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

Donna Kenski
LADCO Data Scientist

Zac Adelman
LADCO Executive Director

July 25, 2018
Ozone CART Analysis
2017 4th Highest Daily 8-hour Average Ozone Concentrations

Lake Michigan Air Directors Consortium • 9501 West Devon Avenue, Suite 701 Rosemont, IL 60018
2015-2017 O3 Design Values
Unadjusted Ozone Trends 2011-2017

Fourth-High Values

3-year Design Values

Design value plotted by end year of 3—year period.
June-July 2018 Was Warmer Than Average in the LADCO Region
What is CART Analysis?

• 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

• 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
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

- 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

Concentration Trends in CART Nodes—Detroit_Oak_Park_Warren
Only Nodes With C3 > 50 ppb
Met Adjusted O3 Trends

Lake Michigan Sites

Milwaukee

IL-Lake Cty, WI-Chiwaukee

Chicago

Sheboygan

Western Michigan

Lake Michigan Air Directors Consortium • 9501 West Devon Avenue, Suite 701 Rosemont, IL 60018
Met Adjusted O3 Trends
Eastern/Southern Sites
Findings

• 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
Update on Air Quality Research and Planning in the LADCO Region
2023 LADCO O3 Transport Modeling TSD

- 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

O3 DV_avg: 2023en

<=50  51-55  56-60  61-65  66-70  71-75  76-80  81-85  >=86
LADCO 2023 DVs

O3 DV_avg: 2023en

- <=50
- 51-55
- 56-60
- 61-65
- 66-70
- 71-75
- 76-80
- 81-85
- >=86
<table>
<thead>
<tr>
<th>AQS ID</th>
<th>County</th>
<th>ST</th>
<th>LADCO 3x3 avrg</th>
<th>LADCO 3x3 max</th>
<th>U.S. EPA 3x3 avrg</th>
<th>U.S. EPA 3x3 max</th>
<th>2009-2013 avrg</th>
<th>2009-2013 max</th>
</tr>
</thead>
<tbody>
<tr>
<td>361030002</td>
<td>Suffolk</td>
<td>NY</td>
<td>71.6</td>
<td>73.1</td>
<td>72.5</td>
<td>74.0</td>
<td>83.3</td>
<td>85.0</td>
</tr>
<tr>
<td>90019003</td>
<td>Fairfield</td>
<td>CT</td>
<td>71.4</td>
<td>74.2</td>
<td>72.7</td>
<td>75.6</td>
<td>83.7</td>
<td>87.0</td>
</tr>
<tr>
<td>240251001</td>
<td>Harford</td>
<td>MD</td>
<td>71.0</td>
<td>73.3</td>
<td>71.4</td>
<td>73.8</td>
<td>90.0</td>
<td>93.0</td>
</tr>
<tr>
<td>360850067</td>
<td>Richmond</td>
<td>NY</td>
<td>70.9</td>
<td>72.4</td>
<td>71.9</td>
<td>73.4</td>
<td>81.3</td>
<td>83.0</td>
</tr>
<tr>
<td>551170006</td>
<td>Sheboygan</td>
<td>WI</td>
<td>70.5</td>
<td>72.8</td>
<td>70.8</td>
<td>73.1</td>
<td>84.3</td>
<td>87.0</td>
</tr>
<tr>
<td>90099002</td>
<td>New Haven</td>
<td>CT</td>
<td>69.9</td>
<td>72.6</td>
<td>71.2</td>
<td>73.9</td>
<td>85.7</td>
<td>89.0</td>
</tr>
<tr>
<td>90013007</td>
<td>Fairfield</td>
<td>CT</td>
<td>69.8</td>
<td>73.7</td>
<td>71.2</td>
<td>75.2</td>
<td>84.3</td>
<td>89.0</td>
</tr>
<tr>
<td>360810124</td>
<td>Queens</td>
<td>NY</td>
<td>69.2</td>
<td>71.0</td>
<td>70.1</td>
<td>71.9</td>
<td>70.0</td>
<td>71.0</td>
</tr>
<tr>
<td>90010017</td>
<td>Fairfield</td>
<td>CT</td>
<td>68.9</td>
<td>71.2</td>
<td>69.8</td>
<td>72.1</td>
<td>78.0</td>
<td>80.0</td>
</tr>
<tr>
<td>260050003</td>
<td>Allegan</td>
<td>MI</td>
<td>68.8</td>
<td>71.5</td>
<td>69.0</td>
<td>71.8</td>
<td>80.3</td>
<td>83.0</td>
</tr>
<tr>
<td>261630019</td>
<td>Wayne</td>
<td>MI</td>
<td>68.3</td>
<td>70.3</td>
<td>69.0</td>
<td>71.0</td>
<td>78.7</td>
<td>81.0</td>
</tr>
<tr>
<td>550790085</td>
<td>Milwaukee</td>
<td>WI</td>
<td>63.6</td>
<td>66.6</td>
<td>64.0</td>
<td>67.0</td>
<td>78.3</td>
<td>82.0</td>
</tr>
</tbody>
</table>
Flexibilities

• 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

<table>
<thead>
<tr>
<th>AQS ID</th>
<th>County, ST</th>
<th>LADCO Water</th>
<th>LADCO No Water</th>
<th>U.S. EPA Water</th>
<th>U.S. EPA No Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3x3 avrg</td>
<td>3x3 max</td>
<td>3x3 avrg</td>
<td>3x3 max</td>
</tr>
<tr>
<td>361030002</td>
<td>Suffolk, NY</td>
<td>71.6</td>
<td>73.1</td>
<td>72.9</td>
<td>74.4</td>
</tr>
<tr>
<td>90019003</td>
<td>Fairfield, CT</td>
<td>71.4</td>
<td>74.2</td>
<td>71.6</td>
<td>74.4</td>
</tr>
<tr>
<td>240251001</td>
<td>Harford, MD</td>
<td>71.0</td>
<td>73.3</td>
<td>70.5</td>
<td>72.8</td>
</tr>
<tr>
<td>551170006</td>
<td>Sheboygan, WI</td>
<td>70.5</td>
<td>72.8</td>
<td>72.3</td>
<td>74.6</td>
</tr>
<tr>
<td>360850067</td>
<td>Richmond, NY</td>
<td>70.9</td>
<td>72.4</td>
<td>65.8</td>
<td>67.2</td>
</tr>
<tr>
<td>90099002</td>
<td>New Haven, CT</td>
<td>69.9</td>
<td>72.6</td>
<td>68.4</td>
<td>71.0</td>
</tr>
<tr>
<td>90013007</td>
<td>Fairfield, CT</td>
<td>69.8</td>
<td>73.7</td>
<td>69.3</td>
<td>73.2</td>
</tr>
<tr>
<td>261630019</td>
<td>Wayne, MI</td>
<td>68.3</td>
<td>70.3</td>
<td>68.3</td>
<td>70.3</td>
</tr>
<tr>
<td>360810124</td>
<td>Queens, NY</td>
<td>69.2</td>
<td>71.0</td>
<td>69.2</td>
<td>71.0</td>
</tr>
<tr>
<td>90010017</td>
<td>Fairfield, CT</td>
<td>68.9</td>
<td>71.2</td>
<td>67.7</td>
<td>70.0</td>
</tr>
<tr>
<td>260050003</td>
<td>Allegan, MI</td>
<td>68.8</td>
<td>71.5</td>
<td>68.7</td>
<td>71.5</td>
</tr>
<tr>
<td>550790085</td>
<td>Milwaukee, WI</td>
<td>63.6</td>
<td>66.6</td>
<td>69.1</td>
<td>72.4</td>
</tr>
</tbody>
</table>

Lake Michigan Air Directors Consortium • 9501 West Devon Avenue, Suite 701 Rosemont, IL 60018
## Bias Filtered DV Forecasts

<table>
<thead>
<tr>
<th>AQS ID</th>
<th>County, ST</th>
<th>LADCO Water</th>
<th>Bias ≤ 15% Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3x3 avrg</td>
<td>3x3 max</td>
</tr>
<tr>
<td>361030002</td>
<td>Suffolk, NY</td>
<td>71.6</td>
<td>73.1</td>
</tr>
<tr>
<td>90019003</td>
<td>Fairfield, CT</td>
<td>71.4</td>
<td>74.2</td>
</tr>
<tr>
<td>240251001</td>
<td>Harford, MD</td>
<td>71.0</td>
<td>73.3</td>
</tr>
<tr>
<td>551170006</td>
<td>Sheboygan, WI</td>
<td>70.5</td>
<td>72.8</td>
</tr>
<tr>
<td>360850067</td>
<td>Richmond, NY</td>
<td>70.9</td>
<td>72.4</td>
</tr>
<tr>
<td>90013007</td>
<td>Fairfield, CT</td>
<td>69.8</td>
<td>73.7</td>
</tr>
<tr>
<td>261630019</td>
<td>Wayne, MI</td>
<td>68.3</td>
<td>70.3</td>
</tr>
<tr>
<td>360810124</td>
<td>Queens, NY</td>
<td>69.2</td>
<td>71.0</td>
</tr>
<tr>
<td>90010017</td>
<td>Fairfield, CT</td>
<td>68.9</td>
<td>71.2</td>
</tr>
<tr>
<td>260050003</td>
<td>Allegan, MI</td>
<td>68.8</td>
<td>71.5</td>
</tr>
<tr>
<td>550790085</td>
<td>Milwaukee, WI</td>
<td>63.6</td>
<td>66.6</td>
</tr>
</tbody>
</table>
O3 Transport Modeling Summary

• 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

US EPA Transport Modeling: Annual EGU SO2 Emissions

SO2 Emissions (tons/year)

- Illinois
- Indiana
- Michigan
- Minnesota
- Ohio
- Wisconsin

Emissions Scenarios:
- 2011en
- 2016fc
- 2023el
- CSAPR Group2 Budget
- CSAPR Assurance Level

Lake Michigan Air Directors Consortium • 9501 West Devon Avenue, Suite 701 Rosemont, IL 60018
Energy Sector Changes Impact on Midwest Air Quality

US EPA Transport Modeling: O3 Season EGU NOx Emissions

- Illinois
- Indiana
- Michigan
- Minnesota
- Ohio
- Wisconsin

- 2011en
- 2016fc
- CSAPR Group2 Budget
- 2023el
- CSAPR Assurance Level
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

**Annual PM$_{2.5}$ Design value**
- $= 3$ year average of annual mean PM$_{2.5}$
Unadjusted 3-Year O3 DVs
Lake Michigan Ozone Study

May – June 2017
Western Shore of Lake Michigan
Motivations for LMOS

- 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
LMOS Objectives

• 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

Ozone peaks first at southern monitors
Ozone plume moves northward

Credit: A. Dickens, LADCO
LMOS Study Design

- **Observations**
  - Aircraft
  - Ship
  - Mobile on-shore
  - Zion, IL Supersite
  - Sheboygan, WI Ground Site

- **Forecasts**
  - WI DNR
  - NOAA NESDIS
  - U. Iowa
  - NWS

Credit: T. Marvel, NASA
LMOS Investigators

• M. Christiansen, C. Stanier, G. Carmichael, E. Stone (University of Iowa)
• T. Bertram (University of Wisconsin)
• D. Millet (University of Minnesota)
• P. Cleary (University of Wisconsin - Eau Claire)
• A. Czarnetzki (University of Northern Iowa)
• B. Pierce (NOAA/NESDIS)
• J. Szykman, R. Long, M. Fuoco (U.S. Environmental Protection Agency)
• A. Dickens, (Wisconsin Dept. of Natural Resources)
• R. Kaleel, D. Kenski (LADCO)
• J. Al-Saadi, L. Judd (NASA Langley Research Center)
• S. Janz, M. Kowalewski (NASA Goddard Space Flight Center)
• S. Conley (Scientific Aviation, Inc)
• N. Abuhassan (GSFC/UMBC)
• S. Shaw (Electric Power Research Institute)
Questions and Contact

Zac Adelman
Executive Director
Lake Michigan Air Directors Consortium
adelman@ladco.org
Distribution of ozone among nodes
Example Model Performance

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
Meteorological Dataset

- 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