Credit: Chelsea Thompson, NOAA

USOS Monthly Meeting #1

January 24, 2024

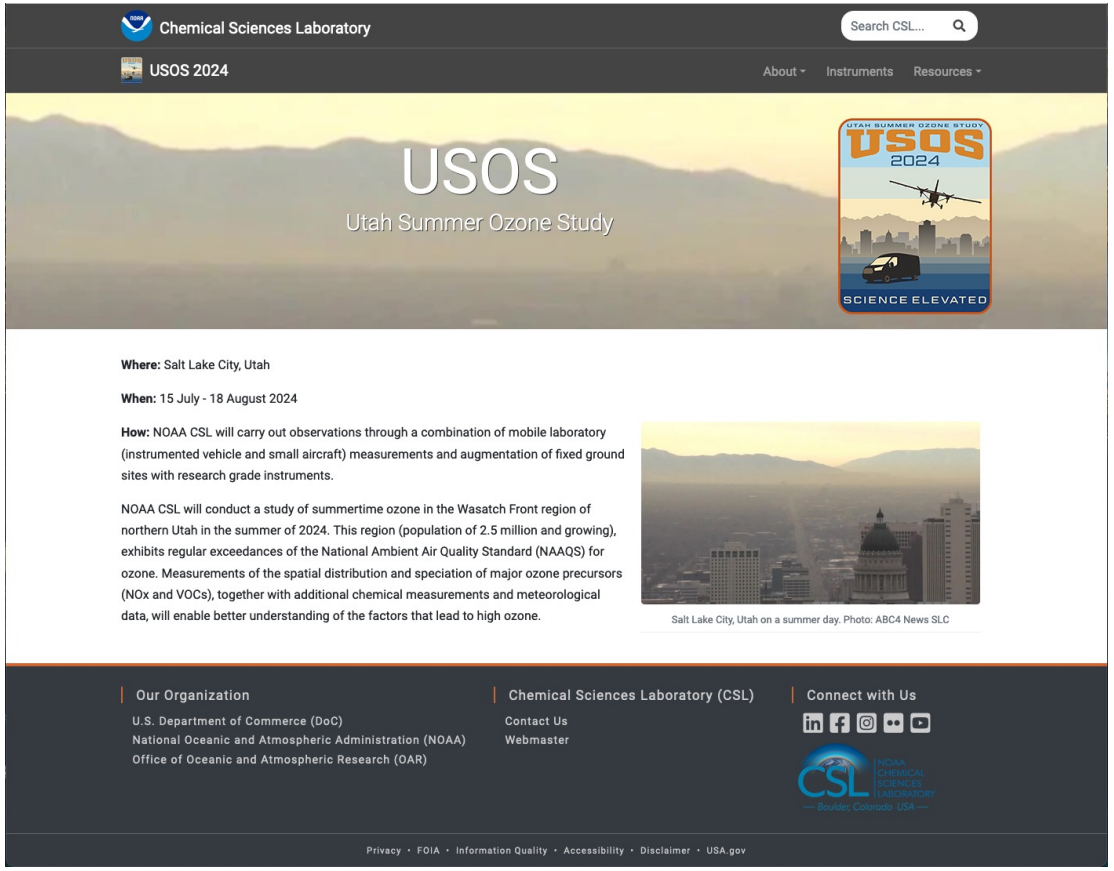
Next meeting: February 21, 1pm Mountain Time
To be added to email list: email caroline.womack@noaa.gov

Agenda

- Outline of USOS scientific goals and updated website (5 min)
- Introduction of team members and points of contact (5 min)
- Status updates from other campaigns and opportunities for cross-collaboration (25 min)
  - Emily Fischer/Shane Murphy: SLC-SOS
  - John Lin: MEEPC
  - Ongoing measurements from UDAQ, past campaigns, TEMPO
- Logistics (data management, travel schedules, etc.) (10 min)
- Open discussion (15 min)

USOS website has been updated

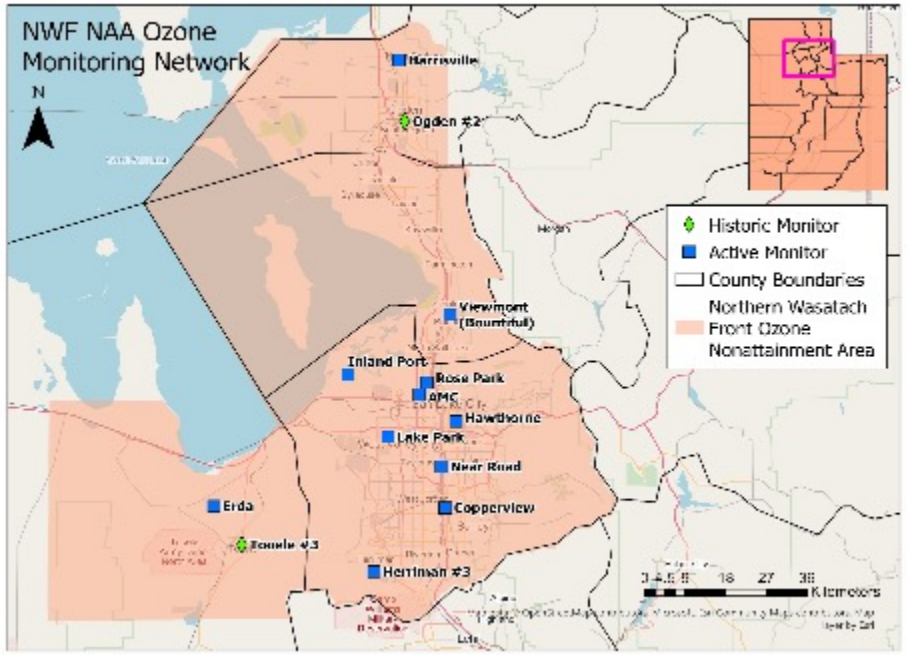
https://csl.noaa.gov/groups/csl7/measurements/2024usos/



<u>Now available:</u>
Updated white paper
Updated payload
Planning calendar

<u>To be added soon:</u>
Data repository
News & Media
Meeting slides

USOS scientific goals



Map courtesy of UDAQ

What are the drivers of high ozone pollution in the summer in the Salt Lake Valley?

Role of NOx and VOC emissions
Role of meteorology
Wildfire smoke
Diurnal patterns
Role of canyon flows
Lake breeze
Industrial and biogenic halogens

USOS: Conduct 5 weeks of measurements by mobile vans, aircraft, and remote sensing
Integrate these measurements into the wider range of existing observations to achieve a holistic look at air quality in SLC

USOS platforms

NOAA Twin Otter

Instrument	Measurement	Institution / PI
Doppler Lidar	3D wind velocities	NOAA CSL / Sunil Baidar, Alan Brewer, Max Holloway, Scott Sandberg
Picarro GHG analyzer	CO, CH_4, CO_2, H_2O	NOAA ARL / Xinrong Ren
Aeris MIRA Ultra	CH_4/C_2H_6	NOAA ARL / Xinrong Ren
Teledyne CAPS	NO, NO_2	NOAA ARL / Xinrong Ren
Ozone analyzer	O_3	NOAA ARL / Xinrong Ren
Filter radiometers	Up/down actinic flux / NO_2 phot. Rate	NOAA CSL
Met package	T, P, RH, Winds, GPS position	NOAA CSL

Based at Salt Lake International
~100 flight hours
July 15 – August 11

NOAA CSL Mobile Lab

Instrument	Species Measured	Institution / PI
Met package	T, P, RH, Winds, GPS Position	NOAA CSL
O3 analyzer	O_3	NOAA CSL
LIF NOy	NO, NO_2, NO_y	NOAA CSL / Drew Rollins, Eleanor Waxman, Wyndom Chace, Kristen Zuraski
Formaldehyde Instrument	CH_2O	EPA ORD / Russell Long
UHSAS	Particle size distributions, surface area, PM mass	NOAA CSL / Chuck Brock
Filter Radiometer	Actinic flux / NO_2 phot. Rate.	NOAA CSL
Picarro GHG analyzer	CO, CH_4, CO_2, H_2O	NOAA CSL / Jeff Peischl, Nell Schaefer
I- CIMS	Speciated reactive N Speciated halogens Oxygenated VOC	NOAA CSL / Mike Robinson, Chris Jernigan
Whole Air Sampler (WAS)	Speciated VOC analyzed by GC-MS	NOAA CSL / Jessica Gilman, Victoria Treadaway, Morgan Selby
PTR-MS	In-situ speciated VOC	NOAA CSL / Carsten Warneke, Chelsea Stockwell, Matt Coggon, Kelvin Bates

Based at Rose Park.
~100 drive hours
July 15 – August 18

NOAA ARL Air Resources Car (ARC)

Instrument	Species Measured	Institution / PI
Picarro G2401	$CO_2/CH_4/CO/H_2O$	NOAA ARL
Aeris Ultra	CH_4/C_2H_6	NOAA ARL
Picarro G2201-i	$^{12}CH_3/^{13}CO_2$ isotopes	NOAA ARL
AE43 Aethalometer	Black carbon mass	NOAA ARL
Met package	T, P, RH, Winds, GPS position	NOAA ARL
2B Tech O3	O_3	NOAA ARL
Teledyne N500 CAPS	NO, NO_2, NOx	NOAA ARL

Likely based at Tech Center
July 15 – August 11

Two JPL Small Mobile Ozone Lidars (SMOL)

Likely based at Hawthorne and Tech Center
July 15 – August 18

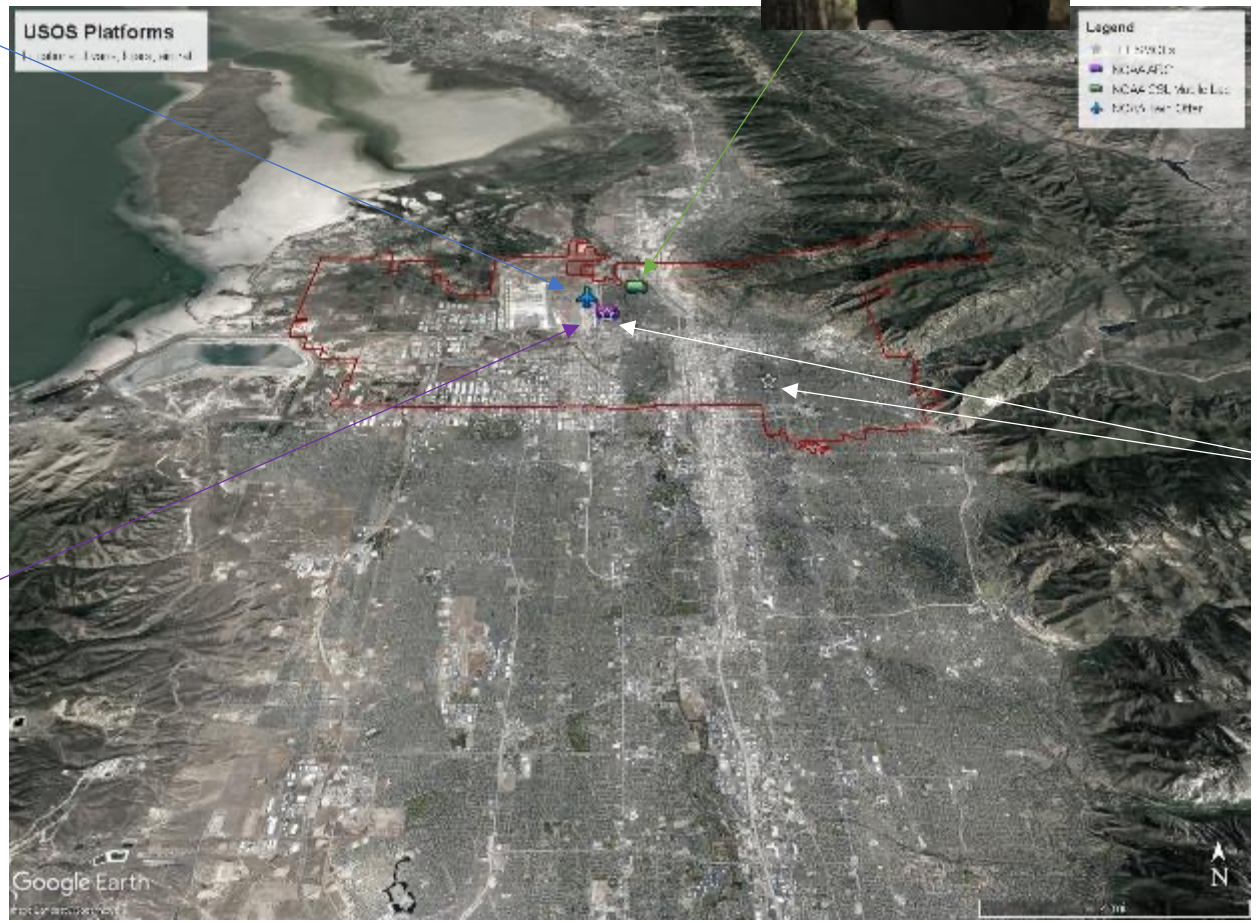
USOS Point of contacts

NOAA Twin Otter

Sunil Baidar
Sunil.baidar@noaa.gov

NOAA Mobile Lab

Carrie Womack
Caroline.Womack@noaa.gov



JPL SMOLs

Thierry Leblanc
thierry.leblanc@jpl.nasa.gov

NOAA Air Resources Car

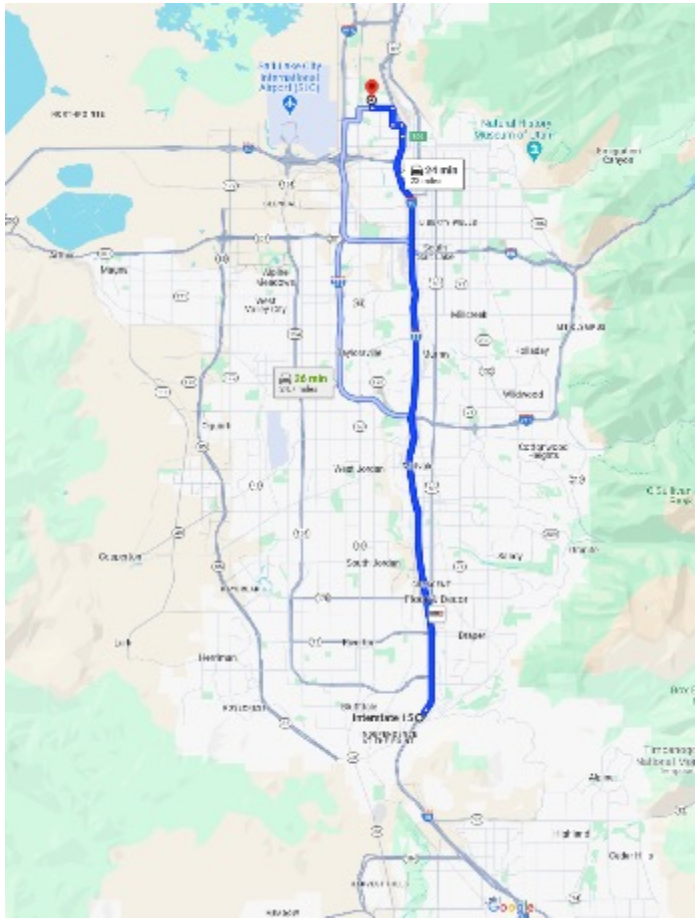
Xinrong Ren
Xinrong.ren@noaa.gv

CSL Modeling contact: Brian McDonald (brian.mcdonald@noaa.gov)

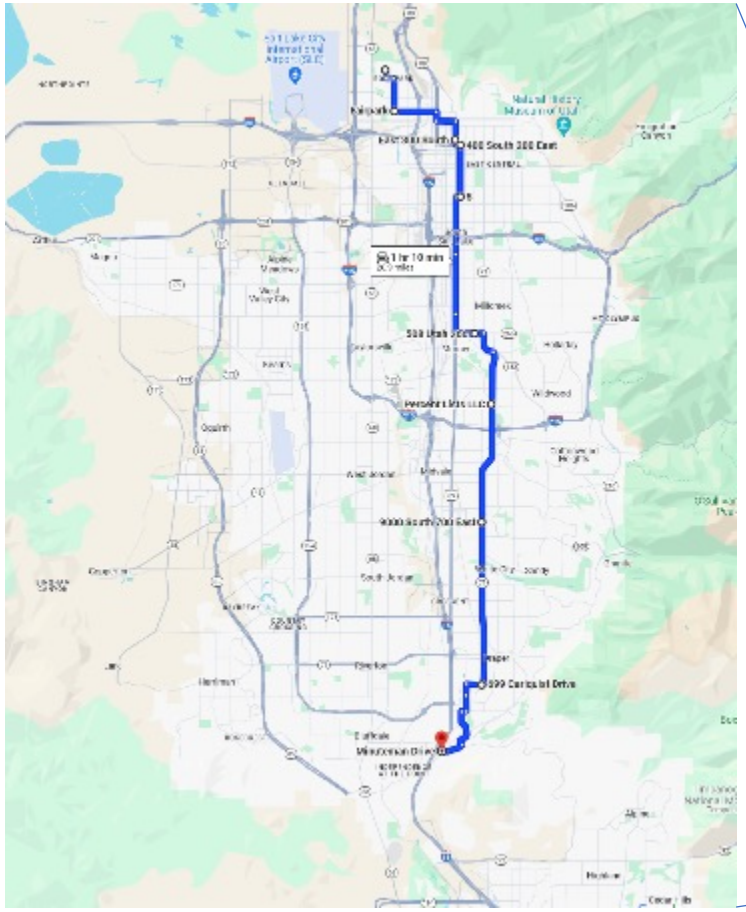
UDAQ Project contacts: Rachel Edie (redie@utah.gov) and Chris Pennell (cpennell@utah.gov)

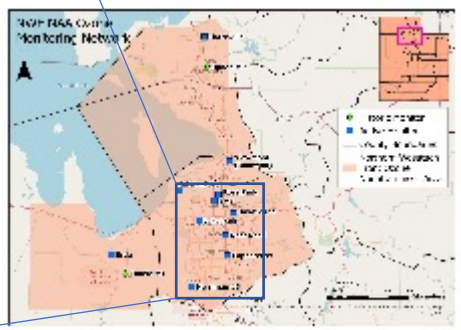
Drives will survey the valley

24 minutes to transect valley via I-15

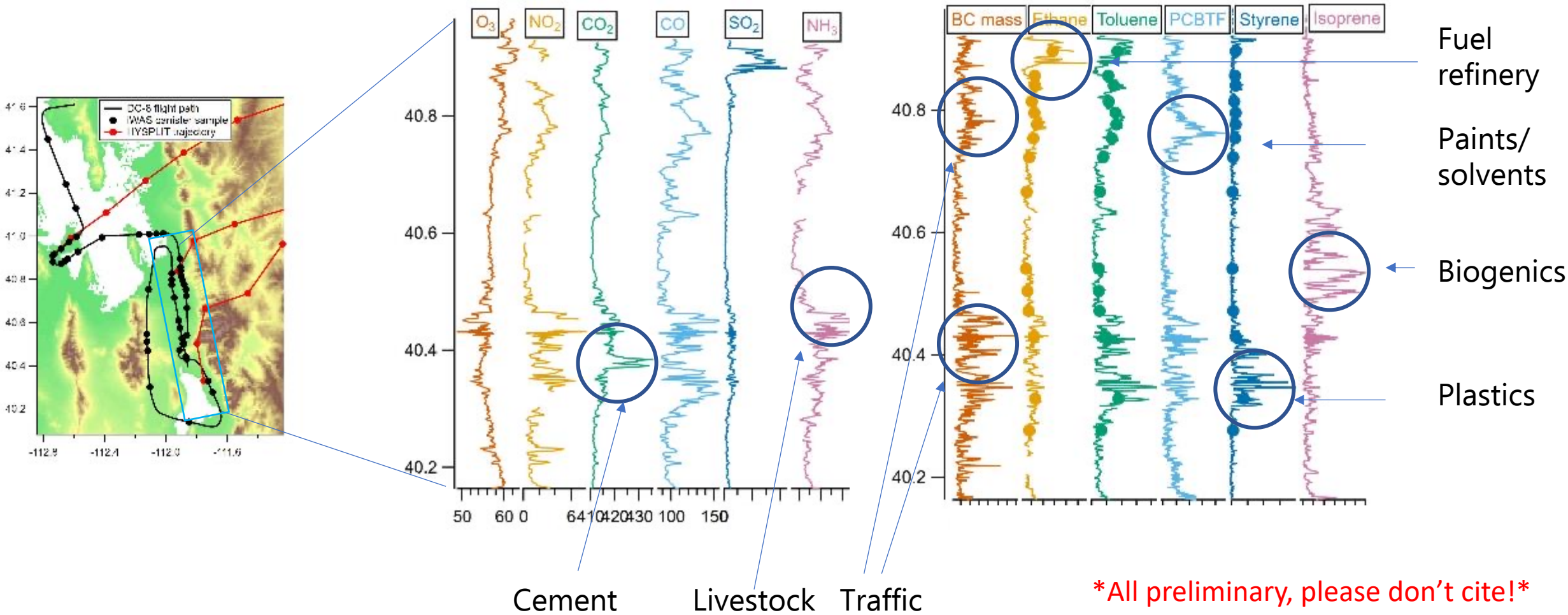


70 minutes to transect valley via surface roads





Sneak peak at some AEROMMA data



Other Projects in SLC in August 2024

- Salt Lake City Summer Ozone Study (SLC-SOS)
  - Instruments deployed on Wyoming Mobile Lab in August 2024
  - Second deployment on NSF/UW King Air in Summer 2025
  - Team: Emily Fischer, Ilana Pollack (CSU), Lu Hu, Wade Permar (Montana), Reem Hannun (NASA), Gannet Hallar (Univ. of Utah)
  - Focused on Ozone Formation Chemistry in SLC

- Methane Emissions from Energy Production to Consumption (MEEPC)
  - Instruments deployed on Wyoming Mobile Lab in August 2024, again in winter 2025
  - Team: John Lin (Univ. of Utah), Seth Lyman (Utah State), Shane Murphy, Jeff Nivitanont, Matt Burkhart (Wyoming)
  - Focused on Quantification of Methane sources in SLC additional work in Uintah Basin.

Wyoming Mobile Research Lab

*Able to operate while driving or stationary

*Can be a ground site when plugged in

Mobile Lab Instrumentation For August 2024

Instrument (Manufacturer, Operator)	Parameters Measured	Sampling rate
CAPS (Aerodyne, CSU)	NO, NO_2	1 Hz
Proton Transfer Reaction-Time of Flight Mass Spectrometer (Ionicon, Montana)	Volatile Organic Compounds (VOCs)	1 Hz
Rapid Ozone Experiment (Nasa)	Ozone	1 Hz
MIRA Ultra Gas Analyzer (Aeris, Wyoming)	Methane, Ethane	1 Hz
10 Species Multi-Gas-Analyzer (MIRO, Wyoming)	CO, CO_2, NO, NO_2, CH_4, SO_2, NH_3, H_2O, O_3, OCS	1 Hz
All-in-one (AIO) Compact Weather Station (Climatronics Model 102780)	Wind Speed and Direction, Relative Humidity, Temperature, Pressure	1 Hz
High-Resolution Differential GPS (Hemisphere GPS Model R100)	Position to within ~1 m	1 Hz

LAND ATMOSPHERE INTERACTIONS RESEARCH

UNIVERSITY OF UTAH

Utah Greenhouse Gas and Air Quality Sites

Real-time CO_2 & CH_4 data plotted at: https://air.utah.edu/

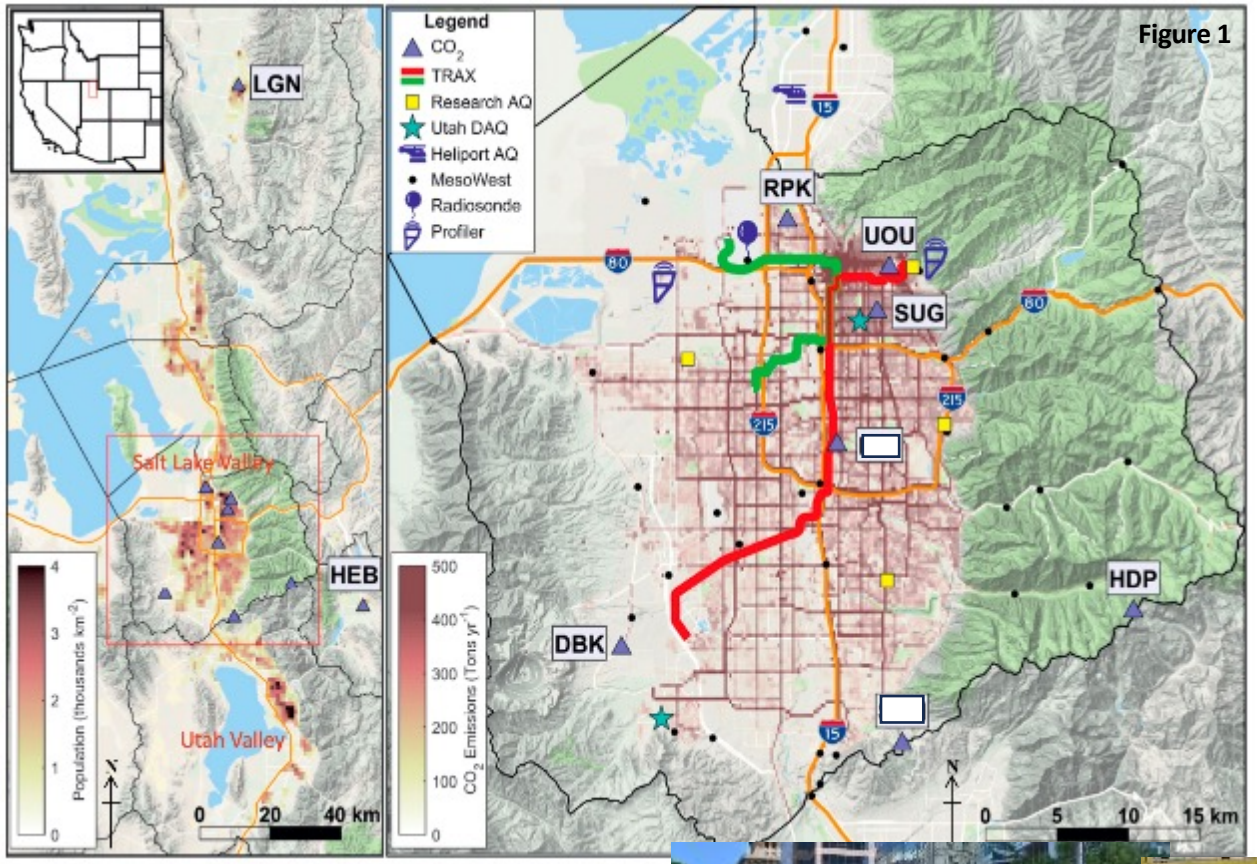


TABLE 1. The urban CO_2 sites along the Wasatch Front in northern Utah. NCAR: National Center for Atmospheric Research.

Site code	Site name	Lat (°N)	Lon (°W)	Elevation (m MSL)	Inlet height (m AGL)	Start year	Notes
DBK	Daybreak	40.5383	112.0697	1,582	5.05	2004	Prior to Oct 2015 inlet height was 9 m AGL
HEB	Heber	40.5067	111.4036	1,721	4.2	2015	
HDP	Hidden Peak	40.5601	111.6454	3,351	17.1	2006	Responsibility of HDP site shifted to the University of Utah from NCAR in 2016
LGN	Logan	41.7616	111.8226	1,392	3.23	2015	
RPK	Salt Lake Center for Science Education	40.7944	111.9319	1,289	3.25	2009	
SUG	Sugarhouse	40.7398	111.8580	1,328	3.86	2005	Moved to the current location from a similar residential location 1.45 km away on 29 Jan 2008
UOU	University of Utah	40.7663	111.8478	1,436	36.2	2001	Moved to the current location from a separate building ~250 m away on campus in 2015

TRAX light rail obs:
CO_2, CH_4, O_3, NO_2, $PM_{2.5}$

* Figures were adapted from Lin et al. 2018

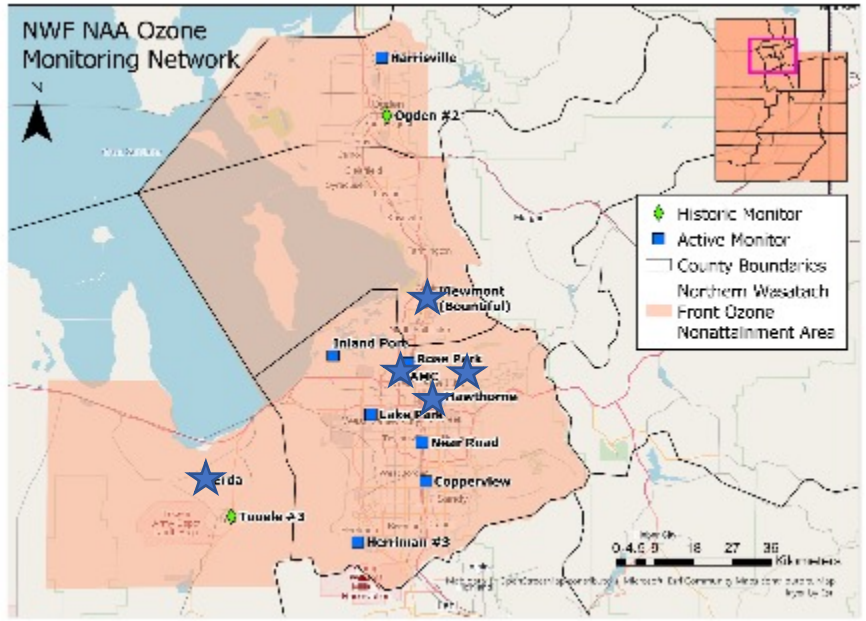
LAND ATMOSPHERE INTERACTIONS RESEARCH

UNIVERSITY OF UTAH

Univ. of Utah campus observations on William Browning Building (not including those in Hallar lab)

Instrument	Chemical Species	Instrument Type	Units
Teledyne T200	NO, NO_2, NO_X	Stationary	ppb
Teledyne T500u	NO_2	Portable/TRAX	ppb
Teledyne T300	O_3	Stationary	ppm
Teledyne T400	CO	Stationary	ppb
LGR UGGA	CO_2, CH_4, H_2O	Stationary/Portable	ppm
2B Technology O_3	O_3	Portable/TRAX	ppm
2B Technology NO_X	NO_2, NO, NO_X	Portable	ppb
Met One Instruments ES642 Remote Dust Monitor.	Particulate Matter > 2.5 ($PM_{2.5}$)	Stationary/Portable	$\mu g/m^3$
Pandora Spectrometers * Boston University/ NASA	O_3, NO_2, CH_2O	Stationary/Column	Total Column [DU]
EM27 Spectrometers * Harvard University & LANL	CO_2, CH_4, CO	Stationary/Column	Total Column [ppm]

Long-term measurements from UDAQ



Site	Weather	NOx and O_3	PM	GHG	VOCs	Remote sensing	Other	
Harrisville	Yes	O_3, NO_2	$PM_{2.5}$, PM_{10}	CO				
Bountiful	Yes	O_3, NO_2, NOx, NOy	$PM_{2.5}$, PM_{10}, Speciated $PM_{2.5}$, Metals in PM_{10}, aethalometer		GC	Ceilometer		★
Hawthorne	Yes	O_3, NO_2, NOx, NOy	$PM_{2.5}$, PM_{10}, Speciated $PM_{2.5}$	CO	GC, HCHO	Ceilometer, Pandora NO_2	SO_2, HCl	★
Herriman	Yes	O_3, NO_2	$PM_{2.5}$, PM_{10}					
Copperview	Yes	O_3, NO_2	$PM_{2.5}$	CO			SO_2	
Inland Port	Yes	O_3, NO_2	$PM_{2.5}$					
Lake Park	Yes	O_3, NO_2	$PM_{2.5}$					
Near Road	No	O_3, NO_2	$PM_{2.5}$	CO				
Rose Park	Yes	O_3, NO_2	$PM_{2.5}$	CO			SO_2	★
Tech Center	Yes	O_3, NO_2, NOx, NOy	$PM_{2.5}$, PM_{10}	CO	GC, HCHO	Ceilometer x 2	SO_2, HCl	★
Red Butte	Yes	O_3, NO_2, NOx, NOy	$PM_{2.5}$		GC, HCHO	Ceilometer		★
Erda	Yes	O_3, NO_2, NOx, NOy	$PM_{2.5}$		GC, HCHO		HCl	

★ = EPA Photochemical Assessment Monitoring Station (PAMS)

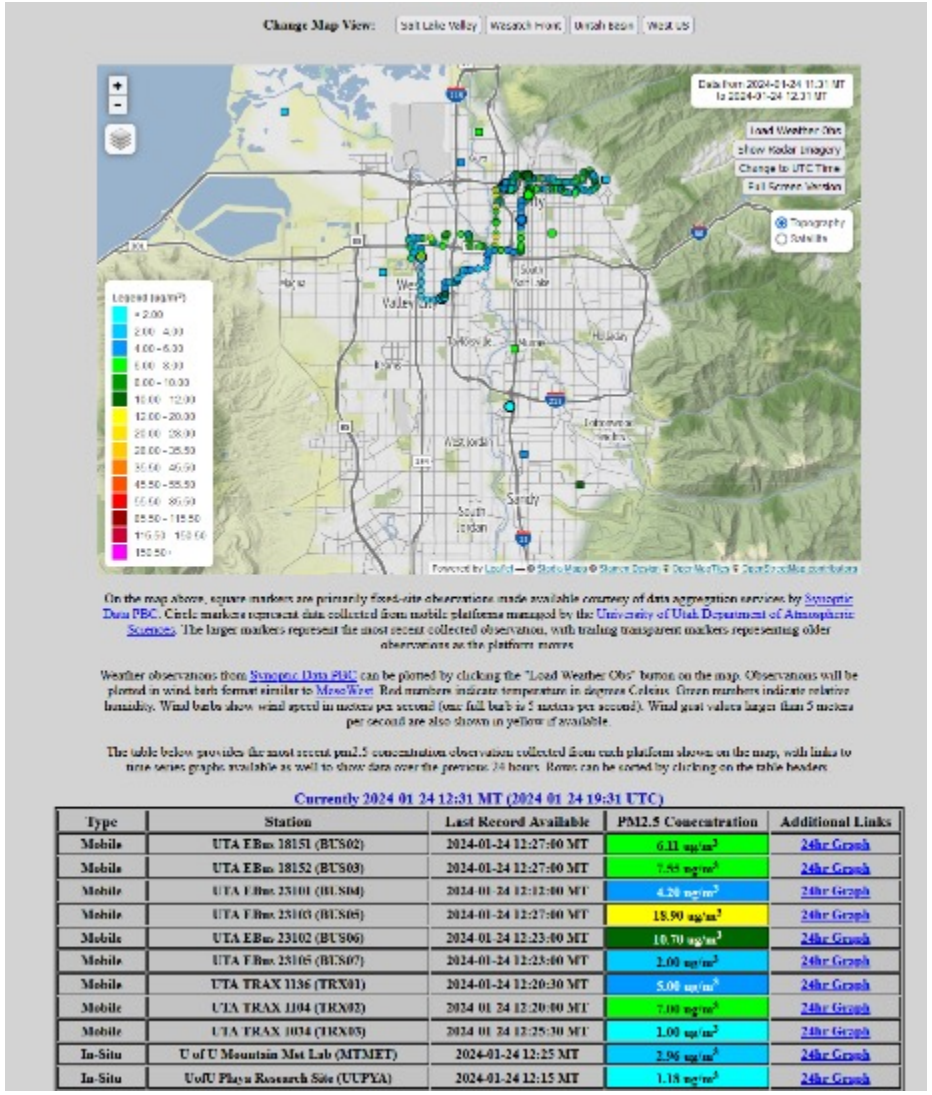
Previous field campaigns in SLC

Dates	Name of Campaign, if any	Season(s)	Valley(s)	Site(s)	Main purpose	Measurements beyond normal UDAQ sampling	Literature	UDAQ page, if DEQ-funded
Jan - Feb 2007	N/A	Winter	Utah	Lindon AQS	Wintertime aerosol	1hr PM2.5, PM10, PM2.5 sulfate and nitrate, BC. 24hr PM2.5 and PM10 by filter, met data	Hansen et al, 2010 - https://doi.org/10.3155/1047-3289.60.3.346	
Jan - Feb 2009	N/A	Winter	Salt Lake	Hawthorne AQS	Wintertime aerosol	Added an AIM for speciated PM2.5, gas phase HONO, HNO3, SO2. Can't tell whether this is just from the UDAQ station	Kuprov et al, 2014 - http://dx.doi.org/10.1080/10962247.2014.903878	
Dec 2010 - Feb 2011	Persistant Cold Air Pools Study (PCAPS)	Winter	Salt Lake	Multiple sites	Boundary layer meteorology	Remote sensing: Wind (scanning Doppler lidar, minisodar, NCAR wind profiler), Vertical temperature (NCAR RASS, microwave radiometer), aerosol and hydrometeor back scatter (ceilometer). Surface met: wind speed, T, RH, radiometer, soil temperature. Set of 5 automated weather stations (AWS) along Traverse Mountains, Hobo dataloggers on three slopes. Radiosondes, powerglider. Aerosol samplers	Lareau et al - http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00255.1 Silcox et al - http://www.sciencedirect.com/science/article/pii/S1352231011011204 Crosman et al, 2017 - http://www.sciencedirect.com/science/article/pii/S0169809516303878 Hall et al, 2014 - https://www.sciencedirect.com/science/article/pii/S135223101400689X Crosman et al, 2016 - https://doi.org/10.1007/s10546-015-0117-6 Sun et al, 2017 - https://journals.ametsoc.org/view/journals/apme/58/12/jamc-d-19-0053.1.xml Foster et al, 2017 - https://doi.org/10.1007/s10546-017-0240-7	
Feb 2012	N/A	Winter	Salt Lake	Hunter High School	Salt Lake vs Las Vegas	BC, CNC, PM10, met, solar radiation	Brown et al, 2017 - https://doi.org/10.1080/10962247.2016.1270236	
Oct 2012 - Feb 2014	N/A	All	Salt Lake	UU AQS Hawthorne AQS Rose Park AQS	Sources of VOCs	48hr filter samples, over 2 weeks at a time in each seaon. Used for 14C analysis	Mouteva et al, 2017 - https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017JD026519	
Jan - Dec 2015	2015 Toxics Study	All	Utah and Salt Lake	West Valley AQS Bountiful AQS Lindon AQS	Sources of VOCs	Carbonyls and VOCs into canisters. Once every 3 days	Kuprov et al (Final Report)	https://deq.utah.gov/air-quality/air-toxics-study-i
Jan - Feb 2015	N/A	Winter	Utah	BYU campus	Wintertime aerosol	Organic aerosol by GC-MS, PM2.5 mass, PM2.5 ions, BC (didn't work), ammonia, nitric acid, NOx, O3, took CO from UDAQ monitor, aerosol scattering	Cropper et al, 2018 - https://doi.org/10.1080/10962247.2017.1363095	
June - Aug 2015	Great Salt Lake Summer Ozone Study	Summer	Salt Lake	Multiple sites	Summer ozone	16 extra O3 sensors, lidar, ceilometers, mini-sodars, ozonesondes, O3 sensors on UTA, KSL helicopter	Horel et al (Final Report) Horel et al, 2016 - https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/asl.680 Blaylock, et al, 2017 - https://journals.ametsoc.org/view/journals/apme/56/2/jamc-d-16-0216.1.xml	https://deq.utah.gov/air-quality/great-salt-lake-summer-ozone-study
June - Aug 2015	GSL Ambient HCl Study	Summer	Salt Lake	Multiple sites	Distribution of halogens	14 passive samplers for HCl	Martin et al (Final Report)	https://deq.utah.gov/air-quality/great-salt-lake-ambient-hydrochloric-acid-study
Dec 2015 - Feb 2016	Salt Lake Valley Wintertime PM2.5 Study	Winter	Salt Lake	UU AQS Hawthorne AQS Neil Armstrong Academy	Wintertime aerosol	CO, O3, NOx, CO2, CH4, H2O, N2O5, NO3	Baasandorj et al, 2017 - http://dx.doi.org/10.1021/acs.est.6b06603 Bares et al, 2018 - https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017JD027917	https://deq.utah.gov/air-quality/winter-inversion-study
Dec 2015 - Feb 2016 and June - Aug 2016	West Valley Air Toxics Study	Winter/Summer	Salt Lake	Neil Armstrong Academy	Wintertime aerosol	PM2.5, AIM aerosol ions, BC, CO, O3, NOx, PTR-MS, GC-MS Organic aerosol	Barickman et al (Final Report) Cropper et al, 2019 - https://www.sciencedirect.com/science/article/pii/S1352231019306107	https://deq.utah.gov/air-quality/west-valley-toxics-study
Jan - Feb 2017 and June - July 2017	Saturation Air Toxics in Davis County	Winter/Summer	Salt Lake	Multiple sites	Source of VOCs	Carbonyls and VOCs into canisters. 2x per day for 5 consecutive days	Daher et al (Final Report)	
Jan - Feb 2017	Utah Winter Fine Particulate Study (UWFPS)	Winter	Utah, Salt Lake, Cache	Lindon AQS UU AQS Logan AQS NOAA Twin Otter	Wintertime aerosol	Twin Otter: NOx, O3, NOy, halogens, HNO3, N2O5, AMS, NH3, UHSAS. UU site: HCHO, AIM, PTR	Baasandorj et al (Final Report) Franchin et al 2018 - https://www.atmos-chem-phys.net/18/17259/2018/acp-18-17259-2018.html McDuffie et al 2019 - https://www.atmos-chem-phys.net/19/9287/2019/ Moravek et al 2019 - https://www.atmos-chem-phys.net/19/15691/2019/ Womack et al 2019 - https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL082028 Hrdina et al 2021 - https://acp.copernicus.org/articles/21/8111/2021/ Womack et al 2023 - https://doi.org/10.1021/acs.est.2c05376	https://deq.utah.gov/air-quality/utah-winter-fine-particulate-study-uwfps

Previous field campaigns in SLC

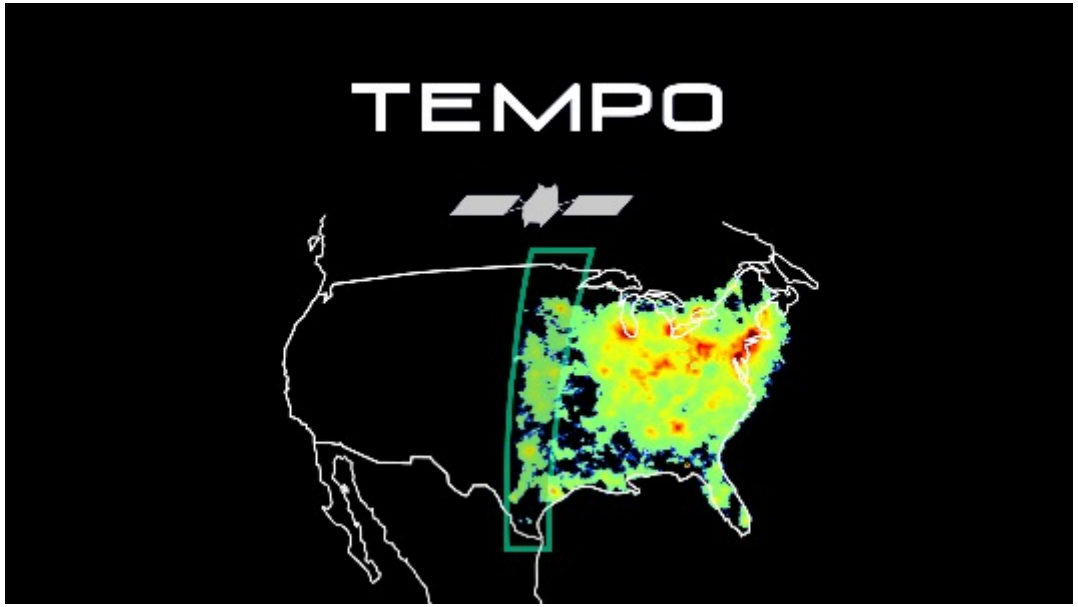
Dates	Name of Campaign, if any	Season(s)	Valley(s)	Site(s)	Main purpose	Measurements beyond normal UDAQ sampling	Literature	UDAQ page, if DEQ-funded
Fall 2018 - Fall 2019	N/A	All	Salt Lake	Multiple sites	GSL dust events	18 Dust trap samplers, analyzed strontium ratio (playa vs dust), as well as other metals	Putman et al, 2022 - https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2022GH000671	
Jan - Mar 2019	Jordan Narrows Gap Ammonia Transport Study	Winter	Salt Lake	Multiple sites	Boundary layer meteorology	Wind LiDAR, AWS, Ceilometers	Hoch et al (Final Report)	https://deq.utah.gov/air-quality/jordan-narrows-gap-ammonia-transport-study
Feb - April 2019	N/A	Winter/Spring	Salt Lake	Bountiful AQS	Source of VOCs	2h HCHO, O3, NOx, BTEX, GC-MS OAM, plus used historical canisters taken every 6 days	Hansen et al (Final Report) Bhardwaj et al, 2021 - https://www.mdpi.com/2073-4433/12/3/375	
May 2019 - March 2020	N/A	All	Salt Lake	Multiple sites	Greenhouse gases	CH4, CO2, PM2.5, BC, NOx on two Google Street View cars	Lin et al 2023 - https://www.sciencedirect.com/science/article/pii/S1352231023004211	
July 2019 - Dec 2020	Characterizing Air Quality Impacts from Exceptional Events	All	Utah	Provo AQS	GSL dust events	Biweekly PM2.5, PM10, TSP filters, metal analysis	Carling et al (Final Report)	https://deq.utah.gov/air-quality/characterizing-air-quality-impacts-from-exceptional-events-along-the-wasatch-front
Sept 2019 and Jan-Feb 2020	Idle-Free Campaign	Winter/Summer	Salt Lake	Bonneville Elementaryand Willow Spring Elementary	Public health and policy	CH4, CO2, NOx, PM2.5, O3, met & weather	Mendoza et al, 2022 - https://www.mdpi.com/2073-4433/13/5/706	
Oct 2019 - July 2021	Red Butte Ozone Study	All	Salt Lake	Red Butte Canyon	Summer ozone	O3 sensors along Red Butte Canyon	Mitchell et al (Final Report)	https://deq.utah.gov/air-quality/the-red-butte-canyon-ozone-network-leveraging-existing-infrastructure-to-probe-background-concentrations-canyon-flows-and-stratospheric-oxidant-exchange
June - September 2022	Impacts of the Great Salt Lake on Summer Ozone Concentrations	Summer	Salt Lake	Multiple sites	Summer ozone	Supplemented existing met measurements with more for summer 2022	Horel et al (Final Report)	https://deq.utah.gov/air-quality/impacts-of-the-great-salt-lake-on-summer-ozone-concentrations-along-the-wasatch-front
Aug - Oct 2022	SAMOZA	Summer	Salt Lake	Tech Center AQS	Summer ozone	O3, PTR-MS, carbonyls by canister, CO	Jaffe et al, (Final Report)	https://deq.utah.gov/air-quality/the-salt-lake-regional-smoke-ozone-and-aerosol-study-samoza

TRAX and Electric buses



- UDAQ-UofU collaboration (2014 – present)
- NOx, O_3, $PM_{2.5}$ sensors on TRAX and electric buses
- Real-time data available
- Contacts: Daniel Mendoza, John Horel, John Lin

TEMPO: Tropospheric Emissions Monitoring Pollution



Successful launch in 2023

First light on August 2, 2023

Expected to be fully operational in summer 2024

Up to 25% of TEMPO's operations will be devoted to "special operations"

Salt Lake City is slated to be scanned sub-hourly… as long as special operations are enabled by summer 2024

Summary of measurements

- 15 stationary sites
- 3 mobile laboratories
- 1 aircraft
- Up to 3 TRAXs, up to 12 electric buses
- 1 – 3 Pandora NO_2 spectrometers, two O_3 lidars, two EM27 GHG spectrometers, 5 ceilometers, daily radiosonde launches
- Dozens of weather stations
- TEMPO sub-hourly scans
- …Maybe more?

Logistics – Data management

- USOS will use the ICARTT format (https://www-air.larc.nasa.gov/missions/etc/IcarttDataFormat.htm) and will host data on the CSL website
- MEEPC (GHG): https://air.utah.edu/
- TRAX/E-bus: https://meso2.chpc.utah.edu/aq/cgi-bin/current_map.cgi
- UDAQ monitoring sites: https://air.utah.gov/
- SMOL TolNET: https://www-air.larc.nasa.gov/missions/TOLNet/
- Pandora NO2: https://pandora.gsfc.nasa.gov/

Logistics - travel

NOAA Twin Otter

S	M	T	W	T	F	S
JUN 23	24	25	26	27	28	29
30	JUL 1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	AUG 1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24

- Installation/deinstallation in Broomfield, CO
- Test & research flights in Denver-Julesburg, CO
- Transit to/from Utah
- Research flights in Salt Lake City

NOAA Mobile Lab

S	M	T	W	T	F	S
JUN 23	24	25	26	27	28	29
30	JUL 1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	AUG 1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24

- Transit to/from Utah
- Deployment in Salt Lake City

Last updated 4 Jan 2024

Open discussion