Enhancing surface data assimilation and near-surface weather forecasts in NGGPS through improved coupling between the land-surface and atmosphere

Zhaoxia Pu
University of Utah

Acknowledgements
Mike Ek and Vijay Tallapragada
NOAA/NCEP/EMC

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Problems/Objectives

- **Near-surface weather forecasts remain a challenging problem in modern numerical weather prediction due to difficulties in surface data assimilation and complicated interaction between the land surface and the atmospheric boundary layer.**

- **We plan to develop effective data assimilation methods and improved near-surface parameterization schemes that can enhance the assimilation of surface observations and near-surface weather forecasts through improved coupling between the land surface and the atmosphere.**

We will use

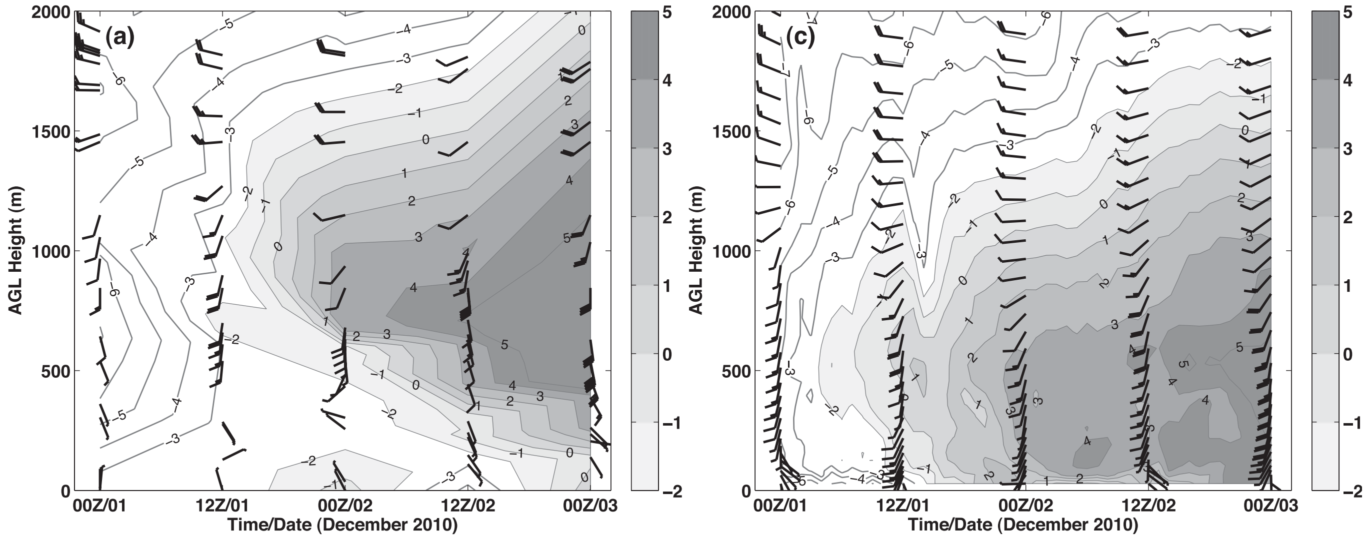
- **NCEP Next Generation Global Prediction System (NGGPS)**
- **The Noah land surface model**
- **The GSI-based hybrid 4dEnVar data assimilation system.**

With emphasis on surface data assimilation, soil moisture data assimilation, and land-atmosphere coupling

Near Surface temperature (and wind) errors are significant

sounding

WRF



WRF

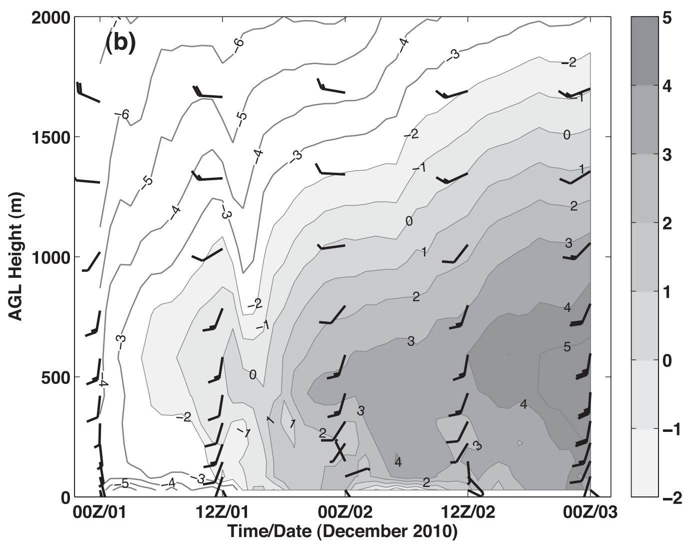


FIG. 8. Time series of vertical profiles of temperature (contour interval is 1°C) and wind at the KSLC (40.77°N, 111.85°W, elevation: 1289 m): (a) sounding observations, (b) ARW simulation from the 1.33-km domain with 37 vertical levels, and (c) ARW simulation from the 1.33-km domain with 70 vertical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

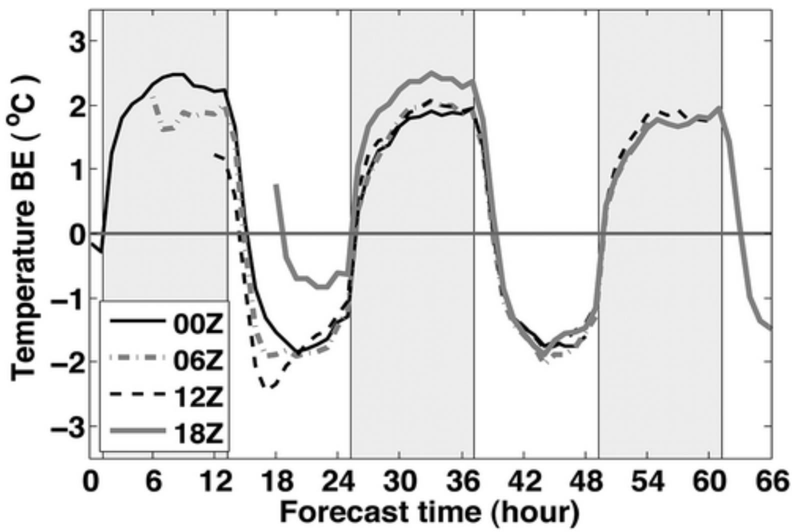
Zhang et al. 2013

The persistent inversion over Salt Lake Valley -- Complex terrain

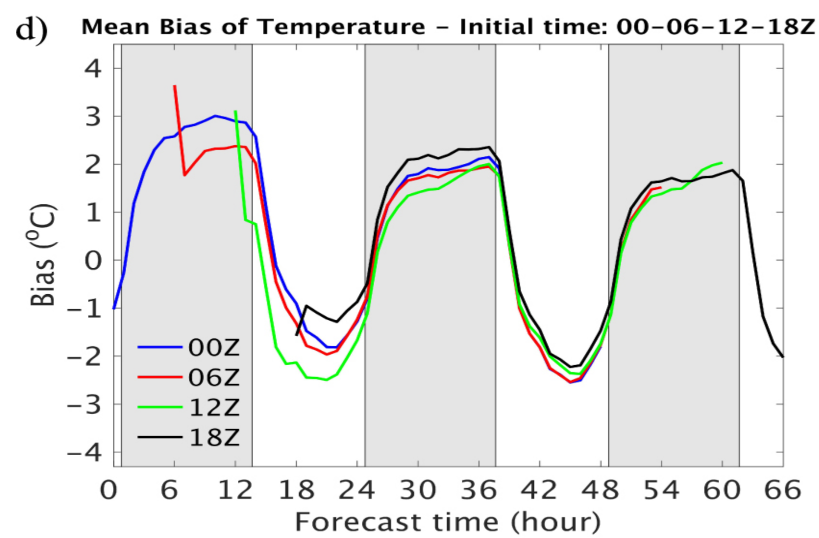
Near-Surface Temperature Forecast Biases

Variation of Mean Bias with Forecast Time – 2-m Temperature
Dugway Proving Ground, Utah

Sep.- Oct. 2011



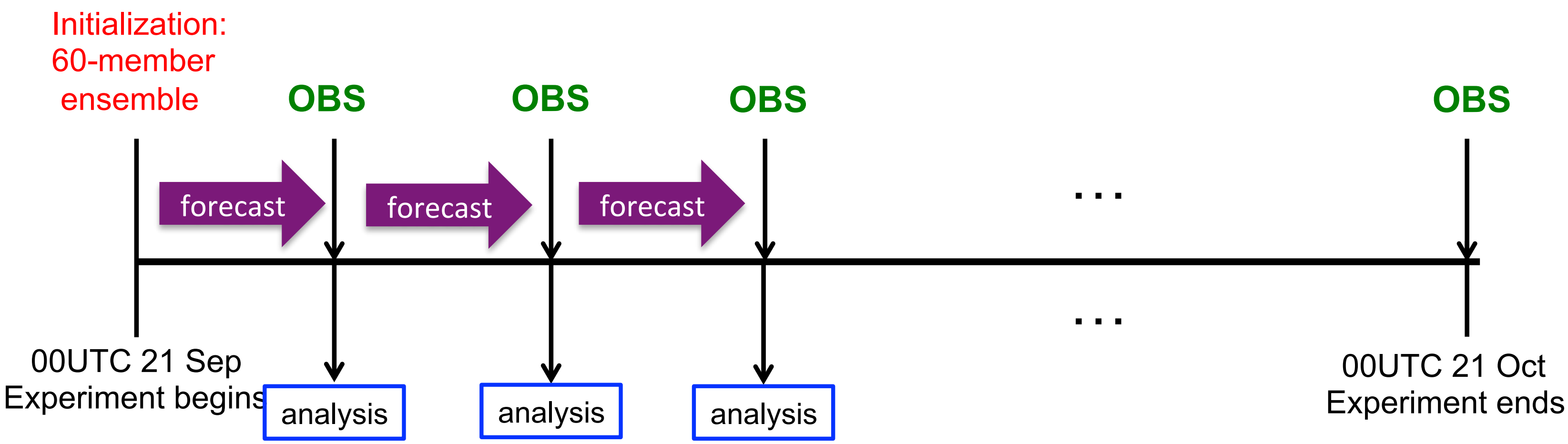
Sep.- Oct. 2012

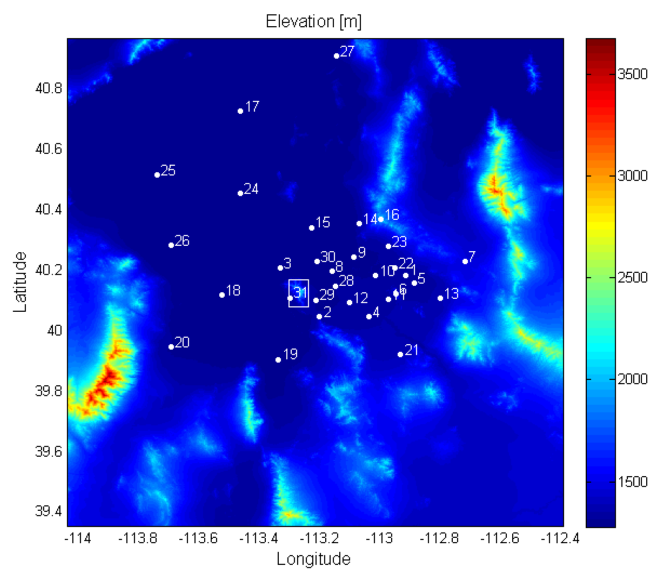


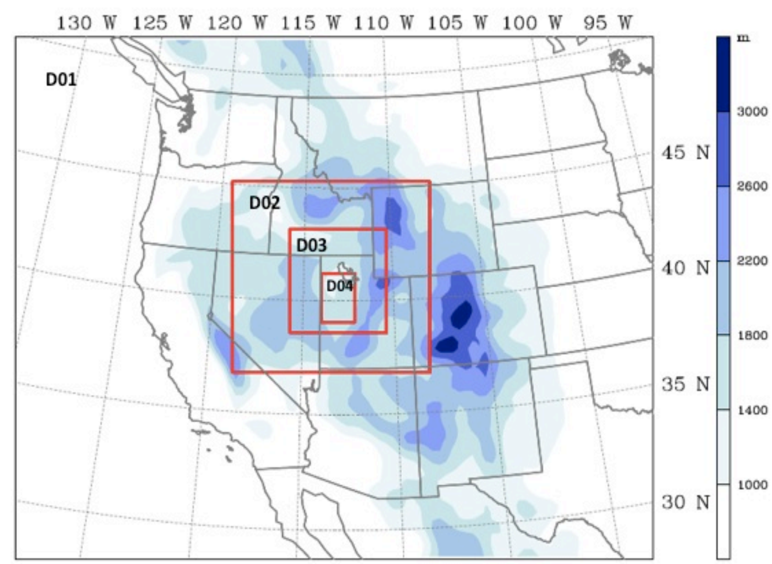
Warm biases during nighttime / Cold biases during daytime

Zhang et al. 2013; Pu 2017

Surface data assimilation with EnKF during MATERHORN fall 2012 experiment



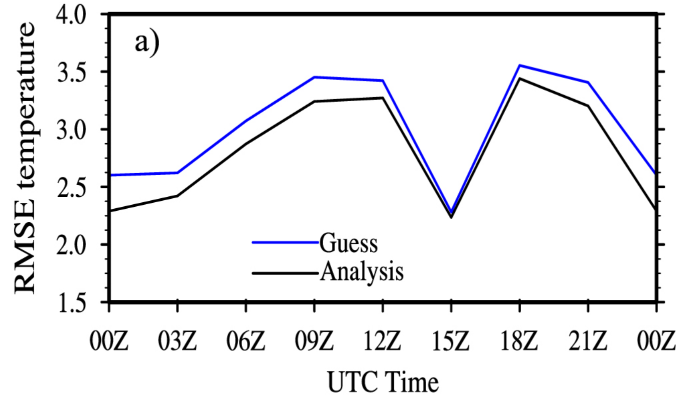




D04 - Dugway Proving Ground

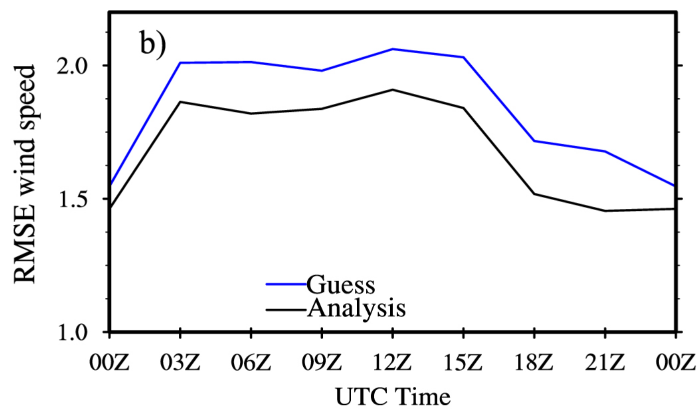
RMS Errors

Temperature



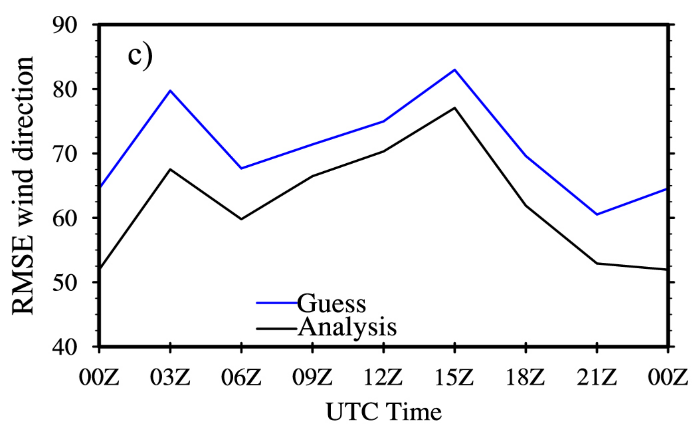
WRF 3-h forecast
vs.
EnKF Analysis

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

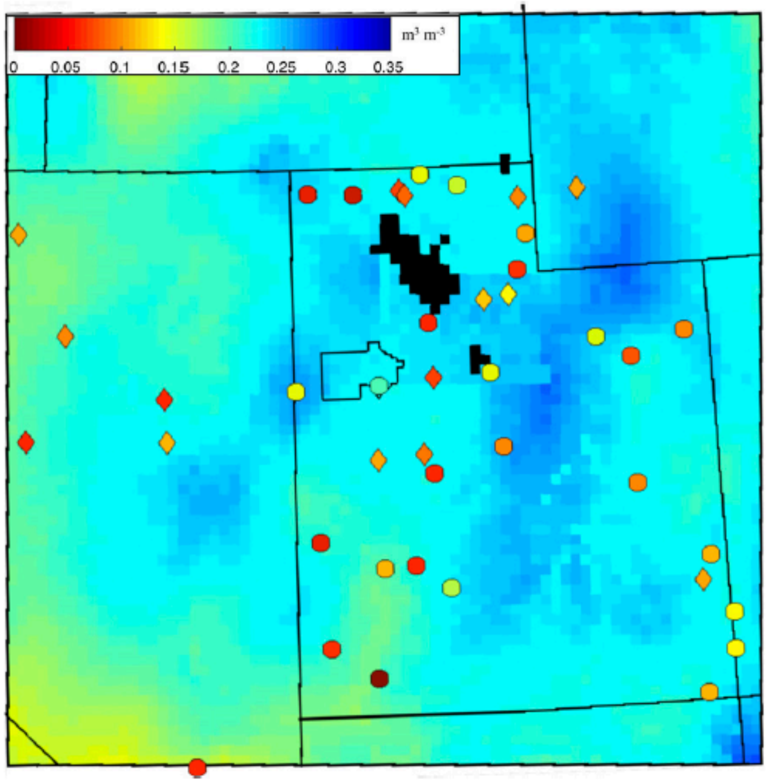


FIG. 8. Mean 0000 UTC 5-cm soil moisture (or equivalent) from the 4DWX-DPG 10-km domain and NASMD stations (SCAN, circles; GPS, diamonds) during September and October 2011–13.

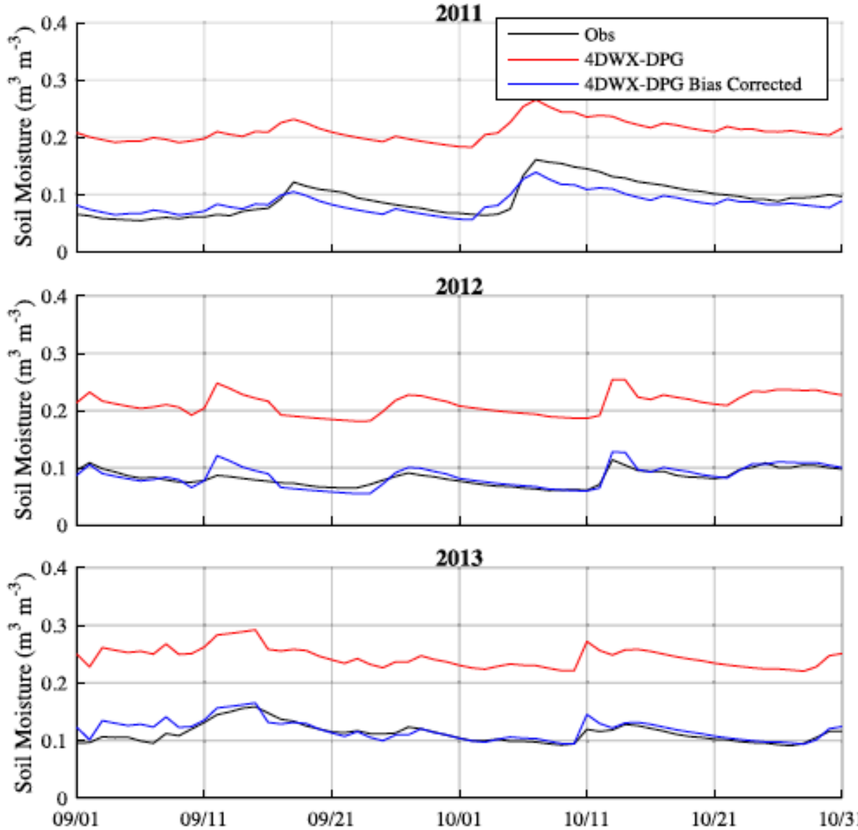


FIG. 9. Mean daily observed (black), 4DWX-DPG (red), and 4DWX-DPG bias-corrected (blue) 5-cm soil moisture for all NASMD stations in the 10-km domain.

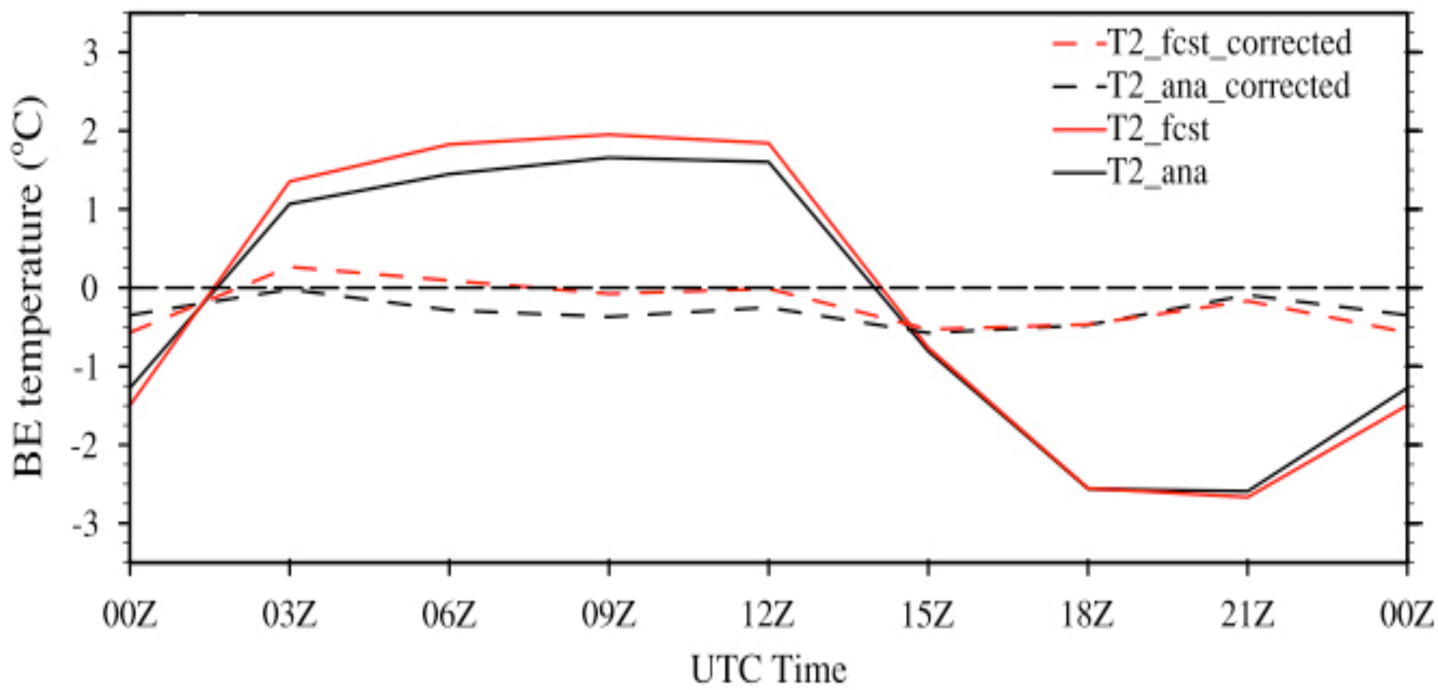
Soil moisture difference

Improved soil moisture conditions can result in better near surface forecasts.

From Massey et al. 2015

Remove diurnal forecast biases in 2-m temperature analysis/forecasts

Fall 2012



Project Milestones

- Evaluate the error characteristics of near-surface weather forecasts; identify the systematic biases.

- Examine the association between errors in near-surface variables within the atmospheric model and uncertainties in soil moisture within the land surface model; explore the statistical relationship/correlations between these two.

- Develop effective ensemble error covariances between near-surface atmospheric variables and soil moisture. Test effective empirical or fully coupled schemes to improve the coupling between the land surface and the atmosphere.

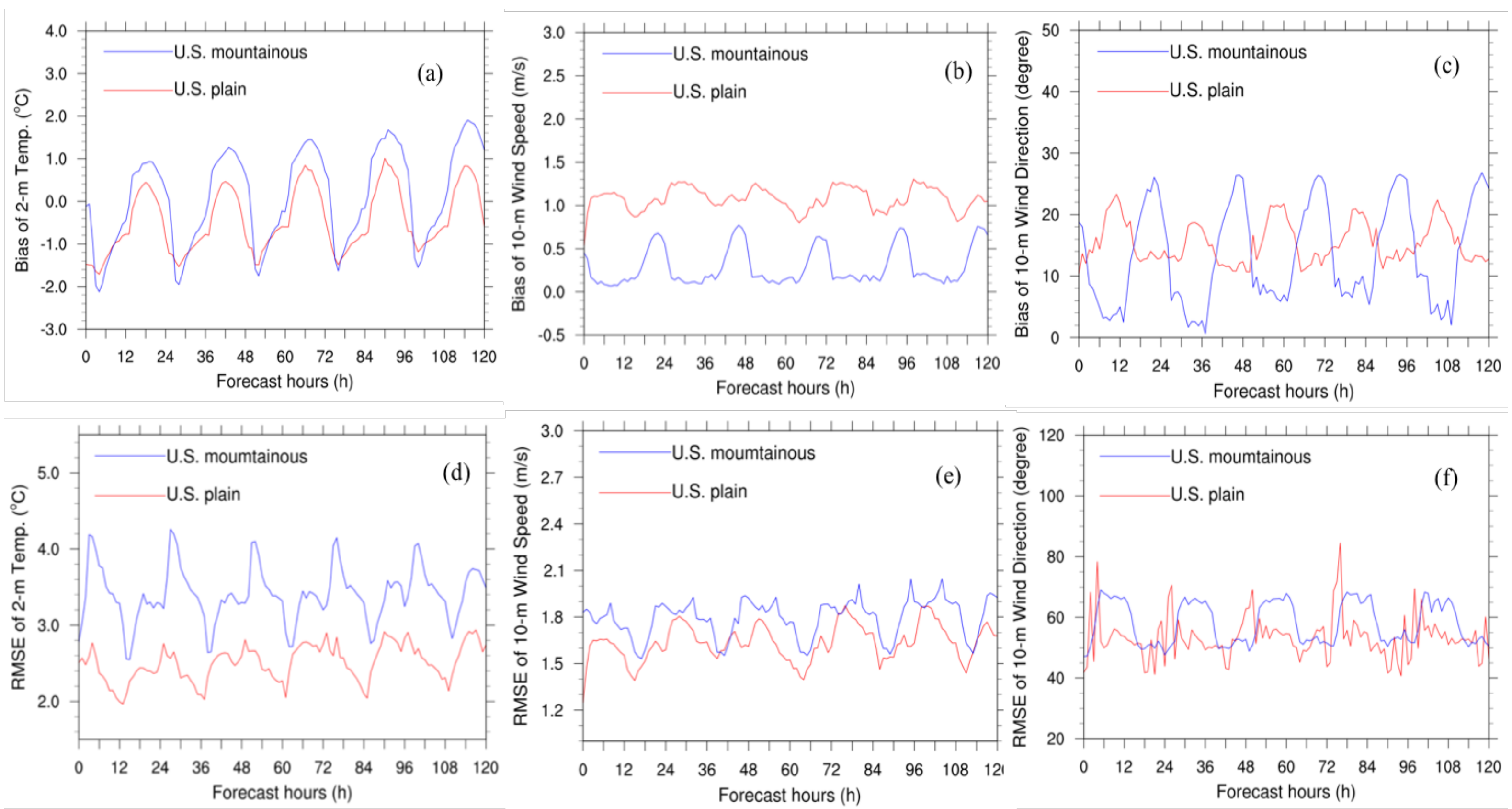
- Establish more realistic ensemble error covariances between near-surface atmospheric variables and middle to upper atmospheric conditions to ensure proper assimilation of surface observations.

- Develop an effective vertical diffusion scheme within the planetary boundary layer parameterization to enhance interaction between the surface heat and moisture fluxes and atmospheric boundary layers.

Evaluate the error characteristics of near-surface weather forecasts (Graduate Student F. Li)

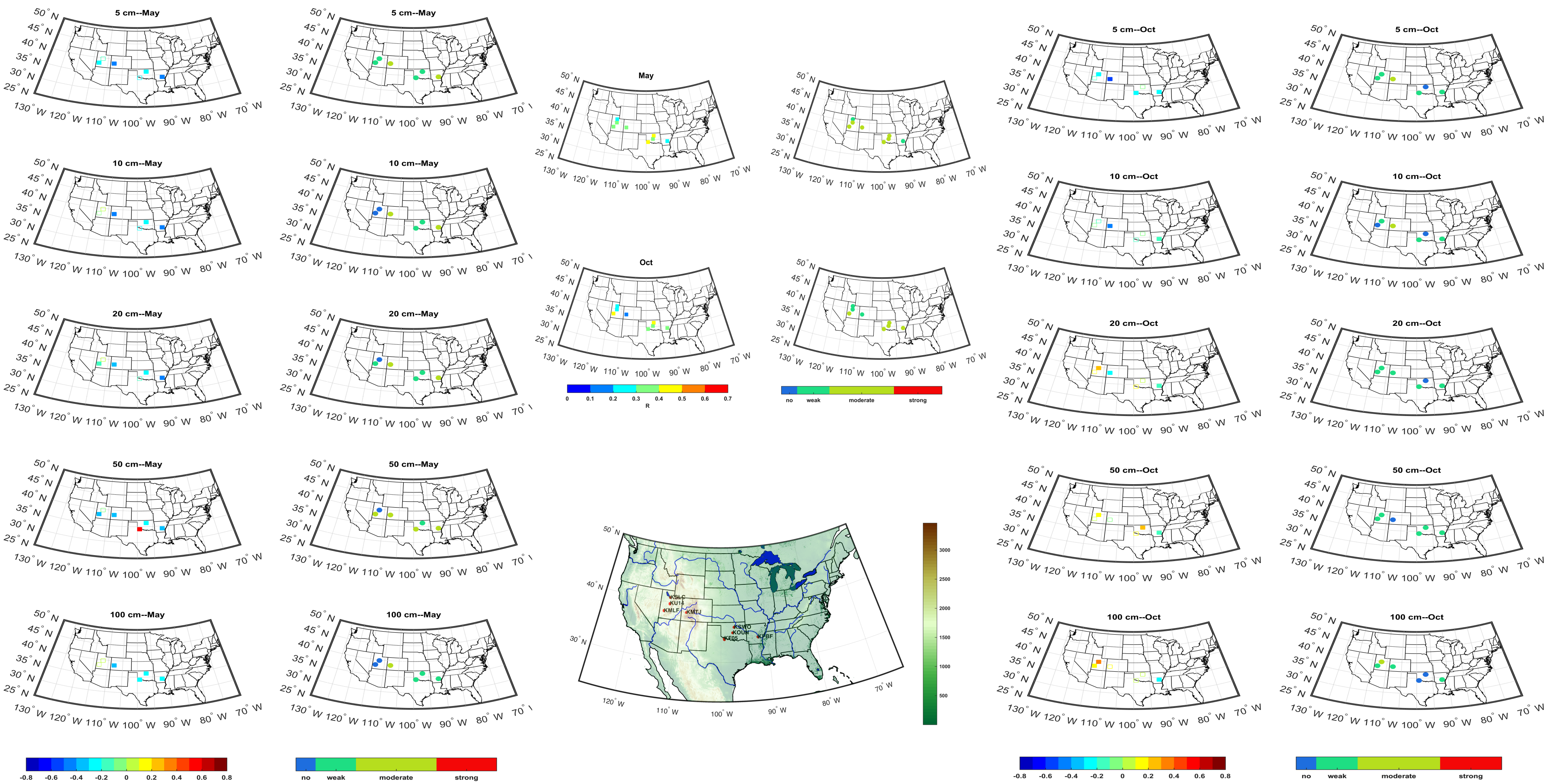
Mean bias and RMSE for 2-m temperature and 10-m winds

GFS. - U. S. Mountainous vs. U. S. Plains
00UTC FCST, June 2016



Correlation between 2-m temperature and soil moisture

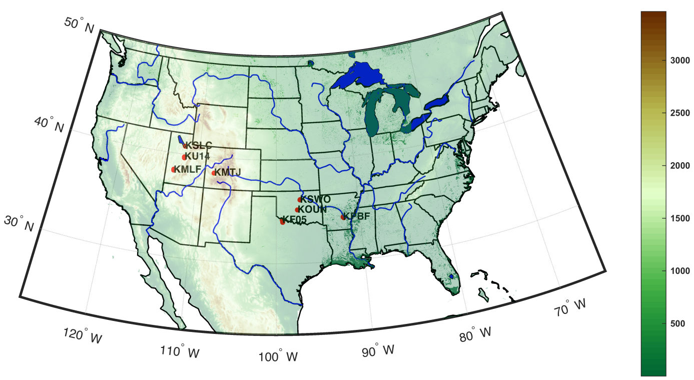
(Graduate Student J. Liu)

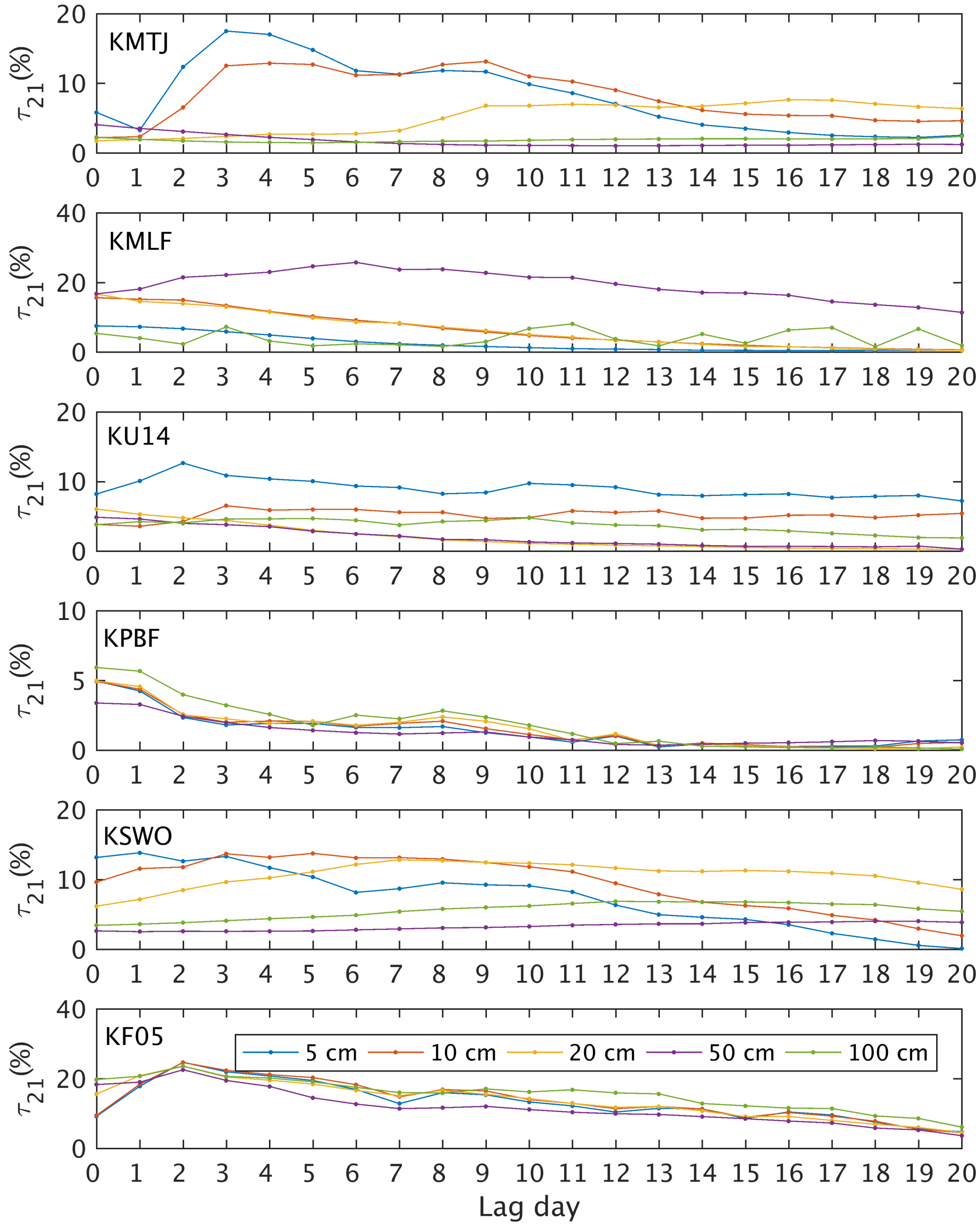


In-situ data (2008-2016)

The most correlation coefficients (R) varies between -0.6 and 0.6.

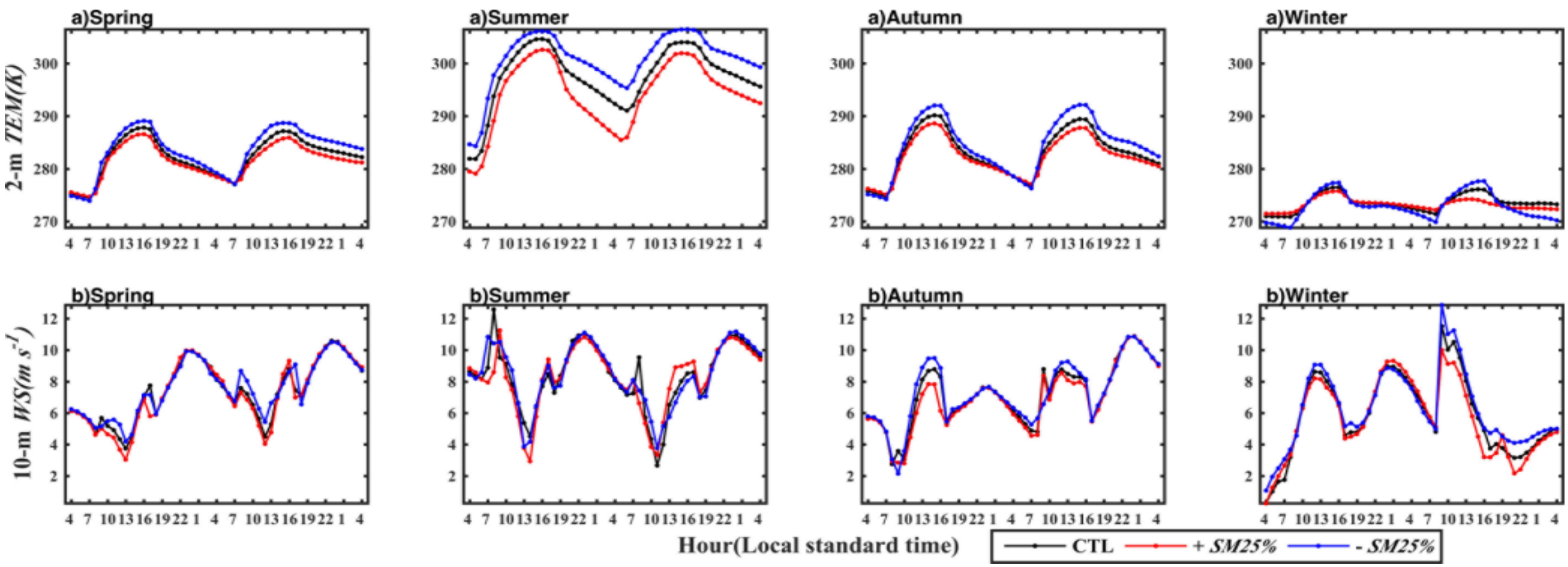
Causality Analysis between 2-m temperature and soil moisture





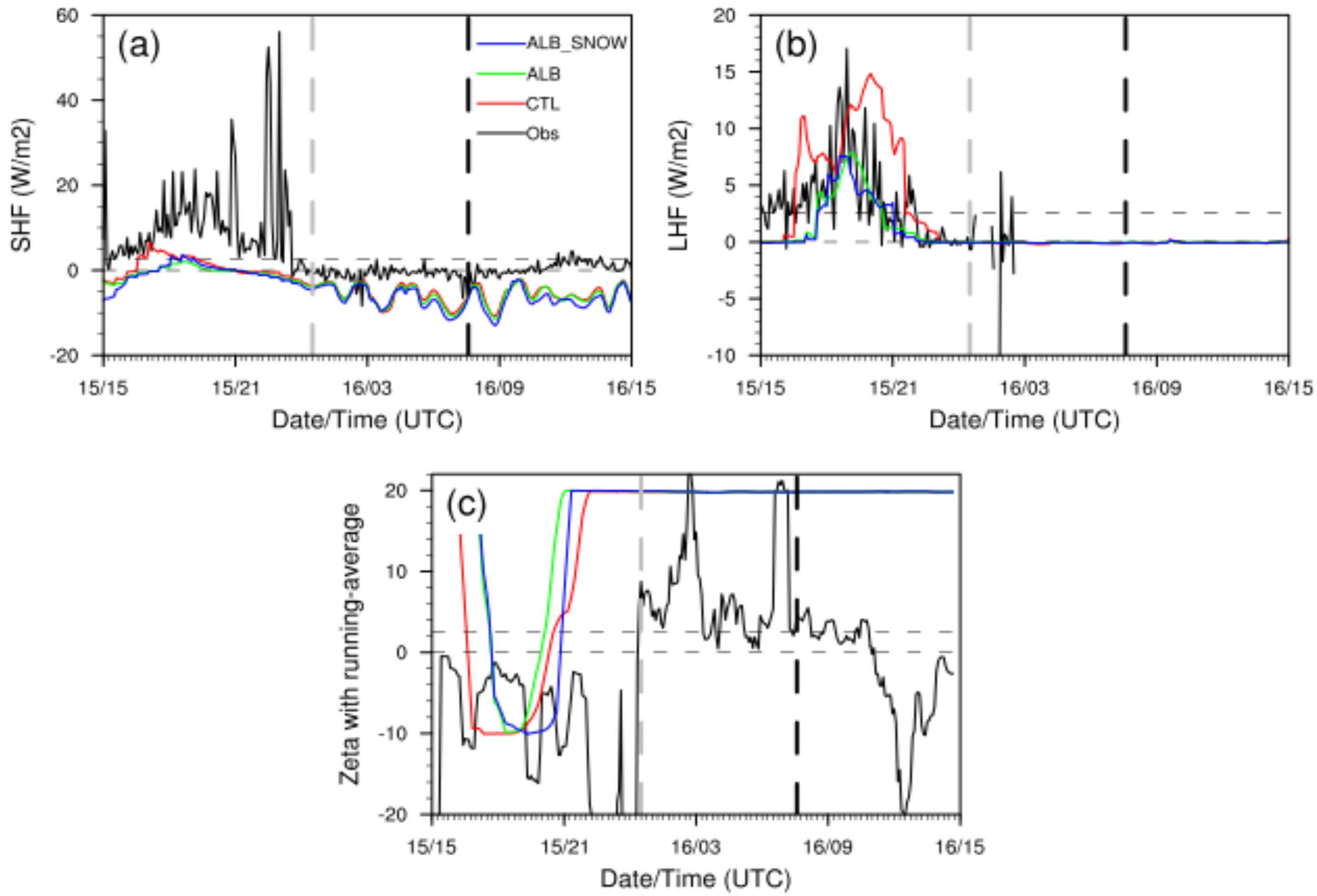
Single column model study (Student J. Liu)

Sensitivity of near-surface variable forecasts to the changes in soil moisture and land use



- As the soil moisture increases, the 2-m temperature decrease and the diurnal temperature variation becomes smaller, while the decrease in soil moisture has opposite effects.
- The most influence of soil moisture on 2-m temperature forecast comes from the first soil layer (5 cm).
- The changes in wind speed and direction with the variation of soil moisture are complicated.

Sensitivity of WRF simulated 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

Moving to the real development

Land Data Assimilation - NASA LIS

- Noah land surface model
- EnKF data assimilation methods

- SMOPS (Soil Moisture Operational Product System)
  X. Zhan, NESDIS/STAR

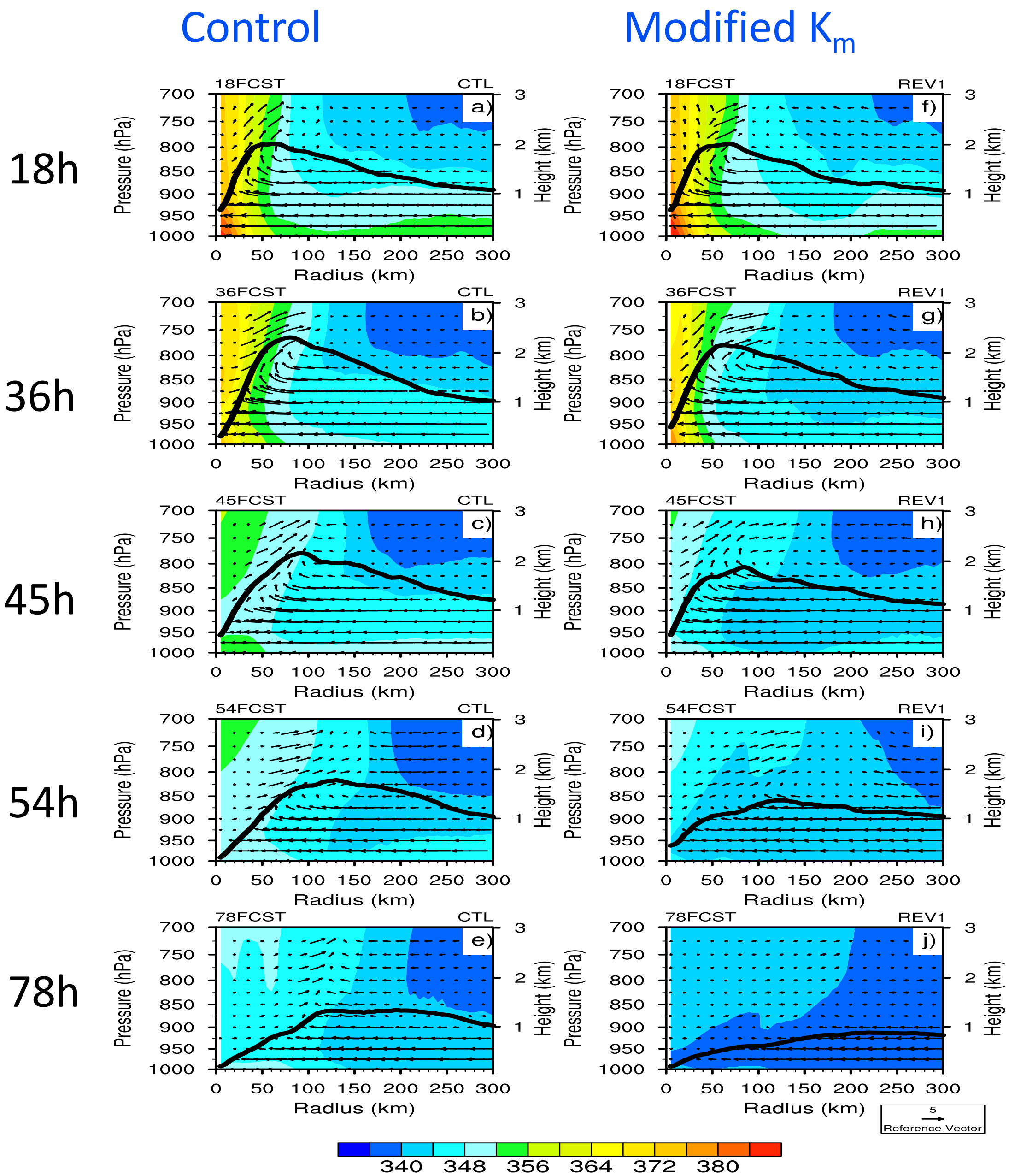
- Understand the issues related to soil moisture data assimilation with EnKF
  (Graduate Student. F. Li – Working progress)

NCEP Next Generation Global Prediction System (NGGPS)

- **FV3**
- **GSI-based 4dEnVar**

(Working progress)

Effects of vertical diffusion of surface heat and moisture fluxes on the evolution of landfalling hurricanes



Azimuthally averaged θ_e (shaded; unit: K); vectors of radial wind (unit: m s^{-1}); w (×5 unit: m s^{-1}) and PBLH (bold solid line; unit: m) for Hurricane Rita from 00 UTC 23 Sep 2005.

The modified K_m enhances the interaction between the surface fluxes and hurricane vortex thus it leads the faster weakening of the hurricane over land (that is more compatible with observed hurricane weakening process).

Zhang and Pu 2017; JAS

Project Milestones - progress, ongoing, future

- Evaluate the error characteristics of near-surface weather forecasts; identify the systematic biases.
- Examine the association between errors in near-surface variables within the atmospheric model and uncertainties in soil moisture within the land surface model; explore the statistical relationship/correlations between these two.

- Develop effective ensemble error covariances between near-surface atmospheric variables and soil moisture. Test effective empirical or fully coupled schemes to improve the coupling between the land surface and the atmosphere.

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- Develop an effective vertical diffusion scheme within the planetary boundary layer parameterization to enhance interaction between the surface heat and moisture fluxes and atmospheric boundary layers.

Thank you for your attention!

Contact:
Zhaoxia.Pu@utah.edu