Interstate Transport Modeling for the 2015 Ozone National Ambient Air Quality Standard

Comprehensive Air Quality Model with Extensions (CAMx) Source Apportionment Modeling Protocol

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CONTENTS

FIGURES

1 Introduction

The Lake Michigan Air Directors Consortium (LADCO) was established by the states of Illinois, Indiana, Michigan, and Wisconsin in 1989. The four states and EPA signed a Memorandum of Agreement (MOA) that initiated the Lake Michigan Ozone Study and identified LADCO as the organization to oversee the study. Additional MOAs were signed by the states in 1991 (to establish the Lake Michigan Ozone Control Program), January 2000 (to broaden LADCO's responsibilities), and June 2004 (to update LADCO's mission and reaffirm the commitment to regional planning). In March 2004, Ohio joined LADCO. Minnesota joined the Consortium in 2012. LADCO consists of a Board of Directors (i.e., the State Air Directors), a technical staff, and various workgroups. The main purposes of LADCO are to provide technical assessments for and assistance to its member states, and to provide a forum for its member states to discuss regional air quality issues.

LADCO is preparing to conduct regional air quality modeling and analysis using the Comprehensive Air Quality Model with Extensions (CAMx). The CAMx Anthropogenic Precursor Culpability Assessment (APCA) tool will be used to assess the impacts of interstate transport of air pollution on ground level ozone concentrations in the Midwest and Northeast U.S. The motivation for this work is to support the statutory obligations of the LADCO states under Clean Air Section 110(a)(2)(D)(i)(i), which requires states to submit "Good Neighbor" state implementation plans (SIPs). These SIP revisions are plans to prohibit emissions in one state from interfering with the attainment or maintenance of the National Ambient Air Quality Standards (NAAQS) in another state.

In support of previous rulemakings (CSAPR, 2011; CSAPR Update, 2016), the U.S. EPA in partnership with states developed a four-step interstate transport framework to address the "Good Neighbor" provisions of the ozone and $PM_{2.5}$ NAAQS. This framework established the following four steps to identify and mitigate high ozone concentrations at locations that were at risk of violating the NAAQS in the future: (1) identify monitors with predicted air quality problems in the future year, (2) identify the upwind states that are "linked" through air mass transport to the problem monitors, (3) identify emissions reductions necessary to prevent upwind states from contributing significantly to NAAQS violations at a downwind monitor, and (4) adopt permanent and enforceable measures needed to achieve the identified emissions reductions.

LADCO will use CAMx to predict ozone concentration in 2023 to address steps (1) and (2) of the four-step interstate transport framework. The LADCO CAMx modeling results will be used to identify ozone monitoring sites that may have nonattainment or maintenance problems for the 2015 ozone NAAQS in 2023. The modeling outputs will also be used to quantify the contributions of emissions in upwind states to the monitors in downwind states that are projected to have NAAQS attainment problems in 2023. In following with U.S. EPA's use of air quality modeling in the CSAPR and CSAPR Update, LADCO will use a screening threshold of 1% of the 2015 Ozone NAAQS (0.70 ppb) to establish links between an upwind state and downwind nonattainment or maintenance problems at surface ozone monitors in the Midwest and Northeast U.S.

This document describes how LADCO will use CAMx source apportionment modeling to link upwind and downwind states and to identify upwind emissions sources that significantly contribute to downwind NAAQS attainment issues. The CAMx APCA modeling outputs of this work will be presented to the LADCO states to support the "Good Neighbor" SIP provisions of their 2015 ozone NAAQS Infrastructure SIPs (iSIP) that are due to EPA in October 2018.

1.1 Organization of the Modeling Protocol

This document presents the LADCO protocol for projecting year 2023 source-receptor relationships using the CAMx APCA technique. This document is organized into the following sections. Section 2 describes the 2023 Air Quality Modeling Platform that we propose to use to forecast 2023 ozone. Section 3 describes our approach for estimating Future Ozone Design Values. This section also includes a discussion on the methods that we will use for identifying sites that are forecast to have ozone NAAQS attainment problems. Section 4 describes the Ozone Source Apportionment modeling that will use to link source regions with problem monitors in the future year. Section 5 describes how LADCO plans to display the Results of the CAMx modeling and source contribution assessments from this study.

2 2023 Air Quality Modeling Platform

LADCO will base our 2023 ozone air quality and interstate transport forecasts on the CAMx modeling platform released by the U.S. EPA in October 2017 in the support of the Interstate Transport SIPs for the 2008 Ozone NAAQS (US EPA, 2017). The EPA 2023EN modeling platform is projected from a 2011 base year and includes a complete set of CAMx inputs, including meteorology, initial and boundary conditions, and emissions data. The future year, or 2023, component of the air quality modeling platform refers to the emissions data only. All other CAMx inputs, including the meteorology data simulated with the Weather Research Forecast (WRF) model, represent year 2011 conditions. We will use the majority of the data and software provided by EPA for this platform, with a few exceptions described below.

2.1 Modeling Year Justification

LADCO selected 2011 as a modeling year for this study because CAMx input data for 2011 are widely available and relatively well-evaluated. 2011 has also been identified as a good year for studying ozone in the Eastern U.S. The US EPA (2015) noted that year 2011 meteorology in the Eastern U.S., including the LADCO region, was warmer and drier than the climatic norm. As compared to other recent years, the summer of 2011 represented typical conditions conducive to high observed ozone concentrations in the Midwest and Northeast U.S.

The triennial National Emissions Inventory (NEI) also synchronized with 2011. Since its first release in 2014, the NEI2011 has undergone several revisions, with the most recent updates to version 6.3 released in October 2017 as part of the U.S. EPA's final 2008 ozone NAAQS interstate transport assessment (US EPA, 2017). The 2011-based emissions modeling platforms are currently the best available national-scale datasets for simulating air quality in the U.S. The U.S. EPA used version 6.3 of the NEI2011-based emissions modeling platform for their preliminary assessment of ozone transport for the 2015 ozone NAAQS (US EPA, 2016). Given recent use of 2011-based data for evaluating interstate transport by the U.S. EPA and the lack of a more contemporary national emissions modeling platform, LADCO believes that using 2011-based data and emissions projections are justified for assessing interstate ozone transport.

2.2 Air Quality Model Configuration

LADCO will base the CAMx air quality modeling platform for this study on the configuration that the U.S. EPA used to support both their October 2017 memo on Interstate Transport SIPs for the 2008 Ozone NAAQS (US EPA, 2015) and their December 2016 technical support document on a preliminary assessment of Interstate Transport for the 2015 Ozone NAAQS (US EPA, 2016). LADCO will CAMx v6.40 (Ramboll-Environ, 2016) as the photochemical grid model (PGM) for this study. CAMx is a three-dimensional, Eulerian air quality model that simulates the chemical transformation and physical transport processes of air pollutants in the troposphere. It includes capabilities to estimate the concentrations of primary and secondary gas and particle phase air pollutants, and dry and wet deposition, from urban to continental spatial scales. As CAMx associates source-level air pollution emissions estimates with air pollution concentrations, it can be used to design and assess emissions reduction strategies pursuant to NAAQS attainment goals.

LADCO selected CAMx for this study because it is a component of recent U.S. EPA modeling platforms for investigating the influence of interstate transport on ozone, and because it has source apportionment capabilities for quantifying air pollution source-receptor relationships. As CAMx is a component of U.S. EPA studies with a similar scope to this project, LADCO is able to leverage the data and software elements that are distributed with U.S. EPA regulatory modeling platforms. Using these elements will save LADCO significant resources relative to building a modeling platform from scratch. CAMx is also instrumented with source apportionment capabilities that will allow LADCO to investigate the sources of air pollution impacting ozone monitors within and downwind of the LADCO region.

Figure 1 shows the U.S. EPA transport modeling domain for the continental U.S. A 12-km uniform grid covers all of the continental U.S. and includes parts of Southern Canada and Northern Mexico. The domain has 25 vertical layers with a model top at about 17,550 meters (50 mb). LADCO will use the same U.S. EPA 12-km domain for this project because it will allow the use of meteorology, initial and boundary conditions, and emissions data that are freely available from U.S. EPA.

As the focus of this study is on ozone, LADCO will use CAMx to simulate the ozone season. LADCO will simulate May through September 2011 with CAMx as individual months using 10-day model spin-up periods for each month.

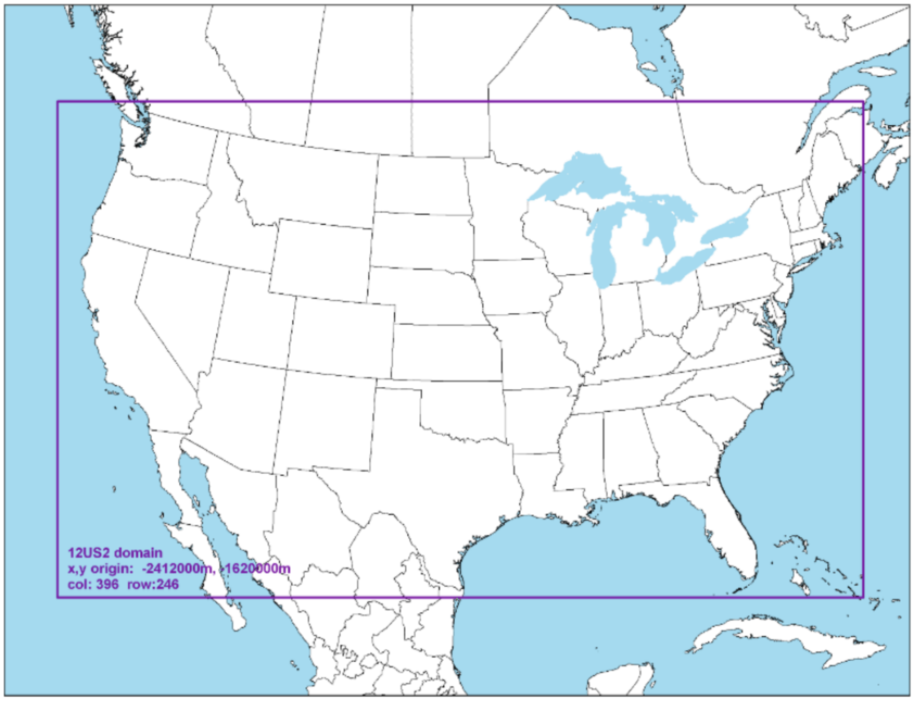

Figure 1. CAMx 12-km modeling domain

2.3 Meteorology Data

LADCO will use the U.S. EPA 2011 WRF data for this study (US EPA, 2017). The U.S. EPA used version 3.4 of the WRF model, initialized with the 12-km North American Model (NAM) from the National Climatic Data Center (NCDC) to simulate 2011 meteorology. Complete details of the WRF simulation, including the input data, physics options, and four-dimensional data assimilation (FDDA) configuration are detailed the EPA 2008 Transport Modeling technical support document (US EPA, 2015). U.S. EPA prepared the WRF data for input to CAMx with version 4.3 of the WRFCAMx software.

2.4 Initial and Boundary Conditions

LADCO will use 2011 initial and boundary conditions for CAMx generated by the U.S. EPA from the GEOS-Chem Global Chemical Transport Model (US EPA, 2017). EPA generated hourly, one-way nested boundary conditions (i.e., global-scale to regional-scale) from a 2011 2.0 degree x 2.5 degree GEOS-Chem simulation. Following the convention of the U.S. EPA ozone transport modeling, year 2011 GEOS-Chem boundary conditions will be used for the 2023 modeling for this study.

2.5 Emissions Data

The 2023 emissions data for this study will be based on the U.S. EPA 2011v6.3 ("EN") emissions modeling platform (US EPA, 2017b). US EPA generated this platform for their final assessment of Interstate Transport for the 2008 ozone NAAQS. Updates from earlier 2011-based emissions modeling platforms included a new engineering approach for forecasting emissions from Electricity Generating Units (EGUs). The US EPA made several changes to the base 2011 and forecasted 2023 emissions in the "EN" platform relative to the earlier "EL" platform (US EPA, 2017b).

LADCO will replace the EGU emissions in the EN platform with 2023 EGU forecasts estimated with the ERTAC EGU Tool[1]. We believe that the ERTAC EGU Tool provides better estimates of the growth and control forecasts for EGUs in the Midwest and Northeast states than the EPA approach used for the "EN" platform. Figure 2 compares state total annual NOx emissions across different inventory years for the LADCO states. The EPA Engineering Analysis NOx emissions used for the 2023EN platform are shown in green. The ERTAC EGU 2023 NOx emissions projection shown in blue ranges from 3% lower than the EPA estimate for MI to 47% higher than the EPA estimate for OH. Averaged across all of the LADCO states, ERTAC EGU estimates 16% higher EGU NOx emissions in 2023 relative to the EPA Engineering Analysis. LADCO will directly use the EPA EN Platform emissions estimates for all other inventory sectors.

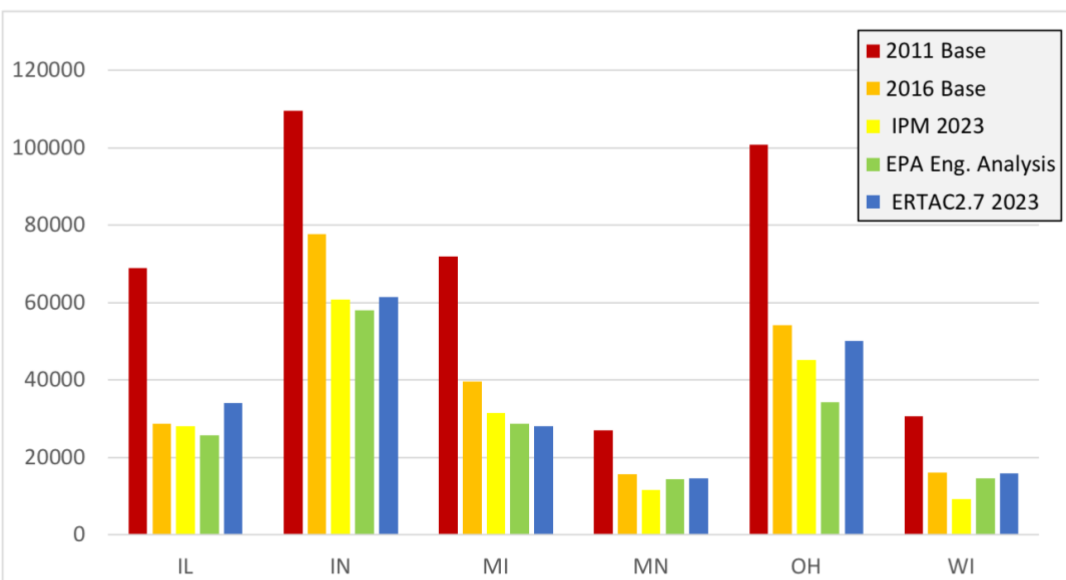

Figure 2. LADCO state annual total EGU NOx emissions (tons/year)

[1] http://www.marama.org/2013-ertac-egu-forecasting-tool-documentation

2.6 U.S. EPA Modeling Platform Benchmarking

LADCO will run a benchmarking simulation of the U.S. EPA 2011 and 2023 CAMx "EN" modeling platforms on our computing cluster. The benchmark simulation will use the exact same CAMx version and configuration as was used by U.S. EPA. The purpose of these simulations is to confirm that LADCO has correctly installed and configured the EPA data and software on our cluster. As LADCO will not be re-running the full base year simulation, we need to verify our installation of the modeling platform on our computing cluster in order to take advantage of the extensive vetting and evaluation of the platform by U.S. EPA. By reproducing the U.S. EPA CAMx modeling results on the LADCO computer, we will inherit by proxy the model evaluation completed by the U.S. EPA, thereby validating the use of the platform for this study.

LADCO will verify the platform installation on our computing systems by comparing the results of the U.S. EPA and LADCO 2011 and 2023 EN simulations. We will conduct limited a time period simulations for one summer month, with spin up, for comparison with the U.S. EPA modeling. LADCO will compare the simulations using daily average and daily maximum 1-hour and 8-hour ozone concentrations at monitoring locations in the Midwest and Northeast.

2.7 Model Performance Evaluation

As future year air quality forecasts cannot be compared to observations for evaluation, LADCO is relying on the model performance evaluation (MPE) conducted by the U.S. EPA on the base modeling platform that we are using for this study (US EPA, 2016). In addition to the MPE for the base year CAMx simulation, the U.S. EPA reported full MPE results for the 2011 WRF modeling (US EPA, 2014) used to drive the CAMx simulations.

LADCO will compare the 2023 ozone forecasts that we generate in this study against the 2023 U.S. EPA "EN" platform results. We will compare daily average and daily maximum 1-hour and 8-hour ozone concentrations at monitoring locations in the Midwest and Northeast. The purpose of this comparison will be to evaluate the changes in the LADCO forecasts that result from the change in the EGU emissions forecasts used for this study relative to the U.S. EPA 2023 modeling.

3 Future Year Ozone Design Values

LADCO will follow the U.S. EPA Draft Guidance for Attainment Demonstration Modeling (US EPA, 2014b), herein referred to as the U.S. EPA Guidance, to calculate future year design values (DVFs) for monitors in the Midwest and Northeast U.S. As we are using a base year of 2011, the base year design values (DVCs) will be estimated using surface observations for the years 2009-2013. LADCO will estimate the DVFs with version 1.2 of the Software for

Modeled Attainment Test Community Edition (SMAT-CE)[2]. SMAT-CE will be configured to use the average ozone concentration in a 3x3 matrix around each monitor across the 10 highest modeled days, per the U.S. EPA Guidance. Additional details of the approaches that LADCO will employ for calculating DVFs are provided in the U.S. EPA's Ozone Transport Modeling Assessments (US EPA, 2016; US EPA, 2015).

LADCO will use the DVFs to identify nonattainment and maintenance sites in 2023 using the most recent 3-year monitored design values (2015-2017) per the CSAPR Update methodology (CSAPR Update, 2016). Under this methodology sites with average DVFs that exceed the 2015 NAAQS (71 ppb or greater) and that are currently measuring nonattainment would be considered nonattainment receptors in 2023. Further, monitoring sites with maximum DVFs that exceeds the NAAQS would be considered a maintenance receptor in 2023. Under the CSAQPR Update, maintenance only receptors include both those sites where the average DVF is below the NAAQS, but the maximum DVF is above the NAAQS; and monitoring sites with average DVFs above the NAAQS but with DVCs that are below the NAAQS.

The sites that LADCO identifies through this process as having potential for nonattainment and maintenance designations for the 2015 ozone NAAQS in 2023 will be the focus of our source apportionment analyses. We will use the CAMx source apportionment APCA technique to assess the impacts of upwind sources on nonattainment and maintenance monitors in downwind states.

4 Ozone Source Apportionment Modeling

LADCO will use the CAMx Anthropogenic Precursor Culpability Assessment (APCA) tool to calculate emissions tracers for identifying upwind sources of ozone at downwind monitoring sites. We selected the APCA technique because it more appropriately associates ozone formation to anthropogenic sources than the CAMx Ozone Source Apportionment Technique (OSAT). If any anthropogenic emissions are involved in a reaction that leads to ozone formation, even if the reaction occurs with biogenic VOC or NOx, APCA tags the ozone as anthropogenic in origin.

LADCO will tag both source regions and emissions inventory sectors for our APCA modeling. LADCO will create emissions tracers for the source regions listed in Table 1 and shown in Figure 3 and Figure 4.

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

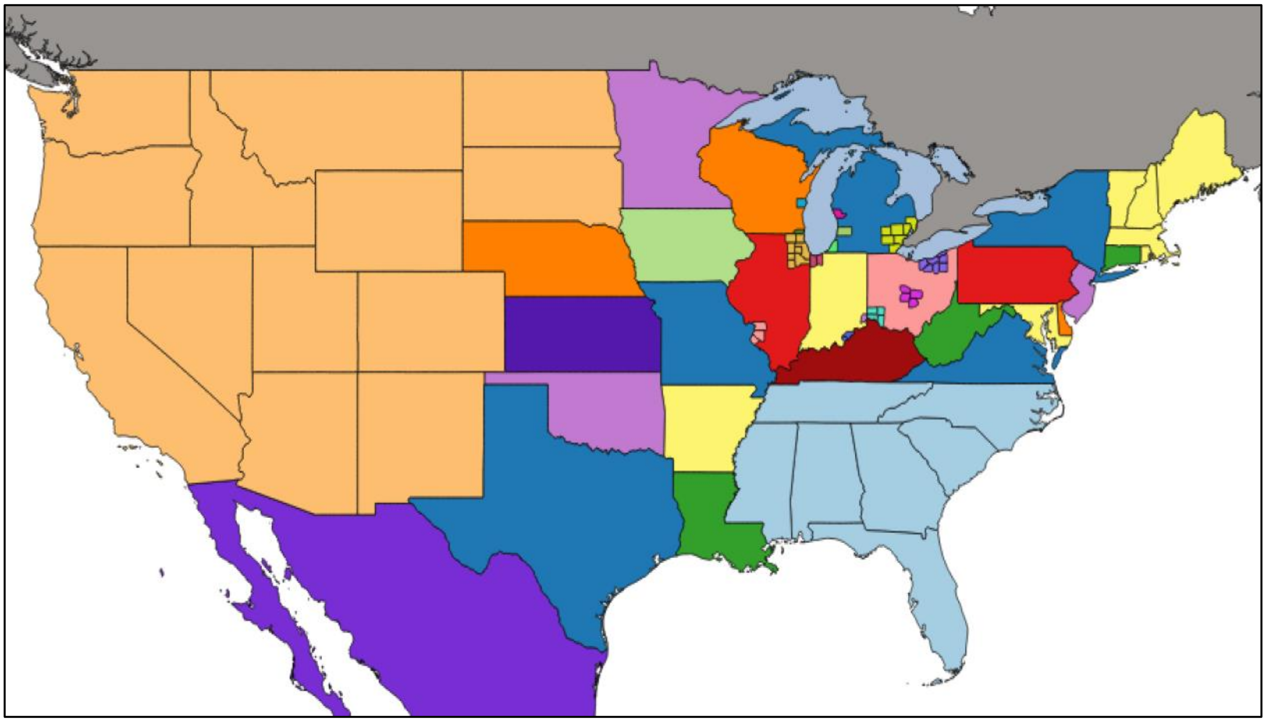

Figure 3. CAMx APCA Source Regions

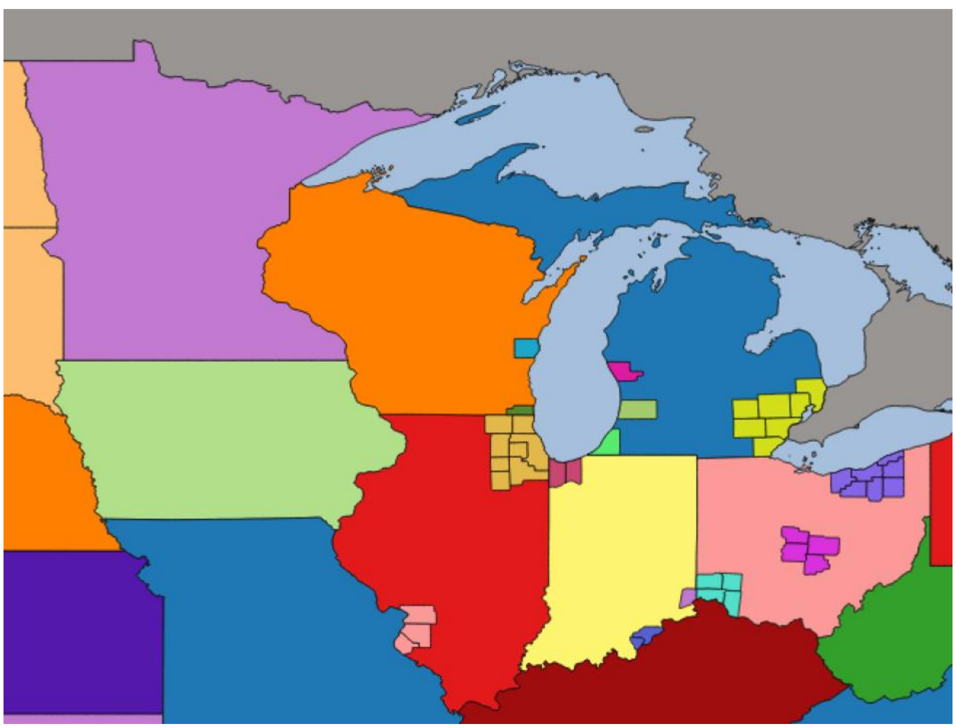

Figure 4. CAMx APCA Source Regions, LADCO zoom

Within each source region, LADCO will tag the following inventory sectors:

- All sources
- Onroad Mobile
- Offroad Mobile
- EGU-Point
- Non-EGU Point
- Non-Point/Area
- Commercial Marine
- Fires
- Biogenic

The 12-km grid that will be used for the CAMx modeling is too coarse to resolve fine scale spatial details of emission source locations, particularly where large point sources are located close to state borders. To ensure that the CAMx APCA tool correctly attributes large point sources to the state in which they are located, LADCO will manually tag individual point sources along state borders. Using a feature in the CAMx APCA tool called point source override, LADCO will force the ozone tracers from these source to be associated with the state in which the sources are located. Figure 5 shows a map of EGUs in the LADCO region. The green squares on the map indicate the sources near the LADCO state borders that will be considered for the point source override treatment in CAMx.

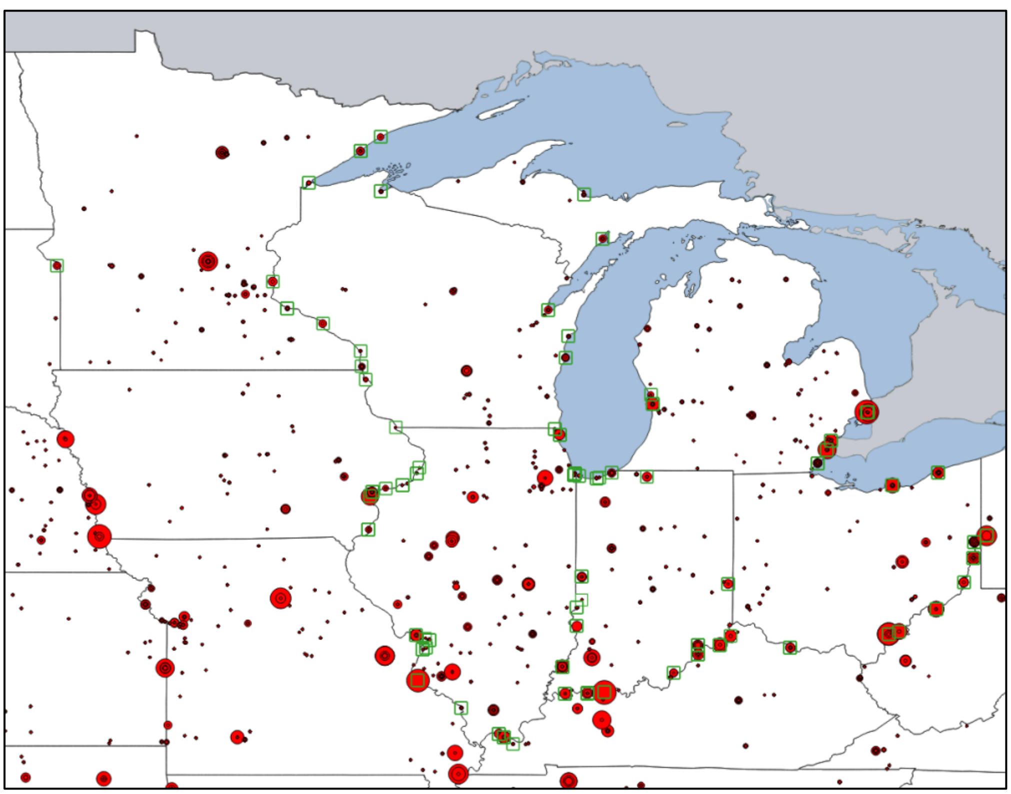

Figure 5. EGU sources in the LADCO region, with green squares indicating potential sources for the CAMx APCA point source override.

We will use the CAMx APCA results to calculate an ozone contribution metric for each potential nonattainment and maintenance monitor in the Midwest and Northeast U.S. (US EPA, 2016). The contribution metric is designed to provide a reasonable representation of individual states and sources to the design values at downwind monitors in future years. In particular, per the CSAPR methodology, downwind monitors are considered to be linked to upwind sources if a modeled contribution assessment shows impacts at a monitor that equal or exceeds 1% of the NAAQS. For the 2015 ozone NAAQS, source regions (and inventory sectors) that contribute 0.70 ppb or more to a monitor would be considered significant contributors to a nonattainment or maintenance monitor.

5 Results

LADCO will display the results of the 2023 modeling using graphical and tabulated summaries of the data. We will generate spatial plots of CAMx ozone concentrations for the 2011 and 2023 modeling years, along with difference plots that show how ozone is forecasted to change in the future. Maps and tabular summaries of the future year design values will illustrate the locations and severity of ozone NAAQS issues at maintenance and nonattainment monitors in 2023. We will generate graphical and tabulated APCA results to demonstrate the linkages between sources and nonattainment and maintenance monitors in 2023. We will use region-sector contribution plots (Figure 6) and spatial plots of APCA tracers (Figure 7) to display the source apportionment modeling results.

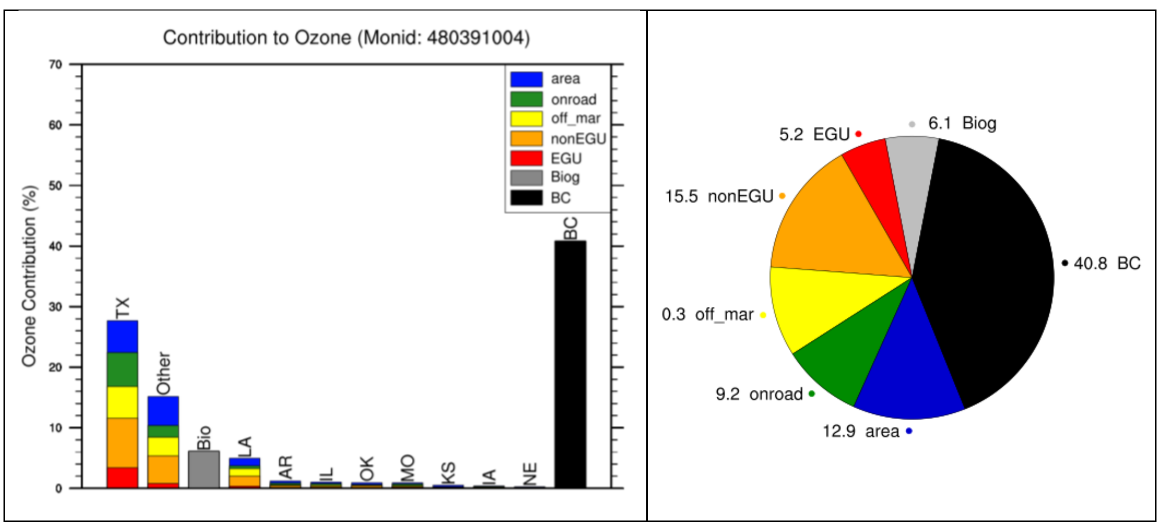

Figure 6. Example APCA region-inventory sector contribution plots

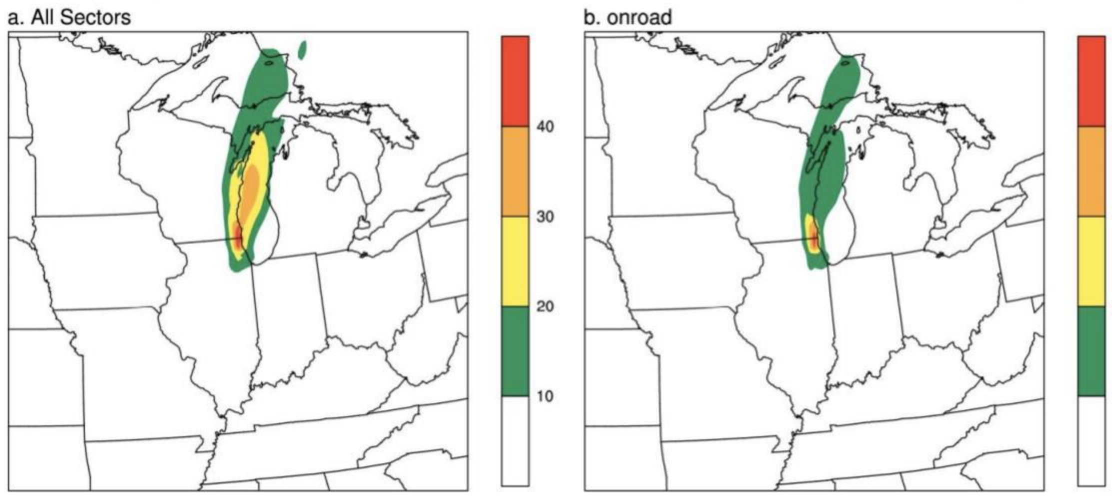

Figure 7. Example APCA tracer concentration spatial plot (units: ppbV)

6 References

Cross State Air Pollution Rule (CSAPR), 76 Fed. Reg. § 48,208 (final rule Aug 8, 2011)(to be codified at 40 C.F.R. pts. 51, 52, 72, 78, 97).

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Table 1. APCA Source Regions

FIPS	APCA Region ID	NAME
17031	1	Chicago-Cook
17043	1	Chicago-DuPage
17063	1	Chicago-Grundy
17089	1	Chicago-Kane
17093	1	Chicago-Kendall
17097	1	Chicago-Lake
17111	1	Chicago-McHenry
17197	1	Chicago-Will
18089	2	Gary-Lake
18127	2	Gary-Porter
55059	3	Chicago-Kenosha
55117	4	Sheboygan
17	6	Illinois
55	7	Wisconsin
18	8	Indiana
39	9	Ohio
26	10	Michigan
27	11	Minnesota
19	12	Iowa
29	13	Missouri
5	14	Arkansas
22	15	Louisiana
48	16	Texas
40	17	Oklahoma
20	18	Kansas
31	19	Nebraska
23	20	Maine
33	20	New Hampshire
50	20	Vermont
25	20	Massachusetts
44	20	Rhode Island

FIPS	APCA Region ID	NAME
9	21	Connecticut
36	22	New York
34	23	New Jersey
42	24	Pennsylvania
10	25	Delaware
24	26	Maryland
	27	Washington DC
54	28	West Virginia
51	29	Virginia
37	30	North Carolina
45	30	South Carolina
47	30	Tennessee
13	30	Georgia
21	31	Kentucky
1	30	Alabama
28	30	Mississippi
12	30	Florida
35	32	New Mexico
4	32	Arizona
8	32	Colorado
49	32	Utah
56	32	Wyoming
30	32	Montana
38	32	North Dakota
46	32	South Dakota
16	32	Idaho
53	32	Washington
41	32	Oregon
6	32	California
32	32	Nevada
	33	Canada
	34	Great Lakes

FIPS	APCA Region ID	NAME
18019	35	Lousiville-Clark
18029	36	Cincinnati-Dearborn
18043	35	Lousiville-Floyd
17119	37	St. Louis-Madison
17133	37	St. Louis-Monroe
17163	37	St. Louis-St Clair
39017	38	Cincinnati-Butler
39025	38	Cincinnati-Clermont
39061	38	Cincinnati-Hamilton
39165	38	Cincinnati-Warren
39035	39	Cleveland-Cuyahoga
39055	39	Cleveland-Geauga
39085	39	Cleveland-Lake
39093	39	Cleveland-Lorain
39103	39	Cleveland-Medina
39133	39	Cleveland-Portage
39153	39	Cleveland-Summit
39041	40	Columbus-Delaware
39045	40	Columbus-Fairfield
39049	40	Columbus-Franklin
39089	40	Columbus-Licking
26093	41	Detroit-Livingston
26099	41	Detroit-Macomb
26115	41	Detroit-Monroe
26125	41	Detroit-Oakland
26147	41	Detroit-St Clair
26161	41	Detroit-Washtenaw
26163	41	Detroit-Wayne
26121	42	Muskegon
26005	43	Allegan
26021	44	Berrien