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| Ozone Transport Commission |
| Draft Technical Support Document for the 2011 Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union Modeling Platform |
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| **Ozone Transport Commission** |
| **9/12/2016** |

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## List of Acronyms

Organizations

CAMD: Clean Air Markets Division 4-4, 4-6, 4-7, 4-8

CenSARA: Central States Air Resource Agencies 1-4, 4-8, 4-11, 4-12, 4-13, 6-19, 8-47, 8-48, 8-49, 8-50, 8-51, 99

CMAS: Community Modeling and Analysis System 5-15, 8-46

EPA: Environmental Protection Agency 1-1, 1-2, 1-3, 1-5, 1-6, 1-7, 1-8, 2-9, 2-10, 2-17, 3-1, 4-4, 4-6, 4-7, 4-8, 5-15, 6-16, 7-37, 8-45, 9-53, 9-56, 9-60, 9-61, 10-62, 11-81, 11-82, 11-87, 11-90, 11-94, 96, 97, 98, 99, 100, 101, 102, 103, 104

ERTAC: Eastern Regional Technical Advisory Committee 4-4, 4-5, 4-6, 4-7, 4-11, 4-12, 4-14, 7-37, 8-45, 8-46, 8-47, 8-49, 8-50, 8-51, 11-87, 99, 100

FLM: Federal Land Manager 1-3, 1-4

FS: Forest Service 1-4

FWS: Fish and Wildlife Service 1-4

LADCO: Lake Michigan Air Directors Consortium 1-4, 4-8, 4-11, 4-12, 4-13, 6-19, 8-45, 8-47, 8-48, 8-49, 8-50, 8-51, 99

MANE-VU: Mid-Atlantic Northeast Visibility Union 1-1, 1-4, 1-7, 2-17, 4-4, 4-8, 5-15, 6-26, 8-45

MARAMA: Mid-Atlantic Regional Air Management Association 1-5, 4-4, 4-10, 4-11, 4-14, 8-45, 8-47, 8-51, 96, 97, 98, 99, 100, 101, 102, 103, 104

MDE: Maryland Department of Environment 4-7, 4-8, 100

NCEP: National Centers for Environmental Prediction 2-11, 7-37

NJDEP: New Jersey Department of Environmental Protection 1-5, 8-45

NOAA: National Oceanic and Atmospheric Administration 2-11

NPS: National Park Service 1-4

NRDC: Natural Resources Defense Council 1-3

NWS: National Weather Service 2-11

NYSDEC: New York State Department of Environmental Conservation 2-11, 2-15, 2-17, 3-1, 3-2, 4-4, 6-16, 7-37, 8-45, 9-53, 9-54, 9-57

ORC: Ozone Research Center 1-5

OTC: Ozone Transport Commission 1-1, 1-4, 1-5, 1-6, 1-7, 2-9, 2-11, 2-17, 3-1, 4-4, 4-8, 5-15, 6-22, 6-36, 7-37, 7-44, 8-45, 9-53, 9-56, 9-60, 10-62, 11-81, 11-87, 11-88, 11-90, 99, 100

OTR: Ozone Transport Region 1-4, 1-6, 1-7, 2-9, 2-10, 3-1, 3-2, 5-15, 6-16, 6-17, 6-18, 6-19, 6-20, 6-21, 7-37, 7-44, 8-45, 10-62, 10-68, 11-85, 11-87, 11-88, 11-89, 11-94

RPO: Regional Planning Organization 1-4, 1-7

SESARM: Southeastern States Air Resource Managers 1-4, 4-8, 4-11, 4-12, 4-13, 8-47, 8-48, 8-49, 8-50, 8-51, 99

UMD: University of Maryland 1-5, 4-8, 6-21

VADEQ: Virginia Department of Environmental Quality 1-5

Regulatory

NAAQS: National Ambient Air Quality Standard 1-2, 1-3, 1-7, 6-16, 9-53, 10-62, 11-81, 11-82

RPG: Reasonable Progress Goal 1-3

SIP: State Implementation Plan 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 7-37, 11-81, 11-87

WOE: Weight of Evidence 11-81

Mathematical

DVC: Design Value (Baseline Concentration) 9-53, 9-54, 9-55, 9-60, 10-62, 11-91

DVF: Design Value (Estimated Future) 9-53, 9-55, 9-60, 10-62

MAGE: Mean Adjusted Gross Error 3-1, 3-2, 6-19, 6-21, 6-22, 6-23, 6-25, 6-26, 6-28, 7-37, 95

MAT: Modeled Attainment Test 9-54

MFB: Mean Fractional Bias 3-1, 6-19, 6-20, 6-22, 6-23, 6-25, 6-27, 6-33, 6-34, 6-35, 7-37, 95

MFE: Mean Fractional Error 3-1, 6-19, 6-20, 6-22, 6-23, 6-24, 6-26, 6-27, 6-33, 6-34, 6-35, 7-37

NMB: Normalize Mean Bias 7-38

NME: Normalized Mean Error 7-38

RMSE: Root Mean Square Error 9-56

RRF: Relative Reduction Factor 11-90

Physical

EC: Elemental Carbon 6-28

NOX: Oxides of Nitrogen 1-6, 3-2, 4-4, 4-5, 4-9, 4-10, 4-11, 4-12, 8-46, 8-47, 8-49, 8-50

OC: Organic Carbon 6-28

PBL: Planetary Boundary Layer 2-16, 2-17, 9-56

PM: Particulate Matter 1-7

PM10: Coarse Particulate Matter 4-5

PM2.5: Fine Particulate Matter 1-7, 1-8, 4-5, 4-11, 4-12, 4-13, 6-16, 6-22, 6-23, 6-24, 6-25, 6-26, 6-27, 6-28, 6-36, 8-48, 8-49, 8-50, 8-51, 9-61, 11-94

RCFM: Reconstituted Fine Mass 6-28, 6-36

VOC: Volatile Organic Compound 1-6, 3-3, 4-9, 4-10, 4-11, 4-12, 8-46, 8-47, 8-48, 8-49, 8-50

Technical Resources

AQS: Air Quality System 6-16, 6-17, 10-62, 11-91

BEIS: Biogenic Emissions Inventory System 3-1, 3-2, 3-3, 4-4, 4-5, 5-15, 11-87

CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations 2-15, 2-16, 2-17

CAMx: Comprehensive Air Quality Model with eXtensions 11-87

CCTM: CMAQ Chemical-Transport Model 5-15

CEMS: Continuous Emission Monitoring System 4-6, 4-7, 7-37

CMAQ: Community Multi-scale Air Quality 3-1, 3-2, 4-4, 5-15, 6-16, 6-17, 6-18, 6-19, 6-21, 6-22, 6-28, 6-36, 9-54, 10-79, 11-81, 11-87

CSN: Chemical Speciation Network 6-16, 6-28, 6-30, 6-31, 6-32, 6-33

DISCOVER-AQ: Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality 6-16, 6-17, 6-21, 11-81, 11-84

EMF: Emission Modeling Framework 4-4

ff10: Flat File 10 4-7, 11-85, 100, 101

FRM: Federal Reference Method 6-16

GEOS: Goddard Earth Observing System 5-15

GHRSST: Group for High Resolution Sea Surface Temperature 7-37

IMPROVE: Interagency Monitoring of Protected Visual Environments 6-16, 6-28, 6-30, 6-31, 6-32

IPM: Integrated Planning Model 4-5, 4-6, 4-7, 4-8, 100

MCIP: Meterorology-Chemistry Interface Processor 2-9

MOVES: MObile Vehicle Emission Simulator 11-85, 11-87, 102

NAM: North American Mesoscale Forecast System 7-37

NCLD: National Land Cover Database 3-1

NEI: National Emissions Inventory 11-82

NLCD: National Land Cover Database 7-37

RRF: Relative Reduction Factor 9-54, 9-55, 10-62

RTMA: Real-Time Mesoscale Analysis 2-11

SLAMS/NAMS: State, Local, and National Air Monitoring Stations 6-16, 6-17

SMOKE: Sparse Matrix Operator Kernel Emissions 4-4, 4-6, 4-7, 4-8, 4-9, 4-10, 4-11, 6-16, 6-21, 7-37, 8-45, 8-46, 8-47, 11-87, 96, 102

TPRO: Temporal Profile File 4-7

TREF: Temporal Cross-Reference File 4-7

WRF: Weather Research and Forecasting 2-9, 2-10, 2-11, 2-12, 2-13, 2-16, 2-17, 5-15, 6-16, 7-37, 9-57

Emission Sources

EGU: Electric Generating Unit 4-4, 4-5, 4-6, 4-7, 4-8, 4-11, 4-12, 4-14, 7-37, 8-45, 8-46, 8-47, 8-49, 8-50, 8-51, 11-87, 100, 101

RWC: Residential Wood Combustion 4-4

# Introduction

## Purpose

The purpose of this document is to technically support the SIP quality modeling efforts undertaken by OTC and MANE-VU for use in regional ozone and haze planning and for inclusion in any member’s SIP submittal for either demonstrating ozone attainment or for showing reasonable further progress for haze.

EPA’s guidance on modeling for ozone, PM2.5, and regional haze includes recommendations for documentation of the modeling platform that should be included in SIP submissions. EPA recommends that the following be included in the technical documentation:

* *Overview of the air quality issue being considered including historical background*
* *List of the planned participants in the analysis and their expected roles*
* *Schedule for completion of key steps in the analysis and final documentation*
* *Description of the conceptual model for the area*
* *Description of periods to be modeled, how they comport with the conceptual model, and why they are sufficient*
* *Models to be used in the demonstration and why they are appropriate*
* *Description of model inputs and their expected sources (e.g., emissions, met, etc.)*
* *Description of the domain to be modeled (expanse and resolution)*
* *Process for evaluating base year model performance (meteorology, emissions, and air quality) and demonstrating that the model is an appropriate tool for the intended use*
* *Description of the future years to be modeled and how projection inputs will be prepared*
* *Description of the attainment test procedures and (if known) planned weight of evidence*
* *Expected diagnostic or supplemental analyses needed to develop weight of evidence analyses*
* *Commitment to specific deliverables fully documenting the completed analysis* (US EPA 2014a)*.*

## Document Outline

The remainder of this section will review the items listed above that are not addressed in other sections of the document. Section 2 is an assessment of the meteorological model used in the platform in order to determine if many of the mechanisms that lead to ozone formation are fundamentally sound. Section 3 assesses whether an upgrade to a more recent biogenic emissions model is warranted. Section 4 describes the methods used in processing emissions for use in the SIP quality modeling platform for the base year. Section 5 describes the setup of the photochemical model. Section 6 assesses the model performance for ozone, PM2.5, and regional haze in the base year. Section 7 describes a methodology for improving performance using nested gridding and analyzed the results from implementing the methodology. Section 8 describes the methods used in processing emissions for use in the SIP quality modeling platform for the future years. Section 9 describes the method for calculating future projected ozone design values and instances where the default method may not be warranted. Section 10 describes the results from future year modeling projections. Section 11 describes the methodology for conducting screening analysis using only ozone episodes, and evidence for its reasonability.

## History

### Clean Air Act

The Clean Air Act was designed to control air pollution in the United States, is administered by the EPA, and its implementing regulations are codified at 40 C.F.R. Subchapter C, Parts 50-97.

The history of national air pollution legislation began with the 1955 Air Pollution Control Act, but the first piece of legislation to control air pollution was the Clean Air Act of 1963. The Air Quality Act of 1967 continued the processes of developing legislation to reduce air pollution, but it was in 1970 that the Clean Air Act in its modern form was adopted. Amendments were added in 1977 and 1990, which further expanded the control of emissions.

One of the programs to come out of the 1970 Clean Air Act Amendments was the creation of NAAQS , thresholds of air pollution considered to be the upper limit of healthy air that are based on the best scientific evidence available that must be met nationally (*Clean Air Act Amendments of 1970* 1970). NAAQS were developed for several pollutants, including ground-level ozone.

The 1970 Clean Air Act also introduced the SIP, which is intended to demonstrate how an area that is not complying with the NAAQS will meet that standard through state programs that become federally enforceable following approval of the SIP. The 1990 amendments expanded the requirements for SIPs, in particular in regards to ground-level ozone (*Clean Air Act Amendments of 1990* 1990).

The 1977 amendments saw the introduction of provisions to reduce visibility impairment at areas termed “Class I” areas, which are significant national parks and other natural areas (*Clean Air Act Amendments of 1977* 1977). This program was further strengthened in 1990 setting requirements for regional haze SIPs, including the setting of RPGs.

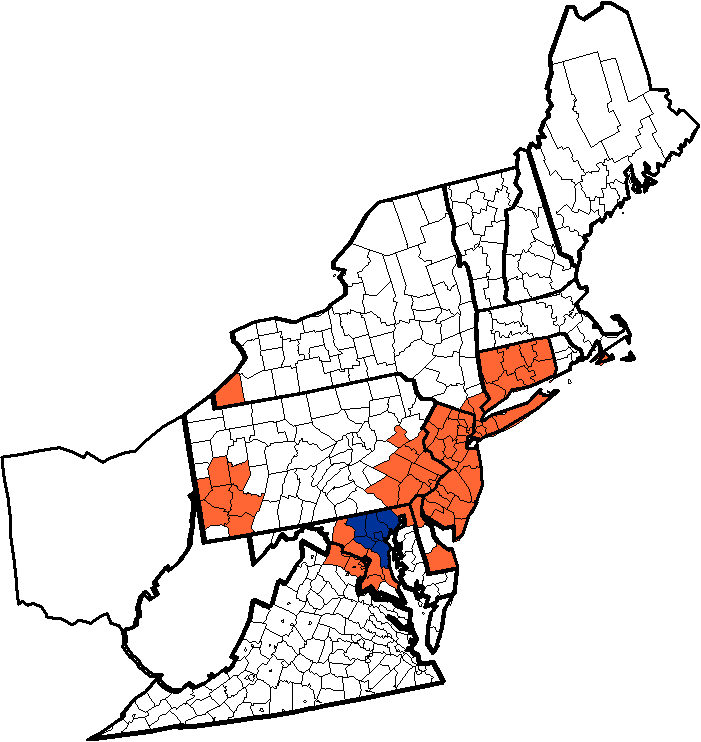
The following is an overview of some of the more recent NAAQS that are applicable to this document, as well as an overview of the regional haze program.

#### 1997 8-hour Ozone NAAQS

In 1997 the primary and secondary NAAQS were set to 0.08 ppm for the three year average of the 4th highest 8-hour average ozone concentration, which due to rounding conventions is equivalent to 84 ppb (US EPA 1997). This standard was revoked as of April 6, 2015 and will no longer be considered in this document (US EPA 2015a).

#### 2008 8-hour Ozone NAAQS

In 2008 the primary and secondary NAAQS were set to 0.075 ppb for the three year average of the 4th highest 8-hour average ozone concentration, which is equivalent to 75 ppb (US EPA 2008). After some delays in timeframes outlined in the Clean Air Act, areas were designated for the 2008 NAAQS as seen in Figure 1‑1and Table 1‑1 (US EPA 2012).

Table 1‑1: Nonattainment areas in the OTR for 2008 Ozone NAAQS

**Marginal  
  
Moderate**

Figure ‑: 2008 Ozone NAAQS Designations in the OTR as originally designated in 2012

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Area Name | State | Classification as of 8/4/16 | No. Counties | 2012 DVs (ppm) |
| Baltimore, MD | MD | Moderate | 6 | 0.089 |
| Greater Connecticut, CT | CT | Moderate | 5 | 0.079 |
| NYC-N. NJ-Long Island, NY-NJ-CT | CT | Moderate | 3 | 0.084 |
| NYC -N. NJ-Long Island, NY-NJ-CT | NJ | Moderate | 12 | 0.084 |
| NYC -N. NJ-Long Island, NY-NJ-CT | NY | Moderate | 9 | 0.084 |
| Allentown-Bethlehem-Easton, PA | PA | Marginal | 3 | 0.076 |
| Dukes County, MA | MA | Marginal | 1 | 0.076 |
| Jamestown, NY | NY | Marginal | 1 | 0.077 |
| Lancaster, PA | PA | Marginal | 1 | 0.077 |
| Phila.-Wilm.-Atl. City, PA-NJ-MD-DE | NJ | Marginal | 9 | 0.083 |
| Phila.-Wilm.-Atl. City, PA-NJ-MD-DE | DE | Marginal | 1 | 0.083 |
| Phila.-Wilm.-Atl. City, PA-NJ-MD-DE | MD | Marginal | 1 | 0.083 |
| Phila.-Wilm.-Atl. City, PA-NJ-MD-DE | PA | Marginal | 5 | 0.083 |
| Pittsburgh-Beaver Valley, PA | PA | Marginal | 7 | 0.080 |
| Reading, PA | PA | Marginal | 1 | 0.077 |
| Seaford, DE | DE | Marginal | 1 | 0.077 |
| Washington, DC-MD-VA | DC | Marginal | 1 | 0.081 |
| Washington, DC-MD-VA | MD | Marginal | 5 | 0.081 |
| Washington, DC-MD-VA | VA | Marginal | 9 | 0.081 |

Following the designation of an area as nonattainment for the criteria pollutant Ozone, the Clean Air Act requires submission of a SIP to demonstrate how that area will be meeting the pollutant standard (NAAQS) in the time period established by the Act. Areas designated as marginal require no air quality modeling (US EPA 2015a). One nonattainment area, Baltimore, MD, was designated moderate, and was expected to require the submission of an attainment demonstration using photochemical modeling, with the attainment demonstration being based on 2018 design values (US EPA 2012). However, following the DC Circuit decision in NRDC vs. EPA on December 23, 2014, the attainment deadline was advanced from December 31, 2018 to July 20, 2018, so that the states now needed to demonstrate attainment using 2017 design values (DC Circuit 2014).

The New York City, NY-NJ-CT nonattainment area, which was originally designated marginal in 2012 was reclassified to moderate effective June 3, 2016 given its continued monitoring of nonattainment (US EPA 2016a).

#### 2015 8-hour Ozone NAAQS

In 2015 the primary and secondary NAAQS were set to 0.070 ppm for the three year average of the 4th highest 8-hour average ozone concentration, which is equivalent to 70 ppb (US EPA 2015b). The Clean Air Act does not require EPA to issue designations for the 2015 Ozone NAAQS until October 1, 2016. Given the planning horizon it is not expected that this platform will be used in demonstrating attainment of the 2015 Ozone NAAQS.

#### Regional Haze

EPA’s regional haze regulations require regional haze SIPs to be updated for the second planning period by July 31, 2018. This SIP requires modeling to demonstrate reasonable further progress towards background visibility conditions at Class I areas and to set 2028 RPGs using estimates of visibility following controls anticipated as the result of the consultation process between the states and FLMs. The controls will be included in each state’s long-term strategy and deemed to be reasonable following a four-factor analysis. The deadline for SIP submittals may be extended to December 31, 2021 if a rule that is currently proposed is finalized (US EPA 2016b). A list of the Class I areas in MANE-VU is in Table 1‑2.

Table 1‑2: List of Class I Areas in MANE-VU (40 CFR 81)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| State | AREA NAME | ACREAGE | FLM | Monitored |
| ME | Acadia National Park | 37,503 | NPS | Yes |
|  | Moosehorn Wilderness Area | 7,501 | FWS | Yes |
| NH | Great Gulf Wilderness Area | 5,552 | FS | Yes |
|  | Presidential Range-Dry River Wilderness Area | 20,000 | FS | No |
| NJ | Brigantine Wilderness Area | 6,603 | FWS | Yes |
| VT | Lye Brook Wilderness | 12,430 | FS | Yes |
| ME & NB, CA | Roosevelt Campobello International Park | 2,721 | Chairman, RCIP Commission | No |

## Geographic Definitions

Throughout the document several geographic definitions will be used that are based on the boundaries of RPOs. To allow for clarity as to which states are included Table 1‑3 has been provided, though in some cases figures are limited to what is within the OTC modeling domain.

Table 1‑3: List of states in geographic areas based on RPOs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| OTC | MANE-VU | SESARM | LADCO | CenSARA |
| Connecticut | Connecticut | Alabama | Illinois | Arkansas |
| District of Columbia | District of Columbia | Florida | Indiana | Iowa |
| Delaware | Delaware | Georgia | Michigan | Kansas |
| Massachusetts | Massachusetts | Kentucky | Minnesota | Louisiana |
| Maryland | Maryland | Mississippi | Ohio | Missouri |
| Maine | Maine | North Carolina | Wisconsin | Nebraska |
| New Hampshire | New Hampshire | South Carolina |  | Oklahoma |
| New Jersey | New Jersey | Tennessee |  | Texas |
| New York | New York | Virginia |  |  |
| Pennsylvania | Pennsylvania | West Virginia |  |  |
| Rhode Island | Rhode Island |  |  |  |
| Virginia | Vermont |  |  |  |
| Vermont |  |  |  |  |

## Participants

### OTC Air Directors

OTC Air Directors will serve as overseers of the work products developed by the OTC Modeling Committee. The OTC Air Directors will oversee the design of ozone control strategies for the OTR and make decisions surrounding modeling of the air quality impacts of policies. The Air Directors will review all OTC SIP quality modeling platform documentation before it is finalized. The state members of the OTC Modeling Committee will keep Air Directors informed of the development of the OTC SIP quality modeling platform.

### OTC Modeling Committee

The OTC Modeling Committee will serve as first tier reviewers of the work products developed for the SIP quality modeling platform. The OTC Modeling Committee will approve technical approaches used in the modeling platform, review results, and approve products for review by the Air Directors. Since members of the three EPA regions are members of the OTC Modeling Committee, they will provide insights into any issues that may occur involving the acceptability of the OTC SIP quality modeling platform in a SIP so that problems can be corrected at the regional level.

### OTC Modeling Planning Group

The OTC Modeling Planning Group will be made up of members of the modeling centers and the OTC Modeling Committee leadership. The workgroup will review technical decisions to bring recommendations on approaches to the OTC Modeling Committee.

### OTC Technical Support Document Workgroup

The OTC TSD Workgroup is responsible for compiling drafts of the technical documentation for review by the OTC Modeling Planning Group.

### OTC Modeling Centers

The OTC Modeling Centers are the state staff and academics that perform modeling and conduct analyses of modeling results. They include NYSDEC, NJDEP, VADEQ, UMD via MDE, and ORC at Rutgers via NJDEP.

### MANE-VU Technical Support Committee

The MANE-VU Technical Support Committee will serve as first tier reviewers of the work products developed for the SIP quality modeling platform with a focus on regional haze issues. Since members of the three EPA regions and the FLMs are members of the TSC, they will provide insights into any issues that may occur involving the acceptability of the OTC SIP quality modeling platform in a SIP so that problems can be corrected at the regional level.

### MARAMA Emission Inventory Leads Committee

The MARAMA Emission Inventory Leads Committee is made up of state staff that make technical recommendations involving the multi-pollutant emissions inventory, as well as quality assure the inventories.

## Schedule

Table 1‑3 provides an overview schedule intended as a guideline for finalization of the modeling in the document, though given that the SIP quality modeling platform is being used for planning that runs on different timelines some revisions may occur.

Table 1‑4: Multi-pollutant modeling schedule using 2011 platform

|  |  |
| --- | --- |
| Process Point | Timeframe |
| 2011 Alpha 2 Inventory for Regional Haze | June 2015 |
| 2011 Base Case Modeling for Regional Haze | August 2015 |
| 2018/2028 Alpha 2 Inventory for Regional Haze | December 2015 |
| 2011 Base Case Modeling for Ozone | June 2016 |
| Draft TSD (excepting Future results) | August 2016 |
| 2017 Beta Inventory for Ozone | August 2016 |
| OTC Stakeholder Meeting | September 2016 |
| 2028 Future Case Modeling for Regional Haze | October 2016 |
| 2017 Future Case Modeling for Ozone | October 2016 |
| Final TSD | November 2016 |
| NYC and Greater CT Attainment SIP Due (US EPA 2016a) | January 1, 2017 |
| Regional Haze SIPs Due | July 31, 2018 |

## Conceptual Model

### Ozone

The interaction of meteorology, chemistry, and topography lead to a complex process of ozone formation and transport. Ozone episodes in the eastern United States often begin with an eastern moving large high pressure area from the Midwest to the OTR, which collects pollution from stationary and mobile sources as it moves. When the air mass settles in the OTR, sometimes even for days, local pollution is added. The air mass, which is stagnant and cloudless exacerbates ozone levels, since it allows sunlight more time to promote ozone formation and increase reactions of VOCs and NOX, the precursors to ozone. Additional pollution can be introduced to the systems from the Southeast through the nocturnal low level jet, a fast moving air mass that resides below the nocturnal boundary layer. This highly polluted air can also be kept from dissipating along the coast due to bay and sea breezes push pollution back to shore.

Some ozone is also natural, or transported internationally leading to ozone that is not considered relatable. This US Background ozone in the Eastern United States is in the range of 30 to 35 ppb though it can be as high as 50 ppb in the Intermountain West (US EPA 2014b).

Another complexity involves the nonlinear relationship between NOX and VOC levels and ozone formation. Areas such as the majority of the landscape in the OTR that have extensive forests that produce high levels of isoprene and other VOCs during the summer month achieve the best ozone reduction through reductions in regional NOX, but dense urban areas such as New York City that lack natural VOC production can be VOC limited, and in some cases NOX reductions increase ozone levels due to less NOX being available to destroy already formed ozone through titration.

To address this great level of complexity that occurs when evaluating the conceptual model of ozone we will be basing the modeling exercise on the conceptual model as described in “The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description (Hudson et al. October 2006).”

### **Visibility**

Under natural atmospheric conditions, the view in the eastern United States wouldextend about 60 to 80 miles, whereas in the western United States this can extend from 110 to 115 miles (Malm May 1999). Current visibility conditions result in less distance that can be viewed due to impacts of anthropogenic pollution. However, the current conditions in the Eastern US are remarkably improved from the early 2000’s when the regional haze program began.

Anthropogenic visibility impairment in the eastern United States is largely due to the presence of light-absorbing and light-scattering PM of which the impact can be estimated through the IMPROVE algorithm. This impact is sensitive to the chemical composition of the particles involved, and also depend strongly on ambient relative humidity. Secondary particles (e.g., ammonium sulfate, ammonium nitrate), which form in the atmosphere through chemical reactions, tend to fall within a size range that is most effective at scattering visible light (NARSTO February 2003) A great level of complexity occurs when evaluating the conceptual model of fine PM2.5. We will be basing the modeling exercise on the conceptual model found in “The Nature of the Fine Particle and Regional Haze Air Quality Problems in the MANE-VU Region: A Conceptual Description (Downs et al. 10 August 2010).”

## Base Year Selection

Analyses of monitored data and meteorological data concluded that for the OTR, 2010, 2011 and 2012 are the candidate base years to model for future ozone NAAQS planning and 2011 is the best base year for future Regional Haze and annual PM2.5 NAAQS planning. Transport patterns of 2011 ozone events in the OTR confirm that using 2011 would be appropriate. When other factors were considered including availability of a national emission inventory, research data availability, and decisions on base years by nearby RPOs and EPA more weight was given to using 2011 as a base year. As a result, 2011 was determined to be the best candidate base year for this multi-pollutant platform (Ozone, Regional Haze and PM2.5). More details can be found in the document “Future Modeling Platform Base Year Determination” produced by the MANE-VU Technical Support Committee (MANE-VU Technical Support Committee 9 October 2013, p.).

## Future Year Selection

Since a 2018 inventory was needed for Baltimore to demonstrate attainment, OTC developed inventories for that year. However, following the DC Circuit decision discussed earlier, developing a 2017 inventory became necessary. As such the 2018 inventory was no longer needed as an ozone modeling inventory.

To conserve resources through multi-pollutant planning, the region also developed a 2028 inventory required for the submission of regional haze SIPs.

As a result we began our modeling platform using 2018 and 2028 future years, and later migrated 2018 to 2017.

## References

Clean Air Act Amendments of 1970 (United States|US 1970).

Clean Air Act Amendments of 1977 (United States|US 1977).

Clean Air Act Amendments of 1990 (United States|US 1990).

Natural Resources Defense Council v. Environmental Protection Agency, No. 12–1321 (DC Circuit 23 December 2014).

Downs, T, Kheirbek, I, Kleiman, G, Miller, P and Weiss, L 2010, *The Nature of the Fine Particle and Regional Haze Air Quality Problems in the MANE-VU Region: A Conceptual Description*, Boston, MA, accessed August 26, 2016, from <http://www.nescaum.org/documents/2010-pm-conceptual-model-\_final\_revised-20100810.pdf/>.

Hudson, R, Downs, T, Fields, R, Kheirbek, I, Kleiman, G, Miller, P and Weiss, L 2006, *The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description*, Boston, MA, accessed July 21, 2016, from <http://170.63.70.137/eea/docs/dep/air/priorities/5a-ozone-conceptual-model.doc>.

Malm, WC 1999, *Introduction to Visibility*, Fort Collins, CO.

MANE-VU Technical Support Committee 2013, *Future Modeling Platform Base Year Selection Analysis*, accessed from <http://otcair.org/MANEVU/Upload/Publication/Reports/Future%20Modeling%20Platform%20Base%20Year%20Selection%20Analysis%20-%20Oct%209%202013%20Final.pdf>.

NARSTO 2003, *Particulate Matter Science for Policy Makers: A NARSTO Assessment*,.

1997 National Ambient Air Quality Standards for Ozone, Vol. 62, No. 138, (United States|US 1997).

2008 National Ambient Air Quality Standards for Ozone, Vol. 73, No. 60 (United States|US 2008).

Air Quality Designations for the 2008 Ozone National Ambient Air Quality Standards, Vol. 77, No. 98 (United States|US 2012).

US EPA 2014a, ‘Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze’, accessed from <https://www3.epa.gov/ttn/scram/guidance/guide/Draft\_O3-PM-RH\_Modeling\_Guidance-2014.pdf>.

US EPA 2014b, *Policy Assessment for the Review of the O3 National Ambient Air Quality Standards*, Research Triangle Park, NC, accessed from <http://www3.epa.gov/ttn/naaqs/standards/ozone/s\_o3\_2008\_pa.html.>.

Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements, Vol. 80, No. 44 (United States|US 2015a).

2015 National Ambient Air Quality Standards for Ozone, Vol. 80, No. 206 (United States|US 2015b).

Determinations of Attainment by the Attainment Date, Extensions of the Attainment Date, and Reclassification of Several Areas for the 2008 Ozone National Ambient Air Quality Standards, Vol. 81, No. 86 (United States|US 2016a).

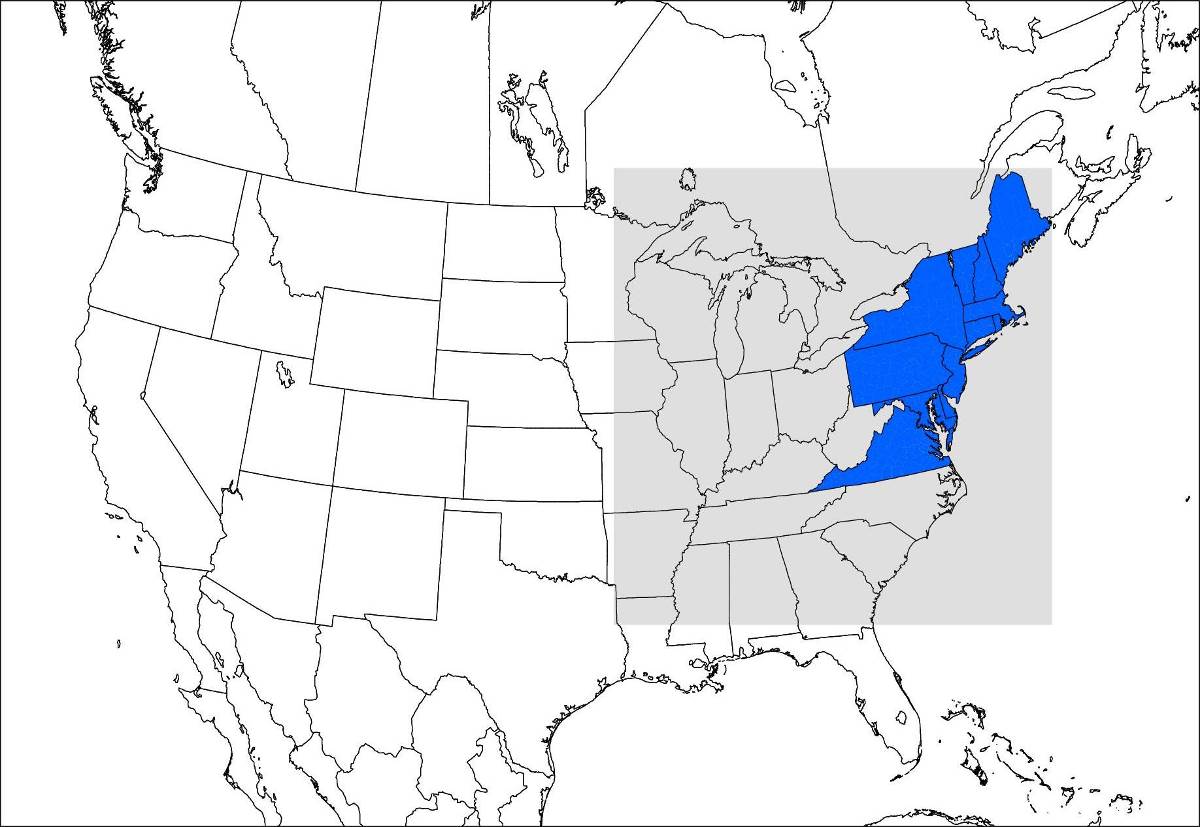
Proposed Rule: Protection of Visibility: Amendments to Requirements for State Plans, Vol. 81, No. 86 (United States|US 2016b).

# Evaluation of Meteorological Modeling using WRF

## Overview

The OTC Modeling Committee extracted the meteorological data from EPA’s 2011 photochemical modeling of the CONUS. That modeling used WRF v.3.4 to develop meteorological data. The OTC modeling used only a subset of the EPA modeling domain as illustrated in Figure 2‑1 (US EPA 2014). The meteorological data for the OTC domain was extracted from the EPA CONUS domain modeling using MCIP (Otte and Pleim 2010). The OTC retained the same 12 km square grid size and 35 layer column depth as was used by EPA.

Figure 2‑1: Extent of EPA CONUS domain with the and OTR Modeling Domain in grey and the OTR states in blue



## Assessment

Certain critical parameters of the model were assessed for their ability to characterize actual conditions occurring over the base year. EPA provides the following guidance concerning evaluation of meteorological models in section 2.6.3.

*While the air quality models used in attainment demonstrations have consistently been subjected to a rigorous performance assessment, in many cases the meteorological inputs to these models have received less rigorous evaluation, even though this component of the modeling is quite complex and has the potential to substantially affect air quality predictions (Tesche, 2002). EPA recommends that air agencies devote appropriate effort to the process of evaluating the meteorological inputs to the air quality model as we believe good meteorological model performance will yield more confidence in predictions from the air quality model. One of the objectives of this evaluation should be to determine if the meteorological model output fields represent a reasonable approximation of the actual meteorology that occurred during the modeling period. Further, because it will never be possible to exactly simulate the actual meteorological fields at all points in space/time, a second objective of the evaluation should be to identify and quantify the existing biases and errors in the meteorological predictions in order to allow for an downstream assessment of how the air quality modeling results are affected by issues associated with the meteorological data. To address both objectives, it will be necessary to complete both an operational evaluation (i.e., quantitative, statistical, and graphical comparisons) as well as a more phenomenological assessment (i.e., generally qualitative comparisons of observed features vs. their depiction in the model data).*

For our assessment 2011 WRF modeled data were compared to data for the year. For several factors we relied on EPA’s own assessments, while looking more specifically at data in the OTR. We also expanded on EPA’s work by looking at the ways WRF modeled temperature, mixing ratio, and the PBL height. Details of the assessment follow.

### Model Performance Analyzed by EPA

#### Winds Speed

EPA found that WRF v. 3.4 slightly over-predicts wind speed in the Eastern United States with the bias being highest during the midday hours. EPA also found that the error in wind displacement tends to be about 5 km, which, being less than the size of a grid cell, should be negligible in affecting position of air masses temporally and spatially (Eyth and Vukovich 2015).

#### Precipitation comparison

EPA found that WRF v. 3.4 performs adequately in terms of spatial pattern recognition and predicting the amount of precipitation throughout the year when compared to the PRISM climate data. The results compared well in the OTR, including the forecast of a high band of coastal precipitation that occurred during the month of August, although the precipitation in March and September appears to be respectively overestimated and underestimated throughout the OTR (US EPA 2014).

#### Solar Radiation

Photosynthetically-activated radiation is important in estimating isoprene, which plays an important role in the formation of ozone and secondary organic aerosols in the heavily forested OTR (Carlton and Baker 2011). EPA evaluated the performance of solar radiation using SURFRAD and ISIS network monitors and found little bias during the fall and winter months, but growing bias during the spring with a peak in the summer, “though the spread in over-predictions tends to be less than 100 W/m2 on average, with a median bias close to zero (US EPA 2014).” WRF also tends to over-predict from about 7 AM to Noon, while under-predicting from 1 PM to 5 PM. Additionally, EPA stated that “radiation performance evaluation also gives an indirect assessment of how well the model captures cloud formation during daylight hours” so cloud cover would be expected to be under-predicted in the morning and over-predicted in the late afternoon.

### Model Performance Analyzed by OTC

#### Temperature and Mixing Ratio

NYSDEC conducted the review of temperature and mixing ratios for the OTC Modeling Committee. NYSDEC relied on RTMA, a component of the NWS Analysis of Record project and produced by NOAA/NCEP.

RTMA provides a high-spatial and temporal resolution analysis/assimilation system for near-surface weather conditions RTMA produces hourly analyses at 5 km and 2.5 km grid resolution for the CONUS NDFD grid. The parameters in RTMA include pressure height and air pressure at the surface, air temperature, dew point temperature, and specific humidity at 2m, U- and V-components of wind momentum at 10m, along with cloud cover and precipitation. Observational data from the RTMA 2.5 (<http://www.nco.ncep.noaa.gov/pmb/products/rtma/#RTMA2p5>) is used in this evaluation and interpolated to the 12km WRF grid.

NYSDEC compared the modeled WRF temperature and mixing ratio values with the real world data from RTMA. NYSDEC found that WRF temperature had a low bias in winter months and a high bias in summer months (Figure 2‑2) and the WRF mixing ratio had a high bias in winter months and a low bias in summer months (Figure 2‑3). When NYSDEC examined the absolute error, they found that WRF had a low absolute error for temperature and a large absolute error for mixing ratios in the summer (Figure 2‑4 and Figure 2‑5). Additionally, several low correlation coefficients were observed in July and August on grid cells along the coastline (Figure 2‑6 and Figure 2‑7).

NYSDEC next compared the diurnal modeled WRF temperature and mixing ratio values during the months of February (winter) and August (summer). In February WRF temperature bias was minimal at all times of day (Figure 2‑8) and the mixing ratio was biased high throughout the 24 hours (Figure 2‑9). In August WRF temperature bias was bias high in the morning hours and bias low in the afternoon (Figure 2‑10). Mixing ratio for August was biased low in the evening (Figure 2‑11). In February the temperature mean absolute error varied between and 1 and 1.5 ºF (Figure 2‑12). The mean absolute error for the mixing ratio in February was worst in the evenings with means around 5 g/kg (Figure 2‑13). In August the temperature mean absolute error was typically around 1 ºF at all times of the day (Figure 2‑14) and was worst in the evening, but had a mean absolute error for the mixing rations that was closer to 1.5 g/kg (Figure 2‑15). Correlation coefficients were much closer to 1 in February for both temperature and mixing ratio than in August, when in some cases during the early evening hours zero correlation was found (Figure 2‑16-Figure 2‑19).

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| --- | --- |
| Figure 2‑2: Monthly average Bias (RMTA – WRF) for Temperature[[1]](#footnote-1) | Figure 2‑3: Monthly average Bias (RMTA – WRF) for Mixing Ratio1 |
| Figure 2‑4: Monthly average absolute error for temperature1 | Figure 2‑5: Monthly average absolute error for mixing ratio1 |
| Figure 2‑6: Correlation coefficients for temperature1 | Figure 2‑7: Correlation coefficients for mixing ratio1 |
| Figure 2‑8: Diurnal BIAS (RMTA – WRF) for temperature in Feb.1 | Figure 2‑9: Diurnal BIAS (RMTA – WRF) for mixing ratio in Feb.1 |
| Figure 2‑10: Diurnal BIAS (RMTA – WRF) for temperature in Aug.1 | Figure 2‑11: Diurnal BIAS (RMTA – WRF) mixing ratio in Aug.1 |
| Figure 2‑12: Diurnal absolute error for temperature in Feb.1 | Figure 2‑13: Diurnal absolute error for mixing ratio in Feb.1 |
| Figure 2‑14: Diurnal absolute error for temperature in Aug.1 | Figure 2‑15: Diurnal absolute error for mixing ratio in Aug.1 |
| Figure 2‑16: Diurnal correlation coefficient for temperature in Feb.1 | Figure 2‑17: Diurnal correlation coefficient for mixing ratio in Feb.1 |
| Figure 2‑18: Diurnal correlation coefficient for temperature in Aug.1 | Figure 2‑19: Diurnal correlation coefficient for mixing ratio in Au.1 |

#### Planetary Boundary Layer

The CALIPSO satellite began operation in 2006 with three instruments, the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), the Imaging Infrared Radiometer (IIR), and the Wide Field Camera (WFC). Its repetition cycle is 16 days. CALIOP is a two-wavelength polarization sensitive Lidar (532 nm and 1064 nm). At 532 nm, it has horizontal and vertical resolutions of 333 m and 30 m (up to 8 km), respectively. The CALIPSO aerosol layer product provides data for PBL height covering vast areas on a regular basis.

The NYSDEC derived PBL-height from the CALIPSO Level-1B-attenuated aerosol backscatter profile using the wavelet transform technique, which assumes a structure from the backscatter profile at the height of the air column where the scattering has a strong increase just under the PBL and a strong negative gradient of the backscatter. They averaged the raw signal over 40km to improve signal-to-noise-ratio, and discarded low-cloud data. Then they extracted and refined the CALIPSO Level-2 aerosol layer-top in the lower atmosphere for PBL-height by choosing:

1. single aerosol-layer top, while rejecting multiple layers data;
2. the layer with the base ≤0.3 km above sea level and the top ≤6.0 km above sea level, while rejecting aloft aerosol layers;
3. the layer with the depth > 0.10 km, while rejecting the potentially noisy outlier layers;
4. the layer with cloud-aerosol-discrimination score: -100 ≤ CAD ≤ -20, while rejecting clouds and low-confidence feature layers; and
5. only daytime data to avoid detection of nighttime residual layers.

Figure 2‑20: Seasonal Frequency of CALIPSO PBL height



Figure 1-22 showed the frequency distribution of CALIPSO PBL height. The PBL is, on average, lower during the winter at 500 – 1000 meter range, and highest during the summer at 1500 – 2000 meter range. WRF underestimated daytime PBL height compared to CALIPSO particularly over water and more so during the summer (Figure 2‑21 and Figure 2‑22). WRF PBL height showed significantly larger land-water contrast than the CALIPSO data, with the underestimation being larger in summer than in winter (Figure 2‑23 - Figure 2‑26).

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| Figure 2‑21: CALIPSO to WRF (PBL height ratio) Winter (D/J/F) 2011 (blue and red dots over land and water respectively) | Figure 2‑22 CALIPSO to WRF (PBL height ratio) Summer (J/J/A) 2011 (blue and red dots over land and water respectively) |

|  |  |
| --- | --- |
| Figure 2‑23: CALIPSO to WRF (PBL height ratio) Winter (D/J/F) 2011 | Figure 2‑24: CALIPSO to WRF (PBL height ratio) Summer (J/J/A) 2011 |

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| Figure 2‑25: CALIPSO to WRF (PBL height ratio) Spring (M/A/M) 2011 | Figure 2‑26: CALIPSO to WRF (PBL height ratio) Fall (S/O/N) 2011 |

One area of uncertainty involves PBL height estimates over bodies of water. CALIPSO data lacks the information necessary to properly evaluate PBL over water.

## Summary

EPA has developed a significant look at the WRF v.3.4 model runs that OTC/MANE-VU is employing in its modeling platform and they have found the model to be quite acceptable for use in their national regulatory processes. OTC reviewed EPA’s assessment and found that WRF v.3.4 modeled the Eastern US appropriately with regards to the factors EPA analyzed. NYSDEC went further to examine how WRF v.3.4 modeled temperature, mixing ratios, and PBL compared to monitored data and also found the results to be reasonable approximations. The data presented in EPA’s documentation as well as OTC’s analysis also provide evidence of areas needing further scrutiny (e.g., PBL height over bodies of water). OTC Modeling Committee expects that the 12 km WRF v.3.4 model results will lead to scientifically sound air quality modeling.

## References

Carlton, AG and Baker, KR 2011, ‘Photochemical Modeling of the Ozark Isoprene Volcano: MEGAN, BEIS, and Their Impacts on Air Quality Predictions’, *Environmental Science & Technology*, vol. 45, no. 10, pp. 4438–4445.

Eyth, A and Vukovich, J 2015, ‘Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform’, accessed March 18, 2016, from <http://www3.epa.gov/ttn/chief/emch/2011v6/2011v6\_2\_2017\_2025\_EmisMod\_TSD\_aug2015.pdf>.

Otte, TL and Pleim, JE 2010, ‘The Meteorology-Chemistry Interface Processor (MCIP) for the CMAQ modeling system: updates through MCIPv3.4.1’, accessed March 16, 2016, from <http://www.geosci-model-dev.net/3/243/2010/gmd-3-243-2010.pdf>.

US EPA 2014, ‘Meteorological Model Performance for Annual 2011 WRF v3.4 Simulation’, accessed March 4, 2016, from <https://www3.epa.gov/ttn/scram/reports/MET\_TSD\_2011\_final\_11-26-14.pdf>.

# Evaluation of Biogenic Model Versions

## Overview

The modeling platform made available by EPA, v. 6.2, relied on BEIS v. 3.6 for biogenic emissions (Eyth and Vukovich 2015, p.2). More recently BEIS v. 3.6.1 was produced which came with more recent land use data which was expected to lead to more accurate results. OTC expects that EPA in future modeling will upgrade to the more recent version of BEIS, but since that has not yet to occur OTC determined that a brief evaluation of BEIS v. 3.6.1 was warranted.

## Assessment

NYSDEC conducted an evaluation of two versions (3.6 and 3.6.1) of the biogenic model BEIS in order to determine which version produced more accurate base year modeling results. The major difference between the two versions of BEIS is the land use data employed by the model: v. 3.6 uses NCLD 2006 and v.3.6.1 uses NCLD 2011 (<http://www.mrlc.gov/>). The land use data in v. 3.6.1 shows much higher levels of isoprene than v. 3.6 (Bash, Baker and Beaver 2015). It was expected that v. 3.6.1 would produce the more accurate results given that it more accurately reflects the state of land use in the base year and also due to the improvements in isoprene production in the newer version.

In order to test the accuracy of the two biogenic model versions, two base year photochemical modeling runs were completed using CMAQ. The details on how CMAQ was configured for these model runs are in a later section (see Section 5). The model runs were completed using the 2011 Alpha 2 inventory (see Section 4).

Overall the difference between using v. 3.6.1 and v. 3.6 did not change the overall bias and error in the modeled results in the OTR as seen in Figure 3‑1 (MFB), Figure 3‑2 (MFE), and Figure 3‑3 (MAGE), but the improvements in the response at the high ozone monitors warrant upgrading to BEIS v. 3.6.1.

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| Figure 3‑1: MFE % for OTR monitors for CMAQ model runs conducted using BEIS 3.61 (left axis) and BEIS 3.6 (bottom axis) | Figure 3‑2: MFB % for OTR monitors for CMAQ model runs conducted using BEIS 3.61 (left axis) and BEIS 3.6 (bottom axis) |

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| Figure 3‑3: MAGE (ppb) for OTR monitors for CMAQ model runs conducted using BEIS 3.61 (left axis) and BEIS 3.6 (bottom axis) |  |

In order to test the impact of design value projections between the two biogenic model versions, two future year photochemical modeling runs were completed using CMAQ. The details on how CMAQ was configured for these model runs are in a later section (see Section 5). The model runs were completed using the 2018 Alpha 2 inventory (see Section 8).

NYSDEC found that using BEIS v. 3.6.1 resulted a greater response to reductions in NOX at many higher valued monitors as seen in Table 3‑1. One exception to this rule was Sherwood Island, CT (Monitor ID #090019003), which saw increases in ozone in both photochemical model runs.

Four monitors, including Sherwood Island, saw no change in projected ozone when v. 3.6.1 was used, and this is likely due to their proximity to the land-water interface. The highest value in the 9x9 grid surrounding the monitor is used in calculating the projected ozone at a monitor. The highest values at the nearby grid cells to these monitors that are likely over water, which means those grid cells are not impacted by changes in biogenic emissions. As a result we would expect to see little to no change in projected ozone at monitors near to the land-water interface. More details on the issues surround projected ozone calculations for monitors near the land-water interface is in Section 9.

Table 3‑1: Modeled 2018 DVFs for 12 high ozone monitors in the OTR comparing BEIS v. 3.6 and BEIS v. 3.6.1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| AQS Code | Site | DVC2011 | DVF BEIS v. 3.6 | DVF BEIS v. 3.6.1 |
| 090019003 | Sherwood Island | 83.7 | 84 | 84 |
| 240251001 | Edgewood | 90 | 82 | 81 |
| 361030002 | BABYLON | 83.3 | 82 | 77 |
| 090010017 | Greenwich Point Park | 80.3 | 80 | 77 |
| 090013007 | Fairfield | 84.3 | 78 | 78 |
| 360810124 | QUEENS COLLEGE | 78 | 78 | 74 |
| 361192004 | WHITE PLAINS | 75.3 | 78 | 74 |
| 090099002 | Hammonasset State Park | 85.7 | 77 | 77 |
| 360850067 | SUSAN WAGNER HS | 81.3 | 77 | 77 |
| 340150002 | Clarksboro | 84.3 | 75 | 75 |
| 360050133 | PFIZER LAB SITE | 74 | 75 | 72 |
| 421010024 | North East Airport (NEA) | 83.3 | 75 | 74 |

## References

Bash, JO, Baker, KR and Beaver, MR 2015, ‘Evaluation of improved land use and canopy representation in BEIS v3.61 with biogenic VOC measurements in California’, *Geoscientific Model Development Discussions*, vol. 8, no. 9, pp. 8117–8154.

Eyth, A and Vukovich, J 2015, ‘Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform’, accessed March 18, 2016, from <http://www3.epa.gov/ttn/chief/emch/2011v6/2011v6\_2\_2017\_2025\_EmisMod\_TSD\_aug2015.pdf>.

# Emissions Inventories and Processing for 2011 12km Base Year Simulation

## Overviews

### ERTAC EGU

The majority of the tools that OTC/MANE-VU are currently using to develop emissions inventory have already become standards in the field including MOVES for onroad emissions, NONROAD for nonroad emissions, EPA’s RWC tool for residential wood combustion, BEIS for biogenic emissions, and EMF for growing inventories for other sectors. However, the ERTAC EGU projection tool is not as well known.

The ERTAC EGU tool has been developed through the ERTAC collaborative process to be used for use in projecting future year EGU emissions. However, some units are partial year reporters or do not have to report SO2 emissions to CAMD due to only being in the NOX Budget Trading Program. To resolve these issues the ERTAC EGU group ran ERTAC EGU projecting the CAMD data to the base year with no growth. This run, called Base Year Equals Future Year or “BY=FY”, allowed missing emissions to be included, as well as smoothing out erratic data that is often created when missing data are replaced with maximum possible values (MARAMA n.d.).

### Alpha

The Alpha version of the inventory was used to generate CMAQ-ready emissions for initial modeling. EPA’s 2011 emissions data from nearly every sector were included directly into CMAQ without SMOKE processing since these data were not altered in any way. The inventories were based on v. 6.2 of the EPA modeling inventory (also called v. “eh”, which is in turn was based on NEI v. 2) and were processed through SMOKE v. 3.5.1 (Eyth and Vukovich 2015). Although OTC/MANE-VU did not process most of the emissions using SMOKE, the SMOKE input files are available on the MARAMA EMF system.

The exceptions that NYSDEC did process using SMOKE are the ERTAC EGU, Small EGU, and Non-EGU Point sectors. ERTAC v. 2.3 was used in the Alpha inventory. These were all processed using SMOKE v. 3.6.

### Alpha 2

The Alpha 2 version of the inventory was simply a correction to the C3 Marine sector to rectify double counting that occurred in the inventories used in the Alpha inventory. This is the version that is intended to be used in 2018 Regional Haze SIPs. EPA’s 2011 emissions data from nearly every sector were included directly into CMAQ without SMOKE processing since these data were not altered in any way. EPA had processed their inventories using SMOKE v. 3.5.1 (Eyth and Vukovich 2015).

### Beta

The Beta v. of the inventory is intended to be used in 2008 Ozone SIPs. The Beta inventory uses some of the same files used in Alpha and Alpha 2 inventories that were provided by EPA, but it also relies on files that were updated in EPA’s “eh” inventory and new inputs compiled by MARAMA, which includes states’ feedback. The sectors that were updated from EPA’s “eh” inventory required SMOKE processing using v. 3.7, and in the case of onroad mobile running SMOKE-MOVES v. 3.7. ERTAC v. 2.3 was upgraded to v. 2.5 for the Beta inventory, which includes updated stacked parameters and the addition of SO2 emissions for NOX only reporters. The following sectors were reprocessed through SMOKE for the Beta inventory:

1. Agriculture
2. Area Source
3. ERTAC EGU
4. Ethanol
5. Non-EGU Point
6. Non-ERTAC IPM EGUs
7. Nonroad
8. Point Oil & Gas
9. Refueling
10. Residential Wood Combustion
11. Wild Fires

## Emission Inventory Sectors

This section lists the emission inventory sectors with a brief description of the sector. A full list of all of the files used are in Appendix A.

#### Agricultural

NH3 emissions, at the county and annual resolution, from nonpoint livestock and from fertilizer application.

#### Agricultural Fugitive Dust

PM10 and PM2.5 at the county and annual resolution from nonpoint fugitive dust sources including building construction, road construction, agricultural dust, and road dust.

#### Area Source

All nonpoint emissions, at the county and annual resolution, not included in other files. Also include agricultural burning, portable fuel container emissions merged into the sector.

#### Biogenic Emissions

Non-anthropogenic emissions at the grid cell and hourly resolution, including emissions from Canada, generated with the BEIS v. 3.61.

#### C1/C2 Marine and Rail

Locomotives and category 1 (C1) and category 2 (C2) commercial marine vessel emissions at the county and annual resolution.

#### C3 Marine

Category 3 (C3) commercial marine vessel emissions at annual resolution - in the Alpha inventory distributed throughout the Atlantic Ocean, and in the Alpha 2 and Beta inventories distributed to shipping lanes.

#### Ethanol Point sources that produce ethanol fuel.

#### ERTAC EGUs

All EGUs that are projected through the ERTAC projection tool, at the point and hourly resolution. These EGUs are from the universe of units with CEMS that are tracked by CAMD (though several units that meet that description are removed at state request) and were almost entirely found in EPA’s sector files projected by IPM.

#### Non-EGU Point

All point emissions at the point and annual resolution, not included in other files. Some units were removed from EPA’s prepared file since they were included in an ERTAC file. In the Beta inventory some sources were determined to be peaking EGUs and temporalized using an hourly emission file.

#### Non-ERTAC IPM EGUs

All units, at the point and annual resolution projected by EPA using IPM that were not projected using ERTAC, In the Beta inventory some sources were confirmed to be peaking EGUs and temporalized using an hourly emission file.

#### NonPoint Oil &Gas

Nonpoint emissions from the oil and gas sector at the county and annual resolution.

#### Nonroad

Mobile emissions, at the county and monthly resolution, processed using NONROAD 2008 from vehicles and equipment that are not included in other files.

#### Onroad

Mobile emissions, at the grid cell and hourly resolution, from onroad vehicles processed using MOVES and SMOKE-MOVES. The MOVES emission factors used for the Alpha and Alpha 2 inventories were produced using MOVES2014 and the emissions factors used for Beta were produced using MOVES2014a.

#### Point Oil & Gas

Point emissions from the oil and gas sector at the point and annual resolution.

#### Prescribed Burn

Point source daily prescribed fires computed using SMARTFIRE2.

#### Refueling

Area source emissions from gas station refueling.

#### Residential Wood Combustion

Nonpoint emissions from residential wood combustion at the county and annual resolution.

#### Wild Fires

Point source daily wildfires computed using SMARTFIRE2.

## Speciation

The speciation and cross-reference files were taken from EPA’s 2011 v6.2 modeling platform and are based on the SPECIATE 4.4 database (Abt Associates 19 February 2014; Eyth and Vukovich 2015, p.2)

## Spatial Allocation

The spatial surrogates for the 12 km domain for both the United States and Canada were extracted from the national grid 12 km U.S. gridding surrogates provided with EPA’s 2011 v6.2 modeling platform (Adelman 1 July 2015; Eyth and Vukovich 2015, p.2).

## Temporal Allocation

In most cases emissions for the sectors were allocated temporally in the same fashion as done in EPA’s 2011 v6.2 modeling platform which is described in section 3.3 (Eyth and Vukovich 2015, p.2). Exceptions to this are sectors called ERTAC EGU, Non-ERTAC IPM EGUs, and Non-EGU point.

In the case of ERTAC EGU, the ERTAC code produces hourly EGU emissions that are ground in the base year CEMS data. As mentioned earlier, the hourly results were developed using ERTAC EGU to create the BY=FY run. V. 1.01 of the ERTAC EGU code was used in all inventories. The inputs files used for the Alpha and Alpha 2 inventories were from ERTAC EGU v. 2.3, and for the Beta inventory from ERTAC EGU v. 2.5. In all cases they were post-processed using v. 1.02 of the ERTAC to SMOKE conversion tool. Given the fine level of detail that ERTAC EGU produces, the hourly ERTAC EGU results are used to temporalize EGUs in the modeling platform. In order to include the temporalization during SMOKE process, hourly ff10 files were produced by the ERTAC to SMOKE post processor in additional to the annual ff10 files.

In the case of Non-ERTAC IPM EGUs and Non-EGU point, some of the units were confirmed to be EGUs that are <25 MW (Small EGUs), through an MDE research project as outlined in Appendix A of the temporalization documentation [cite]. The units were expected to be EGUs based on their SCC and NAICS, and further refinement to the list of EGUs occurred through a state comment period. These units still function as EGUs, but produce too small an amount of power and emissions to be required to report hourly emissions to CAMD and thus are not temporalized through the ERTAC EGU process. MDE has developed a temporalization profile using hourly data from units that burn the same primary fuel and do report to CAMD. The EMF tool was used to create hourly profiles for these units so that they operate during times when electricity demand is highest rather than at a steady rate throughout the year. An example of a gas fired Small EGU in MD is shown in Figure 4‑1 and details on the profiles employed are in Appendix C of the documentation developed by MDE [cite]. An example of the change in daily emissions that result from the application of the temporal profiles on three HEDDs in 2011 are in Table 4‑1.

In order to develop the hourly ff10 files for the Small EGU’s to process in SMOKE a multistep process was implemented. First, default temporal profiles were developed using SMOKE (TREF and TPRO) and they were then imported into EMF. Next hourly ff10 files were produced in EMF using the imported profiles. MDE in conjunction with UMD completed this work.

It should be noted that EPA did undertake an approach to temporalizing some non-CAMD EGUs as well in the 2011 v. 6.2 platform using an average fuel-specific season-to-month factors for each of the 64 IPM regions ((Eyth and Vukovich 2015)). OTC decided our approach was an improvement because it contained a more expansive list of sources that should be temporalized that was confirmed by individual states.

Table 4‑1: Change in emission on selected episode days in July 2011 as the result of Small EGU temporalization

|  |  |  |  |
| --- | --- | --- | --- |
|  | July 20 | July 21 | July 22 |
| MANE-VU | 25 | 41 | 48 |
| LADCO | 211 | 230 | 186 |
| SESARM | 20 | 23 | 19 |
| CenSARA | 83 | 42 | 38 |

Figure 4‑1: Comparison of temporalization of SMOKE defaults, MANE-VU gas temporal profile, and operational data from a typical gas fired Small EGU in MD

## SMOKE Processed Emission Results

In order to quality assure the outputs from SMOKE were properly distributed geographically and develop a better understanding of the geographical and temporalization of emissions we looked at daily emissions on a typical summer day (June 24, 2011) and during an ozone event (July 22, 2011). We looked at NOX, VOC (with and without biogenic emissions) and SO2 gridded emissions. Urban areas, interstates in rural areas, and shipping lanes are clearly distinguishable in the maps of NOX emissions (Figure 4‑2). There are minor differences at this scale on a peak day where one can notice increases in some grid cells during the ozone event (Figure 4‑3). On a typical summer day, VOC emissions are higher as one looks further south which is expected given the greater biogenic emissions found in the south (Figure 4‑4). It is quite noticeable how much VOC emissions increase on an ozone conducive day throughout the modeling domain (Figure 4‑5). When biogenic emissions are removed from the mapping there is little difference between a typical summer day and an ozone event, but one can clearly distinguish urban cores where the majority of anthropogenic VOCs are produced (Figure 4‑6 and Figure 4‑7). One can see the importance of point sources in terms of SO2 emissions and very minor increases throughout the modeling domain during an ozone event (Figure 4‑8 and Figure 4‑9).

Additionally, summary tables of emissions by state, sector, and pollutant were outputted from SMOKE processing. These results are aggregated for the 2011 Alpha 2 inventory in Table 4‑2 and the 2011 Beta inventory in Table 1‑3.

|  |  |
| --- | --- |
| Figure 4‑2: MARAMA Alpha 2 NOX SMOKE Gridded Emissions (June 24, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110624_NOx.jpg | Figure 4‑3: MARAMA Alpha 2 NOX SMOKE Gridded Emissions (July 22, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110722_NOx.jpg |
| Figure 4‑4: MARAMA Alpha 2 VOC All SMOKE Gridded Emissions (June 24, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110624_VOC.jpg | Figure 4‑5: MARAMA Alpha 2 VOC All SMOKE Gridded Emissions (July 22, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110722_VOC.jpg |
| Figure 4‑6: MARAMA Alpha 2 VOC Anthropogenic SMOKE Gridded Emissions (June 24, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110624_VOC_noBIO.jpg | Figure 4‑7: MARAMA Alpha 2 VOC Anthropogenic SMOKE Gridded Emissions (July 22, 2011)  D:\Dropbox\Modeling TSD\MARAMA_A2_20110722_VOC_noBIO.jpg |
| Figure 4‑8: MARAMA Alpha 2 SO2 SMOKE Gridded Emissions (June 24, 2011) | Figure 4‑9: MARAMA Alpha 2 SO2 SMOKE Gridded Emissions (July 22, 2011) |

Table 4‑2: 2011 base case Alpha 2 emissions by pollutant and RPO for aggregated sectors

|  | ERTAC EGU | Non-EGU Point & Small EGU | Nonroad (including M/A/R) | Onroad | Area (including Refueling & RWC) | Oil/Gas | Other (including biogenic) | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NOX | | | | | | | | |
| MANE-VU | 206,647 | 158,385 | 346,366 | 699,944 | 195,502 | 53,407 | 1,018 | 1,661,269 |
| LADCO | 425,419 | 303,668 | 492,498 | 1,064,832 | 181,370 | 85,986 | 12,458 | 2,566,230 |
| SESARM | 415,026 | 283,147 | 435,277 | 1,245,114 | 109,193 | 151,801 | 77,295 | 2,716,854 |
| CENSARA | 476,036 | 325,158 | 711,395 | 1,150,395 | 143,345 | 626,084 | 116,659 | 3,549,072 |
| Canada |  | 159,482 | 218,823 | 249,114 | 59,134 |  |  | 686,553 |
| US EEZ |  |  | 517,740 |  |  |  |  | 517,740 |
| International |  |  | 9,170 |  |  |  |  | 9,170 |
| NOX Total | 1,523,128 | 1,229,840 | 2,731,268 | 4,409,399 | 688,544 | 917,278 | 207,430 | 11,706,887 |
| VOC | | | | | | | | |
| MANE-VU | 2,482 | 53,690 | 366,461 | 356,969 | 678,462 | 29,028 | 21,238 | 1,508,331 |
| LADCO | 7,663 | 169,572 | 469,687 | 538,026 | 786,881 | 85,188 | 227,782 | 2,284,799 |
| SESARM | 9,218 | 234,252 | 367,733 | 586,331 | 790,334 | 144,742 | 496,938 | 2,629,547 |
| CENSARA | 11,975 | 209,440 | 269,531 | 497,121 | 875,210 | 1,520,510 | 1,635,856 | 5,019,642 |
| Canada |  | 1,457 | 157,565 | 117,735 | 532,666 |  |  | 809,423 |
| US EEZ |  |  | 14,792 |  |  |  |  | 14,792 |
| International |  |  | 330 |  |  |  |  | 330 |
| VOC Total | 31,339 | 668,411 | 1,646,099 | 2,096,182 | 3,663,553 | 1,779,468 | 2,381,813 | 12,266,865 |
| SO2 | | | | | | | | |
| MANE-VU | 462,603 | 108,742 | 25,481 | 5,069 | 135,409 | 2,103 | 612 | 740,020 |
| LADCO | 1,502,618 | 357,280 | 6,439 | 5,475 | 25,550 | 1,444 | 7,039 | 1,905,845 |
| SESARM | 1,079,218 | 260,522 | 11,832 | 6,040 | 62,121 | 22,615 | 28,139 | 1,470,487 |
| CENSARA | 1,087,853 | 324,686 | 23,579 | 5,594 | 44,155 | 21,060 | 58,760 | 1,565,688 |
| Canada |  | 436,584 | 36,343 | 1,380 | 36,964 |  |  | 511,271 |
| US EEZ |  |  | 50,654 |  |  |  |  | 50,654 |
| International |  |  | 5,775 |  |  |  |  | 5,775 |
| SO2 Total | 4,132,292 | 1,487,814 | 160,102 | 23,559 | 304,198 | 47,222 | 94,551 | 6,249,738 |
| PM2.5 | | | | | | | | |
| MANE-VU | 17,952 | 28,839 | 27,585 | 26,839 | 161,721 | 1,676 | 27,277 | 291,889 |
| LADCO | 67,914 | 69,045 | 37,267 | 38,503 | 199,911 | 1,547 | 221,987 | 636,174 |
| SESARM | 67,176 | 79,204 | 31,430 | 38,457 | 183,154 | 3,442 | 384,047 | 786,909 |
| CENSARA | 77,558 | 84,589 | 40,187 | 38,085 | 123,174 | 15,966 | 1,026,201 | 1,405,760 |
| Canada |  | 25,777 | 16,908 | 8,934 | 105,607 |  | 323,474 | 480,700 |
| US |  |  | 15,722 |  |  |  |  | 15,722 |
| International |  |  | 716 |  |  |  |  | 716 |
| PM2.5 Total | 230,599 | 287,454 | 169,815 | 150,818 | 773,568 | 22,631 | 1,982,986 | 3,617,870 |
| NH3 | | | | | | | | |
| MANE-VU | 2,925 | 4,974 | 380 | 18,106 | 14,580 | 14 | 165,666 | 206,644 |
| LADCO | - | 8,923 | 523 | 20,419 | 22,967 | 58 | 680,237 | 733,127 |
| SESARM | 444 | 16,497 | 429 | 24,401 | 8,356 | 6 | 579,545 | 629,678 |
| CENSARA | - | 22,208 | 1,121 | 19,701 | 17,123 | 52 | 1,366,962 | 1,427,166 |
| Canada |  | 4,983 | 250 | 15,303 | 3,091 |  | 183,853 | 207,480 |
| US EEZ |  |  | - |  |  |  |  | - |
| International |  |  | - |  |  |  |  | - |
| NH3 Total | 3,369 | 57,585 | 2,702 | 97,929 | 66,117 | 129 | 2,976,263 | 3,204,094 |
| CO | | | | | | | | |
| MANE-VU | 41,340 | 235,436 | 2,769,526 | 3,498,866 | 892,083 | 40,947 | 90,739 | 7,568,938 |
| LADCO | 153,424 | 770,725 | 2,885,340 | 5,234,025 | 1,198,037 | 53,623 | 966,320 | 11,261,494 |
| SESARM | 166,730 | 489,203 | 2,503,935 | 5,616,897 | 1,018,104 | 110,496 | 2,814,505 | 12,719,870 |
| CENSARA | 201,076 | 412,960 | 1,820,066 | 4,791,071 | 783,366 | 474,018 | 6,907,096 | 15,389,654 |
| Canada |  | 585,732 | 1,889,841 | 2,204,940 | 648,333 |  |  | 5,328,846 |
| US EEZ |  |  | 83,618 |  |  |  |  | 83,618 |
| International |  |  | 778 |  |  |  |  | 778 |
| CO Total | 562,570 | 2,494,057 | 11,953,104 | 21,345,799 | 4,539,922 | 679,085 | 10,778,661 | 52,353,197 |

Table 4‑3: 2011 base case Beta emissions by pollutant and RPO for aggregated sectors

|  | ERTAC EGU | Non-EGU Point & Small EGU | Nonroad (including M/A/R) | Onroad | Area (including Refueling & RWC) | Oil/Gas | Other (including biogenic) | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NOX | | | | | | | | |
| MANE-VU | 206,457 | 155,892 | 346,258 | 717,012 | 195,137 | 53,407 | 1,018 | 1,675,179 |
| LADCO | 408,335 | 302,954 | 492,498 | 981,420 | 180,284 | 85,986 | 12,458 | 2,463,934 |
| SESARM | 415,015 | 280,126 | 435,277 | 1,168,980 | 102,231 | 152,364 | 77,295 | 2,631,289 |
| CENSARA | 491,941 | 323,997 | 805,686 | 284,258 | 127,522 | 626,557 | 116,659 | 2,776,620 |
| Canada |  | 159,482 | 218,823 | 249,114 | 59,134 |  |  | 686,553 |
| US EEZ |  |  | 517,740 |  |  |  |  | 517,740 |
| International |  |  | 9,170 |  |  |  |  | 9,170 |
| NOX Total | 1,521,748 | 1,222,451 | 2,825,450 | 3,400,784 | 664,307 | 918,314 | 207,430 | 10,760,484 |
| VOC | | | | | | | | |
| MANE-VU | 2,477 | 53,046 | 366,247 | 362,357 | 701,998 | 29,028 | 21,238 | 1,536,392 |
| LADCO | 7,075 | 168,380 | 469,687 | 480,674 | 822,762 | 85,188 | 227,782 | 2,261,546 |
| SESARM | 8,008 | 233,565 | 367,733 | 554,022 | 825,772 | 144,792 | 496,938 | 2,630,829 |
| CENSARA | 10,069 | 208,963 | 327,909 | 109,269 | 879,881 | 1,520,538 | 1,635,856 | 4,692,484 |
| Canada |  | 1,457 | 157,565 | 117,735 | 532,666 |  |  | 809,423 |
| US EEZ |  |  | 14,792 |  |  |  |  | 14,792 |
| International |  |  | 1 |  |  |  |  | 1 |
| VOC Total | 27,628 | 665,412 | 1,703,934 | 1,624,056 | 3,763,079 | 1,779,546 | 2,381,813 | 11,945,467 |
| SO2 | | | | | | | | |
| MANE-VU | 462,551 | 108,301 | 25,481 | 4,793 | 135,936 | 2,102 | 612 | 739,777 |
| LADCO | 1,500,310 | 357,264 | 6,439 | 4,785 | 25,051 | 1,444 | 7,039 | 1,902,332 |
| SESARM | 1,079,181 | 255,343 | 11,832 | 5,443 | 54,572 | 27,673 | 28,139 | 1,462,182 |
| CENSARA | 1,088,313 | 324,666 | 23,801 | 1,071 | 38,551 | 21,060 | 58,760 | 1,556,222 |
| Canada |  | 436,584 | 36,343 | 1,380 | 36,964 |  |  | 511,271 |
| US EEZ |  |  | 50,654 |  |  |  |  | 50,654 |
| International |  |  | 5,775 |  |  |  |  | 5,775 |
| SO2 Total | 4,130,355 | 1,482,158 | 160,324 | 17,473 | 291,074 | 52,279 | 94,551 | 6,228,214 |
| PM2.5 | | | | | | | | |
| MANE-VU | 17,987 | 28,669 | 27,582 | 27,133 | 159,622 | 1,676 | 27,277 | 289,946 |
| LADCO | 51,636 | 68,899 | 37,267 | 33,650 | 197,691 | 1,547 | 221,987 | 612,677 |
| SESARM | 49,543 | 78,805 | 31,430 | 35,586 | 168,966 | 3,452 | 382,291 | 750,073 |
| CENSARA | 45,622 | 84,418 | 48,640 | 10,236 | 88,011 | 15,977 | 1,026,201 | 1,319,104 |
| Canada |  | 25,777 | 16,908 | 8,934 | 105,607 |  | 323,474 | 480,700 |
| US |  |  | 15,722 |  |  |  |  | 15,722 |
| International |  |  | 716 |  |  |  |  | 716 |
| PM2.5 Total | 164,788 | 286,568 | 178,265 | 115,539 | 719,897 | 22,653 | 1,981,229 | 3,468,939 |
| NH3 | | | | | | | | |
| MANE-VU | 2,923 | 4,950 | 380 | 18,094 | 14,555 | 14 | 165,666 | 206,582 |
| LADCO | 998 | 8,922 | 523 | 19,137 | 22,967 | 58 | 680,237 | 732,842 |
| SESARM | 3,363 | 16,357 | 429 | 23,066 | 8,345 | 6 | 579,545 | 631,110 |
| CENSARA | 6,488 | 22,207 | 1,223 | 4,131 | 14,549 | 52 | 1,389,837 | 1,438,486 |
| Canada |  | 4,983 | 250 | 15,303 | 3,091 |  | 183,853 | 207,480 |
| US EEZ |  |  | 216 |  |  |  |  | 216 |
| International |  |  |  |  |  |  |  |  |
| NH3 Total | 13,772 | 57,419 | 3,020 | 79,732 | 63,507 | 129 | 2,999,138 | 3,216,716 |
| CO | | | | | | | | |
| MANE-VU | 41,310 | 234,702 | 2,768,157 | 3,495,020 | 881,048 | 40,947 | 90,739 | 7,551,923 |
| LADCO | 88,937 | 769,979 | 2,885,340 | 4,684,400 | 1,174,185 | 53,623 | 966,320 | 10,622,785 |
| SESARM | 104,722 | 487,080 | 2,503,935 | 5,271,800 | 876,198 | 110,674 | 2,814,505 | 12,168,913 |
| CENSARA | 199,495 | 412,002 | 2,279,704 | 985,507 | 434,457 | 474,162 | 6,907,096 | 11,692,424 |
| Canada |  | 585,732 | 1,889,841 | 2,204,940 | 648,333 |  |  | 5,328,846 |
| US EEZ |  |  | 83,618 |  |  |  |  | 83,618 |
| International |  |  | 778 |  |  |  |  | 778 |
| CO Total | 434,464 | 2,489,495 | 12,411,373 | 16,641,667 | 4,014,221 | 679,407 | 10,778,661 | 47,449,287 |

## References

Abt Associates 2014, *SPECIATE Version 4.4 Database Development Documentation*, accessed from <https://www3.epa.gov/ttn/chief/software/speciate/speciate\_version4\_4\_finalreport.pdf>.

Adelman, Z 2015, *Emissions Modeling Platform Spatial Surrogate Documentation*, accessed from <ftp://ftp.epa.gov/EmisInventory/2011v6/v2platform/spatial\_surrogates/US\_SpatialSurrogate\_Documentation\_v070115.pdf>.

Eyth, A and Vukovich, J 2015, ‘Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform’, accessed March 18, 2016, from <http://www3.epa.gov/ttn/chief/emch/2011v6/2011v6\_2\_2017\_2025\_EmisMod\_TSD\_aug2015.pdf>.

MARAMA ‘Documentation of ERTAC EGU CONUS 2.3’, accessed May 2, 2016, from <http://marama.org/images/stories/documents/Documentation\_of\_ERTAC\_EGU\_CONUS\_2.3.pdf>.

# 8-hour Ozone/Regional Haze Modeling Using the CMAQ system

## Air Quality Modeling Domain

The modeling domain used in this application represented a subset of the EPA continental-modeling domain that covered the entire 48-state region with emphasis on the OTR. The OTC/MANE-VU modeling domain at 12 km horizontal mesh is displayed in Figure 2‑1. The 12 km domain used in this analysis includes the eastern US with a 172X172 mesh in the horizontal and 35 vertical layers, the same as WRF setup from surface up to 50 mb.

*Photochemical Modeling -- CMAQ*

The CMAQ (version 5.0.2) was used in this study. Photochemical modeling was performed with the CCTM software that is part of the CMAQ modeling package. Version 5.0.2 of this modeling software was obtained from the CMAS modeling center (<http://www.cmascenter.org>). Module options are listed in Table 2.

Table 2: Module options used in compiling the CCTM executable

|  |  |  |
| --- | --- | --- |
| Horizontal advection: yamo | Vertical advection: wrf | Horizontal diffusion: multiscale |
| Vertical diffusion: ACM2 | Gas phase chemical mechanism: CB05 | Biogenic Emission: BEIS |
| Chemical solver: EBI | Aerosol module: aero6 |  |

The following files are saved as running CMAQ:

* Layer 1 hourly-average concentration file (ACONC) which contains whole 154 species
* Dry deposition file (DRYDEP)
* Wet deposition file (WETDEP1)
* Aerosol/visibility file

### Initial/Boundary Conditions/Initial Conditions

The boundary conditions for the 12 km grid were developed from a 2.5 x 2.5 degree GEOS-Chem (version 8) global simulation produced by EPA for use in the 2011 modeling platform (Eyth and Vukovich 2015, p.2). To address the transport of the pollutants through the boundaries, the GEOS-Chem data were used to develop the initial and boundary condition for the 2011 OTC modeling platform. The CMAQ simulations used a 15-day ramp-up period to wash out the effect of the initial fields.

## References

Eyth, A and Vukovich, J 2015, ‘Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform’, accessed March 18, 2016, from <http://www3.epa.gov/ttn/chief/emch/2011v6/2011v6\_2\_2017\_2025\_EmisMod\_TSD\_aug2015.pdf>.

# CMAQ Model Performance and Assessment of 8-hour Ozone/Regional Haze Modeling

## Air Quality Model Evaluation and Assessment

One of the tasks required as part of demonstrating attainment for the 8-hr ozone NAAQS is the evaluation and assessment of the air quality modeling system used to predict future air quality over the region of interest. As part of the attainment demonstration, the SMOKE/CMAQ modeling system was applied to simulate the pollutant concentration fields for the base year 2011 emissions with the corresponding meteorological information. The modeling databases for meteorology using WRF, the emissions using SMOKE, and application of CMAQ provide simulated pollutant fields that are compared to measurements to establish credibility of the modeling system. In the following section a comparison between the measured and predicted concentrations is performed and the results presented, demonstrating the overall utility of the modeling system in this application.

The results presented here should serve as an illustration of the evaluation and assessment performed on the base 2011 CMAQ simulation. Additional information can be made available by request from the New York State Department of Environmental Conservation.

### Simulations

Base case simulations were run using each of the 2011 base case inventories (Alpha, Alpha 2, and Beta). Meteorology, chemistry, boundary conditions, etc. were all held consistent in the base case simulations.

### Summary of Measured Data

The ambient air quality data for both gaseous and aerosol species for the simulation period were obtained from EPA AQS for ozone, AQS for PM2.5 mass, CSN and IMPROVE for PM2.5 speciation, and DISCOVER-AQ. Measured data from all sites within the modeling domain are included here. The model-based data were obtained at the grid-cell corresponding to the monitor location and no interpolation was performed.

#### Ozone

Hourly ozone is measured at a large number of State, Local, and National Air Monitoring Stations (SLAMS/NAMS) across the US on a routine basis, and the data from 226 OTR and 427 non-OTR sites were extracted from the AQS database (<https://aqs.epa.gov/api>).

#### Fine Particulate Matter (PM2.5)

Federal Reference Method (FRM) PM2.5 mass data collected routinely at SLAMS/NAMS sites across the US and the data from 745 sites across the modeling domain were extracted from AQS.

#### Fine Particulate Speciation

The 24-hour average PM2.5 and fine particulate speciation (sulfate (SO4), nitrate (NO3), elemental carbon (EC), organic carbon/organic mass (OC/OM), and soil/crustal matter) from Class I areas across the US collected every 3rd day were obtained from the IMPROVE web site (<http://vista.cira.colostate.edu/IMPROVE>). Additionally, CSN speciated data was downloaded from the AQS system (<https://www3.epa.gov/ttnamti1/speciepg.html>). Data from 58 IMPROVE sites and 127 CSN sites in the modeling domain were used in this analysis.

#### DISCOVER-AQ

Two research airplanes (a NASA P-3B and a UC-12) flew 14 days, sampling in coordination with ground sites, monitoring air quality in the Baltimore-Washington corridor in 2011. The NASA P-3B, spiraled over six ground stations in Maryland and the UC-12 used a LiDAR to observe "profiles" of particulate pollution in the atmosphere. This data resource was predominantly used to inform a qualitative assessment of vertical ozone profiles.

### Evaluation of CMAQ predictions

The following sections provide model evaluation information for the above referenced pollutants over the 12-km modeling domain. Details on the formulas used in this section can be seen in

## Daily Maximum 8-hour Ozone Concentration

Model evaluation statistics, based on daily maximum 8-hour average ozone levels on days having: (1) at least 10 valid observations, and (2) an observed daily maximum ozone concentration of at least 60 ppb, are presented here for all sites across the modeling domain. The data covered the period from April 15 through October 30. Modeling results were computed using the Alpha2 platform. There are 226 OTR and 427 non-OTR SLAMS/NAMS sites. The use of the 60 ppb threshold focuses on model performance evaluation on the highest ozone days.

Figure 6‑1 and Figure 6‑2 display daily averages of observed and predicted daily maximum 8-hour ozone concentrations averaged across all SLAMS/NAMS sites in the OTR and outside of the OTR, respectively. These averages were computed for each day and considered all sites, not just ones that met the threshold. The dashed black line denotes 1:1, colored lines denote linear regression lines, and the green line denotes observed daily maximum ozone ≥60 ppb.

The overall tendency of CMAQ is to over-predict daily maximum ozone – 63% of CMAQ values at OTR sites are higher than observed (Figure 6‑1); 60% of CMAQ values at non-OTR sites are higher than observed (Figure 6‑1). However, at observed daily maximum ozone concentrations >60 ppb, CMAQ tends to under-predict ozone – on such days 68% of CMAQ values at OTR sites are lower than observed, and 77% of CMAQ values at non-OTR sites are lower than observed. The under-prediction in the OTR is less when solely looking at the 1st high maximum and the 4th high maximum (Figure 6‑3). It is also less in the region outside of OTR for the 1st high maximum and the 4th high maximum (Figure 6‑3).

|  |  |
| --- | --- |
| Figure 6‑1: Comparison of daily maximum 8-hour ozone concentrations at OTR sites | Figure 6‑2: Comparison of daily maximum 8-hour ozone concentrations at non-OTR sites |

|  |
| --- |
| Figure 6‑3: Comparison of 1st highest maximum (left) and 4th highest maximum (right) 8-hour ozone concentrations at OTR sites |
| Figure 6‑4: Comparison of 1st highest maximum (left) and 4th highest maximum (right) 8-hour ozone concentrations at non-OTR sites |

CMAQ captured the observed temporal variation well, and CMAQ showed under-prediction early in the ozone season matched observed results well after July. CMAQ captured the observed temporal variation well with both Alpha 2 and Beta emissions with the Beta emissions yielding comparable 8-hour ozone results to Alpha2 emissions though in a few cases Beta results were slightly higher (Figure 6‑5 and Figure 6‑6).

Figure 6‑5: Observed versus predicted 2011 ozone concentration (ppb; mean ± 1 standard deviation) using Alpha 2 Inventory in the OTR where daily max was greater than 40 ppb



Figure 6‑6: Observed versus predicted 2011 ozone concentration (ppb; mean ± 1 standard deviation) using Beta Inventory in the OTR where daily max was greater than 40 ppb



Geographically, the MFE is higher in New England than in the Mid-Atlantic OTR and much higher outside of the region, in particular in LADCO (Figure 6‑7). The Beta emission showed a reducing MFE in comparing to Alpha2 emissions, especially within the inner-OTR region (Figure 6‑8). MFB are small and close to zero bias in the northeast region while in the LADCO region MFB is more negative indicating the CMAQ’s underprediction which may be caused by the boundary conditions (Figure 6‑9). The Beta emissions also showed improvement in correcting the bias prediction, especially in the inner-OTR region (Figure 6‑10). There are several monitors on the Atlantic coast, in particular along the Long Island Sound, that have a positive MFB, and the general under-prediction in the OTR is more prominent in southern New England. Outside of the region MFB shows the most under-prediction in LADCO and CENSARA states. MAGE is most prominent along the I-95 corridor and along Lake Erie, though the highest MAGE is seen at Mt Washington in New Hampshire (Figure 6‑11). Similar to MFE, the Beta emissions also indicated the improvement in reducing error by CMAQ predictions (Figure 6‑12). MAGE is also higher outside of the OTR, in particular in the LADCO and CENSARA states. One potential reason for higher MFE and MAGE in the LADCO and CENSARA regions may be boundary conditions.

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| Figure 6‑7: MFE in daily max 8-hr ozone Alpha 2, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites)    ● <10%  ● 10-15%  ● 15-20%  ● 20-25%  ● 25-30%  ● 30-35%  ● >35% | Figure 6‑8: MFE in daily max 8-hr ozone Beta, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites)    ● <10%  ● 10-15%  ● 15-20%  ● 20-25%  ● 25-30%  ● 30-35%  ● >35% |

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| Figure 6‑9: MFB in daily max 8-hr ozone Alpha 2, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites)    ● <-35%  ● -35 to -25%  ● -25 to -15%  ● -15 to -5%  ● -5 to 5%  ● 5 to 15%  ● >15%  ● <-35%  ● -35 to -25%  ● -25 to -15%  ● -15 to -5%  ● -5 to 5%  ● 5 to 15%  ● >15% | Figure 6‑10: MFB in daily max 8-hr ozone Beta, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites) |

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| Figure 6‑11: MAGE in daily max 8-hr ozone Alpha 2, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites) | Figure 6‑12: MAGE in daily max 8-hr ozone Beta, 60 ppb threshold, Apr 15-Oct 30; only monitors with 10 days greater than 60 ppb threshold (183 of 226 OTR sites; 372 of 427 non-OTR-sites)    ● <4 ppb  ● 4-7 ppb  ● 7-10 ppb  ● 10-13 ppb  ● 13-16 ppb  ● 16-19 ppb  ● >19 ppb  ● <4 ppb  ● 4-7 ppb  ● 7-10 ppb  ● 10-13 ppb  ● 13-16 ppb  ● 16-19 ppb  ● >19 ppb |

Evaluation of Ozone Aloft

On June 8-9 and July 21-23, 2011 ozone sondes were launched at Edgewood, MD (Penn State University), Beltsville, MD (Howard University), and Egbert, ON. UMD flew aircraft spirals over Churchville, MD (0W3), Cumberland, MD (CBE), Easton, MD (ESN), Frederick, MD (FDK), Massey, MD (MD1), Luray, VA (W45), and Winchester, VA (OKV). The NASA P3 from the DISCOVER-AQ program flew spirals over Beltsville, MD, Padonia, MD, Fairhill, MD, Aldino, MD, Edgewood, MD, and Essex, MD.

Averages and standard deviations for the measurements were calculated for each elevation that corresponded to the height of a layer used in CMAQ modeled runs. Grid cells that corresponded temporally and geographically to the measurements from the location of the ozone measurement (e.g., sonde launch site) from DISCOVER-AQ that occurred at the same time as the measurement were used as the prediction with which the observed data would be compared.

Predictions above 3 km were generally accurate when compared to the morning profile, but under-predicted, especially above 8 km (Figure 6‑13). Between 0.5 km and 3 km CMAQ under-predicted observed concentrations by around 5 ppb during both the morning and evening hours. We found that CMAQ predictions were fairly accurate below approximately 0.5 km. The results are similar with CMAQ run with both inline point sources (Run 1) and SMOKE processed point sources (Run 2).

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| Figure 6‑13: Observed ozone concentration (ppb) layer average and standard deviation compared to CMAQ layers up to 10 km | Figure 6‑14: Observed ozone concentration (ppb) layer average and standard deviation compared to CMAQ layers up to 2 km |

## Evaluation of Fine Particulate Matter

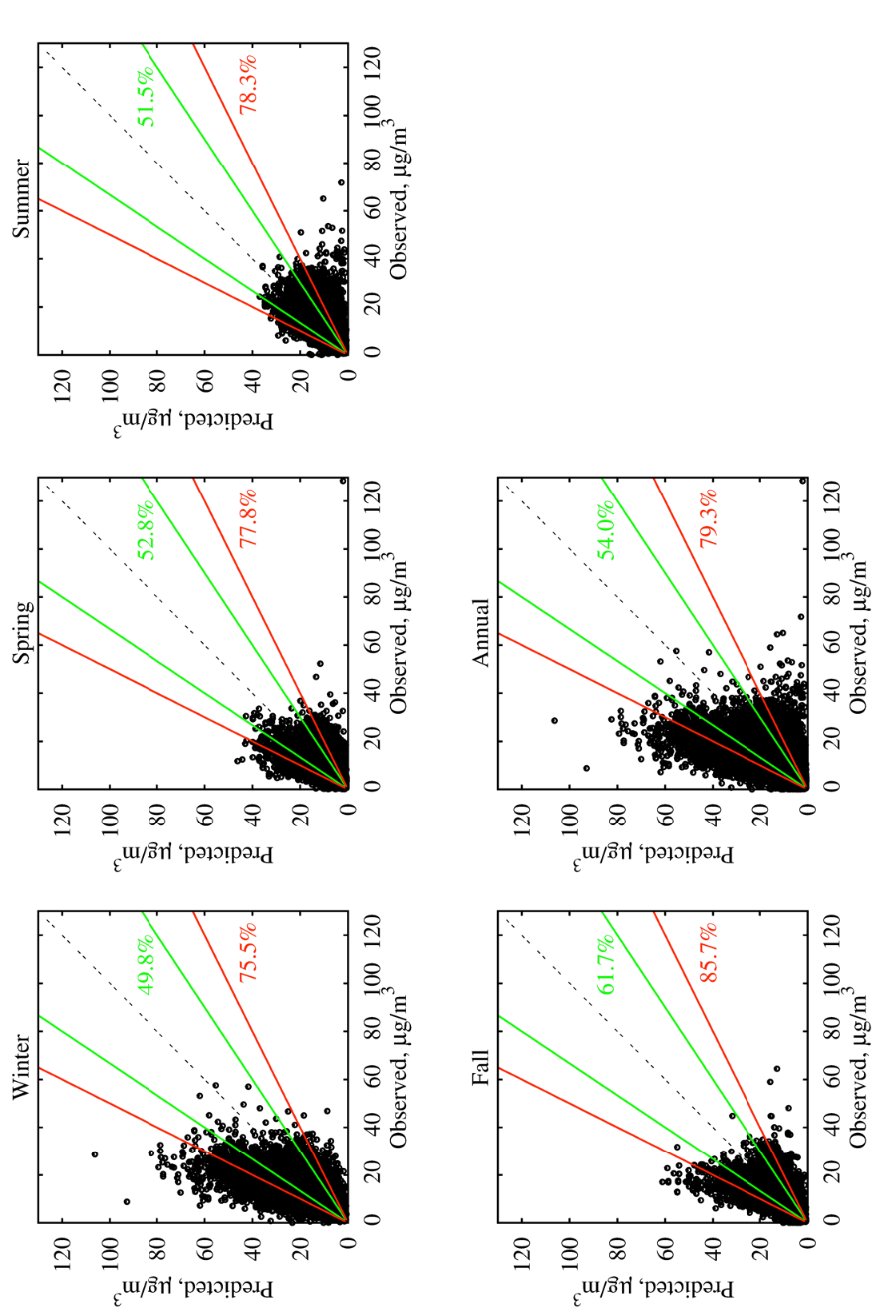
Composite daily average predicted and observed concentrations of PM2.5 FRM mass were compared to determine the validity of the modeling results prior to evaluating individual species needed for haze model validation. Our model performance goals of MFB ≤ ±30% and MFE ≤50% as well as model performance criteria of MFB ≤±60% and MFE ≤75% were set by the OTC modeling committee. These performance goals and criteria were also used by other RPOs when evaluating PM2.5 model performance (Brewer et al. 2007). CMAQ met the MFB ±30% goal on 63% of days, MFB ±60%performance criteria nearly every day. CMAQ met the MFE 50% goal on 82% of days, MFE 75%performance criteria every day as seen in Table 6‑1. MAGE was also found to be acceptably low on 64% of days.

Table 6‑1: Summary statistics for predicted PM2.5 FRM mass

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|  | **All days** (**n=365)** | **1-in-3-day (n=121)** |
| MFB ≤ ±30% | 230 (63.0%) | 79 (65.3%) |
| MFB ≤ ±60% | 360 (98.6%) | 121 (100%) |
| MFE ≤ 50% | 300 (82.2%) | 98 (81.1%) |
| MFE ≤ 75% | 365 (100%) | 121 (100%) |
| MAGE ≤ 5 mg/m3 | 235 (64.4%) | 80 (66.1%) |

Annually, PM2.5 is over predicted, with the great over-prediction occurring during the winter months, with the summer months leaning towards a slight under-prediction (Figure 6‑15).

Figure 6‑15: Comparison of daily observed and predicted PM2.5 FRM mass, annual and by season with 1:1 (dashed), 1:1.5 (green) and 1:2 (red) lines for Winter (D/J/F), Spring (M/A/M), Summer (J/J/A), Fall (S/O/N), and Annually.



When looking temporally, one finds the greatest over-prediction during the winter months and slight under-prediction during the summer (Figure 6‑16, Figure 6‑17) and the result holds for those monitors on the 1 in 3 day schedule. MFE is high throughout the year with the greatest peaks in the summer time (Figure 6‑18, Figure 6‑19). MFB is positive in the winter time which is indicative of the under-prediction and negative during the summer time which is indicative of over-prediction (Figure 6‑20, Figure 6‑21). MAGE is greatest during the winter and summer (Figure 6‑22, Figure 6‑23).

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| Figure 6‑16: Observed and predicted PM2.5 FRM mass, all days |
| Figure 6‑17: Observed and predicted PM2.5 FRM mass, 1-in-3 day schedule |

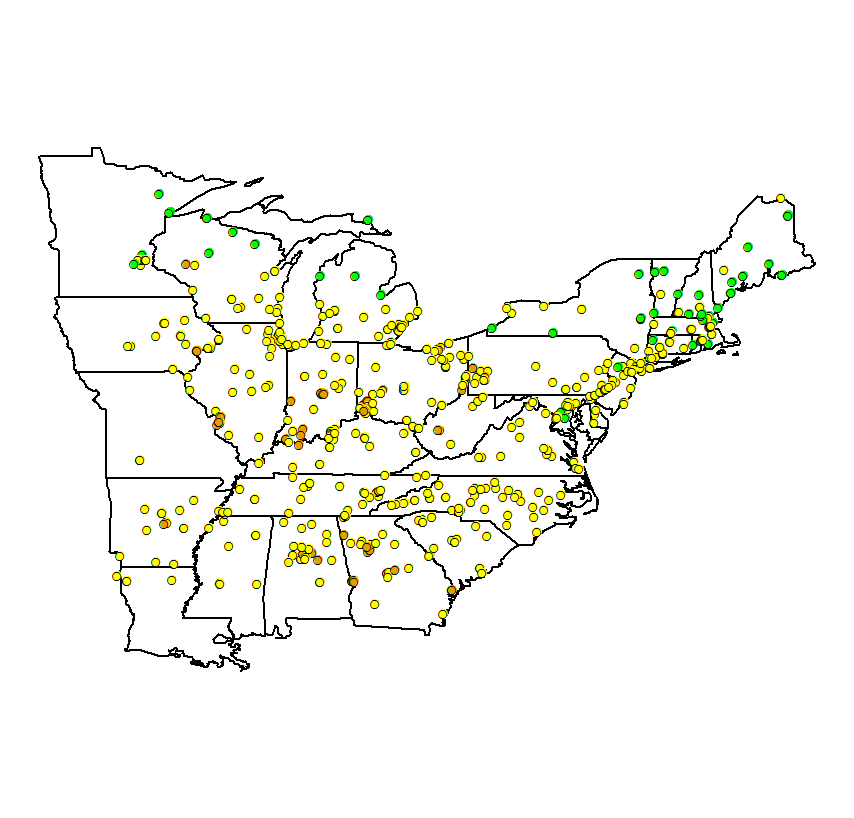
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| Figure 6‑18: MFE PM2.5 FRM mass, all days |
| Figure 6‑19: MFE PM2.5 FRM mass, 1-in-3 day schedule |

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| Figure 6‑20: MFB PM2.5 FRM mass, all days |
| Figure 6‑21: MFB PM2.5 FRM mass, 1-in-3 day schedule |

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| Figure 6‑22: MAGE PM2.5 FRM mass, all days |
| Figure 6‑23: MAGE PM2.5 FRM mass, 1-in-3 day schedule |

As a first step in geographic evaluation we looked at the differences between observed (Figure 6‑24) and predicted values (Figure 6‑25) and one can see that some areas of MANE-VU are achieving different results annually. The greatest MFE for PM2.5 in MANE-VU occurs in northern New England and decreases towards the southern portion of MANE-VU, though there are also some higher MFE values along the coast (Figure 6‑26). The same areas in New England are biased towards over-prediction as well, with under-prediction occurring in more populated portions of MANE-VU (Figure 6‑27). MAGE remains fairly consistent geographically (Figure 6‑28).

Figure 6‑24: Observed annual average PM2.5 FRM mass, 2011 (only monitors with ≥10 days of data are shown)



● <4 μg/m3

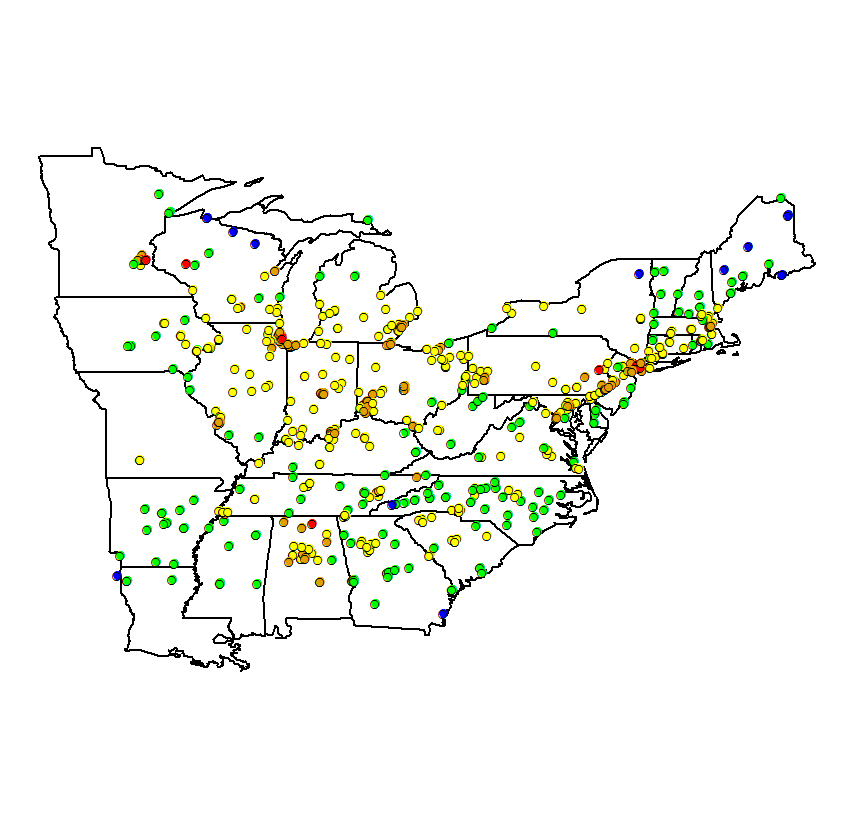
● 4-8 μg/m3

● 8-12 μg/m3

● 12-16 μg/m3

● >16 μg/m3

Figure 6‑25: Predicted annual average PM2.5 FRM mass, 2011 (only monitors with ≥10 days of data are shown)



● <4 μg/m3

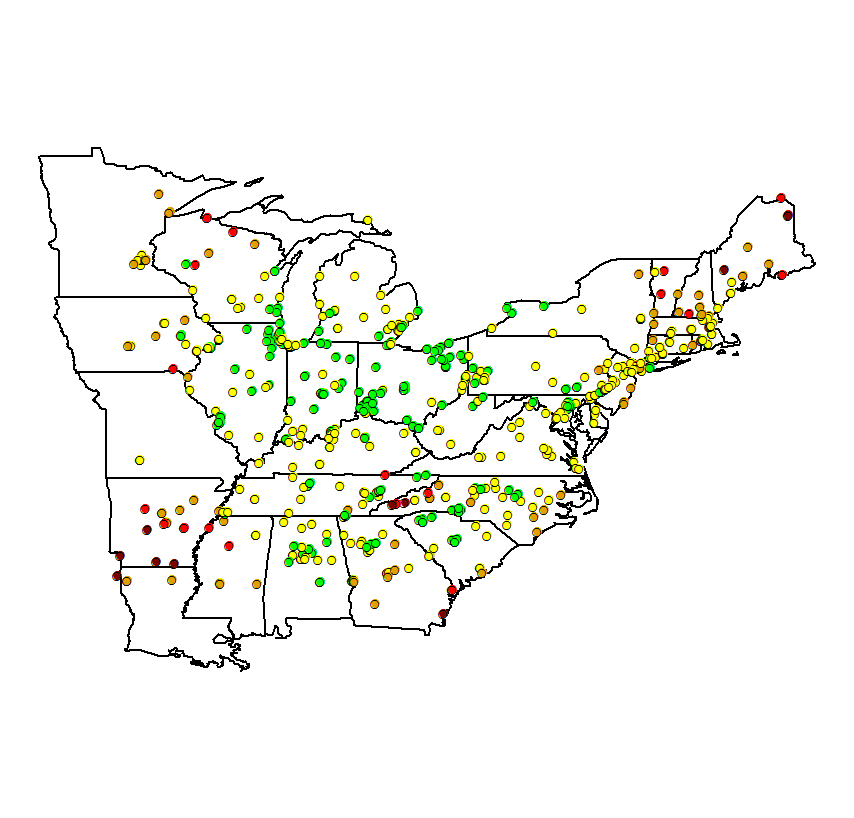
● 4-8 μg/m3

● 8-12 μg/m3

● 12-16 μg/m3

● >16 μg/m3

Figure 6‑26: MFE in PM2.5 FRM mass, 2011 (only monitors with ≥10 days of data are shown)



● <25%

● 25-37.5%

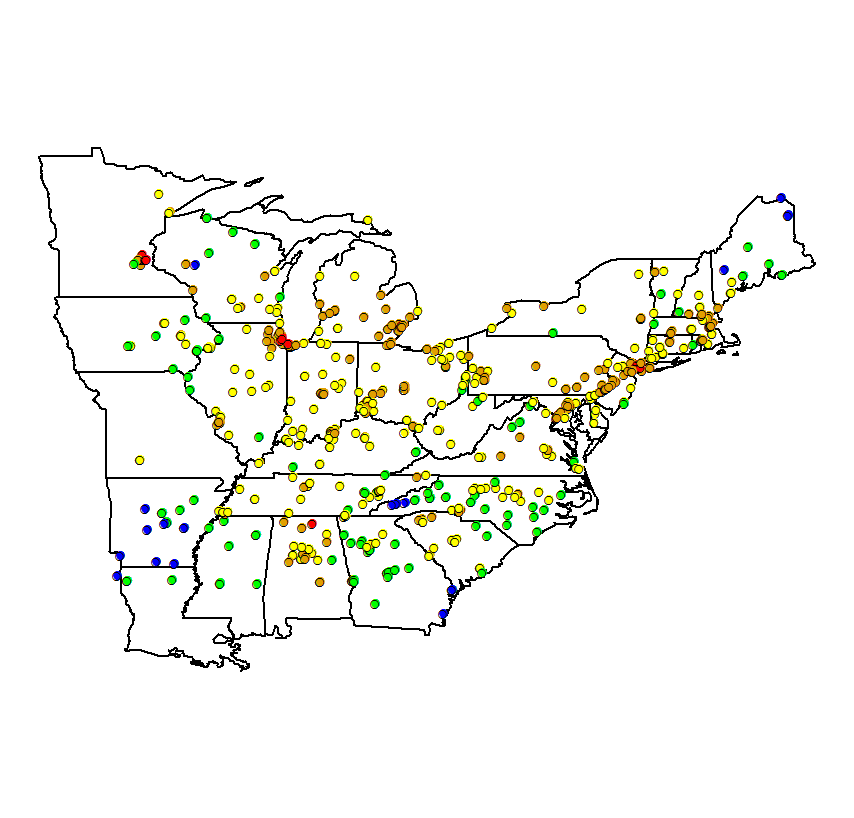
● 37.5-50%

● 50-62.5%

● 62.5-75%

● >75%

Figure 6‑27: MFB in PM2.5 FRM mass, 2011 (only monitors with ≥10 days of data are shown)



● <-60%

● -60 to -30%

● -30 to 0%

● 0 to 30%

● 30 to 60%

● >60%

● <2.5 mg/m3

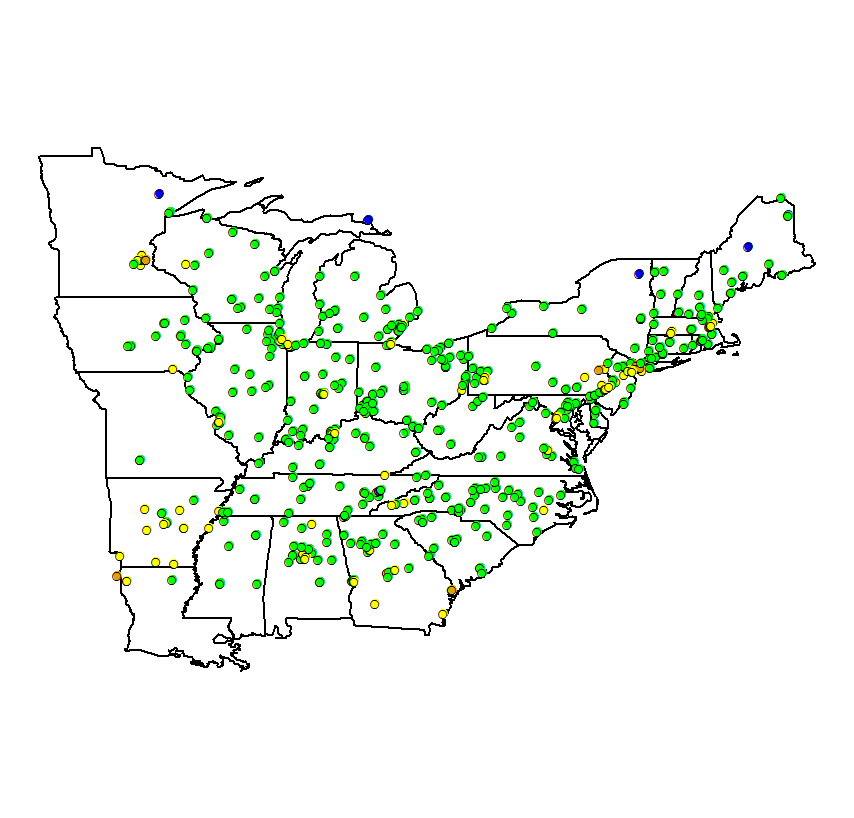
● 2.5-5 mg/m3

● 5-7.5 mg/m3

● 7.5-10 mg/m3

● >10 mg/m3

Figure 6‑28: MAGE in PM2.5 FRM mass, 2011 (only monitors with ≥10 days of data are shown)



● <2.5 μg/m3

● 2.5-5 μg/m3

● 5-7.5 μg/m3

● 7.5-10 μg/m3

● >10 μg/m3

## Evaluation of Visibility

In this section we evaluate the model performance with respect to visibility, in particular of the PM2.5 species used in the IMPROVE algorithm to estimate visibility impairment. Data from 58 IMPROVE sites and 127 CSN sites in the modeling domain were used in this analysis and the data cover the entire 2011 year.

Soil/crustal matter is assumed to consist of oxides of Aluminum (Al), Calcium (CA), Iron (Fe), Silicon (Si), and Titanium (Ti). The IMPROVE OC blanks are assumed to equal zero. Since CMAQ was employed, we used 2.5 m "sharp cutoff" variables as opposed to the sum of I+J modes.

CSN reports EC & OC by TOT and TOR, IMPROVE only by TOR; for this analysis, TOR data from CSN and IMPROVE were combined and CSN TOT data were considered separately. IMPROVE reports blank-corrected OC and CSN does not, so for this analysis, annual average site-specific blank values (generally about 0.2-0.3 μg/m3) were subtracted from the CSN data.

The equations used to calculate RCFM and light extinction are as follows:

Equation 6‑1: Calculation of RCFM

Equation 6‑2: Calculation of extinction from Ammonium Sulfate

Equation 6‑3: Calculation of extinction from Ammonium Nitrate

Equation 6‑4: Calculation of extinction from Elemental Carbon

Equation 6‑5: Calculation of extinction from POM

Equation 6‑6: Calculation of extinction from Soil

Equation 6‑7: Calculation of extinction from Sea Salt

Equation 6‑8: Calculation of extinction from Coarse PM

We found that sulfate was underpredicted consistently throughout the year by 1 μg/m3 with slightly higher over-prediction during summer (Figure 6‑29). Nitrate was over-predicted by small margins during the winter months and very slightly under-predicted during summer (Figure 6‑30). Ammonium was under-predicted throughout most of the year, although there was over-prediction during fall (Figure 6‑31). Elemental carbon was over-predicted at all times of the year compared to TOR observations, though the over-prediction was less during the summer than other times of year (Figure 6‑32). Organic carbon was over-predicted in the winter and under predicted in the summer and neither during the shoulder months compared to TOR observations (Figure 6‑33). Soil was over-predicted throughout the year with the least amount of over-prediction during the spring (Figure 6‑34). Elemental carbon was over-predicted even more when compared to TOT observations than TOR (Figure 6‑35). Organic carbon was over-predicted less in the winter and under-predicted more in the summer compared to TOT observations than TOR (Figure 6‑36). The pattern of over and under-prediction more closely resembles that of organic carbon since the magnitude of organic carbon is much higher than that of elemental carbon (Figure 6‑37).

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| Figure 6‑29: SO4 concentration (observed, CSN and IMPROVE, vs. predicted) |
| Figure 6‑30: NO3 concentration (observed, CSN and IMPROVE, vs. predicted) |
| Figure 6‑31: NH4 concentration (observed, CSN only, vs. predicted) |
| Figure 6‑32: EC (TOR) concentration (observed, CSN and IMPROVE, vs. predicted) |
| Figure 6‑33: OC (TOR) concentration (observed, CSN and IMPROVE, vs. predicted) |
| Figure 6‑34: Soil concentration (observed, CSN and IMPROVE, vs. predicted) |

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| Figure 6‑35: EC (TOR & TOT) concentration (observed, CSN only, vs. predicted) |
| Figure 6‑36: OC (TOR & TOT) concentration (observed, CSN only, vs. predicted) |
| Figure 6‑37: Total Carbon (TOR & TOT) concentration (observed, CSN only, vs. predicted) |

Geographically MFB and MFE for SO4 had the highest magnitude in northern New England (Figure 6‑38 and Figure 6‑39, respectively). MFB for NO3 was lowest in magnitude in northern New England and biased quite low along the I-95 corridor, whereas MFE for NO3 was quite high throughout the region (Figure 6‑40 and Figure 6‑41, respectively). MFB for NH4 often tended to not be too high or low throughout the region and MFE was higher in New England than in the Mid-Atlantic (Figure 6‑42 and Figure 6‑43, respectively). MFB was high throughout the region, with the highest levels along the inner corridor and MFE was higher in New England than in the Mid-Atlantic (Figure 6‑44 and Figure 6‑45, respectively). MFB was high in along the inner corridor and sometimes quite low at more rural sites, and MFE was high throughout the MANE-VU region (Figure 6‑46 and Figure 6‑47, respectively). MFB and MFE were quite high for soil throughout MANE-VU (Figure 6‑48 and Figure 6‑49, respectively).

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| Figure 6‑38: MFB SO4, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑39: MFE SO4, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

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| Figure 6‑40: MFB NO3, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑41: MFE NO3, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

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| Figure 6‑42: MFB NH4, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑43: MFE NH4, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

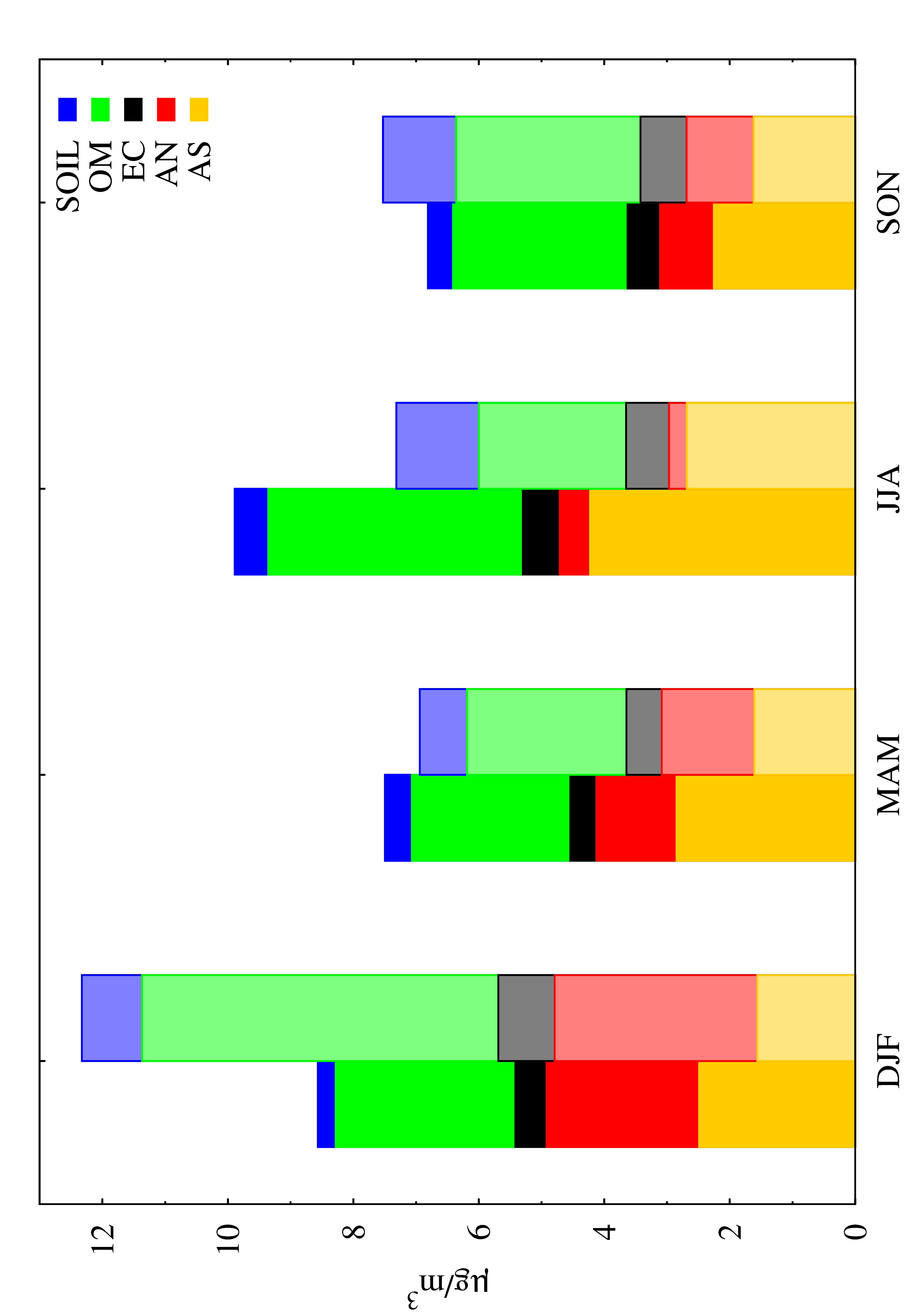
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| Figure 6‑44: MFB EC, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑45: MFE EC, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

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| Figure 6‑46: MFB OC, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑47: MFE OC, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

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| Figure 6‑48: MFB Soil, 2011 (only monitors with ≥10 days of data are shown)    ● <-60%  ● -60 to -30%  ● -30 to 0%  ● 0 to 30%  ● 30 to 60%  ● >60% | Figure 6‑49: MFE Soil, 2011 (only monitors with ≥10 days of data are shown)    ● <25%  ● 25-37.5%  ● 37.5-50%  ● 50-62.5%  ● 62.5-75%  ● >75% |

When the various species are reconstituted as shown in Equation 6‑1 over-prediction by about 3 μg/m3 in the winter months, under-prediction by about 2 μg/m3 in the summer months, and fairly close results during the shoulder seasons (Figure 6‑50) are seen.

Figure 6‑50: 2011 RCFM by season (observed values darker shading, predicted values lighter shading)



## Summary

Various model evaluation statistics are presented here for a variety of gaseous and aerosol species in addition to O3. In general, the CMAQ results were best for daily maximum O3 and daily average PM2.5 and SO4 mass. Other species vary tremendously over the course of a day, or from day to day, and small model over- or under-prediction at low concentrations can lead to large biases on a composite basis. We demonstrate that the model performs reasonably well over the diurnal cycle and not just in terms of daily maximum or average values. Also, we demonstrate that the model can reliably reproduce concentrations above the ground level. The analyses shown in this section demonstrates that OTC’s 2011 based modeling platform can adequately reproduce air pollution produced through photochemical processes to a degree that will allow states to demonstrate future air pollution levels for ozone, PM2.5 and regional haze SIPs.

References

Brewer, P, Tanner, J, Engelbrecht, J, Morris, R and Reynolds, S 2007, ‘Carbon Analyses in the VISTAS Region for PM2.5 and Haze’, accessed August 16, 2006, from <http://www.marama.org/calendar/events/presentations/2007\_07Science/BrewerMVScience07.pdf>.

# Evaluation of 4km Nested Gridding

## Overview

In previous SIP modeling using the 2007 OTC modeling platform we found that error increased towards coastal errors. In Section 6 ozone predictions were less accurate, particularly in terms of MFB, but also MFE and MAGE, at many of the coastal monitors (see Figure 6‑7 through Figure 6‑12). In particular, very high ozone in Long Island sound showed little response to emission reductions. It was expected that due to the intricate meteorology, often due to land-water interface issues, many of the problematic monitors in the OTR that could be improved through better representation of the conditions at those monitors.

Figure ‑: OTC 12km modeling domain and 4km nested grid

One technique to improve model performance in areas with complex meteorology is to conduct photochemical modeling with a finer resolution nested grid in the areas needing improvement. A finer grid allows emissions, particularly from point sources, to be located more precisely. It also allows the greater complexities of meteorology to play a role in modeling. The downside of using a finer grid is the increase in model run time, necessary computing power, and staff resources. Previous research has shown that as the resolution improves from 12 km marginal improvements in results decrease (Thompson and Selin 2012). OTC examined the impact of using a finer, 4km grid in the core of the OTR, as shown in Figure 6‑7 through Figure 6‑12, in order to examine the potential benefits of refined grid modeling.

## Meteorology Processing

NYSDEC ran WRF v. 3.6.1 using the same process and parameters as EPA used in developing the 12km meteorological data.

We relied on NAM from NCEP in 12km grid spacing to drive the WRF model. The NAM archive was missing during early March of 2011 so only the months of January, February, and April until December were processed. This was not expected to introduce major errors given that March is not typically associated with ozone production in the OTR, nor is it during the required ozone monitoring season. NLCD 2006 land use data was employed in this exercise, as was GHRSST for sea surface temperature. GHRSST has a daily resolution of 0.01 x 0.01 degree (about 1km).

## Emission Inventory

We relied on EPA’s modeling inventory “eh” that was based on NEI v. 2 for emissions. At the time that SMOKE processing occurred the Alpha 2 inventory was not available, but since the Alpha 2 inventory is largely uses “eh” directly in the base year this was not seen as introducing any major inaccuracies. The differences of note between the Alpha 2 inventory and the inventory used in this exercise is that CEMS data would have been directly used rather than the ERTAC smoothed EGU data. MOVES and biogenic were not processed using SMOKE at the 4km resolution. If MOVES emission factors were used in 4km SMOKE processing the results would resolve better in particular for mobile emissions along the I-95 corridor. Biogenic emissions were re-gridded from 12km to 4km instead of being processed at 4km resolution.

## Results

NMB results from the 12km in smaller domain are biased negatively and the 4km gridded results are a marked improvement throughout the entirety of the smaller domain (Figure 7‑2 and Figure 7‑3). NME on the other hand does not improve throughout the entirety of the smaller domain. NME results do improve along the I-95 corridor but there are increases in NME in the western part of the smaller domain, in particular in the Pittsburgh areas (Figure 7‑4 and Figure 7‑5).

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| Figure 7‑2: Ozone NMB, July 2011 4 km grid | Figure 7‑3: Ozone NMB, July 2011 12 km grid |
| Figure 7‑4: Ozone NME, July 2011 4 km grid | Figure 7‑5: Ozone NME, July 2011 12 km grid |

We then took a look diurnally for 10 key monitors in the inner corridor (3 in Connecticut, 5 in New York, and 1 each in Maryland and New Jersey). There are clear improvements with predicting average monthly and peak ozone at all ten monitors in the month of June though there are instances such as with monitor 361030002 where the peak is pushed back in the day from where it is observed (Figure 7‑6 through Figure 7‑15).

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| Figure 7‑6: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #090010017 (thick line: monthly avg., thin line: max day) | Figure 7‑7: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #090013007 (thick line: monthly avg., thin line: max day) |
| Figure 7‑8: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #090019003 (thick line: monthly avg., thin line: max day) | Figure 7‑9: Observed and modeled (4km/12km grids) ozone (ppb for June 2011 at monitor #240251001 (thick line: monthly avg., thin line: max day) |

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| Figure 7‑10: Observed and modeled (4km/12km grids) ozone (ppb for June 2011 at monitor #34015002 (thick line: monthly avg., thin line: max day) | Figure 7‑11: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #360050133 (thick line: monthly avg., thin line: max day) |
| Figure 7‑12: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #360810124 (thick line: monthly avg., thin line: max day) | Figure 7‑13: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #360850067 (thick line: monthly avg., thin line: max day) |
| Figure 7‑14: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #361030002 (thick line: monthly avg., thin line: max day) | Figure 7‑15: Observed and modeled (4km/12km grids) ozone (ppb) for June 2011 at monitor #361192004 (thick line: monthly avg., thin line: max day) |

The same pattern holds for July, excepting monitor 240251001, which is underpredicted slightly more on the peak day (Figure 7‑16 through Figure 7‑25).

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| Figure 7‑16: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #090010017 (thick line: monthly avg., thin line: max day) | Figure 7‑17: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #090013007 (thick line: monthly avg., thin line: max day) |
| Figure 7‑18: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #090019003 (thick line: monthly avg., thin line: max day) | Figure 7‑19: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #240251001 (thick line: monthly avg., thin line: max day) |
| Figure 7‑20: Observed and modeled (4km/12km grids) ozone (ppb for July 2011 at monitor #34015002 (thick line: monthly avg., thin line: max day) | Figure 7‑21: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #360050133 (thick line: monthly avg., thin line: max day) |
| Figure 7‑22: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #360810124 (thick line: monthly avg., thin line: max day) | Figure 7‑23: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #360850067 (thick line: monthly avg., thin line: max day) |
| Figure 7‑24: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #361030002 (thick line: monthly avg., thin line: max day) | Figure 7‑25: Observed and modeled (4km/12km grids) ozone (ppb) for July 2011 at monitor #361192004 (thick line: monthly avg., thin line: max day) |

The same pattern also holds for August, with monitors 090019003 and 240251001 having peak concentrations predicted later in the day than observations on the peak day (Figure 7‑26 through Figure 7‑35).

|  |  |
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| Figure 7‑26: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #090010017 (thick line: monthly avg., thin line: max day) | Figure 7‑27: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #090013007 (thick line: monthly avg., thin line: max day) |
| Figure 7‑28: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #090019003 (thick line: monthly avg., thin line: max day) | Figure 7‑29: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #240251001 (thick line: monthly avg., thin line: max day) |
| Figure 7‑30: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #34015002 (thick line: monthly avg., thin line: max day) | Figure 7‑31: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #360050133 (thick line: monthly avg., thin line: max day) |
| Figure 7‑32: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #360810124 (thick line: monthly avg., thin line: max day) | Figure 7‑33: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #360850067 (thick line: monthly avg., thin line: max day) |
| Figure 7‑34: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #361030002 (thick line: monthly avg., thin line: max day) | Figure 7‑35: Observed and modeled (4km/12km grids) ozone (ppb) for August 2011 at monitor #361192004 (thick line: monthly avg., thin line: max day) |

## Conclusion

Use of a 4km nested grid in the OTR does lead to improvements in modeled performance, in particular when looking at predictions during peak days at coastal monitors. When looking at the entirety of the smaller domain there are even disbenefits in terms of model performance in the western portion of the domain. If further work is conducted using 4km modeling that relies on use of OTC inventory, to both conserve computing resources and improve model performance, it is recommended that only the inner corridor be modeled with the finer grid.

References

Thompson, TM and Selin, NE 2012, ‘Influence of air quality model resolution on uncertainty associated with health impacts’, *Atmospheric Chemistry and Physics*, vol. 12, no. 20, pp. 9753–9762.

# Emissions Inventories and Processing for 2017/2018/2028 12 km Future Year Simulation

## Emission Inventory Sectors

All the inventory sectors are the same as in the base year and their brief descriptions can be found in Section 4.

## US Future Year Emissions Inventories

The OTR states, through MANE-VU and MARAMA, developed the majority of the 2017 Beta, 2018 Alpha/Alpha 2, and 2028 Alpha/Alpha 2 inventories based on 2011 inventories as discussed earlier. MARAMA, through a contractor SRA, in consultation with the states, developed the necessary growth and control factors to project the 2011 inventory to a future year and applied them to develop both 2018 and 2028 inventories. These growth factors were used for all the jurisdictions in the OTC, in addition to West Virginia, North Carolina, and the rest of Virginia (McDill, McCusker and Sabo 2015). Growth rates for the states in LADCO were obtained from LADCO and we relied on default assumptions from EPA for all other states (McDill, McCusker and Sabo 2015). The same process was undertaken for the Beta inventory projections to 2017 (McDill, McCusker and Sabo 2016). It should be noted that emissions for mobile sources and the electric energy generating units (EGUs) were not part of this effort.

EGU emissions were processed using the ERTAC EGU tool v. 1.01 and were post-processed using ERTAC to SMOKE version 1.02. The projections for the Alpha and Alpha 2 inventories were based on growth assumptions from the 2014 AEO and the collection of inputs were termed ERTAC EGU v. 2.3 (MARAMA n.d.; US Energy Information Administration April 2014). The projections for the Beta inventory were upgraded to ERTAC v. 2.5, which were processed using the same versions of the code and were based on growth assumptions from the 2015 AEO (‘Documentation of ERTAC EGU CONUS 2.5’ n.d.; US Energy Information Administration April 2015).

EPA provided emission factors developed using MOVES2014a for both 2017 and 2025, as well as other input files needed to run SMOKE-MOVES such as vehicle activity and vehicle population. NYSDEC and NJDEP processed the emission factors for 2017 and 2025, respectively, using SMOKE-MOVES. The MANE-VU Technical Support Committee had determined that using 2025 as a surrogate for 2028 mobile emissions would be a conservative estimate and thus appropriate.

## Canadian Emissions

Canadian emissions were estimated in the future years by taking the ratio of US domain 2011 emissions to 2017, 2018, and 2028 emissions and applying that ratio to the 2010 Canadian emissions used in the base year (McDill, McCusker and Sabo 2015, 2016).

## Application of SMOKE

The 2017 and 2028 inventories were processed by NYSDEC using a template similar to that used for processing 2011 base year emissions for the 12 km domain. In particular, all gridding and speciation profiles, cross-reference files, and temporal allocation profiles used in the 2011 processing were also used for future year processing, excepting the hourly temporal files for ERTAC EGUs for 2017 and 2028 and small EGUs for 2017. A full list of files are in Appendix A.

Emissions for all source categories were processed by SMOKE version 3.7 for 2017 Beta and SMOKE version 3.6 for Alpha and Alpha 2. The SMOKE programs downloaded from CMAS website have been compiled for LINUX system and ready for use.

## SMOKE Processed Emission Results

In order to quality assure the outputs from SMOKE were properly distributed geographically and develop a better understanding of the geographical and temporalization of emissions maps of emissions in each grid cell were produced. These maps were produced from the Alpha 2 inventory. We looked at projected daily emissions on a typical summer day during 2011 (June 24) and projected daily emissions during a 2011 ozone event (July 22). We looked at NOX and SO2 gridded emissions. We chose not to include VOCs since biogenic emissions are held constant and overwhelm regional anthropogenic VOC emissions. Urban areas, interstate highways in rural areas, and shipping lanes are clearly distinguishable in the maps of NOX emissions (Figure 8‑1). There are minor differences at this scale on a peak day where one can notice increases in some grid cells during the ozone event (Figure 8‑2). One can see the importance of point sources in terms of SO2 emissions and there were increases at some grid cells, particularly in the Long Island Sound, on the New England coast and some Pennsylvanian EGUs, during the projected ozone event (Figure 8‑3 and Figure 8‑4).

When one compares the projections to the baseline found in Section 4 one notices that on both the typical summer day and the ozone conducive day that emissions of NOX decrease regionally and that a fair number of SO2 point sources disappear in the projection.

Additionally, summary tables of emissions by state, sector, and pollutant were outputted from SMOKE processing. These results are aggregated for the 2018 Alpha 2 inventory in Table 8‑1, the 2028 Alpha 2 inventory in Table 8‑2, and the 2011 Beta inventory in Table 8‑3.

|  |  |
| --- | --- |
| Figure 8‑1: MARAMA 2018 Projected Alpha 2 NOX SMOKE Gridded Emissions (June 24)  F:\OTC\Committees\Modeling Committee\Work in Progress\2011 Platform Development\Alpha 2 SMOKE outputs\MARAMA_A2_20180624_NOx.jpg | Figure 8‑2: MARAMA 2018 Projected Alpha 2 NOX SMOKE Gridded Emissions (July 22)  F:\OTC\Committees\Modeling Committee\Work in Progress\2011 Platform Development\Alpha 2 SMOKE outputs\MARAMA_A2_20180722_NOx.jpg |
| Figure 8‑3: MARAMA 2018 Projected Alpha 2 SO2 SMOKE Gridded Emissions (June 24)  F:\OTC\Committees\Modeling Committee\Work in Progress\2011 Platform Development\Alpha 2 SMOKE outputs\MARAMA_A2_20180624_SO2.jpg | Figure 8‑4: MARAMA 2018 Projected Alpha 2 SO2 SMOKE Gridded Emissions (July 22)  F:\OTC\Committees\Modeling Committee\Work in Progress\2011 Platform Development\Alpha 2 SMOKE outputs\MARAMA_A2_20180722_SO2.jpg |

Table 8‑1: 2018 base case Alpha 2 emissions by pollutant and RPO for aggregated sectors

|  | ERTAC EGU | Non-EGU Point & Small EGU | Nonroad (including M/A/R) | Onroad | Area (including Refueling & RWC) | Oil/Gas | Other (including biogenic) | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NOX | | | | | | | | |
| MANE-VU | 141,249 | 161,900 | 272,855 | 345,812 | 195,191 | 89,499 | 1,018 | 1,207,525 |
| LADCO | 294,427 | 280,880 | 342,483 | 527,635 | 181,632 | 82,212 | 12,458 | 1,721,726 |
| SESARM | 322,839 | 286,058 | 520,988 | 577,071 | 109,198 | 194,360 | 77,295 | 2,087,808 |
| CenSARA | 403,929 | 336,448 | 397,841 | 574,792 | 143,136 | 663,430 | 116,659 | 2,636,234 |
| Canada |  | 143,534 | 189,400 | 124,557 | 59,134 |  |  | 516,625 |
| US EEZ |  |  | 1,016,290 |  |  |  |  | 1,016,290 |
| International |  |  | 2,380,100 |  |  |  |  | 2,380,100 |
| NOX Total | 1,162,444 | 1,208,820 | 5,119,956 | 2,149,867 | 688,291 | 1,029,500 | 207,430 | 11,566,309 |
| VOC | | | | | | | | |
| MANE-VU | 2,266 | 55,126 | 250,649 | 192,119 | 657,271 | 47,889 | 21,238 | 1,226,558 |
| LADCO | 8,389 | 167,311 | 316,188 | 273,485 | 756,592 | 55,434 | 227,782 | 1,805,180 |
| SESARM | 9,336 | 233,768 | 251,523 | 272,305 | 743,965 | 211,691 | 496,938 | 2,219,525 |
| CenSARA | 12,551 | 222,180 | 207,909 | 254,668 | 835,803 | 1,728,134 | 1,635,856 | 4,897,101 |
| Canada |  | 193,891 | 123,156 | 60,045 | 532,666 |  |  | 909,758 |
| US EEZ |  |  | 41,341 |  |  |  |  | 41,341 |
| International |  |  | 95,716 |  |  |  |  | 95,716 |
| VOC Total | 32,541 | 872,277 | 1,286,483 | 1,052,622 | 3,526,297 | 2,043,148 | 2,381,813 | 11,195,180 |
| SO2 | | | | | | | | |
| MANE-VU | 239,683 | 77,689 | 4,897 | 1,948 | 56,235 | 4,434 | 612 | 385,498 |
| LADCO | 555,498 | 251,320 | 945 | 2,272 | 25,869 | 1,605 | 7,039 | 844,549 |
| SESARM | 430,479 | 171,733 | 2,122 | 2,547 | 60,675 | 29,525 | 28,139 | 725,219 |
| CenSARA | 882,412 | 233,504 | 3,016 | 2,451 | 43,881 | 25,286 | 58,760 | 1,249,310 |
| Canada |  | 362,365 | 32,651 | 607 | 36,964 |  |  | 432,586 |
| US EEZ |  |  | 113,282 |  |  |  |  | 113,282 |
| International |  |  | 1,672,100 |  |  |  |  | 1,672,100 |
| SO2 Total | 2,108,072 | 1,096,611 | 1,829,013 | 9,825 | 223,623 | 60,849 | 94,551 | 5,422,544 |
| PM2.5 | | | | | | | | |
| MANE-VU | 13,776 | 28,341 | 19,768 | 16,436 | 170,115 | 2,560 | 25,958 | 276,954 |
| LADCO | 63,283 | 64,553 | 23,575 | 22,557 | 212,405 | 1,417 | 217,292 | 605,082 |
| SESARM | 66,461 | 72,813 | 26,301 | 21,653 | 184,630 | 4,432 | 384,209 | 760,499 |
| CenSARA | 73,452 | 84,040 | 25,312 | 21,852 | 123,688 | 17,071 | 1,033,122 | 1,378,538 |
| Canada |  | 25,261 | 13,805 | 5,093 | 105,607 |  | 323,474 | 473,240 |
| US |  |  | 27,544 |  |  |  |  | 27,544 |
| International |  |  | 207,330 |  |  |  |  | 207,330 |
| PM2.5 Total | 216,972 | 275,009 | 343,634 | 87,590 | 796,445 | 25,479 | 1,984,056 | 3,729,185 |
| NH3 | | | | | | | | |
| MANE-VU | 2,381 | 5,220 | 419 | 13,243 | 14,920 | 17 | 169,173 | 205,372 |
| LADCO | - | 8,923 | 571 | 14,136 | 23,519 | 59 | 692,892 | 740,099 |
| SESARM | 275 | 16,606 | 606 | 16,682 | 8,431 | 6 | 605,596 | 648,202 |
| CenSARA | - | 23,279 | 1,194 | 14,475 | 17,190 | 48 | 1,394,423 | 1,450,609 |
| Canada |  | 5,232 | 203 | 9,641 | 3,091 |  | 183,853 | 202,020 |
| US EEZ |  |  | 216 |  |  |  |  | 216 |
| International |  |  |  |  |  |  |  |  |
| NH3 Total | 2,656 | 59,260 | 3,208 | 68,176 | 67,152 | 130 | 3,045,936 | 3,246,518 |
| CO | | | | | | | | |
| MANE-VU | 68,463 | 237,066 | 2,550,632 | 2,145,813 | 884,490 | 80,265 | 90,739 | 6,057,469 |
| LADCO | 152,964 | 729,588 | 2,496,295 | 2,915,260 | 1,276,180 | 49,068 | 966,320 | 8,585,675 |
| SESARM | 169,605 | 455,526 | 2,310,513 | 3,002,247 | 1,023,682 | 164,784 | 2,814,505 | 9,940,862 |
| CenSARA | 200,347 | 398,047 | 1,947,730 | 2,853,610 | 787,726 | 502,020 | 6,907,096 | 13,596,576 |
| Canada |  | 568,160 | 2,003,059 | 1,300,915 | 648,333 |  |  | 4,520,467 |
| US EEZ |  |  | 63,245 |  |  |  |  | 63,245 |
| International |  |  | 34,933 |  |  |  |  | 34,933 |
| CO Total | 591,379 | 2,388,387 | 11,406,408 | 12,217,845 | 4,620,411 | 796,137 | 10,778,661 | 42,799,227 |

Table 8‑2: 2028 base case Alpha 2 emissions by pollutant and RPO for aggregated sectors

|  | ERTAC EGU | Non-EGU Point & Small EGU | Nonroad (including M/A/R) | Onroad | Area (including Refueling & RWC) | Oil/Gas | Other (including biogenic) | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NOX |  |  |  |  |  |  |  |  |
| MANE-VU | 157,287 | 156,319 | 205,249 | 213,308 | 192,539 | 109,952 | 1,018 | 1,035,672 |
| LADCO | 317,206 | 257,652 | 250,173 | 315,186 | 181,393 | 79,429 | 12,458 | 1,413,496 |
| SESARM | 326,962 | 271,453 | 233,634 | 335,672 | 103,453 | 216,288 | 77,295 | 1,564,758 |
| CenSARA | 448,052 | 342,985 | 444,053 | 351,529 | 127,495 | 680,492 | 116,659 | 2,511,264 |
| Canada |  | 143,534 | 189,400 | 124,557 | 59,134 |  |  | 516,625 |
| US EEZ |  |  | 557,770 |  |  |  |  | 557,770 |
| International |  |  | 1,859,000 |  |  |  |  | 1,859,000 |
| NOX Total | 1,249,507 | 1,171,943 | 3,739,279 | 1,340,251 | 664,015 | 1,086,161 | 207,430 | 9,458,586 |
| VOC |  |  |  |  |  |  |  |  |
| MANE-VU | 3,184 | 55,840 | 219,555 | 132,470 | 699,334 | 39,140 | 21,238 | 1,170,762 |
| LADCO | 8,751 | 167,753 | 263,821 | 178,055 | 811,119 | 43,931 | 227,782 | 1,701,212 |
| SESARM | 10,330 | 235,514 | 208,253 | 167,262 | 780,868 | 177,362 | 496,938 | 2,076,526 |
| CenSARA | 15,686 | 237,064 | 196,286 | 163,445 | 825,579 | 1,694,250 | 1,635,856 | 4,768,166 |
| Canada |  | 193,891 | 123,156 | 60,045 | 532,666 |  |  | 909,758 |
| US EEZ |  |  | 33,413 |  |  |  |  | 33,413 |
| International |  |  | 84,972 |  |  |  |  | 84,972 |
| VOC Total | 37,951 | 890,062 | 1,129,457 | 701,277 | 3,649,567 | 1,954,683 | 2,381,813 | 10,744,810 |
| SO2 |  |  |  |  |  |  |  |  |
| MANE-VU | 271,979 | 65,242 | 3,598 | 1,881 | 39,869 | 5,837 | 612 | 389,018 |
| LADCO | 565,721 | 205,422 | 3,806 | 2,203 | 26,041 | 1,631 | 7,039 | 811,862 |
| SESARM | 377,251 | 144,700 | 6,121 | 2,493 | 57,660 | 35,235 | 28,139 | 651,599 |
| CenSARA | 953,655 | 209,473 | 19,337 | 2,439 | 38,639 | 24,168 | 58,760 | 1,306,472 |
| Canada |  | 362,365 | 32,651 | 607 | 36,964 |  |  | 432,586 |
| US EEZ |  |  | 9,977 |  |  |  |  | 9,977 |
| International |  |  | 44,104 |  |  |  |  | 44,104 |
| SO2 Total | 2,168,606 | 987,201 | 119,594 | 9,624 | 199,173 | 66,870 | 94,551 | 3,645,620 |
| PM2.5 |  |  |  |  |  |  |  |  |
| MANE-VU | 15,259 | 28,108 | 14,941 | 11,779 | 170,107 | 2,986 | 29,594 | 272,774 |
| LADCO | 70,561 | 61,398 | 16,524 | 14,874 | 225,060 | 1,336 | 227,925 | 617,676 |
| SESARM | 67,797 | 71,052 | 15,519 | 14,548 | 171,406 | 4,921 | 391,321 | 736,565 |
| CenSARA | 79,005 | 85,109 | 22,377 | 14,569 | 89,090 | 17,241 | 1,070,790 | 1,378,181 |
| Canada |  | 25,261 | 13,805 | 5,093 | 105,607 |  | 323,474 | 473,240 |
| US |  |  | 5,987 |  |  |  |  | 5,987 |
| International |  |  | 3,906 |  |  |  |  | 3,906 |
| PM2.5 Total | 232,621 | 270,928 | 93,058 | 60,861 | 761,271 | 26,485 | 2,043,104 | 3,488,330 |
| NH3 |  |  |  |  |  |  |  |  |
| MANE-VU | 2,229 | 4,983 | 459 | 13,087 | 15,049 | 17 | 169,292 | 205,115 |
| LADCO | 505 | 8,570 | 636 | 13,803 | 24,203 | 59 | 709,084 | 756,859 |
| SESARM | 828 | 16,435 | 506 | 16,129 | 8,506 | 7 | 614,094 | 656,505 |
| CenSARA | 1,616 | 23,423 | 1,782 | 14,361 | 14,673 | 45 | 1,420,557 | 1,476,457 |
| Canada |  | 5,232 | 203 | 9,641 | 3,091 |  | 183,853 | 202,020 |
| US EEZ |  |  | 21,202 |  |  |  |  | 21,202 |
| International |  |  | 270,060 |  |  |  |  | 270,060 |
| NH3 Total | 5,179 | 58,643 | 294,848 | 67,021 | 65,522 | 127 | 3,096,879 | 3,588,218 |
| CO |  |  |  |  |  |  |  |  |
| MANE-VU | 51,587 | 239,457 | 2,712,333 | 1,561,530 | 976,393 | 103,418 | 90,739 | 5,735,457 |
| LADCO | 167,143 | 734,519 | 2,555,291 | 2,013,892 | 1,355,846 | 45,583 | 966,320 | 7,838,594 |
| SESARM | 175,042 | 460,756 | 2,379,436 | 2,063,691 | 891,427 | 192,493 | 2,814,505 | 8,977,351 |
| CenSARA | 230,509 | 417,035 | 2,413,115 | 2,002,015 | 446,099 | 513,122 | 6,907,096 | 12,928,991 |
| Canada |  | 568,160 | 2,003,059 | 1,300,915 | 648,333 |  |  | 4,520,467 |
| US EEZ |  |  | 132,827 |  |  |  |  | 132,827 |
| International |  |  | 200,230 |  |  |  |  | 200,230 |
| CO Total | 624,281 | 2,419,927 | 12,396,291 | 8,942,042 | 4,318,099 | 854,616 | 10,778,661 | 40,333,916 |

Table 8‑3: 2017 base case Beta emissions by pollutant and RPO for aggregated sectors

|  | ERTAC EGU | Non-EGU Point & Small EGU | Nonroad (including M/A/R) | Onroad | Area (including Refueling & RWC) | Oil/Gas | Other (including biogenic) | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NOX | | | | | | | | |
| MANE-VU | 99,123 | 151,352 | 264,570 | 381,046 | 180,425 | 75,550 | 1,018 | 1,153,083 |
| LADCO | 271,724 | 281,914 | 357,117 | 544,560 | 181,056 | 66,389 | 12,458 | 1,715,219 |
| SESARM | 276,312 | 263,717 | 325,234 | 614,570 | 102,354 | 134,760 | 77,295 | 1,794,242 |
| CenSARA | 401,928 | 329,949 | 622,921 | 154,499 | 131,281 | 588,721 | 116,659 | 2,345,959 |
| Canada |  | 143,534 | 189,400 | 124,557 | 59,134 |  |  | 516,625 |
| US EEZ |  |  | 460,270 |  |  |  |  | 460,270 |
| International |  |  | 24,340 |  |  |  |  | 24,340 |
| NOX Total | 1,049,087 | 1,170,466 | 2,243,853 | 1,819,232 | 654,251 | 865,421 | 207,430 | 8,009,739 |
| VOC | | | | | | | | |
| MANE-VU | 2,576 | 54,220 | 260,225 | 214,498 | 655,025 | 50,611 | 21,238 | 1,258,392 |
| LADCO | 6,823 | 164,384 | 331,982 | 276,250 | 755,188 | 84,179 | 227,782 | 1,846,588 |
| SESARM | 7,860 | 228,666 | 256,485 | 295,349 | 746,708 | 225,660 | 496,938 | 2,257,666 |
| CenSARA | 10,135 | 225,001 | 226,113 | 63,870 | 834,819 | 1,969,444 | 1,635,856 | 4,965,238 |
| Canada |  | 193,891 | 123,156 | 60,045 | 532,666 |  |  | 909,758 |
| US EEZ |  |  | 15,611 |  |  |  |  | 15,611 |
| International |  |  | 962 |  |  |  |  | 962 |
| VOC Total | 27,394 | 866,162 | 1,214,536 | 910,012 | 3,524,407 | 2,329,894 | 2,381,813 | 11,254,216 |
| SO2 | | | | | | | | |
| MANE-VU | 190,640 | 83,208 | 1,523 | 1,922 | 32,936 | 6,357 | 612 | 317,198 |
| LADCO | 568,813 | 268,588 | 722 | 2,103 | 18,374 | 1,347 | 7,039 | 866,986 |
| SESARM | 321,383 | 206,455 | 905 | 2,379 | 29,509 | 30,346 | 28,139 | 619,116 |
| CenSARA | 830,790 | 265,990 | 1,467 | 518 | 6,437 | 31,987 | 58,760 | 1,195,950 |
| Canada |  | 362,365 | 32,651 | 607 | 36,964 |  |  | 432,586 |
| US EEZ |  |  | 2,803 |  |  |  |  | 2,803 |
| International |  |  | 16,830 |  |  |  |  | 16,830 |
| SO2 Total | 1,911,626 | 1,186,606 | 56,901 | 7,530 | 124,219 | 70,037 | 94,551 | 3,451,470 |
| PM2.5 | | | | | | | | |
| MANE-VU | 14,234 | 28,387 | 18,956 | 17,186 | 157,362 | 3,200 | 28,216 | 267,540 |
| LADCO | 41,124 | 66,045 | 25,024 | 21,862 | 202,736 | 1,376 | 223,842 | 582,008 |
| SESARM | 37,473 | 77,374 | 21,657 | 22,102 | 171,034 | 4,088 | 385,852 | 719,581 |
| CenSARA | 40,942 | 91,684 | 31,650 | 5,742 | 91,570 | 17,208 | 1,043,767 | 1,322,563 |
| Canada |  | 25,261 | 13,805 | 5,093 | 105,607 |  | 323,474 | 473,240 |
| US |  |  | 8,379 |  |  |  |  | 8,379 |
| International |  |  | 2,087 |  |  |  |  | 2,087 |
| PM2.5 Total | 133,773 | 288,752 | 121,557 | 71,984 | 728,310 | 25,871 | 2,005,152 | 3,375,398 |
| NH3 | | | | | | | | |
| MANE-VU | 2,609 | 5,151 | 413 | 13,738 | 14,395 | 17 | 167,741 | 204,063 |
| LADCO | 949 | 9,009 | 563 | 14,082 | 23,034 | 12 | 689,515 | 737,163 |
| SESARM | 3,149 | 16,132 | 462 | 16,753 | 8,432 | 6 | 605,925 | 650,859 |
| CenSARA | 5,627 | 22,805 | 1,315 | 3,117 | 14,702 | 51 | 1,412,037 | 1,459,655 |
| Canada |  | 5,232 | 203 | 9,641 | 3,091 |  | 183,853 | 202,020 |
| US EEZ |  |  | 216 |  |  |  |  | 216 |
| International |  |  |  |  |  |  |  |  |
| NH3 Total | 12,333 | 58,329 | 3,172 | 57,331 | 63,654 | 85 | 3,059,070 | 3,253,975 |
| CO | | | | | | | | |
| MANE-VU | 38,566 | 238,478 | 2,541,821 | 2,279,190 | 864,069 | 73,624 | 90,739 | 6,126,487 |
| LADCO | 85,605 | 762,627 | 2,504,016 | 2,903,900 | 1,177,242 | 48,763 | 966,320 | 8,448,474 |
| SESARM | 100,479 | 481,736 | 2,259,626 | 3,062,300 | 876,020 | 121,867 | 2,814,505 | 9,716,532 |
| CenSARA | 184,816 | 436,622 | 1,997,595 | 640,342 | 448,849 | 472,366 | 6,907,096 | 11,087,685 |
| Canada |  | 568,160 | 2,003,059 | 1,300,915 | 648,333 |  |  | 4,520,467 |
| US EEZ |  |  | 85,941 |  |  |  |  | 85,941 |
| International |  |  | 2,267 |  |  |  |  | 2,267 |
| CO Total | 409,465 | 2,487,623 | 11,394,325 | 10,186,647 | 4,014,513 | 716,619 | 10,778,661 | 39,987,853 |

## References

‘Documentation of ERTAC EGU CONUS 2.5’.

MARAMA ‘Documentation of ERTAC EGU CONUS 2.3’, accessed May 2, 2016, from <http://marama.org/images/stories/documents/Documentation\_of\_ERTAC\_EGU\_CONUS\_2.3.pdf>.

McDill, J, McCusker, S and Sabo, E 2015, ‘Technical Support Document: Emission Inventory Development for 2011, 2018, and 2028 for the Northeastern US Alpha 2 Version’, accessed March 7, 2016, from <http://marama.org/images/stories/documents/2011-2018-2028\_Technical\_Support\_Docs/TSD%20ALPHA2%20Northeast%20Emission%20Inventory%20for%202011%202018%202028%20DraftFinal%2020151123.pdf>.

McDill, J, McCusker, S and Sabo, E 2016, ‘Technical Support Document: Emission Inventory Development for 2011 and 2017 for the Northeastern US Beta Version’, accessed August 16, 2016, from <http://marama.org/images/stories/documents/2011-2017\_BETA\_REI/TSD%20BETA%20Northeast%20Emission%20Inventory%20for%202011%202017%2020160701.pdf>.

US Energy Information Administration 2014, *Annual Energy Outlook 2014 with Projections to 2040*, accessed from <https://www.eia.gov/forecasts/archive/aeo14/pdf/0383(2014).pdf>.

US Energy Information Administration 2015, *Annual Energy Outlook 2015 with Projections to 2040*, accessed from <https://www.eia.gov/forecasts/archive/aeo15/pdf/0383(2015).pdf>.

# Relative Response Factor (RRF) and “Modeled Attainment Test”

## Overview

EPA guidance requires the use of a modeled attainment test, which is described as a procedure in which an air quality model is used to simulate current and future air quality (US EPA 2014). If future estimates, after rounding, of ozone concentrations are less than or equal to 75 ppb, then this element of the attainment test is satisfied. A modeled attainment demonstration thatconsists of analyses which estimate whether selected emissions reductions will result in ambient concentrations that meet the NAAQS or progress goals.

For this modeled attainment test, model estimates are used in a “relative” rather than “absolute” sense. That is, one calculates the ratio of the model’s future to current (baseline) predictions at ozone monitors. These ratios are called RRF. Future ozone concentrations are estimated at existing monitoring sites by multiplying modeled RRF at locations “near” each monitor by the observation-based monitor-specific “baseline” ozone design value. The following equation describes the approach as applied to a monitoring site i:

where DVCi is the baseline concentration monitored at site i, RRFi is the relative response factor calculated for site i, and DVFi is the estimated future design value for site i. The RRF is the ratio of the future 8-hour daily maximum concentration predicted at a monitor to the baseline 8-hour daily maximum concentration predicted at the monitor location averaged over multiple days determined from the base case.

## General Design Value Calculation

The following sections describe the calculation of each of the elements in Equation 1 as implemented by NYSDEC through an in-house computer program written in FORTRAN (n.b. the subscript “i” from equation is dropped in the following description). However, all calculations are still performed on a monitor-by-monitor basis.

It should be noted that while this algorithm describes the techniques OTC uses to calculate RRFs for a typical monitor it in no way precludes states from doing so differently in order to evaluate a particular monitor either in their attainment demonstration or for weight-of-evidence. Further information later in this section describes one particular scenario that might lead states to want to adopt a different method for particular monitors.

### Step 1 - Calculation of DVC

Design values are calculated in accordance with 40 CFR Part 50.10, Appendix I, as 3-year averages of the fourth highest monitored daily 8-hour maximum value at each monitoring site. For example, the design value for 2009-2011 is the average of the fourth highest monitored daily 8-hour maximum values in 2009, 2010 and 2011. Design values are labeled with the *last* year of the design value period, i.e. the design value for the 2009 – 2011 is labeled as “2011 design value”.

For MAT, the guidance defines DVC in Equation 1 as the average of the design values which straddle the baseline inventory year. Here the baseline inventory year is 2011, therefore DVC is the average of the “2010 design value” (determined from 2010-2012 observations), the “2011 design value” (determined from 2010-2012 observations), and the “2012 design value” (determined from 2011-2013 observations). Consequently, DVC is derived from observations covering a five-year period and is a weighted average with 2011 observations “weighted” three times, 2010 and 2012 observations weighted twice, and 2009 and 2013 observations weighted once.

The following criteria concerning missing design values were implemented in the FORTRAN code calculating DVC:

1. For monitors with only four years of consecutive data, the guidance allows DVC to be computed as the average of two design values within that period.
2. For monitors with only three years of consecutive data, the DVC is equal to the design value calculated for that three year period
3. For monitors with less than three years of consecutive data, no DVC can be estimated

### Step 2 - Calculation of RRF

The guidance requires the calculation of RRF with CMAQ output from grids that are “near” a monitor. Because of the 12 km grid spacing used in the CMAQ simulations, model predictions in a 3X3 grid array centered on the monitoring location are considered “near” that monitor. For each day, the maximum base case and control case concentration within that array is selected for RRF calculation as set forth in the guidance document.

Because photochemical models were found to be less responsive to emission reductions on days of lower simulated ozone concentrations, the guidance recommends applying screening criteria to the daily model predictions at individual monitors to determine whether that day’s predictions are to be used to calculate the RRF or not. Only “high ozone days” are to be selected, i.e. days with ozone values that are greater than 60ppb.

**RRF = (average control case over high ozone days selected based on base case concentrations) / (average base case over selected high ozone days)**

In addition, the guidance recommends that preferably ten or more “high ozone days”, as identified below, be selected for RRF calculation. In no case can the RRF be calculated with fewer than five “high ozone days”.

The following describes the logic with which NYSDEC implemented these screening criteria into its FORTRAN code for RRF calculation:

1. Selecting concentrations from grid cells surrounding the monitor
   1. Determine the grid cell in which the monitor is located and include the surrounding 8 grid cells to form a 3X3 grid cell array.
   2. Determine daily maximum 8-hr ozone concentrations for each day for each of the 9 grid cells for both base case and control case.
   3. For each day, pick the highest daily maximum 8-hr ozone value out of all 9 grid cells. This is the daily maximum 8-hr ozone concentration for that monitor for that day to be used in RRF calculations (following the screening criteria listed below).
   4. This is done for the base case only. For the future case the same grid cell is used regardless of whether it is the highest or not.
2. Selecting modeling days to be used in the RRF computation (again done on a monitor-by-monitor basis)
   1. Starting with an ozone threshold (TO3) of 75 ppb and a minimum required number of days (Dmin) of 10, determine all days for which the simulated base case concentration (as determined in step (a) is at or above the threshold TO3.
   2. If the number of such days is greater to or equal Dmin, identify these days and proceed to step (c). Otherwise, continue to b(iii), below.
   3. Lower the threshold (TO3) by 1 ppb interval and go back to b(i) to identify the days. If the minimum number of days is not reached, then reduce that requirement by 1 (but no lower than 5 days) and TO3 ≥60 ppb, and go back to b(i). Otherwise proceed to b(iv) below.
   4. Stop. No RRF can be calculated for this monitor because there were less than 5 days with base case daily maximum concentration ≥60 ppb.
3. RRF computation: Compute the RRF by averaging the daily maximum 8-hr ozone concentrations for base case and control case determined in step (a) over all of the days determined in step (b). The RRF is the ratio of average control case concentrations over average base case concentrations.

### Step 3 - Computation of DVF

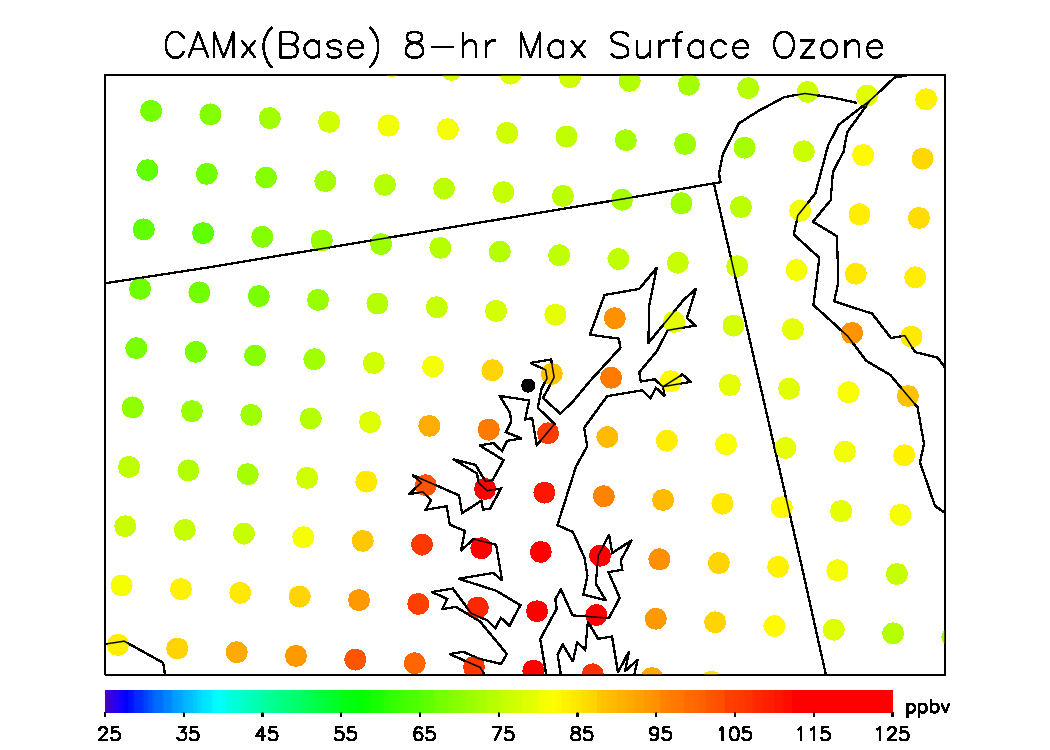
Compute DVF as the product of DVC from step (1) and RRF from step (2). Note, the following conventions on numerical precision (truncation, rounding) were applied:

1. DV are truncated in accordance with 40 CFR Part 50.10, Appendix I. This applies to the 2009, 2010, and 2011 design values.
2. DVC (averages of design values over multiple years) are calculated in ppb and carried to 1 significant digit
3. RRF are calculated and carried to three significant digits
4. DVF is calculated by multiplying DVC with RRF, followed by truncation.

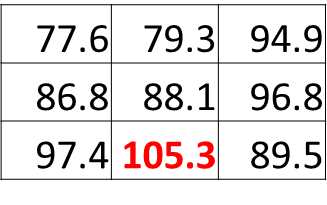
## Land-Water Interface Issues

When monitors are located so as to result in one or more of the 8 additional grid cells falling over a body of water OTC has found that those monitors are often not responsive to changes in emissions. Research conducted by the University of Maryland on the calculation of future design values has demonstrated some potential flaws with EPA modeling guidance in regards to calculating RRFs for these particular monitors.

Figure ‑: Modeled Ozone on July 7, 2011 near Edgewood, MD (Monitor #240251001)



July 7, 2011



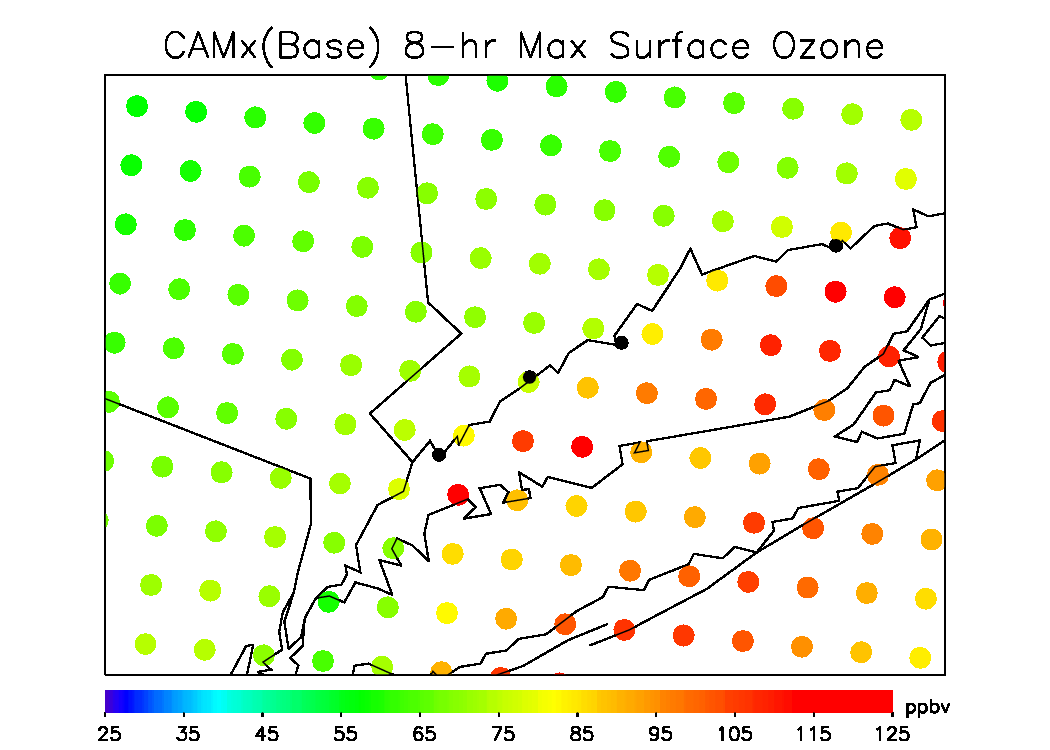
2011 8-hr max Ozone

It is often the case that due to slower dry deposition of ozone, fewer clouds being over bodies of water, PBL venting, PBL height, and high emissions from marine vessels, ozone measurements are much higher over bodies of water than nearby land masses (Goldberg et al. 2014; Loughner et al. 2011, 2014). As a result the maximum values in the 3x3 grid occur in a grid cell over water where ozone pollution is higher and less responsive to changes in emissions.

Since people are not generally exposed to the high levels of ozone that occurs over bodies of water for eight hours, there is less of a need to evaluate these values in regards to the health based ozone standard, yet they are included in modeled design value calculations due to way the 3x3 grid is employed in the default method for calculated projected ozone values.

An example of the misalignment created by the default modeled attainment test can be seen in Figure 9‑1. In this case, the grid cell geographically nearest to the monitor models an 8 hour maximum of 88.1ppb, but the maximum grid cell is largely over water and reads 17.2 ppb higher. This results in modeled ozone calculations on high ozone days that don’t correlate well with monitored data. Similar issues are illustrated in the Long Island Sound in Figure 9‑2.

Figure ‑: Modeled Ozone on July 2, 2011 near monitors in Southern Connecticut



July 22, 2011

This problem can be seen to a greater extent when comparing Figure 9‑3 and Figure 9‑4. The former figure relies on the nearest grid cell for calculations and the latter figure relies on the technique recommended in EPA guidance. The former technique results in calculations that are much less biased, have a lower RMSE, and correspond well to the 1:1 line.

|  |  |
| --- | --- |
| Figure 9‑3: Modeled vs Observed 8-hour maximum Ozone at Edgewood, MD calculated using nearest grid cell (Monitor #240251001)  scatterplot_camxvsMDE_edgewood_8hrmax_2011_V2.png | Figure 9‑4: Modeled vs Observed 8-hour maximum Ozone at Edgewood, MD calculated using nearest maximum from 3x3 grid (Monitor #240251001)  scatterplot_camxvsMDE_edgewood_8hrmax_2011_V2_max.png |

Another technique that could be used to correct potential inaccuracies in calculation of design values at monitors at the land-water interface involves removing grid cells that are of a certain percentage of water. This can be done prior to running the algorithm discussed earlier in the document by applying a mask that contains cells considered to be water cells to the grid and zeroing them out so that they cannot be considered the maximum. Determination of what percentage of the grid cell must be water to be removed should be left to the state submitting the demonstration.

To analyze this technique NYSDEC removed any grid cell that was considered water in the mask provided with the WRF 3.4 package and recalculated the design values. This technique was tested using the Alpha 2 inventory. The results are shown for 10 monitors (3 in Connecticut, 5 in New York, and 1 each in Maryland and New Jersey) in Figure 9‑5 though Figure 9‑24, with the odd numbered figures being those corresponding to values calculated using all of the grid cells and the even numbered figures having the cells containing water removed. The one monitor in New Jersey acts as a control in this case since it is inland and will not be impacted by water grid cells.

At every monitor, except #340150002, removing the water cells resulted in a reduction in the maximum 8-hr ozone on the days examined. #340150002 also happens to be the only one of the 10 monitors examined that had 2011 8-hr maximums that were not grossly overpredicted from the 2011 observed monitors. The other nine monitors saw dramatic improvements in performance on the 10 days examined. When including the water cells the 2011 8-hr modeled values over-predicted observed by as much as 80ppb, often in the 40ppb range, with under-prediction only occurring a few times. However, the over-prediction once the water cells were removed in the worst case was brought down to 40 ppb and some monitors had as many days under-predicted as over-predicted.

|  |  |
| --- | --- |
| Figure 9‑5: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090010017 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑6: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090010017 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑7: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090013007 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑8: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090013007 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑9: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090019003 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑10: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #090019003 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑11: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #240251001 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑12: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #240251001 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑13: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #340150002 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑14: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #340150002 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑15: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360050133 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑16: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360050133 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑17: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360810124 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑18: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360810124 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑19: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360850067 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑20: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #360850067 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑21: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #361030002 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑22: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #361030002 using less water grid cells for 10 selected days ordered by 2011 8-hr max |
| Figure 9‑23: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #361192004 using all grid cells for 10 selected days ordered by 2011 8-hr max | Figure 9‑24: Observed and modeled 8-hr ozone (ppb) for 2011/2018 at monitor #361192004 using less water grid cells for 10 selected days ordered by 2011 8-hr max |

When 2018 projections were examined there was a reduction in future projected ozone at all of the monitors, anywhere from 1 to 12 ppb, except the New Jersey monitor, which was not expected to change given its inland location (Table 9‑1).

Table 9‑1: 2018 ozone projections for 10 key monitors with and without water grids cells

|  |  |  |  |
| --- | --- | --- | --- |
| Monitor ID | DVC | DVF 2018 | DVF 2018 (less water) |
| #090010017 | 80.3 | 80 | 73 |
| #090013007 | 84.3 | 78 | 75 |
| #090019003 | 83.7 | 84 | 76 |
| #240251001 | 90 | 81 | 80 |
| #340150002 | 84.3 | 75 | 75 |
| #360050133 | 74 | 75 | 68 |
| #360810124 | 78 | 78 | 73 |
| #360850067 | 81.3 | 77 | 73 |
| #361030002 | 83.3 | 82 | 78 |
| #361192004 | 75.3 | 78 | 68 |

While the OTC Modeling Committee does not believe that following EPA’s guidance for calculating RRFs is problematic in most instances, monitors such as Edgewood, MD or those along the Long Island Sound should be analyzed in several ways in order to determine a method that produces the least biased results with the lowest error. Examples of some of the methods that could be used to reevaluate monitors at the land-water interface are:

1. Choosing the nearest grid cell to the monitor rather than use the 9 cell grid.
2. Averaging the 9 cell grid rather than using the maximum.
3. Using the maximum value from the 9 cell grid, but exclude grid cells over water though a mask or another technique.

## References

Goldberg, DL, Loughner, CP, Tzortziou, M, Stehr, JW, Pickering, KE, Marufu, LT and Dickerson, RR 2014, ‘Higher surface ozone concentrations over the Chesapeake Bay than over the adjacent land: Observations and models from the DISCOVER-AQ and CBODAQ campaigns’, *Atmospheric Environment*, vol. 84, pp. 9–19.

Loughner, CP, Allen, DJ, Pickering, KE, Zhang, D-L, Shou, Y-X and Dickerson, RR 2011, ‘Impact of fair-weather cumulus clouds and the Chesapeake Bay breeze on pollutant transport and transformation’, *Atmospheric Environment*, vol. 45, no. 24, pp. 4060–4072.

Loughner, CP, Tzortziou, M, Follette-Cook, M, Pickering, KE, Goldberg, D, Satam, C, Weinheimer, A, Crawford, JH, Knapp, DJ, Montzka, DD, Diskin, GS and Dickerson, RR 2014, ‘Impact of Bay-Breeze Circulations on Surface Air Quality and Boundary Layer Export’, *Journal of Applied Meteorology and Climatology*, vol. 53, no. 7, pp. 1697–1713.

US EPA 2014, ‘Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze’, accessed from <https://www3.epa.gov/ttn/scram/guidance/guide/Draft\_O3-PM-RH\_Modeling\_Guidance-2014.pdf>.

# Projected 8-hour Ozone Air Quality 0ver the Ozone Transport Region

## Overview

The US EPA guidance recommends the use of relative reduction factor (RRF) approach to demonstrate the attainment of the 8-hr ozone NAAQS (US EPA 2014). The OTC Modeling Committee implemented this approach in performing attainment assessment of the OTC areas.

## Ozone Results

As described in Section 9, the RRFs were determined for all monitors for future year simulations with emissions data from the Alpha and Alpha 2 inventories for 2018 and Beta for 2017 inventory. The base DVC for 2011 representing the number of DVs estimated on the basis of 3-year averages available from 2009 to 2013 are listed in Table 8‑1 along with the RRF and future year projected ozone concentrations for each monitor identified by its AIRS ID. More information concerning the air quality monitors is in Appendix C. Projected results are provided for Alpha, Alpha 2, and Beta inventories. The values in red represent DVC or DVF that exceed the 75 ppb 8-hr ozone NAAQS.

Table 10‑1: Base case modeling for 2018 Alpha, 2018 Alpha 2, and 2017 Beta inventories

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **OTC** | **State** | **AQS Code** | **DVC** | **2018 Alpha** | | **2018 Alpha 2** | | **2017 Beta** | |
| **DVF** | **RRF** | **DVF** | **RRF** | **DVF** | **RRF** |
| OTR | **CT** | 90010017 | 80.3 | 80.003 | 0.996 | 80.000 | 0.997 |  |  |
| 90011123 | 81.3 | 73.007 | 0.898 | 72.000 | 0.889 |  |  |
| 90013007 | 84.3 | 77.564 | 0.920 | 78.000 | 0.928 |  |  |
| 90019003 | 83.7 | 84.487 | 1.009 | 84.000 | 1.013 |  |  |
| 90031003 | 73.7 | 65.998 | 0.896 | 65.000 | 0.890 |  |  |
| 90050005 | 70.3 | 63.235 | 0.900 | 62.000 | 0.895 |  |  |
| 90070007 | 79.3 | 70.894 | 0.894 | 70.000 | 0.889 |  |  |
| 90090027 | 74.3 | 68.378 | 0.920 | 69.000 | 0.938 |  |  |
| 90099002 | 85.7 | 76.324 | 0.891 | 77.000 | 0.899 |  |  |
| 90110124 | 80.3 | 70.134 | 0.873 | 71.000 | 0.887 |  |  |
| 90131001 | 75.3 | 67.371 | 0.895 | 66.000 | 0.888 |  |  |
| **CT Max** |  |  | **84.487** | **1.009** | **84.000** | **1.013** |  |  |
| **DC** | 110010041 | 76 | 67.002 | 0.882 | 66.000 | 0.879 |  |  |
| 110010043 | 80.7 | 71.145 | 0.882 | 70.000 | 0.879 |  |  |
| **DC Max** |  |  | **71.145** | **0.882** | **70.000** | **0.879** |  |  |
| **DE** | 100010002 | 74.3 | 67.160 | 0.904 | 67.000 | 0.906 |  |  |
| 100031007 | 76.3 | 68.311 | 0.895 | 68.000 | 0.894 |  |  |
| 100031010 | 78 | 69.966 | 0.897 | 69.000 | 0.896 |  |  |
| 100031013 | 77.7 | 69.378 | 0.893 | 69.000 | 0.891 |  |  |
| 100032004 | 75 |  |  | 66.000 | 0.891 |  |  |
| 100051002 | 77.3 | 68.596 | 0.887 | 68.000 | 0.886 |  |  |
| 100051003 | 77.7 | 69.596 | 0.896 | 69.000 | 0.900 |  |  |
| **DE Max** |  |  | **69.966** | **0.904** | **69.000** | **0.906** |  |  |
| **MA** | 250010002 | 73 | 65.999 | 0.904 | 66.000 | 0.911 |  |  |
| 250034002 | 69 | 62.769 | 0.910 | 62.000 | 0.906 |  |  |
| 250051002 | 74 | 66.741 | 0.902 | 67.000 | 0.918 |  |  |
| 250070001 | 77 | 70.794 | 0.919 | 72.000 | 0.938 |  |  |
| 250092006 | 71 | 61.820 | 0.871 | 62.000 | 0.874 |  |  |
| 250094005 | 70 |  |  | 63.000 | 0.910 |  |  |
| 250095005 | 69.3 | 62.467 | 0.901 | 62.000 | 0.908 |  |  |
| 250130008 | 73.7 | 65.423 | 0.888 | 65.000 | 0.886 |  |  |
| 250150103 | 64.7 | 57.816 | 0.894 | 57.000 | 0.888 |  |  |
| 250154002 | 71.3 | 62.808 | 0.881 | 62.000 | 0.879 |  |  |
| 250170009 | 67.3 | 60.146 | 0.894 | 60.000 | 0.895 |  |  |
| 250171102 | 67 | 59.436 | 0.887 | 59.000 | 0.887 |  |  |
| 250213003 | 72.3 | 60.696 | 0.840 | 61.000 | 0.856 |  |  |
| 250250041 | 68.3 | 57.317 | 0.839 | 58.000 | 0.851 |  |  |
| 250250042 | 60.7 | 50.946 | 0.839 | 51.000 | 0.855 |  |  |
| 250270015 | 68.3 | 60.896 | 0.892 | 60.000 | 0.890 |  |  |
| 250270024 | 69 | 60.955 | 0.883 | 60.000 | 0.882 |  |  |
| **MA Max** |  |  | **70.794** | **0.919** | **72.000** | **0.938** |  |  |
| **MD** | 240030014 | 83 | 72.393 | 0.872 | 72.000 | 0.870 |  |  |
| 240051007 | 79 | 70.768 | 0.896 | 70.000 | 0.894 |  |  |
| 240053001 | 80.7 | 74.744 | 0.926 | 74.000 | 0.924 |  |  |
| 240090011 | 79.7 | 73.770 | 0.926 | 73.000 | 0.922 |  |  |
| 240130001 | 76.3 | 67.587 | 0.886 | 67.000 | 0.884 |  |  |
| 240150003 | 83 | 74.559 | 0.898 | 74.000 | 0.897 |  |  |
| 240170010 | 79 | 70.887 | 0.897 | 70.000 | 0.895 |  |  |
| 240199991 | 75 |  |  | 68.000 | 0.907 |  |  |
| 240210037 | 76.3 | 67.899 | 0.890 | 67.000 | 0.888 |  |  |
| 240230002 | 72 | 61.301 | 0.851 | 61.000 | 0.850 |  |  |
| 240251001 | 90 | 82.053 | 0.912 | 81.000 | 0.909 |  |  |
| 240259001 | 79.3 | 71.243 | 0.898 | 70.000 | 0.894 |  |  |
| 240290002 | 78.7 | 69.854 | 0.888 | 69.000 | 0.886 |  |  |
| 240313001 | 75.7 | 66.866 | 0.883 | 66.000 | 0.881 |  |  |
| 240330030 | 79 | 68.801 | 0.871 | 68.000 | 0.868 |  |  |
| 240338003 | 82.3 | 72.037 | 0.875 | 71.000 | 0.873 |  |  |
| 240339991 | 80 |  |  | 69.000 | 0.871 |  |  |
| 240430009 | 72.7 | 63.838 | 0.878 | 63.000 | 0.874 |  |  |
| 245100054 | 73.7 | 68.401 | 0.928 | 68.000 | 0.926 |  |  |
| **MD Max** |  |  | **82.053** | **0.928** | **81.000** | **0.926** |  |  |
| **ME** | 230010014 | 61 | 56.041 | 0.919 | 56.000 | 0.928 |  |  |
| 230031100 | 51.3 |  |  | -8.000 | -9.000 |  |  |
| 230052003 | 69.3 | 63.202 | 0.912 | 63.000 | 0.913 |  |  |
| 230090102 | 71.7 | 66.394 | 0.926 | 68.000 | 0.953 |  |  |
| 230090103 | 66.3 | 61.321 | 0.925 | 63.000 | 0.952 |  |  |
| 230112005 | 62.7 | 56.342 | 0.899 | 55.000 | 0.891 |  |  |
| 230130004 | 67.7 | 62.325 | 0.921 | 63.000 | 0.941 |  |  |
| 230173001 | 54.3 | 49.956 | 0.920 | -8.000 | -9.000 |  |  |
| 230194008 | 57.7 |  |  | -8.000 | -9.000 |  |  |
| 230230006 | 61 | 56.077 | 0.919 | 56.000 | 0.927 |  |  |
| 230290019 | 58.3 | 54.015 | 0.927 | 55.000 | 0.957 |  |  |
| 230290032 | 53 | 49.592 | 0.936 | 50.000 | 0.962 |  |  |
| 230310038 | 60.3 | 54.312 | 0.901 | -8.000 | -9.000 |  |  |
| 230310040 | 64.3 | 58.050 | 0.903 | 58.000 | 0.904 |  |  |
| 230312002 | 73.7 | 66.654 | 0.904 | 65.000 | 0.892 |  |  |
| **ME Max** |  |  | **66.654** | **0.936** | **68.000** | **0.962** |  |  |
| **NH** | 330012004 | 62.3 | 55.771 | 0.895 | 55.000 | 0.892 |  |  |
| 330050007 | 62.3 | 55.341 | 0.888 | 55.000 | 0.884 |  |  |
| 330074001 | 69.3 | 64.303 | 0.928 | 63.000 | 0.916 |  |  |
| 330074002 | 59.7 | 55.396 | 0.928 | 54.000 | 0.916 |  |  |
| 330090010 | 59.7 | 53.891 | 0.903 | 53.000 | 0.900 |  |  |
| 330111011 | 66.3 | 59.319 | 0.895 | 59.000 | 0.895 |  |  |
| 330115001 | 69 | 61.686 | 0.894 | 61.000 | 0.890 |  |  |
| 330131007 | 64.7 | 58.515 | 0.904 | 58.000 | 0.901 |  |  |
| 330150014 | 66 | 60.456 | 0.916 | 60.000 | 0.924 |  |  |
| 330150016 | 66.3 | 60.731 | 0.916 | 61.000 | 0.924 |  |  |
| 330150018 | 68 |  |  | 61.000 | 0.899 |  |  |
| **NH Max** |  |  | **64.303** | **0.928** | **63.000** | **0.924** |  |  |
| **NJ** | 340010006 | 74.3 | 66.350 | 0.893 | 67.000 | 0.905 |  |  |
| 340030006 | 77 | 69.377 | 0.901 | 69.000 | 0.900 |  |  |
| 340071001 | 82.7 | 74.058 | 0.896 | 73.000 | 0.894 |  |  |
| 340110007 | 72 | 64.994 | 0.903 | 64.000 | 0.902 |  |  |
| 340130003 | 78 | 70.418 | 0.903 | 70.000 | 0.905 |  |  |
| 340150002 | 84.3 | 75.828 | 0.900 | 75.000 | 0.898 |  |  |
| 340170006 | 77 | 70.209 | 0.912 | 70.000 | 0.919 |  |  |
| 340190001 | 78 | 69.061 | 0.885 | 68.000 | 0.883 |  |  |
| 340210005 | 78.3 | 70.016 | 0.894 | 69.000 | 0.892 |  |  |
| 340219991 | 76 |  |  | 67.000 | 0.893 |  |  |
| 340230011 | 81.3 | 72.430 | 0.891 | 72.000 | 0.888 |  |  |
| 340250005 | 80 | 72.104 | 0.901 | 72.000 | 0.902 |  |  |
| 340273001 | 76.3 | 67.808 | 0.889 | 67.000 | 0.887 |  |  |
| 340290006 | 82 | 72.455 | 0.884 | 72.000 | 0.882 |  |  |
| 340315001 | 73.3 | 67.062 | 0.915 | 67.000 | 0.917 |  |  |
| 340410007 | 66 |  |  | 57.000 | 0.878 |  |  |
| **NJ Max** |  |  | **75.828** | **0.915** | **75.000** | **0.919** |  |  |
| **NY** | 360010012 | 68 | 61.955 | 0.911 | 61.000 | 0.907 |  |  |
| 360050133 | 74 | 75.051 | 1.014 | 75.000 | 1.020 |  |  |
| 360130006 | 73.3 | 66.578 | 0.908 | 66.000 | 0.904 |  |  |
| 360130011 | 74 | 66.445 | 0.898 | 66.000 | 0.896 |  |  |
| 360150003 | 66.5 | 61.566 | 0.926 | 61.000 | 0.923 |  |  |
| 360270007 | 72 | 63.821 | 0.886 | 63.000 | 0.887 |  |  |
| 360290002 | 71.3 | 65.532 | 0.919 | 65.000 | 0.915 |  |  |
| 360310002 | 70.3 | 64.662 | 0.920 | 54.000 | 1.807 |  |  |
| 360310003 | 67.3 | 61.903 | 0.920 | 60.000 | 0.904 |  |  |
| 360337003 | 45 |  |  | -8.000 | -9.000 |  |  |
| 360410005 | 66 | 59.690 | 0.904 | 59.000 | 0.898 |  |  |
| 360430005 | 62 |  |  | -8.000 | -9.000 |  |  |
| 360450002 | 71.7 | 63.791 | 0.890 | 62.000 | 0.875 |  |  |
| 360530006 | 67 | 61.801 | 0.922 | 61.000 | 0.919 |  |  |
| 360610135 | 73.3 | 73.513 | 1.003 | 74.000 | 1.010 |  |  |
| 360631006 | 72.3 | 67.651 | 0.936 | 65.000 | 0.912 |  |  |
| 360650004 | 61.5 | 56.254 | 0.915 | 55.000 | 0.906 |  |  |
| 360671015 | 69.3 | 63.555 | 0.917 | 63.000 | 0.913 |  |  |
| 360715001 | 67 | 60.468 | 0.903 | 60.000 | 0.902 |  |  |
| 360750003 | 68 | 60.513 | 0.890 | 59.000 | 0.880 |  |  |
| 360790005 | 70 | 62.272 | 0.890 | 61.000 | 0.884 |  |  |
| 360810124 | 78 | 78.187 | 1.002 | 78.000 | 1.010 |  |  |
| 360830004 | 67 | 60.809 | 0.908 | 60.000 | 0.903 |  |  |
| 360850067 | 81.3 | 77.194 | 0.950 | 77.000 | 0.957 |  |  |
| 360870005 | 75 | 68.048 | 0.907 | 68.000 | 0.907 |  |  |
| 360910004 | 67 | 60.481 | 0.903 | 60.000 | 0.900 |  |  |
| 361010003 | 65.3 | 61.167 | 0.937 | 60.000 | 0.932 |  |  |
| 361030002 | 83.3 | 82.217 | 0.987 | 82.000 | 0.986 |  |  |
| 361030004 | 78 | 71.058 | 0.911 | 71.000 | 0.917 |  |  |
| 361030009 | 78.7 | 73.356 | 0.932 | 65.000 | 1.906 |  |  |
| 361111005 | 69 | 64.011 | 0.928 | 63.000 | 0.920 |  |  |
| 361173001 | 65 | 59.157 | 0.910 | 57.000 | 0.891 |  |  |
| 361192004 | 75.3 | 78.448 | 1.042 | 78.000 | 1.041 |  |  |
| **NY Max** |  |  | **82.217** | **1.042** | **82.000** | **1.041** |  |  |
| **PA** | 420030008 | 76.3 | 71.402 | 0.936 | 70.000 | 0.926 |  |  |
| 420030010 | 73.7 | 68.968 | 0.936 | 68.000 | 0.926 |  |  |
| 420030067 | 75.7 | 69.629 | 0.920 | 69.000 | 0.913 |  |  |
| 420031005 | 80.7 | 74.260 | 0.920 | 73.000 | 0.913 |  |  |
| 420050001 | 74.3 | 68.668 | 0.924 | 67.000 | 0.915 |  |  |
| 420070002 | 70.7 | 65.595 | 0.928 | 65.000 | 0.927 |  |  |
| 420070005 | 74.7 | 69.859 | 0.935 | 69.000 | 0.930 |  |  |
| 420070014 | 72.3 | 67.275 | 0.931 | 66.000 | 0.923 |  |  |
| 420110006 | 71.7 | 63.627 | 0.887 | 63.000 | 0.885 |  |  |
| 420110011 | 76.3 | 67.167 | 0.880 | 66.000 | 0.878 |  |  |
| 420130801 | 72.7 | 67.982 | 0.935 | 67.000 | 0.933 |  |  |
| 420170012 | 80.3 | 71.579 | 0.891 | 71.000 | 0.890 |  |  |
| 420210011 | 70.3 | 66.033 | 0.939 | 65.000 | 0.931 |  |  |
| 420270100 | 71 | 66.193 | 0.932 | 66.000 | 0.931 |  |  |
| 420279991 | 72 |  |  | 66.000 | 0.929 |  |  |
| 420290100 | 76.3 | 69.074 | 0.905 | 68.000 | 0.904 |  |  |
| 420334000 | 72.3 | 68.107 | 0.942 | 67.000 | 0.940 |  |  |
| 420430401 | 69 | 62.707 | 0.909 | 62.000 | 0.907 |  |  |
| 420431100 | 74.7 | 67.223 | 0.900 | 67.000 | 0.897 |  |  |
| 420450002 | 75.7 | 68.054 | 0.899 | 67.000 | 0.898 |  |  |
| 420490003 | 74 | 65.904 | 0.891 | 66.000 | 0.894 |  |  |
| 420550001 | 67 | 60.662 | 0.905 | 60.000 | 0.903 |  |  |
| 420590002 | 69 | 62.528 | 0.906 | 62.000 | 0.902 |  |  |
| 420630004 | 75.7 | 70.378 | 0.930 | 70.000 | 0.926 |  |  |
| 420690101 | 71 | 63.502 | 0.894 | 63.000 | 0.893 |  |  |
| 420692006 | 68.7 | 61.445 | 0.894 | 61.000 | 0.893 |  |  |
| 420710007 | 77 | 70.563 | 0.916 | 70.000 | 0.915 |  |  |
| 420710012 | 78 | 71.050 | 0.911 | 70.000 | 0.909 |  |  |
| 420730015 | 71 | 65.206 | 0.918 | 64.000 | 0.912 |  |  |
| 420750100 | 76 |  |  | 67.000 | 0.891 |  |  |
| 420770004 | 76 | 67.321 | 0.886 | 67.000 | 0.884 |  |  |
| 420791100 | 65 | 57.740 | 0.888 | 57.000 | 0.887 |  |  |
| 420791101 | 64.3 | 56.944 | 0.886 | 56.000 | 0.884 |  |  |
| 420810100 | 67 | 60.849 | 0.908 | 60.000 | 0.907 |  |  |
| 420850100 | 76.3 | 68.334 | 0.896 | 68.000 | 0.893 |  |  |
| 420890002 | 66.7 | 59.143 | 0.887 | 59.000 | 0.885 |  |  |
| 420910013 | 76.3 | 68.678 | 0.900 | 68.000 | 0.899 |  |  |
| 420950025 | 76 | 67.290 | 0.885 | 67.000 | 0.884 |  |  |
| 420958000 | 69.7 | 62.054 | 0.890 | 61.000 | 0.889 |  |  |
| 420990301 | 68.3 | 63.020 | 0.923 | 62.000 | 0.920 |  |  |
| 421010004 | 66 | 59.756 | 0.905 | 59.000 | 0.904 |  |  |
| 421010024 | 83.3 | 75.137 | 0.902 | 75.000 | 0.901 |  |  |
| 421011002 | 80 |  |  | 72.000 | 0.901 |  |  |
| 421119991 | 65 |  |  | 56.000 | 0.865 |  |  |
| 421174000 | 69.7 | 65.176 | 0.935 | 65.000 | 0.933 |  |  |
| 421250005 | 70 | 63.959 | 0.914 | 63.000 | 0.908 |  |  |
| 421250200 | 70.7 | 64.132 | 0.907 | 63.000 | 0.900 |  |  |
| 421255001 | 70.3 | 64.838 | 0.922 | 64.000 | 0.915 |  |  |
| 421290006 | 71.7 | 66.007 | 0.921 | 65.000 | 0.913 |  |  |
| 421290008 | 71 | 64.688 | 0.911 | 64.000 | 0.905 |  |  |
| 421330008 | 72.3 | 66.516 | 0.920 | 66.000 | 0.919 |  |  |
| 421330011 | 74.3 | 67.955 | 0.915 | 67.000 | 0.913 |  |  |
| **PA Max** |  |  | **75.137** | **0.942** | **75.000** | **0.940** |  |  |
| **RI** | 440030002 | 73.7 | 67.067 | 0.910 | 67.000 | 0.913 |  |  |
| 440071010 | 74 | 67.407 | 0.911 | 67.000 | 0.911 |  |  |
| 440090007 | 76.3 | 68.525 | 0.898 | 69.000 | 0.914 |  |  |
| **RI Max** |  |  | **68.525** | **0.911** | **69.000** | **0.914** |  |  |
| **VA** | 510130020 | 81.7 | 72.541 | 0.888 | 72.000 | 0.886 |  |  |
| 510590030 | 82.3 | 72.737 | 0.884 | 72.000 | 0.882 |  |  |
| 511071005 | 73 | 65.620 | 0.899 | 65.000 | 0.896 |  |  |
| 511530009 | 70 | 63.336 | 0.905 | 63.000 | 0.903 |  |  |
| 515100009 | 80 | 70.664 | 0.883 | 70.000 | 0.881 |  |  |
| **VA Max** |  |  | **72.737** | **0.905** | **72.000** | **0.903** |  |  |
| **VT** | 500030004 | 63.7 | 57.973 | 0.910 | 57.000 | 0.905 |  |  |
| **VT Max** |  |  | **57.973** | **0.910** | **57.000** | **0.905** |  |  |
| **Outside-OTR** | **AL** | 10331002 | 65 | 49.017 | 0.754 | 48.000 | 0.751 |  |  |
| 10499991 | 66 |  |  | 58.000 | 0.888 |  |  |
| 10510001 | 66.3 | 57.529 | 0.868 | 57.000 | 0.861 |  |  |
| 10550011 | 61.7 | 52.649 | 0.853 | 52.000 | 0.853 |  |  |
| 10730023 | 72.3 | 62.503 | 0.865 | 62.000 | 0.864 |  |  |
| 10731003 | 72 | 63.187 | 0.878 | 63.000 | 0.877 |  |  |
| 10731005 | 75.3 | 65.488 | 0.870 | 65.000 | 0.870 |  |  |
| 10731009 | 72 | 65.390 | 0.908 | 65.000 | 0.912 |  |  |
| 10731010 | 73.7 | 62.910 | 0.854 | 62.000 | 0.854 |  |  |
| 10732006 | 75 | 63.743 | 0.850 | 63.000 | 0.850 |  |  |
| 10735002 | 72 | 62.402 | 0.867 | 62.000 | 0.867 |  |  |
| 10735003 | 71 | 62.700 | 0.883 | 62.000 | 0.887 |  |  |
| 10736002 | 76.7 | 66.790 | 0.871 | 66.000 | 0.871 |  |  |
| 10890014 | 70.7 | 60.632 | 0.858 | 60.000 | 0.857 |  |  |
| 11011002 | 67.3 | 57.656 | 0.857 | 57.000 | 0.857 |  |  |
| 11030011 | 68.7 | 60.655 | 0.883 | 60.000 | 0.883 |  |  |
| 11130002 | 66 | 57.341 | 0.869 | 57.000 | 0.869 |  |  |
| 11170004 | 73.3 | 61.733 | 0.842 | 61.000 | 0.842 |  |  |
| 11190002 | 61 | 55.583 | 0.911 | 55.000 | 0.911 |  |  |
| 11250010 | 58.7 | 51.908 | 0.884 | 51.000 | 0.884 |  |  |
| **AL Max** |  |  | **66.790** | **0.911** | **66.000** | **0.912** |  |  |
| **AR** | 50350005 | 77.3 | 68.488 | 0.886 | 68.000 | 0.886 |  |  |
| 51010002 | 68 | 64.410 | 0.947 | 64.000 | 0.942 |  |  |
| 51130003 | 72.3 | 72.069 | 0.997 | 72.000 | 0.996 |  |  |
| 51190007 | 72.3 | 64.007 | 0.885 | 64.000 | 0.885 |  |  |
| 51191002 | 75.7 | 67.396 | 0.890 | 67.000 | 0.890 |  |  |
| 51191008 | 73 | 65.795 | 0.901 | 65.000 | 0.901 |  |  |
| 51430005 | 71 | 70.794 | 0.997 | 70.000 | 0.997 |  |  |
| **AR Max** |  |  | **72.069** | **0.997** | **72.000** | **0.997** |  |  |
| **GA** | 130210012 | 72.3 | 60.609 | 0.838 | 60.000 | 0.839 |  |  |
| 130510021 | 63.3 | 57.084 | 0.902 | 57.000 | 0.912 |  |  |
| 130550001 | 66.3 | 57.442 | 0.866 | 57.000 | 0.870 |  |  |
| 130590002 | 70.7 | 59.756 | 0.845 | 59.000 | 0.845 |  |  |
| 130670003 | 76 | 63.475 | 0.835 | 64.000 | 0.844 |  |  |
| 130730001 | 68.7 | 59.522 | 0.866 | 59.000 | 0.867 |  |  |
| 130770002 | 65 | 52.501 | 0.808 | 52.000 | 0.808 |  |  |
| 130850001 | 66.3 | 56.547 | 0.853 | 56.000 | 0.851 |  |  |
| 130890002 | 77.3 | 65.620 | 0.849 | 65.000 | 0.849 |  |  |
| 130970004 | 73.3 | 61.257 | 0.836 | 61.000 | 0.840 |  |  |
| 131210055 | 81 | 68.275 | 0.843 | 68.000 | 0.844 |  |  |
| 131270006 | 60 | 56.856 | 0.948 | 57.000 | 0.963 |  |  |
| 131350002 | 76.7 | 64.328 | 0.839 | 64.000 | 0.838 |  |  |
| 131510002 | 80 | 67.928 | 0.849 | 67.000 | 0.849 |  |  |
| 132130003 | 70.3 | 60.381 | 0.859 | 60.000 | 0.857 |  |  |
| 132150008 | 66 | 57.341 | 0.869 | 57.000 | 0.869 |  |  |
| 132230003 | 70.7 | 62.159 | 0.879 | 62.000 | 0.885 |  |  |
| 132319991 | 72 |  |  | 60.000 | 0.844 |  |  |
| 132450091 | 70 | 60.018 | 0.857 | 60.000 | 0.868 |  |  |
| 132470001 | 77 | 64.457 | 0.837 | 64.000 | 0.837 |  |  |
| 132611001 | 64.7 | 57.285 | 0.885 | 57.000 | 0.887 |  |  |
| **GA Max** |  |  | **68.275** | **0.948** | **68.000** | **0.963** |  |  |
| **IA** | 190170011 | 64 | 62.349 | 0.974 | 62.000 | 0.981 |  |  |
| 190450021 | 66.7 | 63.258 | 0.948 | 63.000 | 0.948 |  |  |
| 191130028 | 64.3 | 61.876 | 0.962 | 61.000 | 0.962 |  |  |
| 191130033 | 64 | 61.427 | 0.960 | 61.000 | 0.958 |  |  |
| 191130040 | 62.7 | 60.487 | 0.965 | 60.000 | 0.965 |  |  |
| 191530030 | 59.7 | 58.518 | 0.980 | 58.000 | 0.980 |  |  |
| 191630014 | 63 | 59.321 | 0.942 | 59.000 | 0.941 |  |  |
| 191630015 | 66 |  |  | 61.000 | 0.938 |  |  |
| 191690011 | 61.3 | 60.362 | 0.985 | 60.000 | 0.985 |  |  |
| 191770006 | 65.7 | 64.189 | 0.977 | 64.000 | 0.979 |  |  |
| 191810022 | 63.7 | 63.413 | 0.996 | 63.000 | 0.996 |  |  |
| **IA Max** |  |  | **64.189** | **0.996** | **64.000** | **0.996** |  |  |
| **IL** | 170010007 | 67 | 63.040 | 0.941 | 64.000 | 0.961 |  |  |
| 170190007 | 71 |  |  | 65.000 | 0.921 |  |  |
| 170230001 | 66 | 60.093 | 0.911 | 59.000 | 0.907 |  |  |
| 170310001 | 72 | 67.111 | 0.932 | 67.000 | 0.932 |  |  |
| 170310032 | 77.7 | 67.413 | 0.868 | 65.000 | 0.846 |  |  |
| 170310064 | 71.3 | 61.860 | 0.868 | 60.000 | 0.846 |  |  |
| 170310076 | 71.7 | 66.444 | 0.927 | 66.000 | 0.927 |  |  |
| 170311003 | 69.7 | 55.328 | 0.794 | 53.000 | 0.774 |  |  |
| 170311601 | 71.3 | 66.815 | 0.937 | 66.000 | 0.934 |  |  |
| 170314002 | 71.7 | 57.805 | 0.806 | 58.000 | 0.813 |  |  |
| 170314007 | 65.7 | 53.585 | 0.816 | 52.000 | 0.799 |  |  |
| 170314201 | 75.7 | 61.741 | 0.816 | 51.000 | 1.599 |  |  |
| 170317002 | 76 | 60.792 | 0.800 | 58.000 | 0.776 |  |  |
| 170436001 | 66.3 | 62.441 | 0.942 | 62.000 | 0.938 |  |  |
| 170491001 | 68.3 | 62.187 | 0.911 | 61.000 | 0.907 |  |  |
| 170650002 | 74.3 | 69.582 | 0.937 | 69.000 | 0.941 |  |  |
| 170831001 | 76 | 67.336 | 0.886 | 67.000 | 0.887 |  |  |
| 170859991 | 68 |  |  | 64.000 | 0.946 |  |  |
| 170890005 | 69.7 | 66.870 | 0.959 | 66.000 | 0.956 |  |  |
| 170971007 | 79.3 | 61.196 | 0.772 | 61.000 | 0.774 |  |  |
| 171110001 | 69.7 | 65.539 | 0.940 | 65.000 | 0.946 |  |  |
| 171132003 | 70.3 | 64.753 | 0.921 | 65.000 | 0.925 |  |  |
| 171150013 | 71.3 | 65.026 | 0.912 | 65.000 | 0.917 |  |  |
| 171170002 | 71.3 | 62.887 | 0.882 | 63.000 | 0.886 |  |  |
| 171190008 | 77 | 69.046 | 0.897 | 68.000 | 0.894 |  |  |
| 171191009 | 78.3 | 68.278 | 0.872 | 68.000 | 0.873 |  |  |
| 171193007 | 76.7 | 68.777 | 0.897 | 68.000 | 0.894 |  |  |
| 171199991 | 76 |  |  | 67.000 | 0.892 |  |  |
| 171430024 | 61.7 | 57.042 | 0.925 | 57.000 | 0.925 |  |  |
| 171431001 | 70.7 | 65.362 | 0.925 | 65.000 | 0.925 |  |  |
| 171570001 | 67.7 | 63.110 | 0.932 | 63.000 | 0.932 |  |  |
| 171613002 | 58.3 | 54.884 | 0.941 | 54.000 | 0.938 |  |  |
| 171630010 | 74.7 | 66.304 | 0.888 | 66.000 | 0.888 |  |  |
| 171670014 | 72 |  |  | 64.000 | 0.897 |  |  |
| 171971011 | 64 | 60.326 | 0.943 | 60.000 | 0.943 |  |  |
| 172012001 | 67.3 | 63.141 | 0.938 | 62.000 | 0.934 |  |  |
| **IL Max** |  |  | **69.582** | **0.959** | **69.000** | **0.961** |  |  |
| **IN** | 180030002 | 68.3 | 61.470 | 0.900 | 61.000 | 0.898 |  |  |
| 180030004 | 69.3 | 62.633 | 0.904 | 62.000 | 0.898 |  |  |
| 180110001 | 72.3 | 65.178 | 0.902 | 65.000 | 0.903 |  |  |
| 180150002 | 69 | 63.314 | 0.918 | 62.000 | 0.906 |  |  |
| 180190008 | 78 | 70.021 | 0.898 | 69.000 | 0.890 |  |  |
| 180350010 | 68.7 | 60.614 | 0.882 | 60.000 | 0.879 |  |  |
| 180390007 | 67.7 | 62.230 | 0.919 | 61.000 | 0.915 |  |  |
| 180431004 | 76 | 67.169 | 0.884 | 67.000 | 0.886 |  |  |
| 180550001 | 77 | 70.925 | 0.921 | 70.000 | 0.920 |  |  |
| 180570006 | 71 | 63.488 | 0.894 | 63.000 | 0.890 |  |  |
| 180590003 | 66.7 | 59.356 | 0.890 | 58.000 | 0.883 |  |  |
| 180630004 | 67 | 59.503 | 0.888 | 59.000 | 0.891 |  |  |
| 180690002 | 65 | 59.079 | 0.909 | 58.000 | 0.907 |  |  |
| 180710001 | 66 | 59.935 | 0.908 | 59.000 | 0.903 |  |  |
| 180810002 | 69 | 61.686 | 0.894 | 61.000 | 0.896 |  |  |
| 180839991 | 73 |  |  | 66.000 | 0.916 |  |  |
| 180890022 | 66.7 | 58.916 | 0.883 | 57.000 | 0.862 |  |  |
| 180890030 | 69.7 | 61.197 | 0.878 | 60.000 | 0.873 |  |  |
| 180892008 | 68 | 59.704 | 0.878 | 59.000 | 0.873 |  |  |
| 180910005 | 79.3 | 69.911 | 0.882 | 69.000 | 0.882 |  |  |
| 180910010 | 69.7 | 62.876 | 0.902 | 62.000 | 0.902 |  |  |
| 180950010 | 68.3 | 60.131 | 0.880 | 60.000 | 0.879 |  |  |
| 180970050 | 72.7 | 65.008 | 0.894 | 64.000 | 0.893 |  |  |
| 180970057 | 69 | 61.997 | 0.899 | 61.000 | 0.897 |  |  |
| 180970073 | 72 | 64.577 | 0.897 | 64.000 | 0.894 |  |  |
| 180970078 | 69.7 | 62.625 | 0.899 | 62.000 | 0.897 |  |  |
| 181090005 | 69 | 61.210 | 0.887 | 60.000 | 0.880 |  |  |
| 181230009 | 72.7 | 67.938 | 0.935 | 67.000 | 0.925 |  |  |
| 181270024 | 70.3 | 61.934 | 0.881 | 61.000 | 0.873 |  |  |
| 181270026 | 63 | 57.248 | 0.909 | 57.000 | 0.908 |  |  |
| 181290003 | 70.3 | 64.641 | 0.920 | 64.000 | 0.917 |  |  |
| 181410010 | 62.7 | 58.374 | 0.931 | 58.000 | 0.926 |  |  |
| 181410015 | 69.3 | 63.500 | 0.916 | 63.000 | 0.919 |  |  |
| 181411007 | 64 | 58.643 | 0.916 | 58.000 | 0.919 |  |  |
| 181450001 | 74 | 65.453 | 0.885 | 65.000 | 0.889 |  |  |
| 181630013 | 71.7 | 65.663 | 0.916 | 65.000 | 0.915 |  |  |
| 181630021 | 74 | 67.947 | 0.918 | 67.000 | 0.914 |  |  |
| 181670018 | 65.7 | 58.434 | 0.889 | 58.000 | 0.885 |  |  |
| 181670024 | 64 | 56.307 | 0.880 | 56.000 | 0.878 |  |  |
| 181730008 | 71 | 66.563 | 0.938 | 66.000 | 0.935 |  |  |
| 181730009 | 69.7 | 64.912 | 0.931 | 64.000 | 0.927 |  |  |
| 181730011 | 71 | 66.626 | 0.938 | 66.000 | 0.937 |  |  |
| **IN Max** |  |  | **70.925** | **0.938** | **70.000** | **0.937** |  |  |
| **KY** | 210130002 | 63.3 | 56.831 | 0.898 | 57.000 | 0.901 |  |  |
| 210150003 | 68 | 61.547 | 0.905 | 61.000 | 0.902 |  |  |
| 210190017 | 70 | 63.105 | 0.902 | 62.000 | 0.897 |  |  |
| 210290006 | 72.3 | 66.039 | 0.913 | 65.000 | 0.909 |  |  |
| 210373002 | 76.7 | 68.278 | 0.890 | 68.000 | 0.894 |  |  |
| 210430500 | 67 | 60.059 | 0.896 | 59.000 | 0.894 |  |  |
| 210470006 | 70.7 | 62.683 | 0.887 | 62.000 | 0.887 |  |  |
| 210590005 | 76.3 | 71.653 | 0.939 | 71.000 | 0.935 |  |  |
| 210610501 | 72 | 63.842 | 0.887 | 64.000 | 0.897 |  |  |
| 210670012 | 71.3 | 63.478 | 0.890 | 63.000 | 0.885 |  |  |
| 210890007 | 69.7 | 63.016 | 0.904 | 62.000 | 0.901 |  |  |
| 210910012 | 73.7 | 69.691 | 0.946 | 69.000 | 0.940 |  |  |
| 210930006 | 70.3 | 63.249 | 0.900 | 62.000 | 0.893 |  |  |
| 211010014 | 76.3 | 71.089 | 0.932 | 70.000 | 0.930 |  |  |
| 211110027 | 77 | 69.339 | 0.901 | 68.000 | 0.896 |  |  |
| 211110051 | 77.3 | 70.737 | 0.915 | 70.000 | 0.909 |  |  |
| 211110067 | 82 | 74.530 | 0.909 | 74.000 | 0.904 |  |  |
| 211130001 | 70 | 63.084 | 0.901 | 62.000 | 0.896 |  |  |
| 211390003 | 72.3 | 67.579 | 0.935 | 67.000 | 0.938 |  |  |
| 211451024 | 73.7 | 69.418 | 0.942 | 70.000 | 0.953 |  |  |
| 211850004 | 82 | 71.725 | 0.875 | 71.000 | 0.872 |  |  |
| 211930003 | 65.3 | 62.309 | 0.954 | 62.000 | 0.952 |  |  |
| 211950002 | 65.7 | 64.169 | 0.977 | 64.000 | 0.981 |  |  |
| 211990003 | 66.7 | 58.823 | 0.882 | 59.000 | 0.886 |  |  |
| 212130004 | 69.3 | 60.804 | 0.877 | 61.000 | 0.883 |  |  |
| 212218001 | 69 | 61.734 | 0.895 | 62.000 | 0.902 |  |  |
| 212270008 | 64 | 56.698 | 0.886 | 57.000 | 0.892 |  |  |
| 212299991 | 69 |  |  | 61.000 | 0.890 |  |  |
| **KY Max** |  |  | **74.530** | **0.977** | **74.000** | **0.981** |  |  |
| **LA** | 220150008 | 77.3 | 73.937 | 0.957 | 73.000 | 0.957 |  |  |
| 220170001 | 74.7 | 72.272 | 0.968 | 72.000 | 0.968 |  |  |
| 220730004 | 63.3 | 60.844 | 0.961 | 60.000 | 0.955 |  |  |
| **LA Max** |  |  | **73.937** | **0.968** | **73.000** | **0.968** |  |  |
| **MI** | 260050003 | 82.7 | 74.256 | 0.898 | 75.000 | 0.910 |  |  |
| 260190003 | 73 | 66.160 | 0.906 | 66.000 | 0.906 |  |  |
| 260210014 | 79.7 | 72.073 | 0.904 | 72.000 | 0.912 |  |  |
| 260270003 | 76.7 | 70.273 | 0.916 | 70.000 | 0.924 |  |  |
| 260330901 | 63.5 | 59.969 | 0.944 | 59.000 | 0.945 |  |  |
| 260370001 | 69.3 | 63.396 | 0.915 | 63.000 | 0.912 |  |  |
| 260490021 | 73 | 66.291 | 0.908 | 66.000 | 0.908 |  |  |
| 260492001 | 72.3 | 65.338 | 0.904 | 65.000 | 0.905 |  |  |
| 260630007 | 71.3 | 64.241 | 0.901 | 64.000 | 0.909 |  |  |
| 260650012 | 70.3 | 64.275 | 0.914 | 63.000 | 0.909 |  |  |
| 260770008 | 73.7 | 67.178 | 0.912 | 67.000 | 0.916 |  |  |
| 260810020 | 73 | 66.233 | 0.907 | 66.000 | 0.906 |  |  |
| 260810022 | 72.7 | 65.052 | 0.895 | 65.000 | 0.900 |  |  |
| 260910007 | 75.5 | 67.633 | 0.896 | 67.000 | 0.896 |  |  |
| 260990009 | 76.7 | 70.717 | 0.922 | 70.000 | 0.921 |  |  |
| 260991003 | 77.3 | 71.920 | 0.930 | 71.000 | 0.925 |  |  |
| 261010922 | 72.3 | 66.321 | 0.917 | 66.000 | 0.917 |  |  |
| 261050007 | 73.3 | 66.644 | 0.909 | 66.000 | 0.909 |  |  |
| 261130001 | 68.3 | 63.068 | 0.923 | 62.000 | 0.915 |  |  |
| 261210039 | 79.7 | 73.069 | 0.917 | 73.000 | 0.918 |  |  |
| 261250001 | 76.3 | 70.463 | 0.924 | 70.000 | 0.924 |  |  |
| 261390005 | 76 | 68.955 | 0.907 | 68.000 | 0.907 |  |  |
| 261470005 | 75.3 | 69.073 | 0.917 | 69.000 | 0.920 |  |  |
| 261530001 | 71.7 | 67.061 | 0.935 | 66.000 | 0.926 |  |  |
| 261610008 | 73.3 | 66.454 | 0.907 | 66.000 | 0.903 |  |  |
| 261630001 | 71.7 | 64.480 | 0.899 | 65.000 | 0.907 |  |  |
| 261630019 | 78.7 | 72.451 | 0.921 | 72.000 | 0.925 |  |  |
| **MI Max** |  |  | **74.256** | **0.944** | **75.000** | **0.945** |  |  |
| **MN** | 270031001 | 67 | 62.960 | 0.940 | 62.000 | 0.940 |  |  |
| 270031002 | 66.3 | 64.543 | 0.974 | 64.000 | 0.974 |  |  |
| 270177416 | 55.5 |  |  | -8.000 | -9.000 |  |  |
| 270495302 | 62.5 | 60.431 | 0.967 | 60.000 | 0.974 |  |  |
| 270750005 | 58 | 57.896 | 0.998 | -8.000 | -9.000 |  |  |
| 271095008 | 63.5 | 61.309 | 0.966 | 61.000 | 0.969 |  |  |
| 271370034 | 61.3 |  |  | -8.000 | -9.000 |  |  |
| 271377550 | 49.7 | 46.882 | 0.943 | 46.000 | 0.944 |  |  |
| 271390505 | 63.5 | 61.671 | 0.971 | 61.000 | 0.973 |  |  |
| 271713201 | 63.5 | 61.290 | 0.965 | 61.000 | 0.965 |  |  |
| **MN Max** |  |  | **64.543** | **0.998** | **64.000** | **0.974** |  |  |
| **MO** | 290190011 | 69 | 66.081 | 0.958 | 66.000 | 0.958 |  |  |
| 290270002 | 67.7 | 64.782 | 0.957 | 64.000 | 0.957 |  |  |
| 290390001 | 71.7 | 71.499 | 0.997 | 71.000 | 0.998 |  |  |
| 290770036 | 69.3 | 65.454 | 0.945 | 65.000 | 0.945 |  |  |
| 290770042 | 71.7 | 67.721 | 0.945 | 67.000 | 0.945 |  |  |
| 290990019 | 76.3 | 67.060 | 0.879 | 67.000 | 0.879 |  |  |
| 291130003 | 77 | 67.552 | 0.877 | 67.000 | 0.877 |  |  |
| 291370001 | 68.7 | 66.247 | 0.964 | 66.000 | 0.964 |  |  |
| 291570001 | 74.3 | 68.096 | 0.917 | 68.000 | 0.917 |  |  |
| 291831002 | 82.3 | 72.490 | 0.881 | 72.000 | 0.881 |  |  |
| 291831004 | 77.7 | 66.892 | 0.861 | 66.000 | 0.861 |  |  |
| 291860005 | 72.3 | 64.831 | 0.897 | 64.000 | 0.897 |  |  |
| 291890005 | 71.7 | 121.427 | 1.738 | 121.000 | 1.738 |  |  |
| 291890014 | 79 | 131.855 | 1.712 | 131.000 | 1.712 |  |  |
| 292130004 | 69 | 67.006 | 0.971 | 67.000 | 0.971 |  |  |
| 295100085 | 75.7 | 65.314 | 0.863 | 65.000 | 0.863 |  |  |
| **MO Max** |  |  | **72.490** | **0.997** | **72.000** | **0.998** |  |  |
| **MS** | 280110001 | 71.7 | 69.183 | 0.965 | 69.000 | 0.969 |  |  |
| 280330002 | 72.3 | 64.860 | 0.897 | 64.000 | 0.897 |  |  |
| 280490010 | 67 | 58.089 | 0.867 | 58.000 | 0.871 |  |  |
| 280750003 | 62.7 | 57.552 | 0.918 | 57.000 | 0.909 |  |  |
| 280810005 | 65 | 56.784 | 0.874 | 57.000 | 0.885 |  |  |
| 281619991 | 63 |  |  | 58.000 | 0.925 |  |  |
| **MS Max** |  |  | **69.183** | **0.965** | **69.000** | **0.969** |  |  |
| **NC** | 370030004 | 66.7 | 59.370 | 0.890 | 59.000 | 0.895 |  |  |
| 370110002 | 63.3 | 56.337 | 0.890 | 56.000 | 0.898 |  |  |
| 370119991 | 63 |  |  | 55.000 | 0.879 |  |  |
| 370210030 | 66.7 | 57.435 | 0.861 | 57.000 | 0.860 |  |  |
| 370270003 | 66 | 57.684 | 0.874 | 57.000 | 0.878 |  |  |
| 370330001 | 70.7 | 61.000 | 0.863 | 61.000 | 0.866 |  |  |
| 370370004 | 64 | 55.981 | 0.875 | 55.000 | 0.874 |  |  |
| 370510008 | 68.7 | 59.219 | 0.862 | 59.000 | 0.866 |  |  |
| 370511003 | 70.7 | 60.569 | 0.857 | 60.000 | 0.855 |  |  |
| 370590003 | 71 | 62.587 | 0.882 | 62.000 | 0.880 |  |  |
| 370630015 | 70 | 58.765 | 0.840 | 58.000 | 0.838 |  |  |
| 370650099 | 70 | 61.530 | 0.879 | 61.000 | 0.878 |  |  |
| 370670022 | 75.3 | 65.910 | 0.875 | 65.000 | 0.875 |  |  |
| 370670028 | 69.7 | 61.782 | 0.886 | 62.000 | 0.891 |  |  |
| 370670030 | 72.7 | 63.176 | 0.869 | 63.000 | 0.872 |  |  |
| 370671008 | 72.3 | 63.147 | 0.873 | 63.000 | 0.874 |  |  |
| 370690001 | 69.3 | 59.917 | 0.865 | 59.000 | 0.864 |  |  |
| 370750001 | 70.3 | 64.261 | 0.914 | 64.000 | 0.918 |  |  |
| 370770001 | 70.7 | 65.150 | 0.922 | 65.000 | 0.921 |  |  |
| 370810013 | 74 | 63.492 | 0.858 | 63.000 | 0.857 |  |  |
| 370870008 | 61 |  |  | 56.000 | 0.920 |  |  |
| 370870036 | 67.7 | 61.269 | 0.905 | 61.000 | 0.904 |  |  |
| 370990005 | 67 |  |  | 59.000 | 0.894 |  |  |
| 371010002 | 71.7 | 61.232 | 0.854 | 61.000 | 0.853 |  |  |
| 371070004 | 67.7 | 60.023 | 0.887 | 59.000 | 0.885 |  |  |
| 371090004 | 72.7 | 64.194 | 0.883 | 64.000 | 0.888 |  |  |
| 371170001 | 66.3 | 58.835 | 0.887 | 58.000 | 0.886 |  |  |
| 371190041 | 80 | 68.008 | 0.850 | 67.000 | 0.849 |  |  |
| 371191005 | 75 | 64.478 | 0.860 | 64.000 | 0.859 |  |  |
| 371191009 | 79.7 | 65.800 | 0.826 | 65.000 | 0.824 |  |  |
| 371239991 | 66 |  |  | 56.000 | 0.856 |  |  |
| 371290002 | 63 | 54.117 | 0.859 | 55.000 | 0.875 |  |  |
| 371450003 | 71 | 70.020 | 0.986 | 69.000 | 0.983 |  |  |
| 371470006 | 69.7 | 62.493 | 0.897 | 62.000 | 0.895 |  |  |
| 371570099 | 71 | 63.169 | 0.890 | 62.000 | 0.886 |  |  |
| 371590021 | 75.3 | 65.413 | 0.869 | 65.000 | 0.868 |  |  |
| 371590022 | 75 | 64.680 | 0.862 | 64.000 | 0.855 |  |  |
| 371730002 | 60.7 | 55.006 | 0.906 | 54.000 | 0.906 |  |  |
| 371790003 | 71 | 59.789 | 0.842 | 59.000 | 0.841 |  |  |
| 371830014 | 70.3 | 60.282 | 0.858 | 60.000 | 0.857 |  |  |
| 371830016 | 73 | 62.948 | 0.862 | 63.000 | 0.870 |  |  |
| 371990004 | 69.7 | 61.566 | 0.883 | 61.000 | 0.880 |  |  |
| **NC Max** |  |  | **70.020** | **0.986** | **69.000** | **0.983** |  |  |
| **OH** | 390030009 | 73 | 65.430 | 0.896 | 65.000 | 0.895 |  |  |
| 390071001 | 77.3 | 68.009 | 0.880 | 67.000 | 0.869 |  |  |
| 390090004 | 69 | 61.997 | 0.899 | 62.000 | 0.902 |  |  |
| 390170004 | 77 | 68.592 | 0.891 | 68.000 | 0.890 |  |  |
| 390170018 | 79.7 | 71.013 | 0.891 | 71.000 | 0.896 |  |  |
| 390179991 | 77 |  |  | 67.000 | 0.880 |  |  |
| 390230001 | 75 | 66.165 | 0.882 | 65.000 | 0.880 |  |  |
| 390230003 | 74 | 65.031 | 0.879 | 64.000 | 0.870 |  |  |
| 390250022 | 78.7 | 67.548 | 0.858 | 67.000 | 0.857 |  |  |
| 390271002 | 78.7 | 67.572 | 0.859 | 67.000 | 0.859 |  |  |
| 390350034 | 77.7 | 67.265 | 0.866 | 67.000 | 0.865 |  |  |
| 390350060 | 68.5 | 60.465 | 0.883 | 60.000 | 0.882 |  |  |
| 390350064 | 70 | 63.161 | 0.902 | 63.000 | 0.900 |  |  |
| 390355002 | 76.7 | 66.238 | 0.864 | 66.000 | 0.863 |  |  |
| 390410002 | 73 | 64.218 | 0.880 | 64.000 | 0.877 |  |  |
| 390479991 | 72 |  |  | 61.000 | 0.859 |  |  |
| 390490029 | 80.3 | 72.166 | 0.899 | 71.000 | 0.895 |  |  |
| 390490037 | 75 | 66.420 | 0.886 | 66.000 | 0.883 |  |  |
| 390490081 | 71 | 63.368 | 0.893 | 63.000 | 0.890 |  |  |
| 390550004 | 74.7 | 66.565 | 0.891 | 66.000 | 0.893 |  |  |
| 390570006 | 73 | 63.320 | 0.867 | 63.000 | 0.864 |  |  |
| 390610006 | 82 | 73.669 | 0.898 | 74.000 | 0.904 |  |  |
| 390610010 | 76.3 | 68.144 | 0.893 | 68.000 | 0.893 |  |  |
| 390610040 | 78.7 | 70.854 | 0.900 | 71.000 | 0.903 |  |  |
| 390810017 | 70.3 | 64.078 | 0.912 | 63.000 | 0.904 |  |  |
| 390830002 | 73.7 | 65.136 | 0.884 | 64.000 | 0.880 |  |  |
| 390850003 | 80 | 67.352 | 0.842 | 67.000 | 0.843 |  |  |
| 390850007 | 71.7 | 61.425 | 0.857 | 60.000 | 0.850 |  |  |
| 390870011 | 65 | 58.637 | 0.902 | 58.000 | 0.898 |  |  |
| 390870012 | 70 | 63.287 | 0.904 | 63.000 | 0.901 |  |  |
| 390890005 | 74.3 | 65.228 | 0.878 | 64.000 | 0.874 |  |  |
| 390930018 | 71.7 | 60.601 | 0.845 | 60.000 | 0.843 |  |  |
| 390950024 | 68 | 59.806 | 0.880 | 59.000 | 0.875 |  |  |
| 390950027 | 66.7 | 60.097 | 0.901 | 59.000 | 0.899 |  |  |
| 390950034 | 73.7 | 63.014 | 0.855 | 62.000 | 0.854 |  |  |
| 390970007 | 74.3 | 64.752 | 0.872 | 64.000 | 0.873 |  |  |
| 390990013 | 70.7 | 63.609 | 0.900 | 63.000 | 0.896 |  |  |
| 391030004 | 69 |  |  | 61.000 | 0.898 |  |  |
| 391090005 | 73.3 | 64.951 | 0.886 | 64.000 | 0.882 |  |  |
| 391130037 | 76.7 | 66.944 | 0.873 | 66.000 | 0.868 |  |  |
| 391331001 | 68.3 | 61.108 | 0.895 | 61.000 | 0.895 |  |  |
| 391351001 | 72.3 | 64.296 | 0.889 | 64.000 | 0.895 |  |  |
| 391510016 | 76.7 | 68.217 | 0.889 | 67.000 | 0.884 |  |  |
| 391510022 | 72 | 64.541 | 0.896 | 64.000 | 0.894 |  |  |
| 391514005 | 72.3 | 64.311 | 0.890 | 64.000 | 0.890 |  |  |
| 391530020 | 72 | 65.174 | 0.905 | 64.000 | 0.901 |  |  |
| 391550009 | 71 | 63.311 | 0.892 | 63.000 | 0.892 |  |  |
| 391550011 | 76.3 | 68.250 | 0.895 | 68.000 | 0.894 |  |  |
| 391650007 | 77.7 | 67.591 | 0.870 | 67.000 | 0.866 |  |  |
| 391670004 | 71.3 | 60.619 | 0.850 | 60.000 | 0.843 |  |  |
| 391730003 | 71.3 | 64.113 | 0.899 | 63.000 | 0.897 |  |  |
| **OH Max** |  |  | **73.669** | **0.912** | **74.000** | **0.904** |  |  |
|  | **SC** | 450010001 | 62 | 53.686 | 0.866 | 53.000 | 0.865 |  |  |
| 450030003 | 64.3 | 55.433 | 0.862 | 55.000 | 0.865 |  |  |
| 450070005 | 70 | 59.381 | 0.848 | 59.000 | 0.847 |  |  |
| 450150002 | 62.3 | 55.977 | 0.899 | 55.000 | 0.898 |  |  |
| 450190046 | 64.7 | 58.133 | 0.899 | 60.000 | 0.939 |  |  |
| 450250001 | 64.3 | 56.108 | 0.873 | 56.000 | 0.871 |  |  |
| 450290002 | 61 | 54.144 | 0.888 | 53.000 | 0.885 |  |  |
| 450310003 | 68 | 59.548 | 0.876 | 59.000 | 0.873 |  |  |
| 450370001 | 61.3 | 52.926 | 0.863 | 52.000 | 0.863 |  |  |
| 450450016 | 68 | 57.106 | 0.840 | 57.000 | 0.839 |  |  |
| 450451003 | 65.3 | 55.812 | 0.855 | 55.000 | 0.857 |  |  |
| 450770002 | 69.7 | 59.740 | 0.857 | 60.000 | 0.869 |  |  |
| 450790007 | 67.5 | 57.645 | 0.854 | 58.000 | 0.862 |  |  |
| 450790021 | 60 | 51.486 | 0.858 | 51.000 | 0.863 |  |  |
| 450791001 | 71.7 | 61.232 | 0.854 | 61.000 | 0.862 |  |  |
| 450830009 | 73.7 | 63.249 | 0.858 | 63.000 | 0.855 |  |  |
| 450910006 | 64 | 54.867 | 0.857 | 55.000 | 0.864 |  |  |
|  | **SC Max** |  |  | **63.249** | **0.899** | **63.000** | **0.939** |  |  |
| **TN** | 470010101 | 70.7 | 61.396 | 0.868 | 61.000 | 0.872 |  |  |
| 470090101 | 76.7 | 66.913 | 0.872 | 66.000 | 0.869 |  |  |
| 470090102 | 66.3 | 57.708 | 0.870 | 57.000 | 0.873 |  |  |
| 470259991 | 62 |  |  | 55.000 | 0.892 |  |  |
| 470370011 | 65.7 | 57.494 | 0.875 | 57.000 | 0.874 |  |  |
| 470370026 | 70.3 | 61.744 | 0.878 | 61.000 | 0.874 |  |  |
| 470651011 | 72.3 | 63.284 | 0.875 | 63.000 | 0.876 |  |  |
| 470654003 | 73.3 | 63.698 | 0.869 | 63.000 | 0.865 |  |  |
| 470890002 | 74.7 | 64.347 | 0.861 | 64.000 | 0.861 |  |  |
| 470930021 | 69 | 60.002 | 0.870 | 59.000 | 0.869 |  |  |
| 470931020 | 71.7 | 61.569 | 0.859 | 61.000 | 0.857 |  |  |
| 471050109 | 72.3 | 63.834 | 0.883 | 63.000 | 0.885 |  |  |
| 471210104 | 71.3 | 62.459 | 0.876 | 62.000 | 0.876 |  |  |
| 471490101 | 68.5 | 59.650 | 0.871 | 59.000 | 0.871 |  |  |
| 471550101 | 74.3 | 65.198 | 0.878 | 65.000 | 0.881 |  |  |
| 471570021 | 76.7 | 68.056 | 0.887 | 68.000 | 0.887 |  |  |
| 471570075 | 78 |  |  | 68.000 | 0.880 |  |  |
| 471571004 | 75 | 65.903 | 0.879 | 66.000 | 0.885 |  |  |
| 471632002 | 71.7 | 64.896 | 0.905 | 64.000 | 0.904 |  |  |
| 471632003 | 70.3 | 63.882 | 0.909 | 63.000 | 0.908 |  |  |
| 471650007 | 76.7 | 66.921 | 0.873 | 66.000 | 0.870 |  |  |
| 471650101 | 73 | 63.320 | 0.867 | 63.000 | 0.865 |  |  |
| 471870106 | 70.3 | 60.901 | 0.866 | 60.000 | 0.866 |  |  |
| 471890103 | 71.7 | 62.924 | 0.878 | 62.000 | 0.878 |  |  |
| 500070007 | 61 |  |  | -8.000 | -9.000 |  |  |
| **TN Max** |  |  | **68.056** | **0.909** | **68.000** | **0.908** |  |  |
| **TX** | 482030002 | 72.7 | 71.864 | 0.989 | 71.000 | 0.989 |  |  |
| **TX Max** |  |  | **71.864** | **0.989** | **71.000** | **0.989** |  |  |
| **VA** | 510030001 | 66.7 | 59.543 | 0.893 | 59.000 | 0.891 |  |  |
| 510330001 | 71.7 | 63.684 | 0.888 | 63.000 | 0.885 |  |  |
| 510360002 | 75.7 | 67.146 | 0.887 | 66.000 | 0.884 |  |  |
| 510410004 | 72 | 64.498 | 0.896 | 64.000 | 0.894 |  |  |
| 510610002 | 62.7 | 56.173 | 0.896 | 56.000 | 0.894 |  |  |
| 510690010 | 66.7 | 59.003 | 0.885 | 58.000 | 0.882 |  |  |
| 510719991 | 63 |  |  | 57.000 | 0.909 |  |  |
| 510850003 | 73.7 | 64.716 | 0.878 | 64.000 | 0.875 |  |  |
| 510870014 | 75 | 66.795 | 0.891 | 66.000 | 0.888 |  |  |
| 511130003 | 70.7 | 64.775 | 0.916 | 64.000 | 0.915 |  |  |
| 511390004 | 66.3 | 60.466 | 0.912 | 60.000 | 0.911 |  |  |
| 511479991 | 62 |  |  | 56.000 | 0.919 |  |  |
| 511611004 | 67.3 | 61.209 | 0.910 | 61.000 | 0.912 |  |  |
| 511630003 | 62.3 | 58.400 | 0.937 | 58.000 | 0.935 |  |  |
| 511650003 | 66 | 60.317 | 0.914 | 60.000 | 0.913 |  |  |
| 511790001 | 73 | 63.583 | 0.871 | 63.000 | 0.864 |  |  |
| 511970002 | 64.3 | 59.490 | 0.925 | 59.000 | 0.920 |  |  |
| 516500008 | 74 | 67.510 | 0.912 | 67.000 | 0.907 |  |  |
| 518000004 | 71.3 | 66.965 | 0.939 | 67.000 | 0.944 |  |  |
| 518000005 | 69.7 | 62.361 | 0.895 | 62.000 | 0.893 |  |  |
| **VA Max** |  |  | **67.510** | **0.939** | **67.000** | **0.944** |  |  |
| **WI** | 550030010 | 58.3 |  |  | 55.000 | 0.950 |  |  |
| 550090026 | 68.3 | 61.613 | 0.902 | 62.000 | 0.912 |  |  |
| 550210015 | 67 | 63.456 | 0.947 | 63.000 | 0.950 |  |  |
| 550250041 | 66.3 | 61.937 | 0.934 | 62.000 | 0.943 |  |  |
| 550270001 | 71.5 | 66.252 | 0.927 | 67.000 | 0.938 |  |  |
| 550290004 | 75.7 | 67.691 | 0.894 | 67.000 | 0.892 |  |  |
| 550350014 | 62 |  |  | 58.000 | 0.949 |  |  |
| 550390006 | 70 | 65.100 | 0.930 | 65.000 | 0.941 |  |  |
| 550410007 | 64.7 |  |  | -8.000 | -9.000 |  |  |
| 550550002 | 68.5 | 64.102 | 0.936 | 64.000 | 0.948 |  |  |
| 550590019 | 81 | 63.941 | 0.789 | 62.000 | 0.767 |  |  |
| 550610002 | 75 | 67.470 | 0.900 | 67.000 | 0.901 |  |  |
| 550630012 | 63.3 | 60.015 | 0.948 | 60.000 | 0.958 |  |  |
| 550710007 | 78.7 | 71.704 | 0.911 | 71.000 | 0.913 |  |  |
| 550730012 | 63.3 | 59.116 | 0.934 | 59.000 | 0.939 |  |  |
| 550790010 | 69.7 | 59.419 | 0.853 | 58.000 | 0.846 |  |  |
| 550790026 | 74.7 | 65.071 | 0.871 | 64.000 | 0.870 |  |  |
| 550790085 | 80 | 70.448 | 0.881 | 70.000 | 0.881 |  |  |
| 550870009 | 69.3 | 64.567 | 0.932 | 64.000 | 0.934 |  |  |
| 550890008 | 76.3 | 71.089 | 0.932 | 71.000 | 0.940 |  |  |
| 550890009 | 74.7 | 68.754 | 0.920 | 68.000 | 0.915 |  |  |
| 551010017 | 77.7 | 64.273 | 0.827 | 63.000 | 0.820 |  |  |
| 551050024 | 69.5 | 64.927 | 0.934 | 64.000 | 0.933 |  |  |
| 551110007 | 65 | 62.023 | 0.954 | 62.000 | 0.959 |  |  |
| 551170006 | 84.3 | 77.194 | 0.916 | 77.000 | 0.920 |  |  |
| 551199991 | 63 |  |  | -8.000 | -9.000 |  |  |
| 551250001 | 62 |  |  | -8.000 | -9.000 |  |  |
| 551270005 | 69.3 | 65.031 | 0.938 | 65.000 | 0.946 |  |  |
| 551330027 | 66.7 | 62.218 | 0.933 | 62.000 | 0.934 |  |  |
| **WI Max** |  |  | **77.194** | **0.954** | **77.000** | **0.959** |  |  |
| **WV** | 540030003 | 68 | 60.221 | 0.886 | 59.000 | 0.882 |  |  |
| 540110006 | 69.3 | 62.169 | 0.897 | 61.000 | 0.894 |  |  |
| 540219991 | 60 |  |  | 56.000 | 0.944 |  |  |
| 540250003 | 64.7 | 59.957 | 0.927 | 59.000 | 0.924 |  |  |
| 540291004 | 73 | 67.248 | 0.921 | 66.000 | 0.917 |  |  |
| 540390010 | 72.3 | 68.078 | 0.942 | 67.000 | 0.935 |  |  |
| 540610003 | 69.7 | 64.277 | 0.922 | 64.000 | 0.918 |  |  |
| 540690010 | 72.3 | 64.636 | 0.894 | 64.000 | 0.890 |  |  |
| 541071002 | 68.3 | 58.902 | 0.862 | 59.000 | 0.876 |  |  |
| **WV Max** |  |  | **68.078** | **0.942** | **67.000** | **0.944** |  |  |

## Regional Haze Results

***This section is pending and will be issued as an addendum at a later point.***

# Episodic Modeling using the 2011 Ozone Transport Commission Modeling Platform

## Overview

This protocol presents procedures the OTC is using or plans to use to for episodic model runs using the CMAQ modeling system, an acceptable photochemical model (US EPA 2014). The focus of this modeling is to provide analyses to guide SIP development for the eight-hour ozone standard using a future year of 2018 and potentially be used in the WOE analyses in the aforementioned SIPs. The OTC Commissioners and Air Directors requested that the OTC Modeling Committee develop this tool to allow sensitivity and screening modeling to occur with greater ease and speed than occurred with full year photochemical runs.

The modeling will use a base case episode from June 30 to August 4 2011. This period includes time periods focused on during the DISCOVER-AQ program. Modeling a period of time closer in length to a month will reduce the time and computing resources necessary to model the extensive number of scenarios needed to properly plan for control programs to include in Ozone SIPs.

The objective of this modeling protocol is to maintain and enhance the technical credibility of the study by describing the procedures for conducting a successful modeling project. By including information as to why episodes were selected, concerning the model platform the work was based on, on the model based evaluation of the selected episode, and on how runs should be conducted we are ensuring a replicable exercise that should stand up to scrutiny.

## Selection of Episodes

In recent years the OTC has relied on two modeling platforms for planning work. Both modeling platforms use CMAQ for photochemical modeling. The first of these platforms uses 2007 as a base year for meteorology and emissions inventories, and the second uses 2011. The committee determined that no new modeling platform would be developed as a result of this work thus limiting the choice of episodes of ozone pollution during only those two years. In 2007 and 2011 the committee found four episodes, two per year, that were considered to be valuable for further scrutiny. These were time periods with high ozone values and a relatively large number of exceedances of the 2008 75 ppb NAAQS, which suggested a sustained bought of ozone pollution throughout the region.

Given the level of resources available and because of the purposes of this work for screening purposes OTC determined that only one of four episodes be used. The time periods of the four episodes are in Table 11‑1 and general informative maps of the four episodes in question can be seen in Figure 11‑1 to Figure 11‑8.

Table 11‑1: Descriptions of episodes

|  |  |  |
| --- | --- | --- |
|  | Time Span | Number of Days |
| **Episode A** | May 25-June 12, 2011 | 19 |
| **Episode B** | June 27-August 2, 2011 | 37 |
| **Episode C** | June 15-June 28, 2007 | 19 |
| **Episode D** | July 30-August 4, 2007 | 5 |

We wanted to choose an episode(s) that complies with the primary criteria set forth in EPA’s eight-hour ozone modeling guidance for selecting ozone episodes for eight-hour ozone attainment demonstration modeling:

1. Select periods, preferably during NEI years, for which extensive air quality/meteorological databases exist;
2. Model a sufficient number of days so that the modeled attainment can be applied at all of the ozone monitoring sites that are in violation of the NAAQS;
3. Model time periods that include pollution concentration episodes to ensure the modeling system appropriately include a mix of high and low periods; and
4. Select a mix of episodes reflecting a variety of meteorological conditions that frequently correspond with observed eight-hour daily maximum ozone concentrations greater than the level of the NAAQS at different monitoring sites (US EPA 2014).

|  |  |
| --- | --- |
| Figure 11‑1: Monitored Ozone Data for Episode A (May 25-June 12, 2011) | Figure 11‑2: Number of Days with Ozone > 75ppb for Episode A (May 25-June 12, 2011) |

|  |  |
| --- | --- |
| Figure 11‑3: Monitored Ozone Data for Episode B (June 27-August 2, 2011) | Figure 11‑4: Number of Days with Ozone > 75ppb for Episode B (June 27-August 2, 2011) |

|  |  |
| --- | --- |
| Figure 11‑5: Monitored Ozone Data for Episode C (June 15-June 28, 2007) | Figure 11‑6: Number of Days with Ozone > 75ppb for Episode C (June 15-June 28, 2007) |

|  |  |
| --- | --- |
| Figure 11‑7: Monitored Ozone Data for Episode D (July 30-August 4, 2007) | Figure 11‑8: Number of Days with Ozone > 75ppb for Episode D (July 30-August 4, 2007) |

### Available Data Sets

The summer of 2011 has the benefit of being the best selection in regards to the third criteria since it corresponds with the time period studied by the DISCOVER-AQ project, which provides an additional wealth of data in regards to air quality than is otherwise available. Given the 2007 episodes do not have the corresponding data sets use of 2011 is preferable.

Additionally, the inventories available for use in 2011 are more recent, built upon the NEI, developed with more modern tools (e.g. MOVES 2014 rather than MOVES 2010), and are in formats that the states are now more accustomed to work with (e.g. ff10). These factors would benefit choosing Episode A or B.

### Sufficient Time Span

It is important that there are enough days with high ozone that can be used when calculating relative reduction factors. When comparing the four episodes Episode B has a greater magnitude of exceedances in terms of both the number of monitor-days and the maximum number of violations at a given monitor. When looking at individual states there are a greater number of exceedances in New England save Connecticut in Episode C, but only one monitor is violating in those states so focusing on the states from Connecticut south is of greater importance in choosing episodes. Though as a whole Episode B is the most sufficient in terms of exceedances, none of the episodes seem to capture the meteorological conditions found during the 2013, 2014, and 2015 ozone season where exceedances were centered on the New York City nonattainment area rather than the Baltimore nonattainment area. Also Episode D is so short, only 5 days long, the additional trait of having days that lack exceedances are not met as well.

Table 11‑2: Exceedances of 75ppb by state during episodes in the OTR

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **CT** | **DC** | **DE** | **MA** | **MD** | **ME** | **NH** | **NJ** | **NY** | **PA** | **RI** | **VT** | **VA** | **Total** |
| **Monitor-Days Ep. A** | 20 | 7 | 17 | 4 | 66 | 1 | 0 | 50 | 30 | 63 | 3 | 0 | 12 | **273** |
| **Max Days/Monitor Ep. A** | 3 | 4 | 5 | 2 | 6 | 1 | 0 | 5 | 5 | 5 | 1 | 0 | 4 | **6** |
| **Monitor-Days Ep. B** | 41 | 10 | 22 | 19 | 90 | 4 | 5 | 54 | 43 | 79 | 5 | 1 | 17 | **390** |
| **Max Days/Monitor Ep. B** | 6 | 7 | 5 | 2 | 13 | 2 | 2 | 6 | 7 | 7 | 2 | 1 | 6 | **13** |
| **Monitor-Days Ep. C** | 29 | 6 | 5 | 28 | 38 | 14 | 7 | 25 | 34 | 51 | 8 | 0 | 20 | **265** |
| **Max Days/Monitor Ep. C** | 4 | 2 | 2 | 4 | 4 | 2 | 2 | 3 | 3 | 5 | 3 | 0 | 3 | **5** |
| **Monitor-Days Ep. D** | 21 | 5 | 11 | 15 | 40 | 9 | 4 | 33 | 36 | 68 | 4 | 0 | 19 | **265** |
| **Max Days/Monitor Ep. D** | 4 | 3 | 3 | 2 | 4 | 2 | 2 | 4 | 4 | 4 | 2 | 0 | 3 | **4** |

### Meteorological Conditions

Several major airflows can play important role in creating the conditions for ozone exceedances to occur in the OTR; 1) over mountain interregional transport from sources in the Midwest, 2) multi-state transport from the nocturnal low level jet, and 3) local stagnation (Hudson et al. October 2006). Following the determination of which time periods were appropriate for analysis it was necessary to determine whether these time periods had an appropriate distribution of the different ozone conducive air flows. Selection of an episode that was not representative could have the effect of causing strategies needed to reduce ozone originating form a particular region going unrealized or strategies not being sufficient to overcome situations where all three transport regimes are acting in tandem.

To determine the appropriateness of the episodes in regards to air flows HySplit was employed to conduct back trajectory analyses for two monitors, Westport CT and Edgewood, MD, which have particularly persistent ozone problems. The trajectory analyses were conducted at X height level. Figure 11‑9 to Figure 11‑16 show the trajectory analyses for the four episodes for the two monitors, odd and even figures respectively. Three of the episodes were found to have the necessary airflows to result in sufficient analyses, whereas Episode D lacked a southerly air flow.

|  |  |  |  |
| --- | --- | --- | --- |
| Figure 11‑9: Wind trajectories for Westport, CT monitor during Episode A (May 25-June 12, 2011) | | Figure 11‑10: Wind trajectories for Edgewood, MD monitor during Episode A (May 25-June 12, 2011) | |
| Figure 11‑11: Wind trajectories for Westport, CT monitor during Episode B (June 27-August 2, 2011) | Figure 11‑12: Wind trajectories for Edgewood monitor during Episode B (June 27-August 2, 2011) | | |
| Figure 11‑13: Wind trajectories for Westport, CT monitor during Episode C (June 15-June 28, 2007) | | | Figure 11‑14: Wind trajectories for Edgewood, MD monitor during Episode C (June 15-June 28, 2007) |

|  |  |
| --- | --- |
| Figure 11‑15: Wind trajectories for Westport, CT monitor during Episode D (July 30-August 4, 2007) | Figure 11‑16: Wind trajectories for Edgewood monitor during Episode D (July 30-August 4, 2007) |

### Summary

After examining each episode according to EPA’s four criteria Episode B was selected. It occurred during the year for which better inventory data is available, contained a high number of exceedances as well as enough days without ozone exceedances, and a fair mix of meteorological conditions.

## Modeling Platform

### Model Selection

To ensure that a modeling study can be successfully used as technical support for an attainment demonstration SIP, the air quality model must be scientifically sound and appropriate for the intended application, and be freely accessible to all stakeholders. In a regulatory environment, it is crucial that oversight groups (e.g., EPA), the regulated community, and the interested public have access to and also be convinced of the suitability of the model. EPA in guidance cites the Community Multiscale Air Quality Model (CMAQ) and the CAMx as two appropriate photochemical models to use (US EPA 2014). OTC staff has prior experience using CMAQ, CMAQ is open source allowing for greater scrutiny, and comparisons during prior analyses have shown CMAQ to be superior when analyzing Ozone in the OTR. For these reasons we have chosen CMAQ to conduct our episodic analyses. Several other models are needed to provide inputs to the photochemical model including a meteorological model and an emission processing model. The full list of the models used in the analyses are in Table 11‑3.

Table 11‑3: Model versions used in OTC episodic modeling analyses

|  |  |
| --- | --- |
|  | **Model and Version** |
| **Photochemical Model** | CMAQ v. 5.0.2 |
| **Meteorological Model** | WRF v. 3.4 |
| **Emissions Processing:** |  |
| **Emissions Modeling System** | SMOKE v. 3.5.1 (C3 Marine Emissions Processed with SMOKE v. 3.6) |
| **Biogenic Emissions Model** | BEIS v. 3.6 |
| **Mobile on-road Emissions** | MOVES 2014 |
| **EGU Emission** | ERTAC EGU v. 2.3 |

More details on the selection of the photochemical modeling platform for the OTC modeling platform can found in the OTC modeling protocol.

### Emissions Inventory

When work began on episodic modeling the Alpha 2 inventory was used to supply emissions estimates. There were no changes made beyond the Alpha 2 for the episodic modeling runs. Details on the Alpha inventory are located in “Technical Support Document Emission Inventory Development for 2011, 2018, and 2028 for the Northeastern US Alpha 2 Version (McDill, McCusker and Sabo 2015).”

### Monitor to Model Comparison

When comparing the modeled ozone values obtained from run that only contains the days in July (a slightly shorter period than the episode to be modeled) and the full ozone season there is good agreement between the results. Table 11‑4, Figure 11‑17, July only, compared to Figure 11‑18, full ozone season, and Figure 11‑19, July only, compared to Figure 11‑20, full ozone season, show consistent results for both the 2011 and 2018 modeled results in design value calculations, though in both cases values are higher in the full ozone season, which would be expected since they are based on extreme (4th high) rather than average values.

Table 11‑4: Evaluation of Monitors in the OTR

|  |  |  |
| --- | --- | --- |
|  | **Count** | **% Compared to Monitors with Base** |
| **Monitors with Base Values** | 193 |  |
| **Monitors with Future Values** | 159 | 83% |
| **Monitors with > 5% differential** | 12 | 6% |
| **Monitors with > 1% differential** | 58 | 30% |

|  |  |
| --- | --- |
| Figure 11‑17: Comparison of 4th high 8-hour ozone from July only 2011 runs  avg_max_8h_o3_3a_85ppb.png | Figure 11‑18: Comparison of 4th high 8-hour ozone from full ozone season 2011 runs  avg_max_8h_o3_3a_85ppb.png |

|  |  |
| --- | --- |
| Figure 11‑19: Comparison of 4th high 8-hour ozone from July only 2018 runs  avg_max_8h_o3_3b_85ppb.png | Figure 11‑20: Comparison of 4th high 8-hour ozone from full ozone season 2018 runs  avg_max_8h_o3_3b_85ppb.png |

When you begin to examine the geographic span of monitors that have greater differential between the full ozone season and July run they are largely found along the Southern and coastal OTR, with the highest differentials along the coast as can be seen in Figure 11‑21 and more clearly in Figure 11‑22. Again this would be expected since these are the areas that are most likely to have higher ozone values in other months during the ozone season and that are no longer being considered in calculating RRFs.

Figure 11‑21: Comparison of differences (2018 minus 2011) of 4th high 8-hour ozone from July only and full ozone season

|  |  |  |
| --- | --- | --- |
| avg_max_8h_o3_3a_85ppb.png  July Only | avg_max_8h_o3_3a_85ppb.png  Full Ozone Season | avg_max_8h_o3_3a_85ppb.png |

Figure 11‑22: Comparison of differences (2018 minus 2011) of 4th high 8-hour ozone from July only and full ozone season (only differences greater than 0.5 ppb)

|  |  |  |
| --- | --- | --- |
| avg_max_8h_o3_3b_85ppb.png  July Only | avg_max_8h_o3_3b_85ppb.png  Full Ozone Season | avg_max_8h_o3_3a_85ppb.png |

## Protocol

When conducting episodic modeling runs nearly all of the procedures laid out in the OTC modeling protocol should be followed with some exceptions.

Given the shorter time period in question the recommended using the “ten highest modeled 8-hour average daily maximum ozone days” to calculate the RRF (US EPA 2014). However, this would result in nearly one third of all days being included in the calculation and would also likely include days that would not be included in a full ozone season analysis. Thus at least six maximum modeled 8-hour average daily maximum ozone days should be used when calculating RRF.

The modeling runs consisted of a two week spin up period prior to the actual July 1 – 31 episodic modeling run. More information concerning the air quality monitors is in Appendix C.

Table 11‑5: Monitor comparison of 4th high 8-hour ozone from July only and full ozone season 2018 runs

| **State** | **AQS Code** | **DVC 2011** | **DV 2018 July Only** | **DV 2018 Ozone Season** | **Diff** |
| --- | --- | --- | --- | --- | --- |
| **CT** | **90010017** | 80.3 | 81.034 | 80.685 | -0.349 |
| **90011123** | 81.3 | 72.71 | 72.691 | -0.019 |
| **90013007** | 84.3 | 77.907 | 78.452 | 0.545 |
| **90019003** | 83.7 | 85.379 | 85.602 | 0.223 |
| **90031003** | 73.7 | 64.68 | 65.415 | 0.735 |
| **90050005** | 70.3 | 61.648 | 62.902 | 1.254 |
| **90070007** | 79.3 | 69.913 | 70.257 | 0.344 |
| **90090027** | 74.3 | 68.771 | 69.849 | 1.078 |
| **90099002** | 85.7 | 77.643 | 77.319 | -0.324 |
| **90110124** | 80.3 | 68.68 | 71.804 | 3.124 |
| **90131001** | 75.3 | 66.485 | 66.797 | 0.312 |
| **DE** | **100010002** | 74.3 | 67.243 | 66.842 | -0.401 |
| **100031007** | 76.3 | 68.343 | 67.815 | -0.528 |
| **100031010** | 78 | 69.803 | 69.463 | -0.34 |
| **100031013** | 77.7 | 69.349 | 68.837 | -0.512 |
| **100032004** | 75 | 66.939 | 66.445 | -0.494 |
| **100051002** | 77.3 | 68.855 | 67.969 | -0.886 |
| **100051003** | 77.7 | 69.721 | 69.584 | -0.137 |
| **DC** | **110010041** | 76 | 66.838 | 66.439 | -0.399 |
| **110010043** | 80.7 | 70.971 | 70.548 | -0.423 |
| **ME** | **230010014** | 61 | 56.392 | 56.189 | -0.203 |
| **230031100** | 51.3 | -999 | -999 | NA |
| **230052003** | 69.3 | 63.456 | 62.939 | -0.517 |
| **230090102** | 71.7 | 67.621 | 67.443 | -0.178 |
| **230090103** | 66.3 | 61.674 | 61.976 | 0.302 |
| **230112005** | 62.7 | -999 | -999 | NA |
| **230130004** | 67.7 | 63.319 | 62.902 | -0.417 |
| **230173001** | 54.3 | -999 | -999 | NA |
| **230194008** | 57.7 | -999 | -999 | NA |
| **230230006** | 61 | 56.283 | 56.124 | -0.159 |
| **230290019** | 58.3 | 55.227 | 54.849 | -0.378 |
| **230290032** | 53 | 49.992 | 50.516 | 0.524 |
| **230310038** | 60.3 | -999 | -999 | NA |
| **230310040** | 64.3 | -999 | -999 | NA |
| **230312002** | 73.7 | 65.971 | 65.435 | -0.536 |
| **MD** | **240030014** | 83 | 72.282 | 71.801 | -0.481 |
| **240051007** | 79 | 70.839 | 70.195 | -0.644 |
| **240053001** | 80.7 | 74.298 | 74.253 | -0.045 |
| **240090011** | 79.7 | 72.25 | 73.125 | 0.875 |
| **240130001** | 76.3 | 68.337 | 66.945 | -1.392 |
| **240150003** | 83 | 74.618 | 73.984 | -0.634 |
| **240170010** | 79 | 70.401 | 70.232 | -0.169 |
| **240199991** | 75 | 67.297 | 67.238 | -0.059 |
| **240210037** | 76.3 | 68.071 | 67.169 | -0.902 |
| **240230002** | 72 | 61.729 | 60.884 | -0.845 |
| **240251001** | 90 | 82.131 | 81.223 | -0.908 |
| **240259001** | 79.3 | 70.702 | 70.266 | -0.436 |
| **240290002** | 78.7 | 70.546 | 69.287 | -1.259 |
| **240313001** | 75.7 | 66.522 | 66.226 | -0.296 |
| **240330030** | 79 | 68.366 | 68.156 | -0.21 |
| **240338003** | 82.3 | 71.777 | 71.463 | -0.314 |
| **240339991** | 80 | 69.564 | 69.317 | -0.247 |
| **240430009** | 72.7 | 64.268 | 63.015 | -1.253 |
| **245100054** | 73.7 | 67.471 | 67.953 | 0.482 |
| **MA** | **250010002** | 73 | 65.947 | 66.399 | 0.452 |
| **250034002** | 69 | 62.671 | 62.134 | -0.537 |
| **250051002** | 74 | 66.958 | 67.307 | 0.349 |
| **250070001** | 77 | 71.503 | 71.495 | -0.008 |
| **250092006** | 71 | 63.903 | 61.92 | -1.983 |
| **250094005** | 70 | 62.736 | 63.56 | 0.824 |
| **250095005** | 69.3 | 63.658 | 62.581 | -1.077 |
| **250130008** | 73.7 | -999 | 64.893 | NA |
| **250150103** | 64.7 | -999 | 57.466 | NA |
| **250154002** | 71.3 | 62.625 | 62.259 | -0.366 |
| **250170009** | 67.3 | -999 | 59.921 | NA |
| **250171102** | 67 | 59.281 | 59.053 | -0.228 |
| **250213003** | 72.3 | 63.731 | 63.421 | -0.31 |
| **250250041** | 68.3 | 60.061 | 59.053 | -1.008 |
| **250250042** | 60.7 | 53.484 | 53.21 | -0.274 |
| **250270015** | 68.3 | -999 | 60.426 | NA |
| **250270024** | 69 | 60.612 | 60.41 | -0.202 |
| **NH** | **330012004** | 62.3 | -999 | 55.588 | NA |
| **330050007** | 62.3 | -999 | -999 | NA |
| **330074001** | 69.3 | -999 | -999 | NA |
| **330074002** | 59.7 | -999 | -999 | NA |
| **330090010** | 59.7 | -999 | -999 | NA |
| **330111011** | 66.3 | -999 | 58.849 | NA |
| **330115001** | 69 | -999 | -999 | NA |
| **330131007** | 64.7 | -999 | -999 | NA |
| **330150014** | 66 | 59.415 | 60.786 | 1.371 |
| **330150016** | 66.3 | 59.685 | 61.063 | 1.378 |
| **330150018** | 68 | -999 | 60.802 | NA |
| **NJ** | **340010006** | 74.3 | 66.127 | 67.387 | 1.26 |
| **340030006** | 77 | 69.733 | 68.889 | -0.844 |
| **340071001** | 82.7 | 73.005 | 73.557 | 0.552 |
| **340110007** | 72 | 64.716 | 64.543 | -0.173 |
| **340130003** | 78 | 71.508 | 70.249 | -1.259 |
| **340150002** | 84.3 | 75.284 | 75.27 | -0.014 |
| **340170006** | 77 | 71.082 | 70.64 | -0.442 |
| **340190001** | 78 | 69.105 | 68.442 | -0.663 |
| **340210005** | 78.3 | 69.778 | 69.481 | -0.297 |
| **340219991** | 76 | 67.41 | 67.432 | 0.022 |
| **340230011** | 81.3 | 72.332 | 71.845 | -0.487 |
| **340250005** | 80 | 71.841 | 71.981 | 0.14 |
| **340273001** | 76.3 | 67.585 | 67.386 | -0.199 |
| **340290006** | 82 | 72.874 | 71.9 | -0.974 |
| **340315001** | 73.3 | 65.293 | 66.913 | 1.62 |
| **340410007** | 66 | 58.049 | 57.581 | -0.468 |
| **NY** | **360010012** | 68 | -999 | 61.286 | NA |
| **360050133** | 74 | 79.849 | 76.649 | -3.2 |
| **360130006** | 73.3 | 66.032 | 65.967 | -0.065 |
| **360130011** | 74 | 66.808 | 66.161 | -0.647 |
| **360150003** | 66.5 | -999 | -999 | NA |
| **360270007** | 72 | 62.813 | 63.434 | 0.621 |
| **360290002** | 71.3 | 65.728 | 64.988 | -0.74 |
| **360310002** | 70.3 | -999 | -999 | NA |
| **360310003** | 67.3 | -999 | -999 | NA |
| **360337003** | 45 | -999 | -999 | NA |
| **360410005** | 66 | -999 | -999 | NA |
| **360430005** | 62 | -999 | -999 | NA |
| **360450002** | 71.7 | 64.116 | 62.405 | -1.711 |
| **360530006** | 67 | -999 | -999 | NA |
| **360610135** | 73.3 | 76.408 | 75.048 | -1.36 |
| **360631006** | 72.3 | 66.165 | 65.816 | -0.349 |
| **360650004** | 61.5 | -999 | -999 | NA |
| **360671015** | 69.3 | 63.307 | 62.962 | -0.345 |
| **360715001** | 67 | -999 | 59.979 | NA |
| **360750003** | 68 | 60.928 | 59.592 | -1.336 |
| **360790005** | 70 | 61.868 | 61.867 | -0.001 |
| **360810124** | 78 | 79.322 | 79.877 | 0.555 |
| **360830004** | 67 | -999 | 60.12 | NA |
| **360850067** | 81.3 | 78.321 | 78.317 | -0.004 |
| **360870005** | 75 | 66.758 | 67.648 | 0.89 |
| **360910004** | 67 | -999 | -999 | NA |
| **361010003** | 65.3 | 60.963 | 60.723 | -0.24 |
| **361030002** | 83.3 | 81.147 | 82.656 | 1.509 |
| **361030004** | 78 | 71.541 | 71.143 | -0.398 |
| **361030009** | 78.7 | 74.622 | 74.572 | -0.05 |
| **361111005** | 69 | -999 | 63.663 | NA |
| **361173001** | 65 | 58.222 | 57.513 | -0.709 |
| **361192004** | 75.3 | 80.265 | 79.146 | -1.119 |
| **PA** | **420030008** | 76.3 | 70.151 | 70.966 | 0.815 |
| **420030010** | 73.7 | 67.761 | 68.548 | 0.787 |
| **420030067** | 75.7 | 69.17 | 69.108 | -0.062 |
| **420031005** | 80.7 | 73.668 | 73.61 | -0.058 |
| **420050001** | 74.3 | 67.523 | 68.137 | 0.614 |
| **420070002** | 70.7 | 64.915 | 65.082 | 0.167 |
| **420070005** | 74.7 | 69.157 | 69.437 | 0.28 |
| **420070014** | 72.3 | 66.566 | 66.864 | 0.298 |
| **420110006** | 71.7 | 63.259 | 62.976 | -0.283 |
| **420110011** | 76.3 | 67.191 | 66.521 | -0.67 |
| **420130801** | 72.7 | 67.622 | 67.5 | -0.122 |
| **420170012** | 80.3 | 71.503 | 71.116 | -0.387 |
| **420210011** | 70.3 | 65.447 | 65.594 | 0.147 |
| **420270100** | 71 | 66.19 | 65.723 | -0.467 |
| **420279991** | 72 | 66.653 | 66.527 | -0.126 |
| **420290100** | 76.3 | 68.279 | 68.571 | 0.292 |
| **420334000** | 72.3 | 67.66 | 67.58 | -0.08 |
| **420430401** | 69 | 62.368 | 62.243 | -0.125 |
| **420431100** | 74.7 | 67.377 | 66.67 | -0.707 |
| **420450002** | 75.7 | 67.978 | 67.573 | -0.405 |
| **420490003** | 74 | 65.697 | 65.875 | 0.178 |
| **420550001** | 67 | 60.534 | 60.071 | -0.463 |
| **420590002** | 69 | 60.955 | 61.877 | 0.922 |
| **420630004** | 75.7 | 70.174 | 69.836 | -0.338 |
| **420690101** | 71 | 63.517 | 62.911 | -0.606 |
| **420692006** | 68.7 | 61.459 | 60.873 | -0.586 |
| **420710007** | 77 | 70.214 | 70.077 | -0.137 |
| **420710012** | 78 | 70.247 | 70.555 | 0.308 |
| **420730015** | 71 | 64.039 | 64.709 | 0.67 |
| **420750100** | 76 | 67.564 | 67.277 | -0.287 |
| **420770004** | 76 | 66.909 | 66.727 | -0.182 |
| **420791100** | 65 | 58.146 | 57.156 | -0.99 |
| **420791101** | 64.3 | 57.46 | 56.35 | -1.11 |
| **420810100** | 67 | 60.441 | 60.133 | -0.308 |
| **420850100** | 76.3 | 68.463 | 67.847 | -0.616 |
| **420890002** | 66.7 | 59.088 | 58.593 | -0.495 |
| **420910013** | 76.3 | 68.378 | 68.141 | -0.237 |
| **420950025** | 76 | 66.935 | 66.778 | -0.157 |
| **420958000** | 69.7 | 61.621 | 61.599 | -0.022 |
| **420990301** | 68.3 | 62.277 | 62.469 | 0.192 |
| **421010004** | 66 | 59.739 | 59.358 | -0.381 |
| **421010024** | 83.3 | 75.076 | 74.66 | -0.416 |
| **421011002** | 80 | 72.102 | 71.702 | -0.4 |
| **421119991** | 65 | 56.723 | 55.845 | -0.878 |
| **421174000** | 69.7 | 64.731 | 64.668 | -0.063 |
| **421250005** | 70 | 63.416 | 63.296 | -0.12 |
| **421250200** | 70.7 | 63.744 | 63.539 | -0.205 |
| **421255001** | 70.3 | 63.883 | 64.289 | 0.406 |
| **421290006** | 71.7 | 64.732 | 65.446 | 0.714 |
| **421290008** | 71 | 63.148 | 64.008 | 0.86 |
| **421330008** | 72.3 | 66.991 | 66.132 | -0.859 |
| **421330011** | 74.3 | 67.582 | 67.503 | -0.079 |
| **RI** | **440030002** | 73.7 | 67.261 | 66.734 | -0.527 |
| **440071010** | 74 | 67.994 | 67.339 | -0.655 |
| **440090007** | 76.3 | 69.022 | 69.001 | -0.021 |
| **VT** | **500030004** | 63.7 | -999 | 57.308 | NA |
| **500070007** | 61 | -999 | -999 | NA |
| **VA-OTR** | **510130020** | 81.7 | 72.35 | 71.886 | -0.464 |
| **510590030** | 82.3 | 72.82 | 72.065 | -0.755 |
| **511071005** | 73 | 65.663 | 64.914 | -0.749 |
| **511530009** | 70 | 62.617 | 62.726 | 0.109 |
| **515100009** | 80 | 70.794 | 70.092 | -0.702 |

## References

Hudson, R, Downs, T, Fields, R, Kheirbek, I, Kleiman, G, Miller, P and Weiss, L 2006, *The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description*, Boston, MA, accessed July 21, 2016, from <http://170.63.70.137/eea/docs/dep/air/priorities/5a-ozone-conceptual-model.doc>.

McDill, J, McCusker, S and Sabo, E 2015, ‘Technical Support Document: Emission Inventory Development for 2011, 2018, and 2028 for the Northeastern US Alpha 2 Version’, accessed March 7, 2016, from <http://marama.org/images/stories/documents/2011-2018-2028\_Technical\_Support\_Docs/TSD%20ALPHA2%20Northeast%20Emission%20Inventory%20for%202011%202018%202028%20DraftFinal%2020151123.pdf>.

US EPA 2014, ‘Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze’, accessed from <https://www3.epa.gov/ttn/scram/guidance/guide/Draft\_O3-PM-RH\_Modeling\_Guidance-2014.pdf>.

1. Model Evaluation Statistic Formulae

The statistical formulations that have been computed for each species are as follows:

*Pi* and *Oi* are the individual (daily maximum 8-hour ozone or daily average for the other species) predicted and observed concentrations respectively, and  are the average concentrations, respectively, and N is the sample size.

|  |  |
| --- | --- |
| Observed average, in ppb: | Predicted average, in ppb (only use Pi when Oi is valid): |
| Correlation coefficient, R2: | Normalized mean error (NME), in %: |
| Root mean square error (RMSE), in ppb: | Fractional error (FE), in %: |
| Mean absolute gross error (MAGE), in ppb: | Mean normalized gross error (MNGE), in %: |
| Mean bias (MB), in ppb: | Mean normalized bias (MNB), in %: |
| Mean fractionalized bias (MFB), in %: | Normalized mean bias (NMB), in %: |

1. Emissions Inventory Files

## Emission Inventories

This section lists the emission inventory sectors with a compilation of all of the SMOKE input files in the EMF system, in FF10 or ORL format, that were used for developing model ready emission files, for the Alpha, Alpha 2, and Beta inventories for the base year of 2011 and the projected years of 2018, 2028, and 2017.

#### Agricultural

* 2011
  + Alpha, Alpha 2:   
    ag\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv   
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
  + Beta:   
    *ag\_2011NEIv2\_NONPOINT\_20141108\_04feb2015\_v3*   
    Prepared by EPA, uploaded to MARAMA EMF on February 4, 2015.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_ag\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_14jan2015\_nf\_v1*   
    Prepared by EPA, uploaded to MARAMA EMF on January 14, 2015.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_ag\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0*   
    Prepared by EPA, uploaded to MARAMA EMF on August 20, 2015.

#### Agricultural Fugitive Dust

* 2011
  + Alpha, Alpha 2, Beta:   
    *afdust\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1.csv  
    EPA\_2011\_afdust\_no\_precipadj\_paved\_unpaved\_noNEIv2RPOstates\_23sep2014\_v0.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_afdust\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1  
    MARAMA\_Alpha\_2018\_EPA\_2011\_afdust\_no\_precipadj\_paved\_unpaved\_noNEIv2RPOstates\_23sep2014\_v0\_csv\_v0\_20jan2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on August 25, 2015 and January 20, 2015, respectively.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_afdust\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1  
    MARAMA\_Alpha\_2028\_EPA\_2011\_afdust\_no\_precipadj\_paved\_unpaved\_noNEIv2RPOstates\_23sep2014\_v0*  
    Prepared by MARAMA, uploaded to MARAMA EMF on August 20, 2015.

#### Area Source

* 2011
  + Alpha, Alpha 2:   
    *nonpt\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1.csv*  
    *pfc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv  
    agburn\_monthly\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
  + Beta:   
    *nonpt\_2011NEIv2\_NONPOINT\_20141108\_21jan2015\_v5\_MARAMA  
    pfc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv  
    agburn\_monthly\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*  
    Prepared by EPA and MARAMA, uploaded to MARAMA EMF on September 9, 2015, November 13, 2014 and November 13, 2014, respectively.
* 2018
  + Alpha, Alpha 2:
    - *Annual File:  
      MARAMA\_Alpha\_2018\_nonpt\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1\_csv\_v0\_21jan2015\_nf\_v1  
      MARAMA\_Alpha\_2018\_pfc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_21jan2015\_nf\_v1  
      MARAMA\_Alpha\_2018\_agburn\_monthly\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_20jan2015\_nf\_v1*  
      Prepared by MARAMA, uploaded to MARAMA EMF on January 20, 2015.
    - *Projection Packet:  
      MARAMA 2011 to 2018 Projection NonPoint 2015\_05\_07.csv*Prepared by MARAMA, uploaded to MARAMA EMF on May 7.
* 2028
  + Alpha 2:
    - *Annual File:  
      MARAMA\_Alpha\_2028\_nonpt\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1  
      MARAMA\_Alpha\_2028\_pfc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0  
      MARAMA\_Alpha\_2028\_agburn\_monthly\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0  
      cement\_newkilns\_year\_2025\_from\_ISIS2013\_NEI2011v1\_NONPOINT\_12feb2015\_v1\_MARAMA   
      2018\_cellulosic\_inventory\_06jan2014\_v1\_19nov2015\_nf\_v1\_MARAMA*  
      Prepared by MARAMA, uploaded to MARAMA EMF on August 20, 2015, August 20, 2015, August 20, 2015, November 19, 2015, and November 19, 2015, respectively.
    - *Projection Packet:  
      MARAMA 2011 to 2028 Projection NonPoint 2015\_01\_22.csv*Prepared by MARAMA, uploaded to MARAMA EMF on May 7.

#### Biogenics

* 2011, 2018, 2028, 2017
  + Alpha, Alpha 2:   
    *biogenic\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
  + Beta:   
    *biogenic\_2011eh\_BEIS3\_61\_BELD4\_0\_feb2015\_v0.csv*  
    Prepared by EPA, uploaded to MARAMA EMF on October 21, 2015.

#### C1/C2 Marine and Rail

* 2011
  + Alpha, Alpha 2, Beta:   
    *c1c2\_offshore\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv  
    c1c2rail\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1.csv*  
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_c1c2\_offshore\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_20jan2015\_v0*  
    *MARAMA\_Alpha\_2018\_c1c2rail\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1\_csv\_v0\_20jan2015\_nf\_v1*Prepared by MARAMA, uploaded to MARAMA EMF on January 20, 2015 and June 9, 2015, respectively.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_c1c2\_offshore\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0*  
    *MARAMA\_Alpha\_2028\_c1c2rail\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v1*Prepared by MARAMA, uploaded to MARAMA EMF on August 19, 2015 and August 20, 2015, respectively.

#### C3 Marine

* 2011
  + Alpha:  
    *c3marine\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv  
    c3\_offshore\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
  + Alpha 2, Beta:   
    *c3marine\_2011NEIv2\_NONPOINT\_20141108\_14nov2014\_v1.csv eca\_imo\_nonUS\_nonCANADA\_caps\_vochaps\_2011\_16jun2015\_v1\_orl\_MARAMA.txt*Prepared by EPA, uploaded to MARAMA EMF on January 2, 2015 and June 30, 2015 respectively.
* 2018
  + Alpha, Alpha 2:  
    *MARAMA\_Alpha\_2018\_c3marine\_2011NEIv2\_NONPOINT\_20141108\_14nov2014\_v1\_csv  
    eca\_imo\_nonUS\_nonCANADA\_caps\_vochaps\_2018\_04dec2013\_v0*Prepared by MARAMA and EPA, respectively, uploaded to MARAMA EMF on June 24, 2015 and December 18, 2013, respectively.
* 2028
  + Alpha 2:  
    *MARAMA\_Alpha\_2028\_c3marine\_2011NEIv2\_NONPOINT\_20141108\_14nov2014\_v1  
    eca\_imo\_nonUS\_nonCANADA\_caps\_haps\_2025\_07mar2014\_v0*Prepared by MARAMA and EPA, respectively, uploaded to MARAMA EMF on August 20, 2015 and June 24, 2015, respectively.

#### ERTAC EGUs

* 2011
  + Alpha, Alpha 2:
    - Annual Files: *OTC\_2011\_ERTACEGUv23\_150227\_MENHVTMARICTNYNJDEPAMDDCVA.csv  
      SESARM\_2011\_ERTACEGUv23\_150227\_WVNCSCGAKYTNALMS.csv LADCO\_2011\_ERTACEGUv23\_150227\_MIOHINILWIMN.csv CenSARA\_2011\_ERTACEGUv23\_150227\_TXOKNEKSIAARLAMO.csv*  
      Prepared by ERTAC and OTC, uploaded to MARAMA EMF on February 27, 2015.
    - Hourly Files:   
      Prepared by ERTAC and OTC, not uploaded to the MARAMA EMF system due to size
  + Beta:
    - Annual Files: *OTC\_2011\_ERTACEGUv23\_v24\_20151207\_MENHVTMARICTNYNJDEPAMDDCVA.csv  
      SESARM\_2011\_ERTACEGUv23\_v24\_20151207\_WVNCSCGAKYTNALMS.csv  
      LADCO\_2011\_ERTACEGUv23\_V24\_20151207\_MIOHINILWIMN.csv  
      CenSARA\_2011\_ERTACEGUv23\_v24\_20151207\_TXOKNEKSIAARLAMO.csv*  
      Prepared by ERTAC and OTC, uploaded to MARAMA EMF on December 17, 2015.
    - Hourly Files:   
      Prepared by ERTAC and OTC, not uploaded to the MARAMA EMF system due to size.
* 2018
  + Alpha, Alpha 2:
    - Annual Files: *OTC\_2018\_ERTACEGUv23\_150227\_MENHVTMARICTNYNJDEPAMDDCVA.csv  
      SESARM\_2018\_ERTACEGUv23\_150227\_WVNCSCGAFLKYTNALMS\_2018.csv  
      LADCO\_2018\_ERTACEGUv23\_150227\_MIOHINILWIMN.csv  
      CenSARA\_2018\_ERTACEGUv23\_150227\_TXOKNEKSIAARLAMO.csv*  
      Prepared by ERTAC and OTC, uploaded to MARAMA EMF on April 2, 2015.
    - Hourly Files:   
      Prepared by ERTAC and OTC, not uploaded to the MARAMA EMF system due to size.
* 2028
  + Alpha 2:
    - Annual Files: *OTC\_2028\_ERTACEGUv23\_150611\_MENHVTMARICTNYNJDEPAMDDCVA.csv  
      SESARM\_2028\_ERTACEGUv23\_150611\_WVNCSCGAFLKYTNALMS.csv  
      LADCO\_2028\_ERTACEGUv23\_150611\_MIOHINILWIMN.csv  
      CenSARA\_2028\_ERTACEGUv23\_150611\_TXOKNEKSIAARLAMO.csv*  
      Prepared by ERTAC and OTC, uploaded to MARAMA EMF on July 8, 2015.
    - Hourly Files:   
      Prepared by ERTAC and OTC, not uploaded to the MARAMA EMF system due to size.

#### Non-EGU Point

* 2011
  + Alpha, Alpha 2: *MARAMA\_Alpha\_ptnonipm\_2011NEIv2\_POINT\_20140913\_revised\_20141007\_08oct2014\_nf\_v1\_csv\_23oct2014\_v0*   
    *Ethanol\_plants\_2011\_OTAQ\_17oct2014\_v6.csv*  
    Prepared by EPA and OTC, uploaded to MARAMA EMF on December 11, 2014 and November 13, 2014, respectively.
  + Beta:
    - Annual Files: *ptnonipm\_2011NEIv2\_POINT\_20140913\_revised\_20150115\_09feb2015\_v2\_MARAMA.csv*   
      *ethanol\_plants\_2011NEIv2\_POINT\_20141123\_03feb2015\_v1*  
      Prepared by EPA and MARAMA, uploaded to MARAMA EMF on December 23, 2015 and February 3, 2015, respectively.
    - Hourly Files:   
      Prepared by MDE, not uploaded to the MARAMA EMF system due to size.
* 2018
  + Alpha, Alpha 2:  
    *MARAMA\_Alpha\_2018\_MARAMA\_Alpha\_ptnonipm\_2011NEIv2\_POINT\_20140913\_revised\_20141007\_08oct2014\_nf\_v1\_csv\_23oct2014\_v0\_mar\_v0\_01feb2015\_nf\_v1* *MARAMA\_Alpha\_2018\_Ethanol\_plants\_2011\_OTAQ\_17oct2014\_v6\_csv\_06nov2014\_v0\_v0\_01feb2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on February 1, 2015.
* 2028
  + Alpha 2:  
    *MARAMA\_Alpha\_2028\_ptnonipm\_2011NEIv2\_POINT\_20140913\_revised\_20141007\_08oct2014\_nf\_v1  
    Biodiesel\_Plants\_2018\_ff10\_11apr2013\_v0  
    cellulosic\_new\_Iowa\_plants\_from2018docket\_2011v6\_2\_ff10\_28jan2015\_v0  
    cement\_newkilns\_year\_2025\_from\_ISIS2013\_NEI2011v1\_30jan2015\_v1 MARAMA\_Alpha\_2028\_Ethanol\_plants\_2011\_OTAQ\_17oct2014\_v6*   
    The first file was prepared by MARAMA and the remainder by EPA, uploaded to MARAMA EMF on October 23, 2015, March 17, 2015, March 17, 2015, March 12, 2015, and August 21, 2015, respectively.

#### Non-ERTAC IPM EGUs

* 2011
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_output\_for\_NEI\_smallEGUpt\_from\_NEI\_EGU\_.csv*  
    Prepared by EPA and OTC, uploaded to MARAMA EMF on December 11, 2014.
  + Beta:
    - Annual Files:  
      *ptnonERTAC\_ipm\_2011NEIv2\_20160310.csv*  
      Prepared by EPA and OTC, uploaded to MARAMA EMF on March 10, 2016.
    - Hourly Files:   
      Prepared by MDE, not uploaded to the MARAMA EMF system due to size.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_MARAMA\_Alpha\_output\_for\_NEI\_smallEGUpt\_from\_NEI\_EGU\_\_csv\_v0\_01feb2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on February 1, 2015.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_output\_for\_NEI\_smallEGUpt\_from\_NEI\_EGU\_v0*  
    Prepared by MARAMA, uploaded to MARAMA EMF on October 23, 2015.

#### NonPoint Oil &Gas

* 2011
  + Alpha, Alpha 2, Beta:   
    *np\_oilgas\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*  
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_np\_oilgas\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_21jan2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on January 21, 2015.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_np\_oilgas\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0*  
    Prepared by MARAMA, uploaded to MARAMA EMF on August 20, 2015.

#### Nonroad

* 2011
  + Alpha, Alpha 2:  
    *2011NEIv1\_nonroad\_20130621\_04sep2013\_v4.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on March 2, 2014.
  + Beta:  
    *2011NEIv1\_nonroad\_20130621\_17oct2014\_v6\_MARAMA*   
    Prepared by EPA, uploaded to MARAMA EMF on January 8, 2016.
* 2018
  + Alpha, Alpha 2:  
    *2018\_nonroad\_20130829\_30oct2013\_v2.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on March 5, 2014.
* 2028
  + Alpha 2:  
    *2028\_from\_NEI2025\_nonroad\_ff10\_NCD20130831\_23feb2015\_v3\_MARAMA*   
    Prepared by EPA, uploaded to MARAMA EMF on October 19, 2015.

#### Onroad

* 2011
  + Alpha, Alpha 2:  
    *2011eh\_onroad\_SMOKE\_MOVES\_MOVES2014\_no\_speciated\_pm\_MARAMA*  
    Prepared by EPA, uploaded to MARAMA EMF on October 6, 2015.
* 2018
  + Alpha, Alpha 2:  
    *2018eh\_onroad\_SMOKE\_MOVES\_MOVES2014\_no\_speciated\_pm\_MARAMA*  
    Prepared by EPA, uploaded to MARAMA EMF on October 6, 2015.
* 2028
  + Alpha 2:  
    *2028\_from\_2025eh\_onroad\_SMOKE\_MOVES\_MOVES2014\_no\_speciated\_pm\_v0\_MARAMA*  
    Prepared by EPA, uploaded to MARAMA EMF on October 19, 2015.

#### Point Oil & Gas

* 2011
  + Alpha, Alpha 2:   
    *othpt\_offshore\_oil\_2011NEIv2\_POINT\_20140913\_16sep2014\_v0.csv  
    pt\_oilgas\_2011NEIv2\_POINT\_20140913\_17oct2014\_v2.csv*  
    Prepared by EPA, uploaded to MARAMA EMF on November 5, 2014.
  + Beta:   
    *othpt\_offshore\_oil\_2011NEIv2\_POINT\_20140913\_16sep2014\_v0.csv  
    pt\_oilgas\_2011NEIv2\_POINT\_20140913\_03feb2015\_v4*  
    Prepared by EPA, uploaded to MARAMA EMF on November 5, 2014 and February 3, 2015, respectively.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_othpt\_offshore\_oil\_2011NEIv2\_POINT\_20140913\_16sep2014\_v0\_csv\_v0\_01feb2015\_v0  
    MARAMA\_Alpha\_2018\_pt\_oilgas\_2011NEIv2\_POINT\_20140913\_17oct2014\_v2\_csv\_v0\_01feb2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on February 1, 2015.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_othpt\_offshore\_oil\_2011NEIv2\_POINT\_20140913\_16sep2014\_v0.csv  
    MARAMA\_Alpha\_2028\_pt\_oilgas\_2011NEIv2\_POINT\_20140913\_17oct2014\_v2*  
    Prepared by MARAMA, uploaded to MARAMA EMF on August 18, 2015 and October 23, 2015, respectively.

#### Prescribed Burn

* 2011, 2018, 2028, 2017
  + Alpha, Alpha 2, Beta:   
    *ptfire\_jan\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_feb\_2011v2\_prescribed\_16jan2015\_v0*  
    *ptfire\_mar\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_apr\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_may\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_jun\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_jul\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_aug\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_sep\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_oct\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_nov\_2011v2\_prescribed\_16jan2015\_v0  
    ptfire\_dec\_2011v2\_prescribed\_16jan2015\_v0*  
    Prepared by EPA, uploaded to MARAMA EMF on January 15, 2015.

#### Refueling

* 2011
  + Alpha, Alpha 2:  
    *refueling\_refueling\_2011NEIv2\_POINT\_20140913\_23sep2014\_v0.csv  
    refueling\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*Prepared by EPA, uploaded to MARAMA EMF on November 6, 2014 and November 13, 2014, respectively.
  + Beta:  
    *refueling\_2011NEIv2\_POINT\_20140913\_04dec2014\_v2*Prepared by EPA, uploaded to MARAMA EMF on February 3, 2015.
* 2018
  + Alpha, Alpha 2:  
    *MARAMA\_Alpha\_2018\_refueling\_refueling\_2011NEIv2\_POINT\_20140913\_23sep2014\_v0\_csv\_v0\_02feb2015\_nf\_v1  
    MARAMA\_Alpha\_2018\_refueling\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_21jan2015\_nf\_v1*Prepared by MARAMA, uploaded to MARAMA EMF on February 1, 2015 and January 5, 2015, respectively.
* 2028
  + Alpha 2:  
    *MARAMA\_Alpha\_2028\_refueling\_refueling\_2011NEIv2\_POINT\_20140913\_23sep2014\_v0  
    MARAMA\_Alpha\_2028\_refueling\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0*Prepared by MARAMA, uploaded to MARAMA EMF on October 23, 2015 and August 20, 2015, respectively.

#### Residential Wood Combustion

* 2011
  + Alpha, Alpha 2:   
    *rwc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0.csv*   
    Prepared by EPA, uploaded to MARAMA EMF on November 13, 2014.
  + Beta:   
    *rwc\_2011NEIv2\_NONPOINT\_20141108\_24nov2014\_v3*   
    Prepared by EPA, uploaded to MARAMA EMF on January 5, 2015.
* 2018
  + Alpha, Alpha 2:   
    *MARAMA\_Alpha\_2018\_rwc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0\_csv\_v0\_21jan2015\_nf\_v1*  
    Prepared by MARAMA, uploaded to MARAMA EMF on January 21, 2015.
* 2028
  + Alpha 2:   
    *MARAMA\_Alpha\_2028\_rwc\_2011NEIv2\_NONPOINT\_20141108\_11nov2014\_v0*  
    Prepared by MARAMA, uploaded to MARAMA EMF on August 20, 2015.

#### Wild Fires

* 2011, 2018, 2028, 2017
  + Alpha, Alpha 2:  
    *ptfire\_jan\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_feb\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_mar\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_apr\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_may\_2011v2\_wild\_16jan2015\_v0   
    ptfire\_jun\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_jul\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_aug\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_sep\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_oct\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_nov\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_dec\_2011v2\_wild\_16jan2015\_v0*  
    Prepared by EPA, uploaded to MARAMA EMF on January 15, 2015.
  + Beta:  
    *ptfire\_jan\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_feb\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_mar\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_apr\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_may\_2011v2\_wild\_16jan2015\_v0\_MARAMA   
    ptfire\_jun\_2011v2\_wild\_16jan2015\_v0\_MARAMA  
    ptfire\_jul\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_aug\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_sep\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_oct\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_nov\_2011v2\_wild\_16jan2015\_v0  
    ptfire\_dec\_2011v2\_wild\_16jan2015\_v0*Prepared by EPA and MARAMA, uploaded to MARAMA EMF on January 15, 2015, except the May and June files uploaded March 8, 2016.

1. List of Air Quality Monitors

|  | State | County | AQS Code | Site | Latitude | Longitude |
| --- | --- | --- | --- | --- | --- | --- |
| OTR | **CT** | Fairfield | **90010017** | Greenwich Point Park | 41.003613 | -73.584999 |
|  |  | **90011123** | Western Conn State Univ | 41.399166 | -73.4431 |
|  |  | **90013007** | (blank) | 41.1525 | -73.103104 |
|  |  | **90019003** | Sherwood Island Connector | 41.118332 | -73.3367 |
|  | Hartford | **90031003** | McAuliffe Park | 41.784721 | -72.631699 |
|  | Litchfield | **90050005** | Mohawk Mt-Cornwall | 41.821342 | -73.297302 |
|  | Middlesex | **90070007** | (blank) | 41.552223 | -72.629997 |
|  | New Haven | **90090027** | Criscuolo Park-New Haven | 41.301399 | -72.902901 |
|  |  | **90099002** | Hammonasset State Park | 41.260834 | -72.550003 |
|  | New London | **90110124** | Fort Griswold Park | 41.353619 | -72.078796 |
|  | Tolland | **90131001** | (blank) | 41.976391 | -72.3881 |
|  | (blank) | **90110008** |  | 41.317223 | -72.065002 |
| **DC** | District of Columbia | **110010025** | TAKOMA SCHOOL | 38.583225 | -77.121902 |
|  |  | **110010041** | RIVER TERRACE | 38.897221 | -76.952797 |
|  |  | **110010043** | MCMILLAN PAMS | 38.921848 | -77.013199 |
| **DE** | Kent | **100010002** | PROPERTY OF KILLENS POND STATE PARK; BEH | 38.984749 | -75.555199 |
|  | New Castle | **100031007** | (blank) | 39.551109 | -75.730797 |
|  |  | **100031010** | OPEN FIELD | 39.817223 | -75.563904 |
|  |  | **100031013** | BELLEVUE STATE PARK, FIELD IN SE PORTION | 39.773888 | -75.496399 |
|  | Sussex | **100051002** | Seaford Shipley State Service Center | 38.644478 | -75.612701 |
|  |  | **100051003** | SPM SITE, NEAR UD ACID RAIN/MERCURY COLL | 38.779198 | -75.162697 |
|  | (blank) | **100031003** | Bellefonte River Road Park | 39.761112 | -75.491898 |
|  |  | **100032004** | CORNER OF MLK BLVD AND JUSTISON ST, NO T | 39.739445 | -75.558098 |
| **MA** | Barnstable | **250010002** | TRURO NATIONAL SEASHORE | 41.975803 | -70.023598 |
|  | Berkshire | **250034002** | MT GREYLOCK SUMMIT | 42.636681 | -73.167397 |
|  | Bristol | **250051002** | LEROY WOOD SCHOOL | 41.633278 | -70.879204 |
|  | Dukes | **250070001** | 1 HERRING CREEK RD, AQUINNAH (WAMPANOAG | 41.330467 | -70.785202 |
|  | Essex | **250092006** | LYNN WATER TREATMENT PLANT | 42.474644 | -70.970802 |
|  |  | **250094005** | Newbury-B | 42.814474 | -70.817936 |
|  |  | **250095005** | CONSENTINO SCHOOL. | 42.770836 | -71.102303 |
|  | Hampden | **250130008** | WESTOVER AFB | 42.194382 | -72.555099 |
|  | Hampshire | **250150103** | AMHERST | 42.400578 | -72.523102 |
|  |  | **250154002** | QUABBIN RES | 42.298492 | -72.334099 |
|  | Middlesex | **250170009** | USEPA REGION 1 LAB | 42.626678 | -71.362099 |
|  |  | **250171102** | inactive military resv 680 hudson rd sud | 42.413574 | -71.482803 |
|  | Norfolk | **250213003** | BLUE HILL OBSERVATORY | 42.211773 | -71.113998 |
|  | Suffolk | **250250041** | BOSTON LONG ISLAND | 42.317371 | -70.968399 |
|  |  | **250250042** | DUDLEY SQUARE ROXBURY | 42.329498 | -71.082603 |
|  | Worcester | **250270015** | WORCESTER AIRPORT | 42.274319 | -71.875504 |
|  |  | **250270024** | UXBRIDGE | 42.099697 | -71.6194 |
|  | (blank) | **250094004** | SITE LOCATED OFF PARKING LOT 2. | 42.790268 | -70.808296 |
| **MD** | Anne Arundel | **240030014** | Davidsonville | 38.9025 | -76.653099 |
|  | Baltimore | **240051007** | Padonia | 39.462025 | -76.631302 |
|  |  | **240053001** | Essex | 39.310833 | -76.474403 |
|  | Baltimore (City) | **245100054** | Furley | 39.328892 | -76.552498 |
|  | Calvert | **240090011** | Calvert | 38.53672 | -76.617203 |
|  | Carroll | **240130001** | South Carroll | 39.444168 | -77.041702 |
|  | Cecil | **240150003** | Fair Hill Natural Resource Management Ar | 39.701111 | -75.860001 |
|  | Charles | **240170010** | Southern Maryland | 38.504166 | -76.811897 |
|  | Dorchester | **240199991** | Blackwater NWR | 38.445 | -76.1114 |
|  | Frederick | **240210037** | Frederick Airport | 39.42276 | -77.375198 |
|  | Garrett | **240230002** | Piney Run | 39.705952 | -79.012001 |
|  | Harford | **240251001** | Edgewood | 39.41 | -76.2967 |
|  |  | **240259001** | Aldino | 39.563332 | -76.203903 |
|  | Kent | **240290002** | Millington | 39.305199 | -75.797203 |
|  | Montgomery | **240313001** | Rockville | 39.114445 | -77.106903 |
|  | Prince George's | **240330030** | HU-Beltsville | 39.055279 | -76.878304 |
|  |  | **240338003** | PG Equestrian Center | 38.811939 | -76.744202 |
|  |  | **240339991** | Beltsville | 39.0284 | -76.8171 |
|  | Washington | **240430009** | Hagerstown | 39.565582 | -77.721603 |
|  | (blank) | **240030019** | FT MEADE LAT/LONG POINT IS OF THE SAMPLI | 39.101112 | -76.729401 |
|  |  | **240330002** | LAT/LONG POINT IS OF SAMPLING INLET..... | 39.02 | -76.827797 |
| **ME** | Androscoggin | **230010014** | DURHAM FIRE STATION | 43.974621 | -70.124603 |
|  | Cumberland | **230052003** | CETL - Cape Elizabeth Two Lights (State | 43.561043 | -70.207298 |
|  | Hancock | **230090102** | TOP OF CADILLAC MTN (FENCED ENCLOSURE) | 44.351696 | -68.226997 |
|  |  | **230090103** | MCFARLAND HILL Air Pollutant Research Si | 44.377048 | -68.260902 |
|  | Kennebec | **230112005** | Gardiner, Pray Street School (GPSS) | 44.230621 | -69.785004 |
|  | Knox | **230130004** | Marshall Point Lighthouse | 43.917953 | -69.260597 |
|  | Oxford | **230173001** | (blank) | 44.250923 | -70.860603 |
|  | Sagadahoc | **230230006** | BOWDOINHAM, MERRYMEETING BAY, BROWN'S PT | 44.005001 | -69.827797 |
|  | Washington | **230290019** | Harbor Masters Office; Jonesport Public | 44.531906 | -67.595901 |
|  |  | **230290032** | (blank) | 44.963634 | -67.060699 |
|  | York | **230310038** | WBFD - West Buxton (Hollis) Fire Departm | 43.656765 | -70.629097 |
|  |  | **230310040** | SBP - Shapleigh Ball Park | 43.58889 | -70.877296 |
|  |  | **230312002** | KPW - Kennebunkport Parson'd Way | 43.343166 | -70.471001 |
|  | (blank) | **230031100** | MICMAC HEALTH DEPARTMENT | 46.69643 | -68.032997 |
|  |  | **230050027** | SHELTER IN PARKING LOT OF INTERSECTION O | 43.662373 | -70.2649 |
|  |  | **230090301** | OZONE AND METEOROLOGY MONITORING STARTED | 44.423073 | -68.805702 |
|  |  | **230194008** | WLBZ TV Transmitter Building - Summit of | 44.735977 | -68.670799 |
|  |  | **230230004** |  | 43.793568 | -69.731796 |
|  |  | **230313002** | \_\_\_\_\_\_\_\_\_\_\_NO INFORMATION AT THIS TIME | 43.083332 | -70.75 |
| **NH** | Belknap | **330012004** | FIELD OFFICE ON THE GROUNDS OF THE FORME | 43.566113 | -71.496399 |
|  | Cheshire | **330050007** | WATER STREET | 42.930473 | -72.2724 |
|  | Coos | **330074001** | (blank) | 44.270168 | -71.303802 |
|  |  | **330074002** | CAMP DODGE, GREENS GRANT | 44.308167 | -71.217697 |
|  | Grafton | **330090010** | LEBANON AIRPORT ROAD | 43.629612 | -72.309601 |
|  | Hillsborough | **330111011** | GILSON ROAD | 42.718662 | -71.5224 |
|  |  | **330115001** | MILLER STATE PARK | 42.861752 | -71.878403 |
|  | Merrimack | **330131007** | HAZEN DRIVE | 43.218498 | -71.514503 |
|  | Rockingham | **330150014** | PORTSMOUTH - PEIRCE ISLAND | 43.075333 | -70.748001 |
|  |  | **330150016** | SEACOAST SCIENCE CENTER | 43.045277 | -70.713799 |
|  |  | **330150018** | Londonderry-Moose Hill | 42.862536 | -71.380172 |
|  | (blank) | **330074003** | MONITOR LOCATED IN THE GATEHOUSE FOR THE | 45.051109 | -71.391899 |
|  |  | **330110020** | PEARL ST MUNICIPAL PARKING LOT | 42.995777 | -71.462502 |
|  |  | **330190003** |  | 43.364445 | -72.338303 |
| **NJ** | Atlantic | **340010006** | Brigantine | 39.46487 | -74.4487 |
|  | Bergen | **340030006** | Leonia | 40.870438 | -73.991997 |
|  | Camden | **340071001** | Ancora State Hospital | 39.68425 | -74.861504 |
|  | Cumberland | **340110007** | Millville | 39.422272 | -75.0252 |
|  | Essex | **340130003** | Newark - Firehouse | 40.720989 | -74.192902 |
|  | Gloucester | **340150002** | Clarksboro | 39.800339 | -75.212097 |
|  | Hudson | **340170006** | Bayonne | 40.67025 | -74.126099 |
|  | Hunterdon | **340190001** | Flemington | 40.515263 | -74.806702 |
|  | Mercer | **340210005** | Rider University | 40.283092 | -74.742599 |
|  |  | **340219991** | Wash Crossing | 40.3125 | -74.8729 |
|  | Middlesex | **340230011** | Rutgers University | 40.462181 | -74.429398 |
|  | Monmouth | **340250005** | Monmouth University | 40.277645 | -74.005096 |
|  | Morris | **340273001** | Chester | 40.787628 | -74.6763 |
|  | Ocean | **340290006** | Colliers Mills | 40.064831 | -74.444099 |
|  | Passaic | **340315001** | Ramapo | 41.058617 | -74.255501 |
|  | Warren | **340410007** | Columbia Site | 40.924606 | -75.067825 |
|  | (blank) | **340010005** | NACOTE CREEK RESEARCH STATION | 39.530254 | -74.460297 |
|  |  | **340030005** | TEANECK | 40.898579 | -74.0299 |
|  |  | **340070003** | CAMDEN LAB | 39.923042 | -75.097603 |
| **NY** | Albany | **360010012** | LOUDONVILLE | 42.680752 | -73.757301 |
|  | Bronx | **360050133** | PFIZER LAB SITE | 40.867901 | -73.878098 |
|  | Chautauqua | **360130006** | DUNKIRK | 42.49963 | -79.318802 |
|  |  | **360130011** | WESTFIELD | 42.29071 | -79.5896 |
|  | Chemung | **360150003** | ELMIRA | 42.110958 | -76.8022 |
|  | Dutchess | **360270007** | MILLBROOK | 41.785549 | -73.741402 |
|  | Erie | **360290002** | AMHERST | 42.993279 | -78.7715 |
|  | Essex | **360310002** | WHITEFACE SUMMIT | 88.732162 | -147.806198 |
|  |  | **360310003** | WHITEFACE BASE | 44.393082 | -73.858902 |
|  | Hamilton | **360410005** | PISECO LAKE | 43.44957 | -74.516296 |
|  | Jefferson | **360450002** | PERCH RIVER | 44.087471 | -75.973198 |
|  | Madison | **360530006** | CAMP GEORGETOWN | 42.730461 | -75.784401 |
|  | New York | **360610135** | CCNY | 40.819759 | -73.948303 |
|  | Niagara | **360631006** | MIDDLEPORT | 43.223862 | -78.478897 |
|  | Oneida | **360650004** | CAMDEN | 43.302681 | -75.719803 |
|  | Onondaga | **360671015** | EAST SYRACUSE | 43.052349 | -76.059196 |
|  | Orange | **360715001** | VALLEY CENTRAL HIGH SCHOOL | 41.52375 | -74.215302 |
|  | Oswego | **360750003** | FULTON | 43.284279 | -76.463203 |
|  | Putnam | **360790005** | MT NINHAM | 41.455891 | -73.709801 |
|  | Queens | **360810124** | Queens College 2 | 40.736141 | -73.821503 |
|  | Rensselaer | **360830004** | GRAFTON STATE PARK | 42.781891 | -73.4636 |
|  | Richmond | **360850067** | SUSAN WAGNER HS | 40.596642 | -74.125298 |
|  | Rockland | **360870005** | Rockland County | 41.182079 | -74.028198 |
|  | Saratoga | **360910004** | STILLWATER | 43.012089 | -73.648903 |
|  | Steuben | **361010003** | PINNACLE STATE PARK | 42.091419 | -77.209801 |
|  | Suffolk | **361030002** | BABYLON | 40.745289 | -73.419197 |
|  |  | **361030004** | RIVERHEAD | 40.960781 | -72.712402 |
|  |  | **361030009** | HOLTSVILLE | 81.655982 | -146.115006 |
|  | Ulster | **361111005** | BELLEAYRE MOUNTAIN | 42.144032 | -74.494301 |
|  | Wayne | **361173001** | WILLIAMSON | 43.230862 | -77.171402 |
|  | Westchester | **361192004** | WHITE PLAINS | 41.051922 | -73.763702 |
|  | (blank) | **360050110** | IS 52 | 40.816181 | -73.902 |
|  |  | **360337003** | Y001 | 44.980576 | -74.695 |
|  |  | **360430005** | NICKS LAKE | 43.68578 | -74.985397 |
|  |  | **360551007** | ROCHESTER 2 | 43.146179 | -77.548203 |
|  |  | **360810098** | COLLEGE POINT POST OFFICE | 40.784199 | -73.847603 |
|  |  | **360930003** | SCHENECTADY | 42.799011 | -73.938904 |
| **PA** | Allegheny | **420030008** | Lawrenceville | 40.46542 | -79.9608 |
|  |  | **420030010** | LAT/LON IS APPROXIMATE LOCATION OF SCIEN | 40.445576 | -80.016197 |
|  |  | **420030067** | South Fayette | 40.375645 | -80.169899 |
|  |  | **420031005** | Harrison | 40.613949 | -79.729401 |
|  | Armstrong | **420050001** | LAT/LON IS CENTER OF TRAILER | 40.814182 | -79.564697 |
|  | Beaver | **420070002** | (blank) | 40.562519 | -80.503899 |
|  |  | **420070005** | DRIVEWAY TO BAKEY RESIDENCE | 40.684723 | -80.359703 |
|  |  | **420070014** | (blank) | 40.747795 | -80.316399 |
|  | Berks | **420110006** | Kutztown | 40.51408 | -75.789703 |
|  |  | **420110011** | Reading Airport | 40.38335 | -75.968597 |
|  | Blair | **420130801** | (blank) | 40.535278 | -78.370796 |
|  | Bucks | **420170012** | A420170012LAT/LONG POINT IS OF SAMPLING | 40.107224 | -74.882202 |
|  | Cambria | **420210011** | (blank) | 40.309723 | -78.915001 |
|  | Centre | **420270100** | LAT/LON=POINT SW CORNER OF TRAILER | 40.81139 | -77.876999 |
|  |  | **420279991** | Penn State | 40.7208 | -77.9319 |
|  | Chester | **420290100** | CHESTER COUNTY TRANSPORT SITE INTO PHILA | 39.834461 | -75.768204 |
|  | Clearfield | **420334000** | MOSHANNON STATE FOREST | 41.1175 | -78.526199 |
|  | Dauphin | **420430401** | A420430401LAT/LON POINT IS AT CORNER OF | 40.24699 | -76.847 |
|  |  | **420431100** | A420431100LAT/LON POINT IS AT CORNER OF | 40.272221 | -76.681396 |
|  | Delaware | **420450002** | A420450002LAT/LON POINT IS OF CORNER OF | 39.835556 | -75.372498 |
|  | Erie | **420490003** | (blank) | 42.14175 | -80.038597 |
|  | Franklin | **420550001** | HIGH ELEVATION OZONE SITE | 39.961109 | -77.475601 |
|  | Greene | **420590002** | 75 KM SSW OF PITTSBURGH RURAL SITE ON A | 39.80933 | -80.265701 |
|  | Indiana | **420630004** | (blank) | 40.563332 | -78.919998 |
|  | Lackawanna | **420690101** | A420690101LAT/LON POINT IS AT CORNER OF | 41.479115 | -75.578201 |
|  |  | **420692006** | A420692006LAT/LON POINT IS AT CORNER OF | 41.44278 | -75.6231 |
|  | Lancaster | **420710007** | A420710007LAT/LON POINT AT CORNER OF TRA | 40.046665 | -76.283302 |
|  |  | **420710012** | Lancaster DW | 40.043835 | -76.112396 |
|  | Lawrence | **420730015** | (blank) | 40.99585 | -80.346397 |
|  | Lebanon | **420750100** | LEBANON | 40.337328 | -76.383447 |
|  | Lehigh | **420770004** | A420770004LAT/LONG POINT IS OF SAMPLING | 40.611942 | -75.432503 |
|  | Luzerne | **420791100** | A420791100LAT/LON POINT IS AT CORNER OF | 41.209167 | -76.003304 |
|  |  | **420791101** | A420791101LAT/LON POINT IS AT CORNER OF | 41.265556 | -75.846397 |
|  | Lycoming | **420810100** | MONTOURSVILLE | 41.250801 | -76.923798 |
|  | Mercer | **420850100** | (blank) | 41.215015 | -80.484802 |
|  | Monroe | **420890002** | SWIFTWATER | 41.083061 | -75.323303 |
|  | Montgomery | **420910013** | A420910013LAT/LON POINT IS OF CORNER OF | 40.112221 | -75.309196 |
|  | Northampton | **420950025** | LAT/LON POINT IS CENTER OF TRAILER | 40.628056 | -75.341103 |
|  |  | **420958000** | COMBINED EASTON SITE (420950100) AND EAS | 40.692223 | -75.237198 |
|  | Perry | **420990301** | A420990301LAT/LON POINT IS AT CORNER OF | 40.456944 | -77.165604 |
|  | Philadelphia | **421010004** | Air Management Services Laboratory (AMS | 40.008888 | -75.097801 |
|  |  | **421010024** | North East Airport (NEA) | 40.076401 | -75.011497 |
|  |  | **421011002** | Pennypack Park-Phil | 40.035985 | -75.002405 |
|  | Somerset | **421119991** | Laurel Hill | 39.9878 | -79.2515 |
|  | Tioga | **421174000** | PENN STATE OZONE MONITORING SITE | 41.644722 | -76.939201 |
|  | Washington | **421250005** | (blank) | 40.146667 | -79.902199 |
|  |  | **421250200** | (blank) | 40.170555 | -80.261398 |
|  |  | **421255001** | (blank) | 40.445278 | -80.420799 |
|  | Westmoreland | **421290006** | (blank) | 40.428078 | -79.692802 |
|  |  | **421290008** | LAT/LON POINT IS TRAILER | 40.304695 | -79.505699 |
|  | York | **421330008** | A421330008LAT/LON POINT AT CORNER OF TRA | 39.965279 | -76.699402 |
|  |  | **421330011** | York DW | 39.86097 | -76.462097 |
|  | (blank) | **420010002** |  | 39.93 | -77.25 |
|  |  | **420110001** | A420110001LAT/LONG POINT IS OF SAMPLING | 40.511112 | -75.786102 |
|  |  | **420110009** | A420110009LAT/LONG POINT IS OF SAMPLING | 40.320278 | -75.926697 |
|  |  | **420274000** | PA DEPT CONSERVATION & NATURAL RESOURCES | 40.774555 | -77.622101 |
|  |  | **420290050** | LAT/LON POINT IS OF CORNER OF TRAILER | 39.935665 | -75.604301 |
|  |  | **420814000** | NEXT TO TIADAGHTON SPORTMANS CLUB - NORT | 41.334057 | -77.449097 |
|  |  | **421010014** | Roxborough (ROX) | 40.049618 | -75.240799 |
|  |  | **421010136** | ON AMTRAK RIGHT OF WAY - NEAR AIRPORT HI | 39.927502 | -75.222801 |
| **RI** | Kent | **440030002** | AJ | 41.615238 | -71.720001 |
|  | Providence | **440071010** | FRANCIS SCHOOL East Providence | 41.841572 | -71.360802 |
|  | Washington | **440090007** | US-EPA Laboratory | 41.49511 | -71.423698 |
| **VA** | Alexandria City | **515100009** | Alexandria Health Dept. | 38.810402 | -77.044403 |
|  | Arlington | **510130020** | Aurora Hills Visitors Center | 38.8577 | -77.059196 |
|  | Fairfax | **510590005** | CUB RUN | 38.8941 | -77.4652 |
|  |  | **510590018** | MT VERNON | 38.74232 | -77.07743 |
|  |  | **510590030** | Lee District Park | 38.77335 | -77.104698 |
|  |  | **510591005** | Annandale | 38.83738 | -77.16338 |
|  | Loudoun | **511071005** | Broad Run High School, Ashburn | 39.024731 | -77.489304 |
|  | Prince William | **511530009** | James S. Long Park | 38.852871 | -77.634598 |
| **VT** | Bennington | **500030004** | Morse Airport - State of Vermont Propert | 42.887589 | -73.249802 |
| Outside- OTR | **AL** | Colbert | **10331002** | MUSCLE SHOALS | 34.758781 | -87.650597 |
|  | DeKalb | **10499991** | Sand Mountain | 34.2888 | -85.9698 |
|  | Elmore | **10510001** | DBT, WETUMPKA | 32.498566 | -86.136597 |
|  | Etowah | **10550011** | SOUTHSIDE | 33.904037 | -86.053902 |
|  | Jefferson | **10730023** | North Birmingham | 33.553055 | -86.815002 |
|  |  | **10731003** | (blank) | 33.485558 | -86.915001 |
|  |  | **10731005** | McAdory | 33.331112 | -87.003601 |
|  |  | **10731009** | (blank) | 33.459721 | -87.305603 |
|  |  | **10731010** | Leeds | 33.545277 | -86.549202 |
|  |  | **10732006** | (blank) | 33.386391 | -86.816704 |
|  |  | **10735002** | (blank) | 33.704723 | -86.669197 |
|  |  | **10735003** | (blank) | 33.801666 | -86.942497 |
|  |  | **10736002** | (blank) | 33.578335 | -86.773903 |
|  | Madison | **10890014** | HUNTSVILLE OLD AIRPORT | 34.687672 | -86.586403 |
|  | Montgomery | **11011002** | MOMS, ADEM | 32.40712 | -86.256401 |
|  | Morgan | **11030011** | DECATUR, Alabama | 34.518734 | -86.976898 |
|  | Russell | **11130002** | LADONIA, PHENIX CITY | 32.467972 | -85.083801 |
|  | Shelby | **11170004** | HELENA | 33.317314 | -86.825104 |
|  | Sumter | **11190002** | GASTON (SUMTER) | 32.36401 | -88.201897 |
|  | Tuscaloosa | **11250010** | DUNCANVILLE, TUSCALOOSA | 33.0896 | -87.459702 |
|  | (blank) | **10270001** | ASHLAND | 33.281261 | -85.8022 |
|  |  | **10790002** | SIPSEY (closed 11-01-2007) | 34.342903 | -87.339699 |
|  |  | **11210003** | TALLADEGA, (HONDA) Closed 11/01/06 | 33.498329 | -86.122704 |
| **AR** | Crittenden | **50350005** | MARION | 35.197289 | -90.1931 |
|  | Newton | **51010002** | DEER | 35.832726 | -93.208298 |
|  | Polk | **51130003** | EAGLE MOUNTAIN | 34.454407 | -94.143303 |
|  | Pulaski | **51190007** | PARR | 34.756187 | -92.281303 |
|  |  | **51191002** | NLR AIRPORT | 34.83572 | -92.260597 |
|  |  | **51191008** | DOYLE SPRINGS ROAD | 34.681343 | -92.328697 |
|  | Washington | **51430005** | SPRINGDALE | 36.179699 | -94.116798 |
|  | (blank) | **50970001** |  | 34.649723 | -93.816704 |
|  |  | **51191005** | ADEQ | 34.67627 | -92.337196 |
|  |  | **516500004** |  | 37.000984 | -76.398598 |
| **GA** | Bibb | **130210012** | Macon SE | 32.805408 | -83.543503 |
|  | Chatham | **130510021** | Savannah-E. President Street | 32.069229 | -81.048798 |
|  | Chattooga | **130550001** | Summerville-DNR Fish Hatchery | 34.474293 | -85.407997 |
|  | Clarke | **130590002** | FIRE STATION # 7 | 33.918068 | -83.344498 |
|  | Cobb | **130670003** | Kennesaw-National Guard | 34.015484 | -84.607399 |
|  | Columbia | **130730001** | Evans-Riverside Park | 33.582146 | -82.131203 |
|  | Coweta | **130770002** | Newnan | 33.404041 | -84.746002 |
|  | Dawson | **130850001** | Dawsonville, Georgia Forestry Commission | 34.376316 | -84.059799 |
|  | DeKalb | **130890002** | South DeKalb | 33.687969 | -84.290497 |
|  | Douglas | **130970004** | W. Strickland Street | 33.743656 | -84.779198 |
|  | Fulton | **131210055** | Confederate Avenue | 33.720192 | -84.357101 |
|  | Glynn | **131270006** | Risley Middle School | 31.169735 | -81.495903 |
|  | Gwinnett | **131350002** | GWINNETT TECH | 33.961269 | -84.069 |
|  | Henry | **131510002** | McDonough-County Extension Office | 33.433575 | -84.161697 |
|  | Murray | **132130003** | Fort Mountain | 34.785198 | -84.626404 |
|  | Muscogee | **132150008** | Columbus-Airport | 32.521301 | -84.944801 |
|  | Paulding | **132230003** | Yorkville, King Farm | 33.928501 | -85.045303 |
|  | Pike | **132319991** | Georgia Station | 33.1787 | -84.4052 |
|  | Richmond | **132450091** | Bungalow Road | 33.43335 | -82.022202 |
|  | Rockdale | **132470001** | Monastery | 33.591076 | -84.0653 |
|  | Sumter | **132611001** | Leslie-Union High School | 31.954298 | -84.0811 |
|  | (blank) | **130210013** |  | 32.827969 | -83.788696 |
|  |  | **130893001** | Tucker-Idlewood Road | 33.845741 | -84.213402 |
|  |  | **131130001** | DOT STORAGE FACILITY | 33.455738 | -84.418999 |
|  |  | **132151003** | Columbus-Crime Lab | 32.508713 | -84.880302 |
| **IA** | Bremer | **190170011** | WAVERLY AIRPORT SITE | 42.743057 | -92.5131 |
|  | Clinton | **190450021** | CLINTON, RAINBOW PARK | 41.875 | -90.177597 |
|  | Linn | **191130028** | KIRKWOOD | 41.910557 | -91.651901 |
|  |  | **191130033** | COGGON ELEMENTARY SCHOOL BLDG. NORTHERN | 42.281013 | -91.526901 |
|  |  | **191130040** | Public Health | 41.976768 | -91.687698 |
|  | Polk | **191530030** | CARPENTER | 41.603161 | -93.643097 |
|  | Scott | **191630014** | SCOTT COUNTY PARK | 41.699173 | -90.521896 |
|  | Story | **191690011** | SLATER CITY HALL | 41.882866 | -93.687798 |
|  | Van Buren | **191770006** | LAKE SUGEMA STATE PARK II | 40.69508 | -92.006302 |
|  | Warren | **191810022** | GRAVEL ROAD IN LAKE AQUABI STATE PARK | 41.285534 | -93.584 |
|  | (blank) | **191530058** |  | 41.607777 | -93.571899 |
|  |  | **191630015** | DAVENPORT, JEFFERSON SCH. | 41.53001 | -90.587601 |
|  |  | **191632011** | ARGO, HIGHWAY MAINTENANCE | 41.647499 | -90.430801 |
|  |  | **191770005** | LAKE SUGEMA STATE PARK I | 40.689167 | -91.9944 |
| **IL** | Adams | **170010007** | JOHN WOOD COMMUNITY COLLEGE | 39.915409 | -91.335899 |
|  | Champaign | **170190007** | THOMAS | 40.244913 | -88.188519 |
|  | Clark | **170230001** | 416 S. State St. Hwy 1- West Union | 39.210857 | -87.668297 |
|  | Cook | **170310001** | VILLAGE GARAGE | 41.670994 | -87.732498 |
|  |  | **170310032** | SOUTH WATER FILTRATION PLANT | 41.755833 | -87.545303 |
|  |  | **170310064** | UNIVERSITY OF CHICAGO | 41.790787 | -87.601601 |
|  |  | **170310076** | COM ED MAINTENANCE BLDG | 41.7514 | -87.713501 |
|  |  | **170311003** | TAFT HS | 41.984333 | -87.792 |
|  |  | **170311601** | COOK COUNTY TRAILER | 41.668121 | -87.990601 |
|  |  | **170314002** | COOK COUNTY TRAILER | 41.855244 | -87.752502 |
|  |  | **170314007** | REGIONAL OFFICE BUILDING | 42.060284 | -87.863197 |
|  |  | **170314201** | NORTHBROOK WATER PLANT | 42.139996 | -87.799202 |
|  |  | **170317002** | WATER PLANT | 42.061855 | -87.674202 |
|  | DuPage | **170436001** | MORTON ARBORETUM | 41.813049 | -88.0728 |
|  | Effingham | **170491001** | CENTRAL JR HIGH | 39.067158 | -88.548897 |
|  | Hamilton | **170650002** | TEN MILE CREEK DNR OFFICE | 38.082153 | -88.624901 |
|  | Jersey | **170831001** | ILLINI JR HIGH | 39.110538 | -90.324097 |
|  | Jo Daviess | **170859991** | Stockton | 42.2869 | -89.9997 |
|  | Kane | **170890005** | LARSEN JUNIOR HIGH | 42.049149 | -88.273003 |
|  | Lake | **170971007** | CAMP LOGAN TRAILER | 42.467571 | -87.809998 |
|  | Macon | **171150013** | IEPA TRAILER | 39.866833 | -88.925598 |
|  | Macoupin | **171170002** | IEPA TRAILER | 39.396076 | -89.8097 |
|  | Madison | **171190008** | CLARA BARTON SCHOOL | 38.890186 | -90.148003 |
|  |  | **171191009** | SOUTHWEST CABLE TV | 38.726574 | -89.959999 |
|  |  | **171193007** | WATER PLANT | 38.860668 | -90.105904 |
|  |  | **171199991** | Alhambra | 38.869 | -89.6228 |
|  | McHenry | **171110001** | CARY GROVE HS | 42.221443 | -88.242203 |
|  | McLean | **171132003** | ISU HARRIS PHYSICAL PLANT | 40.518734 | -88.996902 |
|  | Peoria | **171430024** | FIRESTATION | 40.68742 | -89.606903 |
|  |  | **171431001** | PEORIA HEIGHTS HS | 40.745502 | -89.585899 |
|  | Randolph | **171570001** | IEPA TRAILER | 38.176277 | -89.788498 |
|  | Rock Island | **171613002** | ROCK ISLAND ARSENAL | 41.514729 | -90.517403 |
|  | Saint Clair | **171630010** | IEPA-RAPS TRAILER | 38.612034 | -90.1605 |
|  | Sangamon | **171670014** | SPFD\_IB | 39.831522 | -89.640926 |
|  | Will | **171971011** | COM ED TRAINING CENTER | 41.221539 | -88.191002 |
|  | Winnebago | **172012001** | MAPLE ELEMENTARY SCHOOL | 42.334984 | -89.037804 |
|  | (blank) | **170010006** | ST BONIFACE SCHOOL | 39.93301 | -91.404198 |
|  |  | **170190004** | BOOKER T. WASHINGTON ES | 40.123795 | -88.2295 |
|  |  | **170310050** | SE POLICE STATION | 41.707569 | -87.568604 |
|  |  | **170650001** | DALE ELEMENTARY SCHOOL | 37.998222 | -88.493103 |
|  |  | **170971002** | NORTH FIRESTATION | 42.386707 | -87.8414 |
|  |  | **171192007** | IEPA-RAPS TRAILER | 38.793343 | -90.039803 |
|  |  | **171670010** | IDPH WAREHOUSE | 39.844124 | -89.604797 |
|  |  | **171971008** | FITNESS FORUM | 41.57571 | -88.055099 |
|  |  | **172010009** | WALKER SCHOOL | 42.287189 | -89.077003 |
| **IN** | Allen | **180030002** | (blank) | 41.221416 | -85.0168 |
|  |  | **180030004** | Ft. Wayne- Beacon St. | 41.094967 | -85.101799 |
|  | Boone | **180110001** | Perry Worth ELEMENTRY SCHOOL, WEST OF WH | 39.997482 | -86.395203 |
|  | Carroll | **180150002** | Flora-Flora Airport | 40.540455 | -86.553001 |
|  | Clark | **180190008** | Charlestown State Park- 1051.8 meters Ea | 38.393833 | -85.6642 |
|  | Delaware | **180350010** | Albany- Albany Elem. Sch. | 40.300014 | -85.245399 |
|  | Elkhart | **180390007** | Bristol- Bristol Elem. Sch. | 41.718048 | -85.830597 |
|  | Floyd | **180431004** | New Albany- Green Valley Elem. Sch. | 38.308056 | -85.834198 |
|  | Greene | **180550001** | Plummer, 2500 S. W- Citizens gas Plummer | 38.985577 | -86.990097 |
|  | Hamilton | **180570006** | Our Lady of Grace- Noblesville | 40.068298 | -85.9925 |
|  | Hancock | **180590003** | Fortville- Fortville Municipal Building | 39.93504 | -85.8405 |
|  | Hendricks | **180630004** | AVON SCHOOL'S BUS BARN | 39.759003 | -86.397102 |
|  | Huntington | **180690002** | Roanoke- Roanoke Elem. School | 40.960709 | -85.379799 |
|  | Jackson | **180710001** | Brownstown- 225 W & 200 N. Water facilit | 38.920845 | -86.080498 |
|  | Johnson | **180810002** | Indian Creek Elementary School in Trafal | 39.417244 | -86.152397 |
|  | Knox | **180839991** | Vincennes | 38.7408 | -87.4853 |
|  | Lake | **180890022** | Gary-IITRI/ 1219.5 meters east of Tennes | 41.606682 | -87.304703 |
|  |  | **180890030** | Whiting- Whiting HS | 41.6814 | -87.494698 |
|  |  | **180892008** | HAMMOND CAAP- Hammond- 141st St. | 41.639462 | -87.493599 |
|  | LaPorte | **180910005** | Michigan City- 4th Street NIPSCO Gas St | 41.717022 | -86.9077 |
|  |  | **180910010** | LAPORTE OZONE SITE AT WATER TREATMENT PL | 41.629097 | -86.684601 |
|  | Madison | **180950010** | SCHOOL LOCATED ON THE SW CORNER OF US 36 | 40.002548 | -85.656898 |
|  | Marion | **180970050** | Indpls.- Ft. Harrison | 39.858921 | -86.021301 |
|  |  | **180970057** | Indpls- Harding St. | 39.74902 | -86.186302 |
|  |  | **180970073** | Indpls.- E. 16th St. | 39.789486 | -86.060799 |
|  |  | **180970078** | Indpls- Washington Park/ in parking lot | 39.811096 | -86.114502 |
|  | Morgan | **181090005** | Monrovia- Monrovia HS. | 39.575634 | -86.477898 |
|  | Perry | **181230009** | Leopold- Perry Central HS | 38.113159 | -86.6036 |
|  | Porter | **181270024** | Ogden Dunes- Water Treatment Plant | 41.617558 | -87.199203 |
|  |  | **181270026** | VALPARAISO | 41.510292 | -87.038498 |
|  | Posey | **181290003** | ST. PHILLIPS- St. Phillips road CAAP tra | 38.005287 | -87.718399 |
|  | Shelby | **181450001** | TRITON Middle SCHOOL, NORTH OF FAIRLAND | 39.613422 | -85.870598 |
|  | St. Joseph | **181410010** | Potato Creek State Park | 41.551697 | -86.370598 |
|  |  | **181410015** | SOUTH BEND-Shields Dr. | 41.696693 | -86.214699 |
|  |  | **181411007** | (blank) | 41.742599 | -86.110497 |
|  | Vanderburgh | **181630013** | Inglefield/ Scott School | 38.113949 | -87.537003 |
|  |  | **181630021** | Evansville- Buena Vista | 38.013248 | -87.577904 |
|  | Vigo | **181670018** | TERRE HAUTE CAAP/ McLean High School | 39.486149 | -87.401398 |
|  |  | **181670024** | Sandcut/ SITE LOCATED BY HOME BEHIND SH | 39.560555 | -87.313103 |
|  | Warrick | **181730008** | Boonville- Boonville HS | 38.052002 | -87.278297 |
|  |  | **181730009** | Lynnville- Tecumseh HS | 38.1945 | -87.3414 |
|  |  | **181730011** | Dayville | 37.95451 | -87.321899 |
|  | (blank) | **180510011** | TOYOTA SITE | 38.425251 | -87.465897 |
|  |  | **180570005** |  | 40.065193 | -86.008102 |
|  |  | **180890024** | LOWELL CITY WASTEWATER TREATMENT PLANT | 41.263889 | -87.417503 |
|  |  | **180970042** |  | 39.646255 | -86.248802 |
|  |  | **181270020** |  | 41.63139 | -87.086899 |
| **KY** | Bell | **210130002** | MIDDLESBORO | 36.608429 | -83.7369 |
|  | Boone | **210150003** | EAST BEND | 38.918331 | -84.8526 |
|  | Boyd | **210190017** | ASHLAND PRIMARY (FIVCO) | 38.459339 | -82.640404 |
|  | Bullitt | **210290006** | SHEPHERDSVILLE | 37.98629 | -85.711899 |
|  | Campbell | **210373002** | NORTHERN KENTUCKY UNIVERSITY (NKU) | 39.021881 | -84.474503 |
|  | Carter | **210430500** | GRAYSON LAKE | 38.238869 | -82.988098 |
|  | Christian | **210470006** | HOPKINSVILLE | 36.911709 | -87.323303 |
|  | Daviess | **210590005** | OWENSBORO PRIMARY | 37.780777 | -87.075302 |
|  | Edmonson | **210610501** | Mammoth Cave National Park, Houchin Mead | 37.131943 | -86.147797 |
|  | Fayette | **210670012** | LEXINGTON PRIMARY | 38.065029 | -84.497597 |
|  | Greenup | **210890007** | WORTHINGTON | 38.548138 | -82.731201 |
|  | Hancock | **210910012** | LEWISPORT | 37.93829 | -86.897202 |
|  | Hardin | **210930006** | ELIZABETHTOWN | 37.705612 | -85.8526 |
|  | Henderson | **211010014** | BASKETT | 37.871201 | -87.463799 |
|  | Jefferson | **211110027** | Bates | 38.13784 | -85.5765 |
|  |  | **211110051** | Watson Lane | 38.060909 | -85.898003 |
|  |  | **211110067** | CANNONS LANE | 38.22876 | -85.654503 |
|  | Jessamine | **211130001** | NICHOLASVILLE | 37.891472 | -84.588303 |
|  | Livingston | **211390003** | SMITHLAND | 37.155392 | -88.393997 |
|  | McCracken | **211451024** | JACKSON PURCHASE (PADUCAH PRIMARY) | 37.05822 | -88.572502 |
|  | Oldham | **211850004** | BUCKNER | 38.4002 | -85.444298 |
|  | Perry | **211930003** | HAZARD | 37.283291 | -83.209297 |
|  | Pike | **211950002** | PIKEVILLE PRIMARY | 37.482601 | -82.535301 |
|  | Pulaski | **211990003** | SOMERSET | 37.09798 | -84.611504 |
|  | Simpson | **212130004** | FRANKLIN | 36.708607 | -86.566299 |
|  | Trigg | **212218001** | OLD DOVER HIGHWAY CADIZ,KY | 36.78389 | -87.851898 |
|  | Warren | **212270008** | OAKLAND | 37.035439 | -86.250603 |
|  | (blank) | **210370003** | SITE LOCATED AT NORTHERN KY WATER SERVIC | 39.065556 | -84.451897 |
|  |  | **210670001** |  | 38.125832 | -84.4683 |
|  |  | **210830003** |  | 36.899166 | -88.493599 |
|  |  | **211111021** |  | 38.26355 | -85.710297 |
|  |  | **211490001** |  | 37.606388 | -87.253899 |
|  |  | **212090001** |  | 38.385834 | -84.559998 |
|  |  | **212210013** |  | 36.90139 | -88.013603 |
|  |  | **212299991** | Mackville | 37.704601 | -85.0485 |
| **LA** | Bossier | **220150008** | Shreveport / Airport | 32.536259 | -93.748901 |
|  | Caddo | **220170001** | Dixie | 32.676388 | -93.859703 |
|  | Ouachita | **220730004** | Monroe / Airport | 32.509712 | -92.046097 |
| **MI** | Allegan | **260050003** | Holland | 42.767784 | -86.148598 |
|  | Benzie | **260190003** | (blank) | 44.616943 | -86.109398 |
|  | Berrien | **260210014** | Coloma | 42.197788 | -86.3097 |
|  | Cass | **260270003** | Cassopolis | 41.895569 | -86.001602 |
|  | Chippewa | **260330901** | NORTH OF EASTERDAY AVENUE | 46.49361 | -84.364197 |
|  | Clinton | **260370001** | ROSE LAKE, STOLL RD.(8562 E.) | 42.79834 | -84.393799 |
|  | Genesee | **260490021** | (blank) | 43.047222 | -83.670197 |
|  |  | **260492001** | Otisville | 43.168335 | -83.461502 |
|  | Huron | **260630007** | RURAL THUMB AREA OZONE SITE | 43.836388 | -82.642899 |
|  | Ingham | **260650012** | (blank) | 42.738617 | -84.534599 |
|  | Kalamazoo | **260770008** | KALAMAZOO FAIRGROUNDS | 42.278069 | -85.541901 |
|  | Kent | **260810020** | GR-Monroe | 42.984173 | -85.671303 |
|  |  | **260810022** | APPROXIMATELY 1/4 MILE SOUTH OF 14 MILE | 43.176674 | -85.416603 |
|  | Lenawee | **260910007** | 6792 RAISIN CENTER HWY, LENAWEE CO.RD.CO | 41.995567 | -83.946602 |
|  | Macomb | **260990009** | New Haven | 42.731396 | -82.793503 |
|  |  | **260991003** | (blank) | 42.51334 | -83.005997 |
|  | Manistee | **261010922** | (blank) | 44.306999 | -86.242599 |
|  | Mason | **261050007** | LOCATED 550 FT NORTH OF US10 | 43.953335 | -86.294403 |
|  | Missaukee | **261130001** | LOCATED ABOUT 1/4 MILE WEST OF SITE | 44.310555 | -84.891899 |
|  | Muskegon | **261210039** | (blank) | 43.278061 | -86.311096 |
|  | Oakland | **261250001** | Oak Park | 42.463062 | -83.183197 |
|  | Ottawa | **261390005** | Jenison | 42.894451 | -85.852699 |
|  | Schoolcraft | **261530001** | Seney | 46.288876 | -85.950203 |
|  | St. Clair | **261470005** | Port Huron | 42.953335 | -82.4562 |
|  | Washtenaw | **261610008** | TOWNER ST, SOUTH; 2 LANE RESIDENIAL - HO | 42.240566 | -83.599602 |
|  | Wayne | **261630001** | Allen Park | 42.228619 | -83.208199 |
|  |  | **261630019** | East 7 Mile | 42.43084 | -83.000099 |
|  | (blank) | **260890001** |  | 45.028896 | -85.629097 |
|  |  | **261630016** |  | 42.357807 | -83.096001 |
| **MN** | Anoka | **270031001** | Cedar Creek | 45.40184 | -93.203102 |
|  |  | **270031002** | Anoka Airport | 45.13768 | -93.207603 |
|  | Goodhue | **270495302** | Stanton Air Field | 44.473755 | -93.012604 |
|  | Lake | **270750005** | Fernberg Road | 47.948624 | -91.495598 |
|  | Olmsted | **271095008** | Ben Franklin School | 43.996906 | -92.450401 |
|  | Saint Louis | **271377550** | WDSE | 46.81826 | -92.089401 |
|  | Scott | **271390505** | Shakopee | 44.791435 | -93.512497 |
|  | Wright | **271713201** | St. Michael | 45.20916 | -93.669197 |
|  | (blank) | **270177416** | Cloquet | 46.705269 | -92.523804 |
|  |  | **271370034** | VOYAGEURS NATIONAL PARK, NEAR SULLIVAN B | 48.413334 | -92.830597 |
| **MO** | Boone | **290190011** | Finger Lakes | 39.078602 | -92.315201 |
|  | Callaway | **290270002** | New Bloomfield | 38.706081 | -92.093102 |
|  | Cedar | **290390001** | El Dorado Springs | 37.689999 | -94.035004 |
|  | Greene | **290770036** | Hillcrest High School | 37.256138 | -93.299896 |
|  |  | **290770042** | Fellows Lake | 37.319511 | -93.204597 |
|  | Jefferson | **290990019** | Arnold West | 38.448631 | -90.398499 |
|  | Lincoln | **291130003** | Foley | 39.044701 | -90.8647 |
|  | Monroe | **291370001** | MTSP | 39.475136 | -91.789101 |
|  | Perry | **291570001** | (blank) | 37.702641 | -89.698601 |
|  | Saint Charles | **291831002** | West Alton | 38.872547 | -90.226501 |
|  |  | **291831004** | Orchard Farm | 38.899399 | -90.449203 |
|  | Saint Louis | **291890005** | Pacific | 76.9804 | -181.4104 |
|  |  | **291890014** | Maryland Heights | 77.421798 | -180.951798 |
|  |  | **291893001** | Ladue | 38.650259 | -90.350463 |
|  | Sainte Genevieve | **291860005** | Bonne Terre | 37.900841 | -90.423897 |
|  | St. Louis City | **295100085** | Blair Street | 38.656498 | -90.198601 |
|  | Taney | **292130004** | Branson | 36.707726 | -93.222 |
|  | (blank) | **290770026** |  | 37.122631 | -93.263397 |
|  |  | **291890004** | FORMERLY 5962 SOUTH LINDBERGH. | 38.53278 | -90.382401 |
|  |  | **291890006** |  | 38.613659 | -90.495903 |
|  |  | **291895001** |  | 38.766159 | -90.285896 |
|  |  | **291897003** | .7 MILES E FROM OLD SITE ON S SIDE OF ST | 38.720966 | -90.367104 |
|  |  | **295100086** | MARGARETTA CATEGORY B CORE SLAM PM2.5. | 38.673222 | -90.239197 |
| **MS** | Bolivar | **280110001** | Cleveland | 33.746056 | -90.723 |
|  | DeSoto | **280330002** | Hernando | 34.821659 | -89.987801 |
|  | Hinds | **280490010** | Jackson FS19 | 32.385731 | -90.141197 |
|  | Lauderdale | **280750003** | Meridian | 32.364567 | -88.731499 |
|  | Lee | **280810005** | TUPELO AIRPORT NEAR OLD NWS OFFICE | 34.264915 | -88.766197 |
|  | Yalobusha | **281619991** | COFFEEVILLE | 34.0026 | -89.799 |
|  | (blank) | **280890002** |  | 32.564835 | -90.178596 |
|  |  | **281490004** |  | 32.322834 | -90.8871 |
| **NC** | Alexander | **370030004** | Waggin` Trail | 35.929001 | -81.189796 |
|  | Avery | **370110002** | Linville Falls | 35.972221 | -81.933098 |
|  |  | **370119991** | CRANBERRY | 36.1058 | -82.0454 |
|  | Buncombe | **370210030** | Bent Creek | 35.500103 | -82.599899 |
|  | Caldwell | **370270003** | Lenoir (city) | 35.935833 | -81.530296 |
|  | Caswell | **370330001** | Cherry Grove | 36.307034 | -79.4674 |
|  | Chatham | **370370004** | Pittsboro | 35.757221 | -79.159698 |
|  | Cumberland | **370510008** | (blank) | 35.158688 | -78.727997 |
|  |  | **370511003** | Golfview | 34.968887 | -78.962502 |
|  | Davie | **370590003** | Mocksville | 35.897068 | -80.557297 |
|  | Durham | **370630015** | Durham Armory | 36.032944 | -78.905403 |
|  | Edgecombe | **370650099** | Leggett | 35.988335 | -77.582802 |
|  | Forsyth | **370670022** | (blank) | 36.110558 | -80.2267 |
|  |  | **370670028** | NEW O3 SLAMS SITE 4/1/96; REPLACES FERGU | 36.203056 | -80.215797 |
|  |  | **370670030** | (blank) | 36.026001 | -80.342003 |
|  |  | **370671008** | (blank) | 36.050835 | -80.143898 |
|  | Franklin | **370690001** | Franklinton | 36.096188 | -78.463699 |
|  | Graham | **370750001** | Joanna Bald | 35.257931 | -83.795601 |
|  | Granville | **370770001** | Butner | 36.141109 | -78.768097 |
|  | Guilford | **370810013** | Mendenhall School | 36.100712 | -79.810501 |
|  | Haywood | **370870008** | WAYNSVL ELEM SCH | 35.50716 | -82.96337 |
|  |  | **370870036** | Purchase Knob | 35.59 | -83.077499 |
|  | Johnston | **371010002** | West Johnston Co. | 35.590832 | -78.461899 |
|  | Lenoir | **371070004** | Lenoir Co. Comm. Coll. | 35.231461 | -77.568802 |
|  | Lincoln | **371090004** | Crouse | 35.438557 | -81.276802 |
|  | Martin | **371170001** | Jamesville School | 35.810692 | -76.897797 |
|  | Mecklenburg | **371190041** | Garinger High School | 35.240101 | -80.785698 |
|  |  | **371191005** | Arrowood | 35.113163 | -80.919502 |
|  |  | **371191009** | County Line | 35.347221 | -80.695 |
|  | Montgomery | **371239991** | CANDOR | 35.2632 | -79.8365 |
|  | New Hanover | **371290002** | Castle Hayne | 34.364166 | -77.8386 |
|  | Person | **371450003** | Bushy Fork | 36.306965 | -79.092003 |
|  | Pitt | **371470006** | Pitt Agri. Center | 35.638611 | -77.358101 |
|  | Rockingham | **371570099** | Bethany sch. | 36.308887 | -79.8592 |
|  | Rowan | **371590021** | Rockwell | 35.551868 | -80.394997 |
|  |  | **371590022** | Enochville School | 35.534481 | -80.667603 |
|  | Swain | **371730002** | Bryson City | 35.435509 | -83.443703 |
|  | Union | **371790003** | Monroe School | 34.973888 | -80.540802 |
|  | Wake | **371830014** | Millbrook School | 35.85611 | -78.574203 |
|  |  | **371830016** | Fuquay-Varina | 35.596943 | -78.792503 |
|  | Yancey | **371990004** | Mt. Mitchell | 35.765411 | -82.2649 |
|  | (blank) | **370590002** | Cooleemee WATER TREATMENT PLANT | 35.809288 | -80.559097 |
|  |  | **370610002** | Kenansville | 34.954823 | -77.9608 |
|  |  | **370630013** |  | 36.035557 | -78.904198 |
|  |  | **370670027** | NEAR TOWN OF TOBACCOVILLE, BY POLLIROSA | 36.236389 | -80.410599 |
|  |  | **370810011** |  | 36.113335 | -79.703903 |
|  |  | **370870004** | SW CORNER OF ROOF HAYWOOD CO HEALTH DEPA | 35.50528 | -82.964699 |
|  |  | **370870035** | Frying Pan Mountain | 35.379166 | -82.792503 |
|  |  | **370990005** | OZONE MONITOR ON SW SIDE OF TOWER/MET EQ | 35.524445 | -83.236099 |
|  |  | **371310002** | SITE IS APPROX1/2DISTANCE BETWEEN GASTON | 36.484379 | -77.620003 |
|  |  | **371470099** |  | 35.583332 | -77.5989 |
|  |  | **371510004** | SITE AT NEW MARKET ELEMENTARY SCHOOL | 35.830555 | -79.865303 |
|  |  | **371830015** |  | 35.790024 | -78.619698 |
|  |  | **371830017** | TV TOWER LOCATED AT AUBURN NC | 35.676388 | -78.535301 |
|  |  | **371990003** |  | 35.737736 | -82.285202 |
| **OH** | Allen | **390030009** | LIMA BATH | 40.770943 | -84.053902 |
|  | Ashtabula | **390071001** | CONNEAUT | 41.959694 | -80.5728 |
|  | Athens | **390090004** | ATHENS OU | 39.30798 | -82.118202 |
|  | Butler | **390170004** | HAMILTON | 39.383381 | -84.544403 |
|  |  | **390170018** | MIDDLETOWN | 39.52948 | -84.393402 |
|  |  | **390179991** | Oxford | 39.5327 | -84.7286 |
|  | Clark | **390230001** | SPRINGFIELD WELL FIELD | 40.00103 | -83.804604 |
|  |  | **390230003** | MUD RUN | 39.855671 | -83.997704 |
|  | Clermont | **390250022** | BATAVIA | 39.082802 | -84.144096 |
|  | Clinton | **390271002** | LAUREL OAKS\_JVS | 39.430038 | -83.788498 |
|  | Cuyahoga | **390350034** | 5TH DISTRICT | 41.555229 | -81.575302 |
|  |  | **390350060** | GT CRAIG | 41.492119 | -81.678398 |
|  |  | **390350064** | BEREA | 41.361889 | -81.864601 |
|  |  | **390355002** | MAYFIELD | 41.537346 | -81.458801 |
|  | Delaware | **390410002** | DELAWARE | 40.356693 | -83.064003 |
|  | Fayette | **390479991** | Deer Creek | 39.6359 | -83.2605 |
|  | Franklin | **390490029** | NEW\_ALBNY | 40.084499 | -82.815498 |
|  |  | **390490037** | FRANKLIN\_PK | 39.965229 | -82.955498 |
|  |  | **390490081** | MAPLE\_C | 40.0877 | -82.959801 |
|  | Geauga | **390550004** | GEAUGA | 41.515053 | -81.249901 |
|  | Greene | **390570006** | XENIA | 39.665749 | -83.942902 |
|  | Hamilton | **390610006** | SYCAMORE | 39.278702 | -84.366096 |
|  |  | **390610010** | COLERAIN | 39.214939 | -84.690903 |
|  |  | **390610040** | TAFT | 39.12886 | -84.503998 |
|  | Jefferson | **390810017** | STEUBEN | 40.36644 | -80.615601 |
|  | Knox | **390830002** | CENTERBURG | 40.310024 | -82.691704 |
|  | Lake | **390850003** | EASTLAKE | 41.673004 | -81.422501 |
|  |  | **390850007** | JFS (PAINSVILLE) | 41.72681 | -81.242203 |
|  | Lawrence | **390870011** | WILGUS | 38.629009 | -82.4589 |
|  |  | **390870012** | ODOT (IRONTON) | 38.508114 | -82.659302 |
|  | Licking | **390890005** | HEATH | 40.026035 | -82.432999 |
|  | Lorain | **390930018** | SHEFFIELD | 41.420883 | -82.095703 |
|  | Lucas | **390950024** | ERIE | 41.644066 | -83.546303 |
|  |  | **390950027** | WATERVILLE | 41.494175 | -83.718903 |
|  |  | **390950034** | LOW\_SER | 41.675213 | -83.3069 |
|  | Madison | **390970007** | LONDON | 39.788189 | -83.476097 |
|  | Mahoning | **390990013** | (blank) | 41.096142 | -80.658897 |
|  | Miami | **391090005** | MIAMI EAST | 40.084549 | -84.114098 |
|  | Montgomery | **391130037** | EASTWOOD | 39.785629 | -84.134399 |
|  | Portage | **391331001** | Rockwell | 41.182465 | -81.330498 |
|  | Preble | **391351001** | NATIONAL TRAIL SCHOOL | 39.835621 | -84.720497 |
|  | Stark | **391510016** | MALONE\_COL | 40.828053 | -81.378304 |
|  |  | **391510022** | BREWSTER (WANDLE) | 40.712776 | -81.598297 |
|  |  | **391514005** | ALLIANCE | 40.931396 | -81.123497 |
|  | Summit | **391530020** | PATTERSON PARK (PATT\_PARK) | 41.106487 | -81.503502 |
|  | Trumbull | **391550009** | KINSMAN | 41.454235 | -80.591003 |
|  |  | **391550011** | TCSEG | 41.240456 | -80.662598 |
|  | Warren | **391650007** | LEBANON | 39.426891 | -84.200798 |
|  | Washington | **391670004** | MARIETTA\_TWP. | 39.432117 | -81.460403 |
|  | Wood | **391730003** | BOWLING GREEN | 41.377686 | -83.611099 |
|  | (blank) | **390490028** | KOEBEL SCHOOL IN SOUTH COLUMBUS | 39.913761 | -82.957497 |
|  |  | **390870006** |  | 38.52079 | -82.666397 |
|  |  | **390950081** | FRIENDSHIP PARK | 41.719482 | -83.475197 |
|  |  | **391030003** | MEDINA | 41.100868 | -81.911598 |
|  |  | **391030004** | CHIPPEWA | 41.060398 | -81.923897 |
|  |  | **391130019** |  | 39.813889 | -84.195 |
|  |  | **391511009** |  | 40.870277 | -81.331703 |
| **SC** | Abbeville | **450010001** | DUE WEST | 34.325317 | -82.386398 |
|  | Aiken | **450030003** | JACKSON MIDDLE SCHOOL | 33.342224 | -81.788696 |
|  | Anderson | **450070005** | Big Creek | 34.623238 | -82.532097 |
|  | Berkeley | **450150002** | BUSHY PARK PUMP STATION | 32.987251 | -79.936699 |
|  | Charleston | **450190046** | CAPE ROMAIN (VISTAS) | 32.941025 | -79.657204 |
|  | Chesterfield | **450250001** | CHESTERFIELD | 34.615368 | -80.198799 |
|  | Colleton | **450290002** | ASHTON | 33.007866 | -80.964996 |
|  | Darlington | **450310003** | Pee Dee Experimental Station | 34.285694 | -79.744904 |
|  | Edgefield | **450370001** | TRENTON | 33.739964 | -81.8536 |
|  | Greenville | **450450016** | Hillcrest Middle School | 34.751846 | -82.256699 |
|  |  | **450451003** | FAMODA FARM | 35.057396 | -82.372902 |
|  | Pickens | **450770002** | CLEMSON CMS | 34.653606 | -82.838699 |
|  | Richland | **450790007** | PARKLANE | 34.09396 | -80.962303 |
|  |  | **450790021** | CONGAREE BLUFF | 33.814678 | -80.781097 |
|  |  | **450791001** | SANDHILL EXPERIMENTAL STATION | 34.131264 | -80.868301 |
|  | Spartanburg | **450830009** | NORTH SPARTANBURG FIRE STATION #2 (Shady | 34.988705 | -82.075798 |
|  | York | **450910006** | YORK CMS | 34.935818 | -81.228401 |
|  | (blank) | **450110001** | BARNWELL CMS | 33.320343 | -81.4655 |
|  |  | **450210002** | Cowpens | 35.130398 | -81.816597 |
|  |  | **450230002** | Chester | 34.792969 | -81.203697 |
|  |  | **450730001** | LONG CREEK | 34.80526 | -83.237701 |
|  |  | **450870001** | DELTA | 34.539379 | -81.560402 |
|  |  | **450890001** | INDIANTOWN | 33.723808 | -79.565102 |
| **TN** | Anderson | **470010101** | Freel's Bend ozone and SO2 monitoring | 35.965221 | -84.223198 |
|  | Blount | **470090101** | Great Smoky Mountains National Park, Loo | 35.631489 | -83.943497 |
|  |  | **470090102** | Great Smoky Mountains National Park, Cad | 35.603058 | -83.7836 |
|  | Claiborne | **470259991** | SPEEDWELL | 36.47 | -83.8268 |
|  | Davidson | **470370011** | (blank) | 36.205002 | -86.744698 |
|  |  | **470370026** | (blank) | 36.150742 | -86.623299 |
|  | Hamilton | **470651011** | Soddy-Daisy High School | 35.233475 | -85.181602 |
|  |  | **470654003** | (blank) | 35.102638 | -85.162201 |
|  | Jefferson | **470890002** | New Market ozone monitor | 36.105629 | -83.602097 |
|  | Knox | **470930021** | East Knox Elementary School | 36.085506 | -83.764801 |
|  |  | **470931020** | Spring Hill Elementary School | 36.019184 | -83.873802 |
|  | Loudon | **471050109** | Loudon Middle School ozone monitor | 35.720894 | -84.342201 |
|  | Meigs | **471210104** | Meigs County Ozone monitor | 35.289379 | -84.946098 |
|  | Rutherford | **471490101** | Eagleville Ozone Monitor | 35.73288 | -86.5989 |
|  | Sevier | **471550101** | (blank) | 35.696667 | -83.609703 |
|  | Shelby | **471570021** | Frayser Ozone Monitor | 35.217503 | -90.019699 |
|  |  | **471570075** | Memphis-NCORE | 35.151699 | -89.850249 |
|  |  | **471571004** | Edmund Orgill Park Ozone | 35.378155 | -89.834503 |
|  | Sullivan | **471632002** | Blountville Ozone Monitor | 36.541439 | -82.424797 |
|  |  | **471632003** | Kingsport ozone monitor | 36.582111 | -82.485703 |
|  | Sumner | **471650007** | Hendersonville Ozone Site at Old Hickory | 36.297562 | -86.653099 |
|  |  | **471650101** | Cottontown Ozone Monitor | 36.453976 | -86.564102 |
|  | Williamson | **471870106** | FAIRVIEW MIDDLE SCHOOL ozone monitor | 35.951534 | -87.137001 |
|  | Wilson | **471890103** | Cedars of Lebanon Ozone Monitor | 36.060833 | -86.286301 |
|  | (blank) | **470750003** | SHELTER IS IN A FLAT GRASSY AREA NEAR US | 35.468719 | -89.171097 |
|  |  | **470990002** | Lawrence Co ozone monitor | 35.115967 | -87.470001 |
|  |  | **471410004** | TVA PSD SITE IN PUTNAM COUNTY, TN | 36.205151 | -85.399803 |
|  |  | **471550102** | Great Smoky Mountains National Park, Cli | 35.562778 | -83.4981 |
|  |  | **500070007** | PROCTOR MAPLE RESEARCH CTR | 44.528389 | -72.868797 |
| **TX** | Harrison | **482030002** | Karnack | 32.668987 | -94.167503 |
| **VA** | Albemarle | **510030001** | Albemarle High School | 38.076569 | -78.503998 |
|  | Caroline | **510330001** | USGS Geomagnetic Center, Corbin | 38.200871 | -77.377403 |
|  | Charles | **510360002** | Shirley Plantation | 37.344379 | -77.2593 |
|  | Chesterfield | **510410004** | VDOT Chesterfield Residency Shop | 37.357479 | -77.593597 |
|  | Fairfax | **510595001** | LEWINSVILLE | 38.9326 | -77.19822 |
|  | Fauquier | **510610002** | Chester Phelps Wildlife Management Area, | 38.473671 | -77.7677 |
|  | Frederick | **510690010** | Rest | 39.281021 | -78.081596 |
|  | Giles | **510719991** | Horton Station | 37.3297 | -80.5578 |
|  | Hampton City | **516500008** | NASA Langley Research Center | 37.103733 | -76.387001 |
|  | Hanover | **510850003** | Turner Property, Old Church | 37.606129 | -77.218803 |
|  | Henrico | **510870014** | MathScience Innovation Center | 37.556519 | -77.400299 |
|  | Madison | **511130003** | Shenandoah National Park, Big Meadows | 38.521984 | -78.435799 |
|  | Page | **511390004** | Luray Caverns Airport | 38.663731 | -78.504402 |
|  | Prince Edward | **511479991** | Prince Edward | 37.1655 | -78.3069 |
|  | Roanoke | **511611004** | East Vinton Elementary School | 37.283421 | -79.884499 |
|  | Rockbridge | **511630003** | Natural Bridge Ranger Station | 37.626678 | -79.512604 |
|  | Rockingham | **511650003** | ROCKINGHAM CO. VDOT | 38.477531 | -78.819504 |
|  | Stafford | **511790001** | Widewater Elementary School | 38.481232 | -77.370399 |
|  | Suffolk City | **518000004** | Tidewater Community College | 36.90118 | -76.438103 |
|  |  | **518000005** | VA Tech Agricultural Research Station, H | 36.665249 | -76.730797 |
|  | Wythe | **511970002** | Rural Retreat Sewage Treatment Plant | 36.891171 | -81.254204 |
| **WI** | Brown | **550090026** | UW GREEN BAY | 44.530979 | -87.907997 |
|  | Columbia | **550210015** | COLUMBUS | 43.315601 | -89.108902 |
|  | Dane | **550250041** | MADISON EAST | 43.100838 | -89.3573 |
|  | Dodge | **550270001** | Horicon Wildlife Area | 43.46611 | -88.621101 |
|  | Door | **550290004** | NEWPORT PARK | 45.237 | -86.992996 |
|  | Eau Claire | **550350014** | Eau Claire DOT | 44.7614 | -91.413 |
|  | Fond du Lac | **550390006** | FOND DU LAC | 43.687401 | -88.421997 |
|  | Jefferson | **550550002** | JEFFERSON | 43.001999 | -88.818604 |
|  | Kenosha | **550590019** | CHIWAUKEE PRAIRIE-STATELINE | 42.504723 | -87.809303 |
|  | Kewaunee | **550610002** | JUMBOS DRIVE-IN PROPERTY, SOUTH END OF K | 44.443119 | -87.505203 |
|  | La Crosse | **550630012** | LACROSSE - DOT BUILDING | 43.7775 | -91.226898 |
|  | Manitowoc | **550710007** | MANITOWOC/WOODLAND DUNES | 44.138618 | -87.616096 |
|  | Marathon | **550730012** | LAKE DUBAY | 44.707352 | -89.771797 |
|  | Milwaukee | **550790010** | HEALTH CENTER | 43.016666 | -87.933296 |
|  |  | **550790026** | DNR SER HQRS SITE | 43.060974 | -87.913498 |
|  |  | **550790085** | BAYSIDE | 43.181 | -87.900002 |
|  | Outagamie | **550870009** | APPLETON AAL | 44.307381 | -88.395103 |
|  | Ozaukee | **550890008** | (blank) | 43.342999 | -87.919998 |
|  |  | **550890009** | HARRINGTON BEACH PARK | 43.498058 | -87.809998 |
|  | Racine | **551010017** | RACINE | 42.713898 | -87.798599 |
|  | Rock | **551050024** | BELOIT-CUNNINGHAM | 42.509079 | -89.062798 |
|  | Sauk | **551110007** | DEVILS LAKE PARK | 43.435101 | -89.679703 |
|  | Sheboygan | **551170006** | SHEBOYGAN KOHLER ANDRE | 43.679001 | -87.716003 |
|  | Taylor | **551199991** | Perkinstown | 45.2066 | -90.5969 |
|  | Walworth | **551270005** | LAKE GENEVA | 42.580009 | -88.499001 |
|  | Waukesha | **551330027** | CLEVELAND SITE | 43.020077 | -88.215103 |
|  | (blank) | **550030010** | BAD RIVER | 46.602001 | -90.655998 |
|  |  | **550270007** | MAYVILLE | 43.435001 | -88.527802 |
|  |  | **550370001** |  | 45.794998 | -88.400002 |
|  |  | **550410007** |  | 45.563 | -88.8088 |
|  |  | **550450001** | NW CORNER OF TRAILER | 42.53389 | -89.659401 |
|  |  | **550590002** | KENOSHA - BARBERSHOP QUARTET SOCIETY | 42.559166 | -87.826103 |
|  |  | **550710004** | MOBILE SHELTER, APPROX 3/4 MI E OF COLLI | 44.0825 | -87.968597 |
|  |  | **550790041** | MILWAUKEE UWM-NORTH | 43.075001 | -87.884003 |
|  |  | **550790044** | APPLETON AVE | 43.092777 | -88.0056 |
|  |  | **550791025** |  | 42.896389 | -87.878098 |
|  |  | **551091002** | SOMERSET | 45.124435 | -92.662697 |
|  |  | **551170007** | ON ROOF | 43.718334 | -87.813103 |
|  |  | **551230008** | ON HILL NEAR PARK OFFICE AND MAINTENANCE | 43.702221 | -90.568298 |
|  |  | **551250001** | TROUT LAKE | 46.051998 | -89.653 |
|  |  | **551310009** | REPLACED SITE 55-131-0007 | 43.327221 | -88.220299 |
|  |  | **551330017** | WAUKESHA, CARROLL COLLEGE | 43.003887 | -88.231903 |
|  |  | **551390011** | ON SOUTHERN PROPERTY LINE OF PVHC PROPER | 44.075279 | -88.529701 |
| **WV** | Berkeley | **540030003** | MARTINSBURG BALL FIELD | 39.448006 | -77.964104 |
|  | Cabell | **540110006** | HENDERSON CENTER/MARSHALL UNIVERSITY - M | 38.424133 | -82.425903 |
|  | Gilmer | **540219991** | Cedar Creek | 38.8795 | -80.8477 |
|  | Greenbrier | **540250003** | SAM BLACK CHURCH - DOH GARAGE - GREENBRI | 37.908531 | -80.632599 |
|  | Hancock | **540291004** | (blank) | 40.421539 | -80.580704 |
|  | Kanawha | **540390010** | CHARLESTON BAPTIST TEMPLE/SITE MOVED FRO | 38.3456 | -81.628304 |
|  | Monongalia | **540610003** | (blank) | 39.649368 | -79.920898 |
|  | Ohio | **540690010** | (blank) | 40.114876 | -80.700996 |
|  | Wood | **541071002** | Neale Elementary School | 39.323532 | -81.552399 |

1. Box plots demarcations are for the 25th, 50th and 75th percentiles, and red crosses are values greater than 2 standard deviations. [↑](#footnote-ref-1)