Updates on Air Quality Planning and Research in the Great Lakes Region

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Isle Royale NP, MI


Boundary Waters Wilderness, MN

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Ozone CART Analysis

2017 4th Highest Daily 8-hour Average Ozone Concentrations

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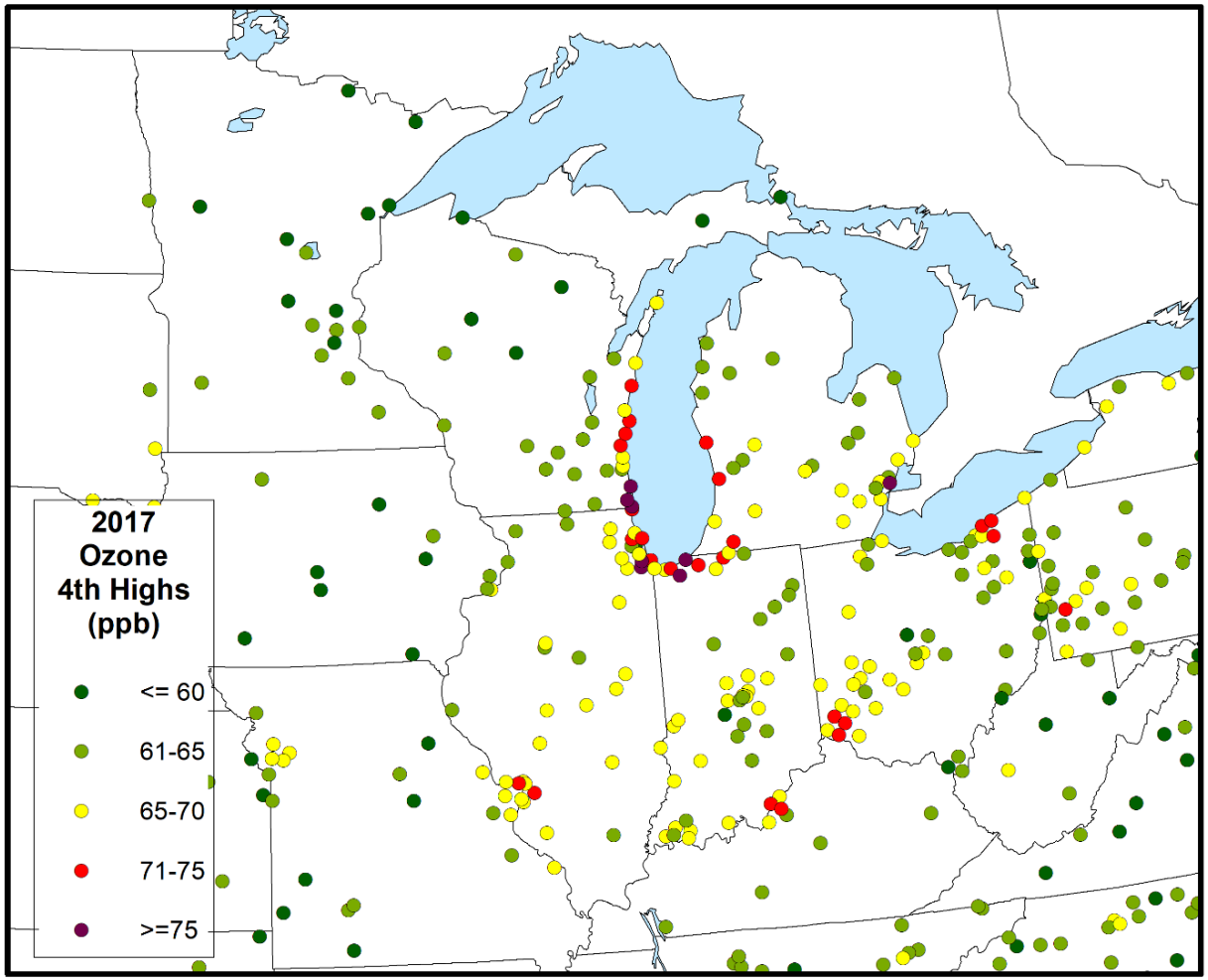

2015-2017 O3 Design Values

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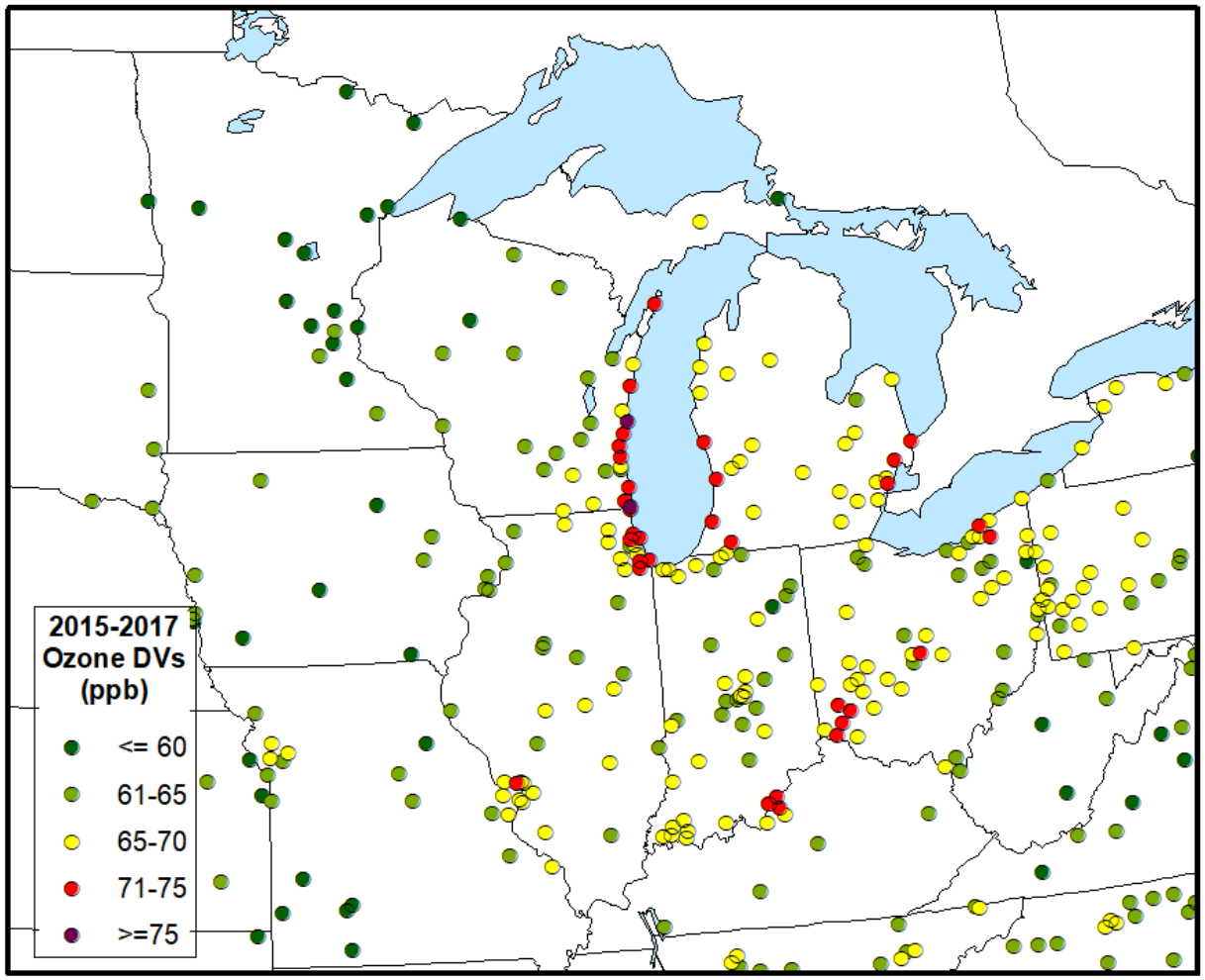

Unadjusted Ozone Trends 2011-2017

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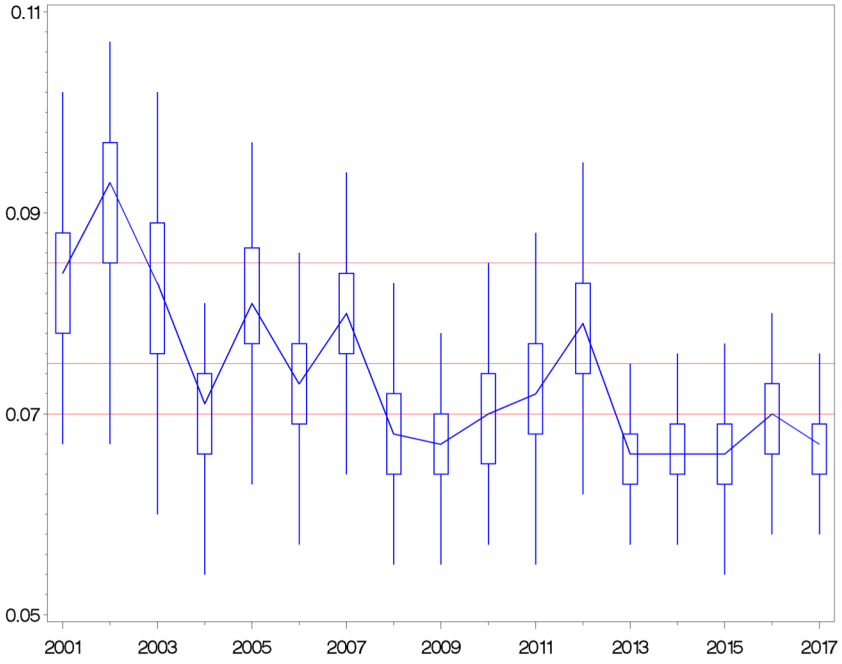
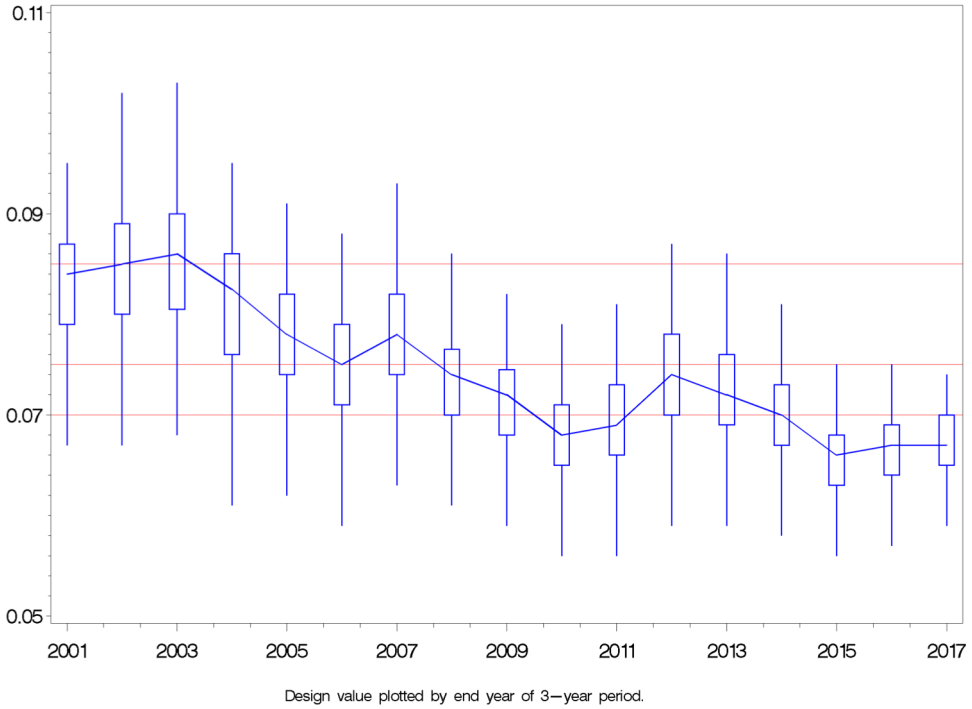
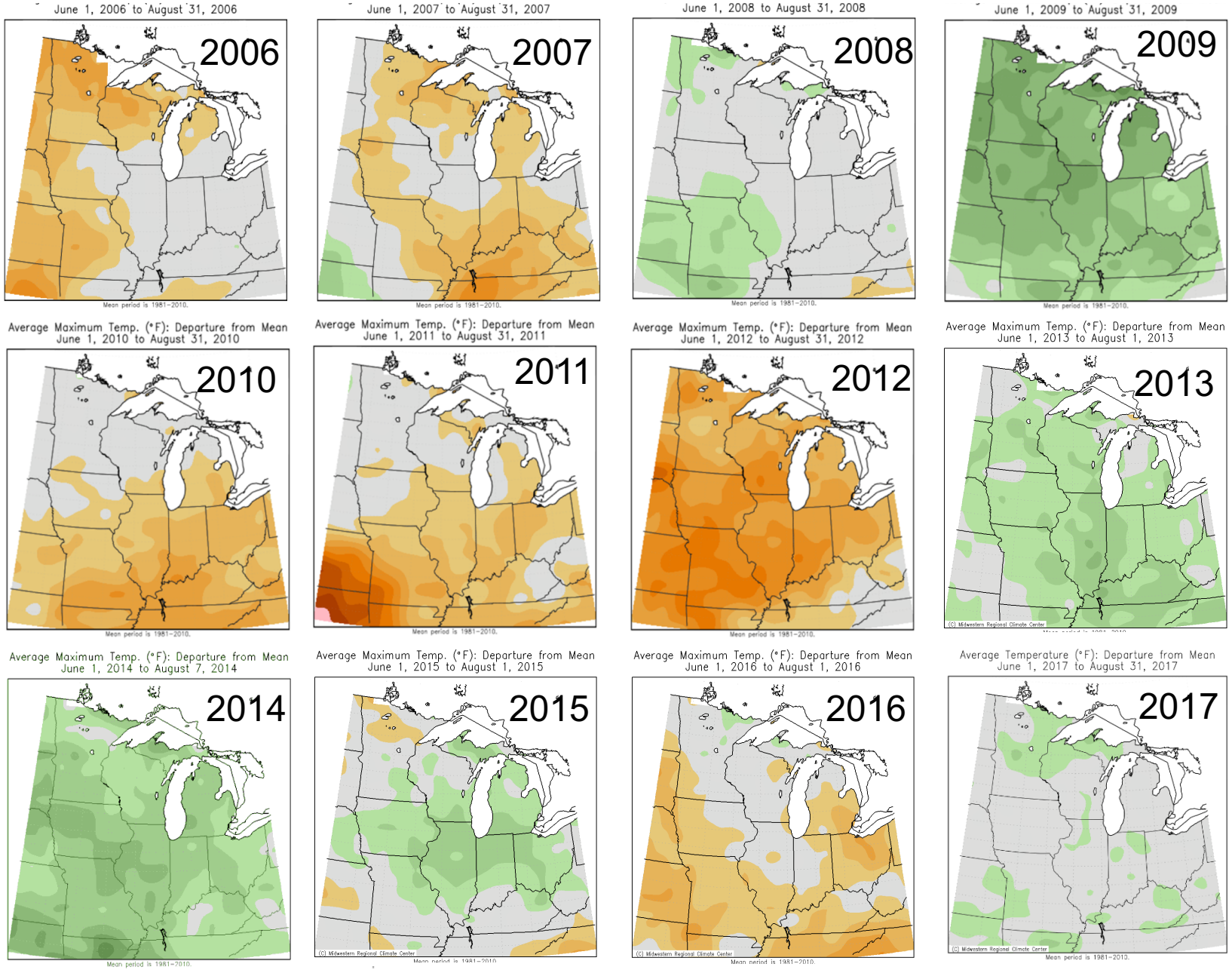
Fourth-High Values



3-year Design Values



Average Maximum Temperature Departure from Mean, Jun-Aug



June-July 2018 Was Warmer Than Average in the LADCO Region

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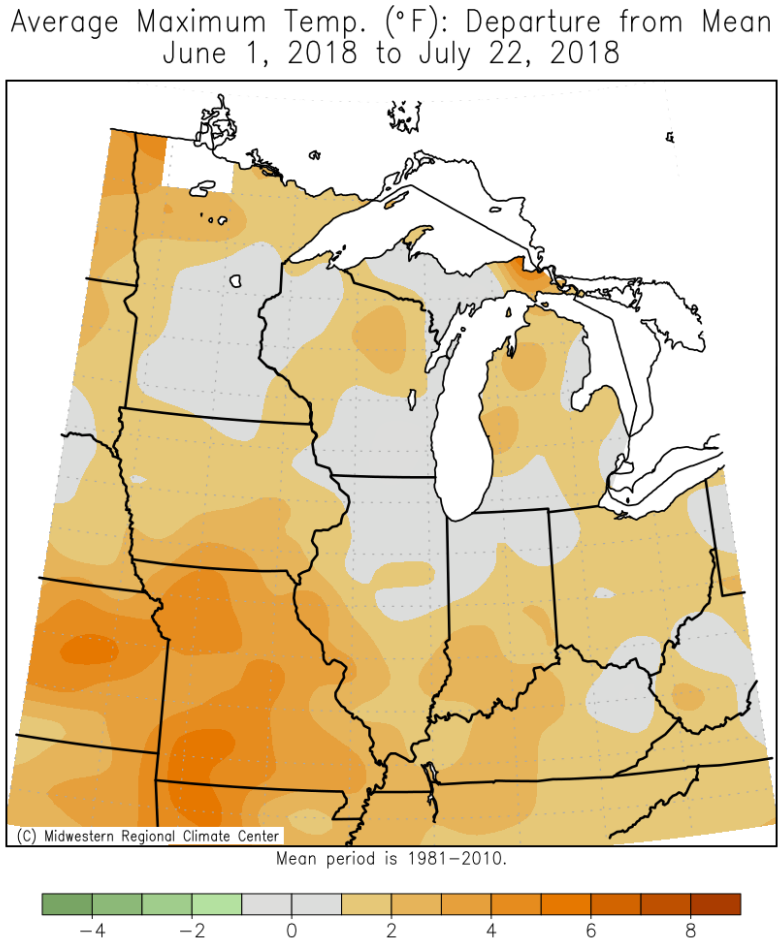

What is CART Analysis?

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- Classification and Regression Tree (CART), 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

Ozone CART Model

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- 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

Sample Tree

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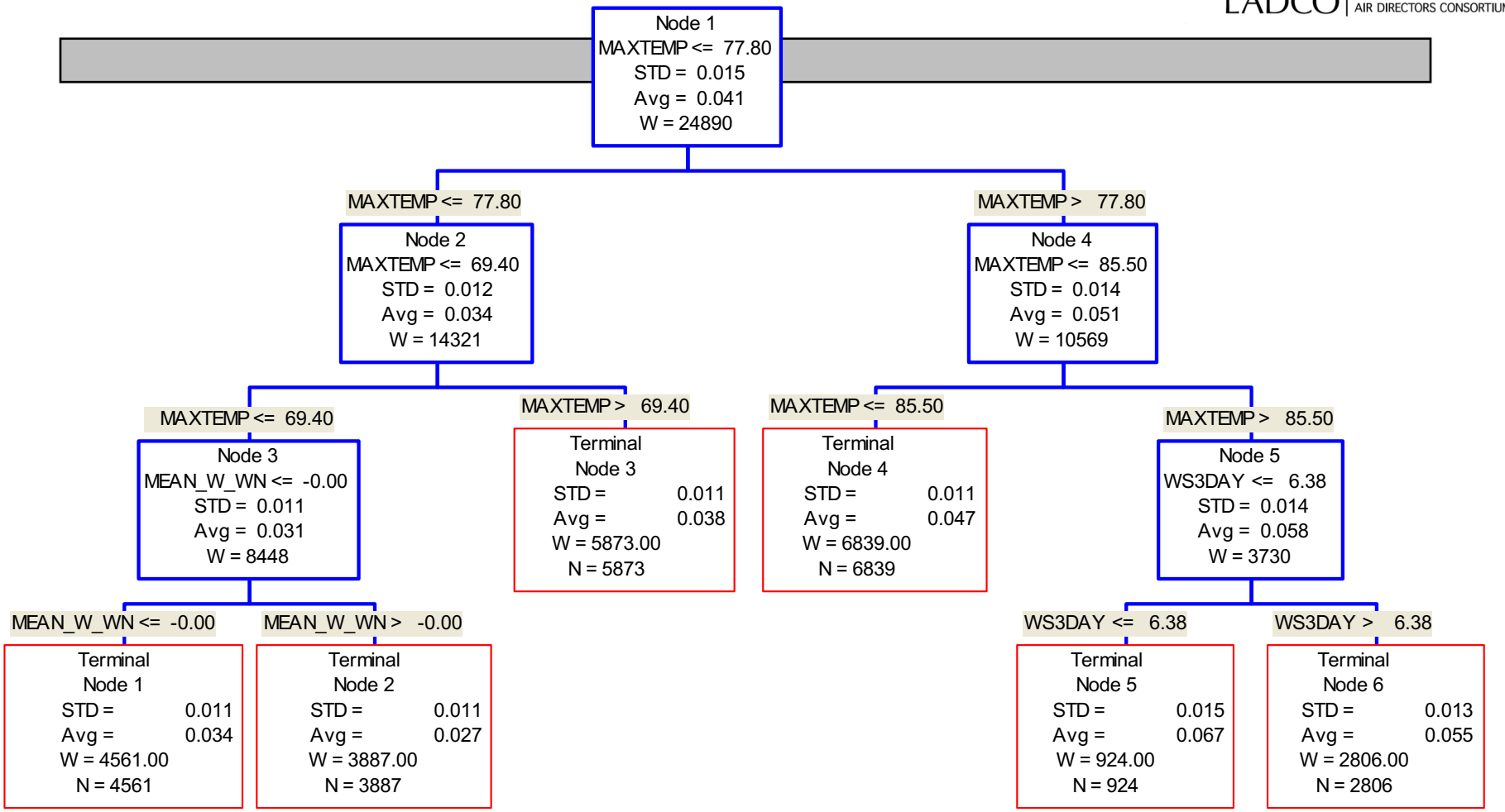

Nodes define a set of days with similar meteorological conditions; looking at trends by node eliminates the effect of changes in meteorology on concentration trends

Meteorological variables

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- 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 speed
  - 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
- Met data comes from National Weather Service data collected at airports; processing done by LADCO, with thanks to EPA and STI

Trend Plot – Detroit area sites

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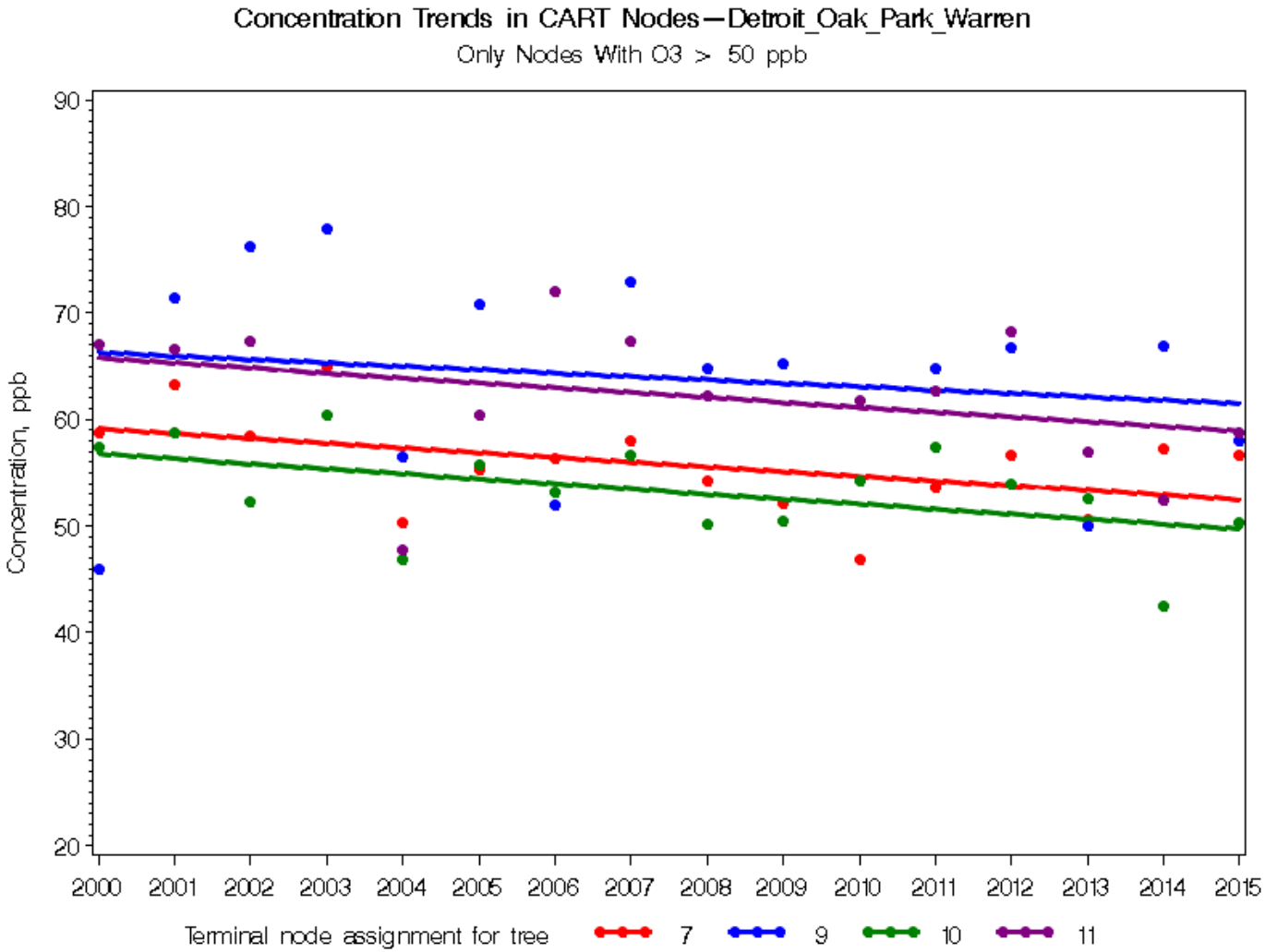

Met Adjusted O3 Trends Lake Michigan Sites

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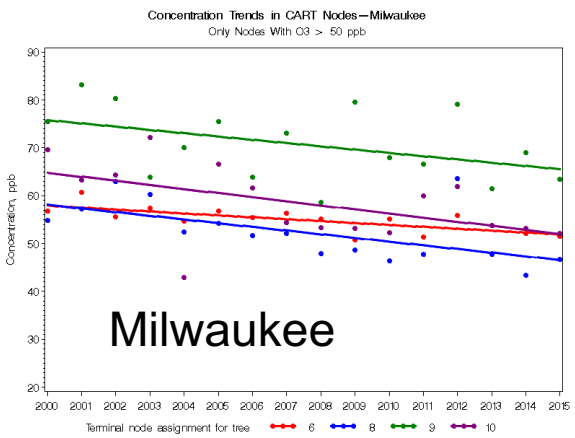

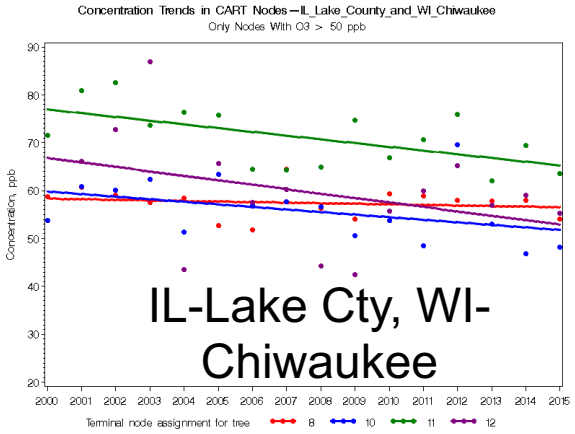

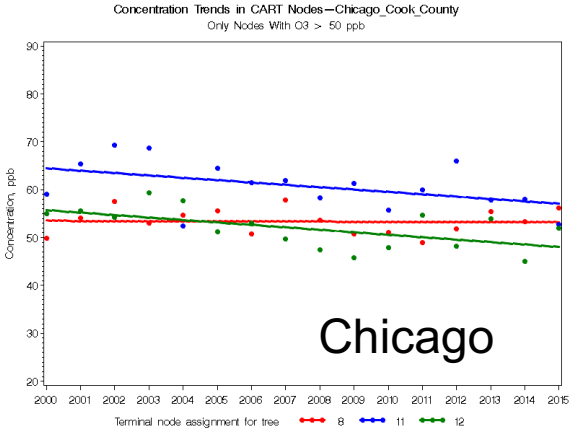

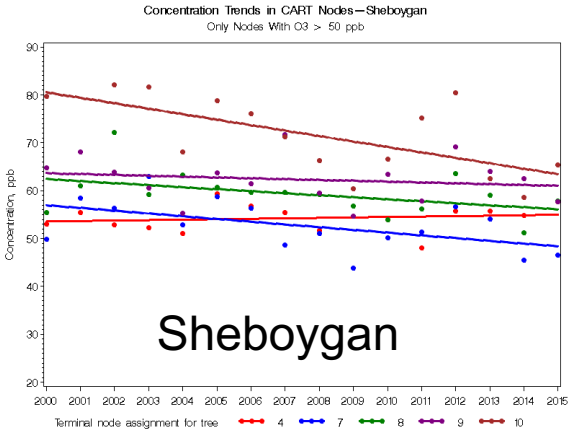

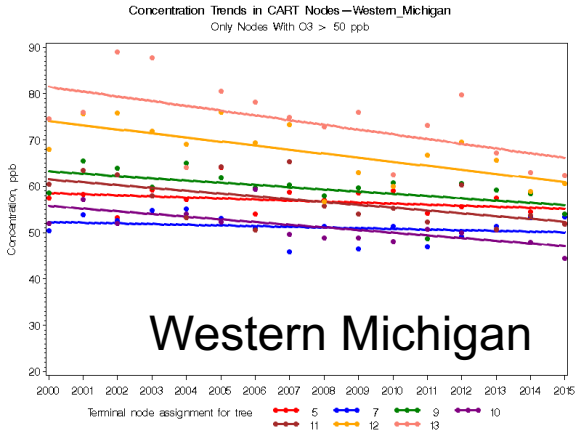

Met Adjusted O3 Trends Eastern/Southern Sites

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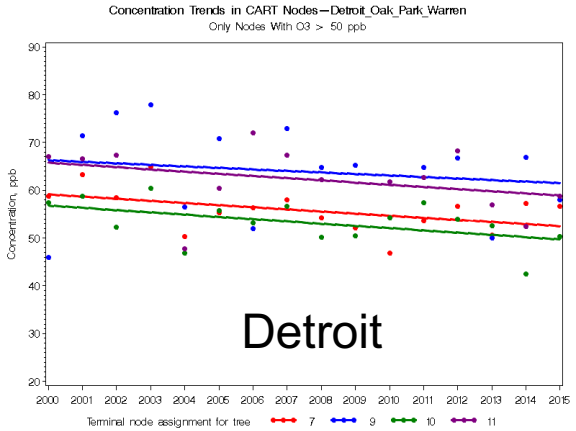

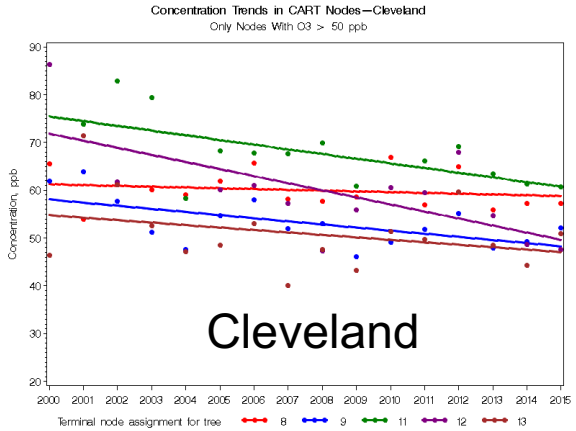

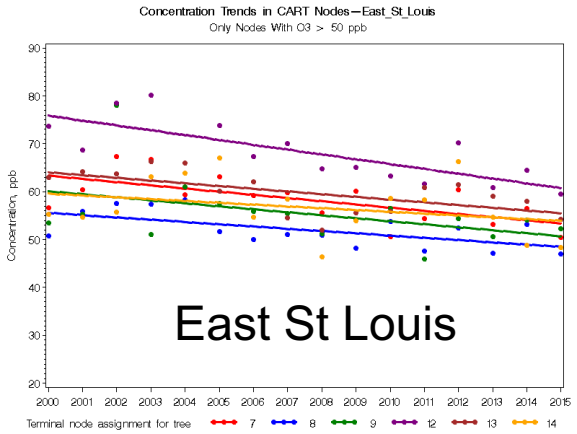

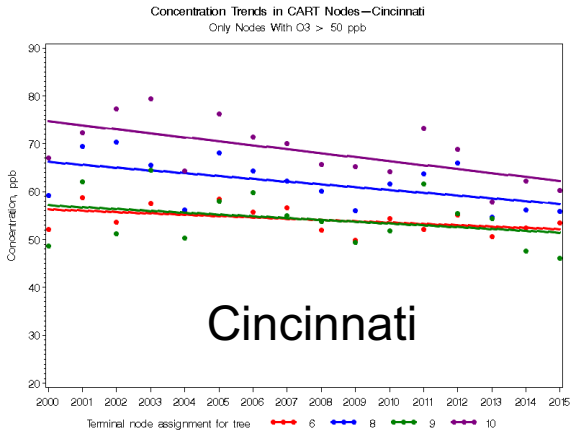

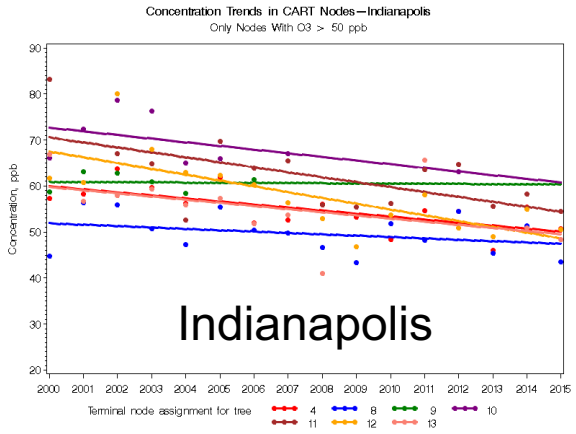

Findings

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- Significant predictors are daily maximum surface temperature, temperature aloft, 2- and 3-day temperature, relative humidity, and 2- and 3-day wind speeds, transport distance
- 2015 data fit well into the 2000-2014 model, especially the high-concentration days
- Trends are slightly to moderately downward in the high concentration nodes (those with average 8-hr concentrations greater than 0.055 ppm)
- Trends are consistent in all 10 areas examined
- Next steps: update for ozone thru 2017

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Update on Air Quality Research and Planning in the LADCO Region

2023 LADCO O3 Transport Modeling TSD

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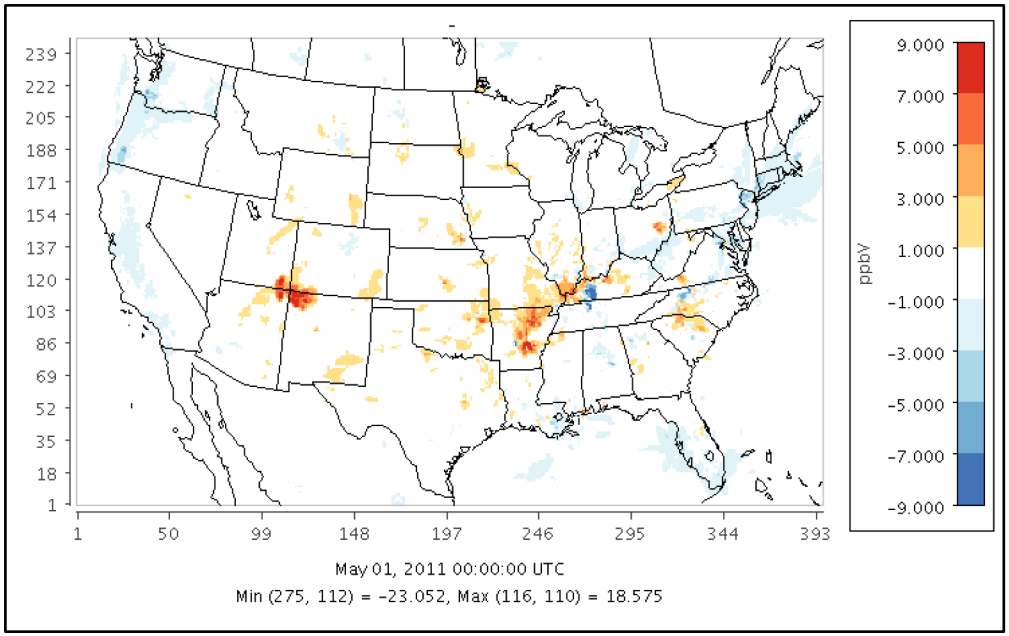
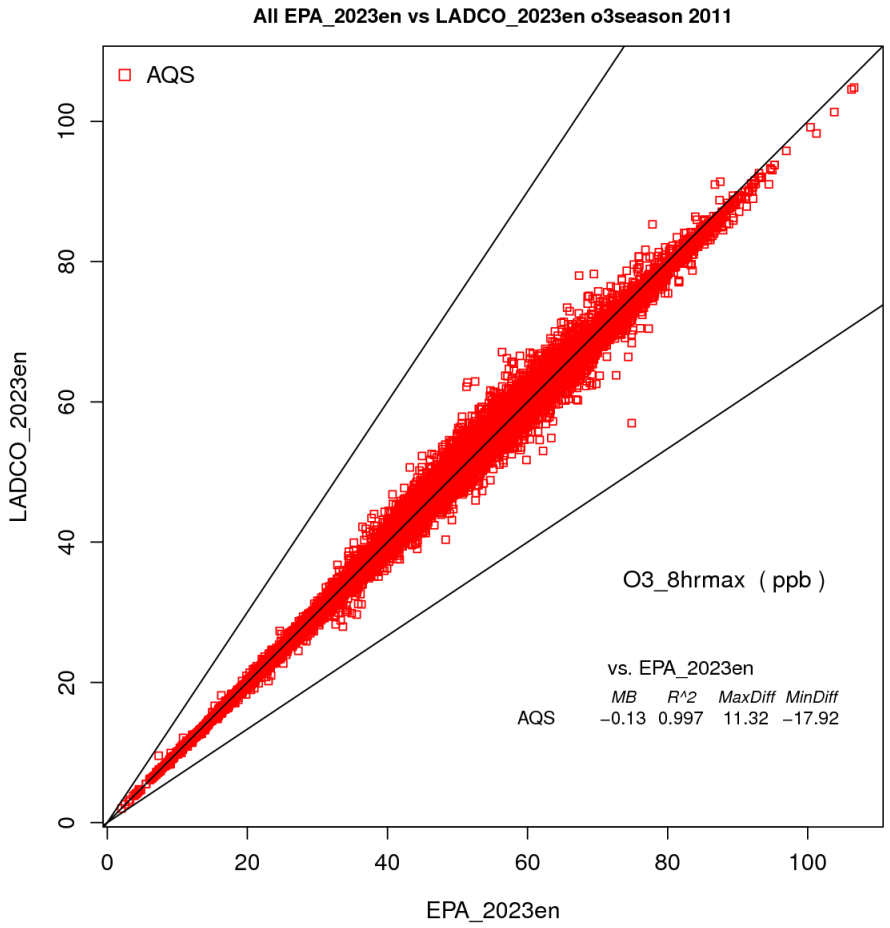
- LADCO reproduced EPA 2011 and 2023 CAMx regional modeling ("EN Platform") as the basis of a transport modeling Technical Support Document (TSD)
- LADCO sensitivity simulation replaced the EPA electricity sector 2023 projections with ERTAC projections
- CAMx used to tag sector and state contributions to 2023 ozone



EPA – LADCO differences in 2023 daily maximum MDA8 O3.

LADCO vs EPA 2023 Forecast



- Simulations are closely correlated ($r^2 = 0.997$)
- LADCO simulation estimates slightly lower O3 across the Great Lakes and Northeast (and Pacific Coast) at AQS sites
- LADCO simulation estimates higher O3 in the 4-corners region and parts of the Southeast

EPA 2023 DVs

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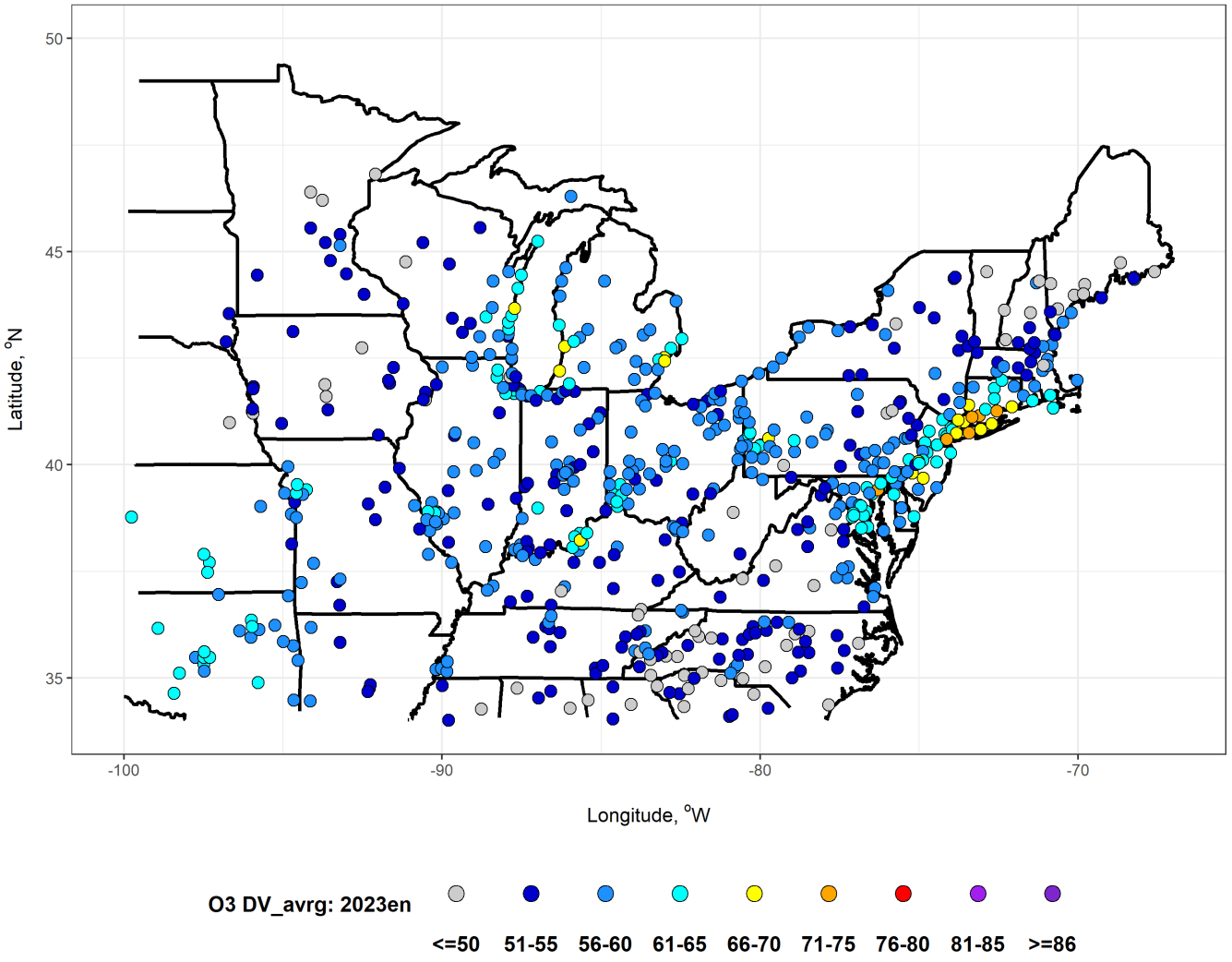

LADCO 2023 DVs

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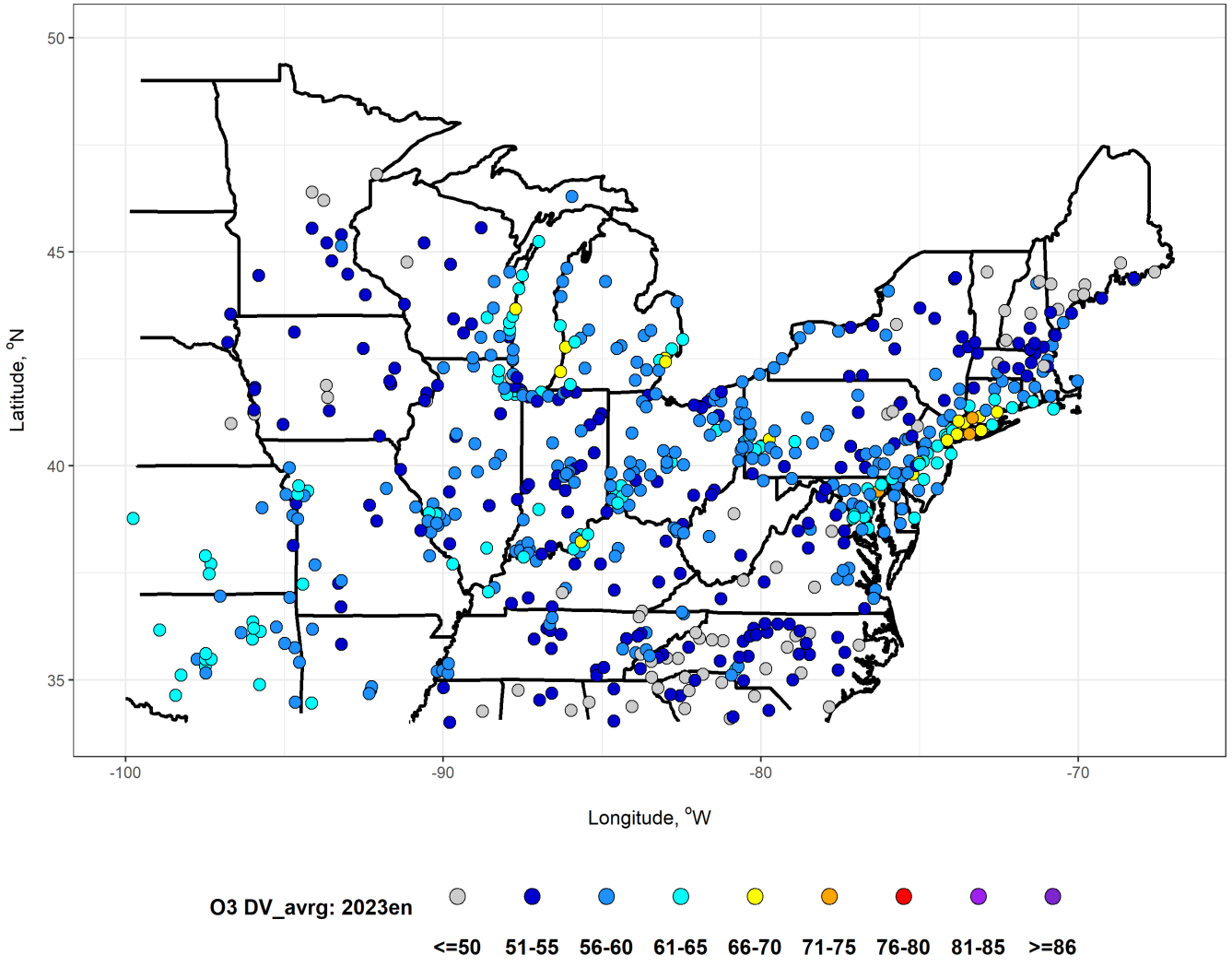

LADCO vs EPA 2023 DVs

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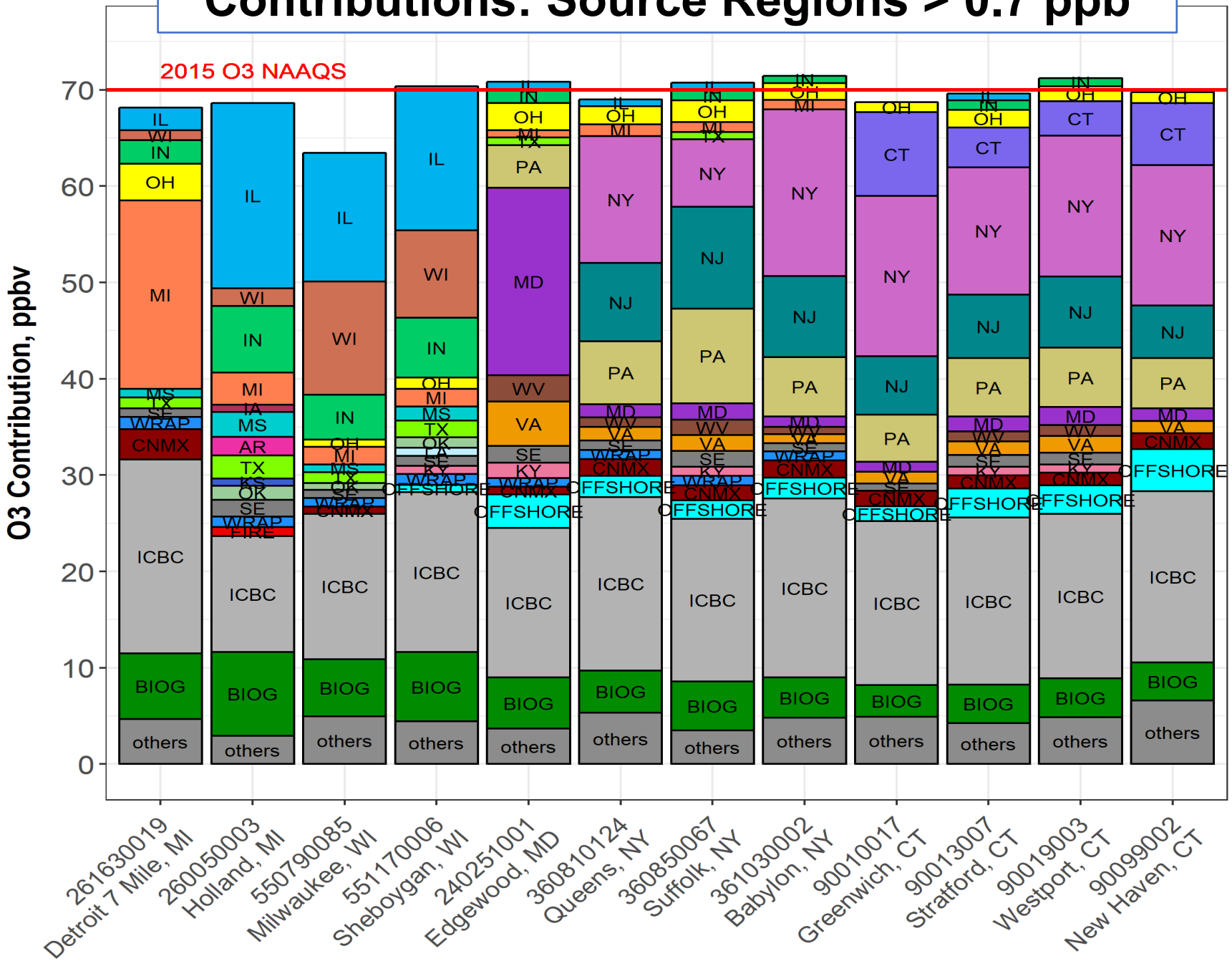
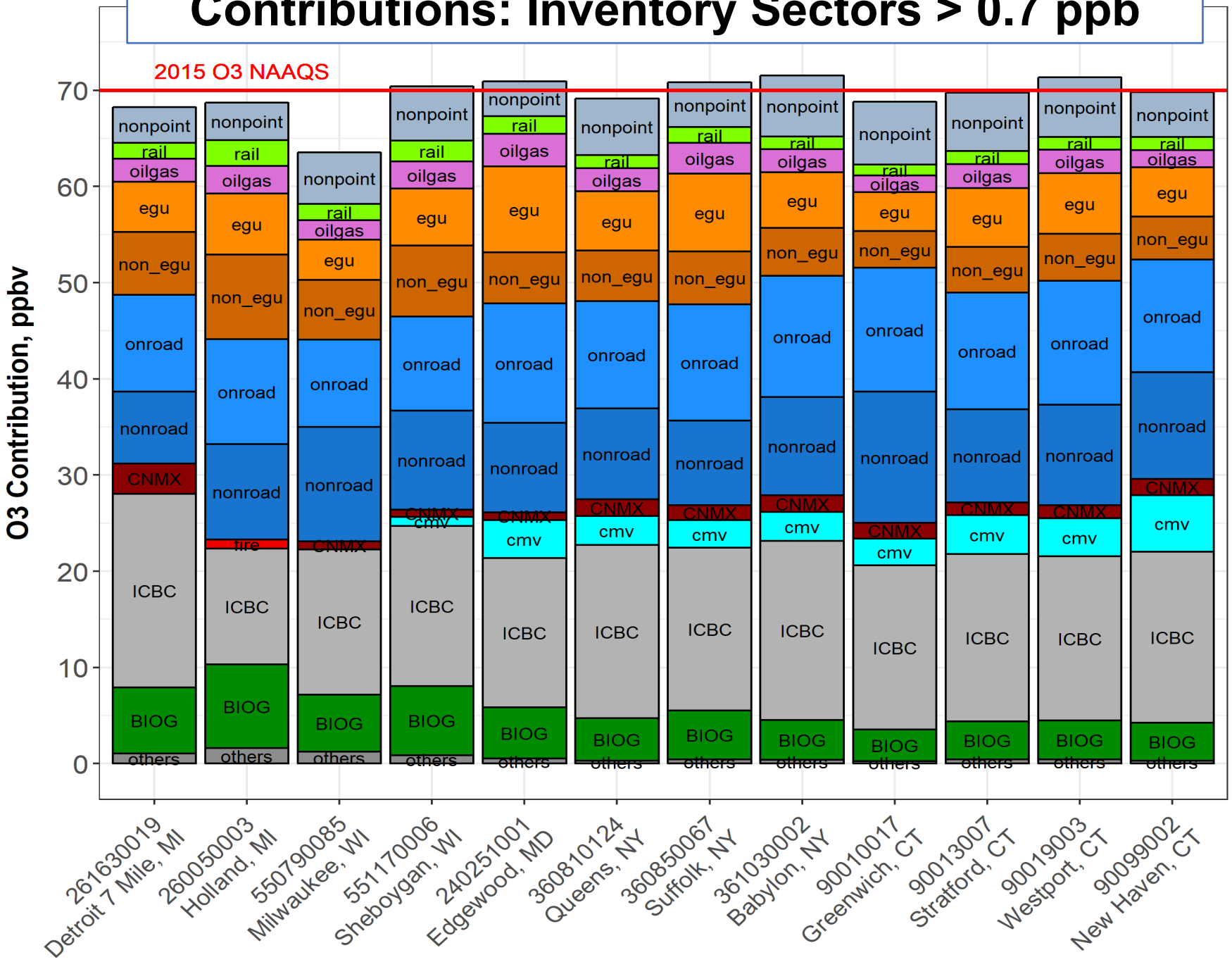
AQS ID	County	ST	LADCO		U.S. EPA		2009-2013	
			3x3 avrg	3x3 max	3x3 avrg	3x3 max	avrg	max
361030002	Suffolk	NY	71.6	73.1	72.5	74.0	83.3	85.0
90019003	Fairfield	CT	71.4	74.2	72.7	75.6	83.7	87.0
240251001	Harford	MD	71.0	73.3	71.4	73.8	90.0	93.0
360850067	Richmond	NY	70.9	72.4	71.9	73.4	81.3	83.0
551170006	Sheboygan	WI	70.5	72.8	70.8	73.1	84.3	87.0
90099002	New Haven	CT	69.9	72.6	71.2	73.9	85.7	89.0
90013007	Fairfield	CT	69.8	73.7	71.2	75.2	84.3	89.0
360810124	Queens	NY	69.2	71.0	70.1	71.9	70.0	71.0
90010017	Fairfield	CT	68.9	71.2	69.8	72.1	78.0	80.0
260050003	Allegan	MI	68.8	71.5	69.0	71.8	80.3	83.0
261630019	Wayne	MI	68.3	70.3	69.0	71.0	78.7	81.0
550790085	Milwaukee	WI	63.6	66.6	64.0	67.0	78.3	82.0

Contributions: Source Regions > 0.7 ppb



Contributions: Inventory Sectors > 0.7 ppb



Flexibilities

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- Alternative Power Sector Modeling
  - ERTAC EGU vs EPA EGU point emissions forecasts
  - ERTAC EGU generally resulted in lower O3 in the Midwest and NE
- Water vs No Water Cells in the Design Value Forecast
  - Should model grid cells that are dominated by water be included in the DV forecast?
  - LADCO does not think that excluding water cells is technically justified
  - DVs that include water cells are generally lower for the monitors in the Great Lakes region
- Bias Filtering for Model Performance
  - Only use model days where the bias is low for calculating future year DVs
  - LADCO applied a 15% bias filter, excluding days with model bias > 15% from the top 10 list of days used for calculating relative response factors

Water vs No Water DV Forecasts

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AQS ID	County, ST	LADCO Water		LADCO No Water		U.S. EPA Water		U.S. EPA No Water	
		3x3 avrg	3x3 max	3x3 avrg	3x3 max	3x3 avrg	3x3 max	3x3 avrg	3x3 max
361030002	Suffolk, NY	71.6	73.1	72.9	74.4	72.5	74.0	74.0	75.5
90019003	Fairfield, CT	71.4	74.2	71.6	74.4	72.7	75.6	73.0	75.9
240251001	Harford, MD	71.0	73.3	70.5	72.8	71.4	73.8	70.9	73.3
551170006	Sheboygan, WI	70.5	72.8	72.3	74.6	70.8	73.1	72.8	75.1
360850067	Richmond, NY	70.9	72.4	65.8	67.2	71.9	73.4	67.1	68.5
90099002	New Haven, CT	69.9	72.6	68.4	71.0	71.2	73.9	69.9	72.6
90013007	Fairfield, CT	69.8	73.7	69.3	73.2	71.2	75.2	71.0	75.0
261630019	Wayne, MI	68.3	70.3	68.3	70.3	69.0	71.0	69.0	71.0
360810124	Queens, NY	69.2	71.0	69.2	71.0	70.1	71.9	70.2	72.0
90010017	Fairfield, CT	68.9	71.2	67.7	70.0	69.8	72.1	68.9	71.2
260050003	Allegan, MI	68.8	71.5	68.7	71.5	69.0	71.8	69.0	71.7
550790085	Milwaukee, WI	63.6	66.6	69.1	72.4	64.0	67.0	69.7	73.0

Bias Filtered DV Forecasts

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AQS ID	County, ST	LADCO Water			Bias ≦ 15% Water		
		3x3 avrg	3x3 max	RRF	3x3 avrg	3x3 max	RRF
361030002	Suffolk, NY	71.6	73.1	0.8606	72.3	73.8	0.8691
90019003	Fairfield, CT	71.4	74.2	0.8539	69.7	72.5	0.8336
240251001	Harford, MD	71.0	73.3	0.7889	71.4	73.7	0.7934
551170006	Sheboygan, WI	70.5	72.8	0.8370	72.3	74.6	0.8585
360850067	Richmond, NY	70.9	72.4	0.8728	71.9	73.4	0.8848
90013007	Fairfield, CT	69.8	73.7	0.8286	68.6	72.4	0.8142
261630019	Wayne, MI	68.3	70.3	0.8689	67.1	69.1	0.8533
360810124	Queens, NY	69.2	71.0	0.8878	68.3	70.0	0.8759
90010017	Fairfield, CT	68.9	71.2	0.8589	68.8	71.1	0.8576
260050003	Allegan, MI	68.8	71.5	0.8321	69.1	71.9	0.8365
550790085	Milwaukee, WI	63.6	66.6	0.8133	67.7	70.9	0.8651

O3 Transport Modeling Summary

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- Recent modeling studies (LADCO, EPA, MOG, TCEQ) forecast that most of the US will be in attainment of the 2015 O3 NAAQS by 2023
- EPA Flexibility Memo (March 2018) lays out analysis alternatives for states to use for quantifying transport, source-receptor linkages, and maintenance
- First attainment deadline for 2015 O3 NAAQS will use DVs for 2018-2020, to demonstrate attainment by 2021
- How will we get the forecasted levels of attainment?
  - The next three O3 season (including 2018) temps are normal or cooler than avg
  - Emissions trends continue to decline along the slope that started in 2011
  - Lower than normal wildfire seasons
  - Long-range transport from outside U.S. flattens or declines

Energy Sector Changes Impact on Midwest Air Quality

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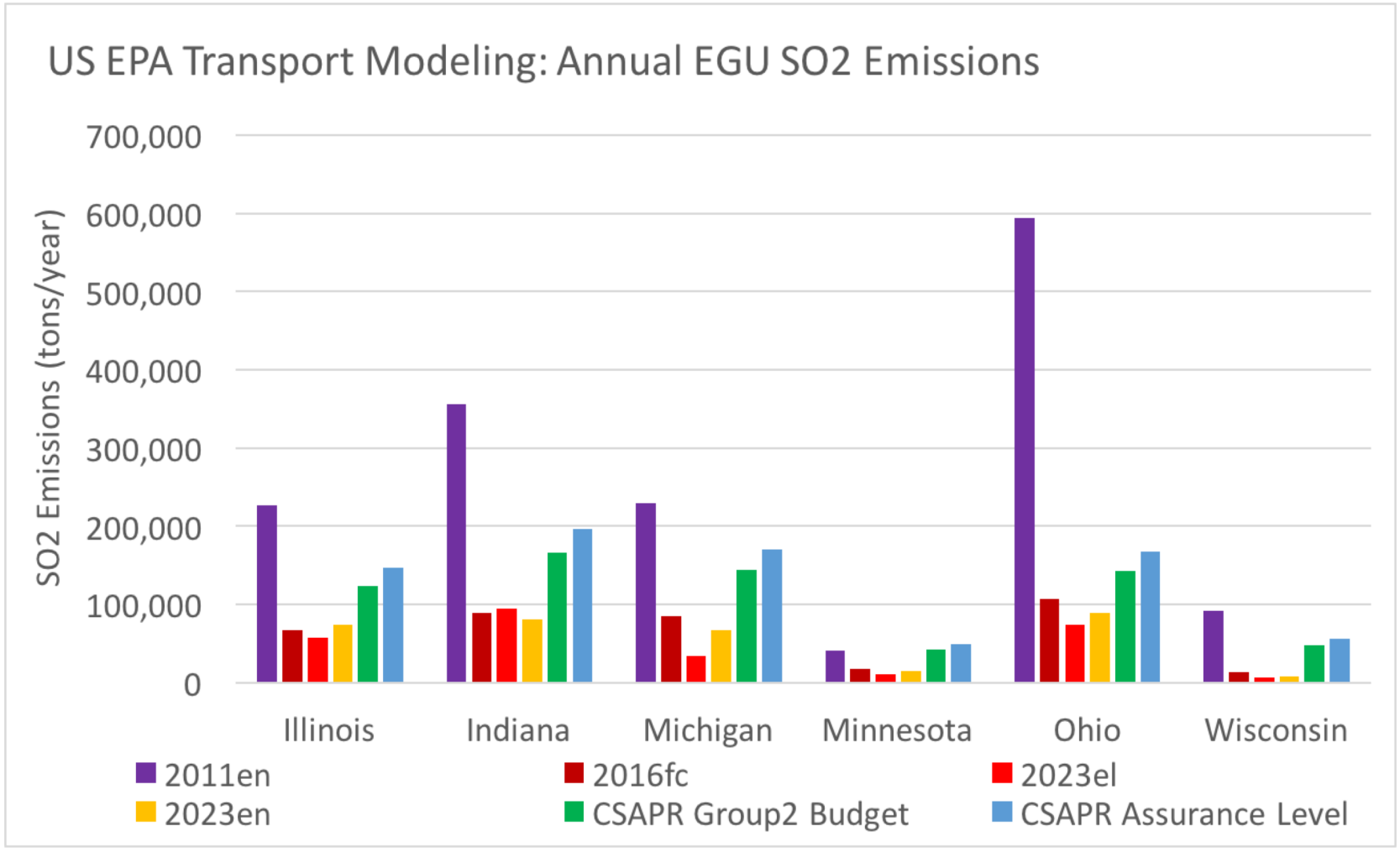

Energy Sector Changes Impact on Midwest Air Quality

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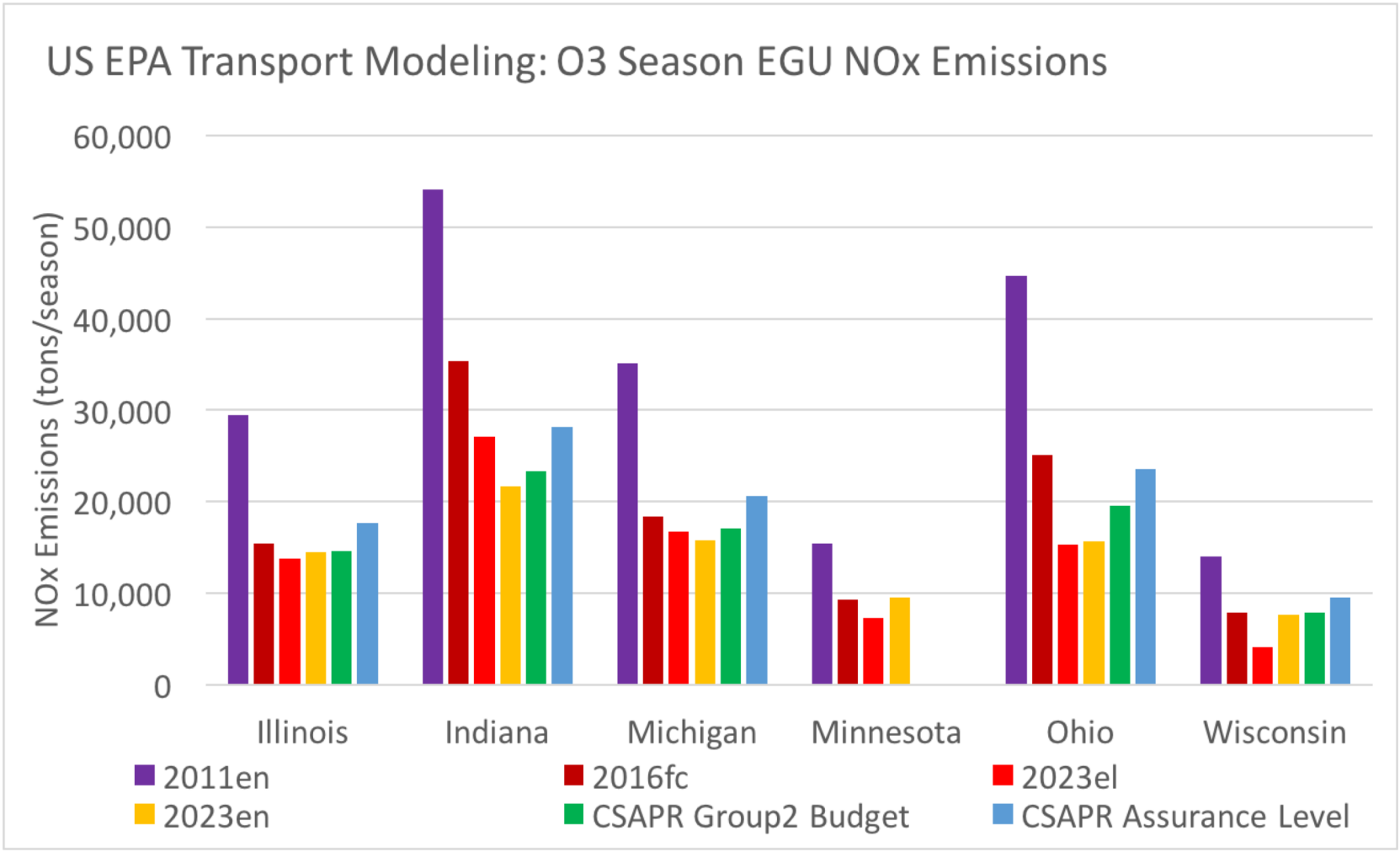

Energy Sector Changes Impact on Midwest Air Quality

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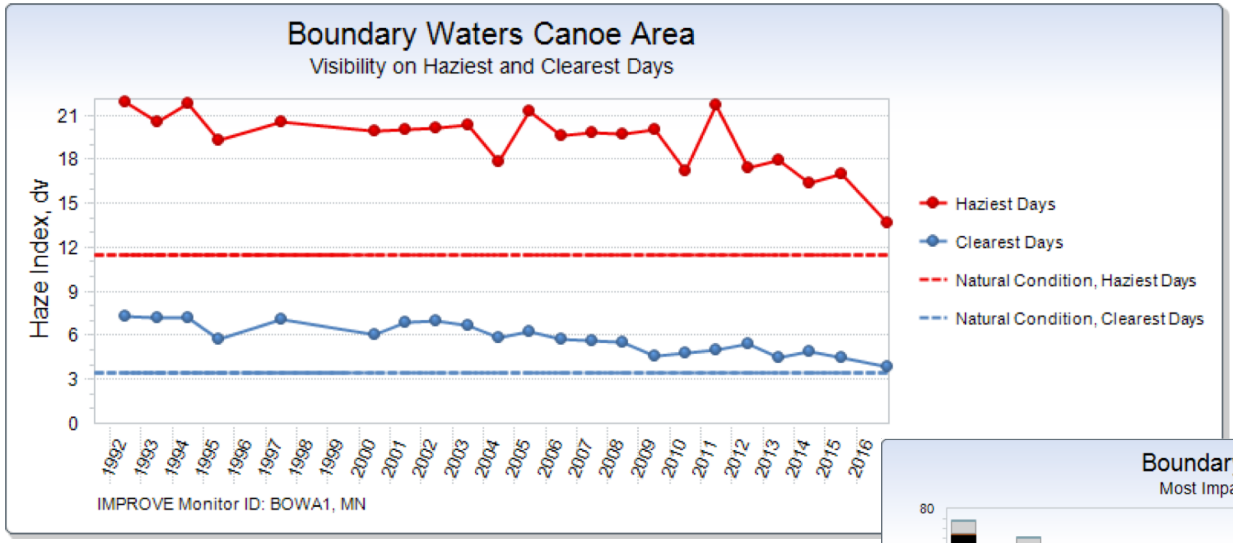

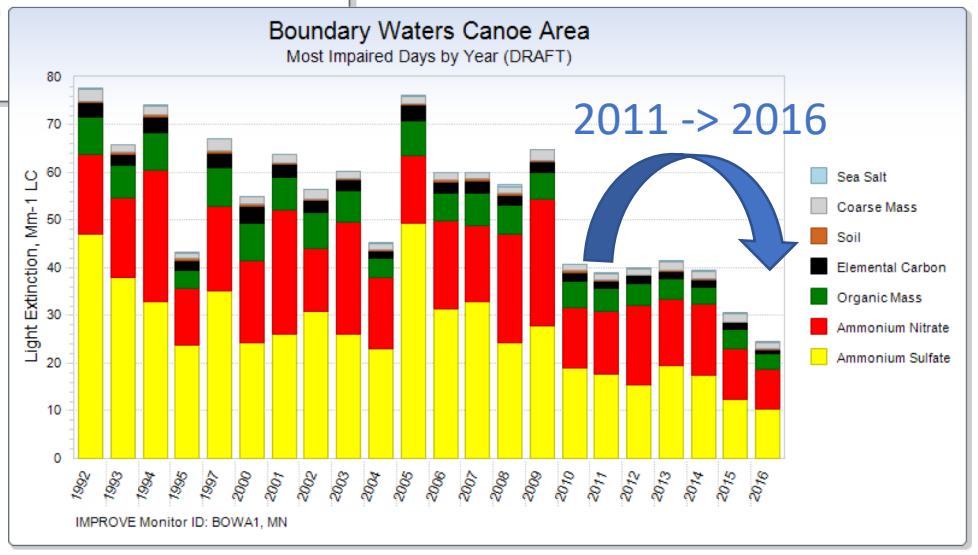

- Boundary Waters (MN) shows improvement in Most Impaired Days metric, starting around 2010
- 2011 to 2016 trend follows emissions
- Driven by NO_3 and SO_4

Recent $PM_{2.5}$ Design Values

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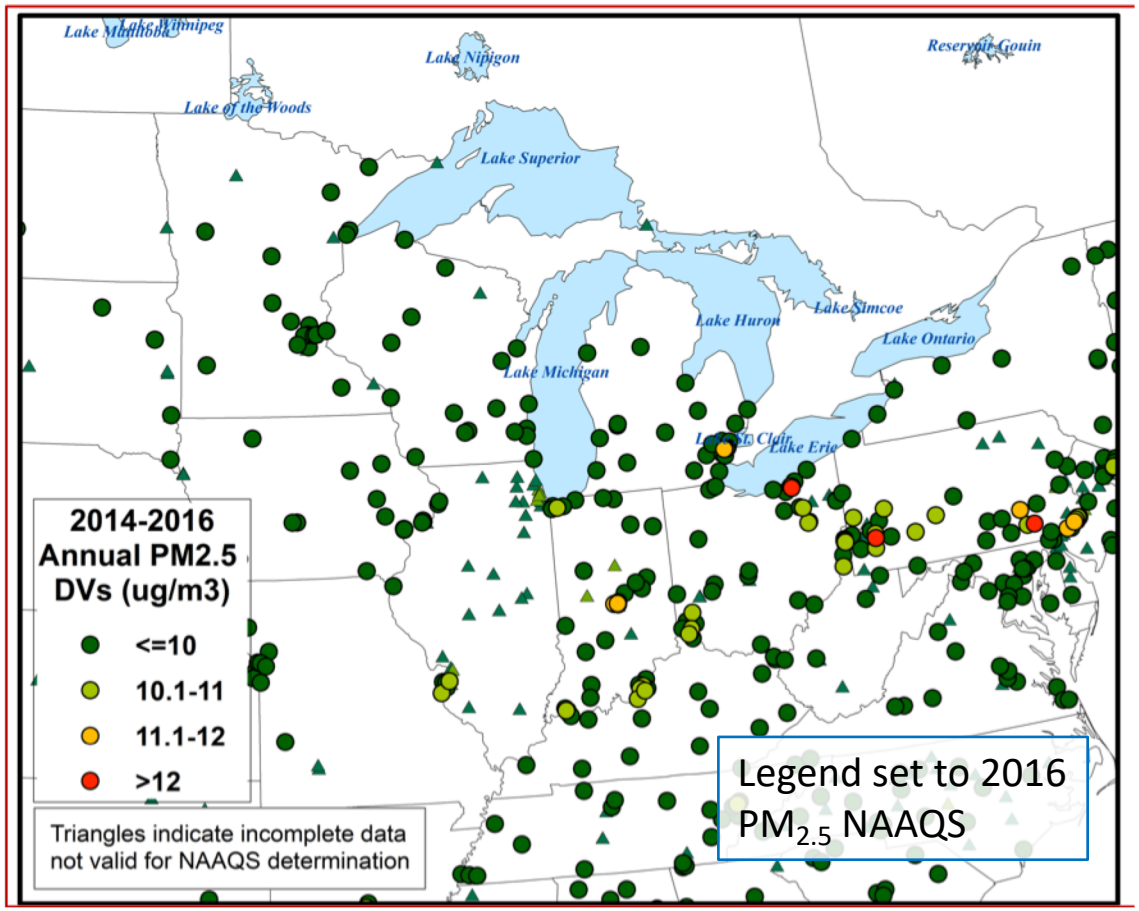
Annual $PM_{2.5}$ Design value = 3 year average of annual mean $PM_{2.5}$



Unadjusted 3-Year O3 DVs

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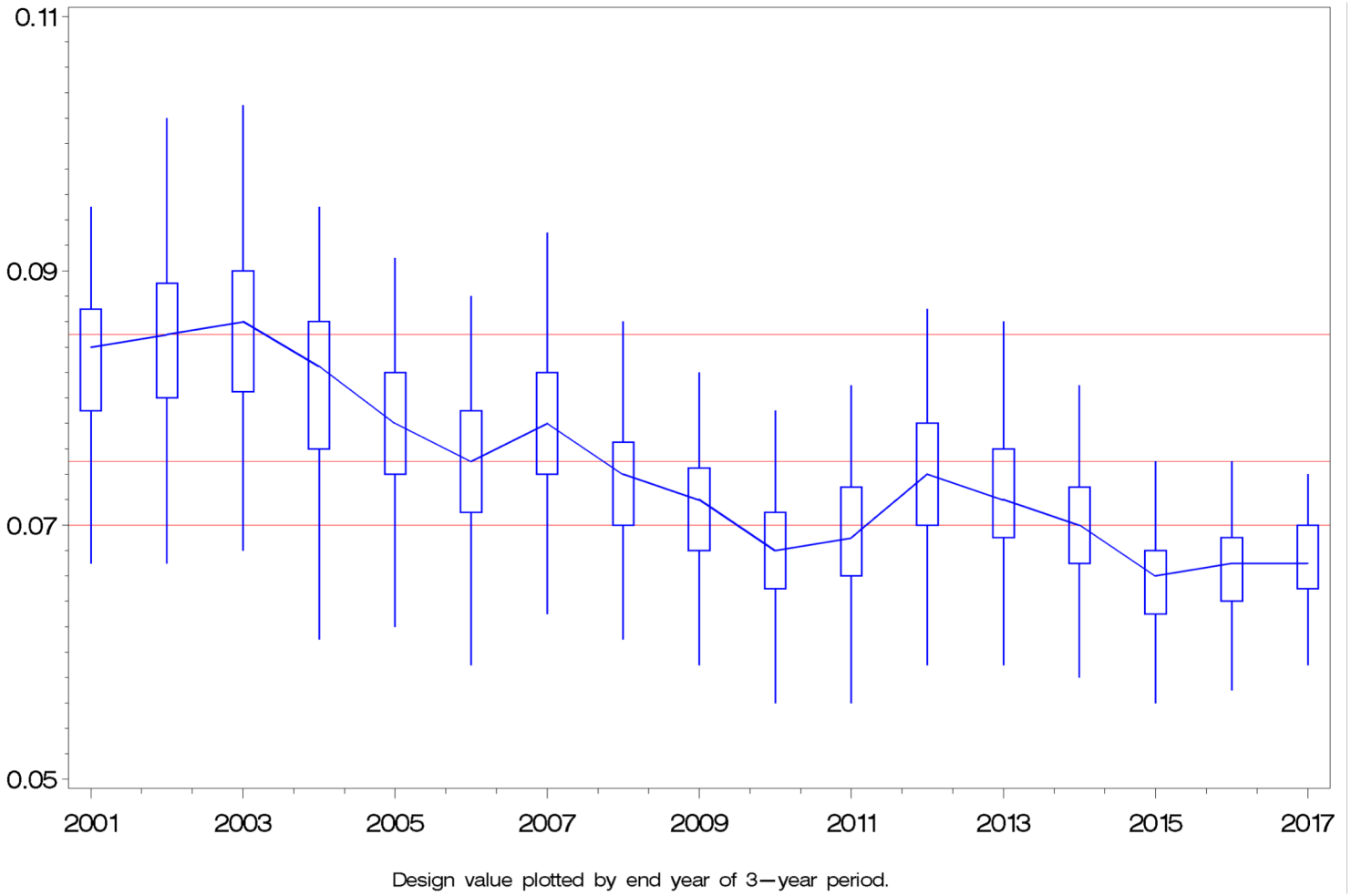

Lake Michigan Ozone Study

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May – June 2017
Western Shore of Lake Michigan

University of Northern Iowa
WISCONSIN UNIVERSITY OF WISCONSIN–MADISON
UNIVERSITY OF MINNESOTA
THE UNIVERSITY OF IOWA
WISCONSIN DEPT. OF NATURAL RESOURCES
EPRI | ELECTRIC POWER RESEARCH INSTITUTE
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NSF
NASA
NOAA
SCIENTIFIC AVIATION
UMBC
GRER
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Motivations for LMOS

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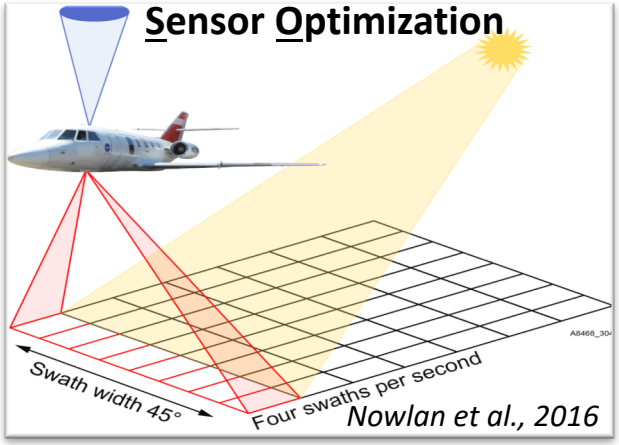
- Persistent high O_3 at some coastal sites
- Planning needs of the LADCO states require further clarity on regional O_3 production
- Last field campaign: summer 1991
- Need for a new study: New instruments/satellites and scarce aloft and over-lake observations

Geostationary Trace gas and Aerosol Sensor Optimization



LMOS Objectives

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- Measure the concentrations of O_3-relevant compounds
- Quantify the relative contribution of inter- and intra-state NO_x and VOC emissions and emissions sources on O_3 production rates along Lake Michigan
- Evaluate and improve meteorological and chemical transport model skill
- Study link between lake breeze circulations and O_3
- Analyze the causes of concentration differences between coastal and inland sites with observations and model data
- Develop best practices for O_3 planning modeling

Typical Regional Ozone Event

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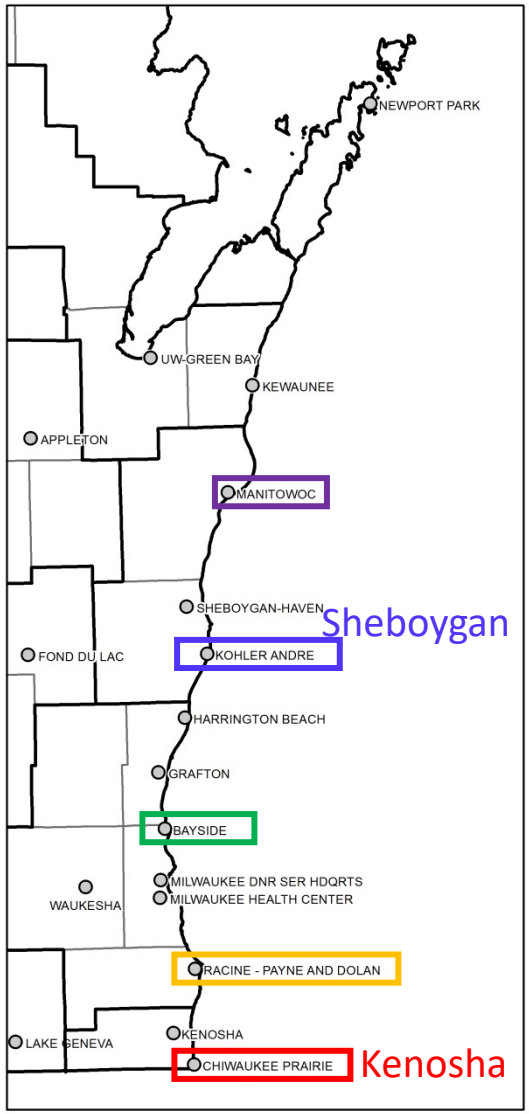

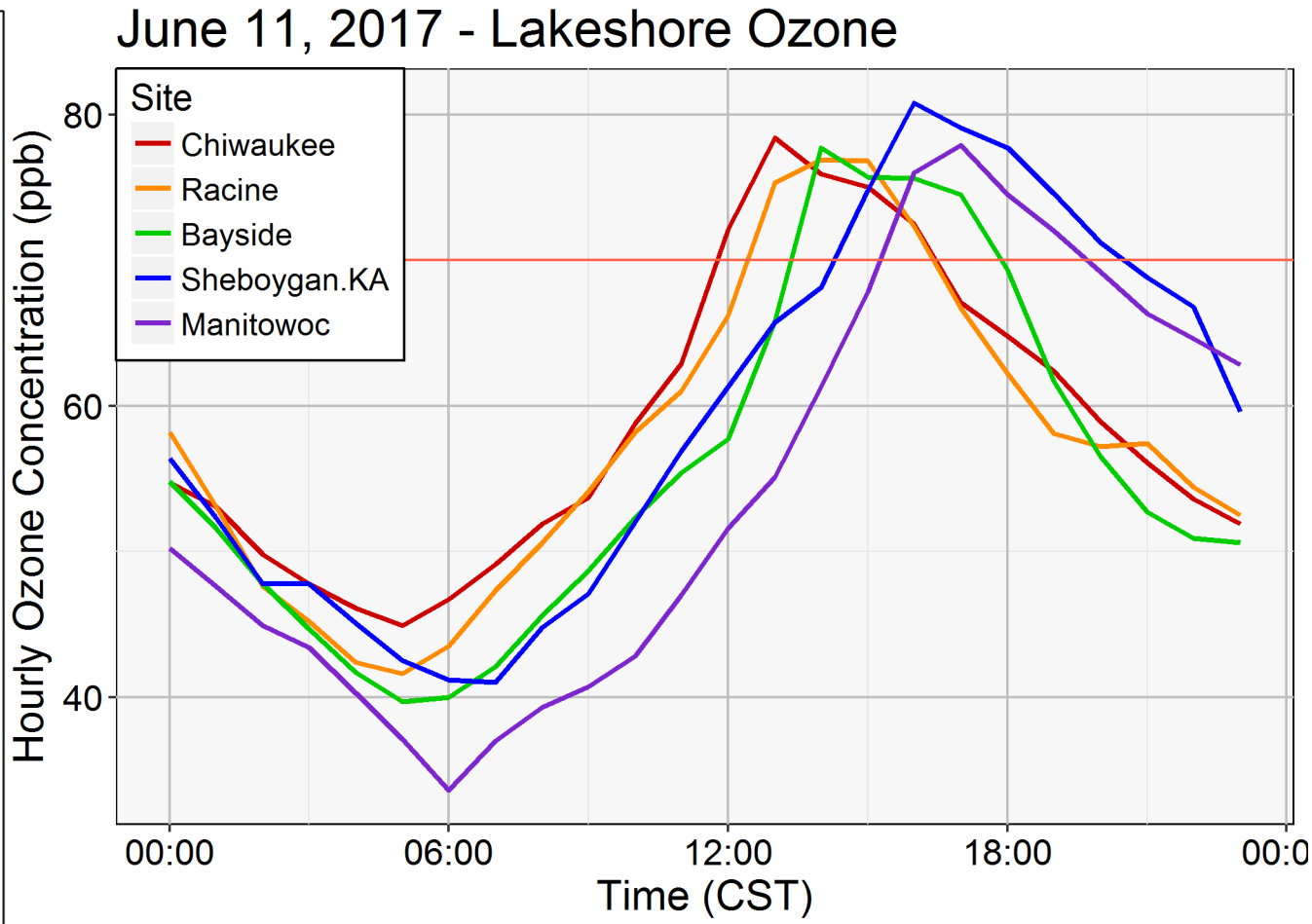

- Ozone peaks first at southern monitors
- Ozone plume moves northward

Credit: A. Dickens, LADCO

LMOS Study Design

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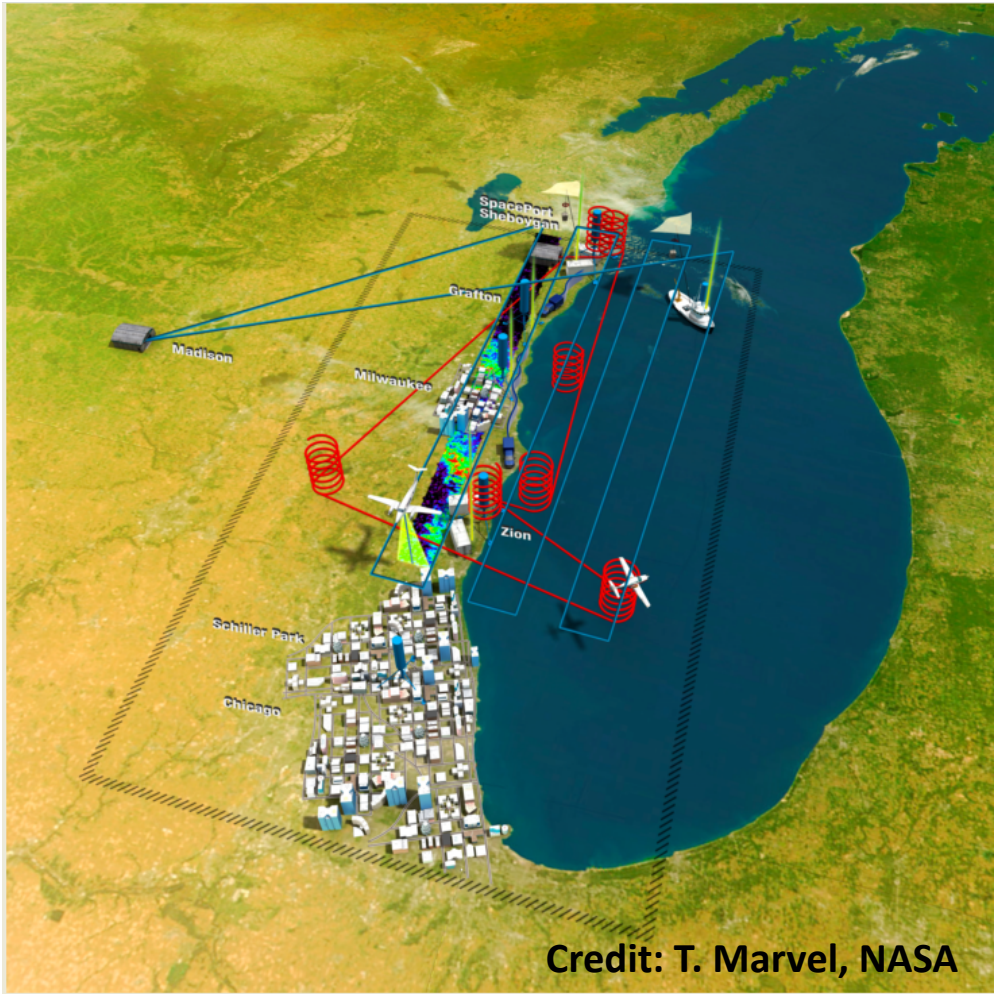
- Observations
  - Aircraft
  - Ship
  - Mobile on-shore
  - Zion, IL Supersite
  - Sheboygan, WI Ground Site
- Forecasts
  - WI DNR
  - NOAA NESDIS
  - U. Iowa
  - NWS



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- A. Dickens, (Wisconsin Dept. of Natural Resources)
- R. Kaleel, D. Kenski (LADCO)
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Questions and Contact

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CART Appendix

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Distribution of ozone among nodes

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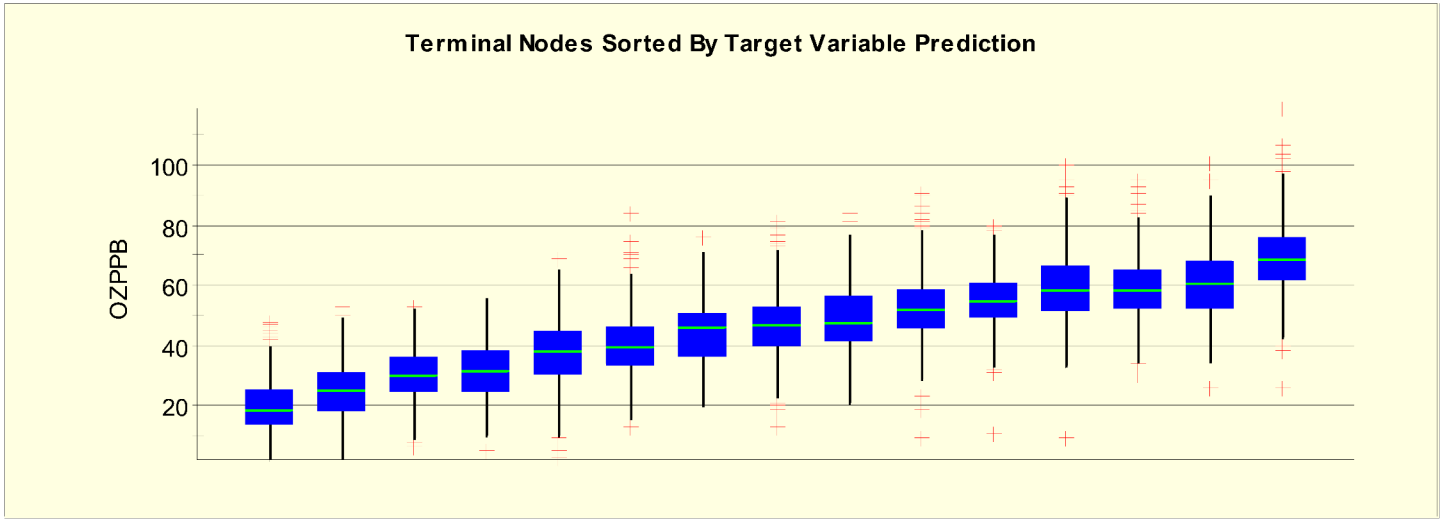

Example Model Performance

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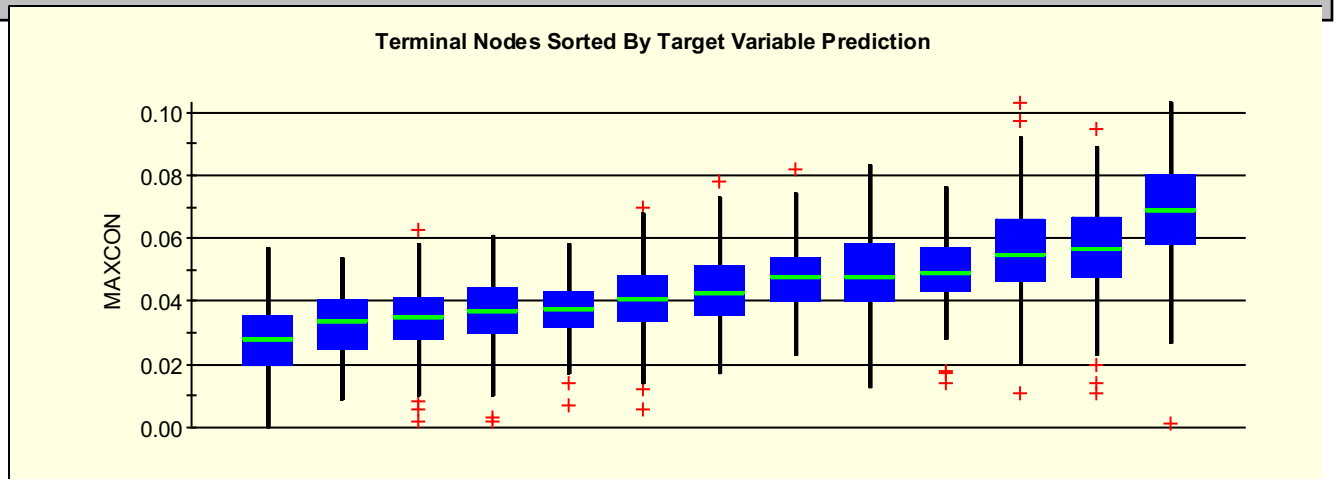
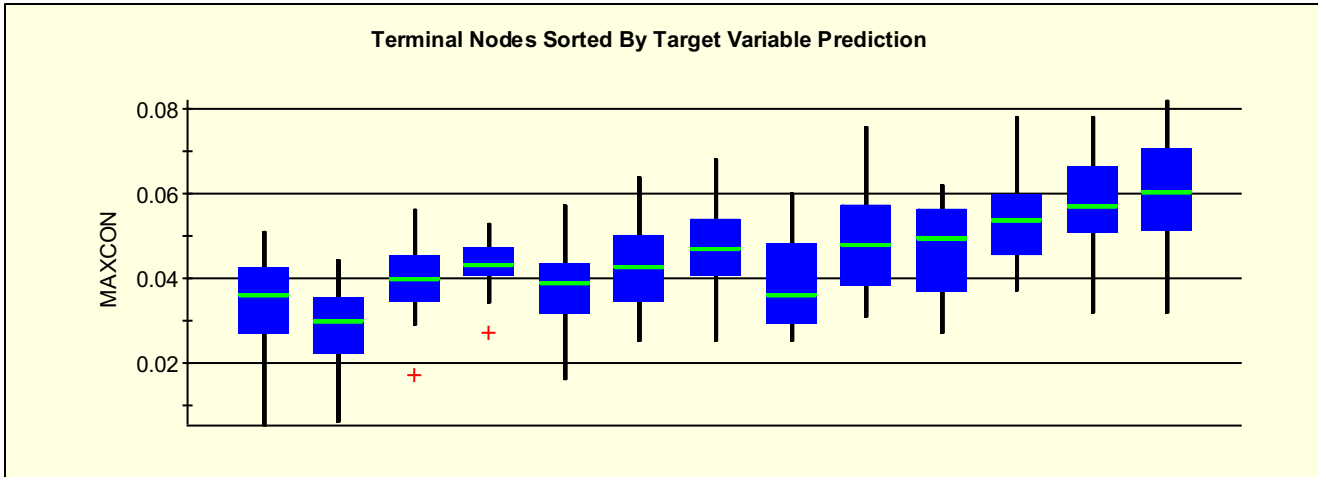
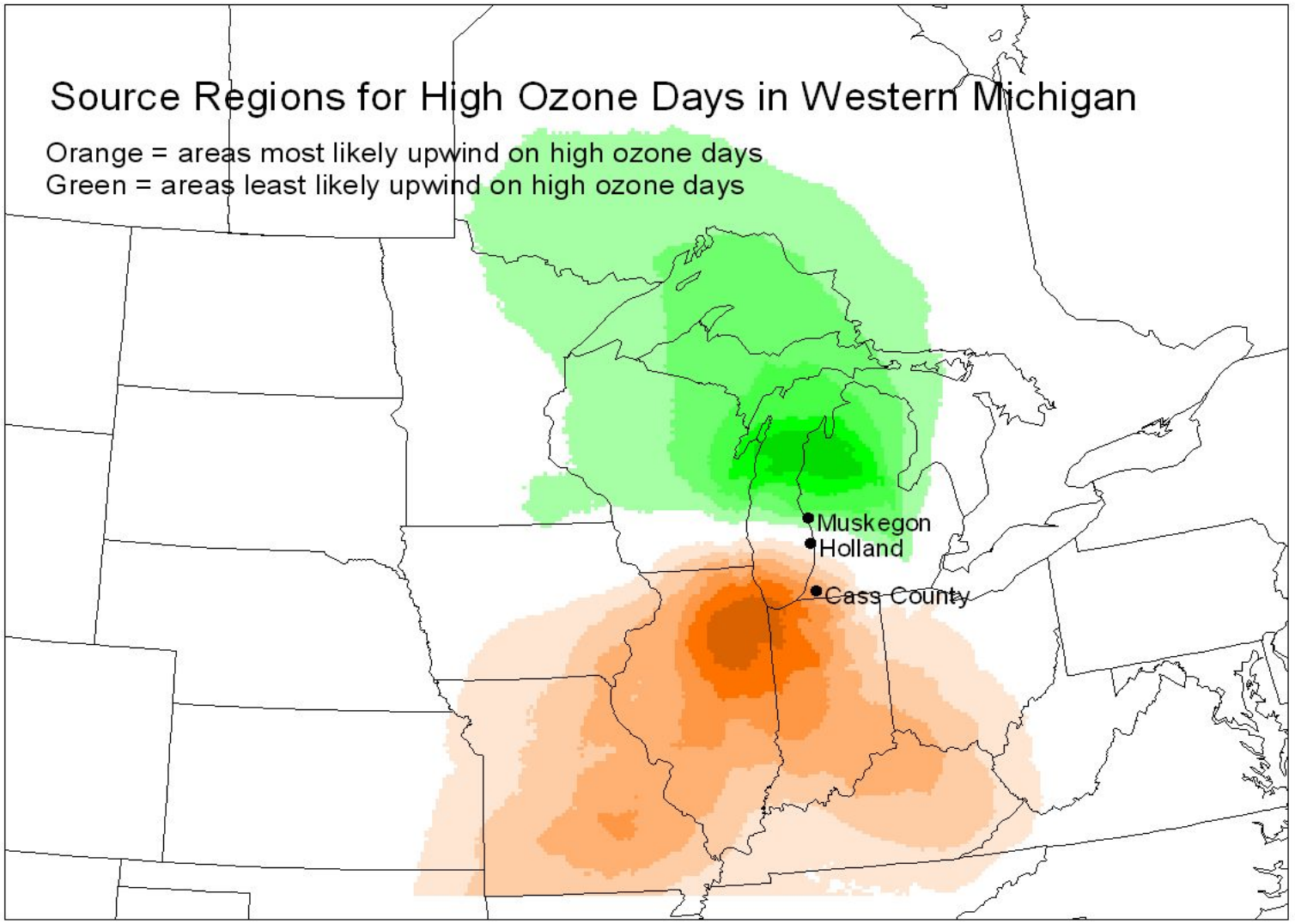
Full data set, 2000-2014



How well does 2014 data fit the 00-13 model? Lower concentrations in all nodes, but general trend is similar. Performance is poorer for low-concentration days.




Source Regions for High Ozone Days in Western Michigan
Orange = areas most likely upwind on high ozone days
Green = areas least likely upwind on high ozone days
Muskegon
Holland
Cass County

Meteorological Dataset

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- Hourly surface observations from 693 sites around the US collected from National Climatic Data Center's 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