Ozone Transport Commission Mid-Atlantic/Northeast Visibility Union 2022 Version 1 Modeling Technical Support Document

Ozone Transport Commission

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Executive Summary

The purpose of this Technical Support Document (TSD) is to detail committee work completed by the Ozone Transport Commission (OTC) to develop and operate a photochemical modeling platform that may be used by member states for their State Implementation Plans (SIP) or other planning purposes. This work was based on version 1 (V1) of the National Emissions Collaborative's 2022 inventory with analytic year projections to 2026. Modeling results and model performance are presented and analyzed for the 2022 base year along with results for 2026.

The modeling exercises documented in this TSD demonstrate acceptable performance of the platform as required for federally approvable SIPs. These exercises are OTC Modeling Committee products primarily related to development and testing of the 2022 modeling platform for the 2022 base and 2026 projected emissions inventories. OTC's 2022 modeling platform relies on generally accepted conservative assumptions regarding emissions inventories and ozone photochemistry.

Specific committee products described in this TSD include the following:

- A detailed description of the Eastern Regional Technical Advisory Committee Electrical Generation Unit (ERTAC EGU) inputs used in the modeling.
- Comparisons of the Community Multi-scale Air Quality (CMAQ) model performance with two different boundary conditions modeling file inputs, two different dry deposition modeling schemes, and two different biogenic emissions models.
- Detailed modeling results for base cases and projection year modeling runs.

For this work, the OTC uses previously established techniques, including data handling for near-water monitoring locations as described in detail in earlier OTC TSDs.

A summary of emissions inventory inputs is provided in this TSD, but greater detail can be found in the Environmental Protection Agency's (EPA) TSD for its 2022 emissions modeling platform as discussed further in Chapter 3.

This TSD does not contain every modeling exercise performed by individual OTC modeling centers with the 2022 based modeling platform. For example, additional exploratory screening analyses, modeling performed outside of committee efforts, and work performed using a "best science" platform are not presented in this TSD. OTC member states performing additional SIP-relevant modeling intend to document those efforts in the supporting documentation for their individual SIPs.

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Section 1: Introduction

1.1 Purpose

The purpose of this Technical Support Document (TSD) is to document the Ozone Transport Commission (OTC)/Mid-Atlantic Northeast Visibility Union (MANEVU) ozone season modeling efforts that were conducted using the EPA's 2022V1 platform.[1] Additional future modeling based on this platform may also be conducted and documented to support efforts including but not limited to additional ozone requirements and regional haze. Previous OTC TSDs for the 2011 and 2016 platforms can be found on the OTC website.[2]

1.2 Document Outline

Environmental Protection Agency (EPA) guidance on photochemical modeling for ozone provides recommendations for conducting modeling and technical analyses in support of attainment demonstrations.[3] This document is organized to demonstrate that the OTC/MANEVU 2022V1 modeling platform satisfies EPA recommendations as follows:

- Section 1 (current section) presents:
    - an overview of the air quality issue being considered, including historical background,
    - a list of participants in the analysis and their roles,
    - a schedule of key dates relevant to ozone modeling, and
    - a description of the conceptual model of ozone formation in the region.
- Section 2 presents:
    - a description of periods to be modeled, how they comport with the conceptual model, and why they are sufficient,
    - the selected models, how they are set up and why they are appropriate,

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[1] US EPA, undated. "OAQPS 2022 Modeling Platform," https://registry.opendata.aws/epa-2022-modeling-platform/; US EPA, last updated on June 6, 2025. "2022v1 Emissions Modeling Platform," https://www.epa.gov/air-emissions-modeling/2022v1-emissions-modeling-platform.

[2] Ozone Transport Commission/MidAtlantic Northeastern Visibility Union, 2018. "2011 Based Modeling Platform Support Document – October 2018 Update," https://otcair.org/upload/Documents/Reports/OTC%20MANE-VU%202011%20Based%20Modeling%20Platform%20Support%20Document%20October%202018%20-%20Final.pdf; Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union, 2023. "2016 Based Modeling Platform Support Document," https://otcair.org/upload/Documents/Reports/2016TSD_January2023_withAppendices.pdf; Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union, 2024. "2016 Based Modeling Platform Technical Support Document: OTC V2/V3 Modeling Platform Update," https://otcair.org/upload/Documents/Reports/OTC_Modeling_TSD2016_Addendum_July2023.pdf.

[3] US EPA, 2018. "Modeling Guidance for Demonstrating Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze," EPA-454/R-18-009, accessed at https://www.epa.gov/sites/default/files/2020-10/documents/o3-pm-rh-modeling_guidance-2018.pdf.

- a description and justification of the domain to be modeled (expanse and resolution),
- a description of model inputs and their expected sources (e.g., emissions, meteorology, etc.), and
- a comparison and determination of best-available biogenic emissions, boundary conditions and dry deposition modeling scheme.

- Section 3 describes:
  - the base year and analytic year 2026 emissions platform,
  - the methods used in processing emissions for use in the SIP quality modeling platform for the base year, and
  - the Eastern Regional Technical Advisory Committee Electrical Generation Unit (ERTAC EGU) configuration in comparison to EPA's EGU product (ptegu).
- Section 4 presents:
  - base year model evaluation, and
  - a comparison of model performance results versus those from the 2016v2/v3 modeling platform.
- Section 5 provides:
  - the analytic (projected) year 2026 modeling results, and
  - the projected analytic year ozone design values.

1.3 History

The Clean Air Act (CAA) requires EPA to establish, and periodically review, primary and secondary National Ambient Air Quality Standards (NAAQS) for the protection of public health and welfare, respectively. To date, criteria for NAAQS have been established for six pollutants, including ground-level (tropospheric) ozone.

The CAA delegates to states the authority to implement plans (i.e., the SIPs) to attain and maintain air quality that is within the NAAQS. These plans will include rules designed to limit the emissions or ambient concentrations of pollutants that may deteriorate air quality within the state. States evaluate these plans, together with other federally enforceable rules, to determine their effect on air quality. Because ozone is a reaction product of other pollutants, mainly nitrogen oxides (NOx) and volatile organic compounds (VOCs), and can be transported long distances, states use national inventories of these pollutants and complex regional scale photochemical models to demonstrate the efficacy of their SIPs in attaining and maintaining compliance with the ozone NAAQS. These "attainment demonstrations" are required under the CAA for certain designated nonattainment areas and the modeling included in this TSD may be used to support those demonstrations. The following is an overview of the current ozone NAAQS for which the modeling documented in this TSD is applicable.

1.4 2015 8-hour Ozone NAAQS

In 2015, EPA set the primary and secondary ozone NAAQS at 0.070 ppm (equivalent to 70 ppb) for the three-year average of the 4th highest 8-hour average ozone concentration [80 FR 65292 (October 26, 2015)]. In 2018, EPA designated the nonattainment areas in the OTR for the 2015 ozone NAAQS as seen in **Table 1-1** [83 FR 25776 (June 4, 2018)]. Interim reclassifications for certain nonattainment areas were published in the Federal Register [87 FR 60897 (October 7, 2022)] with an effective date of November 7, 2022. Four of the five nonattainment areas were reclassified to Serious with effective dates in July and August 2024.[4] These most recent classifications are also listed in the table.

Areas classified as marginal are not required to include modeling demonstrations with their SIPs. However, areas classified, or re-classified, as moderate or higher are required to submit modeling demonstrations and may rely on this TSD to support their SIP submittals.

Table 1-1 *Nonattainment areas and original/current classifications in the Ozone Transport Region for 2015 Ozone NAAQS.*

2015 NAAQS					
Area Name	**State**	**No. Counties**	**Original Classification**	**Interim Classification**	**Current Classification**
Baltimore, MD	MD	6	Marginal	Moderate*	Serious*
Greater Connecticut, CT	CT	5	Marginal	Moderate*	Serious*
NYC-N. NJ-Long Island, NY-NJ-CT	CT	3	Moderate	Moderate	Serious*
	NJ	12			
	NY	9			
Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE	NJ	9	Marginal	Moderate*	Serious*
	DE	1			
	MD	1			
	PA	5			
Washington, DC-MD-VA	DC	1	Marginal	Moderate*QCD	Moderate*QCD
	MD	5			
	VA	9			

*Notes: * - Failed to attain by the original attainment date; QCD - Currently Qualifies for Clean Data.*

1.5 2008 8-hour Ozone NAAQS

In 2008, EPA set the primary and secondary ozone NAAQS at 0.075 ppm (equivalent to 75 ppb) for the three-year average of the 4th highest 8-hour average ozone concentration [73 FR 16436

[4] Baltimore, MD: 89 FR 62663 (August 1, 2024);
Greater Connecticut, CT: 89 FR 60827 (July 29, 2024);
NYC-N. NJ-Long Island, NY-NJ-CT: 89 FR 60314 (July 25, 2024) and 90 FR 35985 (July 31, 2025);
Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE: 89 FR 61025 (July 30, 2024).

(March 27, 2008)]. After delays in timeframes outlined in the CAA, EPA designated nonattainment areas in the OTR for the 2008 ozone NAAQS as shown in **Table 1-2** [77 FR 30088 (May 21, 2012)]. Reclassifications for certain nonattainment areas, effective November 7, 2022 [87 FR 60926 (October 7, 2022)], are also listed in this table.

Table 1-2 *Nonattainment areas and original/current classifications in the Ozone Transport Region for 2008 Ozone NAAQS.*

2008 NAAQS				
Area Name	**State**	**No. Counties**	**Original Classification**	**Current Classification**
Baltimore, MD	MD	6	Moderate	Moderate[CD]
Greater Connecticut, CT	CT	5	Marginal	Serious[CD]
NYC-N. NJ-Long Island, NY-NJ-CT	CT	3	Marginal	Severe*
	NJ	12		
	NY	9		
Allentown-Bethlehem-Easton, PA	PA	3	Marginal	Marginal[CD]
Dukes County, MA	MA	1	Marginal	Marginal[CD]
Jamestown, NY	NY	1	Marginal	Marginal[CD]
Lancaster, PA	PA	1	Marginal	Marginal[CD]
Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE	NJ	9	Marginal	Marginal[CD]
	DE	1		
	MD	1		
	PA	5		
Pittsburgh-Beaver Valley, PA	PA	7	Marginal	Marginal[CD]
Reading, PA	PA	1	Marginal	Marginal[CD]
Seaford, DE	DE	1	Marginal	Marginal[CD]
Washington, DC-MD-VA	DC	1	Marginal	Maintenance
	MD	5		
	VA	9		

*Notes: * - Failed to attain by the original attainment date; CD - Clean Data*

1.6 Geographic Definitions

Throughout this document, several geographic definitions will be used that are based on the boundaries of Regional Planning Organizations (RPOs). **Table 1-3** lists the member states (including DC) of the OTC, MANEVU, Southeastern Air Pollution Control Agencies (SESARM), Lake Michigan Air Directors Consortium (LADCO), and Central States Air Resource Agencies (CenSARA) RPOs.

Table 1-3 List of states in geographic areas based on RPOs.

OTC	MANEVU	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 – DC Area	Vermont			
Vermont				

1.7 Participants

OTC Air Directors

The OTC Air Directors serve as overseers of the work products developed by the OTC Modeling Committee. The OTC Air Directors coordinate the design of control strategies for the Ozone Transport Region (OTR) and make recommendations on policies and strategies that may be implemented to reduce ozone throughout the OTR. Members of the OTC Modeling Committee keep Air Directors informed of progress in development of the OTC SIP quality modeling platform, and Air Directors review all OTC SIP quality modeling platform documentation before it is finalized.

OTC Modeling Committee

The OTC Modeling Committee members serve as first tier reviewers of the work products developed for the SIP quality modeling platform. The OTC Modeling Committee approves technical approaches used in the modeling platform, reviews results, and approves products for review by the Air Directors. Because staff from three EPA regions are members of the OTC Modeling Committee, they help provide insights into any issues that may occur involving SIP acceptability of the OTC modeling platform.

OTC Modeling Planning Group

The OTC Modeling Planning Group consists of members of the modeling centers and the OTC Modeling Committee leadership. The workgroup reviews technical decisions to bring recommendations on approaches to the OTC Modeling Committee.

OTC Technical Support Document Workgroup

The OTC Technical Support Document (TSD) Workgroup, a subgroup of the Modeling Committee, 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 New York State Department of Environmental Conservation (NYSDEC), New Jersey Department of Environmental Protection (NJDEP), Virginia Department of Environmental Quality (VADEQ), and University of Maryland College Park (UMCP) via the Maryland Department of the Environment (MDE).

MANEVU

MANEVU's primary focus is regional haze for the northeastern and mid-Atlantic states. Regional haze SIPs are due every ten years. The next round of regional haze SIP submittals requiring modeling will not be due until 2028, and the deadline may be delayed as the Regional Haze Program is currently under review by EPA. Therefore, regional haze is not discussed further in this TSD.

MARAMA Emission Inventory Leads Committee

The Mid-Atlantic Regional Air Management Association (MARAMA) coordinated the emission inventory for the states of the OTR through the Emission Inventory Leads Committee, which is comprised of state staff who make technical recommendations involving the multi-pollutant emissions inventory, as well as provide quality assurance (QA) of the inventories.

National Emissions Inventory Collaborative

The National Emissions Inventory Collaborative is a partnership between state emissions inventory staff, multi-jurisdictional organizations (MJOs), federal land managers (FLMs), EPA, and others to develop an emissions modeling platform for use in air quality planning. It is structured around workgroups and organized by emissions inventory sectors.

1.8 Schedule

Table 1-4 provides an overview of important dates which guided scheduling modeling referred to in this document.[5] This document reflects modeling conducted using the latest updates of the V1 emissions inventory for 2022 and 2026. All work on future inventories for this platform, other than for 2026, was paused in spring 2025.

[5] Unless otherwise noted, this document refers to inventories and modeling platforms for the 2022 base year and projections.

Table 1-4 *Multi-pollutant modeling dates relevant to the 2022 platform.*

PROCESS POINT	2008 NAAQS TIMEFRAME	2015 NAAQS TIMEFRAME
V1 Inventory for O_3	Fall 2024	
V1 Base Case Modeling for O_3	Spring 2025	
V1 Future Case (2026) Emissions/Modeling for O_3	Summer 2025	
Baltimore, MD; Greater CT; NYC NY-NJ-CT; and PA-NJ-MD-DE Serious 2015 NAAQS Attainment Deadline	--	August 2027[a]
NYC NY-NJ-CT Severe-15 2008 NAAQS Attainment Deadline	July 2027[a]	--

Notes: [a] *Attainment based on prior year ozone data.*

1.9 Ozone Conceptual Model

The interaction of meteorology, chemistry, and topography lead to a complex process of ozone formation and transport. Ozone episodes in the OTR often begin with an area of high pressure setting up over the southeast United States. These summertime high-pressure systems can stay in place for days or weeks. This scenario allows for stagnant surface conditions to form in the OTR, and, in turn, the transported pollution mixes with local pollution in the late morning hours as the nocturnal inversion breaks down. With a high-pressure system in place, the air mass, which is characterized by generally sunny and warm conditions, exacerbates ozone concentrations. This meteorological setup of sunlight and warm temperatures in the presence ozone precursors (NOx and VOCs) promotes ozone formation. In addition, ozone precursors and ozone are transported within the OTR during the late night and/or early morning hours by way of a nocturnal low-level jet (NLLJ), a low altitude fast-moving river of air that at times sets up overnight in a southwest to northeast direction during ozone events in the OTR. All this local and transported polluted air can, in some instances, accumulate along the coastal OTR areas as the air is kept in place due to onshore bay and sea breezes.

Some ozone and its precursors are natural or transported internationally, leading to ozone that is not considered relatable to US human activity. EPA estimates the summer mean U.S. background ozone in the eastern United States on the highest ozone 8-hour average days to be a little less than 30 ppb, while it can be above 40 ppb in the West, and reach almost 50 ppb at high elevations (>1500 m).[6]

[6] US EPA, 2020. "Policy Assessment for the Review of the O_3 National Ambient Air Quality Standards," EPA-452/R-20-001, Section 2.5, accessed from https://www.epa.gov/sites/default/files/2020-05/documents/o3-final_pa-05-29-20compressed.pdf.

Another complexity involves the nonlinear relationship between NO_X and VOC concentrations and ozone formation. Areas that have extensive forests producing high levels of isoprene and other biogenic VOCs during the summer months can more readily control ozone through reductions in regional NO_X emissions from fossil fuel combustion. This is the case in the majority of the landscape in the OTR. Conversely, dense urban areas such as New York City, which have low natural VOC production and high NOx emissions, may more readily benefit locally from VOC emission reductions in combination with regional NOx reductions. In some cases, excess NO_X will destroy already formed ozone, lowering local ozone levels. The phenomenon is known as NOx titration and in areas where this occurs, such as New Haven harbor, reductions of NO_X can increase local ozone levels. Downwind, however, as the NOx concentrations decrease relative to VOCs, the same emissions can promote ozone formation, thus requiring air quality planners to consider a mix of NOx and VOC measures depending on the local and regional conditions.

1.10 Model Base and Analytic Year Selection

The 2022 Emissions Inventory Collaborative used several criteria in selecting 2022 as the base year and subsequent analytic year 2026 such as available inventories, meteorology, monitoring data and wildfires. The base year does not always coincide with the triennial National Emissions Inventory (NEI) years due to these other relevant factors. The 2022 base year did not coincide with an NEI year. The criteria the Collaborative used was multi-pollutant including ozone, PM and regional haze. For ozone, some of the factors considered include:

- 2015 ozone NAAQS serious nonattainment area (NAA) SIPs are due in early 2026.
- For the SIPs due in early 2026, ozone attainment modeling should begin by the end of 2024, therefore emissions inputs would be needed by summer 2024, suggesting some earlier year would need to be identified for the base year.
- The projection year for serious NAA ozone SIPs is 2026, with an attainment date of August 3, 2027, because compliance with the standard will be calculated using the 2023 ozone season.
- The base year for attainment demonstration ozone modeling should be a recent year and discussed with the “appropriate EPA regional office” (EPA, 2018). To meet the August 3, 2027 ozone attainment date, 2023 would be the most recent NEI year released. However, it is not expected to be released until 2026, at which point it would be too late for use in NAA ozone SIPs due in early 2026.

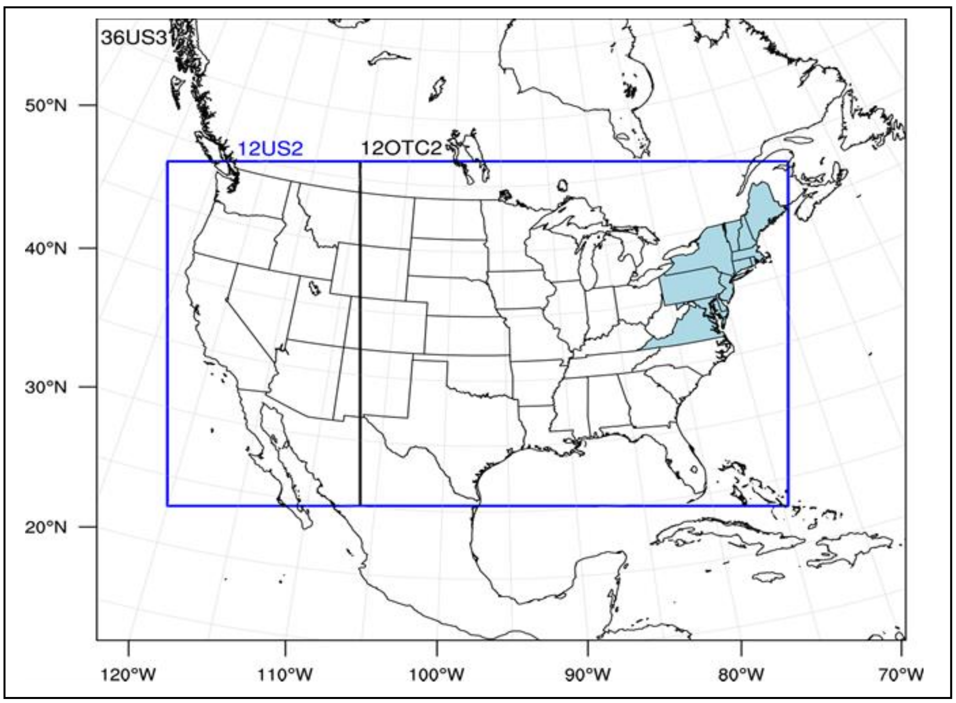
Additional criteria for ozone and regional haze were also considered in determining the base year and analytic years, with more detail in the *2022 Emissions Modeling Platform Development Plan* (version October 31, 2023).[7]

[7] National Emissions Collaborative, 2023. “2022 Emissions Modeling Platform Development Plan,” https://views.cira.colostate.edu/wiki/Attachments/2022%20Collaborative/National%20Emissions%20Collaborative%202022%20EMP%20Development%20Plan%2031Oct2023.pdf.

Section 2: Modeling Methodology and Input Descriptions

Modeling presented in this Technical Support Document (TSD) was performed for the OTC by the New York State Department of Environmental Conservation (NYSDEC). For the 2022 platform, we use the 12US2 modeling domain, an expansion from OTC's 2016 platform modeling that used the 12OTC2 domain (**Figure 2-1**). The 12 km by 12 km domain used in this analysis includes the contiguous U.S. covering the lower 48 states (including DC) and also includes some portions of southern Canada and northern Mexico. The domain is 396 columns by 246 rows in the horizontal, and 35 vertical layers extending from the surface to 50 mb, the same vertical profile as used in the Weather Research Forecast (WRF) model. The modeling platform uses a Lambert conformal projection centered at (97°W, 40°N) and true latitudes 33°N and 45°N. The 12 km by 12 km domain is surrounded by a larger modeling domain, "36US3," with a coarser 36 km by 36 km grid. This larger domain was also used by the EPA for modeling boundary conditions of smaller inner domains.

Figure 2-1 *Graphic of relevant model domains covering the contiguous United States. OTC modeling with the 2022v1 platform uses the 12US2 domain. The 12OTC2 domain was previously used with the 2016 platform.*



2.1 Photochemical Modeling Configurations

The Community Multi-scale Air Quality (CMAQ) photochemical model v5.4 was used for all OTC simulations with the 2022v1 platform. The CMAQ modeling software was obtained from the

Community Modeling and Analysis System (CMAS) modeling center.[8] Key model options are listed in **Table 2-1**.

***Table 2-1** Key model options used for the production runs with the 2022V1 CMAQ modeling by OTC.*

Parameter	Details
Emissions	2022v1
EGU point	ERTAC v22.0
Meteorology	WRF v4.4.2, MCIP v5.4 (provided by EPA)
Boundary conditions, 2022	From 2022 CMAQ 36US3 H-CMAQ BC clean run (by EPA)
Boundary conditions, 2026	From 2026 CMAQ 36US3 H-CMAQ/STAGE/BEIS with EPAEGU (by NYSDEC)
Domain	12US2, 396x246
Modeling period	Annual, 2022
Model layers	35
Model version	CMAQ v5.4.0.5, cb6r5 AERO7 AQ pcSOA
Resolution	12 km by 12 km
Biogenic emissions	In-line MEGAN v3.2
Dry Deposition	M3DRY
Other science option	BDSNP soil model, no Wind Blown Dust model, WWLLNs in-line lightning NOx, in-line NH3 bidi

2.2 Boundary Conditions Inputs

For the 2022 base year, two boundary condition (BC) datasets at 12 km by 12 km resolution, ready for use in 12US2 CMAQ modeling, were downloaded from EPA's AWS Open Data website. A general description can be found online at https://registry.opendata.aws/epa-2022-modeling-platform/. Briefly, EPA ran CMAQ on the larger, coarser 36US3 domain with global boundary conditions generated by the GEOS-Chem model v14.0.1 and Hemispheric CMAQ (H-CMAQ) model v5.4+, respectively, then ran the "BCON" program in CMAQ to extract the BCs for the 12US2 modeling domain.

[8] CMAS, undated. "Community Modeling and Analysis System," https://www.cmascenter.org/.

EPA provided both BC datasets online for download. The BC data from Hemispheric CMAQ (H-CMAQ) was downloaded from https://epa-2022-modeling-platform.s3.amazonaws.com/index.html#bcon/12US2_CMAQ_BCON/HEMI_CMAQ_12US2BC/.

The GEOS-Chem BC data was downloaded from https://epa-2022-modeling-platform.s3.amazonaws.com/index.html#bcon/12US2_CMAQ_BCON/GEOS_CHEM_12US2BC/.

These two datasets were used in OTC modeling to compare performance metrics and determine the most suitable dataset for the OTC. Those analyses are presented in Section 4.

2.3 Dry Deposition Parameterization

Dry deposition is the process by which gases and particles are removed from the atmosphere through contact with surfaces such as vegetation, soil, or water. CMAQ simulates dry deposition using parameterized models that estimate deposition velocities based on surface type, meteorology, and pollutant properties.

The M3Dry (Meteorological Model-agnostic Dry Deposition) scheme has been widely used in CMAQ and was the default option in earlier versions. M3Dry employs a simplified, resistance-based "big-leaf" canopy model that assumes average behavior across vegetation types.

The STAGE (Stomatal and Turbulence Adjusted Gas Exchange) scheme is a newer dry deposition option recently introduced to CMAQ. It features a more physically realistic, multi-layer canopy representation with species-specific stomatal conductance, potentially offering improved modeling of diurnal and seasonal variations. However, STAGE is computationally more demanding.

OTC tested CMAQ performance with both parameterization schemes to determine the best option for the region. Results are presented in Section 4.

2.4 WRF Meteorological Data

The OTC performed its modeling using 2022 meteorology for baseline and all analytic years. EPA members of the 2022 National Emissions Inventory Collaborative conducted meteorological simulations using the WRF model v4.4.2 and shared output available for download on the 12US2 domain. Simulations were performed on the 36 km by 36 km North American domain (36NOAM, different than 36US3) and the 12US2 domain. WRF meteorology output was processed to be CMAQ-ready on the 12US2 domain using the Meteorology-Chemistry Interface Processor v5.4 (MCIP; Otte and Pleim, 2010). The OTC retained the same 12 km by 12 km horizontal resolution and 35-layer column depth as was used by EPA (WRF model layers described in **Table 2-2**). Details including WRF model parameterizations and model performance summaries by U.S. geographic region are provided in the EPA Meteorology Technical Support Document.[9]

[9] US EPA, 2024. "Meteorological Model Performance for Annual 2022 Simulation WRF v4.4.2," EPA-454/R-24-001, https://www.epa.gov/system/files/documents/2024-03/wrf_2022_tsd.pdf.

Table 2-2 *Vertical layers used in the meteorological and photochemical modeling by the OTC.*

WRF/CMAQ	Approximate Height (m AGL)	Pressure (mb)	Sigma Level
35	17,556	50	0
34	14,780	97.5	0.05
33	12,822	145	0.1
32	11,282	192.5	0.15
31	10,002	240	0.2
30	8,901	287.5	0.25
29	7,932	335	0.3
28	7,064	382.5	0.35
27	6,275	430	0.4
26	5,553	477.5	0.45
25	4,885	525	0.5
24	4,264	572.5	0.55
23	3,683	620	0.6
22	3,136	667.5	0.65
21	2,619	715	0.7
20	2,226	753	0.74
19	1,941	781.5	0.77
18	1,665	810	0.8
17	1,485	829	0.82
16	1,308	848	0.84
15	1,134	867	0.86
14	964	886	0.88
13	797	905	0.9
12	714	914.5	0.91
11	632	924	0.92
10	551	933	0.93
9	470	943	0.94
8	390	952.5	0.95
7	311	962	0.96
6	232	971.5	0.97
5	154	981	0.98
4	115	985.75	0.985
3	77	990.5	0.99
2	38	995.25	0.995
1	19	997.63	0.9975
Surface	0	1000	1

Section 3: Emissions Inventories and Processing for the 2022v1 Base Year 12 km Simulation

The National Emission Inventory Collaborative developed the emissions data used in all air quality modeling. The Inventory Collaborative is a partnership between state emissions inventory staff, multi-jurisdictional organizations (MJOs), federal land managers (FLMs), EPA, and others to develop an emissions modeling platform for use in air quality planning. It is structured around workgroups and organized by emissions inventory sectors. Work began on the 2022v1 inventory in July 2022 and continues with platform updates and improvements. The platform details including the EPA TSD can be found on EPA's website.[10]

The EPA uses a two-character naming convention in its emissions modeling platforms. The first character represents the base year, "h" in the case of the 2022 platform. The second character indicates a version number e.g., "c" for version 1 (V1). Throughout this document, we generally refer to EPA's hc platform as version 1 or V1. Documentation for version 1 of the 2022 emissions platform can be found on EPA's website.[11]

To estimate future year electric generation units (EGU) emissions from the power sector, the EPA used calculations as documented in the EPA TSD. An alternate set of EGU emissions was developed by the Eastern Regional Technical Advisory Committee (ERTAC) for use with version 1 of the 2022 platform, which is described in Appendix A. These methods produce nearly identical results for the base year as they rely on actual reported data. However, future year emissions are more likely to diverge based on differing projection methodologies.

National Emission Inventories (NEI) are developed every three years. The 2022 version 1 platform is based on the 2020 National Emissions Inventory (2020 NEI) published in 2023,[12] with many sectors adjusted to better reflect 2022 and/or using data specific to the year 2022. Version 1 includes one analytical (projection) year 2026. The OTC used the 2022v1 platform with ERTAC EGU projected emissions and the Model of Emission of Gases from Nature (MEGAN) biogenic emissions. This configuration was chosen based on extensive model configuration evaluation presented in Section 4 of this TSD.

3.1 Emission Inventory Sectors for the 2022v1 modeling platform

Emission inventories for each model year were developed by sector and are listed below with a brief description. The Sparse Matrix Operator Kernel Emissions (SMOKE) processing system is

[10] US EPA, last updated June 6, 2025. "2022v1 Emissions Modeling Platform," accessed at https://www.epa.gov/air-emissions-modeling/2022v1-emissions-modeling-platform; US EPA, 2025. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v1 North American Emissions Modeling Platform," EPA-454/B-25-001, accessed at https://www.epa.gov/system/files/documents/2025-06/2022v1_emismod_tsd_base_and_2026_may2025_508_6.pdf.

[11] Ibid.

[12] US EPA, 2023. "2020 National Emissions Inventory (NEI) Technical Support Document (TSD)," EPA-454/R-23-001a, accessed at https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-technical-support-document-tsd.

used to allocate emissions temporally and spatially into grids as model-ready input files. The SMOKE processing sector name is identified below in parentheses when describing the input files. For the 2022v1 base year, emissions were either grown from 2020 with 2022 growth data when available or developed/obtained for 2022 as indicated in the description. The 2026 analytic year is discussed below in Section 3.6 and in the EPA Collaborative TSD[13] Specific emission inventory files are listed in Appendix B.

Fugitive Dust (afdust)

This sector contains emissions of PM_{10} and $PM_{2.5}$ from nonpoint fugitive dust sources, including building construction, road construction, agricultural dust from crops, and mining and quarrying, which were all held constant.

Airports (airports)

Emissions from airports, including aircraft and ground support equipment for the top 51 airports. EPA ran the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT) to estimate emissions for this sector. For smaller airports, emissions from aircraft and airport ground support equipment were projected from the 2020 NEI to 2022 based on the 2023 Terminal Area Forecast (TAF).

Biogenic (beis)

Year 2022 emissions from biogenic sources from the US, Canada and Mexico. Generated inline during CMAQ model runs. Version 4 of the Biogenic Emissions Inventory System (BEIS) was used with Version 6 of the Biogenic Emissions Landuse Database (BELD6).

Biogenic (megan)

Year 2022 emissions from biogenic sources from the US, Canada, and Mexico. Generated inline during CMAQ model runs using MEGAN v3.2. These emissions were generated inline during CMAQ model runs.

Fugitive Dust - Canada (canada_afdust)

Particulate matter emissions from Canadian area fugitive dust sources from Environment Canada and Climate Change (ECCC) for 2022 (interpolated between provided 2020 and 2023 emissions) with transport fraction and snow/ice adjustments based on 2022 meteorological data.

Onroad - Canada (canada_onroad)

Onroad mobile source emissions for Canada. 2020 and 2023 Canada inventories provided by ECCC, which were interpolated to 2022. Processing used updated spatial surrogates.

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[13] US EPA, May 2025. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v1 North American Emissions Modeling Platform," https://www.epa.gov/system/files/documents/2025-06/2022v1_emismod_tsd_base_and_2026_may2025_508_6.pdf.

Fugitive Dust Point - Canada (canada_ptdust)

Particulate matter emissions from Canadian point fugitive dust sources. 2022 emissions (which were interpolated between provided 2020 and 2023 emissions) were provided by ECCC. Transport fraction and snow/ice adjustments based on 2022 meteorological data were applied.

Agricultural – Canada & Mexico (canmex_ag)

Canada and Mexico agricultural emissions. Canada emissions were provided by ECCC for 2020 and 2023. Mexico agricultural emissions were provided by Secretariat of Environment and Natural Resources (SEMARNAT) and include updated emissions for six border states representing 2018 developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge.

Area Source – Canada & Mexico (canmex_area)

Canada and Mexico nonpoint source emissions not included in other sectors. Canada: ECCC provided surrogates and 2020 and 2023 inventories that were interpolated to 2022. Mexico: included updated emissions for six border states representing 2018 developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge.

Point Sources – Canada & Mexico (canmex_point)

Canada and Mexico point source emissions not included in other sectors. Canada point sources were provided by ECCC for 2020 and 2023 and interpolated to 2022. Mexico point source emissions for six border states represent 2018 and were developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge.[14]

Commercial Marine Vessels – Category 1 & 2 (cmv_c1c2_12)

Category 1 (C1) and Category 2 (C2), commercial marine vessel (CMV) emissions based on 2022 Automatic Identification System (AIS) data categorized using source classification codes (SCCs) specific to ship type.

Commercial Marine Vessels – Category 3 (cmv_c3_12)

Category 3 (C3) commercial marine vessel (CMV) emissions based on 2022 AIS data categorized using SCCs specific to ship type.

Agricultural emissions (fertilizer)

Agricultural fertilizer ammonia emissions calculated for 2022 based on bidirectional flux calculations computed inline within CMAQ.

[14] US EPA, 2022. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2016v2 North American Emissions Modeling Platform," accessed at https://www.epa.gov/system/files/documents/2022-02/2016v2_emismod_tsd_february2022.pdf.

Agricultural emissions (livestock)

Nonpoint livestock emissions for 2022 developed using a similar method to 2020 NEI but with adjusted animal counts and using 2022 meteorology. Livestock includes ammonia and other pollutants except $PM_{2.5}$.

Onroad – Mexico (mexico_onroad)

Onroad emissions from Mexico. 2020 and 2023 emissions output from the Motor Vehicle Emissions Simulator-Mexico (MOVES-Mexico) model were interpolated to 2022.

Area Source (nonpt)

Nonpoint emission sources not included in other platform sectors. Mostly held constant at 2020 levels, but emissions from some SCCs were adjusted to 2022 based on population, energy consumption ratios, and employment data.

Off road (nonroad)

Nonroad equipment emissions developed for 2022 with MOVES4, including the updates made to spatial apportionment that were developed with the 2016v1 platform. MOVES4 was used for all states except California, which submitted its own emissions for 2020 and 2023 that were then interpolated to 2022.

Oil & Gas – Area (np_oilgas)

Well activity data (production and exploration of oil, gas, etc.) for 2022, processed through the Oil and Gas tool. Abandoned wells based on 2022, plus other state-specific inputs.

Solvent – Area (np_solvents)

Emissions of solvents based on methods used for the 2020 NEI. 2020 NEI emissions were grown to 2022 using a ratio of solvent sales from 2020 and 2021. Includes household cleaners, personal care products, adhesives, architectural and aerosol coatings, printing inks, industrial surface coatings, graphic arts, solvent cleaning operations, dry cleaning, autobody refinishing and pesticides.

Mobile (onroad)

Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles for 2022 developed using VMT from many states, along with VMT data from the 2020 NEI projected to 2022 using factors based on FHWA VM-2 data. Includes the following emission processes: exhaust, extended idle, auxiliary power units, evaporative, permeation, refueling, vehicle starts, off network idling, long-haul truck hoteling, and brake and tire wear. MOVES4 was run for 2022 to generate year-specific emission factors.

Mobile – California (onroad_ca_adj)

California-provided 2022 emissions for CAPs. VOC HAPs were projected from California-provided 2020 NEI HAP emissions using CAP trends. Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles based on Emission Factor (EMFAC), gridded and temporalized based on outputs from MOVES4.

Open burning – nonpoint (openburn)

This new sector for the 2022V1 platform was split out from the prior nonpt sector and includes emissions from yard waste, land clearing, and residential household waste burning.

Oil & Gas – Point (pt_oilgas)

This sector contains emissions from 2022 NEI point sources that include oil and gas production emissions processes for facilities with North American Industry Classification System (NAICS) codes related to Oil and Gas Extraction, Natural Gas Distribution, Drilling Oil and Gas Wells, Support Activities for Oil and Gas Operations, Pipeline Transportation of Crude Oil, and Pipeline Transportation of Natural Gas. Includes U.S. offshore oil production.

Agricultural burning (ptagfire)

Agricultural fire sources for 2022 developed by EPA as point and day-specific emissions. Includes 2022 satellite data and land use. Florida, Georgia, Idaho, and North Carolina have separate datasets and are removed from the national datasets. Washington has supplemental datasets, to be used along with WA from the national datasets.

Point Source – Electric Generating EPA (ptegu)

NEI point source EGUs for 2022, replaced with hourly Continuous Emissions Monitoring System (CEMS) values for NO_X and SO_2, and the remaining pollutants temporally allocated according to CEMS heat input where the units are matched to the NEI. Emissions for all sources not matched to CEMS data come from the 2022 NEI point inventory. EGUs closed in 2022 are not part of the inventory. Annual resolution for sources not matched to CEMS data, hourly for CEMS sources.

Point Source – Electric Generating ERTAC (ptertac)

This sector represents electricity generating unit source emissions for simulating 2022 and future year U.S. air quality with the Eastern Regional Technical Advisory Committee (ERTAC) EGU tool.

Prescribed fires (ptfire-rx)

This sector represents point source day-specific prescribed fires for 2022 computed using SMARTFIRE 2 and BlueSky Pipeline.

Wildfires (ptfire-wild)

This sector represents point source day-specific wildfires for 2022 computed using SMARTFIRE 2 and BlueSky Pipeline.

Prescribed fires – Non-US, North America (ptfire_othna)

This sector represents point source day-specific wildfires and agricultural fires outside of the U.S. for 2022. Canadian fires were computed using SMARTFIRE 2 and BlueSky Pipeline. Mexico, Caribbean, Central American, and other international fires are from v2.5 of the Fire Inventory (FINN) from National Center for Atmospheric Research.

Point Sources – Industrial ERTAC (ptnonertac)

All 2022 NEI point source records not matched to the airports, ptegu ERTAC, or pt_oilgas sectors. Includes 2020 NEI rail yard emissions projected to 2022 using updated R-1 reported yard fuel usage.

Point Sources – Industrial EPA (ptnonipm)

This sector represents all 2022 NEI point source records not matched to the airports, ptegu EPA, or pt_oilgas sectors, including 2020 NEI rail yard emissions projected to 2022 using updated R-1 reported yard fuel usage.

Railway (rail)

This sector represents Class I line-haul rail locomotives emissions from 2020 NEI projected to 2022 using R-1 reported fuel usage. County and annual resolution in Class II and III locomotive emissions were projected from 2020 based on the 2021 U.S. Energy Information Administration's Annual Energy Outlook. Commuter rail was projected from 2020 using fuel use per company from the Federal Transit Administration (FTA) 2022 National Transit Database. Amtrak emissions were adjusted down based on 2020 fuel use reported in Amtrak's FY22 AMTRAK Sustainability Report.

Residential Wood Combustion (rwc)

This sector represents 2020 NEI nonpoint sources with residential wood combustion (RWC) processes, projected to 2022 with state-level adjustment factors derived from the State Energy Data System (SEDS) plus specific adjustments for California and Idaho.

3.2 Speciation

Gaseous chemical speciation of emissions is accomplished through the SMOKE preprocessor based on the selected chemical mechanism. In this case, speciation occurs according to the CB6 mechanism.[15] Specific pollutant species can be found in Table 3-3 of the Collaborative 2022V1 TSD.[16] The chemical speciation approach for total organic gases and $PM_{2.5}$ are based

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[15] Yarwood, G., Jung, J., Whitten, G., Heo, G., Mellberg, J., and Estes, M., 2010. "Up-dates to the Carbon Bond Mechanism for Version 6 (CB6)," in: 9th Annual CMAS Conference, Chapel Hill, NC, October 11–13, 2010, pp. 1–4, accessed at https://www.cmascenter.org/conference/2010/abstracts/emery_updates_carbon_2010.pdf.

[16] US EPA, 2025. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v1 North American Emissions Modeling Platform," EPA-454/B-25-001, accessed at https://www.epa.gov/system/files/documents/2025-06/2022v1_emismod_tsd_base_and_2026_may2025_508_6.pdf.

on the SPECIATE 5.3 database,[17] which provides a repository of speciation profiles from air pollution sources.

3.3 Spatial Allocation

The spatial surrogates for the 12US2 domain for the United States were extracted from the 12US1 U.S. grid surrogates. Spatial factors were applied by county and source classification codes with surrogates from 2020. Most U.S. surrogates were generated with the Spatial Allocator and Surrogate Tool.[18]

3.4 Temporal Allocation

Temporal allocation of the annual or monthly emissions found in the inventory to hourly emissions required by the air quality models is performed during SMOKE processing by the application of temporal profiles.

Temporal profiles are applied to the emissions at the SCC level for each sector. Exceptions to this procedure are the EGU sectors (ptegu/ptertac), which make use of hourly CEMS data. More details on temporal allocation for individual sectors are described in the EPA's 2022V1 TSD.[19] In the case of ERTAC EGU (ptertac), the ERTAC code produces hourly EGU emissions that are grounded in the base year CEM data. Version 3.0 of the ERTAC EGU code was used in all inventories. The input files were from ERTAC EGU v22.0 for the 2022V1 inventory. In all cases they were post-processed using v3.0 of the ERTAC_for_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. To include the temporalization during SMOKE processing, hourly ff10 files were produced by the ERTAC to SMOKE post processor in addition to the annual ff10 files.

3.5 SMOKE Processed Emission Results

In order to quality assure that the outputs from SMOKE were properly distributed geographically and to develop a better understanding of the geographical and temporalization of emissions, daily emissions on July 12, 2022 were plotted. NO_X and VOC emissions were examined with and without including biogenic emissions. Urban areas, interstates in rural areas, and shipping lanes are clearly distinguishable in the maps of NO_X emissions (**Figure 3-1**). Total anthropogenic VOC emissions similarly show high emissions in densely populated areas and lower emissions in between (**Figure 3-2**).

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[17] US EPA, last updated February 1, 2025. "SPECIATE," https://www.epa.gov/air-emissions-modeling/speciate.

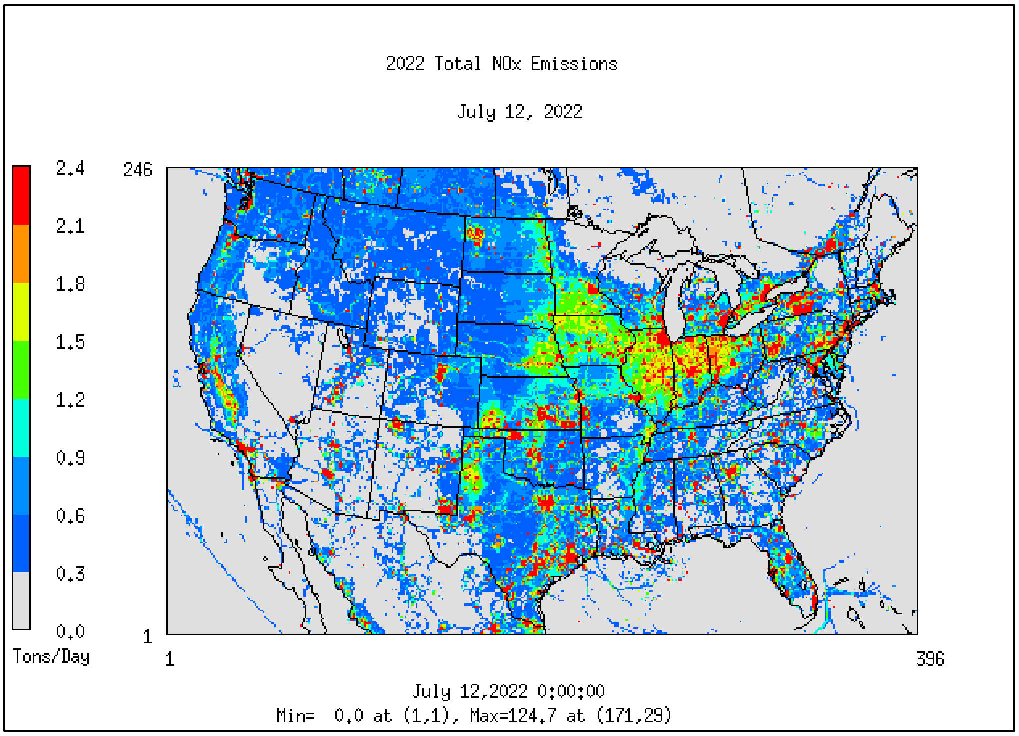
[18] Rain L., and Yang, D., 2016. "Spatial Allocator Surrogate Tool: User's Guide," accessed at https://www.cmascenter.org/sa-tools/documentation/4.2/SurrogateToolUserGuide_4_2.pdf.

[19] US EPA, 2025. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v1 North American Emissions Modeling Platform," EPA-454/B-25-001, accessed at https://www.epa.gov/system/files/documents/2025-06/2022v1_emismod_tsd_base_and_2026_may2025_508_6.pdf.

Only biogenic VOC emissions are shown in **Figure 3-3**, while total VOC emissions (both anthropogenic and biogenic) are displayed in **Figure 3-4**. From these two figures we can see the relative magnitude and importance of VOC emissions from the biogenic sector compared to the anthropogenic sources.

In addition, summary tables of emissions by OTC state, sector, and pollutant were output from SMOKE processing. These results are aggregated for the 2022V1 inventory in **Table 3-1**. Some sectors such as fires and marine vessels were aggregated to simplify the tables. A more detailed breakout of emissions for each individual sector and the remaining states in the continental US is provided by EPA.[20]

***Figure 3-1** 2022 Total NOx Emissions (tons/day) for typical summer weekday.*



[20] US EPA, 2025. "2022v1/2016v3 platform state-modeling sector CAPs emissions report with 2026 final," downloaded from https://gaftp.epa.gov/Air/emismod/2022/v1/reports/2022v1_2016v3_state_sector_report_13jan2025.xlsx.

Figure 3-2 *2022 Total Anthropogenic VOC Emissions (tons/day) for typical summer weekday.*

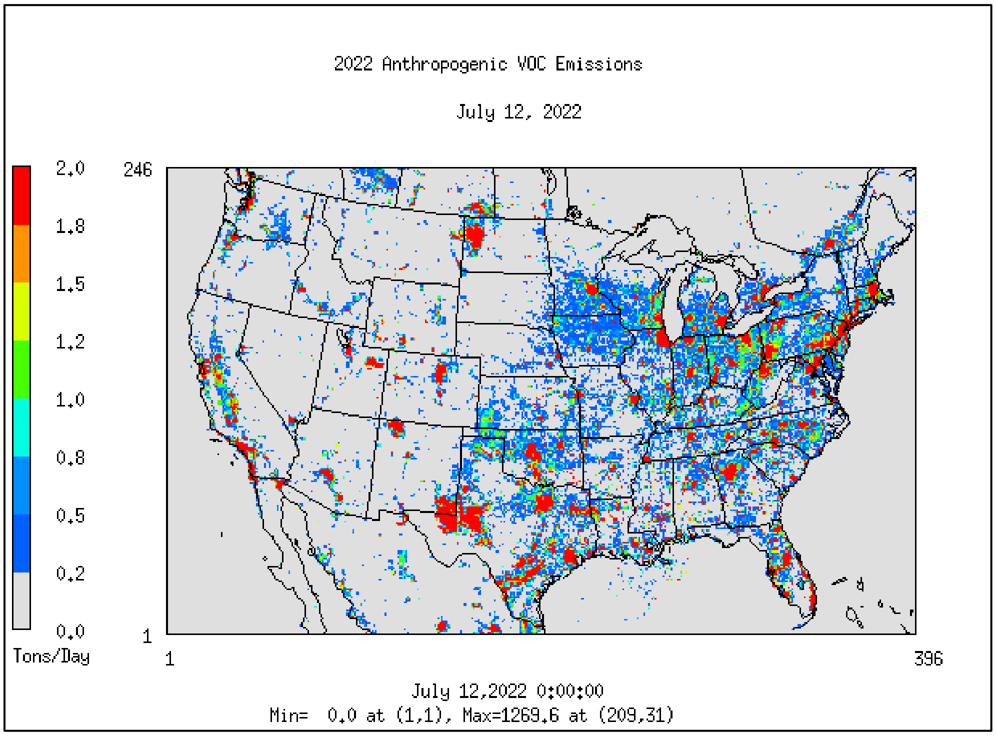


Figure 3-3 *2022 Biogenic VOC Emissions (tons/day) for typical summer weekday.*

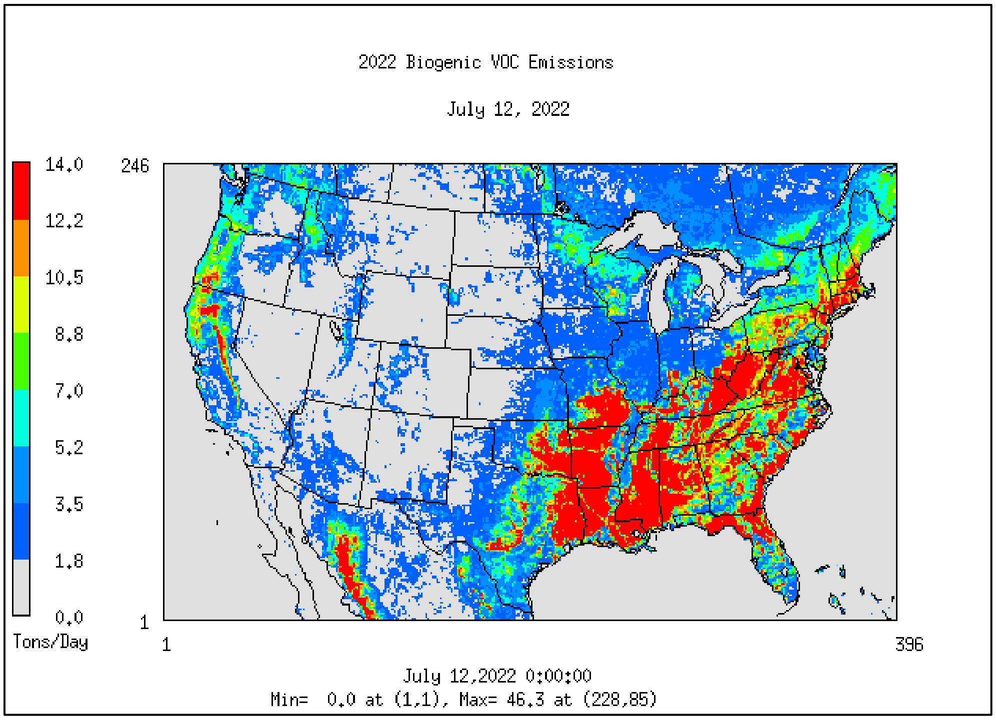


Figure 3-4 *2022 Total VOC Emissions (tons/day) for typical summer weekday.*

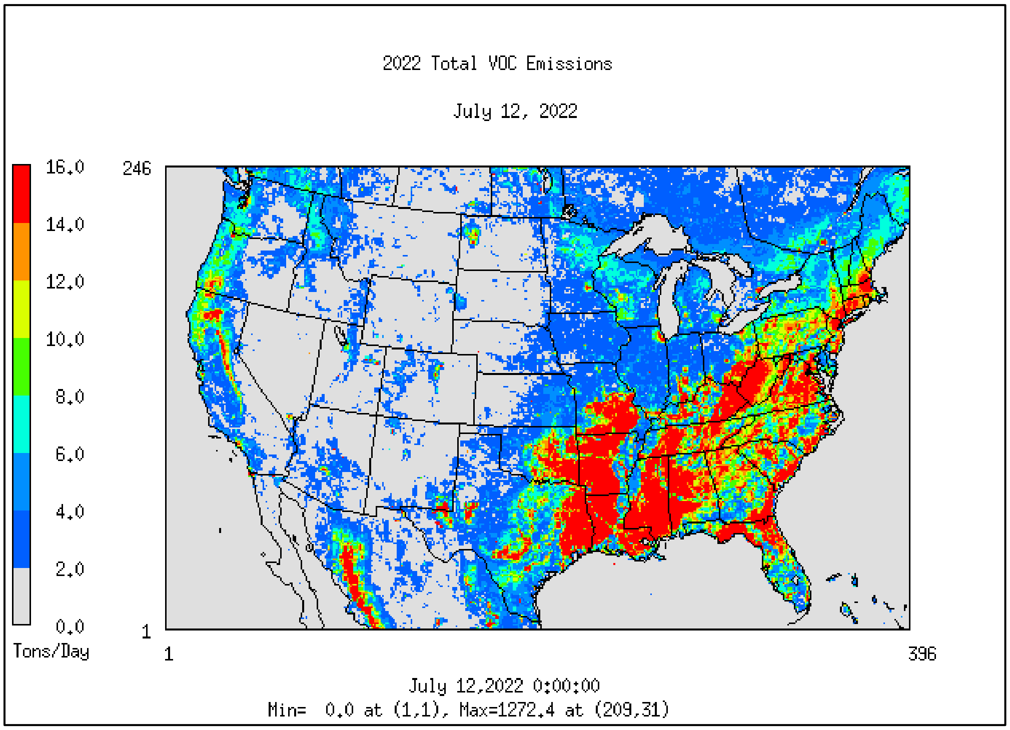


Table 3-1 *2022 V1 Base Year Emissions by state, sector, and pollutant from SMOKE processed emission reports (tons/year). Aggregated sectors: cmv= cmv_c1c2+cmv_c3, ag = fertilizer + livestock, fires = openburn + ptagfire + ptfire-rx + ptfire-wild, oil/gas = pt_oilgas + np_oilgas, bio = biogenic (MEGAN)*

CO																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	Rwc	Total
Connecticut		1,792	5,238	157	0	8,598	119,134	8		106,026	1,701	461	493	181	42,134	285,922
Delaware		1,334	3,119	363	0	2,152	53,529	0		36,146	3,320	569	2,433	31	4,194	107,189
District of Columbia		1	153	13	0	1,012	7,568	0		14,944	0	1	298	32	66	24,089
Maine		1,776	29,898	313	0	10,328	86,846	39		49,177	21,531	3,592	5,431	127	107,064	316,122
Maryland		3,488	16,423	952	0	8,727	214,002	199		191,173	42,865	3,617	7,809	423	33,676	523,354
Massachusetts		6,613	8,865	518	0	12,369	227,119	144		176,139	29,404	967	3,914	562	53,986	520,602
New Hampshire		1,317	10,317	25	0	2,958	66,044	0		57,350	17,950	1,515	538	40	68,148	226,201
New Jersey		7,815	9,436	1,060	0	17,221	296,016	81		230,461	88,218	2,266	3,906	582	21,070	678,133
New York		15,285	49,104	1,212	0	40,240	584,094	2,221		331,754	75,062	24,025	24,159	2,201	190,227	1,339,583
Pennsylvania		8,646	52,700	304	0	39,932	404,413	73,452		488,623	117,486	15,576	36,136	2,337	191,780	1,431,386
Rhode Island		632	1,181	185	0	1,727	28,472	29		26,562	6,722	189	1,145	14	8,076	74,936
Vermont		564	9,809	0	0	2,148	32,494	0		21,105	5,733	1,288	129	75	75,259	148,606
Virginia		10,187	66,622	1,315	0	30,131	293,117	6,757		385,209	194,350	5,780	14,631	1,661	72,520	1,082,279

NH_3																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	Rwc	Total
Connecticut				1	3,065	850	17	0		1,748	22	204	272	1	310	6,491
Delaware				1	11,122	175	7	0		555	314	33	74	0	37	12,318
District of Columbia				0	17	125	1	0		242	0	0	1	0	0	387
Maine				1	7,212	282	15	0		819	1,026	102	309	0	714	10,481
Maryland				3	20,922	1,073	24	0		3,158	1,966	382	292	1	290	28,110
Massachusetts				2	3,629	1,658	31	0		3,248	1,457	176	110	2	419	10,731
New Hampshire				0	2,577	206	11	0		755	1,007	157	69	0	467	5,250
New Jersey				3	5,308	450	49	6		3,942	931	261	636	2	186	11,775
New York				4	39,484	5,611	85	0		6,430	3,530	1,422	491	7	1,368	58,432
Pennsylvania				1	71,182	3,395	67	6		6,547	5,283	1,036	851	7	1,424	89,800
Rhode Island				1	583	266	5	0		409	398	8	10	0	64	1,742
Vermont				0	6,427	88	12	0		361	282	17	12	0	495	7,694
Virginia				4	56,709	1,364	42	12		4,941	3,928	699	1,038	5	561	69,303

NOx																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		221	642	1,051	0	10,795	5,896	59		10,852	32	1,286	2,378	1,015	698	34,926
Delaware		464	1,223	2,739	0	2,115	3,102	6		5,313	59	763	1,862	167	66	17,879
District of Columbia		0	24	90	0	1,011	414	0		1,199	0	50	427	152	4	3,370
Maine		280	2,411	2,093	0	12,108	5,258	32		7,062	633	1,687	6,126	972	1,356	40,017
Maryland		1,325	4,573	6,882	0	10,420	8,160	188		27,271	1,121	3,266	6,556	2,007	531	72,301
Massachusetts		1,967	959	3,509	0	17,035	10,845	235		19,296	763	1,424	8,091	3,032	927	68,083
New Hampshire		221	653	174	0	4,177	3,439	0		6,015	523	1,257	595	304	898	18,257
New Jersey		3,048	2,167	7,529	0	20,547	15,854	95		26,481	788	2,369	6,807	2,845	420	88,949
New York		5,819	11,882	8,246	0	52,265	30,023	1,960		49,494	2,162	10,252	13,133	10,738	2,836	198,809
Pennsylvania		2,217	13,348	2,216	0	44,645	23,043	61,744		81,784	3,248	24,014	30,447	11,453	2,858	301,018
Rhode Island		133	170	1,275	0	2,456	1,652	39		3,034	178	440	990	93	144	10,605
Vermont		80	1,373	3	0	3,301	3,675	0		2,749	164	209	87	563	1,069	13,272
Virginia		4,017	12,098	9,617	0	19,014	14,979	6,551		51,943	4,344	9,995	16,707	7,816	1,105	158,186

$PM_{2.5}$																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut	2,873	32		26	0	4,365	598	12		468	253	274	238	27	6,441	15,609
Delaware	2,228	24		56	0	732	220	0		186	465	117	679	4	636	5,346
District of Columbia	410	0		3	0	709	43	0		71	0	3	91	4	14	1,349
Maine	4,349	43		51	0	6,349	476	2		279	3,331	458	1,453	29	16,709	33,527
Maryland	7,652	77		148	0	4,832	1,003	30		1,006	6,045	521	1,186	51	5,073	27,625
Massachusetts	7,362	115		86	0	5,251	1,139	9		974	4,050	200	1,203	78	8,262	28,730
New Hampshire	2,671	27		4	0	1,584	377	0		224	2,604	298	188	9	10,545	18,530
New Jersey	5,841	132		177	0	7,260	1,569	20		1,062	12,110	494	1,180	73	3,322	33,240
New York	28,765	239		192	0	23,508	2,801	115		2,158	11,255	4,201	1,539	274	29,193	104,240
Pennsylvania	22,345	164		59	0	20,082	2,496	1,489		2,552	17,215	4,608	10,414	291	29,352	111,066
Rhode Island	896	12		30	0	960	152	5		133	883	101	147	3	1,236	4,556
Vermont	4,140	11		0	0	1,127	354	0		119	864	48	131	17	11,914	18,725
Virginia	17,757	228		210	0	17,794	1,704	188		1,671	29,177	1,379	3,182	197	10,787	84,273

PM10																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut	18,998	39		27	0	4,831	636	12		1,570	307	281	254	28	6,451	33,434
Delaware	15,294	26		59	0	805	234	0		556	549	136	735	5	636	19,034
District of Columbia	3,244	0		3	0	768	46	0		352	0	3	102	4	15	4,536
Maine	30,585	49		53	0	7,223	510	2		799	3,906	501	1,740	29	16,709	62,107
Maryland	54,198	87		157	0	6,604	1,073	30		3,140	6,654	586	1,761	53	5,075	79,417
Massachusetts	54,030	130		90	0	5,731	1,210	9		3,685	4,528	205	1,476	80	8,274	79,447
New Hampshire	13,322	30		4	0	1,772	402	0		685	2,900	327	194	9	10,545	30,192
New Jersey	29,954	148		186	0	7,913	1,667	21		3,430	13,791	532	1,625	75	3,332	62,675
New York	196,482	267		201	0	25,845	2,979	127		7,656	12,948	4,469	2,039	283	29,205	282,501
Pennsylvania	134,231	189		62	0	22,923	2,646	1,514		6,831	19,396	5,100	14,490	300	29,368	237,052
Rhode Island	5,539	13		32	0	1,051	161	5		448	969	103	211	3	1,239	9,773
Vermont	35,843	13		0	0	1,261	374	0		352	971	50	167	17	11,916	50,963
Virginia	112,699	249		222	0	20,179	1,811	188		4,539	32,435	1,587	4,530	203	10,791	189,432

SO_2																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		26		10	0	199	8	17		76	14	577	290	1	169	1,387
Delaware		50		81	0	18	3	0		26	71	488	546	0	14	1,297
District of Columbia		0		1	0	7	0	0		10	0	0	20	0	0	38
Maine		31		17	0	718	6	2		37	201	840	2,211	1	552	4,616
Maryland		127		159	0	7,766	10	1		143	443	3,611	836	2	116	13,213
Massachusetts		195		41	0	169	14	5	0	155	285	593	1,068	2	209	2,735
New Hampshire		24		2	0	305	4	0		33	178	339	375	0	335	1,596
New Jersey		322		187	0	240	21	6		183	663	573	652	2	68	2,918
New York		638		106	0	2,392	38	45		305	724	2,740	4,619	8	860	12,476
Pennsylvania		239		52	0	2,965	28	1,157		274	1,158	39,451	13,341	8	820	59,493
Rhode Island		15		16	0	40	2	1		19	67	17	253	0	30	460
Vermont		10		0	0	146	5	0		17	55	2	16	0	415	665
Virginia		420		236	0	1,491	18	170		216	1,904	4,161	12,992	6	264	21,878

VOC																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		145	70,837	37	67	5,285	8,323	35	22,724	8,342	337	68	735	45	6,425	123,404
Delaware		614	37,450	136	797	1,622	4,968	1	4,436	2,527	698	83	510	7	644	54,493
District of Columbia		0	1,938	3	0	313	450	0	4,036	870	0	2	102	6	19	7,741
Maine		172	189,826	71	98	3,366	12,148	64	9,191	3,611	2,187	105	2,370	46	16,320	239,576
Maryland		414	205,531	302	1,173	7,633	14,911	166	37,078	14,371	4,956	255	2,969	84	5,194	295,037
Massachusetts		510	91,816	135	65	7,825	15,339	69	39,196	14,048	2,913	149	3,292	128	8,129	183,614
New Hampshire		182	75,964	6	45	1,956	6,810	0	9,362	4,486	1,502	58	116	15	10,316	110,817
New Jersey		813	116,271	350	123	14,745	19,681	94	58,543	15,223	19,116	140	6,027	120	3,178	254,424
New York		1,592	388,821	379	1,729	32,378	43,531	7,386	112,739	26,791	7,670	1,732	4,522	450	28,683	658,404
Pennsylvania		720	601,234	106	4,075	28,401	29,841	140,783	83,332	40,319	12,664	491	16,822	478	28,741	988,007
Rhode Island		95	16,271	46	9	1,026	1,898	25	6,668	2,278	553	13	785	5	1,221	30,892
Vermont		58	65,813	0	304	4,005	3,793	0	4,881	1,794	532	37	176	27	11,585	93,005
Virginia		1,648	879,137	443	2,820	22,374	21,302	8,311	65,846	26,639	30,873	626	14,101	323	11,657	1,086,102

3.6 US Analytic Year Base Case Emission Inventories

The EPA documentation includes the growth and control assumptions that were used by the Collaborative to derive the analytic year projections. For point source EGUs, the Inventory Collaborative projected emissions using two methods: EPA's and ERTAC-EGU. For analytic year projections, OTC continued to use the ERTAC-EGU projections for its 2022 modeling platform. EPA's non-EGU point source inventories had to be adjusted also to account for differences in what units were included in EPA's inventories vs ERTAC. A detailed description of projection methodologies used for ERTAC EGU emissions can be found in Appendix A. For all other sectors, including Canadian and Mexican sectors, projected emissions were taken directly from the EPA/Inventory Collaborative projections. Documentation for the projections can be found in the 2022V1 TSD on EPA's website.[21]

Maps of projected emissions in each model grid cell were produced to quality assure that the outputs from SMOKE were properly distributed to the modeling domain and to gain a better understanding of the geographic distribution of the emissions.

These maps present emissions for a typical summer weekday, July 12, for 2026 projections. **Figure 3-5** shows total projected 2026 NOx emissions; **Figure 3-6** shows total projected 2026 anthropogenic VOC emissions. With careful examination emission decreases can be seen when comparing the 2026 emissions maps to those for 2022 (**Figure 3-1** and **Figure 3-2**). Additionally, summary tables of emissions for the 2026 analytic year inventory by OTC state, sector, and pollutant were output from SMOKE processing (**Table 3-2**). Some sectors such as fires and marine vessels were aggregated to simplify the tables. A more detailed breakout of analytic year 2026 emissions for every individual sector and the remaining states in the continental US is provided by EPA.[22]

[21] US EPA, 2025. "Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v1 North American Emissions Modeling Platform," EPA-454/B-25-001, accessed at https://www.epa.gov/system/files/documents/2025-06/2022v1_emismod_tsd_base_and_2026_may2025_508_6.pdf.

[22] US EPA, 2025. "2022v1/2016v3 platform state-modeling sector CAPs emissions report with 2026 final," downloaded from https://gaftp.epa.gov/Air/emismod/2022/v1/reports/2022v1_2016v3_state_sector_report_13jan2025.xlsx.

Figure 3-5 *2026 Total NOx Emissions (tons/day) for typical summer weekday.*

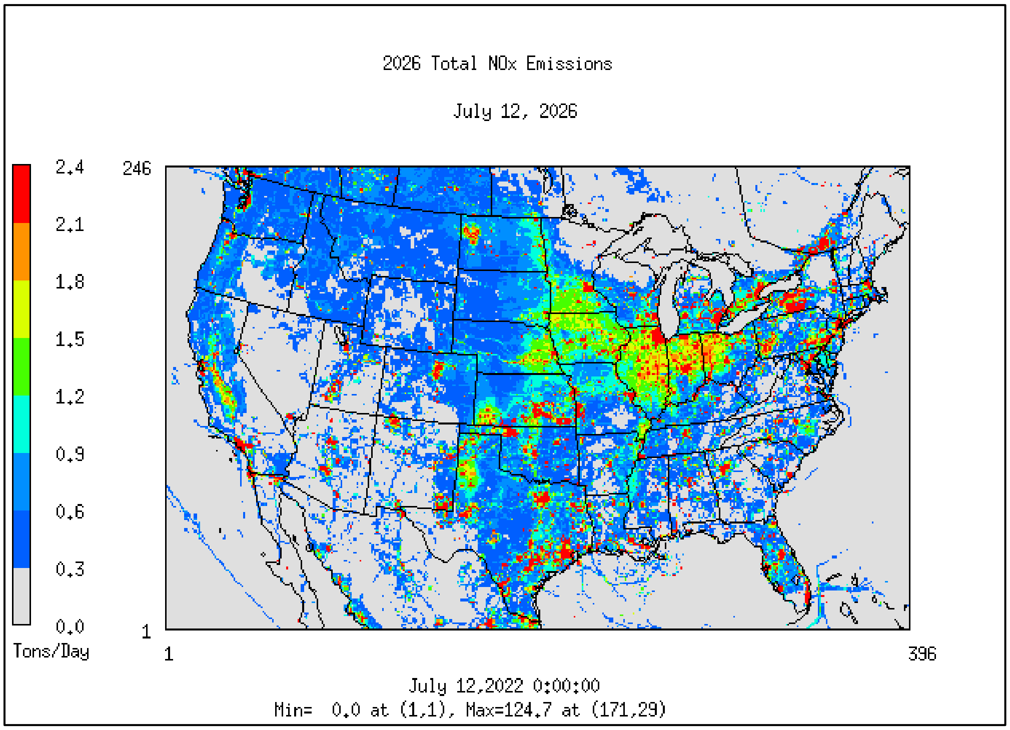


Figure 3-6 *2026 Total Anthropogenic VOC Emissions (tons/day) for typical summer weekday.*

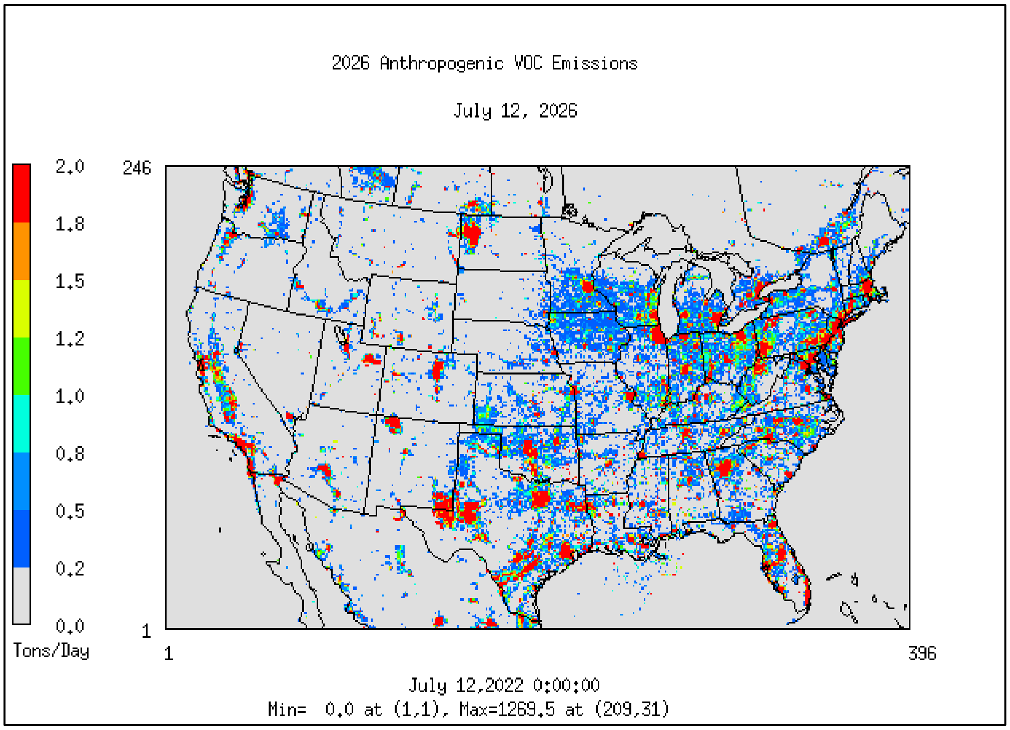


Table 3-2 *2026 V1 Analytic Year Emissions by state, sector, and pollutant from SMOKE processed emission reports (tons/year). Aggregated sectors: cmv= cmv_c1c2+cmv_c3, ag = fertilizer + livestock, fires = openburn + ptagfire + ptfire-rx + ptfire-wild, oil/gas = pt_oilgas + np_oilgas. Bio = bogenic (MEGAN)*

CO																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		2,164	5,238	160	0	8,320	119,874	8		88,835	1,701	213	492	190	42,134	269,328
Delaware		2,068	3,119	374	0	2,111	55,148	0		30,304	3,320	454	2,276	30	4,194	103,398
District of Columbia		1	153	14	0	1,000	7,846	0		12,827	0	1	298	33	66	22,239
Maine		1,805	29,898	316	0	9,936	85,753	39		43,236	21,531	3,191	5,475	123	107,064	308,368
Maryland		3,845	16,423	978	0	8,541	219,362	198		157,123	42,865	2,430	7,731	433	33,676	493,603
Massachusetts		7,169	8,865	527	0	11,929	230,270	144		164,288	29,404	555	3,854	597	53,986	511,587
New Hampshire		1,320	10,317	25	0	2,863	66,412	0		47,514	17,950	1,216	546	39	68,148	216,350
New Jersey		8,653	9,436	1,090	0	16,909	298,705	79		189,276	88,218	1,972	3,931	618	21,070	639,957
New York		16,878	49,104	1,231	0	39,435	603,763	2,151		297,608	75,062	10,558	23,750	2,236	190,227	1,312,004
Pennsylvania		9,357	52,700	307	0	39,106	407,597	70,870		384,505	117,486	13,927	35,082	2,315	191,780	1,325,032
Rhode Island		657	1,181	187	0	1,669	28,684	29		22,320	6,722	94	1,109	14	8,076	70,744
Vermont		580	9,809	0	0	2,033	32,688	0		18,704	5,733	1,058	130	73	75,259	146,068
Virginia		11,360	66,622	1,356	0	30,728	293,643	5,158		318,882	194,350	5,754	13,899	1,658	72,520	1,015,931

NH_3																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut				1	3,055	806	17	0		1,497	22	105	271	1	310	6,086
Delaware				1	11,119	168	8	0		496	314	16	71	0	37	12,230
District of Columbia				0	17	121	1	0		220	0	0	1	0	0	361
Maine				1	7,197	261	15	0		718	1,026	85	307	0	714	10,325
Maryland				3	20,890	1,033	25	0		2,783	1,966	350	285	1	290	27,626
Massachusetts				2	3,623	1,584	32	0		3,019	1,457	61	108	2	419	10,306
New Hampshire				0	2,572	191	11	0		668	1,007	90	74	0	467	5,081
New Jersey				3	5,305	436	51	6		3,359	931	256	649	2	186	11,182
New York				4	39,186	5,540	89	0		5,729	3,530	822	489	7	1,368	56,764
Pennsylvania				1	71,337	3,340	69	6		5,900	5,283	1,062	820	7	1,424	89,249
Rhode Island				1	582	254	5	0		366	398	4	10	0	64	1,682
Vermont				0	6,378	81	12	0		319	282	16	13	0	495	7,596
Virginia				4	56,542	1,333	43	12		4,426	3,928	719	985	5	561	68,558

NOx																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		247	642	1,067	0	9,819	5,248	57		7,236	32	525	2,348	1,046	698	28,966
Delaware		730	1,223	2,709	0	1,965	2,798	6		3,578	59	594	1,627	164	66	15,519
District of Columbia		0	24	94	0	963	348	0		874	0	50	423	157	4	2,937
Maine		284	2,411	2,103	0	9,884	4,700	30		4,877	633	1,376	6,066	935	1,356	34,656
Maryland		1,618	4,573	6,873	0	9,615	7,332	185		18,363	1,121	2,301	6,355	2,056	531	60,922
Massachusetts		2,308	959	3,526	0	15,620	9,620	233		14,652	763	918	7,957	3,207	927	60,690
New Hampshire		217	653	173	0	3,734	3,085	0		3,945	523	534	594	294	898	14,651
New Jersey		3,398	2,167	7,544	0	19,781	13,841	91		17,317	788	1,770	6,782	3,003	420	76,902
New York		6,787	11,882	8,240	0	49,114	27,979	1,858		35,622	2,162	7,913	12,876	10,882	2,836	178,153
Pennsylvania		2,568	13,348	2,195	0	41,518	19,842	60,597		52,447	3,248	23,569	29,221	11,331	2,858	262,744
Rhode Island		142	170	1,272	0	2,242	1,444	37		2,073	178	218	969	95	144	8,983
Vermont		80	1,373	3	0	2,770	3,024	0		1,968	164	125	85	547	1,069	11,208
Virginia		4,508	12,098	9,647	0	18,478	12,661	4,243		33,451	4,344	10,614	15,279	7,808	1,105	134,237

$PM_{2.5}$																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut	2,943	37		27	0	4,346	521	12		410	253	122	242	28	6,441	15,383
Delaware	2,313	29		57	0	753	198	0		158	465	99	594	4	636	5,307
District of Columbia	412	0		3	0	728	33	0		64	0	3	94	4	14	1,356
Maine	4,499	44		52	0	6,281	414	2		238	3,331	429	1,418	27	16,709	33,446
Maryland	7,815	82		152	0	4,897	912	30		884	6,045	309	1,160	53	5,073	27,412
Massachusetts	7,697	122		88	0	5,226	979	9		898	4,050	138	1,176	82	8,262	28,726
New Hampshire	2,810	27		4	0	1,576	331	0		201	2,604	194	188	9	10,545	18,488
New Jersey	6,294	146		181	0	7,316	1,365	20		910	12,110	424	1,196	77	3,322	33,360
New York	29,445	256		195	0	23,586	2,514	114		1,909	11,255	1,882	1,507	278	29,193	102,134
Pennsylvania	22,618	173		60	0	20,147	2,138	1,503		2,197	17,215	4,399	10,068	288	29,352	110,158
Rhode Island	919	12		31	0	953	128	5		116	883	50	144	3	1,236	4,479
Vermont	4,248	11		0	0	1,099	288	0		107	864	44	127	16	11,914	18,718
Virginia	18,161	233		216	0	18,474	1,440	134		1,349	29,177	1,495	3,072	197	10,787	84,736

PM$_{10}$																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut	19,291	47		28	0	4,810	556	12		1,540	307	126	257	29	6,451	33,454
Delaware	15,832	31		61	0	828	212	0		536	549	111	651	4	636	19,451
District of Columbia	3,230	0		3	0	788	35	0		355	0	3	104	4	15	4,537
Maine	31,474	50		54	0	7,165	445	2		770	3,906	472	1,703	28	16,709	62,778
Maryland	54,897	92		161	0	6,477	979	30		3,082	6,654	336	1,734	54	5,075	79,572
Massachusetts	55,403	137		91	0	5,702	1,044	9		3,842	4,528	141	1,446	85	8,274	80,703
New Hampshire	13,955	31		4	0	1,765	355	0		676	2,900	221	194	9	10,545	30,655
New Jersey	32,300	163		191	0	7,975	1,456	21		3,273	13,791	456	1,660	79	3,332	64,696
New York	199,688	285		204	0	25,930	2,683	126		7,527	12,948	1,996	1,987	287	29,205	282,866
Pennsylvania	134,114	199		62	0	22,928	2,276	1,518		6,530	19,396	4,912	14,118	297	29,368	235,719
Rhode Island	5,623	13		32	0	1,043	136	5		440	969	51	208	3	1,239	9,762
Vermont	36,739	13		0	0	1,232	305	0		346	971	45	162	17	11,916	51,746
Virginia	114,775	255		228	0	20,943	1,538	134		4,311	32,435	1,552	4,387	203	10,791	191,553

SO_2																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		29		10	0	184	8	17		94	14	147	291	1	169	965
Delaware		80		84	0	17	3	0		31	71	532	513	0	14	1,346
District of Columbia		0		1	0	6	1	0		13	0	0	20	0	0	41
Maine		31		17	0	585	6	2		48	201	194	2,210	0	552	3,848
Maryland		154		168	0	6,623	11	1		201	443	1,250	801	2	116	9,768
Massachusetts		227		42	0	148	14	5		202	285	180	1,059	2	209	2,374
New Hampshire		23		2	0	360	5	0		44	178	46	392	0	335	1,386
New Jersey		360		197	0	236	21	6		218	663	85	659	2	68	2,514
New York		741		109	0	2,232	40	80		400	724	1,657	4,562	8	860	11,413
Pennsylvania		274		53	0	2,530	29	1,746		357	1,158	43,060	12,667	8	820	62,702
Rhode Island		16		17	0	33	2	1		23	67	8	256	0	30	453
Vermont		10		0	0	122	5	0		24	55	1	16	0	415	646
Virginia		471		248	0	1,529	18	243		309	1,904	3,551	12,271	6	264	20,815

VOC																
	afdust	airports	bio	cmv	ag	nonpt	nonroad	oil/gas	solvents	onroad	fires	ptertac	ptnonertac	rail	rwc	Total
Connecticut		161	70,837	38	66	5,248	7,688	35	22,992	7,017	337	26	717	46	6,425	121,632
Delaware		1,123	37,450	141	797	1,528	4,299	1	4,523	2,089	698	66	488	7	644	53,852
District of Columbia		0	1,938	3	0	313	439	0	4,149	732	0	2	101	7	19	7,703
Maine		174	189,826	72	97	3,256	10,646	63	9,354	3,091	2,187	85	2,272	45	16,320	237,489
Maryland		458	205,531	313	1,171	7,686	14,248	164	38,424	11,848	4,956	212	2,945	86	5,194	293,237
Massachusetts		561	91,816	137	64	7,719	14,283	69	39,659	12,734	2,913	107	3,160	135	8,129	181,486
New Hampshire		173	75,964	6	45	1,951	6,215	0	9,591	3,653	1,502	37	114	14	10,316	109,582
New Jersey		908	116,271	363	122	14,525	18,418	94	59,012	12,517	19,116	128	5,984	126	3,178	250,762
New York		1,798	388,821	388	1,705	33,564	41,761	7,091	114,057	24,468	7,670	1,029	4,344	456	28,683	655,836
Pennsylvania		769	601,234	107	4,088	29,201	28,309	135,581	84,340	30,794	12,664	491	16,203	473	28,741	972,994
Rhode Island		99	16,271	47	9	1,011	1,744	24	6,745	1,901	553	6	762	5	1,221	30,398
Vermont		59	65,813	0	300	4,187	3,523	0	5,002	1,545	532	32	166	26	11,585	92,771
Virginia		1,876	879,137	462	2,806	22,461	19,767	6,911	68,026	21,343	30,873	636	13,553	324	11,657	1,079,832

3.7 Limitations

In April 2025, the Maryland Department of Environment met with EPA and determined that EPA's translation of MDE's submitted emissions resulted in double counted emissions in EPA's Emissions Information System (EIS), and as a result, the point modeling file for the 2022V1 emissions modeling platform. The issue is related to release point apportionment where there are both stack and fugitive emissions. This issue affected 82 point source facilities in Maryland in the base year 2022 and analytic year 2026. This issue affects EPA's ptegu dataset; it remains unclear if the miscounting was translated to the inventory that the OTC used in the modeling presented in this TSD. Other OTC states have confirmed there are no inconsistencies between their point source inventories and the 2022V1 point source inventory, therefore we do not believe this to be a widespread issue within the OTC.

Section 4: Base Year AQ Model Evaluations

4.1 Overview

The OTC evaluated its regional modeling with the 2022v1 emissions platform using CMAQ and EPA's EGU emissions under various boundary conditions, dry deposition schemes, and biogenic emission model options to determine the most suitable model framework for the OTR. Specifically, we compared model performance using boundary conditions from the Hemispheric-CMAQ (H-CMAQ)[23] and the Goddard Earth Observing System-Chemistry (GEOS-Chem)[24] models, the Surface Tiled Aerosol and Gas Exchange (STAGE) and M3Dry dry deposition schemes,[25,26,27] and in-line biogenic emissions from the EPA Biogenic Emissions Inventory System[28] (BEIS) and Model of Emissions of Gases and Aerosols from Nature (MEGAN).[29] We evaluated model performance with surface ozone observations from EPA's Air Quality System from April to October. The results of these evaluations are presented in Sections 4.2 and 4.3. Based on the evaluation results, the configuration using boundary conditions from the H-CMAQ model, the M3Dry dry deposition scheme, and the MEGAN biogenic emissions model, referred to as H-CMAQ/M3Dry/MEGAN, was selected as our production run setup for base year air quality modeling with the 2022v1 platform. Section 4.4 presents the model performance evaluation using this configuration with ERTAC EGU emissions. The New York State Department of Environmental Conservation (NYSDEC) performed all modeling.

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[24] GEOS-Chem, https://geoschem.github.io/index.html, accessed August 22, 2025.

[25] Nemitz, E., Milford, C., and Sutton, M. A., 2001. A two-layer canopy compensation point model for describing bi-directional biosphere-atmosphere exchange of ammonia, *Q. J. Roy. Meteor. Soc.*, 127, 815–833, https://doi.org/10.1002/qj.49712757306.

[26] Massad, R.-S., Nemitz, E., and Sutton, M. A., 2010. Review and parameterization of bi-directional ammonia exchange between vegetation and the atmosphere, *Atmos. Chem. Phys.*, 10, 10359–10386, https://doi.org/10.5194/acp-10-10359-2010.

[27] Appel, K. W., Bash, J. O., Fahey, K. M., Foley, K. M., Gilliam, R. C., Hogrefe, C., Hutzell, W. T., Kang, D., Mathur, R., Murphy, B. N., Napelenok, S. L., Nolte, C. G., Pleim, J. E., Pouliot, G. A., Pye, H. O. T., Ran, L., Roselle, S. J., Sarwar, G., Schwede, D. B., Sidi, F. I., Spero, T. L., and Wong, D. C., 2021. The Community Multiscale Air Quality (CMAQ) model versions 5.3 and 5.3.1: system updates and evaluation, *Geosci. Model Dev.*, 14, 2867–2897, https://doi.org/10.5194/gmd-14-2867-2021.

[28] US EPA, 2025. "Biogenic Emission Inventory System (BEIS)," accessed at https://www.epa.gov/air-emissions-modeling/biogenic-emission-inventory-system-beis.

[29] Guenther, A. B., Jiang, X., Heald, C. L., Sakulyanontvittaya, T., Duhl, T., Emmons, L. K., and Wang, X., 2012. The Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGAN2.1): an extended and updated framework for modeling biogenic emissions, *Geosci. Model Dev.*, 5, 1471–1492, https://doi.org/10.5194/gmd-5-1471-2012.

__Table 4-1__ The ledger of modeling runs and emissions inventory used. Description of selection of boundary conditions, dry deposition schemes, and biogenic models included below. Runs 6 and 8 are the production runs.

Run Number	Run Name	Year	Domain	Run Duration	Boundary Condition	Dry Deposition scheme	Biogenic Emission Model	EGUs	Described in Sections
1	2022 Base-EPAEGU/GEOS-Chem/M3Dry/BEIS	2022	12US2	Annual	GEOS-Chem	M3Dry	BEIS	EPA	4.2
2	2022 Base-EPAEGU/ GEOS-Chem/STAGE/BEIS	2022	12US2	Annual	GEOS-Chem	STAGE	BEIS	EPA	4.2
3	2022 Base-EPAEGU/ H-CMAQ/M3Dry/BEIS	2022	12US2	Annual	H-CMAQ	M3Dry	BEIS	EPA	4.2, 4.3
4	2022 Base-EPAEGU/ H-CMAQ/STAGE/BEIS	2022	12US2	Annual	H-CMAQ	STAGE	BEIS	EPA	4.2
5	2022 Base-EPAEGU/ H-CMAQ/M3Dry/MEGAN	2022	12US2	Annual	H-CMAQ	M3Dry	MEGAN	EPA	4.3
6	**2022 Base-ERTAC/ H-CMAQ/M3Dry/MEGAN**	**2022**	**12US2**	**Annual**	**H-CMAQ**	**M3Dry**	**MEGAN**	**ERTAC**	**3, 4.4, 5**
7	2026 Base-EPAEGU H-CMAQ/STAGE/BEIS	2026	36US3	Annual	H-CMAQ	STAGE	BEIS	EPA	2, 4.4
8	**2026 Base-ERTAC/ H-CMAQ/M3Dry/MEGAN**	**2026**	**12US2**	**Apr - Oct**	**H-CMAQ**	**M3Dry**	**MEGAN**	**ERTAC**	**3, 4.4, 5**

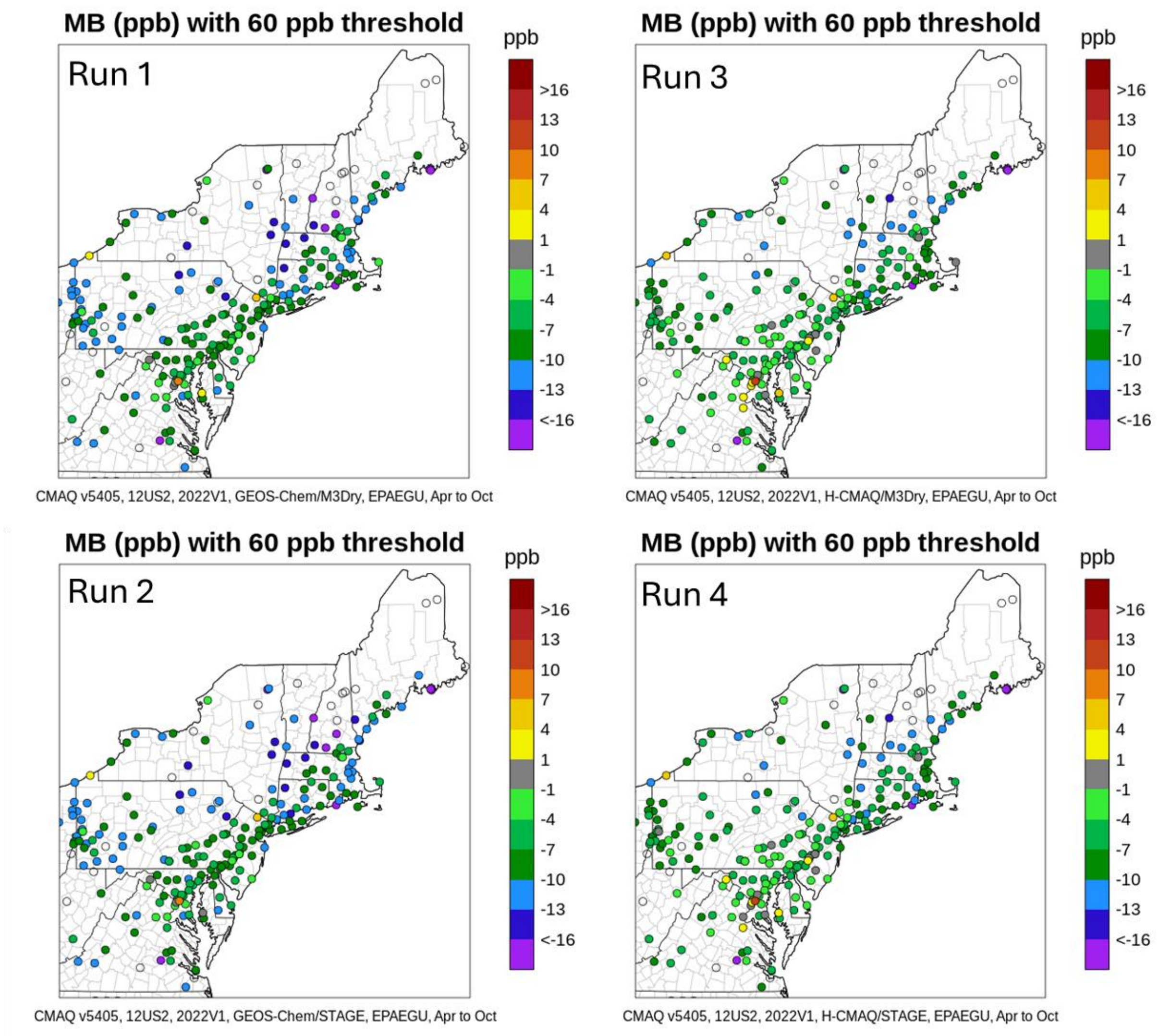
4.2 Boundary Conditions and Dry Deposition Schemes Comparisons

We tested two boundary conditions (BC), H-CMAQ and GEOS-Chem, and two dry deposition schemes, STAGE and M3Dry, to determine the preferred model configuration for the OTR. In this section, model performances were compared among the four model configuration tests: Run 1 through 4 in **Table 4-1**. The BC and dry deposition tests used EPA's EGU and BEIS biogenic emissions.

4.2.1 Mean bias and mean error over OTR

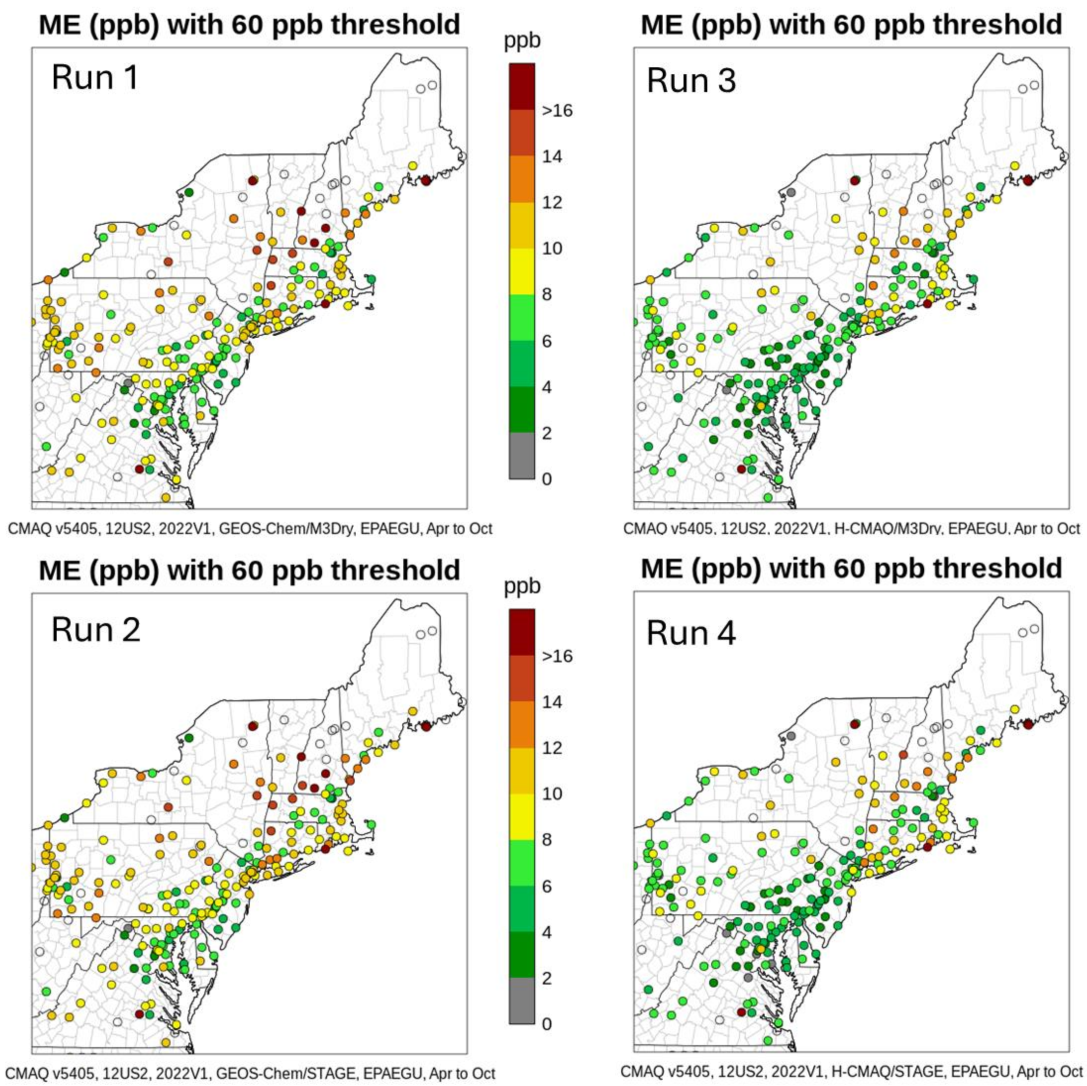
The spatial distribution of performance statistic mean bias (MB) values at each monitor site in the OTR for MDA8 O_3 concentrations greater than or equal to 60 ppb for the four CMAQ model configurations is shown in **Figure 4-1**. Statistical metric definitions are included in Appendix C. For the four modeling runs, MB values fall between -16 ppb and +10 ppb. Overall, the CMAQ model underestimates MDA8 O_3 concentrations at most monitor sites in the OTR when MDA8 O_3 concentrations are greater than or equal to 60 ppb, showing negative biases. However, in general, MB values improve by up to 6 ppb when using the H-CMAQ BC compared to when using the GEOS-Chem, indicating improved model performance for those ozone underestimated sites. The differences in MB values between the two dry deposition options, STAGE and M3Dry, are minor.

Figure 4-1 *Spatial maps of MB for the OTR for the four model configurations when MDA8 O3 concentrations are greater than or equal to 60 ppb.*



We also examined the performance statistics mean error (ME) at each monitor site in the OTR for Runs 1 through 4 when MDA8 O_3 concentrations are greater than or equal to 60 ppb, as shown in **Figure 4-2**. Compared to the GEOS-Chem BC cases, MEs are generally smaller for the H-CMAQ BC with either dry deposition scheme, indicating improved model performance. The differences in ME values between the two dry deposition options are minimal, with slightly smaller ME values at some monitor locations when using M3Dry compared to the STAGE dry deposition option.

Figure 4-2 *Spatial maps of ME in the OTR for the four model configurations when MDA8 O3 concentrations are greater than or equal to 60 ppb.*



4.2.2 Model performance statistics across different regions

We used four commonly applied metrics, MB, ME, normalized mean bias (NMB) and normalized mean error (NME), to illustrate overall model performance. These metrics are widely used in operational assessments of ozone, fine particulate matter, and regional haze modeling applications.[30,31] In **Figure 4-3**, the Kelly plots show the model performance statistics when observed MDA8 O_3 concentrations are greater than or equal to 60 ppb by each climatological

[30] Emery, C., Liu, Z., Russell, A. G., Odman, M. T., Yarwood, G., and Kumar, N., 2017. Recommendations on statistics and benchmarks to assess photochemical model performance. *Journal of the Air & Waste Management Association*, 67, 582-598, https://doi.org/10.1080/10962247.2016.1265027.

[31] Simon, H., Baker, K. R., and Phillips, S., 2012. Compilation and interpretation of photochemical model performance statistics published between 2006 and 2012. *Atmospheric Environment*, 61, 124-139, https://doi.org/10.1016/j.atmosenv.2012.07.012.

region defined by NOAA (**Figure 4-4**) and all OTR Non-Attainment Areas (NAA) (**Figure 4-5**) for the four model configuration runs. Overall, the model performs better with the H-CMAQ BC than with the GEOS-Chem BC. The model performance between the M3Dry and STAGE dry depositions shows similar results on average in each region. Generally, the models perform better in the eastern part of the U.S. than in the western part.

Figure 4-3 *Model performance statistics, including MB, ME, NMB, and NME, when observed maximum daily 8-hour ozone concentrations (MDA8 O_3) are greater than or equal to 60 ppb by each climatological region and OTR NAA for the four model configuration tests.*

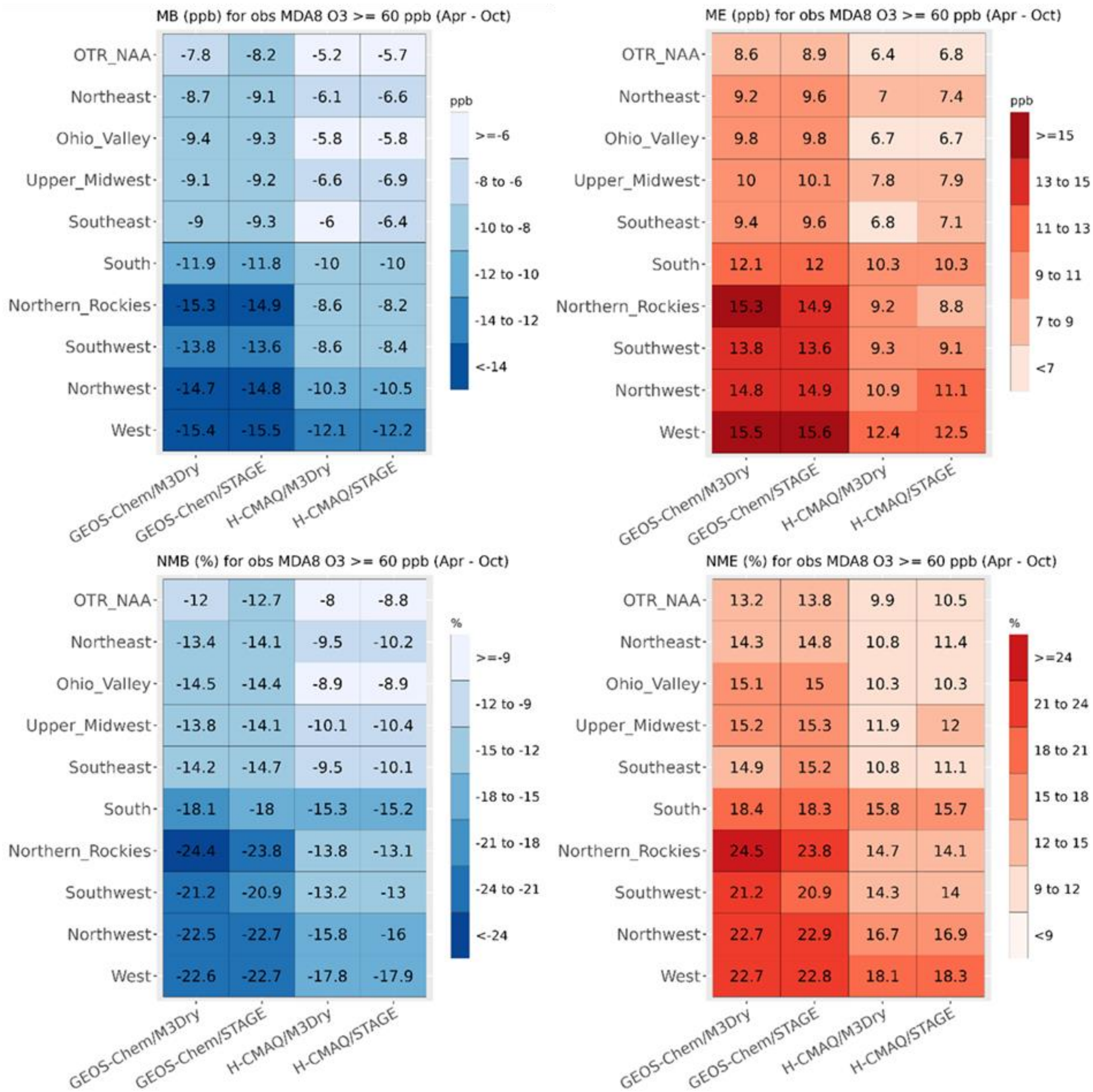


__Figure 4-4__ Map of NOAA climate regions.

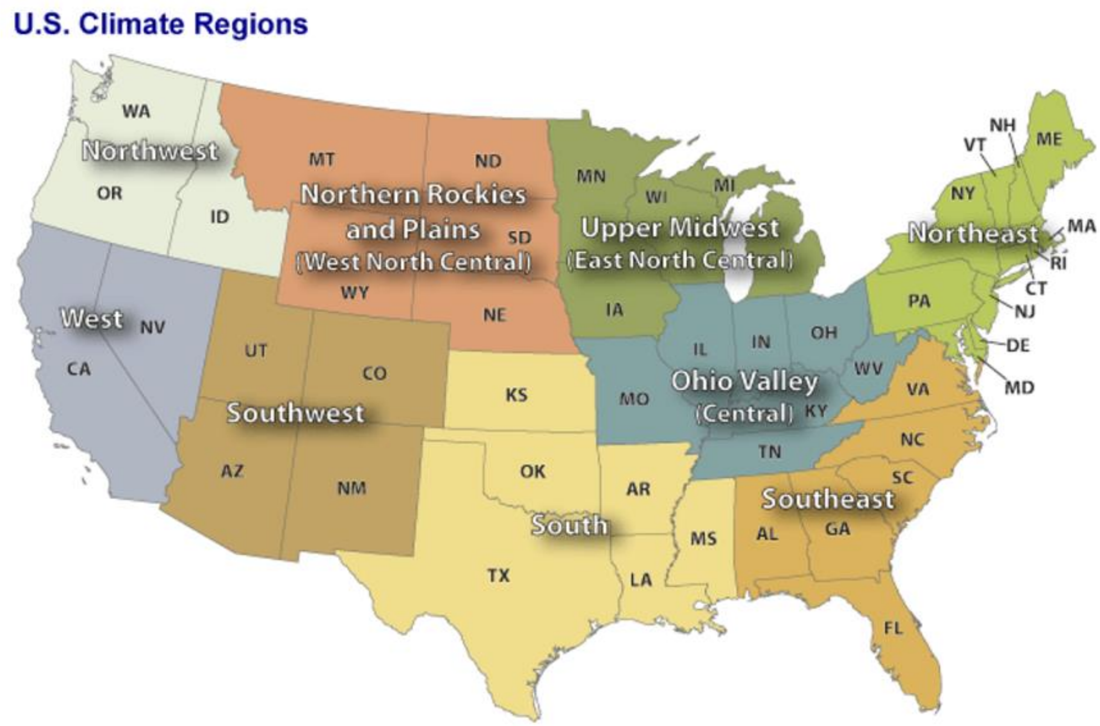
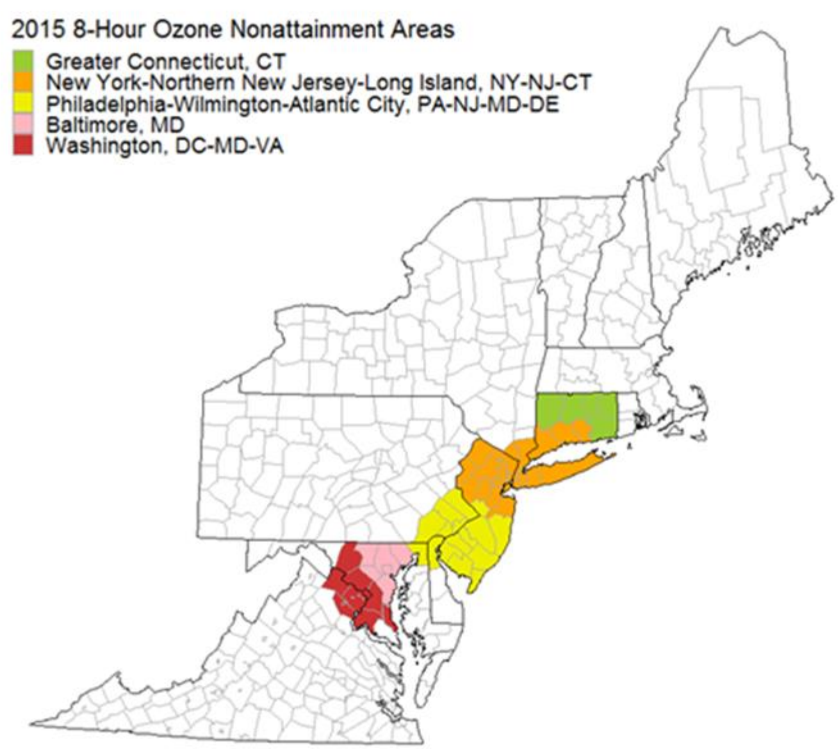


__Figure 4-5__ 2015 8-hour Ozone Nonattainment Areas in the OTR.



We also evaluated model performance statistics in each OTR NAA as shown in **Figure 4-5** for Runs 1 through 4. **Table 4-2** presents model performance statistics, including MB, ME, NMB, and NME, when observed MDA8 O_3 are greater than or equal to 60 ppb in each OTR NAA across the four model configurations for April to October 2022. Overall, the models perform slightly better with the M3Dry dry deposition than with the STAGE option. Compared to the GEOS-Chem BC with M3Dry configuration, using the H-CMAQ BC with M3Dry configuration improves model performance for all of the OTR NAAs. The model performance improves the most in the PA-NJ-MD-DE NAA: from -6.9 to -3.7 ppb for MB, from 7.1 to 4.4 ppb for ME, from -10.7% to -5.8% for NMB, and from 11% to 6.9% for NME.

Model performance statistics from the previous modeling platform are shown in **Table 4-3** for reference.[32] Comparing the performance statistics from the CMAQ modeling using the 2016 V1, 2016 V2/V3 platforms, and 2022 V1 modeling platform with the H-CMAQ/M3Dry configuration, the 2022 V1 modeling platform outperforms the 2016 platforms in the OTR NAAs overall.

[32] Ozone Transport Commission, 2023. "Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union 2016 Based Modeling Platform Technical Support Document: OTC V2/V3 Modeling Platform Update," accessed at https://otcair.org/upload/Documents/Reports/OTC_Modeling_TSD2016_Addendum_July2023.pdf.

Table 4-2 *Performance statistics, including MB, ME, NMB, and NME, when MDA8 O_3 observations are greater than or equal to 60 ppb by OTR NAA across four CMAQ model configurations for April to October 2022.*

NAA area	# of Observations	MB	ME	NMB	NME
Run 1: GEOS-Chem/M3Dry					
CT	67	-9.2	9.7	-14	14.7
NY-NJ-CT	430	-9	9.9	-13.7	15
PA-NJ-MD-DE	258	-6.9	7.1	-10.7	11
MD	109	-6.7	7.5	-10.4	11.8
DC-MD-VA	100	-4.8	7.1	-7.7	11.3
Run 2: GEOS-Chem/STAGE					
CT	67	-10.1	10.4	-15.3	15.8
NY-NJ-CT	430	-9.6	10.4	-14.6	15.7
PA-NJ-MD-DE	258	-7.1	7.3	-11.1	11.4
MD	109	-7.1	7.8	-11.1	12.2
DC-MD-VA	100	-5	7.3	-8	11.5
Run 3: H-CMAQ/M3Dry					
CT	67	-7.4	8.1	-11.2	12.3
NY-NJ-CT	430	-7	8.1	-10.6	12.2
PA-NJ-MD-DE	258	-3.7	4.4	-5.8	6.9
MD	109	-3.6	5.2	-5.6	8.2
DC-MD-VA	100	-1.8	4.8	-2.9	7.6
Run 4: H-CMAQ/STAGE					
CT	67	-8.3	8.8	-12.6	13.4
NY-NJ-CT	430	-7.6	8.6	-11.6	13
PA-NJ-MD-DE	258	-4	4.6	-6.3	7.2
MD	109	-4.1	5.4	-6.4	8.5
DC-MD-VA	100	-2.1	5	-3.4	7.8

Table 4-3 *Performance statistics for the CMAQ model when Maximum Daily 8-hour Observations are greater than or equal to 60 ppb by OTR Non-Attainment Area (NAA) for April to October 2016 (from the 2016 platform).*

		V1_CMAQ531				V2/V3_CMAQ533			
NAA area	**# of Observations**	**MB**	**ME**	**NMB**	**NME**	**MB**	**ME**	**NMB**	**NME**
CT	116	-7.6	12	-11.3	17.8	-10.1	12.2	-15	18
NY-NJ-CT	685	-5.2	9	-7.7	13.2	-7.3	9.9	-10.7	14.6
PA-NJ-MD-DE	519	-6.6	8.2	-9.9	12.3	-8.3	9.2	-12.5	13.8
MD	278	-5.3	9.1	-7.9	13.4	-6.7	10.2	-9.9	15.1
DC-MD-VA	323	-5.6	8	-8.5	12.2	-7.4	8.8	-11.3	13.5

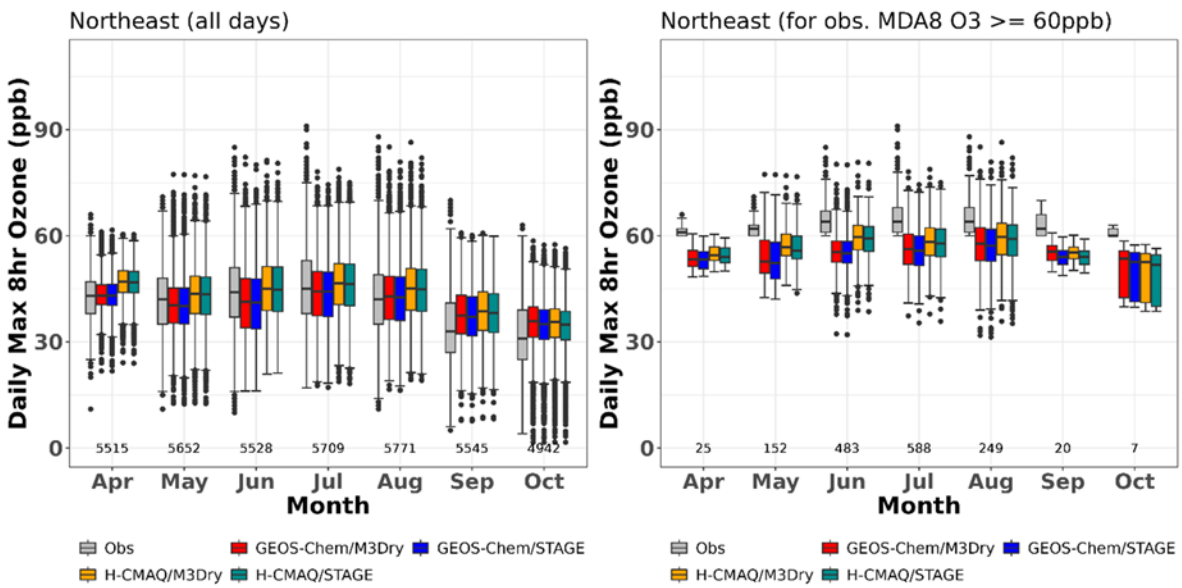
Note: This table is from the 2016 Based Modeling Platform Technical Support Document: OTC V2/V3 Modeling Platform Update, https://otcair.org/upload/Documents/Reports/OTC_Modeling_TSD2016_Addendum_July2023.pdf.

4.2.3 Model evaluations by month

Model performance at monitors in the Northeast NOAA Climate Region is broken down by month, comparing observations (gray), GEOS-Chem BC with M3Dry dry deposition (red), GEOS-Chem BC with STAGE (blue), H-CMAQ BC with M3Dry (orange), and H-CMAQ BC with STAGE (green) distributions, as shown in **Figure 4-6**. Overall, the models with H-CMAQ/M3Dry and H-CMAQ/STAGE consistently estimate higher ozone concentrations than those with GEOS-Chem/M3Dry and GEOS-Chem/STAGE for all months except October. We investigated model performance for all days and for days when observed MDA8 O_3 concentrations are greater than or equal to 60 ppb. For all days, the models with GEOS-Chem/M3Dry and GEOS-Chem/STAGE underestimate concentrations from April to July and overestimate concentrations from September to October. The models with the H-CMAQ BC perform better from May to July than the GEOS-Chem BC.

When analyzing days with observed MDA8 O_3 concentrations of 60 ppb or greater, the models generally underpredict ozone throughout the entire modeling period across all four runs. With H-CMAQ BC, the models predict higher ozone concentrations than those with the GEOS-Chem BC from April to August. The model with H-CMAQ BC performs better than the GEOS-Chem BC on high ozone days. The impact of the two dry deposition options was minimal.

Figure 4-6 *Monthly boxplot distributions for all days and days when MDA8 O_3 is greater than or equal to 60 ppb, comparing observations (gray) for monitor sites in the Northeast, April to October 2022.*



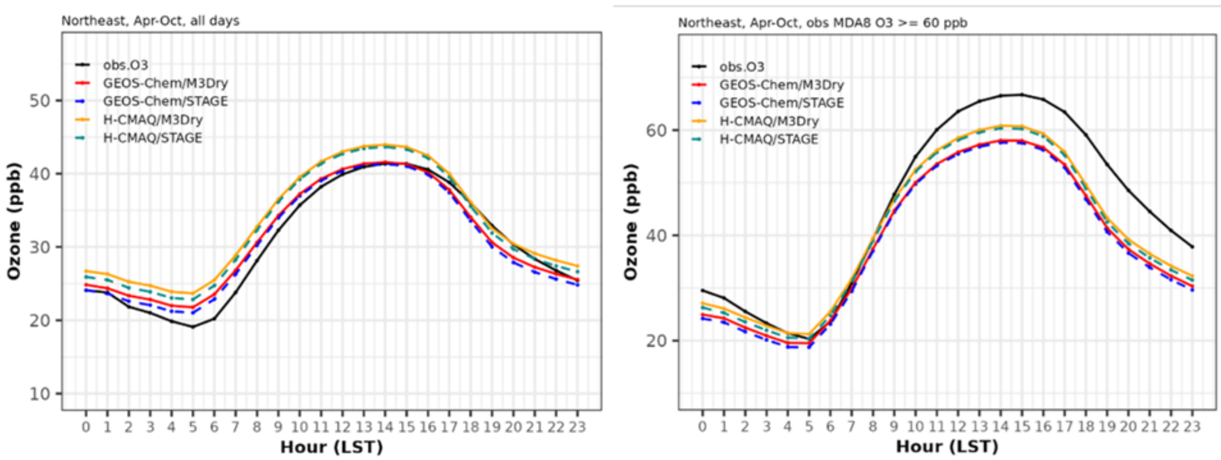
4.2.4 Model diurnal profiles and other evaluations

Diurnal profiles at monitor locations in the Northeast NOAA Climate Region for the four modeling scenarios from April to October are shown in **Figure 4-7**. This includes diurnal profiles for all days and for days when observed MDA8 O_3 is greater than or equal to 60 ppb. For all days, the models with the H-CMAQ BC predict higher ozone concentrations throughout the day than those with the GEOS-Chem BC. The models with the H-CMAQ BC overestimate ozone concentrations until 5 pm and perform well in the evening. The models with the GEOS-Chem BC overestimate morning concentrations and predict the peak daytime ozone concentrations well. However, after the peak, the models tend to underestimate ozone concentrations.

At observed MDA8 O_3 concentrations of 60 ppb or higher, the models tend to underestimate ozone concentrations on average throughout the day, except in the morning hours. With the H-

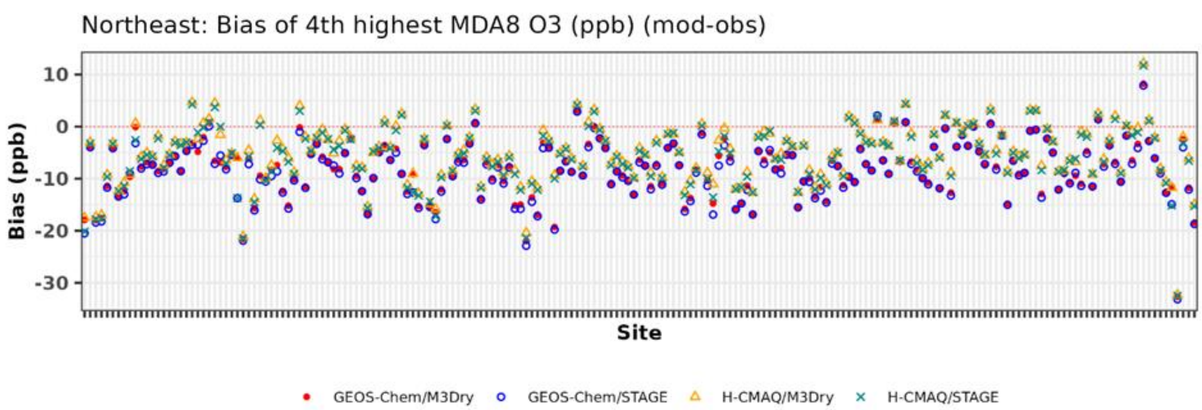
CMAQ BC, the peaks are closer to the observed ozone than with the GEOS-Chem BC. The dry deposition options show minimal difference between the two options.

Figure 4-7 *Diurnal profile at monitor locations in the Northeast NOAA Climate Region.*



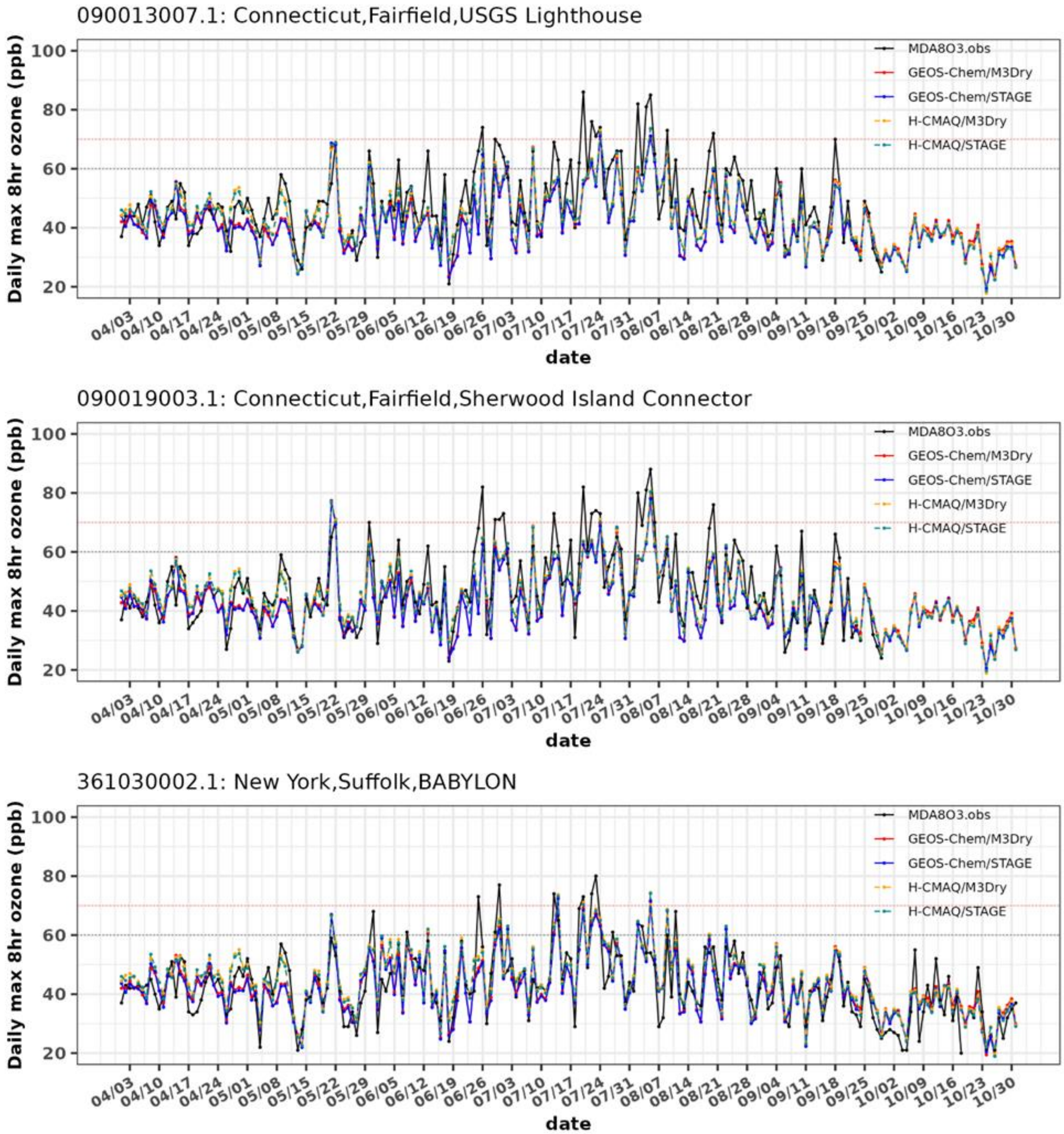
We also compare the bias (modeled minus observed) of the fourth highest observed MDA8 O_3 at each monitor location in the Northeast NOAA Climate Region, as shown in **Figure 4-8**. Overall, the models predict higher ozone concentrations with the H-CMAQ BC than with the GEOS-Chem BC and perform better with more monitoring locations, showing lower biases. The impact of dry depositions is minimal.

Figure 4-8 *Bias (modeled minus observed) of the fourth highest MDA8 O_3 for the monitor locations in the Northeast NOAA Climate Region.*



Finally, the performance of models at selected key nonattainment monitors is evaluated by comparing daily observations with the modeled MDA8 O_3 concentrations, as shown in **Figure 4-9**. The model performances with the two BCs differ most during the early season from April to May, when the models with the H-CMAQ BC tend to estimate higher ozone concentrations than those with the GEOS-Chem BC. Using the H-CMAQ BC, the models sometimes overestimate the peak of ozone concentrations in the early season from April to May. However, all four runs underestimate the peaks for most of the rest of the season at Stratford and Westport in Connecticut, except for October, when monitored data are missing. On the other hand, all four scenarios capture the peak of ozone concentrations for more days at Babylon in New York.

Figure 4-9 *Time series plot of MDA8 O_3 from April to October 2022 for selected monitors: 090013007 (Stratford, CT), 090019003 (Westport, CT), and 361030002 (Babylon, NY).*



In summary, among the boundary condition and dry deposition comparisons, the configuration using H-CMAQ boundary conditions with the M3Dry dry deposition scheme produced the best model performance on high ozone days over the eastern U.S. The differences between the M3Dry and STAGE deposition schemes were smaller than those observed between the H-CMAQ and GEOS-Chem boundary conditions.

4.3 Biogenic Model Comparisons between BEIS and MEGAN

Section 4.2 showed that Runs 1 through 4 underestimated MDA8 O_3 across most areas on high ozone days (i.e., when MDA8 O_3 concentrations were greater than or equal to 60 ppb). Among the configurations, the H-CMAQ boundary condition combined with the M3Dry deposition scheme performed best in simulating MDA8 O_3. We will use this configuration as our model configuration for comparing BEIS and MEGAN biogenic emissions.

Vegetation is a major source of volatile organic compounds (VOCs), which are key precursors in ozone formation during the growing season. Therefore, a better quantification of the contribution of biogenic VOC (BVOC) emissions to regional ozone formation is needed. BEIS estimates BVOC emissions based on simulated meteorology and vegetation data, including the Biogenic Emissions Land Use Database (BELD). MEGAN calculates BVOC emissions as the product of emission activity, affected by meteorological conditions and plant stress factors, and time-independent average emission rates generated using the MEGAN preprocessor.[33,34]

Soil nitrogen oxide (NO) emissions from both agricultural and non-agricultural sources are included as part of the biogenic emissions in both BEIS and MEGAN. Both models use a soil NO calculation based on Yienger and Levy (1995),[35] and MEGAN version 3.2 also offers the Berkeley–Dalhousie Soil NO Parameterization (BDSNP) option.[36,37]

Biogenic emissions were calculated using the in-line biogenic emissions option in CMAQ. For BEIS, version 4 (BEIS4) was used with land use data from BELD version 6. For MEGAN, emissions were calculated using version 3.2 with the BDSNP parameterization module. Finally, EPA's Electricity Generating Unit (EGU) emissions inventory were used for these model comparisons. The terms EPA EGU/BEIS and EPA EGU/MEGAN are used to represent the CMAQ model simulations coupled with the BEIS and MEGAN biogenic emissions models, respectively. The final model configurations use the Eastern Regional Technical Committee (ERTAC) EGU emissions as described in Section 3 and evaluated in Section 4.4.

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[33] Guenther, A. B., Jiang, X., Heald, C. L., Sakulyanontvittaya, T., Duhl, T., Emmons, L. K., and Wang, X., 2012. The Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGAN2.1): an extended and updated framework for modeling biogenic emissions, *Geosci. Model Dev.*, 5, 1471–1492, https://doi.org/10.5194/gmd-5-1471-2012.

[34] Kang, D., Willison, J., Sarwar, G., Madden, M., Hogrefe, C., Mathur, R., Gantt, B., and Alfonso, D. S., 2021. Improving the Characterization of the Natural Emissions in CMAQ. *EM Magazine*. Air and Waste Management Association, Pittsburgh, PA, (10):1-7.

[35] Yienger, J. J. and Levy II, H., 1995. Empirical model of global soil-biogenic NOx emissions, *Journal of Geophysical Research: Atmospheres*, 100, 11447–11464, https://doi.org/10.1029/95JD00370.

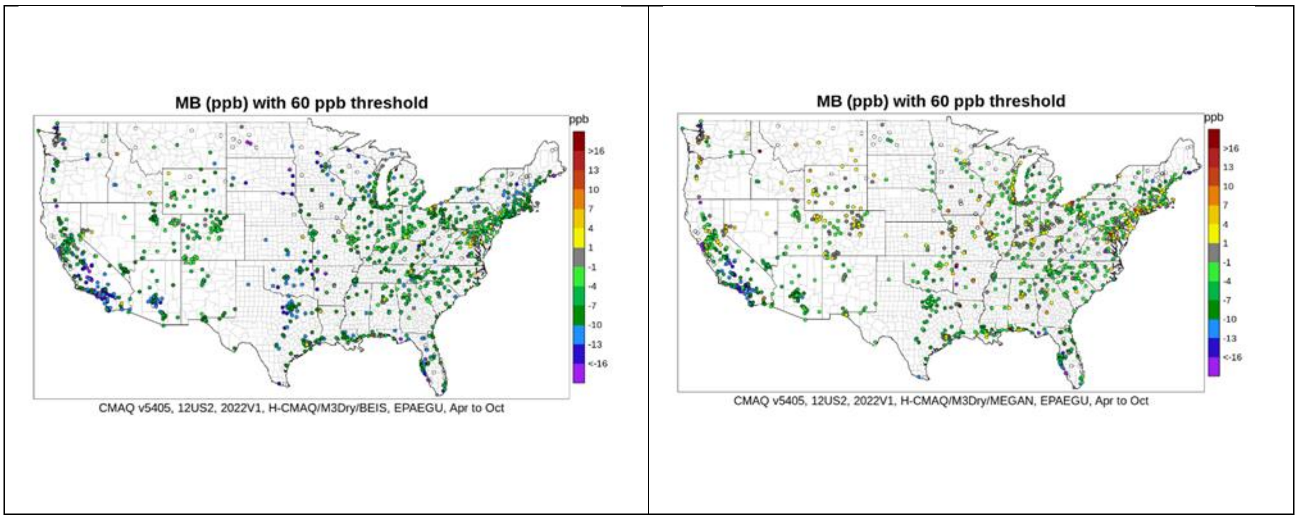
[36] Hudman R. C., Moore N. E., Mebust A. K., Martin R. V., Russell A. R., Valin L. C., and Cohen R. C., 2012. Steps towards a mechanistic model of global soil nitric oxide emissions: implementation and space based-constraints, *Atmos. Chem. Phys.*, 12, 7779–7795, https://doi.org/10.5194/acp-12-7779-2012.

[37] Kang, D., Willison, J., Sarwar, G., Madden, M., Hogrefe, C., Mathur, R., Gantt, B., and Alfonso, D. S., 2021. Improving the Characterization of the Natural Emissions in CMAQ. *EM Magazine*. Air and Waste Management Association, Pittsburgh, PA, (10):1-7.

4.3.1 MB and ME over the CONUS and OTR

The spatial maps of MB and ME of the MDA8 O_3 greater than or equal to 60 ppb from April to October (**Figure 4-10** and **Figure 4-11**) show that both simulations underestimated O_3 during the ozone season across much of the modeling domain on high ozone days (i.e., observed MDA8 $O_3 \geq 60$ ppb). However, EPA EGU/MEGAN simulated higher MDA8 O_3 concentrations (indicated by light-green or light-yellow dots) than EPA EGU/BEIS (blue- or dark-green dots) by up to 20 ppb. In addition, EPA EGU/MEGAN displayed lower ME values than EPA EGU/BEIS by up to 8 ppb for most sites across the Northeast region.

Figure 4-10 *Spatial maps of mean bias (MB) in MDA8 O_3 with a threshold of 60 ppb from EPA EGU/BEIS (left) and EPA EGU/MEGAN (right) in ozone season over CONUS.*



Ozone concentrations were overestimated by EPA EGU/MEGAN in several coastal grid cells defined as water, due to challenges in accurately characterizing the land–water interface in both the air quality and meteorological models. Special attention was given to six monitoring sites where land cover classification (water vs. land) varies (**Figure 4-12**).

At Greenwich and Groton in Connecticut, the WRF model classified the grid cells as water, while the other four sites were classified as land. Better performance (i.e., lower bias) was observed at the four sites classified as land cells, with approximately 5 ppb improvement from EPA EGU/BEIS to EPA EGU/MEGAN. In contrast, EPA EGU/MEGAN significantly overestimated O_3 at the two water-cell sites.

At Greenwich, biogenic emissions from BEIS were zero, whereas MEGAN emissions exhibited a clear diurnal cycle (figure not shown). With BEIS, biogenic emissions are forced to be zero over water cells. However, in the MEGAN model, biogenic emissions from these water-classified cells persisted and were relatively high due to a mismatch between the WRF and MEGAN land-use classifications. A combination of a very shallow planetary boundary layer (PBL) from the WRF model and relatively large biogenic emissions led to the substantial O_3 overestimations at Greenwich and Groton. Further modification of MEGAN is needed in the future development of CMAQ to solve the mismatch issues but was not included in the NYSDEC modeling for this Technical Support Document.

Figure 4-11 *Spatial maps of MB (top) and ME (bottom) in MDA8 O_3 with a threshold of 60 ppb from EPAEGU/BEIS (left) and EPAEGU/MEGAN (right) in ozone season over the OTR.*

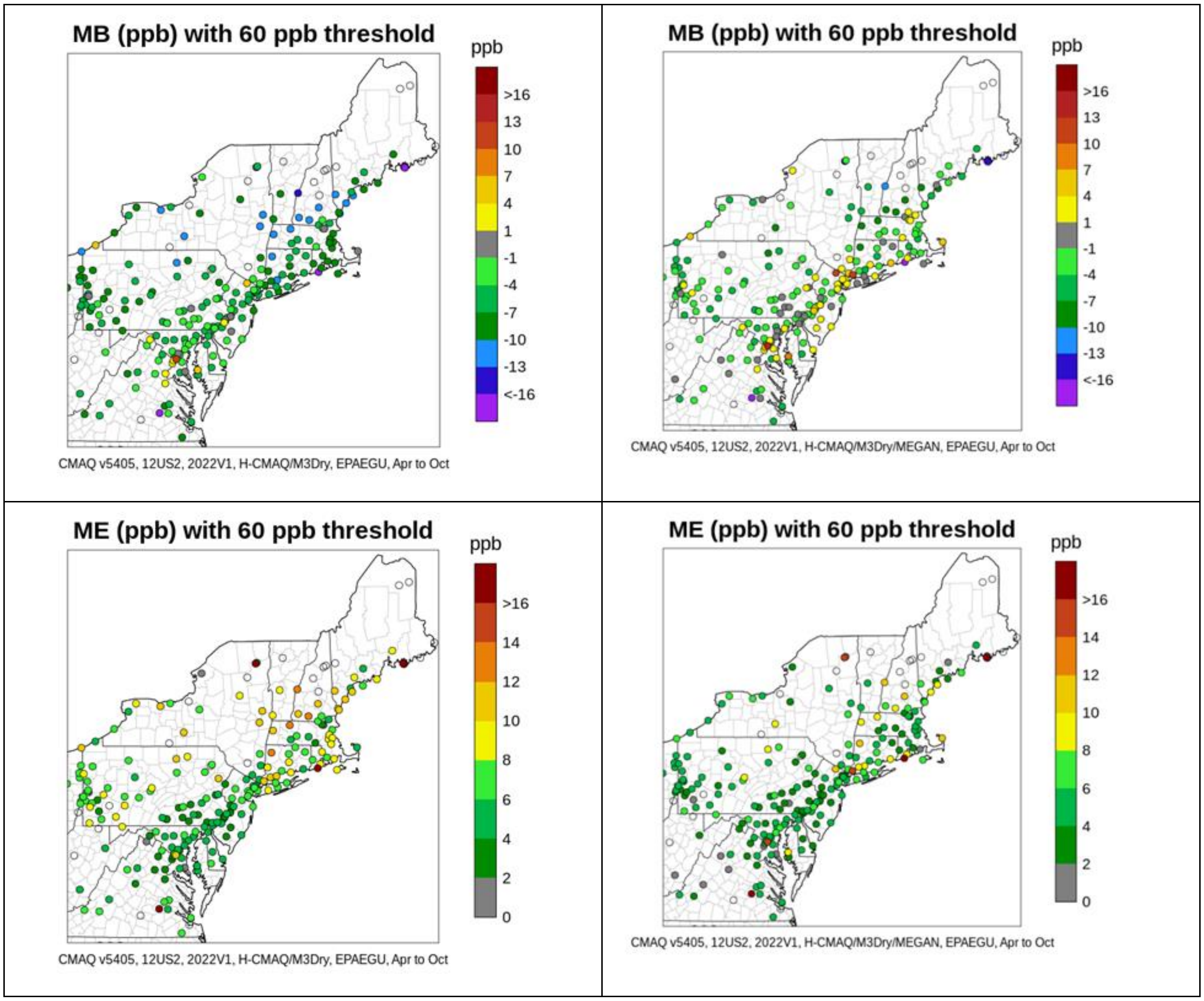


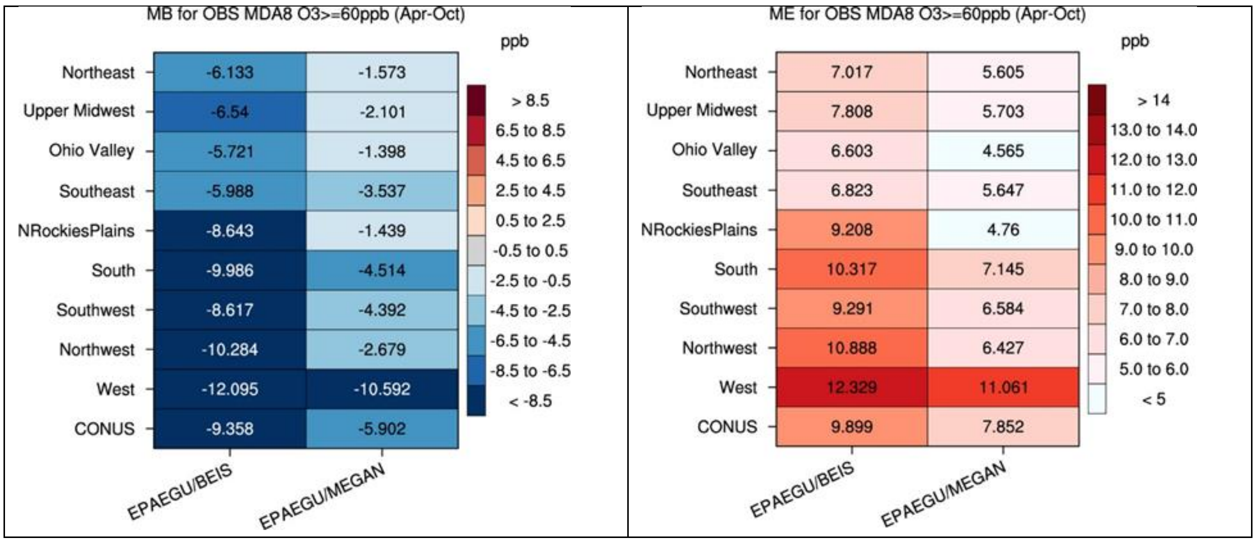
Figure 4-12 *The location of the six monitoring sites over the Connecticut coastal area and their land cover types. The blue colors represent water cells, and the green colors represent land cells.*

4.3.2 Mean bias and mean error across different regions

The Kelly plots showing regional MB and ME of MDA8 O_3 greater than or equal to 60 ppb for the April–October period are presented in **Figure 4-13**. Results are grouped by the nine climate regions defined by NOAA. EPA EGU/MEGAN exhibited significantly smaller MB values across all regions compared to EPA EGU/BEIS. For instance, in the Northeast region, the MB was -6.1 ppb with EPA EGU/BEIS and improved to -1.6 ppb with EPA EGU/MEGAN. Across the entire Continental United States (CONUS), the MB improved from -9.4 ppb to -5.9 ppb by using MEGAN over BEIS.

ME values also decreased in all nine regions, although the reductions were not as pronounced as those observed for MB. On average, the improvements in ME were about 2 ppb when transitioning from BEIS to MEGAN.

Figure 4-13 *Regional mean bias (MB) and mean error (ME) in MDA8 O_3 with a threshold of 60 ppb from EPA EGU/BEIS and EPA EGU/MEGAN during the ozone season.*



4.3.3 Statistical evaluation of maximum daily 8-hour O_3

At each site across the 12US2 domain, we computed model evaluation statistics for the entire April–October 2022 period. Emery et al. (2017)[38] proposed NMB and NME benchmarks for ozone based on the concepts of "goals" and "criteria." For MDA8 O_3, the suggested benchmarks are:

- NMB goal: < ±5%, NMB criteria: < ±15%
- NME goal: < 15%, NME criteria: < 25%

"Goals" represent performance benchmark achieved by roughly one-third (33%) of past model applications and reflect the best performance grid models can typically achieve. "Criteria"

[38] Emery, C., Liu, Z., Russell, A. G., Odman, M. T., Yarwood, G., and Kumar, N., 2017. Recommendations on statistics and benchmarks to assess photochemical model performance. *Journal of the Air & Waste Management Association*, 67, 582-598, https://doi.org/10.1080/10962247.2016.1265027.

represent benchmark met by about two-thirds (67%) of past applications and indicate acceptable performance for most grid models.

Table 4-4 lists the numbers and percentages of monitors across the CONUS that meet these recommended benchmarks for both EPA EGU/BEIS and EPA EGU/MEGAN over the full ozone season. **Table 4-5** presents the corresponding results for monitors in the Northeast (OTR excluding Virginia). Overall, both models met the NMB and NME criteria at the vast majority of sites (>67% of the total sites), with EPA EGU/MEGAN achieving higher percentages. However, EPA EGU/MEGAN showed substantially better performance in meeting the stricter *goal* benchmarks for both NMB and NME. For example, for CONUS monitors, the NMB goal was met at only 142 monitors in the EPA EGU/BEIS configuration, but improved to 546 monitors when using MEGAN. For Northeast monitors, the NMB goal was met at only 32 monitors using EPA EGU/BEIS, but boosted to 103 monitors when using MEGAN.

Table 4-4 *Numbers (and percentages) of monitoring sites meeting NMB and NME goals and criteria across the CONUS (for Observed MDA8 O_3 ≥ 60 ppb, April–October, N=1133).*

CONUS	EPA EGU/BEIS	EPA EGU/MEGAN
NMB goal < ±5%	142 (13%)	546 (48%)
NMB criteria < ±15%	838 (74%)	1024 (90%)
NME goal < 15%	814 (72%)	1014 (89%)
NME criteria < 25%	1104 (97%)	1116 (99%)

Table 4-5 *Numbers (and percentages) of monitoring sites meeting NMB and NME goals and criteria across the Northeast (for Observed MDA8 O_3 ≥ 60 ppb, April–October, N=179).*

Northeast (i.e., region1, OTR excluding VA)	EPA EGU/BEIS	EPA EGU/MEGAN
NMB goal < ±5%	32 (18%)	103 (58%)
NMB criteria < ±15%	153 (85%)	170 (95%)
NME goal < 15%	151 (84%)	167 (93%)
NME criteria < 25%	175 (98%)	178 (99%)

4.3.4 Reasoning for selection of MEGAN for biogenic model option

An analysis of emissions from BEIS and MEGAN (**Figure 4-14**) shows that BEIS predicted lower formaldehyde (HCHO) and isoprene (ISOP) emissions than MEGAN in New York City. Especially, BEIS ISOP emissions were estimated to be lower than MEGAN in the Northeast region. As a result, MEGAN produced higher modeled surface concentrations of both HCHO and isoprene in these areas (**Figure 4-15**). These findings are consistent with previous studies, such as Carlton and Baker (2011)[39] and Wei et al. (2024),[40] which also reported that CMAQ coupled with MEGAN predicts substantially more isoprene emissions than when coupled with

[39] Carlton, A.G. and Baker, K.R., 2011. Photochemical modeling of the Ozark isoprene volcano: MEGAN, BEIS, and their impacts on air quality predictions, *Environ Sci Technol.*, 45, 4438-45, https://doi.org/10.1021/es200050x.
[40] Wei, D., Cao, C., Karambelas, A., Mak, J., Reinmann, A., and Commane, R., 2024. High-Resolution Modeling of Summertime Biogenic Isoprene Emissions in New York City, *Environ. Sci. Technol.*, 58, 13783−13794, https://doi.org/10.1021/acs.est.4c00495.

BEIS. In addition, Wei et al. (2024)[41] reported that CMAQ coupled with MEGAN predicts more reasonable isoprene emissions, which are closer to observations.

Figure 4-14 *Differences in HCHO (left) and Isoprene (ISOP, right) emissions between MEGAN and BEIS in July 2022.*

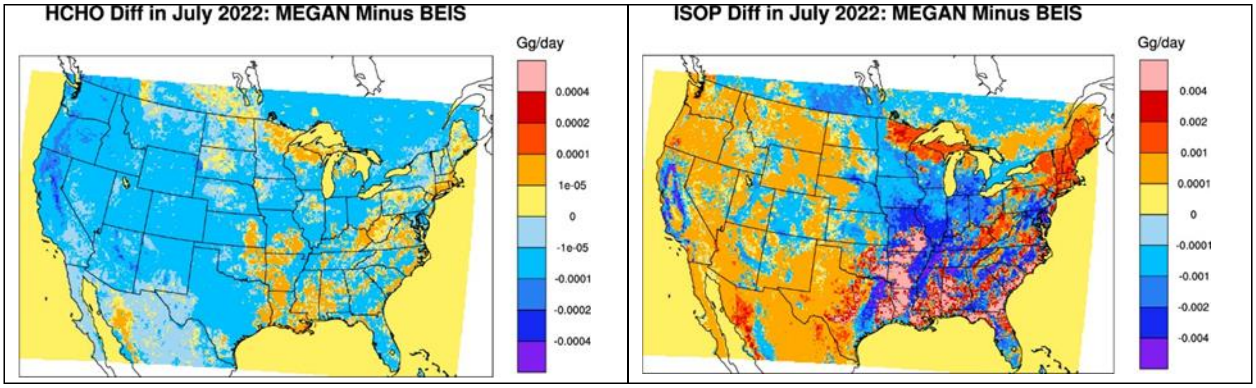
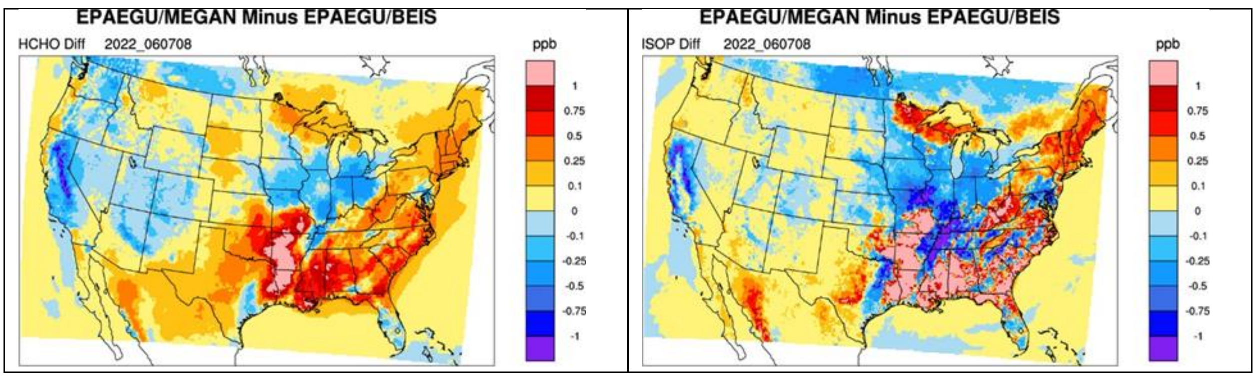


Figure 4-15 *Differences in model simulated HCHO (left) and Isoprene (ISOP, right) surface concentrations between EPA EGU/MEGAN and EPA EGU/BEIS.*



Biogenic volatile organic compound (BVOC) emissions contribute 75% to 80% of total U.S. VOC emissions, according to the EPA 2011 National Emissions Inventory (2011NEIv2).[42] The dominant BVOC species, isoprene, reacts rapidly with hydroxyl radicals to form HCHO. Therefore, isoprene is a key precursor for secondary HCHO formation and is widely recognized as a primary contributor to elevated summer HCHO levels.[43,44,45] This explains the increasing

[41] Ibid.

[42] US EPA, 2015. "Technical Support Document: Preparation of Emissions Inventories for Version 6.2, 2011 Emissions Modeling Platform," accessed at https://www.epa.gov/sites/production/files/2015-10/documents/2011v6_2_2017_2025_emismod_tsd_aug2015.pdf.

[43] Pierce, T., Geron, C., Bender, L., Dennis, R., Tonnesen, G., and Guenther, A., 1998. Influence of increased isoprene emissions on regional ozone modeling, *Journal of Geophysical Research: Atmospheres*, 103(D19), 25611-25629, https://doi.org/10.1029/98JD01804.

[44] Zhang, R., Suh, I., Lei, W., Clinkenbeard, A. D., and North, S. W., 2000. Kinetic studies of OH-initiated reactions of isoprene, *Journal of Geophysical Research: Atmospheres*, 105(D20), 24627-24635, https://doi.org/10.1029/2000JD900330.

[45] Zhang, R., Cohan, A., Biazar, A. P., Cohan, D. S., 2017. Source apportionment of biogenic contributions to ozone formation over the United States, *Atmospheric Environment*, 164, 8-19, https://doi.org/10.1016/j.atmosenv.2017.05.044.

modeled HCHO concentrations in the eastern U.S. using the MEGAN option, which in turn results in increasing O_3 in the East.

Soil NO emissions from both agricultural and non-agricultural sources are included as biogenic emissions in both BEIS and MEGAN.[46] In this study, BEIS calculated soil NO using the method of Yienger and Levy (1995),[47] while MEGAN used the Berkeley–Dalhousie Soil NO Parameterization (BDSNP).[48,49] **Figure 4-16** shows the differences in soil NO emissions between MEGAN and BEIS for July 2022. The BDSNP option in MEGAN produced significantly higher soil NO emissions than the Yienger and Levy (1995)[50] approach in BEIS, particularly in the central United States, a result consistent with findings reported by Kang et al. (2021).[51]

To compare the magnitude of this difference, **Figure 4-17** displays total NO_x (nitrogen oxides, which is the sum of nitric oxide (NO) and nitrogen dioxide (NO_2), i.e., NO + NO_2) emissions from anthropogenic nonpoint (area) sources for July 2022. In many regions, the differences in soil NO emissions between the two models were comparable to, or even exceeded, the anthropogenic nonpoint NO_x emissions in the U.S. Midwest and West. This explains the increases in O_3 concentrations in rural and central U.S. areas (**Figure 4-10**), where the HCHO differences between MEGAN and BEIS showed negative values, as illustrated in **Figure 4-14**. When taking a national perspective, EPA EGU/MEGAN may not be the best option for the Midwest and western U.S. However, the increase in NO was not substantial over the Northeast region. From what is shown in **Figure 4-10**, using the MEGAN biogenic option reduces the model biases significantly in the OTR. This improves the HCHO simulation and is suitable for CMAQ simulations over the Northeast region.

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[46] Kang, D., Willison, J., Sarwar, G., Madden, M., Hogrefe, C., Mathur, R., Gantt, B., and Alfonso, D. S., 2021. Improving the Characterization of the Natural Emissions in CMAQ. *EM Magazine*. Air and Waste Management Association, Pittsburgh, PA, (10):1-7.

[47] Yienger, J. J. and Levy II, H., 1995. Empirical model of global soil-biogenic NOx emissions, *Journal of Geophysical Research: Atmospheres*, 100, 11447–11464, https://doi.org/10.1029/95JD00370.

[48] Hudman, R. C., Moore, N. E., Mebust, A. K., Martin R. V., Russell A. R., Valin L. C., and Cohen R. C., 2012. Steps towards a mechanistic model of global soil nitric oxide emissions: implementation and space based-constraints, *Atmos. Chem. Phys.*, 12, 7779–7795, https://doi.org/10.5194/acp-12-7779-2012.

[49] Kang, D., Willison, J., Sarwar, G., Madden, M., Hogrefe, C., Mathur, R., Gantt, B., and Alfonso, D. S., 2021. Improving the Characterization of the Natural Emissions in CMAQ. *EM Magazine*. Air and Waste Management Association, Pittsburgh, PA, (10):1-7.

[50] Yienger, J. J. and Levy II, H., 1995. Empirical model of global soil-biogenic NOx emissions, *Journal of Geophysical Research: Atmospheres*, 100, 11447–11464, https://doi.org/10.1029/95JD00370.

[51] Kang, D., Willison, J., Sarwar, G., Madden, M., Hogrefe, C., Mathur, R., Gantt, B., and Alfonso, D. S., 2021. Improving the Characterization of the Natural Emissions in CMAQ. *EM Magazine*. Air and Waste Management Association, Pittsburgh, PA, (10):1-7.

Figure 4-16 *Differences in soil NO emissions from agricultural and non-agricultural sources between MEGAN and BEIS in July 2022.*

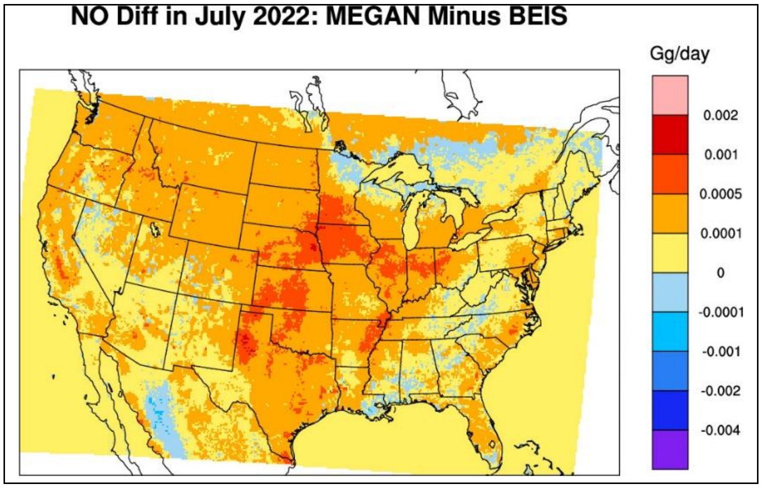
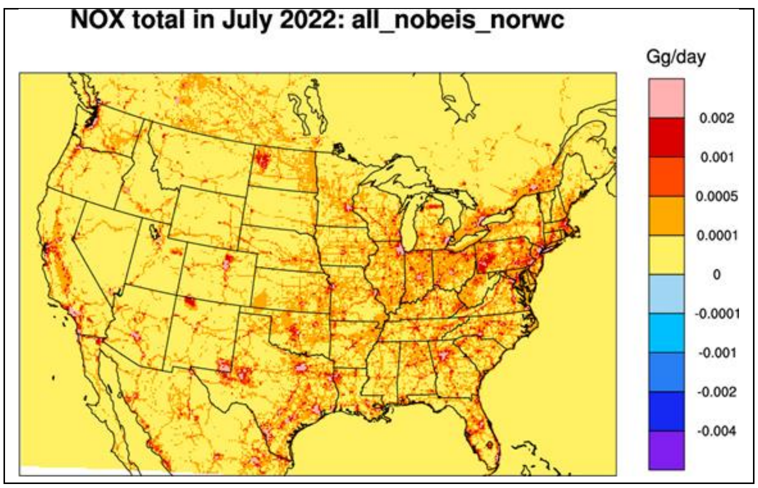


Figure 4-17 *Total NO_x ($NO + NO_2$) emissions from anthropogenic nonpoint (area) sources, excluding Residential Wood Combustion, in July 2022.*



4.4 Production CMAQ Model Simulations Using ERTAC Emissions

Based on the results from Sections 4.2 and 4.3, the H-CMAQ/M3Dry/MEGAN configuration was selected as our setup for modeling with the 2022V1 emissions platform. For the production CMAQ simulations, we replaced emissions from EPA's EGU and nonpoint EGU sectors with corresponding ERTAC emissions (see Section 3). The term ERTAC/MEGAN is used to represent the CMAQ simulations that used ERTAC EGU emissions and were coupled with the MEGAN biogenic emissions model. Final configuration settings for the 2022V1 production run are provided in **Table 2-1**. The model was run for the 2022 annual period. However, as in previous sections, the model performance evaluations were done from April through October. For the analytic year 2026, the model was run covering the period from April to October.

4.4.1 Mean Bias and Mean Error over CONUS and OTR

The spatial distributions of the performance statistics, MB and ME, at each monitoring site across the CONUS and OTR for MDA8 O_3 concentrations greater than or equal to 60 ppb in the production run are shown in **Figure 4-18** and **Figure 4-19**. Overall, the CMAQ run using ERTAC EGU emissions (i.e., ERTAC/MEGAN) continued to underestimate ozone concentrations at most monitoring sites in both the CONUS and OTR on high ozone days, indicating negative biases. However, overestimations were observed in the NY-NJ-CT nonattainment area (NAA) and in the state of Maryland. The spatial patterns and magnitudes of MB and ME values are similar to those from the EPA EGU/MEGAN simulation, as shown in **Figure 4-10** and **Figure 4-11**.

Figure 4-18 *The spatial map of MB in MDA8 O_3 with a threshold of 60 ppb from ERTAC/MEGAN in ozone season over the CONUS and OTR.*

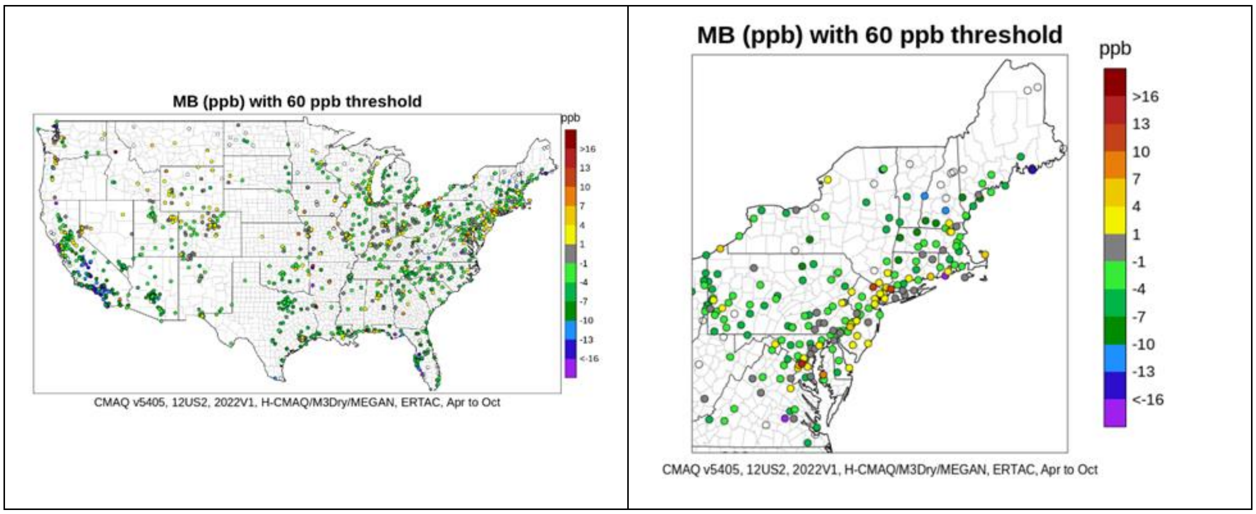
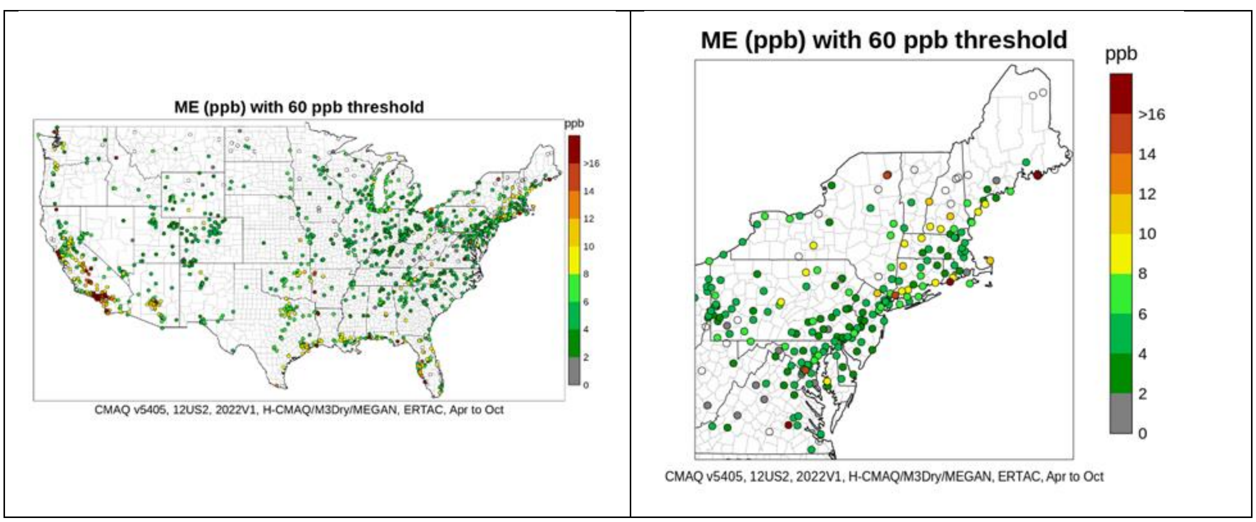


Figure 4-19 *The ME in MDA8 O_3 with a threshold of 60 ppb from ERTAC/MEGAN during the ozone season over the CONUS and OTR.*



4.4.2 Mean Bias and Mean Error for ERTAC simulations across different regions

The Kelly plot showing regional and seasonal MB and ME of MDA8 O_3 greater than or equal to 60 ppb for the April–October period is presented in **Figure 4-20**. The ERTAC/MEGAN simulation produced MB and ME values very similar to those from EPA EGU/MEGAN, as shown in **Figure 4-13**. For the Northeast region, the MB and ME for ERTAC/MEGAN (EPA EGU/MEGAN) were -1.73 ppb (versus -1.57 ppb) and 5.66 ppb (versus 5.61 ppb), respectively, which was a significant improvement in both MB and ME when compared to EPAEGU/BEIS (MB of -6.13 ppb, ME of 7.02 ppb). On average, the model continued to underestimate MDA8 O_3 on high ozone days.

Figure 4-20 *Regional mean bias (MB) and mean error (ME) in MDA8 O_3 with a threshold of 60 ppb from simulations using ERTAC emissions during the ozone season.*

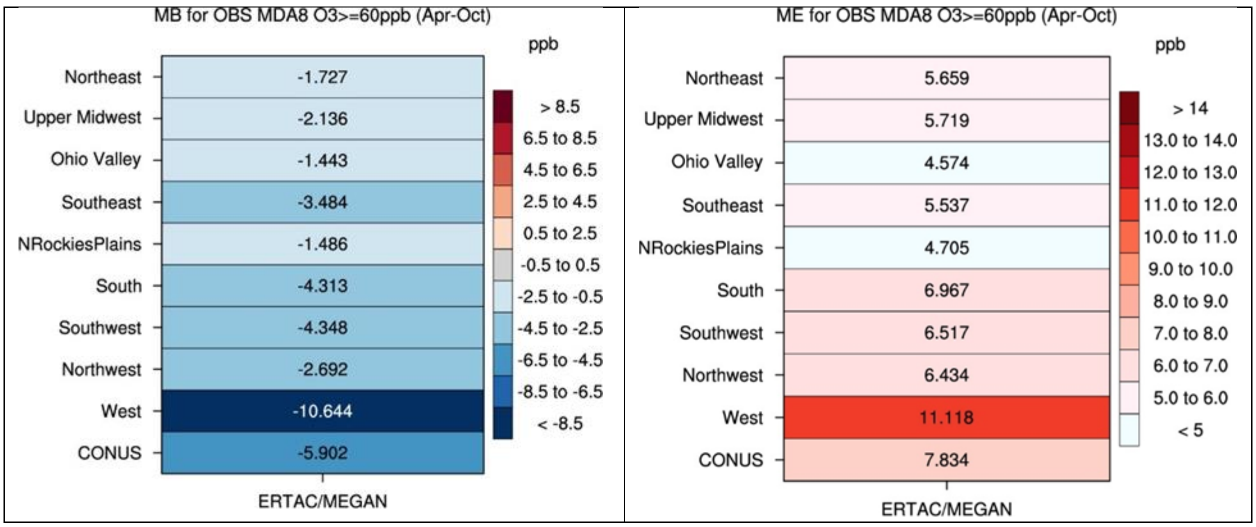


Table 4-6 presents model performance statistics, MB, ME, NMB, and NME, for cases when observed MDA8 O_3 concentrations were greater than or equal to 60 ppb in each OTR NAA, based on the EPA EGU/BEIS and ERTAC/MEGAN model runs for April to October 2022. Results from the EPA EGU/MEGAN configuration are omitted, as they are very similar to those from ERTAC/MEGAN.

Compared to the EPA EGU/BEIS configuration, the ERTAC/MEGAN setup improved model performance across all OTR NAAs. The most significant improvement was observed in the NY-NJ-CT NAA, where MB improved from -7.0 to -0.2 ppb, ME from 8.1 to 6.5 ppb, NMB from -10.6% to -0.2%, and NME from 12.2% to 9.8%.

Table 4-6 *Performance statistics for the CMAQ model (EPAEGU/MEGAN and ERTAC/MEGAN) when Maximum Daily 8-hour Observations are greater than or equal to 60 ppb by OTR Non-Attainment Area (NAA) for April to October 2022.*

		EPA EGU/BEIS				ERTAC/MEGAN			
NAA area	**# of Observations**	**MB**	**ME**	**NMB**	**NME**	**MB**	**ME**	**NMB**	**NME**
CT	67	-7.4	8.1	-11.2	12.3	-2	7.3	-3	11
NY-NJ-CT	430	-7	8.1	-10.6	12.2	-0.2	6.5	-0.2	9.8
PA-NJ-MD-DE	258	-3.7	4.4	-5.8	6.9	-0.4	3.7	-0.7	5.8
MD	109	-3.6	5.2	-5.6	8.2	-1.1	5.2	-1.7	8.2
DC-MD-VA	100	-1.8	4.8	-2.9	7.6	-0.3	5.3	-0.4	8.4

4.4.3 Statistical evaluation of maximum daily 8-hour O_3

Table 4-7 and **Table 4-8** list the number and percentage of monitors across the CONUS and the Northeast that met the recommended *goals* and *criteria* for the ERTAC simulation over the full ozone season. The NMB and NME goals and criteria are described in Section 4.3.3. As with the results discussed in the previous section, ERTAC/MEGAN performed similarly to EPA EGU/MEGAN, but better than EPA EGU/BEIS and successfully met the corresponding NMB and NME *goals* and *criteria*.

Table 4-7 *Numbers (and percentages) of monitoring sites meeting NMB and NME goals and criteria across the CONUS (for Observed MDA8 O_3 ≥ 60 ppb, April–October) using ERTAC emissions and the MEGAN biogenic option (N=1133).*

CONUS	**ERTAC/MEGAN**
NMB goal < ±5%	544 (48%)
NMB criteria < ±15%	1030 (91%)
NME goal < 15%	1016 (90%)
NME criteria < 25%	1115 (98%)

Table 4-8 *Numbers (and percentages) of monitoring sites meeting NMB and NME goals and criteria across the Northeast region (for Observed MDA8 O_3 ≥ 60 ppb, April–October) using ERTAC emissions and the MEGAN biogenic option (N=179).*

Northeast (i.e., region 1, OTR excluding VA)	**ERTAC/MEGAN**
NMB goal < ±5%	100 (56%)
NMB criteria < ±15%	170 (95%)
NME goal < 15%	167 (93%)
NME criteria < 25%	178 (99%)

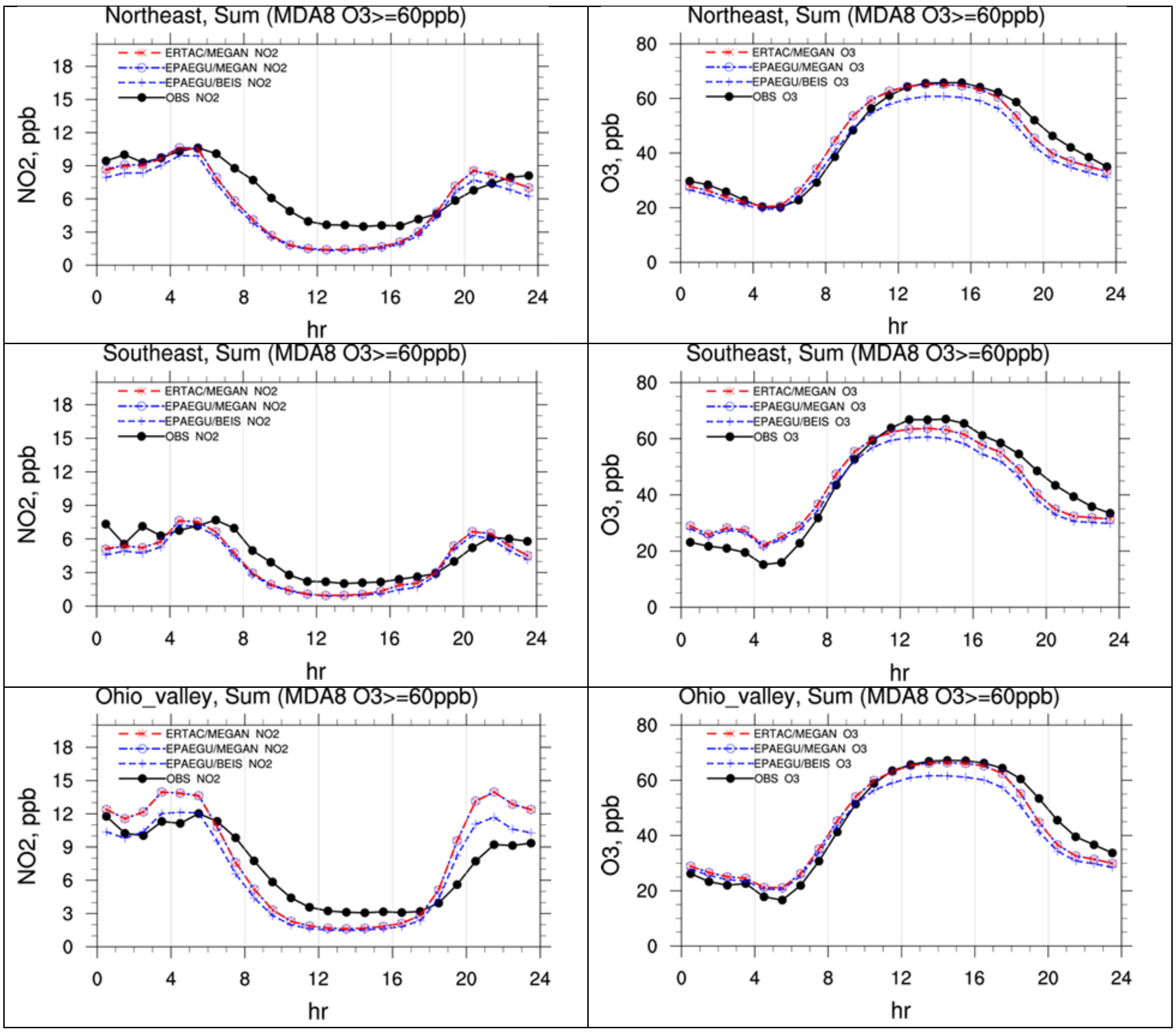
4.4.4 Diurnal O_3 and NO_2 variations for selected regions

There are 293 AQS monitoring sites where O_3 and NO_2 are measured at the same time inside of the model domain. Again, we grouped these sites based on the NOAA Climate Regions map. **Figure 4-21** shows the diurnal variation of O_3 and NO_2 during summer 2022 for three climate regions in the eastern U.S. Three model simulation results are displayed together. They are EPA EGU/BEIS, EPA EGU/MEGAN and ERTAC/MEGAN.

The two simulations using the MEGAN option produced nearly identical results. Modeled daytime NO_2 concentrations were nearly identical among the three models and were lower than observations. At night, modeled NO_2 was either comparable to observations (in the Northeast and Southeast regions) or higher than observed (in the Ohio Valley), with EPA EGU/MEGAN and ERTAC/MEGAN generally producing higher NO_2 than EPA EGU/BEIS.

For O_3, EPA EGU/BEIS consistently underestimated O_3 during the daytime, while EPA EGU/MEGAN and ERTAC/MEGAN significantly improved modeled O_3 concentrations by producing values that more closely matched or were slightly lower than observations throughout the day. However, they were still lower than observed values after 5:00PM.

Figure 4-21 *Mean diurnal cycle of NO_2 (left) and O_3 (right) from observations, EPA EGU/BEIS, EPA EGU/MEGAN and ERTAC/MEGAN simulations for 3 NOAA climate regions in summer (June, July and August) 2022.*



4.4.5 Model evaluations by month and other comparisons

Figure 4-22 shows monthly model performance at monitoring sites in the Northeast NOAA Climate Region, comparing observations (gray), EPA EGU/BEIS results (orange), and ERTAC/MEGAN results (light blue). Overall, the ERTAC/MEGAN configuration consistently estimated higher O_3 concentrations than EPA EGU/BEIS from May through September, while the two configurations produced nearly identical estimates in April and October.

When considering all days, both models overestimated O_3 concentrations in every month. However, on days when observed MDA8 O_3 levels were 60 ppb or higher, both models generally underpredicted O_3 throughout the entire modeling period, except in August, when ERTAC/MEGAN slightly overestimated concentrations. From May to September, ERTAC/MEGAN showed better performance than EPA EGU/BEIS on high ozone days.

Figure 4-22 *Monthly boxplot distributions for all days and days when MDA8 O_3 is greater than or equal to 60 ppb, comparing observations (gray) with model results from EPA EGU/BEIS and ERTAC/MEGAN for monitor sites in the Northeast, April to October 2022.*

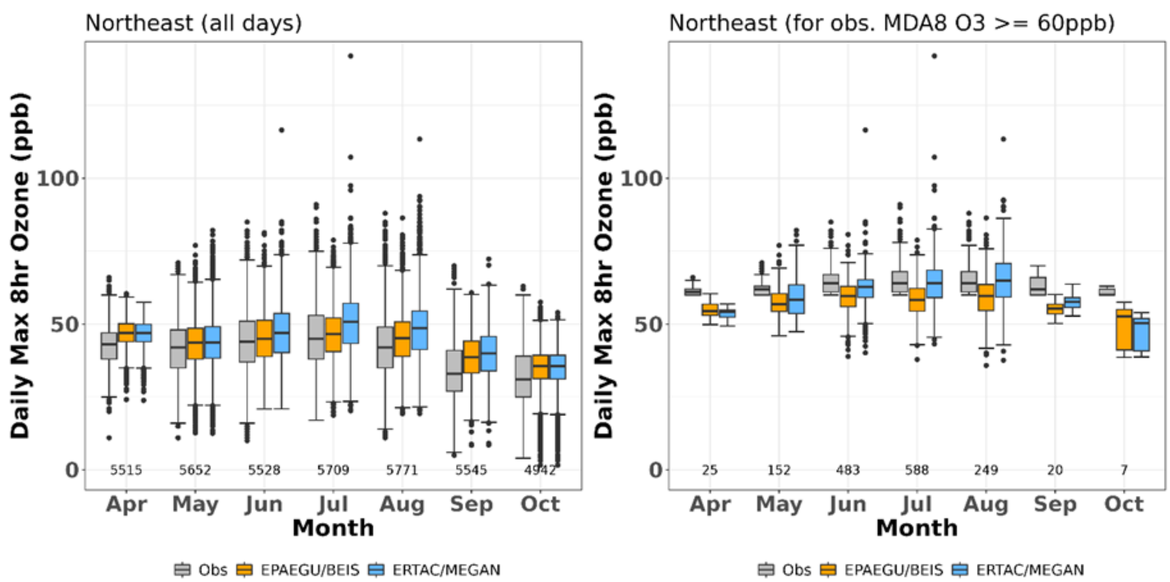
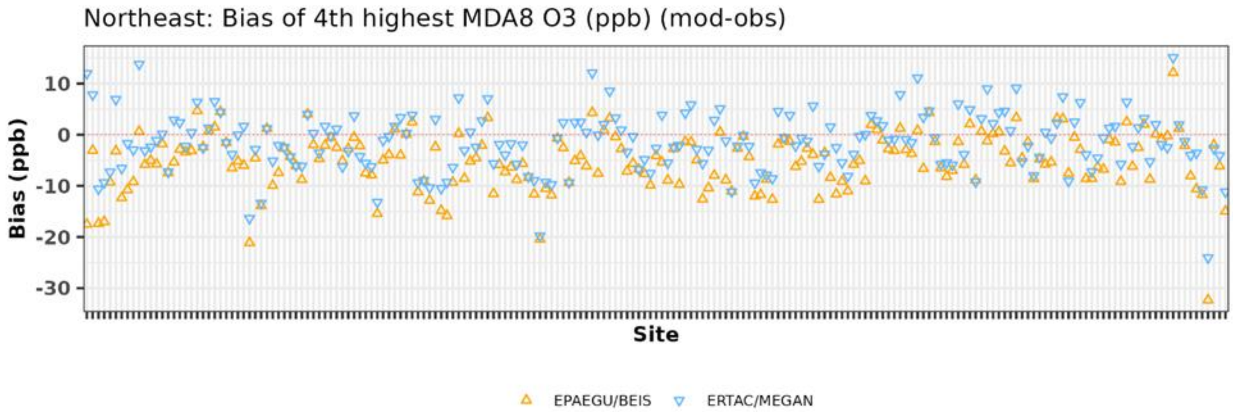


Figure 4-23 shows the bias (modeled minus observed) of the fourth highest observed MDA8 O_3 at each monitoring site in the Northeast NOAA Climate Region. Overall, the ERTAC/MEGAN configuration (blue triangles) predicted higher ozone concentrations than EPA EGU/BEIS (orange triangles) and exhibited a more balanced distribution of positive and negative biases. In contrast, EPA EGU/BEIS showed predominantly negative biases.

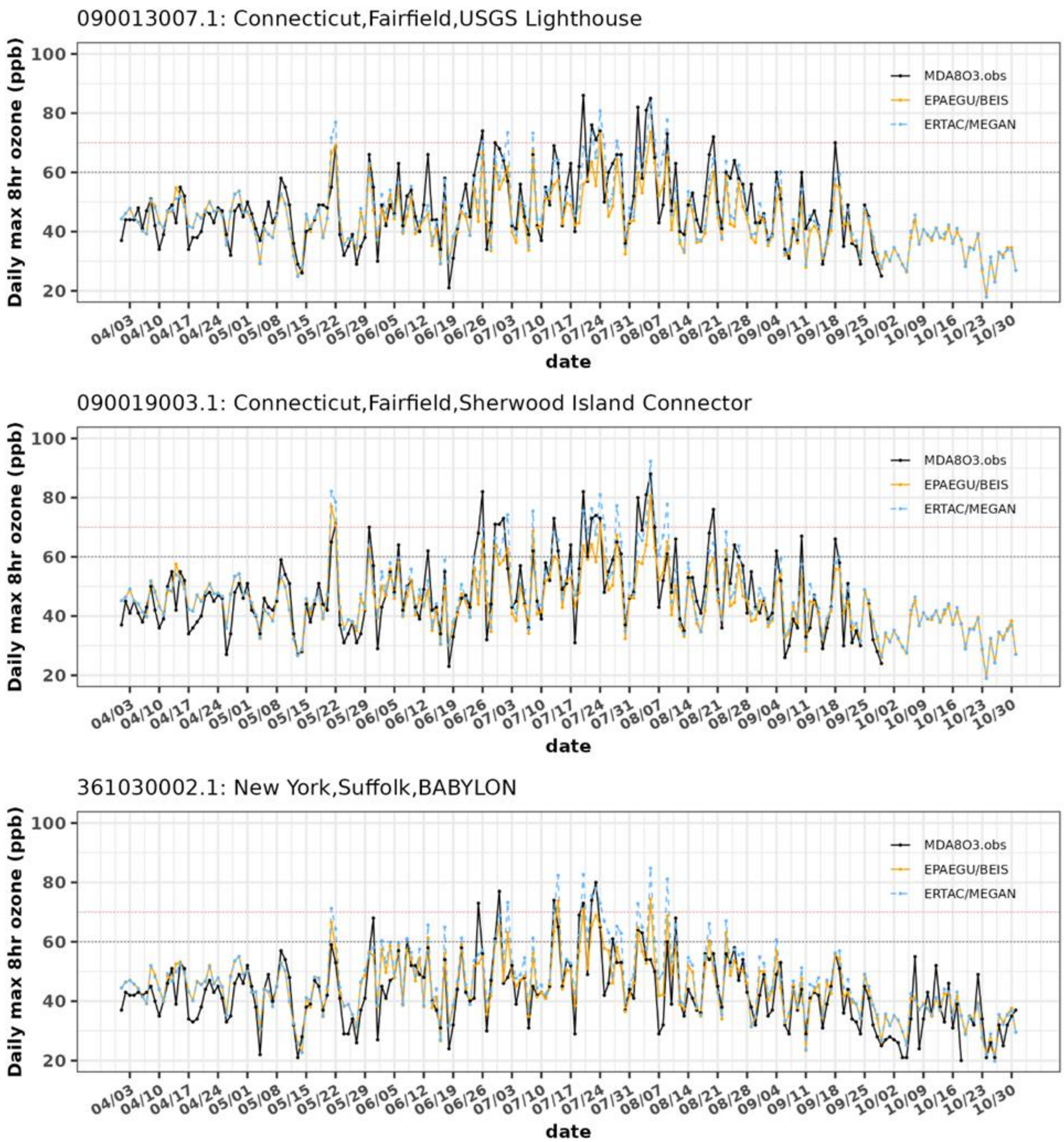
__Figure 4-23__ Bias (modeled minus observed) of the fourth highest MDA8 O_3 for the monitors in the Northeast of NOAA Climate Region (model results from EPA EGU/BEIS and ERTAC/MEGAN).



The performance of the models at selected key nonattainment monitors is evaluated by comparing daily observations with modeled MDA8 O_3 concentrations, as shown in **Figure 4-24**. Both models captured the day-to-day variations in O_3 reasonably well and performed similarly, staying close to observations from April through mid-May and again in October.

The EPA EGU/BEIS model underestimated ozone peaks during most of the vegetation growing season (late May through the end of September) at Stratford and Westport, Connecticut. In contrast, the ERTAC/MEGAN model improved the estimation of O_3 peaks during this period but occasionally overestimated them. At the Babylon site in New York, the EPAEGU/BEIS model more frequently captured ozone peaks, while the ERTAC/MEGAN model tended to overestimate peak concentrations more often.

Figure 4-24 *Time series plot of MDA8 O_3 from April to October 2022 for selected monitors from CMAQ model runs with EPA EGU/BEIS and ERTAC/MEGAN: 090013007 (Stratford, CT), 090019003 (Westport, CT), and 361030002 (Babylon, NY).*



4.4.6 Formaldehyde validation at two individual monitoring sites

Hourly HCHO measurements were collected in 2022 at two sites in New York: the New York Botanical Garden (NYBG) in the Bronx and Flax Pond on Long Island.[52] The measurements were obtained using Picarro cavity ring-down spectroscopy instruments (model G2307). Observed hourly HCHO concentrations were compared with simulations from 3 model runs (i.e., EPA EGU/BEIS, EPA EGU/MEGAN and ERTAC/MEGAN). **Figure 4-25** shows the locations of the two monitoring sites.

Figure 4-25 *Locations of the two monitoring sites in the New York City Area.*

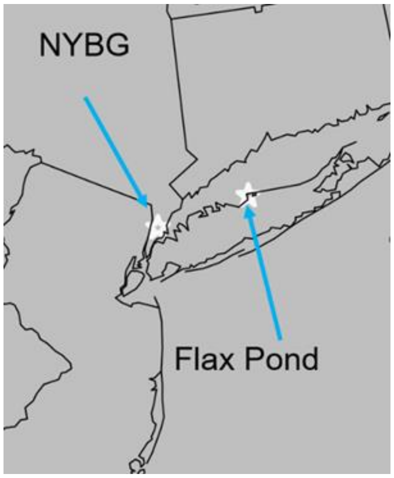


Figure 4-26 shows the monthly mean HCHO concentrations from April to October, based on observations and three model simulations. All three simulations underestimated surface HCHO concentrations in all seven months, with the largest underestimations occurring in July and August. Results from EPA EGU/MEGAN and ERTAC/MEGAN are almost identical. The simulations with MEGAN option improved HCHO modeling at both sites from June to September and performed similarly to those with BEIS option during the other months. The two biogenic options show notable differences during the peak vegetation growing season and similar behavior during the rest of the period.

Using 2023 projected emission from EPA 2016v2/v3 emission platform, Rattigan et al. (2025)[53] found that CMAQ coupled with BEIS underestimated HCHO over these two sites in 2023 as well. Other recent studies also reported that CMAQ underestimated surface HCHO in other

[52] Rattigan, O. V., Furdyna, P., Hirsch, M., Teora, A. C., Felton, H. D., Tian, R. Y., Ninneman, M. A., Hao, W., 2025. Useful hourly measurements of formaldehyde at PAMS sites in New York, *Atmospheric Pollution Research*, 16, 102568, https://doi.org/10.1016/j.apr.2025.102568.

[53] Ibid.

monitoring sites.[54,55] These results highlight the critical role of the biogenic emission scheme in simulating HCHO.

Figure 4-26 *Mean HCHO concentration as a function of month from observations and from EPAEGU/BEIS, EPAEGU/MEGAN and ERTAC/MEGAN simulations. The error bars represent the 95% confidence intervals.*

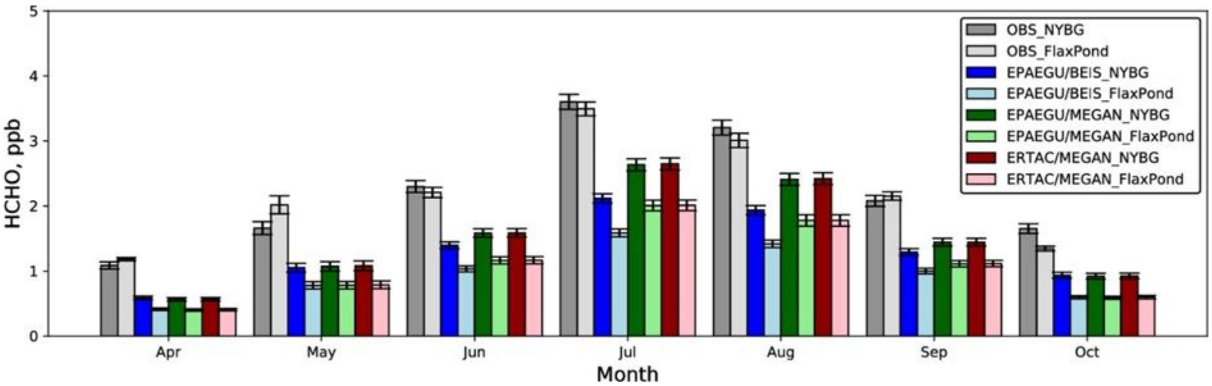
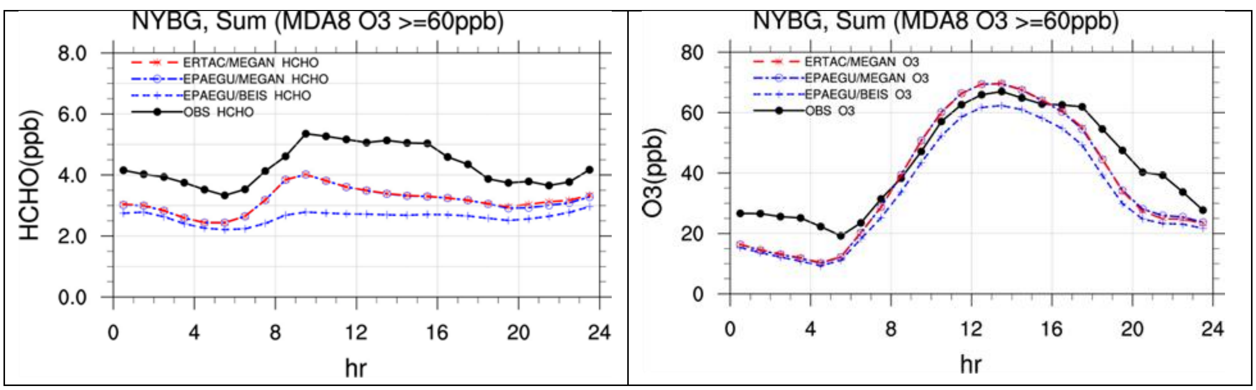


Figure 4-27 and **Figure 4-28** show the mean diurnal cycles of HCHO and O_3 during June, July, and August 2022 at the NYBG and Flax Pond sites. CMAQ with both EGU and ERTAC using the MEGAN option improved the simulations of both HCHO and O_3 compared to those using the BEIS option, particularly in capturing the HCHO diurnal patterns. However, HCHO concentrations remained significantly underestimated throughout the day. In general, all simulations showed better performance for O_3 than for HCHO. Despite the improvements from the MEGAN option, O_3 concentrations were still underestimated after 5:00PM.

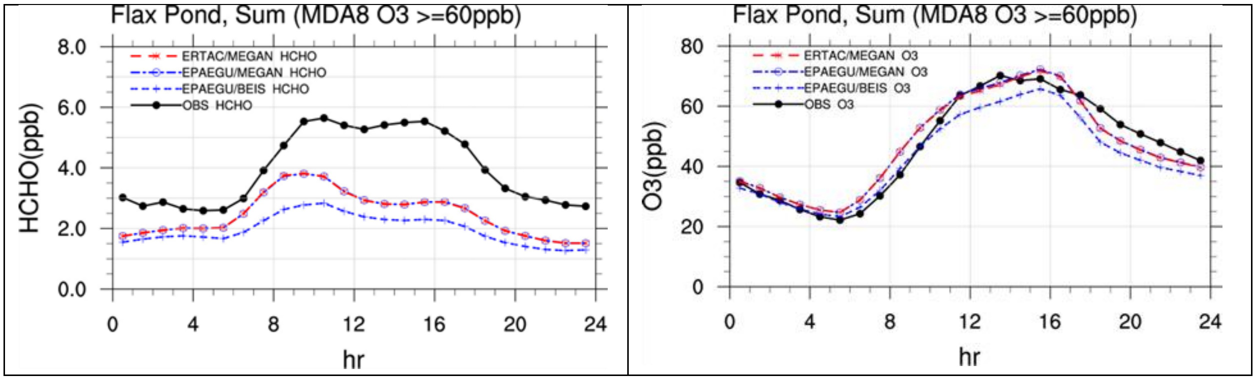
Figure 4-27 *Mean diurnal cycle of HCHO and O_3 in summer 2022 at the NYBG site.*



[54] Skipper, T. N., D'Ambro, E. L., Wiser, F. C., McNeill, V. F., Schwantes, R. H., Henderson, B. A., Piletic, I. R., Baublitz, C. B., Bash, J. O., Whitehill, A. R., Valin, L. C., Mouat, A. P., Kaiser, J., Wolfe, G. M., St Clair, J. M., Hanisco, T. F., Fried, A., Place, B. K., and Pye, H. O. T., 2024. Role of chemical production and depositional losses on formaldehyde in the Community Regional Atmospheric Chemistry Multiphase Mechanism (CRACMM), *Atmos. Chem. Phys.*, 24, 12903–12924, https://doi.org/10.5194/acp-24-12903-2024.

[55] Tao, M., Fiore, A. M., Karambelas, A., Miller, P. J., Valin, L. C., Judd, L. M., Tzortziou, M., Whitehill, A., Teora, A., Tian, Y. and Civerolo, K. L., 2025. Insights into summertime surface ozone formation from diurnal variations in formaldehyde and nitrogen dioxide along a transect through New York City, *Journal of Geophysical Research: Atmospheres*, 130, e2024JD040922. https://doi.org/10.1029/2024JD040922.

Figure 4-28 *Mean diurnal cycle of HCHO and O_3 in summer 2022 at the Flax Pond site.*



4.4.7 Comparison of column NO_2 and HCHO with TROPOMI data

It is well known that tropospheric O_3 formation is controlled by the relative abundance of NO_x and VOCs. In relatively low-NO_x environments, ozone formation is generally limited by the availability of NO_x ("NO_x-limited"). In contrast, ozone formation in urban areas, where NO_x emissions are typically high, is often considered "VOC-limited" or in a transitional regime. Recent studies have demonstrated the utility of satellite-based retrievals of column NO_2 (as a proxy for total NO_x), column HCHO (as a proxy for total VOCs), and the HCHO/ NO_2 ratio for examining spatial patterns of ground-level ozone formation chemistry.[56,57] Comparing similar modeled values from CMAQ simulations serves as a form of dynamic model evaluation, allowing a qualitative assessment of each model's ability to predict O_3 chemical regimes across the OTR and beyond.

For this study, we obtained NO_2 and HCHO retrievals from the TROPOspheric Monitoring Instrument (TROPOMI) aboard the Sentinel-5 Precursor satellite.[58] Daily column amounts of NO_2 and HCHO are available, with an overpass time of approximately 13:30 local time. The horizontal resolution is about 3.5 km × 7 km at the beginning of the mission, improving to 3.5 km × 5.5 km since August 6, 2019. Aggregated 0.05-degree data were provided to the OTC modeling group by a research group at MIT (personal communication).

Because TROPOMI data can be noisy and are often limited by cloud cover, we computed monthly averages to reduce day-to-day variability. To compare with satellite retrievals, we used the "vertintegral" program (https://www.cmascenter.org) to calculate vertical column integrals over all 35 CMAQ model layers.

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[56] Jin, X., Fiore, A., Boersma, K. F., De Smedt, I., and Valin, L., 2020. Inferring Changes in Summertime Surface Ozone–NOx –VOC Chemistry over U.S. Urban Areas from Two Decades of Satellite and Ground-Based Observations, *Environmental Science & Technology*, 54, 6518–6529 https://doi.org/10.1021/acs.est.9b07785.
[57] Tao, M., Fiore, A. M., Karambelas, A., Miller, P. J., Valin, L. C., Judd, L. M., Tzortziou, M., Whitehill, A., Teora, A., Tian, Y. and Civerolo, K. L., 2025. Insights into summertime surface ozone formation from diurnal variations in formaldehyde and nitrogen dioxide along a transect through New York City, *Journal of Geophysical Research: Atmospheres*, 130, e2024JD040922. https://doi.org/10.1029/2024JD040922.
[58] TROPOMI, https://www.tropomi.eu/.

Sections 4.4.3 to 4.4.6 demonstrated that model performance statistics from EPA EGU/MEGAN and ERTAC/MEGAN are almost identical. To be concise in this TSD, we omit the figures from EPA EGU/MEGAN in this section. **Figure 4-29** and **Figure 4-30** show the July 2022 average NO_2 column concentrations from TROPOMI, EPA EGU/BEIS, and ERTAC/MEGAN, both domain-wide and for the Northeast region. For this month, EPA EGU/BEIS tended to underpredict NO_2 in rural areas in the eastern portion of the domain and predicted comparable or slightly lower concentrations in most urban areas. On average, ERTAC/MEGAN predicted higher NO_2 concentrations than EPAEGU/BEIS and overestimated NO_2 compared to TROPOMI, particularly across much of the area west of Chicago.

The differences in soil NO emissions between MEGAN and BEIS, as discussed previously in section 4.3.4, likely contributed to the NO_2 column differences observed in central U.S. regions. In the northeastern portion of the domain, both models underestimated NO_2 in rural areas of Connecticut, Massachusetts, New Jersey, New York, and Pennsylvania.

Figure 4-29 *July 2022 column NO_2 from TROPOMI, EPAEGU/BEIS and ERTAC/MEGAN over CONUS*.

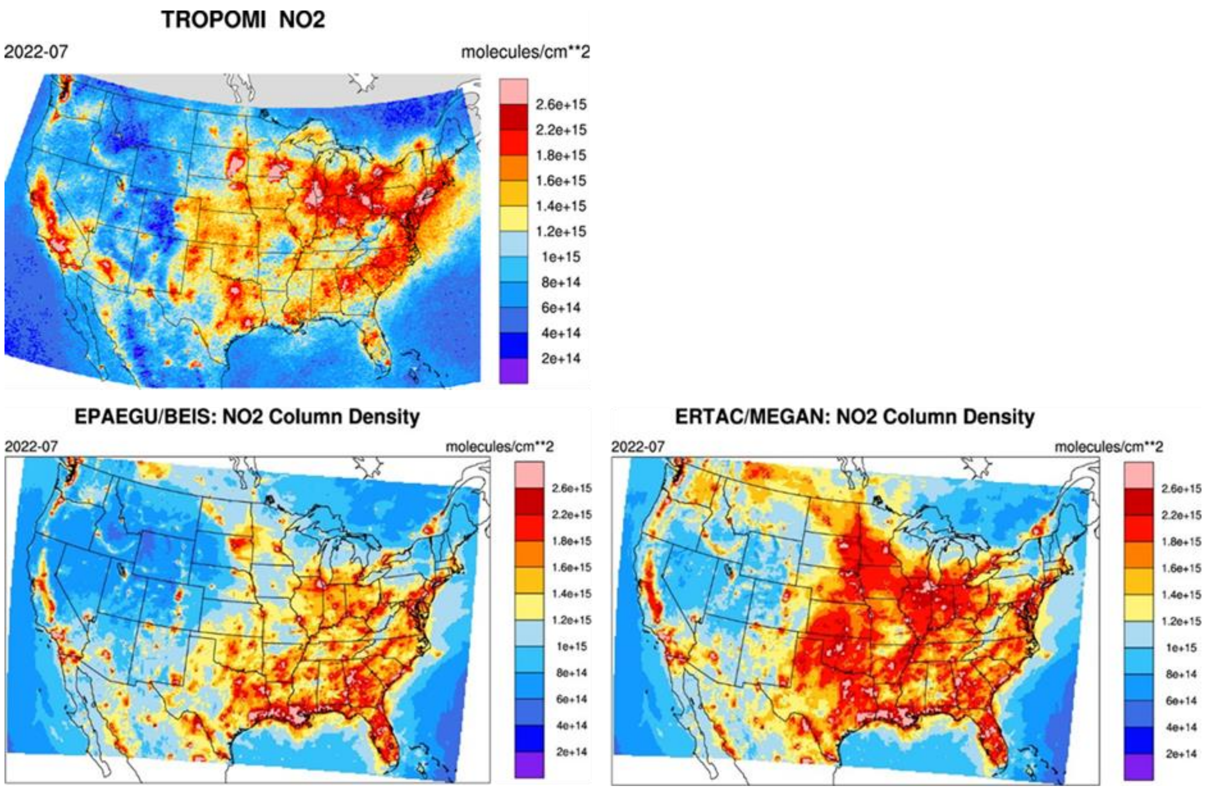


***Figure 4-30** July 2022 column NO_2 from TROPOMI, EPAEGU/BEIS and ERTAC/MEGAN over the Northeast region.*

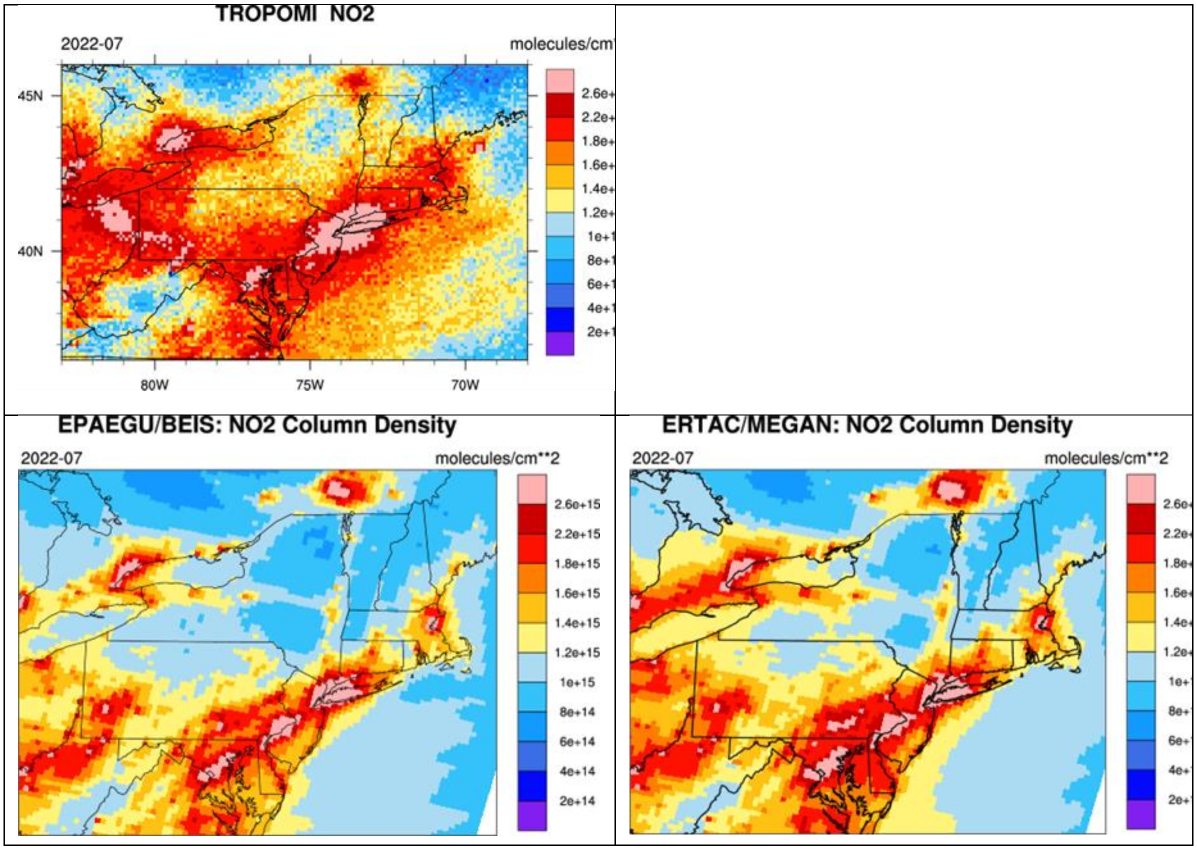


Figure 4-31 displays the July 2022 average NO_2 column concentrations over the New York metropolitan area, using an adjusted legend to emphasize high-NO_2 regions. It is evident that EPA EGU/BEIS and ERTAC/MEGAN underestimated NO_2 in suburban areas, while capturing similar magnitudes to TROPOMI in the urban core. However, the location of the NO_2 maximum appeared slightly misaligned between the model and satellite observations, particularly in the northern parts of the city.

Figure 4-31 *July 2022 column NO_2 from TROPOMI, EPAEGU/BEIS and ERTAC/MEGAN over the New York City area.*

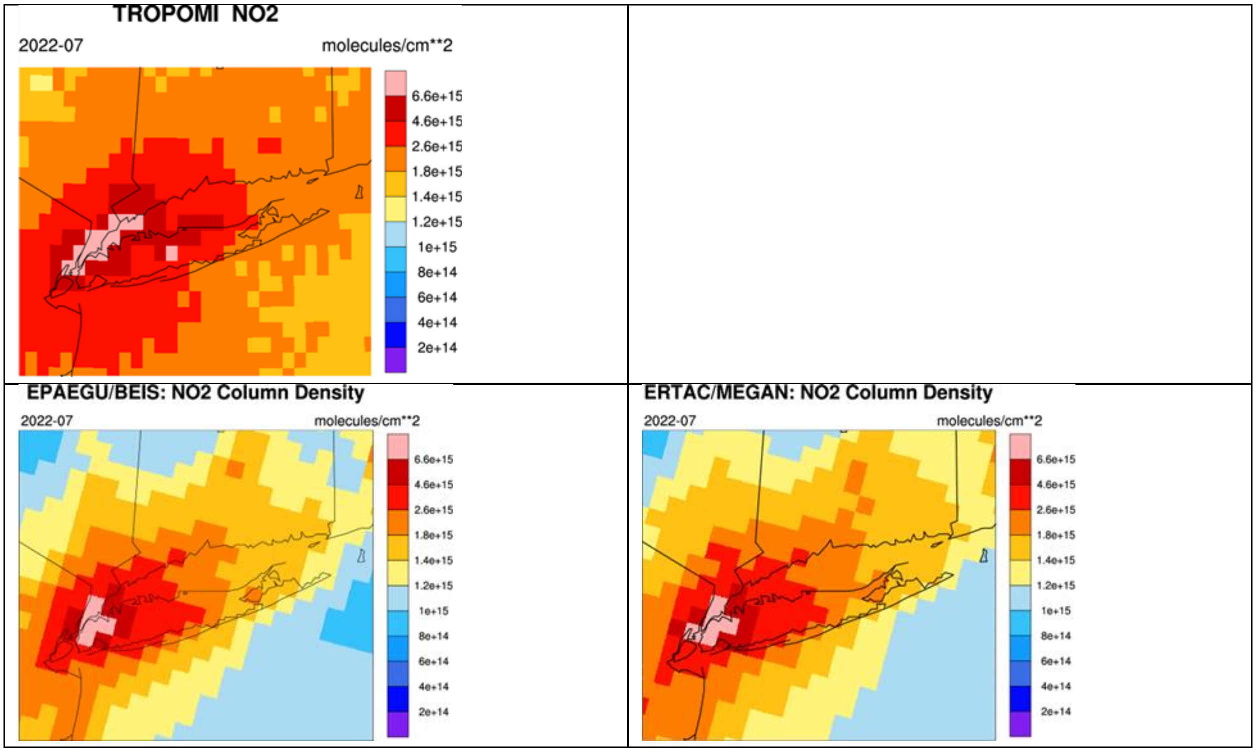


Figure 4-32 and **Figure 4-33** show the July 2022 average HCHO column concentrations from TROPOMI, EPA EGU/BEIS, and ERTAC/MEGAN. Both model configurations qualitatively reproduced the general spatial pattern observed in the satellite data, with higher HCHO concentrations in the South and Southeast, and lower concentrations at northern latitudes. These spatial patterns are consistent with the results reported by Skipper et al. (2024).[59]

Overall, EPA EGU/BEIS predicted lower HCHO concentrations than ERTAC/MEGAN, particularly across the South and Southeast regions. In the Northeast, both models underestimated HCHO in the New York–New Jersey–Connecticut ozone nonattainment area (NY-NJ-CT O_3 NAA), though ERTAC/MEGAN showed better agreement with observations. Along the I-95 corridor, ERTAC/MEGAN produced higher HCHO concentrations than EPAEGU/BEIS, more closely matching the TROPOMI retrievals.

[59] Skipper, T. N., D'Ambro, E. L., Wiser, F. C., McNeill, V. F., Schwantes, R. H., Henderson, B. A., Piletic, I. R., Baublitz, C. B., Bash, J. O., Whitehill, A. R., Valin, L. C., Mouat, A. P., Kaiser, J., Wolfe, G. M., St Clair, J. M., Hanisco, T. F., Fried, A., Place, B. K., and Pye, H. O. T., 2024. Role of chemical production and depositional losses on formaldehyde in the Community Regional Atmospheric Chemistry Multiphase Mechanism (CRACMM), *Atmos. Chem. Phys.*, 24, 12903–12924, https://doi.org/10.5194/acp-24-12903-2024.

Figure 4-32 *July 2022 column HCHO from TROPOMI, EPAEGU/BEIS and ERTAC/MEGAN over CONUS.*

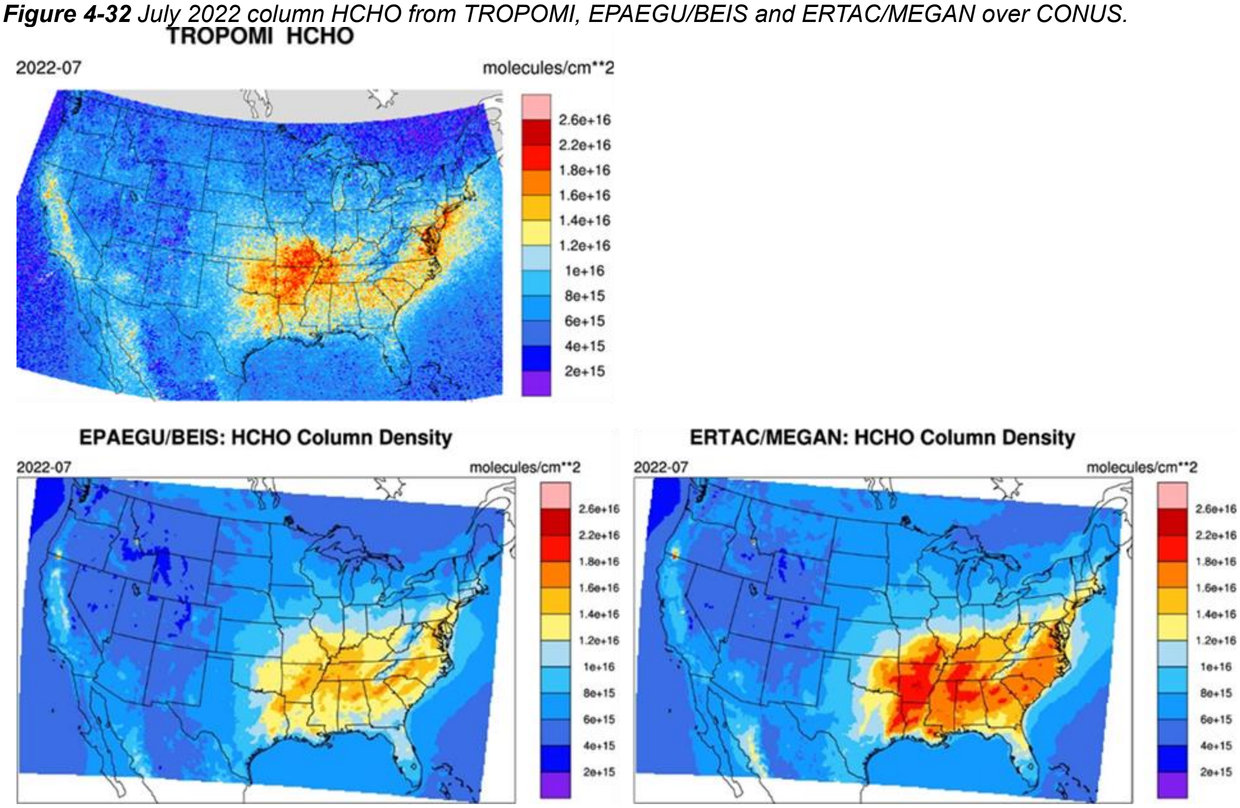


Figure 4-33 *July 2022 column HCHO from TROPOMI, EPA EGU/BEIS and ERTAC/MEGAN over the Northeast region.*

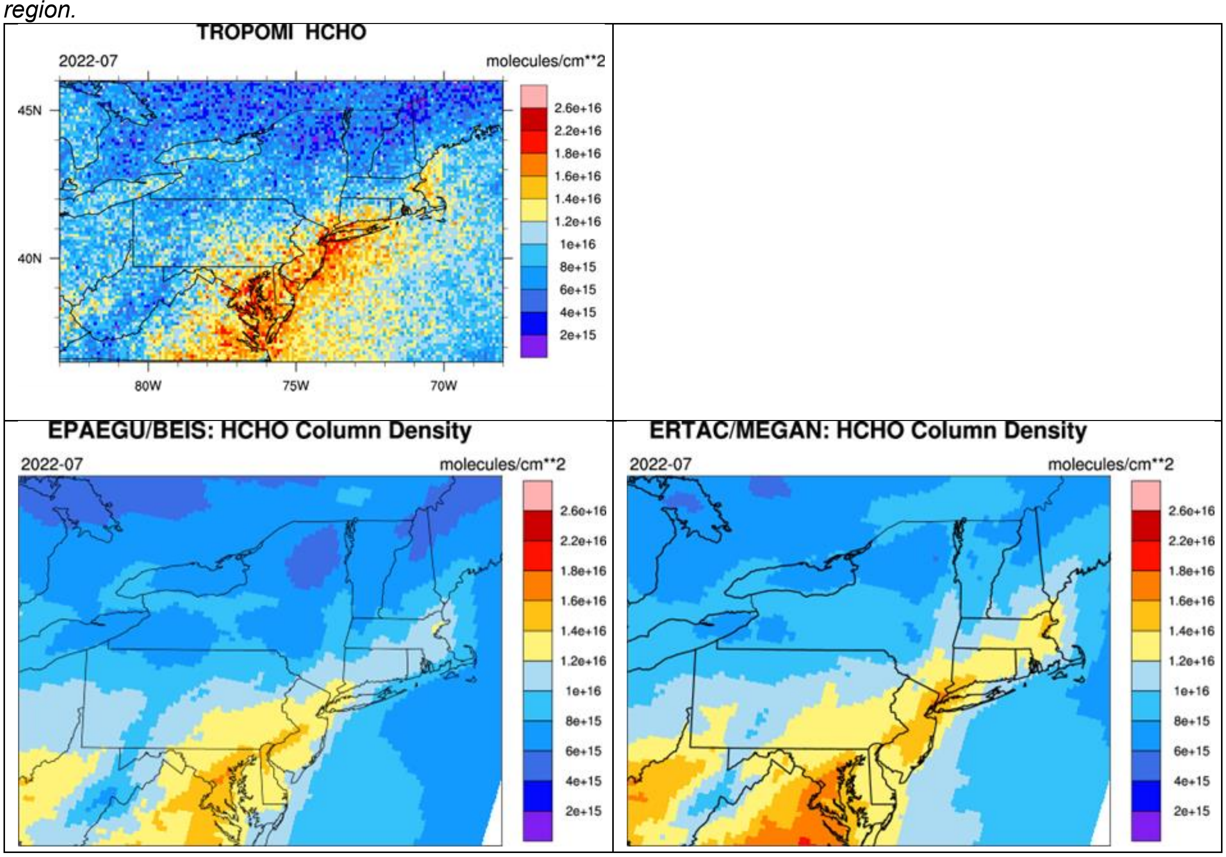
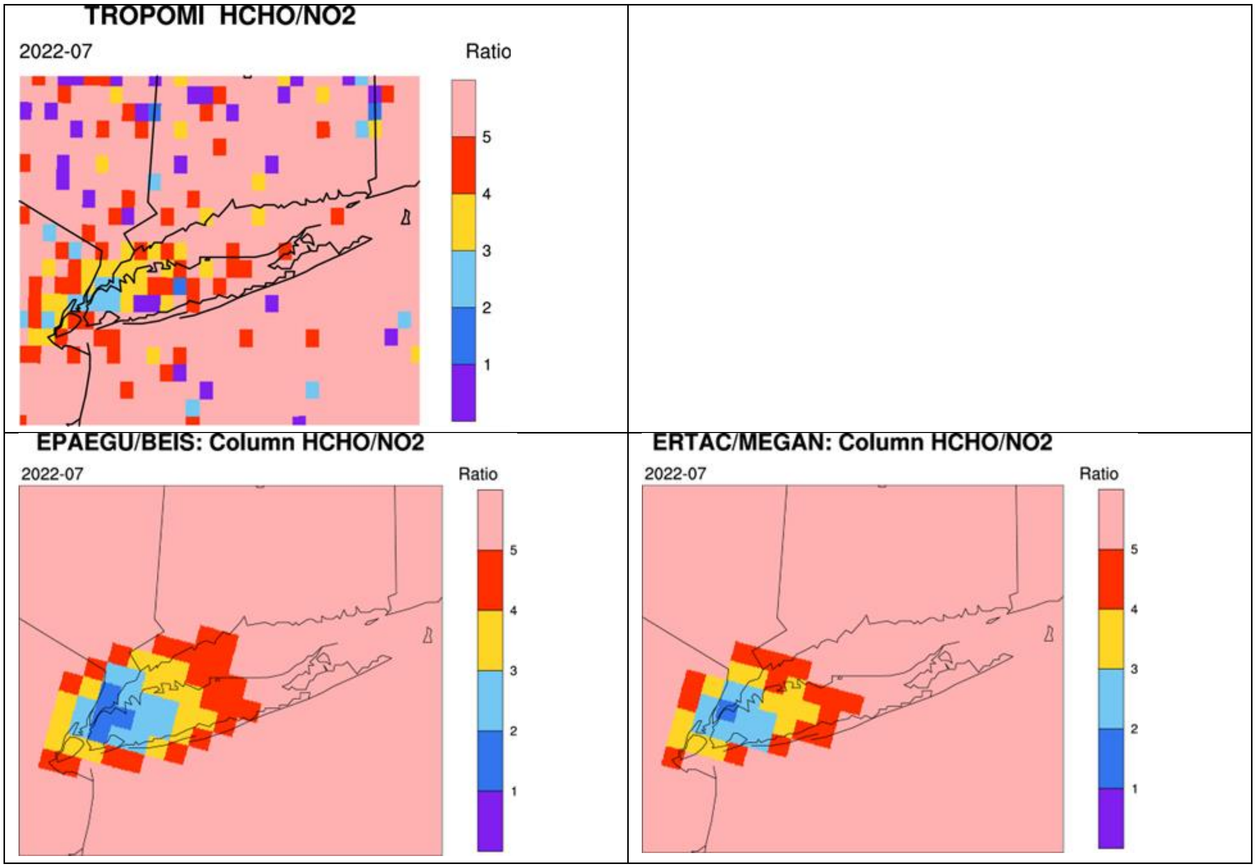


Figure 4-34 shows the July 2022 $HCHO/NO_2$ ratios (formaldehyde-to-NO_2 ratio, or FNR) from TROPOMI, EPA EGU/BEIS, and ERTAC/MEGAN, focusing on the New York City (NYC) urban corridor. Higher FNR values are indicative of NO_x-limited conditions, while lower values suggest VOC-limited conditions. According to Jin et al. (2020),[60] the NYC region is considered to be in a transitional chemical regime when the column FNR falls between 3.3 and 4.2. In this study, we adopted thresholds of FNR < 3 to define VOC-sensitive regimes and FNR > 4 to define NO_x-sensitive regimes, with a particular focus on NYC and its surrounding areas.

Both models qualitatively reproduced the observed NO_x-limited conditions in rural areas. However, they tended to predict slightly larger VOC-limited areas in the urban core compared to satellite observations. This discrepancy is likely due to the models' underestimation of HCHO across much of the NYC area, which results in a lower FNR and thus led the modeled regime toward more VOC-limited conditions.

[60] Jin, X., Fiore, A., Boersma, K. F., De Smedt, I., and Valin, L., 2020. Inferring Changes in Summertime Surface Ozone–NOx –VOC Chemistry over U.S. Urban Areas from Two Decades of Satellite and Ground-Based Observations, *Environmental Science & Technology*, 54, 6518–6529 https://doi.org/10.1021/acs.est.9b07785.

Figure 4-34 *July 2022 HCHO/NO_2 ratio from TROPOMI, EPAEGU/BEIS and ERTAC/MEGAN over New York City area.*



4.5 Summary of Final Model Configuration Option for OTC Modeling

Regional modeling with the 2022v1 emissions platform using CMAQ and EPA's EGU emissions was evaluated under different boundary conditions, dry deposition schemes, and biogenic emission models. Among the boundary condition and dry deposition comparisons, the H-CMAQ boundary condition with M3Dry deposition configuration produced the best model performance on high ozone days over the eastern U.S. The differences between the M3Dry and STAGE dry deposition schemes were smaller than the differences observed between the H-CMAQ and GEOS-Chem boundary conditions.

For the biogenic emissions comparison, MEGAN predicted higher isoprene emissions than BEIS in New York City and most of the Northeast, resulting in higher modeled surface concentrations of both HCHO and isoprene. Additionally, the BDSNP option in MEGAN produced more soil NO compared to the Yienger and Levy (1995)[61] method used in BEIS. As a result, the MEGAN option substantially reduced the underestimation of O_3 across the modeling domain on high ozone days relative to CMAQ modeling with the BEIS option.

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[61] Yienger, J. J. and Levy II, H., 1995. Empirical model of global soil-biogenic NOx emissions, *Journal of Geophysical Research: Atmospheres*, 100, 11447–11464, https://doi.org/10.1029/95JD00370.

Based on these findings, the H-CMAQ/M3Dry/MEGAN configuration was selected for our production runs for modeling with the 2022v1 emissions platform. CMAQ simulations using this configuration, whether with EPA’s EGU emissions or ERTAC’s EGU emissions, demonstrated very similar performance and successfully met the corresponding NMB and NME goals and criteria for high O_3 days.

Section 5: Modeled Projected Ozone Design Values for 2026

Air quality models such as CMAQ are used to simulate base year and future analytic year air quality. Model estimates are used in a “relative” rather than “absolute” sense to estimate analytic year design values. That is, one calculates the ratio of the model’s future to current “baseline” predictions at ozone monitors. The ratios are then multiplied by observed “baseline” ozone design values to project ozone design values for analytic years, also referred to as future ozone design values or DVFs.

The OTC used the 2026 analytic year from the 2022V1 platform to estimate ozone design values. First, we compare the average of the top five to ten highest MDA8 O_3 concentrations in the base year and paired MDA8 O_3 concentrations in the 2026 analytic year in Section 5.1. In Section 5.2, we describe the methodology for calculating projected design values and present the projected design values for 2026 for selected monitoring sites. Projected design values for all of the monitoring sites in the OTR are presented in Appendix D.

5.1 Average of the top five to ten highest MDA8 O_3

Figure 5-1 illustrates the average of the top five to ten highest MDA8 O_3 (greater than or equal to 60 ppb) in the base year (left) and paired MDA8 O_3 in the analytic year (right) in each grid cell for the 2022V1 platforms. The top ten highest MDA8 O_3 concentrations greater than or equal to 60 ppb in a grid cell for the base year are selected and averaged. If the number of the highest MDA8 O_3 concentrations of 60 ppb or greater is between five and ten days in a grid cell, those five to ten days are selected and averaged. However, if there are fewer than five days when MDA8 O_3 concentrations of 60 ppb or greater are in a grid cell, the average is not calculated and thus shown in white color in **Figure 5-1**. The days are chosen based on the base year model outputs and paired with the days from the future year model outputs.

The ratio of the modeled future analytic year to base year MDA8 O_3 averages is the relative response ratio or Relative Response Factor (RRF). **Figure 5-2** shows the relative response ratios for the grid cells identified in **Figure 5-1** as having five to ten days of MDA8 O_3 concentrations greater than or equal to 60 ppb. If there were fewer than five days of MDA8 O_3 concentrations of 60 ppb or greater in a grid cell, the ratios were not calculated and thus shown in white color in **Figure 5-2**. Using the 2022V1 platform, ratios were calculated across much of the I-95 urban corridor and large parts of western Pennsylvania in the OTR. High ratios throughout the region indicate ozone concentrations remained elevated in the 2026 analytic year. A comparison of the 2026 analytic year DVFs from the 2016 V2/V3 and 2022V1 platforms is provided in Appendix E.

Figure 5-1 *Average of the top five to ten MDA8 O_3 in the base year (left) and paired MDA8 O_3 in the analytic year (right) for the 2022/2026 V1 platform.*

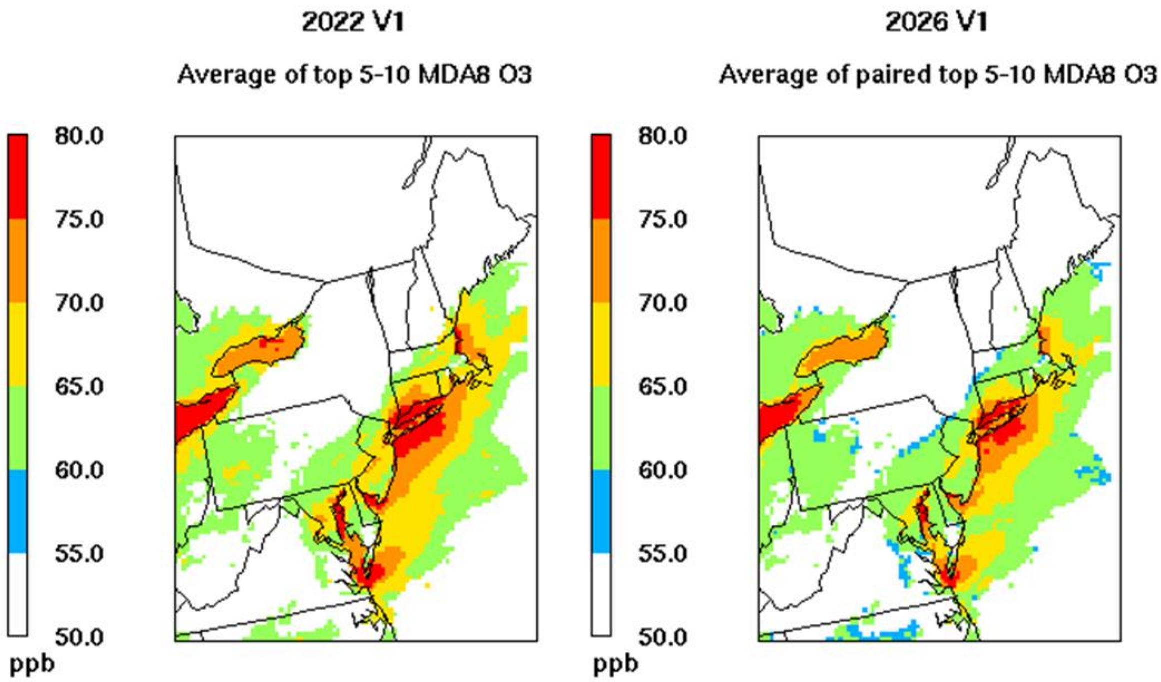
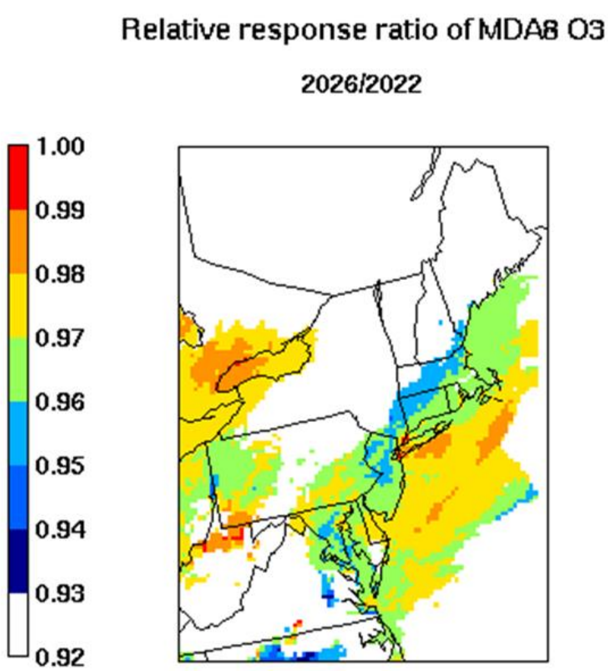


Figure 5-2 *Relative response ratio of the top five to ten MDA8 O_3 in the 2022/2026 V1 platform.*



5.2 Relative Response Factor and Projected Ozone Design Values

For each existing monitoring site, the future analytic year ozone design value is estimated by multiplying the RRF at the location by the observation-based monitor-specific "baseline" ozone design value. The projected future ozone design values are compared to the relevant ozone NAAQS to predict whether attainment will be reached or not.

Equation 5-1 describes the approach as applied to a monitoring site *i*:

$$DVFi = RRFi * DVBi$$ **Equation 5-1**

DVF*i* is the projected future design value (in ppb) at monitoring site i; RRF*i* is the relative response factor calculated at monitoring site *i*; and DVB*i* is the observation-based "baseline" design value (in ppb) at monitoring site *i*.

Ozone predictions from the 2022 (base year) and 2026 (analytic year) CMAQ model simulations were used to calculate projected average and maximum MDA8 O_3 DVFs for 2026. This section describes the procedures for calculating projected 2026 design values following the EPA's guidance.[62,63,64,65]

To discount inaccuracies due to individual grid characteristics, EPA recommends an approach to calculating the *DVFi* that considers model values from the 3x3 array of grid cells centered on the grid where the monitor is located. When one or more grid cells in the 3x3 array occur over a body of water, conditions of overlaying land-based emissions with overwater meteorology at those coastal monitors often cause difficulty in modeling O_3.[66] A water cell is a grid cell where more than 50% of the area is water, as classified by the WRF.

Grid cell characteristics, such as land use, can have a significant effect on modeled ozone concentrations. The maximum values in the 3x3 grid tend to occur in grid cells over water. In these water cells, O3 overpredictions are likely to be more pronounced due to differences in vertical mixing and winds at the land-water interface coupled with land-based emissions allocated to the cell. To reduce the bias, we eliminate or minimize water grids in the RRF

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[62] US EPA, 2018. "Modeling Guidance for Demonstrating Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze," EPA-454/R-18-009, accessed at https://www.epa.gov/sites/default/files/2020-10/documents/o3-pm-rh-modeling_guidance-2018.pdf.

[63] US EPA, 2018. "Air Quality Modeling Technical Support Document for the Updated 2023 Projected Ozone Design Values," accessed at https://www.epa.gov/sites/default/files/2018-06/documents/aq_modelingtsd_updated_2023_modeling_o3_dvs.pdf.

[64] US EPA, 2021. "Air Quality Modeling Technical Support Document for the Final Revised Cross-State Air Pollution Rule Update," accessed at https://www.epa.gov/sites/default/files/2021-03/documents/air_quality_modeling_tsd_final_revised_csapr_update.pdf.

[65] US EPA, 2022. "Air Quality Modeling for the 2016v2 Emissions Platform Technical Support Document," accessed at https://gaftp.epa.gov/aqmg/2016v2_Platform_Modeling_Data/AQ%20Modeling%20TSD_2016v2%20Platform_rev_2022_0119a.pdf.

[66] Ozone Transport Commission, 2023. "Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union 2016 Based Modeling Platform Support Document, Ozone Transport Commission 1st Version," accessed at https://otcair.org/upload/Documents/Reports/2016TSD_January2023_withAppendices.pdf.

calculation following EPA's guidance. The impact of water grids in the RRF calculation was also discussed in our previous 2016 Based Modeling Platform Support Document.[67]

5.2.1 Calculation of Projected Ozone Design Values

RRFs were calculated using two methods: the EPA's standard 3x3 and modified 3x3 (i.e., 3x3 No Water) methodologies. A modified 3x3 method eliminates the grid cells that are classified as water cells from a 3x3 grid cell array centered on the grid cell containing the monitoring site. However, if the monitoring site is located in a water cell, this method includes that water cell in the RRF calculation.

The following steps describe the calculation of each of the elements in **Equation 5-1** as implemented by the New York State Department of Environmental Conservation (NYSDEC) through its in-house computer program. All calculations are performed on a monitor-by-monitor basis.

Step 1 - Calculation of DVB

Design values for monitored data are calculated following 40 CFR Part 50 Appendix U (2015 NAAQS) and are based on MDA8 O_3 concentrations at each monitoring site. Design values are the average of three consecutive fourth-highest annual MDA8 O_3 concentrations at each monitoring site. Monitored design values are labeled with the most recent year of data used in the design value calculation. For example, the 2022 design value for a monitor is the average of the fourth-highest MDA8 O_3 values from 2020, 2021, and 2022 at that monitor.

Average DVB is the average of three consecutive design values starting with the design value of the baseline year. **Equation 5-2** shows the average DVB calculation for the 2022 baseline emissions inventory year for each site *i*:

$$DVBi = \frac{(2022\ DV)i+(2023\ DV)i+(2024\ DV)i}{3}$$ **Equation 5-2**

Here, average DVB is the average of the "2022 DV" (determined from 2020-2022 observations), the "2023 DV" (determined from 2021-2023 observations), and the "2024 DV" (determined from 2022-2024 observations). Consequently, the average DVB is derived from observations covering five years, with 2022 observations "weighted" three times, 2021 and 2023 observations weighted twice, and 2020 and 2024 observations weighted once.

A maximum DVB for the 2022 base year is the highest of the three design values (2022 DV, 2023 DV, and 2024 DV) in the period 2020-2024.

The following criteria are applied for calculating the average DVB when there are missing DVs:

a) For monitors with only four years of consecutive data, the guidance allows DVB to be computed as the average of two design values within that period.

b) For monitors with only three years of consecutive data, the DVB is equal to the design value calculated for that three-year period.

[67] Ibid.

c) For monitors with less than three years of consecutive data, no DVB can be estimated.

Step 2 - Calculation of RRF

According to EPA's guidance for calculating modeled future year design values, output from a photochemical air quality model (such as CMAQ) is used to calculate RRFs using a 3x3 grid cell array from the grid cell where the monitor is located, as well as grid cells immediately surrounding the monitoring site. This is in part due to limitations in the inputs and model physics that can affect model performance at the grid cell level. In addition, possibly inappropriate results may occur due to the artificial geometry of the superimposed grid system when monitoring sites and emission sources are located close to the border of a grid cell.

Following the EPA's approach, for each day, the grid cell with the highest base year MDA8 O_3 value in the 3x3 array is used in the calculation of the RRF. The 10 highest days in the base year modeling are used at each monitoring site. If the base year modeling results do not have 10 days with MDA8 O_3 value >= 60 ppb at a site, but there are at least 5 days with MDA8 O_3 >= 60 ppb, all of the days >= 60 ppb are used. If there are fewer than 5 days with MDA8 O_3 value >= 60 ppb, RRFs and DVFs are not calculated for that site. Therefore, there are 5 to 10 days used in each site's RRF calculation. A site-specific RRF is calculated as follows:

$$RRF = \frac{\text{average future year MDA8 O3 over selected high O3 days}}{\text{average base year MDA8 O3 over selected high O3 days}}$$ **Equation 5-3**

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

a) Selecting O_3 concentrations from grid cells surrounding the monitor.

    a. Identify the grid cell in which the monitor is located and include the surrounding eight grid cells to form a 3x3 grid cell array.

    b. Determine MDA8 O_3 concentrations for each day for each of the nine grid cells for both the base and future year simulations.

    c. For each day, identify the grid cell with the highest MDA8 O_3 value out of all nine grid cells in the base year. This is the MDA8 O_3 concentration for that monitor for that day to be used in the RRF calculation (following the screening criteria listed below).

    d. The future year MDA8 O_3 concentration is chosen by pairing with the same grid cell selected in the base year for that day. (Note that this may not result in selection of the highest future year modeled MDA8 O_3 concentration in the 3x3 grid array overlaying the monitor.)

b) Selecting modeling days to be used in the RRF calculation on a monitor-by-monitor basis.

    a. Identify the ten highest days with the MDA8 O_3 concentrations ≥ 60 ppb in the base year simulation.

b. If there are between five and ten days with ≥ 60 ppb, then use all days with ≥ 60 ppb.

c. An RRF is not calculated for the monitor if there are fewer than five days with the MDA8 O_3 concentration ≥ 60 ppb. These were recorded with "NA."

c) RRF calculations: Compute the RRF by averaging the MDA8 O_3 concentrations for the base year and future year determined in step (a) over all days determined in step (b).

Step 3 - Computation of DVF

For each monitor for which an RRF was able to be calculated, compute DVF as the product of DVB from step (1) and RRF from Step 2. The average and maximum DVFs are calculated as described in **Equations 5-4** and **5-5**, respectively.

$$average\ DVF = average\ DVB * RRF \quad \textbf{Equation 5-4}$$

$$maximum\ DVF = maximum\ DVB * RRF \quad \textbf{Equation 5-5}$$

Note, the following conventions on numerical precision were applied:

a) DVBs are calculated in ppb and rounded to the nearest tenth of a ppb.

b) Model estimates of MDA8 O_3 (in ppb) are calculated to at least four places to the right of the decimal.

c) Multi-day MDA8 O_3 (in ppb) are averaged, maintaining at least four places to the right of the decimal.

d) RRFs are truncated to four places to the right of the decimal.

e) "Pre-truncation" DVFs (ppb) are truncated to one decimal place, and the "final" DVFs (ppb) are truncated to integer values.

5.2.2 Projected Ozone Design Values for 2026 Analytic Year from the 2022V1 Platform

Modeled projected design values for the 2026 analytic year were calculated from the 2022/2026V1 platform using CMAQ model outputs. **Figure 5-3** shows a spatial map of all the DVFs in the OTR calculated using the 3x3 No Water methodology. **Table 5-1** lists the DVFs for the top 23 monitors with maximum DVBs exceeding the 2015 NAAQS in the OTR. This table includes projected average and maximum DVFs for 2026 using the 3x3 No Water methodology, as well as the 2022 (2020-2024) base observed design values (DVBs) and the 2022-2024 observed DVs. As shown on the map and in the table, three sites in Connecticut exceed the 2008 NAAQS, and three additional sites exceed the 2015 NAAQS in the NY-NJ-CT ozone nonattainment area in the OTR.

Projected DVFs for 2026 using both 3x3 and 3x3 No Water methodologies for all monitors in states in the OTR can be found in Appendix D.

***Figure 5-3** Modeled projected DVFs for 2026 with the 2022/2026 V1 platform using the 3x3 No Water methodology in the OTR.*

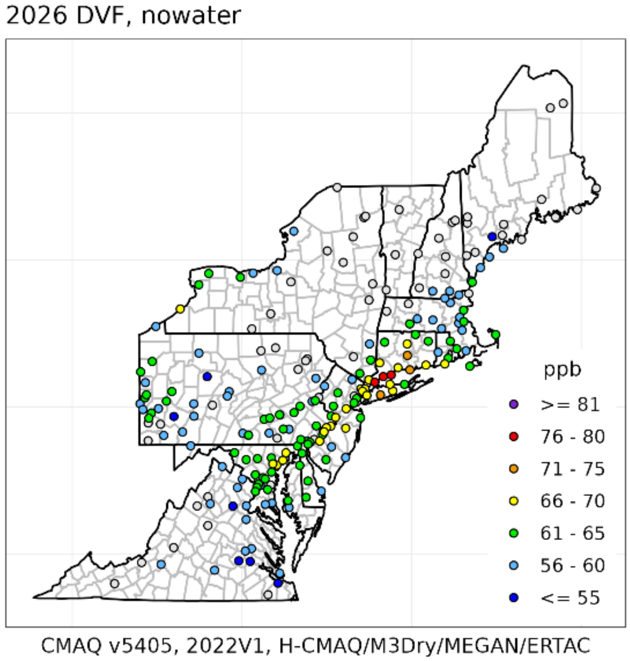


Table 5-1 *Top 23 OTR monitors showing the 2022 (2020-2024) base observed design values (DVB) compared to the 2022-2024 DVs and modeled projected DVFs for 2026 for the 3x3 No Water methodology using the 2022V1 platform.*

Site ID	State	County	Monitored DVs*			Modeled Projected DVFs for 2026 2022 V1, ERTAC/MEGAN 3x3 No Water	
			2022-2024 DVB		2022-2024 DV		
			AVG	MAX		AVG	MAX
90013007	CT	Fairfield	81	82	80	78.3	79.3
90019003	CT	Fairfield	80.7	82	80	78.1	79.3
90010017	CT	Fairfield	78.3	79	79	77.8	78.5
90099002	CT	New Haven	78	79	76	75.1	76.1
90011123	CT	Fairfield	73.3	76	76	70.6	73.3
90079007	CT	Middlesex	74	75	74	71	71.9
361030002	NY	Suffolk	73.7	75	72	71.6	72.9
420170012	PA	Bucks	72.7	73	73	69.6	69.9
361030044	NY	Suffolk	72.5	73	72	70.2	70.7
240053001	MD	Baltimore	70.7	73	71	68.6	70.8
340150002	NJ	Gloucester	69.7	73	73	67.3	70.5
440090008	RI	Washington	72	72	72	69.4	69.4
90110124	CT	New London	71.7	72	71	69.1	69.3
360810124	NY	Queens	71	72	71	69.4	70.4
90090027	CT	New Haven	70.7	72	72	68.1	69.4
90031003	CT	Hartford	70	72	72	67.1	69
240251001	MD	Harford	70	71	71	67.9	68.9
340230011	NJ	Middlesex	70	71	71	66.9	67.8
360610135	NY	New York	70	71	69	68.5	69.5
340210005	NJ	Mercer	69.7	71	71	66.4	67.7
361192004	NY	Westchester	69.3	71	71	67.4	69.1
240259001	MD	Harford	69.3	71	70	67	68.7
340290006	NJ	Ocean	69	71	71	66	67.9

*Data source for the monitored DVs: https://www.epa.gov/air-trends/air-quality-design-values, accessed on 6/4/2025.

Appendix A: Electric Generation Units and Industrial Units Prepared Using the ERTAC Emissions Estimation Tool for C3.0CONUSv22.0

Description: Large EGU and Industrial Units, simulating 2022 and future year (2026, 2032, and 2038) emission estimates with the ERTAC tool for C3.0CONUv22.0

A-1 EXECUTIVE SUMMARY

The Eastern Regional Technical Advisory Committee (ERTAC) Electrical Generating Unit (EGU) Committee projects activity and emissions for EGU and industrial units located in the continental United States (CONUS) that report emissions to the United States Environmental Protection Agency (USEPA) Clean Air and Power Division (CAPD) under 40 CFR Part 75 *Continuous Emission Monitoring*. Most of the EGUs serve a generator of at least 25 megawatts (MW), and most industrial units have a heat input of at least 250 million British thermal units per hour (mmbtu/hr). Data from Part 75-applicable units provide unit-specific hourly emissions and activity data that the ERTAC tool uses to create corresponding hourly future year emissions and activity profiles for existing and new units.

This document details the approach and data sources used to develop emissions for base year 2022 and necessary future years for these units in the C3.0CONUSv22.0 effort. Section A-2 INTRODUCTION describes the source category and the general approach. Section A-3 INVENTORY DEVELOPMENT METHODS describes the ERTAC tool input files and how they are built. Section A-4 DATA COLLECTION AND STAKEHOLDER OUTREACH provides an overview of the variety of data sources used. Periodic updates of the input files drive the creation of new run versions. Key data sources include:

- Hourly nitrogen oxides (NO_X), sulfur dioxide (SO_2), activity data, and facility data collected by CAPD,
- State agency expert knowledge of facilities and their future plans,
- Energy Information Agency (EIA) Annual Energy Outlook (AEO),
- North American Electric Reliability Corporation (NERC), and
- EIA Form 860.

Section A-5 ERTAC INPUT FILES OVERVIEW contains descriptions of each input file used in C3.0CONUSv22.0. Projection years for C3.0CONUSv22.0 include 2026, 2032, and 2038. Section A-6 OUTPUTS describes the base year and projection years output files as well as the ERTAC_for_SMOKE post processor that is used to create ff10 inventory files for air quality modeling purposes. Section A-7 SMOKE MODELING provides details on adjustments made prior to the emissions processing of the ERTAC output files. Section A-8 INTEGRATION OF ERTAC FILE SUBSTITUTIONS provides information on changes necessary to the federal modeling files to incorporate ERTAC outputs. Federal modeling files and ERTAC substitutions are available for 2022 and 2026. Section A-9 EMISSIONS SUMMARIES includes comparisons of the 2022, 2026, 2032, and 2038 outputs.

A-2 INTRODUCTION

The ERTAC tool projects activity and emissions for units located in CONUS that report emissions to the USEPA CAPD as required by 40 CFR Part 75 *Continuous Emission Monitoring*. These units usually serve a generator with a capacity of at least 25 MW. The exceptions to the 25 MW size criteria are mostly in the Northeastern United States where some units are sized less than 25 MW but are required to report emissions and activity to CAMD. Some industrial and institutional units must also report hourly data to CAMD, mainly due to requirements in the NO_X Budget Trading Program. Industrial and institutional boilers with a heat input of at least 250 mmbtu/hr that burn or have burned fossil fuel are included in this category. Any unit reporting hourly data to CAPD is included in the ERTAC tool output unless the unit has unique issues that require its exclusion.

These units are point sources in the Emissions Inventory System (EIS). Load and pollutants, including SO_2 and NO_X, are recorded continuously and reported quarterly as required by 40 CFR Part 75 to USEPA. Other pollutants are estimated by the sources or state staff and reported annually to EIS.

These units are identified by unit identification numbers (Unit IDs) and facility ORIS codes in the CAPD database. Stack parameters, including release height, temperature, and velocity, are obtained from EIS and married with ERTAC tool outputs via the ERTAC_for_SMOKE tool.

The ERTAC committee collects data on these units from a wide variety of sources and uses that information as inputs to the ERTAC tool to estimate hourly emissions in future years. The committee maintains and distributes reference runs for CONUS, including the hourly input, output, summary, and documentation files for each run. These runs and complete documentation of the ERTAC tool are available upon request.

This run, C3.0CONUS22.0, uses the 2022 base year continuous emission monitoring (CEM) data collected by CAPD and growth factors from the EIA AEO 2023 regional high oil and gas (HOG) scenario projection. State staff supplied unit level adjustments in response to outreaches in January and October of 2024. Projections for reference case runs have been prepared for years 2026, 2032, and 2038. Final C3.0CONUv22.0 runs were completed February 2025. The contact person for questions about these run files is Doris McLeod, Virginia Department of Environmental Quality (804-659-1990, doris.mcleod@deq.virginia.gov).

C3.0CONUSv22.0 reference runs comply with the Revised Cross State Air Pollution Rule Update (Revised CSAPR Update) Rule (86 FR 23054). These runs do not include the impacts of the Federal “Good Neighbor Plan” for the 2015 Ozone National Ambient Air Quality Standards (88 FR 36654) and do not include the impacts of the 2024 Clean Air Act §111(d) EGU rules (89 FR 39798). At the time of input file development, the status of litigation and other aspects of these rulemakings were unclear.

A-3 INVENTORY DEVELOPMENT METHODS

The ERTAC EGU tool input files are built from a variety of data sources. Periodic updates of the input files drive the creation of new run versions. Key data sources include:

- Hourly NO_X, SO_2, activity data, and facility data collected by CAPD,

- State agency expert knowledge of facilities and their future plans,
- EIA AEO,
- NERC, and
- EIA Form 860.

Hourly NO_X, SO_2, and activity data are continuously monitored and reported electronically to CAPD by large units as required by 40 CFR Part 75 and in certain cases state regulations. The C3.0CONUSv22.0 hourly base year input file utilizes the data set collected for 2022 that was downloaded January 2024 by EPA. The New York Department of Environmental Conservation (DEC) acquired this data set and applied the CEMConvert tool to create the ERTAC base year hourly input file. The dataset acquired from EPA is available in the 2022_raw_EGU_CEMs_15jan2024.zip file on https://gaftp.epa.gov/Air/emismod/2022/v1/draft/point/.

The primary sources of expected future change in generation are the EIA annual projection of future generation and the NERC projection of peak generation rates. This information is available by region and fuel type. Where states have local activity projections, these are preferred over EIA or NERC estimates. The ERTAC growth committee prepares updates to the growth factors when new versions of the EIA AEO become available, blending the national EIA and NERC data with any state-provided data to create a unified, national growth factor table by electricity market module (EMM) region. The annual change in future generation by unit is estimated by merging these growth files and state knowledge of unit level changes within a generating region. Hourly future emissions of NO_X and SO_2 are calculated by multiplying hourly projected future heat input by future emission rates.

EIA Form 860 contains generator-level specific information about existing and planned generators and associated environmental equipment at electric power plants with one MW or greater of combined nameplate capacity. EIA Form 860 data from 2022 informed state updates to the unit level input characteristics.

A-4 DATA COLLECTION AND STAKEHOLDER OUTREACH

State agency expert knowledge on facilities is collected periodically during coordinated outreach events for state staff. During outreach periods, agencies provide information on new units and controls, fuel switches, shutdowns, and other unit-specific changes as appropriate for inclusion in state implementation plans (SIPs). Owners of facilities are encouraged to work with state staff to determine the most appropriate input characteristics for each unit. Future emission rates in projection runs are assumed to be the same as base year rates unless adjusted by state input. Such input may rely on knowledge of expected emissions controls, fuel switches, or other unit-specific considerations.

After projection year development, results are provided to state and multi-jurisdictional organization (MJO) staff for review prior to finalizing the outputs.

A-5 ERTAC INPUT FILES OVERVIEW

The following paragraphs describe ERTAC tool input files that are created by the ERTAC committee.

- ERTAC Base Year Hourly CEM data (camd_hourly_base.csv) – This comma separated file contains hourly unit level generation and emissions data developed from EPA's CAPD database. The C3.0CONUSv22.0 hourly base year input file utilizes the data set collected for 2022 that was downloaded January 2024 by EPA. This data is available in the 2022_raw_EGU_CEMs_15jan2024.zip file on https://gaftp.epa.gov/Air/emismod/2022/v1/draft/point/. The New York DEC acquired this data set and applied the CEMConvert tool to create the ERTAC base year hourly input file. The CEMConvert tool adjusts substituted hourly information that is well outside the range of normal operations. The nomenclature for this input file uses "camd", which references an older program name (Clean Air Markets Division) for the CAPD. In this document, when referring to the CAPD office or the data supplied by owners, the current terminology of CAPD is used. When referring to the base year hourly CEM data input file, the abbreviation camd is used to accurately identify the name of the file for use in the ERTAC tool.
- ERTAC nonCAMD hourly data (ertac_hourly_noncamd.csv) – This comma separated file contains updates to the hourly data. These changes include updating some units' hourly data with more recent CAPD information, updating some units with incomplete data, and adding data for ORIS 880004 (GSA Central Heating Plant in Washington, D.C.).
- Unit Availability File (ertac_initial_uaf_v2.csv) – This comma separated file contains descriptions of each generating unit derived from a variety of sources, including the CAPD database, state input, EIA Form 860, and EIS. Each row in the table represents a single generating unit. This file is maintained and updated by the ERTAC committee and provides information on changes to specific units from the base to the future year. For example, the unit availability file (UAF) captures actual or planned changes to usage rates, unit efficiency, capacity, or fuels. Agencies also add information on actual and planned new units and shutdowns.
- Control File (ertac_control_emissions.csv) – This optional comma separated file contains known future unit-specific changes to SO_2 or NO_X emission rates in units of pounds per million British thermal units (lbs/mmbtu) and/or control efficiencies (for example, addition of a scrubber or selective catalytic reduction system). This information is provided by state agency staff. This file also provides emission rates for units that did not operate in the base year and for new units.
- Seasonal Controls File (ertac_seasonal_control_emissions.csv) – This optional comma separated file may be used by state agencies to enter seasonal or periodic

future year emissions rates for specific units. This file may be used in addition to, or as an alternative to, the control file.

- Input Variables File (ertac_input_variables_v2.csv) – This comma separated file specifies values for several variables used in a particular ERTAC tool run.
  - Regions and Fuel Characteristics - These fields are not hardwired into the model. Rather, the regions and their characteristics are specified in the input variables file. This file allows agencies to specify variables such as the size, fuel type, and location for new units.
  - Default New Unit Emission Rates - These fields allow the user to adjust the percentile of best performing existing unit emission rates used for determining emission rates applied to new units. Default is 90^{th} percentile.
  - New Unit Hourly Profile Characteristics - For new planned units and generation deficit units (GDUs), users may specify in this file the percentile ranking of the existing unit (operated in the base year) used to create a representative future profile of activity for new units and GDUs.
  - Calculation Methodology - This field allows the user to specify the methodology for determining emission rates and heat rates. Default (blank) mode applies an annual average to SO_2 and heat rate and ozone season/non-ozone season averages to NO_X. The default mode is currently used for projections. The HOURLY mode applies hourly averages, where possible, to each parameter and is used for base year development.

- Growth Factor File (ertac_growth_rates.csv) – This comma separated file contains the annual and peak electrical generation growth factors delineated by geographic region and generating unit type used in a particular run.
- Demand Transfer File (ertac_demand_transfer.csv) – This optional comma separated file allows users to transfer power, on an hourly basis, from one region/fuel-unit type to another. It also allows transfer to or from other, non-fossil fuel fired systems such as nuclear and renewables.

A.5.1 CAPD HOURLY FILE (camd_hourly_base.csv)

The C3.0CONUSv22.0 outputs are the first set of runs to use the base year 2022 data. Base year input files were created from the EPA file 2022_raw_EGU_CEMs_15jan2024.zip available on EPA's website https://gaftp.epa.gov/Air/emismod/2022/v1/draft/point/. New York DEC applied the CEMConvert tool to this data set to create the ERTAC base year hourly input file. The CEMConvert tool ensures that substituted data reflect actual operations of the unit. The CEMConvert tool is designed to identify and correct anomalous data points in the hourly database that resulted from 40 CFR Part 75 substitution methodology since such data may not reflect actual emissions during that hour.

Also, CEM data downloaded from the current version of the CAPD website are no longer in the format required by the camd_hourly_base.csv input file. C3.0CONUS22.0 used CEMConvert developed by EPA with anomaly data correction in place (i.e., option of data correction has been turned on) in preparation of the CEM data (date of download, January 2024). CEMConvert features a useful functionality of re-arranging CEM data into ERTAC-compatible format, and an "on" flag applies data correction to abnormal or out-of-range data (such as done by CEMCorrect). Currently it is unclear how or if CEMConvert may impact units with only partial year data.

Rather than using CEMConvert, an alternative approach to rearrange the base year data into the format required by the ERTAC tool is the development of purpose-specific scripts. Such scripts have been developed. These programs allow the use of CEM data directly from CAPD with no correction of substituted data or the application of the older CEMCorrect, which in prior tests is shown to only correct substituted data.

A.5.2 NON-CAPD HOURLY FILE (ertac_hourly_noncamd.csv)

This file, which is an optional input, allows for adjustments to outdated, abnormal, or missing data in the CAPD hourly file (camd_hourly_base.csv). The file may also be used to append additional data to the camd_hourly_base.csv file. For the C3.0CONUSv22.0 (base year 2022) effort, this file was used to change or add data for the following units:

- ORIS 880004, Units 3, 4, and 5C located at GSA Central Heating in Washington, D.C. did not have any hourly data in the January 2024 download. The April 2024 download, however, did contain complete data sets for these units. Therefore, the April 2024 data from these units were included in the ertac_hourly_noncamd.csv file with the consent of DC Department of Energy and Environment.
- Michigan staff submitted comments that the 2022 hourly data from the January 2024 download did not match the most current hourly data at that time (April 2024). Therefore, the April 2024 hourly data were included in this file for the following units: ORIS 1702, Karn, Unit 4;
  ORIS 10698, Graphic Packaging, BLR08;
  ORIS 55297, New Covert, Unit 001;
  ORIS 63259, Delta, Units DEPC2 and DEPC3; and
  ORIS 880045, University of Michigan, Units 260-03 and 260-04.
- ORIS 10865, Archer Daniels Midland was missing key data for several units. SO_2 was not reported for FBC1 through FBC9. Illinois staff provided the annual reported NO_X and SO_2 in 2022 from EIS for each unit. Using the ratio of annual SO_2/NO_X and multiplying this ratio by the hourly value allowed estimation of the SO_2 hourly value for each hour. Heat input was not reported for FBC1 through FBC8. Using the conversion factor of 1 pound steam = 1,400 btu, the heat input for each hour was added for units FBC1-FBC8.

A.5.3 UNIT AVAILABILITY FILE (ertac_initial_UAF_v2.csv)

The UAF includes a record for each emissions unit and captures actual or planned changes to utilization fractions, unit efficiency, capacity, or fuels. Agencies also add information on actual and planned new units and shutdowns.

The file name for the final C3.0CONUSv22.0 UAF, which contains documentation on each edit or addition to the file and is maintained by Wendy Jacobs of the Connecticut Department of Environmental Protection (DEP), is 2022DRAFTBASEUnit_Availability_v22.0Jan282025.xlsx.

For most units, actual 2022 operational data, as recorded in the 2022 CAMD hourly files, were used by the code to estimate unit characteristics. After using the code to estimate the 2022 values, in some cases inadequate 2022 operational data existed to properly estimate unit characteristics. In these cases, the UAF was filled with reasonable estimates for the following characteristics:

- Nominal heat rates for existing units,
- Max_annual_ERTAC_UF_state_input for all units, where the utilization fraction (UF) represents the utilization fraction of the unit, and
- Unit optimal load threshold from all units.

Where heat rate could not be calculated, the following defaults were applied:

- Boiler gas units – 10,000 British thermal units per kilowatt hour (btu/kw-hr)
- Coal units – 11,000 btu/kw-hr
- Combined Cycle Gas Units – 7,000 btu/kw-hr
- Simple Cycle Gas Units – 10,000 btu/kw-hr
- Oil Units – 12,000 btu/kw-hr

Where the optimal load threshold (UAF Column AV) could not be calculated, a default of 50% of the max_unit_heat_input, converted to MW by 10,000 btu/kw-hr and 1,000 kw/MW, was applied to such units. Where max_annual_UF_state_input (UAF Column AM) could not be calculated, a default of 0.9 was applied to such units. In many cases such units needed more than one of these supplied values to run successfully.

In the UAF, units are described in Column S, BY_camd_hourly_data_type, as "Full", "NEW", "Partial", or "non-EGU."

- "Full" indicates that the unit reported activity and emissions for the entire base year and that growing activity and emissions from the unit using AEO electrical generation growth rates is appropriate.
- "NEW" indicates that the unit was not on-line during the base year in its present configuration. This moniker is assigned to units that commenced

operations after the base year and thus no CAPD data within the base year exists for that unit. It is also applied to units when a fuel switch or process change occurs after the base year. Examples include, but are not limited to, units operating on coal in the base year but natural gas in the future year and units operated as simple cycle units in the base year but combined cycle units in the future year.

- "Partial" indicates that the unit only reported activity and emissions a portion of the year to CAPD but that the unit could reasonably be grown using the ERTAC tool. For these units, which are identified as such by state staff, hourly data outside of the required CAPD reporting period may be blank or may simply not exist in the base year hourly data set. In these situations, the tool provides a listing of "Partial" year reporters in the preprocessor log and creates any required hourly records in the base year so that the unit has a full set of hourly records for growth estimates. Optionally, state agencies may supply the base year annual heat input for such units in the UAF in Column T (BY_Annual HI for Partials). If this data is supplied, the tool calculates the heat input for the non-reported hours of the year by subtracting the CAPD-reported heat input from the state-supplied heat input in Column T and distributes that heat input uniformly to those non-reported hours. The tool will use average values for heat rate and emission rates to construct necessary hourly information from the state-supplied annual heat input estimates. If no annual heat input value is supplied, the tool creates blank fields for the non-reported hours.
- “EXISTING” units operated in the base year (2022) and had reasonably complete datasets.

A.5.4 CONTROLS FILE (ertac_control_emissions.csv) and SEASONAL CONTROLS FILE (ertac_seasonal_control_emissions.csv)

For future year runs, calculated base year emission rates for existing units are used unless data in the controls file or seasonal controls file alter the rates. The controls file may also be used to update or include emission rates for pollutants otherwise not reported to CAPD. For example, in certain instances units may report NO_X to CAPD but not SO_2 emissions. The controls file may be used to include SO_2 emission rates for such units so that base year data reflect a profile of SO_2 emissions consistent with base year unit activity and the state supplied SO_2 emission rate.

The seasonal controls file may be used to enter seasonal or periodic future year emissions rates for specific units for use in future year runs. For example, if a unit is expected in the future year to run a control device during the summer months but not during other times of the year, this file allows the user to provide different emission rates to be applied during future year time periods. This file may be used in addition to, or as an alternative to, the control file. When competing entries are contained in these files, the tool uses the controls file entry. In C3.0CONUSv22.0 runs, Georgia, Indiana, Maryland, Missouri, Pennsylvania, Virginia, and West Virginia included seasonal controls.

The C3.0CONUSv22.0 controls file and seasonal controls file are based on the documentation file called 2022DRAFTBASEControl File_v22.0_February52025.xlsx. This file is maintained by Wendy Jacobs of Connecticut DEP.

A.5.5 GROWTH RATE INPUT FILE (ertac_growth_rates.csv)

The following sections explain the development of the regions included in the growth rates input file as well as the development of the growth rates for years 2026, 2032, and 2038 used in the C3.0CONUSv22.0 runs. Growth factors used in C3.0CONUSv22.0 reference case were developed mainly based on the AEO2023 High Oil and Gas Resource and Technology ("HOG") scenario. Relative peak factors were derived from 2023 NERC ES&D.

A.5.5.1 ERTAC GEOGRAPHIC REGIONAL SYSTEM AND FUEL TYPES

Each unit included in the model is assigned to a geographic region and fuel type bin in the UAF. The geographic regional system provided in **Figure A-1** is used in the C3.0CONUSv22.0 run and is identical to the EIA EMM regional system for AEO2023. NERC growth factors using the NERC regional system are used for peak growth. **Figure A-2** shows these regions for the 2023 NERC data.

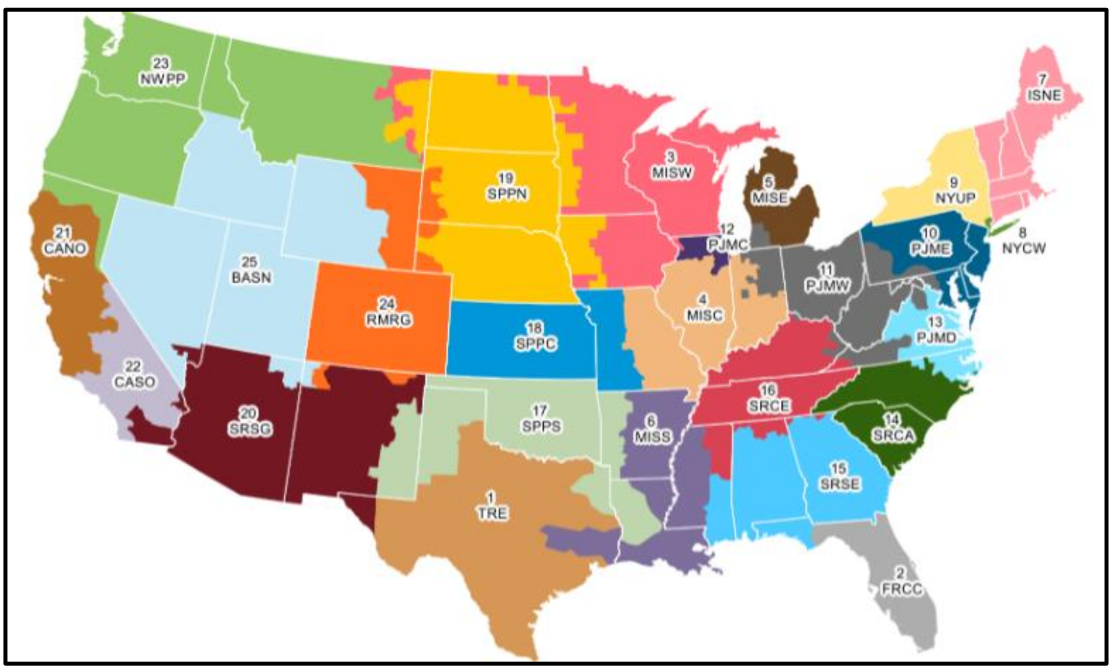


Figure A-1 *Regional Boundaries for Generation, C3.0CONUSv22.0*

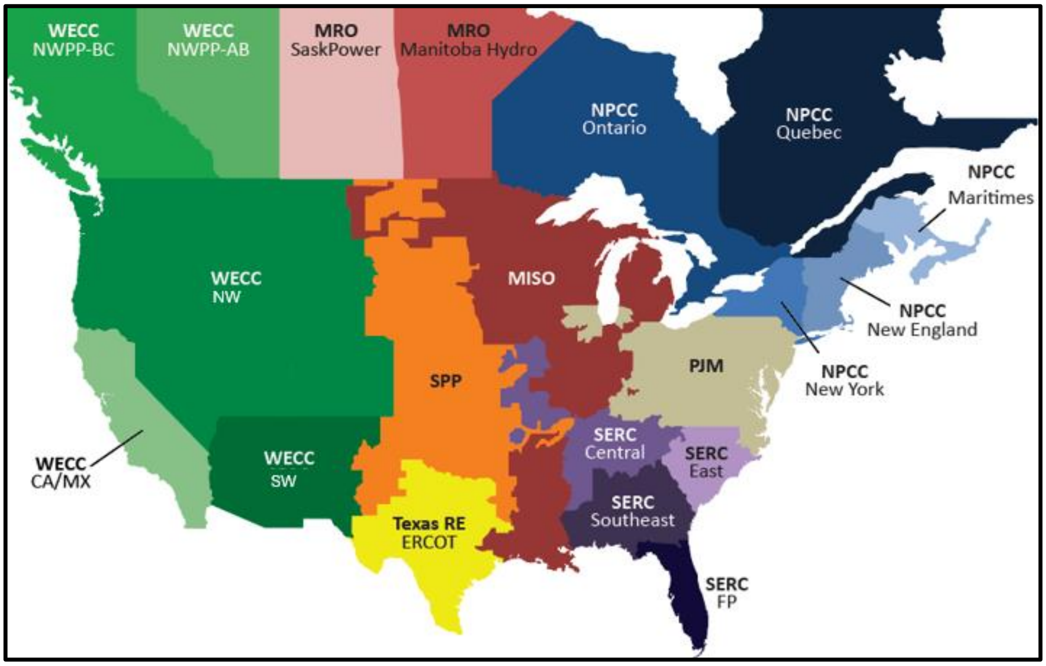


Figure A-2 *NERC Regional Entities*

Because the EIA EMM and NERC regions are not identical, adjustments are required to align these regional systems to develop annual and peak growth rates. To match EIA and NERC, a "best fit" NERC regional growth factor is assigned to each EMM region. In the simplest case, where a clear match between EIA and NERC regional schemes exists, for example NPCC-New England, the NERC relative peak growth rate is assigned to the corresponding EMM region. In more complicated cases, where multiple EMM regions corresponded to a single NERC region, or where regions were organized along substantially different geographic boundaries, the NERC Electricity Supply & Demand (ES&D) data was aggregated and averaged to generate a relative peak growth factor for the (usually larger) corresponding NERC region that was applied to the corresponding ERTAC region (which closely resemble the EMM regions). As an example, the EIA PJME, PJMW, PJMC, PJMD, and SRCA regions correspond to two NERC regions, PJM and SERC. In this case, the relative peak growth factors were derived from PJM and SERC and applied to PJME, PJMW, PJMC, PJMD, and SRCA ERTAC regions. **Table A-1** provides a crosswalk for these regional identifiers.

Table A-1 *EMM to NERC Crosswalk – C3.0CONUSv22.0*

EMM Fuel Region #	Fuel	EMM Region Name	ERTAC Regional Code	Single "Best-Fit" NERC Subregion Peak Growth Code
1	Coal, NG, Oil	Texas Regional Entity (TRE)	TRE	TRE-ERCOT
2	Coal, NG, Oil	Florida Reliability Coordinating Council (FRCC)	FRCC	SERC-FP
3	Coal, NG	Midcontinent ISO/West (MISW)	MISW	SPP-RE/SERC-C/MRO-MISO SPP/MRO-MISO/SERC-C
4	Coal, NG	Midcontinent ISO/Central (MISC)	MISC	SPP/MRO-MISO/SERC-C
5	Coal, NG, Oil	Midcontinent ISO/East (MISE)	MISE	SPP/MRO-MISO/SERC-C

EMM Fuel Region #	Fuel	EMM Region Name	ERTAC Regional Code	Single "Best-Fit" NERC Subregion Peak Growth Code
6	Coal, NG	Midcontinent ISO/South (MISS)	MISS	SPP/MRO-MISO/SERC-C
7	Coal, NG, Oil	NPCC/New England (ISNE)	ISNE	NPCC-NE
8	Coal, NG, Oil	NPCC/NYC & Long Island (NYCW)	NYCW	NPCC-NY
9	Coal, NG, Oil	NPCC/Upstate NY (NYUP)	NYUP	NPCC-NY
10	Coal, NG, Oil	PJM/East (PJME)	PJME	PJM/SERC-E
11	Coal, NG	PJM/West (PJMW)	PJMW	PJM/SERC-E
12	Coal, NG, Oil	PJM/Commonwealth Edison (PJMC)	PJMC	PJM/SERC-E
13	Coal, NG	PJM/Dominion (PJMD)	PJMD	PJM/SERC-E
14	Coal, NG, Oil	SERC Reliability Corporation/East (SRCA)	SRCA	PJM/SERC-E
15	Coal, NG, Oil	SERC Reliability Corporation/Southeast (SRSE)	SRSE	SERC-SE
16	Coal, NG, Oil	SERC Reliability Corporation/Central (SRCE)	SRCE	SPP/MRO-MISO/SERC-C
17	Coal, NG, Oil	South West Power Pool/South (SPPS)	SPPS	SPP/MRO-MISO/SERC-C
18	Coal, NG	Southwest Power Pool/Central (SPPC)	SPPC	SPP/MRO-MISO/SERC-C
19	Coal, NG	Southwest Power Pool/North (SPPN)	SPPN	SPP/MRO-MISO/SERC-C
20	Coal, NG, Oil	WECC/Southwest (SRSG)	SRSG	WECC-SW
21	Coal, NG, Oil	WECC/CA North (CANO)	CANO	WECC-CAMX
22	Coal, NG, Oil	WECC/CA South (CASO)	CASO	WECC-CAMX
23	Coal, NG, Oil	WECC/Northwest Power Pool (NWPP)	NWPP	WECC-NW
24	Coal, NG, Oil	WECC/Rockies (RMRG)	RMRG	WECC-NW
25	Coal, NG, Oil	WECC/Basin (BASN)	BASN	WECC-NW
N/A	Oil	Fuel-unit type oil/simple cycle in NYCW	NYCW3	NPCC-NY

Within each EMM region, individual generation units are further delineated into five fuel-unit types as follows:

- Coal,
- Oil,
- Natural Gas – Combined Cycle,
- Natural Gas – Simple Cycle, and
- Natural Gas – Boilers.

The C3.0CONUSv22.0 inputs also include information for Industrial, Institutional, and EGU-Other units. These units report hourly data under Part 75 but for a variety of reasons may not best be grown using fossil fuel-fired generation estimates from EIA. Industrial units operate at facilities whose primary function is not the creation of electricity to supply to the electrical grid. For example, units at kraft mills, pharmaceutical companies, munitions manufacturers, and other types of industry may be included in the ERTAC tool as an “Industrial” fuel-unit type. “Institutional” units support operations at hospitals, schools, government buildings, and other types of organizations. Units identified as “EGU-Other” typically do produce electricity for sale on the grid. However, these units often burn fuels that are not fossil fuels, such as biomass and biogas. These three types of units are assigned the region “CONUS” and are assigned a fuel-unit type of Industrial, Institutional, or EGU-Other, as appropriate. Growth rates for these units are set at 1.000 since emission trends show that these types of units generally have lower emissions over time.

A.5.5.2 GROWTH FACTORS

Generation for future years by fuel type are based on growth rates differentiated by annual, nonpeak, and peak rates. Average annual regional growth rates are developed by the ERTAC Growth Subcommittee from the EIA AEO. EIA annual average regional growth factors are calculated by dividing AEO future projected generation by base year generation. In certain cases, agencies have developed more refined region-specific growth factors, which are then used to replace the EIA/NERC factors.

Peak growth rates are derived by determining relative peak growth from NERC ES&D data and applying it to the annual growth rates. The derived relative peak growth rates are not delineated by fuel so the ratio of peak to nonpeak growth rates for each fuel within a single region is constant.

Cody Converse (Wisconsin Department of Natural Resources, DNR) developed a Python script to generate growth rates for multiple years. This script relies on the following growth inputs:

- AEO Generation by Fuel Type projections from the Electric Power Projections by Electricity Market Module,
- NERC Net Energy for Load and Peak Hour Demand projections, and
- Base year generation data.

The script performs the following steps to generate a set of output files (one for each analytic year) with annual and peak growth rates for each fuel-unit type in each ERTAC region:

1. Calculates base year generation and natural gas component fractions for the three types of natural gas units,
2. Calculates 'First Pass' annual growth rates from AEO data,
3. Calculates seasonal peak-hour demand and annual net energy load ratios from NERC data,
4. Calculates peak growth multipliers from the seasonal peak-hour demand and annual net energy load ratios,
5. Partitions annual growth rates for natural gas into Boiler Gas, Simple Cycle, and Combined Cycle, and
6. Calculates peak growth rates using annual growth rates and peak growth rate multipliers.

Growth factors used in C3.0CONUSv22.0 reference case were developed based on the AEO2023 HOG scenario. Relative peak factors were derived from 2023 NERC ES&D. The files containing annual and peak growth factors were provided by Cody Converse, Wisconsin

DNR, in the file dated June 13, 2024, and named ERTAC_GRs_REF_HOGS_LZTC_Variations.zip. These growth factors and default growth curve parameters are used in C3.0CONUSv22.0 outputs except for coal for years 2032 and 2038 in region PJMD, which is located within Virginia and West Virginia. In a memorandum dated December 6, 2024, Virginia and West Virginia staff submitted coal growth rates for 2032 and 2038 based on data in Dominion's Integrated Resource Plan dated October 2024.

Nonpeak growth rates are calculated within the ERTAC EGU tool using annual and peak growth rates. Annual average regional growth rates are adjusted to account for the peak hours. Peak and nonpeak growth is assigned to every hour by ordering all hours in the year on the basis of base year utilization. The peak growth factor is assigned by fuel to a limited number of hours with the highest utilization in the base year. Growth is then transitioned gradually to the non-peak growth rate. The number of peak and transition hours are differentiated by fuel and region and are assigned in the growth rates file. **Figure A-3** shows graphically the relationship between annual, peak, and nonpeak growth rates.

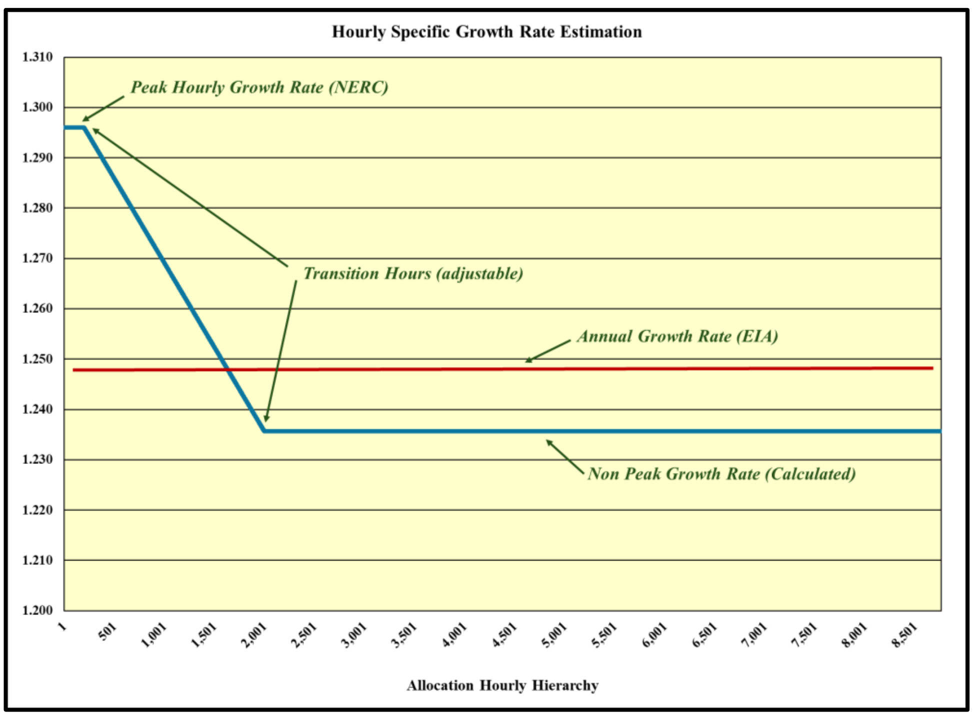


Figure A-3 *Relationship between the annual, peak, and nonpeak growth rates*

Finally, fuel-specific hourly regional growth factors are adjusted to account for activity from new units, shutdowns, and demand transfers. The tool then applies the adjusted hourly growth factors to the base year hourly generation data to estimate hourly future generation. This generation is assigned to the units burning the specified fuel within the region. After generation is assigned, the tool confirms that unit capacity is not exceeded. If the available capacity is fully utilized, new GDUs are created to carry demand that exceeds known unit capacity.

A.5.6 DEMAND TRANSFER FILE (ertac_demand_transfer.csv)

Demand transfer is the movement of generation from one fuel bin or region to another system. This optional, comma separated file may be used to alleviate the creation of a GDU or to more accurately represent a significant system change not anticipated by the EIA in the AEO. For example, this approach was taken in a previous version to address the retirement of Indian Point, a large nuclear power plant near New York City that was not anticipated in the AEO projections.

For C3.0CONUSv22.0 the demand transfer file was used to prevent coal-fired GDUs from being created as well as to balance power between natural gas fuel-unit types. The amount of generation transferred and the number of hours requiring such transfers varied by region and projection year. **Table A-2** summarizes the MW-hrs transfer information for the C3.0CONUSv22.0 runs.

Table A-2 *Demand Transfer (MW-hrs) Summary for C3.0CONUSv22.0*

Year	Transfer Fuel-Unit Type	FRCC	MISC	MISE	MISW	NYCW	NYCW3	NYUP	PJMC	PJMD	PJME	SRCE	SRSG
2026	Fr: BG	103,287											164,816
2026	Fr: Coal			2,128,338						281,732	1,631,698		268,118
2026	Fr: CC								2,458,286				
2026	Fr: Oil		5,316		1,070							18,370	
2026	Fr: SC					16,500	1,261						64,471
2026	To: CC	103,287	5,316	2,128,338	1,070	17,761				281,732	1,556,698	18,370	497,405
2026	To: SC								2,458,286		75,000		
2032	Fr: BG	174,789											
2032	Fr: Coal			9,780,231							13,183,799		
2032	Fr: CC												
2032	Fr: SC					32,379	1,293						85,922
2032	To: BG	174,789									96,300		
2032	To: CC			9,780,231		33,672					12,766,499		319,96
2032	To: SC										321,000		
2038	Fr: BG	192,319											324,969
2038	Fr: Coal									11,072,113	162,314	125,891	
2038	Fr: CC	192,319											
2038	Fr: SC					35,038	1,311	97					105,793
2038	To: BG										162,314		
2038	To: CC					36,349		97		11,072,113		125,891	430,762

BG = boiler gas; CC = combined cycle; SC = simple cycle

One unit in NYCW3 (ORIS 8906, Unit ID CT0001) is subject to 6 NYCRR Subpart 227-3: *Ozone Season Oxides of Nitrogen (NOx) Emission Limits for Simple Cycle and Regenerative Combustion Turbines*. This rule requires applicable units to either reduce emissions or not operate during the summer months. The owner of this unit chose not to operate the unit during the summer months. Therefore, any demand assigned to that unit during May 1 through September 30 (calendar hours 2,161 to 6,552 in non-leap years) was transferred to the combined cycle fuel-unit type in NYCW.

A.5.7 INPUT VARIABLES (ertac_input_variables_v2.csv)

This file allows the user to change various parameters within the tool by region and fuel-unit type. The file specifies the base year and future year; the start and end of the ozone season; the approach for setting hourly hierarchies; the averaging approach for SO_2, NO_X, and heat input; new unit sizing; demand cushion sizing; the optional specification of ORIS IDs where GDUs will be created; and a variety of other data.

One useful aspect of this file is the "Use HIZG" column, Column AW, which is set to either True or False. HIZG hours are hours with Heat Input and emissions but Zero Generation (Gross load). Such hours usually represent start-up and shutdown hours. When this column is set to True, the tool incorporates the activity and emissions in these hours in the outputs. When this column is set to False, the tool does not incorporate such activity and emissions. Typically, HIZG is set to True for CONUS Industrial, Institutional, and EGU-Other units in all runs because these units tend to have incomplete data. Setting HIZG to True for these units helps to create a reasonable profile of emissions for these units in the future year.

HIZG is also set to True for all units when running the 2022 base year data through the ERTAC tool to develop the base year input files so that actual 2022 emissions are represented as closely as possible. HIZG is typically set to False for EGU fuel-unit types (boiler gas, coal, combined cycle, oil, and simple cycle units) in projection years (for example, 2026, 2032, and 2038) so that SIP development is not influenced by start-up and shutdown conditions.

A.5.8 ERTAC EGU CODE VERSION

Version C3.0CONUSv22.0 used the ERTAC v3.0 code dated November 21, 2022. This code version contains the preprocessor, projection processor, python post processor, and ERTAC_for_SMOKE post processor used for these runs as well as perl code for carbon dioxide (CO_2) calculations. The code folder is available upon request to the Executive Director of the Mid Atlantic Regional Air Management Association (MARAMA).

A.5.9 TOOL CALCULATION APPROACH

For development of base year 2022 modeling input files, the tool was run using the hourly calculation methodology for NOx emission rates (lbs/mmbtu), for SO_2 emission rates (lbs/mmbtu), and for heat rate (btu/kw-hr). The hourly calculation method uses hourly heat input and gross load to determine a heat rate for each hour for each unit. The input variables file also had the HIZG set to True for all units in the base year 2022 run. This methodology leaves intact emission rates and heat rates that may be affected by unit upset conditions, malfunction, start up, shutdown, and variations in control applications or feedstock. Outputs from the tool correspond closely to the hourly CAPD data.

For projection years, the tool is run in default mode, which calculates average unit level NO_X emission rates for the ozone season and non-ozone season. In default mode the tool calculates annual average SO_2 emission rates and average annual heat rates for each unit. For the projection years, HIZG is set to False in the input variables file for all units except those identified by the fuel-unit types of Industrial, Institutional, or EGU-Other. Use of default averages and use of HIZG equal to FALSE for most units ameliorate data that could be impacted by unit upset, malfunction, start up, shutdown, and variations in control applications.

For projection year runs, calculated base year emission rates for existing units are adjusted to account for new control equipment or other changes provided in the input files. For new units, two approaches are employed. If a state provides new unit emission rates, those data are preferentially used. Where emission rates are not provided, emission rates based on the 90th percentile best performing existing unit for that fuel-unit type and region are assigned to the new unit. The user may adjust this percentile within the input variables file.

Base year load is grown using hour-specific growth rates as described in Section A.5.5 GROWTH RATE INPUT FILE (ertac_growth_rates.csv). This projected hourly load is converted to heat input (mmbtu) using the unit's heat rate. The emission rates are applied to each unit's future year heat input activity to calculate NO_X and SO_2 emissions.

A-6 OUTPUTS

The ERTAC tool estimates hourly generation and emissions for each unit in the system. In addition, post processors create summary files to facilitate review of the results, as follows:

- Annual base and future year generation (MW-hrs), heat input (mmbtu), SO_2, NO_X emission (tons) and average emission rate (lbs/mmbtu);
- Ozone season base and future year generation and heat input, NO_X emission (tons) and average emission rate (lbs/mmbtu); and
- CO_2 estimates.

The ERTAC_for_SMOKE post processor creates ff10 inventory files that can be used to develop air quality model-ready emission files.

A.6.1 BASE YEAR OUTPUTS

The base year 2022 output files in SMOKE-ready format for C3.0CONUSv22.0 are available on the MARAMA ShareFile site at ERTAC EGU Code/Runs/CONUS-v22.0/C3.0CONUSv22.0_BYFYHRLY/ for ERTAC committee members and available to the public upon request to the Executive Director of MARAMA. As noted in Section A.5.7 INPUT VARIABLES (ertac_input_variables_v2.csv) and Section A.5.9 TOOL CALCULATION APPROACH, this run uses the hourly methodology for emission rate and heat rate calculations and uses HIZG set to True in the input variables file for all units. This methodology leaves intact emission rates and heat rates that may be affected by unit upset, malfunction, start up, shutdown, and variations in control applications or feedstock.

A.6.2 PROJECTION YEAR OUTPUTS

Outputs for the C3.0CONUSv22.0 work are available for years 2026, 2032, and 2038. These projection runs were created with the default calculation methodology using annual average data for SO_2 emission rates and heat rates and using ozone season/non ozone season average data for NO_X emission rates. These runs also set HIZG to FALSE for all units except those with fuel-unit types of Industrial, Institutional, and ERTAC-EGU. These outputs have the following nomenclature:

- C3.0CONUSv22.0_2026,
- C3.0CONUSv22.0_2032, and
- C3.0CONUSv22.0_2038.

These C3.0CONUSv22.0 reference runs comply with the Revised CSAPR Update (86 FR 23054). Analyses by Emily Bull and Jenny Roelke of MDE demonstrated that 2026 emissions respected the estimated budgets in this rule.

These runs do not include the impacts of the Federal “Good Neighbor Plan” for the 2015 Ozone National Ambient Air Quality Standards (88 FR 36654) and do not include the impacts of the 2024 Clean Air Act §111(d) EGU rules (89 FR 39798). At the time of input file development, the status of litigation and other aspects of these rulemakings were unclear.

A.6.3 ERTAC_for_SMOKE

The ERTAC_for_SMOKE post processor, developed by Joseph Jakuta of the D.C. DOEE, was used to create ff10 inventory files for air quality modeling purposes. Pollutants observed and recorded in the CAPD CEM data set include NOx, SO_2, and CO_2. Other pollutants, such as carbon monoxide (CO), ammonia (NH_3), particulate matter with a diameter of no more than 10 micrometers (µm) (PM_{10}), particulate matter with a diameter of no more than 2.5 µm ($PM_{2.5}$), and volatile organic compounds (VOC), are needed for air quality modeling. Stack characteristics are also needed for air quality modeling.

In the ERTAC platform, other pollutants (CO, NH_3, PM_{10}, $PM_{2.5}$, and VOC) are estimated by first comparing NOx in the ERTAC CAMD data with NOx in EPA's 2022 base year Emissions Modeling Platform (EMP), on the assumption that in the base year both platforms use NOx from the CAPD CEM dataset for a majority of units reporting CEM data under 40 CFR 75. If differences in NOx between the two platforms are within ±10%, emission rates (lbs/mmbtu) of

CO, NH_3, PM_{10}, $PM_{2.5}$, and VOC for those units are calculated by dividing EPA's emissions by ERTAC heat input. Quality assurance is done by deriving averages of emission rates for each state-fuel combination. If a unit's emission rate is within ±90% of the average rate for that fuel type in that state, the calculated rate is used. If the unit's emission rate is less than the 10th percentile emission rate, the 10th percentile emission rate is applied. If the unit's emission rate is more than the 90th percentile emission rate, the 90th percentile emission rate is applied. If the base year NO_X difference for an emissions unit between the two platforms falls outside ±10%, emissions for those units are estimated by internal defaults in ERTAC_for_SMOKE. States can provide their own emission rates, in which case, the provided rates will override estimated rates.

The ERTAC_for_SMOKE post processor requires three additional input files:

- ertac_pusp_info_file.csv - This file includes unit specific information such as EPA EIS identification information and stack characteristics.
- ertac_additional_variables.csv - This file includes stack characteristics that may be used for units without unit-specific information in the ertac_pusp_info_file.csv. Information is categorized by state and fuel-unit type.
- ertac_base_year_rates_and_additional_controls.csv - This file includes emission factors for VOC, CO, $PM_{2.5}$, $PM_{10,}$ and NH_3 for each unit. Data is categorized by ORIS code and Unit ID as well as start and end dates.

Two optional input files may be used with ERTAC_for_SMOKE. An optional file called ertac_rpo_listing.csv may be included to parse the results into separate files based on the states listed in each regional planning organization (RPO) within the file. This file was not used in C3.0CONUSv22.0 so that results are not parsed by RPO. All results are included in one file for each year. A second optional file called ertac_additional_smoke_headers.csv allows the user to include helpful information in the header lines of the ERTAC_for_SMOKE outputs. This file was used in C3.0CONUSv22.0 runs. Information inserted into the header lines includes the script run date, the code version, the dates of various input files, the projection year, the type of averaging used, whether HIZG was set to True or False, and the name of the run.

These emission factor data sets for VOC, CO, $PM_{2.5}$, $PM_{10,}$ and NH_3 were developed by Emily Bull and Jenny Roelke of MDE. The emission factor development depends heavily on the crosswalk between EIS identifiers and ORIS and Unit Identifiers. The crosswalk in the ertac_pusp_info_file and the emission factors in the ertac_base_year_rates_and_ additional_controls file were offered to states for review during the comment period.

A-7 SMOKE MODELING

After completing the ERTAC EGU tool and postprocessor runs, Sparce Matric Operator Kernel Emissions (SMOKE) modeling uses the ERTAC data sets to create inputs to the CMAQ and CAMx air quality models. The time scale of ERTAC-compatible outputs from CEMConvert is

Local Time, whereas outputs used by EPA from CEMConvert are Universal Time. As a result, SMOKE modeling for the two platforms differs. For ERTAC EGU runs, the OUTPUT_LOCAL_TIME parameter should be set to N (or default). Moreover, a SMOKE program, smkinv, should be revised and re-compiled prior to SMOKE modeling. These revisions and settings in SMOKE outlined here have previously been implemented in the 2016 platform with the consent of the EPA SMOKE developer. These settings should be strictly applied for the ERTAC platform to work correctly. Otherwise, an incorrect time shift will result.

Additional steps will be needed in situations where the base year is a leap year and the future analytic year is a non-leap year (both conditions must be met). For such cases, February 29 data is removed from the ERTAC platform for future year projections. This "calendar-year" practice is inconsistent with SMOKE processing where the future non-leap year should have the same number of days as the base leap year. If left untreated, temporal profiles are incorrectly shifted forward one day, causing a mismatch between base year and future year emission estimates. The mismatch affects the relative reduction factor calculation and date-sensitive episodic modeling. Solutions have been developed, including script fixes and a CMAQ fix (using next-day emissions). For C3.0CONUSv22.0, 2022 is not a leap year. Therefore, this mis-match problem will not exist, and no fix is necessary.

A-8 INTEGRATION OF ERTAC FILE SUBSTITUTIONS

The ERTAC process for the point source inventory involving Part 75 units requires certain revisions to the modeling platform provided by EPA for use in the ERTAC modeling platform. As **Table A-3** and **Table A-4** show, power generation units in the EPA modeling platform are grouped into two major categories for SMOKE modeling: EGUs with and without CEM data (ptegu sector) and all other industrial point sources (ptnonipm sector). The ERTAC platform also groups units into two major categories: EGUs with and without Part 75 data (ptertac) and all other industrial point sources (ptnonertac). While the categories for each platform are similar, differences in some of the unit-level categorizations lead to the need for the following revisions to the EPA modeling platform for use in the ERTAC modeling platform:

- Some Industrial, Institutional, and EGU-Other Part 75 reporters that are projected in ERTAC to preserve their hourly temporal profile data are in EPA's nonEGU file or EGUs without CEMS file. These sources are removed from the EPA files for the ERTAC platform so that their emissions are not double-counted.
- Some sources categorized as nonEGUs in the ERTAC platform, as they are not best grown by the ERTAC tool, are in EPA's ptegu sector. These sources are moved to the nonEGU file for the ERTAC platform so that their emissions are not excluded and are in the correct sector for analysis purposes.

In order to use the ERTAC inventory without excluding or double counting point source emissions, both the EPA ptegu and ptnonipm sectors must be replaced with the ERTAC ptertac and ptnonertac sectors. Separate runscripts and sectorlist files will be provided for SMOKE processing of the ERTAC sectors. **Table A-3** and **Table A-4** show the 2022 and 2026 EGU and nonegu file substitutions for ERTAC inventory use. EPA did not publish 2022 EMP 2032 and 2038 modeling and inventory files concurrently with the completion of the C3.0CONUSv22.0 effort. Only 2022 and 2026 data from the 2022 EMP were available. Therefore, these descriptions only include substitutions for the 2022 and 2026 modeling files.

Table A-3 *C3.0CONUSv22.0 EGU Point Source File Substitution*

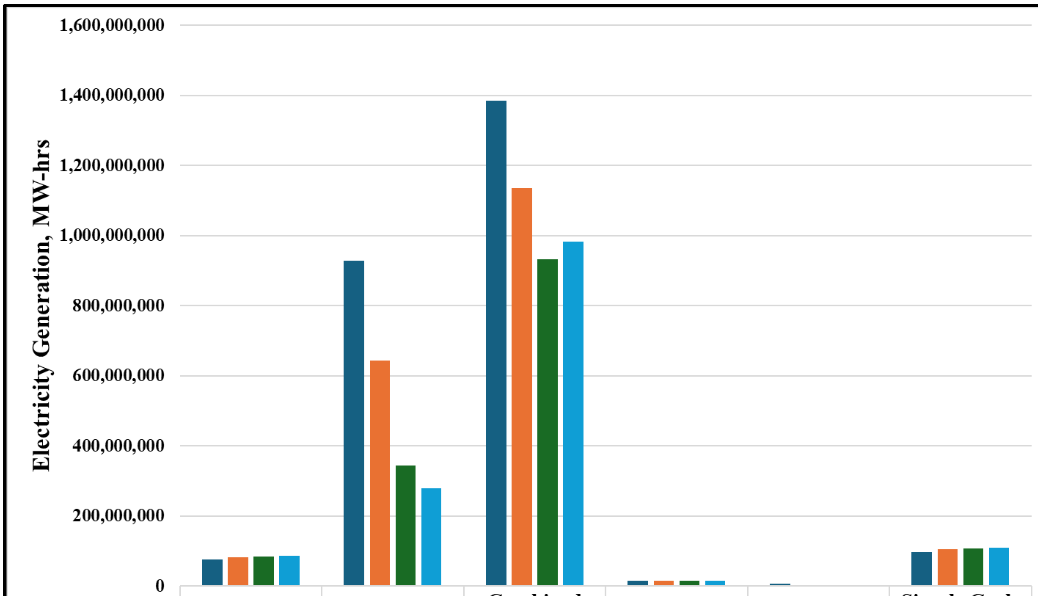
EPA ptegu sector – 2022 Base Year	ERTAC ptertac sector – 2022 Base Year
egu_cems_2022_POINT_20240615_2022cems_stackfix2_23jul2024_v0.csv pthour_01_2022_2022_2022cems_hourly.csv pthour_02_2022_2022_2022cems_hourly.csv pthour_03_2022_2022_2022cems_hourly.csv pthour_04_2022_2022_2022cems_hourly.csv pthour_05_2022_2022_2022cems_hourly.csv pthour_06_2022_2022_2022cems_hourly.csv pthour_07_2022_2022_2022cems_hourly.csv pthour_08_2022_2022_2022cems_hourly.csv pthour_09_2022_2022_2022cems_hourly.csv pthour_10_2022_2022_2022cems_hourly.csv pthour_11_2022_2022_2022cems_hourly.csv pthour_12_2022_2022_2022cems_hourly.csv pthour_12_2022_2022_2022cems_hourly.nexthour.csv egu_noncems_2022_POINT_20240615_2022cems_stackfix2_23jul2024_v0.csv	C3.0CONUSv22.0_BYFYHRLY_fs_ff10_future.csv C3.0CONUSv22.0_BYFYHRLY_fs_ff10_hourly_future.csv egu_noncems_2022_ERTAC_Platform_POINT_20240615_2022cems_stackfix2_23jul2024_v0_nf_v1.csv
EPA ptegu sector – 2026 Future Year	**ERTAC ptertac sector – 2026 FutureYear**
ptegu_2026hc_from_CEMconvert_03jan2025_v0.csv pthour_01_2022_2026hc_2022cems_hourly.csv pthour_02_2022_2026hc_2022cems_hourly.csv pthour_03_2022_2026hc_2022cems_hourly.csv pthour_04_2022_2026hc_2022cems_hourly.csv pthour_05_2022_2026hc_2022cems_hourly.csv pthour_06_2022_2026hc_2022cems_hourly.csv pthour_07_2022_2026hc_2022cems_hourly.csv pthour_08_2022_2026hc_2022cems_hourly.csv pthour_09_2022_2026hc_2022cems_hourly.csv pthour_10_2022_2026hc_2022cems_hourly.csv pthour_11_2022_2026hc_2022cems_hourly.csv pthour_12_2022_2026hc_2022cems_hourly.csv pthour_12_2022_2026hc_2022cems_nexthour.csv	C3.0CONUSv22.0_2026_fs_ff10_future.csv C3.0CONUSv22.0_2026_fs_ff10_hourly_future.csv ptegu_2026hc_ERTAC_Platform_from_CEMconvert_03jan2025_v0.csv

Table A-4 *C3.0CONUSv22.0 nonEGU Point Source File Substitution*

EPA ptnonipm sector – 2022 Base Year	ERTAC ptnonertac sector – 2022 Base Year
nonegu_norail_2022_POINT_20240615_stackfix2_23jul2024_v0.csv 2022v1_platform_railyards_2022_27jun2024_nf_v2.csv	nonegu_norail_2022_ERTAC_Platform_POINT_20240615_stackfix2_23jul2024_v0_v0_2_14may2025_nf_v1.csv 2022v1_platform_railyards_2022_27jun2024_nf_v2.csv
EPA ptnonipm sector – 2026 Future Year	**ERTAC ptnonertac sector – 2026 Future Year**
2026proj_2022v1_platform_railyards_2022_20dec2024_nf_v1.csv 2026proj_v1final_from_egu_to_nonegu_2022_POINT_20240801_02jan2025_v0.csv 2026proj_v1final_nonegu_norail_2022_POINT_20240615_stackfix2_02jan2025_nf_v1.csv	2026proj_v1final_nonegu_norail_2022_ERTAC_Platform_POINT_20240615_stackfix2_02jan2025_nf_v1_01may2025.csv 2026proj_2022v1_platform_railyards_2022_20dec2024_nf_v1.csv

A-9 EMISSIONS SUMMARIES

Figure A-4 provides the national generation by fuel-unit type for year 2022 and for ERTAC projection years 2026, 2032, and 2038. Trends show a reduction in coal-fired energy production, some reduction in energy production from combined cycle units, and small increases in energy production from other types of units.



	Boiler Gas	Coal	Combined Cycle Gas	EGU-Other	Oil	Simple Cycle Gas
2022	76,603,288	927,828,710	1,384,329,328	15,913,905	7,389,327	96,336,249
2026	81,509,570	644,281,621	1,136,128,351	15,913,905	2,848,831	105,369,445
2032	84,923,385	343,927,162	933,155,965	15,913,905	1,487,629	108,063,540
2038	85,521,299	278,399,841	982,572,937	15,913,905	1,190,701	109,533,668

Figure A-4 *National Generation by Fuel-Unit Type (MW-Hrs) for Base Year and Projection Years*

Figure A-5 and **Figure A-6** provide NO_X and SO_2 emissions, respectively, as derived from the ERTAC tool using the C3.0CONUSv22.0 inputs. These emissions estimates include all units in the ERTAC input files, including those identified with Industrial and Institutional fuel-unit types. Data in **Figure A-5** and **Figure A-6** are shown in **Table A-5**.

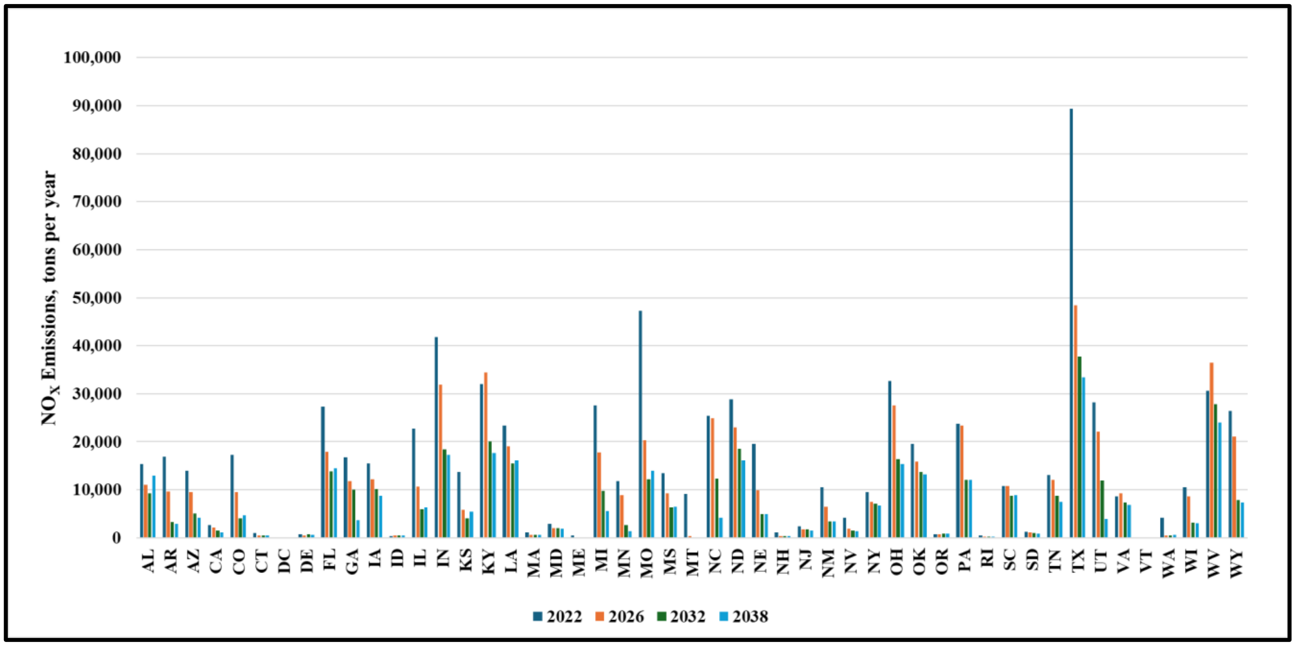


Figure A-5 *NO_X Emissions by State and Year for C3.0CONUSv22.0 Outputs (tons/year)*

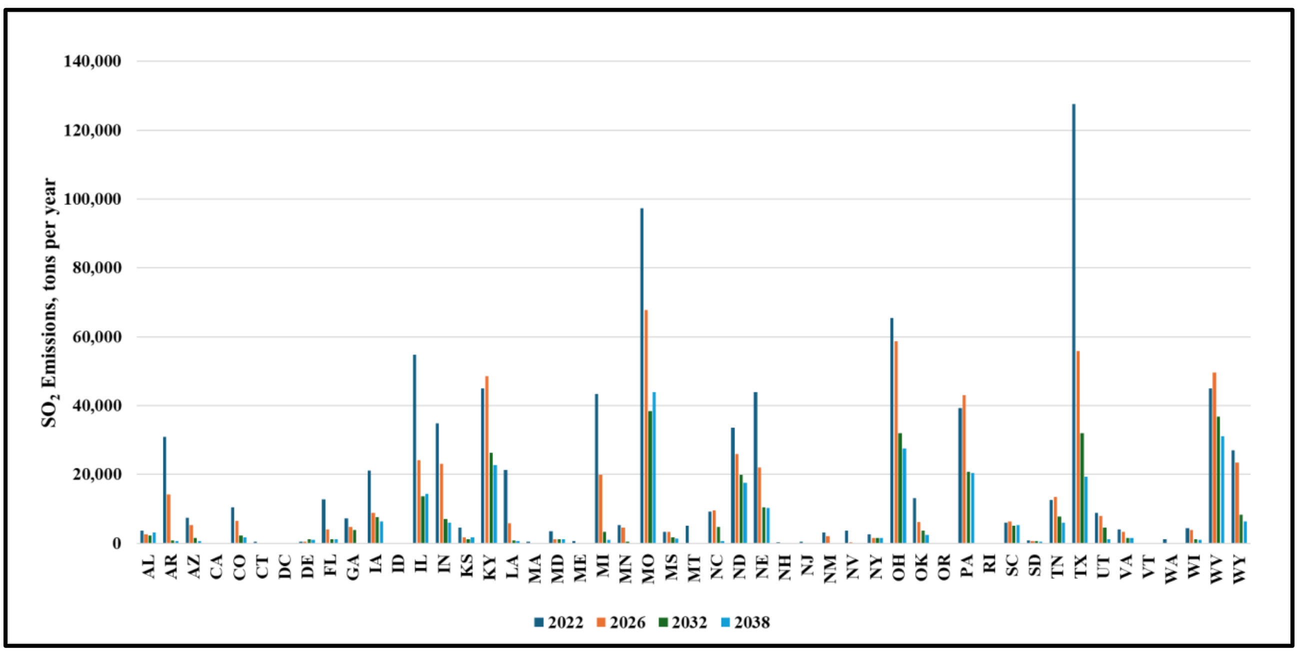


Figure A-6 *SO_2 Emissions by State and Year for C3.0CONUSv22.0 Outputs (tons/year)*

Table A-5 *NO_X and SO_2 Annual Emissions (tons/year) by State, C3.0CONUSv22.0*

State	2022 NO_X	2026 NO_X	2032 NO_X	2038 NO_X	2022 SO_2	2026 SO_2	2032 SO_2	2038 SO2
AL	15,405	11,047	9,299	12,990	3,719	2,549	2,229	3,203
AR	16,898	9,665	3,221	2,919	30,917	14,285	892	658
AZ	13,974	9,442	5,107	4,150	7,372	5,311	1,607	732
CA	2,591	2,068	1,545	1,152	199	148	106	74
CO	17,273	9,480	4,071	4,653	10,402	6,468	2,233	1,791
CT	1,007	473	440	457	570	147	154	158
DC	50	50	50	50	0	0	0	0
DE	703	535	700	657	458	502	1,204	1,101
FL	27,298	17,861	13,845	14,515	12,784	4,116	1,208	1,242
GA	16,695	11,823	9,993	3,607	7,331	4,702	3,899	220
IA	15,460	12,132	10,142	8,697	21,073	8,884	7,627	6,437
ID	380	428	438	439	10	10	10	10
IL	22,703	10,667	5,958	6,378	54,778	24,153	13,677	14,371
IN	41,773	31,913	18,387	17,219	34,830	23,110	7,031	6,073
KS	13,667	5,868	4,044	5,491	4,505	1,789	1,204	1,754
KY	32,014	34,451	20,117	17,602	45,024	48,568	26,288	22,813
LA	23,358	19,074	15,516	16,068	21,292	5,907	812	700
MA	1,175	634	608	624	564	151	159	162
MD	2,911	1,968	1,956	1,901	3,597	1,236	1,220	1,212
ME	442	132	121	126	656	11	11	11
MI	27,582	17,827	9,772	5,535	43,400	19,822	3,251	992
MN	11,785	8,894	2,645	1,360	5,354	4,511	486	152
MO	47,316	20,288	12,167	13,908	97,395	67,709	38,439	43,853
MS	13,508	9,284	6,359	6,446	3,255	3,398	1,656	1,383
MT	9,170	346	117	117	5,155	137	3	3
NC	25,384	24,931	12,271	4,217	9,169	9,580	4,753	639
ND	28,851	23,032	18,480	16,067	33,607	25,947	19,982	17,585
NE	19,613	9,922	4,955	4,948	43,939	22,064	10,380	10,339
NH	1,063	351	338	342	316	24	23	23
NJ	2,329	1,730	1,740	1,549	562	73	75	68
NM	10,559	6,480	3,373	3,429	3,234	2,158	18	19
NV	4,102	1,848	1,442	1,349	3,677	239	172	101
NY	9,476	7,493	7,062	6,747	2,625	1,549	1,493	1,478
OH	32,619	27,620	16,412	15,338	65,456	58,662	32,017	27,603
OK	19,554	15,899	13,703	13,208	13,153	6,142	3,639	2,505
OR	726	753	801	886	37	43	48	57
PA	23,707	23,324	12,098	12,083	39,250	42,974	20,705	20,484
RI	440	217	185	195	17	8	7	7
SC	10,720	10,838	8,758	8,928	6,005	6,286	5,152	5,270
SD	1,186	1,060	985	865	784	706	641	536
TN	13,018	12,000	8,728	7,493	12,561	13,458	7,876	5,947
TX	89,336	48,349	37,794	33,378	127,666	55,926	32,046	19,287
UT	28,166	22,033	11,873	3,877	8,880	7,967	4,633	1,253
VA	8,651	9,233	7,357	6,798	3,990	3,380	1,539	1,560
VT	140	125	125	125	1	1	1	1
WA	4,212	490	498	557	1,129	50	51	56

State	2022 NO_X	2026 NO_X	2032 NO_X	2038 NO_X	2022 SO_2	2026 SO_2	2032 SO_2	2038 SO2
WI	10,519	8,646	3,101	3,074	4,400	3,866	1,192	1,034
WV	30,557	36,473	27,766	23,990	45,068	49,564	36,823	31,106
WY	26,435	21,070	7,871	7,390	27,026	23,496	8,357	6,441

Appendix B: Emission Inventory Files

This section lists the emission inventory sectors and corresponding SMOKE input files that were used for developing the version 1 model ready emissions used in air quality modeling for the base year of 2022 and analytical year 2026.

Fugitive Dust (afdust)

2022

2022hc_proj_afdust_2020NEI_NONPOINT_20230222_17jun2024_v1.csv

2026

2026proj2_2022hc_proj_afdust_2020NEI_NONPOINT_20230222_30dec2024_v0.csv

Airports (airports)

2022

2022proj_airports_2022_point_20240626_top51_adjusted_26jun2024_v0.csv

2026

2026hc_proj_airports_2022_point_20240626_top51_adjusted_ATL_data_18aug2024_v0.csv

Fugitive Dust - Canada (canada_afdust)

2022

canada_BAU19_2022interp_I041_area_dust_12jun2024_v0.csv
canada_BAU19_2022interp_I041_area_livestock_cattle_12jun2024_nf_v2.csv
canada_BAU19_2022interp_I041_area_livestock_other_12jun2024_nf_v2.csv
canada_BAU19_2022interp_I041_area_livestock_poultry_12jun2024_nf_v2.csv
canada_BAU19_2022interp_I041_area_tillage_harvest_12jun2024_v0.csv

2026

canada_BAU19_2026_I041_area_dust_06nov2024_v0.csv
canada_BAU19_2026_I041_area_livestock_cattle_27nov2024_nf_v2.csv
canada_BAU19_2026_I041_area_livestock_other_27nov2024_nf_v2.csv
canada_BAU19_2026_I041_area_livestock_poultry_27nov2024_nf_v2.csv
canada_BAU19_2026_I041_area_tillage_harvest_06nov2024_v0.csv
canada_og2D
canada_BAU19_2022interp_I041_point_UOG_12jun2024_nf_v1.csv

canada_BAU19_2026_I041_point_UOG_27nov2024_nf_v1.csv

Onroad - Canada (canada_onroad)

2022

canada_BAU19_2022interp_I041_T3_onroad_monthly_12jun2024_v0.csv
canada_BAU19_2022interp_I041_T3_onroad_refueling_12jun2024_v0.csv

2026

canada_BAU19_2026_I041_T3_onroad_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_T3_onroad_refueling_06nov2024_v0.csv

Fugitive Dust Point - Canada (canada_ptdust)

2022

canada_BAU19_2022interp_I041_point_dust_monthly_12jun2024_v0.csv

2026

canada_BAU19_2026_I041_point_dust_monthly_06nov2024_v0.csv

Agricultural – Canada & Mexico (canmex_ag)

2022

2019ge_proj_CEDS_from_Mexico_2016INEM_nonpoint_04jan2024_nf_v6.csv
Mexico_2022_area_20240615_borderstates_15jun2024_nf_v3.csv
canada_BAU19_2022interp_I041_area_fertilizer_12jun2024_v0.csv
canada_BAU19_2022interp_I041_area_livestock_cattle_12jun2024_nf_v1.csv
canada_BAU19_2022interp_I041_area_livestock_other_12jun2024_nf_v1.csv
canada_BAU19_2022interp_I041_area_livestock_poultry_12jun2024_nf_v1.csv

2026

2019ge_proj_CEDS_from_Mexico_2016INEM_nonpoint_04jan2024_nf_v6.csv
Mexico_2022_area_20240615_borderstates_15jun2024_nf_v3.csv
canada_BAU19_2026_I041_area_fertilizer_06nov2024_v0.csv
canada_BAU19_2026_I041_area_livestock_cattle_27nov2024_nf_v1.csv
canada_BAU19_2026_I041_area_livestock_other_27nov2024_nf_v1.csv
canada_BAU19_2026_I041_area_livestock_poultry_27nov2024_nf_v1.csv

Area Source – Canada & Mexico (canmex_area)

2022

2019ge_proj_CEDS_from_Mexico_2016INEM_nonpoint_04jan2024_nf_v7.csv
2019ge_proj_CEDS_from_Mexico_2016INEM_nonroad_04jan2024_nf_v1.csv
Mexico_2022_area_20240615_borderstates_15jun2024_nf_v2.csv
Mexico_2022_nonroad_20240615_borderstates_15jun2024_nf_v1.csv
canada_BAU19_2022interp_I041_T4_nonroad_monthly_12jun2024_v0.csv
canada_BAU19_2022interp_I041_T5_rail_12jun2024_nf_v1.csv
canada_BAU19_2022interp_I041_area_EPG_12jun2024_v0.csv
canada_BAU19_2022interp_I041_area_RWC_12jun2024_v0.csv
canada_BAU19_2022interp_I041_area_UOG_12jun2024_v0.csv
canada_BAU19_2022interp_I041_area_other_12jun2024_v0.csv

2026

2019ge_proj_CEDS_from_Mexico_2016INEM_nonpoint_04jan2024_nf_v7.csv
2019ge_proj_CEDS_from_Mexico_2016INEM_nonroad_04jan2024_nf_v1.csv
Mexico_2022_area_20240615_borderstates_15jun2024_nf_v2.csv
Mexico_2022_nonroad_20240615_borderstates_15jun2024_nf_v1.csv
canada_BAU19_2026_I041_T4_nonroad_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_T5_rail_27nov2024_nf_v1.csv
canada_BAU19_2026_I041_area_EPG_06nov2024_v0.csv
canada_BAU19_2026_I041_area_RWC_06nov2024_v0.csv
canada_BAU19_2026_I041_area_UOG_06nov2024_v0.csv
canada_BAU19_2026_I041_area_other_06nov2024_v0.csv

Point Sources – Canada & Mexico (canmex_point)

2022

2019ge_proj_CEDS_from_Mexico_2016_point_20191209_04jan2024_nf_v4.csv
Mexico_2022_point_20240615_borderstates_15jun2024_nf_v1.csv
canada_BAU19_2022interp_I041_T1_airports_monthly_12jun2024_v0.csv
canada_BAU19_2022interp_I041_point_CB6VOC_monthly_12jun2024_v0.csv
canada_BAU19_2022interp_I041_point_UOG_12jun2024_nf_v2.csv
canada_BAU19_2022interp_I041_point_VOC_monthly_12jun2024_v0.csv
canada_BAU19_2022interp_I041_point_nodust_noVOC_monthly_12jun2024_v0.csv
canada_BAU19_2023_I041_point_EPG_monthly_18dec2023_v0.csv

2026

2019ge_proj_CEDS_from_Mexico_2016_point_20191209_04jan2024_nf_v4.csv
Mexico_2022_point_20240615_borderstates_15jun2024_nf_v1.csv
canada_BAU19_2026_I041_T1_airports_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_point_CB6VOC_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_point_EPG_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_point_UOG_27nov2024_nf_v2.csv
canada_BAU19_2026_I041_point_VOC_monthly_06nov2024_v0.csv
canada_BAU19_2026_I041_point_nodust_noVOC_monthly_06nov2024_v0.csv

Continuous emission monitoring – used with ptegu (cem)

2022

pthour_01_2022_2022_2022cems_20240615_hourly.csv
pthour_02_2022_2022_2022cems_20240615_hourly.csv
pthour_03_2022_2022_2022cems_20240615_hourly.csv
pthour_04_2022_2022_2022cems_20240615_hourly.csv
pthour_05_2022_2022_2022cems_20240615_hourly.csv
pthour_06_2022_2022_2022cems_20240615_hourly.csv
pthour_07_2022_2022_2022cems_20240615_hourly.csv
pthour_08_2022_2022_2022cems_20240615_hourly.csv
pthour_09_2022_2022_2022cems_20240615_hourly.csv
pthour_10_2022_2022_2022cems_20240615_hourly.csv
pthour_11_2022_2022_2022cems_20240615_hourly.csv
pthour_12_2022_2022_2022cems_20240615_hourly.csv
pthour_12_2022_2022_2022cems_20240615_nexthour.csv

2026

pthour_01_2022_2026hc_2022cems_hourly.csv
pthour_02_2022_2026hc_2022cems_hourly.csv
pthour_03_2022_2026hc_2022cems_hourly.csv
pthour_04_2022_2026hc_2022cems_hourly.csv
pthour_05_2022_2026hc_2022cems_hourly.csv
pthour_06_2022_2026hc_2022cems_hourly.csv
pthour_07_2022_2026hc_2022cems_hourly.csv
pthour_08_2022_2026hc_2022cems_hourly.csv
pthour_09_2022_2026hc_2022cems_hourly.csv
pthour_10_2022_2026hc_2022cems_hourly.csv
pthour_11_2022_2026hc_2022cems_hourly.csv
pthour_12_2022_2026hc_2022cems_hourly.csv
pthour_12_2022_2026hc_2022cems_nexthour.csv

Commercial Marine Vessels – Category 1 & 2 (cmv_c1c2_12)

2022

cmv_C1C2_01_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_01_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_01_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv

cmv_C1C2_05_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_05_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_05_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_06_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_06_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_06_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_nexthour.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_nexthour.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_nexthour.csv
cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_annual_11jul2024_v0.csv
cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_annual_11jul2024_v0.csv
cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_annual_11jul2024_v0.csv

2026

2026proj_from_cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_US_annual_19aug2024_v0.csv
cmv_C1C2_01_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_01_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_01_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_02_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_03_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_04_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_05_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_05_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_05_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_06_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv

cmv_C1C2_06_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_06_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_07_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_08_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_09_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_10_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_11_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_2026proj_gapfilled_masked_12US1_2022_US_nexthour.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_nexthour.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C1C2_12_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_nexthour.csv
cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_CA_annual_11jul2024_v0.csv
cmv_C1C2_cmv_c1c2_2022_gapfilled_masked_12US1_2022_MX_annual_11jul2024_v0.csv

Commercial Marine Vessels – Category 3 (cmv_c3_12)

2022

cmv_C3_01_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_01_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_01_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_02_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_02_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_02_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_03_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_03_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_03_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_04_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_04_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_04_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_05_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_05_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_05_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_06_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_06_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_06_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv

cmv_C3_07_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_07_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_07_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_08_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_08_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_08_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_09_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_09_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_09_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_10_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_10_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_10_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_11_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_11_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_11_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_nexthour.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_nexthour.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_US_nexthour.csv
cmv_C3_cmv_c3_2022_gapfilled_3PR1_2022_US_annual_18jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_annual_11jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_annual_11jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_US_annual_11jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_36US3_2022_CA_annual_28jun2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_36US3_2022_MX_annual_28jun2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_36US3_2022_US_annual_28jun2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_3HI1_2022_US_annual_22jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_3PR1_2022_US_annual_22jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_9AK1_2022_CA_annual_19jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_9AK1_2022_US_annual_19jul2024_v0.csv

2026

2026proj_from_cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_US_annual_19aug2024_v0.csv
cmv_C3_01_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_01_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_01_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_02_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_02_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_02_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_03_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_03_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_03_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_04_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_04_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_04_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_05_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_05_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv

cmv_C3_05_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_06_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_06_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_06_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_07_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_07_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_07_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_08_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_08_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_08_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_09_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_09_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_09_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_10_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_10_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_10_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_11_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_11_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_11_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_12_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_hourly.csv
cmv_C3_12_cmv_c3_2022_2026proj_gapfilled_masked_12US1_2022_US_nexthour.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_nexthour.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_hourly.csv
cmv_C3_12_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_nexthour.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_CA_annual_11jul2024_v0.csv
cmv_C3_cmv_c3_2022_gapfilled_masked_12US1_2022_MX_annual_11jul2024_v0.csv

Agricultural emissions (fertilizer)

2022

2022hc_fertilizer_NH3_monthly_postCMAQ_17sep2024_v0.csv

Agricultural emissions (livestock)

2022

2022hc_proj_nonFEM_livestock_2020NEI_NONPOINT_20230222_daily_14jun2024_v0.csv
2022hc_proj_nonFEM_livestock_2020NEI_NONPOINT_20230222_monthly_14jun2024_v0.cs
v
livestock_2022hc_FEM_daily_14jun2024_v0.csv
livestock_2022hc_FEM_monthly_14jun2024_v0.csv
livestock_2022hc_daily_prevdec_14jun2024_v0.csv

2026

2026proj2_2022hc_proj_nonFEM_livestock_2020NEI_NONPOINT_20230222_daily_02jan202
5_v0.csv

2026proj2_2022hc_proj_nonFEM_livestock_2020NEI_NONPOINT_20230222_monthly_31dec2024_v1.csv
2026proj2_livestock_2022hc_FEM_daily_02jan2025_v0.csv
2026proj2_livestock_2022hc_FEM_monthly_31dec2024_v1.csv
2026proj2_livestock_2022hc_daily_prevdec_02jan2025_v0.csv

Onroad – Mexico (mexico_onroad)

2022

Mexico_2022interp_onroad_MOVES_12jun2024_v0.csv

2026

Mexico_2026interp_onroad_MOVES_aggSCC_13jul2021_v0.csv

Area Source (nonpt)

2022

2022hc_proj_2020NEI_NONPOINT_20230222_15jun2024_nf_v1.csv

2026
2026proj2_2022hc_proj_2020NEI_NONPOINT_20230222_31dec2024_v1.csv

Off road (nonroad)

2022

nonroad_ff10_2022hc_MOVES_ROC_AE6_13mar2024_v1.csv
2022proj_from_2020NEI_california_nonroad_for_SMOKE_24jan2024_nf_v1.csv

2026

nonroad_ff10_2026hc_MOVES_ROC_AE6_04dec2024_nf_v2.csv
2026proj_from_2020NEI_california_nonroad_for_SMOKE_11dec2024_nf_v1.csv

Oil & Gas – Area (np_oilgas)

2022

2022hc_np_oilgas_Colorado_25jun2024_nf_v2.csv
2022hc_np_oilgas_OGTool_14jun2024_nf_v2.csv
2022hc_np_oilgas_OGTool_TXupdate_14jun2024_nf_v1.csv
2022hc_np_oilgas_Pennsylvania_01apr2024_v0.csv
2022hc_np_oilgas_abandoned_wells_all_wHAPs_14jun2024_v0.csv
2022hc_np_oilgas_blowdown_pigging_02apr2024_v0.csv
2022hc_proj_np_oilgas_2020NEI_NONPOINT_20230222_OK_WY_production_03apr2024_nf_v1.csv

2022hc_np_oilgas_abandoned_wells_all_wHAPs_14jun2024_v0.csv

2026

2026hc_proj_2022hc_np_oilgas_Colorado_04dec2024_v0.csv
2026hc_proj_2022hc_np_oilgas_OGTool_04dec2024_v0.csv
2026hc_proj_2022hc_np_oilgas_OGTool_TXupdate_10dec2024_nf_v1.csv
2026hc_proj_2022hc_np_oilgas_Pennsylvania_04dec2024_v0.csv
2026hc_proj_2022hc_np_oilgas_blowdown_pigging_04dec2024_v0.csv
2026hc_proj_2022hc_np_oilgas_exploration_analytic_FUTURE1A_COsub_PAsub_04dec2024_v0.csv
2026hc_proj_2022hc_proj_np_oilgas_2020NEI_NONPOINT_20230222_OK_WY_production_04dec2024_v0.csv

Solvent – Area (np_solvents)

2022

np_solvents_2022v1_20240221_12mar2024_v0.csv
np_solvents_2022v1_20240221_HAPs_14jun2024_nf_v1.csv

2026

2026proj2_np_solvents_2022v1_20240221_31dec2024_v1.csv
2026proj2_np_solvents_2022v1_20240221_HAPs_31dec2024_v1.csv

Mobile (onroad)

2022

2022hc_onroad_SMOKE_MOVES_MOVES4_forAQ_27jun2024_v0.csv
HOTELING_2022v1_monthly_20240305_18jun2024_nf_v5.csv
ONI_2022v1_projected_from_full_annual_20240226_monthly_18jun2024_nf_v5.csv
SPEED_2017NEI_from_CDBs_MOVES3_fuels_dummy_07nov2022_v1.csv
STARTS_2022v1_monthly_20240301_18jun2024_nf_v5.csv
VMT_2022v1_full_annual_20240226_monthly_18jun2024_nf_v4.csv
VPOP_2022v1_full_annual_20240301_18jun2024_nf_v6.csv

2026

2026hc_onroad_SMOKE_MOVES_MOVES4_forAQ_09dec2024_v0.csv
HOTELING_2022v1_2026hc_MOVES4_19nov2024_nf_v3.csv
HOTELING_2022v1_dummy_bug_workaround_30jul2024_v0.csv
ONI_2022v1_2026hc_MOVES4_full_19nov2024_nf_v3.csv
SPEED_2017NEI_from_CDBs_MOVES3_fuels_dummy_07nov2022_v1.csv
STARTS_2022v1_2026hc_monthly_MOVES4_19nov2024_nf_v3.csv
VMT_2022v1_2026hc_MOVES4_full_19nov2024_nf_v4.csv
VPOP_2022v1_2026hc_MOVES4_19nov2024_nf_v4.csv

Mobile – California (onroad_ca_adj)

2022

HOTELING_2022v1_monthly_20240305_26apr2024_v2.csv
ONI_2022v1_projected_from_full_annual_20240226_monthly_26apr2024_v2.csv
SPEED_2017NEI_from_CDBs_MOVES3_fuels_dummy_06nov2023_nf_v4.csv
STARTS_2022v1_monthly_20240301_26apr2024_v2.csv
VMT_2022v1_full_annual_20240226_monthly_26apr2024_v2.csv
VPOP_2022v1_full_annual_20240301_26apr2024_v2.csv

2026

HOTELING_2022v1_2026hc_MOVES4_24jul2024_nf_v2.csv
ONI_2022v1_2026hc_MOVES4_full_24jul2024_nf_v2.csv
SPEED_2017NEI_from_CDBs_MOVES3_fuels_dummy_06nov2023_nf_v4.csv
STARTS_2022v1_2026hc_monthly_MOVES4_24jul2024_nf_v2.csv
VMT_2022v1_2026hc_MOVES4_full_24jul2024_nf_v3.csv
VPOP_2022v1_2026hc_MOVES4_24jul2024_nf_v3.csv

Open burning – nonpoint (openburn)

openburn_2022hc_proj_2020NEI_NONPOINT_20230222_15jun2024_v0.csv

openburn_2022hc_proj_2020NEI_NONPOINT_20230222_15jun2024_v0.csv

Oil & Gas – Point (pt_oilgas)

2022

cy2020_proj2022_oilgas_2022_POINT_20240615_stackfix2_23jul2024_v0.csv
cy2021_proj2022_oilgas_2022_POINT_20240615_stackfix2_23jul2024_v0.csv
cy2022_oilgas_2022_POINT_20240615_stackfix2_23jul2024_v0.csv

2026

2026hc_proj_NDfix_cy2020_proj2022_oilgas_2022_POINT_20240615_stackfix2_17dec2024_v0.csv
2026hc_proj_NDfix_cy2021_proj2022_oilgas_2022_POINT_20240615_stackfix2_17dec2024_v0.csv
2026hc_proj_NDfix_cy2022_oilgas_2022_POINT_20240615_stackfix2_17dec2024_v0.csv

Agricultural burning (ptagfire)

2022

ptday_agburn_2022v1_all_state_data_02jul2024_v0
ptday_agburn_2022v1_conus_filtered_02jul2024_v0

ptday_agburn_2022v1_prevdec_02jul2024_v0
ptinv_agburn_2022v1_all_state_data_02jul2024_v0.csv
ptinv_agburn_2022v1_conus_filtered_02jul2024_v0.csv

2026

ptday_agburn_2022v1_all_state_data_02jul2024_v0
ptday_agburn_2022v1_conus_filtered_02jul2024_v0
ptday_agburn_2022v1_prevdec_02jul2024_v0
ptinv_agburn_2022v1_all_state_data_02jul2024_v0.csv
ptinv_agburn_2022v1_conus_filtered_02jul2024_v0.csv

Point Source – Electric Generating EPA (ptegu)

2022

egu_cems_2022_POINT_20240615_2022cems_stackfix2_23jul2024_v0.csv
egu_noncems_2022_POINT_20240615_2022cems_stackfix2_23jul2024_v0.csv

2026

ptegu_2026hc_from_CEMconvert_03jan2025_v0.csv

Point Source – Electric Generating ERTAC (ptertac)

2022

C3.0CONUSv22.0_BYFYHRLY-7_fs_ff10_future.csv
C3.0CONUSv22.0_BYFYHRLY-7_fs_ff10_hourly_future.csv
egu_noncems_2022_ERTAC_Platform_POINT_20240615_2022cems_stackfix2_23jul2024_v0_nf_v1.csv

2026

C3.0CONUSv22.0_2026_fs_ff10_future.csv
C3.0CONUSv22.0_2026_fs_ff10_hourly_future.csv
ptegu_2026hc_ERTAC_Platform_from_CEMconvert_03jan2025_v0.csv

Prescribed fires (ptfire-rx)

2022

ptday_2022hc_ptfire_rx_prevdec_09jul2024_v0
ptday_flint_hills_fires_2022_beta_ff10_15mar2024_v0
ptday_idaho_ditch_fires_2022v1_rx_08jul2024_v1
ptday_midwest_crops_fires_2022v1_rx_08jul2024_v0
ptday_pile_burn_2022v1_02aug2024_nf_v1
ptday_sf2_2022v1_20240626_caps_rx_08jul2024_v0
ptday_sf2_2022v1_20240626_haps_rx_08jul2024_v0

ptinv_flint_hills_fires_2022_beta_ff10_02apr2024_v0.csv
ptinv_idaho_ditch_fires_2022v1_rx_08jul2024_v1.csv
ptinv_midwest_crops_fires_2022v1_rx_08jul2024_v0.csv
ptinv_pile_burn_2022v1_02aug2024_nf_v1.csv
ptinv_sf2_2022v1_20240626_caps_rx_08jul2024_v0.csv
ptinv_sf2_2022v1_20240626_haps_rx_08jul2024_v0.csv
ptday_2022hc_ptfire_rx_prevdec_09jul2024_v0
ptday_flint_hills_fires_2022_beta_ff10_15mar2024_v0
ptday_idaho_ditch_fires_2022v1_rx_08jul2024_v1
ptday_midwest_crops_fires_2022v1_rx_08jul2024_v0
ptday_pile_burn_2022v1_02aug2024_nf_v1
ptday_sf2_2022v1_20240626_caps_rx_08jul2024_v0
ptday_sf2_2022v1_20240626_haps_rx_08jul2024_v0
ptinv_flint_hills_fires_2022_beta_ff10_02apr2024_v0.csv
ptinv_idaho_ditch_fires_2022v1_rx_08jul2024_v1.csv
ptinv_midwest_crops_fires_2022v1_rx_08jul2024_v0.csv
ptinv_pile_burn_2022v1_02aug2024_nf_v1.csv
ptinv_sf2_2022v1_20240626_caps_rx_08jul2024_v0.csv
ptinv_sf2_2022v1_20240626_haps_rx_08jul2024_v0.csv

Wildfires (ptfire-wild)

2022

ptday_2022hc_ptfire_wf_prevdec_09jul2024_v0
ptday_idaho_ditch_fires_2022v1_wf_02jul2024_v0
ptday_midwest_crops_fires_2022v1_wf_08jul2024_v0
ptday_sf2_2022v1_20240802_caps_wf_02aug2024_v0
ptday_sf2_2022v1_20240802_haps_wf_02aug2024_v0
ptinv_idaho_ditch_fires_2022v1_wf_02jul2024_v0.csv
ptinv_midwest_crops_fires_2022v1_wf_08jul2024_v0.csv
ptinv_sf2_2022v1_20240802_caps_wf_02aug2024_v0.csv
ptinv_sf2_2022v1_20240802_haps_wf_02aug2024_v0.csv
ptday_2022hc_ptfire_wf_prevdec_09jul2024_v0
ptday_idaho_ditch_fires_2022v1_wf_02jul2024_v0
ptday_midwest_crops_fires_2022v1_wf_08jul2024_v0
ptday_sf2_2022v1_20240802_caps_wf_02aug2024_v0
ptday_sf2_2022v1_20240802_haps_wf_02aug2024_v0
ptinv_idaho_ditch_fires_2022v1_wf_02jul2024_v0.csv
ptinv_midwest_crops_fires_2022v1_wf_08jul2024_v0.csv
ptinv_sf2_2022v1_20240802_caps_wf_02aug2024_v0.csv
ptinv_sf2_2022v1_20240802_haps_wf_02aug2024_v0.csv

Prescribed fires – Non US, North America (ptfire_othna)

2022

prevdec_ptday_2022hc_canada_fires_all_30jun2024_v0
ptday_finn_MX_finn_2022_ff10_15jun2024_v0
ptday_finn_MX_finn_2022_ff10_prevdec_18jun2024_v0
ptday_finn_ONA_finn_2022_ff10_15jun2024_v0
ptday_finn_ONA_finn_2022_ff10_prevdec_18jun2024_v0
ptday_pile_burn_2022_canada_ff10_17jun2024_v0
ptday_sf2_2022_fbp_canada_boreal_bsp_ff10_30jun2024_v0
ptday_sf2_2022_fbp_canada_boreal_bsp_haps_ff10_30jun2024_v0
ptinv_finn_MX_finn_2022_ff10_15jun2024_v0.csv
ptinv_finn_ONA_finn_2022_ff10_15jun2024_v0.csv
ptinv_pile_burn_2022_canada_ff10_17jun2024_v0.csv
ptinv_sf2_2022_fbp_canada_boreal_bsp_30jun2024_v0.csv
ptinv_sf2_2022_fbp_canada_boreal_bsp_haps_30jun2024_v0.csv
prevdec_ptday_2022hc_canada_fires_all_30jun2024_v0
ptday_finn_MX_finn_2022_ff10_15jun2024_v0
ptday_finn_MX_finn_2022_ff10_prevdec_18jun2024_v0
ptday_finn_ONA_finn_2022_ff10_15jun2024_v0
ptday_finn_ONA_finn_2022_ff10_prevdec_18jun2024_v0
ptday_pile_burn_2022_canada_ff10_17jun2024_v0
ptday_sf2_2022_fbp_canada_boreal_bsp_ff10_30jun2024_v0
ptday_sf2_2022_fbp_canada_boreal_bsp_haps_ff10_30jun2024_v0
ptinv_finn_MX_finn_2022_ff10_15jun2024_v0.csv
ptinv_finn_ONA_finn_2022_ff10_15jun2024_v0.csv
ptinv_pile_burn_2022_canada_ff10_17jun2024_v0.csv
ptinv_sf2_2022_fbp_canada_boreal_bsp_30jun2024_v0.csv
ptinv_sf2_2022_fbp_canada_boreal_bsp_haps_30jun2024_v0.csv

Point Sources – Industrial ERTAC (ptnonertac)

2022

nonegu_norail_2022_ERTAC_Platform_POINT_20240615_stackfix2_23jul2024_v0_v0_2_14may2025_nf_v1.csv
2022v1_platform_railyards_2022_27jun2024_nf_v2.csv

2026

2026proj_v1final_nonegu_norail_2022_ERTAC_Platform_POINT_20240615_stackfix2_02jan2025_nf_v1_01may2025.csv
2026proj_2022v1_platform_railyards_2022_20dec2024_nf_v1.csv

Point Sources – Industrial EPA (ptnonipm)

2022

2022v1_platform_railyards_2022_27jun2024_nf_v2.csv
nonegu_norail_2022_POINT_20240615_stackfix2_23jul2024_v0.csv

2026

2026proj_2022v1_platform_railyards_2022_20dec2024_nf_v1.csv
2026proj_v1final_from_egu_to_nonegu_2022_POINT_20240801_02jan2025_v0.csv
2026proj_v1final_nonegu_norail_2022_POINT_20240615_stackfix2_02jan2025_nf_v1.csv

Railway (rail)

2022

2022v1_platform_rail_2022_04jun2024_nf_v1.csv

2026

2026proj_2022v1_platform_rail_2022_16aug2024_v0.csv

Residential Wood Combustion (rwc)

2022

2022hc_from_rwc_2020NEI_NONPOINT_20230222_25jun2024_nf_v2.csv

2026 uses the 2022 input files.

Appendix C: Model Evaluation Statistical Formulae

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

P_i and O_i are the individual (daily maximum 8-hour ozone or daily average for the other species) predicted and observed concentrations respectively, $\overline{P}$ and $\overline{O}$ are the average concentrations, respectively, and N is the sample size.

Observed average, in ppb:

$$\overline{O} = \frac{1}{N}\sum O_i$$

Predicted average, in ppb (only use P_i when O_i is valid):

$$\overline{P} = \frac{1}{N}\sum P_i$$

Correlation coefficient, R^2:

$$R^2 = \frac{\left[\sum (P_i - \overline{P})(O_i - \overline{O})\right]^2}{\sum (P_i - \overline{P})^2 \sum (O_i - \overline{O})^2}$$

Normalized mean error (NME), in %:

$$NME = \frac{\sum |P_i - O_i|}{\sum O_i} \times 100\%$$

Root mean square error (RMSE), in ppb:

$$RMSE = \left[\frac{1}{N}\sum (P_i - O_i)^2\right]^{1/2}$$

Fractional error (FE), in %:

$$FE = \frac{2}{N}\sum \left|\frac{P_i - O_i}{P_i + O_i}\right| \times 100\%$$

Mean absolute gross error (MAGE), in ppb:

$$MAGE = \frac{1}{N}\sum \left|P_i - O_i\right|$$

Mean normalized gross error (MNGE), in %:

$$MNGE = \frac{1}{N}\sum \frac{\left|P_i - O_i\right|}{O_i} \times 100\%$$

Mean bias (MB), in ppb:

$$MB = \frac{1}{N}\sum (P_i - O_i)$$

Mean normalized bias (MNB), in %:

$$MNB = \frac{1}{N}\sum \frac{(P_i - O_i)}{O_i} \times 100\%$$

Mean fractionalized bias (MFB), in %:

$$MFB = \frac{2}{N}\sum \left[\frac{P_i - O_i}{P_i + O_i}\right] \times 100\%$$

Normalized mean bias (NMB), in %:

$$NMB = \frac{\sum (P_i - O_i)}{\sum O_i} \times 100\%$$

Appendix D: Projected DVFs for 2026 for All OTR Monitors

This table includes all monitors in the OTR States showing the 2022 (2020-2024) base observed design values (DVBs) compared to the 2022-2024 observed DVs and modeled projected design values (DVFs) for the 3x3 and 3x3 No Water methodologies using the 2022 V1 platform.

			Observed DVs			Modeled Projected DVFs for 2026			
						2022 V1, ERTAC/MEGAN CMAQ v5.4.0.5			
			2020-2024 DVB		2022-2024 DV	3x3		3x3 No Water	
Site ID	State	County	AVG	MAX		AVG	MAX	AVG	MAX
90010017	CT	Fairfield	78.3	79	79	77.5	78.2	77.8	78.5
90011123	CT	Fairfield	73.3	76	76	70.6	73.3	70.6	73.3
90013007	CT	Fairfield	81	82	80	78.4	79.4	78.3	79.3
90019003	CT	Fairfield	80.7	82	80	79.8	81.1	78.1	79.3
90031003	CT	Hartford	70	72	72	67.1	69	67.1	69
90050005	CT	Litchfield	68	69	69	65	66	65	66
90079007	CT	Middlesex	74	75	74	71	71.9	71	71.9
90090027	CT	New Haven	70.7	72	72	68.7	70	68.1	69.4
90099002	CT	New Haven	78	79	76	75.4	76.4	75.1	76.1
90110124	CT	New London	71.7	72	71	69.3	69.6	69.1	69.3
90131001	CT	Tolland	68	70	70	65	66.9	65	66.9
90159991	CT	Windham	64.3	65	64	61.7	62.4	61.7	62.4
100010002	DE	Kent	64	65	64	62.3	63.3	62.2	63.2
100031007	DE	New Castle	66.5	67	67	64.2	64.7	64.2	64.7
100031010	DE	New Castle	64.3	66	65	61.9	63.6	61.9	63.6
100031013	DE	New Castle	65.3	67	67	62.9	64.5	62.9	64.5
100032004	DE	New Castle	66	68	68	63.6	65.5	63.6	65.5
100051002	DE	Sussex	63.3	65	64	61.4	63.1	61.4	63.1
100051003	DE	Sussex	61	62	62	59.4	60.3	59.3	60.3
110010041	DC	District of Columbia	59.7	60	60	56.9	57.2	56.9	57.2
110010043	DC	District of Columbia	68.7	70	69	65.5	66.8	65.5	66.8
110010050	DC	District of Columbia	NA	NA	NA	NA	NA	NA	NA
230010014	ME	Androscoggin	56.7	58	56	54.3	55.5	53.8	55.1
230031100	ME	Aroostook	49.7	50	49	NA	NA	NA	NA
230039991	ME	Aroostook	NA	NA	NA	NA	NA	NA	NA
230052003	ME	Cumberland	61.7	62	61	59	59.3	58.7	59
230090102	ME	Hancock	66.3	67	66	63.9	64.6	NA	NA
230090103	ME	Hancock	62.3	63	63	60.1	60.7	NA	NA
230112001	ME	Kennebec	54.3	55	54	NA	NA	NA	NA
230130004	ME	Knox	59	59	59	56.8	56.8	NA	NA
230173001	ME	Oxford	NA	NA	NA	NA	NA	NA	NA
230173002	ME	Oxford	53.7	55	52	NA	NA	NA	NA
230194008	ME	Penobscot	58.7	59	58	NA	NA	NA	NA
230230006	ME	Sagadahoc	NA	NA	NA	NA	NA	NA	NA
230230007	ME	Sagadahoc	60	60	60	57.8	57.8	57.7	57.7

230290021	ME	Washington	54.7	56	53	NA	NA	NA	NA
230290032	ME	Washington	NA	NA	NA	NA	NA	NA	NA
230290033	ME	Washington	50	50	50	NA	NA	NA	NA
230310038	ME	York	NA	NA	NA	NA	NA	NA	NA
230310040	ME	York	57.3	58	57	NA	NA	NA	NA
230312002	ME	York	63.7	64	63	61.2	61.5	60.7	61
240030014	MD	Anne Arundel	NA	NA	NA	NA	NA	NA	NA
240031003	MD	Anne Arundel	66	66	NA	64.7	64.7	63.8	63.8
240051007	MD	Baltimore	68.3	69	69	65.8	66.4	65.8	66.4
240053001	MD	Baltimore	70.7	73	71	69.3	71.5	68.6	70.8
240090011	MD	Calvert	61	63	63	58.3	60.2	58.5	60.4
240130001	MD	Carroll	66	67	67	63.4	64.4	63.4	64.4
240150003	MD	Cecil	66.3	67	67	64.2	64.9	64.2	64.9
240170010	MD	Charles	62.7	65	64	60.2	62.4	60.2	62.4
240190004	MD	Dorchester	65	66	66	62.7	63.7	62.3	63.3
240199991	MD	Dorchester	62.3	64	62	60	61.6	60.1	61.7
240210037	MD	Frederick	65.7	67	67	63.6	64.8	63.6	64.8
240230002	MD	Garrett	61	63	63	59.8	61.8	59.8	61.8
240251001	MD	Harford	70	71	71	68	69	67.9	68.9
240259001	MD	Harford	69.3	71	70	67.3	69	67	68.7
240290002	MD	Kent	66.7	68	68	64.3	65.5	64.3	65.5
240313001	MD	Montgomery	64.7	66	65	61.5	62.7	61.5	62.7
240330030	MD	Prince George's	64.7	66	66	61.6	62.8	61.6	62.8
240338003	MD	Prince George's	67	69	68	64	65.9	64	65.9
240339991	MD	Prince George's	68	69	68	65.3	66.2	65.3	66.2
240430009	MD	Washington	63	64	64	61.2	62.1	61.2	62.1
245100054	MD	Baltimore (City)	NA	NA	NA	NA	NA	NA	NA
245105253	MD	Baltimore (City)	70	70	70	68.6	68.6	67.9	67.9
250010002	MA	Barnstable	63.7	65	62	61.5	62.8	61.5	62.8
250030008	MA	Berkshire	62.3	64	64	NA	NA	NA	NA
250051004	MA	Bristol	65.3	66	65	63.6	64.3	63	63.7
250051006	MA	Bristol	63	64	63	61.1	62	60.8	61.8
250070001	MA	Dukes	65	67	66	63	64.9	62.9	64.8
250092006	MA	Essex	66.3	68	68	64.3	65.9	63.7	65.3
250094005	MA	Essex	NA	NA	NA	NA	NA	NA	NA
250095006	MA	Essex	61	62	NA	58.3	59.2	58.3	59.2
250112005	MA	Franklin	59	61	61	NA	NA	NA	NA
250130008	MA	Hampden	65	66	66	62.1	63.1	62.1	63.1
250154002	MA	Hampshire	62.7	63	63	59.9	60.2	59.9	60.2
250170009	MA	Middlesex	61.3	62	62	58.6	59.2	58.6	59.2
250212005	MA	Norfolk	64.5	65	65	63	63.4	62	62.5
250213003	MA	Norfolk	63	67	67	60.9	64.8	60.5	64.3
250230005	MA	Plymouth	62.7	64	64	60.3	61.5	60.3	61.5
250250042	MA	Suffolk	62.7	64	63	60.7	61.9	60.2	61.5
250270015	MA	Worcester	60	62	59	57.3	59.2	57.3	59.2
250270024	MA	Worcester	59.7	60	60	57.3	57.6	57.3	57.6
330012007	NH	Belknap	57	58	58	54.6	55.5	NA	NA
330050007	NH	Cheshire	58	59	59	NA	NA	NA	NA
330074001	NH	Coos	NA	NA	NA	NA	NA	NA	NA
330074002	NH	Coos	55.7	57	55	NA	NA	NA	NA
330090010	NH	Grafton	56	58	58	NA	NA	NA	NA

330099991	NH	Grafton	NA	NA	NA	NA	NA	NA	NA
330111011	NH	Hillsborough	60.3	62	62	57.5	59.2	57.5	59.2
330115001	NH	Hillsborough	62.3	64	64	59.4	61	59.4	61
330131007	NH	Merrimack	58.7	60	60	NA	NA	NA	NA
330150014	NH	Rockingham	60.7	62	62	58.5	59.7	58	59.2
330150016	NH	Rockingham	65.7	67	65	63.3	64.5	62.7	64
330150018	NH	Rockingham	60	61	61	57.3	58.3	57.3	58.3
340010006	NJ	Atlantic	58.3	59	57	56.5	57.2	56.3	57
340030006	NJ	Bergen	69.3	70	70	67.5	68.2	67.5	68.2
340070002	NJ	Camden	65.5	67	NA	63.1	64.5	63.1	64.5
340071001	NJ	Camden	62.7	64	64	60.3	61.6	60.3	61.6
340110007	NJ	Cumberland	64.3	65	65	62.1	62.8	62.1	62.8
340130003	NJ	Essex	NA	NA	NA	NA	NA	NA	NA
340150002	NJ	Gloucester	69.7	73	73	67.3	70.5	67.3	70.5
340170006	NJ	Hudson	66.7	67	67	65	65.3	64.7	64.9
340190001	NJ	Hunterdon	65.7	68	68	63	65.2	63	65.2
340210005	NJ	Mercer	69.7	71	71	66.4	67.7	66.4	67.7
340219991	NJ	Mercer	67	69	69	64	65.9	64	65.9
340230011	NJ	Middlesex	70	71	71	66.9	67.8	66.9	67.8
340250005	NJ	Monmouth	68	70	67	65.6	67.6	65.3	67.2
340273001	NJ	Morris	64.3	66	66	61.6	63.3	61.6	63.3
340290006	NJ	Ocean	69	71	71	66	67.9	66	67.9
340315001	NJ	Passaic	62.7	65	65	59.9	62.1	59.9	62.1
340410007	NJ	Warren	58.7	60	60	56.3	57.6	56.3	57.6
360010012	NY	Albany	60.7	63	63	NA	NA	NA	NA
360050110	NY	Bronx	66.7	67	67	67	67.3	65.3	65.6
360050133	NY	Bronx	69	70	68	71.3	72.3	67.5	68.5
360130006	NY	Chautauqua	68.3	69	69	66.4	67.1	66.4	67.1
360270007	NY	Dutchess	63.3	66	66	60.5	63.1	60.5	63.1
360290002	NY	Erie	67	67	67	65.6	65.6	65.4	65.4
360310002	NY	Essex	64	66	64	NA	NA	NA	NA
360310003	NY	Essex	60.3	62	60	NA	NA	NA	NA
360319991	NY	Essex	NA	NA	NA	NA	NA	NA	NA
360337003	NY	Franklin	NA	NA	NA	NA	NA	NA	NA
360410005	NY	Hamilton	58	60	58	NA	NA	NA	NA
360430005	NY	Herkimer	NA	NA	NA	NA	NA	NA	NA
360450002	NY	Jefferson	61.7	63	60	60.1	61.3	60.1	61.4
360551007	NY	Monroe	65.7	67	65	63.8	65	63.8	65
360610135	NY	New York	70	71	69	70.3	71.3	68.5	69.5
360631006	NY	Niagara	65.7	66	65	64.2	64.5	64	64.3
360671015	NY	Onondaga	62	64	62	NA	NA	NA	NA
360715001	NY	Orange	NA	NA	NA	NA	NA	NA	NA
360750003	NY	Oswego	59.3	61	58	57.6	59.2	57.8	59.4
360790005	NY	Putnam	64.3	68	68	61.7	65.3	61.7	65.3
360810124	NY	Queens	71	72	71	71.3	72.3	69.4	70.4
360850067	NY	Richmond	NA	NA	NA	NA	NA	NA	NA
360850111	NY	Richmond	67	69	66	65.1	67	64.7	66.6
360870005	NY	Rockland	65.3	68	68	62.6	65.2	62.6	65.2
360910004	NY	Saratoga	60	61	61	NA	NA	NA	NA
361010003	NY	Steuben	59	61	60	NA	NA	NA	NA
361030002	NY	Suffolk	73.7	75	72	73	74.2	71.6	72.9

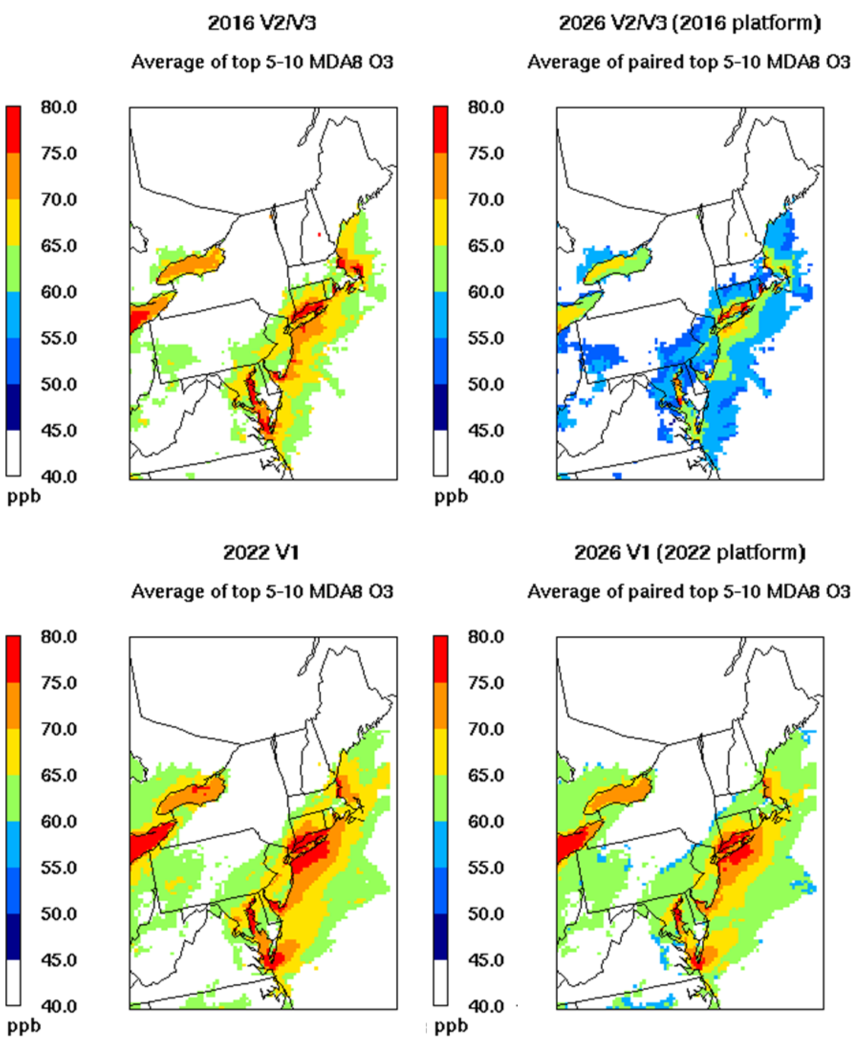
361030004	NY	Suffolk	68	68	68	66.4	66.4	65.6	65.6
361030009	NY	Suffolk	70	70	NA	68.5	68.5	67.7	67.7
361030044	NY	Suffolk	72.5	73	72	70.3	70.8	70.2	70.7
361099991	NY	Tompkins	60.3	62	60	NA	NA	NA	NA
361173001	NY	Wayne	61.7	63	61	60.1	61.3	59.9	61.2
361192004	NY	Westchester	69.3	71	71	71.8	73.5	67.4	69.1
420010001	PA	Adams	63.3	65	65	61.5	63.1	61.5	63.1
420019991	PA	Adams	64	65	65	62.1	63.1	62.1	63.1
420030008	PA	Allegheny	62.7	63	63	60.7	61	60.7	61
420030067	PA	Allegheny	66.7	67	67	64.5	64.8	64.5	64.8
420031008	PA	Allegheny	67	68	68	64.8	65.8	64.8	65.8
420050001	PA	Armstrong	66.3	67	67	63.8	64.5	63.8	64.5
420070002	PA	Beaver	64	64	NA	60.8	60.8	60.8	60.8
420070005	PA	Beaver	65	66	66	62	63	62	63
420070014	PA	Beaver	64	65	63	61	61.9	61	61.9
420110006	PA	Berks	63.3	65	65	61.2	62.8	61.2	62.8
420110011	PA	Berks	67	67	67	64.8	64.8	64.8	64.8
420130801	PA	Blair	NA	NA	NA	NA	NA	NA	NA
420150011	PA	Bradford	60.3	62	61	NA	NA	NA	NA
420170012	PA	Bucks	72.7	73	73	69.6	69.9	69.6	69.9
420210011	PA	Cambria	63	64	63	60.9	61.8	60.9	61.8
420270100	PA	Centre	60.3	65	65	58.1	62.6	58.1	62.6
420279991	PA	Centre	63	64	64	60.7	61.6	60.7	61.6
420290100	PA	Chester	65	65	65	63.1	63.1	63.1	63.1
420334000	PA	Clearfield	54	54	NA	52.4	52.4	52.4	52.4
420430401	PA	Dauphin	63	64	64	61	61.9	61	61.9
420431100	PA	Dauphin	63.3	67	67	61.4	65	61.4	65
420450002	PA	Delaware	NA	NA	NA	NA	NA	NA	NA
420479991	PA	Elk	60.7	63	61	58.9	61.2	58.9	61.2
420490003	PA	Erie	61	63	63	59.4	61.4	59.3	61.2
420510524	PA	Fayette	61.3	65	65	60.2	63.8	60.2	63.8
420550001	PA	Franklin	59.7	62	62	58	60.3	58	60.3
420590002	PA	Greene	NA	NA	NA	NA	NA	NA	NA
420630004	PA	Indiana	63	63	NA	60.7	60.7	60.7	60.7
420690101	PA	Lackawanna	61.7	63	63	NA	NA	NA	NA
420692006	PA	Lackawanna	57.7	60	60	NA	NA	NA	NA
420710007	PA	Lancaster	63.7	65	65	62	63.3	62	63.3
420710012	PA	Lancaster	62	63	63	60	60.9	60	60.9
420730015	PA	Lawrence	61	61	NA	58.3	58.3	58.3	58.3
420750100	PA	Lebanon	NA	NA	NA	NA	NA	NA	NA
420750101	PA	Lebanon	64	64	64	62.1	62.1	62.1	62.1
420770004	PA	Lehigh	62	63	63	59.7	60.7	59.7	60.7
420791101	PA	Luzerne	NA	NA	NA	NA	NA	NA	NA
420810100	PA	Lycoming	60	62	62	57.7	59.6	57.7	59.6
420850100	PA	Mercer	66.3	68	68	64.1	65.7	64.1	65.7
420859991	PA	Mercer	64.3	66	66	62	63.7	62	63.7
420890002	PA	Monroe	62	62	62	59.5	59.5	59.5	59.5
420910013	PA	Montgomery	66	66	66	63.3	63.3	63.3	63.3
420950025	PA	Northampton	65.3	67	65	62.7	64.3	62.7	64.3
420958000	PA	Northampton	NA	NA	NA	NA	NA	NA	NA
421010004	PA	Philadelphia	64.3	65	65	61.8	62.5	61.8	62.5

421010024	PA	Philadelphia	70	70	70	67	67	67	67
421010048	PA	Philadelphia	69.3	70	70	66.6	67.3	66.6	67.3
421119991	PA	Somerset	61.3	63	63	59.4	61	59.4	61
421174000	PA	Tioga	61	62	62	NA	NA	NA	NA
421250005	PA	Washington	NA	NA	NA	NA	NA	NA	NA
421250200	PA	Washington	NA	NA	NA	NA	NA	NA	NA
421255001	PA	Washington	63	63	63	60.4	60.4	60.4	60.4
421255200	PA	Washington	62.5	64	NA	61.1	62.5	61.1	62.5
421290008	PA	Westmoreland	53.3	56	56	51.5	54.2	51.5	54.2
421330008	PA	York	62.5	65	65	60.9	63.4	60.9	63.4
421330011	PA	York	NA	NA	NA	NA	NA	NA	NA
440030002	RI	Kent	63.3	64	62	60.9	61.5	60.9	61.5
440071010	RI	Providence	65.5	66	NA	63.7	64.2	63	63.5
440090007	RI	Washington	67	68	67	65	66	65.1	66.1
440090008	RI	Washington	72	72	72	69.9	69.9	69.4	69.4
500030004	VT	Bennington	59.7	61	61	NA	NA	NA	NA
500070007	VT	Chittenden	59.3	60	60	NA	NA	NA	NA
500210002	VT	Rutland	56.3	58	58	NA	NA	NA	NA
510030001	VA	Albemarle	58.7	60	59	NA	NA	NA	NA
510130020	VA	Arlington	66	67	67	62.9	63.9	62.9	63.9
510330001	VA	Caroline	59.3	62	58	57	59.6	57	59.6
510360002	VA	Charles	58	59	58	54.7	55.6	54.7	55.6
510410004	VA	Chesterfield	59	60	59	55.2	56.2	55.2	56.2
510590030	VA	Fairfax	65	67	66	62.1	64	62.1	64
510610002	VA	Fauquier	57.7	60	58	55.6	57.8	55.6	57.8
510690010	VA	Frederick	58.3	60	60	56.7	58.4	56.7	58.4
510719992	VA	Giles	61.7	63	63	NA	NA	NA	NA
510850003	VA	Hanover	59.7	61	60	56.4	57.6	56.4	57.6
510870014	VA	Henrico	61.3	63	62	57	58.6	57	58.6
511071005	VA	Loudoun	63.3	64	64	60.9	61.6	60.9	61.6
511130003	VA	Madison	61	63	62	59.8	61.8	59.8	61.8
511390004	VA	Page	NA	NA	NA	NA	NA	NA	NA
511479991	VA	Prince Edward	56.7	58	57	56.3	57.6	56.3	57.6
511530009	VA	Prince William	62	64	64	60.1	62.1	60.1	62.1
511611004	VA	Roanoke	58.7	60	59	56.8	58	56.8	58
511630003	VA	Rockbridge	55.7	57	57	NA	NA	NA	NA
511650003	VA	Rockingham	59.3	61	60	NA	NA	NA	NA
511790001	VA	Stafford	60	62	60	57.3	59.2	57.7	59.6
511970002	VA	Wythe	58.3	59	59	NA	NA	NA	NA
516500008	VA	Hampton City	60.7	62	62	58.9	60.1	58.4	59.6
518000004	VA	Suffolk City	56.7	58	58	55.1	56.4	54.2	55.4
518000005	VA	Suffolk City	56.3	57	56	NA	NA	NA	NA

Appendix E: Comparison of the 2026 Analytic Year DVFs From the 2016V2/V3 and 2022V1 Platforms

When comparing the average of the top five to ten MDA8 O_3 in 2022V1 with those in 2016V2/V3, the average of modeled MDA8 O_3 concentrations is larger around the Long Island Sound area and in water grid cells in 2022V1 than in 2016V2/V3. White color indicates that the average is not calculated due to insufficient days with MDA8 O3 concentrations of 60 ppb or greater. In general, the average of MDA8 O_3 concentrations in 2026 from the 2022V1 platform is larger than those from the 2016 V2/V3 platform, as shown in **Figure E-1**.

Figure E-1 *Average of the top five to ten MDA8 O3 in the base year and paired MDA8 O3 in the analytic year for the 2016/2026 V2/V3 (top) and 2022/2026 V1 (bottom) platforms.*



As illustrated in **Figure E-2**, we compared the relative response ratios in each grid cell between the previous 2016V2/V3 platform (left) and the current 2022V1 platform (right). Using the

2022V1 platform, more ratios were calculated because more grid cells had five to ten MDA8 O_3 concentrations of 60 ppb or greater than using the 2016 platform. Additionally, ratios were higher in more grid cells for the 2022 platform than for the 2016 platform.

Figure E-2 *Relative response ratio of the top five to ten MDA8 O3 in the 2016/2026 V2/V3 (left) and 2022/2026 V1 (right) platforms.*

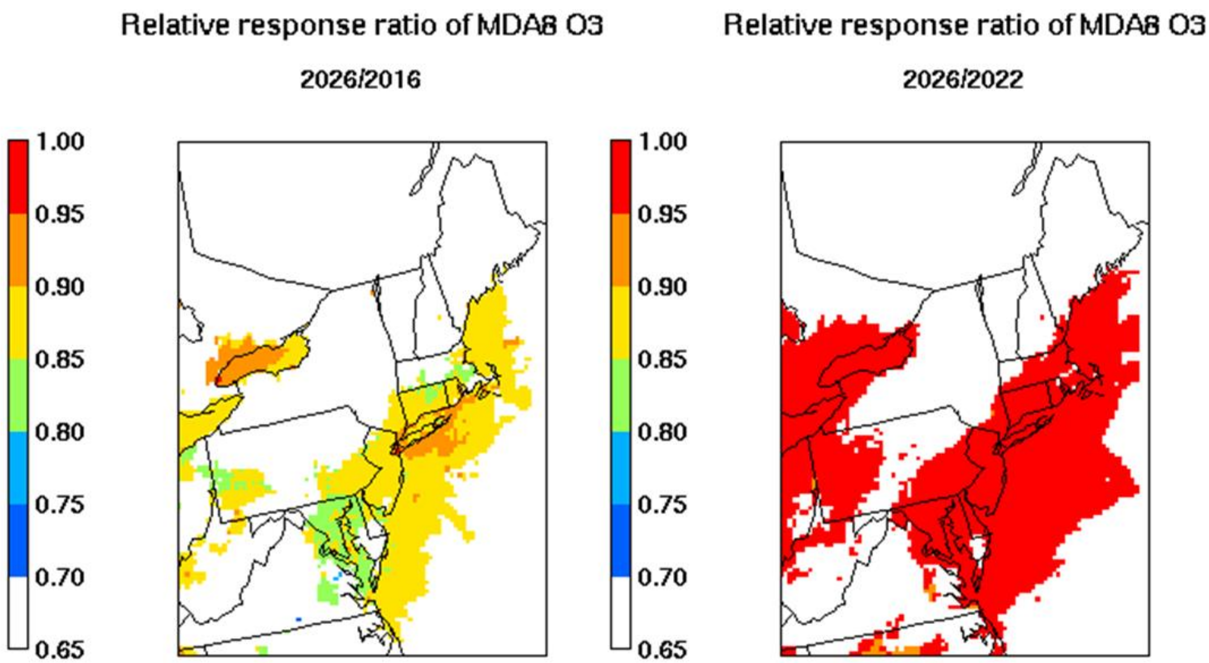


Figure E-3 shows modeled projected DVFs for 2026 from the 2016/2026 V2/V3 platform (left) and 2022/2026 V1 platform (right). Using the previous 2016/2026 V2/V3 platform, no site exceeds the 2008 NAAQS of 75 ppb, and three sites in Connecticut are projected to exceed the 2015 NAAQS of 70 ppb within the NY-NJ-CT NAA. However, using the 2022/2026 V1 platform, projected DVFs are higher than using the previous platform, resulting in the three sites in Connecticut exceeding the higher 2008 NAAQS and three additional sites exceeding the 2015 NAAQS in the NY-NJ-CT NAA in the OTR.

Table E-1 lists the DVFs for the top 23 monitors with maximum DVBs exceeding the 2015 NAAQS in the OTR. This table includes projected average and maximum DVFs for 2026 using the 3x3 No Water methodology, as well as the 2022 (2020-2024) base observed design values (DVBs) and the 2022-2024 observed DVs. As shown in **Figure E-3** and **Table E-1**, three sites in Connecticut exceed the 2008 NAAQS, and three additional sites exceed the 2015 NAAQS in the NY-NJ-CT ozone nonattainment area in the OTR.

Figure E-3 *Modeled projected DVFs for 2026 from the 2016/2026 V2/V3 platform (left) and 2022/2026 V1 platform (right) using the 3x3 No Water methodology in the OTR.*

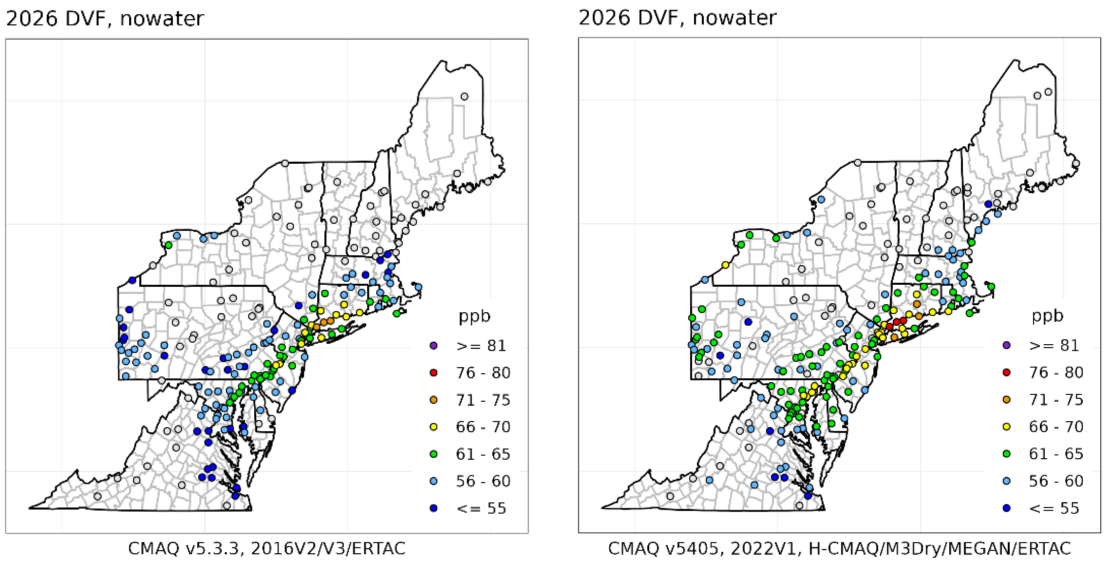


Table E-1 Top 23 OTR monitors showing the 2022 (2020-2024) base observed design values (DVB) compared to the 2022-2024 DVs and modeled projected DVFs for 2026 for the 3x3 No Water methodology using the 2022 V1 platform (blue) as well as the 2016 V2/V3 platform (green) for comparison.

Site ID	State	County	Monitored DVs*			Modeled Projected DVFs for 2026			
			2020-2024 DVB		2022-2024 DV	2016V2/V3** CMAQ v5.3.3 3x3 No Water		2022 V1, ERTAC/MEGAN CMAQ v5.4.0.5 3x3 No Water	
			AVG	MAX		AVG	MAX	AVG	MAX
90013007	CT	Fairfield	81	82	80	73.2	74.1	78.3	79.3
90019003	CT	Fairfield	80.7	82	80	74.6	74.8	78.1	79.3
90010017	CT	Fairfield	78.3	79	79	73	73.7	77.8	78.5
90099002	CT	New Haven	78	79	76	69.5	71.5	75.1	76.1
90011123	CT	Fairfield	73.3	76	76	67.9	68.8	70.6	73.3
90079007	CT	Middlesex	74	75	74	68	68.2	71	71.9
361030002	NY	Suffolk	73.7	75	72	66.4	68.2	71.6	72.9
340150002	NJ	Gloucester	69.7	73	73	64.5	64.7	67.3	70.5
420170012	PA	Bucks	72.7	73	73	68.7	70.2	69.6	69.9
361030044	NY	Suffolk	72.5	73	72	NA	NA	70.2	70.7
240053001	MD	Baltimore	70.7	73	71	61.5	61.7	68.6	70.8
90031003	CT	Hartford	70	72	72	60.9	62.9	67.1	69
90090027	CT	New Haven	70.7	72	72	67	68.2	68.1	69.4
440090008	RI	Washington	72	72	72	NA	NA	69.4	69.4
90110124	CT	New London	71.7	72	71	70.9	72.5	69.1	69.3
360810124	NY	Queens	71	72	71	65.1	66.6	69.4	70.4
240251001	MD	Harford	70	71	71	62.3	63.2	67.9	68.9
340210005	NJ	Mercer	69.7	71	71	62	62.6	66.4	67.7
340230011	NJ	Middlesex	70	71	71	65.5	65.8	66.9	67.8
340290006	NJ	Ocean	69	71	71	63.3	63.5	66	67.9
361192004	NY	Westchester	69.3	71	71	67.6	68.5	67.4	69.1
240259001	MD	Harford	69.3	71	70	61	61	67	68.7
360610135	NY	New York	70	71	69	64.6	66.2	68.5	69.5

* Data source for the monitored DVs: https://www.epa.gov/air-trends/air-quality-design-values, accessed on 6/4/2025.
** Data source for the modeled projected DVFs using the 2016 V2/V3 platform: Ozone Transport Commission/Mid-Atlantic Northeastern Visibility Union 2016 Based Modeling Platform Technical Support Document: OTC V2/V3 Modeling Platform Update, 7/14/2023, https://otcair.org/upload/Documents/Reports/OTC_Modeling_TSD2016_Addendum_July2023.pdf.