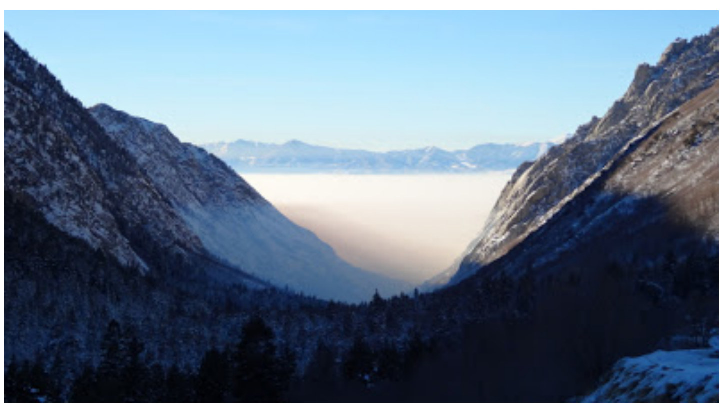
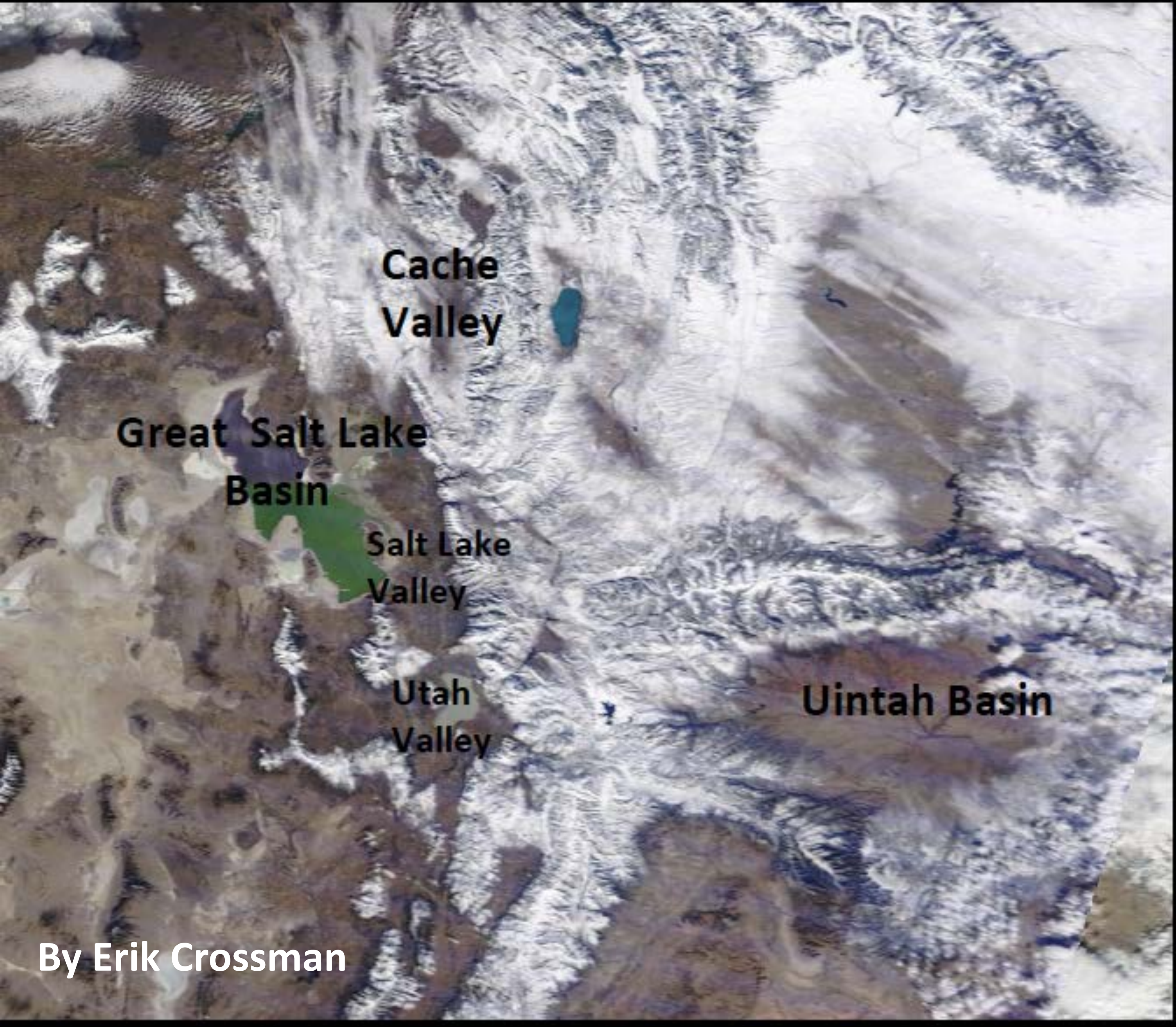
Winter (Dec – Jan) 2015 - 2016

Wintertime $PM_{2.5}$ Study: Chemical Mechanism and Nitrate Chemistry



Utah Division of Air Quality
Contact: mbaasandorj@utah.gov

Utah Basins



Cache Valley

Salt Lake Valley—medium-sized partly open valley with large urban population

Uintah Basin—large very deep basin with small population

Each basin has characteristic snow cover climatology and depth of 'inversion' resulting from confining topography

Utah Basins

Cache Valley

Salt Lake Valley

—medium-sized

LETTER

UINTAH BASIN

doi:10.1038/nature13767

High winter ozone pollution from carbonyl photolysis in an oil and gas basin

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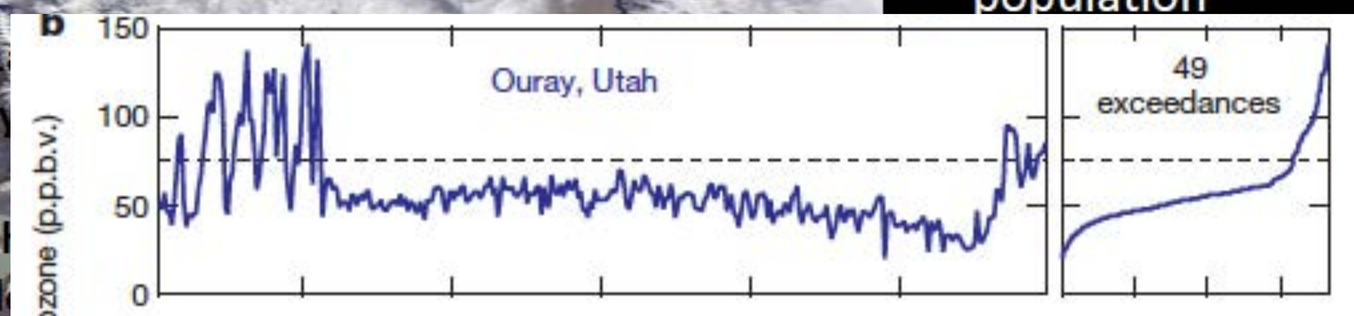
population



cover climatology and depth of 'inversion' resulting from confining topography

By Erik Crossman

Utah Basins

Cache Valley

Salt Lake Valley

Cache Valley

ATMOSPHERIC RESEARCH

ELSEVIER

Atmospheric Research 79 (2006) 108–122

www.elsevier.com/locate/atmos

Meteorological and environmental aspects of one of the worst national air pollution episodes (January, 2004) in Logan, Cache Valley, Utah, USA

Esmaiel Malek [a,*], Tess Davis [a], Randal S. Martin [b], Philip J. Silva [c]

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Received 15 November 2004; accepted 14 May 2005

topography

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UTAH
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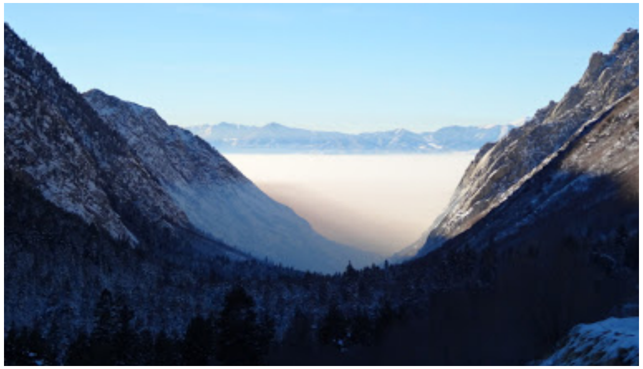
Elevated fine PM episodes between Dec - Feb



Approximately 80% of Utahns live along the Wasatch Front

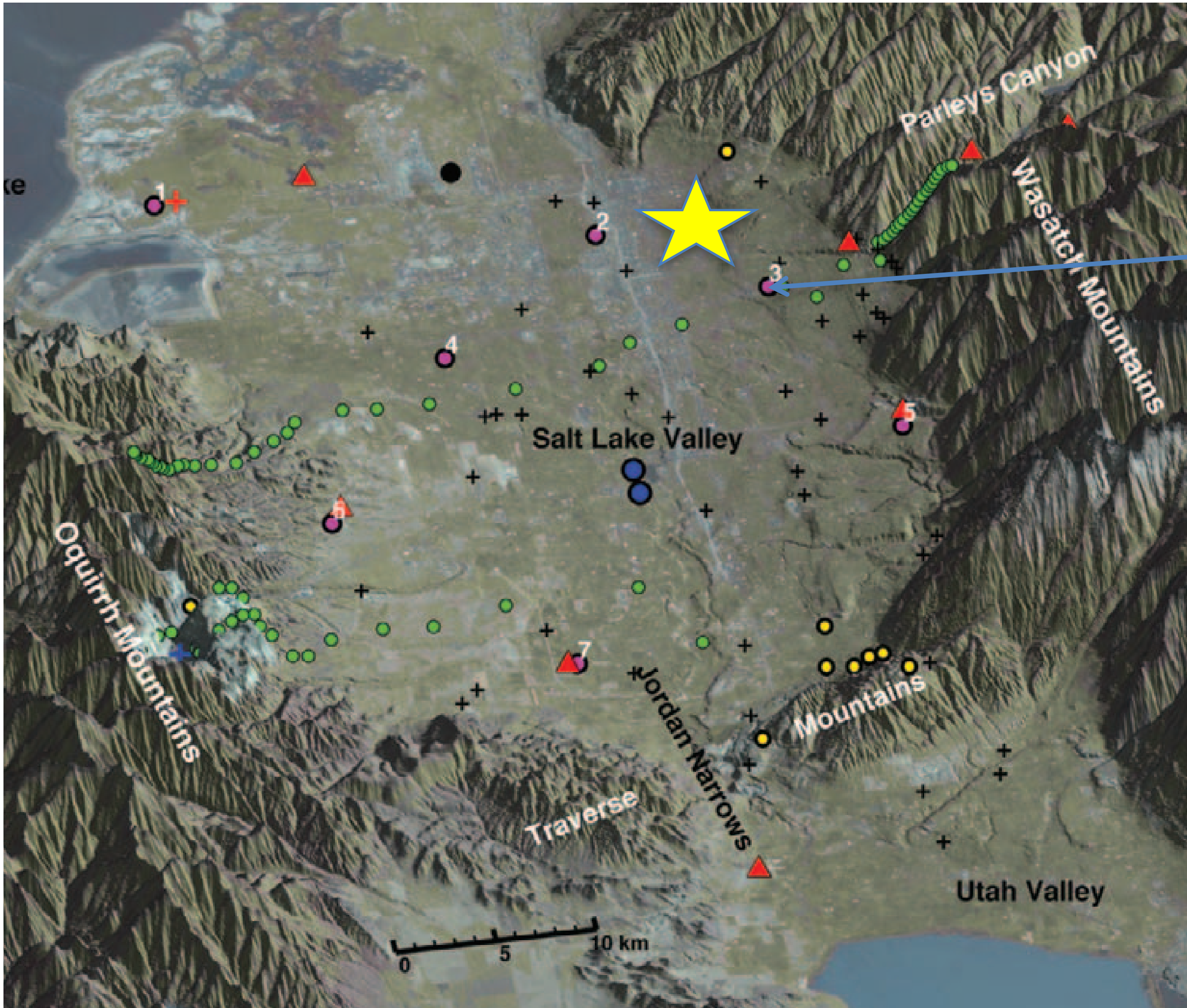
Salt Lake City

From Wikipedia, the free encyclopedia

This article is about the capital of Utah. For other uses, see Salt Lake City (disambiguation).

Salt Lake City, often shortened to **Salt Lake** or **SLC** is the capital and the most populous city in the U.S. state of Utah. With an estimated population of 191,180 in 2013,[3] the city lies at the core of the Salt Lake City metropolitan area, which has a total population of 1,153,340 (2014 estimate). Salt Lake City is further situated within a larger metropolis known as the Salt Lake City-Ogden-Provo Combined Statistical Area. This region is a corridor of contiguous urban and suburban development stretched along an approximately 120-mile (190 km) segment of the Wasatch Front, comprising a total population of 2,423,912 as of 2014.[7] It is one of only two major urban areas in the Great Basin (the other being Reno, Nevada), and the largest in the Intermountain West.

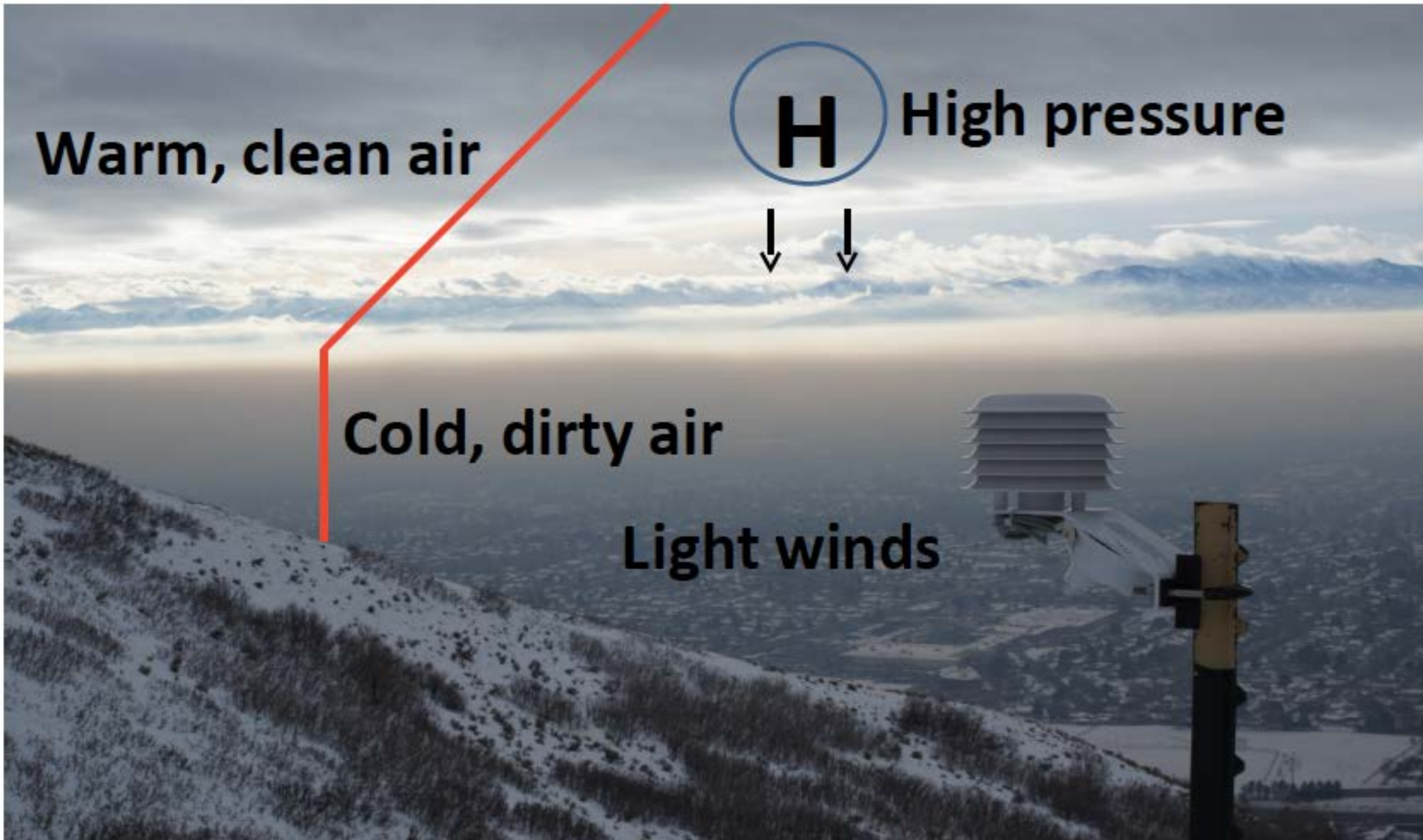
Factors important for SLC air pollution:
Confined topography limits horizontal mixing.



DAQ's Hawthorne Station

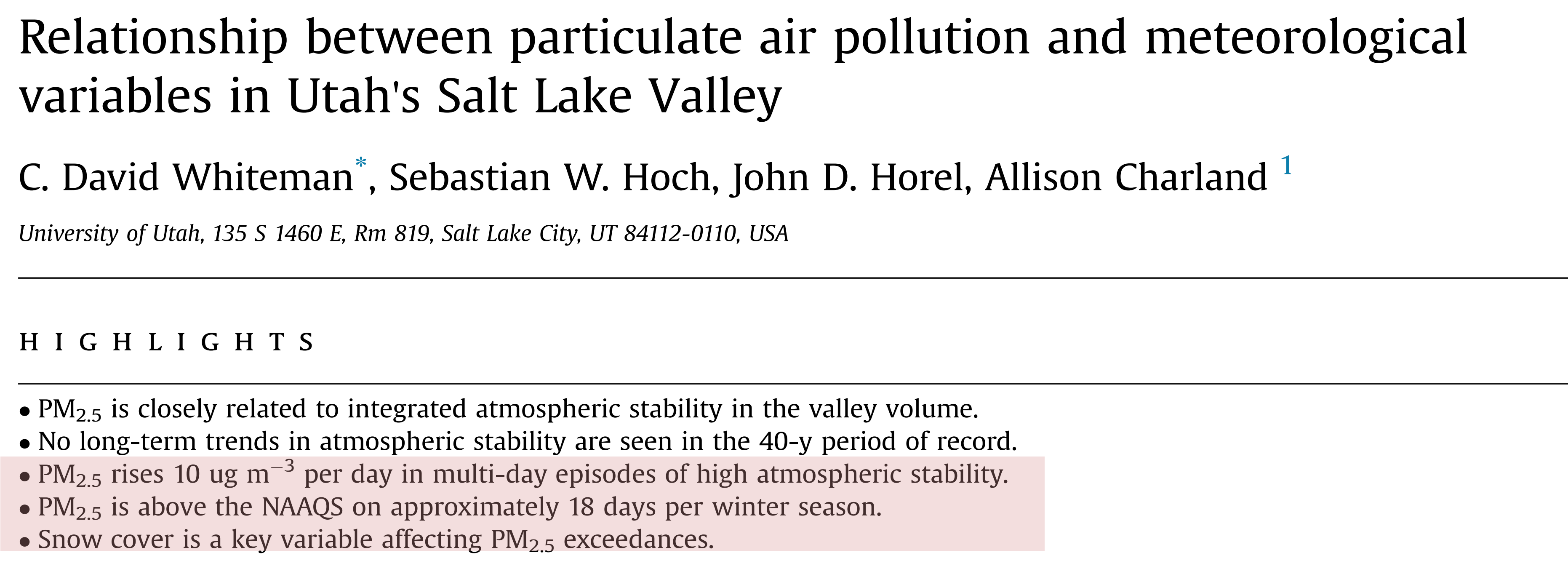
Lareau et al. 2013

Basic Weather Features Associated with Poor Winter Air Quality: Well-Understood



By Erik Crossman

PM events are closely associated with atmospheric stability


Relationship between particulate air pollution and meteorological variables in Utah's Salt Lake Valley

C. David Whiteman*, Sebastian W. Hoch, John D. Horel, Allison Charland [1]

University of Utah, 135 S 1460 E, Rm 819, Salt Lake City, UT 84112-0110, USA

HIGHLIGHTS

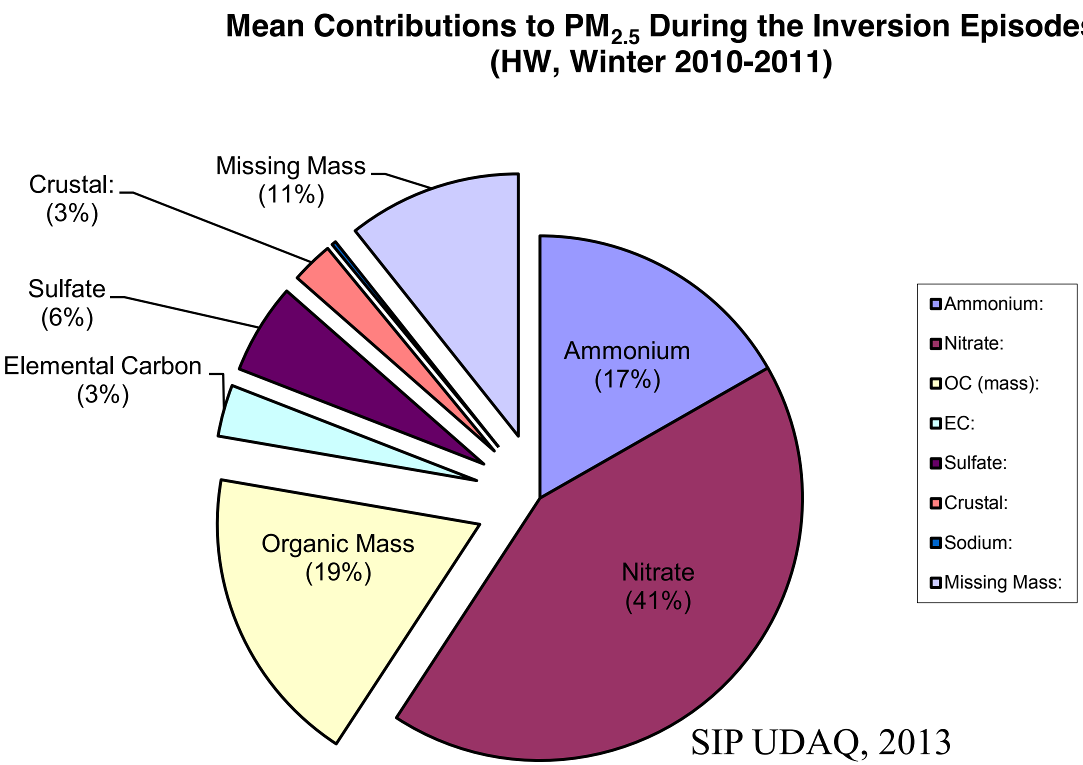
- $PM_{2.5}$ is closely related to integrated atmospheric stability in the valley volume.
- No long-term trends in atmospheric stability are seen in the 40-y period of record.
- $PM_{2.5}$ rises 10 ug m^{-3} per day in multi-day episodes of high atmospheric stability.
- $PM_{2.5}$ is above the NAAQS on approximately 18 days per winter season.
- Snow cover is a key variable affecting $PM_{2.5}$ exceedances.

Atmospheric environment 94 (2014) 742-753

<u>Puzzling facts</u>:

- PM composition is quite uniform throughout the valley.
- Levels (24hr) are uniform despite sources heterogeneity; except the foothills

Major constituent of $PM_{2.5}$ during pollution episodes: NH_4NO_3



SIP UDAQ, 2013

- Secondary sources dominate.
- Dominated by NH_4NO_3 (50 – 75% of the total)
- Secondary NH_4Cl is also a significant contributor (10-15% of the total $PM_{2.5}$) (Kelly et al., 2013)

- Chemical processes leading to PM formation are not understood well.

Long list of uncertainties

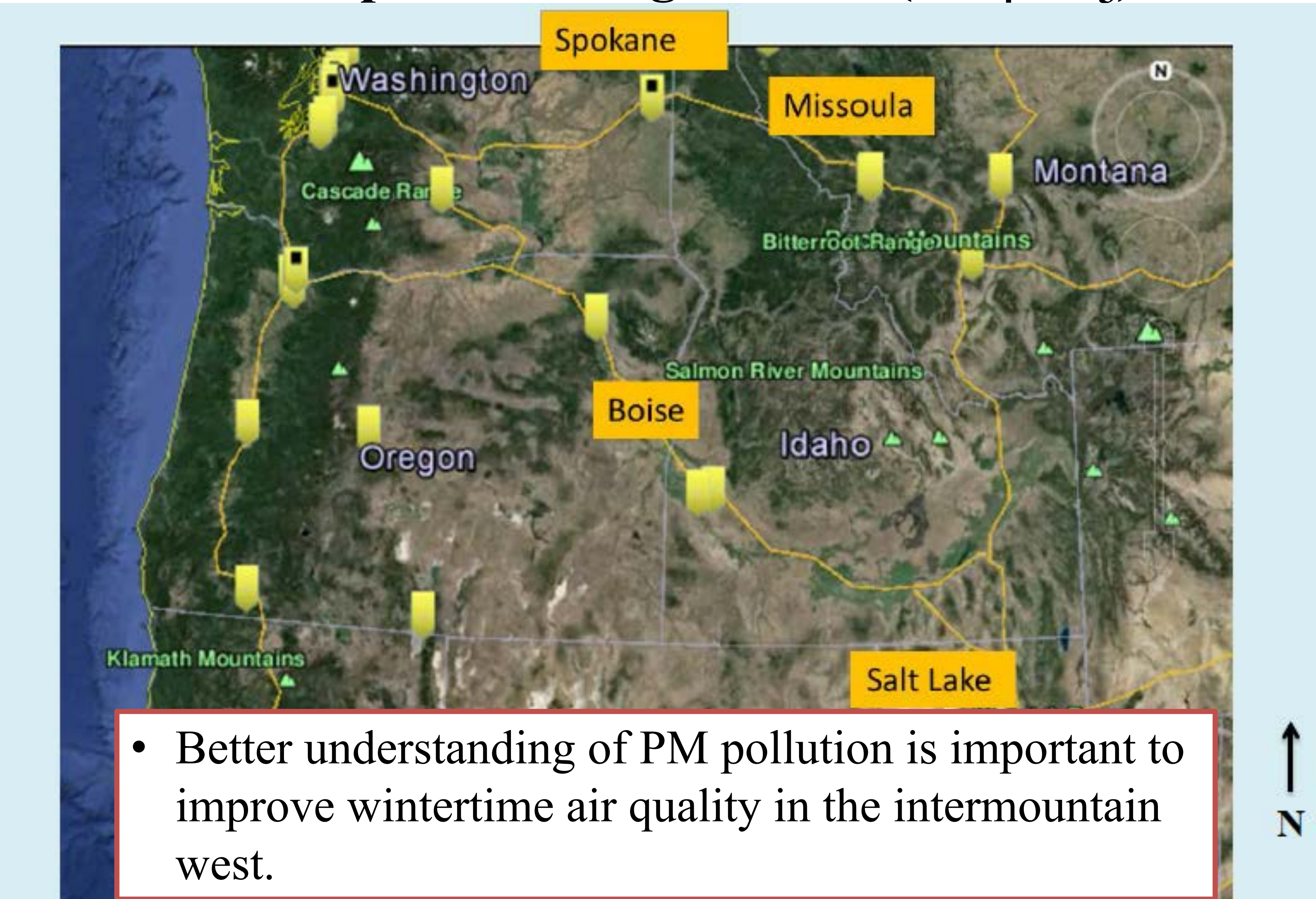
- Nitric acid formation; daytime vs. nighttime
- Sensitivity of O_3 and HNO_3 to changes in NOx and VOCs
- Which precursor limits the PM formation; NH_3 vs. HNO_3
- What are the sources of NH_3?

Other valleys in the intermountain west also experience cold pools and high PM2.5 (NH_4NO_3)

Green, M.C.. (2015). Journal of Applied Meteorology and Climatology

By Watson et al.

Other valleys in the intermountain west also experience cold pools and high PM2.5 (NH_4NO_3)

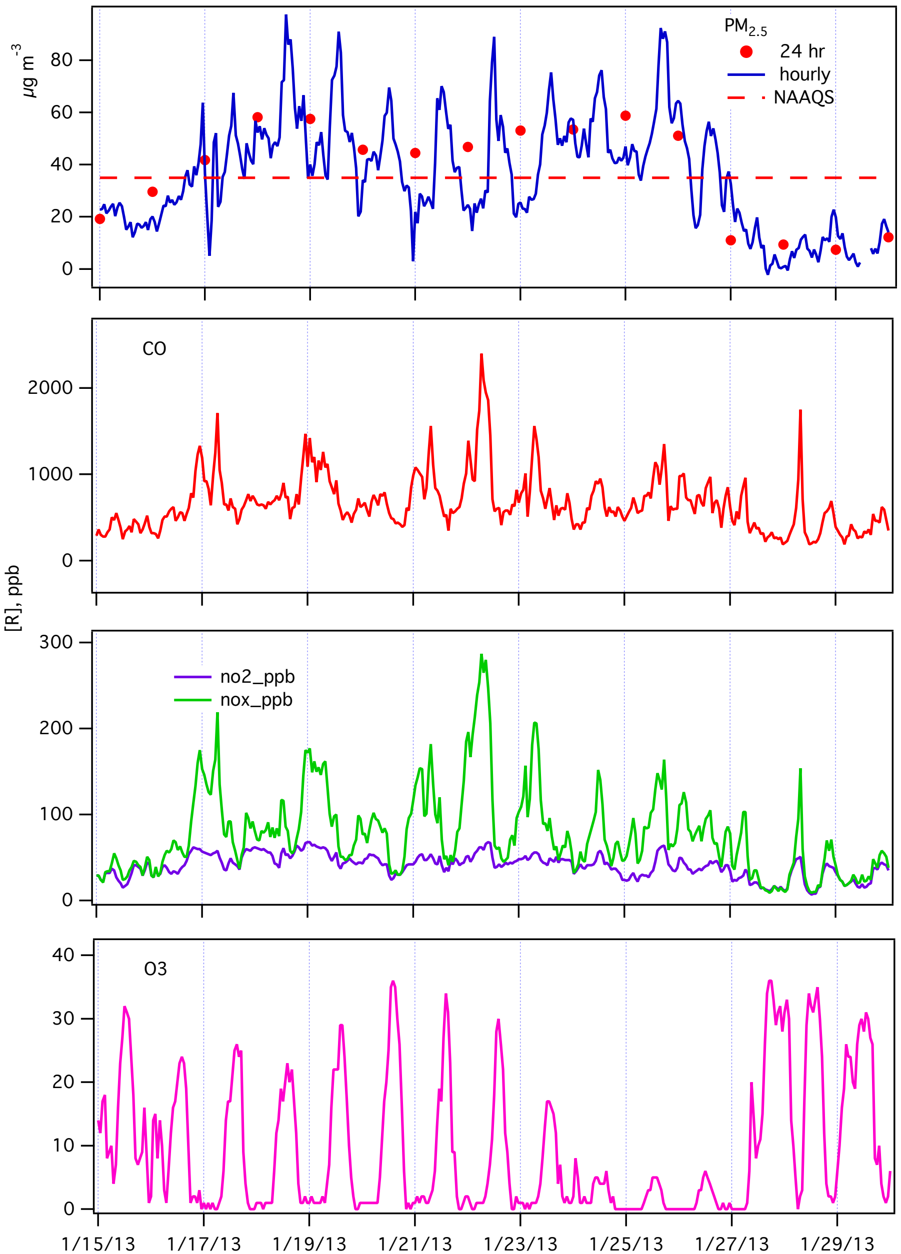


- Better understanding of PM pollution is important to improve wintertime air quality in the intermountain west.

By Watson et al.

Green, M.C.. (2015). Journal of Applied Meteorology and Climatology

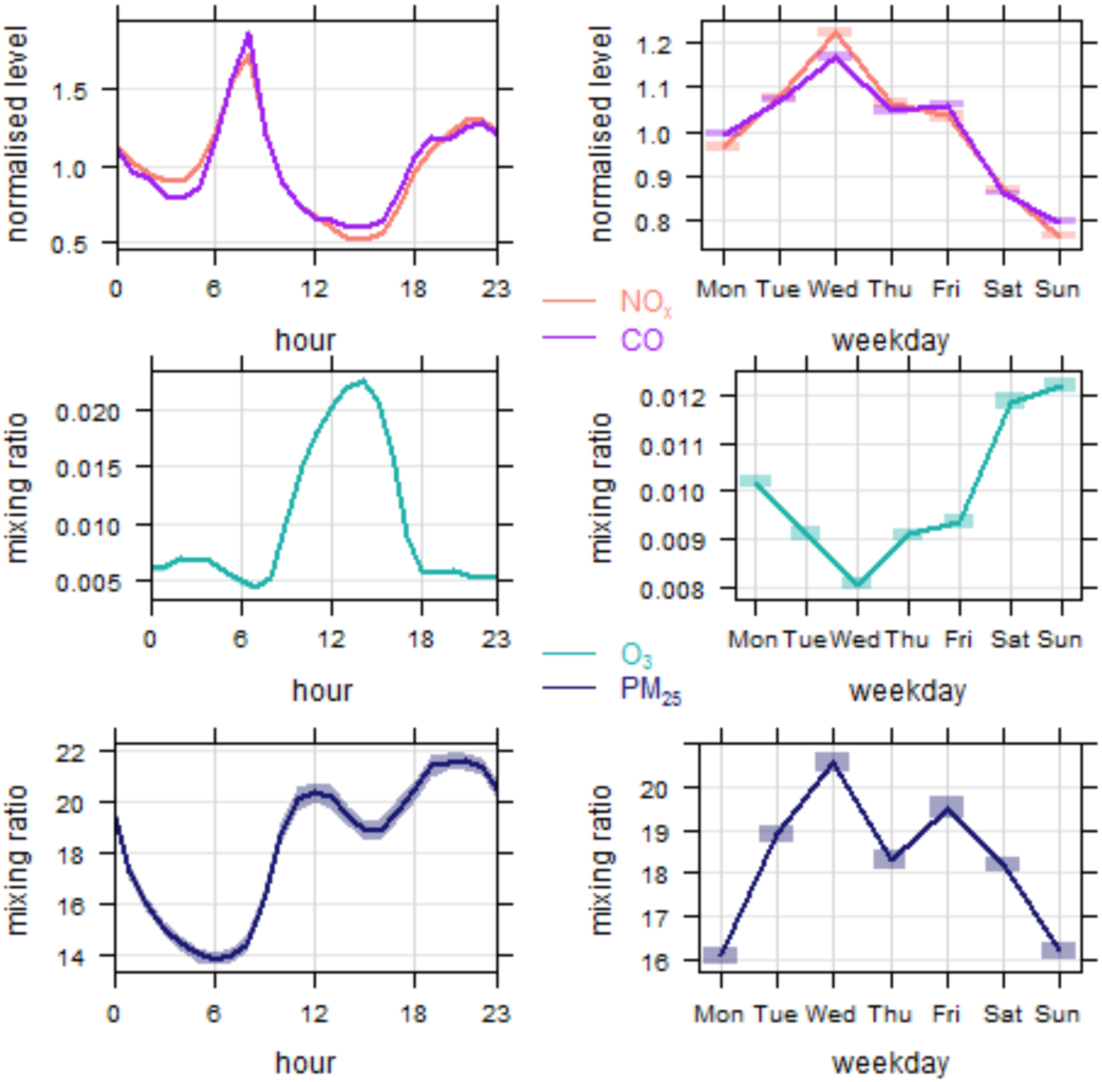
Wintertime PM events: enhancements of primary pollutants, low oxidant levels near surface.



- $PM_{2.5}$ has daytime max
- CO is enhanced.
- Opposite of Uintah basin
- Both NO& NO2 are enhanced.
- NOx: 100-200 ppb
- O_3 is titrated at night due to high NO.
- Low during the day (inefficient photolysis).

Winters (Dec – Jan) 2006 – 2015 at HW, Salt Lake City

Diurnal Profiles and Weekend Effect: 20 % lower $PM_{2.5}$



NOx & CO

- Lower NOx levels on weekends
- 40 % variation in NOx

Ozone

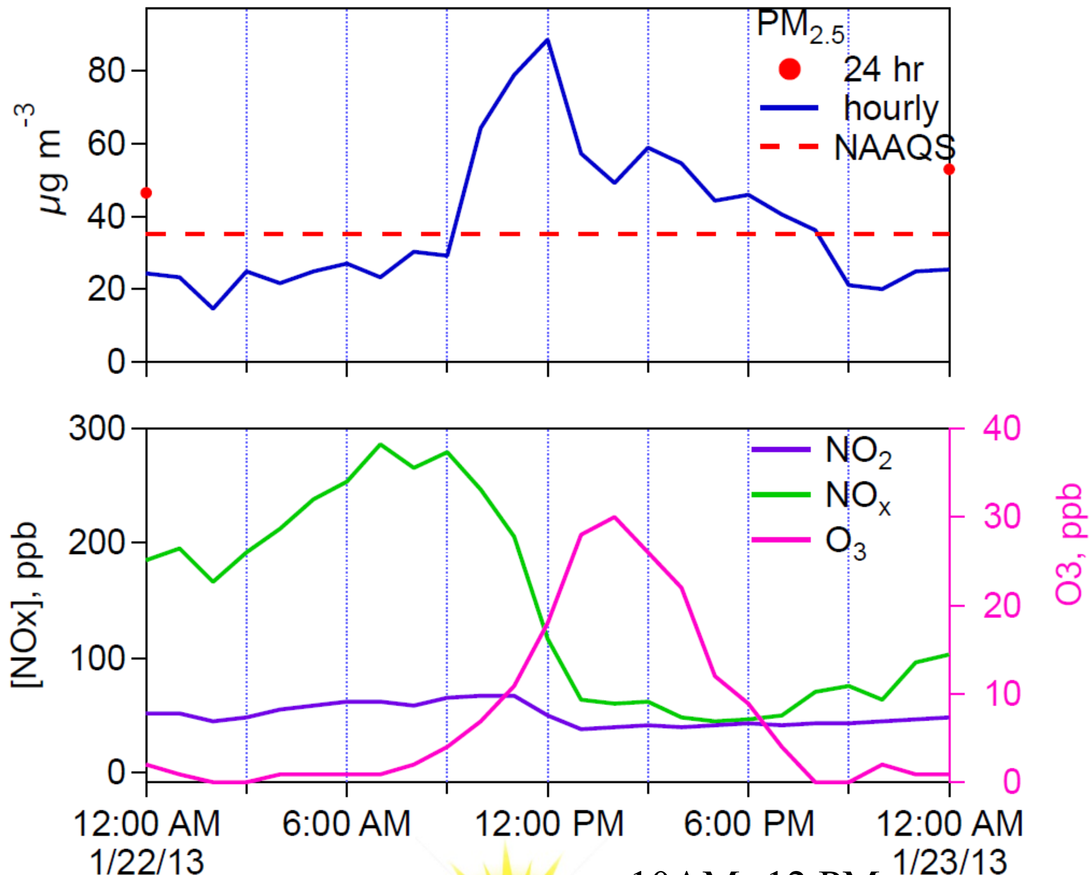
- Higher O_3 on weekends
- Variation is large, ~ 40 %

PM2.5

- Shows less variation
- 20 % lower on weekends
- Diurnal profile shows midday and nighttime peak.
- Nighttime activity
- Effect of Monday is seen on Tuesday

Near surface measurements suggest entrainment of PM from upper layer within the inversion

During inversion Jan 23, 2013
Hawthorne

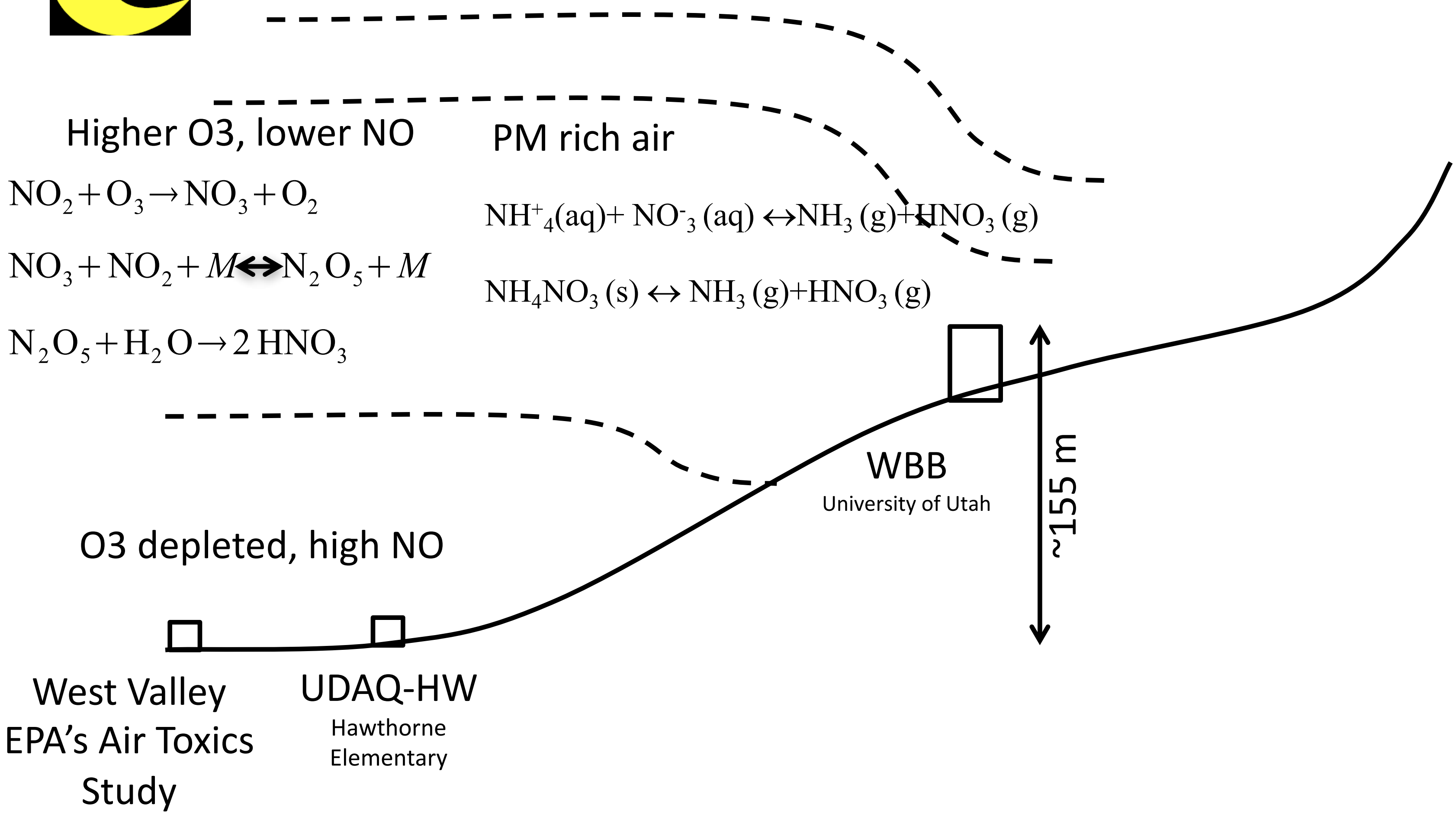


At night
- O_3 is depleted.
- High NOx, CO.
- PM ~ 20 ug/m³.

10AM- 12 PM
- $PM_{2.5}$ shows an increase.
- O_3 increases.
- Sharp decrease in NOx, NO, CO.
- Consistent with downward mixing of PM rich air from upper layer.
- NO_2 levels are sustained throughout the day; 30 – 40 ppb of NO_2 during the day.

Nighttime

Depth of the inversion layer: ~ 400 – 600 m AGL



$NO_2 + O_3 \rightarrow NO_3 + O_2$

$NO_3 + NO_2 + M \leftrightarrow N_2O_5 + M$

$N_2O_5 + H_2O \rightarrow 2\,HNO_3$

$NH_4^+(aq) + NO_3^-(aq) \leftrightarrow NH_3(g) + HNO_3(g)$

$NH_4NO_3(s) \leftrightarrow NH_3(g) + HNO_3(g)$

Coupling between meteorology and chemistry.

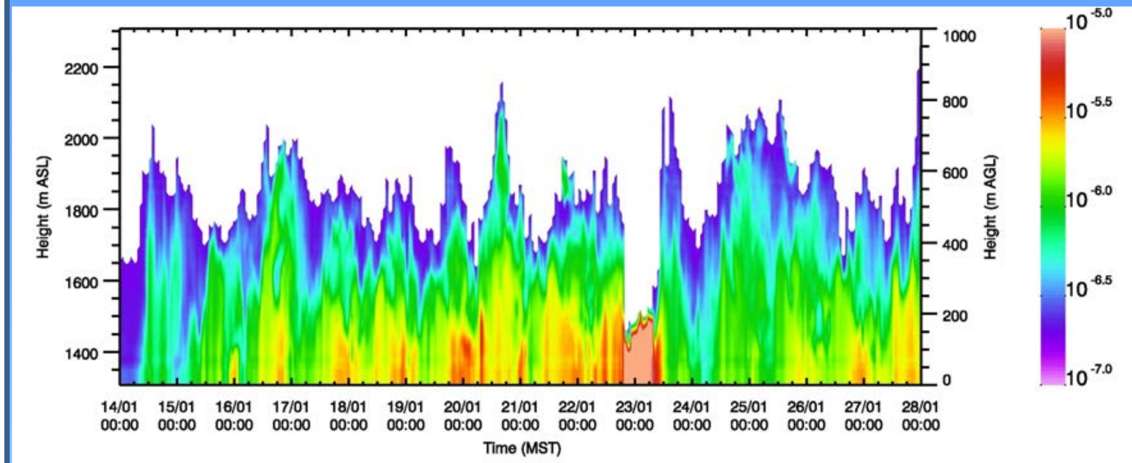
Atmospheric Chemistry Measurements on Univ. of Utah Campus

Existing measurements:
CO2, CH4, CO2 isotopes, H2O isotopes

Species	Instrument (model)	Time resolution (response time)
NO_3, N_2O_5	Cavity Ring Down Spectrometer (CaRDs)	<10 s
NOy	CaRDs	<10 s
NOx	Teledyne API (200 E)	(<5 min)
O_3	Teledyne API (400 E)	(<5 min)
CO	Teledyne API (300E)	(<5 min)
$PM_{2.5}$	TEOM / Metone	Min
Particle size distribution	Optical particle counter	<10 s
NH_3	Innova photoacoustic field gas monitor	(<2 min)

Time evolution of vertical distribution

Vertical measurements of $PM_{2.5}$ & related species



Time evolution of aerosol layer based on back scattering

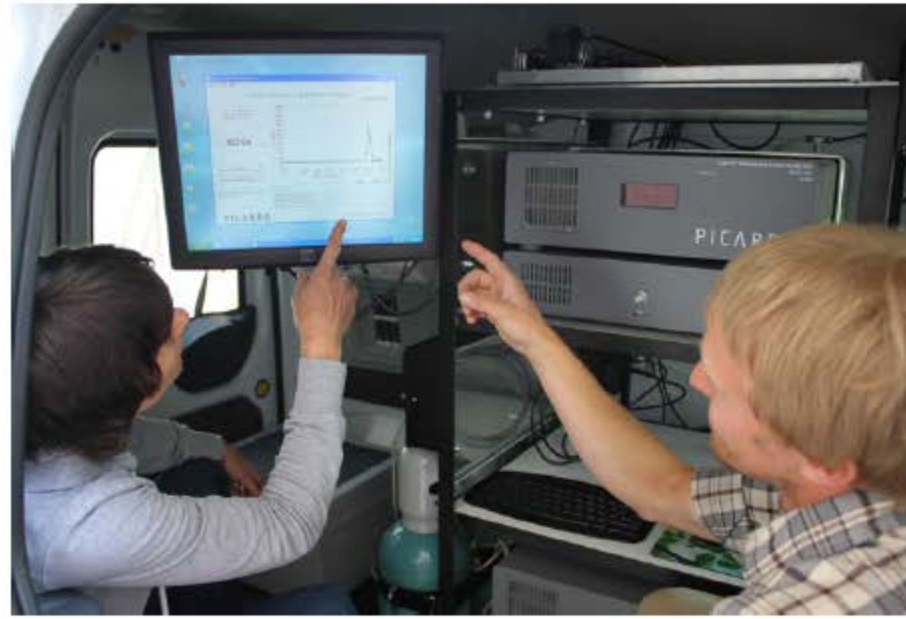
Ceilometer

Scanning Doppler LiDAR

- 3-D fields of ws and wd, evolution
- Advective processes & transport
  - upward mixing/downward mixing

O_3, $PM_{2.5}$, NO_2, met

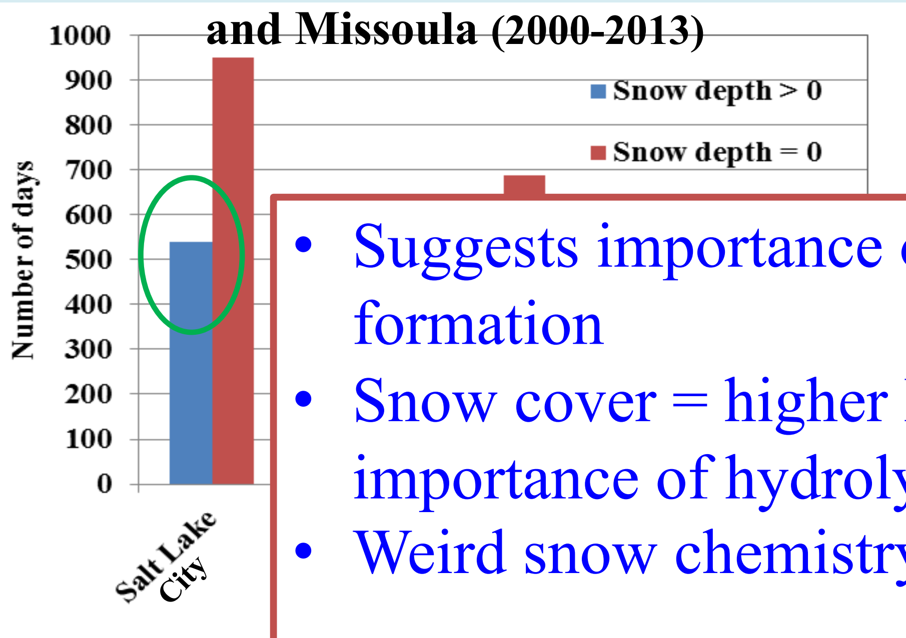
Complementary Obs: The Mobile Lab (aka "Nerdmobile")



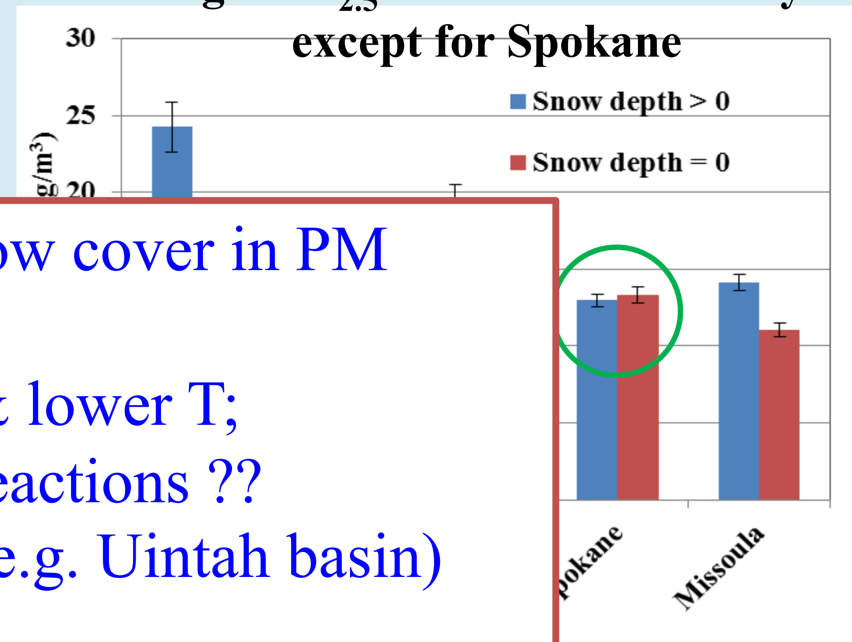
Capability

Carbon dioxide	PM
Carbon monoxide	NOx
Methane	GPS
Ozone	
Flask – trace gases	Temperature
Flask – isotopes	Humidity
Flask – VOCs	Wind

More Snow Cover Days in Salt Lake City and Missoula (2000-2013)

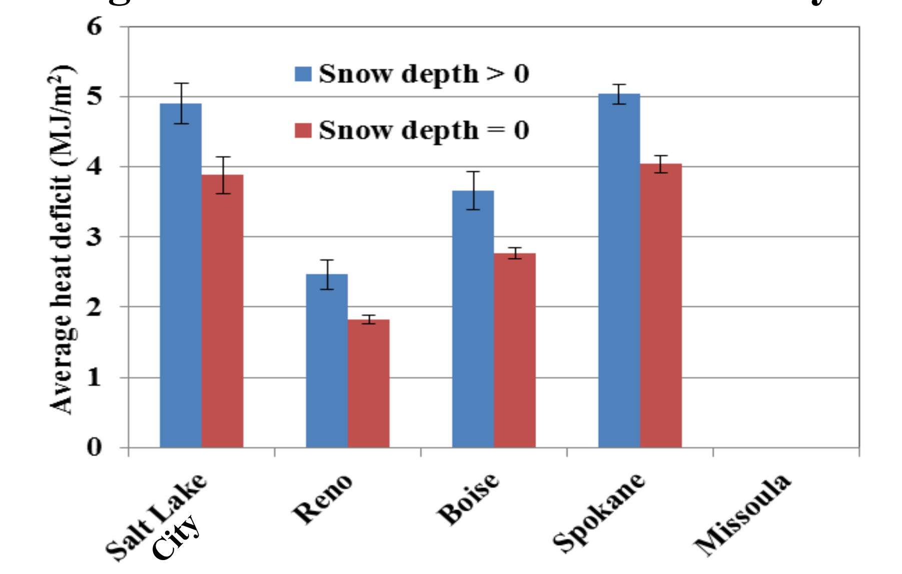


High $PM_{2.5}$ on Snow Cover Days except for Spokane

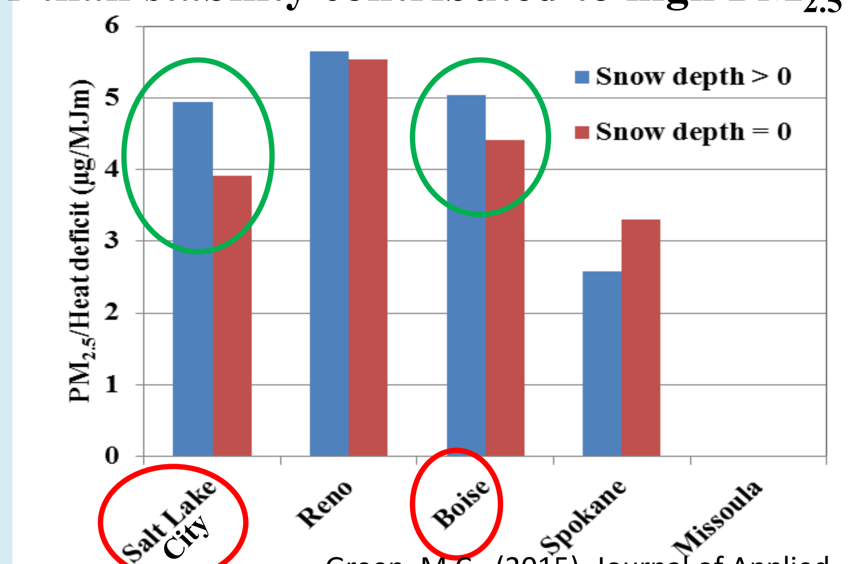


- Suggests importance of snow cover in PM formation
- Snow cover = higher RH & lower T; importance of hydrolysis reactions ??
- Weird snow chemistry ?? (e.g. Uintah basin)

High Heat Deficit on Snow Cover Days



… implies factors other than stability contributed to high $PM_{2.5}$



Normalizing $PM_{2.5}$ by heat deficit control for variations in stability.

Green, M.C.. (2015). Journal of Applied Meteorology and Climatology

Summary

- PM pollution is prevalent in urban mountain valleys and affects large population.
- Evidence of interplay between the dynamics and chemical processes driving the elevated PM levels measured near surface.
- Very interesting chemistry tied to the snow/RH is taking place.
- Many uncertainties regarding the chemical mechanism.
- Vertical and spatial measurements will be key for understanding the chemistry.
- Large scale studies (aircrafts etc.) are needed.