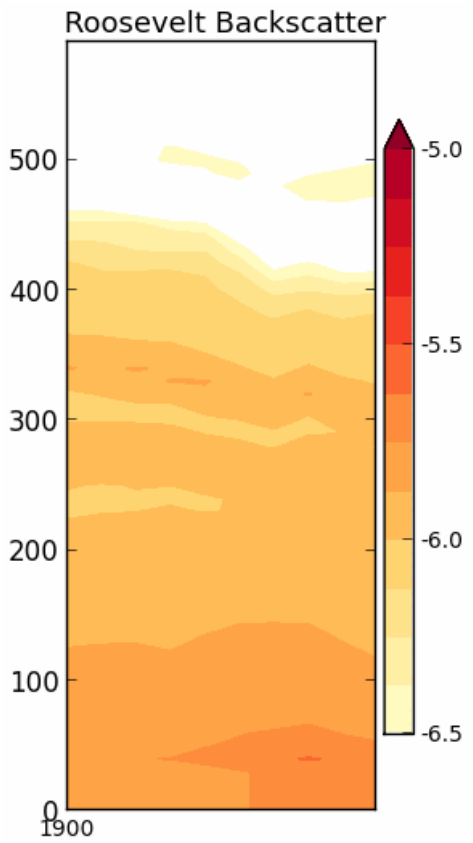
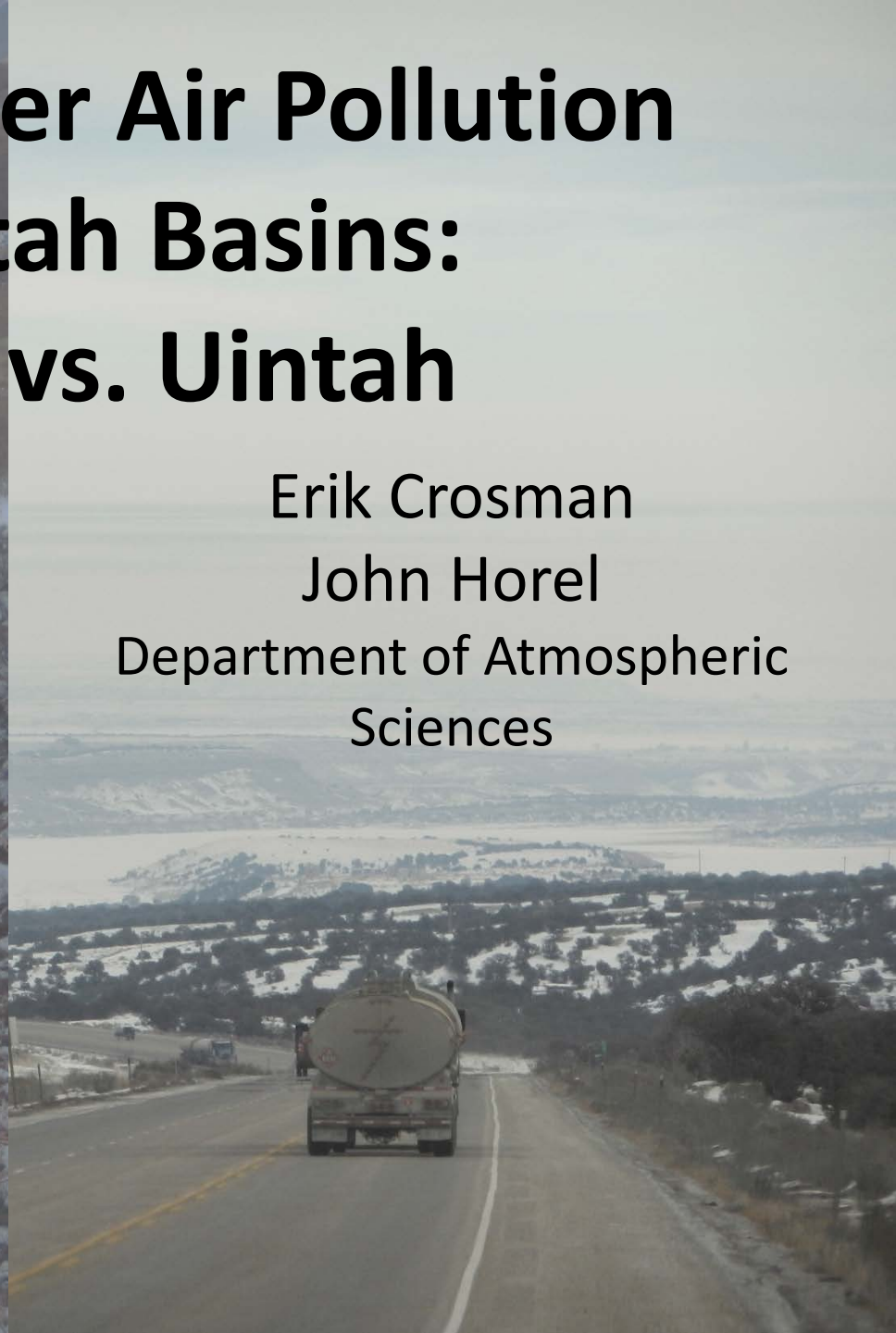


Aerosol Backscatter at Roosevelt:
January 19, 2013
Darker shades indicate higher aerosol concentrations
10 minute window

A Tale of Winter Air Pollution in Two Utah Basins: Salt Lake vs. Uintah

Erik Crosman
John Horel
Department of Atmospheric Sciences



Acknowledgements

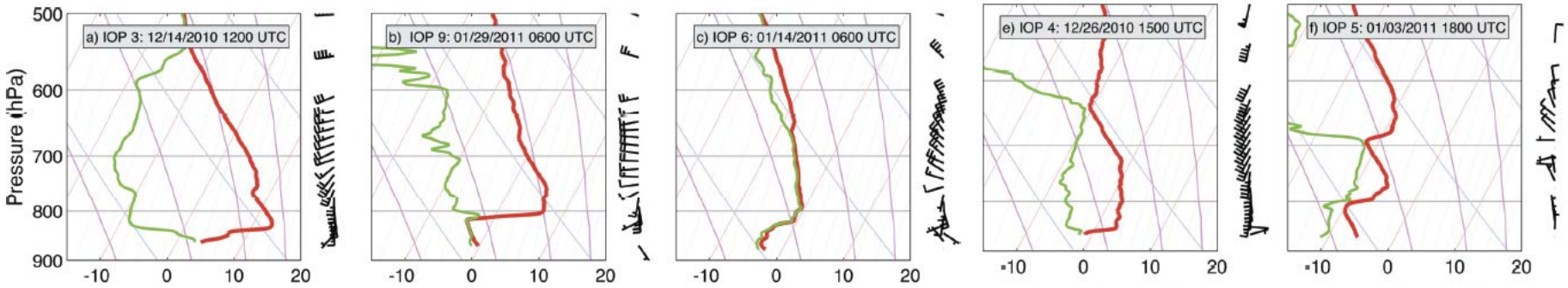
- Salt Lake Valley
  - Neil Lareau
  - Dave Whiteman
  - Sebastian Hoch
  - Joe Young
  - Many others involved in PCAPS
- Uintah Basin
  - Alex Jacques
  - Matt Lammers
  - John Lawson
  - Nola Lucke
  - Erik Neemann
  - Maggie Schoonover
  - MesoWest team

THE PERSISTENT COLD-AIR POOL STUDY

BY NEIL P. LAREAU, ERIK CROSMAN, C. DAVID WHITEMAN, JOHN D. HOREL, SEBASTIAN W. HOCH, WILLIAM O. J. BROWN, AND THOMAS W. HORST

Bull Amer. Meteor. Soc. 2013

Utah's Salt Lake valley was the setting for a wintertime study of multiday cold-air pools that affect air quality in urban basins.



1 December 2010- 10 February 2011

An E&E Publishing Service

AIR POLLUTION: Wintertime ozone has researchers scrambling through heavily drilled parts of rural Utah (Thursday, February 14, 2013)

Margaret Kriz Hobson, E&E reporter

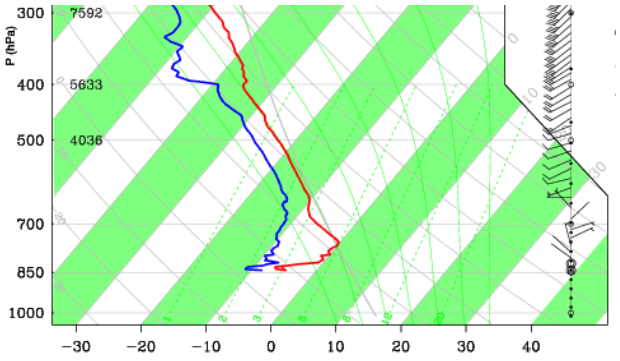
In mid-January, a high-pressure system brought snow and cold temperatures into northern Utah, producing the exact weather conditions that scientists needed to study winter ozone pollution in the heavily drilled Uinta Basin.

State and federal officials quickly dispatched a SWAT team of air pollution researchers to the rural, northeastern corner of Utah. Over the course of the next few weeks, the scientists reported significantly elevated levels of ozone pollution.

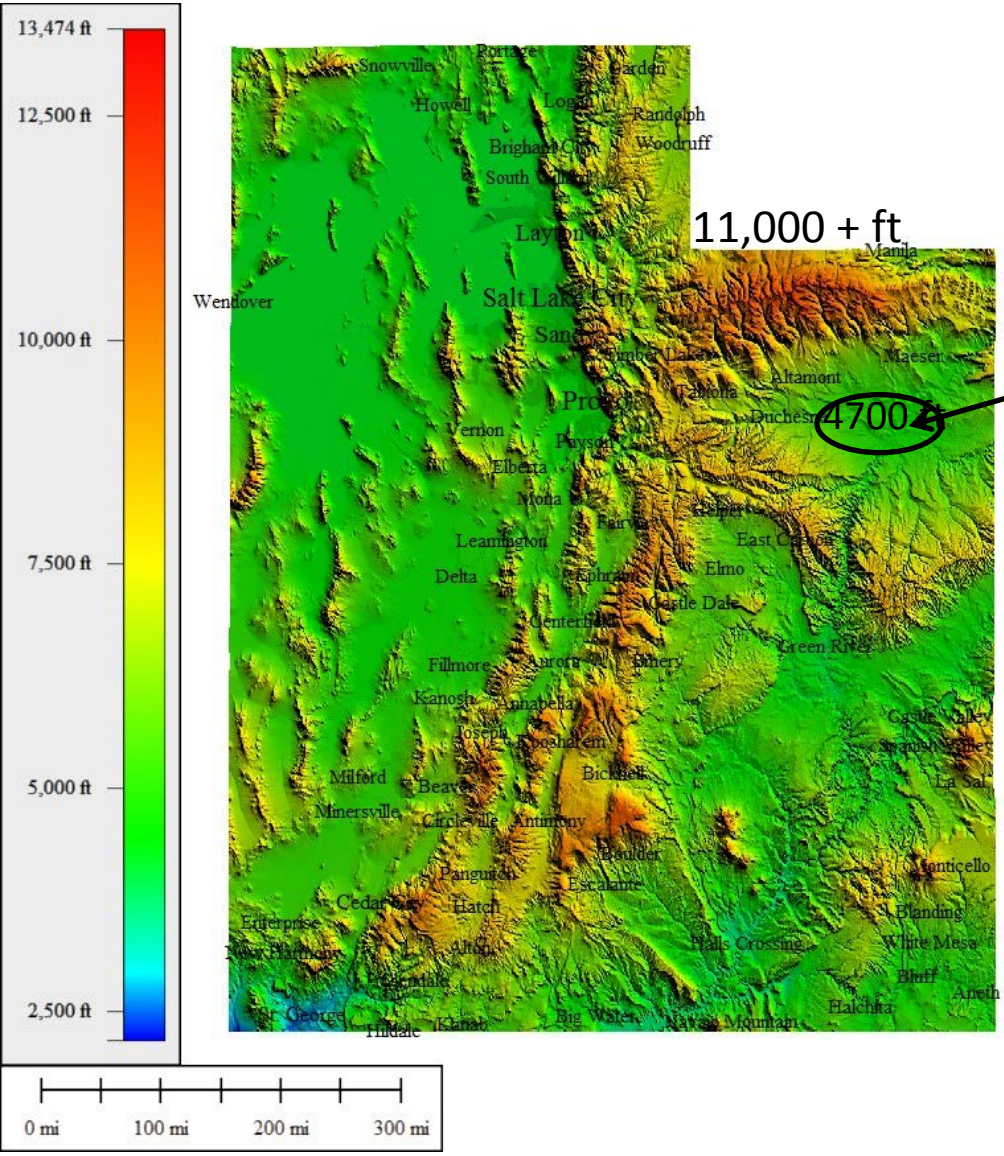
By early February, as a cold-weather air inversion settled over the snow-covered region, the ozone readings soared to levels considered unhealthy for sensitive populations.

2013 Uintah Basin Ozone Study

- Utah DEQ
- EPA
- USU
- NOAA ESRL Air Chemistry
- Colorado State
- U Wyoming
- U Utah



Salt Lake & Uintah Basins

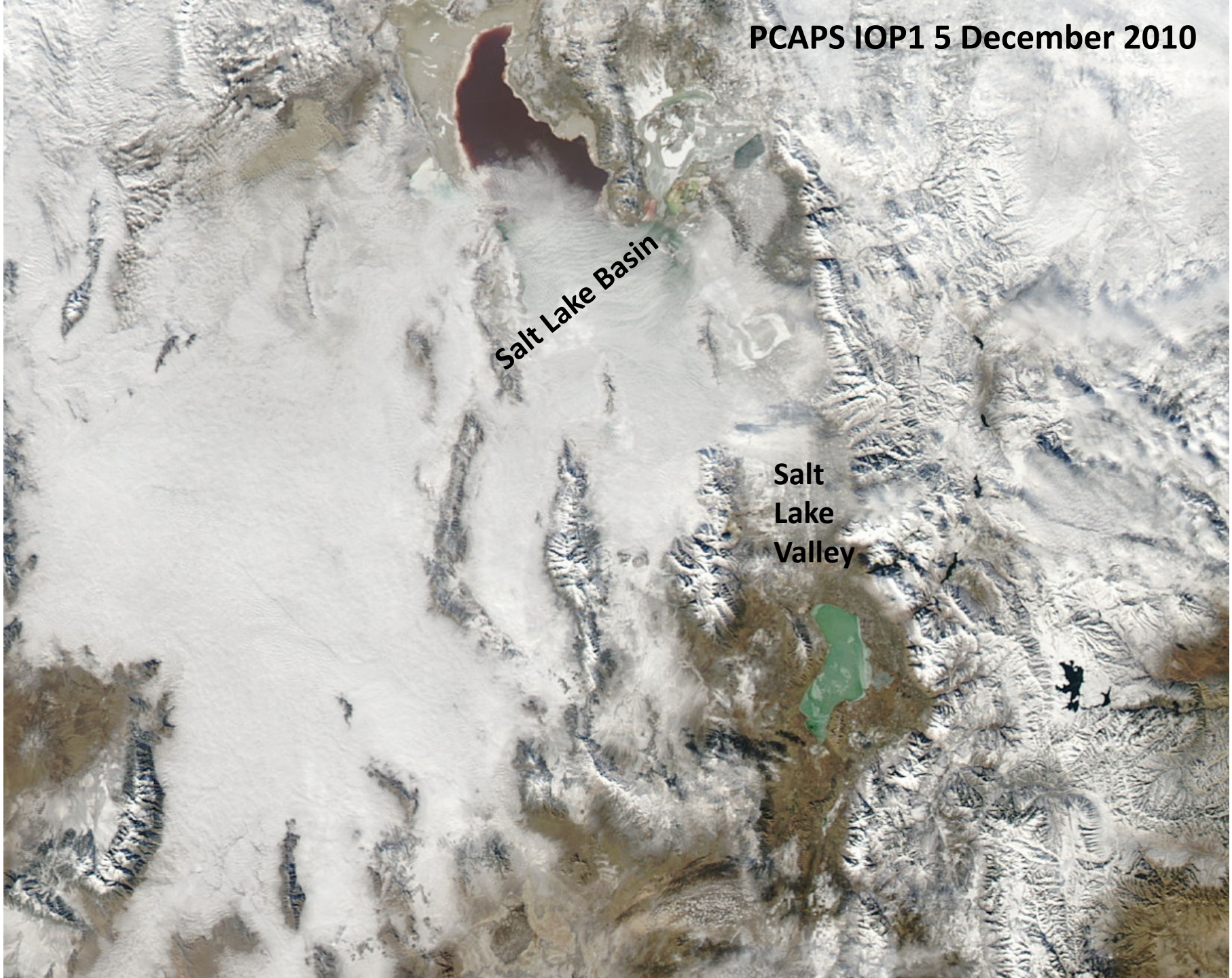


11,000 + ft

4700 ft

Bottom of the basin
Coldest and most polluted air accumulates here

7,000 -8500 ft


PCAPS IOP1 5 December 2010
Salt Lake Basin
Salt
Lake
Valley

While the Salt Lake Valley is the "*Tail on the Dog*"…

The Uintah Basin “*is the Dog*”…

EPA warns of possible ozone crackdown in Uinta Basin

Environment • Pollution control mandates could be coming.

Article Tools

Print Friendly

BY JUDY FAHYS THE SALT LAKE TRIBUNE

PUBLISHED FEBRUARY 4, 2012 6:29 PM

Federal regulators have put the state on notice that another year of high ozone readings in Uintah and Duchesne counties will mean pollution controls might be ordered as early as 2013.

Ozone pollution targeted in new Uinta Basin lawsuit

Clean air • Environmental and health advocates say that EPA regulators are dragging their feet.

Article Tools

Print Friendly

Photos

BY JUDY FAHYS THE SALT LAKE TRIBUNE

PUBLISHED JULY 25, 2012 10:57 AM

Federal regulators are falling short on ozone pollution in the Uinta Basin, say environmental and health advocates who have taken their concerns to court.

The Utah Physicians for a Healthy Environment, the Southern Utah Wilderness Alliance and WildEarth Guardians say the U.S. Environmental Protection Agency has enough information to know pollution reaches unhealthy levels in the basin, which has logged some of the nation's highest ozone-pollution levels in recent years.

Researchers from Utah State University launch a remote-controlled aircraft to help learn about the unusual chemistry in the Uinta Basin that makes emissions from energy development turn into episodes of unhealthy ozone pollution. Courtesy Randal Martin, Utah State University.

Oil and gas wells contribute to basin pollution, new study confirms

Uinta Basin • Filthy airblamed on vehicles, oil,gas, but energy industrypoints finger at weather.

Article Tools

Print Friendly

Photos

BY JUDY FAHYS THE SALT LAKE TRIBUNE

PUBLISHED AUGUST 17, 2012 7:35 AM

Vernal • Oil and natural gas wells, along with cars and trucks, appear to be the key pollution culprits in sometimes making the Uinta Basin's wintertime air unhealthful.

Those are among the early findings of last winter's $5 million study to understand why rural, eastern Utah has logged some of the nation's highest ozone-pollution readings in recent years.

Study finds oil and gas causing pollution problem in eastern Utah

Environment » $5M Uinta Basin study IDs causes of winter pollution, but leaders aren't quite ready to act.

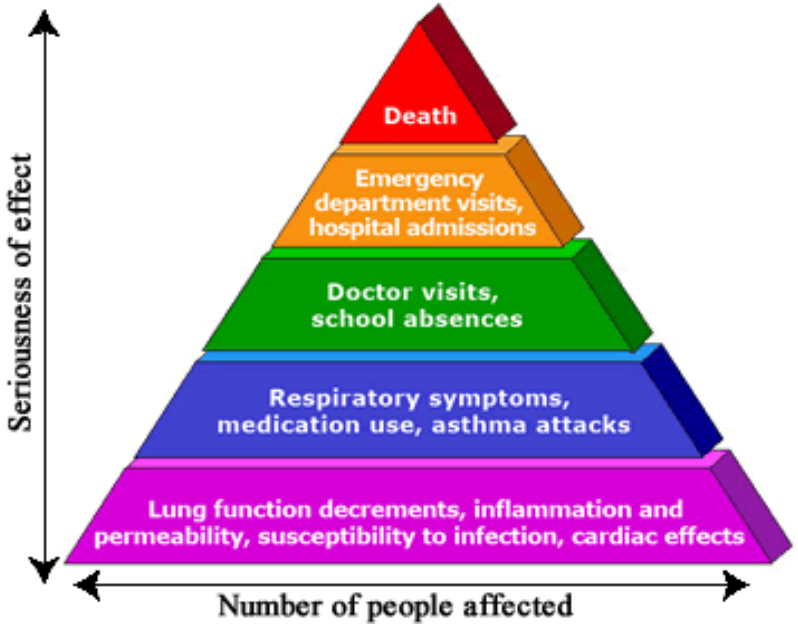
By Judy Fahys | The Salt Lake Tribune
First Published Feb 19 2013 06:56 pm • Last Updated Feb 20 2013 03:25 pm

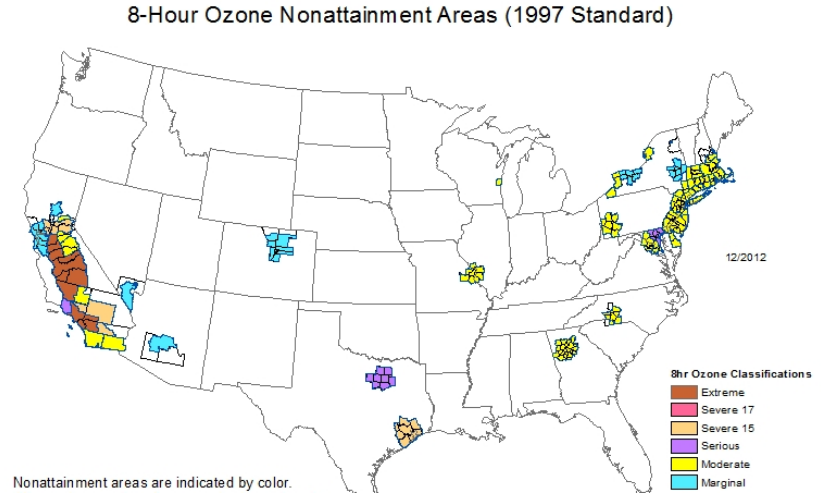
Vernal • Leaders still aren't sure what to do about the Uinta Basin's odd winter ozone problem even though it's clear now that emissions from the oil and gas industry are causing the pollution.

"There is so much we have learned, but there is so much more we need to learn," said Uintah County Commissioner Mike McKee, discussing at a news conference the conclusions of last winter's $5 million ozone study.

Health Effects of Ozone

- Ozone: highly reactive in respiratory system as it interacts with proteins and lipids on the surface of cells leading to cell damage (Devlin et al., 1997, EPA)





Timeline

- 2005-present: high ozone during some winters in Wyoming's Upper Green River Basin
- 2008: EPA sets standard for ozone and nonattainment - 75 ppb: annual 4th highest daily max during 8-h period each of 3 years
- 2009-10 & 2010-11 winters: multiple exceedance days in Uintah Basin
- 2011-2012 winter: Uintah Basin Ozone Study but no 8-h periods higher than 63 ppb with no multi-day stable boundary layers and limited snow cover
- 2012-2013 winter: Uintah Basin Ozone Study with many days of ozone excedances: 4 multi-day stable boundary layer episodes; widespread snow cover in central/eastern portions of the Basin

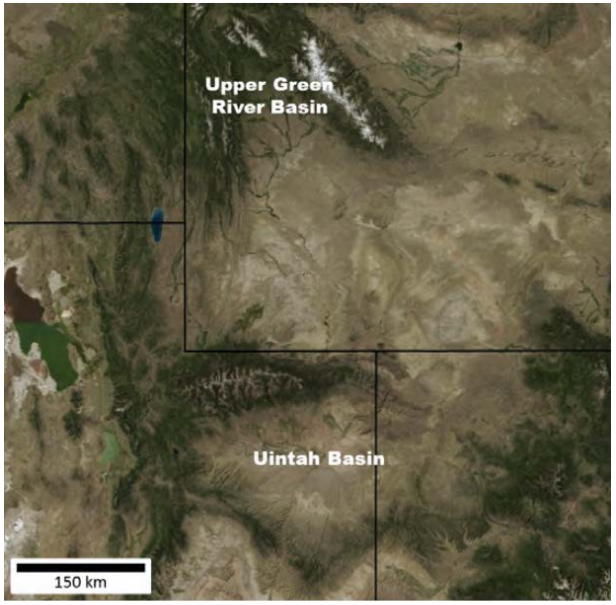


Figure 8. The Uintah and Upper Green River basins.

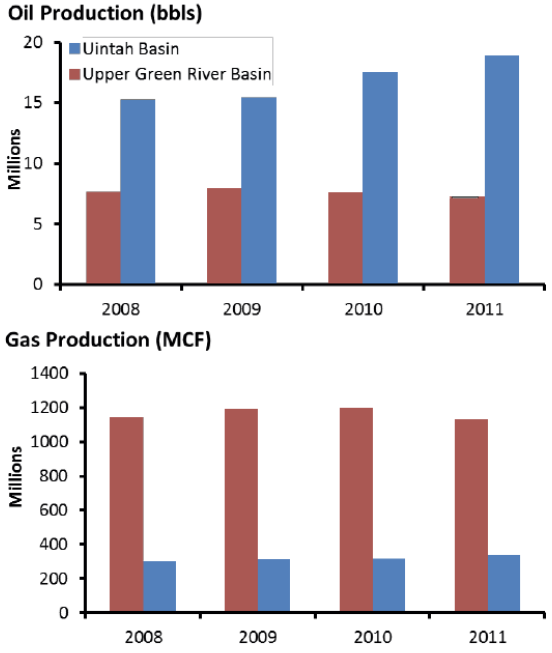


Figure 9. Annual oil and gas production in the Uintah Basin (Duchesne and Uintah counties; Utah DOGM, 2012) and the Upper Green River Basin (Sublette County; WOGCC, 2012).

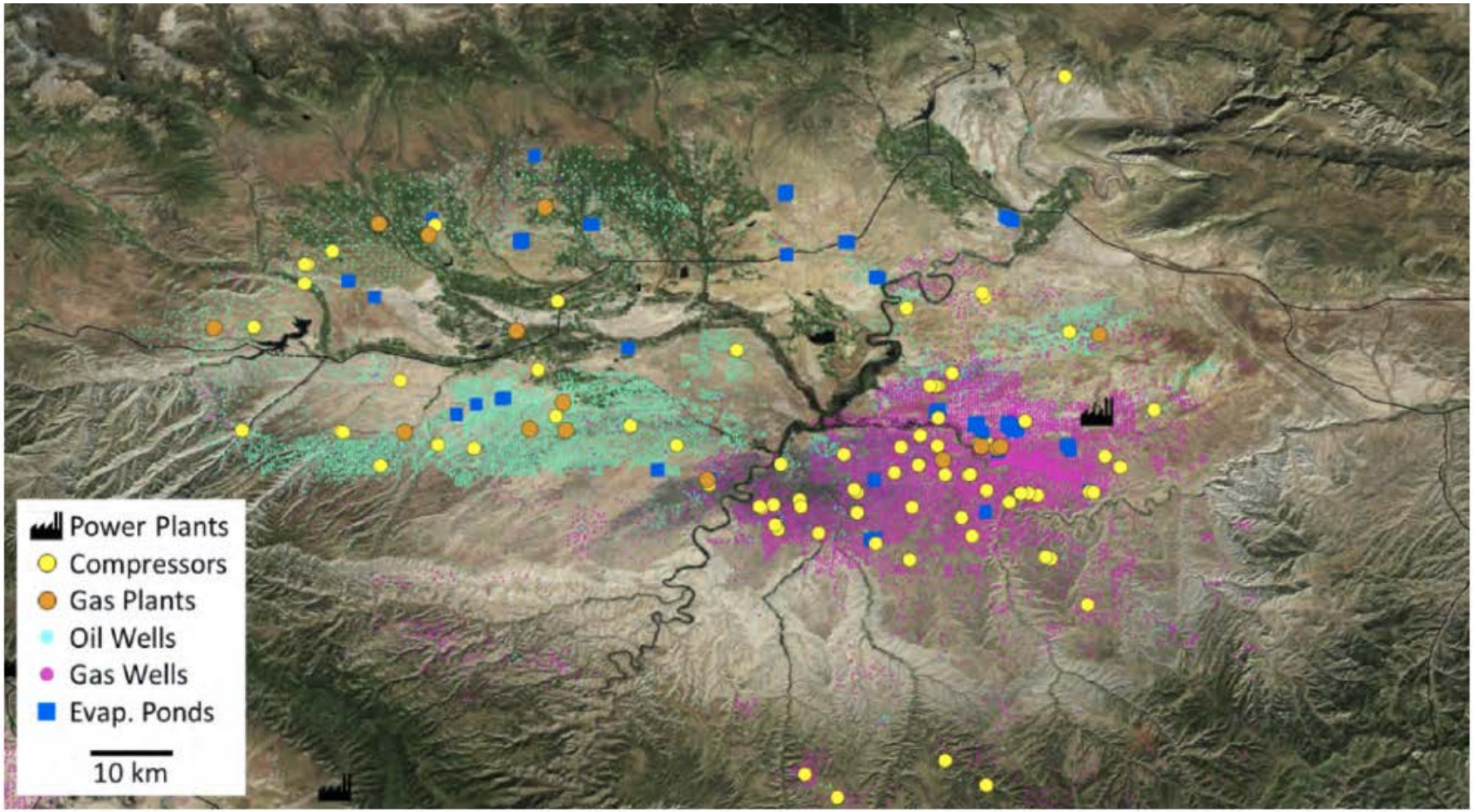


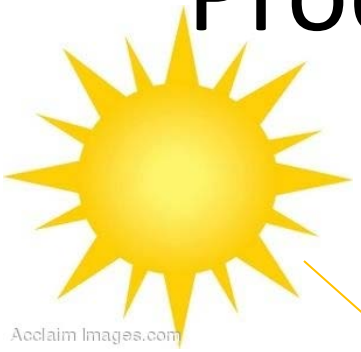
Figure 16. Locations of some oil and gas-related emissions sources in the Uintah Basin (the location of coal-fired power plants are also shown). FINAL REPORT. 2012 UINTAH BASIN WINTER OZONE & AIR QUALITY STUDY

Gas and Oil Rigs Cover Swaths of Uintah Basin

FINAL REPORT. 2012 UINTAH BASIN WINTER OZONE & AIR QUALITY STUDY

- Based on historical records, severe ozone seasons about every 4 years
- Snow cover critical
- Transport of pollutants into Basin not important
- Precursors for producing ozone photochemically Oil & gas operations responsible for:
    - 98% of volatile organic compounds
    - ~60% of NO_x
- Nitrous acid (HONO) may be produced photochemically in snowpack

Production of Ozone in Winter



$$HONO + h\nu \longrightarrow OH + NO$$

$$(Precursors)O + h\nu \longrightarrow O$$

$$O + O2 \longrightarrow O3$$

VOCs, NO_x

HONO

Photochemically produce HONO (nitrous acid) at sunrise in snowpack

Ozone in 2011 vs. 2012

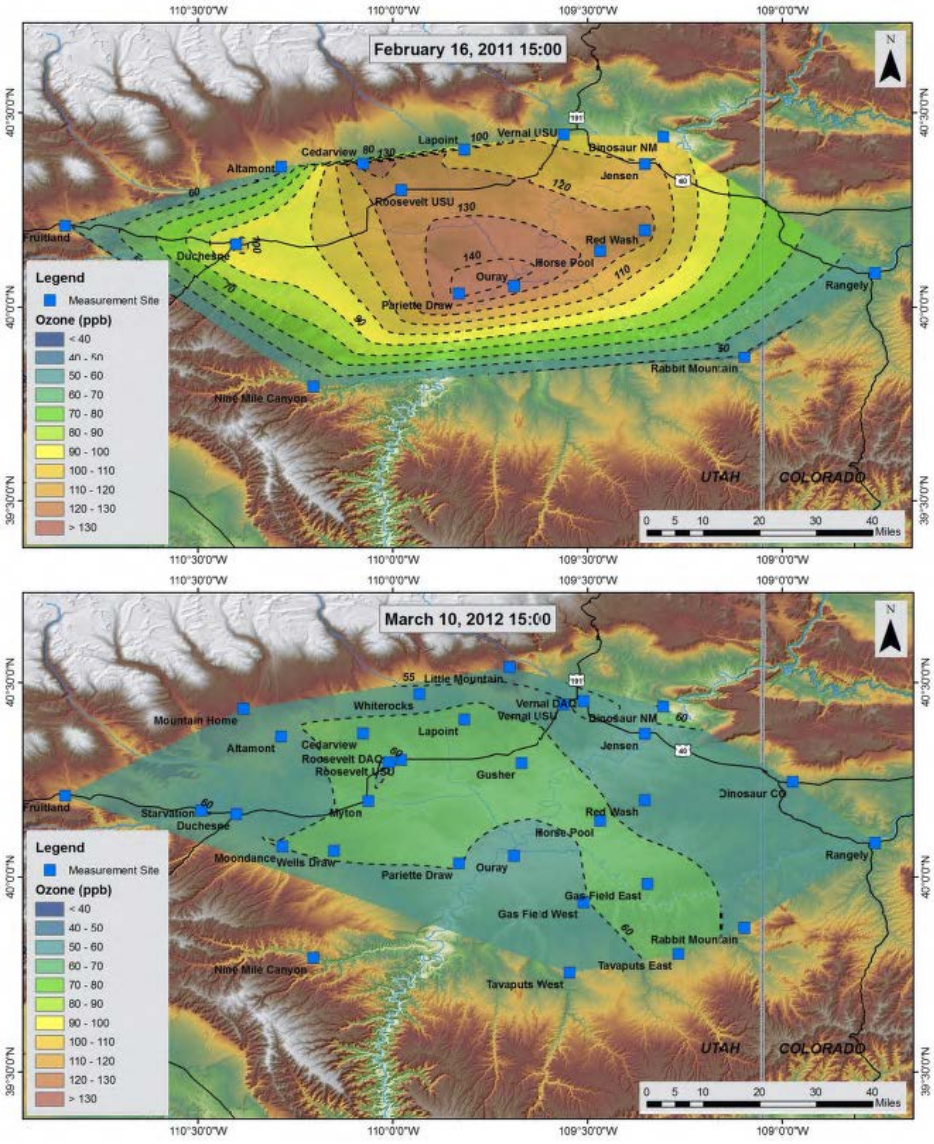
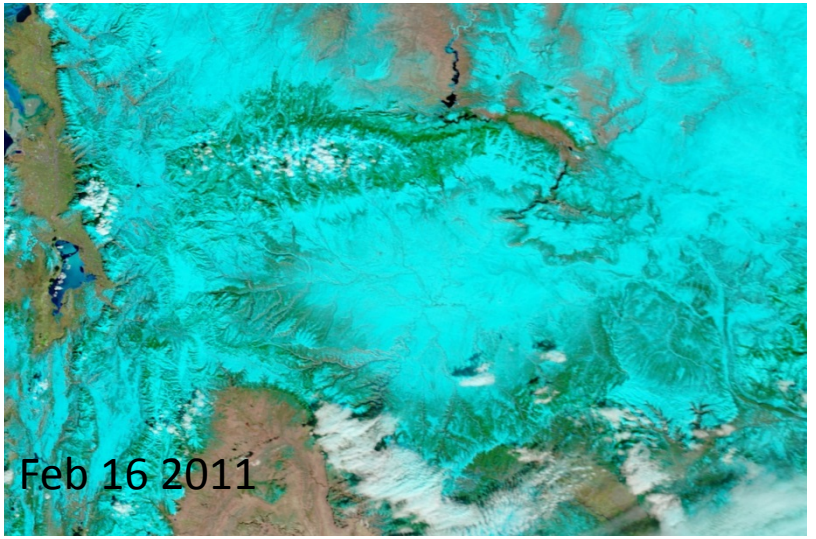
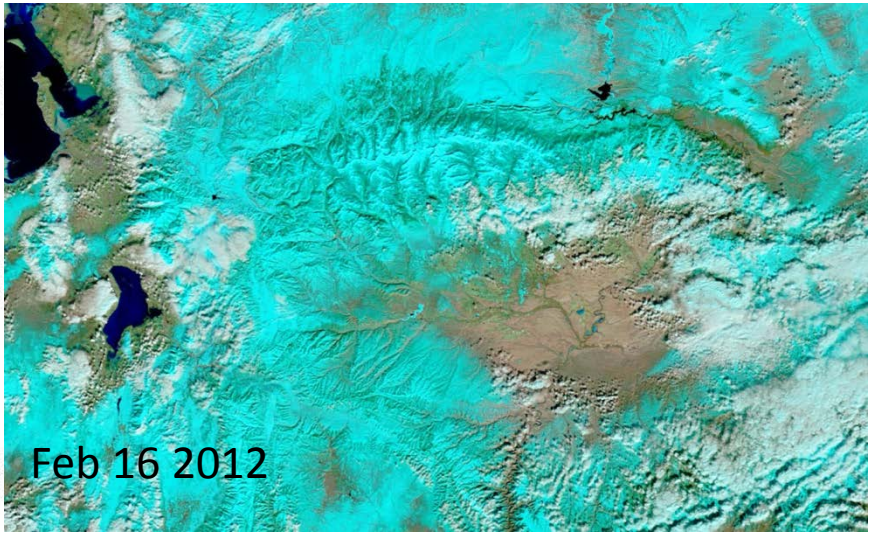


Figure 6. Highest 1-hour average ozone concentrations in the Basin during the 2011 study on 16 Feb. 2011 at 15:00 (top) and the 2012 study on 10 Mar. 2012 at 15:00 (bottom) (Chapter 2). Color scale intervals are the same for both panels. Contour lines are 10 ppb for 2011 map, 5 ppb for 2012 map.

Snow 2011 vs 2012





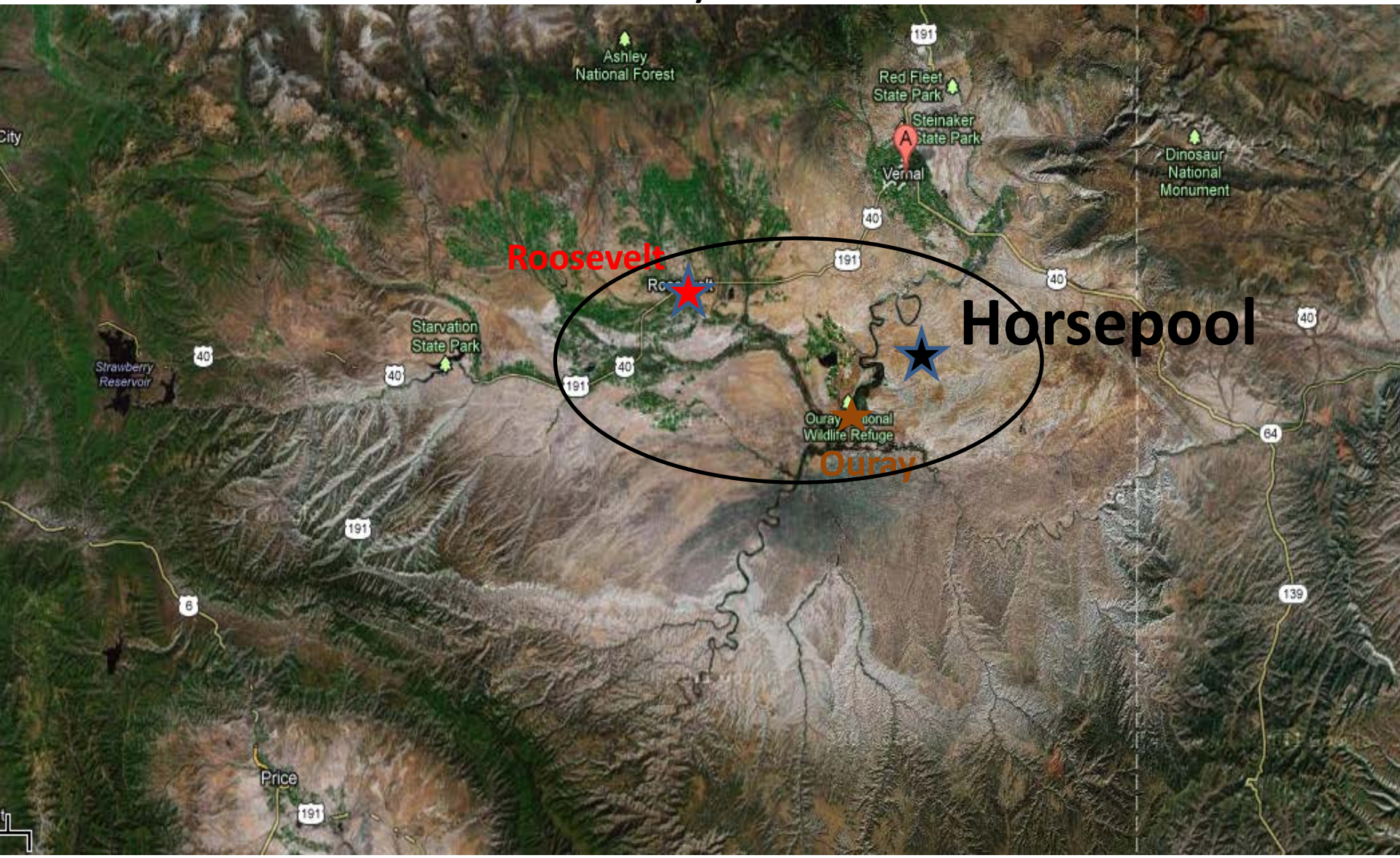
FINAL REPORT. 2012 UINTAH BASIN WINTER OZONE & AIR QUALITY STUDY

Issues needing further study according to 2011-2012 UBOS

- More complete emissions inventory
- Challenges in modeling due to vertical gradients in NO_x and VOCs
- Understanding of ozone formation based largely on summer events in urban areas
- Sensitivity of ozone formation to boundary-layer winds

Overview of U/Utah Field Campaign

Intensive Observation Locations in the Basin for Uintah Basin Ozone Study 2012-2013



Horsepool: The “Center of the Uintah Basin Ozone Study Universe”

NOAA PMEL snow chemistry
NOAA CSD gas-phase chemistry
(NI-PT-CIMS , Filter Radiometrics, PTR-MS VOC)
UC Boulder ‘Sky-Doc’ polar tethered systems
DAQ/USU Air quality
NOAA Topaz ozone lidar
NOAA High Resolution Doppler Lidar (HRDL)

NOAA CIRES Aircraft Observations: 'Porpoising' In and Out of Cold Air Pool*

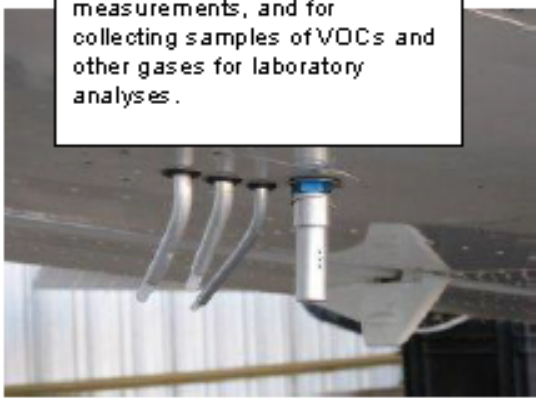


Figure 1. 1998 Mooney TLS turboprop aircraft instrumented for high resolution in situ airborne gas and met measurements, and for collecting samples of VOCs and other gases for laboratory analyses.

*Integrating this data with surface met data and numerical model simulations will be crucial for diagnosing flow in basin..

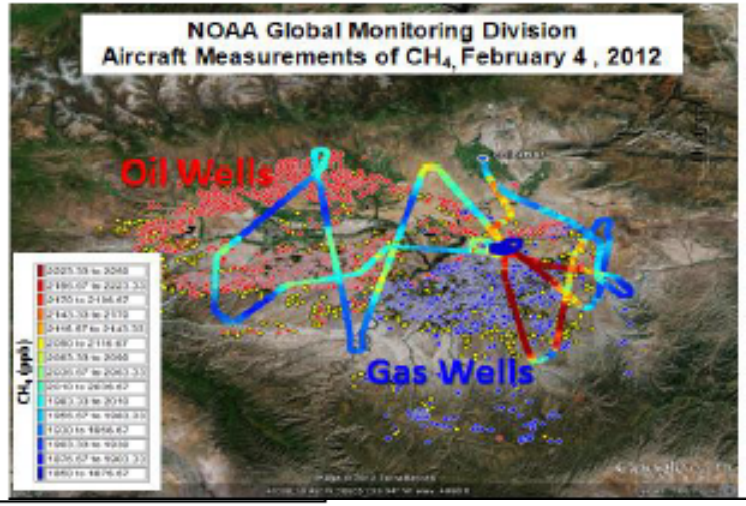
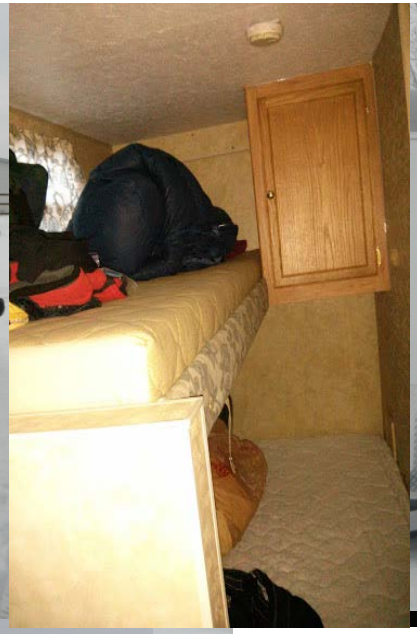


Figure 4. CH_4 concentrations measured in well mixed air over the Uintah Basin oil and gas fields showing higher CH_4 concentrations over the gas field relative to the oil field.

Source: UBOS Winter 2013 Study Plan

Roosevelt: The “Center of Our Universe”

Warm sleeping trailer



UU Mtn Met trailer

Burgers and wireless at Cody’s Café

UU Atmospheric Sciences Uintah Basin 'SWAT' Team

- Goal: Contribute to characterizing basin meteorology (specifically boundary layer evolution -height, winds, thermal structure) on a shoestring
- **Targeted observations in January and February 2013**
- Numerical modeling (Erik Neemann M.S. Thesis project)

SWAT Commandos with heat gun

Laser ceilometer
(continuous vertical profile)

Met tower and rawinsonde research trailer

Mobile ozone and meteorology

Typical UU Group Day's Operations

11 am Launch
Rawinsonde

Horsepool

Ouray

1-4 pm Mobile O_3 Transect

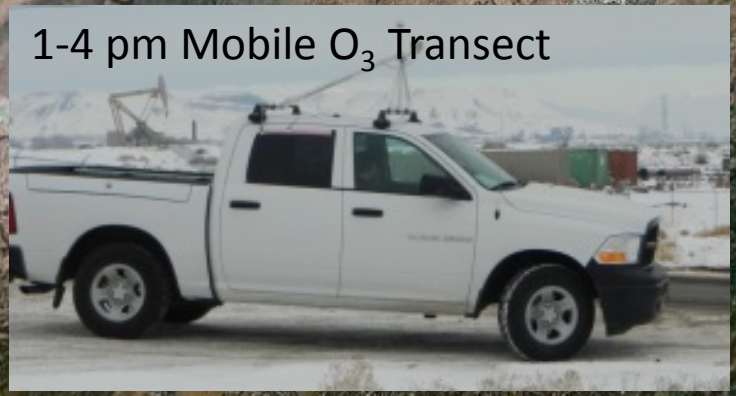



Photo: John Lawson


Typical view (in a region with oil/gas wells…)

The road to Horsepool…


Ouray Natl Wildlife Refuge
NOAA Global Monitoring Division
ozone tethersonde with
automated fishing pole

On good days you can see the mountains…
1 Feb Start of cold air pool

On bad days you can’t…
4 Feb

Balloon Launch Video With Uintah High School

Observations and Modeling

1. **Snow storm frequency and impact of snow on cold air pools**

2. **Differences between cold-air pools in Salt Lake Valley vs. Uintah Basin**

   --Thermodynamics

   --Duration

   --Boundary-layer clouds

   --Boundary-layer flows

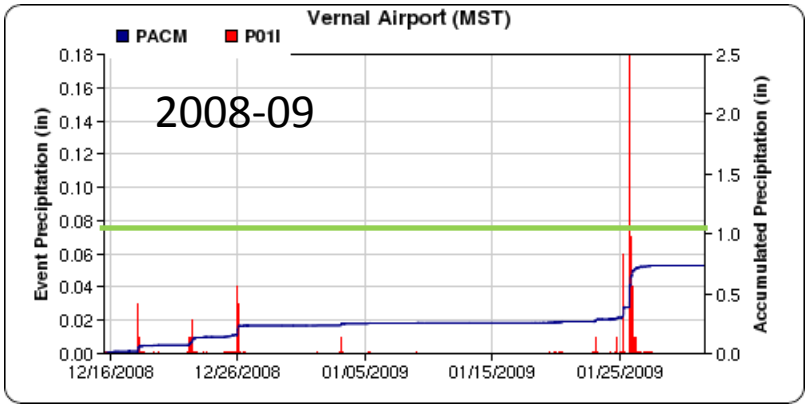
   --Terrain flow interactions

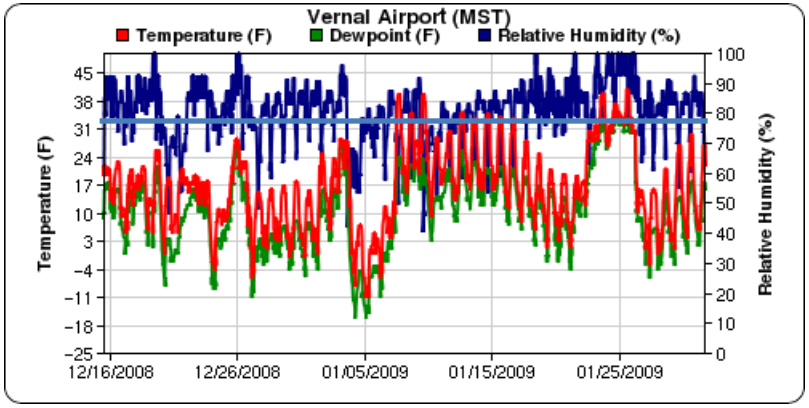
3. **Evolution of aerosol layers**

Sensitivity to timing of snow storms

- Salt Lake Valley (Airport): Average Dec-Feb snowfall 37”
- Average Jan-Feb snow depth 1.5”

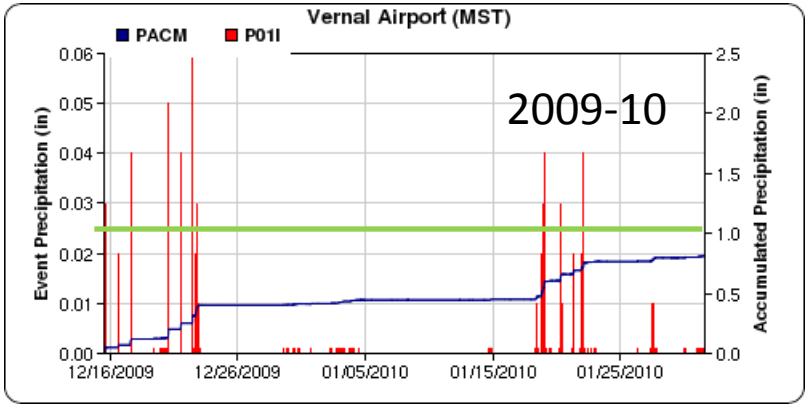
- Uintah Basin (Ouray): Average Dec-Feb snowfall 11.5”
- Average Jan-Feb snow depth 3”

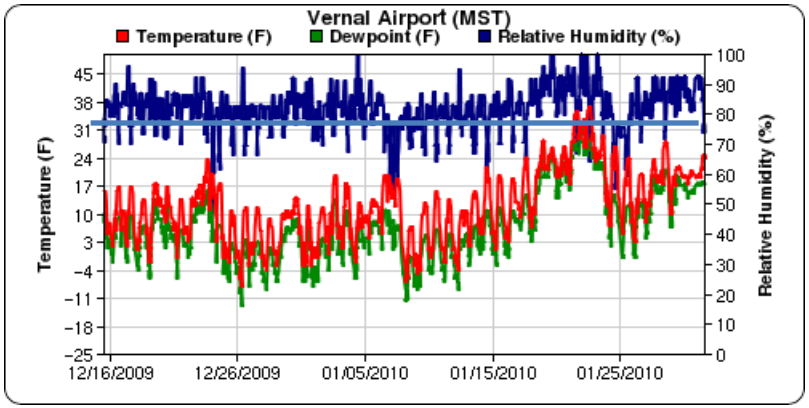


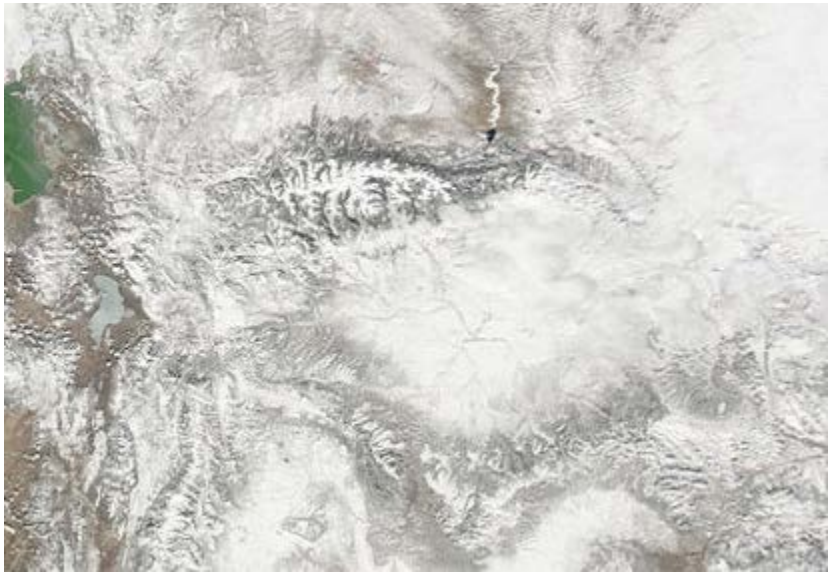


Mid-February 2009.
Vernal -2.0 ^{o}C (+**2.0**)
Salt Lake City 2.5 ^{o}C (+**1.0**)
700 mb (**+0.50**)
Feb snow days **5**

Sensitivity to Timing of Rare Snow Events Leading to Snow Cover

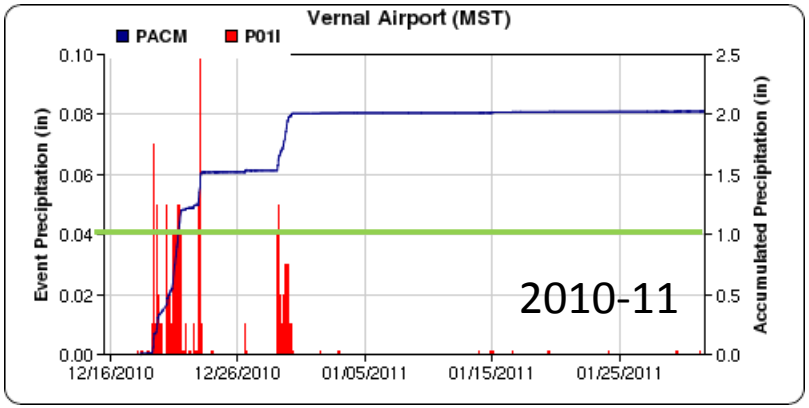


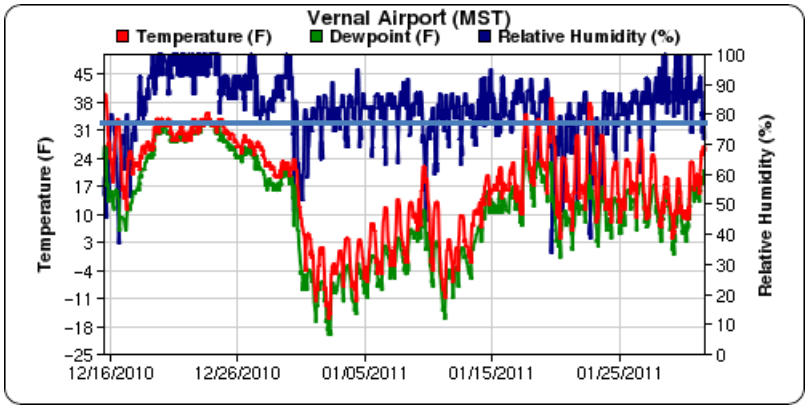




Mid-February 2010.
Vernal -8.0 ^{o}C (**-4.0**)
Salt Lake City 2.5 ^{o}C (**+1.0**)
700 mb (**-1.0**)
Peak ozone **124 ppb**
Feb Snow days **28**

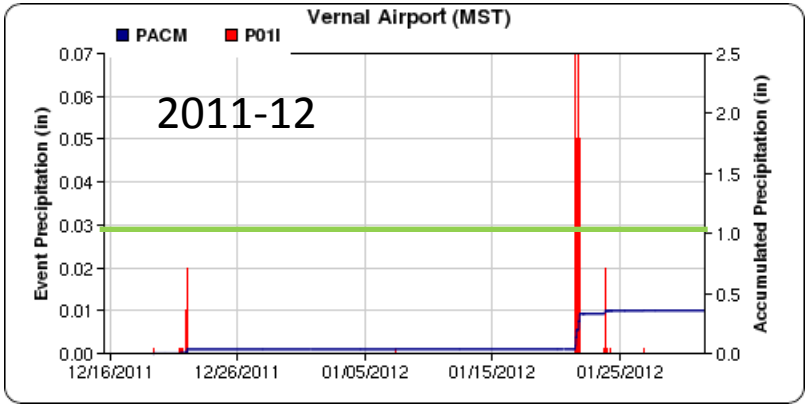
Sensitivity to Timing of Rare Snow Events Leading to Snow Cover

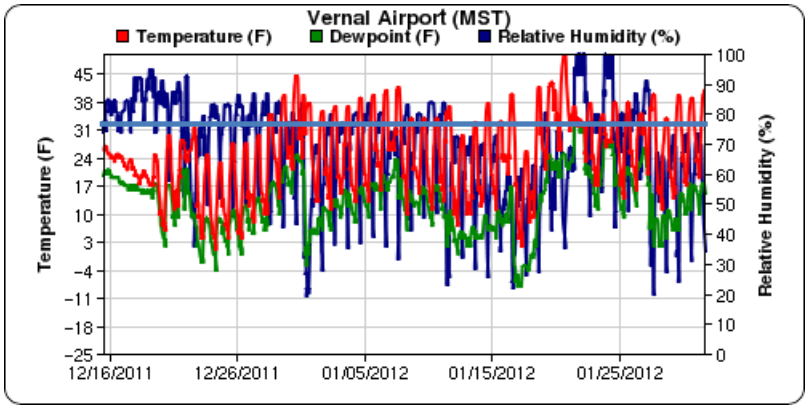




Mid-February 2011.
Vernal -9.0 ^{o}C (**-5.0**)
Salt Lake City 1.0 ^{o}C (**-0.5**)
700 mb (**-2.0**)
Peak ozone **139 ppb**
Feb Snow days **28**

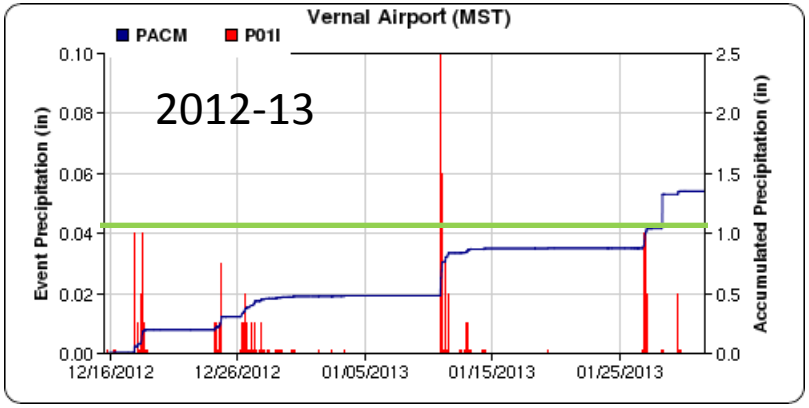
Sensitivity to Timing of Rare Snow Events Leading to Snow Cover

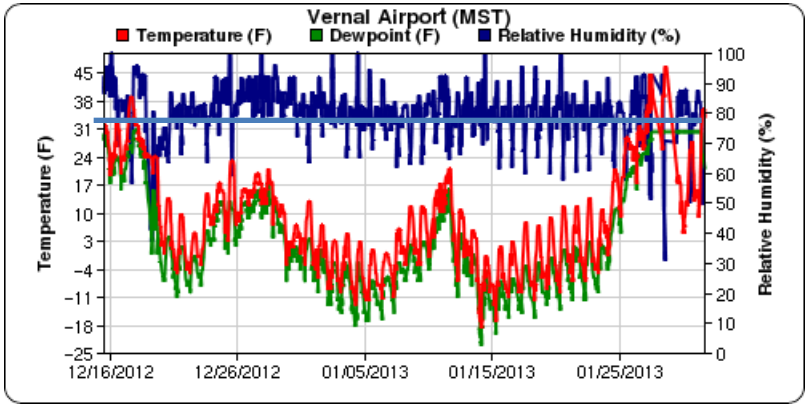




Mid-February 2012.
Vernal -0.5 ^{o}C (**+2.5**)
Salt Lake City 3.0 ^{o}C **(+1.5**)
700 mb (**-1.5**)
Peak ozone **63 ppb**
Feb Snow days **0**

Sensitivity to Timing of Rare Snow Events Leading to Snow Cover

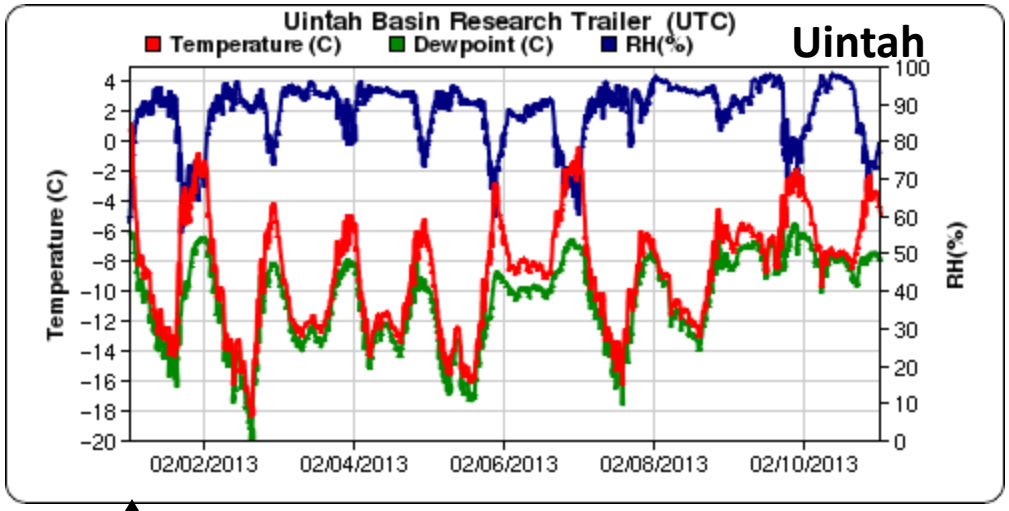




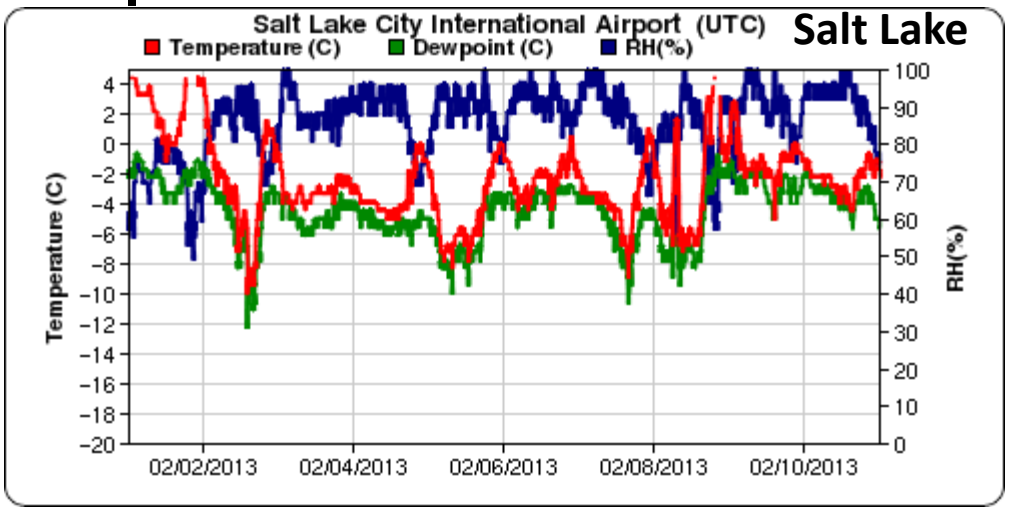
Mid-February 2013.
Vernal -8.5 ^{o}C (**-4.5**)
Salt Lake City -1.7 ^{o}C (**-3.0**)
700 mb (**-2.5**)
Peak ozone **150 ppb**
Feb Snow days **28**

Sensitivity to Timing of Rare Snow Events Leading to Snow Cover

A Tale of Two Valleys: Uintah vs. SLV Surface Temperature

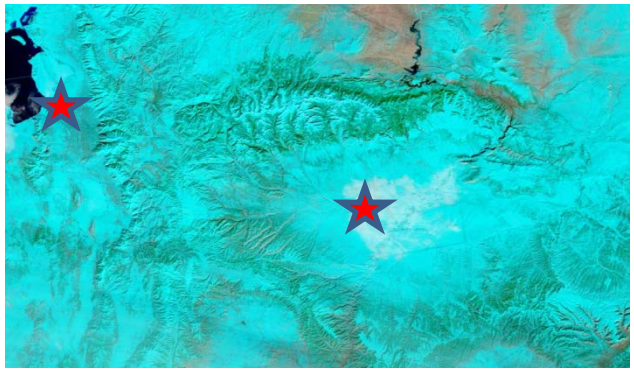


start ?

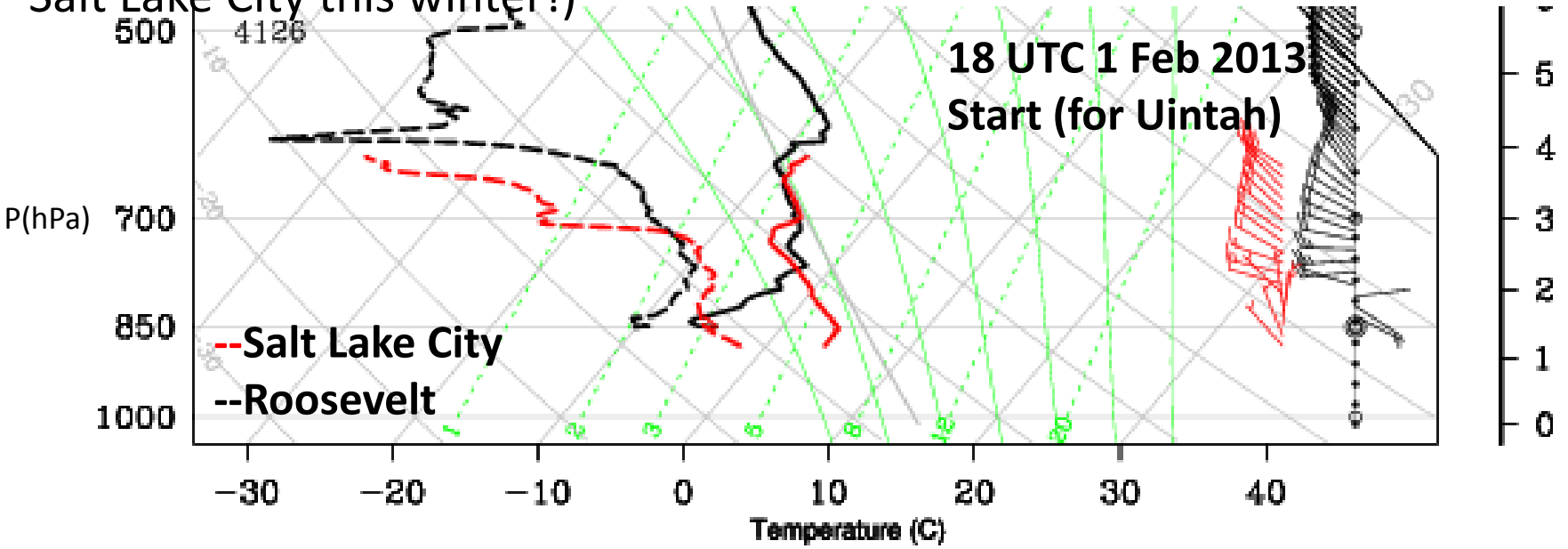


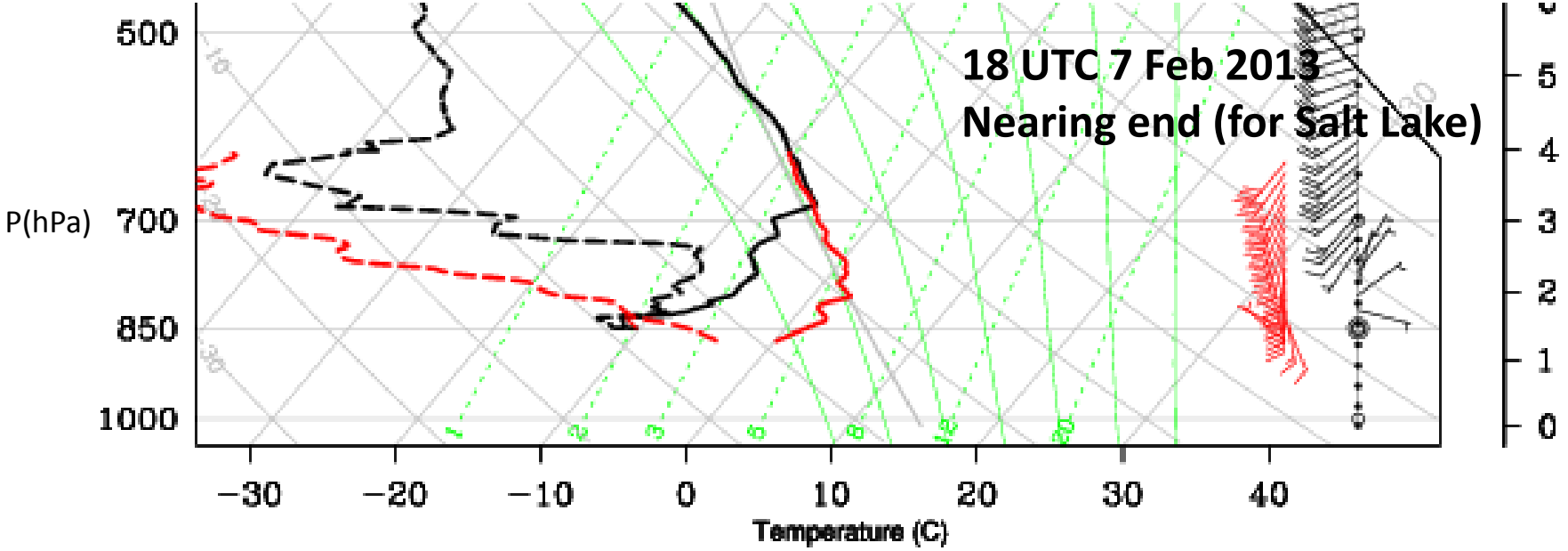
start end

- Salt Lake Valley cold pools > 5 °C higher
- SLV cold pools start later and end sooner

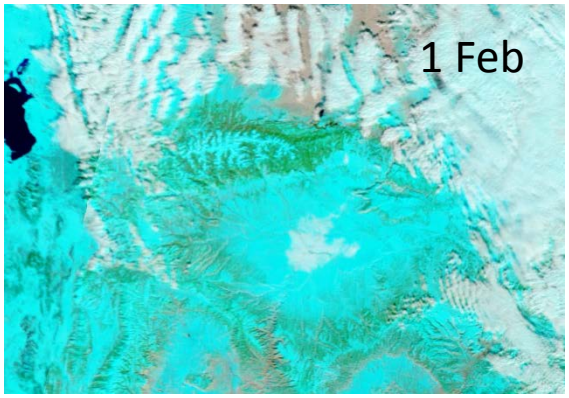


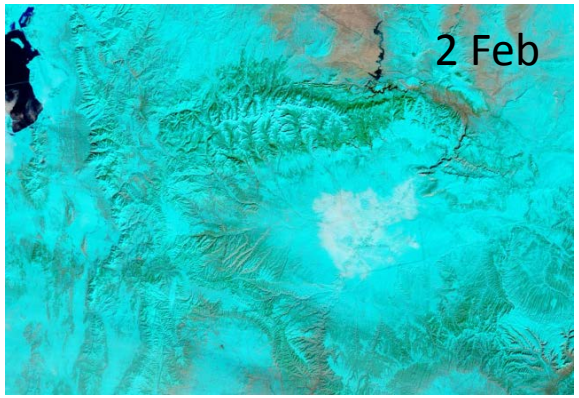
1. Long-lived and intense cold air pools (…and you thought you had it bad in Salt Lake City this winter!)

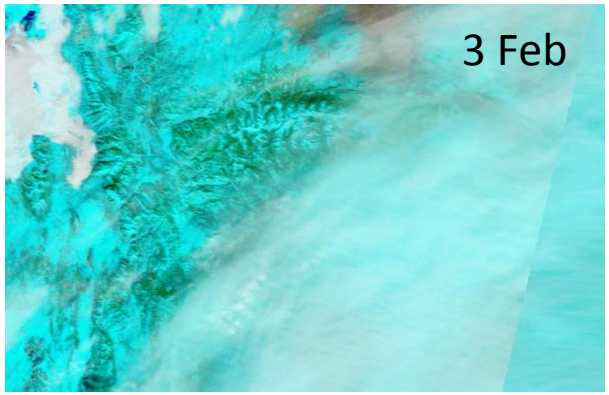


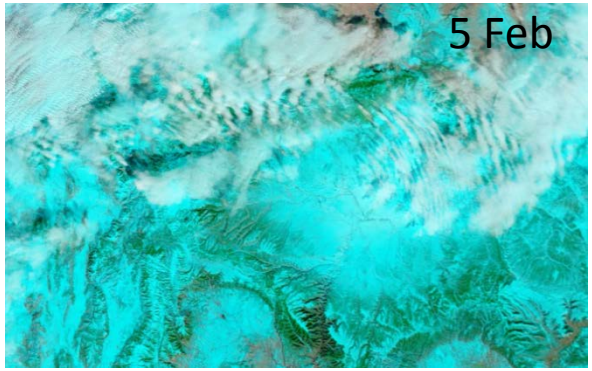


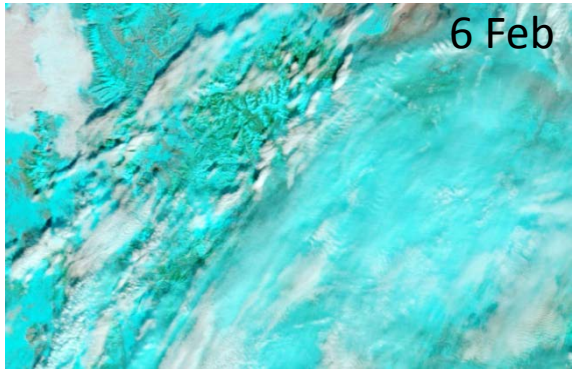
A Tale of Two Valleys: Low Clouds

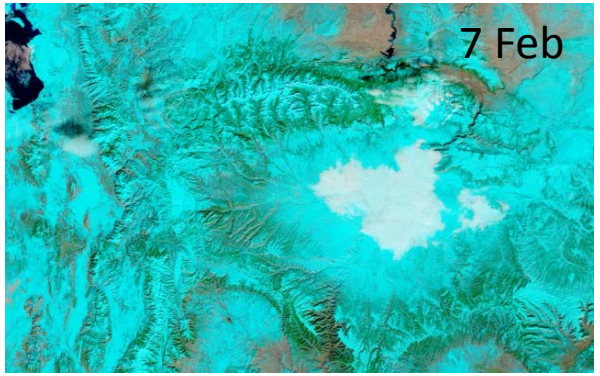












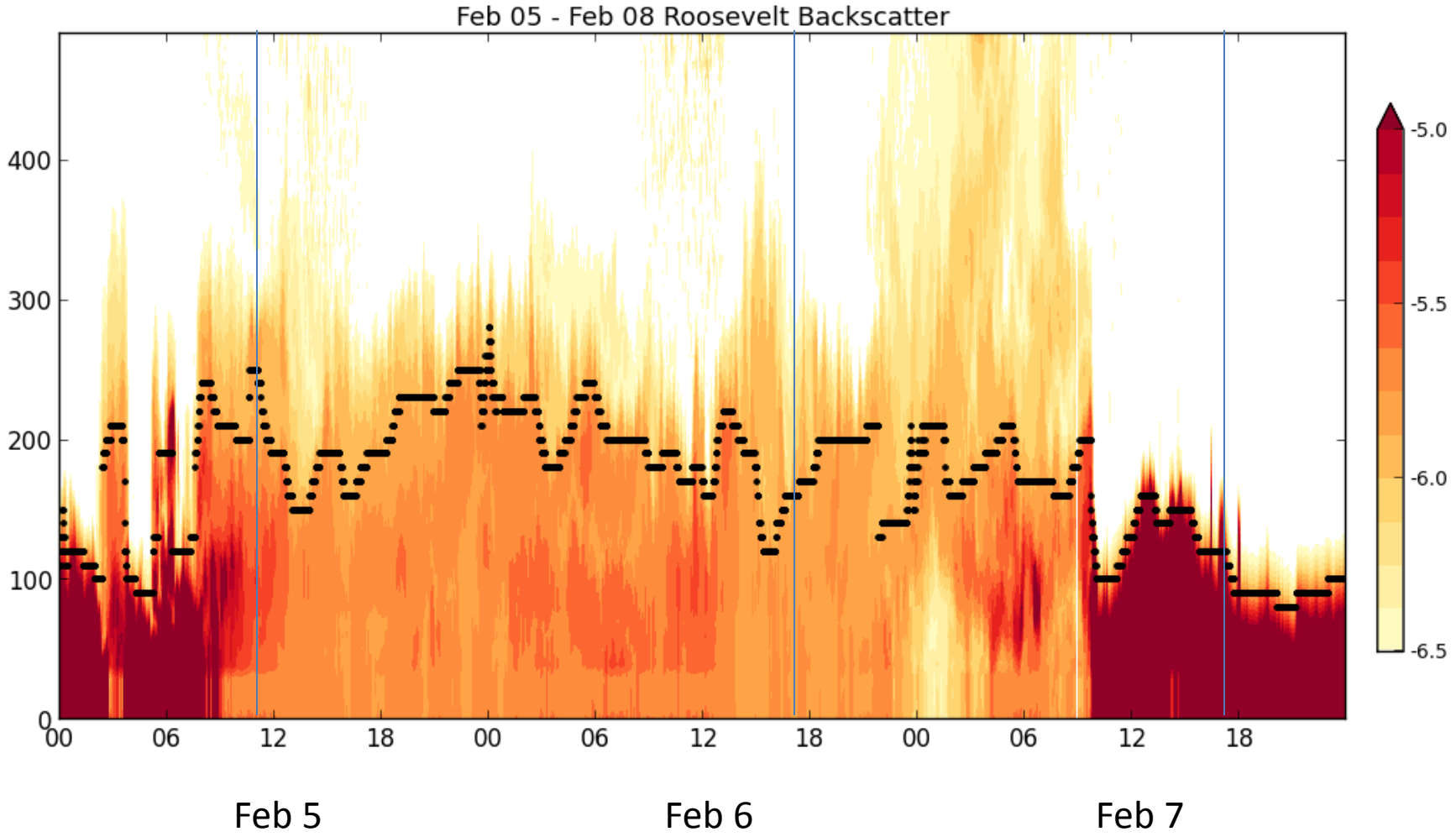
•Salt Lake Valley tends to be filled (including benches) with low stratiform clouds or have none

•Uintah Basin regularly has shallow low clouds/fog in lowest portion of Basin. Very rare in foothills around basin


Typical morning during fog episodes.

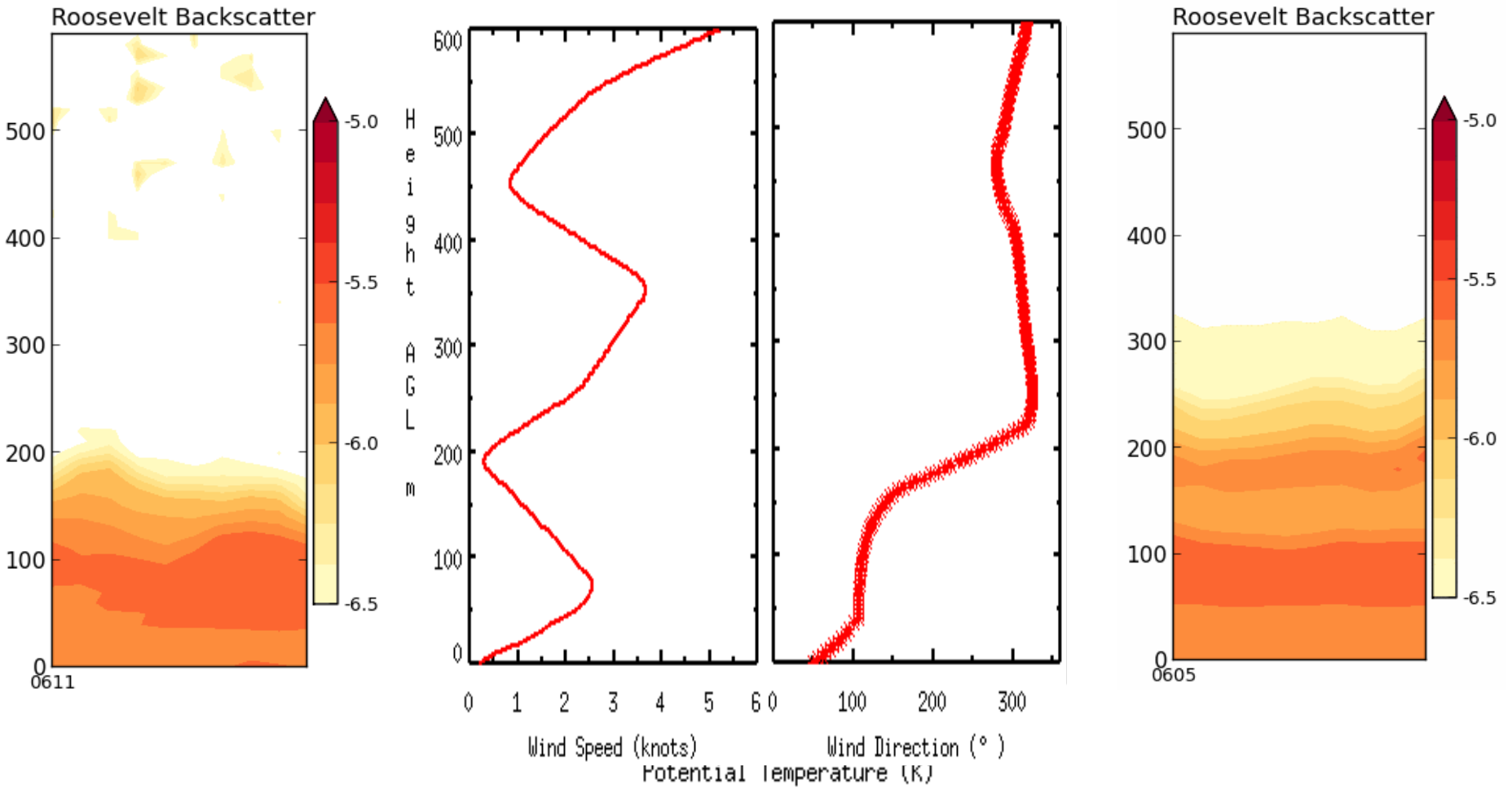
Aerosol Backscatter at Roosevelt

Darker shades indicate higher concentrations;
dark red is fog; black dots- estimate of depth of aerosol layer when no fog

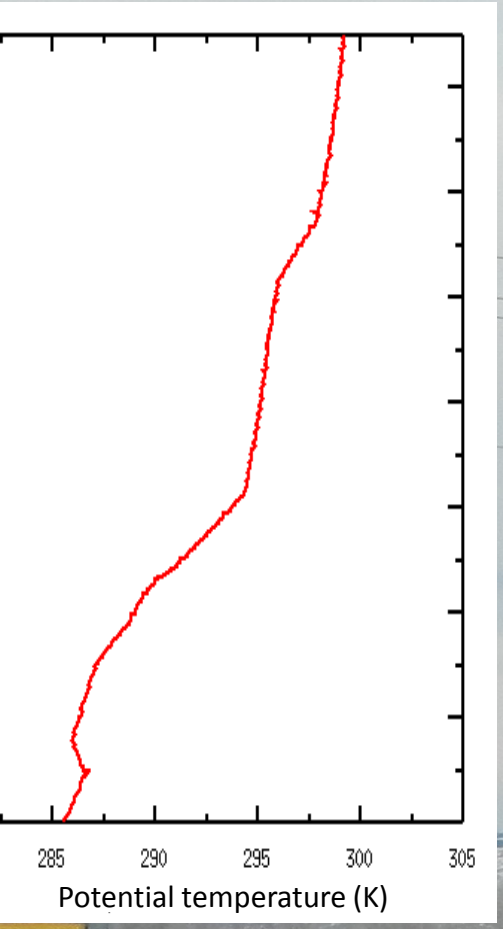


Roosevelt Ceilometer Aerosol Backscatter & 6 Feb Sounding

Darker shades indicate higher aerosol concentrations



Why is there a semi-permanent easterly flow embedded within inversion layer?



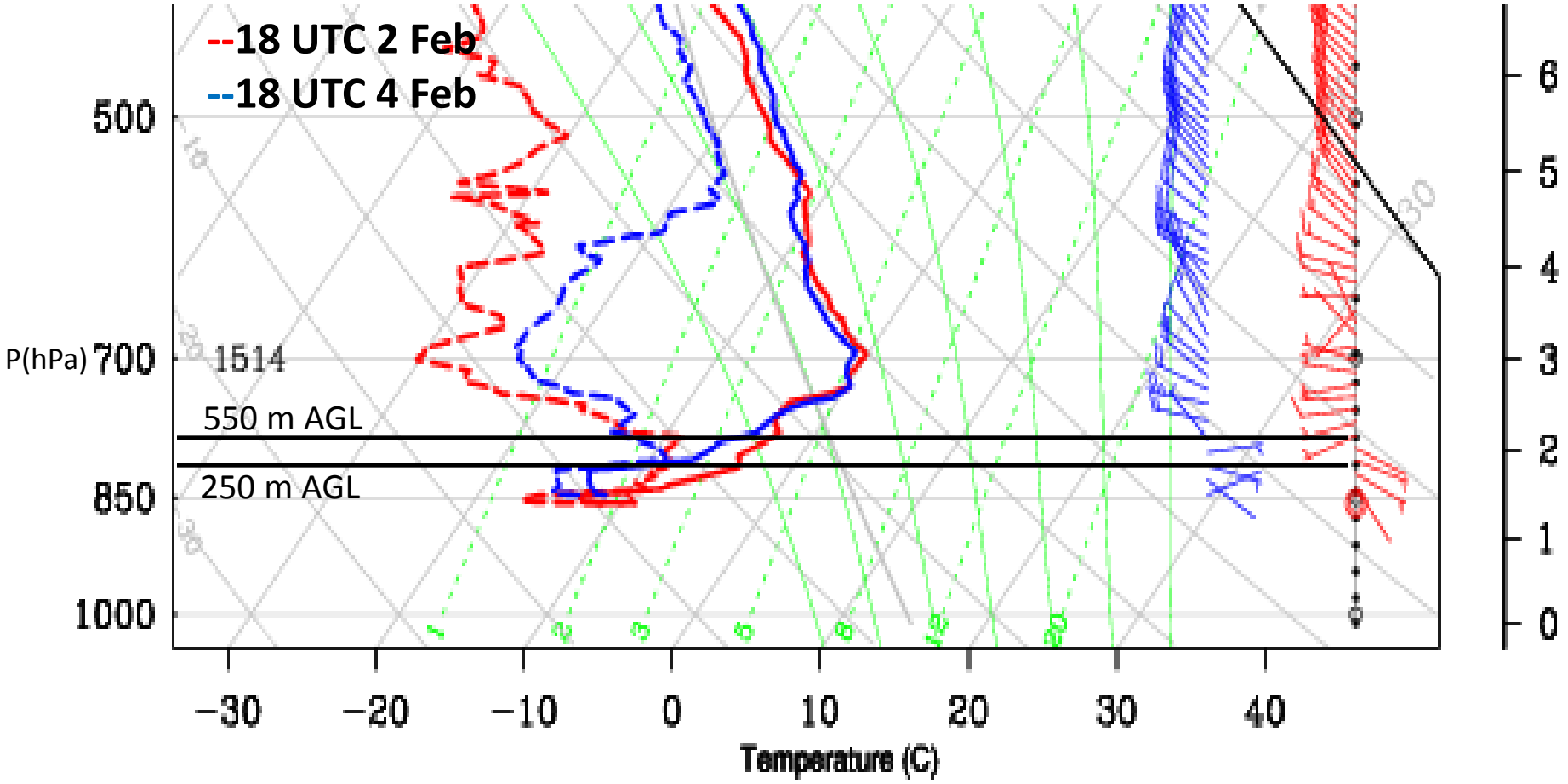
Typical prevailing westerly flow above strong stable layer

Easterly flow ***within*** strong stable layer

Calm near-surface cold pool

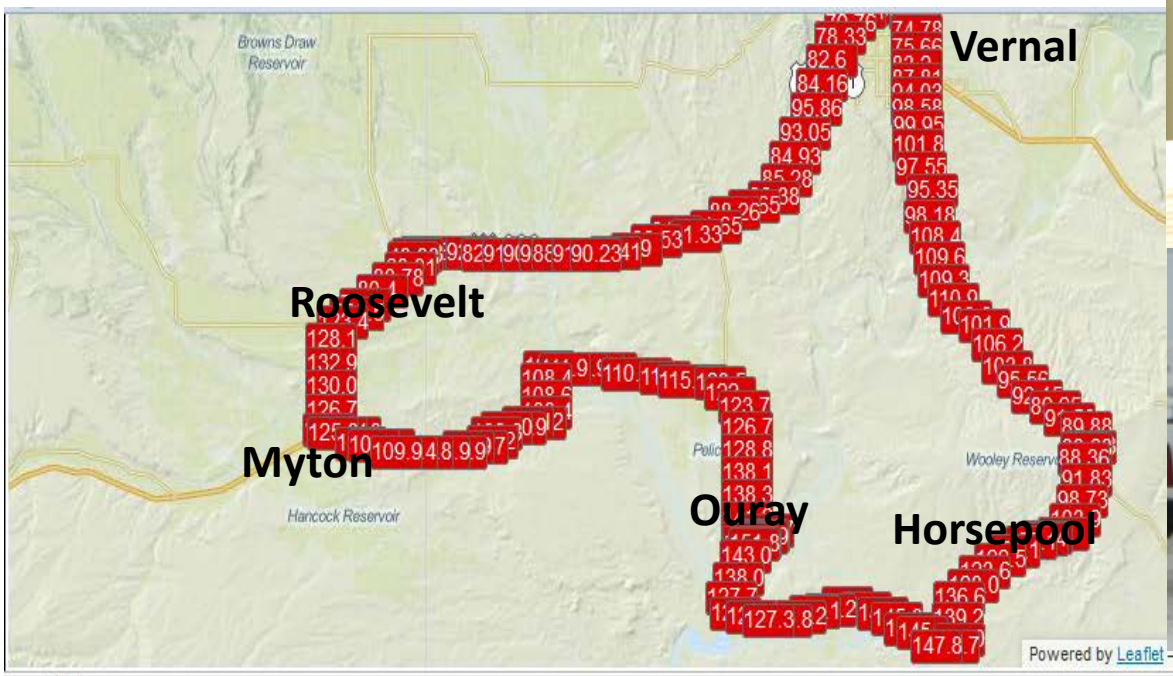
Oil well fire plume 26 January 2013

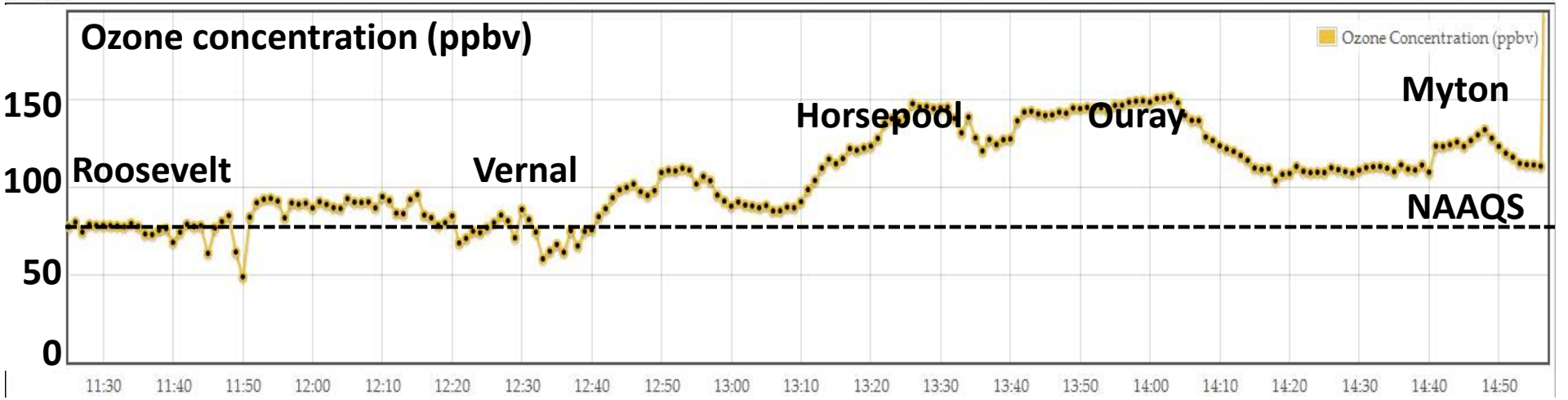
Roosevelt Soundings with Easterly Flow Within Stable Layer

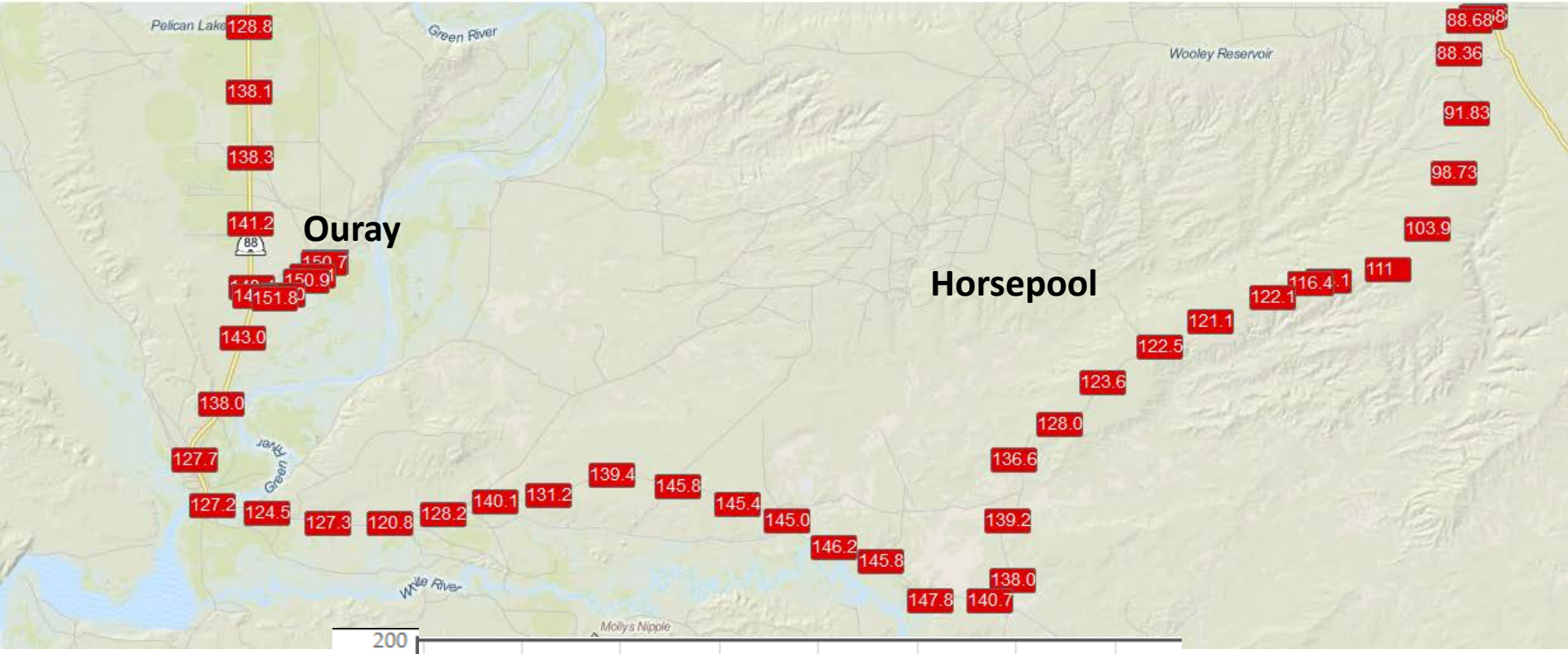


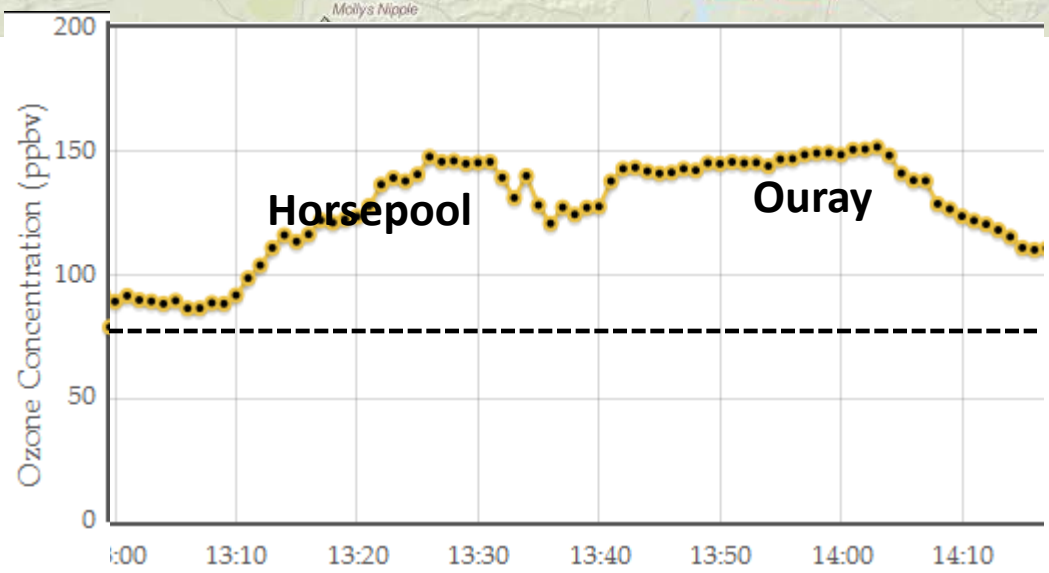

6 Feb 2013: Shallow pollutant layer developing high O_3 levels

6 February Afternoon 0_3 Transect

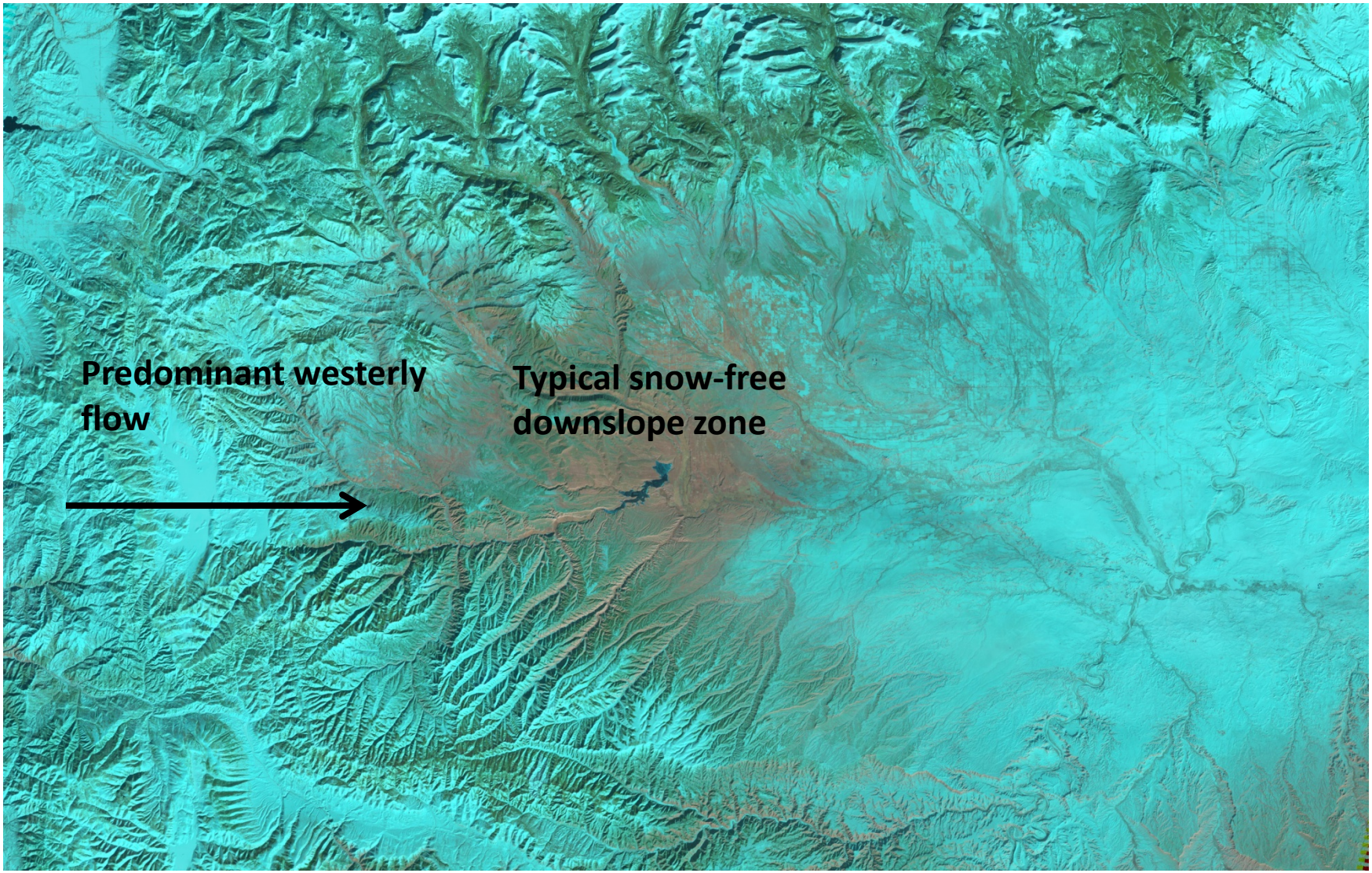





Pelican Lake
Green River
Wooley Reservoir
Ouray
Horsepool
Green River
White River
Molly's Nipple
128.8
138.1
138.3
141.2
150.7
150.9
151.8
143.0
138.0
127.7
127.2
124.5
127.3
120.8
128.2
140.1
131.2
139.4
145.8
145.4
145.0
146.2
145.8
147.8
140.7
138.0
139.2
136.6
128.0
123.6
122.5
121.1
122.1
116.4
111
103.9
98.73
91.83
88.36
88.68

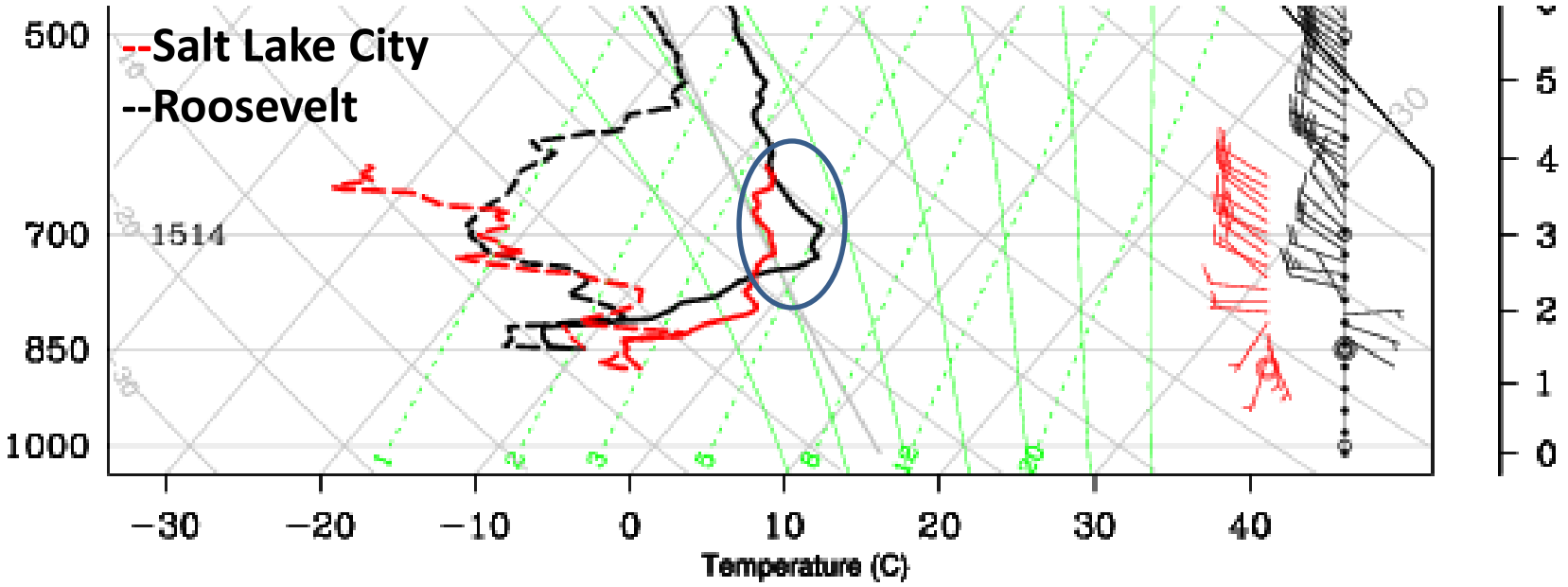

Ozone Concentration (ppbv)
200
150
100
50
0
Horsepool
Ouray
NAAQS
13:10
13:20
13:30
13:40
13:50
14:00
14:10

Impact of Downslope Flow on Snowfall Distribution during cold pool episodes

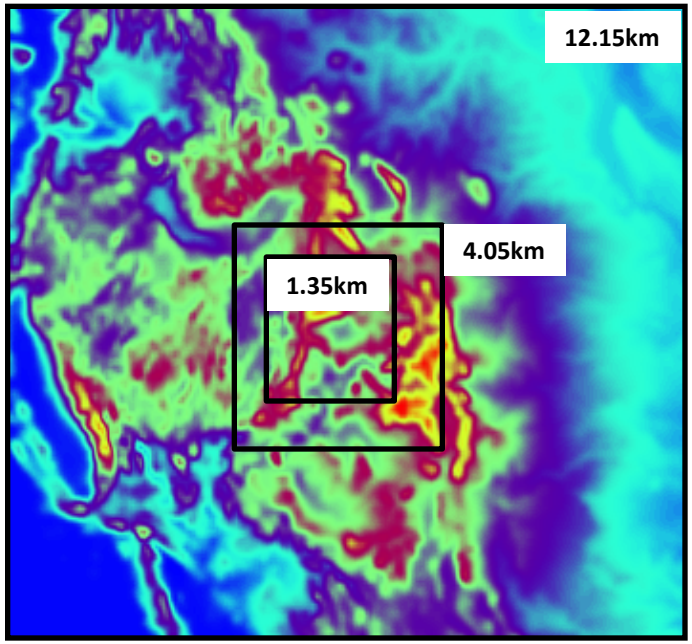


Impact of Downsloping Flow on PCAP Intensity

- Downsloping W/NW Flow strengthens upper portion of Uintah CAP (warms) compared to SLC

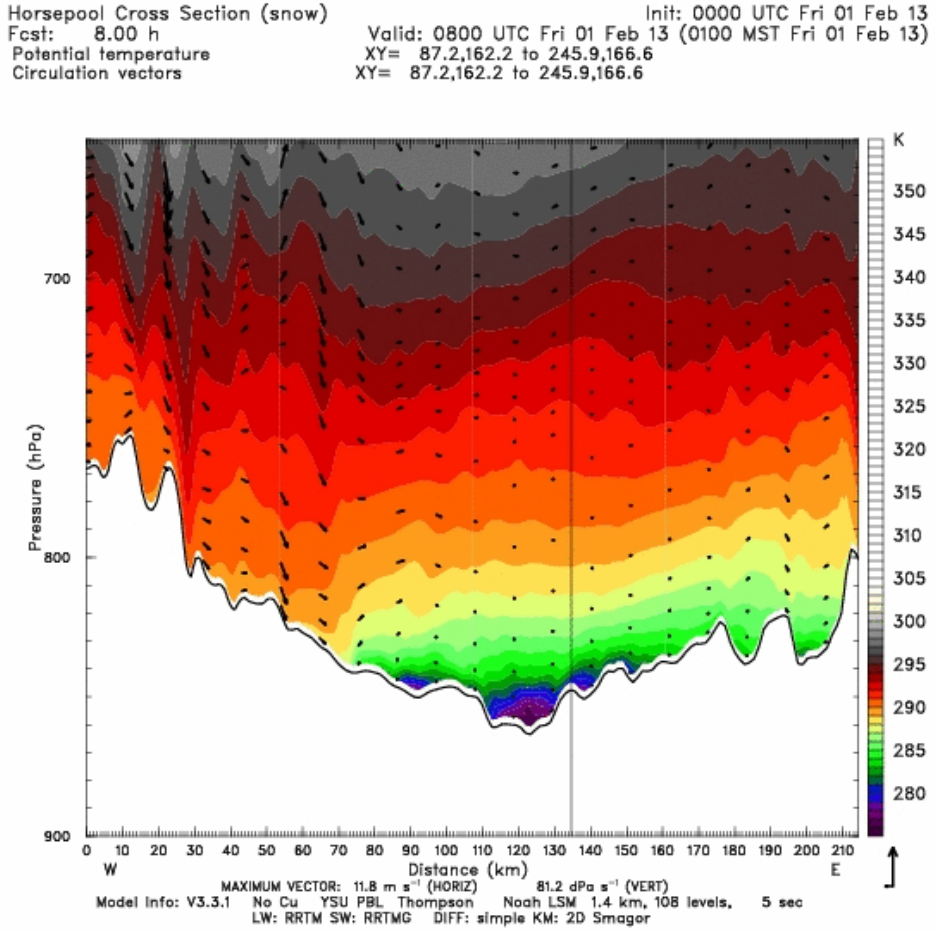


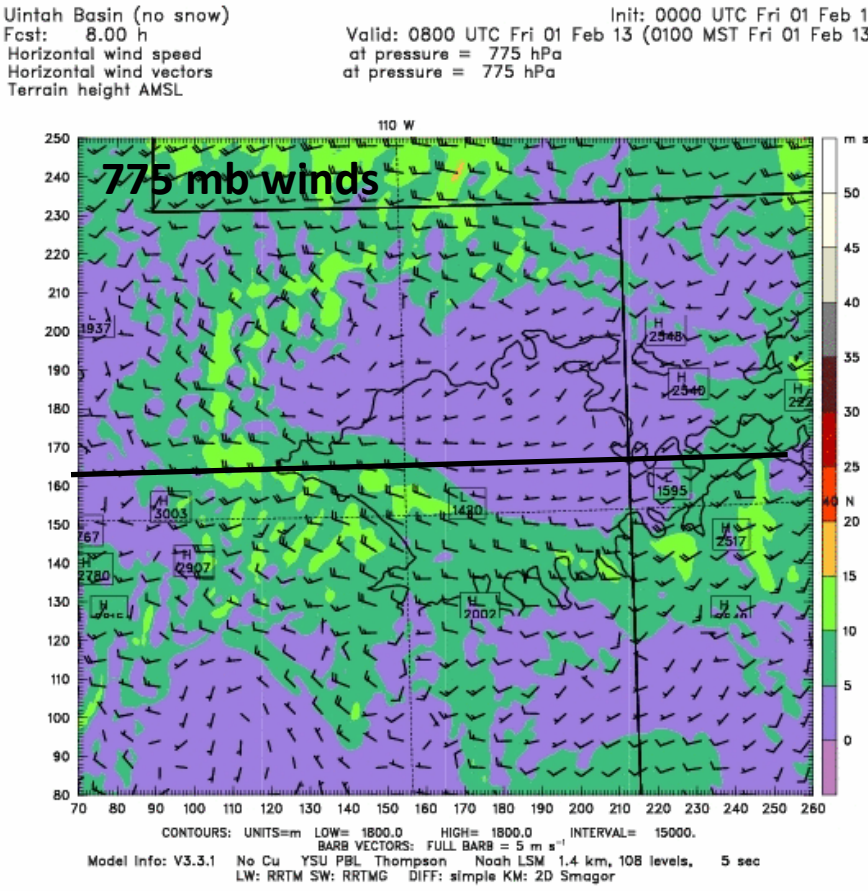
Erik Neemann's WRF Modeling of 1-7 Feb Cold Pool



- Start 00 UTC 1 February 2013, end 00 UTC 7 February 2013
- Nested domains (12.15,4.05,1.35 km)
- Initialization and boundary conditions from NAM analyses
- Idealized snow cover based on elevation
- Number of vertical levels = 109
- Time step = 45 seconds (15, 5 s for inner 2 grids)
- Microphysics: Thompson scheme
- Radiation: RRTM longwave, RRTMG shortwave
- Surface layer: Monin-Obukov
- NOAH land-surface option
- YSU PBL Scheme
- Slope effects for radiation, topo shading

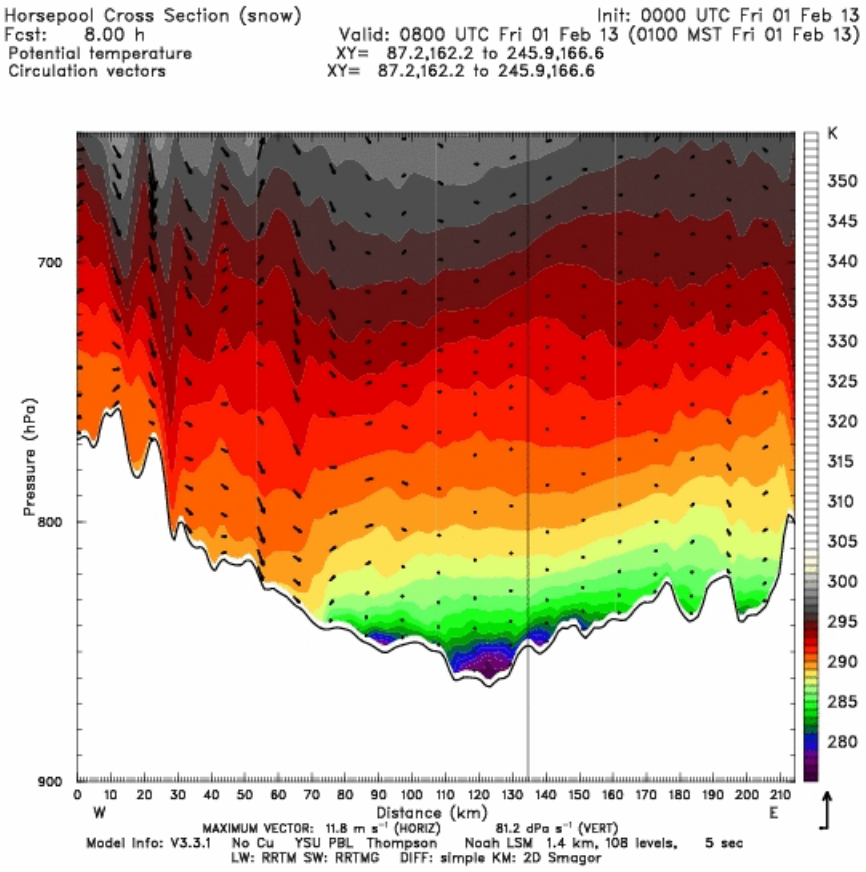
Animation WRF simulations 1-2 Feb Westerly ‘Partial Mix-Out’ of PCAP



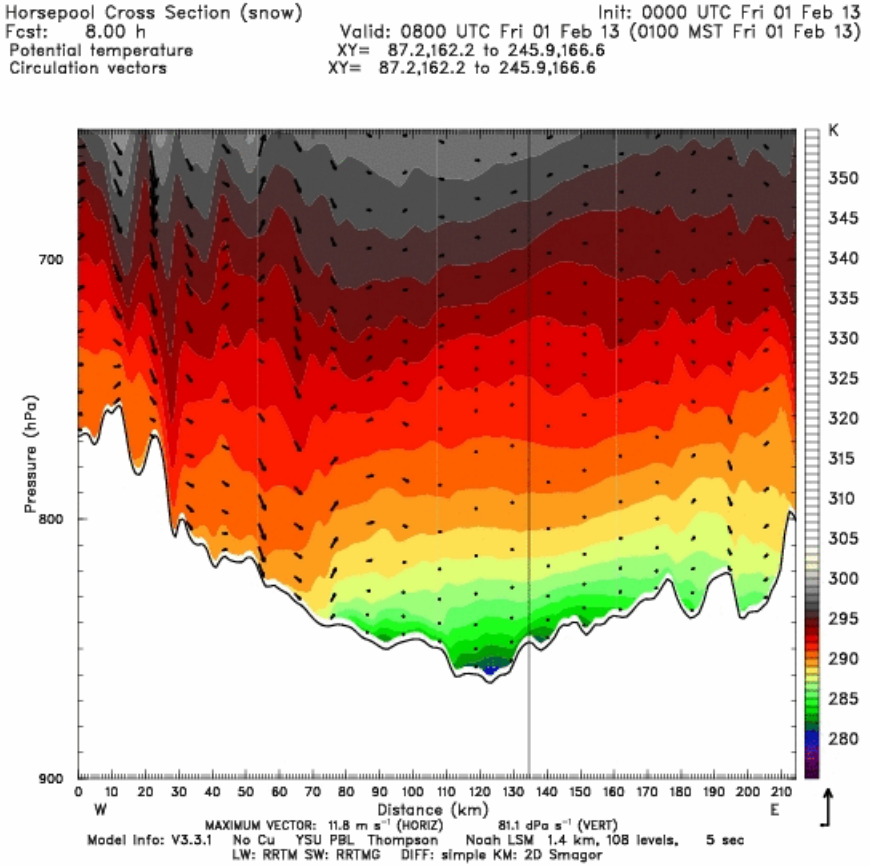


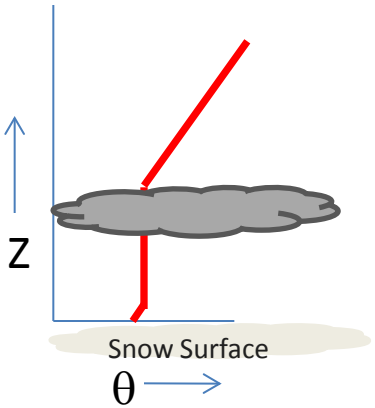
Sensitivity to Snowcover

Snow

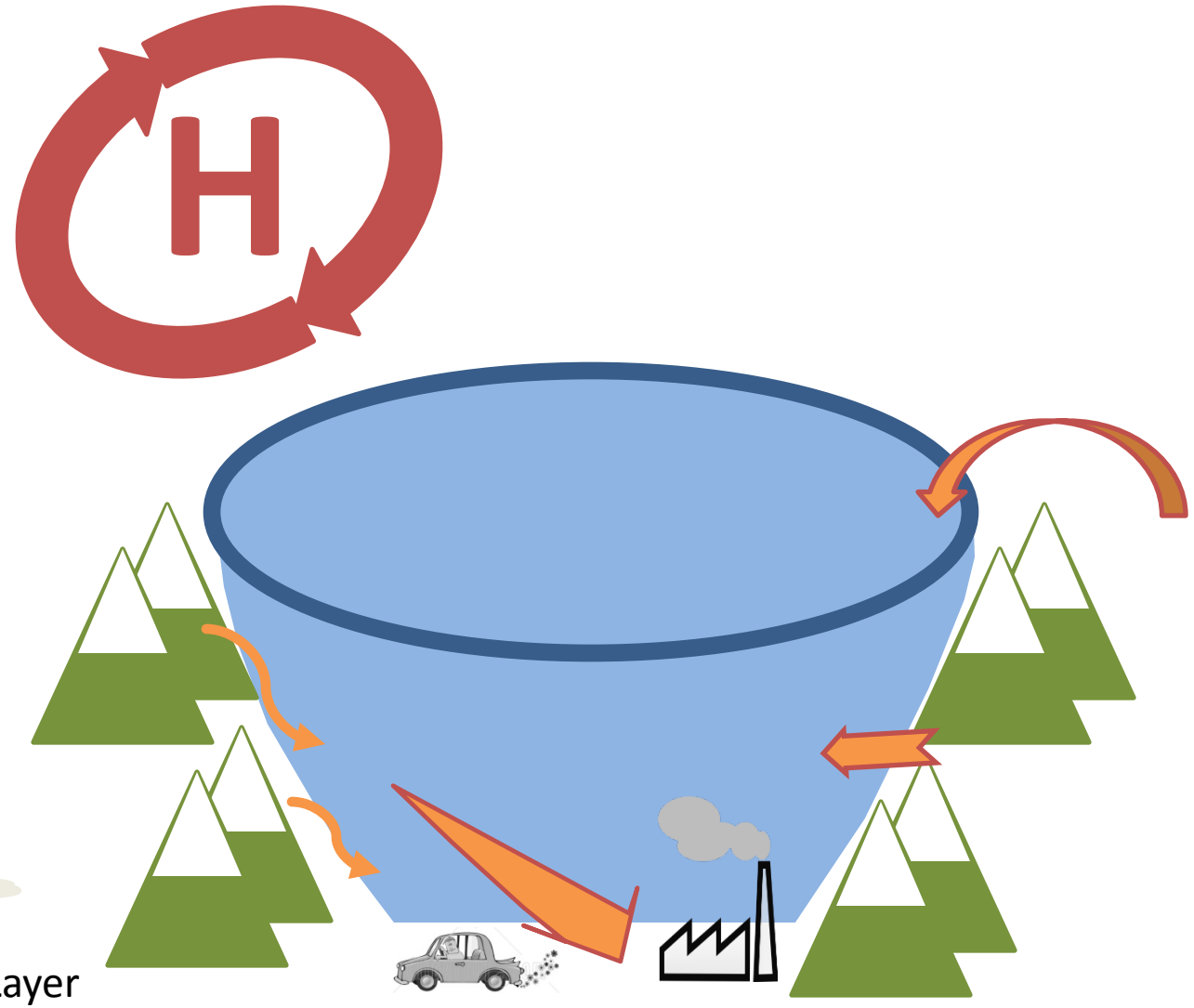


No Snow

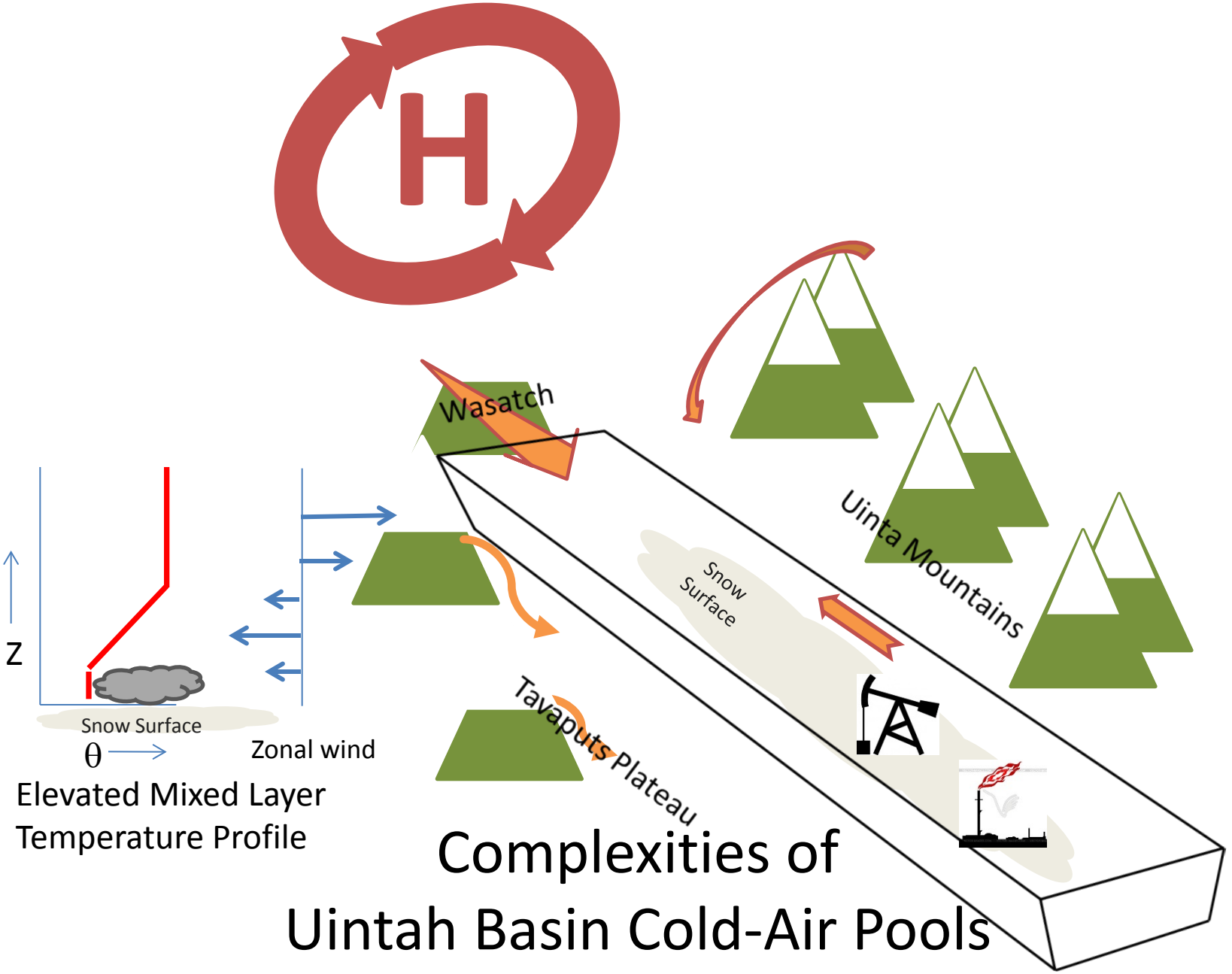




Elevated Mixed Layer
Temperature Profile



Complexities of Salt Lake Valley Cold-Air Pools



Complexities of Uintah Basin Cold-Air Pools

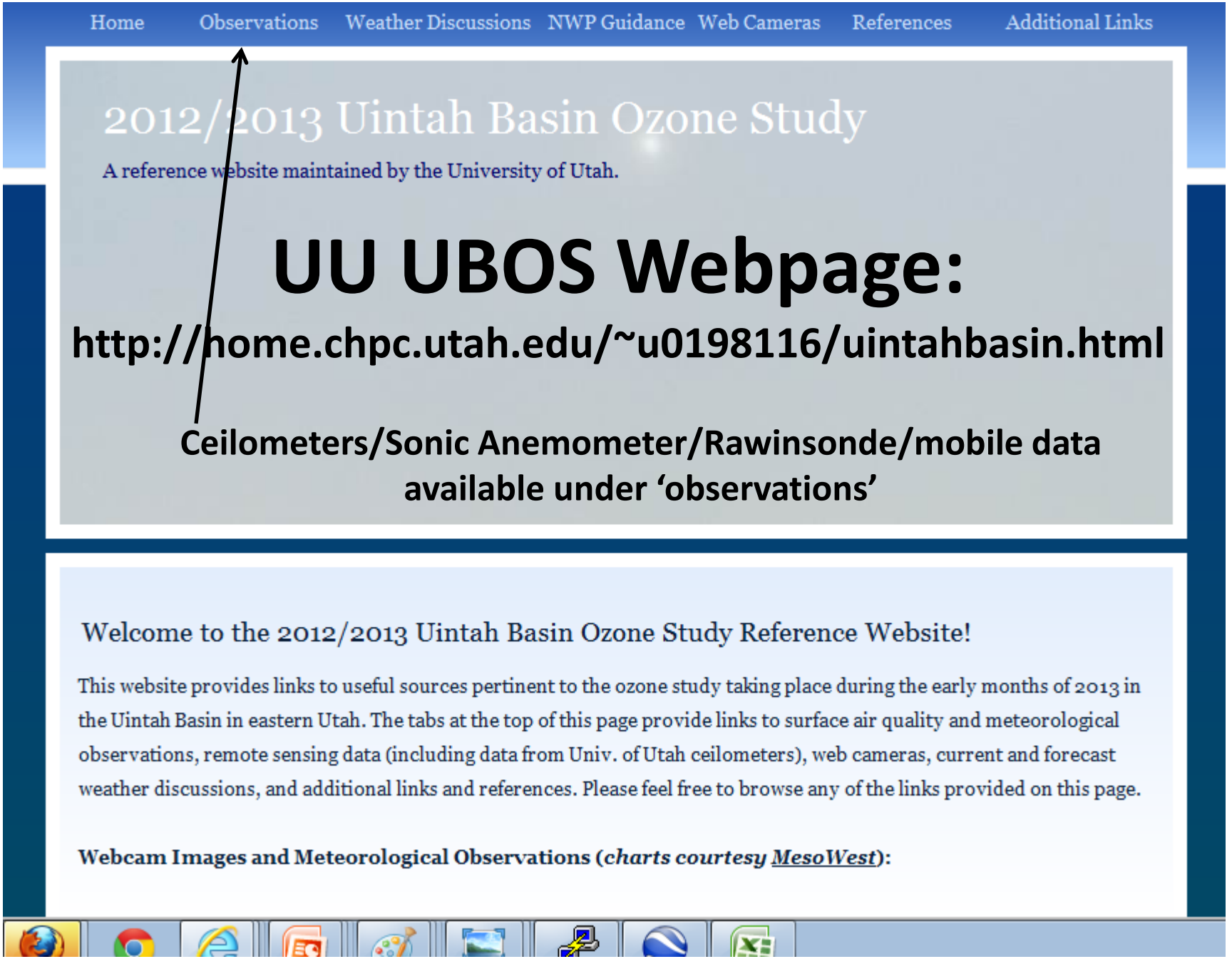
Hypotheses about Uintah Cold-Air Pools

- High ozone events could occur any winter- requires average snow storm(s) in early-mid January leading to ~6 inches of snow cover

- Ozone concentrations near surface build rapidly and remain high:
  - precursor sources scattered throughout basin
  - Emissions into lowest 100-200 m tend to be isolated from basin circulations aloft
  - reduced turbulence in lowest 100-200 m leads to low sublimation rates (and deposition) helping to perpetuate modest snow cover

- Terrain-flow interactions lead to jets and directional shear layers above surface isolated layer
  - Alternating layers of high and reduced aerosol concentrations embedded within stable boundary layer associated with predominantly easterly and westerly/northwesterly flows respectively
  - Provides means to distribute pollutants throughout basin and modest entrainment of cleaner air

- Model results suggest presence of snow cover affects surface energy balance leading to colder temperatures and enhanced stability in lowest 100-200 m with minimal impact aloft


Home
Observations
Weather Discussions
NWP Guidance
Web Cameras
References
Additional Links
2012/2013 Uintah Basin Ozone Study
A reference website maintained by the University of Utah.
UU UBOS Webpage:
http://home.chpc.utah.edu/~u0198116/uintahbasin.html
Ceilometers/Sonic Anemometer/Rawinsonde/mobile data available under 'observations'
Welcome to the 2012/2013 Uintah Basin Ozone Study Reference Website!
This website provides links to useful sources pertinent to the ozone study taking place during the early months of 2013 in the Uintah Basin in eastern Utah. The tabs at the top of this page provide links to surface air quality and meteorological observations, remote sensing data (including data from Univ. of Utah ceilometers), web cameras, current and forecast weather discussions, and additional links and references. Please feel free to browse any of the links provided on this page.
Webcam Images and Meteorological Observations (charts courtesy MesoWest):


The End

An Emerging Global Problem

"…**low-temperature ozone formation** is probably occurring in other regions of the **western US**, and in **Canada**, **Russia**, **Kazakhstan**, **Mongolia** and **China**, where fossil fuel extraction occurs in similar terrain and under similar meteorological conditions. At present, **ozone measurements** in most of these regions in winter **are non-existent**." Schnell et al. 2009