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Statement of work:
Jordan Narrows Gap Ammonia Transport Study - Meteorological Support and Observations

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This statement of work (SOW) summarizes the meteorological observations, analysis, and forecast support to be conducted between **(?)15 December and 30 January (?)**, 2019 in support of the ***(?) Utah Ammonia Air Quality Study (?).***

Background: This study is a follow-on to the January 2017 Utah Winter Fine Particulate Study (UWFPS). UWFPS was a collaborative effort between National Oceanic and Atmospheric Administration (NOAA), United States Environmental Protection Agency (US EPA), Utah Division of Environmental Quality (UDEQ), the University of Utah and other universities to investigate meteorological and chemical processes driving the wintertime fine particulate pollution in the Salt Lake, Cache, and Utah Valleys. One of the outcomes of the UWFPS study (Brown et al. 2018 report) was that a better understanding of ammonia sources and concentrations in the Salt Lake Valley is needed, including improved understanding of the role of air mass exchange and ammonia transport between the Salt Lake and Utah Valleys. This study will provide key meteorological support for the chemistry observations during the upcoming 2018-2019 winter season focusing on ammonia transport and air mass exchange between the Salt Lake and Utah Valleys.

Importance of work covered by this SOW: Basic meteorological guidance through observations, analysis, and weather forecasts of air mass exchange through the Jordan Narrows gap between the Salt Lake and Utah Valleys are necessary for 1) successful intensive observation planning and decision making, 2) characterization of persistent cold-air pool (PCAP) evolution, 3) identification of meteorological processes within the evolving PCAPs affecting air mass exchange, with a focus on the gap flows between the Salt Lake and Utah Valleys, but also including such processes as surface-based mixing and PCAP erosion.

Task 1 - Meteorological Observations in the Jordan Narrows Gap

The meteorological measurements planned for the study to evaluate the meteorological influences on air mass exchange (and thus ammonia transport) through the Jordan Narrows gap are individually addressed below. Quality controlled datasets will be stored for future processing by collaborators, and overviews of the observations ("quicklooks") will be made available regularly via web page access during the field campaign.

1.1 Aerosol backscatter profiles from CL31 ceilometer

A Vaisala CL31 ceilometers will be operated in the Jordan Narrows (JN) gap during the experiment. Backscatter profiles will be available every 16 seconds for 10 m layers at elevations from ~50 above ground level up to 7700 m above the surface. Aerosol backscatter is a qualitative

proxy for aerosol concentration and size. An increase in aerosol backscatter usually indicates an accumulation of particulate pollution in the atmosphere but can also result from changes in aerosol size and/or chemical composition.

1.2 Wind profile in the Jordan Narrows gap from Doppler wind LiDAR retrievals

Vertical profiles of the horizontal wind field will be measured every 15 minutes using Vertical Azimuth Display (VAD) retrievals from a Halo Photonics Streamline Doppler wind LiDAR. The wind profile will be available at 20-50 m elevation intervals for heights from ~80 to ~1200 m above ground level. Successful retrievals will depend on atmospheric aerosol loading in the Atmospheric Boundary Layer (ABL). The LiDAR will be deployed in the Jordan Narrows (JN), to resolve the wind profile throughout the entire depth ABL. The vertically and temporally highly resolved wind profiles will help to understand the air mass exchange between the Salt Lake Valley (SLC) and the Utah Valley (UV), forced by either thermal contrasts or by synoptic pressure gradients. Under persistent cold-air pool (PCAP) conditions a shear layer will indicate the cold pool top at the basin air mass interface.

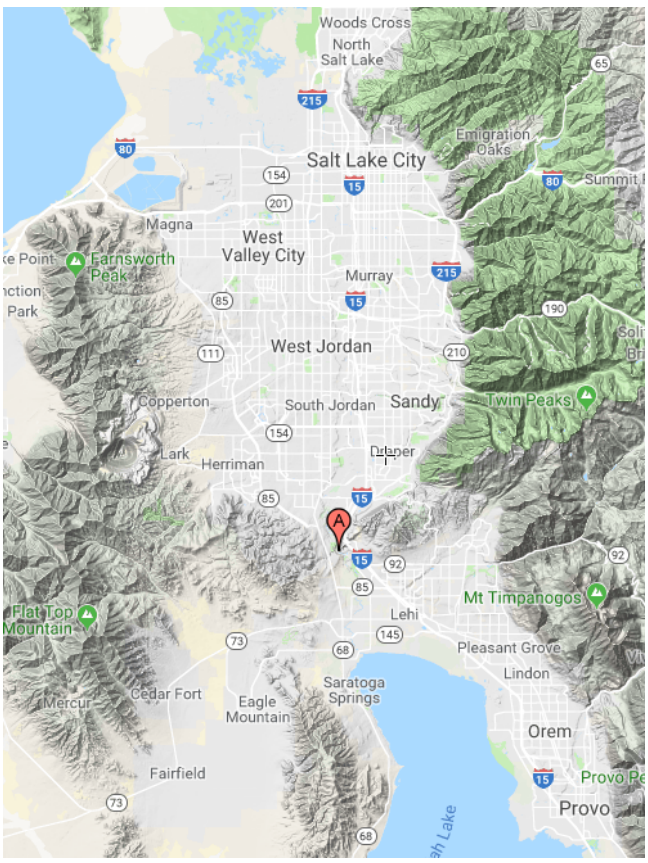


Figure 1: Topographic map of the southern part of the Salt Lake Valley Basin and northern part of the Utah Valley (source: Google). Highlighted is the observation in the Jordan Narrows (JN) gap, where the wind LiDAR and ceilometer will be deployed.

Table 1: Observation sites in the Salt Lake Valley.

Site Name	Site Abbreviation	Elevation (m ASL)	Latitude (°N)	Longitude (°E)
Jordan Narrows	JN	1355 m	40.4705	-111.9328
AWS-1	*UU-1*	*TBD* m	*TBD*	*TBD*
AWS-2	*UU-2*	*TBD* m	*TBD*	*TBD*

For VAD retrieval, the LiDAR requires an unobstructed view of the sky at zenith angles of 0-40 degrees. A location for the deployment has not been finalized, but we anticipate finding and negotiating site access to a suitable (i.e. necessary sky view, safety, security, power access) site. DAQ has previously deployed sensors at Camp Williams and will share their contact information with us.

2.3 Basic weather observations

Basic meteorological variables (wind speed and direction, temperature and relative humidity) are MesoWest stations throughout the SLC and UV. Two additional automatic weather stations (AWS) will be deployed in the vicinity of the JN site to fill observational gaps. These location will be identified through upcoming discussions with the other PIs of the ***(?) Utah Ammonia Air Quality Study (?)***.

2.4 Additional observations

The twice-daily radiosonde ascents from the Salt Lake International Airport (KSLC) will be used to calculate and monitor the evolution of the Valley Heat Deficit (VHD) in the SLV during the experimental phase. The VHD is a measure of cold-pool strength and had been shown to correlate with particulate pollution concentrations. See also Task 3.

Task 2 - Meteorological Analysis

The temporal evolution of the valley cold air pool and air mass exchange at the interface between the Utah and Salt Lake City basin will be investigated based on the aerosol backscatter, vertical wind profiles, National Weather Service radiosonde-based temperature profiles, and additional vertical profiles of temperature obtained from the KSL helicopter, and the TRAX mobile platforms.

2.1 The Valley Head Deficit (VHD) is a measurement of the amount of energy that would be needed to bring a valley or basin atmosphere to a neutral stratification. Calculations will be performed using the twice-daily radiosondes launched by the National Weather Service (NWS) at the Salt Lake International Airport (KSLC). For the Salt Lake Valley, the elevation range between 1300 m asl (valley floor) and the height of 2200 m asl, corresponding to the mean ridge height surrounding the valley, are used. Calculations of VHD reveal the episodes of high atmospheric stability during the passage of high-pressure centers across Northern Utah. Figure 2 shows the analysis for the 2015-2016-winter season.

2.2 Aerosol Backscatter: Figure 3 shows an example of a time-height cross-section of aerosol backscatter (color contours) from a CL31 laser ceilometer during the onset of the 6-16 February 2016 pollution episode. Overlaid are the wind vectors indicating the horizontal wind field retrieved from the Doppler wind LiDAR. Variations in aerosol backscatter point to changes in aerosol concentration or characteristics, mixing height, and to advective and convective processes within the PCAP.

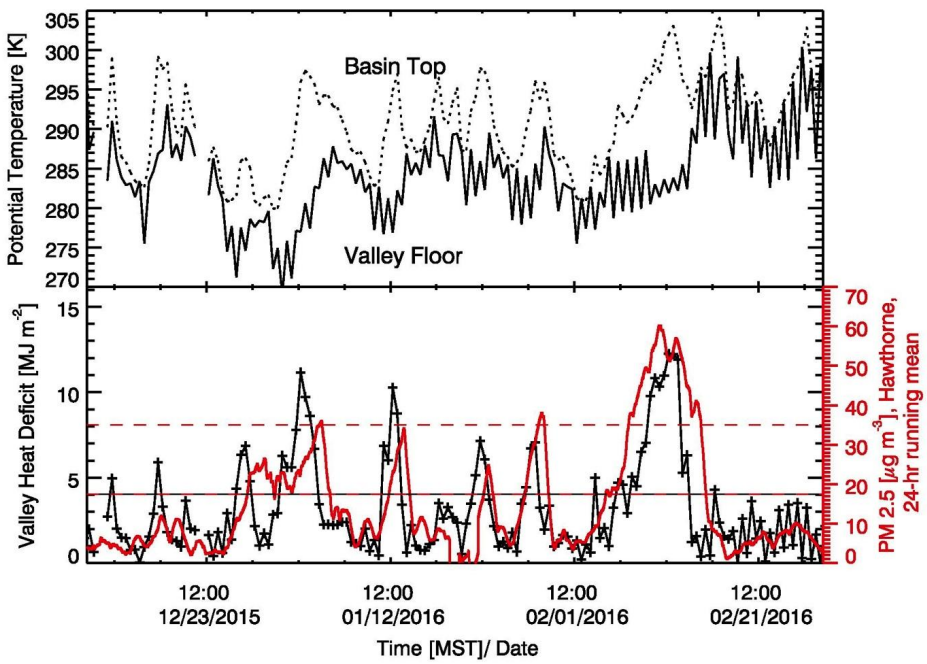


Figure 2: Potential temperature at the base and top of the Salt Lake City Basin from radiosonde observations by the National Weather Service (top), and the Valley Heat Deficit (VHD, black) and the smoothed observations of $PM_{2.5}$ pollutant concentrations (red) from the UDAQ Hawthorne site for the 2015-2016 winter season. Note that the horizontal dashed line marks the NAAQS for $PM_{2.5}$ and the horizontal red-black dashed line marks the VHD threshold value of 4.04 MJ m^{-3} and a $PM_{2.5}$ concentrations of 17.5 μg m^{-3}.

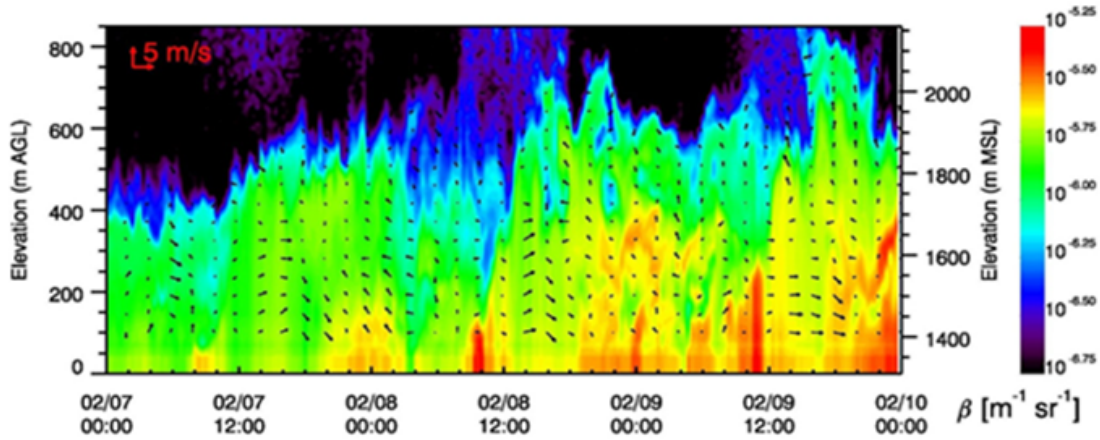


Figure 3: Time-height cross-section of aerosol backscatter at the UDAQ Hawthorne during the initial three days of the build-up period of the 6-16 February 2016 pollution episode. Color contours show backscatter coefficient β. The vertical profile of horizontal winds is shown as vectors.

<u>2.3 Air mass exchange</u> through the Jordan Narrows are expected to impact aerosol concentrations and ammonia concentrations as a result of differential PCAP evolution in the two adjacent topographical basins. We will to evaluate the occurrence, strength and temporal variation of these flows based on the LiDAR observations.

Task 3 - Forecast Support

Weather briefings will be prepared on an as-needed basis for science and field deployment needs. The forecasts will be provided for the basins of northern Utah and will be tailored to fit the specific needs of the science operations planning team.

3.1 Weather Forecast Support

24-7 forecast support will be provided via a private cell phone line in case conditions change rapidly and nowcasting assistance is needed.

3.2 Forecast Products and Weather Forecast Blog

The weather forecasts will be provided on a website similar to that used during the UWFPS study in 2017 (http://uwfps.blogspot.com/). The forecasts will focus on PCAP structure and evolution. Specifically**:** PCAP start and end times and detailed PCAP characteristics (depth, intensity, cloud cover, fog, visibility, ceiling height, wind speed, temperature). This collected information will result in a meteorological event log, which will be one of the deliverables and will be available to all investigators of the ammonia study for future reference of events.

3.3 Forecast Funnel Approach

The forecasts will consist of the following components:

A. Long-term outlook, 5-8 days before: upper-level evolution.
B. Mid-term outlook, 2-4 days before: upper-level evolution, winds aloft and in boundary layer, cloud cover and visibility, PCAP intensity and depth, surface conditions (snow cover, lake temperature).
C. Short-term outlook 6-36 hours before: All the components in B), with the addition of greater forecast specificity for spatial and temporal variations in cloud cover, visibility, PCAP vertical structure, and outlook for gap flows and lake-induced flows
D. Nowcast, 0-6 hr before: All of the components in A) and B), with the addition of observational products (i.e., ceilometers, LiDAR, Mesowest, satellite, etc) to diagnose the current conditions and to inform short-term changes in the PCAP structure and evolution.

3.4 Numerical and observational forecast guidance used

Numerical models that will be used to provide forecasts include (1) the local NOAA National Weather Service Weather Research and Forecast (WRF) model, (2) the National Center for Environmental Prediction (NCEP) Global Forecasting System (GFS), (3) the NCEP High Resolution Rapid Refresh Model (HRRR), (4) the NCEP North American Model (NAM), and (5) the NCEP Short Range Ensemble Forecast (SREF) model suite. The numerical model forecasts will be supplemented with all available observational networks (e.g., snow depth observations, ceilometers, LiDAR, KSL chopper and TRAX observations, radiosondes, satellite imagery) to provide the highest accuracy of short-term forecasts possible.

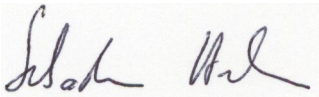
Deliverables:

- Quarterly activity reports
- A short final report will be delivered two month after the end of the field observations
- Quicklook graphics (LiDAR wind field, ceilometer backscatter, AWS time series) will be available on a publicly-accessible website provided to DEQ as a stand-alone archive.
- Processed LiDAR data (VAD retrieved wind fields, ascii data)
- Ceilometer data (raw, hexadecimal ascii)
- AWS data sets (csv)

Budget: 12/01/2018- 06/31/2019

Personnel Costs, Hoch (1.0 months)	$6,178
Personnel Costs, Crosman (1.0 months)	$5,856
Fringe Benefits (37%)	$4,452
Repairs and Maintenance	$300
Supplies	$500
Other (cell modem, power, Truck use)	$450
Total Direct Costs	$17,736
Indirect Costs	$1,774
Total Costs	$19,510

Sincerely,



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