Attachment A

ATTAINMENT DEMONSTRATION AND TECHNICAL SUPPORT DOCUMENT

Appendix A1:
Attainment Demonstration Modeling for the 2008 Ozone National Ambient Air Quality Standard, Lake Michigan Air Directors Consortium, Technical Support Document

Appendix A2:
Air Quality System (AQS) Monitoring Data Values for Indiana's Portion (Lake and Porter Counties), Illinois' Portion, and Wisconsin's Portion of the Chicago-Naperville, IL-IN-WI, 2008 8-Hour Ozone Nonattainment Area Year

Appendix A3:
Mobile Source Emission Budgets and MOVES2014a Input Data and Parameters, Northwest Indiana Regional Planning Commission (NIRPC) Lake, Porter, and LaPorte Counties, Indiana

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ATTAINMENT DEMONSTRATION AND TECHNICAL SUPPORT DOCUMENT FOR INDIANA'S PORTION OF THE CHICAGO-NAPERVILLE, ILLINOIS-INDIANA-WISCONSIN (IL-IN-WI), 2008 8-HOUR OZONE NONATTAINMENT AREA

Lake and Porter Counties, Indiana

Prepared By:
The Indiana Department of Environmental Management

December 2020

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APPENDIX A3 Mobile Source Emission Budgets and MOVES2014a Input Data and Parameters. Northwest Indiana Regional Planning Commission (NIRPC) Lake, Porter, and LaPorte Counties, Indiana

ATTAINMENT DEMONSTRATION AND TECHNICAL SUPPORT DOCUMENT FOR INDIANA'S PORTION OF THE CHICAGO-NAPERVILLE, ILLINOIS-INDIANA-WISCONSIN (IL-IN-WI), 2008 8-HOUR OZONE NONATTAINMENT AREA

Lake and Porter Counties, Indiana

1.0 OVERVIEW

1.1 Introduction

The Chicago-Naperville, IL-IN-WI, nonattainment area for the 2008 8-hour ozone standard was re-classified from moderate to serious effective September 23, 2019 (84 FR 44238). This United States Environmental Protection Agency (U.S. EPA) final ruling was a result of the area not attaining the 2008 8-hour ozone National Ambient Air Quality Standard (NAAQS) by the attainment deadline of July 20, 2018. Sections 172 and Section 182 of Clean Air Act (CAA) stipulate the requirements nonattainment areas must meet. One of the requirements for nonattainment areas designated as serious is to develop state implementation plans (SIPs) that expeditiously attain and maintain the standard. The plan must include a demonstration that the area will meet the ambient air quality standard by the revised applicable attainment date of July 20, 2021.

In accordance with U.S. EPA guidance, this document addresses the CAA's serious nonattainment area requirements found in the final SIP Requirements Rule for the 2008 ozone NAAQS, 40 Code of Federal Register (CFR) 51.1100 *et seq* for a serious area SIP revision. These requirements are further discussed in Section 2.0. Indiana demonstrates that with the combination of current clean air measures and the implementation of local and federally required control measures, air quality in the Chicago nonattainment area will meet the 2008 8-hour ozone standard by July 20, 2021, and beyond. The structure and content of this document address each of the elements required by the CAA and U.S. EPA guidance.

1.2 Ozone Background

Ground level ozone is not emitted directly into the air but is created by chemical reactions with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Ozone formation is promoted by strong sunlight, warm temperatures, and light winds; elevated levels predominantly occur during the hot summer months. Since ozone is formed in the ambient air, control of ozone focuses upon the reduction of precursor emissions (i.e. NO_x and VOCs).

NO_x is formed from the high-temperature reaction of nitrogen and oxygen during combustion processes in sources such as electric utility boilers, industrial fuel-burning sources, and motor vehicles. VOCs include many industrial solvents and coatings, as well as the hydrocarbons (HCs) that are emitted by motor vehicles as evaporative losses from gasoline and tailpipe emissions of unburned HC. Ground level ozone is

associated with several adverse health and environmental impacts, including respiratory impairment and damage to crops and vegetation.

1.3 National Ambient Air Quality Standards (NAAQS)

Ozone is one of the six criteria air pollutants that scientists have identified as being particularly harmful to humans and the environment. NAAQS have been developed for these six pollutants and are used as measurements of air quality. The CAA of 1990 and its Amendments require U.S. EPA to set primary standards at a level judged to be "requisite to protect the public health with an adequate margin of safety" and establish secondary standards that are requisite to protect public welfare from "any known or anticipated effects associated with the pollutant in the ambient air," including effects on crops, vegetation, wildlife, buildings and national monuments, and visibility.

In 1997, U.S. EPA revised the air quality standards for ozone, replacing the 1979 1-hour standard with an 8-hour ozone standard set at 0.08 parts per million (ppm). The standard was challenged legally and upheld by the U.S. Supreme Court in February of 2001. On March 12, 2008, U.S. EPA strengthened the 8-hour ozone standard to a level of 0.075 ppm. On October 1, 2015, U.S. EPA further strengthened the 8-hour ozone standard to a level of 0.070 ppm. The chronicle of strengthening the 8-hour ozone standard is shown in Table 1.1.

Table 1.1: National Ambient Air Quality Standards for Ozone

	Primary Standards		Secondary Standards	
	Level	**Averaging Time**	**Level**	**Averaging Time**
1997 Ozone Standards	0.08 ppm	Three-year average of the fourth highest 8-hour ozone value recorded each year.	Same as primary	
2008 Ozone Standards	0.075 ppm	Three-year average of the fourth highest 8-hour ozone value recorded each year.	Same as primary	
2015 Ozone Standard	0.070 ppm	Three-year average of the fourth highest 8-hour ozone value recorded each year.	Same as primary	

1.4 Nonattainment Area Background

The Chicago-Gary-Lake County, Illinois-Indiana area was subjected to nonattainment area rulemakings under the 1979 1-hour ozone standard and the 1997 8-hour ozone standard. The 1-hour ozone standard was revoked on June 15, 2005. U.S. EPA approved Indiana's redesignation request for attainment under the 1997 8-hour ozone

standard on May 11, 2010 (75 FR 26113). This area remains classified as maintenance. Illinois' portion was also redesignated to attainment and classified as maintenance under the 1997 8-hour ozone standard on August 13, 2012 (77 FR 48062).

Currently, the 2008 8-hour ozone nonattainment area, within which Lake and Porter counties, Indiana, reside, is called the Chicago-Naperville IL-IN-WI nonattainment area (Chicago nonattainment area). On June 11, 2012 (77 FR 34221), U.S. EPA designated this area as nonattainment (in 40 CFR 81.315) and classified it as marginal under Subpart 2 of Part D, Title I of the CAA. This classification subjected the nonattainment area to 8-hour ozone requirements.

On December 5, 2012, Indiana submitted a Request for Redesignation Petition and Maintenance Plan for attainment of the 2008 8-Hour Ozone NAAQS that would have redesignated Lake and Porter counties to attainment separately from the rest of the Chicago nonattainment area. This included a plan to reduce VOCs and NO_x emissions as well as establish motor vehicle emission budgets (MVEBs) for these pollutants. These requests were denied by U.S. EPA effective January 9, 2015.[1]

On May 4, 2016 (81 FR 26697), U.S. EPA finalized its determination that the Chicago nonattainment area failed to attain the 2008 8-hour ozone standard using 2012-2014 monitoring data by the attainment date of July 20, 2015. As required by Section 181(b)(2)(A) of the CAA, the area was reclassified to moderate for the 2008 8-hour ozone NAAQS, effective June 3, 2016.[2] This final rule aligned a new attainment date of July 20, 2018.

On June 15, 2016, Indiana submitted a Request for Redesignation and Maintenance Plan for Ozone Attainment in Indiana's Portion of the Chicago nonattainment area based on 2013-2015 monitoring data indicating attainment of the standard. This submittal requested that Lake and Porter counties be redesignated to attainment and awarded a completeness determination prior to any actions that may be required subsequent to being reclassified to moderate. Indiana formally withdrew this request on November 30, 2017.[3]

On February 28, 2017, Indiana submitted a SIP revision request to address the moderate area requirements for Indiana's Portion (Lake and Porter counties) of the Chicago-Naperville, IL-IN-WI, 2008 8-Hour Ozone Nonattainment Area. On February 13, 2019, U.S. EPA published approval of portions of Indiana's submission.[4]

On August 23, 2019, effective September 23, 2019 (84 FR 44238), U.S. EPA finalized its determination that the Chicago nonattainment area failed to attain the 2008 8-hour

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[1] http://www.gpo.gov/fdsys/pkg/FR-2014-12-10/pdf/2014-28799.pdf
[2] https://www.gpo.gov/fdsys/pkg/FR-2016-05-04/pdf/2016-09729.pdf
[3] https://www.in.gov/idem/airquality/files/redesignation_lakeporter_ozone_2008_withdrawl.pdf
[4] https://www.in.gov/idem/airquality/files/lakeporter_ozone_2008_progress_plan_approval.pdf

ozone standard using 2015-2017 monitoring data by the attainment date of July 20, 2018. As required by Section 181(b)(2)(A) of the CAA, the area was reclassified to serious for the 2008 8-hour ozone NAAQS, effective September 23, 2019.[5] This final rule aligned a new attainment date of July 20, 2021.

On February 27, 2020, Indiana submitted a Request for Redesignation and Maintenance Plan for Ozone Attainment in Indiana's Portion of the Chicago nonattainment area based on 2017-2019 monitoring data indicating attainment of the standard. This submittal requested that Lake and Porter counties be redesignated to attainment prior to any actions that may be required subsequent to the serious classification. Preliminary 2020 monitoring data indicates the area will not attain the standard. Therefore, Indiana is submitting this attainment plan for the serious classification as required by Sections 172(c) and 182(c)(2) of the CAA.

1.5 Nonattainment Area Geography

The specific counties and partial counties that comprise the Chicago-Naperville, IL-IN-WI, nonattainment area as defined in 40 CFR 81.314, 40 CFR 81.315, and 40 CFR 81.350 include: Cook, DuPage, Grundy (partial), Kane, Kendall (partial), Lake, McHenry, and Will counties, Illinois; Kenosha County (partial), Wisconsin; and Lake and Porter counties, Indiana.

Lake and Porter counties are located in Northwest Indiana and contain such cities as Gary, Hammond, East Chicago, Portage, and Valparaiso. Lake and Porter counties are bordered by Lake Michigan to the north, the Indiana counties of Newton and Jasper to the south, and LaPorte to the east. The Illinois counties of Cook, Kankakee, and Will border Lake and Porter counties to the west. In Illinois and Wisconsin, the nonattainment area contains such cities as Chicago, Elgin, Aurora, and Joliet in Illinois, and the City of Kenosha and Village of Pleasant Prairie in Wisconsin.

The Indiana Department of Environmental Management (IDEM), the Illinois Environmental Protection Agency (IEPA), and the Wisconsin Department of Natural Resources (WDNR) are responsible for assuring the nonattainment area for the 2008 8-hour ozone standard complies with the CAA requirements. These state agencies have worked cooperatively with U.S. EPA Region V to address attainment planning issues. Although the agencies have worked together on a comprehensive plan for the multi-state nonattainment area, each State is required to make a separate submittal for its portion of the planning components to U.S. EPA. Attainment demonstrations are SIP submittals and U.S. EPA action on them is taken separately.

2.0 CLEAN AIR ACT REQUIREMENTS

Sections 172 and 182 of the CAA specify the various planning requirements that apply to serious ozone nonattainment areas. Also, because the Chicago-Naperville, IL-IN-WI,

[5] https://www.govinfo.gov/content/pkg/FR-2019-08-23/pdf/2019-17796.pdf

Ozone Nonattainment Area includes portions of at least two (2) states, Section 182(j) of the CAA adds additional plan provisions concerning the coordination of the states involved. The CAA specifies the following requirements:

- Reasonable Further Progress (RFP), NO_x Control, and Milestones;
- Base-Year Emissions Inventory;
- Periodic Inventory and Emissions Statements;
- Reasonably Available Control Measures (RACM) / Reasonably Available Control Technology (RACT);
- Gasoline Vapor Recovery;
- Identification and Quantification of Emissions;
- Permit Program for New and Modified Sources;
- Other Control Measures, Means, or Techniques;
- Compliance with Section 110(a)(2);
- Equivalent Techniques;
- Enhanced Monitoring;
- Demonstration of Attainment;
- Mobile Source Emissions Budgets;
- Enhanced Vehicle Inspection and Maintenance Program;
- Clean-Fuel Vehicle Program;
- Transportation Control;
- De Minimis Rule;
- Special Rule for Modifications of Sources Emitting Less than 100 Tons and Special Rule for Modifications of Sources Emitting 100 Tons or More;
- Contingency Provisions;
- General Offset Requirement; and,
- NO_x Requirements.

2.1 Reasonable Further Progress (RFP), NO_x Control, and Milestones

Sections 172(c)(2), 182(c)(2)(B), 182(c)(2)(C), and 182(g) of the CAA requires a demonstration of RFP, NO_x control, and meeting applicable emissions reduction milestones.

Lake and Porter counties were previously designated nonattainment under the 1-hour ozone standard. The area met all of its 1-hour ozone SIP obligations for the 1997 standard, including a U.S. EPA approved attainment demonstration. The control measures outlined, post Indiana's approved 1999 9% ROP plan, in the 2002, 2005, and 2007 Rate of Progress plans, have been fully implemented. The area was also designated nonattainment for ozone under the 1997 8-hour standard in 2004. Since that time, the area has attained the 1997 8-hour ozone standard and was redesignated to attainment on May 11, 2010 (75 FR 26113).

The first milestone for the 2008 8-hour standard has been fulfilled with Indiana's 2017 Fifteen Percent (15%) ROP and Three Percent (3%) Contingency Plans for the

moderate area classification approved by U.S. EPA on February 13, 2019, effective March 15, 2019, (84 FR 3711).[6]

2.1.1 2020 Nine Percent (9%) and Three Percent (3%) Contingency Plan

In accordance with 172(c)(2), 182(c)(2)(B) and 182(g), Indiana has developed a 2020 Nine Percent (9%) ROP and Three (3%) Contingency Plan. The plan demonstrates Lake and Porter counties will achieve an average emission reduction of 3% per year after the first six years (2011-2017) of the attainment planning period through the attainment date (2018 – 2020), plus an additional 3% contingency reduction through one year beyond the attainment year, i.e. 2021.

Pursuant to 182(c)(2)(C) of the CAA, Indiana substituted NO_x emissions for VOC emissions to fully satisfy the VOC-specific requirements of 182(c)(2)(B). To meet the 9% RFP reduction, 6% of the required reductions are allocated to NO_x emissions and 3% of the required reductions are allocated to VOC emissions. For the 3% contingency reduction, 1% comes from VOC and 2% comes from NO_x reductions through 2020. In total, this demonstrates a reduction in NO_x and VOC emissions of at least 12% from 2018 to 2021.

This plan has been calculated using existing emission control measures and technology. Indiana is seeking U.S. EPA approval of this 2020 Nine Percent (9%) and Three Percent (3%) Contingency Plan (Attachment C).

2.1.2 Existing ROP Plans

Several control measures have been implemented in Lake and Porter counties as part of previous SIP submittals. These ROP plans outline the measures implemented in association with previous SIP submittals that have resulted in permanent and enforceable emission reductions in Lake and Porter counties.

1997 Fifteen Percent (15%) ROP Plan

Indiana's final 15% ROP plan was approved by U.S. EPA on July 18, 1997. The measures include a mix of point, area, and mobile source control measures:

1. Enhanced Vehicle Inspection and Maintenance Program

   Regulatory Basis: 326 IAC 13-1.1
   Implementation Status: Equivalent controls remain in place.

2. Stage II Vapor Recovery

   Regulatory Basis: 326 IAC 8-4-6

[6] https://www.in.gov/idem/airquality/files/lakeporter_ozone_2008_progress_plan_approval.pdf

Implementation Status: Controls remains in place due to gasoline dispensers being allowed to decommission stage II controls because of wide-spread use of on-board vehicle controls.

3. Reformulated Gasoline Program

   Regulatory Basis: CAA-Federal Control Program
   Implementation Status: Control remains in place.

4. National Volatile Organic Compound Emission Standards for Architectural Coatings Rule

   Regulatory Basis: 40 CFR Part 59, Subpart D
   Implementation Status: Control remains in place.

5. Residential Opening Burning Ban

   Regulatory Basis: 326 IAC 4-1
   Implementation Status: Control remains in place for all incorporated areas.

6. Non-Category Technology Guidelines (CTG) RACT

   Regulatory Basis: 326 IAC 8-7
   Implementation Status: Control remains in place.

1999 Nine Percent (9%) ROP Plan

Indiana's final 1999 9% ROP plan was approved by U.S. EPA on January 26, 2000. The reductions included a variety of state and federal measures that affected various industrial and area sources, such as steel mills, small engines (e.g. lawnmowers), gasoline reformulation, and personal solvent usage. The measures included the following:

1. Emission Limits for Benzene from Coke Oven By-Product Recovery Plants

   Regulatory Basis: 326 IAC 14-9
   Implementation Status: Control remains in place.

2. National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coke Oven Batteries

   Regulatory Basis: 326 IAC 20-3-1
   Implementation Status: Control remains in place.

3. Federal Phase I Reformulated Gasoline (RFG) on Small Non-Road Engines

   Regulatory Basis: Clean Air Act Amendments of 1990; Section 211 of the Clean

Air Act
Implementation Status: Control remains in place.

4. Federal Controls on Small Spark-Ignited Engines (July 3, 1995, 60 FR 34581)

   Regulatory Basis: Court-ordered standards for small spark-ignited engines; 40 CFR Part 90
   Implementation Status: Control remains in place.

5. Commercial/Consumer Solvent Reformulation Rule

   Regulatory Basis: 40 CFR 59, Subpart C
   Implementation Status: Control remains in place.

6. Volatile Organic Liquid Storage RACT

   Regulatory Basis: 326 IAC 8-9
   Implementation Status: Control remains in place.

2002 Nine Percent (9%) ROP Plan

Indiana's 2002 9% ROP plan consists of several federal regulations and some measures specific to Indiana, including state rules and negotiated agreements. The reductions included measures that control VOC emissions from steel mill sinter plants, non-road mobile sources, and municipal solid waste landfills. The measures included the following:

1. Additional Reductions from Federal Controls on Small Spark-Ignited Engines (64 FR 15207, March 30, 1999)

   Regulatory Basis: Court-ordered standards for small spark-ignited engines; 40 CFR Part 90
   Implementation Status: Control remains in place.

2. Sinter Plant Rule

   Regulatory Basis: 326 IAC 8-13
   Implementation Status: Control remains in place.

3. Municipal Solid Waste Landfill

   Regulatory Basis: 326 IAC 8-8
   Implementation Status: Control remains in place.

2005 Nine Percent (9%) ROP Plan

Since there were surplus emission reductions from previous plans, no emission reductions were necessary to meet the additional 9% reduction in VOC emissions for the 2005 ROP. However, the plan includes a federal regulation that further reduces VOCs emitted by non-road small engine sources. The measure includes the following:

1. Further Reductions from Federal Controls on Small Spark-Ignited Engines (65 FR 24268, April 25, 2000)

   Regulatory Basis: Federal Standards for small spark-ignited engines; 40 CFR Part 90
   Implementation Status: Control remains in place.

2007 Six Percent (6%) ROP Plan

Indiana's 2007 6% ROP plan consists of several federal regulations and some measures specific to Indiana, including state rules and negotiated agreements. The reductions included measures that control VOC emissions from petroleum refineries, non-road mobile sources, volatile organic liquid storage operations, cold cleaning degreasing operations, and the reformulation of commercial and consumer products. The measures included the following:

1. Further Reductions from Federal Controls on Small Spark-Ignited Engines (69 FR 1823, January 12, 2004)

   Regulatory Basis: Court-ordered standards for small spark-ignited engines; 40 CFR Part 90
   Implementation Status: Control remains in place.

2. Commercial/Consumer Solvent Reformulation Rule

   Regulatory Basis: 40 CFR 59, Subpart C
   Implementation Status: Control remains in place.

3. Petroleum Refineries NESHAP

   Regulatory Basis: 326 IAC 20-16
   Implementation Status: Control remains in place.

4. United States Steel-Gary Works Agreed Order with IDEM (March 22, 1996)

   Control Method: Halts the use of untreated water for quenching (326 IAC 6.8-9-3(7))
   Implementation Status: Control remains in place.

5. Volatile Organic Liquid Storage RACT

Regulatory Basis: 326 IAC 8-9
Implementation Status: Control remains in place.

6. Cold Cleaner Degreasers

Regulatory Basis: 326 IAC 8-3-8
Implementation Status: Control remains in place.

2017 Fifteen Percent (15%) ROP Plan and Three Percent (3%) Contingency Plan

Pursuant to Section 182(b)(1) of the CAA, Indiana developed a 2017 Fifteen Percent (15%) ROP Plan and Three Percent (3%) Contingency Plan. The plans demonstrated a 17% decline in VOCs and a 28% decline in NO_x from 2011-2017. After accounting for creditable VOC reductions, additional reductions were needed to fulfill the total 18% reduction requirement. NO_x emissions were substituted (with an applied offset ratio) and the need was found to be 5.75 tons. The projected creditable-decrease in NO_x from 2011-2017 in the on-road and nonroad sectors was 13.82 tons, leaving an overage of 8.07 tons in NO_x reduction.

In combination with the existing ROP plans, this ROP and Contingency plan fulfilled the requirements for a 15 percent emissions reduction within six (6) years (2012-2017) after the baseline year (2011) and the 3% contingency plan through the previous attainment year (2018).

2.2 Base-Year Emissions Inventory

Section 182(b)(1)(B) of the CAA requires states to develop a comprehensive, accurate, and current inventory of actual emissions from all sources in the nonattainment area, including periodic revisions as the Administrator may determine necessary to assure that the requirements for this part are met. U.S. EPA guidance requires the submittal of a comprehensive state implementation plan quality emissions inventory of ozone precursor emissions (i.e. oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) representative of the base year.

On February 13, 2019, effective March 15, 2019 (84 FR 3711), Indiana fulfilled the requirement for a revised 2011 Base-Year Emissions Inventory for Indiana's portion of the nonattainment area (Lake and Porter counties) classified as moderate. Upon review of this documentation, Indiana has determined that this inventory should be updated to the latest/most recent inventory available based on the 2011v6.3 platform (i.e. 2011en).

This current up-to-date base-year emissions inventory satisfies Indiana's obligation under Section 182(b)(1)(B) of the CAA for the 2008 8-hour ozone standard for Lake and Porter counties classified as serious, as amended by the final ruled titled Implementation of the 2008 National Ambient Air Quality Standard for Ozone: State Implementation Plan Requirements (80 FR 12264, March 6, 2015), for the 2008 8-Hour

Ozone NAAQS. Indiana is seeking U.S. EPA approval of this updated base-year inventory (Attachment D).

Tables 2.1 and 2.2 show the differences between VOCs and NO_x in the two 2011 base-year inventories for Lake and Porter counties. The inventories were pulled under different platforms – 2011v6.2 (approved in 2017) and 2011v6.3 (current version).

Table 2.1: VOC Tons per Ozone Season Day Emissions by Data Category

County	Data Category	VOC 2011v6.2	VOC 2011v6.3	Difference
Lake	EGU	0.44	0.33	-0.11
Lake	Non-Point	12.54	12.65	+0.11
Lake	Non-Road	7.55	11.34	+3.79
Lake	Point	15.39	15.54	+0.15
Lake	On-road	6.92	6.94	+0.02
Porter	EGU	0.19	0.21	+0.02
Porter	Non-Point	5.53	5.61	+0.08
Porter	Non-Road	6.64	10.09	+3.45
Porter	Point	1.68	1.68	0.0
Porter	On-road	2.66	2.64	-0.02

Table 2.2: NO_x Tons per Ozone Season Day Emissions by Data Category

County	Data Category	NO_X 2011v6.2	NO_x 2011v6.3	Difference
Lake	EGU	24.62	18.98	-5.64
Lake	Non-Point	5.80	5.66	-0.14
Lake	Non-Road	8.07	9.68	+1.61
Lake	Point	43.10	47.28	+4.18
Lake	On-road	17.85	17.24	-0.61
Porter	EGU	5.53	5.06	-0.47
Porter	Non-Point	3.89	3.73	-0.16
Porter	Non-Road	4.62	6.16	+1.54
Porter	Point	23.36	23.49	+0.13
Porter	On-road	6.85	7.46	+0.61

2.3 Periodic Inventory and Emissions Statements

Sections 172(c)(3), 182(a)(1), and 182(a)(3) of the CAA requires States to submit a comprehensive, accurate, and current inventory of actual emissions from all sources in the nonattainment area, including periodic revisions as the Administrator may determine necessary to assure that the requirements for this part are met.

In December 2008, U.S. EPA's Air Emissions Reporting Requirements (AERR) rule consolidated and streamlined previous requirements of several older rules for states and local air pollution control agencies to submit emissions inventories for criteria pollutants to EPA's Emissions Inventory System (EIS). In 2015, U.S. EPA finalized further improvements to these reporting requirements.[7]

IDEM's Office of Air Quality (OAQ) collects data, calculates, and stores emissions for point sources on an annual basis in the Emission Inventory Tracking System (EMITS). These point source emissions are uploaded to the National Emissions Inventory (NEI) each year. Airport, nonroad, and area emissions data is collected and available through U.S. EPA's Emission Modeling Clearinghouse.

Section 182(a)(3)(B)(ii) of the CAA requires states to submit certification documentation for this Emissions Statement requirement. Indiana is seeking U.S. EPA approval of this certification request (Attachment G).

2.4 Reasonably Available Control Measures (RACM) / Reasonably Available Control Technology (RACT)

Sections 172 (c)(1) and 182(b)(2) of the CAA requires a demonstration that the state has adopted all reasonable and available control measures to demonstrate attainment as expeditiously as practicable and that no additional measures that are reasonably available will advance the attainment date.

As required by Sections 172 and 182 of the 1990 CAA, in the mid-1990s Indiana promulgated rules requiring RACT for emissions of VOCs. There were no specific rules required by the CAA such as RACT for existing sources beyond statewide rules. Statewide RACT rules have applied to all new sources locating in Indiana since that time. The Indiana rules are found in 326 Indiana Administrative Code (IAC) 8. The serious major source threshold of 50 tons per year (TPY) is addressed for non-CTG sources in 326 IAC 8-7. Local control measures, including some RACT rules specific to Lake and Porter counties, have helped reduce VOC emissions and other types of emissions in Northwest Indiana. These measures include:

326 IAC 8-7	Specific VOC Reduction Requirements
326 IAC 8-8	Municipal Solid Waste Landfills
326 IAC 8-9	Volatile Organic Liquid Storage Vessels
326 IAC 8-11	Wood Furniture Coatings
326 IAC 8-12	Shipbuilding or Ship Repair Operations
326 IAC 8-13	Sinter Plants
326 IAC 8-16	Offset Lithographic Printing and Letterpress Printing
326 IAC 8-17	Industrial Solvent Cleaning Operations

[7] https://www.epa.gov/air-emissions-inventories/air-emissions-reporting-requirements-aerr

326 IAC 8-18	Synthetic Organic Chemical Manufacturing Industry Air Oxidation, Distillation, and Reactor Processes
326 IAC 8-19	Control of Volatile Organic Compound Emissions from Process Vents in Batch Operations
326 IAC 8-20	Industrial Wastewater
326 IAC 8-21	Aerospace Manufacturing and Rework Operations
326 IAC 8-22	Miscellaneous Industrial Adhesives
326 IAC 13	Motor Vehicle Emission and Fuel Standards (including a motor vehicle inspection and maintenance program for Lake and Porter counties)
326 IAC 4-1-4.1(c)	Ban on residential burning in Lake and Porter counties
40 CFR 80.70(f)(3)	Federal requirement for the use of federal reformulated gasoline (RFG) in Lake and Porter counties

Indiana's fully approved and effective rules are found in 326 IAC 8. The following is a list of the applicable rules:

326 IAC 8-1-6	New facilities; general reduction requirements (Best Available Control Technology for Non-Specific Sources)
326 IAC 8-2	Surface Coating Emission Limitations
326 IAC 8-3	Organic Solvent Degreasing Operations
326 IAC 8-4	Petroleum Sources
326 IAC 8-5	Miscellaneous Operations
326 IAC 8-6	Organic Solvent Emission Limitations
326 IAC 8-10	Automobile Refinishing
326 IAC 8-14	Architectural and Industrial Maintenance Coatings
326 IAC 8-15	Standards for Consumer and Commercial Products

Indiana's VOC RACT demonstration under the moderate classification was fully approved on February 13, 2019, effective March 15, 2019 (84 FR 3711).[8]

Indiana certifies that existing VOC rules found in 326 IAC 8 fulfill VOC RACT requirements satisfies nonattainment area CAA requirements. Indiana is seeking U.S. EPA approval of this certification request (Attachment B).

2.5 Gasoline Vapor Recovery

Section 182(b)(3) of the CAA requires states to adopt a system for gasoline vapor recovery of emissions from the fueling of motor vehicles. Indiana has a fully implemented and approved Stage II Vapor Recovery system that was previously required under the 1-hour ozone standard. It can be found in 326 IAC 8-4-6 and further referenced under Section 2.1.2, *1997 Fifteen Percent (15%) ROP Plan* of this document.

[8] https://www.in.gov/idem/airquality/files/lakeporter_ozone_2008_progress_plan_approval.pdf

2.6 Identification and Quantification of Emissions

Section 172(c)(4) of the CAA requires the SIP to identify and quantify the emissions of pollutants (in this case NO_x and VOC) that sources will be allowed from the construction and operation of major new and modified sources in accordance with Section 173(a)(1)(B). These emissions must not interfere with attainment of the ozone standard by the attainment date. Indiana's permitting rules for nonattainment areas that meet this requirement are in rule 326 IAC 2-3, as further described in Section 7.3 of this document.

2.7 Permit Program for New and Modified Sources

Section 172(c)(5) of the CAA requires states to implement a permit program consistent with the requirements of Section 173. Indiana has a long standing and fully implemented New Source Review (NSR) permitting program that is outlined in 326 IAC 2-2 and 326 IAC 2-3, as further described in Section 7.3 of this document. Indiana's NSR program was approved by U.S. EPA on October 7, 1994 (94 FR 24837), as part of the SIP.

Any facility that is not listed in the emissions inventory, or for the closing of which credit was taken in demonstrating attainment, will not be allowed to construct, reopen, modify, or reconstruct without meeting all applicable permit rule requirements, including an air quality analysis to evaluate whether the new source will threaten the NAAQS.

2.8 Other Control Measures, Means, or Techniques

Section 172(c)(6) of the CAA requires plan provisions to include enforceable emission limitations, and such other control measures, means or techniques, as well as schedules and timetables for compliance, as may be necessary or appropriate to provide for attainment by the applicable attainment date.

Existing and future national and regional control measures will ensure that attainment in each county will be maintained with an increasing margin of safety over time. These measures are discussed in greater detail in the Control Strategy Section 7.0.

The modeling conducted by the Lake Michigan Air Director's Consortium (LADCO) for future-year ozone design values consistently shows that existing emission control measures will bring the Chicago nonattainment area into attainment of the 8-hour ozone NAAQS. Federal and local control measures to be phased-in or implemented in the next several years will provide even greater assurance that air quality will continue to meet the standard into the future. A detailed discussion of the photochemical grid modeling, model selection, methodologies, meteorology, model input, and analysis methods is included in Section 3.0. This section presents details of the technical work done to analyze air quality data to demonstrate attainment of the ozone standard. The results of the computer modeling and an analysis of air quality and emission inventory

trends presents strong evidence that existing control measures will improve air quality, thereby assuring air quality levels below the ozone standard by the attainment date.

2.9 Compliance with Section 110(a)(2) of the CAA

Section 172(c)(7) of the CAA requires nonattainment SIPs to meet the applicable provisions of Section 110(a)(2). IDEM has reviewed the requirements of Section 110(a)(2) and has concluded that prior rule submittals, along with this attainment demonstration, have addressed the relevant requirements associated with rule development, state implementation plan submissions, and implementation and enforcement of required control measures. On April 29, 2015 (80 FR 23713), U.S. EPA approved Indiana's Infrastructure SIP Requirements for the 2008 Ozone NAAQS, effective May 29, 2015.[9] U.S. EPA did not act on Section 110(a)(2)(D)(i)(I) of the CAA (Prongs 1 and 2) relating to interstate transport.

2.10 Equivalent Techniques

IDEM has followed U.S. EPA guidance on procedures for modeling, preparing emission inventories, and plan submittals. Therefore, IDEM is not requesting approval for equivalent techniques, as allowed under Section 172(c)(8) of the CAA.

2.11 Enhanced Monitoring

Section 182(c)(1) of the CAA requires States with nonattainment areas classified serious or higher adopt and implement a program to improve air monitoring for ambient concentrations of ozone, NO_X and VOC. U.S. EPA initiated the Photochemical Assessment Monitoring Stations (PAMS) program in February 1993. The PAMS program required the establishment of an enhanced monitoring network in all ozone nonattainment areas classified as serious, severe, or extreme. PAMS are now required at each NCore site located in a core-based statistical area (CBSA) with a population of 1,000,000 or more.

On March 16, 1994 (59 FR 12168), U.S. EPA fully approved Indiana's SIP revision establishing an enhanced monitoring program in Lake and Porter counties as required by Section 182(c)(1) of the CAA. Indiana commits to maintaining an air monitoring network to meet regulatory requirements in Lake and Porter counties and continue working with U.S. EPA through the air monitoring network review process, as required by 40 CFR Part 58, to determine the adequacy of the ozone monitoring network, additional monitoring needs, and recommended monitor decommissions. Air monitoring data from these monitors will continue to be quality assured, reported, and certified according to 40 CFR Part 58. IDEM is seeking U.S. EPA approval of its certification of Indiana's enhanced monitoring program (Attachment H).

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[9] http://www.in.gov/idem/airquality/files/redesignation_state_o3_epa_approval.pdf

2.12 Demonstration of Attainment

Section 182(c)(2)(A) of the CAA requires a demonstration that will provide for attainment of the ozone standard by the applicable attainment date based on photochemical modeling or any other analytical method determined by the Administrator to be at least effective.

The attainment modeling analysis for the Chicago nonattainment area was performed by LADCO using 2017 as the projection year to demonstrate attainment by the moderate statutory deadline established by U.S. EPA (July 20, 2018). VOC and NO_x emissions in the Chicago nonattainment area were projected to remain below the level of the 2008 ozone NAAQS by 2017, and beyond. This conclusion is supported by technical demonstrations that provide supporting evidence of attainment that include a rate of progress and contingency plan, air quality trends, emission trends, and a weight of evidence analyses.

2.12.1 Rate of Progress Plans

Section 182(c)(2)(B) of the CAA requires a plan that demonstrates an additional emissions reduction of 3% per year from the end of the first six-year period averaged over each consecutive 3-year period through the attainment date (2018 – 2020), plus an additional 3% contingency reduction through one year beyond the attainment year, i.e. 2021. In combination with the existing ROP plans, the new 2020 Nine Percent (9%) ROP and Three Percent (3%) Contingency Plan will fulfill this serious nonattainment area CAA requirement as further described in Sections 2.1.

2.12.2 Photochemical Grid Modeling

Section 182(c)(2)(A) and 182(j) of the CAA requires that photochemical grid modeling be used to demonstrate attainment in serious-classification and multi-state ozone nonattainment areas. LADCO has conducted a modeling study that demonstrates attainment of the standard by the applicable attainment date. A discussion of the modeling results that LADCO performed is included in Section 3.0 Modeling. This Technical Supporting Document (TSD) in its entirety can be referenced in Appendix A1.

2.12.3 Air Quality Trends Analysis

Section 110(a)(2)(B) of the CAA requires a monitoring strategy for measuring, characterizing, and reporting ozone concentrations in ambient air. IDEM maintains a comprehensive network of air quality monitors throughout the state with the primary objective of being able to determine compliance with the NAAQS.

Implementation of control strategies has resulted in a significant improvement in air quality in the Chicago nonattainment area. Monitoring data shows that overall area design values are decreasing, air quality peak values are declining, and the number of exceedances is falling. This analysis is further discussed in Section 4.0 Air Quality.

2.12.4 Emission Trends Analysis

In Indiana, control measures have been implemented requiring substantial emissions reductions from mobile, point, and area sources. Since the attainment deadline occurs during the 2021 ozone season, the effective attainment deadline is the end of the 2020 ozone season. Thus, a projection of emissions in 2020 is required. Indiana's emission trends analysis is discussed in Section 5.0 of this document. An analysis of this inventory shows an overall drop in both VOC and NO_x emissions from 2011 to 2020.

2.12.5 Mobile Source Emissions Budgets

Transportation conformity is required under Section 176(c) of the CAA to ensure that federally supported highway and transit project activities are consistent with (i.e. "conform to") the purpose of the SIP. Transportation conformity applies to areas that are designated nonattainment, and those areas redesignated attainment after 1990 ("maintenance" areas with plans developed under Section 175A of the CAA) for transportation-related criteria pollutants.

U.S. EPA requirements outlined in 40 CFR 93.118(e)(4) stipulate that a mobile source emissions budget (for both NO_x and VOC) be established as part of the attainment demonstration. The mobile source emissions budget is necessary to demonstrate conformity of transportation plans with the SIP. The motor vehicle emission budgets are included in Section 6.0 of this document (Appendix A3).

The purpose of transportation conformity is to ensure that Federal transportation actions occurring in the nonattainment area do not hinder the area from attaining and maintaining the 8-hour ozone standard. This means that the level of emissions estimated by the metropolitan planning organization (MPO) must not exceed the motor vehicle emission budgets as defined in this attainment demonstration.

2.13 Enhanced Vehicle Inspection and Maintenance Program

Section 182(c)(3) of the CAA requires states to provide for an enhanced vehicle inspection and maintenance (I/M) testing program to reduce hydrocarbon and NO_x emissions from in-use motor vehicles registered in each urbanized area (in the nonattainment area). Indiana has a fully implemented and approved basic/enhanced vehicle testing program in Lake and Porter counties previously required under the 1-hour ozone standard. The program was approved by U.S. EPA and became effective on May 20, 1996 (61 FR 11142) and can be found at 326 IAC 13-1. Upon review, Indiana has determined and certifies that the existing I/M testing program in Lake and Porter counties satisfy serious nonattainment CAA requirements. Indiana is seeking U.S. EPA approval of this certification request (Attachment F).

2.14 Clean-Fuel Vehicle Program

Section 182(c)(4) of the CAA requires states to have an applicable program. U.S. EPA's Clean-Fuel Fleet Program was established under Part C – Clean-Fuel Vehicles, Sections 241-246 of the 1990 CAA Amendments. The purpose of the program was to reduce emissions in metropolitan areas not meeting air quality standards through the use of clean alternative fuels.

These standards have in effect been superseded by newer, more stringent standards in 40 CFR Part 86 which provide long-term reductions in ozone precursor emissions exceeding those of the CAA clean fuel fleet program. As such, Indiana will be taking no further action to address these standards as they have been rendered obsolete.

2.15 Transportation Control

Beginning six years after an area is designated nonattainment, and each third year thereafter, Section 182(c)(5) of the CAA requires states to submit a demonstration as to whether current aggregate vehicle mileage, aggregate vehicle emissions, congestion levels, and other relevant parameters are consistent with those used for the area's demonstration of attainment.

Indiana was first designated nonattainment in 2012. The first Transportation Control analysis would have been due in 2018, and each third year thereafter. Indiana will conduct its first analysis in 2021, using 2020 data, if necessary.

2.16 De Minimis Rule

Section 182(c)(6) of the CAA requires states to ensure that NSR provisions are followed for existing source modifications. Indiana has a fully implemented and approved De Minimis Rule found under 326 IAC 2-3-1(p) that fulfills this requirement (Attachment E).

2.17 Special Rule for Modifications of Sources Emitting Less than 100 Tons and Special Rule for Modifications of Sources Emitting 100 Tons or More

Sections 182(c)(7) and 182(c)(8) of the CAA require special rules for major stationary sources located in a serious nonattainment area whenever any change at that source results in any increase (other than a de minimis increase) in VOC emissions from any discrete operation, unit, or other pollutant emitting activity at the source. Indiana has fully implemented and approved rules that can be found under 326 IAC 2-3-2(b)(2) and (3) that fulfill these requirements (Attachment E).

2.18 Contingency Measures

Sections 172(c)(9) and 182(c)(9) of the CAA require states to provide for specific measures to be implemented should Lake and Porter counties fail to meet RFP requirements or attain the applicable NAAQS by the attainment date. These contingency measures are required to be implemented without further action by the

state or U.S. EPA. U.S. EPA interprets the contingency requirement to mean additional emission reductions that are enough to equal up to 3% of the emissions in the RFP adjusted base year inventory. These emissions reductions should be realized in the year following the year in which the failure is identified (i.e. 2021).

Indiana has developed a 2020 Nine Percent (9%) ROP Plan and Three Percent (3%) Contingency Plan for the years 2018-2021 that fulfills these requirements, discussed in greater detail in Section 2.1.1.

2.19 General Offset Requirement

Section 182(c)(10) of the CAA requires a ratio of at least 1.2 to 1 for total VOC emission reductions to the total increase in emissions for serious ozone nonattainment areas.

Indiana has a fully implemented and approved rule found under 326 IAC 2-3-3(5)(B) that fulfills this requirement (Attachment E).

2.20 NO_x Requirements

Sections 172 (c)(1) and 182(f) of the CAA require a demonstration that the state has adopted all reasonable and available control measures to demonstrate attainment as expeditiously as practicable and that no additional measures that are reasonably available will advance the attainment date. Specifically, Section 182(f) of the CAA requires States to adopt RACT for all major stationary sources of NO_x.

Section 302 of the CAA defines major stationary source as any facility which has the potential to emit of 100 tons per year of any air pollutant. For serious ozone nonattainment areas, a major source is defined by Section 182(c) as a source that has the potential to emit 50 tons of NO_x per year.

3.0 MODELING

3.1 Photochemical Modeling

Section 182(c)(2)(A) and 182(j) of the CAA requires that photochemical grid modeling be used to demonstrate attainment in areas classified as serious and multi-state ozone nonattainment areas. The attainment modeling analysis for the Chicago ozone nonattainment area was performed by LADCO. This complete analysis can be referenced in Appendix A1. The following paragraphs briefly describe the methods, inputs, and major components of this analysis.

3.1.1 Attainment Test

An attainment demonstration based on air quality modeling is used to determine whether identified emission reduction measures are enough to reduce projected pollutant concentrations to a level that meets the NAAQS by the statutory deadline established by U.S. EPA. This modeling analysis uses 2020 as the projection year to

demonstrate attainment of the 2008 ozone NAAQS. LADCO estimated 2020 emissions for most of the anthropogenic inventory sectors by interpolating between the 2016 and 2023 Inventory Collaborative 2016v1 inventories. Linear interpolation for the emissions was used because 2020 inventories were not readily available for all the sectors at the time that this application initiated. These scenarios are evaluated using the Comprehensive Air Quality Model with Extensions (CAMx) model to determine the likelihood that the 2008 ozone NAAQS will be achieved in the Lake Michigan region in 2020. It should be noted that subsequent review of the modeled emissions indicated double counting for certain emission sectors. While this issue is being corrected and revised modeling will be conducted, IDEM considers the current modeling results as conservative and once the modeling is revised with corrected emissions, the resulting modeled design values should be slightly lower.

The model attainment test uses model estimates in a relative sense to estimate future year design values. U.S. EPA's Air Quality Modeling Group has developed the Software for Modeled Attainment Test Community Edition (SMAT-CE) for this purpose.[10] The MATS software computes the fractional changes, or relative response factors (RRFs), of ozone concentrations at each monitor location using results of the model base year and the future year. Meteorological conditions are assumed to be unchanged for the base and projection years. The resulting estimates of future ozone design values are then compared to the NAAQS. If the future ozone design values are less than or equal to the NAAQS, then the analysis suggests that attainment will be reached.

SMAT-CE software was used according to U.S. EPA's recommended approach (U.S. EPA, 2018).[11] All modeling results are time shifted to local time to be consistent with monitoring measurements. Baseline 2016 design values were calculated by averaging three successive three-year (3-year) design values centered on 2016 (2014-2016, 2015-2017, 2016-2018). The baseline 2016 design values are therefore weighted averages using ambient data from 2014-2018 at each location.

Table 3.1 summarizes the results of the model attainment test for the 2020 future-year. Baseline 2016 design values for monitoring sites in the Chicago nonattainment area are compared to the 2020 design values. All monitoring locations in the Chicago nonattainment area are projected to meet the level of the 2008 ozone NAAQS of 75 parts per billion by 2020.

[10] https://www.epa.gov/scram/photochemical-modeling-tools
[11] https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf

Table 3.1: Attainment Test Results in 2020 (Future-Year) for the Chicago-Naperville, IL-IN-WI, 2008 8-Hour Ozone Nonattainment Area

Air Quality System (AQS) ID	State	County	LADCO 2020 Modeled Future Year (ppb)	2014-2016 Design Value (ppb)
170310001	Illinois	Cook	71.1	69.0
170310032	Illinois	Cook	70.3	70.0
170310076	Illinois	Cook	70.4	69.0
170311003	Illinois	Cook	66.8	69.0
170311601	Illinois	Cook	66.8	69.0
170313103	Illinois	Cook	61.1	62.0
170314002	Illinois	Cook	67.2	66.0
170314007	Illinois	Cook	70.0	71.0
170314201	Illinois	Cook	71.3	71.0
170317002	Illinois	Cook	71.8	72.0
170436001	Illinois	DuPage	67.2	68.0
170890005	Illinois	Kane	66.3	68.0
170971007	Illinois	Lake	71.3	73.0
171110001	Illinois	McHenry	66.3	68.0
171971011	Illinois	Will	62.5	64.0
180890022	Indiana	Lake	65.8	67.0
180892008	Indiana	Lake	64.0	65.0
181270024	Indiana	Porter	67.1	69.0
181270026	Indiana	Porter	66.4	66.0
550590019	Wisconsin	Kenosha	75.2	77.0
550590025	Wisconsin	Kenosha	71.1	71.0

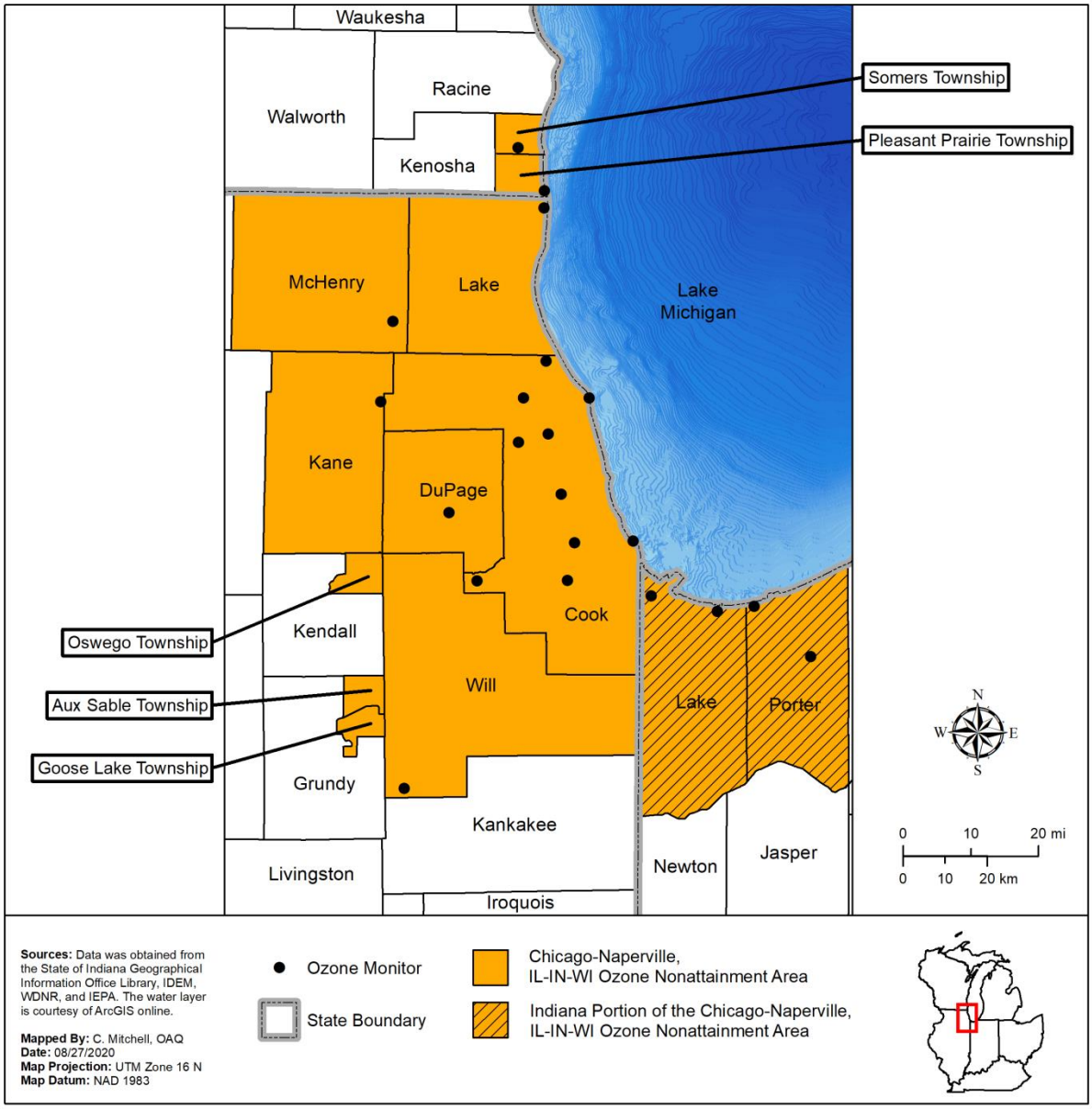
4.0 AIR QUALITY

Section 110(a)(2)(B) of the CAA requires a monitoring strategy for measuring, characterizing, and reporting ozone concentrations in the ambient air. IDEM maintains a comprehensive network of air quality monitors throughout the state with the primary objective of being able to determine compliance with NAAQS. In accordance with Table D-3 of Appendix D of 40 Code of Federal Regulations (CFR) Part 58, starting with the 2017 ozone monitoring season, U.S. EPA mandates seasonal monitoring of ambient ozone concentrations in Indiana and Illinois from March 1st through October 31st and in Wisconsin from March 1st through October 15th.

The current operating ozone network in the Chicago nonattainment area is depicted in Figure 4.1. There are currently twenty-one (21) Federal Reference Method monitors measuring ozone concentrations in the Chicago-Naperville, IL-IN-WI, nonattainment area. Four monitors are in Indiana's portion of the nonattainment area and are operated

by IDEM's Office of Air Quality (OAQ). Fifteen monitors are in Illinois' portion of the nonattainment area and are operated by the IEPA. Two monitors are in Wisconsin's portion of the nonattainment area and are operated by the WDNR.

Figure 4.1: Chicago-Naperville, IL-IN-WI, 2008 8-Hour Ozone Nonattainment Area & Monitors



As explained in 40 CFR Part 50, Appendix P, three (3) consecutive, complete years of ozone monitoring data are required to assess attainment at a monitoring site. The 2008 8-hour primary and secondary ozone ambient air quality standards are met at an ambient air quality monitoring site when the 3-year average of the annual fourth-highest

daily maximum 8-hour average ozone concentration is less than or equal to 0.075 ppm. When this occurs, the site is deemed to be in attainment.

An exceedance of an 8-hour ozone NAAQS occurs when a monitor measures an ozone concentration above the standard. A violation occurs when the 3-year average of the annual fourth highest 8-hour averaged daily ozone level is greater than a standard. This 3-year average is termed the "design value" for the monitor. The design value for a nonattainment area is derived from the monitor with the highest specific design value.

Table 4.1 provides historical certified data for monitors that are currently active as well as any that have been active since 2011.[12] [13] Exceedances of the 2008 8-hour standard of 0.075 ppm are highlighted. Controlling design values from 2011-2013 through 2017-2019 for each state are represented in Chart 4.1. Each monitor's design value for 2017-2019 is compared in Chart 4.2.

[12] http://www.in.gov/idem/airquality/2489.htm
[13] https://www.epa.gov/outdoor-air-quality-data/monitor-values-report

Table 4.1: Design Values for the 2008 8-Hour Chicago Ozone Nonattainment Area from 2011-2013 through 2017-2019

State	County	Site #	Monitor	Three-Year Design Value (ppm)						
				2011-2013	2012-2014	2013-2015	2014-2016	2015 - 2017	2016 - 2018	2017 - 2019
INDIANA	Lake	180890022	Gary IITRI	0.069	0.069	0.065	0.067	0.068	0.070	0.068
	Lake	180890030	Whiting High School	0.070	0.069	0.065				
	Lake	180892008	Hammond- 141st St.	0.070	0.069*	0.063	0.065	0.065*	0.066	0.065
	Porter	181270024	Ogden Dunes	0.072	0.073	0.068	0.069	0.069	0.071	0.070
	Porter	181270026	Valparaiso	0.064	0.065	0.063	0.066	0.069	0.073	0.073
ILLINOIS	Cook	170310001	Alsip	0.071	0.069	0.065	0.069	0.073	0.077	0.075
	Cook	170310032	SWFP	0.080	0.076	0.068	0.070	0.072	0.075	0.073
	Cook	170310064	Ellis Ave.	0.071						
	Cook	170310076	Com Ed	0.072	0.070	0.064	0.069	0.072	0.075	0.072
	Cook	170311003	Taft	0.070	0.070*	0.066	0.069	0.067	0.069	0.067
	Cook	170311601	Lemont	0.071	0.071	0.066	0.069	0.069	0.070	0.068
	Cook	170313103	Schiller Park			0.061	0.062	0.062	0.064	0.063
	Cook	170314002	Cicero	0.072	0.069	0.062	0.066	0.068	0.072	0.068
	Cook	170314007	Des Plaines	0.068	0.069	0.068	0.071	0.071	0.074	0.070
	Cook	170314201	Northbrook	0.077	0.074	0.068	0.071	0.072	0.077	0.074
	Cook	170317002	Evanston	0.080	0.078	0.070	0.072	0.073	0.077	0.075
	DuPage	170436001	Lisle	0.068	0.067	0.064	0.068	0.070	0.071	0.070
	Kane	170890005	Elgin	0.069	0.068	0.065	0.068	0.069	0.071	0.070
	Lake	170971007	Zion	0.080	0.079	0.071	0.073	0.073	0.075	0.071
	McHenry	171110001	Cary	0.071	0.069	0.065	0.068	0.069	0.072	0.071
	Will	171971011	Braidwood	0.064	0.065	0.063	0.064	0.065	0.067	0.066
WI	Kenosha	550590019	Chiwaukee	0.082	0.081	0.075	0.077	0.078	0.079	0.075
	Kenosha	550590025	Water Tower			0.069	0.071	0.073	0.077	0.074

* *Invalid DV*

> 0.075 ppm

Chart 4.1: Highest Design Values by State in the 2008 8-Hour Chicago Ozone Nonattainment Area from 2011-2013 through 2017-2019

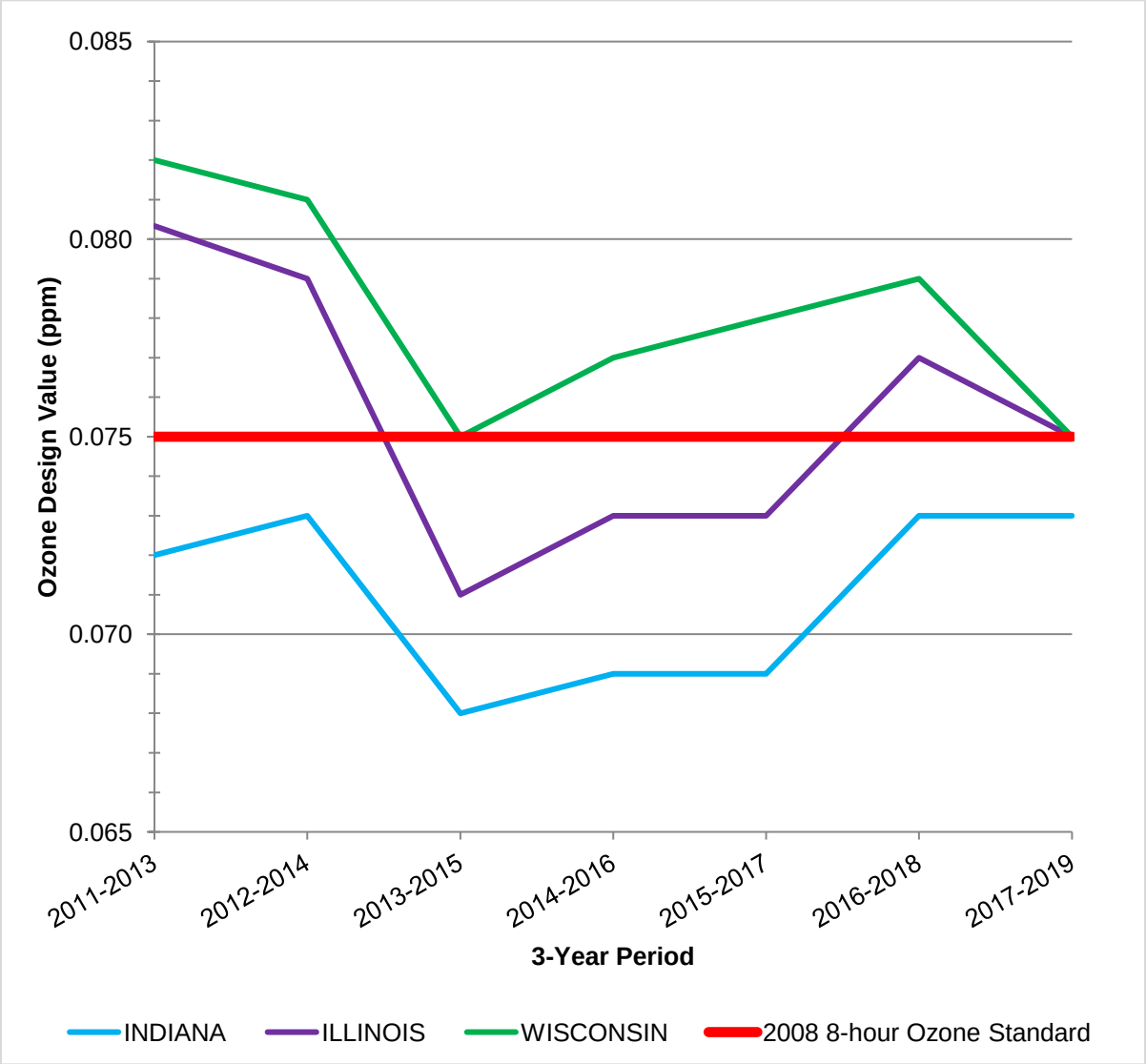
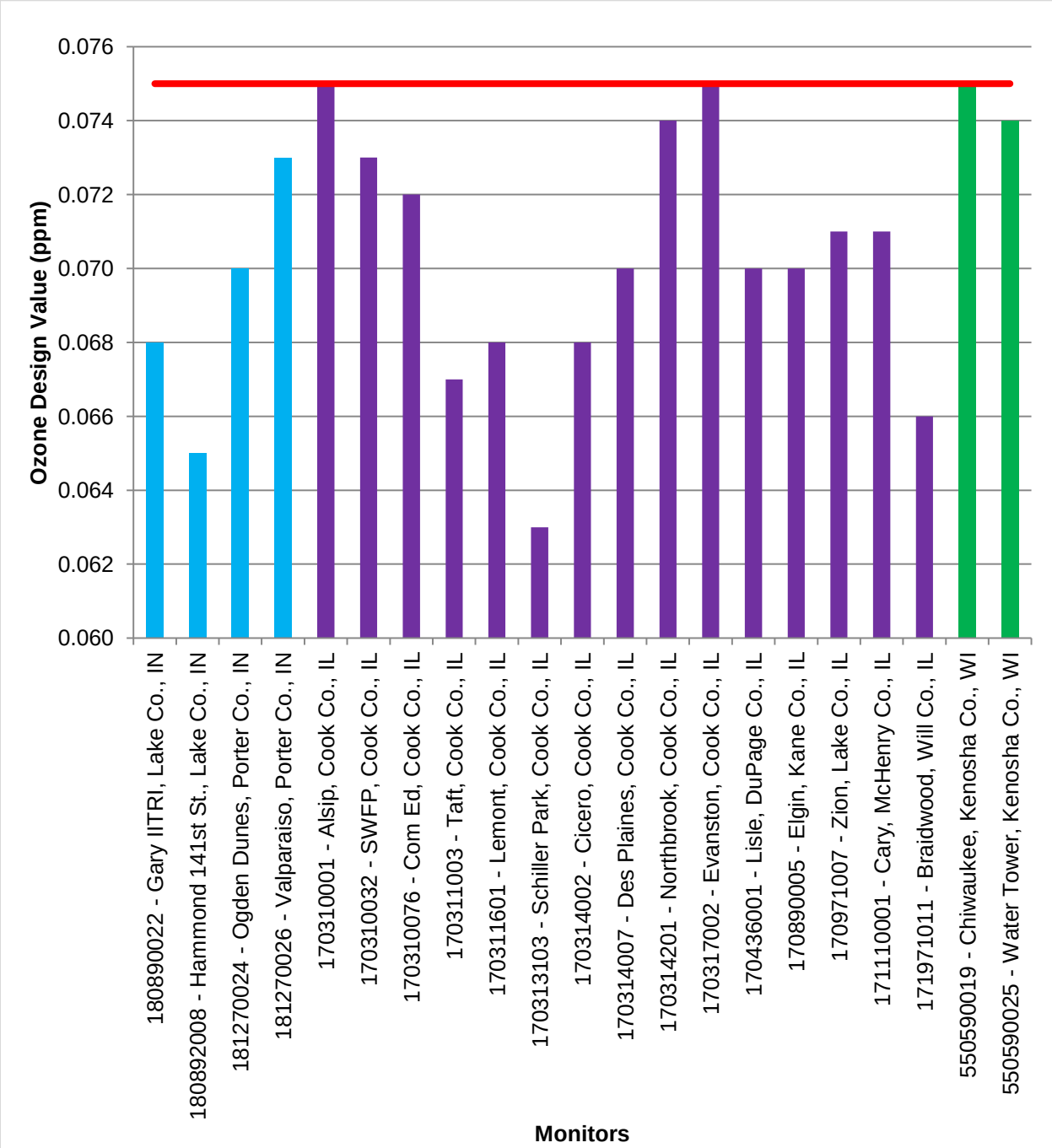


Chart 4.2: Design Values for All Monitors in the 2008 8-Hour Chicago Ozone Nonattainment Area for 2017-2019



5.0 EMISSION TRENDS ANALYSIS

5.1 Inventory

In consultation with U.S. EPA, Illinois, and Wisconsin, Indiana has developed an emissions inventory that represents a comprehensive, accurate, and current inventory of actual emissions from all sources of NO_x and VOCs in Lake and Porter counties for the projected-year of 2020 that is compared to the base-year of 2011. Point source (EGU and non-EGU), non-point, and non-road emissions were compiled from the data available on U.S. EPA's Emissions Modeling Clearinghouse website for the Chicago nonattainment area.[14] Indiana used the 2011v6.3 emissions modeling platform from the National Emissions Inventory Collaborative that includes a full suite of base year (2011) and projection year (2023) inventories, ancillary emission data, and scripts and software for preparing the emissions for air quality modeling. These remaining sectors (EGU, non-EGU, and non-point) were interpolated between 2011 and 2023.

On-road values for Lake and Porter counties in 2020 were produced by U.S. EPA's 2014a version of the MOVES software program by the Northwestern Indiana Planning Commission (NIRPC) (Appendix A3).

5.2 Trends Analysis

Overall emissions of VOCs and NO_x within the Chicago nonattainment area are projected to decrease significantly from 2011 to 2020. Chart 5.1 shows the total projected change for both pollutants over this period. Table 5.1 displays VOC and NO_x emissions by state, emission source sectors (EGU, point, non-point, on-road, and non-road), and totals for the entire nonattainment area. Charts 5.2 and 5.3 are graphical representations of the projected change in emissions by sector for each pollutant. The overall decreases in VOC and NO_x emissions should result in continued decreases in ozone concentrations within the area.

[14] https://www.epa.gov/air-emissions-modeling/2016v1-platform

Chart 5.1: VOC and NO_x Emissions in 2011 (Base-Year) and 2020 (Projected-Year) for the 2008 8-Hour Chicago Ozone Nonattainment Area

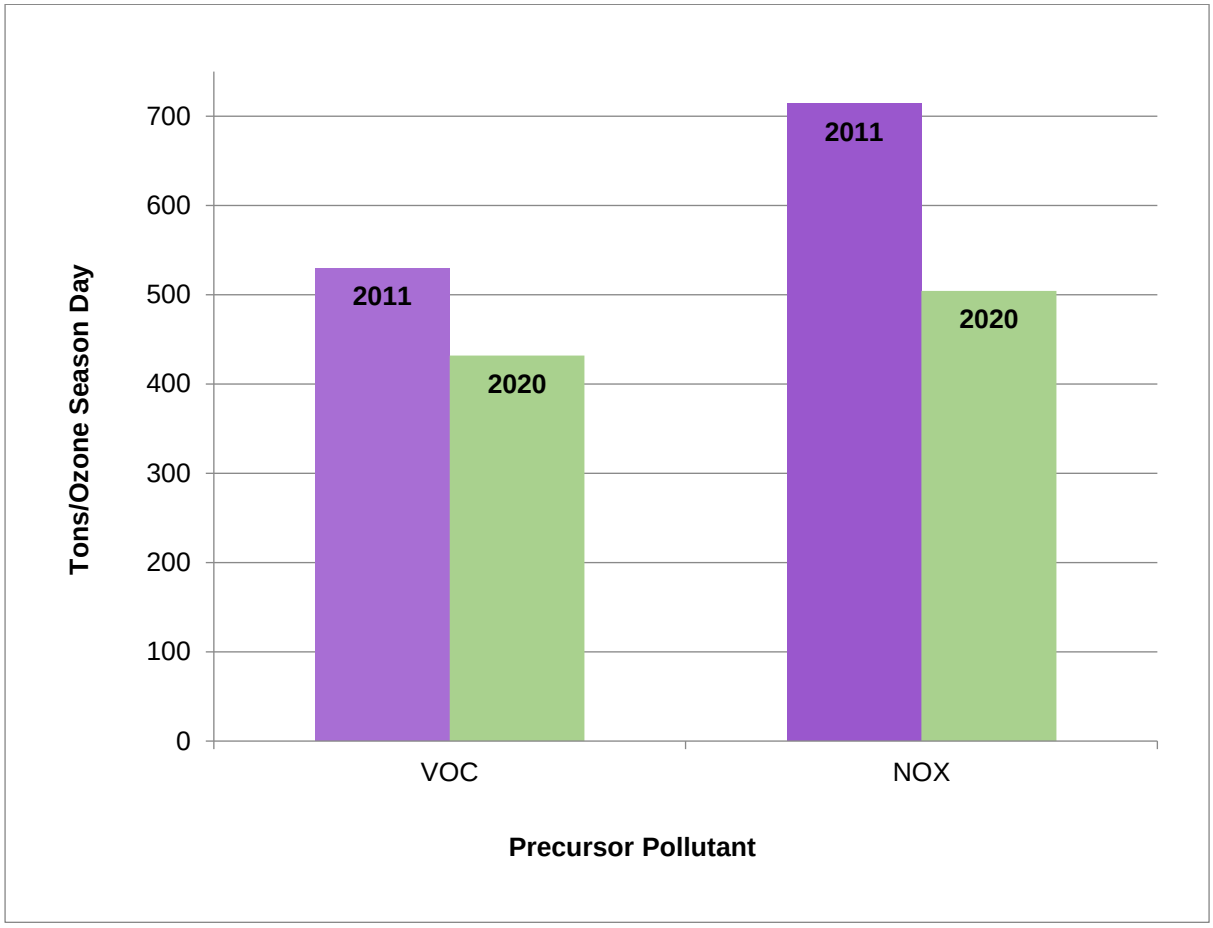


Table 5.1: VOC and NO_x Emissions from 2011 (Base-Year) and 2020 (Projected-Year) and Percent Change in Indiana's, Illinois', and Wisconsin's Portions of the 2008 8-Hour Chicago Ozone Nonattainment Area

Tons/Ozone Season Day		VOC			NOx		
		2011	2020	Change %	2011	2020	Change %
Indiana	EGU	0.54	0.26	-52	24.04	6.52	-73
	Nonpoint	18.26	19.00	4	9.39	9.00	-4
	Non-road	21.43	13.87	-35	15.84	12.73	-20
	On-road	9.58	6.18	-35	24.70	13.01	-47
	Point	17.21	18.72	9	70.78	76.86	9
	TOTAL	**67.03**	**58.03**	**-13**	**144.75**	**118.12**	**-18**
Illinois	EGU	0.40	0.72	82	44.18	21.98	-50
	Nonpoint	193.90	184.47	-5	76.22	74.25	-3
	Non-road	129.76	88.82	-32	117.51	74.63	-36
	On-road	85.83	51.36	-40	255.71	143.90	-44
	Point	41.05	39.50	-4	58.38	58.03	-1
	TOTAL	**450.94**	**364.87**	**-19**	**552.00**	**372.80**	**-32**
Wisconsin	EGU	0.32	0.33	3	6.54	6.30	-4
	Nonpoint	5.18	5.01	-3	1.66	1.48	-11
	Non-road	2.95	1.78	-40	2.24	1.46	-35
	On-road	2.86	1.59	-44	6.29	3.23	-49
	Point	0.31	0.31	1	0.77	0.90	17
	TOTAL	**11.61**	**9.03**	**-22**	**17.50**	**13.37**	**-24**
Chicago Nonattainment Area Totals	EGU	1.26	1.32	4	74.76	34.80	-53
	Nonpoint	217.34	208.48	-4	87.27	84.73	-3
	Non-road	154.13	104.47	-32	135.59	88.82	-34
	On-road	98.27	59.14	-40	286.70	160.14	-44
	Point	58.57	58.52	0	129.93	135.79	5
	TOTAL	**529.58**	**431.93**	**-18**	**714.25**	**504.28**	**-29**

Chart 5.2: VOC Emissions for 2011 (Base-Year) and 2020 (Projected-Year) by Source Sector for the 2008 8-Hour Chicago Ozone Nonattainment Area

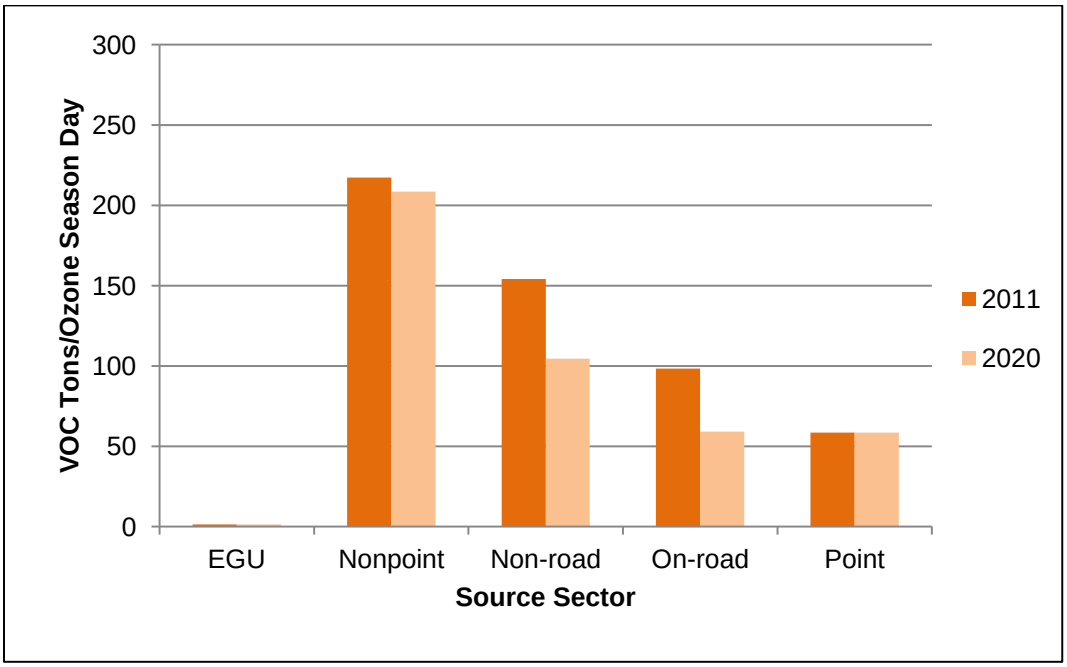
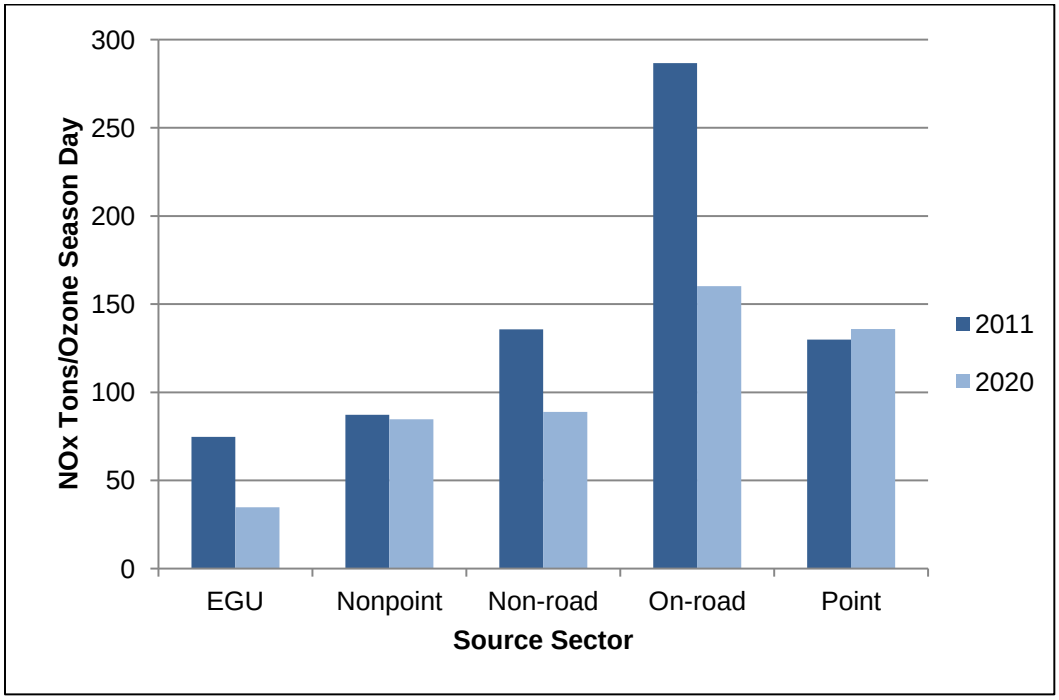


Chart 5.3: NO_x Emissions for 2011 (Base-Year) and 2020 (Projected-Year) by Source Sector for the 2008 8-Hour Chicago Ozone Nonattainment Area



5.2.1 Electric Generating Unit (EGU) Sources

Chart 5.4 shows the trend in regional NO_x emissions (tons per ozone season) from EGUs for the Chicago nonattainment area. Graph 5.5 depicts the trends of NO_x emissions (tons per ozone season) from EGUs in Lake and Porter counties. While ozone and its precursors are also transported into this region from outside areas, this information does provide indication that emissions are decreasing substantially. This is in part a result of national programs affecting all EGUs such as the Acid Rain program, the Clean Air Interstate Rule (CAIR), and now CSAPR. Other sectors of the inventory also impact ozone formation, but large regional sources, such as EGUs, have a substantial impact on the formation of ozone.

These data were taken from U.S. EPA's Clean Air Markets Program Data (AMPD).[15] Data are available sooner for these units than other point sources in the inventory because of the NO_x budgets and trading requirements. Information from 2003 is significant because some EGUs started operation of their NO_x SIP Call controls in order to generate Early Reduction Credits for their future year NO_x budgets. The first season of the NO_x SIP Call budget period began May 31, 2004.

As part of the NO_x SIP Call, states were required to adopt into their rules a budget for all large EGUs. Indiana's budget, which represents a statewide cap on NO_x emissions, is now found in the federal transport rule for NO_x ozone season trading rules at 40 CFR 97, Subpart BBBBB. Although each unit is allocated emissions based upon historic heat input, utilities can meet this budget by over-controlling certain units or purchasing credits from the market to account for overages at other units. To summarize, NO_x emissions have dramatically decreased over the years as represented on these graphs. These emissions, capped by the state rule, should remain at least this low through the maintenance period covered by this request.

[15] http://www.epa.gov/airmarkets/

Chart 5.4: NO_x Emissions, Electric Generating Units – 2008 8-Hour Chicago Nonattainment Area, 2003-2019

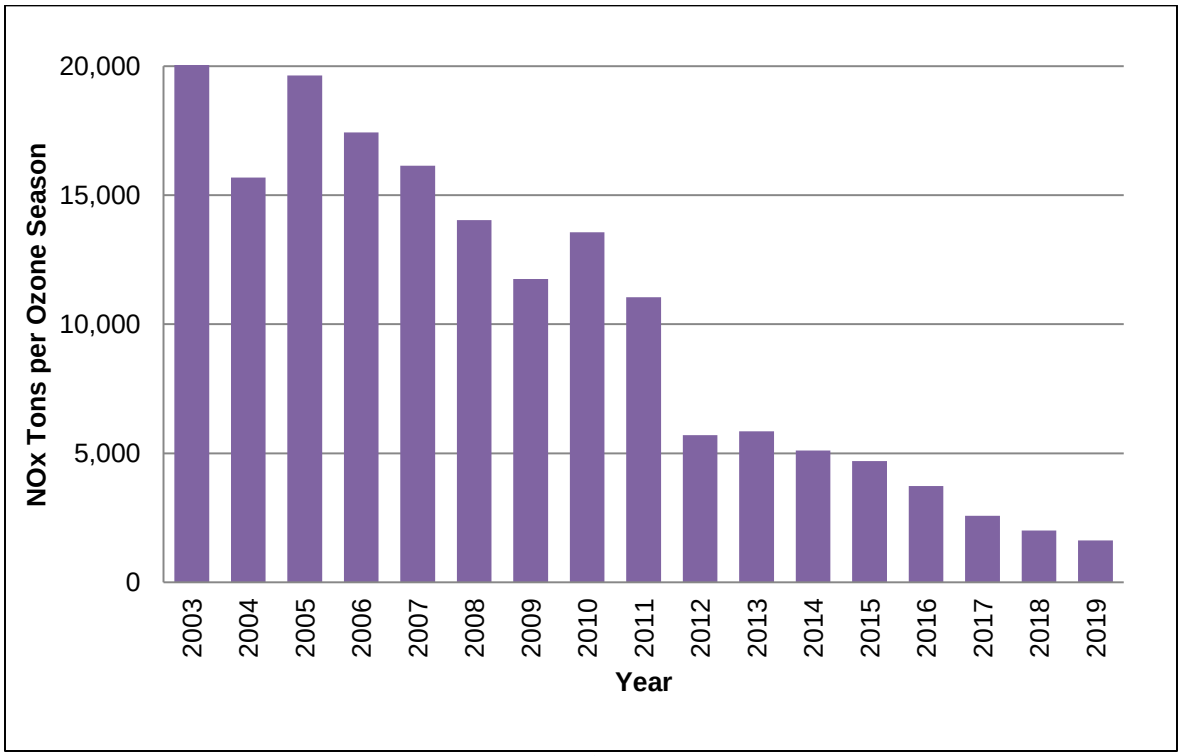
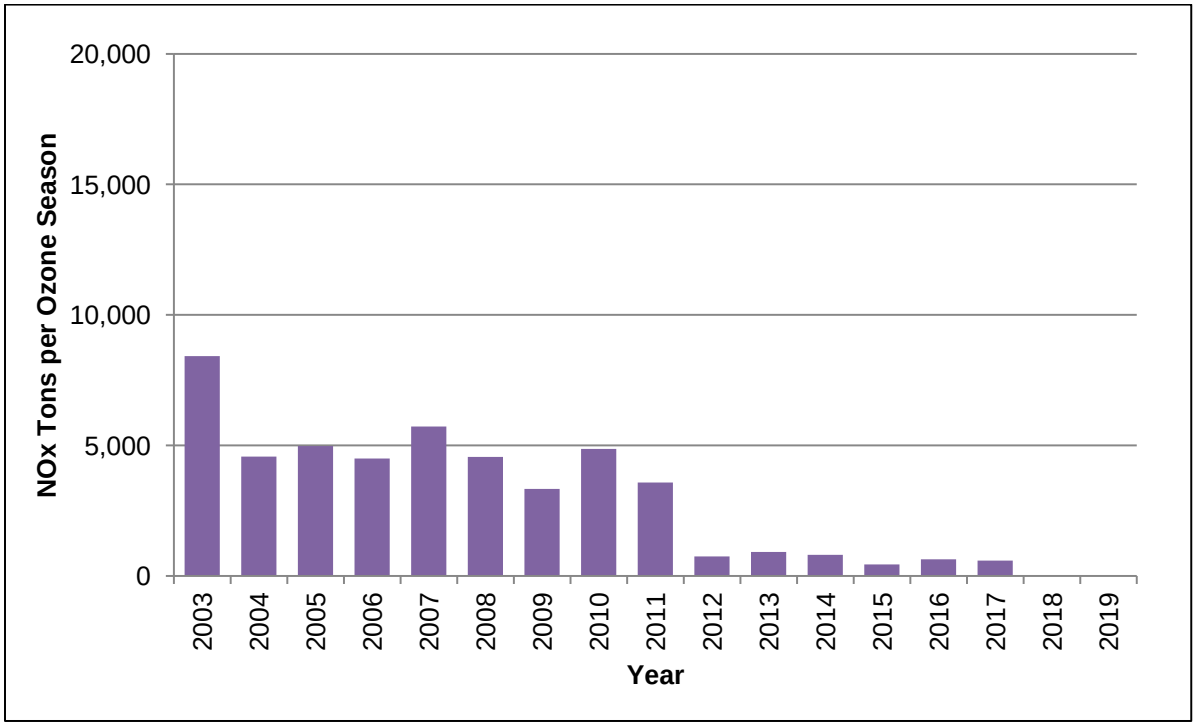


Chart 5.5: NO_x Emissions, Electric Generating Units – Lake and Porter Counties, Indiana, 2003-2019



6.0 MOBILE SOURCE EMISSIONS BUDGETS

U.S. EPA requirements outlined in 40 CFR 93.118(e)(4) stipulate that MVEBs for NO_x and VOC be established as part of a SIP. The MVEBs are necessary to demonstrate conformance of transportation plans and improvement programs with the SIP. A summary of the MVEB calculations and the MOVES methodology used in this area can be found in Appendix A3. In addition, due to the size of the MOVES input and output files, they will be provided electronically to appropriate staff with this submittal.

6.1 Overview

NIRPC is the MPO for the area that includes Lake, Porter, and LaPorte counties. This organization maintains a travel demand forecast model that is used to simulate traffic in the area and is used to predict what that traffic will be like in future years given growth expectations. The model is used mostly to identify where travel capacity will be needed and to determine the infrastructure requirements necessary to meet that need. It is also used to support the calculation of mobile source emissions. The travel demand forecast model is used to predict the total daily Vehicle Miles Traveled (VMT) and U.S. EPA's MOVES software program is used to calculate the emissions per mile. The product of these two outputs, once combined, is the total amount of pollution emitted by on-road vehicles for the analyzed area.

6.2 On-Road Emission Estimates

Broadly described, MOVES is used to generate "emission factors," which are the average emissions per mile (grams/mile) for the ozone precursors: NO_x and VOC. There are numerous variables that can affect the emission factors. The vehicle fleet (vehicles on the road) age and the vehicle types have a major effect on the emission factors. The facility type the vehicles are traveling on (MOVES facility types are Freeway and Arterial and distinguish between urban and rural areas) and the vehicle speeds also affect the emission factor values.

Meteorological factors, such as hourly air temperature and humidity, and the area's Vehicle Inspection/Maintenance program affect the emission factors as well. These data are estimated using the *best available data* to generate emission factors for appropriate ozone precursors, NO_x and VOC. VMT data is generated by the region's travel demand model. Once emission factors are determined, the emission factor(s) is multiplied by the VMT to ultimately determine the quantity of vehicle emissions. It should be noted that each year analyzed will have different emission factors, volumes, speeds, and likely some additional roadway links.

Table 6.1 outlines the on-road emission estimations in tons per summer day (tpsd) for the Lake and Porter ozone nonattainment area for the 2011 base-year and the 2020 projected-year. The 2011 and 2020 emission estimates are based on the actual travel demand model network runs for those specific years.

Table 6.1: Emission Estimations and Projections for On-Road Mobile Sources - Lake and Porter Counties, Indiana, 2011 (Base-Year), 2020 (Projected-Year)

Lake and Porter	2011 (Base-Year)	2020 (Projected-Year)
NO_x tpsd	24.70	13.01
VOC tpsd	9.58	6.18

6.3 Motor Vehicle Emission Budgets

Table 6.2 contains the projected motor vehicle emissions budget (tpsd) for the Lake and Porter counties portion of the Chicago-Naperville, IL-IN-WI ozone nonattainment area. As discussed in Section 2.1, this document contains reductions associated with a demonstrated rate of progress as well as contingency measures for NO_x and VOC emissions between 2011 and 2020. This budget includes the emission estimates for 2020 with a 15% margin of safety that is less than the available surplus emissions after the rate of progress and contingency measures are applied. Since assumptions change over time, IDEM determined a 15% margin of safety to be reasonable to account for such changes within the conformity process and the total decrease in emissions from all sources is sufficient to accommodate this fifteen (15) percent allocation of safety margin to mobile sources while still continuing to maintain total emissions in the area well below the 2011 attainment level of emissions. This fifteen (15) percent safety margin was calculated by adding a straight-line fifteen (15) percent to the mobile source emission estimates for the year 2020. A safety margin, as defined by the conformity rule, looks at the total emissions from all sources in the nonattainment area. The emission estimates derive from the NIRPC travel demand model and MOVES as described above under the NIRPC 2040 Comprehensive Regional Plan. The emissions calculation methodology, latest planning assumptions and margin of safety were approved through the interagency consultation process described in the Transportation Conformity Memorandum of Understanding (MOU) for NIRPC.

Table 6.2: Motor Vehicle Emission Budgets - Lake and Porter Counties, Indiana, 2020 (Projected-Year)

Lake and Porter	2020 (Projected-Year)
NO_x tpsd	14.96
VOC tpsd	7.11

7.0 CONTROL STRATEGY

Several control measures already in place or being implemented over the next few years will reduce point, on-road mobile, and non-road mobile source emissions. The Federal and State control measures in place are discussed below.

7.1 Nitrogen Oxides (NO_x) Rule[16]

On October 27, 1998, U.S. EPA established the NO_x SIP Call which required twenty-two (22) states to adopt rules that would result in significant emission reductions from large EGUs, industrial boilers, and cement kilns in the eastern United States. Indiana adopted this rule in 2001. Beginning in 2004, this rule accounts for a reduction of approximately thirty-one percent (31%) of all NO_x emissions statewide compared to previous uncontrolled years.

These rules were also adopted by twenty-one (21) other states. The resulting effect is that significant reductions have occurred within Indiana and regionally due to the number of affected units. The EGU portion of the NO_x SIP Call was replaced by CAIR and has since been replaced by the CSAPR which continues to result in NO_x controls for EGUs.

On April 21, 2004, U.S. EPA published Phase II of the NO_x SIP Call that established a budget for large (emissions of greater than one ton per day) stationary internal combustion engines. In Indiana, the rule decreased NO_x emissions statewide from natural gas compressor stations by 4,263 tons during the ozone season of May through September. The Indiana Phase II NO_x SIP Call rule became effective in 2006, and implementation began in 2007 (326 IAC 10-5).

7.2 Measures Beyond Clean Air Act (CAA) Requirements

Reductions in ozone precursor emissions have occurred and are anticipated to continue, as a result of state and federal control programs. These additional control measures are summarized below.

7.2.1 Tier II Emission Standards for Vehicles and Gasoline Sulfur Standards[17]

On February 10, 2000, U.S. EPA finalized a federal rule to significantly reduce emissions from cars and light duty trucks including sport utility vehicles (SUVs). This rule required automakers to produce cleaner cars and refineries to make cleaner lower-sulfur gasoline. This rule was phased in between 2004 and 2009 and resulted in a 77% decrease in NO_x emissions from passenger cars, an 86% decrease from smaller SUVs, light duty trucks, and minivans, and a 65% decrease from 8-larger SUVs, vans, and heavier duty truck classes. This rule also resulted in a 12% decrease in VOC emissions

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[16] http://www.gpo.gov/fdsys/pkg/FR-1998-10-27/pdf/98-26773.pdf
[17] http://www.gpo.gov/fdsys/pkg/FR-2000-02-10/pdf/00-19.pdf

from passenger cars, an 18% decrease from smaller SUVs, light duty trucks, and minivans, and a 15% decrease from larger SUVs, vans, and heavier duty trucks.

7.2.2 Tier III Emission Standards for Vehicles and Gasoline Sulfur Standards[18]

On April 28, 2014, U.S. EPA finalized a federal rule to further strengthen Tier II vehicle emission and fuel standards. This rule will require automakers to produce cleaner vehicles and refineries to make cleaner lower-sulfur gasoline. This rule is being phased in between 2017 and 2025. Tier III requires all passenger vehicles to meet an average standard of 0.03 gram/mile of NO_x. When compared to Tier II, the Tier III tailpipe standards for light-duty vehicles are expected to reduce NO_x and VOC emissions by approximately 80%. Tier III vehicle standards also include evaporative standards using onboard diagnostics that will result in a 50% reduction in VOC emissions compared to Tier II reductions. In January 2017, the rule reduced the sulfur content of gasoline to 10 ppm.

7.2.3 Heavy-Duty Diesel Engines[19]

On January 18, 2001, U.S. EPA issued a final rule for Highway Heavy-Duty Engines, a program that includes low-sulfur diesel fuel standards. This rule applies to heavy-duty gasoline and diesel trucks and buses. This rule was phased in from 2004 through 2007 and resulted in a 40% decrease in NO_x emissions from diesel trucks and buses.

7.2.4 Clean Air Non-road Diesel Rule[20]

On June 29, 2004, U.S. EPA issued the Clean Air Non-road Diesel Rule. This rule applies to diesel engines used in industries such as construction, agriculture, and mining. It also contains a cleaner fuel standard similar to the highway diesel program. The engine standards for non-road engines took effect in 2008 and resulted in a 90% decrease in sulfur dioxide (SO_2) emissions from non-road diesel engines. Sulfur levels were also reduced in non-road diesel fuel by 99.5% from approximately 3,000 ppm to 15 ppm.

7.2.5 Non-road Spark-Ignition Engines and Recreational Engine Standards [21]

This standard was effective on January 7, 2003, and regulates NO_x, VOCs, and carbon monoxide (CO) for groups of previously unregulated non-road engines. This standard applies to all new engines sold in the United States and imported after the standards went into effect. The standard applies to large spark-ignition engines (forklifts and airport ground service equipment), recreational vehicles (off-highway motorcycles and all-terrain vehicles), and recreational marine diesel engines. According to U.S. EPA

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[18] http://www.gpo.gov/fdsys/pkg/FR-2014-04-28/pdf/2014-06954.pdf
[19] http://www.gpo.gov/fdsys/pkg/FR-2001-01-18/pdf/01-2.pdf
[20] http://www.gpo.gov/fdsys/pkg/FR-2004-06-29/pdf/04-11293.pdf
[21] http://www.gpo.gov/fdsys/pkg/FR-2002-11-08/pdf/02-23801.pdf

estimates, this rule has resulted in an overall 80% reduction in NO_x, 72% reduction in VOC, and 56% reduction in CO emissions.

7.2.6 Reciprocating Internal Combustion Engine Standards[22]

This standard was effective May 3, 2010 and regulates emissions of air toxics from existing diesel-powered stationary reciprocating internal combustion engines that meet specific site rating, age, and size criteria. These engines are typically used at industrial facilities (e.g. power, chemical, and manufacturing plants) to generate electricity for compressors and pumps and to produce electricity to pump water for flood and fire control during emergencies. The standard applies to stationary diesel engines: (1) used at area sources of air toxics and constructed or reconstructed before June 12, 2006; (2) used at major sources of air toxics, having a site rating of less than or equal to 500 horsepower, and constructed or reconstructed before June 12, 2006; and, (3) used at major sources of air toxics for non-emergency purposes, having a site rating of greater than 500 horsepower, and constructed or reconstructed before December 19, 2002.

Operators of existing engines were required to: (1) install emissions control equipment that would limit air toxics up to 70% for stationary non-emergency engines with a site rating greater than 300 horsepower; (2) perform emission tests to demonstrate engine performance and compliance with rule requirements; and, (3) burn ultra-low sulfur fuel in stationary non-emergency engines with a site rating greater than 300 horsepower. These engine standards took effect in 2013. According to U.S. EPA estimates, this rule has resulted in emission reductions from existing diesel-powered stationary reciprocating internal combustion engines of approximately 1,000, 2,800, and 27,000 tons per year (tpy) of air toxics, $PM_{2.5}$, and CO, respectively.

7.2.7 Category 3 Marine Diesel Engine Standards[23]

This standard was effective on June 29, 2010, and promulgated more stringent exhaust emission standards for new large marine diesel engines with per-cylinder displacement at or above 30 liters (commonly referred to as Category 3 compression-ignition marine engines) as part of a coordinated strategy to address emissions from all ships that affect U.S. air quality. These emission standards are equivalent to those adopted in the amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL Annex VI). The emission standards apply in two stages: near-term standards for newly built engines, which took effect in 2011, and long-term standards requiring an 80% reduction in NO_x emissions that began in 2016.

U.S. EPA is adopting changes to the diesel fuel program to allow for the production and sale of diesel fuel with up to 1,000 ppm sulfur for use in Category 3 marine vessels. The regulations generally forbid production and sale of fuels with more than 1,000 ppm

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[22] http://www.gpo.gov/fdsys/pkg/FR-2010-03-03/pdf/2010-3508.pdf
[23] http://www.gpo.gov/fdsys/pkg/FR-2010-04-30/pdf/2010-2534.pdf

sulfur for use in most U.S. waters unless operators achieve equivalent emission reductions in other ways.

U.S. EPA is also adopting provisions to apply some emission and fuel standards to foreign-flagged and in-use vessels that are covered by MARPOL Annex VI. When this strategy is fully implemented in 2030, U.S. EPA estimates that NO_x and $PM_{2.5}$ emissions in the U.S. will be reduced by approximately 1.2 million tpy and 143,000 tpy, respectively.

7.2.8 Clean Air Interstate Rule (CAIR) / Cross State Air Pollution Rule (CSAPR)[24] [25]

On May 12, 2005, U.S. EPA published the following regulation: "Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (CAIR); Revisions to Acid Rain Program; Revisions to the NO_x budget; Final Rule". This rule established the requirement for states to adopt rules limiting the emissions of NO_x and SO_2 and provided a model rule for the states to use in developing their rules in order to meet federal requirements. The purpose of CAIR was to reduce interstate transport of $PM_{2.5}$, SO_2, and ozone precursors (NO_x).

CAIR applied to any stationary fossil fuel-fired boiler, stationary fossil fuel-fired combustion turbine, or a generator with a nameplate capacity of more than 25 megawatt electrical (MWe) producing electricity for sale. This rule provided annual state caps for NO_x and SO_2 in two phases with Phase I caps for NO_x and SO_2 starting in 2009 and 2010, respectively. Phase II caps were to become effective in 2015. U.S. EPA allowed limits to be met through a cap and trade program if a state chose to participate in the program. SO_2 emissions from power plants in the 28 eastern states and the District of Columbia (D.C.) covered by CAIR were to be cut by 4.3 million tons from 2003 levels by 2010 and 5.4 million tons from 2003 levels by 2015. NO_x emissions were to be cut by 1.7 million tons by 2009 and reduced by an additional 1.3 million tons by 2015. In response to U.S. EPA's rulemaking, Indiana adopted a state rule in 2006 based on the model federal rule (326 IAC 24-1, 326 IAC 24-2, and 326 IAC 24-3). Indiana's rule included annual and seasonal NO_x trading programs, and an annual SO_2 trading program. This rule required compliance effective January 1, 2009.

In July 2008, the D.C. Circuit court vacated CAIR and issued a subsequent remand without vacatur of CAIR in December 2008. The court then directed U.S. EPA to revise or replace CAIR in order to address the deficiencies identified by the court. On July 6, 2011, U.S. EPA finalized the CSAPR as a replacement for CAIR. On August 21, 2012, the U.S. Court of Appeals for the D.C. Circuit vacated CSAPR and directed U.S. EPA to continue administering CAIR "pending the promulgation of a valid replacement." In a subsequent decision on the merits, the Court vacated CSAPR based on a subset of petitioners' claims. On April 29, 2014, the U.S. Supreme Court reversed that decision and remanded the case to the D.C. Circuit court for further proceedings. Throughout

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[24] https://www.epa.gov/csapr/cross-state-air-pollution-rule-csapr-regulatory-actions-and-litigation
[25] https://www.gpo.gov/fdsys/pkg/FR-2016-10-26/pdf/2016-22240.pdf

the initial round of D.C. Circuit proceedings, and the ensuing U.S. Supreme Court proceedings, the stay remained in place and U.S. EPA had continued to implement CAIR.

In order to allow CSAPR to replace CAIR in an equitable and orderly manner, while further D.C. Circuit Court proceedings were held to resolve petitioner's remaining claims, U.S. EPA filed a motion asking the D.C. Circuit Court to lift the stay. U.S EPA also asked the court to toll all CSAPR compliance deadlines that had not passed as of the date of the stay order by three years. On October 23, 2014, the Court granted U.S. EPA's motion. CSAPR became effective on January 1, 2015, for SO_2 and annual NO_x, and then on May 1, 2015, for ozone season NO_x.

On September 7, 2016, U.S. EPA finalized an update to the Cross-State Air Pollution Rule (CSAPR) for 2008 ozone standard. This is a federal implementation plan (FIP) that sets forth new EGU emission budgets for NO_x via allowance trading modifications in 22 eastern states. These affected states failed to submit fully approvable infrastructure SIPs that address interstate transport of emissions. Compliance with these emissions reductions began January 2017 for the annual program and May 2017 for the ozone season program. This final rule became effective on December 27, 2016.

On December 6, 2018, U.S. EPA signed a final action determining that the existing CSAPR Update fully addresses and provides complete remedy for the CAA's good neighbor provision requirements for the remaining CSAPR Update states, including Indiana (83 FR 65878). The final rule went into effect on February 19, 2019. According to U.S. EPA, the final Determination Rule satisfied U.S. EPA's obligation to fully address the good neighbor provision requirements for the 2008 8-hour ozone standard. As such, U.S. EPA required no further action be taken by Indiana to address the good neighbor provision requirements and the supplemental information submitted on March 29, 2018 was unnecessary. Therefore, Indiana withdrew the March 29, 2018, submittal on July 9, 2019.

Downwind states, that have undertaken court challenges to force U.S. EPA to bring the upwind states, including Indiana, into compliance with the CAA's good neighbor provision requirements in the past, challenged U.S. EPA's decision to require no further action in a court filling in the D.C. Circuit on January 30, 2019.[26] On October 1, 2019, the D.C. Circuit struck down the rule, on the basis that future action is required to meet a statutory 2021 deadline.[27]

On September 13, 2019, D.C. Circuit decision on Wisconsin v. U.S. EPA held that U.S. EPA was required to fully address upwind states' Good Neighbor obligations by the downwind states' statutory attainment dates. The court remanded the CSAPR Update without vacatur. The Southern District of New York issued a July 28, 2020 decision in

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[26] https://www.epa.gov/sites/production/files/2019-01/documents/downwinders_19-1020_pfr_01302019.pdf
[27] https://policyintegrity.org/documents/Opinion_19-1019.pdf

NJ v. Wheeler, ruling that U.S. EPA must issue a final federal plan rule by March 15, 2021.

On October 15, 2020, U.S. EPA proposed the revised CSAPR Update in order to fully address 21 states' outstanding transport obligations for the 2008 standard. Starting in 2021 ozone season, the proposed rule would reduce NO_x emissions from power plants in 12 states.

7.2.9 Oil and Natural Gas Industry Standards[28]

This standard was issued on August 16, 2012 and regulates VOC and air toxic emissions from hydraulically fractured natural gas wells and includes requirements for several other sources of pollution in the oil and natural gas industry that were previously unregulated in the United States. U.S. EPA estimated that these standards will apply to approximately 11,400 new natural gas wells hydraulically fractured each year and an additional 1,400 existing natural gas wells refractured annually. These standards took effect in 2015. According to U.S. EPA estimates, this rule has resulted in emission reductions of VOC and air toxics of approximately 190,000-290,000 tpy and 12,000-20,000 tpy, respectively.

7.2.10 Mercury and Air Toxic Standards (MATS)[29] [30]

This standard was effective on April 16, 2012, and regulates emissions of mercury, acid gases, and non-mercury metallic toxic pollutants from new and existing coal and oil-fired EGUs. U.S. EPA estimates that this rule will apply to approximately 1,100 coal-fired and 300 oil-fired EGUs at 600 power plants in the United States. According to U.S. EPA, most facilities will comply with these standards through a range of strategies including the use of existing emission controls, upgrades to existing emission controls, installation of new pollution controls, and fuel switching.

Following promulgation of the rule, U.S. EPA received petitions for reconsideration of various provisions of the rule including requests to reconsider the work practice standards applicable during startup periods and shutdown periods. U.S. EPA granted reconsideration of the startup and shutdown provisions as no opportunity to comment was provided to the public regarding the work practice requirements contained in the final rule. On November 30, 2012, U.S. EPA published a proposed rule reconsidering certain new source standards and startup and shutdown provisions in MATS. U.S. EPA proposed certain minor changes to the startup and shutdown provisions contained in the 2012 final rule based on information obtained in the petitions for reconsideration. On April 24, 2013, U.S. EPA took final action on the new source standards that were reconsidered and also the technical corrections contained in the November 30, 2012, proposed action. U.S. EPA did not take final action on the startup and shutdown

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[28] http://www.gpo.gov/fdsys/pkg/FR-2012-08-16/pdf/2012-16806.pdf
[29] http://www.gpo.gov/fdsys/pkg/FR-2012-02-16/pdf/2012-806.pdf
[30] https://www.epa.gov/mats/regulatory-actions-final-mercury-and-air-toxics-standards-mats-power-plants

provisions. On June 25, 2013, U.S. EPA added new information and analysis to the docket and reopened the public comment period for the proposed revisions. U.S. EPA took final action on the remaining topics open for reconsideration on November 19, 2014. The compliance date for existing sources was April 16, 2015, while the compliance date for new sources was April 16, 2012.

On November 25, 2014, the U.S. Supreme Court accepted several challenges to the rules brought by the utility industry and a coalition of nearly two dozen states. On June 29, 2015, the U.S. Supreme Court ruled that U.S. EPA did not properly account for compliance costs when crafting the MATS rule and remanded the decision to the D.C. Circuit Court for reconsideration. As a response, on November 20, 2015, U.S. EPA proposed to find that regulating emissions of toxic air pollution from power plants is applicable and that considering the possible associated costs of compliance does not change that conclusion. On March 17, 2016, U.S. EPA finalized a number of clarifying changes and corrections to the MATS rule. On April 14, 2016, U.S. EPA confirmed that it is appropriate and necessary to regulate emissions of toxic air pollution after including a consideration of costs. On August 8, 2016, U.S. EPA denied two petitions for reconsideration of the startup and shutdown provisions in MATS. On March 29, 2017, U.S. EPA finalized portions of its proposal to streamline "e-reporting" in MATS. On June 26, 2018, U.S. EPA extended the period during which certain electronic reports can by submitted as PDFs. On April 15, 2020, after evaluating information on the acid gas hazardous air pollutant emissions from EGUs that burn eastern bituminous coal refuse, U.S. EPA established a new subcategory for these units. On May 22, 2020, U.S. EPA completed a reconsideration of the appropriate and necessary finding for MATS, correcting flaws in the approach to considering costs and benefits while ensuring that hazardous air pollutant emissions from power plants continue to be appropriately controlled. On July 17, 2020, U.S. EPA finalized revisions to the electronic reporting requirements to increase data transparency, provide enhanced access to data, and extend the current deadline for alternative electronic data submission via PDF files through December 31, 2023.

7.3 New Source Review (NSR) Provisions[31]

Indiana has a long standing and fully implemented NNSR permitting program that is outlined in 326 IAC 2-3 (Attachment E). U.S. EPA approved the initial rules on October 7, 1994 (94 FR 24837).[32] U.S. EPA approved amendments affecting 326 IAC 2-3-1, 326 IAC 2-3-2, and 326 IAC 2-3-3 to comply with federal rules for NSR Reform on December 31, 2002 (67 FR 80186) and July 8, 2011 (76 FR 40242)[33], which have not been subsequently amended.

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[31] https://www.federalregister.gov/articles/2004/05/20/04-11337/approval-and-promulgation-of-implementation-plans-indiana
[32] https://www.gpo.gov/fdsys/pkg/FR-1994-10-07/html/94-24837.htm
[33] https://www.govinfo.gov/content/pkg/FR-2011-07-08/pdf/2011-17036.pdf

Any facility for which emission reduction credit through closing was taken will not be allowed to construct, reopen, modify, or reconstruct without meeting all applicable permit rule requirements. The review process will be identical to that used for new sources. This program requires an air quality analysis to evaluate whether the new source will threaten the NAAQS.

Indiana commits to maintain the control measures listed above or submit to U.S. EPA as a SIP revision, any changes to its rules or emission limits applicable to NO_x or VOC sources as required for maintenance of the 2008 8-hour ozone standard in Lake and Porter counties, Indiana. Indiana, through IDEM's OAQ and its Compliance and Enforcement Branch, has the legal authority and necessary resources to actively enforce any violations of its rules or permit provisions. IDEM intends to continue enforcing all rules that relate to the emission of ozone precursors in Lake and Porter counties, Indiana.

8.0 WEIGHT OF EVIDENCE

A weight of evidence demonstration relies on the use of supplemental information to support the modeling analysis (Section 3.0 and Appendix A1), demonstrating that the nonattainment area will comply with the ozone standard by the prescribed attainment date. In Sections 4.0, 5.0, and 6.0, this demonstration has included analyses of air quality trends, emission trends, current air quality data, and a summary of projected emission reductions. This section exemplifies two modeling analyses that both conclude attainment of the 2008 8-hour standard in 2017, 2018, and 2020. These are U.S. EPA Modeling Analysis for Interstate Transport "Good Neighbor" Provision and U.S. EPA Modeling Analysis for Heavy Duty Engine (HDE) Final Rulemaking.

8.1 U.S. EPA Modeling Analysis for Interstate Transport "Good Neighbor" Provision

U.S. EPA conducted modeling for the Interstate Transport "Good Neighbor" Provision. This analysis was performed in 2014 and 2016, and was released in the January 2015 "Air Quality Modeling Technical Support Document for the 2008 Ozone NAAQS Transport Assessment" and the August 2016 "Air Quality Modeling Technical Support Document for the Final Cross State Air Pollution Rule Update".[34] These documents assist states in developing "Good Neighbor SIPs" as required by the CAA to address interstate transport of air pollution that affects downwind states' ability to attain and maintain the 2008 8-hour ozone NAAQS. Some of the major federal emission strategies included in the modeling are: NESHAPs for Reciprocating Internal Combustion Engines (RICE), NESHAPs for cement manufacturing plants, the Boiler Maximum Achievable Control Technology (MACT) rule, the Energy Independence and Security Act (EISA) renewable fuel standard (RFS) mandate, New Source Performance Standards (NSPS) for VOC controls, the Mobile Source Air Toxics rule, Tier III Emission Standards for Vehicles and Gasoline Sulfur Standards , Emission Standards for Locomotives and Marine Compression-Ignition Engines, and the Non-road Spark-

[34] https://www.epa.gov/airmarkets/final-cross-state-air-pollution-rule-update

Ignition Engines and Recreational Engine Standards.

This modeling was conducted to identify monitoring sites that may have difficulty attaining the 2008 Ozone NAAQS in 2018 and identify states that were contributing to attainment issues at a given monitoring site. The air quality model used for this rulemaking was the Comprehensive Air Quality Model with Extensions (CAMx) version 6.10. The modeling domain consisted of a 12-kilometer (km) x 12 km coarse grid and 25 vertical layers from the surface up through the troposphere to a height of 50 millibars of pressure covering the continental United States and portions of Canada and Mexico. Base-year 2011 emissions were modeled. Meteorology from 2011 was created using the Weather Research Forecasting (WRF) Model version 3.4 and was used for the base-case and projected year modeling runs. More detailed information on the CAMx input files and additional data used for the photochemical modeling can be found in U.S. EPA's "Air Quality Modeling Technical Support Document for the 2008 Ozone NAAQS Transport Assessment," dated January 2015.

Table 8.1 shows the results of U.S. EPA's "Good Neighbor" Provision modeling for ozone impacts at the ozone monitors in the Chicago nonattainment area. The monitor identification number, county, and state locations are listed, as well as the 2009-2013 8-hour ozone base-period average design values that were used to calculate 2018 projected average design values. Note that the 2009–2013 average design values were calculated by averaging the 3-year design values from 2009–2011, 2010–2012, and 2011–2013.

Model results are used in a relative rather than absolute sense. Relative use of the model results calculates the fractional change in maximum concentrations based on two different emission scenarios, 2011 NEI emissions and 2018 projected emissions for this exercise. This fractional change, also known as an RRF, can be applied to each monitor's average base-period design value to determine ozone impacts. This approach differs from using the absolute or actual modeled result, which may show under- or over-predictions with the actual monitored values. The 2009–2013 average design values were multiplied by the corresponding RRF to determine all 2018 projected average design values. As can be seen in Table 8.1, the results show all modeled 8-hour ozone design values in the entire Chicago nonattainment area are projected to be well below the 2008 8-hour ozone standard of 0.075 ppm.

Table 8.1: Comparison of the Chicago-Naperville, IL-IN-WI, Area Average Design Values with U.S. EPA "Good Neighbor" Provision 2018 Modeling Results

Monitor ID	County	State	Monitored Average Design Value 2009-2013 Base-Period (ppm)	U.S. EPA- Projected Average Design Value 2018 Base-Case (ppm)
17-031-0001	Cook	IL	0.0720	0.0665
17-031-0032	Cook	IL	0.0777	0.0645
17-031-0064	Cook	IL	0.0713	0.0592
17-031-0076	Cook	IL	0.0717	0.0661
17-031-1003	Cook	IL	0.0697	0.0564
17-031-1601	Cook	IL	0.0713	0.0670
17-031-4002	Cook	IL	0.0717	0.0610
17-031-4007	Cook	IL	0.0657	0.0537
17-031-4201	Cook	IL	0.0757	0.0619
17-031-7002	Cook	IL	0.0760	0.0603
17-043-6001	DuPage	IL	0.0663	0.0618
17-089-0005	Kane	IL	0.0697	0.0646
17-097-1007	Lake	IL	0.0793	0.0641
17-111-0001	McHenry	IL	0.0697	0.0640
17-197-1011	Will	IL	0.0640	0.0581
18-089-0022	Lake	IN	0.0667	0.0585
18-089-0030	Lake	IN	0.0697	0.0617
18-089-2008	Lake	IN	0.0680	0.0602
18-127-0024	Porter	IN	0.0703	0.0606
18-127-0026	Porter	IN	0.0630	0.0571
55-059-0019	Kenosha	WI	0.0810	0.0654

U.S. EPA updated this modeling in August 2016 for the final CSAPR update. This changed the projection year to 2017 while the base-year remained 2011. Details on the air quality model selection, meteorological representation, and emission inventories used in the modeling are available in "Air Quality Modeling Technical Support Document for the Final Cross State Air Pollution Rule Update", released in August 2016. Table 8.2

shows the projected results for all the Chicago area ozone monitors will be well below the 2008 8-hour ozone NAAQS.

Table 8.2: Comparison of the Chicago-Naperville, IL-IN-WI, Area Average Design Values with U.S. EPA "Good Neighbor" Provision 2017 Modeling Results

Monitor ID	County	State	Monitored Average Design Value 2009 – 2013 Base-Period (ppm)	U.S. EPA- Projected Average Design Value 2017 Base-Case (ppm)
17-031-0001	Cook	IL	0.0720	0.0687
17-031-0032	Cook	IL	0.0777	0.0661
17-031-0064	Cook	IL	0.0713	0.0612
17-031-0076	Cook	IL	0.0717	0.0684
17-031-1003	Cook	IL	0.0697	0.0575
17-031-1601	Cook	IL	0.0713	0.0683
17-031-4002	Cook	IL	0.0717	0.0607
17-031-4007	Cook	IL	0.0657	0.0561
17-031-4201	Cook	IL	0.0757	0.0644
17-031-7002	Cook	IL	0.0760	0.0641
17-043-6001	DuPage	IL	0.0663	0.0628
17-089-0005	Kane	IL	0.0697	0.0672
17-097-1007	Lake	IL	0.0793	0.0668
17-111-	McHenry	IL	0.0697	0.0664

0001				
17-197-1011	Will	IL	0.0640	0.0598
18-089-0022	Lake	IN	0.0667	0.0607
18-089-0030	Lake	IN	0.0697	0.0639
18-089-2008	Lake	IN	0.0680	0.0596
18-127-0024	Porter	IN	0.0703	0.0636
18-127-0026	Porter	IN	0.0630	0.0585
55-059-0019	Kenosha	WI	0.0810	0.0687

8.2 U.S. EPA Modeling Analysis for HDE Final Rulemaking

U.S. EPA conducted modeling for Tier II vehicles and low-sulfur fuels. This analysis was performed in 2000 to support final rulemaking for the HDE and Vehicle Standards and Highway Diesel Fuel Rule and its expected impact on ozone levels. "Technical Support Document for the Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Air Quality Modeling Analyses" (EPA420-R-00-028) was referenced for support of this ozone attainment demonstration. Base year emissions from 1996 were modeled for 3 ozone episodes: June 12-24, 1995; July 5-15, 1995; and August 7-21, 1995. Results of this modeling show that ozone impacts from these fuel emission control measures, as well as the NO_x SIP Call, would be substantial in Lake and Porter counties. RRFs were calculated for each monitor for the year 2020. For this attainment demonstration Indiana applied these 2020 future-year RRFs to average design values from 2010-2014 for each monitor. Note that the 2010–2014 average design values were calculated by averaging the 3-year design values from 2010-2012, 2011-2013, and 2012-2014. Two monitors did not have valid 2012-2014 3-year design values. For these two monitors (IDs 170310064 and 170311003) only the 2010-2012 and 2011-2013 3-year design values were averaged. The resulting future-year design values for 2020 were calculated and are shown in Table 8.3. The results model 2020 design values for these monitors in the Chicago ozone nonattainment area will continue to attain the 8-hour ozone NAAQS of 0.075 ppm.

Table 8.3: U.S. EPA HDE Rulemaking Air Quality Modeling Analyses for the Chicago-Gary-Lake County, IN-IL, Ozone Nonattainment Area Applied to 2010-2014 Average Design Values

Monitor ID	County	State	Monitored Average Design Value 2010-2014 (ppm)	2020 Modeled RRFs	2020 Future-Year DV (ppm)
180890022	Lake	IN	0.069	0.894	0.061
180892008	Lake	IN	0.07	0.9015	0.063
181270024	Porter	IN	0.072	0.894	0.064
181270026	Porter	IN	0.064	0.9113	0.058
170310001	Cook	IL	0.071	0.9462	0.067
170310032	Cook	IL	0.079	0.9071	0.071
170310064	Cook	IL	0.073	0.9165	0.066
170311003	Cook	IL	0.071	0.8897	0.063
170311601	Cook	IL	0.072	0.9254	0.066
170314002	Cook	IL	0.071	0.8994	0.063
170314201	Cook	IL	0.076	0.9268	0.070
170317002	Cook	IL	0.079	0.9268	0.073
170436001	DuPage	IL	0.067	0.9441	0.063
170890005	Kane	IL	0.069	0.9441	0.065
170971007	Lake	IL	0.08	0.9226	0.073
171110001	McHenry	IL	0.07	0.9404	0.065
171971011	Will	IL	0.064	0.8722	0.055
550590019	Kenosha	WI	0.082	0.9226	0.075

9.0 CONTINGENCY MEASURES

Section 172(c)(9) of the CAA requires that an attainment demonstration contain specific measures that would take effect upon a failure to attain the ozone standard in a given area, without further action by the State or U.S. EPA. U.S. EPA guidance indicates that States must pre-adopt rules with implementation dates pending demonstration of attainment and States will have 60 days after U.S. EPA notification of failure to attain to perform all actions needed to affect full implementation of the measures.

Contingency measures to be considered will be selected from a comprehensive list of measures deemed appropriate and effective at the time the selection is made. Listed below are example measures that may be considered. All the listed contingency measures are potentially effective or proven methods of obtaining significant reductions of ozone precursor emissions. Because it is not possible at this time to determine what control measure will be appropriate at an unspecified time in the future, the list of contingency measures outlined below is not comprehensive. Indiana anticipates that if

contingency measures should ever be necessary, it is unlikely that a significant number (i.e., all those listed below) will be required.

1. Enhancements to the vehicle emissions testing program (increased weight limit, addition of diesel vehicles, etc.)
2. Asphalt paving (lower VOC formulation)
3. Diesel exhaust retrofits
4. Traffic flow improvements
5. Idle reduction programs
6. Portable fuel container regulation (statewide)
7. Park and ride facilities
8. Rideshare/carpool program
9. VOC cap/trade program for major stationary sources
10. NO_x Reasonably Available Control Technology

The selection of measures will be based upon cost-effectiveness, emission reduction potential, economic and social considerations, or other factors that IDEM deems appropriate. IDEM will solicit input from all interested and affected persons in the maintenance area prior to selecting appropriate contingency measures. There will not be any contingency measure implemented without providing the opportunity for full public participation during which the relative costs and benefits of individual measures, at the time they are under consideration, can be fully evaluated.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR 51.102, public participation in this request was provided as follows:

Notice of availability of the complete document and a request for the opportunity for a public hearing was made available on IDEM's website on November 24, 2020, at https://www.in.gov/idem/5474.htm. It remained posted on the site until at least December 27, 2020.

During the public comment period IDEM did not receive any public comments. The deadline during the public comment period to request a hearing was December 27, 2020. There was not a request for a public hearing and therefore the hearing was not required to be held.

A copy of the legal public notice can be found in Attachment I.

11.0 CONCLUSION

Indiana has performed an analysis that shows that the air quality improvements in the Chicago nonattainment area are due to permanent and enforceable emission control measures and that significant regional VOC and NO_x reductions will ensure continued

compliance (maintenance) with the standard. Additionally, Indiana has ensured that all CAA requirements necessary to support this attainment demonstration have been met. Monitored air quality in the Chicago ozone nonattainment area has shown improvement in ozone concentration levels as a result of national and local control strategies implemented since designation. This demonstration shows that NO_x and VOC emission reductions since designation have had a positive effect on regional ozone levels. The modeled attainment demonstration provides the necessary evidence that the Chicago nonattainment area will attain the ozone standard by attainment date of July 20, 2021. Along with the sustained national, regional, and local control measures, and any future measures that will be phased-in or implemented, air quality in the area will meet photochemical model predictions and the area should attain the ozone standard by the attainment date.

This conclusion is supported by technical demonstrations that provide supporting evidence of attainment. These include a 2020 nine percent (9%) rate of progress plan and three (3%) contingency plan, air quality analyses, emissions analyses, on-road analyses, and weight of evidence analyses.

Under the previous 1-hour standard, and under the current 8-hour standard for ozone, emission control measures that are more stringent than in any other portion of Indiana have been implemented in Lake and Porter counties. These controls are comparable to measures implemented elsewhere within the nonattainment area. These controls shall remain in effect to ensure continued compliance with the standard.

This plan satisfies Indiana's obligation under Sections 172 and 182 of the CAA to demonstrate how the area will attain the air quality standard for ozone by the attainment date, and, as a result, realize cleaner air. The development of this plan, along with the plans from Illinois and Wisconsin, will bring this region into compliance with state and federal ozone quality standards, and provide real progress in the state's journey toward cleaner air.

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APPENDIX A1

Attainment Demonstration Modeling for the 2008
Ozone National Ambient Air Quality Standard

Lake Michigan Air Directors Consortium
Technical Support Document

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LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Attainment Demonstration Modeling for the 2008 Ozone National Ambient Air Quality Standard

Technical Support Document

Lake Michigan Air Directors Consortium

9501 W. Devon Ave., Suite 701

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Please direct question/comments to adelman@ladco.org

November 19, 2020

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Document Change Log

Version	Date	Comments/Changes
Draft 1	July 1, 2020	First draft to LADCO states
Draft 2	July 29, 2020	Integrated comments from WI DNR
Draft 3	October 22, 2020	Integrated comments from U.S. EPA Region 5; updated modeling results with LADCO simulation CAMx_LADCO_2016aa2a
Final	November 19, 2020	

Errata/Known Issues

#	Description

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Executive Summary

LADCO prepared this Technical Support Document to support the development of the O_3 NAA SIPs for the states of Wisconsin, Illinois, and Indiana pursuant to the 2008 O_3 NAAQS. LADCO used the Comprehensive Air Quality Model with Extensions (CAMx) v7.0 beta 4 to support these analyses. The LADCO CAMx modeling results are used here to identify O_3 monitoring sites that may have nonattainment or maintenance problems for the 2008 O_3 NAAQS by the attainment date in July 2021. Because the attainment deadline occurs during the 2021 O_3 season, the effective attainment deadline is the end of the 2020 O_3 season and thus resulted in the selection of 2020 as the projection year for this modeling application. LADCO used 2016 as the base modeling year from which we projected air quality in 2020.

LADCO based our 2020 O_3 air quality and NAA attainment forecasts on the CAMx modeling platform released by the U.S. EPA in September 2019 to support regional haze progress assessments. LADCO estimated 2020 emissions for most of the anthropogenic inventory sectors by interpolating between the 2016 and 2023 Inventory Collaborative 2016v1 inventories. We used linear interpolation for the emissions because 2020 inventories were not readily available for all of the sectors at the time that this application initiated. LADCO replaced the Electricity Generating Unit (EGU) emissions in the U.S. EPA 2016fh_16j platform with 2020 EGU forecasts estimated with the ERTAC EGU Tool version 16.1. ERTAC EGU 16.1 integrated state-reported information on EGU operations and forecasts as of December 2019. Overall both the NOx and VOC ozone season day emissions are projected to decrease in 2020 relative to 2016 in all of the LADCO states. The NOx reductions range from 10%-17%, driven primarily by reductions in mobile source emissions. The VOC reductions are more modest, at around 1% in each of the LADCO states and are also driven by reductions in mobile sources. For the anthropogenic sectors only (i.e., excluding biogenics), the ozone season day VOC emissions reductions are closer to 5% in each of the LADCO states.

The LADCO 2020 CAMx simulation predicted lower seasonal maximum O_3 concentrations across the majority of the modeling domain with the largest reductions occurring in the southeast U.S., east Texas, and the Central Valley of California. CAMx predicts that in 2020 the seasonal maximum daily maximum 8-hour average (MDA8) O_3 concentrations will decline along the western Lake Michigan shoreline in the range of 1-5 ppb compared with 2016.

The LADCO 2020 CAMx simulation predicts that no monitor in the region will have an average future year design value (DV_{2020}) that exceeds the 2008 O_3 NAAQS. The O_3 relative reduction factors (RRFs) in the Chicago NAA are in the range of 4-5%. The modest changes to the DVs in 2020 are due primarily to the short time period between the base and future years.

Excluding water cells in the attainment test calculation results in lower DVs_{2020} for the lakeshore monitors in the LADCO region.

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, to provide a forum for its member states to discuss regional air quality issues, and to facilitate training for staff in the member states.

On March 12, 2008, the U.S. EPA revised the primary and secondary National Ambient Air Quality Standard (NAAQS) for ozone (O_3), strengthening the standard to a level of 0.075 parts per million (ppm) for a maximum daily 8-hour average. The form of the 8-hour O_3 NAAQS remained the same as the previous standard, the annual fourth-highest daily maximum averaged over three consecutive years. When U.S. EPA adopts a new or revises an existing NAAQS, it is required by Section 107(d)(1) of the Clean Air Act (CAA) to designate areas as nonattainment, attainment, or unclassifiable. Accordingly, on May 21, 2012, U.S. EPA designated Sheboygan County in eastern Wisconsin as a "marginal" O_3 nonattainment area (NAA) based on 2008-2010 ambient air quality data. On June 11, 2012, U.S. EPA designated the Chicago metropolitan area, including all or portions of eight counties in Illinois, two counties in northwest Indiana (Lake and Porter), and one partial county in southeast Wisconsin (Kenosha) as a "marginal" O_3 NAA based on monitoring data from 2009-2011. The attainment deadline for marginal NAAs to meet the 2008 O_3 NAAQS was July 20, 2015.

On April 11, 2016, U.S. EPA determined that the Chicago metropolitan area failed to attain the 2008 O_3 NAAQS by the applicable attainment date and thus reclassified the area as a "moderate" O_3 NAA. On September 28, 2016, U.S. EPA made a similar determination for Sheboygan County. The attainment deadline for moderate NAAs to meet the 2008 O_3 NAAQS was July 20, 2018.

On August 23, 2019, U.S. EPA determined that the entire Chicago metropolitan area again failed to attain the NAAQS and thus reclassified the area as a "serious" O_3 NAA. On July 15, 2019 EPA approved a revision to the Sheboygan County designation that splits the county into two distinct O_3 NAAs: shoreline and inland. In this same action, U.S. EPA approved a clean data determination for inland Sheboygan County. On July 10, 2020 the U.S. EPA officially redesignated both inland and shoreline Sheboygan County areas to attainment of the 2008 O_3 NAAQS.

The Chicago and Sheboygan nonattainment areas are shown in Figure 1. As a result of the actions for the Chicago NAA described above, the states of Illinois, Indiana, and Wisconsin must submit State Implementation Plans (SIPs) that meet the requirements applicable to "serious" O_3 NAAs. The NAA SIPs, or attainment demonstrations, must include a demonstration which identifies emissions reduction strategies sufficient to achieve the NAAQS by July 20, 2021, the attainment date for serious NAAs. Because the attainment deadline occurs during the 2021 O_3 season, the effective attainment deadline is the end of the 2020 O_3 season.

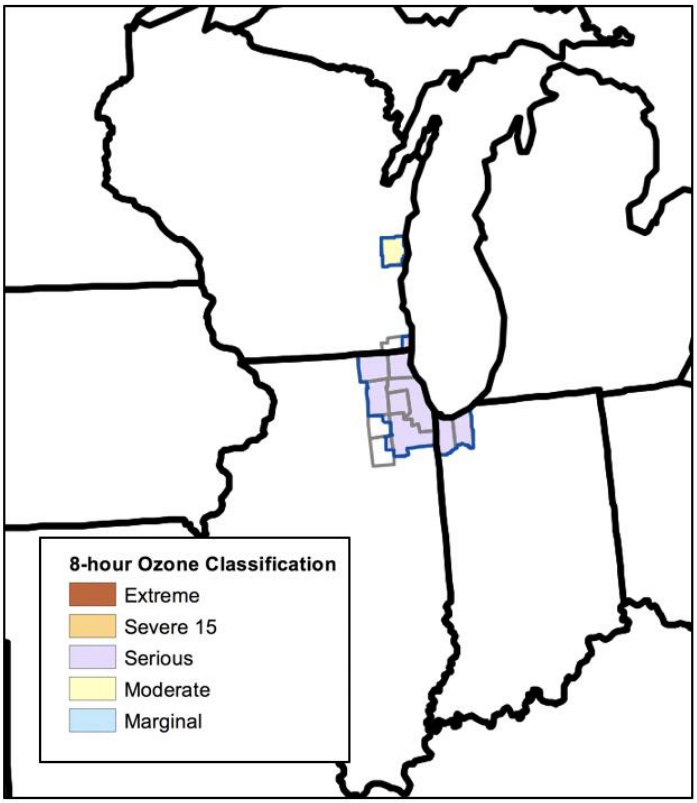

Figure 1. Nonattainment areas in the Lake Michigan region for the 2008 O_3 NAAQS (Source: U.S. EPA, May 2020).

One of LADCO's responsibilities is to provide technical air quality modeling guidance and support to the LADCO states. LADCO prepared this Technical Support Document (TSD) to support the development of the O_3 NAA SIPs for the states of Wisconsin, Illinois, and Indiana pursuant to the 2008 O_3 NAAQS. The analyses prepared by LADCO include preparation of modeling emissions inventories for the base year (2016) and the projected year of attainment (2020), evaluation and application of meteorological and photochemical grid models, analysis of ambient monitoring data, and a modeled attainment test for surface O_3 monitors in the Chicago NAA.

1.1 Project Overview

LADCO conducted regional air quality modeling to support the statutory obligations of the LADCO states under Clean Air Section 172**.** These SIP revisions are plans that describe how states with designated NAAs will bring those areas back into attainment of the NAAQS. LADCO used the Comprehensive Air Quality Model with Extensions (CAMx[1]) to support these analyses. In particular, LADCO used CAMx version 7.0 beta 4 to predict O_3 concentrations in 2020 to determine if current emissions control programs in the region will lead to attainment of the 2008 O_3 NAAQS.

This document describes how LADCO used CAMx modeling to project air quality from a 2016 base year to 2020, and to evaluate if the 2008 O_3 NAAQS NAAs in the LADCO region are predicted to attain the standard. The CAMx modeling outputs of this work are being presented to the IL, IN, and WI state air programs to support their 2008 O_3 NAAQS NAA SIP revisions that are due to EPA on August 3, 2020.

1.2 Organization of the Technical Support Document

This technical support document (TSD) is presented to the LADCO member states for estimating year 2020 O_3 future design values (DVFs). The TSD is organized into the following sections.

- Section 2 describes current surface O_3 conditions in the LADCO region and trends in O_3 concentrations over the past decade
- Section 3 describes the 2016 base year modeling and performance evaluation methods.
- Section 4 describes the 2020 CAMx air quality modeling platform that LADCO used to predict surface O_3 concentrations in 2020.

[1] www.camx.com

- Section 5 describes the approach used for estimating the O_3 DVFs. This section also includes a discussion on the methods used for identifying sites that are forecast to have O_3 NAAQS attainment problems.
- Section 6 presents a discussion of the performance evaluation and modeling results that the LADCO states can use to support their 2008 O_3 NAAQS NAA SIPs.
- The TSD concludes with a summary of significant findings and observations from the LADCO modeling.

2 2016 Ambient Air Quality Data Analysis

LADCO retrieves and conducts analysis on surface O_3 data collected at routine and special-purpose ambient monitors throughout the region. The current monitored O_3 design values (DVs), or the three-year average of the 4th highest daily maximum, 8-hour average O_3 concentrations, are presented in this section along with a discussion of trends in O_3 DVs and other metrics for tracking the changes in surface O_3 concentrations in the region. Design values are labeled by the last year of the three year average. For example, the 2019 O_3 DV is the average of the annual 4th highest daily maximum 8-hour average O_3 concentrations for the years 2017-2019.

2.1 Current Conditions

Figure 2 and Figure 3 are maps of the 2019 and 2020 O_3 design values (DVs) for the surface monitors around Lake Michigan. In Figure 2 warm colors represent O_3 concentrations approaching the 2008 O_3 NAAQS of 75 ppb; sites that are colored red in these plots indicate a violation of the 2008 standard. The 2019 DVs are based on validated data reported to the U.S. EPA. The 2020 DVs plot uses a different color scale, and these data are preliminary and based on unvalidated data reported through July 29, 2020. Note that several months remain in the O_3 season in 2020 and the values will change before the 2020 data become official. Table 1 and Table 2 show the same DVs data in tabulated form. Table 1 shows the annual DVs by 2008 O_3 NAAQS NAA from 2013 to present; the NAA DV is a reading from the “controlling” monitor, or the monitor with the highest 3-year DV in the entire NAA. Table 2 shows the annual DVs for key monitors in the Chicago 2008 O_3 NAAQS NAAs from 2013 to present.

The DV tables and figures show that no monitors in the Chicago NAA have 2019 3-year DVs that violate the 2008 O_3 NAAQS. Through September 30, 2020 one monitor in the Chicago NAA (Northbrook, IL) has a 2020 3-year DV that violates the standard. Between 2013 and 2018, 2015 was the last DV year in which there were no violations of the 2008 O_3 NAAQS in the Chicago NAA.

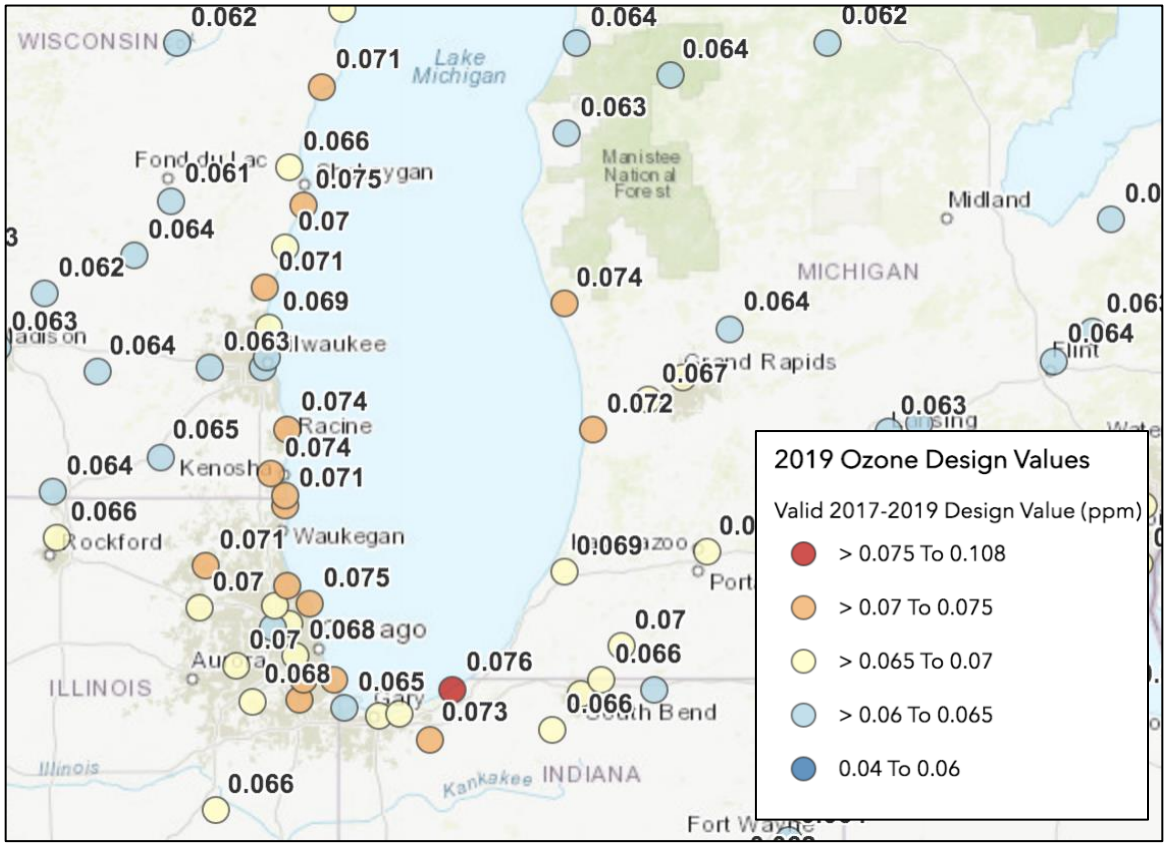

Figure 2. 2019 O_3 design values

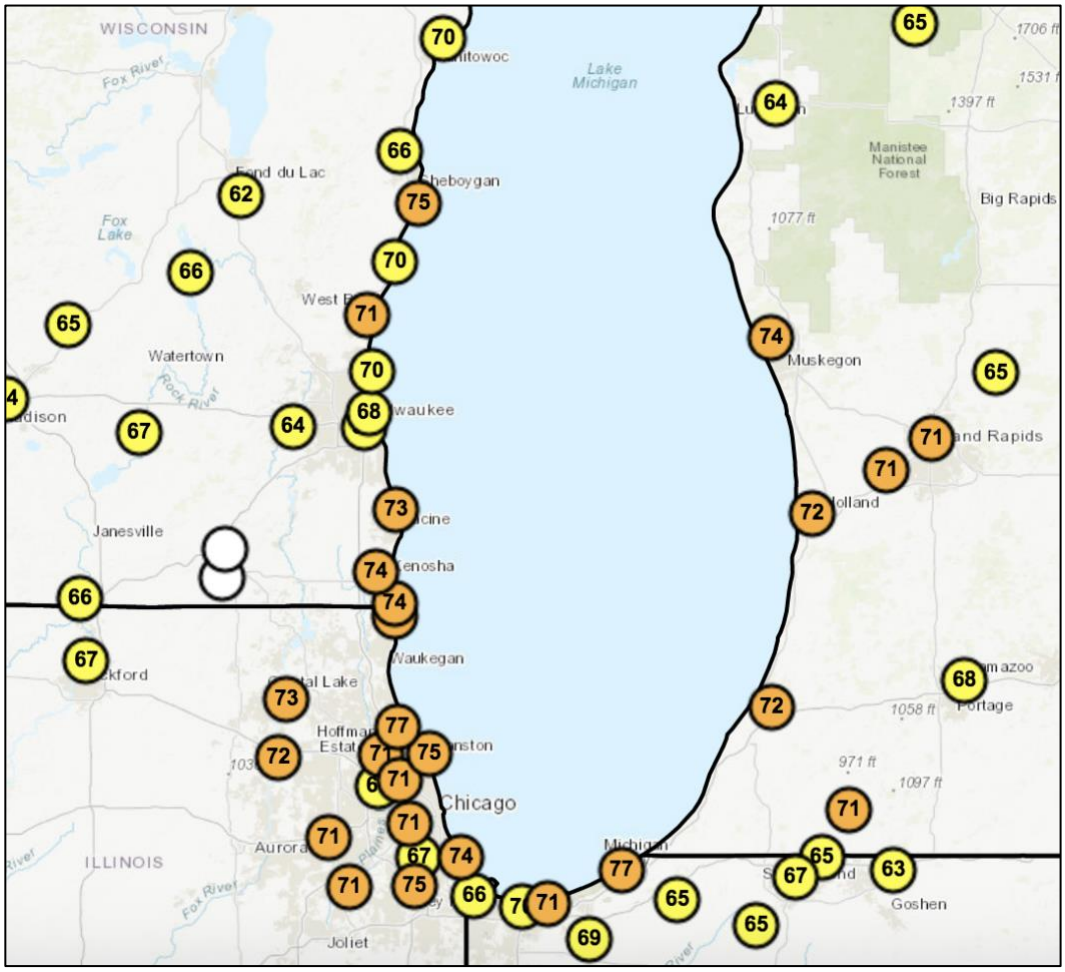

Figure 3. 2020 O_3 design values through September 30, 2020

Table 1. Chicago 2008 O_3 NAAQS NAA design values (ppb) [Source: U.S. EPA Green Book, May 2020]

Designated Area	2013	2014	2015	2016	2017	2018	2019	2020*
Chicago-Naperville, IL-IN-WI	82	81	75	77	78	79	75	77

* 2020 data are preliminary and incomplete; they were retrieved September 30, 2020 from AirNow Tech.

Table 2. Chicago 2008 O_3 NAAQS NAA monitor design values (ppb) [Source: U.S. EPA

Green Book, May 2020]

State	County	AQS Site ID	2013	2014	2015	2016	2017	2018	2019	2020*
NAA: Chicago, IL-IN-WI										
IL	Cook	170310001	71	69	65	69	73	77	75	71
IL	Cook	170310032	80	76	68	70	72	75	73	74
IL	Cook	170310076	72	70	64	69	72	75	72	67
IL	Cook	170311003	70		66	69	67	69	67	67
IL	Cook	170311601	71	71	66	69	69	70	68	68
IL	Cook	170313103			61	62	62	64	63	63
IL	Cook	170314002	72	69	62	66	68	72	68	68
IL	Cook	170314007	68	69	68	71	71	74	70	71
IL	Cook	170314201	77	74	68	71	72	77	74	75
IL	Cook	170317002	80	78	70	72	73	77	75	75
IL	DuPage	170436001	68	67	64	68	70	71	70	66
IL	Kane	170890005	69	68	65	68	69	71	70	72
IL	Lake	170971007	80	79	71	73	73	75	71	71
IL	Will	171971011	64	65	63	64	65	67	66	64
IN	Lake	180890022	69	69	65	67	68	70	68	70
IN	Lake	180892008			63	65		66	65	65
WI	Kenosha	550590019	82	81	75	77	78	79	75	72
WI	Kenosha	550590025			69	71	73	77	74	72

* 2020 data are preliminary and incomplete; they were retrieved September 30, 2020 from AirNow-Tech.

2.2 Meteorology and Transport

Ozone concentrations are significantly influenced by meteorological factors. Ozone production is driven by high temperatures and sunlight, as well as precursor concentrations. Ozone concentrations at a given location are also dependent on wind direction, which governs which sources or source regions are upwind. Wind-drive transport in turn affects how much ozone and ozone precursors impact a given area.

Qualitatively, O_3 episodes in the region are associated with hot weather, clear skies (sometimes hazy), low wind speeds, high solar radiation, and winds with a southerly component. These conditions are often a result of a slow-moving high pressure system to the east of the region. The relative importance of various meteorological factors is

discussed later in this section. Transport of O_3 and its precursors is a significant factor and occurs on several spatial scales. Regionally, over a multi-day period, somewhat stagnant summertime conditions can lead to the build-up in O_3 and O_3 precursor concentrations over a large spatial area. This polluted air mass can be transported long distances, resulting in elevated O_3 levels in locations far downwind. Locally, emissions from urban areas add to the regional background leading to O_3 concentration hot spots downwind. Depending on the synoptic wind patterns (and local land-lake breezes), different downwind areas are affected.

The following key findings related to transport can be made:

- Ozone transport is an issue affecting many portions of the eastern U.S. The Lake Michigan area (and other areas in the LADCO region) both receives high levels of incoming (transported) O_3 and O_3 precursors from upwind source areas on many hot summer days, and contributes to the high levels of O_3 and O_3 precursors affecting downwind receptor areas.
- The presence of Lake Michigan influences the formation and transport of O_3 in the region, particularly at sites within a few kilometers of the shoreline . Depending on large-scale synoptic winds and local-scale lake breezes, different parts of the area experience high O_3 concentrations. For example, during southerly flow, high O_3 can occur in eastern Wisconsin, and during southwesterly flow, high O_3 can occur in western Michigan.
- Downwind shoreline areas around Lake Michigan are affected by transport of O_3 from major cities in the Lake Michigan area and from areas further upwind.

2.3 Ozone Trends

Figure 4 illustrates the 19-year trends in 3-year O_3 DVs at individual surface monitors in the Chicago NAA. The red horizontal lines mark the 2015 and 2008 O_3 NAAQS. After the decadal high year in 2012, surface O_3 concentrations have declined through 2019. While

there has been an increasing trend in O_3 concentrations in the Chicago NAA monitors since the decadal low year in 2015, 2018 was the only year since 2015 that monitored 2008 O_3 NAAQS violations at multiple sites in the NAA.

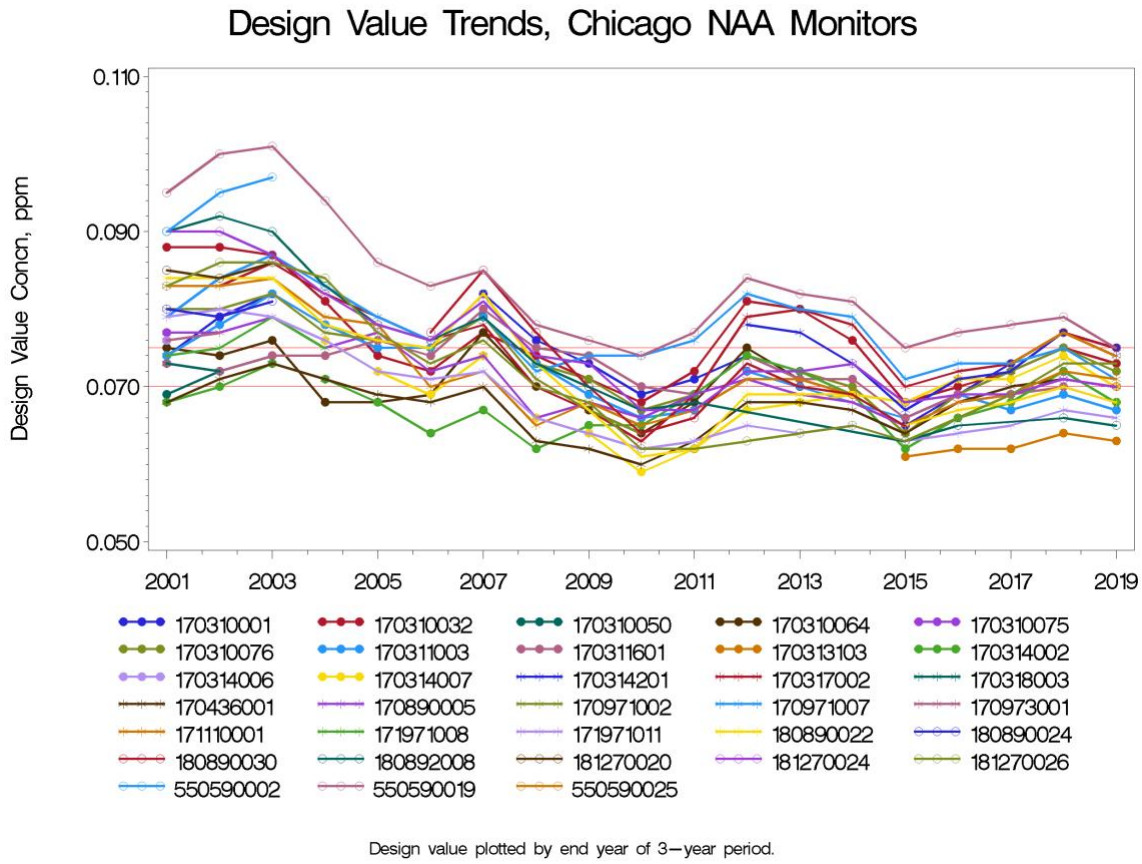

Figure 4. 3-year O_3 design value trends from 2001 to 2019 at all monitors in the Chicago NAA

Given the effect of meteorology on ambient O_3 levels, year-to-year variations in meteorology can make it difficult to assess short term (e.g. – less than 10 years) trends in O_3 concentrations. One approach to adjust the trends in O_3 concentrations for meteorological influences is through the use of Classification and Regression Trees (CART). CART is a statistical technique which partitions data sets into similar groups (Breiman et al., 1984). LADCO performed a CART analysis using data for the period 2005-

2018 for urban and downwind monitors in the 2008 O_3 NAAQS NAAs. The CART model searches through over thirty National Weather Service meteorological variables collected at airports[2] to determine which are most efficient in predicting O_3. Although the exact selection of predictive variables changes from site to site, the most common predictors of high surface O_3 concentrations during the period we analyzed are temperature, wind direction, and relative humidity. Only occasionally were upper air variables, transport time or distance, lake breeze, or other variables significant as predictors.

For each group of monitors in the NAAs we analyzed, LADCO developed regression trees that classify each summer day (May-September) by its meteorological conditions. Similar days are assigned to nodes, which are equivalent to branches of the regression tree. By grouping days with similar meteorology, the influence of meteorological variability on changes in O_3 concentrations is partially controlled for in the trend; the remaining trend is presumed to be due to trends in precursor emissions or other non-meteorological influences.

Trends over the 13-year period ending in 2018 were found to be declining for each monitor or composite area noted. These plots reflect long term trends and are not meant to depict trends over shorter time periods.

2.3.1 Northern Chicago NAA CART Analysis

LADCO used O_3 data from the Zion, IL and Chiwaukee, WI monitoring sites to identify trends in the surface concentrations downwind of Chicago using CART. Meteorological surface and aloft data used in this analysis are from the National Climatic Data Center's Integrated Surface Database and Integrated Radiosonde Archive; we used HYSPLIT trajectories to develop transport vectors.

Figure 5 shows the distribution of O_3 among Zion and Chiwaukee CART nodes. Each boxplot represents a group of days with common meteorological conditions. Node U

[2] National Climatic Data Center Integrated Surface Database

identifies the predictor variables that are associated with the highest mean observed O_3 concentrations at these monitors during the period of analysis (2005-2018). The days captured by this node have an average daily maximum O_3 concentration of 74 ppb and the following meteorological conditions:

- 24-hr southerly transport vector distance is >39 km
- average relative humidity is <70%
- afternoon wind direction is <211 deg
- max temperature is >85 F

Node T identifies the predictor variables that are associated with the second highest mean observed O_3 concentrations at these monitors during the period of analysis. Node T captures days with an average daily maximum O_3 concentration of 65 ppb and the following meteorological conditions:

- 24-hr southerly transport vector is >39 km
- average relative humidity is <70%
- afternoon wind direction is < 211 deg
- max temperature is <85 F and >78 F

CART identifies that the most significant predictors of high O_3 concentrations at Zion and Chiwaukee are warm and dry conditions with southerly flow. Daily maximum temperature is the only meteorological difference between nodes T and U. With all transport variables being equal, the cooler conditions represented by node T group days with an average O_3 concentration that is 9 ppb lower than the warmer days (>85 F) captured in node U.

Figure 6 shows the Zion, IL and Chiwaukee, WI O_3 trends by CART node. The node associated with the highest O_3 concentrations (node U) shows a distinct downward trend in O_3 concentrations during the 13 year CART analysis period. By controlling for the meteorological influence on O_3 concentrations during the most polluted days, this trend indicates that O_3 concentrations in the northern part of the Chicago 2008 O_3

NAAQS NAA are declining as the result of changes to emissions and other non-meteorological predictors.

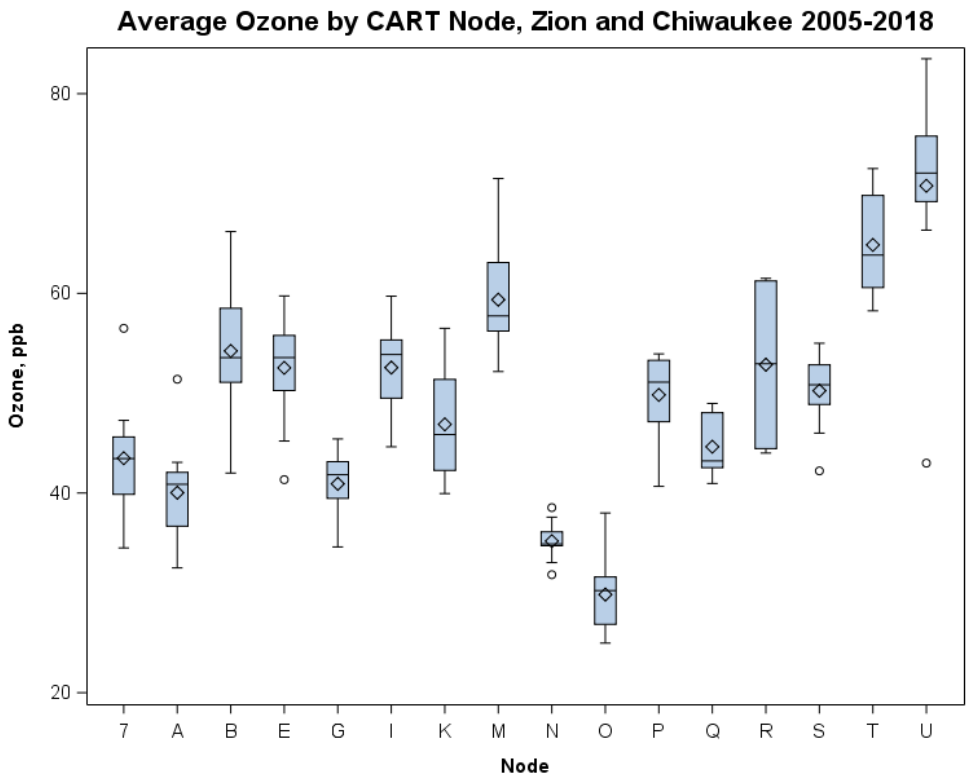

Figure 5. Northern Chicago NAA ozone concentrations by CART node.

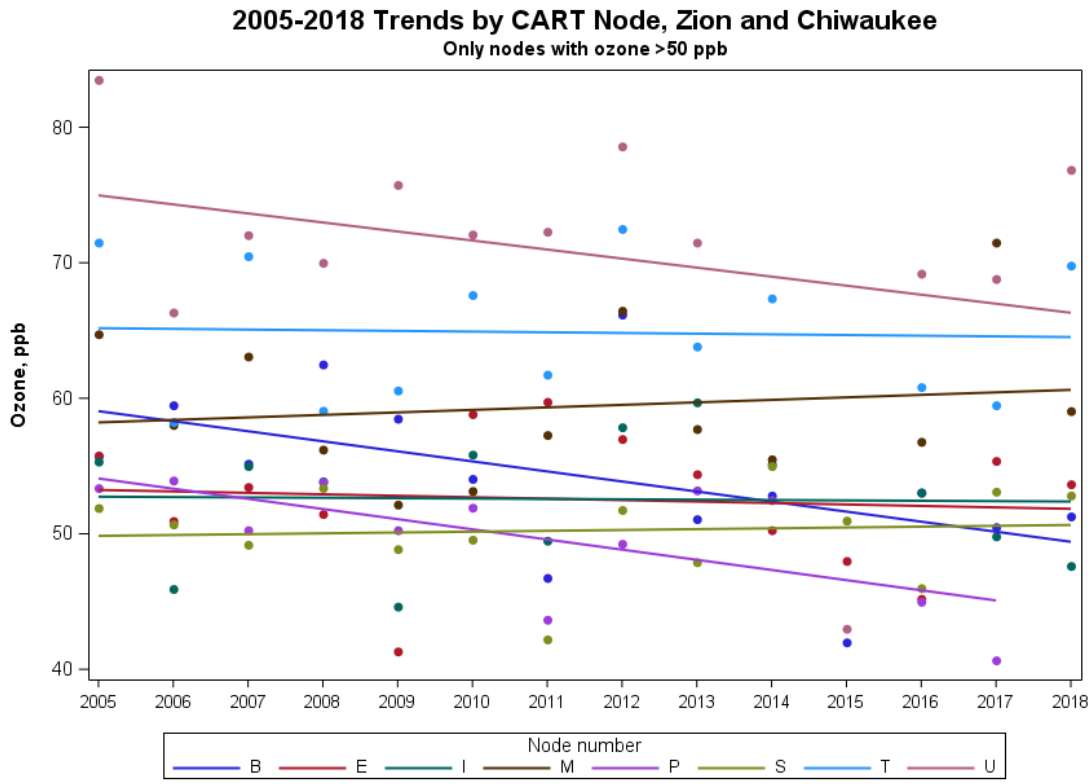

Figure 6. Northern Chicago NAA O_3 trends by CART node

2.4 Conceptual Model of Ozone in the Chicago NAA

A conceptual model is a qualitative summary of the physical, chemical, and meteorological processes that control the formation and distribution of pollutants in a given region. Based on the data and analyses presented above, and of previous conceptual models and technical support documents developed for the Lake Michigan region, a conceptual model of the behavior, meteorological influences, and causes of high O_3 in the Chicago NAA is summarized below:

- Monitoring data show that as of 2019 all of the surface O_3 monitoring sites in the western Lake Michigan region were meeting the 2008 8-hour O_3 NAAQS. Historical O_3 data show a downward trend over the past 19 years, due likely to federal and state emission control programs. Concentrations declined sharply from 2002 through 2010, and again from 2012 through 2015. Although ozone concentrations

at the "controlling" monitors have been on the rise since 2015, there were no 3-year DVs in violation of the 2008 O_3 NAAQS at any monitor in the region in 2019.

- Ozone concentrations are strongly influenced by meteorological conditions, with more high O_3 days and higher O_3 levels during summers with above normal temperatures. Nevertheless, meteorologically adjusted trends at the controlling monitors show that concentrations have declined even on hot days, providing strong evidence that emission reductions of O_3 precursors have been effective.
- Inter- and intra-regional transport of O_3 and O_3 precursors affects many portions of the LADCO states, and is the principal cause of nonattainment in some areas far from population or industrial centers.
- The presence of Lake Michigan influences the formation, transport, and duration of elevated O_3 concentrations along its shoreline. Depending on large-scale synoptic winds and local-scale lake breezes, different parts of the area experience high O_3 concentrations. For example, under southerly flow, high surface O_3 concentrations can occur in eastern Wisconsin, and under southwesterly flow, high surface O_3 can occur in western Michigan.
- A natural lake-land breeze circulation pattern is a major cause of the high O_3 concentrations observed along the lakeshore. This pattern is driven by surface temperature gradients between the lake and the land. At night and in the early morning a land breeze (land –> lake) forms when the lake surface is warmer than the land surface. The land breeze transports O_3 precursors from industrial and mobile sources on land out over the lake. When the sun rises, the O_3 precursors over the lake begin to rapidly react to form O_3, and high over-lake concentrations are often observed during the summer. A lake breeze (lake –> land) forms when the land surface becomes warmer than the lake, typically in the early afternoon during the summer. The lake breeze transports the concentrated O_3 and precursors from the lake, inland to a narrow band along the lake shore. The O_3 concentrations observed along the lakeshore that violate the NAAQS are often associated with lake-land breeze patterns.

- Areas in closer proximity to the Lake shoreline display the most frequent and most elevated O_3 concentrations.

3 2016 Air Quality Modeling and Model Performance Evaluation

3.1 2016 Modeling Platform

LADCO based our 2016 O_3 air quality predictions on the 2016v1 National Emission Inventory Collaborative emissions inventory[3] and the U.S. EPA 2016ff CAMx modeling platform. The meteorology and initial and boundary conditions came from the U.S. EPA 2016ff CAMx modeling platform. LADCO processed most of the 2016 emissions using the U.S. EPA 2016fh_16j Sparse Matrix Operator Kernel Emissions (SMOKE) modeling platform. The CAMx inputs, including the meteorology data simulated with the Weather Research Forecast (WRF) model, emissions data, and boundary conditions represent year 2016 conditions. LADCO used the majority of the data and software provided by U.S. EPA for this platform, with a few exceptions described below.

3.2 Modeling Year Justification

LADCO selected 2016 as a modeling year for this study because at the initiation of this project in late 2019 CAMx input data for 2016 were widely available and they represented the state-of-the-science for emissions and meteorology data. In 2017 a group of multi-jurisdictional organizations (MJOs), states, and EPA established 2016 as the new base year for a national air quality modeling platform[4]. The group concluded that if only one recent year could be selected, that 2016 would serve as a good base year because of fairly typical O_3 conditions and average wildfire conditions. Following from the base year recommendations from that group, several modeling centers,

[3] http://views.cira.colostate.edu/wiki/wiki/10202
[4] Base Year Selection Workgroup Final Report

including U.S. EPA and LADCO, developed data and capabilities for simulating and evaluating air quality in 2016.

Following from the selection of 2016 as the base year for a national modeling platform, starting in late 2017, the MJOs, states, and EPA formed the National Emissions Inventory Collaborative to develop a 2016 emissions inventory and modeling platform. Over 200 participants collaborated across 12 workgroups to develop base and future year emissions to support upcoming regulatory modeling applications. This effort was designed to involve a broad group of emissions experts in the development of a new national emissions modeling platform. LADCO used the 2016 and 2023 inventories developed by the Collaborative for the modeling presented here as they were the most recent inventory data available at the initiation of this project.

LADCO selected 2020 as the future projection year because it aligns with the last O_3 season that will be used to determine attainment of the 2008 O_3 NAAQS.

3.3 Air Quality Model Configuration

LADCO based our CAMx air quality modeling platform for this application on the configuration that the U.S. EPA used for recent regional haze modeling (US EPA, 2019). LADCO used CAMx 7.0 beta 4 (Ramboll, 2018) as the photochemical grid model for this application. 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 drivers of ground level O_3 in the U.S. 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. As CAMx is a component of U.S. EPA studies with a similar scope to this project, LADCO was able to leverage the data and software elements that are distributed with recent U.S. EPA regulatory modeling platforms. Using these elements saved LADCO significant resources relative to building a modeling platform from scratch.

Figure 7 shows the U.S. EPA transport modeling domain for the continental U.S. A 12-km uniform grid (12US2) covers all of the continental U.S. and includes parts of Southern Canada and Northern Mexico. The domain has 36 vertical layers with a model top at about 17,550 meters (50 mb). LADCO used the same U.S. EPA 12-km domain for this project because it supported the use of meteorology, initial and boundary conditions, and emissions data that were freely available from U.S. EPA.

Table 3 summarizes the CAMx science configurations and options LADCO used for the 2016 and 2020 CAMx modeling for this application. We used the Piecewise Parabolic Method (PPM) advection solver for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. We used K-theory for vertical diffusion using the CMAQ-like vertical diffusivities from WRFCAMx. The CB6r4 gas-phase chemical mechanism was selected because it includes the latest chemical kinetic rates and represents improvements over the other alternative CB05 and SAPRC chemical mechanisms as well as active methane chemistry. Additional CAMx inputs were as follows:

> <u>Meteorological Inputs:</u> The U.S. EPA WRF-derived meteorological fields were processed to generate CAMx meteorological inputs using the WRFCAMx processor, as described in Section 3.4.

Initial/Boundary Conditions: LADCO used 2016 chemical boundary conditions for the 12-km continental U.S. modeling domain derived from the U.S. EPA northern hemisphere CMAQ simulations of 2016 (U.S. EPA, 2019c). The EPA 2016 ICBCs are hourly, vertically resolved up to 50 mb, and use the Carbon Bond 6 photochemical mechanism.

Photolysis Rates: LADCO prepared the photolysis rate inputs as well as albedo/haze/ozone/snow inputs for CAMx. Day-specific O_3 column data were based on the Total Ozone Mapping Spectrometer (TOMS) data measured using the satellite-based Ozone Monitoring Instrument (OMI). Albedo were based on land use data. For CAMx there is an ancillary snow cover input that will override the land use based albedo input. LADCO used the TUV photolysis rate processor to prepare clear-sky photolysis rates for CAMx. If there were periods of more than a couple of days where daily TOMS data were unavailable in 2016, the TOMS measurements were interpolated between the days with valid data; in the case where large periods of TOMS data were missing, monthly average TOMS data were used. CAMx was also configured to use the in-line TUV to adjust for cloud cover and account for the effects that modeled aerosol loadings have on photolysis rates; this latter effect on photolysis may be especially important in adjusting the photolysis rates due to the occurrence of PM concentrations associated with emissions from fires.

Landuse: LADCO used landuse/landcover data from the U.S. EPA WRF simulation.

Spin-Up Initialization: A minimum of ten days of model spin up (e.g., December 21-31, 2015) was used for the 12 km modeling domain. LADCO ran monthly CAMx simulations, initializing each month with a 14-day spin-up period.

As the focus of this study is on O_3, LADCO used CAMx to simulate the O_3 season. LADCO simulated April 1 through October 31, 2016 as individual months using 14-day model spin-up periods for each month. LADCO selected a CAMx configuration that was

consistent with previous O_3 modeling applications performed by LADCO and U.S. EPA. U.S. EPA (2019) provided completed details their 2016 CAMx simulation, including a performance evaluation.

Table 3. LADCO 2016 CAMx modeling platform configuration

Science Options	Configuration
Model Codes	CAMx V7.0 beta 4
Simulation Period	March 20-October 31, 2016
Horizontal Grid Mesh	12 km, 396 col x 246 rows
Vertical Grid Mesh	36 layers as in WRF outputs
Grid Interaction	None
Initial Conditions	14 day spin-up on 12 km grid
Boundary Conditions	12km from hemispheric CMAQ (U.S. EPA 2016ff)
Emissions	
Baseline Emissions Processing	SMOKE, MOVES and BEIS
Sub-grid-scale Plumes	None
Chemistry	
Gas Phase Chemistry	CB6r4
Aerosol Chemistry	CF + SOAP
Meteorological Processor	WRFCAMx_v4.7
Horizontal Diffusion	Spatially varying
Vertical Diffusion	CMAQ-like in WRF2CAMx
Diffusivity Lower Limit	Kz_min = 0.1 to 1.0 m^2/s or 2.0 m^2/s
Dry Deposition	Zhang dry deposition scheme (CAMx)
Wet Deposition	CAMx-specific formulation
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) -- Fast Solver
Vertical Advection Scheme	Implicit scheme w/ vertical velocity update (CAMx)
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme
Integration Time Step	Wind speed dependent

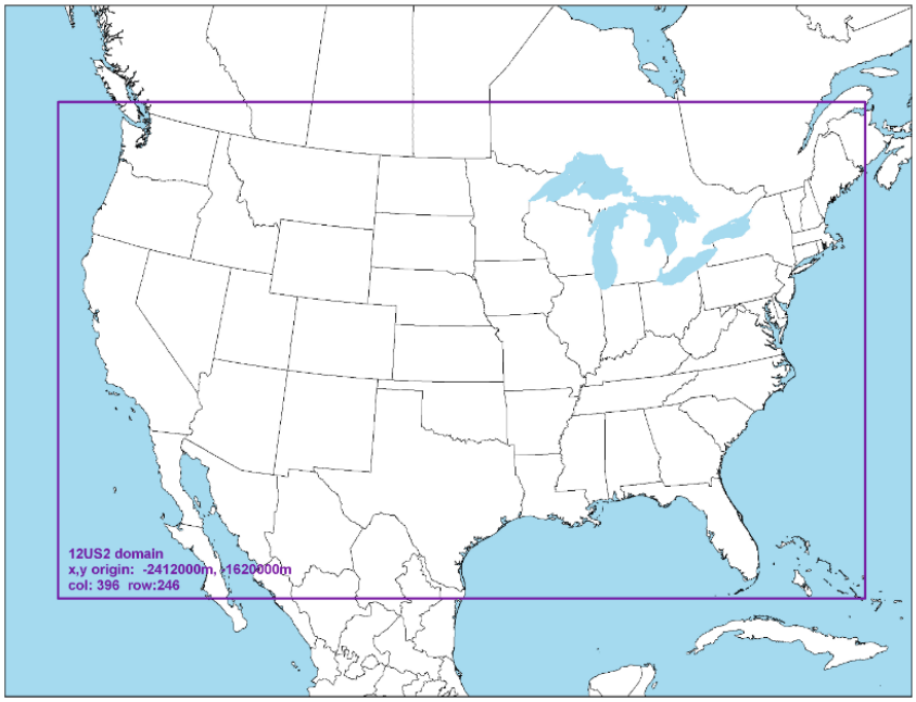

Figure 7. CAMx 12-km modeling domain (12US2)

3.4 Meteorology Data

LADCO used the U.S. EPA 2016 WRF data for this study (US EPA, 2019b). The U.S. EPA used version 3.8 of the WRF model, initialized with the 12-km North American Model (NAM) from the National Climatic Data Center (NCDC) to simulate 2016 meteorology. Complete details of the WRF simulation, including the input data, physics options, and four-dimensional data assimilation (FDDA) configuration are detailed in the Meteorology Model Performance for Annual 2016 Simulation WRFv3.8 report (US EPA, 2019b). LADCO prepared the WRF data for input to CAMx with version 4.6 of the WRFCAMx software.

3.5 Initial and Boundary Conditions

LADCO used 2016 initial and boundary conditions for CAMx generated by the U.S. EPA from a northern hemisphere simulation of the Community Multiscale Air Quality (CMAQ) model (US EPA, 2019c). EPA generated hourly, one-way nested boundary

conditions (i.e., hemispheric-scale to regional-scale) from a 2016 108-km x 108-km polar stereographic CMAQ simulation of the northern hemisphere. Following the convention of the U.S. EPA 2016 regional haze modeling (U.S. EPA, 2019), LADCO used year 2016 CMAQ boundary conditions for modeling 2016 and 2020 air quality with CAMx.

3.6 Emissions Data

The 2016 emissions data for this study were based on the U.S. EPA 2016 v1 ("2016fh_16") emissions modeling platform (http://views.cira.colostate.edu/wiki/wiki/10202). U.S. EPA and the 2016 Collaborative generated this platform for use O_3 NAAQS and Regional Haze SIPs. Twelve different workgroups collaborated to construct 2016 and future year emissions estimates. The first version of the 2016 inventories used 2014 inventory data; later versions of the inventory fully integrated 2016 estimates of emissions activities, growth and controls, and the latest emissions factors. Table 4 lists the 2016 base year inventory components that LADCO used to simulate 2016 air quality for this application.

Table 4. LADCO 2016 emissions modeling platform inventory components

Sector	Abbreviation	Data Source	Year
Agriculture	ag	U.S. EPA 2016fh	2016
Airports	airports	U.S. EPA 2016fh	2016
Biogenic	beis	U.S. EPA 2016fh	2016 meteorology
C1/C2 Commercial Marine	cmv_c1c2	U.S. EPA 2016fh	2016
C3 Commercial Marine	cmv_c2	U.S. EPA 2016fh	2016
Nonpoint	nonpt	U.S. EPA 2016fh	2016
Offroad Mobile	nonroad	U.S. EPA 2016fh	2016
Nonpoint Oil & Gas	np_oilgas	U.S. EPA 2016fh	2016
Onroad Mobile	onroad	U.S. EPA 2016fh	2016
Point Oil & Gas	pt_oilgas	U.S. EPA 2016fh	2016
Agricultural Fires	ptagfire	U.S. EPA 2016fh	2016
Electricity Generation	ptertac	ERTAC 16.1 + Hourly CEMs	2016
Wild and Prescribed Fires	ptfire	U.S. EPA 2016fh	2016
Industrial Point	ptnonertac	U.S. EPA 2016fh	2016
Rail	rail	U.S. EPA 2016fh	2016

Residential Wood Combustion	rwc	U.S. EPA 2016fh	2016
Mexico Anthropogenic	othar/othpt/	U.S. EPA 2016fh	2016
Canada Anthropogenic	othar/othpt	U.S. EPA 2016fh	2015

3.6.1 LADCO 2016 Emissions Summary

The tables in this section summarize the emissions used in the LADCO 2016 CAMx simulation. Figure 8 and Figure 9 are tile plots of the 12-km gridded, daily total NOx and VOC emissions, respectively, for a summer weekday (June 7, 2016). The NOx plot illustrates that the highest emissions occur in proximity urban areas and roadways. The VOC plot shows that biogenic sources dominate VOCs in the southern U.S and along the coasts. Table 5 shows the 2016 O_3 season (May-September) weekday NOx and volatile organic compound (VOC) emissions totals by LADCO member state. Table 6 and Table 7 include inventory sector level O_3 season weekday NOx and VOC emissions by state for 2016.

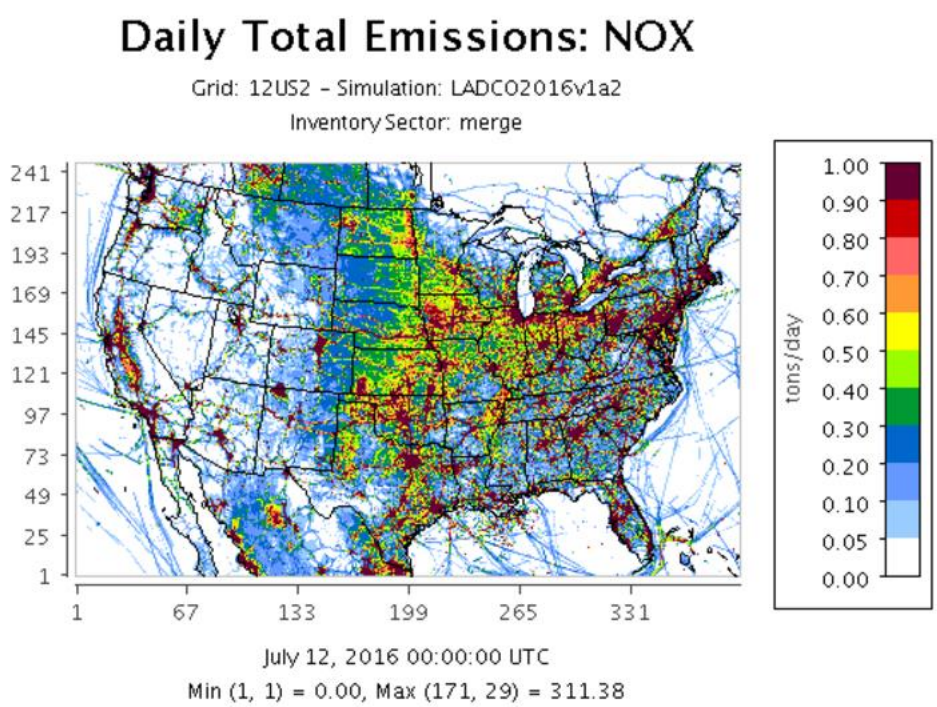

Figure 8. Daily total gridded 2016 NOx emissions for a summer weekday (tons/day)

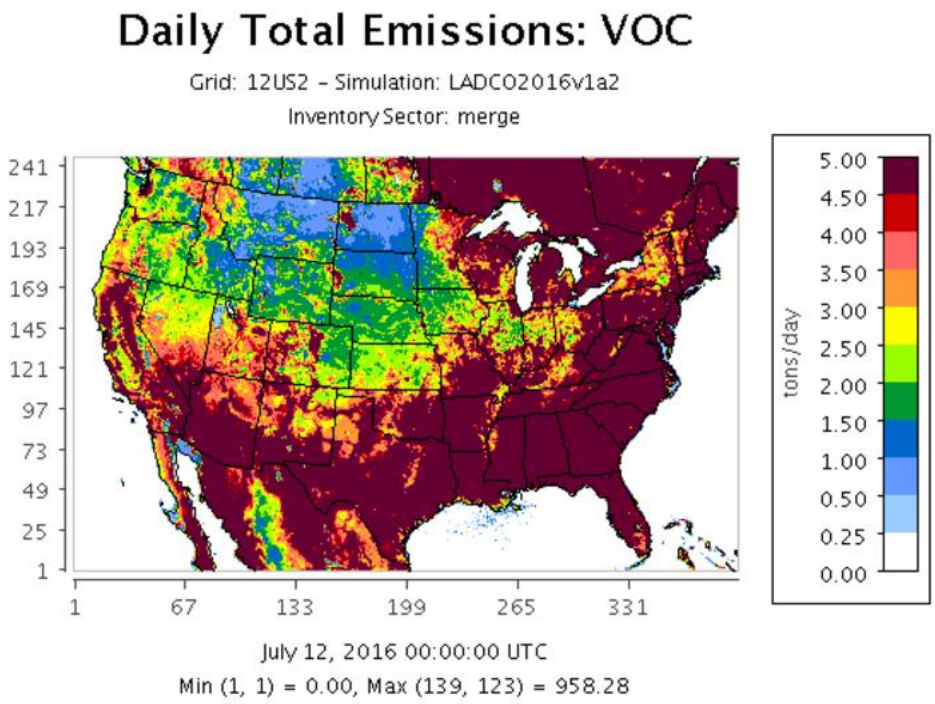

Figure 9. Daily total gridded 2016 VOC emissions for a summer weekday (tons/day)

Table 5. 2016 ozone season weekday emissions total, excluding biogenics (tons/day)

State	NOX	VOC
Illinois	975.2	994.1
Indiana	894.6	660.3
Michigan	807.3	820.1
Minnesota	634.0	711.5
Ohio	956.5	928.4
Wisconsin	510.3	471.8

Table 6. 2016 ozone season weekday NOx emissions by inventory sector (tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
Airports	14.3	2.5	5.4	4.9	3.2	1.7
Biogenic	167.0	89.6	61.7	126.9	74.0	71.8
C1/C2 Commercial Marine	17.1	4.5	15.8	3.0	7.6	5.7
C3 Commercial Marine	0.6	1.0	19.7	1.9	2.0	2.3
Nonpoint	83.8	18.9	66.4	41.6	62.0	36.5
Offroad Mobile	177.6	140.7	85.9	159.6	151.0	80.3
Nonpoint Oil & Gas	38.4	9.8	35.5	0.0	4.4	0.0
Onroad Mobile	347.9	312.6	291.6	193.9	368.1	241.2
Point Oil & Gas	23.5	14.1	29.3	7.8	31.2	1.5
Agricultural Fires	0.0	0.0	0.0	0.2	0.0	0.0
Electricity Generation	84.6	217.5	120.1	55.9	157.4	46.7
Wild and Prescribed Fires	1.0	0.4	1.6	6.5	0.8	1.9
Industrial Point	94.8	129.3	121.78	116.6	102.7	63.2
Rail	91.3	43.0	12.8	38.2	65.5	28.2
Residential Wood Combustion	0.3	0.3	1.5	3.9	0.5	1.1

Table 7. 2016 ozone season weekday VOC emissions by inventory sector (tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	28.3	27.4	12.6	51.5	25.5	20.4
Airports	4.7	1.2	2.1	1.8	1.6	0.9
Biogenic	2386.1	1575.4	3390.2	2894.4	2038.9	2770.9
C1/C2 Commercial Marine	0.9	0.2	0.5	0.1	0.4	0.2
C3 Commercial Marine	0.0	0.1	0.9	0.1	0.1	0.1
Nonpoint	372.5	261.8	351.7	183.9	417.8	177.5
Offroad Mobile	110.6	64.7	91.8	85.6	116.0	71.4
Nonpoint Oil & Gas	162.5	41.3	61.2		42.2	
Onroad Mobile	182.4	160.9	177.7	108.3	217.0	93.6
Point Oil & Gas	3.7	1.0	3.6	0.5	4.6	0.6
Agricultural Fires	0.0	0.0	0.0	0.5	0.0	0.0
Electricity Generation	3.4	3.6	2.64	1.3	3.1	2.0
Wild and Prescribed Fires	16.2	5.8	38.9	187.2	11.9	35.0
Industrial Point	101.0	85.7	62.5	50.8	78.9	59.1
Rail	4.3	2.0	0.6	1.8	3.1	1.3
Residential Wood Combustion	3.6	4.6	13.4	38.1	6.2	9.7

3.7 LADCO Modeling Platform Summary

Table 8 summarizes the LADCO 2016 air quality modeling platform elements.

Table 8. Listing of the LADCO 2016 air quality modeling platform components

Platform Element	Configuration	Reference	Data source
Meteorology Data	WRFv3.8	U.S. EPA, 2019b	U.S. EPA
Initial and Boundary Conditions	2016 Hemispheric CMAQ	U.S. EPA, 2019c	U.S. EPA
2016 Emissions Data	Inventory Collaborative 2016v1 ERTAC16.1 EGU Point and hourly CEMs		Inventory Collaborative and ERTAC
2020 Emissions Data	Inventory Collaborative 2016v1 ERTAC16.1 EGU Point		LADCO and ERTACT
Emissions Modeling Platform	U.S. EPA 2016fh_16j		U.S. EPA
Photochemical Grid Model	CAMxv7.0 beta4	Ramboll, 2018	LADCO

3.8 2016 CAMx Model Performance Evaluation

LADCO simulated 2016 air quality with CAMx using data derived from the U.S. EPA "2016fg" and "2016fh" modeling platforms. The only input data difference between the EPA and LADCO CAMx modeling was the emissions inventories. For their regional haze modeling platform, U.S. EPA used a modified version of the National Inventory Collaborative 2016beta inventory (U.S. EPA, 2019). LADCO used corrected the Inventory Collaborative 2016v1 inventories for this application, and prepared these emissions for CAMx using the U.S. EPA 2016fh_16j SMOKE modeling platform.

The differences between the LADCO and U.S. EPA 2016 modeling configurations are significant enough to warrant a new performance evaluation of LADCO's CAMx simulation. The CAMx model performance evaluation (MPE) presented here focuses on ozone at surface monitors in the states of Illinois (IL), Indiana (IN), and Wisconsin (WI) as these are the states for which this TSD will be used to support NAA SIPs. LADCO used

the Atmospheric Model Evaluation Tool (AMET) version 1.3 to pair the model results and surface observations in space and time, generate bi-variate statistics of model performance, and to produce MPE plots.

LADCO evaluated the CAMx 2016 modeled O_3 concentrations against concurrent measured surface ambient O_3 concentrations using graphical displays of model performance and statistical model performance measures. The statistical measures were compared against established model performance goals and criteria following the procedures recommended in EPA's photochemical modeling guidance documents (e.g., EPA, 1991; 2018).

3.8.1 Available Aerometric Data for the Model Evaluation

The following routine air quality measurement data networks operating in in 2016 were used by LADCO in assessing CAMx O_3 model performance:

EPA AQS Surface Air Quality Data: Data files containing hourly-averaged concentration measurements at a wide variety of state and EPA monitoring networks are available in the Air Quality System (AQS) database throughout the U.S. The AQS consists of many sites that tend to be mainly located in and near major cities. There are several types of networks within AQS that measure different species. The standard hourly AQS AIRS monitoring stations typically measure hourly O_3, NO_2, NO_X and CO concentration and there are thousands of sites across the U.S. Figure 10 shows the locations of AQS surface monitors in the region around Lake Michigan.

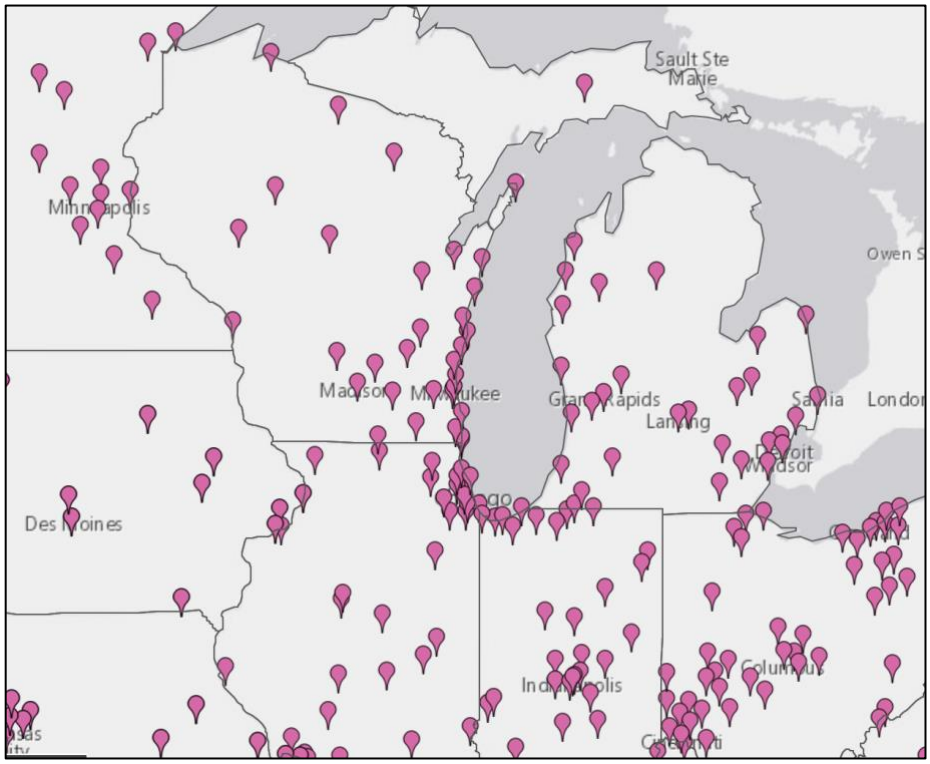

Figure 10. Locations of AQS monitors around Lake Michigan; source: U.S. EPA AirData

CASTNet Monitoring Network: The Clean Air Status and Trends Network (CASTNet) operates approximately 80 monitoring sites in mainly rural areas across the U.S. CASTNet sites typically collect hourly O_3, temperature, wind speed and direction, sigma theta, solar radiation, relative humidity, precipitation and surface wetness. CASTNet also collects weekly (Tuesday to Tuesday) samples of speciated $PM_{2.5}$ sulfate, nitrate, ammonium and other relevant ions and weekly gaseous SO_2 and nitric acid (HNO_3). Figure 11 displays the locations of the approximately 80 CASTNet sites across the U.S.

Figure 11. Locations of CASTNet monitoring sites; source: https://www.epa.gov/castnet

3.8.2 Model Performance Statistics, Goals and Criteria

As recommended by EPA (2018), LADCO used a 60 ppb observed O_3 cut-off threshold when calculating O_3 model performance statistics for this application.

Table 9. Ozone model performance goals

Fractional Bias (FB)	Fractional Error (FE)	Comment
≤±15%	≤35%	Ozone model performance goal that would be considered very good

It should be pointed out that these model performance goals are not used to assign passing or failing grades to model performance, but rather to help interpret the model performance and intercompare across locations, species, time periods and model applications. The model inputs to CAMx vary hourly, but tend to represent average conditions that do not account for unusual or extreme conditions. For example, an accident or large event could cause significant increases in congestion and motor vehicle emissions that are not accounted for in the average emissions inputs used in the model.

EPA compiled and interpreted the model performance from 69 air quality modeling studies in the peer-reviewed literature between 2006 and March 2012 and developed recommendations on what should be reported in a model performance evaluation (Simon, Baker and Phillips, 2012). Included in the most recent EPA guidance (U.S. EPA, 2018), they are useful and were used by LADCO in our model performance evaluation:

- Photochemical modeling MPE studies should at a minimum report the Mean Bias (MB) and Error (ME or RMSE), and Normalized Mean Bias (NMB) and Error (NME) and/or Fractional Bias (FB) and Error (FE). Both the MNB and FB are symmetric around zero with the FB bounded by -200% to +200%.
- The model evaluation statistics should be calculated for the highest temporal resolution available and for important regulatory averaging times (e.g., daily maximum 8-hour O_3).
- It is important to report processing steps in the model evaluation and how the predicted and observed data were paired and whether data are spatially/temporally averaged before the statistics are calculated.
- Predicted values should be taken from the grid cell that contains the monitoring site, although bilinear interpolation to the monitoring site point can be used for higher resolution modeling (< 12 km).
- Evaluation should be performed for subsets of the data including, high observed concentrations (e.g., O_3 > 60 ppb), by subregions and by season or month.
- Evaluation should include more than just O_3 and $PM_{2.5}$, such as SO_2, NO_2 and CO.
- Spatial displays should be used in the model evaluation to evaluate model predictions away from the monitoring sites. Time series of predicted and observed concentrations at a monitoring site should also be used.
- It is necessary to understand measurement artifacts in order to make meaningful interpretation of the model performance evaluation.

We incorporated the recommendations of U.S. EPA (2018) into the LADCO CAMx model performance evaluation. The LADCO evaluation products include qualitative and quantitative evaluation for maximum daily 1-hour and maximum daily 8-hour average (MDA8) O_3, including MDA8 with a 60 ppb threshold.

Table 10. Definition of model performance evaluation statistical measures used to evaluate the CTMs.

Statistical Measure	Mathematical Expression	Notes
Accuracy of paired peak (Ap)	$\frac{P - O_{peak}}{O_{peak}}$	Comparison of the peak observed value (O_{peak}) with the predicted value at same time and location
Normalized Mean Error (NME)	$\frac{\sum_{i=1}^{N} \lvert P_i - O_i \rvert}{\sum_{i=1}^{N} O_i}$	Reported as %
Root Mean Square Error (RMSE)	$\left[\frac{1}{N} \sum_{i=1}^{N} (P_i - O_i)^2 \right]^{1/2}$	Reported as %
Fractional Gross Error (FE)	$\frac{2}{N} \sum_{i=1}^{N} \left\lvert \frac{P_i - O_i}{P_i + O_i} \right\rvert$	Reported as % and bounded by 0% to 200%
Mean Absolute Gross Error (MAGE)	$\frac{1}{N} \sum_{i=1}^{N} \lvert P_i - O_i \rvert$	Reported as concentration (e.g., µg/m^3)
Mean Normalized Gross Error (MNGE)	$\frac{1}{N} \sum_{i=1}^{N} \frac{\lvert P_i - O_i \rvert}{O_i}$	Reported as %
Mean Bias (MB)	$\frac{1}{N} \sum_{i=1}^{N} (P_i - O_i)$	Reported as concentration (e.g., µg/m^3)
Mean Normalized Bias (MNB)	$\frac{1}{N} \sum_{i=1}^{N} \frac{(P_i - O_i)}{O_i}$	Reported as %
Mean Fractionalized Bias (Fractional Bias, FB)	$\frac{2}{N} \sum_{i=1}^{N} \left(\frac{P_i - O_i}{P_i + O_i} \right)$	Reported as %, bounded by -200% to +200%
Normalized Mean Bias (NMB)	$\frac{\sum_{i=1}^{N} (P_i - O_i)}{\sum_{i=1}^{N} O_i}$	Reported as %
Bias Factor (BF)	$\frac{1}{N} \sum_{i=1}^{N} \left(\frac{P_i}{O_i} \right)$	Reported as BF:1 or 1: BF or in fractional notation (BF/1 or 1/BF).

3.8.3 Subregional Evaluation of Model Performance

The evaluation of the LADCO 2016 CAMx 12-km simulation focuses on monthly and O_3 season model performance at monitors in IL, IN, and WI. We also examined summer season

high O_3 episodes in different parts of the region to determine how well the model performs on O_3 exceedance days and locations.

4 2020 Air Quality Projections

LADCO based our 2020 O_3 air quality and NAA attainment forecasts on the CAMx modeling platform released by the U.S. EPA in September 2019 to support regional haze progress assessments. The U.S. EPA 2016fh_16j emissions modeling platform included an emissions projection to 2023. Given the absence of available emissions data for 2020 at the time that this application initiated in late 2019, LADCO used linear interpolation between 2016 and 2023 for most of the emissions sectors to estimate 2020 emissions. An exception was for the stationary point source electricity generating unit (EGU) sector, which used a 2020 forecast estimated by the ERTAC EGU 16.1 model (MARAMA, 2012).

For the CAMx modeling used to predict 2020 air quality, LADCO kept all of the CAMx inputs other than the emissions the same as the 2016 simulation.

4.1 2020 Emissions Data

LADCO estimated 2020 emissions for most of the anthropogenic inventory sectors by interpolating between the 2016 and 2023 Inventory Collaborative 2016v1 inventories. We used linear interpolation for the emissions because 2020 inventories were not readily available for all of the sectors at the time that this application initiated. While LADCO recognizes that emissions do not change linearly, given the relatively short period between the base and future years (4 years), LADCO considers that linear interpolation was justified for this application. LADCO also considers linear interpolation of the emissions to 2020 better than the alternatives of either holding the emissions constant at 2016 levels or using 2023 emissions estimates to simulate air quality in 2020.

LADCO applied two distinct linear interpolation techniques to estimate 2020 emissions. The first method was applied to gridded non-point, low-level emissions (e.g., area and mobile sources) sectors that had already been processed through SMOKE for 2016 and 2023. LADCO calculated the 2020 gridded emissions using Equation 1,

$$E_{2020,i,j,t,p} = 3/7 \times E_{2016,i,j,t,p} + 4/7 \times E_{2023,i,j,t,p} \quad \text{(Equation 1)}$$

where, E = hourly, gridded emissions
i = column
j = row
t = hour
p = pollutant

As Equation 1 would not work for point sources because new units came online and other units shut down between the 2016 base and 2020 future years, LADCO applied Equation 2 to interpolate the non-EGU industrial point sources to 2020.

For each process and pollutant:

$$E_{2020,s,p} = (2020\text{-}2016)*(E_{2023,s.p} - E_{2016,s,p})/(2023\text{-}2016) + E_{2016,s,p} \quad \text{(Equation 2)}$$

where, E = annual emissions
s = point source process
p = pollutant

LADCO developed work-arounds to Equation 2 for (1) units that began operations after 2016 and were included in the 2023 inventory; and (2) units that were in the 2016 inventory but were shut down in the 2023 inventory. After reviewing the sources included in the first list, LADCO established that U.S. EPA developed the 2023 inventories for the new units based on state 2017 NEI submittals. We found that most of the new units that were added to the 2023 inventory by U.S. EPA were already operating by 2020. Without being able to identify all of the unit level startup date information, LADCO made the assumption that all new units listed as operating in 2023 would also be operating in 2020. We calculated the 2020 emissions for these sources using Equation 2, which simplifies to $E_{2020,s.p} = 4/7 \times E_{2023,s.p}$ when we consider that these sources had zero emissions in 2016.

For the second list of sources, or those units that were in the 2016 inventory but not in the 2023 inventory, LADCO found that most of the shutdowns were scheduled before 2020. Several units that we reviewed had already shut down by late-2019 when we were developing the 2020 inventory for this modeling application. LADCO assumed that

all units identified to be shut down by 2023 would also be shut down in the 2020 inventory that we developed for this modeling application. We validated this assumption using internet searches to confirm that the largest units in this second list of sources were in fact shut down by 2020.

LADCO replaced the EGU emissions in the U.S. EPA "2016fh" emissions modeling platform with 2020 EGU forecasts estimated with the ERTAC EGU Tool version 16.1 (MARAMA, 2012). ERTAC EGU 16.1 integrates state-reported information on EGU operations and forecasts as of December 2019. LADCO considers that the ERTAC EGU Tool provides more accurate estimates of the growth and control forecasts for EGUs in the Midwest and Northeast states than the U.S. EPA approach used in U.S. EPA's "2016fh" modeling platform.

4.1.1 LADCO 2020 Electricity Generating Unit Emissions

The ERTAC EGU model for growth was developed around activity pattern matching algorithms designed to provide hourly EGU emissions data for air quality planning. The original goal of the model was to create low-cost software that air quality planning agencies could use for developing EGU emissions projections. States needed a transparent model that was numerically stable and did not produce dramatic changes to the emissions forecasts with small changes in inputs. A key feature of the model includes data transparency; all of the inputs to the model are publicly available. The code is also operationally transparent and includes extensive documentation, open source code, and a diverse user community to support new users of the software.

Operation of the model is straightforward given the complexity of the projection calculations and inputs. The model imports base year Continuous Emissions Monitoring (CEM) data from U.S. EPA and sorts the data from the peak to the lowest generation hour. It applies hour specific growth rates that include peak and off peak rates. The model then balances the system for all units and hours that exceed physical or regulatory limits. ERTAC EGU applies future year controls to the emissions estimates and

tests for reserve capacity, generates quality assurance reports, and converts the outputs to SMOKE-ready modeling files.

ERTAC EGU has distinct advantages over other growth methodologies because it is capable of generating hourly future year estimates which are key to understanding O_3 episodes. The model does not shutdown or mothball existing units because economics algorithms suggest they are not economically viable. Additionally, alternate control scenarios are easy to simulate with the model. In recent years significant effort has been put into the model to help users to prevent the generation of new coal plants to fit demand. The model now allows portability of generation to different fuels like renewables and natural gas to prevent this.

Differences between the U.S. EPA and ERTAC EGU emissions forecasts arise from alternative forecast algorithms and from the data used to inform the model predictions. The U.S. EPA based the EGU emissions forecast in their "2016fh" modeling platform on comments from states and stakeholders received through April 2019. ERTAC EGU 16.1 used CEM data from 2016 and state-reported changes to EGUs received through December 2019. The ERTAC EGU 16.1 emissions used for this modeling application represent the best available information on EGU forecasts for the Midwest and Eastern U.S. available December 2019.

Figure 12 through Figure 17 show gridded daily total 2020 NOx and VOC emissions for a summer weekday (June 7). The spatial patterns seen in these figures match with the patterns in the 2016 emissions figures shown previously. The difference and ratio plots illustrate the locations where emissions are projected to change in 2020 relative to 2016. The NOx ratio plot (Figure 14) shows that the largest NOx emissions reductions will occur along roadways and in urban areas; emissions increases are projected in oil and gas development regions, in Mexico, and in Canadian offshore sources in the Great Lakes. The VOC ratio plot (Figure 17) illustrates small emissions reductions in urban areas and emissions increases in oil and gas development areas.

Table 11 shows the LADCO state total 2020 O_3 season (May 1 – September 30) weekday NOx and VOC emissions. Table 12 and Table 13 show the total 2020 O_3 season weekday NOx and VOC emissions for each LADCO state by emissions inventory sector. Table 14 and Table 15 compare 2020 and 2016 ozone season day NOx and VOC emissions, respectively, by inventory sector for each LADCO state. Negative numbers in these tables indicate emissions reductions in 2020 relative to 2016. Comparisons of the EGU and industrial point source emissions changes between 2016 and 2020 is confounded by the different methods used by the U.S EPA and ERTAC EGU projection models for distinguishing EGU from non-EGU industrial point sources. Some of the decreases in EGU emissions in 2020 are due to sources being reclassified from the EGU to the non-EGU industrial point sector by ERTAC EGU.

Overall both the NOx and VOC ozone season day emissions are projected to decrease in 2020 relative to 2016 in all of the LADCO states. The NOx reductions range from 10%-17%, driven primarily by reductions in mobile source emissions. The VOC reductions are more modest, at around 1% in each of the LADCO states and also driven by reductions in mobile sources. For the anthropogenic sectors only (i.e., excluding biogenics), the ozone season day VOC emissions reductions are closer to 5% in each of the LADCO states.

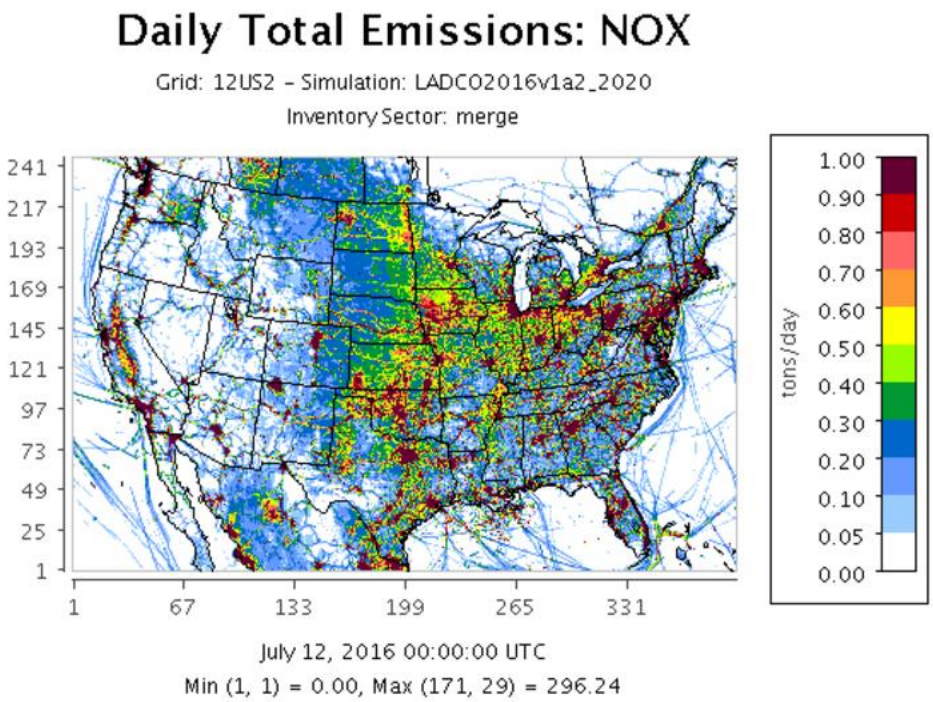

Figure 12. Daily total gridded 2020 NOx emissions for a summer weekday (tons/day)

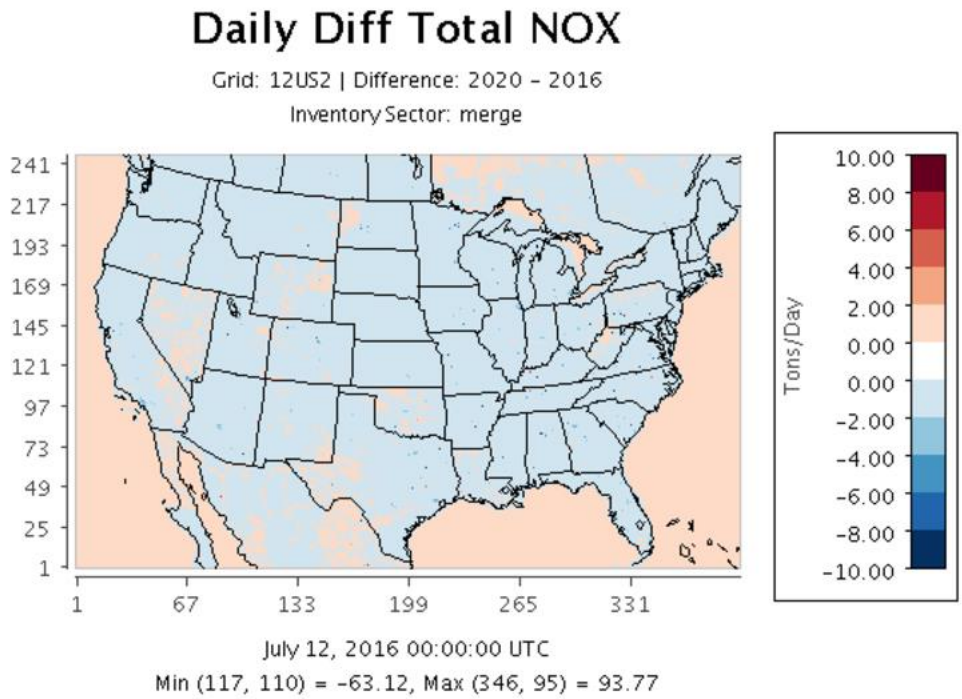

Figure 13. Difference (2020-2016) in daily total gridded NOx emissions for a summer weekday (tons/day)

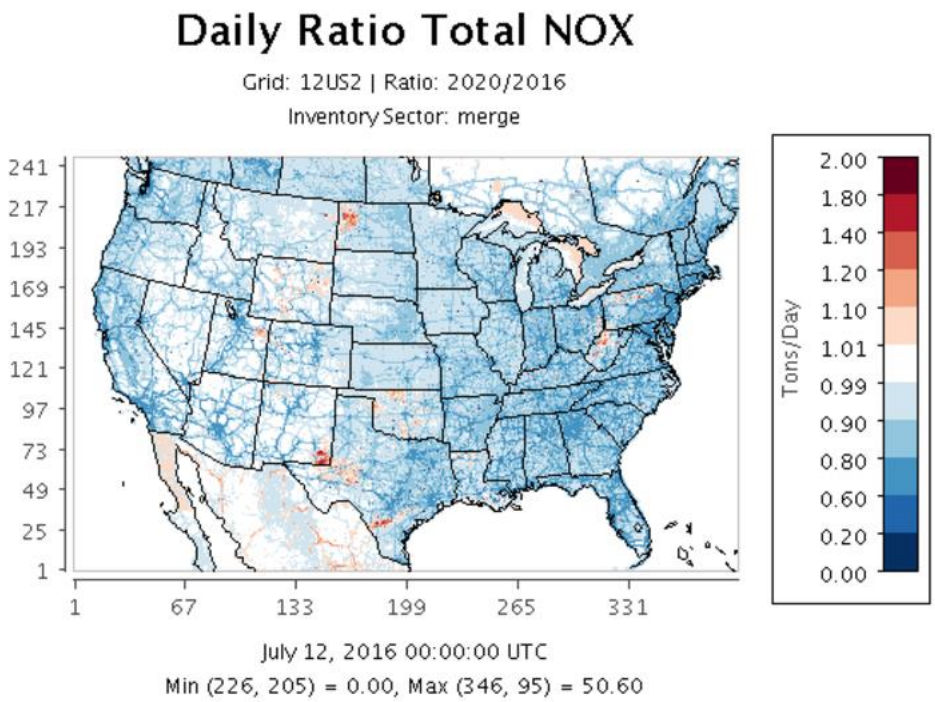

Figure 14. Ratio (2020/2016) of daily total gridded NOx emissions for a summer weekday (unitless)

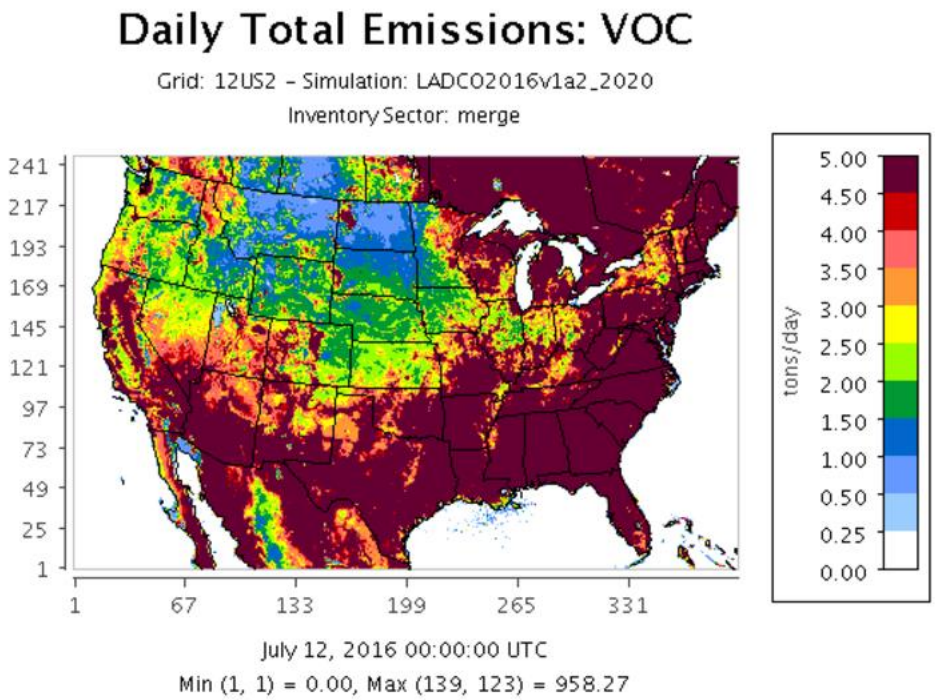

Figure 15. Daily total gridded 2020 VOC emissions for a summer weekday (tons/day)

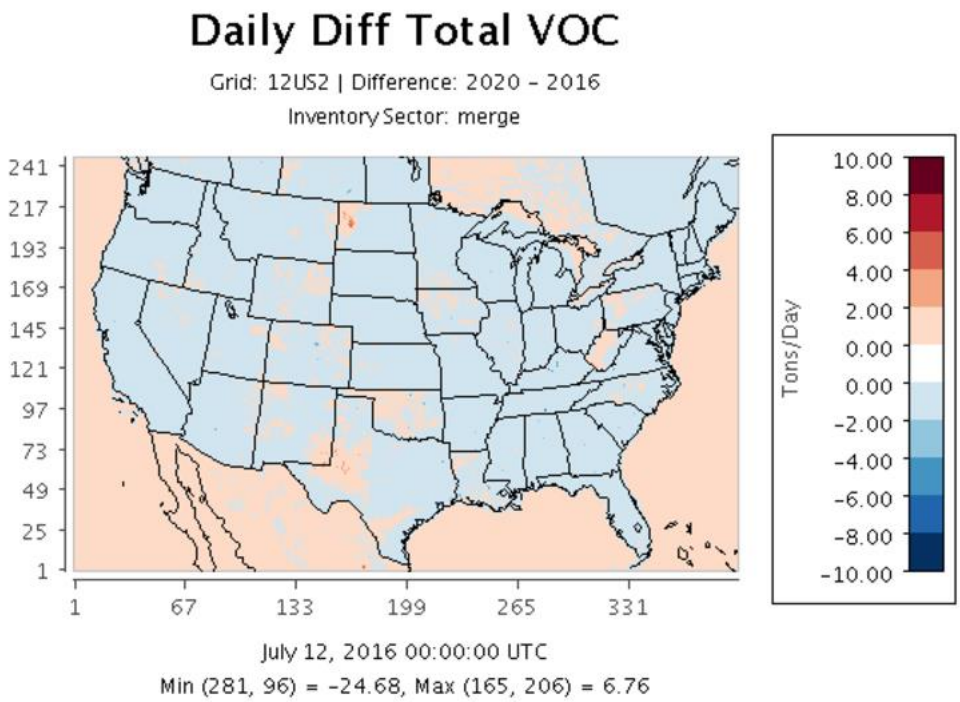

Figure 16. Difference (2020-2016) in daily total gridded VOC emissions for a summer weekday (tons/day)

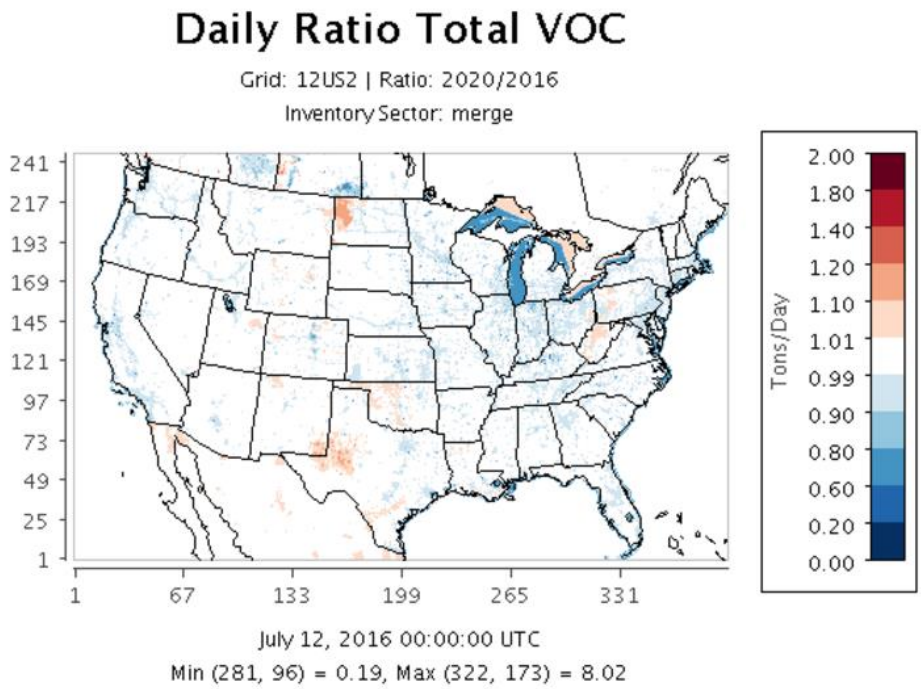

Figure 17. Ratio (2020/2016) of daily total gridded VOC emissions for a summer weekday (unitless)

Table 11. 2020 ozone season weekday emissions total by LADCO state, excluding biogenics (tons/day)

State	NOX	VOC
Illinois	860.8	954.5
Indiana	734.2	627.6
Michigan	693.0	776.5
Minnesota	525.8	685.9
Ohio	806.3	883.6
Wisconsin	429.2	447.9

Table 12. 2020 ozone season weekday NOx emissions by inventory sectors (tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
Airports	15.9	2.8	6.0	5.3	3.3	1.9
Biogenic	167.0	89.6	61.7	126.9	74.0	71.8
C1/C2 Commercial Marine	14.8	3.9	13.8	2.5	6.6	5.0
C3 Commercial Marine	0.6	1.1	20.5	2.0	2.2	2.5
Nonpoint	82.0	18.8	65.2	41.4	61.0	36.1
Offroad Mobile	148.6	117.2	74.0	135.9	127.8	67.8
Nonpoint Oil & Gas	37.7	9.6	33.6	0.0	5.7	0.0
Onroad Mobile	271.7	244.1	224.2	149.8	283.3	183.6
Point Oil & Gas	25.1	17.5	30.1	7.6	34	1.6
Agricultural Fires	0.0	0.0	0.0	0.2	0.0	0.0
Electricity Generation	84.7	150.6	92.3	48.1	118.1	39.7
Wild and Prescribed Fires	1.0	0.4	1.6	6.5	0.8	1.9
Industrial Point	93.1	127.6	118.0	87	101.9	61.8
Rail	85.4	40.3	12.2	35.6	61.0	26.2
Residential Wood Combustion	0.3	0.3	1.5	3.9	0.5	1.1

Table 13. 2020 ozone season weekday VOC emissions by inventory sectors (tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	29.4	28.4	13.0	53.2	26.3	20.6
Airports	4.9	1.2	2.1	1.8	1.5	0.95

Biogenic	2386.1	1575.4	3390.2	2894.4	2038.8	2770.9
C1/C2 Commercial Marine	0.7	0.2	0.4	0.1	0.3	0.2
C3 Commercial Marine	0.0	0.1	1.0	0.1	0.2	0.2
Nonpoint	374.3	262.8	351.6	185.3	420.0	178.3
Offroad Mobile	101.9	60.2	82.4	76.0	105.9	63.2
Nonpoint Oil & Gas	161.0	41.3	59.9	0.0	44.3	0.0
Onroad Mobile	150.3	131.4	145.6	89.0	177.8	77.1
Point Oil & Gas	4.5	1.2	3.7	0.5	6.1	0.8
Agricultural Fires	0.0	0.0	0.0	0.5	0.0	0.0
Electricity Generation	3.5	3.9	2.4	1.1	2.4	2.1
Wild and Prescribe Fires	16.2	5.8	38.9	187.2	11.8	35.0
Industrial Point	100.3	84.7	61.3	50.8	77.9	58.4
Rail	3.9	1.8	0.6	1.6	2.8	1.2
Residential Wood Combustion	3.6	4.6	13.6	38.7	6.2	9.8

Table 14. Difference between base and future year ozone season weekday NOx emissions (2020-2016; tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Airports	1.6 (10%)	0.3 (10%)	0.6 (11%)	0.4 (7%)	0.1 (6%)	0.2 (12%)
Biogenic	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
C1/C2 Commercial Marine	-2.3 (-13%)	-0.6 (-13%)	-2.0 (-13%)	-0.5 (-17%)	-1.0 (-13%)	-0.7 (-12%)
C3 Commercial Marine	0.0 (0%)	0.1 (10%)	0.8 (4%)	0.1 (5%)	0.2 (10%)	0.2 (9%)
Nonpoint	-1.8 (-2%)	-0.1 (-1%)	-1.2 (-2%)	-0.2 (0%)	-1.0 (-2%)	-0.4 (-1%)
Offroad Mobile	-29.0 (-16%)	-23.5 (-17%)	-11.9 (-14%)	-23.7 (-15%)	-23.2 (-15%)	-12.5 (-16%)
Nonpoint Oil & Gas	-0.7 (-2%)	-0.2 (-2%)	-1.9 (-5%)	0.0 (0%)	1.3 (30%)	0.0 (0%)
Onroad Mobile	-76.2 (-22%)	-68.5 (-22%)	-67.4 (-23%)	-44.1 (-23%)	-84.8 (-23%)	-57.6 (-24%)
Point Oil & Gas	1.6 (7%)	3.4 (24%)	0.8 (3%)	-0.2 (-3%)	2.8 (9%)	0.1 (7%)
Agricultural Fires	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Electricity Generation	0.1 (-0%)	-66.9 (-30%)	-27.8 (-23%)	-7.8 (-13%)	-39.3 (-24%)	-7.0 (-15%)

Wild and Prescribe Fires	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Industrial Point	-1.7 (-2%)	-1.7 (-1%)	-3.78 (-3%)	-29.6 (-25%)	-0.8 (-1%)	-1.4 (-1%)
Rail	-5.9 (-6%)	-2.7 (-6%)	-0.6 (-5%)	-2.6 (-7%)	-4.5 (-7%)	-2.0 (-7%)
Residential Wood Combustion	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Total	-121.5 (-10%)	-164.3 (-17%)	-104.1 (-12%)	-89.4 (-12%)	-161.2 (-15%)	-88.7 (-15%)

Table 15. Difference between base and future year ozone season weekday VOC emissions comparison (2020-2016; tons/day)

Sector	Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin
Agriculture	1.1 (4%)	1.0 (4%)	0.4 (3%)	1.7 (3%)	0.8 (3%)	0.2 (1%)
Airports	0.2 (4%)	0.0 (0%)	0.0 (2%)	0.0 (0%)	-0.1 (-3%)	0.0 (0%)
Biogenic	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	-0.1 (0%)	0.0 (0%)
C1/C2 Commercial Marine	-0.2 (-22%)	0.0 (0%)	-0.1 (-20%)	0.0 (0%)	-0.1 (-25%)	0.0 (0%)
C3 Commercial Marine	0.0 (0%)	0.0 (0%)	0.1 (11%)	0.0 (0%)	0.1 (100%)	0.1 (100%)
Nonpoint	1.8 (0%)	1.0 (0%)	-0.1 (0%)	1.4 (1%)	2.2 (1%)	0.8 (0%)
Offroad Mobile	-8.7 (-8%)	-4.5 (-7%)	-9.4 (-10%)	-9.6 (-11%)	-10.1 (-9%)	-8.2 (-11%)
Nonpoint Oil & Gas	-1.5 (-1%)	0.0 (0%)	-1.3 (-2%)	0.0 (0%)	2.1 (5%)	0.0 (0%)
Onroad Mobile	-32.1 (-18%)	-29.5 (-18%)	-32.1 (-18%)	-19.3 (-18%)	-39.2 (-18%)	-16.5 (-18%)
Point Oil & Gas	0.8 (22%)	0.2 (20%)	0.1 (3%)	0.0 (0%)	1.5 (33%)	0.2 (33%)
Agricultural Fires	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Electricity Generation	-.1 (-3%)	0.3 (8%)	-0.24 (-9%)	-0.2 (-15%)	-0.7 (-23%)	-0.1 (-5%)
Wild and Prescribe Fires	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	-0.1 (-1%)	0.0 (0%)
Industrial Point	-0.7 (-1%)	-1.0 (-1%)	-1.2 (-2%)	0.0 (0%)	-1.0 (-1%)	-0.7 (-1%)
Rail	-0.4 (-9%)	-0.2 (-10%)	0.0 (0%)	-0.2 (-11%)	-0.3 (-10%)	-0.1 (-8%)
Residential Wood Combustion	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)
Total	-40.5 (-1%)	-33.0 (-1%)	-44.3 (-1%)	-26.4 (-1%)	-45.0 (-2%)	-24.4 (-1%)

4.2 Evaluation of the LADCO 2020 CAMx Simulation

As future year air quality forecasts cannot be compared to observations for evaluation, LADCO relied on our 2016 MPE results to establish validity in the modeling platform. In addition to the MPE for the base year CAMx simulation, the U.S. EPA reported full MPE results for the 2016 WRF modeling (US EPA, 2019b) and for the 2016 hemispheric CMAQ modeling (U.S. EPA, 2019c) used to drive the LADCO 2020 CAMx simulation.

5 Future Year Ozone Design Values

LADCO followed the U.S. EPA Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze (US EPA, 2018) to calculate design values in 2020 (DV_{2020}) for monitors in IL, IN, and WI. As we used a base year of 2016, we estimated the base year design values using surface observations for the years 2014-2018 ($DV_{2014-2018}$). LADCO estimated the DV_{2020} with version 1.6- of the Software for Modeled Attainment Test Community Edition (SMAT-CE)[5]. SMAT-CE was configured to use the daily max average 8-hr (MDA8) O_3 concentration above 60 ppb in a 3x3 matrix around each monitor across for the 10 highest modeled days, per the U.S. EPA Guidance. If there are less than 10 days with MDA8 O3 greater than 60 ppb, SMAT-CE uses all days, as long as there are at least 5 days that meet the minimum threshold criteria.

SMAT-CE uses a four step process to estimate DVs_{2020}:

1. Calculate $DV_{2014-2018}$ for each monitor
    - The O_3 design value is a three-year average of the 4th highest daily maximum 8 hour average O_3 ($MDA8_4$):

      $$DV_{2016} = (MDA8_{4,2014} + MDA8_{4,2015} + MDA8_{4,2016})/3$$

    - Weighted 5-year average of design values centered on the base model year (2016):

      $$DV_{2014-2018} = (DV_{2016} + DV_{2017} + DV_{2018})/3$$

2. Find highest base year modeled days surrounding each monitor
    - Find ten days with the highest base year modeled MDA8 from within a 3x3 matrix of grid cells surrounding each monitor
    - At least 5 days with modeled MDA8 >= 60 ppb are needed to retain the monitor for the future year DV calculation

3. Calculate relative response factor (RRF) for each monitor

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

- Calculate multi-day average MDA8 for the base and future years from the maximum paired in space values in the 3x3 matrix
- Calculate the RRF as the ratio of the multi-day average future to multi-day average base year MDA8:

$$RRF = MDA8_{2020,avg}/MDA8_{2016,avg}$$

4. Calculate DV_{2020} for each monitor

$$DV_{2020} = RRF * DV_{2014\text{-}2018}$$

LADCO used the DV_{2020} to identify nonattainment and maintenance sites in 2020 using the 5-year weighted average baseline design values (2014-2018) per U.S. EPA (2018). Under this methodology, sites with average DVs_{2020} that exceed the 2008 O_3 NAAQS (76 ppb or greater) and that are currently measuring nonattainment would be considered nonattainment receptors in projected year of 2020.

6 Results and Discussion

6.1 2016 CAMx Model Performance Evaluation Results

LADCO simulated the entire O_3 season (April 1 – October 31, 2016) with CAMx using the 2016 CAMx modeling platform described previously. Figure 18 is a spatial plot of the O_3 season average normalized mean bias (NMB) of daily maximum 8-hour average (MDA8) O_3 concentrations. Each colored symbol on the figure is an AQS or CASTNet monitoring location. Cool colors represent monitors at which the observed MDA O_3 concentrations were underestimated by the CAMx simulation; warm colors represent where CAMx overestimated the observations. Grey and lighter shades represent low bias, or acceptable model performance, relative to the model performance goals discussed in Section 3.8.2. Averaged across the entire O_3 season, there is a low negative bias (i.e., underprediction bias) in the CAMx MDA8 O_3 predictions for sites in the LADCO region. Overall, the model estimates O_3 concentrations in the southeast and mid-Atlantic areas well. CAMx underpredicted observed O_3 in inland California, the west, across the Great Lakes, and the northeastern U.S. The CAMx MDA O_3 overestimates are within the EPA (2018) model performance benchmarks.

The CAMx average monthly NMB for MDA8 O_3 shown in Figure 19 reveals a seasonal trend in the bias. Early in the O_3 season (April – June) CAMx underpredicted O_3 throughout the LADCO region. For many of the northern and near-shore monitors in the LADCO region the monthly averaged NMB values miss the model performance goal for O_3 (+/- 15%) in April and May. In the latter part of the season (July – October), CAMx overpredicted O_3 at most of the monitors in the region. Despite the overpredictions in the later months of the season, the absolute model biases are not as high as they are in April and May.

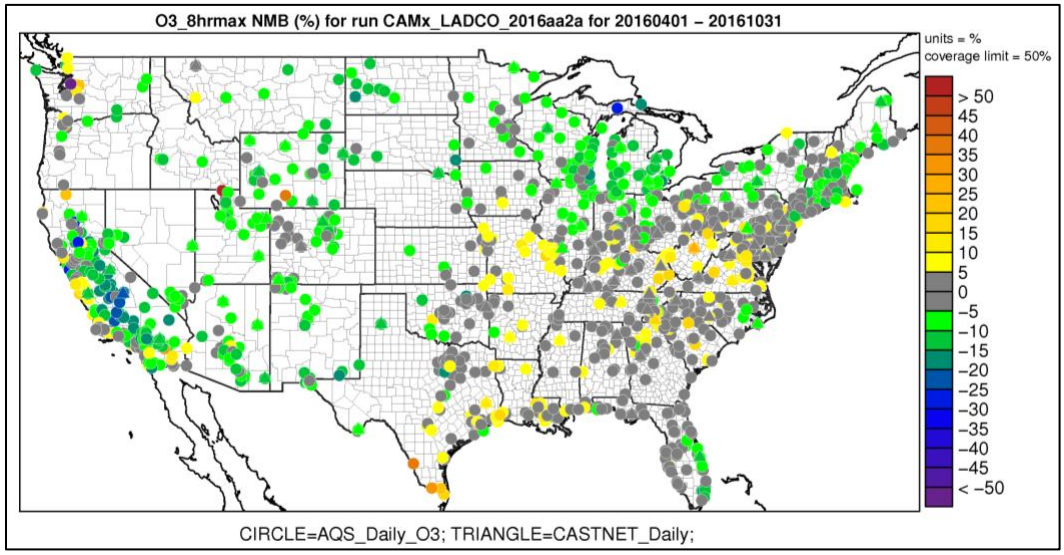

Figure 18. 2016 O_3 season MDA8 O_3 normalized mean bias spatial plot

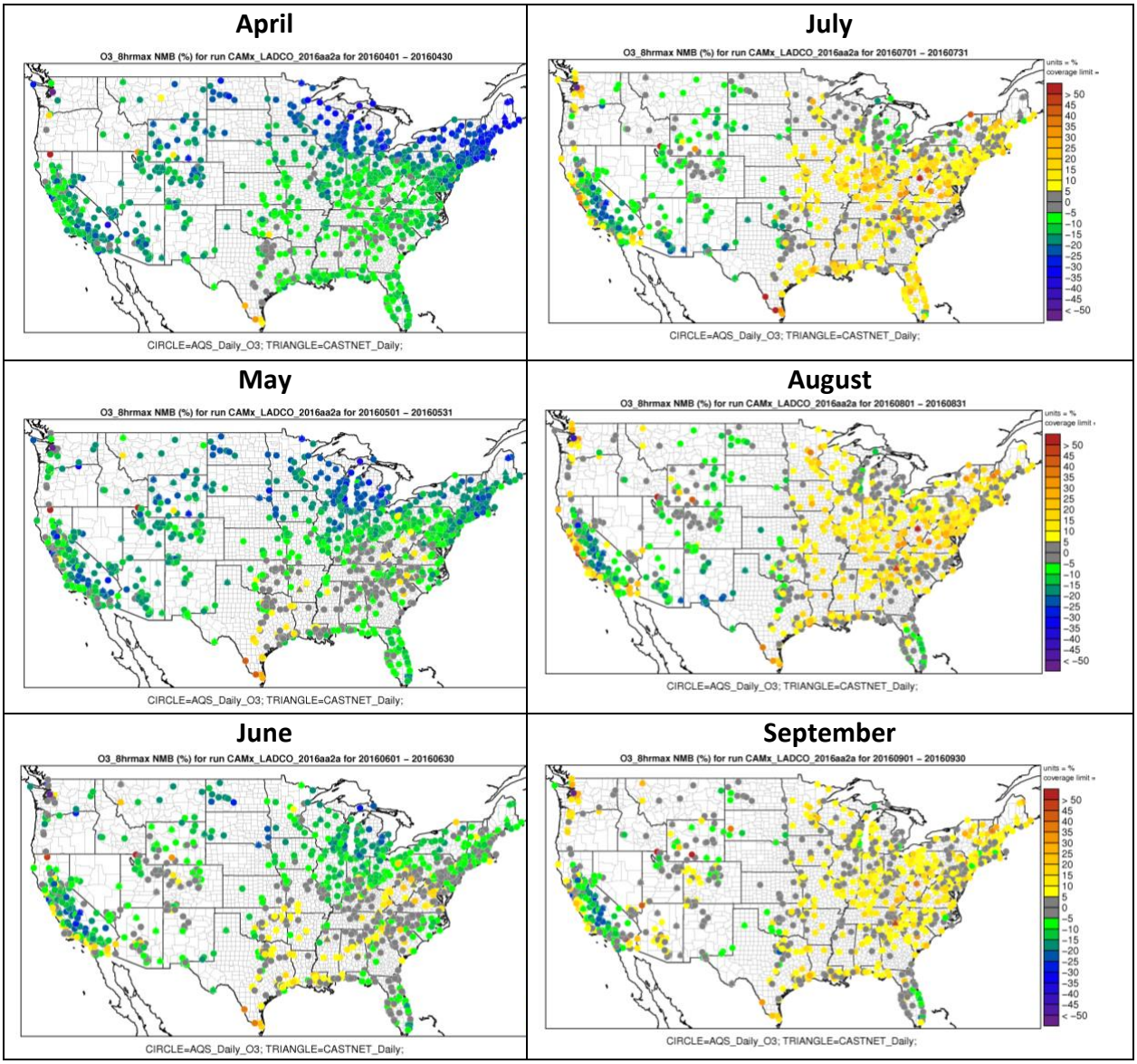

Figure 19. Monthly 2016 MDA8 O_3 normalized mean bias spatial plots

Table 16 and Table 17 show the daily maximum 8-hour average O_3 (MDA8) and daily maximum 1-hour O_3 performance statistics, respectively, for the LADCO 2016 CAMx simulation. Model biases and errors in these tables are O_3 season (April – October) averages across all Air Quality System (AQS) sites in the 12-km modeling domain, and across all AQS sites in each of the states of IL, IN, and WI. Each statistic is calculated for

all observations and for only observations > 60 ppb. The latter is used to determine the performance of the model estimates for high observed concentrations.

As described above, these statistics quantify the LADCO CAMx simulation O_3 underpredictions and also show that the model performance degrades at higher observed concentrations. Despite the model performance deficits shown in these statistics, the O_3 model performance goal for bias (<=15%) is missed only for high concentrations at the WI AQS monitors. The performance goal for error (<=35%) is met across all of the locations and O_3 levels presented here.

Figure 20 through Figure 23 are scatter plots of O_3 season MDA8 O_3 concentrations for AQS and CASTNet monitoring sites in the 12-km domain, and for sites in the states of IL, IN, and WI. Plots are shown both with and without a 60 ppb observed O_3 cutoff. These plots indicate that the CAMx predictions are slightly better for observations of 60 ppb and greater MDA8 O_3 concentrations at the urban and suburban AQS sites than at the more rural CASTNet monitoring locations. The model errors at CASTnet monitors are smaller for MDA8 O_3 concentrations when the 60 ppb threshold wasn't applied.

Table 16. CAMx ozone season MDA8 O_3 performance at AQS monitoring locations

Region	FB (ppb)		FE (ppb)		NMB (%)		NME (%)	
	All	> 60ppb	All	> 60ppb	All	> 60ppb	All	> 60ppb
12-km	-2.9	-13.5	15.4	15.6	-3.1	-12.1	14.5	14.3
IL	-5.5	-15.1	16.0	17.1	-5.0	-13.3	15.1	15.5
IN	-1.2	-12.0	15.5	14.0	-0.9	-10.7	14.8	12.8
WI	-9.5	-21.9	17.5	22.5	-9.5	-19.1	16.7	19.7

Table 17. CAMx ozone season daily maximum 1-hour O_3 performance at AQS monitoring locations

Region	FB (ppb)		FE (ppb)		NMB (%)		NME (%)	
	All	> 60ppb	All	> 60ppb	All	> 60ppb	All	> 60ppb
12-km	-4.7	-13.5	15.5	16.3	-4.8	-12.2	14.6	15.0
IL	-5.8	-13.0	15.4	16.1	-5.3	-11.5	14.6	14.7
IN	-1.9	-10.4	14.9	13.3	-1.6	-9.4	14.3	12.4
WI	-11.1	-22.3	17.9	23.5	-10.8	-19.6	17.0	20.7

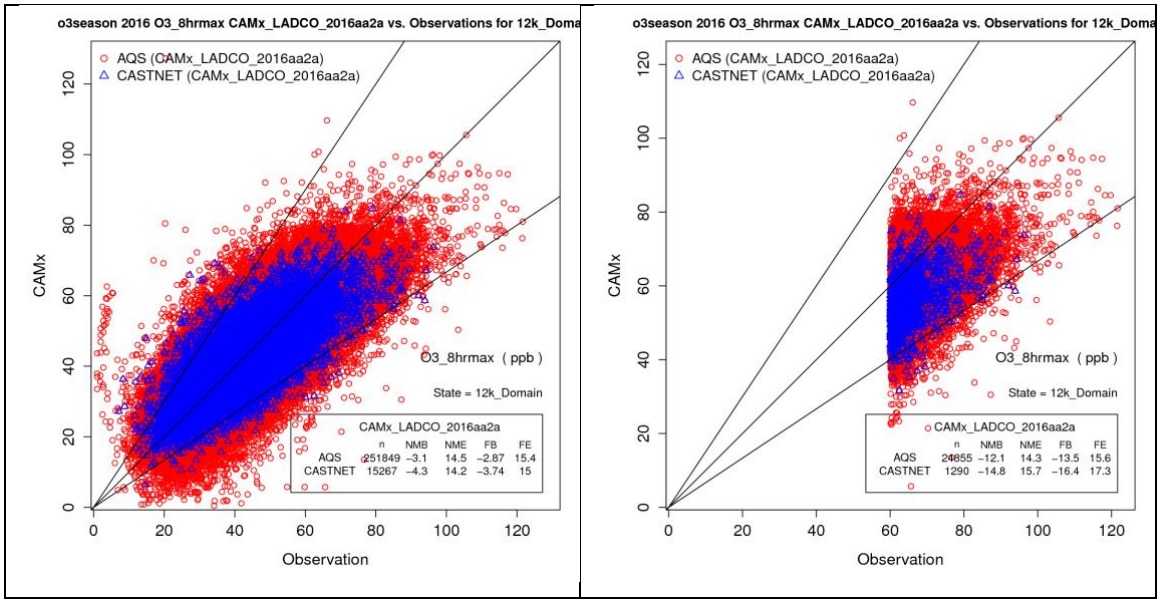

Figure 20. 2016 O_3 season MDA8 O_3 scatter plots for all sites in the 12-km modeling domain; all days (left), days > 60 ppb (right)

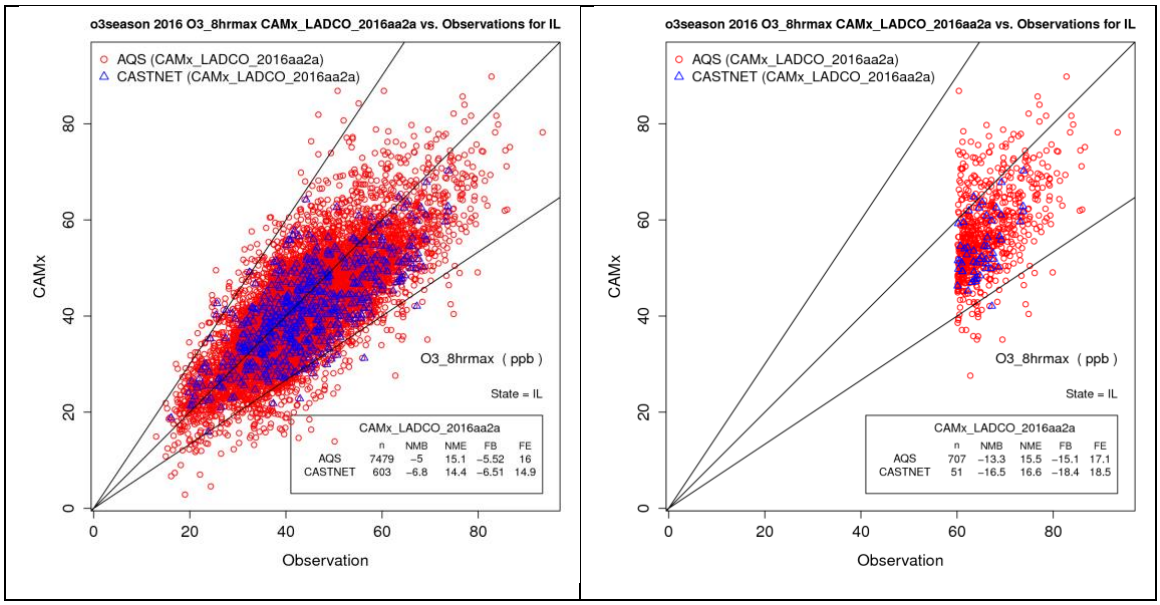

Figure 21. 2016 O_3 season MDA8 O_3 scatter plots for sites in IL; all days (left), days > 60 ppb (right)

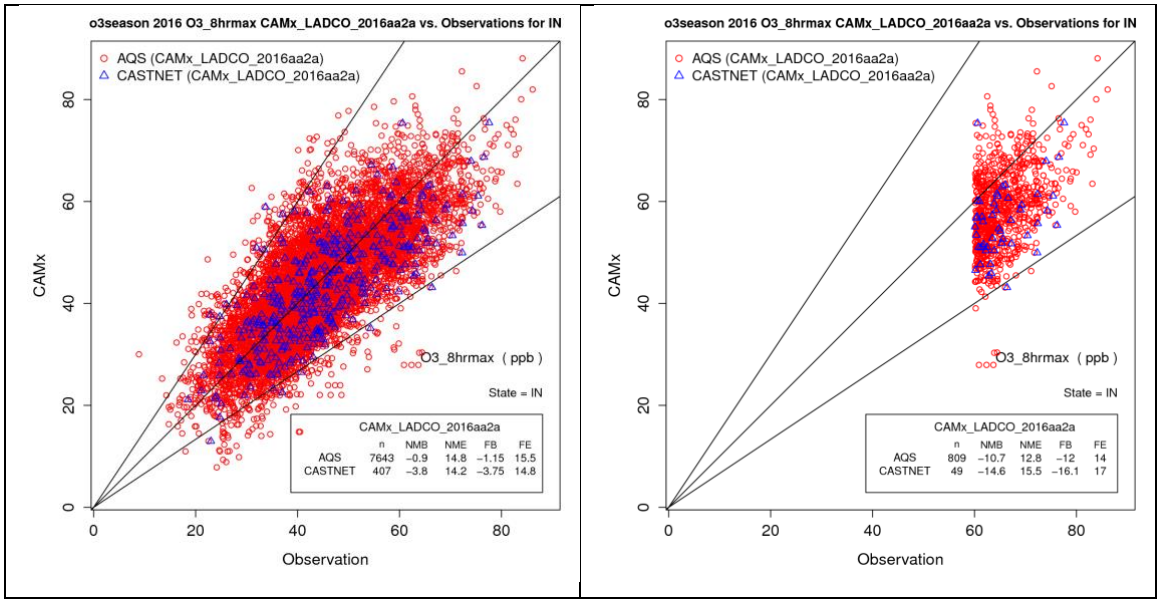

Figure 22. 2016 O_3 season MDA8 O_3 scatter plots for sites in IN; all days (left), days > 60 ppb (right)

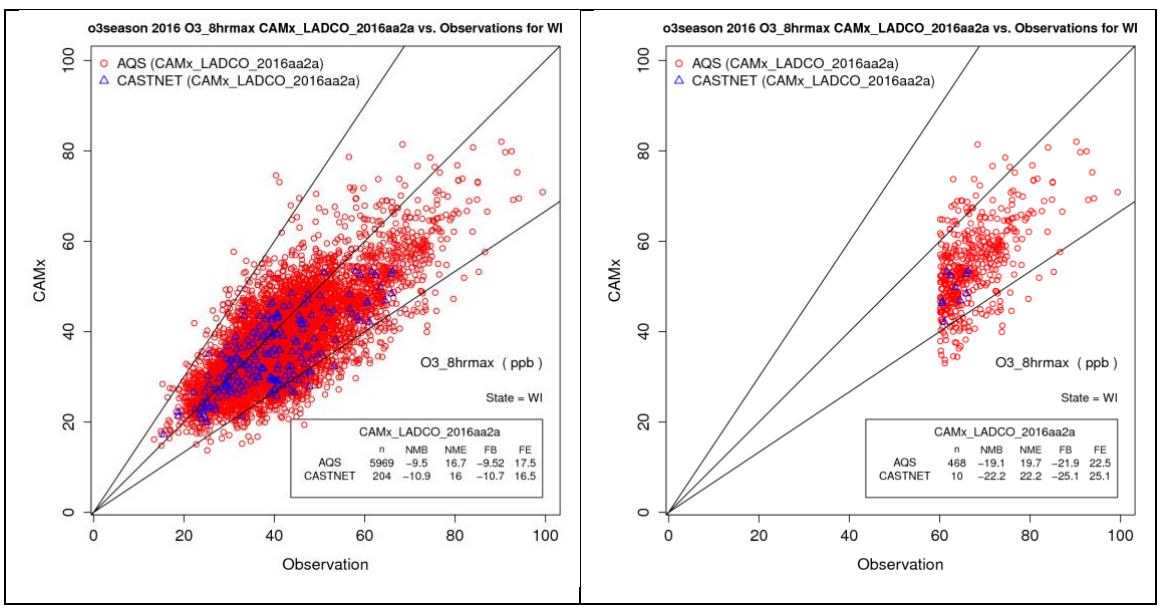

Figure 23. 2016 O_3 season MDA8 O_3 scatter plots for sites in WI; all days (left), days > 60 ppb (right)

Figure 24 through Figure 26 are monthly box and whisker plots of CAMx and observed MDA8 O_3 concentrations for AQS and CASTNet sites in IL, IN, and WI, respectively. The box and whisker plots show the observed and model median concentrations as symbols connected by lines (blue for CAMx and black for observations), the 25th and 75th

percentile concentrations as the bottom and top of each box, and the 5th and 95th percentile concentrations as the bottom and top of each whisker. These plots further highlight the underpredictions during April – June, as seen by the lower median values for CAMx relative to the observations across in all three states during this period. The skill of CAMx to simulate the distribution of observed O_3 concentrations incrementally improves in July – October as seen by the closer correspondence of the median, 75th and 95th percentile observed and predicted concentrations for most of the months in the three states. In general, CAMx has an underprediction in the fourth quantile (i.e., highest concentration) end of the observed O_3 distribution.

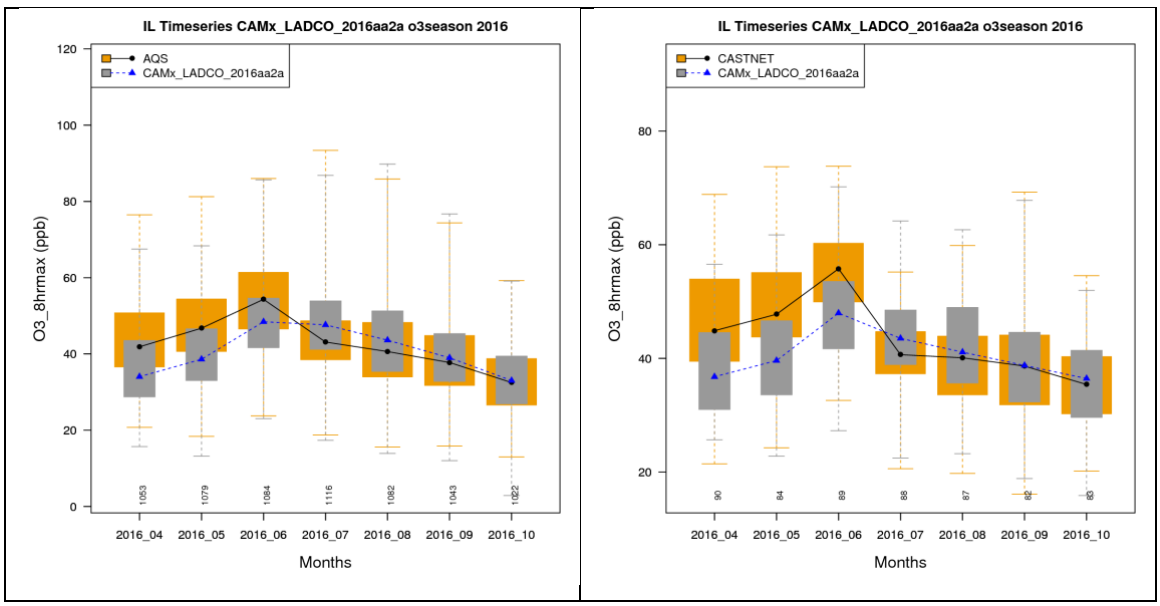

Figure 24. 2016 monthly MDA8 O_3 box and whisker plots comparing CAMx with AQS (left) and CASTNet (right) monitors for sites in IL.

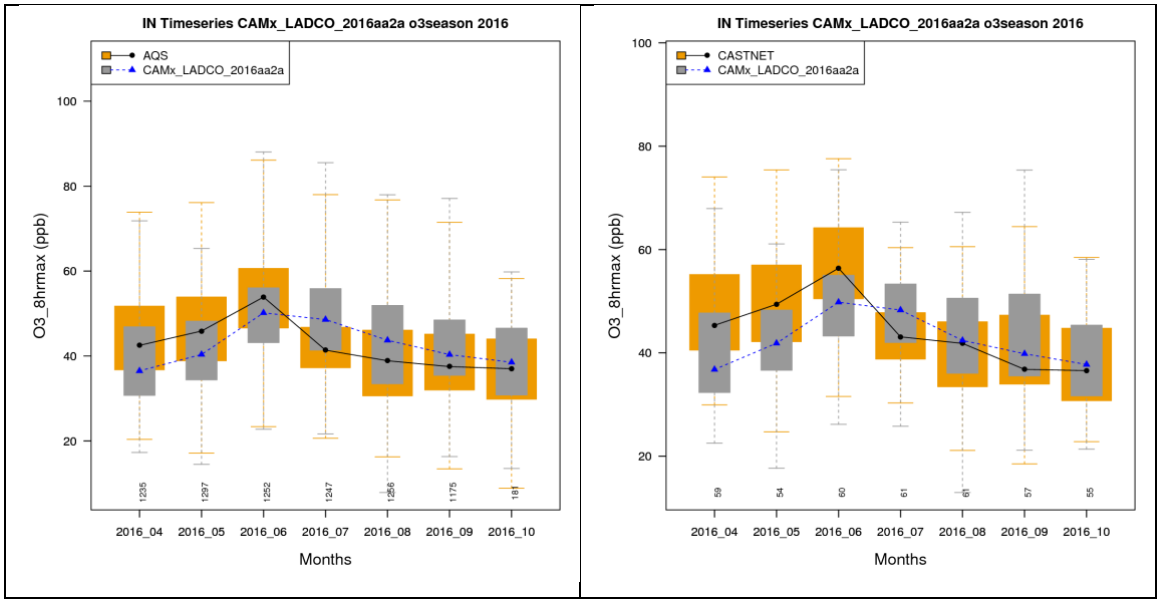

Figure 25. 2016 monthly MDA8 O_3 box and whisker plots comparing CAMx with AQS (left) and CASTNet (right) monitors for sites in IN.

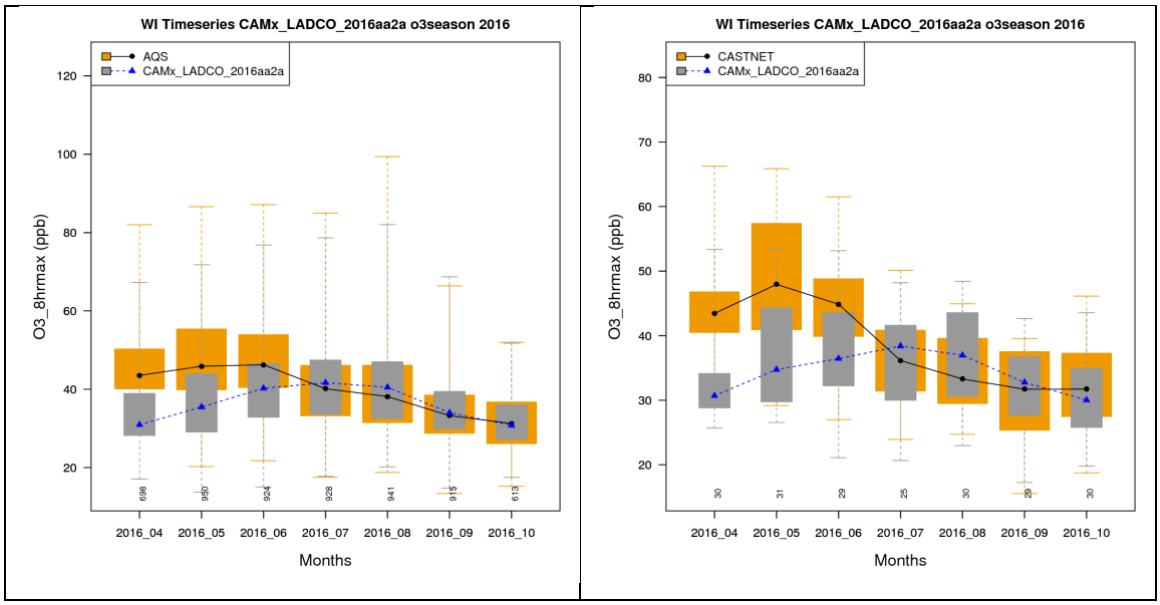

Figure 26. 2016 monthly MDA8 O_3 box and whisker plots comparing CAMx with AQS (left) and CASTNet (right) monitors for sites in WI.

Figure 27 through Figure 29 are monthly concentration-bias plots for MDA8 O_3 in IL, IN, and WI, respectively. These plots superimpose lines of the monthly average MDA8 O_3 CAMx predictions and AQS observed concentrations (right axis) on a bar plot of the

monthly average NMB (left axis). The green and red horizontal lines on these plots are the +/- 15% and 35% bias and error goals and criteria for O_3 modeling. The value that these plots provide is a clear image of the switch in the bias signal from negative to positive biases moving from June to July in all three states, and also a reduction in the absolute bias of the model in the later months of the season, particularly for the AQS sites in IL and WI.

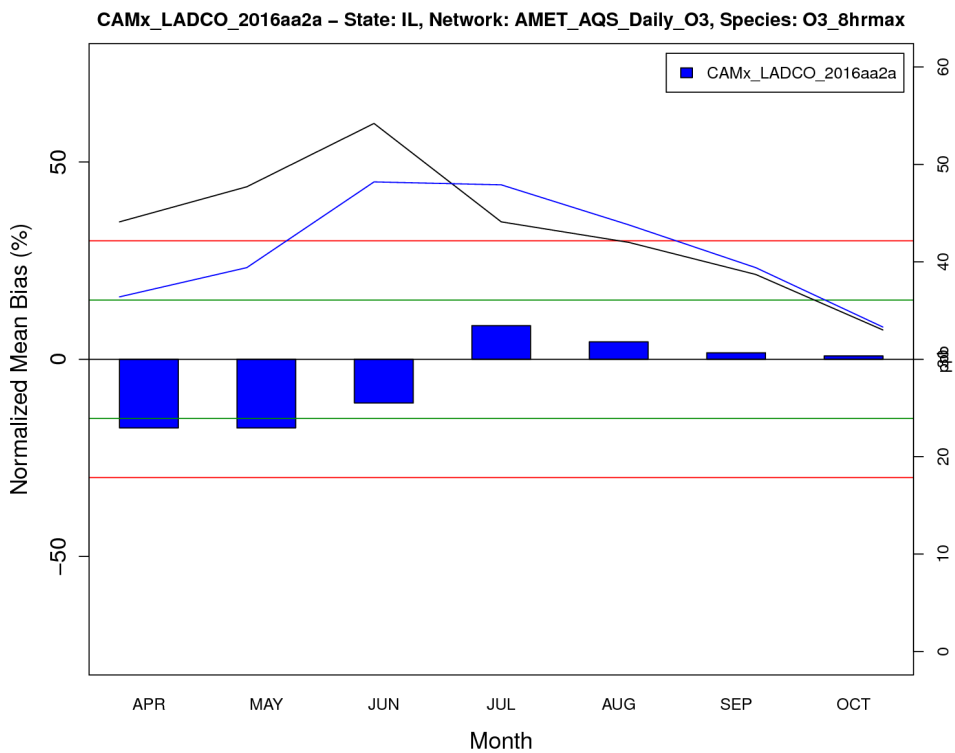

Figure 27. MDA8 O_3 monthly concentration-bias plot for IL AQS sites. Bars plot the average monthly normalized mean bias (left axis), lines are observed (black) and modeled (blue) monthly mean MDA8 O3 concentrations (right axis).

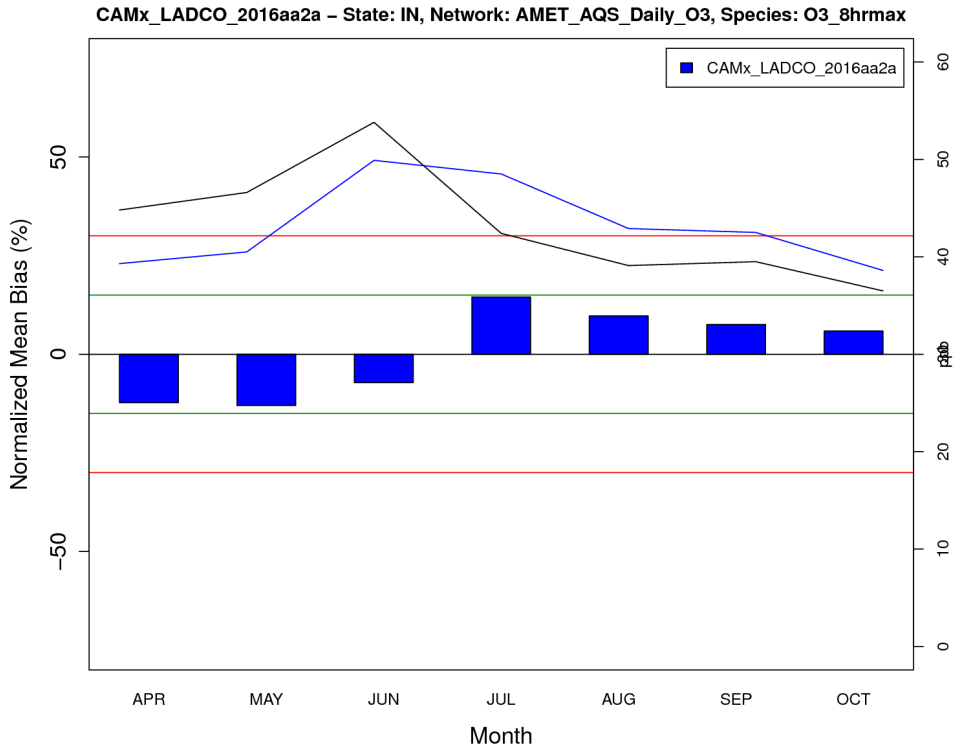

Figure 28. MDA8 O_3 monthly concentration-bias plot for IN AQS sites. Bars plot the average monthly normalized mean bias (left axis), lines are observed (black) and modeled (blue) monthly mean MDA8 O3 concentrations (right axis).

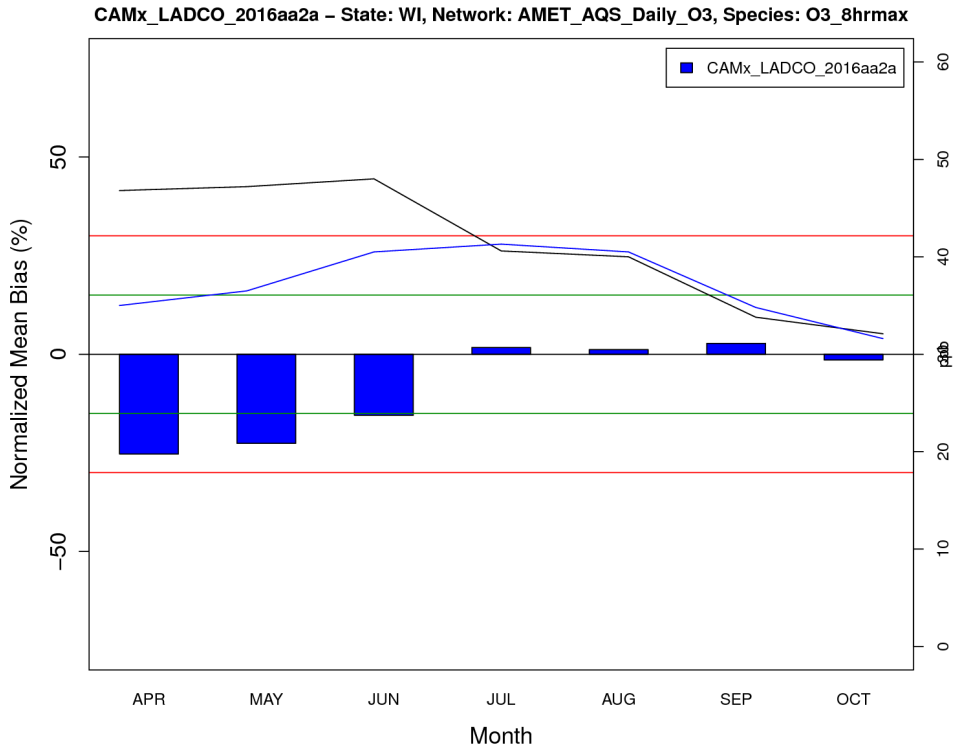

Figure 29. MDA8 O_3 monthly concentration-bias plot for WI AQS sites. Bars plot the average monthly normalized mean bias (left axis), lines are observed (black) and modeled (blue) monthly mean MDA8 O3 concentrations (right axis).

The Appendix of this document includes MDA8 O_3 time series plots for key sites in the Chicago O_3 NAAs. These plots compare the observed MDA8 O_3 concentrations to the CAMx 2016 and 2020 MDA8 O_3 predictions. Each plot shows the concentration comparisons in a top panel and a time series of the model bias in a bottom panel. The green line on the plots is the 2008 O_3 NAAQS (75 ppb).

6.2 CAMx Model Performance Discussion

U.S. EPA (2019) reported model performance for the 2016 CAMx modeling platform upon which we based the LADCO 2016 modeling platform. The U.S. EPA evaluated the model by comparing CAMx-predicted MDA8 O_3 to observations at the U.S. EPA AQS and CASTNet networks. They performed statistical evaluations using modeled and observed

data that were paired in space and time. U.S. EPA developed statistics across spatial and temporal scales and in aggregate across multiple sites by climate region.

The results provided by U.S. EPA from their operational model performance evaluation (MPE) of their 2016 simulation are very similar to the results of the LADCO MPE. U.S. EPA and LADCO both found that the 2016 CAMx modeling platform on average underpredicts April – June MDA8 O_3 and overpredicts July – October MDA8 O_3. The biases in the April – June period are more severe than in the later months. In July – October the mean bias is within +/- 5 ppb at many sites in the LADCO region.

Investigation of the diurnal variability at key monitors demonstrated that CAMx generally captured day to day fluctuations in observed MDA8 O_3 but missed the peaks on many of the highest observed days, particularly during April – June. Figure 36 through Figure 40 compare daily AQS observations of MDA8 O_3 to the LADCO 2016 and 2020 CAMx simulations at monitors in the Chicago NAA.

Despite persistent deficiencies in model performance on days when the observed MDA8 $O_3 \geqq 60$ ppb, the statistics in

Table 18 shows that CAMx performance was still within acceptable model performance criteria at key controlling sites within the Chicago NAA.

Table 18. LADCO CAMx April – September 2016 MDA8 O_3 model performance statistics at key monitors where observations >= 60 ppb

Site_ID	County, ST	Mean Obs	Mean Mod	MB (ppb)	ME (ppb)
170314201	Cook, IL	68.9	59.0	-9.8	11.4
170317002	Cook, IL	68.2	60.9	-7.3	9.2
170971007	Lake, IL	68.2	61.3	-6.9	11.1
550590019	Kenosha, WI	70.3	54.3	-16.0	17.2
550590025	Kenosha, WI	68.0	58.6	-9.4	10.4

6.3 LADCO 2020 Air Quality Projections

LADCO modified the emissions in the U.S. EPA 2016fg CAMx modeling platform to create a LADCO 2016 modeling platform with a projection year to 2020 (see Section 4.1). The LADCO 2020 simulation forecasted air quality for the continental U.S. using the best available information for North American emissions, including EGU emissions forecasts from the ERTAC v16.1 model. Figure 30 and Figure 31 show the O_3 season (April through October) maximum of MDA8 O_3 for the LADCO 2016 and 2020 CAMx simulations, respectively on the CONUS12 modeling domain. Figure 32 shows the difference in O_3 season maximum (2020-2016) between the two simulations. Cool colors indicate that the 2020 simulation forecasted lower O_3 than the 2016 simulation; warm colors indicate higher O_3 in the 2020 forecast. The 2020 CAMx simulation predicted lower seasonal maximum O_3 concentrations across the majority of the modeling domain with the largest reductions occurring in the southeast U.S., east Texas, and the Central Valley of California. Figure 33 zooms into the Lake Michigan area of the difference plot to highlight the predicted changes in O_3 season maximum MDA8 O_3 concentrations. This figure shows that in 2020 CAMx predicts that the seasonal maximum MDA8 O_3 concentrations will decline along the western Lake Michigan shoreline in the range of 1-5 ppb. Note that the trends shown in these figures mask finer temporal resolution features (i.e., hourly and daily) that also exist between the base and future year simulations.

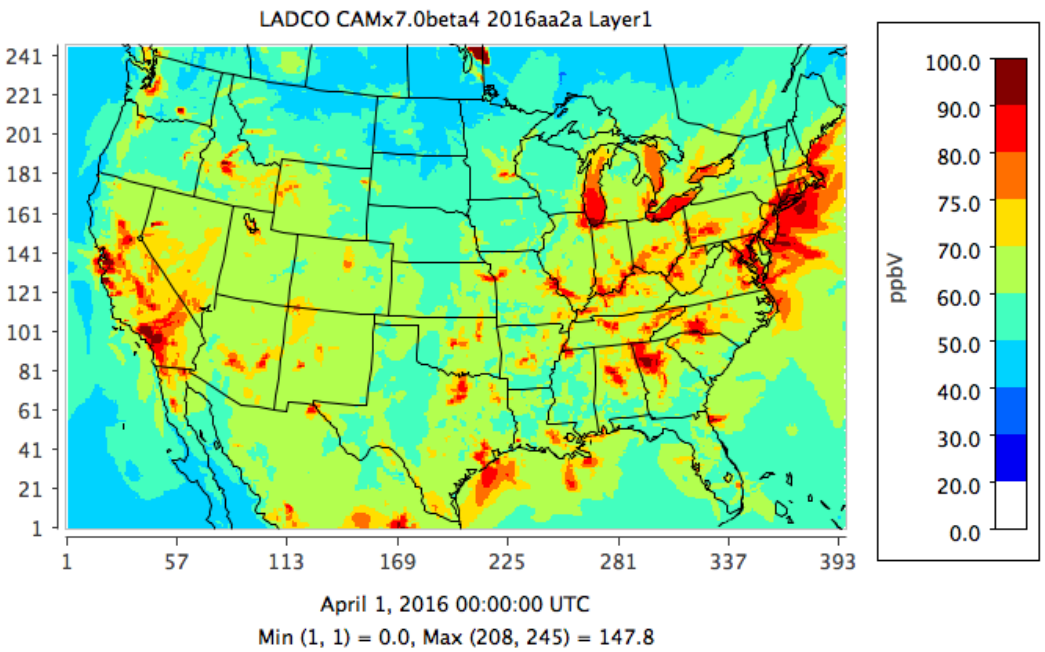

Figure 30. LADCO CAMx 2016aa2a O_3 season maximum MDA8 O_3 concentrations

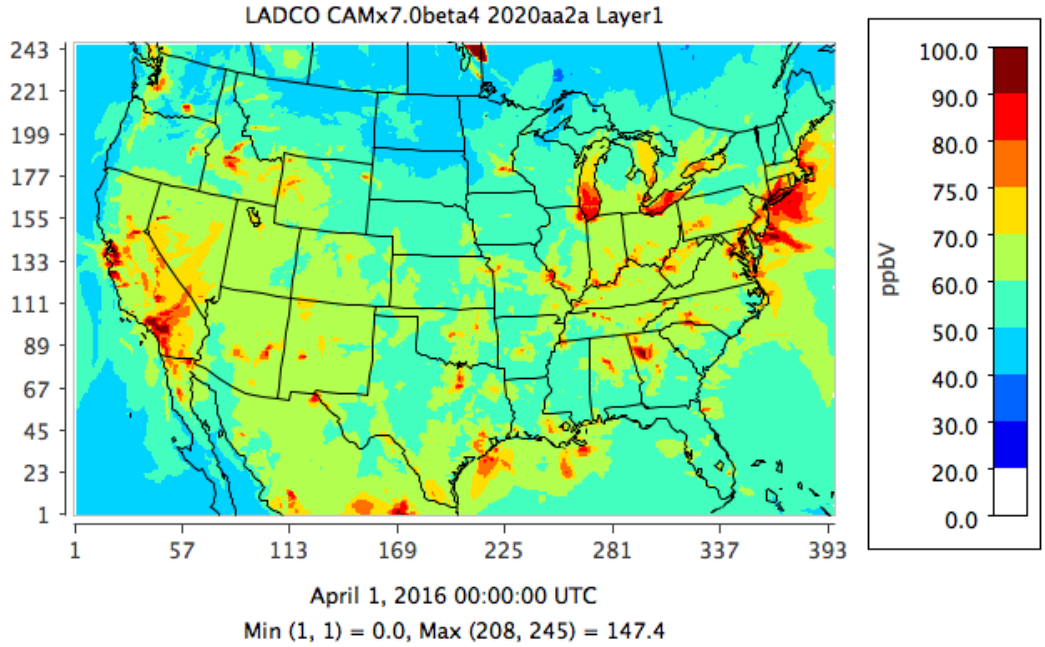

Figure 31. LADCO CAMx 2020aa2a O_3 season maximum MDA8 O_3 concentrations

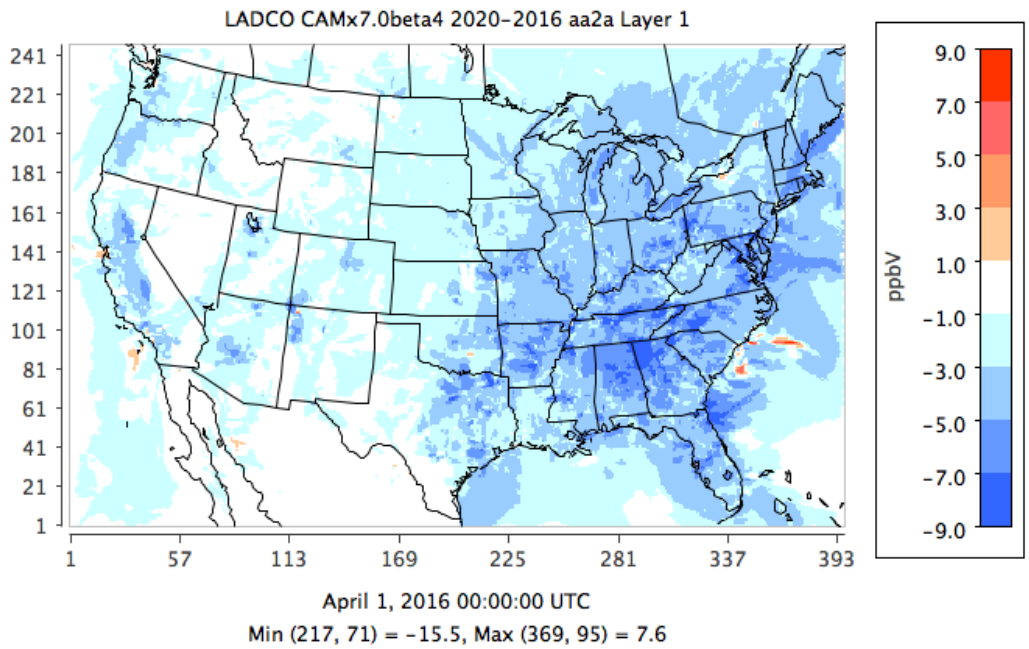

Figure 32. LADCO CAMx difference (2020-2016) in O_3 season maximum MDA8 O_3 concentrations

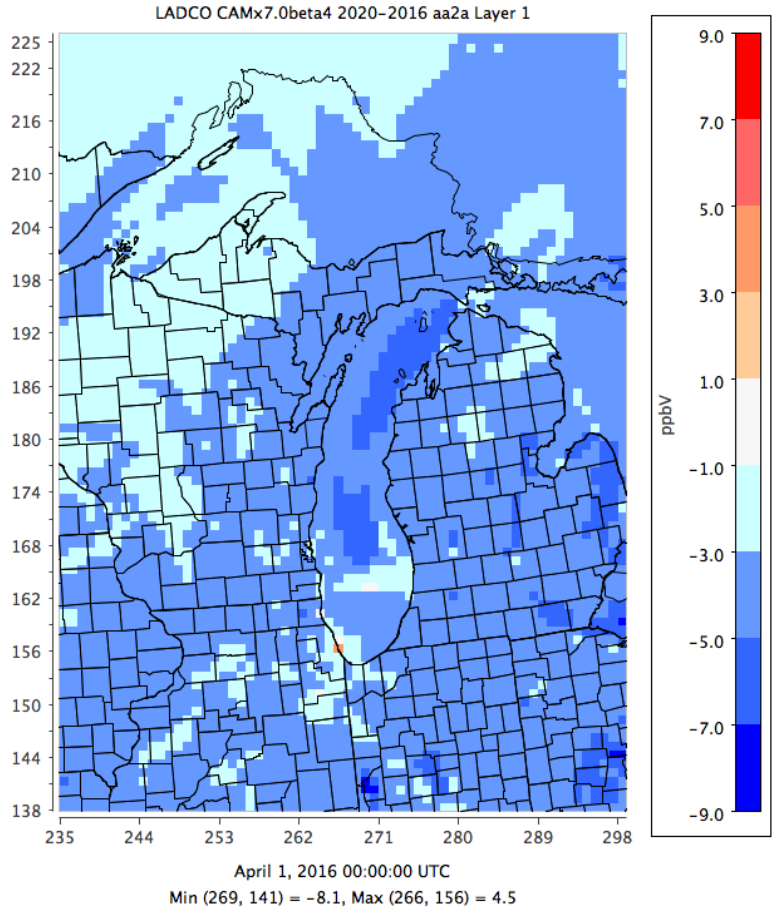

Figure 33. LADCO CAMx difference (2020-2016) in O_3 season maximum MDA8 O_3

concentrations; zoom to the Lake Michigan area

Figure 34 and Figure 35 show the O_3 DV_{2020} and RRFs from the LADCO 2020 simulation, respectively. LADCO generated these results with SMAT-CE using the standard U.S. EPA attainment test configuration (top 10 modeled days, 3x3 cell matrix around the monitor, including water cells). The LADCO O_3 DVs_{2020} presented here used observational data completeness criteria based on the 2015 O_3 NAAQS. The completeness criteria are tied to the level of the standard in cases in which the number of valid observations falls below a statutory threshold but when at least one of the valid observations is greater than the NAAQS (see 40 CFR Part 50 Appendix U, Section 3(d)). By using the 2015 O_3 NAAQS for determining completeness, LADCO includes more available data points in the DV calculations than if we had used the 2008 O_3 NAAQS completeness criteria because the lower standard is more inclusive of the available monitoring data (i.e., there are more MDA8 O_3 observations >= 70 ppb than there are observations >= 75 ppb).

The LADCO 2020 CAMx simulation predicts that no monitor in the region will have an average DV_{2020} that exceeds the 2008 O_3 NAAQS. The RRF plot indicates that most of the DV decreases in the Chicago NAA are in the range of 4-5%. The modest changes to the DVs in 2020 are due primarily to the short time period between the base and future years.

Table 19 presents the average and maximum DVs_{2020} for key monitors in the Chicago 2008 O_3 NAAQS NAA. As of September 30, 2020, the Chicago NAA has one monitor (Northbrook, IL) that is in violation of the 2008 O3 NAAQS.

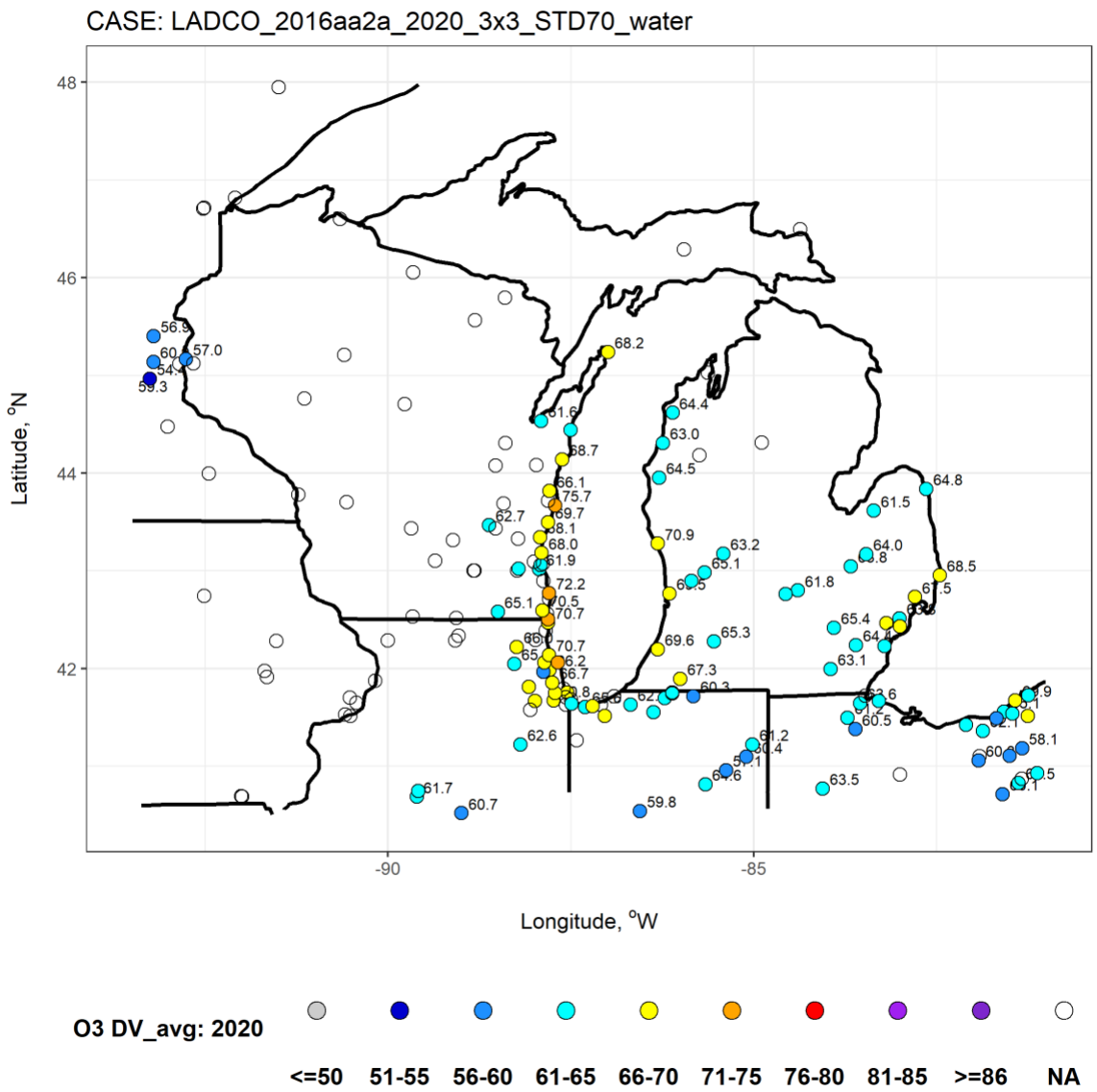

Figure 34. Future year O_3 design values calculated with WATER from the LADCO 2020 CAMx simulation.

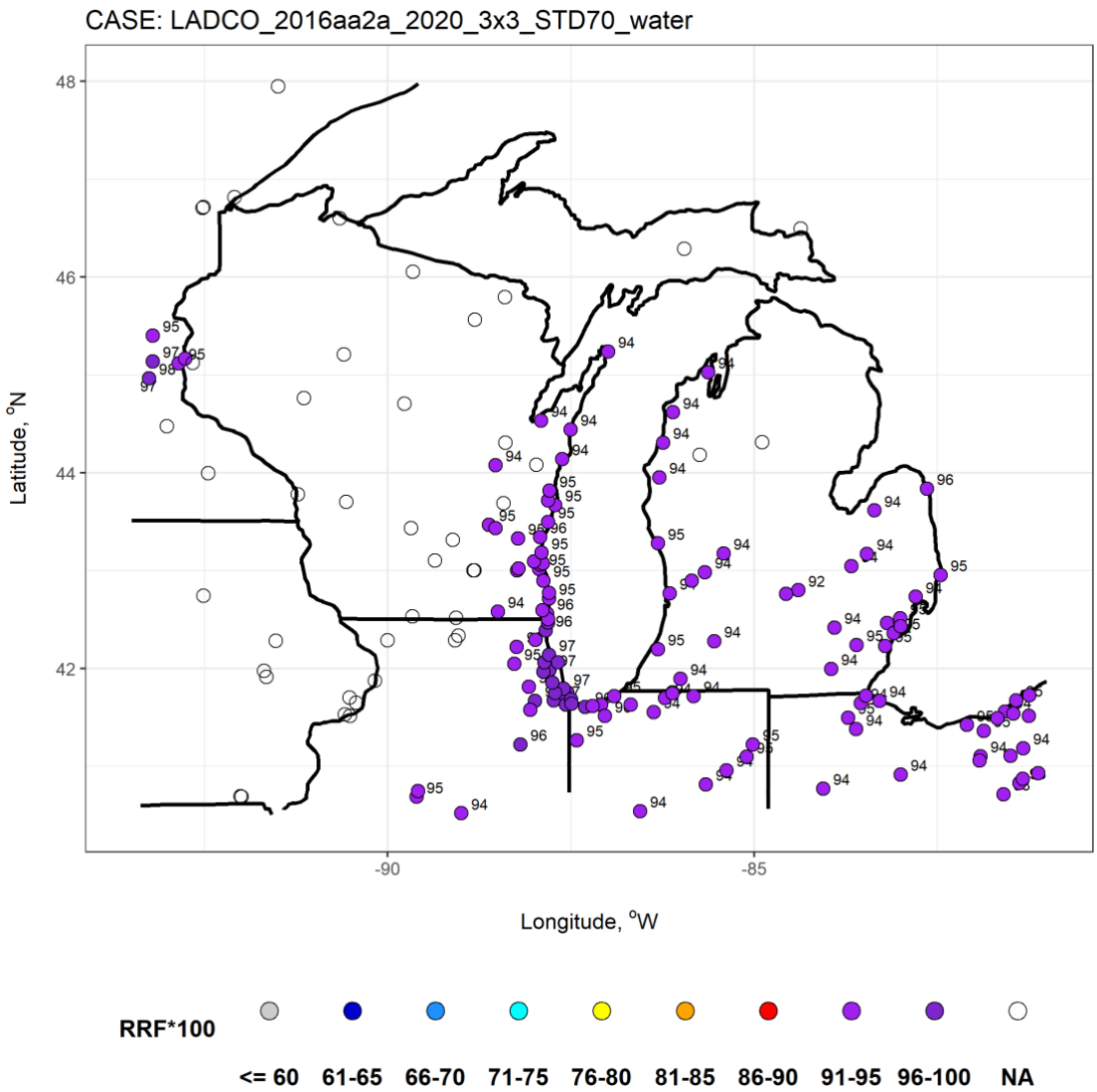

Figure 35. Future year O_3 relative response factors calculated with WATER from the LADCO 2020 CAMx simulation.

Table 19. LADCO 2020 O_3 design values with WATER at key monitors in the Chicago 2008 O_3 NAAQS NAAs

AQS ID	Monitor	ST	LADCO 2020 DVF	2014-2018 DVB	2017-2019 DV	2018-2020 DV*
170310001	Alsip	IL	70	73	75	75
170310032	South Water Filtration Plan	IL	70	72	73	74
170314201	Northbrook	IL	70	73	75	77
170317002	Evanston	IL	71	74	75	75
170971007	Zion	IL	70	73	71	72
550590019	Chiwaukee Prairie	WI	74	78	75	74
550590025	Kenosha Water Tower	WI	70	73	74	74

* Unofficial, as of September 30, 2020

6.3.1 Impacts of Water Cells on Design Values

Confidence in the ability of photochemical models to accurately estimate O_3 over water is a persistent concern with the use of the models for air quality planning. This concern recently prompted measurement campaigns in the Eastern U.S. to address the issue (see the 2017 Lake Michigan Ozone Study, Long Island Sound Tropospheric Ozone Study, and OWLETS). The meteorology and chemistry processes in model grid cells that are dominated by water (> 50% landuse area) are a challenge to simulate because the conventional technical formulations of the models were not optimized for water cells. Even with the introduction of new algorithms to simulate the dynamical and chemical features of water cells, a lack of over-water observations hinders our ability to verify the accuracy of the models in simulating these conditions.

In consideration that the models may not perform well in simulating water cells, EPA and others have presented alterative DVF calculation approaches that exclude water cells. Although not explicitly listed in Attachment A of the EPA's March 2018 memo on O_3 Transport Modeling as a flexibility to consider in developing a Good Neighbor SIP, the EPA used the exclusion of water cells in their own DVF calculations (US EPA, 2017; US

EPA, 2018b). Per EPA (2018, pg. 109), when appropriate there may be cases where certain cells along the periphery of the 3 x 3 array have different modeled responses than what would be expected at the monitor location at the center of array due to a specific local topographic or geographical feature (e.g., a large water body or a significant elevation change). A potential example of this situation would be an array where several cells are over water and where the meteorological conditions and relevant emissions sources differ substantially from the land-based monitor location. Again, in these types of cases and with appropriate justification, air agencies could consider removing the unrepresentative cells from the calculation.

Factoring in the impact of water cells on the DV calculation does not require additional CAMx simulations. It is implemented through a postprocessing sequence per U.S. EPA (2018b) in which model grid cells that are dominated by water (> 50% landuse area) are removed from the 3x3 matrix in the RRF and DVF calculation. One important modification to this process is to override the exclusion condition for cells that contain monitors; in other words, grid cells that contain monitors will be included in the 3x3 matrix regardless of the amount of water coverage in the cell.

Table 20 and Table 21 present the impacts of excluding water cells from the DV_{2020} calculations for the LADCO 2020 CAMx simulation. Excluding water cells in the attainment test calculation has different impacts on the DVs_{2020} for the lakeshore monitors in the LADCO region. The South Water Filtration Plant and Northbrook DVs_{2020} increase if water cells are excluded from the attainment test; the Evanston, Zion, Chiwaukee Prairie, and Kenosha Water Tower DVs_{2020} decrease.

Table 20. LADCO 2020 O_3 design values with NO WATER at key monitors in the Chicago 2008 O_3 NAAQS NAA

AQS ID	Monitor ID	ST	LADCO 2020		2014-2018		2017-2019 DV
			3x3 avrg	3x3 max	3x3 avrg	3x3 max	
170310001	Alsip	IL	70.8	74.6	73.0	77.0	75
170310032	South Water Filtration Plant	IL	70.7	73.4	72.3	75.0	73
170314201	Northbrook	IL	70.8	74.3	73.3	77.0	75
170317002	Evanston	IL	71.3	74.2	74.0	77.0	75
170971007	Zion	IL	70.1	71.4	73.7	75.0	71
550590019	Chiwaukee Prairie	WI	74.2	75.2	78.0	79.0	75
550590025	Kenosha Water Tower	WI	70.1	73.2	73.7	77.0	74

Table 21. Comparison of LADCO 2020 O_3 design values at key monitors in the Chicago 2008 O_3 NAAQS NAA with and without water cells included in the DV calculation

AQS ID	Monitor ID	ST	Water	No Water
			2020 DV	2020DV
170310001	Alsip	IL	70.8	70.8
170310032	South Water Filtration Plant	IL	70.1	70.7
170314201	Northbrook	IL	70.7	70.8
170317002	Evanston	IL	71.6	71.3
170971007	Zion	IL	70.7	70.1
550590019	Chiwaukee Prairie	WI	74.5	74.2
550590025	Kenosha Water Tower	WI	70.5	70.1

7 Conclusions and Significant Findings

LADCO presents in this TSD a regional air quality modeling platform for quantifying and evaluating future year O_3 concentrations pursuant to testing attainment of the 2008 O_3 NAAQS serious designations for the Chicago NAA. After establishing that the LADCO 2016-based modeling platform is an acceptable tool for simulating regional O_3 concentrations, we presented the results from projections of future O_3 concentrations and for calculating DVs_{2020}. A summary of the significant findings from the LADCO modeling follows.

- Finding 1: While the 2016 CAMx modeling platform has an underprediction bias for high O_3 concentrations, the platform skill is consistent with the U.S. EPA 2016 modeling platform used to support recent air quality analyses.
- Finding 2: The LADCO 2020 CAMx simulation predicts that no monitor in the LADCO region will have an average DV_{2020} that exceeds the 2008 O_3 NAAQS.
- Finding 3: Excluding water cells in the attainment test calculation results in both higher and lower DVs_{2020} for the lakeshore monitors in the LADCO region.

As with all regional air quality modeling applications, there are uncertainties in the model inputs and in the model formulation that produce biases in the results presented here. LADCO determined that as of the writing of this TSD the EPA 2016fh emissions modeling platform and the ERTAC EGU 16.1 emissions were the best available data for forecasting air quality in 2020.

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Appendix A: Monitor-specific Ozone Timeseries

Additional LADCO CAMx 2016aa2a simulation MPE plots are available on the LADCO website:

https://www.ladco.org/technical/modeling-results/ladco-2016-modeling/#Air_Quality/CAMx_LADCO_2016aa2a_2020

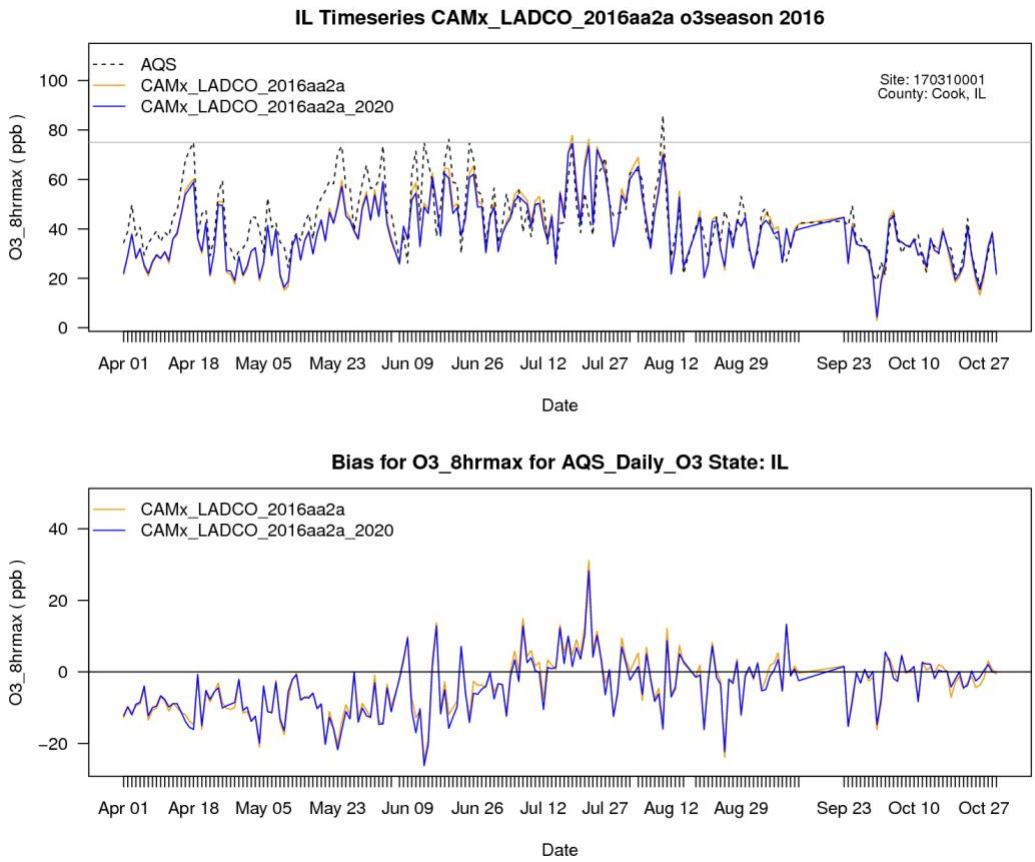

Figure 36. MDA8 O_3 observed, CAMx 2016, and CAMx 2020 concentrations (top) and bias (bottom) at the Alsip, IL monitor

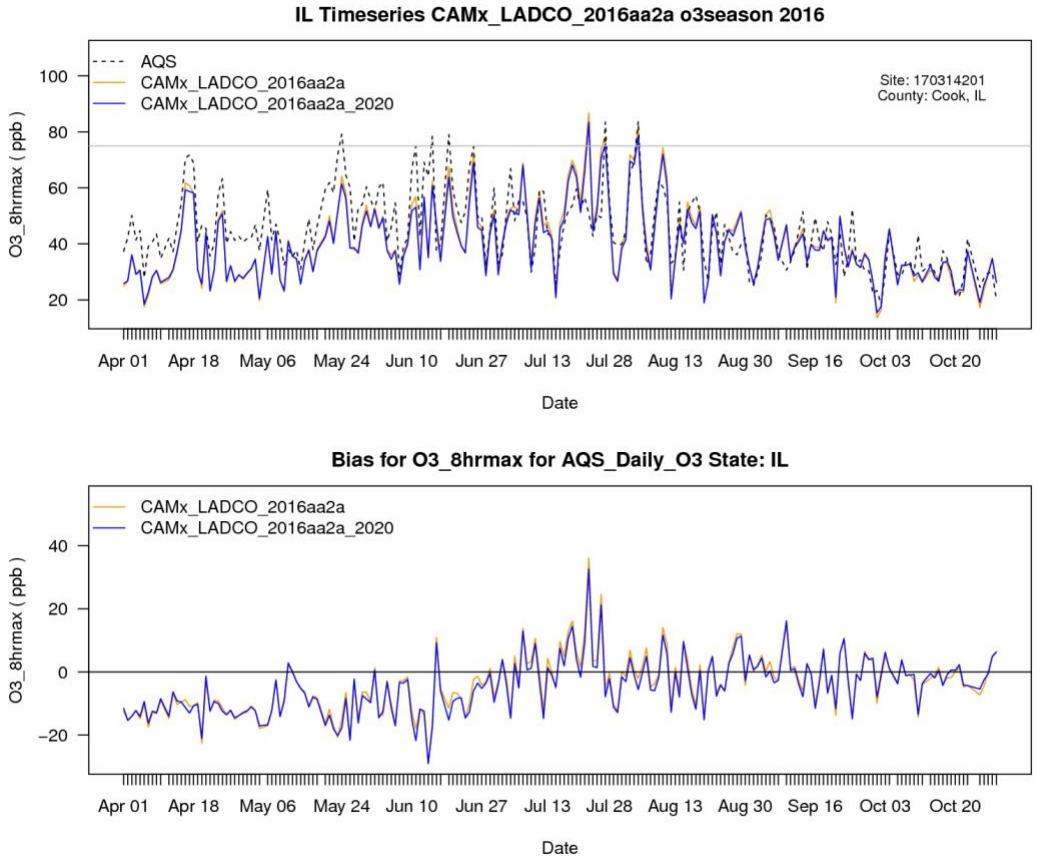

Figure 37. MDA8 O_3 observed, CAMx 2016, and CAMx 2020 concentrations (top) and bias (bottom) at the Northbrook, IL monitor

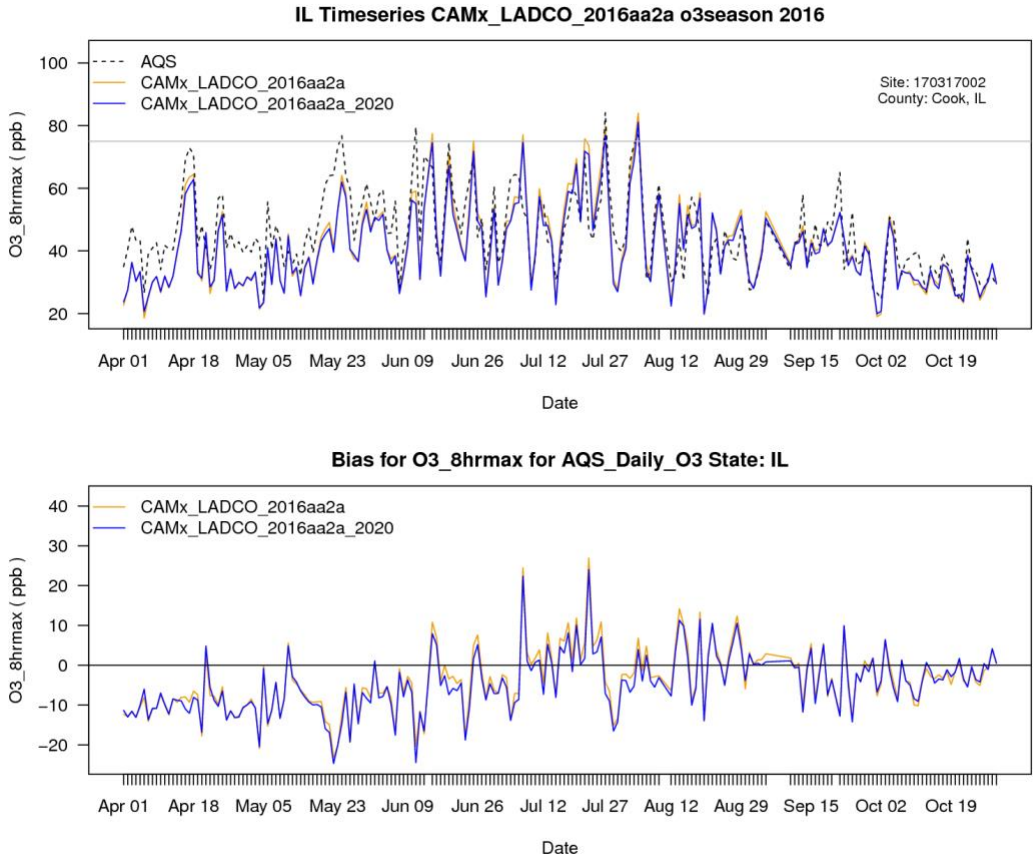

Figure 38. MDA8 O_3 observed, CAMx 2016, and CAMx 2020 concentrations (top) and bias (bottom) at the Evanston, IL monitor

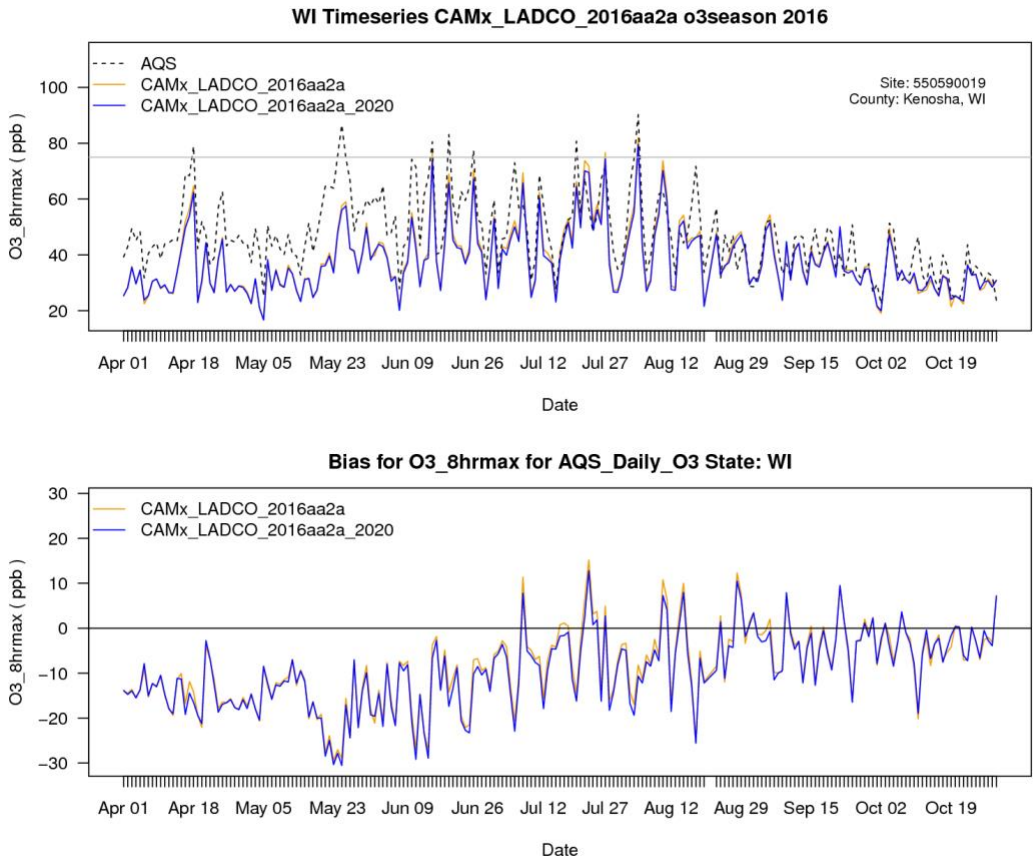

Figure 39. MDA8 O_3 observed, CAMx 2016, and CAMx 2020 concentrations (top) and bias (bottom) at the Chiwaukee Prairie, WI monitor

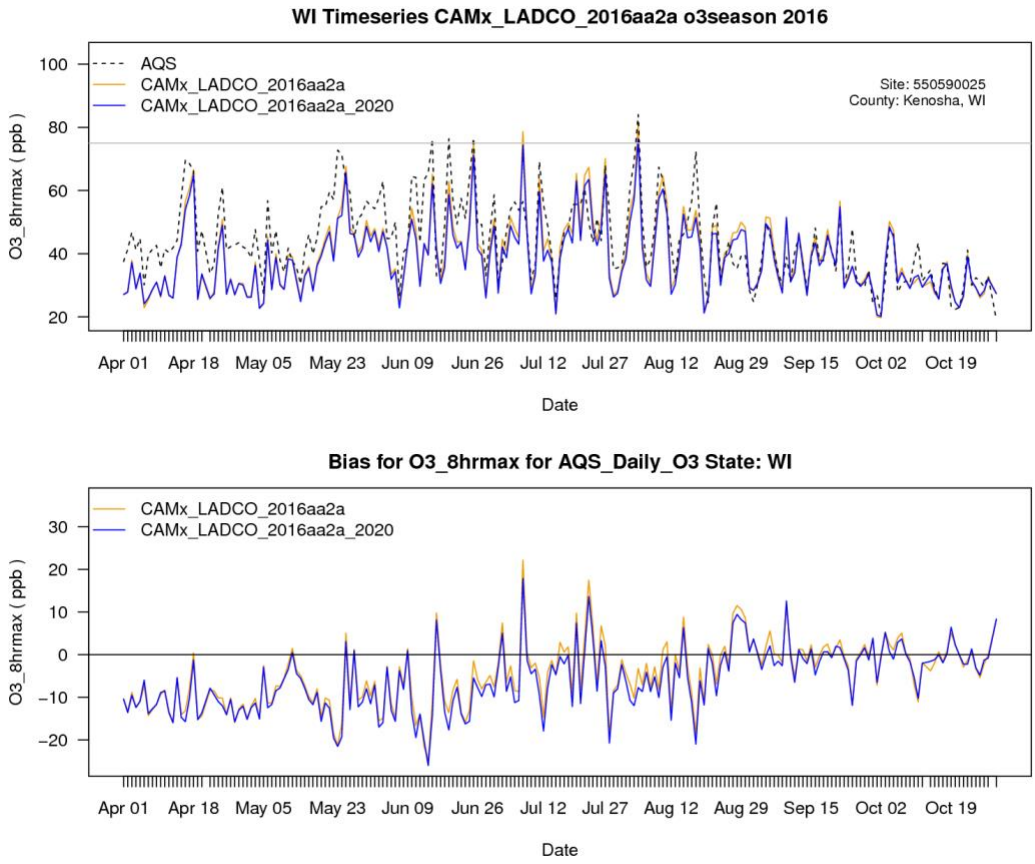

Figure 40. MDA8 O_3 observed, CAMx 2016, and CAMx 2020 concentrations (top) and bias (bottom) at the Kenosha Water Tower, WI monitor

Appendix B: Description of CART Analysis

What is CART Analysis?

- Classification and Regression Tree, aka binary recursive partitioning, decision tree
- Classifies data by yes/no questions -- is temp. < 75, is RH < 80; easy to interpret
- Nonparametric, so insensitive to distributions of variables
- Insensitive to transformations of variables
- Insensitive to outliers and missing data
- Frequently more accurate than parametric models

The beauty of CART is the ease of interpreting the results--you get back a natural-language sequence of questions that anyone can use to classify a new data set You can also adjust the sensitivity of the model to various parameters or outcomes, if it's more important to accurately classify group 1 rather than group 2, for example.

How do you use CART for ozone analysis?

- CART is used to categorize each day by ozone concentration and associated met conditions
- Incorporates 30+ meteorological variables
- Results in a decision tree with 10-15 branches, each describing the meteorological conditions associated with a particular ozone concentration
- Trends are then developed for meteorologically similar days to minimize the effects of meteorological variability on ozone trends

Which meteorology variables were used in the LADCO CART analysis?

These variables were selected from previous model runs that had many more variables included; these are just those that had any influence in previous models:

- Daily precipitation
- Cloud cover

- 850 and 700 mb temperatures at 6 am
- Maximum daily temperature, dew point, relative humidity, pressure
- Average daily wind spee
- Average daily, morning, and afternoon wind direction as N/S and E/W vectors
- Morning, afternoon and evening dewpoint and pressure
- Day of week
- Previous day's average temperature, pressure, wind speed, wind direction
- Change in temperature and pressure from previous day
- 2- and 3-day average wind speed and temperature
- 24-hour transport direction and distance (from Hysplit trajectories)
- Deviation from 10-year averages of 850 and 700 mb temperature and height

Where did the meteorology data come from that were used in the LADCO CART analysis?

- Hourly surface observations from 2379 sites around the US collected from National Climatic Data Center's (NCDC) Integrated Surface Database (mostly airports)
- Upper air observations from 85 sites collected from NCDC's Integrated Global Radiosonde Archive
- Each surface site is paired with closest upper air site (upper air data can be less spatially representative than surface obs)
- Hysplit back trajectories calculated for each site at noon every day to provide transport distance and u,v,w vectors
- Data for each year/site is acquired from NCDC, processed to calculated derived values (daily max/min, mixing heights, e.g.)
- QA flags assigned based on completeness, upper air site proximity
- Lags and deviation from long term means are calculated
- Data are combined and formatted into ASCII and SAS datasets

- Years 2005 to 2018