The Lake Michigan Ozone Study (LMOS) 2017

Brad Pierce
NOAA/NESDIS@CIMSS

Kohler-Andrae State Park, Sheboygan WI
Despite dramatic reductions in ozone precursor emissions, many areas bordering Lake Michigan continue to violate federal air quality standards. This problem has persisted for decades and is one of the most challenging air quality issues in the eastern U.S.
Wisconsin emissions are declining and ozone is improving

NOx = NO + NO2 (nitrogen oxides)  VOC = Volatile Organic Compounds, both are ozone precursors
But there are still coastal sites which are still above the new ozone standard (70ppbv)


- Impact of high ozone on public health in high density urban areas (Chicago, Milwaukee, Detroit, Windsor). Also, these areas serve as large emissions sources.
Lake Michigan and Ozone Formation

- **Land breeze** blows ozone precursor compounds from rush hour over lake.
- The boundary layer height is low due to cold water chilling the air above.
- The pollutants are concentrated near the surface where ozone forms.
- An afternoon **lake breeze** transports the ozone back onto land.
Satellite image of Lake Michigan showing Lake Breeze Front

From Mike Majewski, WDNR
Effects of the lake breeze on ozone concentrations

8-Hour Ozone DVs in ppb
- Data Incomplete
- ≤ 65
- 66 - 75
- 76 - 84
- > 85

Ozone Standards
1997 NAAQS: 84 ppb
2008 NAAQS: 75 ppb

7/31/1984

Ozone
Wind
Hour of Day

Pre/post lake breeze
Lake breeze
Primary science objectives focusing on characterizing the recirculation, aging, and mixing of the Chicago and Milwaukee urban plumes as they move over Lake Michigan and their impact on surface ozone.

White Paper: http://www.ladco.org/
LMOS Measurement Suite

SSEC SPARC Trailer
(HALO Wind Lidar, AERI T/Q profiles, HSRL aerosol extinction, CIMEL aerosol optical depth),

EPA Pandora (Column NO2, HCHO), insitu (O3, NOx, HCHO)

UNI Microwave Radiometer T/Q profiles, SoDAR winds, Pandora (Column NO2, O3)

Insitu super site (UW-Madison/UofM NOy/VOC U-Iowa Aerosol)

NASA airborne column NO2, HCHO, O3, and aerosols
(GEOTASO Airborne UV-VIS Spectrometer, AirHARP Polarimeter)

NOAA Ship (EPA Pandora, ceilometer, insitu O3, (tethered Kite and shipboard),

EPA Geospatial Measurement of Air Pollution (GMAP) mobile van (O3)

Scientific Aviation insitu O3, NO, NO2
Sheboygan Ground Site: Spaceport Sheboygan
Sheboygan Ground Site: Spaceport Sheboygan
UW-Madison SPARC Trailer

- **Boundary Layer Meteorology/Surface Meteorology** Tim Wagner, Univ. of Wisconsin. SPARC: the SSEC Portable Atmospheric Research Center. funded by NOAA
  - *In situ meteorology*: Vaisala T, RH, pressure, wind speed, wind direction, precipitation.

- **O3 Profiles** by Tethered Kite (ozone and meteorology), in conjunction with Dept. of Atmospheric Science, Univ. Wisconsin.
Sheboygan Research Site: Spaceport Sheboygan
EPA Research Trailer

U.S. EPA Federal Reference Methods for Trace Gases along with Formaldehyde (O3 precursor):

- NOx/NOy methods:
  - Teledyne T500U Cavity attenuated phase shift spectroscopy (CAPS)
  - Teledyne 200EUP Photolytic converter – O3 chemiluminescence

- O3 method:
  - 2B Technologies M211 Scrubberless UV

- HCHO
  - Aerodyne QCL
The NOAA Great Lakes Environmental Research Laboratory (GLERL) will be providing the RV R5503 during June 2-22:

- EPA Pandora, ceilometer, insitu O3 measurements using tethered Kite and shipboard
- Based out of Sheboygan, WI during deployment
Mobile Van Measurements: EPA Region
Geospatial Measurement of Air Pollution (GMAP)

Coastal/inland ozone gradients

GMAP has an integrated Differential Ultra Violet Absorption Spectroscopy (DUVAS) that can provide high frequency (1 second) measurements while moving or parked.

Airborne Measurements: NASA GeoTASO, Scientific Aviation insitu O3 and NOx

NASA Beechcraft UC-12 instrument Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO). GeoTASO is a UV-Vis Spectrometer that is an airborne simulator for the future Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission and is used to retrieve column NO2, HCHO, and aerosols.

Scientific Aviation Mooney airplane equipped with meteorological, O3 and NOX measurements. Spirals over key ground sites and measurements within the boundary layer over land and water.  

*Funded by Electric Power Research Institute (EPRI)*
From Caroline Nowlan (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA)

NASA Airborne Remote Sensor
Geostationary Trace Gas and Aerosol Sensor Optimization (GeoTASO)

- Airborne platform
- Column retrievals of NO2, HCHO, O3, SO2, CHOCHO

**NO$_2$ over Denver, 2 August 2014**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground spot</td>
<td>40 m x 80 m</td>
</tr>
<tr>
<td>Ground sample</td>
<td>10 m x 50 m</td>
</tr>
<tr>
<td>Swath</td>
<td>10 km</td>
</tr>
</tbody>
</table>
Scientific Aviation (white)/GeoTASO (orange): Chicago Raster Flight Plan

Chicago emissions with background and offshore profiling
Scientific Aviation (black)/GeoTASO (red): Sheboygan to Zion Raster Flight Plan

Zion to Sheboygan coastal survey with onshore and offshore profiling
Scientific Aviation (blue)/GeoTASO (green): Sheboygan Raster (Three circuits) Flight Plan

Sheboygan survey with background, onshore and offshore profiling
All LMOS Flights with EPA National Emission Inventory 2011 NOx emissions
Thanks to the Jane Brill and the Sheboygan County Chamber for help with LMOS Sheboygan site selection, accommodations, and logistics!

Questions?

brad.pierce@noaa.gov