Open letter to parties interested in the

2017 Lake Michigan Ozone Study

January 26, 2017

1. Introduction

In an April 2016 white paper [*Pierce et al.*, 2016], a field campaign addressing ozone and its precursors over Lake Michigan was proposed. A combination of satellite remote sensing, aircraft remote sensing, and ground-based *in situ* monitoring will be conducted during the period May 22, 2017 to June 22, 2017. This combination of measurements will provide critical observations for understanding several unanswered questions, and for evaluating a new generation of high resolution meteorology, chemical transport, and coupled air quality models attempting to better simulate ozone episodes in the region.

As of January, 2017, many components necessary to make LMOS 2017 a reality are confirmed for participation. This comes thanks to an enthusiastic response from many individuals and groups in the atmospheric chemistry, atmospheric science, and air quality management communities.

The purpose of this letter is to document the aspects of the LMOS 2017 study that are confirmed, and to list the measurement, modeling and funding needs that are pending or that remain. Table 1 lists study components and groups that are tentatively responsible for those components. In cases where participation is not yet confirmed, the reasons vary. In some cases, participation is contingent on funding. In others it is contingent on availability of instruments and personnel. And in others, principle investigators are considering the scientific opportunity of participation.

For those with questions about the Lake Michigan Ozone Study, please contact the members of the Scientific Steering Committee listed below.

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Jassim (Jay) Al-Saadi – j.a.al-saadi@nasa.gov
Tim Bertram – timothy.bertram@wisc.edu
Angela Dickens – angela.dickens@wisconsin.gov
Rob Kaleel –kaleel@ladco.org
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2. Overview of Measurements

Two field sites will be hosting supplemental measurements for LMOS 2017. These are shown in Figure 1 and include

- Zion, Illinois
- Sheboygan, Wisconsin (located at Spaceport Sheboygan)

In addition to these fixed sites, mobile platforms include

- **GeoTASO**: the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) instrument (column NO_2 and formaldehyde, HCHO), on the NASA Langley Research Center Beechcraft UC-12 aircraft flying out of Madison, Wisconsin.[i]
- **GMAP**: EPA region 5 Geospatial Measurement of Air Pollution (GMAP) mobile sampling system. GMAP makes in situ measurements of a wide range of trace gases of relevance to LMOS 2017 via differential UV absorption spectroscopy (UV-DUVAS, Duvas Technologies, DV 3000) and of CH_4 and H_2S (Picarro) from a telescoping mast. To be deployed at Zion, and then used in mobile mode to map spatial gradients.
- ***In situ* aircraft**: Scientific Aviation, scientifically equipped Mooney airplanes with meteorological measurements, a 2B model 205 ozone analyzer, and an Eco Physics model CLD88 NO analyzer. (pending funding).
- **USEPA Lake Guardian ship:** Plans are under development for the Lake Guardian to carry lightweight autonomous samplers for formaldehyde, NO_2 and ozone as well as a ceilometer (boundary layer height) and Pandora (column O_3, NO_2 and formaldehyde). (pending approval).

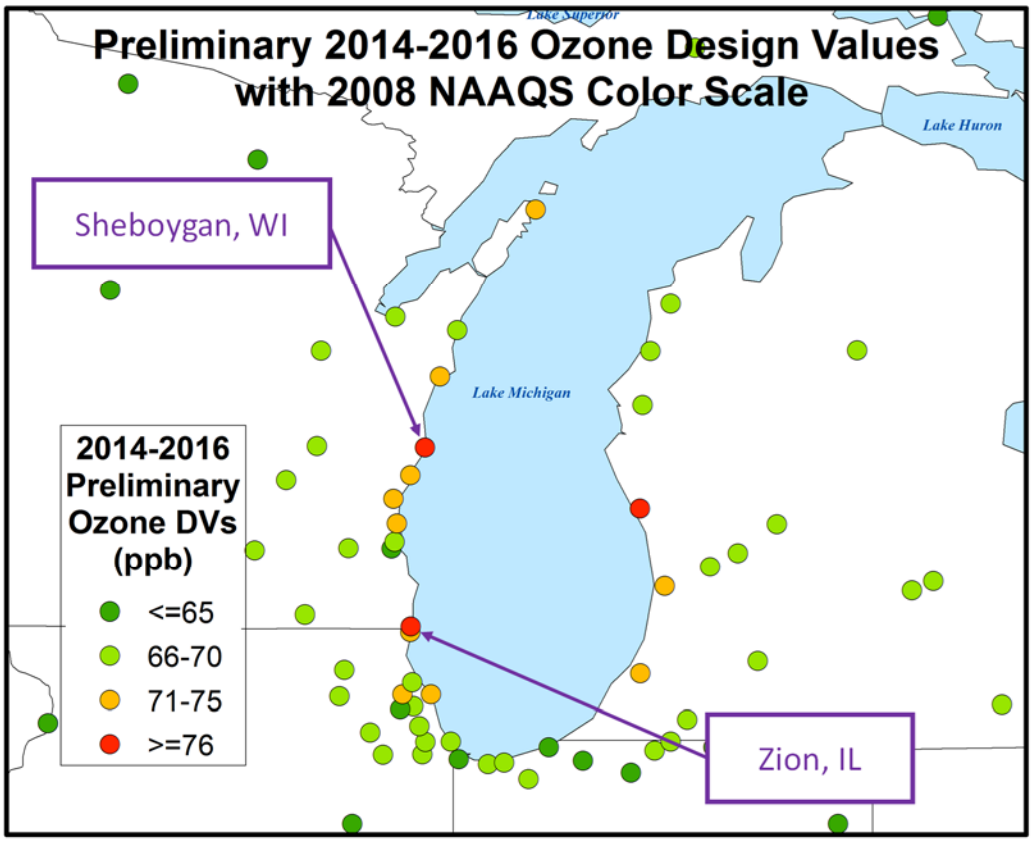

Figure 1. Ground sites hosting measurements for LMOS 2017

Section 3. Science Objectives

1. Determine the concentrations, speciation, and patterns of variability in VOCs, NO_y, and VOC oxidation products, and their relationships to coastal ozone episodes at the Zion, IL sampling site (NSF proposal) and over Lake Michigan and the surrounding airsheds (overall project)

    - *What are the predominant drivers of OH reactivity*?
    - *To what degree does accelerated chemistry in the shallow lake boundary layer contribute to coastal ozone enhancements?*

2. Quantify ozone production efficiency and the sensitivity of coastal ozone production to NO_x and VOC using multiple observation-based methods.

3. Determine the relative time-dependent influences of biogenic-rich and biogenic-poor regional air masses, urban plumes, localized emissions, and Great Lakes shipping emissions on $PM_{2.5}$ at the measurement site (NSF) and throughout the domain (whole project) using source apportionment methods and analysis of transport fields.

    - *What is the relative importance of urban, regional, and local precursors in coastal ozone production?*
    - *What is the relative contribution of inter- and intra-state NO_x and VOC emissions and emissions sources on ozone production rates along Lake Michigan?*

4. Evaluate chemical transport model skill for predicting critical aspects of coastal and lake meteorology, oxidant concentrations, VOC and NO_y speciation, the spatial and vertical distribution of O_3 precursors, and $PM_{2.5}$ sources. Apply the observationally-constrained model to quantify the spatial and temporal variation in NO_x and VOC sensitivity for coastal ozone production, and potential for future changes.

    - *How can configurations and lessons learned in the project "Improving Ozone Simulations in the Great Lakes Region" (EPRI, University of Georgia, and the University of Alabama—Huntsville) be applied to or tested with LMOS 2017.*
    - *What dynamical and chemical processes dominate model errors in predicting coastal ozone?*
    - *How can we improve model emission inventories?*
    - *How well do regional models capture ozone production chemistry as assessed through evaluation of critical measurement indicators (e.g., H_2O_2:HNO_3 ratio, HCHO:NO_x ratio, NO_y and VOC lifetime and partitioning).*

5. To what extent do lake breeze circulations effect ozone production?

6. How can remote sensing products (e.g., measurements of NO_2 and HCHO) be used to constrain ozone predictions?

Section 4. Measurement List and Status

The table below lists measurements and modeling that are part of LMOS 2017. Figures in Section 5 show some of the sites and instrument systems. Green dots indicate confirmed participation 🟢. Blue dots (🔵) indicate participation pending NSF funding; yellow dots (🟡) indicate participation contingent on other factors such as other funding or instrument availability.

Study component	Notes & participation status (i.e., confirmed, pending funding, highly likely, etc.)
Aircraft 1 and aircraft 1 payload 🟢	
Description	NASA Langley Beechcraft UC-12 Jay Al-Saadi, NASA Langley Research Center
Aircraft deployment location	Madison, WI (MSN) Truax Field
Aircraft payload	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 NO_2, HCHO, and aerosols.
Aircraft 2 and aircraft 2 payload 🟡	
Description and Status	Scientific Aviation Mooney Aircraft Pending funding (proposal under consideration by EPRI)
Aircraft deployment location	Sheboygan, WI
Aircraft payload	Meteorological measurements; 2B model 205 ozone analyzer (10 Hz); Eco Physics model CLD88 NO_x analyzer with photolytic converter (switches between NO and NO_x every 20 sec).
Forecast modeling / flight planning support	
4 km WRF + Tracers Forecast	University of Iowa, Charles Stanier & Greg Carmichael 🟢 based on WRF configuration work by EPRI, University of Georgia, and the University of Alabama—Huntsville under the project: "Improving Ozone Simulations in the Great Lakes Region."
3 km WRF + Flexpart for point and area sources	NOAA NESDIS Air Quality Remote Sensing Group 🟢
12 km Ozone Forecast	NWS Operational National Air Quality Forecasting Capability (NAQFC), 12 km 48-hr forecast. CMAQ-NCEP 🟢
Interpretation of national weather, local conditions, lake breeze, air quality forecasts	Wisconsin Department of Natural Resources 🟢 National Weather Service, Sullivan Office 🟢

Zion, IL ground-based chemistry and meteorological vertical profiling	
Location	Zion, Illinois – Location confirmed Illinois Beach State Park EPA Site ID 17-097-1007; 42.4676 N 87.81 W
Routine measurements	O_3 (operational); 10m meteorology
Available space and power	Collocated, air conditioned trailer; 10m sampling tower. Dedicated breaker box is operational providing 110V (200 A) for instrument use.
Needed maintenance or upgrades	General maintenance to verify operation of air conditioning unit and extend/repair the inlet tower will need to be conducted prior to deployment.
Ozone	Routinely monitored by Illinois EPA via UV absorption 🟢
CO	Commercial monitor. Provided by LADCO/State of Indiana. 🟢
NO_x/NO_2 (not true)	Commercial Chemiluminescence Monitor. LADCO/State of Indiana. 🟢
UV, Solar Rad	LADCO/State of Indiana. 🟢
Meteorology	Meteorology tower operated through 2013 by IEPA. Will be repaired or replaced by March 1, 2017 or before. 🟢
Photolysis Rates (JNO_2, JO_3)	Spectral radiance measurement by calibrated filter radiometer (i.e. Metcon). Steering committee is seeking an instrument loan for this. 🟡
SO_2	Commercial monitor, UV Absorption. 🟡
Ceilometer / Boundary Layer Height	Jim Szykman, EPA NERL. 🟢
Column NO_2, O_3, Formaldehyde	Pandora Ground-based Solar Spectrometer. Jim Szykman, EPA NERL. 🟢
Boundary Layer Meteorology (High temporal resolution observations of water vapor, temperature, and wind profiles)	Alan Czarnetzki. Alan.Czarnetzki@uni.edu University of Northern Iowa 🟡 Radiometrics MP-3094A microwave profiler (temperature, water vapor). Atmospheric Systems miniSoDAR (wind speed and direction from 15 to 250 m AGL).
CO, CH_4, CO_2	Cavity Ringdown Spectroscopy. 🔵

Speciated Non-Methane (C2-C12) Hydrocarbons	Canister-based GC-MS. Bertram group in conjunction with WI State Hygiene Lab. 🔵
Select Hydrocarbons and Air Toxics	Continuous automated GC-MS. 🟡
Select VOC and oVOC (alcohols, aldehydes)	PTR-QiTOF. Alkenes, aromatics, aldehydes, terpenoids, ketones, nitriles, organic acids, isoprene + oxidation products, etc. Millet Group, Univ. of Minnesota. 🔵
Nitric acid, select alkyl nitrates and organic acids, $ClNO_2$, N_2O_5	CIMS (I^-), Bertram Group, University of Wisconsin. 🔵
Hydrogen peroxide and organic peroxides	CIMS (I^-), Bertram Group, University of Wisconsin. 🔵
Speciated aerosol chemistry (filter-based inorganic ions, OC/EC, organic molecular markers)	Filter-based aerosol IC, GC-MS, Stone group, University of Iowa. 🟡
Speciated aerosol metals	Filter-based aerosol IC, GC-MS, Stone group, Univ. of Iowa. 🔵
Aerosol size distribution	SMPS, Stanier group, University of Iowa. 🔵

Sheboygan, WI ground-based ozone and formaldehyde and meteorological vertical profiling	
Location	Sheboygan Wisconsin – location confirmed Meteorology: 43.746 N 87.81 W 5 miles north of EPA Site ID 551170006; 43.679 N, 87.716 W
Routine measurements	O_3 (operational/confirmed) at EPA Site 551170006 🟢
Boundary Layer Meteorology Surface Meteorology	Tim Wagner, Univ. of Wisconsin. SPARC: the SSEC Portable Atmospheric Research Center. 🟢 *Profiles:* Atmospheric Emitted Radiance Interferometer (AERI), HSRL Lidar, Doppler lidar wind profiler. *In situ meteorology:* Vaisala T, RH, pressure, wind speed, wind direction, precipitation.
Ceilometer / Boundary Layer Height	Jim Szykman, EPA NERL. 🟢
Column NO_2, O_3, Formaldehyde	Pandora Ground-based Solar Spectrometer. Jim Szykman, EPA NERL. 🟢
O_3 Profiles by Tethered Balloon	Tether (ozone and meteorology) Sonde System, in conjunction with Dept. of Atmospheric Science, Univ. Wisconsin. 🟡
Other Mobile Platforms	
RV Lake Guardian, USEPA Great Lakes Monitoring Program	Research cruise dates to be determined. Discussions underway to carry lightweight autonomous samplers for formaldehyde, NO_2 and ozone as well as a ceilometer (boundary layer height) and Pandora (column O_3, NO_2 and formaldehyde). 🟡
GMAP / EPA region 5 Geospatial Measurement of Air Pollution (GMAP) mobile sampling system.	GMAP makes in situ measurements of a wide range of trace gases of relevance to LMOS 2017 via differential UV absorption spectroscopy (UV-DUVAS, Duvas Technologies, DV 3000) and of CH_4 and H_2S (Picarro) from a telescoping mast. To be deployed at Zion, & then used in mobile mode to map spatial gradients. Marta Fuoco, fuoco.marta@epa.gov 🟡

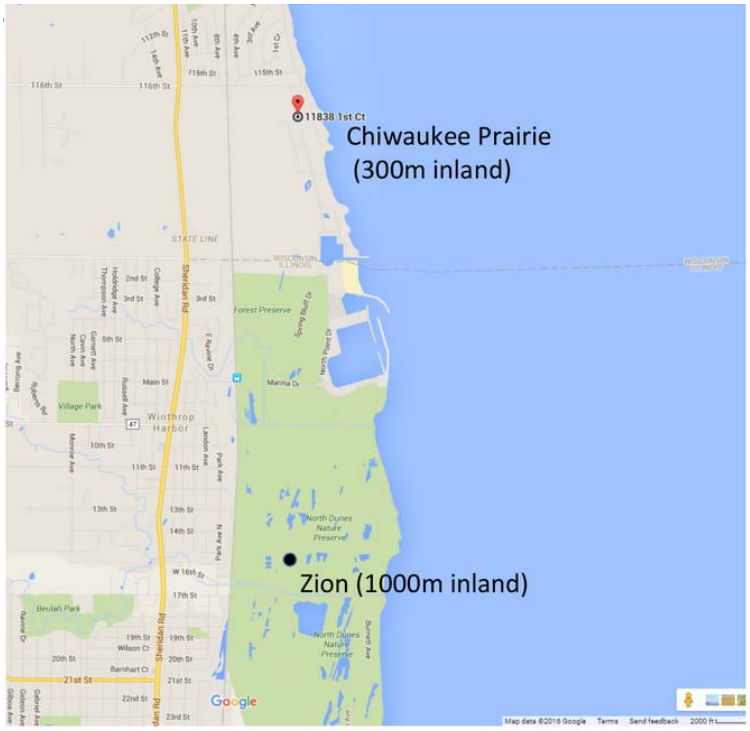

Figure 2. Location of the Zion sampling location within the green area (Illinois Beach State Park and the North Dunes Nature Preserve). The location of Wisconsin's Chiwaukee Prairie monitor is shown for reference.

Figure 3. Aerial image of the Zion sampling location (red box) relative to the coast.

Figure 4. Photographs of the operational O_3 trailer (left) used by Illinois EPA, and the vacant trailer (right) for LMOS 2017 *in situ* sampling.

Figure 5. RV Lake Guardian. 180 feet; 850 ton displacement. Source: http://oceanexplorer.noaa.gov/technology/vessels/lakeguardian/lakeguardian.html

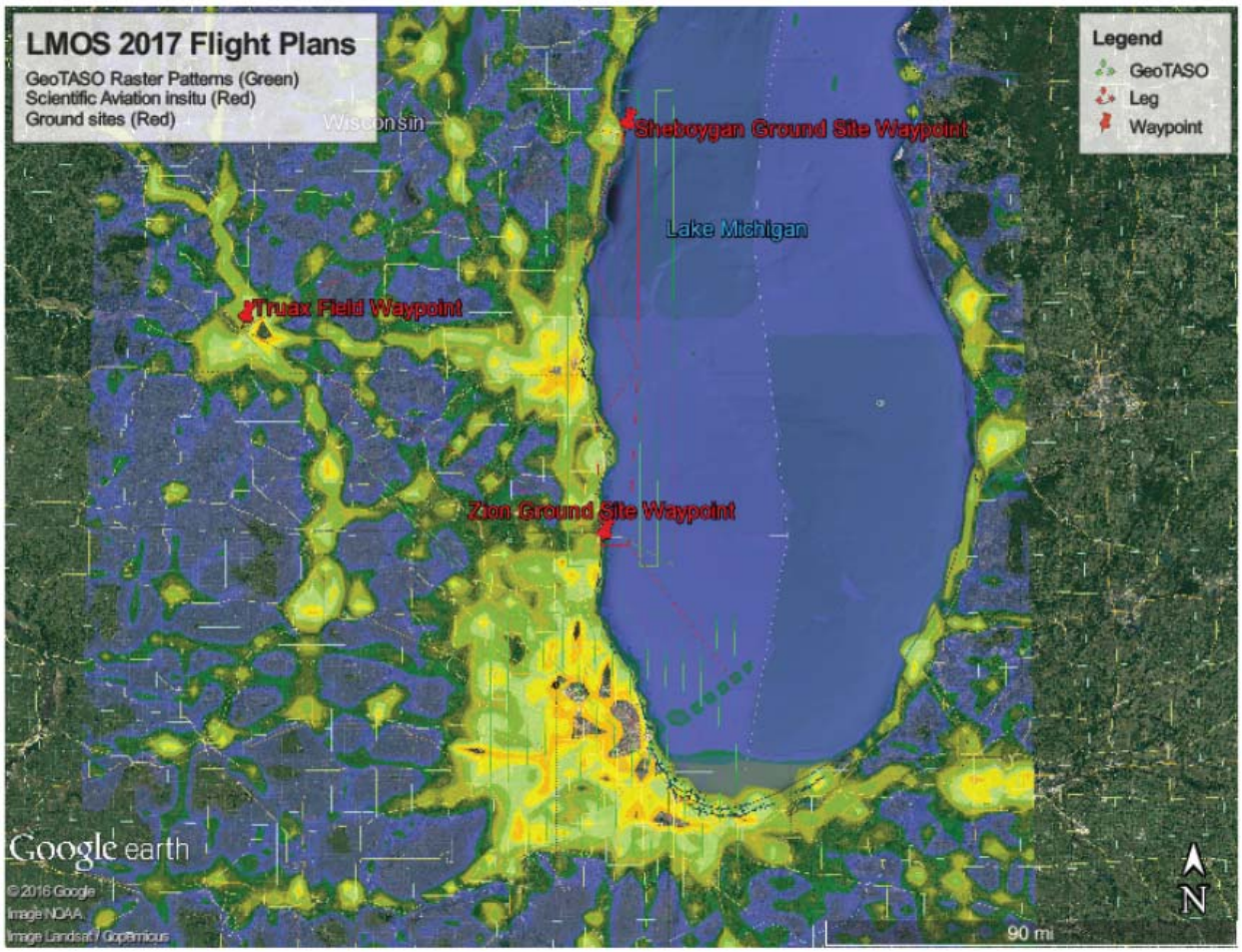

Figure 6. Sample GeoTASO Flight Plan overlaid on 2011 NEI 4km NO emissions. Source: Brad Pierce.

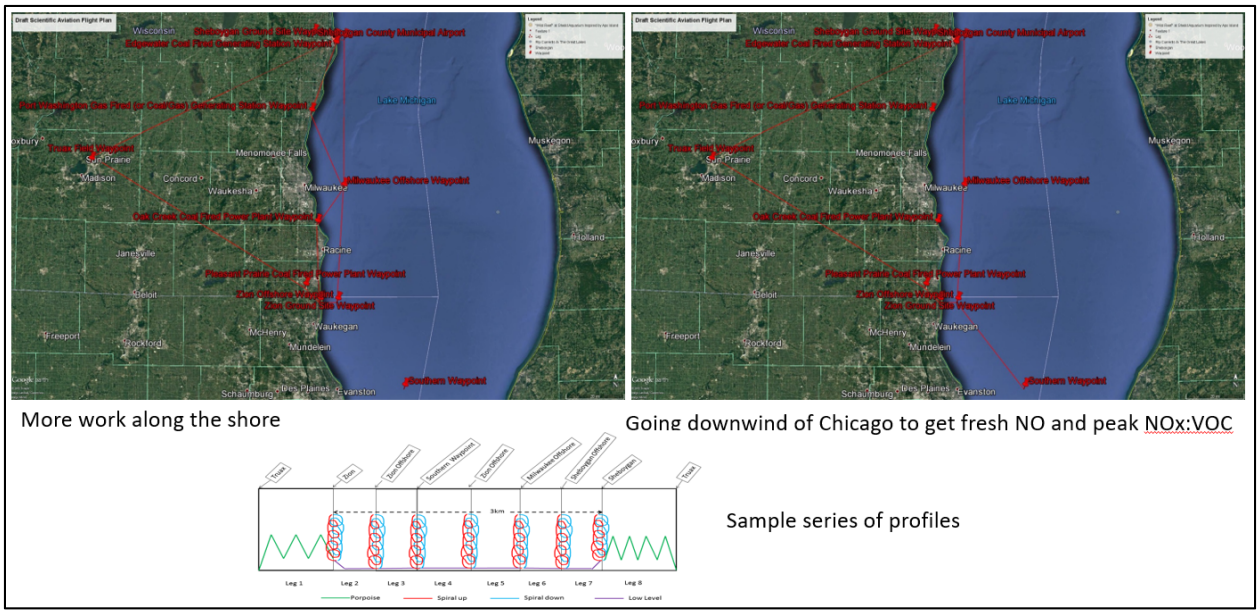

Figure 7. Sample Scientific Aviation Flight Plan

Google map image below showing the location of the Spaceport museum. Satellite image to show the parking location of the SPARC trailer.

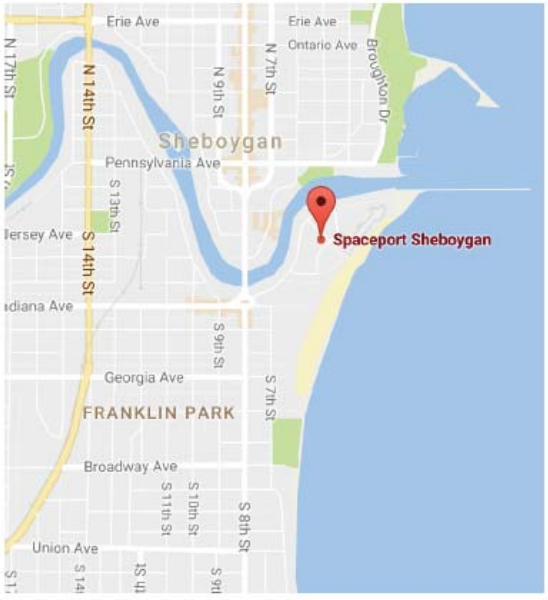

Figure 8. Spaceport Sheboygan Site

Figure 9. Streetview image of the Spaceport Museum from the East.

Figure 10. Exterior photos of EPA GMAP

The white paper is available at:
http://ladco.org/reports/ozone/post08/Great_Lakes_Ozone_Study_White_Paper_Draft_v6.pdf

Pierce, B., R. Kaleel, A. Dickens, T. H. Bertram, C. Stanier, and D. M. Kenski (2016), *White Paper: Lake Michigan Ozone Study 2017 (LMOS 2017)*.

[i] The NASA GEOstationary Coastal and Air Pollution Events (GEO-CAPE) Program has committed the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) instrument for the period May 22 – June 22, 2017. GeoTASO is a UV-Vis Spectrometer that retrieves column concentrations of nitrogen dioxide (NO2), formaldehyde (HCHO), and aerosol optical depth – enabling high resolution spatial mapping of these pollutants. Flight hours have been secured for GeoTASO's participation on NASA Langley Research Center Beechcraft UC-12 aircraft.