The PCAPS/Bingham Mine Experiments

PCAPS
Persistent Cold-Air Pool Study

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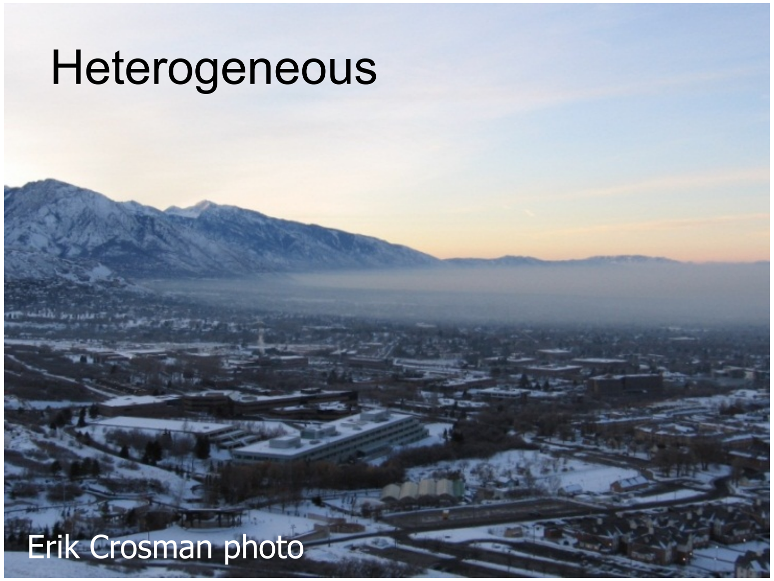
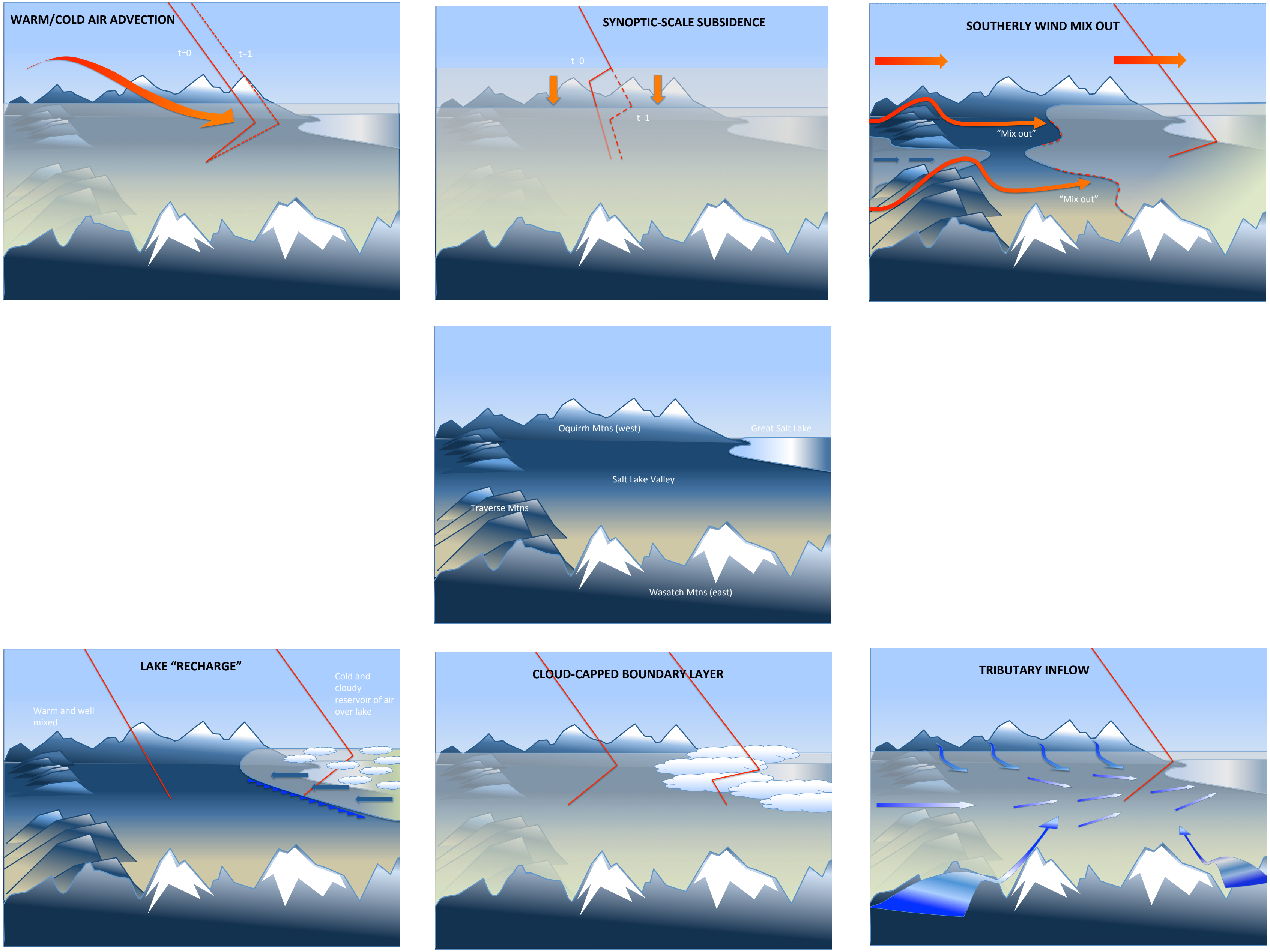
Utah DAQ
16 February 2012
Salt Lake City, UT

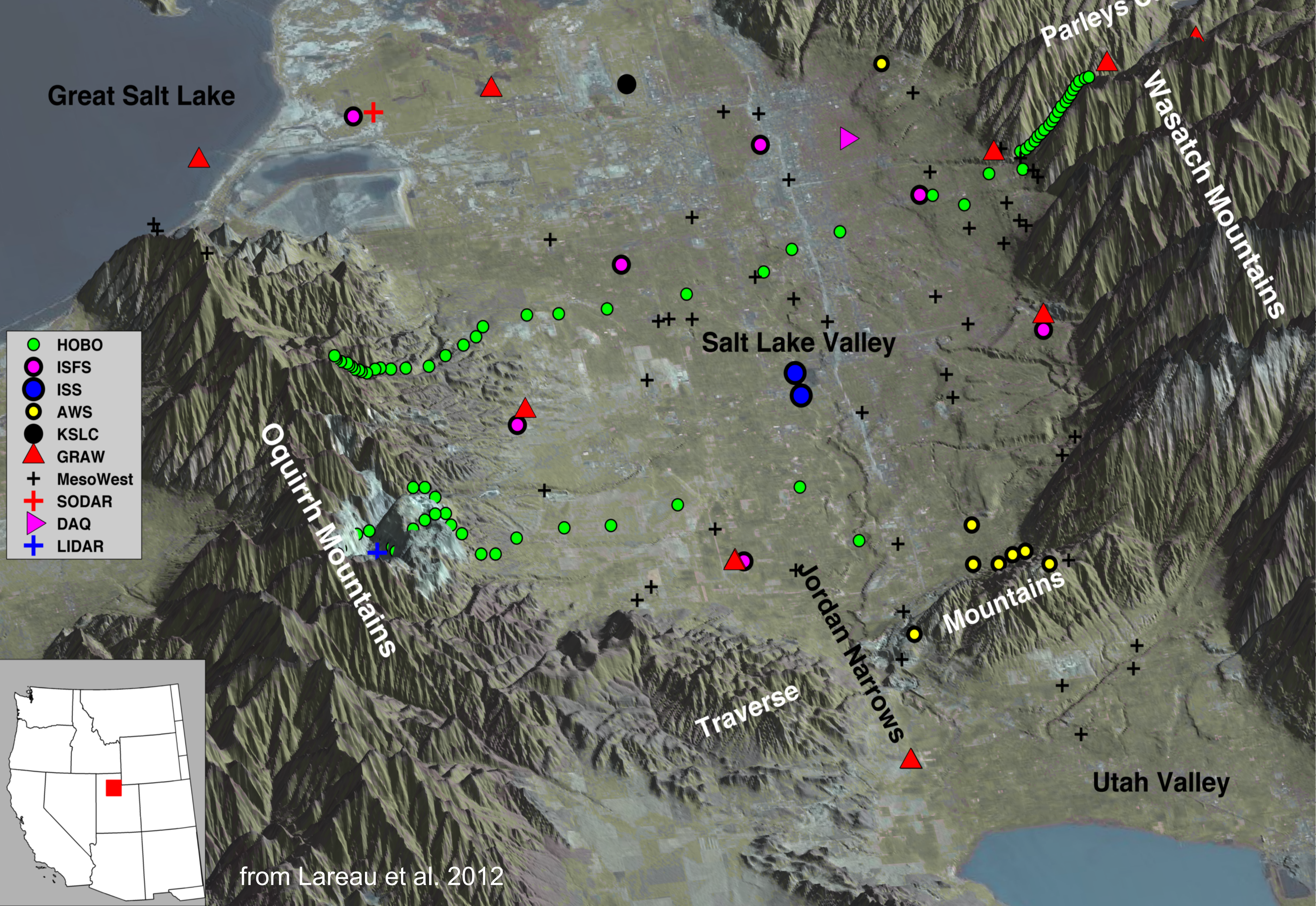
Types of CAPs



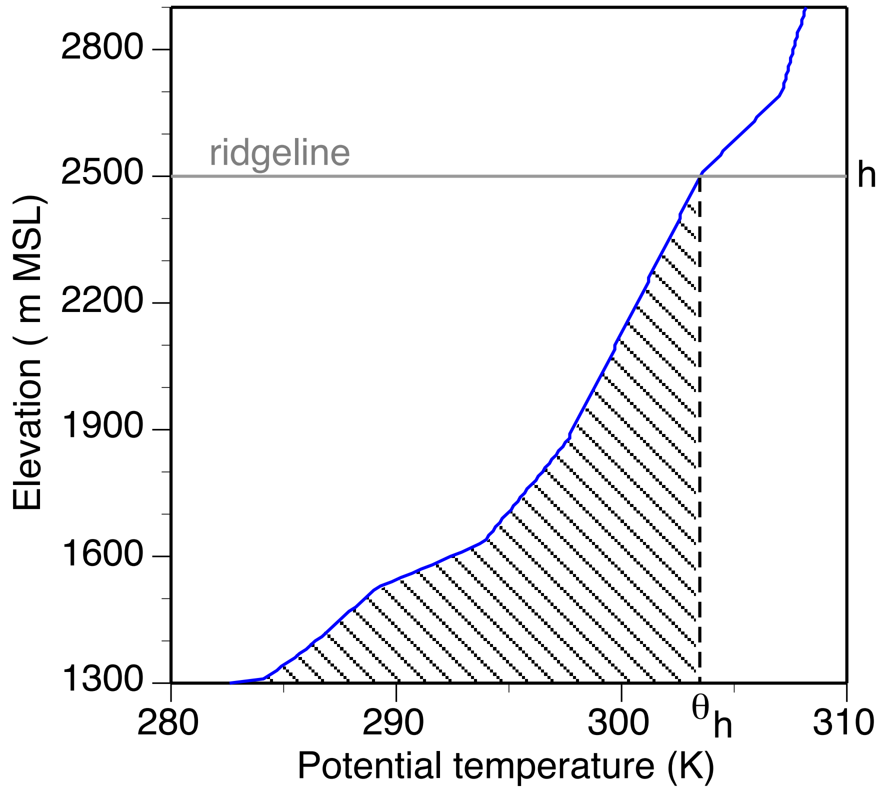


WARM/COLD AIR ADVECTION
t=0
t=1
SYNOPTIC-SCALE SUBSIDENCE
t=0
t=1
SOUTHERLY WIND MIX OUT
"Mix out"
"Mix out"
Oquirrh Mtns (west)
Great Salt Lake
Salt Lake Valley
Traverse Mtns
Wasatch Mtns (east)
LAKE "RECHARGE"
Warm and well mixed
Cold and cloudy reservoir of air over lake
CLOUD-CAPPED BOUNDARY LAYER
TRIBUTARY INFLOW

Field measurements



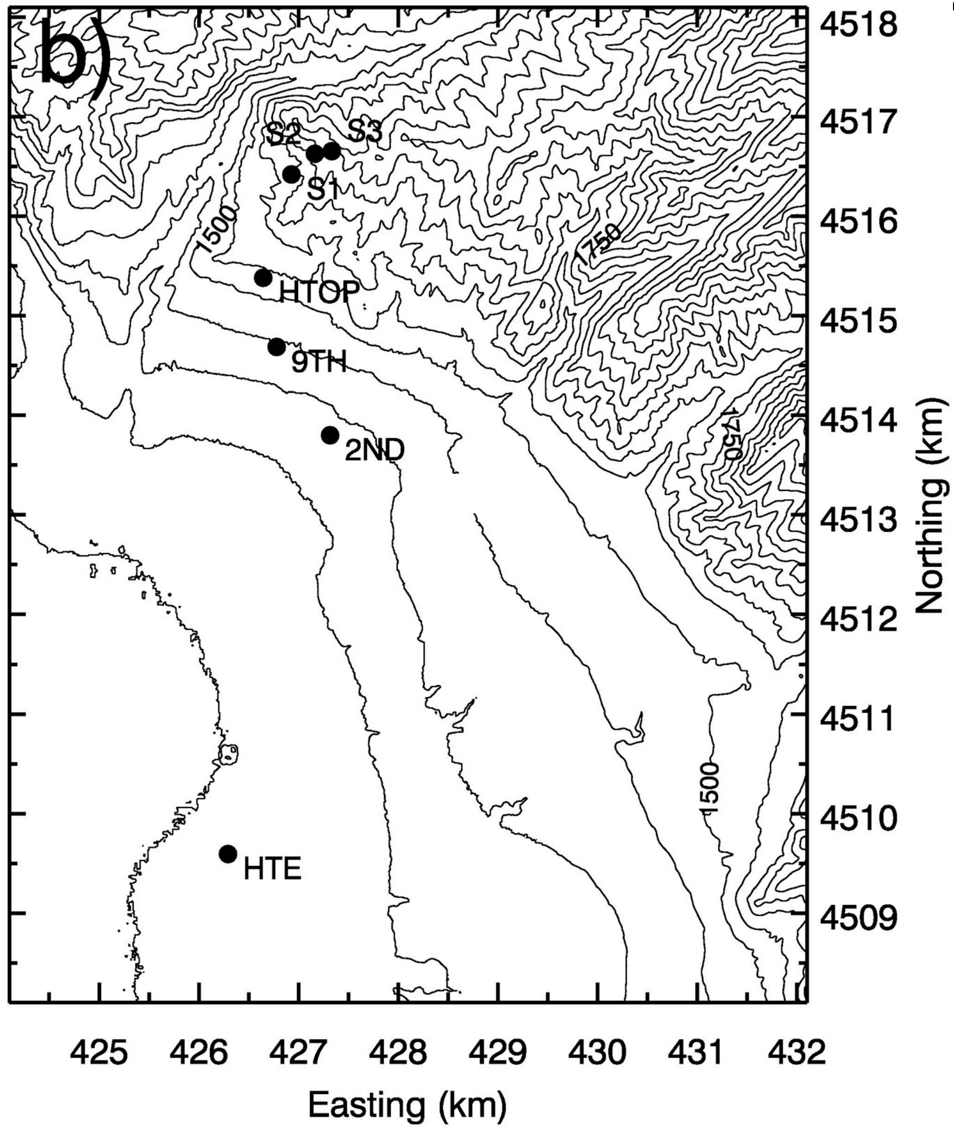
from Lareau et al. 2012



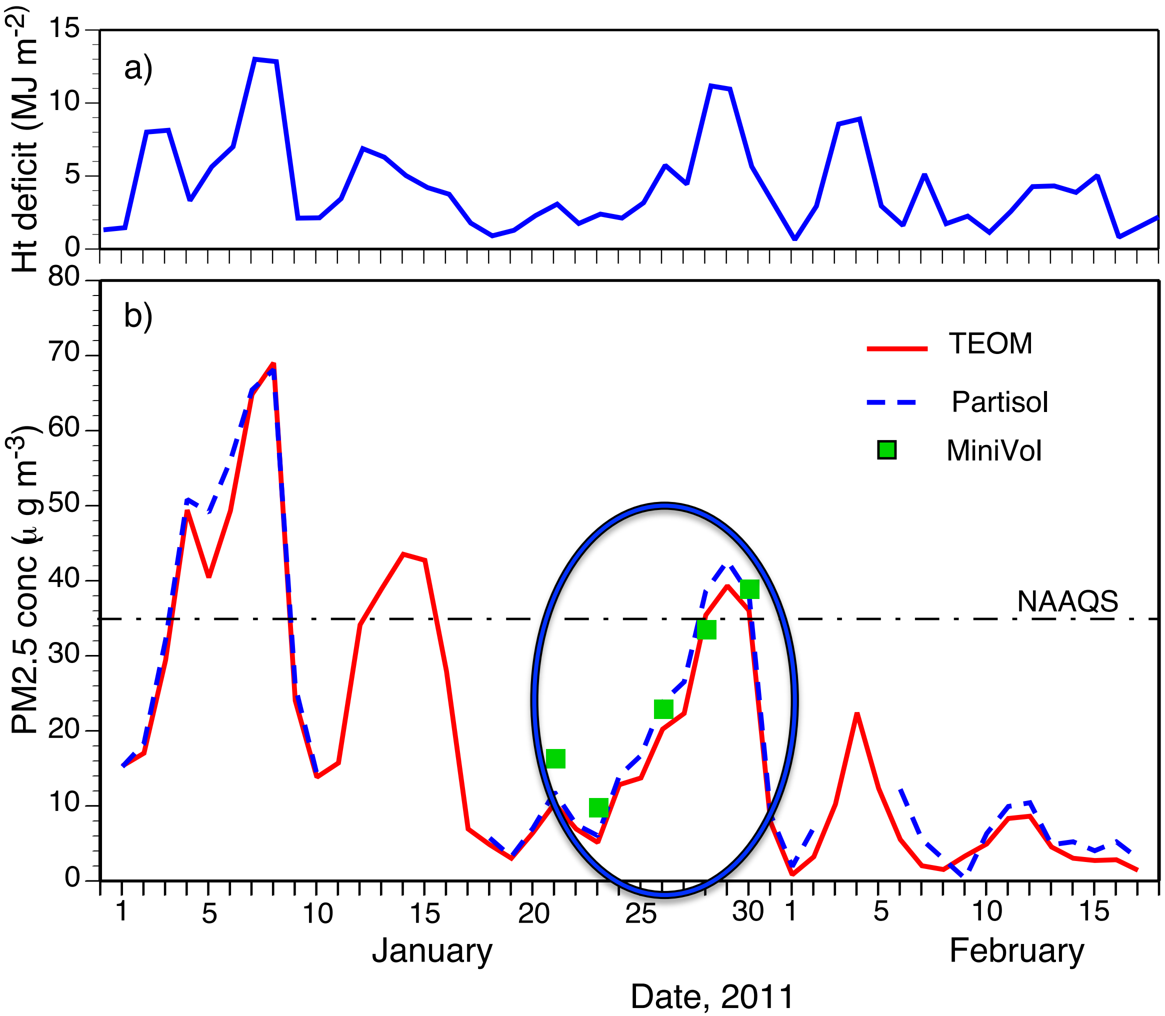
Whiteman, C. D., X. Bian, and S. Zhong, 1999: Wintertime evolution of the temperature inversion in the Colorado Plateau Basin. *J. Appl. Meteor.*, **38**, 1103-1117.

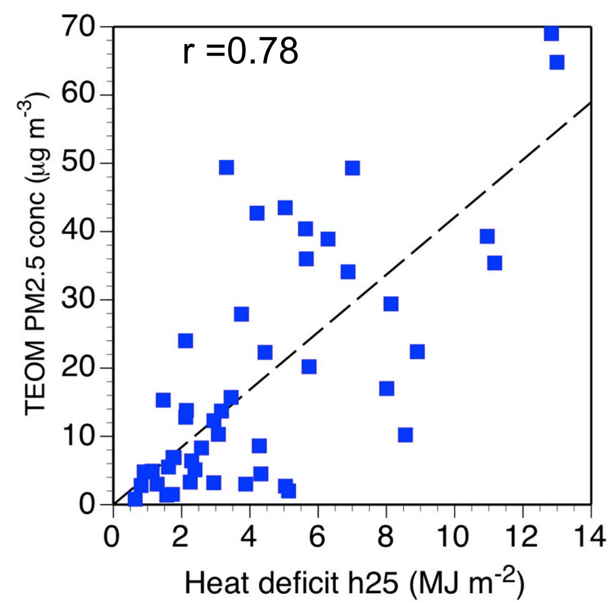
$$h25 = c_p \int_{1300\,m}^{h} \rho(z)\left[\theta_h - \theta(z)\right] dz \quad \left[J\ m^{-2}\right]$$

Introduction – Sampling locations

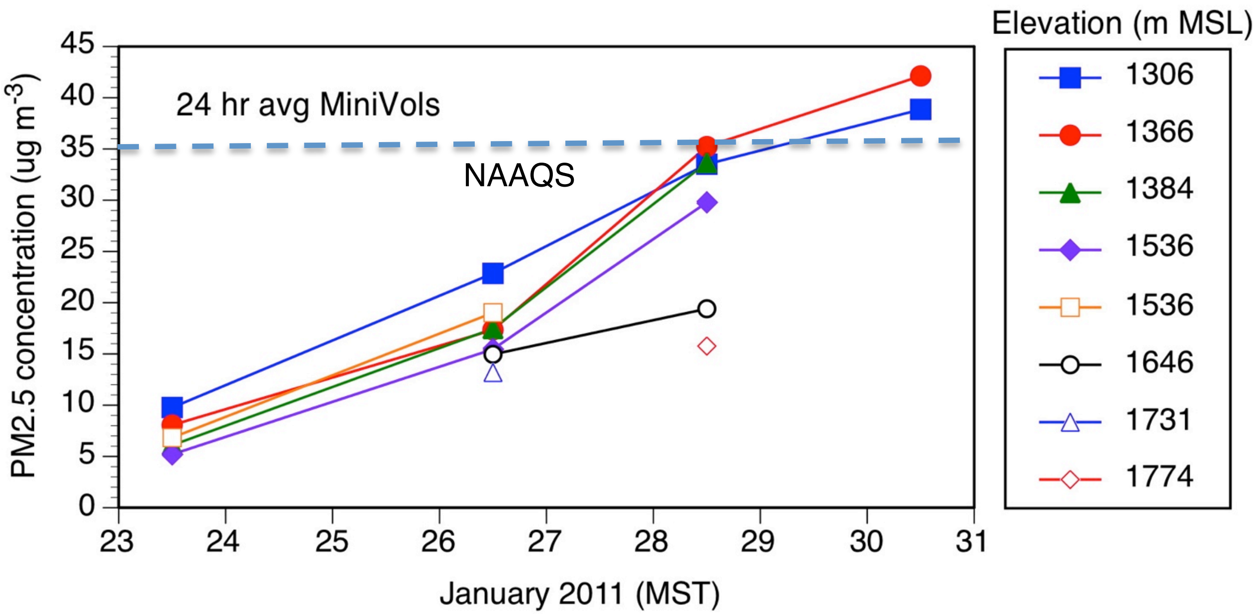


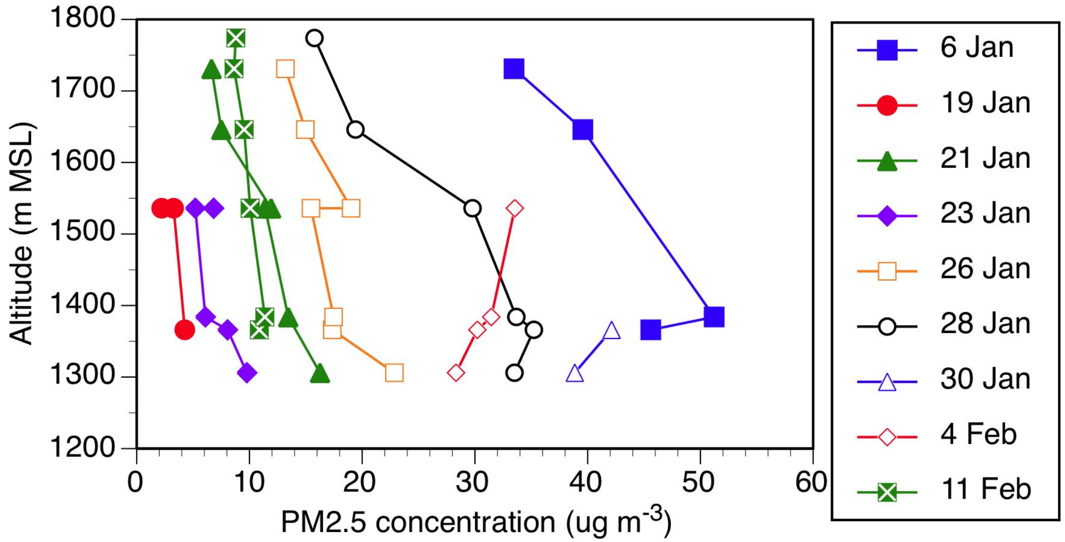
Heat deficit (h25) and PM 2.5 at HTE





Effects of time and altitude



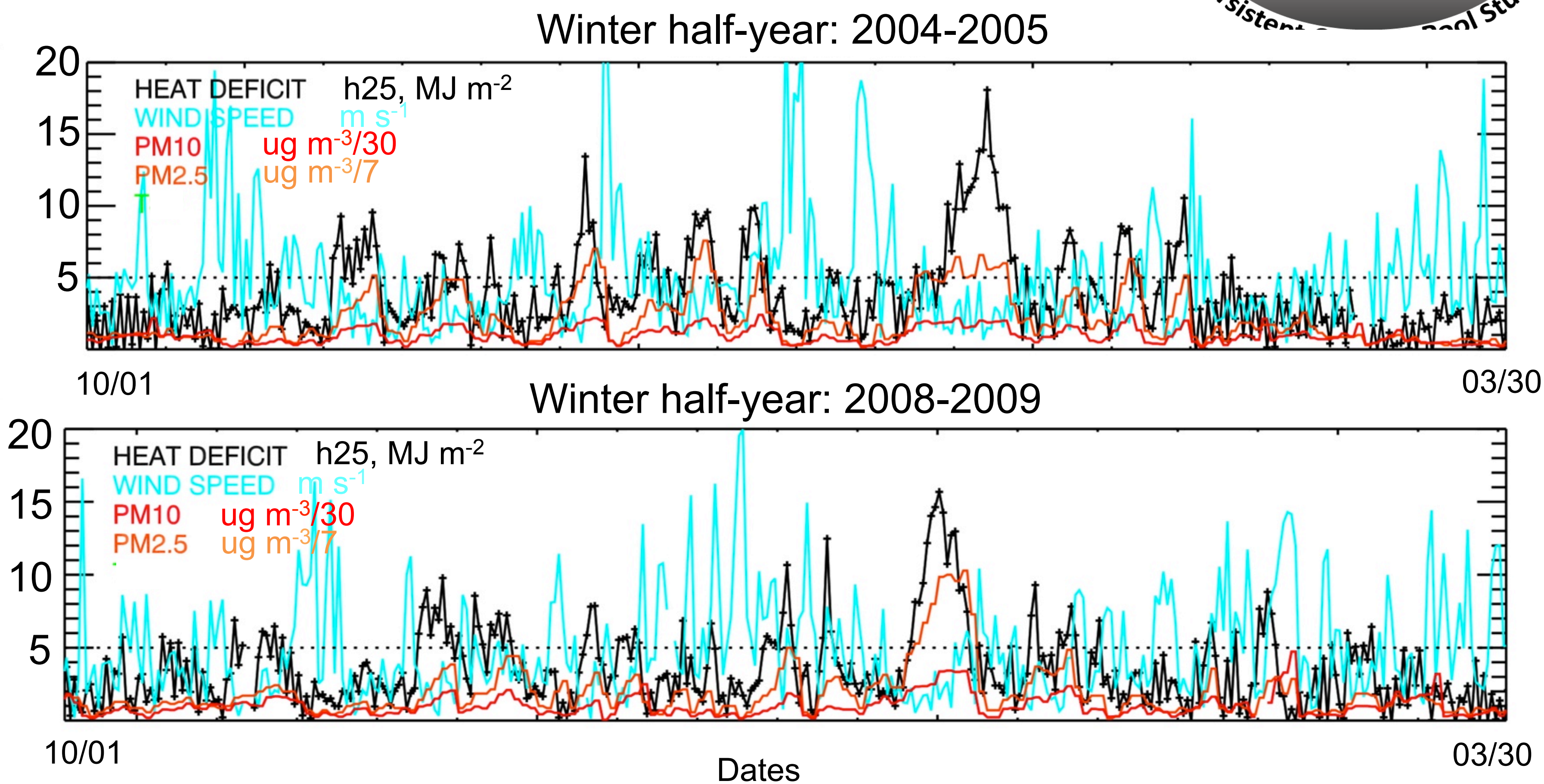


PM2.5 concentrations:

- increase with time
- decrease with elevation

Silcox, G. D., K. E. Kelly, E. T. Crosman, C. D. Whiteman, and B. L. Allen, 2012: Wintertime PM2.5 concentrations in Utah's Salt Lake Valley during persistent, multi-day cold-air pools. *Atmos. Environ.*, **46**, 17-24.

Meteorographs: Time series



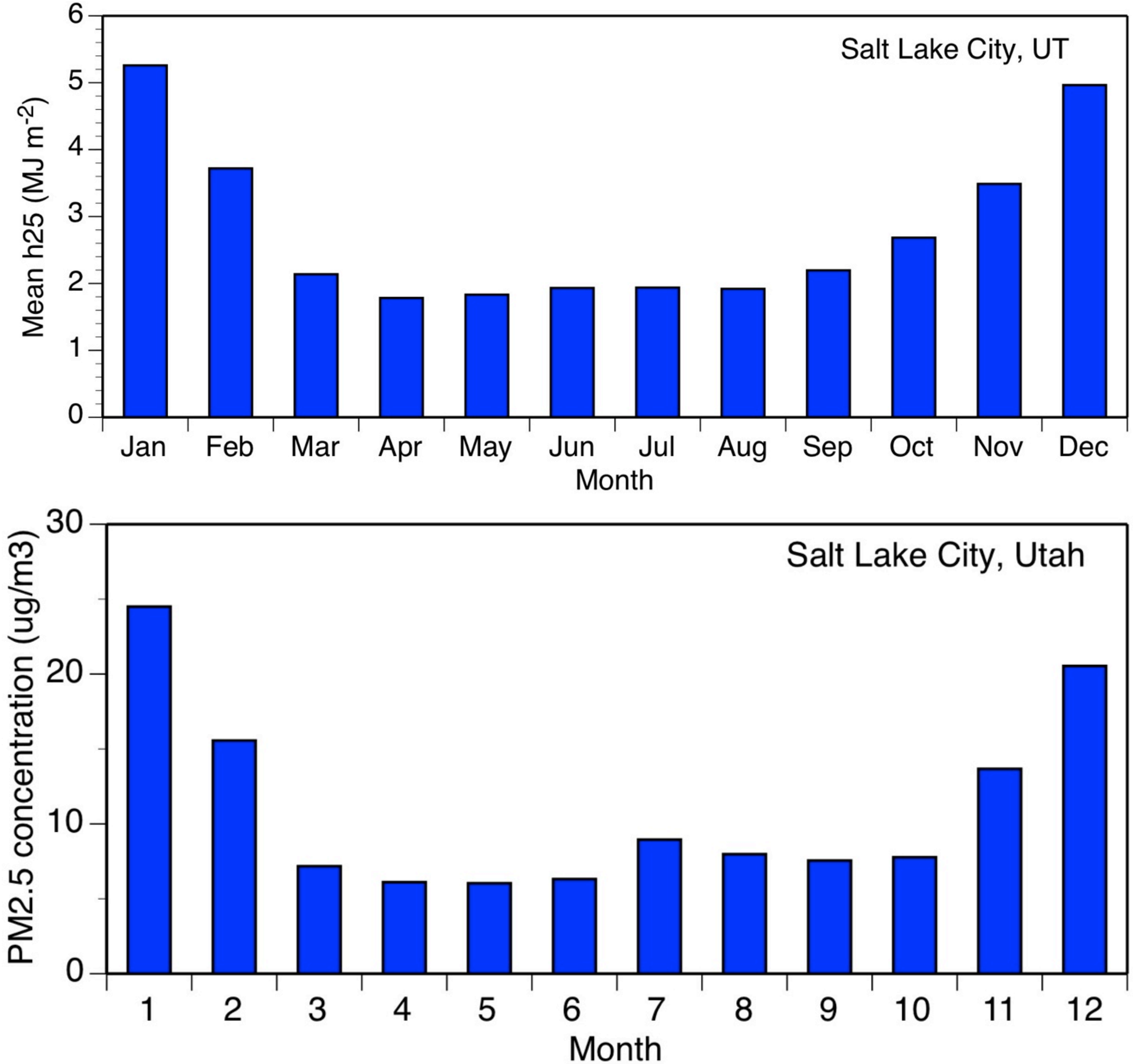
CAP = h25 ≥ 5 MJ m^{-2}

As CAP builds up, PM2.5 and PM10 concentrations increase, but lag

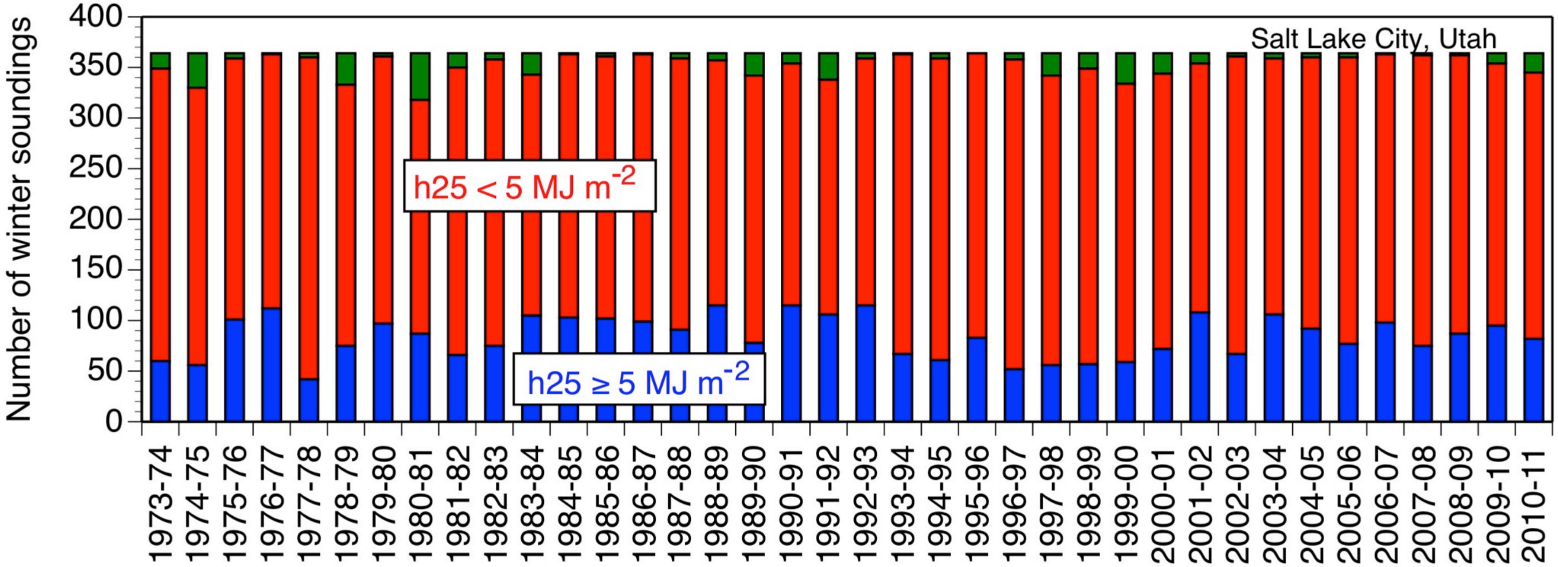
Wind speeds are low during the CAP events

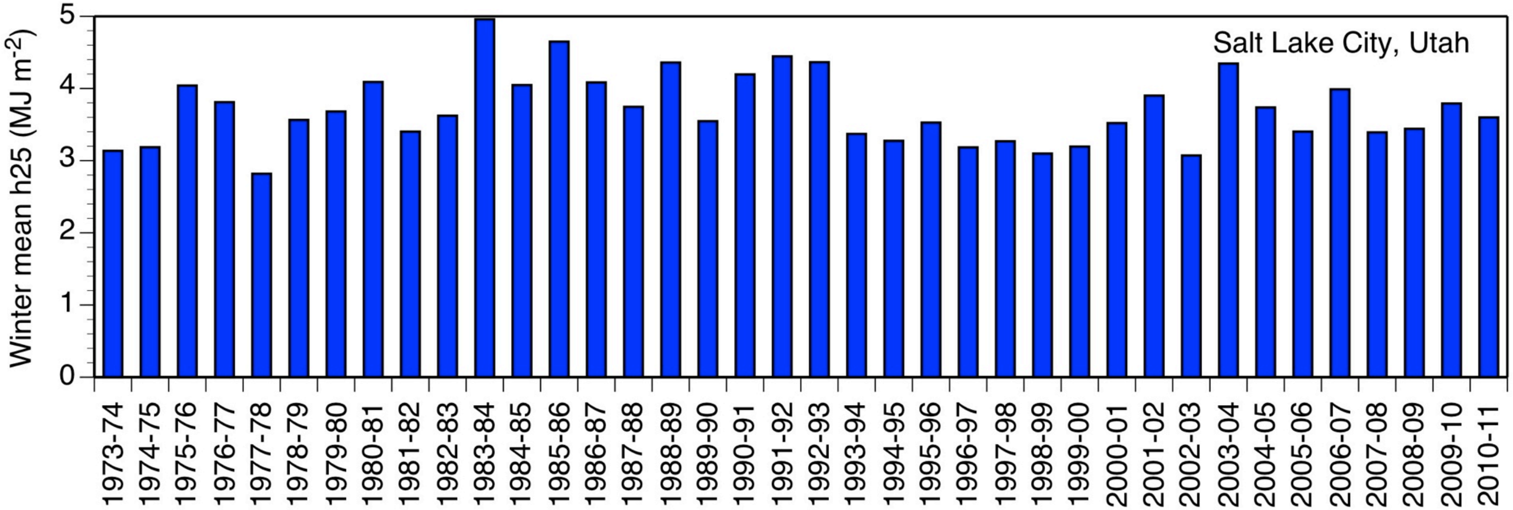
Initiation of high winds often destroys CAPs

h25 and PM2.5 climatologies

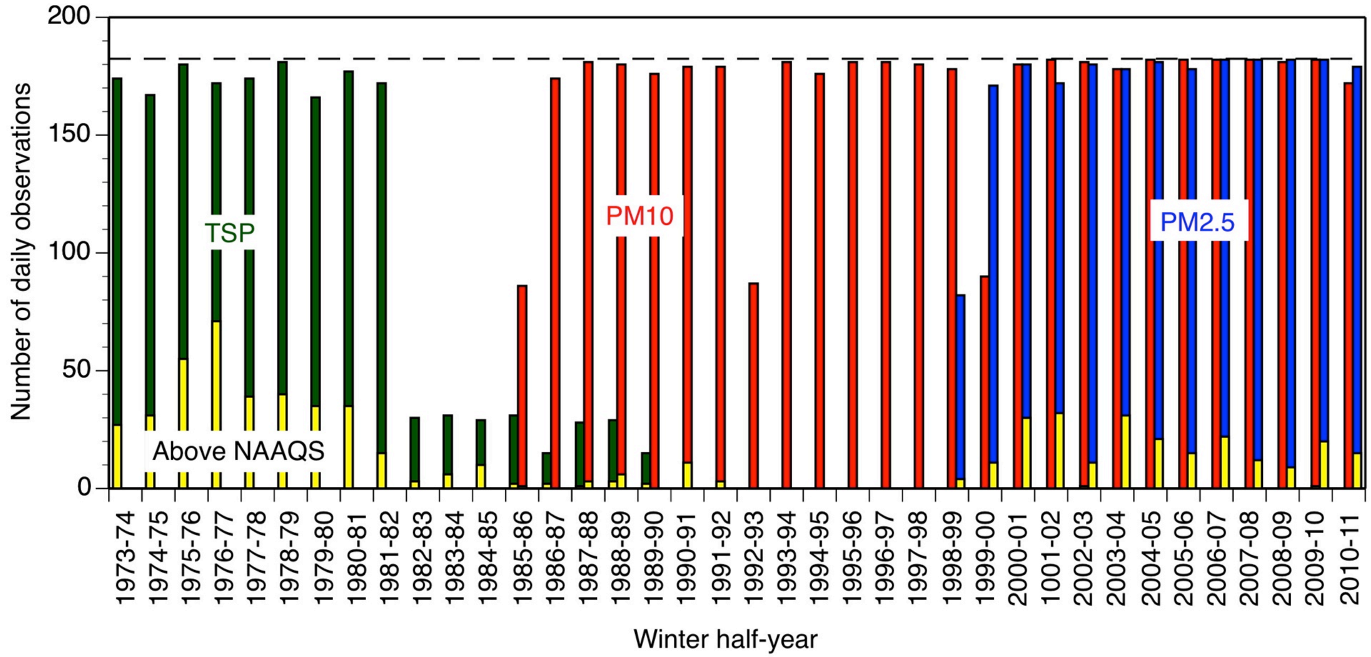


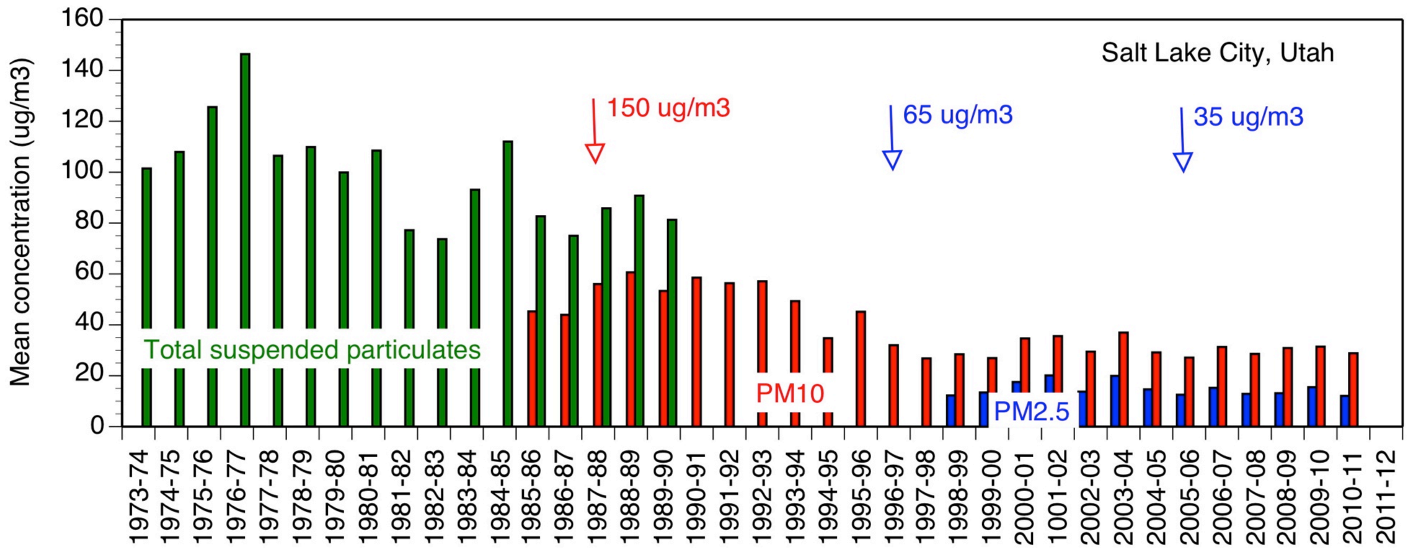
h25 climatology





PM climatology



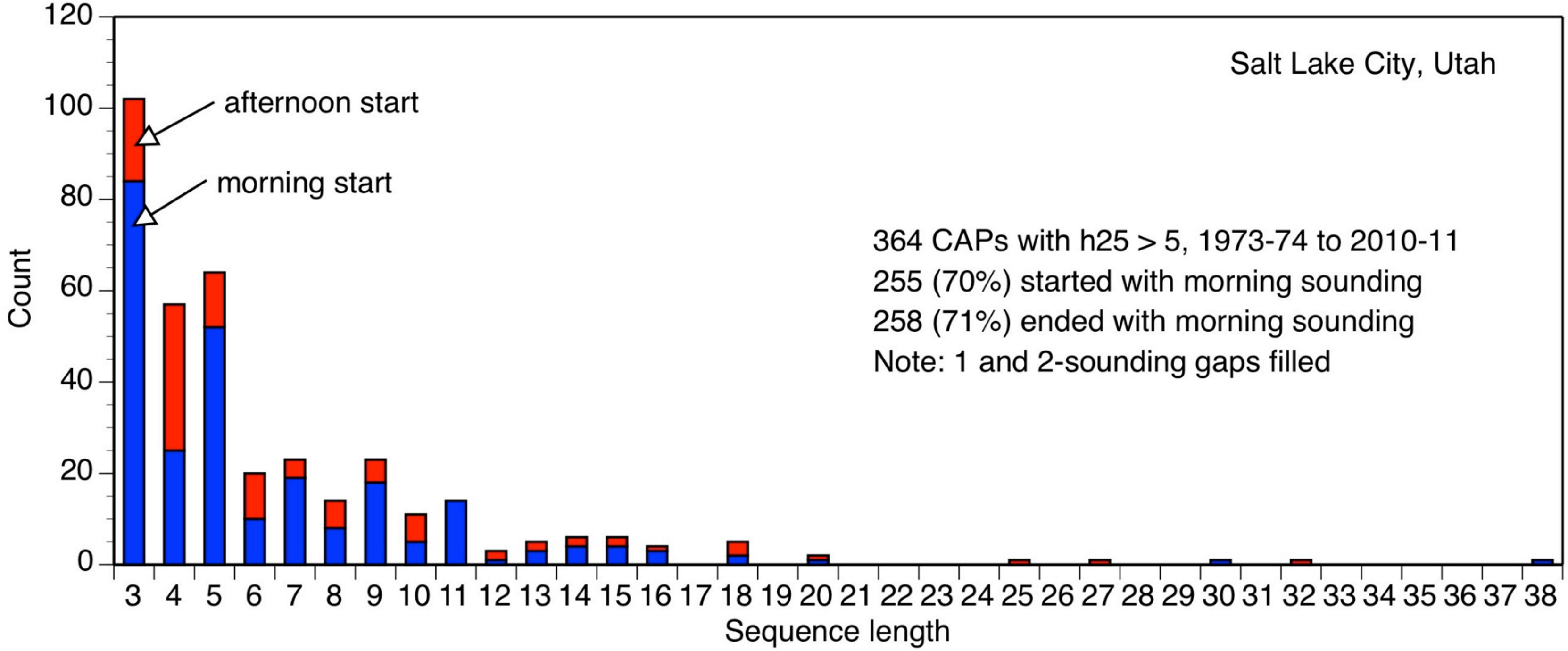


CAP duration

The 4 longest events with heat deficit (h25) continuously above 5 MJ m^{-2}

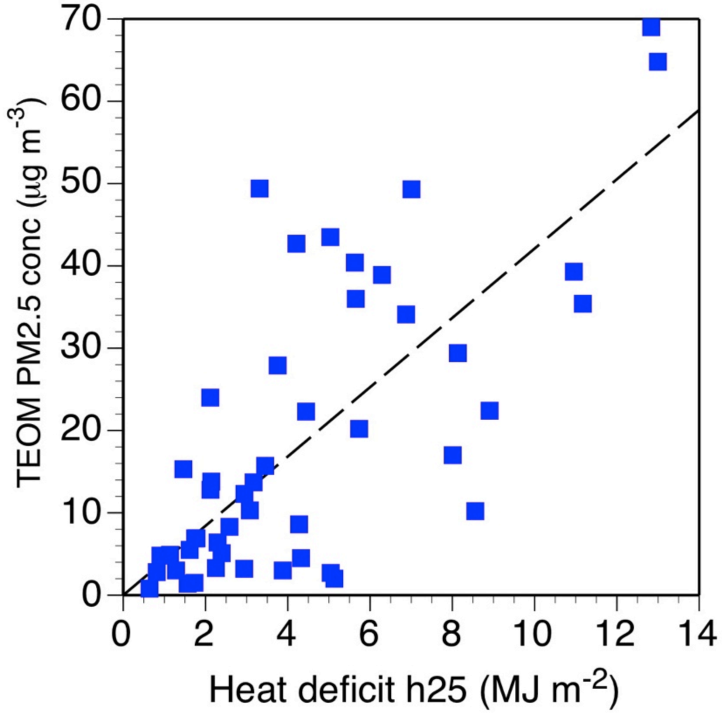
Starting dates	# of days
Jan 27 1984 at 17 MST	13.5
Dec 26 2000 at 05 MST	15
Dec 14 1985 at 17 MST	16
Jan 06 2004 at 05 MST	19

The average winter half-year has 9.6 CAP events (84 soundings).

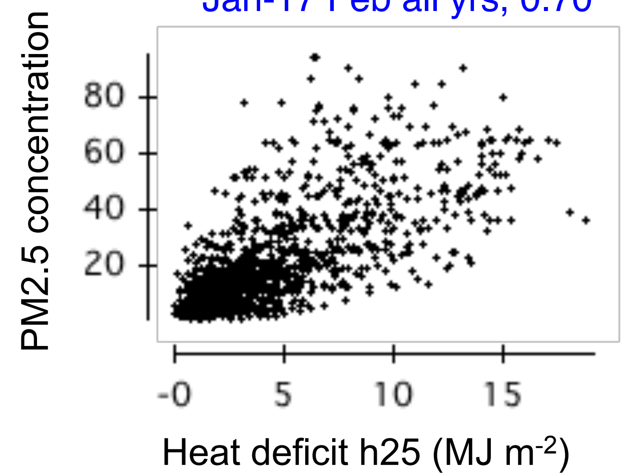


3. $PM_{2.5}$ vs heat deficit

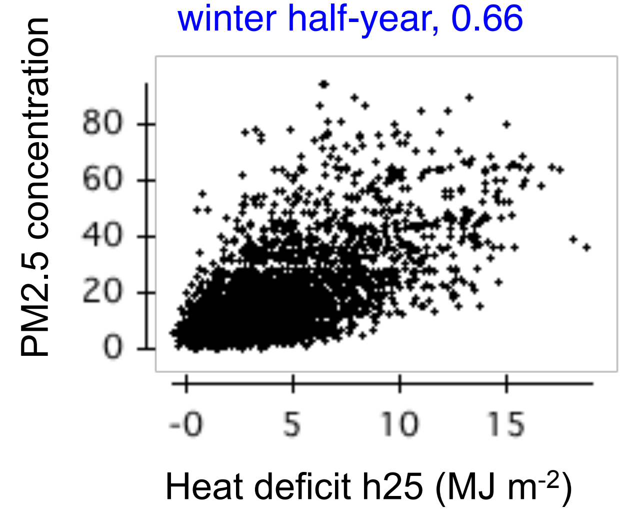
$PM_{2.5}$ vs heat deficit (h25),
Jan-17 Feb 2011, 0.78



$PM_{2.5}$ vs heat deficit (h25)
Jan-17 Feb all yrs, 0.70



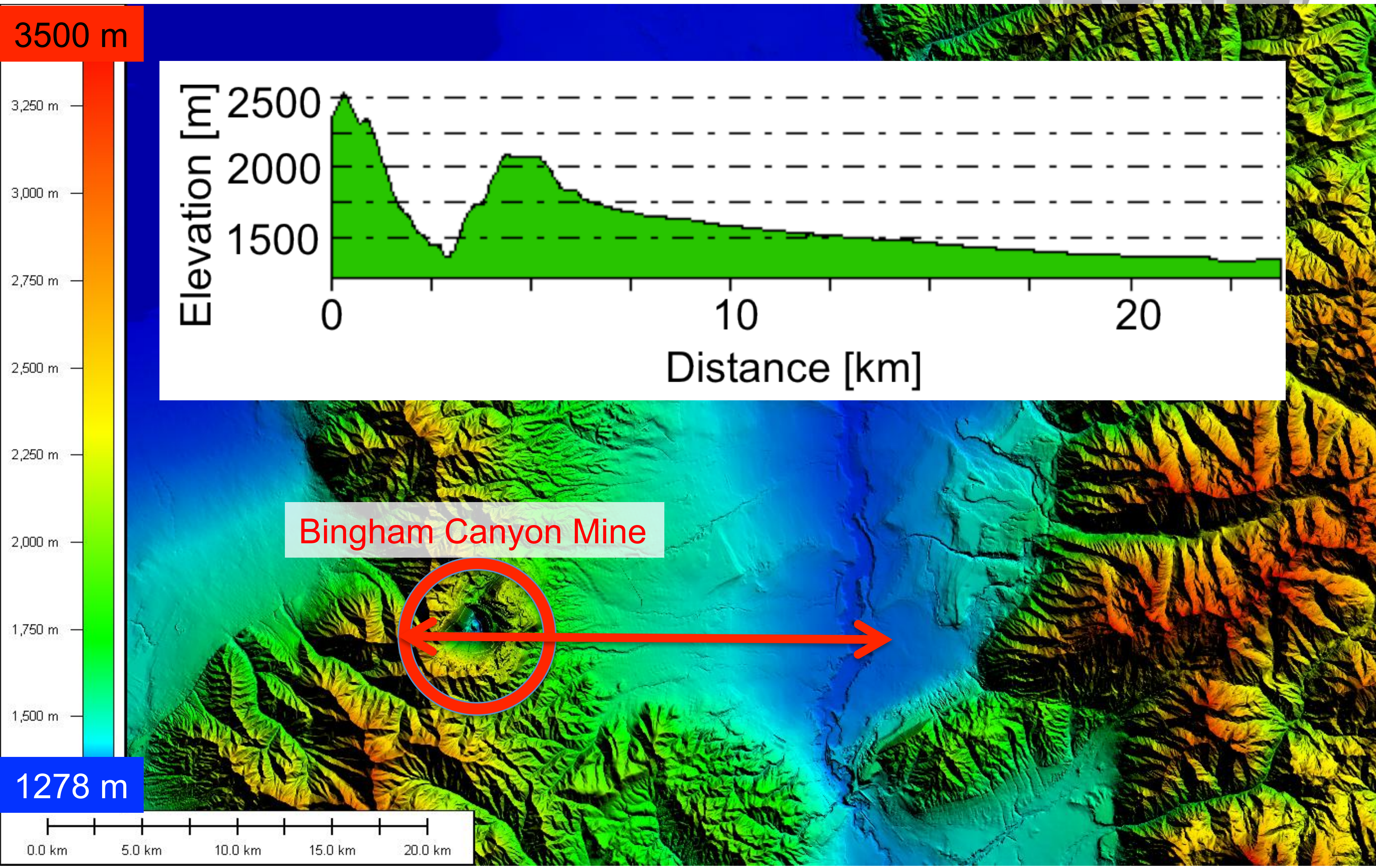
$PM_{2.5}$ vs heat deficit (h25)
winter half-year, 0.66



Bingham Canyon Mine Experiment

Objectives

- What are the differences in the development of the atmospheric boundary layer structures (temperature, humidity and wind) within the *mine basin* and within the adjacent *valley*?
- What are the physical processes responsible for these differences? How does the temperature structure inside the mine depend on ambient winds?


3500 m
3,250 m
3,000 m
2,750 m
2,500 m
2,250 m
2,000 m
1,750 m
1,500 m
1278 m
Elevation [m]
2500
2000
1500
0
10
20
Distance [km]
Bingham Canyon Mine
0.0 km
5.0 km
10.0 km
15.0 km
20.0 km

Topography of the Bingham Canyon Mine

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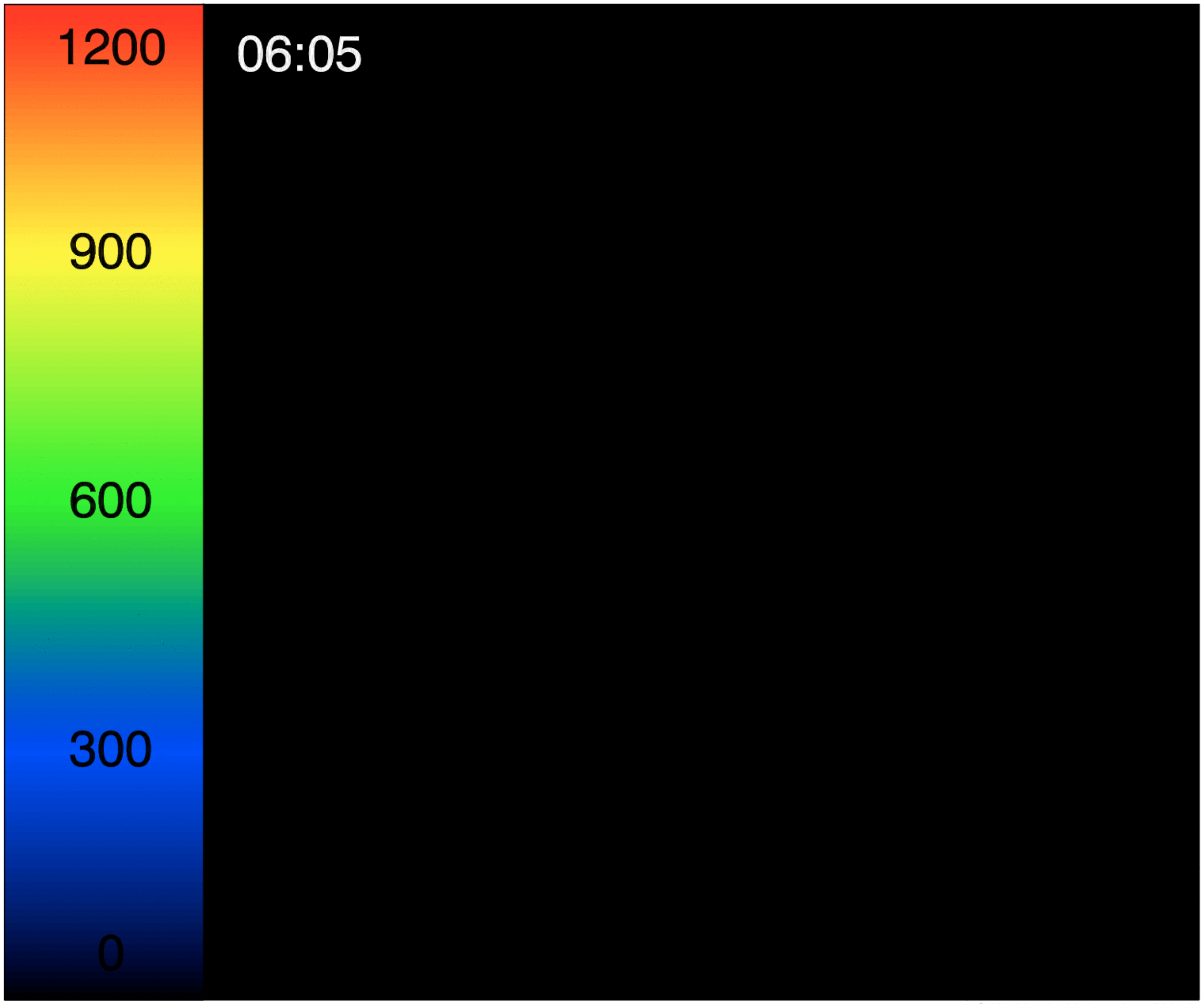
Persistent Cold-Air Pool Study

GLOBAL RADIATION, PARAMETERIZED, [W m^{-2}]

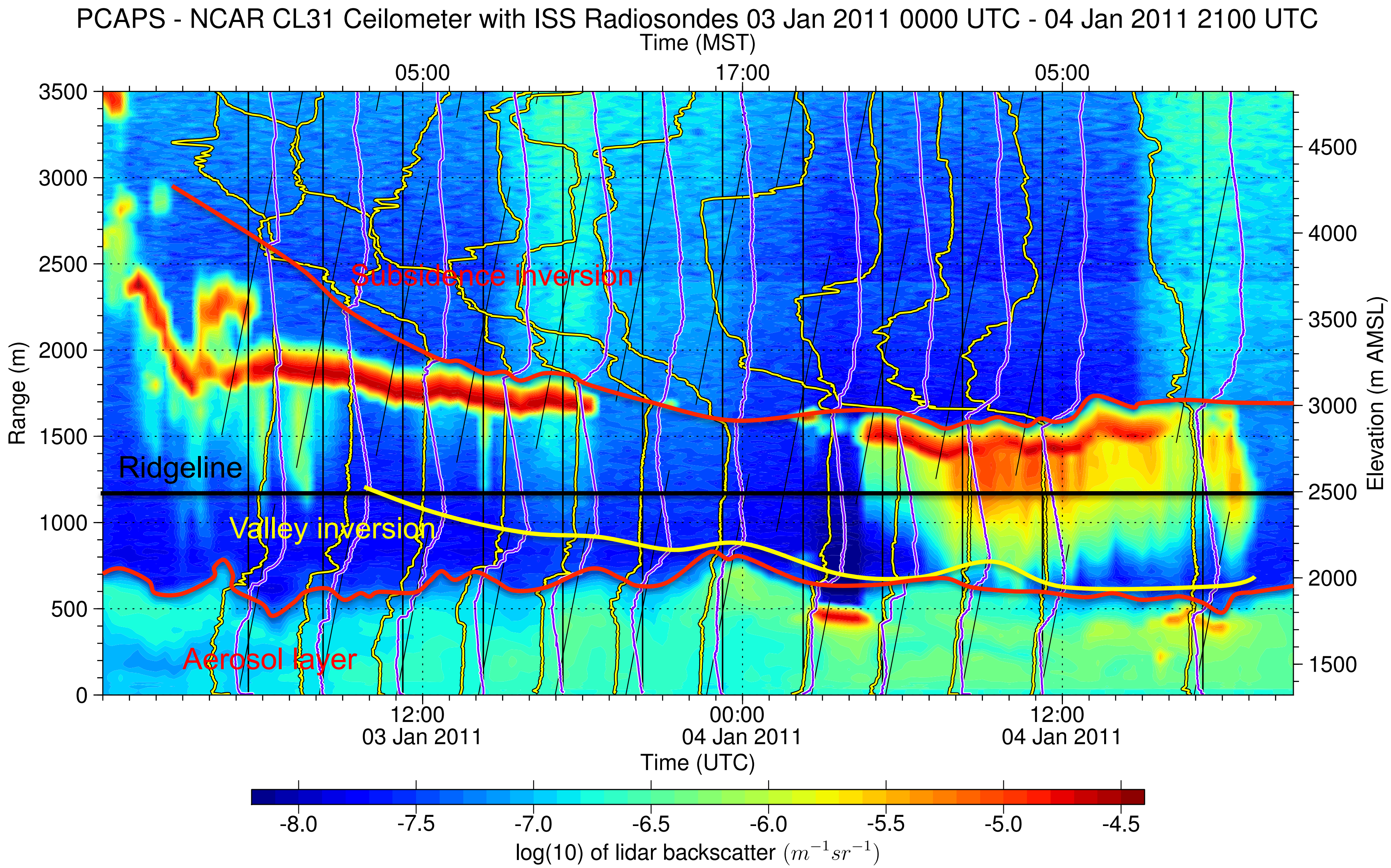


S.W. Hoch, University of Utah

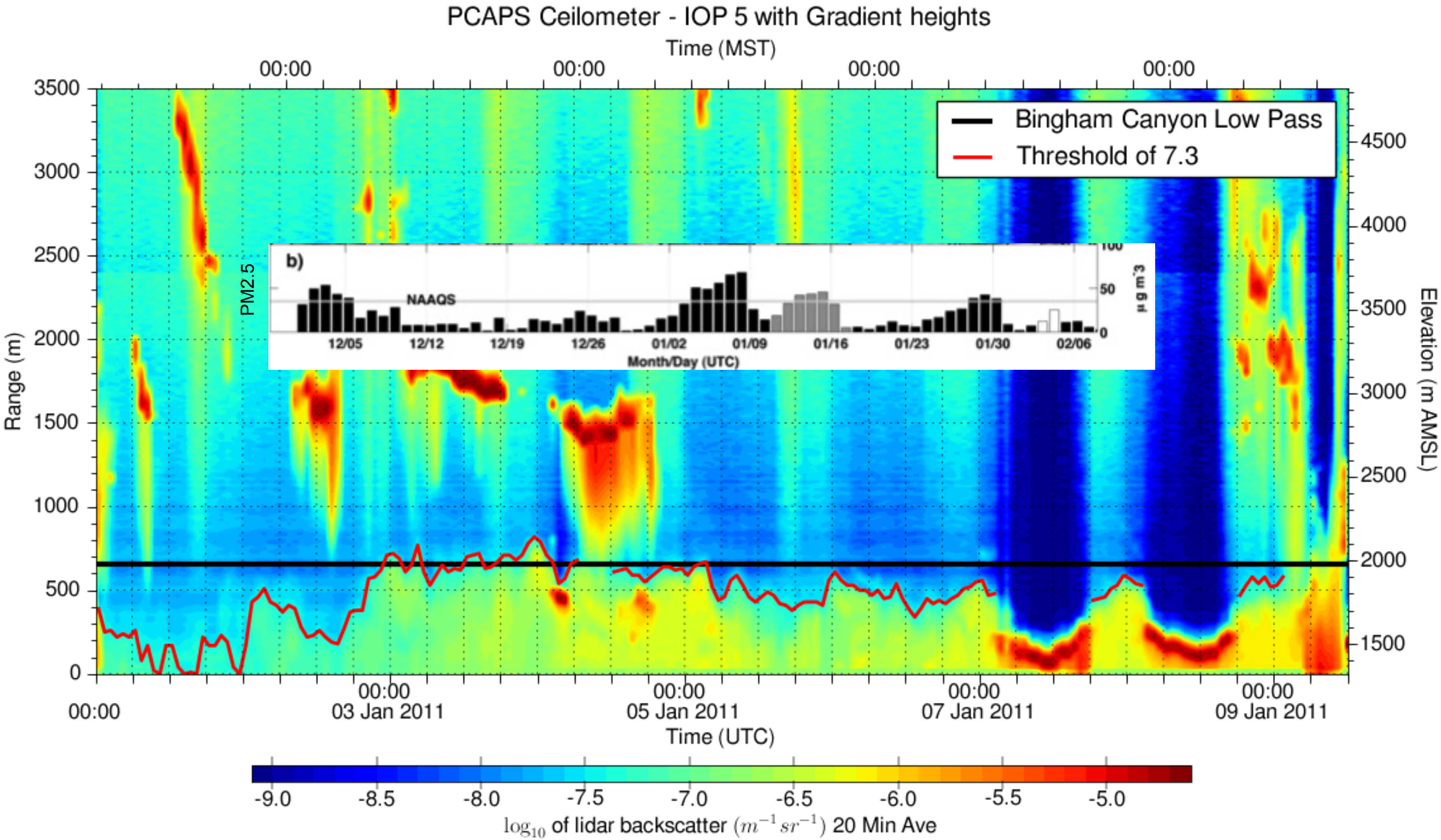
How does solar radiation vary throughout the day in and around the mine?

Laser ceilometer

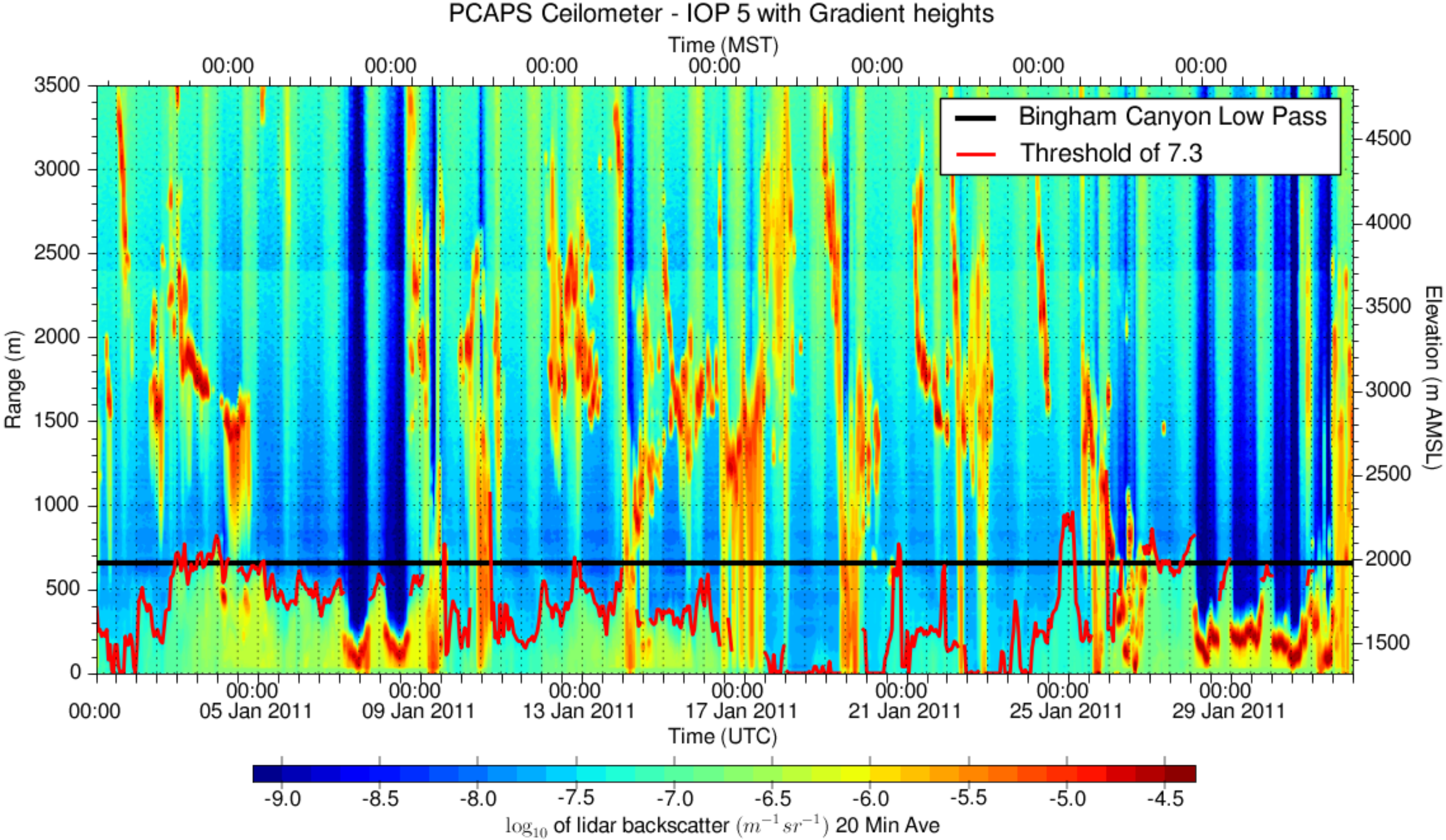
Ceilometer/radiosondes – IOP 5



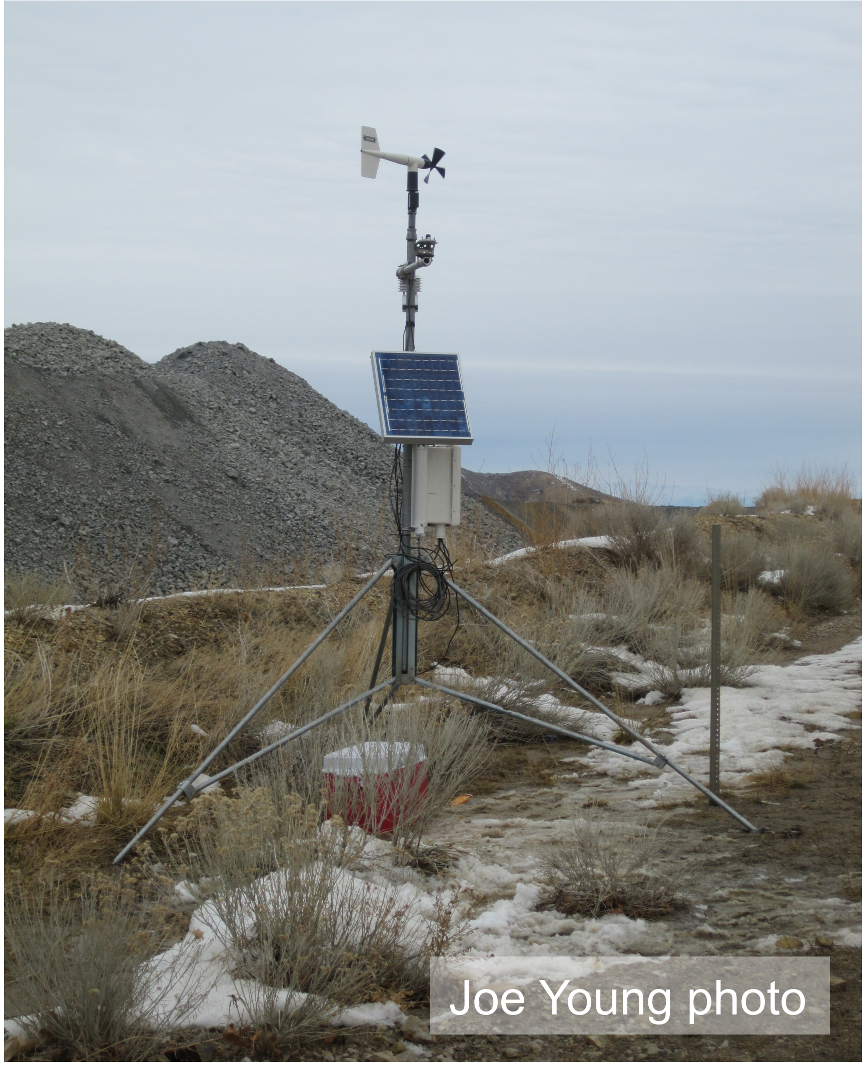
1-9 January 2011 aerosol heights



January 2011 aerosol heights



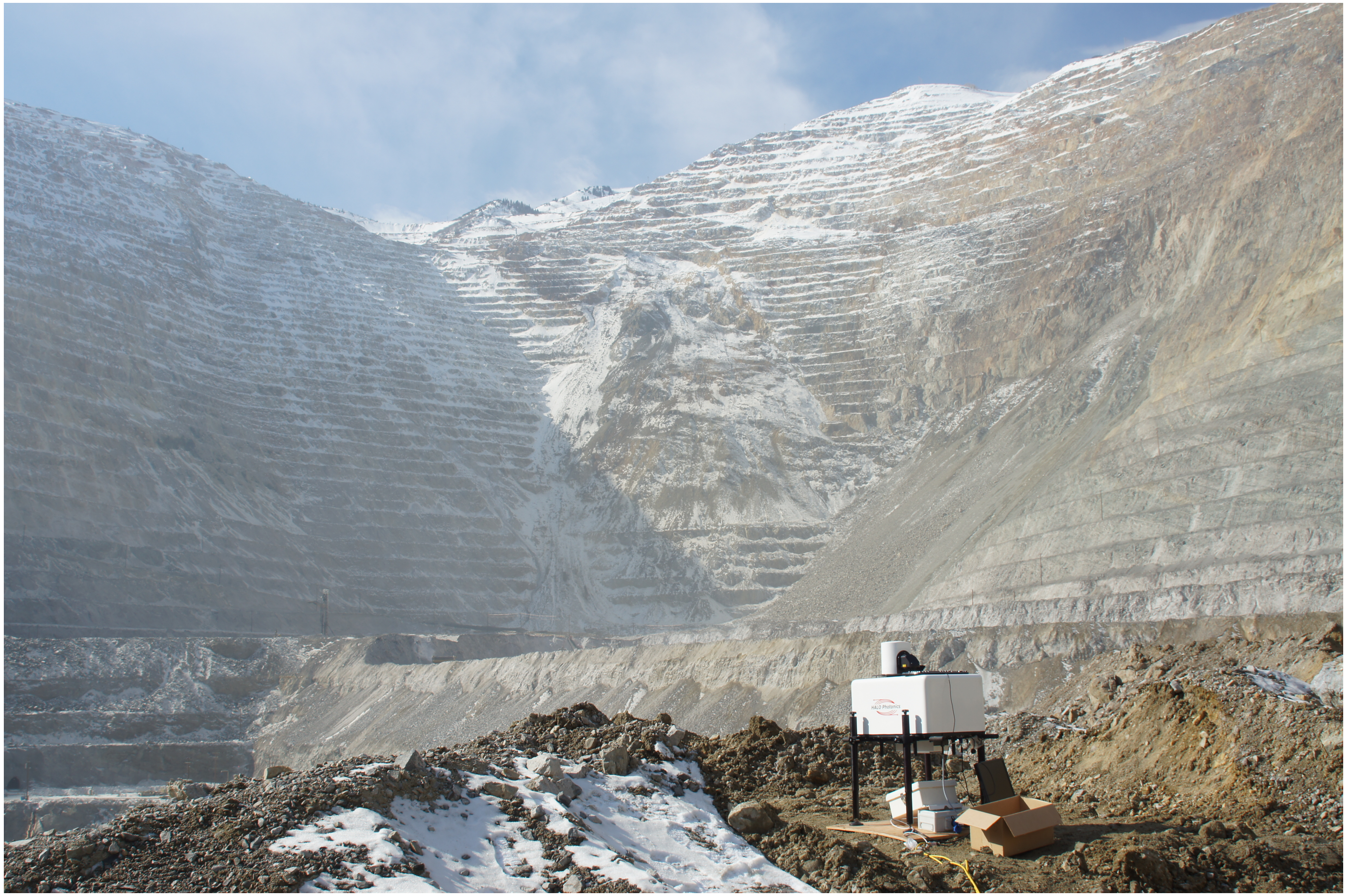
Mine instrumentation I



Automatic weather station

HOBO temperature datalogger

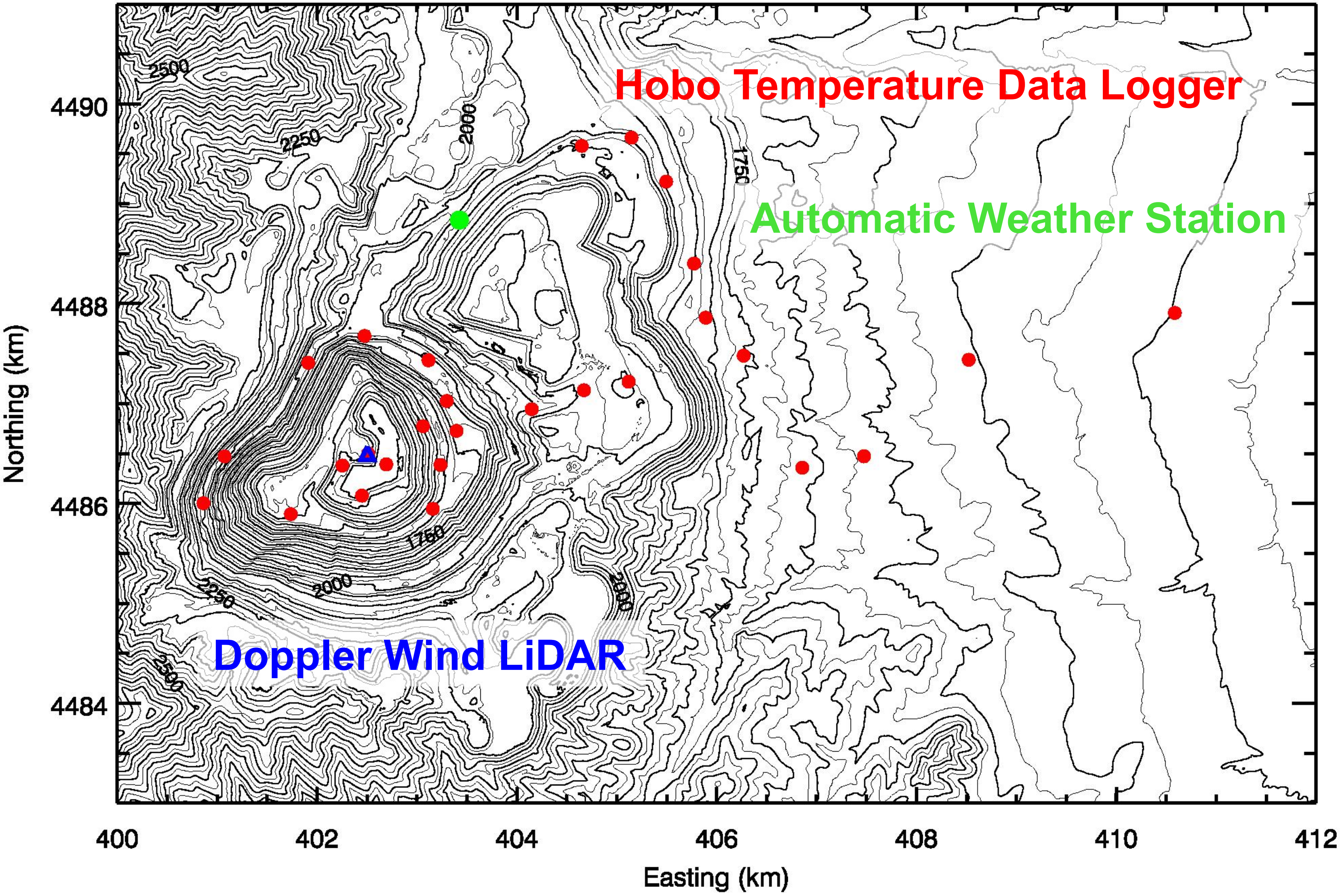
Mine instrumentation II



Location

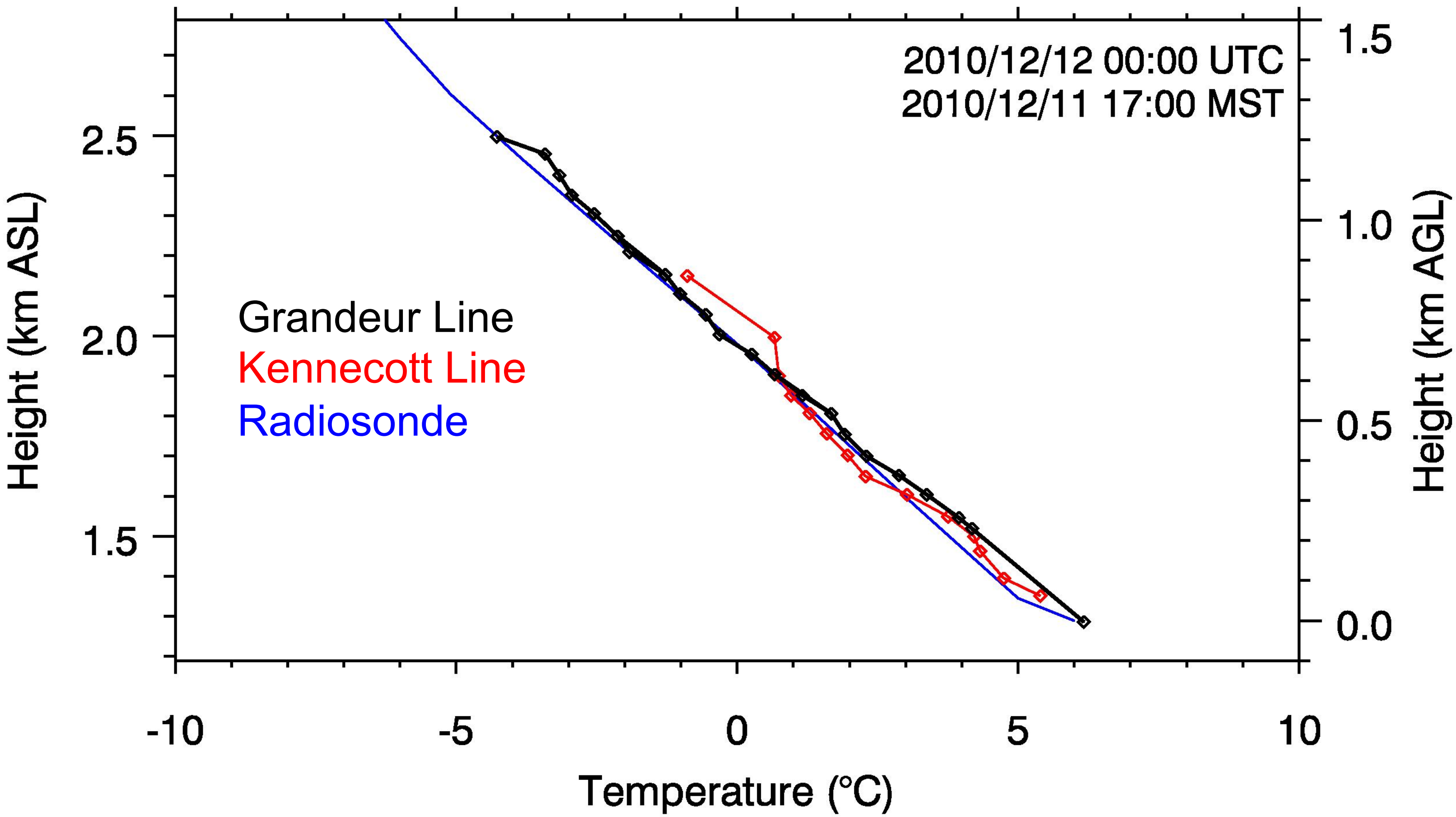
Halo Photonics Streamline
Scanning Doppler Wind LiDAR
Eye safe, Range: 90 m to 7.5 km
Obs: mid-Feb - Apr

Mine instrumentation - Summary

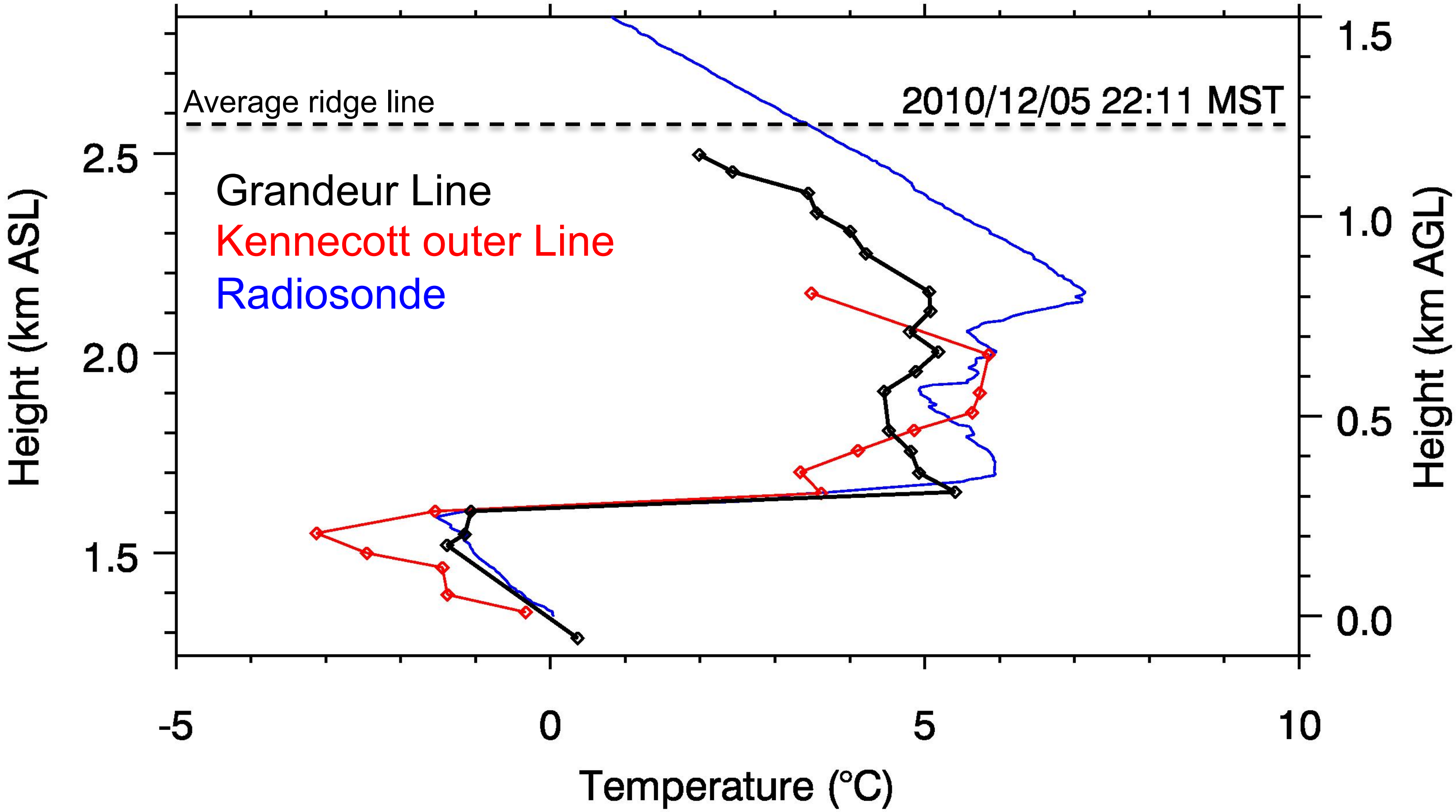


How good are the pseudo-vertical profiles?

Comparison with Radiosonde data



Radiosonde-HOBO line comparison



Initial results / data examples

Bingham Mine – SLV temperature differences

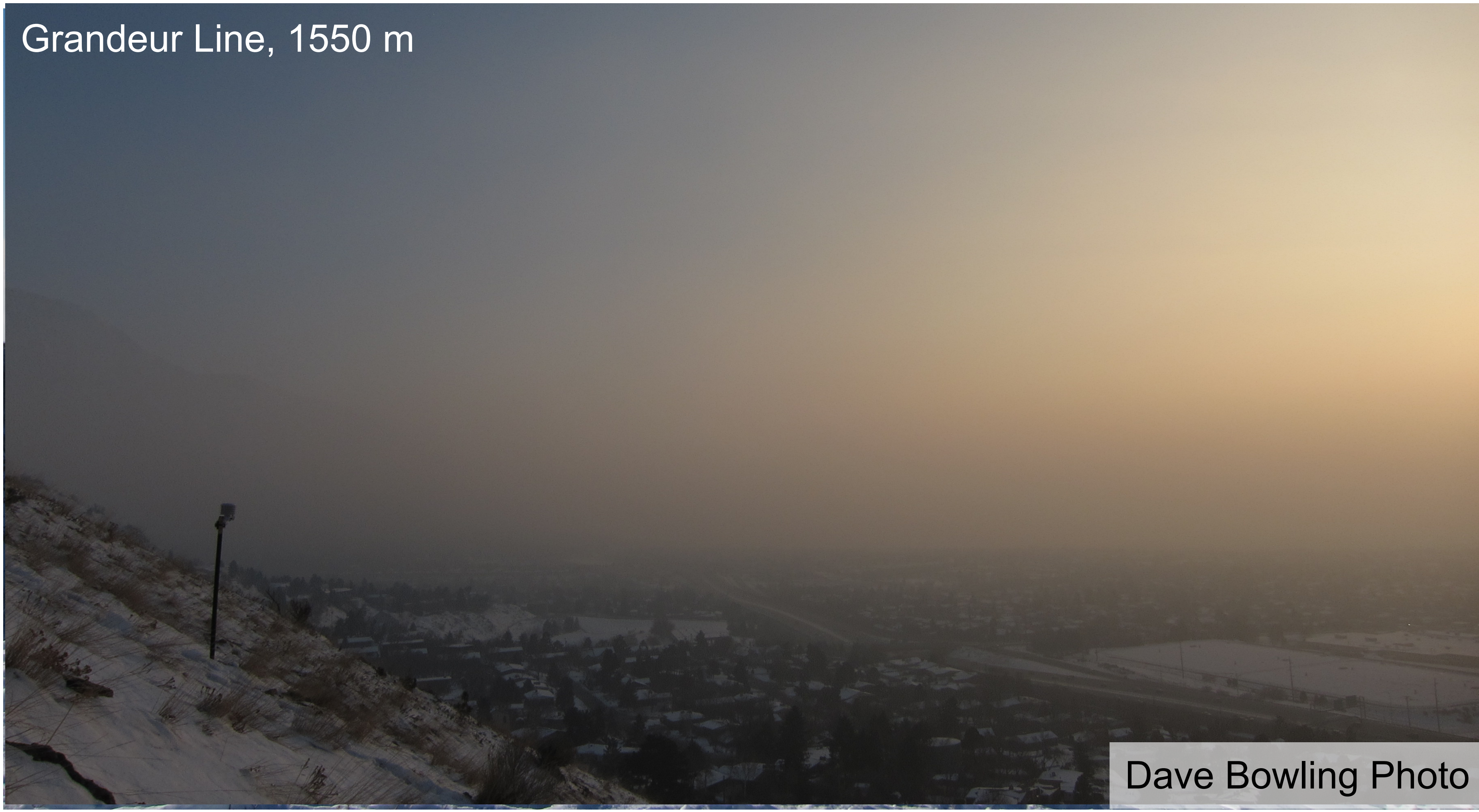
Wind break-ins into Bingham Mine (mix-out event)

Air exchange through Bingham Pass: Export /import of cold air?

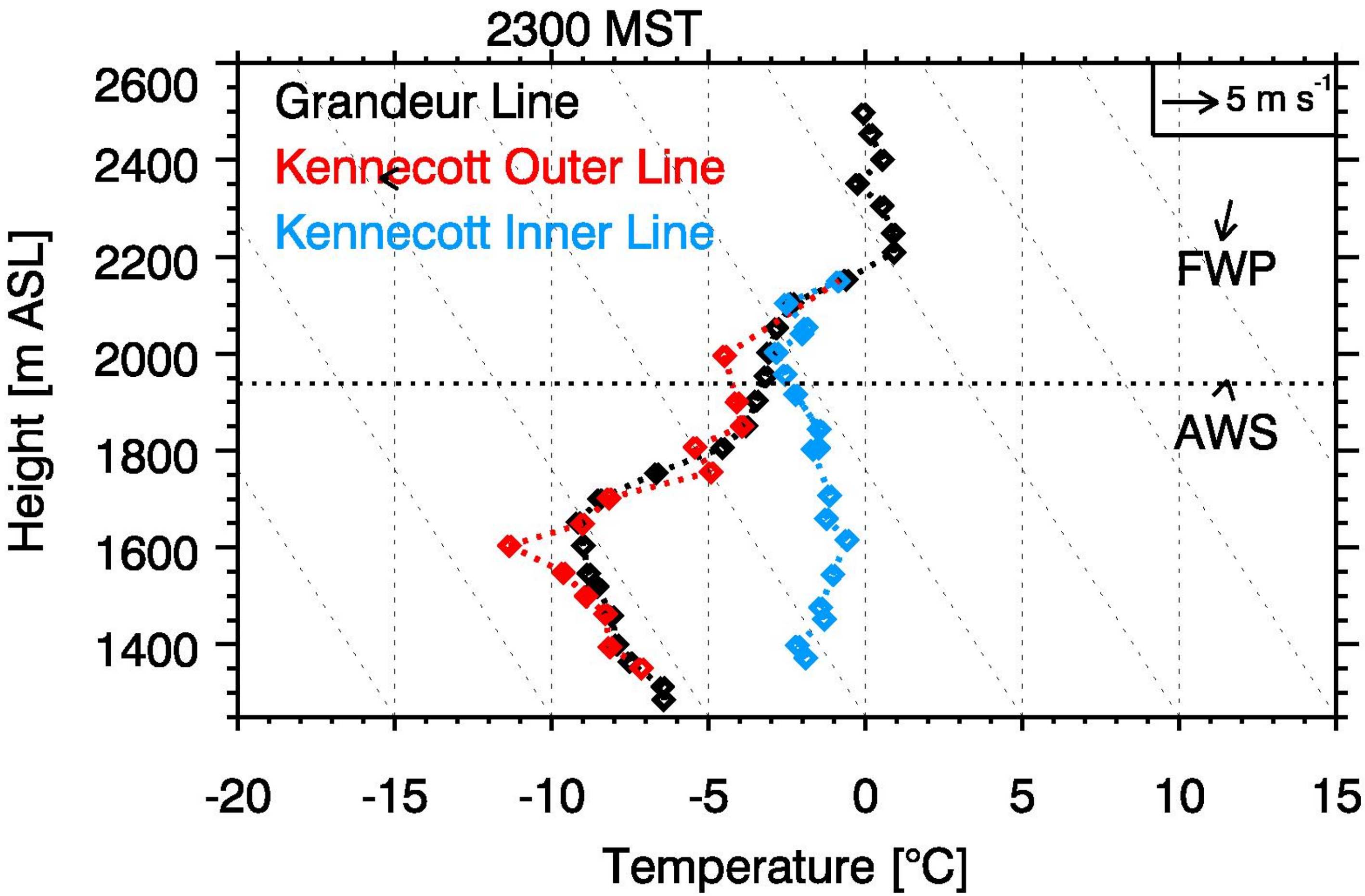
The diurnal cycle of heating in the Bingham Mine

Mine basin-SLV temperature differences

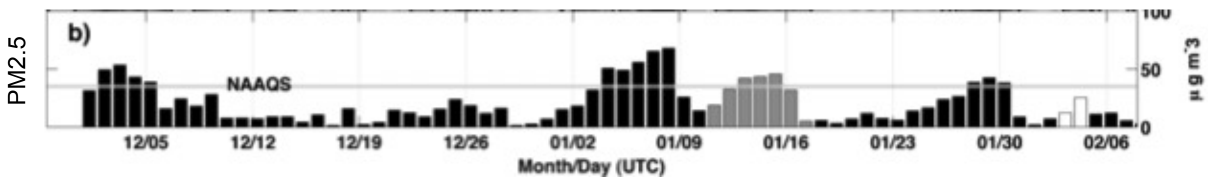
7 - 8 January 2011: shallow cold-air pool in Salt Lake Valley. PCAPS - IOP5



7 - 8 Jan shallow cold-air pool



PCAPS IOP5



Typical of "inversion" situations

Mean Pit– SLB Temperature Differences

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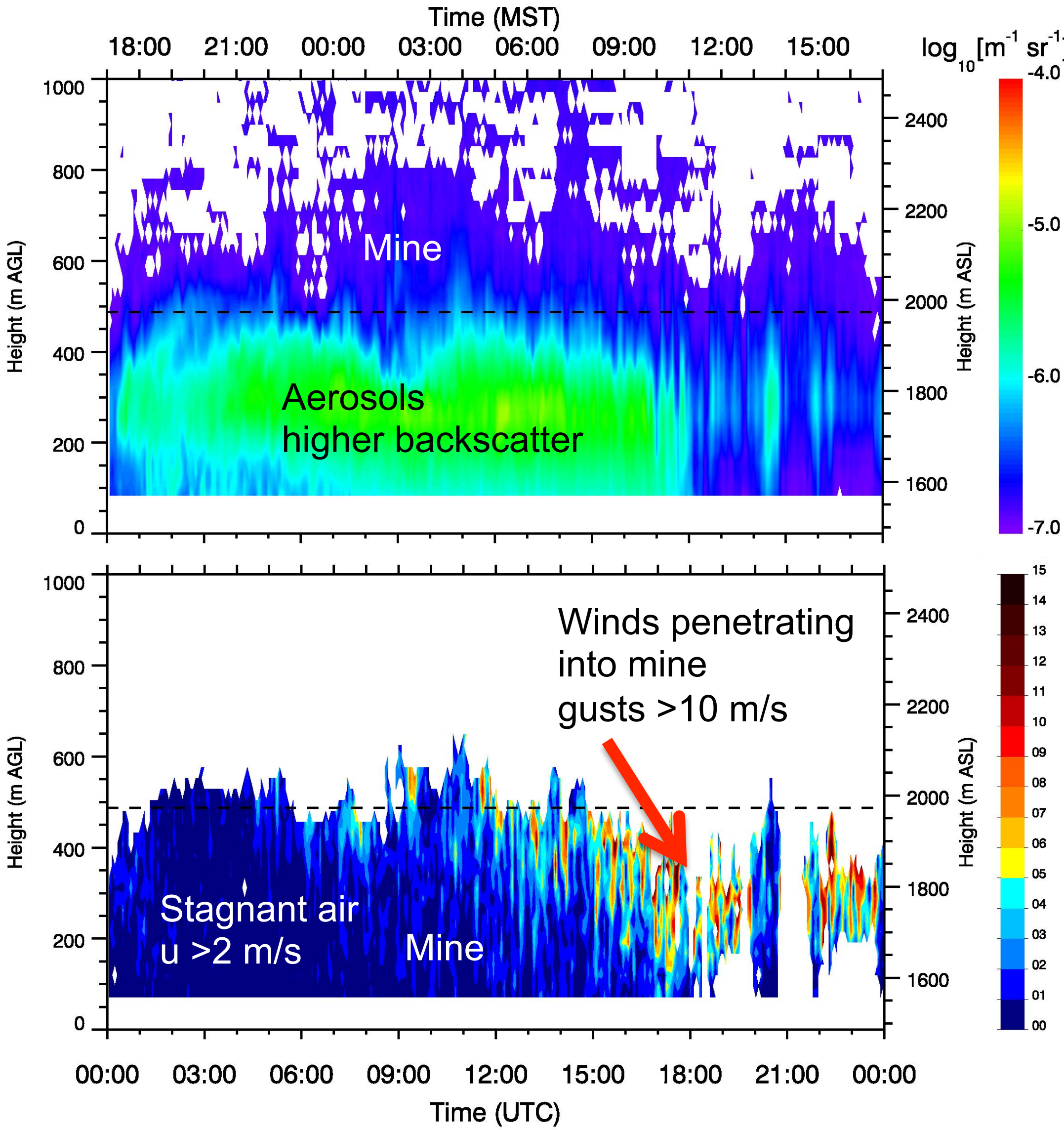
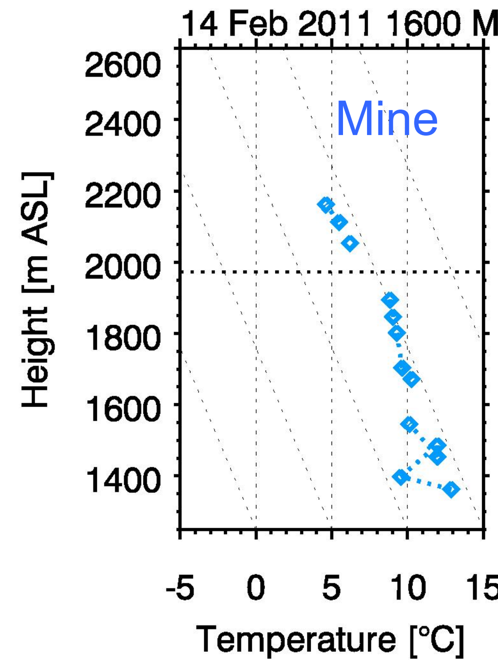
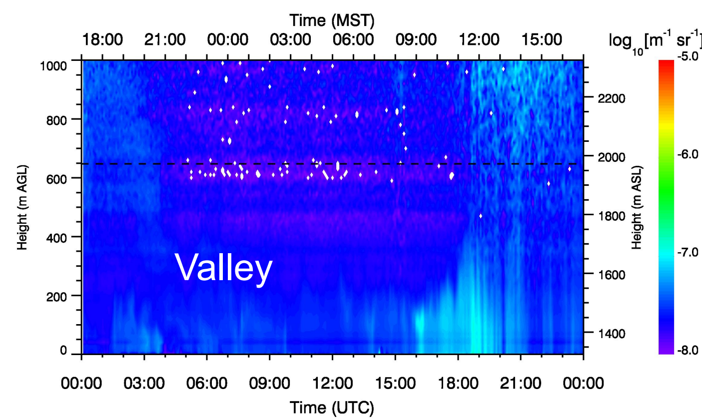
Height (m ASL)	Dec 2010-April 2011	PCAPS - IOP 5 (1-9 Jan 2011)	
2050	-0.3	-0.4	
2000	0.5	0.8	low pass
1950	0.5	1.0	
1900	0.5	0.7	
1850	0.8	1.4	
1800	1.2	2.4	
1700	1.4	2.9	
1650	1.7	3.4	
1600	2.6	5.4	
1550	2.5	5.3	
1450	2.0	3.9	
1400	2.2	4.0	
1360	2.1	3.6	mine floor

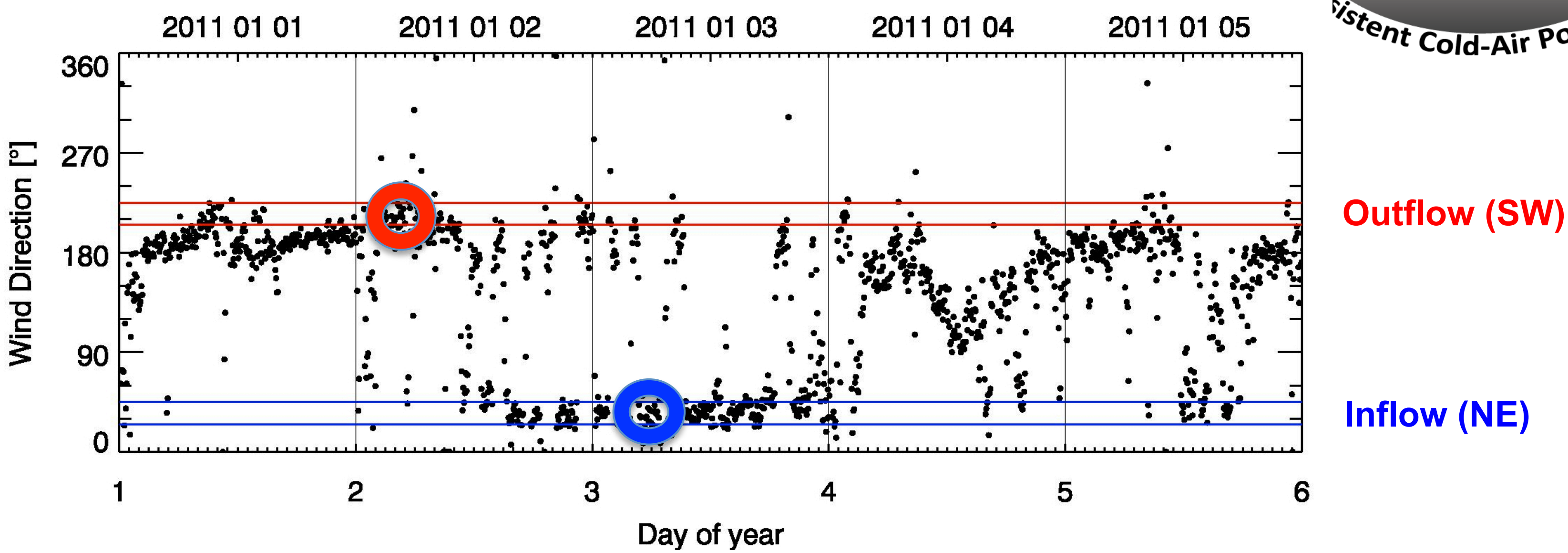
13-14 February 2011 aerosol mix-out event

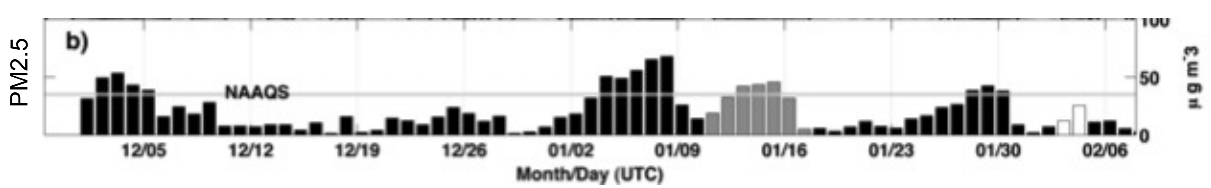






Bingham Mine inflow/outflow

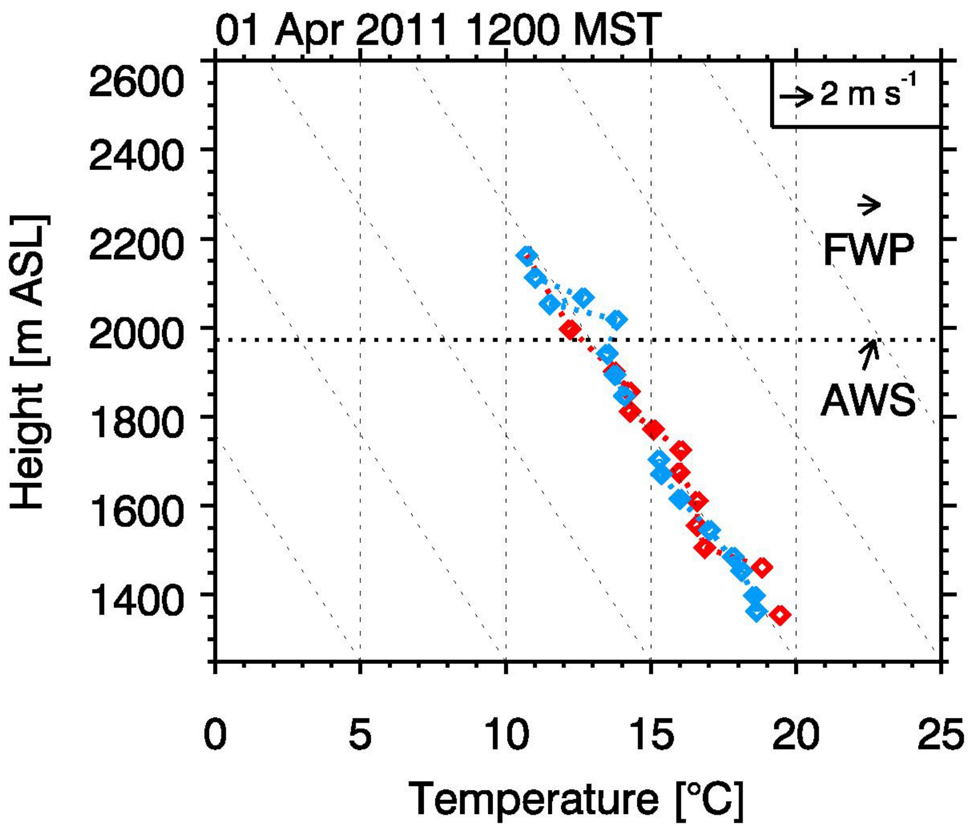




Diurnal heating cycle in Bingham Mine

Mine Atmosphere

Valley Atmosphere



clear day/night with weak winds

Conclusions I – PCAPS and climatology

January 2010-mid-February 2011

- Highest $PM_{2.5}$ concentrations within 75 m above the valley floor. Concentrations then decrease with altitude.
- Strong $PM_{2.5}$ relationship with valley heat deficit (h25, threshold 5 MJ m^{-2})

CAP climatology (38 yr POR) and $PM_{2.5}$ climatology (12.5 yr POR)

CAP and PM2.5:

- Highest frequencies in Dec/Jan related to low daily total solar radiation
- Average of 9.6 multi-day CAP events per winter (~42 days of CAPs)
- Average of 6 multi-day $PM_{2.5}$ events per winter (18 daily NAAQS exceedances)
- Substantial large-scale and local meteorological effects on CAP strength
- Low wind speeds critical to development of CAP events
- Time lag in $PM_{2.5}$ concentrations relative to CAP buildup
- CAP-$PM_{2.5}$ correlation coefficient ~0.66

Conclusions – Bingham Mine

PCAPS Persistent Cold-Air Pool Study

• Temperature profiles from HOBO lines can be used to evaluate spatial and temporal variations in the boundary layer structure of the Bingham Mine and the Salt Lake Valley (SLV).

• The Bingham Canyon Mine behaves differently from other enclosed high-altitude basins. Compared to other basins (incl. SLV), nighttime cooling and inversions are weaker. Physical process: radiative exchange?

• Under wintertime “inversion” conditions (wk background winds, strong valley inversion):

- The mine basin and the adjacent SLV atmospheres are not well-coupled. Valley and basin atmospheres are identically stratified only when they are well mixed (top-down convection or strong wind conditions).

- During extended periods of high heat deficit (corresponding to high particulate events in the valley) the SLV aerosol layer generally does not extend to the elevation of the mine entrance or rim.

- Aerosol emissions within the pit remain largely within the pit (based on the stable atmosphere within the pit and visual observations). Exchange of air between the mine atmosphere and the SLV *above the level of the lowest pass* requires moderate to strong winds or, in “inversion” conditions, temperature differences across the pass at that level. The flow is *into the pit* when the pit atmosphere above the pass is warmer and *out of the pit* when colder. But, the buoyancy equilibrium level of air exiting the pit is well above the aerosol layer in the valley below and cannot be expected to contribute to the aerosol loading there.

2011-2012 Bingham Mine experiment

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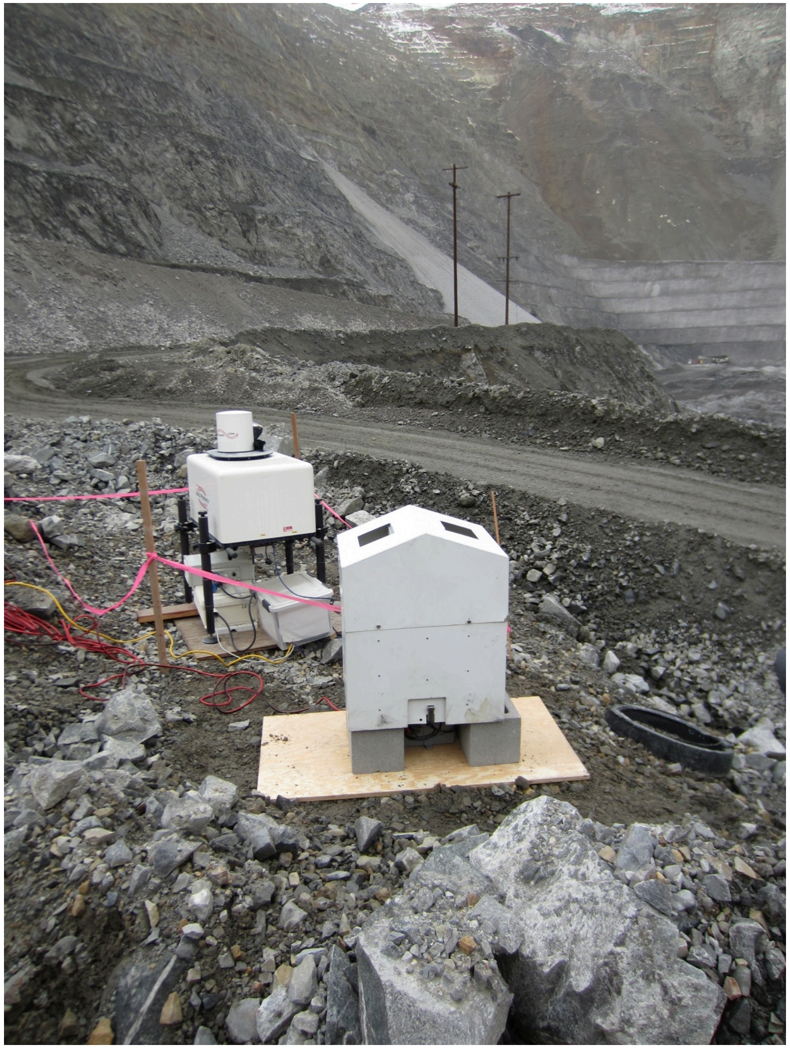
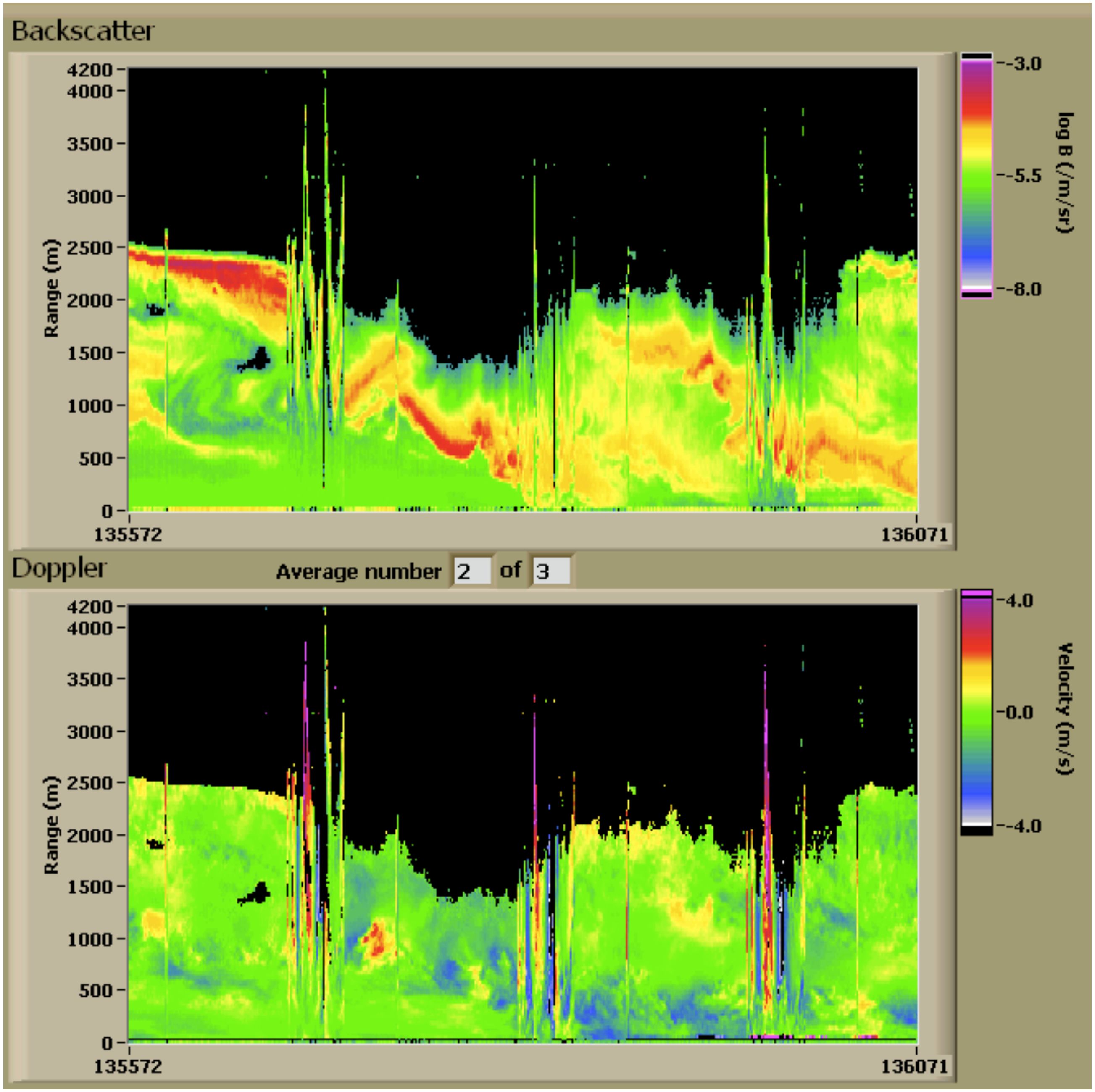


Copperton, Utah:
Laser ceilometer

UU ceilometer online: http://inscc.utah.edu/~jyoung/ceilview/

Bingham Mine:
Scanning Doppler LiDAR and laser ceilometer



PCAPS Persistent Cold-Air Pool Study

Sample Doppler lidar image from the Bingham Mine, Tuesday, 15 February 2012, around 6 am for 30 min.

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Persistent Cold-Air Pool Study

Acknowledgments

University of Utah (Erik Crosman, Chris Ander, and Wesley Harrison)
National Science Foundation (funding, Brad Smull)
Rio Tinto/Kennecott Utah Copper (funding, Chris Kaiser)
KUC (Nathan Armstrong, Jeff Lachowski, others)
National Weather Service (radiosonde data)
Utah Division of Air Quality (AQ data)
Silcox paper co-authors: Geoff Silcox, Kerry Kelly, B. L. Allen (UDAQ)
US Forest Service
Other graduate students working on PCAPS, participants, volunteers

Further information on PCAPS

- http://pcaps.utah.edu
- Lareau, N., E. Crosman, C. D. Whiteman, J. D. Horel, S. W. Hoch, W. O. J. Brown, and T. W. Horst, 2011: The Persistent Cold-Air Pool Study. *Bull. Amer. Meteor Soc.*, submitted.

Don Mallet photo

Cloud-Pool, 25 December 2010, 9:25 MST