Air Quality Modeling Technical Support Document for 12km Modeling of EPA 2023fh1_16j Base Case

Technical Support Document

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1.0 INTRODUCTION

1.1 OVERVIEW

This document serves to provide a technical support document for recently developed air quality modeling and ozone results conducted by Alpine Geophysics, LLC (Alpine) for purposes of individual state review and preparation of modeling analyses in support of future revisions of State Implementation Plans (SIPs). The modeling was conducted to take advantage of an updated version of the Comprehensive Air quality Model with Extensions (CAMx[1]) photochemical grid model (version 7.1) and associated source apportionment tools as applied to the latest available modeling platform at the time of the analysis.

This document describes this modeling effort using EPA's national 36km/12km modeling domain (36US3/12US2B). It uses the 2016/2023fh1_16j1_16j (fh1_16j1_16j) modeling platform which represents EPA's estimation of a projected "base case" that demonstrates compliance with most current on-the-books/on-the-way regulatory measures related to the Revised CSAPR Update final rule[2].

1.2 OVERVIEW OF MODELING APPROACH

The modeling documented here includes simulations using the 12km grid based on EPA's 2016/2023fh1_16j modeling platform. All non-emissions CAMx model inputs were supplied by EPA as distributed in the EPA 2016fh/2023fh1 model simulations. The emissions were taken from the EPA "pre-merged" 2016/2023fh1_16j platform distribution.

1.2.1 Episode Selection

Episode selection is an important component of attainment demonstrations. The modeling used the extended ozone season from April 1 through September 30, 2016 period was selected for the modeling primarily due to the following reasons:

- It is aligned with the 2016 federal, state, and local agency inventory development collaborative.
- It is not an unusually low ozone year.
- Ambient meteorological and air quality data are available.
- A 2016 CAMx modeling platform was available from the EPA that was leveraged for the SIP modeling.
- Recent observations have noted many observed high ozone days fall outside of the typical May through September ozone season.

1.2.2 Model Selection

Details on the rationale for model selection are provided in Section 2. The Weather Research Forecast (WRF) prognostic meteorological model was selected for the modeling using the EPA

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[1] http://www.camx.com

[2] 82 FR 23054

12US2 grid. Additional emission modeling was not required for the 12km simulation as the 2023fh1_16j platform was provided to Alpine in pre-merged CAMx ready format.
Emissions processing was completed by EPA for the 12km domain using the SMOKE emissions model for most source categories. The exceptions are that BEIS model was used for biogenic emissions and there are special processors for fires, windblown dust, lightning, and sea salt emissions. The MOVES2014 on-road mobile source emissions model was used with SMOKE-MOVES to generate on-road mobile source emissions with EPA generated vehicle activity data provided with the modeling platform. An updated version of the CAMx photochemical grid model (version 7.1) was used. With the exception of the CAMx update, the setup is based on the same WRF/SMOKE/BEIS/CAMx modeling system used in EPA’s 2016 platform modeling distribution.

1.2.3 Base and Future Year Emissions Data

The 2023 future year was selected for the attainment demonstration modeling based on an initial need to support control strategy analyses in that and future timelines. The 2016 base case and 2023 future year emissions were based on EPA’s “fh1_16j” inventories with no adjustment and include the update to the commercial marine vessel emissions released shortly after the initial “fh1_16j” emissions were released.

1.2.4 Input Preparation and QA/QC

Quality assurance (QA) and quality control (QC) of the emissions datasets are some of the most critical steps in performing air quality modeling studies. Because emissions processing is tedious, time consuming and involves complex manipulation of many different types of large databases, rigorous QA measures are a necessity to prevent errors in emissions processing from occurring. This modeling study utilized EPA’s pre-QA/QC’d emissions platform that followed a multistep emissions QA/QC approach for the 12km domain.

1.2.5 Meteorology Input Preparation and QA/QC

The CAMx 2016 meteorological inputs are based on WRF meteorological modeling conducted by EPA. Details on the EPA 2016 WRF application and evaluation are provided by EPA (EPA, 2019a).

1.2.6 Initial and Boundary Conditions Development

Initial concentrations (IC) and Boundary Conditions (BC) are important inputs to the CAMx model. We ran the model in calendar quarters with 15 days of model spin-up before the first of each quarter so the ICs, derived from the CAMx 2016fh_16j CAMx7beta6 CAMx simulation, are washed out of the modeling domain. The lateral boundary and initial species concentrations are provided by EPA for the 12US2 modeling domain.

1.2.7 Air Quality Modeling Input Preparation and QA/QC

Each step of the air quality modeling was subjected to QA/QC procedures. These procedures included verification of model configurations, confirmation that the correct data were used and processed correctly, and other graphical and tabular procedures.

2.0 MODEL SELECTION

This section documents the models used in this SIP modeling study. The selection methodology presented in this chapter mirrors EPA's and other's regulatory modeling in support of the 2008 Ozone NAAQS Preliminary Interstate Transport Assessment (Page, 2017; Alpine, 2017a, b; EPA, 2016b) and technical memorandum providing additional information on the Interstate SIP submissions for the 2015 Ozone NAAQS (Tsirigotis, 2018).

Unlike previous modeling guidance that specified a particular model, the EPA now recommends that models be selected for SIP studies on a "case-by-case" basis. The latest EPA guidance (EPA, 2018b) explicitly mentions the CMAQ and CAMx photochemical grid models (PGMs) as the most commonly used PGMs that would satisfy EPA's selection criteria but notes that this is not an exhaustive list and does not imply that they are "preferred" over other PGMs that could also be considered and used with appropriate justification. EPA's current modeling guidelines lists the following criteria for model selection (EPA, 2018b):

- It should not be proprietary;
- It should have received a scientific peer review;
- It should be appropriate for the specific application on a theoretical basis;
- It should be used with data bases which are available and adequate to support its application;
- It should be shown to have performed well in past modeling applications;
- It should be applied consistently with an established protocol on methods and procedures;
- It should have a user's guide and technical description;
- The availability of advanced features (e.g., probing tools or science algorithms) is desirable; and
- When other criteria are satisfied, resource considerations may be important and are a legitimate concern.

For this modeling, we used the WRF/SMOKE/MOVES2014/BEIS/CAMx modeling system as the primary tool for calculating concentrations and light extinction at downwind monitors. The utilized modeling system satisfies all of EPA's selection criteria. A description of the key models to be used in the modeling follows.

WRF/ARW: The Weather Research and Forecasting (WRF)[3] Model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (Skamarock, 2004; 2006; Skamarock et al., 2005). The Advanced Research WRF (ARW) version of WRF was used in this modeling study. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. The effort to develop WRF has been a collaborative partnership, principally among the National

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[3] http://www.wrf-model.org/index.php

Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides operational forecasting a model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community.

SMOKE: The Sparse Matrix Operator Kernel Emissions (SMOKE)[4] modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire and biogenic emission sources for photochemical grid models (Coats, 1995; UNC, 2015). As with most 'emissions models', SMOKE is principally an emission processing system and not a true emissions modeling system in which emissions estimates are simulated from 'first principles'. This means that, except for mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting an existing base emissions inventory data into the hourly gridded speciated formatted emission files required by a photochemical grid model. SMOKE was used by EPA to prepare emission inputs for non-road mobile, area and point sources. These files were adopted and used as-is for this analysis.

SMOKE-MOVES: SMOKE-MOVES uses an Emissions Factor (EF) Look-Up Table from MOVES, gridded vehicle miles travelled (VMT) and other activity data and hourly gridded meteorological data (typically from WRF) and generates hourly gridded speciated on-road mobile source emissions inputs.

MOVES2014: MOVES2014[5] is an EPA on-road mobile source emissions model that was first released in July 2014 (EPA, 2014a,b,c). MOVES2014 includes the on-road mobile source emissions factor information. Emission factors developed by EPA were used in this analysis.

BEIS: Biogenic emissions were modeled by EPA using version 3.61 of the Biogenic Emission Inventory System (BEIS). First developed in 1988, BEIS estimates volatile organic compound (VOC) emissions from vegetation and nitric oxide (NO) emissions from soils. Because of resource limitations, recent BEIS development has been restricted to versions that are built within the Sparse Matrix Operational Kernel Emissions (SMOKE) system.

CAMx: CAMx is a state-of-science "One-Atmosphere" photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (ENVIRON, 2015[6]). CAMx is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. Built on today's understanding that air quality issues are complex, interrelated, and reach beyond the urban scale, CAMx is designed to (a) simulate air quality over many geographic scales, (b) treat a wide variety of inert and chemically active pollutants including ozone, inorganic and organic $PM_{2.5}$ and PM_{10} and mercury and toxics, (c) provide source-receptor, sensitivity, and

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[4] http://www.smoke-model.org/index.cfm

[5] http://www.epa.gov/otaq/models/moves/

[6] http://www.camx.com/files/camxusersguide_v6-20.pdf

process analyses and (d) be computationally efficient and easy to use. The U.S. EPA has approved the use of CAMx for numerous ozone and PM State Implementation Plans throughout the U.S. and has used this model to evaluate regional mitigation strategies including those for most recent regional rules (e.g., Transport Rule, CAIR, NO_X SIP Call, etc.). CAMx Version 7.1 was used in this study.

SMAT-CE: The Software for the Modeled Attainment Test - Community Edition (SMAT-CE)[7] is a PC-based software tool that can perform the modeled attainment tests for particulate matter and ozone and calculate changes in visibility at Class I areas as part of the reasonable progress analyses for regional haze. Version 1.6 was used in this analysis.

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[7] https://www.epa.gov/scram/photochemical-modeling-tools

3.0 EPISODE SELECTION

EPA's most recent modeling guidance (EPA, 2018b) contains recommended procedures for selecting modeling episodes. This modeling used an extended ozone season in 2016 because it satisfies the most criteria in EPA's modeling guidance episode selection discussion.

The extended ozone season of April 1 through September 30, 2016 has been selected for the modeling primarily due to 2016 not being an unusually low ozone year, availability of a 2016 12km CAMx modeling platform from EPA.

4.0 MODELING DOMAIN SELECTION

This section summarizes the modeling domain definitions for the modeling, including the domain coverage, resolution, and map projection. It also discusses emissions, aerometric, and other data available for use in model input preparation and performance testing.

4.1 HORIZONTAL DOMAINS

The modeling used a 12km continental U.S. (12US2) domain nested within a 36km North American domain.

The 36/12km nested grid modeling domain configuration is shown in Figure 4-1. The 12km domain shown in Figure 4-1 represents the CAMx 12km air quality and SMOKE/BEIS emissions modeling domain. The WRF meteorological modeling was run on larger 12km modeling domains than used for CAMx as demonstrated in EPA's meteorological model performance evaluation document (EPA, 2019a). The WRF meteorological modeling domains are defined larger than the air quality modeling domains because meteorological models can sometimes produce artifacts in the meteorological variables near the boundaries as the prescribed boundary conditions come into dynamic balance with the coupled equations and numerical methods in the meteorological model.

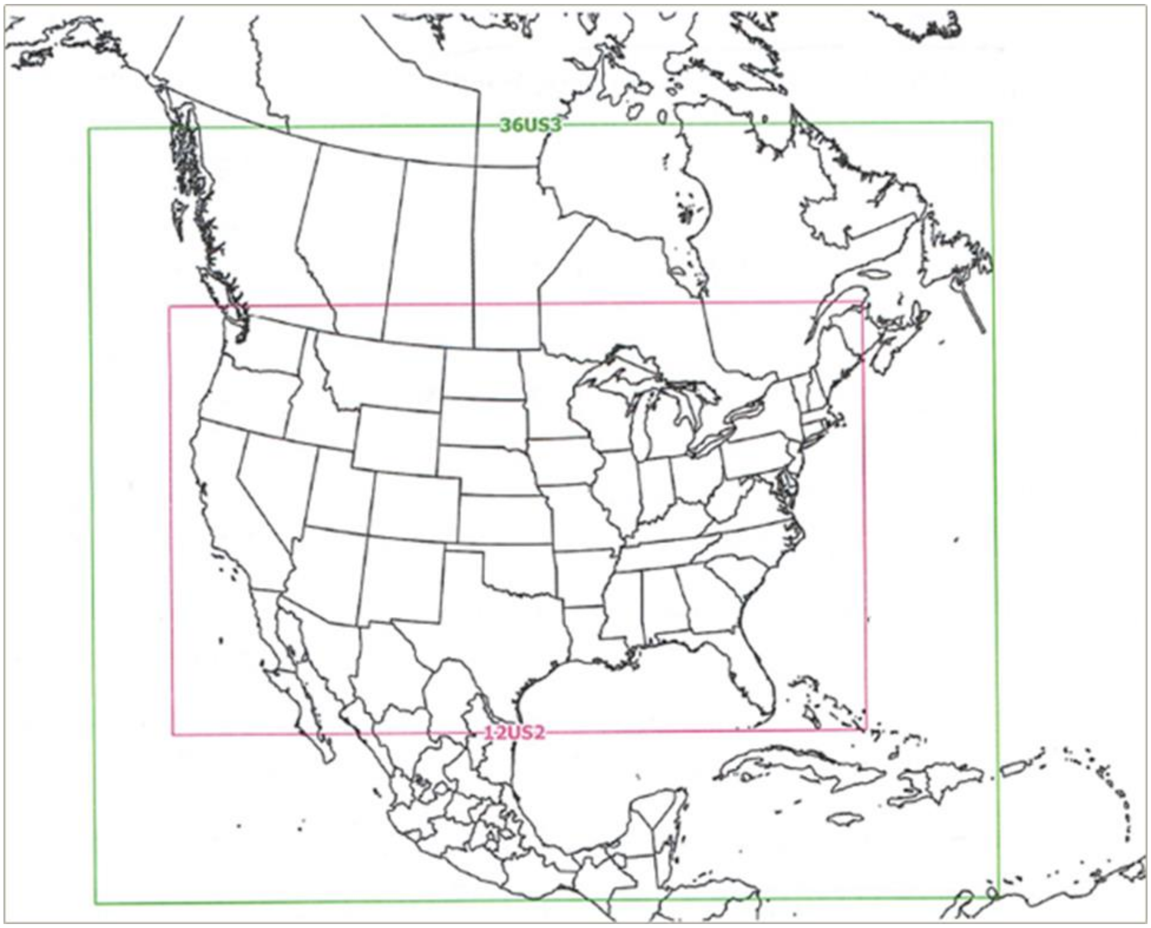

Figure 4-1. Map of 12km CAMx (red) 12US2 modeling domain.

4.2 VERTICAL MODELING DOMAIN

The CAMx vertical structure is primarily defined by the vertical layers used in the WRF meteorological modeling. The WRF model employs a terrain following coordinate system defined by pressure, using multiple layer interfaces that extend from the surface to 50 mb (approximately 19 km above sea level). EPA ran WRF using 35 vertical layers. This same layer structure was used for the CAMx simulations. Table 4-1 displays the WRF/CAMx 35 vertical layers for the 36/12km grid domain.

4.3 DATA AVAILABILITY

The CAMx modeling systems requires emissions, meteorology, surface characteristics, initial and boundary conditions (IC/BC), and ozone column data for defining the inputs.

4.3.1 Emissions Data

Without exception, the 2016 base year and 2023 base case emissions inventories for modeling for this analysis were based on emissions obtained from the EPA's "fh1_16j" modeling platform. This platform was obtained from EPA in January 2020 and represents EPA's best estimate of all promulgated national, regional, and local control strategies.

4.3.2 Air Quality

Data from the Air Quality System (AQS)[8] ambient monitoring network were used to evaluate the model's performance.

4.3.4 Meteorological Data

The 12km meteorological data were generated by EPA using the WRF prognostic meteorological model (EPA, 2019a). WRF was run on the North American 36km and continental U.S. 12km grid (12US2) for the 2016 platform as described in earlier sections.

4.3.5 Initial and Boundary Conditions Data

Initial concentrations (IC) and Boundary Conditions (BC) are important inputs to the CAMx model. We ran 15 days of model spin-up before the first of each quarter, so the ICs are washed out of the modeling domain. The lateral boundaries are provided by a three-dimensional global atmospheric chemistry model, Hemispheric Community Multiscale Air Quality (H-CMAQ) v.5.2.1 and were unchanged from the files EPA used in the "fh" modeling platform (Henderson, 2018). The 2016 boundary concentrations from H-CMAQ were used for the 2016 and 2023 model simulations. The initial conditions for the spin-up period on the 2nd, 3rd and 4th quarters were derived from CAMx model outputs from the "2016fh_camxv7beta6_16j" simulation processed with the CAMx bndextr version 6 processor.

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[8] http://www.epa.gov/air/data/

Table 4-1. WRF and CAMx layers and their approximate height above ground level.

WRF/CAMx Layers	Sigma P	Pressure (mb)	Approx. Height (m AGL)
35	0.00	50.00	17,556
34	0.05	97.50	14,780
33	0.10	145.00	12,822
32	0.15	192.50	11,282
31	0.20	240.00	10,002
30	0.25	287.50	8,901
29	0.30	335.00	7,932
28	0.35	382.50	7,064
27	0.40	430.00	6,275
26	0.45	477.50	5,553
25	0.50	525.00	4,885
24	0.55	572.50	4,264
23	0.60	620.00	3,683
22	0.65	667.50	3,136
21	0.70	715.00	2,619
20	0.74	753.00	2,226
19	0.77	781.50	1,941
18	0.80	810.00	1,665
17	0.82	829.00	1,485
16	0.84	848.00	1,308
15	0.86	867.00	1,134
14	0.88	886.00	964
13	0.90	905.00	797
12	0.91	914.50	714
11	0.92	924.00	632
10	0.93	933.50	551
9	0.94	943.00	470
8	0.95	952.50	390
7	0.96	962.00	311
6	0.97	971.50	232
5	0.98	981.00	154
4	0.99	985.75	115
3	0.99	990.50	77
2	1.00	995.25	38
1	1.00	997.63	19

5.0 MODEL INPUT PREPARATION PROCEDURES

This section summarizes the procedures used in developing the meteorological, emissions, and air quality inputs to the CAMx model for the modeling on the 36/12km grid for the 2016 calendar year period. The 12km CAMx modeling databases are based on the EPA “fh1_16j” platform databases. While some of the data prepared by EPA for this platform are new, many of the files are largely based on earlier 2016 platform versions. More details on the 2016 CAMx database development are provided in EPA documentation as follows:

- Meteorological Model Performance for Annual 2016 WRF v3.8 Simulation (EPA, 2019a).
- National Emissions Inventory Collaborative (2019). 2016v1 Emissions Modeling Platform. Retrieved from http://views.cira.colostate.edu/wiki/wiki/10202.
- Technical Support Document (TSD) - Preparation of Emissions Inventories for the Version 7.2 2016 North American Emissions Modeling Platform (EPA, 2019c).

The modeling procedures used in the modeling are consistent with over 20 years of EPA ozone modeling guidance documents (e.g., EPA, 1991; 1999; 2005a; 2007; 2014e; 2018b), other recent modeling studies conducted for various State and local agencies using these or other state-of-science modeling, as well as the methods used by EPA in support of the recent Transport analyses (EPA, 2010; 2015, 2016b, 2018a).

5.1 METEOROLOGICAL INPUTS

5.1.1 WRF Model Science Configuration

Version 3.8 of the WRF model, Advanced Research WRF (ARW) core (Skamarock, 2008) was used for generating the 2016 simulation. Selected physics options include Pleim-Xiu land surface model, Asymmetric Convective Model version 2 planetary boundary layer scheme, Kain-Fritsch cumulus parameterization utilizing the moisture-advection trigger, Morrison double moment microphysics, and RRTMG longwave and shortwave radiation schemes (Gilliam and Pleim, 2010). The WRF model configuration was prepared by EPA (EPA, 2019a).

5.1.2 WRF Input Data Preparation Procedures

A summary of the WRF input data preparation procedures that were used are listed in EPA’s documentation (EPA, 2019a).

5.1.3 WRF Model Performance Evaluation

The WRF model evaluation approach was based on a combination of qualitative and quantitative analyses. The quantitative analysis was divided into monthly summaries of 2-m temperature, 2-m mixing ratio, and 10-m wind speed using the boreal seasons to help generalize the model bias and error relative to a set of standard model performance benchmarks. The qualitative approach was to compare spatial plots of model estimated monthly total precipitation with the monthly PRISM precipitation. The WRF model performance evaluation for the 12km domain is provided in EPA’s documentation (EPA, 2019a).

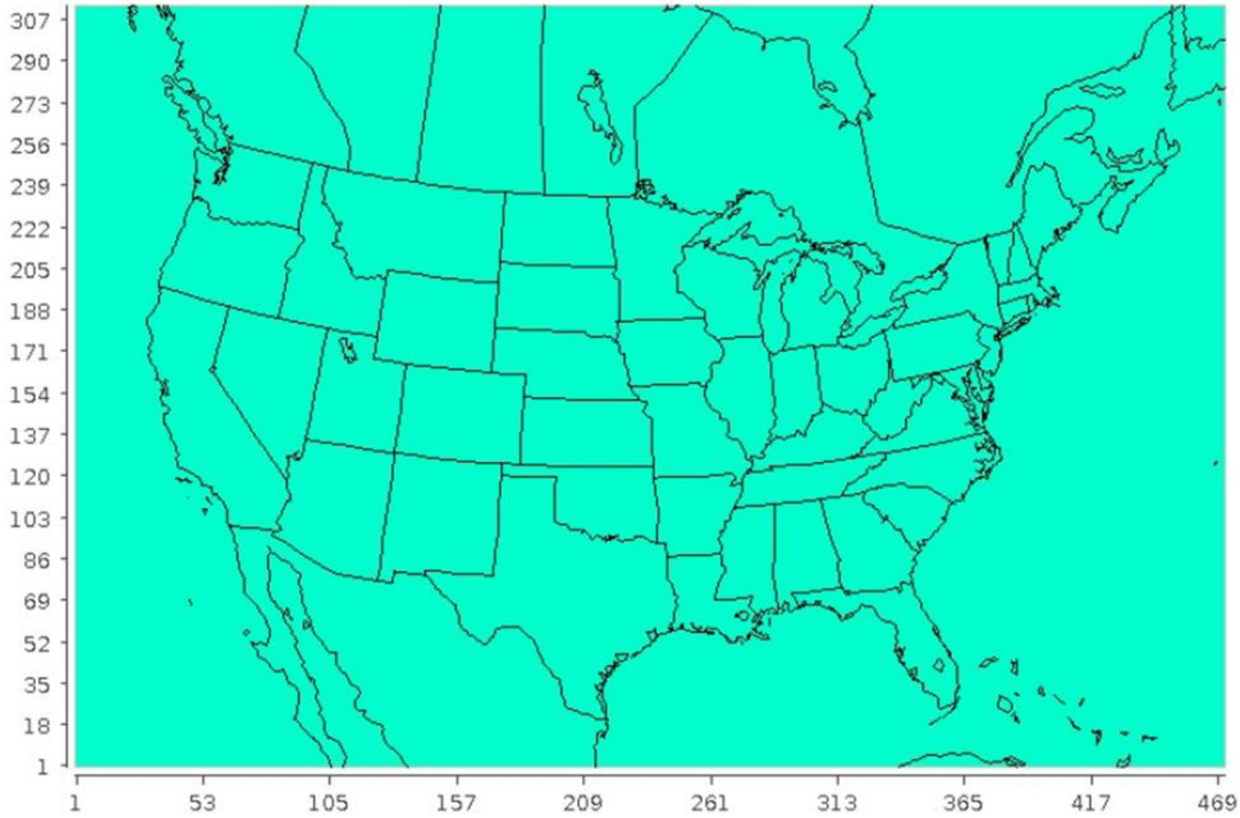

Figure 5-1. Map of 12km WRF domain. Source: EPA, 2019a.

5.1.4 WRFCAMx/MCIP Reformatting Methodology

The WRF meteorological model output data was processed to provide inputs for the CAMx photochemical grid model. The WRFCAMx processor maps WRF meteorological fields to the format required by CAMx. It also calculates turbulent vertical exchange coefficients (Kv) that define the rate and depth of vertical mixing in CAMx. The methodology used by EPA to reform the meteorological data into CAMx format is provided in documentation provided with the wrfcamx conversion utility.

The meteorological data generated by the WRF simulations were processed by EPA using WRFCAMx v4.6 meteorological data processing program to create model-ready meteorological inputs to CAMx. Vertical diffusivities were based on the “YSU” scheme with the EPA application of the “kvpatch” processor to adjust based on land use.

5.2 EMISSION INPUTS

5.2.1 Available Emissions Inventory Datasets

EPA’s 2016 base year and 2023 future year emission inventories from the CMV updated “fh1_16j” modeling platform (EPA, 2019c) were used for all categories without exception.

5.2.2 Development of CAMx-Ready Emission Inventories

CAMx-ready emission inputs were generated by EPA mainly by the SMOKE and BEIS emissions models. CAMx requires two emission input files for each day: (1) low level gridded emissions that are emitted directly into the first layer of the model from sources at the surface with little or no plume rise; and (2) elevated point sources (stacks) with plume rise calculated from stack parameters and meteorological conditions. For this analysis, CAMx was operated using version 7.1.

Additional emission modeling was not required for the simulation as the 2023fh1_16j platform was provided to Alpine in pre-merged CAMx ready format.

5.2.2.1 Episodic Biogenic Source Emissions

Biogenic emissions were generated by EPA using the BEIS biogenic emissions model within SMOKE. BEIS uses high resolution GIS data on plant types and biomass loadings and the WRF surface temperature fields, and solar radiation (modeled or satellite-derived) to develop hourly emissions for biogenic species on the 36km and 12km grids. BEIS generates gridded, speciated, temporally allocated emission files.

5.2.2.2 Point Source Emissions

2016 point source emissions were from the 2016 “fh1_16j” modeling platform. Point sources were developed in two categories: (1) major point sources with Continuous Emissions Monitoring (CEM) devices; and (2) point sources without CEMs. For point sources with continuous emissions monitoring (CEM) data, day-specific hourly NO_x and SO_2 emissions were used for the 2016 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data were based on the annual emissions temporally allocated to each hour of the year using the CEM hourly heat input. The locations of the point sources were converted to the LCP coordinate system used in the modeling. They were processed by EPA using SMOKE to generate the temporally varying (i.e., day-of-week and hour-of-day) speciated emissions needed by CAMx, using profiles by source category from the EPA “fh1_16j” modeling platform.

5.2.2.3 Area and Non-Road Source Emissions

2016 area and non-road emissions were from the 2016 “fh1_16j” modeling platform. The area and non-road sources were spatially allocated to the grid using an appropriate surrogate distribution (e.g., population for home heating, etc.). The area sources were temporally allocated by month and by hour of day using the EPA source-specific temporal allocation factors. The SMOKE source-specific speciation allocation profiles were also used.

5.2.2.4 Wildfires, Prescribed Burns, Agricultural Burns

Fire emissions in 2016v1 were developed based on Version 2 of the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) system (Sullivan, et al., 2008). SMARTFIRE2 was the first version of SMARTFIRE to assign all fires as either prescribed burning or wildfire categories. In past inventories, a significant number of fires were published as unclassified, which impacted the emissions values and diurnal emissions pattern. Recent updates to SMARTFIRE include improved emission factors for prescribed burning.

5.2.2.5 On-Road Motor Vehicle Emissions

On-road motor vehicle emissions were processed by EPA using the SMOKE-MOVES module.

5.2.2.6 QA/QC and Emissions Merging

EPA processed the emissions by major source category in several different "streams", including area sources, on-road mobile sources, non-road mobile sources, biogenic sources, non-CEM point sources, CEM point sources using day-specific hourly emissions, and emissions from fires. Separate Quality Assurance (QA) and Quality Control (QC) were performed for each stream of emissions processing and in each step following the procedures utilized by EPA. SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. In addition, we generated visual displays that included spatial plots of the hourly emissions for each major species (e.g., NOX, VOC, some speciated VOC, SO2, NH3, PM and CO).

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area, low-level, fire, and point emission files were written to generate the CAMx-ready two-dimensional day and domain-specific hourly speciated gridded emission inputs. The point source and, as available elevated fire, emissions were processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

The resultant CAMx model-ready emissions were subjected to a final QA using spatial maps to assure that: (1) the emissions were merged properly; (2) CAMx inputs contain the same total emissions; and (3) to provide additional QA/QC information.

5.2.3 Use of the Plume-in-Grid (PiG) Subgrid-Scale Plume Treatment

Consistent with the EPA "fh" simulation, no PiG subgrid-scale plume treatment was used.

5.2.4 Future-Year Emissions Modeling

Future-year emission inputs were generated by processing the 2023 emissions data provided with EPA's "fh1_16j" modeling platform without exception.

5.3 PHOTOCHEMICAL MODELING INPUTS

5.3.1 CAMx Science Configuration and Input Configuration

CAMx Version 7.1 was used in the modeling. The CAMx model setup used is defined by EPA in its air quality modeling technical support documents (EPA, 2016b, 2018b).

6.0 FUTURE YEAR MODELING

This chapter discusses the 2023 future year modeling resulting from the modeling effort.

6.1 FUTURE YEAR SIMULATED

The modeled 2023 concentrations were used to identify monitoring sites that are projected to be nonattainment for the ozone NAAQS in 2023.

6.2 FUTURE YEAR GROWTH AND CONTROLS

In January 2020, EPA released the revised “fh1_16j” modeling platform that was the source for the 2023 future year emissions in this analysis. This platform has been identified by EPA as the base case for compliance with promulgated federal, state, and local rules at the time of inventory preparation. Additionally, there were several emission categories and model inputs/options that were held constant at 2016 levels as follows:

- Biogenic emissions.
- Wildfires, Prescribed Burns and Agricultural Burning (open land fires).
- Windblown dust emissions.
- Sea Salt.
- 36km CONUS domain Boundary Conditions (BCs).
- 2016 36km and 12km meteorological conditions.
- All model options and inputs other than emissions.

The effects of climate change on the future year meteorological conditions were not accounted. It has been argued that global warming could increase ozone due to higher temperatures producing more biogenic VOC and faster photochemical reactions. The effects of inter-annual variability in meteorological conditions may be more important than climate change given the 12-year difference between the base (2016) and future (2023) years.

6.3 FUTURE YEAR BASELINE AIR QUALITY SIMULATIONS

A 2023 future year base case CAMx simulation was conducted, and 2023 maximum daily 8-hour ozone design value projections were made based on EPA’s latest modeling guidance (EPA, 2018b) for the 12US2 modeling domain in this analysis.

6.3.1 Calculation of Future Ozone Concentrations

The ozone predictions from the 2016 and 2023 CAMx model simulations were used to project 2014-2018 average ozone design values to 2023 using the SMAT-CE tool and following the approach described in the EPA’s guidance for attainment demonstration modeling (EPA, 2018b).

Sites with 2023 average design values that exceed the NAAQS (i.e., 2023 average design values of 71 ppb or greater) are considered nonattainment receptors in 2023.

Modeled nonattainment monitors in the eastern United States, defined using Alpine's 12km simulation, are provided in Table 6-1 along with calculated 2023 average and most current 2018-2020 design values. A full list of monitor locations in the eastern United States and modeled average ozone design values for the 12km domain modeling is provided in Appendix A of this report. National calculated design values are presented in Figure 6-1 below.

Table 6-1. Alpine 12km modeling-identified 8-hour ozone nonattainment monitors.

				Ozone DV (ppb)			
Monitor	**State**	**County**	**Local Name**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
90010017	Connecticut	Fairfield	Greenwich Point Park	79.3	75.8	73.4	82
90013007	Connecticut	Fairfield	Prospect Street	82.0	75.8	74.3	80
90019003	Connecticut	Fairfield	Sherwood Island Connector	82.7	75.6	76.9	79
90099002	Connecticut	New Haven	Hammonasset State Park	79.7	72.0	71.7	80
482010024	Texas	Harris	Houston Aldine	79.3	73.8	74.0	79
550590019	Wisconsin	Kenosha	Chiwaukee Prairie Stateline	78.0	72.1	71.2	74
551170006	Wisconsin	Sheboygan	Sheboygan - Kohler Andrae	80.0	73.9	73.0	75

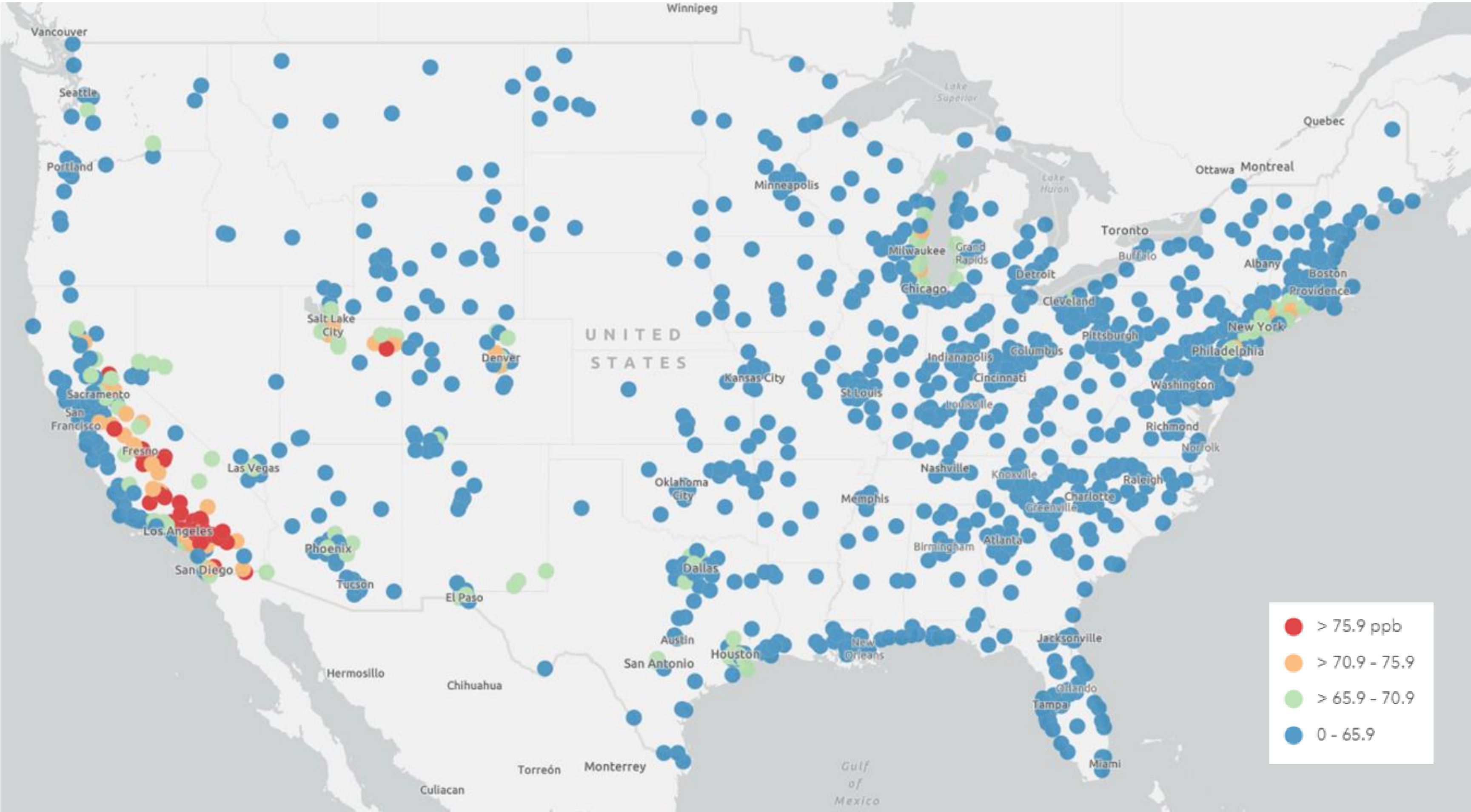

Figure 6-1. 2023fh1_16j Calculated 2023 MDA8 Ozone Design Values (ppb).

7.0 OZONE CONTRIBUTION MODELING

Alpine further performed region and source category-level ozone source apportionment modeling using the CAMx Ozone Source Apportionment Technology (OSAT) /Anthropogenic Precursor Culpability Analysis (APCA) technique to provide information regarding the expected contribution of 2023 base case NOx and VOC emissions from each category within each region to projected 2023 concentrations at downwind air quality monitors. This OSAT/APCA modeling was conducted for select regions and source categories as defined below.

The source apportionment model run tracked the ozone formed from each of the following contribution categories (i.e., “tags”):

- Regions –NOx and VOC emissions from each state or state group tracked individually using the category “tags” listed below;
    - Biogenic/Fires;
    - Anthropogenic Emissions – comprised of the individually tagged categories;
        - On-road mobile,
        - Non-road mobile, stationary area, marine, aircraft, railroad, and C1/C2 marine,
        - Peaking EGU units,
        - Other EGU units, and
        - Non-EGU point sources
- Boundary and Initial Concentrations – concentrations transported into the modeling domain (e.g., international transport, stratospheric intrusion, domain initialization conditions);
- Canada, Mexico, and over water domains – anthropogenic emissions from sources in the portions of Canada and Mexico included in the modeling domain and from sources in the Pacific and Atlantic Oceans or from the Gulf of Mexico or Great Lakes associated with offshore or ocean going (C3) commercial marine vessel activities.

The contribution modeling conducted for this analysis provided contribution to ozone from select source regions, informed by MOG’s 12km OSAT/APCA modeling and displayed in Figure 7-1, for each noted source category individually.

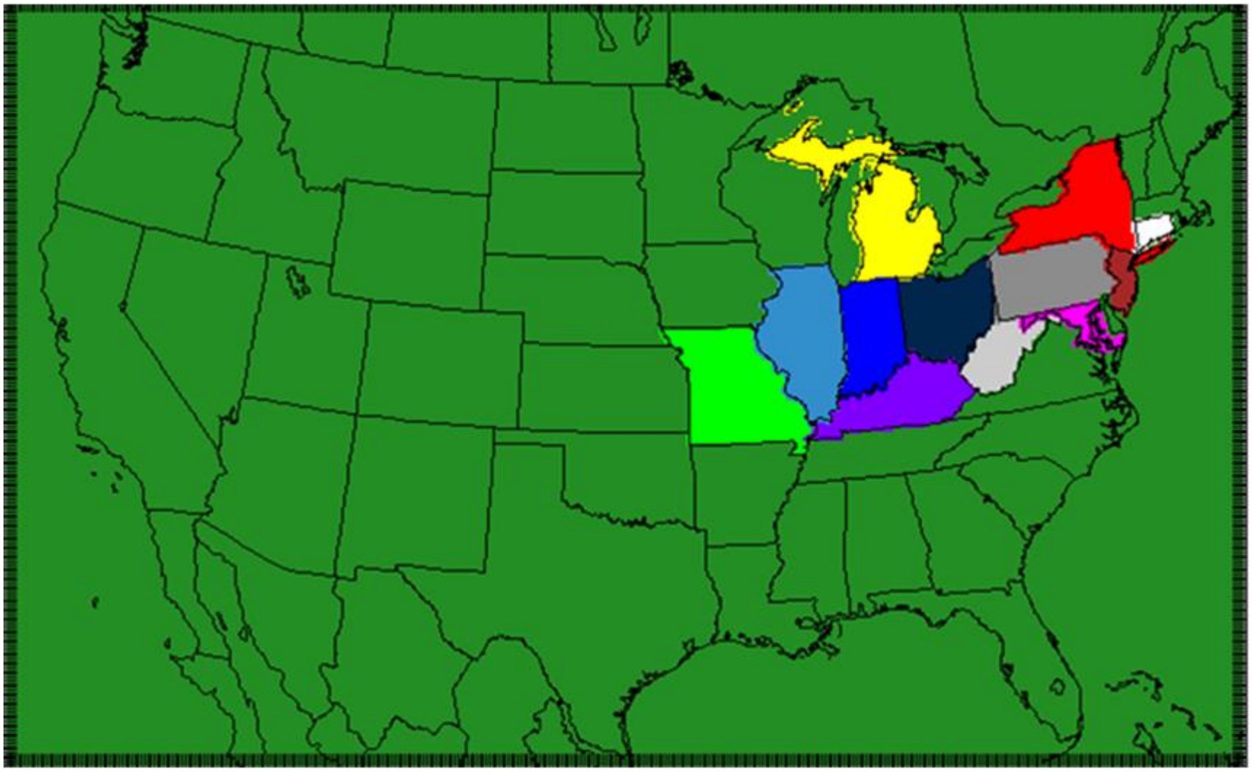

Figure 7-1. OSAT/APCA regions for 12km source contribution modeling.

Consistent with EPA’s approach, the 12km CAMx OSAT/APCA model run was performed for the period May 1 through September 30 using the projected 2023 base case emissions and 2016 meteorology for this period. The hourly contributions from each tag were processed to calculate an 8-hour average contribution metric. Alpine used EPA’s SMAT-CE tool and top ten future year modeled days to develop source apportioned concentration files from which contribution metrics were calculated.

This process for calculating the contribution metric uses the contribution modeling outputs in a “relative sense” to apportion the projected 2023 average design value at each monitoring location into contributions from each individual tag and is consistent with the updated methodology documented in EPA’s March 2018 memorandum. It is important to note that Alpine’s 12km contribution results utilize the approach described by EPA in basing the average future year contribution on future year modeled values.

7.1 OZONE CONTRIBUTION MODELING RESULTS

The contributions from each tagged state’s anthropogenic source sectors were aggregated to calculate total contribution to individually identified 12km domain nonattainment receptors and are provided in Table 7-1.

The EPA has historically found that the 1 percent threshold is appropriate for identifying interstate transport linkages for states collectively contributing to downwind ozone nonattainment or maintenance problems because that threshold captures a high percentage of the total pollution transport affecting downwind receptors.

Based on the approach used in CSAPR and the CSAPR Update, upwind states that contribute ozone in amounts at or above the 1 percent of the NAAQS threshold to a particular downwind nonattainment receptor would be considered to be “linked” to that receptor in step 2 of the CSAPR framework for purposes of further analysis in step 3 to determine whether and what emissions from the upwind state contribute significantly to nonattainment of the NAAQS at the downwind receptors. For the 2008 ozone NAAQS, the value of a 1 percent threshold would be 0.75 ppb. For the 2015 ozone NAAQS the value of a 1 percent threshold would be 0.70 ppb.

Table 7-1. Alpine 12km 2023 APCA Ozone Contribution Calculations (ppb) for Tagged Regions.

Monitor	Name	Ozone DV 2023 Ave (ppb)	APCA Contributions (ppb)											
			CT	NY	NJ	MD	PA	WV	IL	IN	KY	MI	MO	OH
90010017	GREENWICH POINT PARK	73.3	13.81	13.24	12.34	0.63	3.67	0.46	0.44	0.54	0.47	0.66	0.10	1.13
90013007	PROSPECT STREET	75.7	5.08	12.72	11.82	1.01	4.60	0.72	0.72	0.94	0.67	1.48	0.17	1.80
90019003	SHERWOOD ISLAND CONNECTOR	77.9	7.75	13.96	12.65	0.89	5.03	0.58	0.69	0.88	0.60	1.48	0.15	1.50
90099002	HAMMONASSET STATE PARK	71.4	7.60	15.13	6.71	1.09	3.29	0.64	0.90	0.99	0.60	1.51	0.25	2.21
482010024	HOUSTON ALDINE	74.9	0.01	0.02	0.02	0.02	0.03	0.01	0.06	0.03	0.03	0.02	0.35	0.02
550590019	CHIWAUKEE PRAIRIE STATELINE	72.1	0.03	0.26	0.07	0.09	0.41	0.25	25.06	5.82	0.54	1.05	0.96	1.76
551170006	SHEBOYGAN - KOHLER ANDRAE	74.0	0.06	0.41	0.21	0.17	0.67	0.57	18.09	7.50	1.10	1.99	0.83	1.94

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Appendix A

12km MDA8 Ozone Design Value Modeling Results from 2023fh1_16j Projection with Current 2018-2020 Design Value for Eastern United States

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
90010017	Connecticut	Fairfield	79.3	75.8	73.4	82
90011123	Connecticut	Fairfield	77.0	69.0	68.5	71
90013007	Connecticut	Fairfield	82.0	75.8	74.3	80
90019003	Connecticut	Fairfield	82.7	75.6	76.9	79
90031003	Connecticut	Hartford	71.6	63.1	62.4	67
90050005	Connecticut	Litchfield	71.3	62.8	62.2	65
90079007	Connecticut	Middlesex	78.6	69.9	69.1	74
90090027	Connecticut	New Haven	75.6	68.4	67.7	72
90099002	Connecticut	New Haven	79.7	72.0	71.7	80
90110124	Connecticut	New London	74.3	67.8	66.7	73
90159991	Connecticut	Windham	69.6	61.2	60.5	66
100031007	Delaware	New Castle	68.0	58.7	58.3	65
100031010	Delaware	New Castle	73.6	65.2	64.6	-
100031013	Delaware	New Castle	71.0	62.8	62.1	66
100032004	Delaware	New Castle	71.3	63.1	62.4	-
110010041	District of Columbia	District of Columbia	57.0	49.6	49.2	55
110010043	District of Columbia	District of Columbia	71.0	61.8	61.3	69
110010050	District of Columbia	District of Columbia	70.0	61.1	60.6	67
170310001	Illinois	Cook	73.0	68.9	68.4	75
170310032	Illinois	Cook	72.3	68.6	68.4	74
170310076	Illinois	Cook	72.0	68.2	67.8	69
170311003	Illinois	Cook	68.3	64.9	64.2	73
170311601	Illinois	Cook	69.3	63.8	62.8	71
170313103	Illinois	Cook	62.6	58.8	58.9	65
170314002	Illinois	Cook	68.6	65.5	64.8	71
170314007	Illinois	Cook	72.0	67.1	67.3	71
170314201	Illinois	Cook	73.3	68.3	68.5	77
170317002	Illinois	Cook	74.0	69.0	68.0	75
170436001	Illinois	DuPage	69.6	64.1	63.3	71
170830117	Illinois	Jersey	69.0	62.3	61.6	67
170890005	Illinois	Kane	69.3	63.2	62.8	72
170971007	Illinois	Lake	73.6	68.6	67.2	72
171110001	Illinois	McHenry	69.6	63.0	62.6	73
171190008	Illinois	Madison	70.0	63.3	62.7	-

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
171191009	Illinois	Madison	69.0	62.4	61.8	68
171193007	Illinois	Madison	70.6	63.9	63.3	70
171630010	Illinois	Saint Clair	69.0	62.2	61.6	67
180190008	Indiana	Clark	70.3	61.6	61.0	65
180431004	Indiana	Floyd	71.0	62.9	62.4	67
180890022	Indiana	Lake	68.3	63.8	63.6	70
180892008	Indiana	Lake	66.0	62.1	61.7	66
180910010	Indiana	LaPorte	65.0	60.4	59.0	-
180970050	Indiana	Marion	70.3	63.8	63.2	68
180970057	Indiana	Marion	66.0	60.9	60.1	69
180970073	Indiana	Marion	65.5	60.0	59.2	-
180970078	Indiana	Marion	68.5	63.3	62.4	67
180970087	Indiana	Marion	65.3	60.3	59.5	63
181230009	Indiana	Perry	66.6	57.2	56.6	63
181270024	Indiana	Porter	69.6	64.3	64.1	71
181270026	Indiana	Porter	69.3	64.0	63.7	69
181290003	Indiana	Posey	66.6	58.0	57.7	64
181630013	Indiana	Vanderburgh	68.3	59.1	58.9	63
181630021	Indiana	Vanderburgh	69.0	59.7	59.2	66
181730008	Indiana	Warrick	68.6	59.5	58.5	65
181730009	Indiana	Warrick	66.0	56.8	56.0	-
181730011	Indiana	Warrick	67.6	58.4	57.5	63
210150003	Kentucky	Boone	63.0	53.1	53.1	64
210190017	Kentucky	Boyd	65.0	60.8	60.6	61
210290006	Kentucky	Bullitt	65.6	57.7	57.2	65
210373002	Kentucky	Campbell	68.6	61.4	60.7	63
210430500	Kentucky	Carter	62.0	56.4	56.1	57
210890007	Kentucky	Greenup	61.6	56.6	56.2	56
210910012	Kentucky	Hancock	67.5	55.9	54.4	-
211010014	Kentucky	Henderson	68.3	59.4	58.0	-
211110051	Kentucky	Jefferson	68.3	60.6	59.9	65
211110067	Kentucky	Jefferson	74.3	66.1	65.2	72
211451024	Kentucky	McCracken	62.6	55.4	54.9	63
240031003	Maryland	Anne Arundel	74.0	64.2	63.2	72

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
240051007	Maryland	Baltimore	72.0	62.4	61.9	68
240053001	Maryland	Baltimore	72.6	62.8	62.4	69
240090011	Maryland	Calvert	67.6	58.2	57.2	59
240150003	Maryland	Cecil	74.0	63.6	63.1	68
240170010	Maryland	Charles	69.3	59.8	58.7	60
240190004	Maryland	Dorchester	64.6	56.5	55.7	65
240251001	Maryland	Harford	74.0	63.8	63.2	72
240259001	Maryland	Harford	73.0	62.8	62.5	67
240290002	Maryland	Kent	69.3	59.9	59.2	65
240313001	Maryland	Montgomery	67.6	59.2	58.2	63
240330030	Maryland	Prince George's	69.3	60.1	59.7	68
240338003	Maryland	Prince George's	70.6	61.2	60.7	65
240339991	Maryland	Prince George's	69.3	59.9	59.4	71
245100054	Maryland	Baltimore (City)	68.3	59.4	58.7	-
250051004	Massachusetts	Bristol	71.6	64.1	63.4	-
260210014	Michigan	Berrien	73.3	67.8	66.0	72
260990009	Michigan	Macomb	71.6	64.3	63.5	71
260991003	Michigan	Macomb	67.3	60.4	59.9	68
261210039	Michigan	Muskegon	75.0	68.7	67.6	76
261250001	Michigan	Oakland	70.6	64.2	63.7	72
261470005	Michigan	St. Clair	72.0	66.3	64.9	71
261630001	Michigan	Wayne	66.3	60.7	59.8	67
261630019	Michigan	Wayne	73.0	65.1	64.5	71
290470005	Missouri	Clay	66.0	59.6	59.1	67
290470006	Missouri	Clay	68.6	62.3	61.8	66
290990019	Missouri	Jefferson	69.0	61.2	60.8	67
291831002	Missouri	Saint Charles	72.6	65.5	65.1	71
291831004	Missouri	Saint Charles	71.0	63.5	62.9	68
291890005	Missouri	Saint Louis	65.0	58.3	57.8	66
291890014	Missouri	Saint Louis	70.0	62.2	62.1	71
295100085	Missouri	St. Louis City	67.3	60.2	60.0	68
340010006	New Jersey	Atlantic	63.6	56.0	55.8	60
340030006	New Jersey	Bergen	74.3	69.2	68.1	72
340070002	New Jersey	Camden	75.3	67.3	66.8	69

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
340071001	New Jersey	Camden	67.3	58.8	58.5	64
340110007	New Jersey	Cumberland	65.6	57.8	57.5	63
340130003	New Jersey	Essex	68.3	61.6	61.1	66
340150002	New Jersey	Gloucester	73.6	65.7	65.1	69
340170006	New Jersey	Hudson	71.0	64.8	64.1	68
340190001	New Jersey	Hunterdon	71.3	63.3	62.6	65
340210005	New Jersey	Mercer	71.3	63.3	62.7	70
340219991	New Jersey	Mercer	73.3	65.4	65.0	70
340230011	New Jersey	Middlesex	74.6	66.2	65.6	70
340250005	New Jersey	Monmouth	67.3	59.5	58.9	65
340273001	New Jersey	Morris	69.0	61.6	61.2	65
340290006	New Jersey	Ocean	72.6	64.7	63.9	68
340315001	New Jersey	Passaic	67.6	60.1	59.4	65
360050110	New York	Bronx	67.6	63.3	62.8	68
360050133	New York	Bronx	70.6	66.6	66.1	71
360270007	New York	Dutchess	67.0	59.6	59.0	61
360610135	New York	New York	70.3	65.8	65.2	70
360790005	New York	Putnam	69.0	62.1	61.9	62
360810124	New York	Queens	72.3	67.1	66.2	70
360850067	New York	Richmond	76.0	69.9	69.3	-
360870005	New York	Rockland	71.3	64.3	63.7	66
361030002	New York	Suffolk	74.0	67.7	67.0	71
361030004	New York	Suffolk	74.3	67.5	67.0	70
361030009	New York	Suffolk	71.0	64.3	63.8	72
361192004	New York	Westchester	74.0	67.5	67.2	71
390071001	Ohio	Ashtabula	70.0	63.8	62.7	66
390170018	Ohio	Butler	71.3	63.4	62.7	71
390170023	Ohio	Butler	72.3	65.1	63.8	69
390179991	Ohio	Butler	69.5	62.6	61.4	66
390230001	Ohio	Clark	69.3	61.8	60.5	65
390250022	Ohio	Clermont	70.0	62.4	62.1	68
390350034	Ohio	Cuyahoga	69.0	62.5	62.1	71
390350060	Ohio	Cuyahoga	62.6	56.7	55.7	65
390355002	Ohio	Cuyahoga	69.3	62.7	62.1	71

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
390490029	Ohio	Franklin	70.3	63.7	62.1	67
390490037	Ohio	Franklin	65.5	59.0	57.9	-
390490081	Ohio	Franklin	66.3	59.6	58.6	62
390570006	Ohio	Greene	67.3	59.8	58.9	63
390610006	Ohio	Hamilton	73.3	66.2	65.2	74
390610010	Ohio	Hamilton	71.3	64.3	63.8	70
390610040	Ohio	Hamilton	71.3	64.4	63.8	70
390810017	Ohio	Jefferson	63.0	56.5	56.1	62
390850003	Ohio	Lake	73.6	66.9	66.0	74
390850007	Ohio	Lake	69.0	62.6	61.8	68
390870011	Ohio	Lawrence	63.6	58.5	57.6	58
390870012	Ohio	Lawrence	66.0	60.6	60.1	60
391130037	Ohio	Montgomery	70.3	62.4	61.6	69
391650007	Ohio	Warren	71.6	63.8	63.1	72
420030008	Pennsylvania	Allegheny	68.0	61.7	61.1	67
420030067	Pennsylvania	Allegheny	69.6	63.1	61.6	67
420031008	Pennsylvania	Allegheny	69.0	62.2	61.7	68
420050001	Pennsylvania	Armstrong	69.0	61.5	60.8	65
420070002	Pennsylvania	Beaver	68.6	60.7	60.6	64
420070005	Pennsylvania	Beaver	67.3	58.4	57.9	66
420070014	Pennsylvania	Beaver	65.6	57.0	56.2	64
420110011	Pennsylvania	Berks	70.0	62.6	61.9	67
420170012	Pennsylvania	Bucks	79.3	70.8	70.3	74
420290100	Pennsylvania	Chester	72.6	64.2	63.8	64
420430401	Pennsylvania	Dauphin	65.3	58.3	57.5	63
420431100	Pennsylvania	Dauphin	66.0	58.6	57.9	63
420450002	Pennsylvania	Delaware	71.3	63.6	62.8	68
420630004	Pennsylvania	Indiana	69.6	61.3	60.8	66
420710007	Pennsylvania	Lancaster	69.3	61.4	60.7	65
420710012	Pennsylvania	Lancaster	65.0	58.3	57.9	61
420730015	Pennsylvania	Lawrence	66.3	58.2	57.4	60
420750100	Pennsylvania	Lebanon	69.0	61.4	60.7	-
420770004	Pennsylvania	Lehigh	69.6	62.2	61.9	64
420850100	Pennsylvania	Mercer	68.6	60.9	60.2	66

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
420910013	Pennsylvania	Montgomery	71.3	63.8	63.2	68
420950025	Pennsylvania	Northampton	70.0	62.6	62.0	66
420958000	Pennsylvania	Northampton	69.0	61.5	60.7	-
421010004	Pennsylvania	Philadelphia	61.0	54.4	54.0	-
421010024	Pennsylvania	Philadelphia	77.6	69.3	68.8	73
421010048	Pennsylvania	Philadelphia	75.3	67.2	66.6	71
421250005	Pennsylvania	Washington	67.0	61.3	60.6	62
421250200	Pennsylvania	Washington	65.0	58.8	58.0	-
421255001	Pennsylvania	Washington	68.0	60.5	60.6	-
421290008	Pennsylvania	Westmoreland	67.0	61.1	59.7	60
421330008	Pennsylvania	York	65.6	58.3	57.6	61
421330011	Pennsylvania	York	69.0	60.9	60.6	-
440030002	Rhode Island	Kent	71.3	63.8	63.2	67
440090007	Rhode Island	Washington	69.3	61.9	61.3	68
470370026	Tennessee	Davidson	66.0	57.0	55.9	65
471570021	Tennessee	Shelby	66.6	59.4	58.9	66
471570075	Tennessee	Shelby	67.3	60.1	59.2	67
471632002	Tennessee	Sullivan	66.0	60.1	59.8	61
471632003	Tennessee	Sullivan	64.6	59.0	58.6	61
471650007	Tennessee	Sumner	66.3	57.3	56.0	65
480850005	Texas	Collin	74.3	65.6	64.5	75
481210034	Texas	Denton	78.0	68.7	67.7	72
481211032	Texas	Denton	74.0	65.6	64.3	72
481410029	Texas	El Paso	63.6	62.1	61.4	70
481410057	Texas	El Paso	65.3	63.6	63.2	70
481410058	Texas	El Paso	70.0	67.3	67.1	73
481671034	Texas	Galveston	75.6	70.6	69.9	74
482010024	Texas	Harris	79.3	73.8	74.0	79
482010046	Texas	Harris	67.0	63.3	62.5	64
482010047	Texas	Harris	73.6	67.9	67.5	72
482010051	Texas	Harris	70.0	64.0	64.2	70
482010055	Texas	Harris	76.0	69.5	69.7	76
482010062	Texas	Harris	63.0	59.9	59.9	67
482010066	Texas	Harris	75.0	67.9	67.5	69

			MDA8 Ozone DV (ppb)			
Monitor	**State**	**County**	**Modeled 2016**	**Updated 2023**	**CSAPR 2023**	**Current DV (2018-2020)**
482010416	Texas	Harris	72.3	68.5	67.4	73
484390075	Texas	Tarrant	71.0	63.5	62.1	75
484392003	Texas	Tarrant	73.3	64.9	64.2	73
484393009	Texas	Tarrant	75.3	67.0	65.8	76
510130020	Virginia	Arlington	71.0	61.6	61.1	66
510590030	Virginia	Fairfax	70.0	60.1	59.3	64
511071005	Virginia	Loudoun	67.0	58.3	58.0	61
511790001	Virginia	Stafford	62.3	53.4	52.5	59
540219991	West Virginia	Gilmer	58.0	54.4	54.1	54
540290009	West Virginia	Hancock	65.5	58.4	58.0	-
540390020	West Virginia	Kanawha	67.0	64.2	63.6	-
540610003	West Virginia	Monongalia	62.3	58.3	57.2	61
540690010	West Virginia	Ohio	67.0	61.2	60.9	63
541071002	West Virginia	Wood	65.0	58.1	57.6	60
550290004	Wisconsin	Door	72.6	66.0	65.6	72
550590019	Wisconsin	Kenosha	78.0	72.1	71.2	74
550590025	Wisconsin	Kenosha	73.6	68.1	67.5	74
550710007	Wisconsin	Manitowoc	73.0	66.8	66.2	70
550790010	Wisconsin	Milwaukee	65.3	59.8	59.2	-
550790026	Wisconsin	Milwaukee	68.0	62.6	62.4	68
550790085	Wisconsin	Milwaukee	71.6	66.9	66.9	70
550890009	Wisconsin	Ozaukee	73.3	67.9	66.9	70
551010020	Wisconsin	Racine	76.0	70.1	69.5	73
551170006	Wisconsin	Sheboygan	80.0	73.9	73.0	75