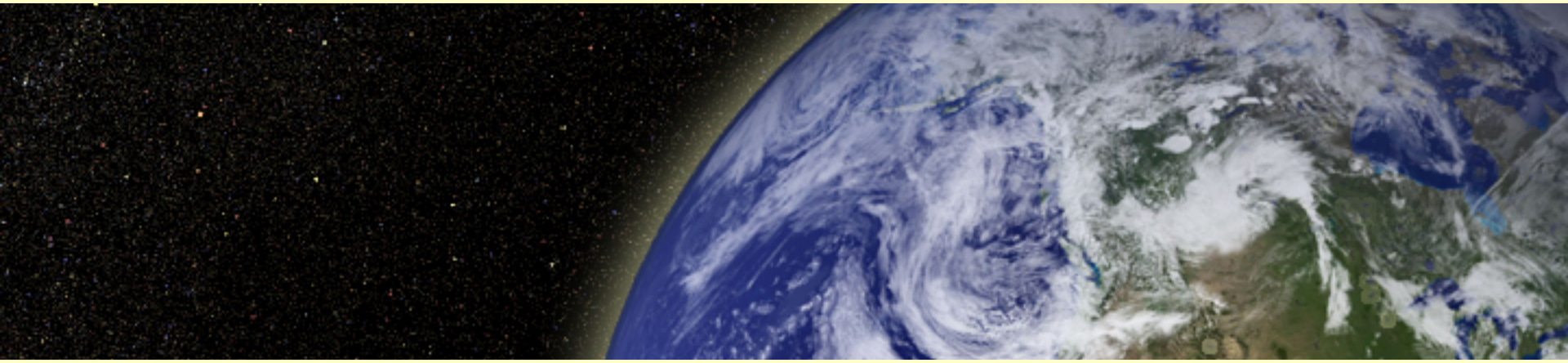
CICS Science Meeting, ESSIC, UMD, 2016

Enhancing Weather Forecasts via Assimilating SMAP Soil Moisture and NRT GVF



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Outline

- **Introduction and Objectives**
- **Semi-coupled LIS/WRF**
- **Validation results:**
  - **NRT GVF impact on WRF forecast**
  - **SMAP SM impact on WRF forecast**
- **Discussion and Summary**

Introduction and Objectives

- Accurate forecasts of temperature and precipitation from numerical weather prediction models rely on the quality of the initialization of land surface state variables (e.g. soil moisture(SM)) and the representativeness of parameters that describe the current land surface status (e.g. green vegetation fraction (GVF))

- **Limitations:** current NCEP Noah LSM within the North American Mesoscale Forecast System (NAM) uses only a multiyear climatology of GVF; satellite SM products are not assimilated in operational forecast models

- Recent research has shown the unique value of satellite-based SM and vegetation cover information and the feasibility of assimilating SM retrievals into the land surface models (LSMs) to improve the land-atmosphere water and energy exchange

- This study **aims at** assessing the impact of assimilating SMAP SM product and near-real-time GVF on the weather forecasts

Datasets and Models

GVF Climatology and NRT GVF

	Temporal Resolution	Spatial Resolution	Data Source
GVF^C	Static 5-year avg	0.1444 Deg	AVHRR
GVF^R	4-day Composite	1 km	MODIS

C: climatology; R: near real time

Validation Data sets

Variable	Temperature (2 m)	Relative Humidity (2 m)	Precipitation
Dataset	PrepBufr (GDAS)	PrepBufr (GDAS)	NCEP National Stage IV Precipitation
Method	Point Statistics	Point Statistics	Grid MODE

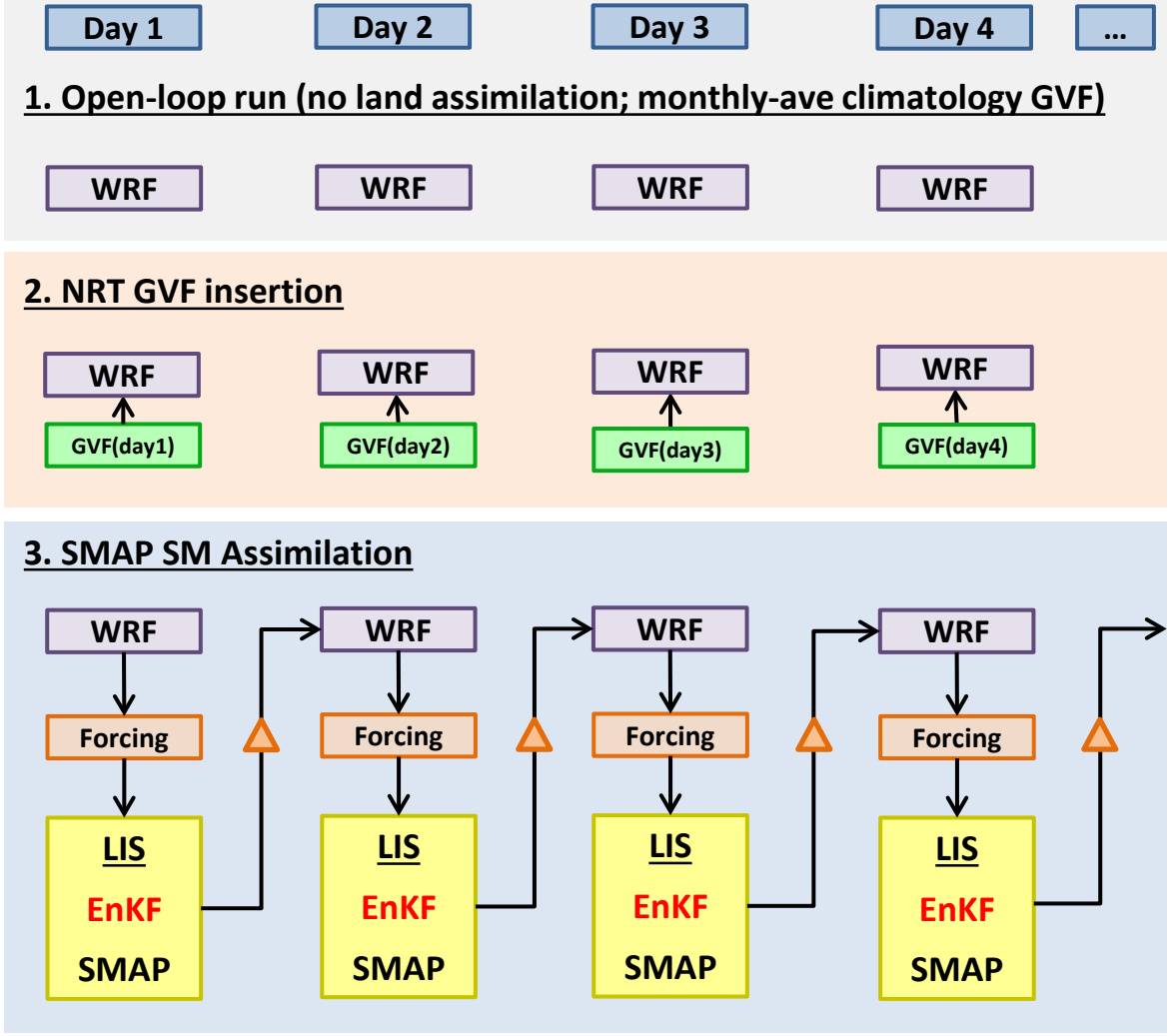
SMAP within SMOPS

- **SMAP SM**
  - SMAP L3 SM Passive product within SMOPS
  - 0.25 Degree, global, daily

Framework and Model

- **LIS**
  - Noah model version 3.3
  - employs advanced data assimilations tools such as the ensemble Kalman Filter (EnKF)
- **NU-WRF**
  - NASA Unified-Weather Research and Forecasting (NU-WRF) Version 7
  - A fully coupled NASA LIS (v7.0rp1) and the standard NCAR Advanced Research WRF (WRF-ARW) (v3.5.1) assimilation system
  - Citation: Peters-Lidard, C.D., at al., 2015

Semi-coupled LIS/WRF

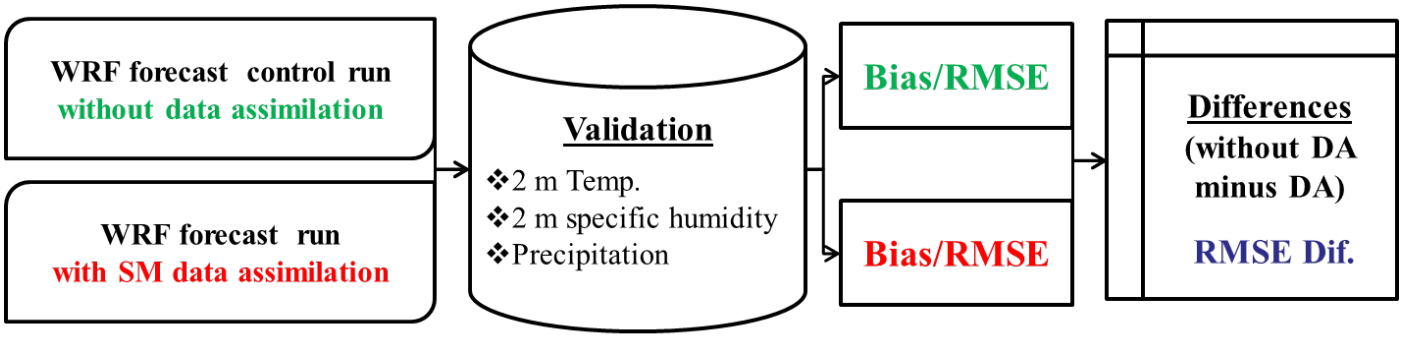


Semi-coupled LIS/WRF

- WRF provides atmospheric forcing data to LIS and receiving updated land surface data (SM, GVF, fluxes, albedo, etc) in return
- LIS is set up to run in parallel on the same grid and with the same terrestrial data and land surface physics as WRF
- Land data assimilation (SMAP SM DA) is conducted in LIS using EnKF, which generate updated initializations daily and feed back to parent WRF for next day run
- Initializations of land states are updated with the assimilation of SMAP SM but with near-surface forcing from parent WRF run

LIS/WRF Experiments and Evaluation Plan

- A series of LIS/WRF runs are performed and compared
  - Climatology GVF vs. NRT GVF; No assimilation vs. SM EnKF assimilation
- Studying period: Sept. 27th – Oct. 9th , 2015
- Forecasts of WRF runs are validated using in situ observations
  - ~1000 sites over CONUS domain and ~200 sites in sub-regions
- RMSEs of WRF forecasts are compared temporally and spatially



- Positive (negative) values represent added (degraded) value by SM assimilation

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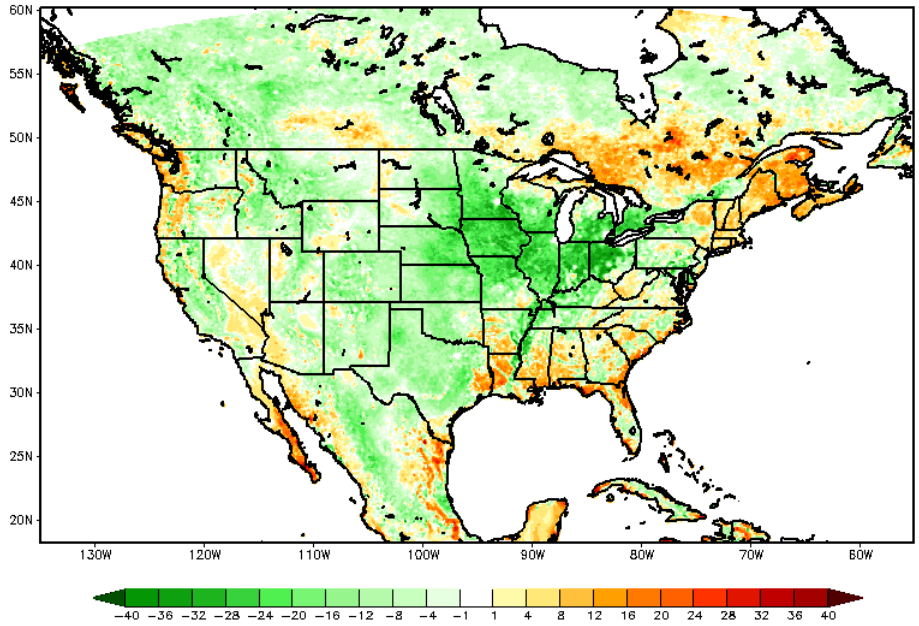
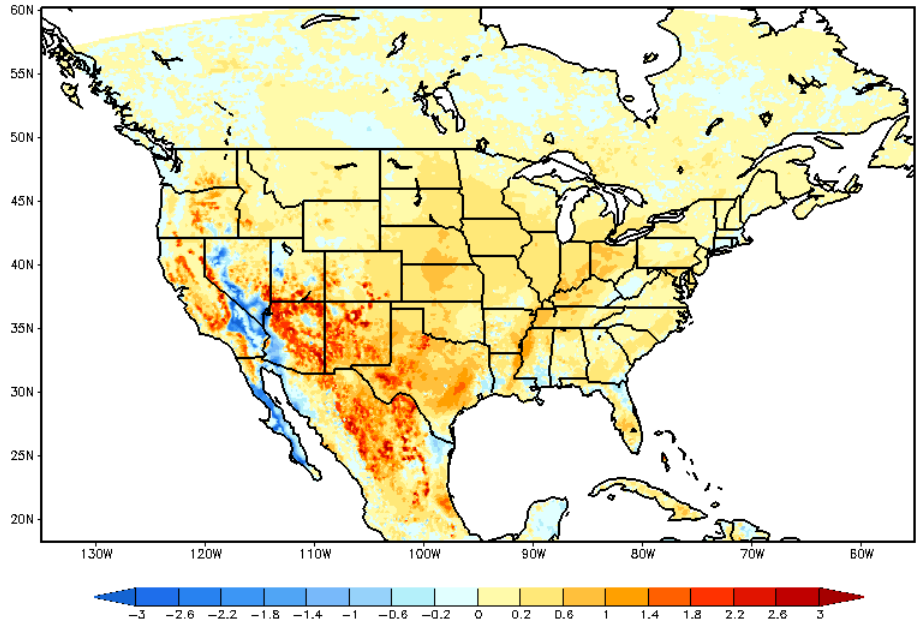
NRT GVF impact on WRF forecast



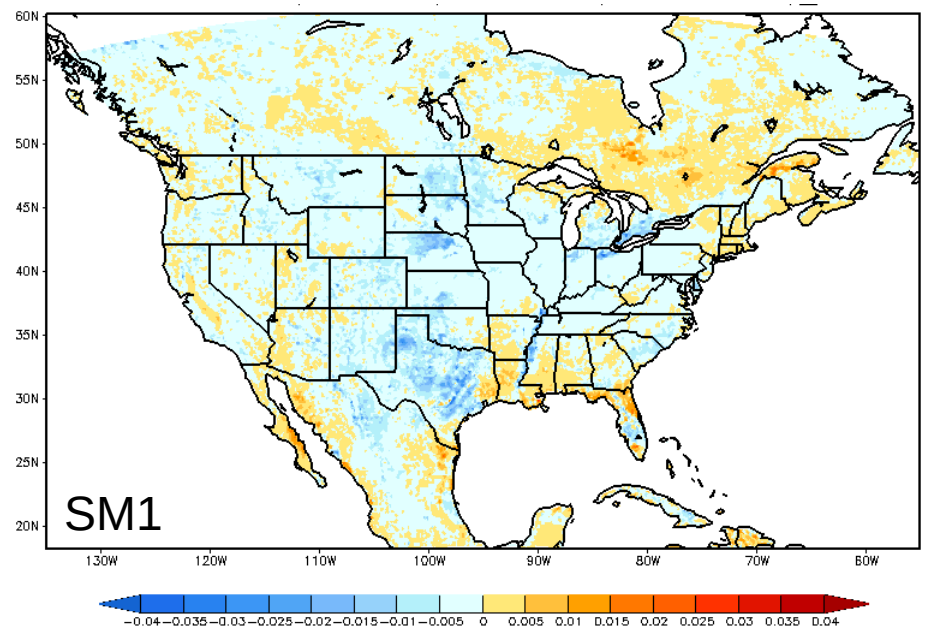
The average GVF differences between NRT GVF and climatology (NRT minus climatology) over the period of Oct. 3rd – Oct. 9th, 2015

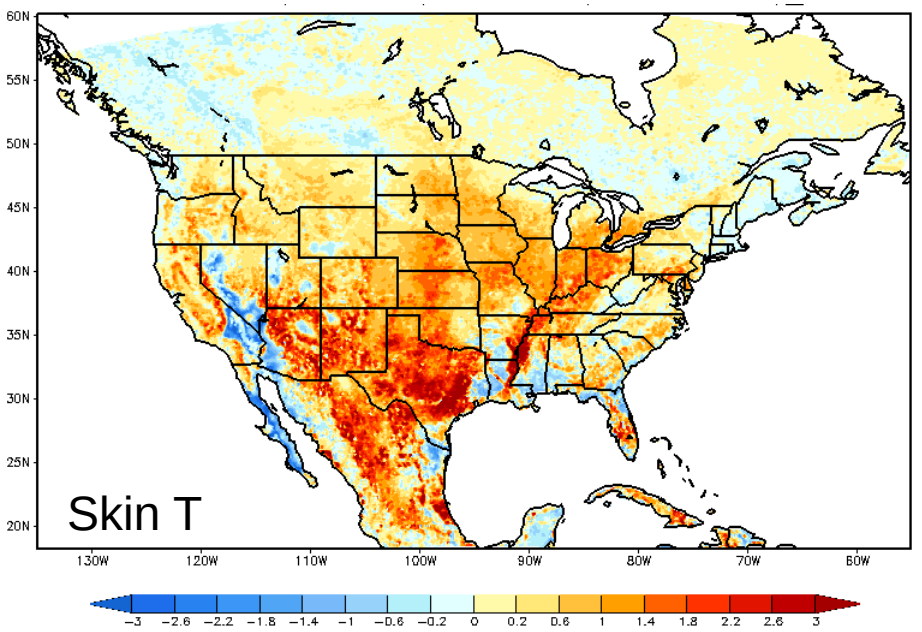


Differences in 2 m surface air temperature (unit: K) at UTC19, over the period of Oct. 3rd – Oct. 9th, 2015 by using NRT GVF and GVF climatology (NRT minus climatology)

The results are physically sound as 2 m surface temperature forecast using NRT GVF increases in response to the negative anomaly compared to GVF climatology, and vice versa

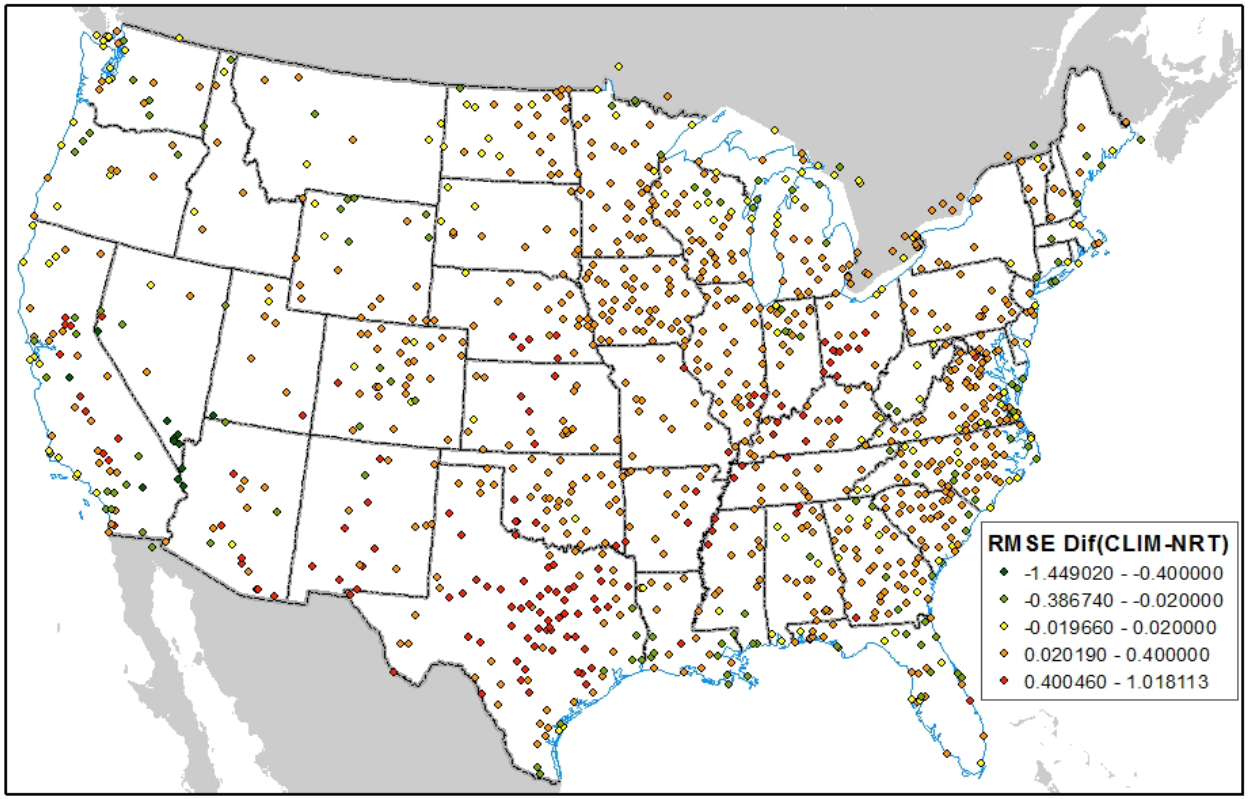
NRT GVF impact on WRF forecast



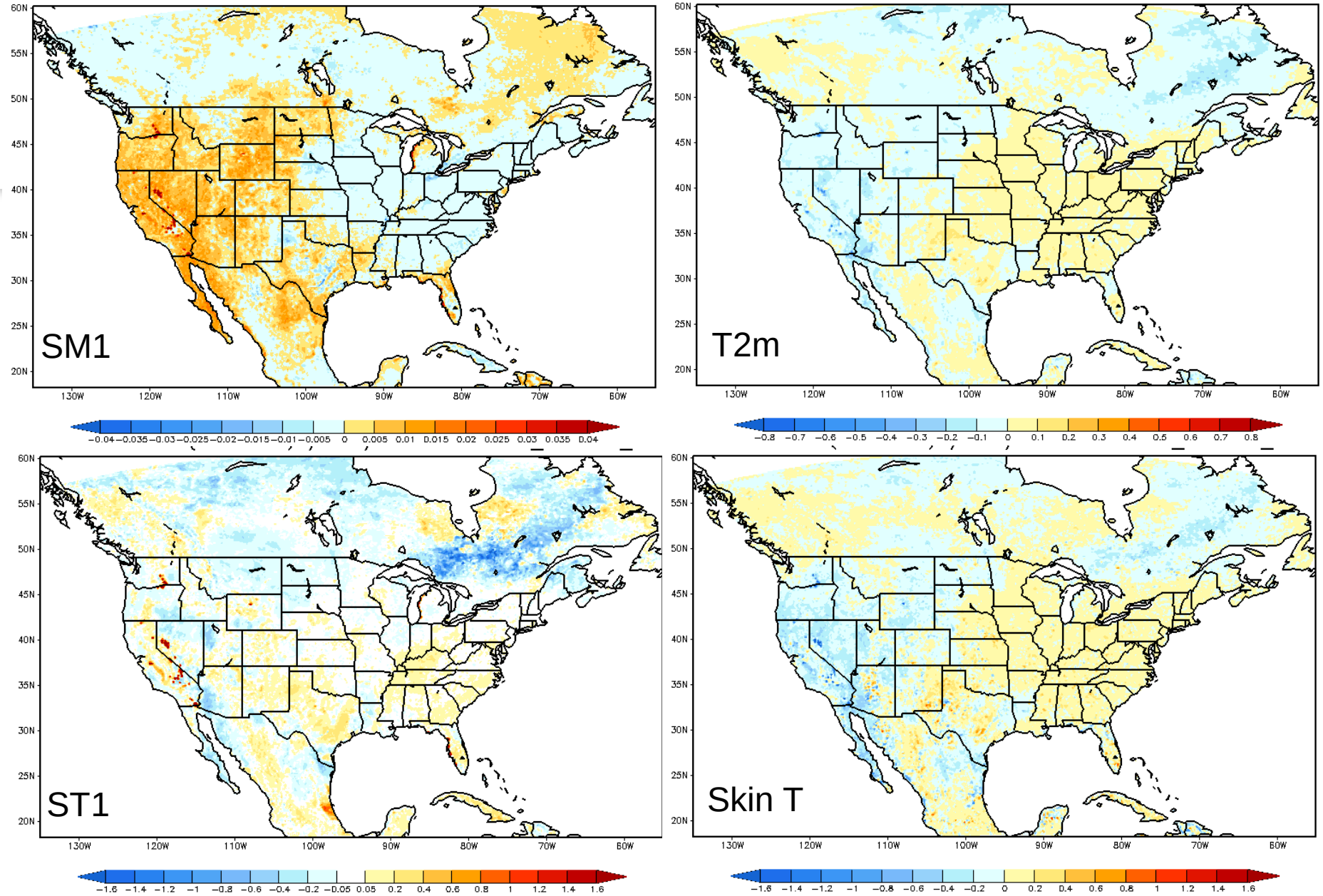


Differences in forecasts from two WRF runs, NRT GVF minus Climatology GVF.
Averaged difference of soil moisture layer 1 (left) and surface skin temperature (right)
at UTC19, over the period of Oct. 3rd – Oct. 9th, 2015

Validation results: RMSE Dif.

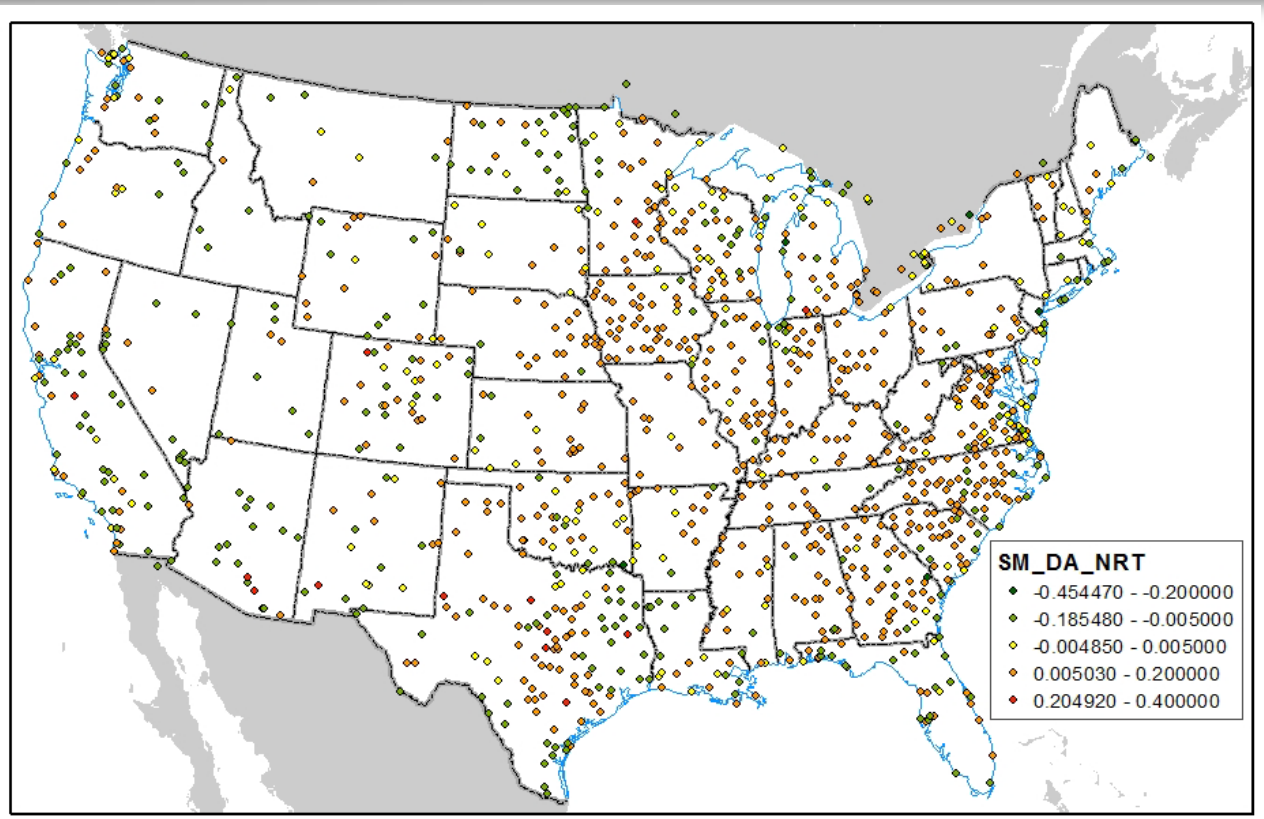


- Difference in RMSE of T2m forecasts from two WRF runs, using climatology GVF and NRT GVF separately
- RMSE Dif = Clim run minus NRT run
- **Warm color: Improvement** **Cool color: Degradation**
- **82.3%** sites show positive impact (1178 sites in total)



Differences in forecasts from two WRF runs, SMAP DA run minus Free run
Averaged difference of Soil moisture layer 1, T-2m, Soil temperature layer 1 and surface skin temperature at UTC19, over the period of Oct. 3rd – Oct. 9th, 2015

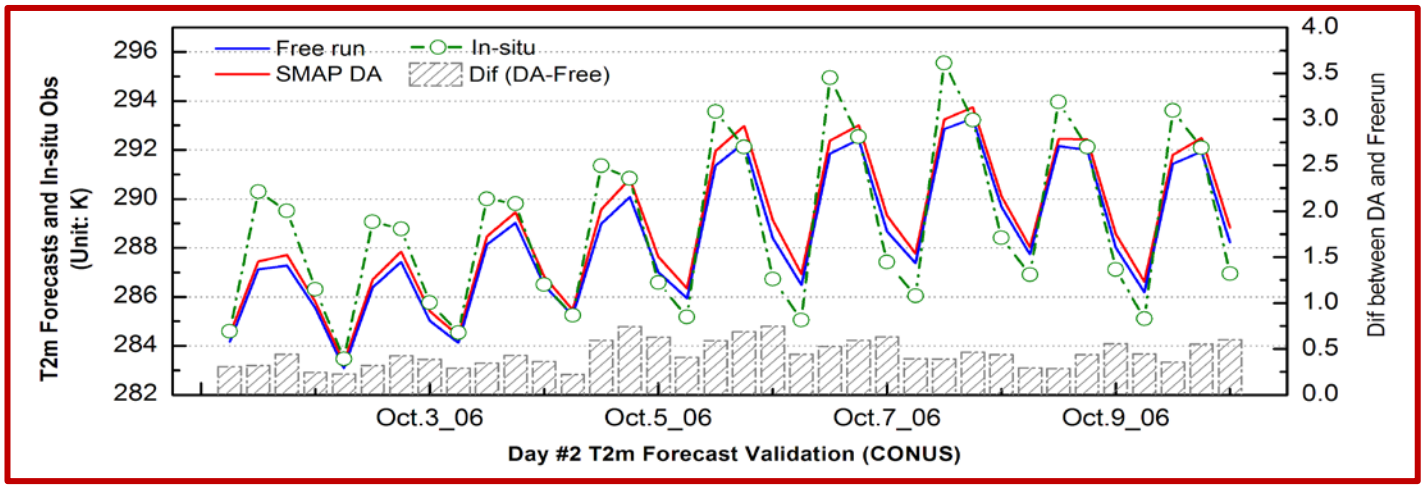
Validation results: RMSE Dif.



- Difference in RMSE of T2m forecasts from WRF free run and SMAP DA run (both using Climatology GVF)
- RMSE Dif = Free run minus SMAP DA
- **Warm color: Improvement** **Cool color: Degradation**
- **62.1%** sites show positive impact (1178 sites in total)
- Slightly improvement over majority of validation sites

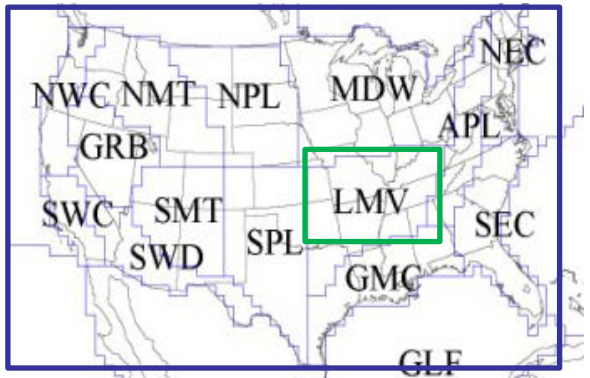
T2m Forecasts compared with In-situ Observations (CONUS Domain)

- Average T2m forecasts from WRF Free run and SMAP DA run compared with In-situ measurements
- Validation domains: CONUS (~1000 sites)
- Validation period: Day 2 forecast, Oct. 2nd – Oct. 9th, 2015
- Corrected daytime cold bias



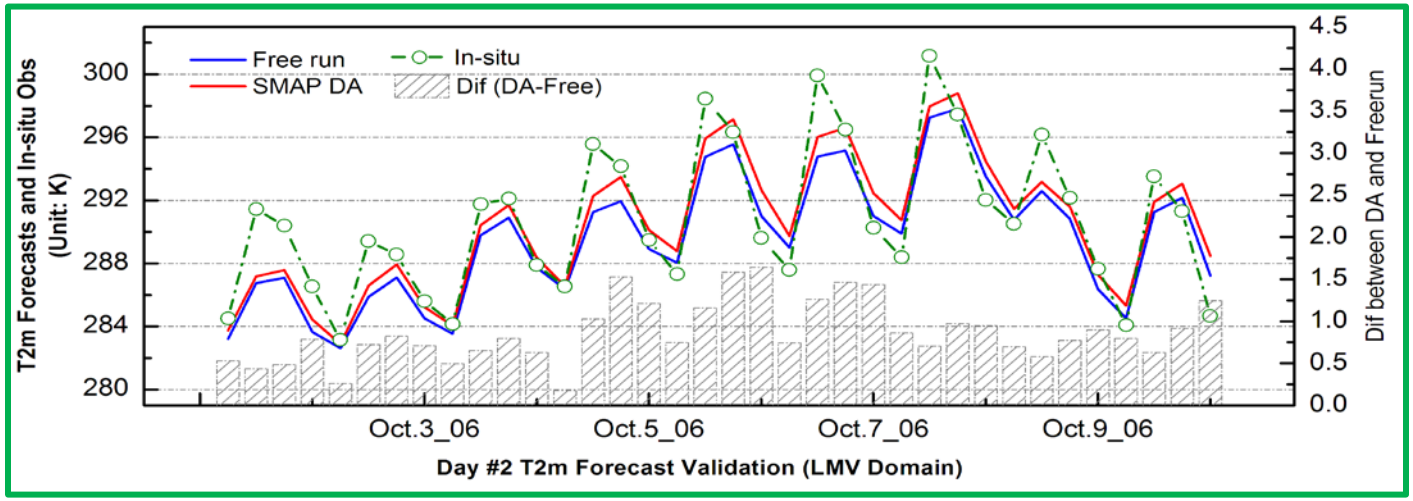
T2m Forecasts compared with In-situ Observations (LMV Domain)

- Average T2m forecasts from WRF Free run and SMAP DA run compared with In-situ measurements
- Validation domains: LMV domain (~200 sites)
- Validation period: Day 2 forecast, Oct. 2nd – Oct. 9th, 2015
- Corrected daytime cold bias



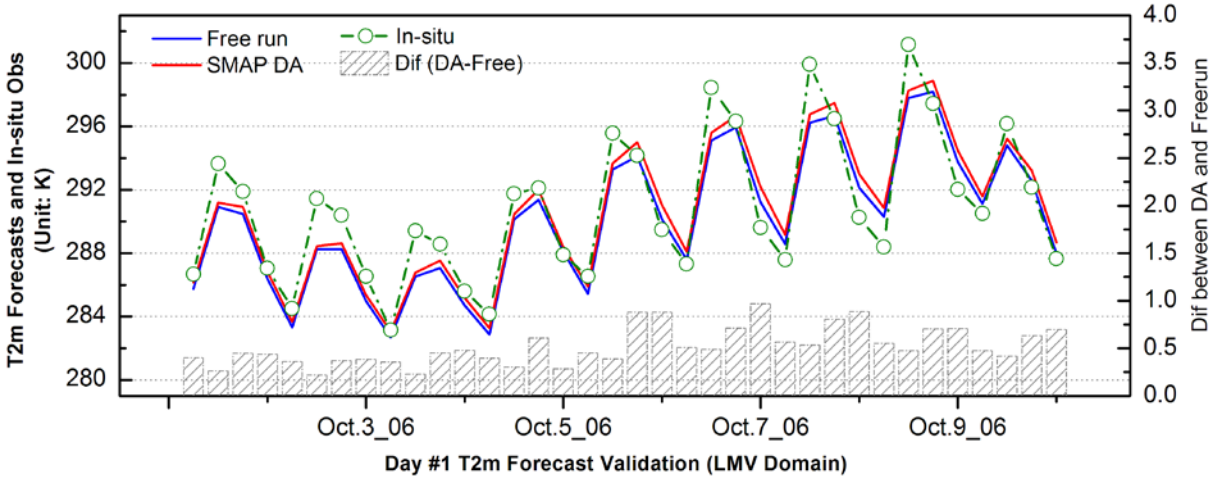
Sub-regions in NCEP WRF-NMM forecast verification system

LMV

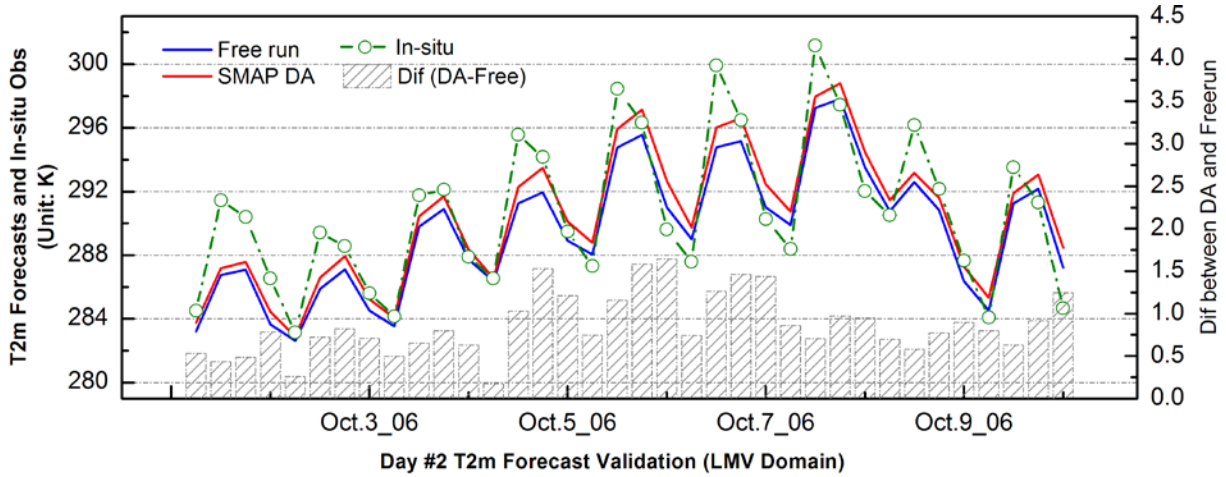


T2m Forecasts compared with In-situ Observations (LMV Domain; 2-Day validation)

Day 1

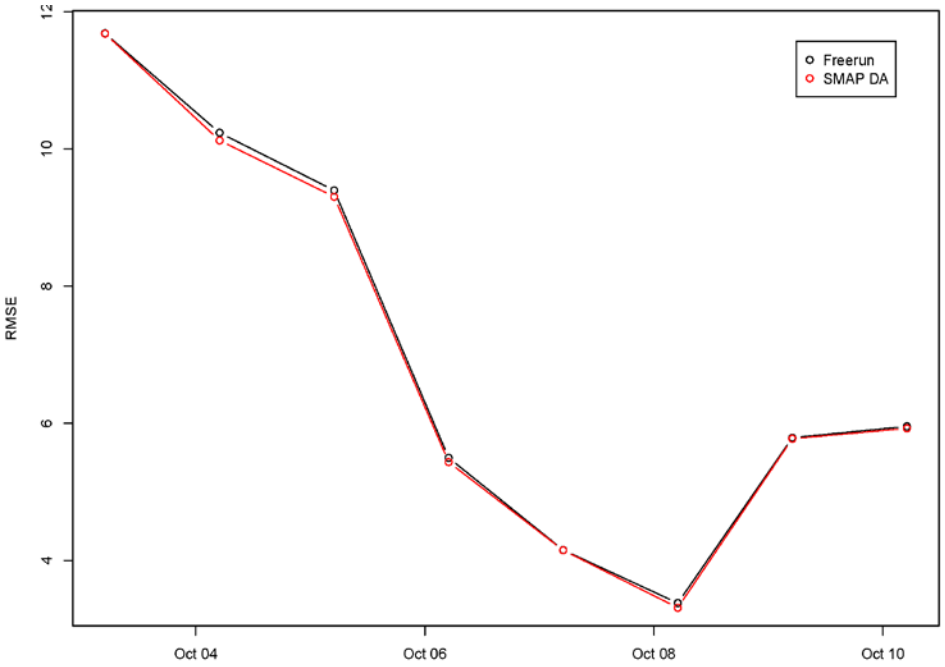


Day 2

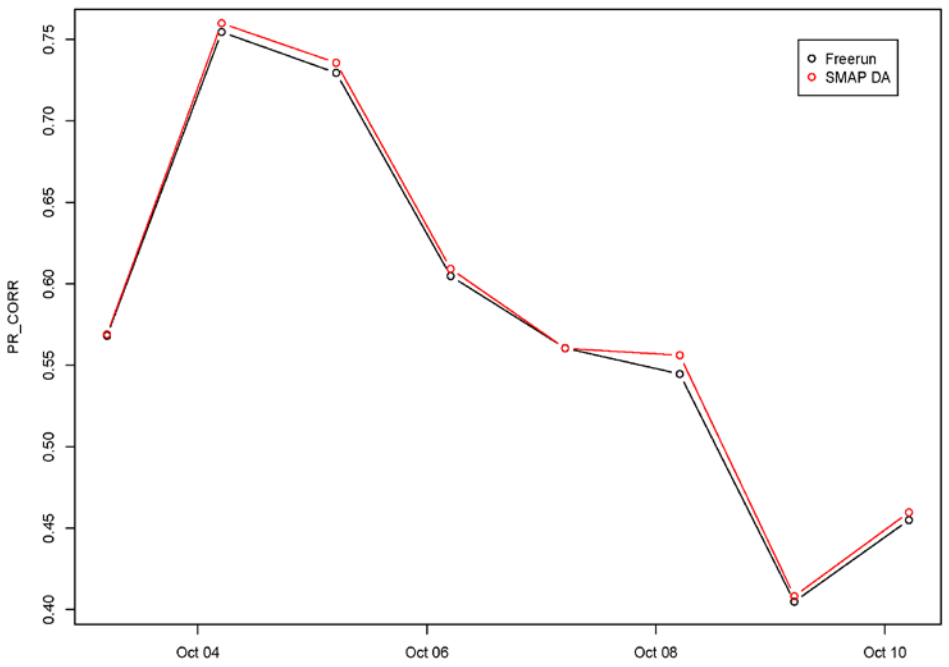


Validation on Precipitation

RMSE Time Series Validation



Correlation Time Series Validation



- Comparison of RMSE (left) and Correlation (right) of 24-h accumulated precipitation from WRF Free-run and SMAP DA run, Oct. 3rd – Oct. 10th, 2015
- Validation uses NCEP National StageIV Precipitation data set
- SMAP DA slightly improves precipitation forecast on Oct. 4, 5, 6 and 8th , showing less RMSE and higher correlation

Summary

- The use of NRT GVF, which is more representative to the reality of surface green cover, can reduce the daytime cold bias in model forecasts compared to the run using multi-year average GVF. The direct replacement of NRT GVF is straightforward, efficient and effective
- Preliminary results on SMAP SM assimilation shows overall positive impact on 2 m temperature forecasts although the extent of the impact is much smaller than direct insertion of NRT GVF
- The impact of assimilating SMAP SM and NRT GVF is greater on day 2 forecasts than day 1 forecasts
- The assimilation of SMAP SM shows positive impact on precipitation forecast

The end

Enhancing Weather Forecasts via Assimilating SMAP Soil Moisture and NRT GVF

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Thanks for your attention!

Comparison of three WRF runs

	WRF w/ NRT GVF	WRF w/ SM DA	WRF w/ SM DA
GVF	NRT vs. Clim	Climatology	Near Real Time
SMAP DA	X	√	√
Comparison	NRT GVF impact	SM impact based on clim GVF	SM impact based on NRT GVF
# sites show improvement	**82.3% (0.15)**	**62.1%(0.01)**	**42.9% (0.005)**