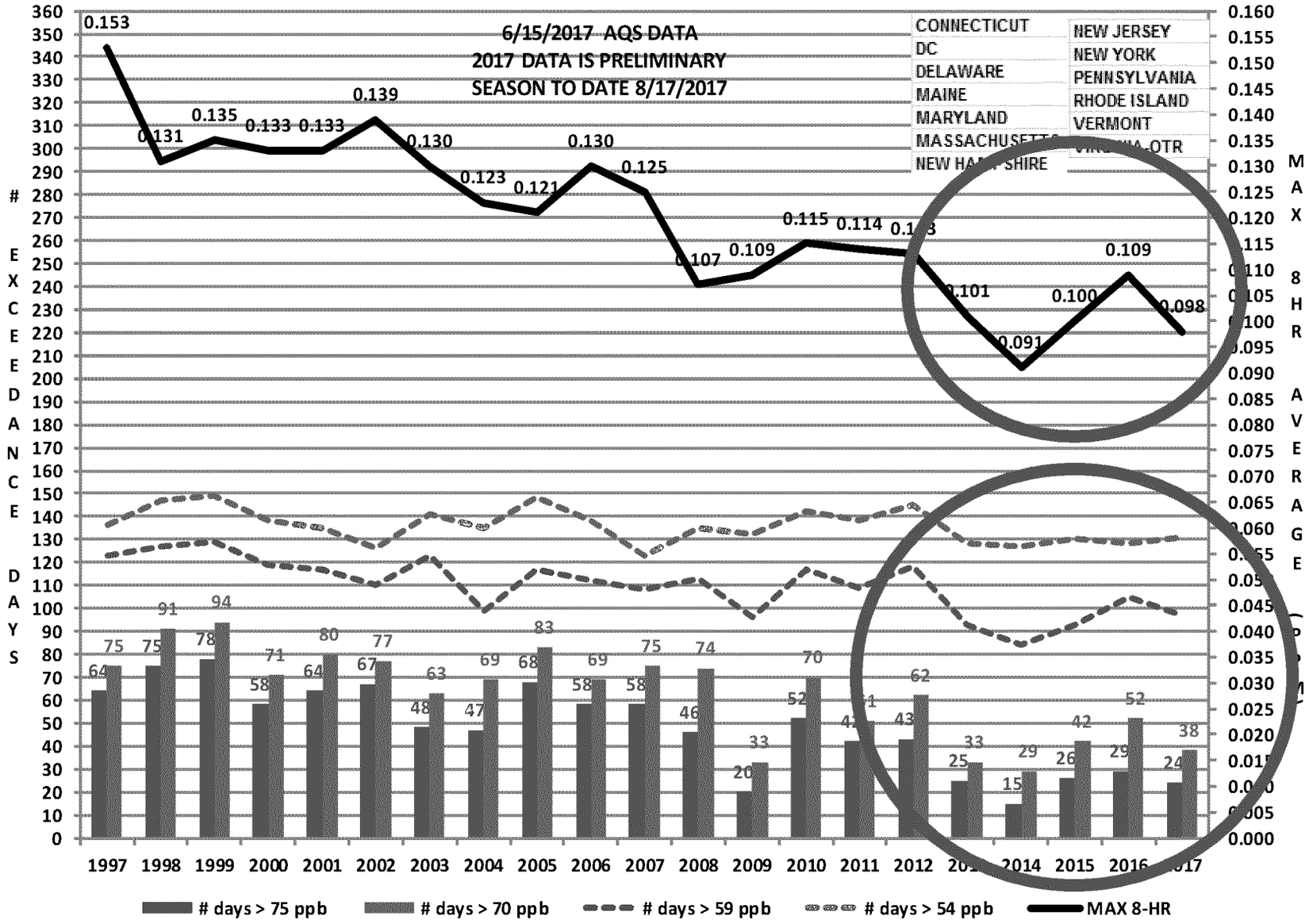
1. OTR 8-Hour Ozone Trend



Ozone in the OTR has been relatively flat or up slightly over the past 5 years with the exception of:

- 2014 was a low ozone year
- 2016 was a little higher than the other years

2. Delayed Designations

- On June 28, 2017 EPA issued a delay of designations in the Federal Register
  - Justification cited Clean Air Act Section 107(d)(1)(B)(i)
  - EPA would have until October 2018 to designate
  - 2017 data would be certified at this point
- However on August 10, 2017 the delay withdrawn in the Federal Register
  - Likely will still be some delay in designations since 120 day letters have not gone out and would have had to in early June
  - Probably not enough data for 2017 data to be considered

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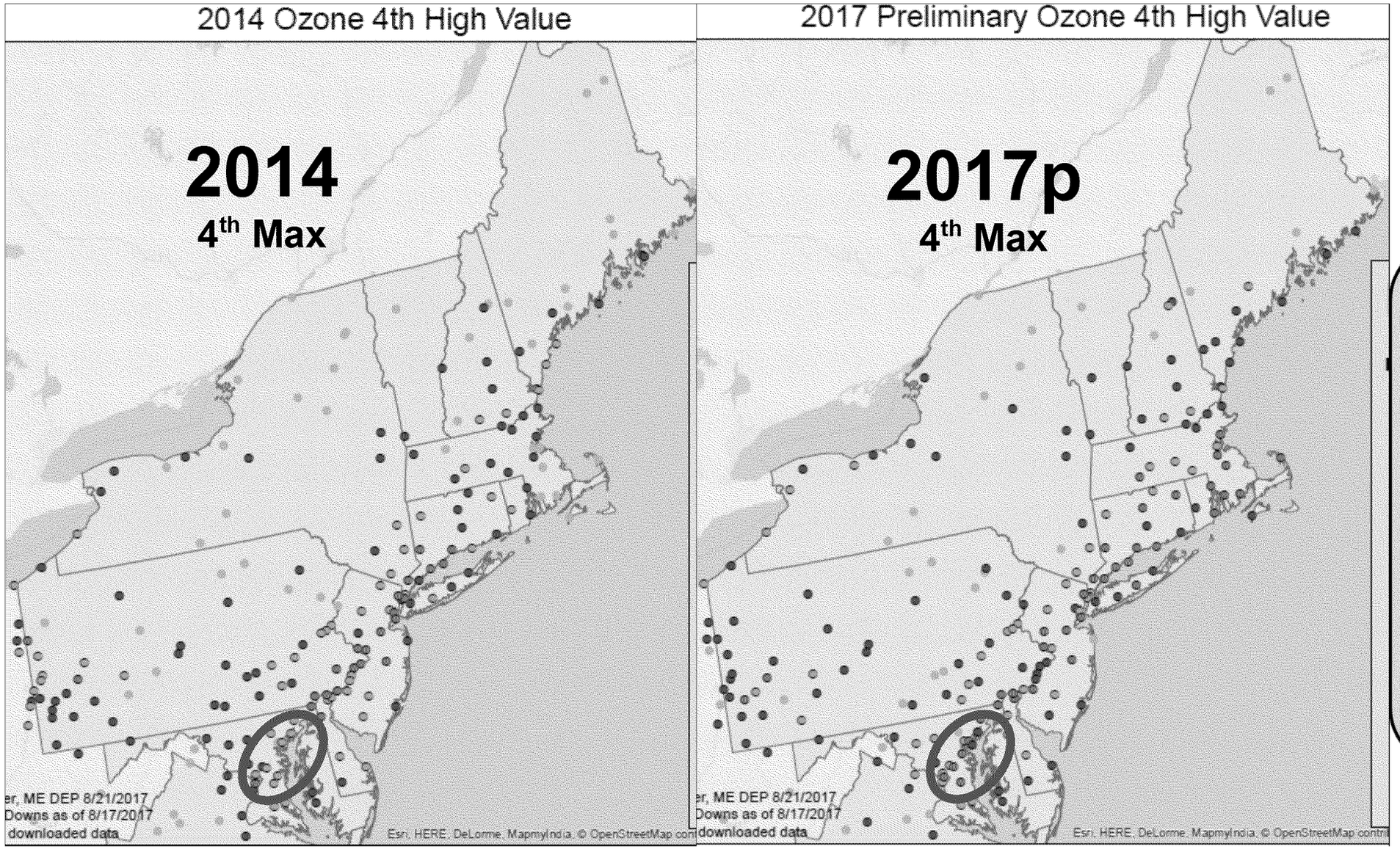
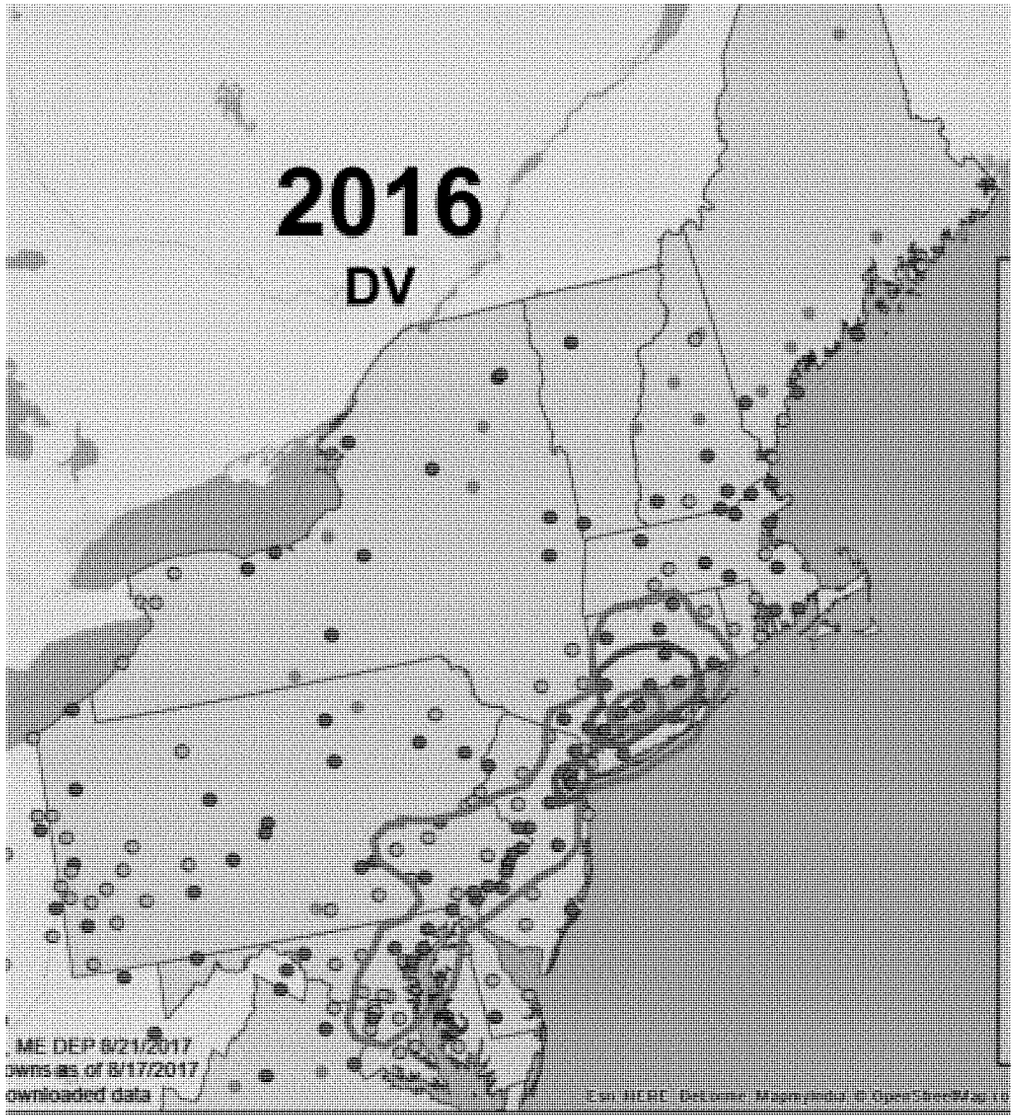
1. 2017 Replaces 2014 for Design Value

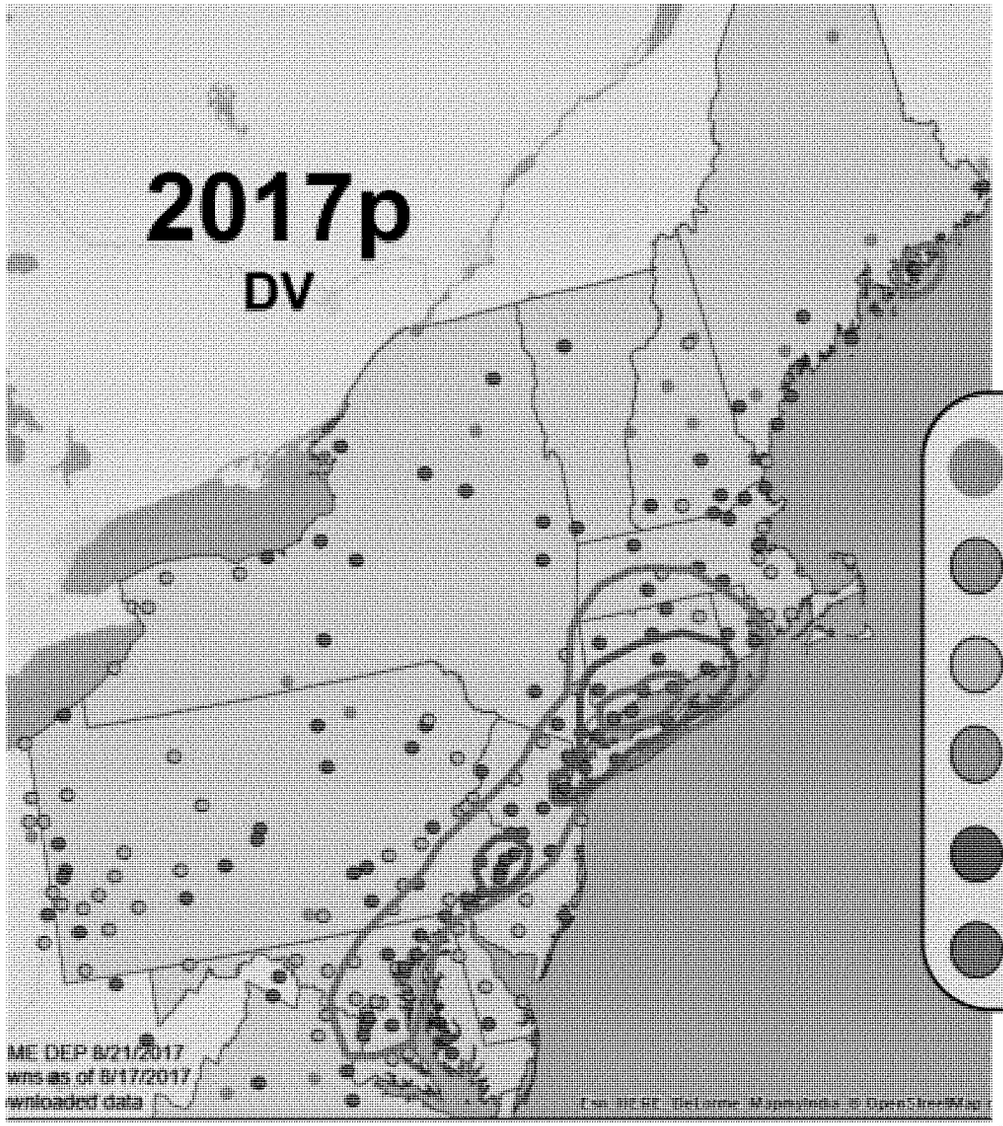


- <61 ppb
- 61 – 65 ppb
- 66 - 70 ppb
- 71 – 75 ppb
- 76 - 80 ppb
- >81 ppb

1. Change to 2015-17 Preliminary 8-hour Ozone Design Values

(excluding potential exceptional events)

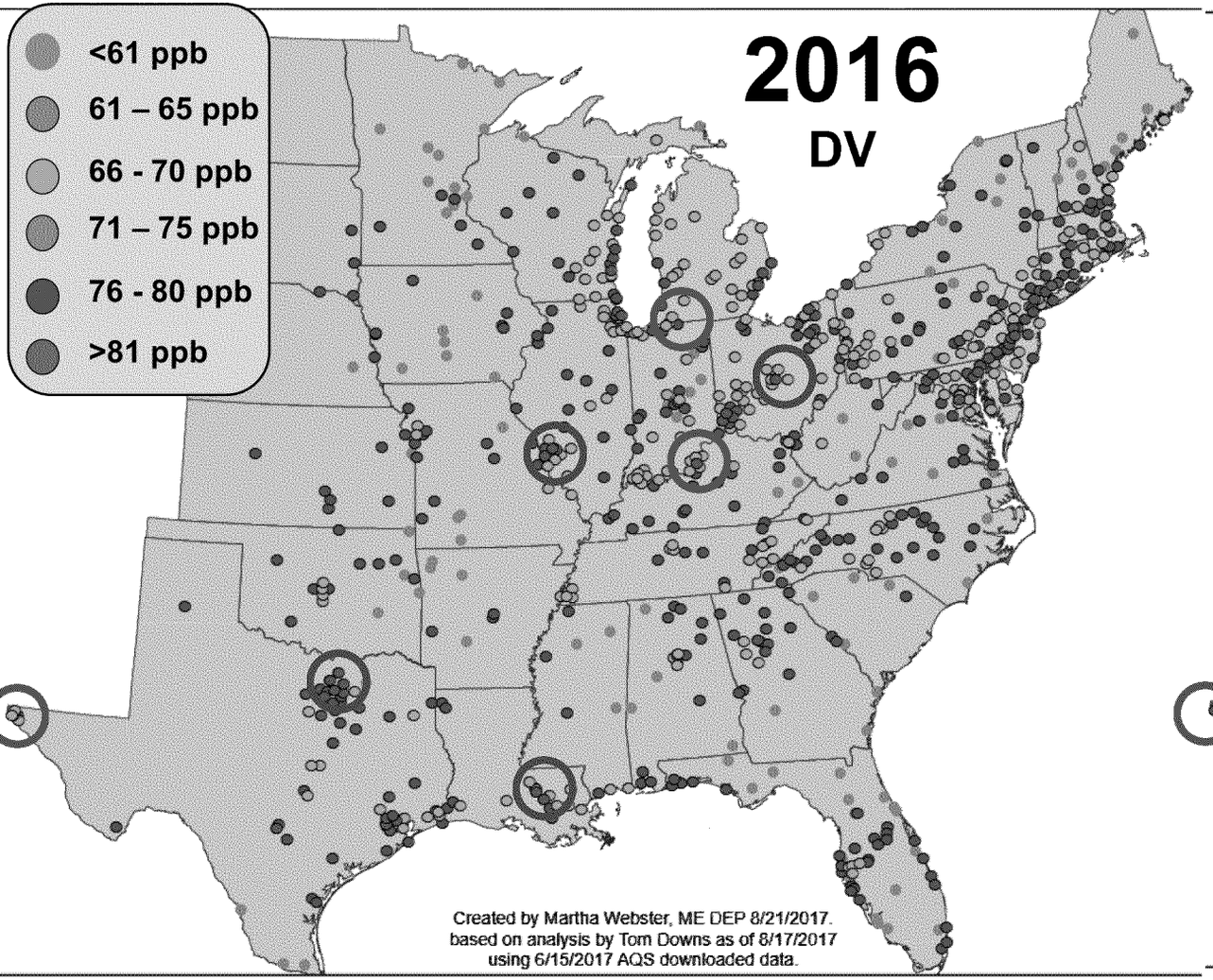


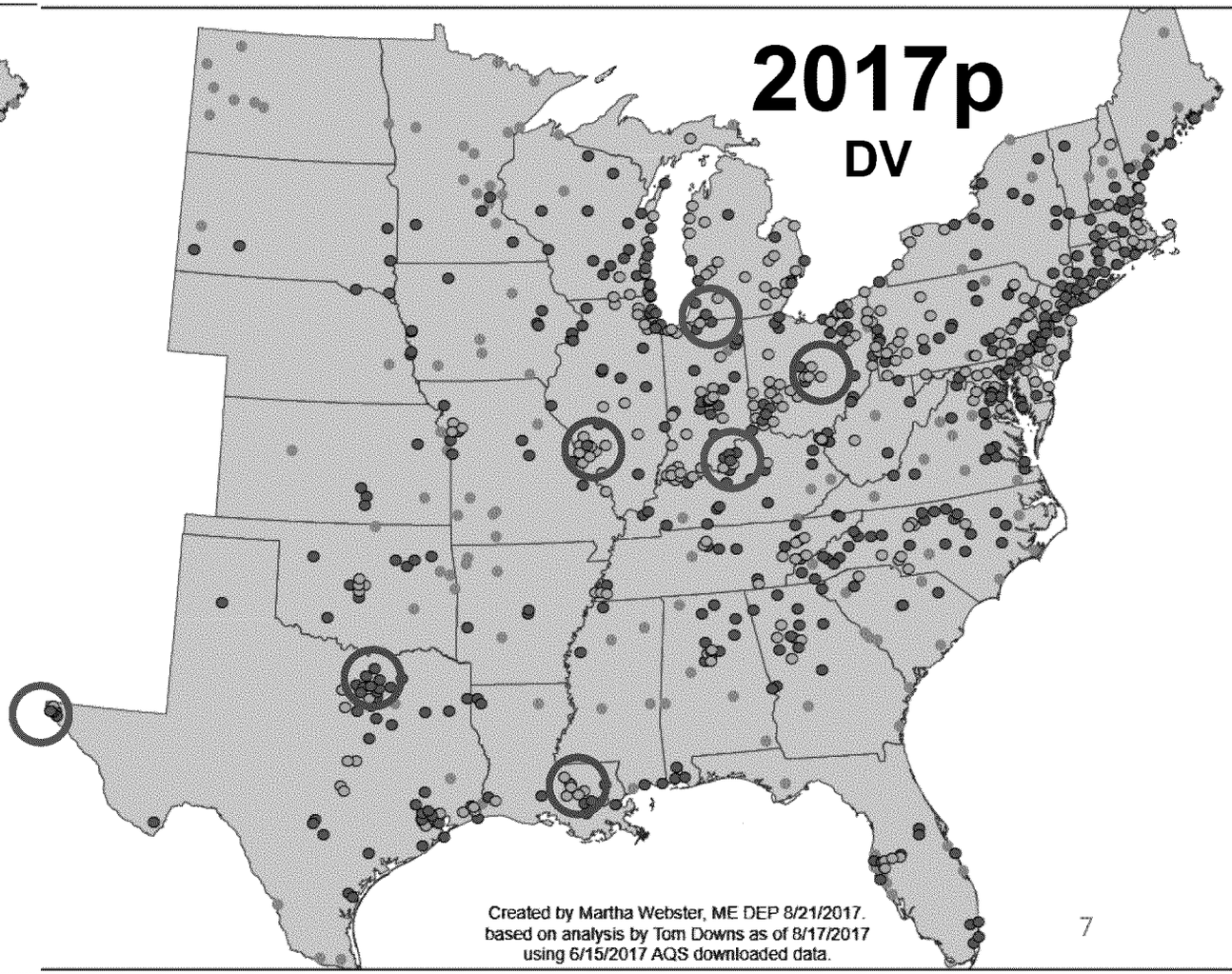


- <61 ppb
- 61 – 65 ppb
- 66 - 70 ppb
- 71 – 75 ppb
- 76 - 80 ppb
- >81 ppb

1. 2014-16 8h Ozone Design Values

(excluding potential exceptional events)





2. Ozone NAAQS Planning Timeline

October 2015

Final 2015 NAAQS

October 2017	Up to October 2018
Non. Area Designations for 2015 NAAQS	Delayed Non. Area Designations for 2015 NAAQS

October 2018

Infrastructure/Transport SIP for 2015 NAAQS Due

October 2020	Up to October 2021*
2015 Ozone Nonattainment SIPs Due	Delayed 2015 Ozone Nonattainment SIPs Due

Attainment by (October):		Delayed Attainment by (??):	
2020 - Marginal	**2023** - Moderate	**2020-2021*** - Marginal	**2023-2024*** - Moderate

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3. Ben Map Rollback Overview

- BenMap provides estimates of air pollution health impacts and associated valuations
- Employed health functions and economic valuations that are used by EPA in RIAs
- Can be performed for monitored or modeled data
- OTC used it to estimate health impacts and valuation avoidance if monitored ozone were reduced to different thresholds
  - Considered four years of ozone monitoring (2013-2016)
  - Considered three ozone thresholds (70, 65, and 40ppb)
  - 2010 census data projected to year analyzed for OTR states

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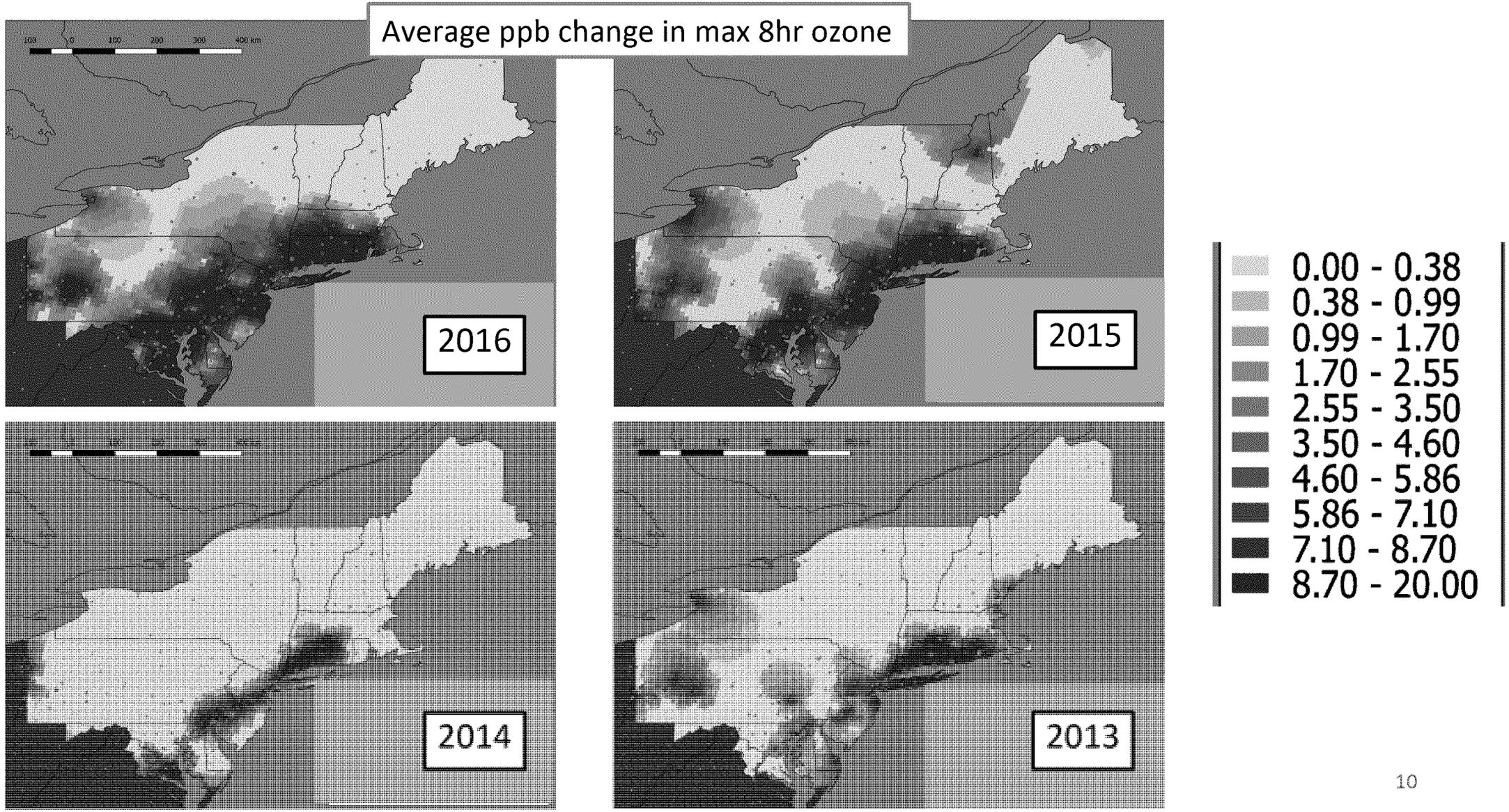
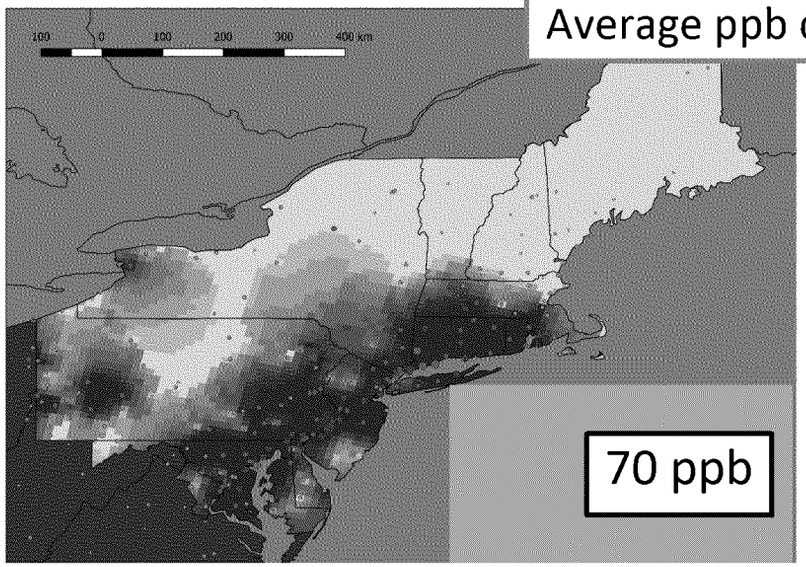
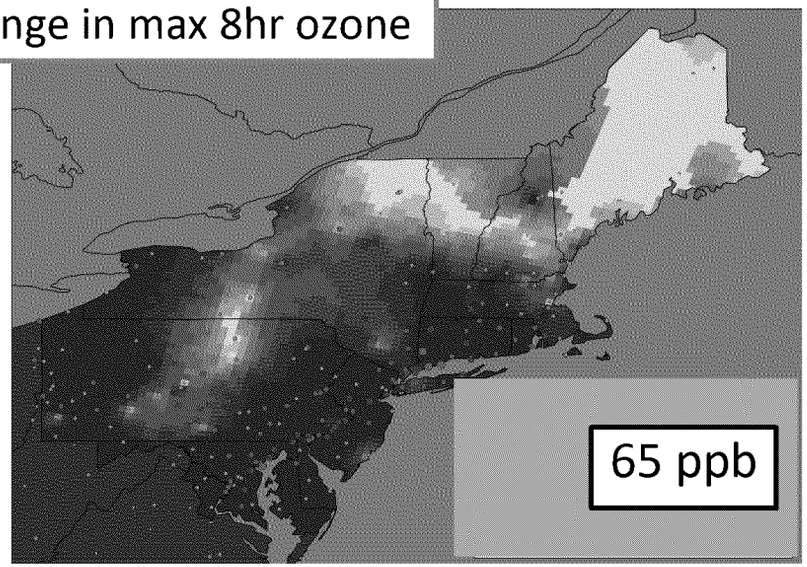
3. Changes in Ozone Concentration after Rollback to 70ppb

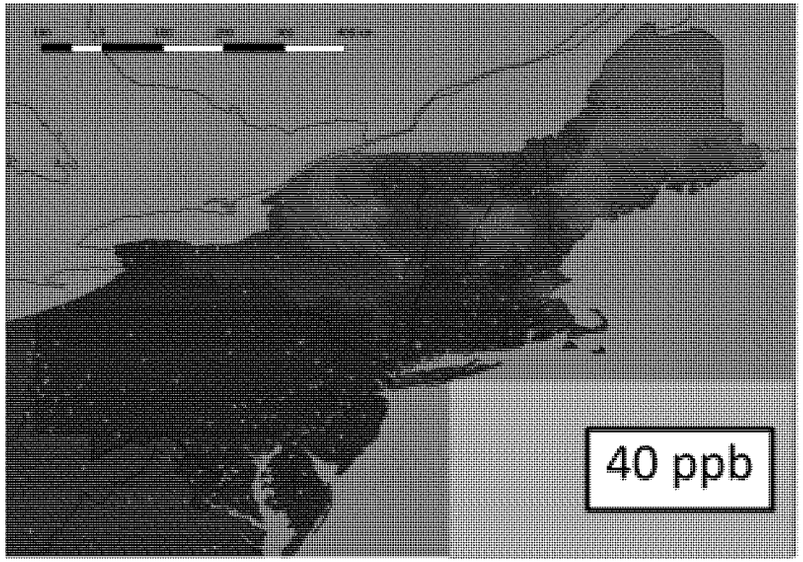


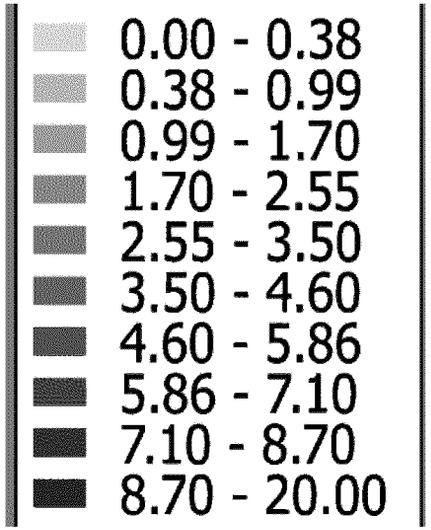
3. Changes in Ozone Concentration after Rollback in 2016 at 3 Ozone Levels

Average ppb change in max 8hr ozone

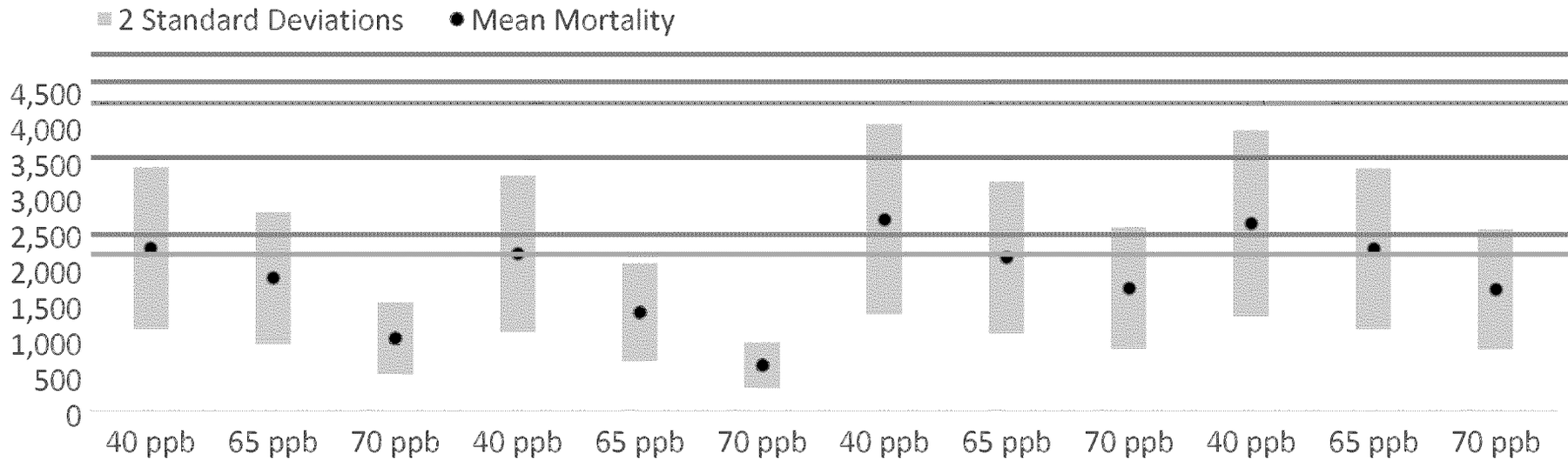


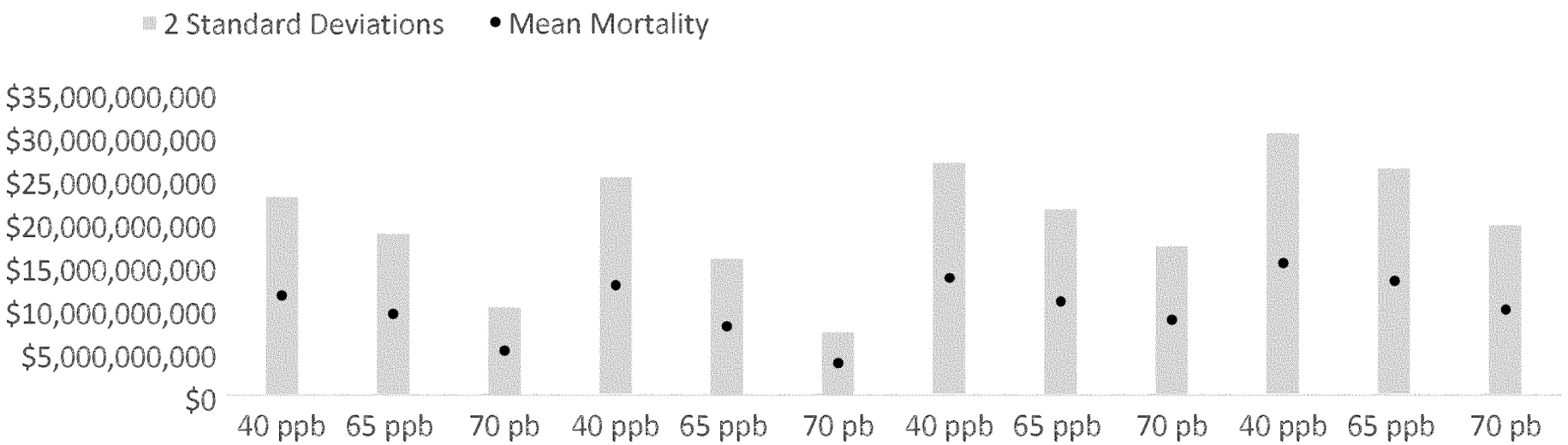






3. Mortality Incidence Reduced and Economic Benefits for Reducing Ozone to 3 Levels in the OTR





Selected 2016 Mortality Incidence in the OTR

- Bladder Cancer (28)
- Oesophagus Cancer (30)
- Ovary Cancer (31)
- Homicide (34)
- HIV/AIDS (38)
- Hepatitis C (41)

4. 2011 Modeling Platform

- Still the focus of:
  - 2008 Ozone NAAQS SIP Modeling Efforts (primarily CMAQ)
  - 2018-21 Regional Haze SIP Modeling for MANE-VU (CMAQ)
  - Contribution assessment research (CAMx)
- Emission Inventories have been updated to MARAMA Gamma for 2011, 2020, and 2023
  - MARAMA Alpha 2028 still currently in use for regional haze modeling

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4. Near-Term Emission Inventories

Alpha
- 2011
- 2018
- 2028

Beta
- 2011
- 2017

Gamma
- 2011
- 2020
- 2023

- Gamma Inventory Improvements are Underway
  - Project future year to **2023 & 2020**
  - Upgrade to **ERTAC v2.7 w/ C-SAPR Update**
  - 2023 Mobile: EPA MOVES & Nonroad
  - 2020 Mobile: 2017→2023 Interpolation
  - EMF Growth for point & maybe area
  - For 2020 some sectors interpolated
  - Other updates for 2011/2023 from EPA v6.3
- Review by States & Stakeholders to Beginning

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4. EPA/Inter Regional Collaboration

- Collaboration with EPA and Inter-Regionally has been vital to inventory development
  - Regularly receive updated modeling platforms from EPA, often through other RPOs
  - Discussions with CAMD on ERTAC have led to:
    - EPA moving to an ERTAC lite process for their modeling
    - Obtaining data on planned shutdowns and controls from CAMD for states that don't participate in ERTAC
  - NOMAD – someone help there
  - Any I am missing?
- Crucial to continued this collaboration for future modeling platforms

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4. OTC Photochemical Modeling Plan

2011 Gamma Emission Inventory Base Case (CMAQ & CAMx)

- To ensure consistent inventories and update chemistry

2017 Beta Emission Inventory Base Case – CAMx Emission Tags

- For Use in Transport Modeling

2023 Gamma Emission Inventory Base Case – CAMx Emission Tags

- For Use in Transport Modeling
- Guidance information for 2015 Ozone NAAQS

2020 Gamma Emission Inventory Base Case – CMAQ

- For use in Serious 2008 NAAQS Nonattainment Ozone SIPs

Update Gamma Emission Inventory and Modeling Documentation

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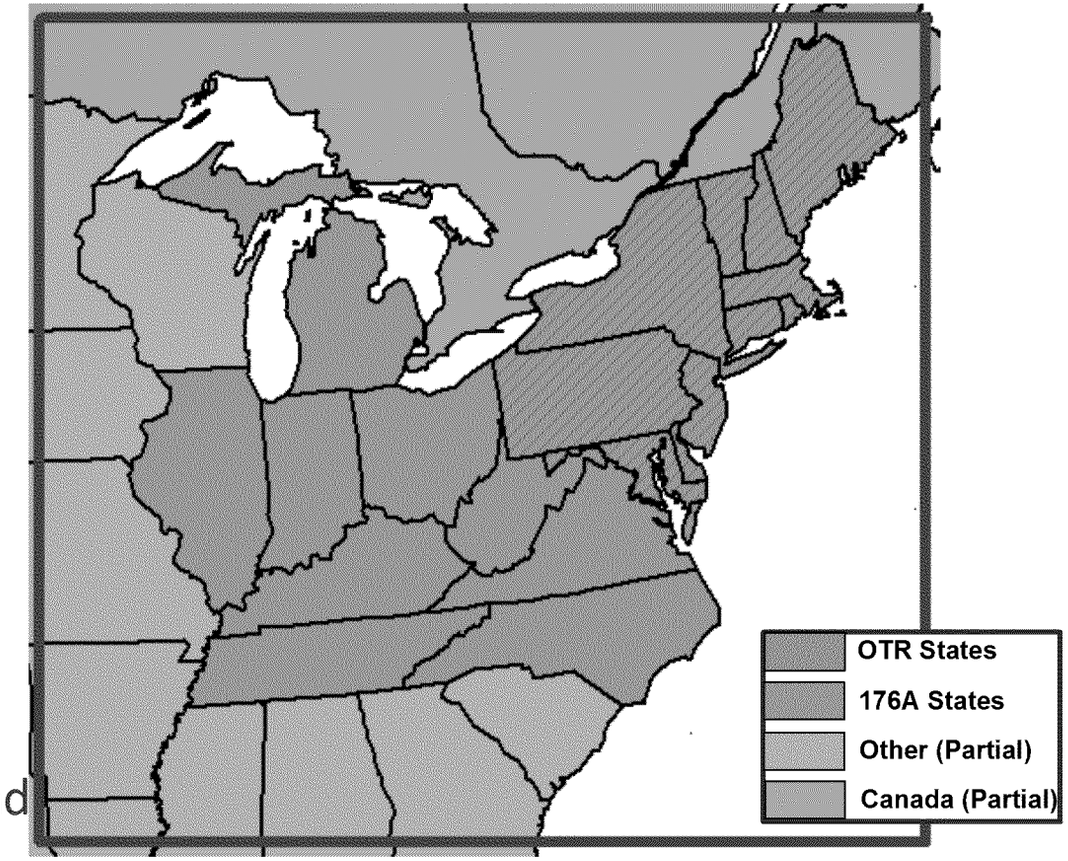
4. OTC Contribution Modeling – Emission Source Tagging

- Emission Years
1. 2023 – Moderate 2015 NAAQS
2. 2017 – Least Projected

- States/Anthropogenic Sectors to tag
  - **All States (& partial states) in Domain**
    - EGU,
    - Area,
    - NonRoad,
    - Marine
    - Non-EGUs (cement kilns, MWC, & others),
    - OnRoad (diesel & others),
    - Oil & Gas (area & point)
  - **Only OTC States individually**
    - RWC, Fires
  - **Entire Domain**
    - Biogenics, Initial Conditions, Boundary Cond
      Zone – US Territorial Waters)

That's 385 Tags

OTC Modeling Domain



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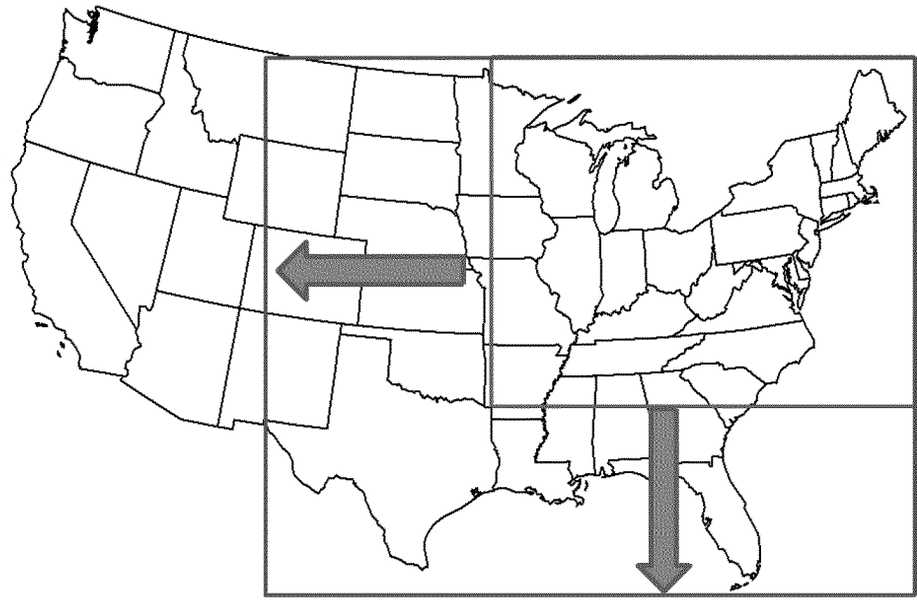
5. New OTC Modeling Platform – Under Development

- In partnership with EPA and other regions nationally for 2015 Ozone NAAQS and for Regional Haze 2021 submittals
- Likely to use a unified domain
  - OTC likely to utilize a larger portion of the national domain than in the past (i.e., east of the Rocky Mountains)
  - Common emission inventories where possible
    - 2014 NEI represents update to 2011
    - 2017 NEI will not be available until 2019
  - 2016 meteorology focus, possibly supplemented with 2015 episodes
  - Projected years, TBD



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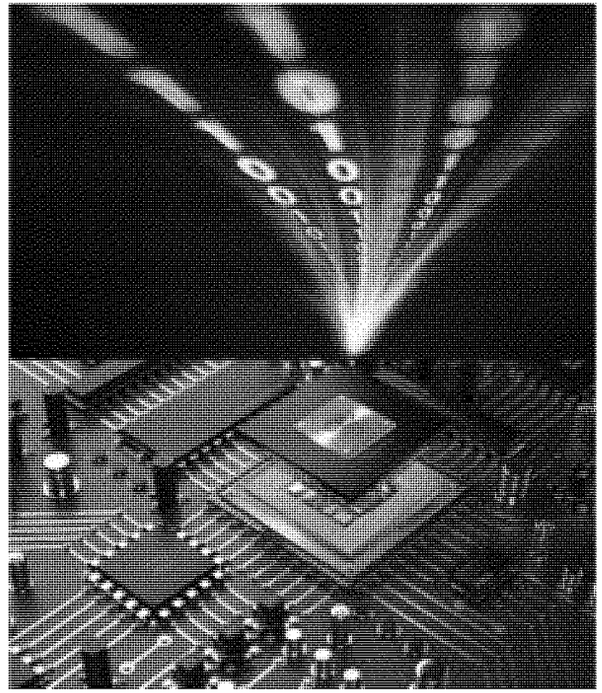
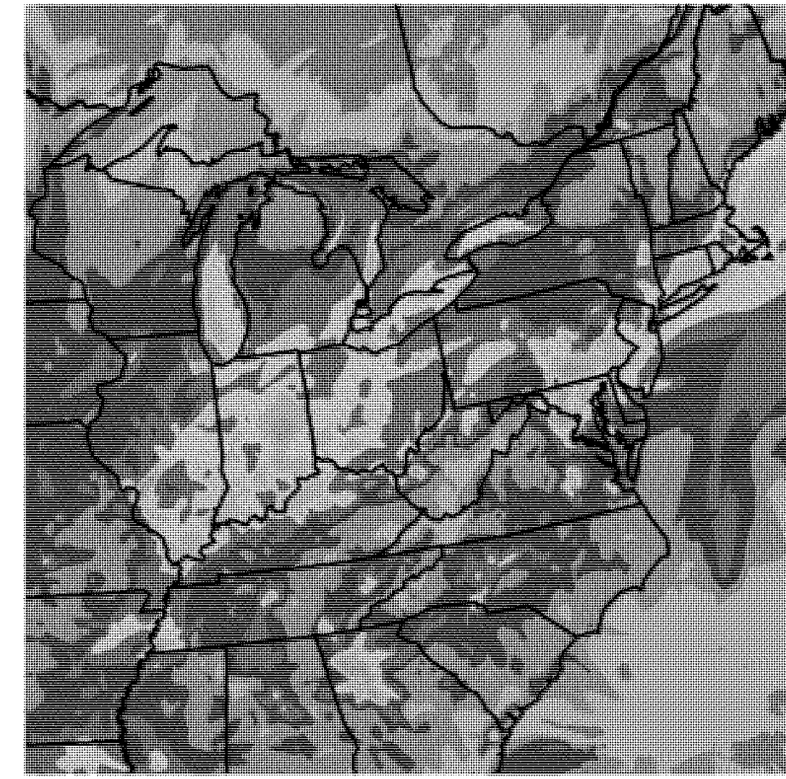
5. New OTC Modeling Platform – Under Development

- EPA will likely do early work with this new platform
  - Won't be SIP quality for state work for at least two years (resource depending)





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6. Enhanced Monitoring Plans (EMP)

- Requires states with moderate or above ozone NAA & OTR states to submit an EMP as part of 2015 Ozone NAAQS process
- Plans due to EPA on 10/1/2019, or 2 years after moderate or above designation* Region 1, 2 and 3 states plan to submit early
- Effort underway to coordinate between states & EPA through OTC workgroup
  - Gain regional benefits from plans
  - More knowledge on transport
  - More knowledge of air/sea affect on ozone
  - Information to improve model performance

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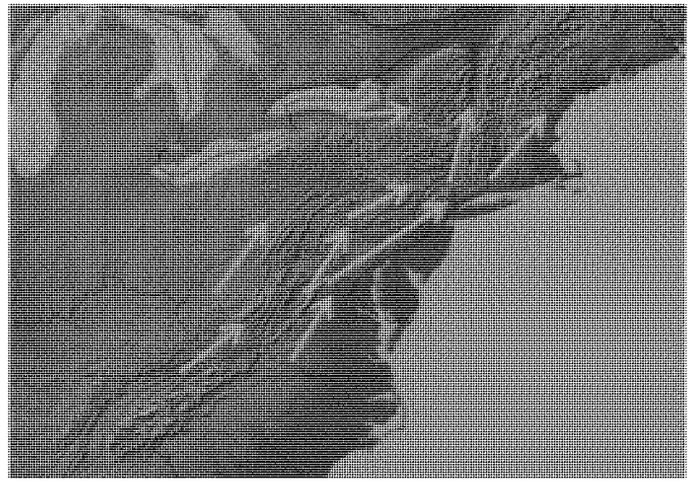
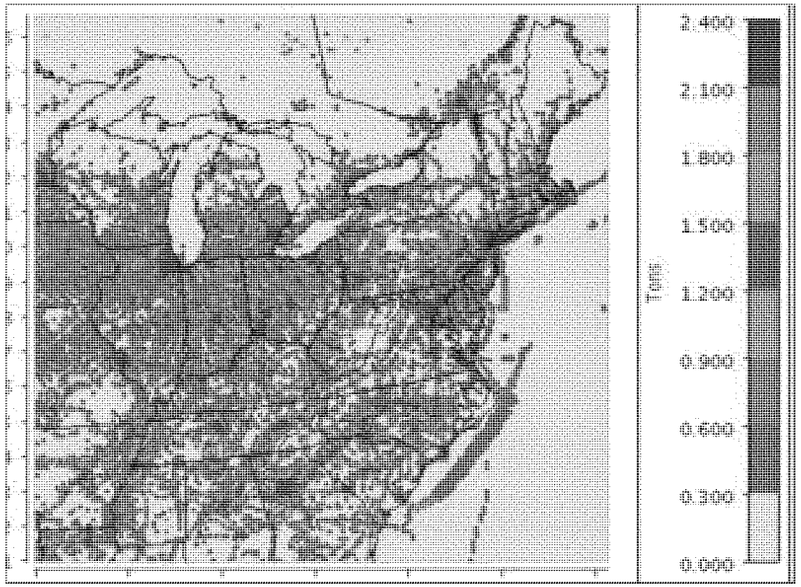
6. OTR Enhanced Monitoring Plans

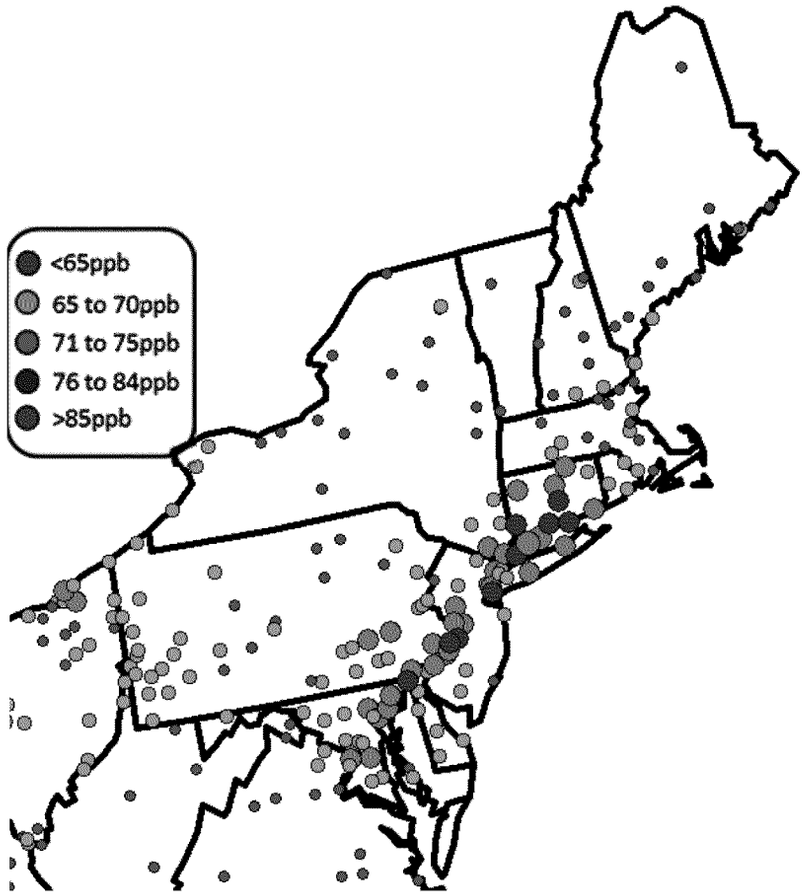
- An opportunity to enhance monitoring network in a coordinated way to collect data for:
  - Better understanding emissions
  - Improve science of transport in the region
  - Meeting attainment in all portions of the OTR



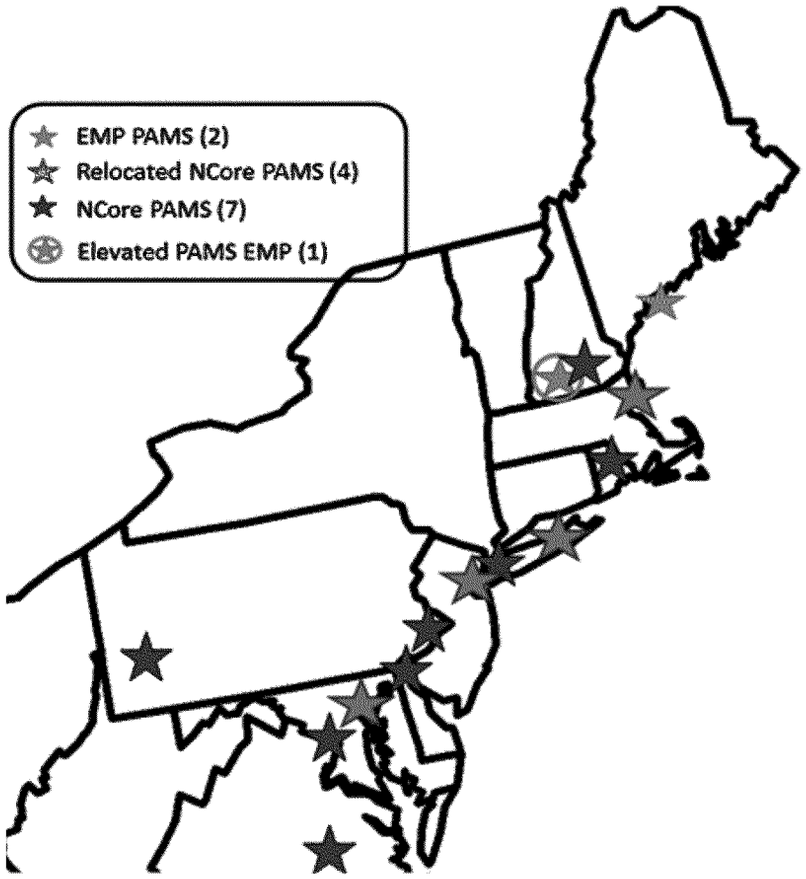


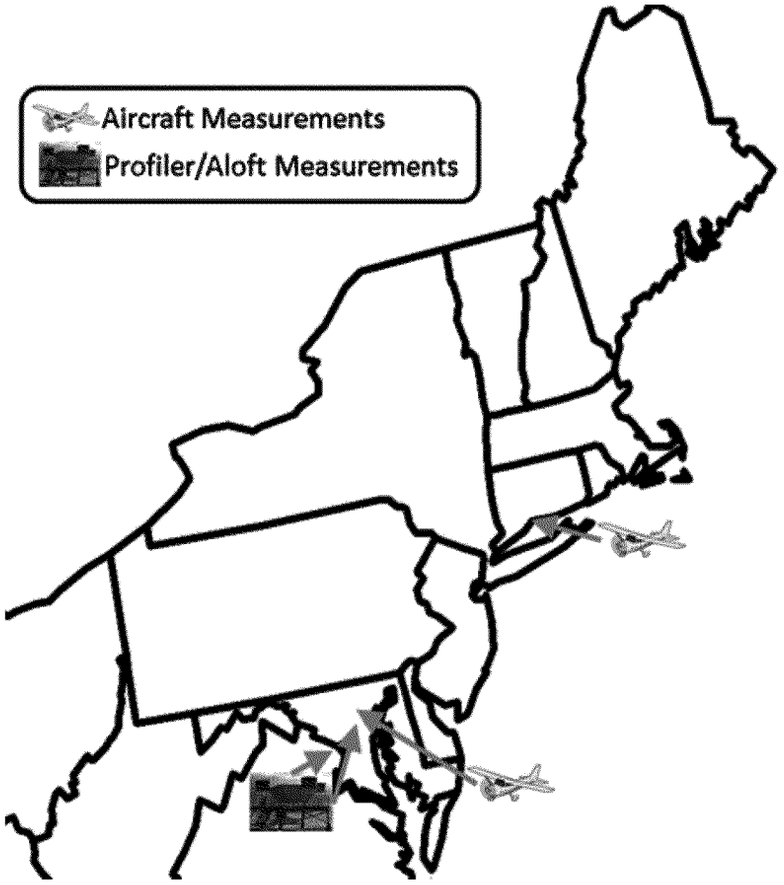
6. Enhanced Monitoring Plans (EMP)

Design Values



Preliminary state suggestions





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7. Conceptual Model

- Conceptual Model last updated August 2010
- Have been advances in our understanding of Ozone since then
  - DISCOVER-AQ Campaign
  - Land-Water Interface
  - NO_X Tipping Point
  - Changing Weather Patterns
  - More Advanced Inventories
- Workgroup is updating several documents with the new information
  - Presentation
  - Technical Document

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8. Conclusions & Next Steps

- Ozone design values in the OTR are up this year
  - Ozone exceedances in 2017 ozone season similar to 2015 and 2016, but more than in 2014
- OTC BenMap modeling indicates that:
  - Reducing Ozone levels will substantially reduce mortality and other health issues related to ozone in the OTR
- Emissions inventories for next round of modeling include:
  - 2011 Gamma and updated model chemistry
  - 2017 Beta with emission tagging
  - 2020 Gamma
  - 2023 Gamma with emission tagging
- Enhanced Monitoring Plans (EMPs) still in early planning discussions

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Questions

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OTC Committee Lead:

Joseph Jakuta

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6. Required Monitoring

- EPA has worked with the states to identify non-required monitoring and opportunities to reduce monitoring expenses
  - Not required under federal regulation (location not needed, reasonably covered by another location, low pollution concentrations)
- EPAs 2015 ozone NAAQS implementation rule
  - Revises enhanced monitoring requirements (PAMS)
    - NCORE locations in MSAs larger than 1 million people
    - Areas classified as Moderate nonattainment for the 2015 ozone NAAQS (NCORE)
  - Requires Enhanced Monitoring Plans for areas classified as Moderate nonattainment for the 2015 ozone NAAQS and all OTR states

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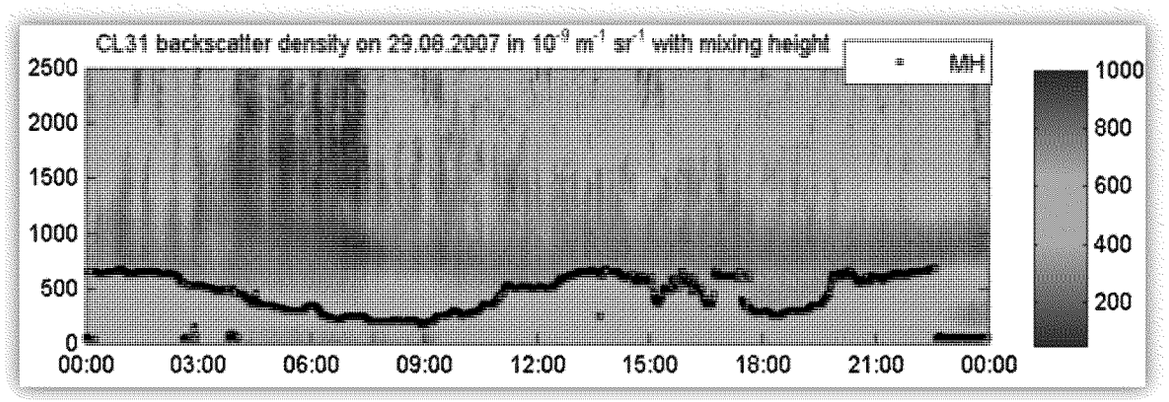
6. Monitoring can include:

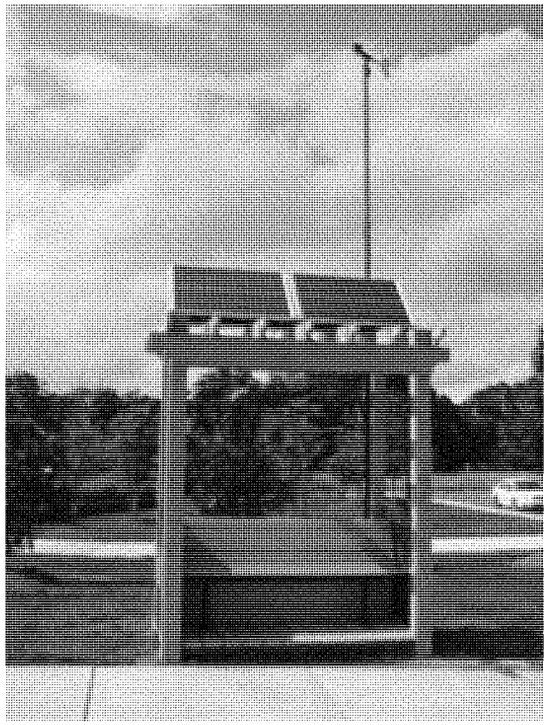
- Upgraded monitoring equipment
  - Trace level monitors (CO)
  - True NO_2
  - Interference free monitors

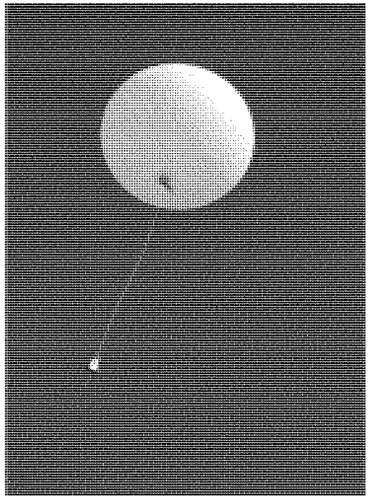


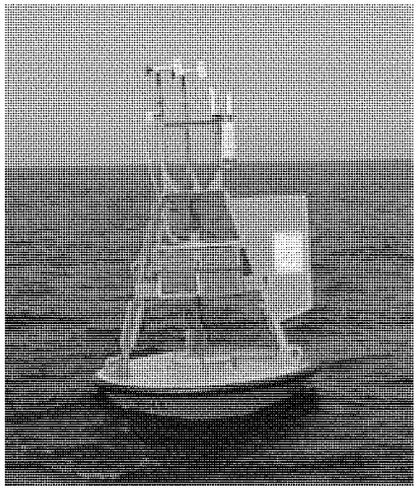
- Use of tools not previously realistic options
  - Ceilometers (measure cloud base – mixing height)
  - Radar Wind Profilers and RASS (winds, temp, mixing height)
  - SODAR (wind and mixing heights)
  - LIDAR (high resolution wind and mixing heights)
  - Microwave Radiometry (temperature, relative humidity (RH), liquid water)
  - PANDORA Spectrometer (total column O_3, SO_2, formaldehyde, BrO, NO_2 and H_2O

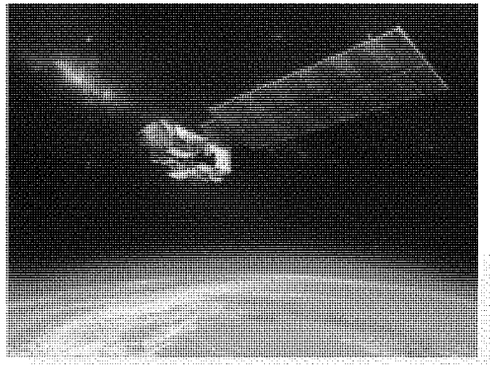
6. Can Also Consider Measurements

- Aloft – Airplanes, balloons, etc.
- Over water – boats, buoys
- Coordination with satellite data









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End Date/Time: Tue 8/22/2017 6:30:00 PM
OTC MC 8 22 2017.pptx
OTC_Modeling_Committee_Fall_2017.pptx

;;
Draft Agenda:

1. Fall 2017 OTC/MANE-VU Meetings Schedule

a. Committees Meeting - Sept. 7, Washington, DC (Hall of the States)
b. Air Directors Meeting - Oct. 10-11, Linthicum Heights, MD (Sheraton BWI)
c. Annual Fall Meeting - Nov. 14-15, Washington, DC (Melrose Hotel)

2. Ozone Season Update – see attached slides OTC MC 8-22-2017.pptx

d. New exceedances
e. Any changes to nonattainment
f. 1-year extension status

3. 2011 Modeling Platform Updates

g. Source Apportionment work from VA DEQ
h. Emission inventory updates
i. Status for tagged ozone model runs
j. Planning for 2028 control projection based on MANE-VU Ask

4. Draft Committee Presentation – see attached slides OTC_Modeling_Committee_Fall_2017.pptx
5. OTC Documents

k. BenMap Report Update
l. Conceptual Model Update
m. TSD Update (including Land-Water Interface)

---GoToMeeting invitation begins---
Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/ Ex. 6
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Location: https://www.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
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End Date/Time: Tue 6/20/2017 6:30:00 PM
2010_O3_conceptual_model_final_revised_20100810.pdf
HYSPLIT Letter.docx
cmaq_beta2_2020_2023.xlsx
June10th_13th_Ozone_Exceedance_Event_Final.pptx

Draft Agenda

1. Current Ozone Event – http://www.maine.gov/dep/ftp/DEP_OZONE/OTC/2017/
2. 2011 Platform

a. 2023 Results
b. 2020/2023 Inventory Update
c. Tagging Runs
d. Tracking Databases - https://www.dropbox.com/sh/fetjsabn2evdrid/AAABihswLsq_K4M4kO_dj7GQa?dl=0

3. BenMap Paper – 2016 Data
4. EMP Workgroup
5. Conceptual Model Workgroup – previous draft attached
6. Letter of support for HYSPLIT – attached

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You can also dial in using your phone.
United States Ex. 6
Access Code: Ex. 6
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The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description

Prepared for the Ozone Transport Commission

Prepared by NESCAUM
Boston, MA

October 2006

Revised
August 2010

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Acknowledgements

NESCAUM thanks the Mid-Atlantic Regional Air Management Association for providing the foundational basis of the 2006 report.

NESCAUM also thanks the following people for their comments and input during the development of the 2006 and revised 2010 reports:

Tad Aburn, Maryland Department of the Environment
Debra Baker, Maryland Department of the Environment
Michael Geigert, Connecticut Department of Environmental Protection
Kurt Kebschull, Connecticut Department of Environmental Protection
Tonalee Key, New Jersey Department of Environmental Protection
Mohammed A. Majeed, Delaware Department of Natural Resources and Environmental Conservation
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Charles Pietarinen, New Jersey Department of Environmental Protection
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Michael Woodman, Maryland Department of the Environment

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Executive Summary

The Ozone Transport Region (OTR) of the eastern United States covers a large area that is home to over 62 million people living in Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and northern Virginia. Each summer, the people who live within the OTR are subject to episodes of poor air quality resulting from ground-level ozone pollution that affects much of the region. During severe ozone events, the scale of the problem can extend beyond the OTR's borders and include over 200,000 square miles across the eastern United States. Contributing to the problem are local sources of air pollution as well as air pollution transported hundreds of miles from distant sources outside the OTR.

To address the ozone problem, the Clean Air Act Amendments require states to develop State Implementation Plans (SIPs) detailing their approaches for reducing ozone pollution. As part of this process, states are urged by the U.S. Environmental Protection Agency (USEPA) to include in their SIPs a conceptual description of the pollution problem in their nonattainment areas. This document provides the conceptual description of the ozone problem in the OTR states, consistent with the USEPA's guidance.

Since the late 1970s, a wealth of information has been collected concerning the regional nature of the OTR's ground-level ozone air quality problem. Scientific studies have uncovered a rich complexity in the interaction of meteorology and topography with ozone formation and transport.

The evolution of severe ozone episodes in the eastern U.S. often begins with the passage of a large high pressure area from the Midwest to the middle or southern Atlantic states, where it assimilates into and becomes an extension of the Atlantic (Bermuda) high pressure system. During its passage east, the air mass accumulates air pollutants emitted by a number of sources in upwind states, including large coal-fired power plants and mobile and area sources. Later, sources within the OTR make their own contributions to the air pollution burden. These expansive weather systems favor the formation of ozone by creating a vast area of clear skies and high temperatures. These two prerequisites for abundant ozone formation are further compounded by a circulation pattern favorable for pollution transport over large distances. In the worst cases, the high pressure systems stall over the eastern United States for days, creating ozone episodes of strong intensity and long duration.

One transport mechanism that can play a key role in moving pollution long distances is the nocturnal low level jet. The jet is a regional scale phenomenon of higher wind speeds a few hundred meters above the ground just above the stable nocturnal boundary layer. The jet has been observed just before or during ozone events. It can convey air pollution several hundreds of miles overnight from the southwest to the northeast, directly in line with the major population centers of the Northeast Corridor stretching from Washington, DC to Boston, Massachusetts. The nocturnal low level jet can extend the entire length of the corridor from Virginia to Maine, and has been observed as far south as Georgia. It can also act to bring pollutants from different directions compared to the prevailing airflow outside the low level jet. It can thus be a

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transport mechanism for bringing ozone and other air pollutants into the OTR from outside the region, as well as move locally formed air pollution from one part of the OTR to another.

Other transport mechanisms occur over smaller scales. These include land, sea, mountain, and valley breezes that can selectively affect relatively local areas. For example, sea breezes can differ in wind direction, thereby bringing air masses trapped in a thin layer over the cooler water back onto shore. Such mechanisms play a vital role in drawing ozone-laden air into some areas, such as coastal Maine, that are far removed from major source regions.

With the knowledge of the different transport scales into and within the OTR, a conceptual picture of bad ozone days emerges. After sunset, the ground cools faster than the air above it, creating a nocturnal temperature inversion. This stable boundary layer extends from the ground to only a few hundred meters in altitude. Above this layer, a nocturnal low level jet can form with higher velocity winds relative to the surrounding air. It forms from the fairly abrupt removal of frictional forces induced by the ground that would otherwise slow the wind. Absent this friction, winds at this height are free to accelerate, forming the nocturnal low level jet. Ozone above the stable nocturnal inversion layer is likewise cut off from the ground, and thus it is not subject to removal on surfaces or chemical destruction from low level emissions, the two most important ozone removal processes. Ozone in high concentrations can be entrained in the nocturnal low level jet and transported several hundred kilometers downwind overnight. The next morning as the sun heats the Earth's surface, the nocturnal boundary layer begins to break up, and the ozone transported aloft overnight mixes down to the surface where concentrations rise rapidly, partly from mixing and partly from ozone generated locally. By the afternoon, abundant sunshine combined with warm temperatures promotes additional photochemical production of ozone from local emissions. As a result, ozone concentrations reach their maximum levels through the combined effects of local and transported pollution. This combined air mass will then continue to blow along with the wind, carrying elevated concentrations of ozone to areas farther downwind, causing late afternoon and even overnight ozone peaks.

Ozone moving over water is, like ozone aloft, relatively isolated from destructive forces. This air pollution is also protected from vertical mixing and dilution by a relatively shallow mixing layer that occurs when the water is cooler than the air above it. When ozone is transported into coastal regions by bay, lake, and sea breezes arising from afternoon temperature contrasts between the land and water, it can arrive highly concentrated.

During severe ozone episodes associated with high pressure systems, these multiple transport features are embedded within a large ozone reservoir arriving from source regions to the south and west of the OTR. Thus a severe ozone episode can contain elements of long-range air pollution transport from outside the OTR, including nocturnal low level jets, regional scale transport within the OTR, and local transport along coastal shores due to bay, lake, and sea breezes.

From this conceptual description of ozone formation and transport into and within the OTR, air quality planners need to develop an understanding of what it will take to

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clean the air in the OTR. There are distinct regional and local components that would best be addressed by implementing national, regional, and local controls, respectively. Observed ozone levels in the elevated reservoir often are close to or exceed 0.060 - 0.070 ppm averaged over 8 hours, which is the range that EPA has proposed for the revised National Ambient Air Quality Standard (NAAQS) for ozone. Given that the regional and national load will continue to play a major role in ozone episodes as the ozone NAAQS is lowered, further strengthening of national rules will be critical in mitigating the ozone problem.

Because weather is always changing, every ozone episode is unique in its specific details. The relative influences of the transport pathways and local emissions vary by hour and day during the course of an ozone episode and between episodes. The smaller scale weather patterns that affect pollution accumulation and its transport underscore the importance of local (in-state) controls for emissions of nitrogen oxides (NO_X) and volatile organic compounds (VOCs), the main precursors of ozone formation in the atmosphere. Larger synoptic scale weather patterns, and pollution patterns associated with them, support the need for NO_X controls across the broader eastern United States.

Studies and characterizations of nocturnal low level jets also support the need for local and regional controls on NO_X and VOC sources as locally generated and transported pollution can both be entrained in nocturnal low level jets formed during nighttime hours. The presence of land, sea, mountain, and valley breezes indicate that there are diverse aspects of pollution accumulation and transport that are area-specific and will warrant policy responses at the local and regional levels beyond a one-size-fits-all approach. In addition, over the course of a day, ozone can be NO_X-sensitive during some hours, and VOC-sensitive during others, indicating temporally varying regional and local influences on ozone formation and transport. This further underscores the need for air quality regulators to adopt a combination of national, regional, and local emission controls to address the problem.

The type of emission controls is important. Regional ozone formation is primarily due to NO_X, but VOCs are also important because they influence how efficiently ozone is produced by NO_X, particularly within urban centers. While reductions in anthropogenic VOCs will typically have less of an impact on long-range ozone transport, they can be effective in reducing ozone in urban areas where ozone production may be limited by the availability of VOCs. Therefore, a combination of localized VOC reductions with additional regional NO_X reductions will help to reduce ozone and precursors in nonattainment areas as well as downwind transport across the entire region.

Photochemical air quality modeling is a powerful yet limited planning tool. While it has undergone considerable improvement over the past decade, it is far from perfect in its ability to replicate ozone transport. There can be large uncertainties in various inputs and processes used by the model, such as precursor emissions inventories, meteorology, and atmospheric chemistry, yet the models can provide useful directionally correct guidance. Given the more recent understanding of the myriad complexities of ozone transport events, it is important that decision-makers use a variety of data sources to characterize the problem and assess possible solutions.

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The recognition that ground-level ozone in the eastern United States is a regional problem requiring a regional solution marks one of the greatest advances in air quality management in the United States. During the 1990s, air quality planners began developing and implementing coordinated regional and local control strategies for NO_X and VOC emissions that went beyond the previous emphasis on urban-only measures. These measures have resulted in significant improvements in air quality across the OTR. Measured NO_X emissions and ambient concentrations have dropped between 1997 and 2005, and the frequency and magnitude of ozone exceedances have declined within the OTR. With the National Ambient Air Quality Standards likely continuing to be lowered over time, inter-regional transport will play an even larger role in the future. To maintain the current momentum for improving air quality so that the OTR states can meet their attainment deadlines, there continues to be a need for additional regional NO_X reductions coupled with appropriate local NO_X and VOC controls.

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1. INTRODUCTION

1.1. Background

Ground-level ozone is a persistent public health problem in the Ozone Transport Region (OTR), a large geographical area that is home to over 62 million people living in Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and northern Virginia. Breathing ozone in the air harms lung tissue, and creates the risk of permanently damaging the lungs. It reduces lung function, making breathing more difficult and causing shortness of breath. It aggravates existing asthmatic conditions, thus potentially triggering asthma attacks that send children and others suffering from the disease to hospital emergency rooms. Ozone poses a significant risk to people with preexisting respiratory illnesses, such as emphysema and bronchitis, and it may reduce the body's ability to fight off bacterial infections in the respiratory system. Ground-level ozone also affects otherwise healthy children and adults who are very active outdoors, either at work or at play, during times of high ozone levels (USEPA, 1999). In addition, evidence suggests that short-term ozone exposure has potential cardiovascular effects that may increase the risk of heart attack, stroke, or even death (USEPA, 2006; Bell *et al.*, 2006).

The Clean Air Act requires states that have areas designated "nonattainment" of the ozone National Ambient Air Quality Standard (NAAQS) to submit State Implementation Plans (SIPs) demonstrating how they plan to attain the ozone NAAQS. The SIPs must also include regulations that will yield the necessary emission reductions to attain the national ozone health standard. As part of the SIP process, the U.S. Environmental Protection Agency (USEPA) urges states to include a conceptual description of the pollution problem in their nonattainment areas. The USEPA has provided guidance on developing a conceptual description, which is contained in Section 11 of the document "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze" (USEPA, 2007) (Appendix A of this report reproduces Section 11 of the USEPA guidance document). This document provides the conceptual description of the ozone problem in the OTR states, consistent with the USEPA's guidance. In the guidance, the USEPA presents a list of questions to help define the ozone problem in a nonattainment area. This report addresses these questions, as well as provides some in-depth data and analyses that can assist states in developing conceptual descriptions tailored to their specific areas, where appropriate.

1.2. Ozone formation

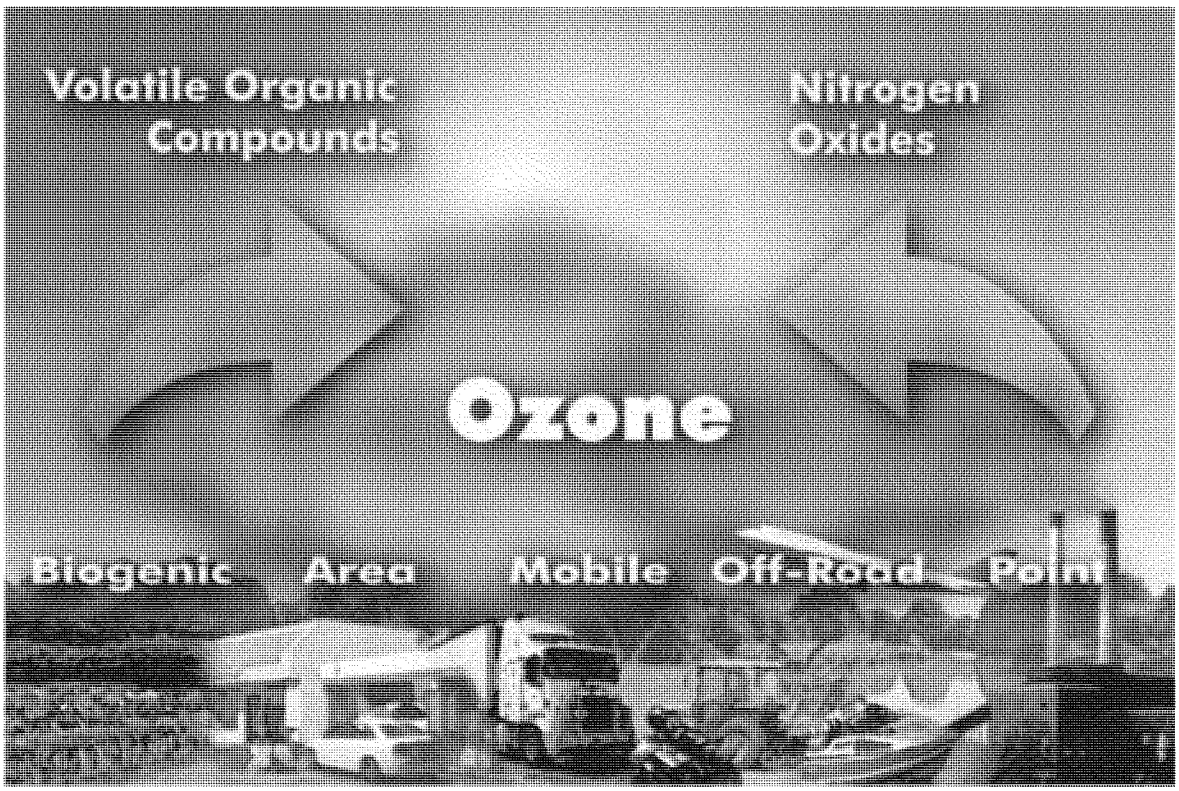
Ground-level ozone is formed in the atmosphere through a series of complex chemical reactions involving sunlight, warm temperatures, nitrogen oxides (NO_X) and volatile organic compounds (VOCs). Figure 1-1 is a conceptual picture of the emission sources and conditions contributing to ozone formation in the atmosphere. There are natural (biogenic) sources of NO_X, such as formation by soil microbes, lightning, and forest fires, but the dominant NO_X sources in the eastern United States arise from human

activities, particularly the burning of fossil fuels in cars, trucks, power plants, and other combustion sources (MARAMA, 2005).

In contrast to NO_X sources, there are significant biogenic sources of VOCs in the eastern United States that can play an important contributing role in ozone formation. Isoprene, a highly reactive natural VOC emitted typically by deciduous trees such as oak, is an important ozone precursor across large parts of the East. Isoprene emissions typically increase with temperature up to a point before high temperatures tend to shut off emissions as leaf stomata (pores) close to reduce water loss. The temperature and sunlight conditions favorable for increased ozone production also tend to be favorable for isoprene emissions (MARAMA, 2005).

Human-caused (anthropogenic) VOC emissions are important and may dominate the VOC emissions by mass (weight) in an urban area, even though natural sources dominate in the overall region. Some anthropogenic VOCs, such as benzene, are toxic, and may increase risks of cancer or lead to other adverse health effects in addition to helping form ozone (MARAMA, 2005).

Figure 1-1. Conceptual picture of ozone formation in the atmosphere



Picture provided by the Maryland Department of the Environment.

The relationship between the relative importance of NO_X and VOC emissions in producing ozone is complex. The relative ratio of NO_X and VOC levels in the local atmosphere can affect the efficiency of local urban ozone production, and this can vary by time (hour or day) at the same urban location, as well as across locations within the same urban area. For example, high NO_X concentrations relative to VOC levels may hinder ozone production through the destruction of ozone by NO_X (sometimes called

"NO_X scavenging"). The same NO_X, however, when diluted relative to VOCs through the downwind transport and dispersal of a pollution plume, will promote ozone formation elsewhere.

1.3. Spatial pattern of ozone episodes in the OTR

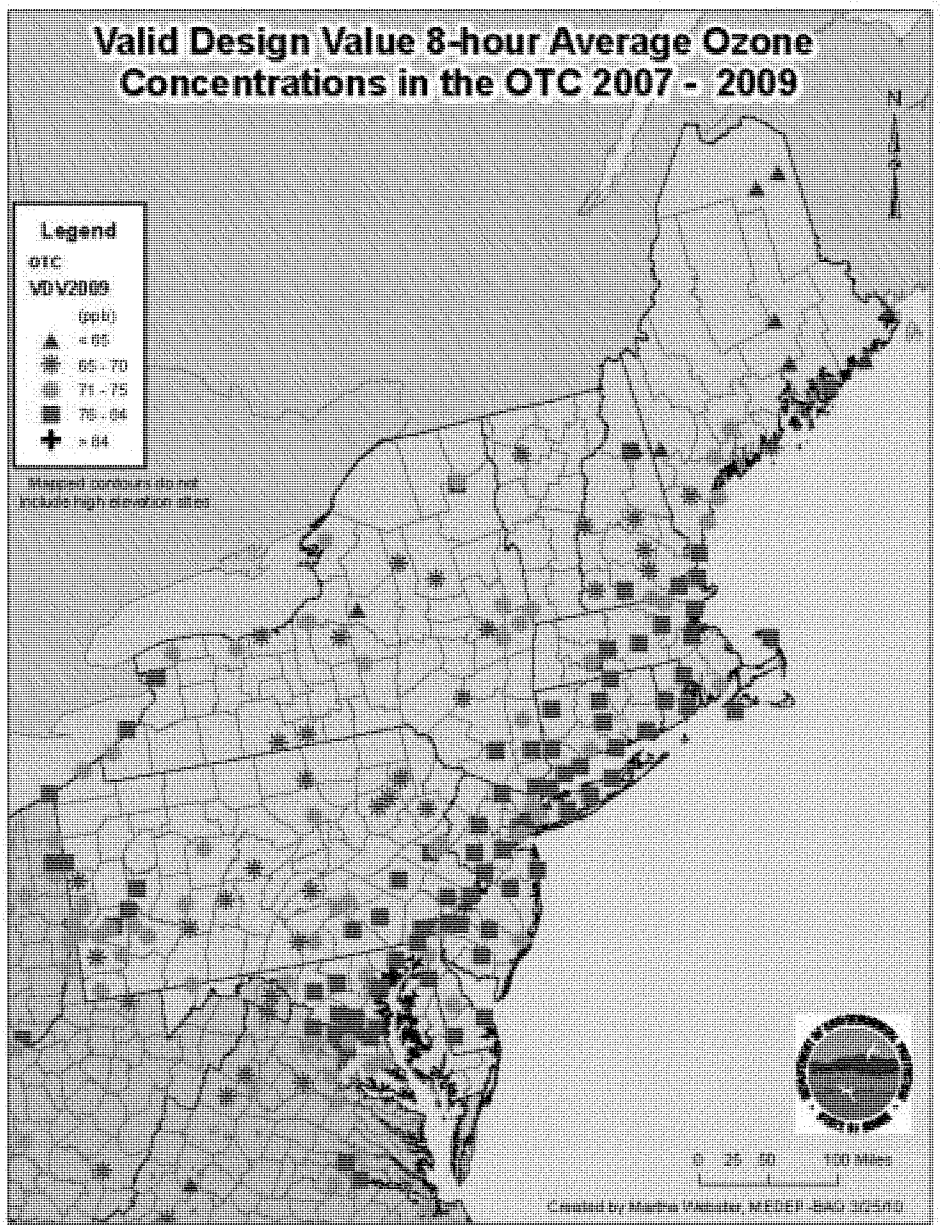
The day-to-day pattern of ground-level ozone varies according to meteorological variables that include, but are not limited to, clouds, air temperature, wind speed, and wind direction. This variability of the daily ozone pattern is tied to variations in the atmosphere's circulations over a range of scales, and how geographic features influence these circulations. These features can include boundaries between land and sea, and the influence of the Appalachian Mountains on winds to their east over the Atlantic Coastal Plain.

For the OTR, Stoeckenius and Kemball-Cook (2005) have identified five general ozone patterns: (1) high ozone throughout the OTR; (2) high ozone confined to the extreme southeastern OTR; (3) high ozone along the I-95 corridor and northern New England; (4) high ozone in the western OTR; and (5) generally low ozone throughout the OTR. Based on a clustering analysis of historical data, Stoeckenius and Kemball-Cook estimated the frequency of occurrence (number of days) for each general ozone pattern in the OTR as 37 percent Type A, 15 percent Type B, 20 percent Type C, 13 percent Type D, and 14 percent Type E. However, not all ozone episodes necessarily neatly fit into one of the five general patterns as daily conditions will vary and a given ozone episode may exhibit characteristics from different class types as the episode evolves. These five general patterns, however, are a useful classification scheme for understanding ozone chemistry and dynamics in the OTR. Appendix B presents the descriptions of the five general ozone patterns and their meteorological attributes as developed by Stoeckenius and Kemball-Cook (2005).

1.4. The regional extent of the ozone problem in the OTR

Air monitoring demonstrates that areas with ozone problems in the OTR do not exist in isolation. The map in Figure 1-2 shows an extensive pattern of closely adjacent ozone monitors throughout the OTR recording elevated levels of ozone during 2007-2009. The figure shows extensive areas throughout the OTR with ozone concentrations exceeding 70 parts per billion (ppb), which is above the upper limit of the USEPA's recently proposed revision for the 8-hour ozone primary NAAQS. The broad spatial reach of the observed high ozone is a strong indication of the regional nature of the OTR's ozone problem.

Figure 1-2. Map of 8-hour ozone design values in the OTR for 2007-2009

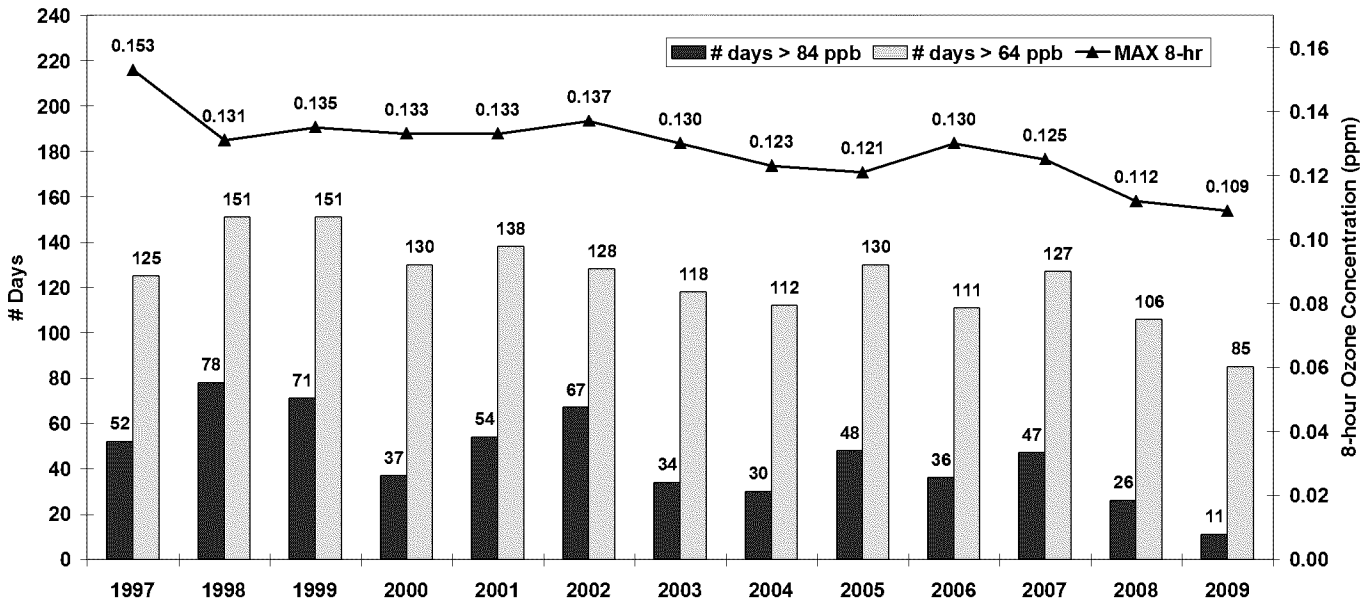


Note: A monitor's design value is the 3-year averag e of the annual 4th maximum 8-hour ozone level for the years 2007-2009. The figure shows the regional nature of ozone levels in the OT R, with clusters of nonattainment areas (design val ues ≥ 71 ppb) along with a broader region of elevated regional ozone (e.g., baseline design values ≥ 65 ppb)

1.5. Ozone trends in the OTR

The number of 8-hour ozone exceedance days vary year-to-year in the OTR, not only due to implementing control measures but also driven by variations in meteorology. During warmer summers conducive for ozone formation, the number of exceedance days at individual monitors in nonattainment areas of the OTR has been frequent, typically with 10 or more days above the 1997 8-hour ozone NAAQS of 0.08 parts per million (ppm) during the course of the summer. Figure 1-3 displays the variation in 8-hour 0.08 ppm (>84 ppb) exceedance days when collectively considering all monitoring sites across the OTR since 1997 (left hand bars in each pair). Also shown are the number of days at or above the 8-hour 0.065 ppm level (right hand bars in each pair), which is the middle of the range from the USEPA's recently proposed revision of the primary ozone NAAQS (0.060 ppm – 0.070 ppm). The figure also includes a line indicating the trend in the maximum 8-hour ozone concentrations observed in the OTR each year.

Figure 1-3. Trends in 8-hour ozone in the OTR 1997-2009



Note: The bars correspond to the number of 8-hour ozone exceedance days per year in the OTR. The left hand bar in each pair of bars gives the annual number of days exceeding 84 ppb (1997 ozone NAAQS level) and the right hand bar gives the annual number of days above 64 ppb. The upper line indicates the trend in maximum 8-hour ozone concentrations in the OTR during 1997-2009. The left side bar of each pair corresponds to exceedances of the 1997 ozone NAAQS, and the right side bar corresponds to the revised 2008 ozone NAAQS. (Figure created by Tom Downs, Maine Dept. of Environmental Protection.)

The variation in high ozone days from year-to-year due to meteorology in addition to changes in ozone precursor emissions makes it difficult to discern a clear trend in Figure 1-3, although there is some indication that the number of exceedance days has declined in recent years. Nguyen and Woodman (2008) have noted a 3-5 year cycle in Maryland during which the number of hot days (≥ 90° F) gradually increases across the cycle period. The number of ozone exceedance days in Maryland (> 84 ppb) followed the

same cycle as hot days until 2002, when a break occurred with annual ozone exceedance days consistently falling below normal regardless of the number of hot days. The departure of the ozone exceedance days from tracking with the hot days cycle coincided with implementation of the NO_X SIP Call in the eastern U.S. as power plants completed installations of controls to reduce NO_X emissions contributing to regional ozone formation and transport. Higher elevation ozone at Shenandoah National Park, an indicator of transport from the Ohio River Valley into the OTR, also dropped during the period from 1993 to 2007 by about an average of 10 ppb at the height of the ozone season in July (Nguyen & Woodman, 2008).

In a trends analysis by Bloomer *et al.*, rural surface ozone levels in the eastern United States decreased by about 6 ppb per decade over the period of 1989 to 2007. The greatest ozone decreases occurred during the periods of highest ozone (i.e., mid-day during the summer months). Over this same time span, summer temperatures increased by about 0.5 °C per decade. Recognizing that ozone generally increases with increasing temperature, Bloomer *et al.* (2010) cited this as additional evidence that emission reductions, including the NO_X SIP Call, rather than changes in weather or the climate were responsible for the ozone decrease.

Chan (2009) has also evaluated regional ground-level ozone trends in Canada and the eastern United States from 1997 to 2006 that takes into account the influence of meteorology. His analysis found a statistically significant decreasing trend in daily maximum 8-hour averaged ozone across much of southeastern Canada and the eastern U.S. The meteorologically-adjusted trend for 8-hour ozone at eastern U.S. monitoring sites was a reduction of about one ppb per year (Chan, 2009). Chan also observed that the trend in lower ozone concentrations did not fall as quickly as the trends for higher ozone concentrations. This could indicate a rising background ozone. Cooper *et al.* (2010) also documented this trend and attributed it to increasing global emissions, particularly in Asia. Rising global temperatures may also play a role by enhancing photochemical production of ozone (see discussion in Section 4.6).

The trends in ozone have important implications for strategies to achieve a future revised ozone NAAQS lower than 0.08 ppm. They may indicate that current ozone control strategies, while relatively effective at reducing higher peak ozone levels, are less effective at reducing lower levels of ozone. In addressing "background" ozone levels, researchers have identified methane reductions as a potentially effective approach (Fiore *et al.*, 2002; 2003). For higher peak ozone concentrations, reducing methane is not typically considered due to its relatively low atmospheric chemical reactivity on the time-scale of multi-day ozone episodes, but methane reductions would have a relatively larger influence on longer-term background ozone levels. Since the beginning of the industrial revolution, global atmospheric methane concentrations have more than doubled (Blunier *et al.*, 1993).

1.6. History of ozone transport science

1.6.1. From the 1970s to the National Research Council report, 1991

Research studies conducted in the 1970s gave some of the earliest indications that pollution transport plays an important role in contributing to air pollution problems in the OTR. One of the first studies to recognize the regional nature of the ozone problem in the OTR (Wolff *et al.*, 1977) observed high ozone levels during the summer of 1975 in air entering the Northeast Corridor from the Midwest (up to 130 ppb), affecting the Northeast from Washington, DC to Boston, MA. Southwest flow along the Corridor appeared to amplify the ozone levels, with levels reaching 315 ppb in southern Connecticut. The combination of long-range transport from the Midwest coupled with complex movements of air parcels within the Corridor led to the early proposition that a multiregional control strategy for ozone precursors would be needed to address the ozone problem in the Northeast Corridor.

In a follow-up to this study, Wolff and Lioy (1980) described their observations of a "river of ozone" extending from the Gulf Coast through the Midwest and into New England during a series of ozone episodes during July 1978. Aircraft flights during the summer of 1979 tracked a mass of air containing ozone and its precursors leaving central Ohio, crossing the length of Pennsylvania, and entering the Northeast Corridor, where it was estimated to contribute upwards of 90 ppb on top of early morning ozone concentrations prior to local ozone formation from local emissions (Clarke & Ching, 1983).

A number of early studies documented the role of large coal-fired power plants in forming significant amounts of ozone pollution that traveled far downwind from the power plant source and contributed to a large elevated reservoir of regional ozone (Davis *et al.*, 1974; Miller *et al.*, 1978; Gillani & Wilson, 1980; Gillani *et al.*, 1981; White *et al.*, 1983). Section 2 below describes in more depth the observed meteorological processes identified as the ozone transport mechanisms important for the OTR.

A number of studies have established that regional ozone formation over the eastern United States is limited primarily by the supply of anthropogenic NO_X, with anthropogenic VOCs having less regional influence compared to their potential urban influence. This is due to the presence of significant amounts of natural VOCs across broad areas of the eastern United States (Trainer *et al.*, 1987; Chameides *et al.*, 1988; Sillman *et al.*, 1990; McKeen *et al.*, 1991; Chameides *et al.*, 1992; Trainer *et al.*, 1993; Jacob *et al.*, 1993).

The presence of dispersed NO_X emissions sources, such as coal-fired power plants, in rural regions rich in isoprene and other natural VOC emissions from trees and other vegetation often leads to elevated regional ozone during the summer months. This ozone can be mixed vertically upward through convection as the atmosphere warms during the day, and become entrained in upper level winds. When captured above the surface boundary layer overnight as the atmosphere cools after sunset, the ozone can be transported downwind long distances. The following morning, mixing of the atmosphere can occur again as the sun warms the earth's surface, bringing the ozone aloft back down

to the ground. The transported ozone then contributes to high background concentrations entering urban areas during the early morning hours before local production of ozone occurs from local precursor emissions (both NO_X and VOCs) (see further discussion in Section 2.3.4).

In 1991, a National Research Council (NRC) committee, synthesizing the best available information at the time on ozone formation and transport in the eastern United States, reported (NRC, 1991):

> High ozone episodes last from 3-4 days on average, occur as many as 7-10 times a year, and are of large spatial scale: >600,000 km^2. Maximum values of non-urban ozone commonly exceed 90 ppb during these episodes, compared with average daily maximum values of 60 ppb in summer. An urban area need contribute an increment of only 30 ppb over the regional background during a high ozone episode to cause a violation of the National Ambient Air Quality Standard (NAAQS) in a downwind area....Given the regional nature of the ozone problem in the eastern United States, a regional model is needed to develop control strategies for individual urban areas.
>
> [Note: The NRC discussion was in the context of the ozone NAAQS at the time of the NRC report, which was 0.12 ppm (120 ppb) averaged over one hour.]

The observed ozone spatial scale of >600,000 km^2 (>200,000 square miles) is comparable to the combined size of Kentucky, Ohio, West Virginia, Pennsylvania, Maryland, New York, and New Jersey. Additional field studies and modeling efforts (described below) since the NRC report have reinforced its basic findings and provide a consistent and coherent body of evidence for the prominence of transport throughout the eastern United States.

1.6.2. Ozone Transport Assessment Group: 1995-1997

The increasing regulatory focus on broader regional approaches to ozone control beyond the OTR began with the Ozone Transport Assessment Group (OTAG) in 1995. OTAG was a unique partnership between the USEPA, the Environmental Council of the States (ECOS), state and federal government officials, industry organizations, and environmental groups. OTAG's goal was "to develop an assessment of and consensus agreement for strategies to reduce ground-level ozone and its precursors in the eastern United States" (OTAG, 1997a). The group assessed transport of ground-level ozone across state boundaries in the 37-state region and culminated in a set of recommendations to the USEPA in 1997.

OTAG supported a significant modeling effort of four regional ozone episodes across the eastern United States. OTAG's Regional and Urban Scale Modeling Workgroup found that on a regional scale, modeled NO_X reductions produced widespread ozone decreases across the eastern United States with limited ozone increases generally confined to some urban areas. Also on a regional scale, VOC reductions resulted in limited ozone decreases generally confined to urban areas (OTAG, 1997b).

The OTAG Air Quality Analysis Workgroup provided additional observational and other analytical results to inform model interpretation and the development of OTAG recommendations. Among its many findings, this Workgroup observed the following about the range of ozone:

> Low wind speeds (< 3 m/sec) enable the accumulation of ozone near local source areas. High winds (> 6 m/sec) reduce the concentrations but contribute to the long-range transport of ozone. The average range of ozone transport implied from an array of diverse methods is between 150 miles and 500 miles. However, the perceived range depends on whether one considers the average concentrations (300–500 miles) or peak concentrations (tens of miles at 120 ppb). (OTAG, 1997c)

In addition, it discussed the increasingly important role of transport as the NAAQS is lowered:

> The relative importance of ozone transport for the attainment of the new 80 ppb 8-hour standard is likely to be higher due to the closer proximity of nonattainment areas. (OTAG, 1997c)

Based on the variety of technical work performed by multiple stakeholders during the process, OTAG reached a number of major conclusions (OTAG, 1997d), including:

- Regional NO_X reductions are effective in producing ozone benefits; the more NO_X reduced, the greater the benefit.
- Ozone benefits are greatest in the subregions where emissions reductions are made; the benefits decrease with distance.
- Both elevated (from tall stacks) and low-level NO_X reductions are effective.
- VOC controls are effective in reducing ozone locally and are most advantageous to urban nonattainment areas.
- Air quality data indicate that ozone is pervasive, that ozone is transported, and that ozone aloft is carried over and transported from one day to the next.

The technical findings of OTAG workgroups were consistent with the modeling and observational studies of regional ozone in the eastern United States already appearing in the scientific literature at that time.

Through its work, OTAG engaged a broad group outside of the scientific community in the discussion of ozone transport. This brought a greater understanding of the role of ozone transport across the eastern United States that was then translated into air quality policy with the creation of a regional ozone control strategy focusing on the reduction of NO_X emissions from power plants.

1.6.3. Northeast Oxidant and Particle Study (NE-OPS) 1998-2002

The Northeast Oxidant and Particle Study (NE-OPS) began in 1998 as a USEPA sponsored project to study air quality issues in the Northeast. The study undertook four major field programs at a field site in northeastern Philadelphia during the summers of 1998, 1999, 2001, and 2002. It involved a collaborative effort among research groups from a number of universities, government laboratories, and representatives of the electric power industry in an investigation of the interplay between the meteorological and chemical processes that lead to air pollution events in the Northeast. A suite of measurement techniques at and above the earth's surface gave a three-dimensional regional scale picture of the atmosphere. The studies found that horizontal transport aloft and vertical mixing to the surface are key factors in controlling the evolution and severity of air pollution episodes in the Northeast (Philbrick *et al.*, 2003a).

At the conclusion of the 2002 summer field study, the NE-OPS researchers were able to draw several conclusions about air pollution episodes in Philadelphia and draw inferences from this to the conditions in the broader region. These include (Philbrick *et al.*, 2003b):

- Transported air pollution from distant sources was a major contributor to all of the major summer air pollution episodes observed in the Philadelphia area.
- Regional scale meteorology is the major factor controlling the magnitude and timing of air pollution episodes.
- Knowledge of how the planetary boundary layer evolves over the course of a day is a critical input for modeling air pollutant concentrations because it establishes the mixing volume.
- Remote sensing and vertical profiling techniques are critical for understanding the processes governing air pollution episodes.
- Ground-based sensors do not detect high levels of ozone that are frequently trapped and transported in layers above the surface.
- Horizontal and vertical transport processes, such as the nocturnal low level jets and early morning breakdown of the nocturnal boundary layer, are frequent contributors of pollutants during the major episodes.
- Specific meteorological conditions are important in catalyzing the region for development of major air pollution episodes.
- Tethered balloon and lidar measurements suggest a very rapid down mixing of species from the residual boundary layer during the early morning hours that is too large to be accounted for on the basis of NO_X reactions alone.

The findings on nocturnal low level jets occurring in concert with ozone pollution episodes are particularly salient for air quality planning for the OTR. In 19 of 21 cases where researchers observed nocturnal low level jets during the NE-OPS 2002 summer campaign in the Philadelphia area, they also saw peak 1-hour ozone levels exceeding 100 ppbv. The nocturnal low level jets were capable of transporting pollutants in air parcels over distances of 200 to 400 km. The field measurements indicating that these jets often occur during periods of large scale stagnation in the region demonstrate the important role nocturnal low level jets can play in effectively transporting air pollutants during air pollution episodes (Philbrick *et al.*, 2003b).

The upper air observations using tethered balloons and lidar indicated the presence of high pollutant concentrations trapped in a residual layer above the surface, thus preserving the pollutants from destruction closer to the surface. Ozone, for example, when trapped in an upper layer during nighttime hours is not subject to destruction by NO_X scavenging from low-level emission sources (i.e., cars and trucks) or deposition to surfaces like vegetation, hence it is available for horizontal transport by nocturnal low level jets. The following day, it can vertically transport back down to the surface through vertical mixing as the nocturnal boundary layer breaks down and daytime convection. When an upper layer of ozone-laden air is horizontally transported overnight by a nocturnal low level jet, downward mixing can increase surface ozone concentrations in the morning that is not the result of local ozone production (Philbrick *et al.*, 2003b).

1.6.4. NARSTO 2000

NARSTO (formerly known as the North American Research Strategy for Tropospheric Ozone) produced "An Assessment of Tropospheric Ozone Pollution – A North American Perspective" in 2000 to provide a policy-relevant research assessment of ozone issues in North America (NARSTO, 2000). While the NARSTO Assessment is continental in scope, it encompasses issues relevant to the OTR, including results from a NARSTO-Northeast (NARSTO-NE) field campaign.

A key policy-relevant finding from the NARSTO Assessment of relevance to the OTR (NARSTO, 2000) relates to ozone transport and mitigation:

- Available information indicates that ozone accumulation is strongly influenced by extended periods of limited mixing, recirculation of polluted air between the ground and aloft, and the long-range transport of ozone and its precursors. As a result, air quality management strategies require accounting for emissions from distant as well as local sources.

The NARSTO Assessment identified the stagnation of synoptic scale (>1000 km^2) high pressure systems as a commonly occurring weather event leading to ozone pollution episodes. These systems are warm air masses associated with weak winds, subsiding air from above, and strong inversions capping the planetary boundary level in the central region of the high. The warm air mass can settle into place for days to more than a week, and slowly track from the Midwest to the East Coast. During the summer, these conditions result in the build up of pollution from local sources with reduced dispersion out of the region. In terms of air quality, these systems coincide with numerous local or urban-scale ozone pollution episodes embedded within a broader regional background of elevated ozone concentrations (NARSTO, 2000 at p. 3-34).

The NARSTO Assessment found that a variety of processes can lead to long-range transport of air pollutants that initially accumulated in these large-scale stagnation events. Over time, pollution plumes meander, merge, and circulate within the high pressure system. Because of the difference in pressures, pollutant plumes that eventually migrate to the edges of a high pressure system get caught in increasing winds at the edge regions, creating more homogeneous regional pollution patterns. Stronger winds aloft capture the regional pollutant load, and can transport it for hundreds of kilometers downwind of the stagnated air mass's center (NARSTO, 2000 at p. 3-34). For example, air flow from west to east over the Appalachian Mountains can move air pollution originating within the Ohio River Valley into the OTR.

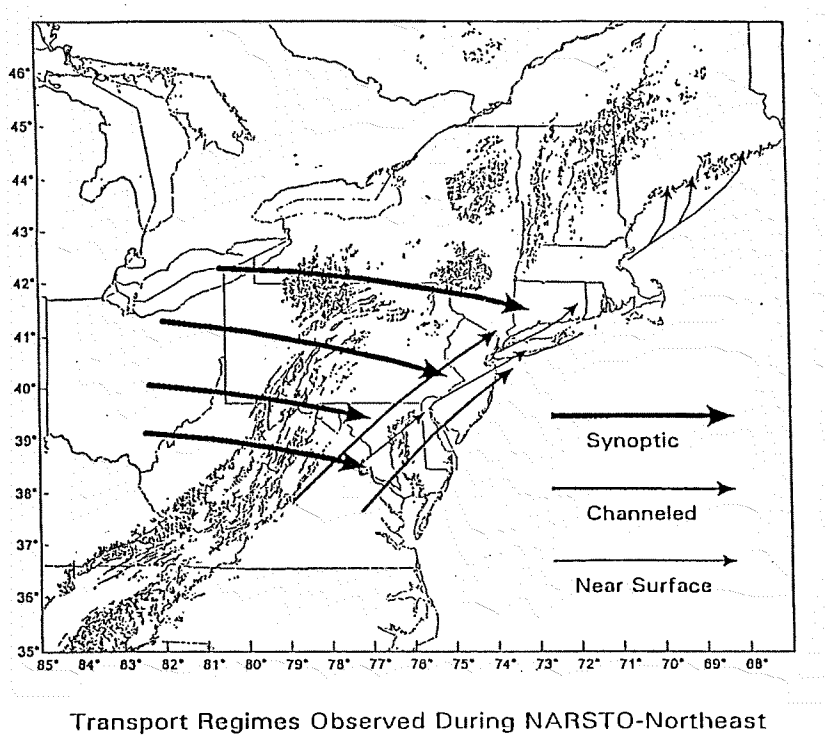
Studies undertaken by the NARSTO-NE field program also observed several regional scale meteorological features arising from geographical features in the eastern U.S. that affect pollutant transport. The NARSTO-NE field program observed nocturnal low level jets on most nights preceding regional high ozone episode day in the OTR (NARSTO, 2000 at p. 3-34), consistent with the observations of the NE-OPS campaign.

Another important smaller scale transport mechanism is the coastal sea breeze that can sweep ashore pollutants originally transported over the ocean parallel to the coastline. An example of this is the high ozone levels seen at times along coastal Maine that move in from the Gulf of Maine after having been transported in pollution plumes from Boston, New York City, and other Northeast Corridor locations (NARSTO, 2000 at pp. 3-34 through 3-37).

As a result of the NARSTO-NE field program, a conceptual picture of pollution transport into and within the OTR is possible. It consists of a combination of large-scale synoptic flow from the Midwest interacting with various regional and smaller-scale transport and meteorological features within the OTR, as illustrated in Figure 1-4. Synoptic-scale transport from west to east across the Appalachian Mountains occurs with the slow-moving stagnant high pressure systems that foster large regional ozone episodes

across eastern U.S. Regional-scale nocturnal low level jets from the southwest to the northeast along the Atlantic Coastal Plain, can occur within the synoptic system. In addition, daytime sea breezes can significantly affect bay and coast line air pollution levels within the OTR (NARSTO, 2000 at 3-36 and 3-37, citing Blumenthal *et al.*, 1997).

Figure 1-4. Conceptual picture of different transport regimes contributing to ozone episodes in the OTR



Long-range (synoptic scale) transport occurs from west to east across the Appalachian Mountains. Regional scale transport also occurs from west to east through gaps in the Appalachian Mountains and in nocturnal low level jets from southwest to northeast over the Northeast Corridor. Daytime sea breezes can affect local coastal areas by bringing in air pollution originally transported near the surface across water parallel to the coast (e.g., along the Maine coastline). Figure from NARSTO, 2000, citing Blumenthal *et al.*, 1997.

Other key findings of the 2000 NARSTO Assessment include:

- Local VOC emission reductions may be effective in reducing ozone in urban centers, while NO_X emission reductions become more effective at distances removed from urban centers and other major precursor emissions.
- The presence of biogenic emissions complicates the management of controllable precursor emissions and influences the relative importance of VOC and NO_X controls.
- The effectiveness of VOC and NO_X control strategies is not uniquely defined by the location or nature of emissions. It is now recognized that the relative effectiveness of VOC and NO_X controls may change from one location to another and even from episode to episode at the same location.

The NARSTO program also produced a comparative summary of the results of major ozone field studies undertaken in Europe and North America prior to 2000 (Solomon *et al.*, 2000). The field studies occurred under a wide range of geographical and climatological conditions, and their results generally affirmed the conclusions of the earlier National Research Council ozone report (NRC, 1991). Some of the key findings of the comparative summary relevant to regional ozone and ozone control strategies in the eastern U.S. include:

(1) reaffirmation that tropospheric ozone is a multi-scale phenomenon extending to continental boundaries;

(2) aerometric conditions aloft are important to ground-level ozone;

(3) biogenic sources make important contributions to VOC and NO_X emissions in parts of eastern North America;

(4) recirculating flow over complex terrain and large water bodies are universally important factors affecting accumulation of ozone at the ground; and

(5) nonlinearities in ozone response to precursor changes create important degrees of freedom in management strategies – VOC and NO_X sensitivities vary extensively in urban and rural areas, making decisions about emissions management complicated.

1.6.5. New England Air Quality Study: 2002-2004

The New England Air Quality Study (NEAQS) has conducted field campaigns during the summers of 2002 and 2004 to investigate air quality on the Eastern Seaboard and transport of North American emissions into the North Atlantic (NEAQS, 2002).

High ozone levels in northern New England occur with light to moderate winds from source regions in the Northeast urban corridor, rather than under locally stagnant conditions. The most important transport pathway leading to high ozone in coastal New Hampshire and Maine is over water rather than over land. Transport over water is particularly important in this northern region of the OTR for several reasons. First, there is a persistent pool of cooler water in the northern and eastern Gulf of Maine and Bay of Fundy. This creates a smoother transport surface for air pollutants relative to land transport, with a decrease in convective (vertical) mixing. Second, deposition of pollutants to the water surface is very small compared to the more rapid deposition occurring on land. Third, the lack of convective mixing allows pollution to be transported in different directions and at different heights in the atmosphere (Angevine *et al.*, 2004).

During the summer of 2002, researchers observed two transport events into coastal northern New England. The first occurring on July 22 through July 23 involved large-scale synoptic transport in a 400-600 m layer over the Gulf of Maine that was in contact with the water's surface. The southwesterly flow brought ozone pollution up from the New York City, Boston and other northeastern urban locations into coastal northern New England. Ozone monitors on Maine's coast extending from the New Hampshire border to Acadia National Park recorded elevated 1-hour average ozone levels between 88 and 120 ppb during this period. In a later episode during August 11-14, ozone and wind observations indicated the role of local-scale transport via a sea breeze

(southeasterly flow) bringing higher ozone levels into coastal New Hampshire from a polluted layer originally transported off shore in the Gulf of Maine in a southwesterly flow arising out of the Northeast's urban corridor. Transport in an elevated layer also occurred with higher ozone recorded at a monitor on Cadillac Mountain in Acadia National Park relative to two monitors located at lower elevations in the park (Angevine *et al.*, 2004; 2006).

A study of ozone at two monitors separated by only 30 km (one on an island 10 km off the New Hampshire coast, the other 20 km inland at a rural location) indicated very different ozone transport influences. The coastal site experienced consistently higher ozone concentrations than the inland site, which was attributed to different transport regimes. The coastal site was influenced by southwesterly flow along the New England coast that brought ozone and precursors from more populated areas to the southwest (e.g., Boston), while the inland site often had a more westerly wind component with fewer upwind pollution sources. At times, however, the sea breeze was a factor, and nearly equalized the ozone concentrations at the two sites by transporting ozone-rich air from the coast to the rural inland location (Darby *et al.*, 2007). Investigation of ozone formation dynamics and precursor levels at the rural site were consistent with a transport mechanism bringing ozone-rich air to the location rather than the observed peak ozone being formed locally (Griffin *et al.*, 2004).

The results of NEAQS indicate the important conditions contributing to ozone transport along the northern New England coast. The cool waters of the Gulf of Maine allow for transport of concentrated air pollutants over distances of 20-200 km in stable layers at the water's surface with little pollutant deposition or dilution. Sea breezes can modify large-scale synoptic transport over the ocean and bring high ozone levels into particular sites located on the coast. Transport within higher layers above the Gulf of Maine can carry pollutants over much greater distances, 200-2000 km.

1.6.6. Regional Atmospheric Measurement, Modeling, and Prediction Program (RAMMPP) 2003

The Regional Atmospheric Measurement, Modeling, and Prediction Program (RAMMPP) is a program led by researchers at the University of Maryland. Its focus is developing a state-of-the-art scientific research tool to improve understanding of air quality in the Mid-Atlantic region of the United States. It has a number of facets, including ozone and $PM_{2.5}$ pollutant level forecasting, aircraft, and surface measurements, real-time weather forecasting, and chemical transport modeling.

During the August 2003 electrical blackout in the eastern United States, one of the largest in North American history, scientists with RAMMPP obtained aircraft measurements in an unplanned "real-world" experimen t investigating changes in air pollution due to the virtual shutdown of numerous coal-fired power plants across a large part of this region (Marufu *et al.*, 2004). Initially, aircraft measurements were collected early in the day on August 15, 2003 above western Maryland, which was outside the blackout region. These measurements were compared with aircraft measurements taken later that day over central Pennsylvania, about 24 hours into the blackout, and to measurements obtained over central Pennsylvania the previous year during a period of similar synoptic patterns as occurred during the blackout. Based on the comparisons, the

RAMMPP scientists inferred a decrease in ozone concentrations of ~50 percent within the blackout region (as well as >90 percent decrease in SO_2 and ~70 percent reduction in light scattered by particles).

The air pollution reductions attributed to the 2003 power plant shutdowns based on the aircraft measurements and other supporting elements were subsequently questioned on several grounds (see comment by Hansen *et al.*, 2005, and reply to comment by Marufu *et al.*, 2005). A modeling reassessment of the 2003 blackout incorporating pollution reductions from power plants and other sources at that time concluded that mobile source reductions in the blackout region had a relatively greater impact on ozone in urban areas than the power plant reductions (Hu *et al.*, 2006). Power plants did have a larger modeled impact on air quality than mobile sources in some of the affected regions, but the ozone impacts were limited and much less (~4 percent) than that initially inferred by Marufu *et al.* (2004) (~50 percent). Despite the diminished projection of ozone reductions during the blackout, the reassessment by Hu *et al.* (2006) suggested that efforts to lower NO_X from power plants would continue to lower ozone in the eastern United States, and that regional and national on-road NO_X control had greater benefits than local control alone.

1.7. Summary

The chemistry of ozone formation in the atmosphere involves reactions of NO_X and VOC emissions from numerous sources during periods of warm temperatures and abundant sunshine. The day-to-day pattern of ground-level ozone in the OTR varies according to a number of meteorological variables, such as sunlight, temperature, wind speed, and wind direction. High levels of ozone within the OTR do not occur in isolation, indicating a broad regional air quality problem. Trends in 8-hour ozone levels since 1997 indicate improvement in air quality, a reflection of numerous control strategies implemented locally, regionally, and nationally to reduce emissions of the pollutants that contribute to ozone formation. For example, with the implementation of the NO_X SIP Call in the eastern U.S. after 2002, a marked departure of ozone exceedance days tracking with high temperature days was observed, with the number of high ozone days falling relative to the number of high temperature days. This has been attributed to power plants completing installations of controls to reduce NO_X emissions that contributed to regional ozone formation and transport.

The scientific literature contains a number of peer reviewed papers describing observed episodes of ozone and precursor pollutant transport. In 1991, a National Research Council report summarized the state-of-the-science, which further highlighted the broad regional nature of the ozone problem in the eastern U.S. Since then, multiple collaborative efforts and field campaigns have further investigated specific aspects of the regional ozone problem affecting the OTR, and these provide a significant foundational basis for informed policy decisions to improve air quality.

In general, the collaborative efforts and field campaigns described in this introductory chapter provide a consistent picture of the main features of ozone formation and transport affecting the OTR. On a regional scale, ozone is most sensitive to anthropogenic NO_X, while anthropogenic VOCs can play a role in local urban areas. The sensitivity of ozone to NO_X and VOC emissions can vary across different locations, as

well as at the same location at different times. Therefore, a combination of NO_X and VOC controls are likely needed for many places to meet ozone air quality standards.

Across a large part of the eastern United States, ozone can be formed by NO_X emissions from power plants, motor vehicles, and other combustion sources in the presence of highly reactive biogenic VOCs (e.g., isoprene). The regional ozone burden can mix vertically upward during the day through convection, and then be transported long distances downwind overnight. Later, it can mix back down to the surface and contribute to an elevated ozone background that downwind local emission sources add their own ozone-forming emissions to, leading to a buildup of even higher ozone levels.

Transport of ozone and its precursors occurs on multiple scales. Large-scale transport can occur over hundreds of miles and over several days through the movement of high pressure systems. These systems bring elevated levels of ozone into the OTR from areas to the west and southwest into the region. On a more moderate scale, , overnight pollutant transport can also occur through the formation of nocturnal low level jets that stretch from southwest to the northeast along the Atlantic Coastal Plain east of the Appalachian Mountains. Nocturnal low level jets have been observed in the OTR on many nights preceding high ozone episode days.

Overnight transport via either the movement of high pressure systems or low level jets occurs above the nocturnal boundary layer that forms at the surface, thus decoupling ozone aloft from ozone-destroying processes occurring at the surface. In addition, because the transport occurs aloft, it is not readily detected by ground-level ozone monitors.

An additional shorter scale transport pathway is also present in the OTR via surface transport over water. Due to greater stability of atmospheric layers over water, vertical mixing is reduced, which also diminishes the likelihood of ozone destruction at the surface. Differences in temperatures between land and water along the coast during the day can create sea breezes that bring surface transport ozone into shorelines. An example of this mechanism is pollution transported over the Gulf of Maine from emission sources in the Northeast Corridor that enter into the coasts of New Hampshire and Maine.

References

Angevine, W.M., C.J. Senff, A.B. White, E.J. Williams, J. Koermer, S.T.K. Miller, R. Talbot, P.E. Johnston, S.A. McKeen, and T. Downs. "Coastal boundary layer influence on pollutant transport in New England." *J. Appl. Meteor.* **43**, 1425-1437, 2004.

Angevine, W.M., M. Tjernström, and M. Žagar. "Model ing of the Coastal Boundary Layer and Pollutant Transport in New England." *J. Appl. Meteor. Climatol.* **45**, 137-154, doi:10.1175/JAM2333.1, 2006.

Bell, M.L., R.D. Peng, and F. Dominici. "The Exposure–Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations." *Envtl. Health Perspect.* **114**, 532-536, doi:10.1289/ehp.8816, 2006.

Bloomer, B.J., K.Y. Vinnikov, and R.R. Dickerson. "Changes in seasonal and diurnal cycles of ozone and temperature in the eastern U.S." *Atmos. Envt.* **44**, 2543-2551, doi:10.1016/j.atmosenv.2010.04.031, 2010.

Blumenthal, D.L., F. Lurmann, N. Kumar., T. Dye, S. Ray, M. Korc, R. Londergan, and G. Moore. *Transport and mixing phenomena related to ozone exceedances in the northeast U.S.* EPRI Report TR-109523, Electric Power Research Institute, Palo Alto, CA, 1997.

Blunier, T., J.A. Chappellaz, J. Schwander, J.M. Barnola, T. Desperts, B. Stauffer, and D. Raynaud. "Atmospheric methane, record from a Greenland Ice Core over the last 1000 year." *Geophys. Res. Lett.* **20**, 2219-2222, 1993.

Chameides, W.L., R.W. Lindsay, J. Richardson, and C.S. Kiang. "The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study." *Science* **241**, 1473-1475, 1988.

Chameides, W.L., F. Fehsenfeld, M.O. Rodgers, C. Cardelino, J. Martinez, D. Parrish, W. Lonneman, D.R. Lawson, R.A. Rasmussen, P. Zimmerman, J. Greenberg, P. Middleton, and T. Wang. "Ozone precursor relationships in the ambient atmosphere." *J. Geophys. Res.* **97**, 6037-6055, 1992.

Chan, E. "Regional ground-level ozone trends in the context of meteorological influences across Canada and the eastern United States from 1997 to 2006." *J. Geophys. Res.* **114**, D05301, doi:10.1029/2008JD010090, 2009.

Clarke, J.F., and J.K.S. Ching. "Aircraft observations of regional transport of ozone in the northeastern United States." *Atmos. Environ.* **17**, 1703-1712, 1983.

Cooper, O.R. *et al.* "Increasing springtime ozone mixing ratios in the free troposphere over western North America." *Nature* **463**, doi:10.1038/nature08708, 2010.

Darby, L.S., *et al.* "Ozone differences between near-coastal and offshore sites in New England: Role of meteorology." *J. Geophys. Res.* **112**, D16S91, doi:10.1029/2007JD008446, 2007.

Davis, D.D., G. Smith, and G. Klauber. "Trace gas analysis of power plant plumes via aircraft measurement: O_3, NO_X, and SO_2 chemistry." *Science* **186**, 733-736, 1974.

Fiore, A.M., D.J. Jacob, B.D. Field, D.G. Streets, S.D. Fernandes, and C. Jang. "Linking ozone pollution and climate change: The case for controlling methane." *Geophys. Res. Lett.* **29**, 1919, doi: 10.1029/2002GL015601, 2002.

Fiore, A., D.J. Jacob, H. Liu, R.M. Yantosca, T.D. Fairlie, and Q. Li. "Variability in surface ozone background over the United States: Implications for air quality policy." *J. Geophys. Res.* **108**, 4787, doi:10.1029/2003JD003855, 2003.

Gillani, N.V., and W.E. Wilson. "Formation and transport of ozone and aerosols in power plant plumes." *Annals N.Y. Acad. Sciences* **338**, 276-296, 1980.

Gillani, N.V., S. Kohli, and W.E. Wilson. "Gas-to-particle conversion of sulfur in power plant plumes – I. Parameterization of the conversion rate for dry, moderately polluted ambient conditions." *Atmos. Environ.* **15**, 2293-2313, 1981.

Griffin, R.J., C.A. Johnson, R.W. Talbot, H. Mao, R.S. Russo, Y. Zhou, and B.C. Sive. "Quantification of ozone formation metrics at Thompson Farm during the New England Air Quality Study (NEAQS) 2002." *J. Geophys. Res.* **109**, D24302, doi:10.1029/2004JD005344, 2004.

Hansen, D.A., E.M. Knipping, and N. Kumar. "Comment on ''The 2003 North American electrical blackout: An accidental experiment in atmospheric chemistry'' by L. T. Marufu et al." *Geophys. Res. Lett.* **32**, L10812, doi:10.1029/2004GL021962, 2005.

Hu, Y., M.T. Odman, and A.G. Russell. "Re-examination of the 2003 North American electrical blackout impacts on regional air quality." *Geophys. Res. Lett.* **33**, L22810, doi:10.1029/2006GL027252, 2006.

Jacob, D.J., J.A. Logan, G.M. Gardner, R.M. Yevich, C.M. Spivakovsky, S.C. Wofsy, S. Sillman, and M.J. Prather. "Factors regulating ozone over the United States and its export to the global atmosphere." *J. Geophys. Res.* **98**, 14,817-14,826, 1993.

MARAMA (Mid-Atlantic Regional Air Management Association). *A guide to mid-Atlantic regional air quality.* MARAMA. Baltimore, MD, pp. 2-3, 2005. Available at www.marama.org/reports.

Marufu, L.T., B.F. Taubman, B. Bloomer, C.A. Piety, B.C. Doddridge, J.W. Stehr, and R.R. Dickerson. "The 2003 North American electrical blackout: An accidental

experiment in atmospheric chemistry." *Geophys. Res. Lett.* **31**, L13106, doi:10.1029/2004GL019771, 2004.

Marufu, L.T., B.F. Taubman, B. Bloomer, C.A. Piety, B.G. Doddridge, J.W. Stehr, and R.R. Dickerson. "Reply to comment by D. A. Hansen et al. on 'The 2003 North American electrical blackout: An accidental experiment in atmospheric chemistry'." *Geophys. Res. Lett.* **32**, L10813, doi:10.1029/2005GL022385, 2005.

McKeen, S.A., E.-Y. Hsie, and S.C. Liu. "A study of the dependence of rural ozone on ozone precursors in the eastern United States." *J. Geophys. Res.* **96**, 15,377-15,394, 1991.

Miller, D.F., A.J. Alkezweeny, J.M. Hales, and R.N. Lee. "Ozone formation related to power plant emissions." *Science* **202**, 1186-1188, 1978

NARSTO. *An Assessment of Tropospheric Ozone Pollution*. NARSTO, July 2000.

NEAQS (New England Air Quality Study) 2002. Available at http://www.al.noaa.gov/NEAQS/ (accessed June 20, 2006).
Nguyen, D. and M. Woodman. *Air Quality Variability in Maryland due to Climate Cycles and Emissions*. Presentation at the 2008 National Air Quality Conferences, Portland, OR, April 6-9, 2008. Available at http://www.epa.gov/airnow/2008conference/Forecasting/Tuesday/nguyen_aqvariability.pdf (accessed April 23, 2010).

NRC (National Research Council). *Rethinking the ozone problem in urban and regional air pollution*. National Academy Press. Washington, DC, pp. 105-106, 1991.

OTAG (Ozone Transport Assessment Group). *OTAG Technical Supporting Document*, Appendix K – Summary of Ozone Transport Assessment Group recommendations to the U.S. Environmental Protection Agency as of June 20, 1997a. Available at http://www.epa.gov/ttn/naaqs/ozone/rto/otag/finalrpt/chp1/toc.htm.

OTAG (Ozone Transport Assessment Group). *OTAG Technical Supporting Document*. Chapter 2 – Regional and Urban Scale Modeling Workgroup. 1997b. Available at http://www.epa.gov/ttn/naaqs/ozone/rto/otag/finalrpt/chp2_new/toc.htm.

OTAG (Ozone Transport Assessment Group). *OTAG Technical Supporting Document*. Chapter 4 – Air Quality Analysis Workgroup. 1997c. Available at http://www.epa.gov/ttn/naaqs/ozone/rto/otag/finalrpt/chp4/toc.htm.

OTAG (Ozone Transport Assessment Group). *OTAG Technical Supporting Document*. Chapter 1 – Overview. 1997d. Available at http://www.epa.gov/ttn/naaqs/ozone/rto/otag/finalrpt/.

Philbrick, C.R., W.F. Ryan, R.D. Clark, B.G. Doddridge, P. Hopke, and S.R. McDow. "Advances in understanding urban air pollution from the NARSTO-NEOPS program."

83rd American Meteorological Society 5th Conference on Atmospheric Chemistry, Long Beach, CA, Feb. 8-12, 2003a.

Philbrick, C.S., W. Ryan, R. Clark, P. Hopke, and S. McDow. *Processes controlling urban air pollution in the Northeast: Summer 2002.* Final Report for the Pennsylvania Department of Environmental Protection, July 25, 2003b. Available at http://lidar1.ee.psu.edu/neopsWeb/publicSite/neopsdep/Final%20Rep-Part%201-7.pdf.

Sillman, S., J.A. Logan, and S.C. Wofsy. "The sensitivity of ozone to nitrogen oxides and hydrocarbons in regional ozone episodes." *J. Geophys. Res.* **95**, 1837-1851, 1990.

Solomon, P., E. Cowling, G. Hidy, and C. Furiness. "Comparison of scientific findings from major ozone field studies in North America and Europe." *Atmos. Environ.* **34**, 1885-1920, doi:10.1016/S1352-2310(99)00453-7, 2000.

Stoeckenius, T. and Kemball-Cook, S. "Determination of representativeness of 2002 ozone season for ozone transport region SIP modeling." Final Report prepared for the Ozone Transport Commission, 2005.

Trainer, M., E.J. Williams, D.D. Parrish, M.P. Buhr, E.J. Allwine, H.H. Westberg, F.C. Fehsenfeld, and S.C. Liu. "Models and observations of the impact of natural hydrocarbons on rural ozone." *Nature* **329**, 705-707, 1987.

Trainer, M., D.D. Parrish, M.P. Buhr, R.B. Norton, F.C. Fehsenfeld, K.G. Anlauf, J.W. Bottenheim, Y.Z. Tang, H.A. Wiebe, J.M. Roberts, R.L. Tanner, L. Newman, V.C. Bowersox, J.F. Meagher, K.J. Olszyna, M.O. Rodgers, T. Wang, H. Berresheim, K.L. Demerjian, and U.K. Roychowdhury. "Correlation of ozone with NOy in photochemically aged air." *J. Geophys. Res.* **98**, 2917-2925, 1993.

USEPA. *Ozone and your Health*, EPA-452/F-99-003, September 1999. Available at http://www.airnow.gov/index.cfm?action=static.brochure.

USEPA. *Technical Support Document for the Final Clean Air Interstate Rule: Air Quality Modeling*. USEPA OAQPS, March 2005. Available at http://www.epa.gov/cleanairinterstaterule/pdfs/finaltech02.pdf.

USEPA. *Air Quality Criteria for Ozone and Related Photochemical Oxidants: Volume 1*. USEPA, EPA-600/R-05/004aF, February 2006.

USEPA. *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, EPA-454/B-07-002, April 2007.

White, W.H., D.E. Patterson, and W.E. Wilson, Jr. "Urban exports to the nonurban troposphere: Results from Project MISTT." *J. Geophys. Res.* **88**, 10,745-10,752, 1983.

Wolff, G.T., and P.J. Lioy. "Development of an ozone river associated with synoptic scale episodes in the eastern United States." *Environ. Sci. Technol.* **14,** 1257-1260, 1980.

Wolff, G.T., P.J. Lioy, R.E. Meyers, R.T. Cederwall, G.D. Wight, R.E. Pasceri, and R.S. Taylor. "Anatomy of Two Ozone Transport Episodes in the Washington, D.C., to Boston, Mass., Corridor." *Environ. Sci. Technol.* **11**, 506-510, 1977.

2. METEOROLOGY AND EVOLUTION OF OZONE EPISODES IN THE OZONE TRANSPORT REGION

The following sections describe current knowledge of the factors contributing to ozone episodes in the OTR. The general description of weather patterns comes mainly from the work of Ryan and Dickerson (2000) done for the Maryland Department of the Environment. Further information is drawn from work by Hudson (2005) done for the Ozone Transport Commission and from a mid-Atlantic regional air quality guide by MARAMA (2005). The regional nature of the observed ozone episodes in the OTR is reinforced in modeling studies by the USEPA for the Clean Air Interstate Rule.

2.1. Large-scale weather patterns

Ryan and Dickerson (2000) have described the general meteorological features conducive to ozone formation and transport that are pertinent to the OTR. On the local scale, meteorological factors on which ozone concentrations depend are the amount of available sunlight (ultraviolet range), temperature, and the amount of space (volume) in which precursor emissions mix. Sunlight drives the key photochemical reactions for ozone and its key precursors and the emissions rates of many precursors (isoprene for example) are temperature dependent. Emissions confined within a smaller volume result in higher concentrations of ozone. Winds in the lowest 2 km of the atmosphere cause horizontal mixing while vertical temperature and moisture profiles drive vertical mixing. High ozone is typically associated with weather conditions of few clouds, strong temperature inversions, and light winds.

The large-scale weather pattern that combines meteorological factors conducive to high ozone is the presence of a region of upper air high pressure (an upper air ridge) with its central axis located west of the OTR. The OTR east of the axis of the high-pressure ridge is characterized by subsiding (downward moving) air. This reduces upward motion necessary for cloud formation, increases temperature, and supports a stronger lower level inversion. While the upper air ridge is located west of the OTR, surface high pressure is typically quite diffuse across the region. This pattern occurs throughout the year but is most common and longer lived in the summer months (Ryan and Dickerson, 2000).

The large, or synoptic, scale, weather pattern sketched above has important implications for transport into and within the OTR. First, the persistence of an upper air ridge west of the OTR drives generally west to northwest winds that can carry ozone generated outside the OTR into the OTR. A key point from this wind-driven transport mode is that stagnant air is not always a factor for high ozone episodes in the OTR. Second, the region in the vicinity of the ridge axis, being generally cloud free, will experience significant radiational cooling after sunset and therefore a strong nocturnal inversion will form. This inversion, typically only a few hundred meters deep, prevents ozone and its precursors from mixing downward overnight. Above the inversion layer, there is no opportunity for destruction of the pollutants by surface deposition, thus increasing the pollutants' lifetimes aloft and consequently their transport distances. Third, with diffuse surface high pressure, smaller scale effects can become dominant in the

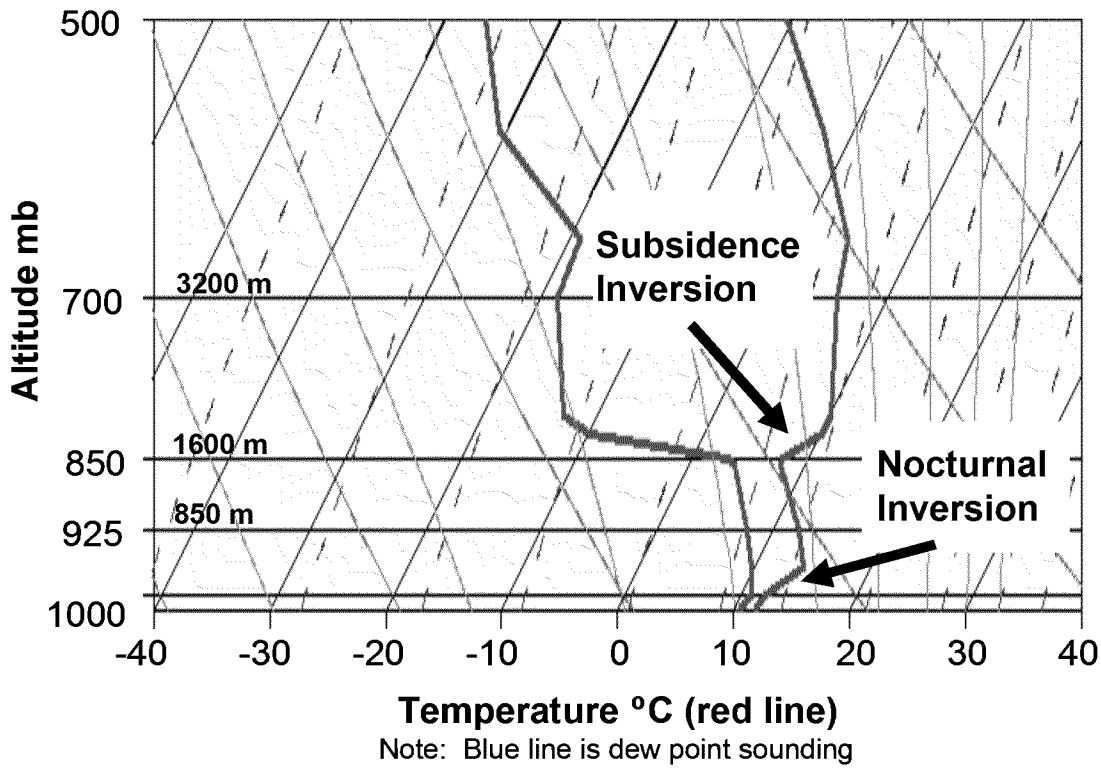
lowest layers of the atmosphere. These include bay and land breezes, the Appalachian lee side trough, and the development of the nocturnal low level jet. Nocturnal low level jets are commonly observed during high ozone events in the OTR (Ryan and Dickerson, 2000).

2.2. Meteorological mixing processes

An important element in the production of severe ozone events is the ability of the atmosphere through temperature inversions to inhibit the vertical mixing processes that under normal conditions would lead to dilution of the emitted pollutants. For the purposes of this discussion, we focus on two major classes of temperature inversions, (1) nocturnal (radiative) and (2) subsidence.

Figure 2-1 shows an example of nocturnal and subsidence inversions in a temperature profile taken over Albany, NY, on September 1, 2006 at 7 a.m. eastern standard time. The figure shows two distinct temperature inversions – the ground-based nocturnal inversion and an inversion at about 1600 meters caused by the sinking motion (subsidence) of the atmosphere in a high pressure system.

Figure 2-1. Temperature profile taken over Albany, NY, on September 1, 2006 at 7 a.m. eastern standard time



2.2.1. Nocturnal inversions

At night, the Earth's surface cools more rapidly than the air. The surface also cools the lowest hundred meters of the atmosphere. The air above this layer cools more slowly, and a temperature inversion forms. The inversion divides the atmosphere into two

layers that do not mix. Below the nocturnal surface inversion, the surface winds are weak and air pollutants can be reduced through dry deposition. Above the inversion, the pollutants are trapped above the surface. Winds can transport pollutants in the upper-level ozone reservoir through the night. Transport can be enhanced by a nocturnal low level jet as the inversion isolates the winds from the friction of the rough surface.

In the morning, the sun warms the Earth's surface, and conduction and convection transfer heat upward to warm the air near the surface. By about 10:00 – 11:00 a.m., the temperature of the surface has risen sufficiently to remove the inversion. Air from above and below the inversion can then mix freely. Depending on whether the air above the inversion is cleaner or more polluted than the air at the surface, this mixing can either lower or increase air pollution levels.

2.2.2. Subsidence inversions

Severe ozone events are usually associated with high pressure systems. In the upper atmosphere, the winds around a high pressure system move in a clockwise direction. A high pressure system is formed as upper-level air subsides, increasing the air pressure at the surface. As upper-level subsidence continues, the air at the ground is pushed away horizontally, a process called "divergence." As the subsiding air descends, it is heated by adiabatic processes. When this warmer air meets the colder air below, it forms an inversion. The height of a subsidence inversion ranges from caps pollution 1200 to 2000 meters. It is far more difficult to break down than the nocturnal inversion and can last from hours to days. The subsidence inversion limits vertical mixing in the middle of the day during an air pollution episode, keeping pollutants trapped closer to the ground.

2.3. Meteorological transport processes

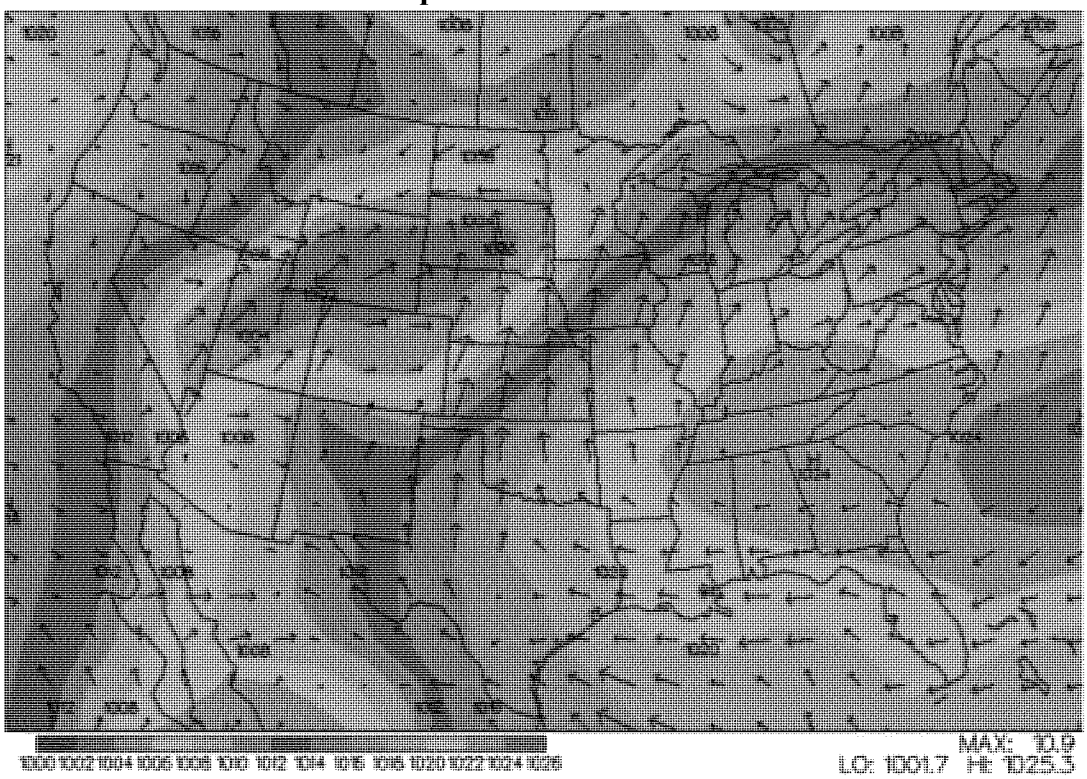
2.3.1. Introduction

Figure 2-2 shows the classic synoptic weather pattern at the Earth's surface associated with severe ozone episodes within the OTR. A quasi-stationary high pressure system (the Bermuda high) extends from the Atlantic Ocean westward into interior southeastern U.S., where a second weaker high is located. Surface winds, circulating clockwise around the high, are especially light in the vicinity of the secondary high. Farther north, a southwesterly flow strengthens toward New York and southern New England. This situation illustrates two circulation regimes often existing in OTR ozone episodes: more stagnant conditions in southern areas and a moderate transport flow in the OTR from southwest to northeast.

The Appalachian Mountains induce changes in the wind field that also play important roles in the formation and transport of ozone in the OTR. The mountains act as a physical barrier confining, to some degree, pollution to the coastal plain. They also induce local effects such as mountain and valley breezes, which, in the case of down-slope winds, can raise surface temperatures thereby increasing chemical reactivity. In addition, a lee side trough can develop on the east of mountains as a result of dynamics from a system just west of the mountains. A leeside trough helps to channel a more concentrated ozone plume, and contribute to the formation of nocturnal low level jets, the engine of rapid nighttime transport.

The Atlantic Ocean also plays a strong role during ozone episodes where sea breezes can draw either heavily ozone-laden or clean marine air into coastal areas.

Figure 2-2. Schematic of a typical weather pattern associated with severe ozone episodes in the OTR



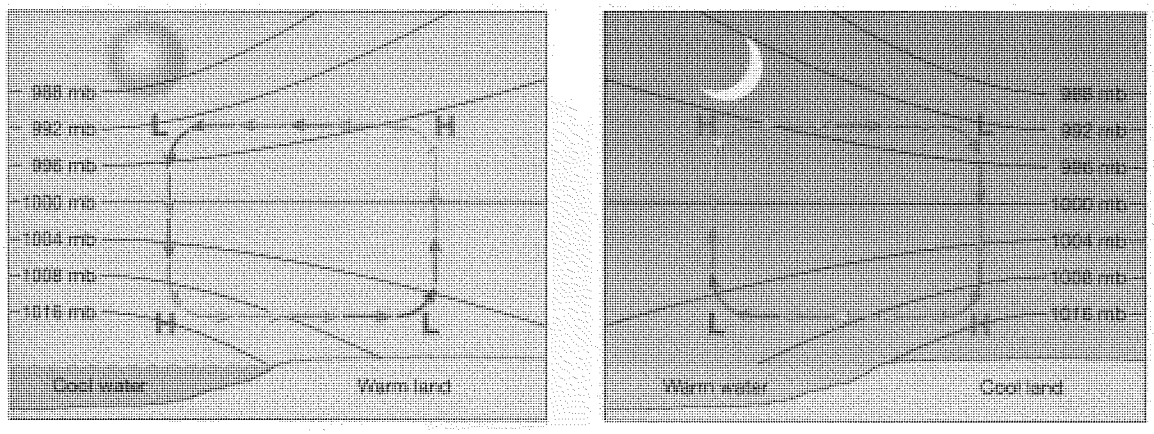
Meteorological processes that transport ozone and its precursors into and within the OTR can roughly be broken down into three levels: ground, mid and upper. The following sections discuss the three wind levels associated with meteorological transport processes in more detail.

2.3.2. Ground level winds

Land, sea, mountain, and valley breezes

In the OTR, land and sea breezes, and mountain and valley breezes can have an important influence on local air quality. These local winds are driven by a difference in temperature that produces a difference in pressure. Figure 2-3 shows a schematic of the formation of a sea breeze. The sea breeze forms in the afternoon when the land is considerably hotter than the ocean or bay, and the air flows inland from the ocean. At night, land cools more quickly than the ocean, and a land breeze blows out to sea. Because the nighttime land and water temperature differences are usually much smaller than in the day, the land breeze is generally weaker than the sea breeze. Sea breezes typically only penetrate a few kilometers inland because they are driven by temperature contrasts that disappear inland.

Figure 2-3. Illustration of a sea breeze and a land breeze



a) Sea Breeze **b) Land Breeze**

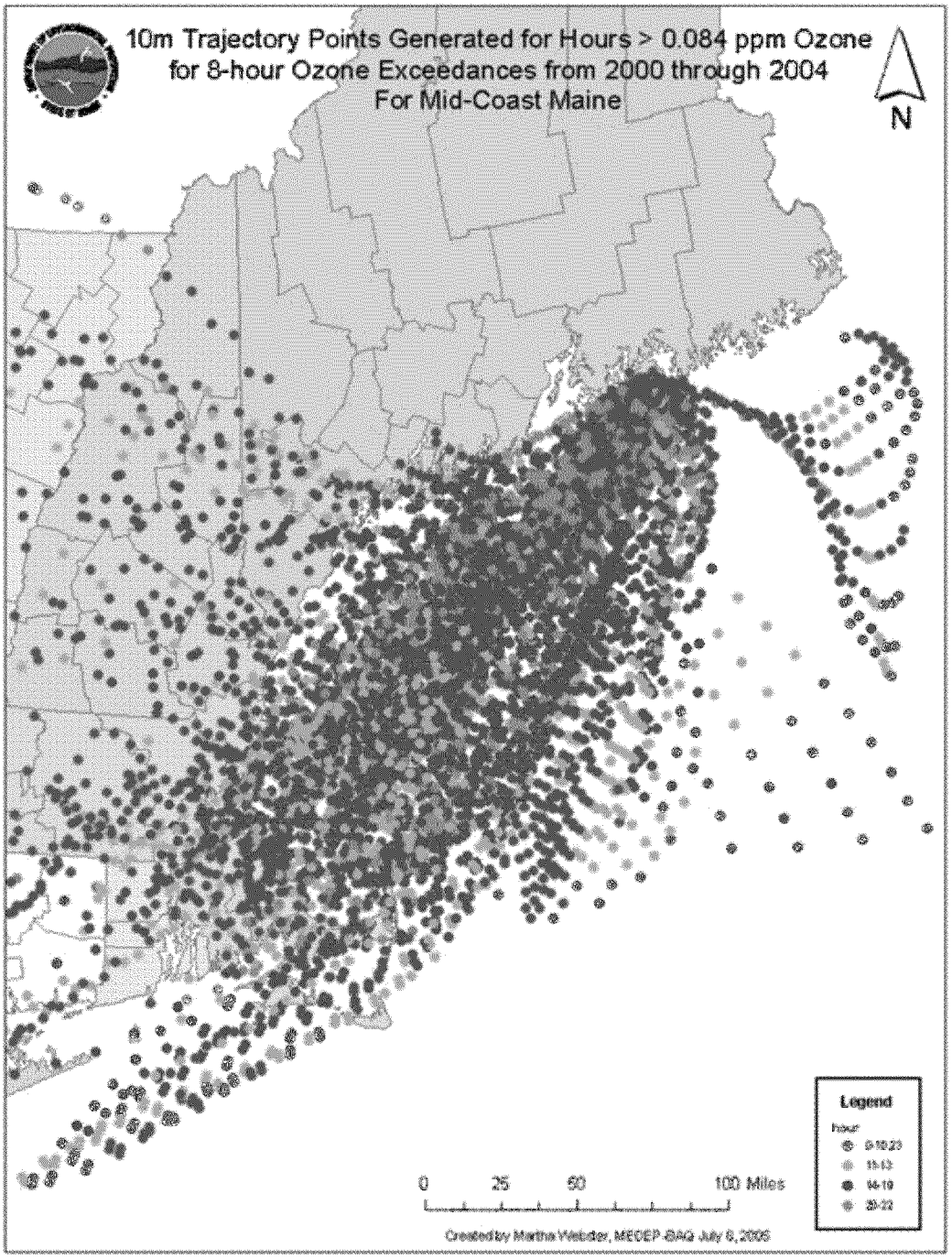
Figure from *Lutgens & Tarbuck*, 2001.

Along coastlines, such as coastal New England, sea breezes bring in air pollution transported near the surface over water from urban locations located to the southwest. Ray et al. (1996) have described high ozone levels transported over the Gulf of Maine and brought inland by sea breezes to coastal regions of Maine. Figure 2-4 shows 24-hour back trajectories of air parcels at a height of 10 m arriving at mid-coastal Maine during the 2000 – 2004 ozone seasons on days coastal ozone monitors recorded 8-hour concentrations exceeding 84 ppb. The bundle of trajectories demonstrates a clear propensity for maximum ozone levels to be transported across the Gulf of Maine before coming ashore with the sea breeze (ME DEP, 2010).

A similar situation occurs along the New Hampshire coast, where ozone events are driven by distinctively different wind directions than experienced inland. An analysis of wind directions at the time inland New Hampshire monitoring sites measured unhealthy ozone levels between 1995 and 2002 discerned an overwhelming trend of winds coming from the southwest. By contrast, high ozone levels at New Hampshire coastal sites were associated largely with a sea breeze from the southeast that brought in pollution transported over water from the Boston metropolitan area and possibly other urban areas in the Northeast Corridor (NH DES, 2010).

Sea breezes can also affect air quality in coastal cities because, under stagnant synoptic-scale winds, a city's emissions may be recirculated or pushed back over land after having drifted out over the sea before sea breeze circulation begins. In the absence of a shift in winds due to a sea breeze, the city's air pollution will be blown away. The sea breeze circulation acts like a barrier and pushes the polluted air back over the land. The sea breeze only pushes a few miles inland, which is where the barrier to mixing lies. Later in the day, the air may be quite clean on the ocean side of the city, but the air is usually quite dirty on the inland side. The city suffers from its own recirculated pollution as the sea breeze prevents pollution from the city to flow away from it. Appendix C presents more detailed information on sea breezes and flow over the ocean that contributes to ozone transport in parts of the OTR.

Figure 2-4. Average 2000 – 2002 wind direction freq uency associated with elevated one-hour ozone levels in coastal Maine



The bay breeze is a shallow circulation over large inland bays, which usually extends only a couple hundred meters above the surface. For example, the northern Chesapeake Bay region suffers from the highest ozone concentrations in the state of Maryland, often due to the development of the bay breeze. The formation of this micro-

scale circulation has been known to create a sharp gradient of observed ozone concentrations across its boundary. A bay breeze event occurs when a non-onshore wind flow switches to onshore flow perpendicular to the shoreline. This circulation allows the build up of ozone along the bay breeze boundary. Landry *et al.* (2010) reviewed five years of Maryland data (2004–2009) and found that the bay breeze played a significant role in approximately one-third of all days exceeding the 8-hour ozone standard of 75 ppb. The ozone measured east of the bay breeze boundary ranged from +17 to +39 ppb higher than sites to the west.

Mountain and valley breezes are also driven by a temperature contrast. In the daytime, the side of the mountain will heat up more quickly than the valley, and hence a flow from the valley to the mountain results. At night this flow is reversed as the mountain side cools more quickly than the valley. As a result of these differences in cooling and heating, during the day, warm winds blow up toward the peaks from the valley below, while at night, cool air sinks and flows down the valley, settling in the lowest points. Local topography is very important in generating this phenomenon, making the breeze unique to a particular area.

Mountains and valleys also serve to isolate air in the valleys, while air at the mountaintops may be coming from very far away. Mountain winds, inversions, and mixing are quite complex. On a quiet night, the mountaintops may be in the free troposphere, open to long-range transport, while the valley below is usually capped by a nocturnal inversion, isolating pollution in the valley. Air quality measurements taken during plane flights in the Shenandoah River Valley have shown that the air pollutants in the valley may be rather different from the air at the nearby peaks. Cities on the western side of the mountains will find that the Appalachians are capable of damming pollution up against them (MARAMA, 2005 at pp. 42-43).

Appalachian lee side trough

The Appalachian lee side trough forms on the leeward (downwind) side of the Appalachian Mountains. In the OTR, a lee side trough forms when winds blow over the Appalachian Mountains and down the lee side of the mountain range to the coastal plain. As the column descends down the lee side, it stretches vertically and spins faster, pulling up air and creating low pressure, thus rotating the winds to the southwest. Because the air is typically rather dry, and the trough itself is rather weak, it does not usually lead to showers and thunderstorms the way a trough associated with other weather systems would. It does cause winds to shift their direction, so a wind that comes over the mountains from the west will turn and blow from the southwest along the coastal plain. Therefore, when surface winds on the coastal plain are from the southwest, if the Appalachian lee side trough is in place, it may be that the air actually came from the west, descended, and turned. The implication for air quality policy is straightforward. Pollution making its way over the mountains from the west will turn once it reaches the coastal plain and come from the southwest. Because surface winds are then from the southwest, when the Appalachian lee side trough is in place, the limits of a nonattainment area's airshed will be expanded farther south and west than they might otherwise be (MARAMA, 2005 at pp. 41-42). Studies have observed high ozone levels in the OTR

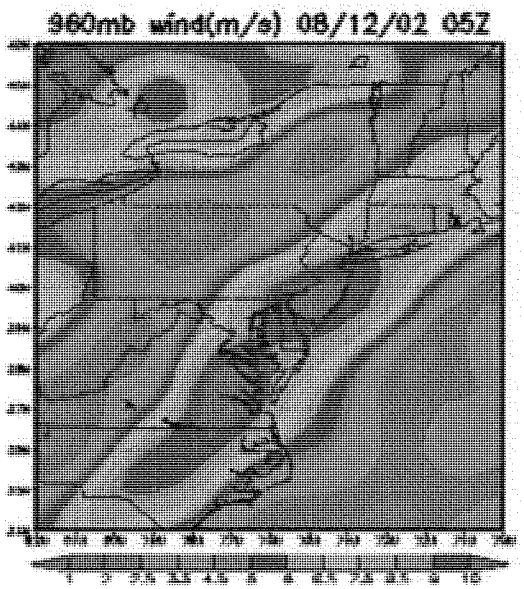
associated with a lee side trough east of the Appalachian Mountains and aligned with the Northeast Corridor (Gaza, 1998; Seaman & Michelson, 2000; Kleinman *et al.*, 2004).

2.3.3. Nocturnal low level jets

The nocturnal low level[a] jet is a localized region of rapid winds in the lower atmosphere (typically 500-1500 m above the ground level) that can form at night under the same calm conditions often present in a pollution episode. Forming just above the nighttime temperature inversion, the nocturnal low level jet depends on isolation from the surface provided by the inversion. It is primarily a nocturnal phenomenon that occurs more frequently during the spring and summer seasons.

A nocturnal low level jet is generally found where a range of mountains meets a flat plain. There is a particularly strong nocturnal low level jet in the Great Plains of the central United States on the eastern side of the Rocky Mountains. On the Eastern Seaboard, a nocturnal low level jet can develop along the Atlantic Coastal Plain located to the east of the Appalachian Mountains and to the west of the Atlantic Ocean. Figure 2-5 shows an example of a nocturnal low level jet. While the typical wind speed minimum of a nocturnal low level jet is often defined as more than 12 meters per second (m s^{-1}), Ryan (2004) has proposed a weaker minimum speed criterion of 8 m s^{-1} in the East because of the expected weaker terrain-induced forcing in this region. The mid-Atlantic nocturnal low level jet has a width of 300-400 km (to its half peak value) and a length scale of more than 1500 km, following closely the orientation of the Appalachian Mountains (Zhang *et al.*, 2006).

Figure 2-5. Example of a nocturnal low level jet



Note: The low level jet (shown by red, orange, and yellow) normally sets up along the eastern side of the Appalachian Mountains and blows from southwest to northeast (source: University of Maryland).

[a] "Low level" in this instance is relative to upper level jets occurring in the upper troposphere to lower stratosphere at heights of 10-15 km above the ground level. It is not a "ground level" phenomenon of the types described in the previous section.

The nocturnal low level jet forms in the absence of strong synoptic systems. Surface winds run parallel to the mountains, which in the case of the OTR is southwest running over the Atlantic Coastal Plain in front of the Appalachian Mountains. The nocturnal low level jet forms because land cools quicker than the air above it at night. The quickly cooling land results in the air closest to the surface cooling quicker than the air higher above. This creates a temperature inversion that separates the atmosphere into layers. The warmer air above the inversion layer (~200-800 m above ground) disengages from the frictional effect of the surface and increases in speed. In the eastern United States, the nocturnal low level jet has been observed in Georgia, the Carolinas and Virginia (Weisman, 1990; Sjostedt *et al.*, 1990) in addition to the OTR (NARSTO, 2000). Appendix D provides a descriptive example of the evolution of a nocturnal low level jet occurring over the length of the OTR during a period of high ozone in July 2002.

The amount of ozone within the nocturnal low level jet can be measured by balloon-launched ozone sensors called "ozonesondes". During an event on July 12-13, 2008, Howard University launched two ozonesondes from Beltsville, MD, one as a nocturnal low level jet emerged at 10:30 p.m. local time and one later at 2:30 a.m. during peak winds. As the jet increased in peak winds, ozone levels increased within the jet from just above 80 ppb to almost 95 ppb. The jet traveled over 22 mph for above 14 hours, resulting in a total transport distance of more than 300 miles. (MDE, 2009).

In southern New Hampshire, indications of a nocturnal low level jet were seen and modeled during a July 2001 episode. The core of the nocturnal low level jet occurred at around 500 m and reached maximum wind speeds of greater than 10 m/s. On one occasion, the jet extended southward across the mid-Atlantic and southern states, and westward to mid-Pennsylvania and West Virginia. The jet transported ozone and precursors that helped to produce elevated daytime ozone levels in southern New Hampshire during this period (Mao & Talbot, 2004).

2.3.4. Ozone and precursors higher aloft

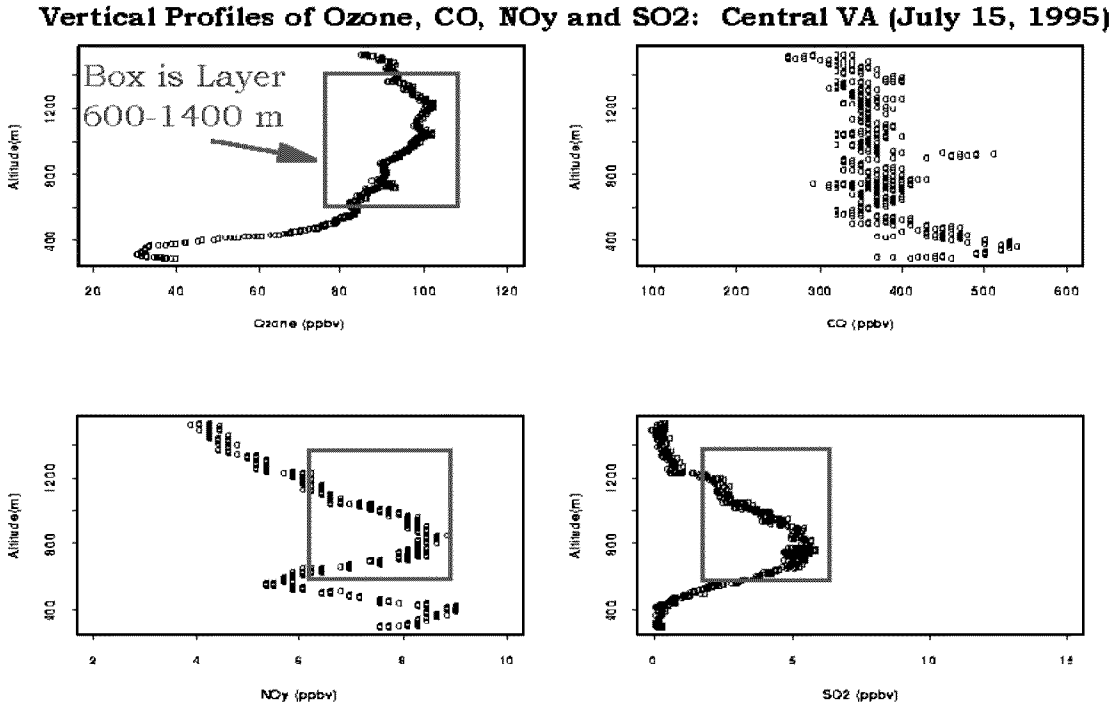
Theoretical and numerical model simulations have suggested for some time that there is a strong regional component to urban air quality in the northeastern United States (Liu *et al.*, 1987; Sillman *et al.*, 1990; McKeen *et al.*, 1990). Since 1992, thousands of aircraft flights have been made to measure vertical profiles of ozone, the nitrogen oxides, carbon dioxide, sulfur dioxide, and aerosol particles during high ozone episodes.[b] Figure 2-6 shows the results of profiles taken over central Virginia on July 15, 1995, at about 9:00 am on the last day of a four-day severe ozone episode. During this episode, winds measured at Dulles Airport in Sterling, Virginia in the 500-3000 m layer, where ozone was at a maximum, were consistently from the west to the north. There were no periods of stagnation or reversal of wind direction during this period. Figure 2-6 shows that the ozone mixing ratio above the boundary layer is much larger than that at the ground, peaking at about 1200 meters.

[b] These measurements were made as part of the University of Maryland's RAMMPP (Regional Atmospheric Measurement, Modeling, and Prediction Program) under the sponsorship of ARMA, MARAMA (Mid-Atlantic Regional Air Management Association), VADEQ (Virginia Department of Environmental Quality), and NCDEQ (North Carolina Department of Environmental Quality).

An examination of the various pollutant data in Figure 2-6 helps to identify possible sources of the elevated ozone. It should be noted that while both automobiles and power plants emit NO_X, automobiles emit carbon monoxide (CO) but not sulfur dioxide (SO_2), while power plants emit SO_2 but not CO. The CO profile is not correlated well with the ozone data, indicating that the source of the ozone is not from local sources, i.e., automobiles. The peak in the NO_Y[c] profile at around 800 meters is an indication of "aged air" (hence transport) as a number of studies have found a strong relationship between increasing ozone and NO_Y in photochemically aged air masses (Trainer *et al.*, 1993; Kleinman *et al.*, 1994; Olszyna *et al.*, 1994). Finally, the peak in the SO_2 profile, which occurs above the nocturnal inversion, is unlikely to come from local sources. Indeed the presence of the SO_2 leads to the conclusion that the air is coming from power plants west of the Appalachian Mountains.

[c] $NO_Y = NO + NO_2$ + all other oxidized nitrogen products of NO_X, excluding N_2O.

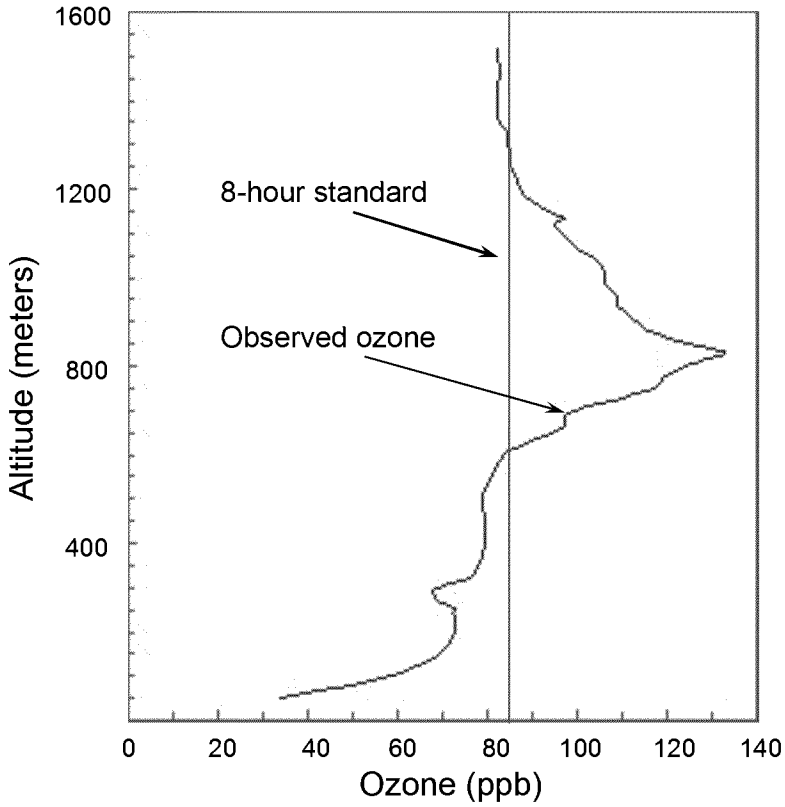
Figure 2-6. Altitude profiles for ozone, carbon monoxide, NO_Y, and SO_2 taken on July 15, 1995



During the same July 1995 period, measurements aloft in other parts of the OTR also recorded high ozone overnight in layers 500 m or higher above the surface. Ozone aloft concentrations above Poughkeepsie, NY and New Haven, CT approached levels of 120 ppb or greater on the night of July 14 (Zhang *et al.*, 1998; Zhang & Rao, 1999). Figure 2-7 displays the aircraft measurements above Poughkeepsie, NY around 4 a.m. EST.

This aloft ozone at night has the potential of reaching the surface the next day as the mixing height rises in the morning due to surface warming. A study in central North Carolina obtained vertical measurements of ozone from a 610 m tall tower and found a strong correlation between nighttime and early morning ozone concentrations in the residual layer above the nocturnal boundary layer and the maximum ground level concentration the following afternoon (Aneja *et al.*, 2000).

Figure 2-7. Observed vertical ozone profile measured above Poughkeepsie, NY at about 4 a.m. EST on July 14, 1995

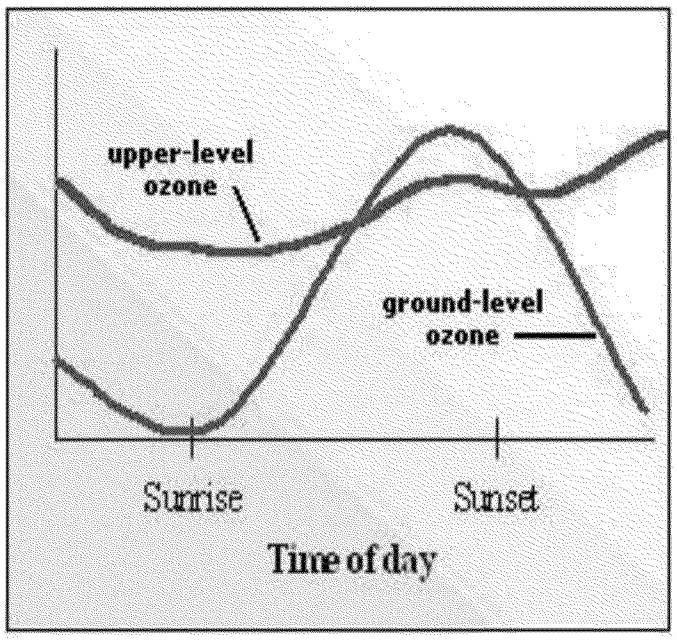


Note: The figure includes a vertical line at 85 ppb for comparing aloft measurements with the 8-hour ozone NAAQS (observed ozone data from Zhang & Rao, 1999).

The upper air measurements since 1992 reinforce the previously mentioned observations by Clarke and Ching (1983) during the summer of 1979, in which aircraft measurements recorded aloft ozone concentrations of about 90 ppb transported overnight from eastern Ohio and entering into the Northeast Corridor over a region stretching from the lower Hudson River Valley north of New York City down across eastern Pennsylvania and into Maryland just west of Baltimore. The measurements also showed NO_X aloft during the overnight hours that could contribute to additional ozone formation in the OTR as it mixed down to the surface in the morning. Further transport up the Northeast's urban corridor can occur via the formation of the Appalachian lee side trough and nocturnal low level jets (Taubman *et al.*, 2004).

Absent transport, ground-level ozone concentrations typically increase during daylight hours as a result of photochemical production and decrease substantially at night when ozone removal exceeds production (see Figure 2-8). At higher elevations, however, concentrations of ozone and ozone precursors may remain high at night, as there is minimal downward mixing of the atmospheric transport layers at night. During daylight hours, when solar energy heats the ground, the resulting warm air near the ground begins to rise. Rising air creates an unstable atmospheric situation resulting in the up- and downward mixing of air masses (including ozone transport layers). Thus ground level ozone concentrations typically rise for several hours immediately after sunrise.

Figure 2-8. Typical day/night ozone cycle at ground level and aloft



Note: Solar ultraviolet energy helps to create ozone that is present in high quantities late in the day. At night, there is no ultraviolet sunlight to create ozone and ground level objects and gases act to remove ozone, resulting in the curve in blue, which represents ozone at ground level. Ozone at higher elevations, conversely, is often not depleted at night and may remain at elevated concentrations throughout the day (red curve).

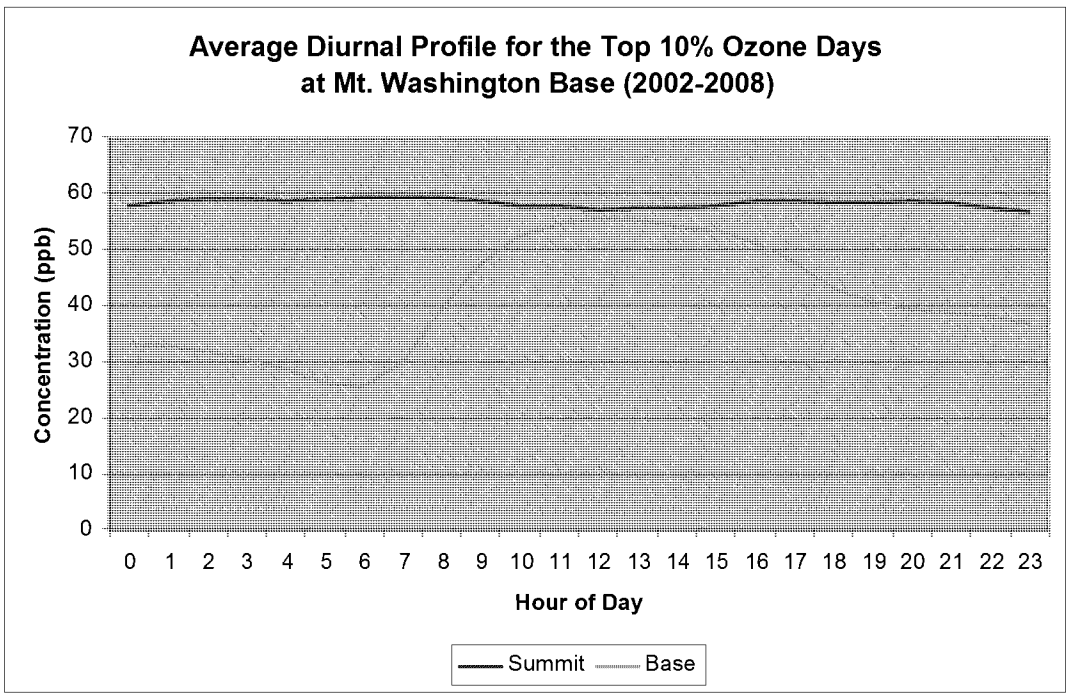
Monitoring data demonstrate this pattern. Towards the northern end of the OTR in New Hampshire stands Mt. Washington. The mountain is surrounded by hundreds of miles of forest and very few major emission sources within 75 miles. The mountain has ozone monitors at its 2,000 foot elevation base and at its 6,288 foot summit. When the wind patterns are right, significant amounts of ozone can be measured at both the base and summit. Because the summit of Mt. Washington is high enough to be exposed to high elevation transport (synoptic flows), downward mixing is not a factor in creating the peak ozone values it experiences. Transport time from upwind source areas appears to be the single largest factor in determining the time at which the maximum ozone level occurs at the summit. As suggested by Figure 2-9, the ozone at the base of the mountain is also dependent on this same long range transport that mixes downward from higher elevations once the mixing layer breaks up with the morning sun. While the highest ozone concentrations at the summit often occur overnight, there is actually a dip during the day when the mixing layer below breaks and allows vertical mixing. Relatively cleaner air from below mixes up and more polluted air from above mixes down, causing the summit measurements to dip and the base levels to rise (see Table 2-1).

Table 2-1. Night and daytime patterns of ozone at the base and summit of Mt. Washington, NH

Mt. Washington Monitor Location	Percent of Hourly Maxima During Daylight Hours (9 a.m. to 5 p.m.)	Percent of Hourly Maxima During Overnight Hours (6 p.m. to 8 a.m.)
Summit	18%	82%
Base (Camp Dodge)	80%	20%

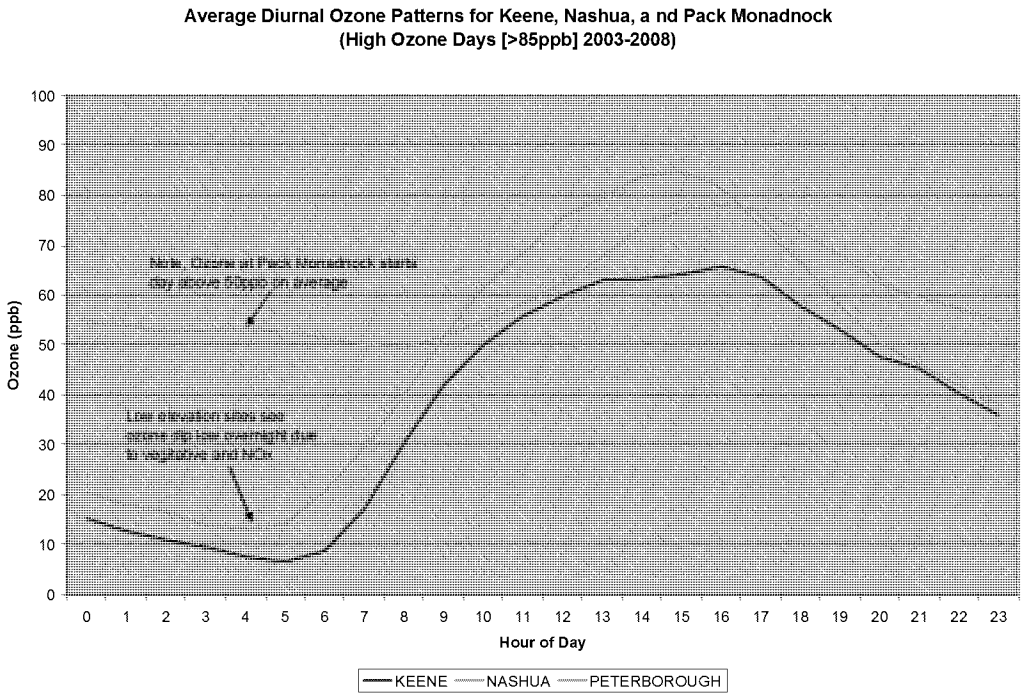
Note: Daylight heating hours are hours of the day when solar energy drives vertical mixing of transport layers

Figure 2-9. Average diurnal ozone patterns at the summit and base of Mt Washington, NH during high ozone days



A similar pattern can be found farther south in New Hampshire. Figure 2-10 compares ozone profiles from a mountaintop monitor located at Pack Monadnock Mountain (2,288 feet) with nearby low elevation monitors in Keene and Nashua, NH. In this case, the mountain site is not as far removed from emission sources. Some of the observed ozone is the result of local emissions and some comes from ozone and precursors brought into the area from synoptic scale transport patterns and the East Coast low level jet.

Figure 2-10. Average diurnal ozone patterns at the summit and near the base of Pack Monadnock Mountain, NH during high ozone days

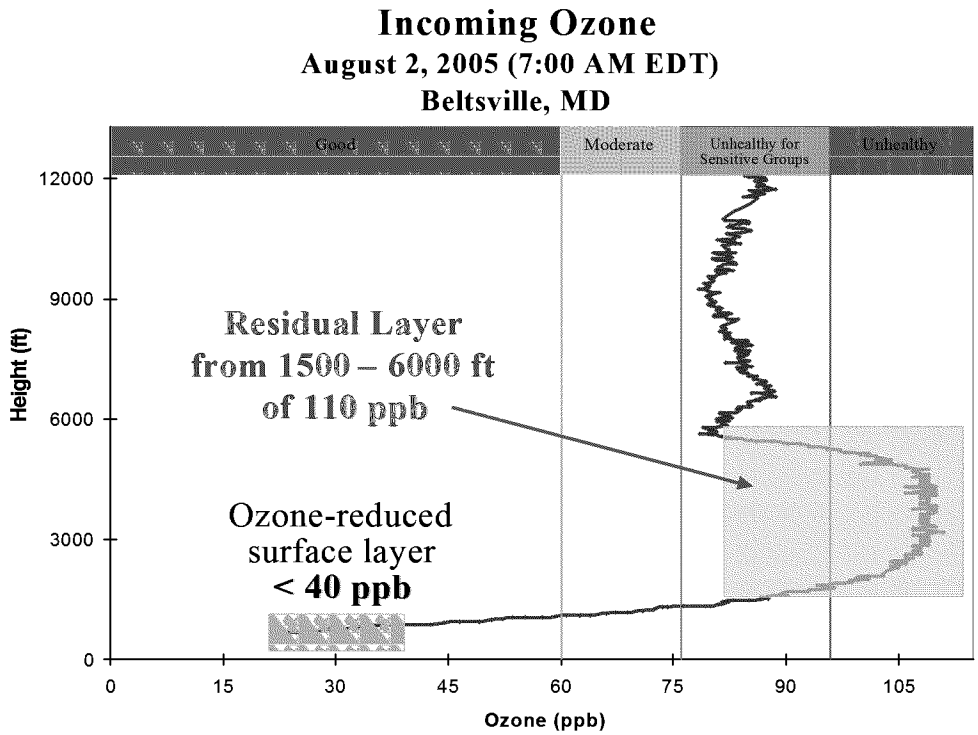


2.4. The "ozone reservoir"

The presence of high levels of ozone and precursors aloft across a large spatial region gives rise to the concept of an "ozone reservoir" forming in the eastern United States. The pollutants in this reservoir are not subject to destruction at the surface, and can be transported long distances in the wind flows created by the synoptic scale weather patterns conducive to ozone formation and transport. Transport up the Northeast's urban corridor can subsequently occur augmented by the Appalachian lee side trough and nocturnal low level jet (Taubman *et al.*, 2004).

In the ozone reservoir aloft, concentrations of ozone between 1,500 and 6,000 feet routinely can reach levels approaching and exceeding 100 ppb, while ozone at the surface can be below 40 ppb (Figure 2-11). This ozone air mass can be quickly transported long distances by strong winds like the jet stream. This effectively disconnects the location of emission sources that produce ozone from the location where ground-level concentrations of ozone are the highest.

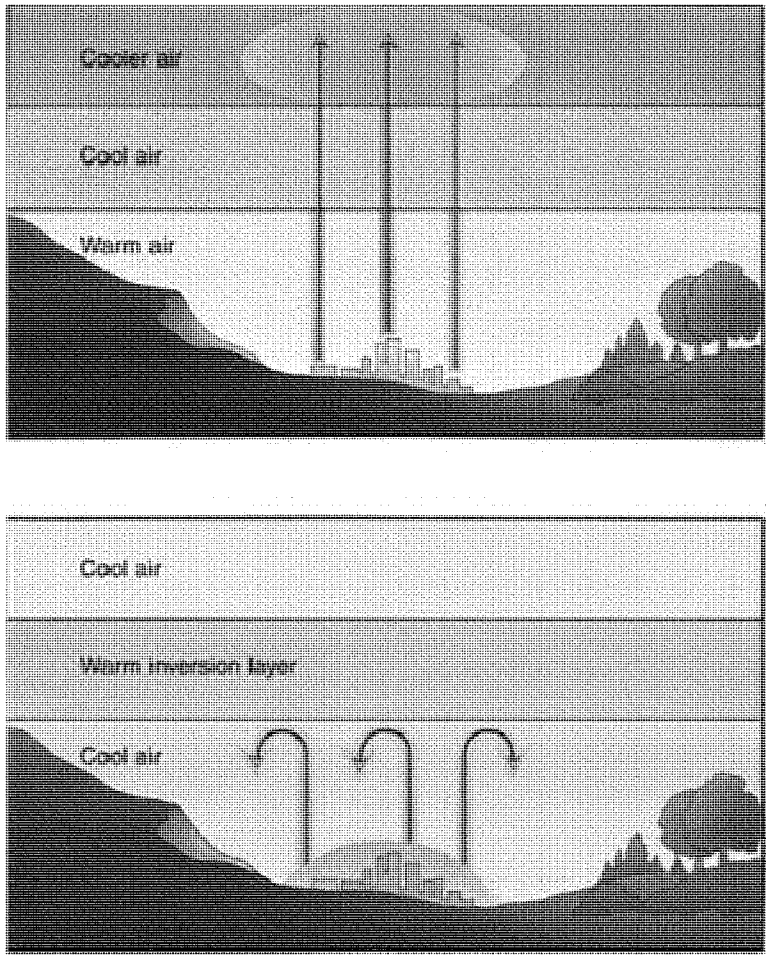
Figure 2-11. Concentration of ozone by altitude based on ozonesonde measurements



Source: Maryland Department of the Environment & Ho ward University

A simple conceptual picture of how the ozone reservoir forms is as follows: ozone produced during the day by sunlight acting on NO_X and VOCs is lifted high in the atmosphere by convection, mixing it within a relatively thick atmospheric boundary layer. At night, the boundary layer created by surface cooling after the sun goes down is closer to the ground than typical daytime boundary layers (Figure 2-12). As it forms, it leaves ozone from the daytime boundary layer in a residual layer aloft.

Figure 2-12. Mixing of ground-level ozone aloft during the day (above) and prevention of aloft ozone mixing down due to a nighttime inversion (below)



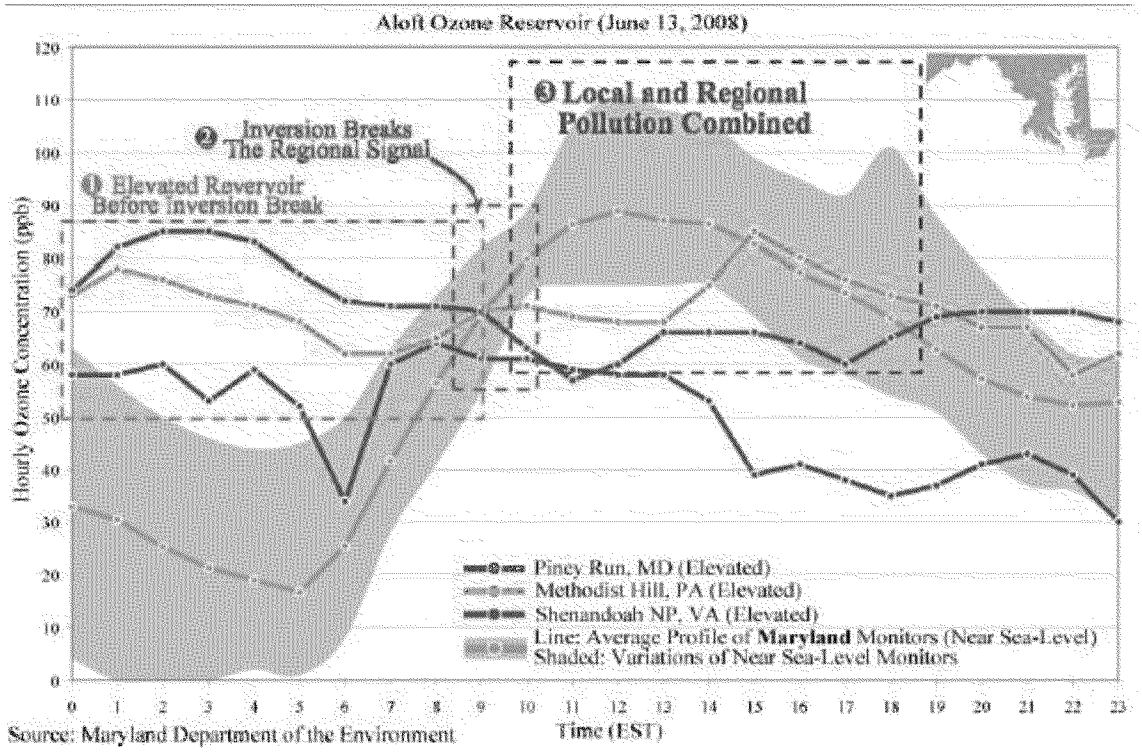
Source: Science Education Resource Center, Carleton College, MN.

In the morning, ozone within the stable and shallow nocturnal boundary layer is very low due to ozone loss mechanisms like dry deposition and NO_X titration. However the ozone cutoff from the ground in the residual layer is not destroyed and can travel for hundreds of miles in the strong winds of the free troposphere. As the nocturnal boundary layer lifts due to the sun's warming of the ground, the elevated ozone and its precursors mix down to the surface where they contribute to surface ozone concentrations.

The concentration level of this ozone reservoir can be measured by looking at the differences between elevated and ground-level ozone monitors over time. As described previously for Mt. Washington, NH, high elevation monitors are often above the top of the nocturnal boundary layer and directly measure aloft ozone concentrations. As the day progresses, mid-elevation monitors show the start of the ozone reservoir mixing down. The nocturnal inversion breaks up between 8-10 a.m. and ground-level monitors measure high levels of ozone comparable to the concentration at high elevation monitors. By

midday, the regional and local air pollutants have mixed and are indistinguishable (see Figure 2-13).

Figure 2-13. Comparison of the diurnal ozone concentrations measured by high elevation monitors (red, pink, and blue) and ground-level monitors (gray) on June 13, 2008



This pattern of "up..over..down" ozone transport via the ozone reservoir has been repeatedly observed across the OTR, as previously described in the published results of numerous field and modeling studies. A major trend over time, however, has been the magnitude of ozone concentrations within the elevated reservoir. While concentrations up to 180 ppb were common in the 1990s, current peaks are closer to 100 ppb as a result of regional NO_X reductions from power plants, motor vehicles, and other sources. Despite this reduction in transported ozone, levels are still well above the upper end of the range for the proposed revision for the ozone NAAQS (60 – 70 ppb).

2.5. Ozone background and exceptional events

With an ozone NAAQS of 0.08 ppm and the likely revision to a more stringent level in the range of 0.060 – 0.070 ppm as proposed by EPA, concerns have been raised over the ability to attain the current or a future ozone NAAQS due to ozone contributions thought to be beyond the control of air quality planners. To address these concerns, Congress amended section 319 of the Clean Air Act when it passed the Safe Accountable Flexible Efficient-Transportation Equity Act: A Legacy for Users (SAFE–TEA–LU) of 2005. Congress added to CAA section 319 language containing criteria to be applied by the USEPA for determining when air quality conditions could be attributed to "exceptional events," thus not counting as an excee dance or violation of a NAAQS. The

concept of "exceptional events" is to identify instances of degraded air quality for which the normal CAA planning and regulatory processes are not appropriate.

The amended CAA section 319 defines an exceptional event as an event that affects air quality; is an event that is not reasonably controllable or preventable; is an event caused by human activity that is unlikely to recur at a particular location or a natural event; and is determined by EPA to be an exceptional event. The statutory definition of exceptional event specifically excludes stagnation of air masses or meteorological inversions; a meteorological event involving high temperatures or lack of precipitation; or air pollution relating to source noncompliance. The USEPA has established by rule what is required by states to demonstrate the occurrence of exceptional events, thus allowing the exclusion of air quality monitoring data that would otherwise show an exceedance or violation of a NAAQS (72 Fed. Reg. 13560 (March 22, 2007)). Examples of exceptional events for ozone include stratospheric intrusions[d] and ozone generated from large forest fires.

At the time the USEPA lowered the ozone NAAQS from a 1-hour level of 0.12 ppm to an 8-hour average of 0.08 ppm, concern was expressed that the new lower level would be difficult to achieve due to frequently occurring naturally elevated hourly ozone levels of ≥0.05 and ≥0.06 ppm during winter and spring. The elevated levels were attributed to air from the upper troposphere and stratosphere being transported to the surface. Most elevated ozone occurrences were during April and May, based on air monitoring at rural sites in the northern U.S., southern Canada, and northern Europe where anthropogenic local sources of air pollution as well as photochemistry were believed to have little influence on ozone levels during these times (Lefohn *et al.*, 2001). It follows that if stratospheric ozone is a relatively frequent cause of or significant contributor to exceedances of the 0.08 ppm ozone NAAQS, it will also be of concern in addressing a future ozone NAAQS set at an even lower level.

A modeling study by Fiore *et al.* (2003) has concluded that much of the observed ozone variability, including high springtime ozone events, in relatively remote areas of the U.S. are attributable to anthropogenic air pollution rather than being of predominate stratospheric origin. The researchers pointed out that one cannot assume regional photochemistry during the spring is inactive, as springtime UV radiation levels are comparable to the summer. Because the modeling was able to reproduce the ozone behavior seen at remote monitoring sites, Fiore *et al.* (2003) proposed that previous interpretations attributing a greater stratospheric component were underestimating the role of regional and hemispheric pollution. The results indicated that the natural ozone background is typically in the range of 10-25 ppb, and never exceeds 40 ppb. The contribution of hemispheric pollution above the natural background ranges from 4-12 ppb and only rarely exceeds 20 ppb. The stratospheric contribution is minor, always below 20 ppb. This is consistent with earlier findings that stratospheric ozone contributions are highest in the upper troposphere while contributions to ozone at the surface are typically small (Parrish *et al.*, 1993; Dibb *et al.*, 1994; Mauzerall *et al.*, 1996).

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[d] A stratospheric intrusion is the entrainment of ozone-rich air from the stratosphere into the troposphere, which is the lowest layer of the atmosphere at the earth's surface. A stratospheric intrusion is typically associated with the passage of strong frontal systems or severe thunderstorms, and may occur primarily in the spring (USEPA, 1986).

Even during the winter it cannot be assumed that high ozone levels are necessarily stratospheric in origin. Ozone levels at a site in rural Wyoming during February, when the ground was snow-covered and air temperatures were as low as -17 C, reached a hourly peak average of 140 ppb just after solar noon (122 ppb 8-hour average) (Schnell *et al.*, 2009). A stratospheric intrusion was discounted due the diurnal ozone behavior, the presence of a high pressure system preventing stratospheric air from mixing downward, and an ozonesonde profile indicating the highest ozone was contained in a shallow surface layer with no enhancement at higher altitudes. It was suggested that a more likely source for the ozone was photochemical production from precursors associated with a developed natural gas field in the area.

In general, stratospheric intrusions leading to high surface ozone appear to be relatively rare (Logan, 1989; Cooper *et al.*, 1998; Fiore *et al.*, 2003). At Mt. Washington, NH, the highest point in the OTR, observed ozone levels greater than 80 ppb at night were associated with westerly (71 percent) and southwesterly (29 percent) transport, implicating pollution transport from industrialized/urban areas of the Midwest and the East Coast. Stratospheric ozone appeared to contribute to only about 5 percent of the extreme ozone events, but occurred under conditions also conducive to photochemical ozone production, making the relative contributions difficult to discern (Fischer *et al.*, 2004). The use of wind profiler radars suggested a stratospheric contribution to ground level ozone in Montreal, QC, during an event in early May when nighttime ozone increased from a typical level of 15 ppb to 30 ppb. Typical daytime levels of 30 ppb increased to 50 ppb (Hocking *et al.*, 2007). The increase in daytime ozone of 20 ppb is consistent with the modeling results of Fiore *et al.* (2003).

In addition to stratospheric ozone intrusions, another potential type of "exceptional event" is ozone associated with long r ange transport of smoke from forest fires. These would qualify as "exceptional events" to the extent they are considered by the USEPA as meeting the criteria set out in CAA section 319. Examples of observed elevated surface ozone concentrations attributed to long range transport from wildfires include impacts in the Washington, DC area from forest fires in central Quebec (Colarco *et al.*, 2004), and in Houston, TX from forest fires in eastern Alaska and western Canada (Morris *et al.*, 2006).

2.6. Summary

This section has summarized current knowledge of the meteorological processes that affect local ozone levels within the OTR. A conceptual description of transport processes within the OTR can be divided into three principle components: surface winds, the nocturnal low level jet, and winds in the free troposphere. All three modes of transport depend on the location of the high pressure system. Surface winds are the result of interaction between the synoptic flow and local effects, such as the sea breeze and the Appalachian lee side trough. The nocturnal low level jet results from the combination of shallow nocturnal inversions and conducive terrain. It has been observed throughout the Eastern Seaboard from Georgia to Maine. The nocturnal low level jet can transport ozone that formed within the OTR or was transported into the OTR from outside the region. Transport aloft is dominated by the anti-cyclonic flow around a high pressure system, which can lead to transport of an ozone reservoir into the OTR created by emissions in

areas that lie outside the OTR. Local emissions within the OTR add to the polluted air mixing down from above that arrived from more distant locations.

Atmospheric modeling by the USEPA underscores the observations that the OTR's ozone problem has contributions from outside and upwind of the region. Pollution sources in the Ohio River Valley and the Southeast significantly contribute to ozone nonattainment problems in various portions of the OTR.

Stratospheric sources of ozone appear to make relatively little contribution to surface ozone concentrations relevant to exceedances of the ozone NAAQS. Long distance transport from large wildfires can have an impact on local air quality and can be considered "exceptional events" for purposes of air quality planning.

References

Aneja, V.P., R. Mathur, S.P. Arya, Y. Li, G.C. Murray, Jr., and T.L. Manuszak. "Coupling the Vertical Distribution of Ozone in the Atmospheric Boundary Layer." *Environ. Sci. Technol.* **34**, 2324-2329, doi:10.1021/es990997+, 2000.

Clarke, J.F., and J.K.S. Ching. "Aircraft observations of regional transport of ozone in the northeastern United States." *Atmos. Environ.* **17**, 1703-1712, 1983.

Colarco, P.R., M.R. Schoeberl, B.G. Doddridge, L.T. Marufu, O. Torres, and E.J. Welton. "Transport of smoke from Canadian forest fires to the surface near Washington, D.C.: Injection height, entrainment, and optical properties." *J. Geophys. Res.* **109**, D06203, doi:10.1029/2003JD004248, 2004.

Cooper, O.R., J.L. Moody, J.C. Davenport, S.J. Otmans, B.J. Johnson, X. Chen, P.B. Shepson, and J.T. Merrill. "Influence of springtime weather systems on vertical ozone distributions over three North American sites." *J. Geophys. Res.* **103**, 22,001-22,013, 1998.

Dibb, J.E., L.D. Meeker, R.C. Finkel, J.R. Southon, M.W. Caffee, and L. A. Barrie. "Estimation of stratospheric input to the Arctic troposphere: ^{7}Be and ^{10}Be in aerosols at Alert, Canada." *J. Geophys. Res.* **99,** 12,855–12,864, doi:10.1029/94JD00742, 1994.

Fiore, A., D.J. Jacob, H. Liu, R.M. Yantosca, T.D. Fairlie, and Q. Li. "Variability in surface ozone background over the United States: Implications for air quality policy." *J. Geophys. Res.* **108**, 4787, doi:10.1029/2003JD003855, 2003.

Fischer, E.V., R.W. Talbot, J.E. Dibb, J.L. Moody, and G.L. Murray. "Summertime ozone at Mount Washington: Meteorological controls at the highest peak in the northeast." *J. Geophys. Res.* **109**, D24303, doi:10.1029/2004JD004841, 2004.

Gaza, R.S. "Mesoscale meteorology and high ozone in the northeast United States." *J. Appl. Meteor.* **37**, 961-977, 1998.

Hocking, W.K., T. Carey-Smith, D.W. Tarasick, P.S. Argall, K. Strong, Y. Rochon, I. Zawadzki, and P.A. Taylor. "Detection of stratospheric ozone intrusions by windprofiler radars." *Nature* **450**, 281-284, 2007.

Hudson, R. "A Conceptual Model for Ozone Transport." University of Maryland, Dept. of Atmospheric and Oceanic Science. Prepared for the Ozone Transport Commission. Draft Nov. 29, 2005.

Kleinman, L., Y.N. Lee, S. Springston, L. Nunnermacker, X. Zhou, R. Brown, K. Hallock, P. Klotz, D. Leahy, J. Lee, and L. Newman. "Ozone Formation at a Rural Site in the Southeastern United States." *J. Geophys. Res.* **99**, 3469-3482, 1994.

Kleinman, L., W.F. Ryan, P.H. Daum, S.R. Springston, Y.-N. Lee, L.J. Nunnermacker, and J. Weinstein-Lloyd. "An ozone episode in the Philadelphia metropolitan area." *J. Geophys. Res.* **109**, D20302, doi:10.1029/2004JD004563, 2004.

Landry, L., D. Nguyen, and M. Woodman, "The Influence of the Chesapeake Bay on Maryland Air Quality," 16th Conference on Air Pollution Meteorology, MS, Atlanta GA, January 20, 2010.

Lefohn, A.S., S.J. Oltmans, T. Dann, and H.B. Singh. "Present-day variability of background ozone in the lower troposphere." *J. Geophys. Res.* **106**, 9945-9958, 2001.

Liu, S. C., M. Trainer, F. C. Fehsenfeld, D. D. Parrish, E. J. Williams, D. W. Fahey, G. Hubler, and P. C. Murphy. "Ozone production in the rural troposphere and the implications for regional and global ozone distributions." *J. Geophys. Res.* **92**, 4191–4207, 1987.

Logan, J. "Ozone in rural areas of the United States." *J. Geophys. Res.* **94**, 8511-8532, 1989.

Lutgens, F., and E. Tarbuck. *The Atmosphere: An Introduction to Meteorology*, 8th ed., 512 pp., Prentice Hall, Upper Saddle River, New Jersey, 2001.

Mao, H., and R. Talbot. "Role of meteorological processes in two New England ozone episodes during summer 2001." *J. Geophys. Res.* **109**, D20305, doi:10.1029/2004JD004850, 2004.

MARAMA (Mid-Atlantic Regional Air Management Association). *A guide to mid-Atlantic regional air quality.* MARAMA. Baltimore, MD, pp. 2-3, 2005. Available at www.marama.org/reports.

Mauzerall, D.L., D.J. Jacob, S.-M. Fan, J.D. Bradshaw, G.L. Gregory, G.W. Sachse, and D.R. Blake. "Origin of tropospheric ozone at remote high northern latitudes in summer." *J. Geophys. Res.* **101**, 4175-4188, 1996.

McKeen, S. A., M. Trainer, E. Y. Hsie, R. K. Tallamraju, and S. C. Liu. "On the indirect determination of atmospheric OH radical concentrations from reactive hydrocarbon measurements." *J. Geophys. Res.* **95**, 7493–7500, 1990.

MDE. *Maryland's Ozone Conceptual Model Report (Draft).* Maryland Department of the Environment, November 13, 2009.

ME DEP. *Trajectory Analysis for Mid-Coast Maine.* Maine Department of Environmental Protection, communication from Tom Downs, May 20, 2010.

Morris, G.A., *et al.* "Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004." *J. Geophys. Res.* **111**, D24S03, doi:10.1029/2006JD007090, 2006.

NARSTO. *An Assessment of Tropospheric Ozone Pollution*. NARSTO, July 2000.

NH DES. Communication from Jeff Underhill, New Hampshire Department of Environmental Services, 2010.

Olszyna, K.J., E.M. Bailey, R. Simonaitis and J.F. Meagher. "O_3 and NO_y Relationships at a Rural Site." *J. Geophys. Res.* **99**, 14,557-14,563, 1994.

Parrish, D.D., J.S. Holloway, M. Trainer, P.C. Murphy, G.L. Forbes, and F.C. Fehsenfeld. "Export of North American ozone pollution to the North Atlantic Ocean." *Science* **259**, 1436-1439, 1993.

Ray, J.D., R.L. Heavner, M. Flores, and C.W. Michaelsen. "Surface level measurements of ozone and precursors at coastal and offshore locations in the Gulf of Maine." *J. Geophys. Res.* **101**, 29,005-29,011, 1996.

Ryan, W.F. and R.R. Dickerson. "Regional transport of pollutants and implications for 8-hour ozone non-attainment areas in Maryland." Report prepared for the Maryland Department of the Environment, Final version 2.2, 2000.

Ryan, W.F. "The low level jet in Maryland: Profiler observations and preliminary climatology." Report prepared for the Maryland Department of the Environment, Air and Radiation Administration, 2004.

Schnell, R.C., S.J. Oltmans, R.R. Neely, M.S. Endres, J.V. Molenar, and A.B. White. "Rapid photochemical production of ozone at high concentrations in a rural site during winter." *Nature Geoscience* **2**, 120-122, doi:10.1038/ngeo415, 2009.

Seaman, N.L. and S.A. Michelson. "Mesoscale Meteorological Structure of a High-Ozone Episode during the 1995 NARSTO-Northeast Study." *J. Appl. Meteor.* **39**, 384-398, doi:10.1175/1520-0450(2000)039<0384:MMSOAH>2.0.CO;2, 2000.

Sillman, S., J. A. Logan, and S. C. Wofsy. "A regional scale model for ozone in the United States with subgrid representation of urban and power plant plumes." *J. Geophys. Res.* **95**, 5731–5748, 1990.

Sjostedt, D.W., J.T. Sigmon, and S.J. Colucci. "The Carolina nocturnal low-level jet: Synoptic climatology and a case study." *Weather and Forecasting*. **5**, 404-415, 1990.

Stoeckenius, T. and Kemball-Cook, S. "Determination of representativeness of 2002 ozone season for ozone transport region SIP modeling." Final Report prepared for the Ozone Transport Commission, 2005.

Taubman, B.F., L.T. Marufu, C.A. Piety, B.G. Doddridge, J.W. Stehr, and R.R. Dickerson. "Airborne Characterization of the Chemical, Optical, and Meteorological Properties, and Origins of a Combined Ozone-Haze Episode over the Eastern United States." *J. Atmos. Sci.* **61**, 1781-1793, doi:10.1175/1520-0469(2004)061<1781:ACOTCO>2.0.CO;2, 2004.

Trainer, M., *et al.* "Correlation of Ozone with NO_y in Photochemically Aged Air." *J. Geophys. Res.* **98**, 2917-2925, 1993.

USEPA. *Guideline on the Identification and Use of Air Quality Data Affected by Exceptional Events*. USEPA OAQPS, EPA-450/4-86-007, July 1986.

Weisman, R.A. "An observational study of warm season southern Appalachian lee troughs. Part I: Boundary layer circulation." *Monthly Weather Review*. **118**, 950-962, 1990.

Zhang J. and S.T. Rao. "The role of vertical mixing in the temporal evolution of ground-level ozone concentrations." *J. Appl. Meteor.* **38**, 1674-1691, 1999.

Zhang, J., S.T. Rao, and S.M. Daggupaty. "Meteorological Processes and Ozone Exceedances in the Northeastern United States during the 12–16 July 1995 Episode." *J. Applied Meteor.* **37**, 776-789, 1998.

Zhang, D.-L., S. Zhang, and S.J. Weaver. "Low-Level Jets over the Mid-Atlantic States: Warm-Season Climatology and a Case Study." *J. Appl. Meteor. Climatol.* **45**, 194-209, 2006.

3. OZONE-FORMING POLLUTANT EMISSIONS

The pollutants that affect ozone formation are volatile organic compounds (VOCs) and nitrogen oxides (NO_X). The emissions dataset presented for the OTR in the first section below is from the 2002 MANE-VU (Mid-Atlantic/Northeast Visibility Union) Version 2 regional haze emissions inventory. MANE-VU is the regional planning organization (RPO) for the mid-Atlantic and Northeast states coordinating regional haze planning activities for the region. While the context of the MANE-VU inventory is regional haze, it includes inventories of NO_X and VOCs that also inform air quality planners on sources important to ozone formation.[e] To provide a fuller context of precursor emissions contributing to regional ozone affecting the OTR, the section following the MANE-VU information presents NO_X and VOC emissions information from the 2002 National Emissions Inventory (NEI) for states in adjacent RPOs.

Note that in future inventory efforts, the USEPA's Motor Vehicle Emission Simulator (MOVES) model will be replacing the previous mobile source inventory models – MOBILE for on-road and NONROAD for non-road emissions inventory development. On average, this change is anticipated to: (1) lower modeled CO and VOC emissions; (2) increase modeled NO_X and PM emissions; (3) lower the percent NO_X reduction from modeled control measures; and (4) raise the percent PM reduction from modeled control measures for the on-road and non-road sectors (Dolce, 2009).

3.1. Emissions inventory characteristics in the OTR

3.1.1. Volatile organic compounds (VOCs)

Existing emission inventories generally refer to VOCs as hydrocarbons whose volatility in the atmosphere makes them particularly important in enhancing ozone formation in the presence of NO_X.

As shown in Figure 3-1, the VOC inventory for the OTR is dominated by mobile and area sources. Most VOC emissions in the OTR, however, come from natural sources, which are not shown in the figure. Among the human-caused VOC emissions, on-road mobile sources of VOCs include exhaust emissions from gasoline passenger vehicles and diesel-powered heavy-duty vehicles as well as evaporative emissions from transportation fuels. VOC emissions may also originate from a variety of area sources (including solvents, architectural coatings, and dry cleaners) as well as from some point sources (e.g., industrial facilities and petroleum refineries).

Naturally occurring (biogenic) VOC emissions are caused by the release of natural organic compounds from plants in warm weather. Many natural VOCs that contribute to ozone formation are highly reactive. Isoprene, for example, is a highly reactive five-carbon natural VOC emitted from mostly deciduous trees (e.g., oaks) that plays an important role in enhancing regional ozone formation across the eastern U.S.

[e] The description of OTR state inventories discussed in the first section does not include the portion of Virginia in the Washington, DC metropolitan area. Information for Virginia is in the following section and comes from the 2002 National Emissions Inventory.

(Trainer *et al.*, 1987; Chameides *et al.*, 1988). Because biogenic VOC emissions are large and reactive, they are the most important part of the VOC inventory for understanding and predicting ozone formation. Biogenic VOCs are not included in Figure 3-1, but nationally, they represent roughly two-thirds of all annual VOC emissions (USEPA, 2006a). Modeling biogenic emissions can be difficult as it requires simulating biological responses to a range of environmental conditions, such as leaf temperature and the amount of sunlight reaching a leaf surface.

Figure 3-1. 2002 MANE-VU state VOC inventories in the OTR

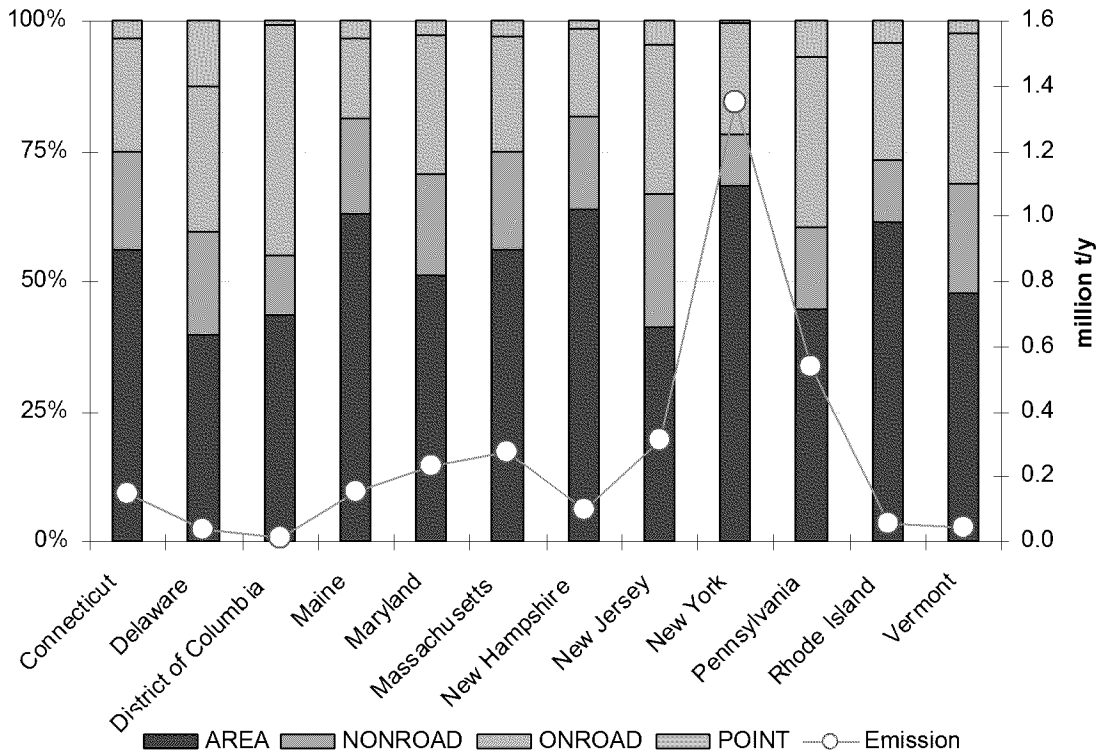


Figure key: Bars = Percentage fractions of four source categories; Circles = Annual emissions amount in 10^6 tons per year. The Virginia portion of the Washington, DC metropolitan area is not shown in the figure.

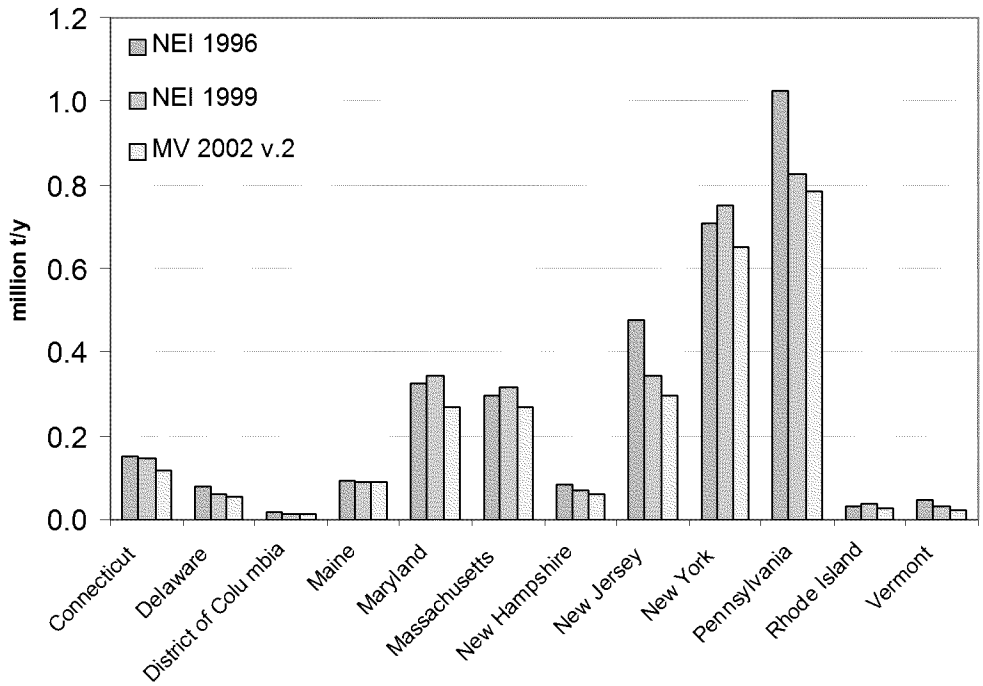
3.1.2. Oxides of nitrogen (NO_X)

NO_X emissions are a fundamental necessity for the atmospheric formation of ozone. Without NO_X, ozone formation during warm summer days would virtually cease, regardless of the amount of reactive VOCs present. By contrast, without VOCs, NO_X would still produce ozone in the presence of sunlight, albeit at a much diminished efficiency.

Figure 3-2 shows NO_X emissions in the OTR at the state level. Since 1980, nationwide emissions of NO_X from all sources have shown little change. In fact, emissions increased by 2 percent between 1989 and 1998 (USEPA, 2000). This increase is most likely due to industrial sources and the transportation sector, as power plant

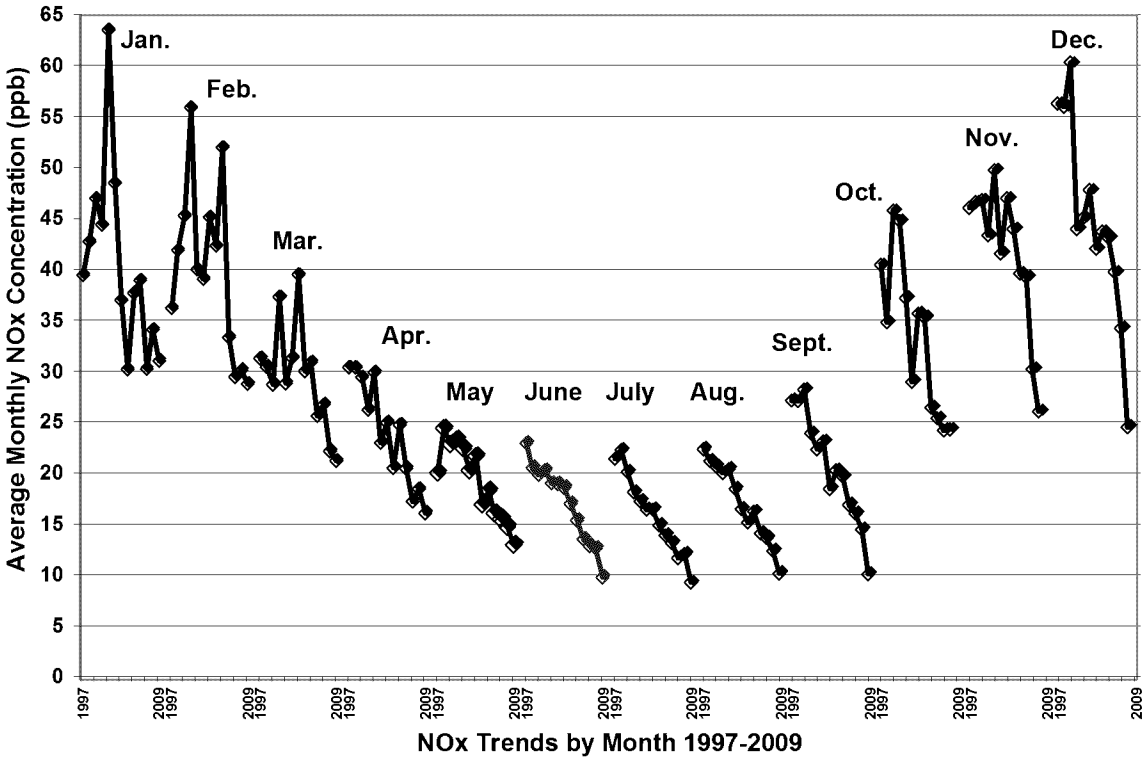
combustion sources have implemented modest emissions reductions during the same time period. Most states in the OTR experienced declining NO_X emissions from 1996 through 2002, except Massachusetts, Maryland, New York, and Rhode Island, which show an increase in NO_X emissions in 1999 before declining to levels below 1996 emissions in 2002.

Figure 3-2. State level nitrogen oxides emissions



Monitored ambient NO_X trends from 1997 to 2009 corroborate and extend the downward trend in NO_X emissions seen in the emissions inventories for the OTR. As shown in Figure 3-3, the monthly averaged NO_X concentrations indicate decreases in NO_X over this time period in the OTR. The NO_X reductions likely come from decreasing vehicle NO_X emissions due to more stringent motor vehicle standards as well as NO_X reductions from the OTR NO_X Budget Program and the NO_X SIP Call (mainly power plants). The higher NO_X levels measured during the colder months may be for several reasons, including relatively lower atmospheric mixing heights during colder months (i.e., less volume for pollutants to disperse in), less stringent NO_X requirements for power plants during months outside the April – September OTR ozone season, and increased space heating demands (e.g., NO_X from combustion of residential heating oil and wood, as well as increased generation for electric heat).

Figure 3-3. Plot of average monthly monitored NO_X trends in OTR 1997-2009



Note: The NO_X trends are 24-hour levels averaged by month during 1997-2009 (figure courtesy of Tom Downs, Maine Department of Environmental Protection).

Power plants and mobile sources generally dominate state and national NO_X emissions inventories. Nationally, power plants account for more than one-quarter of all NO_X emissions, amounting to over six million tons. The electric sector plays an even larger role, however, in parts of the industrial Midwest where high NO_X emissions have a particularly significant power plant contribution. By contrast, mobile sources dominate the NO_X inventories for more urbanized mid-Atlantic and New England states to a far greater extent, as shown in Figure 3-4. In these states, on-road mobile sources – a category that mainly includes highway vehicles – represent the most significant NO_X source category. Emissions from non-road (i.e., off-highway) mobile sources, primarily diesel-fired engines, also represent a substantial fraction of the inventory.

Figure 3-4. 2002 MANE-VU state NO_X inventories in the OTR

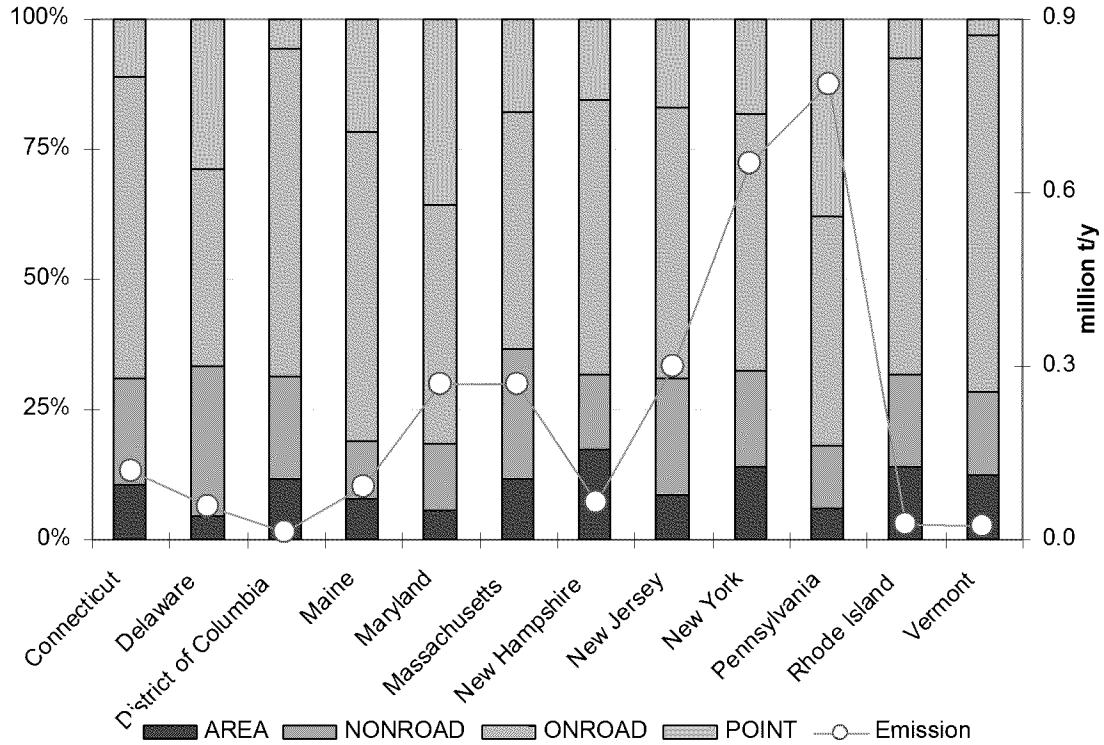


Figure key: Bars = Percentage fractions of four source categories; Circles = Annual emissions amount in 10^6 tons per year. The Virginia portion of the Washington, DC metropolitan area is not shown in the figure.

3.2. Emissions inventory characteristics outside the OTR

NO_X and VOC emissions in the OTR are only one component of the emissions contributing to ozone affecting the OTR. As regional modeling for the NO_X SIP Call and CAIR have shown, emission sources, primarily of NO_X, located outside the OTR can significantly contribute to ozone transported into the OTR. Here we present regional emissions information grouped by the three eastern RPOs – MANE-VU, VISTAS (Visibility Improvement State and Tribal Association of the Southeast), and the MWRPO (Midwest RPO). Table 3-1 lists the states in each RPO.

The inventory information is extracted from the USEPA final 2002 National Emissions Inventory (NEI). For consistency, the MANE-VU information here also comes from the 2002 NEI rather than from the MANE-VU Version 2 regional haze emissions inventory described above. The differences between the inventories are not great, as the NEI and the MANE-VU Version 2 inventory are both based on the same inventory information provided by the states.

Table 3-1. Eastern U.S. RPOs and their state members

RPO	State
MWRPO	Illinois
MWRPO	Indiana
MWRPO	Michigan
MWRPO	Ohio
MWRPO	Wisconsin
MANE-VU	Connecticut
MANE-VU	Delaware
MANE-VU	District of Columbia
MANE-VU	Maine
MANE-VU	Maryland
MANE-VU	Massachusetts
MANE-VU	New Hampshire
MANE-VU	New Jersey
MANE-VU	New York
MANE-VU	Pennsylvania
MANE-VU	Rhode Island
MANE-VU	Vermont
VISTAS	Alabama
VISTAS	Florida
VISTAS	Georgia
VISTAS	Kentucky
VISTAS	Mississippi
VISTAS	North Carolina
VISTAS	South Carolina
VISTAS	Tennessee
VISTAS	Virginia
VISTAS	West Virginia

Table 3-2 presents VOC emissions by source sector and RPO for the eastern United States. The NO_X emissions by source sector and RPO are presented in Table 3-3. Regionally, NO_X emissions are more important with respect to regional ozone formation and transport. Emissions of NO_X in combination with abundant naturally occurring VOC emissions from oaks and other vegetation have been shown to be important sources of regional ozone in the eastern U.S. (Trainer *et al.*, 1987; Chameides *et al.*, 1988).

Table 3-2. VOC emissions in eastern RPOs

RPO	Point Area	On-road	Non-road		Total
MWRPO	234,938	1,182,186	660,010	492,027	2,569,160
MANE-VU	93,691	1,798,158	793,541	494,115	3,179,504
VISTAS	458,740	2,047,359	1,314,979	609,539	4,430,617

Table 3-3. NO_X emissions in eastern RPOs

RPO	Point Area	On-road	Non-road		Total
MWRPO	1,437,284	184,790	1,290,178	723,844	3,636,096
MANE-VU	680,975	268,997	1,297,357	534,454	2,781,783
VISTAS	2,094,228	266,848	2,160,601	812,615	5,334,293

3.3. Are NO_X or VOC control strategies most effective at reducing ozone?

The effectiveness of a NO_X-focused or VOC-focused control strategy to reduce ozone is not constant by location or emissions; rather it is a changing chemical characteristic of an air parcel affecting a particular location. As a result, the effectiveness of a NO_X or VOC-focused control strategy can vary within an air parcel as it dynamically evolves over time with transport, dispersion, and photochemical aging (NARSTO, 2000 at Chapter 3.2).

On a regional basis, OTAG, CAIR and other modeling studies have consistently shown that NO_X reductions have the greatest impact on regional daily ozone concentrations, while VOC reductions have more local impacts. This is largely a result of significant naturally occurring VOC emissions (especially isoprene) in large forested regions of the eastern U.S. Observed results from regional NO_X reductions at power plants (i.e., the NO_X SIP Call) are now indicating that significant ozone reductions are occurring on a regional basis as a result of regional NO_X strategies. A USEPA report finds a strong association between areas with the greatest NO_X emission reductions due to the NO_X SIP Call and downwind sites exhibiting the greatest improvement in ozone in 2005 (USEPA, 2006b). The EPA findings are supported by a number of studies appearing in the peer-reviewed science literature. Collectively, these studies have found a strong association between the power plant NO_X reductions of the NO_X SIP Call and lower transported ozone levels in the eastern U.S. (Frost *et al.*, 2006; Kim *et al.*, 2006; Gégo *et al.*, 2007 & 2008; Gilliland *et al.*, 2008; Godowitch *et al.*, 2008a & 2008b; Hudman *et al.*, 2009). Of special note were the findings, based on back trajectory analyses, that ozone reductions in downwind regions east and northeast of the Ohio River Valley could be tied to NO_X reductions at power plants in the Ohio River Valley (Gégo *et al.*, 2007; Godowitch *et al.*, 2008b). A study based on ozone observations and modeling also suggested that air quality models underestimated the decrease in the long-range transport of ozone and its precursors after implementation of the NO_X SIP Call (Gilliland *et al.*, 2008).

As a general rule, VOC reductions may be effective at reducing urban-scale ozone pollution in lieu of or in combination with local NO_X reductions, while regional NO_X controls are most effective at reducing regional ozone. While a general rule can be outlined in evaluating the potential effectiveness of NO_X and VOC-focused control strategies, the optimal strategy for a specific location will depend on the particular circumstances of that location. Exceptions to a VOC-only strategy for an urban area can occur when the urban area has large natural VOC emissions, ozone is transported from

upwind, or there is recirculation of aged local pollution (e.g., sea breeze effect). Furthermore, because the conditions causing individual ozone episodes can vary, a given urban area may change in sensitivity between a NO_X and VOC-focused strategy depending on a particular episode's conditions (NARSTO, 2000). Therefore, the appropriate combination of VOC and NO_X controls at the local level depends on local circumstances with the realization that a single approach focusing on NO_X or VOC-only controls is not necessarily effective for all episode types. It is clear, however, that regional NO_X reductions provide regional ozone reductions during episodic events, and this will influence ozone levels being transported into local urban areas.

The role of longer-lived VOCs, such as methane, in contributing to the broader regional (and global) ozone background is an additional consideration in weighing the respective merits of NO_X and VOC-based strategies. As mentioned earlier in Section 1.5, the anthropogenic contribution to the ozone background has important implications for strategies to achieve a future revised ozone NAAQS lower than 0.08 ppm (e.g., 0.060 – 0.070 ppm). Current ozone control strategies, while relatively effective at reducing episodic peak ozone levels, are less effective at reducing lower chronic (i.e., background) levels of ozone. In addressing the anthropogenic "background" ozone (i.e., the portion not due to natural sources), methane can have a major impact. For higher peak ozone concentrations, reducing methane is not typically considered due to its relatively low atmospheric chemical reactivity on the time-scale of multi-day ozone episodes, but methane reductions would have a relatively larger influence on longer-term background ozone levels (Fiore *et al.*, 2002; 2003). Regional and global measures to reduce methane would not only have the benefit of reducing rising background ozone levels for purposes of achieving air quality standards, but would also help address the threat of climate change, as both ozone and methane are greenhouse gases.

3.4. Summary

There are large emissions of VOCs and NO_X within and outside the OTR that contribute to local and regional ozone problems. Naturally occurring VOC emissions play an important role in combination with human-caused NO_X emissions in forming regional ozone across large sections of the eastern U.S. Regional NO_X control strategies are demonstrating success in reducing regional ozone. On a more local scale, some combination of VOC and NO_X controls may be needed, with the specific combination dependent upon local circumstances. Measures to reduce methane, on a broad regional and global scale, can help address the anthropogenic component of a rising chronic ozone background, as well as help address climate change.

References

Chameides, W.L., R.W. Lindsay, J. Richardson, and C.S. Kiang. "The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study." *Science* **241**, 1473-1475, 1988.

Dolce, G. *MOVES2009 Update*, USEPA, Office of Transportation and Air Quality. Presentation to Ozone Transport Commission, Mobile Source Committee, Buffalo, NY, September 3, 2009. Available at http://www.otcair.org/document.asp?fview=meeting# (accessed April 28, 2010).

Fiore, A.M., D.J. Jacob, B.D. Field, D.G. Streets, S.D. Fernandes, and C. Jang. "Linking ozone pollution and climate change: The case for controlling methane." *Geophys. Res. Lett.* **29**, 1919, doi: 10.1029/2002GL015601, 2002.

Fiore, A., D.J. Jacob, H. Liu, R.M. Yantosca, T.D. Fairlie, and Q. Li. "Variability in surface ozone background over the United States: Implications for air quality policy." *J. Geophys. Res.* **108**, 4787, doi:10.1029/2003JD003855, 2003.

Frost, G. J., *et al.* "Effects of changing power plant NO_X emissions on ozone in the eastern United States: Proof of concept." *J. Geophys. Res.* **111**, D12306, doi:10.1029/2005JD006354, 2006.

Gégo, E., P.S. Porter, A. Gilliland, and S.T. Rao. "Observation-Based Assessment of the Impact of Nitrogen Oxides Emissions Reductions on Ozone Air Quality over the Eastern United States." *J. Appl. Meteor. Climatol.* **46**, 994-1008, doi:10.1175/JAM2523.1, 2007.

Gégo, E., A. Gilliland, J. Godowitch, S.T. Rao, P.S. Porter, and C. Hogrefe. "Modeling Analyses of the Effects of Changes in Nitrogen Oxides Emissions from the Electric Power Sector on Ozone Levels in the Eastern United States." *J. Air & Waste Manage. Assoc.* **58**, 580–588, doi:10.3155/1047-3289.58.4.580, 2008.

Gilliland, A.B., C. Hogrefe, R.W. Pinder, J.M. Godowitch, K.L. Foleya, and S.T. Rao. "Dynamic evaluation of regional air quality models: Assessing changes in O_3 stemming from changes in emissions and meteorology." *Atmos. Environ.* **42**, 5110–5123, doi:10.1016/j.atmosenv.2008.02.018, 2008.

Godowitch, J.M., C. Hogrefe, and S.T. Rao. "Diagnostic analyses of a regional air quality model: Changes in modeled processes affecting ozone and chemical-transport indicators from NO_X point source emission reductions." *J. Geophys. Res.* **113**, D19303, doi:10.1029/2007JD009537, 2008a.

Godowitch, J.M., A.B. Gilliland, R.R. Draxler, and S.T. Rao. "Modeling assessment of point source NO_X emission reductions on ozone air quality in the eastern United States." *Atmos. Environ.* **42**, 87-100, doi:10.1016/j.atmosenv.2007.09.032, 2008b.

Hudman, R.C., L.T. Murray, D.J. Jacob, S. Turquety, S. Wu, D.B. Millet, M. Avery, A.H. Goldstein, and J. Holloway. "North American influence on tropospheric ozone and the effects of recent emission reductions: Constraints from ICARTT observations." *J. Geophys. Res.* **114**, D07302, doi:10.1029/2008JD010126, 2009.

Kim, S.-W., A. Heckel, S.A. McKeen, G.J. Frost, E.-Y. Hsie, M.K. Trainer, A. Richter, J.P. Burrows, S.E. Peckham, and G.A. Grell. "Satellite-observed U.S. power plant NOx emission reductions and their impact on air quality." *Geophys. Res. Lett.* **33**, L22812, doi:10.1029/2006GL027749, 2006.

NARSTO. *An Assessment of Tropospheric Ozone Pollution*. NARSTO, July 2000.

Trainer, M., E.J. Williams, D.D. Parrish, M.P. Buhr, E.J. Allwine, H.H. Westberg, F.C. Fehsenfeld, and S.C. Liu. "Models and observations of the impact of natural hydrocarbons on rural ozone." *Nature* **329**, 705-707, 1987.

USEPA. *National Air Quality and Emission Trends Report, 1998*, EPA 454/R-00-003, 2000. Available at http://www.epa.gov/oar/aqtrnd98/.

USEPA. *2002 Final National Emissions Inventory (NEI)* 2006a. Available at ftp://ftp.epa.gov/EmisInventory/2002finalnei/ (accessed October 10, 2006). [The 2002 NEI reports national annual emissions for total anthropogenic VOC emissions as 16.8 million tons, and total biogenic VOC emissions as 41.8 million tons.]

USEPA. *NO_X Budget Trading Program 2005 Compliance and Environmental Results*, EPA430-R-06-013, 2006b. Available at http://www.epa.gov/airmarkets/fednox/.

4. WHAT WILL IT TAKE TO CLEAN THE AIR?– LINKING THE SCIENCE TO POLICY

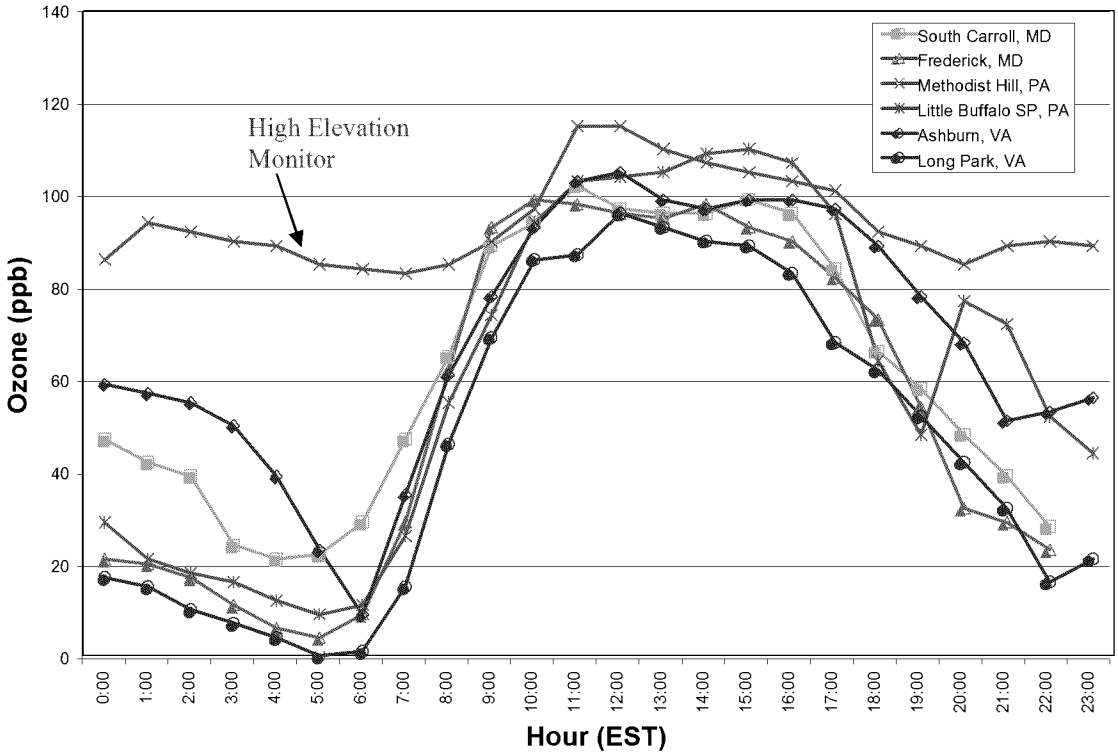
4.1. The three phases of a bad ozone day and the ozone reservoir

With the atmospheric chemistry, meteorology, and air emission inventory elements presented in the previous sections, a conceptual description emerges of ozone problem in the OTR. Consider a typical "day," defin ed as starting at sunset, for a severe ozone event associated with a high pressure system. Conceptually, a bad ozone day can be considered as occurring in three phases. During phase one, a nocturnal inversion forms as the temperature of the earth drops following sunset, isolating the surface from stronger winds only a few hundred feet overhead. Ozone near the surface can be destroyed by deposition. In a city, overnight, NO_X emissions can react with ozone, further reducing its concentration, so that by morning, very little ozone is left below the nocturnal inversion due to NO_X titration. At this time, the nocturnal inversion is at its strongest, and winds at the surface are typically calm. A large reservoir of ozone remains above the nocturnal inversion. Ozone and its precursors, both from the previous day's local emissions and from transport, remain largely intact. There are no surfaces and no new NO_X to remove the ozone.

During phase two of a bad ozone day, the nocturnal inversion breaks down at mid-morning, with the result that the ozone and precursors above the inversion can now mix with the air near the surface. The result of this vertical mixing is a sudden rise in ozone concentrations near the surface.

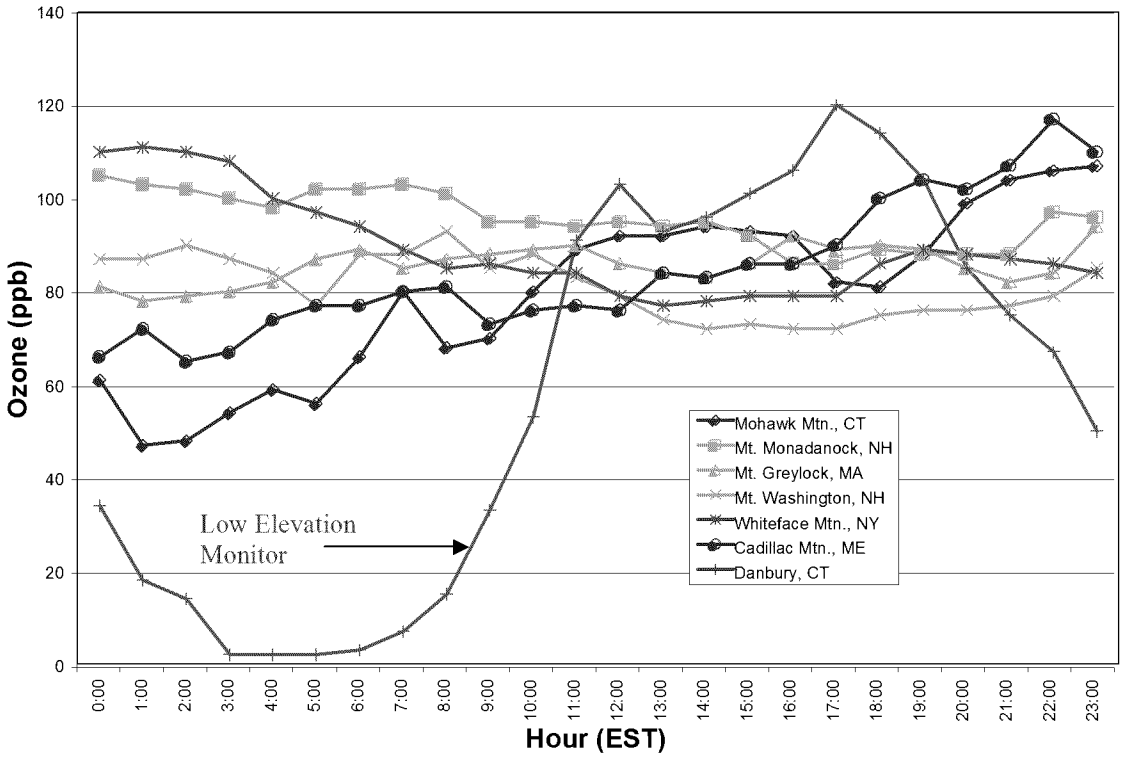
In phase three of a bad ozone day, ozone concentrations reach their highest levels in the afternoon through the combined accumulation of local pollution produced that day mixed with the transported regional pollution load brought in overnight from the ozone reservoir. Figure 4-1 shows this graphically for the southern OTR. The ozone monitor at Methodist Hill, PA is a high elevation site located at 1900 ft in altitude in south central Pennsylvania, and is above the nocturnal inversion. In the early morning hours of August 12, 2002 (e.g., 5 a.m.), it recorded ozone concentrations above 80 ppb, which was much higher than what other lower elevation monitors in the region were recording (e.g., Little Buffalo State Park, PA, South Carroll County, MD, Frederick, MD, Ashburn, VA, Long Park, VA). The high ozone levels seen at Methodist Hill, PA are above the nocturnal boundary layer and indicate the presence of significant ozone produced at some earlier point in time and transported into the region. With the break up of the nocturnal inversion after sunrise (e.g., starting about 7 a.m.), ozone concentrations at the lower elevation monitors show a rapid increase. This reflects the mixing down of the ozone reservoir from higher altitude to the surface in combination with local ozone production near the surface now that the sun has begun inducing its photochemical production.

Figure 4-1. Hourly ozone profiles in the southern OTR, August 12, 2002



The ozone reservoir extends across the OTR, as seen on the same night in high elevation ozone monitoring sites in the northern OTR. Figure 4-2 shows the hourly ozone concentrations measured on August 12, 2002 at Mohawk Mountain, CT, Cadillac Mountain, ME, Mt. Greylock, MA, Mt. Monadanock, NH, Mt. Washington, NH, and Whiteface Mountain, NY. As with Methodist Hill, PA on this day, these sites show elevated ozone concentrations during nighttime hours, as compared to lower elevation sites below the nocturnal inversion (e.g., Danbury, CT). By mid-day, however, the nocturnal boundary layer has broken down, mixing the transported ozone from the reservoir above into the locally produced ozone below. Appendix E provides more detail on contributions to the ozone reservoir within and outside the OTR.

Figure 4-2. Hourly ozone profiles of high elevation monitors in the northern OTR, August 12, 2002



Data provided by Tom Downs, Maine Department of Environmental Protection.

4.2. Chronology of an ozone episode – August 2002

The chronology of a historical ozone episode occurring in the OTR from August 8 to August 16, 2002 provides a real-world example that pieces together the elements of the ozone conceptual description given in this document. Surface maps from the period provide a synoptic overview of major weather systems that were influencing air quality across the OTR during that time. Meteorological insights combined with ozone concentration information provide a picture of the evolving ozone episode on a day-by-day basis. Figure 4-3, Figure 4-4, and Figure 4-5, respectively, show eight-panel displays of surface weather maps, back trajectories, and 8-hour maximum ozone concentrations from each day. The daily progression shows the formation of high ozone that shifts from west to east, and ultimately northward, during successive days of the episode according to local ozone formation and transport shaped by wind patterns within and outside of the OTR.

The August 2002 episode began with a slow-moving high pressure system centered over the Great Lakes initiating a northerly flow over the OTR on August 8. Over the next several days, the high drifted southeastward and became extended across a large part of the eastern U.S., bringing high temperatures to the region. Calm conditions west of the OTR on August 10 were pivotal for the formation of ozone, which first began building in the Ohio River Valley. Over the next four days, 8-hour ozone concentrations climbed well above the 85 ppb (0.08 ppm) NAAQS over a wide area of the OTR. Large parts of the heavily populated Northeast Corridor experienced 8-hour ozone levels above 100 ppb during the height of the episode, which far exceeded the 85 ppb NAAQS.

The following chronology provides a day-by-day evolution of the August 2002 ozone episode. Parts of this description are taken from Ryan (2003).

August 8: A high pressure system over the Great Lakes produces NW-N prevailing surface winds (~4-8 mph) throughout the region. Maximum daily temperatures approach or exceed 80° F.

August 9: Wind speeds fall off but the direction remains NW-N as the high moves into the Pennsylvania-New York region. Temperatures rise as cloud cover declines. Background ozone levels begin to build in the Ohio River Valley with 8-hour maximum concentrations reaching the 60-80 ppb range.

August 10: High pressure is directly over the mid-Atlantic. With dew points still in the mid-50°'s F, the skies are extraordinarily dear throughout the day. Temperatures (except in northern-most areas) approach 90°F while surface-level winds turn to more southerly directions. With high pressure overhead, the back trajectories suggest very light winds and recirculation. Calm conditions through the morning hours in the lower Ohio River Valley promote increasingly higher levels of ozone noted in surface observations – now reaching above the 85 ppb 8-hour ozone NAAQS over much of Indiana, Ohio, and other states along the Ohio River, as well as states around Lake Michigan and large portions of the southeastern U.S. Ozone levels above the 8-hour NAAQS now begin appearing for the first time in the western and southern parts of the OTR.

August 11: Surface high pressure drops slowly southeastward across the mid-Atlantic with the center in western North Carolina drifting to coastal South Carolina during the day. The upper level ridge has also moved east and is located over the mid-Atlantic. Circulation around the high becomes well established. A surface-level trough descends from north of the Great Lakes during the day, passes eastward through the Ohio River Valley and stalls over the Allegheny Mountains and southward. Peak temperatures are in the low to mid-90°'s F. Morning winds are low-to-calm in the area east of the Mississippi – the area of ozone now reaches from eastern Wisconsin to Tennessee and eastward to Georgia up through the Carolinas into the OTR, covering most of Pennsylvania, New York, New Jersey, Connecticut, Rhode Island and Massachusetts. Winds are generally south to southwest as is reflected in the boundary layer back trajectories. The key factor driving local ozone production appears to be a very stable boundary layer. The 8 a.m. sounding at the Washington-Dulles airport shows a very strong low-level inversion from 950-900 millibars (mb) with a deep residual layer beneath a continuing strong subsidence inversion – now based at 760 mb.

August 12: The upper level ridge remains quasi-stationary with its axis over the mid-Atlantic. The center of high pressure at 850 mb is over North Carolina and Georgia. At the surface, the characteristic Appalachian lee side trough forms. Temperatures exceed 90° F throughout the OTR except in coastal Maine. Winds are fairly strong from the northwest. This is reflected in the back trajectories that show a shift to westerly transport. Elevated upwind ozone concentrations at 11 a.m. on August 11 occur in the vicinity of the origin of the back trajectories, on the order of 78-86 ppb. Ozone concentrations fall this day west of the Appalachians but increase markedly across the mid-Atlantic. The area of highest ozone has pushed eastward and now extends from southern Maine across central Pennsylvania down through Maryland into the Carolinas, Georgia, and eastern

Tennessee. Ozone builds throughout the day as circulation forces it to the northeast between the stalled trough and a cold front approaching from the Midwest. Some of the highest 8-hour concentrations occur through the central to southern OTR on this day.

August 13: Calm conditions prevail as the trough reaches coastal New Jersey by 8 a.m. Generally clear skies allow temperatures to reach the mid-90°'s F everywhere except in coastal Maine. Dew points, which had been rising since August 8, reach the upper 60°'s F. A morning sounding at the Washington-Dulles airport showed a continuing strong low level inversion with a residual mixed layer to 850 mb ending just beneath a weak secondary inversion. The cap aloft has lifted to ~ 630 mb and the sounding is more unstable compared to previous day's between the two inversion layers. The Appalachian lee side trough continues in place from late on August 12. As is typically the case, the highest ozone concentrations are found in proximity to this boundary. The highest 8-hour ozone concentrations are along the eastern portions of the OTR from northeastern Virginia through New Jersey, Long Island, Connecticut, and into eastern Massachusetts. By 8 p.m., showers associated with the approaching cold front have reached into Ohio.

August 14: By 8 a.m., the trough has dissipated and the high is moving offshore, resulting in an increasing southerly wind component, which pushes maritime air northward. Dew points remain in the upper 60°'s F and peak temperatures reach into the 90°'s F everywhere and top 100° F in several locations. Ozone concentrations build again, with the highest levels concentrated in the central OTR from eastern Pennsylvania across to Massachusetts. A "hotspot" of ozone appears in upstate New York at the eastern end of Lake Ontario, and may be the result of transport from the west across the lake. Ozone concentrations decrease south and west of Baltimore and along coastal New Jersey as cleaner maritime air pushes in from the south.

August 15: This episode ends in a very different manner than the standard high ozone episode. Instead of the passage of a sharp cold front, this episode ends gradually as cleaner air sweeps north, winds increase, and the atmosphere steadily destabilizes. Ozone concentrations fall across the middle and lower OTR as low level flow becomes more southeast and the Bermuda high fills in westward. The highest levels, still exceeding the 8-hour ozone NAAQS, now occur in the northern reaches of the OTR in upstate New York, Vermont, New Hampshire, and Maine.

August 16: Cloud cover spreads over the region with ozone falling further. The new high building into the upper Midwest pushes the remains of the showers out of the Northeast. A spot of high ozone persists in central New Jersey. This is the last exceedance day in a string of seven exceedance days within the OTR during this extended episode.

Figure 4-3. Surface weather maps for August 9-16, 2002

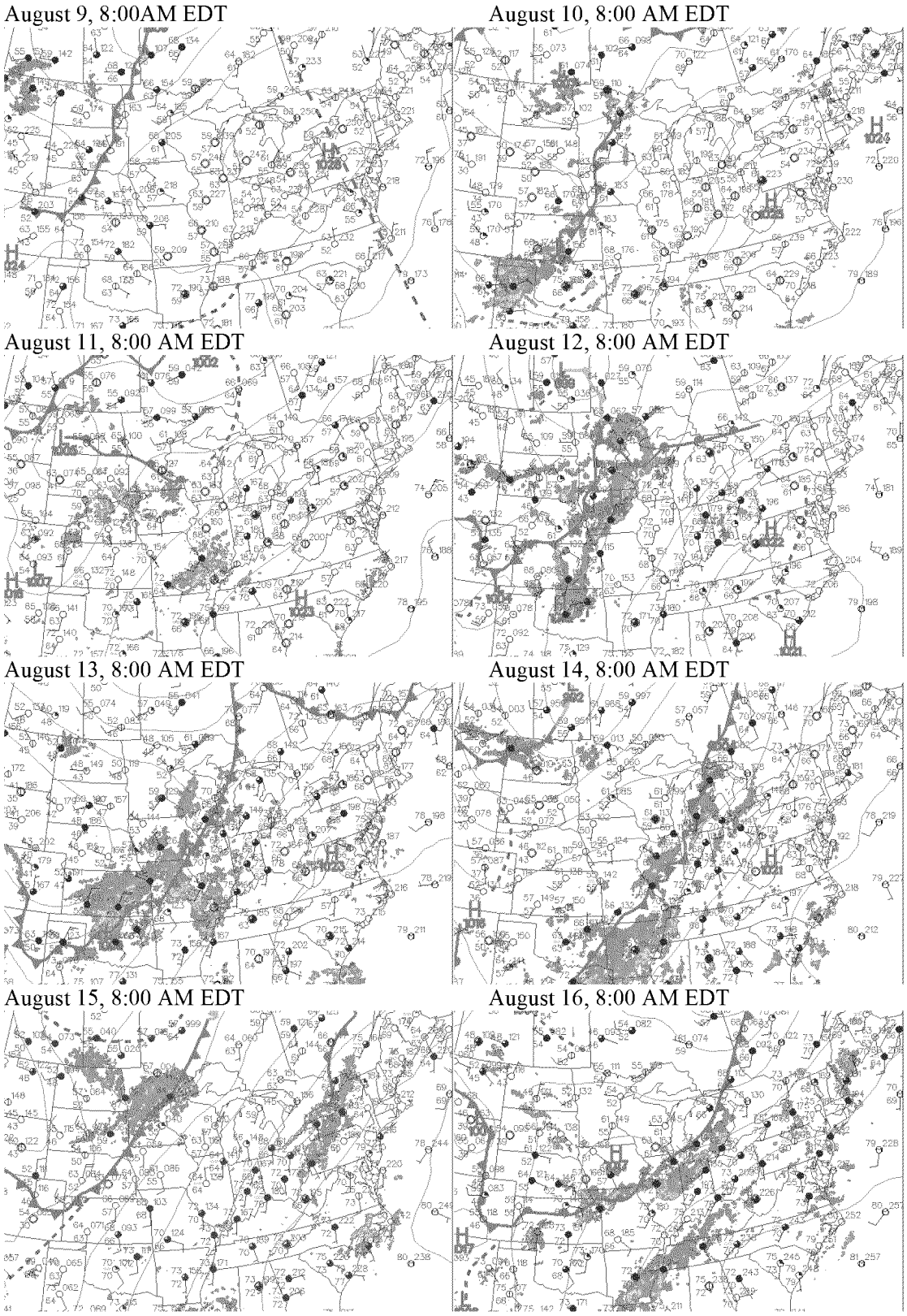
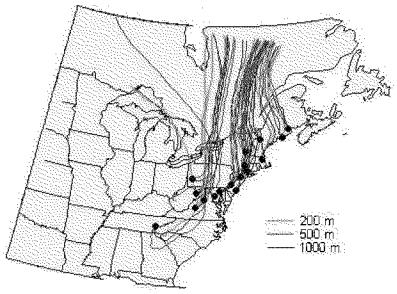
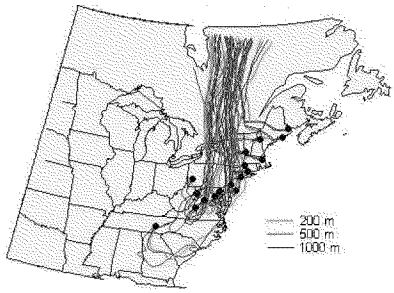


Figure 4-4. HYSPLIT 72-hour back trajectories for August 9-16, 2002

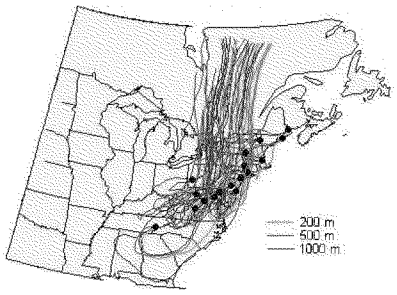
Aug 9, 2002 8 am EDT



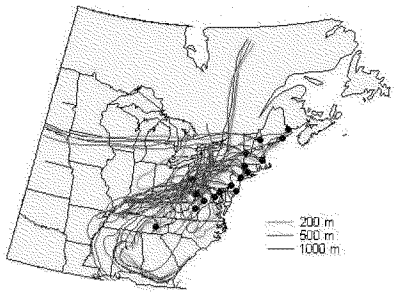
Aug 10, 2002 8 am EDT



Aug 11, 2002 8 am EDT



Aug 12, 2002 8 am EDT



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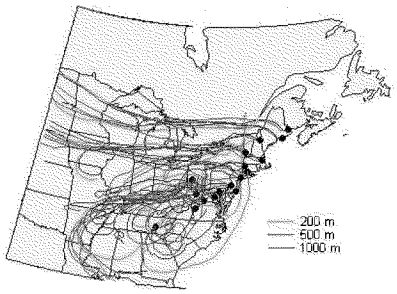
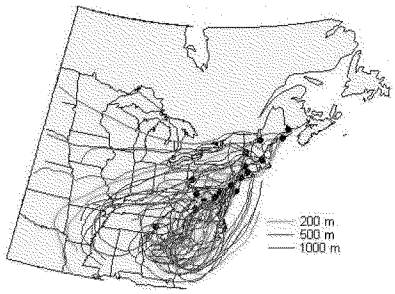
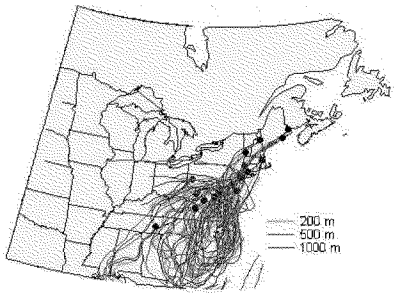


Aug 14, 2002 8 am EDT



Aug 15, 2002 8 am EDT



Aug 16, 2002 8 am EDT

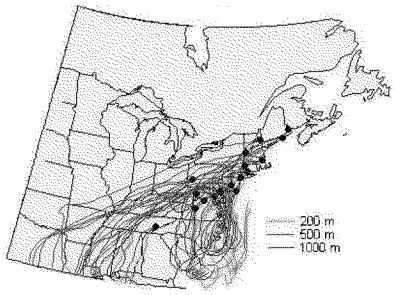
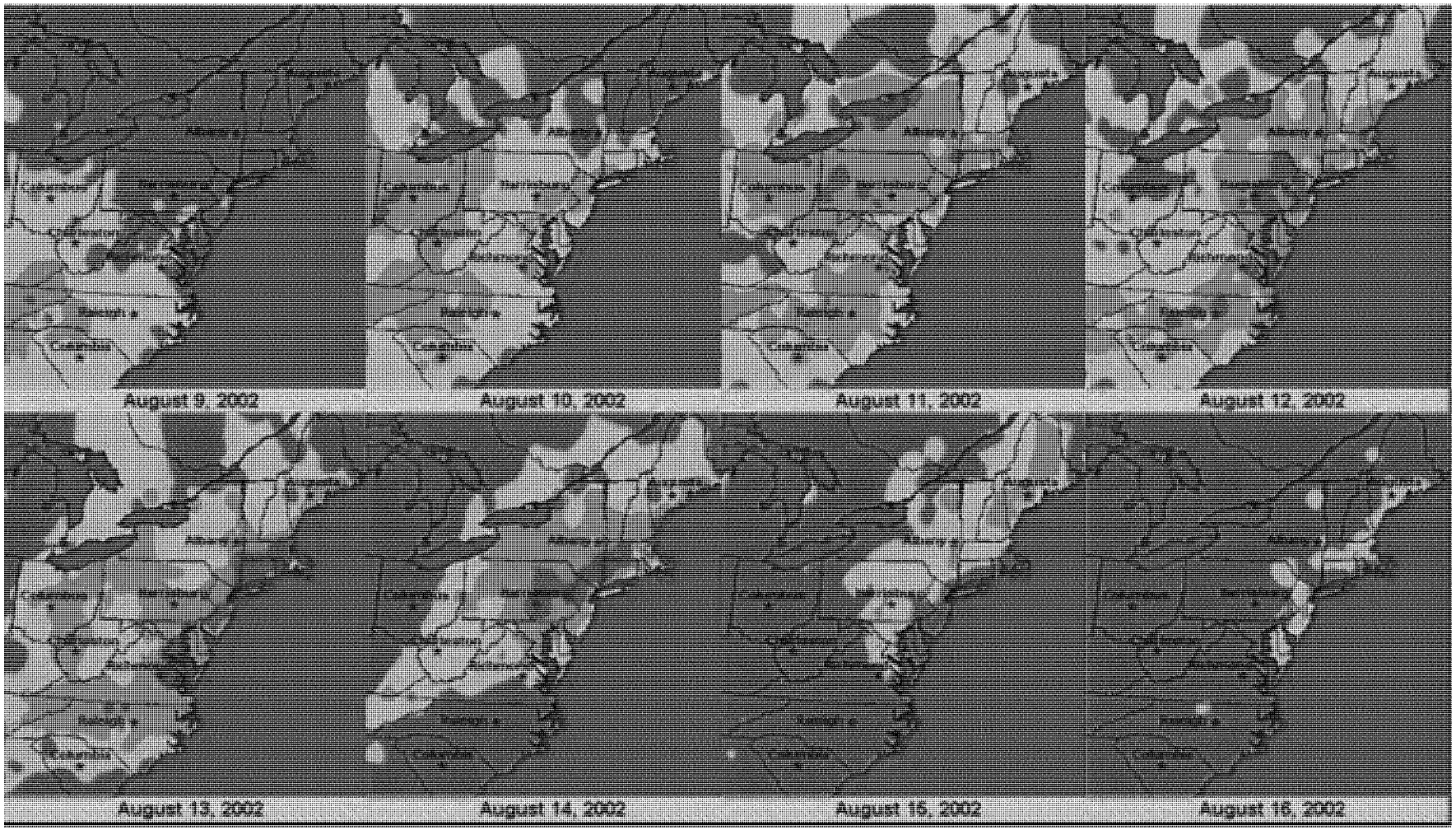


Figure 4-5. Spatially interpolated maps of maximum 8-hour surface ozone concentrations August 9 – 16, 2002



4.3. Clean Air Act provisions

As is evident from the myriad source regions and transport pathways affecting the OTR, the regional ozone nonattainment problem presents a significant challenge to air quality planners. To improve air quality, emission reductions of the appropriate pollutants must occur at the appropriate levels (i.e., stringency of controls) and over the appropriate geographic extent. States have primary responsibility for achieving the goals of the Clean Air Act, as they are responsible for developing State Implementation Plans and implementing and enforcing emission reduction programs to meet the health-protective National Ambient Air Quality Standards (NAAQS).

When Congress passed the Clean Air Act Amendments of 1990, it recognized that air pollution transcends political boundaries and that tools for addressing transport must be made available to state and federal governments. Accordingly, several Clean Air Act provisions deal with transported pollution, including: (1) prohibiting the USEPA from approving State Implementation Plans that interfere with another state's ability to attain or maintain a NAAQS; (2) requiring the USEPA to work with states to prevent emissions that contribute to air pollution in a foreign country; (3) allowing states to form ozone transport regions; (4) requiring states in ozone transport regions to adopt a prescribed set of controls in order to achieve a minimum level of regional emission reductions; and (5) allowing states to petition the USEPA for timely relief from stationary source emissions that interfere with attainment or maintenance of a NAAQS, and requiring the USEPA to act on such petitions within a very short, prescribed timeframe. Taken together, these provisions provide a framework for air quality planning. Its inherent principles are:

- Timely action is critical in order to protect public health;
- States must act locally to address air pollution;
- While acting locally, states must also consider their impacts downwind in addition to in-state impacts when developing state implementation plans (SIPs), and ameliorate such impacts through SIPs;
- Regional actions have been and can continue to be effective;
- To be effective on a regional level, states working together must work off of a level playing field;
- National rules are important and will play a more critical role as more states and nonattainment areas become involved in air quality planning.

What the science tells us of the nature of the ozone problem in the OTR supports this framework. The smaller scale weather patterns that affect pollution accumulation and transport underscore the importance of local (in-state) controls for NO_X and VOC emissions. Larger synoptic scale weather patterns, and pollution patterns associated with them, support the need for NO_X controls across the eastern United States. Studies and characterizations of interstate ozone transport also support the need for local and regional controls on NO_X and VOC sources. The key issues is to identify and control the source of these emissions, whether they are transported in the free troposphere, nocturnal low level jet, or land, sea, bay, mountain, and valley breezes.

The mix of emission controls is also important for states to consider. While long-range transport of ozone is primarily due to NO_X, VOCs are important because they

contribute to ozone formation by influencing how efficiently ozone is produced by NO_X, particularly within urban centers. While reductions in anthropogenic VOCs will typically have less of an impact on the long-range transport of ozone, they can be effective in reducing ozone in those urban areas where ozone production may be limited by the availability of VOCs.

Another dynamic in play is the level of the NAAQS in relation to the ozone levels of the elevated reservoir. As NAAQS are set at lower levels, transported ozone will likely play a more prominent role in the ozone problem that states will need to address through their SIPs. Therefore, a combination of localized VOC reductions in urban centers with additional NO_X reductions (from both mobile and point sources) across a larger region will help to reduce ozone and precursors in nonattainment areas as well as their downwind transport across the entire region (NESCAUM, 1997).

4.4. Past regional efforts

While states are somewhat limited in their ability to directly affect emissions reductions beyond their own geo-political boundaries, over the past 15-20 years, the Northeast states have acted regionally with tremendous success. Such efforts have included:

- In 1989, regional low volatility gasoline (i.e., Reid Vapor Pressure pf 9.0 pounds per square inch (psi)) was introduced into the NESCAUM region, resulting in significant VOC reductions;
- In 1994, the California Low Emission Vehicle (LEV) program commenced in the Northeast Corridor as regulations were adopted by Maine, Massachusetts, New York, and Vermont. To date, four additional states have joined the program, which continues to yield reductions in NO_X, VOC, CO, and air toxics.
- In 1994, the states of the Ozone Transport Commission agreed to promulgate regional NO_X RACT controls and a NO_X cap-and-trade program. The adopted regional RACT deadline was 1995. By 1999, the NO_X Budget Program was implemented over the 12-state region from Maine to Washington, DC. In 2002, the USEPA reported that the NO_X Budget sources "emitted at a level approximately 12 percent below 2001 allocations" (USEPA, 2002). Progress continues with a more stringent cap taking effect in 2003.
- In 1997, eight OTR states petitioned the USEPA under section 126 of the Clean Air Act, requesting NO_X emissions reductions on certain stationary sources in the Eastern U.S. In 1999, four more OTR members filed section 126 petitions. The USEPA granted four of the initial eight state petitions in 2000.[f]
- Beginning in 2001, the states of the Ozone Transport Commission agreed to support a suite of model rules for inclusion in SIPs as appropriate to address ozone nonattainment. Model rules to address the 1-hour ozone NAAQS included

[f] The initial eight section 126 OTR states were Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont. The additional four OTR members filing section 126 petitions were Delaware, the District of Columbia, Maryland, and New Jersey. The four granted petitions were from Connecticut, Massachusetts, New York, and Pennsylvania.

controls for: (1) architectural and industrial maintenance coatings; (2) portable fuel containers; (3) consumer products; (4) solvent cleaning; (5) mobile equipment repair and refinishing; and (5) additional NO_X controls for industrial boilers, cement kilns, stationary reciprocating engines, and stationary combustion engines. Several of the model rules have been or are being updated to reflect more current technology and emission reductions needed to address the 8-hour ozone standard.

These regional efforts led the way for similar broader regional and national programs. For mobile sources, the USEPA promulgated its federal Reformulated Gasoline Program in 1995 and the National LEV program in 1998. For stationary sources, the USEPA in 1998 promulgated the NOx SIP Call. This program expanded the OTR NO_X Budget Program, involving 20 states, and put in place a regional NO_X cap in 2003. The NO_X SIP Call also served as a response to the aforementioned Section 126 petitions under the Clean Air Act, which were filed by states in 1997.

In addition to the OTR, other regions in the eastern United States affected by regional transport have experienced benefits from the geographically expanded ozone control initiatives. For example, ozone levels in western Michigan are dominated by transport from major urban areas in the Lake Michigan area (e.g., Chicago, Gary, and Milwaukee) as well as from other source areas in the eastern United States. Regional control programs were found to be an effective method to address ozone transport and achieve the ozone NAAQS in this region (USEPA, 2009).

In 2005, the USEPA took a further step to address the regional ozone problem by issuing the Clean Air Interstate Rule (CAIR), which required additional NO_X reductions in 25 eastern states and the District of Columbia. The CAIR rule establishes an annual NO_X cap of 1.3 million tons in the eastern United States to be achieved by 2015. The cap, however, was virtually achieved by 2009, as NO_X emissions from sources covered by state adoption of CAIR were only 1.305 million tons (USEPA, 2010).

The USEPA projected that CAIR would achieve NO_X reductions of 2 million tons in 2015, a 61% decrease from 2003 levels. This would be a significant step forward in improving air quality, but the time allowed to achieve these reductions is later than the deadline many eastern states are facing to meet the current 8-hour ozone NAAQS. CAIR, therefore, only partially provides the OTR with a regional measure to help achieve the Clean Air Act's goal of attaining the ozone air quality health standard within the Act's mandatory deadlines.

A number of parties challenged CAIR in court, and it was initially vacated in its entirety on July 11, 2008 by the U.S. Court of Appeals for the District of Columbia Circuit (*North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir.)). The D.C. Circuit subsequently modified its opinion by remanding CAIR back to EPA without vacatur so that CAIR remains in effect while the USEPA develops a replacement rule consistent with the court's opinion.

4.5. New ozone standards

While the OTR states have made demonstrable progress towards meeting the 1997 ozone NAAQS through a combination of local and regional VOC and NO_X control measures, evolving understanding of ozone's impacts on human health has led to the need for a newer, more protective primary ozone NAAQS. In 2006, the Clean Air Scientific Advisory Committee (CASAC) – an independent review committee of expert scientists – made a unanimous recommendation to the USEPA to revise the primary ozone standard within a range of 0.060 – 0.070 ppm (CASAC, 2006). After initially promulgating a revised primary ozone NAAQS of 0.075 ppm 8-hour average in 2008, the USEPA reconsidered its initial action and re-proposed in 2010 a more stringent primary ozone NAAQS within the CASAC-recommended range (75 Fed. Reg. 2938-3052 (January 19, 2010)). The USEPA has also proposed secondary ozone NAAQS of a different form from the primary ozone NAAQS to better protect welfare values, such as forests and agricultural crops. The proposed secondary standard would be a weighted sum of daytime hourly ozone concentrations over a three month warm weather growing season. Regardless of the final revised ozone NAAQS levels, achieving new more protective standards will require maintaining the momentum of states' efforts to reduce VOC and NO_X emissions. New strategies will be needed that may be a combination of deeper emission reductions from existing sources and new measures on previously uncontrolled sources or types of activities.

Even with the lower NO_X emissions of 2009, many monitoring locations in the OTR recorded ozone levels that would put them in violation of a more stringent revised ozone primary NAAQS in the USEPA-proposed range of 0.060 – 0.070 ppm, 8-hour average. This indicates that the CAIR NO_X cap, originally established to assist states in meeting an ozone NAAQS of 0.08 ppm, will not be sufficient to address the more stringent ozone NAAQS expected from the USEPA. Analysis by the OTC indicates that it is feasible to cost effectively further reduce power plant NO_X emissions in the eastern United States down to an annual cap of 900,000 tons by 2015.

A more stringent 8-hour ozone NAAQS also has implications for what may be considered an ozone "episode." As mentioned in Section 1 and described in Appendix B, the classic OTR-wide high ozone episode is typically a summertime multi-day event associated with the slow passage of a high pressure system from the west to east that also brings sunny skies and high temperatures. There are also four other types of patterns associated with elevated ozone in the OTR. With a more stringent 8-hour ozone NAAQS, about 60 percent of days during an extended six month ozone season could experience an ozone exceedance somewhere in the OTR, based on recent history. For example, between 2003 and 2009, the average annual number of days during which at least one ozone monitor in the OTR exceeded 64 ppb was 112 out of ~180. This number of ozone exceedance days may implicate other weather patterns in addition to those identified in Appendix B. Futhermore, a conceptual model of ozone formation and transport for a multi-day ozone "episode" is not readily applicable to a secondary ozone NAAQS that is a summation of weighted hourly ozone concentrations over a three month period. It is known that the relative effectiveness of VOC versus NO_X control measures at reducing ozone can vary in location and time, thus a greater diversity of control measures will be needed to address a broader range of conditions leading to ozone formation.

4.6. Future climate change and ozone

Warmer temperatures can enhance ozone formation, thus leading to the potential for a "climate penalty" of increasing ozone with a warming climate. A statistical analysis by Bloomer *et al.* (2009) that looked at 21 years of ozone and temperature observations across the rural eastern U.S. discerned a relationship between rising temperatures and increasing ozone. A change in the relationship around 2002 also indicated reducing NO_X precursor emissions has the potential to mitigate the climate penalty. According to the Bloomer *et al.* analysis, ozone increased by an average of ~3.2 ppbv/°C prior to 2002. After 2002, a smaller climate penalty factor of ~2.2 ppbv/°C was observed as ozone levels fell by ~10 percent. The decrease in ozone was attributed to a 43 percent reduction in power plant NO_X emissions.

This historical analysis is directionally consistent with air quality modeling studies summarized below that projected deteriorating air quality in a warmer future climate when anthropogenic precursor emissions were held constant. When emissions reductions were incorporated into the modeling, air quality improvements were predicted, although perhaps not as great as would have otherwise occurred in the absence of future warmer temperatures.

A review article by Weaver *et al.* (2009) summarizes and compares the results of several modeling experiments of U.S. regional ozone impacts from climate change projected to *circa* 2050. All the modeling experiments held anthropogenic emissions of ozone precursors constant at present-day levels, but allowed biogenic VOC emissions to respond to simulated climate changes. This was done to investigate solely the influence of climate change on ground-level ozone independent of changes in anthropogenic precursor emissions in the future. The studies compared present and future ozone levels corresponding to the maximum daily eight-hour average. On a national scale, the different modeling experiments were in general agreement in projecting an increase in ozone of roughly 2-8 ppb for a large part of the country due to future climate change alone. Some regions, however, were predicted to experience little change in ozone concentrations, or even decreases. While these general features were common across the various modeling experiments, the regional patterns of increasing or decreasing future ozone varied across the models. These differences were attributed to differences in the modeling systems, model configuration, and experimental design choices among the different research groups. Specific examples included differences in cloud cover affecting surface sunlight levels, average maximum daily temperature, number of rainy days, and boundary layer depth.

Of special note were modeling results predicting a greater increase in the future 95th percentile maximum daily eight-hour averages as compared to the mean maximum (Nolte *et al.*, 2008). Because the current primary ozone air quality standard is based on the 4th maximum annual eight-hour average, this accentuated projected increase at the higher end of the daily maximum eight-hour averages has implications for air quality planners in developing control strategies to achieve as well as maintain attainment ozone air quality standards (Weaver *et al.*, 2009).

When the modeling included future decreases in ozone precursor emissions consistent with the reductions expected from EPA's Clean Air Interstate Rule (to be re-

proposed by EPA following a court-ordered remand), the projected 95th percentile eight-hour ozone levels no longer increased in much of the United States. Projected ozone levels decreased by at least 5 ppb nearly everywhere across the U.S., with large portions of the eastern and central U.S. predicted to see decreases of up to 15 ppb (Nolte *et al.*, 2008). A modeling study by Liao *et al.* (2007) also projected ozone decreases in 2050 for 4th maximum 8-hour ozone averages, with ozone becoming even more sensitive to NO_X in the future as NO_X reductions continue to occur while anthropogenic VOC reductions are offset by increases in biogenic VOCs in a warmer climate.

This suggests that continuing efforts to reduce ozone precursor emissions will have success in mitigating and improving ozone air quality despite countervailing pressure from future climate change. Maintaining precursor emissions at current levels, however, could result in higher future ozone levels under projected climate change through *circa* 2050. Even with continued emission reductions, it has been pointed out that the "climate penalty" will require stronger emissio n controls to meet a given air quality standard (Bloomer *et al.*, 2009; Jacob & Winner, 2009; Racherla & Adams, 2009).

4.7. Summary: Building upon success

A conceptual understanding of ozone as a regional problem in the OTR and throughout the eastern U.S. is now well established. With this evolution in understanding, regional approaches to the ozone problem are now underway, starting with the 1990 Clean Air Act Amendments that created the Ozone Transport Region. This initial regional approach, however, did not include large source regions outside of the OTR containing many large coal-fired power plants and other pollution sources contributing to the long-range transport of ozone into the OTR.

In 1998, the USEPA took another step in addressing the regional problem by finalizing the NO_X SIP Call, which covered emissions of NO_X, the main precursor of regional ozone, in additional parts of the East. Even with these reductions, air quality modeling has projected continuing significant contributions from upwind sources in out-of-state regions. As a result, the USEPA promulgated a further round of regional NO_X reductions in the East with the adoption of CAIR in 2005. With the modeling foundation for CAIR, the USEPA has presented a compelling technical case on the need for additional regional NO_X reductions in the eastern U.S. to reduce ozone levels and protect public health. While states in the Northeast disagree with the extent of NO_X reductions and the timeline for those reductions to occur, the program is an excellent next step toward reducing ozone in the OTR.

There is a tendency to characterize the nonattainment problems persisting after implementation of CAIR and other federal programs as "residual," but care must be taken in assessing these continuing nonattainment problems. A "residual" ozone problem is better characterized as a persistent nonattainment problem that still requires broad regional responses coupled with local controls. As this conceptual description points out, one of the great lessons and successes seen in the history of air quality policy was the shift from urban-only air pollution control strategies to broader regional approaches in the East at the end of the 1990s (e.g., NO_X SIP Call). The danger exists, however, that the perception of a "residual" ozone problem as being o nly a local issue will ignore the

lessons learned from effective regional approaches and possibly stall much needed national rules.

The current suite of local and regional controls have a proven track record of success, and have helped to significantly lower NO_X, VOC, and ozone levels across the eastern U.S. As described earlier in this report, monitored NO_X emissions and ambient concentrations have dropped between 1997 and 2008, and the frequency and magnitude of ozone exceedances have declined within the OTR. In the near future, however, there will very likely be a new health-based primary ozone NAAQS within the range of 0.060 – 0.070 ppm averaged over eight hours. The conceptu al model of regional ozone formation and transport, along with a track record of demonstrated progress in achieving cleaner air within this conceptual model framework, provides direction to air quality planners for meeting the new challenge of a more health-protective ozone NAAQS. To maintain the current momentum for improving air quality so that the OTR states can meet current and future attainment deadlines, the direction is for deeper and broader regional NO_X reductions coupled with appropriate local NO_X controls and regional and local VOC controls.

References

Bloomer, B.J., J.W. Stehr, C.A. Piety, R.J. Salawitch, and R.R. Dickerson. "Observed relationships of ozone air pollution with temperature and emissions." *Geophys. Res. Lett.* **36**, L09803, doi:10.1029/2009GL037308, 2009.

CASAC (Clean Air Scientific Advisory Committee). Letter from Dr. Rogene Henderson, Chair, CASAC, to EPA Administrator Stephen L. Johnson, "Clean Air Scientific Advisory Committee (CASAC) Peer Review of EPA's 2nd Draft Ozone Staff Paper," October 24, 2006, EPA-CASAC-07-001 (p. 2).

Hudson, R. "A Conceptual Model for Ozone Transport." University of Maryland, Dept. of Atmospheric and Oceanic Science. Prepared for the Ozone Transport Commission. Draft Nov. 29, 2005.

Jacob, D.J. and D.A. Winner. "Effect of climate change on air quality." *Atmos. Environ.* **43**, 51-63, doi:10.1016/j.atmosenv.2008.09.051, 2009.

Liao, K.-J., E. Tagaris, K. Manomaiphiboon, S. L. Napelenok, J.-H. Woo, S. He, P. Amar, and A. G. Russell. "Sensitivities of Ozone and Fine Particulate Matter Formation to Emissions under the Impact of Potential Future Climate Change." *Environ. Sci. Technol.* **41**, 8355–8361, doi:10.1021/es070998z, 2007.

NARSTO. *An Assessment of Tropospheric Ozone Pollution*. NARSTO, July 2000.

NESCAUM. *The Long Range Transport of Ozone and Its Precursors in the Eastern United States*. NESCAUM, Boston, MA, p.6, 1997.

Nolte, C. G., A. B. Gilliland, C. Hogrefe, and L. J. Mickley. "Linking global to regional models to assess future climate impacts on surface ozone levels in the United States." *J. Geophys. Res.* **113**, D14307, doi:10.1029/2007JD008497, 2008.

Racherla, P.N. and P.J. Adams. "U.S. Ozone Air Quality under Changing Climate and Anthropogenic Emissions." *Environ. Sci. Technol.* **43**, 571–577, doi:10.1021/es800854f, 2009.

Ryan, W.F. *Air Quality Forecast Report Philadelphia Forecast Area 2002*. The Pennsylvania State University, Department of Meteorology, University Park, PA, March 2003. Available at http://www.meteo.psu.edu/~wfryan/phl_2002_final_report.htm.

USEPA. *OTC NO_X Budget Program Compliance Report 2001*. U.S. Environmental Protection Agency, Washington, DC, p. 1, 2002.

USEPA. *Western Michigan Ozone Study*. U.S. Environmental Protection Agency, Region 5, Chicago, IL, April 24, 2009. Available at http://www.epa.gov/reg5oair/Western-Michigan-Report-Final.pdf (accessed April 19, 2010).

USEPA. *Clean Air Markets – Data and Maps, Emissions: Preliminary Quick Reports, 2009 Annual CAIR NO_X Program*. USEPA Clean Air Markets Division, 2010. Available on-line at http://camddataandmaps.epa.gov/gdm/ (accessed April 19, 2010).

Weaver, C.P. *et al*. "A Preliminary Synthesis of Modeled Climate Change Impacts on U.S. Regional Ozone Concentrations." *Bull. Am. Met. Soc.* **90**, 1843-1863, doi:10.1175/2009BAMS2568.1, 2009.

Appendix A: USEPA Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze

From "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze," U.S. Environmental Protection Agency, EPA-454/B-07-002, Section 11, April 2007.

Appendix A: EPA Guidance Document Excerpt

11.0 How Do I Get Started? - A "Conceptual Description"

A State/Tribe should start developing information to support a modeled attainment demonstration by assembling and reviewing available air quality, emissions and meteorological data. Baseline design values should be calculated at each monitoring site, as described in Section 3. For PM applications, speciated data should be reviewed to get a sense of what component(s) might be contributing most significantly to nonattainment or light extinction. If past modeling has been performed, the emission scenarios examined and air quality predictions may also be useful. Readily available information should be used by a State/Tribe to develop an initial conceptual description of the nonattainment or reasonable haze problem in the area which is the focus of a modeled demonstration. A conceptual description is instrumental for identifying potential stakeholders and for developing a modeling/analysis protocol. It may also influence a State's choice of air quality model, modeling domain, grid cell size, priorities for quality assuring and refining emissions estimates, and the choice of initial diagnostic tests to identify potentially effective control strategies. In general, a conceptual description is useful for helping a State/Tribe identify priorities and allocate resources in performing a modeled demonstration.

In this Section, we identify key parts of a conceptual description. We then present examples of analyses which could be used to describe each of these parts. We note that initial analyses may be complemented later by additional efforts performed by those implementing the protocol.

11.1 What Is A "Conceptual Description"?

A "conceptual description" is a qualitative way of characterizing the nature of an area's nonattainment or regional haze problem. It is best described by identifying key components of a description. Examples are listed below. There are 3 different examples. One each for ozone, annual $PM_{2.5}$, and regional haze. The examples are not necessarily comprehensive. There could be other features of an area's problem which are important in particular cases. For purposes of illustration later in the discussion, we have answered each of the questions posed below. Our responses appear in parentheses.

11.1.1 8-Hour Ozone NAAQS

1. Is the nonattainment problem primarily a local one, or are regional factors important?

(Surface measurements suggest transport of ozone close to 84 ppb is likely. There are some other nonattainment areas not too far distant.)

2. Are ozone and/or precursor concentrations aloft also high?

(There are no such measurements.)

3. Do violations of the NAAQS occur at several monitoring sites throughout the nonattainment area, or are they confined to one or a small number of sites in proximity to one another?

(Violations occur at a limited number of sites, located throughout the area.)

4. Do observed 8-hour daily maximum ozone concentrations exceed 84 ppb frequently or just on a few occasions?

(This varies among the monitors from 4 times up to 12 times per year.)

5. When 8-hour daily maxima in excess of 84 ppb occur, is there an accompanying characteristic spatial pattern, or is there a variety of spatial patterns?

(A variety of patterns is seen.)

6. Do monitored violations occur at locations subject to mesoscale wind patterns (e.g., at a coastline) which may differ from the general wind flow?

(No.)

7. Have there been any recent major changes in emissions of VOC or NO_X in or near the nonattainment area? If so, what changes have occurred?

(Yes, several local measures [include a list] believed to result in major reductions in VOC [quantify in tons per summer day] have been implemented in the last five years. Additionally, the area has seen large regional NO_X reductions from the NO_X SIP call.)

8. Are there discernible trends in design values or other air quality indicators which have accompanied a change in emissions?

(Yes, design values have decreased by about 10% at four sites over the past [x] years. Smaller or no reductions are seen at three other sites.)

9. Is there any apparent spatial pattern to the trends in design values?

(No.)

10. Have ambient precursor concentrations or measured VOC species profiles changed?

(There are no measurements.)

11. What past modeling has been performed and what do the results suggest?

(A regional modeling analysis has been performed. Two emission scenarios were modeled: current emissions and a substantial reduction in NO_X emissions throughout the regional domain. Reduced NO_X emissions led to substantial predicted reductions in 8-hour daily maximum ozone in most locations, but changes near the most populated area in the nonattainment area in question were small or nonexistent.)

12. Are there any distinctive meteorological measurements at the surface or aloft which appear to coincide with occasions with 8-hour daily maxima greater than 84 ppb?

(Other than routine soundings taken twice per day, there are no measurements aloft. There is no obvious correspondence with meteorological measurements other than daily maximum temperatures are always > 85 F on these days.)

Using responses to the preceding questions in this example, it is possible to construct an initial conceptual description of the nonattainment area's ozone problem. First, responses to questions 1 and 11 suggest there is a significant regional component to the area's nonattainment problem. Second, responses to questions 3, 4, 7, 8, and 11 indicate there is an important local component to the area's nonattainment problem. The responses to questions 4, 5 and 12 indicate that high ozone concentrations may be observed under several sets of meteorological conditions. The responses to questions 7, 8, and 11 suggest that ozone in and near the nonattainment area may be responsive to both VOC and NO_X controls and that the extent of this response may vary spatially. The response to question 6 suggests that it may be appropriate to develop a strategy using a model with 12 km grid cells.

The preceding conceptual description implies that the State/Tribe containing the nonattainment area in this example will need to involve stakeholders from other, nearby States/Tribes to develop and implement a modeling/analysis protocol. It also suggests that a nested regional modeling analysis will be needed to address the problem. Further, it may be necessary to model at least several distinctive types of episodes and additional analyses will be needed to select episodes. Finally, sensitivity (i.e., diagnostic) tests, or other modeling probing tools, will be needed to assess the effects of reducing VOC and NO_X emissions separately and at the same time.

11.1.2 Annual $PM_{2.5}$ NAAQS

1. Is the nonattainment problem primarily a local one, or are regional factors important?

(Surface measurements suggest that only design values in or immediately downwind of the city violate the NAAQS. However, other nearby design values come close to the concentration specified in the NAAQS.)

2. What is the relative importance of measured primary and secondary components of $PM_{2.5}$ measured at sites violating the NAAQS?

(Secondary components (i.e., SO_4, NO_3, OC) constitute about 80% of the measured mass of $PM_{2.5}$. There are higher concentrations of primary $PM_{2.5}$ in the core urban area compared to the suburbs and more rural areas.)

3. What are the most prevalent components of measured $PM_{2.5}$?

(The most important components in ranked order are mass associated with SO_4, OC and inorganic primary particulate matter (IP).)

4. Does the measured mix of PM components appear to roughly agree with mix of emission categories surrounding the monitoring sites?

(No. Relative importance of measured crustal material (IP) appears less than what might be inferred from the inventory.)

5. Do there appear to be any areas with large gradients of primary $PM_{2.5}$ in monitored or unmonitored areas?

(Cannot really tell for sources of crustal material until we resolve the preceding inventory/monitoring discrepancy. There are no other obvious major sources of primary particulate matter.)

6. Is there any indication of what precursor might be limiting formation of secondary particulate matter?

(No indicator species analyses have been performed. Past analyses performed for ozone-related SIP revisions suggest that ozone in this area may be limited by availability of VOC.)

7. Do monitored violations occur at locations subject to mesoscale wind patterns (e.g., at a coastline) which may differ from the general wind flow?

(No.)

8. Have there been any recent major changes in emissions of PM or its precursors in or near the nonattainment area? What?

(Yes, measures believed to result in major reductions in VOC and NO_X have been implemented in the last 5 years. Reductions in power plant NO_X have resulted from the NO_X SIP call and SO_2 emissions reductions have resulted from the national program to reduce acid deposition.)

9. Are there discernible trends in design values or other air quality indicators which have accompanied a change in emissions?

(The trend appears to be downward, but the most recent air quality data has been higher. Overall, the period of record is insufficiently long to tell.)

10. Is there any apparent spatial pattern to the trends in design values?

(No.)

11. What past modeling has been performed and what do the results suggest?

(A regional modeling analysis has been performed for ozone and $PM_{2.5}$. Two emission scenarios were modeled: current emissions and a substantial reduction in NO_X and SO_2 emissions throughout a regional domain. Reduced NO_X emissions led to substantial predicted reductions in 8-hour daily maximum ozone in most locations. Modeled SO_2 reductions from the CAIR rule had a strong impact on sulfate concentrations.)

12. Are there any distinctive meteorological measurements at the surface or aloft which appear to coincide with occasions with $PM_{2.5}$ concentrations in excess of 15.0 $\mu g/m^3$?

(Other than routine soundings taken twice per day, there are no measurements aloft. There is no obvious correspondence with meteorological measurements other than daily maximum temperatures are often > 85 F on days with the highest $PM_{2.5}$ observations.)

13. Do periods with high measured particulate matter or components of particulate matter appear to track each other or any other measured pollutant?

(There appears to be some correspondence between measured high concentrations of SO_4 and ozone.)

Using responses to the preceding questions in this example, it is possible to construct an initial conceptual description of the nonattainment area's ozone problem. First, responses to questions 1, 2 and 3 suggest there is a significant regional component to the area's nonattainment problem. Second, responses to questions 1 and 3 indicate there is a local component to the problem. The responses to questions 11, 12 and 13 suggest that there may be a link between reducing ozone and reducing particulate matter. Thus, it may be appropriate to assess effects of previously committed to strategies to reduce ozone and national PM control measures before simulating additional control measures. The responses to questions 4 and 5 suggest that it is premature to determine whether a "local area analysis" will be needed. The response to question 7 suggests that it may not be necessary to model with very small grid cells, at least for the secondary components of $PM_{2.5}$.

The preceding conceptual description implies that the State containing the nonattainment area in this example will need to involve stakeholders from other, nearby States to develop and implement a modeling/analysis protocol. It also suggests that a nested regional modeling analysis will be needed to address the problem.

11.1.3 Example Regional Haze Application

1. What components of particulate matter appear to have high concentrations on days with poor visibility?

(Mass associated with SO_4 and coarse particulate matter (CM) seem to have the highest concentrations on most such days.)

2. What are typical values for the humidity adjustment factor during the times of year when most of the days with poor visibility occur?

(Typical values appear to be about "4.0".)

3. Does visibility appear to track well among nearby Class I areas?

(Yes, but not always.)

4. Does poor visibility seem to occur under any specific meteorological conditions?

(This information is not readily available.)

5. Does poor visibility seem to coincide with high observed concentrations of any particular other pollutant?

(There seems to be some correspondence with high regional ozone concentrations.)

6. What components of particulate matter appear to have relatively high concentrations on days with good visibility?

(Coarse particulate matter and OC.)

7. What are typical values for the humidity adjustment factor during times of year when most of the days with good visibility occur?

(About "2.3".)

8. Does good visibility appear to occur under any specific meteorological conditions?

(Don't know.)

Answers to the preceding questions suggest that strategies to reduce sulfate concentrations and, perhaps, regional ozone concentrations might be effective in reducing light extinction on days when visibility is currently poor. The responses suggest that a strategy which focuses on this alone should first be tried for the days with good visibility as well. Even though sulfate concentrations appear low on such days, the fact that sulfates scatter light efficiently (see Equation (6.1)) and relative humidity is still high enough to enhance this effect is worth considering. Responses suggest that further meteorological analyses would be worthwhile prior to selecting strategies to simulate with a resource intensive regional model.

It should be clear from the preceding examples that the initial conceptual description of an area's nonattainment problem draws on readily available information and need not be detailed. It is intended to help launch development and implementation of a modeling/analysis protocol in a productive direction. It will likely be supplemented by subsequent, more extensive modeling and ambient analyses performed by or for those implementing the modeling/analysis protocol discussed in Section 12.0.

Questions like those posed in Section 11.1 can be addressed using a variety of analyses ranging in complexity from an inspection of air quality data to sophisticated mathematical analyses. We anticipate the simpler analyses will often be used to develop the initial conceptual description. These will be followed by more complex approaches or by approaches requiring more extensive data bases as the need later becomes apparent. These analyses are intended to channel resources available to support modeled attainment demonstrations onto the most productive paths possible. They will also provide other pieces of information which can be used to reinforce conclusions reached with an air quality model, or cause a reassessment of assumptions made previously in applying the model. As noted in Section 7, corroboratory analyses should be used to help assess whether a simulated control strategy is sufficient to meet the NAAQS.

Appendix B: Ozone pattern classifications in the OTR

Appendix B: Ozone pattern classifications in the OTR

The following five types of ozone patterns in the OTR are taken from: Stoeckenius, T. and Kemball-Cook, S. "Determination of representativeness of 2002 ozone season for ozone transport region SIP modeling." Final Report prepared for the Ozone Transport Commission, 2005. Figure B-1 shows the 850 mb height and wind fields and Figure B-2 shows the surface temperatures and 10 meter wind fields for the five patterns (reproduced from Figures 3-2 and 3-5 of Stoeckenius & Kemball-Cook, 2005).

"Type A" – High ozone throughout the OTR. This pattern is characterized by strong high pressure over the southeastern states extending from the surface to 500 mb with high temperatures extending into New England and southwest surface winds throughout the OTR. The 850 mb temperatures and heights, and surface temperatures are above average at all locations except Washington DC; winds are southwest to west throughout the OTR except more variable at LaGuardia and magnitudes of resultant wind vectors are higher than average (indicative of a fairly steady, well defined flow regime), east-west surface pressure gradients are near neutral but southwest-northeast gradients along the I-95 corridor and in the west (Pittsburgh to Buffalo) are positive, which is consistent with the southwest flow. The stable air mass and high temperatures promote ozone formation throughout the OTR under these conditions.

"Type B" – High ozone confined to the extreme southeastern OTR. This pattern is characterized by an upper-level trough offshore of the OTR and a surface high centered over Kentucky. This results in cooler air advection over nearly all of the OTR with northwest flow aloft and a more westerly flow at the surface. The 850 mb heights are lower than average (especially in New England) and surface winds are more frequently from the northwest along the I-95 corridor than under Type A. Temperatures at 850 mb along the I-95 corridor are only slightly cooler than under Type A but inland temperatures, especially in the north, are much cooler (e.g., at Buffalo); similarly, surface temperatures along the I-95 corridor are about the same as under Type A but temperatures are cooler in Buffalo and Albany. Type B events have the strongest positive west-east surface pressure gradients of any category, consistent with the northwest winds but gradients from Washington to New York and Boston are positive. The cooler air over the western OTR and westerly to northwesterly flow result in the higher ozone levels being confined to just the extreme southern portion of the OTR under this pattern.

"Type C" – High ozone along the I-95 corridor and northern New England. This pattern is characterized by an extension of the semi-permanent Bermuda high into the southeastern U.S. and an area of high surface and 850 mb temperatures extending from Maryland to Maine; the 500 mb pattern is nearly zonal (east-west flow) while flow at the surface is generally from the southwest. The 850 mb heights are intermediate between Type A and Type B but 850 mb temperatures are very high along the I-95 corridor and slightly cooler further inland. Winds are more consistently south - southwest at all sites than under other episode types and almost no northwest-north-northeast winds are seen at LaGuardia in contrast to other types. Resultant wind vector magnitudes are much higher

than average, consistent with the steady southwest flow. Southwest – northeast pressure gradients along the I-95 corridor and from Pittsburgh to Buffalo are positive, consistent with the southwest flow. Average east-west pressure gradients are near zero. These conditions result in above average ozone levels all along the I-95 corridor with advection north into coastal and interior New England. Ozone levels are slightly below average in the extreme southeastern and western OTR.

"Type D" – High ozone in the western OTR. This pattern is characterized by an area of mean upper level divergence with associated cut-off low at 850 mb off the Outer Banks of North Carolina. A relatively vigorous mean low pressure center can be seen at the surface. An east-west temperature gradient across the OTR is evident at 850 mb. Surface temperatures along the I-95 corridor and in Albany are below average but surface temperature is above average at Buffalo. The 850 mb heights are the highest of any episode type due to a strong ridge over New England. Surface winds are mostly east-northeast along the I-95 corridor from DC to New York but more variable further north. In contrast to episode types A, B, or C, the southwest-northeast pressure gradients along the I-95 corridor are negative, consistent with the northeast surface winds. West-east pressure gradients are flat. These conditions result in below average ozone in the eastern OTR due to the on-shore flow in the north and cyclonic conditions in the south but above average ozone levels in the western OTR due to stable, warm conditions with light winds.

"Type E" – Generally low ozone throughout the OTR. This category includes days with moderately low to lowest average ozone readings of all OTR exceedance days used in the characterization scheme. The Bermuda high is shifted east relative to the other types and flow over the southeastern U.S. is only weakly anti-cyclonic with a nearly zonal flow pattern at the 850 and 500 mb levels over the OTR. Temperatures at the surface and aloft are the coolest of any episode type. While winds aloft are nearly westerly, surface winds are generally south-southeast over most of the OTR. The southwest-northeast pressure gradients are negative along the I-95 corridor and east-west gradients are positive, consistent with the southeast flow. These conditions result in below average ozone throughout the OTR due to the relatively low temperatures and southeasterly onshore flow at coastal locations.

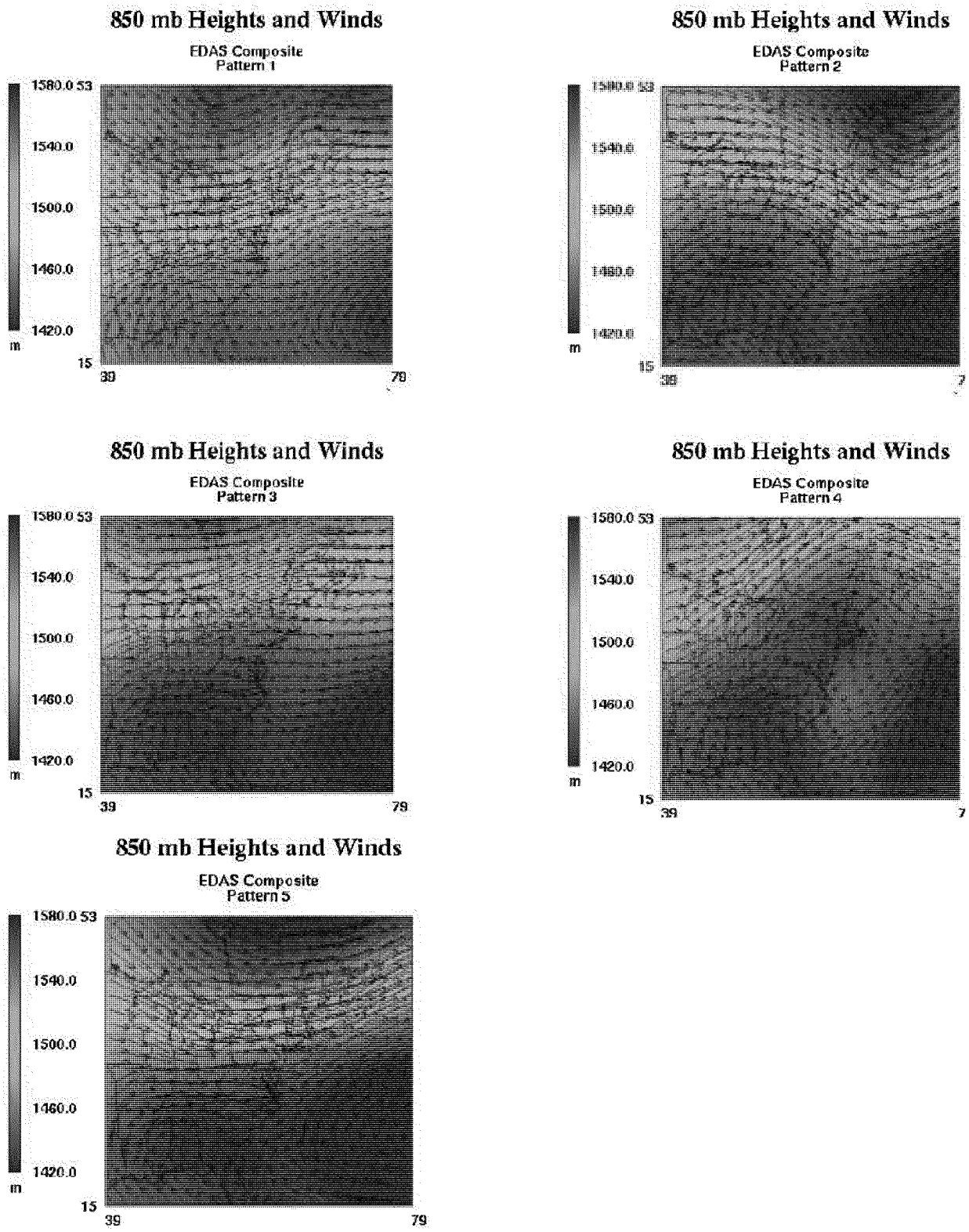


Figure B-1. Average 850 mb height and wind fields for each episode (pattern) type identified by Stoeckenius and Kemball-Cook (pattern numbers refer to the episode types listed in text): Pattern 1 = Episode Type E, 2 = B, 3 = A, 4 = D, 5 = C) (Figure 3-2 of Stoeckenius & Kemball-Cook (2005)).

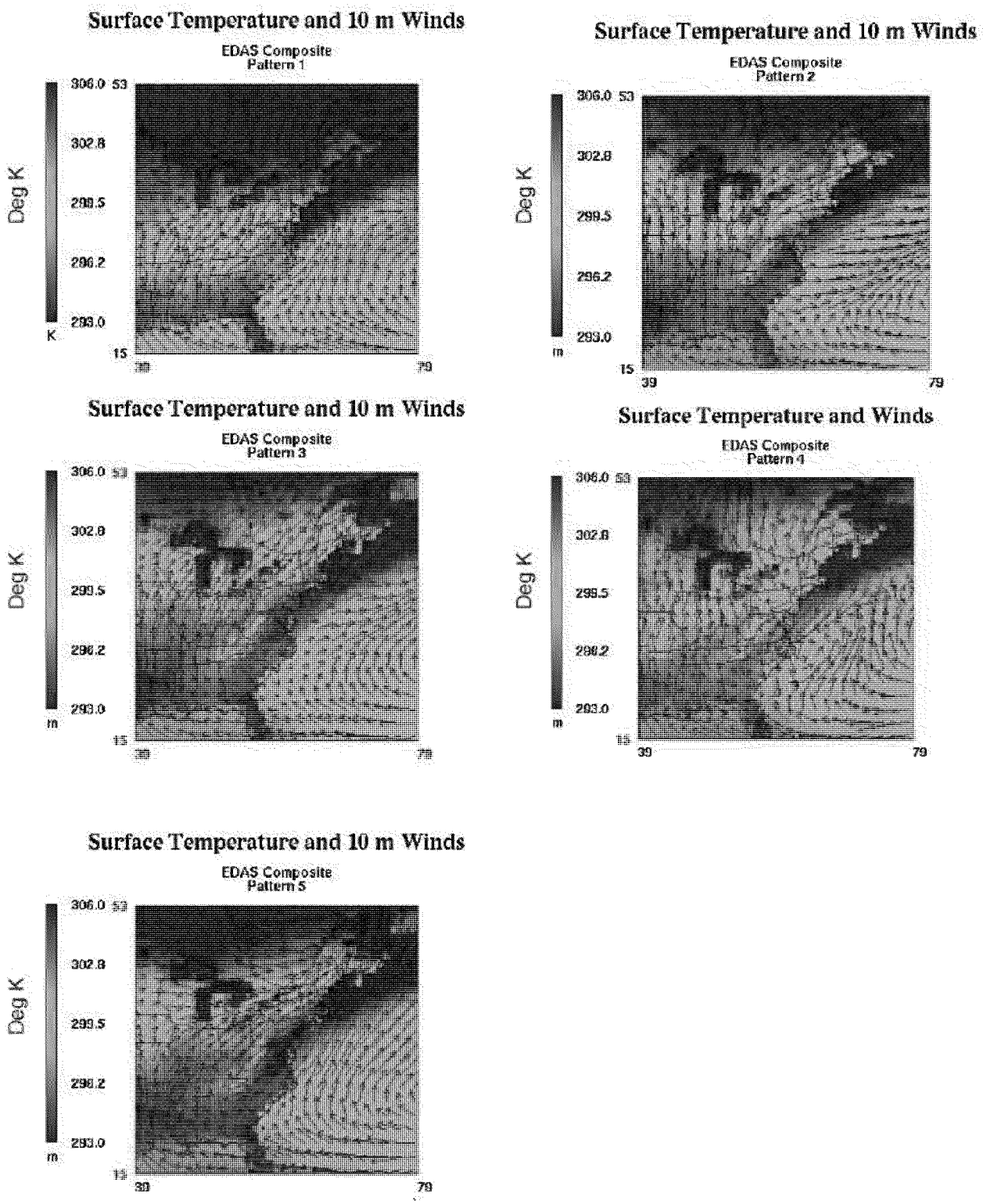


Figure B-2. Average surface temperature and 10 m wind fields for each episode (pattern) type identified by Stoeckenius and Kemball-Cook (pattern numbers refer to the episode types listed in text): Pattern 1 = Episode Type E, 2 = B, 3 = A, 4 = D, 5 = C) (Figure 3-5 of Stoeckenius & Kemball-Cook (2005)).

Appendix C: The sea breeze and flow over the ocean in-depth

Appendix C: The sea breeze and flow over the ocean in-depth

Figure C-1 displays a general description of ozone transport in coastal New England. This figure shows 90th percentile ozone concentration wind direction plots at four sites along the coast. For the first site, Lynn, MA, high ozone days are affected mainly by winds from the southwest bringing ozone up the coast to the site. At the second site, Newbury, MA, winds arrive to the site from two directions, up the coast, in a similar pattern seen at Lynn, but also from the ocean. The high ozone days therefore can result from ozone and its precursors coming from inland or from the ocean in the sea breeze. At the two northern sites in Maine, Cape Elizabeth and Acadia National Park, winds on high ozone days come mostly off the ocean. This is mainly due to the orientation of the Maine coastline, as summertime winds generally come from the southwest, therefore traveling over the ocean before arriving to these sites.

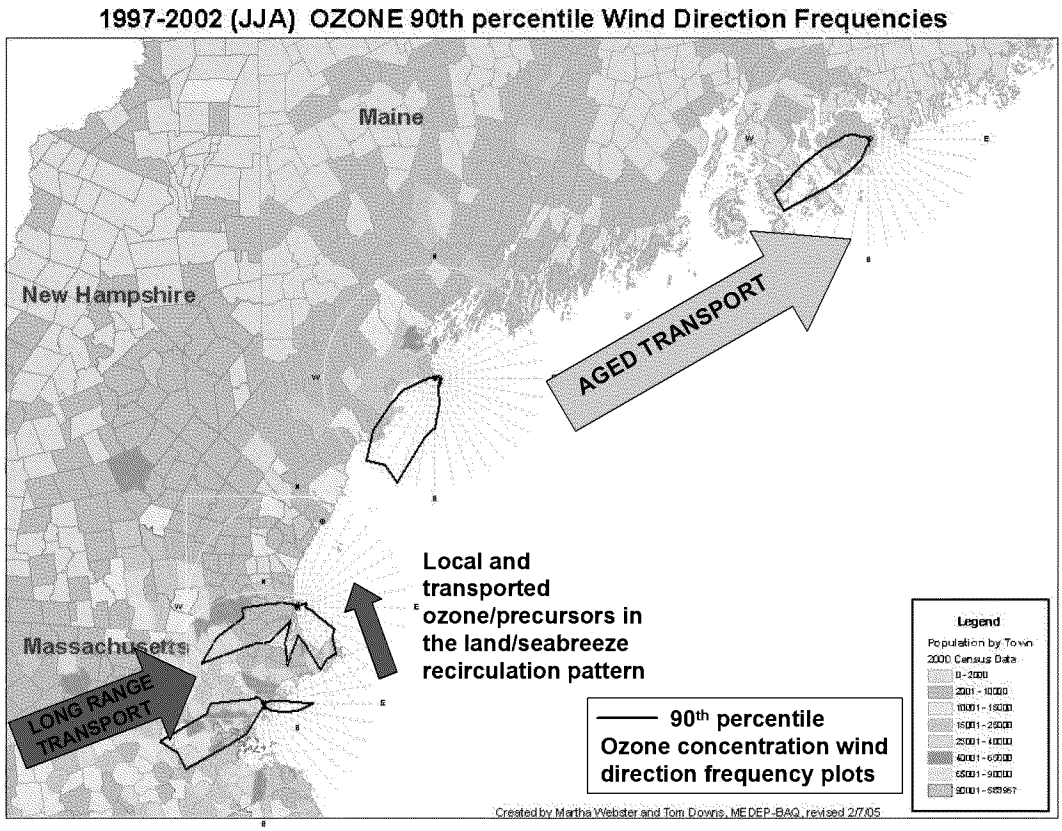


Figure C-1. 90th percentile ozone concentration wind direction frequency plots at four coastal sites in northern New England (figure provided by Tom Downs, Maine Department of Environmental Protection).

Figure C-2 displays wind directions at Newbury, MA on June 29, 1997 where hourly ozone concentrations ranged from 88 ppb to 107 ppb during the afternoon hours and a sea breeze can be identified. The forward trajectory starting in Boston at 6 a.m. shows winds pushing air from the Boston metro area out into the harbor throughout the day. The hourly ozone wind rose at Newbury, MA shows the afternoon wind shift that

occurred on this day where vector direction indicates wind direction and magnitude indicates ozone concentrations. Morning winds came from a west/northwesterly direction when hourly ozone concentrations at the site ranged from 47 to 68 ppb. At 1 p.m., the wind shifted direction, now coming off the ocean from the southeast, accompanied by a 20 ppb increase in hourly ozone. Hourly ozone levels then continued to increase in the early afternoon, peaking at 107 ppb at 3 p.m. This increase in ozone levels accompanying a shift in winds pushing air masses from the ocean to a coastal site illustrates how the sea breeze can contribute to poor air quality along the coast. The poor air quality could be a result of polluted air from Boston being pushed back to the site in the sea breeze. Sea breezes, however, are not always associated with worsening air quality as the afternoon sea breeze doesn't always bring in polluted air.

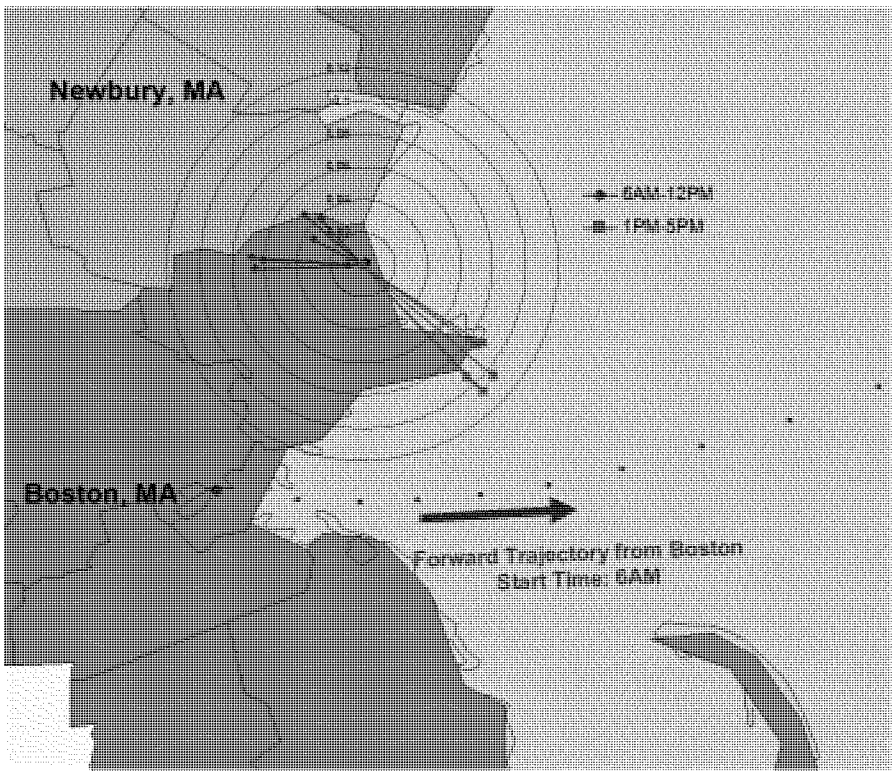


Figure C-2. Example of a sea breeze effect occurring in Newbury, MA on June 29, 1997 (figure data provided by Tom Downs, Maine Department of Environmental Protection).

At sites further north in Maine, the sea breeze effect is less dramatic due to the orientation of the Maine coastline. Figure C-3 shows a similar ozone wind rose plot for Cape Elizabeth, ME on the same day illustrated in Figure C-2. With the exception of the winds at 6 a.m. that came from the northwest, the winds arrived to the site from the southwest direction. There are some slight shifts in wind direction, particularly a shift after 5 p.m. that began to bring winds from the inland side of the coast, but it is difficult to determine whether these shifts are due to a sea breeze effect or if the evening shift is due to the weakened sea breeze. Winds are generally moving up the coast, over water, and winds in the same direction of the sea breeze can bring poor air quality. On this day, ozone concentrations ranged between 89 and 102 ppb between 3 p.m. and 7 p.m.

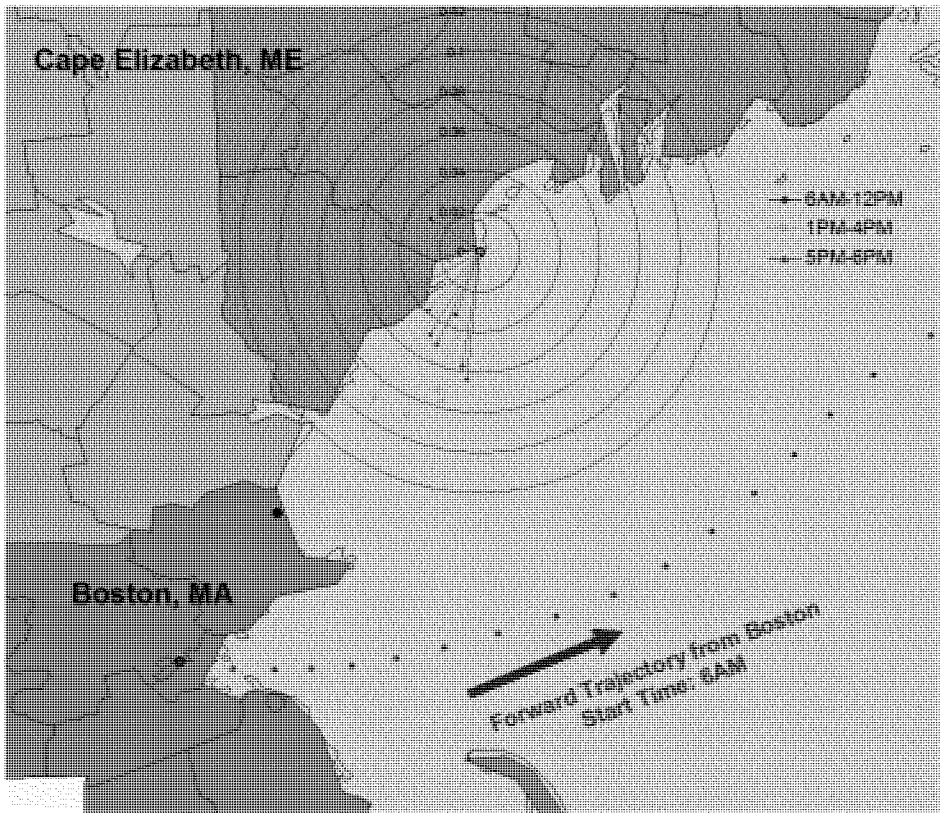


Figure C-3. Wind directions and ozone concentrations at Cape Elizabeth, ME on June 29, 1997 (figure data provided by Tom Downs, Maine Department of Environmental Protection).

Transport over the ocean is commonly observed downwind of the New York City metropolitan area during the summer months due its proximity to the Atlantic Ocean and the Long Island Sound. The four pollution rose plots presented in Figure C-4 represent the frequency of wind direction on the highest 10 percentile ozone concentration days from April 1 to October 31 during the years 1997 to 2005. The winds on the highest ozone days point at the New York City metropolitan area at all locations along the Connecticut shoreline. Going along the Connecticut shoreline to the east (towards Groton), the predominant wind frequency direction shifts increasingly to the west, tracking the upwind location of the New York City metropolitan area.

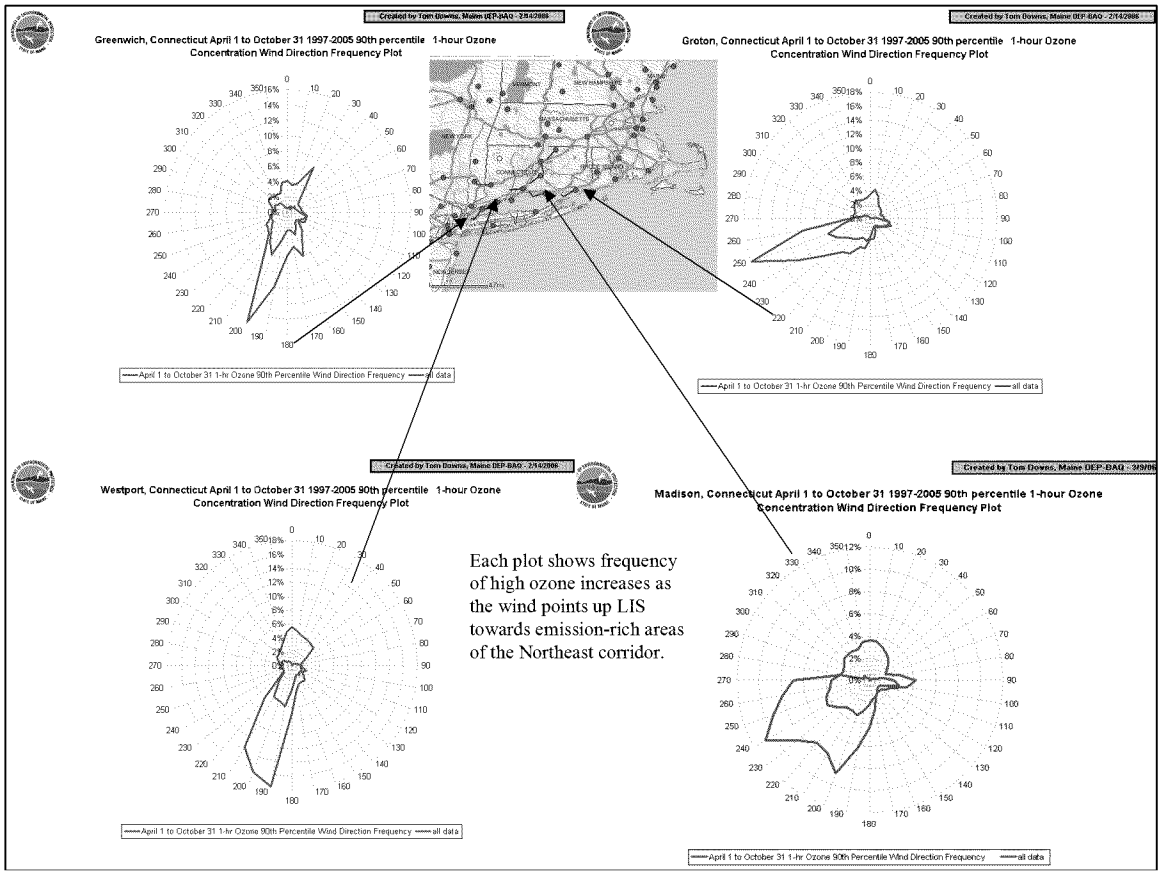


Figure C-4. Wind rose plots along Connecticut shoreline for the time period April 1 to October 31 during the years 1997 through 2005. The elongated red outlines pointing to the southwest to west are wind directions on the highest 10 percentile ozone concentration days at four Connecticut coastal locations. For comparison, the blue outlines are the wind rose plots for all days over the same period. The high ozone day wind rose plots indicate pollution flow over Long Island Sound that tracks the upwind location of the New York City metropolitan area.

Appendix D: Observed nocturnal low level jet across the OTR, July 2002

Appendix D: Observed nocturnal low level jet across the OTR, July 2002

An example of the nocturnal low level jet across the OTR can be seen on the nights of July 22 through July 24, 2002, as night time winds at altitudes between 450 m and 1500 m were observed at several coastal sites. Figure D-1 shows wind profiler data on the night of July 22-July 23, 2002 for five sites along the east coast: Fort Meade, MD (FME), Orange, MA (ORE), Stow, MA (STW), Appledore Island, ME (ADI), and Pease Air Force Base, NH (PSE). These wind "barb" plots show wind direction (direction of arrow indicating where wind is coming from), wind speed (wind barb color), time of day (UTC time, x-axis), and altitude (meters, y-axis). The location of the nocturnal low level jet appears within the circle in each wind barb plot of Figure D-1. The figure shows a weak nocturnal low level jet at the southernmost site, Fort Meade, with wind speeds of 15 to 25 knots between 300 m and 500 m in the early part of the night. Further north, the nocturnal low level jet is more pronounced with wind speeds between 500 m and 1500 m above ground reaching 40 knots. Figure D-1 shows on this day the nocturnal low level jet extending from Maryland up through southern Maine. In addition, the wind barb plots show the northeasterly direction of the nocturnal low level jet. Above this jet, we see slower winds coming from the west to all the sites.

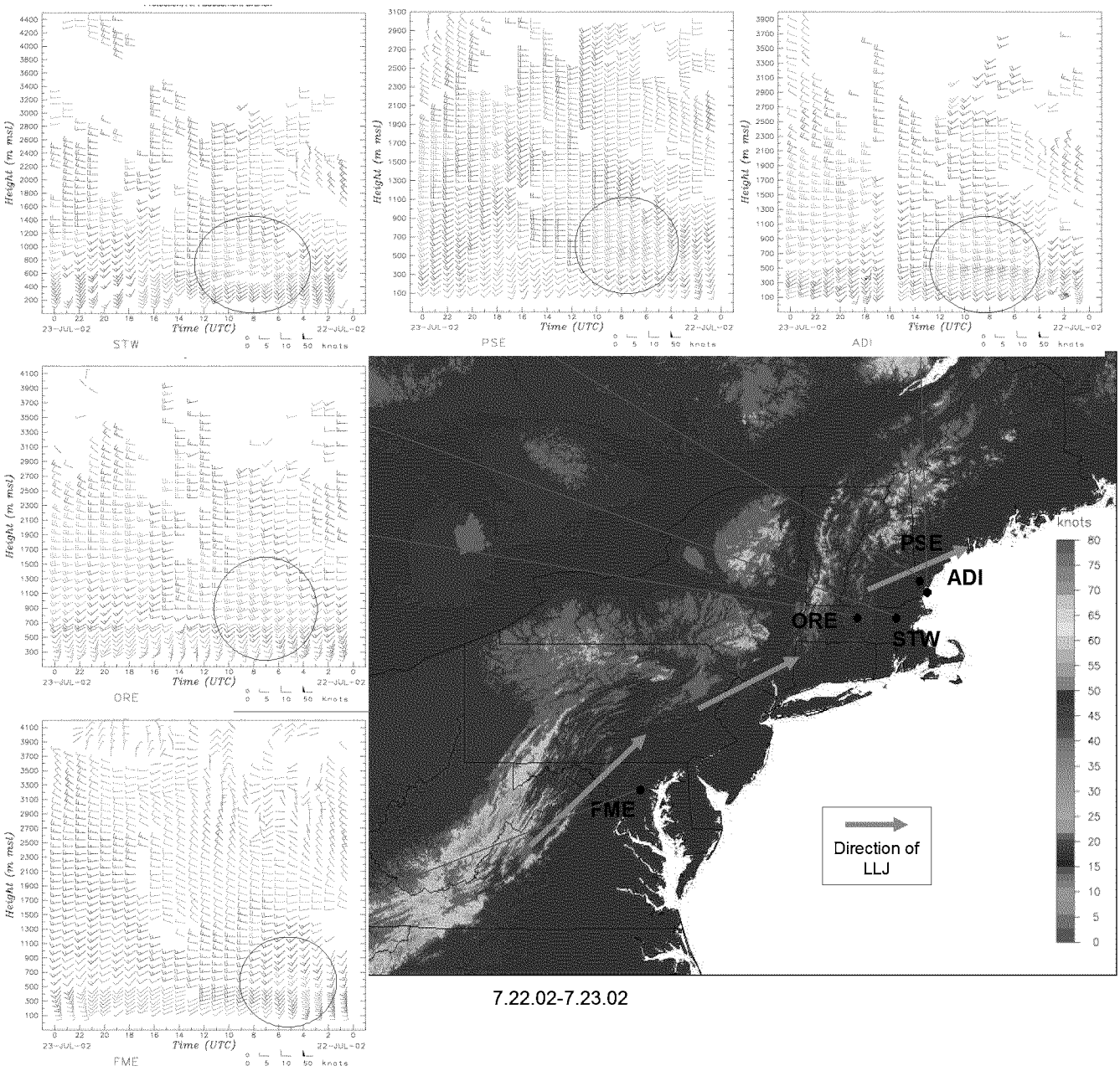


Figure D-1. Nocturnal low level jet on July 22 – 23 , 2002. Note: Circles in the wind barb plots indicate the location of the nocturnal low level jet.

Figure D-1 shows that throughout the night, the nocturnal low level jet travels in a northeasterly direction along the east coast. The pollution implications of this nocturnal low level jet episode can be seen in Figure D-2. The Cadillac Mountain ozone monitor is located on the coast of Maine at an elevation of 466 m. At this elevated position, we can see how the nocturnal low level jet affects overnight and early morning ozone levels. Between midnight and 4 a.m. during the northeasterly nocturnal low level jet, hourly ozone concentrations at Cadillac Mountain are between 70 ppb and 80 ppb. Ozone levels

had begun to increase early in the evening on July 22 and continued to increase throughout the night and peak at 3 a.m. This increasing nighttime ozone at an elevated position corresponds to the nocturnal low level jet bringing air up the coast during the night. Conversely, at Cape Elizabeth, a ground level site relatively close to Cadillac Mountain, night time ozone levels are much lower than on top of Cadillac Mountain. This difference in ozone at upper and lower levels shows how the nocturnal inversion can isolate air masses above and below the inversion.

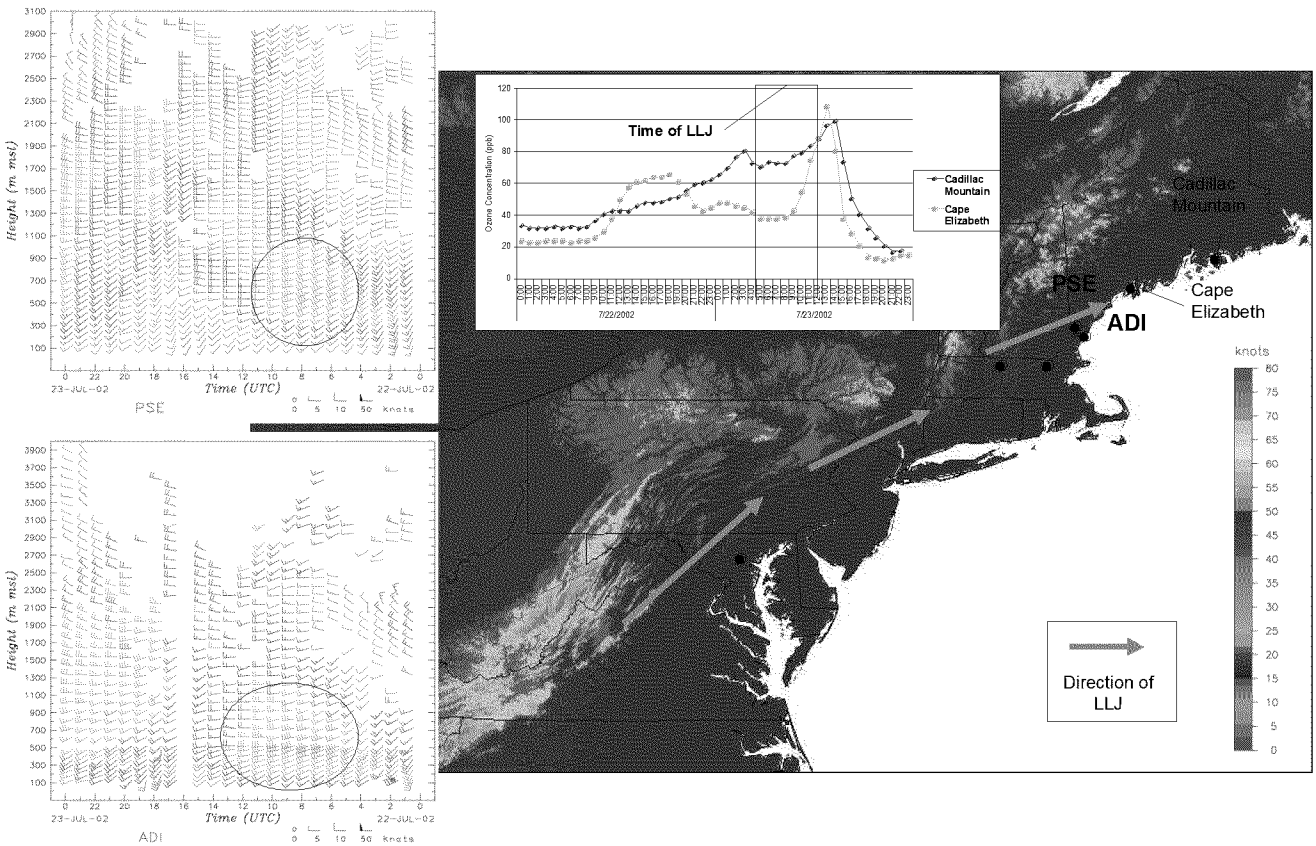


Figure D-2. Nocturnal low level jet with hourly ozone concentrations at Cadillac Mountain, ME and Cape Elizabeth, ME on July 22 – 23, 2002. Note: Circles in the wind barb plots indicate the location of the nocturnal low level jet.

The air mass affecting early morning ozone concentrations in Figure D-2 can be roughly tracked using wind speed and wind direction information from Cadillac Mountain, Pease, Appledore Island, and Orange. Assuming the nocturnal low level jet occurs for five hours that night (based on neighboring wind barb plots), the air mass arriving at Cadillac Mountain at 3 a.m. during peak ozone conditions was over central Massachusetts around 11 p.m. on July 22 when the nocturnal low level jet began to form. Tracking this farther back shows that the air mass affecting Cadillac Mountain was over western Connecticut around 6 p.m. on July 22. Looking at ozone levels in Cornwall, CT, we see that high ozone conditions existed in this region during the afternoon of July 22 with the average hourly ozone at 112 ppb between 4 p.m. and 7 p.m. Elevated ozone from this region first slowly traveled up the coast in the evening. When the nocturnal low level

jet formed, it quickly pushed ozone up the coast affecting ozone levels at Cadillac Mountain, an elevated site in the jet, in the early morning hours (~3 a.m.).

Figure D-3 shows wind profiler information for the next day, July 24, 2002. In this case we see a stronger nocturnal low level jet between midnight and 8am that originates further to the south. The Fort Meade and Rutgers (RUT) sites show the nocturnal low level jet in the early part of the evening with flow in the northeasterly direction. At higher altitudes slower winds from the west pass over the nocturnal low level jet. Further north, a strong nocturnal low level jet can be seen at Stow, Appledore Island, and Pease. It is difficult to determine if a nocturnal low level jet exists at Orange as high winds continue at the upper altitudes and data are missing for the highest altitudes. Figure D-3 demonstrates an example of the nocturnal low level jet passing along the east coast as far south as Maryland and as far north as southern Maine.

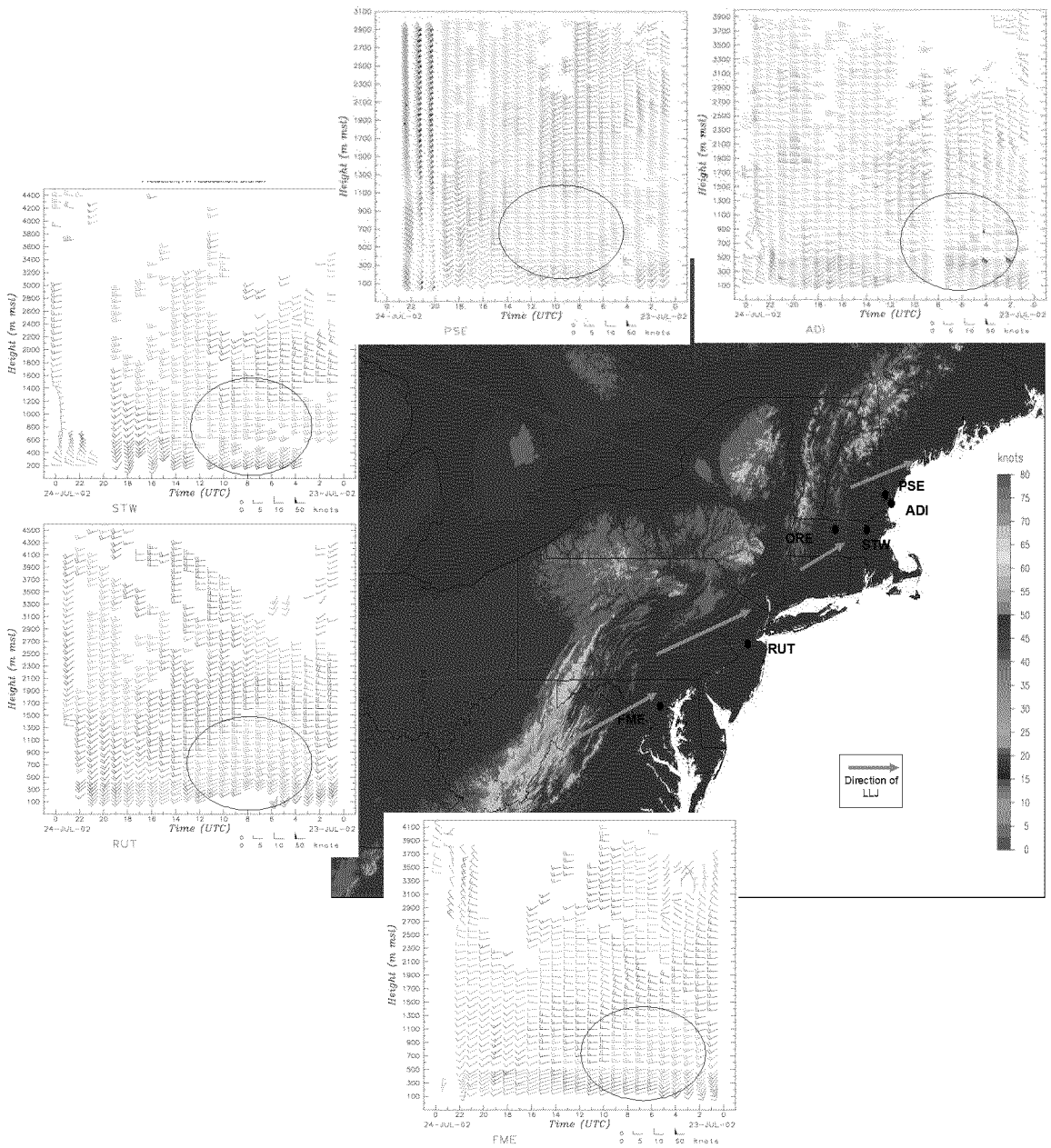


Figure D-3. Nocturnal low level jet on July 23 – 24 , 2002. Note: Circles in the wind barb plots indicate the location of the nocturnal low level jet. Data are inconclusive for identifying a nocturnal low level jet at Orange, MA.

Figure D-3 shows that the nocturnal low level jet occurred on the night of July 23-24 as it did on the previous night. Figure D-4 shows ozone levels overnight on the July 23-24 at Cadillac Mountain and Cape Elizabeth. In this case, we see that low ozone is occurring at both sites during the early hours of July 24. Applying the same methods utilized earlier, wind speed and wind direction information from Cadillac Mountain indicate that the air arriving at Cadillac Mountain was also roughly over central Massachusetts at 10 p.m. on July 23 (same wind direction and wind speed as previous day). Wind profiler data show that winds moved this air mass from eastern New York and western Connecticut in the late afternoon. Average ozone levels between 4 p.m. and 7 p.m. were 53 ppb at Cornwall, CT. Therefore, much like on the previous day, air masses were tracked back to the western Connecticut area upwind. In this case, however, low levels of ozone existed in the air mass.

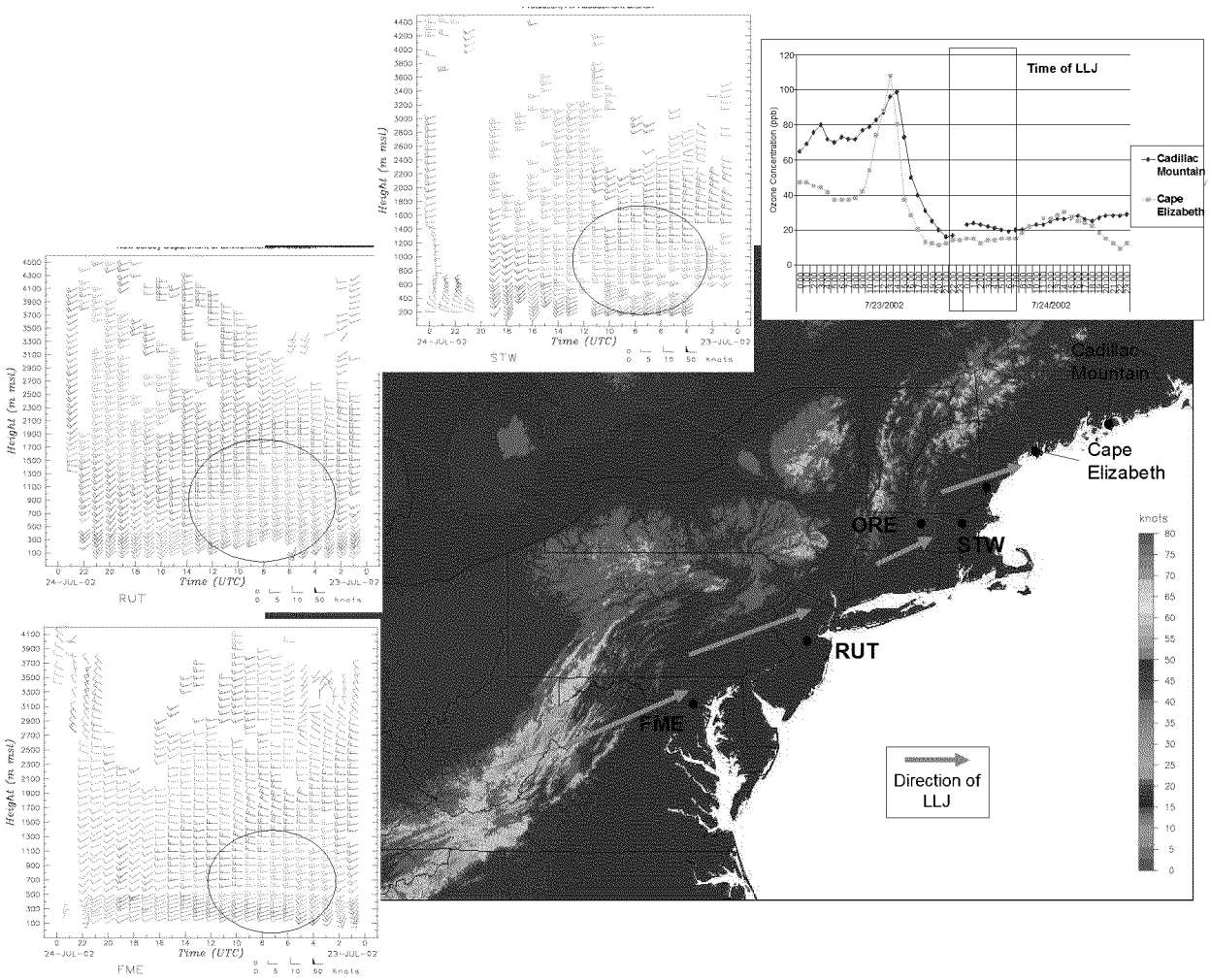


Figure D-4. Nocturnal low level jet with hourly ozone concentrations at Cadillac Mountain, ME and Cape Elizabeth, ME on July 23 – 24, 2002. Note: Circles in the wind barb plots indicate the location of the nocturnal low level jet. Data are inconclusive for identifying a nocturnal low level jet at Orange, MA.

Examining the wind profiler data from 4 p.m. to midnight on July 23 (Figure D-1 and Figure D-3), we see high winds at all altitudes developing throughout the region. Figure D-5 shows that these high winds are part of a weather front that passed through the region in the afternoon of July 23. This corresponds with the sharp drop in ozone levels at Cornwall, CT, Cadillac Mountain, ME, and Cape Elizabeth, ME (Figure D-6) as the front pushed ozone out of the region. This explains the low levels of ozone seen at Cadillac Mountain during the nocturnal low level jet in the early hours of July 24. This example demonstrates that not all nocturnal low level jets are associated with high ozone levels at elevated sites. A necessary condition for the transport of ozone in a nocturnal low level jet is the presence of upwind elevated ozone levels. The front that pushed through the region on the previous day resulted in "clean" air being transported in the nocturnal low level jet.

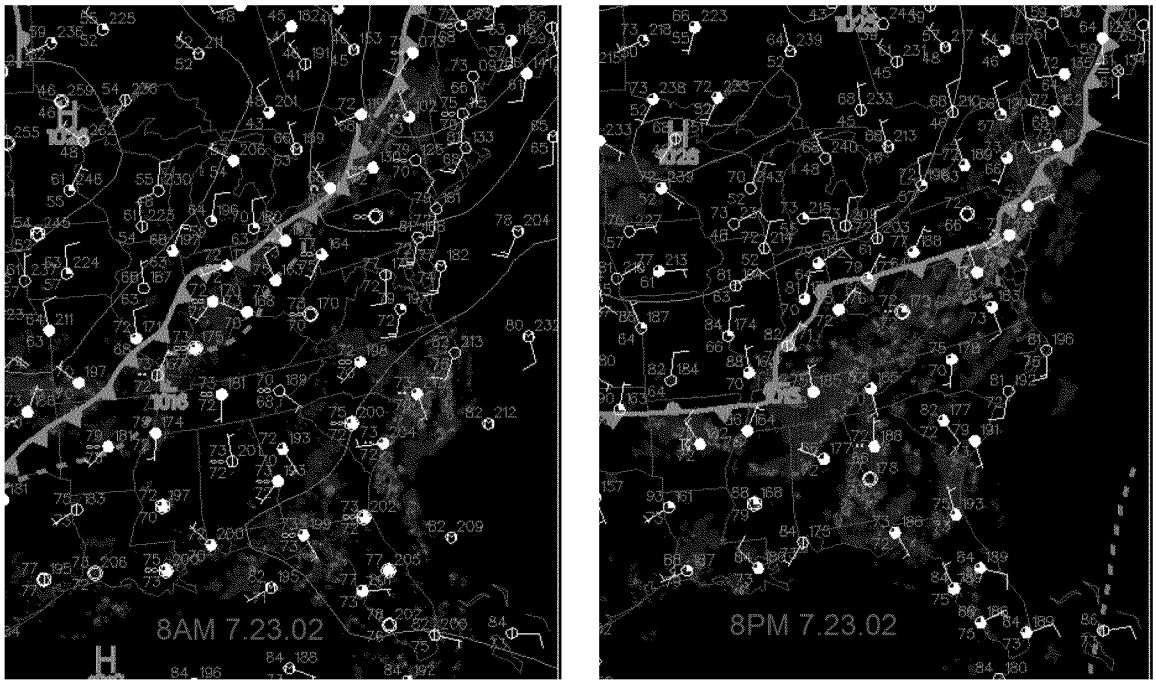


Figure D-5. Weather map displaying a front passing through the East on July 23, 2002.

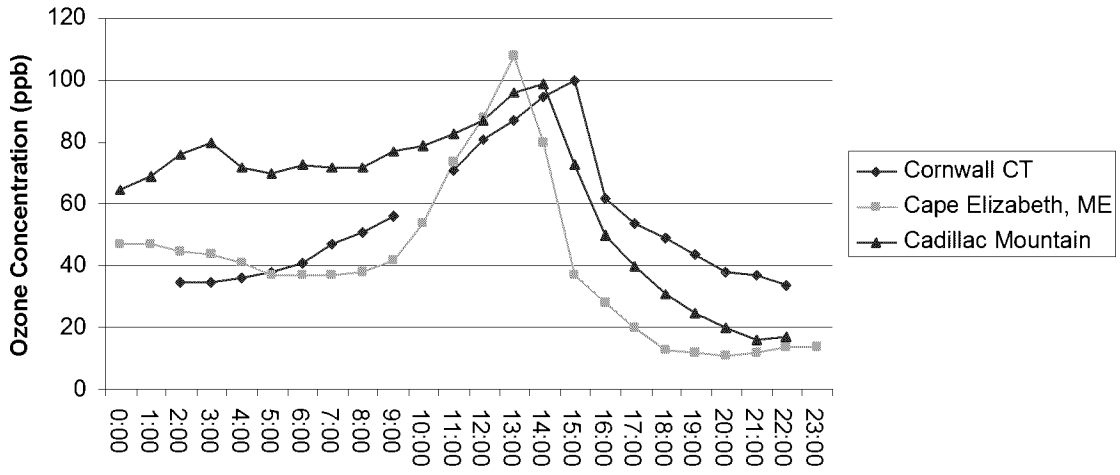


Figure D-6. Hourly ozone concentrations on July 23, 2002 at three sites.

Appendix E: Contributions to the ozone reservoir

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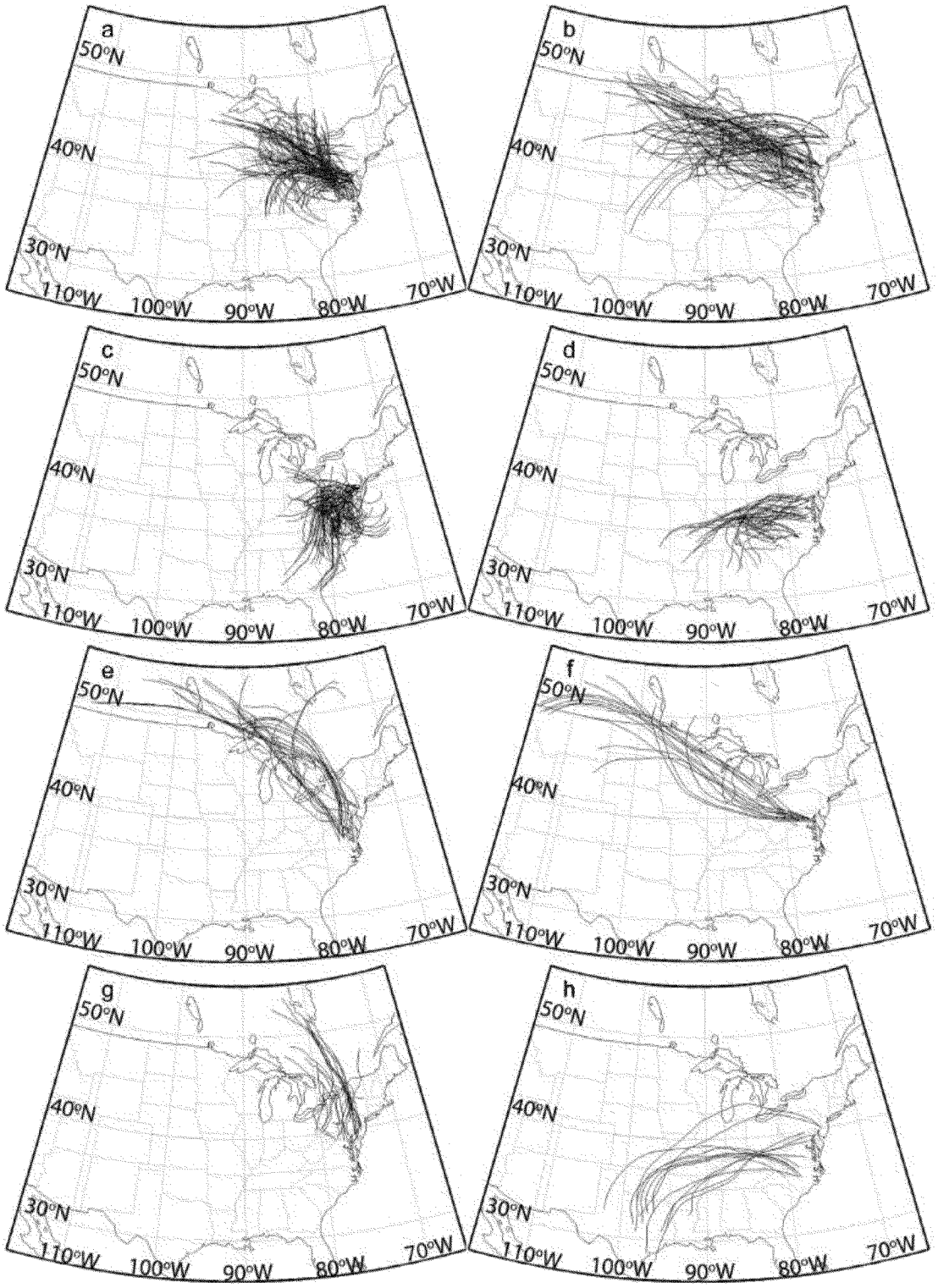
Contributions to the ozone reservoir can come from two sources. The first is from the residual local ozone and precursors in the atmosphere at sunset. The second is from transport of ozone and precursors from outside of the local region. To identify these outside sources, Taubman *et al.* (2006) have made an analysis of the complete set of aircraft flights undertaken by RAMMPP between 1992 and 2003 in the middle and southern portions of the Ozone Transport Region. Initially, the data were divided into morning and afternoon profiles to identify diurnal patterns. Little diurnal variation was observed in the carbon monoxide and sulfur dioxide profiles. The ozone values were greater in the afternoon than the morning, while ozone in the lower free troposphere (i.e., above the boundary level), where long-range transport is possible, was consistently ~55 ppb.

Transport patterns and source regions during summertime haze and ozone episodes were analyzed with a cluster analysis of back trajectory data. Eight clusters were identified, which were then divided into morning and afternoon profiles. Table G-1 lists the characteristics of each cluster, and Figure G-1 shows the back trajectories calculated for each profile divided by cluster at an altitude of 2000 meters. The median profile values were calculated and statistical differences were determined using a nonparametric procedure. When the greatest trajectory density lay over the northern Ohio River Valley, which has large NO_X and sulfur dioxide sources, the results were large ozone values, a large SO_2/CO ratio, large scattering particles, and high aerosol optical depth over the mid-Atlantic U.S. In contrast, relatively clean conditions over the mid-Atlantic occurred when the greatest trajectory density lay over the southern Ohio River Valley and nearly missed many large NO_X and SO_2 sources. The greatest afternoon ozone values occurred during periods of stagnation that were most conducive to photochemical production. The least pollution occurred when flow from the north-northwest was too fast for pollution to accumulate and when flow was from the north, where there are few urban or industrial sources.

Similar results were obtained in the northern portion of the Ozone Transport Region. Periods of ozone greater than 80 ppb measured at the summit of Mount Washington (elevation 1910 m) in northern New Hampshire over the summers of 1998 to 2003 coincided with westerly (71 percent) and southwesterly (29 percent) transport, based on backward trajectory analyses (Fischer *et al.*, 2004). Low ozone events were more typically associated with transport trajectories from the northwest. Higher ozone transported from industrialized areas to the west/southwest and lower ozone from the northwest has also been found in back trajectory analyses by Yu *et al.* (2009).

Figure G-1: Maps of the 2 km, 48 hr HY-SPLIT back trajectory clusters for mid-Atlantic region



Note: Cluster groupings are a) cluster 1, b) cluster 2, c) cluster 3, d) cluster 4, e) cluster 5, f) cluster 6, g) cluster 7, and h) cluster 8. Figure from Taubman *et al.*, 2006.

In Taubman *et al.* (2006), ozone transport over several hundred kilometers into the mid-Atlantic U.S. was estimated by calculating the ratio of the residual layer ozone between 500 m and 2 km in the upwind morning profiles to the downwind afternoon boundary layer values between 100 m and 2 km. The greatest level of transported ozone (69-82 percent) occurred when the maximum trajectory density lay over the southern and northern Ohio River Valley (clusters 1, 2, 4, and 6); ~59 percent of the total profiles). The least amount of transported ozone (55-58 percent) was associated with fast southwesterly flow (cluster 8; ~3 percent of the total profiles), fast north-northwesterly flow or clean northerly flow from regions with relatively few urban or industrial pollution sources (clusters 5 and 7; ~6 percent of the total profiles), and stagnant conditions within the mid-Atlantic conducive to greater local ozone production (cluster 3; ~27 percent of the total profiles). The average amount of ozone transported into the Baltimore-Washington urban corridor is 64 percent of the total observed ozone in the afternoon boundary layer. If the background ozone is removed, then this value is lowered to 55 percent.

When trajectory density plots were overlaid on maps with the largest annual NO_X and SO_2 emitters, specific source regions were identified. The results indicate that the areas of maximum trajectory density together with wind speed are effective predictors of regional pollution and loadings. Additionally, due to the Lagrangian nature of the dataset, the regionally transported contribution to the total afternoon boundary layer column ozone content in each cluster could be quantified.

Table G-1. Cluster groups for air mass trajectories into mid-Atlantic Region

Cluster	Description	Upwind Region
1	Large ozone values, large SO_2/CO ratio, large highly scattering particles. Moderate northwesterly flow – aged point source air.	Northern Ohio River Valley
2	Small ozone values, large SO_2/CO ratio. Northwesterly flow at higher wind speeds than Cluster 1 – aged po int source air.	Northern Ohio River Valley, extending into the Great Lakes region
3	Large ozone values, small SO_2/CO ratio. Stagnant conditions with light southerly flow.	Central mid-Atlantic region
4	Small ozone values, small SO_2/CO ratio. Moderate southwesterly flow, small pollution loading – fewer point sources.	Southern Ohio River Valley
5	Fairly fast north-northwesterly flow. Flow too fast for pollution to accumulate from source region.	Northern Great Lakes
6	Moderately large ozone values, SO_2/CO ratio very large, smaller less scattering particles. Northwesterly flow, but faster wind speeds than Clusters 1 and 2. Crosses several large SO_2 and NO_X sources.	Northern Ohio River Valley
7	Least pollution of any of the clusters. Flow is out of the north. Relatively cool, dry continental air.	Eastern Ontario, western Quebec
8	Small ozone values, small SO_2/CO ratio. Fast southwest flow. Very few trajectories.	Vicinity of Texas

Consistent results were seen in a trajectory cluster analysis by Hains *et al.* (2007). Groupings of trajectories identified six distinct cluster types associated with ozone in the mid-Atlantic region. Integrated NO_X emissions along the paths of each back trajectory cluster were positively correlated with ozone levels, and large ozone values in several cluster groups were associated with regions of high NO_X source density in the Northern Ohio River Valley.

A study by Davis *et al.* (2010) looked at air mass types coupled with back trajectories that provided results consistent with the studies described above, but which would not have been evident from looking at air mass types or back trajectories alone. For example, warm humid conditions are generally not conducive to ozone formation. Air masses of this type arriving at a site in Shenandoah Valley, Virginia, coming from the north and east have very low ozone concentrations. However, the same air mass type traveling moderate distances from the west at low speed over the Ohio Valley and Midwestern source regions has ozone levels 30 ppb higher than those traveling longer distances from the north or northeast.

References

Davis, R.E., C.P. Normile, L. Sitka, D.M. Hondula, D.B. Knight, S.P. Gawtry, and P.J. Stenger. "A comparison of trajectory and air mass approaches to examine ozone variability." *Atmos. Environ.* **44**, 64–74, doi:10.1016/j.atmosenv.2009.09.038, 2010.

Fischer, E.V., R.W. Talbot, J.E. Dibb, J.L. Moody, and G.L. Murray. "Summertime ozone at Mount Washington: Meteorological controls at the highest peak in the northeast." *J. Geophys. Res.* **109**, D24303, doi:10.1029/2004JD004841, 2004.

Hains, J.C., B.F. Taubman, A.M. Thompson, J.W. Stehr, L.T. Marufu, B.G. Doddridge, and R.R. Dickerson. "Origins of chemical pollution derived from Mid-Atlantic aircraft profiles using a clustering technique." *Atmos. Environ.* **42**, 1727–1741, doi:10.1016/j.atmosenv.2007.11.052, 2008.

Taubman, B.F., J.C. Hains, A.M. Thompson, L.T. Marufu, B.G. Doddridge, J.W. Stehr, C.A. Peity, and R.R. Dickerson. "Aircraft vertical profiles of trace gas and aerosol pollution over the mid-Atlantic United States: Statistics and meteorological cluster analysis." *J. Geophys. Res.* **111**, D10S07, doi:10.1029/2005JD006196, 2006.

Yu, S., R. Mathur, D. Kang, K. Schere, and D. Tong. "A study of the ozone formation by ensemble back trajectory-process analysis using the Eta–CMAQ forecast model over the northeastern U.S. during the 2004 ICARTT period." *Atmos. Environ.* **43**, 355-363, doi:10.1016/j.atmosenv.2008.09.079, 2009.

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 5/16/2017 5:00:00 PM
End Date/Time: Tue 5/16/2017 6:30:00 PM
cmaq_beta2_2020.ppt
Source Apportionment Modeling Options 170515.docx
OTC_Modeling_Committee_Spring_Caucus_2017.pptx

Note this call will be a joint call with MANE-VU TSC during the first portion of the call.
Agenda

1. FLM Modeling Tools
2. 2011 Platform

a. 2020 Modeling Results [attached]
b. Inventory Status
c. Contribution Assessment Planning [attached]

3. Draft Caucus Slides [attached and updated]

---GoToMeeting invitation begins---
Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/ Ex. 6
You can also dial in using your phone.
United States - Ex. 6
Access Code: Ex. 6
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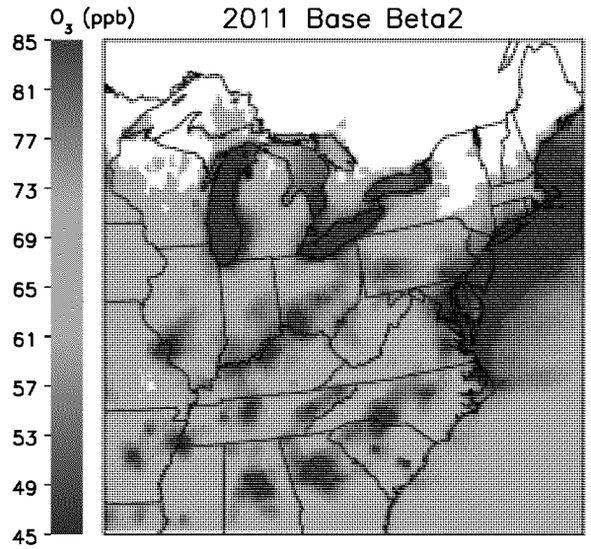
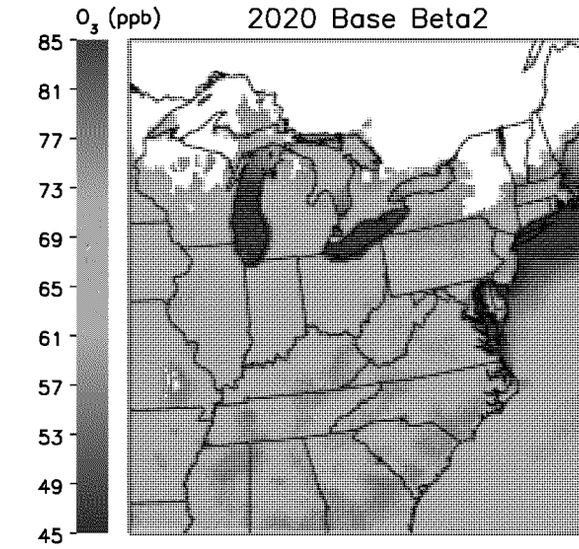
Modeling Committee Update

OTC State Caucus



June 5, 2017



OZONE TRANSPORT COMMISSION

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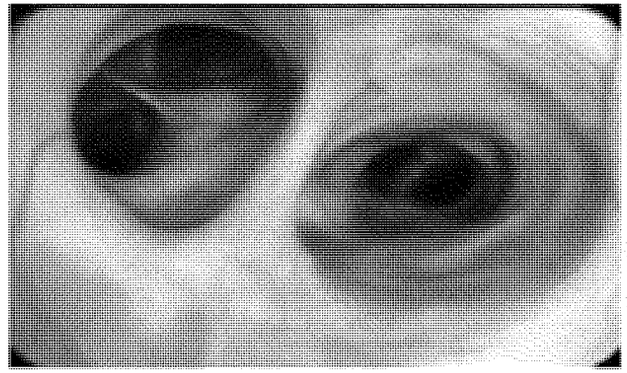
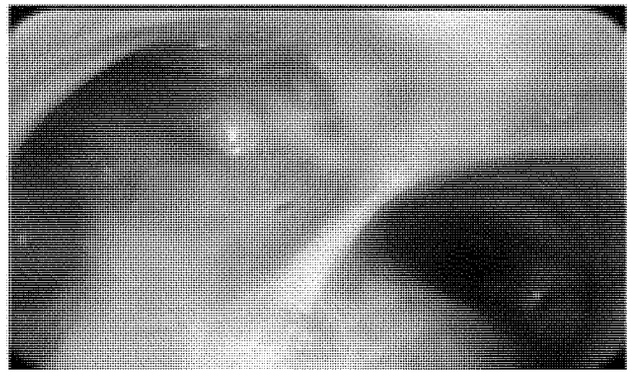
Ozone Health Effects

Healthy airway



Inflamed airway due to ozone inhalation



Ozone Health Effects
• Decreases lung function
• Coughing and pain in the chest
• Increases susceptibility to respiratory infections
• Permanent damage to lungs
• Promotes allergic reactions
• Death

Overview

1. Monitored Results
2. OTC 2011 Modeling Platform
   a) Recent Modeling
   b) Planned Modeling
3. EPA Ozone Contribution Modeling

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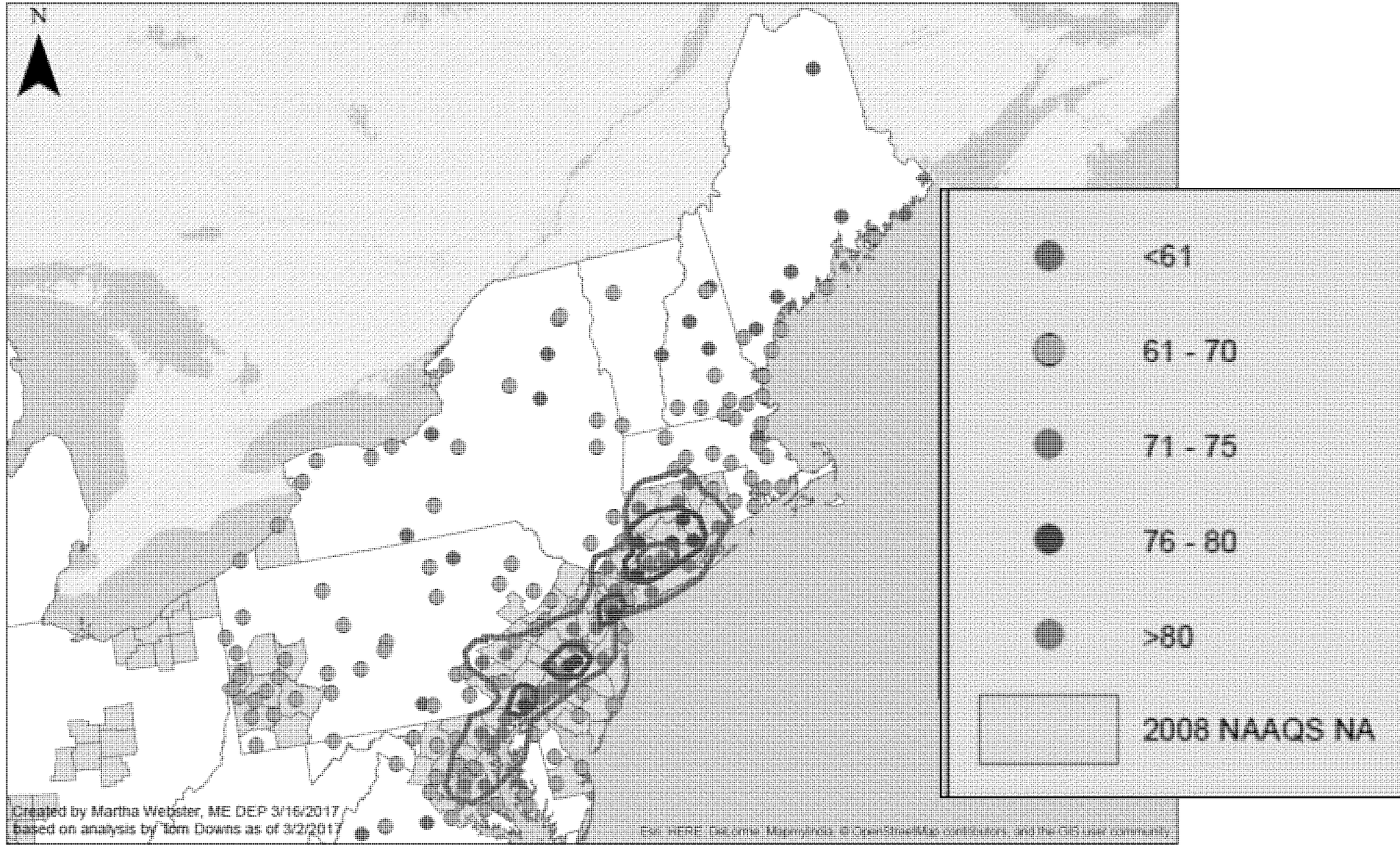
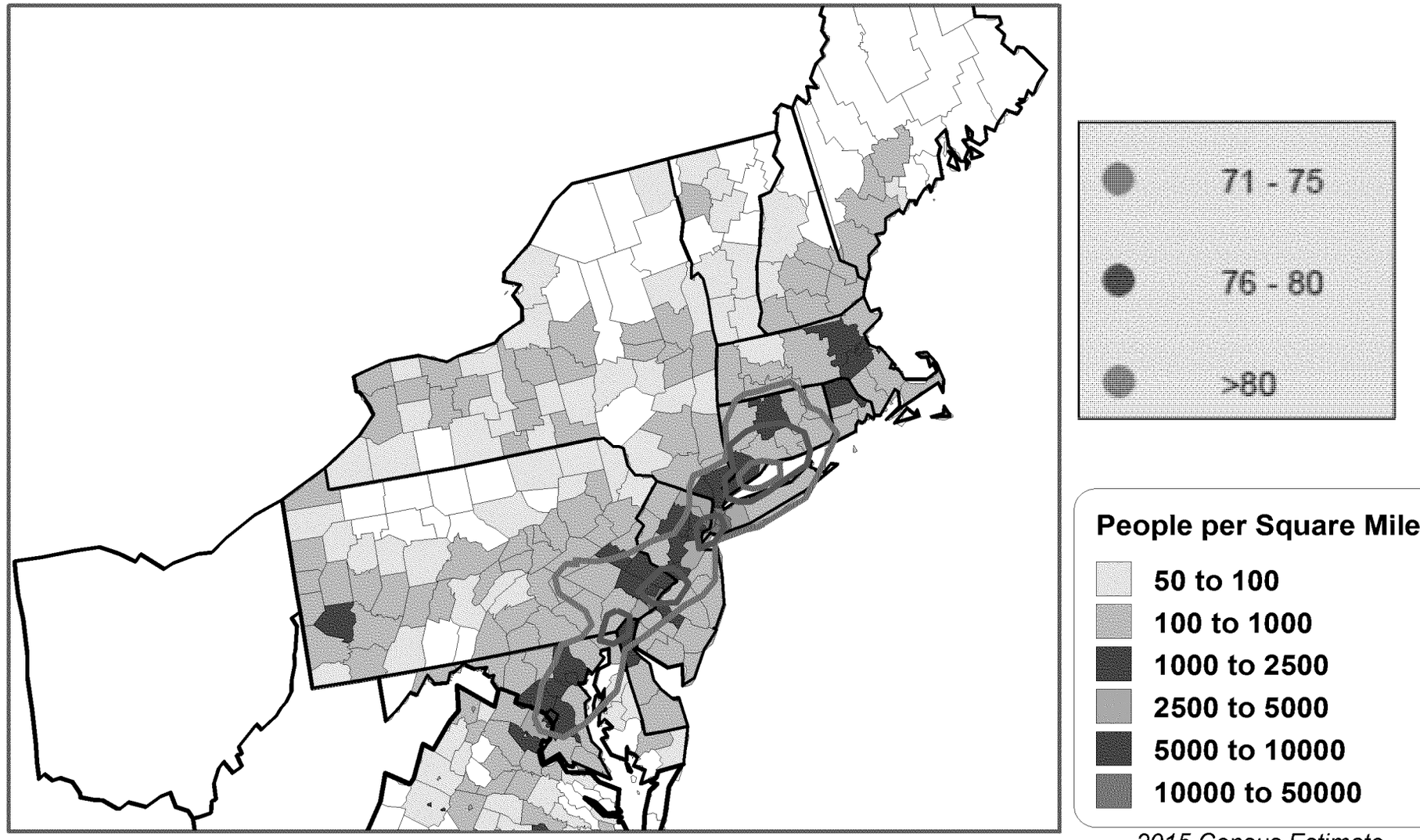
1. 2014-16 8h Ozone Preliminary Design Value

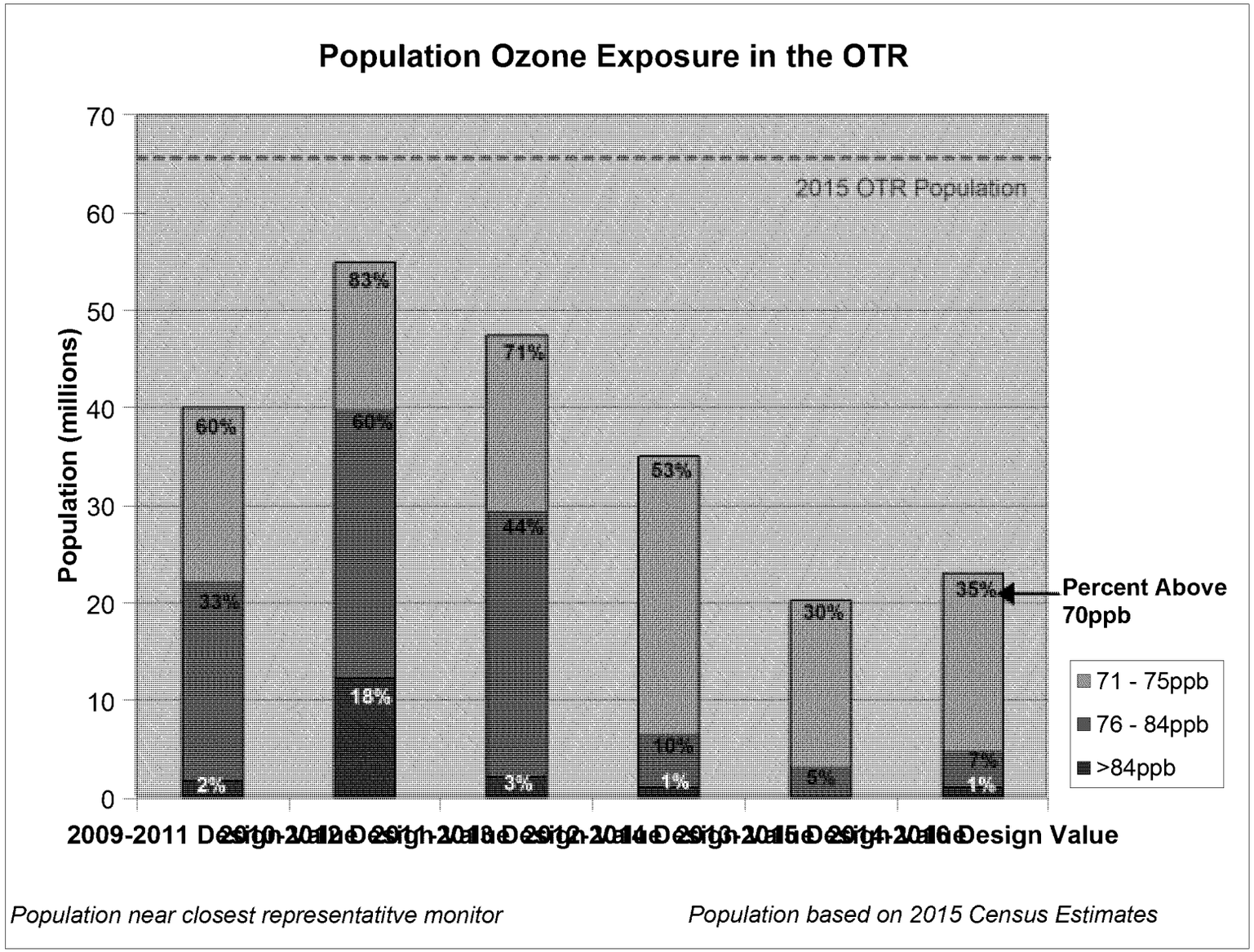


1. OTR Population Density and 2013-15 Design Values

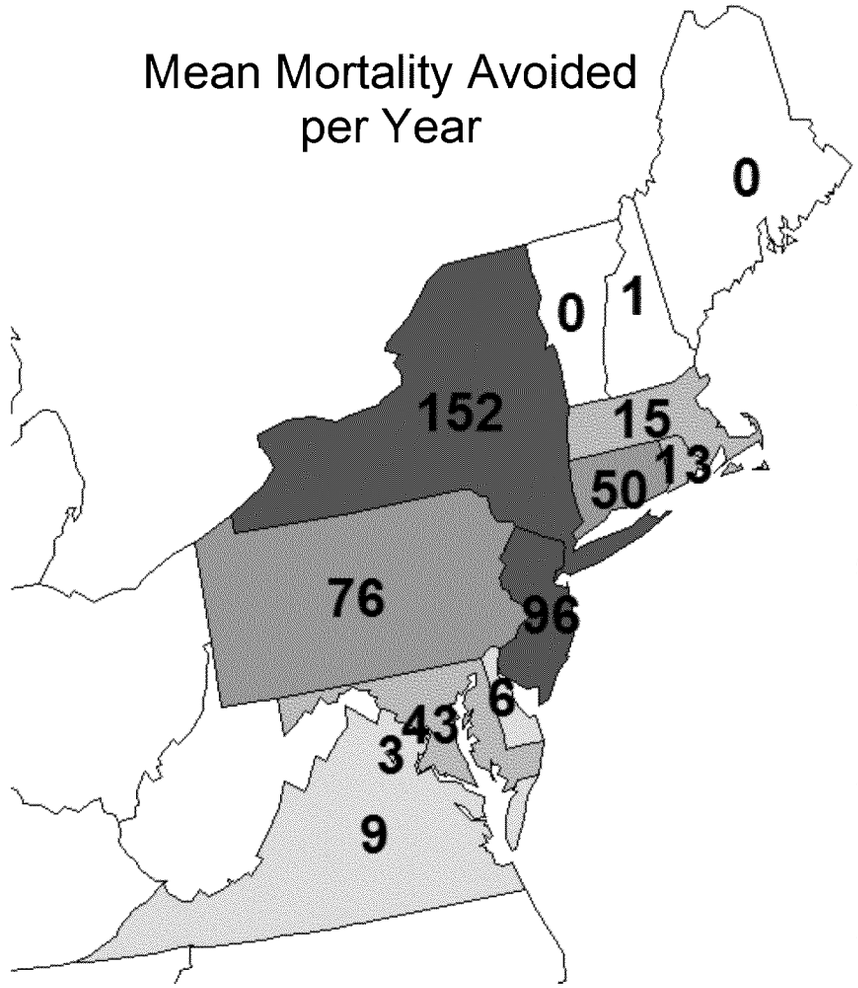


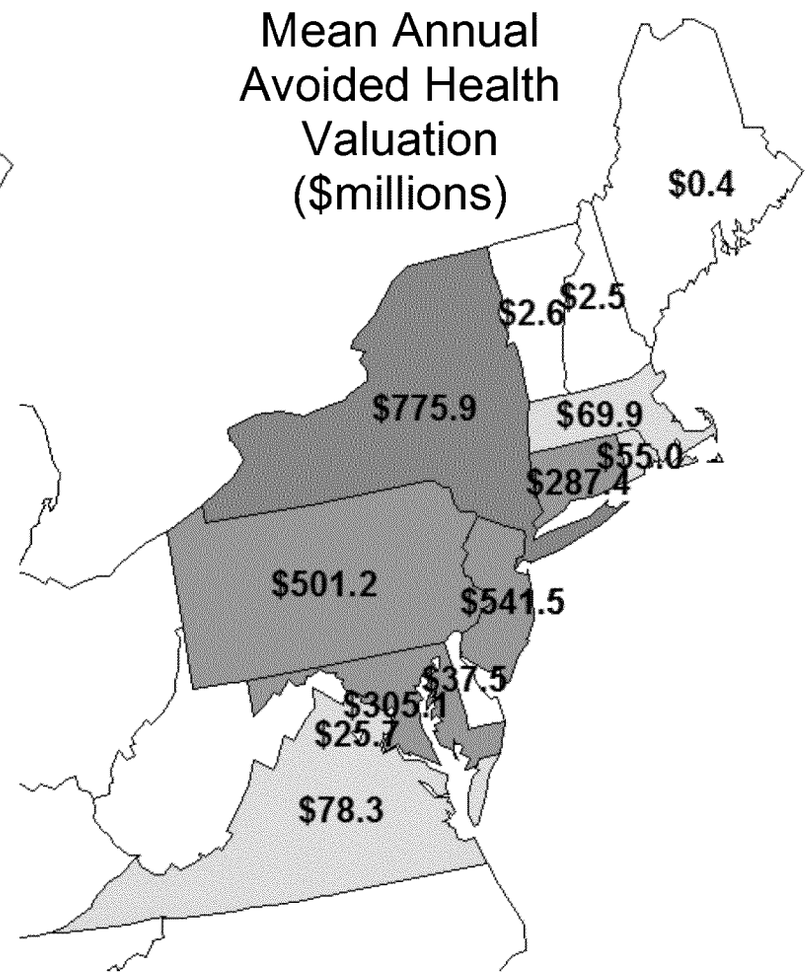
2015 Census Estimate

Population Exposed to Ozone Violations



1. BenMap Modeled Benefits of Fully Meeting the 2008 Ozone NAAQS (70ppb) during 2013-15





Values presented are the mean of calculations and does not reflect uncertainties inherent in the process.

1. 2017 Ozone Season (through 5/2)

- 6 Exceedance days
- 18 Monitors in 8 OTR states
- 7 Monitors in 3 states already exceed for 2015-17 (2015 NAAQS)
- Strong likelihood of warmer than normal summer in the eastern US

State	Monitor	Prelim 2015-17 DV
CT	Westport	75
CT	Stratford	73
CT	Greenwich	71
CT	Danbury	71
NY	NYC-Susan Wagner HS	71
PA	Bristol	71
PA	NEA	72

NJ	Ramapo	4/11	74
NY	Millbrook	4/11	71
PA	South Fayette	4/14	72
PA	NEWG	4/11	71
PA	NEA	4/11	73
VT	Bennington	4/10	71

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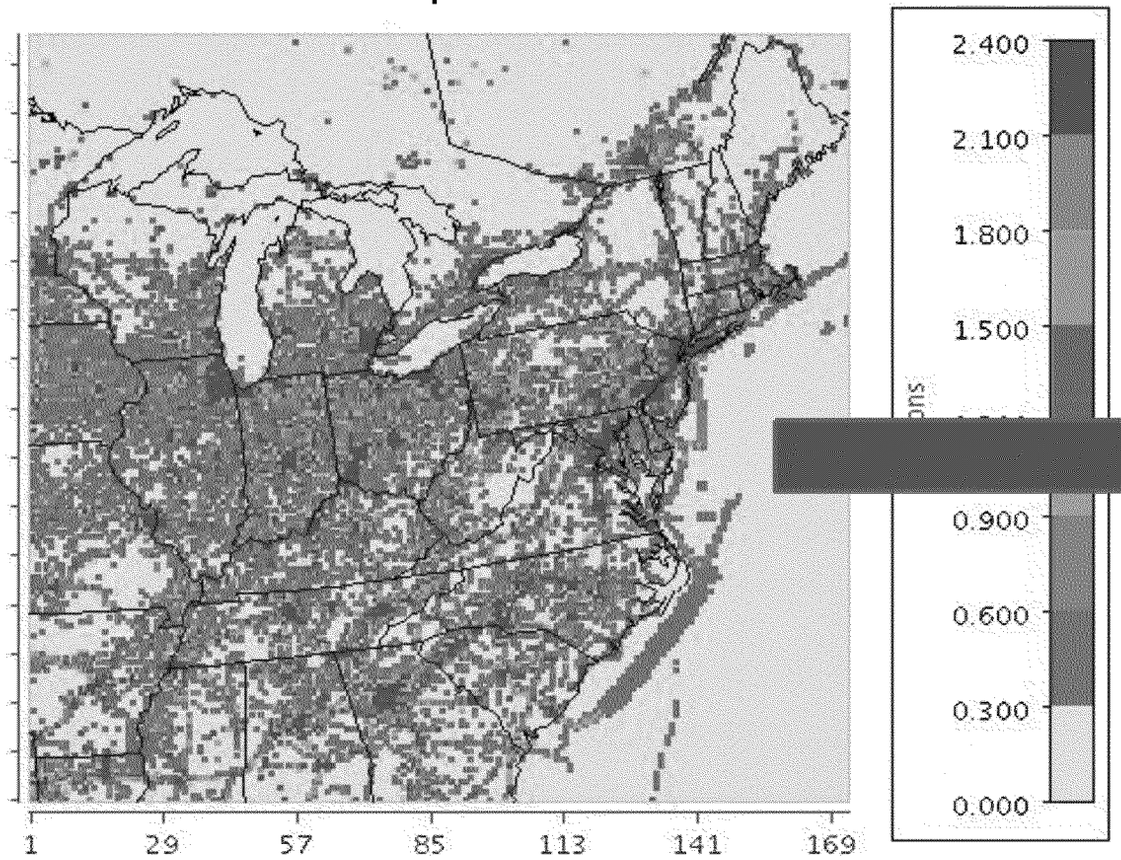
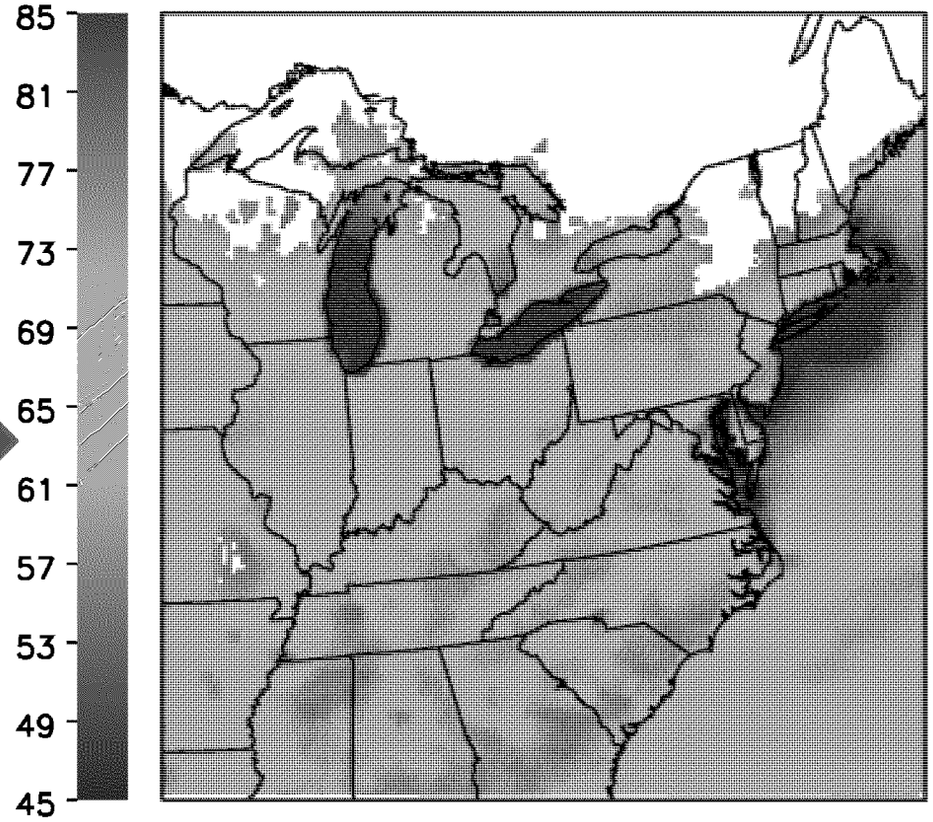
2. OTC Modeling

OTC 2011 NOx Emissions – July 22 – MARAMA Alpha2 Emissions



OTC CMAQ Modeled Ozone for 2020 – MARAMA Beta2 Emissions



2. 2020 and 2023 Modeling

- **2020** projected modeling for:
  - 2008 Serious nonattainment area SIP planning
  - 2015 Marginal nonattainment area projection
- **2023** projected modeling for:
  - 2015 Moderate nonattainment area SIP planning
- **Phase 1:** Modeling performed with interpolated emissions for near term information
  - Results will be shown today
- **Phase 2:** Modeling performed with MARAMA "Gamma" emissions
  - Emissions will be tagged for contribution modeling with CAMx

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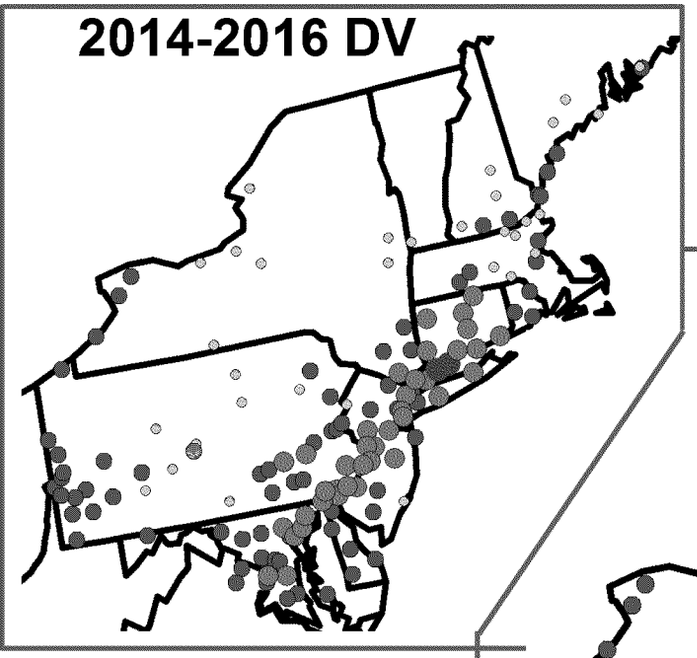
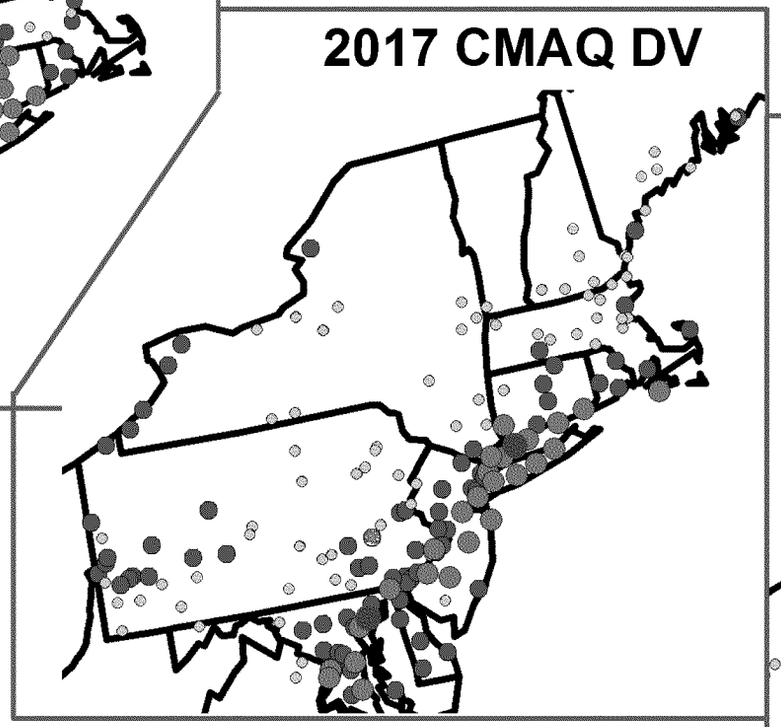
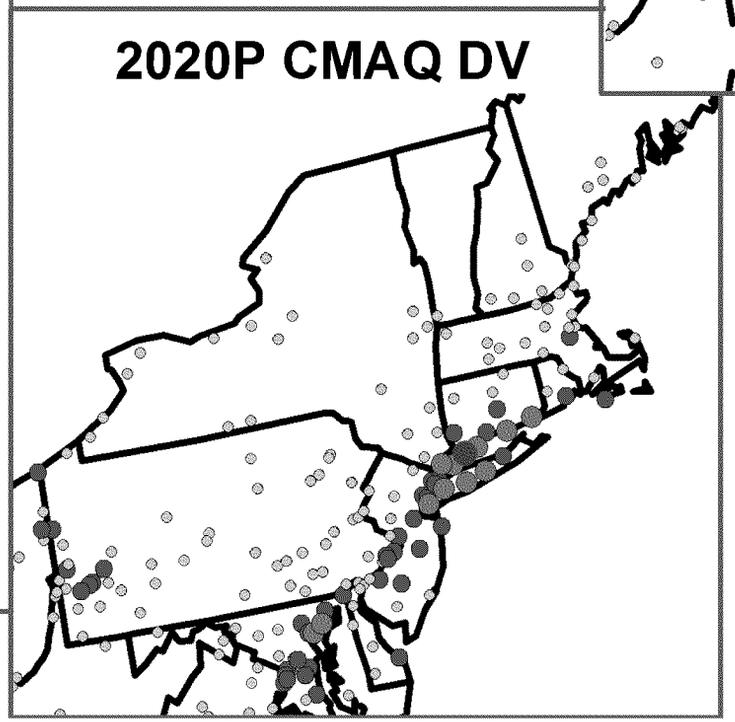
2. Recent Modeling – Projected Year Comparison



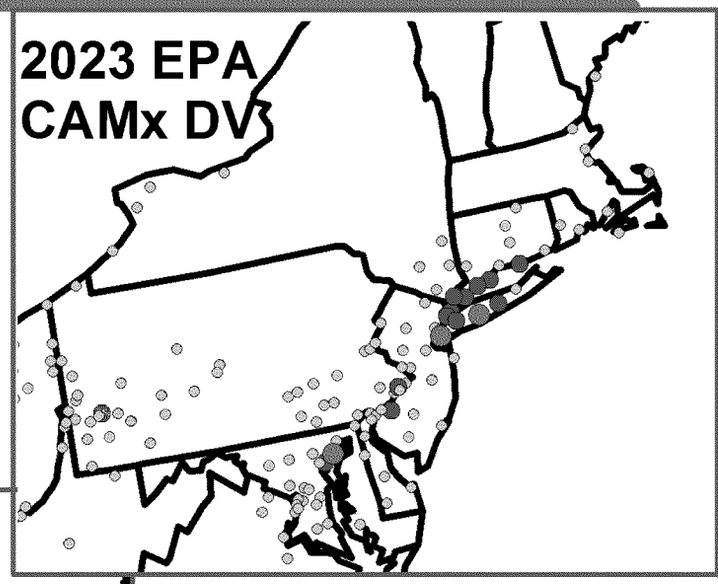
2017 Beta Emissions



Phase 1 2020 Interpolated Emissions



- >81ppb
- 76 – 80ppb
- 71 – 75ppb
- 65-70ppb
- <65ppb



2023 EPA V1 Emissions

2. Who Contributes to Us?/Who do we Contribute to?

We will tag emissions in modeling to answer these questions

- Years to be run (in order by priority)

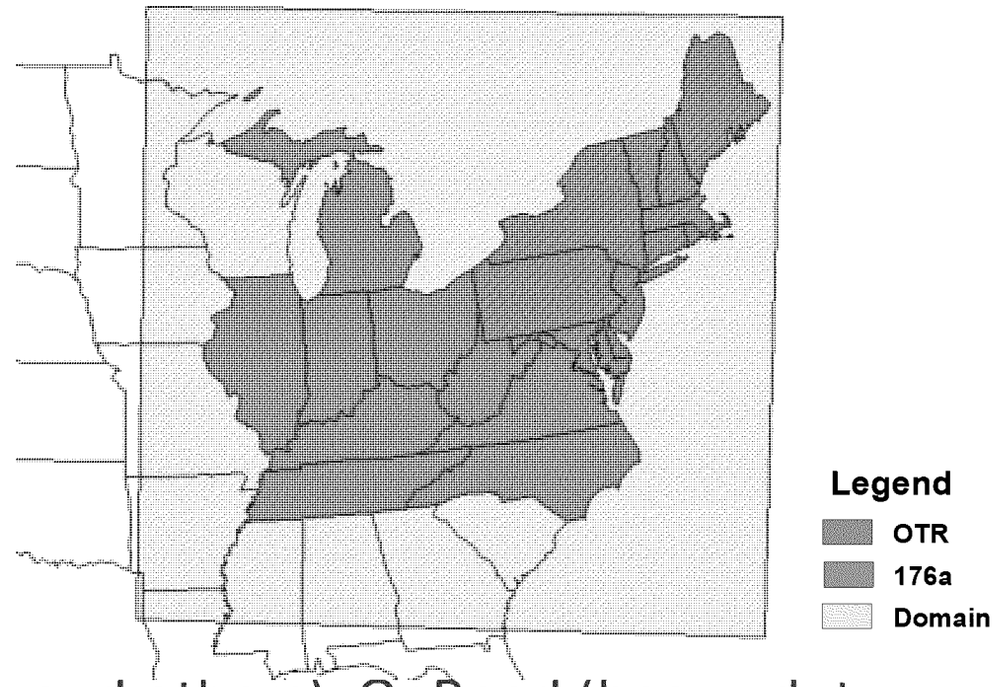
1. 2017 – Least Projected
2. 2023 – Moderate 2015 NAAQS
3. 2020 – Marginal 2015 NAAQS

- States to tag

4. OTR states + DC (13)
5. 176A States (9)
6. Southern and western partial states (2)
7. Canada & offshore (2)

- Anthropogenic Sectors to tag
  - EGU, Non-EGUs (cement kilns, pulp/paper, and others), OnRoad (heavy-duty & others), NonRoad, Oil & Gas (8)

OTC Modeling Domain



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5. Existing EPA Contribution Modeling

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3. Currently Available: EPA Contribution Modeling

This modeling is problematic due to overly optimistic emission reductions from power plants EPA relies upon

- Considers all monitors currently exceeding:
  1. The 2015 Ozone NAAQS
  2. The 2008 Ozone NAAQS
- EPA ozone contribution modeling with:
  3. 2017 emission inventories
  4. 2023 emission inventories
- Highlighted states contribute 1% or more of the applicable NAAQS

Answers the questions:

1. What states contribute to current nonattainment
2. What states will still contribute 1% or more should monitors currently in nonattainment not reach attainment by 2023

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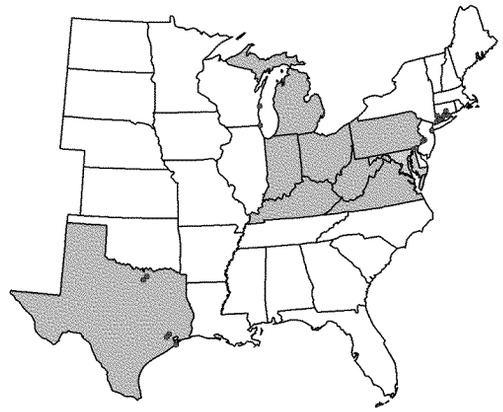
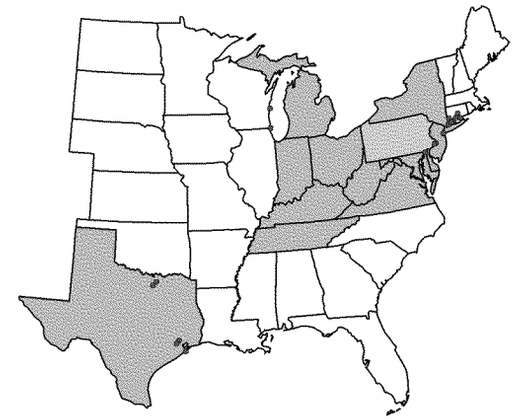
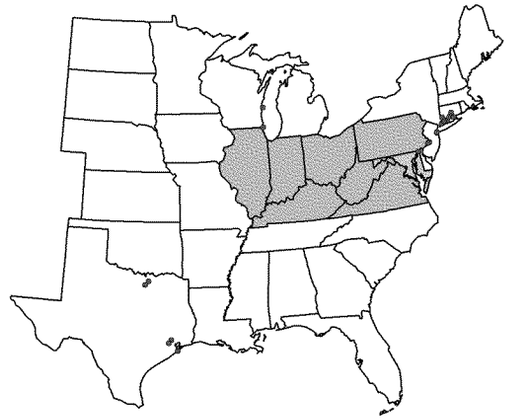
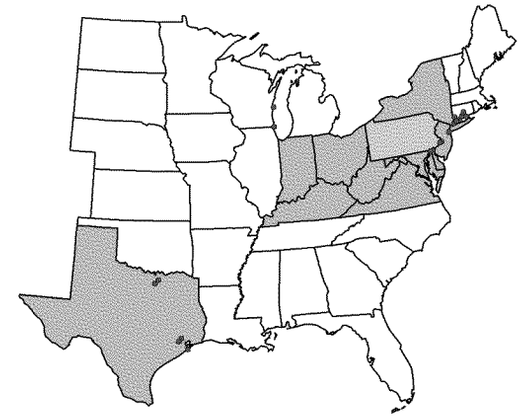
3. 2008 Ozone NAAQS: 75ppb - ≥1% Contributing States

	Connecticut	Maryland	New York	Pennsylvania
Contributors with 2017 Emissions				
Contributors with 2023 Emissions				

Data Source: USEPA Contribution Modeling

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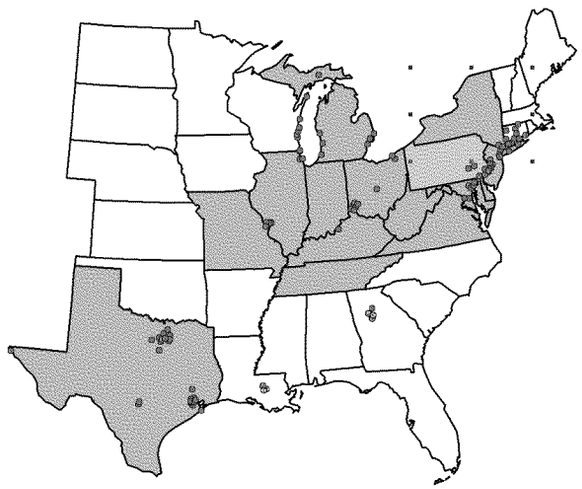
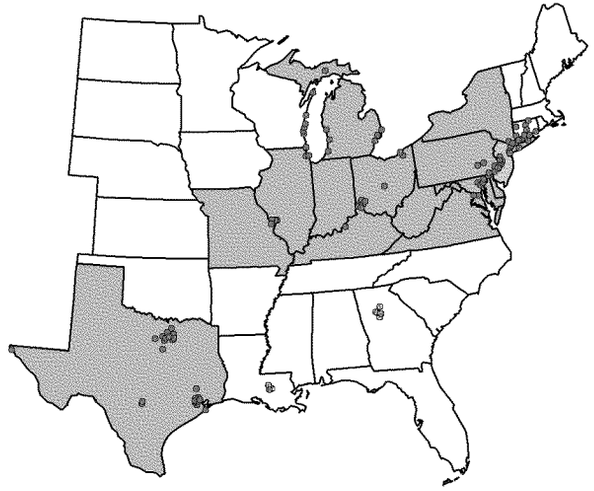
3. 2015 Ozone NAAQS: 70ppb - ≥1% Contributing States

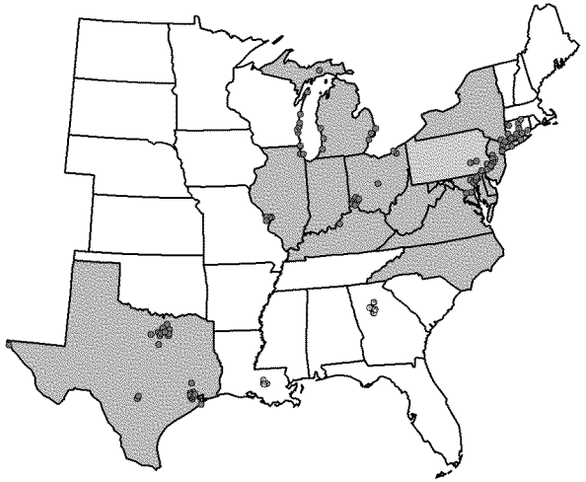
Pennsylvania | **Connecticut** | **New Jersey**

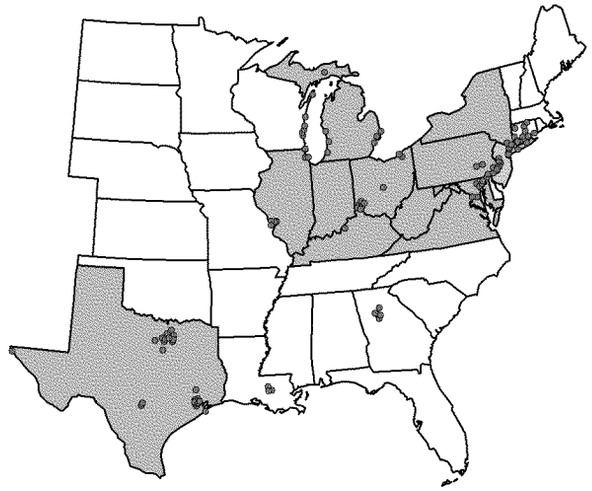
Contributors with 2017 Emissions





Contributors with 2023 Emissions





Data Source: USEPA Contribution Modeling

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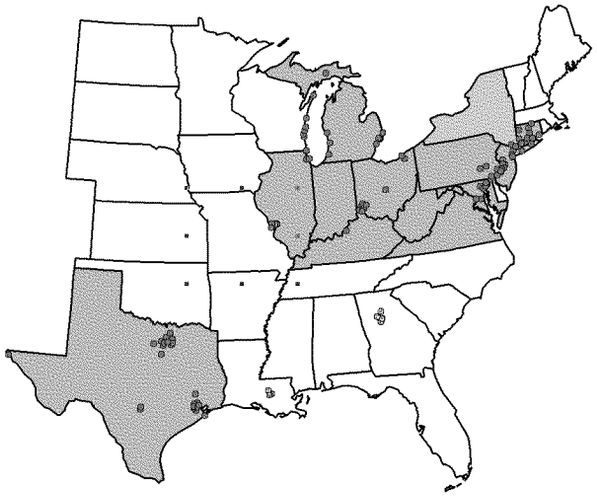
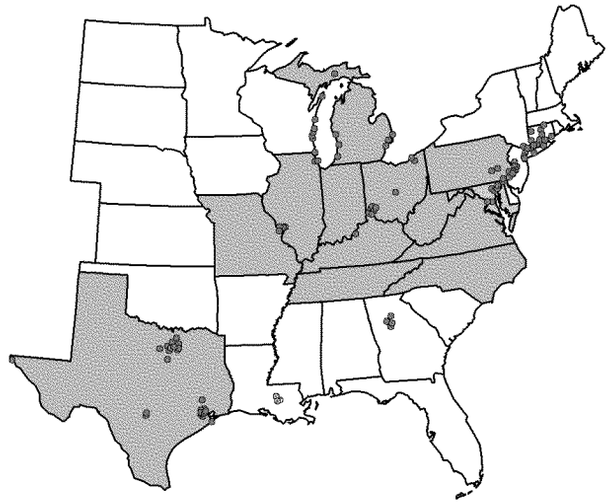
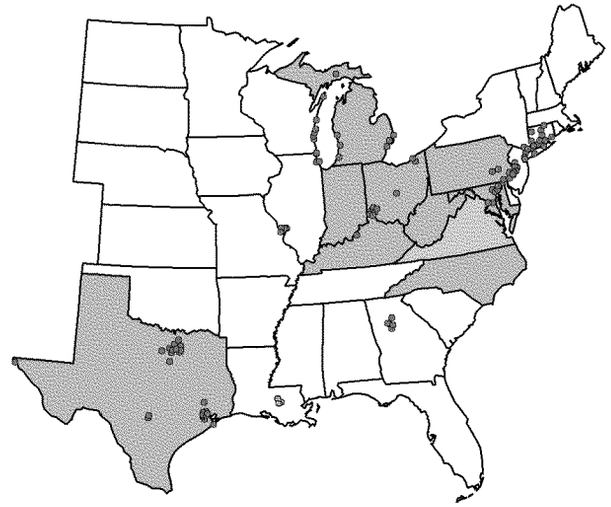
3. 2015 Ozone NAAQS: 70ppb - ≥1% Contributing States

New York | **Maryland** | **Virginia**

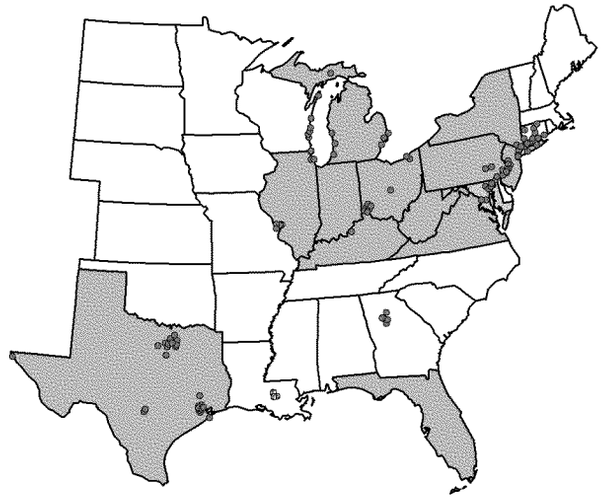
Contributors with 2017 Emissions

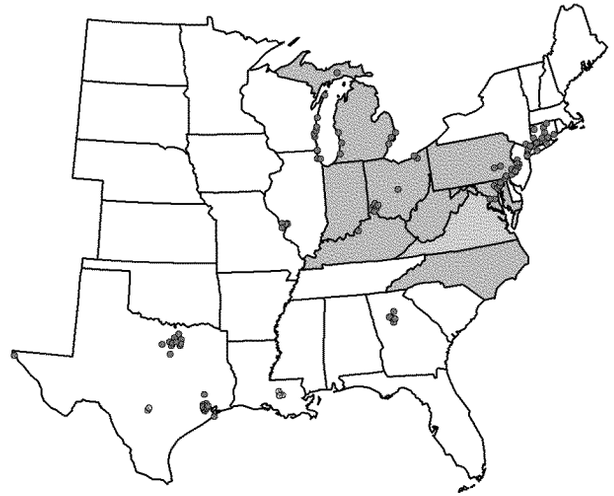






Contributors with 2023 Emissions





Data Source: USEPA Contribution Modeling

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1% (Plus) Contributing States to 2014-16 OTR Ozone Violations

2008 NAAQS	2014-16 Design Value Violations								2017 Emissions			
Downwind	**Upwind**								**OTR**			
Connecticut	IN	MI	OH	VA	WV				MD	NJ	NY	PA
Maryland	KY	IN	MI	OH	TX	VA	WV		PA			
New York	KY	IN	MI	OH	TX	VA	WV		MD	NJ	PA	
Pennsylvania	KY	IN	MI	OH	TN	TX	VA	WV	DE	MD	NJ	NY
176A Included	KY	IN	MI	OH	TN	VA	WV					
176A Excluded	IL	NC										
Plus	TX											

2015 NAAQS	2014-16 Design Value Violations											2017 Emissions			
Downwind	**Upwind**											**OTR**			
Connecticut	KY	IN	MI	OH	VA	WV						MD	NJ	NY	PA
Maryland	IL	IN	KY	MI	MO	NC	OH	TN	TX	VA	WV	PA			
New Jersey	IL	IN	KY	MI	MO	OH	TX	VA	WV			DE	MD	NY	PA
New York	IL	IN	KY	MI	OH	TX	VA	WV				CT	MD	NJ	PA
Pennsylvania	IL	IN	KY	MI	MO	OH	TN	TX	VA	WV		DE	MD	NY	PA
Virginia	IL	IN	KY	MI	NC	OH	TX	VA	WV			MD	PA		
176A Included	IL	IN	KY	MI	NC	OH	TN	VA	WV						
176A Excluded	None														
Plus	MO	TX													

EPA contribution modeling with 2017 emissions.

State ozone contributions of greater than 1% of the NAAQS to monitors currently (2014-16) violating the NAAQS are indicated.

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3. 1% (plus) OTR State Contributions to Downwind Violations

Both 2008 and 2015 NAAQS

Upwind	Downwind					
Connecticut	NY					
Delaware	NJ	PA				
DC	MD	VA				
Maryland	CT	NJ	NY	PA	VA	
Massachusetts	NY					
New Jersey	CT	NY	PA			
New York	CT	NJ	PA			
Pennsylvania	CT	NJ	NY	OH	PA	VA
Virginia	CT	NJ	NY	PA	VA	

EPA contribution modeling with 2017 emissions.

State ozone contributions of greater than 1% of the NAAQS to monitors currently (2014-16) violating the NAAQS are indicated.

Data Source: USEPA Contribution Modeling

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4. Conclusions & Next Steps

- Ozone exceedances in OTR in 2016 ozone season similar to 2015
- Already several monitors are violating the 2015 NAAQS for 2015-2017
- OTC modeling indicates that:
  - Phase 1 Interpolated 2020 modeling shows modest improvement from 2017, but nowhere near the improvement EPA 2023 modeling indicates
  - Exceedances of the 2015 NAAQS are projected for 2020 in CT, MD, NJ, and NY
  - Exceedances of the 2008 NAAQS are projected for 2020 in CT, MD and NY
  - Phase 1 interpolated 2023 modeling should be available prior to the June Annual Meeting
- Phase 2 Emissions inventory projections to 2020 & 2023 being prepared for transport & attainment SIP
  - Improved Gamma emission inventories to be available during summer/fall 2017
  - MARAMA Gamma Emission can be tagged for source apportionment modeling

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Questions

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Joseph Jakuta

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ED_001650_00042820-00021

May 8, 2017
From: OTC Modeling Committee
To: OTC Air Directors

Re: Recommendations for Source Apportionment Modeling for use in OTC Members Good Neighbor SIP

Background

States are required under section 110(a)(2)(d) of the Clean Air Act to submit SIP revisions that demonstrate how they will address air pollution from their state that contributes to nonattainment or interferes with maintenance of the NAAQS in a downwind state.[1] These SIPs, called Good Neighbor SIPs are due three years after a NAAQS is updated, which for the 70ppb 2015 Ozone NAAQS makes the due date October 2018. In the absence of an approved Good Neighbor SIP, EPA can issue a Federal Implementation Plan (FIP).

For the 2008 Ozone NAAQS, EPA adopted the CSAPR Update rule as a Good Neighbor FIP.[2] However, EPA cautioned that CSAPR Update was only a "partial remedy" for most affected states, meaning there are still unfilled Good Neighbor obligations from upwind states beyond meeting the requirements of the CSAPR Update.

When determining which states contribute to nonattainment or interfere with maintenance in other states, EPA typically considers emissions anticipated in the future year that corresponds to the attainment date for moderate nonattainment. EPA conducts photochemical modeling that "tags" individual states to determine which states contribute to areas projected to be in nonattainment or have issues with maintenance.

For the CSAPR Update, EPA conducted contribution assessment modeling for the year 2017, which is the year that moderate nonattainment areas such as the NYC Metro area are required to attain the 2008 ozone standard of 75 ppb. In addition, EPA recently conducted preliminary contribution assessment modeling for the year 2023, which is the year that any area designated as a moderate nonattainment area for the 2015 ozone NAAQS would be required to attain the 70 ppb standard.

OTC has expressed several concerns with EPA's 2023 contribution assessment approach. Flaws identified by OTC include the use of the IPM model to project future emissions from electricity generating units instead of using the ERTAC EGU model, the use of anticipated future year emissions instead of current emissions, and the use of average ozone season contributions instead of contributions on peak days.[3]

OTC is working to provide OTC states with an alternative to EPA's preliminary 2023 modeling so

[1] *Clean Air Act Amendments of 1990.*
[2] US EPA, "Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS."
[3] Ozone Transport Commission, "RE: Notice of Availability of the Environmental Protection Agency's Preliminary Interstate Ozone Transport Modeling Data for the 2015 Ozone National Ambient Air Quality Standard (NAAQS)."

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that the states can meet the October 2018 deadline for submitting Good Neighbor SIPs for the 70 ppb ozone standard.

This document describes options and recommendations for conducting source apportionment modeling to assist the states in their 2015 Good Neighbor SIP submittals and to make the case for what obligations still remain for 2008 Good Neighbor SIP submittals. The OTC Modeling Committee is requesting advice from the OTC Air Directors on several major decisions so that the OTC Committee can move forward with source apportionment modeling:

1. Geographical areas to tag
2. Sectors to tag
3. Year(s) to model
4. Period should be looked at (e.g., ozone season average, ozone episodes)
5. Receptors

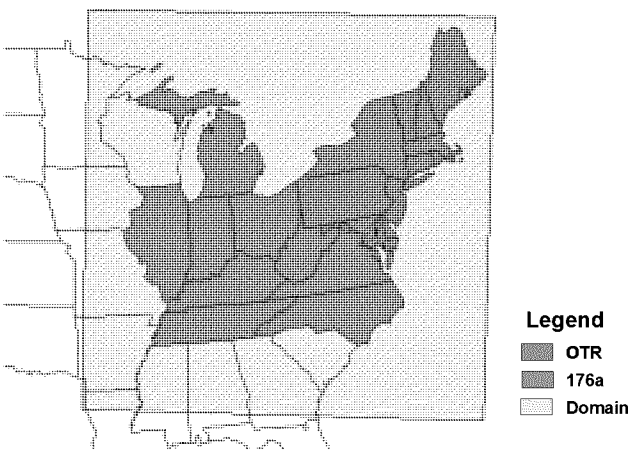
The primary purpose of this modeling is to determine whether each OTR state has sufficient emissions controls to prevent contributing to nonattainment or interfering with maintenance in another state. Downwind nonattainment or maintenance areas for the 70 ppb standard are expected to include: the New York Metro area (CT-NJ-NY), the Baltimore area, the Philadelphia area, several counties outside of the Philadelphia metro area in Pennsylvania.

A second important purpose of this modeling is to enable OTR states to identify states that are contributing to nonattainment or interfering with maintenance in the OTR in order to be able to comment on the adequacy of SIPs submitted by those states.

Geography to Tag

It is important to "tag" emissions from a) each OTR state, b) any state that may be affected by emissions from an OTR state, and c) any state that may have emissions contributing to nonattainment or interfering with maintenance in an OTR state. For each receptor location, the model identifies how much ozone is formed due to each tagged set of emissions.

Figure 1:Map of potential states to tag.



2023 emissions files provided by EPA are already tagged by state for each of the lower 48 US states and Washington, DC as well as for Canada/Mexico, tribes, biogenic emissions, fires, and offshore emissions (note the latter three are not assigned to a specific geography, but the entire modeling domain). Because that tagging is already complete, OTC modelers can potentially use it.

This leaves the question of whether we should combine the states that are partially in the domain or were not included in the 176(a) to save on computing time. Wisconsin and South

Carolina are wholly in the modeling domain and Georgia, Alabama, Mississippi, Arkansas, and Missouri likely have enough geographic area within the domain to maintain separate tagging. To ensure that all tagging is summed correctly, the Modeling Committee recommends that states not specifically tagged in OTC model runs be grouped together under a more general geographic tag, such as "other states."

Tagging emissions coming from outside domain boundaries should also be considered, either as a whole or individually for each cardinal direction.

Sectors to Tag

EPA's contribution assessments have typically tagged emissions by states not sectors. The CSAPR and CSAPR Update FIPs required control of EGU emissions. However, the CSAPR Update rule was found to be a partial remedy and other sectors would need be controlled. As a result it would be necessary to determine what other sectors need to control. Inventory files are kept separate for certain sectors prior to modeling, so tagging emissions based on the already existing separate sectors could result in a lower workload than tagging subsectors. This would mean that we could look at EGUs separately from other point sources, but could not look at ICI boilers separate from Cement Kilns for example. Looking at heavy-duty diesel trucks separate from the rest of the onroad emissions presents a similar challenge. Also the smaller the sector, the less likely an attributable contribution could be determined. The currently separated ozone relevant inventory files are:

1. Area Source
2. Non-ERTAC IPM EGUs
3. Biogenic Emissions
4. NonPoint Oil &Gas
5. C1/C2 Marine and Rail
6. Nonroad
7. IMO C3 Marine
8. Onroad
9. ERTAC EGUs
10. Point Oil & Gas
11. Non-EGU Point
12. Refueling

Year(s) to Model

OTC has six emissions inventories available that could be used in ozone sources apportionment. The inventories (Table 1) are in different states of completion and quality. Each year has its own pros and cons for use in source apportionment modeling and each additional year modeled adds to the level of resources needed to conduct modeling

Table 1: Available Inventories

Year	Level	Status	Notes
2011	Gamma	In Development	Beta 2 is Complete
2017	Beta 2	Complete	
2018	Alpha 2	Complete	

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2020	Gamma	In Development	Several sectors will be interpolated
2023	Gamma	In Development	
2028	Alpha 2	Complete	

OTC has stated in several comments to EPA concerning Good Neighbor SIPs that source apportionment should be conducted on data from the years used to determine nonattainment and not future year projections. Ozone designations for the 2015 NAAQS will be based on data from 2014-2016. Ideally we would use data from those years, but those inventories are not yet available. At this point we will examine the pros and cons of the available inventories.

2011

Pros: 2011 is a well-developed and quality assured inventory. 2011 relies on historical data rather than projections.

Cons: 2011 was several years before the data used to calculate 2015 NAAQS design values and was not even used in the 2008 NAAQS design value calculation. 2011 Gamma has not been tagged with state information. Using this year in addition to a future year would add time and effort to the process. This year also predates many shut downs and fuel switches and controls that occurred added since 2011.

2017

Pros: 2017 is a well-developed and quality assured inventory and is the closest we have to a current year inventory. 2017 is when moderate areas were supposed to have attained the 2008 NAAQS, making it potentially useful for demonstrating what is lacking in terms of the partial remedy. 2017 has been tagged with state information.

Cons: The 2017 projections will likely be proven incorrect when actual 2017 data becomes available. It does not include any future controls that are required but not yet implemented.

2020

Pros: 2020 corresponds to the marginal attainment date for 2015 Ozone NAAQS, which is the classification expected for all parts of the OTC outside of the NYC area (assuming EPA follows traditional patterns in selecting the size of the nonattainment area). Good neighbor obligations may be needed even for marginal areas to attain and maintain the NAAQS. 2020 is also the expected attainment date if the parts of the OTR that are not attaining the 2008 Ozone NAAQS get bumped up to serious nonattainment. Tags should be maintained if adjustment factors are applied to the 2017 or 2023 inventory.

Cons: The 2020 inventory is the least developed of the inventories being discussed since several sectors (e.g., onroad mobile, nonroad) are being interpolated. Additional quality control for the 2020 inventory is planned, but an updated version will not be available until the end of 2017.

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2023

Pros: 2023 corresponds to the moderate attainment date for the 2015 Ozone NAAQS, which is the classification expected for the New York City area (and if EPA follows some governors' recommendations, a larger area along the I-95 corridor may be included in this area). 2023 is also the year that EPA has modeled to show state-by-state contributions, and we expect upwind states to use 2023 if they conduct source apportionment modeling. The 2023 inventory obtained from EPA has been tagged with state information.

Cons: Use of this year is somewhat inconsistent with previous OTC statements on the use of future projections when determining contributions. 2023 would be irrelevant if EPA revokes the 2015 Ozone NAAQS.

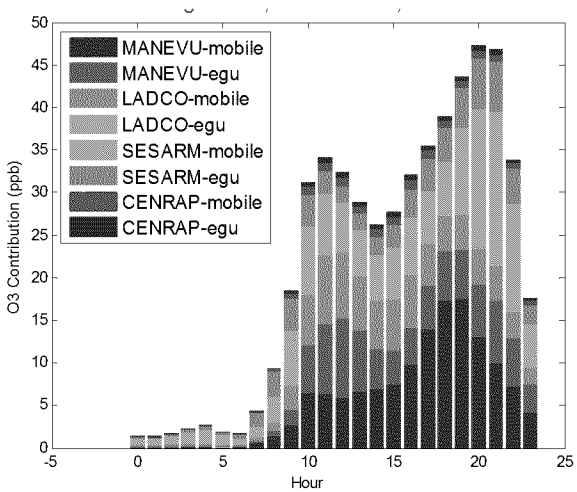
2018 and 2028

2018 and 2028 are the lowest quality emissions inventories and do not have any particular relevance to planning dates for ozone. Therefore the Modeling Committee does not recommend source apportionment modeling for these years.

Time Span

It has been past practice for EPA to conduct source apportionment work for the entire ozone season, however past comments and statements from OTC have shown the need to look at particular high ozone events rather than averaging out impacts over an ozone season. OTC has also invested resources in analyzing particular ozone events from the 2011 base year and has developed an episodic modeling platform.[4] OTC could take the approach of modeling a shorter time span than the full ozone season such as June through August.

Figure 2: CMAQ ISAM results for Edgewood, MD (240251001), June 8, 2011



Results during several ozone events could also be examined on an hourly basis. This is important due changes that can occur diurnally that can result in upwind impacts being shown to be less due to averaging than they actually are during times when high ozone levels occur. Figure 2 provides an example.

Receptors

Utilize monitoring sites as receptors within the OTR modeling domain that have been identified as potentially exceeding the 2015 ozone standard and monitoring sites that have predicted concentrations within 5 ppm below the 2015 ozone standard. In the OTR this will include at least the CT-NJ-NY area, the Philadelphia area, the Pittsburgh area, the Baltimore area, and the

[4] Ozone Transport Commission, *Technical Support Document for the 2011 Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union Modeling Platform*.

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Washington area.

Modeling Resources

At this point the modeling committee is examining potential tools to use to reduce the amount of SMOKE processing necessary, so an estimate of the time needed for SMOKE processing is not yet determined.

Completing a typical CAMx run takes 10-20 minutes per modeling day, so a typical ozone season run would take 2-3 days to complete, whereas a July only run would take about a half a day. Running around 100 tags would increase the time per modeling day to 1-2 hours, which would increase time for an ozone season run to 2-3 weeks, and a summer run would take around 9 days.

Post processing with around 100 tags would expect to take 2-4 weeks per run.

MDE through the University of Maryland, NJDEP though the Rutgers Ozone Research Center, and VADEQ have the ability to run CAMx OSAT or APCA. MDE has volunteered to conduct the run of 2023 and NJDEP has volunteered to conduct the run of 2017. All three of these centers, plus NYSDEC have the ability to conduct SMOKE processing.

Recommendations

The OTC Modeling Committee recommends the following approach:

- Conduct runs using CAMx OSAT.
- 260 tags as follows:
    - Tag the 176(a) petition states and the OTR states individually, Canada, offshore, and a southern and mid-western "other state tag" (26 tags).
    - Tag EGUs, non-EGU point (cement kilns, pulp & paper, refineries, and other point sources separately), onroad (heavy-duty diesel and other onroad sources separately), nonroad, point oil and gas, and other emissions groups (10 tags)
    - Biogenics, fires, and boundary conditions as a whole (3 tags).
- Run these on the June-August season only.
- Run 2017, 2023, and potentially 2020 prioritized in that order.
- Provide post processing analysis of:
    - Each OTR state's contribution to receptors in other states,
    - Contributions by sector for each OTR state that contributes more than 1% of the ozone to a nonattainment or maintenance receptor in another state,
    - Contributions from individual states to receptors in the OTR, and
    - Contributions by sector from individual states outside the OTR that contribute at least 1% to concentrations at receptors in the OTR.
    - Conduct an hourly post processing of two ozone events to be determined.

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From: Joseph Jakuta
Location: https://global.gotomeeting.com/join Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Mon 4/24/2017 5:00:00 PM
End Date/Time: Mon 4/24/2017 6:30:00 PM
Source Apportionment Modeling Options.docx
2020-2023 Screening Modeling Outline 170420.docx
OTC_Modeling_Committee_Spring_ADs_2017.pptx

Agenda:

1. Source Apportionment Recommendations
2. 2011 Platform Development Status

a. 2020/2023 Inventory
b. Screening Runs

3. Presentation

---GoToMeeting invitation begins---
Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/ Ex. 6
You can also dial in using your phone.
United States Ex. 6
Access Code: Ex. 6
---GoToMeeting invitation ends---

2020/2023 Screening Modeling Overview

4/20/2017

OTC Modeling Committee

Purpose

The purpose of this work is the develop informative screening modeling using available the 2011 Beta 2 modeling platform[1] and minimal resources in order to gain an understanding as to the expected ozone levels in 2020 and 2023 while considering on the books measures. 2020 and 2023 are the marginal and moderate attainment dates respectively, and the expectation given current monitored data is that some parts of the Ozone Transport Region will be classified at those levels. The work should be completed in time to provide an update at the OTC Air Directors Meeting in Mid-May. Given the screening nature of the work, only ozone season runs are necessary.

This work is not intended to be a SIP quality inventory project, or even lead there, since the expectation is that a more recent base year will be needed for any SIP submissions.

Inventories

ERTAC EGU

ERTAC EGU is the only inventory sector that has been specifically developed for 2020 and 2023 from a 2011 base at this point. The current working version is v2.6. This version has the downside of not accounting for C-SAPR 2.[2] C-SAPR 2 is the one major federal emission reduction program that impacts ozone formation not accounted for in the inventories and should be factored into the 2020 and 2023 screening inventories. In order to account for C-SAPR 2 we are reducing the emissions in each state in the program to the level of their budget allocation. It is expected that by 2023 and possibly 2020 that any excess allowances carried over in 2017 will be exhausted so the system as a whole will be meeting the budget levels. To develop the percentage reduction that is to be applied to the 2020 and 2023 ERTAC EGU inventory the emission in each year respectively was summed as was that state's budget and they were divided. There are slight discrepancies between the units in ERTAC and in C-SAPR 2 in each of the states but these issues are expected to be minimal. Also states with lower relative budgets will have their emissions overestimated and states with higher relative budgets or not in the program will have their emissions underestimated. The percentage reductions are being applied annually, which would result in non-ozone season emissions being too low, but since only ozone season is being modeled in this exercise it will not matter. The reductions are found in Table 1.

Table 1:

[1] Ozone Transport Commission, *Technical Support Document for the 2011 Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union Modeling Platform*.

[2] US EPA, "Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS."

RPO		Percentage Reductions for Screening			
	2018 C-SAPR Cap	2020	2023	2020	2020
CENSARA	126,870.00	172,835.45	181,653.16	-27%	-30%
LADCO	82,364.00	106,964.53	104,559.47	-23%	-21%
MANE-VU	28,977.00	42,243.80	42,700.03	-31%	-32%
SESARM	99,456.00	136,949.56	138,079.64	-27%	-28%

2020/2023 Other Sectors

Due to timing factors, available resources, and the inclusion of major ozone precursor reduction programs in existing inventories all other sectors will simply have a percentage reduction applied to the 2017 Beta 2 inventory on a sector/RPO basis. The percentage reduction will be based on a straight line interpolation between EPA's 2017 'ek'[3] and the 2023 'el'[4] inventories for NO_X and VOC emissions developed from summary files provided by EPA. 2023 will be processed in this fashion as well due to complications with the chemistry and SMOKE processing method EPA used for 2023 differing from the approach used for the Beta 2 platform. The relevant numbers are in the table below and sectors not listed below (e.g., biogenics) will be held constant. Also C3 marine was included with C1 and C2 in the summary files provided by EPA, but previous inventories showed that C3 did not have substantial reductions so those factors will only be applied to C1C2rail. Also the SMOKEd files for six sectors (C1C2rail, C3, non-point oil and gas, onroad, point oil and gas, and RWC) were note separated by RPO for 2017 so a factor was calculated for the entire domain. To avoid issues with modeling domain geography, Texas, Oklahoma, and Louisiana were excluded from CENSARA. The factors developed for screening are in Table 2.

Table 2: Adjustment factors for 2020 & 2023 screening inventory development.

Sector	RPO	Modeling Inventories				Percentage Reductions for Screening			
		NO_X		VOC		NO_X	VOC	NO_X	VOC
		2017	2023	2017	2023	2020	2020	2023	2023
Area	CENSARA	42,660.77	42,887.54	309,905.24	298,345.64	0%	-2%	1%	-4%
Area	LADCO	174,184.55	175,042.89	591,902.00	584,142.26	0%	-1%	0%	-1%
Area	MANE-VU	182,128.64	169,826.16	540,692.47	534,367.77	-3%	-1%	-7%	-1%
Area	SESARM	100,974.79	102,290.22	703,225.00	690,572.07	1%	-1%	1%	-2%
C1C2Rail & C3	Merged RPOs	1,273,271.74	1,016,239.68	46,214.91	38,156.41	-10%	-9%	-20%	-17%
Non-ERTAC Point	CENSARA	84,004.46	87,716.72	72,905.20	73,098.54	2%	0%	4%	0%
Non-ERTAC Point	LADCO	251,332.38	256,641.26	165,904.88	166,634.72	1%	0%	2%	0%
Non-ERTAC Point	MANE-VU	131,284.47	130,819.11	54,477.67	54,951.11	0%	0%	0%	1%
Non-ERTAC Point	SESARM	248,983.68	250,093.07	229,061.31	227,678.89	0%	0%	0%	-1%
NonPoint O&G	Merged RPOs	730,217.19	772,883.36	2,903,720.03	2,114,961.39	3%	-14%	6%	-27%
Nonroad	CENSARA	130,005.76	92,515.45	93,313.28	77,948.49	-14%	-8%	-29%	-16%
Nonroad	LADCO	231,525.16	173,454.90	327,365.81	268,858.02	-13%	-9%	-25%	-18%
Nonroad	MANE-VU	155,163.72	124,993.32	257,292.94	219,686.71	-10%	-7%	-19%	-15%
Nonroad	SESARM	170,756.03	129,662.97	251,056.83	208,326.80	-12%	-9%	-24%	-17%
Onroad	Merged RPOs	3,033,139.19	1,785,897.92	1,516,368.70	987,796.40	-21%	-17%	-41%	-35%
Point O&G	Merged RPOs	444,591.09	448,121.72	166,540.84	187,951.87	0%	6%	1%	13%
RWC	Merged RPOs	35,583.56	34,999.74	438,496.53	416,305.61	-1%	-3%	-2%	-5%

[3] Eyth and Vukovich, "Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform."

[4] US EPA, "Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform."

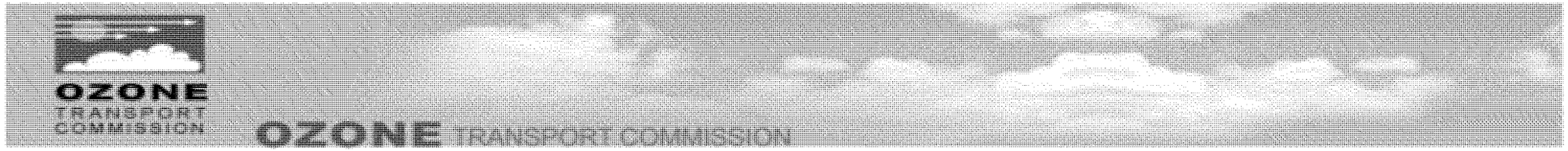
Schedule

Early-March: SMOKE Processing of ERTAC (NYSDEC will process emission factors)
Early April: Apply percentage reductions to other sectors (NYSDEC will process emission factors)
Mid-April: Photochemical modeling (UMD via MDE will run 2020, ORC via NJDEP will run 2023)
Late-April: Post processing
Early May: Committee review
Mid-May: Air Director Meeting

Modeling Committee Update

OTC Air Directors Meeting

May 9, 2017



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Overview

1. Monitored Results
2. Ozone NAAQS Schedule
3. Enhanced Monitoring Plan (EMP)
4. OTC 2011 Modeling Platform
   a) Recent Modeling
   b) Emission Inventory
   c) Planned Modeling
5. EPA Ozone Contribution Modeling
6. 2015/2016 Platform

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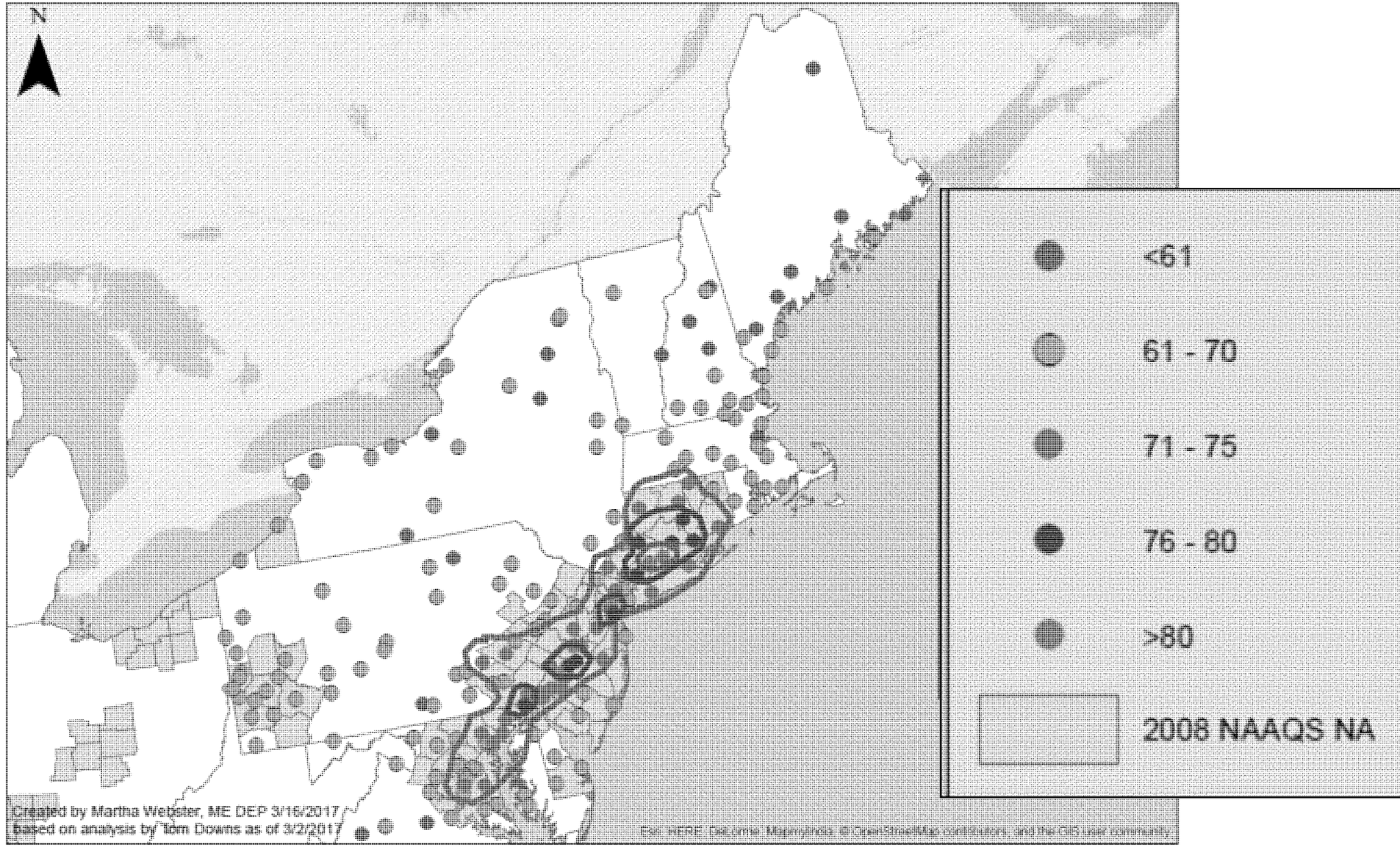
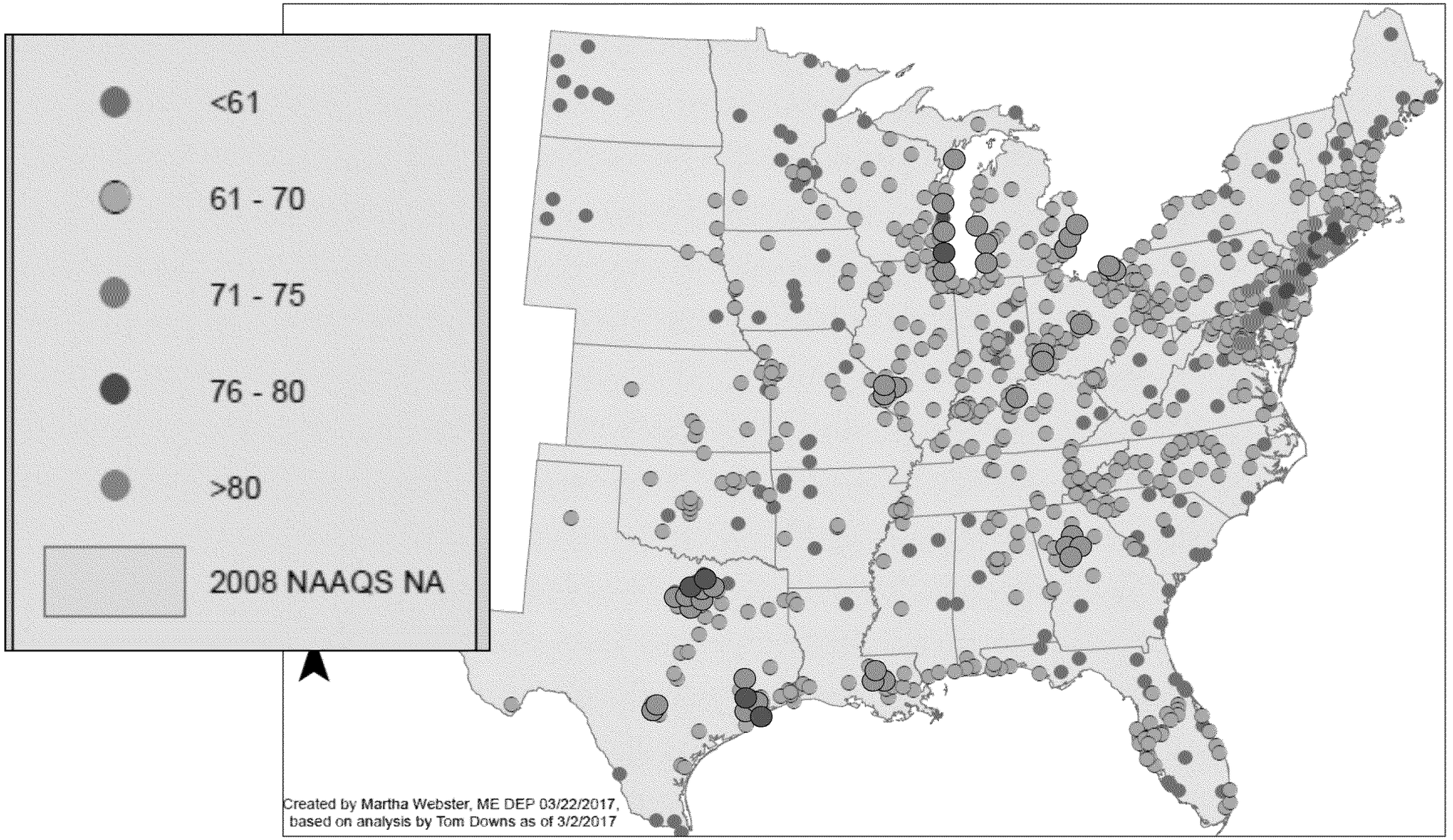
1. 2014-16 8h Ozone Preliminary Design Value



1. 2014-16 8hr Ozone Preliminary Design Value



2. Ozone NAAQS Planning Timeline

October 2015
Final 2015 NAAQS

October 2017
EPA Nonattainment Area Designations for 2015 NAAQS

October 2018
Infrastructure/Transport SIP for 2015 NAAQS Due

October 2020
2015 Ozone Nonattainment SIPs Due

Attainment by (October):
2020 - Marginal
2023 - Moderate
2026 - Serious

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3. Enhanced Monitoring Plans (EMP)

- Requires states with moderate or above ozone NAA & OTR states to submit an EMP as part of 2015 Ozone NAAQS process
- Plans due to EPA on 10/1/2019, or 2 years after moderate or above designation
- Effort underway to coordinate between states & EPA through OTC workgroup
  - Gain regional benefits from plans
  - More knowledge on transport
  - More knowledge of air/sea affect on ozone
  - Information to improve model performance
- Will be future updates at OTC meetings and opportunity for comment

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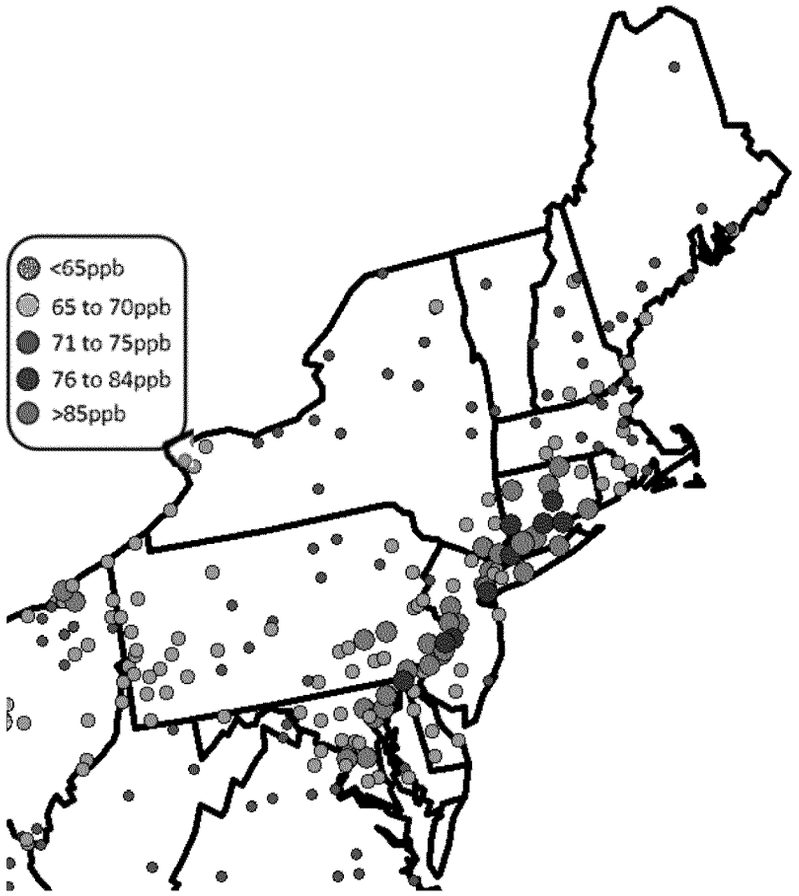
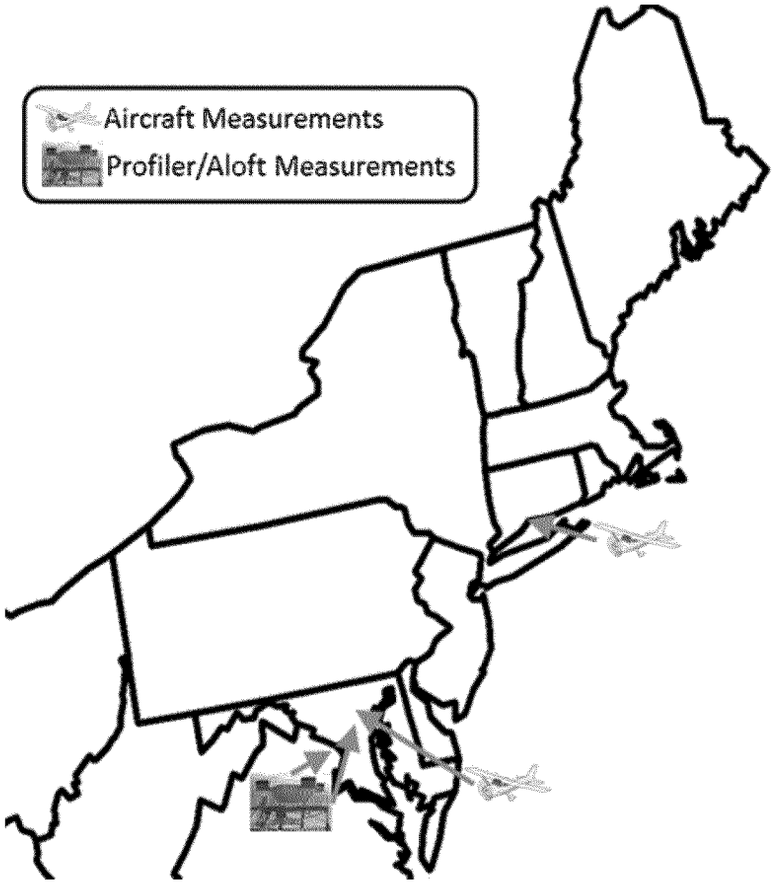
3. Enhanced Monitoring Plans (EMP)

Design Values



Preliminary state suggestions



4. Recent OTC Modeling

- 2017 Base Case
- 2017 Near water RRF adjustments
- 2017 Comparison between photochemical models

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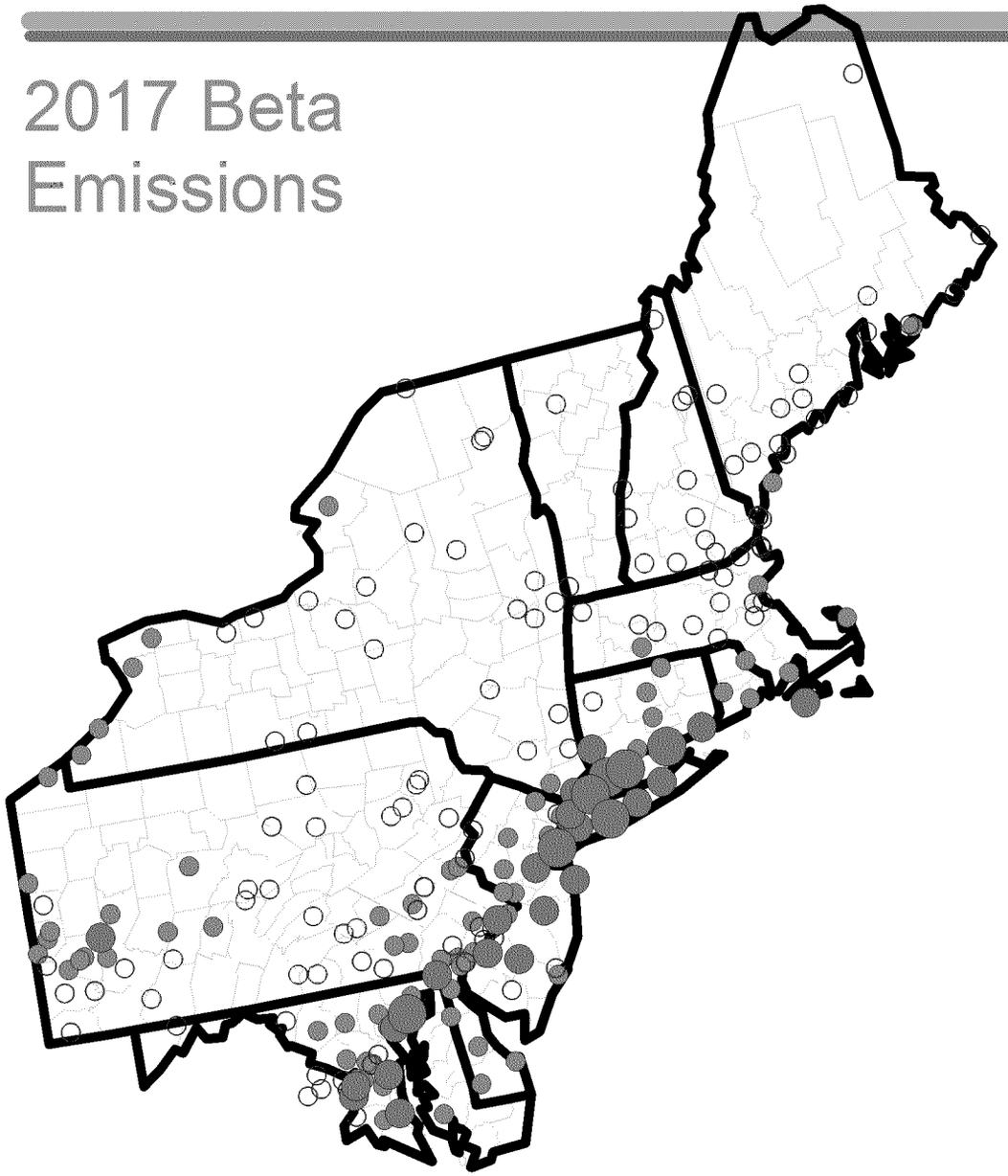
4. 2017 and 2023 Base Case Modeling Results

2017 Beta Emissions



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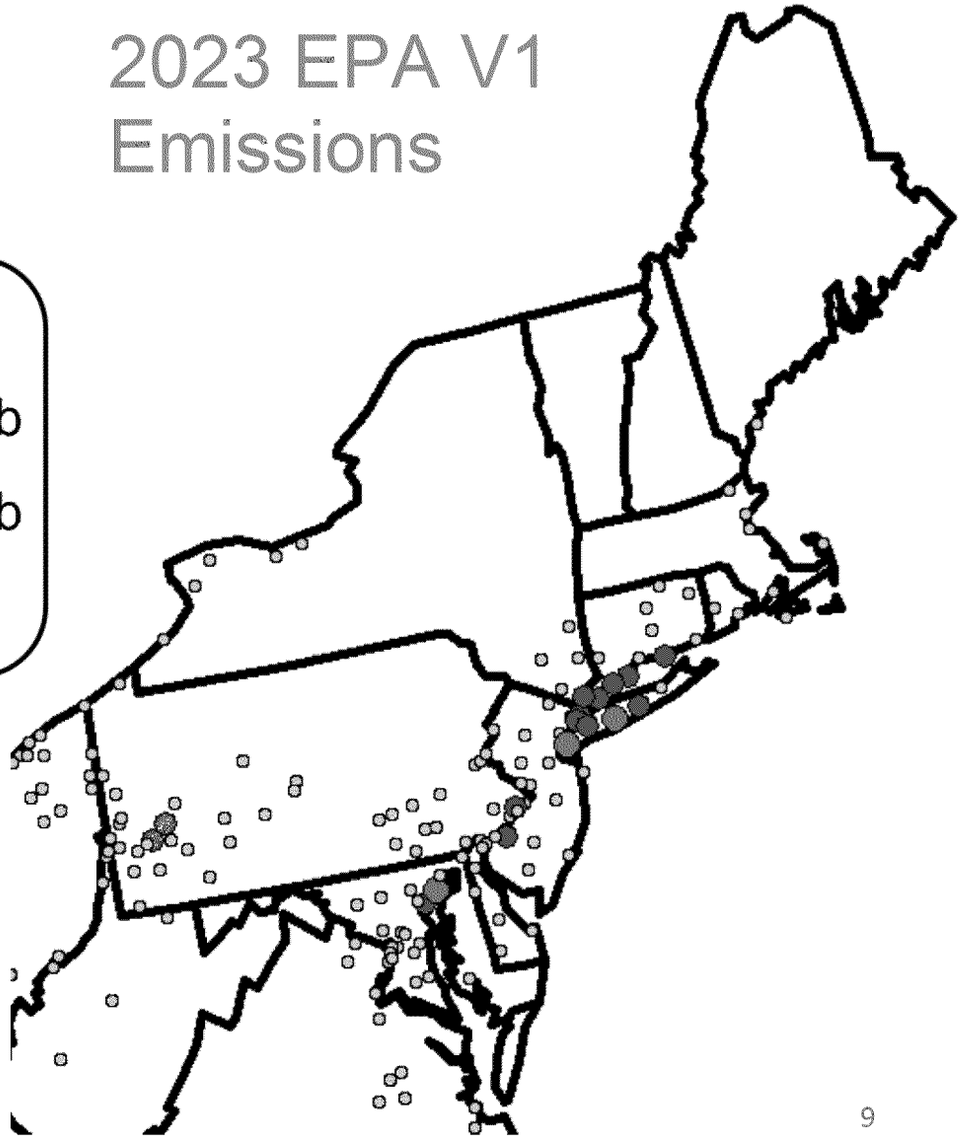
71 - 75ppb
65 - 70ppb
< 65ppb

2023 EPA V1 Emissions



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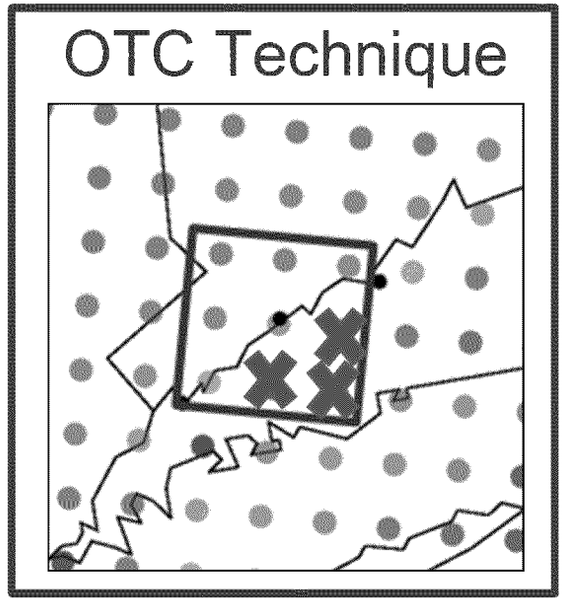
4. Land-Water Interface Monitors

Suggestion

1. Process modeling both ways
   - EPA guidance technique
   - OTC modified technique
2. Use OTC modified technique for SIP submittals
3. Provide a supporting OTC created document that includes:
   - results for EPA guidance technique
   - a description of the OTC modified technique and its performance



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4. CMAQ Vs. CAMx

AQS Code		Site	DVC 2011	CMAQ DVF 2017 beta2	CAMx DVF 2017 CB5 beta2 kvpatch	EPA CAMx DVF 2017 Ek
090019003	CT	Sherwood Island – Westport	83.7	83	78	76
240251001	MD	Edgewood	90.0	81	81	78
360850067	NY	SUSAN WAGNER HS	81.3	78	76	75
090010017	CT	Greenwich Point – Greenwich	80.3	77	74	74
090013007	CT	Lighthouse-Stratford	84.3	77	76	75
090099002	CT	Hammonasset – Madison	85.7	77	77	76
361030002	NY	BABYLON	83.3	77	77	76
090011123	CT	Western Conn State Univ-Danbury	81.3	74	73	71
240053001	MD	Essex	80.7	74	73	71
340150002	NJ	Clarksboro	84.3	74	74	72
360810124	NY	QUEENS COLLEGE 2	78.0	74	74	73
090110124	CT	Fort Griswold Park-Groton	80.3	73	72	70
240090011	MD	Calvert	79.7	73	71	69
240150003	MD	Fair Hill	83.0	73	73	69

4. CMAQ v5.0.2 Vs. CAMx v6.40

Summary

- Over OTR (including VA) ozone monitors, CMAQ & CAMx had similar performance, with CAMx a little bit better than CMAQ in terms of NMB, NME & R.
- CMAQ & CAMx yielded similar 2017 DVF, but CAMx had lower DVF over CT monitors near coast.

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4. Current OTC 2020/2023 Screening Modeling

Modeling intended to provide early direction & SIP support

- 2020 interpolated projection (2008 NAAQS Serious Nonattainment)
  - Interpolation between Beta 2017 & EPA 2023 inventories
  - IPM data to be replaced with ERTAC for EGUs
- 2023 projection (2015 NAAQS Moderate Nonattainment)
  - CSAPR-U Cap estimated adjustment factor
  - EPA 2023 inventory
  - IPM data to be replaced with ERTAC for EGUs
  - Non-EGU point to have adjustment factors applied
  - CSAPR-U Cap estimated adjustment factor

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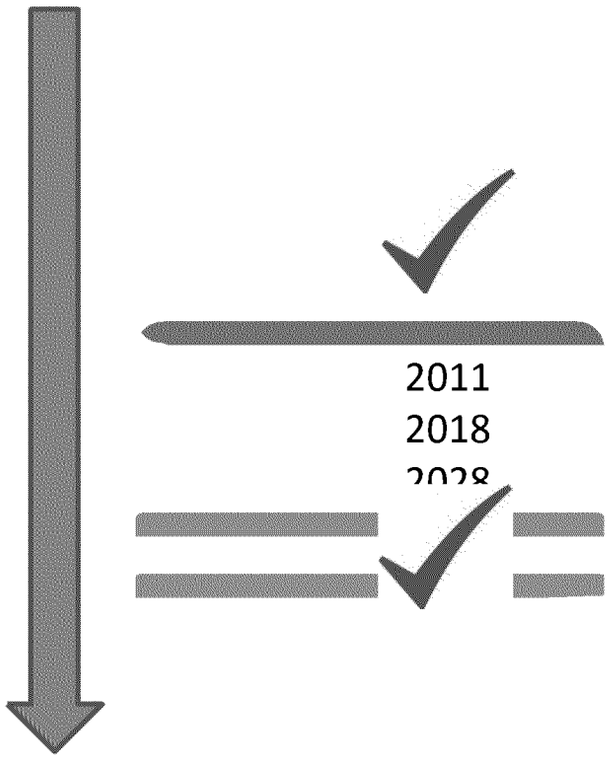
4. Near-Term Emission Inventories



- Gamma Inventory Improvements are Beginning
  - Project future year to **2023 & 2020**
  - Upgrade to **ERTAC v2.6**
  - 2023 Mobile: EPA MOVES & Nonroad
  - 2020 Mobile: 2017→2023 Interpolation
  - Remove rules no longer considered OTB
  - EMF Growth for point & maybe area
  - For 2020 some sectors interpolated
  - Other updates for 2011/2023 from EPA v6.3

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4. Gamma Inventory Photochemical Modeling Plan

Beta Modeling Complete & Documented

2011 Gamma Emission Inventory Base Case

- To ensure consistent inventories and update chemistry

2023 Gamma Emission Inventory Base Case

- For use in transport modeling
- Will include ERTAC rather than IPM

2020 Gamma Emission Inventory Base Case

- For use in Serious 2008 NAA
- Possibly for use in transp

Update Documentation

OTC Option: Tag emissions to perform contribution modeling with our own data and preferences

Document X in Packet

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4. Direction: Source Apportionment Modeling (1)

Which year(s) should source apportionment modeling be conducted for?

2011	2020	2023
- OTC has called for contribution assessment to use existing data	- DV based on 2 2016 not 201 - Inconsistent v EPA - Marginal Nonattainment Year - Inconsistent v EPA - Less robus inventory	- Best future year inventory - Consistent with EPA & other RPOs - Doesn't address attainment dates outside of NYC Metro

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4. Direction: Source Apportionment Modeling (2)

Which states should be tagged?

176(a)

- Members have analyses pointing to these states
- Less states being modeled, less resources needed

- May miss impacts some states (e.g Georgia)

Domain

- Covers all potential contributors available for analysis

- Most resources ne
- Texas, Georgia, other edge states fully modeled

C-SAPR U

- Less resources than full domain

- Excludes North Carolina
- Texas and other edge states not fully modeled

Also do states north of Connecticut and DC need tags?

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4. Direction: Source Apportionment Modeling (3)

Which sectors should be tagged?

- EGUs
- Onroad Mobile
- Non-EGUs (e.g., ICI Boilers)
- Oil & Gas
- Others (e.g., Marine, Nonroad)

What combination with states?

Sectors by themselves
- May not provide enough information to assess contribution

Sectors in each state
- May provide too detailed information especially if there a lot of combinations
- May be too resource intensive resource wise

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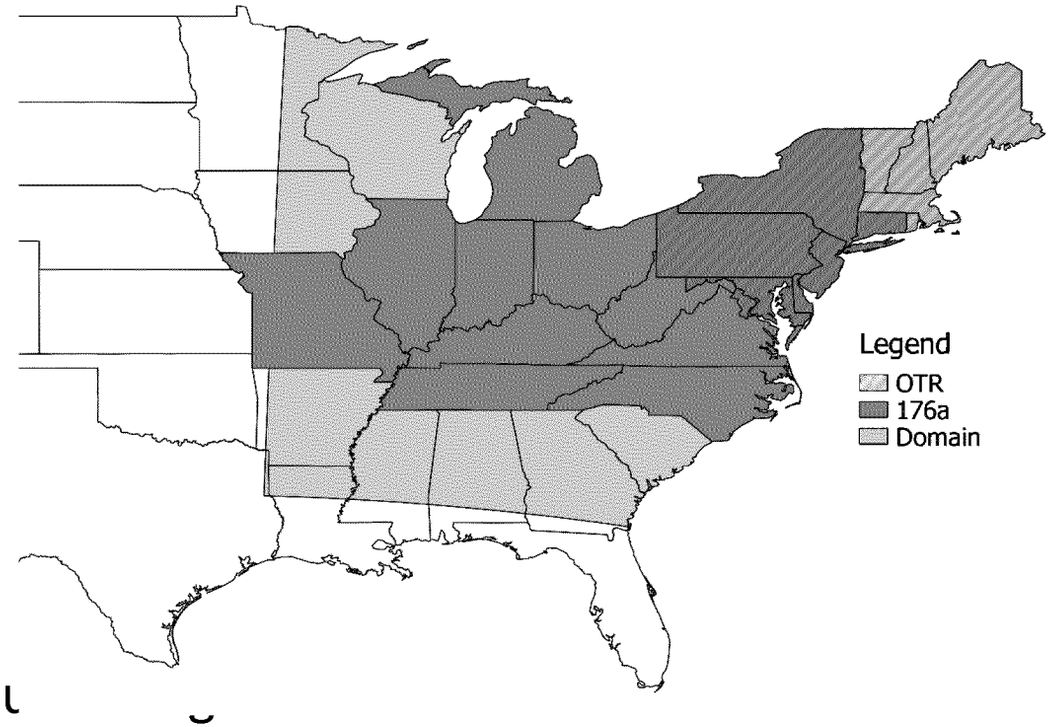
4. Direction: Source Apportionment Modeling (5)

- In Summary
  - Which year(s) should be modeled for source apportionment?
    1. 2011
    2. 2020
    3. 2023
  - Which states should be tagged?
    4. OTR states (13)
    5. 176A States (10)
    6. Canada? Partial states? Boundary?
  - Which sectors should be tagged?
    - EGU, OnRoad, NonRoad, Area, Biogenic, Su



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4. Direction: Source Apportionment Modeling (4)

- Slide on Resources! Talk to shan

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5. Currently Available: EPA Contribution Modeling

- Considers all monitors currently exceeding:
  1. The 2015 Ozone NAAQS
  2. The 2008 Ozone NAAQS
- EPA ozone contribution modeling with:
  3. 2017 emission inventories
  4. 2023 emission inventories
- Highlighted states contribute 1% or more of the applicable NAAQS

Answers the questions:

1. What states contribute to current nonattainment
2. What states will still contribute 1% or more should monitors currently in nonattainment not reach attainment by 2023

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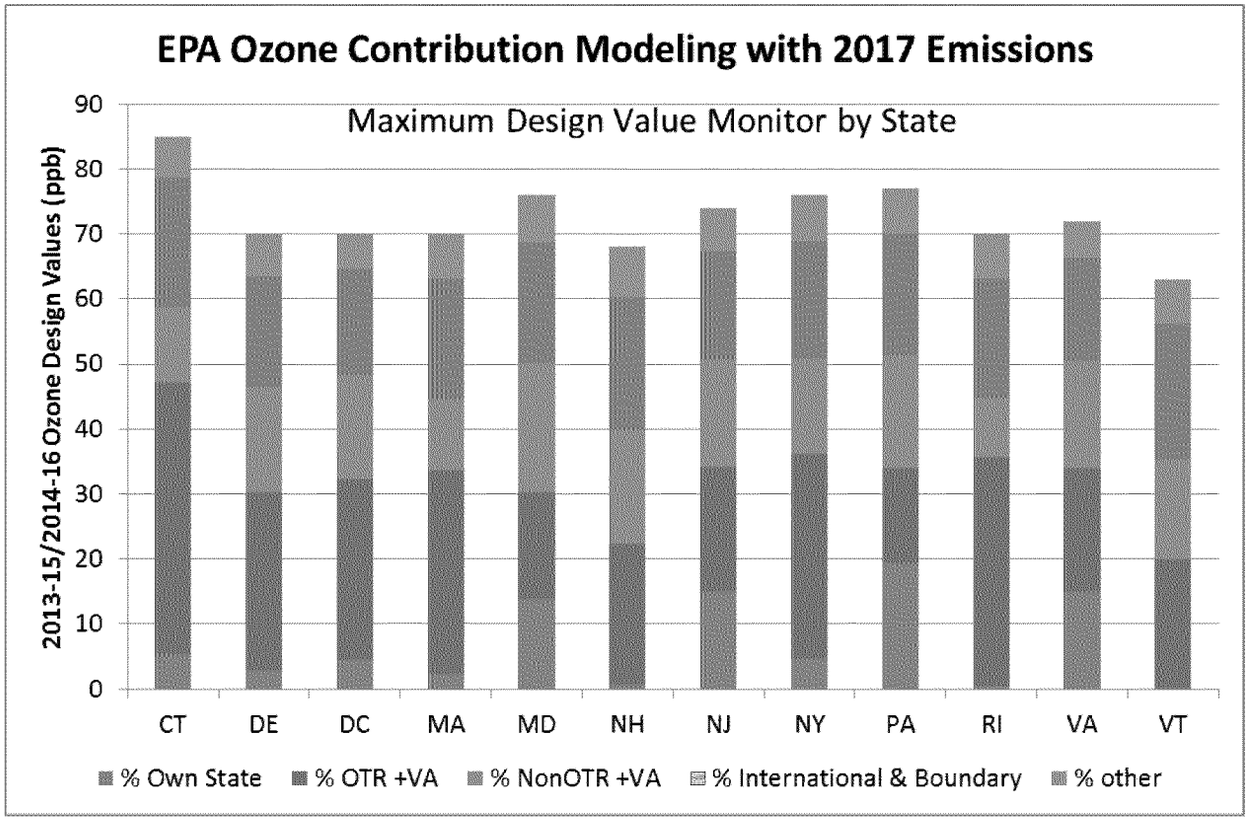
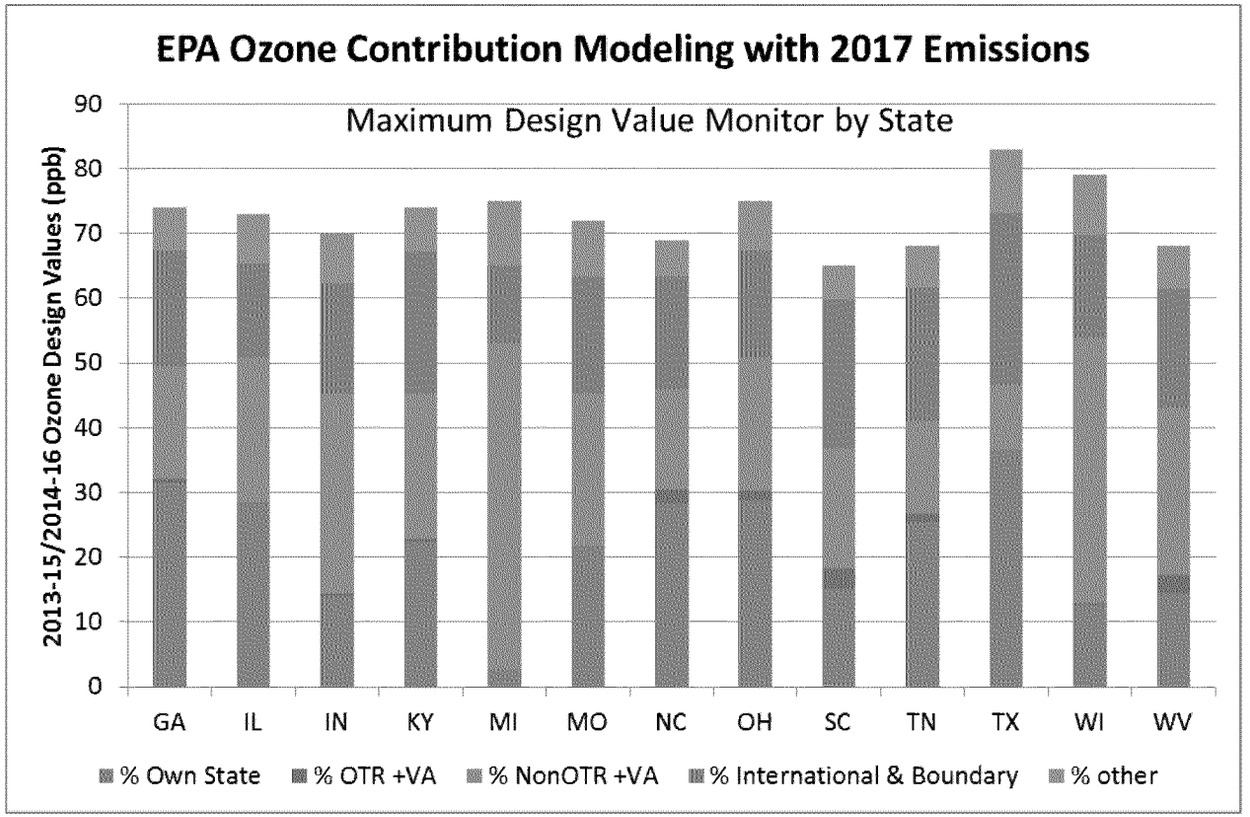
5. Contribution for Monitors with Current Maximum Design Value





Data Source: USEPA Contribution Modeling

5. Contribution Range for Monitors with Current Design Values Over Threshold

>75ppb	% Own		% OTR +VA		% NonOTR +VA		% International & Boundary		% other	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
CT	4%	13%	37%	51%	12%	17%	22%	25%	6%	10%
MD	18%	18%	22%	22%	26%	26%	25%	25%	9%	9%
PA	25%	29%	15%	19%	23%	25%	23%	24%	9%	9%

>70ppb	% Own		% OTR +VA		% NonOTR +VA		% International & Boundary		% other	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
CT	4%	14%	37%	51%	9%	17%	20%	26%	6%	10%
MA	9%	9%	45%	45%	11%	11%	19%	19%	16%	16%
MD	18%	32%	15%	24%	20%	26%	21%	25%	8%	10%
NJ	5%	20%	26%	41%	18%	24%	22%	26%	8%	9%
NY	6%	25%	30%	42%	10%	19%	20%	27%	7%	11%
PA	20%	35%	0%	26%	21%	30%	21%	31%	7%	10%
RI	6%	6%	48%	48%	15%	15%	19%	19%	12%	12%
VA	18%	21%	24%	26%	23%	25%	22%	25%	8%	8%

Data Source: USEPA Contribution Modeling

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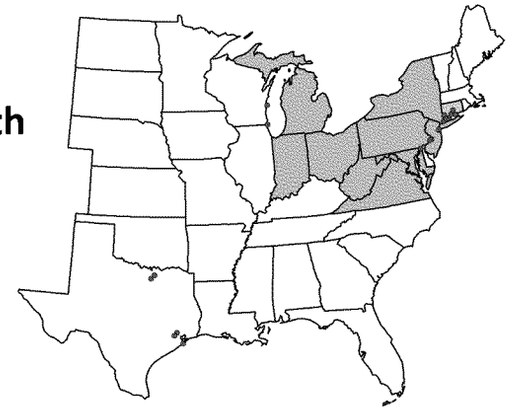
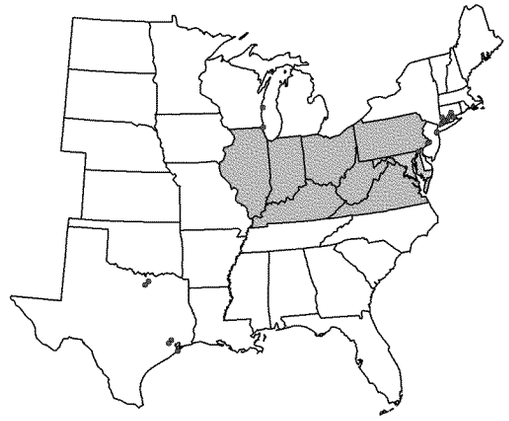
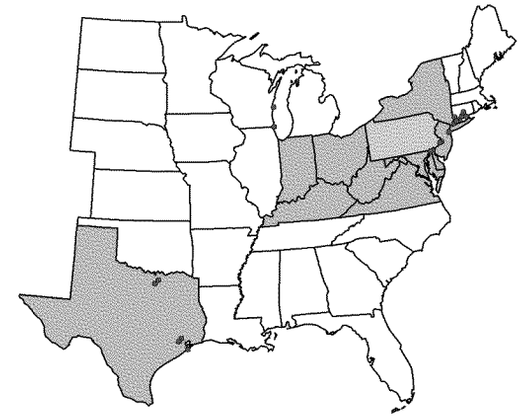
5. 2008 Ozone NAAQS: 75ppb - ≥1% Contributing States

	Connecticut	Maryland	New York	Pennsylvania
Contributors with 2017 Emissions				
Contributors with 2023 Emissions				

Data Source: USEPA Contribution Modeling

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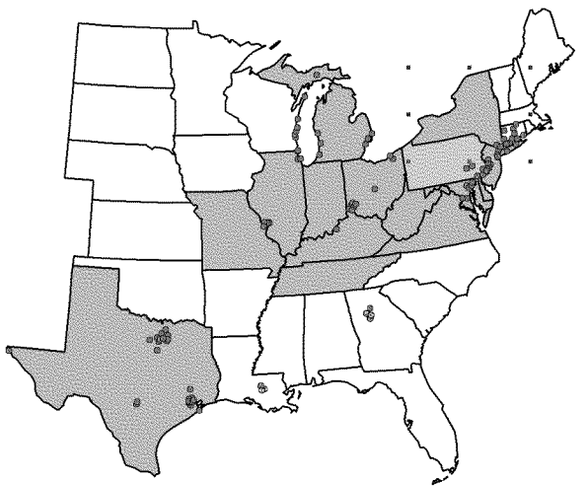
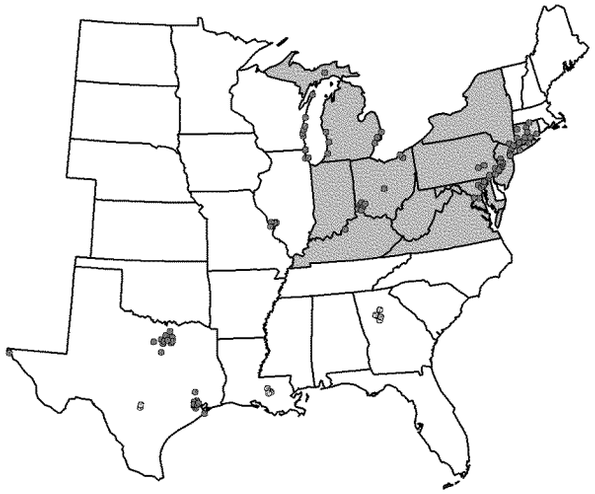
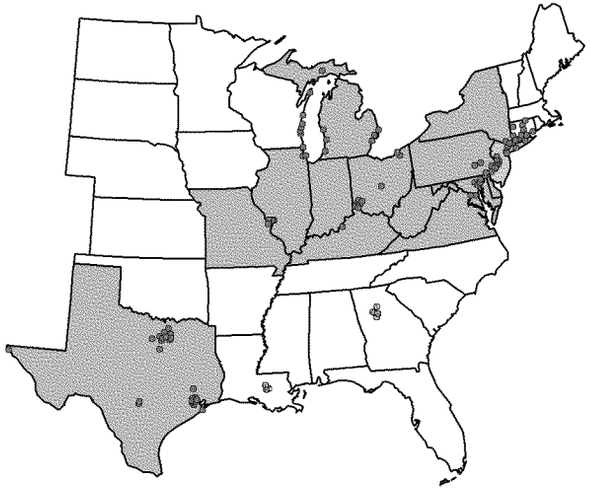
5. 2015 Ozone NAAQS: 70ppb - ≥1% Contributing States

Pennsylvania | **Connecticut** | **New Jersey**

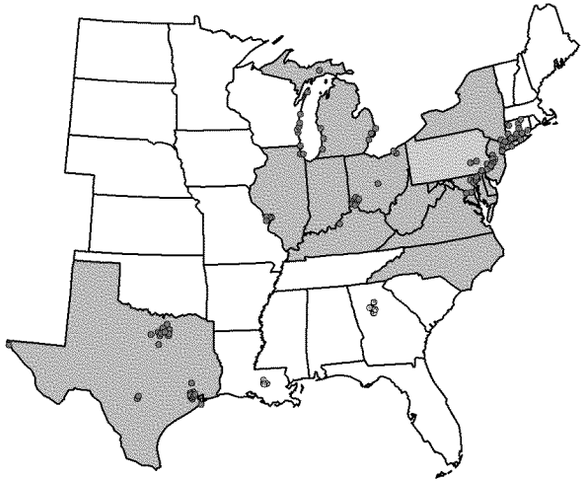
Contributors with 2017 Emissions

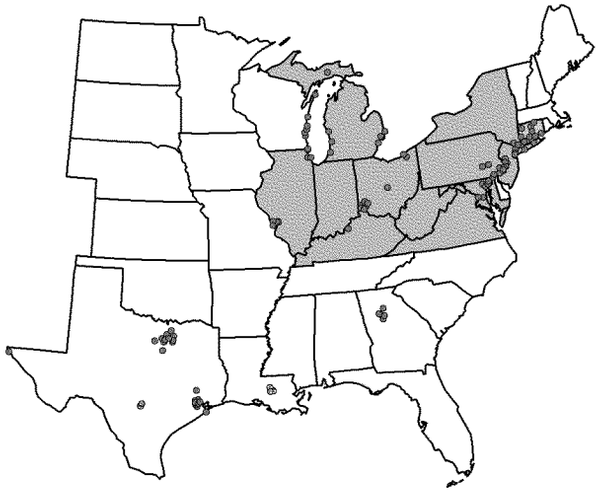






Contributors with 2023 Emissions





Data Source: USEPA Contribution Modeling

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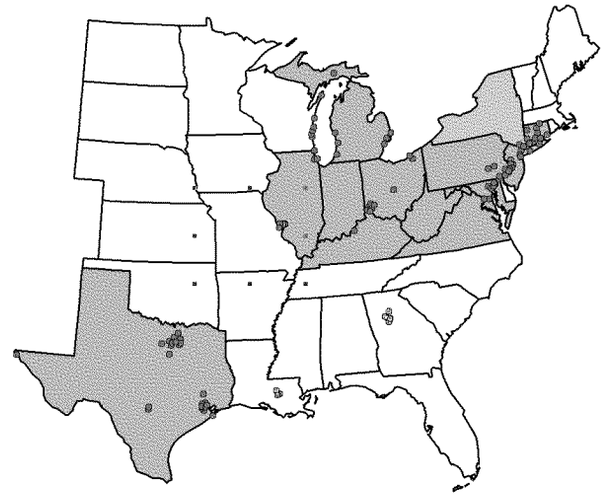
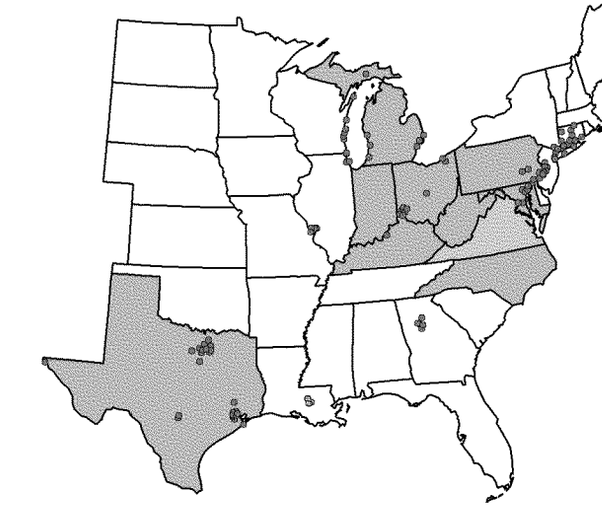
5. 2015 Ozone NAAQS: 70ppb - ≥1% Contributing States

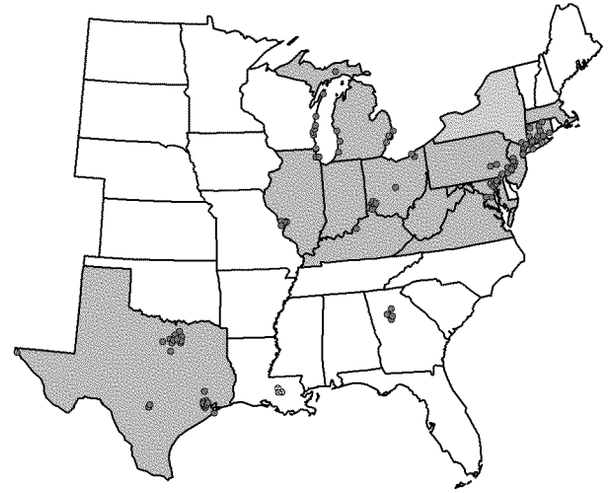
New York | **Maryland** | **Virginia**

Contributors with 2017 Emissions





Contributors with 2023 Emissions



Data Source: USEPA Contribution Modeling

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Inter-RPO Base Year Workgroup

- Via Federal/RPO collaborative workgroup developed recommendations for the next base year
- 2014 (most recent NEI year) was not recommended due to it being not conducive for ozone formation
- Recommended using both 2015 & 2016 as dual base years

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Inter-RPO Collaboration on 2015/2016 platform

- EPA appears to be more unwilling to help manage modeling platform
- Right now RPOs collaborate fairly well on developing inventory, but everyone goes their separate in managing it, partially because EPA did that for us with 2011
- RPOs don't collaborate on actual modeling beyond discussions
- Need to extend modeling domain to the west and south which will increase computing resources needed
  - Texas always shows up as a contributor to OTC
  - Will reduce impact of western and southern boundary conditions
- We need to determine how best to share resources and possibly collaborate more

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Conclusions & Next Steps

- Ozone exceedances in OTR in 2016 ozone season similar to 2015
- OTC modeling indicates that:
  - CMAQ performs reasonably well when modeled values for monitor grid cells are compared to monitored data
  - CMAQ & CAMx perform comparably
- Enhanced Monitoring Plans (EMPs) undergoing preliminary discussions
- Emissions inventory projections to 2020 & 2023 being prepared for transport & attainment SIP
  - Initial modeling will be performed with an interpolated inventory
  - Improved Gamma emission inventories to be available during summer/fall 2017

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Questions

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ED_001650_00042825-00030

May 8, 2017
From: OTC Modeling Committee
To: OTC Air Directors

Re: Recommendations for Source Apportionment Modeling for use in OTC Members Good Neighbor SIP

Background

States are required under section 110(a)(2)(d) of the Clean Air Act to submit SIP revisions that demonstrate how they will address air pollution from the state contributes to nonattainment or interferes with maintenance of the NAAQS in a downwind state.[1] These SIPs, called Good Neighbor SIPs are due three years after a NAAQS is updated, which for the 70ppb 2015 Ozone NAAQS makes the due date October 2018. EPA can later issue a Federal Implementation Plan (FIP) if states do not submit Good Neighbor SIPs, which they did for the 2008 Ozone NAAQS through the C-SAPR Update rule.[2] However, this FIP was only considered by EPA to be a "partial remedy" meaning there are still unfilled Good Neighbor obligations from upwind states.

When determining who contributes to nonattainment EPA typically projects an inventory that is reliant on IPM for EGU projections to the future year that corresponds to the attainment date for moderate nonattainment and conducts photochemical modeling that tags individual states to determine which states contribute to which monitors that are projected to be in nonattainment of have issues with maintenance. OTC has expressed several flaws with this approach including the use of IPM over ERTAC, the use of future year projections, and looking at average ozone season contribution over contribution on peak days.

This document is intended to provide the OTC Air Directors with options and recommendations for conducting source apportionment modeling to assist the states in their 2015 Good Neighbor SIP submittals and to make the case for what obligations still remain for 2008 Good Neighbor SIP submittals. There are several major decisions that need to be made before the OTC Committee can move forward with modeling:

1. Year(s) to model
2. Geographical areas to tag
3. Sectors to tag
4. Period should be looked at (e.g., ozone season average, ozone episodes)

Year(s) to Model

OTC has six inventories available that could be used in ozone sources apportionment. The inventories (Table 1) are in different states of completion and quality, though the level of quality is not significant between the different inventories. Each year has its own pros and cons for use in source apportionment modeling and each additional year modeled adds to the level

[1] *Clean Air Act Amendments of 1990.*
[2] US EPA, "Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS."

of resources needed to conduct modeling

Table 1: Available Inventories

Year	Level	Status	Notes
2011	Gamma	In Development	Beta 2 is Complete
2017	Beta 2	Complete	
2018	Alpha 2	Complete	
2020	Gamma	In Development	Several sectors will be interpolated
2023	Gamma	In Development	
2028	Alpha 2	Complete	

OTC has stated in several comments to EPA concerning Good Neighbor SIPs that source apportionment should be conducted on data from the years used to determine nonattainment and not future year projections. Ozone designations for the 2015 NAAQS will be based on data from 2014-2016. Ideally we would use data from those years, but those inventories are not yet available making 2017 the year closest to meeting that recommendation. 2017 has the added benefit of being the year that moderate nonattainment areas were supposed to have met the NAAQS so modeling of 2017 could be used to make cases for what is needed from upwind states to complete the partial remedy.

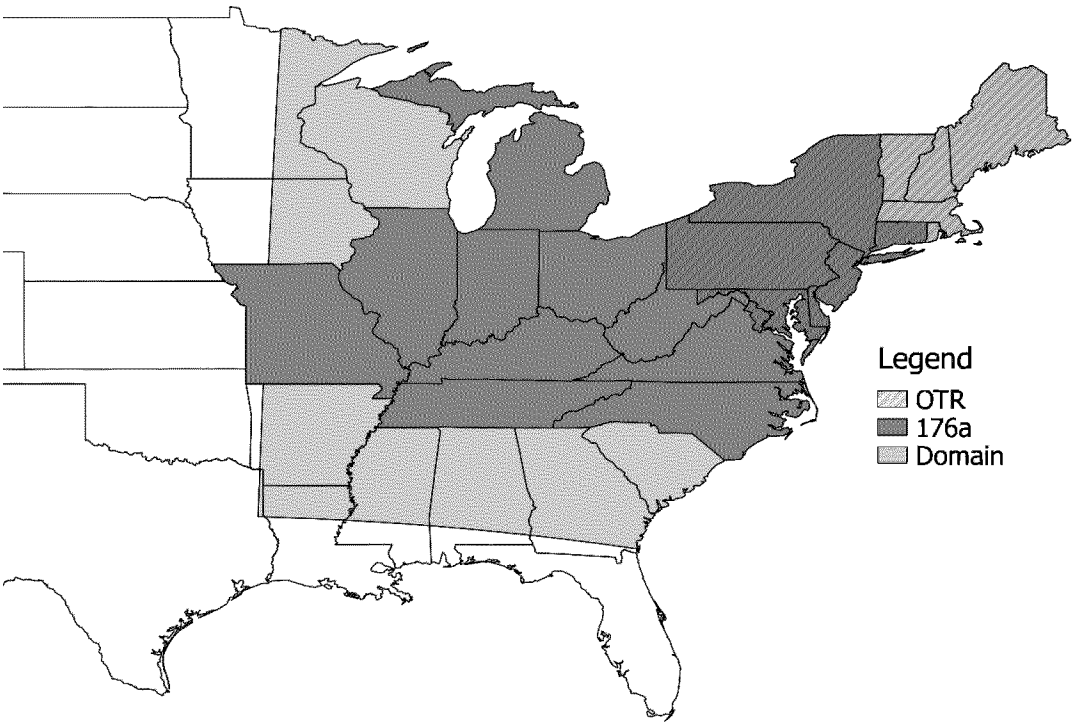
2020 corresponds to the marginal attainment date for 2015 Ozone NAAQS, which is the classification expected for all parts of the OTC outside of the NYC area (assuming EPA follows traditional patterns in selecting the size of the nonattainment area). Good neighbor obligations should be met in time for these areas to attain the NAAQS. 2020 is also the expected attainment date if the parts of the OTR that are not attaining the 2008 Ozone NAAQS get bumped up to serious nonattainment. The 2020 inventory will be the least developed of the inventories being discussed since several sectors (e.g., onroad mobile, nonroad) are being interpolated.

2023 corresponds to the moderate attainment date for the 2015 Ozone NAAQS, which is the classification expected for the New York City area (or if EPA follows some governor recommendations the I-95 corridor). 2023 is also the year that EPA has modeled to show contribution and we expect upwind states to use if they conduct source apportionment modeling. This year would follow generally accepted practices, but also not correspond as well with previous statements made by OTC.

2011 is too far in the past and is not recommended for this work. 2018 and 2028 are the lowest quality and do not have any particular relevance to planning dates for ozone and are not recommended for use.

Geography to Tag

Figure 1: Map of potential states to tag.



One option is to tag the states in the OTR. All states from Connecticut south in the OTR should be tagged since they would be expected to contribute to nonattainment or interfere with maintenance. The remainder of New England has not been included in recent transport FIPs, so to save on resources it may make sense to exclude those five states from analysis. With the exception of Missouri all of the states that were included in the petition under 176(a) because are wholly within the modeling domain and are expected to contribute to nonattainment or maintenance. Wisconsin and South Carolina are wholly within the modeling domain, but were not included petition and South Carolina is not included in the C-SAPR Update. The remainder of the states are in and outside of the domain to differing degrees, though only Georgia, Alabama, Mississippi and Arkansas likely have enough geographic area within the domain to warrant tagging. Marine emissions and Canadian emissions could also be considered for tagging as could the domain boundaries, either as a whole or individually for each cardinal direction.

There are two approaches that could be considered for geographic tagging. One is to process the tags prior to SMOKE processing and the other issue to assign 12x12 grid cells to particular states. The former is more accurate but will involve reprocessing some inventories through SMOKE which takes additional resources. The latter would be less accurate and could create problems when large point sources or major metropolitan areas are along state boundaries.

Sectors to Tag

EPA's contribution assessments have typically relied on solely tagging of emissions from states and not for sectors. The FIPs that followed then tended towards control of EGUs. However, the C-SAPR Update rule was found to be a partial remedy and other sectors would need be controlled. As a result it would be necessary to determine what other sectors need to be control. Inventory files are kept separate for certain sectors prior to margining them so tagging emissions based on the already existing sectors could result in a lower workload than tagging subsectors. This would mean that we could look at EGUs separately from other point sources, but could not look at ICI boilers separate from Cement Kilns for example. Also the smaller the sector the less likely that attributable contribution could be determined. The currently separated ozone relevant inventory files are:

1. Area Source
2. Biogenic Emissions
3. C1/C2 Marine and Rail
4. IMO C3 Marine
5. ERTAC EGUs
6. Non-EGU Point
7. Non-ERTAC IPM EGUs
8. NonPoint Oil &Gas
9. Nonroad
10. Onroad
11. Point Oil & Gas
12. Refueling

One other aspect of tagging sectors is whether we would conduct a model that looks only at sectors or whether we would look at sectors within a state (e.g., EGUs versus EGUs in PA, EGUs in MD, etc.). The former approach has the downside of requiring two runs be conducted, one for state tags and one for sector tags, and the latter has the downside of substantially increasing the run time due have a larger number of tags and making contribution from some sectors since contributions from a sector in a particular state might not amount to much.

Time Span

It has been past practice for EPA to conduct source apportionment work for the entire ozone season, however past comments and statements from OTC have shown the need to look at particular high ozone events rather than averaging out impacts over an ozone season. OTC has also invested resources in an analyzing particular ozone events from the 2011 base year and developed an episodic modeling platform.[3] OTC could take the approach of using the episodic modeling platform to more quickly runs with an increased number of tags and focus more on contribution during the higher ozone days that occurred in July of the base year rather.

[3] Ozone Transport Commission, *Technical Support Document for the 2011 Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union Modeling Platform*.

Modeling Resources

A typical CAMx run takes 10-20 minutes/modeling day to run so a typical ozone season run would take 2-3 days to complete whereas the July only run would take about a half a day. Running upwards of 100 tags would increase the time per modeling day to 1-2 hours, which would increase running time for an ozone season run to 2-3 weeks and a July episode run would take around 3 days.

Post processing with upwards of 100 tags would expect to take 2-4 weeks.

Recommendations

The OTC Modeling Committee recommends the following approach.

Strawman recommendation

- Run 2020 & 2023
- Tag the 1% contributing states and the OTR states, Canada, and boundary conditions as a whole (24 tags).
- Tag only EGUs, non-EGU point, onroad, nonroad, c1c2rail, c3, and point oil and gas (7 tas)
- Run these on the July ozone episode only.

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 2/20/2018 6:00:00 PM
End Date/Time: Tue 2/20/2018 7:30:00 PM
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....
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Draft Agenda

1. Meeting Schedule
2. Richmond Meeting
3. 2011 Platform

a. Gamma Inventory Documentation - http://www.marama.org/technical-center/emissions-inventory/2011-gamma-inventory-and-projections
b. GN SIP Modeling

i. Contribution Assessment
ii. Control Case Modeling

c. 2020 CMAQ Modeling
d. 2028 CMAQ Modeling
e. Modeling TSD

4. 2016 Inventory Development
5. Ring Marine Paper

---GoToMeeting invitation begins---
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https://global.gotomeeting.com/join/ Ex. 6
You can also dial in using your phone.
United States Ex. 6
Access Code: Ex. 6
---GoToMeeting invitation ends---

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Thur 3/23/2017 5:00:00 PM
End Date/Time: Thur 3/23/2017 6:30:00 PM
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CMAQ and CAMx Comparison 0320_2017.pptx
2020-2023 Screening Modeling Outline.doc
OTC_Comment_Letter_NODA_2015_O3_Std_Implementation_170321.docx

Agenda:

1. Meeting Schedule
2. CMAQ vs CAMX discussions

a. NYSDEC
b. UMD

3. 2011/2023/2020 Modeling

c. 2023/2020 screening runs
d. Emissions inventory development
e. SMOKE processing

4. NODA Letter
5. Committee Meeting Slides [forthcoming]
6. Rescheduling April Call

---GoToMeeting invitation begins---
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You can also dial in using your phone.
United States + Ex. 6
Access Code: Ex. 6
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April 6, 2017

United States Environmental Protection Agency
Air and Radiation Docket and Information Center
1301 Constitution Ave. N.W., Washington, DC 20460
Mail Code: 2822T

Attention: Docket ID No: EPA-HQ-OAR-2016-0751

RE: Notice of Availability of the Environmental Protection Agency's Preliminary Interstate Ozone Transport Modeling Data for the 2015 Ozone National Ambient Air Quality Standard (NAAQS)

The Ozone Transport Commission (OTC) appreciates the opportunity to review and comment on the United States Environmental Protection Agency (EPA)'s preliminary ozone transport modeling data relevant to the 2015 ozone NAAQS in its "Notice of Availability of the Environmental Protection Agency's Preliminary Interstate Ozone Transport Modeling Data for the 2015 Ozone National Ambient Air Quality Standard (NAAQS)." (Transport NODA) (82 FR 1733, January 6, 2017)

The OTC is a multi-state organization created under the Clean Air Act (CAA) led by Governors and state air official representatives from 12 states and the District of Columbia to advise the EPA on finding solutions to the common problem of ground level ozone and precursor pollutants. The Commission ensures public health protection by identifying practical and cost-effective emissions reduction solutions. Ground-level ozone is a criteria pollutant formed by precursors and transported across state lines directly affecting the health of more than 66 million people in the northeast and mid-Atlantic region particularly the young, elderly, and persons with compromised health.

Section 110(a)(2)(D)(i)(1) of the CAA, also known as the "Good Neighbor" (GN) provision, requires each state to include in its State Implementation Plan (SIP) provisions that prohibit emissions that will significantly contribute to nonattainment of, or interfere with maintenance of, a NAAQS in a downwind state. Per the CAA, the GN SIPs are due within 3 years of promulgation of a revised NAAQS, i.e. by October 26, 2018 for the 2015 ozone standard. The EPA memorandum of October 1, 2015 noted that the GN provision for the 2015 ozone NAAQS can be addressed in a timely fashion using the framework of the Cross-State Air Pollution Rule (C-SAPR). If EPA finds that states have not timely submitted GN SIPs or disapproves such a SIP, then EPA must promulgate Federal Implementation Plans (FIPs) to satisfy the GN provision. EPA has applied the C-SAPR framework to address the GN provision for previous standards for ozone and other criteria pollutants.

The Transport NODA addresses steps 1 and 2 of the four-step C-SAPR framework, using preliminary modeling for 2023 to identify projected nonattainment and maintenance receptors and identifying upwind states that contribute to these receptors. EPA notes that states may choose to modify or supplement these data when developing their GN SIPs, and/or EPA may update these data for potential future analyses or regulatory actions related to interstate ozone transport for the 2015 ozone NAAQS. ***However the Transport NODA, in its current form, as we will make the case, is not technically sound to an extent that it should be considered an acceptable technical underpinning of a GN SIP.***

As many areas within the OTR continue to monitor nonattainment of the 2015 ozone standard, it is critical to the OTC that Good Neighbor requirements for the 2015 ozone standard are addressed on schedule.

The OTC states offer the following comments regarding various aspects of the Transport NODA.

Air Quality Modeling Underprediction

EPA used the Version 6.3 emission inventory and the Comprehensive Air Quality Model with Extensions (CAMx) v6.32 for base year and future year air quality modeling to identify receptors and quantify contributions[1]. The platform was nearly identical to that used to model 2017 ozone levels to identify receptors and quantify contributions for the C-SAPR Update Rule[2]. Ozone season monitoring data for two of the years (2015 and 2016) that constitute the 2017 design value (DV) period are available, so some comparison of the modeled projections to monitored values is possible. Since the procedure for determining monitored DVs is specifically designed to minimize anomalies in a particular year from having too much weight, large swings in DVs for 2017 are not expected when compared to the 2015 and 2016 values.

Table 1 compares 2015 and preliminary 2016 monitored DVs at the 23 worst sites in the OTR with 2017 modeled future design values (DVFs) from EPA's C-SAPR Update Rule. The differences are substantial, with all but two sites underpredicted by the C-SAPR Update Rule modeling for 2017. The results in Table 1 show that the 2017 C-SAPR Update Rule projections underpredicted the preliminary 2016 DVs by 5ppb or more at 15 sites, and by 10 ppb or more at 4 sites. Some of the largest differences occur at the Connecticut coastal sites (e.g. Westport, Greenwich and Stratford) which recorded the highest preliminary 2016 DVs in the OTR. Note: For comparison, Table 1 also shows 2017 DVFs predicted by the OTC with the Community Multi-Scale Air Quality (CMAQ) model, which are somewhat higher than EPA's projections, but still tend to underpredict the preliminary 2016 measured DVs. Although EPA's Tier 3 Motor Vehicle Emission and Fuel Standards commence in 2017, EPA projects the program will provide an average decrease in ozone DVs of only about 0.6 ppb[3]. Even lower ozone benefits are projected by EPA[4] for Connecticut from the C-SAPR Update in 2017.

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[1] US EPA, "Technical Support Document (TSD) Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the Year 2023," December 2016.

[2] US EPA, *Air Quality Modeling Technical Support Document for the Final Cross State Air Pollution Rule Update*, Technical Support Document, (Office of Air Quality Planning and Standards, August 2016).

[3] US EPA, *Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule*, Regulatory Impact Analysis EPA-420-R-14-005, (Office of Transportation and Air Quality, March 2014).

[4] US EPA, *Ozone Transport Policy Analysis Final Rule TSD*, August 2016.

The projections used in the 2017 C-SAPR Update Rule are clearly under predicting current DVs in the Ozone Transport Region (OTR) often by large amounts. Since the projections contained in the Transport NODA rely on the same underlying platform and many of the same methodologies, the 2023 projections are likely to underpredict as well. As a result, the Transport NODA modeling should not be used as the basis for any 110(a)(2)(d) SIPs for areas that could contribute to nonattainment or interfere with maintenance of the ozone NAAQS in the OTR.

Table 1: Monitored and Modeled Results at Top 20 Ozone Monitors in OTR by 2016 Design Value (in ppb)

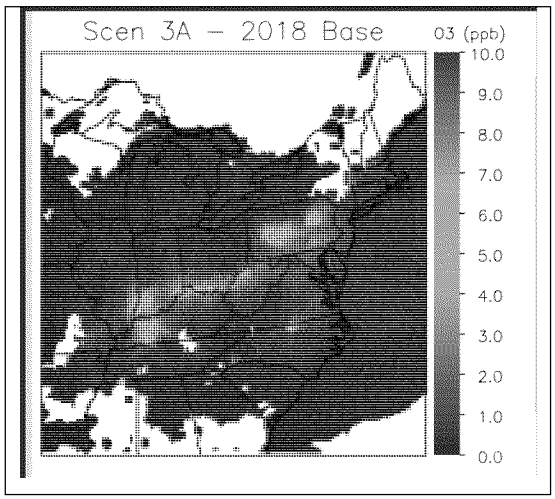
State	County	Site	AQS Code	2016 DV (Prelim.)	2015 DV	2017 EPA C-SAPR Update DVF[5]	2017 OTC CMAQ DVF[6]
CT	Fairfield	Westport Sherwood Island	90019003	85	84	76	83
CT	Fairfield	Greenwich Point Park	90010017	82	81	74	77
CT	Fairfield	Stratford	90013007	81	83	75	77
CT	Middlesex	Middletown	90070007	79	80	69	70
CT	Fairfield	Western Conn State Univ	90011123	78	76	71	74
PA	Philadelphia	North East Airport (NEA)	421010024	77	73	73	73
PA	Bucks	Bristol	420170012	77	75	70	70
CT	New Haven	Criscuolo Park-New Haven	90090027	76	76	66	67
NY	Richmond	Susan Wagner HS	360850067	76	74	75	78
MD	Cecil	Fair Hill	240150003	76	73	69	73
CT	New Haven	Hammonasset State Park	90099002	76	78	76	77
CT	Hartford	McAuliffe Park	90031003	75	76	65	66
CT	Litchfield	Mohawk Mt-Cornwall	90050005	74	70	61	62
NJ	Middlesex	Rutgers University	340230011	74	72	70	71
NY	Westchester	White Plains	361192004	74	73	71	73
NJ	Bergen	Leonia	340030006	74	74	68	68
NJ	Mercer	Wash Crossing	340219991	73	71	66	66
NJ	Ocean	Colliers Mills	340290006	73	72	71	72
NJ	Gloucester	Clarksboro	340150002	73	73	72	74
CT	Tolland	Stafford	90131001	73	76	65	67
PA	Chester	New Garden	420290100	73	69	64	66
MD	Harford	Edgewood	240251001	73	71	78	81
MD	Harford	Aldino	240259001	73	70	66	70

Integrated Planning Model (IPM) Projection Flaws

The EPA modeling is based on a 2023 Electric Generating Unit (EGU) inventory that relied on IPM model v5.16 for projecting EGU activity and emissions[7]. OTC modeling has shown that

Figure 1: Scenario 3A (NOX Control Case) versus 2018 Alpha 2 OTC Ozone Modeling

[5] US EPA, "Data File with Ozon0e Design Values and Ozone Contributions," August 2016.
[6] Ozone Transport Commission, *Technical Support Document for the 2011 Ozone Transport Commission/Mid-Atlantic Northeastern Visibility*



The EPA modeling is based on a 2023 Electric Generating Unit (EGU) inventory that relied on IPM model v5.16 for projecting EGU activity and emissions[7]. OTC modeling has shown that substantial ozone reductions can occur even if emissions are lowered at power plants. This is demonstrated in Figure 1 where emissions from several units have been substantially reduced from the base case resulting in localized ozone benefits in the 6 ppb range.

Given this sensitivity of modeling results to EGU emissions, if IPM's projections are incorrect, then the results of the modeling may also be incorrect. This would in turn affect conclusions about future year ozone levels, linkages between upwind and downwind states, and contribution responsibilities. Ongoing

EGU projection efforts in the OTC and other areas using the Eastern Regional Technical Advisory Committee's (ERTAC) EGU Forecasting Tool have shown that the IPM modeling has potential flaws which could adversely affect the transport remedies developed by states that rely on the IPM-based modeling to assess their GN responsibilities, thereby providing downwind states with insufficient relief from transported ozone pollution. Some of these potential flaws with the IPM modeling include:

Potential reductions from the Clean Power Plan (CPP) and C-SAPR Update

The current projections include substantial reductions from the CPP, which was recently stayed by the Supreme Court pending judicial review. If the rule is ultimately vacated, or if significant delays occur during the judicial review process, then the anticipated emission reductions will not occur by 2023. If EPA does continue to include the CPP in its future projections, it should consider using a more conservative approach for determining future year emissions. The mass-based, no-interstate-trading approach likely overestimates future emission reductions. The Regional Greenhouse Gas Initiative (RGGI) is already in place in the Northeastern US, so a trading-based approach to the CPP is far more likely in this region.

In addition, the C-SAPR Update (81 FR 74504, October 26, 2016), which is scheduled to take effect in the 2017 ozone season, may be eliminated under a proposed Congressional Review Act disapproval resolution. This would mean that states relying on the modeling presented in this Transport NODA would be taking enforceable emissions reduction credit based on a rule whose outcome is uncertain at this time. Any GN SIP that relies on emission reductions that are ultimately not enforceable must be disapproved by EPA. States should quantify these emission reductions to include in their Good Neighbor SIPs if they choose to use this platform.

IPM predictions and assumptions

The IPM modeling predicts that a significant number of new units, capacity expansions, controls, and retirements will occur by 2023. However there is little evidence (i.e. supporting

Union Modeling Platform, Washington, DC (OTC, November 15, 2016).

[7] US EPA, "EPA Base Case v.5.16 for 2015 Ozone NAAQS Transport NODA Using IPM Incremental Documentation," December 2016.

permit applications or adopted federal or state specific rules) to indicate that this will occur in such a short period. Also, some units have a consistent history of being projected by IPM as undergoing an operational change which does not ultimately occur. For example, IPM has consistently predicted that a number of coal-fired EGUs in the Northeast will retire, even though there are no current plans to retire these units. Finally, IPM assumes that installed emission controls will operate throughout the ozone season. Based on multiple detailed analyses of NOx emissions data provided to EPA and the states, it has been shown that in reality, NOx controls are not consistently operated. The potentially unrealistic predictions and assumptions associated with the IPM modeling have resulted in significantly overoptimistic emissions reduction projections, compared with other EGU emissions projections tools such as the ERTAC EGU Forecasting Tool.

The ERTAC EGU workgroup has developed an extensive EGU dataset of state-approved unit-specific information on emission levels, air pollution control equipment, and retirement plans. Table 2 compares ozone season NOx emissions projected by the IPM and ERTAC tools. ERTAC projects 2023 emissions will be 77% higher than projected by IPM. IPM projects far less NOx emissions from coal than projected by ERTAC (only PA, MD, and VA continue to have emissions from coal in IPM). While some of these changes may indeed occur, they are far more aggressive than can be expected considering the feedback received from states through the ERTAC EGU data review process and on-the-books rules. Another notable difference is IPM's projection that oil units do not run in 2023. Many of these units, in the New York City area in particular, are must-run units needed for electric reliability. These must-run units often operate on the worst air quality days during the ozone season, so the IPM appears to under-represent an important temporal component regarding NAAQS attainment and maintenance in its projections.

Table 2: 2023 Ozone Season NOx Emissions (tons) by State and Fuel Type in ERTAC v2.6 and IPM v5.16

	Coal		Gas		Oil	
State	**ERTAC**	**IPM**	**ERTAC**	**IPM**	**ERTAC**	**IPM**
CT	95.45		316.34	375.41	38.15	
DC						
DE	304.24		567.21	527.74	117.30	
MA			686.43	944.20	31.48	
MD	5080.60	1063.67	257.02	770.73	499.58	
ME			237.31	142.11	8.38	
NH	524.98		99.59	140.01	9.14	
NJ	987.36		1294.54	1283.64	28.43	
NY	1112.69		5165.84	4251.50	258.05	
PA	21961.03	8260.34	2277.51	4708.48	442.16	
RI			299.22	237.25		
VA	5562.51	2265.19	1952.97	3427.05	141.74	
VT				0.35		
Grand Total	**35628.86**	**11589.20**	**13153.99**	**16808.47**	**1574.40**	**0**

EPA should conduct a true-up of IPM emissions projections (e.g. comparing C-SAPR Update projections to actual emissions), in order to better assess IPM accuracy. In future EPA modeling of utility sector emissions, EPA should modify some of IPM's input assumptions regarding unit retirements, shutdowns, and operation of controls to better reflect currently known conditions. EPA should also consider utilizing the ERTAC EGU Forecasting Tool as a basis or supplement for its EGU emissions projections.

Other Emission Inventory Projections

Though OTC has concerns about the use of IPM for projecting future year emissions from EGUs we appreciate the willingness of EPA to use the growth factors that were submitted by our states for many other inventory sectors. States often have more direct knowledge as to changes in local emission inventories, and EPA's use of this data has strengthened the relevant sectors of the 2023-projected emissions inventory.

Meteorology

The EPA relies exclusively on 2011 meteorology for the modeling presented in this Transport NODA. While OTC research has shown that 2011 was conducive to ozone formation and thus an appropriate choice in many ways, we also found that the 2011 meteorology had some notable air flow differences from other high ozone years in our region. One specific concern is that the 2011 meteorology contains a relatively weak southerly air flow compared to other modeled years (2002, 2005, and 2007) and consequently produces significant differences in the state contribution modeling results.

Historically, the southwesterly airflow pattern which carries ozone and its precursors up the Atlantic coast, when combined with westerly upper level transport, can lead to ozone exceedances in the OTR. When such airflows occur, states such as North Carolina can become contributors to ozone nonattainment in our region. Here we will look at an analysis of the airflows impacting the Lewes, Delaware monitor as an example. As Figure 1 shows, the southerly transport pattern during high ozone days was relatively weak in 2011 compared to many other years. This figure contains a graphic illustration of the major air flow patterns for the Lewes ozone monitoring station in Delaware over a number of years. Figure 2, which compares air flows from 2011 to the other seven years analyzed, further illustrates the lack of transport from the south in 2011 compared to other recent years. This meteorological difference likely contributed to the exclusion of southern states as significant contributors to the OTR according to the 2011-based modeling, even though previous CSAPR modeling identified these states as significant contributors for modeled years with more prominent southerly air flow, e.g. in 2007.[8]

[8] US EPA, *Air Quality Modeling: Final Rule Technical Support Document*, Research Triangle Park, NC, Technical Support Document (Office of Air Quality Planning and Standards, June 2011).
[9] Sonoma Technology, Inc., "Delaware Trajectory Assessment," Technical Memorandum, (October 6, 2016).

Figure 2: Difference comparison maps for Lewes for high-ozone days versus all ozone-season days (2008–2015). Arrows indicate major flow patterns. Dashed circles in 2011 and 2015 indicate lack of flow from certain areas[9]

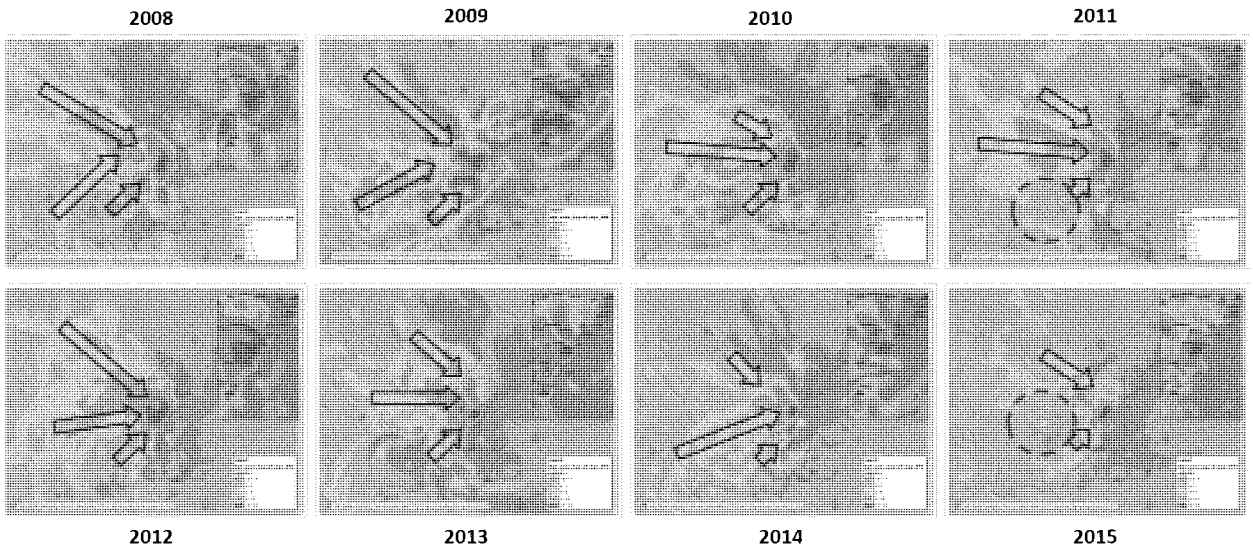
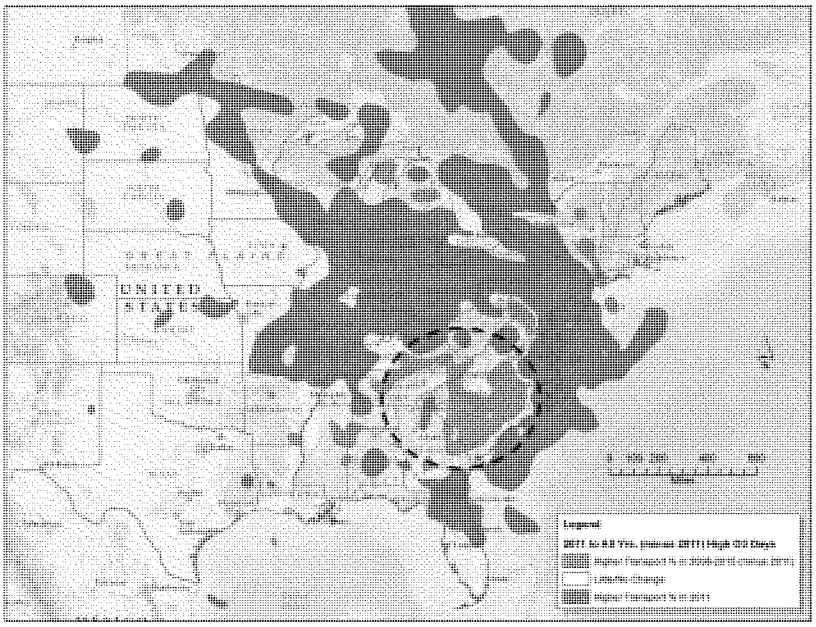


Figure 3: Difference comparison composite map for high-ozone days in 2011 versus high ozone days in all other years at the Lewes monitoring site. The dashed circle indicates there was less southwesterly air flow in 2011 compared to all other years[10]



OTC requests that future EPA analyses consider all meteorological regimes, including the southerly transport flows that have been shown to contribute to ozone transport into the Northeast. This could be accomplished by using 2015 and 2016 meteorology for future transport modeling efforts or by including projections from 2012 (reflecting 2012 meteorology) in addition to 2011.

[9] Sonoma Technology, Inc., "Delaware Trajectory Assessment," Technical Memorandum, (October 6, 2016).
[10] Ibid.

Shorter Contribution Time Period

Scientific literature shows that short-term exposure to ozone can be problematic to human health.[11,12] As a result, the EPA has determined that the most appropriate way to show that an area is in nonattainment of the health-based standard is by using a 4th highest 8-hour average ozone concentration. However, in the modeling conducted by EPA to show contribution to ozone nonattainment through the GN process, EPA derives the 8-hour attainment assessment from a cumulative ozone season average contribution calculation.

Research from OTC states has shown that various upwind states can contribute significantly (>1% of the ozone NAAQS) over a high ozone period of 8 hours as the transport patterns shift during the day. However, despite the fact that different regions dominate, each for several hours, EPA is applying a seasonal average mathematical calculation, which diminishes the role of some of these contributing states, and thus fails to include them in a remedy to ozone nonattainment in the OTR. In the Northeast, significant ozone contributions can come from many upwind locations and seasonal averages may oversimplify the situation leading to only a partial solution to the ozone transport problem.

The following are two examples using the CMAQ Integrated Source Apportionment Method (CMAQ ISAM) to display the importance of looking at short term contribution. CMAQ ISAM was applied to compute the ozone contribution associated with the mobile and EGU NOx and VOC emissions from regions of MANE-VU, LADCO, SESARM and CENRAP within the OTC modeling domain at four monitors, Greenwich, CT, Westport, CT, Edgewood, MD and Babylon, NY. The modeling was conducted by New York State Department of Environmental Conservation and used CMAQ_ISAM v5.0.2, the NEI 2011 v1 for emissions inventory, EPA's 2011 12-km WRF meteorology, and GEOS-Chem boundary conditions.

Figure 3 shows the contributions from mobile sources and EGUs on June 8, 2011 at Edgewood, MD. Emissions from the LADCO region have a strong impact in the morning and emissions from the SESARM region have a strong impact during the highest ozone hours. In fact the emissions from SESARM contribute more to ozone levels on several hours than local MANE-VU emissions do. However, if these contributions are averaged over the course of a day, the signals from LADCO and SESARM lose strength because ozone impacts are not

Figure 4: CMAQ ISAM results for Edgewood, MD (240251001), June 8, 2011

[11] Michelle L. Bell, Jonathan M. Samet, and Francesca Dominici, "Ozone and Mortality: A Meta-Analysis of Time-Series Studies and Comparison to a Multi-City Study (The National Morbidity, Mortality, and Air Pollution Study)," 2004, http://biostats.bepress.com/jhubiostat/paper57/.
[12] Xue-yan Zheng et al., "Association between Air Pollutants and Asthma Emergency Room Visits and Hospital Admissions in Time Series Studies: A Systematic Review and Meta-Analysis," ed. Tim S. Nawrot, *PLOS ONE* 10, no. 9 (September 2015): e0138146.

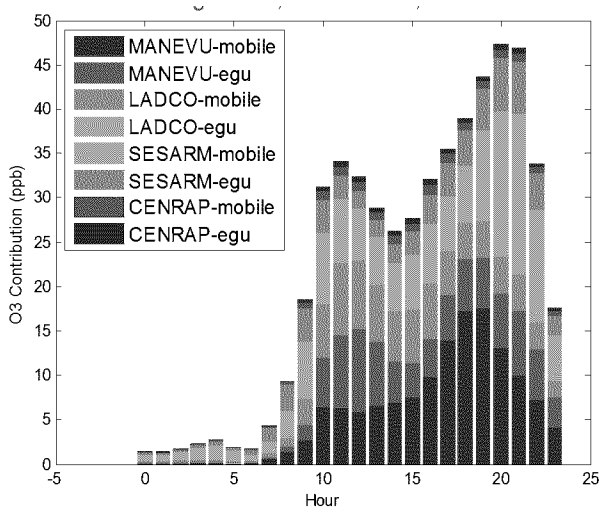


Figure 3 shows the contributions from mobile sources and EGUs on June 8, 2011 at Edgewood, MD. Emissions from the LADCO region have a strong impact in the morning and emissions from the SESARM region have a strong impact during the highest ozone hours. In fact the emissions from SESARM contribute more to ozone levels on several hours than local MANE-VU emissions do. However, if these contributions are averaged over the course of a day, the signals from LADCO and SESARM lose strength because ozone impacts are not particularly high during the morning or evening hours.

To ensure that a full remedy will be effective over many years of varying meteorology, EPA must better evaluate how individual 8-hour ozone events build, and should consider shorter timeframes when looking at contributions.

Use of Projections to Determine Contributions

EPA's use of future year emission projections to make attainment/nonattainment determinations and to identify the need for additional remedies is problematic.

The IPM-projected 2023 emission estimates rely on unenforceable emissions reductions. EPA's current IPM modeling runs assume that all unenforceable emission reductions will occur on time so that only the remedy from the resulting assessment would be needed. This assumption is overly optimistic. (See pages 3-5 above for OTC's issues with IPM assumptions)

Meeting ozone attainment depends on a monitoring demonstration, and a modeling study is applied to demonstrate that plans are on the right track to meet attainment requirements. Stretching the application of future year modeling to determine which areas will and will not be in attainment, and then developing a remedy for only those areas is highly problematic. This approach assumes knowledge of future economic strength and energy-based market forces, and future weather patterns, all of which affect emissions as well as monitored and predicted ozone levels. Inaccurate assumptions or calculations including use of unenforceable emission limits could mean the remedy fails.

Future year projections should not be used as the basis for state contributions in developing an interstate ozone transport remedy. This should be done using the known emissions of a base year. Applying already-identified future year enforceable emission reductions is an acceptable part of the remedy. If a state's contribution will be addressed with controls projected by IPM, then such a remedy needs to be adopted and used in GN SIPs.

State's Use of EPA Modeling for GN SIP

In the Transport NODA, EPA stated that "These data are considered preliminary because states may choose to modify or supplement these data in developing their GN SIPs." ***Please confirm that EPA's intent of this statement is that the modeling in this Transport NODA is not of sufficient quality to be used in a GN SIP without additional improvement, modification, or supplement, i.e. it is not "SIP quality." This includes some of the issues listed above such as the uncertain future of the CPP, among other things.***

Conclusion

Based on the evidence provided, the projections included in the Transport NODA cannot stand alone as the basis for GN SIP submissions. States that choose to use the data provided in this NODA for GN SIP submissions must include state reduction programs in their SIPs which reflect the emissions reductions accounted for in this modeling.

Not all states have the resources to conduct their own transport modeling and thus are reliant on EPA's modeling efforts. EPA's modeling must be as accurate as possible for states to discharge their obligations to reduce pollution transport and also to determine which upwind states contribute to such transport. The Mid-Atlantic Regional Air Management Association (MARAMA) is working to develop an alternative 2011/2023 modeling platform for state use in GN SIPs. This alternative modeling platform utilizes the ERTAC EGU model for EGU projections which addresses many of the technical issues with IPM outlined above and excludes emission reductions that are not currently enforceable.

The OTC recommends that states utilize MARAMA's modeling platform for their GN SIP submissions. For future transport modeling, OTC recommends that EPA use the ERTAC EGU model. Additionally, contribution assessments should be developed using base year data rather than less reliable future year projections, ozone events rather than entire ozone seasons, and at least two years of meteorological data, to better capture the variety of flow patterns that can contribute to transport impacts. These methodologies will ensure that EPA and states have reliable data to support future transport work.

If you have any questions, please do not hesitate to contact me.

Sincerely,

David C. Foerter
Executive Director
(202) 508-3840
dfoerter@otcair.org

CC: OTC Air Directors

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/8 Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 1/16/2018 6:00:00 PM
End Date/Time: Tue 1/16/2018 7:30:00 PM
259-4282-1-PB.pdf
EPA-HQ-OAR-2017-0548-0065.pdf
NEW EPA Proposed NA 2015 O3 NAAQS.PPTX
201801 2028 Controlled Workplan_20180116.pdf

...
,,,
Draft Agenda

1. Designation Update
2. 2011 Modeling Platform

a. CAMx Modeling
b. 2020 Development
c. EMF Training – 2028 Visibility Modeling
d. GN SIP Resolution Modeling
e. TSD

3. 2016 Inventory
4. Conceptual Model
5. Shale NOX Paper (attached)

---GoToMeeting invitation begins---
Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/ Ex. 6
You can also dial in using your phone.
United States Ex. 6
Access Code: Ex. 6
---GoToMeeting invitation ends---

In addition, EPA is providing advanced notice of proposed approval of Missouri's 2008 base year emissions inventory in accordance with section 172(c)(3) of the CAA. If finalized, approval of the redesignation request would change the official designation of St. Louis area for the 1997 annual $PM_{2.5}$ NAAQS, found at 40 CFR part 81, from nonattainment to attainment.

Dated: December 15, 2017.

James B. Gulliford,

Regional Administrator, Region 7.

[FR Doc. 2018–00037 Filed 1–4–18; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 81

[EPA–HQ–OAR–2017–0548; FRL–9972–84–OAR]

EPA Responses to Certain State Designation Recommendations for the 2015 Ozone National Ambient Air Quality Standards: Notice of Availability and Public Comment Period

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notification of availability and public comment period.

SUMMARY: Notice is hereby given that the Environmental Protection Agency (EPA) has posted on our public electronic docket and internet website responses to certain state and tribal area designation recommendations for the 2015 Ozone National Ambient Air Quality Standards (NAAQS) (2015 Ozone NAAQS). These responses include our intended designations for the affected areas. The EPA invites the public to review and provide input on our intended designations during the comment period specified in the **DATES** section. The EPA sent its responses directly to the states and tribes on or about December 20, 2017. The EPA intends to make final designation determinations for the areas of the country addressed by these responses no earlier than 120 days from the date the EPA notified states and tribes of the agency's intended designations.

DATES: Comments must be received on or before February 5, 2018. Please refer to **SUPPLEMENTARY INFORMATION** for additional information on the comment period.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–HQ–OAR–2017–0548, at *http://www.regulations.gov.* Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from *regulations.gov.* The EPA may publish any comment received to our public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.,* on the Web, Cloud, or other file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *https://www2.epa.gov/dockets/commenting-epa-dockets.*

FOR FURTHER INFORMATION CONTACT: For general questions concerning this action, please contact Denise Scott, U.S. EPA, Office of Air Quality Planning and Standards, Air Quality Policy Division, C539–01, Research Triangle Park, NC 27709, telephone (919) 541–4280, email at *scott.denise@epa.gov.* The EPA contacts listed at the beginning of the **SUPPLEMENTARY INFORMATION** can answer questions regarding areas in a particular EPA Regional office.

SUPPLEMENTARY INFORMATION:

Regional Office Contacts:

Region I—Richard Burkhart (617) 918–1664

Region II—Omar Hammad (212) 637–3347

Region III—Maria Pino (215) 814–2181

Region IV—Jane Spann (404) 562–9029

Region V—Kathleen D'Agostino (312) 886–1767

Region VI—Carrie Paige (214) 665–6521

Region VII—Lachala Kemp (913) 551–7214

Region VIII—Chris Dresser (303) 312–6385

Region IX—Laura Lawrence (415) 972–3407

Region X—Karl Pepple (206) 553–1778

The public may inspect the recommendations from the states and tribes, our recent letters notifying the affected states and tribes of our intended designations, and area-specific technical support information at the following locations:

Regional offices	States
Dave Conroy, Chief, Air Programs Branch, EPA New England, 1 Congress Street, Suite 1100, Boston, MA 02114–2023, (617) 918–1661.	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
Richard Ruvo, Chief, Air Programs Branch, EPA Region II, 290 Broadway, 25th Floor, New York, NY 10007–1866, (212) 637–4014.	New Jersey, New York, Puerto Rico, and Virgin Islands.
Cynthia H. Stahl, Acting Associate Director, Office of Air Program Planning, EPA Region III, 1650 Arch Street, Philadelphia, PA 19103–2187, (215) 814–2180.	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia.
R. Scott Davis, Chief, Air Planning Branch, EPA Region IV, Sam Nunn Atlanta Federal Center, 61 Forsyth Street SW, 12th Floor, Atlanta, GA 30303, (404) 562–9127.	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
John Mooney, Chief, Air Programs Branch, EPA Region V, 77 West Jackson Street, Chicago, IL 60604, (312) 886–6043.	Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.
Alan Shar, Acting Chief, Air Planning Section, EPA Region VI, 1445 Ross Avenue, Dallas, TX 75202, (214) 665–6691.	Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.
Mike Jay, Chief, Air Programs Branch, EPA Region VII, 11201 Renner Blvd., Lenexa, KS 66129, (913) 551–7460.	Iowa, Kansas, Missouri, and Nebraska.
Monica Morales, Air Program Director, EPA Region VIII, 1595 Wynkoop Street, Denver, CO 80202–1129, (303) 312–6936.	Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.
Doris Lo, Air Planning Office, EPA Region IX, 75 Hawthorne Street, San Francisco, CA 94105, (415) 972–3959.	American Samoa, Arizona, California, Guam, Hawaii, Nevada, Northern Mariana Islands, Navajo Nation, and the Hopi Tribe.

Regional offices	States
Debra Suzuki, Manager, State and Tribal Air Programs, EPA Region X, Office of Air, Waste, and Toxics, Mail Code OAQ–107, 1200 Sixth Avenue, Seattle, WA 98101, (206) 553–0985.	Alaska, Idaho, Oregon, and Washington.

The information can also be reviewed online at *https://www.epa.gov/ozone-designations* and in the public docket for these ozone designations at *https://www.regulations.gov* under Docket ID No. EPA–HQ–OAR–2017–0548.

I. What is the purpose of this action?

The purpose of this notice of availability is to solicit input from interested parties other than states and tribes on the EPA's recent responses to the state and tribal designation recommendations for the 2015 Ozone NAAQS. These responses, and their supporting technical analyses, can be found at *https://www.epa.gov/ozone-designations* and in the public docket for these ozone designations at *https://www.regulations.gov* under Docket ID No. EPA–HQ–OAR–2017–0548.

On October 1, 2015, the EPA Administrator signed a notice of final rulemaking that revised the primary and secondary ozone NAAQS (80 FR 65292; October 26, 2015). The EPA established the revised primary and secondary ozone NAAQS at 0.070 parts per million (ppm). The 2015 Ozone NAAQS are met at an ambient air quality monitoring site when the 3-year average of the annual fourth highest daily maximum 8-hour average ozone concentration (*i.e.,* the design value) is less than or equal to 0.070 ppm. The revised standards will improve public health protection, particularly for at-risk groups including children, older adults, people of all ages who have lung diseases such as asthma, and people who are active outdoors, especially outdoor workers. They also will improve the health of trees, plants and ecosystems.

After the EPA promulgates a new or revised NAAQS, the Clean Air Act (CAA) requires the EPA to designate all areas of the country as either "Nonattainment," "Attainment," or "Unclassifiable," for that NAAQS. The process for these initial designations is contained in CAA section 107(d)(1) (42 U.S.C. 7407). After promulgation of a new or revised NAAQS, each governor or tribal leader has an opportunity to recommend air quality designations, including the appropriate boundaries for Nonattainment areas, to the EPA. The EPA considers these recommendations as part of its duty to promulgate the formal area designations and boundaries for the new or revised NAAQS. By no later than 120 days prior to promulgating designations, the EPA is required to notify states, territories, and tribes, as appropriate, of any intended modifications to an area designation or boundary recommendation that the EPA deems necessary.

On November 6, 2017, the EPA established initial air quality designations for most areas in the United States, including most areas of Indian country, for the 2015 primary and secondary ozone NAAQS 82 FR 54232, November 16, 2017). In that action, the EPA designated 2,646 counties, including Indian country located in those counties, two separate areas of Indian country, and five territories as Attainment/Unclassifiable and three counties as Unclassifiable.

This current action provides the EPA's intended designation of all remaining undesignated areas. On or about December 20, 2017, consistent with section 107(d)(1)(b)(ii) of the CAA, the EPA notified affected states and tribes of the remaining recommended designations.[1] While the EPA is in agreement with the recommendations for most areas, the EPA indicated that in some instances it intended to modify a state or tribal recommends. States and tribes have the opportunity during the 120-day process to provide additional information for the EPA to consider in making the final designation decisions. We stand ready to assist and hope to resolve any differences regarding the proper designation for all remaining areas within the 120-day process provided by the CAA.

Once designations take effect, they govern what subsequent regulatory actions states, tribes, and the EPA must take in order to improve or preserve air quality in each area.

II. Instructions for Submitting Public Comments and Internet Website for Rulemaking Information

A. Invitation To Comment

The purpose of this notice is to solicit input from interested parties, other than the states and tribes to which we have sent notification letters, on the EPA's recent responses to the designation recommendations for the 2015 Ozone NAAQS. These responses, and their supporting technical analyses, can be found at *https://www.epa.gov/ozone-designations* and in the public docket for these ozone designations at Docket ID No. EPA–HQ–OAR–2017–0548. The EPA Docket Office can be contacted at (202) 566–1744, and is located at EPA Docket Center Reading Room, WJC West Building, Room 3334, 1301 Constitution Avenue NW, Washington, DC 20004. The hours of operation at the EPA Docket Center are 8:30 a.m.–4:30 p.m., Monday–Friday.

CAA section 107(d)(1) provides a process for air quality designations that involves recommendations by states, territories, and tribes to the EPA and responses from the EPA to those parties, prior to the EPA promulgating final area designations and boundaries. The EPA is not required under the CAA section 107(d)(1) to seek public comment during the designation process, but we are electing to do so for these areas with respect to the 2015 Ozone NAAQS in order to gather additional information for the EPA to consider before making final designations for the specific areas addressed in the EPA's recent letters to states and tribes. The EPA invites public input on our responses to states and tribes regarding these areas during the 30-day comment period provided in this notice. In order to receive full consideration, input from the public must be submitted to the docket by February 5, 2018. This notice and opportunity for public comment does not affect any rights or obligations of any state, or tribe, or of the EPA, which might otherwise exist pursuant to the CAA section 107(d).

Please refer to the **ADDRESSES** section in this document for specific instructions on submitting comments and locating relevant public documents.

In establishing Nonattainment area boundaries for a particular area, CAA section 107(d)(1)(A) requires the EPA to include within the boundaries both the area that does not meet the standard and any nearby area contributing to ambient air quality in the area that does not meet the NAAQS. We are particularly interested in receiving comments, supported by relevant information addressing the section 107(d)(1)(A) criteria, if you believe that a specific geographic area should not be categorized as Nonattainment, or if you

[1] Note that the EPA completed the area designations for the U.S. territories of American Samoa, Guam, Northern Mariana Islands, Puerto Rico and the U.S. Virgin Islands in the November 6, 2017, designations action.

believe that an area the EPA had indicated that it intends to designate as Attainment/Unclassifiable or Unclassifiable should in fact be categorized Nonattainment based on the presence of a violating monitor in the area or based on contribution to ambient air quality in a nearby areas. Please be as specific as possible in supporting your views.

- Describe any assumptions and provide any technical information and/or data that you used.
- Provide specific examples to illustrate your concerns, and suggest alternatives.
- Explain your views as clearly as possible.
- Provide your input by the comment period deadline identified.

The EPA intends to complete designations for all of the areas addressed in the responses to the states and tribes no later than April 30, 2018. This would complete the designation process for the 2015 Ozone NAAQS.

B. What should I consider as I prepare my comments for the EPA?

1. *Submitting CBI.* Do not submit CBI information to the EPA through *https://www.regulations.gov* or email. Clearly mark the part or all of the information that you claim to be CBI. For CBI in a disk or CD ROM that you mail to the EPA, mark the outside of the disk or CD ROM as CBI and then identify electronically within the disk or CD ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 Code of Federal Regulations (CFR) part 2. Send or deliver information identified as CBI only to the following address: Tiffany Purifoy, OAQPS CBI Officer, U.S. EPA, Office of Air Quality Planning and Standards, Mail Code C404–02, Research Triangle Park, NC 27711, telephone (919) 541–0878, email at *purifoy.tiffany@epa.gov,* Attention Docket ID No. EPA–HQ–OAR–2017–0548.

2. *Tips for Preparing Your Comments.* When submitting comments, remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, **Federal Register** date and page number).
- Follow directions.
- Explain why you agree or disagree; suggest alternatives and substitute language for your requested changes.

C. Where can I find additional information for this rulemaking?

The EPA has also established a website for this rulemaking at *https://www.epa.gov/ozone-designations.* The website includes the state, territorial and tribal recommendations, the EPA's intended area designations, information supporting the EPA's preliminary designation decisions, the EPA's designation guidance for the 2015 Ozone NAAQS as well as the rulemaking actions and other related information that the public may find useful.

Dated: December 21, 2017.

Peter Tsirigotis,

Acting Director, Office of Air Quality Planning and Standards.

[FR Doc. 2018–00024 Filed 1–4–18; 8:45 am]

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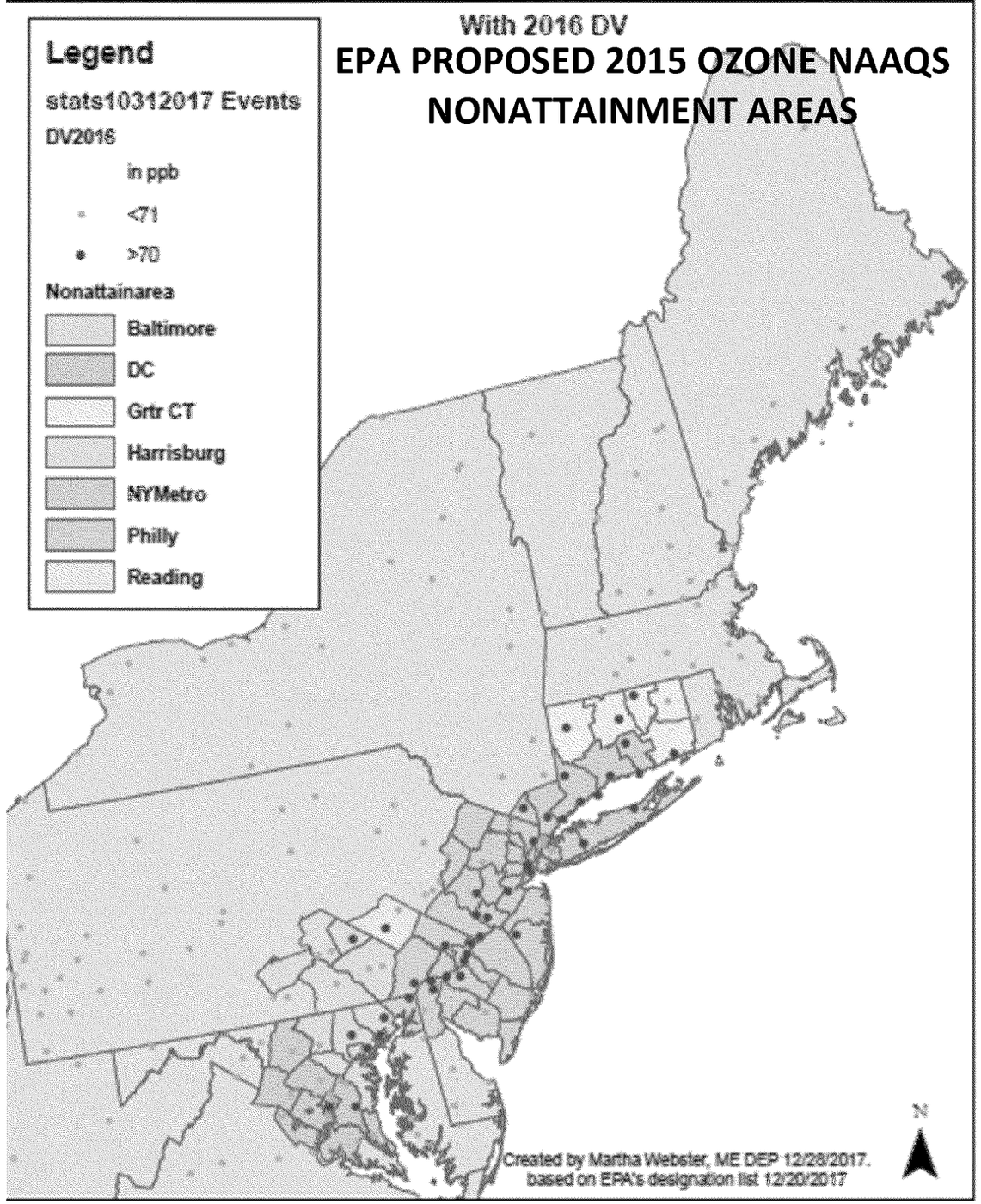
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Philly
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Created by Martha Webster, ME DEP 12/28/2017.
based on EPA's designation list 12/20/2017

EPA PROPOSED 2015 OZONE NAAQS NONATTAINMENT AREAS
Detroit
Cleveland
Chicago
Columbus
Cincinnati
St Louis
Louisville
Atlanta
Dallas
Baton Rouge
Houston
N
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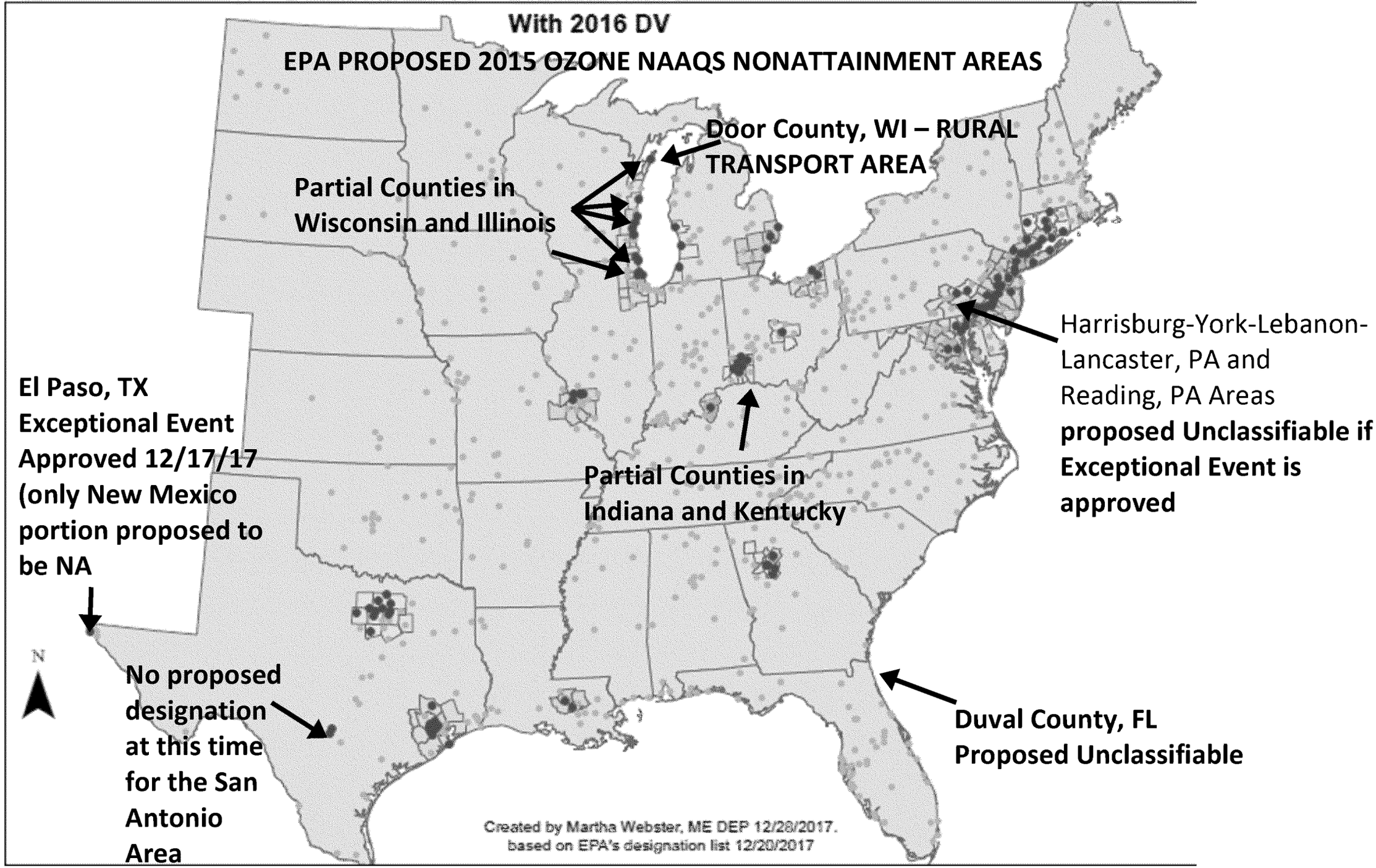
With 2016 DV
EPA PROPOSED 2015 OZONE NAAQS NONATTAINMENT AREAS
Door County, WI – RURAL TRANSPORT AREA
Partial Counties in Wisconsin and Illinois
Harrisburg-York-Lebanon-Lancaster, PA and Reading, PA Areas proposed Unclassifiable if Exceptional Event is approved
El Paso, TX Exceptional Event Approved 12/17/17 (only New Mexico portion proposed to be NA
Partial Counties in Indiana and Kentucky
N
No proposed designation at this time for the San Antonio Area
Duval County, FL Proposed Unclassifiable
Created by Martha Webster, ME DEP 12/28/2017.
based on EPA's designation list 12/20/2017

To: Houyoux, Marc[Houyoux.Marc@epa.gov]
From: POWERnews
Sent: Thur 6/8/2017 2:45:31 PM
Subject: More Retirements for Coal Units, Even One Recently Converted to Gas

.

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KCP&L Will Retire Five Coal-Fired Units and One Unit Recently Converted to Gas

Kansas City Power & Light Co. (KCP&L) plans to retire five coal-fired generating units at two stations by the end of next year. It will also close, by December 31, 2019, a unit that was just converted from coal to... Read More

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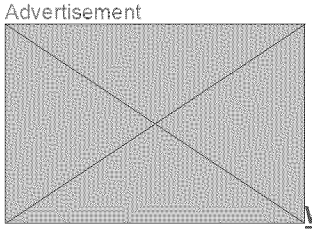

Webinar: Improve Non-Ferrous Tubing Inspection Performance With Lower Cost of Ownership

Normally, Eddy Current Technology inspection components are selected for individual performance levels, not their combined contributions. An inspection approach that deploys tightly integrated technologies and components can lead to improvements in efficiency and integrity. This delivers more predictability and consistency.

Join our webinar on June 28/29. We will present a combined approach that can significantly enhance inspections. We'll demonstrate how a tightly integrated system can improve acquisition, analysis and management of an inspection. Register today.

Kemper, Now Slated to Start in Late June, Will Need Costly Post In-Service Improvement Projects

Mississippi Power's Kemper County integrated gasification combined cycle (IGCC) project is now expected to be in service by the end of June, but the company expects it will need post in-service improvements. Read More

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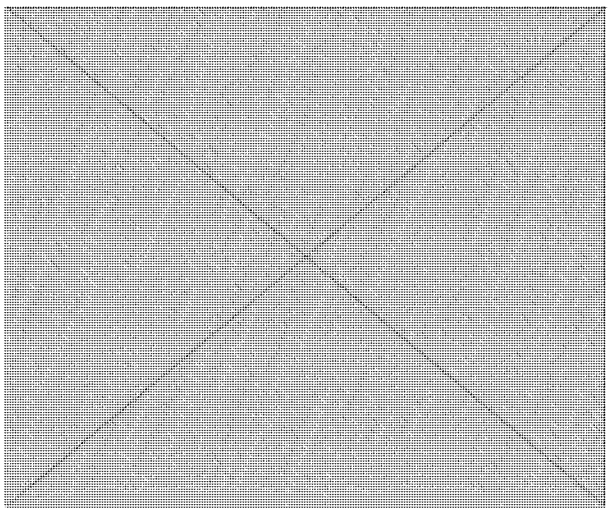

EPA Extends Deadline for 2015 Ozone NAAQS Area Designations

The Environmental Protection Agency (EPA) is giving states an extra year to develop air quality plans related to the 2015-National Ambient Air Quality Standards (NAAQS) for ground-level ozone. Read More

Dominion to Reassess Plans for Millstone's Continued Operation after Connecticut Nuclear Support Bill Thwarted

Dominion Energy told *POWER* it will begin a "strategic reassessment" of its plans for the 2,111-MW Millstone Nuclear Power Station in Connecticut after state legislators effectively blocked a bill that would have provided it a mechanism to bid for state... Read More

Southern Co. to File Rate Case for Kemper IGCC, Already Economically Unviable in Face of Cheap Gas

Southern Co. announced yet another lag beyond a new in-service date for its Kemper County integrated gasification combined cycle (IGCC) project. Along with concerns about delays and mounting cost increases afflicting the plant's coal gasification component are how it will... Read More

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Careers in Power

- SOLAR FINANCE AND TRANSACTION MANAGER OPPORTUNITY - Heelstone Energy - Winston Salem, North Carolina
- Sr Real Estate Project Manager - ComEd, an Exelon Company - BALTIMORE, MD

Industry Press Releases

- ENGIE Turns to GE to Boost Generation Capacity by 6 Percent and Improve Station's Greenhouse Impact in Australia
- Shanahan Engineering awarded operations and maintenance contract by SEPCO
- The new transformer oil pump from Kelvion for the first time combines maintenance-free sleeve bearings with a lightweight aluminum case
- Midwest Energy Emissions Corp. Completes the Acquisition of Full Patent Rights from Energy & Environmental Research Center Foundation
- ABB's new microgrid technology lights up rural communities and businesses
- GE Launches PROflex*, a New Flexible and Competitively Priced Reverse Osmosis System

The Deep Dispute over "Deep Decarbonization"

Evolving Workforce and Safety Practices for Wind Farms

Offshore Wind Contract Conundrum Heads to Supreme Court

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- Lead Analyst IT - ComEd, an Exelon Company - OAKBROOK TERRACE, IL
- Facilities Drafter (Temporary) - ComEd, an Exelon Company - PLYMOUTH MEETING, PA

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From: Sustainable City Network
Sent: Thur 6/8/2017 12:13:09 AM
Subject: Top News: Bitter Reaction as Trump
Bails on Climate Accord

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June 7, 2017

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Crescent Electric: High Bay LED lights have a 50,000 hour life expectancy and a 5-year warranty. Contact us for an energy audit.

Bitter Reaction as Trump Bails on Climate Accord

257 U.S. Mayors Beg to Differ

By Randy Rodgers
Publisher & Executive Editor

Some of the 257 U.S. mayors, members of the Mayors National Climate Action Agenda, who recently released an open letter to President Trump to oppose his actions thus far against climate action.

The sustainability community erupted with nearly universal dismay, outrage and resolve in the face of President Donald Trump's

decision to pull the United States out of the Paris climate agreement

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promise, pitting his administration against the 71 percent of U.S. citizens who believe climate change is a clear and present danger, and joining only the countries of Syria and Nicaragua in defiance of the accord, which was signed by nearly 200 nations.

The administration's official website at WhiteHouse.gov claims the Paris deal "created a taxpayer funded U.N. climate slush fund," an idea made popular by conspiracy theorists who believe the United Nations' effort to combat climate change is a veiled attempt to erode American sovereignty. Citing disputed facts about the cost in jobs and the "negligible" environmental benefits of the pact, Trump said the Paris Accord was "negotiated badly" by the Obama administration and imposed unrealistic carbon reductions on the U.S. "while giving countries like China a free pass for years to come."

In justifying his decision, Trump famously said, "I was elected to represent the citizens of Pittsburgh, not Paris." That statement ignored two important facts: 1) In the 2016 presidential election, Hillary Clinton won 75 percent of the vote in the city of Pittsburgh; and 2) Pittsburgh and Paris are actually on the same planet, which is really what the Paris Accord was all about.

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Latest News

Cities Selected for Equitable Economic Development Fellowship

WASHINGTON -- National League of Cities, PolicyLink and the Urban Land Institute announced the selection of six additional cities for pa...

APPA, National Lab to Improve Electric Reliability

WASHINGTON -- The American Public Power Association has signed a Memorandum of Understanding with the Lawrence Berkeley National Laborat...

NY to Help Farmers Cut Energy Costs and Utilize Clean Energy

ALBANY, N.Y. -- Governor Andrew Cuomo announced the release of a comprehensive strategic plan to help farms across New York State cut energy c...

DOT Announces $527 Million in Infrastructure Grants to

Elaine L. Chao announced the Federal Aviation Administration will award $527.8...

CaGBC launches Canada's first Zero Carbon Building Standard

VANCOUVER, B.C. -- The Canada Green Building Council has taken a major step toward achieving Canada's climate change commitments with the laun...

Blue Accounting to Protect Great Lakes Source Water

ANN ARBOR, Mich. -- The Great Lakes Commission recently brought together water professionals from around the Great Lakes basin to discuss regi...

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Energy Department Adds $20 Million in Research Awards

WASHINGTON -- The U.S. Department of Energy announced it is honoring additional commitments to 10 previously selected Advanced Research ...

EPA: Atlanta Area Attains 2008 8-Hour Ozone Standard

ATLANTA -- The U.S. Environmental Protection Agency announced that it is taking final action to approve the state of Georgia's request to...

Energy Department to Fund 19 Tribal Energy Projects

WASHINGTON -- The U.S. Department of Energy Office of Indian Energy Policy and Programs announced funding for 19 Indian tribes to take t...

EPA Brownfields Cleanup Funding Announced for Earth Conservancy

WASHINGTON -- The U.S. Environmental Protection Agency selected 172 communities and organizations across the country including Earth Con...

Practice Greenhealth and ACCO Announce Partnership

WASHINGTON -- Practice Greenhealth is constantly looking for

Online Course

Lean Thinking: Process Mgmt Made Easy

Sustainable City Network and NWETC have teamed up to offer this 6-hour online course June 20-22 on the Lean process improvement system.

This course will challenge your ideas about how you think about and evaluate the work you do.

Our Lean Master

ways to enrich your experience as an organizational member. One way is by c...

Product & Industry Announcements

Adventist Health System Receives Gallup Great Workplace Award

ORLANDO, Fla. -- Adventist Health System has been named a 2017 Gallup Great Workplace Award winner. This marks the seventh consecutive year th...

Applied Medical Installs Nearly Three Megawatts of Solar

RANCHO SANTA MARGARITA, Calif. -- Applied Medical, a developer and provider of minimally invasive surgical devices, announced the completion o...

Econolite Introduces EOS Traffic Control Software

ANAHEIM, Calif. -- Econolite recently introduced EOS traffic controller software. EOS is a next-generation, easy-to-use, web-based user interf...

Orion Lighting to Upgrade VA Hospitals to LED Lighting

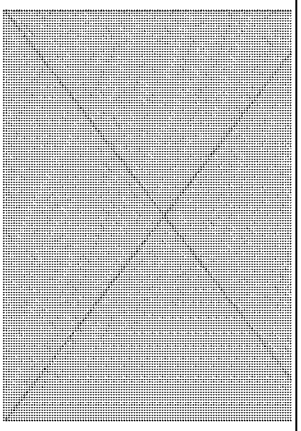
MANITOWOC, Wis. -- Orion Energy Systems, a designer and manufacturer of high performance, energy-efficient LED retrofit lighting products, ann...

DOE to Improve Energy Efficiency at Federal Facilities

DALLAS -- Lockheed Martin has been selected for a U.S. Department of Energy contract to improve energy and water efficiency at federal ...

HHS Announces Over $70 Million in Grants to Address Opioid Crisis

WASHINGTON -- U.S. Department of Health and Human Services Secretary Tom Price, M.D., announced the availability of more than $70 millio...



Vol. 23: Read it now

certified instructor, Brion Hurley, is principal Lean consultant at Rockwell Collins. He will introduce the history of Lean concepts, derived from the Toyota Production System,

and explain how and why they have come full-circle back to the United States.

Results of Lean initiatives have led to increased customer and stakeholder satisfaction, reduced costs, reduced risks, increased sales, and more flexible and agile organizations. Perhaps the largest benefit has been more engaged employees, where people enjoy the work they do.

Examples of Lean successes can be found within city and state agencies, utilities, nonprofits, law firms, military, public schools, startup companies, movie studios and even farming!

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Online Course

Creating a Sustainability Strategy

Sustainable City Network will present a webinar series in July for any personnel who are responsible for developing sustainability plans, greenhouse gas emission inventories, climate

Sustainable City Network operates a website (www.sCityNetwork.com), customized e-newsletters, online training, conferences and other interactive tools dedicated to providing quality and timely information on sustainability products, services and best practices in business, industry, government, education and healthcare.

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Sustainable City Network
801 Bluff St
Dubuque, IA 52001
563.588.3853

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The 6-hour online course, Creating a Sustainability Strategy for Your Organization, will be delivered live on July 11-13. Sessions will be recorded so registrants may attend live or via on-demand streaming video.

This course, featuring veteran instructor Antonia Graham, will focus on the implementation and strategic thinking that is required to implement a Sustainability Plan. This course will teach you how to incorporate storytelling and systems thinking into a strategic plan that gets your plan implemented and enables you to move the needle further and faster to create a more sustainable community.

This course will be presented in three 2-hour sessions held on consecutive days, July 11-13. (Group rates available on the registrations page.)

Sustainable City Network operates a website (www.sCityNetwork.com), customized e-newsletters, online training, conferences and other

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Rajan[srajan@otcair.org]
From: Joseph Jakuta
Sent: Mon 3/27/2017 1:41:06 PM
Subject: RE: Follow Up: Modeling Committee Call 3/23
OTC_Modeling_Committee_Spring_2017 03102017.pptx

Attached are the draft slides that some have requested.

Joseph

From: Joseph Jakuta
Sent: Thursday, March 23, 2017 2:57 PM
To: 'Kurt.Kebschull@ct.gov' <Kurt.Kebschull@ct.gov>; 'paul.bodner@ct.gov' <paul.bodner@ct.gov>; 'Pete.Babich@ct.gov' <Pete.Babich@ct.gov>; 'wendy.jacobs@ct.gov' <wendy.jacobs@ct.gov>; 'Michael.Geigert@ct.gov' <Michael.Geigert@ct.gov>; 'Kiernan.Wholean@ct.gov' <Kiernan.Wholean@ct.gov>; 'rama.tangirala@dc.gov' <rama.tangirala@dc.gov>; 'Robert.Clausen@state.de.us' <Robert.Clausen@state.de.us>; 'Mark.Prettyman@state.de.us' <Mark.Prettyman@state.de.us>; 'glenn.pacheco@state.ma.us' <glenn.pacheco@state.ma.us>; 'steven.coughlin@state.ma.us' <steven.coughlin@state.ma.us>; 'michael.woodman@maryland.gov' <michael.woodman@maryland.gov>; 'molla.sarros@maryland.gov' <molla.sarros@maryland.gov>; 'george.aburn@maryland.gov' <george.aburn@maryland.gov>; 'brian.hug@maryland.gov' <brian.hug@maryland.gov>; 'jennifer.hains@maryland.gov' <jennifer.hains@maryland.gov>; 'hannah.ashenafi@maryland.gov' <hannah.ashenafi@maryland.gov>; 'tom.downs@maine.gov' <tom.downs@maine.gov>; 'William.Longfellow@maine.gov' <William.Longfellow@maine.gov>; 'david.healy@des.nh.gov' <david.healy@des.nh.gov>; 'jeffrey.underhill@des.nh.gov' <jeffrey.underhill@des.nh.gov>; 'judy.rand@dep.nj.gov' <judy.rand@dep.nj.gov>; 'Shan.He@dep.nj.gov' <Shan.He@dep.nj.gov>; 'sharon.davis@dep.nj.gov' <sharon.davis@dep.nj.gov>; 'eric.zalewsky@dec.ny.gov' <eric.zalewsky@dec.ny.gov>; 'michael.ku@dec.ny.gov' <michael.ku@dec.ny.gov>; 'winston.hao@dec.ny.gov' <winston.hao@dec.ny.gov>; 'margaret.valis@dec.ny.gov' <margaret.valis@dec.ny.gov>; 'senolan@pa.gov' <senolan@pa.gov>; 'kdalal@pa.gov' <kdalal@pa.gov>; 'droble@pa.gov' <droble@pa.gov>; 'darren.austin@dem.ri.gov' <darren.austin@dem.ri.gov>; 'doris.mcleod@deq.virginia.gov' <doris.mcleod@deq.virginia.gov>; 'jlin@deq.virginia.gov' <jlin@deq.virginia.gov>; 'Kristen.Stumpf@deq.virginia.gov' <Kristen.Stumpf@deq.virginia.gov>; 'Michael.Kiss@deq.virginia.gov' <Michael.Kiss@deq.virginia.gov>; 'Thomas.Ballou@deq.virginia.gov' <Thomas.Ballou@deq.virginia.gov>; 'Dan.Riley@vermont.gov' <Dan.Riley@vermont.gov>; 'heidi.hales@vermont.gov' <heidi.hales@vermont.gov>; 'aring1@umd.edu' <aring1@umd.edu>; 'kayin.serpil@epa.gov' <kayin.serpil@epa.gov>; 'mcconnell.robert@epa.gov' <mcconnell.robert@epa.gov>; 'burkhart.richard@epa.gov' <burkhart.richard@epa.gov>; 'biton.leiran@epa.gov'

<biton.leiran@epa.gov>; 'kelly.bob@epa.gov' <kelly.bob@epa.gov>; 'Wieber.Kirk@epa.gov' <Wieber.Kirk@epa.gov>; 'forde.raymond@epa.gov' <forde.raymond@epa.gov>; 'huang.gavin@epa.gov' <huang.gavin@epa.gov>; 'Schmitt.Ellen@epa.gov' <Schmitt.Ellen@epa.gov>; 'ellsworth.todd@epa.gov' <ellsworth.todd@epa.gov>; 'timin.brian@epa.gov' <timin.brian@epa.gov>; 'Houyoux.Marc@epamail.epa.gov' <Houyoux.Marc@epamail.epa.gov>; 'jefferson.catrice@epa.gov' <jefferson.catrice@epa.gov>; 'jmcdill@marama.org' <jmcdill@marama.org>; 'swierman@marama.org' <swierman@marama.org>; 'smccusker@marama.org' <smccusker@marama.org>; 'ahmadi@nescaum.org' <ahmadi@nescaum.org>; 'pmiller@nescaum.org' <pmiller@nescaum.org>; Wick Havens <WHavens@otcair.org>; David Foerter <dfoerter@otcair.org>; Joseph Jakuta <JJakuta@otcair.org>; 'emily.bull@maryland.gov' <emily.bull@maryland.gov>
Cc: 'frank.gao@state.de.us' <frank.gao@state.de.us>; 'glenn.keith@state.ma.us' <glenn.keith@state.ma.us>; 'mark.wert@state.ma.us' <mark.wert@state.ma.us>; 'diane.nelson@maryland.gov' <diane.nelson@maryland.gov>; 'kathy.wehnes@maryland.gov' <kathy.wehnes@maryland.gov>; 'roger.thunell@maryland.gov' <roger.thunell@maryland.gov>; 'timothy.wallace@maryland.gov' <timothy.wallace@maryland.gov>; 'joel.dreessen@maryland.gov' <joel.dreessen@maryland.gov>; 'husain.waheed@maryland.gov' <husain.waheed@maryland.gov>; 'martha.e.webster@maine.gov' <martha.e.webster@maine.gov>; 'michael.sheehan@dec.ny.gov' <michael.sheehan@dec.ny.gov>; 'rob.sliwinski@dec.ny.gov' <rob.sliwinski@dec.ny.gov>; 'afleck@pa.gov' <afleck@pa.gov>; 'karen.slattery@dem.ri.gov' <karen.slattery@dem.ri.gov>; 'Sonya.Lewis-Cheatham@deq.virginia.gov' <Sonya.Lewis-Cheatham@deq.virginia.gov>; 'bennet.leon@vermont.gov' <bennet.leon@vermont.gov>; 'sehrman@eng.umd.edu' <sehrman@eng.umd.edu>; 'tcanty@atmos.umd.edu' <tcanty@atmos.umd.edu>; 'dgoldb@atmos.umd.edu' <dgoldb@atmos.umd.edu>; 'arnold.anne@epa.gov' <arnold.anne@epa.gov>; 'conroy.dave@epa.gov' <conroy.dave@epa.gov>; 'leon-guerrero.tim@epa.gov' <leon-guerrero.tim@epa.gov>; 'chow.alice@epa.gov' <chow.alice@epa.gov>; 'possiel.norm@epa.gov' <possiel.norm@epa.gov>; Andy Bodnarik <ABodnarik@otcair.org>; Kromeklia Bryant <kbryant@otcair.org>; Shyamala Rajan <srajan@otcair.org>
Subject: Follow Up: Modeling Committee Call 3/23

Dear Modeling Committee,

Attached are the notes from today's call. Don't forget that feedback on the presentation is due by April 5 COB.

Also if you could fill out the schedule for the April call reschedule by COB 3/27.
http://doodle.com/poll/kt3a6486y5urn9xg

Joseph Jakuta

Program Manager

OTC / MANE-VU

202.508.3839

444 North Capitol Street NW #322

Washington, DC 20001

Website:www.otcair.org

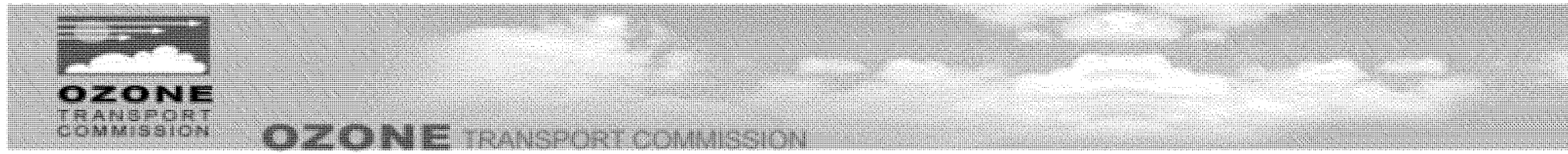
Twitter: @OzoneOTC

Modeling Committee Update

OTC Committee Meeting

April 11, 2017

Washington, DC



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Overview

1. Monitored Results
2. Ozone NAAQS Schedule
3. Enhanced Monitoring Plan (EMP)
4. OTC 2011 Modeling Platform
   a) TSD
   b) Inventory
   c) Modeling
      i. Comparison of modeling for monitored grid cell vs 3x3 cluster
      ii. CMAQ vs CAMx

Cloud in Corner Indicates Slide use only in State Committee Meeting

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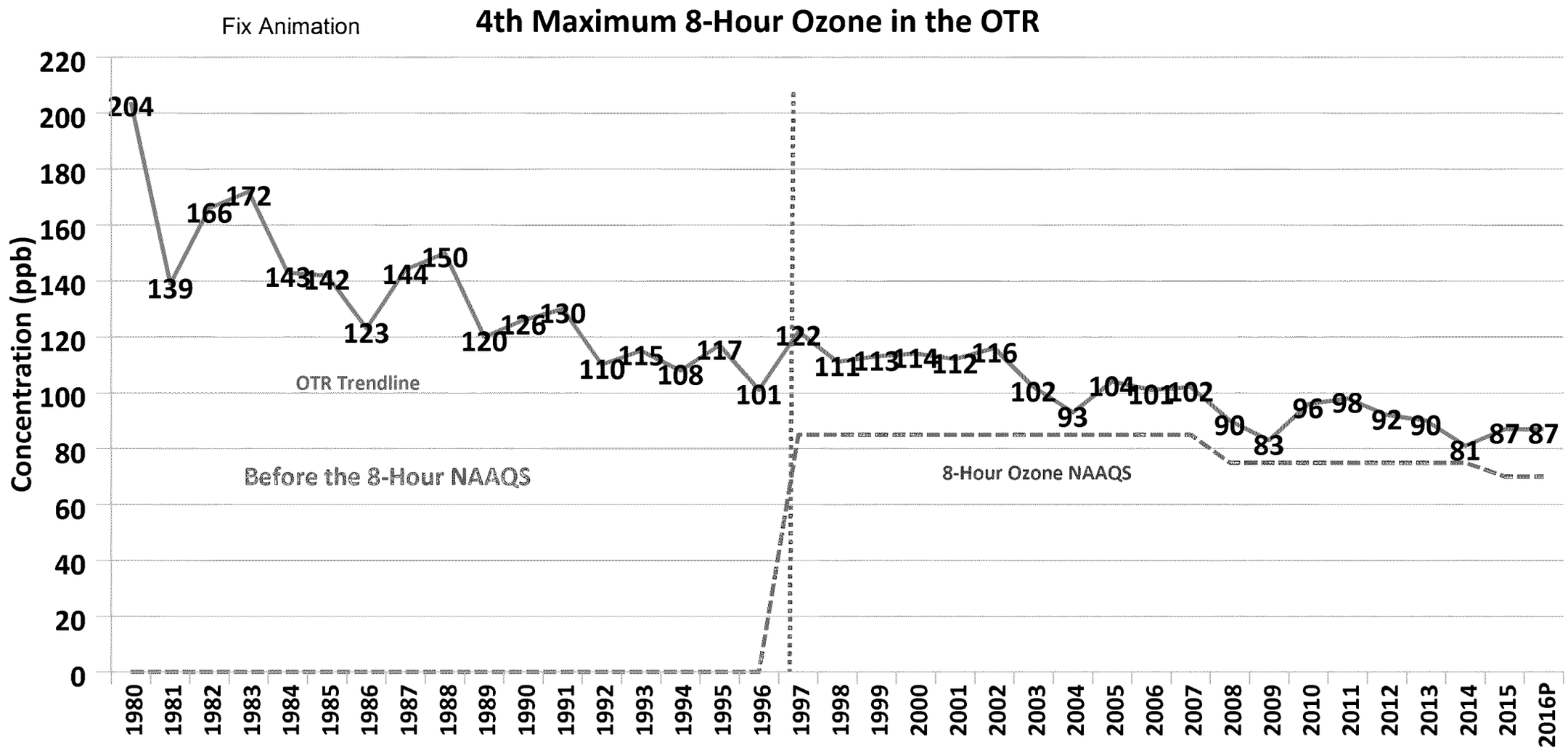
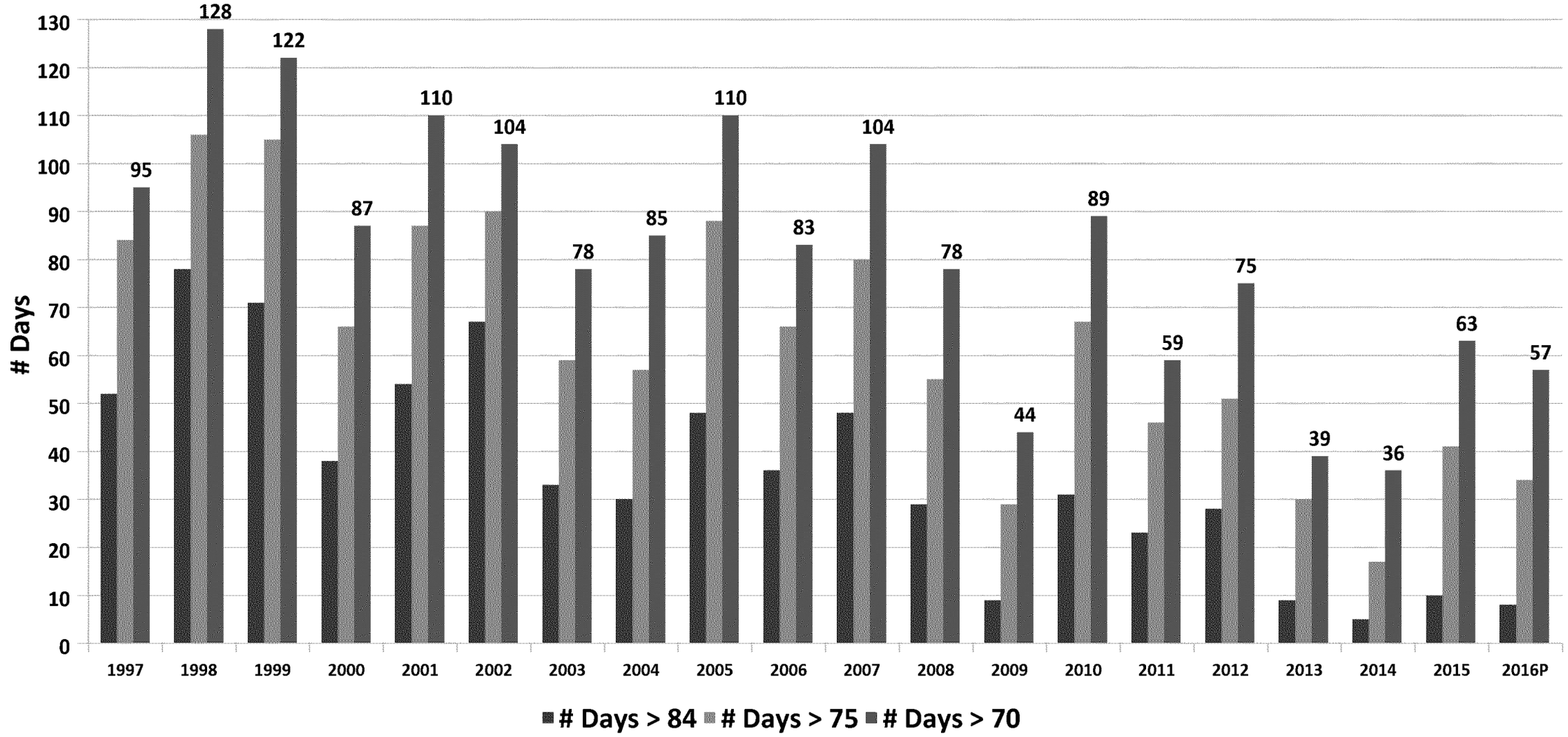
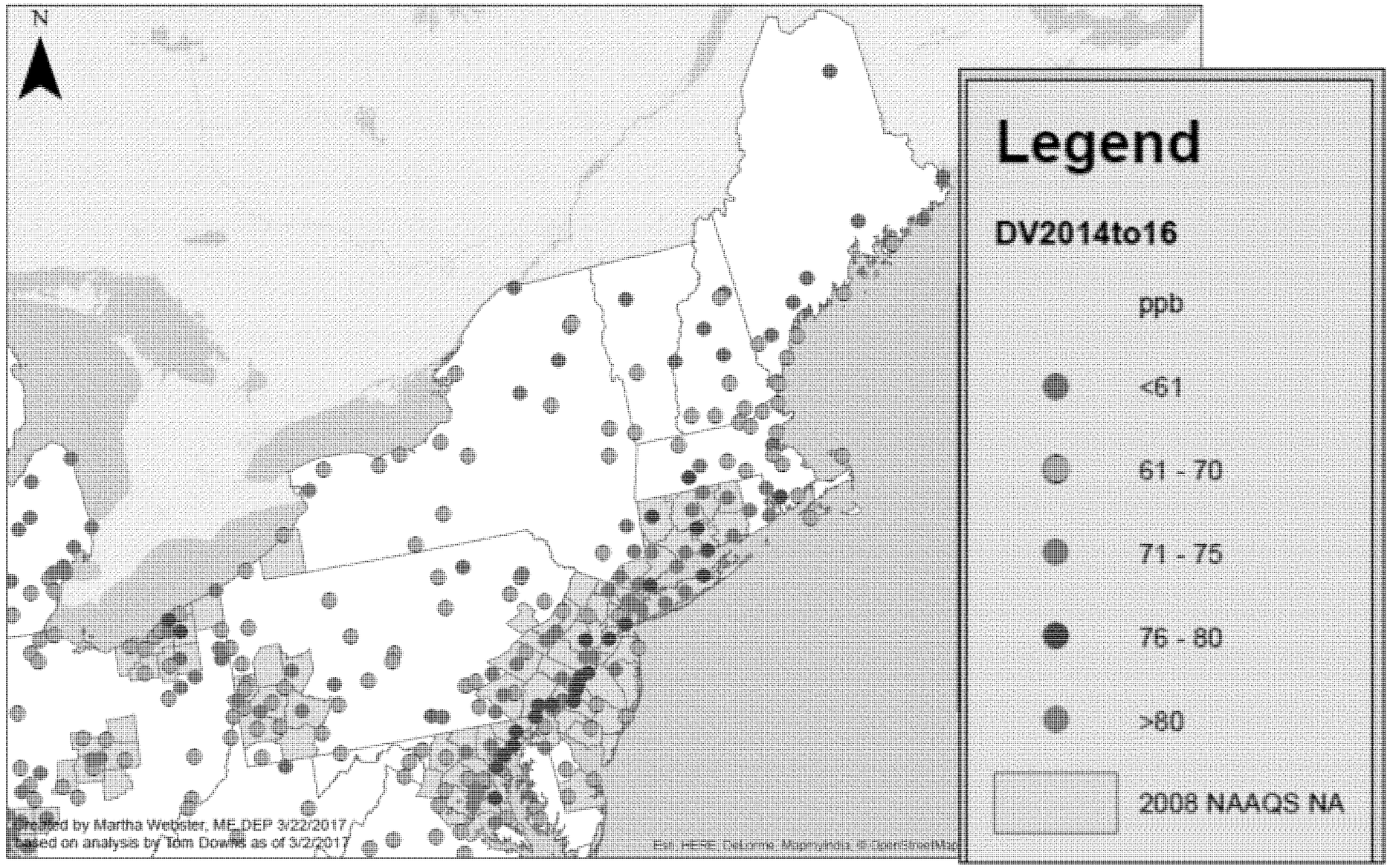
Ozone Trends in the OTR



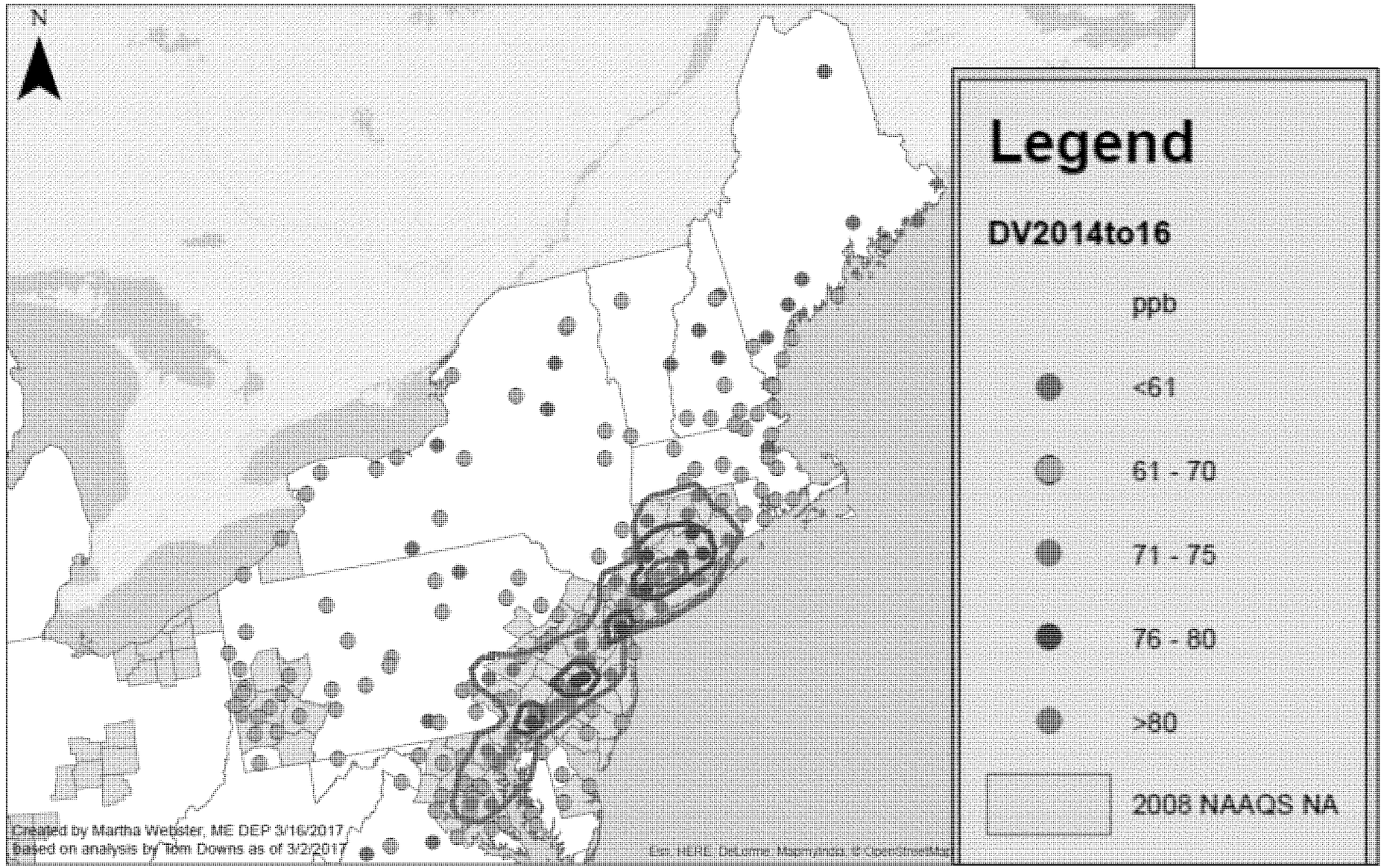
Trends for OTR Exceedance Days



2016 4th High 8hr Ozone Value (Preliminary)



2014-16 8hr Ozone Preliminary Design Value



Ozone Planning Timeline

October 2015
Final 2015 NAAQS

December 2015
Effective Date for 2015 NAAQS

October 2016
Submit 2015 NAAQS Nonattainment Designation Recommendations (2013-15)

January 1, 2017
NYC & Greater CT 2008 Ozone Demonstration Due

October 2017
EPA Nonattainment Area Designations for 2015 NAAQS

October 2018
Infrastructure/Transport SIP for 2015 NAAQS Due

October 2020
2015 Ozone Nonattainment SIPs Due

Attainment by (October):
2020 - Marginal **2023** - Moderate **2026** - Serious

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Enhanced Monitoring Plans (EMP)

- Individual States in the OTR required to submit an EMP as part of the 2015 Ozone NAAQS process
- Plans are due to EPA in 2018
- Effort underway to coordinate between the states and EPA through OTC workgroup
  - Gain regional benefits from plans
  - More knowledge on transport
  - More knowledge of air/sea affect on ozone
  - Information to improve model performance
- Will be future updates at OTC meetings and opportunity for comment

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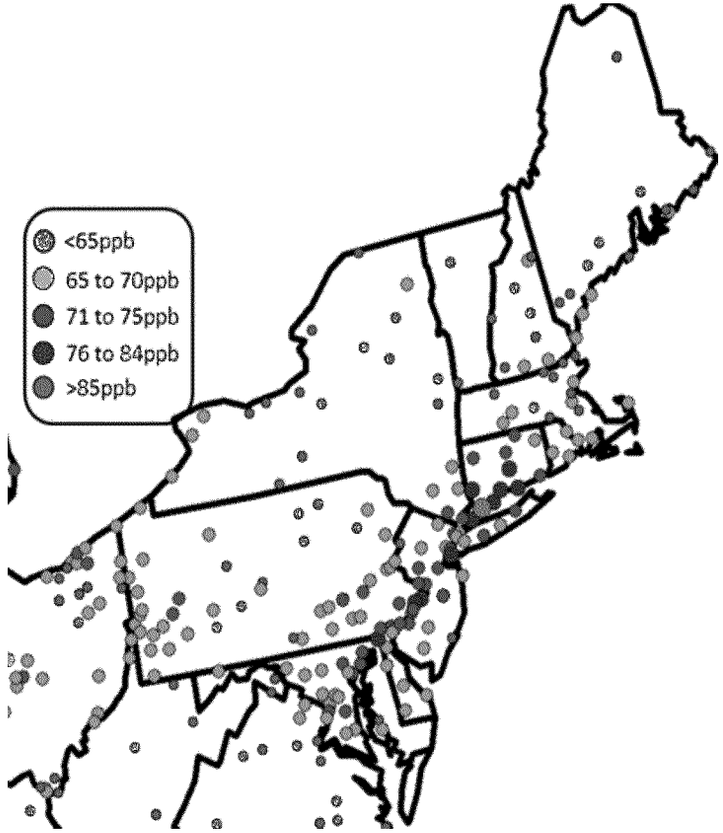
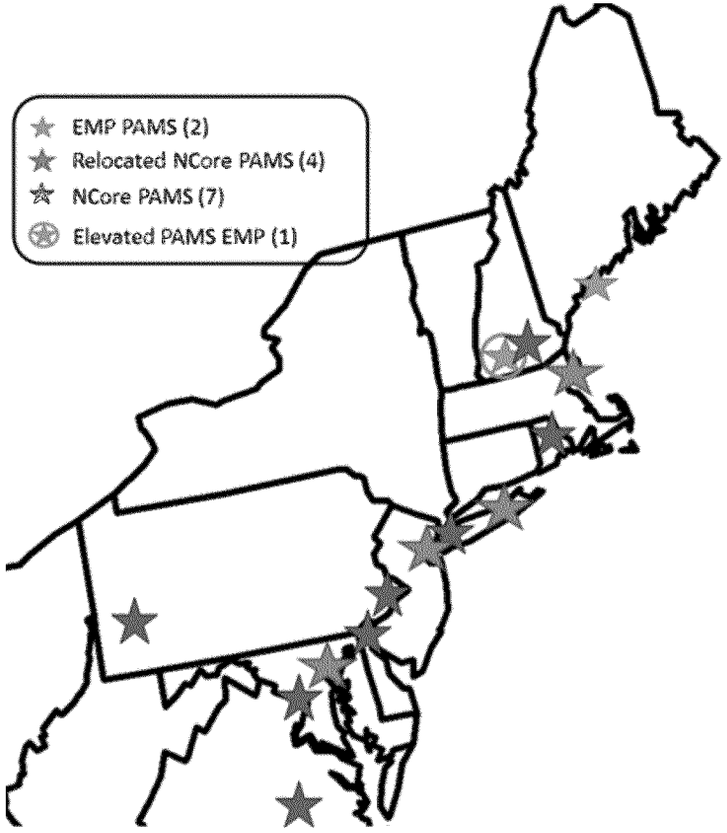
Enhanced Monitoring Plans (EMP)

Design Values



Preliminary state suggestions



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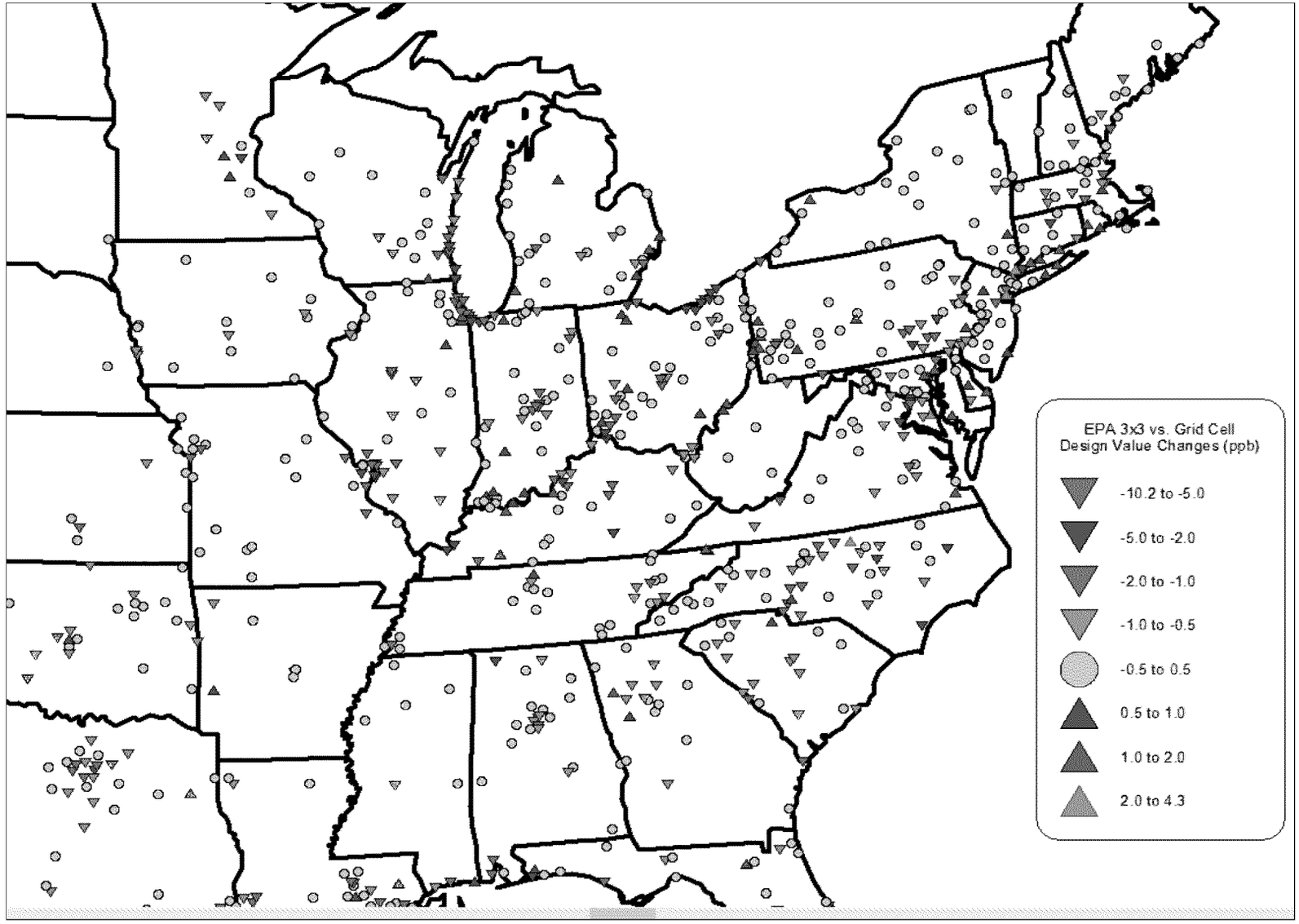
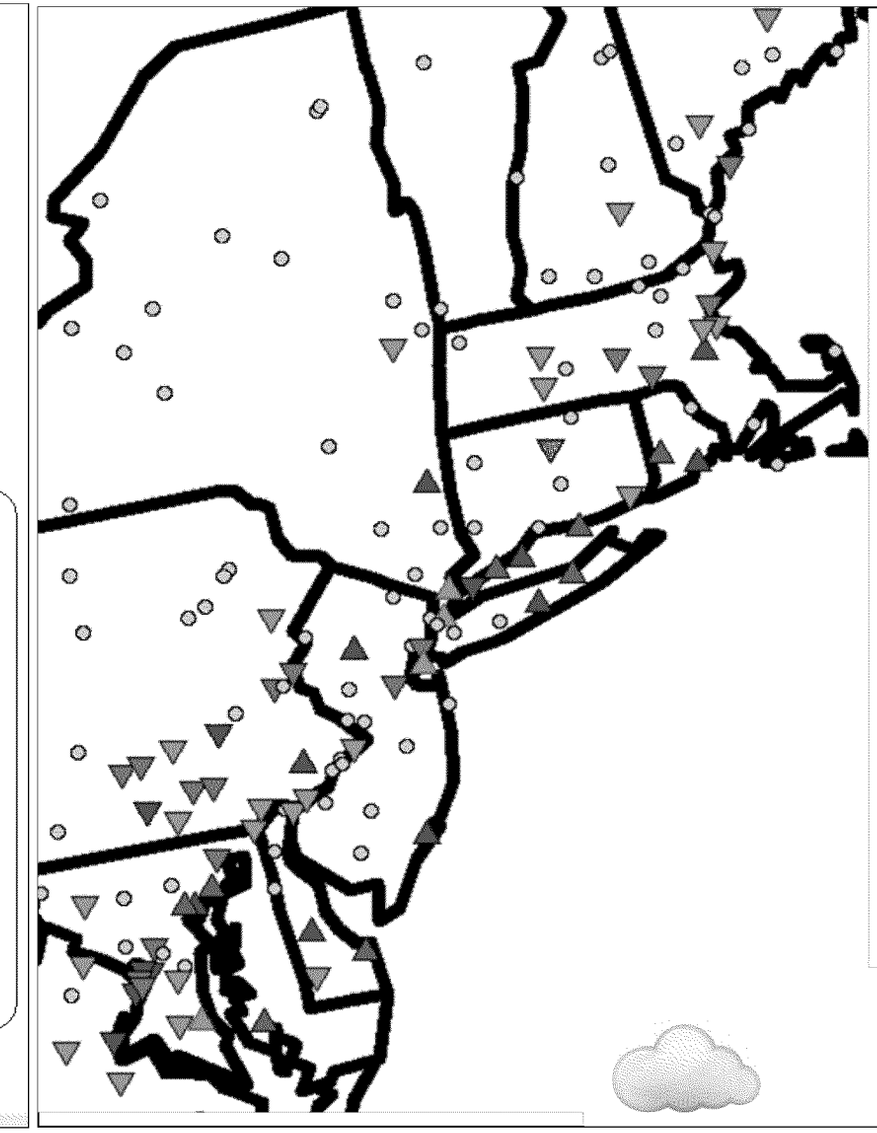
EPA Modeled 2018 Effect on Design Values

Changing from Monitor Grid Cell to 3x3 Grid Cell Cluster Calculations





Recent Modeling

- Comparison between photochemical models

(Insert)

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Current OTC 2020/2023 Modeling

Modeling intended to provide early direction and SIP support

- 2020 interpolated projection (2008 NAAQS Serious Nonattainment)
  - Interpolation between Bata 2017 and EPA 2023 inventories
  - Includes EPA MOVES modeling for 2023
  - IPM data to be replaced with ERTAC for EGUs
  - CSAPR2 Cap estimated adjustment factor
- 2023 projection (2015 NAAQS Moderate Nonattainment)
  - EPA 2023 inventory
  - IPM data to be replaced with ERTAC for EGUs
  - CSAPR2 Cap estimated adjustment factor

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Near-Term OTC/MARAMA Emission Inventories

Alpha
- 2011
- 2018
- 2028

Beta
- 2011
- 2017

Gamma
- 2011
- 2020
- 2023

- Gamma Inventory Improvements are Beginning
  - Project future year to **2023 & 2020**
  - Upgrade to **ERTAC v2.6**
  - 2023 Mobile: EPA MOVES & Nonroad
  - 2020 Mobile: 2017->2023 Interpolation
  - Remove rules no longer considered OTB
  - EMF Growth for point and maybe area
  - For 2020 some sectors interpolated
  - Other updates for 2011/2023 from EPA v6.3
- Review by States & Stakeholders to Follow

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Gamma Inventory Photochemical Modeling Plan

Beta Modeling Complete and Documented

2011 Gamma Emission Inventory Base Case

- To ensure consistent inventories

2023 Gamma Emission Inventory Base Case

- For use in transport modeling

2020 Gamma emission Inventory Base Case

- For use in Serious 2008 NAAQS Ozone SIPs

Update Documentation

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Conclusions/Next Steps

- The 2016 ozone season has brought similar ozone exceedances as 2015 in the OTR
- Enhanced Monitoring Plans (EMPs) are being discussed
- Emission inventory projections to 2020 and 2023 are being prepared for transport and attainment SIP support
  - Initial modeling will be performed with an interpolated inventory
  - Improved Gamma emission inventories should become available during summer/fall 2017
- OTC modeling indicates that:
  - CMAQ performs reasonably well when modeled values for monitor grid cells are compared to monitored data
  - CMAQ and CAMx perform comparably

ED_001650_00042860-00015

Questions

- Committee Chair:
  - Jeff Underhill (NH)
    jeffrey.underhill@des.nh.gov (603) 271-1102
- Modeling Lead:
  - Mike Ku (NY)
    michael.ku@dec.ny.gov (518) 402-8402
- Emissions Inventory Lead:
  - Julie McDill (MARAMA)
    jmcdill@marama.org (443) 901-1882
- OTC Committee Lead:
  - Joseph Jakuta
    jjakuta@otcair.org (202) 508-3839

ED_001650_00042860-00016

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 1/16/2018 6:00:00 PM
End Date/Time: Tue 1/16/2018 7:30:00 PM
259-4282-1-PB.pdf
EPA-HQ-OAR-2017-0548-0065.pdf
NEW EPA Proposed NA 2015 O3 NAAQS.PPTX

...
,,,
Draft Agenda

1. Designation Update
2. 2011 Modeling Platform

a. CAMx Modeling
b. 2020 Development
c. EMF Training
d. GN SIP Resolution Modeling
e. TSD

3. 2016 Inventory
4. Conceptual Model
5. Shale NOX Paper (attached)

---GoToMeeting invitation begins---
Please join my meeting from your computer, tablet or smartphone.
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You can also dial in using your phone.
United States Ex. 6
Access Code Ex. 6
---GoToMeeting invitation ends---

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United States Ex. 6
Access Code: Ex. 6
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From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
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End Date/Time: Tue 2/20/2018 7:30:00 PM
Ring_et_al_AtmosEnviro_Supplemental_2018.pdf
Ring_Atmos.Enviro._2018.pdf
otc_2023sa_update_short.pptx

....
;;;;
Draft Agenda

1. Meeting Schedule
2. Richmond Meeting
3. 2011 Platform

a. Gamma Inventory Documentation - http://www.marama.org/technical-center/emissions-inventory/2011-gamma-inventory-and-projections
b. GN SIP Modeling

i. Contribution Assessment
ii. Control Case Modeling

c. 2020 CMAQ Modeling
d. 2028 CMAQ Modeling
e. Modeling TSD

4. 2016 Inventory Development
5. Ring Marine Paper

---GoToMeeting invitation begins---
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Access Code: Ex. 6
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From: Joseph Jakuta
Location: https://global.gotomeeting.com/join Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 8/22/2017 5:00:00 PM
End Date/Time: Tue 8/22/2017 6:30:00 PM
OTC MC 8 22 2017.pptx
OTC_Modeling_Committee_Fall_2017.pptx

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Draft Agenda:

1. Fall 2017 OTC/MANE-VU Meetings Schedule

a. Committees Meeting - Sept. 7, Washington, DC (Hall of the States)
b. Air Directors Meeting - Oct. 10-11, Linthicum Heights, MD (Sheraton BWI)
c. Annual Fall Meeting - Nov. 14-15, Washington, DC (Melrose Hotel)

2. Ozone Season Update – see attached slides OTC MC 8-22-2017.pptx

d. New exceedances
e. Any changes to nonattainment
f. 1-year extension status

3. 2011 Modeling Platform Updates

g. Source Apportionment work from VA DEQ
h. Emission inventory updates
i. Status for tagged ozone model runs
j. Planning for 2028 control projection based on MANE-VU Ask

4. Draft Committee Presentation – see attached slides OTC_Modeling_Committee_Fall_2017.pptx
5. OTC Documents

k. BenMap Report Update
l. Conceptual Model Update
m. TSD Update (including Land-Water Interface)

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Access Code: Ex. 6
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From: Joseph Jakuta
Location: https://www.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 6/20/2017 5:00:00 PM
End Date/Time: Tue 6/20/2017 6:30:00 PM
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HYSPLIT Letter.docx
cmaq_beta2_2020_2023.xlsx
June10th_13th_Ozone_Exceedance_Event_Final.pptx

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Draft Agenda

1. Current Ozone Event – http://www.maine.gov/dep/ftp/DEP_OZONE/OTC/2017/
2. 2011 Platform

a. 2023 Results
b. 2020/2023 Inventory Update
c. Tagging Runs
d. Tracking Databases - https://www.dropbox.com/sh/fetjsabn2evdrid/AAABihswLsq_K4M4kO_dj7GQa?dl=0

3. BenMap Paper – 2016 Data
4. EMP Workgroup
5. Conceptual Model Workgroup – previous draft attached
6. Letter of support for HYSPLIT – attached

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Access Code: Ex. 6
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EPA-HQ-OAR-2017-0548-0065.pdf
NEW EPA Proposed NA 2015 O3 NAAQS.PPTX
201801 2028 Controlled Workplan_20180116.pdf

...
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Draft Agenda

1. Designation Update
2. 2011 Modeling Platform

a. CAMx Modeling
b. 2020 Development
c. EMF Training – 2028 Visibility Modeling
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e. TSD

3. 2016 Inventory
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5. Shale NOX Paper (attached)

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From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 11/21/2017 6:00:00 PM
End Date/Time: Tue 11/21/2017 7:30:00 PM
final_2008_o3_naaqs_transport_memo_10-27-17b.pdf
US EPA_2016_Technical Support Document (TSD) Updates to Emissions Inventories for the.pdf
OTC Mobile Charge 171102.docx
OTC SAS Charge 171102.docx

;;
Dear OTC/MANE-VU Committees,
You are all being invited to the Modeling Committee call to hear a discussion with OAQPS staff concerning the 2023 modeling conducted in regards to ozone transport obligations. If you have any specific questions you would like to see addressed during the discussion please email them to me before noon on Monday.
Agenda

1. EPA Discussion of 2023 Modeling
2. OTC Modeling Committee Business

a. Fall Meeting – SAS/Mobile Charges Impact
b. EMF Training
c. 2016 Inventory Development
d. 2011 Platform Status

i. Inventory Updates
ii. 2023 Source Tag Modeling
iii. TSD

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You can also dial in using your phone.
United States Ex. 6
Access Code: Ex. 6
---GoToMeeting invitation ends---

To: Eyth, Alison[Eyth.Alison@epa.gov]
Cc: Possiel, Norm[Possiel.Norm@epa.gov]; Houyoux, Marc[Houyoux.Marc@epa.gov]
From: Julie McDill
Sent: Mon 5/15/2017 8:38:35 PM
Subject: RE: Inter-RPO share tomorrow

Hi Alison,

In response to your question about our timing needs, the NE has its hands full preparing a modeling demonstration for the 2015 ozone NAAQS good neighbor SIP. I would be surprised if anyone in the NE has any time available this summer to work with 2016. However, I think LADCO is planning to work with your platform when it is prepared.

I understood from OAQPS on the last coordination call that you do not anticipate preparing a v2 of this 2016 inventory. I believe if the NE were choosing we would prefer you wait to develop this platform and prepare it with v2 of 2014 NEI. But others, like LADCO, might not agree with that approach if they wish to work with it this summer.

However, that said, if you were doing anything new with mobile emissions, that would be good to know.

Talk to you in June

Julie

From: Eyth, Alison [mailto:Eyth.Alison@epa.gov]
Sent: Monday, May 15, 2017 4:22 PM
To: Julie McDill <jmcdill@marama.org>
Cc: Possiel, Norm <Possiel.Norm@epa.gov>; Houyoux, Marc <Houyoux.Marc@epa.gov>
Subject: RE: Inter-RPO share tomorrow

Hi Julie,

That's fine. We are still in the early stages of pulling together 2016, but a lot will be happening over the next month and I will be able to prepare something for the June call. I'll have a lot more info and numbers together by then.

We are planning to do our initial modeling for 2016 over the summer (July-August timeframe). We will need some time to review the results prior to releasing the data. I'm not sure exactly how long all of that will take, but late summer / early fall seems likely. We should discuss your specific timing needs on our upcoming calls. Perhaps there will be some useful products we can provide in the meantime.

Thanks,

Alison

From: Julie McDill [mailto:jmcdill@marama.org]
Sent: Monday, May 15, 2017 3:50 PM
To: Eyth, Alison <Eyth.Alison@epa.gov>
Cc: Possiel, Norm <Possiel.Norm@epa.gov>; Houyoux, Marc <Houyoux.Marc@epa.gov>
Subject: Re: Inter-RPO share tomorrow

Hi Alison,

I prefer to cancel tomorrow's call as without an agenda it might be a waste everyone's time. Do you think you could provide a presentation on the EPA 2016 V1 plan for the June call? When do you expect the 2016 V1 to be complete?

Julie

From: Eyth, Alison <Eyth.Alison@epa.gov>
Sent: Monday, May 15, 2017 3:07:24 PM
To: Julie McDill

Cc: Possiel, Norm; Houyoux, Marc
Subject: RE: Inter-RPO share tomorrow

Julie,

I'm open to having a discussion tomorrow to answer questions, but I won't have a presentation prepared.

Do you want to open it up and let people ask questions and talk about anything they might be doing on their sides?

Alison

From: Julie McDill [mailto:jmcdill@marama.org]
Sent: Monday, May 15, 2017 1:46 PM
To: Eyth, Alison <Eyth.Alison@epa.gov>
Subject: Inter-RPO share tomorrow

Hello Alison,

I wonder if you are ready to provide a presentation on EPA's V1 plan for the 2014 platform tomorrow?

No worries if you are not! Certainly not nearly enough notice.

I would be happy to cancel the call and put off to next month's call which would be Jun 20th.

Cheers!

Julie McDill P.E.

Senior Engineer

MARAMA

From: Joseph Jakuta
Location: https://global.gotomeeting.com/join/ Ex. 6
Importance: Normal
Subject: OTC Modeling Committee
Start Date/Time: Tue 12/20/2016 6:00:00 PM
End Date/Time: Tue 12/20/2016 7:30:00 PM
Travis et al_2016_Why do models overestimate surface ozone in the Southeast United States.pdf
2020-2023 Screening Modeling Outline.doc

;;
Agenda:

1. Meeting Update
2. 2011 Platform Update

a. TSD – Version with fixed Errata posted
b. Inventory

i. ERTAC v2.6
ii. Other Sectors

c. Modeling
d. 2020/2023 Plan

3. Paper

---GoToMeeting invitation begins---
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United States Ex. 6
Access Code: Ex. 6
---GoToMeeting invitation ends---

Atmos. Chem. Phys., 16, 13561–13577, 2016
www.atmos-chem-phys.net/16/13561/2016/
doi:10.5194/acp-16-13561-2016
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Atmospheric Chemistry and Physics
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EGU

Why do models overestimate surface ozone in the Southeast United States?

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Received: 3 February 2016 – Published in Atmos. Chem. Phys. Discuss.: 16 March 2016
Revised: 5 October 2016 – Accepted: 6 October 2016 – Published: 1 November 2016

Abstract. Ozone pollution in the Southeast US involves complex chemistry driven by emissions of anthropogenic nitrogen oxide radicals (NO_x ◀ NO C NO_2/ and biogenic isoprene. Model estimates of surface ozone concentrations tend to be biased high in the region and this is of concern for designing effective emission control strategies to meet air quality standards. We use detailed chemical observations fromtheSEAC ^{4}RSaircraftcampaigninAugustandSeptember 2013, interpreted with the GEOS-Chem chemical transport model at 0.25° ffi 0.3125° horizontal resolution, to better understand the factors controlling surface ozone in the Southeast US. We find that the National Emission Inventory (NEI) for NO_x from the US Environmental Protection Agency(EPA)istoohigh.ThisfindingisbasedonSEAC ^{4}RS observations of NO_x and its oxidation products, surface network observations of nitrate wet deposition fluxes, and OMI satellite observations of tropospheric NO_2 columns. Our results indicate that NEI NO_x emissions from mobile and industrial sources must be reduced by 30–60%, dependent on the assumption of the contribution by soil NO_x emissions. Upper-tropospheric NO_2 from lightning makes a large contribution to satellite observations of tropospheric NO_2 that must be accounted for when using these data to estimate surface NO_x emissions. We find that only half of isoprene oxidation proceeds by the high-NO_x pathway to produce ozone; this fraction is only moderately sensitive to changes in NO_x

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emissions because isoprene and NO_x emissions are spatially segregated. GEOS-Chem with reduced NO_x emissions provides an unbiased simulation of ozone observations from the aircraft and reproduces the observed ozone production efficiency in the boundary layer as derived from a regression of ozone and NO_x oxidation products. However, the model is still biased high by 6 – 14ppb relative to observed surface ozone in the Southeast US. Ozonesondes launched during midday hours show a 7ppb ozone decrease from 1.5km to the surface that GEOS-Chem does not capture. This bias may reflect a combination of excessive vertical mixing and net ozone production in the model boundary layer.

1 Introduction

Ozone in surface air is harmful to human health and vegetation. Ozone is produced when volatile organic compounds (VOCs) and carbon monoxide (CO) are photochemically oxidized in the presence of nitrogen oxide radicals (NO_x ◀ NO C NO_2/. The mechanism for producing ozone is complicated, involving hundreds of chemical species interacting with transport on all scales. In October 2015, the US Environmental Protection Agency (EPA) set a new National Ambient Air Quality Standard (NAAQS) for surface ozone as a maximum daily 8h average (MDA8) of 0.070ppm not to be exceeded more than three times per year. This is the latest in a succession of gradual tightening of the NAAQS from 0.12ppm (1h average) to 0.08ppm in 1997and to 0.075ppm in 2008, responding to accumulating evidence that ozone is detrimentaltopublichealthevenatlowconcentrations(EPA, 2013). Chemical transport models (CTMs) tend to significantlyoverestimatesurfaceozoneintheSoutheastUS(Linet al., 2008; Fiore et al., 2009; Reidmiller et al., 2009; Brown-Steiner et al., 2015; Canty et al., 2015), and this is an issue for the design of pollution control strategies (McDonald-Buller et al., 2011). Here we examine the causes of this overestimate by using the GEOS-Chem CTM to simulate NASA SEAC^{4}RS aircraft observations of ozone and its precursors over the region in August–September 2013 (Toon et al.,2016),togetherwithadditionalobservationsfromsurface networks and satellite.

A number of explanations have been proposed for the ozone model overestimates in the Southeast US. Fiore et al. (2003) suggested excessive modeled ozone inflow from the Gulf of Mexico. Lin et al. (2008) proposed that the ozone dry deposition velocity could be underestimated. McDonald-Buller et al. (2011) pointed out the potential role of halogen chemistry as a sink of ozone. Isoprene emitted from vegetation is the principal VOC precursor of ozone in the Southeast US in summer, and Fiore et al. (2005) found that uncertainties in isoprene emissions and in the loss of NO_x from formation of isoprene nitrates could also affect the ozone simulation. Horowitz et al. (2007) found a large sensitivity of ozone to the fate of isoprene nitrates and the extent to which they release NO_x when oxidized. Squire et al. (2015) found that the choice of isoprene oxidation mechanism can alter both the sign and magnitude of the response of ozone to isoprene and NO_x emissions.

The SEAC^{4}RS aircraft campaign in August–September 2013 provides an outstanding opportunity to improve our understanding of ozone chemistry over the Southeast US. The SEAC^{4}RS DC-8 aircraft hosted an unprecedented chemical payload including isoprene and its oxidation products, NO_x and its oxidation products, and ozone. The flights featured extensive boundary layer mapping of the southeast as well as vertical profiling to the free troposphere (Toon et al., 2016). We use the GEOS-Chem global CTM with high horizontal resolution over North America (0.25° ffi 0.3125°) to simulate and interpret the SEAC^{4}RS observations. We integrate into our analysis additional Southeast US observations during the summer of 2013, including from the NOMADSS aircraft campaign, the SOAS surface site in Alabama, the SEACIONS ozonesonde network, the EPA Clean Air Status and Trends Network (CASTNET) ozone network, the National Acid Deposition Program (NADP) nitrate wet deposition network, and NO_2 satellite data from the OMI instrument. Several companion papers apply GEOS-Chem to simulate other aspects of SEAC^{4}RS and concurrent data for the Southeast US, including aerosol sources and optical depth (Kim et al., 2015), isoprene organic aerosol (Marais et al., 2016), organic nitrates (Fisher et al., 2016), formaldehyde and its relation to satellite observations (Zhu et al., 2016), and sensitivity to model resolution (Yu et al., 2016).

2 GEOS-Chem model description

We use the GEOS-Chem global 3-D CTM (Bey et al., 2001) in version 9.02 (http://www.geos-chem.org) with modifications described below. GEOS-Chem is driven with assimilated meteorological data from the Goddard Earth Observing System (GEOS-5.11.0) of the NASA Global Modeling and Assimilation Office (GMAO). The GEOS-5.11.0 data have a native horizontal resolution of 0.25° latitude by 0.3125° longitude and a temporal resolution of 3h (1h for surface variables and mixing depths). We use a nested version of GEOS-Chem (Chen et al., 2009) with native 0.25° ffi 0.3125° horizontal resolution over North America and adjacent oceans (130–60° W, 9.75–60° N) and dynamic boundary conditions from a global simulation with 4° ffi 5° horizontal resolution. Turbulent boundary layer mixing follows a non-local parameterization based on K-theory (Holtslag and Boville, 1993) implemented in GEOS-Chem by Lin and McElroy (2010). Daytimemixingdepthsarereducedby40%fromtheGEOS-5.11.0 data as described by Kim et al. (2015) and Zhu et al. (2016) to match aircraft lidar observations. The GEOS-Chem nested model simulation is conducted for August–

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September 2013, following 6 months of initialization at 4° ffi 5° resolution.

2.1 Chemistry

The chemical mechanism in GEOS-Chem version 9.02 is described by Mao et al. (2010, 2013). We modified aerosol reactive uptake of HO_2 to produce H_2O_2 instead of H_2O in order to better match H_2O_2 observations in SEAC^{4}RS. We also include a number of updates to isoprene chemistry, listed comprehensively in the Supplement (Tables S1 and S2) and described here more specifically for the low-NO_x pathways. Companion papers describe the isoprene chemistry updates relevant to isoprene nitrates (Fisher et al., 2016) and organic aerosol formation (Marais et al., 2016). Oxidation of biogenic monoterpenes is also added to the GEOS-Chem mechanism (Fisher et al., 2016) but does not significantly affect ozone.

A critical issue in isoprene chemistry is the fate of the isoprene peroxy radicals ($ISOPO_2$/ produced from the oxidation of isoprene by OH (the dominant isoprene sink). When NO_x is sufficiently high, $ISOPO_2$ reacts mainly with NO to produce ozone (high-NO_x pathway). At lower NO_x levels, $ISOPO_2$ may instead react with HO_2 or other organic peroxy radicals, or isomerize, in which case ozone is not produced (low-NO_x pathways). Here we increase the molar yield of isoprene hydroperoxide (ISOPOOH) from the $ISOPO_2$ C HO_2 reaction to 94% based on observations of the minor channels of this reaction (Liu et al., 2013). Oxidation of ISOPOOH by OH produces isoprene epoxides (IEPOX) that subsequently react with OH or are taken up by aerosol (Paulot et al., 2009b; Marais et al., 2016). We use updated rates and products from Bates et al. (2014) for the reaction of IEPOX with OH.

$ISOPO_2$ isomerization produces hydroperoxy-aldehydes (HPALDs) (Peeters et al., 2009; Crounse et al., 2011; Wolfe et al., 2012), and we explicitly include this in the GEOS-Chem mechanism. HPALDs go on to react with OH or photolyze at roughly equal rates over the Southeast US. We use the HPALD C OH reaction rate constant from Wolfe et al. (2012) and the products of the reaction from Squire et al. (2015). The HPALD photolysis rate is calculated using the absorption cross section of MACR, with a quantum yield of 1, as recommended by Peeters and Müller (2010). The photolysis products are taken from Stavrakou et al. (2010). Self-reaction of $ISOPO_2$ is updated following Xie et al. (2013).

A number of studies have suggested that conversion of NO_2 to nitrous acid (HONO) by gas-phase or aerosol-phase pathways could provide a source of HO_x radicals following HONO photolysis (Li et al., 2014; Zhou et al., 2014). This mechanism would also provide a catalytic sink for ozone when NO_2 is produced by the NO C ozone reaction, viz.,

$$NO\ C\ O_3\ !\ NO_2\ C\ O_2; \quad (R1)$$

$$NO_2\ !\ HONO\ .\text{by various pathways}/; \quad (R2)$$

$$HONO\ C\ h\ !\ NO\ C\ OH: \quad (R3)$$

Observations of HONO from the NOMADSS campaign (https://www2.acom.ucar.edu/campaigns/nomadss) indicate a mean daytime HONO concentration of 10 ppt in the Southeast US boundary layer (Zhou et al., 2014), whereas the standard gas-phase mechanism in GEOS-Chem version 9.02 yields less than 1 ppt. We add the pathway proposed by Li et al. (2014), in which HONO is produced by the reaction of the HO_2 ffH_2O complex with NO_2, but with a slower rate constant ($k_{HO_2ffH_2OCNO_2}$ D 2ffi10 ^{12} cm^3 molecule ^{1} s ^{1}) to match the observed ↑ 10 ppt daytime HONO in the Southeast US boundary layer. The resulting impact on boundary layer ozone concentrations is negligible.

2.2 Dry deposition

The GEOS-Chem dry deposition scheme uses a resistance-in-series model based on Wesely (1989) as implemented by Wang et al. (1998). Underestimation of dry deposition has been invoked as a cause for model overestimates of ozone in the eastern US (Lin et al., 2008; Walker, 2014). Daytime ozone deposition is determined principally by stomatal uptake. Here, we decrease the stomatal resistance from 200 sm ^{1} for both coniferous and deciduous forests (Wesely, 1989) by 20% to match summertime measurements of the ozone dry deposition velocity for a pine forest in North Carolina (Finkelstein et al., 2000) and for the Ozarks oak forest in southeastern Missouri (Wolfe et al., 2015), both averaging 0.8 cm s ^{1} in the daytime. The mean ozone deposition velocity in GEOS-Chem along the SEAC^{4}RS boundary layer flight tracks in the Southeast US averages 0.7 – 0.3 cm s ^{1} for the daytime (09:00–16:00 local) surface layer. Deposition is suppressed in the model at night due to both stomatal closure and near-surface stratification, consistent with the Finkelstein et al. (2000) observations.

Deposition flux measurements for isoprene oxidation products at the Alabama SOAS site (http://soas2013.rutgers.edu) indicate higher deposition velocities than simulated by the standard GEOS-Chem model (Nguyen et al., 2015). The diurnal cycle of dry deposition in GEOS-Chem compares well with the observations from SOAS (Nguyen et al., 2015). As an expedient, Nguyen et al. (2015) scaled the Henry's law coefficients for these species in GEOS-Chem to match their observed deposition velocities and we follow their approach here. Other important depositing species include HNO_3 and peroxyacetyl nitrate (PAN), with mean deposition velocities along the SEAC^{4}RS Southeast US flight tracks in daytime of 3.9 and 0.6 cm s ^{1}, respectively.

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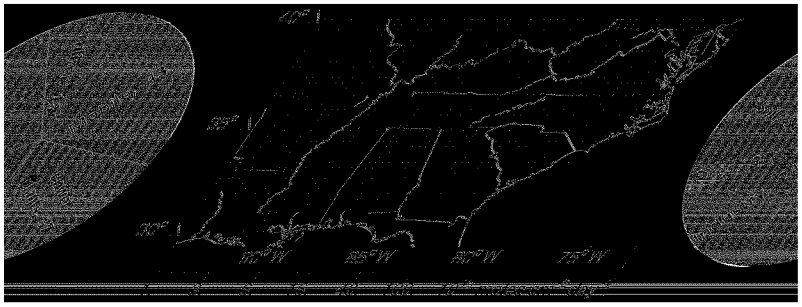

Figure 1. Surface NO_x emissions in the Southeast US in GEOS-Chem for August and September 2013 including fuel combustion, soils, fertilizer use, and open fires (total emissions D 153GgN). Anthropogenic emissions from mobile sources and industry in the National Emission Inventory (NEI11v1) for 2013 have been decreased by 60% to match atmospheric observations (see text). Lightning contributes an additional 25GgN to the free troposphere (not included in the figure). The emissions are mapped on the 0.25° ffi 0.3125° GEOS-Chem grid. The pie chart gives the sum of August–September 2013 emissions (GgN) over the Southeast US domain as shown on the map (94.5–75° W, 29.5–40° N).

2.3 Emissions

We use hourly US anthropogenic emissions from the 2011 EPA National Emissions Inventory (NEI11v1) at a horizontal resolution of 0.1° ffi 0.1° and adjusted to 2013 using national annual scaling factors (EPA NEI, 2015). The scaling factor for NO_x emissions is 0.89, for a 2013 US NEI total of 3.5TgNa ^{1}. Further information on the use of the NEI11v1 in GEOS-Chem can be found at http://wiki.seas.harvard.edu/geos-chem/index.php/EPA/NEI11_North_American_emissions. Soil NO_x emissions, including emissions from fertilizer application, are computed according to Hudman et al. (2012), with a 50% reduction in the Midwestern US based on a previous comparison with OMI NO_2 observations (Vinken et al., 2014). Open fire emissions are from the daily Quick Fire Emissions Database (QFED) (Darmenov and da Silva, 2014) with diurnal variability from the Western Regional Air Partnership (Air Sciences, 2005). We emit 40% of open fire NO_x emissions as PAN and 20% as HNO_3 to account for fast oxidation taking place in the fresh plume (Alvarado et al., 2010). Following Fischer et al. (2014), we inject 35% of fire emissions above the boundary layer, evenly between 3.5 and 5.5km altitude. Lightning is an additional source of NO_x but is mainly released in the upper troposphere, as described below.

Initial implementation of the above inventory in GEOS-Chem resulted in an 60–70% overestimation of NO_x and HNO_3 measured from the SEAC^{4}RS DC-8 aircraft and a 70% overestimation of nitrate (NO_3 / wet deposition fluxes measured by the NADP across the Southeast US. Correcting this bias required a ↑ 40% decrease in surface NO_x emissions. Assuming strongly reduced soil and fertilizer NO_x emissions (18% of total NO_x emissions in the southeast) and open fires (2%), also considering the large uncertainty in these emissions, would be insufficient to correct this bias. Emissions from power plant stacks are directly measured but account for only 12% of NEI NO_x emissions on an annual basis (EPA NEI, 2015). Several local studies in recent years have found that NEI NO_x emissions for mobile sources may be too high by a factor of 2 or more (Castellanos et al, 2011; Fujita et al., 2012; Brioude et al., 2013; Anderson et al., 2014). We can achieve the required 40% decrease in total NO_x emissions by reducing NEI emissions from mobile and industrial sources (all sources except power plants) by 60% or alternatively by reducing these sources by 30% and zeroing out soil and fertilizer NO_x emissions. Since it is apparent that there is some minimum contribution by soil NO_x emissions, we assessed the impact of the approach of reducing the non-power-plant NEI emissions by 60%. The spatial overlap between anthropogenic and soil NO_x emissions is such that we cannot readily arbitrate between these two scenarios. Comparisons with observations will be presented in the next section.

We constrain the lightning NO_x source with satellite data as described by Murray et al. (2012). Lightning NO_x is mainly released at the top of convective updrafts following Ott et al. (2010). The standard GEOS-Chem model uses higher NO_x yields for midlatitudes lightning (500molflash ^{1}) than for tropical (260molflash ^{1}) (Huntrieser et al., 2007, 2008; Hudman et al., 2007; Ott et al., 2010) with a fairly arbitrary boundary between the two at 23° N in North America and 35° N in Eurasia. Zhang et al. (2014) previously found that this leads GEOS-Chem to overestimate background ozone in the southwestern US and we find the same here for the eastern US and the Gulf of Mexico. We treat here all lightning in the 35° S–35° N band as tropical and thus remove the distinction between North America and Eurasia.

Figure 1 gives the resulting surface NO_x emissions for the Southeast US for August and September 2013. With the original NEI inventory, fuel combustion accounted for 81% of total surface NO_x emissions in the Southeast US (not including lightning). If the required reduction of non-power-plant

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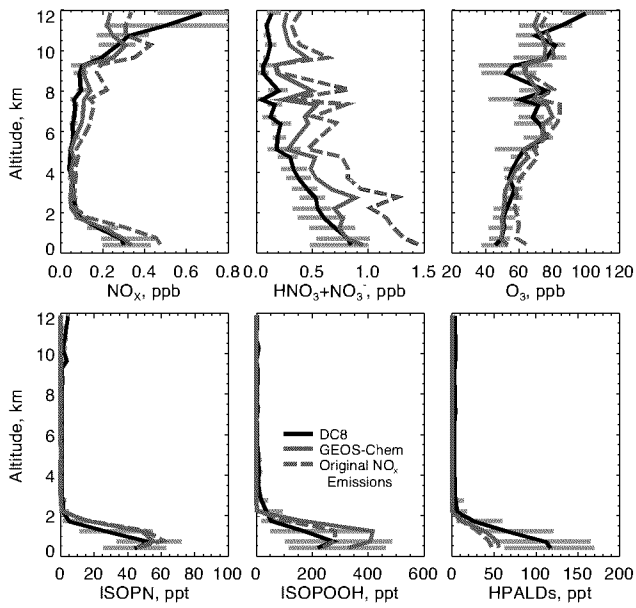

Figure 2. Median vertical concentration profiles of NO_x, total inorganic nitrate (gas HNO_3 C aerosol NO_3 /, ozone, isoprene nitrate (ISOPN), isoprene hydroperoxide (ISOPOOH), and hydroperoxyaldehydes (HPALD) for the SEAC^{4}RS flights over the Southeast US (domain of Fig. 1). Observations from the DC-8 aircraft are comparedtoGEOS-Chemmodelresults.Thedashedredlineshows model results before adjustment of NO_x emissions from fuel combustionandlightning(seetext).The25thand75thpercentilesofthe DC-8 observations are shown as grey bars. The SEAC^{4}RS observations have been filtered to remove open fire plumes, stratospheric air, and urban plumes as described in the text. Model results are sampled along the flight tracks at the time of flights and gridded to the model resolution. Profiles are binned to the nearest 0.5km. The NOAA NO_yO_3 four-channel chemiluminescence (CL) instrument made measurements of ozone and NO_y (Ryerson et al., 1998), NO (Ryerson et al., 2000), and NO_2 (Pollack et al., 2010). Total inorganic nitrate was measured by the University of New Hampshire Soluble Acidic Gases and Aerosol (UNH SAGA) instrument (Dibb et al., 2003) and was mainly gas-phase HNO_3 for the SEAC^{4}RS conditions.ISOPOOH,ISOPN,andHPALDsweremeasuredbythe Caltech single mass analyzer CIMS (Crounse et al., 2006; Paulot et al., 2009a; Crounse et al., 2011).

NEI emissions is 60%, the contribution from fuel combustion would be 68%.

Biogenic VOC emissions are from MEGAN v2.1, includingisoprene,acetone,acetaldehyde,monoterpenes,and > C_2 alkenes. We reduce MEGAN v2.1 isoprene emissions by 15% to better match SEAC^{4}RS observations of isoprene fluxes from the Ozarks (Wolfe et al., 2015) and observed formaldehyde (Zhu et al., 2016). Yu et al. (2016) show the resulting isoprene emissions for the SEAC^{4}RS period.

3 Overestimate of NO_x emissions in the EPA NEI inventory

Figure 2 shows simulated and observed median vertical distributions of NO_x, total inorganic nitrate (gas-phase HNO_3 C aerosol NO_3 /, and ozone concentrations along the SEAC^{4}RS flight tracks over the Southeast US. Here and elsewhere the data exclude urban plumes as diagnosed by $[NO_2] > 4$ppb, open fire plumes as diagnosed by $[CH_3CN] > 200$ppt, and stratospheric air as diagnosed by $[O_3] = [CO] > 1.25$molmol ^{1}. These filters exclude < 1, 7, and 6% of the data, respectively. We would not expect the model to be able to capture these features even at native resolution (Yu et al., 2016).

Model results in Fig. 2 are shown both with the original NO_x emissions (dashed line) and with non-power-plant NEI fuel emissions decreased by 60% (solid line). Decreasing emissions corrects the model bias for NO_x and also largely corrects the bias for inorganic nitrate. Boundary layer ozone is overestimated by 12ppb with the original NO_x emissions but this bias disappears after decreasing the NO_x emissions. Results are very similar if we decrease the non-power-plant NEI fuel emissions by only 30% and zero out soil and fertilizer emissions. Thus the required decrease of NO_x emissions may involve an overestimation of both anthropogenic and soil emissions.

Further support for decreasing NO_x emissions is offered by observed nitrate wet deposition fluxes from the NADP network (NADP, 2007). Figure 3 compares simulated and observed fluxes for the model with decreased NO_x emissions. Model values have been corrected for precipitation bias following the method of Paulot et al. (2014), in which the monthly deposition flux is assumed to scale to the 0.6th power of the precipitation bias. We diagnose precipitation bias in the GEOS-5.11.0 data relative to high-resolution PRISM observations (http://prism.oregonstate.edu). For the Southeast US, the precipitation bias is 34% in August and 21%inSeptember2013.WeseefromFig.3thatthemodel with decreased NO_x emissions reproduces the spatial variability in the observations with only C8% bias over the Southeast US and C7% over the contiguous US. In comparison, the model with original emissions had a 63% overestimation of the nitrate wet deposition flux nationally and a 71% overestimation in the southeast. The high deposition fluxes along the Gulf of Mexico in Fig. 3, both in the model and in the observations, reflect particularly large precipitation.

The model with decreased NO_x emissions also reproduces the spatial distribution of NO_x in the Southeast US boundary layer as observed in SEAC^{4}RS. This is shown in Fig. 4 with simulated and observed concentrations of NO_x along the flight tracks below 1.5km altitude. The spatial correlation coefficient is 0.71. There are no obvious spatial patterns of model bias that would point to specific source sectors as responsible for the NO_x emission overestimate, beyond the

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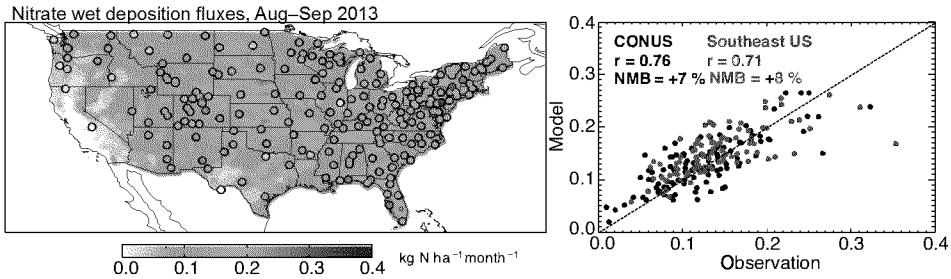

Figure 3. Nitrate wet deposition fluxes across the US in August–September 2013. Mean observations from the NADP network (circles in the left panel) are compared to model values with decreased NO_x emissions (background). Also shown is a scatterplot of simulated vs. observed values at individual sites for the whole contiguous US (black) and for the Southeast US (green). The correlation coefficient (r) and normalized mean bias (NMB) are shown inset, along with the 1:1 line.

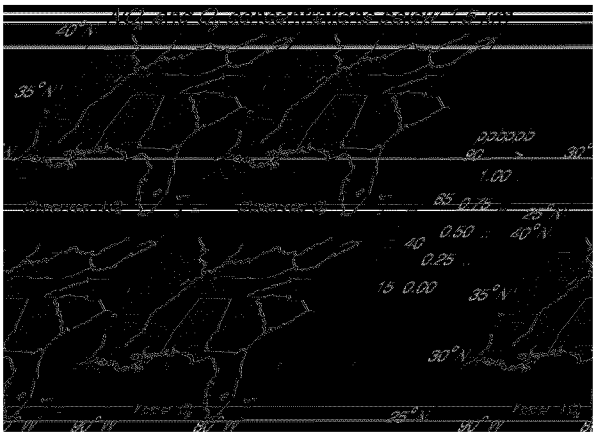

Figure 4. Ozone and NO_x concentrations in the boundary layer (0–1.5km) during SEAC^{4}RS (6 August to 23 September 2013). Observations from the aircraft and simulated values are averaged over the 0.25° ffi 0.3125° GEOS-Chem grid. NO_x above 1ppb is shown in black. The spatial correlation coefficient is 0.71 for both NO_x and O_3. The normalized mean bias is 11.5% for NO_x and 4.5% for O_3.

blanket30–60%decreaseofnon-power-plantNEIemissions needed to correct the regional emission total.

4 Using satellite NO_2 data to verify NO_x emissions: sensitivity to upper troposphere

Observations of tropospheric NO_2 columns by solar backscatter from the OMI satellite instrument offer an additional constraint on NO_x emissions (Duncan et al., 2014; Lu et al., 2015). We compare the tropospheric columns simulated by GEOS-Chem with the NASA operational retrieval (Level 2, v2.1) (NASA, 2012; Bucsela et al., 2013) and the Berkeley High-Resolution (BEHR) retrieval (Russell et al., 2011). The NASA retrieval has been validated to agree with surfacemeasurementstowithin − 20%(Lamsaletal.,2014). Both retrievals fit the observed backscattered solar spectra to obtain a slant tropospheric NO_2 column, Ω_s, along the optical path of the backscattered radiation detected by the satellite. The slant column is converted to the vertical column, Ω_v, by using an air mass factor (AMF) that depends on the vertical profile of NO_2 and on the scattering properties of the surface and the atmosphere (Palmer et al., 2001):

$$\Omega_v = \frac{\Omega_s}{AMF} = \frac{\Omega_s}{AMF_G \int_0^{z_T} w(z) S(z)\, dz}. \quad (1)$$

In Eq. (4), AMF_G is the geometric air mass factor that dependsontheviewinggeometryofthesatellite, $w(z)$ isascatteringweightcalculatedbyaradiativetransfermodelthatdescribes the sensitivity of the backscattered radiation to NO_2 as a function of altitude, $S(z)$ is a shape factor describing the normalized vertical profile of NO_2 number density, and z_T is the tropopause. Scattering weights for NO_2 retrievals typically increase by a factor of 3 from the surface to the upper troposphere (Martin et al., 2002). Here we use our GEOS-Chem shape factors to recalculate the AMFs in the NASA and BEHR retrievals as recommended by Lamsal et al. (2014) for comparing model and observations. We filter out cloudy scenes (cloud radiance fraction > 0.5) and bright surfaces (surface reflectivity > 0.3).

Figure 5 shows the mean NO_2 tropospheric columns from BEHR, NASA, and GEOS-Chem (with NO_x emission reductions applied) over the Southeast US for August–September 2013. The BEHR retrieval is on average 6% higher than the NASA retrieval. GEOS-Chem is on average 11 − 19% lower than the NASA retrieval and 16 − 18% lower than the BEHR retrieval. With the original NEI NO_x emissions, GEOS-Chem would be biased high against both retrievals by 26–31%. The low bias in the model with reduced NO_x emissions does not appear to be caused by an overcorrection of surface emissions but rather by the upper troposphere. Figure 6 (top left panel) shows the mean vertical profile of NO_2 number density as measured from the aircraft by two independent instruments (NOAA and UC Berkeley) and simulated by GEOS-Chem. At the surface, the median difference is 1.8 ffi 10^9 moleculescm $^{-3}$, which is

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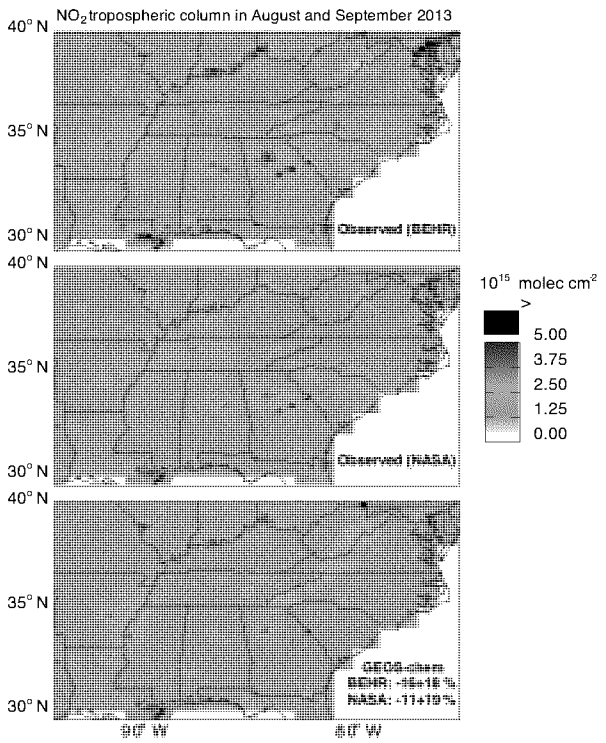

Figure 5. NO_2 tropospheric columns over the Southeast US in August–September 2013. GEOS-Chem (sampled at the 13:30 local time overpass of OMI) is compared to OMI satellite observations using the BEHR and NASA retrievals. Values are plotted on the 0.25° ffi 0.3125° GEOS-Chem grid. The GEOS-Chem mean bias over the figure domain and associated spatial standard deviation are inset in the bottom panel.

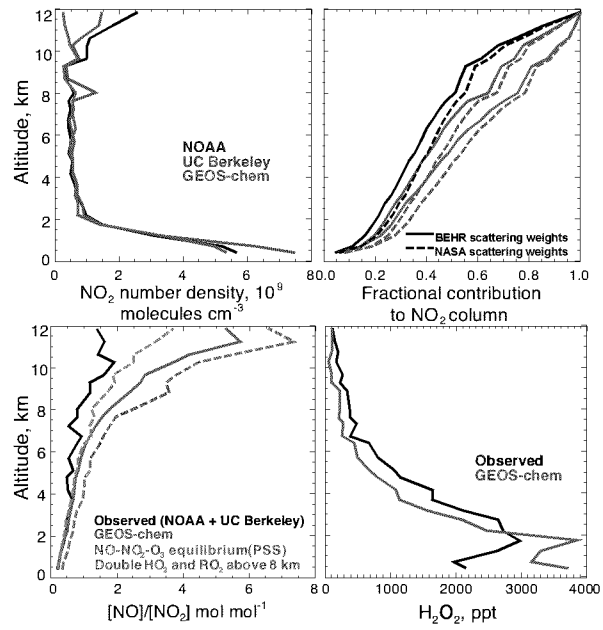

Figure 6. Vertical distribution of NO_2 over the Southeast US during SEAC^{4}RS (August–September 2013) and contributions to tropospheric NO_2 columns measured from space by OMI. The top left panel shows median vertical profiles of NO_2 number density measured from the SEAC^{4}RS aircraft by the NOAA and UC Berkeley instruments and simulated by GEOS-Chem. The top right panel shows the fractional contribution of NO_2 below a given altitude to the total tropospheric NO_2 slant column measured by OMI, accounting for increasing sensitivity with altitude as determined from the retrieval scattering weights. The bottom left panel shows the median vertical profiles of the daytime $[NO]=[NO_2]$ molar concentration ratio in the aircraft observations (NOAA for NO and UC Berkeley for NO_2/ and in GEOS-Chem. Also shown is the ratio computed from NO–NO_2–O_3 photochemical steady state (PSS) as given by Reactions (4) and (6) (blue) and including Reaction (5) with doubled HO_2 and RO_2 concentrations above 8km (purple). The bottom right panel shows the median H_2O_2 profile from the model and from the SEAC4RS flights over the Southeast US. H_2O_2 was measured by the Caltech CIMS (see Fig. 2).

within the NOAA and UC Berkeley measurement uncertainties of − 0.030ppbv C 7% and − 5%, respectively. The observations show a secondary maximum in the upper troposphere above 10km, absent in GEOS-Chem. It has been suggested that aircraft measurements of NO_2 in the upper troposphere could be biased high due to decomposition in the instrument inlet of thermally unstable NO_x reservoirs such as HNO_4 and methyl peroxy nitrate (Browne et al., 2011; Reed et al., 2016). This would not affect the UC Berkeley measurement (Nault et al., 2015) and could possibly account for the difference with the NOAA measurement in Fig. 6.

The top right panel of Fig. 6 shows the cumulative contributions from different altitudes to the slant NO_2 column measured by the satellite, using the median vertical profiles from the left panel and applying mean altitude-dependent scattering weights from the NASA and BEHR retrievals. The boundarylayerbelow1.5kmcontributesonly19–28%ofthe column. The upper troposphere above 8km contributes 32–49% in the aircraft observations and 23% in GEOS-Chem. Much of the observed upper-tropospheric NO_2 likely originates from lightning and is broadly distributed across the southeast because of the long lifetime of NO_x at that altitude (Li et al., 2005; Bertram et al., 2007; Hudman et al., 2007).TheNO $_2$ verticalprofile(shapefactor)assumedinthe BEHR retrieval does not include any lightning influence, and the Global Modeling Initiative (GMI) model vertical profile assumed in the NASA retrieval has little contribution from the upper troposphere (Lamsal et al., 2014). These underestimates of upper-tropospheric NO_2 in the retrieval shape factors will cause a negative bias in the AMF and therefore a positive bias in the retrieved vertical columns.

The GEOS-Chem underestimate of observed upper-tropospheric NO_2 in Fig. 6 is partly driven by $NO=NO_2$ partitioning. The bottom left panel of Fig. 6 shows the $[NO]=[NO_2]$ concentration ratio in GEOS-Chem and in the observations (NOAA for NO, UC Berkeley for NO_2/. One would expect the $[NO]=[NO_2]$ concentration ratio in the

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daytime upper troposphere to be controlled by photochemical steady state:

$$NO + O_3 \rightarrow NO_2 + O_2; \quad (R4)$$

$$NO + HO_2 = RO_2 \rightarrow NO_2 + OH = RO; \quad (R5)$$

$$NO_2 + h\nu \xrightarrow{O_2} NO + O_3: \quad (R6)$$

If Reaction (R5) plays only a minor role then $[NO] = [NO_2] \cdot k_6 = (k_4[O_3])$, defining the $NO–NO_2–O_3$ photochemical steady state (PSS). The PSS plotted in Fig. 6 agrees closely with GEOS-Chem. Such agreement has previously been found when comparing photochemical models with observed $[NO] = [NO_2]$ ratios from aircraft in the marine upper troposphere (Schultz et al., 1999) and lower stratosphere (Del Negro et al., 1999). The SEAC^{4}RS observations show large departure. The NO_2 photolysis frequencies k_6 computed locally by GEOS-Chem are on average within 10% of the values determined in SEAC^{4}RS from measured actinic fluxes (Shetter and Muller, 1999), so this is not the problem.

A possible explanation is that the model underestimates peroxy radical concentrations and hence the contribution of Reaction (5) in the upper troposphere. Zhu et al. (2016) found that GEOS-Chem underestimates the observed HCHO concentrations in the upper troposphere during SEAC^{4}RS by a factor of 3, implying that the model underestimates the HO_x source from convective injection of HCHO and peroxides (Jaeglé et al., 1997; Prather and Jacob, 1997; Müller and Brasseur, 1999). HO_2 observations over the central US in summer during the SUCCESS aircraft campaign suggest that this convective injection increases HO_x concentrations in the upper troposphere by a factor of 2 (Jaeglé et al., 1998). The bottom right panel of Fig. 6 shows median modeled and observed vertical profiles of the HO_x reservoir hydrogen peroxide (H_2O_2) during SEAC^{4}RS over the Southeast US. GEOS-Chem underestimates observed H_2O_2 by a mean factor of 1.7 above 8 km. The bottom left panel of Fig. 6 shows the $[NO] = [NO_2]$ ratio in GEOS-Chem with HO_2 and RO_2 doubled above 8 km. Such a change corrects significantly the bias relative to observations.

The PSS and GEOS-Chem simulation of the $NO = NO_2$ concentration ratio in Fig. 6 use $k_4 = 3.0 \times 10^{-12} \exp(-1500/T)\ cm^3\ molecule^{-1}\ s^{-1}$ and spectroscopic information for k_6 from Sander et al. (2011). It is possible that the strong thermal dependence of k_4 has some error, considering that only one direct measurement has been published for the cold temperatures of the upper troposphere (Borders and Birks, 1982). Cohen et al. (2000) found that reducing the activation energy of k_4 by 15% improved model agreement in the lower stratosphere. Correcting the discrepancy between simulated and observed $[NO] = [NO_2]$ ratios in the upper troposphere in Fig. 6 would require a similar reduction to the activation energy of k_4, but this reduction would negatively impact the surface comparison. This inconsistency of the observed $[NO] = [NO_2]$ ratio with basic theory needs to be resolved, as it affects the inference of NO_x emissions from satellite NO_2 column measurements. Notwithstanding this inconsistency, we find that NO_2 in the upper troposphere makes a significant contribution to the tropospheric NO_2 column observed from space.

5 Isoprene oxidation pathways

Measurements aboard the SEAC^{4}RS aircraft included first-generation isoprene nitrates (ISOPN), isoprene hydroperoxide (ISOPOOH), and hydroperoxy-aldehydes (HPALDs) (Crounse et al., 2006; Paulot et al., 2009a; St. Clair et al., 2010; Crounse et al., 2011; Beaver et al., 2012; Nguyen et al., 2015). Although measurement uncertainties are large (30, 40, and 50%, respectively; Nguyen et al., 2015), these are unique products of the $ISOPO_2 + NO$, $ISOPO_2 + HO_2$, and $ISOPO_2$ isomerization pathways and thus track whether oxidation of isoprene proceeds by the high-NO_x pathway (producing ozone) or the low-NO_x pathways. Figure 2 (bottom row) compares simulated and observed concentrations. All three gases are restricted to the boundary layer because of their short lifetimes. Mean model concentrations in the lowest altitude bin (Fig. 2, approximately 400 m above ground) differ from observations by +19% for ISOPN, +70% for ISOPOOH, and −50% for HPALDs. The GEOS-Chem simulation of organic nitrates including ISOPN is further discussed in Fisher et al. (2016). Our HPALD source is based on the $ISOPO_2$ isomerization rate constant from Crounse et al. (2011). A theoretical calculation by Peeters et al. (2014) suggests a rate constant that is 1.8 times higher, which would reduce the model bias for HPALDs and ISOPOOH and increase boundary layer OH by 8%. St. Clair et al. (2015) found that the reaction rate of ISOPOOH + OH to form IEPOX is approximately 10% faster than the rate given by Paulot et al. (2009b), which would further reduce the model overestimate. For both ISOPOOH and HPALDs, GEOS-Chem captures much of the spatial variability ($r = 0.80$ and 0.79, respectively).

Figure 7 shows the model branching ratios for the fate of the $ISOPO_2$ radical by tracking the mass of $ISOPO_2$ reacting via the high-NO_x pathway ($ISOPO_2 + NO$) and the low-NO_x pathways over the Southeast US domain. The mean branching ratios for the Southeast US are $ISOPO_2 + NO$ 54%, $ISOPO_2 + HO_2$ 26%, $ISOPO_2$ isomerization 15%, and $ISOPO_2 + RO_2$ 5%. The lack of dominance of the high-NO_x pathway is due in part to the spatial segregation of isoprene and NO_x emissions (Yu et al., 2016). This segregation also buffers the effect of changing NO_x emissions on the fate of isoprene. Our original simulation with higher total NO_x emissions (unadjusted NEI11v1) had a branching ratio for the $ISOPO_2 + NO$ reaction of only 62%.

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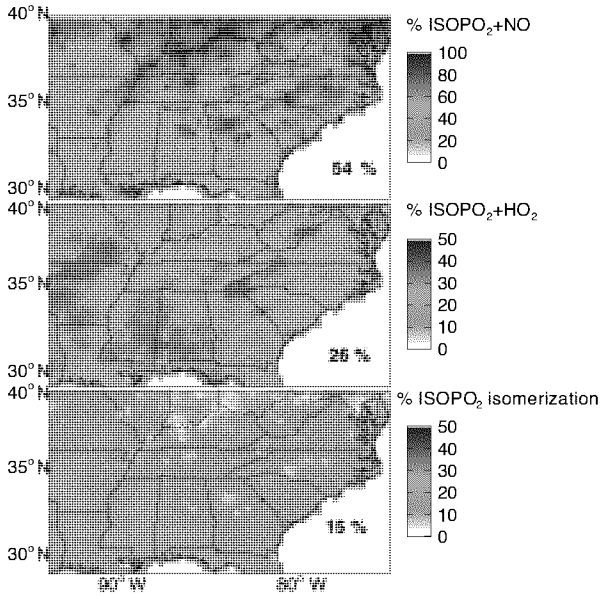

Figure 7. Branching ratios for the fate of the isoprene peroxy radical ($ISOPO_2$) as simulated by GEOS-Chem over the Southeast US for August–September 2013. Values are percentages of $ISOPO_2$ that react with NO, HO_2, or isomerize from the total mass of isoprene reacting over the domain. Note the difference in scale between the top panel and the lower two panels. Regional mean percentages for the Southeast US are shown inset. They add up to less than 100% because of the small $ISOPO_2$ sink from reaction with other organic peroxy radicals (RO_2).

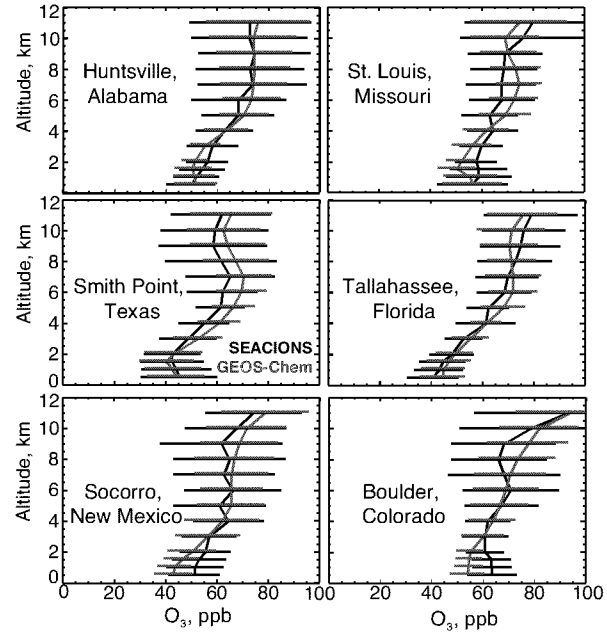

Figure 8. Mean ozonesonde vertical profiles at the US SEACIONS sites (http://croc.gsfc.nasa.gov/seacions/) during the SEAC^{4}RS campaign in August–September 2013. An average of 20 sondes were launched per site between 09:00 and 16:00 local time. Ozonesondes at Smith Point, Texas, were only launched in September. Model values are coincident with the launches. Data are averaged vertically over 0.5km bins below 2km altitude and 1.0km bins above. Also shown are standard deviations.

6 Implications for ozone: aircraft and ozonesonde observations

Figure 2 compares simulated and observed median vertical profiles of ozone concentrations over the Southeast US during SEAC^{4}RS. There is no significant bias through the depth of the tropospheric column. The median ozone concentration below 1.5km is 49ppb in the observations and 51ppb in the model. We also find excellent model agreement across the US with the SEACIONS ozonesonde network (Fig. 8). The successful simulation of ozone is contingent on the decrease in NO_x emissions. As shown in Fig. 2, a simulation with the original NEI emissions overestimates boundary layer ozone by 12ppb.

The model also has success in reproducing the spatial variability of boundary layer ozone seen from the aircraft, as shown in Fig. 4. The correlation coefficient is r D 0:71 on the 0.25° ffi 0.3125° model grid, and patterns of high and low ozone concentration are consistent. The highest observed ozone (> 75ppb) was found in air influenced by agricultural burning along the Mississippi River and by outflow from Houston over Louisiana. GEOS-Chem does not capture the extreme values and this probably reflects a dilution effect (Yu et al., 2016).

A critical parameter for understanding ozone production is the ozone production efficiency (OPE) (Liu et al., 1987), defined as the number of ozone molecules produced per molecule of NO_x emitted. This can be estimated from atmospheric observations by the relationship between odd oxygen (O_x ◀ O_3 C NO_2) and the sum of products of NO_x oxidation, collectively called NO_z and including inorganic and organic nitrates (Trainer et al., 1993; Zaveri, 2003). The O_x vs. NO_z linear relationship (as derived from a linear regression) provides an upper estimate of the OPE because of rapid deposition of NO_y, mainly HNO_3 (Trainer et al., 2000; Rickard et al., 2002).

Figure 9 shows the observed and simulated daytime (09:00–16:00 local) O_x vs. NO_z relationship in the SEAC^{4}RS data below 1.5km, where NO_z is derived from the observations as NO_y NO_x ◀ HNO_3 C aerosol nitrate C PAN C alkyl nitrates. The resulting OPE from the observations (17.4 – 0.4 mol mol^{-1}) agrees well with GEOS-Chem (16.7 – 0.3 mol mol^{-1}). Previous work during the INTEX-NA aircraft campaign in summer 2004 found an OPE of 8 below 4km (Mena-Carrasco et al., 2007). By selecting INTEX-NA data only for the southeast and below 1.5km we find an OPE of 14.1 – 1.1 (Fig. 9, right panel). The median NO_z was 1.1ppb during SEAC^{4}RS and 1.5ppb during INTEX-NA, a decrease of approximately 40%. With

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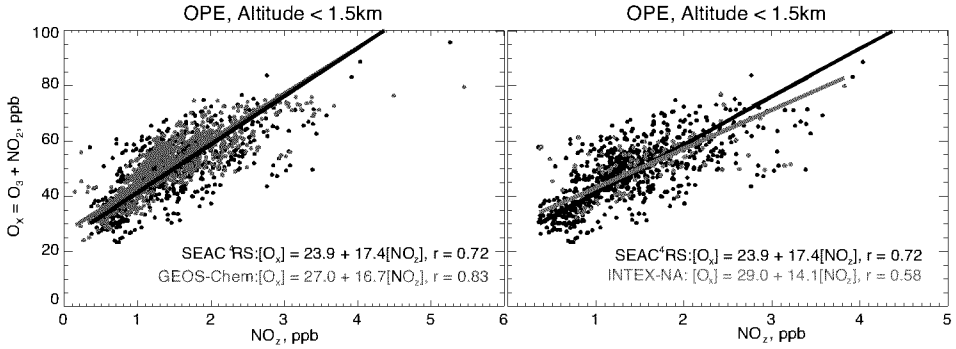

Figure 9. Ozone production efficiency (OPE) over the Southeast US in summer estimated from the relationship between odd oxygen (O_x) and the sum of NO_x oxidation products (NO_z) below 1.5 km altitude. The left panel compares SEAC^{4}RS observations to GEOS-Chem values for August–September 2013 (data from Fig. 2). The right panel compares SEAC^{4}RS observations to INTEX-NA aircraft observations collected over the same Southeast US domain in summer 2004 (Singh et al., 2006). NO_z is defined here as HNO_3 + aerosol nitrate + PAN + alkyl nitrates, all of which were measured from the SEAC^{4}RS and INTEX-NA aircraft. The slope and intercept of the reduced-major-axis (RMA) regression are provided inset with the correlation coefficient (r). Observations for INTEX-NA were obtained from ftp://ftp-air.larc.nasa.gov/pub/INTEXA/.

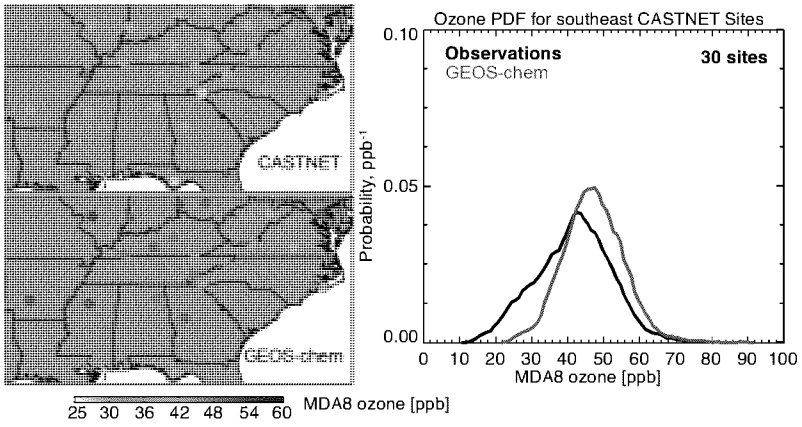

Figure 10. Maximum daily 8h average (MDA8) ozone concentrations at the 30 CASTNET sites in the Southeast US in June–August 2013. The left panels show seasonal mean values in the observations and GEOS-Chem. The right panel shows the probability density functions (pdfs) of daily values at the 30 sites.

the original NEI11v1 NO_x emissions (53% higher), the OPE from GEOS-Chem would be 14.7 − 0.3. Both the INTEX-NA data and the model are consistent with the expectation that OPE increases with decreasing NO_x emissions (Liu et al., 1987).

7 Implications for ozone: surface air

Figure 10 compares maximum daily 8h average (MDA8) ozone values at the US CASTNET (EPA, 2016) sites in June–August 2013 to the corresponding GEOS-Chem values. The model has a mean positive bias of 6 − 14 ppb with no significant spatial pattern. The model is unable to match the low tail in the observations, including a significant population with MDA8 ozone less than 20 ppb. The improvements to dry deposition described in Sect. 2.2 minimally reduce (approximately 1 ppb) GEOS-Chem ozone compared to SEAC^{4}RS boundary layer and CASTNET surface MDA8 ozone observations. The reduction of daytime mixing depths described in Sect. 2 results in a small increase in mean MDA8 ozone (approximately 2 ppb).

The positive bias in the model for surface ozone is remarkable considering that the model has little bias relative to aircraft observations below 1.5 km altitude (Figs. 2 and 4). A standard explanation for model overestimates of surface ozone over the Southeast US, first proposed by Fiore et al. (2003) and echoed in the review by McDonald-Buller et al. (2011), is excessive ozone over the Gulf of Mexico, which is the prevailing low-altitude inflow. We find that this is not the case. SEAC^{4}RS included four flights over the Gulf of Mexico, and Fig. 11 compares simulated and observed vertical profiles of ozone and NO_x concentrations that show no

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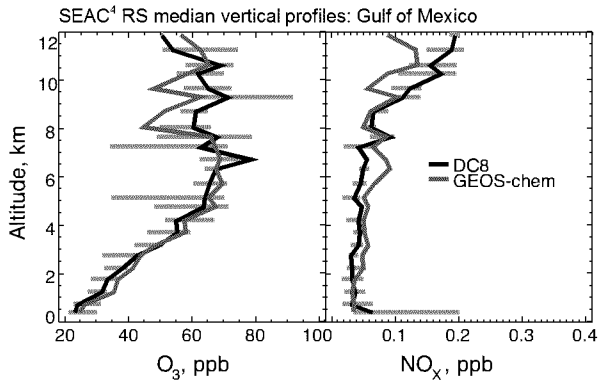

Figure 11. Median vertical profiles of ozone and NO_x concentrations over the Gulf of Mexico during SEAC^{4}RS. Observations are from four SEAC^{4}RS flights over the Gulf of Mexico (12 August and 4, 13, 16 September). GEOS-Chem model values are sampled along the flight tracks. The 25th and 75th percentiles of the aircraft observations are shown as horizontal bars.

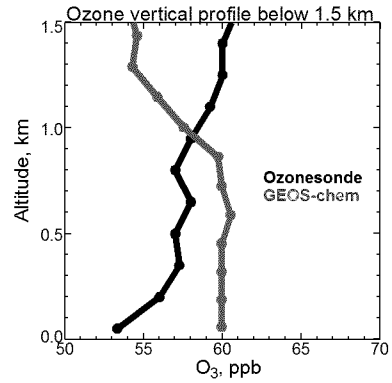

Figure 12. Median vertical profile of ozone concentrations over St. Louis, Missouri, and Huntsville, Alabama, during August and September 2013. Observations from SEACIONS ozonesondes launched between 10:00 and 13:00 local time (57 launches) are compared to GEOS-Chem results sampled at the times of the ozonesonde launches and at the vertical resolution of the model (11 layers below 1.5km, red circles). The ozonesonde data are shown at 150m resolution. Altitude is above local ground level.

systematic bias. The median ozone concentration in the marine boundary layer is 26ppb in the observations and 29ppb in the model. This successful simulation is due to our adjustment of lightning NO_x emission (Sect. 2.3); a sensitivity test with the original (twice higher) GEOS-Chem lightning emissions in the southern US increases surface ozone over the Gulf of Mexico by up to 6ppb. The aircraft observations in Fig. 4 further shown no indication of a coastal depletion that might be associated with halogen chemistry. Remarkably, the median ozone over the Gulf of Mexico is higher than approximately 8% of MDA8 values at sites in the southeast.

It appears instead that there is a model bias in boundary layer vertical mixing and chemistry. Figure 12 shows the median ozonesonde profile at a higher vertical resolution over the Southeast US (Huntsville, Alabama, and St. Louis, Missouri, sites) during SEAC^{4}RS as compared to GEOS-Chem below 1.5km. The ozonesondes indicate a decrease of 7ppb from 1.5km to the surface, whereas GEOS-Chem features a reverse gradient of increasing ozone from 1.5 to 1km with flat concentrations below. This implies a combination of two model errors in the boundary layer: (1) excessive vertical mixing and (2) net ozone production whereas observations indicate net ozone loss.

8 Conclusions

We used aircraft (SEAC^{4}RS), surface, satellite, and ozonesonde observations from August and September 2013, interpreted with the GEOS-Chem chemical transport model, to better understand the factors controlling surface ozone in the Southeast US. Models tend to overestimate ozone in that region. Determining the reasons behind this overestimate is critical to the design of efficient emission control strategies to meet the ozone NAAQS.

A major finding from this work is that NEI11v1 for NO_x (the limiting precursor for ozone formation) is biased high across the US by as much as a factor of 2. Evidence for this comes from (1) SEAC^{4}RS observations of NO_x and its oxidation products, (2) NADP network observations of nitrate wet deposition fluxes, and (3) OMI satellite observations of NO_2. Presuming no error in emissions from large power plants with continuous emission monitors (14% of unadjusted NEI inventory), we find that emissions from other industrial sources and mobile sources must be 30–60% lower than NEI values, depending on the assumption of the contribution from soil NO_x emissions. We thus estimate that anthropogenic fuel NO_x emissions in the US in 2013 were 1.7–2.6 Tg N a^{-1}, as compared to 3.5 Tg N a^{-1} given in the NEI.

OMI NO_2 satellite data over the Southeast US are consistent with this downward correction of NO_x emissions but interpretation is complicated by the large contribution of the free troposphere to the NO_2 tropospheric column retrieved from the satellite. Observed (aircraft) and simulated vertical profiles indicate that NO_2 below 2km contributes only 20–35% of the tropospheric column detected from space while NO_2 above 8km (mainly from lightning) contributes 25–50%. Current retrievals of satellite NO_2 data do not properly account for this elevated pool of upper-tropospheric NO_2, so that the reported tropospheric NO_2 columns are biased high. More work is needed on the chemistry maintaining high levels of NO_2 in the upper troposphere.

Isoprene emitted by vegetation is the main VOC precursor of ozone in the southeast in summer, but we find that only 50% reacts by the high-NO_x pathway to produce ozone. This is consistent with detailed aircraft observations of isoprene oxidation products from the aircraft. The high-NO_x

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fraction is only weakly sensitive to the magnitude of NO_x emissions because isoprene and NO_x emissions are spatially segregated. The ability to properly describe high- and low-NO_x pathways for isoprene oxidation is critical for simulating ozone and it appears that the GEOS-Chem mechanism is successful for this purpose.

Our updated GEOS-Chem simulation with decreased NO_x emissions provides an unbiased simulation of boundary layer and free-tropospheric ozone measured from aircraft and ozonesondes during SEAC^{4}RS. Decreasing NO_x emissions is critical to this success as the original model with NEI emissions overestimated boundary layer ozone by 12ppb. The ozone production efficiency (OPE) inferred from O_x vs. NO_z aircraft correlations in the mixed layer is also well reproduced. Comparison to the INTEX-NA aircraft observations over the southeast in summer 2004 indicates a 14% increase in OPE associated with a 40% reduction in NO_x emissions.

Despite the successful simulation of boundary layer ozone (Figs. 2 and 9), GEOS-Chem overestimates MDA8 surface ozone observations in the Southeast US in summer by 6 – 14ppb. Daytime ozonesonde data indicate a 7ppb decrease from 1.5km to the surface that GEOS-Chem does not capture. This may be due to excessive boundary layer mixing and net ozone production in the model. Excessive mixing in GEOS-Chem may be indicative of an overestimate of sensible heat flux (Holtslag and Boville, 1993), and thus an investigation of boundary layer meteorological variables is warranted. Such a bias may not be detected in the comparison of GEOS-Chem with aircraft data, generally collected under fair-weather conditions and with minimal sampling in the lower part of the boundary layer. An investigation of relevant meteorological variables and boundary layer source and sink terms in the ozone budget to determine the source of bias and its prevalence across models will be the topic of a follow-up paper.

9 Data availability

The SEAC^{4}RS airborne trace gas and particle measurements and SEACIONS ozonesonde measurements are available from the NASA LaRC Airborne Science Data for Atmospheric Composition (http://www-air.larc.nasa.gov/cgi-bin/ArcView/seac4rs) with doi:10.5067/Aircraft/SEAC4RS/Aerosol-TraceGas-Cloud.

Observations for INTEX-NA were also obtained from NASA LaRC (http://www-air.larc.nasa.gov/cgi-bin/ArcView/intexna) with doi:10.5067/Aircraft/INTEXA/Aerosol-TraceGas.

The Supplement related to this article is available online at doi:10.5194/acp-16-13561-2016-supplement.

Acknowledgements. We are grateful to the entire NASA SEAC^{4}RS team for their help in the field. We thank Tom Ryerson for his measurements of NO and NO_2 from the NOAA NO_yO_3 instrument. We thank L. Gregory Huey for the use of his CIMS PAN measurements. We thank Fabien Paulot and Jingqiu Mao for their helpful discussions of isoprene chemistry. We thank Christoph Keller for his help in implementing the NEI11v1 emissions into GEOS-Chem. We acknowledge the EPA for providing the 2011 North American emission inventory and in particular George Pouliot for his help and advice. These emission inventories are intended for research purposes. A technical report describing the 2011 modeling platform can be found at https://www.epa.gov/sites/production/files/2015-10/documents/nei2011v2_tsd_14aug2015.pdf. A description of the 2011 NEI can be found at https://www.epa.gov/air-emissions-inventories/national-emissions-inventory. This work was supported by the NASA Earth Science Division and by STAR Fellowship Assistance Agreement no. 91761601-0 awarded by the US Environmental Protection Agency (EPA). It has not been formally reviewed by EPA. The views expressed in this publication are solely those of the authors. JAF acknowledges support from a University of Wollongong Vice Chancellor's Postdoctoral Fellowship. This research was undertaken with the assistance of resources provided at the NCI National Facility systems at the Australian National University through the National Computational Merit Allocation Scheme supported by the Australian Government.

Edited by: L. Ganzeveld
Reviewed by: three anonymous referees

References

Air Sciences, Inc.: 2002 Fire Emission Inventory for the WRAP Region – Phase II, Western Governors Association/Western Regional Air Partnership, Denver and Portland, 2005.

Alvarado, M. J., Logan, J. A., Mao, J., Apel, E., Riemer, D., Blake, D., Cohen, R. C., Min, K.-E., Perring, A. E., Browne, E. C., Wooldridge, P. J., Diskin, G. S., Sachse, G. W., Fuelberg, H., Sessions, W. R., Harrigan, D. L., Huey, G., Liao, J., Case-Hanks, A., Jimenez, J. L., Cubison, M. J., Vay, S. A., Weinheimer, A. J., Knapp, D. J., Montzka, D. D., Flocke, F. M., Pollack, I. B., Wennberg, P. O., Kurten, A., Crounse, J., Clair, J. M. St., Wisthaler, A., Mikoviny, T., Yantosca, R. M., Carouge, C. C., and Le Sager, P.: Nitrogen oxides and PAN in plumes from boreal fires during ARCTAS-B and their impact on ozone: an integrated analysis of aircraft and satellite observations, Atmos. Chem. Phys., 10, 9739–9760, doi:10.5194/acp-10-9739-2010, 2010.

Anderson, D. C., Loughner, C. P., Diskin, G., Weinheimer, A., Canty, T., P., Salawitch, R. J., Worden, H. M., Fried, A., Mikoviny, T., Wisthaler, A., and Dickerson, R. R.: Measured and modeled CO and NO_y in DISCOVER-AQ: An evaluation of emissions and chemistry over the eastern US, Atmos. Environ., 96, 78–87, doi:10.1016/j.atmosenv.2014.07.004, 2014.

Bates, K. H., Crounse, J. D., St Clair, J. M., Bennett, N. B., Nguyen, T. B., Seinfeld, J. H., Stoltz, B. M., and Wennberg, P. O.: Gas Phase Production and Loss of Isoprene Epoxydiols, J. Phys. Chem. A, 118, 1237–1246, doi:10.1021/Jp4107958, 2014.

ED_001650_00043175-00012

Beaver, M. R., Clair, J. M. St., Paulot, F., Spencer, K. M., Crounse, J. D., LaFranchi, B. W., Min, K. E., Pusede, S. E., Wooldridge, P. J., Schade, G. W., Park, C., Cohen, R. C., and Wennberg, P. O.: Importance of biogenic precursors to the budget of organic nitrates: observations of multifunctional organic nitrates by CIMS and TD-LIF during BEARPEX 2009, Atmos. Chem. Phys., 12, 5773–5785, doi:10.5194/acp-12-5773-2012, 2012.

Bertram, T. H., Perring, A. E., Wooldridge, P. J., Crounse, J. D., Kwan, A. J., Wennberg, P. O., Scheuer, E., Dibb, J., Avery, M., Sachse, G., Vay, S. A., Crawford, J. H., McNaughton, C. S., Clarke, A., Pickering, K. E., Fuelberg, H., Huey, G., Blake, D. R., Singh, H. B., Hall, S. R., Shetter, R. E., Fried, A., Heikes, B. G., and Cohen, R. C.: Direct Measurements of the Convective Recycling of the Upper Troposphere, Science, 315, 816–820, doi:10.1126/science.1134548, 2007.

Bey, I., Jacob, D. J., Yantosca, R. M., Logan, J. A., Field, B. D., Fiore, A. M., Li, Q. B., Liu, H. G. Y., Mickley, L. J., and Schultz, M. G.: Global modeling of tropospheric chemistry with assimilated meteorology: Model description and evaluation, J. Geophys. Res.-Atmos., 106, 23073–23095, doi:10.1029/2001jd000807, 2001.

Borders, R. A., and Birks, J. W.: High-Precision Measurements of Activation Energies over Small Temperature Intervals: Curvature in the Arrhenius Plot for the Reaction NO C O_3 > NO_2 C O_2, J. Phys. Chem. A, 86, 3295–3302, 1982.

Brioude, J., Angevine, W. M., Ahmadov, R., Kim, S.-W., Evan, S., McKeen, S. A., Hsie, E.-Y., Frost, G. J., Neuman, J. A., Pollack, I. B., Peischl, J., Ryerson, T. B., Holloway, J., Brown, S. S., Nowak, J. B., Roberts, J. M., Wofsy, S. C., Santoni, G. W., Oda, T., and Trainer, M.: Top-down estimate of surface flux in the Los Angeles Basin using a mesoscale inverse modeling technique: assessing anthropogenic emissions of CO, NO_x and CO_2 and their impacts, Atmos. Chem. Phys., 13, 3661–3677, doi:10.5194/acp-13-3661-2013, 2013.

Browne, E. C., Perring, A. E., Wooldridge, P. J., Apel, E., Hall, S. R., Huey, L. G., Mao, J., Spencer, K. M., Clair, J. M. St., Weinheimer, A. J., Wisthaler, A., and Cohen, R. C.: Global and regional effects of the photochemistry of $CH_3O_2NO_2$: evidence from ARCTAS, Atmos. Chem. Phys., 11, 4209–4219, doi:10.5194/acp-11-4209-2011, 2011.

Brown-Steiner, B., Hess, P. G., and Lin, M. Y.: On the capabilities and limitations of GCCM simulations of summertime regional air quality: A diagnostic analysis of ozone and temperature simulations in the US using CESM CAM-Chem, Atmos. Environ., 101, 134–148, doi:10.1016/j.atmosenv.2014.11.001, 2015.

Bucsela, E. J., Krotkov, N. A., Celarier, E. A., Lamsal, L. N., Swartz, W. H., Bhartia, P. K., Boersma, K. F., Veefkind, J. P., Gleason, J. F., and Pickering, K. E.: A new stratospheric and tropospheric NO_2 retrieval algorithm for nadir-viewing satellite instruments: applications to OMI, Atmos. Meas. Tech., 6, 2607–2626, doi:10.5194/amt-6-2607-2013, 2013.

Canty, T. P., Hembeck, L., Vinciguerra, T. P., Anderson, D. C., Goldberg, D. L., Carpenter, S. F., Allen, D. J., Loughner, C. P., Salawitch, R. J., and Dickerson, R. R.: Ozone and NO_x chemistry in the eastern US: evaluation of CMAQ/CB05 with satellite (OMI) data, Atmos. Chem. Phys., 15, 10965–10982, doi:10.5194/acp-15-10965-2015, 2015.

Castellanos, P. Marufu, L. T., Doddridge, B. G., Taubman, B. F., Schwab, J. J., Hains, J. C., Ehrman, S. H., and Dickerson, R. R.: Ozone, oxides of nitrogen, and carbon monoxide during pollution events over the eastern United States: An evaluation of emissions and vertical mixing, J. Geophys. Res., 116, D16307, doi:10.1029/2010JD014540, 2011.

Chen, D., Wang, Y., McElroy, M. B., He, K., Yantosca, R. M., and Le Sager, P.: Regional CO pollution and export in China simulated by the high-resolution nested-grid GEOS-Chem model, Atmos. Chem. Phys., 9, 3825–3839, doi:10.5194/acp-9-3825-2009, 2009.

Cohen, R. C., Perkins, K. K., Koch, L. C., Stimpfle, R. M., Wennberg, P. O., Hanisco, T. F., Lanzendorf, E. J., Bonne, G. P., Voss, P. B., Salawitch, R. J., Del Negro, L. A., Wilson, J. C., McElroy, C. T., and Bui, T. P.: Quantitative constraints on the atmospheric chemistry of nitrogen oxides: An analysis along chemical coordinates, J. Geophys. Res., 105, 24283–24304, 2000.

Crounse, J. D., McKinney, K. A., Kwan, A. J., and Wennberg, P. O.: Measurement of gas-phase hydroperoxides by chemical ionization mass spectrometry (CIMS), Anal. Chem., 78, 6726–6732, 2006.

Crounse, J. D., Paulot, F., Kjaergaard, H. G., and Wennberg, P. O.: Peroxy radical isomerization in the oxidation of isoprene, Phys. Chem. Chem. Phys., 13, 13607–13613, doi:10.1039/c1cp21330j, 2011.

Darmenov, A. and da Silva, A.: The Quick Fire Emissions Dataset (QFED) – Documentation of versions 2.1, 2.2 and 2.4, NASA Technical Report Series on Global Modeling and Data Assimilation, NASA TM-2013-104606, 32, 183 pp., Draft Document (12939kB), 2013.

Dibb, J. E., Talbot, R. W., Scheuer, E. M., Seid, G., Avery, M. A., and Singh, H. B.: Aerosol chemical composition in Asian continental outflow during the TRACE-P campaign: Comparison with PEM-West B, J. Geophys. Res., 108, 8815, doi:10.1029/2002jd003111, 2003.

Del Negro, L. A., Fahey, D. W., Gao, R. S., Donnelly, S. G., Keim, E. R., Neuman, J. A., Cohen, R. C., Perkins, K. K., Koch, L. C., Salawitch, R. J., Lloyd, S. A., Proffitt, M. H., Margitan, J. J., Stimpfle, R. M., Bonne, G. P., Voss, P. B., Wennberg, P. O., McElroy, C. T., Swartz, W. H., Kusterer, T. L., Anderson, D. E., Lait, L. R., and Bui, T. P.: Comparison of modeled and observed values of NO_2 and JNO_2 during the Photochemistry of Ozone Loss in the Arctic Region in Summer (POLARIS) mission, J. Geophys. Res., 104, 26687, doi:10.1029/1999jd900246, 1999.

Duncan, B. N., Prados, A. I., Lamsal, L. N., Liu, Y., Streets, D. G., Gupta, P., Hilsenrath, E., Kahn, R. A., Nielsen, J. E., Beyersdorf, A. J., Burton, S. P., Fiore, A. M., Fishman, J., Henze, D. K., Hostetler, C. A., Krotkov, N. A., Lee, P., Lin, M., Pawson, S., Pfister, G., Pickering, K. E., Pierce, R. B., Yoshida, Y., and Ziemba, L. D.: Satellite data of atmospheric pollution for U.S. air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid, Atmos. Environ., 94, 647–662, doi:10.1016/j.atmosenv.2014.05.061, 2014.

EPA: Integrated Science Assessment for Ozone and Related Photochemical Oxidants, US Environmental Protection Agency, Research Triangle Park, NC, 2013.

EPA: US Environmental Protection Agency Clean Air Markets Division Clean Air Status and Trends Network (CASTNET)

ED_001650_00043175-00013

[Hourly Ozone], available at: www.epa.gov/castnet?Date, last access: 18 March 2016.

EPA NEI (National Emissions Inventory v1): Air Pollutant Emission Trends Data, available at: http://www.epa.gov/ttn/chief/trends/index.html last access: 23 June 2015.

Finkelstein, P. L., Ellestad, T. G., Clarke, J. F., Meyers, T. P., Schwede, D. B., Hebert, E. O., and Neal, J. A.: Ozone and sulfur dioxide dry deposition to forests: Observations and model evaluation, J. Geophys. Res.-Atmos., 105, 15365–15377, doi:10.1029/2000jd900185, 2000.

Fiore, A. M., Jacob, D. J., Liu, H., Yantosca, R. M., Fairlie, T. D., and Li, Q.: Variability in surface ozone background over the United States: Implications for air quality policy, J. Geophys. Res.-Atmos., 108, 4787, doi:10.1029/2003jd003855, 2003.

Fiore, A. M., Horowitz, L. W., Purves, D. W., Levy, H., Evans, M. J., Wang, Y., Li, Q., and Yantosca, R.: Evaluating the contribution of changes in isoprene emissions to surface ozone trends over the eastern United States, J. Geophys. Res., 110, D12303, doi:10.1029/2004jd005485, 2005.

Fiore, A. M., Dentener, F. J., Wild, O., Cuvelier, C., Schultz, M. G., Hess, P., Textor, C., Schulz, M., Doherty, R. M., Horowitz, L. W., MacKenzie, I. A., Sanderson, M. G., Shindell, D. T., Stevenson, D. S., Szopa, S., Van Dingenen, R., Zeng, G., Atherton, C., Bergmann, D., Bey, I., Carmichael, G., Collins, W. J., Duncan, B. N., Faluvegi, G., Folberth, G., Gauss, M., Gong, S., Hauglustaine, D., Holloway, T., Isaksen, I. S. A., Jacob, D. J., Jonson, J. E., Kaminski, J. W., Keating, T. J., Lupu, A., Marmer, E., Montanaro, V., Park, R. J., Pitari, G., Pringle, K. J., Pyle, J. A., Schroeder, S., Vivanco, M. G., Wind, P., Wojcik, G., Wu, S., and Zuber, A.: Multimodel estimates of intercontinental source-receptor relationships for ozone pollution, J. Geophys. Res., 114, D04301, doi:10.1029/2008jd010816, 2009.

Fischer, E. V., Jacob, D. J., Yantosca, R. M., Sulprizio, M. P., Millet, D. B., Mao, J., Paulot, F., Singh, H. B., Roiger, A., Ries, L., Talbot, R. W., Dzepina, K., and Pandey Deolal, S.: Atmospheric peroxyacetyl nitrate (PAN): a global budget and source attribution, Atmos. Chem. Phys., 14, 2679–2698, doi:10.5194/acp-14-2679-2014, 2014.

Fisher, J. A., Jacob, D. J., Travis, K. R., Kim, P. S., Marais, E. A., Chan Miller, C., Yu, K., Zhu, L., Yantosca, R. M., Sulprizio, M. P., Mao, J., Wennberg, P. O., Crounse, J. D., Teng, A. P., Nguyen, T. B., St. Clair, J. M., Cohen, R. C., Romer, P., Nault, B. A., Wooldridge, P. J., Jimenez, J. L., Campuzano-Jost, P., Day, D. A., Hu, W., Shepson, P. B., Xiong, F., Blake, D. R., Goldstein, A. H., Misztal, P. K., Hanisco, T. F., Wolfe, G. M., Ryerson, T. B., Wisthaler, A., and Mikoviny, T.: Organic nitrate chemistry and its implications for nitrogen budgets in an isoprene- and monoterpene-rich atmosphere: constraints from aircraft (SEAC^{4}RS) and ground-based (SOAS) observations in the Southeast US, Atmos. Chem. Phys., 16, 5969–5991, doi:10.5194/acp-16-5969-2016, 2016.

Fujita, E. M., Campbell, D. E., Zielinska, B., Chow, J. C., Lindhjem, C. E., DenBleyker, A., Bishop, G. A., Schuchmann, B. G., Stedman, D. H., and Lawson, D. R.: Comparison of the MOVES2010a, MOBILE6.2, and EMFAC2007 mobile source emission models with on-road traffic tunnel and remote sensing measurements, J. Air Waste Manage., 62, 1134–1149, doi:10.1080/10962247.2012.699016, 2012.

Holtslag, A. and Boville, B.: Local versus nonlocal boundary-layer diffusion in a global climate model, J. Climate, 6, 1825–1842, 1993.

Horowitz, L. W., Fiore, A. M., Milly, G. P., Cohen, R. C., Perring, A., Wooldridge, P. J., Hess, P. G., Emmons, L. K., and Lamarque, J. F.: Observational constraints on the chemistry of isoprene nitrates over the eastern United States, J. Geophys. Res.-Atmos., 112, D12S08, doi:10.1029/2006jd007747, 2007.

Hudman, R. C., Jacob, D. J., Turquety, S., Leibensperger, E. M., Murray, L. T., Wu, S., Gilliland, A. B., Avery, M., Bertram, T. H., Brune, W., Cohen, R. C., Dibb, J. E., Flocke, F. M., Fried, A., Holloway, J., Neuman, J. A., Orville, R., Perring, A., Ren, X., Sachse, G. W., Singh, H. B., Swanson, A., and Wooldridge, P. J.: Surface and lightning sources of nitrogen oxides over the United States: Magnitudes, chemical evolution, and outflow, J. Geophys. Res., 112, D12S05, doi:10.1029/2006jd007912, 2007.

Hudman, R. C., Moore, N. E., Mebust, A. K., Martin, R. V., Russell, A. R., Valin, L. C., and Cohen, R. C.: Steps towards a mechanistic model of global soil nitric oxide emissions: implementation and space based-constraints, Atmos. Chem. Phys., 12, 7779–7795, doi:10.5194/acp-12-7779-2012, 2012.

Huntrieser, H., Schlager, H., Roiger, A., Lichtenstern, M., Schumann, U., Kurz, C., Brunner, D., Schwierz, C., Richter, A., and Stohl, A.: Lightning-produced NO_x over Brazil during TROCCINOX: airborne measurements in tropical and subtropical thunderstorms and the importance of mesoscale convective systems, Atmos. Chem. Phys., 7, 2987–3013, doi:10.5194/acp-7-2987-2007, 2007.

Huntrieser, H., Schumann, U., Schlager, H., Höller, H., Giez, A., Betz, H.-D., Brunner, D., Forster, C., Pinto Jr., O., and Calheiros, R.: Lightning activity in Brazilian thunderstorms during TROCCINOX: implications for NO_x production, Atmos. Chem. Phys., 8, 921–953, doi:10.5194/acp-8-921-2008, 2008.

Jaeglé, L., Jacob, D. J., Wennberg, P. O., Spivakovsky, C. M., Hanisco, T. F., Lanzendorf, E. L., Hintsa, E. J., Fahey, D. W., Keim, E. R., Proffitt, M. H., Atlas, E., Flocke, F., Schauffler, S., McElroy, C. T., Midwinter, C., Pfister, L., and Wilson, J. C.: Observed OH and HO_2 in the upper troposphere suggest a major source from convective injection of peroxides, Geophys. Res. Lett., 24, 3181–3184, 1997.

Jaeglé, L., Jacob, D. J., Wang, Y., Weinheimer, A. J. Ridley, B. A., Campos, T. L., Sachse, G. W., and Hagen, D. E.: Sources and chemistry of NO_x in the upper troposphere over the United States, Geophys. Res. Lett., 25, 1705–1708, 1998.

Kim, P. S., Jacob, D. J., Fisher, J. A., Travis, K., Yu, K., Zhu, L., Yantosca, R. M., Sulprizio, M. P., Jimenez, J. L., Campuzano-Jost, P., Froyd, K. D., Liao, J., Hair, J. W., Fenn, M. A., Butler, C. F., Wagner, N. L., Gordon, T. D., Welti, A., Wennberg, P. O., Crounse, J. D., St. Clair, J. M., Teng, A. P., Millet, D. B., Schwarz, J. P., Markovic, M. Z., and Perring, A. E.: Sources, seasonality, and trends of southeast US aerosol: an integrated analysis of surface, aircraft, and satellite observations with the GEOS-Chem chemical transport model, Atmos. Chem. Phys., 15, 10411–10433, doi:10.5194/acp-15-10411-2015, 2015.

Lamsal, L. N., Krotkov, N. A., Celarier, E. A., Swartz, W. H., Pickering, K. E., Bucsela, E. J., Gleason, J. F., Martin, R. V., Philip, S., Irie, H., Cede, A., Herman, J., Weinheimer, A., Szykman, J. J., and Knepp, T. N.: Evaluation of OMI operational standard NO_2 column retrievals using in situ and surface-based NO_2 observa-

ED_001650_00043175-00014

tions, Atmos. Chem. Phys., 14, 11587–11609, doi:10.5194/acp-14-11587-2014, 2014.

Li, Q., Jacob, D. J., Park, R., Wang, Y. Heald, C. L., Hudman, R., and Yantosca, R. M.: North American pollution outflow and the trapping of convectively lifted pollution by upper-level anticyclone, J. Geophys. Res., 110, D10301, doi:10.1029/2004JD005039, 2005.

Li, X., Rohrer, F., Hofzumahaus, A., Brauers, T., Haseler, R., Bohn, B., Broch, S., Fuchs, H., Gomm, S., Holland, F., Jager, J., Kaiser, J., Keutsch, F. N., Lohse, I., Lu, K., Tillmann, R., Wegener, R., Wolfe, G. M., Mentel, T. F., Kiendler-Scharr, A., and Wahner, A.: Missing gas-phase source of HONO inferred from Zeppelin measurements in the troposphere, Science, 344, 292–296, doi:10.1126/science.1248999, 2014.

Lin, J., Youn, D., Liang, X., and Wuebbles, D.: Global model simulation of summertime U.S. ozone diurnal cycle and its sensitivity to PBL mixing, spatial resolution, and emissions, Atmos. Environ., 42, 8470–8483, doi:10.1016/j.atmosenv.2008.08.012, 2008.

Lin, J.-T. and McElroy, M. B.: Impacts of boundary layer mixing on pollutant vertical profiles in the lower troposphere: Implications to satellite remote sensing, Atmos. Environ., 44, 1726–1739, doi:10.1016/j.atmosenv.2010.02.009, 2010.

Liu, S. C., Trainer, M., Fehsenfeld, F. C., Parrish, D. D., Williams, E. J., Fahey, D. W., Hubler, G., and Murphy, P. C.: Ozone Production in the Rural Troposphere and the Implications for Regional and Global Ozone Distributions, J. Geophys. Res., 92, 4191–4207, 1987.

Liu, Y. J., Herdlinger-Blatt, I., McKinney, K. A., and Martin, S. T.: Production of methyl vinyl ketone and methacrolein via the hydroperoxyl pathway of isoprene oxidation, Atmos. Chem. Phys., 13, 5715–5730, doi:10.5194/acp-13-5715-2013, 2013.

Lu, Z., Streets, D. G., de Foy, B., Lamsal, L. N., Duncan, B. N., and Xing, J.: Emissions of nitrogen oxides from US urban areas: estimation from Ozone Monitoring Instrument retrievals for 2005–2014, Atmos. Chem. Phys., 15, 10367–10383, doi:10.5194/acp-15-10367-2015, 2015.

Mao, J., Jacob, D. J., Evans, M. J., Olson, J. R., Ren, X., Brune, W. H., Clair, J. M. St., Crounse, J. D., Spencer, K. M., Beaver, M. R., Wennberg, P. O., Cubison, M. J., Jimenez, J. L., Fried, A., Weibring, P., Walega, J. G., Hall, S. R., Weinheimer, A. J., Cohen, R. C., Chen, G., Crawford, J. H., McNaughton, C., Clarke, A. D., Jaeglé, L., Fisher, J. A., Yantosca, R. M., Le Sager, P., and Carouge, C.: Chemistry of hydrogen oxide radicals (HO_x) in the Arctic troposphere in spring, Atmos. Chem. Phys., 10, 5823–5838, doi:10.5194/acp-10-5823-2010, 2010.

Mao, J., Paulot, F., Jacob, D. J., Cohen, R. C., Crounse, J. D., Wennberg, P. O., Keller, C. A., Hudman, R. C., Barkley, M. P., and Horowitz, L. W.: Ozone and organic nitrates over the eastern United States: Sensitivity to isoprene chemistry, J. Geophys. Res.-Atmos., 118, 11256–11268, doi:10.1002/jgrd.50817, 2013.

Marais, E. A., Jacob, D. J., Jimenez, J. L., Campuzano-Jost, P., Day, D. A., Hu, W., Krechmer, J., Zhu, L., Kim, P. S., Miller, C. C., Fisher, J. A., Travis, K., Yu, K., Hanisco, T. F., Wolfe, G. M., Arkinson, H. L., Pye, H. O. T., Froyd, K. D., Liao, J., and McNeill, V. F.: Aqueous-phase mechanism for secondary organic aerosol formation from isoprene: application to the southeast United States and co-benefit of SO_2 emission controls, Atmos. Chem. Phys., 16, 1603–1618, doi:10.5194/acp-16-1603-2016, 2016.

Martin, R. V., Chance, K., Jacob, D. J., Kurosu, T. P., Spurr, R. J. D., Bucsela, E., Gleason, J. F., Palmer, P. I., Bey, I., Fiore, A. M., Li, Q., Yantosca, R. M., and Koelemeijer, R. B. A.: An improved retrieval of tropospheric nitrogen dioxide from GOME, J. Geophys. Res., 107, 4437, doi:10.1029/2001jd001027, 2002.

McDonald-Buller, E. C., Allen, D. T., Brown, N., Jacob, D. J., Jaffe, D., Kolb, C. E., Lefohn, A. S., Oltmans, S., Parrish, D. D., Yarwood, G., and Zhang, L.: Establishing policy relevant background (PRB) ozone concentrations in the United States, Enviriron. Sci. Technol., 45, 9484–9497, doi:10.1021/es2022818, 2011.

Mena-Carrasco, M., Tang, Y., Carmichael, G. R., Chai, T., Thongbongchoo, N., Campbell, J. E., Kulkarni, S., Horowitz, L., Vukovich, J., Avery, M., Brune, W., Dibb, J. E., Emmons, L., Flocke, F., Sachse, G. W., Tan, D., Shetter, R., Talbot, R. W., Streets, D. G., Frost, G., and Blake, D.: Improving regional ozone modeling through systematic evaluation of errors using the aircraft observations during the International Consortium for Atmospheric Research on Transport and Transformation, J. Geophys. Res., 112, D12S19, doi:10.1029/2006jd007762, 2007.

Müller, J. F. and Brasseur, G.: Sources of upper tropospheric HO_x: A three-dimensional study, J. Geophs. Res., 104, 1705–1715, 1999.

Murray, L. T., Jacob, D. J., Logan, J. A., Hudman, R. C., and Koshak, W. J.: Optimized regional and interannual variability of lightning in a global chemical transport model constrained by LIS/OTD satellite data, J. Geophys. Res., 117, D20307, doi:10.1029/2012jd017934, 2012.

NADP: National Atmospheric Deposition Program (NRSP-3) in: Illinois State Water Survey, Office, N. P., 2204 Griffith Dr., Champaign, IL 61820, 2007.

NASA, U. G.: OMI/Aura Level 2 Nitrogen Dioxide (NO_2/ Trace Gas Column Data 1-Orbit subset Swath along CloudSat track 1-Orbit Swath 13 ffi 24km, version 003, Center, N. G. S. F., 2012.

Nault, B. A., Garland, C., Pusede, S. E., Wooldridge, P. J., Ullmann, K., Hall, S. R., and Cohen, R. C.: Measurements of $CH_3O_2NO_2$ in the upper troposphere, Atmos. Meas. Tech., 8, 987–997, doi:10.5194/amt-8-987-2015, 2015.

Nguyen, T. B., Crounse, J. D., Teng, A. P., St Clair, J. M., Paulot, F., Wolfe, G. M., and Wennberg, P. O.: Rapid deposition of oxidized biogenic compounds to a temperate forest, P. Natl. Acad. Sci USA, 112, 392–401, doi:10.1073/pnas.1418702112, 2015.

Ott, L. E., Pickering, K. E., Stenchikov, G. L., Allen, D. J., DeCaria, A. J., Ridley, B., Lin, R.-F., Lang, S., and Tao, W.-K.: Production of lightning NO_x and its vertical distribution calculated from three-dimensional cloud-scale chemical transport model simulations, J. Geophys. Res., 115, D04301, doi:10.1029/2009jd011880, 2010.

Palmer, P. I., Jacob, D. J., Chance, K., Martin, R. V., Spurr, R. J. D., Kurosu, T. P., Bey, I., Yantosca, R., Fiore, A., and Li, Q.: Air mass factor formulation for spectroscopic measurements from satellites: Application to formaldehyde retrievals from the Global Ozone Monitoring Experiment, J. Geophys. Res., 106, 14539, doi:10.1029/2000jd900772, 2001.

Paulot, F., Crounse, J. D., Kjaergaard, H. G., Kroll, J. H., Seinfeld, J. H., and Wennberg, P. O.: Isoprene photooxidation: new insights into the production of acids and organic nitrates, Atmos. Chem. Phys., 9, 1479–1501, doi:10.5194/acp-9-1479-2009, 2009a.

ED_001650_00043175-00015

Paulot, F., Crounse, J. D., Kjaergaard, H. G., Kurten, A., St Clair, J. M., Seinfeld, J. H., and Wennberg, P. O.: Unexpected Epoxide Formation in the Gas-Phase Photooxidation of Isoprene, Science, 325, 730–733, doi:10.1126/Science.1172910, 2009b.

Paulot, F., Jacob, D. J., Pinder, R. W., Bash, J. O., Travis, K., and Henze, D. K.: Ammonia emissions in the United States, European Union, and China derived by high-resolution inversion of ammonium wet deposition data: Interpretation with a new agricultural emissions inventory (MASAGE_NH_3), J. Geophys. Res.-Atmos., 119, 4343–4364, doi:10.1002/2013jd021130, 2014.

Peeters, J. and Müller, J. F.: HO(x) radical regeneration in isoprene oxidation via peroxy radical isomerisations. II: experimental evidence and global impact, Phys. Chem. Chem. Phys., 12, 14227–14235, doi:10.1039/c0cp00811g, 2010.

Peeters, J., Nguyen, T. L., and Vereecken, L.: HO_x radical regeneration in the oxidation of isoprene, Phys. Chem. Chem. Phys., 11, 5935–5939, doi:10.1039/b908511d, 2009.

Peeters, J., Müller, J. F., Stavrakou, T., and Nguyen, V. S.: Hydroxyl radical recycling in isoprene oxidation driven by hydrogen bonding and hydrogen tunneling: the upgraded LIM1 mechanism, J. Phys. Chem. A, 118, 8625–8643, doi:10.1021/jp5033146, 2014.

Pollack, I. B., Lerner, B. M., and Ryerson, T. B.: Evaluation of ultraviolet light-emitting diodes for detection of atmospheric NO_2 by photolysis – chemilumenescence, J. Atmos. Chem., 65, 111–125, doi:10.1007/s10874-011-9184-3, 2010.

Prather, M. J. and Jacob, D. J.: A persistent imbalance in HO_x and NO_x photochemistry of the upper troposphere driven by deep tropical convection, Geophys. Res. Lett., 24, 3189–3192, 1997.

Reed, C., Evans, M. J., Di Carlo, P., Lee, J. D., and Carpenter, L. J.: Interferences in photolytic NO_2 measurements: explanation for an apparent missing oxidant?, Atmos. Chem. Phys., 16, 4707–4724, doi:10.5194/acp-16-4707-2016, 2016.

Reidmiller, D. R., Fiore, A. M., Jaffe, D. A., Bergmann, D., Cuvelier, C., Dentener, F. J., Duncan, B. N., Folberth, G., Gauss, M., Gong, S., Hess, P., Jonson, J. E., Keating, T., Lupu, A., Marmer, E., Park, R., Schultz, M. G., Shindell, D. T., Szopa, S., Vivanco, M. G., Wild, O., and Zuber, A.: The influence of foreign vs. North American emissions on surface ozone in the US, Atmos. Chem. Phys., 9, 5027–5042, doi:10.5194/acp-9-5027-2009, 2009.

Rickard, A. R., Salisbury, G., Monks, P. S., Lewis, A. C., Baugitte, S., Bandy, B. J., Clemitshaw, K. C., and Penkett, S. A.: Comparison of Measured Ozone Production Efficiencies in the Marine Boundary Layer at Two European Coastal Sites under Different Pollution Regimes, J. Atmos. Chem., 43, 107–134, 2002.

Russell, A. R., Perring, A. E., Valin, L. C., Bucsela, E. J., Browne, E. C., Wooldridge, P. J., and Cohen, R. C.: A high spatial resolution retrieval of NO_2 column densities from OMI: method and evaluation, Atmos. Chem. Phys., 11, 8543–8554, doi:10.5194/acp-11-8543-2011, 2011.

Ryerson, T. B., Buhr, M. P., Frost, G. J., Goldan, P. D., Holloway, J. S., Hübler, G., Jobson, B. T., Kuster, W. C., McKeen, S. A., Parrish, D. D., Roberts, J. M., Sueper, D. T., Trainer, M., Williams, J., and Fehsenfeld, F. C.: Emissions lifetimes and ozone formation in power plant plumes, J. Geophys. Res., 103, 22569–22583, 1998.

Ryerson, T. B., Williams, E. J., and Fehsenfeld, F. C.: An efficient photolysis system for fast-response NO_2 measurements, J. Geophys. Res., 105, 26447, doi:10.1029/2000jd900389, 2000.

Sander, S. P., Abbatt, J., Barker, J. R., Burkholder, J. B., Friedl, R. R., Golden, D. M., Huie, R. E., Kolb, C. E., Kurylo, M. J., Moortgat, G. K., Orkin, V. L., and Wine, P. H.: Chemical Kinetics and Photochemical Data for Use in Atmospheric Studies, Evaluation No. 17, JPL Publication 10-6, Jet Propulsion Laboratory, Pasadena, 2011.

Schultz, M. G., Jacob, D. J., Wang, Y., Logan, J. A., Atlas, E. L., Blake, D. R., Blake, N. J., Bradshaw, J. D., Browell, E. V., Fenn, M. A., Flocke, F., Gregory, G. L., Heikes, B. G., Sachse, G. W., Sandholm, S. T., Shetter, R. E., Singh, H. B., and Talbot, R. W.: On the origin of tropospheric ozone and NO_x over the tropical South Pacific, J. Geophys. Res., 104, 5829, doi:10.1029/98jd02309, 1999.

Shetter, R. E. and Muller, M.: Photolysis frequency measurements using actinic flux spectroradiometry during the PEM-Tropics mission: Instrumentation description and some results, J. Geophys. Res., 104, 5647–5661, doi:10.1029/98JD01381, 1999.

Singh, H. B., Brune, W. H., Crawford, J. H., Jacob, D. J., and Russell, P. B.: Overview of the summer 2004 Intercontinental Chemical Transport Experiment–North America (INTEX-A), J. Geophys. Res., 111, doi:10.1029/2006jd007905, 2006.

Squire, O. J., Archibald, A. T., Griffiths, P. T., Jenkin, M. E., Smith, D., and Pyle, J. A.: Influence of isoprene chemical mechanism on modelled changes in tropospheric ozone due to climate and land use over the 21st century, Atmos. Chem. Phys., 15, 5123–5143, doi:10.5194/acp-15-5123-2015, 2015.

St. Clair, J. M., McCabe, D. C., Crounse, J. D., Steiner, U., and Wennberg, P. O.: Chemical ionization tandem mass spectrometer for the in situ measurement of methyl hydrogen peroxide, Rev. Sci. Instrum., 81, 094102, doi:10.1063/1.3480552, 2010.

St. Clair, J. M., Rivera-Rios, J. C., Crounse, J. D., Knap, H. C., Bates, K. H., Teng, A. P., Jorgensen, S., Kjaergaard, H. G., Keutsch, F. N., and Wennberg, P. O.: Kinetics and Products of the Reaction of the First-Generation Isoprene Hydroxy Hydroperoxide (ISOPOOH) with OH, J. Phys. Chem. A, 120, 1441–1451, doi:10.1021/acs.jpca.5b06532, 2015.

Stavrakou, T., Peeters, J., and Müller, J.-F.: Improved global modelling of HO_x recycling in isoprene oxidation: evaluation against the GABRIEL and INTEX-A aircraft campaign measurements, Atmos. Chem. Phys., 10, 9863–9878, doi:10.5194/acp-10-9863-2010, 2010.

Toon, O. B., Maring, H., Dibb, J., Ferrare, R., Jacob, D. J., Jensen, E. J., Luo, Z. J., Mace, G. G., Pan, L. L., Pfister, L., and Rosenlof, K. H.: Planning, implementation, and scientific goals of the Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys ($SEAC^4RS$) field mission, J. Geophys. Res.-Atmos., 121, 4967–5009, doi:10.1002/2015JD024297, 2016.

Trainer, M., Parrish, D. D., Buhr, M. P., Norton, R. B., Fehsenfeld, F. C., Anlauf, K. G., Bottenheim, J. W., Tang, Y. Z., Wiebe, H. A., Roberts, J. M., Tanner, R. L., Newman, L., Bowersox, C., Meagher, J. F., Olszyna, K. J., Rodgers, M. O., Wang, T., Berresheim, H., Demerjian, K. L., and Roychowdhury, U. K.: Correlation of ozone with NO_y in photochemically aged air, J. Geophys. Res., 98, 2917–2925, 1993.

ED_001650_00043175-00016

Trainer, M., Parrish, D. D., Goldan, P. D., Roberts, J., and Fehsenfeld, F. C.: Review of observation-based analysis of the regional factors influencing ozone concentrations, Atmos. Environ., 34, 2045–2061, 2000.

Vinken, G. C. M., Boersma, K. F., Maasakkers, J. D., Adon, M., and Martin, R. V.: Worldwide biogenic soil NO_x emissions inferred from OMI NO_2 observations, Atmos. Chem. Phys., 14, 10363–10381, doi:10.5194/acp-14-10363-2014, 2014.

Walker, T. W.: Applications of Adjoint Modeling in Chemical Composition: Studies of Tropospheric Ozone at Middle and High Northern Latitudes, Graduate Department of Physics, University of Toronto, 2014.

Wang, Y., Jacob, D. J., and Logan, J. A.: Global simulation of tropospheric O_3-NO_x-hydrocarbon chemistry, 1. Model formulation, J. Geophys. Res., 103, 10727–10755, 1998.

Wesely, M. L.: Parameterization of Surface Resistances to Gaseous Dry Deposition in Regional-Scale Numerical-Models, Atmos. Environ., 23, 1293–1304, doi:10.1016/0004-6981(89)90153-4, 1989.

Wolfe, G. M., Crounse, J. D., Parrish, J. D., St Clair, J. M., Beaver, M. R., Paulot, F., Yoon, T. P., Wennberg, P. O., and Keutsch, F. N.: Photolysis, OH reactivity and ozone reactivity of a proxy for isoprene-derived hydroperoxyenals (HPALDs), Phys. Chem. Chem. Phys., 14, 7276–7286, doi:10.1039/c2cp40388a, 2012.

Wolfe, G. M., Hanisco, T. F., Arkinson, H. L., Bui, T. P., Crounse, J. D., Dean-Day, J., Goldstein, A., Guenther, A., Hall, S. R., Huey, G., Jacob, D. J., Karl, T., Kim, P. S., Liu, X., Marvin, M. R., Mikoviny, T., Misztal, P. K., Nguyen, T. B., Peischl, J., Pollack, I., Ryerson, T., St. Clair, J. M., Teng, A., Travis, K. R., Ullman, K., Wennberg, P. O., and Wisthaler, A.: Quantifying Sources and Sinks of Reactive Gases in the Lower Atmosphere using Airborne Flux Observations, Geophys. Res. Lett., 42, 8231–8240, doi:10.1002/2015GL065839, 2015.

Xie, Y., Paulot, F., Carter, W. P. L., Nolte, C. G., Luecken, D. J., Hutzell, W. T., Wennberg, P. O., Cohen, R. C., and Pinder, R. W.: Understanding the impact of recent advances in isoprene photooxidation on simulations of regional air quality, Atmos. Chem. Phys., 13, 8439–8455, doi:10.5194/acp-13-8439-2013, 2013.

Yu, K., Jacob, D. J., Fisher, J. A., Kim, P. S., Marais, E. A., Miller, C. C., Travis, K. R., Zhu, L., Yantosca, R. M., Sulprizio, M. P., Cohen, R. C., Dibb, J. E., Fried, A., Mikoviny, T., Ryerson, T. B., Wennberg, P. O., and Wisthaler, A.: Sensitivity to grid resolution in the ability of a chemical transport model to simulate observed oxidant chemistry under high-isoprene conditions, Atmos. Chem. Phys., 16, 4369–4378, doi:10.5194/acp-16-4369-2016, 2016.

Zaveri, R. A.: Ozone production efficiency and NO_x depletion in an urban plume: Interpretation of field observations and implications for evaluating O_3-NO_x-VOC sensitivity, J. Geophys. Res., 108, 4436, doi:10.1029/2002jd003144, 2003.

Zhang, L., Jacob, D. J., Yue, X., Downey, N. V., Wood, D. A., and Blewitt, D.: Sources contributing to background surface ozone in the US Intermountain West, Atmos. Chem. Phys., 14, 5295–5309, doi:10.5194/acp-14-5295-2014, 2014.

Zhou, X., Ye, C., Pu, D., Stutz, J., Festa, J., Spolaor, M., Weinheimer, A. J., Campos, T. L., Haggerty, J. A., Cantrell, C. A., Mauldin, L., Guenther, A. B., Hornbrook, R. S., Apel, E. C., and Jensen, J. B.: Tropospheric HONO Distribution and Chemistry in the Southeastern US, American Geophysical Union, Fall Meeting 2014, abstract #A31J-08, 2014.

Zhu, L., Jacob, D. J., Kim, P. S., Fisher, J. A., Yu, K., Travis, K. R., Mickley, L. J., Yantosca, R. M., Sulprizio, M. P., De Smedt, I., Gonzalez Abad, G., Chance, K., Li, C., Ferrare, R., Fried, A., Hair, J. W., Hanisco, T. F., Richter, D., Scarino, A. J., Walega, J., Weibring, P., and Wolfe, G. M.: Observing atmospheric formaldehyde (HCHO) from space: validation and intercomparison of six retrievals from four satellites (OMI, GOME2A, GOME2B, OMPS) with SEAC^{4}RS aircraft observations over the Southeast US, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-162, in review, 2016.

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From: Joseph Jakuta
Sent: Fri 8/4/2017 3:52:21 PM
Subject: Reminder: OTC Modeling Committee BenMap Feedback by 8/4
BenMap Rollback Analysis 170613.docx

Dear OTC Modeling Committee,

This is a reminder that feedback on the BenMap is due 8/4.

Joseph Jakuta

Program Manager

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Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

June 13, 2017

Prepared by Ozone Transport Commission

Executive Summary

In 2008, the 8-hour ozone national ambient air quality standard (NAAQS) was lowered to 70 ppb. This paper uses tool developed by EPA, BenMAP, to look at what the health benefits would have been had the region in its entirety had met this standard in each year since the standard was in place.

To conduct the analysis, 2013-2016 ozone season monitored ozone levels within the OTR were used as were health benefits and economic functions that came from peer reviewed sources employed in many of EPA's studies.

We found that approximately 500 persons would have not died prematurely during the period from 2013-2016 had the OTR air quality held a level that met the 70 ppb Ozone NAAQS. There would have been an approximate economic benefit to the region of $4 billion from that reduced mortality. Benefits were also found in reduced hospital visits, asthma exacerbations, and lost educational productivity.

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Analysis of the Potential Health Impacts of Reducing Ozone Levels in the OTR Using BenMAP

Introduction

In 2015, the 8-hour ozone National Ambient Air Quality Standard (NAAQS) was lowered to 70 ppb.[1] This was the high end of the range recommended by the Clean Air Scientific Advisory Committee (CASAC) originally and Administrator McCarthy in the rule proposal. The lower end of the range proposed by EPA was 65 ppb. Additionally, recent research has shown health effects form ozone occur at even lower levels. As a result we looked at three levels of ozone in this analysis 70 ppb, 65 ppb, and 40 ppb.

Each year that air quality does not meet the NAAQS the health of the populations exposed to the poor air quality are impacted. As a result the analysis will focus on each ozone season for which data is available, 2013-2016.

Several states in the Ozone Transport Region (OTR) had monitored design values that were above the standard set by EPA. Given that the primary NAAQS are set to a level to adequately protect the public health, this implies that populations in the OTR would receive a health benefit if the entire OTR were to meet the NAAQS. This paper looks at the benefits that would have occurred each year from 2013-2016 had the entire OTR met the 2015 NAAQS as estimated the Environmental Benefits Mapping and Analysis Program (BenMAP) Community Edition (CE) program.[2]

Methods

Overview of the Health Impact Functions

BenMAP CE v1.3.52 was employed to process the health impact functions. These functions are developed to calculate the change in health incidence for a given population due to a change in air quality. The health impact functions typically consist of four variables: change in air quality, population, baseline incidence rate, and effect estimates that are drawn from epidemiological literature. The health impact functions used in the analysis were all functions provided in the downloadable version of BenMAP CE. The typical health impact function (Δy) is log-linear as follows:

$$\Delta y = y_0(e^{\beta \Delta q}-1)pop$$

where y_0 is the baseline incidence rate, β is the effect estimate, Δq is the change in air quality, and pop is the population.

[1] US EPA, "2015 National Ambient Air Quality Standards for Ozone."

[2] US EPA, "Environmental Benefits Mapping and Analysis Program – Community Edition: User's Manual."

Change in Air Quality

Monitored ozone data were obtained throughout the entire OTR and the states that border the region (Ohio, West Virginia, and the remainder of Virginia) for 2013-2016 from the Air Quality System monitor network and the data was originally compiled by staff at the Maine Department of Environmental Protection. The Voronoi Neighborhood Averaging (VNA) inverse distance interpolation squared technique was used to interpolate to grid cells between monitors. The bordering states were included so that the VNA would not result in inappropriate values along the western and southern borders of the OTR. Data was not available from Canada to prevent this from occurring along the northern border, but exceedances are less common in that region so the monitors would not be rolled back anyway.

Annual ozone season data was imported, but in many cases monitors only are operated during a shorter time period when conditions are conducive to ozone formation as defined in federal regulations (see Table 1). Furthermore, BenMap requires a certain thresholds to be met for the data at a particular monitored to be considered acceptable. The default values were considered too stringent since several monitors with 4th high 8-hour ozone values above 70 ppb would be excluded so they were altered to . 4th high ozone data for each year can be seen in .

Table 1: Ozone Monitoring Season Requirements (40 CFR 58 Appendix D (4)(i))

State	Start Date	End Date
Connecticut	March 1	September 30
Delaware	March 1	October 31
District of Columbia	March 1	October 31
Maine	April 1	September 30
Maryland	March 1	October 31
Massachusetts	March 1	September 30
New Hampshire	March 1	September 30
New Jersey	March 1	October 31
New York	March 1	October 31
Pennsylvania	March 1	October 31
Rhode Island	March 1	September 30
Vermont	April 1	September 30
Virginia	March 1	October 31

Following import of each year's monitored ozone data, BenMAP CE was employed to conduct an analysis termed "roll back." In this approach a mathematical technique is used to lower the monitors so that each meets a threshold, in these cases a 4th highest daily maximum 8-hour ozone average concentration of 70 ppb, 65 ppb, or 40 ppb. Technically the NAAQS is the average of 3 years of the 4th highest daily maximum 8-hour ozone averages. This is necessary since BenMAP CE only accepts one year worth of air quality data in an analysis. After rolling back, the monitor data was then interpolated geographically using an inverse distance weighting technique.

There are three techniques for rolling back the monitored values to the standard: percentage reduction, incremental, and peak shaving that need to be applied to the inter-day and intra-day rollback. The peak shaving technique was employed for the inter-day rollback so values meeting the standard would not have reductions applied, which would result in more conservative results. The percentage technique was employed for the intra-day rollback since it best reflected the implementation of measures that would affect each hour of the day equally.

In conducting the analysis, including a background rate was necessary to prevent monitors from being lowered below what would occur absent anthropogenic emissions. There are a variety of estimates for background, and even several values considered background (e.g., United States Background (USB) and North American Background (NAB). For this aspect of the modeling we used a value of 30 ppb which is associated with lower levels of NAB found in the Eastern United States in the summer time as was presented in Figure 3-9 of EPA's Integrated Scientific Assessment for the 2015 Ozone NAAQS.[3] Peak shaving was used as the inter-day rollback method and percentage reduction was used as the intra-day rollback method. In both cases 30 ppb was used for the background level.

One potential flaw with the rollback approach is that only monitors that have 4th highest values above 70 ppb were rolled back to the standard. However, in a case where controls are put on to achieve such a monitored level, downwind areas would also have reduced ozone concentrations even though their monitors are already below the standard. As a result, the health effects downwind, in New England in particular, are lower than what would be experienced in a real world scenario.

Population

US population data were based on estimates of populations in the corresponding year projected from 2010 block-level US Census data. The geographic extent of population was limited to the population that lives in the 12 full states in the OTR, the District of Columbia and

[3] Lin Zhang et al., "Improved Estimate of the Policy-Relevant Background Ozone in the United States Using the GEOS-Chem Global Model with 1/2° × 2/3°Horizontal Resolution over North America"; US EPA, *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*.

the nine cities/counties in Virginia that are considered part of the region. The total population used for each year is in Table 2.

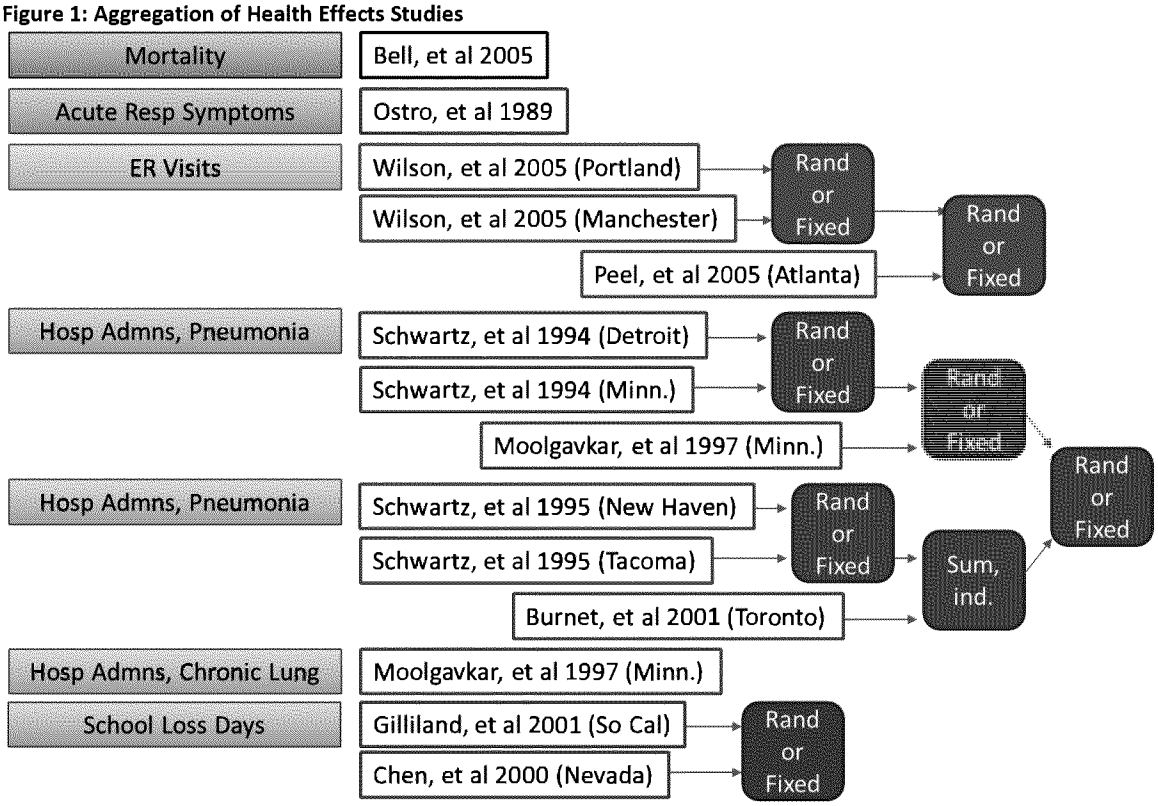
Table 2: Population by Year Analyzed

Year	2013	2014	2015	2016
Population	66,403,000	66,610,000	66,928,000	67,301,000

Selection of Health Impact Functions

There is evidence of a relationship between long-term exposure to concentrations of ozone and premature respiratory mortality, which is one of a few studies that detect an increase in mortality from long-term ozone exposure.[4] However there remain questions as to whether the effects found in the long-term do indeed exist since this is a newer development, so this paper will only examine short-term mortality. Additionally, several functions representing morbidity, including acute respiratory symptoms, respiratory hospital admissions, respiratory emergency rooms visits, and school loss days, were used, which are functions typically used in EPA studies. The process to aggregate the results of the health studies is in Figure 1.

Figure 1: Aggregation of Health Effects Studies



[4] Jerrett et al., "Long-Term Ozone Exposure and Mortality."

Baseline Incidence Rates

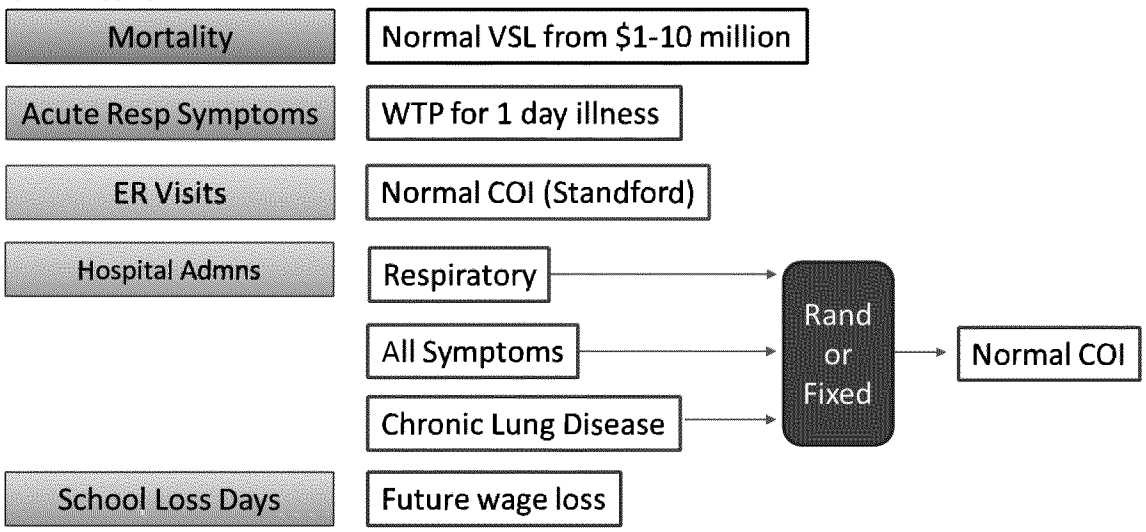
Baseline incidence rates that are part of EPA's dataset were used in this analysis. Projections of mortality incidence rates were available for 2015 which coincided with one of the years analyzed so it was determined to be the most appropriate data set and were used in the mortality health impact functions. Other effects incidence for 2014 were used the other health endpoints, since it also coincided with one of the years analyzed, excepting school loss days where 2000 was and acute respiratory systems which has a slightly different form than the other functions so baseline incidence rates are not included in the equation.

Economic Analysis

In order to quantify the impact of the health benefits the reduced incidence is multiplied by a valuation estimated through one of several techniques. In the case of mortality we will use the Value of Statistical Life (VSL) based upon a normal distribution. The VSL uses differences in salaries and the inherent risk of a job to infer the rate at which life is valued. A Willingness to Pay (WTP) estimate was used to monetize acute respiratory symptoms. WTP relies on survey data to determine how much people value not having an adverse health effect. Cost of Illness (COI) estimates were used to value emergency room visits and hospital admissions. COI totals up the amount spent on medicine, hospital visits, etc. due to an adverse heath effect. Since the VSL is based on hedonic economic analysis it best characterizes the complete value of the effect, with the WTP estimates characterizing less of the true cost, and COI capturing the least of the true cost. The process undertaken to aggregate the economic results are in Figure 2.

Additionally, income effects were adjusted to the year analyzed and all valuations are in 2010 U.S. Dollars, inflated using the Consumer Price Index (CPI) and Employer Costs for Employee Compensation (ECEC).

Figure 2: Aggregation of Economic Evaluations



Results

Monitor Rollback

The majority of the reductions in ozone concentrations occurred in the I-95 corridor between Washington, DC and New York City, with smaller reductions extending north to Boston. The largest reduction at a single monitor occurred in Harford County, Maryland, which is the monitor with the highest ozone levels in the region. There were also noticeable reductions in the Pittsburgh area and in Jefferson County, NY. Overview maps of the changes in average 8 hour maximum ozone concentrations in the OTR after being rolled back to 70 ppb in odd numbered figures from Figure 1 through Figure 8 and to 65 ppb in the even number figures.

Figure 3: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2013

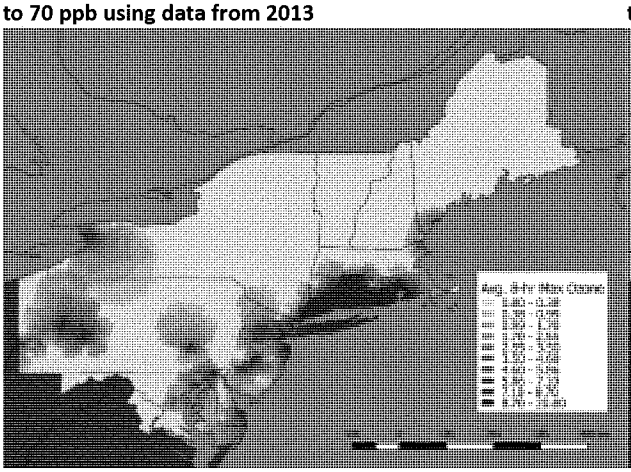


Figure 4: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2013

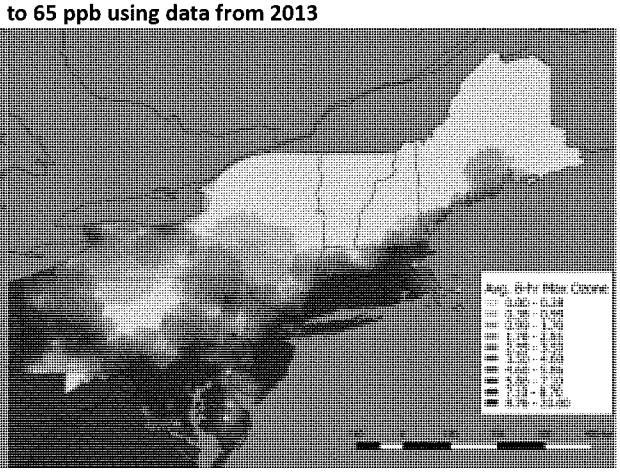


Figure 5: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2014

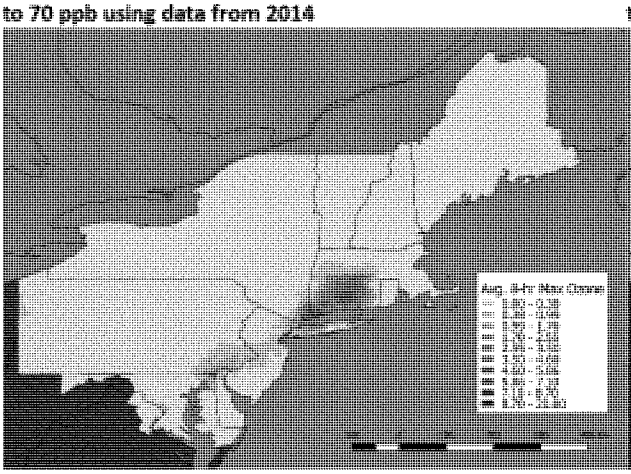


Figure 6: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2014

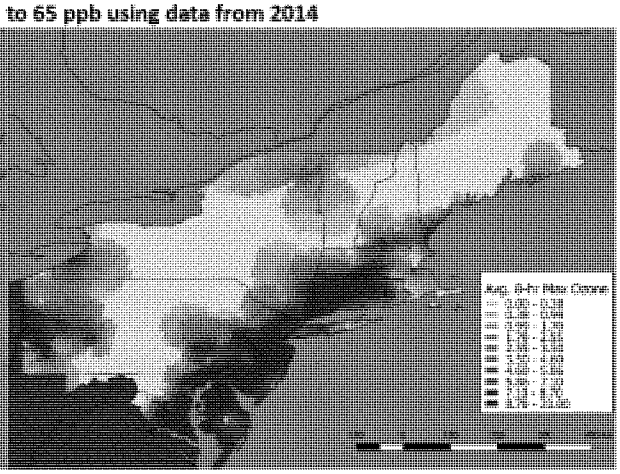


Figure 7: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2015

Figure 8: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2015

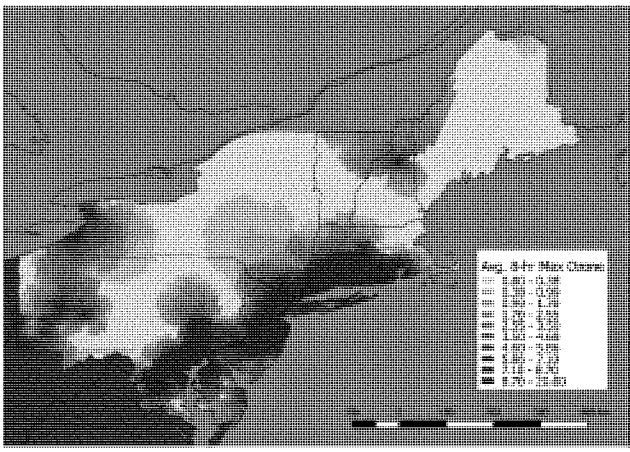


Figure 9: Change in avg. 8-hour max. ozone due to roll back to 70 ppb using data from 2016

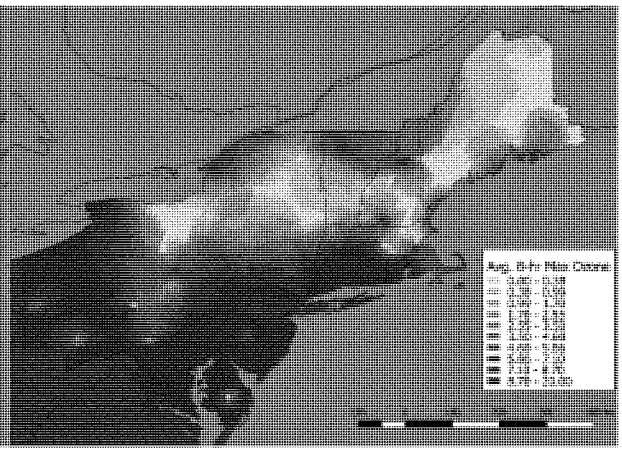
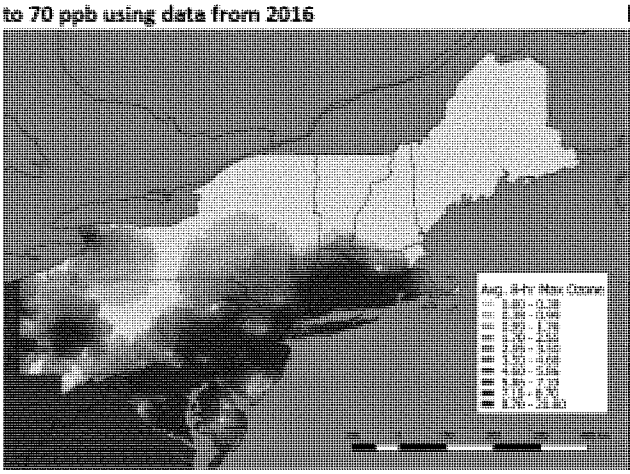
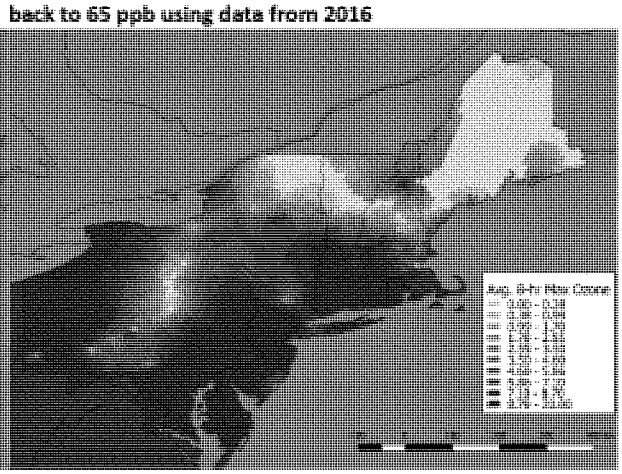


Figure 10: Change in avg. 8-hour max. ozone due to roll back to 65 ppb using data from 2016





Health Impact

After processing the health impact functions, we found that had the entire OTR had 4th highest monitor results at or under 70 ppb it is expected that there would have been anywhere from 50 to 860 fewer short term mortalities due to ozone exposure. A similar pattern of results happened for 65 and 40 ppb rollbacks, but with higher levels of reduced mortality. Emergency room visit were not found to be significant different than 0. The same pattern of results occurred for the other health endpoints as mortality with the magnitude being of hospital admissions being about half of the mortality incidence, acute respiratory symptoms being roughly 2000 times, and school loss days being roughly 500 times. A full listing of the pooled mortality is in Table 3.

ADD Reduced mortality maps. County/state?

Economic Impact

Following analysis of the health impacts, economic impacts were estimated using the previously discussed techniques. The value of the mortalities outweigh the other economic impacts

considerably, though one should consider that some economic benefits such as reduced personal suffering may not have been monetized for morbidity due to the data, such as cost of illness estimates, used in developing the cost estimates. Again emergency room visits were not found to be significantly different from zero. A full break down of the economic impacts is in Table 4.

Add economic impact maps.

Table 3: Estimated Ozone-Related Health Impacts Following Monitor Rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR

	Mortality, All Causes[5]			**Emergency Room** Visits Respiratory[6,7]			**Hospital Admissions** Respiratory[8,9,10,11,12]			**Acute Respiratory Symptoms**[13]			**School Loss Days**[14,15]		
	Mean	-2σ	2σ	Mean	-2σ	2σ	Mean	-2σ	2σ	Mean	-2σ	2σ	Mean	-2σ	2σ
2013															
40	2,280	1,146	3,415	2,247	-449	4,944	1,284	377	2,191	4,197,816	1,892,705	6,502,927	1,202,964	486,281	1,919,647
65	1,620	813	2,427	1,689	-339	3,717	927	274	1,581	3,075,827	1,381,628	4,770,027	890,618	360,100	1,421,135
70	817	410	1,224	911	-184	2,006	466	142	789	1,610,165	721,417	2,498,912	456,384	184,554	728,213
2014															
40	2,193	1,101	3,284	2,175	-435	4,786	1,246	365	2,127	4,045,310	1,822,237	6,268,383	1,152,382	465,887	1,838,876
65	1,378	692	2,065	1,535	-308	3,378	788	237	1,339	2,648,090	1,188,791	4,107,388	752,984	304,483	1,201,484
70	97	48	145	111	-16	237	57	16	98	194,477	85,659	303,295	54,890	22,216	87,563
2015															
40	2,642	1,331	3,953	2,601	-511	5,713	1,489	449	2,530	4,747,440	2,164,519	7,330,360	1,374,614	485,734	2,263,494

[5] Bell, Dominici, and Samet, "A Meta-Analysis of Time-Series Studies of Ozone and Mortality with Comparison to the National Morbidity, Mortality, and Air Pollution Study."
[6] Peel et al., "Ambient Air Pollution and Respiratory Emergency Department Visits."
[7] Wilson et al., "Air Pollution, Weather, and Respiratory Emergency Room Visits in Two Northern New England Cities: An Ecological Time-Series Study"; Peel et al., "Ambient Air Pollution and Respiratory Emergency Department Visits."
[8] Moolgavkar, Luebeck, and Anderson, "Air Pollution and Hospital Admissions for Respiratory Causes in Minneapolis-St. Paul and Birmingham"; Schwartz, "PM10 Ozone, and Hospital Admissions for the Elderly in Minneapolis-St. Paul, Minnesota"; Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan."
[9] Schwartz, "PM10 Ozone, and Hospital Admissions for the Elderly in Minneapolis-St. Paul, Minnesota."
[10] Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan."
[11] Schwartz, "Short Term Fluctuations in Air Pollution and Hospital Admissions of the Elderly for Respiratory Disease."
[12] Burnett et al., "Association between Ozone and Hospitalization for Acute Respiratory Diseases in Children Less than 2 Years of Age."
[13] Ostro and Rothschild, "Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants."
[14] Chen et al., "Elementary School Absenteeism and Air Pollution."
[15] Gilliland et al., "The Effects of Ambient Air Pollution on School Absenteeism due to Respiratory Illnesses."

65	2,142	1,076	3,207	2,164	-432	4,760	1,205	367	2,043	3,877,164	1,748,947	6,005,381	1,098,322	444,039	1,752,605
70	1,716	862	2,570	1,928	-384	4,240	978	299	1,657	3,299,106	1,489,185	5,109,027	928,840	375,517	1,482,164
2016															
40	2,620	1,317	3,923	2,545	-506	5,595	1,501	446	2,557	4,677,157	2,115,095	7,239,219	1,311,394	530,069	2,092,719
65	2,266	1,139	3,394	2,276	-454	5,006	1,294	384	2,204	4,099,376	1,849,093	6,349,658	1,147,950	464,077	1,831,822
70	1,698	853	2,543	1,736	-347	3,819	983	301	1,665	3,132,862	1,410,641	4,855,084	880,268	355,906	1,404,630

Table 4: Estimated Ozone-Related Economic Impacts (2010$) Following Monitor Rollback to 70, 65, and 40 ppb for 2013-2016 in the OTR

	Mortality, All Causes			Emergency Room Visits Respiratory			Hospital Admissions Respiratory		
	Mean	**-2σ**	**2σ**	**Mean**	**-2σ**	**2σ**	**Mean**	**-2σ**	**2σ**
2013									
40	$11,519,485,792	$170,072,048	$22,868,899,536	$509,316	-$101,640	$1,120,272	$17,891,342	$3,592,111	$32,190,572
65	$8,183,599,069	$118,798,281	$16,248,399,858	$382,767	-$76,847	$842,381	$12,950,816	$2,639,298	$23,262,334
70	$4,126,489,541	$59,035,201	$8,193,943,881	$206,500	-$41,650	$454,650	$6,530,442	$1,373,233	$11,687,650
2014									
40	$12,648,785,052	$185,735,180	$25,111,834,924	$493,020	-$98,521	$1,084,561	$17,384,086	$3,543,232	$31,224,939
65	$7,950,936,124	$114,978,588	$15,786,893,660	$347,812	-$69,830	$765,455	$11,000,544	$2,310,460	$19,690,629
70	$557,195,395	$7,314,816	$1,107,075,975	$25,055	-$3,552	$53,663	$795,696	$150,790	$1,440,601
2015									
40	$13,347,150,544	$206,971,208	$26,487,329,880	$589,428	-$115,683	$1,294,538	$20,805,265	$4,452,512	$37,158,018
65	$10,819,146,524	$160,019,168	$21,478,273,880	$490,483	-$97,806	$1,078,773	$16,908,091	$3,596,006	$30,220,176
70	$8,669,561,586	$128,426,438	$17,210,696,734	$436,934	-$86,989	$960,857	$13,660,378	$2,955,097	$24,365,659

2016									
40	$15,255,727,776	$228,054,912	$30,283,400,640	$576,679	-$114,542	$1,267,901	$20,948,661	$4,361,190	$37,536,133
65	$13,196,190,772	$194,904,888	$26,197,476,656	$515,766	-$102,811	$1,134,343	$18,070,052	$3,796,628	$32,343,475
70	$9,887,347,069	$145,099,195	$19,629,594,943	$393,345	-$78,685	$865,375	$13,815,612	$2,928,737	$24,702,488
	Minor Restricted Activity Days			**School Loss Days**					
2013									
40	$378,135,792	$164,688,099	$591,583,485	$81,691,996	$33,186,346	$130,197,645			
65	$277,064,326	$120,219,727	$433,908,926	$60,480,895	$24,570,206	$96,391,584			
70	$145,041,617	$62,772,411	$227,310,823	$30,992,525	$12,590,824	$49,394,225			
2014									
40	$382,971,923	$166,639,358	$599,304,488	$78,257,018	$31,791,330	$124,722,707			
65	$250,695,532	$108,713,734	$392,677,330	$51,134,326	$20,773,428	$81,495,224			
70	$18,412,065	$7,832,693	$28,991,437	$3,727,499	$1,514,454	$5,940,543			
2015									
40	$427,648,203	$188,380,062	$666,916,344	$93,348,569	$33,107,338	$153,589,799			
65	$349,252,600	$152,180,268	$546,324,932	$74,585,860	$30,300,006	$118,871,715			
70	$297,181,893	$129,578,103	$464,785,684	$63,076,564	$25,624,412	$100,528,715			
2016									

40	$444,322,290	$194,091,767	$694,552,814	$89,055,374	$36,177,323	$141,933,425
65	$389,432,952	$169,678,489	$609,187,416	$77,956,033	$31,668,925	$124,243,140
0	$297,612,933	$129,445,862	$465,780,005	$59,778,074	$24,284,628	$95,271,519

To: Eyth, Alison[Eyth.Alison@epa.gov]
Cc: Houyoux, Marc[Houyoux.Marc@epa.gov]; Strum, Madeleine[Strum.Madeleine@epa.gov]; Fox, Tyler[Fox.Tyler@epa.gov]; Possiel, Norm[Possiel.Norm@epa.gov]
From: Gregory Stella
Sent: Tue 12/6/2016 3:04:09 PM
Subject: Re: 2014 NEI Modeling Platform

Hi Alison,

Just checking in to see if there is any new information on the release of (1) the 2014 modeling platform and (2) the 2011el and 2023 platform.

Thanks,

Greg

On 10/26/2016 4:04 PM, Eyth, Alison wrote:
> Greg,
>
> I think you saw that there are flat files for 2014 for the five NEI data categories posted here:
>
> ftp://ftp.epa.gov/EmisInventory/2014/flat_files/
>
> We are working on preparing a modeling platform for NATA. We are still running sectors for this, and it's a HAP platform. We will post the emissions inputs after we have reviewed the results - probably by the end of the year.
>
> The 2011el case has been prepared but we haven't packaged it yet. Let me know if you need that even without the 2023. We are still working on 2023. I think our plan is to release that by the end of the year if all goes well.
>
> Alison
>
>
> -----Original Message-----
> From: Gregory Stella [mailto:gms@alpinegeophysics.com]
> Sent: Wednesday, October 26, 2016 3:48 PM
> To: Eyth, Alison <Eyth.Alison@epa.gov>
> Cc: Houyoux, Marc <Houyoux.Marc@epa.gov>; Strum, Madeleine <Strum.Madeleine@epa.gov>; Gregory Stella <gms@alpinegeophysics.com>; Fox, Tyler <Fox.Tyler@epa.gov>
> Subject: Re: 2014 NEI Modeling Platform
>
> Alison,
>
> Just following up to see what's the latest on the release of the 2014 modeling platform as well as whether we should soon be expecting to see the 2011/2023 platform for the 2015 ozone NAAQS.
>
> Thanks in advance,
>
> Greg
>
>
> On 9/26/2016 9:52 AM, Eyth, Alison wrote:
>> Greg,
>>

>> We are having some discussions about this in the near future.
>> We can provide the flat files themselves pretty soon.
>>
>> We are working on building a new HAP-CAP platform for NATA that includes updated speciation profiles, spatial surrogates, and temporal profiels. I'm not sure of the timing of when we can release this, but we're still in the middle of building it. The timing of the release of this platform is on our list of things to discuss in the very near future.
>>
>> Alison
>>
>> -----Original Message-----
>> From: Gregory Stella [mailto:gms@alpinegeophysics.com]
>> Sent: Monday, September 26, 2016 9:44 AM
>> To: Eyth, Alison <Eyth.Alison@epa.gov>
>> Cc: Houyoux, Marc <Houyoux.Marc@epa.gov>; Gregory Stella
>> <gms@alpinegeophysics.com>
>> Subject: 2014 NEI Modeling Platform
>>
>> Hi Alison,
>>
>> I saw that the 2014 NEI has made it to the FTP site. Are there plans to release a SMOKE modeling platform version anytime soon?
>>
>> Thank you,
>>
>> Greg

To: Loftus, Jonathan P - DNR[Jonathan.Loftus@wisconsin.gov]; Gamas, Julia[Gamas.Julia@epa.gov]
Cc: Karen Mongoven[kmongoven@4cleanair.org]
From: Houyoux, Marc
Sent: Wed 1/11/2017 7:39:53 PM
Subject: RE: Reminder: Comments on EPA Emissions Inventory SIP Guidance due 1/17/17
EI guidance Dec-2016 vs Apr-2014.docx

Jon,

Yes. The attached version is a "track changes" version from the previous guidance. Please feel free to share this with others.

Best regards,

Marc

Marc Houyoux

Group Leader

Emissions Inventory and Analysis Group

EPA/OAQPS/AQAD

919-541-3649

From: Loftus, Jonathan P - DNR [mailto:Jonathan.Loftus@wisconsin.gov]
Sent: Wednesday, January 11, 2017 1:14 PM
To: Gamas, Julia <Gamas.Julia@epa.gov>; Houyoux, Marc <Houyoux.Marc@epa.gov>
Subject: Re: Reminder: Comments on EPA Emissions Inventory SIP Guidance due 1/17/17

Hi Julia and Marc,

What was the date of the proposed updated guidance (i.e., before the Dec. 2016 revised version)? This updated guidance is basically any changes to EPA's previous SIP inventory guidance (I think that guidance was from 2014), correct?

Also, is there a redline version of the updated guidance that indicates changes made to the 2014 guidance? That would expedite any review for us.

Thanks,

Jon Loftus, Wisconsin DNR

From: Karen Mongoven [mailto:kmongoven@4cleanair.org]
Sent: Friday, January 06, 2017 12:12 PM
To: Karen Mongoven
Subject: Reminder: Comments on EPA Emissions Inventory SIP Guidance due 1/17/17

TO: NACAA EMISSIONS AND MODELING COMMITTEE

Marc Houyoux, EPA's Emissions Inventory and Analysis Group Leader, asked me to remind you that comments on EPA's **Draft Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter NAAQS and Regional Haze Regulations** are due by **Tuesday, January 17, 2017**. Comments should be sent by email to Julia Gamas (gamas.julia@epa.gov) and Marc Houyoux (Houyoux.Marc@epa.gov).

I am told that EPA posted a slightly updated version in late December which added a small amount of reference information regarding the Clean Power Plan as well as updated links to reflect the EPA's new web addresses.

The latest draft guidance has not yet been updated with the final Regional Haze Rule, but has been updated to reflect the final PM2.5 and Ozone rules. EPA does know of one significant

comment on the wording of the RFP inventory section of the guidance that isn't consistent with the PM2.5 implementation rule (and intends to fix this).

The draft guidance (updated draft dated December 2016) is available on EPA's website at:

https://www.epa.gov/air-emissions-inventories/air-emissions-inventory-guidance-documents

Here is a direct link to the document (pdf): https://www.epa.gov/sites/production/files/2016-12/documents/2016_ei_guidance_for_naaqs.pdf

If you have any questions, please contact Marc at his email address listed above, or by telephone at 919-541-3649.

* * *

Karen K. Mongoven

Senior Staff Associate

National Association of Clean Air Agencies

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Washington, DC 20001

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Fax: (202) 624-7863

kmongoven@4cleanair.org

DRAFT

Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations

DRAFT

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Acronyms and Abbreviations Used in this Guidance

AEO	Annual Energy Outlook
AERR	Air Emissions Reporting Rule
APU	Auxiliary power unit
BEIS	Biogenic Emissions Inventory System
BELD3	Biogenic Emissions Land Use Database, version 3
AT	Air Taxis
C1	Category 1 (marine vessel)
C2	Category 2 (marine vessel)
C3	Category 3 (marine vessel)
CAA	Clean Air Act
CAMD	Clean Air Markets Division
CAP	Criteria air pollutant
CAS	Chemical Abstracts Service
CEMS	Continuous Emissions Monitoring System(s)
CMV	Commercial marine vessel
CNG	Compressed natural gas
CO	Carbon monoxide
CO2	Carbon dioxide
DARS	Data Attribute Rating System
DOE	Department of Energy
ECA-IMO	Emissions Control Area-International Maritime Organization
EDD	Effective date of designation
EDMS	Emissions and Dispersion Modeling System
EE	Energy efficiency
EGU	Electric Generating Unit
EIA	Energy Information Administration
EIIP	Emissions inventory Improvement Program
EIS	Emissions Inventory System
EMCH	Emissions Modeling Clearinghouse
EPA	Environmental Protection Agency
EPMM	Electric Power Market Model
ERTAC	Eastern Regional Technical Advisory Committee
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FRS	Federal Registry Service
GA	General Aviation
GHG	Greenhouse gas
GIS	Geographic Information Systems

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GSE	Ground support equipment
HAP	Hazardous air pollutant
Hg	Mercury
HCl	Hydrochloric acid
IPM	Integrated Planning Model
IPP	Inventory Preparation Plan
LPG	Liquified petroleum gas
LTO	Landing and takeoff
MARKAL	Market Allocation (model)
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MIMS	Multimedia Integrated Modeling System
MOVES	Motor Vehicle Emissions System
NAAQS	National Ambient Air Quality Standards
NAA	Nonattainment area
NAICS	North American Industry Classification System
NATA	National Air Toxics Assessment
NEEDS	National Electric Energy Data
NEI	National Emissions Inventory
NEMS	National Energy Modeling System
NESHAP	National Emission Standard for Hazardous Air Pollutants
NH_3	Ammonia
NLDN	National Lightning Detection Network
NMIM	National Mobile Inventory Model
NONROAD	Nonroad emissions model
NMHC	Non-methane hydrocarbon
NO_X	Nitrogen Oxides
O_3	Ozone
OAP	Office of Atmospheric Programs
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation
OECA	Office of Enforcement and Compliance Assurance
ORIS	Office of Regulatory Information Systems
OTAQ	Office of Transportation Air Quality
OTR	Ozone Transport Region
PM	Particulate matter
$PM_{2.5}$	Particulate matter with diameter 2.5 microns and less
PM_{10}	Particulate matter with diameter 10 microns and less
QAPP	Quality Assurance Project Plan
RE	Renewable energy
RICE	Reciprocating Internal Combustion Engines
RFP	Reasonable Further Progress
ROP	Rate of Progress

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SCC	Source classification code
SIP	State implementation plan
SMOKE	Sparse Matrix Operator Kernel Emissions
SO_2	Sulfur Dioxide
SSM	Startup, Shutdown, and Malfunction
STEEM	Ship Traffic, Energy and Environmental Model
TAF	Terminal Area Forecast
TCA	1,1,1-trichloroethane
TDM	Travel demand model
TIP	Tribal Implementation Plan
TOG	Total organic gases
TRI	Toxics Release Inventory
U.S.	United States
USDA	U.S. Department of Agriculture
VMT	Vehicle miles traveled
WFU	Wildland fire use
WLF	Wildland fire
WRF	Weather Research and Forecasting
VOC	Volatile organic compounds

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1 Introduction

1.1 Purpose

This document provides guidance on how to develop emissions inventories to meet state implementation plan (SIP) requirements for complying with the 8-hour ozone national ambient air quality standard (NAAQS[1]), the 24-hour and annual fine particulate matter (PM2.5) NAAQS[2], and the regional haze regulations. It is intended for use by the United States (U.S.) Environmental Protection Agency (EPA) Regional offices; state, local, and tribal air quality management authorities; and the general public. This guidance is designed to implement national policy on these emissions inventories as embodied in the Clean Air Act (CAA), the Ozone SIP Requirements Rule for the 2008 ozone NAAQS (also called the Ozone Implementation Rule)[3], the $PM_{2.5}$[4] SIP Requirements Rule[5], and the Regional Haze Regulations.[6]

This document does not substitute for provisions or regulations of the CAA enumerated above, nor is it a regulation itself. As the term "guidance" suggests, it provides recommendations on how to implement the inventory requirements. Thus, it does not impose binding, enforceable requirements on any party, nor does it assure that the EPA will approve all instances of its application, as the guidance may not apply to a particular situation based upon the circumstances.

The EPA and state, local, and tribal decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Final decisions by the EPA regarding a particular SIP demonstration will only be made based on the statute and regulations, and will only be made following a final submission and after notice and opportunity for public review and comment. Interested parties are free to raise questions and objections about the appropriateness of the application of this guidance to a particular situation; the EPA will, and state, local, and tribal air agencies should, consider whether or not the recommendations in this guidance are appropriate in that situation.

Through the provisions of the Tribal Authority Rule, tribes are not required to develop emissions inventories. If tribes choose to develop an emissions inventory that may become part of a SIP or Tribal Implementation Plan (TIP) inventory covered by this guidance, the tribes are encouraged to follow the provisions of this guidance. Notwithstanding the possible development by local and tribal air agencies, inventories prepared for NAAQS implementation will be called "SIPs" in the remainder of this document.

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3 Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements; (40 CFR 51 Subpart AA; see also https://www.epa.gov/ozone-pollution/implementation-2008-national-ambient-air-quality-standards-naaqs-ozone-state).

4

5 Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements, (40 CFR 51 Subpart Z; see also https://www.epa.gov/pm-pollution/implementation-national-ambient-air-quality-standards-naaqs-fine-particulate-matter).

6 Regional Haze Regulations (40 CFR 51 Subpart P) proposed to be amended by Protection of Visibility: Amendments to Requirements for State Plans; Proposed Rule (81 FR 26942, May 4, 2016). See also https://www.epa.gov/visibility/visibility-regulatory-actions.

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1.2 Other Inventory Guidance and Resources

This document is a guide for state, local, and tribal air agencies (called "air agencies" in this guidance) for preparing and submitting their emissions inventories for the 8-hour ozone NAAQS, 24-hour and annual $PM_{2.5}$ NAAQS, and for the regional haze program. It is not a procedures document that comprehensively covers the methods for compiling and documenting emissions inventories. Furthermore, the predecessors to this guidance have historically relied on separate guidance documents to add information for various specific purposes. In Section 2.3, we list the various inventory components needed for 8-hour ozone, $PM_{2.5}$, and regional haze implementation and identify the associated sections of this guidance and other relevant guidance materials.

In addition to this guidance, the "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment for Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze" (http://www3.epa.gov/ttn/ scram/guidance_sip.htm), or "Modeling Guidance", covers the creation of emissions inventories for use in air quality modeling. These modeling inventories differ from the inventories covered in this document in that they usually have a larger spatial extent (i.e., a multi-state area as opposed to just the nonattainment area or individual state) and require extra processing steps to obtain the spatial and temporal resolution of the air quality model input species. To the extent the Modeling Guidance covers future-year emissions, efforts have been made to harmonize the future-year guidance in that Guidance with the information included in Section 5 of this document.

In accordance with 40 CFR Subpart A Section 51.5(b), states are urged to use applicable, state-of-the art techniques for estimating emissions. A number of inventory development resources are available from the EPA for use by air agencies for estimating base year emissions inventories. Table 1 provides these references and a brief description of how they can be used. More information on how these resources can be applied is provided in Sections 4 and 5.

Table 1: List of EPA estimation resources for emissions inventories

Resource and website	Description
National Emissions Inventory (NEI)	Summaries of the latest NEI data and documentation are available from links provided at this website. More detailed data are available to air agencies from the Emissions Inventory System (EIS).
Emission Factors used for the National Emissions Inventory (NEI)[λ]	The National Emissions Inventory (NEI) program provides emissions estimation tools (that include emission factors) and point-source emission factors based on EPA rule development efforts. In many cases, these factors are more recent than those in WebFire and AP-42, and agencies are encouraged to rely on these where available.

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Emissions Inventory System	The EIS allows for summaries and extraction of detailed data for use by air agencies. The EIS allows both state-submitted as well as the composite EPA-state data used for the NEI to be queried and downloaded. Training on reports is also available, and Appendix A provides an EIS quick reference for county and facility reports.
Local-scale emissions inventory development	In 2010, the EPA completed a project to assess the building of multi-pollutant inventories at the scale of nonattainment areas. A project description and the final report are available; the latter documents the recommended actions for state and local agencies that want to develop local-scale emissions inventories, including SIP planning inventories.
Electric Generating Unit emissions data from Continuous Emissions Monitoring Systems (CEMS)[Δ]	Carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and heat input data from Electric Generating Units (EGUs) collected by the EPA. Heat input data can be used to estimate hourly emissions of other pollutants using emission factors.
Emissions Inventory Improvement Program (EIIP) Documentation, Volumes 1-9	Emissions estimation procedures for point, area (nonpoint) and mobile sources. While much of the information included in these reports is still relevant, the EIIP documentation for point and nonpoint sources has some outdated parts, and the sections below indicate some of those limitations and alternative resources. The EIIP documentation for mobile sources (volume 4) is out of date because it refers to previous versions of EPA emissions models. ***Use more current resources, listed below for mobile sources and fires.*** While EIIP is also out of date for biogenic sources, these sources are relevant only for modeling inventories and not for the inventories covered by this guidance.
Emission Factors – WebFire and AP-42	Emission factors are used to estimate emissions, generally by multiplying by some activity value for that emissions activity, where no better method of emissions quantification or estimation is available. ***AP-42 is not an appropriate source of emission factors for mobile sources other than road dust.***
General Principles for the 5-Year Regional Haze Progress Reports for the Initial Regional Haze State Implementation Plans	This document has been developed by the EPA for the EPA Regional offices and states in preparing and reviewing the 5-year progress reports for the initial Regional Haze SIPs. This document summarizes and clarifies the requirements for the first 5-year reports, including emissions inventory aspects.

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Motor Vehicle Emissions System (MOVES)	The model, technical documentation, and guidance on the use and application of the MOVES model for on-road and nonroad mobile sources.
State and Local Transportation Policy and Guidance	Webpage that provides state and local agencies with direction on how to implement strategies for controlling emissions from mobile sources. Includes links to guidance documents that describe process for securing SIP air quality credits for voluntary and innovative emission reduction programs. See also link to nonroad documentation now available from the MOVES page.
Transportation Conformity	General information, policy and technical guidance about transportation conformity.

λ From this main web page, obtain factors using the link to the latest available NEI or NEI Plan.

Δ Select "Data Sets and Published Reports".

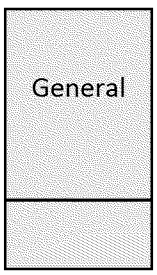
Many other resources from other organizations exist. Where specific methods or tools from non-EPA organizations are included in this documentation, this document includes relevant references for those materials to help readers find these additional sources of information.

In addition to base year emissions, emissions projections are needed for a variety of reasons, including redesignation maintenance plans, the attainment projected inventory for a nonattainment area (NAA), air quality modeling for attainment plans, and projecting reasonable progress goals for visibility improvement as part of Regional Haze SIPs. In Section 5, this guidance provides information on methods for emissions projections. The EPA provides emissions projections data and documentation as part of its modeling platforms that are available at the Emissions Modeling Clearinghouse (https://www.epa.gov/air-emissions-modeling). On-road and nonroad mobile source projections are covered in the mobile regulatory documentation associated with MOVES. Additional nonroad mobile projections information (for aircraft, commercial marine vessels, and locomotives) are included as part of this documentation in the nonroad mobile sources part of Section 5.

1.3 Summary of Relevant Statutory Provisions

Numerous sections of the CAA apply to the implementation of emissions inventory requirements. This section provides a brief synopsis of some of those sections that may be relevant for reference in later sections of this guidance. All of the sections below are a part of CAA Title I – Programs and Activities.

- **Section 110(a)** describes the basic requirements for SIPs, which provide for implementation, maintenance, and enforcement of the NAAQS.
    - **Section 110(a)(1)** specifies parameters for infrastructure SIPs.
    - **Section 110(a)(2)** specifies a "notice and public hearing"[7] process is needed.



[7] Public hearings are explained at 40 CFR 51.102(a).

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Section 110(a)(2)(F) specifies that infrastructure SIPs shall require, as may be prescribed by the EPA Administrator, "periodic reports on the nature and amounts of emissions and emissions-related data" from stationary sources.

- **Section 110(a)(2)(K)** requires infrastructure SIPs to provide for air quality modeling as determined necessary by the Administrator and allows the EPA to require the submission upon request of data related to that air quality modeling.
- **Section 110(a)(2)(J)** addresses requirements related to Part C of the CAA, related to prevention of significant deterioration and visibility protection.

Readers should refer to the "Guidance on Infrastructure State Implementation Plan (SIP) Elements under Clean Air Act Sections 110(a)(1) and 110(a)(2)"; September 2013.

- **Section 110(p)** requires states to submit "reports" according to the Administrator's schedule, "relating to emissions reductions, vehicle miles traveled, congestion levels, or any other information the Administrator may deem necessary to assess the development effectiveness, need for revision, or implementation of any plan or plan revision" for a SIP.

General

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- **Sections 169A and 169B** focus on visibility protection for Federal class I areas and require the EPA to promulgate regulations establishing requirements for implementation plans to assure reasonable progress towards improving visibility. To do this, the EPA has codified the regional haze program requirements in 40 CFR 51.308 and 51.309.

Regional Haze

- **Section 172(c)(3)** in Part D, Subpart 1 describes NAA SIP requirements for all criteria air pollutants (CAPs) – carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone, particulate matter (PM), and SO_2 – that, unless superseded by subsequent NAAQS-specific subparts, apply to SIPs for NAAs submitted to the EPA. This section includes a requirement that such SIPs include a current inventory of actual emissions in a NAA. It allows the EPA Administrator to require periodic updates needed to determine if the general requirements of nonattainment SIPs (i.e., Subpart 1) are met.

General

- **Section 175A** describes maintenance plans, which are SIP revisions that provide for the maintenance for 10 years of any primary NAAQS for which an area has been redesignated to attainment and may include additional control measures necessary

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to ensure this maintenance. Updated emissions inventories are to be included in a maintenance plan.

Ozone

- **Section 182(a)-(f)** provide SIP inventory requirements for all areas designated as nonattainment for the ozone NAAQS.
  - **Section 182(a)** includes SIP requirements for ozone NAAs classified as Marginal and above.
    - **Section 182(a)(1)** requires a current and comprehensive inventory of actual emissions of all sources of ozone precursors to be included in a SIP.
    - **Section 182(a)(3)(A)** requires periodic inventories to be provided by a state to EPA, until an area is redesignated to attainment, no later than the end of each 3-year period after the submission of the inventory for 182(a)(1).
    - **Section 182(a)(3)(B)** requires areas to include in their SIP a requirement for stationary sources of NO_X and volatile organic compounds (VOC) to provide the state with an annual statement showing actual emissions of NO_X and VOC.
  - **Section 182(b)** includes SIP requirements for ozone NAAs classified as Moderate and above.
    - **Section 182(b)(1)(A)** requires a rate of progress (ROP) demonstration, and describes requirements for annual reductions in VOC and NO_X emissions as necessary to attain the ozone NAAQS.
    - **Section 182(b)(1)(B)** requires a baseline emissions inventory for NO_X and VOC from all anthropogenic sources in the NAA to be included in ozone SIPs for purposes of ROP/reasonable further progress (RFP) demonstrations.
  - **Section 182(c)** includes SIP requirements for ozone NAAs classified as Serious and above. This section defines major sources for areas classified as Serious as sources that emit or have the potential to emit at least 50 tons of VOC per year.
    - **Section 182(c)(2)(A)** requires an attainment demonstration based on photochemical modeling. A modeling inventory is needed for the attainment demonstration analysis.
    - **Section 182(c)(2)(B)** requires a RFP demonstration, and describes

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requirements for a timeline of VOC emissions reductions. RFP demonstrations must include baseline emissions for comparison against the emissions reductions.

- **Section 182(d)** defines major sources for areas classified as Severe as sources that emit or have the potential to emit at least 25 tons of VOC per year.
- **Section 182(e)** defines major sources for areas classified as Extreme as sources that emit or have the potential to emit at least 10 tons of VOC per year.
- **Section 182(f)** provides that all major source CAA requirements for VOC also apply for NO_X unless a waiver is received.

- **Section 182(j)(1)** requires states in a multi-state ozone NAA to take all reasonable steps to coordinate, substantively and procedurally, the revisions and implementation of SIPs for a multi-state ozone NAA.
- **Section 184(b)(2)** defines major sources for areas within the ozone transport region (OTR) as any stationary source that emits, or has the potential to emit, 50 tons per year of VOC. Per the requirement for Section 182(f), this definition also applies to sources of NOx.

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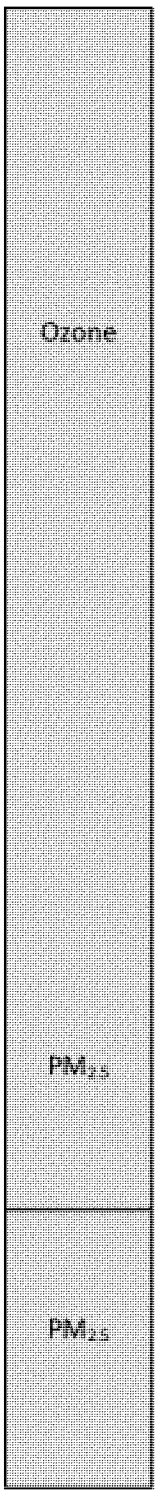
- **Section 189(a)(2)** in Part D, Subpart 4 provides a different and earlier schedule (18 months rather than 3 years) for PM SIPs than provided for in the general provision in Part D, Subpart 1.
- **Section 189(b)(3)** (also Part D, Subpart 4) defines major sources in Serious PM NAAs as sources that emit 70 tons per year of PM_{10}. Inventories for PM SIPs for Serious NAAs should establish the inventory of major point sources using the lower threshold. This section of the CAA has been determined through the courts to be the appropriate governing section for $PM_{2.5}$ implementation as well as PM_{10}.



It is important to note the distinction between a requirement in the CAA that an inventory be a SIP submission or included in a SIP submission, a requirement that a state's SIP provide for the preparation and submission to EPA of an inventory or other emissions information, and a requirement that a SIP demonstrate some fact (such that a NAAQS will be attained by a future date) that can only be

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established by using sound emission inventory information in an appropriate manner. This distinction is important because if an inventory is a required SIP submission, then certain procedural requirements apply. Inventories that are SIP submissions, or included in SIP submissions, must comply with all procedural requirements that are applicable to any other SIP submission including but not necessarily limited to those specified CAA section 110 and 40 CFR 51.102, 103 and Appendix V. This document clarifies which emission inventories are required SIP submissions and which are not.

1.4 Summary of Guidance Contents

This guidance document will define parts of and considerations for emissions inventories to meet SIP requirements for complying with the 8-hour ozone NAAQS, the $PM_{2.5}$ NAAQS (24-hour and annual), and the regional haze regulations. Section 2 provides an overview of the creation, documentation, and submission of the planning inventories. Section 3 has subsections for each of the separate inventory requirements or recommendations, with details provided for all requirements except the base year and projected emissions inventories. Sections 4 and 5 provide the detailed guidance on developing base year emissions inventories and projected emissions inventories, respectively.

2 SIP Inventory Overview

There are two categories of emissions inventories associated with SIP development: *planning* inventories and *modeling* inventories. Modeling inventories are used for modeled attainment demonstrations and setting reasonable progress goals for visibility protection. Planning inventories are needed for ozone and $PM_{2.5}$ SIPs to quantify nonattainment area emissions, and they are used as a part of RFP analysis and transportation conformity. The primary focus of this guidance is the planning inventories, whereas the modeling inventories are primarily addressed in the modeling guidance that is provided separately in the Modeling Guidance document (see Section 1.2).

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Generally, the EPA recommends that the planning inventories and modeling inventories be consistent, though there are exceptions. The exceptions are noted where they arise throughout this guidance and the Modeling Guidance; however, the EPA generally encourages air agencies to minimize inconsistencies where possible.

The many aspects of planning inventories are covered more thoroughly in Section 3. These aspects include the timing for submitting the various inventory components, the inventory preparation plan (IPP), the base year NAA inventory, the RFP baseline inventory, the ozone periodic inventory, the ozone emissions statement requirement for SIPs, the maintenance inventories, the attainment projected inventory for the NAA, public hearings, and inventory approval by the EPA.

In this section, we provide an overview of the creation, documentation, and submission of the planning inventories. Section 2.1 lists the various steps associated with building the planning inventory parts of a SIP and identifies the relevant sections of this document that address those steps. The discussions between air agencies and the EPA regarding the inventory approval process is described in Section 2.2. In Section 2.3, we list all of the required inventory components, including modeling inventories that are needed for ozone, $PM_{2.5}$, or regional haze, but otherwise defer to the Modeling Guidance for the factors

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for air agencies to consider in building those inventories. In Sections 2.4 and 2.5, we describe other federal emissions reporting requirements that are relevant to NAAQS implementation and provide definitions of key terms needed to understand, develop, and submit emissions inventories for SIPs.

2.1 Recommended Steps for Building the Inventory Parts of a SIP

Throughout this document, we describe many technical components that could be included in inventories in a SIP for ozone, $PM_{2.5}$, or regional haze implementation. Before air agencies start to create those components, it is important to recognize that there is a process associated with building them. This section describes the process agencies should undertake for a successful inventory development and submittal effort.

The inventory development process involves both required and optional steps. Some optional steps may be taken by the air agency if it believes it is in its best interest to do so, and optional steps can also become critical to a particular SIP development process and identified as such by an EPA Regional office. Thus, a fundamental part of the process is establishing and maintaining open lines of communication between the air agency and the respective Regional office. The Regional office should be viewed by the air agency as the typical starting point for questions related to planning and modeling inventory development, and the Regional office staff will direct questions needing EPA headquarters input as they arise.

A key aspect of this guidance is identifying opportunities for states to leverage existing work to help them meet the implementation requirements. This starts in Section 2.4 with a description of how work done in support of the NEI can be helpful for the SIP inventory work.

Table 2 provides a list of steps for completing the planning inventory and related parts of a SIP. The list is provided in groups of steps that occur in phases presented roughly in chronological order. The second column of the table indicates the section(s) of this document that give more information on the particular step. States and Regional offices should look for opportunities to be efficient where possible to reduce workload. For example:

- an Inventory Preparation Plan for an air agency that has prepared emission inventory SIPs for a given NAAQS may not be needed, could reference a past plan, or could need fewer details;
- combining documentation from separate steps into a single document where that makes sense; and
- referencing externally provided inventory documentation where externally prepared emissions data have been used in the SIP inventory is acceptable (in this case, the air agency would just explain why the externally prepared data are applicable for the SIP inventory).

Table 2: Steps for building the inventory parts of a SIP

Inventory-related SIP development step	Document section
Planning	
• Review this guidance.	All

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• Become familiar with inventory development resources.	1.1 1.2
• During development of the Inventory Preparation Plan, clarify and discuss the inventory approval process that your Regional office will use, including all requirements, reporting formats and elements to be included, timing, and technical documentation contents.	2.2 (general) 3.1 (timing)
• Understand required and potentially required inventory components for the SIP. Determine which inventories must be created for your SIP.	2.3
• Understand inventory definitions and data requirements.	2.5
• Understand timing requirements of submitted components.	3.1
• Prepare and finalize the Inventory Preparation Plan.	3.2
• Prepare a quality assurance project plan (QAPP)	3.2
• Understand requirements and choose key inventory features, including inventory year(s), the pollutants and precursors to be included, and priority emissions sources.	4
Creating Inventories	
• Assess what inventories already exist that can be used as a starting point.	2.4 3.3
• Create base-year planning inventories.	4
• Quality assure and refine base year inventory data in accordance with the IPP and QAPP.	0
• Create projected planning emission inventories.	5
• Quality assure and refine projected planning emission inventories in accordance with the IPP and QAPP.	5.5
Preparing Documentation	
• Review requirements with respective Regional office in light of the particular challenges associated with a given SIP development process, such a first nonattainment SIP development for a state, area, or air agency staff.	2.2
• Prepare documentation.	3.10
Public Hearings	3.9
Submit to the EPA for Approval	3.10

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2.2 Discuss the Inventory Approval Process with EPA

Early in the SIP planning process, air agencies should discuss the emissions inventory approval process for that specific SIP with their respective EPA Regional office. These discussions should address the tangible items (e.g., reports, data files, summary spreadsheets) that will be delivered to the EPA as necessary to support the EPA's review and approval.

A common source of confusion is whether inventories must undergo public review. Inventories that are SIP submissions, or are included in SIP submissions, must comply with all procedural requirements that are applicable to any other SIP submission including but not necessarily limited to those specified in CAA section 110 and 40 CFR 51.102, 103 and Appendix V. Details on the public review issue are addressed in more detail in Section 3.9.

As new issues arise during the SIP development process, air agencies or the EPA Regional offices may need to reassess the previously discussed inventory approval process. Both agencies should be aware of possible changes that are needed as the inventory development process occurs, and either party should raise concerns about the need for discussion and possible revision of the process. Details of the process and documentation can be modified through additional discussions as the need arises. As the inventory development process works far better when lines of communication remain open, the EPA encourages periodic coordination meetings or check-ins during the inventory development periods.

Table 3 provides a list of tangible reports, summaries, and data files that could be included as part of the inventory efforts for SIPs. Some of these items are needed to meet statutory and/or regulatory requirements, and these are listed in Tables 4 through 6 below. The form of reports, summaries, and data files to be included should be clarified with the Regional office at the start of the inventory development process for SIPs. States should discuss and confirm with the EPA Regional office the items to be included in the SIP to avoid inadvertent omission of items required for approval of the inventory parts of the SIP. While certain recommended items in Table 3 are not specifically required by the regulations, the EPA review of the required elements requires supporting documentation so that the EPA can assess whether the approaches used for developing inventories are technically sufficient and meet the requirements to use appropriate methods and current, accurate information.

One notable and important difference between regional haze and the other two programs (ozone attainment SIPs and PM2.5 attainment SIPs) is that there is no requirement to submit detailed emissions inventory data as an element of a required Regional Haze SIP. While the regional haze program expects that inventories will be used to accomplish the required elements of the Regional Haze SIP and the regional haze regulations require the SIP to provide for the preparation of emission inventories for particular timeframes,[8] the detailed emissions inventory data are not submitted as a SIP (or SIP revision) like the data must be for ozone and $PM_{2.5}$. The recommended items in Table 3, however, will allow the

[8] *See* 40 CFR 51.308(d)(4)(v) (Regional Haze SIPs must "provide for" statewide emissions inventories of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I Federal area.). The proposed amendments to the Regional Haze Rule would similarly require state's Regional Haze SIPs for the second and subsequent implementation periods to provide for such emissions inventories. Protection of Visibility: Amendments to Requirements for State Plans; Proposed Rule (81 FR 26942, May 4, 2016).

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EPA to make a determination whether the emissions information used in Regional Haze analysis is sufficient for the purposes of the SIP.

Following receipt of an emissions inventory from air agencies, the EPA will determine if it is part of a SIP submission or not. If an emissions inventory is provided to the EPA as a component of a SIP submittal, then EPA will process that SIP submittal, including the emissions inventory component, in accordance with applicable laws and regulations (FN: CAA section 110 and 40 CFR 51.102, 103 and Appendix V). As an example, emissions inventories required by CAA § 182(a)(1) are to be provided to EPA as a SIP submission (FN: See 80 FR 12264,12291). Conversely, if an emissions inventory is provided to the EPA outside of a SIP submittal, then EPA will review and process that inventory as necessary.

Table 3: Recommended items to include in inventory information provided to the EPA

	Inventory Item	Ozone	$PM_{2.5}$	Regional Haze
Planning Inventories	Inventory Preparation Plan	X	X	X
	Emissions Inventory Report, with explanations of methods, quality assurance and emissions summaries. All inventories can be included in such a report, including base year and projected inventories. The inventories to be included depend on the NAAQS, the nonattainment classification, and the stage of implementation (initial SIP, redesignation, etc.).	X	X	
	Emissions Inventory Report, with explanations of methods, quality assurance and emissions summaries. All inventories can be included in such a report, including base year, most recent year, and projected inventories.			X
	Tables or spreadsheets of emissions summaries included in the inventory report	X	X	X
	Detailed emissions inventory files, databases, or spreadsheets	X	X	
Modeling Inventories	Modeling Demonstration Report – The emissions information can be a section in a larger report or could have its own report. The content should include methods, quality assurance, and emissions summaries for the modeling inventories, including projected inventories. A statewide emissions summary is needed, and this can be included in the planning inventory SIP for convenience.	X	X	X
	Tables or spreadsheet summaries of emissions inventory used for modeling	X	X	X
	Detailed emissions inventory files, databases, or spreadsheets	X	X	
	Detailed data about emissions controls used to model	X	X	

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Other	Emission Statement SIP showing the state's program to require sources to submit emissions statements annually	X		

2.3 Planning and Modeling Inventory Components

The ozone, $PM_{2.5}$, or regional haze implementation rules have specific inventory requirements for SIPs to support attainment, maintenance, and/or reasonable progress demonstrations. Additionally, there are possible inventory details that could be required or advisable for various reasons. One major distinction between the inventory requirements of the ozone and $PM_{2.5}$ rules versus the proposed Regional Haze Rule is that the former two rules require inventories for NAAs, while the latter expects that states develop statewide inventories. This section provides a list for each of the three rules for the required and possible inventory components of SIPs, with additional details for the types of planning inventories.

2.3.1 Ozone SIP Inventory Components

The Ozone Implementation Rule (40 CFR part 51, Subpart AA) provides the regulatory requirements for inventories of actual emissions that support ozone NAAQS implementation by air agencies. In Table 4 below, we list the inventory components that could be part of preparing an ozone SIP and identify the governing portion of the CAA for required SIP elements, rule citation and deadline for required SIP elements and the applicable guidance in which they are addressed. The deadlines are expressed in months after the effective date of designation (EDD) of the area.

States and other air agencies that perform modeled attainment demonstrations should also refer to the Modeling Guidance (http://www3.epa.gov/ttn/scram/guidance_sip.htm), which includes a section on emissions inventories for modeling. As part of that guidance, emissions inventory summaries are described for inclusion in technical documentation about the modeled attainment demonstration. To assist the public when it comments on the SIP submittal and to facilitate EPA review of the SIP submissions, these summaries of modeling inventories can be submitted as part of the documentation provided with the emissions inventory SIP, but are not required SIP elements.

Table 4: Ozone SIP emissions inventory components

Inventory Component	Required by CAA? (CAA Section)	Regulatory Citation (Due Date)	Guidance Sections and/or Document(s)
Inventory Preparation Plan			This document, Section 3.2
Base year inventory for the NAA	Yes 182(a)(1)	40 CFR 51.1115(a) (24 months after EDD)	This document, Section 3.3 and Section 4
ROP/RFP baseline NAA inventory (part of the ROP/RFP plan(s); for Moderate and above areas)	Moderate & above: 182(b)(1)(B) Serious & above: 182(c)(2)(B)	40 CFR 51.915 40 CFR 51.1110(b) (36 months after EDD)	This document, Section 3.4 and Section 4
Periodic NAA inventory	Yes 182(a)(3)	40 CFR 51.915 40 CFR 51.1115(b) (No later than the end of each 3-year period	This document, Section 3.5 and Section 4

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		after required base year submission)	
Attainment projected inventory for the NAA[+]		Summary required by 40 CFR 51.114 (b)	This document, Section 3.8 and Section 5
Maintenance NAA inventory	Yes[‡] 175A(a)		This document, Section 3.7 and Section 4
Source Emission Statements requirement for SIPs	Yes 182(a)(3)(B)	40 CFR 51.915 (24 months after EDD)	This document, Section 3.6
Inventories for modeled attainment demonstrations (base and projected attainment year)	Yes[Δ] 182(c)(2)(A)	40 CFR 51.908 40 CFR 51.1108 (Timing depends on nonattainment classification)	*See* the Modeling Guidance. Summaries of inventories (base and projected attainment year) are encouraged to be included in technical documentation.
Public hearing requirement for SIP inventories	Yes 110(a)(2)	40 CFR 51.102	This document, Section 3.9
Planning inventory documentation			This document, Section 3.10

+ If this inventory is the mechanism by which the ROP/RFP plan requirements will show the emissions reductions required for ROP/RFP, then this inventory or its summary would necessarily become part of the ROP/RFP plan(s). Motor vehicle emissions budgets for purposes of transportation conformity are the on-road portion of the projected emissions associated with the ROP/RFP plan.

‡ Maintenance NAA inventories are only associated with maintenance SIPs rather than attainment demonstration SIPs.

Δ While modeling inventories are not an explicit requirement of the CAA, it is presumed here that states would not be able to perform credible modeled attainment demonstrations without modeling inventories.

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2.3.2 Annual and 24-Hour $PM_{2.5}$ SIP Inventory Components

The $PM_{2.5}$ SIP Requirements Rule (40 CFR part 51, Subpart Z) provides the regulatory requirements for inventories of actual emissions that support $PM_{2.5}$ NAAQS implementation by state, local, and tribal agencies. In Table 5 below, we list the inventory components that could be part of a $PM_{2.5}$ SIP and provide a map to the governing portion of the CAA, regulations, and the applicable guidance.

For areas that perform modeled attainment demonstrations, please also refer to the Modeling Guidance, which includes a section on emissions inventories for modeling. As part of that guidance, summaries are described for statewide inventories. For convenience, these summaries can be included in the emissions inventory SIP. Areas that do not perform modeled attainment demonstrations would not need to provide the statewide inventories for $PM_{2.5}$.

Table 5: $PM_{2.5}$ SIP emissions inventory components

Inventory Component	Required by CAA? (CAA Section)	Regulatory Citation (Due Date)	Guidance Sections and/or Document(s)
Inventory Preparation Plan			This document, Section 3.2
Base year inventory for the NAA	Yes 172(c)(3)	Moderate 40 CFR 51.1008(a)(1)[α]	This document, Section 3.3 and Section 4

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		(18 months after EDD)	
Attainment projected inventory for the NAA		Moderate: 40 CFR 51.1008(a)(2)[α] (18 months after EDD)	This document, Section 3.8 and Section 5
Maintenance NAA inventory	Yes[+] 175A(a)		This document, Section 3.7 and Section 4
Inventories for modeled attainment demonstrations (base year and projected attainment year)	Yes[Δ] 189(a)(1) for Moderate areas and 189(b)(1) for Serious areas	40 CFR 51.1001 and Appendix W (18 months after EDD)	Modeling Guidance. Summaries of statewide inventories (base and projected attainment year) are encouraged to be included in technical documentation.
Public hearing requirement for SIP inventories	Yes 110(a)(2)	40 CFR 51.102	This document, Section 3.9
Planning inventory documentation			This document, Section 3.10

[α] If an area is reclassified as Serious, the applicable requirements refer back to this subsection from 40 CFR 51.1008(b). If a Serious area has failed to meet the $PM_{2.5}$ NAAQS by the Serious area attainment date, then see 40 CFR 51.1008(c), which still refers back to the Moderate area requirements and has a 12 month deadline.

[+] Maintenance NAA inventories are only associated with maintenance SIPs rather than attainment demonstration SIPs.

[Δ] While modeling inventories are not an explicit requirement of the CAA, it is presumed here that states would not be able to perform credible modeling attainment demonstrations without modeling inventories.

2.3.3 Regional Haze SIP Inventory Components

The Regional Haze Rule (40 CFR part 51, Subpart P) has significantly different inventory requirements from ozone and $PM_{2.5}$ implementation rules. One reason for this difference is the time horizon of the regional haze program. The program consists of implementation periods that are referred to as the first planning period, second planning period and so forth. There are parts of regional haze implementation plans that have been completed via the SIP for the first implementation period (ending in 2018) and may not need to be revisited in SIPs for later implementation periods, but for completeness we also explain these here. Another difference is that the Regional Haze Rule requires the use of statewide planning inventories rather than inventories for only a smaller NAA. Finally, the most important difference is that there is no requirement that emission inventories be submitted as a SIP revision. While the inventories are needed to support the SIP and the SIP must provide for the specified emission inventory information, the detailed statewide inventories need not be submitted.

As noted above, the EPA proposed changes to the Regional Haze Rule in May 2016.[9] If finalized, these changes would apply only for the second and subsequent planning periods; requirements for the first planning period are governed by the existing Regional Haze Rule. This section briefly discusses the existing requirements related to emission inventories for the first planning period, and then goes on to address the same requirements as proposed for the second and subsequent planning periods.

For the first planning period, the Regional Haze Rule in 40 CFR 51.308(d)(3)(iii) required a SIP submission

[9] Protection of Visibility: Amendments to Requirements for State Plans; Proposed Rule (81 FR 26942, May 4, 2016).

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to include the technical basis on which the State was relying to determine its apportionment of emission reduction obligations necessary to achieve reasonable progress towards natural visibility conditions, including identification of the "baseline emissions inventory" used for such technical analysis. The rule indicated that the baseline emissions inventory year for the first planning period is presumed to be the most recent year of the consolidated periodic emissions inventory (as defined in Subpart A and commonly called the NEI). As a result, this "baseline" inventory used in the SIPs reflects a year from the 2000-2004, for which the 2002 was the applicable NEI year. For the first planning period, most states also used a year from this period as the base year for their regional air quality modeling (states that were members of the Lake Michigan Air Directors Consortium (LADCO) also used 2005 in their air quality modeling).

In addition, 40 CFR 51.308(d)(4)(v) required that the plan provide for a statewide inventory of emissions for a "baseline" year, for the most recent year in which data are available ("recent year"), and estimates of future projected emissions. This section made it clear that the inventories associated with the planning effort needed to be "statewide." This document does not explain in detail the emission inventory requirements for SIPs for the first implementation period, which have already been submitted and acted upon by the EPA.

The regional haze rule at present also includes a requirement for 5-year progress reports in 40 CFR 51.308(g). The initial 5-year progress report (for the first planning period) is required to be a SIP revision.[10] Because many of the first of these required 5-year progress report SIP revisions have already been submitted and the remaining progress reports should be far along in preparation as of the date of this document, this document does not address the first-required progress reports. For guidance on these first required 5-year progress reports, readers should use the separate guidance document "General Principles for the 5-Year Regional Haze Progress Reports for the Initial Regional Haze State Implementation Plans."

The EPA has proposed to revise the Regional Haze Rule so that the next required progress report would be due on January 31, 2025. Thereafter, progress reports would be due midway between "10-year" SIP revisions, with due dates of July 31 of 2033, 2043, etc. Under the proposed revisions, these future periodic progress reports would not be required to be SIP revisions. Section 308 (g)(4), as it would be amended under the proposed revisions, requires states to analyze the change in emissions over the period since the previous plan revision (i.e., the SIP revisions due in 2021, 2028, and every 10 years thereafter). The requirement sets out that "[e]missions changes should be identified by type of source or activity," and this guidance provides recommendations for what emissions summaries these reports should include to accomplish that objective. In addition, the proposed Regional Haze rule revisions specify that the analysis of historical emissions must extend at least through the most recent year for which the state has submitted emission inventory information to the EPA in compliance with the triennial reporting requirement of the Air Emissions Reporting Rule (AERR), 40 CFR part 51, Subpart A. For data (such as EGU data) that are submitted directly to the EPA and then made available by EPA, the data used must be the most recent year for which the EPA has provided state-level summary data or an

[10] On May 4, 2016, the US EPA proposed amendments to the regulatory requirements for the Regional Haze SIPs that included a proposed change such that the 5 year progress reports would no longer be a SIP revision.

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internet-based tool by which the State may obtain such a summary. Further, section (g)(5) as amended would require an assessment of any significant changes in anthropogenic emissions within or outside the state that have occurred since the previous SIP revision.

Section 40 CFR 51.308(f) of the Regional Haze Rule requires 10-year SIP revisions for the second and subsequent implementation periods; EPA proposed revisions to the requirements for SIP revisions in May 2016. As it would be revised, section 308(f)(2) specifies that the SIP revision include a long-term strategy and section (f)(2)(iv) requires that the state document the technical basis for its determinations of the emission reductions from anthropogenic sources that are necessary for achieving reasonable progress towards natural visibility conditions. The proposed wording in this section requires that a state "identify the baseline emissions inventory on which its strategies are based." In the context of this particular provision (308(f)(2)(iv)), the phrase "baseline emissions inventory" refers to source emissions corresponding to the baseline of current on-the-books emission control measures, which is the starting point for consideration of any additional measures that are necessary to achieve reasonable progress. It does not refer to the 2000-2004 "baseline period" that appears in other parts of section 308. In the proposed section 308(f)(2)(iv), the baseline emissions inventory year is further explained to mean the most recent inventory year submitted to the EPA under the triennial reporting requirements of AERR or another year if justified. Thus, the term "baseline emission inventory" in this section could be the same as the "recent year" inventory.

In the proposed rule revision, section 308(f)(6)(v) mirrors a part of section 308(d)(4) by specifying that SIP revisions for the second and subsequent planning periods must provide for a statewide inventory of emissions for a "baseline year," for the most recent year in which data are available ("recent year"), and estimates of projected emissions. In this context, "baseline year" refers to a year in the 2000-2004 period. A state that has submitted statewide inventory information in its SIP revision for the first implementation period has demonstrated that its SIP does provide for the creation of this "baseline year" inventory. In its SIP revision for the second and subsequent implementation periods, a state will need to describe its process for preparing, or providing essential information for the collective preparation of, a statewide emission inventory for the latest "recent year" and a projection inventory for the last year of the implementation period.

Table 6 summaries a list of the Regional Haze SIP emissions inventory components, including the appropriate references to the CAA, the regulations, and the relevant sections of this guidance.

Table 6: Regional haze SIP emissions inventory components

Inventory Component	Required? (CAA Section)	Regulatory Citation (Due Date)	Guidance Sections and/or Document(s)
Inventory Preparation Plan			This document, Section 3.2
Baseline statewide inventory Recent year statewide inventory Projected statewide inventory (For the first planning period)	Yes 169A(b)[+]	40 CFR 51.308(d)(4)(v) (completed)	Previously completed as part of initial Regional Haze SIP for the first planning period.
5-year (or "periodic" as proposed in the revised Regional Haze Rule) progress report, recent	Yes 169A(b)[+]	40 CFR 51.308(g)(4) and (5) (see guidance noted	This document, Section 3.5.2 and Section 3.10.3

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year statewide inventory		above)	
10-year SIP revisions, baseline statewide inventory [Δ]	Yes 169A(b)[+]	40 CFR 51.308(f)(6)(v) (varied dates)	May refer to the emissions from the first planning period
10-year SIP revisions, recent year statewide inventory [Δ]	Yes 169A(b)[+]	40 CFR 51.308(f)(6)(v) (varied dates)	This document, Section 3.5.2 and Section 4
10-year SIP revisions, projected statewide inventory[Δ]	Yes 169A(b)[+]	40 CFR 51.308(f)(6)(v) (varied dates)	This document, Section 3.8 and Section 5
Documentation			This document, Section 3.10

+ CAA 169A(b) provides the authority to provide guidelines to the states on appropriate techniques and methods to implement the visibility protection goals in the CAA. This has been done through regulations as codified in 40 CFR 51.308 and 51.309.

Δ If modeling is done to support the 10-year SIP revision, these are modeling inventories.

2.4 Other Relevant Federal Emissions Reporting Requirements

The Air Emissions Reporting Rule (AERR), 40 CFR part 51, Subpart A, requires states to provide to the EPA annual statewide emissions inventory data, regardless of whether that state has nonattainment areas. This regulation requires reporting of actual emissions of CO, NO_X, VOC, SO_2, $PM_{2.5}$, particulate matter with diameter ten microns and less (PM_{10}), and ammonia (NH_3). For $PM_{2.5}$, the AERR requires states to report primary (i.e., "direct") $PM_{2.5}$, which is defined as the sum of filterable $PM_{2.5}$ and condensable PM. The agencies are required to report the filterable $PM_{2.5}$ and condensable PM separately where they are present from the source (see Section 4.2.1). States may delegate the reporting requirements to local air agencies. Tribes can also submit these data to the NEI, but are not required to do so. These data are used by the EPA's Office of Air and Radiation's (OAR) Office of Air Quality Planning and Standards (OAQPS) to build the NEI, and a complete version that includes all sources of emissions (with minor exceptions) is released every 3 years.

The AERR includes both triennial and annual statewide reporting requirements, with more extensive reporting requirements for triennial inventory years. Triennial years for the NEI include 2011, 2014, and every 3rd year thereafter. For the interim annual inventories, reporting is limited to emissions data from only the larger point sources (Type "A" sources), as defined by Appendix A of 40 CFR part 51, Subpart A. For the triennial inventories, lower point source thresholds are given in Appendix A, consistent with the definition of major sources in 40 CFR part 70. All other sources of emissions must be reported as nonpoint or mobile sources on a county basis in the triennial submissions. Additionally, lower point source thresholds may apply to ozone, $PM_{2.5}$, PM_{10}[11], and CO NAAs, depending on the area's nonattainment classification.

The AERR requirements are relevant for SIP planning inventory purposes in several ways. First, the AERR and its associated EIS (data system) provide the appropriate data elements (fields to be reported) for

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inventories for electronic transfer to the EPA. Second, AERR-based inventories are often used as a starting point for SIP inventories. Third, in some cases, AERR submissions can meet some of the inventory requirements described in this document. Finally, the resources provided by the EPA for states to meet their AERR reporting obligations, such as emissions inventory tools and models, associated documentation, emission factors, new emissions methods, and quality assurance approaches, can assist inventory developers when making inventories for SIP planning and modeling purposes.

As a point of clarification, air agencies must meet all relevant planning inventory SIP requirements regardless of the availability or use of the EPA data associated with the AERR/NEI process. While the EPA resources can be helpful to states in meeting those requirements, the SIP requirements and the associated public review and Regional office approval process are independent requirements that must be met. It would not be sufficient to merely point to the EPA's publication of the NEI as having met the SIP emissions inventory requirements. However, it may be sufficient for a state to submit as a SIP revision an inventory that contains some or all of the same data as in the NEI, with sufficient justification and using the applicable public comment process.

2.5 Emissions Inventory Definitions

Emissions inventory work requires knowledge of many terms and codes. In this section, we define the terms relevant to inventories that are used throughout this document. This section also references external materials needed for obtaining definitions of all valid fields that can be used for building inventories, which are based on the tables used to submit data to the EPA for the AERR. Many definitions relevant for emissions inventories are defined in the CAA or codified in the AERR and the implementation rules. These are included here for a convenient reference in a single location since these terms are used throughout this document. Without these definitions, the meaning of the subsequent sections would be less clear. The sample below is not intended to represent a comprehensive list of inventory related definitions.

2.5.1 Source Category/Data Category

Traditionally, the term "source category" has been used to identify the major types of emissions inventory groupings: stationary point sources, stationary area (or nonpoint) sources[12], on-road mobile sources, nonroad mobile sources. In addition, fires and biogenic sources are sometimes included as additional source categories.

In practice, some inventories have started including large moveable facilities, such as asphalt plants, in the point sources inventory without associating them with a specific county. Additionally, some mobile sources such as locomotives and commercial marine vessels (CMVs) are treated as nonpoint data (i.e., the formatting of it) for the purpose of reporting these data to the EPA via the EIS (see also Section 4.8.5 as well as the EIS information referenced in Table 1). Similarly, because of the data format and their physical nature (i.e., a discrete geographic location), rail yards and airports are treated as point data in

[12] Over time, stationary area sources have been renamed "nonpoint" sources to avoid confusion with the air toxics regulatory term "area sources," which are often sources that meet the criteria pollutant definition of point sources. Likewise, the term "stationary" is often ignored in common use for both the point source and nonpoint labels.

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the EIS.

With the advent of the EIS, the preferred term for indicating subsets of inventory data has become "data category" rather than "source category" because the groupings have much more to do with how the data are created and the data structure than the features of the actual emissions sources included in the category. For example, locomotives and commercial marine vessels are included in the nonpoint data category for inventories in the EIS, but in fact are nonroad mobile sources. Additionally, the EIS ushered in a new data category called "events," which are typically wildfires or prescribed fires (agricultural fires are part of the nonpoint data category), but in principle could include other significant, short-duration, emissions events.[13]

2.5.2 Types of Emissions: Annual, Seasonal, Actual, Potential, and Allowable

Various terms are used in this and other documents to reference various types of emissions. Here, we provide a brief list of definitions associated with various emissions types.

Actual emissions means the emissions of a pollutant from an affected source determined by taking into account actual emission rates associated with normal source operation and actual or representative production rates (i.e., capacity utilization and hours of operation) (40 CFR 51.491). This is in contrast with potential emissions or allowable emissions. These actual emissions should include emissions of a pollutant that occur during periods of startup, shutdown, and malfunction (see Section 4.8.1). In addition, please see Section 4.1 for a description of selecting a year for creating actual emissions estimates.

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Allowable emissions means the emissions of a pollutant from an affected source determined by taking into account the most stringent of all applicable SIP emissions limits and the level of emissions consistent with source compliance with all federal requirements related to attainment and maintenance of the NAAQS and the production rate associated with the maximum rated capacity and hours of operation (unless the source is subject to federally enforceable limits that restrict the operating rate, or hours of operation, or both) (40 CFR 51.491).

Annual emissions are defined in the AERR (40 CFR 51.50) as actual emissions for a plant, point, or process that are measured or calculated to represent a calendar year. This means that annual emissions should include all emissions of the relevant sources at a facility or from a nonpoint or mobile process occurring during a calendar year. In general, unless otherwise specified, annual emissions means actual emissions, as defined above.

Average season day emissions means the sum of all emissions during the applicable season divided by the number of days in that season. This definition is used in the context of inventories developed for SIPs associated with the 24-hour $PM_{2.5}$ NAAQS.

[13] While the EIS is not currently configured to accept event data other than for fires, this means that the idea of an "event" could be expanded to other types of events that are not currently inventoried because of the difficult nature and non-routine nature of these types of emissions.

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[14]Potential to emit means the maximum capacity of a stationary source to emit a pollutant under its physical and operational design (40 CFR 51.301). Also called "potential emissions," 40 CFR 51.301 also defines this term to specify that any physical or operational limitation on the capacity of the source to emit a pollutant including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation or the effect it would have on emissions is federally enforceable. Secondary emissions do not count in determining the potential to emit of a stationary source.

As described in "Potential to Emit: A Guide for Small Businesses" (EPA-456/B-98-003), potential to emit considers the equipment design and can also consider certain controls and limitations on the operation of the equipment. Potential emissions can be expressed as *potential controlled emissions*, which are the pollutant emissions while a source is operating at the maximum design capacity, a schedule of 8760 hours per year, and considering the efficiency of the control equipment. In contrast, *potential uncontrolled emissions* are simply the pollutant emissions while the source is operating at the maximum design capacity and a schedule of 8760 hours per year without factoring in controls.

Startup, Shutdown, and Malfunction (SSM) emissions are emissions that occur during startup, shutdown, or malfunctions at industrial facilities. As a factual matter, the emissions rate during periods of SSM can be much larger than the emissions rates during periods of normal operating procedure (that is, not during periods of SSM). However, applicable emissions limitations apply at all times, including during periods of SSM.[15] More information about the startup and shutdown emissions in the SIP inventory context is described in Sections 4.3 and 4.8.1.

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Ozone season day emissions means an average day's emissions for a typical ozone season work weekday. The state shall select, subject to EPA approval, the particular month(s) in the ozone season and the day(s) in the work week to be represented, considering the conditions assumed in the development of RFP plans and/or emissions budgets for transportation conformity.

2.5.3 Duration and Timing of Emissions

Inventory start date means the first day of the inventory period. This can be used for compiling and reporting monthly or other shorter period emissions, including events.

Inventory end date means the last day of the inventory period. This can be used for compiling and reporting monthly or other shorter period emissions, including events.

Inventory year or Emissions year means the year for which emissions estimates are reported (40 CFR 51.50).

See also "Emission Type" in codes Section 2.5.14.

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[14]

[15] On May 22, 2015, the EPA issued a final action to ensure that states have plans in place that are fully consistent with CAA and court decisions concerning SSM operations. This action included a "SIP call" that directs 36 states to correct specific SSM provisions in their SIPs. The SIP submission deadline for the states subject to this action is November 22, 2016. See the rule website for more information.

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2.5.4 Data Elements

The term data elements means parts of a data file that contain individual items of data. These are also called fields or variables. Examples of key data elements associated with emissions inventories include emissions; activity; emission factors; state/county identifiers; facility, unit, and process identifiers; plant names; control measure codes; and process codes. This list is just a sample and is not intended to represent a comprehensive list of required codes (see also Section 2.5.7).

Note that emissions data categories (Section 2.5.1) are not a data element per se, but rather emissions inventory submissions usually are broken out into separate datasets for each data category.

2.5.5 Throughput and Activity

Throughput means a measurable factor or parameter that relates directly or indirectly to the emissions of an air pollution source during the period for which emissions are reported (40 CFR 51.50). Throughput is also called activity. Depending on the source category, activity information may refer to the amount of fuel combusted, raw material processed, product manufactured, or material handled or processed. It may also refer to population, employment, miles travelled, or number of existing units. Activity throughput is typically the value that is multiplied against an emission factor to generate an emissions estimate. Consequently, it is important to coordinate activity used for a given emissions source with the available emission factors for that source.[16]

There are some special types of activities always used for certain categories. Examples for mobile sources include:

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Vehicle Miles Traveled (VMT): The number of miles travelled within a year or as an average daily value for all vehicles within a group (e.g., vehicle type, fuel type, and county). See also MOVES Technical Guidance (http://www.epa.gov/otaq/models/moves/index.htm#sip).

Vehicle population: The number of vehicles of a certain type and fuel usage within a group (such as a county).

Equipment population: The number of nonroad equipment units of a certain type and fuel usage within a group (such as a county).

2.5.6 Emission Factors

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

[16] Some air agencies have raised the concern that throughput at industrial facilities is considered confidential business information (CBI), however, this field is required by the AERR. Since this field is "emission data" required by the AERR, it cannot be protected as CBI under CAA section 114(c).

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Emission factors have long been the fundamental key to developing emissions inventories for air quality NAAQS implementation. More information on emission factors is available from the Clearinghouse for Inventories and Emissions Factors (https://www.epa.gov/chief/) on the EPA website.

The general equation for emissions estimation is:

where:

E = emissions,
A = activity total,
EF = emission factor, and
ER = overall emission reduction efficiency percent.

The *ER* term is the combination of the relevant percents related to emissions controls and rules that reduce emissions, as listed in Section 2.5.18.

Emission factors are not limited to factors that are only represent broad national industry averages published by the EPA. Emission factors can also be stack-, process-, unit-, or facility-specific, depending on the basis of the source test information. Whether for a single facility or a group of facilities of the same type, it is still considered an emission factor for the purposes of this guidance.

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2.5.7 Emissions Reporting Data Elements

The Ozone Implementation Rule and $PM_{2.5}$ SIP Requirements Rule refer to the AERR and this guidance for information on reporting data elements. Since the AERR is focused on emissions submitted for the annual NEI inventory, it only includes definitions for those data and fields that are *required* by the NEI program. For ozone SIP inventories, ozone season day emissions are required, but are optional for reporting in accordance with the AERR. For PM SIP inventories, either or both annual or average season day emissions can be included (depending on the circumstances), but the average season day emissions are optional for reporting for AERR purposes.

The many required and optional data elements for emissions inventories are described in Excel files called Staging Requirements. These files are comprehensive for all of the required and optional fields that can be submitted to the EPA for SIP inventories, not only the submissions for the NEI. The shared field list for NEI and SIP inventories helps air agencies by promoting clarity and familiarity through common data element definitions across multiple inventory requirements. The descriptions provided in those Excel files are very limited, so this document provides additional information for the most important of these fields. These spreadsheets are available at the Emissions Inventory Training website at https://www.epa.gov/air-emissions-inventories/air-emissions-inventory-training using the links for "Training Materials" listed for each training on the page. Within the Zip file provided for the "Training

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Materials" links, an Excel file is available that includes "staging requirements" and lists the data elements and their definitions.

Although many fields in the Staging Requirements are optional for AERR reporting purposes, some of these fields can be critical for inventory development for SIPs and even the NEI. By "optional," we mean those fields that are not explicitly required by the AERR or that are not enforced during electronic reporting as needing to be provided to successfully submit the data to the EPA. The list below identifies fields that are "optional" but that are strongly recommended to be included in all emissions inventories, documentation, and reporting as applicable for the sources in the state or NAA. For example, control parameters are optional only because emissions controls do not exist on every unit and process in an inventory, thus the EPA cannot enforce this during electronic reporting as a required field. However, the control information is required by the AERR when it exists at the emissions source and should be provided for SIP inventories.

Unit Description: This field describes the unit in words. It can be invaluable in determining incorrect source classification codes (SCCs).

Unit design capacity: Unit design capacity means a measure of the size of a point source, based on the reported maximum continuous throughput or output capacity of the unit (40 CFR 51.50). Useful for boilers, this field is needed when trying to understand the cost per ton of pollutant emissions reduced associated with controls on boilers. The cost per ton is generally higher for smaller boilers. The design capacity can be critical in SIP planning for insuring that good decisions are made about controls on stationary boilers and other units. While required by the AERR, the EIS does not enforce this field as many states do not have this information available. By including these data in SIP inventory development, states can help to further improve the data available to them for decision making as well as for consideration by the EPA.

Control measure: This field is a unique code for the type of control device or operational measure (e.g., wet scrubber, flaring, process change, and ban) used to reduce emissions (see 40 CFR 51.50). When assessing whether an emissions source can be further controlled to contribute emissions reductions needed for attainment, it is imperative to know whether there is a control measure included on a unit or process. The type of measure is also needed to understand whether other controls can be added. The associated data elements such as control efficiency, capture efficiency, rule effectiveness, and rule penetration are all useful as well for the same reasons. These latter control parameters are also needed when calculating potential controlled emissions.

Alternative facility names or identifiers: This field can be very useful in matching the facility with other databases, such as the Toxics Release Inventory, the Federal Registry System, or the National Electric Energy Data System (NEEDS) database. If air agencies change their agency IDs (facility, unit, process, and release point) from one year to the next, this table can help prevent creating duplicates in the EIS and other databases.

EIS IDs: While the EIS Facility ID, Unit ID, Process ID, and Release Point ID (see Section 2.5.15) are not required by the AERR or for SIP inventories, it is the standard by which the EPA compiles and reports all

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point source inventories. The EPA reports and modeling all use these EIS IDs, and so to the extent air agency databases can use these IDs in their data systems, it helps facilitate matching across the many purposes for inventories.

Release Point Geographic Coordinates: As described in Section 2.5.17, the EIS and inventories generally can have location coordinates (i.e., latitude/longitude) for a facility or at individual release point locations.

2.5.8 Point Sources

As defined by the AERR in 40 CFR 51.50, point sources are large, stationary (non-mobile), identifiable sources of emissions that release pollutants into the atmosphere. A point source is a facility that is a major source under 40 CFR part 70 for one or more of the pollutants for which reporting is required by 40 CFR 51.15 (a)(1). This does not include the emissions of hazardous air pollutants, which are not considered in determining whether a source is a point source for ozone, $PM_{2.5}$, and regional haze emissions inventory development and reporting. These point sources can be associated with a single point or group of points in space. Examples of important point source emissions categories include power plants, industrial boilers, petroleum refineries, cement plants, and other industrial plants.

According to the ozone and $PM_{2.5}$ Implementation Rules, the AERR governs the emissions level above which sources are inventoried as point sources. While the AERR also requires data from state agencies for use in the NEI, the AERR emissions point source thresholds have been coordinated with the various SIP implementation rules and definitions of major sources and, therefore, they apply to all inventories provided to the EPA. The AERR bases the emissions level on a potential to emit emissions size threshold. Table 7 provides the potential to emit point source reporting thresholds included in the AERR. For evaluating the potential to emit threshold, it is appropriate to use potential *controlled* emissions for controlled sources. As shown in Table 7, special requirements apply to NAA sources, where even lower thresholds may apply depending upon the severity of the NAA classification.

Air agencies may include point sources at even lower levels in their NEI or SIP planning and modeling inventories. The AERR thresholds simply provide a minimum requirement. Depending on the nature of the nonattainment problem and the need to characterize smaller sources as point sources, a state may want to consider and the EPA Regional offices may encourage lower thresholds so air agencies can produce effective SIPs.

Type A source means a large point source with potential annual emissions of any CAP or CAP precursor greater than or equal to the corresponding emission threshold listed in the AERR. These sources must be reported by states every year and have higher reporting thresholds. The thresholds are not repeated in the table below because they are not relevant for the definition of point sources for SIP inventory purposes, which follow the Type B thresholds for triennial reporting as shown below. See Appendix A of 40 CFR part 51, Subpart A for the Type A source thresholds.

Type B source means a point source smaller than a Type A source with potential annual emissions of any CAP or CAP precursor greater than or equal to the relevant Type B emission threshold listed in the AERR and in this section. Type B point sources are required by the AERR to be included in a state or local

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inventory submission for point sources in the triennial years and are applicable to SIP planning and modeling inventories as well.

Table 7: Point source triennial reporting thresholds (potential to emit) for criteria pollutants in the Air Emissions Reporting Rule[17]

Pollutant		Triennial NEI thresholds: potential to emit (tons/yr)	
		Type B sources (default)	NAA sources
1	SO2.....	≥ 100	≥ 100
2	SO2.....		$PM_{2.5}$ (Serious) ≥ 70
3	VOC or NOx....	≥ 100	≥ 100
4	VOC or NOx....	.....	O_3 (Moderate within OTR) ≥ 50[+]
5	VOC or NOx....	.....	O_3 (Serious) ≥ 50
6	VOC or NOx....	.....	O_3 (Severe) ≥ 25
7	VOC or NOx....	.....	O_3 (Extreme) ≥ 10
8	VOC or NOx....	.....	$PM_{2.5}$ (Serious) ≥ 70
9	VOC.....	.....	O_3 (within OTR) ≥ 50[+]
10	CO.....	≥ 1000	≥ 1000[+]
11	CO.....	.....	CO (all areas) ≥ 100
12	Pb.....	≥ 0.5[18*]	≥ 0.5
13	PM_{10}.....	≥ 100	≥ 100
14	PM_{10}.....	.....	PM_{10} (Serious) ≥ 70
15	$PM_{2.5}$.....	≥ 100	≥ 100
16	$PM_{2.5}$.....	.....	$PM_{2.5}$ (Serious) ≥ 70
17	NH_3.....	≥ 100	≥ 100
18	NH_3.....	.....	$PM_{2.5}$ (Serious) ≥ 70

[+] This threshold for ozone nonattainment areas is incorrectly listed in the AERR as 100 tpy. This is not consistent with other regulations. The EPA is working to make this correction in the AERR.

* The lead threshold is in actual emissions rather than potential to emit to be consistent with the lead monitoring rule requirements.

2.5.9 Nonpoint Sources

Nonpoint sources are also called "area sources".[19] These sources collectively represent individual sources of emissions that have not been inventoried as specific point or mobile sources. These individual sources treated collectively as nonpoint sources are typically too small, numerous, or difficult to inventory using the methods for the other classes of sources. Examples of key nonpoint sources include residential combustion, institutional and commercial boilers, agricultural burning, industrial and non-industrial solvents and graphic arts, degreasing, most agricultural sources, consumer products, architectural coatings, and sources of dust including roads and construction.

17

18

[19] This data category type is different from the air toxics definitional of "area sources" as defined by CAA section 112(a)(2).

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2.5.10 On-road Mobile Sources

On-road mobile sources are also called "highway mobile sources." These sources are the motor vehicles (e.g., automobiles, buses, trucks) traveling on local and highway roads. A motor vehicle is any self-propelled vehicle used to carry people or property on a street or highway (40 CFR 51.50). On-road mobile sources should be estimated by the latest recommended on-road mobile source models. Currently, that means the MOVES model for all states but California, and the [20]EMFAC[21] model for California.

2.5.11 Nonroad Mobile Sources

Nonroad mobile sources are also called "off-highway" mobile sources. These are defined as a nonroad engine or nonroad vehicle. As per 40 CFR 51.50, a nonroad engine is an internal combustion engine (including the fuel system) that is not used in a [on-road] motor vehicle or a vehicle used solely for competition, or that is not affected by sections 111 or 202 of the CAA. Also defined by 40 CFR 51.50, a nonroad *vehicle* (rather than engine) is a vehicle that is run by a nonroad engine and that is not a [on-road] motor vehicle or a vehicle used solely for competition. Examples of nonroad mobile sources include aircraft, airport ground support equipment, locomotives, CMVs, construction equipment powered by an internal combustion engine, agricultural equipment powered by an internal combustion engine, and lawn and garden engines and equipment.

There are a variety of tools for estimating emissions from nonroad mobile sources. The EPA develops and maintains approaches for aircraft, locomotives, and CMVs, which are documented as part of the NEI program (for the latest approaches, refer to the latest NEI documentation.

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Starting with the MOVES2014a version of MOVES, the MOVES model should be [22]used for nonroad source emissions. MOVES2014a includes features not previously available in MOVES that simplify processing of emissions output and includes updated fuel input files that result in small changes in emission results. In addition, the prior tools available for nonroad emissions estimations (NONROAD2008 and NMIM2008) may no longer work with current operating systems, and the EPA cannot continue to provide technical support for these models. Therefore, the EPA recommends that for modeling nonroad emissions, MOVES2014a be used for all new SIP development, although state and local agencies that have already completed significant work with MOVES2014, NONROAD2008, or NMIM2008 can continue to do so to allow for timely submission of the SIP. As a general matter, air agencies should review and possibly update and customize the MOVES model inputs to give better emissions estimates for their state.

Unlike models for onroad emissions, the EPA does not specifically "approve" nonroad models. However, use of alternative models can be justified as part of a SIP submission. For example, California has previously developed and used a state-specific approach for estimating its nonroad source emissions for SIP purposes, called OFFROAD2007

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[20]

[21] The EMFAC model name is not an acronym. The documentation and website for EMFAC do not include a further explanation of the name.

[22]

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(http://www.arb.ca.gov/msei/offroad/downloads/models/offroad2007_1215_exe.zip). This model has now been replaced by category-specific methods for many categories (see http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles). As described by the website, the OFFROAD2007 model is still the default approach for categories not listed with newer methods on the website. Any use of such an alternative approach is subject to review by the EPA as part of the review of the SIP, and thus states are encouraged to coordinate with Regional offices on any use of alternative models.

2.5.12 Events

Starting with the 2008 NEI, the EIS introduced a new data category called "Events," which are discrete and large emissions sources that individually occur over a short period of time, but which can collectively result in a significant amount of emissions. Example events captured by this data category include naturally occurring wildfire and a managed prescribed burns. In EIS, these data are stored as day-specific events that can span many days for a given fire/event. More information on events data and its unique nature is available in Section 4.8.7.

2.5.13 Biogenic Sources

For the purposes of creating emissions inventories, biogenic emissions come from natural sources. They need to be accounted for in photochemical grid models, as many types of biogenic emissions are widespread and ubiquitous contributors to atmospheric chemistry leading to ozone and PM formation. In the NEI, only the emissions from vegetation and soils are included, but other relevant sources include volcanic emissions, lightning, and sea salt spray.

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Biogenic emissions from vegetation and soils are computed using models that utilize spatial information on vegetation and land use. The models also use environmental conditions of temperature and solar radiation to apply emission factors. The model inputs are typically horizontally allocated (gridded), and the outputs are gridded biogenic emissions, which can then be summed for use in planning inventories and speciated and utilized as input to photochemical grid models. As described in Section 4.8.6, a variety of models are available to estimate the emissions from vegetation and soils.

2.5.14 Inventory Codes

The list provided below is a sample of the codes that can be used in building inventories; it is not a comprehensive list of codes that should be used in building inventories. The EIS is the repository for the most updated valid codes used for building inventories. Dozens of tables of codes are available to EIS users from the "Reporting Code Tables" link on the EIS Gateway. For others who do not have access to the EIS (e.g., contractors not working for a state, international users, and the general public), the EPA periodically posts Microsoft ® Access ® compilations of these codes at the Emissions Inventory System Gateway under the "Reporting Code Tables" link.

Source classification codes: An SCC means a process-level code that describes the equipment and/or operation [or practice] that is emitting pollutants (40 CFR 51.50).[23] These codes are 8 digits for point

[23] Several air agencies have raised the concern that SCC at industrial facilities is considered CBI. However, this field is "emission data" required by the AERR and thus cannot be provided as CBI under CAA section 114(c).

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sources and 10 digits for nonpoint and mobile sources. The codes have multi-level descriptions, which are included in the EIS codes table. These codes are also used in the emission factors online database WebFire (https://www.epa.gov/electronic-reporting-air-emissions/webfire). The EPA also provides a web service with the most current list of codes, available at https://ofmpub.epa.gov/sccwebservices/, and an SCC search page at https://ofmpub.epa.gov/sccsearch/.

North American Industry Classification System (NAICS) codes: The NAICS codes are U.S. Department of Commerce's codes for businesses by products or services and have replaced Standard Industrial Classification (SIC) codes. They are assigned to facilities in inventories to identify the primary industrial activity of the facility.

Federal Information Processing Standards (FIPS) state and county codes: Federal Information Processing Standards (FIPS) codes means the system of unique identifiers maintained by the National Institute of Standards and Technology, which are used to identify counties and county equivalents (e.g., parishes, boroughs) of the U.S. and its territories (e.g., American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and US Virgin Islands). In the EIS Codes Tables, additional codes have been added to support offshore regions and sources, such as asphalt plants, that do not remain in a single county during the entire year.

Tribal codes: A three-digit code that represents the American Indian Tribe or Alaskan Native entity. The EIS Table also identifies which EPA region is associated with the tribe. These codes are used instead of FIPS state and county codes when reporting emissions from tribal areas.

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Pollutant codes: Pollutant code means a unique code for each reported pollutant assigned by the reporting format specified by the EPA for each inventory year (40 CFR 51.50). All of the criteria pollutants, except for lead, have codes that describe them: CO, NOX, VOC, SO2, NH3, PM10-PRI, PM10-FIL, PM25-PRI, PM25-FIL, and PM-CON. Lead and the hazardous air pollutants (HAPs) use numerical codes[24] to represent them, for example elemental lead is 7439921 and elemental mercury is 7439976.

Control measure codes: Control measure means the name of the type of control device (e.g., wet scrubber, flare, baghouse) or practice (e.g., product substitution). The EIS Code Tables use a three-digit numeric control measure code to represent each of the different types of controls, and identifies each as a device or a practice. The control device type codes were updated with additional codes in 2013. These codes are required when control devices are present because they are critical to understanding the nature of the emissions source and the possibility of additional emissions reductions to achieve attainment.

Emission calculation method: This field is the code describing how the emissions for a pollutant were calculated (e.g., by stack test, continuous emissions monitor, EPA emission factor, etc.) (40 CFR 51.50). This is a required field for inventories because it allows the EPA to get some sense of the quality of the emissions estimate. Comment fields can also be used to further explain the origin of the emissions

[24] These numerical codes are the unique numerical identifiers assigned and maintained by the Chemical Abstracts Service (CAS) and are often referred to as CAS numbers or CAS registry numbers. The CAS numbers often appear with dashes embedded in the string of numbers, but these are dropped for most inventory reporting purposes.

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estimate.

Reporting period type: This field is the code describing the time period covered by the emissions reported (i.e., annual, 5-month ozone season (previously used for NOx SIP call), ozone season day, or average season day) (40 CFR 51.50). In concert with the release of the final PM SIP Requirements Rule, a new code ("ASD") has been updated in EIS to support submissions to EIS of average season day emissions used for SIPs addressing the 24-hour $PM_{2.5}$ standard. This field is also called the emission type code in some references.

2.5.15 Point Source Facility Details

See also Section 2.5.7, which points to the spreadsheets available that list all required and optional emissions inventory data elements.

Facility Inventory means the data tables of all facility information included in the EIS, but could also be used to refer to similar data tables for any inventory storage system. The facility inventory is the complete list of facilities, units, processes, and stacks associated with all point sources. It is designed to be the latest repository of facility information and needs updating only when changes occur to facilities. The facility inventory concept was intended to allow facility data to be constant except where real changes occur, allowing easier building and submitting of inventories and encouraging the use of consistent facility IDs, unit ID, process ID, and stack IDs from one inventory year to the next.

Physical address means the location address (street address or other physical location description), locality name, state, and a postal zip code of the facility. This is the physical location where the emissions occur, not the corporate headquarters or a mailing address (40 CFR 51.50).

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Site name (also called Facility Site Name) means the name of the facility emitting emissions that are included in the inventory (40 CFR 51.50).

EIS ID means any facility, unit, process, or release point (stack) ID generated by the EIS and intended to remain constant for the life of that facility, unit, process, or stack across inventory years. The proper names of the EIS IDs in the EIS system are EIS Facility Site Identifier, EIS Emission Unit Identifier, EIS Emission Process Identifier, and EIS Release Point Identifier.

Agency ID means any facility, unit, process, or release point (stack) ID generated by an agency reporting emissions to the EPA. These IDs are used in the air agency data systems and may not match the EIS IDs described above. The EPA tracks both the EIS IDs and agency IDs within the EIS. Using consistent agency IDs from year to year is highly encouraged, as it allows the EPA to more readily see which facilities are being reported for the AERR requirements. Using inconsistent agency IDs can result in duplicative facilities, units, processes, and release points within the EPA data systems.

Facility ID code (also called "Facility site identifier)" means the unique codes for a plant or facility treated as a point source, containing one or more pollutant-emitting units (40 CFR 51.50). The EPA's reporting format for a given inventory year may require several facility ID codes to ensure proper matching between databases (e.g., the state's own current and most recent facility ID codes, the EPA-assigned facility ID codes, and the ORIS (Department of Energy) ID code if applicable).

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Unit ID code means a unique code for the unit that generates emissions, typically a physical piece of equipment or a closely related set of such equipment (40 CFR 51.50). An example of a closely related set of equipment is a boiler and its control equipment. The EPA's reporting format for a given inventory year may require multiple unit ID codes to ensure proper matching between databases (e.g., the state's own current and most recent unit ID codes, the EPA-assigned unit ID codes if any, and the ORIS (Department of Energy) ID code if applicable).

Process ID code is also called the "emission process identifier" and it means a unique code for the process generating the emissions, typically a description of a process (40 CFR 51.50).

Release Point ID code means a unique code for the point where emissions from one or more processes release into the atmosphere (40 CFR 51.50). Traditionally called a Stack ID, but this was changed with EIS to acknowledge that many emissions releases do not come from stacks, such as fugitive emissions.

Release point type code means the code for physical configuration of the release point (40 CFR 51.50). The physical configurations include fugitive, vertical, horizontal, goose neck, vertical with rain cap, and downward-facing vent. The first two types are the most common. The release point type is particularly important for dispersion modeling needed for permitting, risk modeling, and other purposes.

Release Point Diameter Measure (or Stack diameter) means the inner physical diameter of a stack (40 CFR 51.50). This should be measured at the exit release point of the emissions, and the expected reported units are feet.

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Release Point Height Measure (or Stack height) means physical height of a stack above the surrounding terrain (40 CFR 51.50). Expected reported units are feet.

Release Point Exit Gas Flow Rate Measure (or Exit gas flow rate) means the numeric value of the flow rate of a stack gas (40 CFR 51.50). Various units are permitted by the EIS.

Release Point Exit Gas Temperature Measure (or Exit gas temperature) means the numeric value of the temperature of an exit gas stream in degrees Fahrenheit (40 CFR 51.50).

Release Point Exit Gas Velocity Measure (or Exit gas velocity) means the numeric value of the velocity of an exit gas stream (40 CFR 51.50). Various units are permitted by the EIS.

2.5.16 Alternative IDs

In addition to the primary facility, unit, process, and release point IDs, alternative IDs can be very useful for matching information in a given inventory to other databases. In the case of the EIS, it stores not only the EIS unique IDs, but also the air agency IDs. Other IDs are stored as well, including the following:

EIA Plant Code (a.k.a ORIS Plant Code). This plant ID is defined by the U.S. Department of Energy (DOE) Energy Information Administration (EIA) and used in its EIA-767 form. It has previously been defined as the Office of Regulatory Information System (ORIS) code, though that term is no long used by DOE. The EPA's Office of Atmospheric Programs' (OAP) Clean Air Markets Division (CAMD) uses whatever code was originally assigned to the facility as the tracking code for compiling data for its emissions markets in

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support of the acid rain program and NO_X trading, in particular the CEMS data.

CAMD Unit ID. In addition to the EIA facility IDs, CAMD uses unit IDs for storing the emissions markets data as well. The EIS stores the unit codes used by CAMD as an alternative ID called "EPACAMD," and the values are usually based on the CAMD hourly CEMS data reports. These have historically also been referred to as ORIS Boiler or ORIS Unit IDs, however, those references are no longer valid.

IPM/NEEDS ID. The EPA Integrated Planning Model (IPM) is used to forecast future-year electricity demand and emissions. Underlying this model is the National Electric Energy Data System (NEEDS) database that contains the generation unit records used to construct the "model" plants that represent existing and planned/committed units in EPA modeling applications of IPM. This database mostly uses IDs that are often the same as the EIA Plant Codes and the CAMD Unit IDs, but this database has more units than are included in the hourly CEMS data. In the EIS, the EPA stores these alternative IDs as "EPAIPM" IDs.

Toxics Release Inventory (TRI) ID is used by the EPA's Office of Environmental Information to build the Toxics Release Inventory from facility-submitted facility-total emissions to air, water, and land. This database includes NH_3, which is why it can be relevant to the NAAQS for $PM_{2.5}$ implementation. In the EIS, the EPA stores these alternative IDs as "EPATRI" IDs.

Federal Registry Service (FRS) ID is used by the EPA's Office of Environmental Information to link many EPA databases with facility information (see https://www.epa.gov/enviro/facility-registry-service-frs).

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2.5.17 Location Definitions

Geographic locations are critical in point source inventories for identifying the location of the emissions. In the EIS, locations can be provided for both the facility center and for individual release points. Fugitive release points have additional parameters that can be specified, such as the orientation of the release, and these parameters are listed in the spreadsheets available that list all required and optional emissions inventory data elements, referenced in Section 2.5.7.

Latitude Measure (or just latitude) is the measure of the angular distance on a meridian north or south of the equator. Reported as decimal degrees.

Longitude Measure (or just longitude) is the measure of the angular distance on a meridian east or west of the prime meridian. Reported as decimal degrees.

Horizontal Accuracy Measure is the measure of accuracy (in meters) of the latitude/longitude coordinates.

In addition, refer to https://www.epa.gov/geospatial/latitudelongitude-data-standard for more information on the proper usage of the following code set.

Horizontal Collection Method Code is the method used to determine the latitude/longitude coordinates for a point on the earth. For example, 001 is address matching-house number, and 004 is address matching nearest intersection.

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Horizontal Reference Datum Code represents the reference datum used to determine the latitude/longitude coordinates. Options are: 001 (North American Datum of 1927), 002 (North American Datum of 1983), and 003 (World Geodetic System of 1984).

Geographic Reference Point Code represents the place for which geographic coordinates were established. Code value should be 106 (e.g., point where substance is released).

2.5.18 Control Data Elements

Control efficiency means the efficiency by which a control device or measure reduces emissions for a particular pollutant. For emissions reporting in accordance with the AERR, this data element applies for both point and nonpoint sources and is called the "*Percent Control Measures Reduction Efficiency.*" For point sources, the data element is included in the "*Control Pollutant Table*" of the facility staging tables. For nonpoint sources, the data element is included in the "*Control Pollutant Table*" of the nonpoint staging tables. In the EIS, it is a percent and should be reported as a value greater than or equal to 0.1 and less than or equal to 99.9 (the EIS allows for one decimal place only).

Control Capture efficiency means the percentage of an exhaust gas stream actually collected for routing to a set of control devices (40 CFR 51.50). It is sometimes combined within the value for the control efficiency, but unlike control efficiency, it is not pollutant-specific. For emissions reporting in accordance with the AERR, this data element is for point sources only, and it is called "*Percent Control Capture Efficiency*" and is included in the "*Control Approach Table*" of the facility staging tables. It is a percent and should be reported as a value greater than or equal to 0.1 and less than or equal to 99.9 (the EIS allows for one decimal place only).

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Control Effectiveness means the percentage of time or activity throughput that a control approach is operating as designed, including the capture and reduction devices. This percentage accounts for the fact that controls typically are not 100 percent effective because of equipment downtime, upsets and decreases in control efficiencies (40 CFR 51.50).

Control effectiveness is an estimate of the portion of the reporting period's activity for which the overall control system or measure (including both capture and control measures) were operating as designed (regardless of whether the control measure is due to rule or voluntary). It applies to both point and nonpoint sources and is not pollutant-specific. For point source emissions reporting in accordance with the AERR, this data element is called "*Percent Control Approach Effectiveness*" and is included in the "*Control Approach Table*" of the facility staging tables. For nonpoint source emissions reporting in accordance with the AERR, this data element is also called "*Percent Control Approach Effectiveness*" and is included in the "*Control Approach Table*" of the nonpoint staging tables. In the EIS, it is a percent and should be reported as a value greater than or equal to 0.1 and less than or equal to 99.9 (the EIS allows for one decimal place only). For nonpoint, see also "rule effectiveness," below.

Rule penetration means the percentage of a nonpoint source category activity that is covered by the reported control measures (40 CFR 51.50). For emissions reporting in accordance with the AERR, this data element is called "*Percent Control Approach Penetration*" and is included in the "*Control Approach Table*" of the nonpoint staging tables. In the EIS, it is a percent and should be reported as a value greater

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than or equal to 0.1 and less than or equal to 99.9 (the EIS allows for one decimal place only).

Rule effectiveness means a rating of how well a regulatory program achieves all possible emissions reductions. It is analogous to the "control effectiveness" above and, for emissions reporting in accordance with the AERR, this information is reported using the EIS Control Effectiveness field for nonpoint (see above). Like control effectiveness, it should reflect the assumption that controls typically are not 100 percent effective because of equipment downtime, upsets, decreases in control efficiencies, noncompliance, and other deficiencies in emission control. Rule effectiveness adjusts the control efficiency from what could be realized under ideal conditions to what is actually emitted in practice due to less than ideal conditions.

2.5.19 EIS Sectors, Tiers, and Facility Type

Because emissions inventories are large and detailed, most reports about emissions inventories include summaries of the contents of those emissions. Some summaries use the data categories described above (point, nonpoint, on-road, nonroad, events, and biogenic). For other summaries, that level of detail is not enough. The EIS SCC tables provide three other mechanisms for summaries, all of which depend on SCC.

First, the SCCs have a four-part description, and the first three levels of this description could be used as a summary category. Second, the SCCs are assigned to "Tiers" using the fields "Tier 1 Description," "Tier 2 Description," and "Tier 3 Description." These Tiers have been used traditionally as part of many EPA reports and trends for criteria emissions. While wildfires are included in the "Miscellaneous" Tier 1, wildfires are sometimes separately broken out from Miscellaneous because of their natural origin and because they can be a large contributor for some pollutants. Finally, the EIS Sectors can be used to summarize emissions (this is the field "Sector" in the EIS SCC code table). The EIS Sector was added with the creation of the EIS and allocates emissions to about 60 categories with multi-pollutant inventories in mind. Whereas the Tiers are more useful for criteria pollutants, the EIS Sectors work better for the combination of HAPs and CAPs. The EIS Sectors can also be further aggregated to provide custom summaries; one example of this is presented in the report "2008 National Emissions Inventory: Review, Analysis and Highlights" (EPA-454/R-13-005, May 2013).

2.5.20 Other Terms

High electricity demand day (HEDD) means an ozone season day when demand for electricity is high. A study of the Northeast Corridor[25] air quality has indicated that NO_X emissions from EGUs during HEDD periods may be significantly greater than emissions that occur on an average ozone season day.

Distributed generation means the use of small power generators sited at or near the point of energy consumption. This usually occurs during periods of peak energy demand or emergency loss of the normal EGU generating capacity. Distributed generation sources of electricity can include rooftop solar or wind sources, biomass combustion, as well as backup fossil fueled generators or other engines. The combustion sources of distributed generation can cause emissions that could be of interest for SIP

[25] "High Electric Demand Day and Air Quality in the Northeast." White Paper Prepared by the Northeast States for Coordinated Air Use Management. June 5, 2006. Available at: http://www.nescaum.org/documents/high-electric-demand-day-and-air-quality-in-the-northeast/final-white-paper-hi-electric-demand-day-06052006.pdf.

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planning purposes.

RFP projected emissions means the estimated emissions for direct $PM_{2.5}$ and $PM_{2.5}$ plan precursors by sector for the years in which quantitative milestones are due for a nonattainment area.

3 SIP Inventory Requirements and Recommendations

As described in Section 2, there are many required and potentially required inventory efforts needed as part of a SIP development effort. This section covers the fundamental attributes of planning inventories and their preparation. The topics covered include the timing of the various inventory components (Section 3.1), the inventory preparation plan (Section 3.2), the base year inventories (Section 3.3), the ROP/RFP baseline NAA inventory (Section 3.4), the ozone periodic inventory (Section 3.5), the ozone emissions statement requirement for SIPs (Section 3.6), maintenance inventories (Section 3.7), the projected inventories (Section 3.8), public hearings (Section 3.9), and submitting the inventory to the EPA for approval (Section 3.10). The details of inventory preparation for base year inventories and projected inventories are left for Sections 4 and 5, respectively.

3.1 Inventory Component Timing

Table 8 provides the timing requirements and recommendations (for optional items) for the inventory components of SIPs. Where this table is inconsistent with the ozone, $PM_{2.5}$, or regional haze regulatory text that is applicable at the time a SIP is prepared and reviewed, the regulations have precedence over the information provided here.

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Table 8: Timing of emissions inventory components

Inventory Component	Required:	Timing
Inventory Preparation Plan		Prior to preparation of emissions inventories covered by the SIP.
Base year NAA inventory	Ozone	Within 2 years of the effective date of designations
	$PM_{2.5}$	Within 18 months from the date of a nonattainment designation.
ROP/RFP baseline NAA inventory	Ozone	*Moderate & above:* Within 3 years of the effective date of designations. *Serious & above:* Additional plan within 4 years.
	$PM_{2.5}$	Within 18 months from the date of a nonattainment designation.
Periodic NAA inventory	Ozone	The end of each 3-year period after SIP submittal until the NAA is redesignated to attainment.
Source Emission Statements requirement for SIPs	Ozone	Within 2 years of the effective date of designations.
Base case statewide inventory	Ozone and $PM_{2.5}$+	With modeled attainment demonstration (if required, for convenience, can be included with the inventory SIP).

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Attainment projected inventory for the NAA	Ozone: summary only	For Ozone, With SIP and/or ROP/RFP plan. On-road portion can become the motor vehicle emissions budget.
	$PM_{2.5}$	Within 18 months from the date of a nonattainment designation.
Projected statewide inventory (summaries)	Ozone and $PM_{2.5}$[+]	With modeled attainment demonstration (for convenience, can be included with the inventory SIP).
Baseline statewide inventory (summaries)	Haze	Previously completed for initial Regional Haze SIPs. Subsequent progress reports and SIP revisions may refer to this inventory.
Recent statewide inventory (summaries)	Haze	Needed for the progress reports that are due every 5 years (or periodically) from submittal of initial Regional Haze SIP.[Δ] Also needed to support Regional Haze SIPs for second and subsequent implementation periods, due every 10 years beginning on July 31, 2018[α]
Projected statewide inventory for 2018 (summaries)	Haze	Previously completed to support first Regional Haze SIP (due by December 17, 2007)
Projected statewide inventory for 2028, 2038, etc. (summaries)	Haze	To support Regional Haze SIPs for second and subsequent implementation periods, due every 10 years beginning on July 31, 2018[α].
Public hearing	Ozone and $PM_{2.5}$	Prior to submittal of inventory for approval by the EPA.
Inventory documentation	All	With associated SIP.
Maintenance NAA inventory	Ozone and $PM_{2.5}$	After attainment, with a redesignation SIP.

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+ Only required in association with modeled attainment demonstration. If the inventory needed for the modeled attainment demonstration is not the entire state, then a "statewide" inventory would not need to be provided, but rather the emissions from the part of the state included in the modeling domain could be provided instead.

Δ On May 4, 2016, the EPA proposed to revise the timing of and requirements for the 5-year progress report requirement so that it is not considered a SIP revision, while the 10-year requirement would remain a SIP revision (see https://www.epa.gov/visibility/proposed-rulemaking-amendments-regulatory-requirements-state-regional-haze-plans).

α In the same proposed revision noted in the previous footnote, the EPA proposed to revise the requirements for submitting SIPs that include an extension of the due date to July 31, 2021. Subsequent interim progress report submission deadlines have been proposed to be adjusted so that second and subsequent progress reports would be due by January 31, 2025, July 31, 2033, and every 10 years thereafter.

3.2 Inventory Preparation Plan

Air agencies can use IPPs as a planning tool to guide inventory preparation and to help ensure that emission estimates are of a high quality and consistent with CAA requirements. In accordance with 40 CFR 51.5(b), states are urged to use applicable, state-of-the art techniques for estimating emissions. In some cases, the EPA Regional offices will have a preset list of expectations for air agencies to include in their SIP and will provide this information to the agency at the start of the SIP planning process. In these cases, an IPP may not be needed, especially for air agencies with prior SIP development experience for a particular NAAQS.

The IPPs are an opportunity for state and local agencies to tell their EPA Regional office how they plan to compile their emissions inventories and allow the EPA to provide feedback prior to the agency spending

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resources in preparing their inventory. They can also allow the EPA Regional offices to coordinate to maintain consistency across attainment plans where that is advisable. The IPPs can be especially valuable for agencies with new nonattainment problems, less experienced inventory staff or for agencies otherwise needing additional feedback on inventory development.

If used, IPPs precede the development of inventories; therefore, the timing of IPPs is early in the SIP planning process. The EPA recommends that air planning agencies coordinate with their Regional office on the need for a plan, the timing of delivery of the plan, the response time back from the EPA on the plan, and any other IPP approval process details. Agencies should recognize that time may also be needed in their planning schedule to address the EPA comments on the plan, while the EPA Regional offices will attempt to provide as timely feedback as possible.

A high-quality IPP could be a strong foundation for the emissions inventories used in planning and/or attainment modeling, which are themselves critical pieces of SIP development; therefore, the IPP should include enough details for the EPA to properly assess what the agency plans to do. The content can include a number of key elements, for which a checklist is provided in Table 9. The actual elements to include in a specific IPP can depend on a number of factors, depending on the needs of the state or local agency as well as the EPA for understanding the inventory plans.

Table 9: Checklist of elements to consider for including in Inventory Preparation Plans

IPP Element	Important for a High Quality IPP?
Inventory objectives – the purpose and scope of the inventory	Y
The inventory year(s) and rationale for selecting them	Y
The pollutants to be included, including the expected definition of VOC (for inventories needing VOC)	Y
For $PM_{2.5}$, the temporal basis expected to be used for the SIP emissions, which can include annual, average season day, or both (see Section 4.5)	Y
A list of inventories to be included with the SIP, including the types (e.g., reports, data summaries) and formats of information (i.e., electronic data files and their expected formats, electronic media used for transfer), that the agency intends to include in their SIP	Y
Plans for (or results of) identifying the most important source sectors to the nonattainment problem	Y
The source categories to be included, the emissions level(s) for defining point sources, and if available, the expected priority for these	Y
The plans for compiling the inventory, including any other known inventories and how the agency plans to assess and improve upon what is already available	
A summary of expected approach differences among different inventories that could be the same (e.g., between a base year NAA inventory and a base year modeling inventory)	
For projected inventories: The drivers for future-year emissions growth and reductions	Y+
The source categories to be forecast	Y+

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The expected approaches for forecasting each source category	Y+
A plan for public review	
Important sources of emissions or other inventory uncertainties	
Quality assurance steps to be taken	Y
A schedule for inventory preparation, review, and submission to the EPA, including any plans to submit pieces of the inventory separately and in accordance with regulatory timeline requirements	Y

+ If a projected inventory is required.

In addition to Table 9, other inventory planning resources may be of use for agency planning purposes. During the preparation of their IPPs, state and local agencies are referred to Volume I of the EIIP guidance, available at https://www.epa.gov/air-emissions-inventories/volume-1-introduction, which discusses emissions inventory planning and development. While somewhat out of date, the EIIP volumes still can help guide new inventory developers, especially with basic information about creating emissions. Users of that document should defer to this guidance where newer information is provided, such as updated versions of mobile models. For stationary point sources, a good resource is EIIP Volume II, Chapter 1, Section 3. For nonpoint sources, EIIP Volume III, Chapter 1, Section 2 gives nonpoint-specific planning information. The mobile source volumes for EIIP are more out of date and the EPA Office of Transportation and Air Quality (OTAQ) mobile source guidance is preferable (see Table 1).

A quality assurance plan should always be a part of the IPP. In cases where a more formal QAPP is developed, the QAPP will satisfy the need for an IPP quality assurance plan. In some cases, the EPA Regional offices will include a QAPP or other quality assurance requirement as part of their CAA section 105 grant to a state that typically includes funding for emissions inventory development. Each Regional office manages its own quality assurance plan. Information about EPA quality assurance specifications and tools as well as a map that links to each Regional office's quality assurance project are available at https://www.epa.gov/quality.

For additional information on quality assurance planning, Chapter 2 of Volume VI, "*Quality Assurance Procedures and DARS software*" (https://www.epa.gov/air-emissions-inventories/volume-6-quality-assurance-procedures-and-dars-software) provides some general guidance for quality assurance and some specific approaches to uncertainty evaluation. Other quality assurance resources include Section 0 of this guidance, and quality assurance steps described in the latest NEI Technical Support Documentation available at the latest NEI documentation page link on the main NEI web page. Where air agencies are relying on their NEI submission as a starting point for meeting any SIP inventory requirements, a QAPP developed for that air agency's NEI submission may offer a starting point for the SIP inventory QAPP.

3.3 Base Year Inventory

The purpose of the base year inventory is to provide a current and comprehensive data source for emissions contributing to the air quality problem addressed by the SIP. In the case of ozone and $PM_{2.5}$, the inventory requirement is for the NAA, whereas for regional haze, the inventory requirement is for a statewide inventory. As listed in Table 4 and Table 5, the ozone or $PM_{2.5}$ SIPs can include statewide inventories as part of the modeled attainment demonstration, and these can be included as separate

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inventory submissions included with the NAA inventory.

The general SIP provisions in CAA section 172(c)(3) explains that base year inventories should include a "comprehensive, accurate, current inventory of actual emissions from all sources" in the applicable area. Details associated with preparing a base year inventory are provided in Section 4, including selection of year(s), temporal extent, spatial extent, pollutants to include, approaches for developing emissions, data codes, and quality assurance. Additionally, CAA section 182(a)(1) provides a specific base year inventory requirement for ozone SIPs. $PM_{2.5}$ SIPs generally rely on the general SIP provisions in CAA 172(c)(3), though some PM-specific elements of CAA section 189 impact the timing and other aspects of $PM_{2.5}$ SIP inventories. Other requirements for SIP inventories are found in the SIP implementation rules as listed in Table 4.

The base year inventory is the starting point from which the other SIP-related inventories are derived. These other inventories should relate to the base year inventory with regard to the emissions sources included, pollutants, temporal aspect, and other key aspects that allow the SIP to be a coherent and connected plan across the various inventories. For planning purposes, the base year inventory provides a way for decision makers to consider the sources of emissions that contribute relevant pollutants and consider emissions reductions strategies needed for the SIP.

Section 4.1 covers the choice of inventory years for the base year inventory. The choice of the inventory year for the planning is a critical one that significantly impacts the workload of inventory staff and greatly depends on availability of data and timing of other inventory efforts required by the EPA.

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Section 4.2 covers the pollutants to be included in the base year inventory. These pollutants differ depending on the nature of the air quality problem for a given SIP. Where feasible, the EPA encourages planning agencies to include precursors for all ongoing nonattainment problems in a state to promote efficiency in preparing multiple base year inventories, and to allow for the consideration of emissions reduction strategies that improve air quality across multiple air quality concerns and nonattainment issues. In addition, states may wish to include emissions of HAPs, which can have co-benefit reductions associated with strategies aimed at reducing ozone, $PM_{2.5}$, and/or regional haze.

The spatial and temporal extent of the base year inventories are also an important inventory characteristic. These topics are covered fully in Sections 4.4 and 4.5. Each of the implementation rules for ozone, $PM_{2.5}$, or regional haze has different considerations and requirements associated with the planning inventories. For example, ozone NAA inventories must include ozone season day emissions, the $PM_{2.5}$ NAA inventories can be either annual or season day (depending on the nature of the $PM_{2.5}$ nonattainment problem), and the regional haze inventories are only annual.

The Ozone Implementation Rule and $PM_{2.5}$ SIP Requirements Rule require inventories for the NAA. These inventories are called the base year inventory for the NAA. These inventories may need to be updated through multiple iterations of a SIP when they are used a baseline inventories for assessing progress for ROP/RFP. For regional haze, the inventory is commonly called the baseline inventory. For clarity here, we also call the regional haze inventory the baseline *statewide* inventory to distinguish it from a NAA inventory.

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3.4 Rate of Progress and Reasonable Further Progress Baseline NAA Inventory

RFP is a concept included in the CAA under Part D, Title I to assure that states take steps to ensure that the air quality in NAAs makes steady and incremental progress toward attaining air quality standards. The ROP/RFP baseline NAA inventory is necessary for ozone NAAs designated as Moderate and above. This baseline inventory is part of a plan or plans that meet the RFP requirements as described by the CAA and the Ozone Implementation Rule, and summarized here. The $PM_{2.5}$ SIP Requirements Rule also includes requirements for RFP as described below. Though there are specific considerations related to ROP and RFP, **the anthropogenic portion of the base year inventory for the NAA also serves as the base ROP/RFP baseline NAA inventory for both ozone and $PM_{2.5}$ SIP development.**

3.4.1 Ozone ROP/RFP Requirements and Timing

CAA section 182(b)(1)(A) requires Moderate and above NAAs to submit a plan to ensure a 15 percent VOC reduction (accounting for growth) by 6 years after the NAA designation, which is the Moderate area maximum attainment date. The 15 percent reduction requirement is commonly called "rate of progress" or ROP. According to the Ozone Implementation Rule, air agencies must submit this plan within 3 years after the area's nonattainment designation. This timing aligns with the Moderate NAA deadline for submitting attainment demonstration SIPs.

In addition, CAA section 182(c)(2)(B) requires each Serious and above ozone NAA to submit a plan to achieve at least a further annual 3 percent VOC reduction. Additionally, CAA section 182(c)(2)(C) allows for substitution of NO_X for VOC emissions reductions in the plan under certain conditions. This requirement is also called "annual RFP." As described by the Ozone Implementation Rule, the annual RFP requirement applies for any remaining 3-year periods out to the attainment date beyond the first 6 years. According to the Ozone Implementation Rule, air agencies with NAAs classified as Serious and higher must submit this plan within 4 years after the area's nonattainment designation. This timing aligns with the Serious and higher areas' deadline for submitting attainment demonstration SIPs; however, these NAAs still must submit the plan for ROP within 3 years.

States maintain the flexibility to submit plans early to provide more time for implementation of their SIP control measures. The EPA recommends that states complete their ROP/RFP plans as expeditiously as practicable after designation to provide as much time as possible for sources to implement the emission reductions.

The associated terminology for the various plans and inventories can be confusing, and so the terminology used in this guidance is described here. In this guidance, we use "ROP/RFP plan" to refer generally to all plans (i.e., those addressing just the 15 percent ROP requirement for Moderate areas as well as plans additionally addressing the annual RFP requirement). For Serious and above areas, since the timing allows that two separate plans for ROP and annual RFP could be submitted (i.e., at 3 years and 4 years after designations, respectively), it may also be necessary to refer to such plans separately. Consequently, this guidance uses "ROP/RFP plan(s)" to allow for the idea that multiple plans could be submitted. Lastly, in the case where the individual plans must be referenced, they will be called "ROP plan" and "RFP plan."

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3.4.2 Ozone ROP/RFP Emissions Guidance

The same ROP/RFP baseline NAA inventory is used for all ROP/RFP plan(s), regardless of whether they address the ROP requirement (for Moderate areas) or both ROP and annual RFP (for Serious and above). As implied by the name, these inventories include emissions data just for the NAA region and not other areas in a state. The purpose of the ROP/RFP baseline NAA inventory is to provide a reference point to determine the emissions reductions that must be achieved for the 15 percent VOC (or NO_X) reduction and the subsequent 3 percent reductions for Serious areas and above out to the attainment date. This requirement stems from CAA requirements.

For ozone, VOC and NO_X should be included in the ROP/RFP baseline NAA inventory. Further, the EPA expects that the year of the ROP/RFP baseline NAA inventory will be the same year used for the base year inventory for the NAA.

For ozone, the ROP/RFP baseline NAA inventory emissions should be provided using the same base year as is used for base year inventory for the nonattainment area. In most cases, the ROP/RFP baseline inventory should also have the same emissions values as are in the base year inventory for the NAA. One key exception is that biogenic emissions should not be included in the ROP/RFP baseline.

The EPA also expects that the spatial extent of the ROP/RFP baseline NAA inventory will also match the base year NAA inventory so that they are both either "whole county" inventories or both consistently "partial county" inventories. Section 4.4.1 provides more information on partial county inventories.

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In the event that updated ROP/RFP plan(s) are needed after initial submittal to meet the requirements of the Ozone Implementation Rule, the ROP/RFP baseline NAA inventory may also need to be updated. This can occur with significant methods changes, such as updated mobile models. For example, after an initial ROP/RFP plan has been submitted as part of a SIP, a new mobile model may become available that alters the emissions estimates. It would be inconsistent to compare estimates from a new mobile model at the end of a 6-year period to estimates using an old model at the beginning of that 6-year period, and so the EPA could be unable to determine whether a 15 percent reduction (or subsequent 3 percent reductions) can be (or has been) achieved by an ROP/RFP plan. Thus, an updated ROP/RFP baseline NAA inventory may need to be created using the updated mobile model to appropriately meet the requirements of the Ozone Implementation Rule.

Additional ROP/RFP emissions reductions guidance is provided in Section 3.8.2.

3.4.3 $PM_{2.5}$ RFP Requirements and Timing

Section 172 of the CAA addresses the $PM_{2.5}$ attainment plan provisions in general. In addition, Section 189(c) of the CAA requires that $PM_{2.5}$ SIPs contain quantitative milestones, which are to be achieved every 3 years until the area is redesignated attainment and which demonstrate reasonable further progress. For Moderate areas, these quantitative milestone years would be no later than 4.5 and 7.5 years after designation of the area. For Serious areas, these quantitative milestone years are no later than 7.5 and 10.5 years after designation of the area. Most (if not all) Serious areas will have first been Moderate areas, and thus could also be subject to the quantitative milestone at 4.5 years as well.

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In the $PM_{2.5}$ SIP Requirements Rule, one required element of an RFP plan is RFP projected emissions by sector and precursor pollutant for each applicable quantitative milestone year. In addition, the emissions reductions must show that the implementation schedule (of reductions) achieves either (1) generally linear progress toward the projected attainment date; or (2) stepwise progress toward the projected attainment date. The rule also holds out the possibility that a state could develop an approvable RFP plan even if emissions of one or more $PM_{2.5}$ plan precursors were not decreasing; however, additional analysis would need to be done (as described in the rule).

3.4.4 $PM_{2.5}$ RFP Emissions Guidance

For $PM_{2.5}$ SIPs, all plan precursors must be included in the RFP emissions provided as part of the RFP plan. Further, the EPA expects that the year of the RFP baseline emissions will be the same year used for the base year inventory for the NAA.

Unlike other emissions inventory requirements, the $PM_{2.5}$ RFP requirement does not specify that detailed projected emissions *inventory* data must be developed and submitted to the EPA. The emissions requirement for most sectors is for *"RFP projected emissions for direct $PM_{2.5}$ and all $PM_{2.5}$ plan precursors for each applicable milestone year,"* which does not indicate a detailed emissions inventory.[26] In addition, the $PM_{2.5}$ SIP Requirements Rule preamble specifically indicates emissions provided by sector and pollutant are expected. It would be sufficient to include a table that has rows for each sector and columns for the baseline and projected emissions of all relevant pollutants.

States may be able to develop their RFP projected emissions in some cases with less effort than it would take to do a detailed emissions inventory projection. One approach for the calculating sector/pollutant emissions for the milestone years would be to rely on the projected attainment inventory for the NAA and use linear interpolation from the baseline year to the milestone year(s). To take this approach, states should explain why the linear assumption makes sense for a particular sector. For example, residential work combustion emissions are projected to the future in part through phase-in rate assumptions for newer and lower emitting woodstoves. Using this sort of "% adoption per year" approach would support using a linear rate of change assumption such that the whole residential wood combustion sector could be interpolated between the baseline year and the projected attainment year.

3.5 Periodic Inventories

The Ozone Implementation Rule requires a periodic inventory for the NAA, and the Regional Haze Rule requires a "recent year" statewide inventory. The ozone periodic inventories should be consistent with the base year inventory in the temporal extent (seasonal, annual, or both), spatial extent (statewide, NAA counties, partial counties), and sources inventoried. In some cases for ozone, it may also be advisable to have the emissions inventory methods of the periodic inventory consistent with the base year inventory, but this decision should be made in consultation with the relevant EPA Regional office. Regional offices may consider additional relaxation of the consistency recommendation above in specific instances. For regional haze, the "recent year" inventory must always be statewide. There is no expectation that the recent year inventories for regional haze will use consistent methodologies as were

[26] For the purposes of motor vehicle emissions budgets for transportation conformity (as required by 40 CFR part 93), an inventory of onroad mobile source emissions in the NAA *is* required (*see* 40 CFR 51.1012(a)(2)).

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used for the baseline inventory for a year in the range of 2002-2004 submitted as part of the first Regional Haze SIP revision. Rather, the most recent emission estimation methods would be expected to be used.

3.5.1 Ozone Periodic Inventory

For ozone, the requirement in 182(a)(3)(A) is that the periodic inventory be submitted no later than each 3-year period after the submission of the base year NAA inventory. This language provides the flexibility to air agencies to submit sooner than 3 years, but not later than 3 years. If any other current NAA inventory is being submitted to the EPA for any reason, including ROP/RFP plans, then states should consider also using that data to meet the periodic inventory requirement. Also, if the air agency comes into attainment and receives a Clean Data Determination prior to the 3-year period, or if a maintenance plan (with a maintenance inventory) is being submitted prior to or in sync with this 3-year timetable, then the these actions are very likely to make it unnecessary for the air agency to submit a separate ozone periodic inventory.

Since the periodic inventory requirement in the CAA does not specify the degree of detail required for the periodic inventory, the EPA has defined the necessary components through the AERR. Thus, whether the inventory is submitted as a separate submission or through the AERR, it would need to be consistent with requirements of the AERR in order to meet the statutory periodic inventory requirements.

The periodic inventory is a check-in with the air agency on how the emissions are trending, and had previously been considered to not have "regulatory significance" or been treated as a SIP submission. This is no longer EPA's recommended approach. In accordance with the CAA, periodic inventories are a revision to the inventory portion of the ozone SIP and are thus subject to CAA section 110 and 40 CFR 51.102, 103, and Appendix V. For discussion of public hearings, please see Section 3.9 of this guidance document.

To meet the periodic inventory requirement for ozone, the periodic inventories must include ozone season day emissions values. Since this emissions type is allowed to be submitted to the EPA through EIS for the AERR, it is *possible* that the AERR submission could meet the periodic inventory requirement *if the conditions listed in Table 10 apply.* As with all SIP requirements, air agencies should coordinate with the Regional office regarding what is appropriate for a particular NAA.

Table 10: Conditions for AERR submittal to meet ozone periodic inventory requirement

Condition	Comment
Public hearing requirement	A public hearing has been offered and either no party requested a public hearing or a public hearing has been held. Evidence should be provided that this requirement has been met.
Ozone season day emissions must be submitted for the NAA counties	If ozone season day emissions cannot be extracted from the EIS (as is the case in 2014), using an AERR submission to meet the periodic inventory requirement is only acceptable if approved by the Regional office.

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Emissions are submitted for mobile sources.	Ongoing review of the AERR may result in requiring mobile model inputs and making emissions data optional. If this occurs, the SIP periodic inventory must still include *emissions*. Thus, emissions would need to be submitted for the NAA counties regardless of any AERR requirements to be able to meet the periodic ozone inventory requirement.
Complete – all sectors	Using the AERR to meet the periodic inventory requirement is only possible during triennial years (see Section 2.4) because the EIS only accepts nonpoint and mobile data during these years, and these data categories must be included to be complete.
Submitted within 3 years since the base year inventory.	It is acceptable to be less than 3 years, after which time the triennial submissions would be every three years.
Partial county approach approved by Regional office	The EIS does not support partial counties. In some cases, it may be acceptable to use the entire county emissions for the periodic submission.
Notification	If the AERR approach is approved, the Regional office should be notified in writing when the submission has been completed.
Documentation	Must be created. Submission is at the request of the EPA Regional office. The degree of documentation for periodic inventories can be less than that of other inventories because of the lack of regulatory significance.

3.5.2 Regional Haze Recent Year Inventory

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For the Regional Haze Rule, a recent year inventory is needed to support the analyses required with each 5-year (or "periodic," as proposed) progress report or 10-year SIP revision. The inventory is not submitted with the SIP or progress report, but emissions summaries are expected as part of the analysis provided with the SIP. The inventory to be used is a complete statewide annual inventory as was the initial baseline inventory (included in the original Regional Haze SIP). See Table 1 above for the latest reference materials with guidance on the Regional Haze Progress Reports. Since the regional haze requirement is for inventories to be statewide and cover emissions over an annual period, the spatial and temporal aspects better match the AERR reporting requirements as compared to the NAA inventories required for ozone and $PM_{2.5}$ implementation. In addition, since the recent year inventory is not an element of the SIP that must be submitted itself, there is not a public hearing requirement for the inventories used for regional haze. Thus, the AERR inventories are an appropriate starting point for meeting the requirement for the recent year **inventory for regional haze**
. If better information becomes available for particular source sectors at a time when it can be incorporated into a state's long-term strategy development, it should be.

The inventory approach for the recent year inventories needed for 5-year (or "periodic," as proposed) progress reports and 10-year SIP revisions is relatively straightforward. The following list provides considerations for states in developing their inventories:

- The rule prescribes that the inventory year is the same as triennial AERR year that has most recently been submitted by the state to the EPA, with additional special considerations

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- For the recent year emissions inventory for a 10-year SIP revision, states can use another inventory year if adequately justified (*see* 40 CFR 51.308(f)(2)(iv)). One example of using another year would be to update the EGU portion of the inventory to use more current data that is available because of CEMs. There may also be better information on a particular source sector in a special study that collected more refined source-specific information but for a different year.

- For the 5-year (or "periodic," as proposed) progress reports, 40 CFR 51.308(g)(4) specifically requires that any newer data reported directly to the EPA (like the CEM data) be used if summaries of the data are available from the EPA.

- The inventory can be the same as the NEI or can be revised from the NEI. The proposed revision to the rule does not say that the inventory must be the NEI inventory, rather, it says that the year must be the same year.

- States must identify the recent inventory in their plan, but the inventory does not need to be submitted to the EPA.

- States may rely on EPA-provided parts of the NEI to support the recent year inventory data needed for their plan.

3.6 Emissions Statement Requirement for SIPs

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For ozone NAAs, states should develop emission reporting programs for VOC and NO_X sources in accordance with CAA section 182(a)(3)(B). The required state program and associated regulation defines how states obtain emissions data directly from facilities and report it to the EPA as part of SIP inventories and for the AERR. This is called an Emission Statement regulation, and it outlines how facilities must report emissions and facility activity data to an air agency. Once the air agency develops the Emission Statement regulation, the regulation should be sent to the EPA as a SIP for approval by the deadline as specified in Table 8. As an element of a SIP, the public hearing requirements apply to the Emission Statement SIP. Air agencies must ensure that their emissions reporting program, promulgated in accordance with CAA section 182(a)(3)(B), complies with all applicable statutory and regulatory requirements on a continuing basis.

To properly implement the emissions reporting requirements, Emission Statement regulations should be coordinated carefully with the AERR and any associated guidance and specifications, the Modeling Guidance, and this guidance. The required and optional data elements needed for inventories (described in Section 2.5.7) should be included as fields for reporting to the EPA. Where the AERR/EIS has required fields, those fields should be required by the Emission Statement regulations. In addition, the Emission Statement regulations should require ozone season emissions in accordance with the final Ozone Implementation Rule.

Additional details on developing emission statement regulations can be found in a dated, but still relevant guidance document titled, "Guidance on the Implementation of an Emission Statement Program (DRAFT)," available at https://www.epa.gov/air-emissions-inventories/implementation-

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emission-statement-program. Where data elements to be collected are mentioned, users of that guidance should defer to the paragraph above, explaining that data elements should be coordinated with AERR/EIS requirements and the recommendations in this guidance for optional fields.

3.7 Maintenance Inventories

Maintenance inventories reflect the emissions conditions associated with a NAAQS redesignation to attainment following an initial area designation of nonattainment. Thus, the attainment year inventory for the maintenance demonstration should reflect emissions during the first year for which monitoring data showed compliance with the standard on which the state is basing their maintenance demonstration. Otherwise, all characteristics of the attainment year inventory are the same as the base year inventory submitted with the implementation plan prior to attainment. An attainment year maintenance inventory is a component of a maintenance plan and is, therefore, submitted to the EPA as a SIP revision. Thus all guidance in this document for completeness, temporal extent, spatial extent, public hearings, documentation, and summaries applies to these inventories.

The on-road portion of the inventory for the relevant pollutants and precursors for the last year of the maintenance plan would be the motor vehicle emissions budget(s) required for maintenance areas by 40 CFR 93.118(b). States may elect to also establish motor vehicle emissions budgets for the interim year or years for which they have submitted inventories or for the attainment year of the maintenance plan. Those decisions should be made through the interagency consultation process that is required by CAA section 176(c)(4)(D) and 40 CFR 93.105.

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Specific additional guidance for maintenance plan SIPs is also available in the memorandum titled, "Maintenance Plan Guidance Document for Certain 8-hour Ozone Areas Under Section 110(a)(1) of Clean Air Act", which can be found at (https://www3.epa.gov/ttn/naaqs/aqmguide/collection/cp2/20050520_wegman_maintenance_8-hr_ozone_section_110(a)(1).pdf).

3.8 Projected Inventories

The purpose of the projected inventories is to provide an emissions estimate for a year beyond the base year. These inventories are also called future-year inventories. Projected inventories will reflect the effects of control measures needed to reduce emissions and bring nonattainment areas and states into compliance with a NAAQS and regional haze rules.

For ozone and $PM_{2.5}$ implementation, the projected inventories are used for modeled attainment demonstrations, ROP/RFP plans, and in maintenance plans to show that the attainment year inventory will not be exceeded in future years. For the modeled attainment demonstration, the projected inventory represents the emissions needed to attain a NAAQS (according to the modeling) in a future year. For the ozone ROP/RFP plan(s), expected percent reductions of pollutants on specific timetables need to be shown. Those the ROP/RFP plan(s) require only the "expected reductions" and not projected inventories, calculating expected reductions involves estimation of emissions reductions, which can result in a projected inventory that shows the remaining emissions after those reductions have occurred.

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For regional haze, the proposed rule revisions of section 308(f)(6)(v) include the requirement for states SIPs to "provide for" a statewide inventory of estimates of future projected emissions. The purpose of this projected inventory is to address the SIP requirement to focus on emission reduction measures that are designed to achieve reasonable further progress by 2028 by reducing emissions that lead to regional haze.

In addition for regional haze, the proposed rule revisions, if adopted, would eliminate an existing requirement for projecting emissions. The existing section 308(g)(4) of the regional haze regulations (regarding progress reports in between SIP revisions) states that the analysis tracking the change in emissions over the past 5 years must be based on the most recent updated emissions inventory, with estimates projected forward as necessary and appropriate to account for emissions changes during the applicable 5-year period. The proposed revisions of section 308(g) would *remove* mention of projecting emissions. The proposed tracking analysis would encompass emissions up to the year of the most recent NEI submission for all sources, and for relevant sources up to the most recent year for which the EPA has provided a summary of emission information submitted by sources directly to the EPA.

Additional relevant provisions of 40 CFR part 51 must be considered for ozone, $PM_{2.5}$, and regional haze implementation purposes. Subpart G of 40 CFR part 51 provides some foundational regulatory aspects of the control strategy development needed for creating projected inventories, including what SIPs must include with regard to control strategies and their associated inventories. In particular, 40 CFR 51.114 "Emissions data and projections" reads:

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(a) Except for lead, each plan must contain a detailed inventory of emissions from point and area sources. Lead requirements are specified in §51.117. The inventory must be based upon measured emissions or, where measured emissions are not available, documented emission factors.

(b) Each plan must contain a summary of emission levels projected to result from application of the new control strategy.

(c) Each plan must identify the sources of the data used in the projection of emissions.

In addition, 40 CFR 51.116 "Data availability" reads:

(a) The State must retain all detailed data and calculations used in the preparation of each plan or each plan revision, and make them available for public inspection and submit them to the Administrator at his request.

(b) The detailed data and calculations used in the preparation of plan revisions are not considered a part of the plan.

(c) Each plan must provide for public availability of emission data reported by source owners or operators or otherwise obtained by a State or local agency. Such emission data must be correlated with applicable emission limitations or other measures. As used in this paragraph, correlated means presented in such a manner as to show the relationship between measured or

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estimated amounts of emissions and the amounts of such emissions allowable under the applicable emission limitations or other measures.

Thus, states should keep these requirements in mind as they develop their projected inventories so that these required SIP elements can be included.

3.8.1 Attainment Year Projected Inventories

As listed in Table 4, there are two possible attainment year projection inventories. The first is the *attainment projected inventory for the NAA*. The second is the *projected inventory for the modeled attainment demonstration*.

For ozone SIPs, as described in Section 3.8.2, one possible use of the attainment projected inventory for the NAA is for showing emissions reductions associated with an ROP/RFP plan. While it is conceivably possible to estimate the emissions reductions (rather than future year emissions inventories) required by the ROP/RFP plan, the most common way to estimate the reductions is by creating future-year inventories and *then* calculating the difference between the ROP/RFP baseline and the attainment projected inventories for the NAA.

For $PM_{2.5}$ SIPs, the attainment projected inventory for the NAA is a required element of the SIP. The detailed requirements for various aspects of this inventory are included in the regulatory text at 40 CFR 51.1008(a)(2) for Moderate areas and 40 CFR 51.1008(b)(2) for Serious areas. For the attainment projected inventory for the NAA, a key difficulty can be calculating projected emissions for partial counties, which would not necessarily be available from the modeling inventory. It may be possible to use the gridding aspect of modeled inventories to estimate emissions in partial counties for nonpoint and mobile sources. This issue is addressed more completely in Section 4.4.1.

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In addition, the on-road mobile portion of the attainment projected inventory for the NAA can serve as the motor vehicle emissions budgets for the ozone and $PM_{2.5}$ NAAQS. Specific requirements for motor vehicle emissions budgets for ozone (NOx and VOCs) and $PM_{2.5}$ (direct $PM_{2.5}$, NOx and possibly VOCs, SO_2 and ammonia) can be found in 40 CFR 93.102(b). Since these budgets are required for transportation conformity purposes by 40 CFR 93.118(b), such inventories provide a convenient and consistent way to meet that requirement. In this case, the on-road inventory should be created in accordance with transportation conformity guidance (http:/www.epa.gov/otaq/stateresources/transconf/).

Creating projected inventories includes a large number of data sources and requires estimates for stationary point, nonpoint, on-road mobile, and nonroad mobile sources. In addition, some areas may choose to use average fires to represent these highly variable (from year to year) and large contributors to emissions. Biogenic sources are not generally forecast into the future because they are so dependent on meteorology. Section 5 covers the details on projected inventories.

3.8.2 Rate of Progress and Reasonable Further Progress Emissions Reductions

As described in Section 3.4 and the Ozone Implementation Rule, Moderate and above NAAs must have a plan for meeting a 15 percent VOC emissions reduction (ROP plan) within 6 years after the NAA designation. Serious and above NAAs must also have a plan (RFP plan) to meet a requirement for an

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additional 3 percent per year VOC reduction (annual RFP) for each 3-year period after the initial 6 years (after the NAA designation) until the attainment date. In both cases, the VOC reductions can be substituted with NO_X reductions when specific conditions apply. Serious and above areas may submit two separate plans since the annual RFP plan is due 1 year later. Collectively, this guidance calls these plans the ROP/RFP plan(s).

In particular for the ROP requirement, an attainment year projected inventory for the NAA can also meet the ROP requirement by providing a projected inventory that shows the 15 percent VOC (or NO_X, as applicable) reductions when compared to the ROP/RFP baseline NAA inventory. For Serious and above areas, an additional projected inventory may be needed to meet the ROP requirement. This is because the ROP requirement at 6 years can be earlier than the expected attainment date. In the case for Serious and above areas, ROP plans cannot use the projected attainment inventory for the NAA, but rather should use an inventory projected at the 6-year interval.

To estimate the emissions reductions associated with ROP/RFP plans, air agencies should rely on the same techniques as for other projection purposes, which are described in Section 5. When these reductions are calculated by creating projected inventories, the on-road portion of the inventories may also need to follow transportation conformity guidance (http:/www.epa.gov/otaq/stateresources/transconf/) so that it can be used to set the motor vehicle emissions budgets.

The emissions projections should include emissions growth where it occurs, emissions reductions intentionally included to meet the reductions needed for ROP/RFP, as well as emissions reductions occurring for other reasons (e.g., as co-benefits from implementation of other NAAQS and from national mobile source or stationary source rules). These emissions projections will result not only in estimated reductions (that are required to be included in the ROP/RFP plans), but also in projected emissions inventories. Thus, the EPA recommends that summaries of these inventories are included in the ROP/RFP plan(s) to communicate the emissions reductions by comparing against the ROP/RFP baseline NAA inventory.

3.8.3 Regional haze emissions reductions

The requirement of 308(f)(6)(v) that states provide for estimates of future projected emissions supports the purpose of the SIP to focus on emission reduction measures that are designed to achieve reasonable further progress by 2028. As described in the preamble of the proposed regional haze rule, the state's long-term strategy to address regional haze must include enforceable emission limitations." The EPA expects that the estimates of future projected emissions to meet the requirements of 308(f)(6)(v) would therefore include the projected impacts of these enforceable emission limitations.

The proposed revision to the Regional Haze Rule does not assume that all sources in a state must be subject to an analysis of the four factors laid out in 308(f)(2)(i), but subsection 308(f)(2)(v) requires the state to identify the sources considered by the state in developing its long-term strategy and the criteria used to select the sources considered. As proposed, once the emission reductions measures for these sources are identified pursuant to the four-factor analysis, the emission reductions from those measures

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would be part of the projection of end-of-implementation period emissions (2028, 2038, etc.) needed to set the reasonable progress goals. The emissions projection techniques provided in Section 5 below can provide the necessary technical guidance to support states in projecting their future emissions.

3.9 Public Hearings

For ozone and $PM_{2.5}$ implementation, some emissions inventories are considered a part of the SIP under the CAA (see sections 172(c)(3), 182(a)(1)(A) and 182(a)(3)(A)), and in this guidance we have called these planning inventories. Thus, for ozone and $PM_{2.5}$ SIPs, detailed emissions inventories data are required to be included in the public participation associated with SIPs as specified in CAA section 110(a)(2). For regional haze, the detailed emissions inventory data are not expected to be a part of the information provided for a public hearing on the regional haze SIP. If emissions inventory information (but not the [27]detailed data) is included as part of a SIP submission, the emissions information in the SIP submission stills need to be included as part of the information provided as specified in CAA section 110(a)(2).

In addition, 40 CFR 51.102 (a) further explains that a public hearing requirements means "The State must hold a public hearing or provide the public the opportunity to request a public hearing." Thus, the phrase "or provide the opportunity to request" means that it is possible that public hearings on inventories will have no one request a public hearing[28].

There are policy reasons that support the need for detailed emissions inventories data to be approved with the SIP. Some emissions inventories must be used as a basis for ozone RFP plans for areas classified as Moderate or above. Additionally, all NAAs seeking redesignation to attainment will rely on an emissions inventory for purposes of submitting a maintenance plan under CAA section 175(A). Because the emissions inventories and projections play such a fundamental role in determining the reductions necessary to attain and maintain the standard, they need to receive full public scrutiny and be formally incorporated into the SIP.

As explained in the final Ozone SIP Requirements Rule, the EPA is no longer advising states to follow our existing September 29, 1992, guidance titled, ''Public Hearing Requirements for 1990 Base-Year Emissions Inventories for Ozone and Carbon Monoxide Nonattainment Areas" in implementing certain SIP adoption and submission procedures for the emissions inventory requirements under CAA sections 182(a)(1) and 182(a)(3)(A) for purposes of the 2008 ozone NAAQS. In that guidance, the EPA indicated it could provide states with a time-limited *"de minimus"* deferral of the CAA's state public hearing requirement for the emissions inventory SIP revision until the inventory needs had "regulatory significance." As there is nothing in the CAA provisions that provides for waiver or delay of the public

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[28] A public hearing must be offered for every SIP submittal, but a hearing does not need to actually occur if no one requests a hearing. The detailed requirements for public notice and hearings are given in 40 CFR 51.102. See also Attachment B of "Regional Consistency for the Administrative Requirements of State Implementation Plan Submittals and the Use of Letter Notices," EPA memorandum dated April 6, 2011, from Janet McCabe, Deputy Assistant Administrator for the Office of Air & Radiation to the Regional Administrators, www3.epa.gov/airquality/urbanair/sipstatus/docs/FINALSIPGuidelinesSubLtrsPN.pdf.

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notification and hearing requirements specified in CAA section 110(a) *de minimus* or otherwise, we no longer believe it is appropriate to advise states to follow the 1992 guidance. We remind states that the EPA's implementing regulations at 40 CFR part 51 (Requirements for Preparation, Adoption, and Submittal of Implementation Plans) provide flexibility for states to streamline SIP-related public notification and hearing procedures (for example, only holding a public hearing if one is requested, per 40 CFR 51.102), and we encourage states to take advantage of those provisions in meeting the emissions inventory requirements under CAA sections 182(a)(1) and 182(a)(3)(A).

For areas classified as Moderate or above, the state would need to provide the EPA with verification that a public hearing was offered for the emissions inventory for any emissions inventory SIP revision at the time the state submits the emissions inventory SIP.

In instances where a public hearing is held for the emissions inventory SIP revision, the EPA clarifies here what is required by EPA regulations to be published and present for public review. Because emissions inventory data can be voluminous, it is common to summarize that data for public hearing purposes. The EPA does not interpret 40 CFR 51.102 to require that at a public hearing, held in accordance with that provision, every database entry related to the emissions inventory must be summarized, presented, and/or made available. Rather, the EPA expects that, in general, emissions inventory summaries would be the primary source of information for public review, so long as the detailed emissions inventory data are available to the public in accordance with the CAA and EPA regulations. Air agencies must comply with 40 CFR 51.102(d)(2), and 40 CFR part 51, Appendix V.

At a minimum, the state should include summaries of the actual emissions. The EPA recommends using the same tables as those recommended in the EI Guidance for inclusion in the SIP documentation for the purpose of the public review (see Section 3.10.3 of this guidance "What to Submit").

3.10 Submit Inventory Parts of SIP to the EPA

40 CFR part 51 contains the requirements for SIPs, and many general provisions in Part 51 impact the requirements for emissions inventory SIPs. Section 3.10.1 summarizes the applicable regulations. In addition, the two key concerns for submitting information on inventories are: (1) how to submit, including the format and (2) what to submit. These concerns are addressed in Sections 3.10.2 and 3.10.3, respectively.

3.10.1 Regulatory Requirements in Addition to Implementation Rules

The general regulatory requirements for SIP submissions are available in several subparts of 40 CFR part 51 that have an impact on the emissions inventory SIPs.

- Subpart F – Procedural Requirements
  - §51.102 Public hearings (see Section 3.9 above)
  - §51.103 Submission of plans, preliminary review of plans:
    Cites Appendix V as the source of the requirements that constitutes an official plan submission.
- Subpart G – Control Strategy
  - §51.112 Demonstration of adequacy

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This section requires a presentation of emissions levels expected to result from implementation of each measure of a control strategy (*in the modeled attainment demonstration).*

- §51.114 Emissions data and projections
  This section has three subsections:
  (a) requires a detailed inventory of emissions from point and area sources that are based on measure emissions or, where measured emissions are not available, documented emission factors;
  (b) requires that the plan contain a summary of emission levels projected to result from application of the new control strategy; and
  (c) requires that each plan must identify the sources of the data used in the projection of emissions.
- §51.116 Data availability
  Subsection (c) requires that each plan must provide for public availability of emission data reported by source owners or operators or otherwise obtained by a state or local agency. It also requires correlation of emission data with applicable emission limitations or other measures.

- Subpart Q – Reports
  - §51.322 – Sources subject to emissions reporting
    This section points to Subpart A, which is the AERR.
  - §51.323 – Reportable emissions data and information
    This section also points to Subpart A.
- Appendix V – Criteria for Determining the Completeness of Plan Submissions
  - 2.2 Technical Support. This subsection of Appendix V lists various parts of the SIP that must be included that can be met as part of the EI SIP, including:

    (b) Identification of the location of affected sources included the EPA attainment/nonattainment designations of the locations and the status of the attainment plan for the affected area(s).

    (c) Quantification of the changes in plan allowable emissions from the affected sources; estimates of changes in current actual emissions from affected sources or, where appropriate, quantification of changes in actual emissions from affected sources through calculations of the differences between certain baseline levels and allowable emissions anticipated as a result of the revision.

    (e) Modeling information required to support the proposed revision, including input data (which includes emissions).

  - 3.2 Paper Plan Submissions. This section addresses the EPA's voluntary guidelines for which states are requested to adhere for paper and electronically formatted submissions.

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3.10.2 How to Submit Inventory Parts of a SIP

The EPA generally encourages air agencies to provide all parts of the SIP related to emission inventories using digital media. For the Ozone SIP Requirements Rule, the preamble specifically indicates that "states must make available the inventory data to the EPA as electronic files in ... electronic media, such as FTP, zip drives, or DVDs." In most cases, it's simply best practice to provide this information digitally. Because of the challenges that can arise with the use of formats that are supported by one agency and not the other, air agencies should provide documentation at least in formats that are readily transferrable, such as PDF for documentation files. Other formats can also be considered and agreed upon in advance, and such details would be ideal to be included in an IPP.

When paper plans are submitted, some guidelines provided in 40 CFR part 51, Appendix V apply. In accordance with section 3.2(a) of Appendix V, the EPA requires that when submitting one paper plan, it must be accompanied by an electronic duplicate of the entire paper submission, preferably as a word searchable document format (PDF).

For the format, the above information is provided as guidance. There are no specific formatting *requirements* added by this guidance for the inventory data, emissions summaries, or documentation submitted as part of the SIP. Requirements are included in implementation rules, and the ozone, $PM_{2.5}$, and regional haze implementation rules do not specify required formats for submitting inventory information. For ozone and $PM_{2.5}$, however, the *data elements* required for submitted emissions inventories are to use the elements required by the AERR.

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Currently, the AERR data format does not directly support the use of partial counties. Thus, inventories with partial counties are not currently able to use the EIS formats and states would need to use some identifier in the format to denote partial counties.

The following provides a list of best practices that the EPA encourages air agencies to use when submitting the Inventory Parts of a SIP:

- In accordance with Subpart A, detailed inventory data are required as part of emission inventory SIPs. When providing full detailed inventory data (i.e., facility-SCC-pollutant data for point sources or county-SCC-pollutant data for nonpoint sources):
    - Use the data elements required by the AERR. This is required by the ozone and $PM_{2.5}$ implementation rules.
    - Coordinate with your Regional office about what format is going to be used. If EIS format is used, consider submitting this to the EIS, but first contact the EPA NEI program to make sure any such submission will not conflict with other inventories already submitted to the EIS.
    - If not using the EIS format, use Excel®, Access® or a rigorous delimited text format. For a delimited text format, make sure that the text fields have double quotes and that the delimiter chosen (e.g., a tab) does NOT appear in any of the text fields, since this will prevent the delimited dataset from being imported easily into other data systems.

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- For documents, use a readily available word processor format (e.g., Microsoft Word®) or convert the document to PDF format.
- At times, it can be very time consuming to convert tables from a spreadsheet and insert them into a word processor, especially if the information changes and has to be updated. The guidance below recommends a lot of summary tables. Rather than cut/pasting into a text file, states may consider creating a spreadsheet with individual worksheets (tabs) labeled as each table included in the document. Then, just reference those tables/tabs from document. This can be done with words only (e.g., "see Table 1 in Excel file") or using a more sophisticated data link between the word processor and spreadsheet software.

3.10.3 What to Submit

With regard to exactly what to submit, the information provided here provides guidance on what would be acceptable in most cases. The list of tangible data items and documentation forms the basis of what the EPA will review and ultimately approve for a SIP. [29]Table 11 provides the suggested inventory elements of an Emissions Inventory SIP and indicates whether they are relevant for ozone, $PM_{2.5}$, and/or Regional Haze SIPs. Refer to the tables in Section 2.3 for more information on which elements are required and which are optional.

This section (and Table 11) does not include RFP inventories since those are submitted with a separate ROP/RFP plan. Similarly, it does not include information needed for a modeling attainment demonstration submittal to the EPA, with the exception of the inclusion of statewide inventory summaries for ozone and $PM_{2.5}$ SIPs for areas that have modeled attainment demonstrations as part of their SIP requirements.

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Table 11: Suggested Elements of an Emissions inventory SIP Document

SIP Planning Inventory Documentation Element	Ozone	$PM_{2.5}$	Haze
Background: Includes key elements explained in this guidance, such as the nature of the air quality problem (or arrival at attainment status for maintenance SIPs), priority source categories and point sources, pollutants covered, spatial extent, and other key inventory aspects.	Y		
• **Overall base year emissions summaries:** All emissions are for relevant pollutants only. Data categories would minimally be point, nonpoint, nonroad mobile, and on-road mobile, and fires, though more detailed categories are acceptable. Biogenic sources and other sources can optionally be included as well, and may be required by Regional offices for areas doing modeled attainment demonstrations.	See Table 12		
• **Overall projected attainment year emissions summaries:** The same as the base year summaries except using the attainment projected inventory for the NAA. Required for $PM_{2.5}$ SIPs. *These*			n /

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summaries are optional for the ozone Emissions Inventory SIP. For ozone and when developed in accordance with transportation conformity guidance, the on-road portion also can set the motor vehicle emission budgets for VOC and NO_X. If not provided in the Emission Inventory SIP, the summaries would be needed in the Modeled Attainment Demonstration.			a
• **Overall recent year emissions summaries compared to projected emissions:** All emissions are for relevant pollutants only. Data categories would minimally be point, nonpoint, nonroad mobile, on-road mobile, and fires.			See Table 12
Stationary Point Sources:			
• Introduction with more detailed documentation of the emissions from stationary point sources, including the point source emissions threshold, how the point sources were identified, how emission estimates were made including emission factors, activity data, and control assumptions.	Y		
• This section includes additional point source emissions summaries.	See Table 13		
Stationary Area (Nonpoint) Sources:			
• Introduction with more detailed documentation of the emissions from stationary nonpoint sources, including how the nonpoint sources were identified, the model version used, which sources were not addressed and why, how partial county emissions were estimated, and how emission estimates were made including models or tools, emission factors, activity data, and control assumptions.	Y		
• This section includes additional nonpoint source emissions summaries.	See Table 14		
Nonroad Mobile Sources			
• Introduction with more detailed documentation of the emissions from nonroad mobile sources, including how the nonroad mobile sources were identified, which sources were not addressed and why, how partial county emissions were estimated, and how emissions estimates were made including model version, source of input data, input and output data files, and any post-processing methods used to develop the	Y		

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inventory.			
• This section includes additional nonroad source emissions summaries.	See Table 14		
On-road Mobile Sources			
• Introduction with more detailed documentation of the emissions from on-road mobile sources, the model and version used, how partial county emissions were estimated, and how emissions estimates were made including sources of input data, input and output data files, and any post-processing methods used to develop the inventory.	Y		
• This section includes additional on-road source emissions summaries.	See Table 14		
Other Sources			
• If applicable, a description of other sources in the emissions inventory not included and reasons why they are not included.	Y		
• If applicable, this section includes summaries of other sources of emissions.	See Table 14		
Demonstration of Public Hearing: A brief description of the public hearing process, a summary of the results, and any other relevant materials. The purpose of this section is to provide evidence for the public hearing and what the air agency learned through the process.	Y	Y	N

Table 12 provides the summaries to include in the background section. In the table, "data category" is consistent with the definition provided in Table 11 and Section 2.5.1. If both the base year inventory and the attainment projected inventory are included in the background, then the same summaries should generally be provided for both.

Table 12: Summaries to include in the background

Emissions Summaries	**Ozone**	**$PM_{2.5}$**	**Haze**
Annual baseline, recent year emissions, projected emissions, and emissions difference for the state by data category. The baseline emissions may from the original SIP may be used.			Y
Annual base year emissions *and/or* average season day emissions for the NAA by data category		Y+	
Annual base year emissions *and/or* average season day emissions for the NAA by data category and county (or partial county) λ		Y+	
Ozone season day base year emissions for the NAA by data category	Y		
Ozone season day base year emissions for the NAA by data category and county (or partial county) Δ	Y		

+ Either annual or season-day emissions need to be reported (but not necessarily both), depending on the temporal basis used

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for the emissions in the SIP. For areas that have nonattainment for both the annual standard and the 24-hour standard and are using average-season-day inventory for their 24-hour SIP, then summaries of both temporal resolutions would be needed.

‡ For SIPs that include air quality modeling, this section can include both summaries of the planning and the modeling inventories. Since modeling domains are usually much larger, multi-state areas, the resolution of the modeling inventory summaries depends on the modeling guidance and the preferences of the Regional office. One option is to include county-level detail for the state(s) included in the NAA, but state-level detail for surrounding states.

λ Partial county emissions can be included rather than, or in addition to, full county, where applicable.

Δ Providing both the county and partial county could provide more flexibility for states when submitting periodic inventories.

Table 13 provides the recommended minimal contents for summaries to include in the point sources section. If both the base year inventory and attainment projected inventory are included in the background, then the same summaries should generally be provided for both.

Table 13: Summaries to include in the point sources section

Emissions Summaries	Ozone	$PM_{2.5}$	Haze
Annual recent year emissions, projected emissions, and emissions difference for each point source as a facility total, within the state.			Y
Annual base year emissions *and/or* $PM_{2.5}$ average season day base year emissions for each point source as a facility total, within the NAA.		Y	
Ozone season day base year emissions for each point source as a facility total, within the NAA.	Y		
These summaries should include: the county, Agency Facility ID, plant name, physical address, total control efficiency, key control devices, NAICS code, and actual and/or projected emissions. Other summaries may be included as well, such as by SCC or other fields that are necessary to describe the inventory effectively. The Agency Facility ID or some other ID should be included that can easily map to the EPA facility records in EIS. This can be more difficult when air agencies change their Agency Facility IDs.			

Table 14 provides the recommended minimal contents for summaries to include in the nonpoint and mobile sources sections. If both the base year inventory and the attainment projected inventory are included in the background, then the same summaries should generally be provided for both.

Table 14: Summaries to include in the nonpoint and mobile sources sections

Emissions Summaries	Ozone	$PM_{2.5}$	Haze
Annual recent year emissions, projected emissions, and emissions difference by county and SCC (or SCC group‡), within the state.			Y
Annual base year emissions *and/or* average season day emissions by county and SCC (or SCC group‡), within the NAA.		Y	
Ozone season day base year emissions by county and SCC (or SCC group‡), within the NAA.	Y		
For county and emissions processes reported that have reductions associated with rules, these summaries should include any control efficiencies or rule effectiveness assumed and actual and/or projected emissions. Projected attainment year emissions summaries may also be required for areas performing modeled attainment demonstrations.			

‡ See additional information below on SCC groups.

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SCC groups for on-road and nonroad mobile sources can be useful in limiting the size of summaries without much loss of information. For example, SCC groups can be formed by vehicle type and fuel, dropping the road classifications. Vehicle types can be further grouped into light duty and heavy duty. The amount of grouping appropriate depends on what a particular summary and SIP are trying to communicate. SCC groups can be suggested as appropriate by Regional offices or air agencies as part of the consultation for what will be included in the emissions inventory SIP.

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4 Developing Current Emissions inventories

This section covers the decisions that states will need to make regarding any "current" emissions inventory, including a base year NAA or state inventory, RFP baseline inventory, periodic inventory (for ozone or regional haze), or maintenance inventory. As a reminder, all inventories described in this section are inventories of actual emissions; these inventories do not contain emissions based on potential to emit nor allowable emissions. In accordance with 40 CFR 51.5(b), states are urged to use applicable, state-of-the art techniques for estimating emissions.

4.1 Inventory Years

A fundamental step in creating a base year inventory is the choice of inventory year. The Ozone, $PM_{2.5}$ and Regional Haze Implementation Rules include specific language regarding the choice of inventory years, and those regulatory requirements supersede any guidance provided in this section. Since the purpose of the base year inventory is to represent relatively current emissions conditions, there is a general preference to use as recent a year as practical. This means that the year of emissions estimates is usually several years earlier than the year in which the inventory work is done, given the time that it takes to compile an emissions inventory (for example, an inventory with 2014 emissions may not be compiled until 2016).

The primary considerations in choosing a baseline inventory year as covered in this guidance are: (1) the implementation rule requirements, (2) transportation conformity requirements, and (3) the availability of data. This is in contrast to inventories used for air quality modeling, for which meteorology, and availability of ambient data are the primary considerations, with inventory availability secondary. This is because the meteorological conditions selected should be associated with ozone formation that is representative of either the ambient data relied upon for designation to nonattainment or recent ambient data, as appropriate. Choosing a year based solely on inventory availability could result in choosing an inappropriate year (considering ambient measurements and the meteorology that led to those measured concentrations). As a result, the base year(s) used in the planning inventories can be different than the modeling base year and associated modeling inventory.

4.1.1 Ozone baseline year

For ozone, states should become familiar with the specific rule requirements. The 2008 Ozone Implementation Rule in 40 CFR 51.1115(a) specifies that the "inventory year shall be selected consistent with the baseline year for the RFP plan as required by Section 51.1110(b), which reads as follows:

> (b) *Baseline emissions inventory for RFP plans.* For the RFP plans required under this section, at the time of the designation for the 2008 ozone NAAQS the baseline emissions inventory shall be the emissions inventory for the most recent calendar year for which a complete triennial inventory is required to be submitted to EPA under the provisions of subpart A of this part. States may use an alternative baseline emissions inventory provided the state demonstrates why it is appropriate to use the alternative baseline year, and provided that the year selected is between the years 2008 to 2012. All states associated with a multi-state nonattainment area must consult and agree on a single alternative baseline year.

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Thus, for the 2008 ozone standard, the 2011 inventory year is the presumed inventory year. Guidance on the considerations for using an alternative baseline year is provided below in Section 0.

The consideration of transportation conformity requirements is important because the rule has its own language about selecting a base year. The applicable section of the rule is 40 CFR 93.119(e), which reads:

> (e) *Baseline year for various NAAQS*. The baseline year is defined as follows:
>
> ...
>
> (4) The most recent year for which EPA's Air Emissions Reporting Rule (40 CFR Part 51, Subpart A) requires submission of on-road mobile source emissions inventories as of the effective date of designations, in areas designated nonattainment for a NAAQS that is promulgated after 1997.

This requirement impacts the 2008 and 2015 ozone standards. For convenience, OTAQ provides an online table that lists the appropriate base year for use for transportation conformity purposes (*see* https://www.epa.gov/state-and-local-transportation/baseline-year-baseline-year-test-40-cfr-93119). Unlike the ozone implementation rule, the transportation conformity rule does not include a provision for an alternative baseline year; thus, states that wish to select an alternative year are advised to consult with their Regional office as part of their SIP development.

Lastly, the consideration of "availability" is simply what data are (or will be) available to the air agency during the time alloted for SIP preparation. Often, the triennial NEI year inventories (as described above) are useful starting points for meeting the various "current" inventory requirements associated with SIPs. For these triennial NEI years, states are already required to have prepared and provided to the EPA inventories of criteria pollutants and precursors as well as model inputs for on-road and nonroad mobile sources. In some cases, the states have submitted their data to the EPA, but the complete NEI is not yet available because there is a 6-12 month lag between when the emissions have been submitted and when the inventory is released by the EPA. In this case, the state should make every effort to use the most currently available information and incorporate any new information that is made available by the NEI release at the earliest practical time.

Other benefits of using an NEI year is that NEI data are available for all states, and information from more than one state may be needed for attainment demonstration modeling purposes. Additionally, other data needed for modeling (e.g., meteorology and SMOKE inputs) are more likely to be available for the triennial NEI years.

4.1.2 $PM_{2.5}$

For $PM_{2.5}$, states should become familiar with the specific rule requirements. The $PM_{2.5}$ SIP Requirements Rule at 40 CFR 51.1008(a)(1)(i) states:

> (i) The inventory year shall be one of the 3 years for which monitored data were used for the designations or another technically appropriate year if justified by the state in the plan submission.

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For the 2012 $PM_{2.5}$ NAAQS, the EPA used ambient data from 2011 through 2013 to designate $PM_{2.5}$ NAAs; thus any of these three years can be used as the baseline year. The idea behind this connection is that the inventory should represent the emissions conditions in the local area associated with the nonattainment problem. Given this purpose, situations may arise where the most applicable available inventory year is not one of these 3 ambient-data years.

Two examples of such situations are offered here. In the first, a newer inventory may be advisable. Because of time that it takes for designations to occur and the period allowed for SIP submittal, a significant increase in emissions could occur between the designation period and the time SIPs are submitted. This has occurred in some areas due to oil and gas development, for example. In this case, it may be more appropriate to use an inventory year that is newer than one of the 3 years of data used for designations, to represent the higher emissions or different source mix associated with a more recent year. Another example is that in an area where mobile sources are a small part of the emissions inventory, emissions may not have changed much from a year prior to the 3-year period of ambient data. In this case, an available inventory prior to one of the 3 years may sufficiently represent the inventory. In both cases, the air agency preparing the SIP should explain these issues as part of its justification for not using one of the three years.

The inventory baseline year is the same year used for the RFP baseline year. In addition, states must meet quantitative milestone requirements as described in 40 CFR 51.1013(a). Within the 3 years available for choosing a base year, a large source of emissions may be reduced. If a state chooses a year after those reductions have occurred, then the state would not get the benefit of those reductions in meeting their RFP and quantitative milestone requirements. In addition, if those emissions were a key part of the nonattainment problem, then the choice of the later year would not follow the guidance that the year selected be representative of the conditions leading to nonattainment.

The considerations for availability of emissions for $PM_{2.5}$ planning inventories are the same as for ozone as described in the previous subsection.

4.1.3 Regional Haze

As described in Section 2.3.3, the year of the baseline inventory has previously been set. For the initial Regional Haze SIPs, the year used should have fallen between and inclusive of the 2000 to 2004 baseline period. Most areas used 2002 as their baseline inventory year in their initial SIPs based on an OAQPS memo about this issue.

The proposed Regional Haze Rule revision addresses what states must do for subsequent planning periods, and this proposed revision would require that states create and use a recent year inventory as part of their SIP analysis. As described in Section 2.3.3 above, the 5-year progress reports and 10-year SIP revisions include specific language regarding the inventory year to use for developing those plans, which we address here in more detail.

For the progress reports, an inventory is used to compare back to the most recent previous inventory from the previous SIP revision. The proposed analysis year for this comparison is the most recent year for which the state has submitted emission inventory information to the EPA in compliance with the

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triennial reporting requirements of the AERR. In addition, the proposed rule revision states the following: "With respect to sources that report directly to a centralized emissions data system operated by the Administrator, the analysis must extend through the most recent year for which the Administrator has provided a State-level summary of such reported data or -an internet-based tool by which the state may obtain such a summary." This latter requirement refers (at least) to the direct reporting of the CEM data for EGU sources. Thus, the emissions year(s) for the progress report tracking analysis would include the most recent NEI year that had been reported by the state and any newer EGU (or other) data available through direct facility reporting.

For the 10-year SIP revisions, an inventory is used as a starting point to examine future emissions reductions and assess expected progress on visibility improvements. Similar to the progress report requirement, the proposed rule revision at 40 CFR 308(2)(f)(iv) would require this starting year to be the most recent year for which the state has submitted emission inventory information to the EPA in compliance with the triennial reporting requirements of the AERR. This section also allows for a different year if "the State adequately justifies the use of another inventory year." Section 4.1.4 provides more information on considerations for choosing an alternative year.

4.1.4 Considerations for choosing an alternative base year

For both ozone and $PM_{2.5}$ SIPs and regional haze, the governing implementation rules allow states to choose a different year than one of the presumptive years as described in the subsections above. In general, states seeking to use newer inventory years will be easily able to justify that choice on the basis of improvement in meeting the CAA requirement for a "current" inventory (see CAA 172(c)(3) for $PM_{2.5}$ and 182(a)(1) for ozone). It is presumed that because of ongoing control programs for mobile and stationary sources, which get additional reductions each year, more recent year inventories will reflect lower emissions levels.

Another common reason for choosing a different base year includes a desire to have the base year for planning inventories consistent with the base year used for modeling inventories. The modeling base year is determined in part by meteorology that is conducive to formation of ambient levels of a NAAQS pollutant that are above the NAAQS. Other reasons may also exist for choosing a different year, and these should be provided as part of SIP documentation. Ideally, any such decisions would be made in the planning phase of SIP development, in consultation with the Regional office.

4.2 Pollutants and Pollutant Precursors to Include in Inventories

This section describes the pollutants and precursors that should be included in the planning inventories for the ozone, $PM_{2.5}$, and regional haze rules. Pollutants for ROP/RFP inventories are also described in Section 3.4.2. Because many sources emit more than one of the precursor pollutants, and because the precursor pollutants have the potential to be transported across state boundaries, the EPA encourages air agencies to develop inventories for all pollutants, where possible, to support integrated, regional-scale modeling and control strategy development for ozone, $PM_{2.5}$, and regional haze.

Section 172(c)(3) of the CAA requires "the relevant pollutant or pollutants" to be included in inventories

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for SIPs. The ozone, $PM_{2.5}$ and regional haze implementation rules include specific language regarding the pollutants and precursors to be included, and those regulatory requirements supersede any guidance provided in this section.

For the 8-hour ozone NAAQS, the pollutants to be inventoried are VOC and NO_X. The ROP/RFP baseline NAA inventory for ozone should also include VOC and NO_X. For the $PM_{2.5}$ NAAQS, the pollutants to be inventoried are primary emissions (including both the filterable and condensable portions) of PM_{10} and $PM_{2.5}$, and emissions of SO_2, NH_3, VOC, and NO_X. The EPA has finalized the requirement that PM_{10} emissions are to be reported with the $PM_{2.5}$ inventories because PM_{10} emissions are often used as the basis for calculating $PM_{2.5}$ emissions. For regional haze, the pollutants to be inventoried include all of the pollutants and precursor pollutants identified for ozone and $PM_{2.5}$, excluding CO.

4.2.1 Condensable PM emissions

As mentioned previously, the AERR identifies reporting requirements for the implementation rules. In the past, a source of confusion has been the AERR requirement for reporting primary PM_{10} and primary $PM_{2.5}$ emissions, which states, "As applicable, also report filterable and condensable components." The AERR also defines condensable PM as:

> *Material that is vapor phase at stack conditions but which condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack. Note that all condensable PM, if present from a source, is typically in the $PM_{2.5}$ size fraction and, therefore, all of it is a component of both primary $PM_{2.5}$ and primary PM_{10}.*

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While the wording in the AERR is clear that the EPA expects reporting of all components of primary PM including condensable portion (and as individual components), the rule does not clarify "as applicable" by identifying those sources that are expected to have condensable PM. To clarify this issue, Table 15 provides a list of source types for which condensable PM is expected by the AERR.

Table 15: Source types expected to include condensable PM

EIS Sectors (and subsectors)	Subsectors and Degree of Condensable	Data Categories
Commercial Cooking	High	Nonpoint
Fuel Combustion – Electric Generating Utilities – all fuel types	Low, except Gas Turbines are negligible	Point
Fuel Combustion – Industrial Boilers – all fuel types		Point Nonpoint
Fuel Combustion – Commercial/Institutional – all fuel types	Moderate and depends on control technology	Point Nonpoint
Fuel Combustion – Residential – Oil, Natural Gas, Other	Significant	Nonpoint
Industrial Processes – Cement Manufacturing (Kilns)	Low	Point
Industrial Processes – Chemical Manufacturing		

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(Fuel Fired Process Heaters, Carbon Black Fuel Fired Furnaces and Dryers, Charcoal Manufacturing, Fuel Fired Ore Calciners, Ammonia Production Fuel Fired Reformers, Fuel Fired Incinerators, other fuel fired equipment)	Low – Moderate, depends on industry	
Industrial Processes – Ferrous Metals (Silicon Metal Electric Smelting Furnaces, Electric Arc Furnaces, Electric Induction Furnaces, Basic Oxygen Furnaces, Iron & Steel Pouring/Casting, Foundry Cupolas, fuel fired equipment)	Primary metals: High, others Low - Moderate	Point
Industrial Processes – NEC[+] (Brick Manufacturing Kilns, Lime Manufacturing Kilns, Glass Manufacturing Furnaces, Mineral Wool Blow Chambers, Fuel Fired Process Heaters, Coke Manufacturing Ovens, other fuel fired equipment)	Coke Ovens: High, others Low	Point
Industrial Processes – Non-ferrous Metals (Aluminum Ore Electro-reduction, Smelting Furnaces, Zinc Electrothermal Furnaces, Pouring/Casting, Rolling/Drawing/Extruding, Fuel Fired Process Heaters, other fuel fired equipment)	Primary metals: High, Asphalt electrode facilities: High, Drying: High; Others: Low	Point
Industrial Processes – Oil & Gas Production (Gas Well Dehydrators, Gas & Oil Well Heaters, Fuel Fired Compressor Engines, Heater Treaters, Process Heaters, Steam Generators)	High	Point Nonpoint
Industrial Processes – Petroleum Refineries (Process Heaters, Catalytic Cracking Units, Coke Calciners, Flares, Process Gas Incinerators, other fuel combustion)	Low	Point
Industrial Processes – Pulp & Paper (Recovery Furnaces, Lime Kilns, Paper Machine/Pulp Dryer, Sawmill Sanding: Cyclone Exhaust, Particleboard Cooler or Dryer, Smelt Dissolving Tank, Particleboard Presses)	Moderate – High	Point
Waste Disposal (Landfill Flares, Other Landfill Gas Waste Gas Combustion, Incinerators)	Low - Moderate	Point

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For stationary point and nonpoint sources, the EPA recognizes that emission factors for condensable PM are limited, as well as emission factors for many industrial sources of filterable $PM_{2.5}$. Resource constraints for many years have made it infeasible for EPA to conduct sufficient testing programs to populate all of the necessary emission factors. Nevertheless, state and local air agencies and their facilities are responsible for estimating emissions from sources required by the AERR.

In response to this issue, the EPA continues to work to help state and local air agencies meet their responsibilities. The EPA has devised a mechanism to more readily collect source test data for use in developing improved emission factors. More information on this approach can be found at https://www.epa.gov/electronic-reporting-air-emissions/electronic-reporting-tool-ert. The EPA invites industry, state, local and tribal agencies to provide source test data they may collect during the

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preparation of PM inventories to support the development of emission factors.

Additionally, the EPA has used available existing emission factors to develop a "PM augmentation tool" (see https://www.epa.gov/air-emissions-inventories/pm-augmentation). The tool uses ratios of the most applicable available emission factors to calculate one PM component from another. In the absence of improved PM condensable emission factors or facility-specific source data, inventory developers can use this tool to calculate PM condensable emissions from filterable $PM_{2.5}$ or total $PM_{2.5}$ emissions.

Condensable PM emissions are not an issue associated with mobile sources. The MOVES model used for these sectors produces primary emission estimates for PM, including particle components (e.g., elemental carbon and organic carbon) and gaseous hydrocarbons (e.g., VOC, non-methane organic gases). These pollutant metrics would include both "filterable" and "condensable" PM. These are currently not separable in MOVES, and for SIP inventory purposes, they can be reported as they are output from MOVES without additional modification.

4.2.2 Regulatory Definition of VOC

The EPA's current regulatory definition of VOC (40 CFR 51.100(s)) excludes constituents considered to be negligibly reactive in atmospheric photochemistry. These include methane, ethane, methylene chloride, 1,1,1-trichloroethane (TCA), several Freon compounds, acetone, perchloroethylene, and others. States should use the CFR reference above to find the complete list. Over time, additional compounds may be exempted from this VOC definition. The exempt compounds are considered negligibly reactive, although some can influence the formation of ozone when present in sufficient amounts; for example, methane impacts on ozone have been observed in areas of high methane emissions associated with oil and gas development. The emission factors used to estimate organic emissions generally account for nonmethane hydrocarbons (NMHCs).

For SIP purposes, state, local and tribal agencies should report VOC as defined by the EPA (40 CFR 51.100(s)). This is the case regardless of the treatment of methane for modeling inventories, which is addressed in more detail below.

4.2.3 Treatment of Methane

The treatment of methane in emissions inventories may be relevant for emissions used in modeled attainment demonstrations. Methane is not expected in other planning inventories associated with SIPs. This section is included to explain the context for which methane emissions can be important and to specifically note its possible relationship to the VOC emissions that are associated with SIP planning inventories. In some cases, air agencies interested in considering non-VOC-based estimates of methane in their modeling inventories may optionally choose to consider methane as part of non-modeling inventories as well.

The air quality models used for modeled attainment demonstrations use methane as one of the modeled pollutants. However, these models have typically used a fixed concentration of methane that does not change. Thus, typical applications have not used methane emissions from emissions inventories.

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Unlike the air quality models, the emissions processing steps to prepare emissions inventories for use in air quality models do compute methane emissions. Methane has traditionally been calculated by applying a factor to the VOC emissions to calculate total organic gases (TOG). These TOG emissions are then split during emissions processing into "model species" that include methane. With the low reactivity of methane and the absence of its use in air quality modeling for ozone, the VOC-to-TOG factors and the methane part of the speciation factors were not given much scrutiny. Previous versions of this guidance encouraged inventory developers to simply use the default VOC-to-TOG factors that were associated with the speciation profiles without further analysis, since the methane emissions were not used. This approach may still be appropriate for most or all NAAs for their modeled attainment demonstration.

In limited situations, air agencies may want to investigate the extent that methane emissions play a role in ozone episodes. Hence, additional efforts going beyond the use of the default VOC-to-TOG profiles and default methane fractions from the speciation profiles may develop over time. In this case, it may be of interest to include methane emissions inputs to air quality models to achieve sufficient model performance for a modeled attainment demonstration. Approaches can include incorporating methane emissions from other sources into emissions inventories used for modeled air quality. For example, the MOVES model estimates methane emissions directly, so there would be no need to use VOC speciation to estimate those emissions. Air agencies considering methane as a contributing factor should consult with their EPA Regional office to discuss the best sources for such data as this inventory development area is undergoing many changes at this time. Furthermore, more specific VOC-to-TOG factors and speciation profiles may be useful, particularly for analysis related to areas of very high methane emissions. These issues are all associated with modeled attainment demonstrations, and do not affect the VOC emissions reported as part of the emissions inventory SIP.

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4.3 Identification of Priority Sources

The Ozone Implementation Rule and $PM_{2.5}$ SIP Requirements Rule refer to the AERR requirements for creating the inventories used for SIPs. This includes the AERR requirement that inventories must include all sources of emissions. Thus, inventories used for SIPs are expected to be complete, with emissions from all sources characterized in some way. In addition, to better understood routine emissions sources, emissions from known or quantifiable fugitive sources such as leaking tanks or valves should be included in inventories when these emissions can be quantified in both the base and future years and because their reductions could help in achieving attainment. These emissions should not be excluded based on an invalid assumption that they are "malfunctions." In addition, startup/shutdown emissions should be included in inventories (see Section 4.8.1).

While completeness is required, there is no requirement that all parts of an emissions inventory be completed with the same degree of rigor. Because emissions inventory development is time consuming and expensive, it is wise for inventory developers first to focus their resources on the sources of emissions making up the bulk of the pollutants relevant for the NAAQS in question. To the extent that an inventory is to be used for multiple NAAQS or for multi-pollutant analysis, then the larger sources important for all relevant pollutants should be characterized with as much technical rigor as is feasible.

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Fortunately, existing inventories can help states guide their initial understanding of the sources of pollutants in a particular area. Air agencies can rely on the latest NEI or previously compiled SIP inventories to guide further development. The NEI is commonly used as a starting point for state and regional planning purposes for NAAQS implementation and regional haze planning. The EIS can help by providing emissions summaries for counties or groups of counties and for emissions sectors or SCCs.

For additional information, the Particulate Emissions volume of the EIIP technical report (see https://www.epa.gov/air-emissions-inventories/volume-9-particulate-emissions) provides thorough recommendations for identifying sources of PM emissions. These recommendations can be useful for other pollutants as well.

Starting with an existing inventory poses some risks and challenges. Here we try to address the most common issues associated with SIP inventories when starting with existing inventories:

1. **How do I know which sources in an existing inventory should get further review?**
   The EPA suggests the following considerations in deciding which sources to be reviewed:
   a. The largest contributors to the pollutants of interest (i.e., the pollutants contributing to ozone and/or $PM_{2.5}$ formation) using some coarse groupings, such as the EIS Sectors, Tier 2, or Tier 3 groups.
   b. Sources within the NAA (or contributing to it in the case of modeling attainment demonstration inventories). Special considerations to sources closest to and upwind of violating monitors may deserve special attention.
   c. Knowledge about the growth or retraction of a particular sector of the economy. Oil and gas production is a recent example of a quickly growing industrial source of emissions.
   d. Considering whether the proportion of emissions associated with a particular source is likely to have an impact on the outcome of decisions. Emissions methods/changes for sectors that are likely to have a large impact on the planning process should get higher priority.
   e. Assessing whether the approaches used in the preparation of SIP emissions are updated with current approaches, including appropriate emission factors. This is particularly important for source categories for which there is large uncertainty and those with ongoing research.

2. **What if the original inventory does not use good approaches?**
   The EPA recommends starting with inventories that have available and clear documentation. If an inventory developer cannot figure out how the emissions were estimated, then it will be difficult to build upon those results.

   With documentation, inventory developers should be able to evaluate the quality of approaches used. As part of the NEI program, the EPA publishes updated methods for many nonpoint emissions categories. The highest quality point source emissions estimates are based on facility-specific testing, and where not available, current emission factors. Mobile emissions should be based on the latest mobile models, using as many location-specific inputs as possible.

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If it is determined that a starting inventory does not use the latest methods, it is advisable to reassess those emissions with newer methods (or other available inventories) prior to deciding if that category requires even further work.

3. **If I need to make updates, where are the latest approaches available?**
The EPA's NEI program is a good source of the latest approaches and approaches in development. In many cases, multi-jurisdictional organizations also have updated approaches for various emissions sectors. The Emissions Inventory Improvement Program volumes still have a lot of valuable information on emissions, though some sections are outdated (see https://www.epa.gov/air-emissions-inventories/emission-inventory-improvement-program-eiip). Approaches have historically included AP-42 and WebFire emission factors, though these resources are outdated for some sectors. For more information on updated emission factors, see Section 4.6.

4. **What do I do if the NEI approach has added PM or other emissions that I did not report, and I think that they are invalid?**
The EPA commonly augments PM emissions provided by states in the NEI because many states do not report total $PM_{2.5}$ and neglect the condensable portion of PM emissions (see also Section 4.2.1). Consistent with the requirements for complete SIP inventories, the EPA works to create a complete and accurate NEI. If emissions have been added erroneously, states should make those improvements, but should also let the NEI program staff know that there may be a flaw in their methods and provide a better source of information. Just because a source has not reported condensable emissions does not mean that they do not exist or should not have been characterized. In some cases, states may need to go back to sources to clarify that condensable PM emissions must be provided to the state agencies.

Another source for added EPA criteria pollutant and precursor emissions is NH_3 for point sources from the TRI. Since these are emissions that the facility submits to the EPA through the TRI program, they should potentially be considered as a source of information when identifying sources
of NH_3.

Only the facility total emissions are available from the TRI program (with stack and fugitive emissions denoted separately). This is not generally enough detail for a SIP inventory. For SIP inventories for $PM_{2.5}$, air agencies would need to follow up to develop more refined information about the facility NH_3 so that NH_3 emissions could be included in the SIP inventories. If the source is a "point source" based on the AERR thresholds for other pollutants, then including NH_3 emissions as part of the point source emissions is required by the AERR and, therefore, in $PM_{2.5}$ SIP inventories in accordance with the $PM_{2.5}$ SIP Requirements Rule. If the source is not a point source based on thresholds of other pollutants, than the AERR NH_3 threshold of 100 tpy potential to emit would apply in determining if the facility should be reported as a point source.

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Otherwise, the emissions should be included as a nonpoint source in the SIP inventory. If a state air agency believes that these emissions are erroneous or unimportant, some discussion of these sources should be included in their SIP as to why the NH_3 emissions as identified by TRI are not being included in a SIP inventory in some form. For incorrect TRI emissions, states should consider coordinating with the facility and the EPA's TRI program to improve the emission estimates.

4.4 Spatial Extent

The spatial extent of an inventory refers to counties, states, or other geographic regions covered by the emissions data. As described in previous sections, inventories needing to be included in SIPs are either for the NAA area only (for ozone and $PM_{2.5}$) or are for the entire state (for regional haze and ozone or $PM_{2.5}$ when modeled attainment demonstrations are needed). Modeled attainment demonstrations are likely to use emissions from a regional multi-state area. While it is not a SIP requirement to submit an inventory for other states, the emissions are needed to do the modeling.

A number of complicating issues related to spatial extent arise with inventories. Below, more information is provided on partial counties, when point-source locations are needed for emissions that have traditionally been nonpoint sources, shapefile-based inventories, and link-based mobile emissions.

4.4.1 Nonattainment Areas with Partial Counties

In some cases, NAAs do not follow county boundaries. Since most inventories and many underlying datasets are available at the county level, this poses a challenge for emissions calculations, in particular for nonroad and mobile sources.

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Air agencies may wish to use full-county emissions in meeting some SIP requirements, despite the designation of partial-county NAAs. The EPA has considered the advisability of using whole-county emissions to represent partial county emissions and has determined that this is not possible. In particular, using whole-county emissions would pose a challenge for using these inventories for ROP/RFP analyses, which can only include reductions within the NAA. Thus, areas designated as partial counties should estimate those partial county emissions using one of the approaches described here.

For point sources, Geographic Information System (GIS) technology enables straightforward selection of point sources into a partial-county NAA by intersecting a dataset of point source latitude/longitude coordinates with a shapefile of the NAA boundaries.

For nonpoint and mobile sources, available inventories and methods are often designed to create county totals, making partial counties much more difficult. A variety of acceptable approaches exist for calculating partial county emissions, though the particular approaches chosen should be agreed to as part of developing the plan for the SIP planning inventory as described in Section 2.2.

1. Custom calculations: Air agencies could develop a custom approach to estimate emissions using activity data estimated for the partial county area. Since many source categories need to be estimated, this could be a very labor intensive approach, or could be used for just key categories where other approaches are insufficient.

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2. Shapefile-based inventories: See Section 4.4.3.

3. Use of spatial allocation surrogates: Some sources of data exist at sub-county resolution, including road networks, travel demand model results (see also Section 4.4.4), and census data that are available at census tracts or blocks. When the emissions activity can be reasonably assumed to follow an allocation method based on one such surrogate dataset, GIS techniques can be followed to apportion a county emissions estimate to a partial county NAA based on the patterns of these sub-county data.

4. Use of gridded modeling data: Modeled attainment demonstrations rely on air quality modeling that uses gridded emissions data, which could be resolved at a sub-county resolution. Gridding resolutions of 12-km, 4-km, or even 1-km have been used. Similar to what was described above in the previous approach, emissions processing relies on spatial surrogates to apportion county-level data to grid cells needed for modeling. Rather than take a custom spatial surrogate approach, these gridded data may be sufficient to apportion county-level data to a partial-county NAA using GIS overlay techniques. Such an approach would sum the parts of the gridded data intersecting the partial county area to provide the partial county area inventory. The primary difference in this approach compared to the previous approach is the intermediate step of using the gridded data. This could be appealing since those gridded data may already be available from modeling done for attainment demonstrations.

5. Expert judgment: When there is no appropriate sub-county data surrogate available, when air quality modeling is not part of the SIP process, or when a category is relatively unimportant to the SIP planning process, other methods may be advisable. In this case, an air agency should explain their rationale to the respective EPA Regional office and come to agreement on a technically reasonable approach. Such approaches could include using the entire county estimated emissions, assuming some fraction based on understanding of county activities, or taking an area-proportional (uniform distribution) approach. In this latter approach, the partial county emissions are assumed to be the total county emissions times the area of the partial county divided by the area of the total county.

Since these partial county emissions calculations could need to be done for a variety of inventories and for SIP revisions, considerations should be made for the repeatability of the approach so that it does not become overwhelming to the analysis. In collaboration with the EPA Regional office, a balance needs to be found among level of effort, technical credibility, and repeatability.

The latest spatial approaches and data are available with the latest emissions modeling platform data on the Emissions Modeling Clearinghouse (EMCH). The EIIP Volume III, Chapter 1, Section 4.3 provides some additional information on spatial allocation; however, the examples used for spatial allocation approaches are much too old for most applications, and more sophisticated spatial surrogate approaches are available than those given as examples. In particular, except in rare circumstances, the use of population data as an allocation method is outdated and not recommended.

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4.4.2 Point Source Locations Needed for Modeling of Traditional Nonpoint Sources

In some cases, the details needed in a modeled attainment demonstration push inventory developers to use point-source locations for source categories that have traditionally been nonpoint sources. Some examples include sources of agricultural ammonia, dry cleaners, and gas stations. Rather than creating a much larger point source inventory, one approach is to keep a source as nonpoint, but use an emissions processing technique for modeling known as area-to-point allocation.

While this topic is primarily one for consideration in modeling inventories, it is included here because the planning inventory often provides a starting point for the modeling inventory (for the NAA counties). To the extent that modeling needs can drive additional detail in the planning inventories, this area-to-point feature can allow small sources to be included as nonpoint sources in a planning inventory but still allow point source locations to be used for modeling.

In area-to-point allocation, the emissions processor for modeling starts with county-wide estimates and a user-provided dataset that allocates county wide emissions to discrete latitude/longitude points (within the county). The inventory developer still must obtain the point source locations and proportion of countywide emissions, but the point source inventory remains more focused on the largest sources. Using an area-to-point allocation approach also avoids having to define stack parameters for inclusion of small sources in the point source inventory, which is useful because the stack parameters are not necessarily relevant to or available for these source categories.

4.4.3 Shapefile-based Inventories

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The EPA collects inventories for the NEI for commercial marine and locomotives using GIS shapefile-based inventories. Rather than including emissions as a county total, the emissions are allocated to individual sub-county areas or lines, each with its own GIS polygon shape. This approach was developed primarily to support fine scale and risk modeling that are done at a scale finer than most modeled attainment demonstrations.

These inventories can be useful for computing partial county emissions for those categories using this approach. Otherwise, it is not expected that states would need to start with the shapefile-based inventories for SIP planning. In some cases, states may wish to use such inventories in circumstances where the CMV and locomotive emissions spatial distribution is critical to the modeled attainment demonstration in some way. This may be important in NAAs that contain large ports and/or are near major coastal or inland waterways. Even in this case, use of county total inventories with appropriate spatial allocation using other techniques will still be able to allocate emissions sufficiently for both nonattainment area inventories (if partial counties are needed) and for modeled attainment demonstrations.

4.4.4 Link-based On-road Mobile Emissions and Travel Demand Models

SIP planning and modeling inventories often put great focus on mobile sources through the use of detailed emissions by roadway segments (or links) and the use of travel demand models (TDMs). This possibility is simply mentioned here for completeness and is not necessarily recommended, since these efforts are often substantial. The approach can also help with partial county emissions estimates.

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4.5 Temporal Basis

Various temporal bases may be needed for meeting different inventory requirements for SIPs. These can be different for ozone, $PM_{2.5}$, and regional haze. The emissions that should be used in planning inventories for ozone SIPs are ozone season day emissions. The emissions that should be used in planning inventories for $PM_{2.5}$ SIPs are annual emissions for SIPs addressing the annual or 24-hour $PM_{2.5}$ NAAQS or seasonal emissions for SIPs addressing the 24-hour $PM_{2.5}$ NAAQS. At a state's option, an inventory may contain both annual and average season data emissions for SIPs addressing the 24-hour $PM_{2.5}$ NAAQS. The temporal basis for emissions in Regional Haze SIPs is always annual actual emissions.

4.5.1 Temporal Considerations for Ozone SIPs

For ozone SIPs, ozone season day emissions (as defined in Section 2.5.2) are used for the base year inventory for the NAA. Since other planning inventories must be consistent with the base year inventory, inventories such as the projected attainment year inventory for the NAA and the periodic inventories must also include ozone season day emissions. Additionally, for states that include modeled attainment demonstrations in their SIP, statewide (or modeling domain-wide) ozone season day emissions and statewide annual emissions may also be important for Regional office evaluation and approval of the modeled attainment demonstration.

Ozone season day emissions are defined in Section 2.5.2. As explained in the [30]definition, states must select the representative months and work week days to include in the calculation of the ozone season day emissions. The temporal basis for these emissions should be representative of the conditions leading to nonattainment, as recommended by the state and approved by the EPA prior to finalizing the emissions approach to be used. The EPA acknowledges that there could be instances where ozone values are elevated above the level of the NAAQS only in non-summer months or on weekend days, including when winter emissions or weekend emissions dominate the episode. In recognition of this situation, the terminology used has changed from "summer day emissions" to "ozone season emissions." The general expectation of high emissions activity on weekdays is the basis for the weekday specification in the definition of ozone season day emissions. However, in the event that weekend emissions were to be higher than weekday emissions, the state should consider whether weekday emissions are sufficiently representative of the nonattainment problem. Since the goal of the definition of ozone season day emissions is representativeness of the emissions contributing to the ozone nonattainment problem, if including the weekend emissions resulted in a better representation of emissions, then states may be able to justify including weekend emissions in coordination with the EPA Regional office.

In general, to calculate ozone season day emissions, reporting agencies should estimate emissions for a specific period (month, week, selected days, or a day) where emissions (and other factors) resulted in ozone values above the level of the NAAQS leading to nonattainment. The preference should be given for weekdays as previously described, unless there is a reason to use other days. An ozone season day emissions value should be calculated by summing the emissions on those days and dividing by the number of days included in the sum.

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For mobile source emissions, mobile source emissions models can produce output for an average weekday or weekend day. Consult the EPA's MOVES Technical Guidance, "*MOVES2014 and 2014a Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and transportation Conformity*". This guidance provides numerous recommendations including how to determine temperatures to use in calculating emissions for base year and attainment year NAA inventories.

As noted in the preamble for the Ozone Implementation Rule, HEDD periods could have higher emissions than during other periods, which could contribute to ozone formation in a particular nonattainment area. Additional contributing factors to HEDD-period impacts include location and timing of the HEDD-related emissions, emissions amounts from other sources during the HEDD period, and meteorology. If an air agency determines that emissions increases (within a NAA) associated with HEDD periods significantly contribute to ozone nonattainment, then the air agency should include those higher emissions in the planning inventories: the base year inventory for the NAA (which also serves as the ROP/RFP baseline), and the attainment projected inventory for the NAA. As described above, in consultation with the EPA Regional office, air agencies should select periods to use for defining the appropriate days to include in the calculation of ozone season day emissions that are representative of the conditions leading to nonattainment. Thus, air agencies that have determined HEDD periods are important should select such periods as part of their ozone season day emissions estimation approach. As a result, air agencies could estimate HEDD emissions in a way that represents an appropriate portion of their NAA emissions inventories. More information on how to estimate HEDD-related emissions is provided in Section 4.8.1.

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4.5.2 Temporal Considerations for $PM_{2.5}$ SIPs

The emissions must be reported as annual total emissions, average-season-day emissions, or both, as appropriate for the relevant PM2.5 NAAQS. The rationale for the type(s) of emissions provided must be included as part of the attainment plan. When seasonal emissions are included, the rationale for the seasonal period must also be included as part of the attainment plan. A discussion of the EPA's rationale for including the option of seasonal or annual inventories is provided in Section IV.B.2.d of the $PM_{2.5}$ Implementation Rule preamble. The regulatory text for this requirement is also provided at 40 CFR 51.1008(a)(1)(iii).

In the case of the 24-hour NAAQS, the form of the NAAQS is based upon monitored values on particular days with high levels of ambient $PM_{2.5}$, and in some nonattainment areas, those days may occur only during a distinct and definable season of the year. For the $PM_{2.5}$ NAAQS, states can meet the inventory requirement with different combinations of temporal resolutions for the emissions. For the annual standard, annual emissions must be submitted. For the 24-hour standard, states must submit either an annual or an average-season-day inventory and optionally may submit both. For a nonattainment area for both the annual and 24-hour standard, states can meet the inventory requirement with only an annual inventory or with both an annual and average-season-day inventory.

In contrast with the annual $PM_{2.5}$ NAAQS, the 24-hour $PM_{2.5}$ NAAQS is designed to protect against peak exposures. Thus, for the 24-hour $PM_{2.5}$ NAAQS, there are circumstances in which the EPA believes that a

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seasonal emissions inventory alone may be sufficient for attainment planning purposes. 40 CFR 51.1008(a)(1)(iii) allows states to use seasonal inventories for attainment plan development for attaining the 24-hour $PM_{2.5}$ standard in areas that are designated nonattainment for only the 24-hour standard. Use of a seasonal emissions inventory will also be appropriate only if the monitored violations of the 24-hour $PM_{2.5}$ NAAQS in the area occur during an identifiable season. In the event that it is appropriate to rely solely on a seasonal emissions inventory, the state should confer with the EPA concerning the exact length of the season and the start and stop dates of the season. The duration and start and stop dates of the season will be an important component of the attainment plan and must be approved by the EPA along with other elements of the attainment plan for a given nonattainment area. Further, seasonal inventories must use average-season-day emissions values for this purpose, as defined by 40 CFR 51.1000. The nature of some seasonal $PM_{2.5}$ emissions sources (e.g., residential wood combustion) does not allow for only weekday emissions to be included in the inventory; therefore, all days must be included. The state would need to explain the rationale for the duration of the season used for the inventory as part of the attainment plan submission. To justify the use of a seasonal emissions inventory, the state must demonstrate why a seasonal emissions inventory is appropriate for the particular $PM_{2.5}$ nonattainment area in question.

4.6 Emission Factors for SIP Emissions Inventories

As expressed in 40 CFR 51.114(a), inventories "must be based on measured emissions or, where measured emissions are not available, documented emission factors." Given that the preference is measured data, the intent of the regulations is for emissions to be specific to the source of the emissions. To ensure that emissions estimates that use factors are high quality, the emission factors for SIP development should come from credible sources. The possible sources necessarily differ for stationary, on-road mobile, and nonroad sources. The mobile sources with EPA models are the most straightforward. For all states but California, on-road mobile emissions should be estimated with the latest EPA on-road model, MOVES. For California, the most recent EPA-approved version of EMFAC should be used. For stationary sources and remaining nonroad mobile categories, there are several approaches that can be acceptable, with the guiding principle of using credible sources of data. Where emissions inventory SIPs are to be approved by the EPA, inventory developers should work with the appropriate EPA Regional office to make sure the emission factors are acceptable.

Air agencies should pay close attention to the methods that they are using to calculate emissions to ensure updated approaches are used. It would be difficult for an EPA Regional office to approve an inventory that used an outdated method for an important part of the inventory if an updated method was available at the start of the SIP planning inventory development effort. Since the EPA could have multiple approaches posted for the same sector and some of those approaches could be outdated, air agencies should not assume that all EPA-posted methods are equivalent and acceptable. For example, some emission factors from AP-42 for nonpoint sources are outdated when compared to nonpoint methods and factors used for the NEI. The EPA recommends that air agencies refer to the latest NEI development web pages and contact Regional offices to confirm that their planned approaches are up to date. The IPP process described above can be helpful in this process.

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For most stationary point sources, air agencies have rules in place that require the submission of point source data to the state for air planning purposes. Much of these data are then submitted to the EPA as part of the NEI and used as the basis for point source inventories in SIPs. These state rules may have their own requirements about emission factors and source tests to be used; where possible, these rules should follow this guidance.

The EPA recommends selecting emission factors based on the hierarchy of emission factor sources shown in Table 16, which is consistent with the requirement in 40 CFR 51.114(a) that emission inventories for SIPs use measured data or emissions factors if measured data are not available. The higher up on this hierarchy the emission factor chosen, the better the quality of the emissions estimate. Based on the emission factor approach used, the states should also set the required "emission calculation method code" (see Section 2.5.14) for inclusion in their inventory data.

Table 16: Hierarchy of emission factors for use in point source emissions inventories

Rank	Emission Factor Approach	Emission factor method code to use
1	Continuous emissions monitoring system	1
2	Facility/process-specific emission factor. Average of representative stack tests (on one stack) downstream of controls (or if no controls).	4
3	Single representative facility/process-specific stack test downstream of controls (or if no controls).	4
4	Facility/process-specific uncontrolled emission factor, plus control efficiency. Average of representative stack tests (on one stack) upstream of controls, adjusted based on expected control efficiency.	24
5	Single representative facility/process-specific stack test upstream of controls, adjusted based on expected control efficiency.	24
6	Site-specific emission factor. Average of representative stack tests across multiple stacks or processes, downstream of controls (or if no controls).	10
7	Site-specific uncontrolled emission factor, plus control efficiency. Average of representative stack tests across multiple stacks or processes, upstream of controls, adjusted based on expected control efficiency. Only makes sense when all processes measured are fed to the same type/combination of control devices.	30
8	Material balance	3
9	Manufacturer specification	7
10	Best available other emission factor for uncontrolled or including controls, which is one of:	
	EPA emission factor	8
	S/L/T emission factor	9
	Vendor emission factor	11
	Trade group emission factor	12
	Other emission factor	13

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Best11 available pre-control emission factor, plus control efficiency, which is one of:		
	EPA emission factor, plus control efficiency	28
	S/L/T emission factor, plus control efficiency	29
	Vendor emission factor, plus control efficiency	31
	Trade group emission factor, plus control efficiency	32
	Other emission factor, plus control efficiency	33
12	Engineering judgement	2
13	Emission factor with best available speciation profile, one of:	
	EPA speciation profile	5
	S/L/T speciation profile – e.g., to calculate metals emissions from filterable $PM_{2.5}$ or volatile HAP from VOC.	6

4.7 Inventory Data Codes

Building inventories includes the use of various codes, such as SCCs, state/county FIPS, tribal, control measure, NAICS, pollutant and emission method codes. A full accounting of all possible codes is available as part of the EIS "Reporting Code Tables" available to EIS users using the "Reporting Code Tables" link at the left-hand side. The codes are also available to non-EIS users (on a somewhat more delayed timetable) at https://www.epa.gov/air-emissions-inventories/emission-inventory-system-eis-gateway under the "EIS Code Tables (Including SCCs)" link. There are more than 60 separate lists of codes that define all of the required and optional coded data elements based on the AERR. As we have noted above, the AERR is relevant as the rule that codifies the correct development of all inventories submitted to the EPA.

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4.7.1 Codes to Use for Nonattainment Area Inventories

Air agencies developing inventories for SIP planning should use valid EIS codes in all of their inventories. Since codes change over time, the EPA has adopted the approach in the EIS to "retire" codes when no longer needed and to add codes when needed. Codes are generally retired in coordination with NEI development cycles, ideally retiring codes only when plenty of notice has been provided to states in advance of an NEI inventory submission period. As such, codes that are retired may have already been used as part of a SIP development process, and that is okay. This is the advantage to retiring codes rather than removing them. Conversely, the EPA may not be able to retire a code until an appropriate point in the triennial NEI cycle. If an air agency wishes to submit a SIP-related inventory to the EIS for the NEI or another purpose, it will need to use valid (and not retired) codes for the year being submitted.

4.7.2 How to Request New Codes or Code Retirements

In general, if a new code is needed for compiling an inventory, then an air agency staff member should contact the EPA to request a new code. The recommended contact method is to use the call or email using the contact information listed for "Facility Inventory and Point Emissions" on the EIS contacts page at https://www.epa.gov/air-emissions-inventories. Requests for codes should include which code

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table(s) are affected, why existing codes are not sufficient, and a recommendation for a code and its definition and purpose. While the EPA anticipates that code retirement requests will usually come from the EPA rather than from external groups, a code retirement request should be made using the same mechanisms.

The EPA most often gets requests for new SCC codes since new emissions processes arise in industries, or processes are newly identified as having emissions associated with them. If an air agency inventory developer cannot find an appropriate SCC code for an inventory process, a choice needs to be made to either use a generic ("miscellaneous") SCC or to request a new SCC. For cases in which the contribution of the emissions process to any one precursor pollutant is minimal, inventory developers may choose to report using one of the miscellaneous SCCs. If the process is a significant source of one or more pollutants or that process might be a part of a control program, then an SCC request is probably warranted. The EPA staff will evaluate the SCC request to make sure that a similar code does not already exist, consider codes that have been created but not yet activated for use in submitted inventories[31], assess the need for the SCC, and either indicate an existing appropriate SCC to use or assign a new appropriate code.

4.8 Estimation of Base Year Emissions

This section describes the estimation of base year emissions for use in planning inventories for ozone, $PM_{2.5}$ and regional haze implementation. Subsections cover point, nonpoint, on-road mobile, nonroad mobile, biogenic sources, and fires, respectively.

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4.8.1 Stationary Point

Stationary point sources can be estimated through continuous measurements and through more traditional methods. EIIP Volume II, Chapter 1, Sections 1 through 7 provide still-relevant information on compilation and calculation of point source inventories. Readers developing point source inventories should also use that report as a resource.

Sources estimated with CEMS

The best estimate of stationary point source emissions is obtained through the use of CEMS. Several pollutants, including NO_X, SO_2, CO_2, and mercury (Hg) can be measured with CEMS. Fuel heat input on an hourly basis is usually also be collected as part of the EPA's CEMS programs, and heat content can be used to estimate emissions for other pollutants using emission factors (with specific test-based factors preferred). More information and guidance on CEMS can be found at http://www.epa.gov/airmarkets/emissions/continuous-factsheet.html.

The vast majority of CEMS-equipped sources use these measurements as part of reporting programs to the EPA. In particular, the Acid Rain Program and NO_X SIP call and other trading programs collect data as part of the EPA's Clean Air Markets. Through that program, CEMS-based emissions are available through

[31] Some SCCs are set up for use in collecting source test data and developing emission factors. Sometime after that, the SCCs can be used for creating and submitting inventories, depending on the availability of emission factors and/or the interest for using those SCCs by industry and air agencies.

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the "Data and Maps" resource, including emissions summaries and files ready to be used in the SMOKE system used for emissions modeling.

For a few sources, emissions must be reported only for part of the year. In these cases, users of the data should be careful not to override the annual emissions estimates for such units with the partial-year data included in the CEMS databases. This can be a particular challenge for modeling inventories, where the more temporal resolution is useful for the time periods covered, but the other time periods must use a different approach to apportion the remaining emissions to the rest of the year.

Other (non-CEMS) sources

EIIP Volume II, Chapter 1, Section 4 provides general emission estimation procedure information. It provides a table similar to Table 16, but also focuses on the cost associated with the different approaches. It acknowledges that the cost incurred with collecting the more specific source test data should be commensurate with the need for a higher data quality. Like the EIIP figure, Table 16 also lists the more costly (and better) approaches higher on the list. The EIIP volume provides guidance on each of the various methods of computing emissions.

The remainder of EIIP Volume II includes chapters that address various combustion, manufacturing, and production activities that are point sources. Information in these chapters can be used to estimate ozone, $PM_{2.5}$, and regional haze precursor emissions where they address the source categories of interest. In some cases, the EIIP chapters are somewhat dated and so may not cover newer emissions processes. In these cases, inventory developers should adapt the techniques or develop new techniques to ensure there estimates are relevant to the sources. The EIIP point source chapters within Volume II cover topics as follows (numbers correspond to chapter numbers):

2. Boilers
3. Hot mix asphalt plants
4. Fugitive emissions from equipment leaks
5. Wastewater collection and treatment
6. Semiconductor manufacturing
7. Surface coating operations
8. Paint and ink manufacturing
9. Secondary metal production
10. Oil and gas production
11. Plastic products manufacturing
12. Effects of control device efficiencies and malfunctions
13. Stone mining and quarrying
14. Uncontrolled emission factors for criteria pollutants
15. Packaging and graphic arts
16. Chemical manufacturing

Each industry- or source-specific document contains a brief description; identification of emission points; an overview of methods available for estimating emissions; example calculations for each

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technique presented; a brief discussion on quality assurance (QA) and quality control (QC); and the SCCs needed for entry of the data into a database management system. The SCCs included in each volume apply to the process emission points, in-process fuel use, storage tank emissions, fugitive emissions, and control device fuel (if applicable).

For NH_3 sources, a report is also available in the "nonpoint" section of EIIP entitled "Estimating Ammonia Emissions from Anthropogenic Nonagricultural Sources - Draft Final Report" (April 2004) and covers many point source processes as well as nonpoint ones. Although a lot of research has been done on possible new approaches to agricultural NH_3 estimation as point sources, these "farm-based" approaches have not been completed yet. At this time, the EPA augments agricultural NH_3 sources only as nonpoint sources, rather than as point sources. Readers should see Section 4.8.2 for more information on emissions estimation from nonpoint sources.

A final resource is to use the facility-total NH_3 from the TRI. For SIP planning inventory purposes, these emissions should be apportioned to individual processes, but at least can be a starting point in the absence of other information. TRI provides emissions by stack and fugitive, with all stack emissions summed together and all fugitive emissions together. This level of detail would not be sufficient for a significant NH_3 source and so, while TRI can be a starting point, additional information would need to be gathered from the facility to apportion the emissions to the processes at the facility.

Startup/shutdown emissions

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The regulatory expectations for SSM emissions are included as part of 40 CFR part 52 in the EPA's "State Implementation Plans: Response to Petition for Rulemaking; Restatement and Update of EPA's SSM Policy Applicable to SIPs; Findings of Substantial Inadequacy; and SIP Calls to Amend Provisions Applying Excess Emissions During Periods of Startup, Shutdown, and Malfunction" final rule (SSM rule). A fact sheet and list of affected states is available on the website for this action.

The requirements of the Ozone and $PM_{2.5}$ Implementation Rules and the Regional Haze Rule require the reporting of historical annual-total emissions only (and in some areas "typical" seasonal and/or daily emissions for certain pollutants), not day-to-day emissions. As noted in the preamble of the final SSM rule:

> *"Actual emissions during SSM events should be included in these annual emissions. While data formats are available from the EPA to allow a state to segregate the total annual emissions during SSM events from annual emissions during other types of operation, segregation is not a requirement and few states do so" (80 FR 113, page 33950).*

The key takeaway message from this guidance is that since startup/shutdown emissions are planned and predictable, they should be included in SIP planning inventories. While the final SSM rule generalizes that "SSM" emissions should be included, this guidance clarifies that this means startup/shutdown rather than malfunction as further described below. In addition, states should pay particular attention to estimating startup/shutdown emissions if these types of emissions are believed by the air agency to have a significant contribution to the NAAQS design values.

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Since malfunctions are, by nature, unpredictable and given the myriad different types of malfunctions that can occur, malfunction emissions would be difficult to estimate and future-year malfunction events cannot be readily predicted. Thus, states are not obligated to include malfunction emissions in the base inventory for the NAA, ROP/RFP plans, or attainment projected inventory for the NAA. However, to the extent that malfunctions become a regular and predictable event, then such emissions should be quantified with regular and predictable emissions and included in emission inventories for planning purposes. The elimination of high emissions during routinely reoccurring malfunctions could potentially help achieve significant emissions reductions needed by a state in attaining the relevant NAAQS.

For sources with CEMs that capture emission rates at all times, the CEM will capture the startup/shutdown emissions without taking any of the other steps described below. Without CEMs, estimating startup/shutdown emissions becomes more complicated.

Startup/shutdown emissions can be quantified by assessing the emissions during startup or shutdown periods using traditional emissions estimation approaches of throughput and emission factors. However, the throughput and emission factors must be customized for the activity during these periods. Generally, emissions rates during these periods are higher and less well characterized than a typical operating emissions rate, and so some degree of expert judgement may be needed in assessing these emissions. For example, if control devices are not effective or active during these periods, the emissions during these types would not be able to reflect controlled emissions rates. If device emissions rates are associated with an operating temperature and the emissions are higher during a warm-up period, adjustments to the emissions during the startup period could be made.

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In addition to estimating the actual emissions during startup/shutdown periods, another approach to estimate startup/shutdown emissions is to adjust control parameters via the emissions calculation parameters of rule effectiveness or primary capture efficiency. Using these parameters for startup/shutdown adjustments is not their original purpose, but can be a simple way to account for the emissions and still have a record of the routine versus startup/shutdown portions of the emissions. For example, a lower capture efficiency or rule effectiveness can adjust the estimate of emissions to be higher, accounting for extra emissions from startup/shutdown activities. In the absence of measurements of throughput and/or emissions rates during startup/shutdown periods, expert judgment may need to be used to define the adjustment factors to use. This approach, however, can complicate the use of the control parameters during development and documentation of control strategies since the control parameters reflect things other than controls – thus, care should be taken when using this approach.

Emissions associated with HEDD periods

As described in Section 4.5, when air agencies have determined that emissions associated with HEDD periods are important for addressing their nonattainment problem, those air agencies should include HEDD-related emissions in their planning inventories. This subsection first describes what information is available to help assess when HEDD periods occur and to help provide activity data that could be used as part of estimating the associated emissions. Second, this subsection describes how to consider HEDD-

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related emissions in planning inventories (e.g., the base year inventory for the NAA) as compared to those in modeling inventories.

Emissions from HEDD periods can include additional emissions from more typical EGU boilers, turbines, and other units (collectively called peaking units), and also from combustion-based sources of distributed generation such as large back-up generators and other engines. A key challenge in developing emissions estimates for HEDD-periods is determining when the peaking units and distributed generation units were operating and consequently produced emissions. In the case of peaking units, many of these sources have CEMS that record activity and emissions levels, and these data are reported to EPA. In the case of distributed generation units, little or no information may be readily available in part because the energy produced by the backup generators and other engines is not measured by the electric utilities and independent system operators (ISOs), but rather may be experienced by the utilities and ISOs as an unmeasured demand reduction.

During HEDD periods, energy customers may use backup generators to participate in demand response programs. Though some useful information may be available from the utilities and ISOs running those programs, there may also be no information available. The specific rules, reporting, and frequency of use will vary by the utility or ISO that is offering the demand response program. Demand response program requirements vary and can include: (a) completely excluding the use of backup generators, (b) allowing the use of backup generators and requiring some reporting, and (c) not requiring customers to report anything about actions taken to provide the demand response. The lack of data on demand response backup activity has been noted by others based on past analyses.[32,33] Where emissions from demand response programs may be important, air agencies should first collaborate with their state energy and public utility commission counterparts who may have established mechanisms for information collection and sharing. Air agencies may also need to assess the demand response programs in their area by working directly with utilities and/or ISOs.

Starting in 2015, the National Emission Standard for Hazardous Air Pollutants (NESHAP) and New Source Performance Standards for Reciprocating Internal Combustion Engines (RICE) (40 CFR part 60, Subparts IIII and JJJJ, and 40 CFR part 63, Subpart ZZZZ), also called the RICE rules, now require owners/operators of emergency engines participating in emergency demand response programs to report the dates and times that the engines operate for emergency demand response as well as engine information such as horsepower and model year. While the RICE rules do not require the reporting of NO_X emissions or information about non-emergency programs, they will start to help provide information useful for understanding the activity of these back-up generators and engines, which may also be helpful for ozone planning purposes.

While it may continue to be difficult to find data needed for assessing HEDD-related emissions, air agencies may still include these emissions in both their modeling inventories and planning inventories.

[32] White paper: "*Air Quality, Electricity, and Back-up Stationary Diesel Engines in the Northeast*," Northeast States for Coordinated Air Use Management (NESCAUM), August 1, 2012.

[33] See also the Mid-Atlantic Distributed Resources Initiative (MADRI) working group meeting information available at http://sites.energetics.com/madri/meetings_2012.html.

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The HEDD-related emissions included by air agencies in planning inventories should have some logical relationship with the emissions in modeling inventories. The planning inventories will of course be limited spatially to the NAA, while the modeling inventories will cover a larger area. Air agencies should extract the appropriate NAAs to include in the planning inventories. Temporally, the modeling inventories will include day- and hour-specific emissions for seasonal or episodic periods, which can include HEDD periods, while the planning inventories will be an ozone season day emissions value. As explained in Section 4.5, the days used to calculate the ozone season day emissions are chosen for the particular SIP in consultation with the Regional office. Some examples of possible relationships between the modeling inventories (episode-specific) and the planning inventories (ozone season day) are as follows:

- Ozone season day emissions could be an average across all days of the episode-specific emissions used in the modeled attainment demonstration.
- Ozone season day emissions could be an average of a longer episode or series of episodes that overlap with the episodic period used for the modeled attainment demonstration.
- Ozone season day emissions could be a representative selection of the episodic-specific emissions, such as a median emissions value or using a single day emissions value that somehow is representative of other days.

These are not the only possible examples. Any approach chosen to determine appropriate HEDD-related ozone season day emissions should be developed in consultation with the Regional office and should seek to meet the overall goal for the base year inventory. Namely, the NAA inventory should be representative of the emissions conditions within the NAA that typically lead to nonattainment problems.

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4.8.2 Stationary Nonpoint

Nonpoint sources collectively represent individual sources that have not been inventoried as specific point or mobile sources. These individual sources treated collectively as nonpoint sources are typically too small, numerous, or difficult to inventory using the methods for the other classes of sources.

Stationary nonpoint sources can be estimated through numerous different approaches. Though some approaches are outdated, the EIIP Volume III, Chapter 1, Sections 1 through 6 provide relevant information on compilation and calculation of nonpoint source inventories. Also, the Volume III webpage contains numerous supplemental reports for specific source categories.

For many categories, more updated approaches are included in the EPA tools developed for use by air agencies in developing inventories. The latest tools are provided as part of the materials for the latest NEI – either as developmental materials for an ongoing NEI effort, or as supporting materials to document a completed NEI effort.

Table 17 provides a list of emissions categories, pollutants, and available approaches documentation and/or tools. Older versions of the tools used for the 2011 NEI are still available as part of the 2011 NEI documentation at https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-documentation under the "Data and documentation" link.

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Table 17: List of nonpoint categories, pollutants, and available approaches and tools

EPA-estimated emissions source description	Possible Overlap with Point	Available Nonpoint Resources (Posted year)
Agricultural Fertilizer Application		2014_Fertilizer_Application_v1.0_22apr2016.zip (2016) Old: ag_fertilizer_application_2011.zip (2013)
Agricultural Fires		2014 Draft Agricultural Burning and Grass/Pasture Estimated Emissions (2016)
Agricultural Tilling		2014_Agricultural_Tilling_v3.1_10mar2016.zip (2016)
Animal Husbandry		2014_Ag_Livestock_v1.0_20may2016.zip (2016) Old: animal_livestock_emissions_2011.zip (2009)
Architectural Coatings		Solvent_Tool_v1_5.zip (2016) EIIP, Volume III, Chapter 3 (1995)
Asphalt Paving	Y	2014_NPt_Asphalt_18nov2015_edit03302016.zip (2016) EIIP, Volume III, Chapter 17 (2001)
Asphalt Roofing Kettles	Y	See abstract available with the EIIP Volume III website (2000)
Autobody Refinishing	Y	Solvent_Tool_v1_5.zip (2016)
Aviation Gasoline		2014_Av_Gas_Stage_1_15nov2015.zip (2015) 2014_Av_Gas_Stage_2_15nov2015.zip (2015)
Backyard Barbecues		2014_Backyard_BBQs_15nov2015.zip (2016)
Commercial Cooking		2014_Commercial_Cooking_v1.2_08mar2016.zip (2016)
Consumer & Commercial – All personal care products		Solvent_Tool_v1_5.zip (2016) EIIP Volume III, Chapter 5 (1996)
Consumer & Commercial – All household products		Solvent_Tool_v1_5.zip (2016) EIIP Volume III, Chapter 5 (1996)
Consumer & Commercial – All coatings and related products		Solvent_Tool_v1_5.zip (2016)
Consumer & Commercial – All adhesives and sealants		Solvent_Tool_v1_5.zip (2016) EIIP Volume III, Chapter 5 (1996)
Consumer & Commercial – All FIFRA related products		Solvent_Tool_v1_5.zip (2016)
Degreasing	Y	Solvent_Tool_v1_5.zip (2016)
Dental Preparation and Use		epa_mercury_dataset__62714(2).zip (2015) Documentation for the 1999 Base Year Nonpoint area source National Emissions inventory for HAPs, page A-30 (2000)
Dry Cleaning	Y	Solvent_Tool_v1_5.zip (2016) EIIP, Volume III, Chapter 4 (1996)
Dust – Paved Roads		2014_Road_Dust_v2.1_09mar2016.zip (2016)
Dust – Unpaved Roads		2014_Road_Dust_v2.1_09mar2016.zip (2016)
Dust – Construction		2014_Construction_Dust_v3.0_18feb2016.zip (2016)
Gasoline Distribution/Marketing	Y	2014_Gasoline_Distribution_v1.0_with_PT_subtraction_01apr2016.zip (2016) EIIP, Volume III, Chapter 11 (2001)
General Laboratory Activities		epa_mercury_dataset__62714(2).zip (2015)
Graphic Arts	Y	Solvent_Tool_v1_5.zip (2016)

		EIIP Volume III, Chapter 7 (1996)
Human Cremation	Y	cremation_2011.zip (2013)
Industrial, Commercial/Institutional Fuel Combustion	Y	ICI Tool v1_4.zip (2015) Estimating Ammonia Emissions From Anthropogenic Nonagricultural Sources - Draft Final Report (April 2004)
Industrial Surface Coating	Y	Solvent_Tool_v1_5.zip (2016) EIIP, Volume III, Chapter 8 (1997)
Lamp Breakage (Landfill emissions)		epa_mercury_dataset_62714(2).zip (2015)
Lamp (Fluorescent) Recycling		epa_mercury_dataset_62714(2).zip (2015)
Landfills	Y	EIIP, Volume III, Chapter 15 (2001)*
Mining and Quarrying		2014_Mining_and_Quarrying_v2.3_09mar2016.zip (2016)
Oil and Gas Production	Y	OIL_GAS_TOOL_2014_NEI_EXPLORATION_V1_5.zip (2016) OIL_GAS_TOOL_2014_NEI_PRODUCTION_V1_5_Access2007.zip (2016) OIL_GAS_TOOL_2014_NEI_PRODUCTION_V1_5_Access2013.zip (2016)
Open Burning (Leaves, Brush, Residential Household Waste, Land Clearing)		2014_Open_Burning_v1.1_03mar2016.zip (2016)
Other Special Purpose Coatings	Y	Solvent_Tool_v1_5.zip (2016)
Pesticide Application		2014_Agricultural_Pesticides_v2.0_18feb2016.zip (2016) EIIP Volume III, Chapter 9 (2001)
Portable Gas Cans (Residential and Commercial)		2014_Portable_Fuel_Containers_25nov2015.zip (2016)
Publicly Owned Treatment Works	Y	2014_POTW_nonpoint_emissions_23march2016.zip (2016)
Residential Heating - Fossil Fuels		2014_Residential_Heating_non-Wood_v1.2_09mar2016.zip (2016) See also abstracts available for coal, fuel oil & kerosene, gas & liquified petroleum gas (LPG) available with the EIIP Volume III website (1999).
Residential Heating – Wood		2014_RWC_v3.0_28apr2016.zip (2016) EIIP, Volume III, Chapter 2 (2001)
Structure Fires		EIIP, Volume III, Chapter 18 (2001)
Traffic Markings		Solvent_Tool_v1_5.zip (2016) EIIP, Volume III, Chapter 14 (1997)
Vehicle Fires		See abstract available with the EIIP Volume III website (2000)
Waste Disposal (Incineration)		Estimating Ammonia Emissions From Anthropogenic Nonagricultural Sources - Draft Final Report (April 2004)

* Landfill emissions estimates are available in the NEI as point sources, based on the activity information submitted to the EPA as part of the Greenhouse Gas Reporting Rule.

As indicated in Table 17 by the column "Possible Overlap with Point," some source types can have emissions in both the point source data category and the nonpoint one. Some categories that may have both types of sources are denoted, and this list is based on what has been seen in the NEI. The list of categories in this situation depend on an individual state's policies, such as what the emissions size threshold is for a point source and whether any categories are treated as point sources despite having

low individual emissions.

To prevent overestimation of nonpoint emissions for sectors that also have point sources, it is important to perform point/nonpoint reconciliation. This reconciliation starts by subtracting the activity associated with the point sources from the total activity data (prior to computing the nonpoint emissions). Since point sources often have emissions controls, it is usually not sufficient to just subtract point source *emissions* from total activity-based emissions to prevent double counting. Subtracting *controlled* point source emissions from *uncontrolled* total activity-based emissions would result in too much nonpoint emissions. Rather, the point source activity must be determined and subtracted from total activity to get the nonpoint activity estimate. Alternatively, *uncontrolled* point source emissions can be calculated and subtracted from the total activity-based emissions estimates to derive a nonpoint emissions estimate.

Part of developing refined nonpoint emissions estimates for a SIP could involve the use of surveys to collect data. Inventory preparers often use survey questionnaires to gather point source emissions inventory data. The EIIP Volume III, Chapter 24, written in 2000, provides guidance on developing and conducting surveys for area source inventories. Since this document predates some of the newer online survey techniques, the sections describing the use of the internet are outdated. As part of the documentation for inventories, survey design and results should be kept and included in any documentation reports or appendices.

4.8.3 On-road Mobile

Emissions from on-road vehicles are the result of several emission processes, including the combustion of fuel while vehicles are starting, idling, and moving, evaporation of fuel from the fuel system and during refueling, and from brake wear and tire wear.

For all states but California, on-road mobile emissions should be estimated with the latest EPA on-road mobile model, MOVES[34]. MOVES estimates emissions for many combinations of vehicle classifications and fuel types. Readers should follow the latest MOVES guidance. For California, the most recent EPA-approved version of EMFAC should be used.

The available guidance covers using MOVES for inventory development in SIPs in states other than California. The guidance focuses on determining what the appropriate inputs are and how MOVES should be run to develop emissions estimates for on-road vehicles. It describes when default MOVES inputs are appropriate for SIPs and regional conformity analysis and what factors to consider for providing locality-specific MOVES inputs.

MOVES estimates emissions for multiple source use types (the terminology that MOVES uses to describe vehicle type) and fuel types. MOVES also estimates emissions for different road types that represent rural and urban unrestricted and restricted (accessed only by an on or off ramp) access roads, as well as off-network emissions such as vehicle starts, evaporative emissions while parked, and hoteling emissions when long-haul combination trucks are parked for long periods with the engine running under load.

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One of the key elements for use of MOVES is creating a Run Specification (RunSpec) file, which defines the place and time period of the analysis as well as the vehicle types, road types, fuel types, and the emission-producing processes and pollutants that will be included in the MOVES run. The MOVES Technical Guidance describes using the MOVES graphical user interface GUI to set up a MOVES run for a particular scale (e.g., county), time period, set of pollutants, and the vehicle types, road types, and fuel types applicable to a particular area and time.

Another key element for use of MOVES is entering local meteorology, fleet, activity, fuel, and control measure information using the County Data Manager. The MOVES Technical Guidance discusses when local data should be used in place of model default data, as well as potential sources of local data.

For some input parameters, there is overlap with the inputs needed for other models, such as the nonroad mobile models (e.g., meteorology and fuels). Efforts should be made to use the same source of data across multiple categories when the inputs are shared. Not doing so calls into question the validity of one or both approaches. Air agencies should explain the use of shared inputs, or reasons for not using them, as part of the documentation provided with their inventories.

4.8.4 Nonroad Mobile Equipment

Nonroad mobile equipment emissions result from the use of fuel in a diverse collection of vehicles and equipment, including:

- recreational vehicles, such as all-terrain vehicles and off-road motorcycles;
- logging equipment, such as chain saws;
- agricultural equipment, such as tractors;
- construction equipment, such as graders and back hoes;
- industrial equipment, such as forklifts and sweepers;
- residential and commercial lawn and garden equipment, such as leaf and snow blowers;
- recreational marine vessels, such as power boats.

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Starting with MOVES 2014, MOVES incorporates and expands upon the capabilities of the older NONROAD model. States are required to use MOVES for any nonroad source emissions estimates for SIP development that is started since the release of MOVES 2014.

MOVES nonroad capabilities include predicting emissions for all of these nonroad equipment categories listed above. Emissions from CMVs, locomotives, and aircraft are estimated in other ways and described in Section 4.8.5. The MOVES nonroad capabilities include more than 80 basic and 260 specific types of nonroad equipment and further stratifies equipment types by horsepower rating. Fuel types include gasoline, diesel, compressed natural gas (CNG), and Liquified Petroleum Gas (LPG).

The nonroad capabilities of the MOVES model estimates emissions for all criteria pollutant and precursors from both exhaust and non-exhaust processes (diurnal, refueling spillage, vapor displacement, hot soak, running loss, take permeation, hose permeation, and crankcase emissions). NONROAD supports many SIP-related inventory development needs, including support for partial counties and seasonal emissions.

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Air agencies have the option of replacing default model inputs with more representative data. Common input adjustments include equipment population, geographic allocations, and local growth rates. If agencies make changes to default model values, the agency should submit the input files to the EPA as well as a description of why the defaults were changed. Additional guidance on improving nonroad estimates for lawn and garden equipment can be found in EIIP, Volume IV, Chapter 3.

For some input parameters, there is overlap with the inputs needed for other models, such as the on-road mobile models (e.g., meteorology and fuels). Efforts should be made to use the same source of data across multiple categories when the inputs are shared. Not doing so calls into question the validity of one or both approaches. Air agencies should explain the use of shared inputs, or reasons for not using them, as part of the documentation provided with their inventories.

4.8.5 Other Nonroad Mobile

The MOVES model does not provide air agencies with a tool for estimating emissions for CMVs, aircraft, and locomotives. Thus, separate methods are used for each of these emissions sectors.

For purposes of reporting data to the EPA, aircraft emissions are often reported as point sources, with this being a requirement for reporting data to the EIS for use in the NEI. Likewise, the CMV and locomotive data are included in the nonpoint data category in the EIS. While these sources are still mobile sources from the traditional standpoint of emissions categories, for data formatting and reporting purposes in the EIS, they are treated along with these non-mobile data categories.

4.8.5.1 Aircraft

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The aircraft sector includes all aircraft types used for public, private, and military purposes. This includes four types of aircraft: (1) commercial, (2) air taxis (AT), (3) general aviation (GA), and (4) military. A critical detail about the aircraft is whether each aircraft is turbine- or piston-driven, which allows the emissions estimation model to assign the fuel used, jet fuel or aviation gas, respectively. The fraction of turbine- and piston-driven aircraft is either collected or assumed for all aircraft types. NEI data are available for this sector for use as a starting point in SIPs, though the NEI includes military aircraft only where state or local air agencies have submitted military aircraft emissions data.

Commercial aircraft include those used for transporting passengers, freight, or both. Commercial aircraft tend to be larger aircraft powered with jet engines. ATs carry passengers, freight, or both, but usually are smaller aircraft and operate on a more limited basis than the commercial aircraft. GA includes most other aircraft used for recreational flying and personal transportation. Finally, military aircraft are associated with military purposes, and they sometimes have activity at non-military airports.

The national AT and GA fleet includes both jet- and piston-powered aircraft. Most of the AT and GA fleet are made up of larger piston-powered aircraft, though smaller business jets can also be found in these categories. Military aircraft cover a wide range of aircraft types such as training aircraft, fighter jets, helicopters, and jet-powered and piston-powered planes of varying sizes.

Emissions at airports also include other sources that are a part of the nonroad equipment emissions described in Section 4.8.4. These emissions come from aircraft auxiliary power units (APUs) and aircraft

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ground support equipment (GSE) typically found at airports, such as aircraft refueling vehicles, baggage handling vehicles, and equipment, aircraft towing vehicles, and passenger buses. In the NEI point source inventory, these APUs and GSE are located at the airport facilities as point sources along with the aircraft exhaust emissions (though not as part of the aircraft sector). Emissions from APUs and from GSE can be calculated using the EPA's NONROAD model and by the Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System (EDMS). If the air agency chooses to calculate these emissions with the EDMS, care should be taken to remove exclude those emissions from emissions associated with the NONROAD model.

The EPA collaborates with the FAA to develop and maintain methods for estimating aircraft emissions using EDMS, which also estimates emissions from aircraft in addition to the APUs and GSE as noted above. The emissions developed in this way are associated with aircrafts' landing and takeoff (LTO) cycle. The EPA encourages state and local air agencies to collect aircraft LTO activity data that can be used in improving estimates using the EPA EDMS-based methods. More details on the EPA methods are available in the documentation and methods associated with the latest NEI year found at https://www.epa.gov/air-emissions-inventories/national-emissions-inventory.

The aircraft sector includes numerous SCCs as shown in Table 18, and all but two of these are associated with the NEI point source inventory. Historically, airport emissions have been calculated as a nonpoint source, but with the latest approaches having all airport locations readily available, such a simplification is no longer needed. The result of this change from nonpoint to point sources is that most of the SCCs are shown as 10-digit SCCs (usually used just for nonpoint sources) but are now used as point SCCs.

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Table 18: Aircraft SCCs and Data Categories in EPA Estimates

SCC	Data Category	SCC Description	EPA estimates
2275001000	Point	Mobile Sources; Aircraft; Military Aircraft; Total	X
2275020000	Point	Mobile Sources; Aircraft; Commercial Aircraft; Total: All Types	X
2275050011	Point	Mobile Sources; Aircraft; General Aviation; Piston	X
2275050012	Point	Mobile Sources; Aircraft; General Aviation; Turbine	X
2275060011	Point	Mobile Sources; Aircraft; Air Taxi; Piston	X
2275060012	Point	Mobile Sources; Aircraft; Air Taxi; Turbine	X
2260008005	Point	Mobile Sources; Off-highway Vehicle Gasoline 2-Stroke; Aircraft Ground Support Equipment	X
2265008005	Point	Mobile Sources; Off-highway Vehicle Gasoline 4-Stroke; Aircraft Ground Support Equipment	X
2267008005	Point	Mobile Sources; LPG; Aircraft Ground Support Equipment	X
2268008005	Point	Mobile Sources; CNG; Aircraft Ground Support Equipment	X
2270008005	Point	Mobile Sources; Off-highway Vehicle Diesel; Aircraft Ground Support Equipment	X
2275070000	Point	Mobile Sources; Aircraft; Aircraft Auxiliary Power Total	X

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2275085000	Nonpoint	Mobile Sources; Aircraft; Unpaved Airstrips; Total	
2275087000	Nonpoint	Mobile Sources; Aircraft; In-flight (non-Landing-Takeoff cycle)	X

In June 2012, the EPA promulgated standards for NO_X emissions from commercial aircraft engines. Information about this rule including fact sheets, test procedures, and emissions documentation is available on the EPA website for this purpose. In that rule, the EPA adopted Tier 6 and Tier 8 standards for NO_X on new aircraft engines, with compliance dates in 2013 and 2014. Prior rules published in 2005 and 1997 also reduce aircraft NO_X emissions with engine standards (documented on the same website). When estimating emissions from aircraft, it is best practice to consider the impacts of these rules for improving the accuracy of emissions inventories. This is why the EPA recommends using the EPA EDMS-based approach with locality-specific data.

State or local air agencies may determine that the EPA default method is not appropriate for SIP purposes, though the EPA recommends considering the approach but using more locality-specific activity information. For areas that have provided the EPA locality-specific airport activity data, the NEI estimates may very well provide emissions needed to meet SIP requirements. The EPA method is more robust than older methods and includes national control programs as noted below. As shown in the table above, the EPA's methods do not estimate emissions from unpaved airstrips (SCC 2275085000). Furthermore, the "in-flight" SCC (2275087000) is covered by the EPA's method for only lead (Pb) emissions and is related to general aviation aircraft that still use leaded fuel. Air agencies may want to consider unpaved airstrips and/or in-flight emissions for other pollutants as part of their inventories for improved model performance or other reasons, though doing so may not be necessary depending on the significance of those emissions in a particular area. Any locality-specific data or custom emissions associated with aircraft sources are expected to be included with supporting documentation for the emissions inventory used for a SIP.

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4.8.5.2 Commercial Marine

The CMV emissions category includes boats and ships used either directly or indirectly in the conduct of commerce or military activity. The majority of vessels in this category are powered by diesel engines that are either fueled with distillate or residual fuel oil blends. For the purpose of this inventory, we assume that Category 3 (C3) vessels primarily use residual blends while Category 1 and 2 (C1 and C2) vessels typically use distillate fuels. Another consideration for emissions estimation of CMV sources is auxiliary engines. All three types of vessels may have auxiliary engines that are used for onboard power generation or other needs.

The C3 inventory includes vessels which use C3 engines for propulsion. C3 engines are defined as having displacement above 30 liters per cylinder. C3 inventories typically include emissions from both propulsion and auxiliary engines used on these vessels, as well as those on gas and steam turbine vessels. Geographically, the inventories include port and interport emissions that occur within the area that extends 200 nautical miles (nm) from the official U.S. shoreline, which is roughly equivalent to the border of the U.S. Exclusive Economic Zone. For national inventories created by the EPA, only some of these emissions are allocated to states based on official state boundaries that typically extend 3 nm

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offshore. The EPA recommends that state water boundaries also be used when determining which emissions should be included with a particular state or county.

The C1 and C2 vessels tend to be smaller ships that operate closer to shore, and along inland and intercoastal waterways, with engines greater than or equal to 37kW. Naval vessels are not included in C1 and C2 vessel inventories, though Coast Guard vessels are included. While these C1/C2 vessels are most often associated with near-land applications and thus included as within state waters, sometimes these vessels are used outside of state waters, particularly in the Gulf of Mexico. In these cases, as with C3 vessels, the EPA recommends that state water boundaries be used when calculating emissions associated with a particular state or county.

The CMV source category does not include recreational marine vessels, which are generally less than 100 feet in length, most being less than 30 feet and powered by either inboard or outboard engines. The calculation of these emissions is included in the NONROAD model, and these emissions are, therefore, considered "nonroad equipment."

The EPA develops and maintains methods for estimating CMVs, and these methods are used as "fallback" methods for use in the NEI. They are also available as a fallback for states without other data for this sector. At this time, the EPA's methods are top-down national methods, which apportion nationally estimated emissions values to the states and counties. In the latest such approaches (used for the 2008 and 2011 NEI), this apportionment includes allocation to GIS shapefiles for ports and underway emissions. These shapefiles are available with the latest NEI documentation and include separate files for ports and underway. Key differences associated with various EPA methods from the 2002 NEI through the 2011 NEI have focused on allocation of emissions to the shapefiles, which has been done in collaboration with state and local air agencies.

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The current EPA methods also use emissions types. Each of the CMV SCCs requires an appropriate emissions type (M=maneuvering, H=hoteling, C=cruise, Z=reduced speed zone), because emission factors vary by emission type. For the NEI, each SCC and emissions type combination was allocated to a shapefile identifier in the nonpoint inventory. The allowed combinations of SCCs and emission types are shown in Table 19. The default values are those assumed when the actual emission type may be unknown; for example, emissions that occur in shipping lanes are assumed to be 'cruising' and cannot be 'hoteling,' which only occurs at ports.

Table 19: Commercial marine SCCs and emission types in EPA emissions

SCC	SCC Description	Allowed	Default
2280002100	Marine Vessels, Commercial Diesel Port	M	M
2280002200	Marine Vessels, Commercial Diesel Underway	C	C
2280003100	Marine Vessels, Commercial Residual Port	H	H
2280003100	Marine Vessels, Commercial Residual Port	M	H

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2280003200	Marine Vessels, Commercial Residual Underway	C	C
2280003200	Marine Vessels, Commercial Residual Underway	Z	C

State or local agencies may determine that the EPA default method is not appropriate for SIP purposes or may need further refinement by air agencies in developing SIPs. For example, the general calculation method may be a reasonable approach, but the activity and spatial allocation achieved from a top-down approach could be improved by using the same methods with locally resolved input data to calculate emissions for specific areas.

When estimating CMV emissions, reporting agencies should consider national regulations that decrease emissions from this sector, such as increasingly stringent emissions requirements for new marine diesel engines and sulfur requirements for marine diesel fuel and adjust their estimates accordingly. Emissions reductions resulting from requirements for new marine engines are generally not immediately reflected in inventories as newer engines are gradually incorporated into the vessel fleet and as older engines/vessels are retired. Emissions reductions resulting from the use of lower sulfur fuels are generally seen more quickly, though estimating impacts can be complicated by vessels coming from other parts of the world with different fuel standards. Table 20 provides a list of more recent relevant regulations and associated references for the CMV category. Older Tier 1 and 2 regulations on marine diesel engines, dating back to 1999, are also listed on the websites shown in the table.

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Table 20: Commercial marine vessel recent regulations and impacted pollutants

Regulation	Pollutants impacted	Reference
Great Lakes Steamship Repower Incentive Program (January, 2012)	SO_2, $PM_{2.5}$	Regulations for Emissions from Marine Vessels
Tier 2 and Tier 3 Emissions Standards for Category 3 Marine Diesel (April, 2010). Includes both engine standards and fuel sulfur limits.	SO_2, NO_X, $PM_{2.5}$	
Tier 3 and Tier 4 Emission Standards for Category 1 and 2 Marine Diesel Engines (June, 2008).	$PM_{2.5}$, NO_X	
Nonroad Diesel Tier 4 Rule (May 2004). Decreased allowable levels of sulfur in marine diesel fuel by 99%, taking effect in 2007.	SO_2	

For states needing to refine their emissions estimates beyond the values produced by the EPA's default methods, Table 21 provides a list of the latest resources for states in better understanding how to calculate emissions for the CMV sources. The newer references are included higher in the table. The EPA's recent method updates have occurred in conjunction with rule development efforts, and so some of these documents are associated with inventories developed for the rules listed above. Even newer methods may become available over time and can be considered for use in SIP planning inventory development. Much of this information is also available on the EPA nonroad mobile website under

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"Other Nonroad Reference Material". Any locality-specific data or custom emissions associated with CMV emissions are expected to be included with supporting documentation for the emissions inventory used for a SIP.

Table 21: Current EPA methods for commercial marine vessel emissions.

Inventory approach resource	CMV Approaches For…	Reference
Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (April, 2009)	Ocean going (generally C3) vessels, harbor craft, cargo handling,	https://archive.epa.gov/sectors/web/pdf/ports-emission-inv-april09.pdf
Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines (June, 2009)	Bottom-up port C3 emissions for 89 deep water and 28 Great Lake ports in the U.S. and interport emissions from the Waterway Network Ship Traffic, Energy and Environmental Model (STEEM).	https://nepis.epa.gov/Exe/ZyPDF.cgi/P1005ZGH.PDF?Dockey=P1005ZGH.PDF See Chapter 3.
Category 2 Vessel Census, and Spatial Allocation Assessment and Category 1 and Category 2 in-Port/At-Sea Splits (EPA-HQ-OAR-2003-0190-0423)	C1 and C2 vessels	https://www.regulations.gov/document?D=EPA-HQ-OAR-2003-0190-0423
Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder (May 2008)	C1 and C2 propulsion, C1 marine auxiliary, <37kW commercial propulsion, and <37kW marine auxiliary.	https://nepis.epa.gov/Exe/ZyPDF.cgi/P10024CN.PDF?Dockey=P10024CN.PDF. Chapter 1 provides more in-depth description of engine types, while Chapter 3 provides emissions calculation approach.
Emissions Inventory Improvement Program	Evaporative VOC emissions from marine transport of petroleum liquids, including the loading and unloading of the petroleum liquids.‡	EIIP, Volume III, Chapter 12 "Marine Vessel Loading, Ballasting, and Transit."

‡ These emissions are often included in as part of the nonpoint inventory rather than associated with the CMV sector.

Older approaches are also available. In 1999, the EPA sponsored two studies, "Commercial Marine Activity for Great Lake and Inland River Ports in the United States," and "Commercial Marine Activity for Deep Sea Ports in the United States." Both of these reports are available at the website for Reports related to Emissions Control Areas for Marine Vessels. These studies provide activity profiles for approximately 150 ocean, lake, and river ports, and present a method for an inventory preparer to allocate time-in-mode activity data from one of four typical ports to another port that has similar

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characteristics. Activity profiles for a typical port include: 1) number of vessels in each category; 2) vessel characterization, including propulsion size (horsepower), capacity tonnage, and engine age; and 3) number of hours at each time-in-mode associated with cruising, reduced speed, maneuvering, and hoteling. These methods provide alternative approaches for state and local air agencies in preparing SIP inventories, but care should be taken to incorporate the impact of national rules incorporated into the newer approaches as documented in Table 21.

4.8.5.3 Locomotives

The locomotive emissions category includes diesel-electric engines, which use 2- or 4-stroke diesel engines and an alternator or a generator to produce the electricity required to power its traction motors. The EPA default approach does not include locomotives powered by electricity or steam. It is believed that the number of wood or coal driven steam locomotives in the U.S. is currently very small; therefore, these types of locomotives are not generally included. In specific instances, if such sources are relevant to a NAA, then they may need to be included. The locomotive sources are further divided into categories: Class I line haul; Class II/III line haul; Passenger; Commuter; and Yard.

In the NEI, rail yard emissions are treated as point sources. Whether rail yards should be treated as a point source for SIP planning purposes depends on the importance of these emissions to the NAA and the analyses that need to be done for any modelled attainment demonstration. Emissions at these sources can include both stationary sources (e.g., switching engines) and mobile sources (locomotives). Because of the mobile source component, a rail yard doesn't necessary meet the technical definition of a major source. Nevertheless, for NAAs where rail yards are a significant source, the EPA recommends that states consider treating these as point sources so that the best spatial allocation can be used for modeled attainment demonstration.

Several definitions come into play in determining the locomotive category, which impacts the SCC that should be used.

- Class I railroads are those that operate in many different states over thousands of miles of track. They are defined by the U.S. Surface Transportation Board as having annual carrier operating revenues of $250 million or more. As of 2014, there were 8 such railroads in the U.S.: Amtrak and seven freight railroads, designated Class I based on 2011 measurements released in 2013 ("Class I Railroad Statistics". Association of American Railroads. April 17, 2013.)
- Class II/III railroads are also known as short line and regional railroads, and they range in size from very small (a few carloads of freight per month) to multi-state railroads just under Class I size. Class II railroads are defined as having revenues greater than $20.5 million but less than $277.7 million for a least 3 consecutive years. Switching and terminal railroads are excluded from Class II status. A Class III railroad is defined as a rail company with annual operating revenue of less than $20 million.
- Line haul refers to higher power usage of locomotive engines during extended mileage. It is also associated with a test cycle used for estimating emission factors intended to represent emissions during line-haul activity.

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The EPA develops and maintains methods for estimating locomotive emissions, and these methods are used in the NEI in the absence of more updated data from air agencies. They are also available as a fallback for states without other data for this sector. The EPA's 2011 national rail estimates were developed by applying growth factors to the 2008 NEI values based on railroad freight traffic data from the 2008 and 2011 "R-1" reports submitted by all Class I rail lines to the Surface Transportation Board and employment statistics from the American Short Lines and Regional Railroad Association for Class II and III. In the latest such approaches (used for the 2008 and 2011 NEI), this apportionment includes allocation to GIS shapefiles for line-haul and rail yard emissions. The EPA project report *Development of 2011 Railroad Component for National Emissions Inventory* (September 2012) provides the EPA's latest estimation approach and references the 2008 approach as well. The report for the 2008 NEI was another project report, called Documentation for Locomotive Component of the National Emissions Inventory methodology (May 2011) and available in the zip file posted with the 2008 NEI documentation. Ongoing work for the 2014 NEI and future inventories will further improve upon past methods.

The 2008 and 2011 EPA default method was developed with a consortium of the EPA, state, and industry, led by the Eastern Regional Technical Advisory Committee (ERTAC). The ERTAC group provided data and reviewed methods as is described in the 2008 NEI Technical Support Document and associated documentation. Table 22 lists the locomotive SCCs used in the EPA default methodology. Other SCCs exist as valid SCCs, but are not used in the EPA method, so states should consider this when comparing the EPA estimates to locality-specific estimates and when merging emissions inventories that include both state/local components and the EPA estimates.

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Table 22: Locomotive SCCs

SCC	Description	EPA Estimated?	Data Category
2285002006	Mobile Sources Railroad Equipment Diesel Line Haul Locomotives: Class I Operations	Yes – in shape files	Nonpoint
2285002007	Mobile Sources Railroad Equipment Diesel Line Haul Locomotives: Class II / III Operations	Yes-in shape files	Nonpoint
2285002008	Mobile Sources Railroad Equipment Diesel Line Haul Locomotives: Passenger Trains (Amtrak)	no	Nonpoint
2285002009	Mobile Sources Railroad Equipment Diesel Line Haul Locomotives: Commuter Lines	no	Nonpoint
2285002010	Railroad Equipment Diesel Yard Locomotives	no	Nonpoint
28500201	Internal Combustion Engines Railroad Equipment Diesel Yard	Yes – as point sources	Point

State or local agencies may determine that the EPA default method is not appropriate for SIP purposes or may need further refinement by air agencies in developing SIPs. A number of ways to improve the EPA estimates were noted in the original 2011 report (see ftp://ftp.epa.gov/EmisInventory/2011/doc/2008nei_locomotive_report.pdf) that documented the approach used for the 2008 NEI. For the Class I line-haul emissions, the report identifies the most

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important considerations such as the rail link-level freight tonnage. Other variables were not addressed in the methodology, including track grade and track speed. While the method calculated railroad-specific fleet- averaged emission factors from industry fleet data, it is noted that emissions from individual engines are highly variable even for the regulated engine categories depending on variables such as the specific locomotive model, operation cycle, and conditions of operation. Furthermore, the EPA approach does not address the seasonality of the emissions, while activity levels of different engines do vary seasonally and could impact emissions for seasonal inventories. Any locality-specific data or custom emissions associated with locomotive sources are expected to be included with supporting documentation for the emissions inventory used for a SIP.

For the rail yard emissions, we have already noted above the consideration of rail yards as point sources. In addition, the 2011 report mentioned in the last paragraph notes additional considerations for improvements. For example, using the tonnage hauled as an indicator of the amount of switching activity is an assumption that could reduce uncertainty. The variability associated with actual switching duty-cycles and in the number of switchers operating at some rail yards seasonally was not considered in the method.

Locomotive idling emissions is another issue that is not clearly considered in the default EPA methodology and could have an impact on emissions estimates. During normal operations, locomotives have numerous reasons why they may remain idling including the switching operations noted above. The EPA has included regulations on idle emissions to help address this source. More details on idling emissions from locomotives is available in "Control of Emissions from Idling Locomotives" (EPA, March 2008).

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The EPA website on locomotive emissions regulations provides a resources for understanding the regulations that apply to locomotives and how those may impact emissions. Only one recent regulation impacts emissions from locomotives, while several older regulations also apply. In June 2008, the EPA published the *Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder.* This rule includes standards for existing and remanufactured locomotives, Tier 3 and Tier 4 standards for newly built locomotives, and idle reduction requirements for new and remanufactured locomotives. The rule reduces emissions of $PM_{2.5}$ and NO_X. The emissions estimation approach used for this rule is available in Chapter 3 of the Regulatory Impact Assessment for the rule, and this approach differs from the EPA method used for the NEI. Associated with the rule, the EPA developed a fact sheet on locomotive emission factors (April, 2009) that can be used in estimating emissions from locomotives.

4.8.6 Biogenic and Geogenic Sources

Biogenic sources are a subset of natural emissions sources that may contribute significantly to an emissions inventory. Vegetation (i.e., forests and agriculture) is the predominant biogenic source of VOC and is typically the only source that is included in a biogenic VOC emissions inventory. Microbial activity in the soil contributes to natural biogenic NO_X and CO emissions.

The EPA makes available biogenic emissions estimates as part of the NEI. Starting with the 2008 NEI, the

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biogenic vegetation and soil emissions have been included in the official NEI releases. In some cases, these EPA-generated emissions may be sufficient for use in SIP inventories other than modeling inventories.

Biogenic emissions from vegetation and soils are computed using a model which utilizes spatial information on vegetation and land use and environmental conditions of temperature and solar radiation.[35] The model inputs are typically horizontally allocated (gridded) data, and the outputs are gridded biogenic emissions that can then be speciated and utilized as input to photochemical grid models. Several models exist, as described in the following subsections.

Modeled biogenic vegetation emissions are significant for understanding ozone formation, particularly in the Eastern U.S., and the dependence on meteorology makes using case-specific meteorology very important. In addition, the impact and model characterization of biogenic terpene and sequiterpene on secondary aerosol formation for PM modeling is thought to be important. Emissions data developers should consider the latest available information on this issue where biogenic sources are key sources in their modeling region.

Biogenic Emissions Inventory System (BEIS)

The EPA has developed the Biogenic Emissions Inventory System, version 3.6 (BEIS3.6) for use in estimating biogenic emissions. This model can be run both as part of a CMAQ model run and alternatively as a module of the SMOKE system. The CMAQ approach is described by the CMAQ wiki at http://www.airqualitymodeling.org/cmaqwiki/index.php?title=CMAQv5.1_Biogenic_Emissions_(BEIS)_Update. The latest documentation on the SMOKE approach to run BEIS is available at http://www.cmascenter.org/smoke/.

The key inputs to BEIS include:

- Temperature data at 2 meters, which can be obtained from modeled meteorological data, such as data from the Weather Research and Forecasting (WRF) Model. Such data are also needed for input to air quality models used for modeled attainment demonstrations sometimes needed as part of SIPs. The BEIS3.14 documentation has more information on the meteorological inputs.
- Land-use data from the Biogenic Emissions Land Use Database, version 4.1 (BELD4). BELD4 data provides data on the 230 vegetation classes at 1-km resolution over most of North America. These data are available at https://www.epa.gov/air-emissions-modeling/biogenic-emission-sources. These land use data can be created with the Multimedia Integrated Modeling System (MIMS) Spatial Allocator (https://www.cmascenter.org/sa-tools/). Air agencies can alternatively rely on the EPA's 12-km gridded data for modeling domains that overlap with the EPA national domain, provided with the EPA's latest modeling platform on the Emissions Modeling Clearinghouse.

[35] In most cases, ozone, PM, and regional haze modeling includes the emissions from vegetation and soils, but not other potentially relevant sources such as volcanic emissions, lightning, and sea salt.

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Other Biogenic Models

Other biogenic models such as Model of Emissions of Gases and Aerosols from Nature (MEGAN) (http://wiki.seas.harvard.edu/geos-chem/index.php/MEGAN_v2.1_plus_Guenther_2012_biogenic_emissions) are acceptable as well, provided that the users have demonstrated their suitability for the modeling application through model performance evaluation (see Modeling Guidance for more information). A version of MEGAN has also been incorporated into an air quality model called the WRF model coupled with Chemistry (WRF-CHEM) (http://www.pnl.gov/atmospheric/research/wrf-chem/). California has developed a GIS-based biogenic model called BEIGIS (http://www.arb.ca.gov/ei/biogenicei.htm). The EPA previously made a comparison between BEIS and MEGAN (available at http://www.cmascenter.org/conference/2008/slides/pouliot_tale_two_cmas08.ppt).

BEIS, MEGAN, and other models continue to evolve and so agencies using these models should evaluate the suitability of one model over the other as part of a modeled attainment demonstration. Once a choice has been made for modeling purposes, emissions should also be summed across the NAA for inclusion in the base year inventory for the NAA and/or the attainment projected inventory for the NAA.

Geogenic and Other Natural Sources

Geogenic emissions are primarily the result of oil or natural gas seeps and soil wind erosion. In addition, lightning may also be a significant contributor to natural NO_X emissions in an inventory area. Volcanoes and fumaroles (i.e., vapor or gas vents in a volcanic region) can be additional sources of geogenic emissions.

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As a source of ozone precursor emissions, geogenic sources are usually less significant than biogenic sources. However, geogenic wind erosion may contribute substantially to PM emissions in an area. In 2012, the EPA released CMAQ v5.0 that includes a module that dynamically estimates hourly natural emissions of fine and coarse dust particles due to wind action over arid and agricultural land. This allows the contribution of this source to be included in a modeled attainment demonstration without the need to prepare an emissions inventory first. The windblown dust approach is based on the work of J.S. Fu et al. (2016). For the emissions inventory SIP, air agencies using this feature should evaluate the results of the CMAQ-based approach to determine if it provides a reasonable representation of dust emissions in their modeling domain. Often times, CMAQ overestimates ambient crustal matter concentrations without the addition of windblown dust and so adding emissions may not be advisable.

If windblown dust emissions are included in SIP planning, such emissions should be included in the base year and attainment projected inventories to meet the requirements for a complete emissions inventory. In the case of using CMAQ, this would require that the CMAQ-based emissions be summed for the NAA. Since CMAQ produces gridded emissions estimates, air agencies would need to sum emissions from the relevant grid cells or portions of cells associated with the NAA and/or other geopolitical regions as appropriate. One relevant detail about the AERR regarding windblown dust is that they are specifically exempted from the reporting requirements in 40 CFR 51.20(d)

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State, local and tribal agencies should also prepare an inventory of all other significant geogenic sources in the inventory area. Methods for estimating VOC emissions from oil and gas seeps, as well as NO_X emissions from lightning, are described in the EIIP document, *Volume V, Biogenic Sources Preferred Methods* available at https://www.epa.gov/air-emissions-inventories/volume-5-biogenic-sources. For oil and gas seeps, the preferred method is to develop a local emission factor based on the study of oil or gas seeps in the inventory area.

Lightning produces NO, which is oxidized to NO_2 in the presence of ozone or in a photochemically reactive atmosphere. This NO_X is formed in the mid-upper troposphere and can impact the distribution of reactive nitrogen as well as ozone. NO emissions from lightning can be estimated by collecting activity data on the cloud-to-ground lightning flashes, assuming a frequency of intra-cloud flashes based on the value for cloud-to-ground lightning flashes, and applying appropriate emission factors (in molecules NO per flash) to these activity levels. Because lightning is not a direct source of NO_2, accounting for this source category is more important for air quality modeling purposes than for SIP planning inventory purposes. Given the altitude of these emissions, it is not usually important to include these emissions in the base year inventory for the NAA or in the attainment projected inventory for the NAA.

CMAQ v5.0 includes a parameterized approach to estimate NO_X emissions and its vertical distribution that is generated from lightning. Over the Continental U.S., the approach can use lightning flash totals from the National Lightning Detection Network (NLDN). For cases where such data are not available, an alternate algorithm can be used that estimates the number of lightning flashes based on the modeled convective precipitation. The peer reviewed literature contains both a description of the approach (Allen et al., 2011) and a model evaluation (Appel et al., 2010). More information is available from the CMAQ v5.0 wiki (see https://www.airqualitymodeling.org/index.php/CMAQ_version_5.0_(February_2012_release)_Technical_Documentation#Lightning_NOx_emissions).

4.8.7 Wildland Fires

Because the CAA specifies that planning inventories (e.g., the base year inventory for the NAA) must include all sources of emissions, the inventories should, therefore, include fires. Thus, wildfires and prescribed fires, including wildland fire use, should be included in the NAA inventories when they overlap with NAA boundaries. Generally, areas will find that the estimates available in the NEI will suffice for providing a reasonable estimate of these emissions, with the purpose of providing a general idea of the level of contribution to the overall emissions within the NAA.

Wildland fires (WLFs) are generally defined as any non-structure fire that occurs in the wild land (an area in which human activity and development are essentially non-existent, except for roads, railroads, power lines, and similar transportation facilities). The National Wildfire Coordinating Group[36] has identified the following two types of WLFs.[37]

[36] The National Wildfire Coordinating Group was formed under a cooperative agreement between the Departments of Agriculture and the Interior and consists of representatives from each of the Federal land management agencies and the National Association of State Foresters.

[37] Definitions are derived from the *Glossary of Wildland Fire Terminology*, National Wildfire Coordinating Group, PMS 205, July 2012. Available at http://www.nwcg.gov/glossary-of-wildland-fire-terminology.

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- *Prescribed fire* is any fire intentionally ignited by management actions in accordance with applicable laws, policies, and regulations to meet specific land or resource management objectives.
- *Wildfire* is any fire started by an unplanned ignition caused by lightning; volcanoes; other acts of nature; unauthorized activity; or accidental, human-caused actions, or a prescribed fire that has developed into a wildfire.

Wildland fires are a unique source of emissions with respect to NAAQS attainment planning. For ozone, $PM_{2.5}$, and regional haze planning purposes, these fires are major sources of primary $PM_{2.5}$ and VOC and a moderate source of NO_X. They can consequently impact the ambient $PM_{2.5}$ and ozone; however, they have a number of unique properties:

- Depending on the fuel source and acreage burned, both prescribed and wildfires can emit significant emissions, but emissions from prescribed fires are generally lower due to the burning characteristics and the relative amounts of flaming and smoldering emissions. In addition, prescribed fires can be used to prevent future wildfires, which are generally larger, hotter, more dangerous, and more polluting.
- Wildfires are naturally occurring events for which the emissions are generally not reasonable to prevent or control. As such, air agencies may request that the EPA exclude from regulatory determinations ambient data influenced by the wildfire if the request meets the criteria, schedule, and procedural requirements for an exceptional event set forth in 40 CFR 50.14.[38]
- Fire emissions can rise very high in the atmosphere on plumes, and the pollutants can be transported beyond state boundaries. Fires occurring outside NAAs can have impacts within NAAs on days that may not be determined to be exceptional events.
- Since wildfires and prescribed fires generally occur in forests and rangelands, they are less likely to be within the boundaries of NAAs, which are usually urbanized areas.
- Fires can also reduce ozone formation because their smoke can block sunlight that otherwise would result in more ozone.

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SmartFire emissions

The EPA has adopted for use in the NEI a satellite-based approach to estimate fire emissions at specific locations and as daily emissions. The SmartFire approach (see http://www.airfire.org/smartfire/) was developed by researchers with support from the U.S. Forest Service (USFS). The EPA and USFS have worked together to implement approaches for collecting activity data from states to feed SmartFire for use in calculating emissions. The SmartFire approach uses the following general equation to estimate wildfires and prescribed fires. Accurate estimates of fire emissions rely on accurate estimates of the terms in the equation below.

*Emissions = Area burned * Fuel Load Available * Fuel Consumed (Burn Efficiency) * Emission Factors*

[38] "Treatment of Data Influenced by Exceptional Events; Final Rule" (72 FR 13560, March 22, 2007). EPA is updating the 2007 exceptional events rule and expects to release the revised final rule before October 1, 2016.

The SmartFire2 (SF2) approach has been used most recently for the 2011 and 2014 NEIs.

SF2 estimates the "area burned" term in the above equation, in conjunction with the BlueSky framework model that estimates the last three terms in the above equation. The "fuel load available" term is estimated using the Fuel Characteristic Classification System (FCCS) maps in the BlueSky model. The "fuel consumed" term is estimated from BlueSky using the CONSUME3 model, which predicts the fraction of fuel that burns based on many parameters including fuel moisture. Finally, the "emission factors" term is estimated in BlueSky using the Fire Emissions Prediction Simulator which relies on EFs from the literature apportioned by flaming and smoldering combustion. Since SF2 was recently developed, direct references to its development in conjunction with updated BlueSky methods are not yet available; however, the following reference can be used in general for past applications of these process models in the SF/BlueSky process: https://www.airfire.org/smartfire/. Reid (2013) provides more exacting details on the specific procedures used in developing the NEI prescribed and wildfires. As new NEI years are developed and resources are available, additional improvements to SF2 are expected.

Some states have determine that SF2 is not sufficient for their needs because the satellite-based methods can miss detection of prescribed burning that occurs under thick tree canopies. As a general matter, the EPA encourages all users of SmartFire to work with their forestry agencies to obtain and use local-specific information about area burned, fuel types, fuel load, burn efficiency, and emission factors.

Exceptional Events and Inventories

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When developing design values for a particular NAAQS, certain ambient monitoring data may be excluded if an exceptional events submittal is approved by the EPA (see 40 CFR §50.1, 40 CFR §50.14, and 40 CFR §51.930). It has been suggested during the course of developing this guidance that emissions associated with exceptional events should be removed from the inventories. The purpose of this recommendation was the improvement of model performance evaluations and projected attainment modeling.

In spite of potential impacts on modeled concentrations, in most cases, the EPA does not recommend removing fire emissions from inventories for the following reasons. First, it is not necessary to remove fires from use in the model performance evaluation because the EPA does not expect ambient data to be removed from the model performance evaluation (www3.epa.gov/ttn/scram/guidance_sip.htm). Second, the EPA recommends holding the emissions of fires constant between the base and future years for the purpose of future year inventories (such as are required for $PM_{2.5}$ NAAQS) and for calculating a modeled relative response as part of a modeled attainment demonstration. This approach ensures that the modeled fires have a minimal influence on estimated future year concentrations that are calculated using the relative change in modeled concentrations. Third, even though in some cases there may be a direct causal link between fire emissions and monitored air quality data, resulting in exceptional events, removing fire emissions directly associated with an exceptional event from an inventory requires knowledge of exactly which fire(s) at specific locations on specific days and hours contributed to the exceptional event. This may be especially difficult when multiple fires over multiple days lead to identified exceptional events. Therefore, from an inventory perspective, it may not be straightforward to remove emissions specifically associated with any particular exceptional event. Determining which

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emissions to remove from the inventory could be a significant effort with limited benefit.

The EPA therefore encourages states to use a representative mix of prescribed fire and wildfire in their inventories. In the past, some plans under previous $PM_{2.5}$ NAAQS have estimated the actual fire emissions and temporal and spatial patterns from a given year and used this estimate as the assumed future baseline for planning, while others have used average emissions over multiple years. Other approaches may be appropriate as well. Moreover, regardless of the approach used, the EPA still encourages states to submit actual wildfire and prescribed fire activity data that are critical to developing emissions estimates to the NEI as suggested in the AERR. Additionally, the EPA encourages states to consult with their EPA Regional office about the fire approach to be used. While other approaches may be more suitable in particular situations, the recommendations provided here provide a starting point for discussions about the most appropriate approach for a particular area.

4.9 Quality Assurance

As part of the 8-hour ozone NAAQS, $PM_{2.5}$ NAAQS, and regional haze rules, state, local and tribal agencies are strongly encouraged to perform QA checks and procedures on their inventories. State, local and tribal agencies can develop and select the QA procedures they will perform, and should include the details of their QA program (including specific procedures) in their IPPs.

The purpose of QA is to ensure the development of a complete, accurate, and consistent emissions inventory. A well-developed and well-implemented QA program fosters confidence in the inventory and in any resulting regulatory and/or control program.

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When air agencies are using data from the NEI, additional QA is warranted considering the purpose for SIPs is not the purpose for which the NEI was developed. Since a great deal of QA is done on the data used for the NEI, most of the QA work has been done and so starting with the NEI can often save time.

The overall QA program provides routine and consistent checks and documentation points in the inventory development process to verify data integrity, correctness, and completeness; identifies and reduces errors and omissions; maximizes consistency within the inventory preparation and documentation process; and facilitates internal and external inventory review processes. Quality assurance activities include technical reviews, accuracy checks, and the use of approved, standardized procedures for emission calculations, and should be included in inventory development planning, data collection and analysis, emission calculations, and reporting.

4.9.1 QA Reference Materials and Planning

The EPA has developed several guidance documents designed to assist state, local and tribal agencies in designing and implementing their QA programs. The EIIP Volume VI, addresses QA issues, including the following:

- Chapter 1: *Introduction - The Value of QA/QC*
- Chapter 2: *Planning and Documentation*
- Chapter 3: *General QA/QC Methods*
- Chapter 4: *Evaluating the Uncertainty of Emission Estimates*
- Chapter 5: *Model QA Plan*

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- Appendix A: *Example Audit Report*
- Appendix B: *Technical Systems Audit Checklist Example*
- Appendix C: *Example 1 of Data Quality Audit Checklist*
- Appendix D: *Example 2 of Data Quality Audit Checklist*
- Appendix E: *Performance Evaluation Checklist Example*
- Appendix F: *EIIP Recommended Approach to Using the Data Attribute Rating System (DARS)*

On October 20, 2008, the EPA issued the latest version of the EPA Quality Program Policy (CIO 2106.0). This policy supersedes the previous CIO 2105.0 (formerly EPA Order 5360.1 A2). This policy established among other things, the requirement for QAPPs for all EPA-supported programs that generate environmental data. As described by the "EPA Requirements for QA Project Plans" guidance:

The purpose of a QA Project Plan is to document planning results for environment data operations and to provide a project-specific blueprint for obtaining the type and quality of environmental data needed for a specific decision or use.

The orders describing the QA requirements are available at the EPA's website for Agency-wide Quality System Documents (https://www.epa.gov/quality/agency-wide-quality-system-documents). That website also includes specifications for non-EPA organizations: "EPA Requirements for Quality Management Plans" (EPA/240/B-01/001; March 2001) and "EPA Requirements for QA Project Plans" (EPA/240/B-01/003; March 2001). Additional documentation is also available on the same website under the subheading of "General Guidance" that air agencies may find helpful in developing their own quality assurance plans for their inventory development efforts.

States should also consult with their EPA Regional office to determine how to meet the quality assurance planning requirements for the SIP planning inventory development.

4.9.2 Types of Problems in Emissions Inventories

Emissions inventories are compiled from a large number of disparate data sources, which can lead to many types of data problems. These problems can be divided into *value* errors and *structure* errors. *Value* errors are errors in the values of emissions inventory data fields, such as the emissions amounts, incorrect codes, missing values that are required, or incorrect data such as facility names, stack heights, or latitude/longitude locations. Correct quality assurance can identify these errors and allow data developers to correct them before the data are used for their intended purpose.

Structure errors refers to those data problems that cause databases to not work, such as missing records in relational database tables (e.g., "widows" and "orphans"), duplicate records (i.e., multiple records that represent the same emissions, causing double counting), or incorrect formats (e.g., the wrong number of fields, missing fields that are required, mismatched data types, such as integer versus text). Data with no structure errors are described as having good "data integrity." Generally, these types of problems should be automatically prevented by using robust data systems to manage the data in ways that match the expected downstream data use, but this is not always the case. For example, data systems managing emissions inventory data should be developed with the AERR requirements in mind, since these are the governing requirements for SIP-related inventories.

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4.9.3 Checks Available through the EPA's Emissions Inventory System

While many inventories used for SIPs are not also submitted to the EPA through its EIS (the system the EPA uses to build the NEI), the EIS does have a large number of documented QA checks that the system performs as it is loading data submitted by air agencies. This automated QA provides a large number of data integrity checks that air agencies can consider including in their own data systems or checking as part of their inventory QA. To access a list of these checks, EIS users must use the EIS Gateway and use the "QA Checks" link under the "Reference Data" heading on the left of the Gateway interface. The checks are not otherwise published on the EPA's website and can be requested by non-EIS users by using the "Contact Us" link provided at https://www.epa.gov/chief. The list has more than 600 data checks that are performed automatically by the EIS. While many of these checks are only relevant for getting data into the EIS, they promote standardization of inventories and proper formatting in accordance with the AERR, which (as noted previously) provides the EPA's standards for inventory preparation including for SIP inventories.

Since the timing of development of SIP inventories is rarely, if ever, coincident with the timing required for submitting emissions for the NEI, it is generally not feasible for air agencies to submit SIP inventories to EIS. However, the same types of checks can and should be done on SIP inventories to insure appropriate inventory quality.

The EIS checks include both critical errors and warnings. Critical errors prevent data getting into the EPA data system until they are corrected, whereas warnings allow the data to go through, but may need to be resolved to ensure the data transmitted to the EPA are correct. Examples of critical errors include:

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- Checks that data codes for required fields use valid values (for the given inventory year; see also Section 4.7)
- Fields required by the AERR and for data integrity are present
- Certain fields are within a critical range check (e.g., a year is between 1900 and 2050, stack height is between 1 and 1300 meters)
- Certain fields have appropriate lengths (e.g., ZIP codes are between 5 and 10 characters)
- Percentages are provided as percentages (1 to 100) and not as a fraction
- Data element types (e.g., integer, text, numerical) of required data fields are provided consistent with their required type.
- MOVES county database submission contains the correct files
- NMIM county database submission contains the correct files
- Conflict with pollutants reported for grouped pollutants versus individual members of the group.
- If stack diameter information is reported, the release point exit gas flow rate or velocity should be reported. Both may also be reported.

Examples of warnings include:

- Checks that data codes for optional fields use valid values (for the given inventory year)
- Data value is longer than the allowable width (some text fields will be truncated if longer than

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what the EIS allows).

- Emissions value is outside of a presumed valid range
- Exit Gas Stack temperature is outside an appropriate range
- When submitting monthly data, all months are not submitted together
- File names of mobile data files use incorrect file extensions
- Data element types (e.g., integer, text, numerical) of optional data fields are inconsistent with their required type.

4.9.4 Inventory Comparisons

Inventory comparisons can be used in multiple ways to effectively identify problems in new inventories. This is most useful when a high-quality prior inventory is already available. In states with a long history of developing SIPs, past inventories will be readily available for such comparisons. In states with new or emerging attainment problems, the EPA suggests comparing SIP inventories to the NEI. Even when the comparisons reveal problems not with the new inventory but with the one being compared, this can increase confidence in the inventory of interest.

Emissions are one of the obvious things to compare, and these comparisons are usually done on a pollutant-by-pollutant basis for pollutants important to a given analysis. As noted in the section on ranking techniques (Section 4.9.7), ranked emissions (e.g., facility, unit, county, SCC group) can be compared to the same ranked emissions from other inventories. Such comparisons will often identify differences worth further exploration when one large source appears on one list and not the other.

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In addition to ranking, all records across an inventory (or inventory summary) can be compared and percent differences can be computed. This is usually done by computing "new emissions – old emissions" divided by "old emissions." Large or unexpected percent differences can be investigated further to make sure that the differences have some reasonable explanation, such as newer emissions being controlled, a downturn in activity for one inventory, process changes, fuel changes, or a partial or complete facility closure. In some cases, methods changes may be the reason for such differences, including updated emission factors or test data.

For nonpoint emissions, graphical inventory comparisons can be useful. This can be done by not only using calculated percent differences or ranking, but also using GIS techniques to map county level emissions and their differences. It can be very useful to map the old emissions, new emissions, and the computed difference or percent difference side-by-side. This can reveal areas of large emissions that have significantly changed from one inventory to the next, raising questions for further exploration. When comparing to an EPA inventory that used EPA methods for a particular sector, this could reveal that the SIP planning inventory is a better inventory with updated methods, or it could reveal that outdated methods are being used. In any case, making the comparison will help inventory developers understand the potential improvements that could be made or that have been made, which will help in understanding reviewers' expected reactions to the data.

For multi-state inventories needed for SIP development, state-to-state comparisons may be useful in addition to county maps. This is especially true if emissions for one state were developed differently

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from emissions for another state. The EPA encourages states to work together to promote consistent approaches across a multi-state NAA, but a final QA check of the consistency can be done using the comparison techniques described here.

4.9.5 Checking Data Codes

As described in Section 4.7, air agencies should check the inventory data codes they are using against valid codes. Valid codes are defined by the EPA within the EIS. Air agencies that start with the NEI may significantly minimize the burden of this recommendation.

4.9.6 Point Versus Nonpoint and Reconciliation

Several quality assurance issues arise related to point versus nonpoint sources and inventories: (1) correct identification of point sources, (2) prevention of double counting across point and nonpoint, and (3) prevention of missing nonpoint emissions.

Minimum thresholds are specified in the AERR for which sources with facility total potential to emit emissions above those thresholds must be treated as a point source in SIP planning inventories. This is more fully explained in Section 2.5.7, with lower thresholds relevant for ozone and PM NAAs. Air agencies should implement a QA check (or otherwise have a data collection process) that ensures all facilities with potential emissions (potential controlled emissions, if applicable) that are greater than these thresholds are included in their inventory as point sources. See also Section 2.5.2 for more information on calculating potential emissions.

When a particular type of source includes contributions from both point and nonpoint sources, double counting can occur. Quality assurance steps should be taken to ensure that double counted emissions have been prevented. A good example of this is smaller boilers. Both point source facilities (based on the potential to emit thresholds) and smaller facilities are likely to have emissions from non-industrial boilers. For instance, some large institutional facilities such as hospitals may be included as a point source with their associated boiler emissions, whereas smaller institutional facilities are not included as point sources and would thus be included as a nonpoint source under an "institutional/commercial" boiler SCC.

The EPA provides calculation approaches for many nonpoint emissions that allow for subtracting out the activity of the point source parts prior to estimating nonpoint emissions, including that for the institutional/commercial boiler example. This is called "point/nonpoint reconciliation." Whether nonpoint emissions are estimated by the EPA or by air agencies, an assessment of quality should be done to ensure that sectors associated with both point and nonpoint sources do not double count emissions. See also Section 4.8.2 for additional information on preventing double counting. A list of source sectors with potential point/nonpoint overlap is provided in Table 17 above and in the latest NEI Technical Support Document, available at https://www.epa.gov/air-emissions-inventories/national-emissions-inventory.

A third type of QA should be done for categories that have both point and nonpoint contributions. It involves an assessment of potentially missing nonpoint emissions. Because the requirement for SIP inventories is to include emissions from all sources, it is not sufficient to exclude nonpoint emissions

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when part of a sector is covered by point sources, unless it can be shown that the nonpoint portion is negligible. At a minimum, air agencies should consider the tools available from the EPA to estimate nonpoint sectors (see Section 4.8.2) and evaluate whether or not their point source inventory covers all of the activity associated with the nonpoint categories. For inventory years not covered by EPA tools, agencies should compare point total activity as collected from point sources versus the same type of activity data used in the EPA tools. For example, U.S. DOE fuel consumption data can be used for industrial, commercial, and institutional boilers. The source of the activity data used for the latest EPA nonpoint methods is included in the descriptions of those methods in the nonpoint tools described in Section 4.8.2 and with the latest NEI documentation.

4.9.7 Ranking Techniques

Ranking emissions records can be a very useful tool to identifying value errors in emissions values or other numeric inventory data fields, or at least in finding records that need further investigation. Ranking involves first defining a set of sources and a level of aggregation of emissions and then ordering those emissions values from highest to lowest or lowest to highest. This analysis must be done one pollutant at a time. An analyst then considers whether those sources at the top of the list make sense.

Point sources, facility level emissions ranking

For point sources, ranking can be done at the facility total, unit total, or process level (i.e., at the SCC level), and each level has its place for reviewing inventories. A facility level ranking can often be followed by subsequent investigation to understand the reasons (at the unit and/or process level) for very high or very low values. An analyst using a ranking procedure would assess the facilities with the largest emissions and seek to understand whether they make sense. For example, for combustion products such as NO_X or SO_2, one would expect to see large EGUs and other industrial sources. Ranking of emissions values is usually done for one pollutant at a time, reviewing most carefully those pollutants that are most critical to the particular purpose of the inventory. For example, an inventory supporting ozone analysis would want to review NO_X and VOC most carefully.

It can be useful to compare the list of top facilities for a given pollutant from one inventory to a previous or alternative inventory for a given state or NAA. This can raise questions regarding large changes from one inventory to another, which could be explained (e.g., a decrease due to controls) or could identify a problem (e.g., a missing value or data entry problem). In addition, facility-level ranking can use additional grouping such as by industry code (i.e., NAICS), to identify unexpectedly high or low emissions for facilities within a particular industry.

Point sources, sub-facility emissions ranking

Unit- and process-level summaries can additionally be ranked for more specific analyses. For example, all boilers could be ranked and particularly high or low emissions values investigated. Similarly, all natural gas processes at particular unit types (e.g., boilers) or by industry (NAICS) could be ranked. These rankings can show real variations, but they can also find incorrect values that stand out when ordered and reviewed in this way. There are many variations that could produce useful results, and which ones are useful for a particular inventory depends on many factors and the purpose of the inventory.

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Nonpoint and mobile source ranking

Nonpoint and mobile emissions can also be ranked as technique to help with QA. Since these inventories are primarily compiled at the county/SCC resolution, the ranking can be done only at combinations of county, SCC, and for specific pollutants. Total county nonpoint emissions could be ranked to look for overly high or low values, but the same effect can be accomplished in a visual way with mapping approaches (see Section 4.9.9). Specific SCCs can also be selected and the emissions by county ranked, or individual counties selected and SCCs ranked and compared to other counties.

Since nonpoint emissions are based on various types of activity data that also has a county or other spatial resolution (such as census tract), these activity data can be used to "normalize" the nonpoint emissions prior to ranking. For example, emissions coming from households (e.g., residential heating, residential wood combustion, consumer solvents) can be divided by population or housing data and ranked for identify possibly strange results. Since some of the activity data used for these categories starts with state or regional resolution and is subdivided to apportion to the county resolution, such comparisons can reveal illogical outcomes of such approaches. For example, while it makes sense that residential wood combustion occurs more per household in rural areas, it wouldn't make sense for a very low population county to have a disproportionate amount of emissions and urban areas have none.

4.9.8 Outlier Analyses

One result of the ranking approaches described above will be to identify outliers. However, such ranking is a relatively unsophisticated way of identifying such outliers. A more robust approach can be used for point sources where states have the underlying activity data reported by facilities on a per-process basis. Dividing emissions by activity values would produce a set of implied emission factors, or rates. The rates for a similar set of processes (based on SCC) and control devices in use might be expected to be within an order of magnitude of each other. Emission rate values that are too far outside the expected relationship could be further investigated to better understand the source of any unexpected values, which might include an error in the units of measure or the presence of controls or an incorrect SCC, as well as data entry errors for emission values or other related fields.

4.9.9 Using Maps to QA Nonpoint Emissions

Nonpoint and mobile source emissions data are associated with states and counties and, therefore, are ideal candidates for mapping with GIS software. By mapping emissions values for individual SCCs or groups of SCCs, data analysts can identify unexpected patterns in the data that could signal an error in creating the data. Though it is technically more challenging to use GIS software, this approach can often be more valuable than ranking in identifying data problems.

Like the ranking techniques, GIS maps can also use emissions data normalized by some other underlying or related spatial data, such as population, land use, urban/rural designations, or housing. This type of information is increasingly available online from the U.S. Census Bureau and other sources. Data analysts can use the other data to identify unexpected relationships that possibly indicate bad assumptions made in the underlying methods.

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4.9.10 Expected Pollutants

Air agencies can use their expertise with emissions sources to identify which pollutants are expected from particular processes. In addition, for the 2014 NEI cycle, the EPA has provided a list of expected pollutants for each SCC. While this list is not comprehensive for any pollutant that can be associated with a process, it provides a bare minimum of essential pollutants associated with SCCs. For example, NO_X is always expected as a by-product of combustion processes. In addition to expected pollutants, analysts can also identify pollutants that are not expected from a particular process, such as SO_2 from an evaporative process.

Once identified, such lists can be used to cross-check inventories to identify either problems with reported emissions, pollutant codes used, or process codes used. For example, if a combustion process does not have NO_X emissions, it could be that the wrong pollutant code was used in reporting the NO_X and its showing up as something else. Or, the process itself may be incorrectly using a combustion process code.

Expected pollutants can also help with making sure the correct PM components are provided for PM inventories, in particular that condensable PM emissions are included in the total PM emissions and that both filterable and condensable PM emissions are reported. This issue was described in Section 4.2.1 along with a list of the types of sources expected to have such emissions.

Some emissions data analysts may not be familiar with various sources enough to know which pollutants should be expected. For point sources, agency staff can rely on the sum total of all reported data across multiple sources for a particular process to get a good idea of what should be expected. For example, if all but one industrial boiler burning natural gas reported VOC, then it would be worth further investigation as to why VOC was not reported for that one. Since the AERR specifies that all criteria pollutants must be reported if any one pollutant exceeds the potential to emit threshold, one should expect that similar processes from multiple facilities would have many, if not all, the same pollutants.

There are other ways to identify expected pollutants. These include looking at past inventories created by the same air agency or looking at the NEI. Another way is to see what emission factors are available for the process in Webfire. While these are not foolproof ways of finding expected pollutants, they can be very helpful. Comparing a draft inventory with such a list can also identify unexpected pollutants to consider. Used with ranking techniques, knowing what pollutants are expected can also help when you find zero or null values for a facility, unit, or process.

4.9.11 Facility and Release Point Locations

Facility and release point (e.g., stack) locations are key elements of inventories that are used primarily in preparation of inventories for air quality modeling and also in permit modeling. Facility locations are also used in mapping point sources for various public communications purposes or other reasons needing less precision. While facility resolution is acceptable for many modeling applications, including 12-km gridded modeling, the need for release point locations increases for finer resolution modeling. Thus, for 4-km or 1-km modeling, release point location information should be considered.

With regard to the more detailed release point coordinates, the EPA recognizes the need for air agencies

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to leverage SIP inventory development efforts for possible use for other inventory needs. Thus, air agencies should be particularly attuned to release point geographic coordinates for sources that could be involved in permitting or risk analysis. For regulatory dispersion modeling, release point location is critical (rather than only facility location).

The EPA's EIS and other inventory data systems support two types of locations: facility and release point. There are four key errors that can occur, and each can be identified with their own type of check, as listed below.

- Facility is not consistent with the state/county FIPS code
  This error can be found using GIS, SAS® or other calculations to compare the latitude/longitude location with the county boundaries using some tolerance. Because county boundaries have varying degrees of accuracy, a tolerance should be used that allows for locations near, but not always 100% within, county boundaries.
- Facility location is not consistent with the physical location of the facility
  Since some facilities can be on very large tracts of land, facility locations developed using geocoded addresses or facility entrances are often not accurate with regard to the actual location of the facility. For emissions inventory purposes, the EPA encourages that facility locations be positioned on top of a part of the facility that emits one or more pollutants, and the facility centroid is often sufficient for doing so. Using freely available mapping software such as Google Maps, latitude/longitude locations can be plotted on satellite images to ensure that values are on top of an emitting source and not on the road, at the corporate headquarters, or in some other invalid location.
- Release point location is not consistent with facility location
  This check is only useful once the facility location is accurate. Such an error can be found using GIS, SAS® or other calculations to determine the distance between the facility location and the release point locations. Alternatively, a subtraction of the absolute values of the latitudes and longitudes can be used to determine the difference in degrees. If that linear distance or the distance in degrees is greater than some preset criteria, then the locations can be investigated further. For some types of facilities such as refineries or major chemical complexes, the facilities may be very spread out and therefore may have legitimately large distances between release points.
- Release point location is not consistent with the physical location of the release points
  For many applications, including some SIP modeling applications, all release points using the same (usually facility) latitude/longitude is sufficient. However, with the availability of inexpensive GPS technology, it is more realistic for facilities to collect and submit individual release point location information. Furthermore, for some types of analysis, particular fine scale modeling for permitting and risk analysis, correct release point locations can make the difference between a good analysis and a useless one. It is very difficult to check the accuracy of release point locations, but using mapping software overlaid on satellite images can provide some sense of whether the release points are meaningful or not. Coordinates reported to one-ten-thousandth of a degree (four digits after the decimal point) give a precision of

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approximately 30 feet. Thus, a simple check to see if such values are useful is to examine the number of decimal places included in a given database.

Since a facility's location is not likely to change, the EPA has implemented a procedure in the EIS that allows latitude/longitudes to be locked, meaning that they cannot be changed accidently during a data exchange with a state. We encourage air agencies to implement a similar approach in their data systems so that the efforts of QA done on one inventory can be inherited by other inventories created by that agency. Locking mechanisms prevent the data from being changed inadvertently through a new data collection that relies on data from an unverified data source. Thus, a comparison of the locations used in the SIP inventory to any locked and verified site coordinates in EIS would also highlight potential errors.

4.9.12 Release Point Parameters

Like release point locations, release point parameters (also called stack parameters) are key elements of inventories that are used primarily in preparation of inventories for air quality modeling. The release point parameters impact the modeling of emissions from facilities because they specify details of the way the emissions are released (e.g., they specify how high off the ground the pollutants are emitted and the exit velocity and temperature of those emissions). One basic and important distinction for release points is whether the release point is a stack or a fugitive type of emissions, and different types of parameters are specified for stacks than for fugitive emissions sources.

Correct release point parameters for stacks are important for modeling done for ozone and $PM_{2.5}$ modeled attainment demonstrations as well as modeling done for Regional Haze SIPs, whereas fugitive release parameters are not as critical for that purpose. This is because stack emissions parameters impact the modeling of plume rise and therefore determine how high the emissions rise in the modeled layers of the air quality model. Fugitive emissions are emitted in the modeled surface layer with no additional characterization. This is in contrast to more detailed plant-level modeling (i.e., done for permit modeling or risk modeling purposes), where both stack and fugitive parameters are critical. Because the focus of this document is on SIP purposes, we focus on stack parameters here.

Stack parameters included in the EIS and historically are stack height, stack diameter (at the exit point of the emissions), exit gas velocity, exit gas flow rate, and exit gas temperature. Additionally, a release point type is available in the EIS to specify a code for whether the "stack" has a particular orientation of vertical, horizontal, goose neck, vertical with rain cap, or a downward facing vent. Valid release point codes are available in the EIS reporting code tables in the EIS Gateway.

Quality assurance for stack parameters can be done using several of the QA methods already described. Range checks can be applied; these can be the default EIS range checks (see Section 4.9.3) or range checks developed by an air agency. A more robust range check could be developed for specific types of processes associated with a release point or for specific NAICS codes. For example, one would expect higher stacks for EGUs than for lumber mills. Additionally, ranking techniques can be applied to stack parameters (see Section 4.9.7), including options for grouping ranked stack parameters by facility, unit, process and/or specific types of facilities, units, or processes. This is somewhat complicated by the fact that multiple units or processes can feed a given release point, and when this happens, the predominant

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unit or process could be used for grouping purposes. Finally, more sophisticated outlier analysis could additionally be used, by finding correlations between stack parameters such as height and diameter and investigating those combinations that statistically fall outside an expected relationship or ratio.

4.9.13 Biogenic QA/QC

Biogenic emissions are somewhat more challenging to QA than emissions for other source categories because they may be generated differently (i.e., as part of a gridded, hourly modeling exercise rather than more basic inventory development techniques). The following list provides some basic checks that can be done as part of the generation of biogenic emissions:

1. Check the biogenic emissions tool logs for warnings/errors.
2. Check the logs to confirm that the expected inputs were used.
3. Compare state or county total emissions to another year or case's biogenic emission totals.
4. Ensure that summer emissions are greater than winter emissions. This can be done by summing the emissions across the modeled summer days (e.g., May-October) and for the other models and then comparing the totals on a state and/or county basis. As a quick (but less rigorous) check, example summer hourly or daily emissions can be visually compared to example winter hourly or daily emissions using software that displays the gridded emissions.
5. Visually inspect sample days of the gridded, hourly emissions using software that displays the gridded emissions. The VOC emissions should generally be higher in southern latitudes because of warmer temperatures. This difference should be more pronounced in winter in cases where the southern areas have more actively growing vegetation. The NO emission should generally be higher in agricultural areas with significant fertilizer application.

4.9.14 Timing of QA and Follow-up

As air agencies, as well as the EPA Regional offices, work quickly to meet relevant inventory and SIP deadlines, data problems are exacerbated when they are discovered too late in the process. A key part of making sure that a QA plan is effective is deciding (as part of the planning) when a given QA check is to be done and ensuring (as part of implementing that plan) that it is actually done. To do this effectively, QA steps should be timed in a QA plan at the earliest possible time that the step can be performed so that errors are caught as early in the process as possible. Furthermore, assurances must be put in place that someone is confirming that the checks have been done along the way, so that errors are caught. At the end of the data development process, some accounting for the history of the QA should be available along with the data, so that others can confirm that the checks have been done and can be reassured. Where possible, evidence of completion of each QA step should be referenced, such as a comparison report.

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5 Developing Projected Emissions Inventories

5.1 Projected Emissions Overview

Emissions estimates for future years[39] are called "emissions projections" or "projected emissions." These projections include emissions growth (due to increased or decreased activities) and emissions controls due to regulations, settlement agreements (or consent decrees), fuel-switches, or other programs that reduce emissions in specific ways in the future. Emissions controls can be either on-the-books or considered as part of a control strategy to reduce emissions as part of SIP planning. For point sources, emissions projections can also include facility and/or unit-level shutdowns due to settlement agreements (or consent decrees) and/or ownership decisions.

The primary goal in making projections is to obtain a reasonable and technically credible estimate of future-year emissions that accounts for key variables. The EPA encourages the air agencies to incorporate in their analyses the variables that have historically been shown to drive their economy and emissions, as well as the changes in growth patterns and regulations that are expected to take place between the time of their base year and projected attainment year. For details on which future year(s) should be modeled for attainment demonstrations, readers should refer to the Modeling Guidance (https://www3.epa.gov/ttn/scram/ guidance_sip.htm).

5.1.1 Readily Available Projections Information

The EPA's latest projection approaches and data are available as a part of the EPA's "emissions modeling platform" development. These platforms are released and updated periodically in accordance with the EPA regulatory and analysis activity on the Emissions Modeling Clearinghouse at https://www.epa.gov/air-emissions-modeling. While each platform comes with a single or limited set of future years included, the data and thoroughly documented approaches can help air agencies to develop and improve their own emissions projections.

Additionally, as part of SIP planning, various situations lead to requirements for states to implement Reasonably Available Control Technology (RACT) and Best Available Control Technology (BACT) as part of their attainment planning. The emissions reductions expected based on these programs would need to be include in emissions projections used for modeled attainment demonstrations and other projected emissions such as the projected attainment inventory for the nonattainment area (see also Section 3.8.1).

5.1.2 Background Materials

For point sources, Volume II "Point Sources" of the EIIP series includes Chapter 12 "How to Incorporate the Effects of Air Pollution Control Device Efficiencies and Malfunctions into Emission Inventory Estimates" was published in 2000 and still provides the authoritative information related to point source projections. In particular, Appendix A "Clearing Up the Rule Effectiveness Confusion" and Appendix B

[39] Technically, projected emissions could be made from a base year to a year that has already occurred when data are not yet available for a very recent year. However, for the purposes of the remainder of this guidance, we will assume projected emissions refers to future year projected emissions.

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"Emission Inventories and Proper Uses of Rule Effectiveness" provide a thorough discussion of rule effectiveness that is relevant for current emissions projections.

In addition, the 1999 EIIP report entitled "Procedures for Preparing Emissions Projections" (https://www.epa.gov/air-emissions-inventories/volume-10-emissions-projections-final-report) introduces the basic concepts behind emissions projections issues and approaches. The concepts of control efficiency, capture efficiency, rule effectiveness, and rule penetration are introduced in Section 2.5.18. The EIIP document provides information on how to use these factors to estimate projected emissions. However, some key features of this document need to be updated, including the reference to the Economic Growth and Analysis System, which is no longer supported by the EPA. Other outdated concepts include the assumption that economic growth can be a good indicator of emissions growth. While some correlation can exist, it cannot be assumed but rather must be demonstrated for a particular industry or facility. The correlation has not been well observed historically in the NEI data because of various issues including technology improvements and fuel-switching that often reduce emissions without regulation.

In this section, we will address an overall approach for tackling emissions projection issues that incorporates use of this document and points out where other approaches or new data are available to amend the information included in that report.

Some general aspects of the EIIP projections document that are now out of date are as follows.

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- The latest SCC codes are available as described in Section 2.5.14.
- The AP-42 emission factor website is now https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors.
- The reference in the Table 2.1-1 web link is no longer applicable. Instead, the following information can be used to help provide similar information:
    - Energy consumption by industry report, 2002: http://www.eia.doe.gov/oiaf/analysispaper/industry/consumption.html
    - Annual Energy outlook report, early release 2014: http://www.eia.gov/forecasts/aeo/er/index.cfm
- The references in Table 2.1-2 are also out of date and should be updated as follows:
    - U.S. EPA Emissions trends reports. These reports can be used to provide the historical trends of emissions sectors based on the NEI: https://www.epa.gov/air-trends
    - Integrated Planning Model: See reference provided above in Section 1.2
    - Multiple Projections System - is no longer in use
    - California Emission Forecasting System: http://www.arb.ca.gov/ei/drei/maintain/database.htm

The EPA recommends that developers of projected emissions take the steps in the bulleted list below. Each of these steps corresponds to a subsequent subsection.

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- Identify sectors of the inventory that require projections and sectors for which projections are not advisable, and prioritize these sectors based on their expected impact on the modeling region (Section 5.2).
- Collect the available data and models that can be used to project emissions for each of the sectors (Section 5.3).
- For key sectors, determine what information will impact the projection results the most, and ensure that the data values reflect conditions or expectations of the inventory region (Section 5.4.
- Quality assurance (Section 5.5)

5.2 Identify and Prioritize Key Sectors and Regions for Projections

Emissions data developers should evaluate their inventories for those sectors and regions that are most critical to their modeling results. The purpose of identifying these key sectors is to direct more resources and efforts to estimating future-year emissions for these sectors in the subsequent steps.

Sectors can be subsets of the larger groups of stationary area, on-road mobile, nonroad mobile, and point sources. For ozone modeling, it will be most important to ensure correct projections for sectors with higher NO_X emissions. In larger urban areas that contain VOC-limited regions, sectors with higher VOC emissions will also be important. Mobile sources are typically large contributors to both VOC and NO_X; therefore, they are usually a priority in estimation of future-year emissions, particularly for urban areas. For PM and regional haze modeling, the relative importance of primary $PM_{2.5}$ emissions and its precursors will depend on the area of the country. Primary $PM_{2.5}$ emissions may be important in urban areas or areas heavily influenced by local sources such as residential wood combustion or industrial facilities. In the East, SO_2 emissions may be of primary importance. For $PM_{2.5}$ planning, NO_X, VOC, and NH_3 will vary in importance depending on the particular situation, which needs to be assessed as part of the SIP planning process.

Emissions data developers should consider the proximity of the emissions and the expectation of long-range transport when reviewing projection assumptions. Those emissions that have an impact on the nonattainment status (whether transported from outside areas or locally generated) should be given highest priority in evaluating the projection assumptions. For example, less priority can be given to emissions from distant states and/or for pollutants that do not transport from those states to the NAA.

In some cases, there are sectors that are very difficult or highly uncertain to project into the future. Wildfire emissions is a common example of such a sector, since models are not readily available that estimate the magnitude and location of future-year emissions. In these cases, it is reasonable to create an "average year" inventory and temporal distribution of the emissions. Other approaches to future-year fire emissions include holding the emissions constant at the same levels as included in the base year.

5.3 Collect Available Data and Models for Each Sector Needing Projections

For each sector needing projections (and in particular for the priority sectors), air agency staff should collect and review growth and control information. The sources of such information depend upon the

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sector of interest. Some data resources and approaches are available and provided here, and new data and approaches will become available subsequent to the publication of this document. The information provided here is a snapshot of information that will grow and adapt over time, and emissions modelers should seek out such new information as part of this step.

Emissions modelers can rely on available default data for sectors and regions with lower priority for consideration (as described in the previous section). For sectors and regions that are important to modeling the NAA, emissions modelers should spend additional effort obtaining improved information from other modeling applications (such as modeling done by RPOs or other states) or developing the improved information themselves.

As mentioned previously, the EPA provides control assumptions with its modeling data used for promulgating air quality rules and impact assessments. The EPA approaches typically include the impacts of federal rules that have been finalized. Impacts of proposed rules are rarely included, as the changes in emissions impacts can be very large between the proposed and final rules. These data are posted at the Emissions Modeling Clearinghouse. Sometimes, more current information is available than what is available from the EPA, for example, when reconsideration amendments are developed and finalized after the EPA has publicly released its projected inventories. In the subsequent subsections, we focus on sources of growth information.

5.3.1 Electric Generating Units

This section conveys the general principles and key criteria that inform development and review of EGU emission projections in support of CAA-related state regulatory actions (such as SIPs) subject to EPA approval. The section includes technical information related to EGU emission inventories, key modeling/projection input assumptions, appropriate data sources, and general methodological criteria to be used by states and EPA Regional offices.

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This guidance does not recommend or restrict the use of any specific tool to generate credible projections of EGU emissions. It explains a process for documenting credible data and input assumptions with accompanying justifications; describes how to demonstrate a reasonable relationship between inputs and outputs for a given application; and identifies relevant resources that should be taken into consideration.

Emission projections for EGUs do not tend to follow a simple growth path from historical emission data. The composition and behavior of the generating fleet, and resulting power sector emission patterns across facilities, states, and regions, vary substantially over time based on changing economic conditions as well as changes in fuel markets and regulatory requirements. Therefore, evaluating the credibility of power sector emission projections necessitates evaluating the reasonableness of several key projection elements or assumptions, while keeping in mind that appropriateness of the method also depends on the span of future year(s) being projected (the "modeling horizon"). These projection elements include:

1. Electricity demand, taking into account the on-the-books energy efficiency programs and policies directly influencing demand growth over the modeling horizon

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2. The composition of the future generating fleet; if the future year(s) provides enough lead time, consideration of economic entry (new facility construction) and exit (existing facility retirement) that would change the composition of the fleet.

3. Generation pattern across facilities that is consistent with economic factors, power system operability, reliability, and environmental regulatory constraints

4. Potential emissions at each generator, taking into account pollution content of available fuels as well as the ability of control equipment or processes to capture that pollution

State, tribal and local agencies have the choice to independently develop power sector emission projections or to use emissions projections from other entities (federal or regional bodies, including RTOs and ISOs). If a state, tribal or local agency chooses to develop independent projections (or to derive such projections from other available forecasts), data sources should be referenced and clear justification should be stated for the projection methodology, including a clear demonstration of the relationship between demand, cost, generation capacity and emissions. Documentation supporting any set of power sector emission projections should include:

1. Inventory of all sources of generation accounted for in the projections, including but not limited to all individual emitting EGUs

2. Information regarding electricity demand for the future year:
    a. The demand forecast for EGU projections should be referenced and documented (potential sources include AEO, NERC, regional transmission organizations, independent system operators, state energy offices or public utility commissions, and regional councils that develop energy planning).

    b. Identify the energy efficiency (EE) programs and/or policies explicitly included in the demand forecast. This clarifies which EE programs or policies are influencing the growth rate assumptions. (For example, AEO explicitly includes federal appliance standards, lighting efficiency standards, building energy codes and other federal energy efficiency programs).[40]
3. A detailed profile of future capacity, including:
    a. Projected changes to the operable fleet, such as retired capacity, new capacity (including renewable sources such as wind, solar, geothermal, and hydro), changes to capacity type (e.g., refueling), and pollution control retrofits
    b. Physical characteristics of the operable fleet, including capacity, fuel type, heat rate, renewable energy capacity factor and pollution controls (i.e., list of emissions controls and their associated removal efficiencies for pollutants of concern)

4. A detailed profile of projected power system operation, including generation, fuel use, and emissions

[40] Refer to U.S. EPA's Resource for States on estimating EE/RE relative to EIA's Annual Energy Outlook for SIPs located in Section 5.3.11 of this document for more information.

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5. A detailed list of all of the constraints (with the corresponding future compliance dates) that apply to reduce emissions at one or more sources, such as:
    a. Federal, state and local rules
    b. NSR settlements
    c. Consent decrees
    d. Rate or permit requirements
    e. All other on-the-books regulatory requirements

6. Representations of the following, or if not directly factored in, reasoning and methodology explaining how these elements are accounted for indirectly:
    a. Fuel supplies and/or prices
    b. Generator availability constraints
    c. Minimum generation requirements (such as qualifying renewable energy (RE) generation to meet RPS targets)
    d. Cost and performance characteristics of existing and potential new generation and pollution control technology options
    e. Transmission, reserve margin, and other system operating constraints

7. Unit-level generation, fuel type and use, pollution control configuration, and emissions

8. Any other information used in and/or relevant to the projection

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Electric generating unit projections for different purposes (such as attainment demonstrations, maintenance plans, and reasonable further progress plans), as well as varying factors such as pollutants, geographic areas, and/or how far the projection period is into the future, may prompt adaptation of different approaches. There are two main types of methodologies states can consider when projecting EGU emissions for SIPs: optimization methods and non-optimization methods.

1. Optimization methods are those that use computational algorithmic models that seek the "least-cost" optimal dispatch based on economic assumptions while obeying physical constraints of generators within the selected universe of EGUs. Examples of typical constraints within an optimization method include, but are not limited to, ramp rates, outage schedules, transmission limits, system reserve margin limits, and emission limitations. Optimization methods are generally used for longer-term projections at the national or regional scale. In some cases, optimization approaches may under-represent non-economic factors that affect unit operations.

2. Non-optimization methods are those that follow a prescribed set of rules and relationships to simulate the behavior of EGUs based on electricity demand trends, historical electricity production trends and data from other forecasting models. Generally, these frameworks employ statistical analysis or algorithms to estimate how EGUs will generate in a future year based on certain expected conditions. To the extent that these methods are based largely on past EGU behavior, their projections can be relatively insensitive to potential changes over time in

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economic and regulatory factors that affect EGU behavior. These non-optimization methods are generally used for shorter-term projections at the regional, state, or local scale.

Whether a state uses an optimization or non-optimization EGU projection method, states should provide information to EPA that documents the methodology and how the chosen projection method adequately addresses the analytic drivers described above, in the context of the associated regulatory action and with the timeframe of the projections taken into account. For example, for a given area, there may be a reasonable justification to use recent historical data to represent fleet behavior in the near future (e.g., 1-5 years). However, projecting for years farther into the future (e.g., 10-20 years) may necessitate an optimization approach in order to allow for a better representation of the economic and regulatory drivers that affect fleet behavior and associated emissions.

A state may also consider whether limited modifications to other EGU projections (such as those provided by EPA, EIA, or ISO/RTOs) may reasonably address the analytic drivers described above. Such an approach should include documentation of where and how the modified set of EGU projections differs from the unmodified (original) set of projections, and why it is appropriate for the given regulatory action or future scenario to make such modifications without conducting a more thorough or complete analysis.

5.3.1.1 Existing Material for More Information

The resources listed in this section can provide additional information that may be helpful for EGU emissions projections.

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Guidance for 1-Hour SO2 Nonattainment Area SIP Submissions. This document describes non-binding recommendations on a wide range of issues that are likely to arise as state, local and tribal governments develop nonattainment SIPs for the 1-hour SO2 NAAQS. This document is available at https://www.epa.gov/so2-pollution/guidance-1-hour-sulfur-dioxide-so2-nonattainment-area-state-implementation-plans-sip.

Roadmap for Incorporating Energy Efficiency and Renewable Energy in SIPs/TIPs. This document provides a roadmap to assist state, tribal and local agencies with accounting for and incorporating energy efficiency (EE) and RE policies and programs in SIPs and TIPs. The roadmap accomplishes this task by clarifying guidance the EPA issued in 2004 on incorporating EE/RE policies and programs into SIPs, as well as related guidance EPA issued in 2004 and in 2005. This document is available at https://www.epa.gov/energy-efficiency-and-renewable-energy-sips-and-tips/energy-efficiencyrenewable-energy-roadmap.

Resource for States on estimating EE/RE relative to EIA's Annual Energy Outlook for SIPs. This document helps states identify their on-the-books energy efficiency and renewable energy policies and estimate the incremental electricity savings of these policies; develop a methodology for projecting a jurisdiction's energy demand both with and without the incremental electricity savings; and estimate the change in power sector emissions attributable to the incremental electricity savings. For more information visit: https://www.epa.gov/sites/production/files/2015-08/documents/including_ee_and_re_policies_in_ed_projections_03302015_final_508.pdf.

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Assessing the Multiple Benefits of Clean Energy Programs: A Resource for States. This document helps state energy, environmental, and economic policy makers identify the spectrum of EGU projection tools and methodologies to quantify the energy, environmental (specifically greenhouse gas, criteria air pollutants, and health), and economic benefits of clean energy. This document is available at https://www.epa.gov/statelocalclimate/assessing-multiple-benefits-clean-energy-resource-states.

EPA's AVERT (AVoided Emissions geneRation Tool). This tool estimates the NOx, SO_2 and CO_2 EGU emissions from implementing EE/RE programs and policies. This tool can estimate the EGU emission impacts at the EGU, county, state and regional levels in the short-term future (1-5 years). Outputs from AVERT are compatible with the SMOKE interface. For more information visit: https://www.epa.gov/avert.

TSD for Incorporating RE and Demand-Side EE Impacts into State Plan Demonstrations for the Clean Power Plan (CPP). This technical support document describes various quantitative approaches for projecting the future year direct energy impacts (MWhs) of energy efficiency and renewable energy programs and policies. This document is available at https://www.epa.gov/sites/production/files/2015-11/documents/tsd-cpp-incorporating-re-ee.pdf

5.3.1.2 Examples of Existing EGU Projection Tools

There are specific approaches available that can be used in ways that meet the general principles and key criteria explained in Section 5.3.1. The EPA uses the IPM to model future electricity demand and emissions trading programs that now dominate the prediction of future-year emissions from EGUs. The IPM meets the criteria provided in the EPA resource document listed above. According to the IPM user's document:

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> *"IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. It provides forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints. IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of SO_2, NO_X, carbon dioxide (CO_2), mercury (Hg), and HCl from the electric power sector."*

More information on IPM and IPM-based emissions are available at the Power Sector Modeling EPA website (https://www.epa.gov/airmarkets/power-sector-modeling).

Other EGU projection models and tools exist and could be used for estimation of future-year emissions and, in these cases, the states are advised to make sure that the tools meet the criteria laid out in this document because EPA will use these criteria to assess any EGU projection information submitted as part of SIPs. Mention of specific tools in this guidance should not be taken as an endorsement or guarantee that such tools will meet the criteria that the EPA will use to evaluate EGU emissions projections. Alternative tools include the ERTAC Tool, the National Energy Modeling System (NEMS), the Electric Power Market Model (EPMM) and the Market Allocation (MARKAL) model. There is also a Northeast-specific version of MARKAL called NE-MARKAL. The subsections below provide additional information and reference links for some of these alternative approaches.

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The ERTAC Tool

The ERTAC tool is an open-source tool developed by the ERTAC group of state and regional associations that benefits from an in-depth collaboration among a large multi-state region. More information on this tool is available on the ERTAC EGU website (http://www.marama.org/2013-ertac-egu-forecasting-tool-documentation), including sample files and documentation.

The ERTAC tool is designed to estimate future EGU activity and emissions using user-supplied, unit-specific information, CAMD hourly emissions data, and AEO and NERC growth forecasts by fuel and region. The ERTAC tool outputs hourly future-year activity, SO_2 emissions, and NO_X emissions by keying off the historical CAMD hourly data from the SIP base year. For the future-year *planning* inventories, the ERTAC results can be aggregated to match the annual or season-day resolution needed for the regulation being supported (see Section 4.5). For modeled attainment demonstrations (not covered by this guidance), the ERTAC hourly future-year data outputs may then be used in conjunction with an emissions preprocessor and an air quality model to evaluate the effect of HEDD periods as well as other EGU impacts that might be of shorter duration than the modeled period.

Other Approaches

The NEMS model (available at: https://www.eia.gov/forecasts/aeo/info_nems_archive.cfm) was developed by EIA and uses Annual Energy Outlook (AEO) projections of energy supply, demand and prices, and it couples with regulatory/SIP and trading assumptions and known future control installations to create future year NO_X, SO_2 and heat input estimates.
The Regional Energy Deployment System (ReEDS), developed by National Renewable Energy Labs (NREL) is a long-term capacity-expansion model for the deployment of electric power generation technologies and transmission infrastructure throughout the contiguous United States. The MARKAL model is a data-driven energy system optimization model geared more towards basic, preliminary analyses of energy policies at EGUs but does not provide plant-specific detail. However, NE-MARKAL is a state-based and regionally specific version of MARKAL. NE-MARKAL represents each Northeast jurisdiction and can examine the criteria air pollutant outcomes with plant-specific detail from various technology options and overall system constraints. More information is available at: http://www.nescaum.org/topics/ne-markal-model. MARKAL is also relevant for other sectors and more information is included in Section 5.3.6.

Preventing Double Counting of Emissions between EGUs and Other Categories

To prevent double-counting of emissions sources between EGUs and other categories, emissions developers should be careful to match the sources of emissions from external models such as IPM with the base year emissions sources. This helps to ensure that the EGU part of the point source inventory is separated from the non-EGU part based on the facilities included in the future-year EGU model. In the case of IPM, the facilities are defined using NEEDS. The NEEDS records should be compared to the base year point inventory using the ORIS Plant ID field from both. In some cases (e.g., co-generation facilities), only some of the units at the facilities are included in NEEDS; therefore, the separation of EGUs from

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non-EGUs should be done at the unit level, not by facility. One resource for this information is also in the NEI, which contains a field that indicates whether the units are NEEDS units or not.

5.3.2 Non-EGU Stationary Sources

Non-EGU stationary sources include both the point and nonpoint sources, but the methods for projecting them to the future can rely on many of the same sources of information.

Since 2006 (EPA, 2006a), the EPA has been assuming that emissions growth does not track with economic growth for many stationary sources (both point and nonpoint). This "no-growth" assumption is based on an examination of historical emissions and economic data. Emissions (as of 2005) had declined for several years and those reductions could not be directly attributed to specific control programs despite increasing economic-based growth factors for many metrics over the same time period. While the EPA continues to work toward improving the projection approach in its own work, we are still using this no-growth assumption for many emissions sectors. Of course, where air agencies have better data about the expected growth in emissions or the possibility of sources reaching their permit limits, that information should be included in developing more refined emissions projections.

The EPA creates and uses data that quantify assumed base year growth (projections), controls, settlement agreements (or consent decrees), and other unit and facility-specific information on non-EGU point and stationary area sources. These are included in the most recent emissions platform Technical Support Document (TSD) available at the Emissions Modeling Clearinghouse. The TSDs include the methodologies and background information for projecting sources such as Portland cement, refineries, oil and gas, industrial/commercial/institutional boilers, residential wood combustion, agricultural sources, fuel sulfur rules, corn and cellulosic ethanol and biodiesel plants, and several other categories. The data sources include national sources with regional and state-specific information as well as projection information provided by regional modeling centers and states and local air agencies.

In addition, the EPA encourages air agencies to consider the latest settlement agreements and consent decrees that are updated periodically by the EPA's Office of Enforcement and Compliance Assurance (OECA) at: https://www.epa.gov/enforcement/air-enforcement.

The additional resources described in Section 5.3.6 are also used by the EPA to develop projections used in its modeling platforms. These same resources are available to state, local, and tribal agencies to develop their own projection methods for non-EGU stationary sources.

Finally, for nonpoint sources, Section 3 of the EIIP projections document provides additional details about projecting nonpoint-source. However, several of the references or statements in that document are now out of date, as follows.

- The web sites for SCCs, AP-42 emission factors, and more information about area-source inventories are out of date. These should be updated to the same sites as were listed in the point sources section above. Furthermore, this guidance includes more updated information than the EIIP report referenced.

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- The ASEM model mentioned in Section 3.2 of the EIIP projection document was not completed and is not available.
- The references in Table 3.1-2 are out of date and should be updated as follows:
    - U.S. EPA Emissions trends reports. These reports can be used to provide the historical trends of emissions sectors based on the National Emissions inventory: https://www.epa.gov/air-trends/
    - Multiple Projections System is no longer in use

    California Emission Forecasting System: this system is no longer available. Interested parties should contact California Air Resources Board for more information on their latest emissions projection approaches.

The tools and data sources described in Section 5.3.6 below should also be considered for use for projection of point and nonpoint stationary source emissions.

5.3.3 On-Road Mobile Sources

As described in Section 4.8.3, for all states but California, on-road mobile emissions should be estimated with the latest EPA on-road mobile model, MOVES, following the EPA's latest guidance available at the MOVES website. For California, the latest EPA-approved version of EMFAC should be used.

Emissions preparation with MOVES for projected emissions is much like preparation for a base year. MOVES includes assumptions about emissions reductions associated with national emissions programs including the effects of national vehicle and fuel standards. Some MOVES inputs, such as meteorology, should be the same as for the base year inventory. Others, such as VMT and vehicle population should be grown/reduced to reflect expected changes in population and activity. MOVES default estimates for future VMT and vehicle population are based on national growth rates and should not be used for SIP inventory purposes because growth rates vary substantially from county to county.

Because of the change to the using the MOVES model and the newer guidance provided on the OTAQ websites, the EIIP projections document is no longer relevant for on-road mobile sources.

5.3.4 Nonroad Mobile Equipment

Section 5 of the EIIP projections document provides details about projecting nonroad mobile sources. While some information is still valid, several of the references or statements in that document are now out of date, as follows.

- The name "Office of Mobile Sources" has changed to "OTAQ" and it has a new primary website.
- The EPA's NONROAD model has been incorporated into the MOVES model and should no longer be used for new SIP development.
- According to a California Air Resources Board website, category-specific inventory models and methods have replaced most uses of California's OFFROAD model. The information on California's nonroad emissions is available at a different website URL. A link to the OFFROAD2007 model is also available from this page to be used for categories not listed on that page.

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MOVES includes assumptions about emissions reductions associated with nonroad source national emissions programs. MOVES also includes assumptions about national growth in nonroad activity and equipment population. Local estimates of future activity and equipment populations should be substituted for the national estimates when possible.

5.3.5 Other Nonroad Mobile Sources

Aircraft, locomotives, and CMV sources of emissions do not have a specific model designed for projections, and so additional effort is needed for these three inventory components.

For aircraft emissions, FAA data can be used to estimate growth for aircraft emissions. The FAA provides summary historical and forecast statistics on passenger demand and aviation activity at U.S. airports. The summary level forecasts are based on individual airport projections. The Terminal Area Forecast (TAF) includes forecasts for active airports in the National Plan of Integrated Airport Systems (NPIAS). The TAF system can be accessed at the FAA's TAF query page. The TAF system allows users to create their own forecast scenarios. The TAF database, which contains a query data application, allows the public to access and print historical and forecast (up to 2040) aviation activity data by individual airport, state or FAA region. Air agencies can use this information to adjust their base year emissions based on projected airport activity.

For locomotives and marine vessel emissions, the best source of data on the impact of national rules from OTAQ is the websites provided for each of the rules and their associated *Federal Register* notices. As described for the base year emissions in Section 4.8.5, the locomotive marine rule information is included at the EPA website for that regulation. For CMV sources, Table 20 (from the base year emissions section) provides a good list of individual rules and references. Since each rule is different, there is no single guidance that can be made about how these should be incorporated. However, the EPA incorporates these data into their modeling platforms, and the most recent projection methodologies are documented in the TSDs included with the modeling platforms on the Emissions Modeling Clearinghouse at https/www.epa.gov/air-emissions-modeling .

Additionally for C3 vessels, emissions data are available from an Emissions Control Area-International Maritime Organization (ECA-IMO) collaboration. These emissions are available at a fine-grid resolution and are subject to various engine and fuel standards in the future. Like base year emissions, air agencies should consider the state versus federal waters when deciding what parts of the ECA-IMO data to use (see Section 4.8.5.2). Growth/control factors have been developed for this C3 CMV inventory, and the EPA is using them for future year C3 CMV inventory development. New approaches are likely to develop over time, so air agency staff should consult the web pages listed here for the latest available information. The latest EPA modeling platform projection methodology for C3 marine emissions is also available in the latest emissions modeling platform TSD at the Emissions Modeling Clearinghouse mentioned previously.

5.3.6 Other Projection Resources

In addition to sector-specific resources, there are other sources of information that projection developers can use for more than a single sector as information to help determine the most applicable

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growth rates for the modeling region. These include the Bureau of Labor Statistics "Employment Outlook," Census Bureau data, Trade Organizations and individual facilities, and the Chemical Economics Handbook. The following paragraphs provide a brief description and additional references for each of the sources of data just listed.

Sources for EPA nonpoint methods

As described in Section 4.8.2, the EPA develops methods for numerous nonpoint methods. Each of these methods depends on some surrogate activity. Many of these activity sources come from USDA, DOE, U.S. Census Bureau, and Department of Labor databases available online. Appendix B provides a list of nonpoint sectors and associated activity reports and websites. These data do not include future-year projections, but may include newer information than were used for estimating the base year information. As such, these data can help with understanding the possible changes in activity (and perhaps emissions) from the date of the underlying base year activity data to the present day. It should be noted that emissions for 1 year (e.g., 2011) may be estimated using activity data from a prior year (e.g., 2009) because of timing needed for preparing the data does not match with the timing of the release of the underlying data. When emissions are estimated using data earlier than the emissions base year, it further strengthens the benefit of newer activity data. Furthermore, these datasets often include historical trends, which could be of use in understanding what may happen in the future.

Since the base year emissions for nonpoint methods are calculated based on direct activity indicators such as population, fuel consumption, employment, and VMT, projections of these direct activity indicators may also be used to estimate future emissions. Population is related to sectors such as consumer products, architectural coatings, portable fuel containers, and commercial cooking. VMT also plays a major role in calculation of paved road emissions. Growth projections for population and fuel consumption are readily available from the U.S. Census and the DOE's Annual Energy Outlook (see below). VMT projections are provided periodically as part of the EPA emissions modeling platforms and may be available in some states from other sources. Employment projections may also be available in some states and could be used for industrial categories where the state believes that employment is an appropriate surrogate for facility activity and therefore emissions growth or retraction.

MARKAL

The MARKAL model is a public sector, data-driven, energy-system optimization model. A user inputs the structure of the energy system to be modeled and data to characterize each of the technologies and resources included in the model run. MARKAL calculates the least cost set of technologies over time to satisfy specific demands, using linear and mixed-integer linear programming techniques. Outputs of the model include the technological mix at intervals in the future, energy demand, and estimates of criteria and GHG emissions, among others. The DOE uses MARKAL for its System for the Analysis of Global Energy Markets (SAGE) model. SAGE is used to produce EIA's annual International Energy Outlook.

The EPA has applied MARKAL for technology and emissions evaluations, which required the development of the EPA MARKAL technology database (EPANMD). This technology-rich database represents the major sectors in the U.S. energy system, including the commercial, industrial, residential,

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transportation, and electricity generation sectors. The DOE's AEO and the NEMS were used to construct the energy supply, demand, and technology characterizations. Data for technologies not represented in the AEO and NEMS were derived from other widely recognized authoritative sources (e.g., Electric Power Research Institute's Technical Assessment Guide and DOE's Office of Transportation Technology's Quality Metrics report). More information on the EPA's use of MARKAL and the EPANMD can be found on the website for "EPAUS9R - An Energy Systems Database for use with the Market Allocation (MARKAL) Model" and EPA report number NRMRL-RTP-375 (EPA, 2006b).

Control Strategy Tool (CoST)

The purpose of CoST is to estimate the emission reductions and engineering costs associated with control strategies applied to point, nonpoint, and mobile sources of air pollutant emissions to support the analyses of air pollution policies and regulations. Control strategy results can be exported to CSV files or viewed in a graphical table that supports sorting, filtering, and plotting. The results can also be merged with the original inventory to create controlled emissions inventories that can be exported to files that can be input to the emissions model SMOKE. CoST allows for user-supplied control measures data, provides tracking of analyses and outputs, and supports built-in QA.

The Control Measure dataset focuses on criteria pollutants and their precursors, and it includes primary control efficiencies, co-pollutant control efficiencies, and control costs. The data also includes an extensive set of mobile source control measures. More information on the Control Measure dataset and CoST is available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-analysis-modelstools-air-pollution.

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Annual Energy Outlook

The EIA's AEO forecast data was a primary input for the final version of EGAS. However, with EGAS no longer being supported by the EPA, the latest versions of the AEO are the best available source of socioeconomic forecast data for many industrial sectors. The latest AEO data are available at: http://www.eia.gov/forecasts/aeo/er/index.cfm.

Census Bureau

The U.S. Census Bureau provides data on total employees, total payroll, number of establishments, and value of shipments by NAICS code (2 digit - 6 digit) for specific years. This database is ideal for examining changes in the number of establishments between the two latest available years and also for historical changes. Therefore, the actual census data are useful primarily to evaluate emissions changes from the base year to the present (or most recently available year) and comparing to the data included in the AEO. The census data are available at http://www.census.gov/2010census/data/.

In addition, the Census Bureau projects future population, which is available at http://www.census.gov/population/projections/. This information can be used to help project nonpoint emissions categories that include population as an activity input for the base year emissions.

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Trade Organizations and Individual Facilities

Trade organizations can also be a helpful resource because they often have projections for future-year growth of their industry and may be aware of pending facility closures or new facility construction. This resource is most relevant for large industrial sources that usually are included in point source inventories. In addition, emissions modelers should consider contacting large sources of emissions in their modeling region for their expectations of emissions growth or reduction. In many cases, large industries may be willing to provide such information when presented with what will be used if no additional information can be provided. Additional information may be found in permit applications for future development or controls at individual facilities. Except in the case of permit applications, emissions projections developers should be aware of possible conflicts of interest for this source of information. For example, industry groups or facilities may have an incentive to under-represent future-year emissions in hopes of avoiding additional requirements for reducing emissions. However, many industrial representations have been valuable stakeholders who are interested in providing accurate information.

Chemical Economics Handbook

The Chemical Economics Handbook, produced by SRI Consulting (a part of IHS, Inc.[41]), is a series of reports on prices, production and consumption of hundreds of chemical industry products and commodities. Past and current information on chemical products and commodities is available, and projections of future prices, production and consumption are often available. Reports on specific industries are also available. Reports at an industry level can often be used to verify the efficacy of future industry modeling results. Each report is updated every 3 years. Projections, some up to 5 years from the current day, are often prepared using proprietary methods. Reports are available by subscription, and can be obtained as hard copy, CD, or at http://www.sriconsulting.com/CEH/Public/index.html.

5.4 Evaluate and Refine Data for Projections in Inventory Region

For key sectors, emissions projections developers should determine what information will impact the projection results the most, and ensure that the data values reflect conditions or expectations of the modeling region. The key information is identified based on a combination of base-year emissions data and growth and control rates. An iterative process is helpful to complete this step, as follows:

- Estimate future-year emissions by combining the base-year emissions with the projection information (as described in the EIIP document referenced in Section 5.1).
- Review future-year emissions data to identify large sectors of key pollutants (e.g. NO_X, SO_2, $PM_{2.5}$, NH_3 and VOC). Emissions summaries by state/SCC or state/NAICS for point sources can be helpful for this step to consolidate the data to review.

[41] A number of other industry reports appears to be available from the IHS home page from the "Industries" tab. Some of these websites appear to have databases available for a fee, but they have yet not been assessed by EPA for applicability to emissions projections.

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- For the largest future-year emissions sectors, review the growth and control assumptions, compare among all available data sources, and/or collect additional information to refine the assumptions. A representative growth rate should be identified from the available data sources and all information known about the sources and sectors. Stakeholder review of the data can be helpful during this step; for example, an industrial facility with large projected emissions may be able to review the data and provide additional information (e.g., expected capacities, fuels or controls) for a more informed future-year emissions estimate.
- Additionally, data developers should also compare the future-year emissions to base-year emissions, and if economic-based growth is used, to identify overall growth rates for industrial sectors and scrutinize excessively high growth rates, especially when associated with significant emissions.
- Using the new information, repeat step 1 and continue these steps until a satisfactory future-year projection across the entire inventory has been completed.

Emissions models (e.g., CoST, SMOKE, MOVES, IPM, etc.) provide the capability to create future-year inventories using base year inventories and projection information. Emissions modelers will need to convert the projected emissions data into specific formats for input to these models. Prior to starting this step, data developers should determine which emissions model will be used to perform the calculations and make sure that the type of information needed by the model is being collected.

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5.5 QA for Projected Inventories

As mentioned in the previous subsection, final review of the inventories is an iterative process. During each iteration, adaptations of the methods described in Section 0 can be used for QA of projected emissions inventories. The following list gives examples of some of the ways of the methods for base year inventories can be adapted for projected emissions inventories.

- The same checks used for finding structure errors for base year emissions should be used for ensuring the projected inventories use the correct structures. The EIS checks are less relevant since projected emissions are more likely to be in a modeling format (since they are used for modeling) than are base year inventories. Even so, data developers should make sure that data structure or formatting problems do not lead to incorrect emissions data being used in planning inventories or modeling.
- Like base year inventories, data codes should be compared to lists of valid codes. It is just as important to have future-year SCCs be valid as it is for base year SCCs.
- Ranking techniques can be used to identify facilities, units, and processes that have been grown to unrealistic values. Ranking sources by emissions values can identify any that rise to the top of the list of largest sources without a good reason why. Ranking techniques can also be used for projected nonpoint emissions data.
- Inventory comparisons can be made between projected and base year inventories to help make sure:

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- Location information is consistent between base and future year (needed for modeling only).
- Release point parameters are consistent between base and future year. Where controls have been added, one may expect that the release point parameters could change, for example, with higher stacks or lower exit gas temperatures (needed primarily for modeling).
- Emissions increases and decreases at the facility, unit, and process level are consistent with what is expected.
- Emissions increases and decreases at the county and county/SCC levels are consistent with what is expected. If certain sectors are being held constant (i.e., no better data/approaches are available), then data developers can confirm that these sectors did not change emissions.

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6 References

Allen, D. J., Pickering, K. E., Pinder, R. W., Henderson, B. H., Appel, K. W., and Prados, A.: Impact of lightning-NO on Eastern United States photochemistry during the summer of 2006 as determined using the CMAQ model, Atmos. Chem. Phys. Discuss., 11, 17699-17757, doi:10.5194/acpd-11-17699-2011, 2011.

Appel, K. W., Foley, K. M., Bash, J. O., Pinder, R. W., Dennis, R. L., Allen, D. J., and Pickering, K.: A multi-resolution assessment of the Community Multiscale Air Quality (CMAQ) Model v4.7 wet deposition estimates for 2002–2006, Geosci. Model Dev. Discuss., 3, 2315-2360, doi:10.5194/gmdd-3-2315-2010, 2010.

EPA, 2006a. Regulatory Impact Analyses, 2006 National Ambient Air Quality Standards for Particle Pollution. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October, 2006. Docket # EPA-HQ-OAR-2001-0017, # EPAHQ-OAR-2006-0834. Appendix D: http://www.epa.gov/ttn/ecas/regdata/RIAs/Appendix%20D--Inventory.pdf.

EPA, 2006b. Shay, C. L., S. Yeh, J. Decarolis, D. H. Loughlin, C. L. Gage, And E. Wright. EPA U.S. National MARKAL Database: Database Documentation. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/057, 2006.

Fu, J.S., Dong, X., Huang, K., Tong, D., and Zhuang, G.: Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, Atmospheric Chemistry and Physics, 16, 8157-8180, 2016.

Reid, S.B., Technical Memorandum, Sonoma Technology, Inc., Preparation of Version 2 of the Wildland Fire Emissions Inventory for 2011, April 26, 2013.

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Appendix A
Emissions Inventory System - Quick Reference
How to Create County and Facility NO_x and VOC Summaries for Select Counties

For access to the Emissions Inventory System (EIS), refer to
https://www.epa.gov/air-emissions-inventories/emission-inventory-system-eis-gateway .

See also Online EIS training "Reports – May 2012" at
https://www.epa.gov/air-emissions-inventories/emission-inventory-training

Create a summary of NO_X and VOC emissions BY SECTOR and COUNTY for a group of counties

1. Select "Request Reports" from the left hand sidebar on the EIS Gateway.
2. Under the Emissions Summaries heading, select "By Geography."
3. Select *Report Type* "County by Sector."
4. Click the *Data Set or Selection* bar. This brings you to a "filter" that allows you to select an inventory on which to run a report.

   To find a version of the NEI, type "NEI V" in the search box under the *Data Set or Selection*. Then, click the appropriate row for the year and version of the inventory for your needs.
5. Click on the *Pollutants* bar to access the pollutant filter. Use the search box provided and type in "VOC" and select that resulting row for VOC (click on it with the mouse). Repeat this for NO_X. Typing both filters at the same time will not work.
6. Because we are looking at counties, go directly to the *County* filter. DO NOT SELECT A STATE FIRST from the *State* filter (this will select all counties in selected states, even if you then select specific counties in the *county* filter). Use the search box in the *County* filter to find the counties of interest either by name or State/County FIPS code. Select the counties of interest by clicking on those rows. If no counties are selected, all counties will be returned.
7. Lastly, select your *Sectors* using the *Sectors* search box. If no sectors are selected, the report will be created with all sectors. The EIS Sectors are explained in more detail in Section of the 2011 NEI technical documentation.
8. Click the "Request Download" button at the bottom of the screen. These reports are run by EIS every 15 minutes and are available under the Report Download section on the left hand sidebar of the Gateway.

   Note: Using the "Run Report" button will give you a faster response and display the summary on the screen, but may not include all records for your report. A warning is given at the top of the screen if the "Run Report" result is incomplete.

Create a summary of NO_X and VOC emissions BY FACILITY for a group of counties

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