MATERHORN-Fog: Climatology, Synoptic Conditions, Real-time WRF Forecasting and Evaluation with Observations

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University of Notre Dame

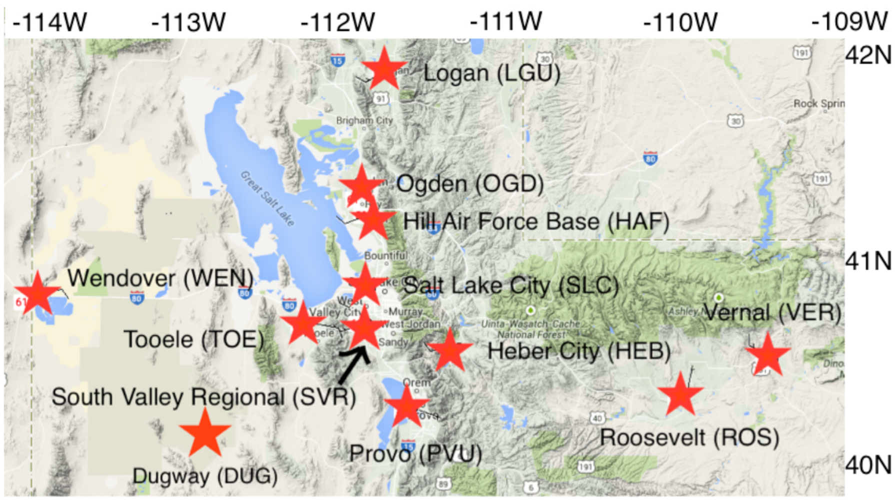
Outline

- The climatology, frequency, and distribution of cold season fog events in northern Utah
- Large-scale synoptic conditions
- Real-time high-resolution WRF forecasting during MATERHORN-Fog
- Evaluation of WRF model performance with MATERHORN-Fog observations
- On-going data assimilation and sensitivity studies

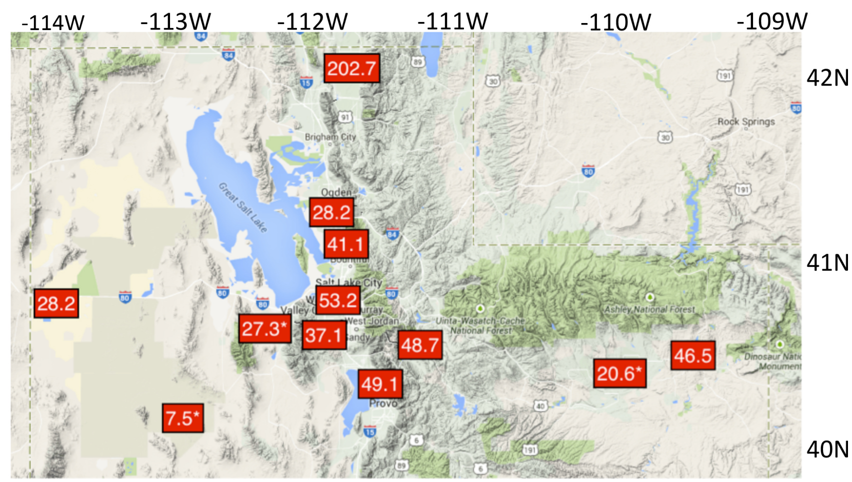
The climatology, frequency, and distribution of cold season fog events in northern Utah

(Hodges and Pu 2015: *Pure and Applied geoscience*, in press)

ASOS stations used



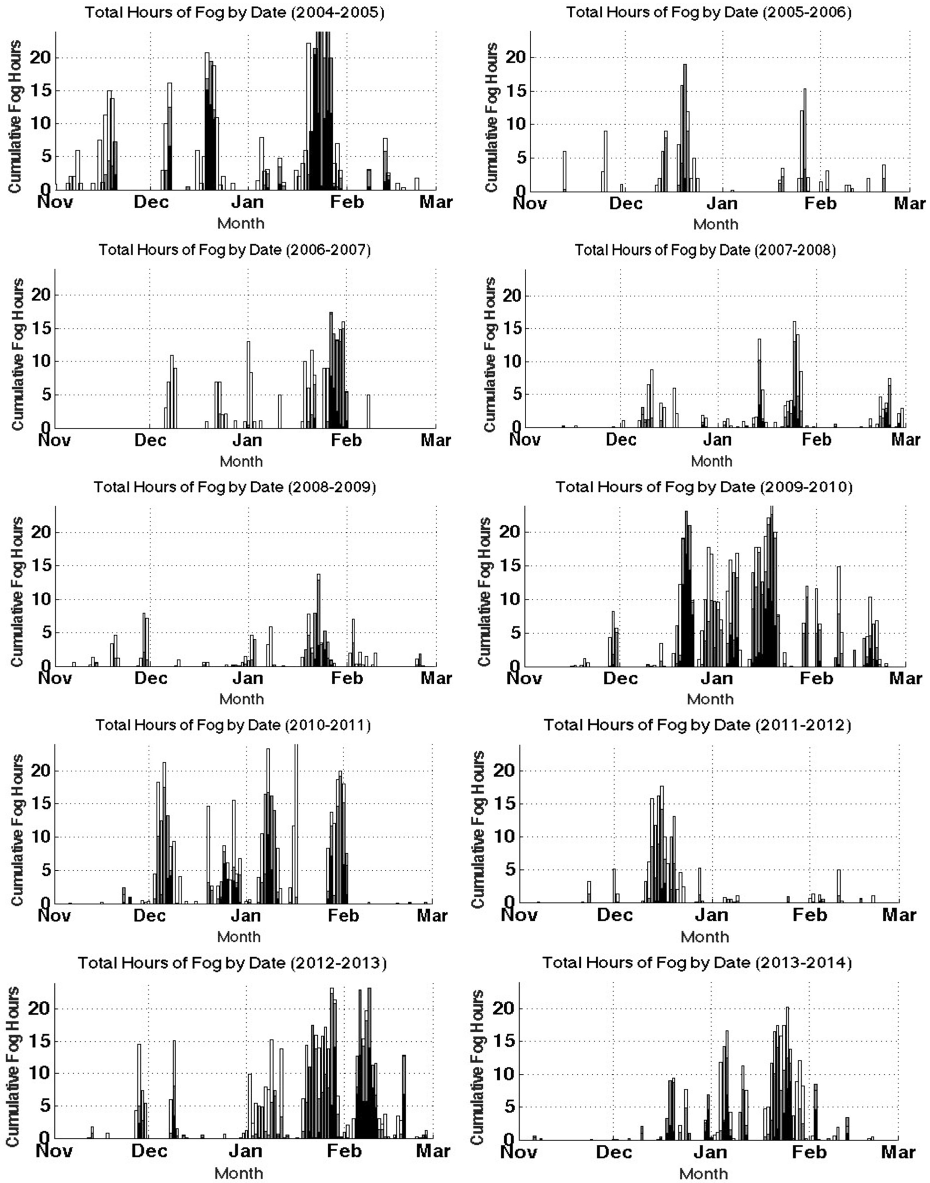
Annual fog hours
(average over 2004-2014)

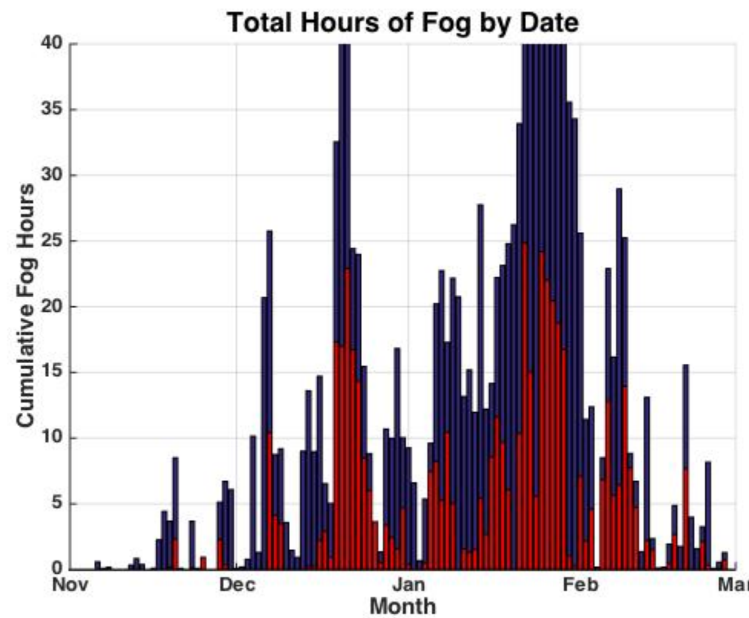


Uses 10-year mesowest surface observations.

Salt Lake City

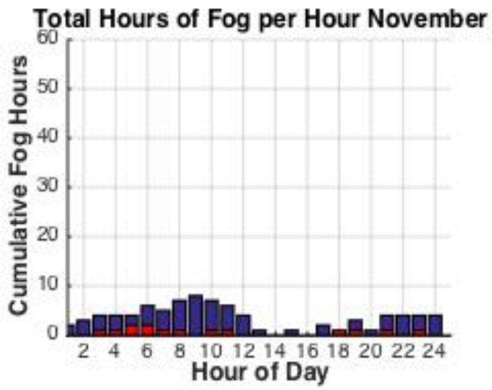
Annual hours of fog per date 2004-2014

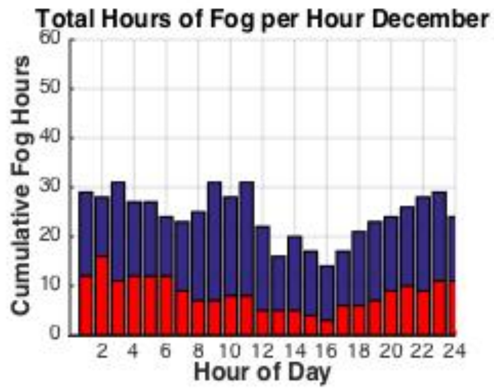


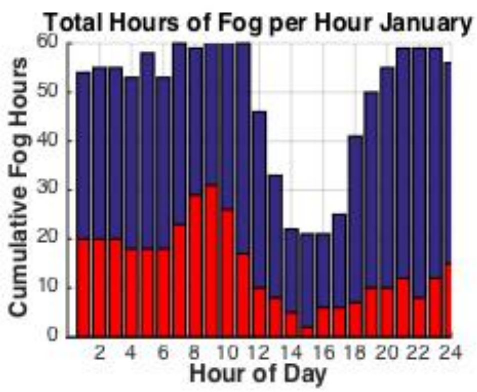


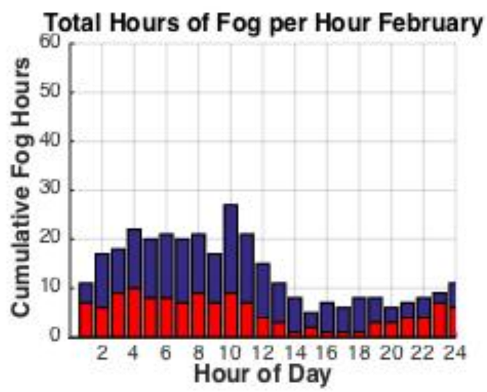
Significant variability was observed in both timing and quantity from year-to-year.

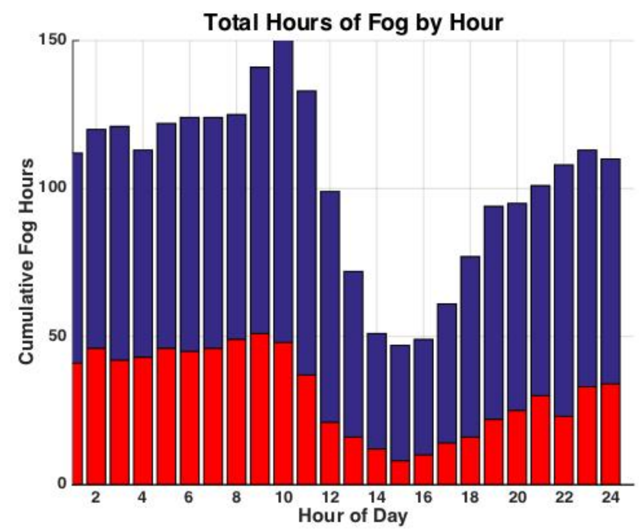
Salt Lake City





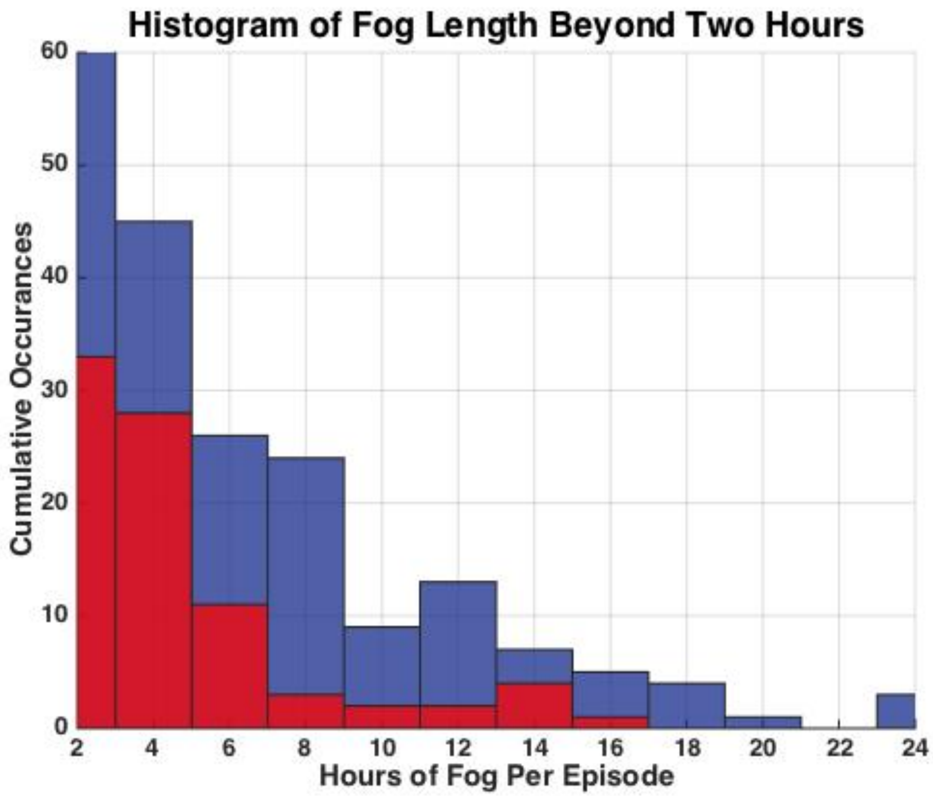






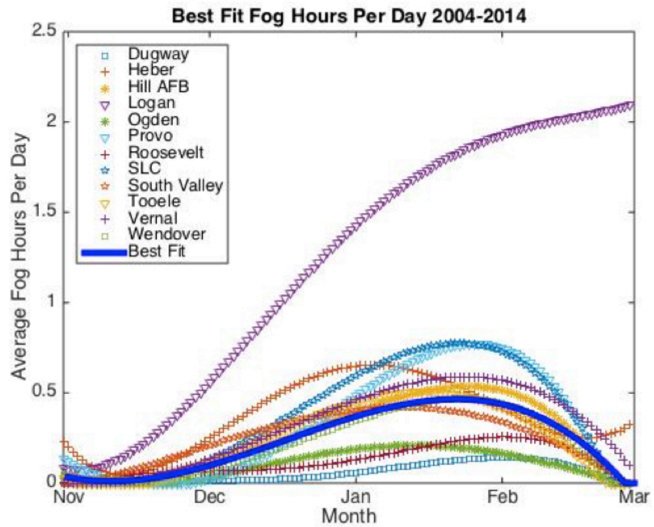
. There is a peak in fog near dawn and a minimum in the afternoon hours, although it is the weakest in December when solar insolation is less.

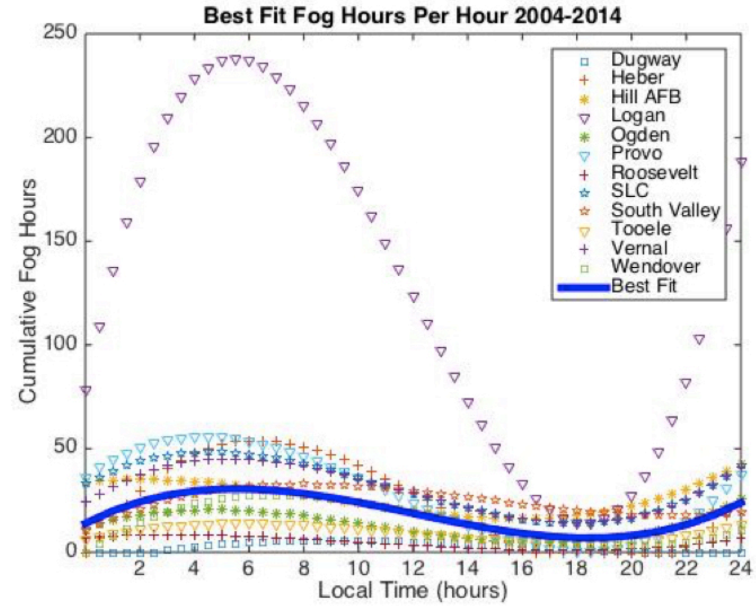
Salt Lake City

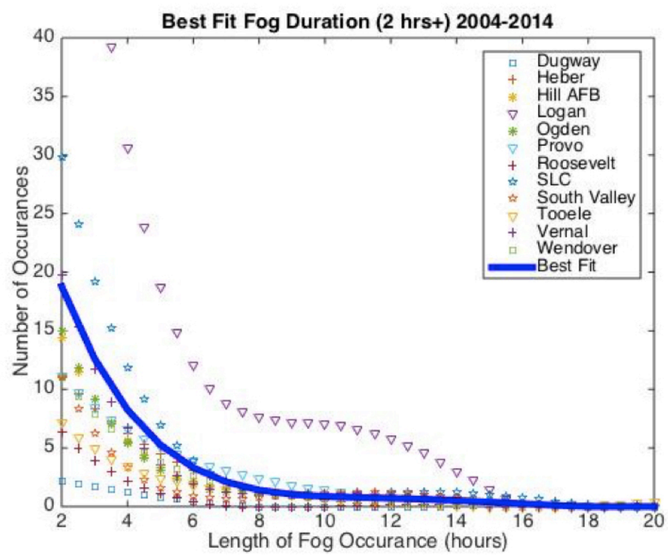


Cumulative number of fog events that lasted at least two hours, per hour. The number of fog events quickly decreases but roughly stabilizes between 6 and 16 hours.

Statistics over northern Utah







Typically fog peaks for most stations in late January but there is some variability evident. Most stations peak in fog near dawn and see a minimum in the afternoon. All stations see a rapid drop in fog persistence beyond two hours with a plateau from about 8 to 14 hours.

Summary of fog climatology

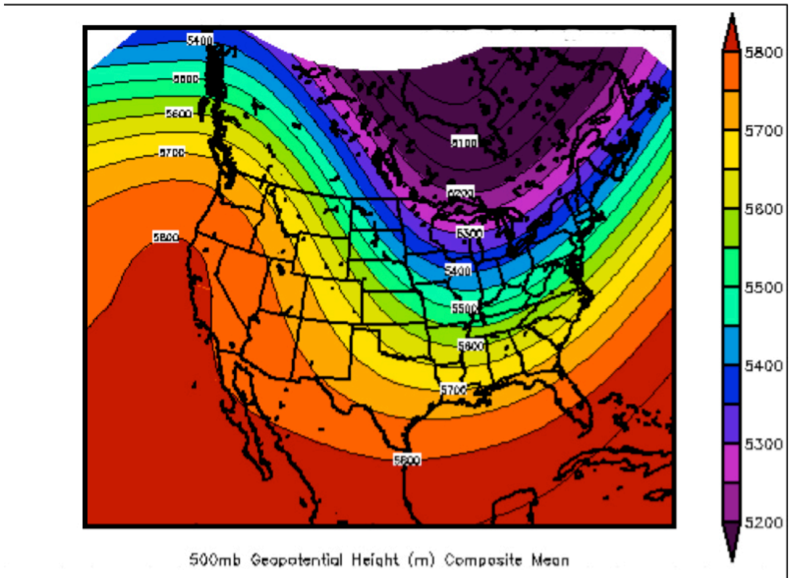
- There is significant variability among the valleys in northern Utah in terms of both quantity and timing of fog events. Fog occurs more frequently in locations close to lakes such as the Great Salt Lake or Utah Lake than in locations farther away. It is also noted that small, enclosed valleys have higher amounts of fog than more broad, open valleys.

- Throughout the region there is a distinct peak in fog in late January for most stations. A strong peak in fog occurrences near dawn is also found for all cold-season months.

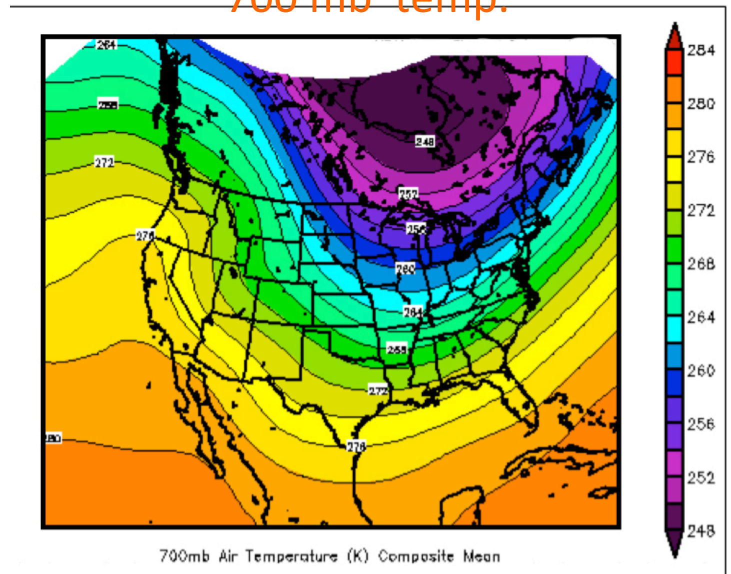
- The influence of local, mesoscale conditions on the fog distribution is evident in many stations. It is found that the existence of fog at one location is a very poor predictor of fog at nearby locations on a daily timescale, which implies serious forecasting difficulties over complex terrain. However, it is also found that on an annual timescale the amount of fog at one location can be used to estimate the amount of fog at another location.

Synoptic conditions

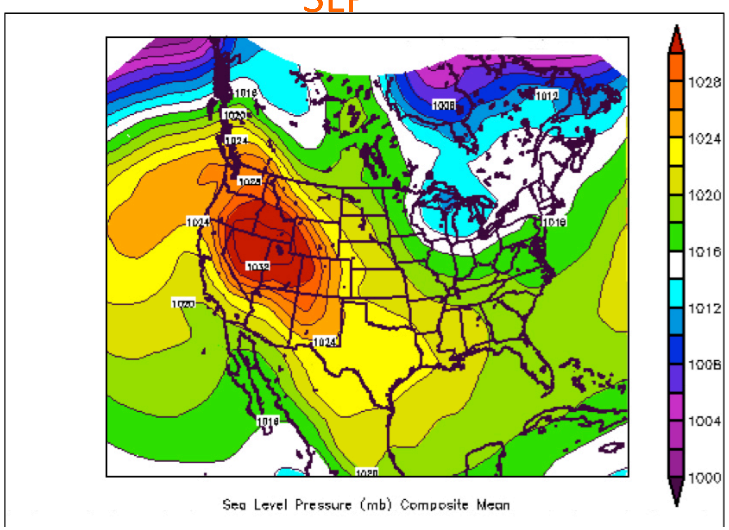
500 mb GH



700 mb temp.



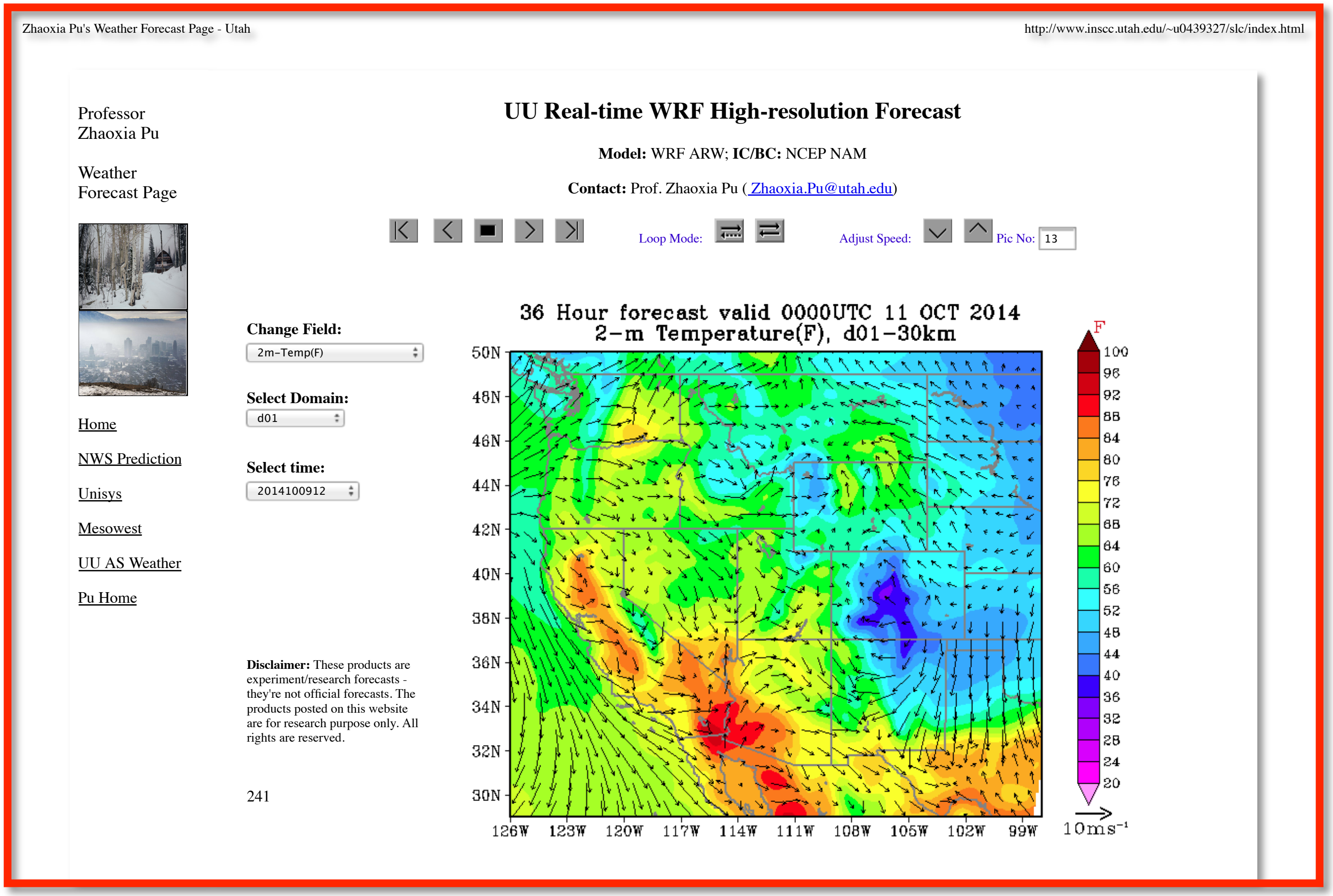
SLP



- Average synoptic conditions for fog include a large scale ridge to the west, occasional passing shortwaves focused to the NE, and high surface pressure over the Great Basin.

- Snow on the ground
- Inversion

Real Time WRF High resolution forecasting

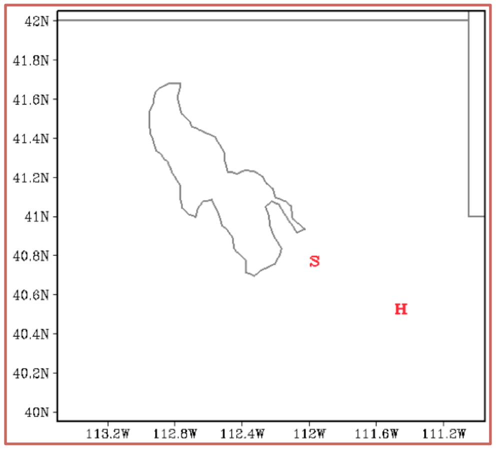


http://www.inscc.utah.edu/~pu/slc/index.html

Model Specifications

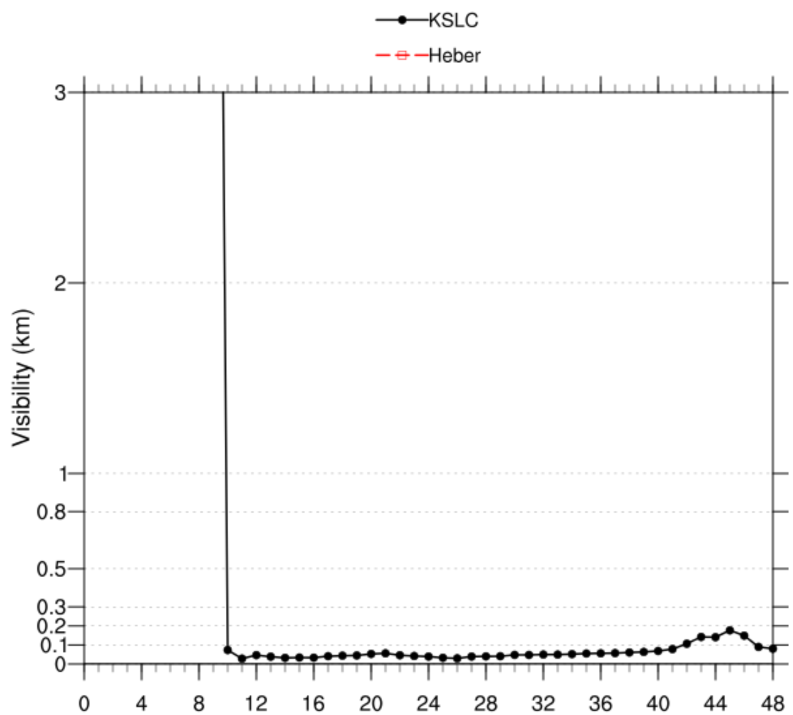
- WRF ARW V3.3
- Four one-way nested domains
  - Horizontal resolutions of 30km/10km/3.3km/1.1km
- Two sets of 48-h forecasts per day from 00Z and 12Z
- Initial and boundary conditions derived from NCEP NAM

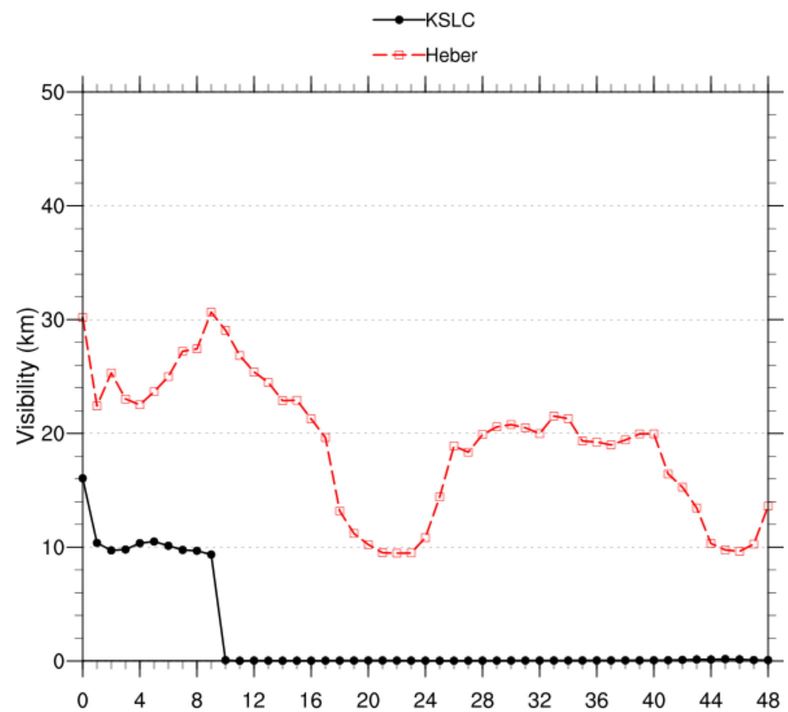
Locations of nested model domains



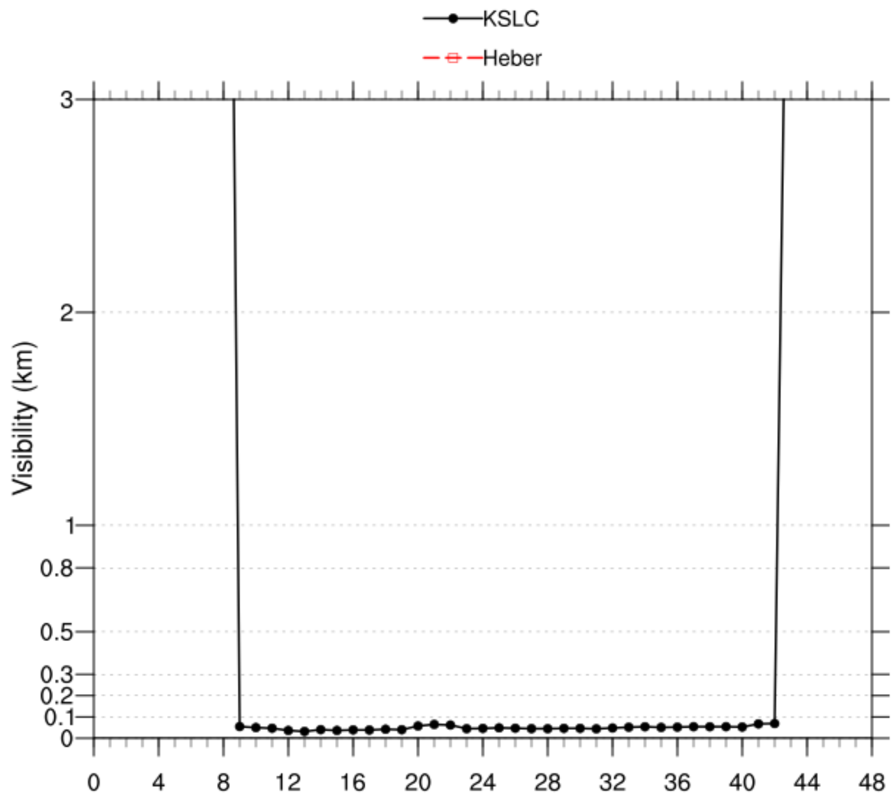
A map of d04 of the WRF model used, the bounds by which all of the sounding figures in this presentation were made. The red “S” denotes the Salt Lake site and the “H” denotes Heber.

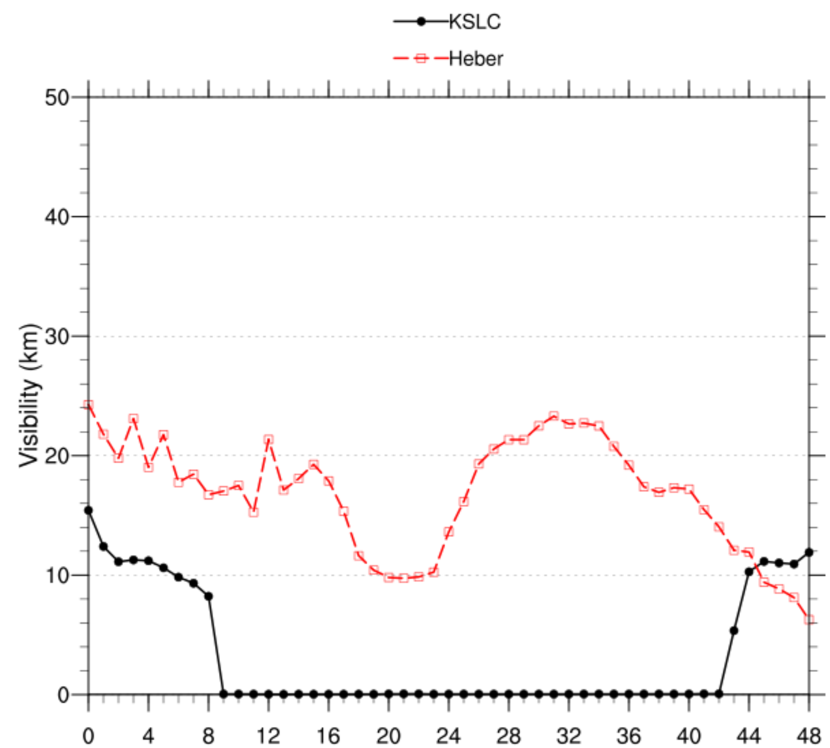
48h visibility forecast from 00UTC 08 Jan 2015

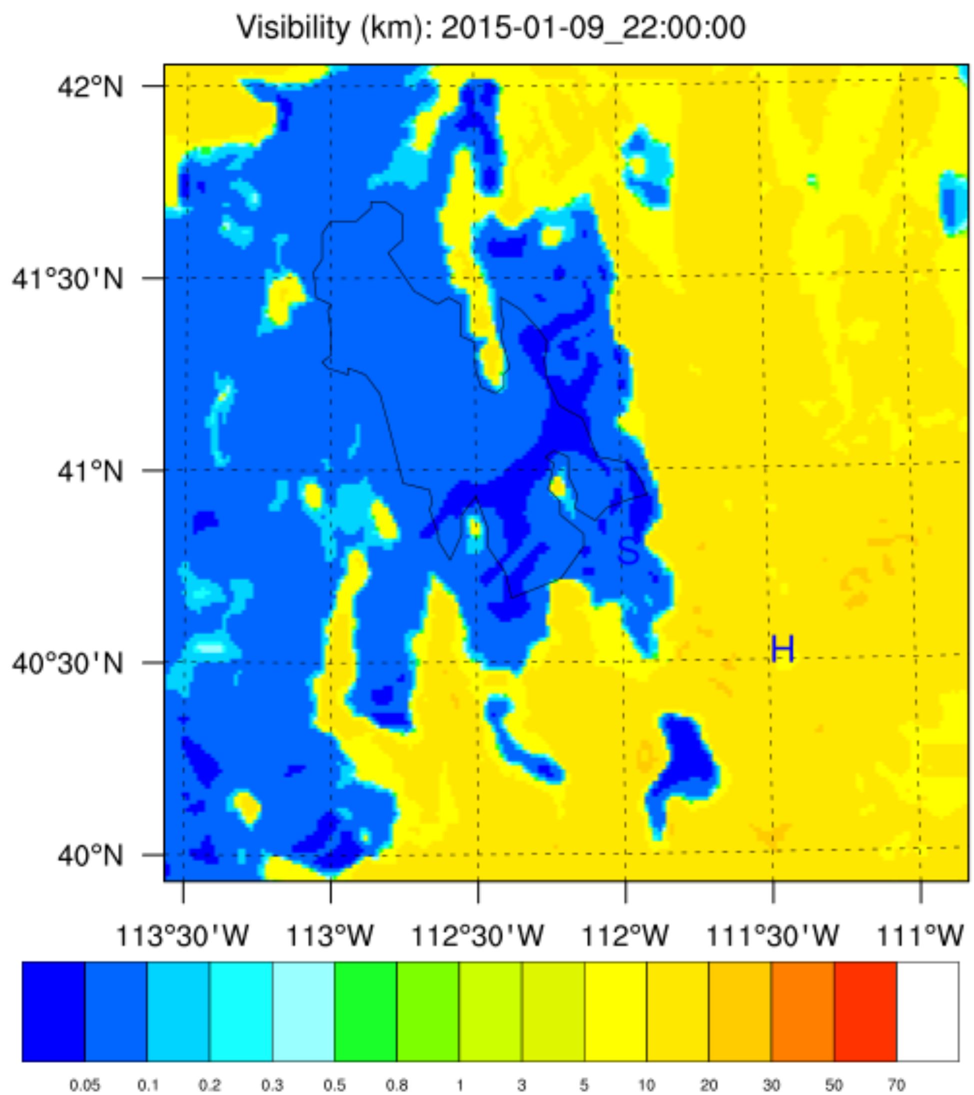




48h visibility forecast from 00UTC 09 Jan 2015






Visibility (km): 2015-01-09_22:00:00
42°N
41°30'N
41°N
40°30'N
40°N
113°30'W
113°W
112°30'W
112°W
111°30'W
111°W
S
H
0.05
0.1
0.2
0.3
0.5
0.8
1
3
5
10
20
30
50
70

Evaluation of wrf forecasts of fog events against observations during materhorn fog-x

Preliminary results

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Background and Goal

- Three major fog events were recorded during the MATERHORN Fog-X field campaign
  - January 8-9
  - January 9-10
  - January 15-16
- WRF was run real-time to provide forecasting during the campaign
- Both synoptic and mesoscale evaluations were performed to identify the source of the errors

Model Specifications

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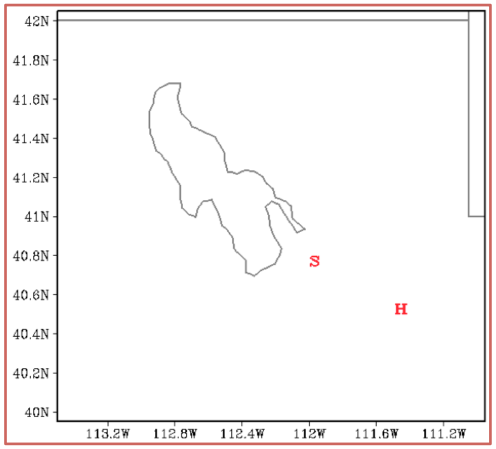


A map of d04 of the WRF model used, the bounds by which all of the sounding figures in this presentation were made. The red "S" denotes the Salt Lake site and the "H" denotes Heber.

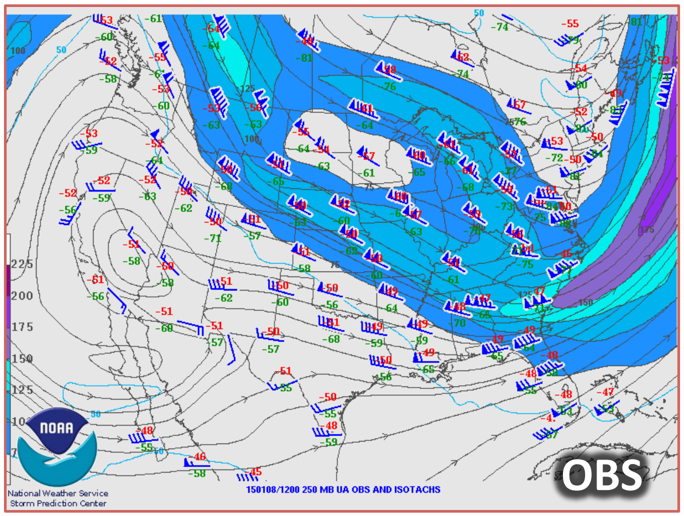
Discussion of Fog Forecast Results

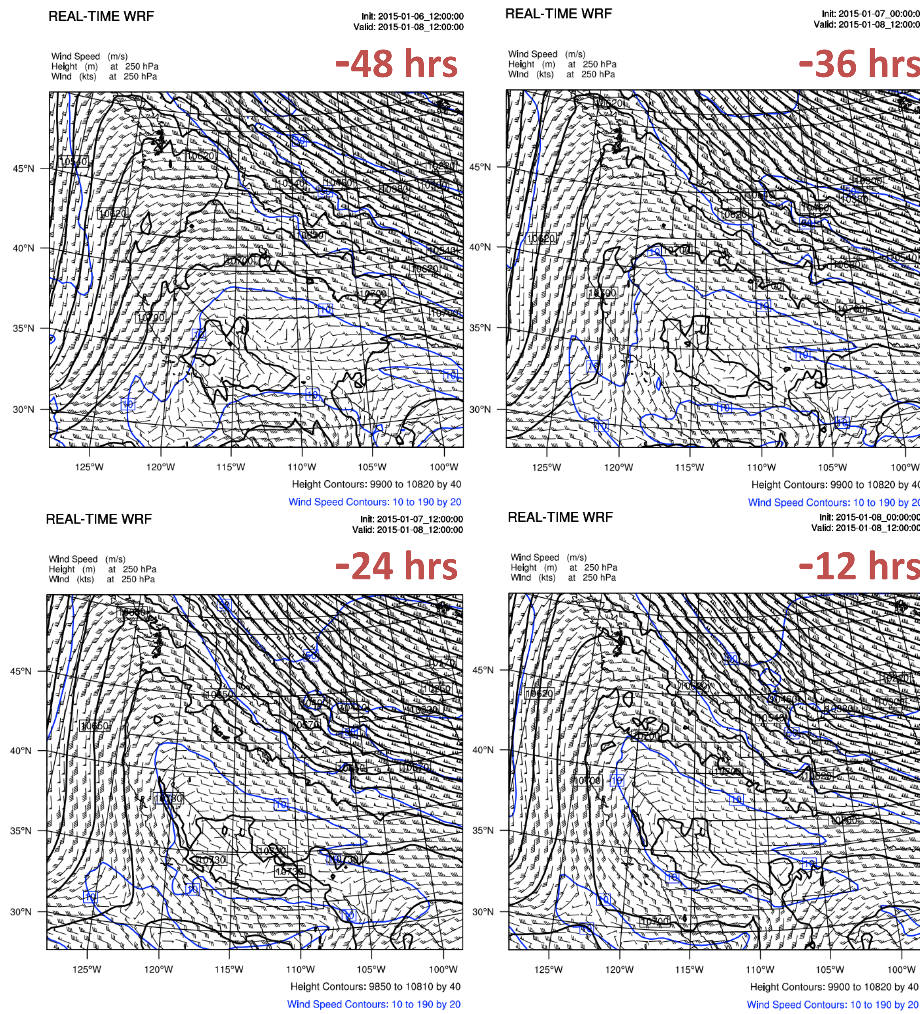
- In every case for the Salt Lake site, fog was over-predicted.
- Fog was predicted by the WRF for the Heber site, a gross undenotr-prediction.

- What is causing these prediction errors?

Error Investigation: Synoptic Scale

250 mb analysis
Valid: January 08 1200 UTC

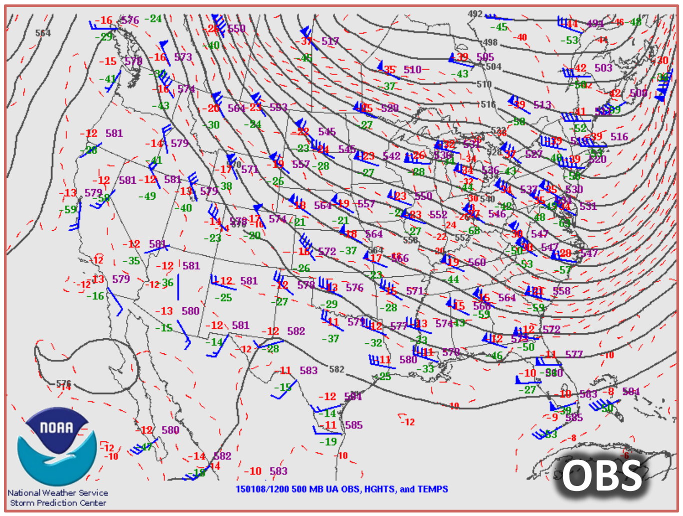


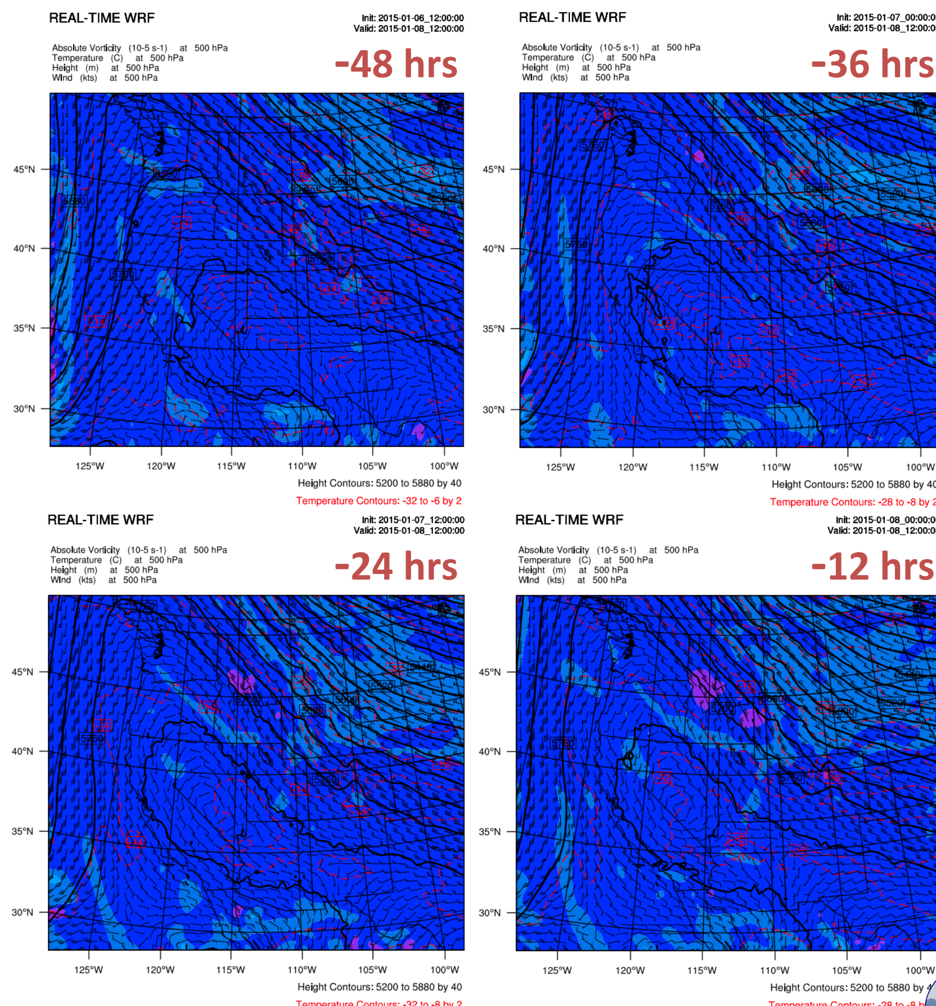


Summary of Discrepancy:
No apparent errors

Error Investigation: Synoptic Scale

500 mb analysis
Valid: January 08 1200 UTC

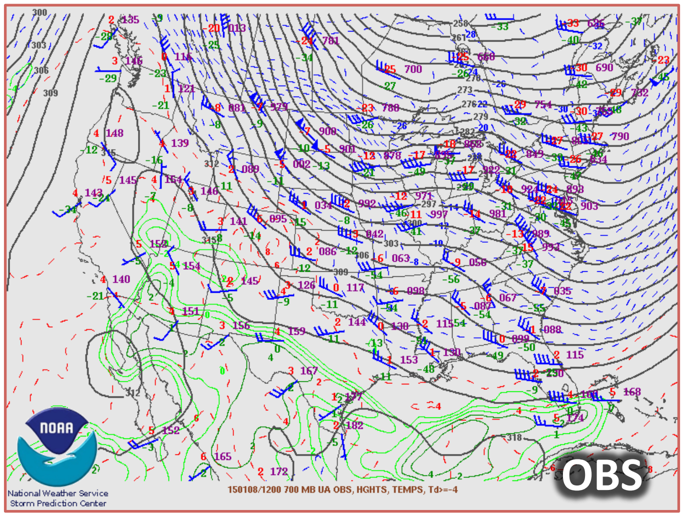


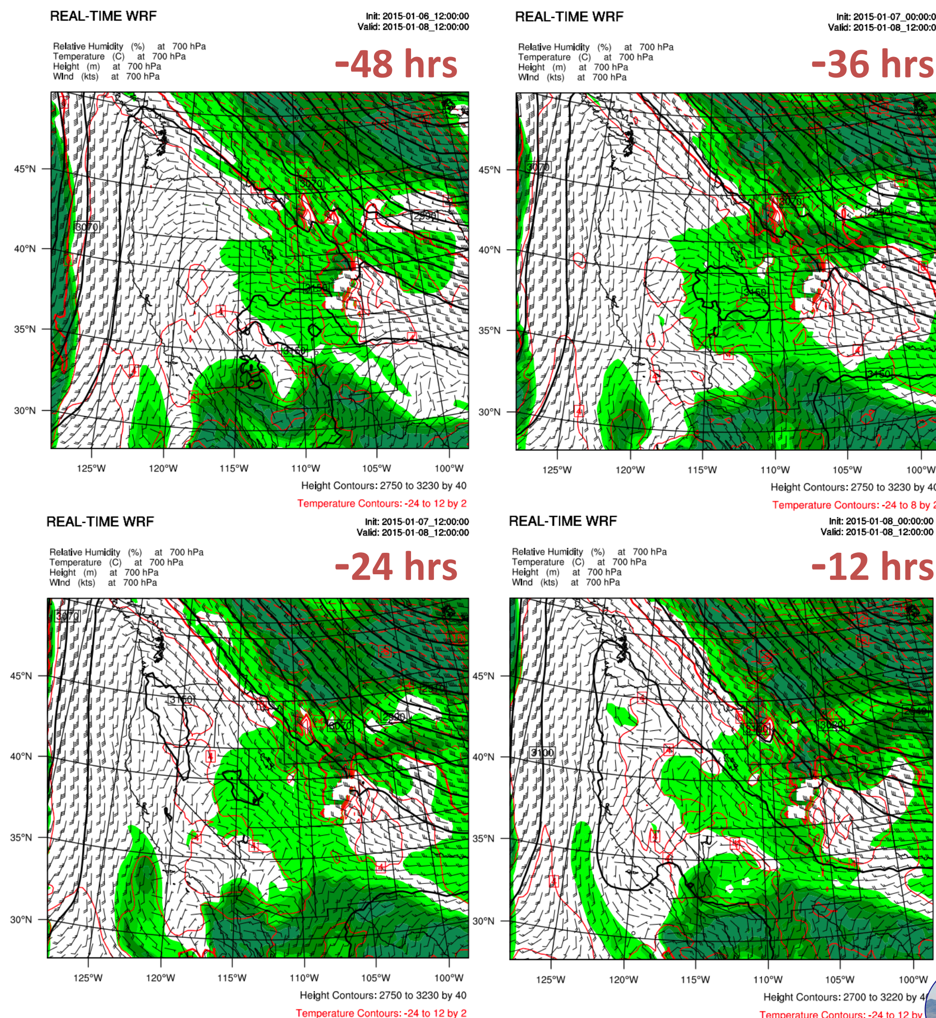


Summary of Discrepancy:
No apparent errors

Error Investigation: Synoptic Scale

700 mb analysis
Valid: January 08 1200 UTC





Summary of Discrepancy:
Failed to capture the two distinct anticyclonic circulations until -24.
No errors after -24.

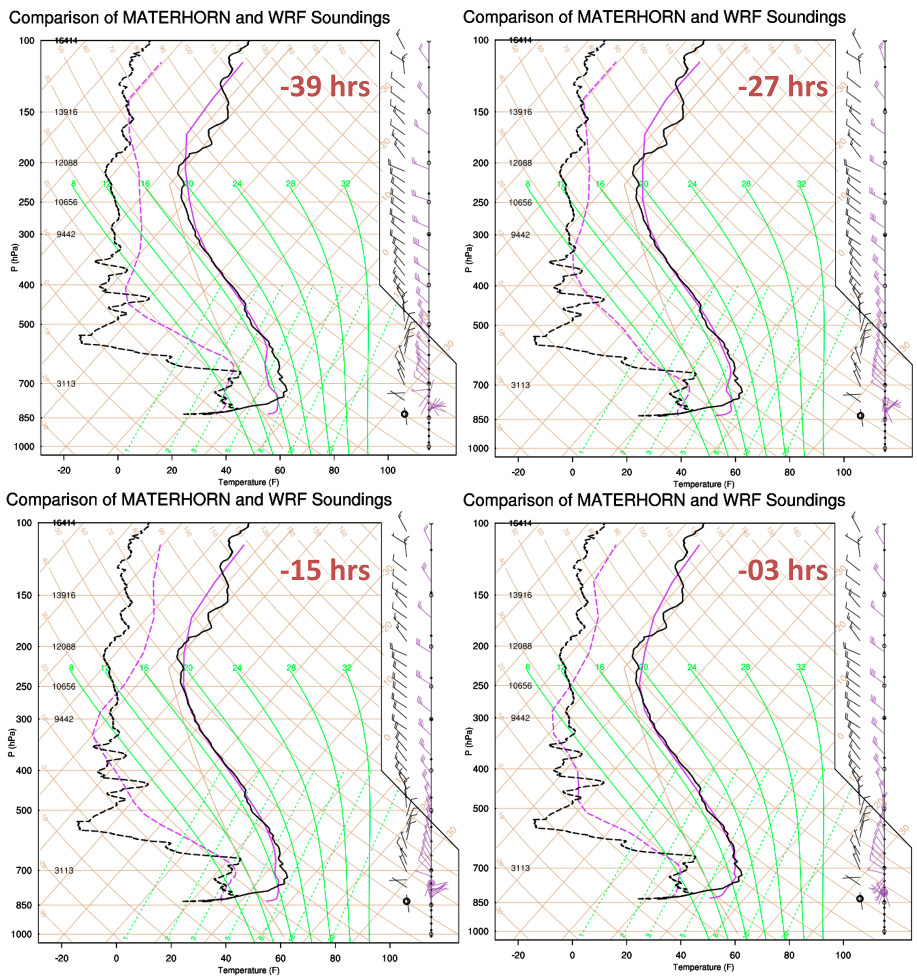
Discussion of Synoptic Errors

- Few errors were captured in the synoptic scale across the generation, mature, and dissipation stages of each event.
- If errors were present, they are confined to the lowest levels of the atmosphere.
- Mesoscale environment must now be analyzed to determine source of serious error.

Mesoscale Error Example 1

Site: Heber

Valid: January 08 1439 UTC



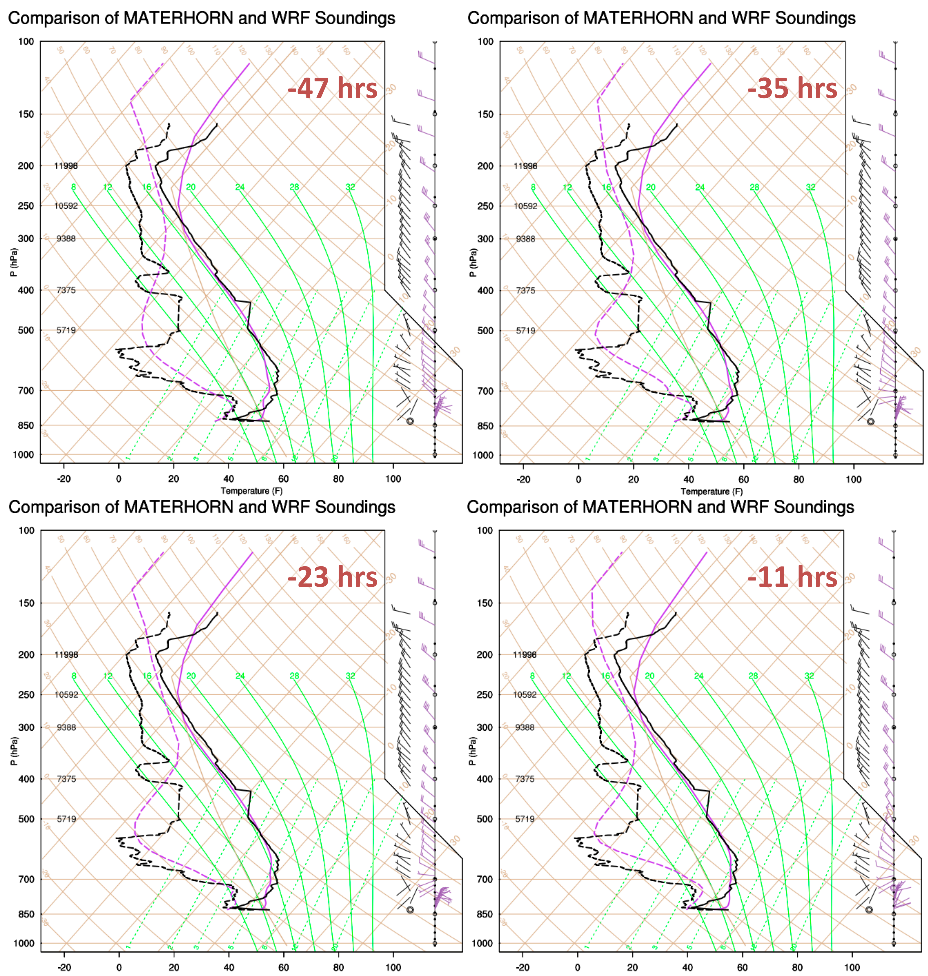
Observations
WRF Solution

Nearly all errors are confined below observed inversion.

Mesoscale Error Example 2

Site: Heber

Valid: January 09 1119 UTC



Observations

WRF Solution

Once again, nearly all errors are confined below observed inversion.

Chachere and Pu // University of Utah

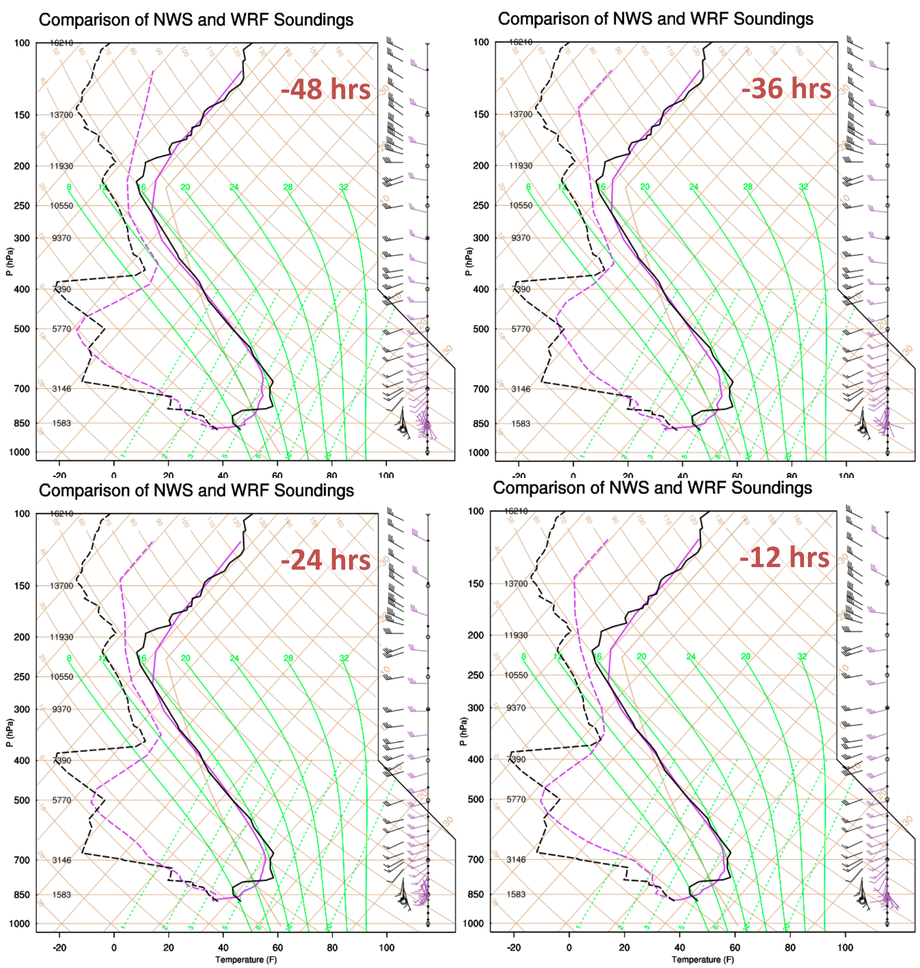
Heber Mesoscale Error Summary

- All serious errors are seen below the capping inversion, which is poorly predicted by the model.
- At the current resolution, the model cannot see the properties of the valley boundary layer, causing serious temperature and relative humidity errors.

Mesoscale Error Example 3

Site: Salt Lake

Valid: January 16 0000 UTC



Observations

WRF Solution

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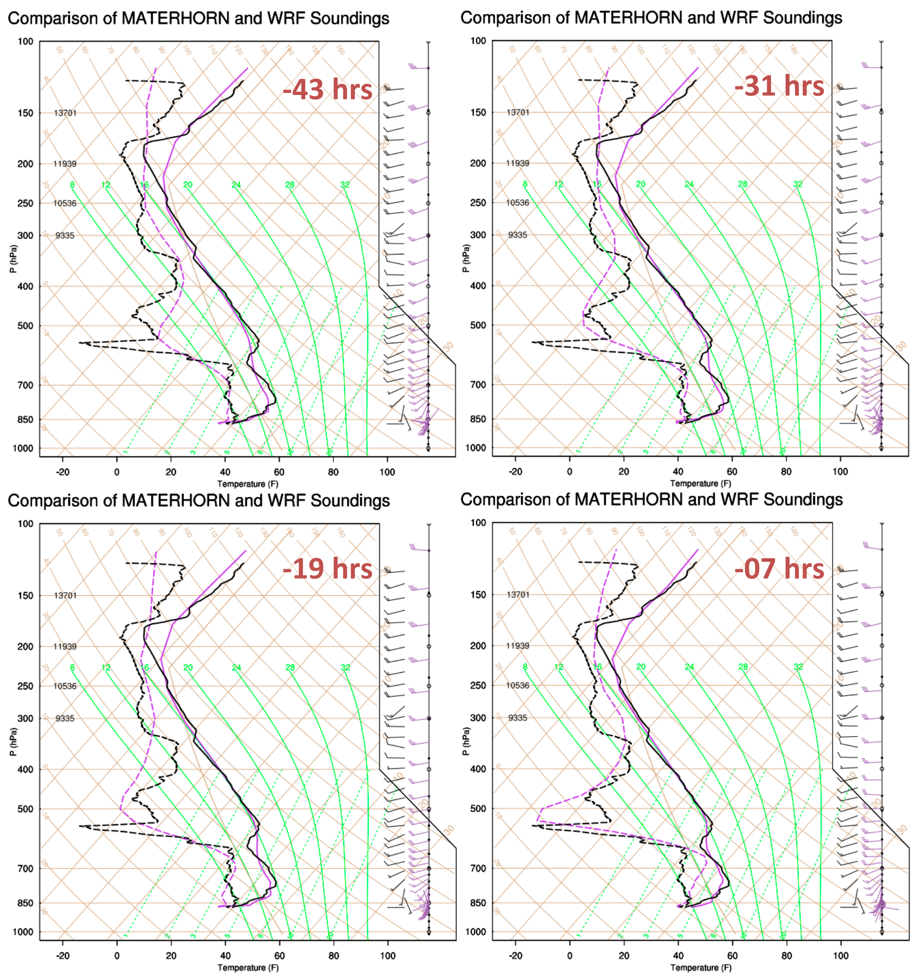
Mesoscale Error Example 4

Site: Salt Lake

Valid: January 10 0715 UTC



Observations	WRF Solution

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Salt Lake Mesoscale Error Summary

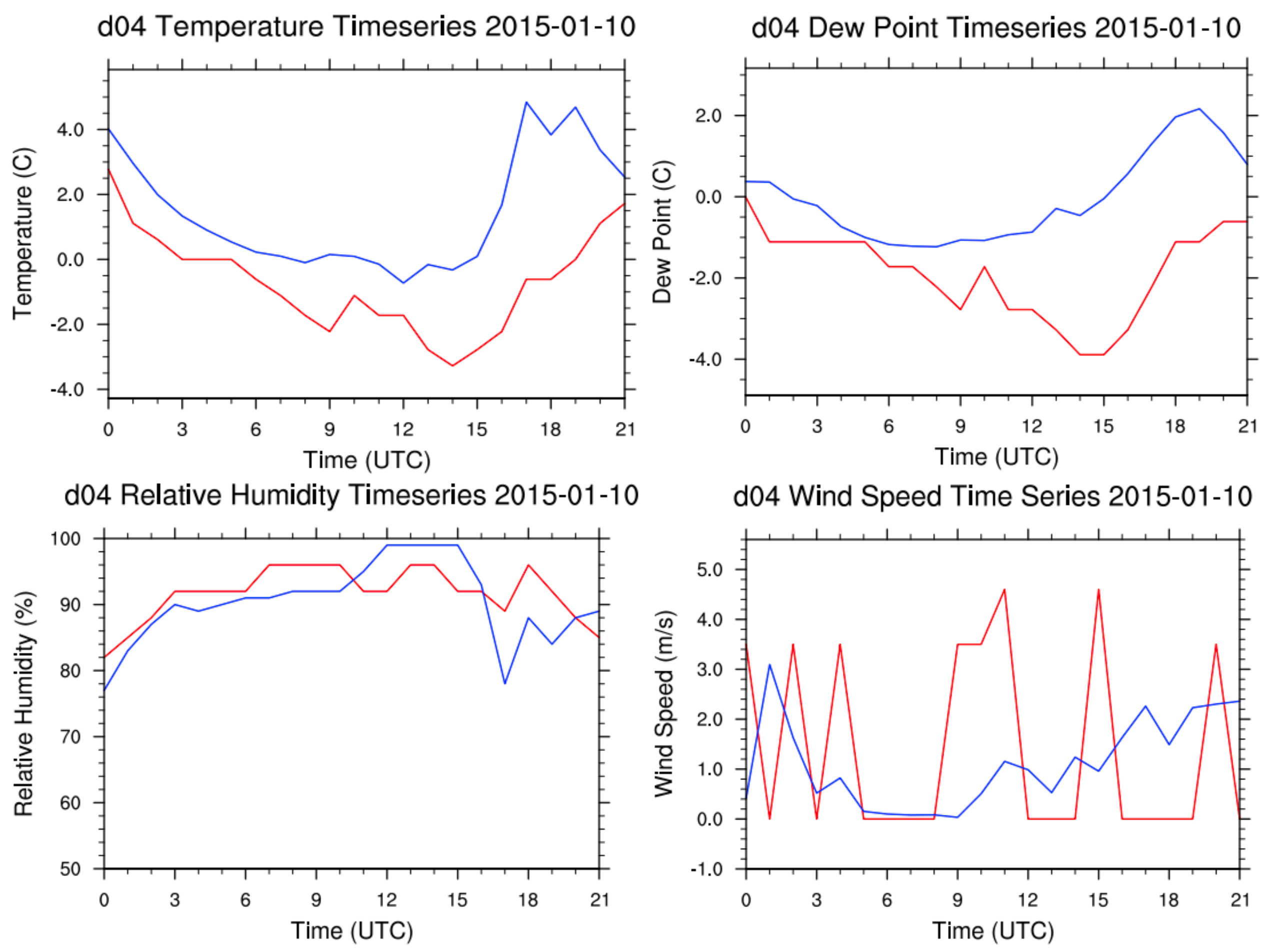
- All serious errors, once again, are seen below the observed capping inversion.
- The model misses the mixed layer that grows in the day in the Salt Lake Valley, causing an over-prediction of fog.
- At night, the model is correct due to the absence of the mixed layer.

MesoWest Comparisons - Surface

Site: Salt Lake

Observations
WRF Solution

Valid: January 10

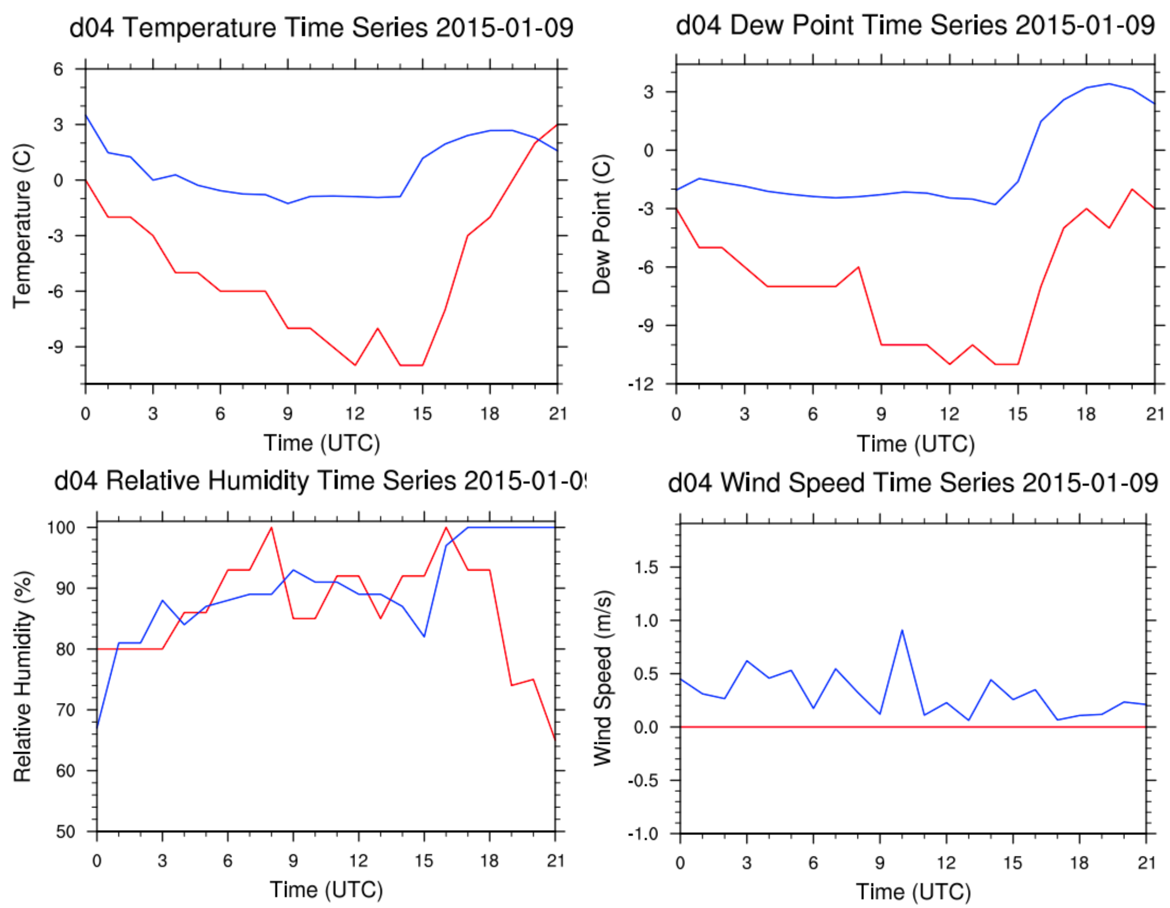


MesoWest Comparisons -Surface

Site: Heber

Observations
WRF Solution

Valid: January 09



Summary and On-going Work

- Through a study comparing MATERHORN observations to modeled solutions, have deduced that WRF does not resolve valley boundary layer properties well if at all.
- Hope to improve these errors by:
  - Assimilating Surface MesoWest, soundings, and tethersonde data
  - Conducting sensitivity studies by varying physical parametrization schemes, vertical resolution, and initial/boundary conditions.

Contributions to MATERHORN-X and MATERHORN-M
Pu Group at University of Utah

- Real time forecasts support MATERHORN-X Dry, Fall, Spring and Fog Experiments
- Evaluation of WRF model performance during MATERHORN Dry, Fall, Spring, and Fog Experiments with observations
- Fog climatology and synoptic conditions
- Data Assimilation
- Predictability studies
- 4 published/accepted journal papers; 3 in submission and preparation, and more …