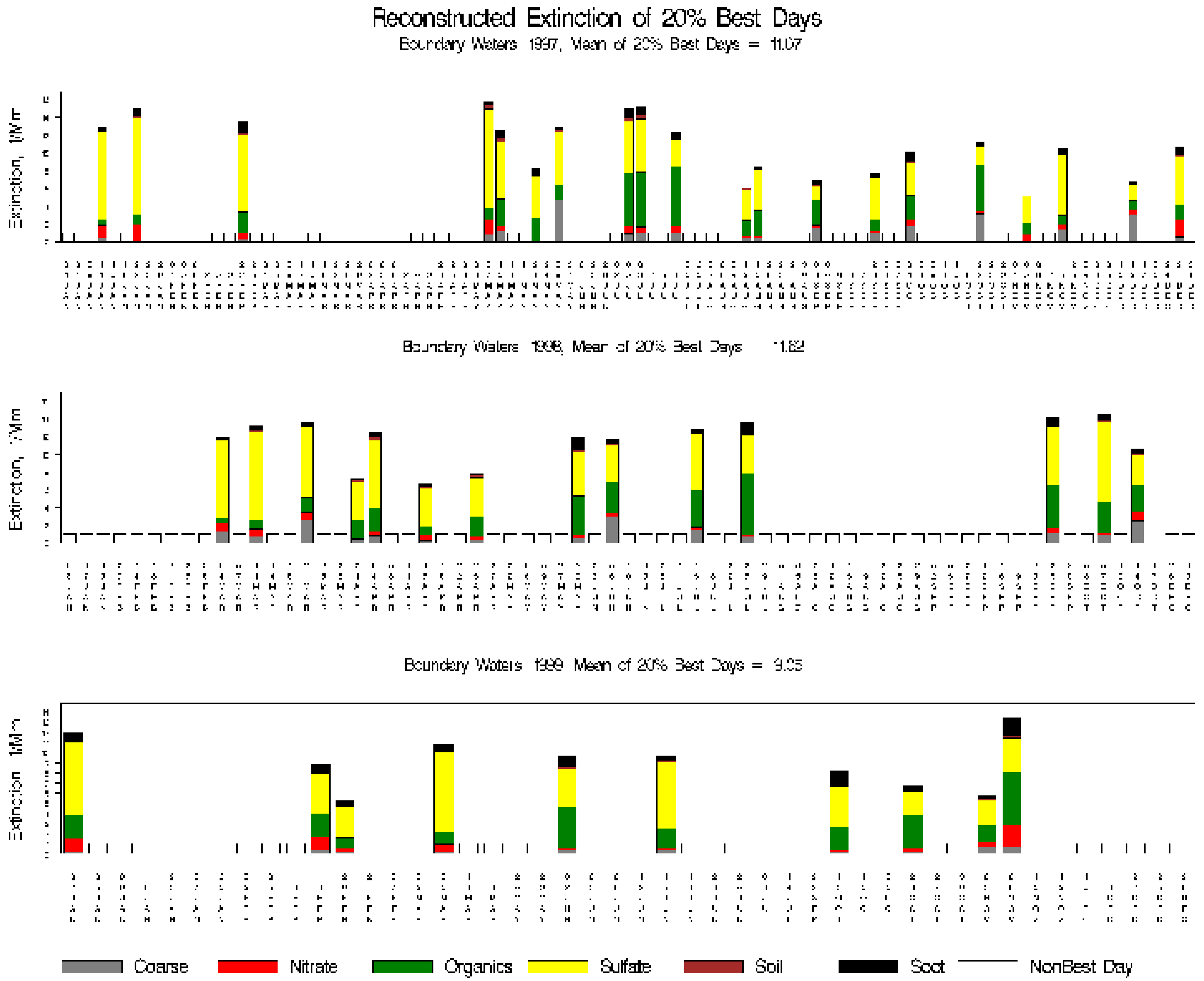


Figure 28(c). Daily Light Extinction and Chemical Composition for 20% Best Days at Boundary Waters Canoe Area

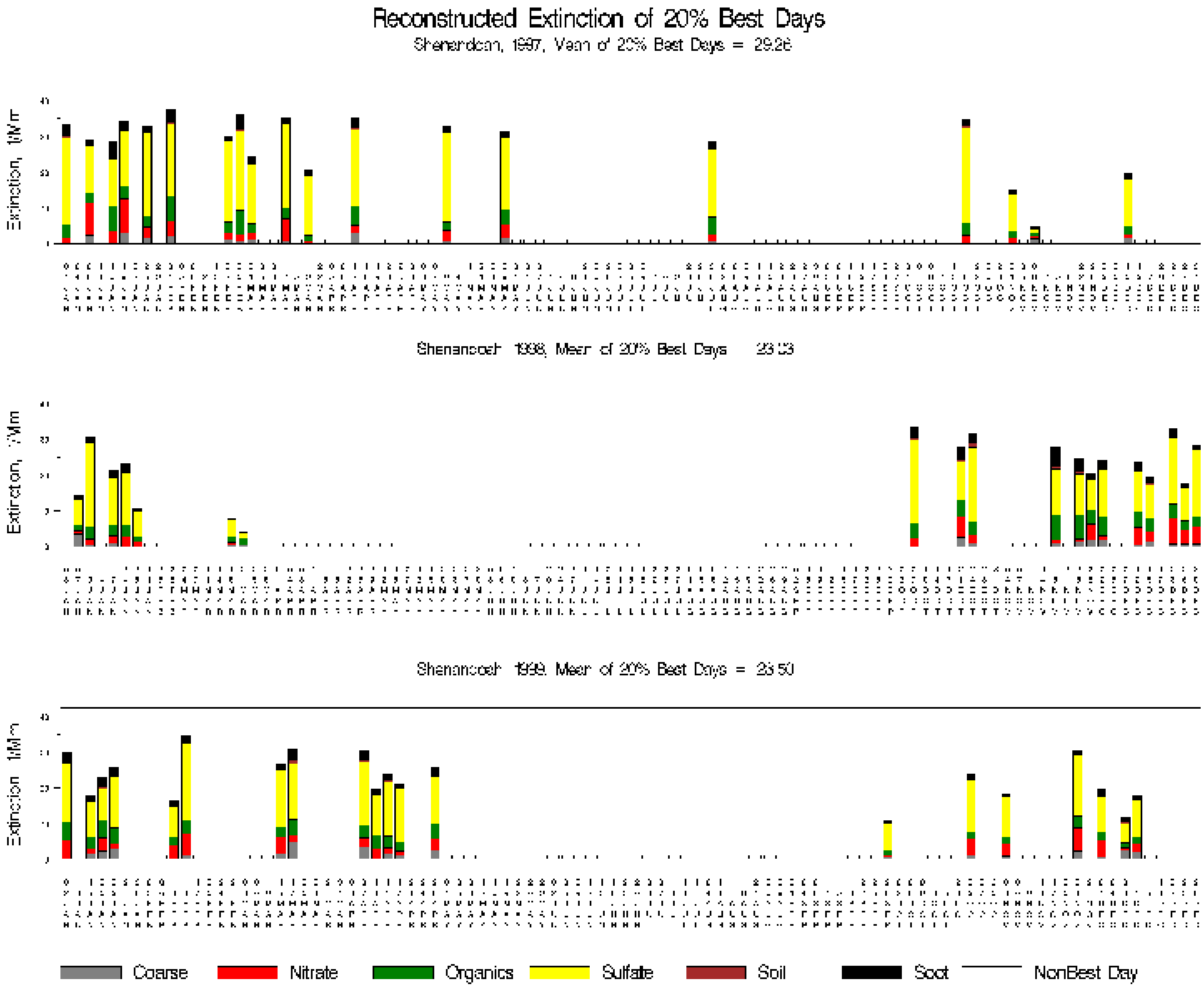
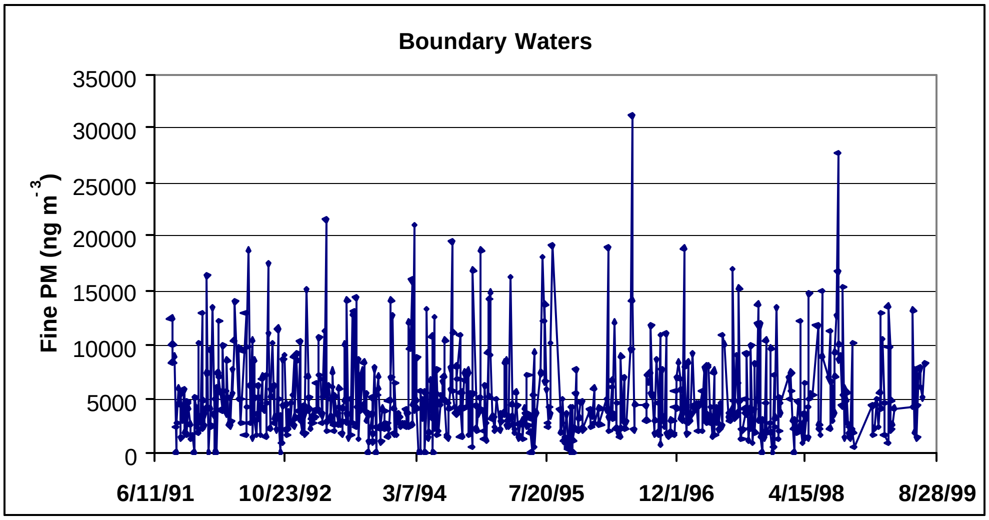


Figure 28(d). Daily Light Extinction and Chemical Composition for 20% Best Days at Shenandoah National Park

Further information on the seasonal variability between the upper Midwest and the Appalachians is provided in Figures 29 and 30. First, as seen in Figure 29, the daily $PM_{2.5}$ concentrations for a recent multi-year period show no seasonal pattern at Boundary Waters Canoe Area, and a regular cycle of high summer concentrations and low winter concentrations at Shenandoah (AER, 2001).



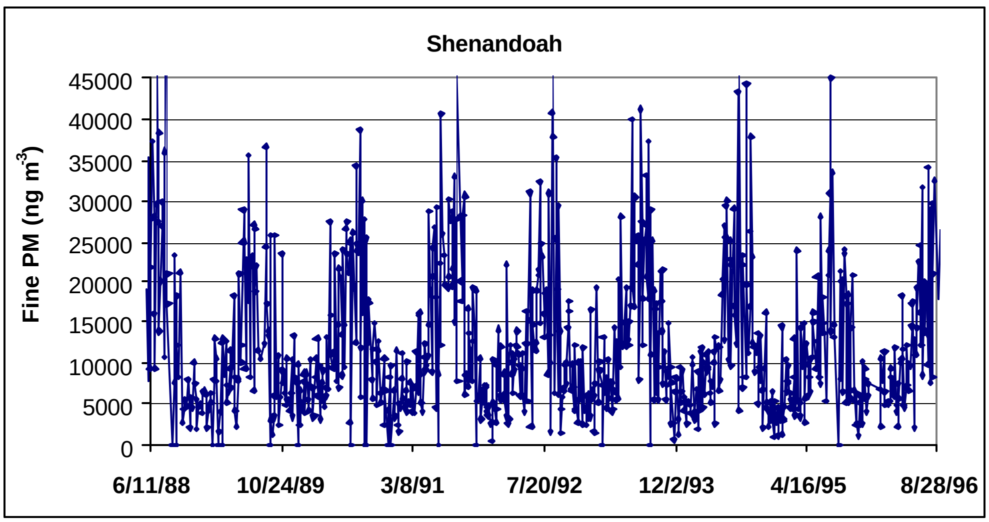


Figure 29. Daily PM2.5 Concentrations at Boundary Waters Canoe Area (top) and Shenandoah National Park (bottom)

Second, as seen in Figure 30, the mean hourly light scattering (and relative humidity) show little seasonal variation at Boundary Waters Canoe Area (although there is some indication of slightly higher scattering during winter associated with slightly higher relative humidity possibly due to icy fog), and substantially higher scattering during summer at Great Smoky Mountains National Park. Note also that the relative humidity is high during all seasons, with values generally greater than 70% during the summer. (Note, when the relative humidity is 70% or higher, small changes in relative humidity can cause very large changes in light scattering.)

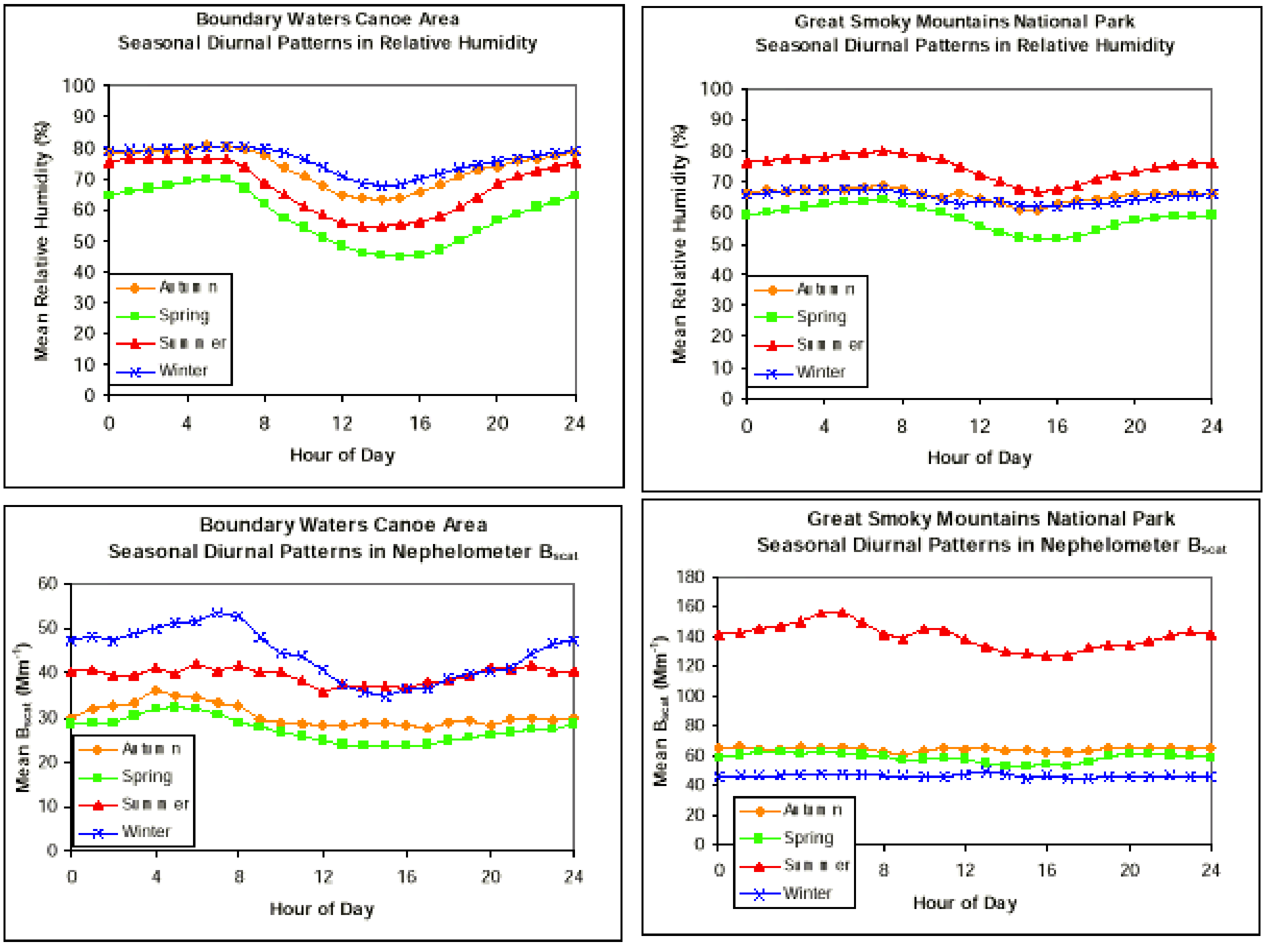


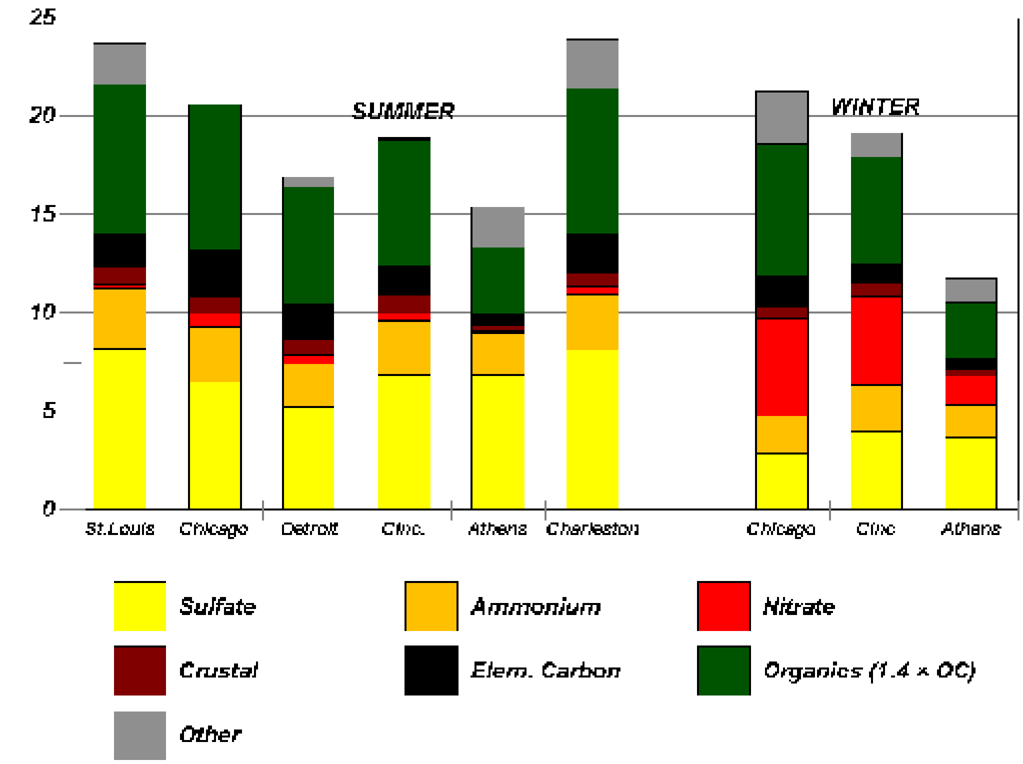
Figure 30. Relative Humidity and Light Scattering for Boundary Waters Canoe Area (left) and Great Smoky Mountains National Park (right) from 1993 to August 1997

Further information on chemical composition across the upper Midwest is available from the MARCH-Midwest study. These data, which are summarized in Figure 31, show:

- Fine particle mass is mostly affected by sulfates, organics, and, in the winter, nitrates.

- Light extinction is mostly affected by sulfates (60 -80%) in the summer, and sulfates (30 - 50%) and nitrates (25 - 40%) in the winter.

- Urban-rural differences include higher average organic and nitrate concentrations at the urban sites.



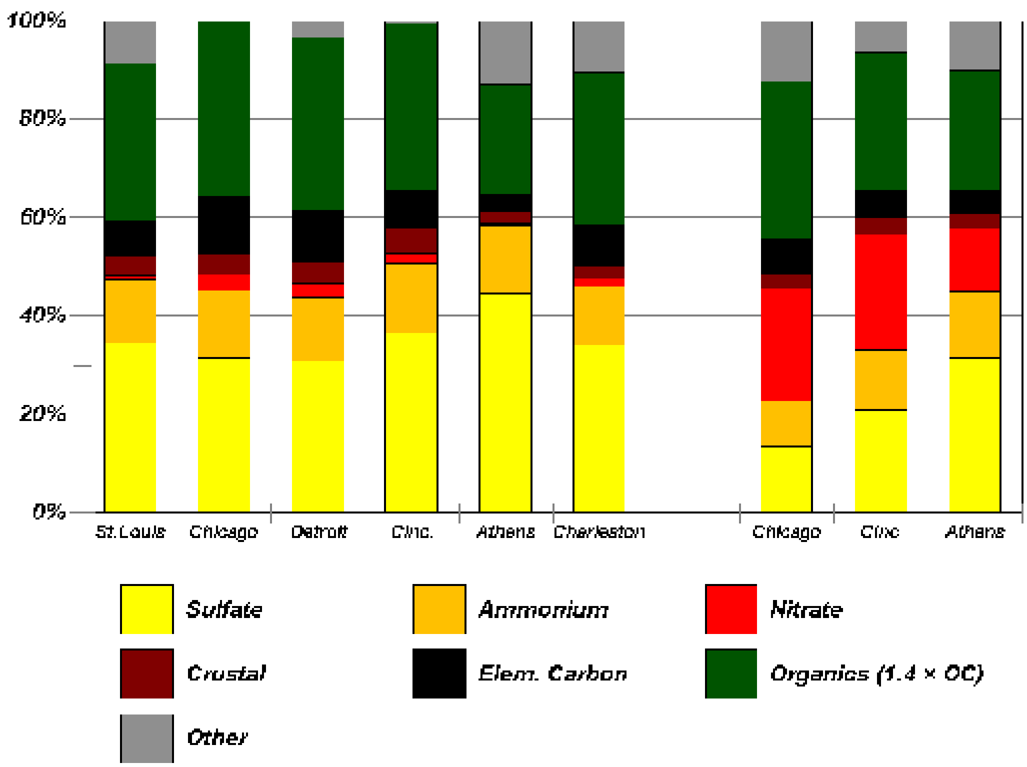


Figure 31. Average $PM_{2.5}$ Chemical Composition – MARCH-Midwest Study

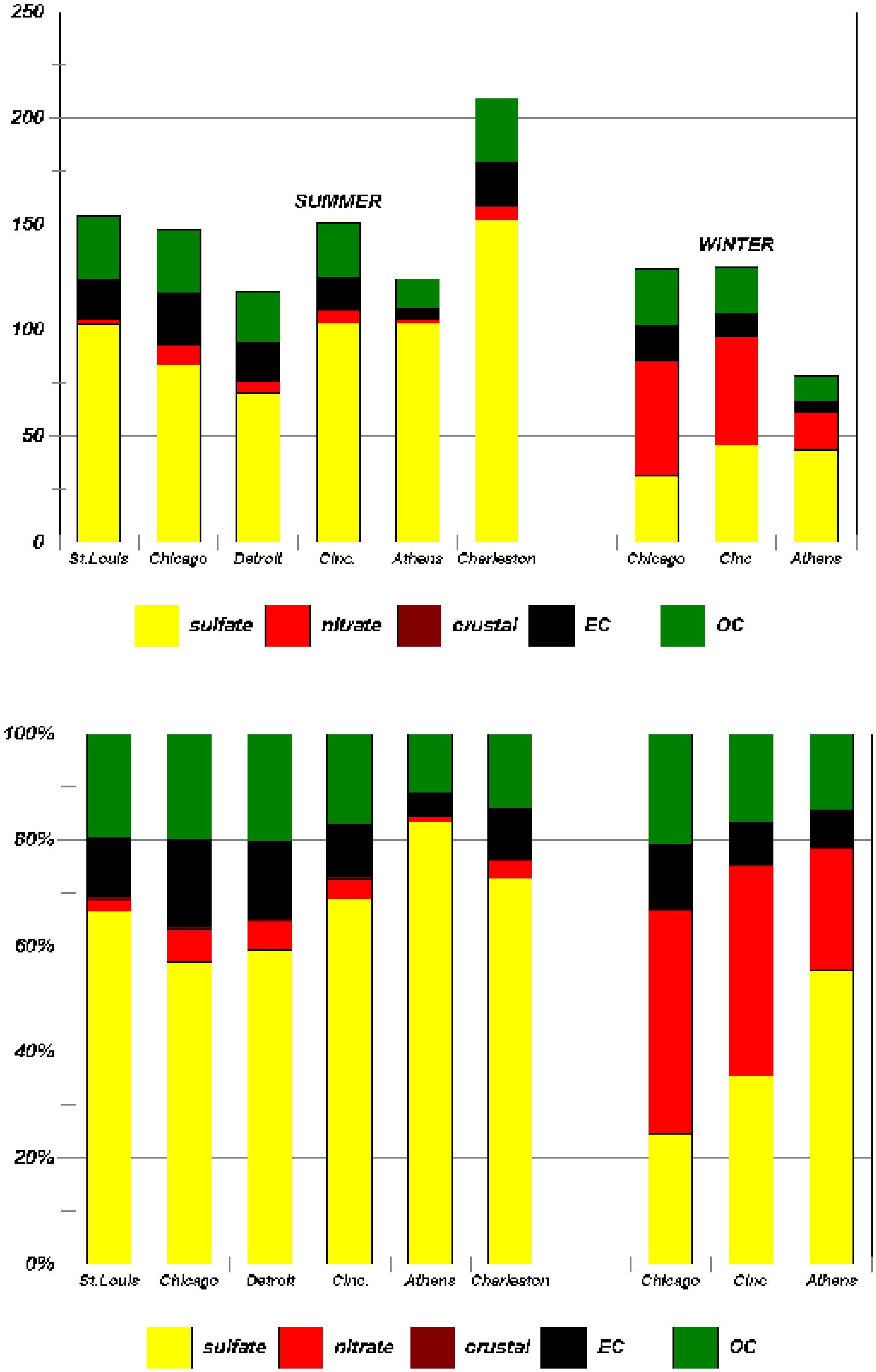


Figure 32. Average Light Extinction Chemical Composition – MARCH-Midwest Study

Meteorological Conditions Associated with Most and Least Impaired Days

To assess the meteorological conditions on the 20% worst and 20% best visibility days, back trajectories were calculated with HYSPLIT for a 48-hour period and a 200 m start height (NOAA, 2001). A set of back trajectory maps for several sites in the eastern half of the U.S. are presented in Figure 33 below. (Similar plots for other sites are provided in Appendix III.) As can be seen, the worst visibility days (red lines) are generally associated with southerly-southwesterly flow, and the best visibility days (blue lines) with northerly flow, especially for the more northern Class I areas (Boundary Waters Canoe Area and Acadia National Park).

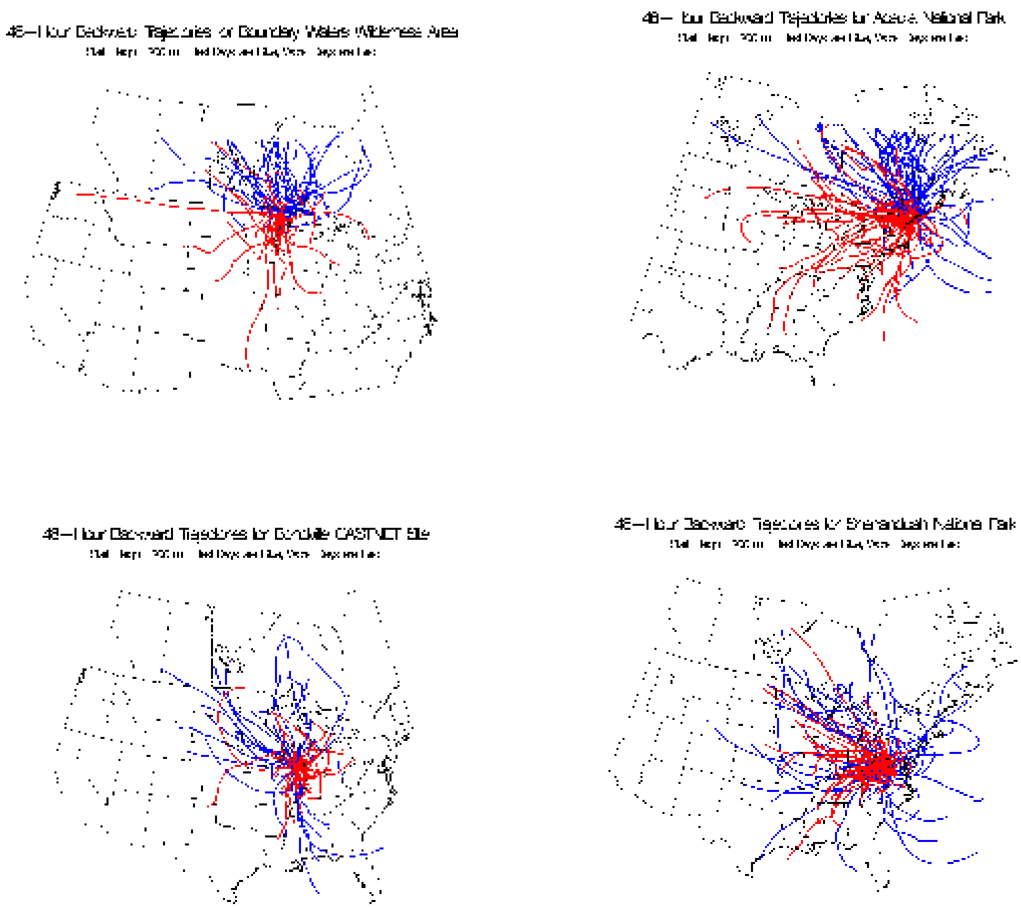


Figure 33. Back Trajectories for 20% worst (red) and 20% best (blue) days in Boundary Waters Canoe Area (top left), Acadia National Park (top right), Bondville, IL (bottom left), and Shenandoah National Park (bottom right), 1997 - 1999

Interpretation of the back trajectory plots may be complicated by the number of trajectory lines. Ensemble averaging of the results, as seen in Figure 34, produces a clearer picture of likely upwind areas on the 20% best and 20% worst visibility days.

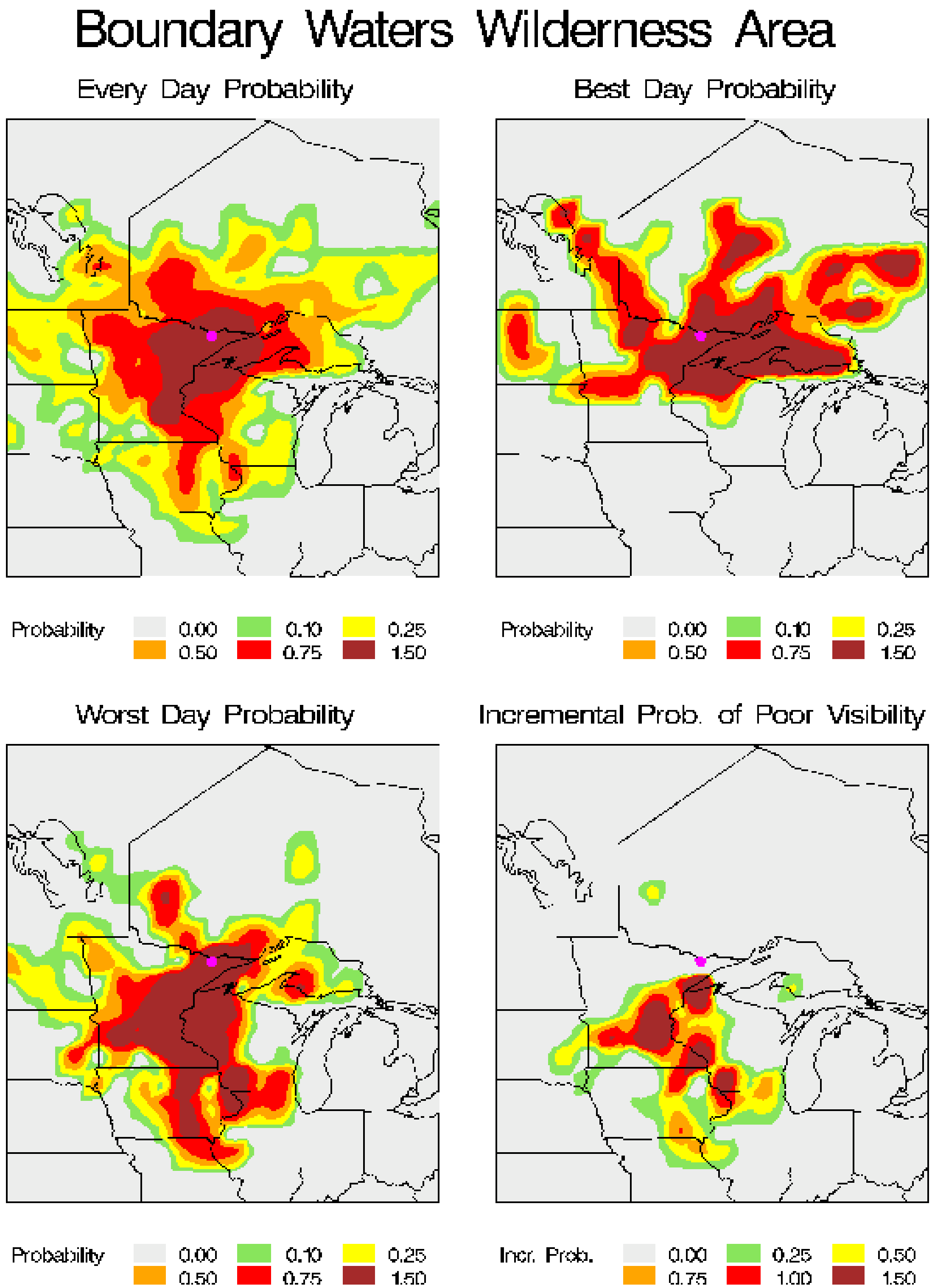


Figure 34. Ensemble Average of Back Trajectories for Boundary Waters Canoe Area

Relationship of Visibility, Fine Particles, and Ozone
As indicated by the September 1999 episode, periods of poor visibility often occur in conjunction with elevated levels of other regional pollution, such as ozone (during the summer) and fine particles[7]. Existing scientific evidence shows that regional haze, fine particles, and ozone have common precursor pollutants, emission sources, atmospheric processes, spatial scales of transport, and geographic areas of concern. It is, therefore, desirable to integrate visibility control strategies with those for ozone and fine particles.

Based on data from Bondville, IL; Boundary Waters Canoe Area; and Shenandoah National Park, the relationship between regional haze and fine particles is fairly strong, as shown in Figure 35.

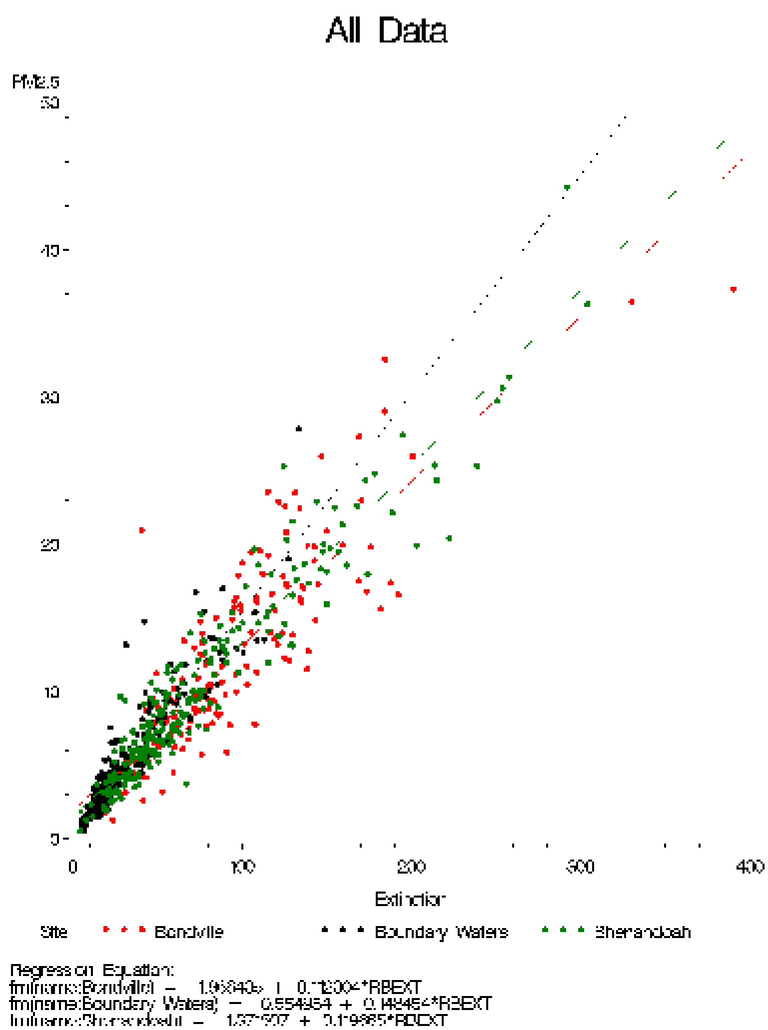


Figure 35. PM2.5 v. Light Extinction for Bondville, Boundary Waters, and Shenandoah

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[7] Previous studies of other historical episodes have shown that synoptic scale hazy air masses contain elevated ozone (> 0.08 ppm) and sulfate (>20 ug/m^3). See, for example, June 23 - July 5, 1975 (Husar, et al, 1976), and August 16 - 29, 1976. (USEPA, 1977).

The relationship between regional haze and ozone is generally not as strong as the relationship between regional haze and fine particles. As seen in Figure 36 below, the regional haze and ozone relationship is strongest during the summer, when the highest ozone concentrations occur in the eastern half of the U.S.

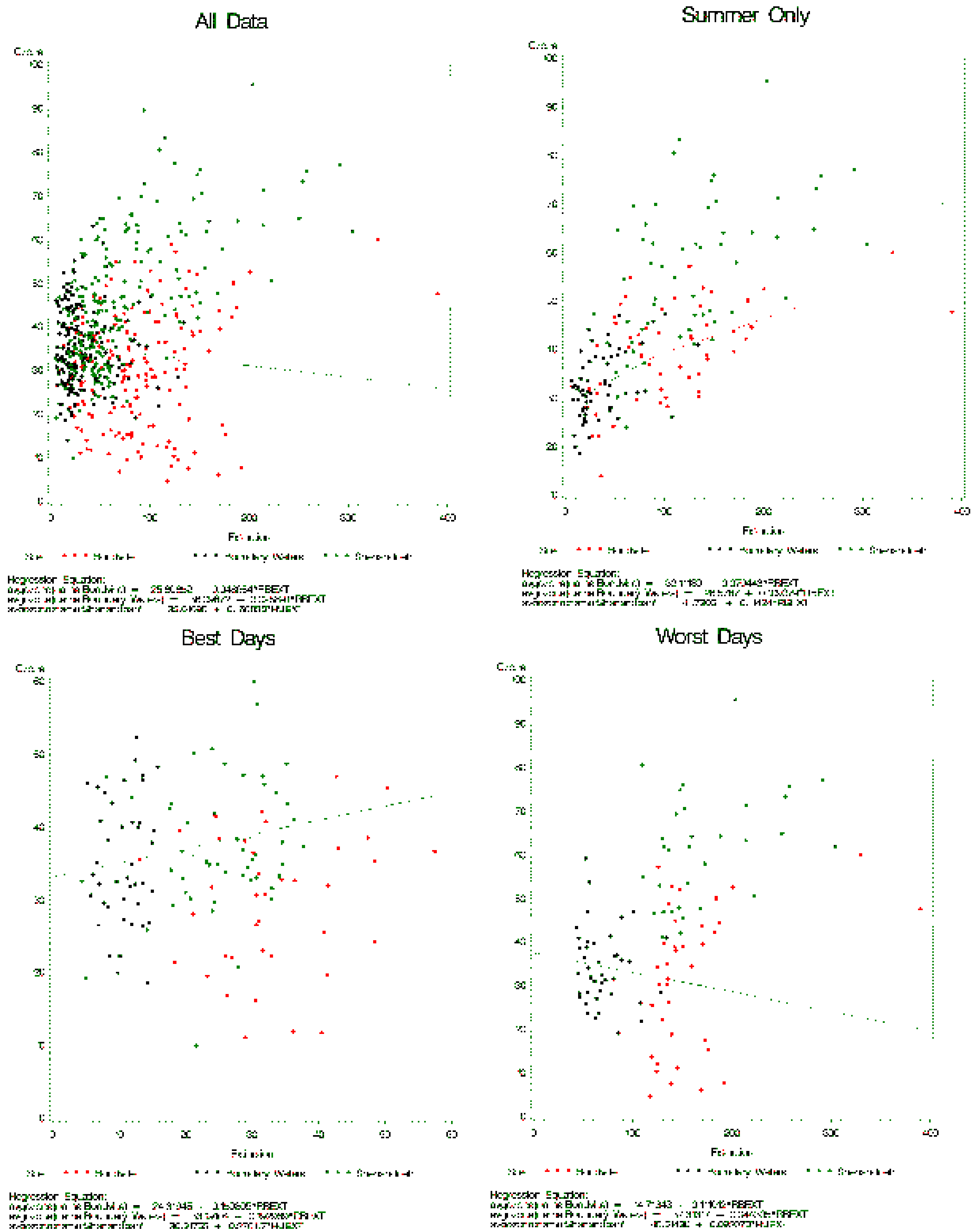


Figure 36. Ozone v. Light Extinction for Bondville, Boundary Waters, and Shenandoah for All Days (top left), Summer Days (top right), 20% Best Visibility Days (bottom left), and 20% Worst Visibility Days (bottom right)

Section 4
Visibility Trends

The change in visibility levels over time can be assessed based on two types of measurements. First, observations of visual range are available from hundreds of airport weather stations for most of the 20th century. Although these observations provide the longest record of data, they are limited because of observer variations and inconsistent reporting procedures. Second, more accurate measurements are available from the IMPROVE and CASTNet monitoring networks, but these data only exist for about the last 10 years. Both sets of data are considered here.

Airport Data

The airport observations since about 1950 are summarized below (Malm, 1999):

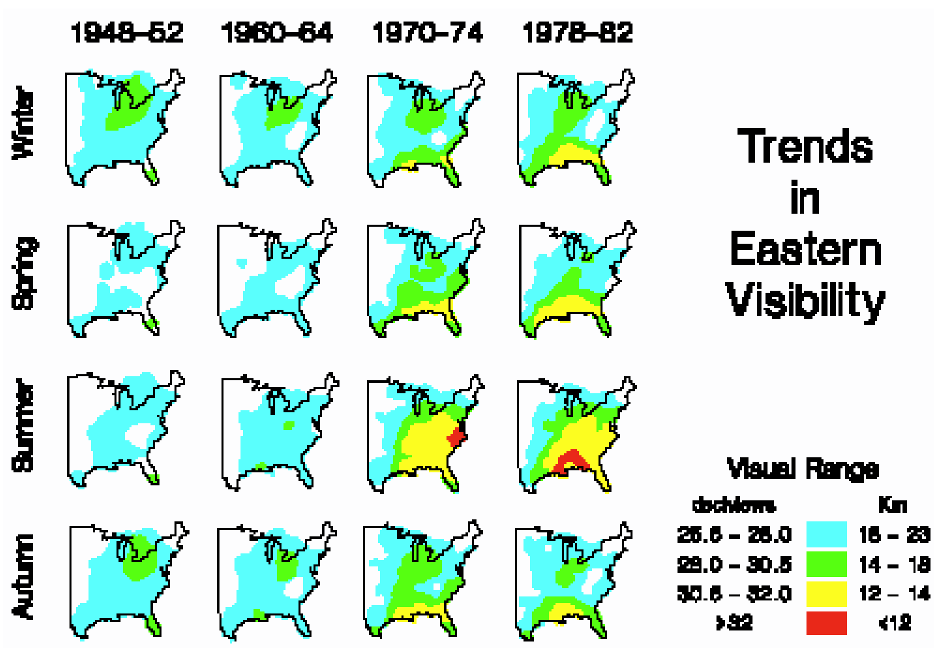


Figure 37. Trends in Median Visual Range in the Eastern Half of the U.S.

The airport data show that visibility has declined significantly over time in the eastern U.S., especially in the Southeast.

These visibility trends are related to SO_2 emissions trends. Figure 38 shows the trends in sulfur emissions and visibility for the Northeast and Southeast for the winter and summer months for the period 1940 - 1985 (Malm, 1999).

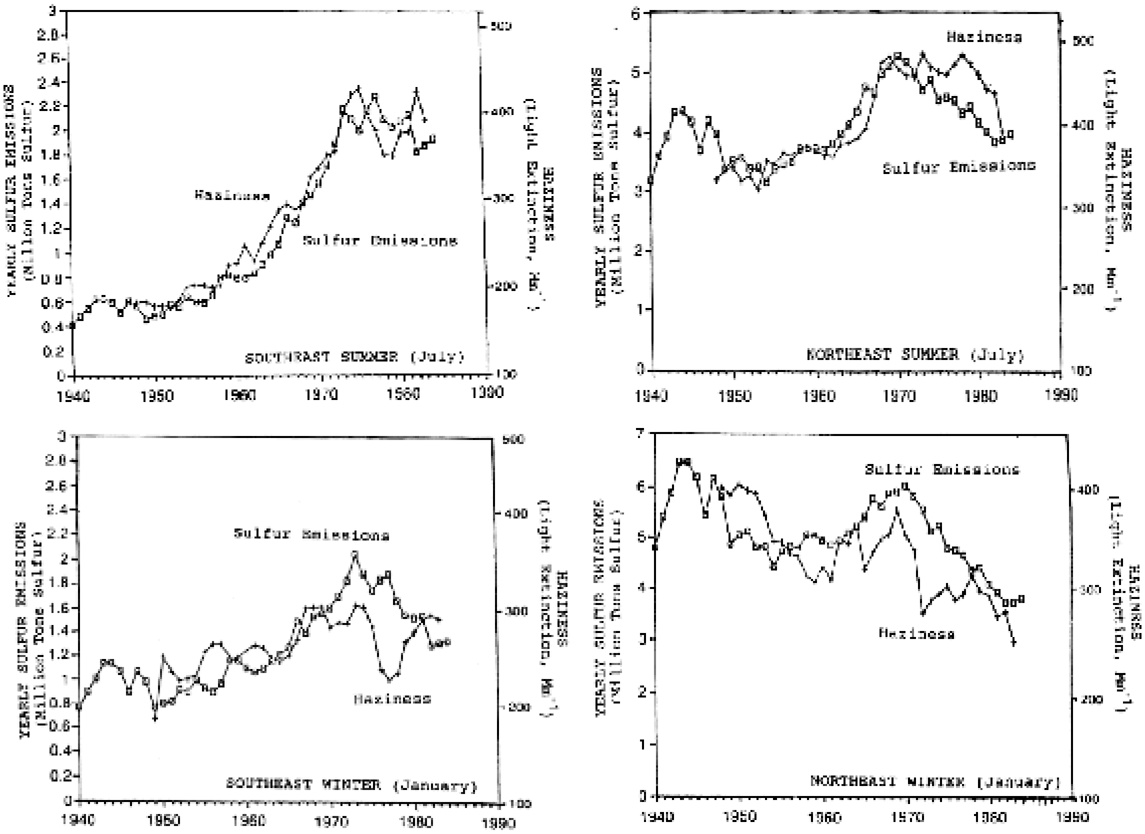


Figure 38. Trends in Regional SO_2 Emissions and Deciviews in the Southeast (left) and Northeast (right) for Summer (top) and Winter (bottom) Months

As noted by Malm (1999), “these data show that sulfur dioxide emissions provide a plausible explanation for variability observed in regional visibility and sulfate concentration variations.” Further discussion of the effect of SO_2 emissions changes in recent years pursuant to Title IV of the Clean Air Act Amendments of 1990 on visibility levels is provided below.

IMPROVE/CASTNet Data

Composite time series plots of light extinction for the 20% worst, median, and best days for the western and eastern U.S. are presented in Figure 39 (USEPA, 2001d):

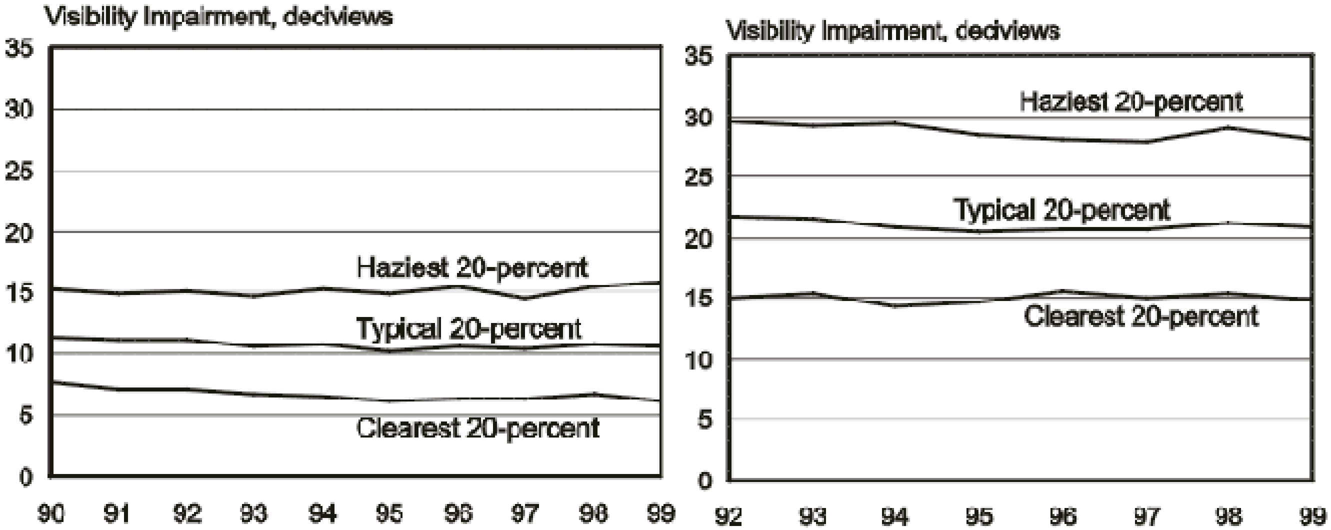


Figure 39. Trends in Visibility for the 20% Worst, 20% Median, and 20% Best Days in the Western (left) and Eastern U.S. (right)

As can be seen, the worst days in the west are only slightly more impaired than the best days in the east. Also, the 20% worst days in the east improved by about 1.5 deciviews since 1992. Composite time series plots showing the relative species contributions to light extinction on the 20% worst, median, and best days are presented below (USEPA, 2001d).

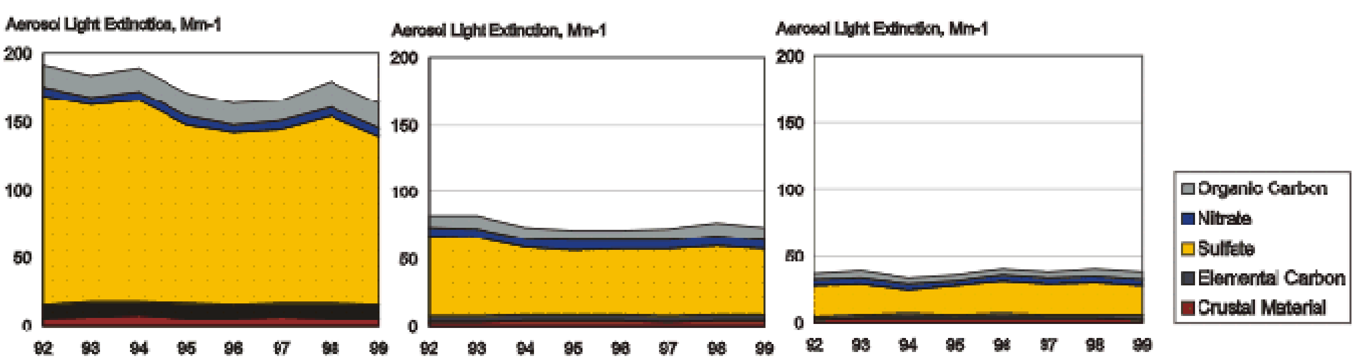


Figure 40. Trends in Chemical Composition for the 20% Worst, 20% Median, and 20% Best Days in the Eastern U.S.

As can be seen, sulfates are the leading contributor to visibility impairment in the eastern half of the U.S., accounting for 75 - 80% on the 20% worst days, 60 - 70% on the 20% median days, and 50 - 60% on the 20% best days.

The improvement for the 20% worst days in the east is consistent with the reduction in sulfate concentrations due to the reduction in SO_2 emissions pursuant to Title IV of the Clean Air Act Amendments of 1990 (see Figure 41). Most of the emissions reductions occurred at (Phase I) utilities located in the northern part of the eastern U.S.

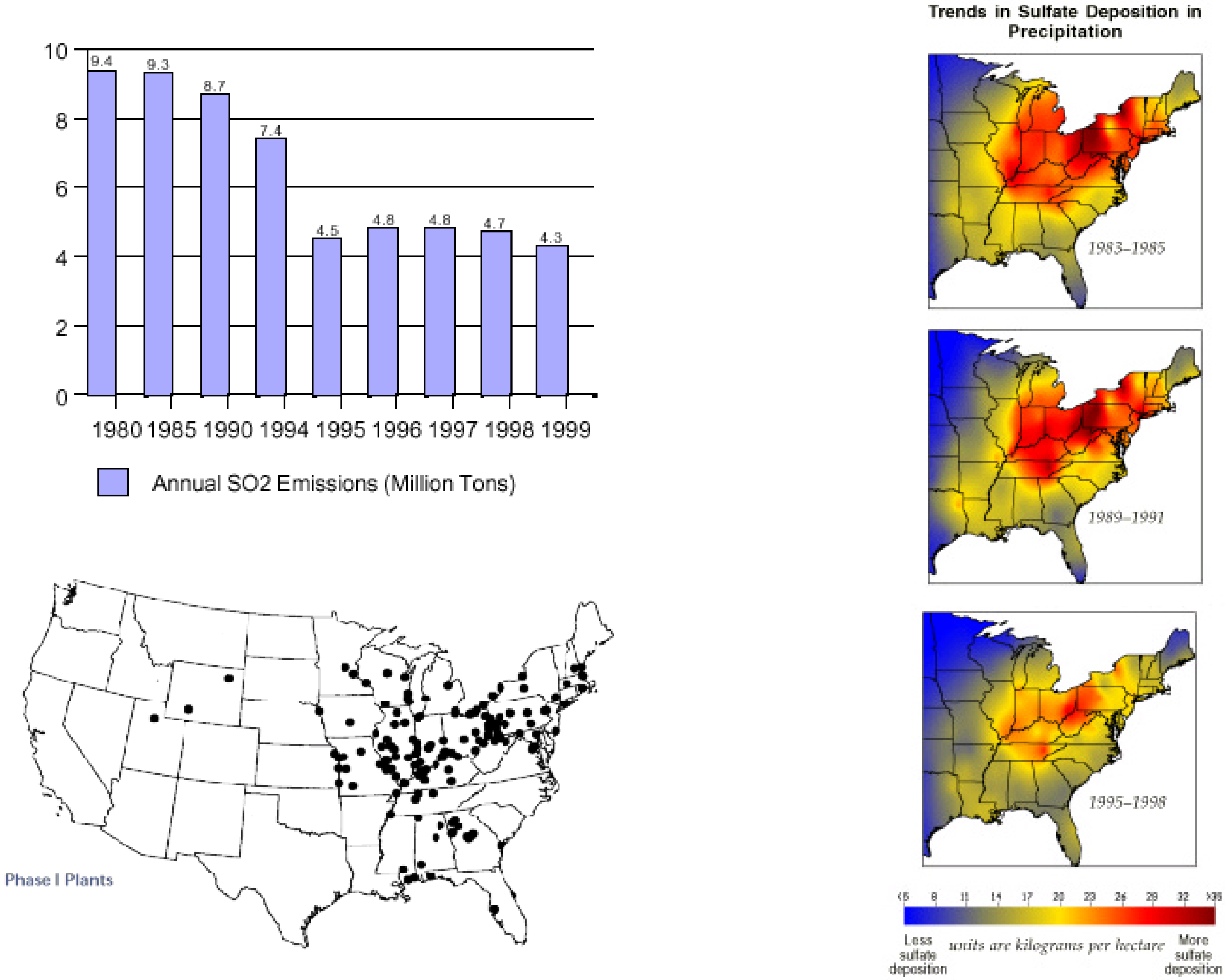


Figure 41. Recent Trends in SO_2 Emissions (Title IV, Phase I Units) and Sulfate Levels in the Eastern Half of the U.S.

Section 5
Summary

An initial assessment of the regional haze problem in the upper Midwest (i.e., the five-state region covered by the Midwest RPO) was performed by reviewing existing reports and analyzing available air quality data. A major shortcoming of this assessment is the lack of visibility-related measurements in this region. In view of this deficiency, the results reported here are considered to be preliminary. Further data collection and analyses are recommended to provide a more complete and detailed understanding of the regional haze problem in the upper Midwest.

The key findings of this initial assessment are as follows:

C Visibility impairment exists in the two Class I areas in the upper Midwest, in downwind Class I areas in the eastern half of the U.S., and in other areas (e.g., major urban areas in the upper Midwest). Although current conditions in the upper Midwest Class I areas approach "natural conditions" on the 20% best visibility days, they are significantly worse on the 20% worst visibility days (see Figure 42). Fine particles, which play a major role in visibility impairment, also reach unhealthy levels across a large portion of the eastern U.S.

C Visibility levels and $PM_{2.5}$ concentrations vary...

  C spatially, with better visibility and lower $PM_{2.5}$ concentrations occurring to the north (near Class I areas in the upper Midwest), and poorer visibility and higher $PM_{2.5}$ concentrations occurring to the south (near Ohio River Valley)

  C seasonally, with the worst and best visibility days occurring throughout the year in Class I areas in the upper Midwest, and the worst visibility days occurring during summer and the best visibility during winter elsewhere in eastern U.S.

  C chemically, with sulfates dominating on the worst visibility days during summer (note, organics are a distant second), and nitrates being important on worst visibility days during winter/fall (note, sulfates are also important and organics are a distant third)

(Note: these points suggest that the air quality situation in the Class I areas in the upper Midwest differs from that in other Class I areas in the eastern U.S.)

- Worst visibility days are associated with southerly-westerly flow for many sites in the eastern U.S., and the best visibility days with northerly flow

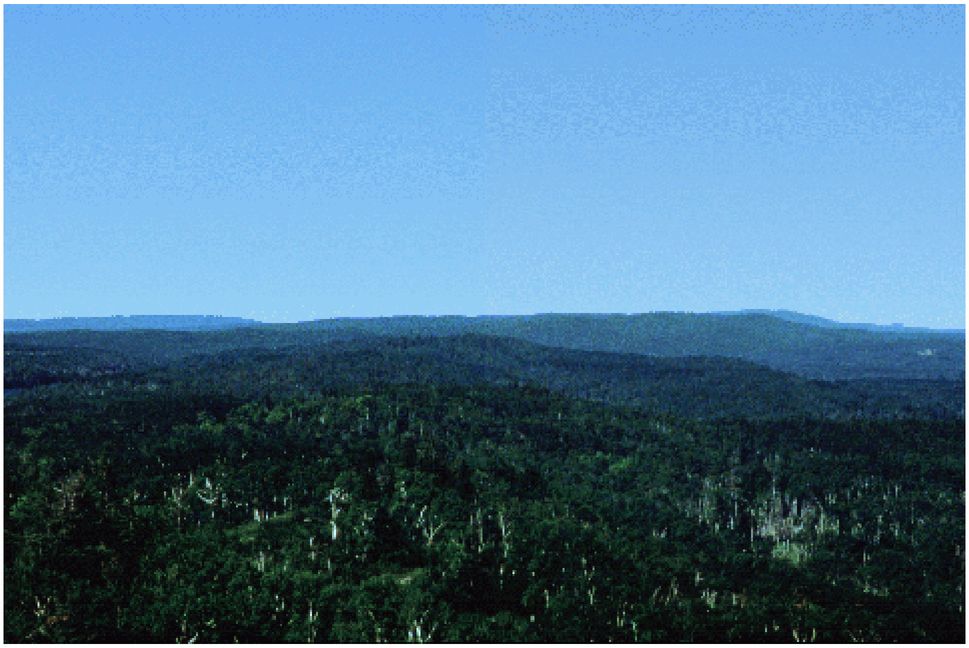
- Poor visibility is related to elevated concentrations of fine particles and (during the summer) ozone

- Visibility levels have deteriorated during the last half century, but appear to be improving in recent years due to SO_2 emission reductions

20% Best Days

Natural Conditions
(deciviews = 3.7)

Current Conditions
(deciviews = 7)



20% Worst Days

Natural Conditions
(deciviews = 11.3)

Current Conditions
(deciviews = 20)

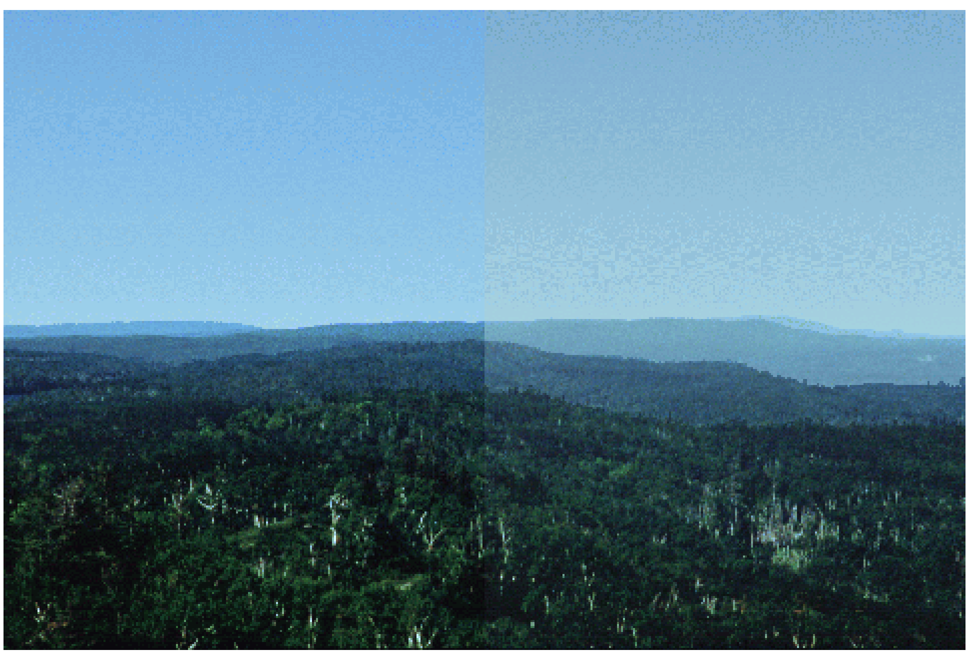


Figure 42. Natural Conditions v. "Current" Conditions on 20% Best and 20% Worst Days in Isle Royale National Park

Section 6
References

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Appendix I

Regulatory Requirements for Regional Haze Program

Section 169A of the Clean Air Act requires 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.” According to the preamble of the final rules, areas designated as mandatory Class I Federal areas are those national parks exceeding 6000 acres, wilderness areas and national memorial parks exceeding 5000 acres, and all international parks which were in existence on August 7, 1977[7]. There are 156 of these national parks and wilderness areas across the country, including many well-known parks and wilderness areas, such as the Grand Canyon, Great Smokies, Shendandoah, Yellowstone, and Yosemite.

In 1980, the U.S. Environmental Protection Agency (USEPA) promulgated regulations to address visibility impairment that is ‘‘reasonably attributable’’ to one or a small group of sources (i.e., plume blight), but deferred action on regional haze regulations until monitoring, modeling, and scientific knowledge about the relationship between pollutants and visibility effects improved (45 FR 80066). 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.’’ As such, in 1999, USEPA promulgated regulations to address visibility impairment due to regional haze (64 FR 35714, July 1, 1999). Regional haze is visibility impairment caused by the cumulative air pollutant emissions from numerous sources over a wide geographic area. The ultimate goal of the program is to achieve “natural” conditions by 2064.

Given the effect of regional pollutant transport in contributing to haze in Class I areas, USEPA encourages states to work together in “regional partnerships” to develop and implement multi-state strategies to reduce emissions of visibility-impairing fine particle pollution. Five regional planning organizations were identified by USEPA to receive

[7] Although states and tribes may designate additional areas as Class I, the requirements of the visibility program under section 169A of the Clean Air Act only apply to the mandatory Class I Federal areas. As for other areas, such as cities and tribal lands, the preamble says that the secondary NAAQS for fine particles were established to protect the public welfare against visibility impairment on a nationally uniform basis. USEPA also recognizes that the regional haze rules will improve visibility outside of Class I areas and will, therefore, improve local visibility impacts that may persist after attainment of the secondary standard. Consequently, the only protection for urban areas would seem to be that provided by the secondary NAAQS for fine particles (which in reality may not be very much since very hazy conditions can occur on days with $PM_{2.5}$ concentrations well below the 24-hour NAAQS of 65 ug/m3, as seen in Figures 17 and 19), as well as that which may result from programs to address visibility impairment in the Class I areas. Although the preamble also says that tribal lands are not afforded the same legal protection under the Clean Air Act as Class I areas, USEPA suggests that modeling analyses aimed at addressing Class I areas should add receptor locations to analyze the visibility improvements at selected tribal locations. Furthermore, USEPA encourages “…the consideration of impacts on visibility in tribal locations in regional planning efforts.”

grant funds to implement these regulations. The Midwest Regional Planning Organization (RPO) is led by the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, and the tribes located in these five States. Federal Land Managers (FLMs), USEPA, and stakeholders also participate in the regional planning process. The Lake Michigan Air Directors Consortium (LADCO) receives grant funds on behalf of the Midwest RPO.

The provisions of the Transportation Equity Act for the 21st Century (TEA-21) establish a timetable for regional haze SIPs by first creating certain deadlines for $PM_{2.5}$ monitoring and area designations, and then linking those deadlines to deadlines for the regional haze program[8]. For those states participating in a regional planning effort, the SIP requirements are as follows:

Initial SIP (due 1 year after $PM_{2.5}$ designations)
(a) how that emissions from your state contribute to visibility impairment in Class I area in another state (or emissions from another state contribute to visibility impairment in Class I area in your state)
(b) describe regional planning process
(c) list of BART-eligible sources
(d) commit to submit control strategy SIP

Control Strategy SIP (due 3 years after $PM_{2.5}$ designations, but not later than December 31, 2008)
- establish reasonable progress goals to ensure improvement for most impaired days and no degradation for least impaired days
- determine baseline and natural visibility conditions for most and least impaired days
- long-term control strategy
- monitoring strategy
- BART emission limits and compliance schedule

Progress Reports (due 5 years after submittal of control strategy SIP and every 5 years thereafter)
- Evaluate progress toward reasonable progress goal; reinitiate regional planning, if not "on track"

Comprehensive SIP Revision (due July 31,2018 and every 10 years thereafter)
(a) Evaluate and reassess control strategy SIP

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8 On May 14, 1999, a panel of the Court of Appeals for the District of Columbia Circuit remanded the $PM_{2.5}$ NAAQS to USEPA. In response to USEPA's petition for review of this decision, on February 27, 2001, the U.S. Supreme Court upheld USEPA's authority to set air quality standards under the Clean Air Act and USEPA's position that the Act requires these standards to be based solely on public health considerations. The Court, however, also found USEPA's implementation policy for ozone to be unlawful and on remand they directed the Circuit Court to dispose of any other preserved challenge to the NAAQS.