Scope of Work

2015 Great Salt Lake Summer Ozone Study
Project Period: 15 July 2014-14 January 2016

Investigators:
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1) Project Background

A Division of Air Quality (DAQ) study found high surface ozone concentrations near the Great Salt Lake during summer 2012 (Arens and Harper 2013). No studies have been completed to assess the areal extent of summer ozone over and near the Great Salt Lake, nor the vertical depth within which ozone is confined above the lake's surface. This information is necessary to improve daily forecasts of ozone provided by DAQ staff as well as evaluate the performance of air quality models required for future Utah State Implementation Plans for ozone along the Wasatch Front.

The influence of warm season sea and lake breezes on the meteorology and air quality of mid-latitude coastal regions has been studied extensively both observationally and numerically (see the review by Crosman and Horel 2010). University of Utah researchers in the Department of Atmospheric Sciences have been studying during the past decade the impacts of the Great Salt Lake on atmospheric transport that affects air pollution along the Wasatch Front (Zumpfe and Horel 2007; Crosman and Horel 2008; 2010; 2012; 2014). PI Horel has led or co-led two National Science Foundation projects (Lake Breeze System of the Great Salt Lake 2008-2012; Persistent Cold Air Pool Study 2010-2014) that have incorporated a mix of numerical studies and field work (summer 2008 in the Tooele Valley; and winter 2010-11 in the Salt Lake Valley) that have examined lake and land breeze flows associated with the Great Salt Lake.

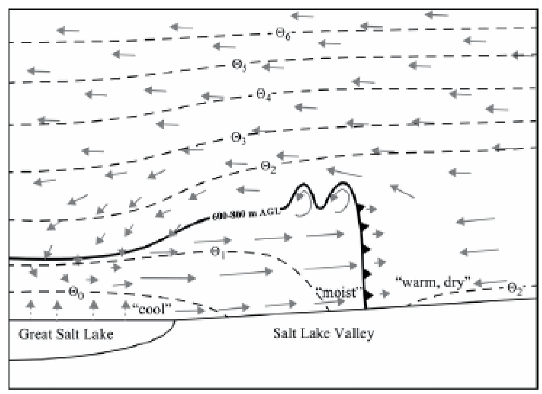

Figure 1. Schematic summary of the lake breeze system in the Salt Lake Valley on 17 Oct 2000 (Zumpfe and Horel 2007). Winds in the y–z plane (solid gray vectors), evaporation from the GSL (dashed gray vectors), potential temperature (dashed black lines) and its magnitude (indicated by subscripts), and vertical and horizontal boundaries of the lake breeze (solid black line), including the lake-breeze front (portion of solid black line annotated by triangles.

Figure 1 (Zumpfe and Horel 2007) provides a snapshot view of the structure of the lake breeze as it penetrates into the areas surrounding the lake. While the basic thermodynamic and dynamic structures of lake and land breezes are understood, how those circulations affect ozone concentrations along the Wasatch Front is not: the air trapped beneath the stable layer over the lake at times during the summer contains low concentrations of ozone while at other times exhibits very high concentrations (Arens and Harper 2013). Figure 2 attempts to summarize the physical processes affecting ozone concentrations near the Great Salt Lake, including transport of ozone precursors from the surrounding urban areas towards the lake, photochemical generation over the lake, and transport of precursors and ozone back towards the Wasatch Front by lake breezes.

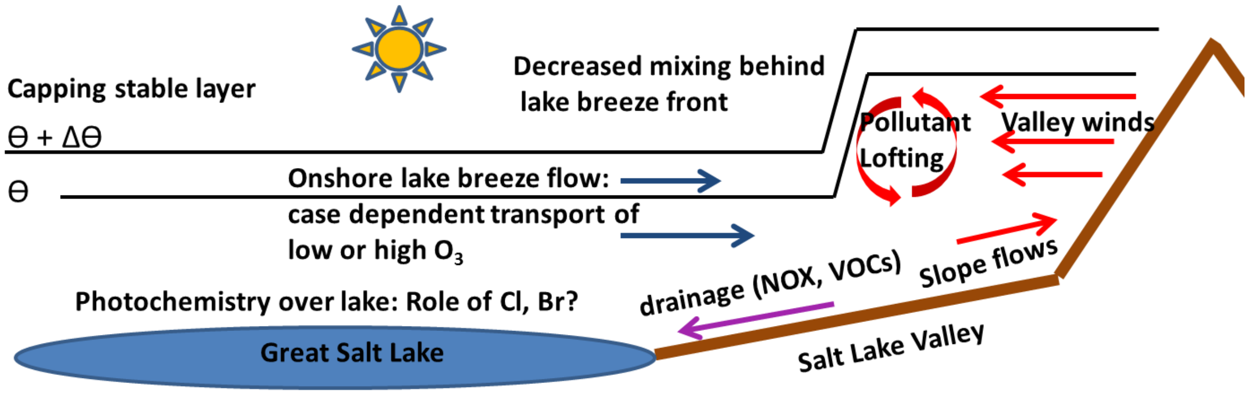

Figure 2. Schematic summary of the physical processes affecting ozone concentrations over and surrounding the Great Salt Lake (adapted from Crosman and Horel 2014).

The core objectives of this project are:

1. **Determine the areal and vertical extent of ozone concentrations over and surrounding the Great Salt Lake during the summer**

2. **Improve understanding of the physical processes that control ozone concentrations near the Great Salt Lake during the summer to improve forecasts of ozone concentrations along the Wasatch Front.**

2) Task Descriptions

a) Develop 2015 Summer Ozone Field Campaign Operations Plan

Project lead Seth Arens, DAQ, will coordinate the planning for the 2015 summer ozone field campaign that will involve substantive participation from DAQ, University of Utah, and Utah State University researchers. All of the researchers involved in this project have extensive field experience including most recently:

- S. Arens (DAQ) led the 2012 Utah Ozone Study

- E. Crosman and J. Horel (Department of Atmospheric Sciences, University of Utah) helped lead the Persistent Cold-Air Pool Study (Lareau et al. 2013) and participated in the 2013 Uintah Basin Ozone Study (Neemann et al. 2014)

- S. Bush (Department of Biology, University of Utah) has collected extensive meteorological and trace gas measurements using the mobile laboratory, referred to as the Nerdmobile

- Randal S. Martin (Utah State University) has extensive research experience in local and regional air pollutant measurements, including initial research into the Uinta Basin wintertime ozone episodes.

The Operations Plan will detail two modes of operation: (1) automated data collection from equipment placed in the field for the entire summer and (2) intensive observing periods during which researchers will collect more extensive data. DAQ project lead Arens will lead the planning and coordinate the deployment of an extensive array of automated ozone sensors near the Great Salt Lake for the entire 2015 summer combined with some additional surface-based meteorological sensors. University of Utah and Utah State University researchers will participate more on data collection efforts defined to take place during intensive observing periods.

Preliminary discussions have identified the necessity to deploy instrumentation during intensive observation periods with high enough spatiotemporal resolution to capture both (1) the pool of high ozone concentrations immediately over the lake, and (2) the vertical profiles of transport away from this core region into the Tooele Valley, Salt Lake Valley, and Ogden areas (Fig. 3). The operations plan for the intensive observational periods will be formulated after further scientific discussion among the research parties. However, capturing whether or not the high ozone pool extends north into Gunnison Bay, characterizing the vertical profiles of ozone are in the near-lake environment (i.e., Antelope Island) versus the onshore environment (i.e., Tooele and Salt Lake Valleys) will likely be important goals within these intensive observational periods. Ozone and meteorological data will be collected in late-August and early September 2014 over a several day period by university researchers to assist the planning for the summer 2015 field study. The instrumentation to be deployed during this prototyping for the 2015 field campaign will be a reduced set compared to that available for the 2015 Summer Ozone Field Campaign. Prior data collected during summer 2012 and 2013 will also be examined.

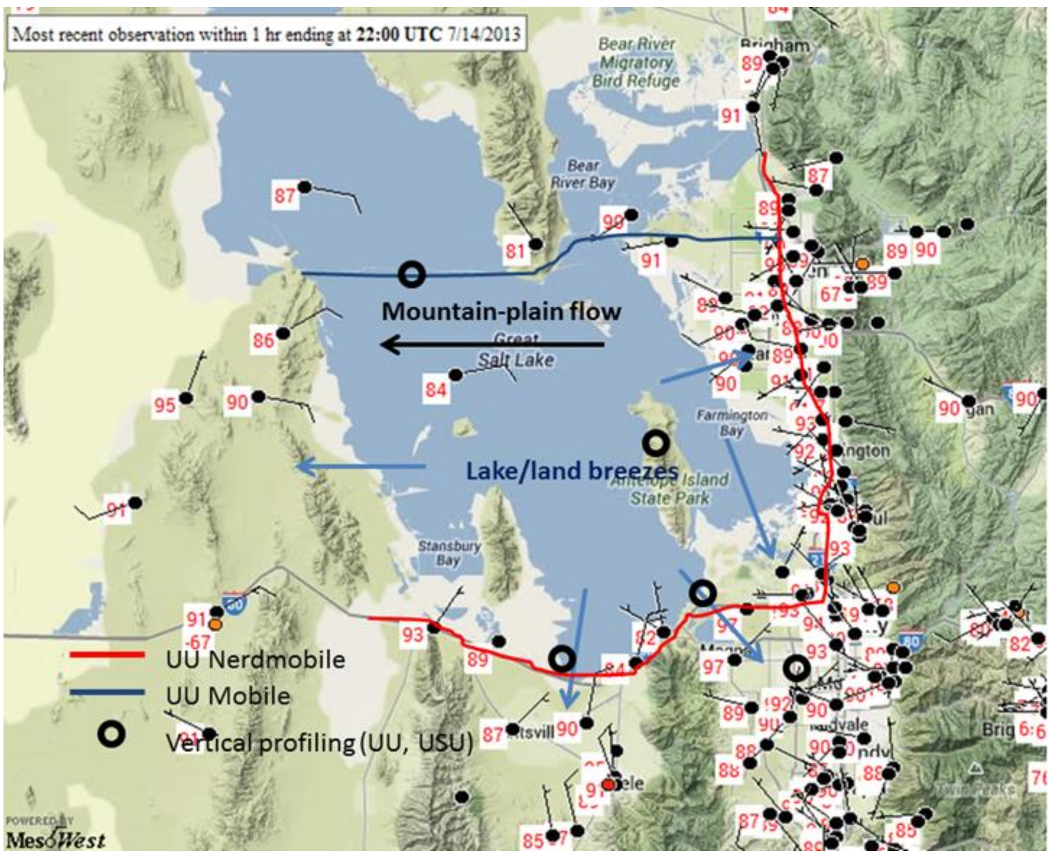

Figure 3. Locations of surface observing sites around the Great Salt Lake combined with possible paths of mobile sensors (black and red lines) and launching of UAVs (open circles).

b) 2015 Summer Ozone Field Campaign

1. Based on the operations plan to be developed for the Field Campaign, an extensive array of automated ozone sensors will be deployed by the DAQ near the Great Salt Lake for the entire 2015 summer combined with some additional DAQ surface-based meteorological sensors.

2. University of Utah and Utah State University researchers will focus during summer 2015 on collecting targeted observations during several 3-5 day intensive observing periods, e.g., one near the summer solstice when available actinic flux is highest and others later in the season when ozone concentrations are likely near their peak. One observing period may be selected to coincide with widespread wildfires in the Intermountain West and subsequent transport of precursors and ozone into the Wasatch Front area.
3. Transects several times per day using ozone sensors mounted on two University of Utah vehicles will be conducted to document horizontal variations in ozone between the fixed observations collected from DAQ sensors. The transect routes will be selected to investigate the roles of lake and land breezes and mountain, valley, plain circulations on ozone transport. Permission will be sought from Union Pacific Railroad to transit the lake causeway to sample ozone concentrations across the lake. Figure 4 demonstrates the capabilities to measure ozone from the Department of Atmospheric Sciences vehicle while Figure 5 is an example from the Department of Biology mobile atmospheric laboratory (referred to as the Nerdmobile).

4. The vehicle-mounted sensors will be calibrated frequently relative to ozone reference standards provided by Utah State University as well as compared to DAQ air monitoring station.

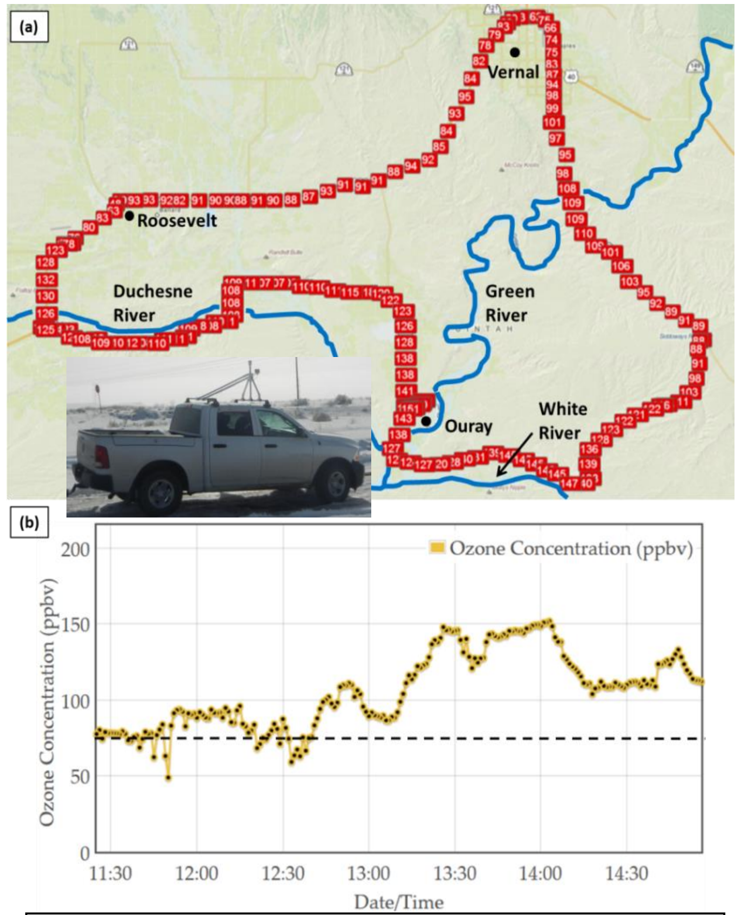

Figure 4. Mobile transect of ozone concentration from 6 February 2013 as a function of (a) geographic location in the Uintah Basin and (b) time (from Neemann et al. 2014). Data collected from Ozone 2-B sensor mounted on University of Utah truck (see inset).

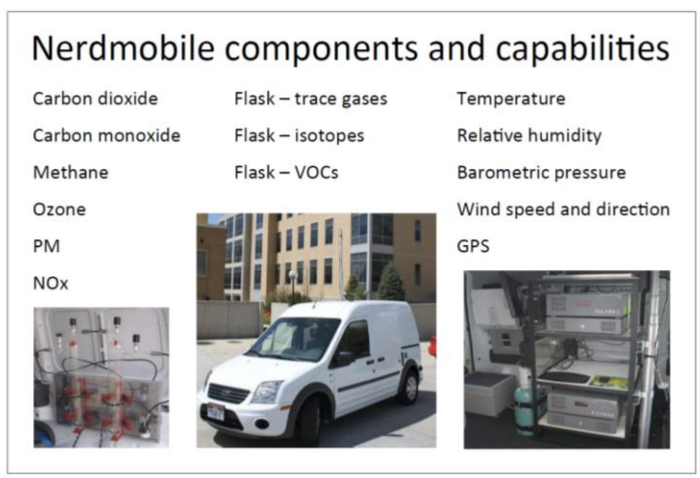

Figure 5. Capabilities of the mobile atmospheric laboratory (Nerdmobile) available from the Department of Biology, University of Utah.

5. Coordinated UAV flights using Utah State University and University of Utah plane and copter platforms will be conducted to obtain vertical profiles of ozone over and near the Great Salt Lake during the intensive observing periods. The current version of the USU airframe is a battery operated, custom-built "AggieAir Warthog". The UAV has a 2.4 m wingspan, 2 kg payload, and an approximate flight duration of 45 minutes. A modified 2B Technologies O_3 monitor, along with HOBO temperature sensors are used to map out the pollutant and temperature structures. Figure 6 shows a pair of vertical O_3 "curtains" as measured during the 2013 Uinta Basin campaign. Figure 7 provides an example of the vertical profiles available from the University of Utah quadcopter sonde system.

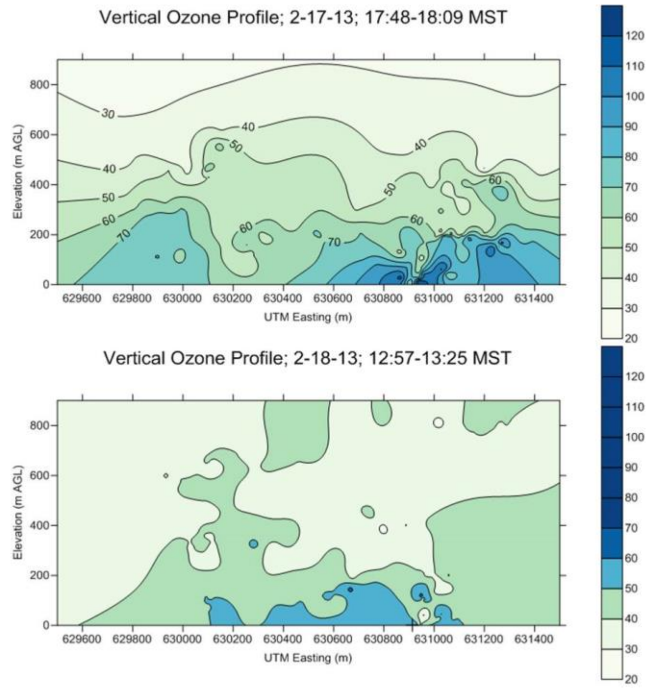

Figure 6. Paired vertical O_3 showing the devolution of an O_3 episode as measured by USU's UAV platform at the Horse Pool sampling loation in Utah's Uinta Basin.

6. A limited number of vertical profiles of meteorological parameters (wind, temperature, and moisture) from reusable sondes available from the University of Utah will be used to help define the vertical structure of the boundary layer in the near-shore environment in coordination with the UAV observations.

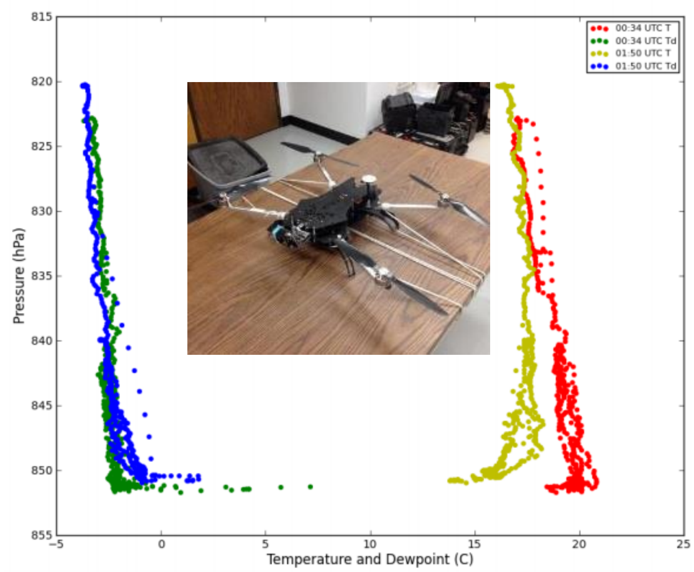

Figure 7. Vertical profiles of temperature (yellow and red) and dewpoint temperature (green and blue) collected from the University of Utah quadcopter sonde system (inset). Capabilities to carry an ozonesonde will be developed for the summer 2015 field campaign.

3) Deliverables

Specific deliverables to be provided during and upon completion of this project are:

1. Preliminary project plan for the 2015 Great Salt Lake Summer Ozone Study will be completed during Fall 2014 with the final project plan completed during Spring 2015.

2. Preliminary results from August-September 2014 prototyping presented to DAQ in December 2014.

3. All data collected during the 2014 prototyping and 2015 Field Campaign will be stored at the University of Utah and made accessible via web-based interfaces in convenient formats to DAQ and other researchers for evaluation, planning and model verification purposes.

4. A report will be provided detailing the data collected, the spatial and temporal variations in ozone concentrations as a function of proximity to the Great Salt Lake, and the interactions of the physical processes associated with the Great Salt Lake that affect the formation, transport, and dissipation of ozone along the Wasatch Front.

4) Schedule and Cost

All members of the field campaign team will be in frequent communication with DAQ staff throughout the project. We intend to be available for the technical stakeholder and communication strategy meetings. Specific project milestones are:

- October 15. Preliminary field campaign plan completed. Initial processing of prototype data collected during August-September 2014 completed.
- December 15. Preliminary results from August-September 2014 prototyping presented to DAQ in December 2014
- April 15. Final plan for 2015 Field Campaign completed. Bench testing and calibration of all equipment to be used during intensive observing periods completed.
- May 15. DAQ staff deploy automated sensors.
- June 15-September 1. Several 3-5 day intensive observing periods undertaken.
- October 15. Preliminary results from 2015 Field Campaign summarized to DAQ staff.
- January 15. Submit final report

Budget Explanation and Roles

The proposed schedule is 18 months (July 15, 2014 – January 14, 2016). The total cost for the project is $65,000 (University of Utah $48,750; Utah State University, $16,250). DAQ lead Seth Arens will provide overall coordination for the project. University of Utah PI J. Horel will provide overall direction for the academic researchers at the University of Utah and Utah State University. He will also coordinate with postdoctoral researcher E. Crosman regarding data collection and analysis efforts using the sensors available in the Mountain Meteorology Group in the Department of Atmospheric Sciences (e.g., 2B technology ozone sensor mounted on a University of Utah truck, wet chemistry reusable ozone sondes mounted on a University of Utah UAV copter, reusable sondes for meteorological vertical profiles).

Postdoctoral researcher S. Bush, Department of Biology, will coordinate data collection efforts using the Nerdmobile, a state-of-the-art mobile atmospheric laboratory.

Utah State University PI R. Martin will coordinate the deployment of field equipment provided by Utah State University as a subcontract to the University of Utah. This effort will include field-deployable reference standards for ozone, and ozone and meteorological sensors mounted on an UAV platform.

Funds are primarily requested to support the field collection efforts and subsequent analyses by researchers in the Department of Atmospheric Sciences and Biology at the University of Utah and at the Utah State University. Vehicle costs at the University of Utah are estimated for two vehicles for 15 days of operation for 300 miles per day. Funds to purchase supplies for preparing and calibrating field equipment are also requested.

If funding is available to support additional field collection efforts, then effort contributed by the researchers at the University of Utah and Utah State University will continue to be split proportionately 75% and 25% respectively.

Budget 15 July 2014-14 January 2016

Salaries: 2 postdocs (S. Bush 1.5 mo FTE, E. Crosman 1.5 mo FTE)	$15,000
Salaries: 2 grad students (6 mo FTE total)	$12,000
Fringe Benefits (37% for postdocs; 14% graduate student)	$7,230
Lab & Technical Supplies	$2,611
6560B Vehicle expenses (including mileage)	$6,000
6280B Subcontracts under $25k to Utah State University	$16,250
Items Excluded from F&A Calculation:	
Total Direct	**$59,091**
Direct Costs for F&A Calculation	$59,091
Indirect (F&A) Cost	**$5,909**
Grand Total	**$65,000**

References

Arens, S., K. Harper, 2013: 2012 Utah Ozone Study. Division of Air Quality. DAQK-15-13. 46 pp.

Crosman, E., and J. Horel, 2008: MODIS-derived surface temperature of the Great Salt Lake, *Remote Sensing of Environment*., 113, 73-81.

Crosman, E., and J. Horel, 2010: Numerical sensitivity studies of sea and lake breezes: a review. *Boundary Layer Meteorology*. **137**, 1-29.

Crosman, E. and J. Horel, 2012: Idealized Large-Eddy Simulations of Sea and Lake Breezes: Sensitivity to Lake Diameter, Heat Flux and Stability. *Boundary Layer Meteorology*. 144, 309-328.

Crosman, E. and J. Horel, 2014: Observations of Wintertime Great Salt Lake Breezes during Cold Air Pools. In preparation for submission to *Boundary Layer Meteorology.*

Lareau, N., E. Crosman, C. Whiteman, J. Horel, S. Hoch, W. Brown, T. Horst, 2013: The Persistent Cold-Air Pool Study. *Bull Amer. Meteor. Soc*. **94**, 51–63.

Neemann, E., E. Crosman, J. Horel, L. Avey, 2014: Simulations of a cold-air pool associated with elevated wintertime ozone in the Uintah Basin, Utah. Submitted to *Atmospheric Chemistry and Physics*.

Tyndall, D., and J. Horel, 2013: Impacts of mesonet observations on meteorological surface analyses. *Wea. Forecasting*. 28, 254-269.

Whiteman, C. D., S. W. Hoch, J. D. Horel, and A. Charland, 2014: Relationship between particulate air pollution and meteorological variables in Utah's Salt Lake Valley. *Atmospheric Environment*. In press.

Zumpfe, D., J. Horel, 2007: Lake-breeze fronts in the Salt Lake Valley. *J. Appl. Meteor*., 46, 196-211.