Inter-basin Transport, Canyon Circulations, and Lake Breezes: Atmospheric Mixing and Air Mass Exchange Processes and their Effect on Pollution Concentrations in Utah's Salt Lake Valley

[1]Sebastian W. Hoch, [1]Erik T. Crosman, and [2]Randal S. Martin

(1) University of Utah, Salt Lake City, UT (2) Utah State University, Logan UT

3rd Annual Conference:
Air Quality – Science For Solutions
Logan UT, 28 March 2019

Introduction

The Salt Lake Valley (SLV, Figure 1) and other densely populated topographic basins in northern Utah and throughout the world suffer from prolonged pollution episodes during wintertime that are associated with Persistent Cold Air Pools (PCAPs). PCAPs develop when high pressure systems and subsidence temperature inversions trap colder air and anthropogenic emissions in topographic basins. The feedback between meteorological and chemical processes in PCAPs has received increasing attention in recent years.

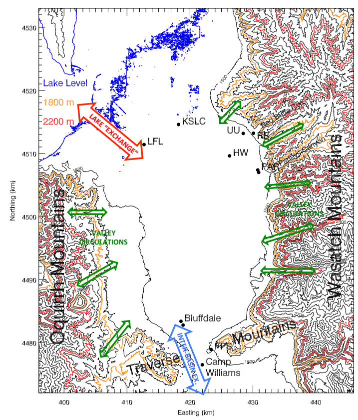


Fig. 1: Topographic map of the Salt Lake Valley and selected observational sites.

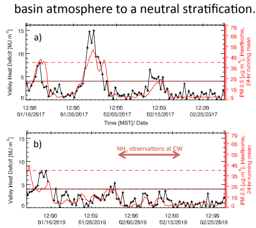
Cold-Air Pool Exchange Processes

While atmospheric mixing and transport processes are generally suppressed under the statically stable atmospheric conditions of PCAPs, some thermally and synoptically driven processes still work to modulate particulate pollutant ($PM_{2.5}$, NH_4NO_3) and pollutant precursor (NH_3, NO_X, etc.) concentrations within and along the edges of the PCAPs.

For the SLV, these processes include (1) **canyon circulations** through tributaries, (2) **lake breeze circulations** from the Great Salt Lake (GSL); (3) **synoptically forced airmass exchanges with** the atmosphere over the **GSL** and (4) **inter-basin exchanges** between the Utah Valley and Salt Lake Valley.

The Valley Heat Deficit

The Valley Heat Deficit H (Whiteman et al. 2014) is a thermodynamic measure of the intensity or strength of a cold-air pool, corresponding to the amount of energy that would be needed to bring a valley or basin atmosphere to a neutral stratification.



$$H_h = c_p \int_{1288\ \mathrm{m}}^{h} \rho(z)[\theta_h - \theta(z)]\mathrm{d}z \quad [\mathrm{J\,m^{-2}}]$$

The Valley Heat Deficit can be calculated from twice-daily radiosonde ascents from the Salt Lake International Airport (KSLC).

Fig. 2: Time series of the Valley Heat Deficit for the SLV and $PM_{2.5}$ concentrations for a) early 2017 and b) early 2019.

Inter-Basin Transport Estimates

In January and February 2019, the Jordan Narrows Ammonia Transport Study investigated inter-basin atmospheric transport between the SLV and Utah Valley, using a Doppler wind LiDAR, automatic weather stations, and ammonia (NH_3) observations.

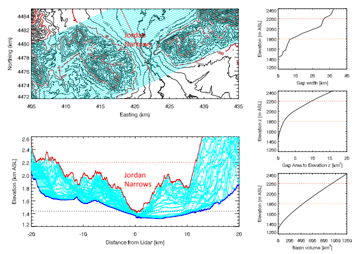


Fig. 3: Topographic analysis of the Jordan Narrows Gap and the Salt Lake Valley to calculate the gap cross section and basin volume.

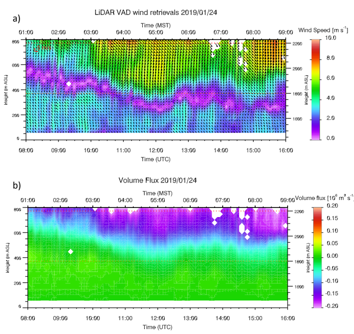


Fig. 4: a) Time-height cross sections of the vertical wind field in the Jordan Narrows from LiDAR VAD retrievals, and b) estimated volume flux through the gap, for the early morning of 24 January 2019.

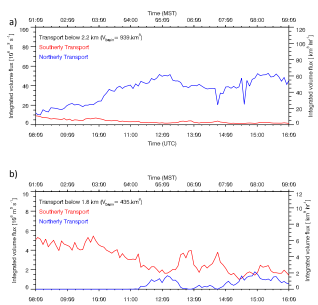


Fig. 5: Time series of the integrated volume flux through the Jordan Narrows gap to a) 2200 m ASL and b) 1800 m ASL.

For two weeks in February 2019, high-frequency observations of ammonia (NH_3) and carbon dioxide (CO_2) concentrations were conducted in the Jordan Narrows. During this period, large scale synoptic conditions were not conducive for the development of PCAP conditions. Nevertheless, elevated ammonia (and carbon dioxide) concentrations correlated well with meteorological conditions (Fig.6).

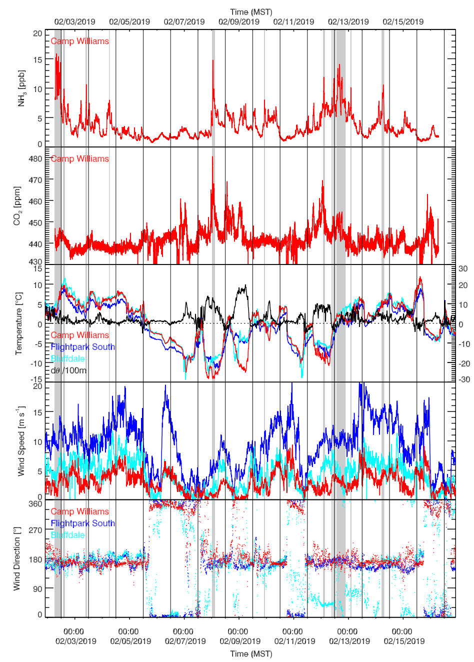


Fig. 6: Time series of a) ammonia (NH_3) and b) carbon dioxide (CO_2) concentration at Camp Williams (CW) in the Jordan Narrows, and c) temperatures, d) wind speeds and e) wind directions at CW, Bluffdale, and Flightpark South (FPS) for 2-17 February 2019. Static stability is indicated in c) as the potential temperature gradient between CW and FPS. Times with NH_3 concentrations above 8 ppb are highlighted.

Mass Flux Estimates

Future work

Canyon Circulations

During the January 2017 Utah Winter Fine Particulate Study (UWFPS) thermally-driven canyon circulations in two tributary canyons, the smaller Red Butte Canyon (RB) and larger Parleys Canyon (PAR), were investigate for their role in modulating pollutant concentrations.

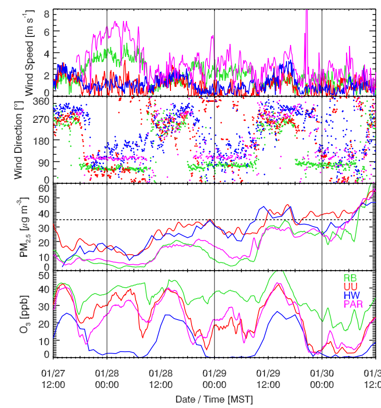


Fig. 2: Time series of the Valley Heat Deficit for the SLV and $PM_{2.5}$ concentrations for a) early 2017 and b) early 2019.

Lake Breezes and "Lake Recharge"

A mini-SoDAR deployed near the shore of the Great Salt Lake (LFL) during UWFPS captured thermally driven lake breezes as well as synoptically forced air mass exchanges. A typical "lake recharge" event was captured on 3 February 2017 and led to large spatial pollution gradients in the SLV, as illustrated below.

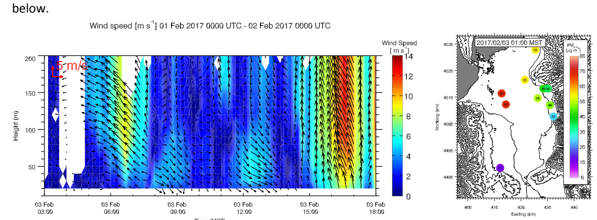


Fig. 2: Time series of the Valley Heat Deficit for the SLV and $PM_{2.5}$ concentrations for a) early 2017 and b) early 2019.

Acknowledgements: Funding from the Utah Department of Environmental Quality and the National Science Foundation (grant 1723337).