Utah Summer Ozone Study 2024 (USOS)

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The NOAA Chemical Sciences Laboratory (CSL) will conduct a study of summertime ozone in the Wasatch Front region of northern Utah in the summer of 2024. This region (population of 2.5 million and growing), exhibits regular exceedances of the National Ambient Air Quality Standard (NAAQS) for ozone. Measurements of the spatial distribution and speciation of major ozone precursors (NO_x and VOCs) and the structure of the planetary boundary layer within the Great Salt Lake basin, together with additional chemical measurements and meteorological data, will enable better understanding of the factors that lead to high ozone.

Scientific Objectives

The NOAA CSL summary of the study objectives is below.

1. Determine spatial distributions, speciation and sources of Volatile Organic Compounds (VOCs) in the Wasatch Front region. Sources and VOC classes to investigate will include, but not be limited to the following.
    a. Volatile Chemical Products (VCPs) from sources such as household chemicals, consumer products, cooking, etc.
    b. Biogenic hydrocarbons (BVOCs), including their transport from vegetated mountain regions and canyons surrounding the urban areas.
    c. Petroleum refineries in North Salt Lake and Davis Counties.
    d. Pyrogenic VOCs during wildfire impacted periods.
2. Determine spatial distributions, speciation and sources of nitrogen oxides (NO_x = $NO+NO_2$) and total reactive nitrogen, NO_y. Areas of interest include the following.
    a. Mobile source emissions from vehicles
    b. Industrial sources, including mining operations associated with Bingham Copper
    c. Soil NO_x from agricultural regions adjacent to the urban areas
3. Determine spatial distributions, speciation and sources of halogens, including chlorine, bromine and potentially iodine compounds. Emphasis on the following topics.
    a. Emissions, transport and chemical transformation from the US Magnesium facility
    b. Aerosolization and heterogeneous chemistry associated with the Great Salt Lake and surrounding playas
4. Characterize of important processes affecting the planetary boundary layer and transport of pollutants within and between basins within the region, with focus on

a. The lake-urban area interchange
b. Boundary layer growth and entrainment of the residual layer into the daytime convective boundary layer during morning hours.
c. The role of stagnant air periods in the build-up of O_3.
d. Characterize flow and transport patterns in complex terrain, such as canyon flows, upslope-downslope flows, and inter-valley exchange.

5. Determine the sensitivity of local O_3 formation to NO_x and VOCs, and potentially halogens, based on modeling of the observations listed above.
6. Determine of the influence of wildfire emissions on O_3 formation in the urban areas of the Wasatch Front.

Operations and Logistics

NOAA CSL will carry out the required observations through measurements on an instrumented mobile laboratory and light aircraft. This section also describes collaborative efforts, including additional field studies proposed through other agencies and satellite remote sensing capabilities.

NOAA CSL Mobile Laboratory

NOAA CSL has conducted recent air quality studies in U.S. urban areas using its mobile laboratory. These include the 2021 Southwest Urban NO_x and VOC Experiment (SUNVEx) and the 2018 New York Investigations of Consumer product Emissions (NYICE). CSL is in the process of upgrading the current mobile laboratory to increase instrument capacity and versatility. Figure 1 and Table 1 describe the mobile laboratory and proposed instrument suite for USOS. We anticipate the mobile laboratory will conduct a series of drives through the Wasatch region during the 5-week study period. We expect the drives to consist of repeat tracks through the urban regions and around major emission sources, to be defined in consultation with the Utah Department of Air Quality (UDAQ).

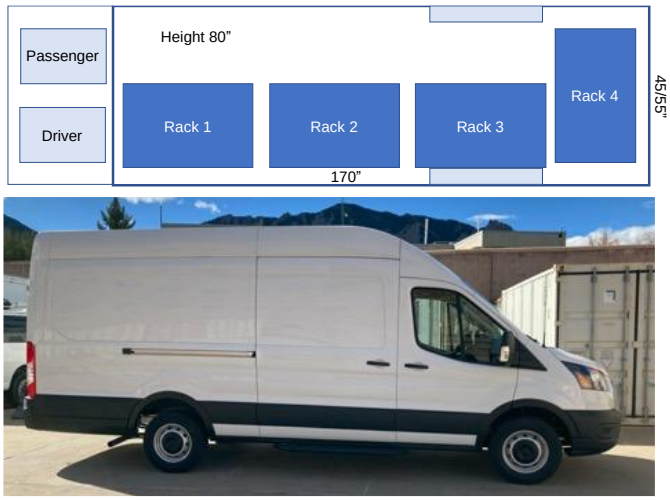

Figure 1: Photograph and planned layout of the CSL mobile laboratory

During periods when the Mobile Lab is not driving, it will operate as a fixed ground site at Rose Park, a long-term monitoring site maintained by UDAQ. This site is located in a residential area in the northern part of Salt Lake City, and lies between downtown, the Salt Lake International Airport, and regions of dense industrial activity. It is a region that regularly experiences high levels of O_3, but is not immediately next to any major emission sources such as highways.

Rack	Instrument	Species Measured
1	Met package	T, P, RH, Winds, GPS Position
1	Filter Radiometer	Actinic flux / NO_2 phot. rate
2	LIF NOy	NO, NO_2, NO_y, O_3
2	Formaldehyde Instrument *(tentative)*	CH_2O
2	Ultra High Sensitivity Aerosol Spectrometer (UHSAS)	Particle size distributions, surface area, PM mass
3	Picarro GHG analyzer	CO, CH_4, CO_2, H_2O
3	Iodide time of flight chemical ionization mass spectrometer (I^- ToF CIMS)	Speciated reactive N Speciated halogens Oxygenated VOC
4	Whole Air Sampler (WAS)	Speciated VOC analyzed by GC-MS
4	Proton transfer reaction time of flight mass spectrometer (PTR-ToF-MS)	In-situ speciated VOC

Table 1: CSL mobile laboratory instrument package. All instruments operate at 1 second time resolution except for the discrete WAS canister samples. All instruments are available from NOAA CSL and represent a research grade instrument suite for addressing ozone air quality.

NOAA Twin Otter Aircraft

The Atmospheric Remote Sensing Group (ARS) at NOAA CSL will deploy the Doppler Lidar, which maps the 3D wind velocities, turbulence and aerosol backscatter, on board the NOAA Twin Otter aircraft. The complex terrain in northern Utah plays an integral role in the structure of the boundary layer. The build-up of ground-level ozone is therefore tied to the dynamic behavior of the boundary layer. The lidar measurements can also provide key constraints on the role of the long-range transport of wildfire smoke.

The payload will also include an in-situ chemical package provided by the NOAA Air Resources Laboratory (ARL), which can measure O_3, NO_x, and greenhouse gases, The Twin Otter will make repeated surveys of the boundary layer at different times of day, altitudes and during different pollution conditions. thereby constraining the vertical distribution of these key pollutants above the urban areas of Salt Lake City.

NOAA Aircraft Operations (AOC) has granted 150 hours of flight time for flights in summer 2024 in Colorado and Utah. Following test flights and initial surveys in the Denver, CO area, the Twin Otter will base at Salt Lake International Airport (July 15 – August 11) and conduct roughly 25 flights of ~4 hour duration, in repeated flight plans designed to fully survey the Great Salt Lake basin.

Instrument	Measurement
Doppler Lidar	3D wind velocities, boundary layer height
Picarro GHG analyzer	CO, CH_4, CO_2, H_2O
Aeris MIRA Ultra	CH_4/C_2H_6
Teledyne CAPS	NO, NO_2

Ozone analyzer	O_3
Filter radiometers	Upward and downward actinic flux / NO_2 phot. rate
Met package	T, P, RH, Winds, GPS position

Table 2: NOAA Twin Otter instrument package during USOS. The Doppler Lidar, radiometers, and met package will be provided by NOAA CSL, while the in-situ chemical instruments will be provided by NOAA ARL

NOAA ARL Air Resources Car

In addition to the CSL Mobile Laboratory, the NOAA Air Resources Laboratory will also deploy its Air Resources Car (ARC) to Salt Lake City during USOS. The ARC is a modified commercial SUV and its payload includes research grade instruments for measuring NO_x, O_3, black carbon, PM, and greenhouse gases. The ARC and the Mobile Lab will coordinate drives to more fully investigate the horizontal distribution of primary pollutants near point and area sources.

Upward-facing remote sensing spectrometers

To further constrain the vertical structure of O_3 and key precursors such as NO_2 and HCHO, upward-facing remote sensing instruments will be used. JPL will provide two SMOL miniature ozone lidars, deployed as part of the TOLNet network. These will be installed at existing UDAQ monitoring sites. Additionally, the Pandora network of NO_2 and HCHO spectrometers already includes a spectrometer at UDAQ's Hawthorne site, and up to two more may be available during summer 2024. It is expected that these data products will provide a valuable connection between the ground-based Mobile Lab observations and the aircraft and satellite-based remote sensing observations (see below).

Other concurrent field studies

In addition to USOS, the Great Salt Lake area will host several summer campaigns in the summer of 2024, focusing on air quality (led by Colorado State University and the University of Wyoming) and urban greenhouse gas emissions (led by the University of Utah). Additionally, UDAQ and academic partners maintain an extensive network of long-term monitoring stations of air quality and weather. These stations are based a ground sites, mobile sites such as the TRAX light rail system, and laboratories at the University of Utah. The USOS campaign will work closely with UDAQ and its academic partners to collaborate on data collection and data distribution.

TEMPO Satellite

The Tropospheric Emissions Monitoring of Pollution (TEMPO) instrument is expected to be fully operational in the summer of 2024. It is an ultraviolet / visible spectrometer in geostationary orbit that measures atmospheric composition, including NO_2, CH_2O and CHOCHO (glyoxal), proxies for NO_x and VOCs that are relevant to ozone formation. It may also provide measurements of BrO to constrain halogen species. NOAA CSL has already led in one major airborne field intensive (AEROMMA) in 2023 that will assist with the validation of TEMPO. The TEMPO satellite provides hourly column products

across the CONUS, but also has the ability to conduct sub-hourly high time-resolution scans across smaller areas. USOS has been provisionally granted a number of these sub-hourly scans in 2024 in order to explore the use of this new remote sensing tool to define the spatial distribution of NO_x and VOC sensitivity in ozone photochemistry, as well as to constrain halogen emissions and their role in ozone production.

Schedule

In accordance with the requested period of operations specified by UDAQ, NOAA CSL will conduct 5 weeks of mobile lab measurements (July 15 - August 18) and 4 weeks of aircraft measurements (July 15 – August 11). These dates span the periods of greatest frequency of ozone exceedance events in July and the most probable occurrence of wildfire influence in August.

Figure 2 shows map of the Northern Wasatch Front ozone non-attainment area (NAA) with existing monitoring sites that could be considered for planning of CSL mobile laboratory drives, and target areas for Twin Otter flights.

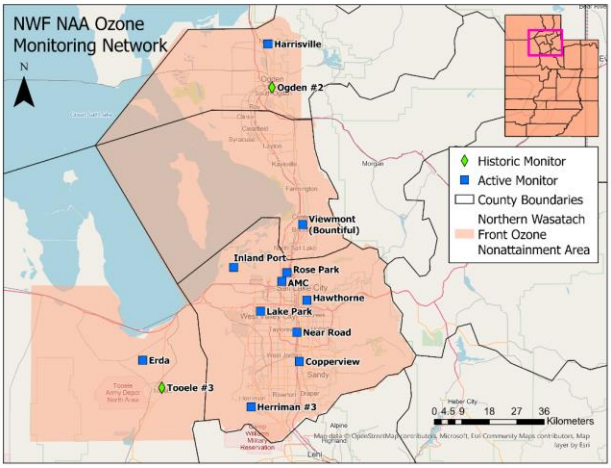

Figure 2: Map of Northern Wasatch Front ozone non-attainment area. Map courtesy of UDAQ

Modeling Support

In addition to the field intensive and observations, NOAA CSL will conduct analysis and modeling of the data. NOAA CSL will perform three-dimensional chemical transport modeling utilizing WRF-Chem. The three-dimensional modeling allows for simulation of chemistry with meteorology, and to directly assess heatwaves, biogenic and wildfire emissions, and interstate transport of air pollution on the Wasatch Front Region. Figure 3 shows the NOAA CSL WRF-Chem setup, which includes a 12 km x 12 km contiguous US simulation that provides boundary conditions for a nested 4 km x 4 km regional domain over the Mountain West. We will simulate the entire period of the measurement campaign. The NOAA CSL WRF-Chem settings are listed in Table 2. The WRF-Chem model will be evaluated with the field-intensive atmospheric observations, routine air quality monitoring, and satellite remote sensing data, including analysis of formaldehyde columns and point source VOC emissions.

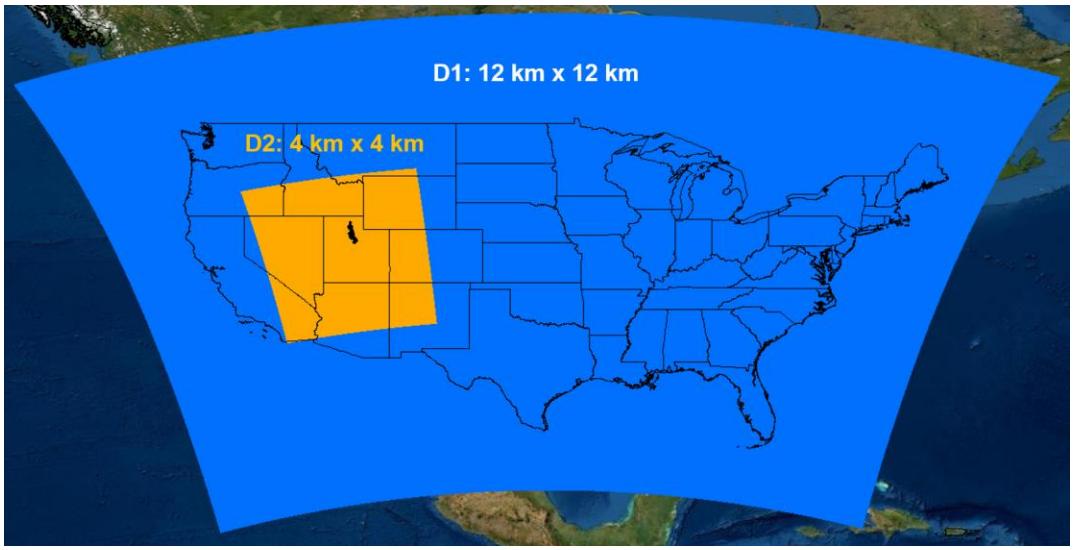

Figure 3. Map of WRF-Chem model domain including an outer domain (D1) of the contiguous US at 12 km x 12 km horizontal spatial resolution that feeds an inner domain (D2) of the Mountain West at 4 km x 4 km horizontal spatial resolution. The Wasatch Front Region is denoted by the dark black outline.

Table 3. NOAA CSL WRF-Chem Model Configuration.[a]

Settings	**Description**
Horizontal Resolution	12 km x 12 km + nested Western US 4 km x 4km domain
Vertical Resolution	50 levels (up to 50 hPa)
Meteorology	North American Mesoscale Model
Surface Layer	Mellor-Yamada Nakanishi and Niino
Planetary Boundary Layer	Mellor-Yamada Nakanishi and Niino Level 2.5
Cumulus Scheme	Grell-Devenyi (GD) Ensemble Cumulus
Land Surface	Noah Land Surface Model
Microphysics	WRF Single Moment 5-Class
Short- and Long-Wave Radiation	Rapid Radiative Transfer Model for General Circulation Models
Gas-Phase Chemistry	RACM-ESRL-VCP (updated oxy-VCP chemistry)
Photolysis	Madronich Photolysis (TUV)

a. See http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3/contents.html for full description of model options.

NOAA CSL will augment the WRF Chem modeling with 1-D chemical box modeling, similar to CSL's analysis used for the 2017 Utah Winter Fine Particulate Study (UWFPS). The goal of USOS box modeling will be to assess NO_x and VOC sensitivities, the influence of halogens on summer ozone, and the influence of wildfires on locally produced and transported ozone.

Anticipated Deliverables

NOAA CSL will adhere to reporting requirements as specified in agreement with UDAQ. The goal of reporting and analysis will be to provide timely information in support of the schedule for the Utah SIP requirements. We anticipate the following deliverables.

- Archiving of quality-controlled data from the NOAA study and collaborators on a publicly accessible, NOAA CSL maintained web site.
- Archiving of model results, as appropriate, accessible to UDAQ
- A preliminary report of findings, to be delivered at a time to be agreed upon by UDAQ and CSL
- A final report and executive summary, to be delivered as agreed upon by UDAQ and CSL
- Peer reviewed publications in the scientific literature describing major results from the study over a period of 1-3 years after conclusions of the field intensive
- Presentations at scientific conferences, such as the American Meteorological Society and American Geophysical Union
- A data and science meeting, to be held approximately 1 year after the study to discuss scientific results with UDAQ, regional stakeholders, air quality managers and scientists.