Cold-air Pool Exchange Processes and their impact on Air Quality in the Salt Lake City Basin

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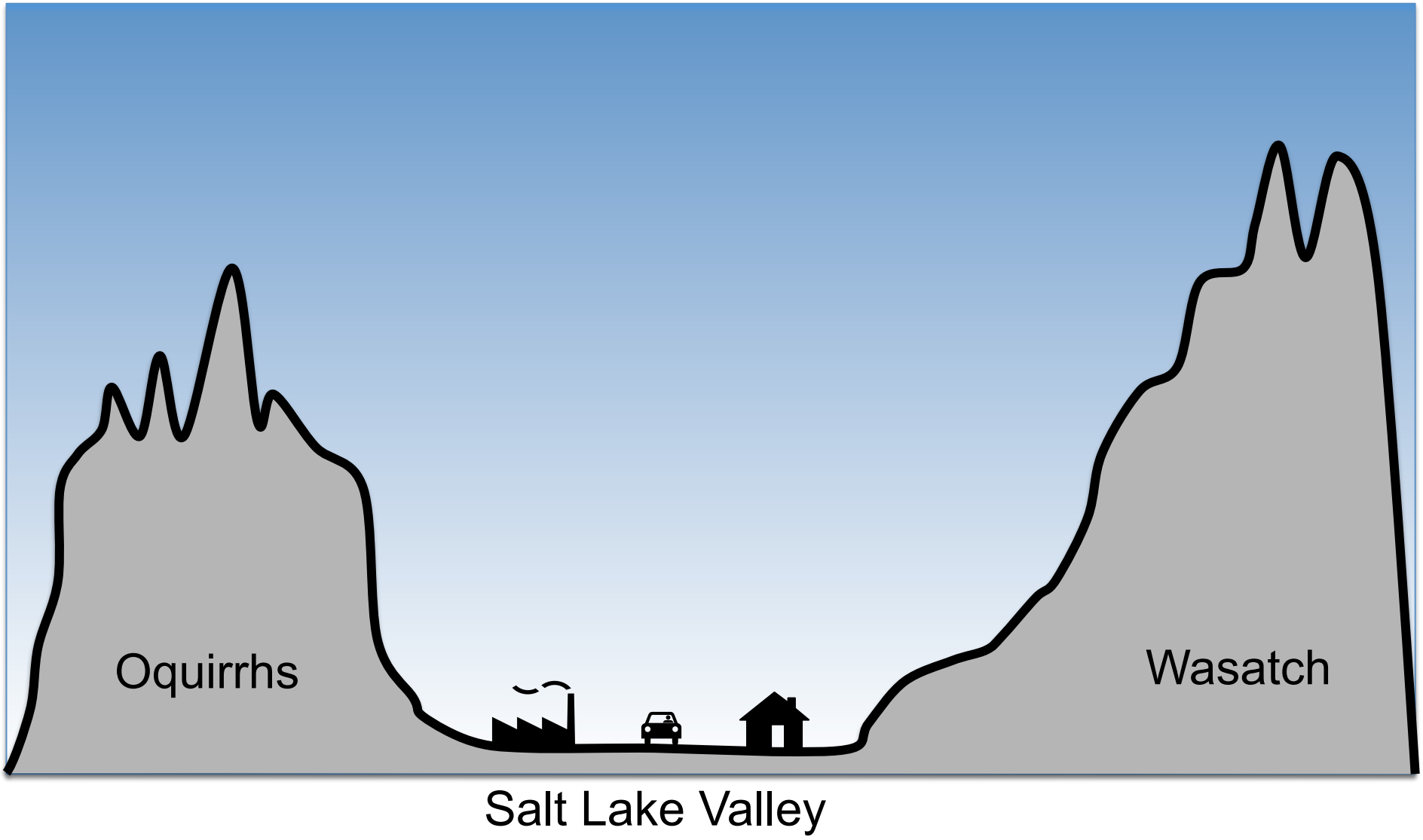
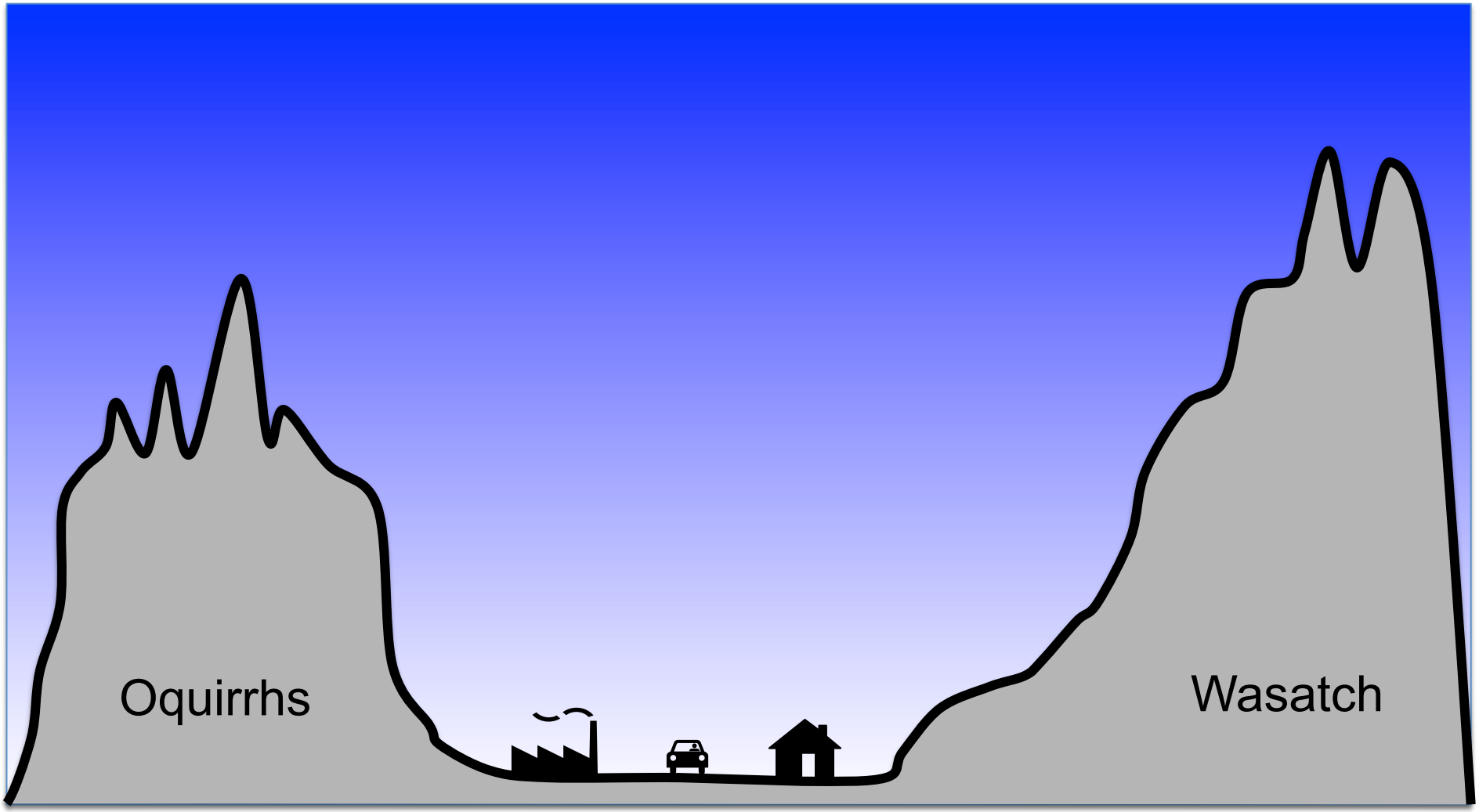
Mountain Meteorology Group

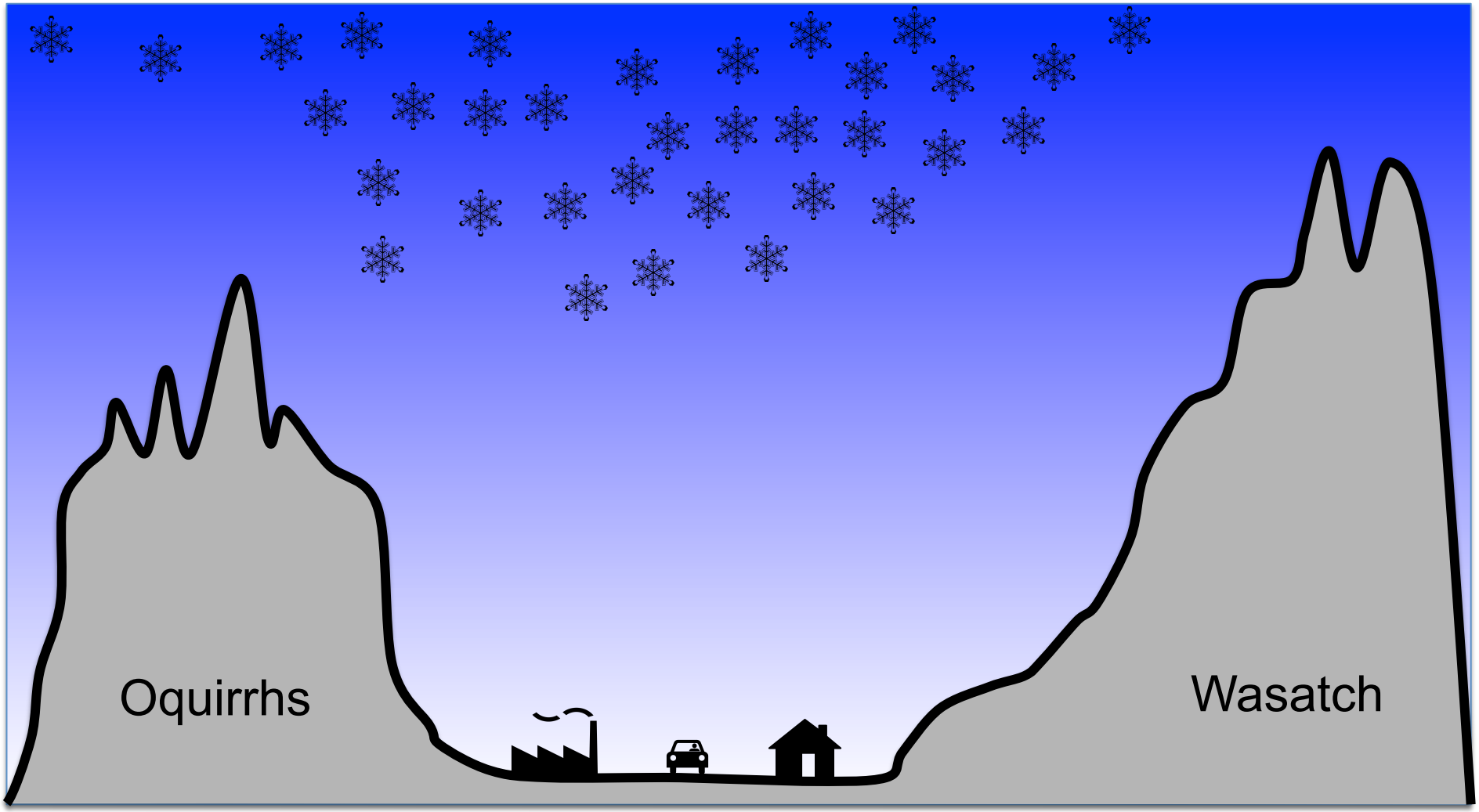
Air Quality: Science for Solutions. March 30, 2017, Salt Lake City, UT

How do our Pollution Episodes develop?

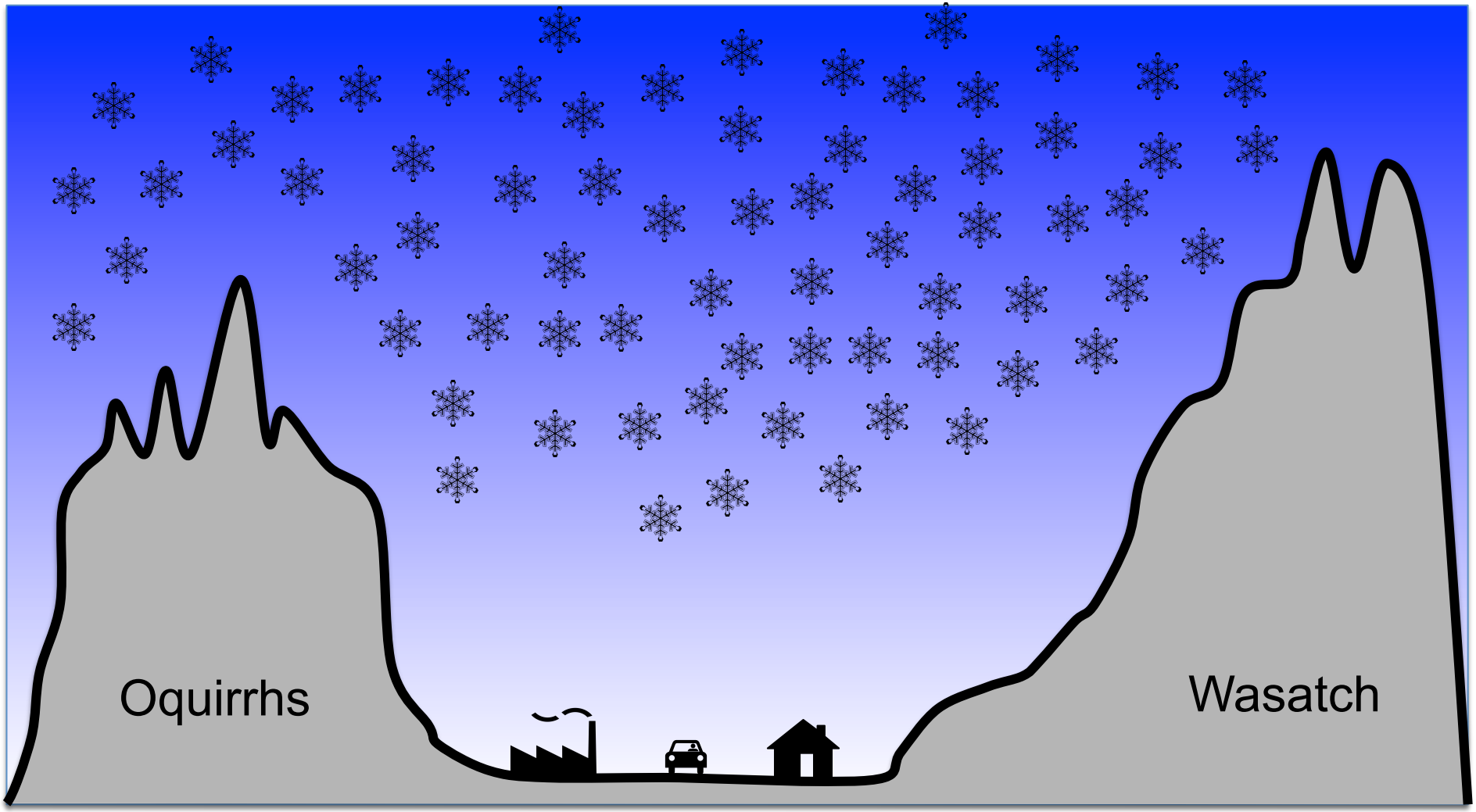




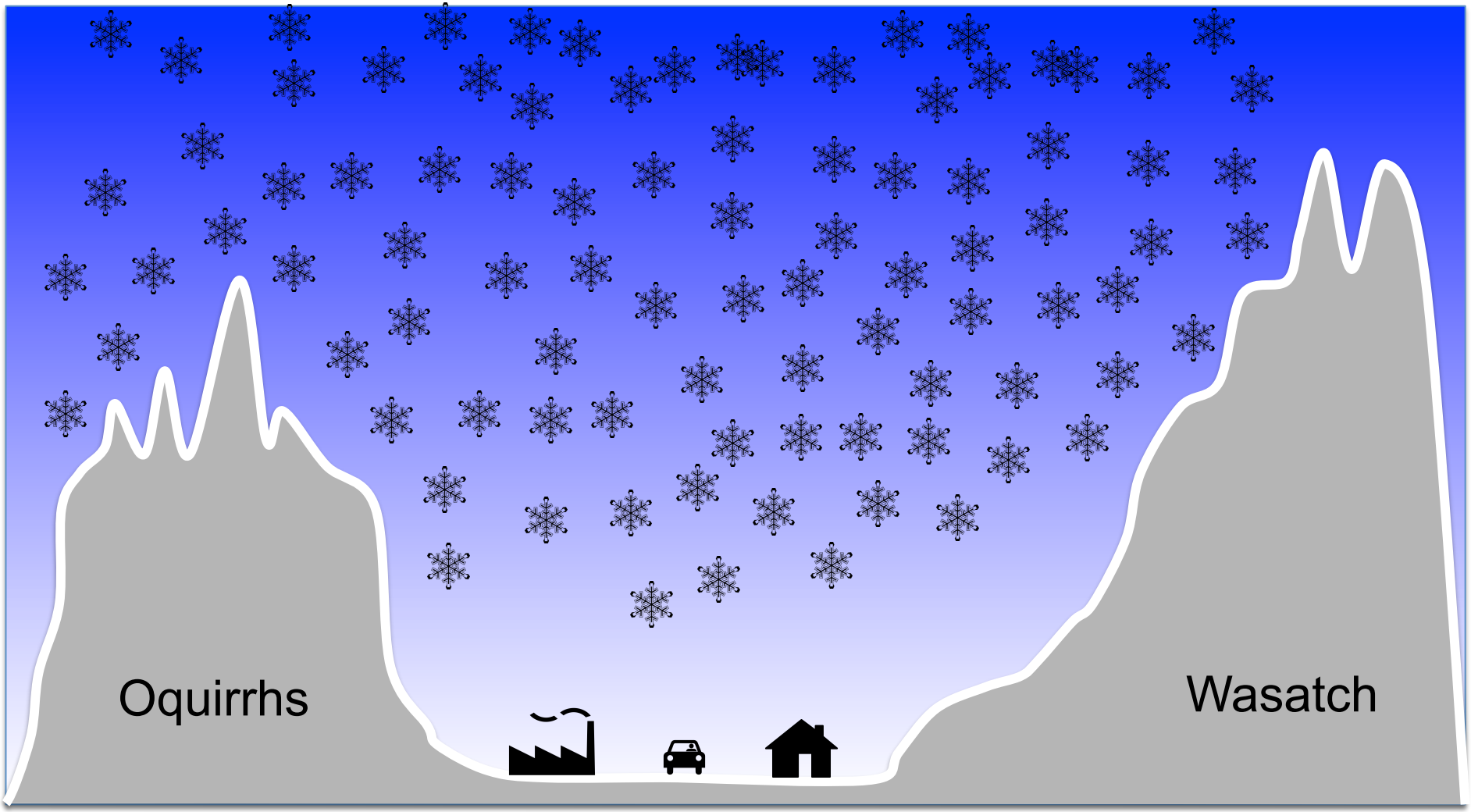
Salt Lake Valley



Salt Lake Valley

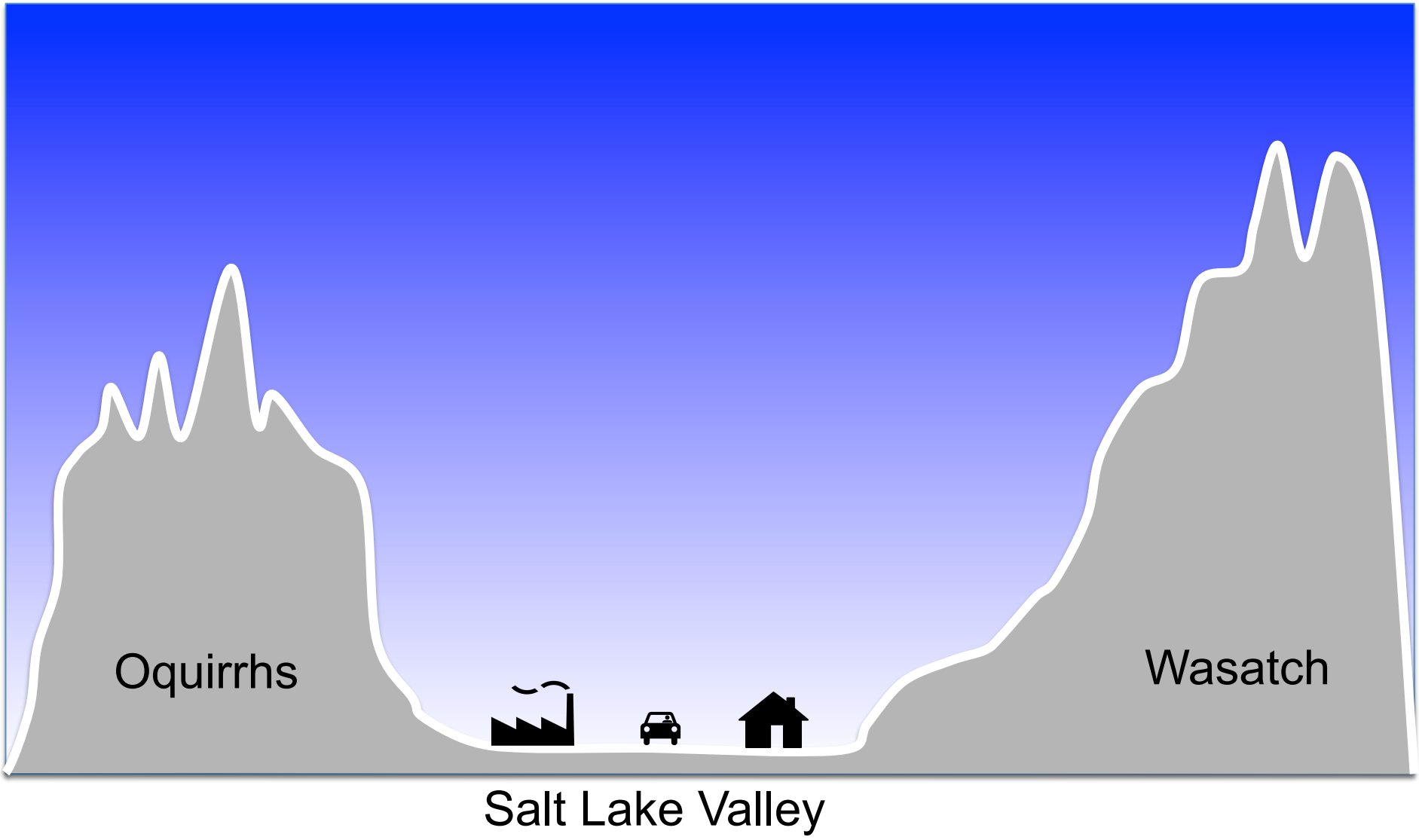


Salt Lake Valley

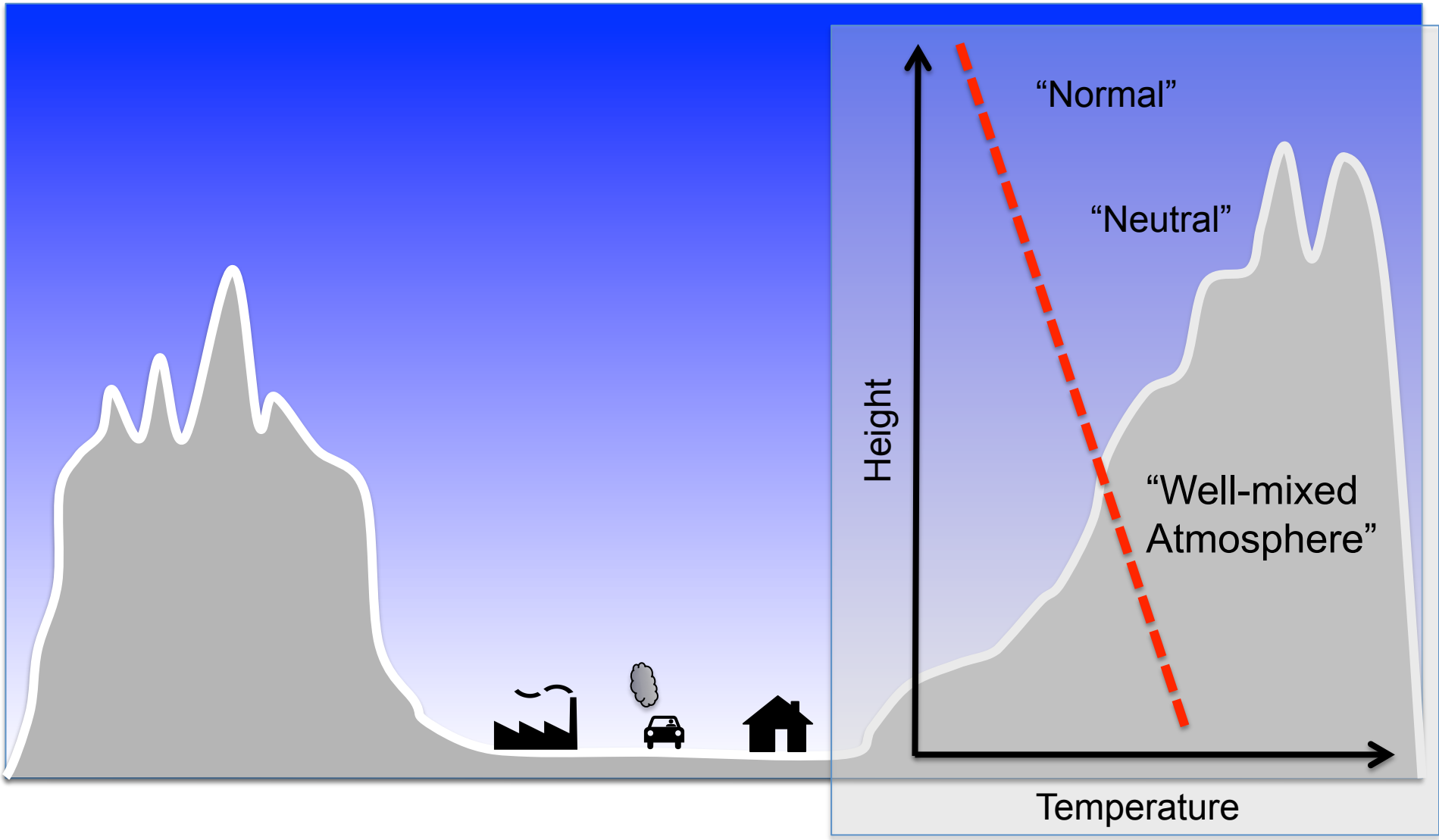


Salt Lake Valley

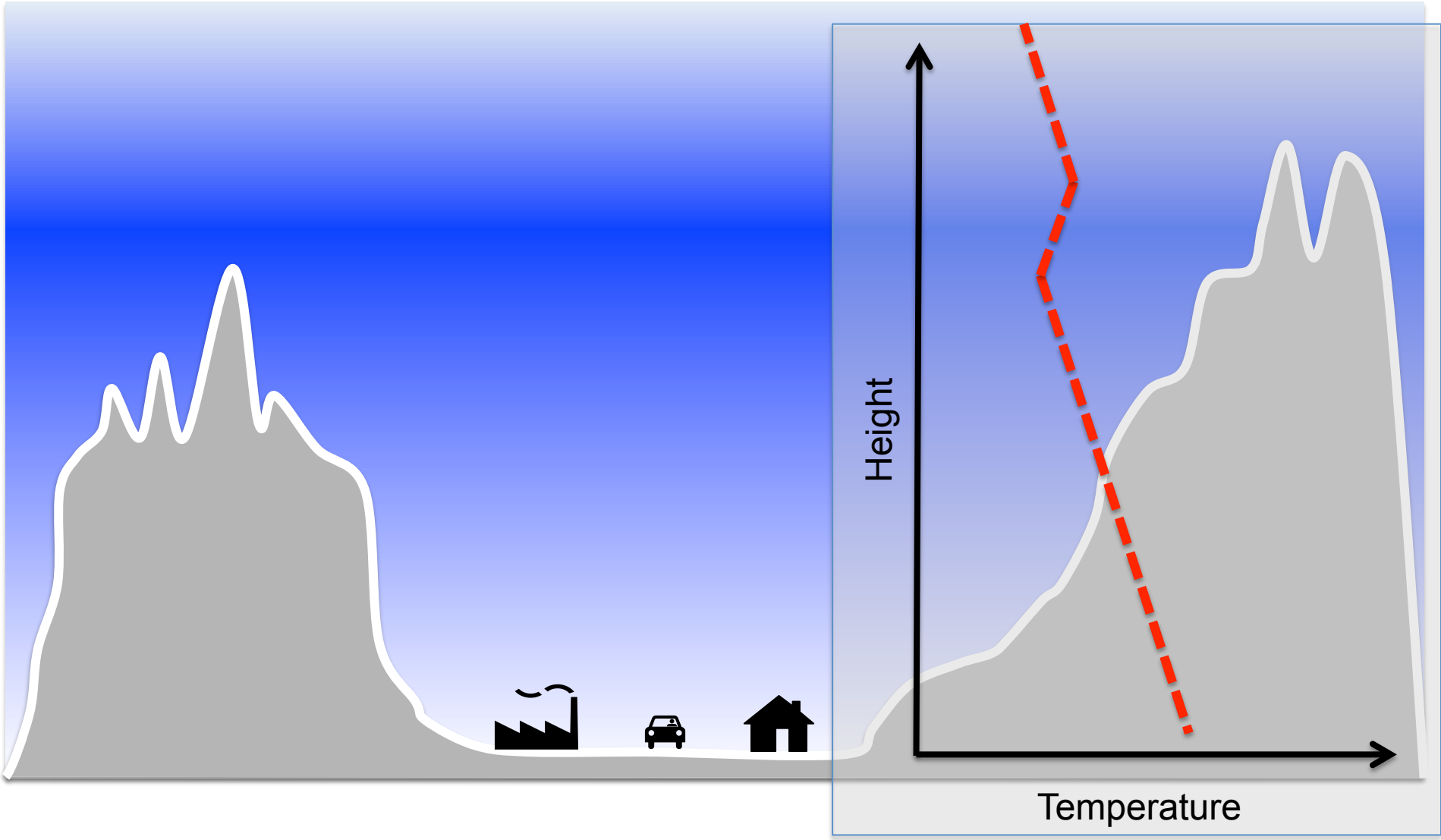
Cold air in place, snow cover



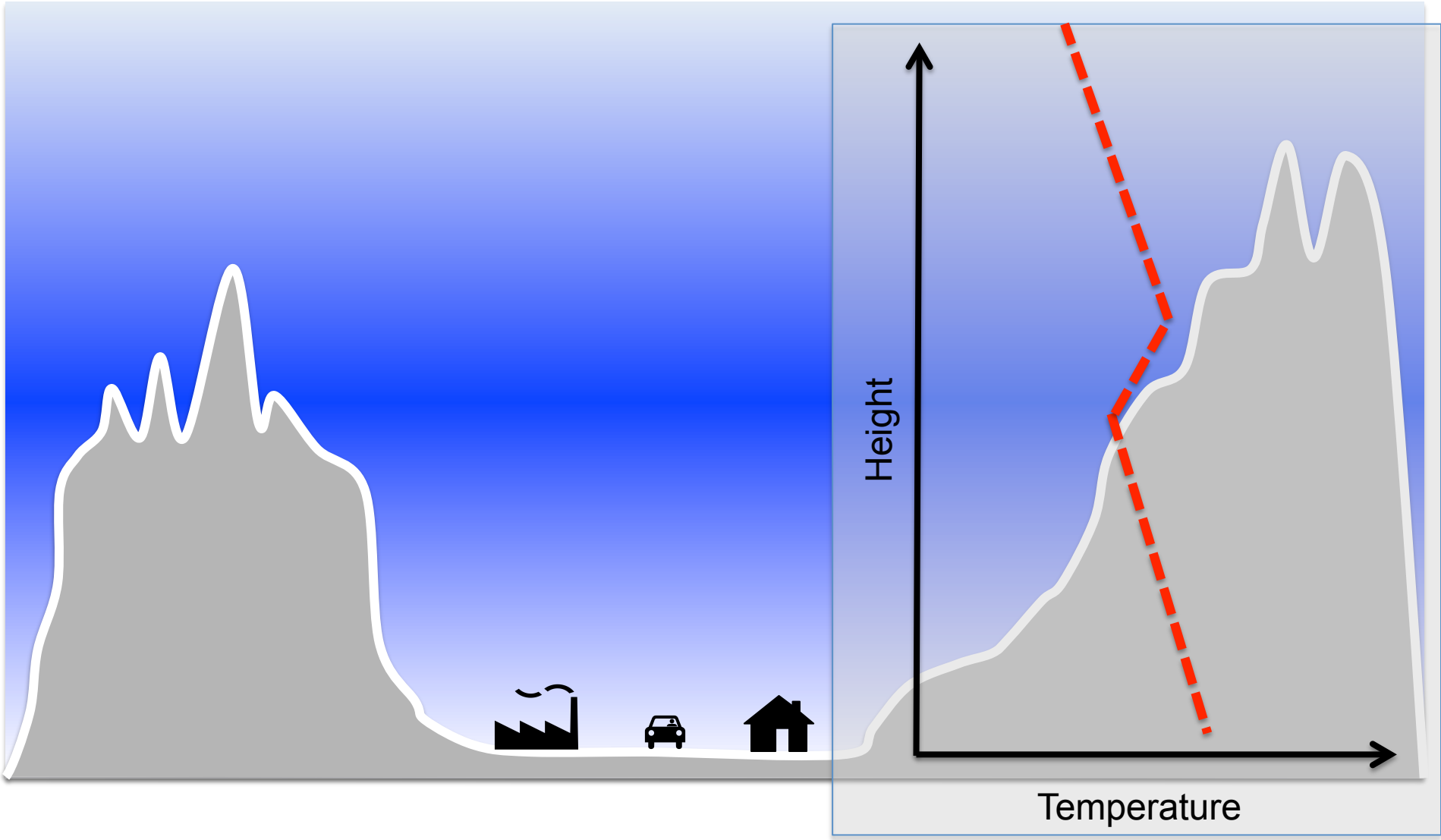
Cold air in place, snow cover



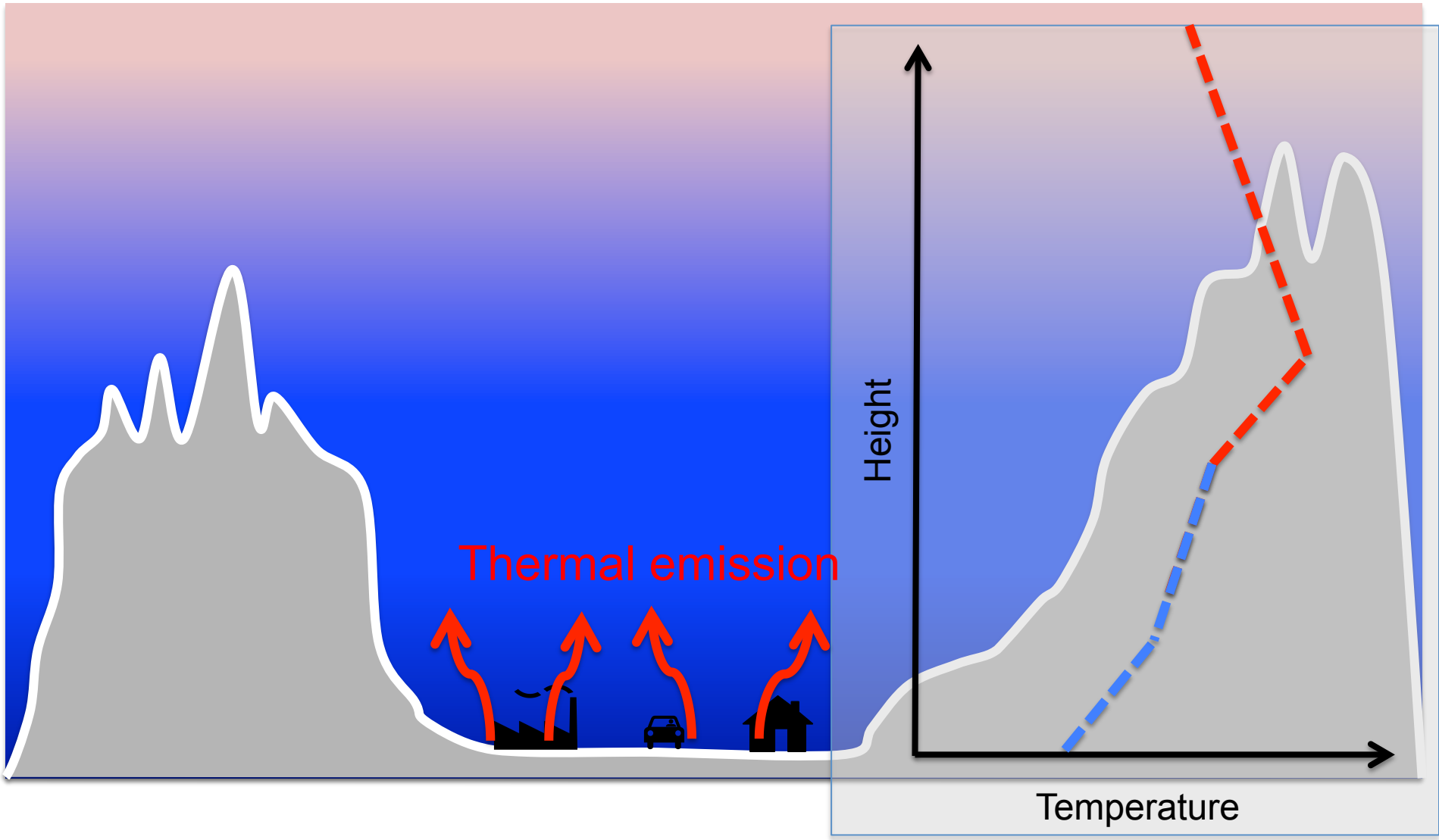
High pressure moves in. Warm-air advection aloft.

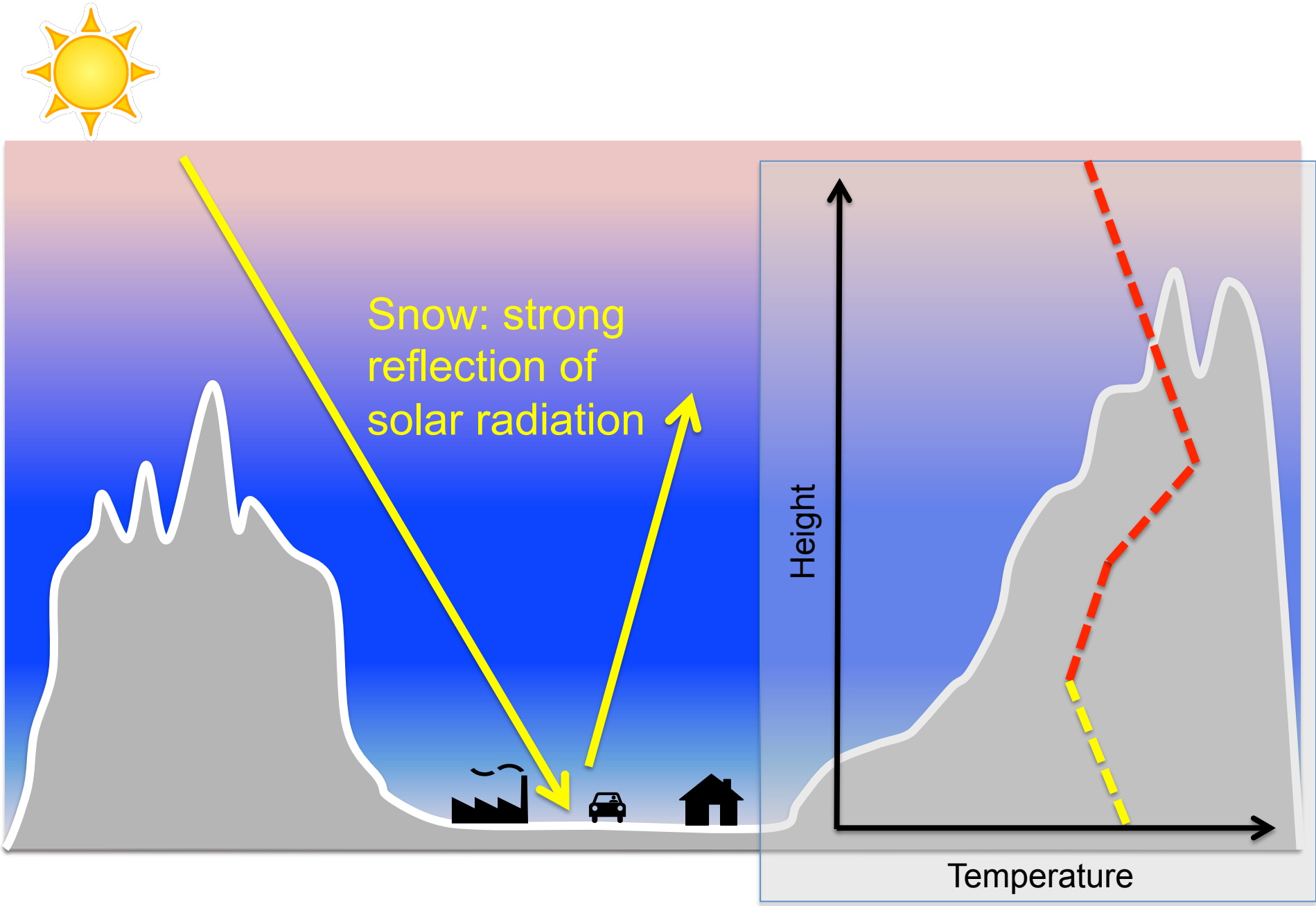


Warm-air advection aloft continues.

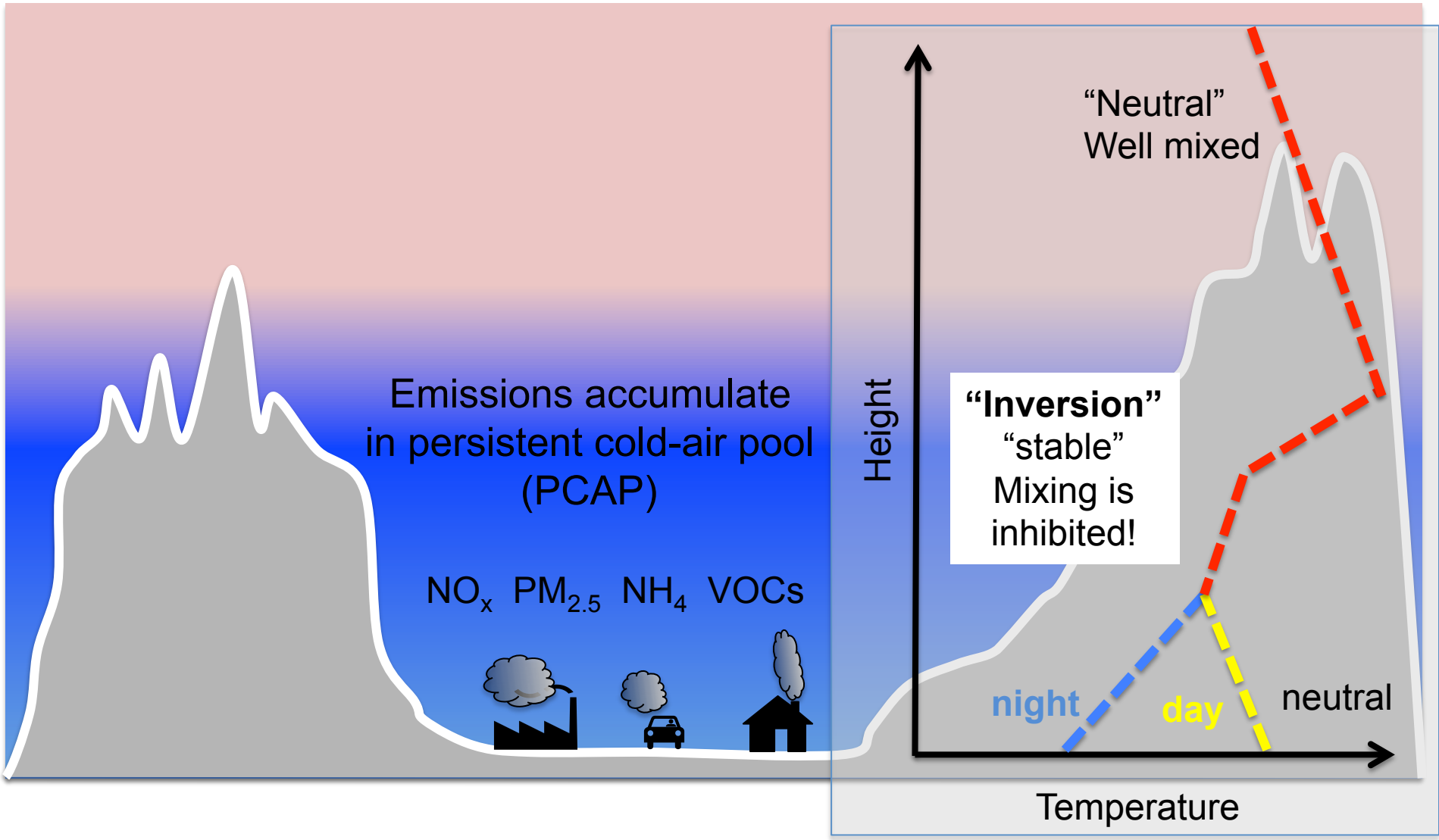


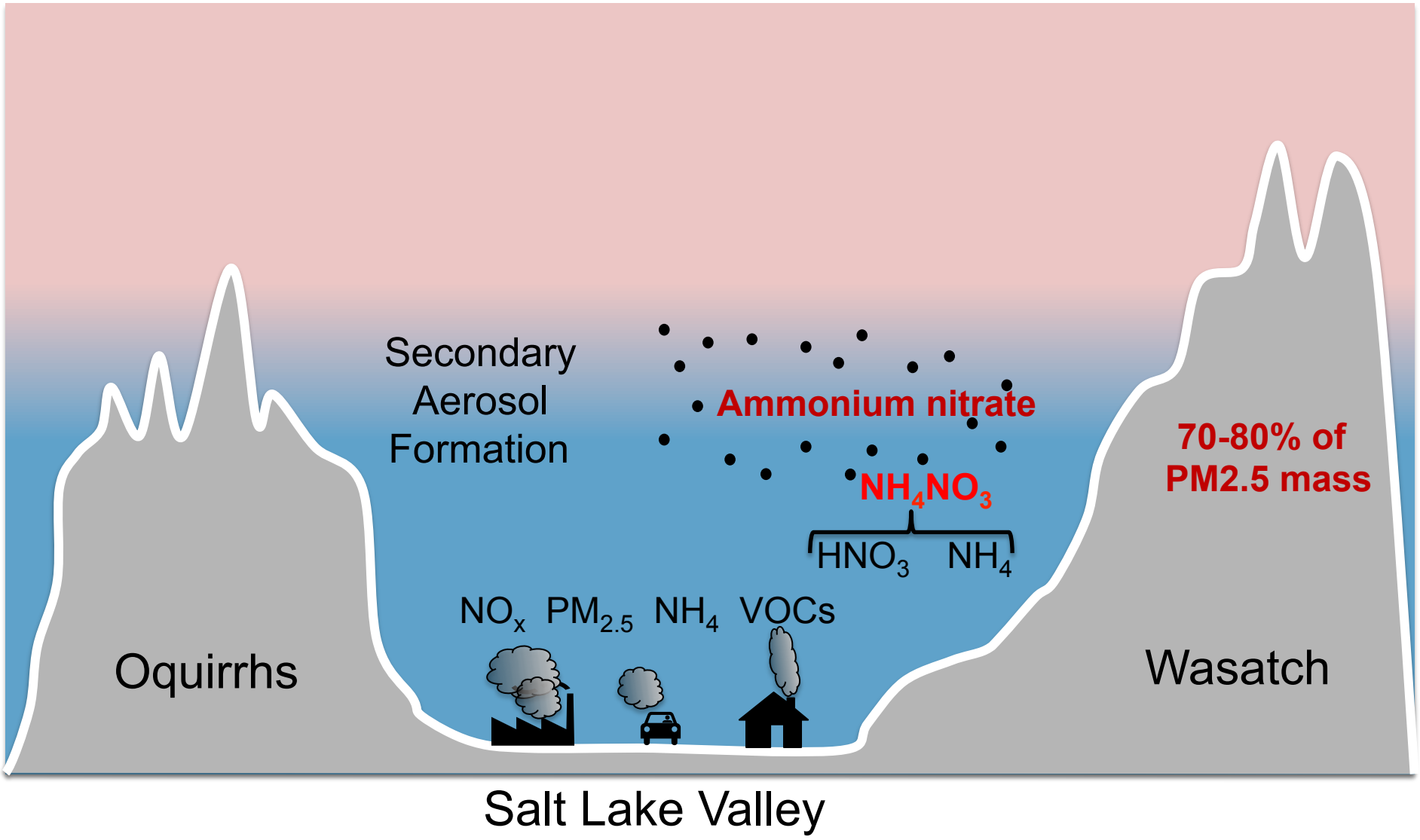
Clear nights & snow cover. Warming aloft continues.



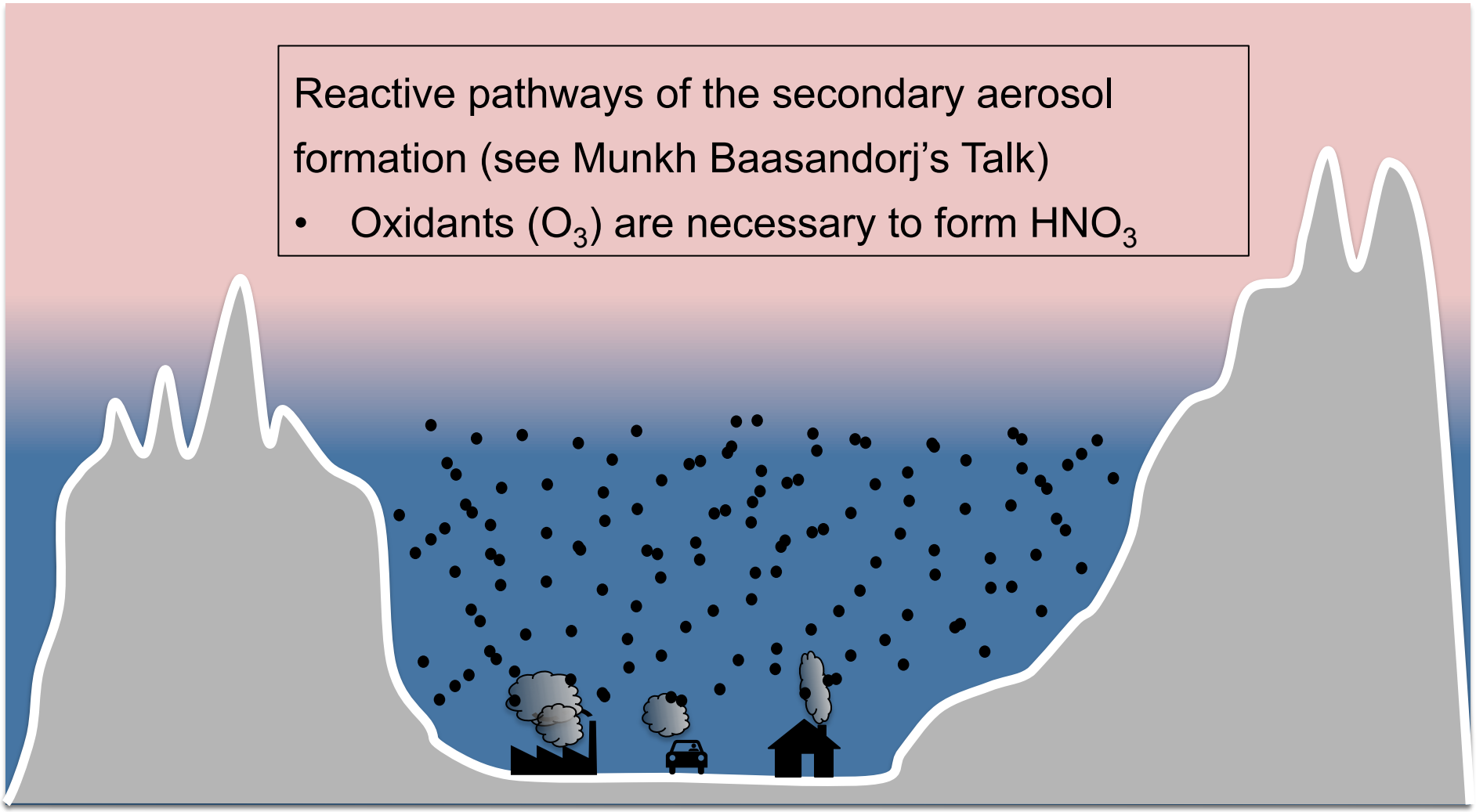

Snow: strong reflection of solar radiation
Height
Temperature

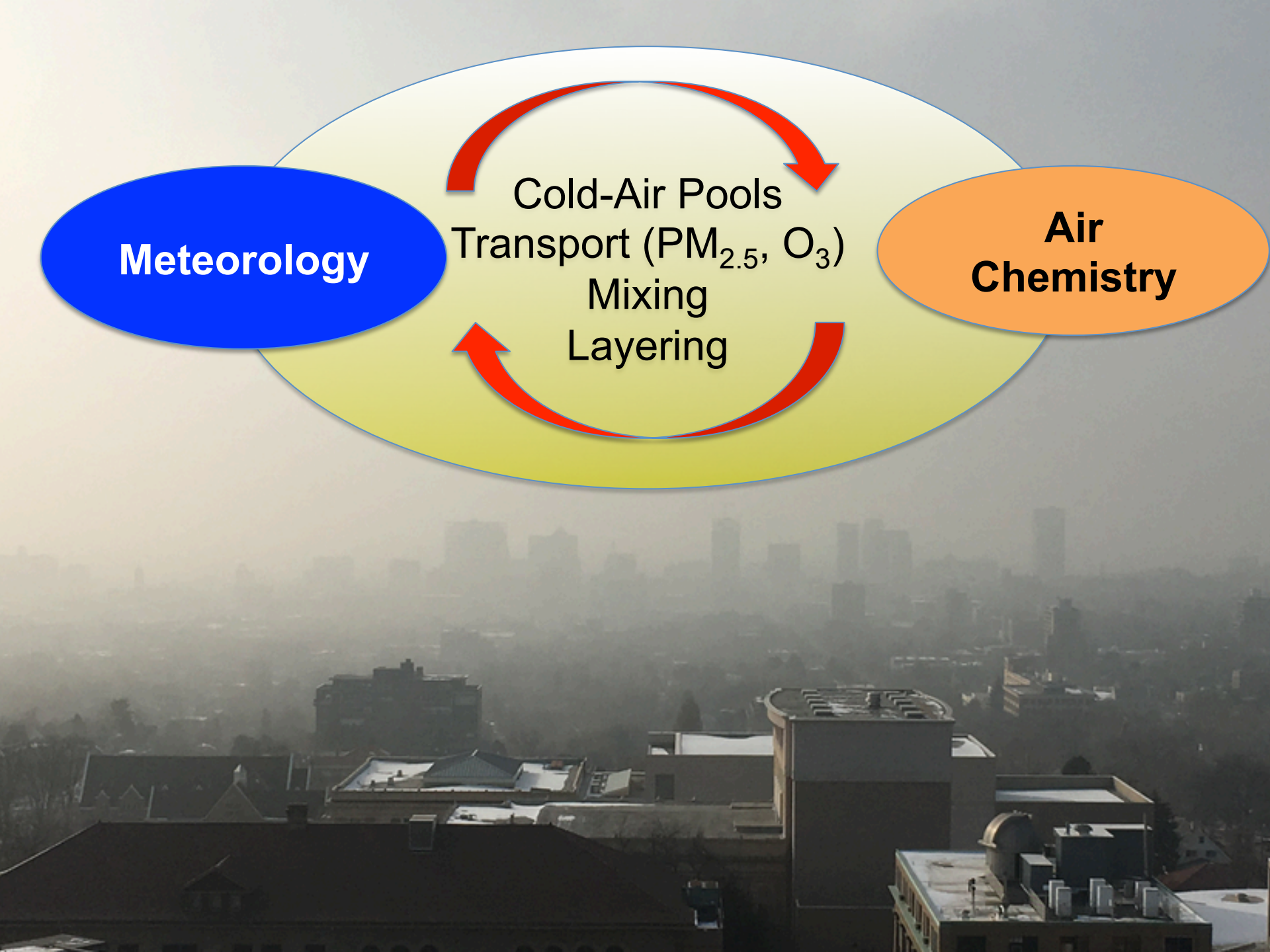
A Persistent Cold-Air Pool (PCAP) has developed



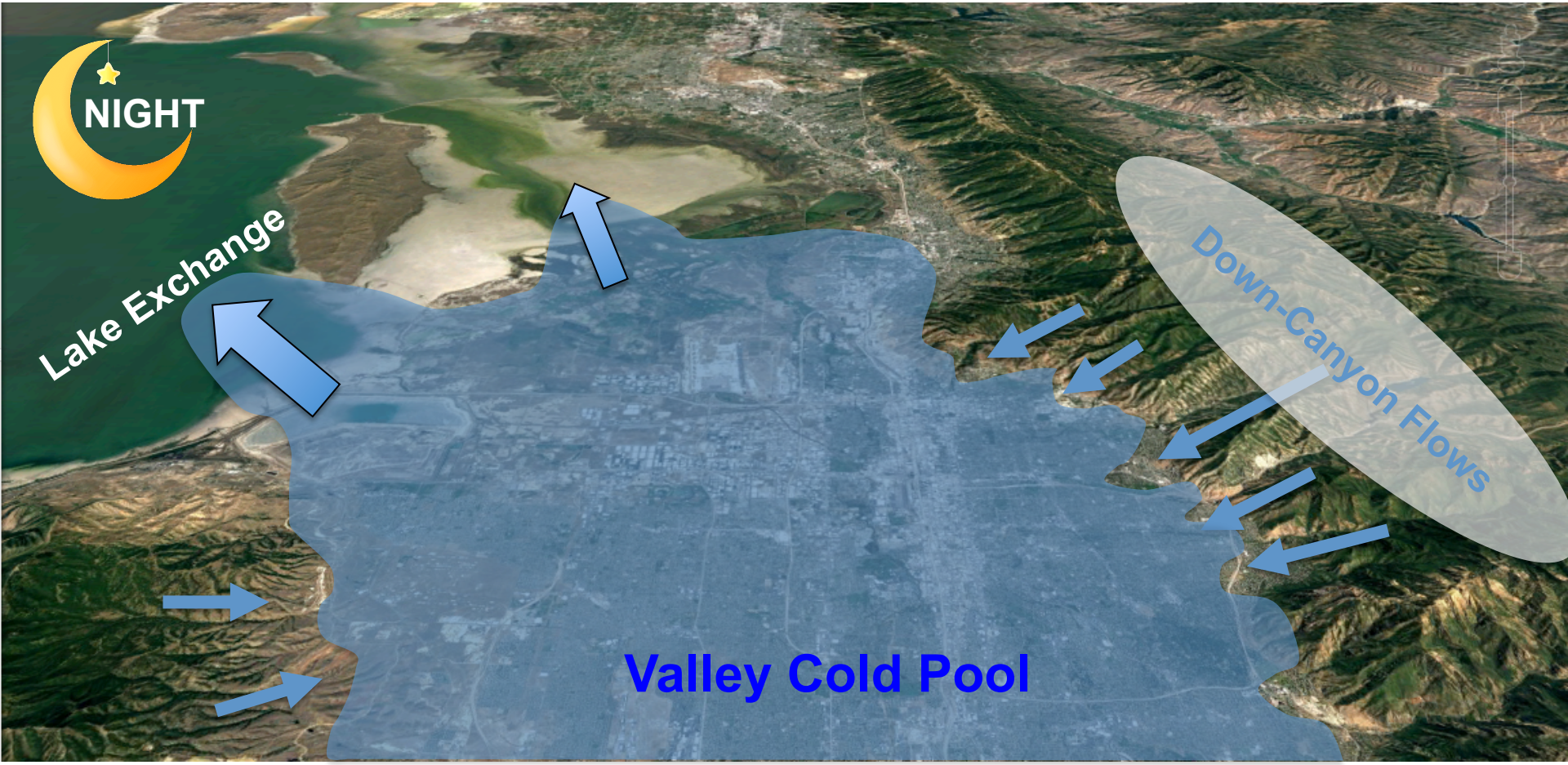

Secondary
Aerosol
Formation
Ammonium nitrate
NH_4NO_3
HNO_3 NH_4
70-80% of
PM2.5 mass
NO_x $PM_{2.5}$ NH_4 VOCs
Oquirrhs
Wasatch
Salt Lake Valley

Pollution Episode

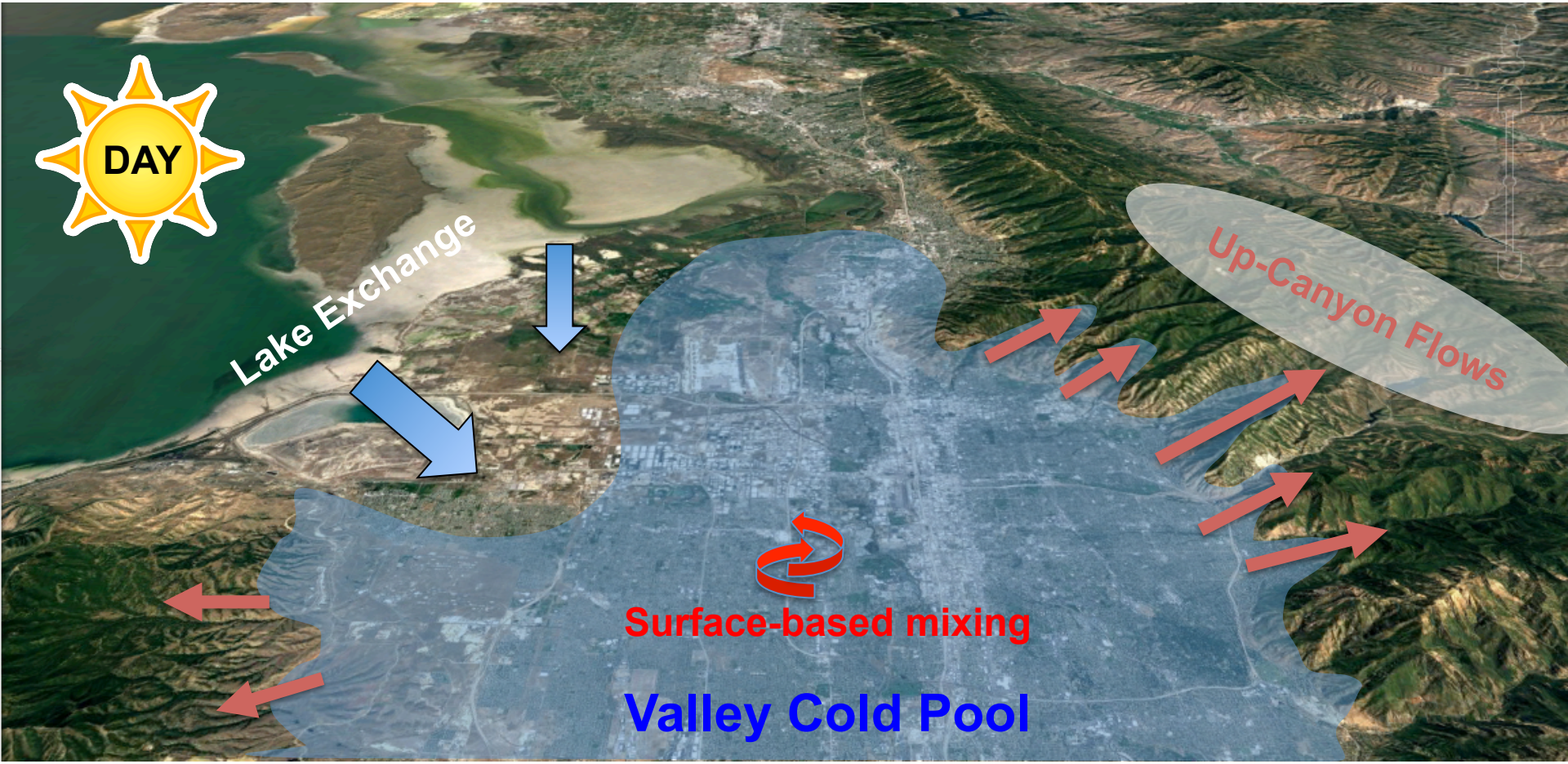



Meteorology
Cold-Air Pools
Transport ($PM_{2.5}$, O_3)
Mixing
Layering
Air Chemistry

Night-time exchange processes

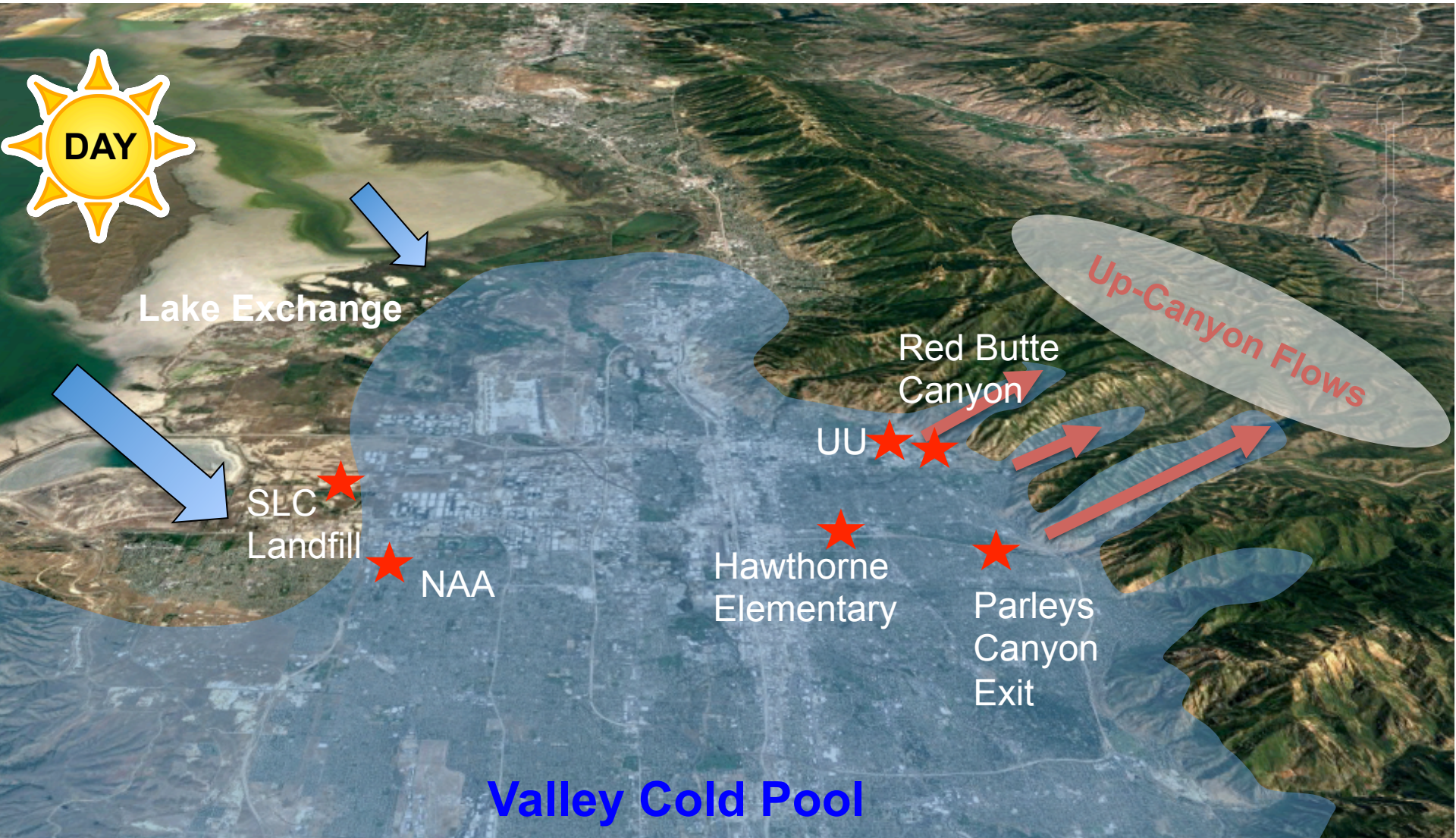


Day-time exchange processes



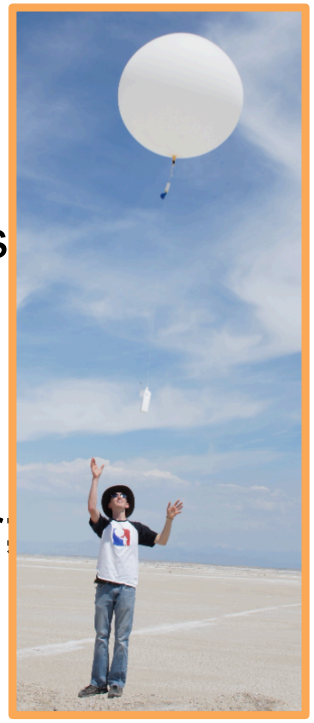
Observations

- 2015-2016 Salt Lake Valley $PM_{2.5}$ Pollution Study
- 2016-2017 Utah Wintertime Fine Particulate Study



Observations / Methods

- Temperature profiles (weather balloons, pseudo-vertical profiles)
- Wind profiles (Doppler Wind LiDAR, SoDAR)
- Aerosol loading (laser light backscatter; ceilometer)
- $PM_{2.5}$ concentrations (fine particulate pollution)
- Ozone concentrations (O_3)
- Surface winds / temperatures (AWS, MesoWest)



Observation Platforms

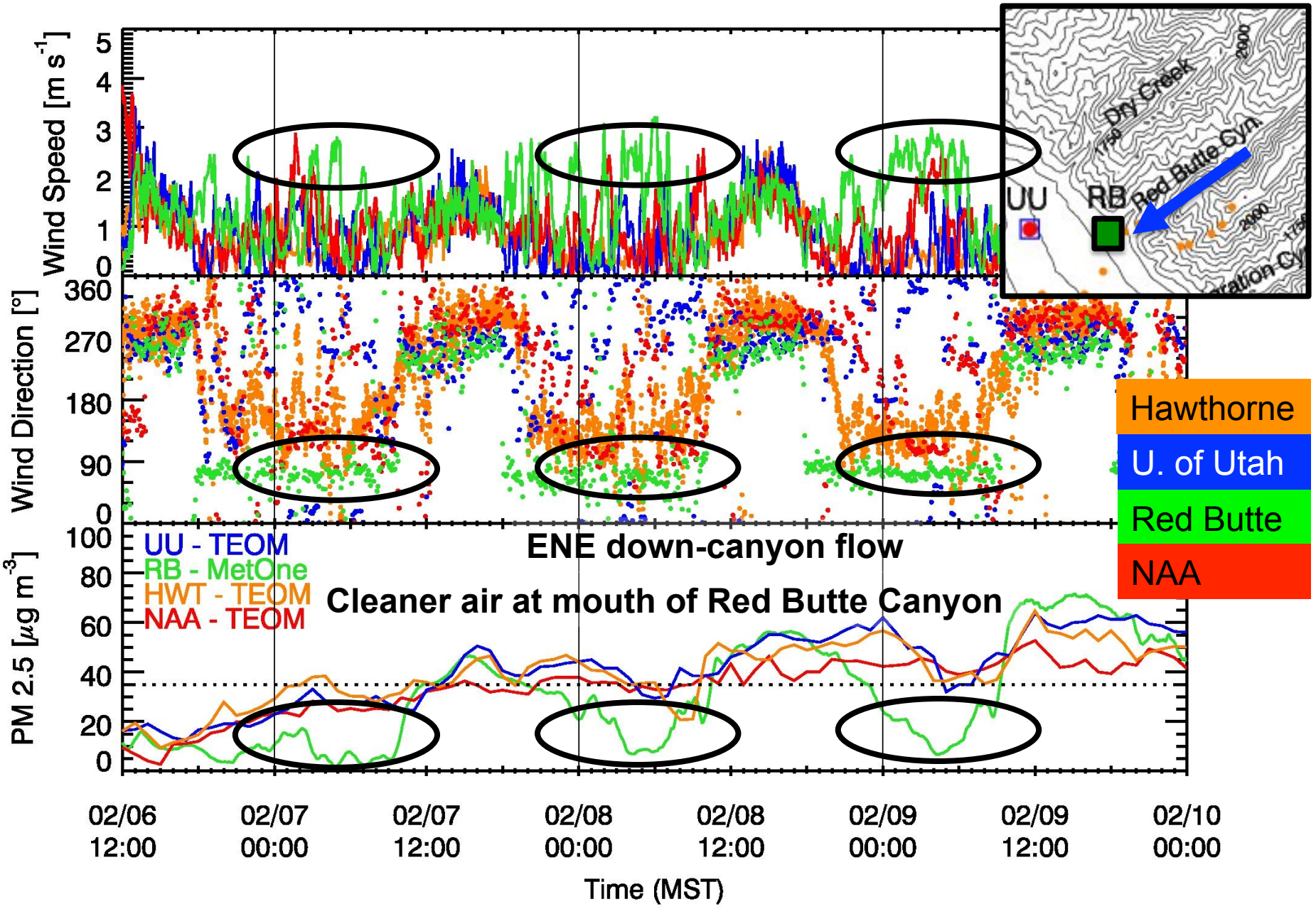
- Surface - based
- Mobile (KSL news helicopter, TRAX light rail)

See Mitchell et al. - next talk!

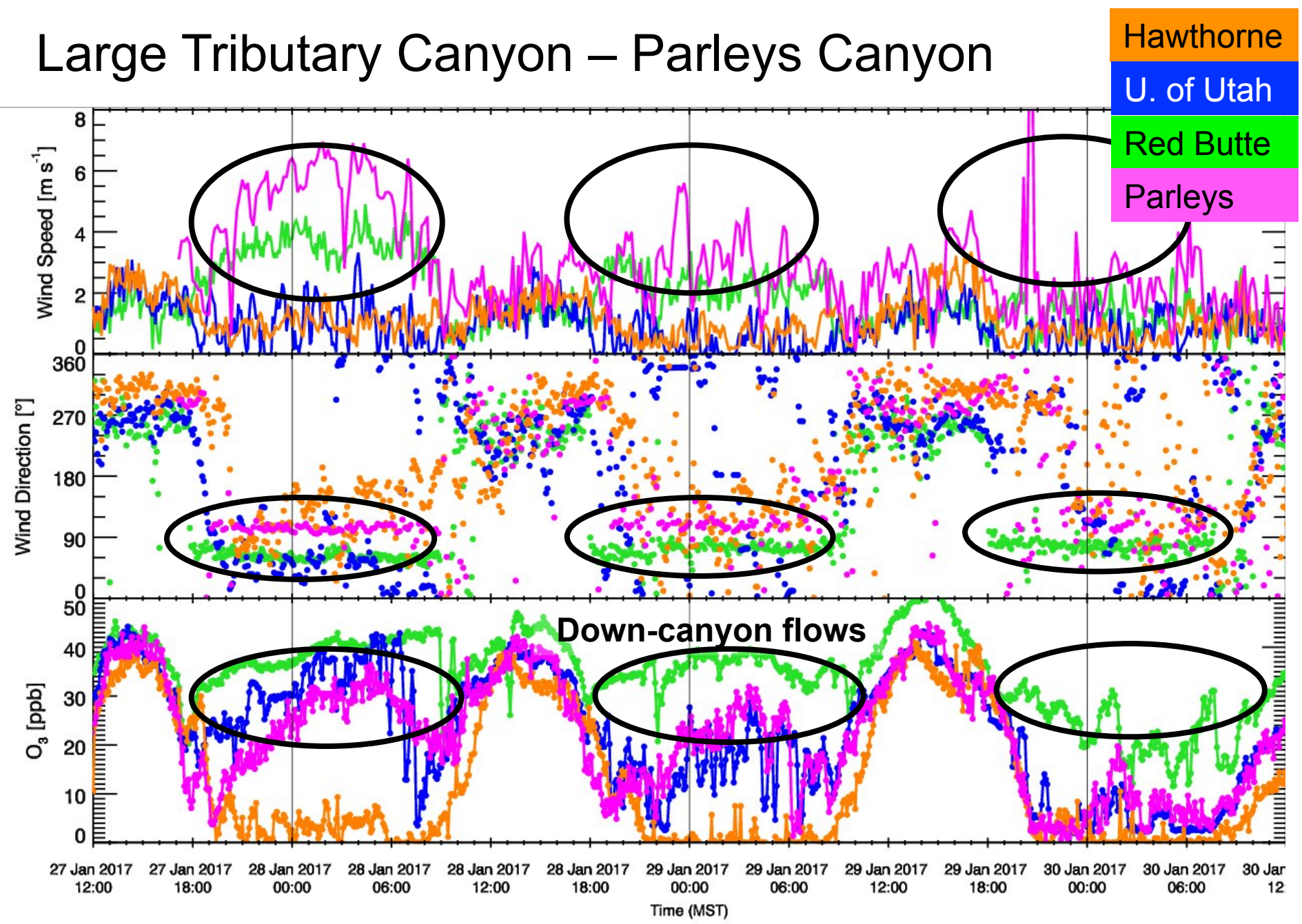
Slope and Canyon Flows

Thermal contrasts between basin floor and surrounding valleys drive daytime up-valley and up-slope and nighttime down-slope and down-valley flows.

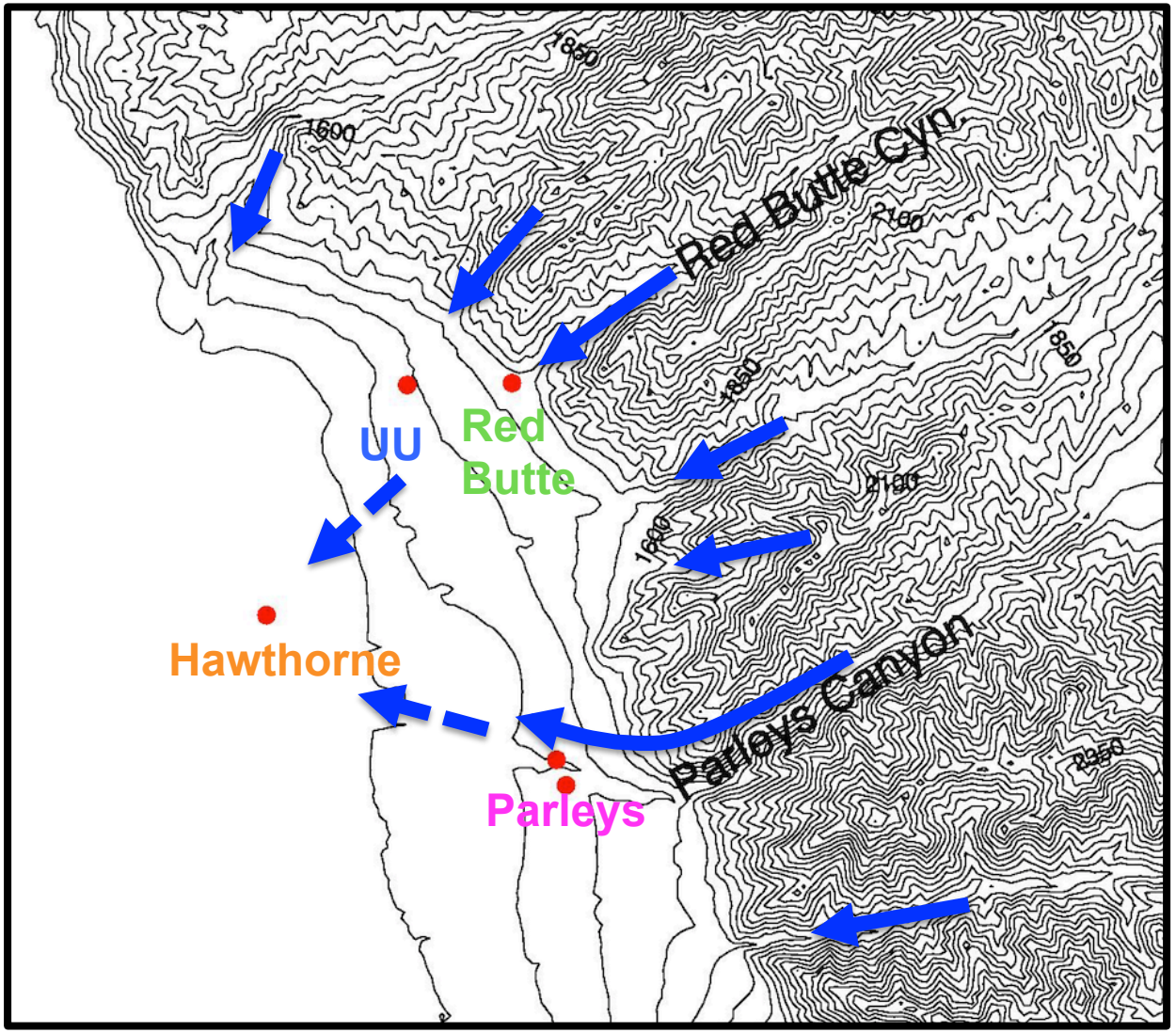
Small Tributary Canyon – Red Butte Canyon (Feb 2016)



Large Tributary Canyon – Parleys Canyon



Preliminary data (UWFPS)

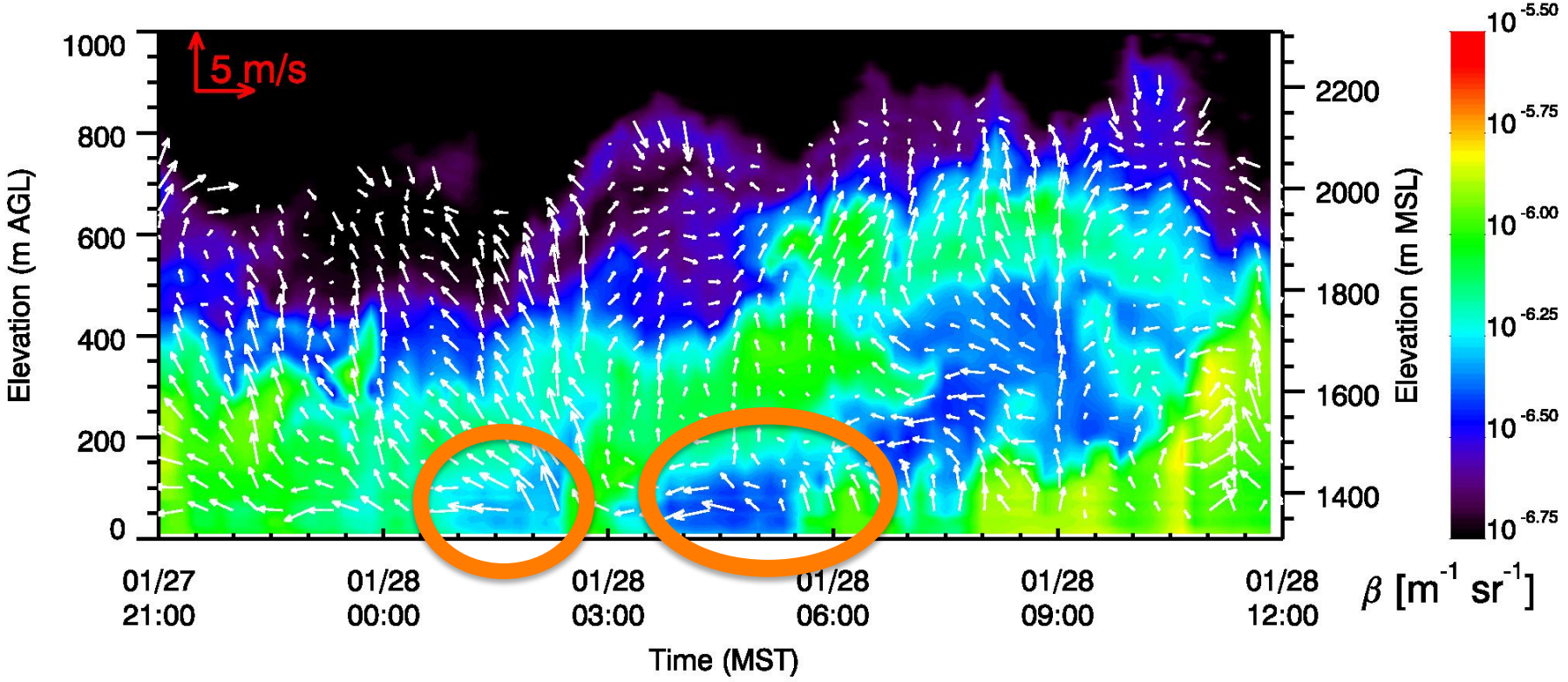


Nighttime, at mouth of tributary canyons:

➔Lower $PM_{2.5}$

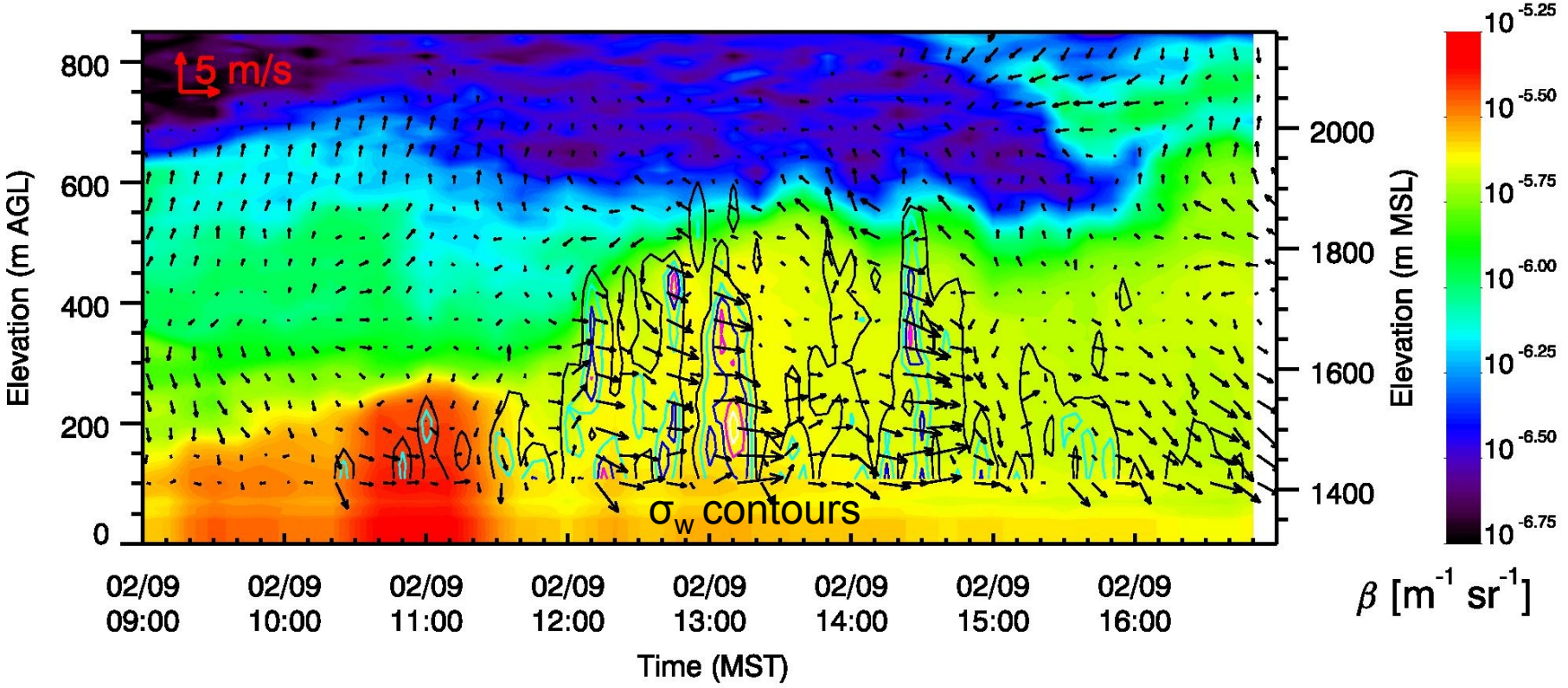
➔Higher O_3

Effect of drainage flows near the basin center



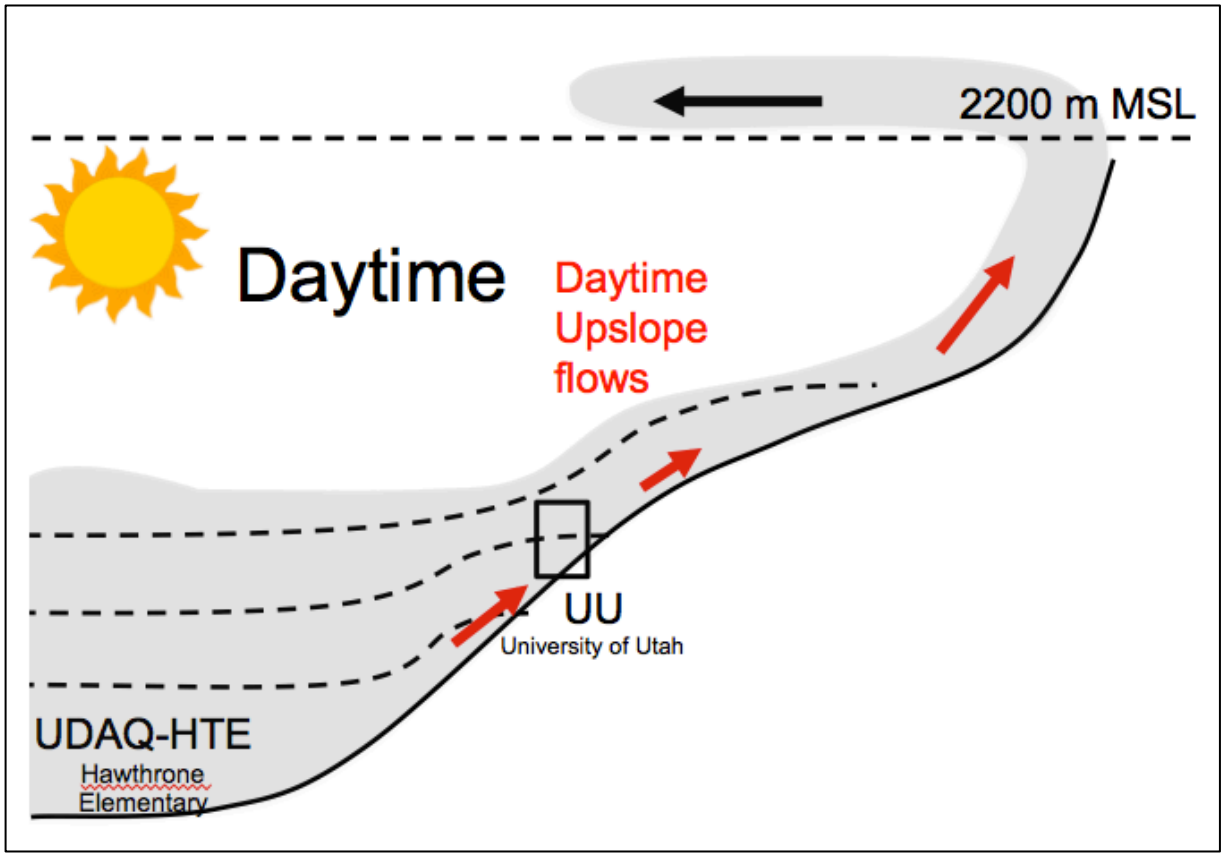
Time–height cross section of LiDAR wind, aerosol backscatter at Hawthorne Elementary

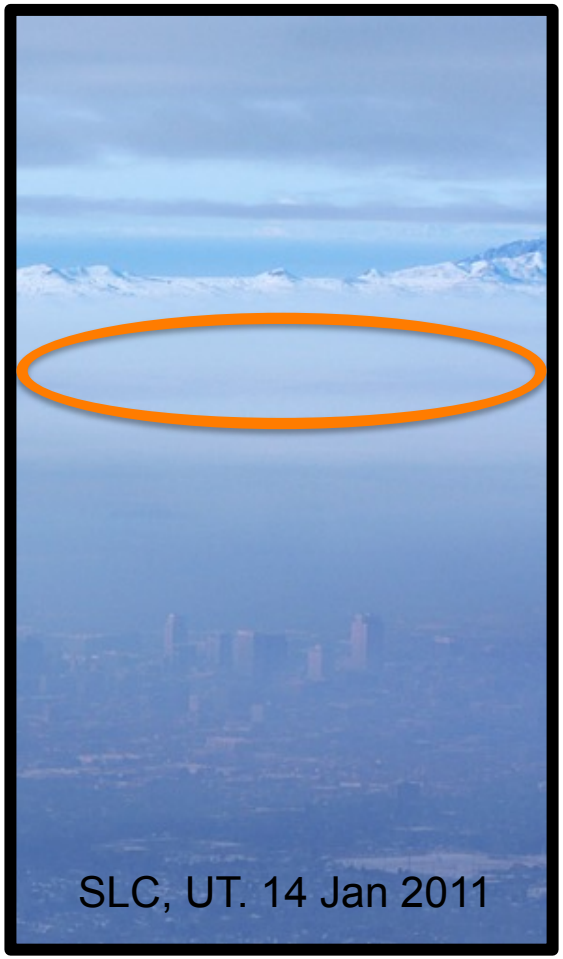
Daytime heating – Ventilation – Aerosol layering?



- σ_w (vertical velocity variance) from Lidar stares shows convection at the base of the PCAP

Daytime heating – Ventilation – Aerosol layering?

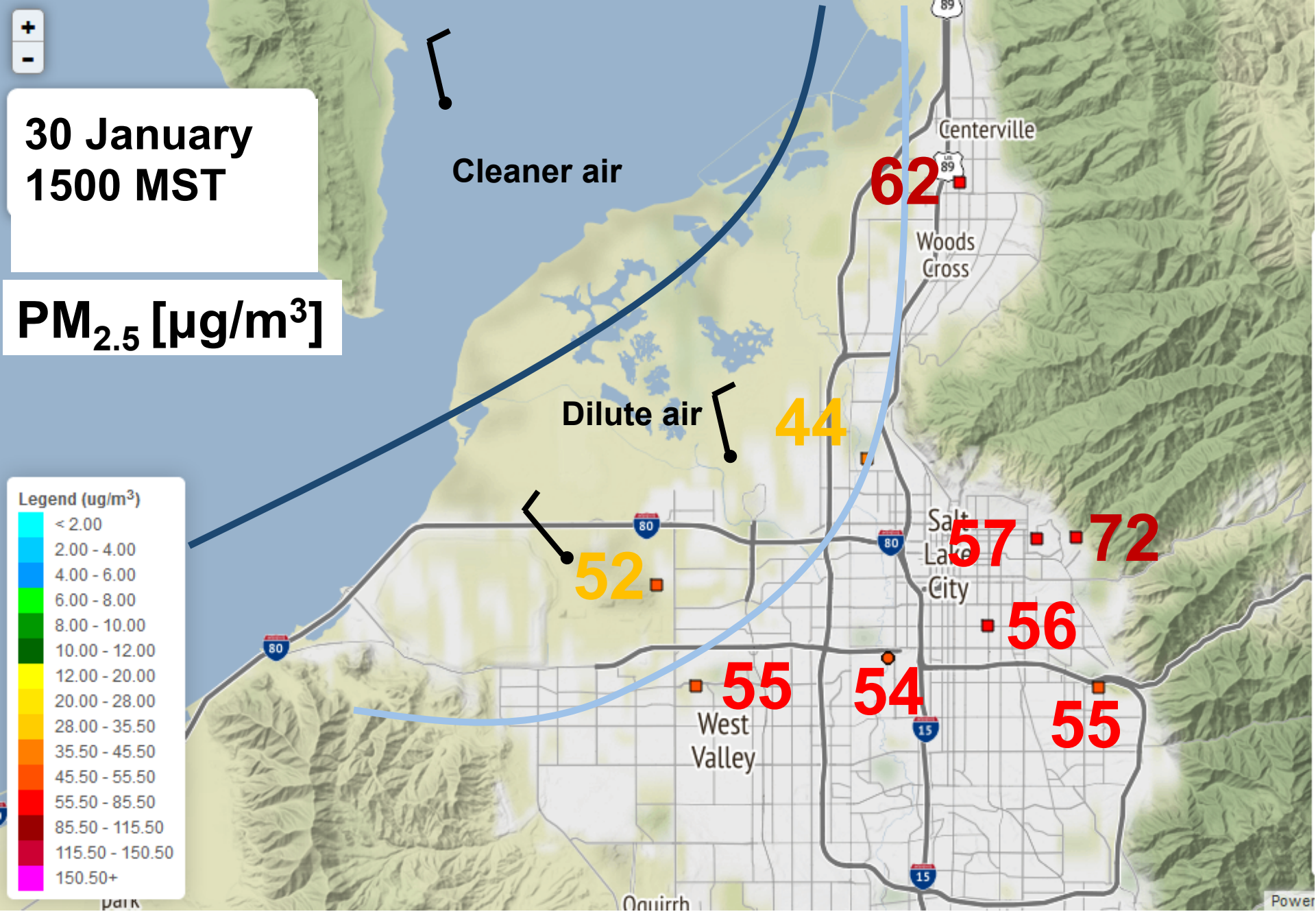


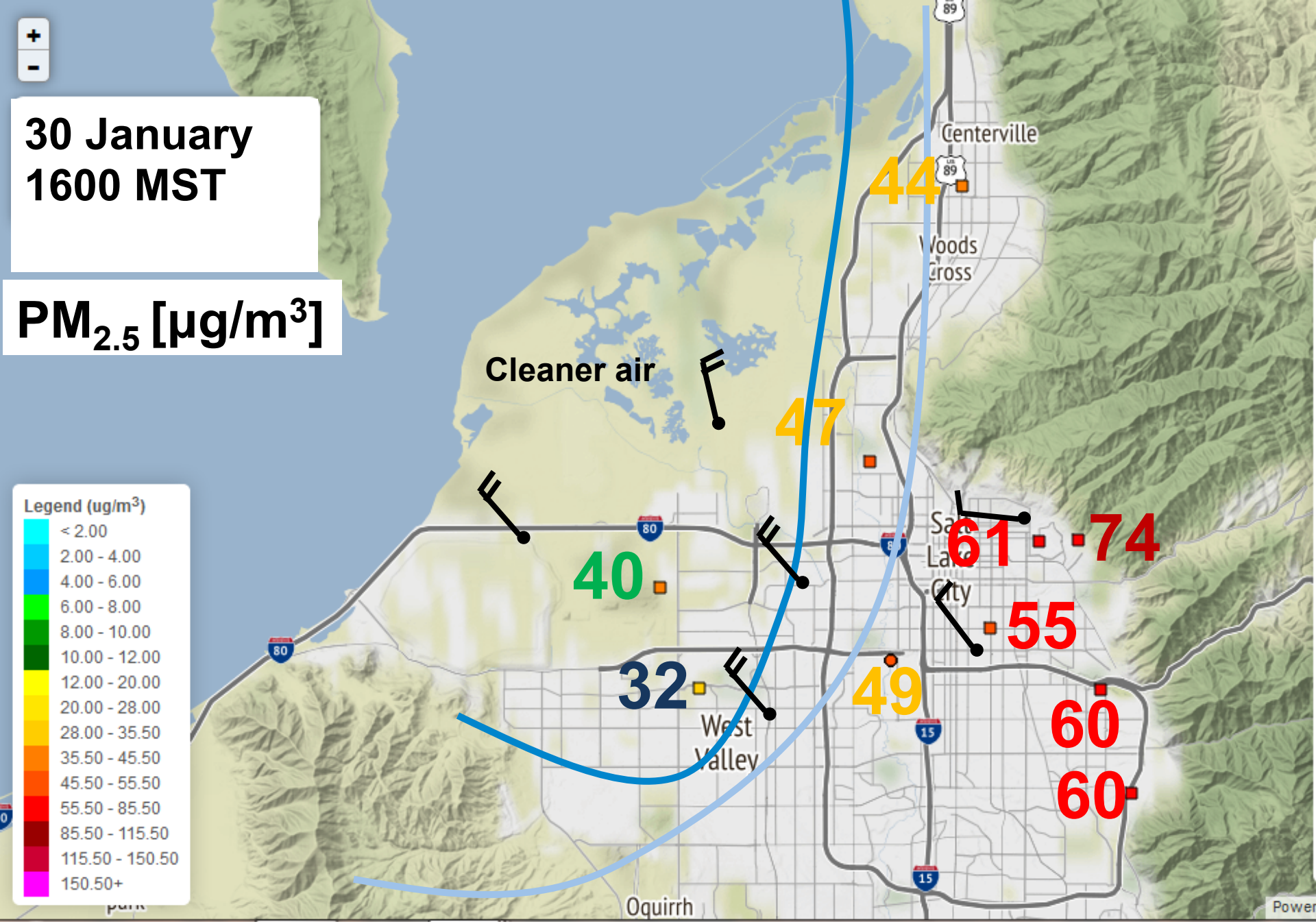


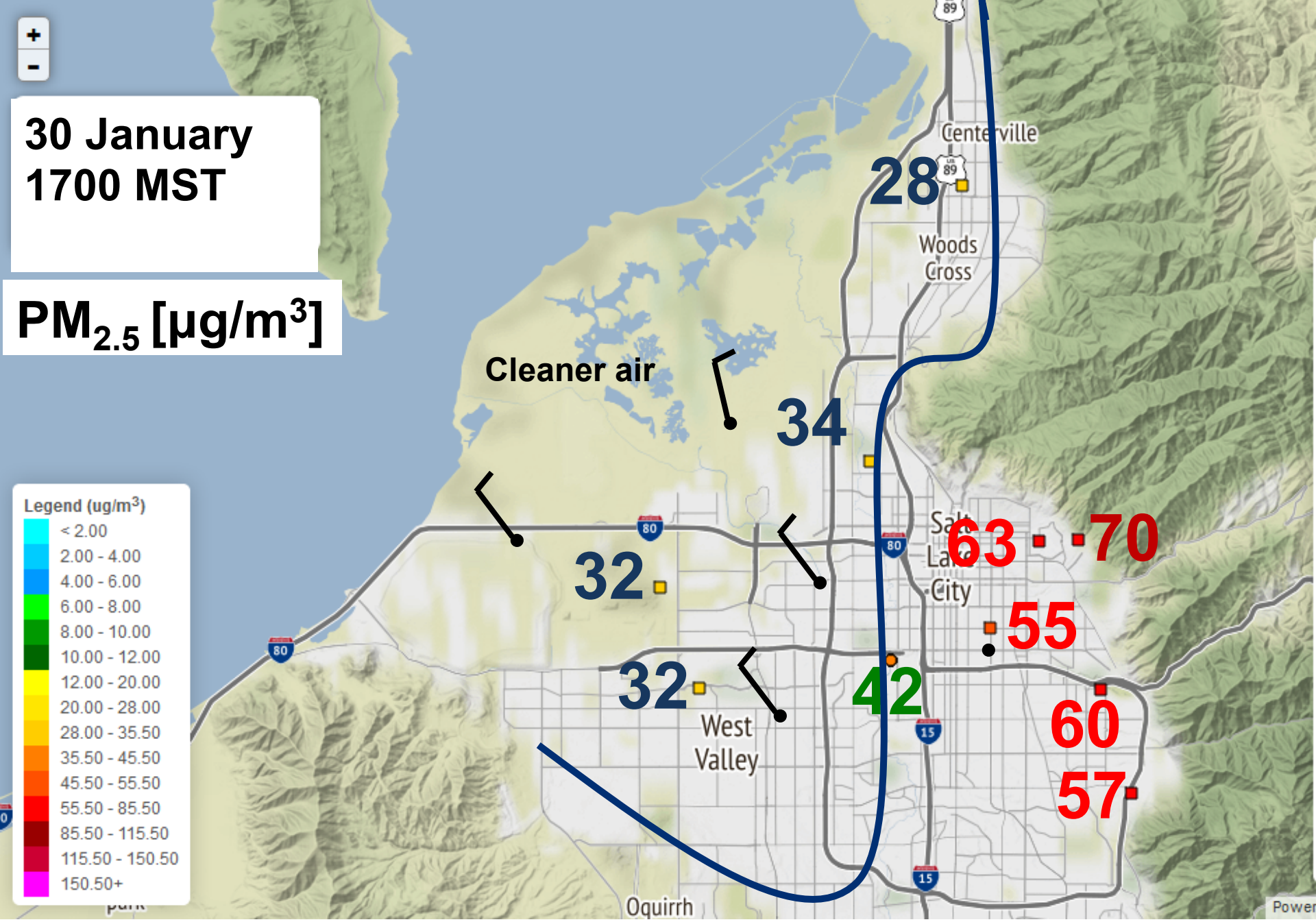
Pollution is ejected along the sidewalls into elevated layers and advected with the weak mean flow. ➔Ventilation

Lake Exchange Processes

Different air masses develop over the Great Salt Lake and the valley floor (water versus land surface)


30 January
1500 MST
PM2.5 [µg/m3]
Cleaner air
Dilute air
Centerville
Woods Cross
Salt Lake City
West Valley
62
44
52
57
72
56
55
54
55
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+


30 January
1600 MST
PM2.5 [µg/m3]
Cleaner air
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+
Centerville
Woods Cross
West Valley
Oquirrh
44
47
40
61
74
55
32
49
60
60

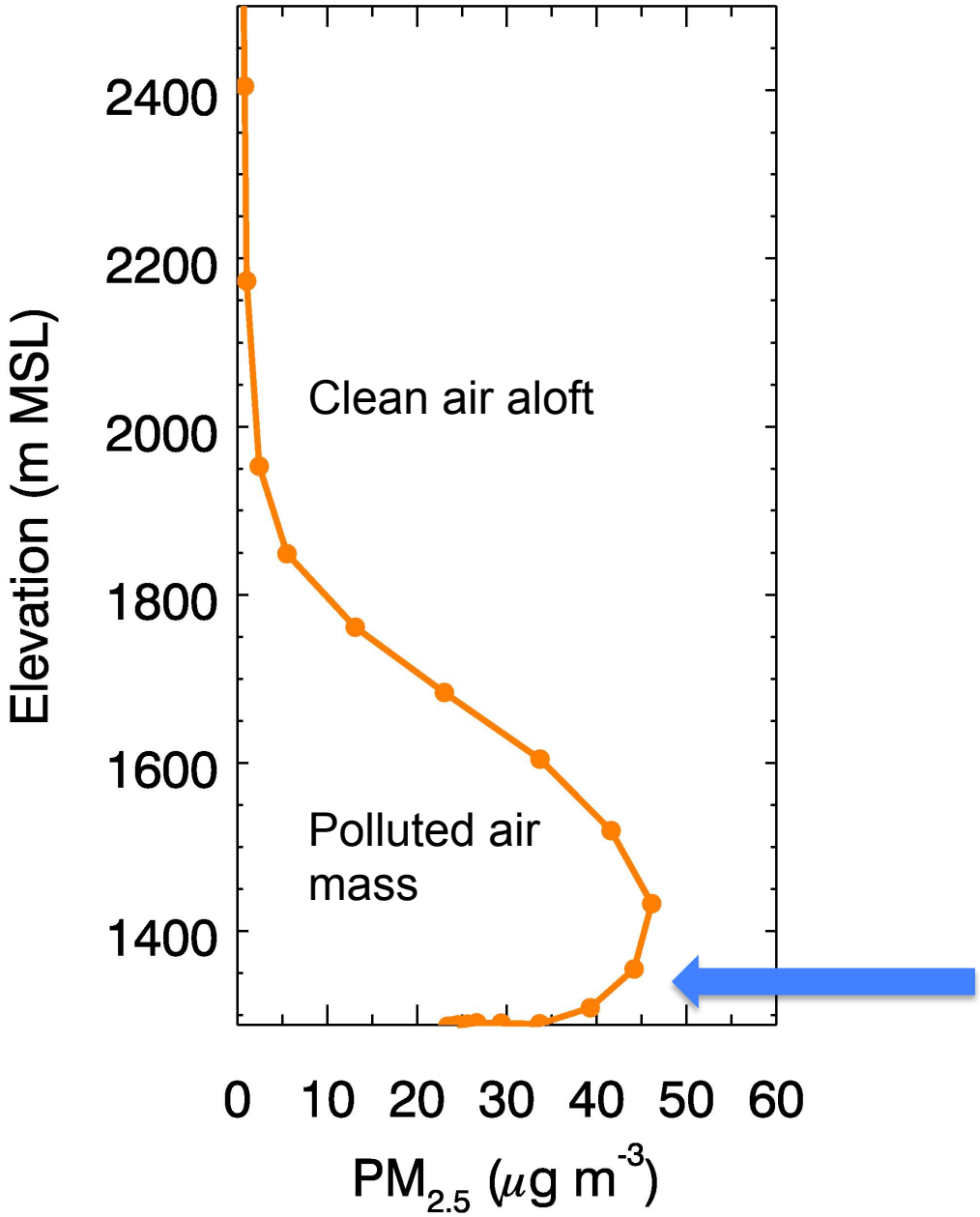

30 January
1700 MST
PM2.5 [µg/m3]
Cleaner air
28
34
32
32
42
63
70
55
60
57
Centerville
Woods Cross
West Valley
Oquirrh
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+

30 January
1700 MST

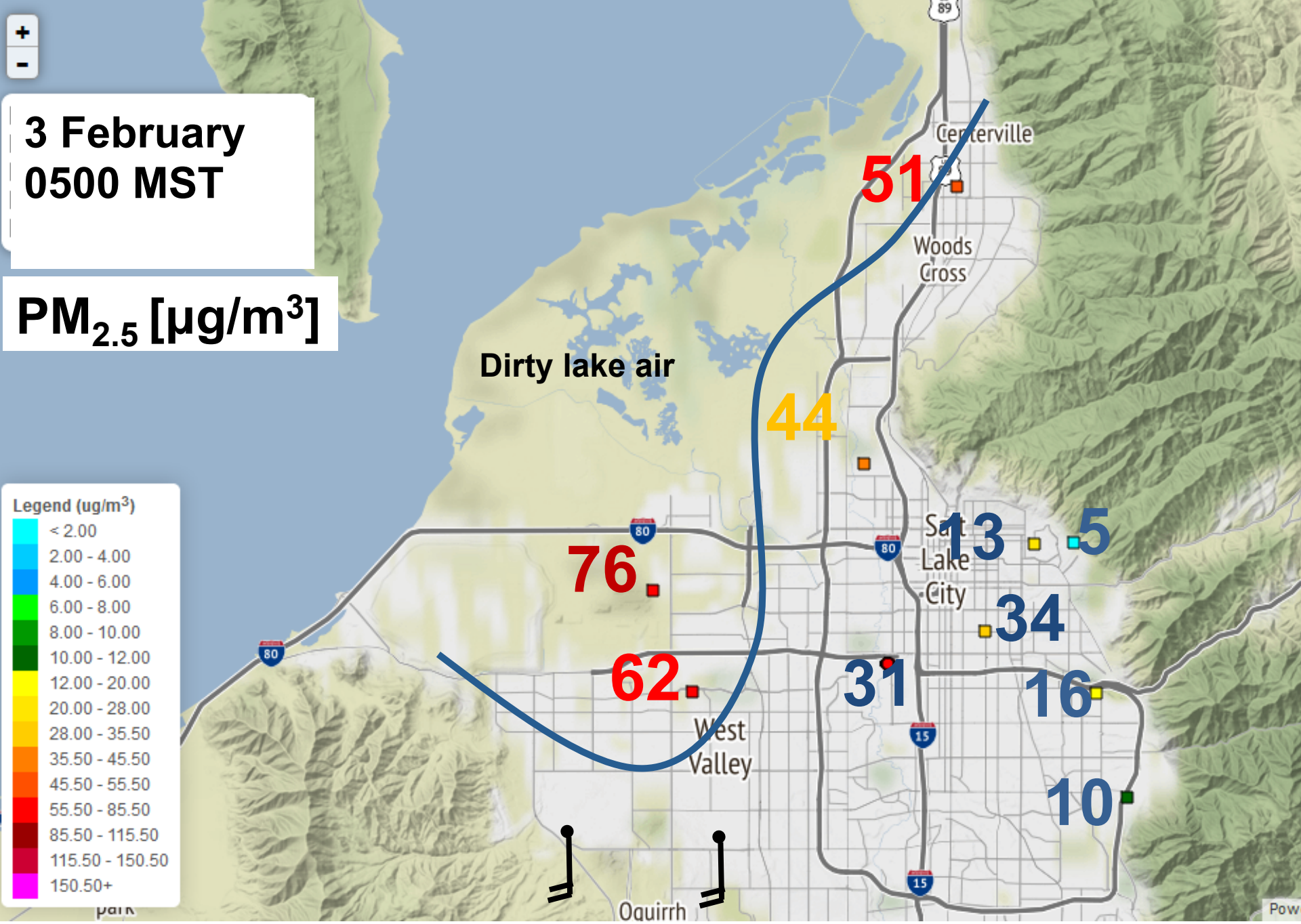
Legend (ug/m^3)
- < 2.00
- 2.00 - 4.00
- 4.00 - 6.00
- 6.00 - 8.00
- 8.00 - 10.00
- 10.00 - 12.00
- 12.00 - 20.00
- 20.00 - 28.00
- 28.00 - 35.50
- 35.50 - 45.50
- 45.50 - 55.50
- 55.50 - 85.50
- 85.50 - 115.50
- 115.50 - 150.50
- 150.50+

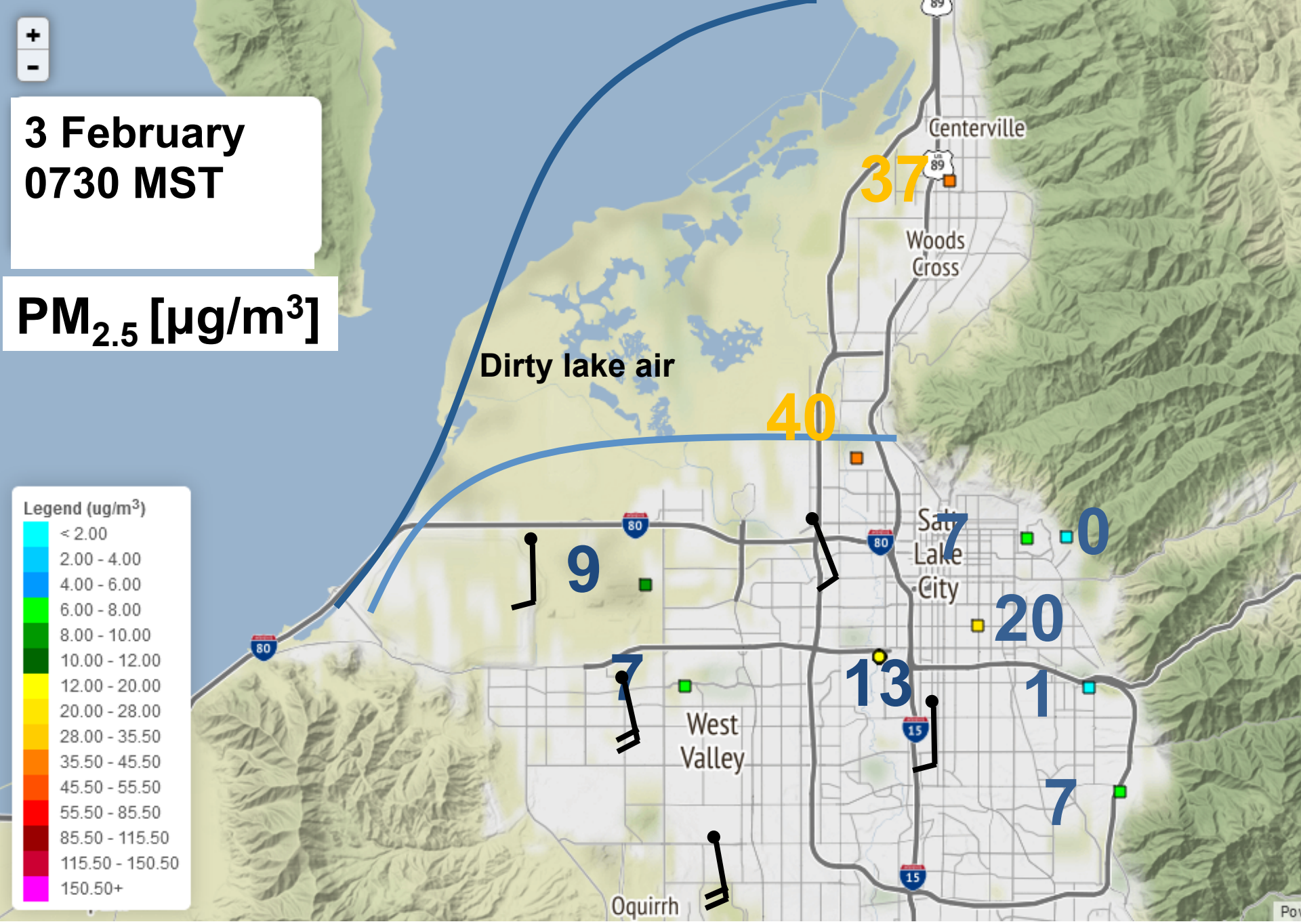
Centerville
28
Woods Cross
84
Salt Lake City
63
70
55
42
60
57
Oquirrh

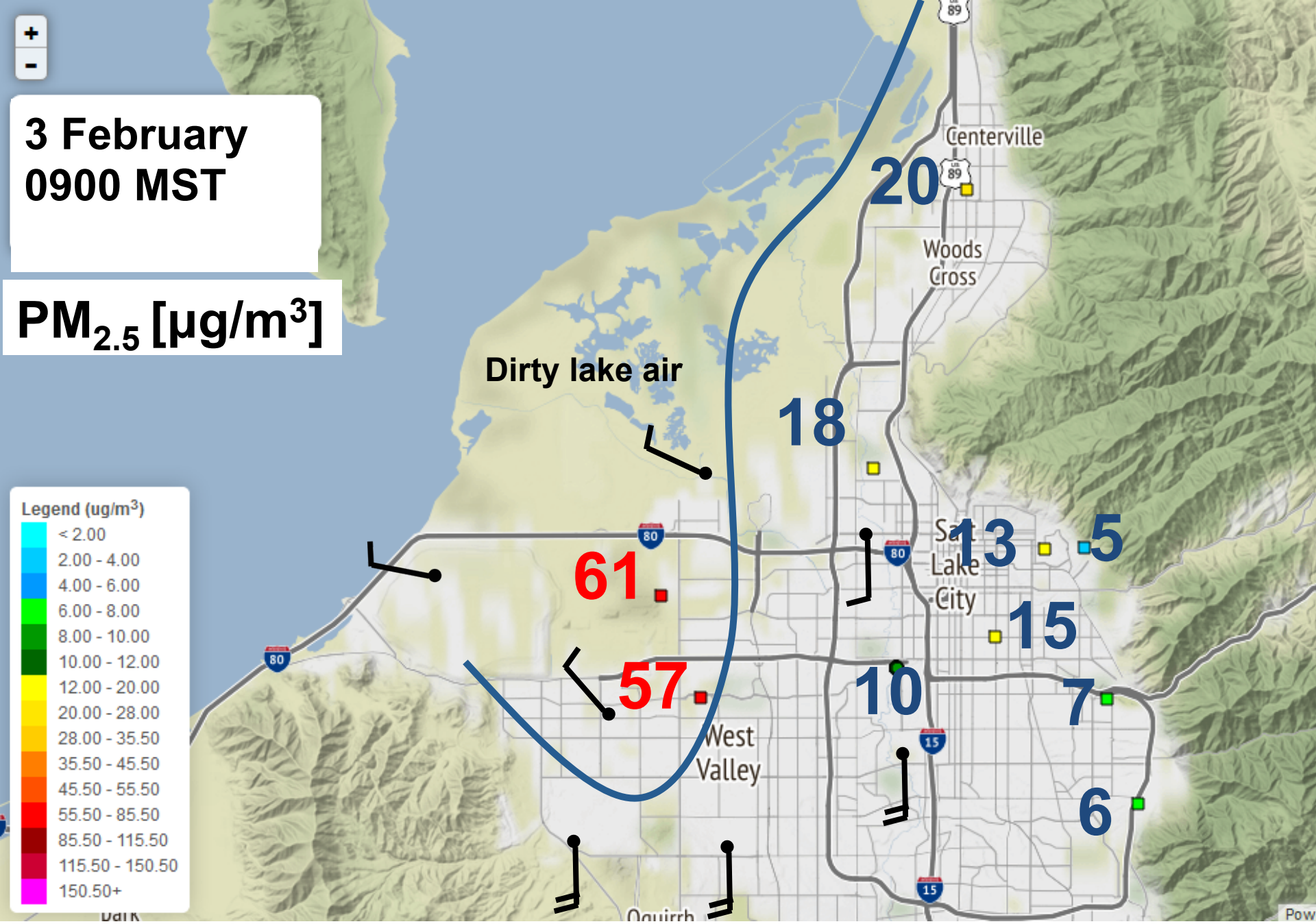
30 January 1700- 1700 MST



Colder and cleaner air is advected from the lake, undercutting the very polluted air.


3 February
0500 MST
PM2.5 [µg/m3]
Dirty lake air
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+
Centerville
Woods Cross
Salt Lake City
West Valley
Oquirrh
51
44
76
62
13
5
34
31
16
10
80
15
89


3 February
0730 MST
PM2.5 [µg/m3]
Dirty lake air
40
37
Centerville
Woods Cross
Salt Lake City
West Valley
Oquirrh
9
7
0
20
7
13
1
7
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+


3 February
0900 MST
PM2.5 [µg/m3]
Dirty lake air
Legend (ug/m3)
< 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 20.00
20.00 - 28.00
28.00 - 35.50
35.50 - 45.50
45.50 - 55.50
55.50 - 85.50
85.50 - 115.50
115.50 - 150.50
150.50+
Centerville
Woods Cross
Salt Lake City
West Valley
20
18
61
57
13
5
15
10
7
6

View from the “avenues”, 3 February 2017

Conclusions

- Meteorological processes play an important role in modulating particulate pollution concentrations during pollution episodes.

- These processes may directly affect concentrations but also indirectly by transporting oxidants necessary for secondary aerosol formation.

- Slope and valley flows bring cleaner and ozone-rich air into the cold pool at night.

Conclusions (cont.)

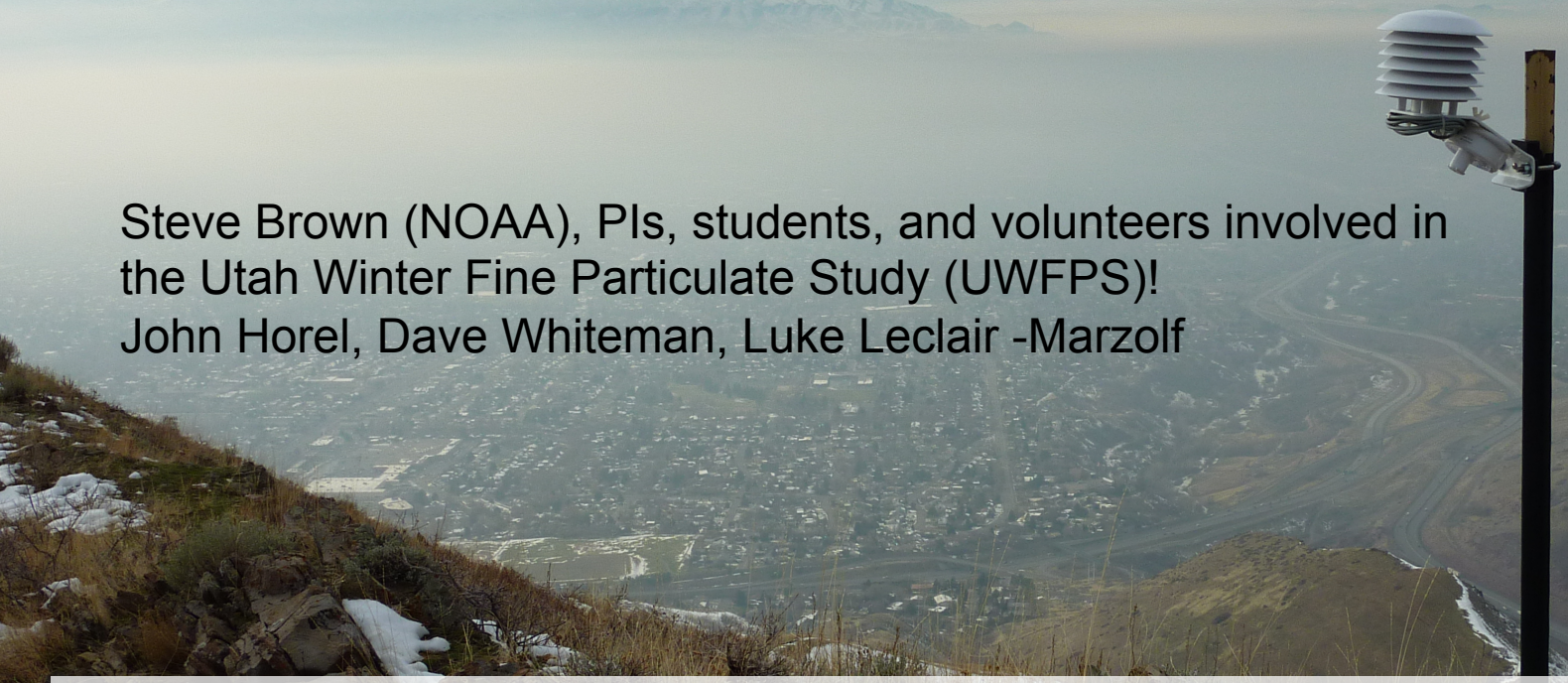
- During the day, pollution is transported up the tributary valleys. Some pollution may be ventilated into elevated layers.

- The air mass above the Great Salt Lake can serve as a reservoir of clean or polluted air. Air mass exchanges can modulate air quality significantly.

- Temporal and spatial variations in aerosol concentrations indicate that a single measurement at one location may not be representative for all areas in a populated basin.

Acknowledgements

Funding: National Science Foundation (Grant # AGS-1723337)
Utah Division for Environmental Quality



Steve Brown (NOAA), PIs, students, and volunteers involved in the Utah Winter Fine Particulate Study (UWFPS)!
John Horel, Dave Whiteman, Luke Leclair -Marzolf

Volunteers willing to house equipment:
Wim Cardoen & Gwen Latendresse, The Country Club (Amedee, Steve Garcia, Mike Buckley), Brad Leinberger, Brad Krab, First Baptist Church (Father Dennis), Rebecca Paulson (UU), Steiner Center (Clark) , Judy Pechman, ARUP labs (John Taylor), Ed Butterfield, E&S Computers, Sue Pope (UU), Red Butte Gardens, Huntsman Institute, …