MANE-VU TECHNICAL MEMORANDUM

Contribution of Non-Sulfate Aerosols to MANE-VU Regional Haze

Prepared by
Northeast States for Coordinated Air Use Management (NESCAUM)

January 2012

Members of Northeast States for Coordinated Air Use Management

Arthur Marin, Executive Director
Northeast States for Coordinated Air Use Management

Anne Gobin, Bureau Chief
Connecticut Department of Energy and Environmental Protection, Bureau of Air Management

Melanie Loyzim, Bureau Director
Maine Department of Environmental Protection, Bureau of Air Quality

Nancy L. Seidman, Deputy Assistant Commissioner
Massachusetts Department of Environmental Protection, Bureau of Waste Prevention

Robert Scott, Director
New Hampshire Department of Environmental Services, Air Resources Division

William O'Sullivan, Director
New Jersey Department of Environmental Protection, Office of Air Quality Management

David Shaw, Director
New York Department of Environmental Conservation, Division of Air Resources

Douglas L. McVay, Chief
Rhode Island Department of Environmental Management, Office of Air Resources

Richard A. Valentinetti, Director
Vermont Department of Environmental Conservation, Air Pollution Control Division

MANE-VU TECHNICAL MEMORANDUM

Contribution of Non-Sulfate Aerosols to MANE-VU Regional Haze

Prepared by
NESCAUM

January 2012

CONTRIBUTION OF NON-SULFATE AEROSOLS TO MANE-VU REGIONAL HAZE

Project Manager

Paul Miller, Ph.D., NESCAUM

Principal Contributors

Laura Shields, Ph.D., NESCAUM

George Allen, NESCAUM

Paul Miller, Ph.D., NESCAUM

Lisa Rector, NESCAUM

Acknowledgments

NESCAUM gratefully acknowledges the funding support provided by the United States Environmental Protection Agency under a cooperative agreement with the Ozone Transport Commission in support of the MANE-VU Regional Planning Organization.

NESCAUM also thanks the following individuals for providing support on this work:

Rich Poirot, VT DEC
Leiran Biton, NESCAUM
Leah Weiss, NESCAUM

NESCAUM is solely responsible for the content of this technical memorandum and any errors it may contain.

Printed: January 2012

TABLE OF CONTENTS

FIGURES

TABLES

Executive Summary

Sulfate is the dominant contributor to poor visibility (haze) in federally-protected Class I areas (e.g., national parks and wilderness areas) of the Mid-Atlantic/Northeast Visibility Union (MANE-VU) region. Accordingly, MANE-VU members have placed heavy focus on reducing sulfate in their initial strategy to improve regional visibility. The region has observed reductions in sulfur dioxide (SO_2) emissions and corresponding improvements in visibility. However, in order to achieve long-term visibility goals, reductions in non-sulfate components will be needed.

This technical memorandum provides an overview of the chemical factors, after sulfate, that play significant roles in causing poor visibility in MANE-VU's Class I areas. In addition to sulfate, the key aerosol components of haze include nitrate, elemental carbon, organic carbon, and crustal materials such as dust/soil or sea salt. The relative importance of these components to visibility at a given Class I area can differ based on the area's proximity to sources, meteorological conditions, and seasonal patterns.

We use available Interagency Monitoring of Protected Visual Environments (IMPROVE) network data collected at representative monitoring sites in or near MANE-VU Class I areas to assess the relative contribution of non-sulfate aerosols to visibility. Complementary information is also provided, summarizing current or potential regulations and efforts to reduce non-sulfate aerosols and their precursors that can have an impact on visibility in the MANE-VU region.

We investigate three sulfate scenarios in assessing contributions of non-sulfate aerosols in the MANE-VU region: 1) historical average sulfate levels during 2000-2009, 2) sulfate levels reduced 50% below historical average levels, and 3) sulfate completely removed (i.e., 100% reduction). The three scenarios are separately analyzed for the 20% worst visibility days and the 20% best visibility days.

When half of the sulfate contribution is removed, sulfate remains the dominant aerosol factor in visibility impairment, contributing 51-59% and 35-41% to the overall aerosol light extinction on the haziest and cleanest days, respectively, at MANE-VU Class I areas. When the entire sulfate contribution is removed, the four most northern Class I sites in MANE-VU (located in Maine, New Hampshire, and Vermont) are at or approach natural haze conditions in the East on the 20% worst and best days. The southern-most Class I area in the MANE-VU region, Brigantine in New Jersey, remains well above natural visibility conditions, largely due to the non-sulfate aerosols. Even for the northern MANE-VU sites, it must be kept in mind that sulfate accounts for 9 – 12% of natural background visibility impairment in the East, hence sulfate would not be removed completely. Therefore, reductions in non-sulfate contributors will be necessary at all these sites in order to bring visibility closer to natural conditions.

In the absence of sulfate, the next top contributors to poor visibility at the MANE-VU Class I areas are organic carbon (30-57%) and nitrate (12-38%) for both clean and hazy days. Organic carbon is the key contributor in summer months, and nitrate is the key contributor in winter months. The nitrate contribution in the absence of sulfate could be underestimated as additional nitrate potentially would form as less sulfate becomes available to compete chemically for ammonium in the atmosphere.

In addressing non-sulfate aerosols in the MANE-VU region, there are a number of measures already being undertaken or under consideration to reduce these pollutants from their associated sources. In most cases, these measures are to address other policy goals, such as public health protection, rather than specifically aimed at regional visibility improvement. As with many air programs, they provide additional co-benefits beyond public health protection.

Examples of measures that can affect carbon aerosol levels include reducing emissions from wood combustion devices (e.g., outdoor wood boilers), reducing black carbon (soot) from diesel exhaust, and addressing volatile organic compound (VOC) emissions from gasoline storage tanks and other sources. Measures that can affect nitrate aerosols include further reducing oxides of nitrogen (NO_x) from electric power plants, light-duty vehicles, and other sources.

In summary, sulfate is the dominant historical contributor to poor visibility in the Class I areas of the MANE-VU region. However, in order to achieve long-term visibility goals, reductions in non-sulfate aerosols will be needed. Pollution control measures in place or under consideration at the state and federal levels will address some of the emissions of these non-sulfate aerosols. Quantifying the extent of these reductions and their potential impact on visibility in MANE-VU's Class I areas can be an important part of future work in developing "beyond sulfate" strategies to achieve natural background visibility in the region.

1. INTRODUCTION

An objective of the Mid-Atlantic/Northeast Visibility Union (MANE-VU) is to reduce the regional air pollution haze blurring scenic vistas in national parks and wilderness areas (Class I areas)[1] of the Mid-Atlantic and Northeast regions. MANE-VU has made significant steps toward a coordinated approach for reducing regional haze and preserving these important assets in the region. The initial MANE-VU strategies focus on sources of sulfur dioxide (SO_2), which is a precursor of sulfate particles, the dominant component of haze in the MANE-VU region. MANE-VU predicts that the regional 2018 SO_2 emissions from all source sectors will be less than 40% of the 2002 levels (MARAMA, 2011). MANE-VU members also recognize that their long-term visibility goals necessitate a multi-pollutant approach such that other non-sulfate particles must also be addressed.

In addition to sulfate, the key chemical components of haze include nitrate, elemental carbon (EC), organic carbon (OC), and crustal materials such as dust/soil or sea salt. The relative importance of these components to each Class I area can differ based on the area's proximity to sources, meteorological conditions, and seasonal patterns. The purpose of this technical memorandum is to investigate which chemical factors, after sulfate, play significant roles in causing poor visibility in MANE-VU Class I areas. We examine the available monitoring data from representative measurement sites located in or near the Class I areas to assess the relative contribution of non-sulfate aerosols to visibility. Complementary information is also provided, summarizing current or potential regulations and efforts to reduce non-sulfate particulate matter and their precursors that can have an impact on visibility in the MANE-VU region.

---

[1] The MANE-VU region has 7 of the 156 identified federally protected Class I areas. They include: Acadia National Park (ME), Moosehorn Wilderness Area (ME), Great Gulf Wilderness Area (NH), Presidential Range-Dry River Wilderness Area (NH), Brigantine Wilderness Area (NJ), Lye Brook Wilderness Area (VT), and Roosevelt Campobello International Park (New Brunswick).

2. METHODS

2.1. The IMPROVE Program

The data analyzed in this study are from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The latest IMPROVE report (Hand et al., 2011) provides details on the network. The US Environmental Protection Agency (EPA), the four federal land management agencies,[2] and regional-state organizations collaborate on the IMPROVE program. The program is specifically designed to establish current visibility at Class I areas, determine long-term trends of visibility at these sites, and monitor regional haze in accordance with the Regional Haze Rule (RHR). Air quality measurements in the network began in 1988 with 36 initial sites; the network now consists of 212 sites (including 42 discontinued sites).

The particulate matter (PM) monitors at the IMPROVE sites collect 24-hour samples every third day. The monitors consist of four independent samplers equipped with different filter substrates specific to the intended analysis. The off-line analyses include mass, light absorption, elemental, ion, and carbon analysis. Each sample is subject to artifacts (positive and negative) during sampling, shipping, storage, and analysis. Throughout this long-term study, improvements in technique and materials have helped reduce some of these artifacts. All IMPROVE data are available for downloading at the Federal Land Manager Environmental Database (FED) website.[3]

2.2. Sulfate Scenarios at MANE-VU IMPROVE Sites

This technical memorandum investigates the existing MANE-VU IMPROVE site data using three sulfate scenarios: 1) historical sulfate levels during 2000-2009, 2) sulfate levels reduced 50% below historical levels, and 3) sulfate completely removed (i.e., 100% reduction). These hypothetical scenarios highlight the contributions of non-sulfate components to light extinction. Light extinction (b_{ext}) is a visibility metric that summarizes the light scattering and absorption of ambient gases and particles, using measured species concentrations. Increasing values of light extinction indicate poorer visibility.

A revised IMPROVE algorithm, developed in 2005 and adopted by MANE-VU in December 2006, reduces bias for high and low light extinction extremes and is more consistent with the recent literature (Pitchford et al., 2007). Some of the major changes from the original algorithm are the inclusion of a sea salt term and the employment of site-specific Rayleigh (gas) scattering values based upon annual temperature and elevation. The revised equation, expressed as a summation of different component contributions, is shown below, and further details can be found in Pitchford et al., 2007:

---

[2] National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service.

[3] Federal Land Manager Environmental Database: http://views.cira.colostate.edu/fed/ (accessed October 2011)

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

In the equation, the units for b_{ext} and Rayleigh scattering are in inverse megameters (Mm^{-1}); the numeric multipliers are constant dry mass extinction efficiency terms with units of m^2/g; the unitless water growth terms for the small ($f_S(RH)$) and large ($f_L(RH)$) size distribution sulfate and nitrate components and for sea salt ($f_{SS}(RH)$) are functions of relative humidity (RH); and the component concentrations in brackets are in units of $\mu g/m^3$. The following equations apportion total sulfate, nitrate, and organic mass concentrations into the small and large size fractions:

$$\begin{aligned} &[\text{Large X}] = [\text{Total X}]/\ 20\ \mu g/m^3 \times [\text{Total X}], \text{ for } [\text{Total X}] < 20\ \mu g/m^3 \\ &[\text{Large X}] = [\text{Total X}], \text{ for } [\text{Total X}] \geq 20\ \mu g/m^3 \\ &[\text{Small X}] = [\text{Total X}] - [\text{Large X}] \end{aligned}$$

IMPROVE results are often displayed in 5-year baseline periods (e.g., 2000-2004 and 2005-2009) in order to smooth out the variability due to annual changes in emissions and weather patterns. Also useful for comparison purposes are plots of the 20% best visibility and the 20% worst visibility days.

We downloaded the species-specific light extinction values as determined by the new IMPROVE equation for 2000 through 2009 at the MANE-VU IMPROVE sites. Table 2-1 lists the five IMPROVE sites located in the region. Note that the Great Gulf and Moosehorn IMPROVE sites represent two separate Class I areas. The next section presents the results determined under the sulfate scenarios.

Table 2-1. Locations of MANE-VU IMPROVE sites

IMPROVE site	State	Start of operation	Latitude	Longitude	Class I area
Acadia National Park	ME	Mar-88	44.377	-68.261	Acadia National Park
Brigantine National Wildlife Refuge	NJ	Sep-91	39.465	-74.449	Brigantine Wilderness Area
Great Gulf Wilderness Area	NH	Jun-95	44.308	-71.218	Great Gulf Wilderness Area Presidental Range-Dry River WA
Lye Brook Wilderness Area	VT	Sep-91	43.148	-73.127	Lye Brook Wilderness Area
Moosehorn National Wildlife Refuge	ME	Dec-94	45.126	-67.266	Moosehorn Wilderness Area Roosevelt Campobello International Park

Source: Hand et al., 2011.

3. RESULTS & DISCUSSION

3.1. Removing Sulfate

Figure 3-1 provides a glance into the overall temporal trends of the sulfate and non-sulfate aerosol light extinction contributions using the 5-year baseline periods of 2000-2004 and 2005-2009. For the annual 20% cleanest (left column) and 20% haziest (right column) days, each data point represents the average light extinction of sulfate (yellow diamonds) and non-sulfate components (green triangles) determined at the IMPROVE site for those days over the 5 year period. The lines connecting the data points illustrate that the average values have decreased between the two periods. Notice that on the cleanest days, the sulfate and non-sulfate contributions are relatively the same, whereas the sulfate contribution is more than double the non-sulfate contribution on the haziest days.

The data in Figure 3-2 and Figure 3-3 represent estimations of the light extinction contributors under the hypothetical sulfate scenarios for the 20% haziest and 20% cleanest days, respectively. Each bar shows the average contributors at a monitoring site. The first set of bars displays the unaltered averages over 2000-2009. To determine the averages in the middle set, half of the contribution by sulfate was removed from the 24-hour measurements and the annual 20% worst and 20% best days were recalculated. Similarly, the third set of bars illustrate the average worst and best days when the sulfate contribution is completely removed, simulating deep reductions in SO_2 emissions. The top chart (a) of each figure shows the absolute contributions to light extinction, and the bottom chart (b) of each figure shows the relative contributions.

As seen in the figures, when half of the sulfate contribution is removed, sulfate remains the dominant factor in light extinction. This scenario most closely corresponds to the MANE-VU prediction that SO_2 emissions in 2018 will be 60% below 2002 levels (MARAMA, 2011). With a 50% sulfate reduction, sulfate contributes 51-59% and 35-41% to the overall aerosol light extinction on the haziest and cleanest days, respectively. Visibility on the 20% worst days is within a range of 62 – 121 Mm^{-1}, which remains well above natural visibility conditions of ~33 Mm^{-1} (~12 dv). Visibility on the 20% best days is in the range of 16 – 34 Mm^{-1}, which approaches the natural background of ~15 Mm^{-1} (~4 dv) (MARAMA, 2011). Brigantine consistently has the poorest visibility of all the MANE-VU sites under worst and best conditions.

When the entire sulfate contribution is removed, the four most northern MANE-VU sites are at or approach natural haze conditions in the East on the 20% worst (~33 Mm^{-1}) and best (~15 Mm^{-1}) days. Brigantine in New Jersey, however, remains well above natural visibility conditions, largely due to the non-sulfate aerosols. Even for the northern MANE-VU sites, it must be kept in mind that sulfate accounts for 9 – 12% of the natural background visibility impairment in the East (Malm, 1999), so absolute light extinction levels will be higher than given in the figures. Reductions in non-sulfate contributors will be necessary to bring these sites and Brigantine closer to natural levels.

In the “no sulfate” simulation, the next top light extinction contributors are OC (30-57%) and nitrate (12-38%) for both clean and hazy days. Nitrates, like sulfates, are highly hygroscopic, meaning they readily incorporate water. This behavior further complicates the light extinction of these components; the associated water makes these species contribute disproportionately greater to light extinction than based simply on their relative mass contribution to total particulates (NESCAUM, 2001).

The results shown in Figure 3-2 and Figure 3-3 represent simple simulations with the available data. The calculations do not consider future reductions in non-sulfate sources nor the possible changes in the gas-to-particle phase conversions as the sources of sulfate are reduced. This may be particularly relevant for nitrate substitution of sulfate, as ammonium bonds more strongly to sulfate than nitrate. As less sulfate becomes available, the chemical balance of ammonia may shift to the remaining nitrate, thus increasing particle-phase nitrate. More information is needed to model such changes; in the meantime, these simulated scenarios with the existing data provide rough estimates.

Figure 3-1. Average light extinction contributions of sulfate and non-sulfate components over 5-year baseline periods

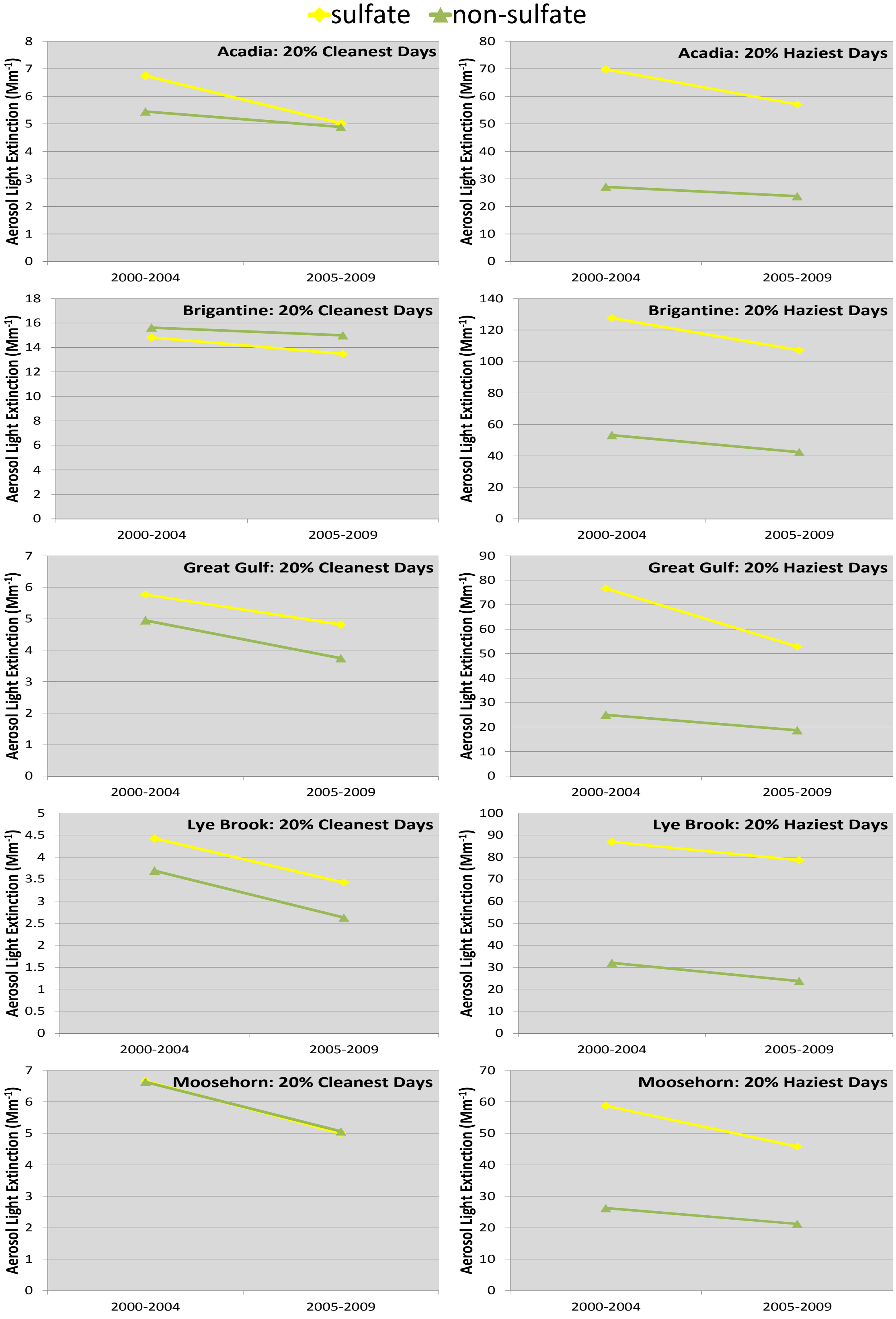


Figure 3-2. Average light extinction on 20% haziest days

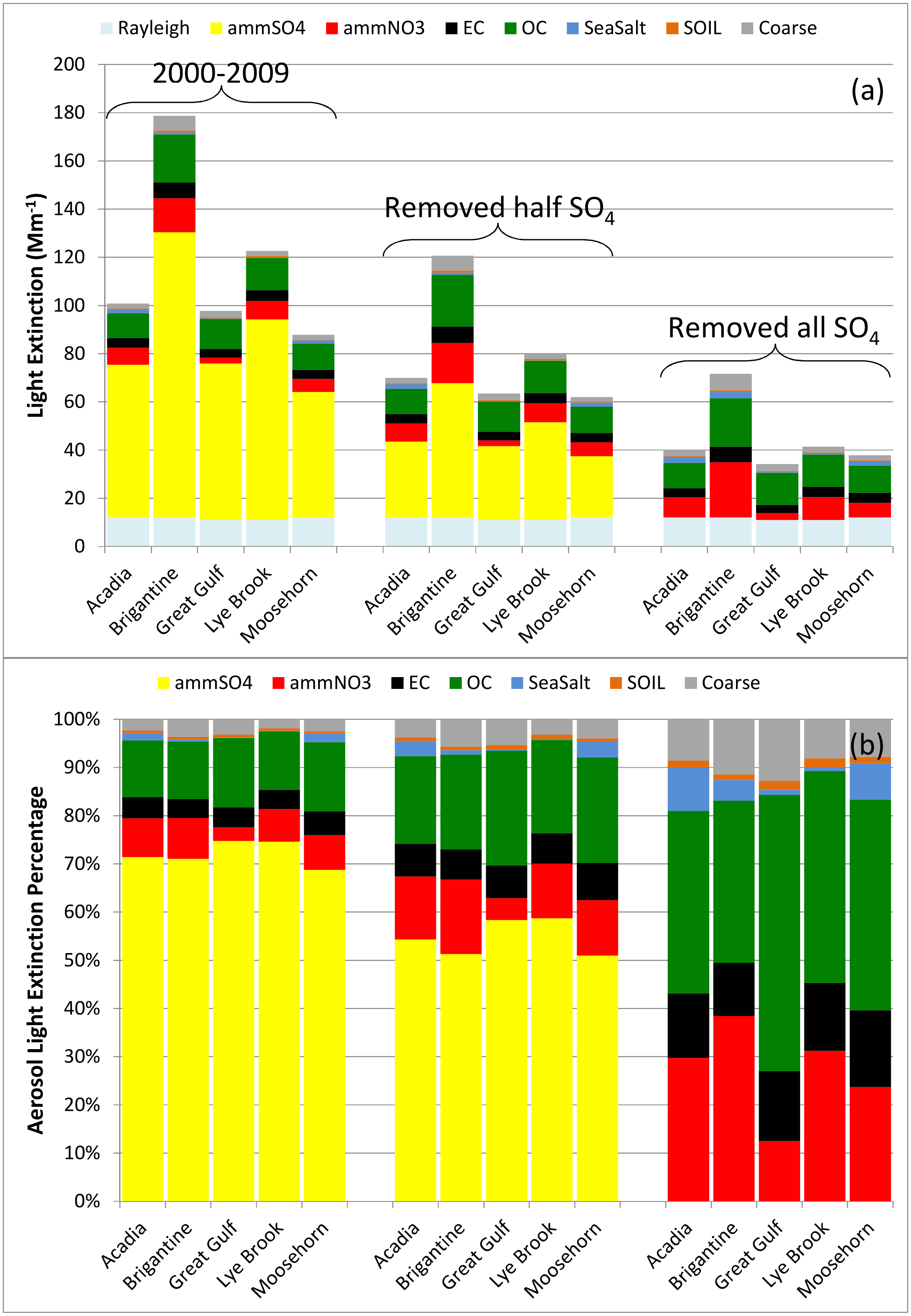
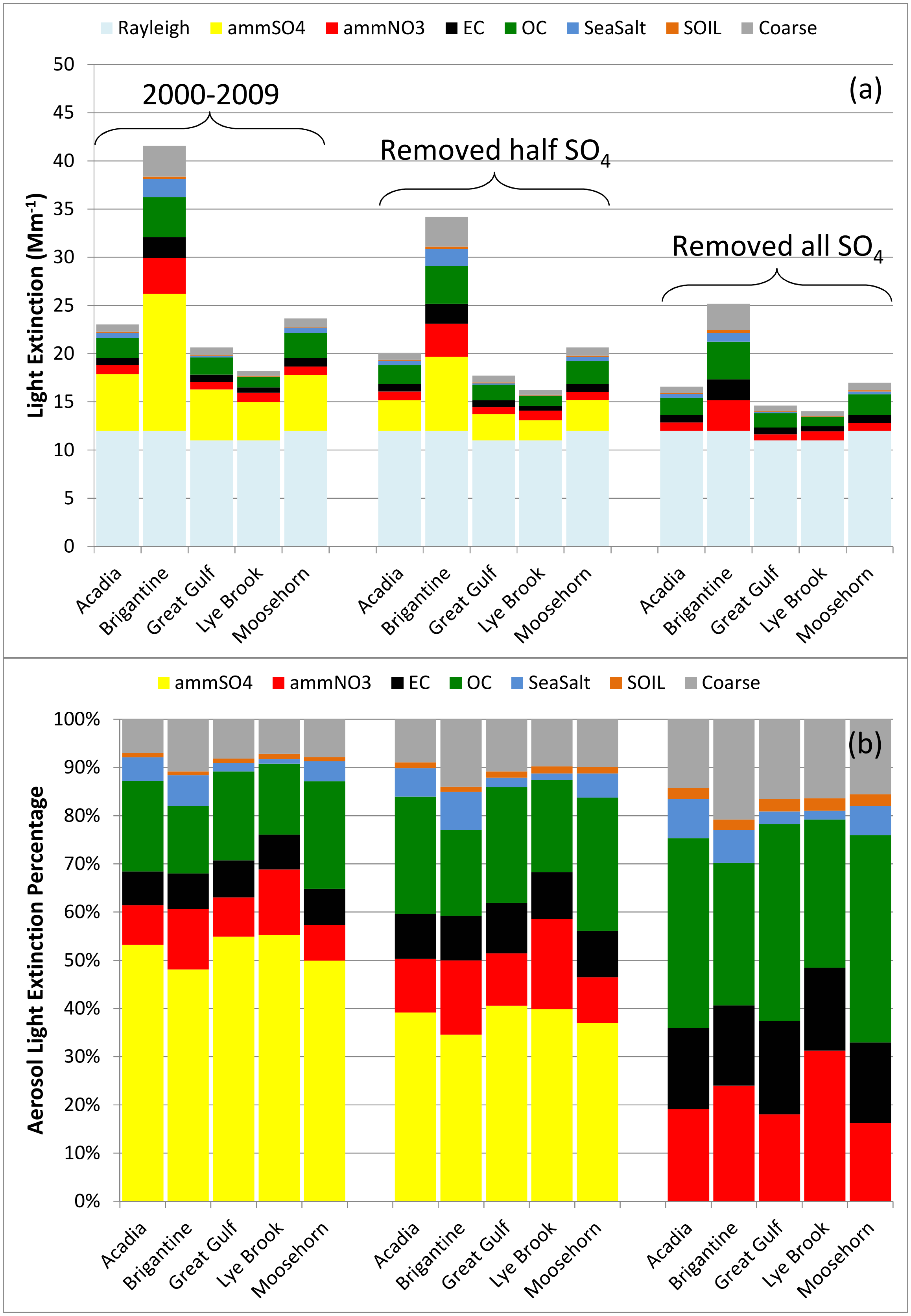


Figure 3-3. Average light extinction on 20% cleanest days



3.2. Seasonality

When recalculating the total light extinction under the different sulfate scenarios, the best and worst haze days shift; a day in the top 20% or bottom 20% may not necessarily fall under the same percentile when the sulfate contribution is reduced. Figure 3-4 and Figure 3-5 display the quarterly percentage breakdown for days that are the 20% haziest and cleanest, respectively, under the different sulfate scenarios. The first quarter (Q1) consists of the three months of January, February, and March, the second quarter (Q2) consists of April, May, and June, and so on for the third and fourth quarters.

In general, the most dramatic seasonal changes are the first quarter (winter) increase and third quarter (summer) decrease in hazy days as the sulfate contribution is reduced. This observation is most pronounced at the Brigantine site. The Great Gulf site maintains relatively the same amount of haziest days by season. Figure 3-5 displays the opposite changes for the cleanest days plus a noticeable second quarter (spring) percentage increase. The Lye Brook site maintains relatively the same amount of cleanest days by season under the different scenarios.

It is little surprise that the percentage of summertime hazy days drops when sulfate is removed as a contributor. Sulfate contributions peak during the warmer months. The wintertime meteorological conditions are less ideal for the oxidation of sulfate from SO_2. Likewise, when sulfate is removed as a contributor, the relative percentage of hazy days during the winter increases. Because sulfate is already at a minimum during this period, the non-sulfate components are increasingly significant. Figure 3-6 provides a view of the general temporal trends of the non-sulfate components.

Figure 3-6 displays the light extinction temporal trends of ammonium nitrate (ammNO3), EC, OC, sea salt, and soil at the Acadia site from 2000 through 2009. The overall trend through 2009 is consistent with previous reports (MARAMA, 2011; NESCAUM, 2010a). Figure 3-6 shows the temporal results at the Acadia site as an illustrative example. The trend lines represent moving averages based on 31 samples (~90 days). The moving average smoothes out the plotted data, making the overall trend easier to follow. The OC light extinction (green line) tends to peak during the summer months. The ammonium nitrate light extinction (red) exhibits the opposite behavior by peaking during the winter months. It is difficult to discern a clear temporal pattern for EC (black). Soil (orange) contributes little to the overall light extinction at all sites. Sea salt (blue) plays a small role only at the sites located close to the coast (Acadia, Brigantine, and Moosehorn).

The seasonal trend shows that ammonium nitrate contributes more to aerosol light extinction during the winter months relative to the summer. Ammonia bonds more weakly to nitrate than it does to sulfate, and ammonium nitrate tends to dissociate at higher temperatures. Consequently, ammonium nitrate becomes more stable at lower temperatures. The precursor, NO_x, has higher levels in the MANE-VU region during the colder months. Such behavior has several reasons: less dispersion during colder months due to lower atmospheric mixing heights; less stringent regulations on power plants outside the ozone season; and increased NO_x emissions due to increased heating demands (NESCAUM, 2010b).

Figure 3-4. Quarterly percentages of 20% haziest days by sulfate scenario

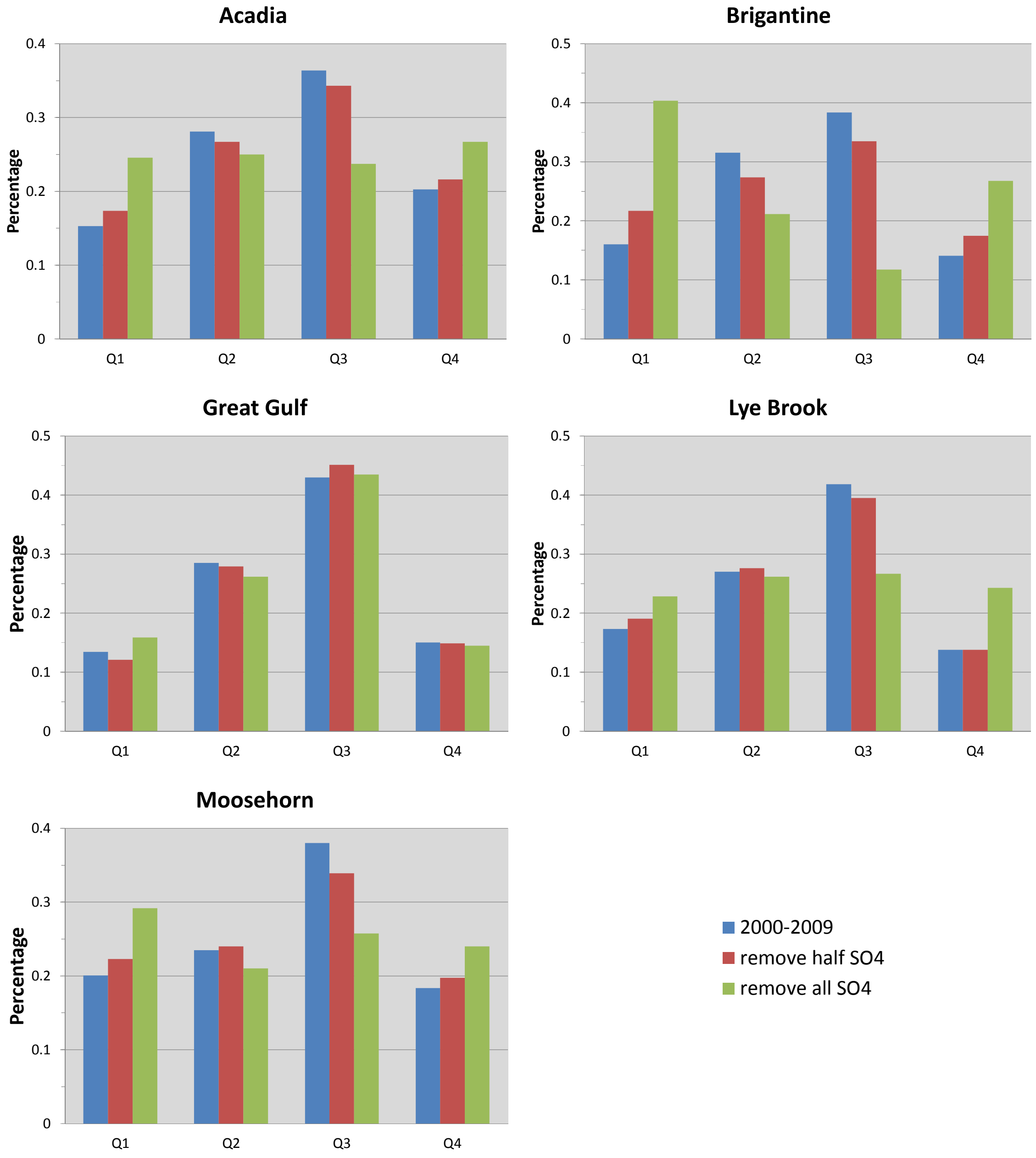


Figure 3-5. Quarterly percentages of 20% cleanest days by sulfate scenario

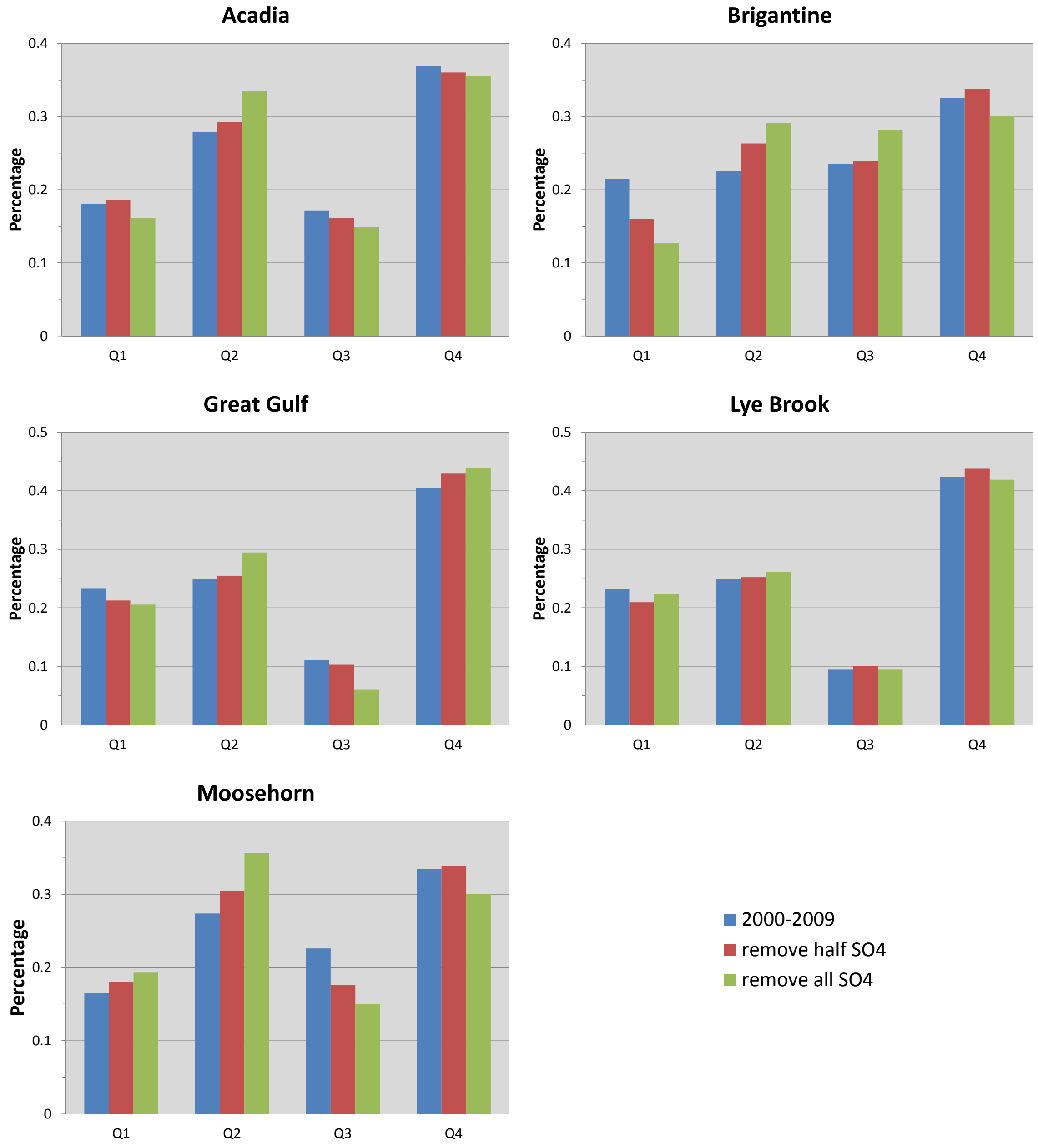
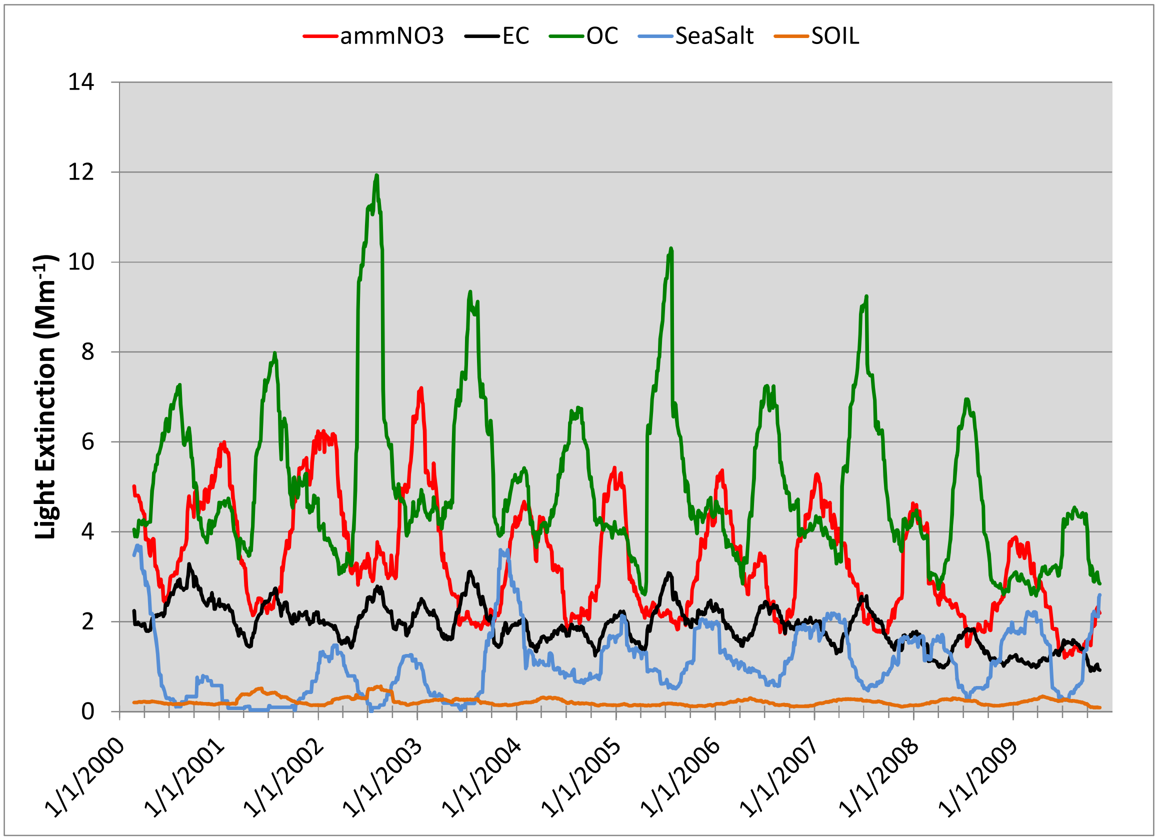


Figure 3-6. Light extinction temporal series by individual non-sulfate species at Acadia from 2000 through 2009



As presented in Figure 3-2, the top two light extinction contributors to the haziest days after sulfate is removed are OC and nitrate. Figure 3-7 compares the ammonium nitrate light extinction with the OC light extinction on the 20% worst haze days from 2000 to 2009 under the no sulfate scenario. Each marker represents one day, and they are color-coded to distinguish the winter (blue) and summer (red) months from the remaining months (green). In this figure, the winter months are December, January, and February; the summer months are June, July, and August. The figure is separated into five site plots: (a) Acadia, (b) Brigantine, (c) Great Gulf, (d) Lye Brook, and (e) Moosehorn. For the wintertime hazy days, the light extinction has a low OC contribution and a varying nitrate contribution. The trend reverses for the summertime haze days: the nitrate contribution is relatively low and the OC contribution varies. The hazy days during the rest of the year fall in between the two extremes with mixed contributions from OC and nitrate. The figure demonstrates that, after the sulfate contribution, OC is the top summertime factor to visibility impairment and nitrate the top wintertime factor.

Note that the July 7, 2002 data point is not plotted for Brigantine, Great Gulf, and Lye Brook (it was not in the top 20% haziest days determined for Acadia and Moosehorn). A Quebec wildfire event heavily influenced the sites on this sampling day. Long-range transport of smoke emissions from wildfires (and prescribed burning to a lesser extent) can be a potential source of OC and some EC at the IMPROVE monitoring sites in the MANE-VU region during the summertime (NESCAUM, 2006).

Figure 3-7. Comparison of OC and ammonium nitrate light extinction contributions to the 20% haziest days under the no sulfate scenario

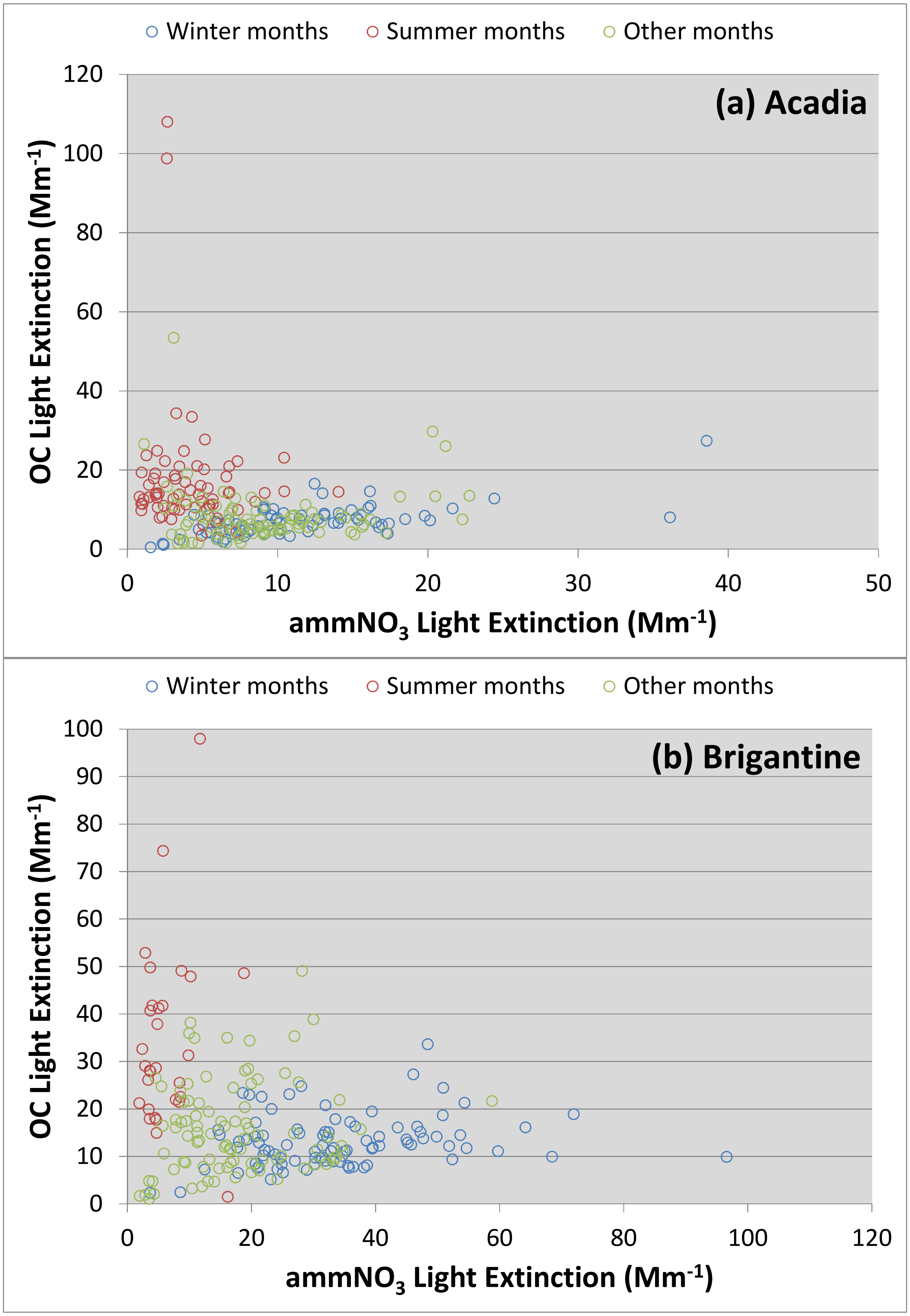


Figure 3-7 (continued). Comparison of OC and ammonium nitrate light extinction contributions to the 20% haziest days under the no sulfate scenario

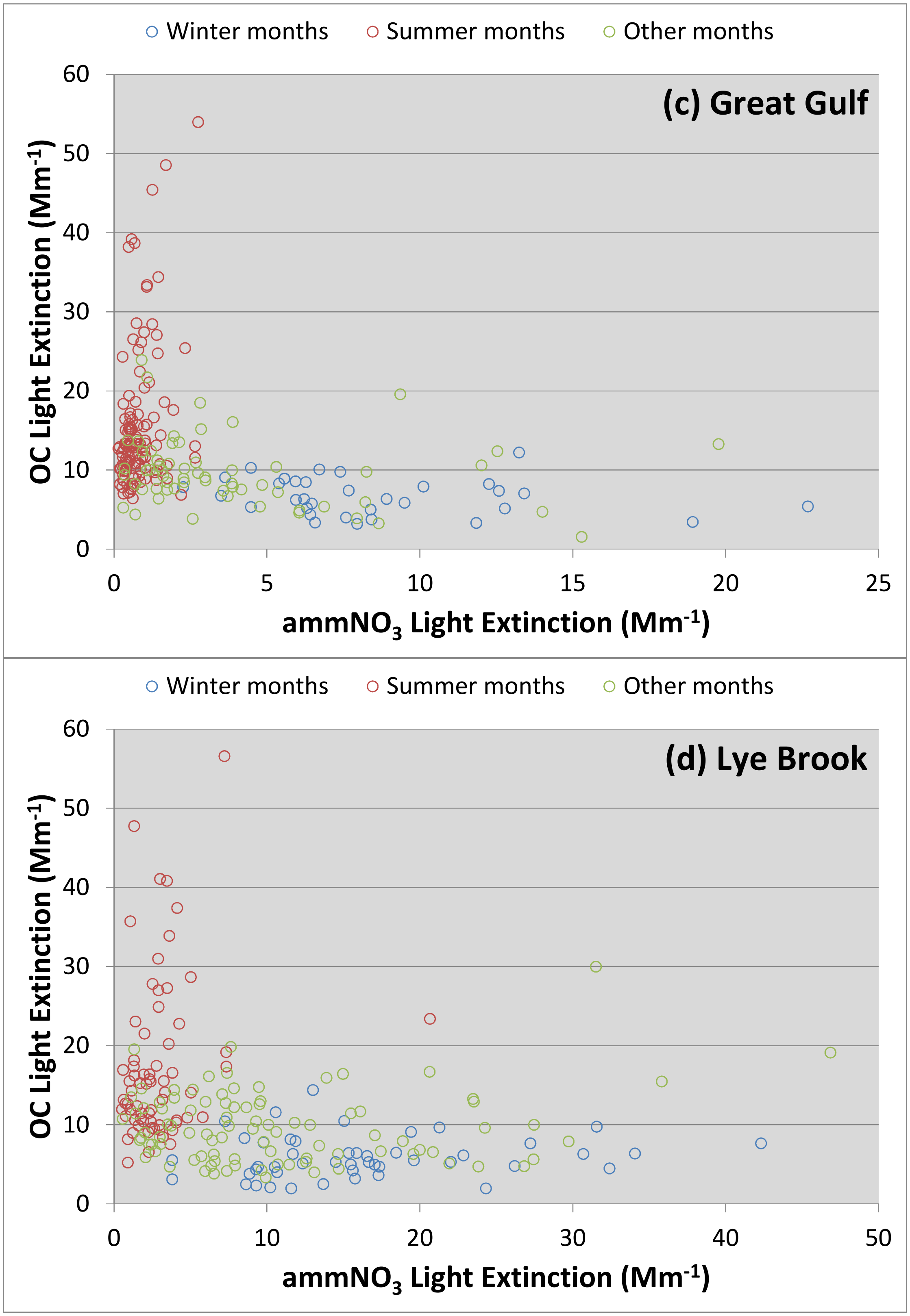
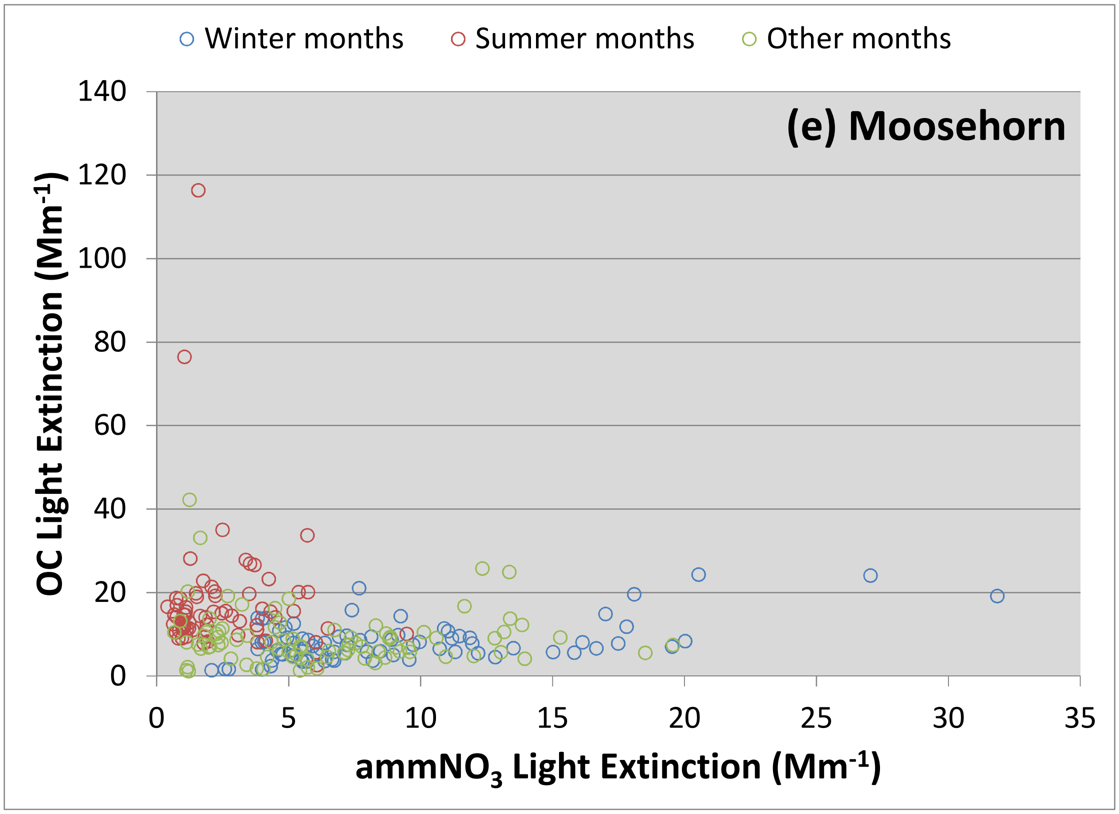


Figure 3-7 (continued). Comparison of OC and ammonium nitrate light extinction contributions to the 20% haziest days under the no sulfate scenario



Due to the dominance sulfate has had in visibility impairment, MANE-VU has placed major attention on the sources of sulfate. However, in order to ultimately reach the region’s visibility goals, MANE-VU needs to look at measures that address the non-sulfate components. The results presented here show that sources of summertime OC and wintertime nitrates are of particular concern. Measures for these and the other non-sulfate components are described in section 4.

4. CONTROL MEASURES

The following subsections discuss how the MANE-VU states are addressing or planning to address the non-sulfate contributors to regional haze, and review measures already undertaken or under consideration to reduce haze-forming pollutants from their associated sources. In most cases, these measures are to address other policy goals, such as public health protection, rather than specifically aimed at regional visibility improvement. As with many air programs, they provide additional co-benefits beyond public health protection.

4.1. Residential Wood Combustion

Reviews of air pollutant emission inventories and air monitoring data show that residential wood combustion represents a significant portion of winter particulate emissions. Nationally, the US EPA estimates that residential wood combustion is responsible for over 420,000 tons per year of fine particulate ($PM_{2.5}$) emissions, making it one of the largest direct $PM_{2.5}$ emissions source categories in the total emission inventory.

Many in-use wood burning appliances are less efficient and emit more particulate pollution than achievable with more advanced designs and technologies. For example, of the approximately 10 million wood stoves currently in use in the U.S., an estimated 70 to 80 percent of them are older, inefficient, conventional stoves that pollute at much higher levels than US EPA-certified wood stoves. In addition, almost all of the installed 500,000 outdoor wood boilers do not meet the US EPA's voluntary Phase II standard, or state-specific standards (see Table 4-1).

Along with higher PM emissions, conventional wood burning appliances also emit higher levels of polycyclic aromatic hydrocarbons (PAHs), polycyclic organic matter (POMs), and black carbon. Due to these significant emissions contributions, the MANE-VU states have been engaged in activities on the state and federal fronts to reduce residential wood combustion emissions.

4.1.1. Federal residential wood heater new source performance standards

Currently, the only federal regulation that applies to residential wood heating devices is the New Source Performance Standard (NSPS) for residential wood heaters, codified in 40 CFR (Code of Federal Regulations) part 60. This regulation, adopted in 1988, applies only to new units and has not been revised since its adoption. At the urging of a number of states, the US EPA launched a review of the NSPS and may propose a revision to it in the first quarter of 2012.

Listed below are important issues related to a revised NSPS for residential wood heating devices:

- Devices regulated under the standard
- Fuel types
- Regulated pollutants
- Emission limits
- Test methods
- Compliance assurance mechanisms

- Form of the standard

Individually and through NESCAUM, a number of MANE-VU states are engaged with the US EPA in each of these issues as the agency reviews the 1988 NSPS. The following paragraphs provide some additional background on each of the above listed items.

Devices regulated under the standard

Several MANE-VU states are seeking an expansion of the types of wood combustion sources covered under an NSPS and removal of current exemptions from an NSPS. Examples of currently exempted wood combustion sources include fireplaces, masonry heaters, pellet stoves, outdoor/indoor wood boilers, and outdoor/indoor furnaces.

Fuel types

A wide variety of devices burn solid fuels other than wood, such as coal, corn, and switchgrass, and multi-fuel devices are capable of burning a range of fuels in addition to wood. To help ensure that all solid fuels used for residential heating meet an emission standard, a number of MANE-VU states and NESCAUM have requested that the US EPA expand the scope of the NSPS to all solid fuels, test multi-fuel devices for additional fuels, and develop fuel specifications for manufactured fuels, such as wood pellets.

Regulated pollutants

Several MANE-VU states and NESCAUM have recommended to the US EPA that it develop emission standards for residential wood heaters beyond PM to include key criteria pollutants such as CO, VOCs, NO_x, SO_x, and PAHs. Addressing black carbon from these sources is also important, as residential wood burning represents one of the largest sources of direct PM emissions in the United States.

Emissions limits

In developing emission standards for a revised NSPS, section 111 of the Clean Air Act requires the US EPA to set an NSPS reflecting best demonstrated technology (BDT) control levels. A number of MANE-VU states and NESCAUM are providing the US EPA with information on wood heater emission limits established throughout the world so that a revised NSPS can incorporate considerations of technology improvements and emission limits achieved elsewhere, particularly in Europe.

Test methods

Currently, the US EPA's test program uses a certification method in lieu of on-site stack testing to assure compliance with an NSPS for a covered residential wood burning appliance. Several MANE-VU states and NESCAUM have recommended to the US EPA that the test should represent worst case emission scenarios, including burn rate and fuel type. Testing should also simulate all operations that are feasible in the real world and be standardized to the extent possible across similar device types. Relevant to visibility as well as public health, the testing should continue to measure total particulate matter.

Compliance assurance mechanisms

Several MANE-VU states are concerned about the lack of oversight and follow-up on testing of units as defined in the current residential wood heater NSPS. On behalf of the states, NESCAUM recommended to the US EPA that it continue with the current standard process of the US EPA Office of Enforcement and Compliance Assurance (OECA) reviewing and approving certifications rather than pursuing alternative certification procedures. NESCAUM also requested that a third-party process should only be used for a voluntary program, with auditing of the results to determine their effectiveness.

Form of the standard

Several MANE-VU states and NESCAUM have requested the use of a common metric across the variety of devices that could be regulated under the NSPS. The goal is to allow a consumer to compare emissions performance not only across different units within a class but also to compare emissions among different types of devices. Additionally, given the recent movement towards incentives for energy efficient units, the states have urged the US EPA to develop a standardized efficiency test method and performance level under a revised NSPS.

4.1.2. MANE-VU state measures for residential wood combustion

Outdoor wood boilers

As a result of a number of public complaints of air pollution from excessively smoking outdoor wood boilers (OWBs – also referred to as “hydronic heaters”) on neighboring properties, several MANE-VU states in 2007 requested that NESCAUM assist in developing a model rule for these wood boilers. Since that time, eight MANE-VU states[4] have adopted emission standards specific to OWBs. Several states also limit the types of fuel that can be burned by the devices, require notifications to buyers of their responsibilities, and establish setback and stack height standards. In addition, many state and local governments have considered or enacted bans on the use of OWBs. Some bans only apply to new uses or consist of seasonal restrictions, but others apply to all use of the devices. Table 4-1 summarizes the adopted rules.

In developing their regulatory programs, a number of states have relied on the US EPA’s review of test results submitted by OWB manufacturers under the agency’s voluntary OWB qualification program (New York State does its own review to determine compliance and certification). In early 2011, states became concerned about the quality of that review and reassessed the previous test results submitted to the US EPA. The reassessment found significant issues with 21 of the 23 units qualified under the US EPA’s voluntary program, calling into question the validity of the test results (NYSERDA, 2011). Several states are now reconsidering the use of test results submitted to the US EPA’s voluntary program as a basis for determining compliance with state rules.

---

[4] Maine, Maryland, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont.

Table 4-1. Overview of MANE-VU state outdoor wood boiler regulations

	Emission Limits	Setback Rqt	Stack Height Rqt	Nuisance Provisions	Visible Emissions Limits	Notice to Buyer	Seasonal Limits
CT		Yes	Yes	No	No	No	No
ME	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h; Voluntary technology-forcing limit is 0.06lb PM/MMBtu	Yes	Yes	Yes	Yes	Yes	No
MD	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	No	No	Yes	Yes	No	Yes
MA	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	Yes	Yes	Yes	Yes	Yes	No
NH	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	Yes	Yes	Yes		Yes	No
NJ	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	No	No	No	Yes	No	No
NY	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	Yes	Yes	Yes	Yes	Yes	No
PA	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	Yes	Yes	Yes	Yes	No	No
RI	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	No	No	Yes	Yes	Yes	No
VT	PM ≤ 0.32lb/MMBtu output (wt'd avg) with no individual test run to exceed 18.0g/h	Yes	No	Yes	No	Yes	No

State change-out programs

Several states have developed change-out programs for residential wood burning devices. Under these efforts, consumers receive financial incentives (rebates) to replace older appliances with either non-wood burning equipment, pellet stoves, or US EPA-certified wood stoves. Because US EPA-certified wood stoves emit approximately 70 percent less pollution than older conventional wood stoves, a successful changeout campaign can significantly reduce particulate matter emissions.

The costs of many local changeout programs, including advertising, are covered by a partnership of government agencies, gas utilities, and appliance manufacturers, distributors, and retailers. The rebate amount to consumers varies significantly, depending on the funds available to the implementating agency. Most of the change-out programs have focused on indoor woodstoves. Vermont, New Hampshire, and Pennsylvania have implemented short term change-out programs for indoor woodstoves. In 2011, Vermont implemented the first voluntary change-out program focused on outdoor wood boilers.

4.2. Industrial, Commercial, and Institutional Wood Boilers

Total overall emissions from wood combustion in industrial, commercial, and institutional (ICI) boilers are small in comparison to residential wood combustion. There are efforts, however, to increase the use of ICI wood-fired boilers, such as at schools and hospitals. These settings, however, can expose sensitive populations to potential increases in particulate matter and other health damaging pollutants. The following section highlights activities taking place at the federal and state levels to address emissions from this source category.

4.2.1. Federal rules for ICI wood-fired boilers

In March 2011, the US EPA promulgated an area source rule for ICI wood-fired boilers putting forth common particulate matter standards for new wood-fired boilers having a heat input rate larger than 10 million British thermal units per hour (MMBtu/h).[5] The emission limit for units between 10 to 30 MMBtu/h is 0.07 lb/MMBtu, and 0.03 lb/MMBtu for units with heat inputs equal to or greater than 30 MMBtu/h. For units less than 10 MMBtu/h, the US EPA adopted a work practice standard requiring a tune-up program for the boilers.

4.2.2. State measures for ICI wood-fired boilers

While federal regulation has standardized emission limits for new ICI wood-fired boilers larger than 10 MMBtu/h heat input, the extent and level of regulation for smaller units varies from state to state, as shown in the table below. Several states regulate ICI boilers down to 1 MMBtu/h in size, while others have set the threshold as high as 10 MMBtu/h. The form of the standard and the modeling required to estimate impacts also varies by state. To investigate the potential for harmonizing state ICI rules, the states are investigating the need for a common rule as previously done for outdoor wood boilers.

---

[5] 76 Fed. Reg. 15554 (March 21, 2011).

Table 4-2. Overview of state industrial, commercial, and institutional wood boiler requirements

	Threshold for Triggering Permit	Emission Limit	Threshold for Modeling Impacts
Connecticut	15 tons per year of any single pollutant	0.10 lb/MMBtu	Required if the source's emissions exceeds any of the following: - $PM_{2.5}$: ≥ 10 tons/year - PM_{10} or SO_2: ≥ 15 tons/year - NO_x: ≥ 40 tons/year - CO: ≥ 100 tons/year
Delaware	≥1	0.30 lb/MMBtu	
Maine	≥10	0.30 lb/MMBtu	Required if the source's emissions exceeds any of the following: - PM_{10} or $PM_{2.5}$: > 25 tons/year - SO_2: > 15 tons/year - CO: > 250 tons/year - NO_x: > 100 tons/year - Lead: > 0.6 tons/year - Chromium: > 0.2 tons/year
Massachusetts "Areas of Critical Concern"(*)	≥3	0.1 lb/MMBtu	Required if the source's emissions exceeds any of the following: - $PM_{2.5}$: ≥ 10 tons/year - PM_{10}: ≥ 15 tons/year - SO_2: ≥ 40 tons/year - NO_x: ≥ 40 tons/year - CO: ≥ 100 tons/year MassDEP may require dispersion modeling for any plan application, including emission increases less than the cited thresholds
Massachusetts state-wide outside of "Areas of Critical Concern"	≥3	0.2 lb/MMBtu	Same as above

(*) MA "Areas of Critical Concern" are listed in Table 3 of 310 Code of MA Regulations (CMR) 7.02.

	Threshold for Triggering Permit	Emission Limit	Threshold for Modeling Impacts
New Hampshire	>2	0.30 lb/MMBtu	- Required of units ≥ 2 MMBtu/h (heat input)—criteria pollutants only. - Combustion of virgin fuels, including biomass, is not subject to New Hampshire's state toxics rule.
New Jersey	≥1	No recent determination	Required of: - major sources (e.g. facilities emitting more than 100 tons/year of PM); - sources cited in an existing non-attainment area; - for any unit requiring a permit (over 1 MMBtu/h) if there is a substantial public concern.
New York	>1	Variable depending on size based on NY's Table 1 under 6NYCRR subpart 227-1.2(b)	Required if the source’s emissions exceeds any of the following: - PM_{10}: > 15 tons/year - $PM_{2.5}$: > 10 tons/year - CO: > 100 tons/year - NO_x: > 40 tons/year - Lead: > 0.6 tons/year
Pennsylvania	>2	0.32 lb/MMBtu	Required of: - major sources (e.g. facilities emitting more than 100 tons/year of PM); - sources cited in an existing non-attainment area.
Rhode Island	>1	BACT analysis – most recent determination for 8.56 MMBtu/hr - 0.10 lb/MMBtu PM10 and 0.06 lb/MMBtu PM2.5	- Required when emissions exceed acceptable ambient levels (AALs). - Required if an applicant requests an expedited permit review.
Vermont	~7.1 (regulated as 900 ft^2 or more of heating surface; estimated MMBtu/h noted)	Decided on a case-by-case basis. Recent determinations of 0.20 lb/MMBtu	- Required of sources with annual emissions of any criteria pollutant exceeds 10 tons per year when Action Levels for air toxics are exceeded (not always required).

4.3. Black Carbon Measures

Reductions in black carbon in the MANE-VU region occur from strategies and projects that reduce particulate matter in diesel exhaust, of which black carbon is a major component. This most commonly encompasses measures involving heavy-duty diesel trucks, construction equipment, locomotives, and marine engines.

While the US EPA has set more stringent emission limits for newly manufactured engines, a number of project-specific measures have been undertaken in the MANE-VU region to address existing diesel engines that pre-date the more stringent new engine standards. These projects help retrofit existing diesel engines with diesel particulate filters, assist in purchasing hybrid diesel trucks, provide auxiliary power units to reduce idling emissions from diesel locomotives, and replace older marine engines with more modern, efficient, and cleaner ones. The projects are largely funded through environmental mitigation settlement agreements arising from government enforcement actions, and through federal funding via the US EPA appropriated annually under the Diesel Emissions Reduction Act (DERA) and with economic stimulus funding from the American Recovery & Reinvestment Act (ARRA). Many, but not all, of the DERA and ARRA projects have been coordinated through two regional collaboratives involving the MANE-VU states, local agencies, and the US EPA. These collaboratives are the Mid-Atlantic Diesel Collaborative[6] and the Northeast Diesel Collaborative.[7]

To provide project examples, Appendix A is a non-exhaustive list of activities in the MANE-VU region that address diesel emissions and, by extension, black carbon. Many additional projects are occurring in the MANE-VU region, and the diesel collaborative websites provide information on a number of these.

4.4. Volatile Organic Compound (VOC) Measures

Volatile organic compounds (VOCs) compose a significant source of secondary OC. VOCs, also referred to as hydrocarbons, react in the atmosphere to form secondary organic aerosols via condensation and oxidation processes. The control of VOCs from pollution sources has long been an active area in state and regional regulatory planning, primarily in strategies to reduce ground level ozone (smog) as well as air toxics (e.g., benzene). Examples include national and state-adopted California motor vehicle tailpipe emission standards, and programs to reduce gasoline evaporation during refueling and from a motor vehicle’s fuel system (e.g., Stage I and II controls at gasoline stations; onboard refueling and vapor recovery (ORVR) on cars). Additional efforts within the MANE-VU region have looked at regional coordination and working with the US EPA to reduce VOC emissions from asphalt paving, asphalt production plants, cement kilns, glass furnaces, industrial, commercial, and institutional boilers, small engines (< 50 horsepower), ship lightering, and other sources. These examples of past efforts are not all inclusive, and additional information on measures taken or considered in the MANE-VU region is available on the Ozone Transport Commission website www.otcair.org.

---

[6] Mid-Atlantic Diesel Collaborative: http://www.marama.org/diesel/

[7] Northeast Diesel Collaborative: http://www.northeastdiesel.org/

Looking forward, the MANE-VU states are currently considering at least four new model rules for potential state adoption to reduce VOCs in the region. These would reduce emissions from:

- Stationary Above-Ground Storage Tanks;
- Consumer Products;
- Motor Vehicle and Mobile Equipment Non-assembly Line Coating Operations;
- Architectural, Industrial, and Maintenance Coatings.

The proposed VOC model rules are described in an Ozone Transport Commission (OTC) draft technical support document (TSD) summary presented at an OTC meeting in March 2011 (OTC, 2011a). The following sections summarizing the proposed model rules are brief extracts taken from the draft TSD. Also included is a description of potential future national tailpipe emission standards for light-duty vehicles coupled with low sulfur gasoline that can further reduce VOCs and other pollutants in the MANE-VU region.

4.4.1. Stationary above-ground storage tanks

The MANE-VU states working through the OTC developed a model rule for public comment in 2011 to address VOCs, such as gasoline, stored in large above-ground stationary storage tanks. These facilities are typically located at refineries, terminals, and pipeline breakout stations. The available control measures are grouped into five categories: deck fittings and seals, domes, roof landings, degassing and cleaning, and inspection and maintenance.

There is some overlap between the model rule and federal standards for storage tanks (e.g., New Source Performance Standards), particularly with regard to deck fittings, seals, and tank inspection requirements, but the federal standards do not generally address roof landings and tank cleaning nor do they require external floating roof tanks to be covered with domes, as the model rule does.

To reduce VOC emissions from stationary above-ground storage tanks, the OTC model rule proposed the following controls:

- **Deck fittings, seals:** Evaporative VOC losses can occur from deck fittings, particularly slotted guidepoles, and rim seal systems. Control measures include gasketing deck fittings, installing pole sleeves and floats on slotted guidepoles, and gap requirements for rim seals. These measures can result in up to an 80% reduction in standing loss emissions from external floating roof tanks.

- **Domes**: Wind blowing across external floating roof tanks causes evaporative VOC losses. Installing domes on external floating roof tanks can result in about a 60% reduction of remaining VOC emissions after upgrading deck fittings.

- **Roof Landing Controls:** When enough liquid is removed from a floating roof tank such that the roof cannot be lowered farther (i.e., the roof rests on its legs or suspended by cables or hangers), the contact between the floating roof and the VOC liquid is broken as the remaining liquid is removed. This is referred to as a “roof landing.” The vapor space between the floating roof and the liquid surface enables VOC vapors to accumulate and escape from the tank as it sits idle or when refilled. Control options include requiring lander height settings that minimize the vapor space, installation of vapor recovery/control for use when the roof is landed, or modifying the tank to reduce the landed height to one foot or less. The control measures can reduce VOC losses by 60% to 100%, depending on the measure and how the tank is operated.

- **Cleaning and Degassing**: Stationary storage tanks must be cleaned periodically. Before a tank is cleaned, it must be degassed (which is the removal of gases, such as gasoline vapor) so personnel can safely enter to clean the tank and remove accumulated sludge. The sludge removed from the tank can contain residual VOC liquid that may evaporate when exposed to the atmosphere. Measures to reduce VOC evaporation include control of emissions during degassing and controlling exhaust from sludge receiving vessels (such as vacuum trucks). New Jersey has a proposed rule that would require 95% control of emissions during degassing, until the concentration level in a tank is 5,000 parts per million (ppm) as methane, and control of exhaust from the receiving vessel (e.g., vacuum truck).
- **Inspection and Maintenance:** An inspection and maintenance program seeks to reduce VOC emissions by assuring that tank components are in good condition and operating properly. A proposed program in New Jersey for external floating roof tanks would include a full inspection of gap widths for deck fittings and secondary seals annually and of primary seals every five years. Internal floating roof tanks would be inspected annually, with a full inspection of deck fittings and seal gaps each time the tank is emptied and degassed (no less than every 10 years).

4.4.2. Consumer products

The revised OTC model rule for consumer products is based on the California Air Resources Board's (CARB's) 2006 Consumer Products Regulatory Amendments that were adopted by CARB in 2006. The 2006 CARB amendments have more restrictive VOC limits for 13 existing consumer product categories (including subcategories), and three new categories (disinfectant, sanitizer, and temporary hair color; including subcategories) will be regulated for the first time with VOC limits. The revised model rule would achieve VOC reductions through reformulation of the affected product categories by the manufacturers. This may involve switching to a water-based formulation, using an exempt solvent, increasing product solids, or formulating with a non-VOC propellant. Manufacturers can still comply with the proposed model rule through the use of an Innovative Products Exemption (IPE) or an Alternate Control Plan (ACP). The revised OTC model rule for consumer products would apply to anyone who sells, supplies, offers for sale, or manufactures consumer products for use in an OTC member jurisdiction.

4.4.3. Motor vehicle and mobile equipment (MVME) non-assembly line coating operations

The 2009 OTC model rule for Motor Vehicle and Mobile Equipment Non-assembly Line Coating Operations (2009 OTC MVME Model Rule) seeks to limit the

VOC content in coatings and cleaning solvents used in motor vehicle and mobile equipment non-assembly line coating operations. Implementation of the model rule would reduce VOC emissions by limiting the VOC content of coatings and cleaning solvents and provide work practice standards for preventing emissions from equipment cleaning and cleaning supply storage.

The 2009 OTC MVME Model Rule applies to people who supply, sell, offer for sale, distribute, manufacture, use or apply automotive coatings and associated cleaning solvents subject to the Model Rule. The model rule limits the VOC content of coatings used in non-assembly line coating operations and limits the VOC content of cleaning solvent to 25 grams per liter. The 2009 OTC MVME Model Rule allows the use of higher VOC content cleaning solutions for special uses and sets lower VOC content limits for many of the formulations resulting from switching from solvent-based formulations to water-based formulations.

4.4.4. Architectural, industrial, and maintenance coatings

The OTC developed its 2002 Architectural and Industrial Maintenance (AIM) Coatings model rule based upon the 2000 CARB Suggested Control Measure (SCM). In 2007, CARB proposed an updated SCM for architectural coatings, which generally lowers VOC emissions through product reformulation and improves definitions of many categories from the 2000 SCM. Of the 47 coating categories regulated in the 2000 SCM, 15 categories have been eliminated (replaced by new categories or deemed unnecessary), 10 categories were added, and 19 have stricter VOC limits. The updated SCM also contains some revised compliance and reporting requirements.

The OTC reviewed the 2007 CARB SCM and found that most of the changes were appropriate for the OTC. The OTC model rule, however, adds some categories that are specific to the Ozone Transport Region (OTR),[8] and assigned different limits to three other categories (aluminum roof, bituminous roof, and roof coatings). The OTC model rule is an update of the 2002 Model Rule that has been adopted by most states across the OTR. It includes all the new categories defined in the 2007 CARB SCM as well as the following eight specialty coating categories specific to the OTR:

- Calcimine Recoaters
- Conjugated Oil Varnish (new addition)
- Concrete Surface Retarders
- Conversion Varnish
- Impacted Immersion coatings
- Nuclear Coatings
- Reactive Penetrating Carbonate Stone Sealer (new addition)
- Thermoplastic Rubber Coatings and Mastics

4.4.5. Tier 3 motor vehicle standards and low sulfur gasoline

In 2012, the US EPA may propose a “Tier 3” program to strengthen light-duty vehicle emissions standards similar to those of the Low-Emission Vehicle (LEV) III

---

[8] The Ozone Transport Region consists of the MANE-VU jurisdictions plus several northern Virginia counties in the Washington, DC metropolitan area.

requirements under consideration in California. Coupled to the change in tailpipe standards would be a lowering of gasoline sulfur content from 30 ppm to 10 ppm. Lowering sulfur content in gasoline immediately improves the efficiency of catalytic converters in the existing motor vehicle fleet by reducing sulfur poisoning of catalyst surfaces. Nationally, the Tier 3 program with low sulfur gasoline could result in a 26% decrease in VOC emissions by 2030 (NACAA, 2011), along with significant reductions in other pollutants, such as NO_x (discussed below).

4.5. Measures Addressing NO_x

The historic focus of NO_x control measures in the MANE-VU region has been to reduce acidic deposition under the Acid Rain Program and to address ground level ozone (smog) for purposes of attaining or maintaining the ozone national ambient air quality standard (NAAQS). The following sections describe recent developments that further expand upon existing NO_x control strategies. Of particular note are new or potential air quality regulations that would result in annual NO_x reductions, rather than focused on warm weather months during the ozone season. Annual measures would reduce NO_x during colder parts of the year in the MANE-VU region when nitrate particles are relatively more stable and are a greater contributor to regional haze.

4.5.1. Federal Clean Air Interstate Rule (CAIR) and Cross-State Air Pollution Rule (CSAPR)

The US EPA has now twice tried to promulgate a rule to reduce the cross-state transport of air pollution in the eastern U.S. The first attempt in 2005 was the Clean Air Interstate Rule (CAIR), which was remanded by the D.C. Circuit Court of Appeals back to the US EPA in 2008 over several legal issues, but allowed to go into effect while EPA developed a replacement transport rule. CAIR requires seasonal (May through September) reductions in NO_x emissions in 25 eastern states and the District of Columbia to address ozone pollution, and annual SO_2 and NO_x reductions in 23 states and the District of Columbia to address $PM_{2.5}$ pollution. With specific regard to NO_x emissions, CAIR required a reduction of 1.7 million tons, or 53%, from 2003 levels. In 2015, CAIR would reduce NO_x emissions by 2 million tons, achieving a regional emissions level of 1.3 million tons, a 61% reduction from 2003 levels.[9]

While the pollution sources to be controlled under CAIR were at a state's own choosing, the US EPA believed that the reduction targets could be met through "highly cost effective" control measures on power plants, and proposed an EPA-administered interstate cap-and-trade program for power plants as the default compliance option for covered states. In the MANE-VU region, CAIR covers NO_x emissions in Connecticut (ozone season only), Delaware (ozone season only), Maryland (annual), Massachusetts (ozone season only), New Jersey (ozone season only), New York (annual), Pennsylvania (annual), and the District of Columbia (annual).

In response to the court's remand, the US EPA promulgated the Cross-State Air Pollution Rule (CSAPR) in the summer of 2011 to replace CAIR.[10] The rule restricted the extent of interstate emissions trading previously allowed under CAIR, and

---

[9] 70 Fed. Reg. 25162 (May 12, 2005).

[10] 76 Fed. Reg. 48208 (August 8, 2011).

specifically targeted SO_2 and NO_x emissions from large electric generating units (EGUs) greater than 25 MW in size. CSAPR required annual SO_2 and NO_x reductions in 23 eastern states, and ozone season NO_x reductions in 20 states. For the MANE-VU region, CSAPR required annual NO_x emission reductions from the states of Maryland, New Jersey, New York, and Pennsylvania.

While CSAPR covers fewer MANE-VU states than the remanded CAIR program, over the eastern U.S. the full rule would achieve an additional 100,000 tons of NOx reduced annually relative to CAIR (1.2 million tons emitted instead of 1.3 million tons), and reductions would be achieved one year earlier (2014 instead of 2015) (USEPA, 2011a). Just before CSAPR's effective date of January 1, 2012, however, the D.C. Circuit Court of Appeals stayed CSAPR, and the previously remanded CAIR rule went back into effect pending the resolution of the CSAPR litigation. As of January 2012, regional reductions of NO_x (and SO_2) continue to occur through re-implementation of CAIR. Because CAIR has been remanded on its merits, and CSAPR is stayed pending a court ruling on its merits, the future status of reductions under either rule is uncertain until all litigation is resolved.

4.5.2. Federal Tier 3 gasoline light-duty vehicle standards

The US EPA is expected to propose in early 2012 tighter national tailpipe emission standards for on-road gasoline light duty vehicles. This proposal can have a significant impact for the MANE-VU region, as this emission sector contributes almost 30% of NO_x emissions to the total NO_x emissions inventory (Table 4-3).

Table 4-3. Relative source contributions of NO_x emissions in MANE-VU region in 2007

Source	NO_x Emissions (%)
Highway vehicles	52
On-road gasoline light-duty vehicles	*29*
On-road diesel vehicles	*22*
Off-highway	13
Fuel combustion: Electric utilities	13
Fuel combustion: Residential	5
Other industrial processes	4
Fuel combustion: Industrial	2
Other miscellaneous (sum of source sectors contributing <1.7% each to total NO_x)	11

Source: MANE-VU 2007 Inventory provided by the Mid-Atlantic Regional Air Management Association (November 2011).

Of significant note for the Tier 3 rulemaking is a potential requirement to lower gasoline sulfur content from 30 parts per million (ppm) to 10 ppm. A l0 ppm sulfur gasoline standard would reduce NO_x emissions by approximately 25 percent from the *existing* fleet of gasoline-powered vehicles. Sulfur reduces the efficiency of the catalysts that reduce NO_x emissions, so reducing fuel sulfur content can result in immediate pollution benefits from cars already on the road that have catalytic converters.

Based on mobile source emissions modeling, if Tier 3 low sulfur gasoline was implemented nationally in 2017, it would reduce upwind NO_x emissions by more than 60,000 tons per year in eight Midwest states and almost 65,000 tons per year in ten southeastern states (NESCAUM, 2011).

Within the MANE-VU region, 10 ppm sulfur gasoline would reduce NO_x emissions by over 51,000 tons annually (NESCAUM, 2011). This reduction is about three times greater than what will be obtained from implementing CSAPR in the MANE-VU states. Lowering sulfur content in gasoline would also have an effect on sulfate fine particles, although highway vehicle emissions are a small contributor to total sulfate in the MANE-VU region (<1%) (USEPA, 2011b).

4.6. NO_x Controls under Consideration by MANE-VU

The MANE-VU states are currently considering at least four potential measures to further reduce NO_x in the region. These would reduce emissions from:

- Stationary Generators;
- Natural Gas-Fired Industrial, Commercial, and Institutional Boilers, Steam Generators, Process Heaters, and Water Heaters;
- High Electric Demand Day Combustion Turbines (HEDDCT);
- Oil and Gas Boilers Serving EGUs.

The proposed NO_x model rules are described in an OTC draft technical support document (TSD) summary presented at an OTC meeting in March 2011 (OTC, 2011b). Unlike the federal rules above, the MANE-VU NO_x rules may only apply during the warm months of the ozone season, rather than annually. If the rule requires a change, however, that is fundamental to the operation of the source (e.g., combustion equipment modification), it could result in annual NO_x reductions as well. The following sections summarizing the proposed model rules are brief extracts taken from the draft TSD.

4.6.1. Stationary generators

The OTC model rule, if adopted, would apply to all stationary generators (new and existing, as well as emergency and non-emergency) in a state, with some exceptions provided depending on the engine’s application or size. It would require new emergency generators to meet emissions standards set by the US EPA, which would ensure that all new installations would at least be meeting a minimum level of control. For existing, non-emergency generators, each generator would be required to make an approximate 90% reduction in its NO_x emissions. Each new non-emergency generator would be required to make an approximate 90% reduction in its NO_x emissions beyond the US EPA standards for manufacturers of emergency generators.

The number of non-emergency generators in a state would have to be known in order to estimate total reductions from the amount of NO_x emissions reduced per generator. For peak and baseload engines, their combined capacity would have the potential to emit about 48 tons of NO_x for every hour of operation (based upon the assumption of no controls on the engine and an average emission factor of 32 lb/MWh

NO_x, per AP-42). If these peak and baseload engines were controlled, their emissions could be reduced by approximately 90%, which would result in a regional reduction of about 43 tons of NO_x for every hour of operation.

4.6.2. Natural gas-fired industrial, commercial, and institutional boilers, steam generators, process heaters, and water heaters

This model rule addresses NO_x emissions ICI boilers, steam generators, process heaters, and water heaters by using ultra low NO_x burners (ULNBs) to control emissions. If the MANE-VU states were to adopt the full control measure in the model rule, the estimated achievable NO_x reductions in the region are about 53 tons per day.

4.6.3. High electric demand day combustion turbines (HEDDCT)

For the purpose of this rule, a high electric demand day combustion turbine (HEDDCT) is defined as a 5 to 15 MW or larger (depending on distribution of generating units in individual states) natural gas- or distillate fuel oil-fired combustion turbine that generates and delivers electricity to power the grid for commercial sale, that began operating prior to May 1, 2007 and was operated less than or equal to 50 percent of the time during the ozone seasons of 2007 through 2009. The focus of this rule is on NO_x emissions emitted by HEDDCTs typically for only a few hours a year, but often on the hottest summer days when air quality is poorest. As such, this measure may have relatively little to no impact on particulate nitrate during cooler periods when electricity demand is less. During the ozone season, it is estimated implementation of this model rule could reduce MANE-VU regional NO_x emissions by 2,500 tons.

4.6.4. Oil and gas boilers serving EGUs

This model rule seeks to regulate oil-fired and gas-fired boilers that provide steam to an electric generating unit with a nameplate capacity of 25 MW or greater, and includes a unit serving a cogeneration facility. The proposed model rule assumes use of low NO_x burners and/or a selective non-catalytic reduction system on existing oil- and gas-fired boilers. These control devices are used widely in industry throughout the United States and are reasonably available given their extensive use. Estimated annual NO_x reductions in the MANE-VU region are about 3,500 tons.

5. CONCLUSIONS

Sulfate is the dominant contributor to poor visibility in the Class I areas of the MANE-VU region. Accordingly, MANE-VU members have placed heavy focus on reducing sulfate in their initial strategy to improve regional visibility. The region has observed reductions in SO_2 emissions and corresponding improvements in visibility. However, in order to achieve long-term visibility goals, reductions in non-sulfate aerosols will be needed.

The key non-sulfate contributors are analyzed by simulating the best and worst haze conditions at the MANE-VU IMPROVE sites under different hypothetical sulfate scenarios – 50% sulfate removal and 100% sulfate removal. Organic carbon (OC) is the key contributor in summer months, and nitrate is the key contributor in winter months.

Currently, pollution control measures in place or under consideration will address some of the emissions of these non-sulfate components. Regarding OC, MANE-VU members are considering adopting OTC model rules that will reduce VOC emissions from:

- Stationary Above-Ground Storage Tanks;
- Consumer Products;
- Motor Vehicle and Mobile Equipment Non-assembly Line Coating Operations;
- Architectural, Industrial, and Maintenance Coatings.

Regarding nitrate, federal rules will potentially require large NO_x reductions in EGU (CSAPR) and light-duty gasoline vehicle (Tier 3) emissions. In addition, MANE-VU members are considering adopting OTC model rules that reduce NO_x emissions from:

- Stationary Generators;
- Natural Gas-Fired Industrial, Commercial, and Institutional Boilers, Steam Generators, Process Heaters, and Water Heaters;
- High Electric Demand Day Combustion Turbines (HEDDCT);
- Oil and Gas Boilers Serving EGUs.

As MANE-VU prepares to expand its long-term strategy beyond sulfate, these control measures can play a role in achieving the national goal of natural background visibility at protected scenic vistas. Quantifying the extent of these reductions and their potential impact on visibility in MANE-VU's Class I areas are beyond the scope of this memorandum, but this would be an important part of future work in developing "beyond sulfate" strategies to achieve natural background visibility in the region.

6. REFERENCES

Hand, J. L., S. A. Copeland, D. E. Day, A. M. Dillner, H. Indresand, W. C. Malm, C. E. McDade, C. T. Moore, Jr., M. L. Pitchford, B. A. Schichtel, and J. G. Watson, 2011. IMPROVE (Interagency Monitoring of Protected Visual Environments): Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report V. Cooperative Institute for Research in the Atmosphere Report ISSN 0737-5352-87, Colorado State University, Fort Collins, CO, June 2011. Available at: http://vista.cira.colostate.edu/improve/Publications/Reports/2011/2011.htm

Malm, W. C., 1999. Introduction to Visibility. Prepared for the Cooperative Institute for Research in the Atmosphere, May 1999. Available at: http://vista.cira.colostate.edu/improve/Education/intro_to_visibility.pdf

MARAMA, 2011. Mid-Atlantic/Northeast Visibility Union Second Interim Report. Prepared by the Mid-Atlantic Regional Air Management Association for the Mid-Atlantic/Northeast Visibility Union, September 2011. Available at: http://www.marama.org/publications_folder/reports/VisibilityInterimReport_sep2011.pdf

NACAA, 2011. Cleaner Cars, Cleaner Fuel, Cleaner Air: The Need for and Benefits of Tier 3 Vehicle and Fuel Regulations. National Association of Clean Air Agencies (NACAA), Washington, DC, October 2011.

NESCAUM, 2001. Regional Haze and Visibility in the Northeast and Mid-Atlantic States. Prepared by Northeast States for Coordinated Air Use Management for the Ozone Transport Commission, January 31, 2001. Available at: http://www.nescaum.org/documents/regional-haze-and-visibility-in-the-northeast-and-mid-atlantic-states/report010131haze.pdf/

NESCAUM, 2006. Regional Aerosol Intensive Network (RAIN): Preliminary Data Analysis. Prepared by Northeast States for Coordinated Air Use Management for the Mid-Atlantic/Northeast Visibility Union (MANE-VU) Regional Planning Organization, May, 2006. Available at: http://www.nescaum.org/documents/2006-05-memo8-rain.pdf/

NESCAUM, 2010a. MANE-VU Technical Memorandum: Tracking Visibility Progress 2004-2008. Prepared by Northeast States for Coordinated Air Use Management for the Mid-Atlantic/Northeast Visibility Union (MANE-VU) Regional Planning Organization, May 12, 2010. Available at: http://www.nescaum.org/documents/tracking-progress-final-05-12-10.pdf/

NESCAUM, 2010b. The Nature of Fine Particle and Regional Haze Air Quality Problems in the MANE-VU Region: A Conceptual Description. Prepared by Northeast States for Coordinated Air Use Management for the Ozone Transport Commission, August 2010. Available at: http://www.nescaum.org/documents/2010-pm-conceptual-model-_final_revised-20100810.pdf/

NESCAUM, 2011. Assessment of Clean Gasoline in the Northeast and Mid-Atlantic States. Northeast States for Coordinated Air Use Management (NESCAUM), Boston, MA, November 21, 2011. Available at: http://www.nescaum.org/documents/nescaum-tier-3-low-s-gasoline-20111121.pdf/

NYSERDA, 2011. Review of EPA Method 28 Outdoor Wood Hydronic Heater Test Results. Prepared by Brookhaven National Laboratory for the New York State Energy and Research Development Authority, September 2011. NYSERDA Report No. 11-17.

OTC, 2011a. TSD VOC Section, Draft for Public Comment. Presented at the Ozone Transport Commission (OTC) Stationary Area Source/Modeling/Mobile Source Committee Meeting, Linthicum, MD, March 16, 2011. Available at: http://otcair.org/upload/Documents/Meeting%20Materials/TSD%20VOC%20Section%20Public%20Draft%20for%20Comment.pdf

OTC, 2011b. TSD NOx Section, Draft for Public Comment. Presented at the Ozone Transport Commission (OTC) Stationary Area Source/Modeling/Mobile Source Committee Meeting, Linthicum, MD, March 16, 2011. Available at: http://www.otcair.org/upload/Documents/Meeting%20Materials/TSD%20NOx%20Section%20Public%20Draft%20for%20Comment.pdf

Pitchford, M., W. Malm, B. Schichtel, N. Kumar, D. Lowenthal, and J. Hand, 2007. Revised Algorithm for Estimating Light Extinction from IMPROVE Particle Speciation Data. *Journal of Air & Waste Management Association*, 57: 1326-1336.

USEPA, 2011a. Cross State Air Pollution Rule: Reducing Air Pollution, Protecting Public Health. Presented by US Environmental Protection Agency, December 15, 2011. Available at: http://www.epa.gov/crossstaterule/pdfs/CSAPRPresentation.pdf (accessed December 28, 2011).

USEPA, 2011b. 2008 National Emissions Inventory (NEI). Version 1.5, updated May 16, 2011. Available at: http://www.epa.gov/ttnchie1/net/2008inventory.html (accessed December 28, 2011).

Appendix A: Examples of black carbon/diesel emissions reduction projects in MANE-VU region

Baltimore-Washington, DC regional diesel anti-idling campaign, 2010

In 2010, a cooperative effort between the Metropolitan Washington Council of Governments (COG), the District Department of the Environment (DDOE), the District Department of Transportation (DDOT), and the Maryland Department of the Environment (MDE) undertook a regional idle reduction campaign to inform truck and bus drivers about reducing diesel emissions through anti-idling measures.

Black carbon spatial gradients and temporal trends study in Boston, MA, 2008-2012

A NESCAUM project funded through MassDEP to better characterize black carbon spatial gradients in Boston, MA and analyze black carbon temporal trends from 2000 to 2008 to see if mobile source measures are plausible factors for decreasing black carbon trends in Boston.

Connecticut Locomotive Genset Project, 2009-2010

A project funded under ARRA and managed by NESCAUM to repower a vintage switch locomotive in New Haven, CT with a new engine/generator-set configuration that lowered the locomotive’s particulate matter and other air pollutant emissions.

Freight Locomotive Project, 2008-2011

A US EPA-funded project managed by NESCAUM to purchase and install 17 auxiliary power units on locomotives based in Rhode Island, Connecticut, and Massachusetts. The auxiliary power units allow for idle reduction of the locomotives, lessening the amount of particulate matter and other air pollutants released from locomotive diesel engines.

Heavy-duty diesel vehicle inspection and maintenance (I/M) programs

A number of MANE-VU states are pursuing a regional effort to demonstrate quantifiable reductions of particulate matter and other air pollutants from state heavy-duty vehicle I/M programs. Along with regional consistency, a goal of the effort is to obtain reduction credits from these I/M programs for air quality state implementation plans.

Heavy-duty diesel vehicle opacity standards, 1999-current

In 1999, a number of MANE-VU states developed a regional smoke opacity enforcement program for on-road heavy-duty diesel trucks. States in the region are now considering making the opacity cutpoints more stringent and are evaluating technical information in support of that process.

Leased Construction Equipment Retrofit Project, 2009-2011

A US EPA-funded project managed by NESCAUM to retrofit up to 20 pieces of leased construction equipment in the northeastern states from New Jersey to Maine with active diesel particulate filters.

Massachusetts Markets Diesel Reduction Program, 2010-2011

A project funded by MassDEP to establish a rebate program focused on Massachusetts-based markets, warehouses, and distribution centers to encourage partnerships between owners and operators of diesel equipment at these locations with vendors of diesel emission control technologies and services to reduce equipment emissions.

Metropolitan Washington DC retrofit project, 2009-2010

With DERA funding, this project is to retrofit seven municipal non-road construction units in the DC metropolitan area, and repower two passenger vessels operating on the Potomac River.

Northeast Diesel Collaborative Construction Retrofit Program, 2007-2009

A US EPA-funded project managed by NESCAUM that retrofitted five large pieces of diesel-powered construction equipment with diesel particulate filters operating at construction sites in New England.

Northern New England Ferry Repower Project, 2009-2011

A project funded under ARRA and managed by NESCAUM to repower eight marine vessels with Tier 0 engines in Maine, New Hampshire, and Vermont, including ferries and tugboats. The vessels had new fuel-efficient Tier 2-certified engines installed that have lower particulate matter and other air pollutant emissions.

Northeast Regional Hybrid Consortium, 2009-2011

A US EPA-funded project managed by the Environmental Defense Fund that provides funding support to truck fleets to purchase hybrid trucks. The target fleets are those primarily operated by states, municipalities, and public service entities. Through the replacement of older conventional diesel trucks, the project will assist penetration of hybrid trucks into the market and reduce emissions of particulate matter and other air pollutants.

Pittsburgh School Bus Retrofit Rebate, 2007-2011

Funded initially by the Heinz Foundation, a fund has been established to assist school bus owners and vendors in Pittsburgh to retrofit pre-2007 model school buses with cleaner technologies that will reduce particulates and other air pollutants.

Port of Wilmington, DE diesel engine replacements, 2010

With funding from DERA, the Delaware Department of Natural Resources and Environmental Control (DNREC) is partnering with the US EPA in the purchase of four heavy-duty diesel engine replacements for three large cargo loading vehicles and one construction vehicle operating at the Port of Wilmington.

Railroad Auxiliary Power Unit Project, 2010-2012

A US EPA-funded project managed by NESCAUM to purchase and install Tier 3-certified auxiliary power units on 29 regional freight locomotives operating in

Connecticut, Massachusetts, New Hampshire, and Vermont. The auxiliary power units allow for idle reduction of the locomotives, reducing the amount of particulate matter and other air pollutants released from locomotive diesel engines.

South Jersey Equipment Repower/Retrofit Project, 2010-2012

A project funded by the US EPA and managed by NESCAUM to reduce emissions from in-use port diesel equipment operating at the South Jersey Port in Camden, NJ. The project will repower up to 48 heavy duty non-road diesel machines with cleaner diesel engines to reduce emission of particulate matter and other air pollutants.

Tower Gantry Crane Engine Repower/Diesel Particulate Filter Retrofit Project, 2010-2012

A project funded by the US EPA and managed by NESCAUM to repower 16 tower cranes with newer cleaner diesel engines and retrofit one repowered crane with a diesel particulate filter. The tower cranes are used in high-rise construction projects in the New York City metropolitan area.

VT DEC Diesel Reductions, 2009-2010

This project by the Vermont Department of Environmental Conservation (VT DEC) funded through an environmental mitigation settlement is to evaluate and recommend a strategic plan for reducing diesel emissions in Vermont, and coordinate efforts with the regional Northeast Diesel Collaborative.