United States
Environmental Protection
Agency

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

EPA-454/R-12-004
August 2012

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC 27711
August 2012

(This page intentionally left blank)

Table of Contents

List of Appendices

I. Introduction

This document describes the air quality modeling performed by EPA in support of the 2017-2025 Light-Duty Vehicle Greenhouse Gas Final Rule (hereafter referred to as LD GHG). A national scale air quality modeling analysis was performed to estimate the impact of the vehicle standards on future year: annual and 24-hour $PM_{2.5}$ concentrations, daily maximum 8-hour ozone concentrations, annual nitrogen and sulfur deposition levels, and select annual and seasonal air toxic concentrations (formaldehyde, acetaldehyde, benzene, 1,3-butadiene and acrolein) as well as visibility impairment. To model the air quality benefits of this rule we used the Community Multiscale Air Quality (CMAQ) model.[1] CMAQ simulates the numerous physical and chemical processes involved in the formation, transport, and destruction of ozone, particulate matter and air toxics. In addition to the CMAQ model, the modeling platform includes the emissions, meteorology, and initial and boundary condition data which are inputs to this model.

Emissions and air quality modeling decisions are made early in the analytical process to allow for sufficient time required to conduct emissions and air quality modeling. For this reason, it is important to note that the inventories used in the air quality modeling and the benefits modeling, which are presented in Section 6.2 and 6.3, respectively of the RIA, are slightly different than the final vehicle standard inventories presented in Chapter 4 of the RIA. However, the air quality inventories and the final rule inventories are generally consistent, so the air quality modeling adequately reflects the effects of the rule.

Air quality modeling was performed for three emissions cases: a 2005 base year, a 2030 reference case projection without 2017-2025 light-duty vehicle standards, and a 2030 control case projection with 2017-2025 light-duty vehicle standards. The year 2005 was selected for the LD GHG base year because this is the most recent year for which EPA had a complete national emissions inventory at the time of emission and air quality modeling.

The remaining sections of the Air Quality Modeling TSD are as follows. Section II describes the air quality modeling platform and the evaluation of model predictions of $PM_{2.5}$ and ozone using corresponding ambient measurements. In Section III we present the results of modeling performed for 2030 to assess the impacts on air quality of the vehicle standards. Information on the development of emissions inventories for the LD GHG Rule and the steps and data used in creating emissions inputs for air quality modeling can be found in the Emissions Inventory for Air Quality Modeling TSD (EITSD; EPA-HQ-OAR-2010-0799). The docket for this final rulemaking also contains state/sector/pollutant emissions summaries for each of the emissions scenarios modeled.

---

[1] Byun, D.W., and K. L. Schere, 2006: Review of the Governing Equations, Computational Algorithms, and Other Components of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System. Applied Mechanics Reviews, Volume 59, Number 2 (March 2006), pp. 51-77.

II. Air Quality Modeling Platform

The 2005-based CMAQ modeling platform was used as the basis for the air quality modeling of the 2017-2025 LD GHG final rule. This platform represents a structured system of connected modeling-related tools and data that provide a consistent and transparent basis for assessing the air quality response to projected changes in emissions. The base year of data used to construct this platform includes emissions and meteorology for 2005. The platform was developed by the U.S. EPA's Office of Air Quality Planning and Standards in collaboration with the Office of Research and Development and is intended to support a variety of regulatory and research model applications and analyses. This modeling platform and analysis is fully described below.

A. Air Quality Model

CMAQ is a non-proprietary computer model that simulates the formation and fate of photochemical oxidants, primary and secondary PM concentrations, acid deposition, and air toxics, over regional and urban spatial scales for given input sets of meteorological conditions and emissions. The CMAQ model version 4.7 was most recently peer-reviewed in February of 2009 for the U.S. EPA.[2] The CMAQ model is a well-known and well-respected tool and has been used in numerous national and international applications.[3,4,5] CMAQ includes numerous science modules that simulate the emission, production, decay, deposition and transport of organic and inorganic gas-phase and particle-phase pollutants in the atmosphere. This 2005 multi-pollutant modeling platform used CMAQ version 4.7.1[6] with a minor internal change made by the U.S. EPA CMAQ model developers intended to speed model runtimes when only a small subset of toxics species are of interest. CMAQ v4.7.1 reflects updates to version 4.7 to improve the underlying science which include aqueous chemistry mass conservation improvements, improved vertical convective mixing and lowered Carbon Bond Mechanism-05 (CB-05) mechanism unit yields for acrolein (from 1,3-butadiene tracer reactions which were updated to be consistent with laboratory measurements).

---

[2] Allen, D., Burns, D., Chock, D., Kumar, N., Lamb, B., Moran, M. (February 2009 Draft Version). Report on the Peer Review of the Atmospheric Modeling and Analysis Division, NERL/ORD/EPA. U.S. EPA, Research Triangle Park, NC. CMAQ version 4.7 was released on December, 2008. It is available from the Community Modeling and Analysis System (CMAS) as well as previous peer-review reports at: http://www.cmascenter.org.

[3] Hogrefe, C., Biswas, J., Lynn, B., Civerolo, K., Ku, J.Y., Rosenthal, J., et al. (2004). Simulating regional-scale ozone climatology over the eastern United States: model evaluation results. *Atmospheric Environment, 38(17),* 2627-2638.

[4] United States Environmental Protection Agency. (2008). *Technical support document for the final locomotive/marine rule: Air quality modeling analyses.* Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division.

[5] Lin, M., Oki, T., Holloway, T., Streets, D.G., Bengtsson, M., Kanae, S., (2008). Long range transport of acidifying substances in East Asia Part I: Model evaluation and sensitivity studies. Atmospheric Environment, 42(24), 5939-5955.

[6] CMAQ version 4.7.1 model code is available from the Community Modeling and Analysis System (CMAS) at: http://www.cmascenter.org as well as at EPA-HQ-OAR-0472-DRAFT-11662.

B. Model domains and grid resolution

The CMAQ modeling analyses were performed for a domain covering the continental United States, as shown in Figure II-1. This domain has a parent horizontal grid of 36 km with two finer-scale 12 km grids over portions of the eastern and western U.S. The model extends vertically from the surface to 100 millibars (approximately 15 km) using a sigma-pressure coordinate system. Air quality conditions at the outer boundary of the 36 km domain were taken from a global model and did not change over the simulations. In turn, the 36 km grid was only used to establish the incoming air quality concentrations along the boundaries of the 12 km grids. Only the finer grid data were used in determining the impacts of the 2017-2025 LD GHG emission standard program changes. Table II-1 provides some basic geographic information regarding the CMAQ domains.

In addition to the CMAQ model, the LD GHG modeling platform includes (1) emissions for the 2005 base year, 2030 reference case projection, 2030 control case projection, (2) meteorology for the year 2005, and (3) estimates of intercontinental transport (i.e., boundary concentrations) from a global photochemical model. Using these input data, CMAQ was run to generate hourly predictions of ozone, $PM_{2.5}$ component species, nitrogen and sulfate deposition, and a subset of air toxics (formaldehyde, acetaldehyde, acrolein, benzene, and 1,3-butadiene) concentrations for each grid cell in the modeling domains. The development of 2005 meteorological inputs and initial and boundary concentrations are described below. The emissions inventories used in the LD GHG air quality modeling are described in the EITSD found in the docket for this rule (EPA-HQ-OAR-2010-0799).

Table II-1. Geographic elements of domains used in LD GHG modeling.

	CMAQ Modeling Configuration		
	National Grid	**Western U.S. Fine Grid**	**Eastern U.S. Fine Grid**
Map Projection	Lambert Conformal Projection		
Grid Resolution	36 km	12 km	12 km
Coordinate Center	97 deg W, 40 deg N		
True Latitudes	33 deg N and 45 deg N		
Dimensions	148 x 112 x 14	213 x 192 x 14	279 x 240 x 14
Vertical extent	14 Layers: Surface to 100 millibar level (see Table II-3)		

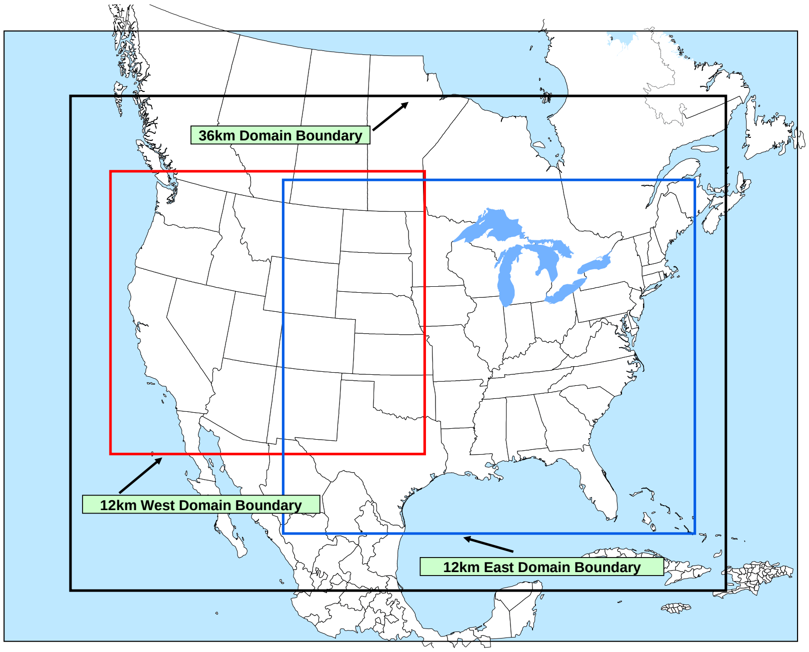

Figure II-1. Map of the CMAQ modeling domain. The black outer box denotes the 36 km national modeling domain; the red inner box is the 12 km western U.S. fine grid; and the blue inner box is the 12 km eastern U.S. fine grid.

C. Modeling Simulation Periods

The 36 km and both 12 km CMAQ modeling domains were modeled for the entire year of 2005. These annual simulations were performed in quarterly segments (i.e., January through March, April through June, July through September, and October through December) for each emissions scenario. With this approach to segmenting an annual simulation we were able to model several quarters at the same time and, thus, reduce the overall throughput time for an annual simulation. The 36 km domain simulations included a "ramp-up" period, comprised of 10 days before the beginning of each quarter, to mitigate the effects of initial concentrations. For the 12 km Eastern domain simulations we used a 3-day ramp-up period for each quarter, the ramp-up periods are not considered as part of the output analyses. Fewer ramp-up days were used for the 12 km simulations because the initial concentrations were derived from the parent 36 km simulations.

For the 8-hour ozone results, we are only using modeling results from the period between May 1 and September 30, 2005. This 153-day period generally conforms to the ozone season across most parts of the U.S. and contains the majority of days with observed high ozone concentrations in 2005. Data from the entire year were utilized when looking at the estimation of $PM_{2.5}$, total nitrogen and sulfate deposition, visibility and toxics impacts from this final rulemaking.

D. LD GHG Modeling Scenarios

As part of our analysis for this rulemaking, the CMAQ modeling system was used to calculate daily and annual $PM_{2.5}$ concentrations, 8-hour ozone concentrations, annual and seasonal air toxics concentrations, annual total nitrogen and sulfur deposition levels and visibility impairment for each of the following emissions scenarios:

2005 base year

2030 reference case projection without the vehicle standards

2030 control case projection with the vehicle standards

Model predictions are used in a relative sense to estimate scenario-specific, future-year design values of $PM_{2.5}$ and ozone. Specifically, we compare a 2030 reference scenario, a scenario without the vehicle standards, to a 2030 control scenario which includes the vehicle standards. This is done by calculating the simulated air quality ratios between the 2030 future year simulation and the 2005 base. These predicted change ratios are then applied to ambient base year design values. The ambient air quality observations are average conditions, on a site-by-site basis, for a period centered around the model base year (i.e., 2003-2007). The raw model outputs are also used in a relative sense as inputs to the health and welfare impact functions of the benefits analysis. The difference between the 2030 reference case and 2030 control case was used to quantify the air quality benefits of the rule. Additionally, the differences in projected annual average $PM_{2.5}$ and seasonal average ozone were used to calculate monetized benefits by the BenMAP model (see Section 6.3 of the RIA).

The design value projection methodology used here followed EPA guidance[7] for such analyses. For each monitoring site, all valid design values (up to 3) from the 2003-2007 period were averaged together. Since 2005 is included in all three design value periods, this has the effect of creating a 5-year weighted average, where the middle year is weighted 3 times, the 2nd and 4th years are weighted twice, and the 1st and 5th years are weighted once. We refer to this as the 5-year weighted average value. The 5-year weighted average values were then projected to the future years that were analyzed for the final rule.

Concentrations of $PM_{2.5}$ in 2030 were estimated by applying the modeled 2005-to-2030 relative change in $PM_{2.5}$ species to the 5 year weighted average (2003-2007) design values. Monitoring sites were included in the analysis if they had at least one complete design value in the 2003-2007 period. EPA followed the procedures recommended in the modeling guidance for projecting $PM_{2.5}$ by projecting individual $PM_{2.5}$ component species and then summing these to calculate the concentration of total $PM_{2.5}$. The $PM_{2.5}$ species are defined as sulfates, nitrates, ammonium, organic carbon mass, elemental carbon, crustal mass, water, and blank mass (a fixed value of 0.5 $\mu g/m^3$). EPA's Modeled Attainment Test Software (MATS) was used to calculate the future year design values. The software (including documentation) is available at: **http://www.epa.gov/scram001/modelingapps_mats.htm**. For this latest analysis, several datasets and techniques were updated. These changes are fully described within the technical support document for the Final Transport Rule AQM TSD.[8]

[7] U.S. EPA, 2007: Guidance on the Use of Models and Other Analyses for Demonstrating Attainment for Ozone, $PM_{2.5}$, and Regional Haze, Office of Air Quality Planning and Standards, Research Triangle Park, NC.
[8] U.S. EPA, 2011: Cross-State Air Pollution Rule (Final Transport Rule) Air Quality Modeling Final RuleTechnical Support Document, Docket EPA-HQ-OAR-2009-0491-4140.

To calculate 24-hour $PM_{2.5}$ design values, the measured 98th percentile concentrations from the 2003-2007 period at each monitor are projected to the future. The procedures for calculating the future year 24-hour $PM_{2.5}$ design values have been updated for the final rule. The updates are intended to make the projection methodology more consistent with the procedures for calculating ambient design values.

A basic assumption of the old projection methodology is that the distribution of high measured days in the base period will be the same in the future. In other words, EPA assumed that the 98th-percentile day could only be displaced "from below" in the instance that a different day's future concentration exceeded the original 98th-percentile day's future concentration. This sometimes resulted in overstatement of future-year design values for 24-hour $PM_{2.5}$ at receptors whose seasonal distribution of highest-concentration 24-hour $PM_{2.5}$ days changed between the 2003-2007 period and the future year modeling.

In the revised methodology, we do not assume that the seasonal distribution of high days in the base period years and future years will remain the same. We project a larger set of ambient days from the base period to the future and then re-rank the entire set of days to find the new future 98th percentile value (for each year). More specifically, we project the highest 8 days per quarter (32 days per year) to the future and then re-rank the 32 days to derive the future year 98th percentile concentrations. More details on the methodology can be found in a guidance memo titled "Update to the 24 Hour $PM_{2.5}$ NAAQS Modeled Attainment Test" which can be found here: http://www.epa.gov/ttn/scram/guidance/guide/Update_to_the_24-hour_PM25_Modeled_Attainment_Test.pdf.

The future year 8-hour average ozone design values were calculated in a similar manner as the $PM_{2.5}$ design values. The May-to-September daily maximum 8-hour average concentrations from the 2005 base case and the 2030 cases were used to project ambient design values to 2030. The calculations used the base period 2003-2007 ambient ozone design value data for projecting future year design values. Relative response factors (RRF) for each monitoring site were calculated as the percent change in ozone on days with modeled ozone greater than 85 ppb[9].

We also conducted an analysis to compare the absolute and percent differences between the 2030 control case and the 2030 reference cases for annual and seasonal formaldehyde, acetaldehyde, benzene, 1,3-butadiene, and acrolein, as well as annual nitrate and sulfate deposition. These data were not compared in a relative sense due to the limited observational data available.

E. Meteorological Input Data

The gridded meteorological input data for the entire year of 2005 were derived from simulations of the Pennsylvania State University / National Center for Atmospheric Research

[9] As specified in the attainment demonstration modeling guidance, if there are less than 10 modeled days > 85 ppb, then the threshold is lowered in 1 ppb increments (to as low as 70 ppb) until there are 10 days. If there are less than 5 days > 70 ppb, then an RRF calculation is not completed for that site.

Mesoscale Model. This model, commonly referred to as MM5, is a limited-area, nonhydrostatic, terrain-following system that solves for the full set of physical and thermodynamic equations which govern atmospheric motions.[10] Meteorological model input fields were prepared separately for each of the three domains shown in Figure II-1 using MM5 version 3.7.4. The MM5 simulations were run on the same map projection as CMAQ.

All three meteorological model runs configured similarly. The selections for key MM5 physics options are shown below:

- Pleim-Xiu PBL and land surface schemes
- Kain-Fritsh 2 cumulus parameterization
- Reisner 2 mixed phase moisture scheme
- RRTM longwave radiation scheme
- Dudhia shortwave radiation scheme

Three dimensional analysis nudging for temperature and moisture was applied above the boundary layer only. Analysis nudging for the wind field was applied above and below the boundary layer. The 36 km domain nudging weighting factors were 3.0 x 10^4 for wind fields and temperatures and 1.0 x 10^5 for moisture fields. The 12 km domain nudging weighting factors were 1.0 x 10^4 for wind fields and temperatures and 1.0 x 10^5 for moisture fields.

All three sets of model runs were conducted in 5.5 day segments with 12 hours of overlap for spin-up purposes. All three meteorological modeling domains contained 34 vertical layers with an approximately 38 m deep surface layer and a 100 millibar top. The MM5 and CMAQ vertical structures are shown in Table II-3 and do not vary by horizontal grid resolution.

Table II-3. Vertical layer structure for MM5 and CMAQ (heights are layer top).

CMAQ Layers	MM5 Layers	Sigma P	Approximate Height (m)	Approximate Pressure (mb)
0	0	1.000	0	1000
1	1	0.995	38	995
2	2	0.990	77	991
3	3	0.985	115	987
	4	0.980	154	982
4	5	0.970	232	973
	6	0.960	310	964
5	7	0.950	389	955
	8	0.940	469	946
6	9	0.930	550	937
	10	0.920	631	928
	11	0.910	712	919
7	12	0.900	794	910
	13	0.880	961	892
	14	0.860	1,130	874
8	15	0.840	1,303	856

[10] Grell, G., J. Dudhia, and D. Stauffer, 1994: A Description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5), NCAR/TN-398+STR., 138 pp, National Center for Atmospheric Research, Boulder CO.

	16	0.820	1,478	838
	17	0.800	1,657	820
9	18	0.770	1,930	793
	19	0.740	2,212	766
10	20	0.700	2,600	730
	21	0.650	3,108	685
11	22	0.600	3,644	640
	23	0.550	4,212	595
12	24	0.500	4,816	550
	25	0.450	5,461	505
	26	0.400	6,153	460
13	27	0.350	6,903	415
	28	0.300	7,720	370
	29	0.250	8,621	325
	30	0.200	9,625	280
14	31	0.150	10,764	235
	32	0.100	12,085	190
	33	0.050	13,670	145
	34	0.000	15,674	100

The 2005 meteorological outputs from all three MM5 sets were processed to create model-ready inputs for CMAQ using the Meteorology-Chemistry Interface Processor (MCIP), version 3.4.[11]

Before initiating the air quality simulations, it is important to identify the biases and errors associated with the meteorological modeling inputs. The 2005 MM5 model performance evaluations used an approach which included a combination of qualitative and quantitative analyses to assess the adequacy of the MM5 simulated fields. The qualitative aspects involved comparisons of the model-estimated synoptic patterns against observed patterns from historical weather chart archives. Additionally, the evaluations compared spatial patterns of monthly average rainfall and monthly maximum planetary boundary layer (PBL) heights. Qualitatively, the model fields closely matched the observed synoptic patterns, which is not unexpected given the use of nudging. The operational evaluation included statistical comparisons of model/observed pairs (e.g., mean normalized bias, mean normalized error, index of agreement, root mean square errors, etc.) for multiple meteorological parameters. For this portion of the evaluation, five meteorological parameters were investigated: temperature, humidity, shortwave downward radiation, wind speed, and wind direction. The three individual MM5 evaluations are described elsewhere.[12,13,14] The results of these analyses indicate that the bias and error values associated with all three sets of 2005 meteorological data were generally within the range of past meteorological modeling results that have been used for air quality applications.

[11] Byun, D.W., and Ching, J.K.S., Eds, 1999. Science algorithms of EPA Models-3 Community Multiscale Air Quality (CMAQ modeling system, EPA/600/R-99/030, Office of Research and Development).
[12] Baker K. and P. Dolwick. Meteorological Modeling Performance Evaluation for the Annual 2005 Eastern U.S. 12-km Domain Simulation, USEPA/OAQPS, February 2, 2009.
[13] Baker K. and P. Dolwick. Meteorological Modeling Performance Evaluation for the Annual 2005 Western U.S. 12-km Domain Simulation, USEPA/OAQPS, February 2, 2009.
[14] Baker K. and P. Dolwick. Meteorological Modeling Performance Evaluation for the Annual 2005 Continental U.S. 36-km Domain Simulation, USEPA/OAQPS, February 2, 2009.

F. Initial and Boundary Conditions

The lateral boundary and initial species concentrations are provided by a three-dimensional global atmospheric chemistry model, the GEOS-CHEM[15] model (standard version 7-04-11[16]). The global GEOS-CHEM model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS). This model was run for 2005 with a grid resolution of 2.0 degree x 2.5 degree (latitude-longitude) and 30 vertical layers up to 100 mb. The predictions were used to provide one-way dynamic boundary conditions at three-hour intervals and an initial concentration field for the 36-km CMAQ simulations. The future base conditions from the 36 km coarse grid modeling were used to develop the initial/boundary concentrations for the subsequent 12 km Eastern and Western domain model simulations.

G. CMAQ Base Case Model Performance Evaluation

The CMAQ predictions for ozone, fine particulate matter, sulfate, nitrate, ammonium, organic carbon, elemental carbon, a selected subset of toxics, and nitrogen and sulfur deposition from the 2005 base year evaluation case were compared to measured concentrations in order to evaluate the performance of the modeling platform for replicating observed concentrations. This evaluation was comprised of statistical and graphical comparisons of paired modeled and observed data. Details on the model performance evaluation including a description of the methodology, the model performance statistics, and results are provided in Appendix A.

III. CMAQ Model Results

As described above, we performed a series of air quality modeling simulations for the continental U.S in order to assess the impacts of the 2017-2025 light-duty vehicle greenhouse gas final rule. We looked at impacts on future ambient $PM_{2.5}$, ozone, and air toxics levels, as well as nitrogen and sulfur deposition levels and visibility impairment. In this section, we present the air quality modeling results for the 2030 LD GHG control case relative to the 2030 reference case.

A. Impacts of LD GHG Standards on Future 8-Hour Ozone Levels

This section summarizes the results of our modeling of ozone air quality impacts in the future with the 2017-2025 LD GHG vehicle standards. Specifically, we compare a 2030 reference scenario, a scenario without the 2017-2025 light-duty vehicle standards, to a 2030 control scenario which includes the 2017-2025 light-duty vehicle standards. Our modeling indicates that there will be very small changes in ozone across most of the country. In addition, ozone

---

[15] Yantosca, B., 2004. GEOS-CHEMv7-01-02 User's Guide, Atmospheric Chemistry Modeling Group, Harvard University, Cambridge, MA, October 15, 2004.
[16] Henze, D.K., J.H. Seinfeld, N.L. Ng, J.H. Kroll, T-M. Fu, D.J. Jacob, C.L. Heald, 2008. Global modeling of secondary organic aerosol formation from aromatic hydrocarbons: high-vs.low-yield pathways. *Atmos. Chem. Phys.*, 8, 2405-2420.

concentrations in some areas will decrease and ozone concentrations in some other areas will increase. The ozone impacts are related to downstream emissions changes from VMT rebound and upstream emissions changes in electrical power generation and fuel production. In some areas the ozone impact is a result of a combination of the various emissions changes but in other areas the impact is likely mainly the result of one of the types of emissions changes. Some of the ozone increases and decreases are related mainly to upstream emissions changes in electricity generation. Some areas saw increases in ozone due mainly to increased demand for electricity from electric vehicles (e.g. Las Vegas, Dayton, and Little Rock) while other areas saw decreases in ozone due mainly to projected power plant closings (e.g. northeast West Virginia).[17] Some of the ozone decreases are mainly related to upstream emissions reductions from reduced refinery demand as fuel production decreases (e.g. the Gulf Coast) and some of the ozone increases are mainly related to increased emissions of NO_X from the VMT rebound effect (e.g. Knoxville and Atlanta). Figure III-1 presents the changes in 8-hour ozone design value concentration in 2030 between the reference case and the control case.[18] Appendix B details the state and county 8-hour maximum ozone design values for the ambient baseline and the future reference and control cases.

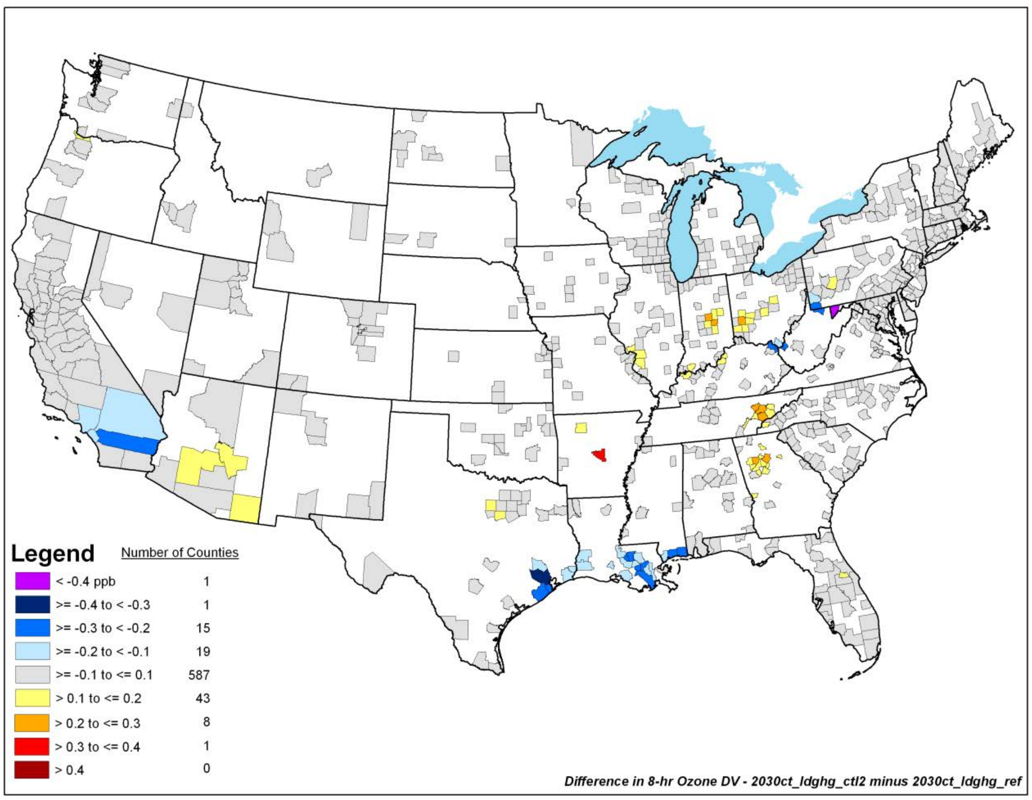

Figure III-1. Projected Change in 2030 8-hour Ozone Design Values Between the Reference Case and Control Case

[17] Section 4.7.3.1 has more information on the IPM modeling which was done to project future electricity demand and plant locations.
[18] An 8-hour ozone design value is the concentration that determines whether a monitoring site meets the 8-hour ozone NAAQS. The full details involved in calculating an 8-hour ozone design value are given in appendix I of 40 CFR part 50.

As can be seen in Figure III-1, the majority of the ozone design value impacts are between + 0.30 ppb and -0.030 ppb. However, there are two counties that will experience 8-hour ozone design value decreases of more than 0.30 ppb; Garrett County, Maryland, and Harris County, Texas. The maximum projected decrease in an 8-hour ozone design value is 0.47 ppb in Garrett County, Maryland. There are also one county, Pulaski County in Arkansas, with a projected design value increase greater than 0.30 ppb.

B. Impacts of LD GHG Standards on Future Annual $PM_{2.5}$ Levels

This section summarizes the results of our modeling of annual average $PM_{2.5}$ air quality impacts in the future due to the 2017-2025 LD GHG vehicle standards. We compare a 2030 reference scenario, a scenario without the vehicle standards, to a 2030 control scenario which includes the vehicle standards. Our modeling indicates that the majority of the modeled counties will experience small changes of between 0.05 $\mu g/m^3$ and -0.05 $\mu g/m^3$ in their annual $PM_{2.5}$ design values due to the vehicle standards. Figure III-2 presents the changes in annual $PM_{2.5}$ design values in 2030.[19]

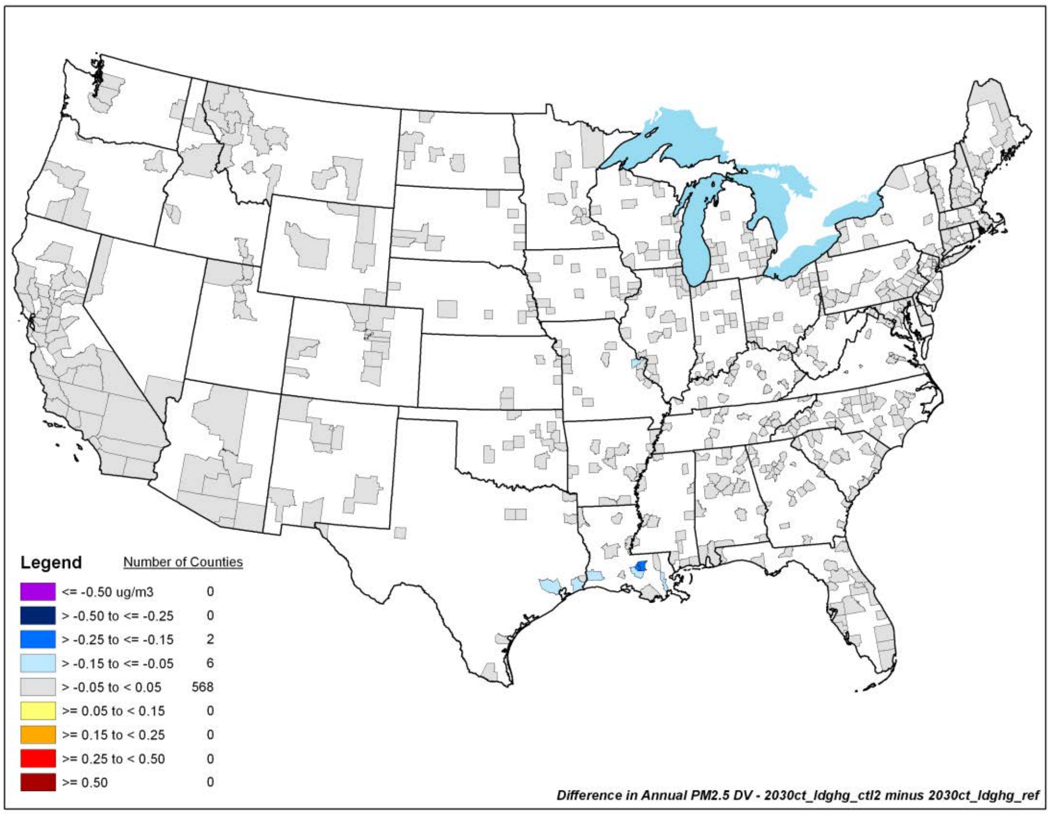

Figure III-2. Projected Change in 2030 Annual $PM_{2.5}$ Design Values Between the Reference Case and Control Case

[19] An annual $PM_{2.5}$ design value is the concentration that determines whether a monitoring site meets the annual NAAQS for $PM_{2.5}$. The full details involved in calculating an annual $PM_{2.5}$ design value are given in appendix N of 40 CFR part 50.

As shown in Figure III-2, eight counties will experience decreases larger than 0.05 μg/m^3. These counties are in the Gulf Coast and in Missouri. The maximum projected decrease in an annual $PM_{2.5}$ design value is 0.16 μg/m^3 in West Baton Rouge County, Louisiana. The decreases in annual $PM_{2.5}$ design values in the gulf coast are likely due to emission reductions related to lower fuel production. Additional information on the emissions reductions that are projected with this final action is available in Section 4.7of the RIA. Appendix C details the state and county annual $PM_{2.5}$ design values for the ambient baseline and the future reference and control cases.

C. Impacts of LD GHG Standards on Future 24-hour $PM_{2.5}$ Levels

This section summarizes the results of our modeling of 24-hour $PM_{2.5}$ air quality impacts in the future due to the 2017-2025 light-duty vehicle standards. Specifically, we compare a 2030 reference scenario, a scenario without the vehicle standards, to a 2030 control scenario which includes the vehicle standards. Our modeling indicates that the majority of the modeled counties will experience changes of between -0.05 μg/m^3 and 0.05 μg/m^3 in their 24-hour $PM_{2.5}$ design values. Figure III-3 presents the changes in 24-hour $PM_{2.5}$ design values in 2030.[20]

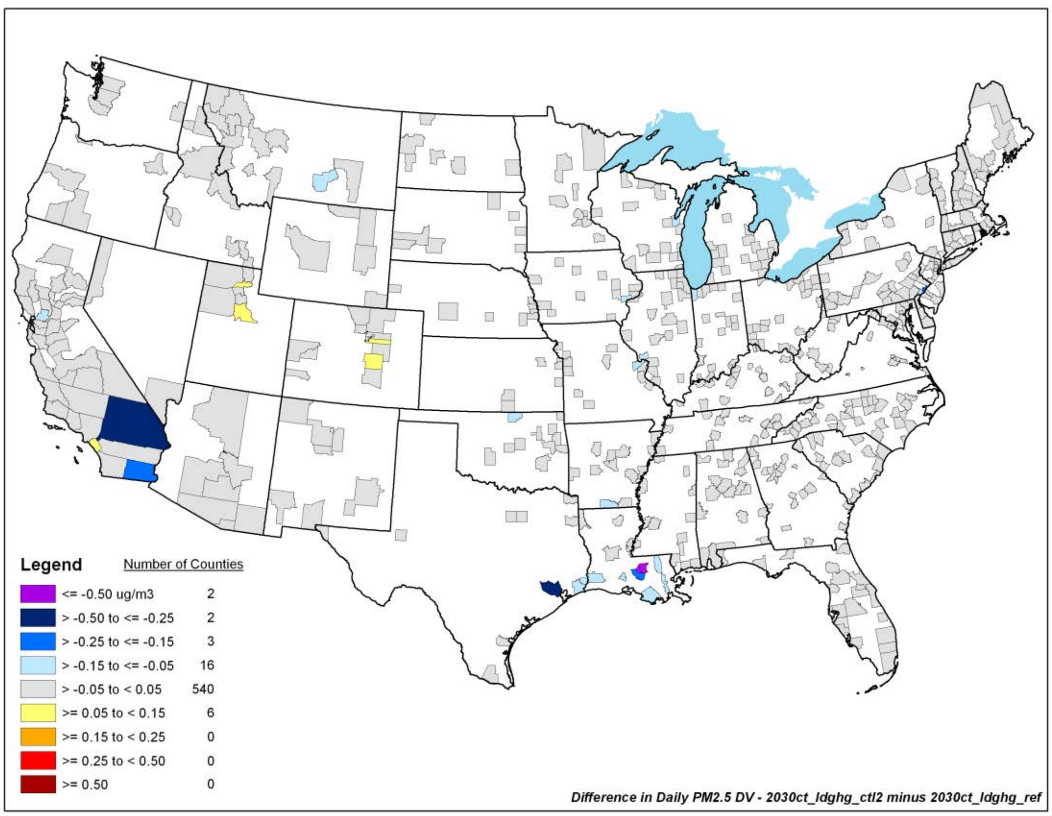

Figure III-3. Projected Change in 2030 24-hour $PM_{2.5}$ Design Values Between the Reference Case and the Control Case

[20] A 24-hour $PM_{2.5}$ design value is the concentration that determines whether a monitoring site meets the 24-hour NAAQS for $PM_{2.5}$. The full details involved in calculating a 24-hour $PM_{2.5}$ design value are given in appendix N of 40 CFR part 50.

As shown in Figure III-3, design value concentrations will increase more than 0.05 μg/m^3 in six counties and design value concentrations will decrease more than 0.05 μg/m^3 in 23 counties. The increases in 24-hour $PM_{2.5}$ design values in some counties are likely due to increased emissions from the VMT rebound effect or increased electricity generation. The maximum projected increase in a 24-hour $PM_{2.5}$ design value is 0.14 μg/m^3 in El Paso County, Colorado. The decreases in 24-hour $PM_{2.5}$ design values in some counties are likely due to emission reductions related to lower fuel production. The maximum projected decrease in a 24-hour $PM_{2.5}$ design value is 0.76 μg/m^3 in East Baton Rouge County, Louisiana. Additional information on the emissions changes that are projected with this final action is available in Section 4.7 of the RIA. Appendix D details the state and county 24-hour $PM_{2.5}$ design values for the ambient baseline and the future reference and control cases.

D. Impacts of LD GHG Standards on Future Toxic Air Pollutant Levels

The following sections summarize the results of our modeling of air toxics impacts in the future from the vehicle emission standards required by LD GHG. We focus on air toxics which were identified as national and regional-scale cancer and noncancer risk drivers in the 2005 NATA assessment and were also likely to be significantly impacted by the standards. These compounds include benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein. Our modeling indicates that national average ambient concentrations of the modeled air toxics change less than 1 percent across most of the country due to the final standards. Because overall impacts are relatively small in future years, we concluded that assessing exposure to ambient concentrations and conducting a quantitative risk assessment of air toxic impacts was not warranted. However, we did develop population metrics, including the population living in areas with changes in concentrations of various magnitudes.

1. Acetaldehyde

Overall, the air quality modeling does not show substantial nationwide impacts on ambient concentrations of acetaldehyde as a result of the standards finalized in this rule. Annual and seasonal percent changes in ambient concentrations of acetaldehyde are typically between ±1 percent across the country with decrease up to 10 percent in a few urban areas (Figures III-4 through III-6). Annual and seasonal reductions in ambient acetaldehyde in 2030 range between 0.001 and 0.01 μg/m^3 across much of the country with decreases as high as 0.1 μg/m^3 in urban areas; these changes are mainly associated with reductions from upstream sources including fuel production, refining, storage and transport. Specifically, the winter season shows decreases of 1 percent to 10 percent in the Midwest as well as urban areas in the Northeast, Florida, Louisiana, Texas, Colorado, Utah, and California (Figure III-5).

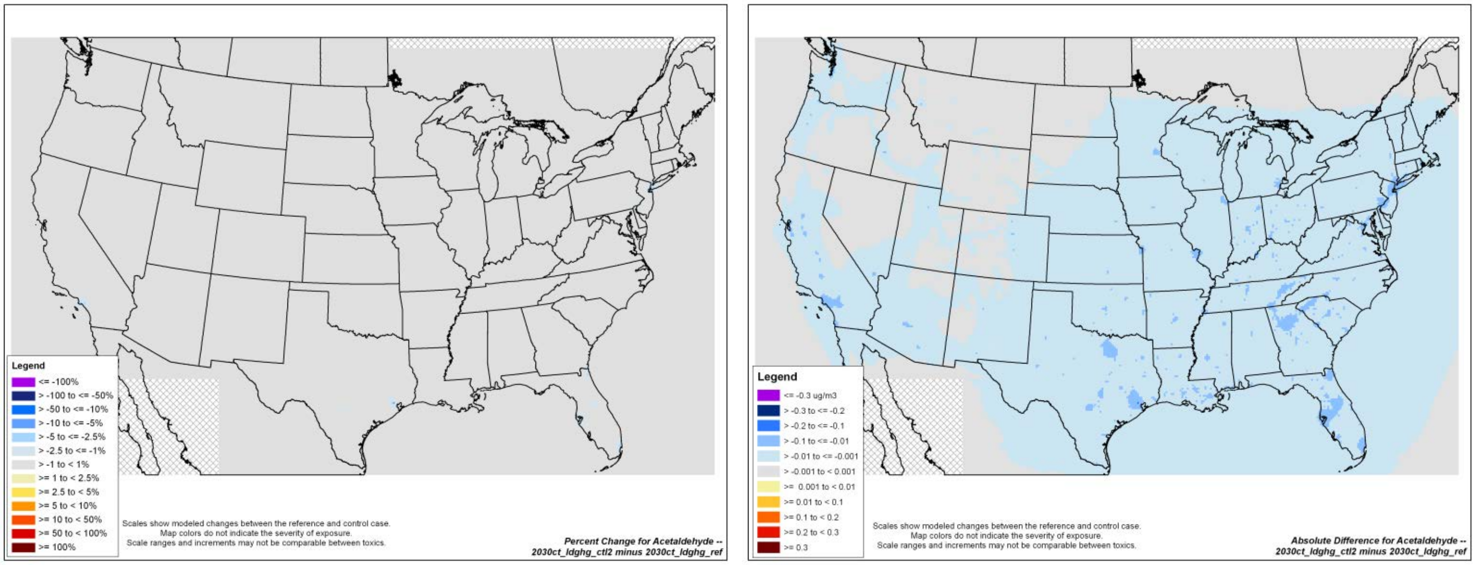

Figure III-4. Changes in Annual Acetaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

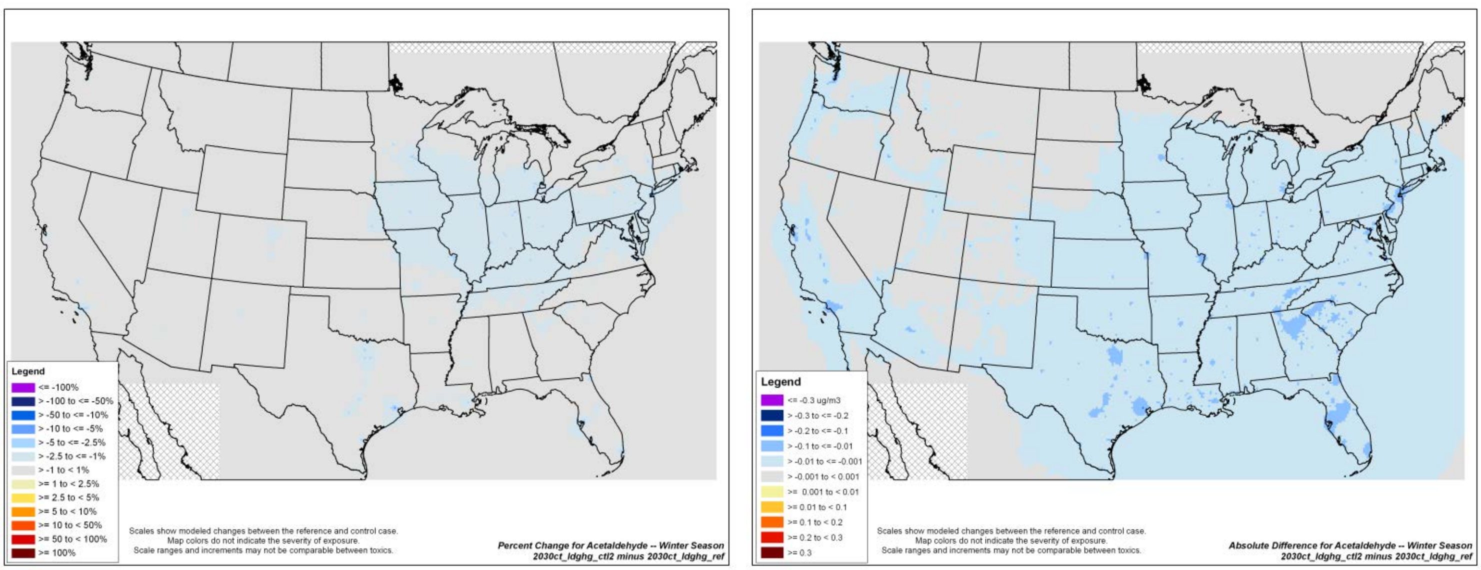

Figure III-5. Changes in Winter Acetaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

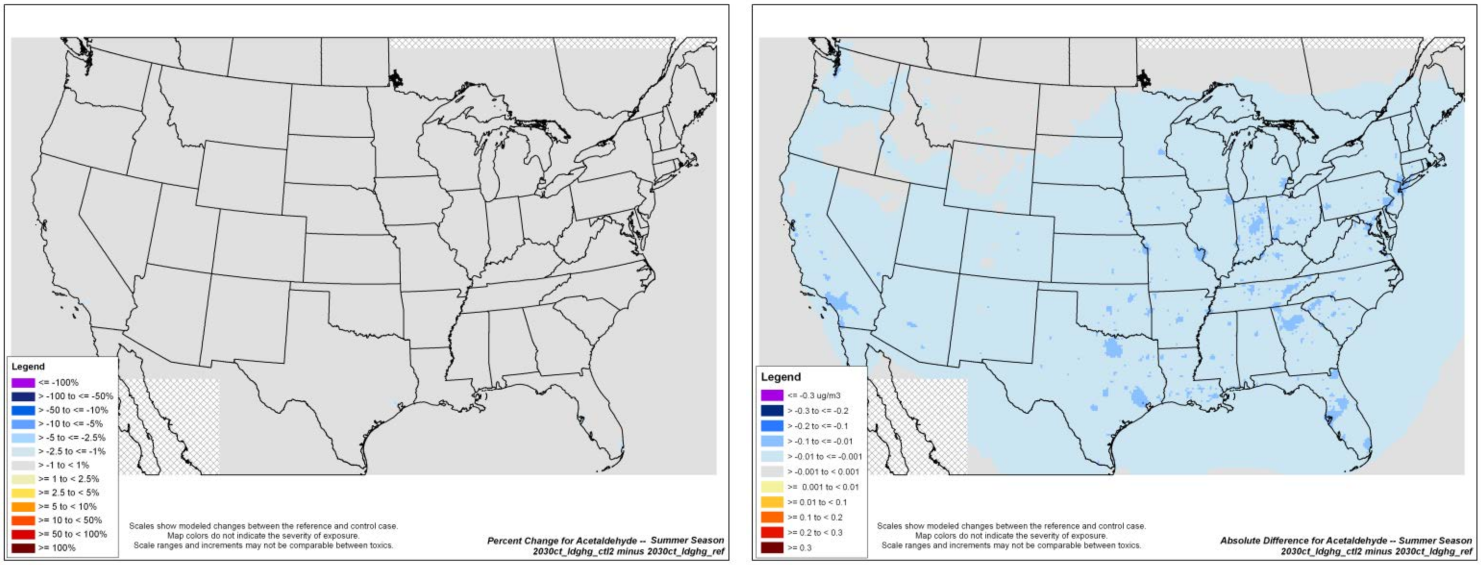

Figure III-6. Changes in Summer Acetaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

2. Formaldehyde

Our modeling projects that the standards finalized in this rule do not show substantial impacts on ambient formaldehyde concentrations. In 2030, annual and seasonal percent changes in ambient concentrations of formaldehyde are less than 1 percent across much of the country, with a decrease ranging from 2.5 to 10 percent in Oklahoma (Figures III-7 to III-8). Likwise, ambient annual and seasonal formaldehyde reductions in 2030 generally range from 0.001 to 0.1 µg/m³ and are associated with upstream reductions in fuel production, refining, storage and transport. Decreases in Oklahoma are greater than 0.3 µg/m³ and due to reductions in emissions from refineries in that area. Increases in annual and seasonal ambient formaldehyde concentrations range between 0.001 to 0.1 µg/m³ in areas associated with increased emissions from power plants.

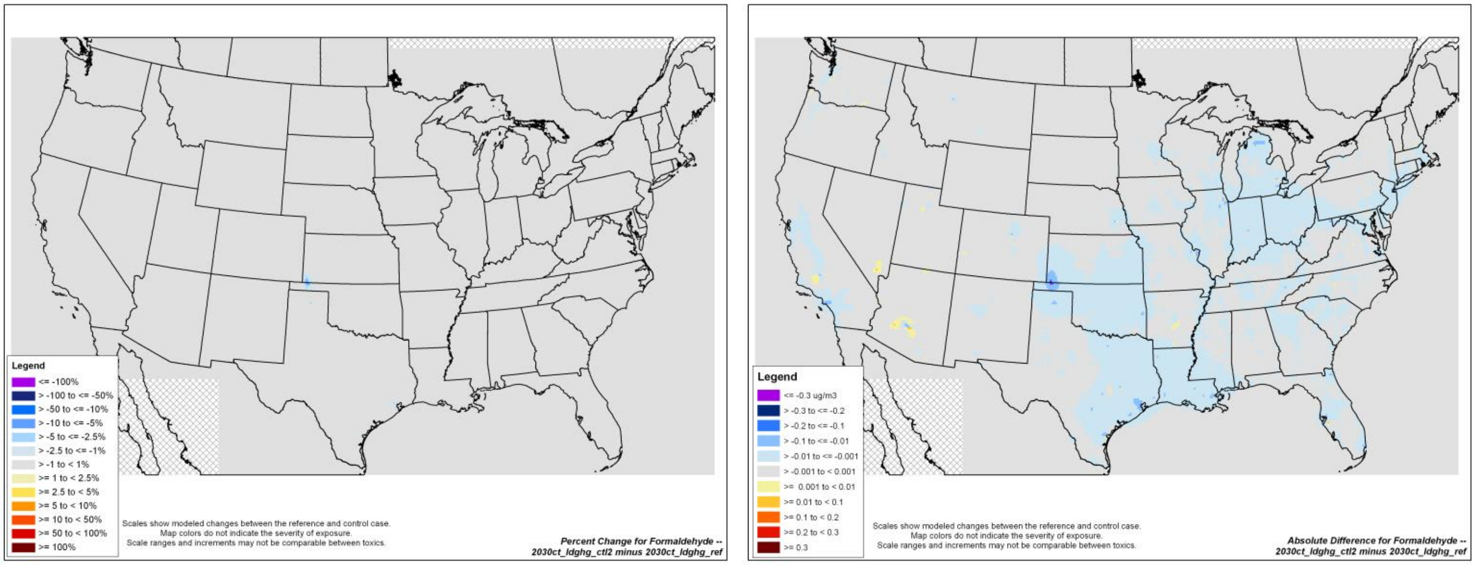

Figure III-7. Changes in Annual Formaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

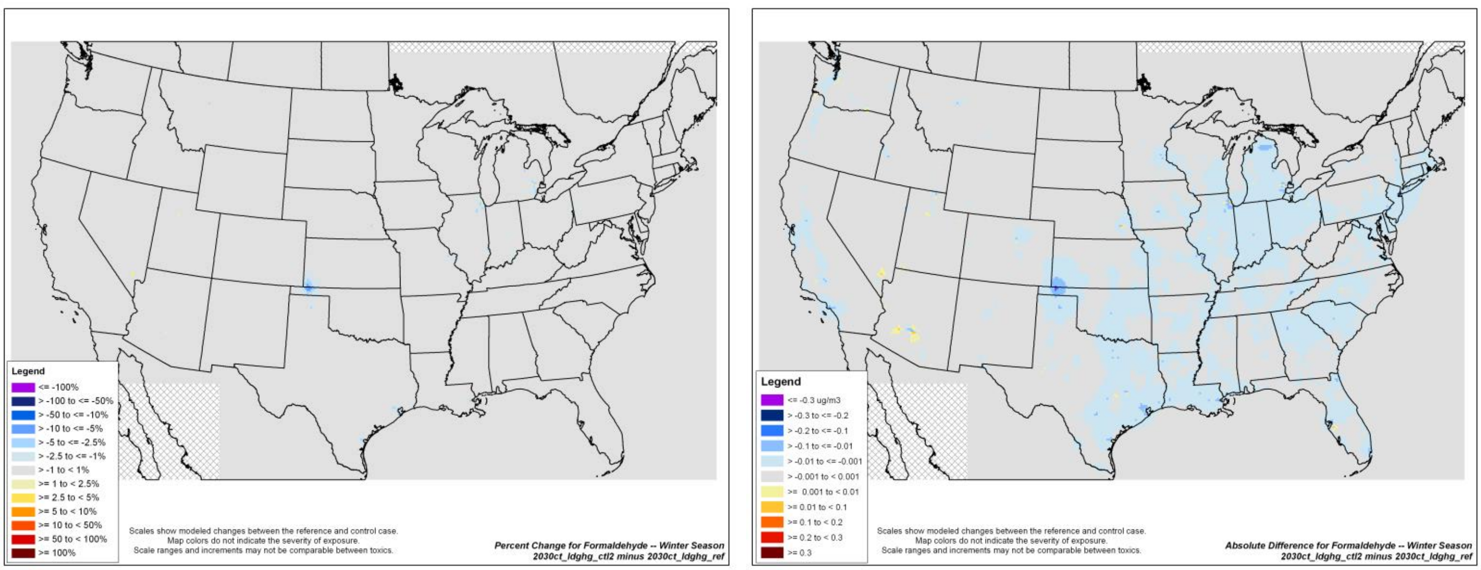

Figure III-8. Changes in Winter Formaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

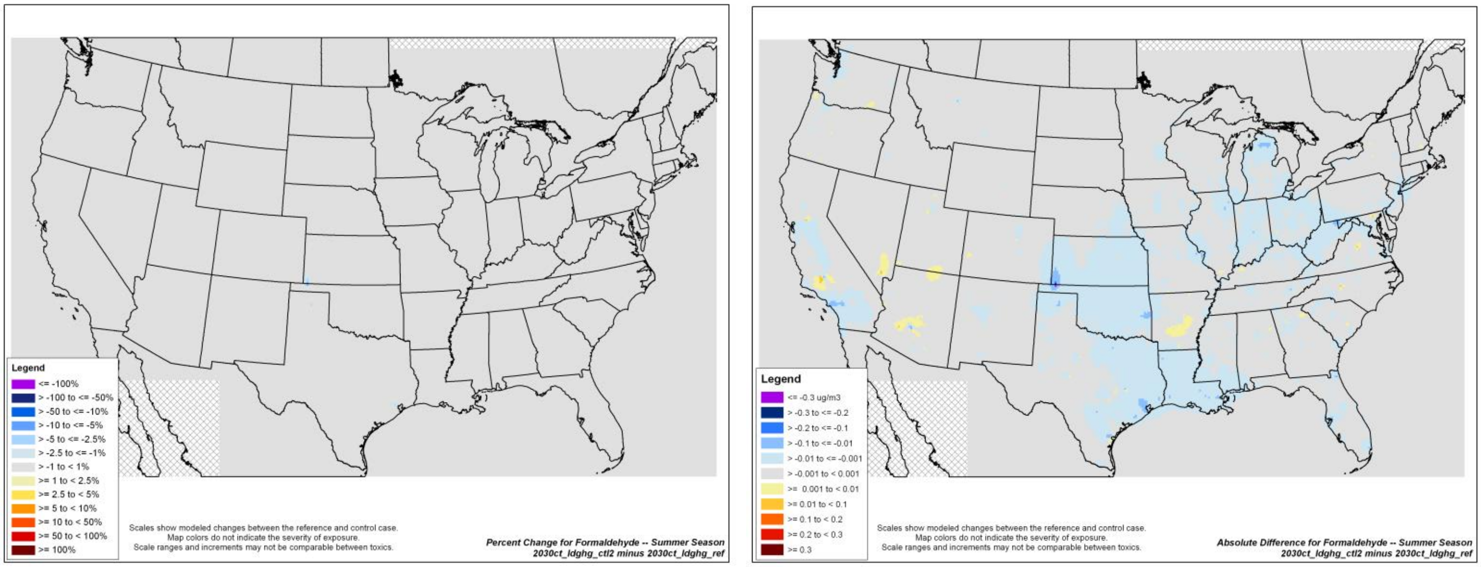

Figure III-9. Changes in Summer Formaldehyde Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

3. Benzene

Our air quality modeling projects that the standards finalized in this rule will not have a significant impact on ambient benzene concentrations. Figures III-10, III-11, and III-12 show decreases in annual and seasonal ambient benzene concentrations ranging between ± 1 percent nationwide; with a few areas, mainly in the Gulf Coast region, are projected to have benzene reductions from 1 to 10%, likely due to decreases in refinery emissions. Annual and seasonal absolute changes in ambient benzene in 2030 are generally ± 0.001 μg/m³ in the western half of the U.S. with decreases up to 0.01 μg/m³ across the eastern half of the U.S due to upstream reductions in fuel production, refining, storage and transport.

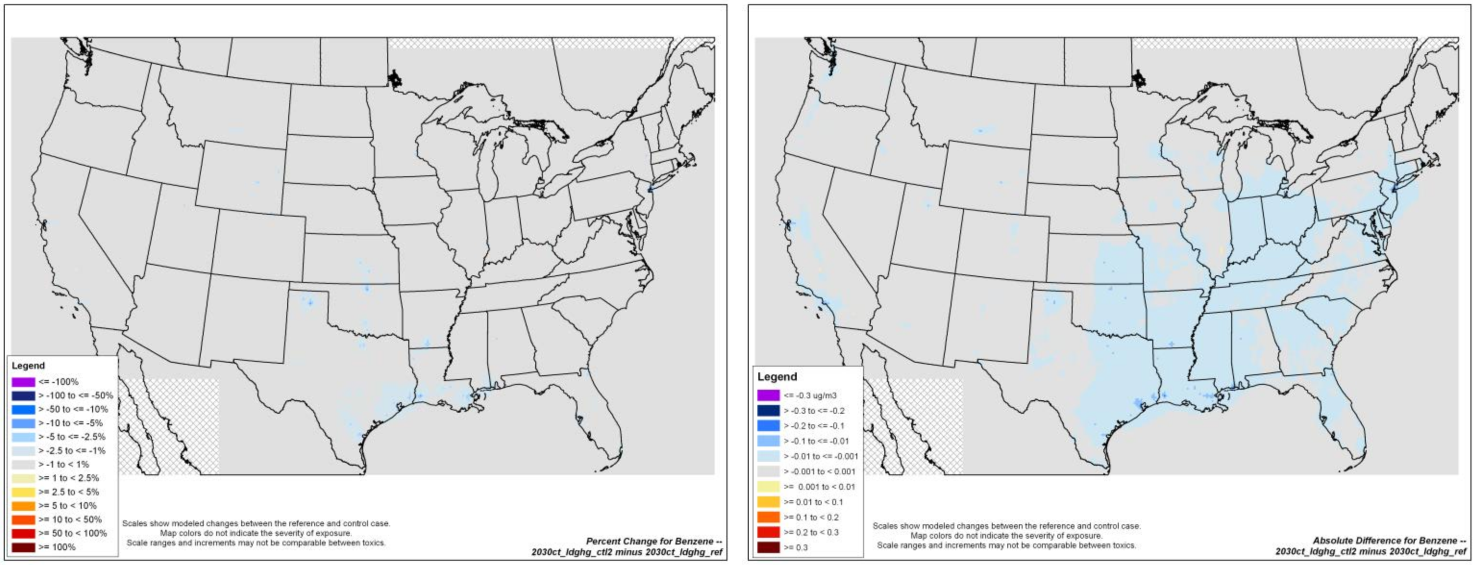

Figure III-10. Changes in Annual Benzene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

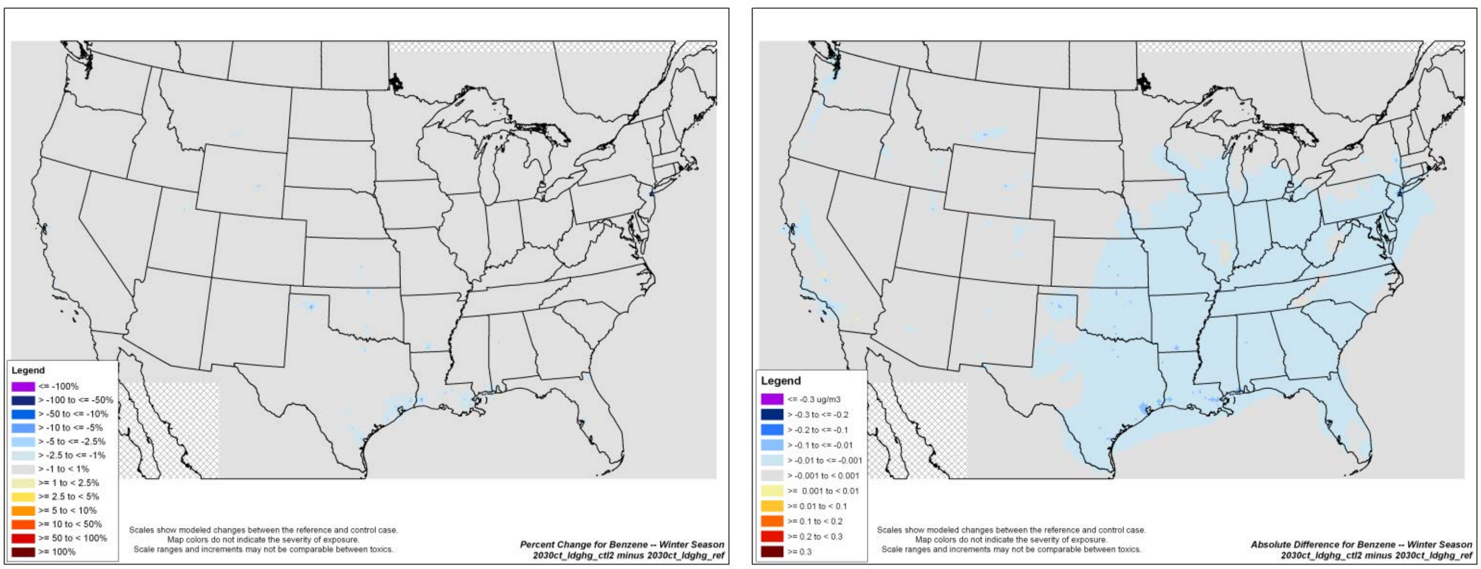

Figure III-11. Changes in Winter Benzene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

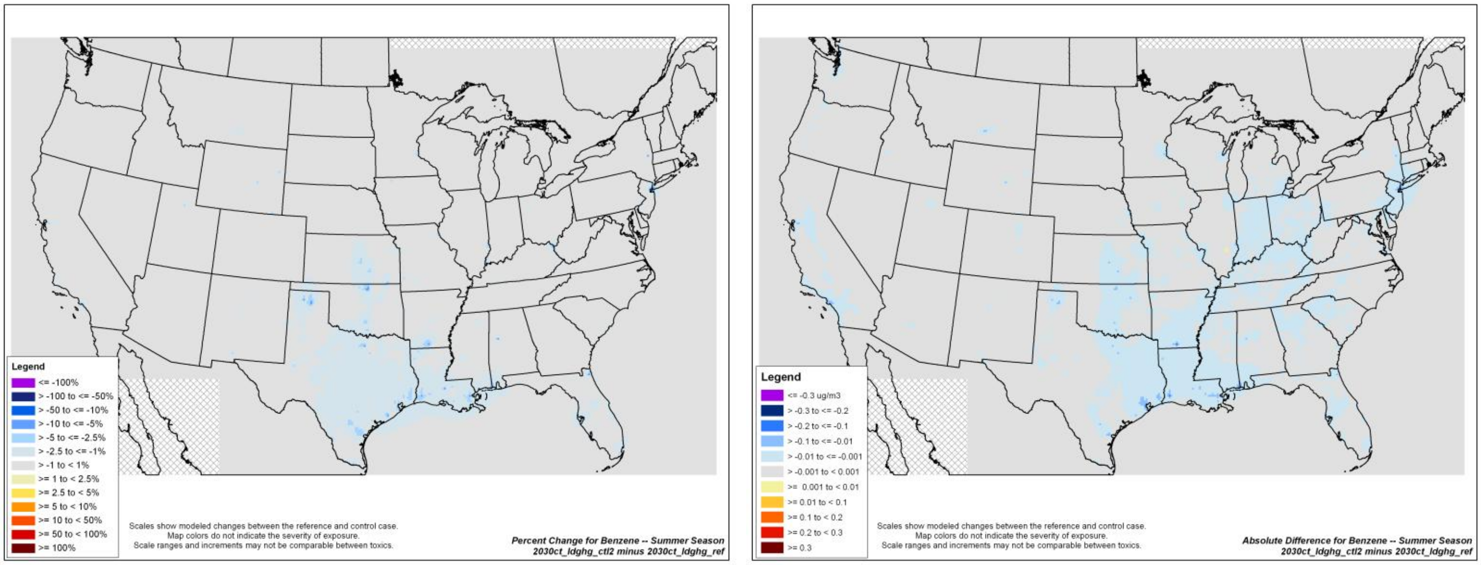

Figure III-12. Changes in Summer Benzene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

4. 1,3-Butadiene

Our air quality modeling results do not show substantial impacts on ambient concentrations of 1,3-butadiene from the final standards. As shown in Figures III-13 to III-15, annual and seasonal ambient concentrations of 1,3-butdiene are generally between ± 1 percent across the country in 2030. Some areas in Texas, Nebraska and Utah have 1,3-butadiene increases on the order of 1 to 5 percent; however, as shown in the map on the right, all changes in annual and seasonal absolute concentrations are between ± 0.001 µg/m³ nationwide.

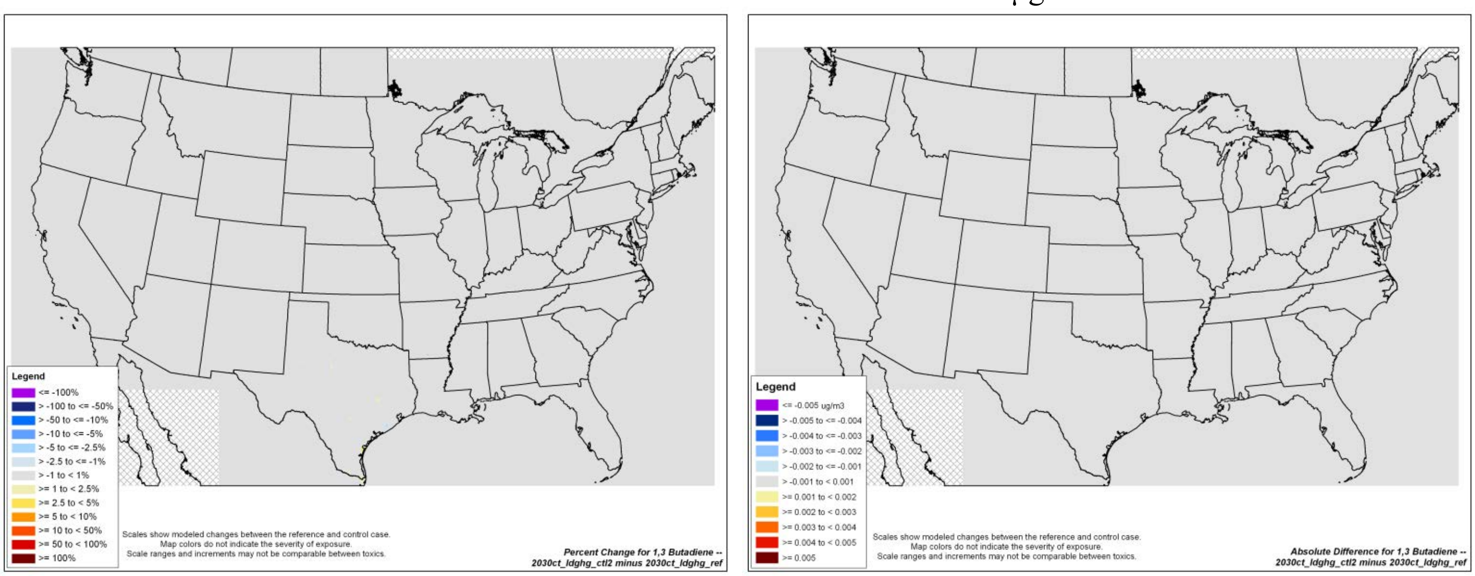

Figure III-13. Changes in Annual 1,3-Butadiene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

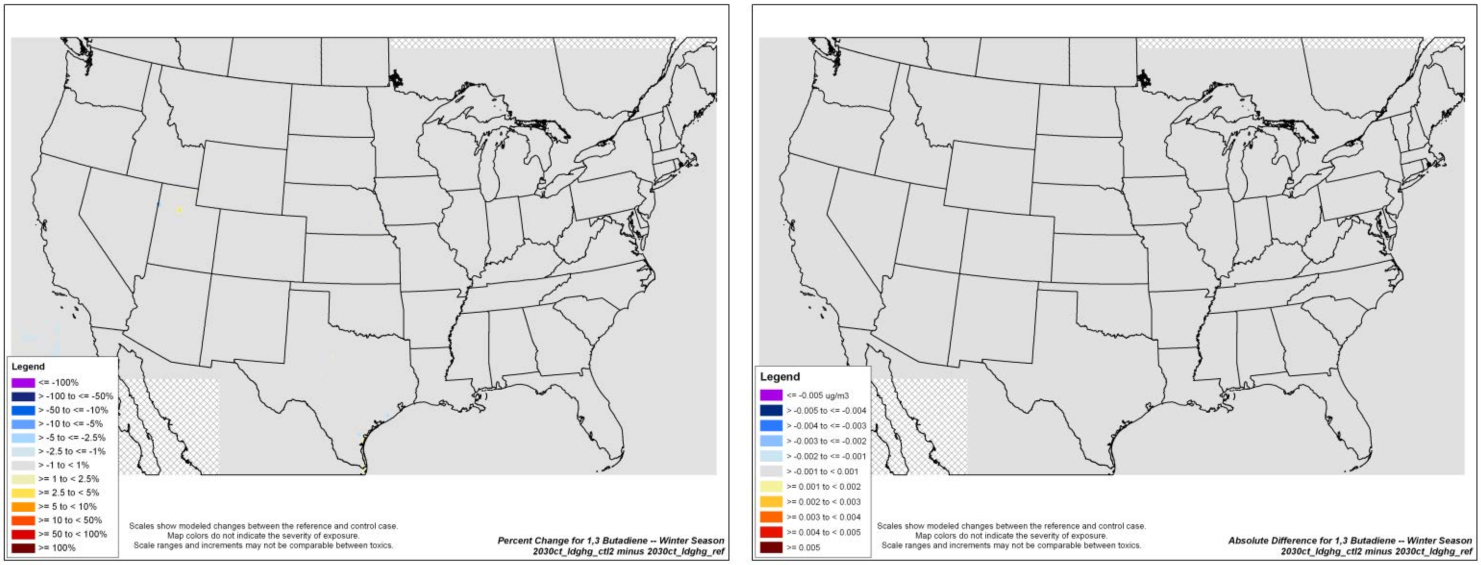

Figure III-14. Changes in Winter 1,3-Butadiene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

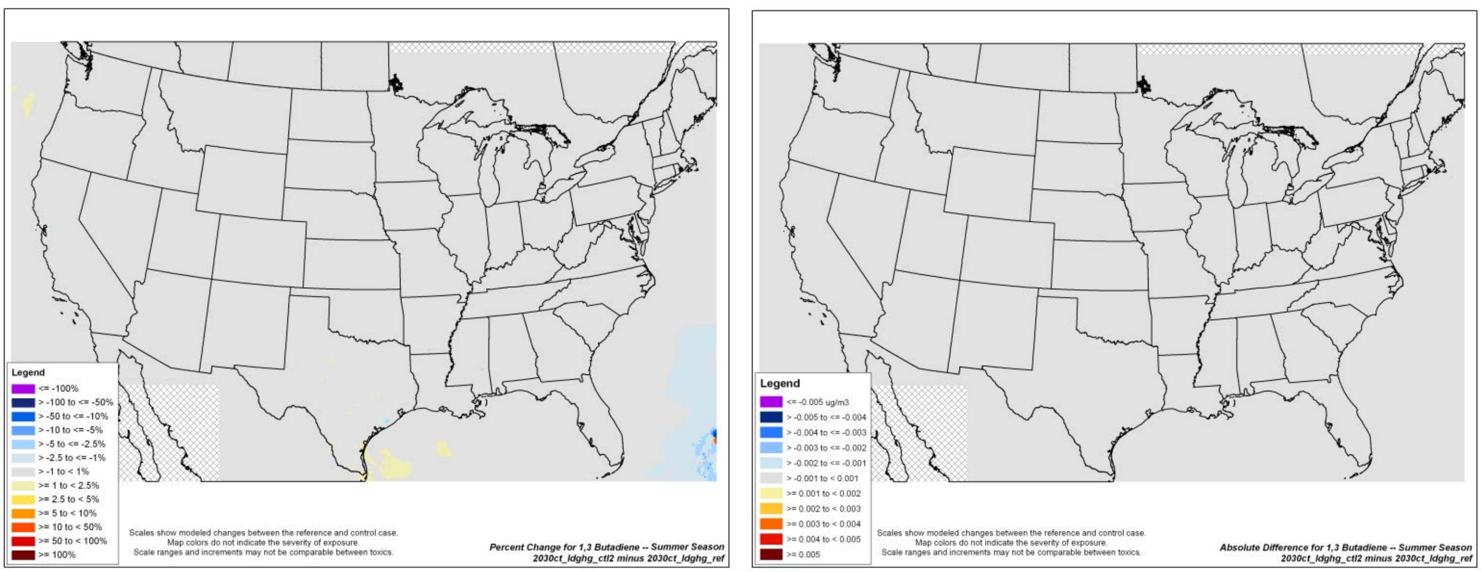

Figure III-15. Changes in Summer 1,3-Butadiene Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

5. Acrolein

Our air quality modeling results do not show substantial impacts on ambient concentrations of acrolein from the standards finalized in this rule. In 2030, annual and seasonal percent changes in ambient acrolein concentrations are generally ± 1 percent nationwide (Figures

III-16 to III-18). Parts of the Midwest, Texas, Arizona, New Mexico and Utah have decreases in ambient acrolein concentrations generally between 1 and 10 percent and increases of similar magnitude in a few urban areas; however, all absolute changes in ambient acrolein concentrations are between ± 0.001 µg/m³ in 2030.

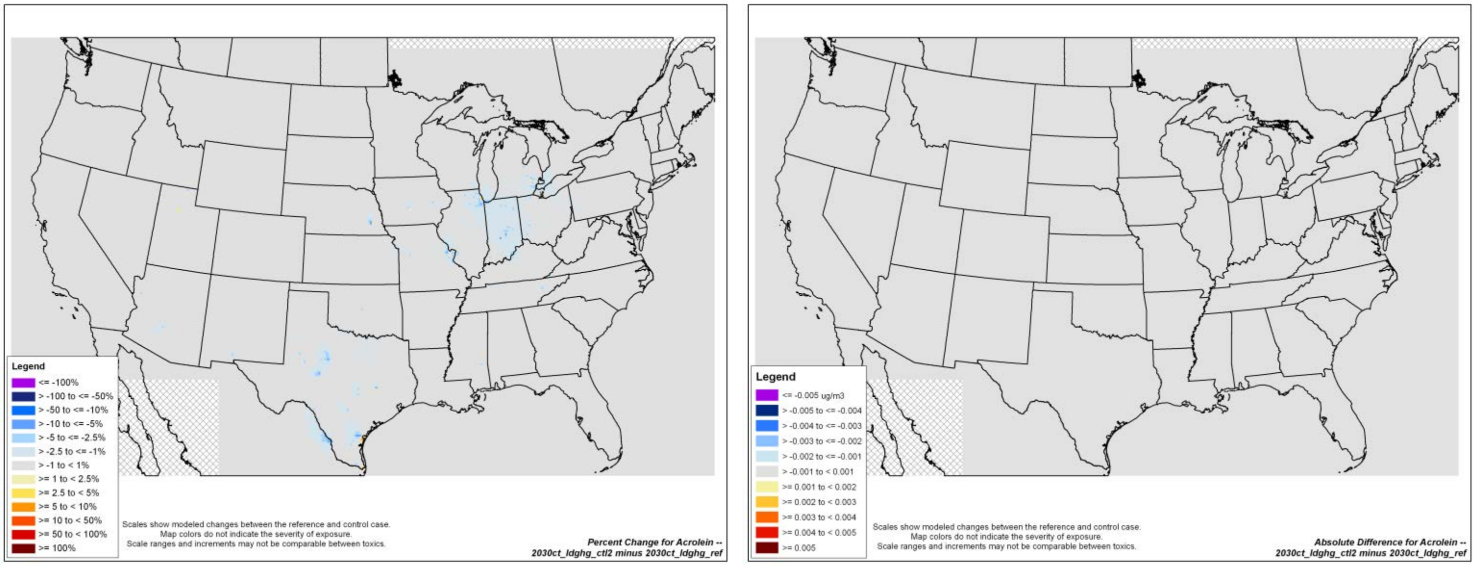

Figure III-16. Changes in Annual Acrolein Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

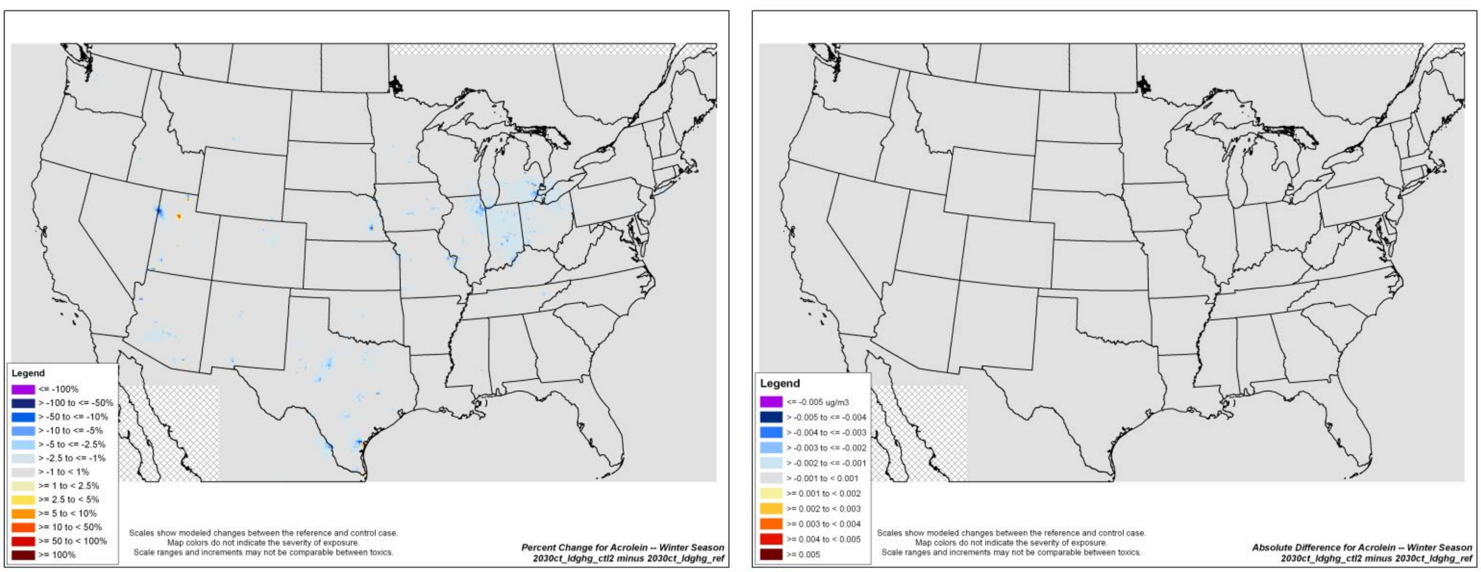

Figure III-17. Changes in Winter Acrolein Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

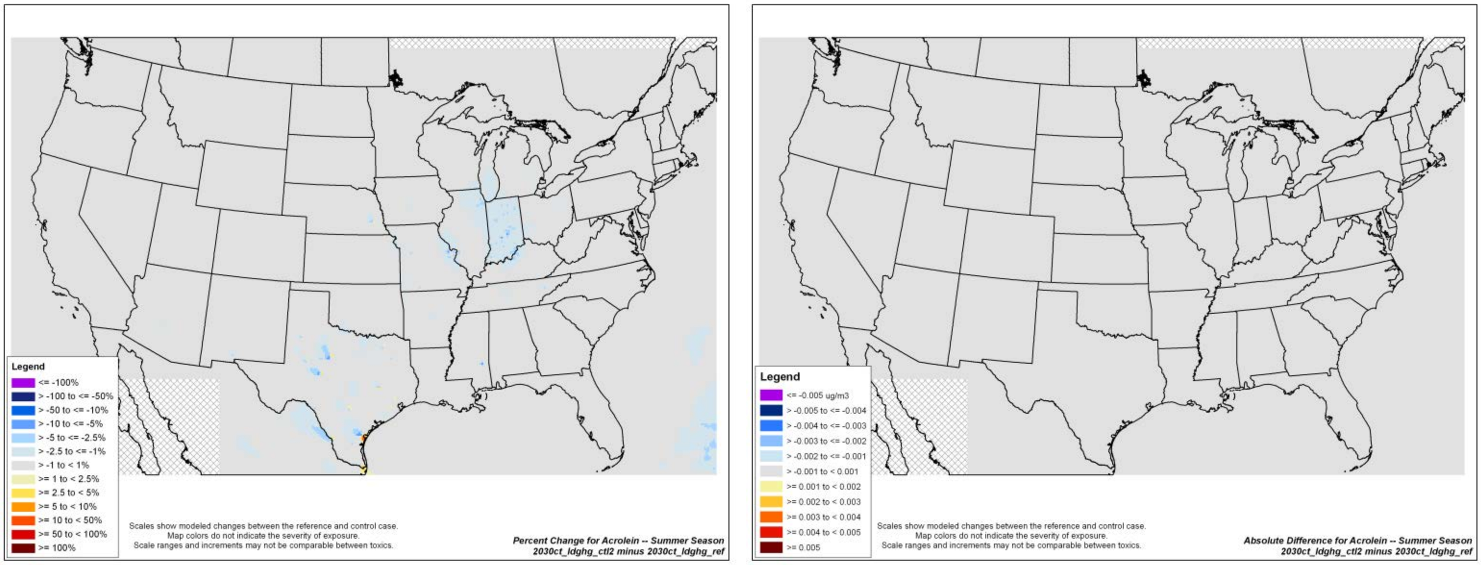

Figure III-18. Changes in Summer Acrolein Ambient Concentrations Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

E. Population Metrics

To assess the impact the rule's of projected changes in air quality, we developed population metrics that show population experiencing changes in annual ambient concentrations across the modeled air toxics. As shown in Table III-1, over 98 percent of the U.S. population is projected to experience a less than one percent change in formaldehyde and 1,3-butadiene. Over 83 percent of the U.S. population is projected to experience a less than one percent change in acetaldehyde, benzene and acrolein, and over 12 percent are projected to experience a 1 to 5 percent decrease in these pollutants.

Table III-1 Percent of Total Population Experiencing Changes in Annual Ambient Concentrations of Toxic Pollutants in 2030 as a Result of the Final Standards

Percent Change	Acetaldehyde	Formaldehyde	Benzene	1,3-Butadiene	Acrolein
≤ -100	--	--	--	--	--
> -100 to ≤ -50	--	--	--	--	--
> -50 to ≤ -10	--	--	--	--	--
> -10 to ≤ -5	0.0%	0.0%	0.8%	--	0.2%
> -5 to ≤ -2.5	1.5%	0.1%	1.8%	0.0%	2.0%
> -2.5 to ≤ -1	15.3%	1.2%	13.0%	0.2%	10.3%
> -1 to < 1	83.1%	98.7%	84.4%	99.2%	86.1%
≥ 1 to < 2.5	--	--	0.0%	0.6%	0.9%
≥ 2.5 to < 5	--	--	--	0.0%	0.0%
≥ 5 to < 10	--	--	--	--	0.0%
≥ 10 to < 50	--	--	--	--	--
≥ 50 to < 100	--	--	--	--	--
≥ 100	--	--	--	--	--

F. Impacts of LD GHG Standards on Future Annual Nitrogen and Sulfur Deposition Levels

Our air quality modeling projects increases in nitrogen deposition in some localized areas across the US along with a few areas of decreases in nitrogen deposition. Figure III-19 shows that for nitrogen deposition the vehicle standards will result in annual percent increases of more than 2% in some areas. The increases in nitrogen deposition are likely due to projected upstream emissions increases in NO_X from increased electricity generation and increased driving due to the rebound effect. Figure III-19 **Error! Reference source not found.** also shows that for nitrogen deposition the vehicle standards will result in annual percent decreases of more than 2% in a few areas in West Virginia and New Mexico. The decreases in nitrogen deposition are likely due to projected upstream emissions decreases in NO_X from changes in the location of electricity generation. The remainder of the country will experience only minimal changes in nitrogen deposition, ranging from decreases of less than 0.5% to increases of less than 0.5%.

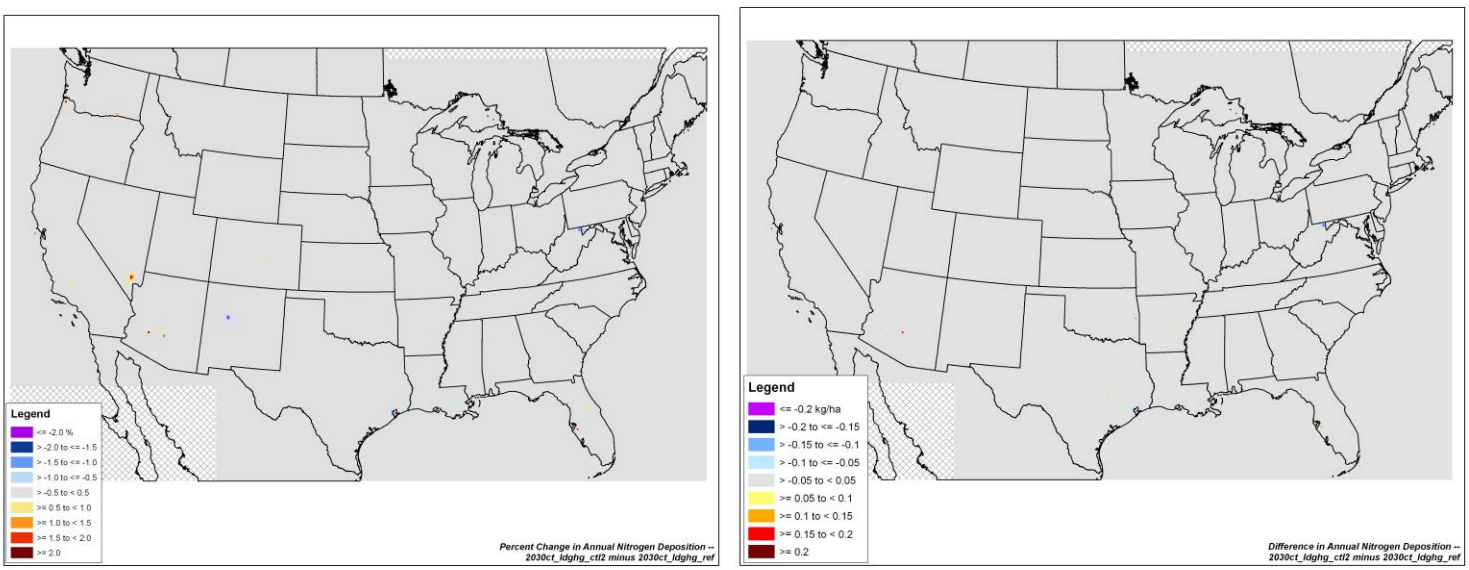

Figure III-19. Changes in Annual Total Nitrogen Deposition Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in μg/m³ (right)

Our air quality modeling projects both increases and decreases in sulfur deposition in localized areas across the U.S. Figure III-20**Error! Reference source not found.** shows that for sulfur deposition the vehicle standards will result in annual percent decreases of more than 2% in many areas. The decreases in sulfur deposition are likely due to projected upstream emissions decreases from changes in the location of electricity generation and from reduced gasoline production. **Error! Reference source not found.**Figure III-20 also shows that for sulfur deposition the vehicle standards will result in annual percent increases of more than 2% in some areas. The increases in sulfur deposition are likely due to projected upstream emissions increases from increased electricity generation. The remainder of the country will experience only minimal changes in sulfur deposition, ranging from decreases of less than 0.5% to increases of less than 0.5%.

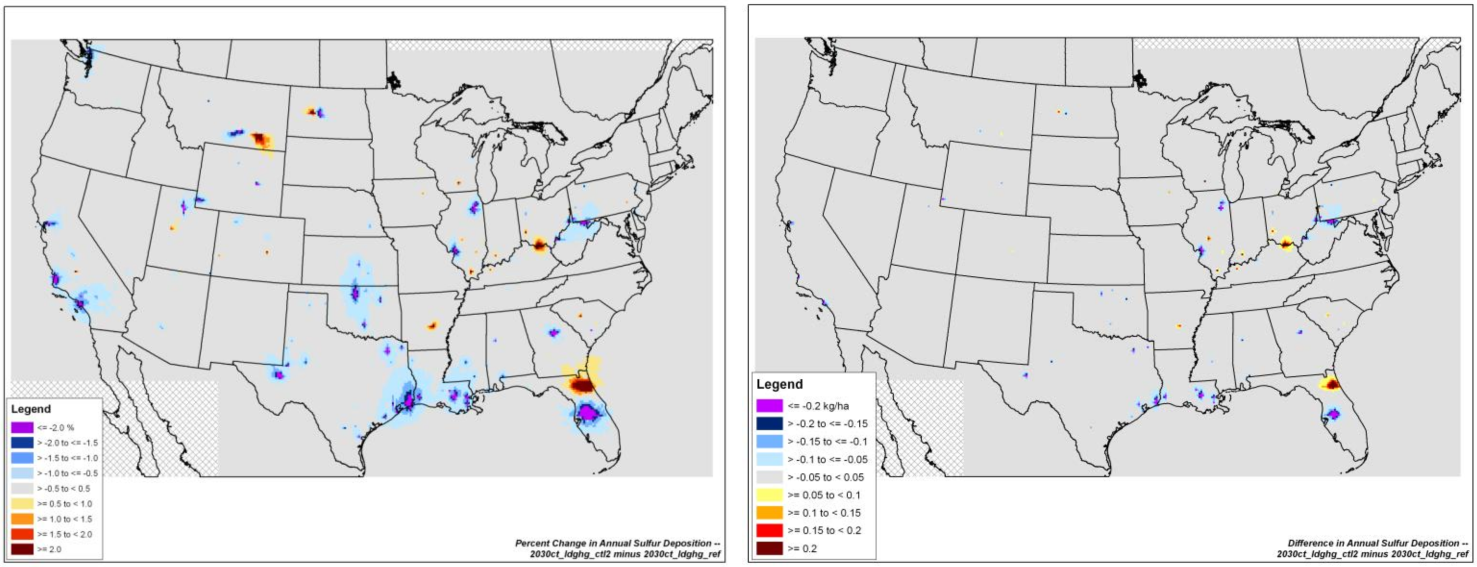

Figure III-20. Changes in Annual Total Sulfur Deposition Between the Reference Case and the Control Case in 2030: Percent Changes (left) and Absolute Changes in µg/m³ (right)

G. Impacts of LD GHG Standards on Future Visibility Levels

Air quality modeling conducted for this final rule was used to project visibility conditions in 139 mandatory class I federal areas across the U.S. in 2030. The impacts of this action were examined in terms of the projected improvements in visibility on the 20 percent worst visibility days at Class I areas. We quantified visibility impacts at the Class I areas which have complete IMPROVE ambient data for 2005 or are represented by IMPROVE monitors with complete data. Sites were used in this analysis if they had at least 3 years of complete data for the 2003-2007 period[21].

Visibility for the 2030 reference case and 2030 control case was calculated using the regional haze methodology outlined in section 6 of the photochemical modeling guidance, which applies modeling results in a relative sense, using base year ambient data. The $PM_{2.5}$ and regional haze modeling guidance recommends the calculation of future year changes in visibility in a similar manner to the calculation of changes in $PM_{2.5}$ design values. The regional haze methodology for calculating future year visibility impairment is included in MATS (http://www.epa.gov/scram001/modelingapps_mats.htm)

In calculating visibility impairment, the extinction coefficient values[22] are made up of individual component species (sulfate, nitrate, organics, etc). The predicted change in visibility (on the 20 percent worst days) is calculated as the modeled percent change in the mass for each of the $PM_{2.5}$ species (on the 20% worst observed days) multiplied by the observed concentrations. The future mass is converted to extinction and then daily species extinction

[21] Since the base case modeling used meteorology for 2005, one of the complete years must be 2005.
[22] Extinction coefficient is in units of inverse megameters (Mm^{-1}). It is a measure of how much light is absorbed or scattered as it passes through a medium. Light extinction is commonly used as a measure of visibility impairment in the regional haze program.

coefficients are summed to get a daily total extinction value (including Rayleigh scattering). The daily extinction coefficients are converted to deciviews and averaged across all 20 percent worst days. In this way, we calculate an average change in deciviews from the base case to a future case at each IMPROVE site. Subtracting the 2030 reference case from the corresponding 2030 reference case deciview values gives an estimate of the visibility benefits in Class I areas that are expected to occur from the rule.

The following options were chosen in MATS for calculating the future year visibility values for the rule:

New IMPROVE algorithm
Use model grid cells at (IMPROVE) monitor
Temporal adjustment at monitor- 3x3 for 12km grid, (1x1 for 36km grid)
Start monitor year- 2003
End monitor year- 2007
Base model year 2005
Minimum years required for a valid monitor- 3

The “base model year” was chosen as 2005 because it is the base case meteorological year for the final LD GHG Rule modeling. The start and end years were chosen as 2003 and 2007 because that is the 5 year period which is centered on the base model year of 2005. These choices are consistent with using a 5 year base period for regional haze calculations.

The results show that all the modeled areas will continue to have annual average deciview levels above background in 2030.[23] The results also indicate that the majority of the modeled mandatory class I federal areas will see very little change in their visibility. Some mandatory class I federal areas will see improvements in visibility due to the light-duty standards and a few mandatory class I federal areas will see visibility decreases. The average visibility at all modeled mandatory class I federal areas on the 20% worst days is projected to improve by 0.003 deciviews, or 0.01%, in 2030. The greatest improvement in visibility will be seen at Sipsey Wilderness, Alabama, Aqua Tibia Wilderness, California, and Wilderness Lake, Washington with a 0.02 DV improvement due to the 2017-2025 light-duty standards. The greatest degradation of visibility is projected to be seen at Wolf Island, Georgia with a degradation of 0.03 DV in 2030 as a result of the 2017-2025 light-duty standards. Section 6.2.2.5 of the LD GHG final rule RIA contains more details on the visibility portion of the air quality modeling. Table III-2 contains the full visibility results for the 20% worst days from 2030 for the 139 analyzed areas.

[23] The level of visibility impairment in an area is based on the light-extinction coefficient and a unitless visibility index, called a “deciview”, which is used in the valuation of visibility. The deciview metric provides a scale for perceived visual changes over the entire range of conditions, from clear to hazy. Under many scenic conditions, the average person can generally perceive a change of one deciview. The higher the deciview value, the worse the visibility. Thus, an improvement in visibility is a decrease in deciview value.

Table III-2. Visibility Levels in Deciviews for Individual U.S. Class I Areas on the 20% Worst Days for Several Scenarios

Class 1 Area (20% worst days)	State	2005 Base	2030 LDGHG Reference	2030 LDGHG Control	Natural Background
Sipsey Wilderness	AL	29.88	20.54	20.52	11.39
Caney Creek Wilderness	AR	26.69	19.84	19.84	11.33
Upper Buffalo Wilderness	AR	26.97	20.17	20.18	11.28
Chiricahua NM	AZ	12.89	12.08	12.07	6.92
Chiricahua Wilderness	AZ	12.89	12.08	12.07	6.91
Galiuro Wilderness	AZ	12.89	12.09	12.09	6.88
Grand Canyon NP	AZ	11.86	10.92	10.91	6.95
Mazatzal Wilderness	AZ	13.95	12.46	12.45	6.91
Mount Baldy Wilderness	AZ	11.32	10.74	10.74	6.95
Petrified Forest NP	AZ	13.56	12.65	12.65	6.97
Pine Mountain Wilderness	AZ	13.95	12.42	12.41	6.92
Saguaro NM	AZ	14.39	13.43	13.43	6.84
Sierra Ancha Wilderness	AZ	14.45	13.28	13.28	6.92
Superstition Wilderness	AZ	14.15	12.85	12.85	6.88
Sycamore Canyon Wilderness	AZ	15.45	14.67	14.67	6.96
Agua Tibia Wilderness	CA	22.36	18.41	18.39	7.17
Ansel Adams Wilderness (Minarets)	CA	15.24	14.39	14.39	7.12
Caribou Wilderness	CA	13.65	12.68	12.67	7.29
Cucamonga Wilderness	CA	18.44	15.64	15.64	7.17
Desolation Wilderness	CA	12.87	12.10	12.09	7.13
Emigrant Wilderness	CA	16.87	15.94	15.94	7.14
Hoover Wilderness	CA	11.61	11.07	11.06	7.12
John Muir Wilderness	CA	15.24	14.34	14.34	7.14
Joshua Tree NM	CA	18.90	16.39	16.41	7.08
Kaiser Wilderness	CA	15.24	14.11	14.10	7.13
Kings Canyon NP	CA	23.73	22.19	22.19	7.13
Lassen Volcanic NP	CA	13.65	12.66	12.66	7.31
Lava Beds NM	CA	14.13	13.19	13.19	7.49
Mokelumne Wilderness	CA	12.87	12.08	12.07	7.14
Pinnacles NM	CA	17.90	15.42	15.42	7.34
Point Reyes NS	CA	22.40	21.00	21.00	7.39
Redwood NP	CA	18.55	17.66	17.66	7.81
San Gabriel Wilderness	CA	18.44	15.54	15.53	7.17
San Gorgonio Wilderness	CA	21.43	19.27	19.28	7.10
San Jacinto Wilderness	CA	21.43	18.10	18.11	7.12
San Rafael Wilderness	CA	19.43	17.40	17.39	7.28
Sequoia NP	CA	23.73	21.68	21.67	7.13
South Warner Wilderness	CA	14.13	13.31	13.31	7.32
Thousand Lakes Wilderness	CA	13.65	12.65	12.64	7.32
Ventana Wilderness	CA	17.90	16.37	16.37	7.32
Yosemite NP	CA	16.87	15.95	15.95	7.14
Black Canyon of the Gunnison NM	CO	10.00	9.21	9.21	7.06
Eagles Nest Wilderness	CO	8.82	8.05	8.05	7.08

Flat Tops Wilderness	CO	8.82	8.32	8.31	7.07
Great Sand Dunes NM	CO	11.82	11.20	11.20	7.10
La Garita Wilderness	CO	10.00	9.49	9.49	7.06
Maroon Bells-Snowmass Wilderness	CO	8.82	8.27	8.26	7.07
Mesa Verde NP	CO	12.14	11.31	11.31	7.09
Mount Zirkel Wilderness	CO	9.72	9.20	9.19	7.08
Rawah Wilderness	CO	9.72	9.15	9.14	7.08
Rocky Mountain NP	CO	12.85	12.15	12.15	7.05
Weminuche Wilderness	CO	10.00	9.46	9.46	7.06
West Elk Wilderness	CO	8.82	8.21	8.21	7.07
Everglades NP	FL	22.48	18.43	18.43	11.15
Okefenokee	GA	27.21	20.28	20.29	11.45
Wolf Island	GA	27.21	20.12	20.15	11.42
Craters of the Moon NM	ID	14.06	12.94	12.94	7.13
Sawtooth Wilderness	ID	14.97	14.70	14.70	7.15
Mammoth Cave NP	KY	32.00	22.29	22.29	11.53
Acadia NP	ME	22.75	18.34	18.33	11.45
Moosehorn	ME	21.19	17.58	17.58	11.36
Roosevelt Campobello International Park	ME	21.19	17.57	17.56	11.36
Isle Royale NP	MI	21.31	18.19	18.19	11.22
Seney	MI	25.05	20.80	20.80	11.37
Boundary Waters Canoe Area	MN	20.20	16.56	16.56	11.21
Voyageurs NP	MN	19.62	16.61	16.61	11.09
Hercules-Glades Wilderness	MO	26.95	21.00	21.00	11.27
Anaconda-Pintler Wilderness	MT	17.11	16.69	16.68	7.28
Bob Marshall Wilderness	MT	16.13	15.63	15.63	7.36
Cabinet Mountains Wilderness	MT	14.31	13.65	13.65	7.43
Gates of the Mountains Wilderness	MT	11.94	11.48	11.47	7.22
Glacier NP	MT	19.62	18.73	18.73	7.56
Medicine Lake	MT	18.21	17.17	17.17	7.30
Mission Mountains Wilderness	MT	16.13	15.50	15.49	7.39
Red Rock Lakes	MT	11.19	10.62	10.62	7.14
Scapegoat Wilderness	MT	16.13	15.59	15.59	7.29
Selway-Bitterroot Wilderness	MT	17.11	16.74	16.74	7.32
UL Bend	MT	15.49	15.00	15.00	7.18
Linville Gorge Wilderness	NC	29.66	20.08	20.07	11.43
Shining Rock Wilderness	NC	28.54	19.49	19.48	11.45
Lostwood	ND	19.61	17.64	17.64	7.33
Theodore Roosevelt NP	ND	17.88	16.02	16.02	7.31
Great Gulf Wilderness	NH	21.43	16.46	16.46	11.31
Presidential Range-Dry River Wilderness	NH	21.43	16.39	16.39	11.33
Brigantine	NJ	28.68	20.96	20.95	11.28
Bandelier NM	NM	11.97	10.51	10.51	7.02
Bosque del Apache	NM	13.81	12.40	12.40	6.97
Carlsbad Caverns NP	NM	16.51	14.48	14.47	7.02
Gila Wilderness	NM	13.12	12.41	12.40	6.95
Pecos Wilderness	NM	9.60	8.85	8.85	7.04
Salt Creek	NM	18.27	16.19	16.18	6.99

San Pedro Parks Wilderness	NM	10.42	9.63	9.62	7.03
Wheeler Peak Wilderness	NM	9.60	8.66	8.65	7.07
White Mountain Wilderness	NM	13.01	12.05	12.05	6.98
Jarbidge Wilderness	NV	12.26	11.92	11.92	7.10
Wichita Mountains	OK	23.63	18.27	18.26	11.07
Crater Lake NP	OR	13.21	12.49	12.49	7.71
Diamond Peak Wilderness	OR	13.21	12.39	12.39	7.77
Eagle Cap Wilderness	OR	17.34	16.31	16.31	7.34
Gearhart Mountain Wilderness	OR	13.21	12.61	12.61	7.46
Hells Canyon Wilderness	OR	19.00	17.57	17.58	7.32
Kalmiopsis Wilderness	OR	16.38	15.36	15.36	7.71
Mount Hood Wilderness	OR	14.68	13.03	13.03	7.77
Mount Jefferson Wilderness	OR	15.80	14.78	14.78	7.81
Mount Washington Wilderness	OR	15.80	14.78	14.77	7.89
Mountain Lakes Wilderness	OR	13.21	12.42	12.42	7.57
Strawberry Mountain Wilderness	OR	17.34	16.37	16.37	7.49
Three Sisters Wilderness	OR	15.80	14.87	14.87	7.87
Cape Romain	SC	27.43	19.70	19.70	11.36
Badlands NP	SD	16.82	14.91	14.90	7.30
Wind Cave NP	SD	15.95	14.21	14.21	7.24
Great Smoky Mountains NP	TN	30.56	21.28	21.27	11.44
Joyce-Kilmer-Slickrock Wilderness	TN	30.56	20.97	20.97	11.45
Big Bend NP	TX	17.21	15.35	15.34	6.93
Guadalupe Mountains NP	TX	16.51	14.47	14.46	7.03
Arches NP	UT	10.77	9.98	9.97	6.99
Bryce Canyon NP	UT	11.62	10.95	10.95	6.99
Canyonlands NP	UT	10.77	10.12	10.11	7.01
Capitol Reef NP	UT	10.86	10.39	10.39	7.03
James River Face Wilderness	VA	28.93	19.62	19.62	11.24
Shenandoah NP	VA	29.42	19.58	19.58	11.25
Lye Brook Wilderness	VT	24.11	16.87	16.86	11.25
Alpine Lake Wilderness	WA	16.99	15.06	15.04	7.86
Glacier Peak Wilderness	WA	13.29	12.18	12.17	7.80
Goat Rocks Wilderness	WA	12.67	11.35	11.34	7.82
Mount Adams Wilderness	WA	12.67	11.39	11.39	7.78
Mount Rainier NP	WA	17.07	15.36	15.35	7.90
North Cascades NP	WA	13.29	12.15	12.14	7.78
Olympic NP	WA	15.83	14.31	14.31	7.88
Pasayten Wilderness	WA	15.35	14.36	14.36	7.77
Dolly Sods Wilderness	WV	29.94	19.65	19.64	11.32
Otter Creek Wilderness	WV	29.94	19.73	19.72	11.33
Bridger Wilderness	WY	10.73	10.29	10.29	7.08
Fitzpatrick Wilderness	WY	10.73	10.29	10.28	7.09
Grand Teton NP	WY	11.19	10.57	10.56	7.09
North Absaroka Wilderness	WY	11.30	10.90	10.90	7.09
Teton Wilderness	WY	11.19	10.68	10.68	7.09
Washakie Wilderness	WY	11.30	10.90	10.90	7.09
Yellowstone NP	WY	11.19	10.61	10.61	7.12

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

Appendix A

Model Performance Evaluation for the 2005-Based Air Quality Modeling Platform

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC 27711
August 2012

A.1. Introduction

An operational model performance evaluation for ozone, $PM_{2.5}$ and its related speciated components, specific air toxics (i.e., formaldehyde, acetaldehyde, benzene, 1,3-butadiene, and acrolein), as well as nitrate and sulfate deposition was conducted using 2005 State/local monitoring sites data in order to estimate the ability of the CMAQ modeling system to replicate the base year concentrations for the 12-km Eastern and Western United States domain [1]. Included in this evaluation are statistical measures of model versus observed pairs that were paired in space and time on a daily or weekly basis, depending on the sampling frequency of each network (measured data). For certain time periods with missing ozone, $PM_{2.5}$, air toxic observations and nitrate and sulfate deposition we excluded the CMAQ predictions from those time periods in our calculations. It should be noted when pairing model and observed data that each CMAQ concentration represents a grid-cell volume-averaged value, while the ambient network measurements are made at specific locations.

Model performance statistics were calculated for several spatial scales and temporal periods. Statistics were generated for the 12-km Eastern US domain (EUS), 12-km Western US domain (WUS), and five large subregions[2]: Midwest, Northeast, Southeast, Central, and West U.S. The statistics for each site and subregion were calculated by season (e.g., "winter" is defined as December, January, and February). For 8-hour daily maximum ozone, we also calculated performance statistics by subregion for the May through September ozone season[3]. In addition to the performance statistics, we prepared several graphical presentations of model performance. These graphical presentations include:

(1) regional maps which show the normalized mean bias and error calculated for each season at individual monitoring sites, and

(2) bar and whisker plots which show the distribution of the predicted and observed data by month by subregion.

A.1.1 Monitoring Networks

The model evaluation for ozone was based upon comparisons of model predicted 8-hour daily maximum concentrations to the corresponding ambient measurements for 2005 at monitoring sites in the EPA Air Quality System (AQS). The observed ozone data were measured and reported on an hourly basis. The $PM_{2.5}$ evaluation focuses on concentrations of $PM_{2.5}$ total mass and its components including sulfate (SO_4), nitrate (NO_3), total nitrate ($TNO_3=NO_3+HNO_3$), ammonium (NH_4), elemental carbon (EC), and organic carbon (OC) as well as wet deposition for nitrate and sulfate. The $PM_{2.5}$ performance statistics were calculated for each season and for the entire year, as a whole. $PM_{2.5}$ ambient measurements for 2005 were

[1] See section II.B. of the main document (Figure II-1) for the description and map of the CMAQ modeling domains.

[2] The subregions are defined by States where: Midwest is IL, IN, MI, OH, and WI; Northeast is CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT; Southeast is AL, FL, GA, KY, MS, NC, SC, TN, VA, and WV; Central is AR, IA, KS, LA, MN, MO, NE, OK, and TX; West is AK, CA, OR, WA, AZ, NM, CO, UT, WY, SD, ND, MT, ID, and NV.

[3] In calculating the ozone season statistics we limited the data to those observed and predicted pairs with observations that exceeded 60 ppb in order to focus on concentrations at the upper portion of the distribution of values.

obtained from the following networks: Chemical Speciation Network (CSN), Interagency Monitoring of PROtected Visual Environments (IMPROVE), Clean Air Status and Trends Network (CASTNet), and National Acid Deposition Program/National Trends (NADP/NTN). NADP/NTN collects and reports wet deposition measurements as weekly average data. The pollutant species included in the evaluation for each network are listed in Table A-1. For $PM_{2.5}$ species that are measured by more than one network, we calculated separate sets of statistics for each network. The CSN and IMPROVE networks provide 24-hour average concentrations on a 1 in every 3 day, or 1 in every 6 day sampling cycle. The $PM_{2.5}$ species data at CASTNet sites are weekly integrated samples. In this analysis we use the term "urban sites" to refer to CSN sites; "suburban/rural sites" to refer to CASTNet sites; and "rural sites" to refer to IMPROVE sites.

Table A-1. $PM_{2.5}$ monitoring networks and pollutants species included in the CMAQ performance evaluation.

Ambient Monitoring Networks	Particulate Species							Wet Deposition Species	
	$PM_{2.5}$ Mass	SO_4	NO_3	TNO_3[a]	EC	OC	NH_4	SO_4	NO_3
IMPROVE	X	X	X		X	X			
CASTNet		X		X			X		
STN	X	X	X		X	X	X		
NADP								X	X

[a] $TNO_3 = (NO_3 + HNO_3)$

The air toxics evaluation focuses on specific species relevant to the 2017-2025 Light-Duty Greenhouse Gas final rule (hereafter referred to as LD GHG), i.e., formaldehyde, acetaldehyde, benzene, 1,3-butadiene, and acrolein. Similar to the $PM_{2.5}$ evaluation, the air toxics performance statistics were calculated for each season and for the entire year, as a whole to estimate the ability of the CMAQ modeling system to replicate the base year concentrations for the 12-km Eastern and Western United States domains. As mentioned above, seasons were defined as: winter (December-January-February), spring (March-April-May), summer (June-July-August), and fall (September-October-November). Toxic measurements for 2005 were obtained from the National Air Toxics Trends Stations (NATTS).

A.1.2 Model Performance Statistics

The Atmospheric Model Evaluation Tool (AMET) was used to conduct the evaluation described in this document.[4] There are various statistical metrics available and used by the science community for model performance evaluation. For a robust evaluation, the principal

[4] Appel, K.W., Gilliam, R.C., Davis, N., Zubrow, A., and Howard, S.C.: Overview of the Atmospheric Model Evaluation Tool (AMET) v1.1 for evaluating meteorological and air quality models, *Environ. Modell. Softw.*,26, 4, 434-443, 2011. (http://www.cmascenter.org/)

evaluation statistics used to evaluate CMAQ performance were two bias metrics, normalized mean bias and fractional bias; and two error metrics, normalized mean error and fractional error.

Normalized mean bias (NMB) is used as a normalization to facilitate a range of concentration magnitudes. This statistic averages the difference (model - observed) over the sum of observed values. NMB is a useful model performance indicator because it avoids over inflating the observed range of values, especially at low concentrations.

Normalized mean bias is defined as:

$$\text{NMB} = \frac{\sum_{1}^{n}(P - O)}{\sum_{1}^{n}(O)} * 100$$

Normalized mean error (NME) is also similar to NMB, where the performance statistic is used as a normalization of the mean error. NME calculates the absolute value of the difference (model - observed) over the sum of observed values.

Normalized mean error is defined as:

$$\text{NME} = \frac{\sum_{1}^{n}|P - O|}{\sum_{1}^{n}(O)} * 100$$

Fractional bias is defined as:

$$\text{FB} = \frac{1}{n}\left(\frac{\sum_{1}^{n}(P - O)}{\sum_{1}^{n}\left(\frac{P + O}{2}\right)}\right) * 100$$, where P = predicted and O = observed concentrations.

FB is a useful model performance indicator because it has the advantage of equally weighting positive and negative bias estimates. The single largest disadvantage in this estimate of model performance is that the estimated concentration (i.e., prediction, P) is found in both the numerator and denominator. Fractional error (FE) is similar to fractional bias except the absolute value of the difference is used so that the error is always positive.

Fractional error is defined as:

$$\text{FE} = \frac{1}{n}\left(\frac{\sum_{1}^{n}|P - O|}{\sum_{1}^{n}\left(\frac{P + O}{2}\right)}\right) * 100$$

The "acceptability" of model performance was judged by comparing our CMAQ 2005 performance results to the range of performance found in recent regional ozone, $PM_{2.5}$, and air toxic model applications.[5,6,7,8,9,10,1112,13,14, 15,16] These other modeling studies represent a wide range of modeling analyses which cover various models, model configurations, domains, years and/or episodes, chemical mechanisms, and aerosol modules. Overall, the ozone, $PM_{2.5}$, air toxics concentrations and nitrate and sulfate deposition model performance results for the 2005 CMAQ simulations performed for the 2017-2025 LD GHG final rule are within the range or close to that found in other recent applications. The model performance results, as described in this report, give us confidence that our applications of CMAQ using this 2005 modeling platform provide a scientifically credible approach for assessing ozone and $PM_{2.5}$ concentrations for the purposes of the 2017-2025 LD GHG Final Rule.

---

[5] Appel, K.W., Bhave, P.V., Gilliland, A.B., Sarwar, G., and Roselle, S.J.: evaluation of the community multiscale air quality (CMAQ) model version 4.5: sensitivities impacting model performance: Part II – particulate matter. Atmospheric Environment 42, 6057-6066, 2008.

[6] Appel, K.W., Gilliland, A.B., Sarwar, G., Gilliam, R.C., 2007. Evaluation of the community multiscale air quality (CMAQ) model version 4.5: sensitivities impacting model performance: Part I – ozone. Atmospheric Environment 41, 9603-9615.

[7] Appel, K.W., Roselle, S.J., Gilliam, R.C., and Pleim, J.E.,: Sensitivity of the Community Multiscale Air Quality (CMAQ) model v4.7 results for the eastern United States to MM5 and WRF meteorological drivers. Geoscientific Model Development, 3, 169-188, 2010.

[8] Foley, K.M., Roselle, S.J., Appel, K.W., Bhave, P.V., Pleim, J.E., Otte, T.L., Mathur, R., Sarwar, G., Young, J.O., Gilliam, R.C., Nolte, C.G., Kelly, J.T., Gilliland, A.B., and Bash, J.O.,: Incremental testing of the Community multiscale air quality (CMAQ) modeling system version 4.7. Geoscientific Model Development, 3, 205-226, 2010.

[9] Hogrefe, G., Civeroio, K.L., Hao, W., Ku, J-Y., Zalewsky, E.E., and Sistla, G., Rethinking the Assessment of Photochemical Modeling Systems in Air Quality Planning Applications. Air & Waste Management Assoc., 58:1086-1099, 2008.

[10] Phillips, S., K. Wang, C. Jang, N. Possiel, M. Strum, T. Fox, 2007: Evaluation of 2002 Multi-pollutant Platform: Air Toxics, Ozone, and Particulate Matter, 7th Annual CMAS Conference, Chapel Hill, NC, October 6-8, 2008. (http://www.cmascenter.org/conference/2008/agenda.cfm).

[11] 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. http://dx.doi.org/10.1016/j.atmosenv.2012.07.012

[12] Strum, M., Wesson, K., Phillips, S.,Pollack, A., Shepard, S., Jimenez, M., M., Beidler, A., Wilson, M., Ensley, D., Cook, R., Michaels H., and Brzezinski, D. Link Based vs NEI Onroad Emissions Impact on Air Quality Model Predictions. 17th Annual International Emission Inventory Conference, Portland, Oregon, June 2-5, 2008. (http://www.epa.gov/ttn/chief/conference/ei17/session11/strum_pres.pdf)

[13] Tesche, T.W., Morris, R., Tonnesen, G., McNally, D., Boylan, J., Brewer, P., 2006. CMAQ/CAMx annual 2002 performance evaluation over the eastern United States. Atmospheric Environment 40, 4906-4919.

[14] U.S. Environmental Protection Agency; Technical Support Document for the Final Clean Air Interstate Rule: Air Quality Modeling; Office of Air Quality Planning and Standards; RTP, NC; March 2005 (CAIR Docket OAR-2005-0053-2149).

[15] U.S. Environmental Protection Agency, Proposal to Designate an Emissions Control Area for Nitrogen Oxides, Sulfur Oxides, and Particulate Matter: Technical Support Document. EPA-420-R-007, 329pp., 2009. (http://www.epa.gov/otaq/regs/nonroad/marine/ci/420r09007.pdf)

[16] U.S. Environmental Protection Agency, 2010, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. EPA-420-R-10-006. February 2010. Sections 3.4.2.1.2 and 3.4.3.3. Docket EPA-HQ-OAR-2009-0472-11332. (http://www.epa.gov/oms/renewablefuels/420r10006.pdf)

A.2. Evaluation for 8-hour Daily Maximum Ozone

The 8-hour ozone model performance bias and error statistics for each subregion and each season are provided in Table A-2. The distributions of observed and predicted 8-hour ozone by month in the 5-month ozone season for each subregion are shown in Figures A-1 through A-5. Spatial plots of the normalized mean bias and error for individual monitors are shown in Figures A-6 through A-7. The statistics shown in these two figures were calculated over the ozone season using data pairs on days with observed 8-hour ozone of $\geq$ 60 ppb.

In general, CMAQ slightly over-predicts seasonal eight-hour daily maximum ozone for the five subregions, with the exception of a slight under-prediction in the winter at the Midwest and Northeast subregions (Table A-2). Model performance for 8-hour daily maximum ozone for all subregions is typically better in the spring, summer, and fall months, where the bias statistics are within the range of approximately 0.4 to 16.8 percent and the error statistics range from 13.8 to 22.7 percent The five subregions show relatively similar eight-hour daily maximum ozone performance.

Table A-2. Daily maximum 8-hour ozone performance statistics by subregion, by season.

Subregion	Season	No. of Obs	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	Winter	8,304	8.5	24.6	8.0	27.3
	Spring	12,916	0.4	13.8	1.6	14.7
	Summer	13,474	3.9	17.5	7.0	19.2
	Fall	10,166	2.3	19.0	4.6	20.5
Midwest	Winter	1,819	-5.7	23.2	-7.9	28.2
	Spring	10,981	2.2	14.4	3.8	15.3
	Summer	15,738	3.1	13.6	4.2	14.1
	Fall	9,136	3.2	16.4	5.8	18.9
Southeast	Winter	5,150	8.2	17.4	7.9	18.5
	Spring	17,857	1.1	11.9	2.6	12.6
	Summer	19,617	16.8	22.7	19.5	24.2
	Fall	12,008	11.0	18.0	14.0	20.6
Northeast	Winter	3,497	-9.7	22.7	-12.5	29.1
	Spring	11,667	1.9	14.7	2.5	15.7
	Summer	15,489	8.6	17.7	10.6	18.6
	Fall	9,438	4.3	17.9	7.3	21.3
West	Winter	18,285	27.2	33.1	27.4	33.9
	Spring	25,814	2.2	14.1	2.9	14.5
	Summer	28,380	5.4	17.0	6.0	17.3
	Fall	19,588	5.7	18.6	7.5	19.8

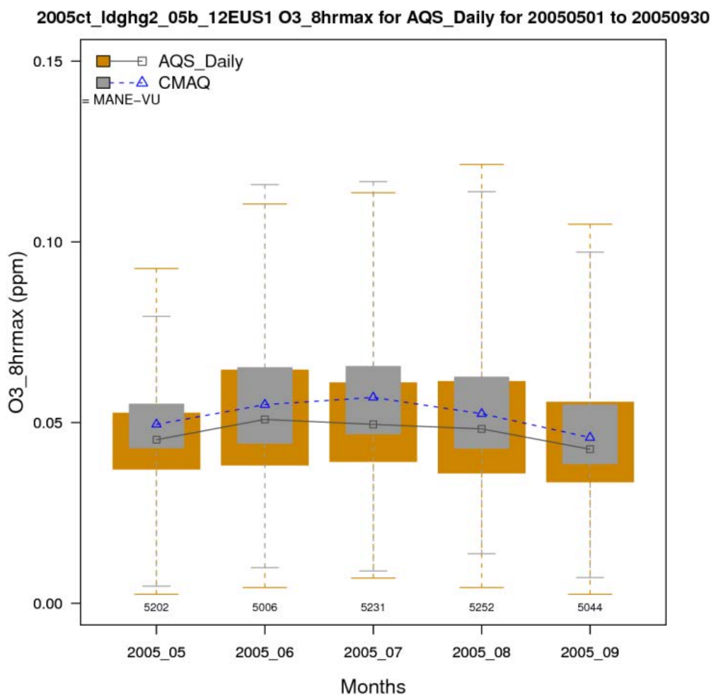

Figure A-1. Distribution of observed and predicted 8-hour daily maximum ozone by month for the period May through September for the Northeast subregion. [symbol = median; top/bottom of box = 75th/25th percentiles; top/bottom line = max/min values]

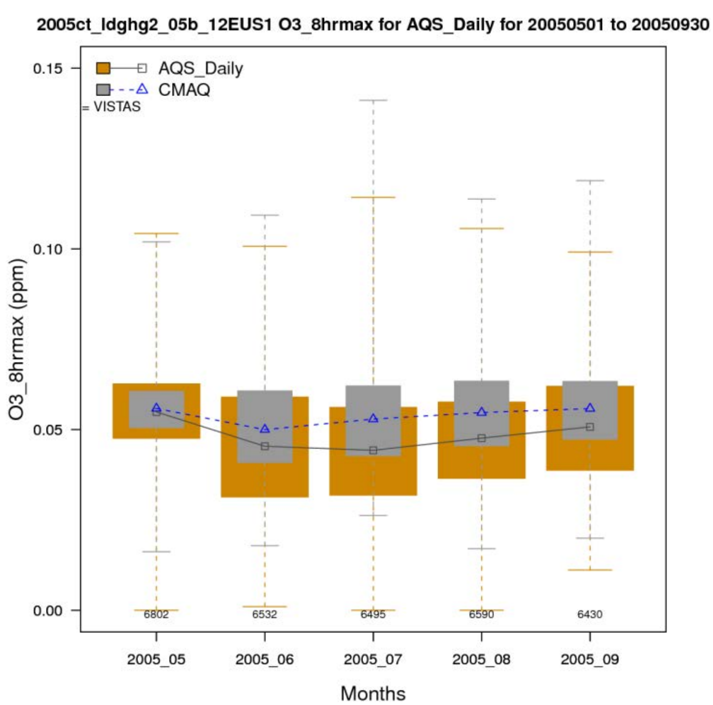

Figure A-2. Distribution of observed and predicted 8-hour daily maximum ozone by month for the period May through September 2005 for the Southeast subregion.

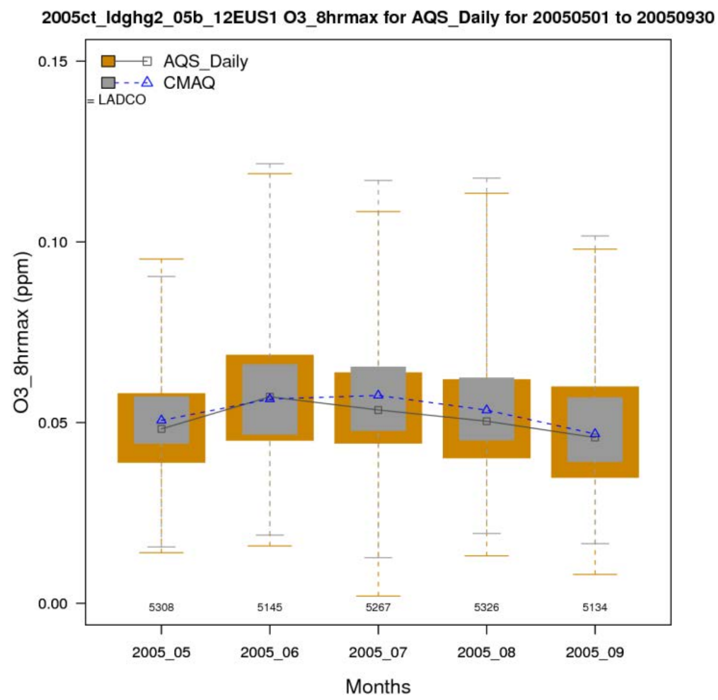

Figure A-3. Distribution of observed and predicted 8-hour daily maximum ozone by month for the period May through September for the Midwest subregion.

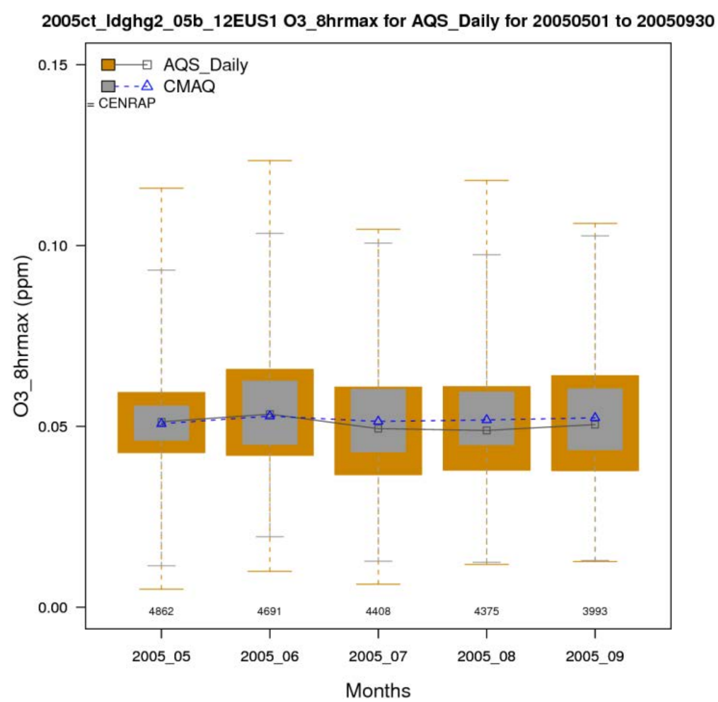

Figure A-4. Distribution of observed and predicted 8-hour daily maximum ozone by month for the period May through September for the Central states subregion.

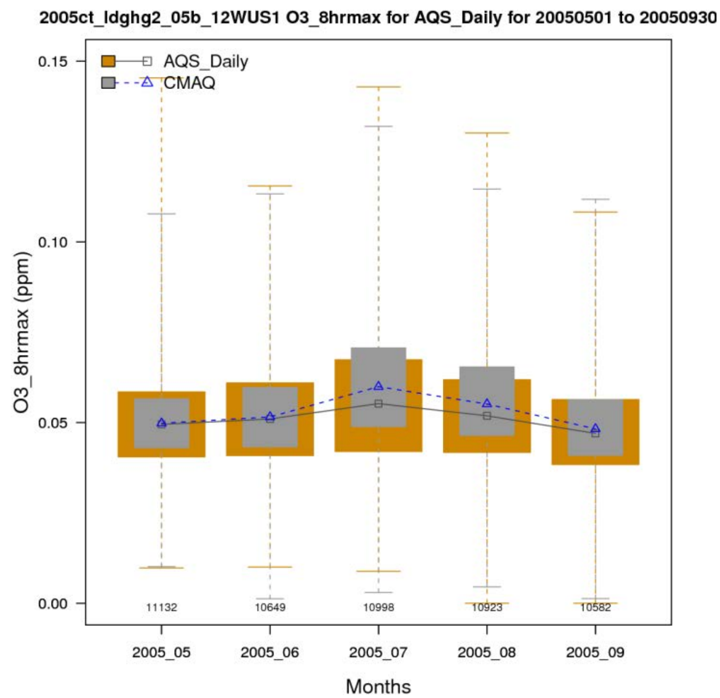

Figure A-5. Distribution of observed and predicted 8-hour daily maximum ozone by month for the period May through September for the Western states subregion.

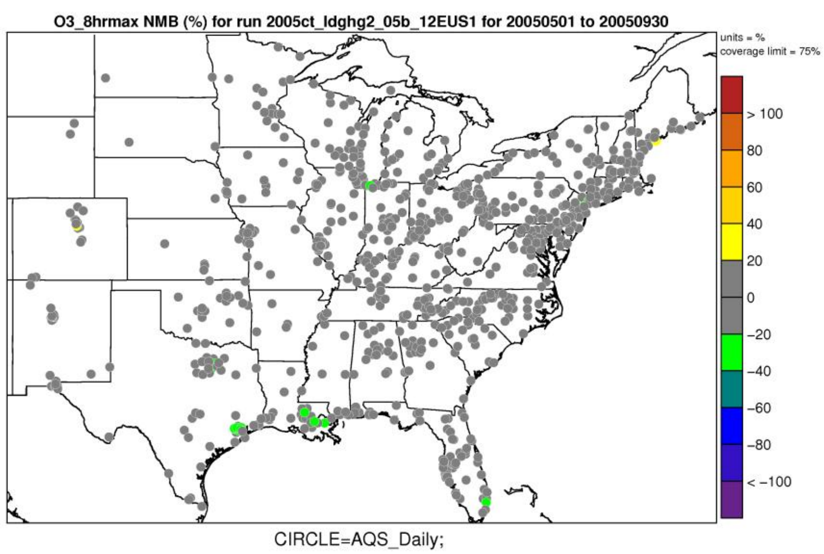

Figure A-6a. Normalized Mean Bias (%) of 8-hour daily maximum ozone greater than 60 ppb over the period May-September 2005 at monitoring sites in Eastern modeling domain.

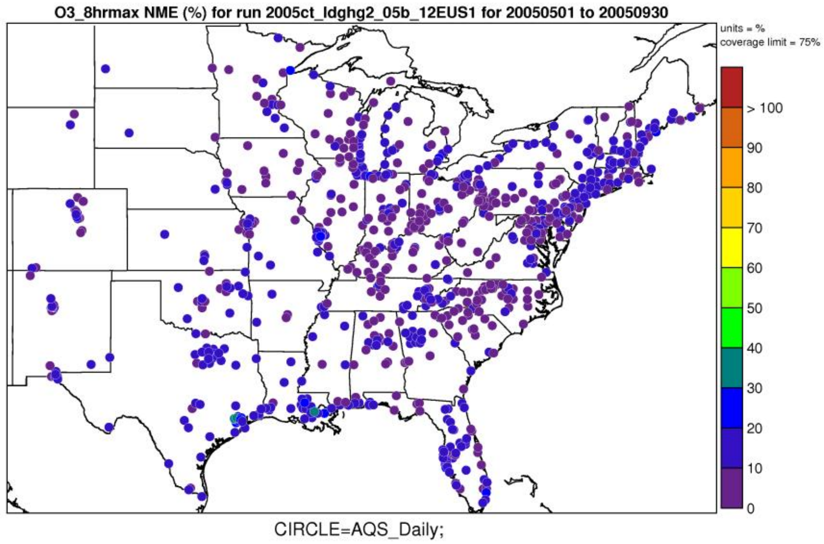

Figure A-6b. Normalized Mean Error (%) of 8-hour daily maximum ozone greater than 60 ppb over the period May-September 2005 at monitoring sites in Eastern modeling domain.

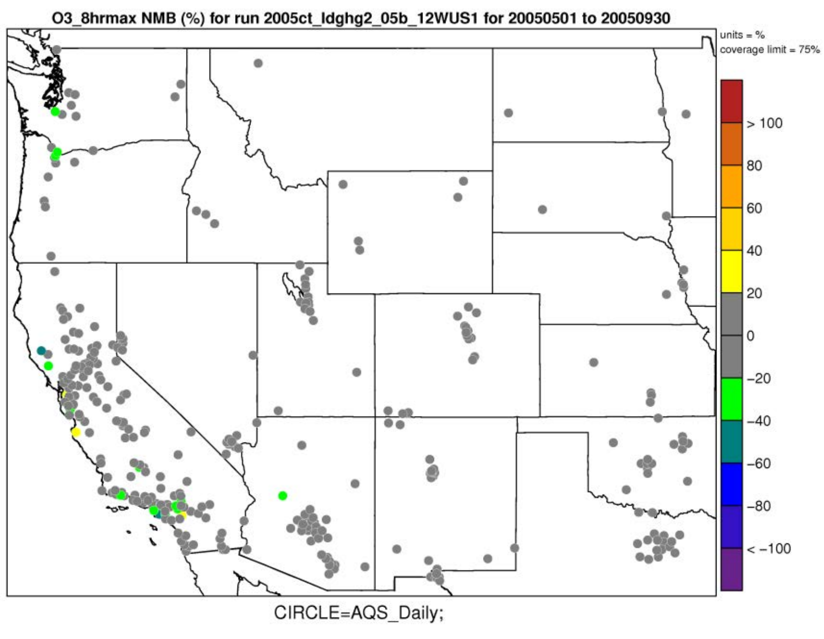

Figure A-7a. Normalized Mean Bias (%) of 8-hour daily maximum ozone greater than 60 ppb over the period May-September 2005 at monitoring sites in Western modeling domain.

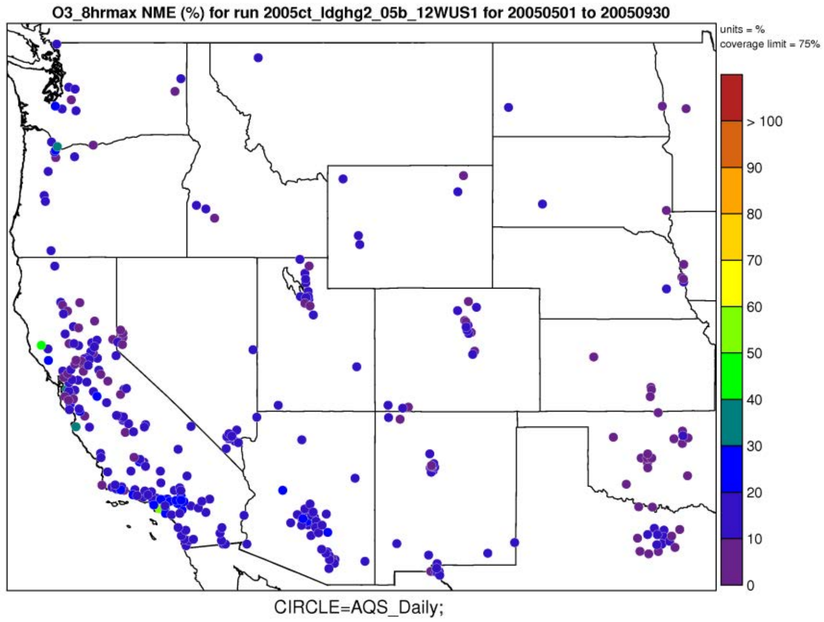

Figure A-7b. Normalized Mean Error (%) of 8-hour daily maximum ozone greater than 60 ppb over the period May-September 2005 at monitoring sites in Western modeling domain.

A.3. Evaluation of $PM_{2.5}$ Component Species

The evaluation of 2005 model predictions for $PM_{2.5}$ covers the performance for the individual $PM_{2.5}$ component species (i.e., sulfate, nitrate, organic carbon, elemental carbon, and ammonium). Performance results are provided for each $PM_{2.5}$ species. As indicated above, for each species we present tabular summaries of bias and error statistics by subregion for each season. These statistics are based on the set of observed-predicted pairs of data for the particular quarter at monitoring sites within the subregion. Separate statistics are provided for each monitoring network, as applicable for the particular species measured. For sulfate and nitrate we also provide a more refined temporal and spatial analysis of model performance that includes (1) graphics of the distribution of 24-hour average concentrations and predictions by month for each subregion, and (2) spatial maps which show the normalized mean bias and error by site, aggregated by season.

A.3.1. Evaluation for Sulfate

The model performance bias and error statistics for sulfate for each subregion and each season are provided in Table A-3. The distributions of observed and predicted suflate by month for each subregion are shown in Figures A-8 through A-12. Spatial plots of the normalized mean bias and error by season for individual monitors are shown in Figures A-3 through A-20. As seen in Table A-3, CMAQ generally under-predicts sulfate in the five U.S. subregions throughout the entire year.

Table A-3. Sulfate performance statistics by subregion, by season for the 2005 CMAQ model simulation.

Subregion	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	CSN	Winter	771	-16.0	38.4	-14.3	41.8
		Spring	875	-15.1	32.2	-11.3	33.8
		Summer	851	-30.4	42.3	-37.3	54.2
		Fall	587	-9.9	34.9	-3.6	36.7
	IMPROVE	Winter	608	-19.4	40.2	-14.2	43.6
		Spring	722	-17.6	31.3	-11.9	32.4
		Summer	688	-28.1	39.2	-25.7	46.2
		Fall	622	-15.8	31.4	-7.5	37.1
	CASTNet	Winter	72	-33.2	34.7	-35.4	37.9
		Spring	77	-24.6	27.8	-23.6	29.6
		Summer	72	-33.3	36.9	-38.2	45.9
		Fall	75	-21.1	23.7	-19.6	26.4
Midwest	CSN	Winter	598	0.7	38.8	-4.9	38.9
		Spring	637	19.2	42.8	15.1	36.8
		Summer	621	-10.7	28.6	-0.9	30.8
		Fall	639	-12.2	26.6	-3.9	27.4
	IMPROVE	Winter	143	3.3	35.8	-0.4	34.4
		Spring	171	4.6	35.3	6.6	35.1
		Summer	182	-18.7	30.1	-6.0	36.0
		Fall	126	-18.0	26.7	-7.2	31.3
	CASTNet	Winter	142	-14.1	22.0	-16.8	26.8
		Spring	155	-6.1	22.4	-4.6	21.7
		Summer	161	-16.6	21.9	-14.2	23.9
		Fall	157	-20.0	22.6	-16.1	21.8
Southeast	CSN	Winter	888	-4.8	37.1	-4.4	37.0
		Spring	918	-5.2	27.4	-6.1	29.4
		Summer	866	-18.0	32.8	-19.8	39.0
		Fall	911	-10.5	27.7	-5.8	29.4
	IMPROVE	Winter	469	-1.7	36.8	0.5	37.5
		Spring	525	-6.6	29.0	-6.0	31.7
		Summer	500	-24.1	35.6	-30.8	47.0
		Fall	496	-11.7	29.2	-6.2	34.4
	CASTNet	Winter	264	-18.6	22.9	-17.9	24.0
		Spring	292	-13.5	21.2	-14.8	22.9
		Summer	268	-21.3	24.8	-28.4	32.7
		Fall	273	-18.4	21.2	-19.2	23.3
Northeast	CSN	Winter	828	-9.1	35.1	-13.9	34.8
		Spring	894	8.2	37.2	4.3	34.9
		Summer	874	-8.7	27.2	-3.0	30.9
		Fall	902	-9.0	28.8	0.1	31.0
	IMPROVE	Winter	561	-7.2	31.2	-11.1	33.3

Subregion	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
		Spring	689	7.05	37.9	3.6	38.2
		Summer	649	-12.9	32.3	-4.5	37.7
		Fall	591	-6.8	32.3	7.7	35.4
	CASTNet	Winter	193	-14.9	22.5	-19.0	25.8
		Spring	206	-0.3	25.1	-1.4	26.4
		Summer	192	-15.6	20.5	-12.7	22.0
		Fall	195	-12.3	18.4	-7.3	18.0
West	CSN	Winter	830	-5.2	57.7	1.8	54.4
		Spring	867	-3.8	36.9	0.0	36.2
		Summer	853	-32.1	43.7	-23.3	42.5
		Fall	900	-7.6	47.2	0.4	43.4
	IMPROVE	Winter	2343	22.3	58.6	34.0	56.9
		Spring	2620	-3.6	33.6	3.5	35.3
		Summer	2281	-24.7	41.2	-16.4	42.9
		Fall	2343	-0.2	40.2	11.5	41.3
	CASTNet	Winter	250	6.5	35.9	17.9	37.5
		Spring	273	-18.4	27.1	-17.0	27.6
		Summer	281	-35.1	38.7	-36.0	41.5
		Fall	268	-10.7	23.6	-5.0	24.3

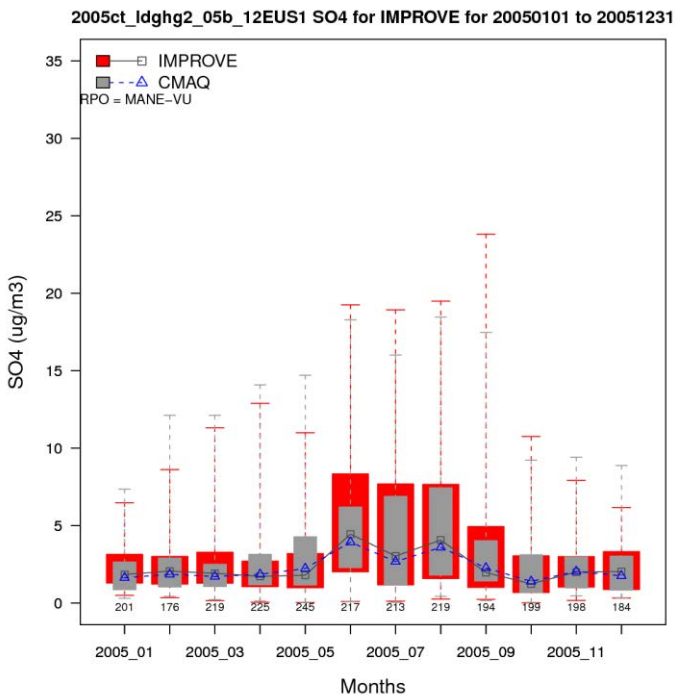

Figure A-8a. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at IMPROVE sites in the Northeast subregion. [symbol = median; top/bottom of box = $75^{th}/25^{th}$ percentiles; top/bottom line = max/min values]

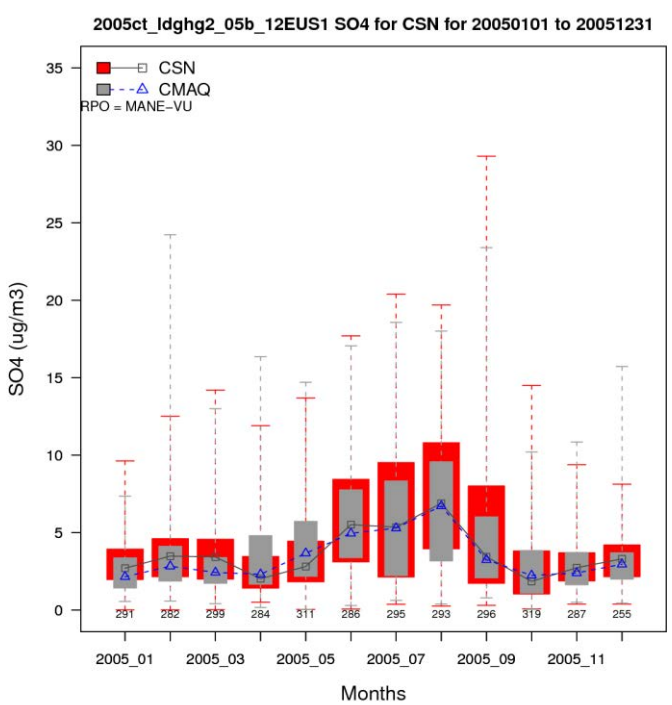

Figure A-8b. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at CSN sites in the Northeast subregion.

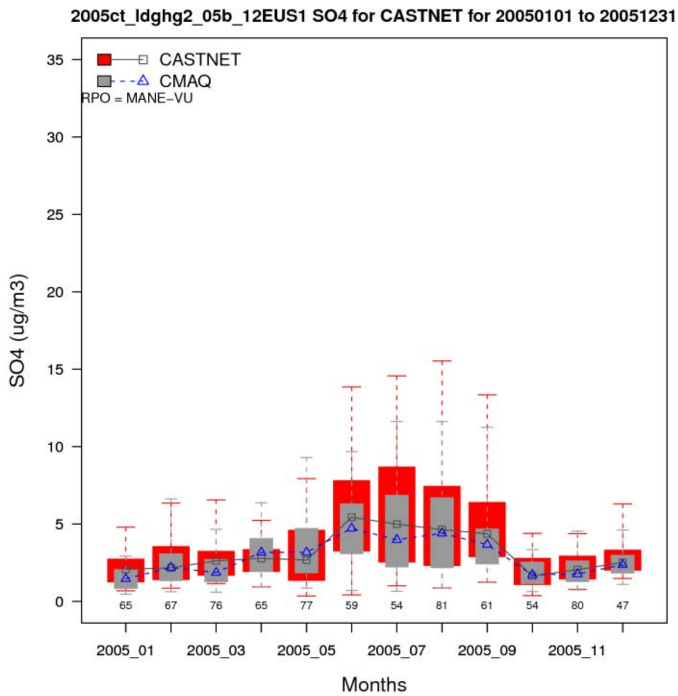

Figure A-8c. Distribution of observed and predicted weekly average sulfate by month for 2005 at CASTNet sites in the Northeast subregion.

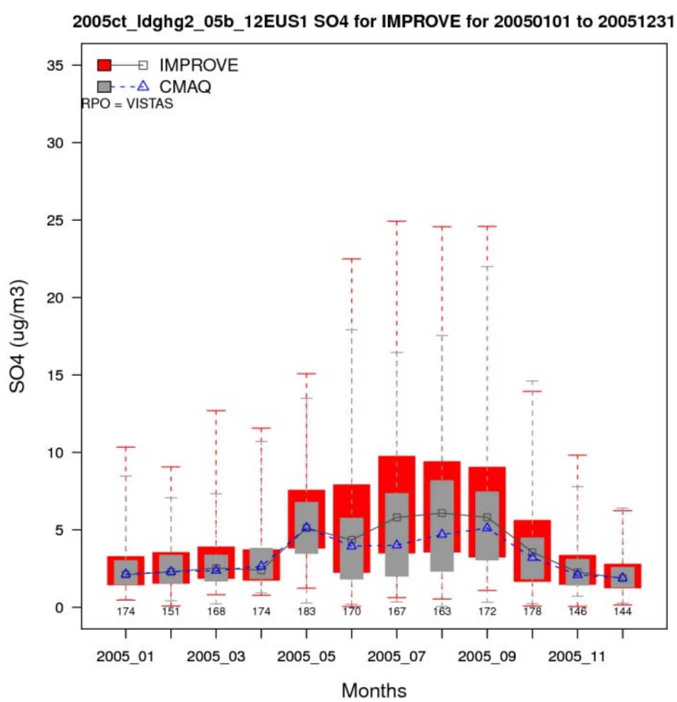

Figure A-9a. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at IMPROVE sites in the Southeast subregion.

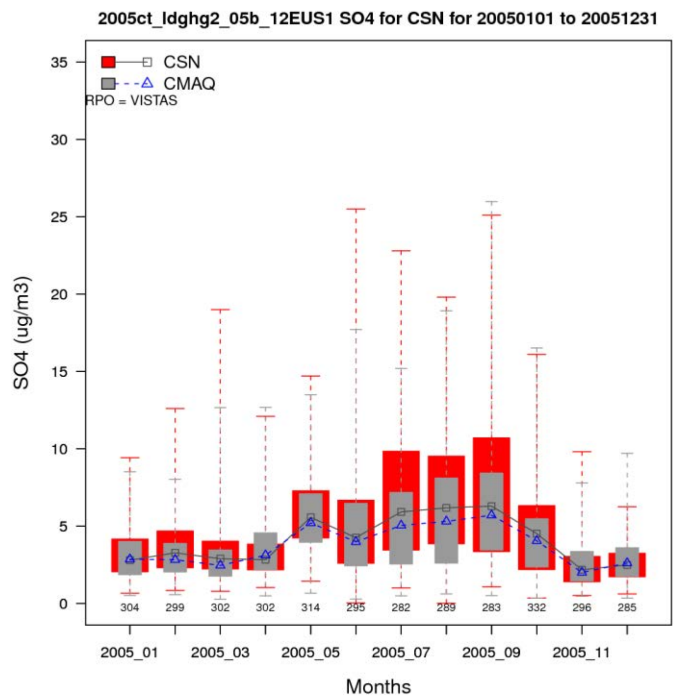

Figure A-9b. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at CSN sites in the Southeast subregion.

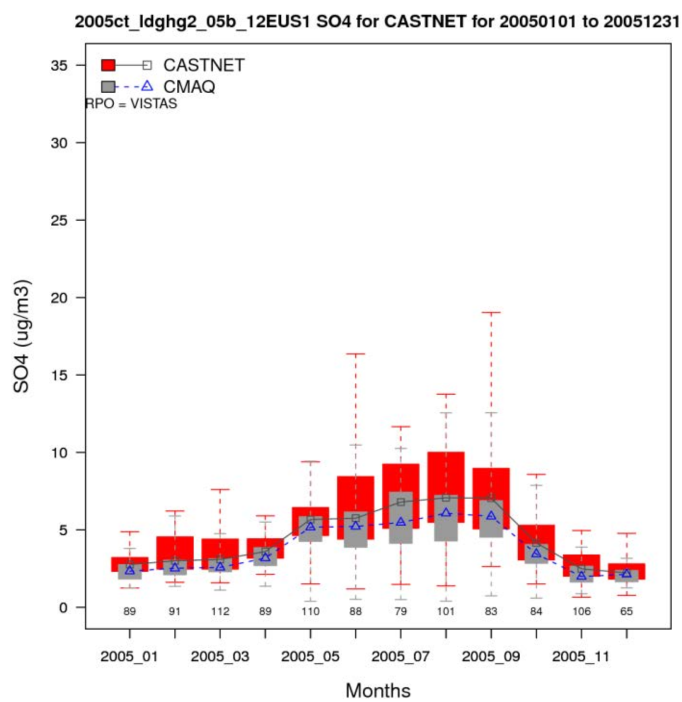

Figure A-9c. Distribution of observed and predicted weekly average sulfate by month for 2005 at CASTNet sites in the Southeast subregion.

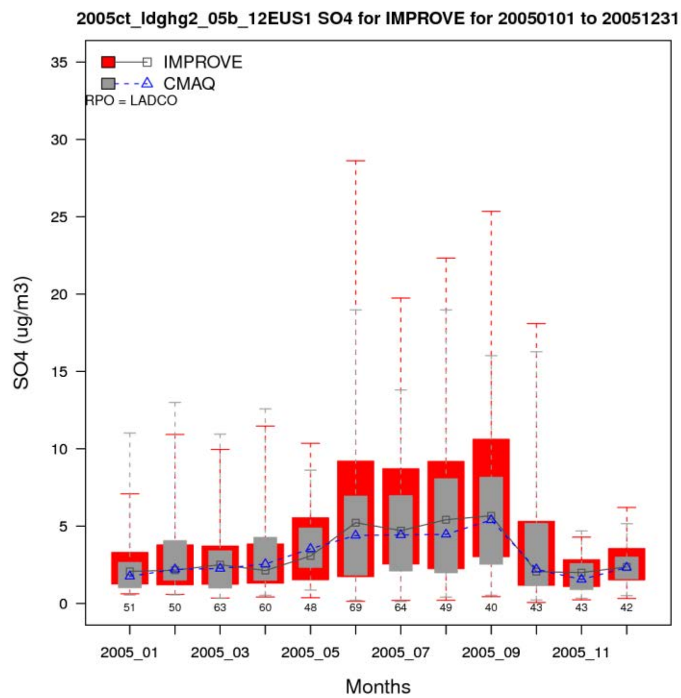

Figure A-10a. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at IMPROVE sites in the Midwest subregion.

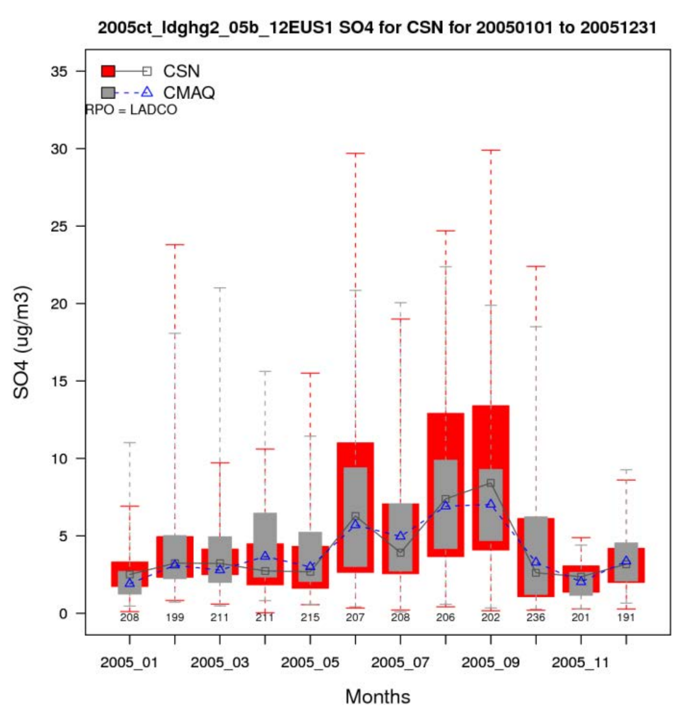

Figure A-10b. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at CSN sites in the Midwest subregion.

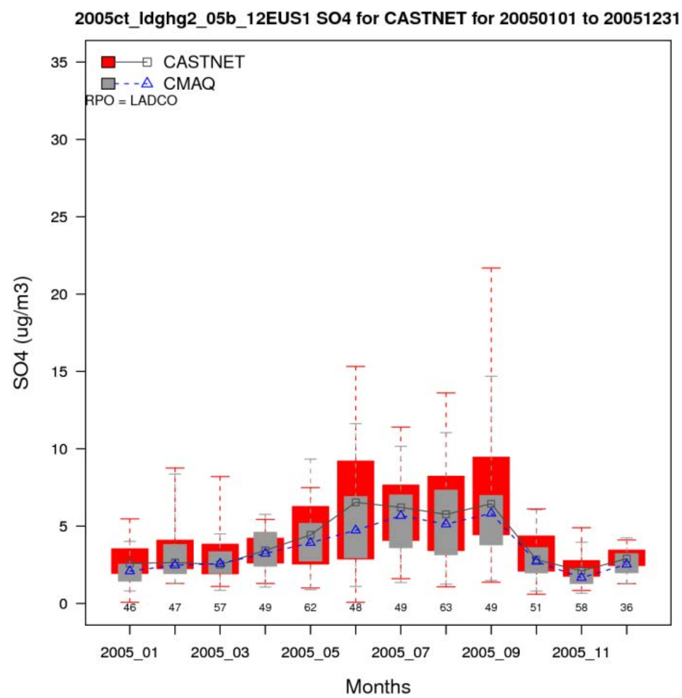

Figure A-10c. Distribution of observed and predicted weekly average sulfate by month for 2005 at CASTNet sites in the Midwest subregion.

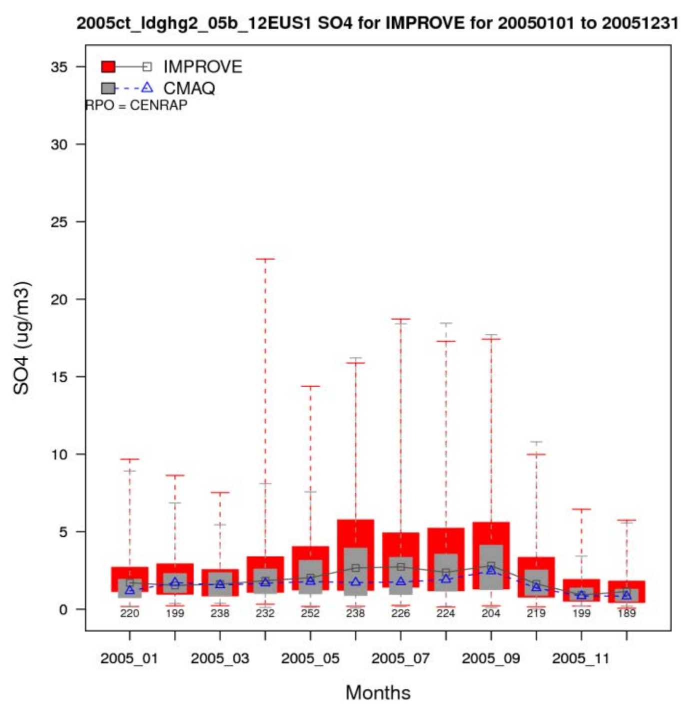

Figure A-11a. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at IMPROVE sites in the Central states subregion.

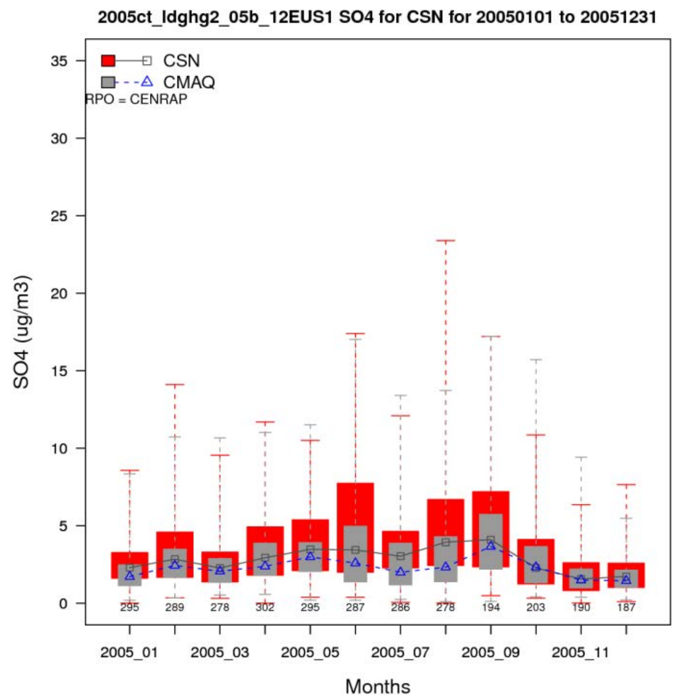

Figure A-11b. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at CSN sites in the Central states subregion.

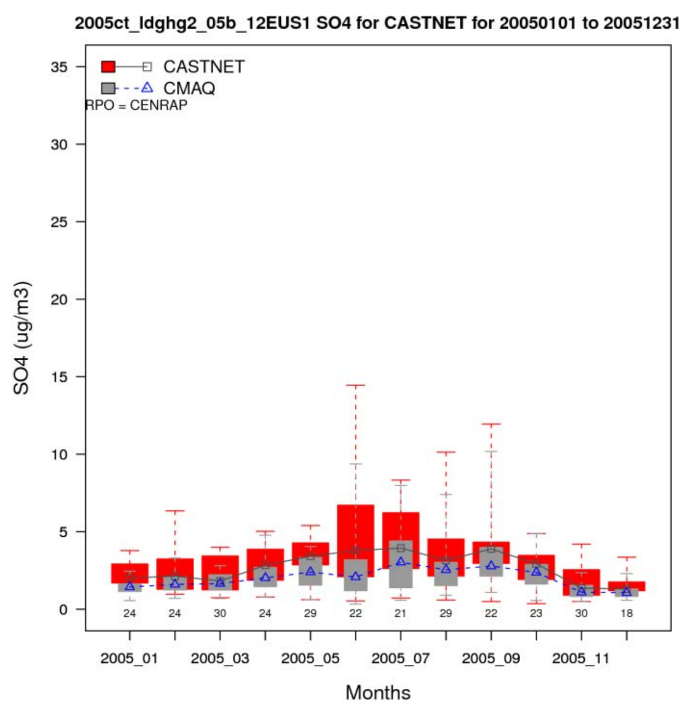

Figure A-11c. Distribution of observed and predicted weekly average sulfate by month for 2005 at CASTNet sites in the Central states subregion.

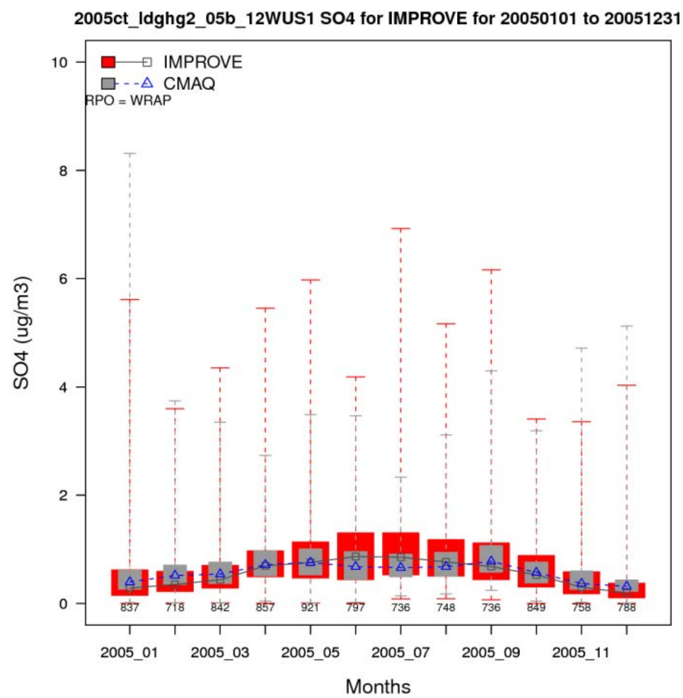

Figure A-12a. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at IMPROVE sites in the Western states subregion.

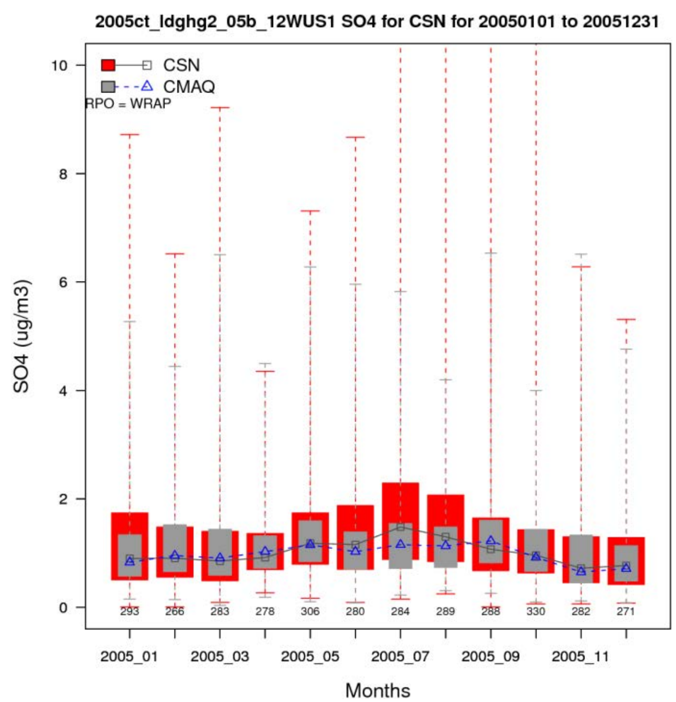

Figure A-12b. Distribution of observed and predicted 24-hour average sulfate by month for 2005 at CSN sites in the Western states subregion.

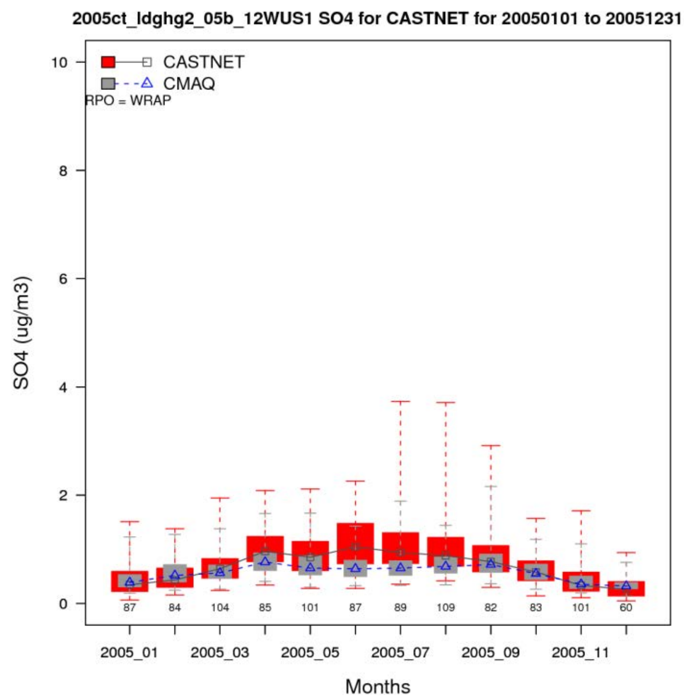

Figure A-12c. Distribution of observed and predicted weekly average sulfate by month for 2005 at CASTNet sites in the Western states subregion.

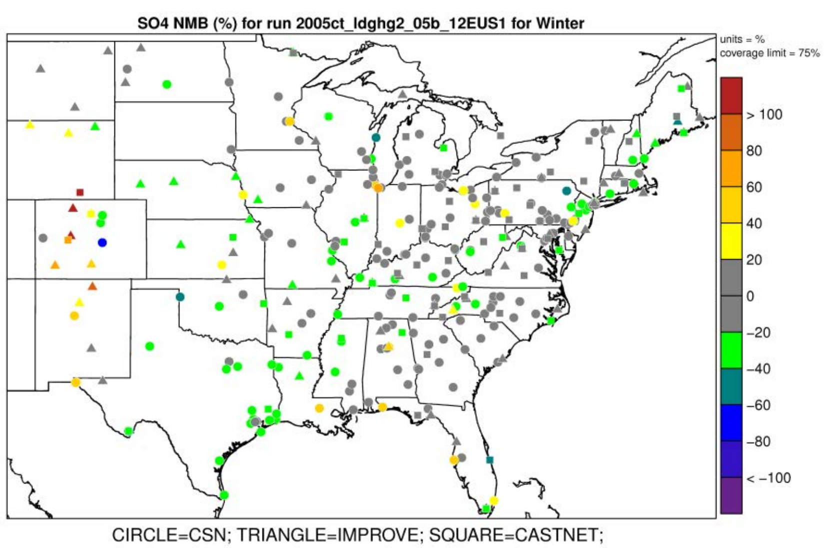

Figure A-13a. Normalized Mean Bias (%) of sulfate during winter 2005 at monitoring sites in Eastern modeling domain.

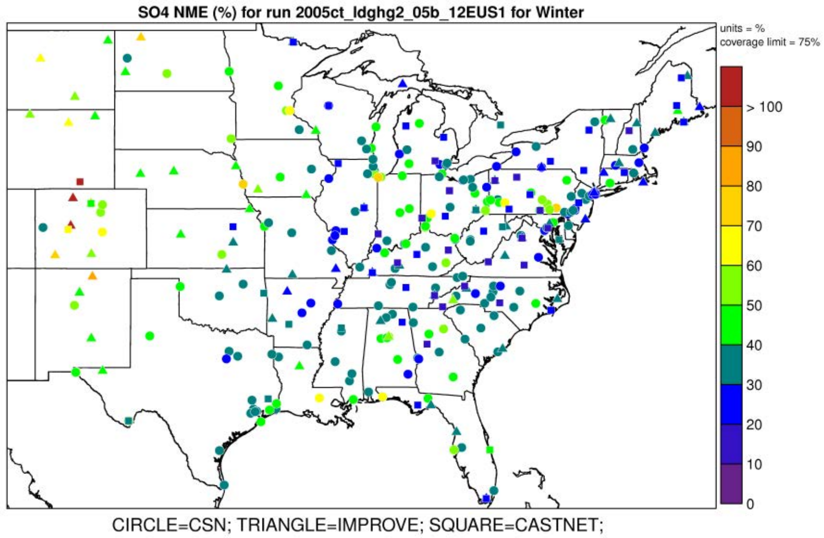

Figure A-13b. Normalized Mean Error (%) of sulfate during winter 2005 at monitoring sites in Eastern modeling domain.

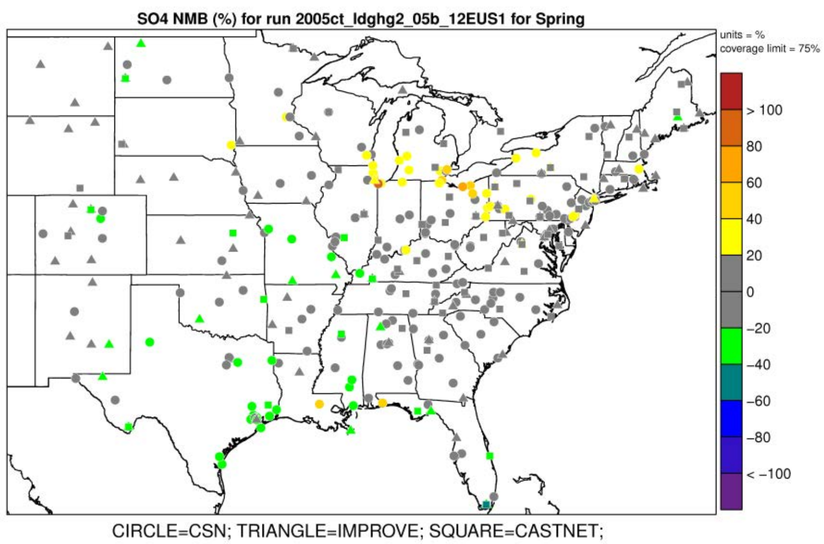

Figure A-14a. Normalized Mean Bias (%) of sulfate during spring 2005 at monitoring sites in Eastern modeling domain.

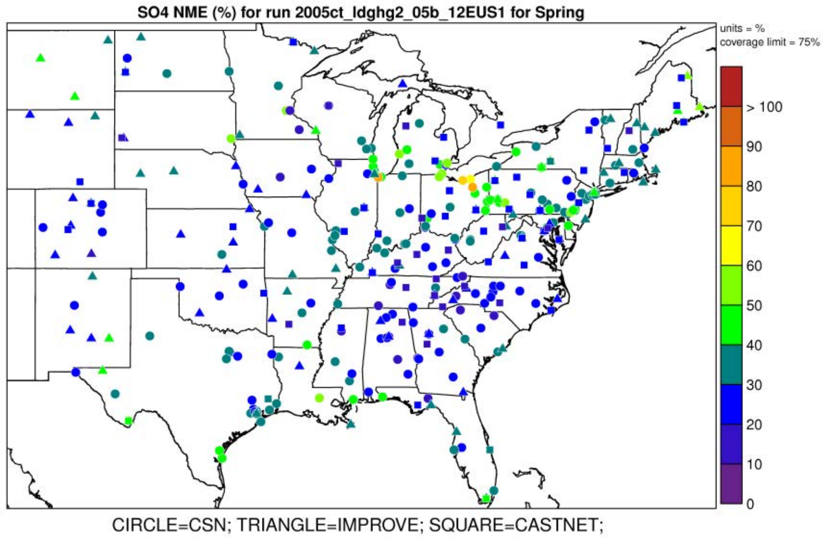

Figure A-14b. Normalized Mean Error (%) of sulfate during spring 2005 at monitoring sites in Eastern modeling domain.

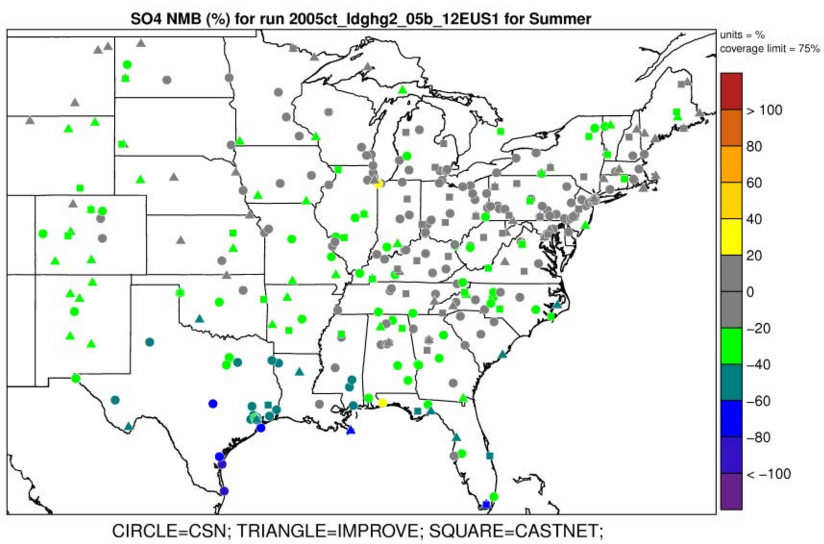

Figure A-15a. Normalized Mean Bias (%) of sulfate during summer 2005 at monitoring sites in Eastern modeling domain.

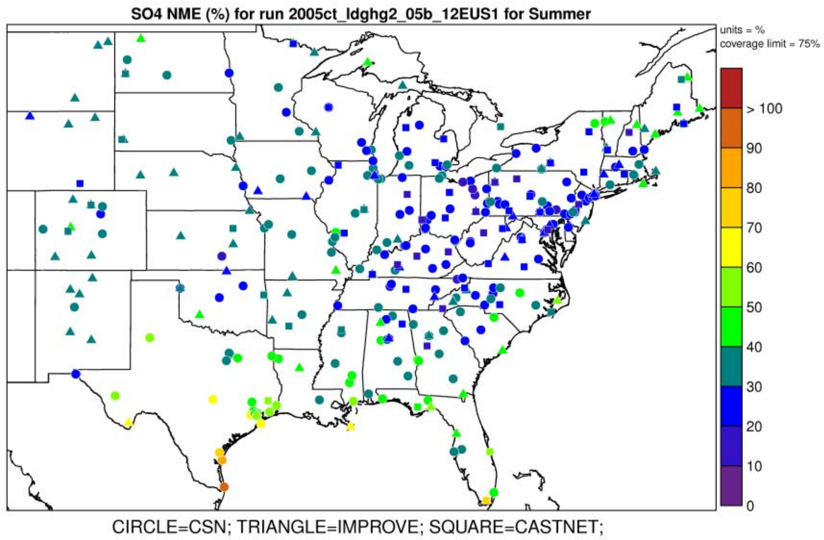

Figure A-15b. Normalized Mean Error (%) of sulfate during summer 2005 at monitoring sites in Eastern modeling domain.

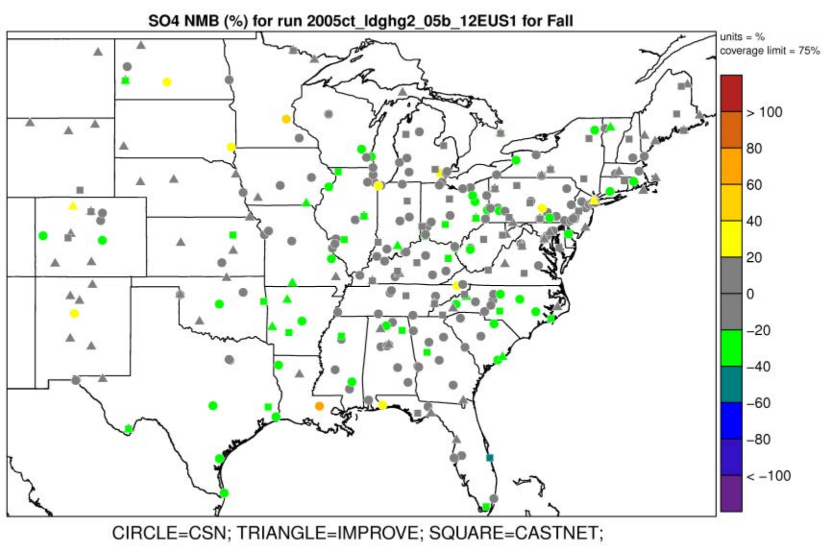

Figure A-16a. Normalized Mean Bias (%) of sulfate during fall 2005 at monitoring sites in Eastern modeling domain.

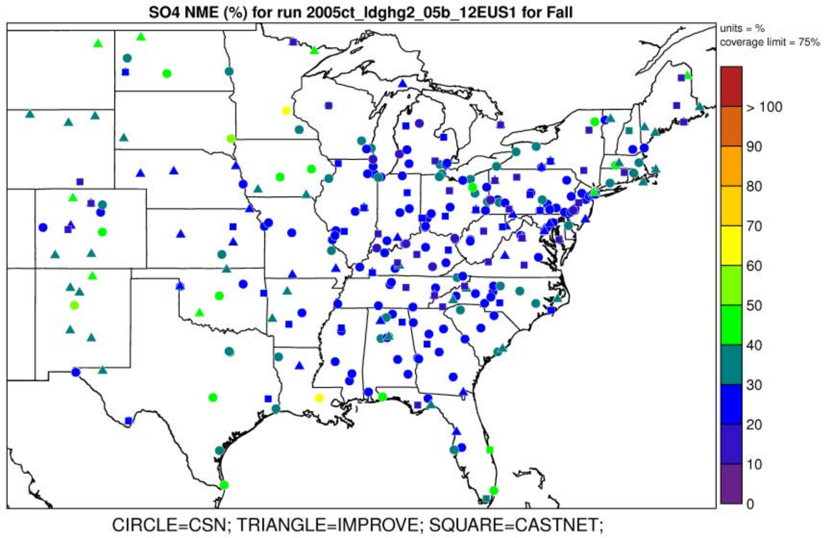

Figure A-16b. Normalized Mean Error (%) of sulfate during fall 2005 at monitoring sites in Eastern modeling domain.

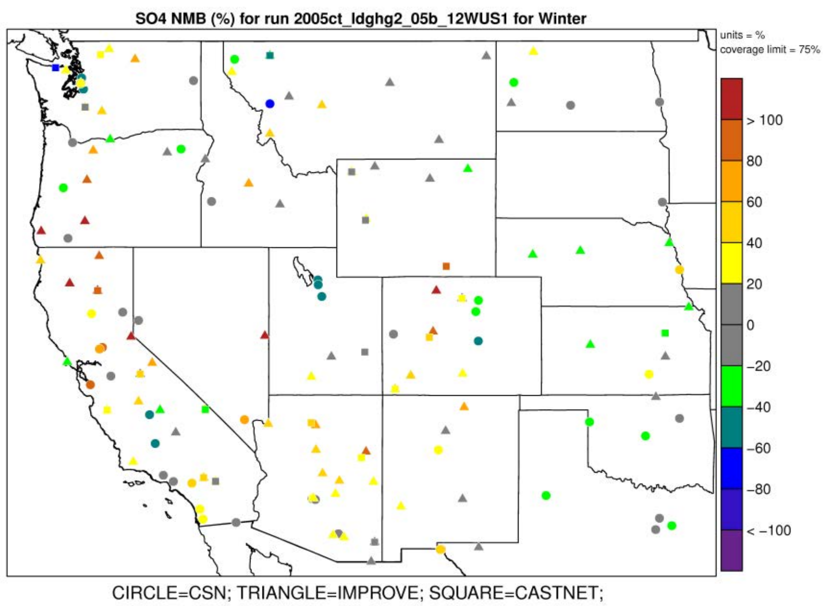

Figure A-17a. Normalized Mean Bias (%) of sulfate during winter 2005 at monitoring sites in Western modeling domain.

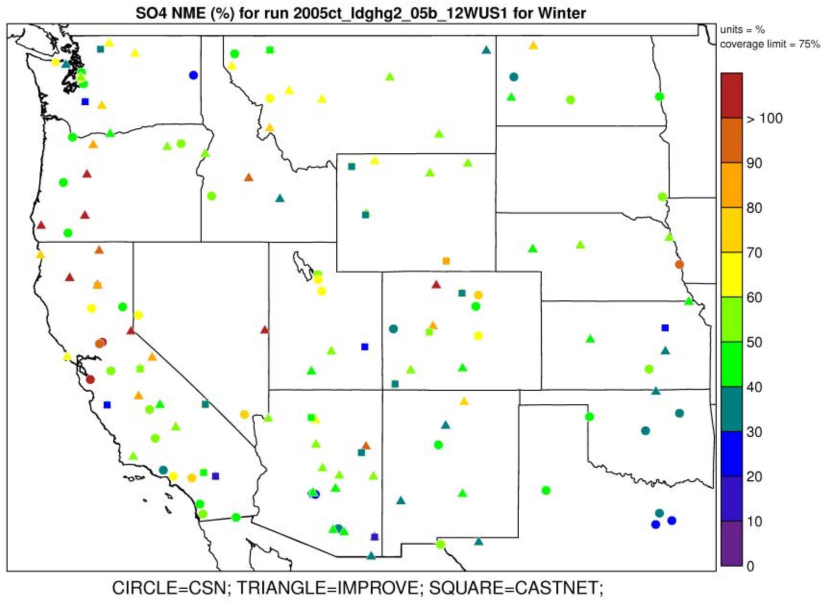

Figure F-17b. Normalized Mean Error (%) of sulfate during fall 2005 at monitoring sites in Western modeling domain.

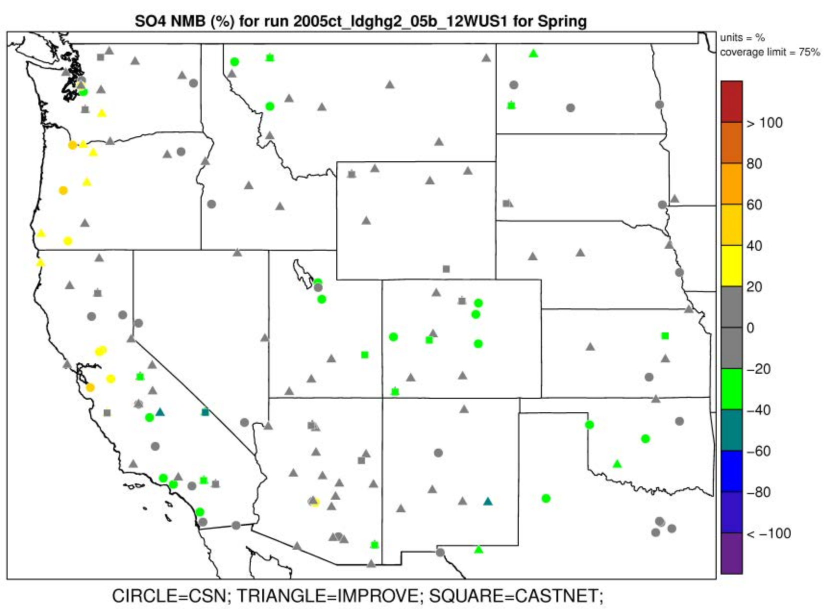

Figure A-18a. Normalized Mean Bias (%) of sulfate during spring 2005 at monitoring sites in Western modeling domain.

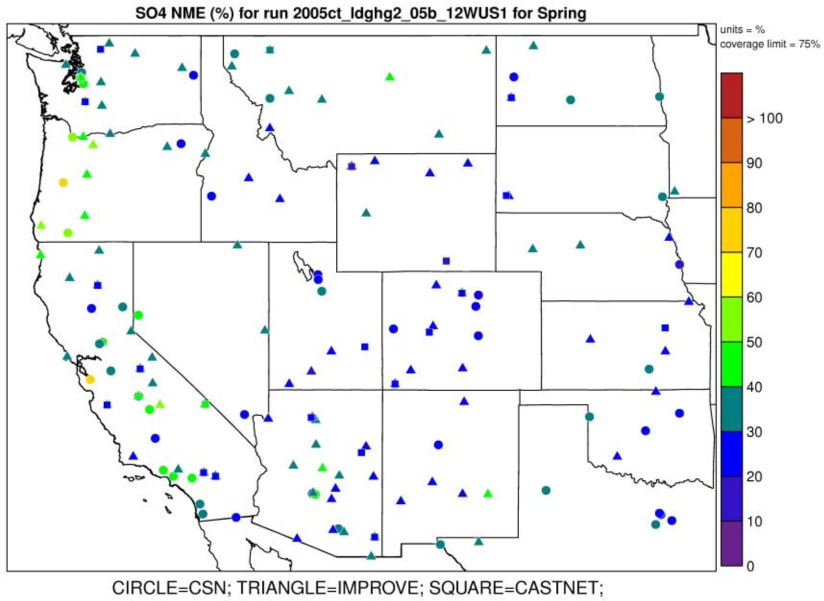

Figure A-18b. Normalized Mean Error (%) of sulfate during spring 2005 at monitoring sites in Western modeling domain.

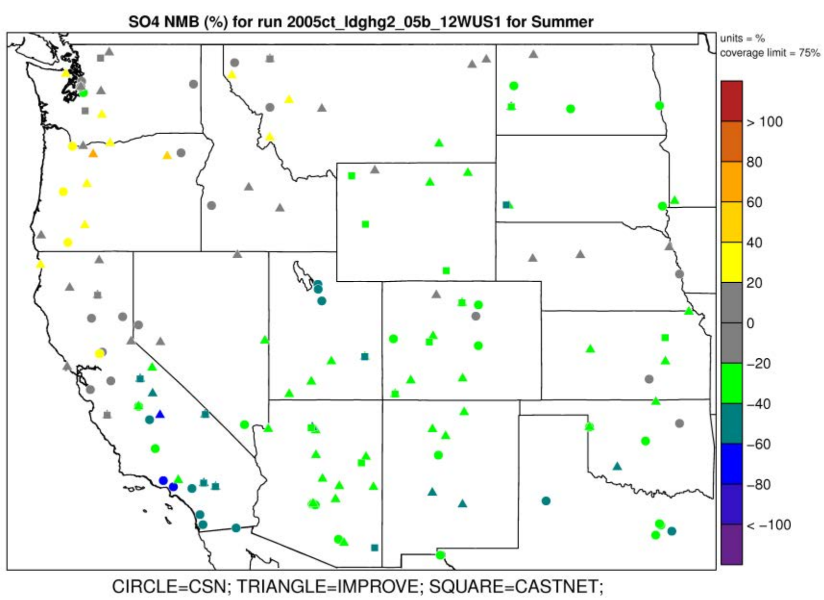

Figure A-19a. Normalized Mean Bias (%) of sulfate during summer 2005 at monitoring sites in Western modeling domain.

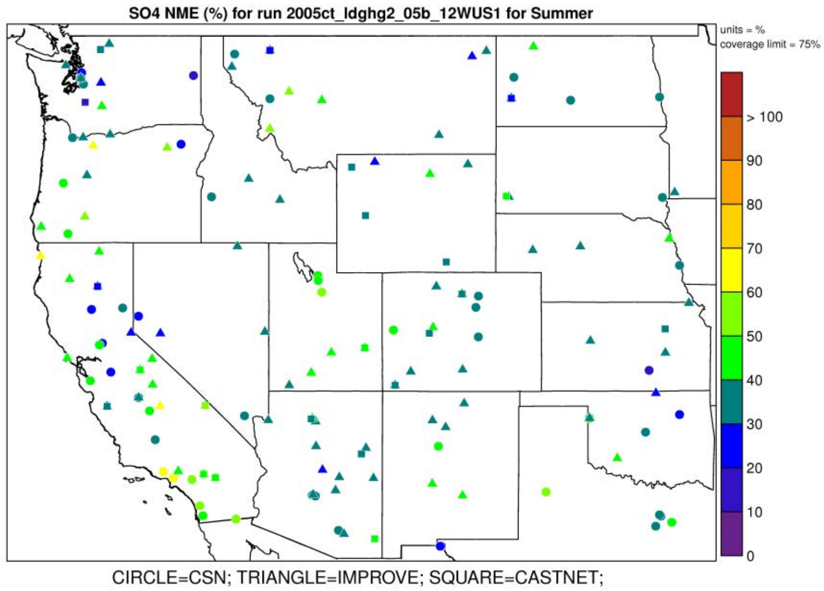

Figure A-19b. Normalized Mean Error (%) of sulfate during summer 2005 at monitoring sites in Western modeling domain.

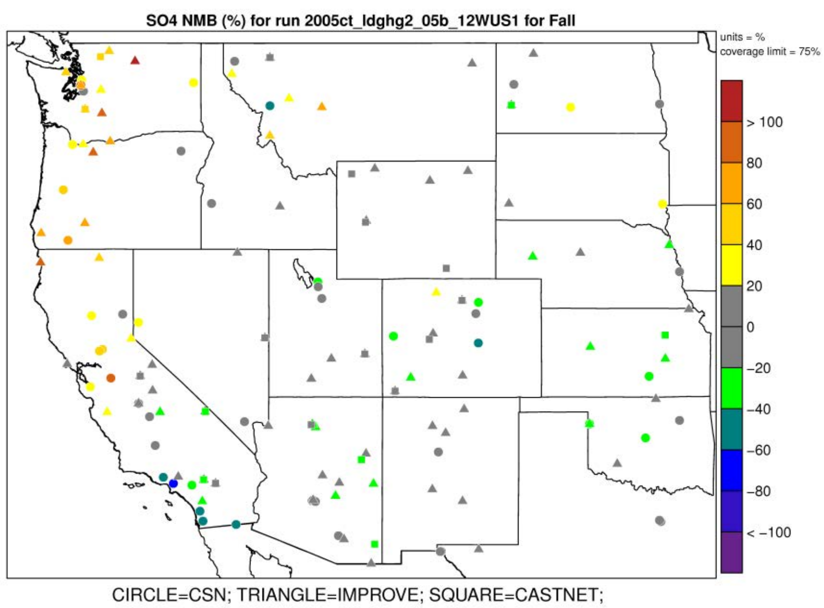

Figure A-20a. Normalized Mean Bias (%) of sulfate during fall 2005 at monitoring sites in Western modeling domain.

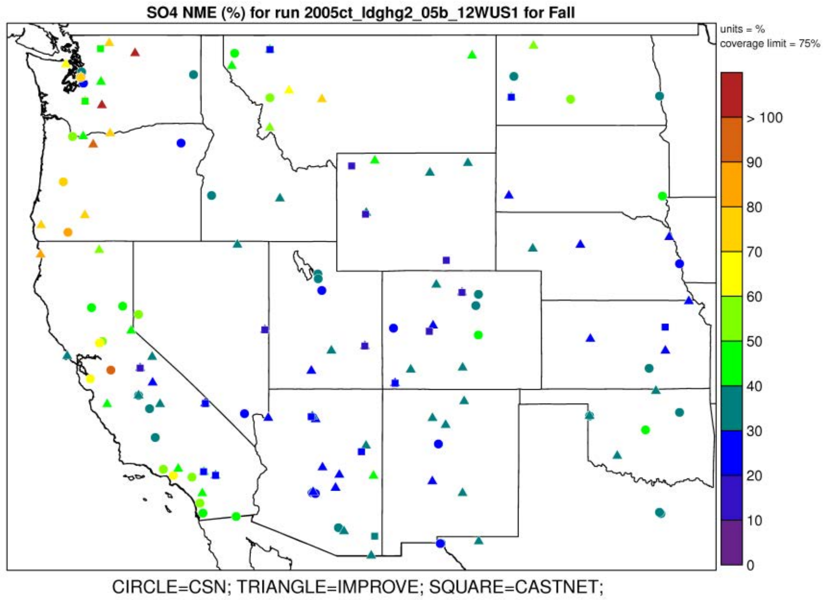

Figure A-20b. Normalized Mean Error (%) of sulfate during fall 2005 at monitoring sites in Western modeling domain.

A.3.1. Evaluation for Nitrate

The model performance bias and error statistics for nitrate for each subregion and each season are provided in Table A-4. This table includes statistics for particulate nitrate, as measured at CSN and IMPROVE sites, and statistics for total nitrate, as measured at CASTNet sites. The distributions of observed and predicted nitrate by month for each subregion are shown in Figures A-21 through A-25. Spatial plots of the normalized mean bias and error by season for individual monitors are shown in Figures A-26 through A-33. Overall, nitrate and total nitrate performance are over-predicted in the Northeast, Midwest, Southeast and Central U.S.; with the exception at the urban monitors (CSN) where nitrate is under-predicted in the winter. Likewise, nitrate is under-predicted at CSN sites during the summer in the Southeast and Northeast. Model performance shows an under-prediction in the West for all of the seasonal assessments of nitrate and total nitrate.

Table A-4. Nitrate performance statistics by subregion, by season for the 2005 CMAQ model simulation.

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	CSN	Winter	479	-4.5	48.9	-5.3	59.1
		Spring	503	30.0	62.1	15.3	66.0
		Summer	485	28.1	102.0	-41.4	95.4
		Fall	460	107.0	133.0	19.4	88.9
	IMPROVE	Winter	608	5.1	54.9	-6.5	70.7
		Spring	722	49.1	78.6	-3.8	91.0
		Summer	688	21.8	112.0	-56.1	111.0
		Fall	622	164.0	193.0	14.3	108.0
	CASTNet	Winter	72	26.9	38.9	26.6	36.7
		Spring	77	14.6	34.3	7.7	31.3
		Summer	72	-0.2	26.3	-6.1	27.6
		Fall	75	52.8	60.1	35.9	44.0
Midwest	CSN	Winter	598	-20.9	40.5	-21.3	48.8
		Spring	637	63.3	83.4	40.5	65.4
		Summer	621	43.4	98.2	-10.8	83.6
		Fall	639	69.5	98.1	24.2	74.3
	IMPROVE	Winter	143	-27.3	47.7	-29.8	72.7
		Spring	171	54.8	87.6	-3.5	90.3
		Summer	182	25.4	100.0	-41.4	99.7
		Fall	126	108.0	141.0	0.7	102.0
	CASTNet	Winter	142	6.9	21.4	0.3	21.8
		Spring	155	38.4	42.1	31.7	35.6
		Summer	161	53.4	56.0	40.7	43.1
		Fall	157	73.6	74.0	51.1	51.4

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Southeast	CSN	Winter	888	-23.5	61.7	-55.5	85.6
		Spring	918	39.9	98.0	-10.8	92.2
		Summer	866	-26.8	85.6	-83.3	115.0
		Fall	911	78.6	141.0	-28.1	108.0
	IMPROVE	Winter	469	-2.5	82.4	-58.6	98.8
		Spring	525	59.8	117.0	-29.3	108.0
		Summer	500	-14.2	112.0	-92.7	136.0
		Fall	496	105.0	184.0	-46.8	125.0
	CASTNet	Winter	264	24.4	35.9	20.8	35.2
		Spring	292	31.7	44.9	21.8	39.6
		Summer	268	28.8	47.2	17.0	42.6
		Fall	273	73.8	81.9	45.8	58.9
Northeast	CSN	Winter	829	-1.6	43.9	-1.2	49.7
		Spring	894	43.5	77.6	32.9	68.5
		Summer	874	-5.7	89.9	-58.3	101.0
		Fall	902	76.3	109.0	-11.0	86.2
	IMPROVE	Winter	561	42.1	77.5	32.8	76.0
		Spring	689	74.1	113.0	31.5	93.2
		Summer	649	11.2	115.0	-61.5	113.0
		Fall	586	116.0	157.0	-8.9	100.0
	CASTNet	Winter	193	23.6	30.7	31.3	35.4
		Spring	206	49.0	51.4	37.4	42.4
		Summer	192	53.6	61.3	33.3	49.5
		Fall	195	85.3	87.8	54.1	60.5
West	CSN	Winter	831	-44.0	63.8	-60.1	87.1
		Spring	859	-37.2	58.2	-68.4	89.0
		Summer	846	-72.8	76.4	-132.0	137.0
		Fall	896	-47.7	69.8	-66.5	95.5
	IMPROVE	Winter	2,344	-29.7	77.5	-83.2	121.0
		Spring	2,613	-38.4	76.5	-87.4	118.0
		Summer	2,279	-73.6	83.9	-144.0	152.0
		Fall	2,335	-31.8	82.0	-75.1	121.0
	CASTNet	Winter	250	34.6	52.9	41.7	54.6
		Spring	273	-1.9	32.7	6.2	32.4
		Summer	281	-6.8	31.2	-5.8	33.0
		Fall	268	15.9	40.5	28.2	46.6

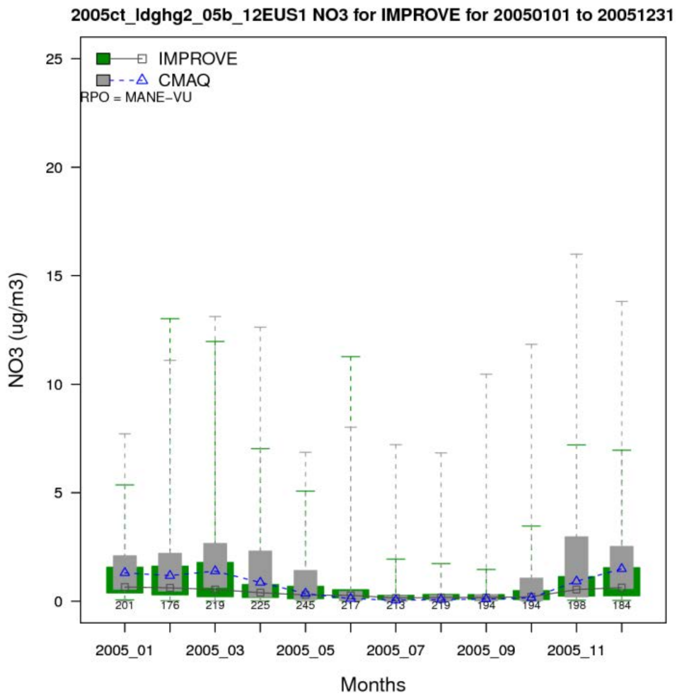

Figure A-21a. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at IMPROVE sites in the Northeast subregion. [symbol = median; top/bottom of box = 75th/25th percentiles; top/bottom line = max/min values]

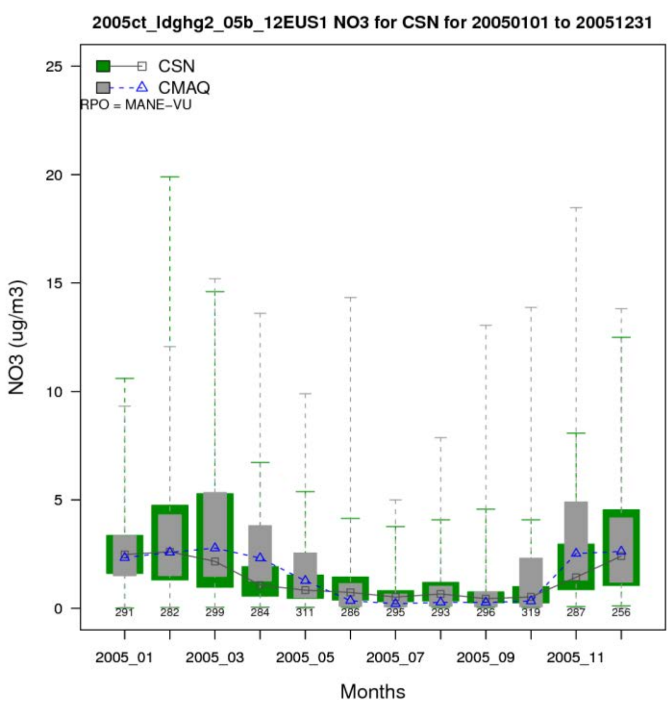

Figure A-21b. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at CSN sites in the Northeast subregion.

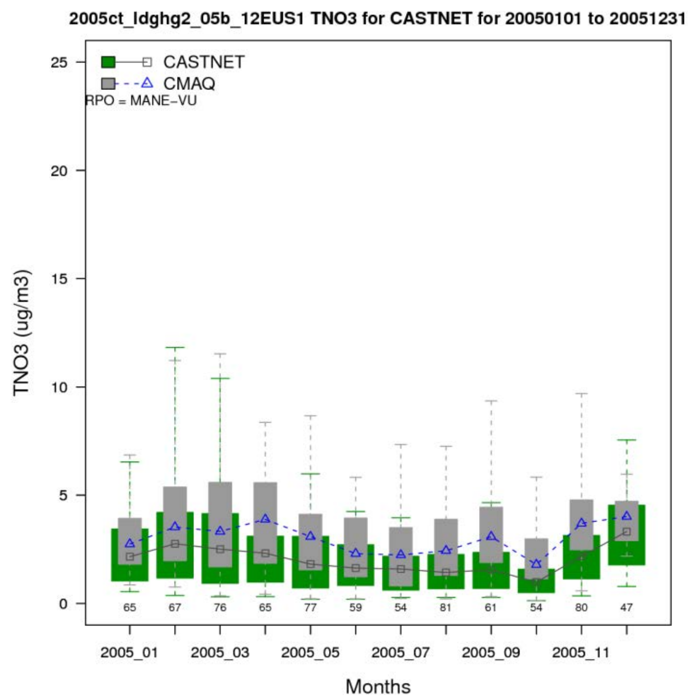

Figure A-21c. Distribution of observed and predicted weekly average total nitrate by month for 2005 at CASTNet sites in the Northeast subregion.

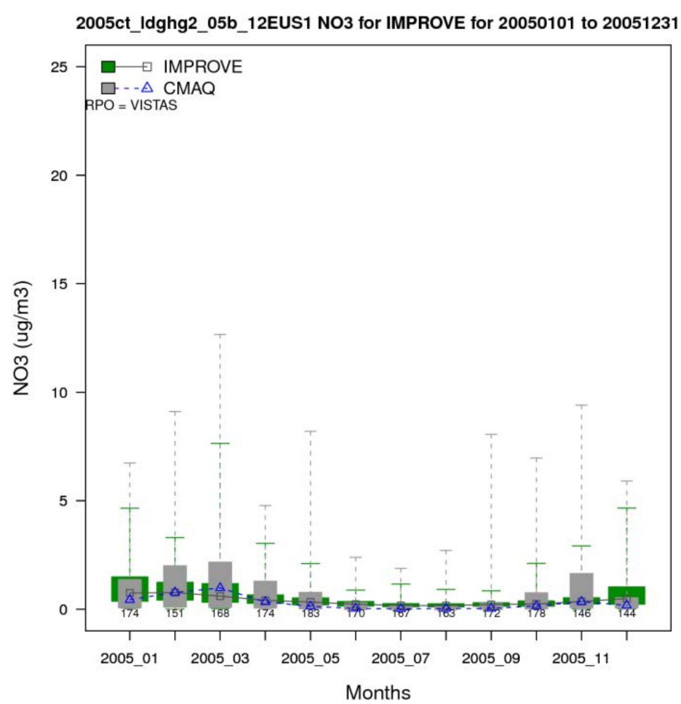

Figure A-22a. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at IMPROVE sites in the Southeast subregion.

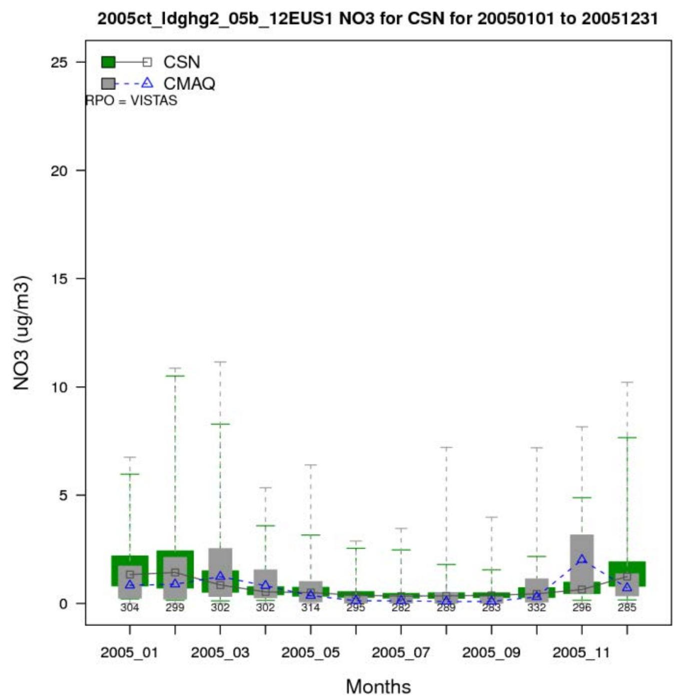

Figure A-22b. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at CSN sites in the Southeast subregion.

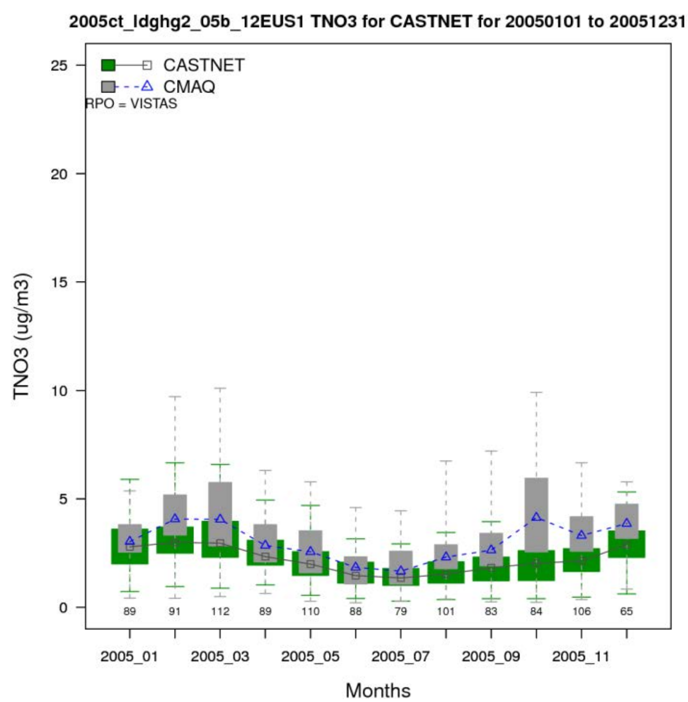

Figure A-22c. Distribution of observed and predicted weekly average total nitrate by month for 2005 at CASTNet sites in the Southeast subregion.

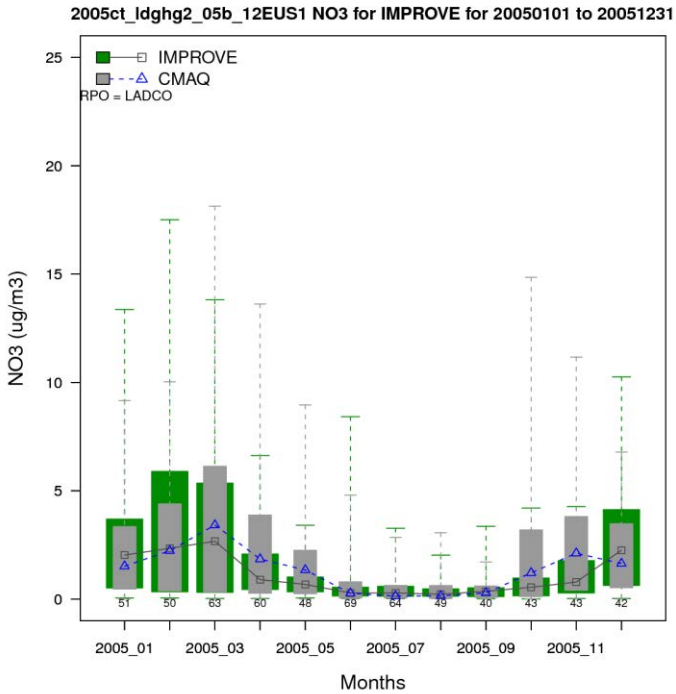

Figure A-23a. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at IMPROVE sites in the Midwest subregion.

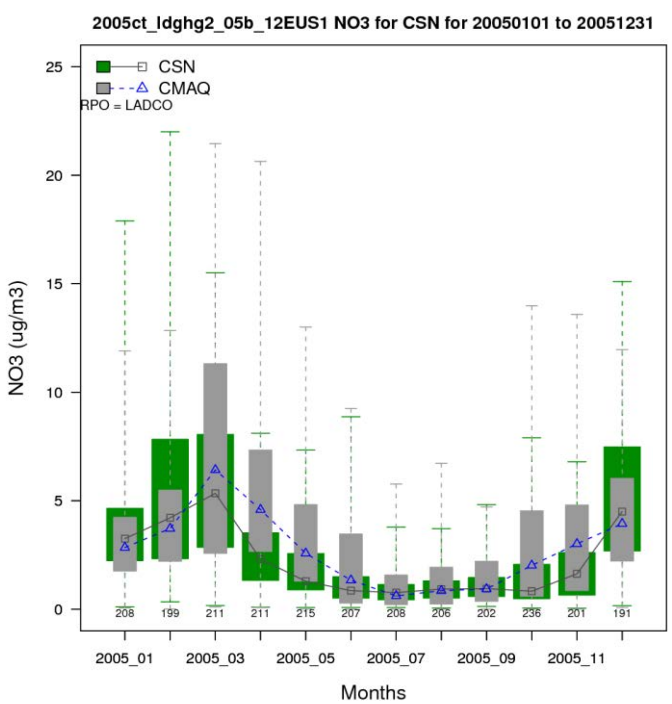

Figure A-23b. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at CSN sites in the Midwest subregion.

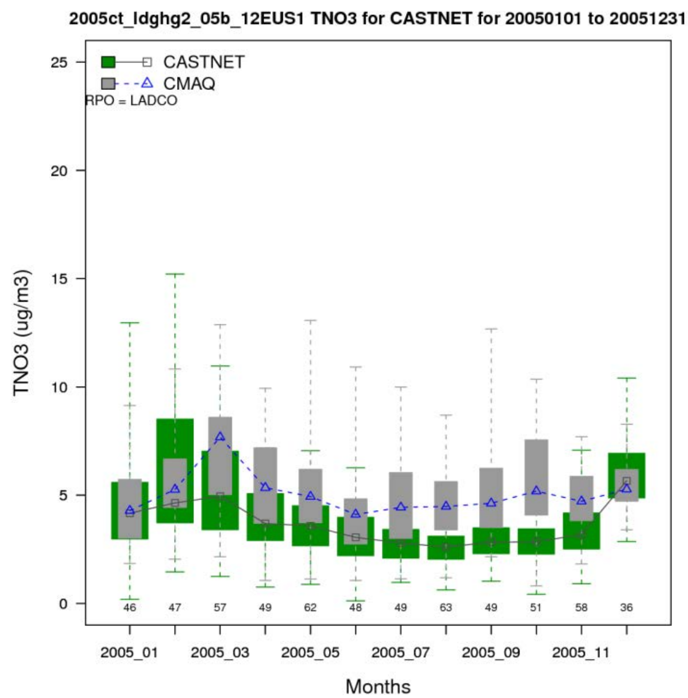

Figure A-23c. Distribution of observed and predicted weekly average total nitrate by month for 2005 at CASTNet sites in the Midwest subregion.

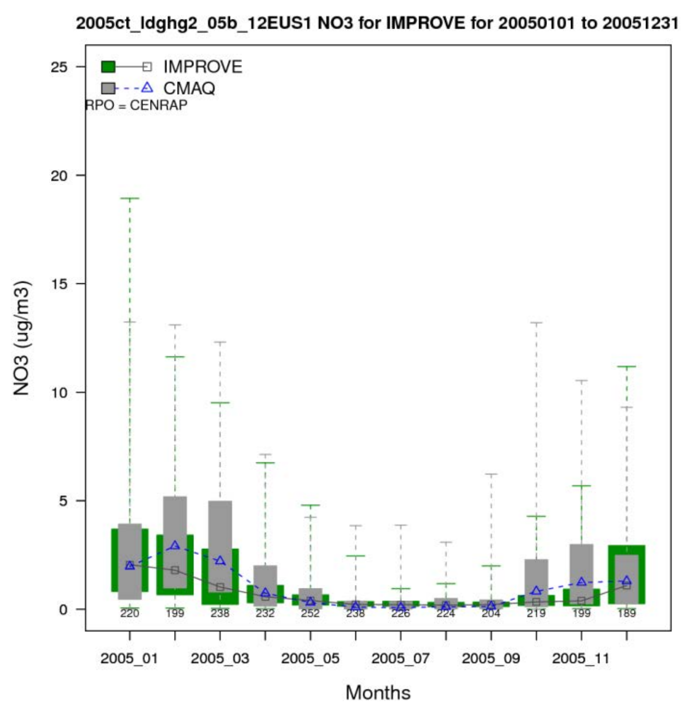

Figure A-24a. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at IMPROVE sites in the Central states subregion.

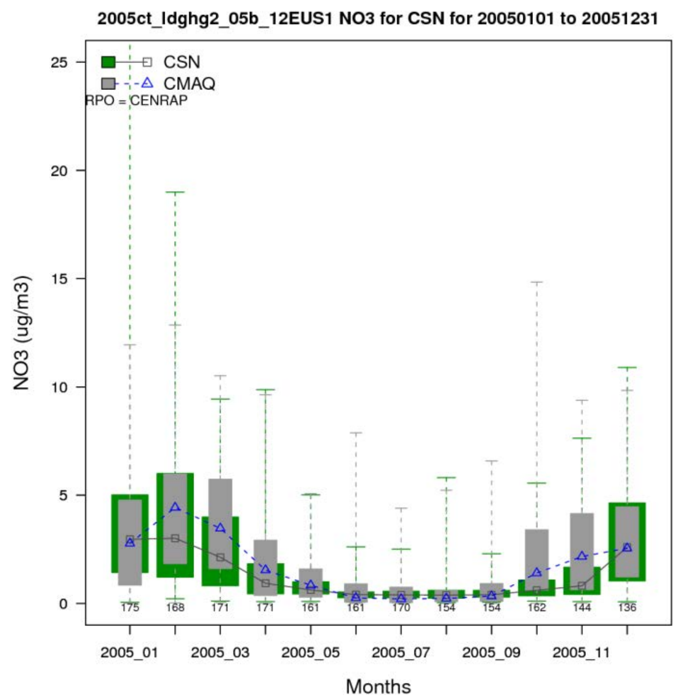

Figure A-24b. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at CSN sites in the Central states subregion.

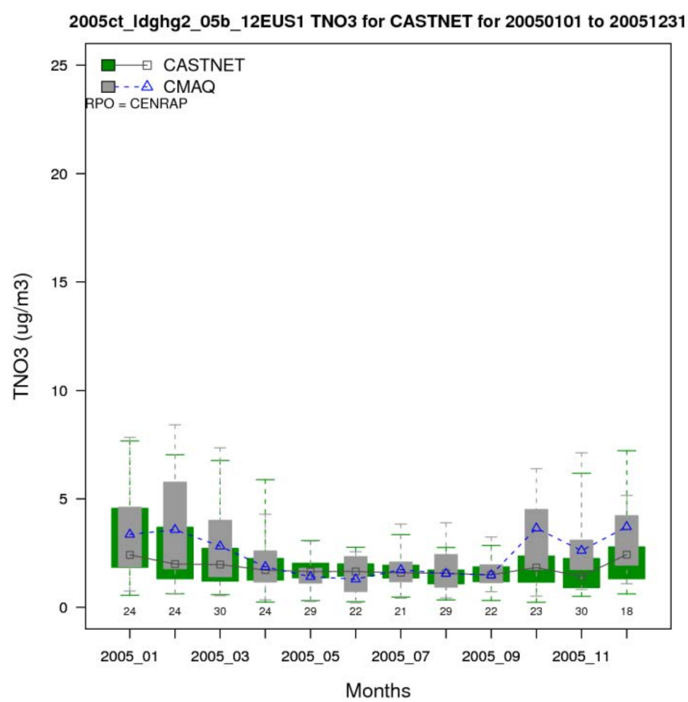

Figure A-24c. Distribution of observed and predicted weekly average total nitrate by month for 2005 at CASTNet sites in the Central states subregion.

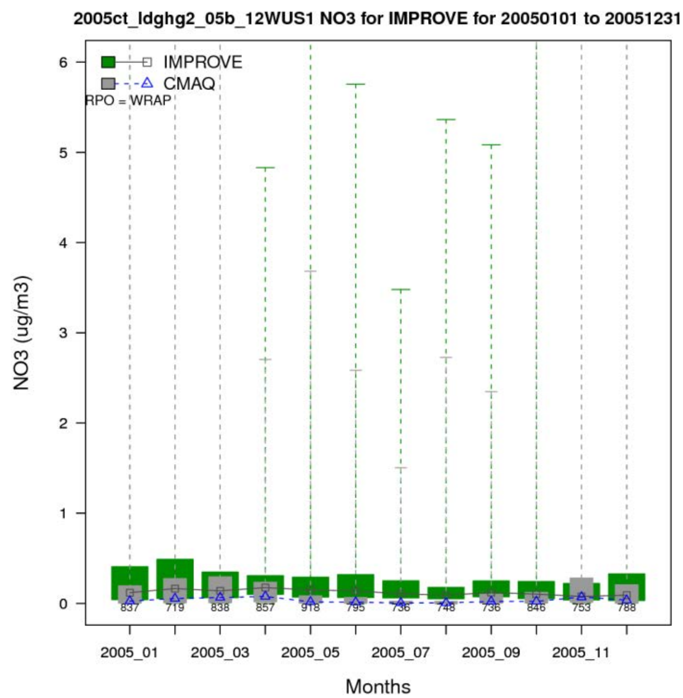

Figure A-25a. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at IMPROVE sites in the Western states subregion.

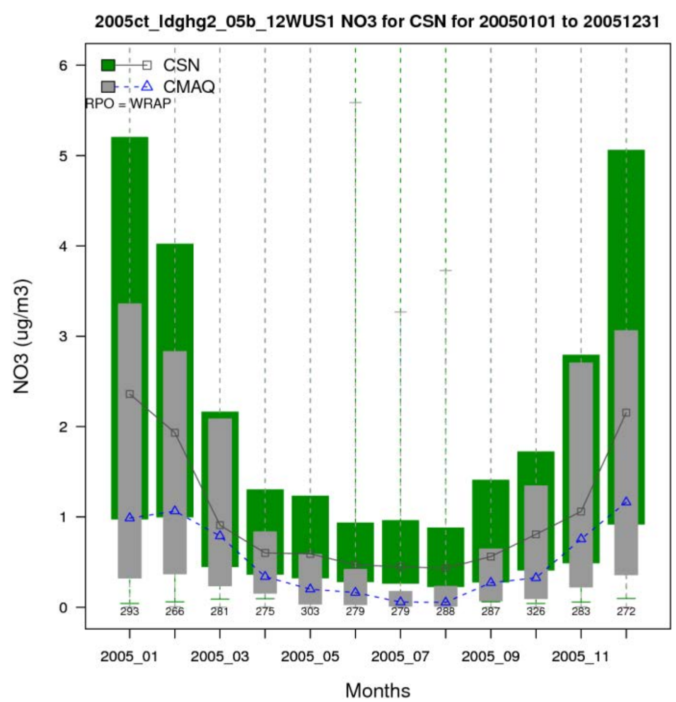

Figure A-25b. Distribution of observed and predicted 24-hour average nitrate by month for 2005 at CSN sites in the Western states subregion.

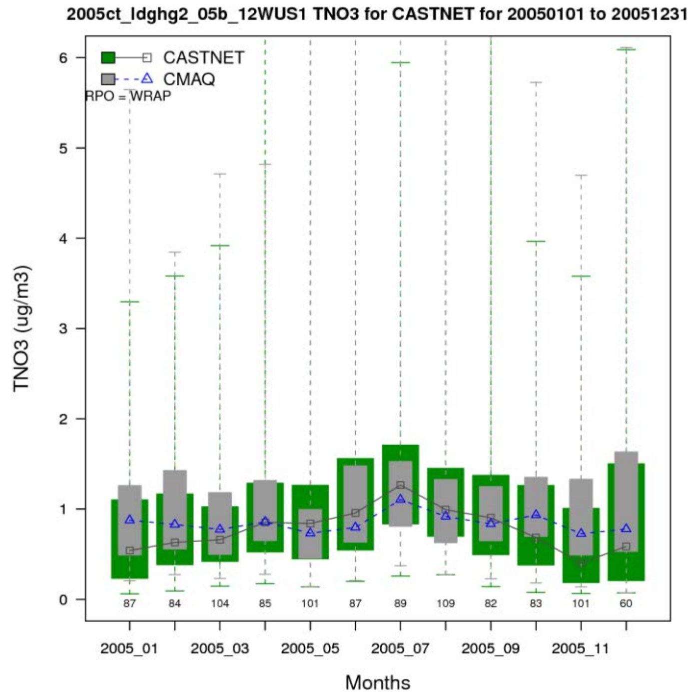

Figure A-25c. Distribution of observed and predicted weekly average total nitrate by month for 2005 at CASTNet sites in the Western states subregion.

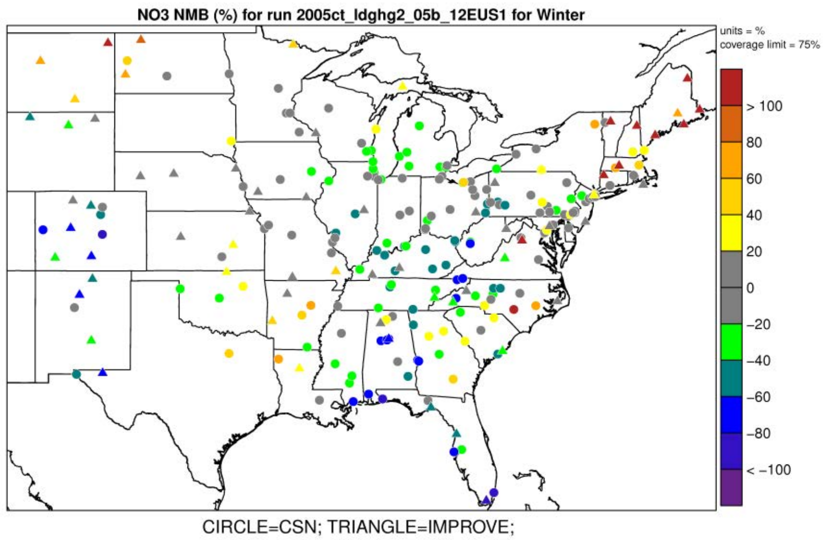

Figure A-26a. Normalized Mean Bias (%) for nitrate during winter 2005 at monitoring sites in Eastern modeling domain.

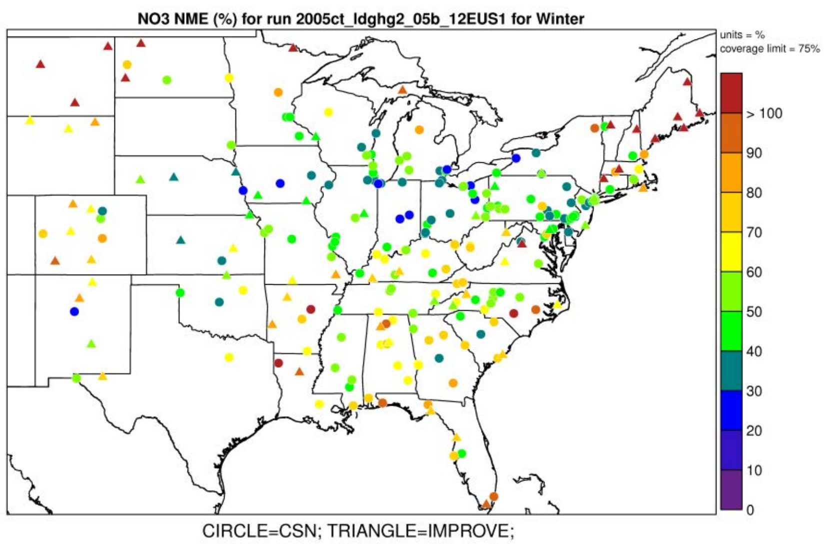

Figure A-26b. Normalized Mean Error (%) for nitrate during winter 2005 at monitoring sites in Eastern modeling domain.

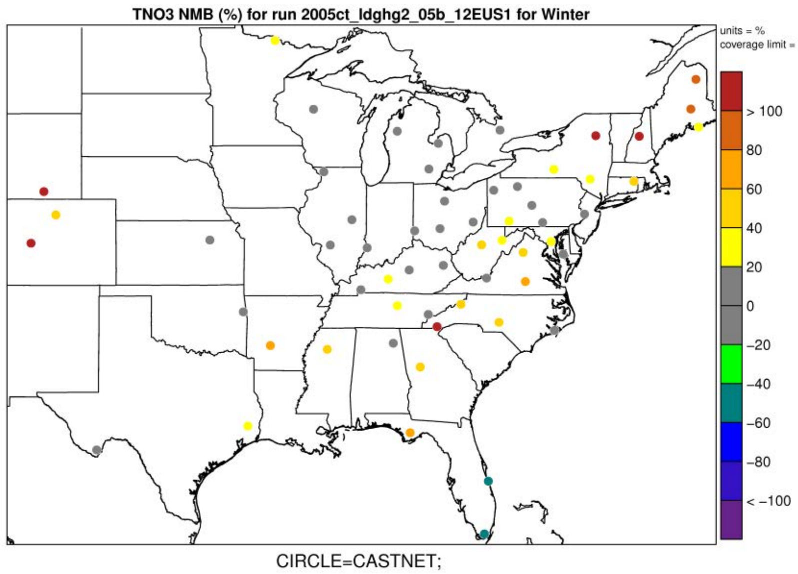

Figure A-26c. Normalized Mean Bias (%) for total nitrate during winter 2005 at monitoring sites in Eastern modeling domain.

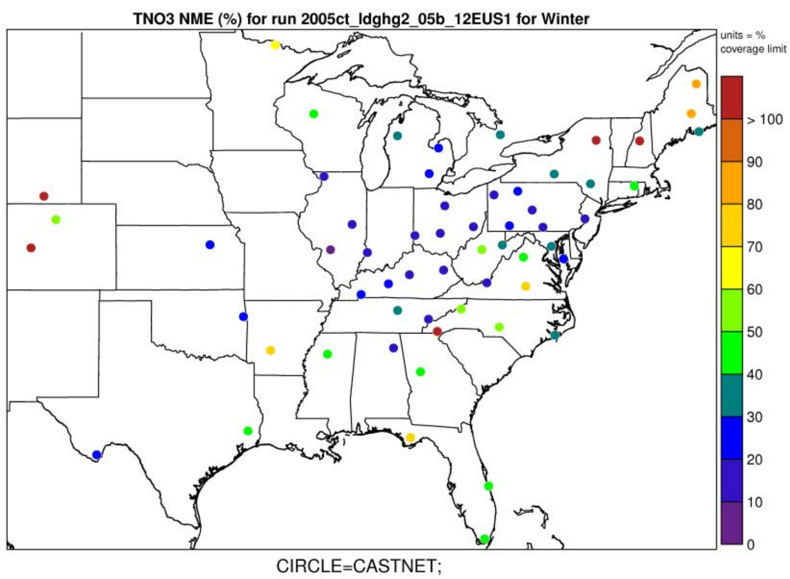

Figure A-26d. Normalized Mean Error (%) for total nitrate during winter 2005 at monitoring sites in Eastern modeling domain.

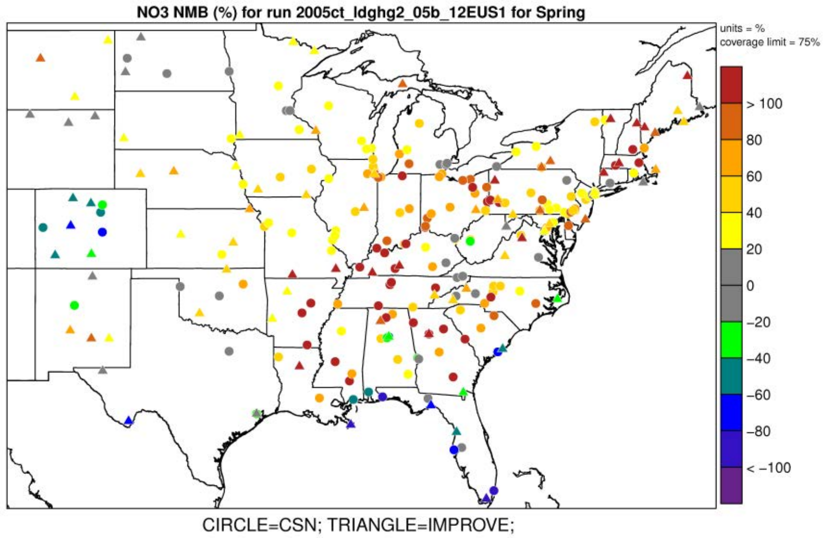

Figure A-27a. Normalized Mean Bias (%) for nitrate during spring 2005 at monitoring sites in Eastern modeling domain.

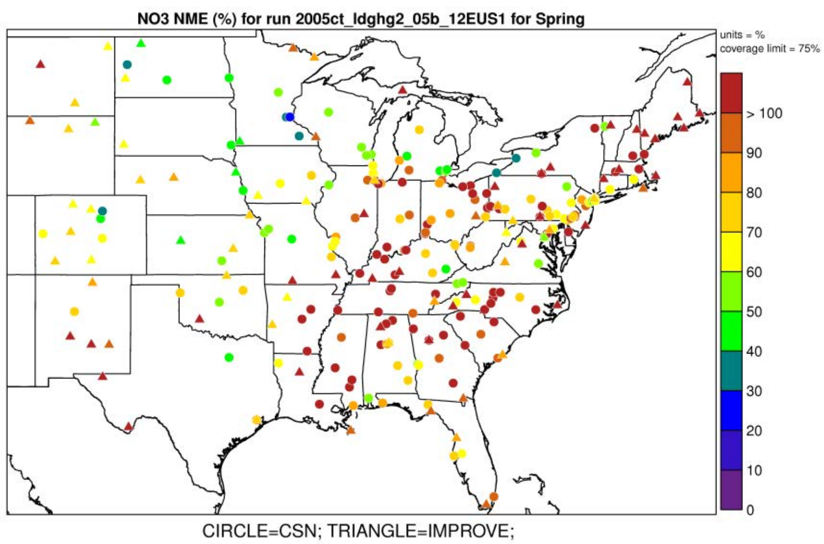

Figure A-27b. Normalized Mean Error (%) for nitrate during spring 2005 at monitoring sites in Eastern modeling domain.

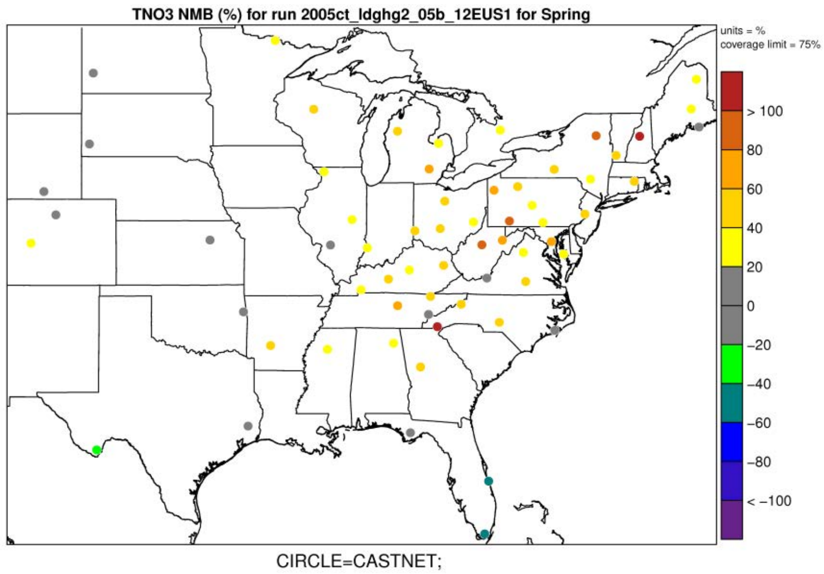

Figure A-27c. Normalized Mean Bias (%) for total nitrate during spring 2005 at monitoring sites in Eastern modeling domain.

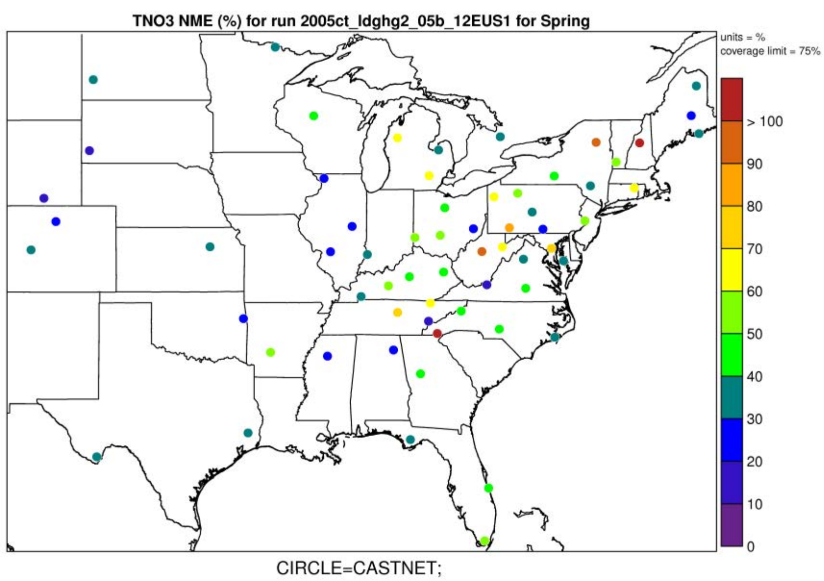

Figure A-27d. Normalized Mean Error (%) for total nitrate spring 2005 at monitoring sites in Eastern modeling domain.

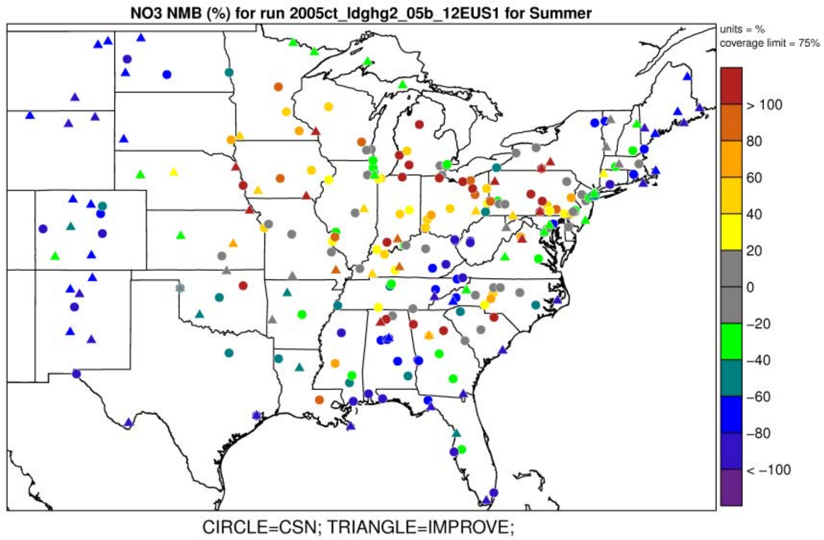

Figure A-28a. Normalized Mean Bias (%) for nitrate during summer 2005 at monitoring sites in Eastern modeling domain.

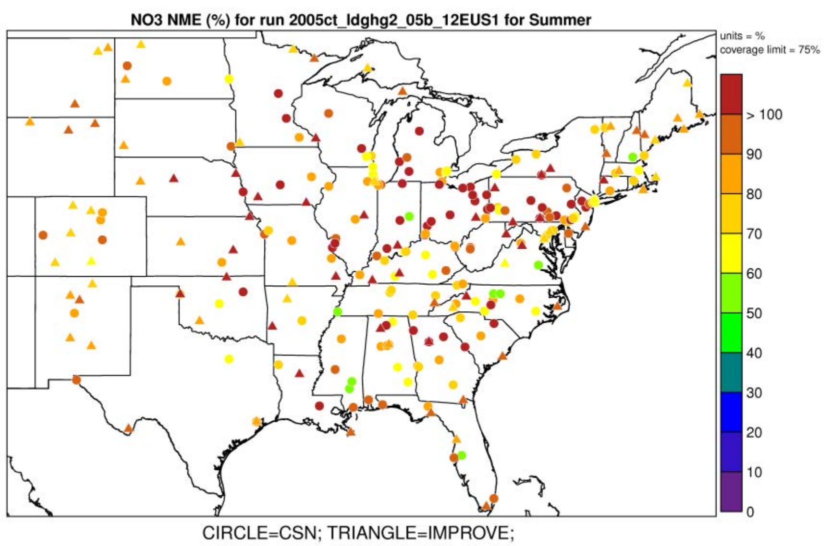

Figure A-28b. Normalized Mean Error (%) for nitrate during summer 2005 at monitoring sites in Eastern modeling domain.

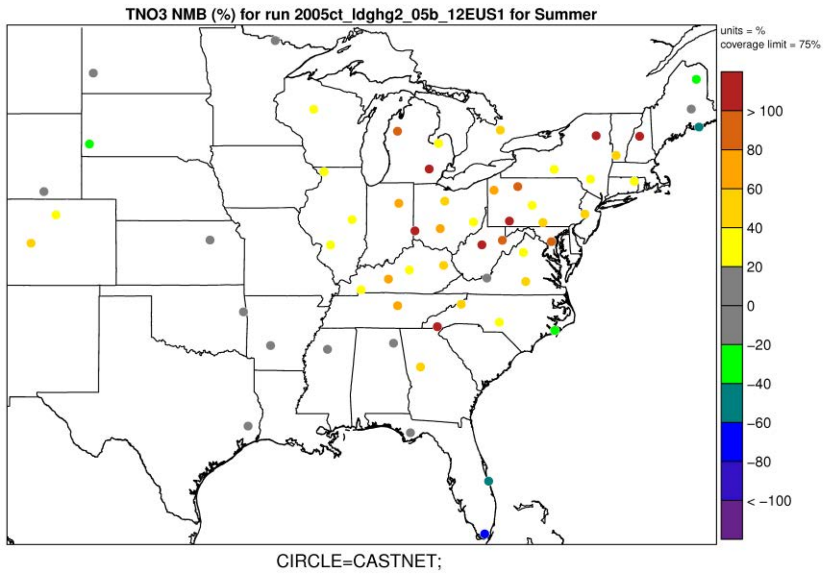

Figure A-28c. Normalized Mean Bias (%) for total nitrate during summer 2005 at monitoring sites in Eastern modeling domain.

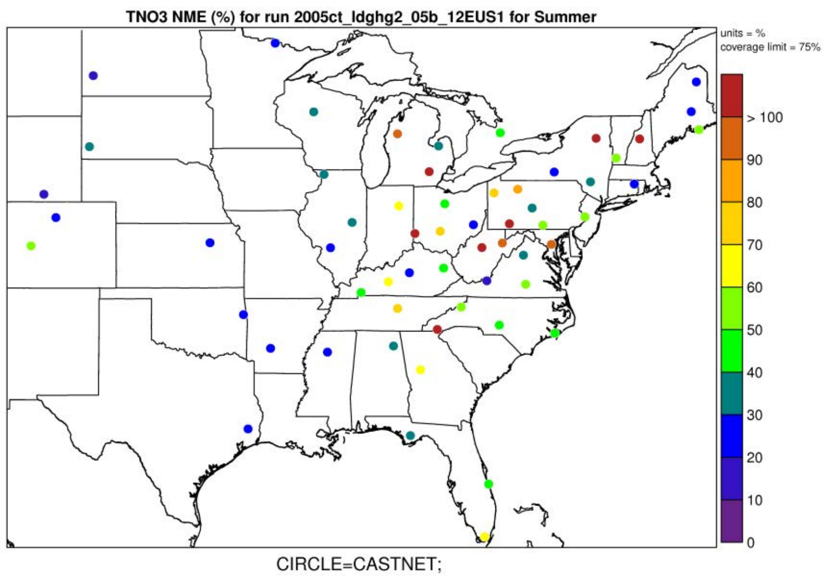

Figure A-28d. Normalized Mean Error (%) for total nitrate summer 2005 at monitoring sites in Eastern modeling domain.

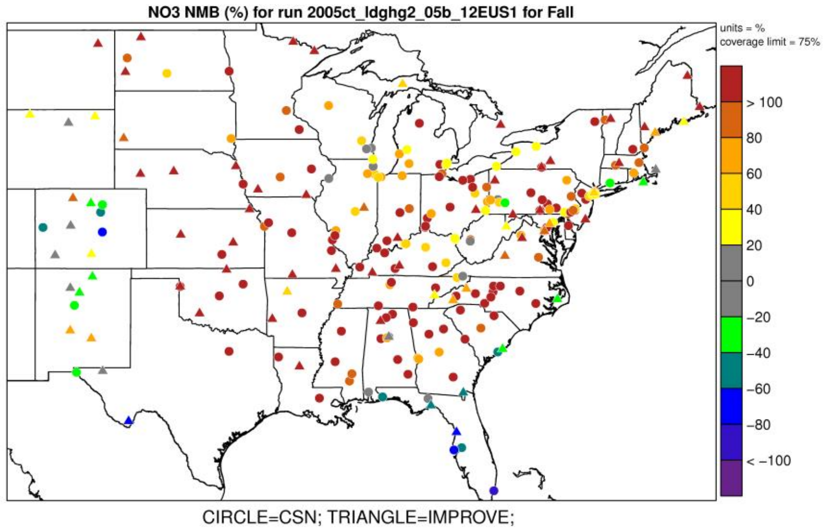

Figure A-29a. Normalized Mean Bias (%) for nitrate during fall 2005 at monitoring sites in Eastern modeling domain.

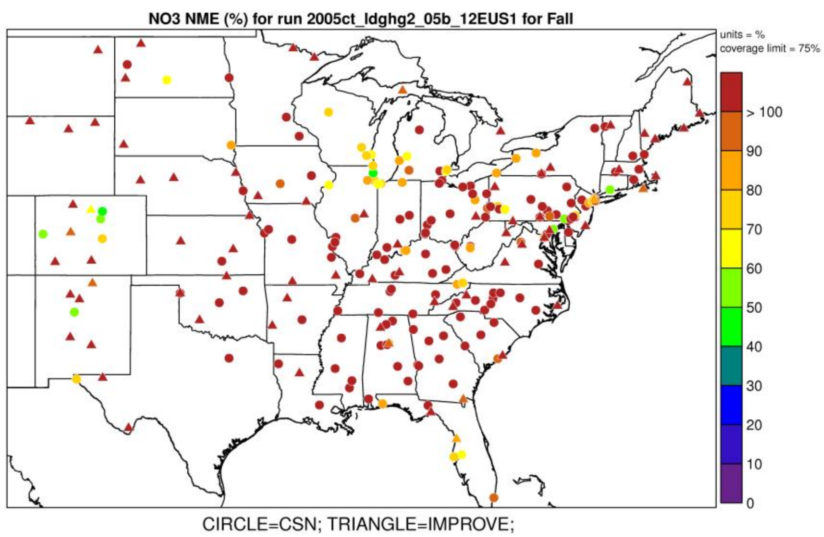

Figure A-29b. Normalized Mean Error (%) for nitrate during fall 2005 at monitoring sites in Eastern modeling domain.

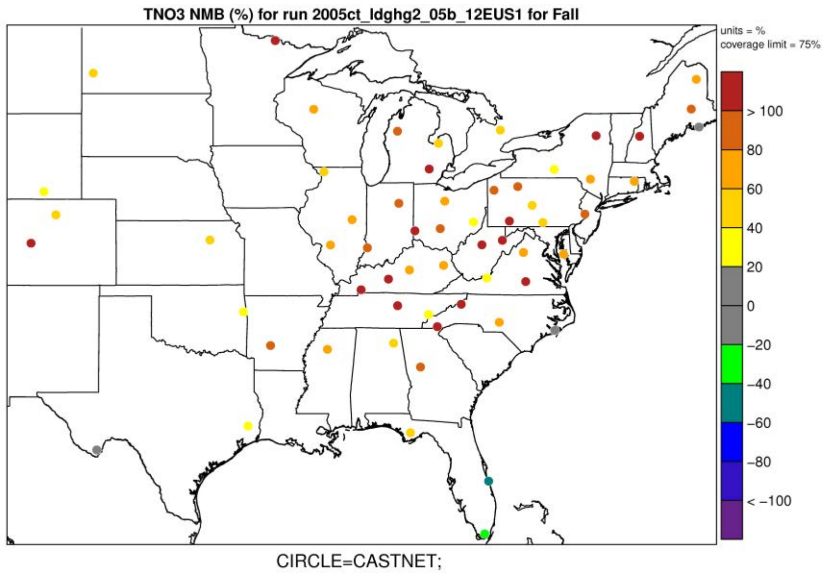

Figure A-29c. Normalized Mean Bias (%) for total nitrate during fall 2005 at monitoring sites in Eastern modeling domain.

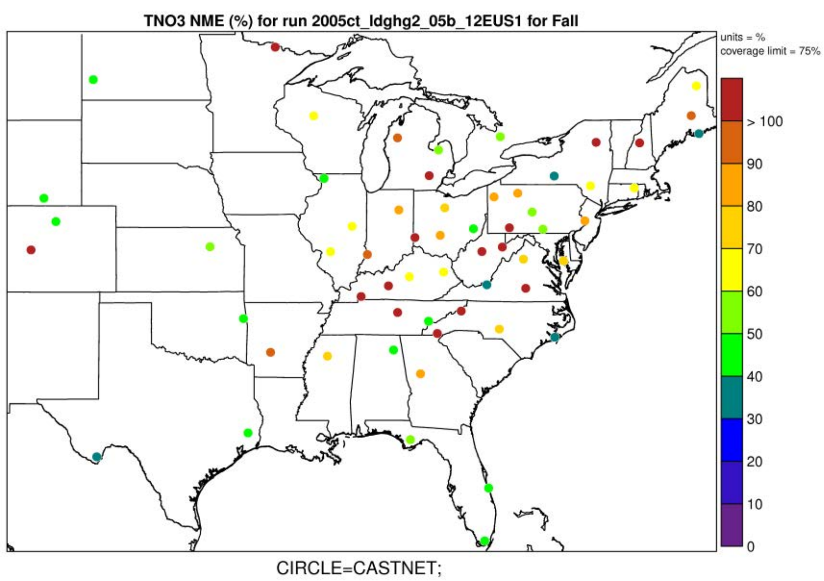

Figure A-29d. Normalized Mean Error (%) for total nitrate fall 2005 at monitoring sites in Eastern modeling domain.

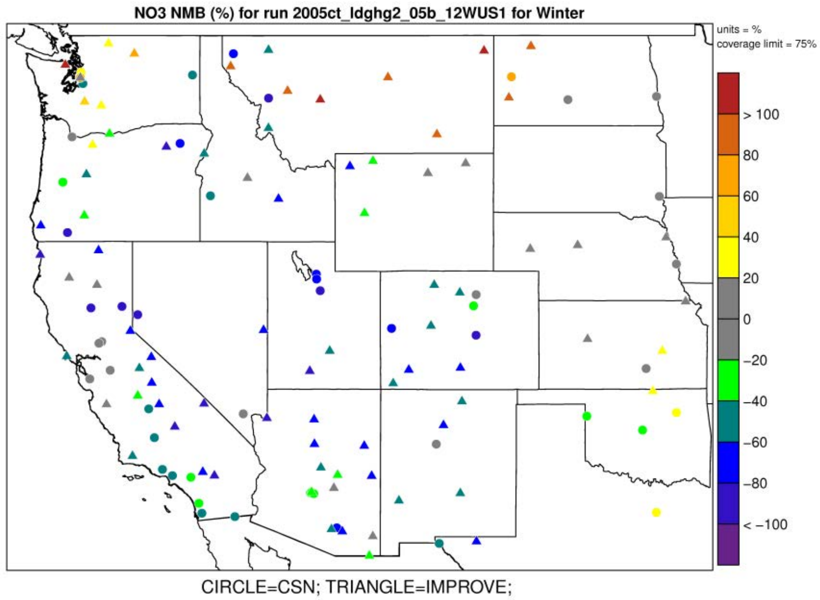

Figure A-30a. Normalized Mean Bias (%) for nitrate during winter 2005 at monitoring sites in Western modeling domain.

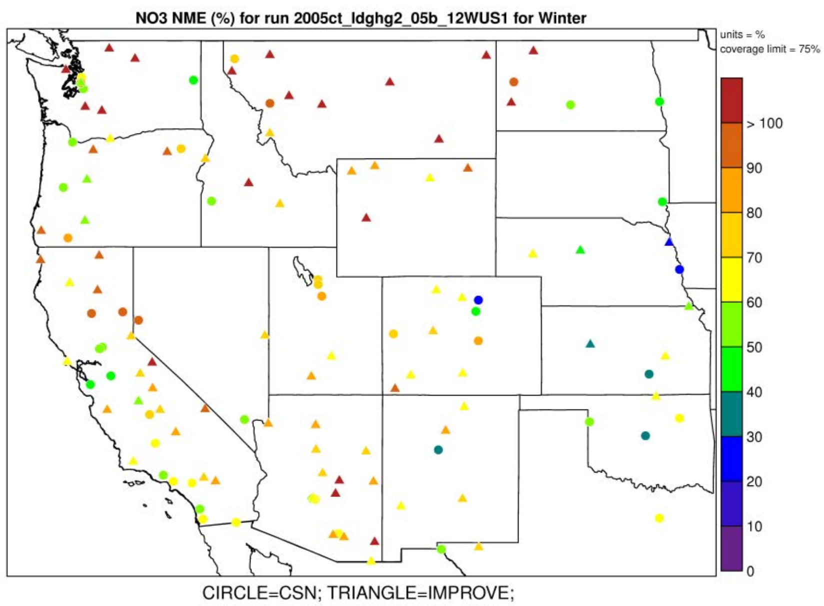

Figure A-30b. Normalized Mean Error (%) for nitrate during winter 2005 at monitoring sites in Western modeling domain.

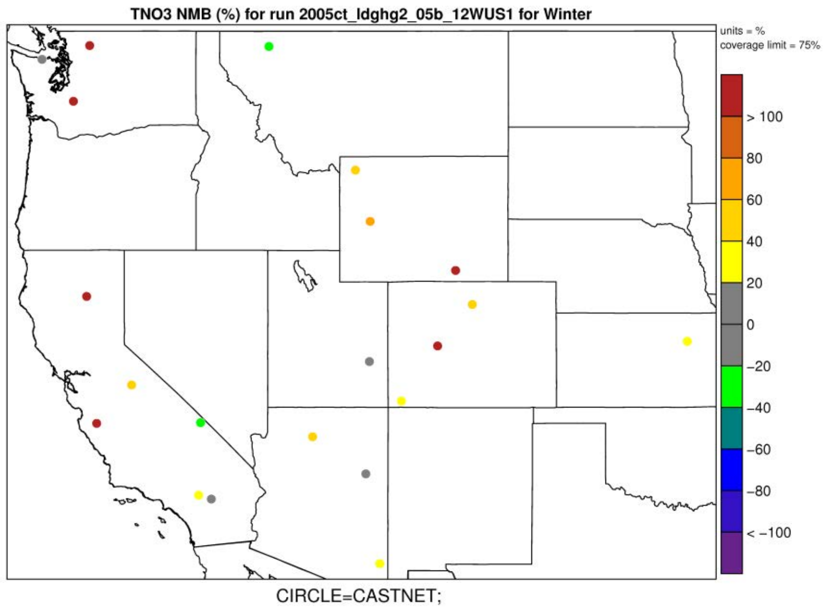

Figure A-30c. Normalized Mean Bias (%) for total nitrate during winter 2005 at monitoring sites in Western modeling domain.

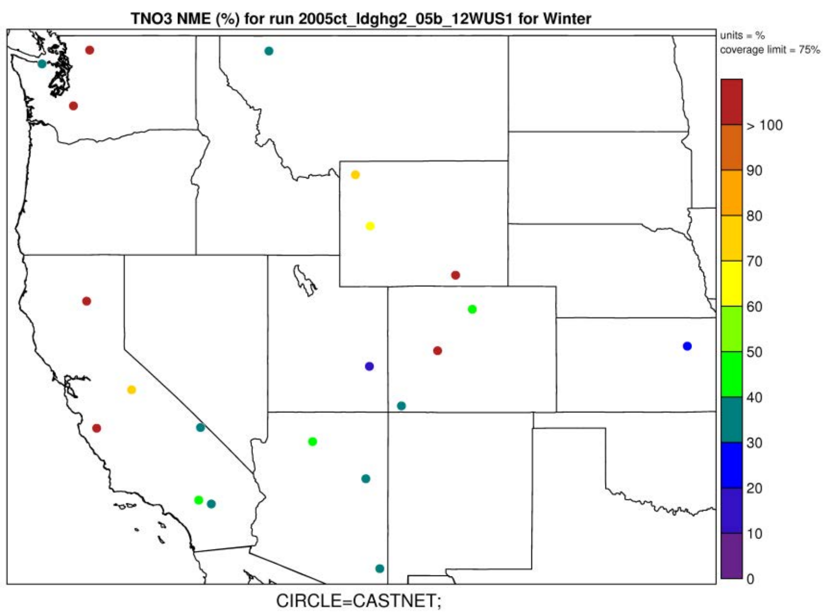

Figure A-30d. Normalized Mean Error (%) for total nitrate winter 2005 at monitoring sites in Western modeling domain.

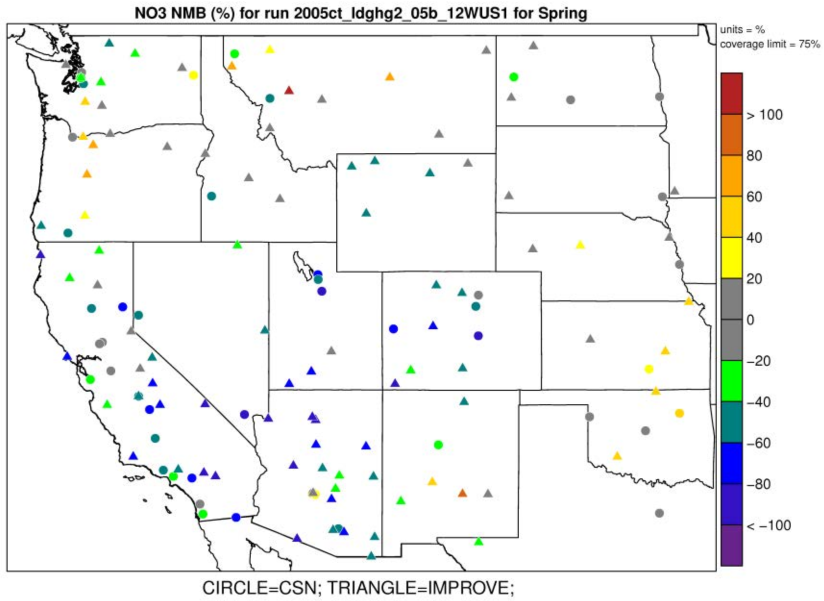

Figure A-31a. Normalized Mean Bias (%) for nitrate during spring 2005 at monitoring sites in Western modeling domain.

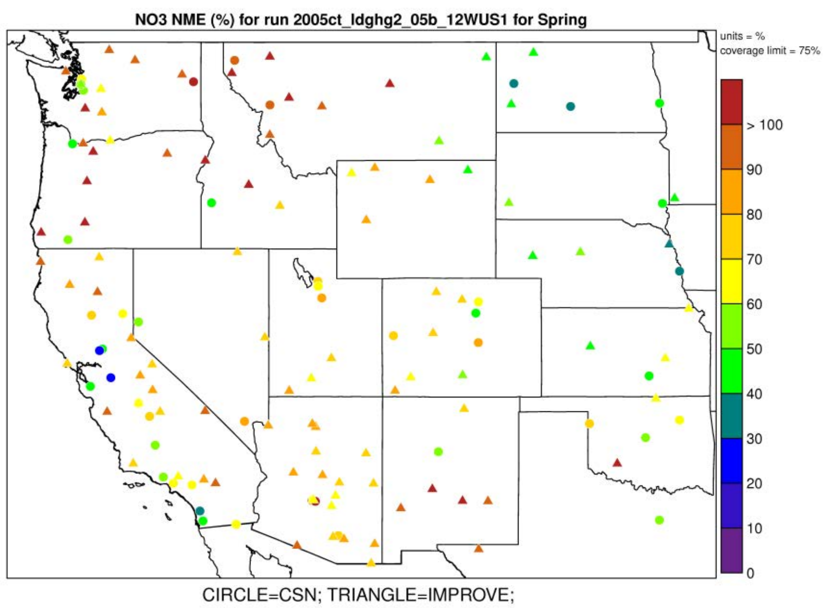

Figure A-31b. Normalized Mean Error (%) for nitrate during spring 2005 at monitoring sites in Western modeling domain.

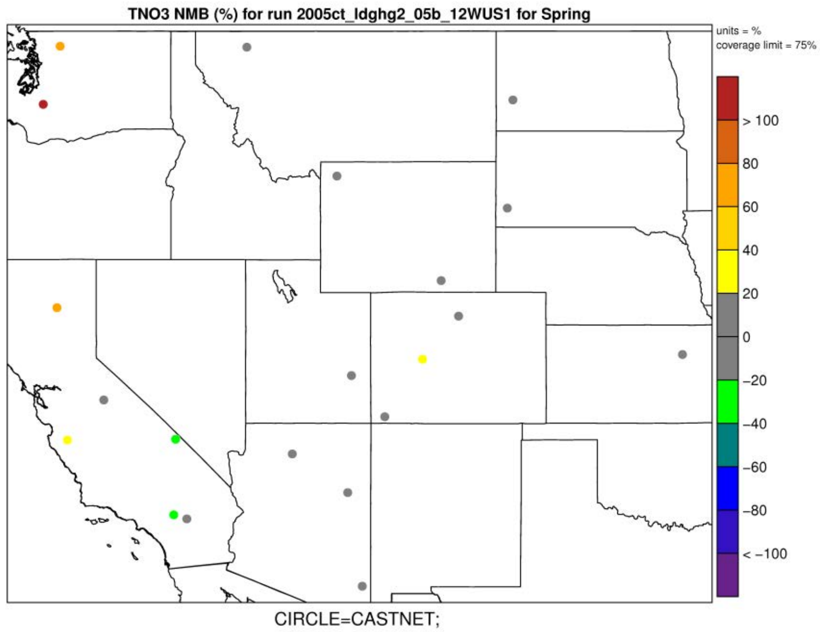

Figure A-31c. Normalized Mean Bias (%) for total nitrate during spring 2005 at monitoring sites in Western modeling domain.

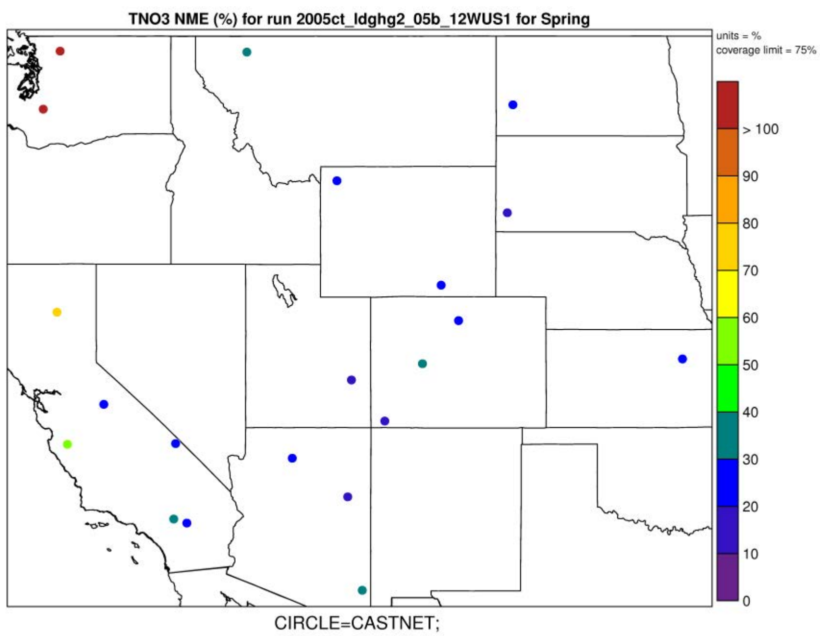

Figure A-31d. Normalized Mean Error (%) for total nitrate spring 2005 at monitoring sites in Western modeling domain.

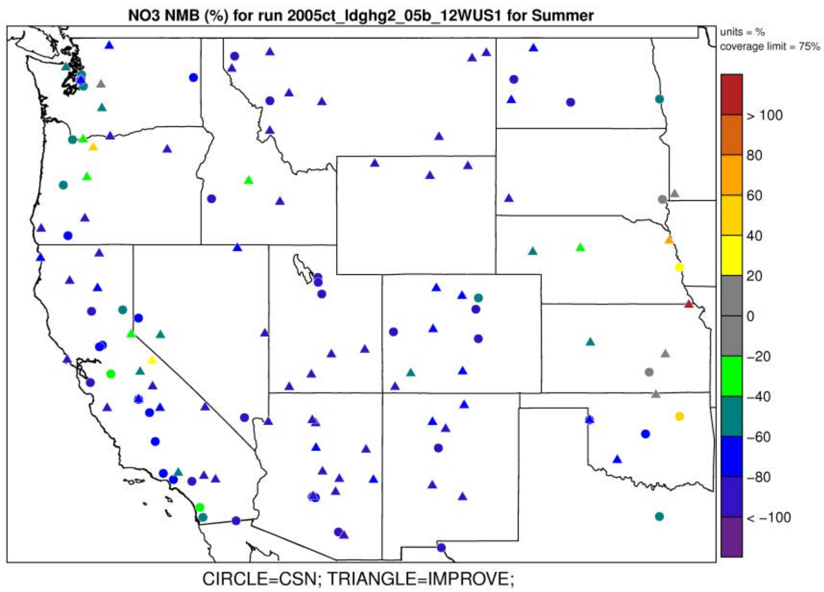

Figure A-32a. Normalized Mean Bias (%) for nitrate during summer 2005 at monitoring sites in Western modeling domain.

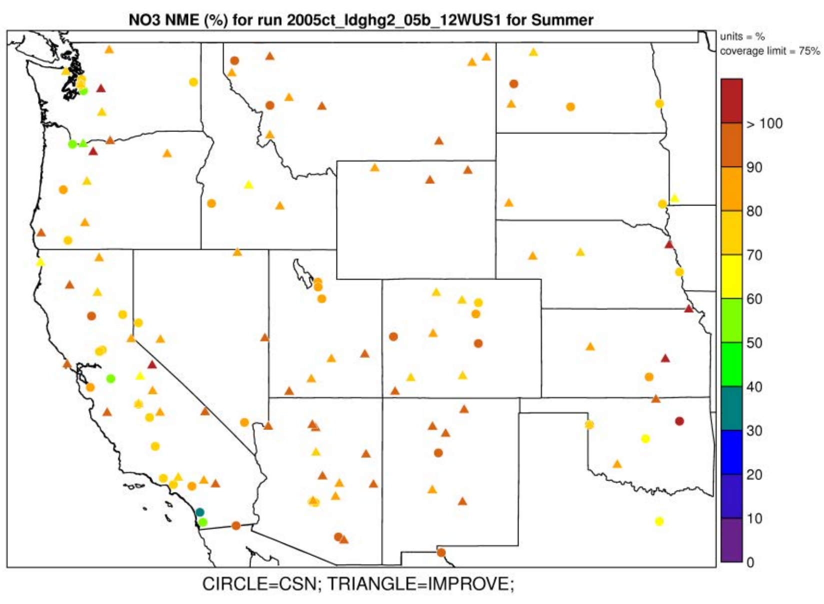

Figure A-32b. Normalized Mean Error (%) for nitrate during summer 2005 at monitoring sites in Western modeling domain.

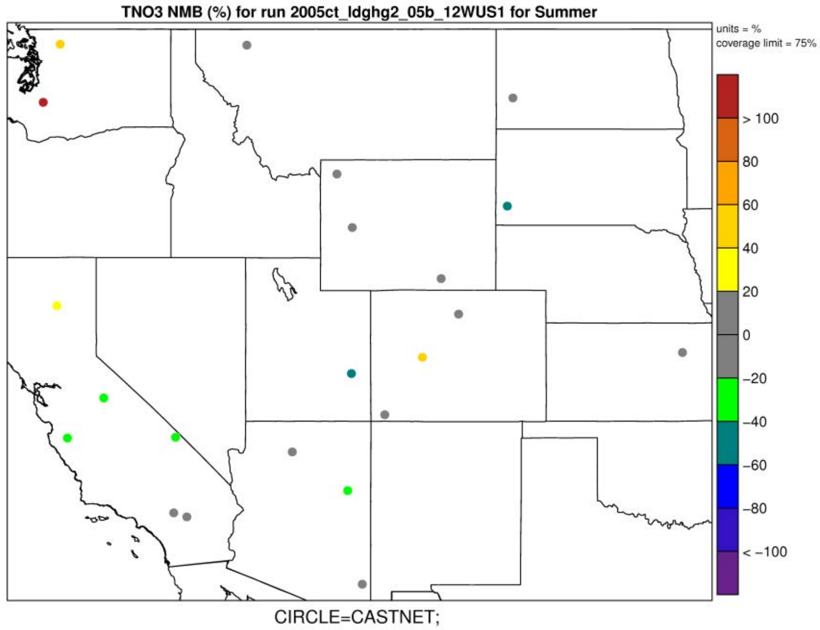

Figure A-32c. Normalized Mean Bias (%) for total nitrate during summer 2005 at monitoring sites in Western modeling domain.

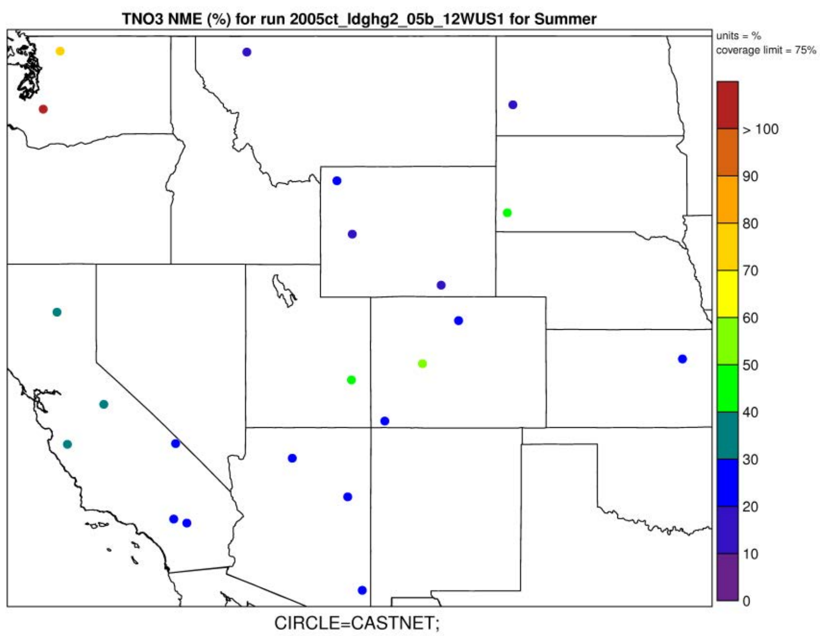

Figure A-32d. Normalized Mean Error (%) for total nitrate summer 2005 at monitoring sites in Western modeling domain.

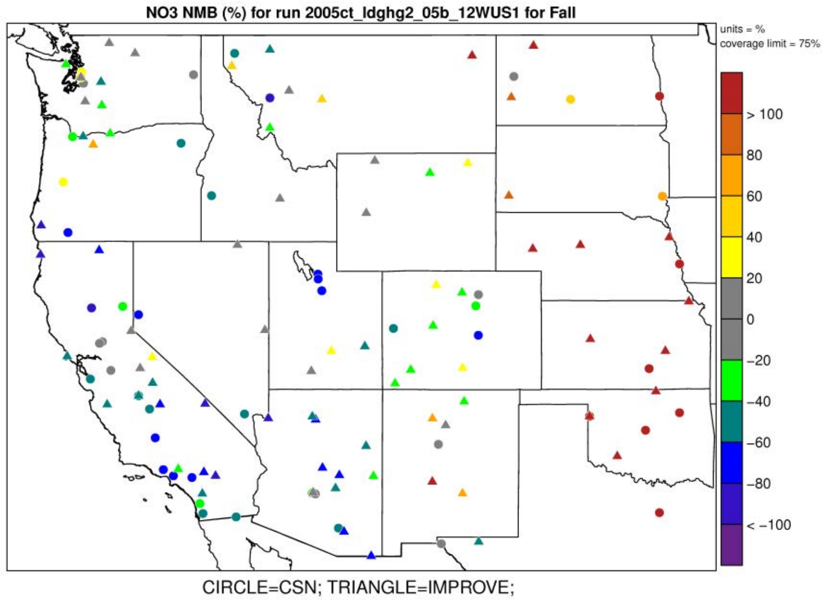

Figure A-33a. Normalized Mean Bias (%) for nitrate during fall 2005 at monitoring sites in Western modeling domain.

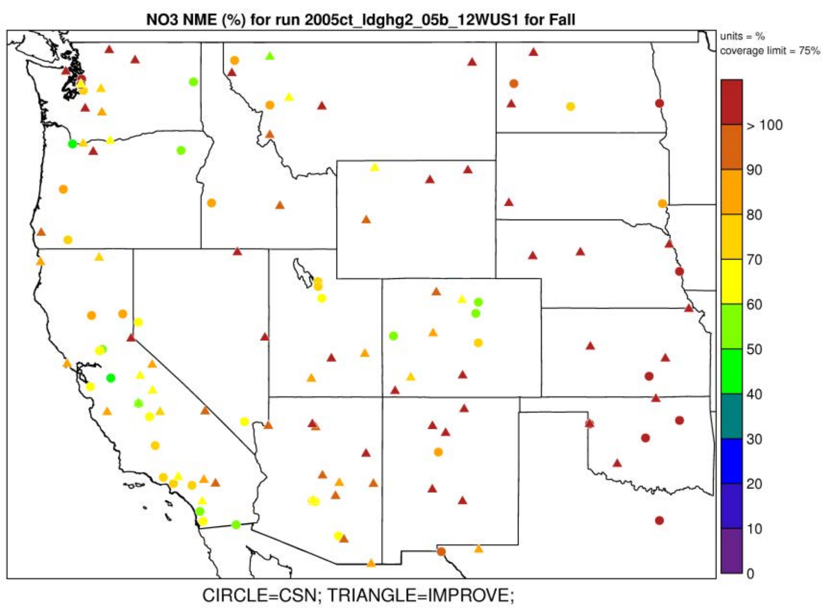

Figure A-33b. Normalized Mean Error (%) for nitrate during fall 2005 at monitoring sites in Western modeling domain.

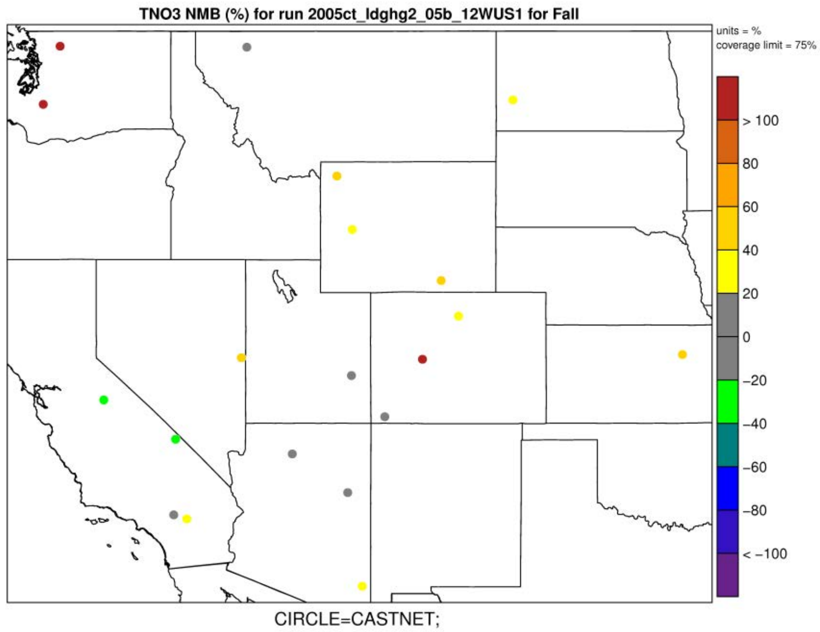

Figure A-33c. Normalized Mean Bias (%) for total nitrate during fall 2005 at monitoring sites in Western modeling domain.

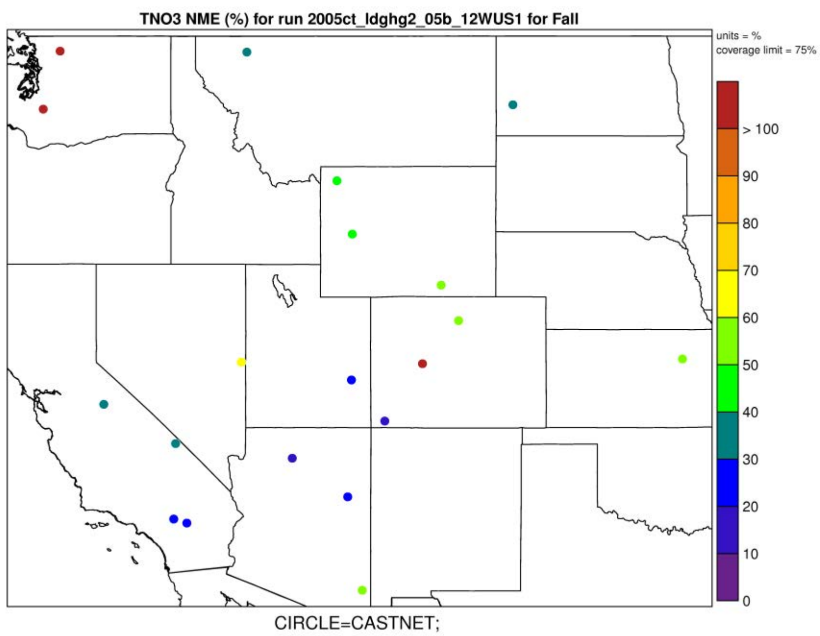

Figure A-33d. Normalized Mean Error (%) for total nitrate fall 2005 at monitoring sites in Western modeling domain.

H. Seasonal Ammonium Performance

The model performance bias and error statistics for ammonium for each subregion and each season are provided in Table A-5. These statistics indicate model bias for ammonium is generally ± 40 percent or less for all seasons in each subregion. During the summer, there is slight to moderate under-prediction in the subregions for urban sub-urban locations. In other times of the year ammonium tends to be somewhat over predicted with a bias of 19 percent, on average across the subregions for urban locations.

Table A-5. Ammonium performance statistics by subregion, by season for the 2005 CMAQ model simulation.

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	CSN	Winter	771	-1.1	43.5	-0.2	50.8
		Spring	875	5.8	42.2	8.1	43.4
		Summer	851	-20.9	45.9	-24.0	60.8
		Fall	587	18.5	55.3	23.4	55.8
	CASTNet	Winter	72	3.8	37.9	4.4	42.6
		Spring	77	17.3	34.4	11.3	32.5
		Summer	72	-16.9	29.5	-19.6	35.7
		Fall	75	17.7	44.4	24.8	46.5
Midwest	CSN	Winter	598	-8.2	31.9	-3.0	33.4
		Spring	637	49.6	63.6	39.4	51.3
		Summer	621	0.4	37.1	16.5	41.9
		Fall	639	8.2	37.7	22.3	41.3
	CASTNet	Winter	142	-10.5	24.3	-4.8	25.1
		Spring	155	45.8	53.2	37.5	42.1
		Summer	161	-4.8	25.9	-1.5	27.5
		Fall	157	20.9	45.6	27.4	41.5
Southeast	CSN	Winter	888	-8.1	41.5	-8.0	44.1
		Spring	918	9.4	39.9	9.9	40.4
		Summer	866	-13.7	36.8	-8.1	44.2
		Fall	911	4.1	42.6	14.5	45.6
	CASTNet	Winter	264	-6.0	28.0	-6.4	29.5
		Spring	292	9.0	31.2	7.3	30.8
		Summer	268	-31.8	35.3	-44.9	48.6
		Fall	273	-8.3	36.5	-6.8	40.9
Northeast	CSN	Winter	828	2.8	34.5	6.8	34.3
		Spring	894	33.3	54.7	35.5	50.4
		Summer	874	-10.5	36.1	4.5	43.9
		Fall	902	18.8	50.6	30.1	51.2
	CASTNet	Winter	193	23.3	38.7	27.2	37.5

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
		Spring	206	43.4	49.7	32.8	38.9
		Summer	192	-23.0	29.7	-26.2	34.5
		Fall	195	9.7	39.4	14.4	36.4
West	CSN	Winter	829	-27.6	60.7	-11.8	65.5
		Spring	859	-0.3	52.7	18.8	51.3
		Summer	849	-33.0	53.0	-4.7	51.6
		Fall	886	-21.3	63.6	9.5	58.6
	CASTNet	Winter	250	-2.3	41.0	7.6	39.3
		Spring	273	-8.8	32.1	-4.5	31.7
		Summer	281	-33.3	40.2	-34.4	44.6
		Fall	268	-3.1	32.1	1.7	31.4

I. Seasonal Elemental Carbon Performance

The model performance bias and error statistics for elemental carbon for each subregion and each season are provided in Table A-6. The statistics show clear over prediction at urban sites in all subregions. For example, NMBs typically range between 50 and 100 percent at urban sites in the Midwest, Northeast, and Central subregions with only slightly less over prediction at urban sites in the Southeast. Rural sites show much less over prediction than at urban sites with under predictions occurring in the spring, summer, and fall at rural sites in the Southeast, Midwest and Central subregions. In the West, the model tends to over predict at both urban and rural sites during all seasons. In addition, the predictions for urban sites have greater error than the predictions for rural locations in the West.

Table A-6. Elemental Carbon performance statistics by subregion, by season for the 2005 CMAQ model simulation.

Subregion	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	CSN	Winter	816	101.0	132.0	56.5	77.5
		Spring	938	90.6	114.0	45.5	70.6
		Summer	875	109.0	132.0	41.9	80.7
		Fall	618	93.6	111.0	57.5	70.7
	IMPROVE	Winter	589	9.6	54.5	4.9	47.1
		Spring	716	-9.4	55.8	-10.1	53.7
		Summer	701	-30.5	46.8	-38.3	56.2
		Fall	620	-17.2	34.8	-16.0	41.1
Midwest	CSN	Winter	602	122.0	137.0	69.3	76.5
		Spring	637	64.1	85.2	48.9	61.5
		Summer	621	48.0	64.6	38.2	54.4
		Fall	642	53.1	73.1	39.8	55.6
	IMPROVE	Winter	182	61.4	79.6	22.9	45.9
		Spring	184	17.9	56.8	-11.8	51.1
		Summer	185	-13.8	40.9	-37.3	53.8
		Fall	145	-12.6	33.4	-19.2	48.2
Southeast	CSN	Winter	889	37.3	61.4	30.2	49.3
		Spring	914	37.1	62.6	36.6	54.1
		Summer	866	39.9	68.9	37.7	61.1
		Fall	909	12.0	45.7	18.2	45.6
	IMPROVE	Winter	491	-3.1	44.4	-0.8	48.6
		Spring	530	-17.1	44.9	-11.4	45.2
		Summer	493	-41.4	48.4	-55.7	71.4
		Fall	481	-27.0	39.0	-22.9	45.6
Northeast	CSN	Winter	831	97.5	110.0	57.7	67.1

Subregion	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
		Spring	881	90.2	107.0	57.0	68.7
		Summer	866	64.7	87.8	45.3	63.2
		Fall	901	52.2	82.5	34.6	56.6
	IMPROVE	Winter	603	45.4	72.9	22.7	53.1
		Spring	658	28.1	63.0	11.3	54.3
		Summer	596	-20.6	45.6	-37.8	57.4
		Fall	591	30.9	57.3	6.0	49.3
West	CSN	Winter	808	43.6	84.7	21.4	66.9
		Spring	822	99.5	123.0	44.0	73.9
		Summer	806	112.0	126.0	57.5	72.3
		Fall	867	52.1	86.6	26.3	64.0
	IMPROVE	Winter	2,315	0.2	63.5	-15.0	64.6
		Spring	2,567	17.3	68.2	-1.7	54.1
		Summer	2,285	28.8	76.7	18.2	58.4
		Fall	2,348	7.4	66.0	-9.4	59.2

J. Seasonal Organic Carbon Performance

The model performance bias and error statistics for organic carbon for each subregion and each season are provided in Table A-7. The statistics in this table indicate a tendency for the modeling platform to somewhat under predict observed organic carbon concentrations during the spring, summer, and fall at urban and rural locations across the Eastern subregions. Likewise, the modeling platform under predicts organic carbon during all seasons at urban and rural locations in the Western subregion, except in the summer at rural sites. These biases and errors reflect sampling artifacts among each monitoring network. In addition, uncertainties exist for primary organic mass emissions and secondary organic aerosol formation. Research efforts are ongoing to improve fire emission estimates and understand the formation of semi-volatile compounds, and the partitioning of SOA between the gas and particulate phases.

Table A-7. Organic Carbon performance statistics by subregion, by season for the 2005 CMAQ model simulation.

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Central U.S.	CSN	Winter	544	0.2	57.7	14.9	59.7
		Spring	628	-34.8	52.4	-32.0	63.3
		Summer	595	-51.4	54.1	-69.8	76.3
		Fall	493	-30.8	45.2	-28.0	56.7
	IMPROVE	Winter	589	-8.1	51.1	-12.0	47.9
		Spring	715	-38.5	57.6	-38.1	61.1
		Summer	699	-50.1	52.3	-69.9	74.3
		Fall	619	-44.4	48.2	-54.4	62.3
Midwest	CSN	Winter	566	4.3	53.2	21.8	54.2
		Spring	605	-29.4	45.9	-17.8	52.8
		Summer	619	-53.1	54.6	-69.7	73.2
		Fall	595	-28.5	41.3	-16.4	52.0
	IMPROVE	Winter	182	3.4	38.4	1.6	37.1
		Spring	184	-25.9	36.4	-32.9	44.6
		Summer	185	-48.4	51.4	-64.6	68.9
		Fall	144	-35.0	43.6	-43.8	61.5
Southeast	CSN	Winter	871	-25.7	45.4	-15.2	50.6
		Spring	901	-35.6	48.7	-28.8	57.0
		Summer	857	-55.8	57.7	-75.9	80.7
		Fall	880	-39.9	46.0	-42.8	57.3
	IMPROVE	Winter	491	-10.1	45.1	-11.5	50.9
		Spring	529	-9.2	49.1	-15.1	50.3
		Summer	492	-48.6	54.2	-66.5	75.0
		Fall	481	-33.8	41.2	-41.7	53.2
Northeast	CSN	Winter	806	27.9	59.3	31.3	55.2
		Spring	832	2.2	50.7	8.5	53.1

Region	Network	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
		Summer	859	-47.3	51.6	-61.0	69.1
		Fall	830	-4.4	47.1	3.7	53.3
	IMPROVE	Winter	602	48.2	69.3	31.6	52.1
		Spring	657	3.8	46.3	-3.1	46.1
		Summer	596	-47.0	51.5	-59.3	66.3
		Fall	588	14.3	47.4	-1.9	43.9
West	CSN	Winter	803	-26.5	67.4	-20.2	70.0
		Spring	823	-12.2	60.4	-4.1	60.3
		Summer	840	-24.1	41.6	-28.7	50.5
		Fall	881	-28.3	57.1	-26.2	58.6
	IMPROVE	Winter	2,273	-16.8	58.6	-22.6	64.5
		Spring	2,529	-23.1	51.8	-25.3	57.0
		Summer	2,268	4.4	65.2	-1.3	60.3
		Fall	2,171	-21.7	56.9	-26.3	61.9

K. Seasonal Hazardous Air Pollutants Performance

A seasonal operational model performance evaluation for specific hazardous air pollutants (formaldehyde, acetaldehyde, benzene, acrolein, and 1,3-butadiene) was conducted in order to estimate the ability of the CMAQ modeling system to replicate the base year concentrations for the 12-km Eastern and Western United States domains. The seasonal model performance results for the East and West are presented below in Tables A-8 and A-9, respectively. Toxic measurements from 471 sites in the East and 135 sites in the West were included in the evaluation and were taken from the 2005 State/local monitoring site data in the National Air Toxics Trends Stations (NATTS). Similar to $PM_{2.5}$ and ozone, the evaluation principally consists of statistical assessments of model versus observed pairs that were paired in time and space on daily basis.

Model predictions of annual formaldehyde, acetaldehyde and benzene showed relatively small to moderate bias and error percentages when compared to observations. The model yielded larger bias and error results for 1,3 butadiene and acrolein based on limited monitoring sites. Model performance for HAPs is not as good as model performance for ozone and $PM_{2.5}$. Technical issues in the HAPs data consist of (1) uncertainties in monitoring methods; (2) limited measurements in time/space to characterize ambient concentrations ("local in nature"); (3) commensurability issues between measurements and model predictions; (4) emissions and science uncertainty issues may also affect model performance; and (5) limited data for estimating intercontinental transport that effects the estimation of boundary conditions (i.e., boundary estimates for some species are much higher than predicted values inside the domain).

As with the national, annual $PM_{2.5}$ and ozone CMAQ modeling, the "acceptability" of model performance was judged by comparing our CMAQ 2005 performance results to the limited performance found in recent regional multi-pollutant model applications.[17,18,19] Overall, the normalized mean bias and error (NMB and NME), as well as the fractional bias and error (FB and FE) statistics shown below indicate that CMAQ-predicted 2005 toxics (i.e., observation vs. model predictions) are within the range of recent regional modeling applications.

---

[17] Phillips, S., K. Wang, C. Jang, N. Possiel, M. Strum, T. Fox, 2007: Evaluation of 2002 Multi-pollutant Platform: Air Toxics, Ozone, and Particulate Matter, 7th Annual CMAS Conference, Chapel Hill, NC, October 6-8, 2008.

[18] Strum, M., Wesson, K., Phillips, S., Cook, R., Michaels, H., Brzezinski, D., Pollack, A., Jimenez, M., Shepard, S. Impact of using lin-level emissions on multi-pollutant air quality model predictions at regional and local scales. 17th Annual International Emission Inventory Conference, Portland, Oregon , June 2-5, 2008.

[19] Wesson, K., N. Fann, and B. Timin, 2010: Draft Manuscript: Air Quality and Benefits Model Responsiveness to Varying Horizontal Resolution in the Detroit Urban Area, Atmospheric Pollution Research, Special Issue: Air Quality Modeling and Analysis.

Table A-8. Air toxics performance statistics by season in the Eastern domain for the 2005 CMAQ model simulation.

Air Toxic Species	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Formaldehyde	Winter	1,646	-51.7	61.1	-45.4	67.8
	Spring	1,545	-52.7	64.9	-35.0	67.1
	Summer	1,835	-52.3	63.2	-28.9	57.9
	Fall	1,932	-50.7	61.8	-38.3	59.9
Acetaldehyde	Winter	1,570	-39.5	49.7	-40.3	56.0
	Spring	1,486	-25.6	49.8	-21.1	54.0
	Summer	1,778	58.9	91.2	48.9	68.4
	Fall	1,881	0.3	57.1	-5.4	55.4
Benzene	Winter	3,182	-32.0	68.2	-11.3	58.5
	Spring	3,099	-39.0	66.7	-25.6	63.5
	Summer	3,270	-38.4	68.6	-20.5	66.4
	Fall	3,433	-32.5	64.9	-18.3	59.6
1,3-Butadiene	Winter	2,649	-63.1	89.8	-21.2	87.0
	Spring	2,726	-77.7	92.8	-48.2	92.4
	Summer	2,782	-73.4	87.8	-54.8	87.6
	Fall	2,877	-61.7	81.5	-49.9	85.8
Acrolein	Winter	612	-90.4	94.7	-124.0	135.0
	Spring	430	-82.3	91.3	-117.0	127.0
	Summer	834	-95.9	99.0	-137.0	154.0
	Fall	1,002	-95.1	98.8	-149.0	153.0

Table A-9. Air toxics performance statistics by season in the Western domain for the 2005 CMAQ model simulation.

Air Toxic Species	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Formaldehyde	Winter	441	-22.1	68.4	-34.7	73.7
	Spring	514	-30.0	57.4	-22.1	61.2
	Summer	657	-25.4	38.5	-21.7	41.4
	Fall	595	-26.2	43.1	-27.5	49.5
Acetaldehyde	Winter	426	-21.1	68.5	-33.1	73.1
	Spring	499	-24.5	56.1	-23.6	61.9
	Summer	646	-1.3	46.4	7.9	44.7
	Fall	584	-17.6	51.4	-16.2	56.0
Benzene	Winter	880	-39.6	58.4	-37.9	64.2
	Spring	891	-31.9	56.1	-30.7	61.9
	Summer	1,086	-43.4	65.0	-25.5	64.2
	Fall	880	-39.5	58.4	-37.9	64.2
1,3-Butadiene	Winter	752	-43.4	98.4	-28.4	100.0
	Spring	788	-18.3	91.4	-24.8	81.1
	Summer	725	-33.8	81.8	-35.9	80.3
	Fall	764	-45.7	88.1	-36.0	90.4

Acrolein	Winter	201	-95.3	95.3	-164.0	165.0
	Spring	190	-95.8	95.8	-167.0	169.0
	Summer	316	-96.2	98.8	-172.0	178.0
	Fall	295	-96.9	98.2	-173.0	175.0

L. Seasonal Nitrate and Sulfate Deposition Performance

Seasonal nitrate and sulfate deposition performance statistics for the 12-km Eastern and Western domains are provided in Tables A-10 and A-11, respectively. The model predictions for seasonal nitrate deposition generally show small under-predictions for the Eastern and Western NADP sites (NMB values range from 1% to -27%). However, nitrate deposition is over predicted in the East and West during the winter. Sulfate deposition performance in the East and West shows the similar predictions (NMB values range from -3% to 33%). The errors for both annual nitrate and sulfate are relatively moderate with values ranging from 60% to 87% which reflect scatter in the model predictions versus observation comparison.

Table A-10. Nitrate and sulfate wet deposition performance statistics by season in the Eastern domain for the 2005 CMAQ model simulation.

Wet Deposition Species	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Nitrate	Winter	1,788	31.4	74.7	13.5	72.5
	Spring	1,882	-1.7	57.3	-2.9	64.8
	Summer	1,975	-23.2	61.8	-20.0	75.3
	Fall	1,736	7.0	65.7	-5.8	74.2
Sulfate	Winter	1,788	33.6	69.9	24.1	72.1
	Spring	1,882	6.4	59.6	12.4	67.4
	Summer	1,975	3.2	73.9	6.4	79.4
	Fall	1,736	-3.2	61.6	-9.9	74.2

Table A-11. Nitrate and sulfate wet deposition performance statistics by season in the Western domain for the 2005 CMAQ model simulation.

Wet Deposition Species	Season	No. of Obs.	NMB (%)	NME (%)	FB (%)	FE (%)
Nitrate	Winter	649	8.0	82.1	5.3	83.3
	Spring	768	-0.9	67.1	2.5	73.6
	Summer	641	-27.5	63.5	-23.1	79.6
	Fall	674	-4.9	75.9	-6.5	84.4
Sulfate	Winter	649	24.9	86.7	25.6	88.8
	Spring	768	16.6	73.0	18.2	77.3
	Summer	641	-5.1	73.8	-1.7	81.6
	Fall	674	-8.7	76.7	-5.0	86.7

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

Appendix B

8-Hour Ozone Design Values for Air Quality Modeling Scenarios

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC 27711
August 2012

Table B-1. 8-Hour Ozone Design Values for 2017-2025 LD GHG Scenarios
(units are ppb)

State	County	2005 Baseline DV	2030 Reference Case DV	2030 Control Case DV
Alabama	Baldwin	77.3	59.13	59.09
Alabama	Clay	74.0	51.06	51.12
Alabama	Colbert	72.0	48.97	49.01
Alabama	Elmore	70.7	50.76	50.81
Alabama	Etowah	71.7	50.99	51.02
Alabama	Houston	71.0	52.37	52.42
Alabama	Jefferson	83.7	59.36	59.43
Alabama	Lawrence	72.0	52.91	52.94
Alabama	Madison	77.3	55.43	55.47
Alabama	Mobile	76.7	60.19	60.13
Alabama	Montgomery	69.3	49.72	49.76
Alabama	Morgan	77.3	60.10	60.14
Alabama	Russell	71.3	51.69	51.78
Alabama	Shelby	85.7	59.51	59.61
Alabama	Sumter	64.0	52.55	52.55
Alabama	Talladega	72.0	51.63	51.66
Alabama	Tuscaloosa	73.3	51.81	51.86
Arizona	Cochise	71.3	59.66	59.77
Arizona	Coconino	73.0	59.85	59.85
Arizona	Gila	80.3	56.91	57.02
Arizona	Maricopa	83.0	63.23	63.34
Arizona	Pima	76.0	56.53	56.61
Arizona	Pinal	79.3	55.87	55.96
Arizona	Yuma	75.0	57.61	57.61
Arkansas	Crittenden	87.3	62.32	62.36
Arkansas	Newton	72.7	54.59	54.77
Arkansas	Polk	75.0	60.03	60.00
Arkansas	Pulaski	79.7	55.12	55.49
California	Alameda	78.3	65.74	65.72
California	Amador	83.0	64.63	64.63
California	Butte	83.7	65.08	65.10
California	Calaveras	91.3	73.83	73.78
California	Colusa	67.0	53.56	53.54
California	Contra Costa	73.3	65.53	65.50

California	El Dorado	96.0	71.88	71.93
California	Fresno	98.3	79.79	79.74
California	Glenn	67.0	53.58	53.57
California	Imperial	85.0	68.83	68.81
California	Inyo	82.3	66.04	66.04
California	Kern	110.0	92.09	92.14
California	Kings	85.7	67.66	67.63
California	Lake	60.7	49.08	49.09
California	Los Angeles	114.0	97.20	97.07
California	Madera	79.3	63.51	63.48
California	Marin	49.7	42.32	42.31
California	Mariposa	86.3	69.67	69.66
California	Mendocino	56.7	45.49	45.49
California	Merced	89.3	70.68	70.67
California	Monterey	61.0	50.09	50.09
California	Napa	59.3	48.27	48.26
California	Nevada	96.3	72.85	72.88
California	Orange	84.3	80.72	80.59
California	Placer	94.0	70.60	70.64
California	Riverside	112.3	109.58	109.34
California	Sacramento	97.3	73.60	73.65
California	San Benito	75.0	59.51	59.51
California	San Bernardino	123.3	119.53	119.32
California	San Diego	87.7	70.43	70.40
California	San Francisco	46.0	45.98	45.96
California	San Joaquin	75.3	62.16	62.12
California	San Luis Obispo	70.7	56.89	56.87
California	San Mateo	53.7	49.60	49.57
California	Santa Barbara	76.0	60.97	60.92
California	Santa Clara	75.3	59.81	59.83
California	Santa Cruz	61.3	52.02	52.00
California	Shasta	79.3	64.28	64.28
California	Siskiyou	63.5	50.83	50.83
California	Solano	73.5	58.80	58.79
California	Sonoma	47.7	37.96	37.96
California	Stanislaus	84.7	68.68	68.65
California	Sutter	82.0	66.17	66.13
California	Tehama	82.7	65.60	65.60
California	Tulare	103.7	82.27	82.25

California	Tuolumne	80.0	64.22	64.17
California	Ventura	89.7	71.06	71.04
California	Yolo	78.7	62.11	62.11
Colorado	Adams	69.0	57.71	57.76
Colorado	Arapahoe	78.7	63.21	63.26
Colorado	Boulder	77.0	61.57	61.61
Colorado	Denver	73.0	61.06	61.11
Colorado	Douglas	83.7	67.12	67.21
Colorado	El Paso	73.3	61.27	61.31
Colorado	Jefferson	81.7	67.84	67.90
Colorado	La Plata	72.0	62.18	62.20
Colorado	Larimer	76.0	61.13	61.16
Colorado	Montezuma	72.0	64.43	64.43
Colorado	Weld	76.7	66.46	66.48
Connecticut	Fairfield	92.3	74.33	74.31
Connecticut	Hartford	84.3	61.34	61.37
Connecticut	Litchfield	87.7	63.75	63.79
Connecticut	Middlesex	90.3	69.06	69.06
Connecticut	New Haven	90.3	70.34	70.34
Connecticut	New London	85.3	64.15	64.15
Connecticut	Tolland	88.7	64.58	64.62
D.C.	Washington	84.7	64.05	64.10
Delaware	Kent	80.3	59.37	59.38
Delaware	New Castle	82.3	63.48	63.50
Delaware	Sussex	82.7	61.41	61.41
Florida	Alachua	72.0	48.57	48.62
Florida	Baker	68.7	48.71	48.74
Florida	Bay	78.7	57.74	57.78
Florida	Brevard	71.3	53.64	53.68
Florida	Broward	65.0	53.85	53.88
Florida	Collier	68.3	48.66	48.73
Florida	Columbia	72.0	52.08	52.10
Florida	Duval	77.7	56.62	56.64
Florida	Escambia	82.7	60.30	60.33
Florida	Highlands	72.3	56.15	56.19
Florida	Hillsborough	80.7	60.36	60.37
Florida	Holmes	70.3	53.29	53.31
Florida	Lake	76.7	57.11	57.21
Florida	Lee	70.3	52.87	52.94

Florida	Leon	71.0	50.43	50.47
Florida	Manatee	77.3	56.26	56.28
Florida	Marion	73.0	48.09	48.16
Florida	Miami-Dade	71.3	61.23	61.22
Florida	Orange	79.3	61.11	61.21
Florida	Osceola	72.0	51.09	51.17
Florida	Palm Beach	65.0	54.19	54.23
Florida	Pasco	76.3	55.94	55.98
Florida	Pinellas	72.7	52.55	52.59
Florida	Polk	74.7	52.79	52.79
Florida	St Lucie	66.5	51.67	51.71
Florida	Santa Rosa	80.0	59.30	59.33
Florida	Sarasota	77.3	54.05	54.10
Florida	Seminole	76.0	55.52	55.64
Florida	Volusia	68.3	47.69	47.75
Florida	Wakulla	71.3	51.67	51.70
Georgia	Bibb	81.0	53.73	53.83
Georgia	Chatham	68.3	50.92	50.93
Georgia	Chattooga	75.0	52.56	52.63
Georgia	Clarke	80.7	51.47	51.63
Georgia	Cobb	82.7	54.85	55.08
Georgia	Columbia	73.0	53.34	53.39
Georgia	Coweta	82.0	57.39	57.46
Georgia	Dawson	76.3	48.52	48.64
Georgia	De Kalb	88.7	64.39	64.55
Georgia	Douglas	87.3	57.10	57.22
Georgia	Fayette	85.7	61.58	61.69
Georgia	Fulton	91.7	66.57	66.73
Georgia	Glynn	67.0	48.40	48.45
Georgia	Gwinnett	88.7	60.34	60.57
Georgia	Henry	89.7	61.28	61.40
Georgia	Murray	78.0	56.27	56.34
Georgia	Muscogee	75.7	52.48	52.59
Georgia	Paulding	80.3	52.43	52.54
Georgia	Richmond	80.3	58.47	58.53
Georgia	Rockdale	90.0	59.45	59.61
Georgia	Sumter	72.3	50.72	50.74
Idaho	Ada	76.0	66.53	66.55
Idaho	Canyon	66.0	54.67	54.71

Idaho	Elmore	63.0	54.12	54.14
Idaho	Kootenai	67.0	54.29	54.34
Illinois	Adams	70.0	56.18	56.18
Illinois	Champaign	68.3	54.48	54.49
Illinois	Clark	66.0	52.53	52.52
Illinois	Cook	77.7	67.55	67.48
Illinois	Du Page	69.0	60.21	60.21
Illinois	Effingham	70.0	55.67	55.62
Illinois	Hamilton	73.0	55.44	55.46
Illinois	Jersey	78.7	58.03	58.17
Illinois	Kane	74.3	60.21	60.22
Illinois	Lake	78.0	65.99	65.98
Illinois	McHenry	73.3	57.28	57.29
Illinois	McLean	73.0	56.35	56.36
Illinois	Macon	71.3	56.21	56.24
Illinois	Macoupin	73.0	51.83	51.92
Illinois	Madison	83.0	63.51	63.64
Illinois	Peoria	72.7	58.58	58.57
Illinois	Randolph	72.0	55.95	55.99
Illinois	Rock Island	65.3	50.89	50.89
Illinois	St Clair	81.7	64.00	64.17
Illinois	Sangamon	70.0	52.13	52.18
Illinois	Will	71.7	58.16	58.16
Illinois	Winnebago	69.0	52.95	52.95
Indiana	Allen	79.3	60.57	60.66
Indiana	Boone	79.7	61.52	61.55
Indiana	Carroll	74.0	56.38	56.46
Indiana	Clark	80.3	60.65	60.72
Indiana	Delaware	76.3	56.82	56.94
Indiana	Elkhart	79.0	60.41	60.45
Indiana	Floyd	77.7	62.17	62.25
Indiana	Greene	78.3	62.02	62.05
Indiana	Hamilton	82.7	62.86	63.08
Indiana	Hancock	78.0	59.39	59.67
Indiana	Hendricks	75.3	59.04	59.03
Indiana	Huntington	75.0	58.11	58.17
Indiana	Jackson	74.7	57.95	58.01
Indiana	Johnson	76.7	60.17	60.25
Indiana	Lake	81.0	68.67	68.67

Indiana	La Porte	78.5	63.51	63.51
Indiana	Madison	76.7	57.12	57.31
Indiana	Marion	78.7	61.14	61.31
Indiana	Morgan	77.0	60.28	60.36
Indiana	Perry	81.0	63.04	63.07
Indiana	Porter	78.3	64.98	64.98
Indiana	Posey	71.7	55.10	55.14
Indiana	St Joseph	79.3	60.89	60.91
Indiana	Shelby	77.3	61.53	61.65
Indiana	Vanderburgh	77.3	59.47	59.55
Indiana	Vigo	74.0	57.58	57.57
Indiana	Warrick	77.7	58.39	58.51
Iowa	Bremer	66.3	52.29	52.32
Iowa	Clinton	71.3	55.52	55.54
Iowa	Harrison	74.7	58.90	58.92
Iowa	Linn	68.3	53.79	53.79
Iowa	Montgomery	65.7	50.65	50.68
Iowa	Palo Alto	61.0	49.66	49.65
Iowa	Polk	63.0	48.18	48.20
Iowa	Scott	72.0	55.38	55.39
Iowa	Story	61.0	46.63	46.64
Iowa	Van Buren	69.0	54.25	54.26
Iowa	Warren	64.5	48.33	48.35
Kansas	Douglas	73.0	54.12	54.15
Kansas	Johnson	75.3	56.91	56.97
Kansas	Leavenworth	75.0	58.09	58.11
Kansas	Linn	73.3	55.51	55.52
Kansas	Sedgwick	71.3	54.45	54.45
Kansas	Sumner	71.7	54.60	54.59
Kansas	Trego	70.7	59.74	59.74
Kansas	Wyandotte	75.3	59.32	59.33
Kentucky	Bell	71.7	51.02	51.12
Kentucky	Boone	75.7	58.31	58.32
Kentucky	Boyd	77.3	60.49	60.27
Kentucky	Bullitt	74.0	59.55	59.59
Kentucky	Campbell	83.0	68.33	68.39
Kentucky	Carter	71.0	54.61	54.51
Kentucky	Christian	78.0	55.65	55.69
Kentucky	Daviess	75.7	59.21	59.26

Kentucky	Edmonson	73.7	56.07	56.12
Kentucky	Fayette	70.3	52.92	53.00
Kentucky	Greenup	76.7	60.54	60.32
Kentucky	Hancock	74.0	57.11	57.15
Kentucky	Hardin	74.7	58.02	58.07
Kentucky	Henderson	75.3	57.29	57.40
Kentucky	Jefferson	78.3	63.93	64.04
Kentucky	Jessamine	73.3	56.22	56.28
Kentucky	Kenton	78.7	62.11	62.16
Kentucky	Livingston	73.7	56.24	56.27
Kentucky	McCracken	73.3	57.56	57.56
Kentucky	McLean	73.0	56.61	56.70
Kentucky	Oldham	83.0	61.51	61.71
Kentucky	Perry	72.3	54.44	54.45
Kentucky	Pike	66.7	50.93	50.93
Kentucky	Pulaski	70.3	55.53	55.55
Kentucky	Simpson	75.7	55.60	55.64
Kentucky	Trigg	70.0	50.86	50.88
Kentucky	Warren	72.0	54.48	54.53
Louisiana	Ascension	82.0	66.46	66.27
Louisiana	Beauregard	75.0	63.89	63.73
Louisiana	Bossier	78.0	58.58	58.50
Louisiana	Caddo	79.0	59.83	59.74
Louisiana	Calcasieu	82.0	68.56	68.40
Louisiana	East Baton Rouge	92.0	74.34	74.13
Louisiana	Iberville	85.0	69.51	69.30
Louisiana	Jefferson	83.0	67.45	67.27
Louisiana	Lafayette	82.0	63.97	63.84
Louisiana	Lafourche	79.3	64.04	63.81
Louisiana	Livingston	78.3	63.02	62.84
Louisiana	Ouachita	75.3	57.31	57.33
Louisiana	Pointe Coupee	83.7	69.42	69.21
Louisiana	St Bernard	78.0	63.14	63.03
Louisiana	St Charles	77.3	62.48	62.31
Louisiana	St James	76.3	62.29	62.07
Louisiana	St John The Baptis	79.0	65.98	65.75
Louisiana	St Mary	76.0	60.36	60.17

Louisiana	West Baton Rouge	84.3	68.92	68.68
Maine	Cumberland	72.0	53.64	53.73
Maine	Hancock	82.0	61.30	61.36
Maine	Kennebec	69.7	51.45	51.52
Maine	Knox	75.3	55.81	55.88
Maine	Oxford	61.0	48.75	48.76
Maine	Penobscot	67.0	51.33	51.36
Maine	Sagadahoc	68.5	50.77	50.84
Maine	York	74.0	56.15	56.21
Maryland	Anne Arundel	89.7	64.22	64.27
Maryland	Baltimore	85.3	70.45	70.46
Maryland	Calvert	81.0	59.24	59.27
Maryland	Carroll	83.3	59.81	59.85
Maryland	Cecil	90.7	64.96	64.99
Maryland	Charles	86.0	62.55	62.60
Maryland	Frederick	80.3	56.22	56.26
Maryland	Garrett	75.5	58.92	58.44
Maryland	Harford	92.7	74.48	74.50
Maryland	Kent	82.0	59.21	59.24
Maryland	Montgomery	83.0	60.88	60.88
Maryland	Prince Georges	91.0	66.04	66.09
Maryland	Washington	78.3	56.14	56.18
Massachusetts	Barnstable	84.7	65.47	65.50
Massachusetts	Berkshire	79.7	59.36	59.37
Massachusetts	Bristol	82.7	63.22	63.24
Massachusetts	Dukes	83.0	65.13	65.15
Massachusetts	Essex	83.3	67.76	67.78
Massachusetts	Hampden	87.3	63.46	63.51
Massachusetts	Hampshire	85.0	62.00	62.05
Massachusetts	Middlesex	79.0	60.12	60.16
Massachusetts	Norfolk	84.7	64.99	64.98
Massachusetts	Suffolk	80.3	63.01	63.05
Massachusetts	Worcester	80.0	57.75	57.80
Michigan	Allegan	90.0	71.36	71.34
Michigan	Benzie	81.7	64.36	64.41
Michigan	Berrien	82.3	66.00	65.99
Michigan	Cass	80.7	62.00	62.01
Michigan	Clinton	75.7	57.09	57.13

Michigan	Genesee	79.3	61.51	61.54
Michigan	Huron	75.7	60.74	60.77
Michigan	Ingham	76.0	58.48	58.50
Michigan	Kalamazoo	75.3	58.06	58.05
Michigan	Kent	81.0	60.96	60.96
Michigan	Leelanau	75.7	60.51	60.50
Michigan	Lenawee	78.7	61.98	61.98
Michigan	Macomb	86.0	68.68	68.67
Michigan	Mason	79.7	61.09	61.10
Michigan	Missaukee	73.7	57.84	57.83
Michigan	Muskegon	85.0	66.94	66.94
Michigan	Oakland	78.0	64.86	64.83
Michigan	Ottawa	81.7	63.03	63.02
Michigan	St Clair	82.3	63.85	63.91
Michigan	Schoolcraft	79.3	62.09	62.13
Michigan	Washtenaw	78.3	62.38	62.39
Michigan	Wayne	82.0	66.12	66.11
Minnesota	Anoka	67.7	60.84	60.83
Minnesota	St Louis	65.0	52.66	52.65
Mississippi	Adams	74.7	58.83	58.80
Mississippi	Bolivar	74.3	56.22	56.26
Mississippi	De Soto	82.7	60.11	60.13
Mississippi	Hancock	79.0	61.43	61.30
Mississippi	Harrison	83.0	63.17	62.95
Mississippi	Hinds	71.3	47.22	47.30
Mississippi	Jackson	80.3	62.39	62.12
Mississippi	Lauderdale	74.3	56.43	56.44
Mississippi	Lee	73.7	51.12	51.17
Missouri	Cass	74.7	56.30	56.33
Missouri	Cedar	75.7	56.99	56.99
Missouri	Clay	84.7	64.63	64.66
Missouri	Clinton	83.0	61.73	61.78
Missouri	Greene	73.0	54.11	54.17
Missouri	Jefferson	82.3	66.78	66.85
Missouri	Lincoln	87.0	67.64	67.64
Missouri	Monroe	71.7	55.13	55.15
Missouri	Perry	77.5	58.54	58.57
Missouri	Platte	77.0	59.85	59.88
Missouri	St Charles	87.0	65.78	65.87

Missouri	Ste Genevieve	79.7	64.65	64.66
Missouri	St Louis	88.0	70.47	70.48
Missouri	St Louis City	84.0	66.95	67.11
Montana	Yellowstone	59.0	52.60	52.62
Nebraska	Douglas	68.7	56.30	56.33
Nebraska	Lancaster	56.0	43.93	43.92
Nevada	Churchill	64.0	51.68	51.69
Nevada	Clark	83.7	69.55	69.59
Nevada	Washoe	70.7	55.64	55.64
Nevada	White Pine	72.3	59.06	59.09
Nevada	Carson City	65.0	50.19	50.20
New Hampshire	Belknap	71.3	51.70	51.73
New Hampshire	Cheshire	70.7	51.45	51.49
New Hampshire	Coos	77.0	59.25	59.27
New Hampshire	Grafton	67.0	51.88	51.91
New Hampshire	Hillsborough	78.7	59.56	59.63
New Hampshire	Merrimack	71.7	52.32	52.36
New Hampshire	Rockingham	77.0	58.42	58.48
New Hampshire	Sullivan	70.0	53.13	53.16
New Jersey	Atlantic	79.3	59.84	59.84
New Jersey	Bergen	86.0	72.25	72.18
New Jersey	Camden	89.3	68.01	68.01
New Jersey	Cumberland	83.3	60.16	60.17
New Jersey	Gloucester	87.0	66.65	66.65
New Jersey	Hudson	85.7	75.11	75.01
New Jersey	Hunterdon	89.0	65.53	65.53
New Jersey	Mercer	88.0	68.24	68.25
New Jersey	Middlesex	88.3	68.26	68.26
New Jersey	Monmouth	87.3	69.36	69.34
New Jersey	Morris	83.3	61.99	61.98
New Jersey	Ocean	93.0	70.23	70.24
New Jersey	Passaic	81.0	63.42	63.41
New Mexico	Bernalillo	77.0	61.34	61.39

New Mexico	Dona Ana	75.3	62.51	62.43
New Mexico	Eddy	69.0	61.65	61.64
New Mexico	Lea	71.0	63.97	63.96
New Mexico	Sandoval	73.3	58.20	58.25
New Mexico	San Juan	71.3	66.38	66.37
New York	Albany	73.7	55.74	55.75
New York	Bronx	74.7	65.60	65.54
New York	Chautauqua	86.7	72.56	72.60
New York	Chemung	68.7	53.98	54.01
New York	Dutchess	75.7	55.43	55.45
New York	Erie	85.0	68.74	68.74
New York	Essex	77.0	62.41	62.43
New York	Hamilton	71.7	56.49	56.52
New York	Herkimer	68.3	55.39	55.39
New York	Jefferson	78.0	62.86	62.87
New York	Madison	72.0	55.22	55.25
New York	Monroe	76.3	60.70	60.72
New York	Niagara	82.7	70.39	70.38
New York	Oneida	68.3	53.73	53.74
New York	Onondaga	73.7	58.40	58.41
New York	Orange	82.0	60.25	60.27
New York	Oswego	78.0	65.88	65.89
New York	Putnam	84.3	65.09	65.10
New York	Queens	80.0	66.67	66.60
New York	Rensselaer	77.3	58.38	58.40
New York	Richmond	88.3	74.48	74.38
New York	Saratoga	79.7	60.22	60.25
New York	Schenectady	70.0	53.64	53.66
New York	Suffolk	90.3	76.93	76.86
New York	Ulster	77.3	57.94	57.97
New York	Wayne	68.0	56.05	56.07
New York	Westchester	87.7	73.50	73.46
North Carolina	Alexander	77.0	56.79	56.82
North Carolina	Avery	70.0	53.10	53.13
North Carolina	Buncombe	74.0	53.47	53.52
North Carolina	Caldwell	74.3	54.77	54.81
North Carolina	Caswell	76.3	53.22	53.28
North Carolina	Chatham	73.3	52.33	52.37
North Carolina	Cumberland	81.7	57.62	57.68

North Carolina	Davie	81.3	57.66	57.70
North Carolina	Durham	77.0	53.41	53.48
North Carolina	Edgecombe	77.0	56.87	56.90
North Carolina	Forsyth	80.0	57.69	57.74
North Carolina	Franklin	78.7	55.74	55.79
North Carolina	Graham	78.3	56.21	56.35
North Carolina	Granville	82.0	59.09	59.13
North Carolina	Guilford	82.0	56.70	56.80
North Carolina	Haywood	78.3	59.17	59.22
North Carolina	Jackson	76.0	54.81	54.91
North Carolina	Johnston	77.3	53.26	53.32
North Carolina	Lenoir	75.3	55.78	55.81
North Carolina	Lincoln	81.0	58.57	58.60
North Carolina	Martin	75.0	58.34	58.35
North Carolina	Mecklenburg	89.3	66.14	66.17
North Carolina	New Hanover	72.3	55.15	55.17
North Carolina	Person	77.3	59.63	59.63
North Carolina	Pitt	76.3	54.41	54.44
North Carolina	Rockingham	77.0	55.40	55.44
North Carolina	Rowan	86.7	60.86	60.90
North Carolina	Swain	66.3	48.01	48.09
North Carolina	Union	79.3	55.73	55.81
North Carolina	Wake	80.3	56.42	56.48
North Carolina	Yancey	76.0	54.27	54.33
North Dakota	Billings	61.5	54.35	54.35
North Dakota	Burke	57.5	52.29	52.27
North Dakota	Cass	60.0	49.12	49.11
North Dakota	McKenzie	61.3	55.05	55.04
North Dakota	Mercer	59.3	55.89	55.90
North Dakota	Oliver	57.7	54.74	54.74
Ohio	Allen	78.7	60.85	60.88
Ohio	Ashtabula	89.0	71.81	71.83
Ohio	Butler	83.3	64.23	64.40
Ohio	Clark	81.0	59.70	59.83
Ohio	Clermont	81.0	64.91	64.98
Ohio	Clinton	82.3	60.43	60.52
Ohio	Cuyahoga	79.7	65.23	65.21
Ohio	Delaware	78.3	59.99	60.06
Ohio	Franklin	86.3	65.99	66.12

Ohio	Geauga	79.3	60.24	60.27
Ohio	Greene	80.3	59.67	59.81
Ohio	Hamilton	84.7	66.77	66.84
Ohio	Jefferson	78.0	59.78	59.74
Ohio	Knox	77.7	57.93	58.04
Ohio	Lake	86.3	69.10	69.09
Ohio	Lawrence	70.7	55.81	55.60
Ohio	Licking	78.0	57.72	57.83
Ohio	Lorain	76.7	62.38	62.39
Ohio	Lucas	81.3	65.09	65.09
Ohio	Madison	79.7	58.46	58.53
Ohio	Mahoning	78.7	57.82	57.84
Ohio	Medina	80.3	62.75	62.73
Ohio	Miami	76.7	56.10	56.28
Ohio	Montgomery	74.0	54.31	54.58
Ohio	Portage	83.7	63.03	63.05
Ohio	Preble	73.0	54.38	54.47
Ohio	Stark	81.0	61.73	61.75
Ohio	Summit	83.7	64.68	64.71
Ohio	Trumbull	84.3	62.55	62.59
Ohio	Warren	88.3	65.78	65.94
Ohio	Washington	82.7	63.80	63.77
Ohio	Wood	80.0	62.48	62.48
Oklahoma	Adair	75.7	60.43	60.42
Oklahoma	Canadian	76.0	58.20	58.29
Oklahoma	Cherokee	75.7	61.13	61.12
Oklahoma	Cleveland	74.7	57.32	57.38
Oklahoma	Comanche	77.5	58.97	58.98
Oklahoma	Creek	76.7	58.74	58.72
Oklahoma	Dewey	72.7	56.48	56.47
Oklahoma	Kay	78.0	59.74	59.69
Oklahoma	Mc Clain	72.0	55.05	55.10
Oklahoma	Mayes	78.5	63.64	63.59
Oklahoma	Oklahoma	80.0	60.10	60.16
Oklahoma	Ottawa	78.0	60.47	60.45
Oklahoma	Pittsburg	72.0	57.67	57.65
Oklahoma	Tulsa	79.3	62.08	62.06
Oregon	Clackamas	66.3	58.94	58.96
Oregon	Jackson	68.0	51.67	51.72

Oregon	Lane	69.3	53.78	53.82
Oregon	Marion	65.7	53.46	53.52
Oregon	Multnomah	57.0	68.04	68.22
Pennsylvania	Adams	76.3	56.01	56.04
Pennsylvania	Allegheny	83.7	65.40	65.50
Pennsylvania	Armstrong	83.0	64.55	64.63
Pennsylvania	Beaver	83.0	65.77	65.76
Pennsylvania	Berks	80.0	60.80	60.82
Pennsylvania	Blair	74.3	57.85	57.92
Pennsylvania	Bucks	88.0	69.65	69.65
Pennsylvania	Cambria	74.7	60.32	60.38
Pennsylvania	Centre	78.3	60.93	60.99
Pennsylvania	Chester	86.0	61.77	61.81
Pennsylvania	Clearfield	78.3	60.25	60.26
Pennsylvania	Dauphin	79.3	63.45	63.48
Pennsylvania	Delaware	83.3	63.87	63.87
Pennsylvania	Erie	81.3	66.40	66.43
Pennsylvania	Franklin	72.3	52.56	52.61
Pennsylvania	Greene	80.0	64.68	64.44
Pennsylvania	Indiana	80.0	63.60	63.75
Pennsylvania	Lackawanna	75.3	56.29	56.30
Pennsylvania	Lancaster	83.3	64.29	64.31
Pennsylvania	Lawrence	72.3	54.70	54.71
Pennsylvania	Lehigh	83.3	62.68	62.71
Pennsylvania	Luzerne	76.3	56.96	56.99
Pennsylvania	Lycoming	77.3	59.28	59.31
Pennsylvania	Mercer	82.0	60.87	60.92
Pennsylvania	Montgomery	85.7	66.66	66.68
Pennsylvania	Northampton	84.3	63.02	63.04
Pennsylvania	Perry	77.0	59.17	59.20
Pennsylvania	Philadelphia	90.3	71.54	71.51
Pennsylvania	Tioga	77.7	60.55	60.59
Pennsylvania	Washington	78.3	63.29	63.17
Pennsylvania	Westmoreland	79.0	61.89	61.96
Pennsylvania	York	82.0	62.89	62.94
Rhode Island	Kent	84.3	63.16	63.16
Rhode Island	Providence	82.3	61.24	61.25
Rhode Island	Washington	86.0	65.49	65.50
South Carolina	Abbeville	79.0	57.18	57.22

South Carolina	Aiken	76.0	54.21	54.26
South Carolina	Anderson	76.5	53.33	53.39
South Carolina	Barnwell	73.0	53.96	54.02
South Carolina	Berkeley	67.3	49.77	49.82
South Carolina	Charleston	74.0	55.86	55.90
South Carolina	Cherokee	74.0	53.45	53.47
South Carolina	Chester	75.7	53.85	53.89
South Carolina	Chesterfield	75.0	55.79	55.84
South Carolina	Colleton	72.3	52.99	53.02
South Carolina	Darlington	76.3	55.50	55.53
South Carolina	Edgefield	70.0	49.93	49.98
South Carolina	Oconee	73.0	50.88	50.91
South Carolina	Pickens	78.7	54.79	54.83
South Carolina	Richland	82.3	55.15	55.23
South Carolina	Spartanburg	82.3	59.29	59.33
South Carolina	Union	76.0	56.10	56.14
South Carolina	Williamsburg	69.3	49.93	49.97
South Carolina	York	76.7	55.04	55.08
South Dakota	Custer	70.0	62.13	62.13
South Dakota	Jackson	67.5	58.93	58.94
South Dakota	Minnehaha	66.0	52.81	52.80
Tennessee	Anderson	77.3	51.43	51.66
Tennessee	Blount	85.3	57.15	57.42
Tennessee	Davidson	77.7	53.22	53.28
Tennessee	Hamilton	81.0	55.52	55.60
Tennessee	Jefferson	82.3	52.80	52.99
Tennessee	Knox	85.0	56.11	56.42
Tennessee	Loudon	85.0	56.70	56.84
Tennessee	Meigs	80.0	53.55	53.66
Tennessee	Rutherford	76.3	52.25	52.34
Tennessee	Sevier	80.7	55.31	55.44
Tennessee	Shelby	80.7	57.24	57.28
Tennessee	Sullivan	80.3	65.33	65.35
Tennessee	Sumner	83.0	57.70	57.79
Tennessee	Williamson	75.3	51.58	51.64
Tennessee	Wilson	78.7	54.01	54.09
Texas	Bexar	85.0	67.42	67.43
Texas	Brazoria	94.7	76.77	76.47
Texas	Brewster	64.0	53.24	53.24

Texas	Cameron	66.0	58.17	58.16
Texas	Collin	90.3	67.04	67.12
Texas	Dallas	88.3	69.69	69.73
Texas	Denton	94.0	66.54	66.62
Texas	Ellis	81.7	60.25	60.34
Texas	Galveston	85.0	68.99	68.72
Texas	Gregg	84.3	70.66	70.66
Texas	Harris	100.7	83.04	82.73
Texas	Harrison	79.0	62.56	62.52
Texas	Hidalgo	65.7	55.41	55.39
Texas	Hood	83.0	57.29	57.38
Texas	Hunt	78.0	62.12	62.12
Texas	Jefferson	84.7	69.75	69.54
Texas	Johnson	87.0	60.93	61.04
Texas	Kaufman	74.7	57.34	57.37
Texas	Montgomery	85.0	66.37	66.24
Texas	Nueces	72.3	60.14	60.11
Texas	Orange	78.0	63.04	62.84
Texas	Parker	88.7	60.81	60.93
Texas	Rockwall	79.7	62.26	62.27
Texas	Smith	81.0	66.03	66.03
Texas	Tarrant	95.3	68.10	68.20
Texas	Travis	81.3	61.99	62.02
Texas	Victoria	72.3	57.76	57.66
Texas	Webb	61.3	51.51	51.50
Texas	El Paso	77.7	63.54	63.45
Utah	Box Elder	76.0	63.36	63.37
Utah	Cache	68.7	56.84	56.87
Utah	Davis	81.3	69.19	69.17
Utah	Salt Lake	81.0	68.50	68.51
Utah	San Juan	70.3	61.21	61.23
Utah	Tooele	78.0	63.88	63.93
Utah	Utah	76.7	66.45	66.43
Utah	Washington	78.5	61.43	61.44
Utah	Weber	80.3	66.44	66.43
Vermont	Bennington	72.0	53.83	53.86
Vermont	Chittenden	69.7	55.50	55.52
Virginia	Arlington	86.7	67.20	67.21
Virginia	Caroline	80.0	57.57	57.64

Virginia	Charles City	80.3	62.98	62.99
Virginia	Chesterfield	76.7	58.95	58.96
Virginia	Fairfax	90.0	67.37	67.41
Virginia	Fauquier	72.7	53.92	53.95
Virginia	Frederick	72.3	52.34	52.38
Virginia	Hanover	81.3	60.69	60.72
Virginia	Henrico	82.0	62.49	62.51
Virginia	Loudoun	80.7	57.03	57.06
Virginia	Madison	77.7	57.19	57.19
Virginia	Page	74.0	55.13	55.14
Virginia	Prince William	78.7	57.56	57.56
Virginia	Roanoke	74.7	55.74	55.80
Virginia	Rockbridge	69.7	54.20	54.23
Virginia	Stafford	81.7	59.91	59.95
Virginia	Wythe	72.7	56.08	56.07
Virginia	Alexandria City	81.7	61.16	61.19
Virginia	Hampton City	76.7	63.18	63.19
Virginia	Suffolk City	76.7	67.51	67.49
Washington	Clark	59.5	59.54	59.53
Washington	King	72.3	63.55	63.47
Washington	Klickitat	64.5	52.91	52.93
Washington	Pierce	68.7	58.25	58.16
Washington	Skagit	46.0	46.96	46.91
Washington	Spokane	68.3	54.61	54.66
Washington	Thurston	65.0	51.91	51.82
Washington	Whatcom	57.0	55.15	55.05
West Virginia	Berkeley	75.0	54.69	54.70
West Virginia	Cabell	78.7	61.53	61.32
West Virginia	Greenbrier	69.7	57.39	57.39
West Virginia	Hancock	75.7	59.18	59.15
West Virginia	Kanawha	77.3	59.75	59.76
West Virginia	Monongalia	75.3	62.37	62.09
West Virginia	Ohio	78.3	60.91	60.82
West Virginia	Wood	79.0	60.98	60.96
Wisconsin	Ashland	63.0	51.70	51.71
Wisconsin	Brown	73.7	58.79	58.82
Wisconsin	Columbia	72.7	55.47	55.52
Wisconsin	Dane	72.0	55.72	55.74
Wisconsin	Dodge	74.7	58.29	58.31

Wisconsin	Door	88.7	68.95	68.99
Wisconsin	Florence	66.3	53.77	53.78
Wisconsin	Fond Du Lac	73.7	58.35	58.36
Wisconsin	Forest	69.5	55.94	55.95
Wisconsin	Jefferson	74.3	57.56	57.60
Wisconsin	Kenosha	84.7	72.61	72.58
Wisconsin	Kewaunee	82.7	65.20	65.23
Wisconsin	Manitowoc	85.0	67.72	67.75
Wisconsin	Marathon	70.0	56.09	56.09
Wisconsin	Milwaukee	82.7	68.79	68.83
Wisconsin	Oneida	69.0	55.88	55.89
Wisconsin	Outagamie	74.0	59.02	59.01
Wisconsin	Ozaukee	83.3	69.01	69.04
Wisconsin	Racine	80.3	69.09	69.05
Wisconsin	Rock	74.0	57.25	57.26
Wisconsin	St Croix	69.0	55.37	55.38
Wisconsin	Sauk	69.7	54.14	54.16
Wisconsin	Sheboygan	88.0	70.64	70.67
Wisconsin	Vernon	69.7	53.39	53.41
Wisconsin	Vilas	68.7	55.69	55.70
Wisconsin	Walworth	75.7	57.75	57.80
Wisconsin	Washington	72.3	57.91	57.94
Wisconsin	Waukesha	75.0	60.12	60.17
Wyoming	Campbell	67.3	62.13	62.13
Wyoming	Sublette	70.0	65.07	65.06
Wyoming	Teton	62.7	54.90	54.90

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

Appendix C

Annual $PM_{2.5}$ Design Values for Air Quality Modeling Scenarios

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC 27711
August 2012

Table C-1. Annual $PM_{2.5}$ Design Values for 2017-2025 LD GHG Scenarios (units are ug/m^3)

State Name	County Name	Baseline DV	2030 Reference Case DV	2030 Control Case DV
Alabama	Baldwin	11.44	7.32	7.31
Alabama	Clay	13.27	8.30	8.30
Alabama	Colbert	12.75	8.13	8.12
Alabama	DeKalb	14.13	8.65	8.64
Alabama	Escambia	13.19	9.21	9.20
Alabama	Etowah	14.87	9.25	9.25
Alabama	Houston	13.22	9.24	9.24
Alabama	Jefferson	18.57	12.12	12.12
Alabama	Madison	13.83	8.44	8.44
Alabama	Mobile	12.90	8.55	8.54
Alabama	Montgomery	14.24	9.66	9.66
Alabama	Morgan	13.32	8.38	8.37
Alabama	Russell	15.73	10.48	10.48
Alabama	Shelby	14.43	9.16	9.15
Alabama	Sumter	11.92	7.67	7.66
Alabama	Talladega	14.51	9.01	9.00
Alabama	Tuscaloosa	13.56	8.67	8.66
Alabama	Walker	13.86	8.78	8.77
Arizona	Cochise	7.00	6.52	6.51
Arizona	Coconino	6.49	5.95	5.95
Arizona	Gila	8.94	8.16	8.16
Arizona	Maricopa	12.59	10.21	10.20
Arizona	Pima	6.04	5.08	5.08
Arizona	Pinal	7.77	6.85	6.85
Arizona	Santa Cruz	12.94	12.08	12.08
Arkansas	Arkansas	12.45	8.60	8.59
Arkansas	Ashley	12.83	9.32	9.31
Arkansas	Crittenden	13.36	8.43	8.42
Arkansas	Faulkner	12.79	9.01	9.01
Arkansas	Garland	12.40	8.70	8.69
Arkansas	Mississippi	12.61	8.12	8.11
Arkansas	Phillips	12.10	7.97	7.97
Arkansas	Polk	11.65	8.26	8.26
Arkansas	Pope	12.79	9.31	9.30

Arkansas	Pulaski	14.05	9.75	9.74
Arkansas	Union	12.86	9.19	9.17
Arkansas	White	12.57	8.99	8.99
California	Alameda	9.34	8.51	8.51
California	Butte	12.73	10.34	10.33
California	Calaveras	7.77	6.45	6.44
California	Colusa	7.39	6.56	6.55
California	Contra Costa	9.47	8.29	8.28
California	Fresno	17.17	14.47	14.46
California	Imperial	12.71	11.51	11.47
California	Inyo	5.25	4.86	4.86
California	Kern	19.17	15.25	15.23
California	Kings	17.28	13.98	13.97
California	Lake	4.62	4.03	4.03
California	Los Angeles	18.19	14.50	14.46
California	Mendocino	6.46	5.35	5.35
California	Merced	14.78	12.39	12.39
California	Monterey	6.96	5.87	5.86
California	Nevada	6.71	5.73	5.73
California	Orange	15.75	12.99	12.96
California	Placer	9.80	8.12	8.11
California	Plumas	11.46	9.73	9.73
California	Riverside	20.95	17.32	17.30
California	Sacramento	11.88	10.36	10.36
California	San Bernardino	19.67	16.72	16.71
California	San Diego	13.46	11.75	11.75
California	San Francisco	9.62	8.69	8.68
California	San Joaquin	12.94	11.18	11.18
California	San Luis Obispo	7.94	6.46	6.45
California	San Mateo	9.03	8.02	8.02
California	Santa Barbara	10.37	8.69	8.67
California	Santa Clara	11.38	10.46	10.47
California	Shasta	7.41	5.98	5.98
California	Solano	9.99	8.97	8.94
California	Sonoma	8.21	6.96	6.96
California	Stanislaus	14.21	11.67	11.67
California	Sutter	9.85	8.07	8.06
California	Tulare	18.51	15.12	15.10
California	Ventura	11.68	9.49	9.47

California	Yolo	9.03	7.77	7.77
Colorado	Adams	10.06	7.95	7.96
Colorado	Arapahoe	7.96	6.32	6.33
Colorado	Boulder	8.32	6.97	6.96
Colorado	Delta	7.44	6.18	6.17
Colorado	Denver	9.76	7.69	7.70
Colorado	Elbert	4.40	3.76	3.76
Colorado	El Paso	7.94	6.48	6.49
Colorado	Larimer	7.33	6.42	6.42
Colorado	Mesa	9.28	7.90	7.90
Colorado	Pueblo	7.45	6.26	6.26
Colorado	San Miguel	4.65	4.19	4.19
Colorado	Weld	8.78	7.34	7.34
Connecticut	Fairfield	13.21	8.99	8.99
Connecticut	Hartford	11.03	7.71	7.71
Connecticut	Litchfield	8.01	5.13	5.13
Connecticut	New Haven	13.12	8.92	8.92
Connecticut	New London	10.96	7.63	7.63
Delaware	Kent	12.52	7.79	7.78
Delaware	New Castle	14.87	9.44	9.42
Delaware	Sussex	13.39	8.22	8.22
District Of Columbia	District of Columbia	14.16	8.90	8.90
Florida	Alachua	9.59	6.29	6.30
Florida	Bay	11.46	7.84	7.83
Florida	Brevard	8.32	5.30	5.29
Florida	Broward	8.22	5.68	5.68
Florida	Citrus	9.00	5.55	5.55
Florida	Duval	10.44	7.38	7.39
Florida	Escambia	11.72	8.27	8.26
Florida	Hillsborough	10.74	7.14	7.13
Florida	Lee	8.36	5.57	5.56
Florida	Leon	12.56	8.85	8.85
Florida	Manatee	8.81	5.37	5.37
Florida	Marion	10.11	6.73	6.73
Florida	Miami-Dade	9.45	6.26	6.26
Florida	Orange	9.61	6.22	6.22
Florida	Palm Beach	7.84	5.56	5.56
Florida	Pinellas	9.82	6.47	6.46

Florida	Polk	9.53	6.34	6.29
Florida	St. Lucie	8.34	5.44	5.44
Florida	Sarasota	8.77	5.52	5.51
Florida	Seminole	9.51	6.10	6.09
Florida	Volusia	9.27	5.88	5.88
Georgia	Bibb	16.54	11.02	11.01
Georgia	Chatham	13.93	9.37	9.37
Georgia	Clarke	14.90	9.58	9.57
Georgia	Clayton	16.50	10.44	10.43
Georgia	Cobb	16.15	10.42	10.41
Georgia	DeKalb	15.48	9.46	9.45
Georgia	Dougherty	14.46	10.11	10.11
Georgia	Floyd	16.13	10.52	10.52
Georgia	Fulton	17.43	11.05	11.05
Georgia	Glynn	12.25	8.66	8.67
Georgia	Gwinnett	16.07	10.27	10.27
Georgia	Hall	14.16	9.06	9.06
Georgia	Houston	14.19	9.18	9.18
Georgia	Lowndes	12.58	9.12	9.12
Georgia	Muscogee	15.39	10.26	10.26
Georgia	Paulding	14.12	8.62	8.62
Georgia	Richmond	15.68	10.76	10.76
Georgia	Walker	15.49	9.80	9.80
Georgia	Washington	15.14	10.31	10.30
Georgia	Wilkinson	15.27	10.15	10.14
Idaho	Ada	8.41	7.43	7.43
Idaho	Bannock	7.66	6.91	6.91
Idaho	Benewah	9.59	8.66	8.66
Idaho	Canyon	8.46	7.15	7.15
Idaho	Franklin	7.70	6.43	6.43
Idaho	Idaho	9.58	8.85	8.85
Idaho	Shoshone	12.08	10.88	10.88
Illinois	Adams	12.50	8.76	8.76
Illinois	Champaign	12.53	8.30	8.30
Illinois	Cook	15.75	11.03	11.04
Illinois	DuPage	13.82	9.61	9.60
Illinois	Jersey	12.89	8.64	8.62
Illinois	Kane	14.34	10.03	10.02
Illinois	Lake	11.81	8.32	8.32

Illinois	McHenry	12.40	8.62	8.62
Illinois	McLean	12.39	8.42	8.42
Illinois	Macon	13.24	9.06	9.06
Illinois	Madison	16.72	11.33	11.31
Illinois	Peoria	13.34	9.27	9.26
Illinois	Randolph	13.11	8.60	8.59
Illinois	Rock Island	12.01	8.49	8.48
Illinois	Saint Clair	15.58	10.43	10.41
Illinois	Sangamon	13.13	9.28	9.28
Illinois	Will	13.63	9.33	9.32
Illinois	Winnebago	13.57	9.73	9.73
Indiana	Allen	13.67	9.69	9.69
Indiana	Clark	16.44	10.11	10.10
Indiana	Delaware	13.69	9.00	8.99
Indiana	Dubois	15.19	9.22	9.22
Indiana	Floyd	14.85	8.93	8.92
Indiana	Henry	13.64	8.93	8.93
Indiana	Howard	13.93	9.44	9.43
Indiana	Knox	14.03	8.65	8.65
Indiana	Lake	14.33	10.20	10.19
Indiana	LaPorte	12.69	8.80	8.79
Indiana	Madison	13.97	9.19	9.19
Indiana	Marion	16.05	10.57	10.57
Indiana	Porter	13.21	9.18	9.18
Indiana	St. Joseph	13.69	10.13	10.12
Indiana	Spencer	14.32	8.43	8.43
Indiana	Tippecanoe	13.70	9.21	9.21
Indiana	Vanderburgh	14.99	9.90	9.90
Indiana	Vigo	13.99	8.82	8.82
Iowa	Black Hawk	11.16	8.08	8.08
Iowa	Clinton	12.52	8.90	8.90
Iowa	Johnson	12.08	8.80	8.80
Iowa	Linn	10.79	7.71	7.70
Iowa	Montgomery	10.02	7.15	7.15
Iowa	Muscatine	12.92	9.36	9.35
Iowa	Palo Alto	9.53	7.08	7.08
Iowa	Polk	10.64	7.69	7.69
Iowa	Pottawattamie	11.13	8.23	8.23
Iowa	Scott	14.42	10.50	10.49

Iowa	Van Buren	10.84	7.81	7.81
Iowa	Woodbury	10.32	7.79	7.78
Iowa	Wright	10.37	7.54	7.54
Kansas	Johnson	11.10	7.92	7.92
Kansas	Linn	10.47	7.61	7.60
Kansas	Sedgwick	10.36	7.65	7.64
Kansas	Shawnee	10.93	8.15	8.14
Kansas	Sumner	9.89	7.33	7.32
Kansas	Wyandotte	12.73	9.23	9.23
Kentucky	Bell	14.10	8.58	8.57
Kentucky	Boyd	14.49	8.73	8.73
Kentucky	Bullitt	14.92	9.02	9.01
Kentucky	Campbell	13.67	8.04	8.04
Kentucky	Carter	12.22	7.05	7.05
Kentucky	Christian	13.20	7.93	7.93
Kentucky	Daviess	14.10	8.17	8.17
Kentucky	Fayette	14.87	8.92	8.92
Kentucky	Franklin	13.37	7.81	7.81
Kentucky	Hardin	13.58	7.95	7.94
Kentucky	Henderson	13.93	8.75	8.74
Kentucky	Jefferson	15.55	9.38	9.38
Kentucky	Kenton	14.39	8.63	8.63
Kentucky	Laurel	12.55	7.39	7.39
Kentucky	McCracken	13.41	8.26	8.25
Kentucky	Madison	13.61	7.88	7.88
Kentucky	Perry	13.21	7.95	7.93
Kentucky	Pike	13.49	7.91	7.90
Kentucky	Warren	13.83	8.22	8.22
Louisiana	Caddo	12.53	8.62	8.60
Louisiana	Calcasieu	11.07	7.84	7.74
Louisiana	Concordia	11.42	7.63	7.61
Louisiana	East Baton Rouge	13.38	9.59	9.43
Louisiana	Iberville	12.90	9.19	9.10
Louisiana	Jefferson	11.52	7.36	7.31
Louisiana	Lafayette	11.08	7.48	7.45
Louisiana	Ouachita	11.97	8.49	8.48
Louisiana	Rapides	11.03	7.50	7.48
Louisiana	Tangipahoa	12.03	7.97	7.93
Louisiana	Terrebonne	10.74	7.16	7.13

Louisiana	West Baton Rouge	13.51	9.70	9.53
Maine	Androscoggin	9.90	7.51	7.51
Maine	Aroostook	9.74	8.88	8.88
Maine	Cumberland	11.13	8.39	8.39
Maine	Hancock	5.76	4.35	4.35
Maine	Kennebec	9.99	7.66	7.66
Maine	Oxford	10.13	8.18	8.18
Maine	Penobscot	9.12	7.11	7.11
Maryland	Anne Arundel	14.82	9.88	9.88
Maryland	Baltimore	14.76	9.63	9.63
Maryland	Cecil	12.68	7.79	7.78
Maryland	Harford	12.51	7.70	7.70
Maryland	Montgomery	12.47	7.82	7.82
Maryland	Prince George's	13.03	8.05	8.05
Maryland	Washington	13.70	8.71	8.71
Maryland	Baltimore (City)	15.76	10.44	10.44
Massachusetts	Berkshire	10.65	7.82	7.82
Massachusetts	Bristol	9.58	6.71	6.71
Massachusetts	Essex	9.58	7.05	7.05
Massachusetts	Hampden	12.17	8.87	8.87
Massachusetts	Plymouth	9.87	7.11	7.11
Massachusetts	Suffolk	13.07	9.73	9.73
Massachusetts	Worcester	11.29	8.18	8.18
Michigan	Allegan	11.84	8.23	8.23
Michigan	Bay	10.93	7.81	7.81
Michigan	Berrien	11.72	8.17	8.16
Michigan	Genesee	11.61	8.06	8.06
Michigan	Ingham	12.23	8.43	8.43
Michigan	Kalamazoo	12.84	9.00	9.00
Michigan	Kent	12.89	8.97	8.97
Michigan	Macomb	12.70	8.96	8.96
Michigan	Missaukee	8.26	6.29	6.29
Michigan	Monroe	13.92	9.32	9.31
Michigan	Muskegon	11.61	8.27	8.27
Michigan	Oakland	13.78	9.54	9.54
Michigan	Ottawa	12.55	8.71	8.71
Michigan	Saginaw	10.61	7.60	7.60
Michigan	St. Clair	13.34	9.79	9.79
Michigan	Washtenaw	13.88	9.43	9.43

Michigan	Wayne	17.50	12.27	12.27
Minnesota	Cass	5.70	4.76	4.76
Minnesota	Dakota	9.30	7.11	7.11
Minnesota	Hennepin	9.76	7.47	7.47
Minnesota	Mille Lacs	6.54	5.25	5.25
Minnesota	Olmsted	10.13	7.53	7.53
Minnesota	Ramsey	11.32	8.79	8.79
Minnesota	Saint Louis	7.51	6.08	6.07
Minnesota	Scott	9.00	6.87	6.87
Minnesota	Stearns	8.58	6.78	6.77
Mississippi	Adams	11.29	7.49	7.47
Mississippi	Bolivar	12.36	8.44	8.43
Mississippi	DeSoto	12.43	7.80	7.79
Mississippi	Forrest	13.62	9.00	8.98
Mississippi	Harrison	12.20	8.07	8.06
Mississippi	Hinds	12.56	8.34	8.33
Mississippi	Jackson	12.04	7.76	7.73
Mississippi	Jones	14.39	9.45	9.44
Mississippi	Lauderdale	13.07	8.53	8.52
Mississippi	Lee	12.57	7.98	7.97
Mississippi	Lowndes	12.79	8.35	8.34
Mississippi	Pearl River	12.14	8.11	8.09
Mississippi	Warren	12.32	8.29	8.27
Missouri	Boone	11.84	8.33	8.33
Missouri	Buchanan	12.80	9.59	9.59
Missouri	Cass	10.67	7.61	7.60
Missouri	Cedar	11.12	7.77	7.77
Missouri	Clay	11.03	7.93	7.92
Missouri	Greene	11.75	8.29	8.28
Missouri	Jackson	12.78	9.23	9.22
Missouri	Jefferson	13.79	9.40	9.39
Missouri	Monroe	10.87	7.44	7.44
Missouri	Saint Charles	13.29	8.98	8.93
Missouri	Sainte Genevieve	13.34	8.98	8.97
Missouri	Saint Louis	13.46	8.90	8.88
Missouri	St. Louis City	14.56	9.63	9.61
Montana	Cascade	5.72	5.11	5.10
Montana	Flathead	9.99	8.67	8.67
Montana	Gallatin	4.38	4.14	4.14

Montana	Lake	9.06	7.99	7.99
Montana	Lewis and Clark	8.20	7.33	7.33
Montana	Lincoln	14.93	12.84	12.84
Montana	Missoula	10.52	9.16	9.16
Montana	Ravalli	9.01	7.97	7.97
Montana	Rosebud	6.58	6.11	6.12
Montana	Sanders	6.75	6.13	6.13
Montana	Silver Bow	10.14	8.94	8.93
Montana	Yellowstone	8.14	7.07	7.05
Nebraska	Cass	9.99	7.29	7.29
Nebraska	Douglas	9.88	7.21	7.21
Nebraska	Hall	7.95	5.98	5.97
Nebraska	Lancaster	8.90	6.35	6.35
Nebraska	Lincoln	7.57	6.28	6.27
Nebraska	Sarpy	9.79	7.13	7.13
Nebraska	Scotts Bluff	6.04	5.11	5.10
Nebraska	Washington	9.29	6.90	6.90
Nevada	Clark	9.44	8.19	8.18
Nevada	Washoe	8.11	6.80	6.80
New Hampshire	Belknap	7.28	5.34	5.34
New Hampshire	Cheshire	11.53	8.63	8.63
New Hampshire	Coos	10.24	8.37	8.37
New Hampshire	Grafton	8.43	6.42	6.42
New Hampshire	Hillsborough	10.18	7.44	7.44
New Hampshire	Merrimack	9.72	7.08	7.08
New Hampshire	Rockingham	9.00	6.61	6.61
New Hampshire	Sullivan	9.86	7.47	7.47
New Jersey	Atlantic	11.47	7.24	7.23
New Jersey	Bergen	13.09	8.71	8.71
New Jersey	Camden	13.31	8.53	8.50
New Jersey	Essex	13.27	8.53	8.52
New Jersey	Gloucester	13.46	8.48	8.44
New Jersey	Hudson	14.24	9.42	9.42
New Jersey	Mercer	12.71	8.17	8.17
New Jersey	Middlesex	12.15	7.88	7.87
New Jersey	Morris	11.50	7.39	7.39
New Jersey	Ocean	10.92	6.81	6.81
New Jersey	Passaic	12.88	8.41	8.41
New Jersey	Union	14.94	9.66	9.66

New Jersey	Warren	12.72	8.23	8.23
New Mexico	Bernalillo	7.03	5.69	5.69
New Mexico	Chaves	6.54	5.65	5.64
New Mexico	Dona Ana	9.95	8.53	8.53
New Mexico	Grant	5.93	5.49	5.48
New Mexico	Sandoval	7.99	7.15	7.15
New Mexico	San Juan	5.92	5.25	5.25
New Mexico	Santa Fe	4.76	4.19	4.19
New York	Albany	11.83	9.15	9.15
New York	Bronx	15.43	10.79	10.79
New York	Chautauqua	9.80	6.39	6.39
New York	Erie	12.62	8.74	8.74
New York	Essex	5.94	4.52	4.52
New York	Kings	14.20	9.43	9.43
New York	Monroe	10.64	7.72	7.72
New York	Nassau	11.66	7.55	7.55
New York	New York	16.18	10.98	10.99
New York	Niagara	11.96	8.58	8.58
New York	Onondaga	10.08	7.19	7.20
New York	Orange	10.99	7.33	7.33
New York	Queens	12.18	8.02	8.02
New York	Richmond	13.31	8.46	8.46
New York	St. Lawrence	7.29	5.82	5.82
New York	Steuben	9.00	6.00	6.00
New York	Suffolk	11.52	7.41	7.42
New York	Westchester	11.73	7.56	7.56
North Carolina	Alamance	13.94	8.36	8.36
North Carolina	Buncombe	12.60	7.69	7.68
North Carolina	Caswell	13.19	7.72	7.71
North Carolina	Catawba	15.31	9.13	9.13
North Carolina	Chatham	11.99	7.06	7.05
North Carolina	Cumberland	13.73	8.75	8.74
North Carolina	Davidson	15.17	8.91	8.91
North Carolina	Duplin	11.30	6.97	6.97
North Carolina	Durham	13.57	8.27	8.27
North Carolina	Edgecombe	12.37	7.76	7.75
North Carolina	Forsyth	14.28	8.29	8.29
North Carolina	Gaston	14.26	8.36	8.36
North Carolina	Guilford	13.79	8.15	8.15

North Carolina	Haywood	12.98	8.55	8.54
North Carolina	Jackson	12.09	7.43	7.43
North Carolina	Lenoir	11.12	6.88	6.88
North Carolina	McDowell	14.24	8.95	8.95
North Carolina	Martin	10.86	6.73	6.73
North Carolina	Mecklenburg	15.31	9.27	9.27
North Carolina	Mitchell	12.75	7.65	7.64
North Carolina	Montgomery	12.35	7.32	7.32
North Carolina	New Hanover	9.96	6.11	6.11
North Carolina	Onslow	10.98	6.76	6.76
North Carolina	Orange	13.12	7.81	7.80
North Carolina	Pitt	11.59	7.27	7.27
North Carolina	Robeson	12.78	7.99	7.98
North Carolina	Rowan	14.02	8.35	8.35
North Carolina	Swain	12.65	7.76	7.76
North Carolina	Wake	13.54	8.29	8.29
North Carolina	Watauga	12.05	6.84	6.84
North Carolina	Wayne	12.96	8.29	8.29
North Dakota	Billings	4.61	4.13	4.13
North Dakota	Burke	5.90	5.49	5.49
North Dakota	Burleigh	6.61	5.55	5.54
North Dakota	Cass	7.72	6.37	6.37
North Dakota	McKenzie	5.01	4.57	4.57
North Dakota	Mercer	6.04	5.35	5.35
Ohio	Athens	12.39	7.18	7.17
Ohio	Butler	15.36	10.03	10.03
Ohio	Clark	14.64	9.47	9.47
Ohio	Clermont	14.15	8.49	8.49
Ohio	Cuyahoga	17.37	11.63	11.63
Ohio	Franklin	15.27	9.75	9.76
Ohio	Greene	13.36	8.25	8.25
Ohio	Hamilton	17.54	10.99	11.00
Ohio	Jefferson	16.51	9.97	9.96
Ohio	Lake	13.02	8.57	8.57
Ohio	Lawrence	15.14	9.44	9.43
Ohio	Lorain	13.87	9.01	9.01
Ohio	Lucas	14.38	9.72	9.70
Ohio	Mahoning	15.12	9.85	9.85
Ohio	Montgomery	15.54	9.95	9.95

Ohio	Portage	13.37	8.62	8.62
Ohio	Preble	13.70	8.70	8.70
Ohio	Scioto	14.65	8.86	8.86
Ohio	Stark	16.26	10.41	10.40
Ohio	Summit	15.17	10.09	10.09
Ohio	Trumbull	14.53	9.50	9.50
Oklahoma	Caddo	9.22	6.78	6.78
Oklahoma	Cherokee	11.79	8.48	8.47
Oklahoma	Kay	10.26	7.74	7.71
Oklahoma	Lincoln	10.28	7.41	7.40
Oklahoma	Mayes	11.70	8.54	8.53
Oklahoma	Muskogee	11.89	8.73	8.71
Oklahoma	Oklahoma	10.07	7.07	7.06
Oklahoma	Ottawa	11.69	8.55	8.55
Oklahoma	Pittsburg	11.09	7.94	7.94
Oklahoma	Sequoyah	12.99	9.57	9.56
Oklahoma	Tulsa	11.52	8.33	8.31
Oregon	Jackson	10.32	9.23	9.23
Oregon	Klamath	11.20	9.98	9.98
Oregon	Lane	11.93	10.72	10.72
Oregon	Multnomah	9.13	7.77	7.77
Oregon	Union	8.35	7.17	7.17
Pennsylvania	Adams	13.05	8.19	8.19
Pennsylvania	Allegheny	20.31	12.68	12.67
Pennsylvania	Beaver	16.38	10.52	10.51
Pennsylvania	Berks	15.82	10.48	10.48
Pennsylvania	Bucks	13.42	8.53	8.53
Pennsylvania	Cambria	15.40	9.51	9.49
Pennsylvania	Centre	12.78	8.03	8.02
Pennsylvania	Chester	15.22	9.61	9.60
Pennsylvania	Cumberland	14.45	9.34	9.34
Pennsylvania	Dauphin	15.13	9.43	9.42
Pennsylvania	Delaware	15.23	9.79	9.75
Pennsylvania	Erie	12.54	8.40	8.40
Pennsylvania	Lackawanna	11.73	7.58	7.57
Pennsylvania	Lancaster	16.55	10.55	10.54
Pennsylvania	Lehigh	14.50	9.64	9.64
Pennsylvania	Luzerne	12.76	8.43	8.43
Pennsylvania	Mercer	13.28	8.42	8.42

Pennsylvania	Northampton	13.68	8.96	8.95
Pennsylvania	Perry	12.81	8.27	8.27
Pennsylvania	Philadelphia	15.19	9.91	9.87
Pennsylvania	Washington	15.17	8.82	8.82
Pennsylvania	Westmoreland	15.49	9.25	9.24
Pennsylvania	York	16.52	10.57	10.57
Rhode Island	Providence	12.14	8.87	8.88
South Carolina	Beaufort	11.52	7.19	7.19
South Carolina	Charleston	12.21	7.80	7.80
South Carolina	Chesterfield	12.56	7.85	7.84
South Carolina	Edgefield	13.17	8.44	8.44
South Carolina	Florence	12.65	7.98	7.98
South Carolina	Georgetown	12.85	8.38	8.37
South Carolina	Greenville	15.65	9.73	9.73
South Carolina	Greenwood	13.53	8.35	8.35
South Carolina	Horry	12.04	7.63	7.63
South Carolina	Lexington	14.64	9.21	9.21
South Carolina	Oconee	10.95	6.42	6.41
South Carolina	Richland	14.24	8.84	8.84
South Carolina	Spartanburg	14.17	8.56	8.56
South Dakota	Brookings	9.37	7.41	7.41
South Dakota	Brown	8.42	6.96	6.96
South Dakota	Codington	10.14	8.28	8.28
South Dakota	Custer	5.64	4.98	4.98
South Dakota	Jackson	5.39	4.63	4.62
South Dakota	Minnehaha	10.18	7.79	7.79
South Dakota	Pennington	8.77	7.79	7.79
Tennessee	Blount	14.30	9.02	9.02
Tennessee	Davidson	14.21	8.75	8.75
Tennessee	Dyer	12.28	7.69	7.68
Tennessee	Hamilton	15.67	9.86	9.86
Tennessee	Knox	15.64	9.64	9.64
Tennessee	Lawrence	11.69	7.34	7.33
Tennessee	Loudon	15.49	9.99	9.98
Tennessee	McMinn	14.29	8.91	8.90
Tennessee	Maury	13.21	8.30	8.29
Tennessee	Montgomery	13.80	8.56	8.55
Tennessee	Putnam	13.37	7.99	7.99
Tennessee	Roane	14.49	8.89	8.88

Tennessee	Shelby	13.71	8.57	8.56
Tennessee	Sullivan	14.16	9.12	9.12
Tennessee	Sumner	13.68	7.96	7.96
Texas	Bowie	12.85	8.99	8.98
Texas	Dallas	12.77	8.78	8.77
Texas	Ector	7.78	6.37	6.37
Texas	El Paso	9.09	7.66	7.66
Texas	Harris	15.42	11.29	11.21
Texas	Harrison	11.69	7.77	7.75
Texas	Hidalgo	10.98	8.98	8.98
Texas	Jefferson	11.56	7.97	7.90
Texas	Nueces	10.42	7.29	7.26
Texas	Orange	11.51	8.18	8.13
Texas	Tarrant	12.23	8.23	8.23
Utah	Box Elder	8.40	6.72	6.72
Utah	Cache	11.56	9.43	9.43
Utah	Davis	10.31	8.21	8.21
Utah	Salt Lake	12.02	9.50	9.50
Utah	Utah	10.52	8.44	8.45
Utah	Weber	11.16	8.81	8.81
Vermont	Addison	8.94	7.16	7.16
Vermont	Bennington	8.52	6.47	6.47
Vermont	Chittenden	10.02	8.02	8.03
Vermont	Rutland	11.08	8.83	8.83
Virginia	Arlington	14.27	8.84	8.85
Virginia	Charles	12.37	7.46	7.45
Virginia	Chesterfield	13.44	8.10	8.09
Virginia	Fairfax	13.88	8.84	8.84
Virginia	Henrico	13.51	8.09	8.08
Virginia	Loudoun	13.57	8.65	8.65
Virginia	Page	12.79	7.50	7.50
Virginia	Bristol City	13.93	8.25	8.25
Virginia	Hampton City	12.17	7.40	7.39
Virginia	Lynchburg City	12.84	7.48	7.48
Virginia	Norfolk City	12.78	7.89	7.89
Virginia	Roanoke City	14.27	8.53	8.52
Virginia	Salem City	14.69	9.00	8.99
Virginia	Virginia Beach City	12.40	7.55	7.54
Washington	King	11.24	9.16	9.16

Washington	Pierce	10.55	9.09	9.10
Washington	Snohomish	9.91	8.71	8.71
Washington	Spokane	9.97	7.80	7.80
West Virginia	Berkeley	15.93	10.48	10.48
West Virginia	Brooke	16.52	10.02	10.01
West Virginia	Cabell	16.30	10.23	10.22
West Virginia	Hancock	15.76	9.60	9.60
West Virginia	Harrison	13.99	8.40	8.39
West Virginia	Kanawha	16.52	9.94	9.94
West Virginia	Marion	15.03	9.03	9.02
West Virginia	Marshall	15.19	8.82	8.81
West Virginia	Monongalia	14.35	8.12	8.11
West Virginia	Ohio	14.58	8.30	8.29
West Virginia	Raleigh	12.90	7.37	7.37
West Virginia	Wood	15.40	9.65	9.65
Wisconsin	Ashland	6.07	4.93	4.93
Wisconsin	Brown	11.39	9.40	9.38
Wisconsin	Dane	12.20	8.95	8.96
Wisconsin	Dodge	11.04	8.12	8.11
Wisconsin	Forest	7.41	5.87	5.86
Wisconsin	Grant	11.79	8.56	8.56
Wisconsin	Kenosha	11.98	8.53	8.52
Wisconsin	Manitowoc	10.20	7.99	7.98
Wisconsin	Milwaukee	14.08	10.39	10.40
Wisconsin	Outagamie	10.96	8.71	8.70
Wisconsin	Ozaukee	11.60	8.51	8.51
Wisconsin	St. Croix	10.09	7.82	7.82
Wisconsin	Sauk	10.22	7.34	7.33
Wisconsin	Taylor	8.24	6.44	6.44
Wisconsin	Vilas	6.78	5.42	5.42
Wisconsin	Waukesha	13.91	10.44	10.45
Wyoming	Campbell	6.29	5.92	5.91
Wyoming	Converse	3.58	3.27	3.26
Wyoming	Fremont	8.17	7.29	7.29
Wyoming	Laramie	4.48	3.78	3.78
Wyoming	Sheridan	9.70	8.73	8.73

Air Quality Modeling Technical Support Document: 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards Final Rule

Appendix D

24-Hour $PM_{2.5}$ Design Values for Air Quality Modeling Scenarios

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC 27711
August 2012

Table D-1. 24-hour $PM_{2.5}$ Design Values for 2017-2025 LD GHG Scenarios (units are ug/m^3)

State Name	County Name	Baseline DV	2030 Reference Case DV	2030 Control Case DV
Alabama	Baldwin	26.21	16.06	16.03
Alabama	Clay	31.88	16.81	16.80
Alabama	Colbert	30.43	15.30	15.29
Alabama	De Kalb	32.08	16.77	16.76
Alabama	Escambia	29.03	18.65	18.62
Alabama	Etowah	35.18	18.54	18.54
Alabama	Houston	28.66	18.02	18.02
Alabama	Jefferson	44.06	28.17	28.16
Alabama	Madison	33.58	16.72	16.71
Alabama	Mobile	30.03	18.25	18.21
Alabama	Montgomery	32.05	18.51	18.50
Alabama	Morgan	31.58	14.71	14.70
Alabama	Russell	35.55	22.87	22.87
Alabama	Shelby	32.05	18.14	18.13
Alabama	Sumter	28.90	15.93	15.92
Alabama	Talladega	33.46	18.21	18.20
Alabama	Tuscaloosa	29.80	16.52	16.50
Alabama	Walker	32.82	16.86	16.84
Arizona	Cochise	16.62	15.62	15.61
Arizona	Coconino	17.11	15.75	15.75
Arizona	Gila	22.12	19.97	19.97
Arizona	Maricopa	32.80	24.39	24.39
Arizona	Pima	12.27	9.65	9.65
Arizona	Pinal	17.55	14.37	14.38
Arizona	Santa Cruz	36.08	33.78	33.78
Arkansas	Arkansas	29.16	17.87	17.86
Arkansas	Ashley	28.91	20.62	20.60
Arkansas	Crittenden	35.06	18.16	18.16
Arkansas	Faulkner	29.87	18.86	18.86
Arkansas	Garland	29.27	18.43	18.42

Arkansas	Phillips	29.18	17.68	17.67
Arkansas	Polk	26.13	15.73	15.72
Arkansas	Pope	28.32	18.06	18.06
Arkansas	Pulaski	31.93	21.38	21.33
Arkansas	Union	28.70	19.54	19.45
Arkansas	White	29.91	19.03	19.02
California	Alameda	32.58	26.54	26.55
California	Butte	52.55	37.47	37.46
California	Calaveras	20.55	15.05	15.04
California	Colusa	26.16	22.02	22.02
California	Contra Costa	34.70	28.97	28.97
California	Fresno	60.22	47.04	47.01
California	Imperial	40.21	33.37	33.20
California	Inyo	20.00	18.42	18.42
California	Kern	64.54	51.14	51.16
California	Kings	58.06	44.34	44.30
California	Lake	12.94	11.97	11.97
California	Los Angeles	50.97	44.24	44.27
California	Mendocino	15.30	10.35	10.35
California	Merced	46.15	34.55	34.54
California	Monterey	14.35	11.96	11.95
California	Nevada	16.55	13.00	12.99
California	Orange	43.76	38.85	38.90
California	Placer	29.88	24.02	24.00
California	Plumas	32.44	26.18	26.18
California	Riverside	59.13	49.07	49.06
California	Sacramento	49.22	45.56	45.56
California	San Bernardino	55.50	46.40	46.13
California	San Diego	35.55	31.46	31.47
California	San Francisco	30.91	26.52	26.48
California	San Joaquin	41.88	33.39	33.38
California	San Luis Obispo	22.58	18.00	18.00
California	San Mateo	29.41	25.69	25.69
California	Santa Barbara	24.07	22.49	22.48

California	Santa Clara	38.61	35.47	35.47
California	Shasta	20.42	14.39	14.37
California	Solano	34.76	29.97	29.89
California	Sonoma	29.10	23.86	23.85
California	Stanislaus	51.48	39.22	39.19
California	Sutter	38.55	29.18	29.16
California	Tulare	56.63	42.79	42.75
California	Ventura	30.30	26.06	26.03
California	Yolo	30.38	24.71	24.70
Colorado	Adams	25.35	19.09	19.12
Colorado	Arapahoe	21.27	16.83	16.89
Colorado	Boulder	21.12	17.09	17.09
Colorado	Delta	20.76	15.98	15.97
Colorado	Denver	26.44	20.79	20.81
Colorado	Elbert	13.18	10.92	10.94
Colorado	El Paso	16.51	13.71	13.85
Colorado	Larimer	18.30	15.89	15.90
Colorado	Mesa	23.51	19.45	19.48
Colorado	Pueblo	15.42	12.54	12.55
Colorado	San Miguel	10.11	9.47	9.46
Colorado	Weld	22.90	19.43	19.43
Connecticut	Fairfield	36.27	23.28	23.28
Connecticut	Hartford	31.83	19.43	19.43
Connecticut	Litchfield	27.16	13.31	13.30
Connecticut	New Haven	38.37	22.87	22.87
Connecticut	New London	32.03	17.50	17.49
Delaware	Kent	32.14	19.09	19.09
Delaware	New Castle	36.66	22.90	22.88
Delaware	Sussex	33.78	19.76	19.76
District of Columbia	Washington	36.35	21.15	21.20
Florida	Alachua	21.35	13.35	13.34
Florida	Bay	28.08	17.97	17.96
Florida	Brevard	20.73	12.76	12.74
Florida	Broward	18.63	13.26	13.25

Florida	Citrus	21.22	11.68	11.68
Florida	Duval	24.35	17.79	17.77
Florida	Escambia	28.80	20.67	20.67
Florida	Hillsborough	23.44	14.81	14.79
Florida	Lee	17.70	11.92	11.91
Florida	Leon	27.03	18.20	18.19
Florida	Manatee	19.57	11.20	11.19
Florida	Marion	22.56	13.16	13.18
Florida	Miami-Dade	19.13	12.42	12.42
Florida	Orange	21.83	12.74	12.74
Florida	Palm Beach	18.22	13.36	13.35
Florida	Pinellas	21.73	14.47	14.47
Florida	Polk	19.30	12.49	12.47
Florida	St Lucie	18.18	11.20	11.18
Florida	Sarasota	19.22	11.90	11.89
Florida	Seminole	22.08	12.04	12.04
Florida	Volusia	22.00	12.42	12.41
Georgia	Bibb	33.56	21.21	21.20
Georgia	Chatham	28.45	18.67	18.67
Georgia	Clayton	35.88	20.80	20.79
Georgia	Cobb	35.04	19.57	19.56
Georgia	De Kalb	33.92	19.30	19.30
Georgia	Dougherty	34.15	23.36	23.36
Georgia	Floyd	35.12	20.67	20.66
Georgia	Fulton	37.66	22.61	22.61
Georgia	Glynn	26.13	18.02	18.01
Georgia	Gwinnett	32.81	18.06	18.06
Georgia	Hall	30.11	19.25	19.25
Georgia	Houston	29.63	17.38	17.37
Georgia	Lowndes	25.68	16.65	16.65
Georgia	Muscogee	34.58	22.07	22.06
Georgia	Paulding	33.02	18.28	18.27
Georgia	Richmond	32.70	23.22	23.22
Georgia	Walker	30.98	18.24	18.24

Georgia	Washington	30.83	18.67	18.66
Georgia	Wilkinson	33.16	20.38	20.37
Idaho	Ada	28.36	23.48	23.48
Idaho	Bannock	27.08	23.78	23.78
Idaho	Benewah	32.94	28.89	28.90
Idaho	Canyon	31.80	24.12	24.11
Idaho	Franklin	36.76	29.35	29.32
Idaho	Idaho	28.43	26.35	26.35
Idaho	Lemhi	36.53	32.73	32.74
Idaho	Power	33.36	29.35	29.35
Idaho	Shoshone	38.16	33.34	33.35
Illinois	Adams	31.41	17.57	17.56
Illinois	Champaign	31.32	18.69	18.69
Illinois	Cook	43.03	28.30	28.29
Illinois	Du Page	34.64	25.10	25.06
Illinois	Hamilton	31.60	16.70	16.68
Illinois	Jersey	32.18	19.29	19.24
Illinois	Kane	34.83	24.75	24.75
Illinois	Lake	33.08	21.05	21.05
Illinois	La Salle	28.92	18.70	18.68
Illinois	McHenry	31.58	20.15	20.14
Illinois	McLean	33.43	19.98	19.97
Illinois	Macon	33.25	18.03	18.03
Illinois	Madison	39.16	24.58	24.54
Illinois	Peoria	32.76	20.20	20.18
Illinois	Randolph	28.96	19.75	19.74
Illinois	Rock Island	30.90	22.10	22.11
Illinois	St Clair	33.70	22.43	22.41
Illinois	Sangamon	33.41	21.07	21.07
Illinois	Will	36.45	23.76	23.75
Illinois	Winnebago	34.73	24.38	24.37
Indiana	Allen	33.10	22.63	22.64
Indiana	Clark	37.57	20.71	20.68
Indiana	Delaware	32.07	20.26	20.26

Indiana	Dubois	35.36	21.54	21.55
Indiana	Elkhart	34.43	24.65	24.64
Indiana	Floyd	33.26	17.00	16.99
Indiana	Henry	31.86	19.26	19.25
Indiana	Howard	32.21	19.57	19.56
Indiana	Knox	35.92	21.04	21.04
Indiana	Lake	38.98	29.14	29.01
Indiana	La Porte	33.00	21.25	21.24
Indiana	Madison	32.82	19.86	19.85
Indiana	Marion	38.47	23.90	23.90
Indiana	Porter	32.96	22.38	22.36
Indiana	St Joseph	33.16	23.52	23.52
Indiana	Spencer	32.32	15.24	15.23
Indiana	Tippecanoe	35.68	20.52	20.51
Indiana	Vanderburgh	34.80	22.50	22.48
Indiana	Vigo	34.88	20.22	20.22
Iowa	Black Hawk	30.78	21.40	21.40
Iowa	Clinton	33.95	23.11	23.12
Iowa	Johnson	34.67	23.24	23.24
Iowa	Linn	30.60	19.84	19.84
Iowa	Montgomery	27.50	16.99	16.97
Iowa	Muscatine	36.03	26.58	26.52
Iowa	Palo Alto	25.73	17.34	17.33
Iowa	Polk	31.46	21.78	21.79
Iowa	Pottawattamie	28.60	20.49	20.48
Iowa	Scott	37.10	24.47	24.48
Iowa	Van Buren	28.36	18.86	18.86
Iowa	Woodbury	26.40	19.20	19.19
Iowa	Wright	28.65	18.75	18.74
Kansas	Johnson	29.30	22.09	22.08
Kansas	Linn	25.38	17.75	17.72
Kansas	Sedgwick	25.37	17.96	17.96
Kansas	Shawnee	29.16	21.37	21.35
Kansas	Sumner	22.84	15.66	15.64

Kansas	Wyandotte	29.58	20.91	20.89
Kentucky	Bell	29.90	16.78	16.76
Kentucky	Boyd	33.15	16.11	16.08
Kentucky	Bullitt	34.63	17.31	17.29
Kentucky	Campbell	31.20	16.14	16.15
Kentucky	Carter	29.91	13.79	13.78
Kentucky	Christian	33.60	15.69	15.67
Kentucky	Daviess	33.86	16.79	16.77
Kentucky	Fayette	32.23	17.51	17.51
Kentucky	Franklin	32.17	16.60	16.58
Kentucky	Hardin	32.81	15.72	15.72
Kentucky	Henderson	31.85	17.33	17.31
Kentucky	Jefferson	36.44	20.27	20.25
Kentucky	Kenton	34.74	18.91	18.93
Kentucky	Laurel	25.16	13.89	13.88
Kentucky	McCracken	33.62	16.76	16.76
Kentucky	Madison	30.11	14.70	14.69
Kentucky	Perry	28.54	13.39	13.35
Kentucky	Pike	30.52	15.17	15.16
Kentucky	Warren	33.14	15.74	15.74
Louisiana	Caddo	27.56	18.67	18.64
Louisiana	Calcasieu	26.38	17.17	17.05
Louisiana	Concordia	26.16	15.70	15.67
Louisiana	East Baton Rouge	29.36	20.44	19.67
Louisiana	Iberville	28.62	20.91	20.75
Louisiana	Jefferson	27.06	16.32	16.21
Louisiana	Lafayette	24.28	15.80	15.73
Louisiana	Ouachita	28.91	19.27	19.25
Louisiana	Rapides	30.26	18.45	18.41
Louisiana	Tangipahoa	29.61	18.00	17.93
Louisiana	Terrebonne	26.25	15.98	15.91
Louisiana	West Baton Rouge	29.08	20.25	19.52
Maine	Androscoggin	26.56	18.88	18.88
Maine	Aroostook	24.23	21.01	21.01

Maine	Cumberland	29.20	19.36	19.36
Maine	Hancock	19.43	11.95	11.95
Maine	Kennebec	26.21	18.36	18.36
Maine	Oxford	28.36	21.29	21.28
Maine	Penobscot	22.03	15.71	15.71
Maryland	Anne Arundel	36.16	25.14	25.17
Maryland	Baltimore	35.84	22.88	22.89
Maryland	Cecil	30.82	19.28	19.28
Maryland	Harford	31.21	17.50	17.51
Maryland	Montgomery	30.93	17.26	17.27
Maryland	Prince Georges	33.46	17.62	17.63
Maryland	Washington	33.43	20.44	20.44
Maryland	Baltimore City	39.01	27.46	27.49
Massachusetts	Berkshire	31.06	21.51	21.52
Massachusetts	Bristol	25.07	16.12	16.12
Massachusetts	Essex	28.72	19.16	19.17
Massachusetts	Hampden	33.13	23.10	23.10
Massachusetts	Plymouth	28.48	17.61	17.61
Massachusetts	Suffolk	32.17	21.61	21.61
Massachusetts	Worcester	30.66	20.44	20.45
Michigan	Allegan	33.82	23.40	23.40
Michigan	Bay	31.68	20.43	20.41
Michigan	Berrien	31.32	20.50	20.50
Michigan	Genesee	30.46	21.23	21.23
Michigan	Ingham	31.96	21.72	21.72
Michigan	Kalamazoo	31.17	20.31	20.30
Michigan	Kent	36.53	23.18	23.18
Michigan	Macomb	35.32	26.66	26.68
Michigan	Missaukee	24.83	15.46	15.45
Michigan	Monroe	38.88	23.40	23.38
Michigan	Muskegon	34.71	22.48	22.48
Michigan	Oakland	39.94	24.02	24.05
Michigan	Ottawa	34.24	24.81	24.79
Michigan	Saginaw	30.66	19.93	19.92

Michigan	St Clair	39.61	28.31	28.30
Michigan	Washtenaw	39.46	22.69	22.69
Michigan	Wayne	43.88	31.01	31.02
Minnesota	Cass	18.02	13.55	13.54
Minnesota	Dakota	25.42	18.43	18.44
Minnesota	Hennepin	27.25	19.03	19.04
Minnesota	Mille Lacs	22.03	16.48	16.47
Minnesota	Ramsey	28.38	20.62	20.60
Minnesota	St Louis	23.53	16.88	16.89
Minnesota	Scott	24.98	17.45	17.46
Mississippi	Adams	27.48	16.46	16.44
Mississippi	Bolivar	28.98	18.93	18.92
Mississippi	De Soto	30.82	15.48	15.47
Mississippi	Forrest	30.48	20.77	20.76
Mississippi	Harrison	29.00	18.13	18.11
Mississippi	Hinds	28.83	17.05	17.03
Mississippi	Jackson	26.96	16.19	16.16
Mississippi	Jones	31.21	20.54	20.53
Mississippi	Lee	32.18	16.38	16.36
Mississippi	Lowndes	32.44	16.97	16.95
Mississippi	Warren	30.26	18.58	18.55
Missouri	Boone	30.23	18.77	18.77
Missouri	Buchanan	30.10	20.82	20.81
Missouri	Cass	25.61	16.43	16.41
Missouri	Cedar	28.70	18.51	18.49
Missouri	Clay	28.04	19.37	19.36
Missouri	Greene	28.27	18.96	18.95
Missouri	Jackson	27.88	19.93	19.92
Missouri	Jefferson	33.43	20.73	20.71
Missouri	Monroe	27.83	17.53	17.52
Missouri	St Charles	33.16	19.40	19.33
Missouri	Ste Genevieve	31.44	18.50	18.50
Missouri	St Louis	33.21	23.16	23.14
Missouri	St Louis City	34.35	21.65	21.60

Montana	Cascade	20.15	17.37	17.37
Montana	Flathead	27.17	24.14	24.14
Montana	Gallatin	29.55	26.59	26.60
Montana	Lake	43.66	38.93	38.93
Montana	Lewis And Clark	33.53	28.67	28.69
Montana	Lincoln	42.71	36.18	36.19
Montana	Missoula	44.64	37.29	37.31
Montana	Ravalli	45.11	37.76	37.76
Montana	Rosebud	19.73	18.31	18.33
Montana	Sanders	20.42	18.39	18.39
Montana	Silver Bow	35.00	28.85	28.85
Montana	Yellowstone	19.38	16.38	16.33
Nebraska	Cass	28.30	19.97	19.96
Nebraska	Douglas	25.76	18.70	18.70
Nebraska	Hall	19.16	13.54	13.53
Nebraska	Lancaster	24.77	17.35	17.34
Nebraska	Scotts Bluff	16.66	13.67	13.66
Nebraska	Washington	24.01	17.25	17.24
Nevada	Clark	25.26	21.15	21.18
Nevada	Washoe	30.78	23.29	23.33
New Hampshire	Belknap	20.55	12.06	12.06
New Hampshire	Cheshire	30.23	20.95	20.95
New Hampshire	Coos	26.50	17.89	17.88
New Hampshire	Grafton	23.00	14.88	14.88
New Hampshire	Hillsborough	28.66	20.89	20.90
New Hampshire	Merrimack	25.65	16.43	16.44
New Hampshire	Rockingham	26.35	16.40	16.40
New Hampshire	Sullivan	28.92	18.26	18.26
New Jersey	Bergen	37.03	22.18	22.18
New Jersey	Camden	37.37	20.90	20.86
New Jersey	Essex	38.38	22.71	22.71
New Jersey	Hudson	41.43	29.74	29.74
New Jersey	Mercer	34.75	19.20	19.20
New Jersey	Middlesex	34.82	19.82	19.80

New Jersey	Morris	32.32	18.53	18.52
New Jersey	Ocean	31.56	15.97	15.97
New Jersey	Passaic	36.30	21.40	21.42
New Jersey	Union	40.47	24.58	24.57
New Jersey	Warren	34.06	20.65	20.64
New Mexico	Bernalillo	18.60	14.66	14.67
New Mexico	Chaves	15.68	12.36	12.35
New Mexico	Dona Ana	32.95	26.58	26.59
New Mexico	Grant	13.00	12.09	12.09
New Mexico	Sandoval	15.68	13.60	13.59
New Mexico	San Juan	12.40	10.94	10.93
New Mexico	Santa Fe	9.78	8.47	8.47
New York	Albany	34.26	26.70	26.72
New York	Bronx	38.87	26.13	26.13
New York	Chautauqua	29.15	16.34	16.34
New York	Erie	35.35	25.99	26.01
New York	Essex	22.45	14.01	14.01
New York	Kings	36.94	22.59	22.60
New York	Monroe	32.20	20.00	20.00
New York	Nassau	34.01	19.15	19.14
New York	New York	39.70	26.00	26.03
New York	Niagara	33.87	22.25	22.24
New York	Onondaga	27.35	17.88	17.90
New York	Orange	28.92	18.99	19.01
New York	Queens	35.56	22.26	22.27
New York	Richmond	34.93	20.75	20.74
New York	St Lawrence	22.05	16.73	16.73
New York	Steuben	27.81	15.39	15.39
New York	Suffolk	34.66	18.35	18.37
New York	Westchester	33.51	19.10	19.09
North Carolina	Alamance	31.72	17.97	17.96
North Carolina	Buncombe	30.05	15.77	15.76
North Carolina	Caswell	29.45	15.97	15.96
North Carolina	Catawba	34.53	18.93	18.92

North Carolina	Chatham	26.94	13.67	13.66
North Carolina	Cumberland	30.78	17.65	17.65
North Carolina	Davidson	31.35	18.41	18.40
North Carolina	Duplin	28.30	15.30	15.30
North Carolina	Durham	31.02	16.40	16.39
North Carolina	Edgecombe	26.78	16.68	16.68
North Carolina	Forsyth	31.92	18.32	18.32
North Carolina	Gaston	30.86	16.10	16.09
North Carolina	Guilford	30.63	17.66	17.65
North Carolina	Haywood	27.74	16.40	16.39
North Carolina	Jackson	24.96	13.83	13.82
North Carolina	Lenoir	25.20	15.68	15.68
North Carolina	McDowell	31.55	17.36	17.35
North Carolina	Martin	24.83	14.92	14.91
North Carolina	Mecklenburg	32.33	18.41	18.41
North Carolina	Mitchell	30.25	15.44	15.43
North Carolina	Montgomery	28.21	14.75	14.75
North Carolina	New Hanover	25.40	13.80	13.80
North Carolina	Onslow	24.61	14.57	14.56
North Carolina	Orange	29.35	15.34	15.33
North Carolina	Pitt	26.21	16.28	16.28
North Carolina	Robeson	29.92	16.44	16.43
North Carolina	Rowan	30.23	17.35	17.34
North Carolina	Swain	27.34	15.07	15.07
North Carolina	Wake	31.63	17.00	17.00
North Carolina	Watauga	30.43	15.65	15.64
North Carolina	Wayne	29.72	17.04	17.03
North Dakota	Billings	13.07	11.48	11.48
North Dakota	Burke	16.73	14.99	14.99
North Dakota	Burleigh	17.62	14.27	14.24
North Dakota	Cass	21.22	15.92	15.91
North Dakota	McKenzie	11.96	10.52	10.52
North Dakota	Mercer	16.98	14.44	14.44
Ohio	Athens	32.32	16.16	16.15

Ohio	Butler	39.23	23.38	23.39
Ohio	Clark	35.37	19.59	19.59
Ohio	Clermont	34.46	17.05	17.05
Ohio	Cuyahoga	44.20	29.24	29.25
Ohio	Franklin	38.51	21.56	21.58
Ohio	Greene	32.21	17.13	17.13
Ohio	Hamilton	40.60	22.26	22.28
Ohio	Jefferson	41.96	24.24	24.24
Ohio	Lake	37.16	20.80	20.81
Ohio	Lawrence	33.77	18.23	18.22
Ohio	Lorain	31.56	19.23	19.24
Ohio	Lucas	36.34	26.10	26.11
Ohio	Mahoning	36.83	21.41	21.41
Ohio	Montgomery	37.80	22.86	22.87
Ohio	Portage	34.32	18.82	18.83
Ohio	Preble	32.85	17.78	17.77
Ohio	Scioto	34.55	18.35	18.35
Ohio	Stark	36.90	20.43	20.41
Ohio	Summit	38.06	21.32	21.33
Ohio	Trumbull	36.23	21.40	21.41
Oklahoma	Caddo	23.97	16.28	16.26
Oklahoma	Cherokee	27.55	20.22	20.20
Oklahoma	Kay	31.80	25.08	24.98
Oklahoma	Lincoln	27.83	18.86	18.84
Oklahoma	Mayes	28.71	21.63	21.59
Oklahoma	Muskogee	29.54	20.84	20.81
Oklahoma	Oklahoma	27.12	18.38	18.36
Oklahoma	Ottawa	29.14	20.39	20.38
Oklahoma	Pittsburg	26.37	18.46	18.45
Oklahoma	Sequoyah	31.43	22.77	22.76
Oklahoma	Tulsa	30.37	21.43	21.40
Oregon	Jackson	33.72	29.00	29.01
Oregon	Klamath	44.08	37.84	37.85
Oregon	Lane	48.95	42.20	42.20

Oregon	Multnomah	29.88	25.17	25.18
Oregon	Union	27.38	23.15	23.15
Pennsylvania	Adams	34.93	20.14	20.14
Pennsylvania	Allegheny	64.27	40.42	40.41
Pennsylvania	Beaver	43.42	23.50	23.48
Pennsylvania	Berks	37.71	27.05	27.06
Pennsylvania	Bucks	34.01	21.33	21.32
Pennsylvania	Cambria	39.04	19.85	19.82
Pennsylvania	Centre	36.28	21.23	21.22
Pennsylvania	Chester	36.70	22.60	22.60
Pennsylvania	Cumberland	38.00	25.91	25.92
Pennsylvania	Dauphin	38.04	25.99	25.99
Pennsylvania	Delaware	35.24	21.55	21.44
Pennsylvania	Erie	34.46	20.05	20.06
Pennsylvania	Lackawanna	31.55	18.06	18.09
Pennsylvania	Lancaster	40.83	30.18	30.19
Pennsylvania	Lehigh	36.40	24.35	24.36
Pennsylvania	Luzerne	32.46	20.68	20.69
Pennsylvania	Mercer	36.30	20.46	20.48
Pennsylvania	Northampton	36.72	23.22	23.20
Pennsylvania	Perry	30.46	20.38	20.38
Pennsylvania	Philadelphia	37.30	22.09	21.92
Pennsylvania	Washington	38.14	19.91	19.90
Pennsylvania	Westmoreland	37.12	18.87	18.86
Pennsylvania	York	38.24	28.30	28.35
Rhode Island	Providence	30.62	20.31	20.33
South Carolina	Charleston	27.93	15.73	15.73
South Carolina	Chesterfield	28.77	15.90	15.89
South Carolina	Edgefield	32.23	17.07	17.06
South Carolina	Florence	28.81	16.43	16.42
South Carolina	Greenville	32.55	19.07	19.07
South Carolina	Greenwood	30.01	16.09	16.08
South Carolina	Horry	28.30	16.60	16.59
South Carolina	Lexington	32.86	19.13	19.14

South Carolina	Oconee	27.98	14.51	14.52
South Carolina	Richland	33.20	18.70	18.70
South Carolina	Spartanburg	32.46	17.61	17.61
South Dakota	Brookings	23.54	16.73	16.73
South Dakota	Brown	18.73	14.06	14.05
South Dakota	Codington	23.67	17.46	17.46
South Dakota	Custer	14.36	11.63	11.63
South Dakota	Jackson	12.73	10.22	10.21
South Dakota	Minnehaha	24.17	17.31	17.32
South Dakota	Pennington	18.58	16.32	16.32
Tennessee	Blount	32.54	18.44	18.43
Tennessee	Davidson	33.50	17.86	17.85
Tennessee	Dyer	31.92	17.49	17.49
Tennessee	Hamilton	33.53	20.65	20.65
Tennessee	Knox	36.66	20.01	20.01
Tennessee	Lawrence	28.48	14.78	14.78
Tennessee	Loudon	32.20	19.75	19.74
Tennessee	Mc Minn	32.73	17.40	17.40
Tennessee	Maury	30.96	16.50	16.48
Tennessee	Montgomery	36.30	17.63	17.62
Tennessee	Putnam	32.66	16.11	16.10
Tennessee	Roane	30.24	15.46	15.45
Tennessee	Shelby	33.50	16.54	16.54
Tennessee	Sullivan	31.13	18.69	18.69
Tennessee	Sumner	33.66	15.02	15.01
Texas	Bowie	29.42	18.71	18.69
Texas	Dallas	27.44	17.79	17.79
Texas	Ector	17.81	13.39	13.39
Texas	El Paso	22.93	18.95	18.94
Texas	Harris	30.81	20.24	19.91
Texas	Harrison	25.95	17.24	17.22
Texas	Hidalgo	26.42	22.15	22.15
Texas	Nueces	27.55	18.24	18.19
Texas	Orange	27.78	18.19	18.08

Texas	Tarrant	25.76	17.07	17.07
Utah	Box Elder	33.20	25.67	25.69
Utah	Cache	56.95	40.95	41.00
Utah	Davis	38.95	29.47	29.49
Utah	Salt Lake	50.14	37.77	37.79
Utah	Tooele	30.53	23.95	23.99
Utah	Utah	44.00	33.47	33.54
Utah	Weber	38.58	28.79	28.87
Vermont	Addison	31.73	19.82	19.82
Vermont	Bennington	26.47	17.09	17.10
Vermont	Chittenden	30.13	22.03	22.03
Vermont	Rutland	30.60	25.42	25.44
Virginia	Arlington	34.18	18.66	18.69
Virginia	Charles City	31.76	16.74	16.73
Virginia	Chesterfield	31.25	15.58	15.57
Virginia	Fairfax	34.47	18.87	18.88
Virginia	Henrico	31.95	16.65	16.65
Virginia	Loudoun	34.45	19.12	19.13
Virginia	Page	30.06	16.33	16.32
Virginia	Bristol City	30.24	15.94	15.93
Virginia	Hampton City	29.01	15.82	15.82
Virginia	Lynchburg City	30.71	15.67	15.66
Virginia	Norfolk City	29.66	16.72	16.72
Virginia	Roanoke City	32.70	17.53	17.52
Virginia	Salem City	34.06	18.79	18.78
Washington	King	29.16	24.78	24.81
Washington	Pierce	41.82	36.25	36.28
Washington	Snohomish	34.36	31.22	31.21
Washington	Spokane	29.86	22.25	22.26
West Virginia	Berkeley	34.51	23.71	23.71
West Virginia	Brooke	43.90	25.12	25.13
West Virginia	Cabell	35.10	18.10	18.07
West Virginia	Hancock	40.64	20.85	20.85
West Virginia	Harrison	33.53	16.07	16.04

West Virginia	Kanawha	36.98	18.35	18.33
West Virginia	Marion	33.68	15.86	15.83
West Virginia	Marshall	33.98	17.53	17.52
West Virginia	Monongalia	35.65	14.68	14.64
West Virginia	Ohio	32.00	16.65	16.64
West Virginia	Raleigh	30.67	14.26	14.28
West Virginia	Summers	31.26	14.14	14.14
West Virginia	Wood	35.44	17.96	17.94
Wisconsin	Ashland	18.61	12.58	12.58
Wisconsin	Brown	36.56	31.28	31.21
Wisconsin	Dane	35.57	25.62	25.64
Wisconsin	Dodge	31.82	21.64	21.64
Wisconsin	Forest	25.26	17.02	17.00
Wisconsin	Grant	34.35	25.06	25.07
Wisconsin	Kenosha	32.78	22.65	22.66
Wisconsin	Manitowoc	29.70	22.72	22.71
Wisconsin	Milwaukee	39.92	28.15	28.18
Wisconsin	Outagamie	32.87	26.53	26.53
Wisconsin	Ozaukee	32.53	22.60	22.59
Wisconsin	St Croix	26.66	19.75	19.75
Wisconsin	Sauk	28.63	21.53	21.54
Wisconsin	Taylor	25.38	18.17	18.18
Wisconsin	Vilas	22.61	16.43	16.43
Wisconsin	Waukesha	35.48	25.25	25.27
Wyoming	Campbell	18.63	17.12	17.11
Wyoming	Converse	10.00	9.30	9.29
Wyoming	Fremont	29.80	23.98	23.99
Wyoming	Laramie	11.93	9.94	9.93
Wyoming	Sheridan	30.86	27.21	27.25

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC	Publication No. EPA-454/R-12-004 August, 2012