Near-surface weather prediction and surface data assimilation: challenges, development, and potential data needs

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International Surface Working Group (ISWG)

Moss Landing Marine Lab, Moss Landing, California

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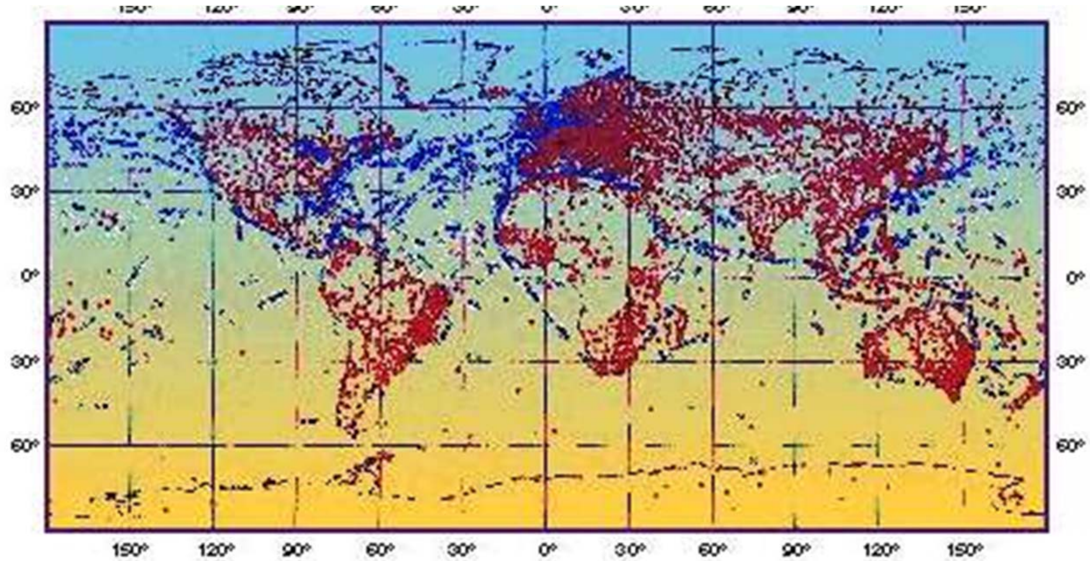
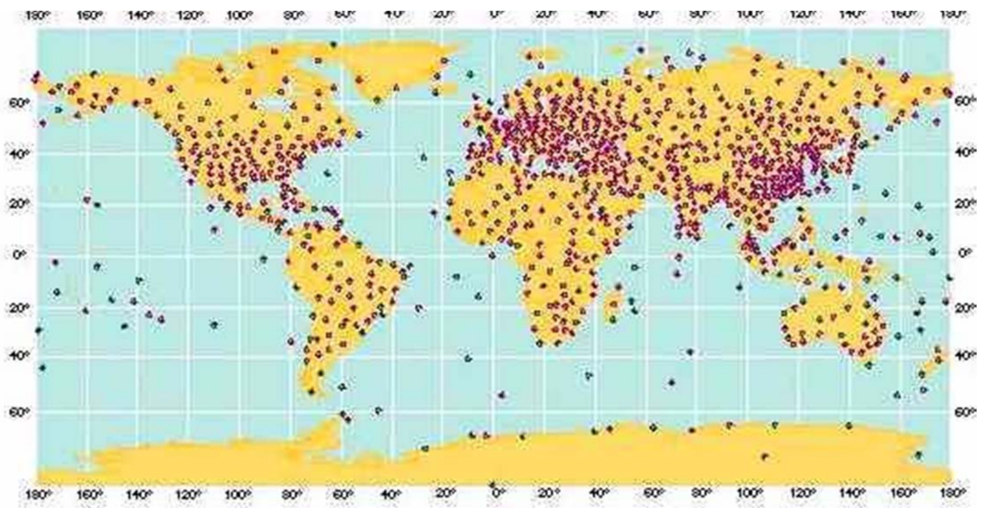
About this talk

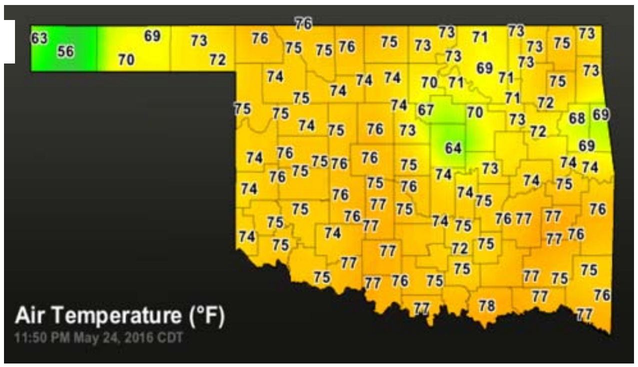
- Surface observations and their impacts on extreme weather events
- Challenges in surface data assimilation over complex terrain and near-surface weather forecasts
- Preliminary investigation on the errors of near surface temperature analysis and forecasts and sensitivity studies
- Problems and data needs

Surface observations are the major conventional observations

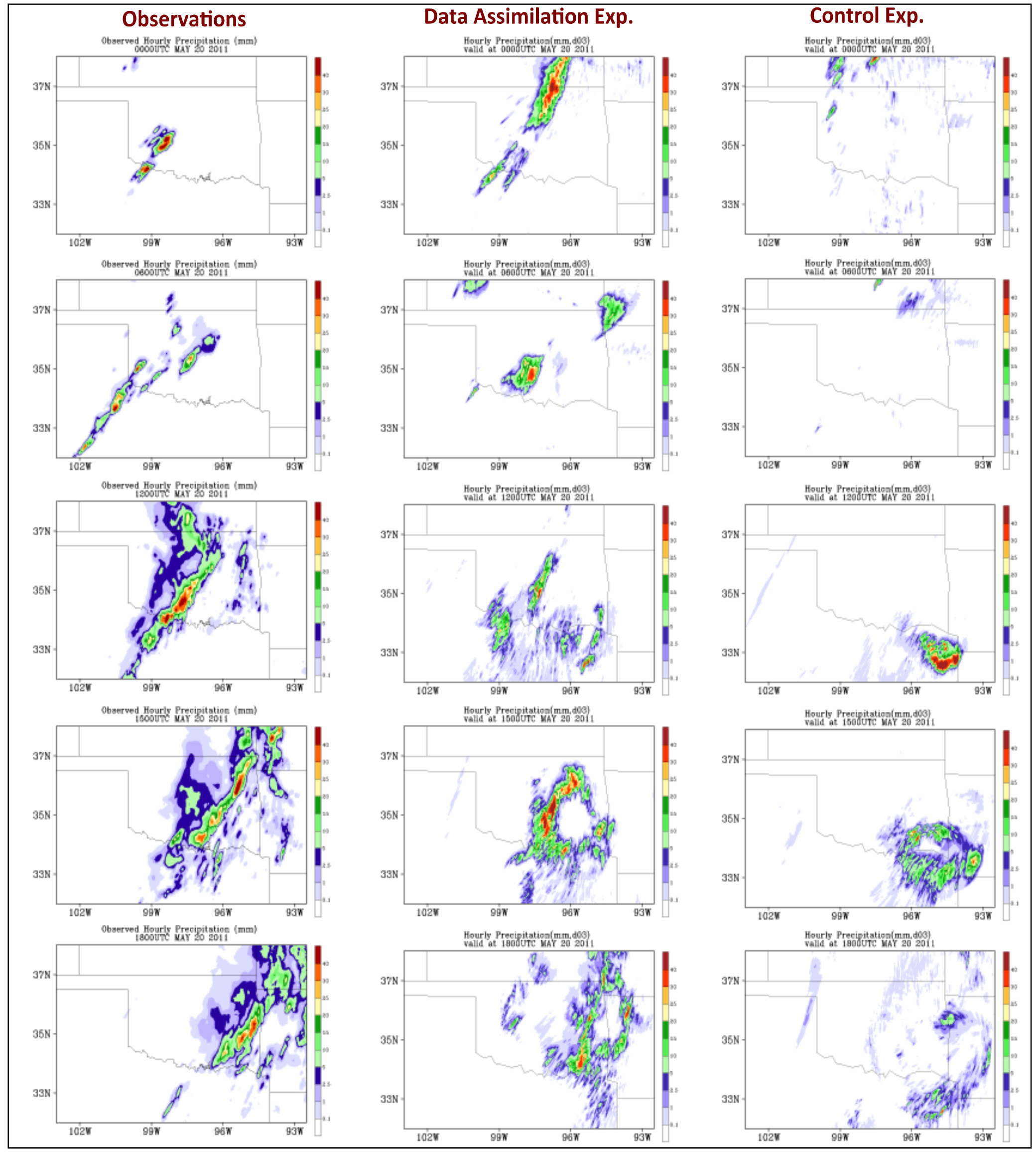




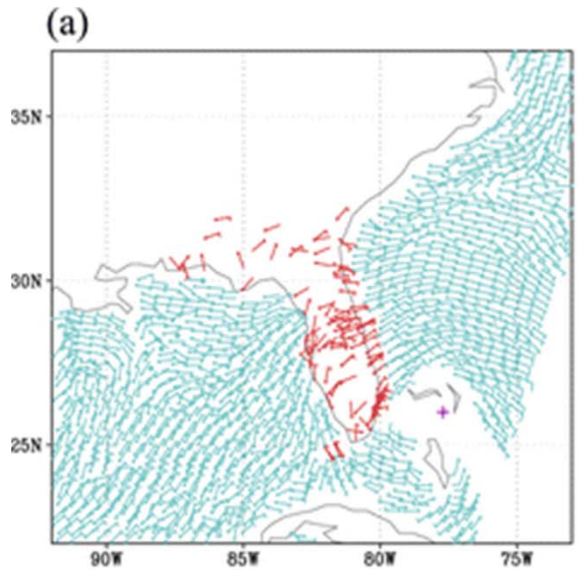
Impact of surface mesonet data assimilation WRF numerical simulation of a MCS



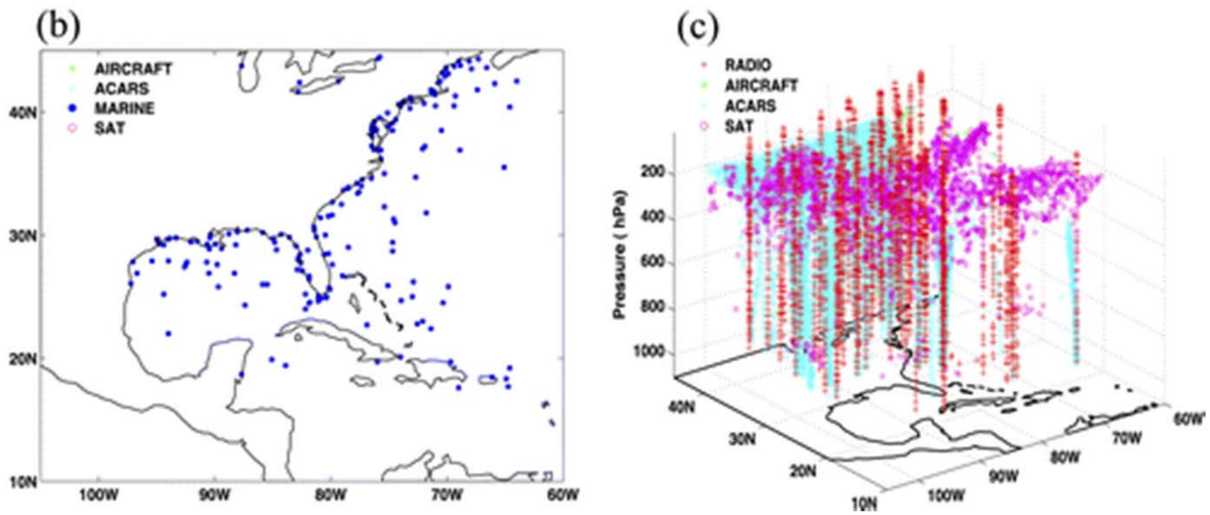
NEXRAD DA No-DA



Impact of surface data assimilation on prediction of landfalls of Hurricane Katrina (2005)

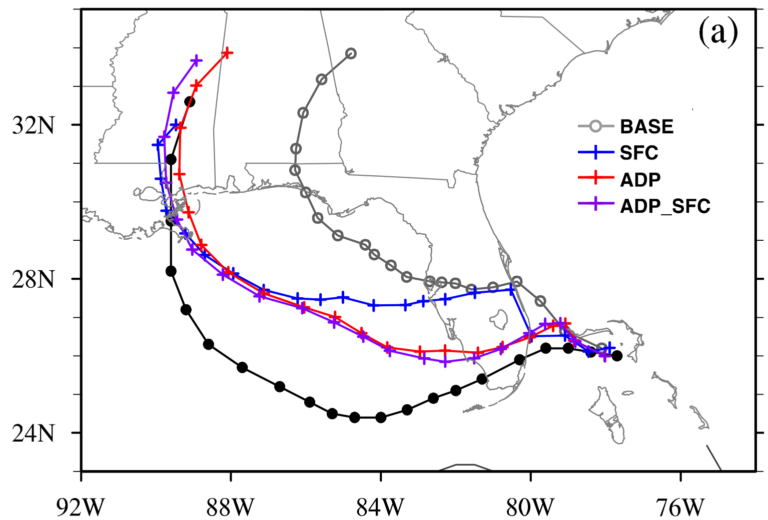


QuikSCAT Ocean Surface winds + Surface Mesonet data

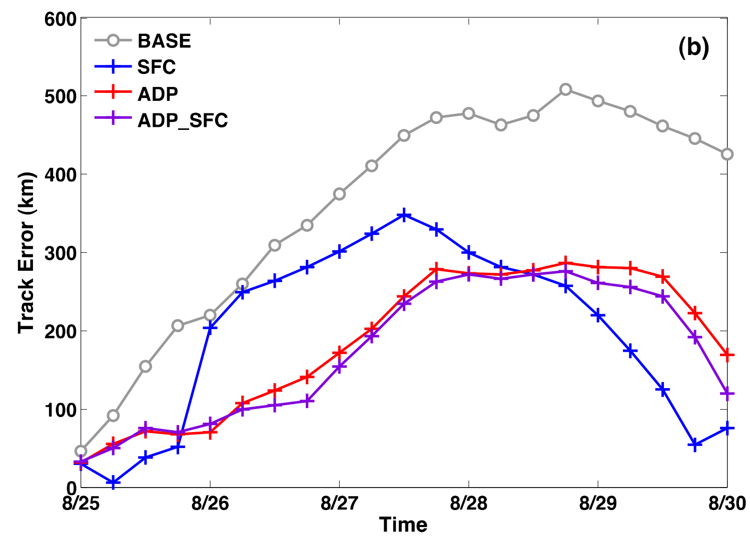


Impact of surface data assimilation on prediction of landfalls of Hurricane Katrina (2005) with EnKF

Track



Track errors



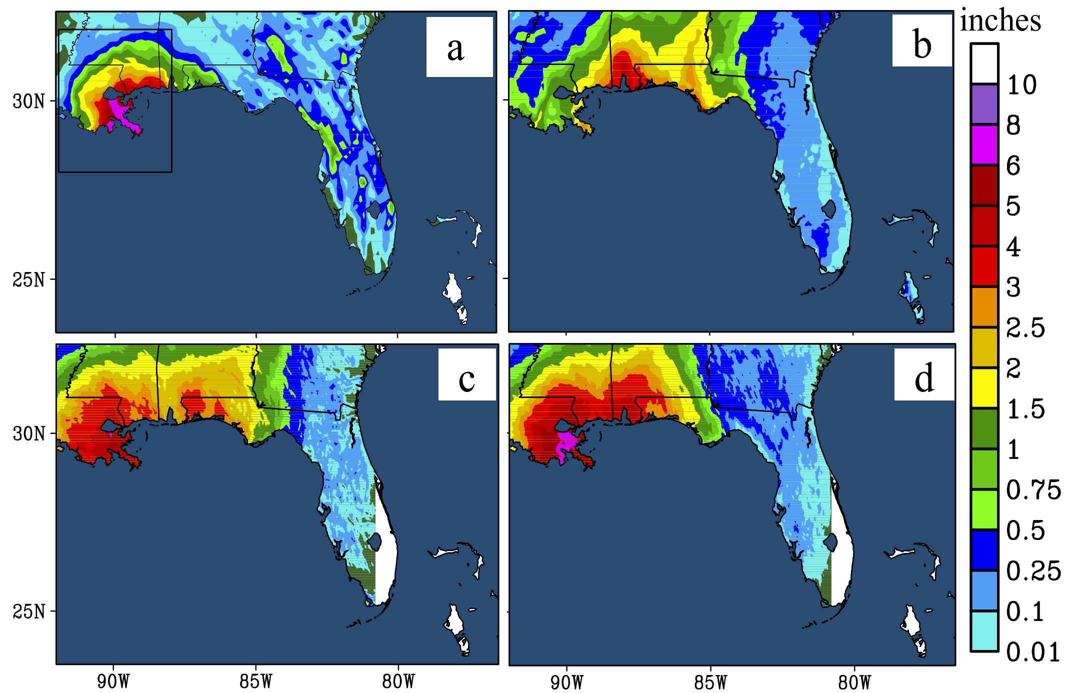
Base - Assimilation of center position
SFC - Assimilation of center position and surface data
ADP – Assimilation of NCEP conventional data
ADP_SFC - Assimilation of NCEP conventional data and surface observations
Data assimilation performed in first 18 hours. Forecast extends till 5 days.

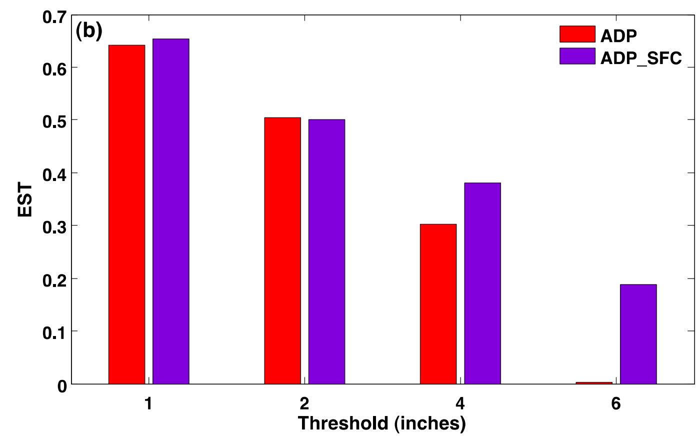
Zhang and Pu, 2014 MWR

Impact of surface data assimilation on prediction of landfalls of Hurricane Katrina (2005) with EnKF

Daily (24h) accumulated precipitation (inches)

12 UTC 29 August (108 h)

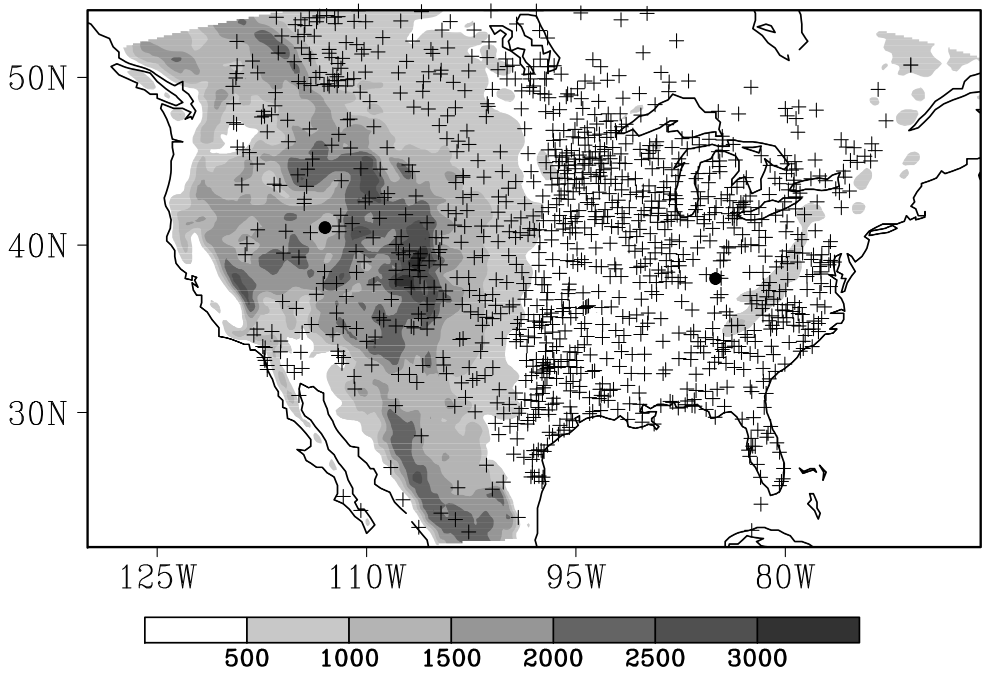




(a) CCPA analysis (b) SFC, (c) ADP, and (d) ADP_SFC.

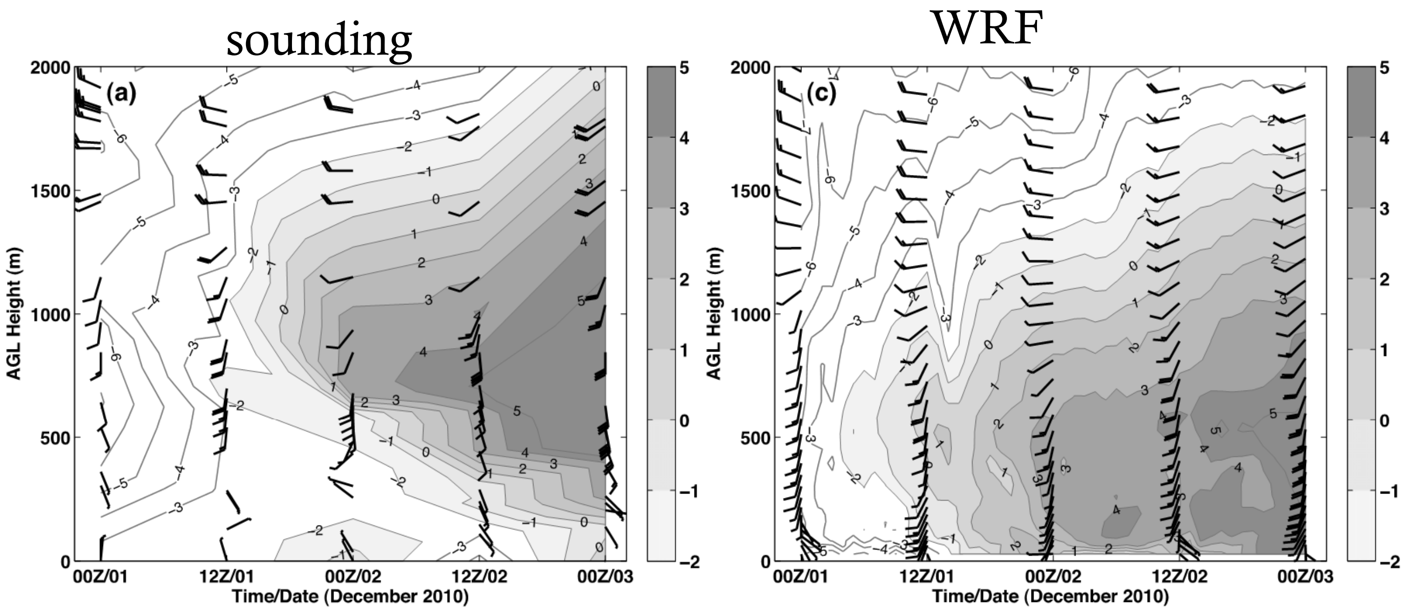
Zhang and Pu, MWR (2014)

Challenges of surface analysis and forecasts over complex terrain



- Mismatch between realistic and model terrain heights
- Poor representation of the land use and land surface processes
- Complicated interaction between the boundary layer and surface
- Predictability is under a combined influence from the limited model ability and the unpredictably intrinsic features.

The persistent inversion over Salt Lake Valley -- Complex terrain



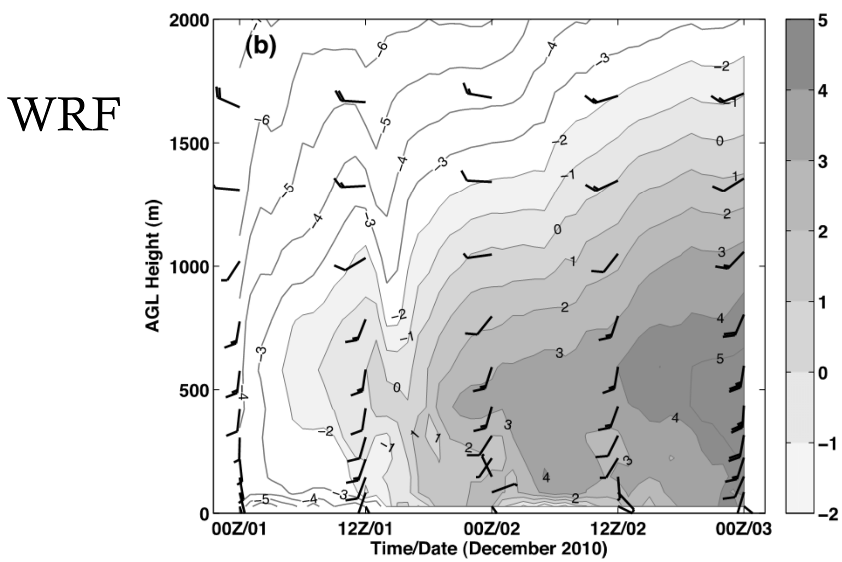


FIG. 8. Time series of vertical profiles of temperature (contour interval is 1°C) and wind at the KSLC (40.77°N, 111.85°W, elevation: 1289 m): (a) sounding observations, (b) ARW simulation from the 1.33-km domain with 37 vertical levels, and (c) ARW simulation from the 1.33-km domain with 70 vertical levels. Shaded contours represent temperatures greater than −2°C.

Zhang et al. (2013) WAF

The Mountain Terrain Atmospheric Modeling and Observations Program (MATERHORN)

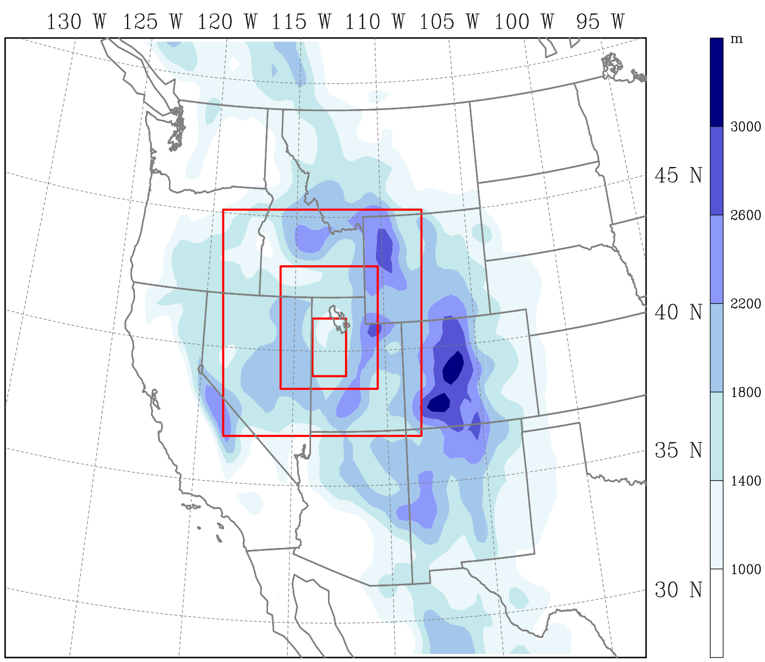
MATERHORN-M

- **To evaluate model performance in predicting synoptic and local flows over mountainous terrain and thus [model evaluation]**

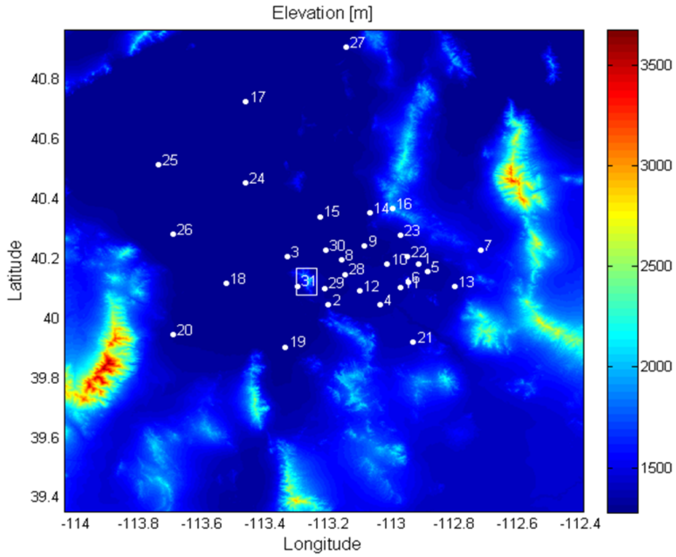
- **To improve predictability [data assimilation]**

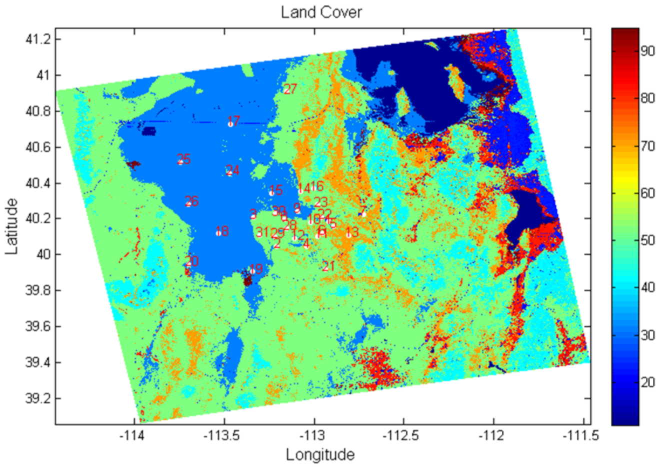
- **Two field experiments were conducted over Dugway Proving Ground (DPG), Utah during the fall 2012 (Sep. 21 – Oct. 20, 2012) and spring 2013 (May of 2013)**

Evaluate WRF near-surface temperature and wind forecasts



30km/10km/3.3km/1.1 km





WRF real-time forecasting

- **WRF model configuration**
  - WRF V3.3
  - Model horizontal resolution 30km/10km/3.3km/1.1 km
  - 4 sets of 48-h forecasts per day from 00Z, 06Z, 12Z and 18Z.

- **Performed during pre-MATERHORN 2011 and MATERHORN fall 2012**

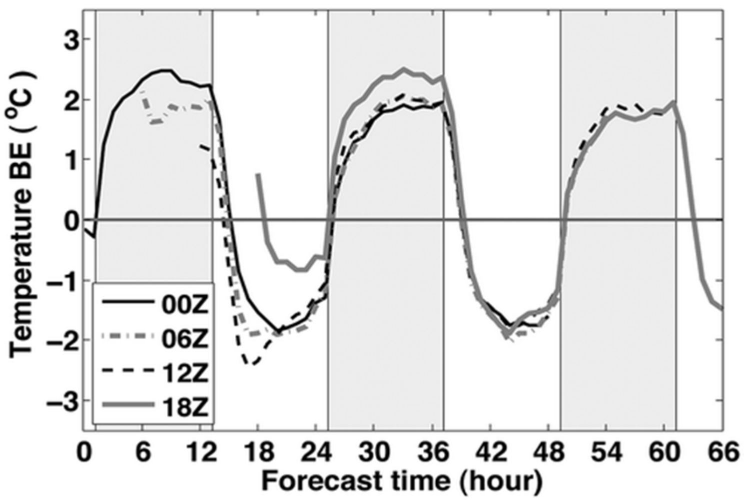
- Fall 2011 [Sep. 15 – Oct. 14, 2011] - 120 48-h forecast / 4 times per day
- Fall 2012 [Sep. 25 – Oct. 24, 2012] - 120 48-h forecast / 4 times per day

- **Post-field evaluation is conducted** with the verification against
  - Surface Mesonet observations: 2-m temperature and 10-m wind [SAMS]
  - Sounding observations [Sagebrush and Playa] during IOPs
  - Lidar profiles over Granite mountain area during some IOPs

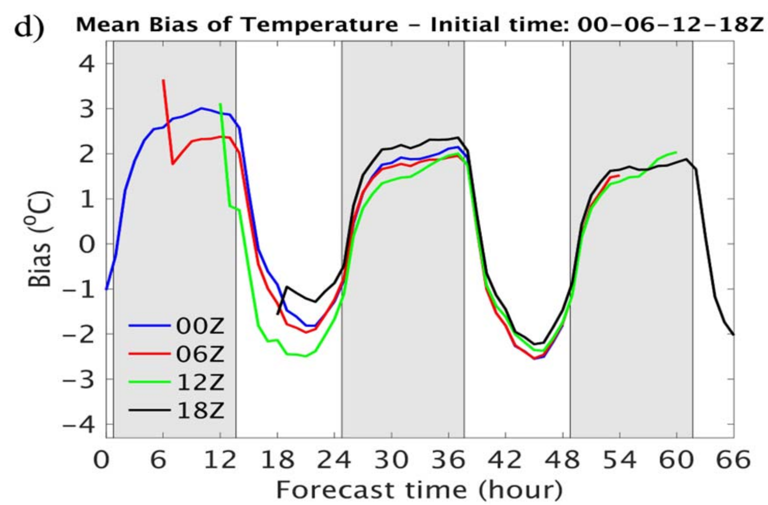
Temperature forecast biases

Variation of Mean Bias with Forecast Time – 2-m Temperature

Sep.- Oct. 2011



Sep.- Oct. 2012



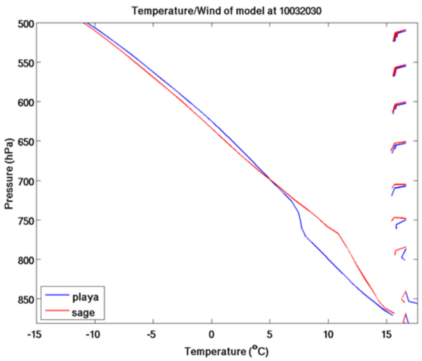
- Warm bias during nighttime
- Cold bias during daytime.

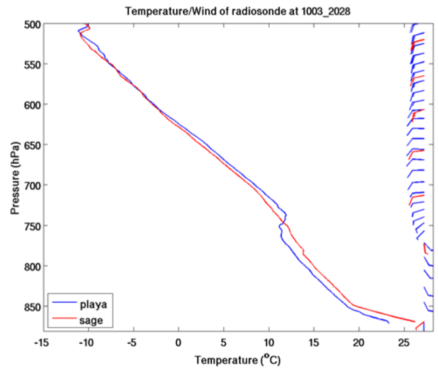
- Statistically, wind speed bias is very small in most of stations.

Sagebrush versus Playa

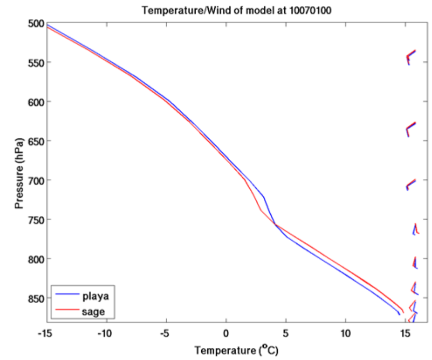
Model simulations **vs.** Radiosonde data of temp/wind

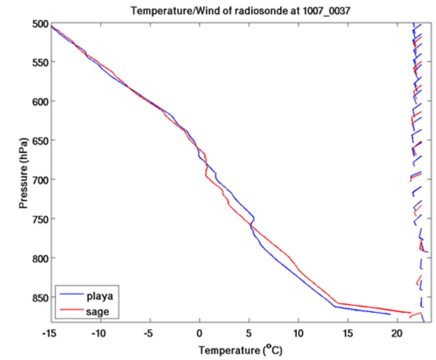
2030 UTC 3 Oct. 2012





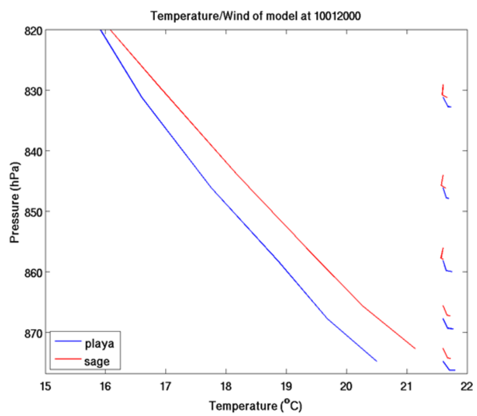
0030 UTC 7 Oct. 2012



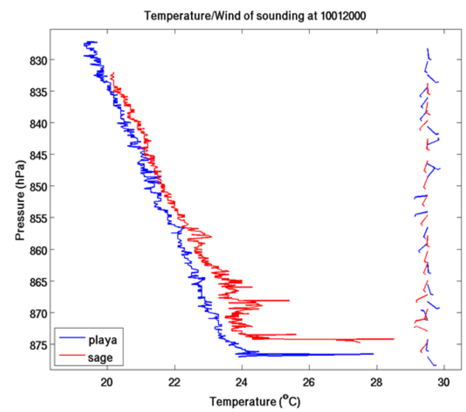


2000 UTC 1 Oct. 2012

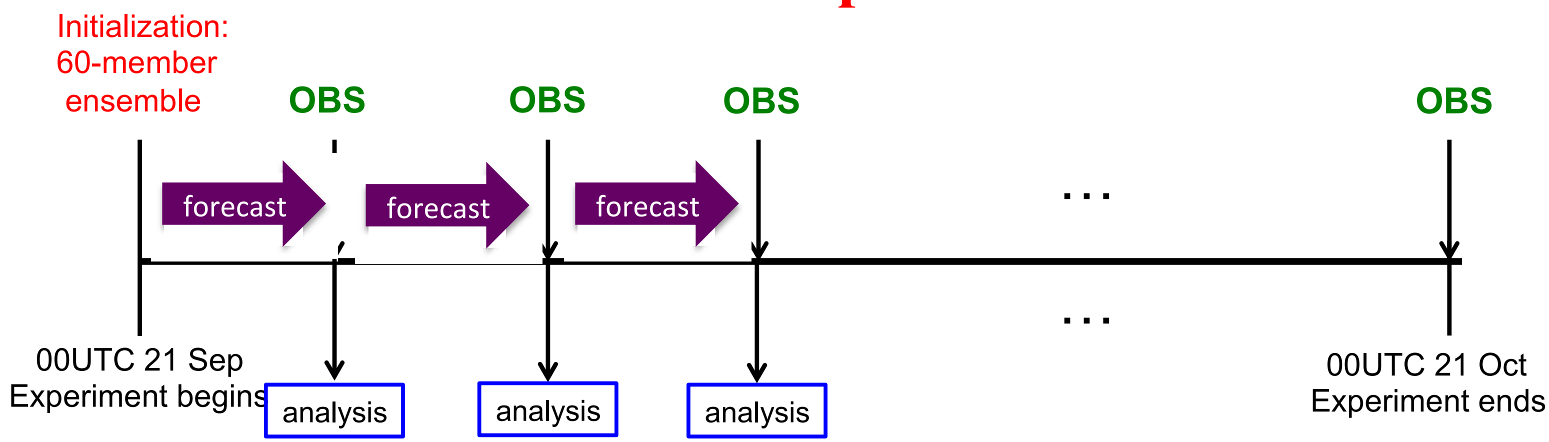
Model simulations

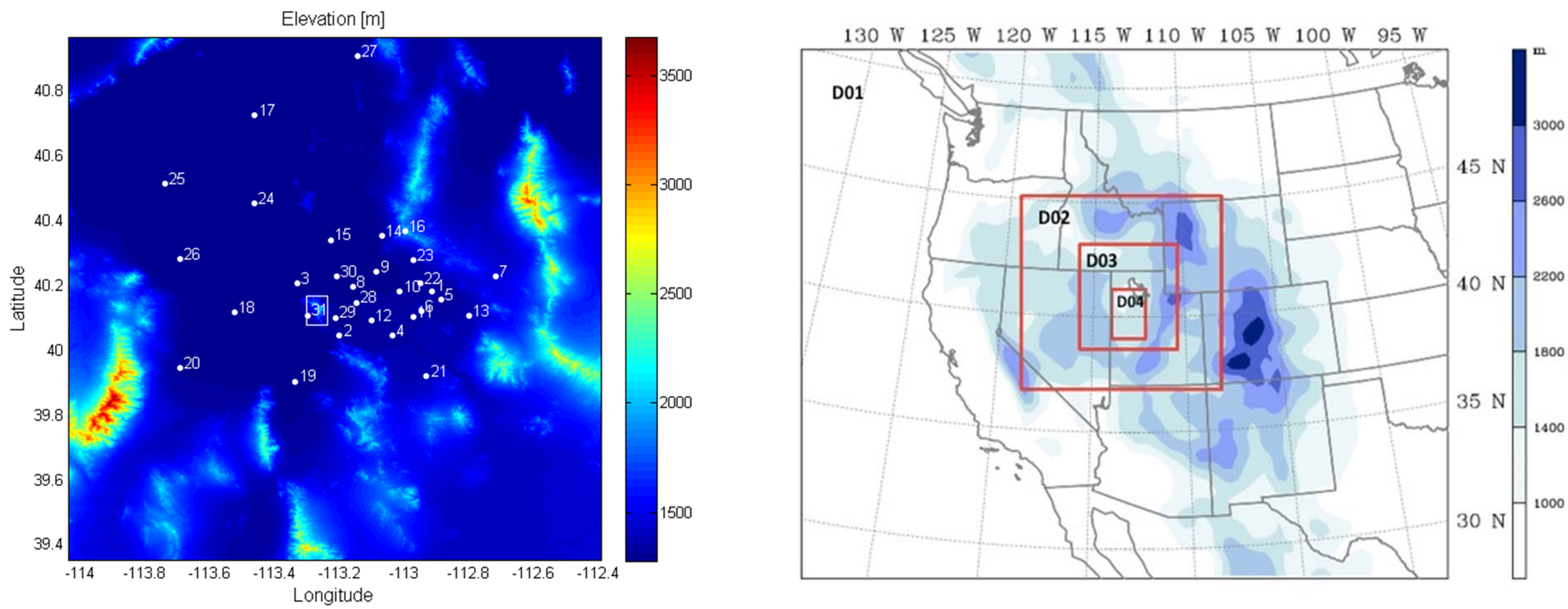


Tethersonde data of temp/wind



EnKF analysis and forecast cycles for MATERHORN fall 2012 experiment

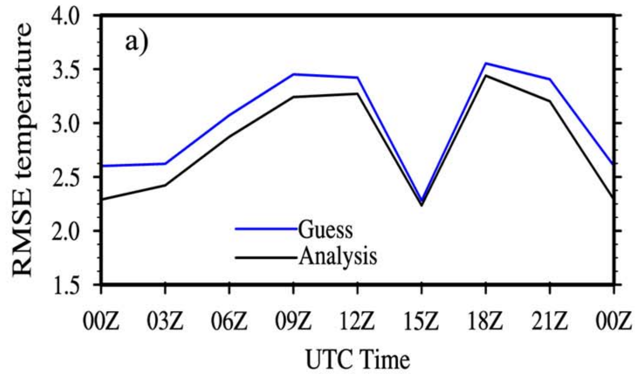




D04 - Dugway Proving Ground

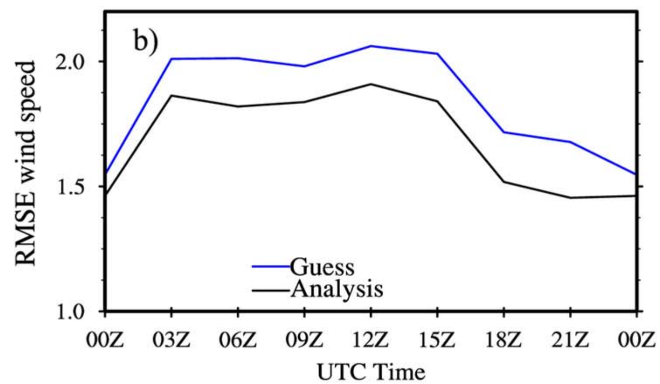
RMS Errors

Temperature



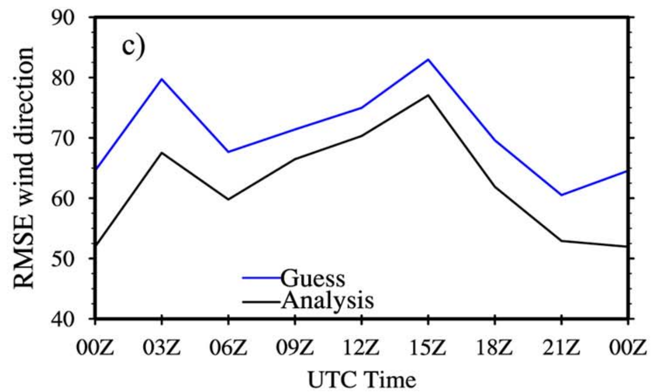
WRF 3-h forecast
vs.
EnKF Analysis

Wind speed



Averaged over whole month (21 September to 20 October 2012) over all 60 ensemble members based on the average of all surface stations

Wind direction



Sensitivity of near-surface temperature forecasts to soil moisture errors

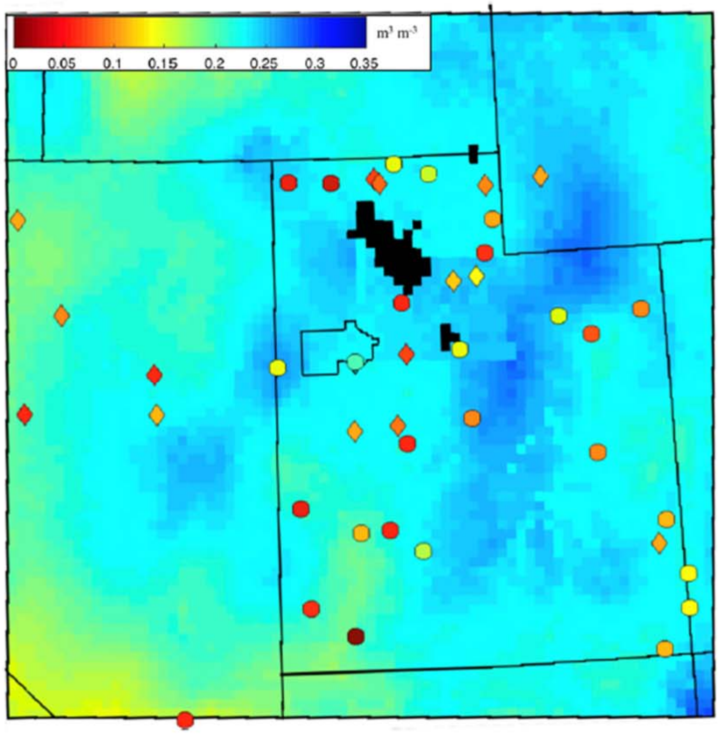


FIG. 8. Mean 0000 UTC 5-cm soil moisture (or equivalent) from the 4DWX-DPG 10-km domain and NASMD stations (SCAN, circles; GPS, diamonds) during September and October 2011–13.

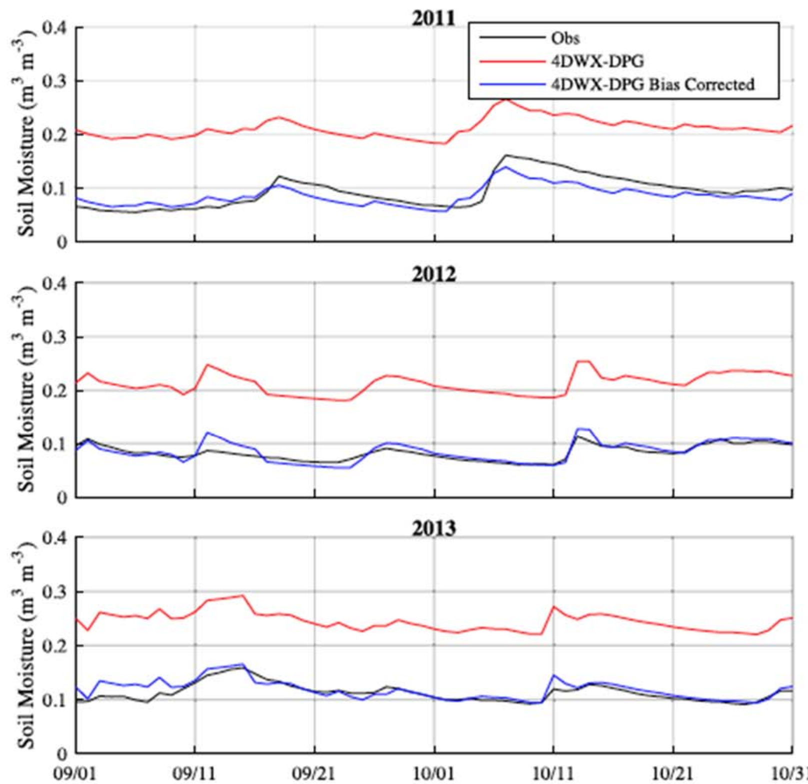
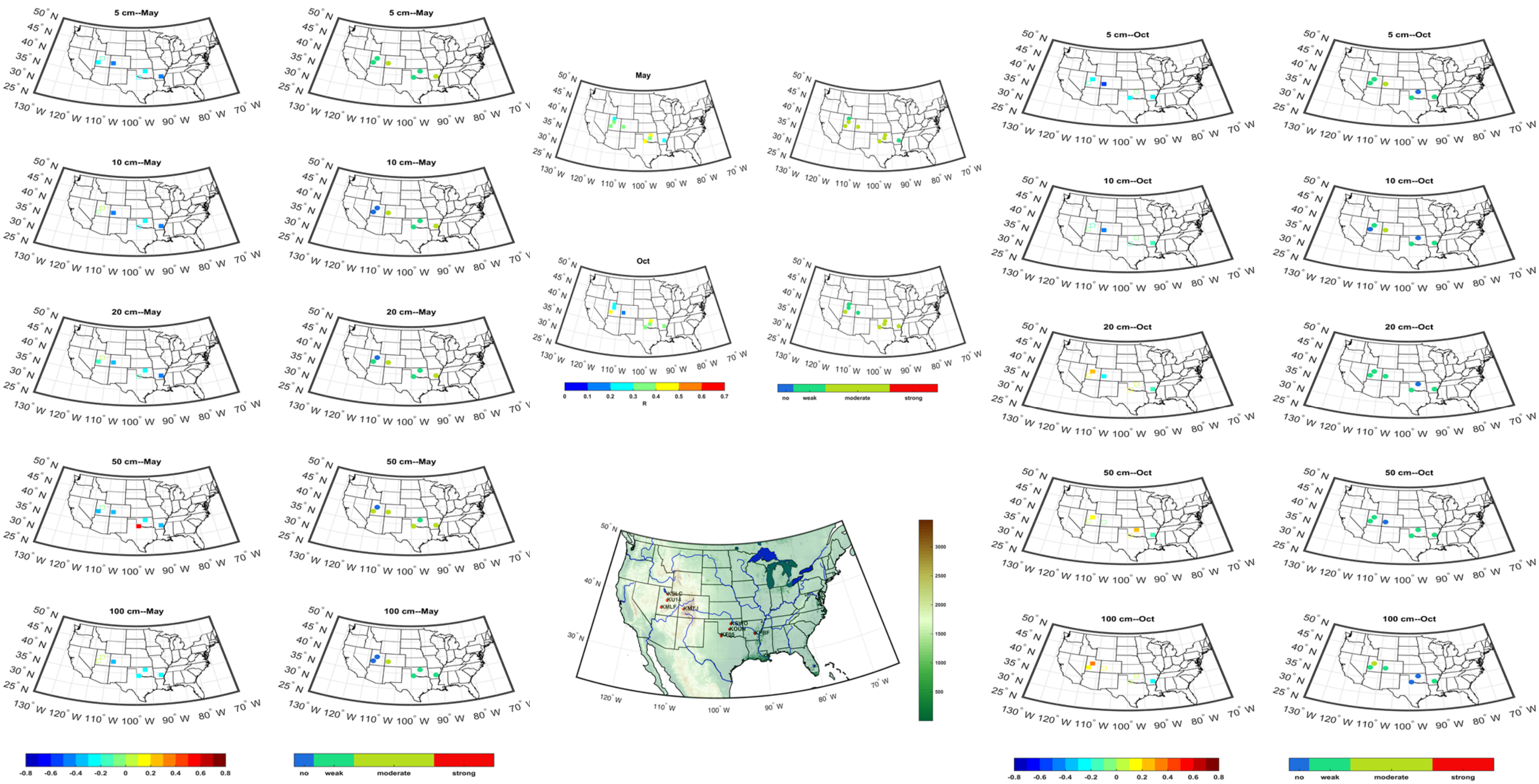


FIG. 9. Mean daily observed (black), 4DWX-DPG (red), and 4DWX-DPG bias-corrected (blue) 5-cm soil moisture for all NASMD stations in the 10-km domain.

Soil moisture difference

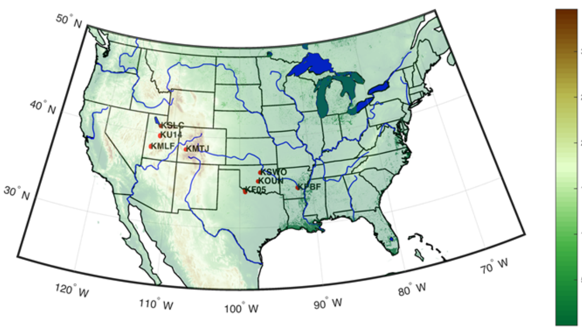
Masey et al. 2015

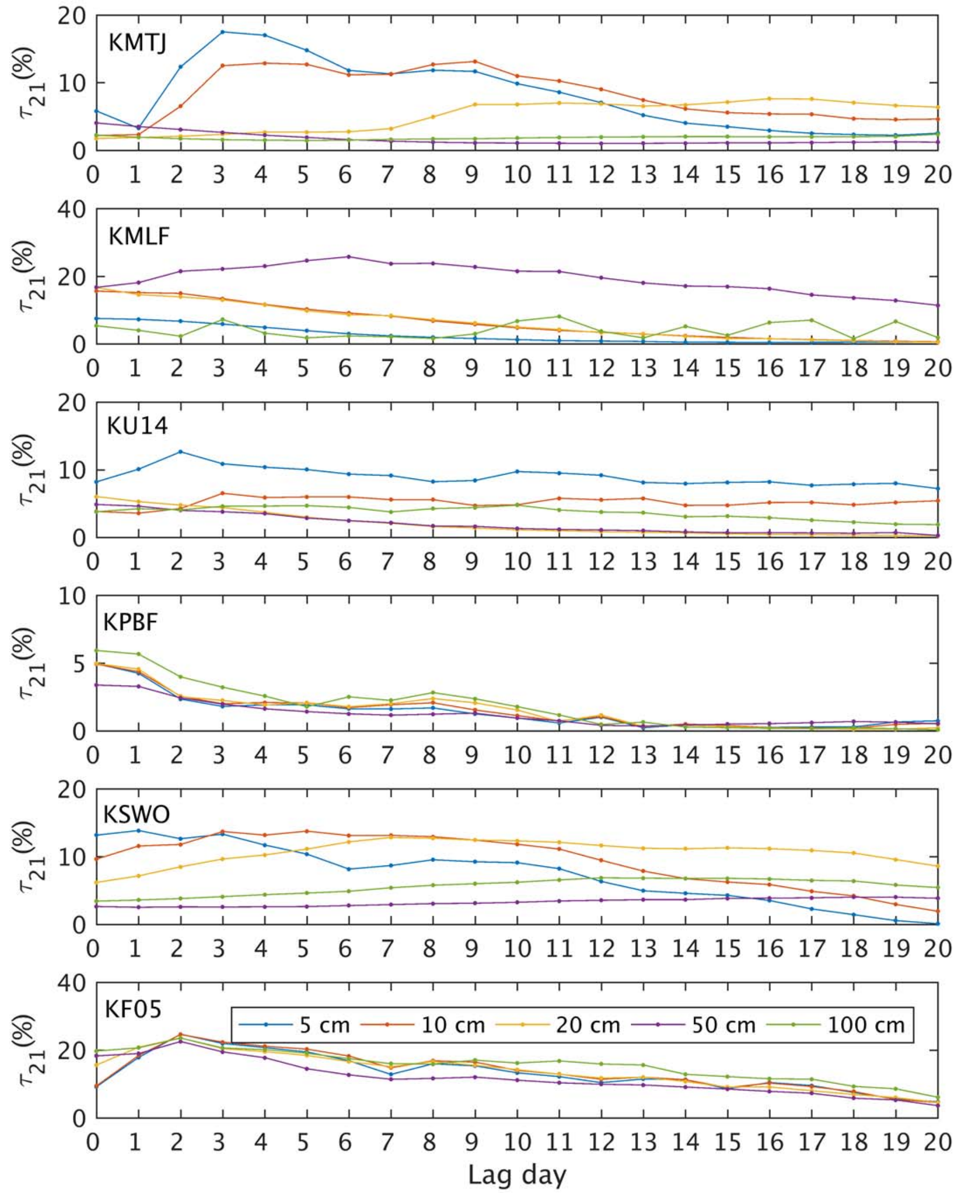
Correlation between 2-m temperature and soil moisture



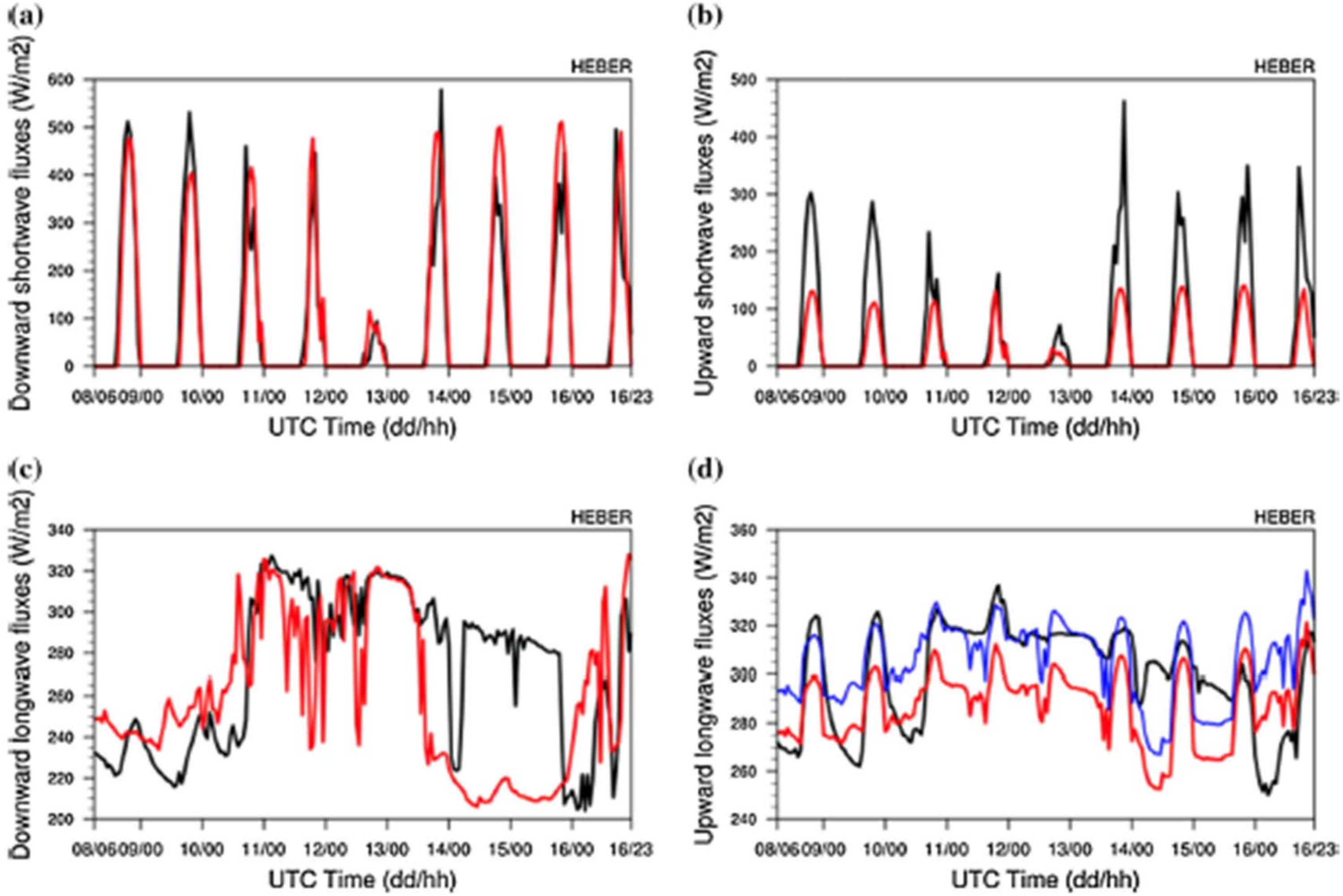
The most correlation coefficients (R) varies between -0.5 and 0.5.

Causality Analysis between 2-m temperature and soil moisture





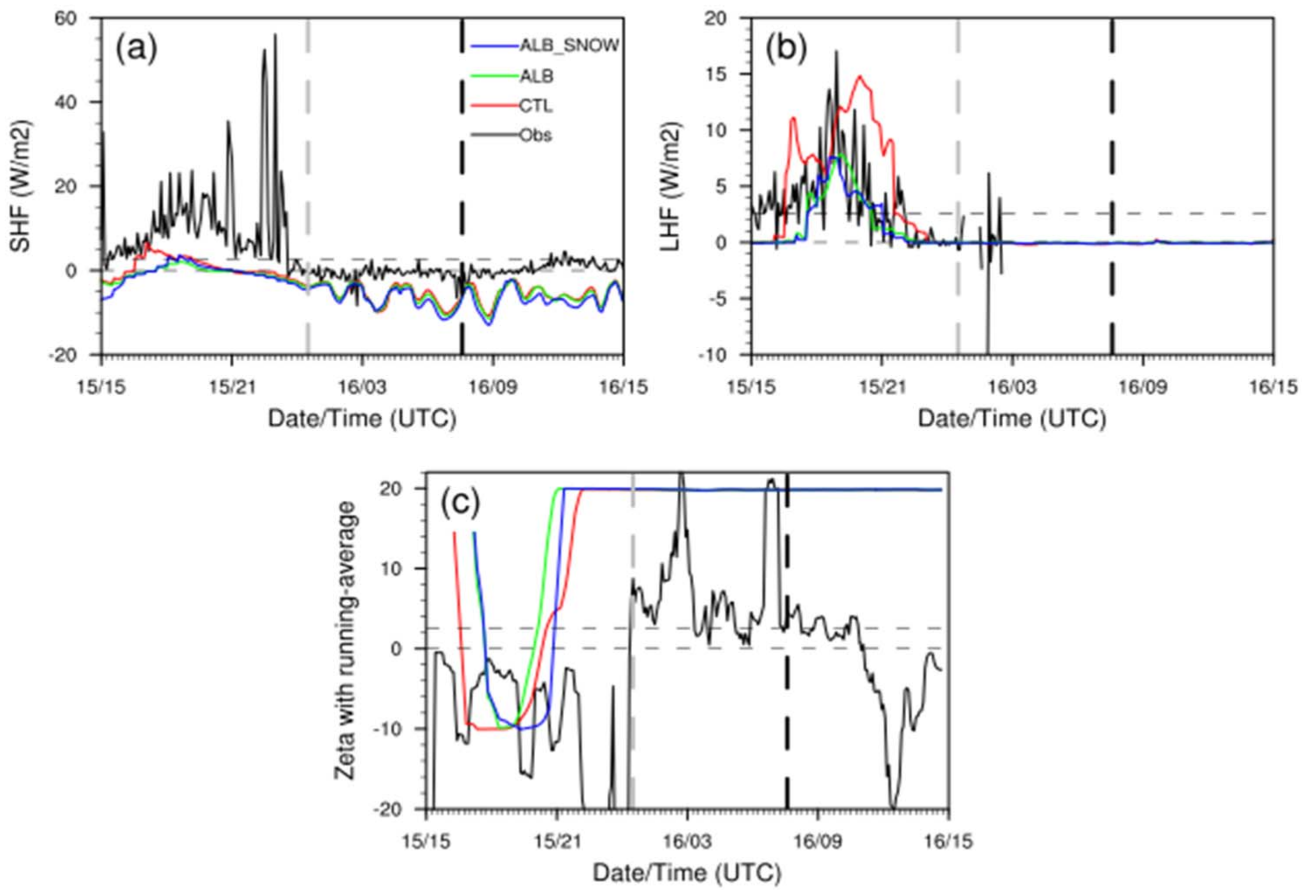
Surface Radiation Balance Over Heber City
06 UTC 08 – 23 UTC 16 Jan. 2015



a Downward shortwave fluxes (W m^{-2}), b Upward shortwave fluxes (W m^{-2}), c Downward longwave fluxes (W m^{-2}), d upward longwave fluxes (W m^{-2}). T he blue line in d represents the net longwave radiation fluxes from the surface

Pu et al. 2016, PAAG

Sensitivity of surface fluxes to snow-cover and albedo



(a) surface sensible heat flux (SHF, unit: W m^{-2}), (b) surface latent heat flux (LHF, unit: W m^{-2}) and (c) near surface stability (ζ) between the observation and different simulations.

15 UTC 15 to 15 UTC 16 Jan 2015

Concluding remarks

- Surface observations have significant impacts on forecasts of extreme weather events

- There are challenges in surface analysis and forecasts over complex terrain. Reducing errors in diurnal variation of 2-m temperature is a large area for the future study.

- Observation requirements
  - More atmospheric soundings and soil state observations over complex terrain
  - Satellite or remote sensing surface observations on land cover (e.g., snow cover, etc.), surface fluxes, energy balance, etc.

- Improve near-surface layer parameterizations and land-atmospheric coupling schemes

Thank you!

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