Enhancing NCEP GFS Forecasts via Assimilating Satellite Soil Moisture, Vegetation and Snow Observations

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Land Data Initialization – An Operational Prospective

For the land surface to provides accurate estimates of surface energy fluxes at the lower boundary to the atmosphere – the specification of the current land surface states needs to be as realistic as possible (e.g., soil moisture, soil temperature, vegetation cover, vegetation characteristics, albedo, available energy – and on).

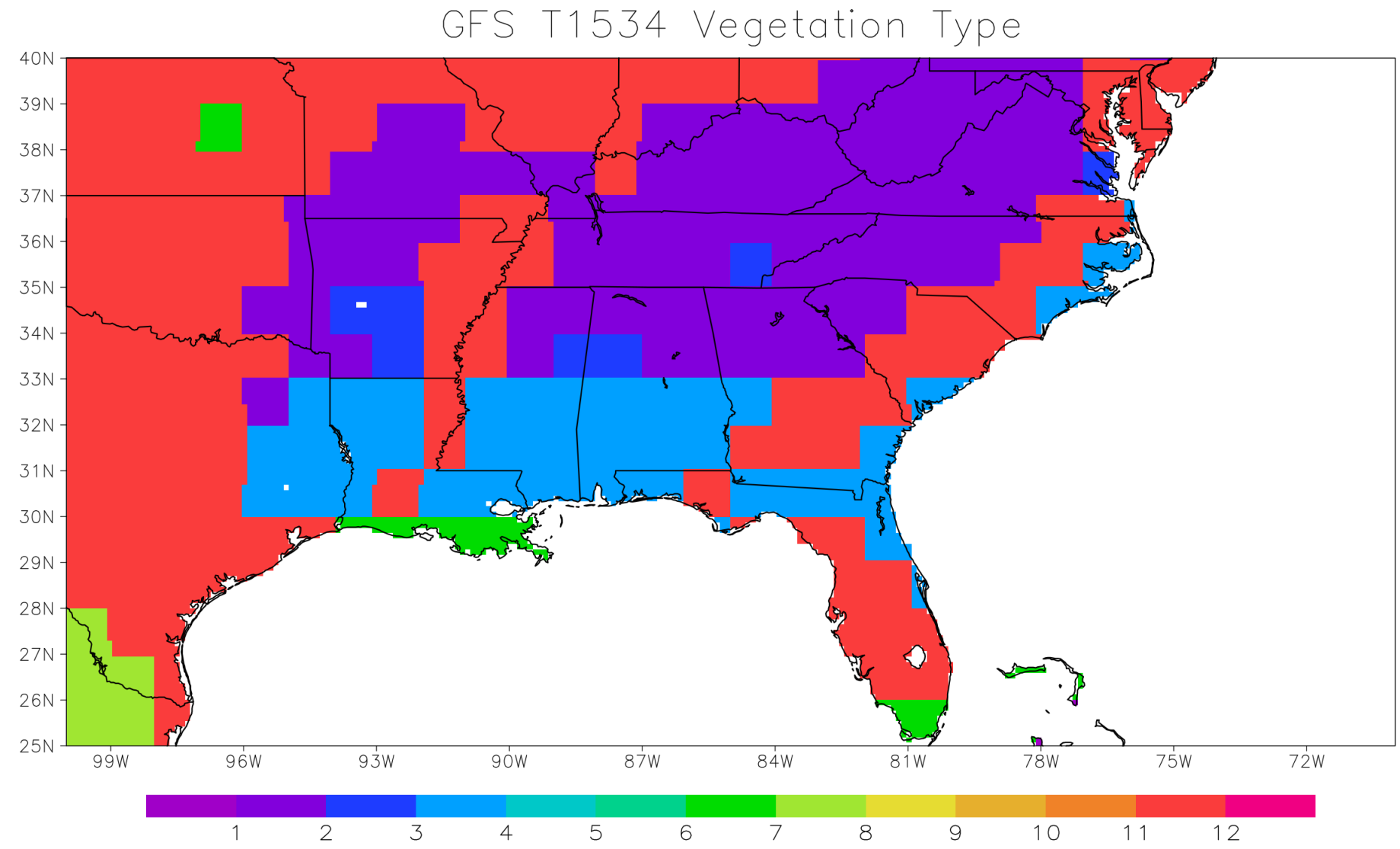
Remote sensing is increasingly providing high resolution and more accurate observations to help specify the current land surface state.

A short case study:

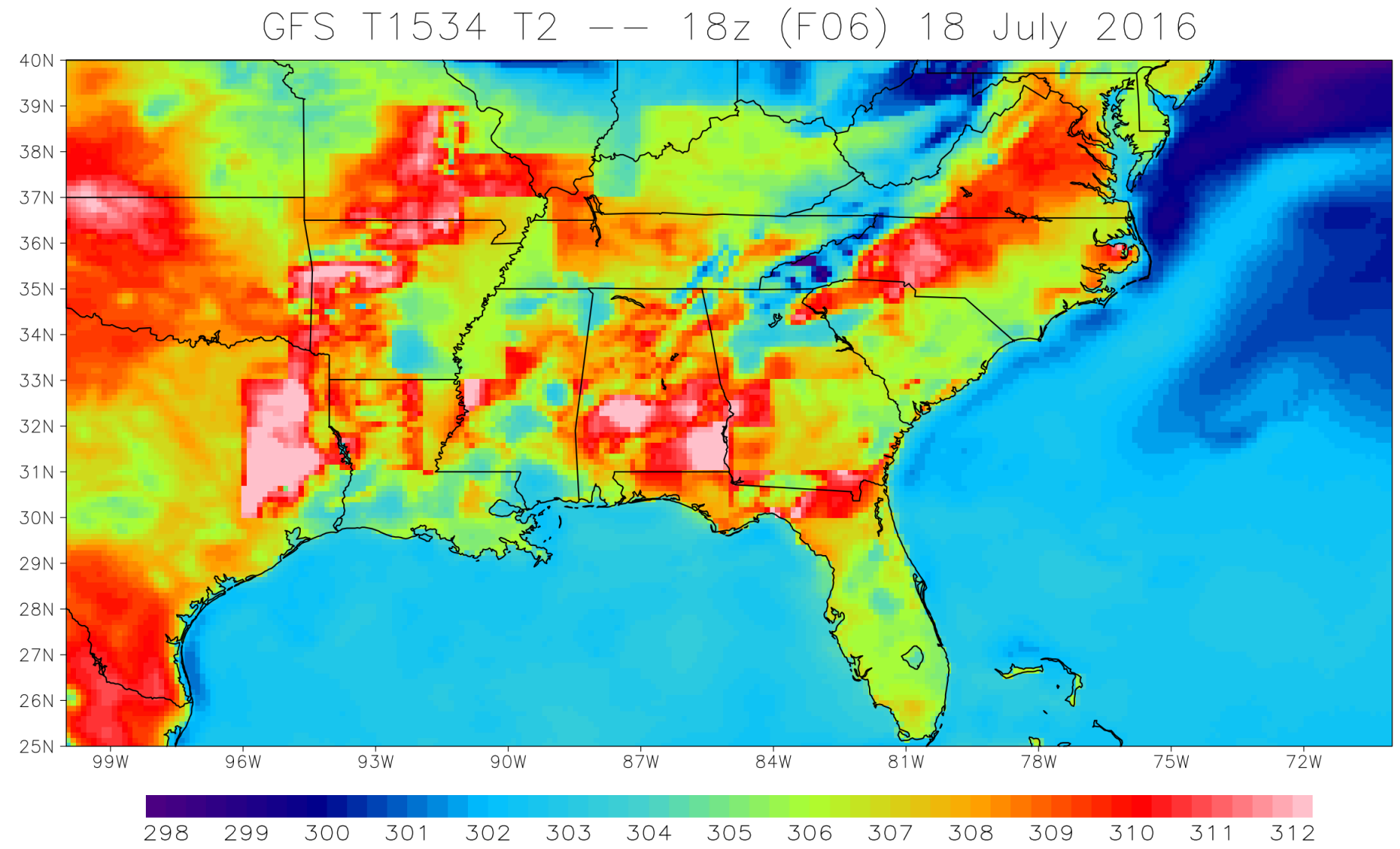
The current operational GFS (T1534; ~13 km) uses vegetation type dataset aggregated to 1.0° (coarse).

A 6-hour forecast (18 UTC) from 18 July 2016 was used to highlight several land surface fields directly affected by using coarse information when high resolution information is available.

Land Data Initialization – An Operational Prospective



Land Data Initialization – An Operational Prospective



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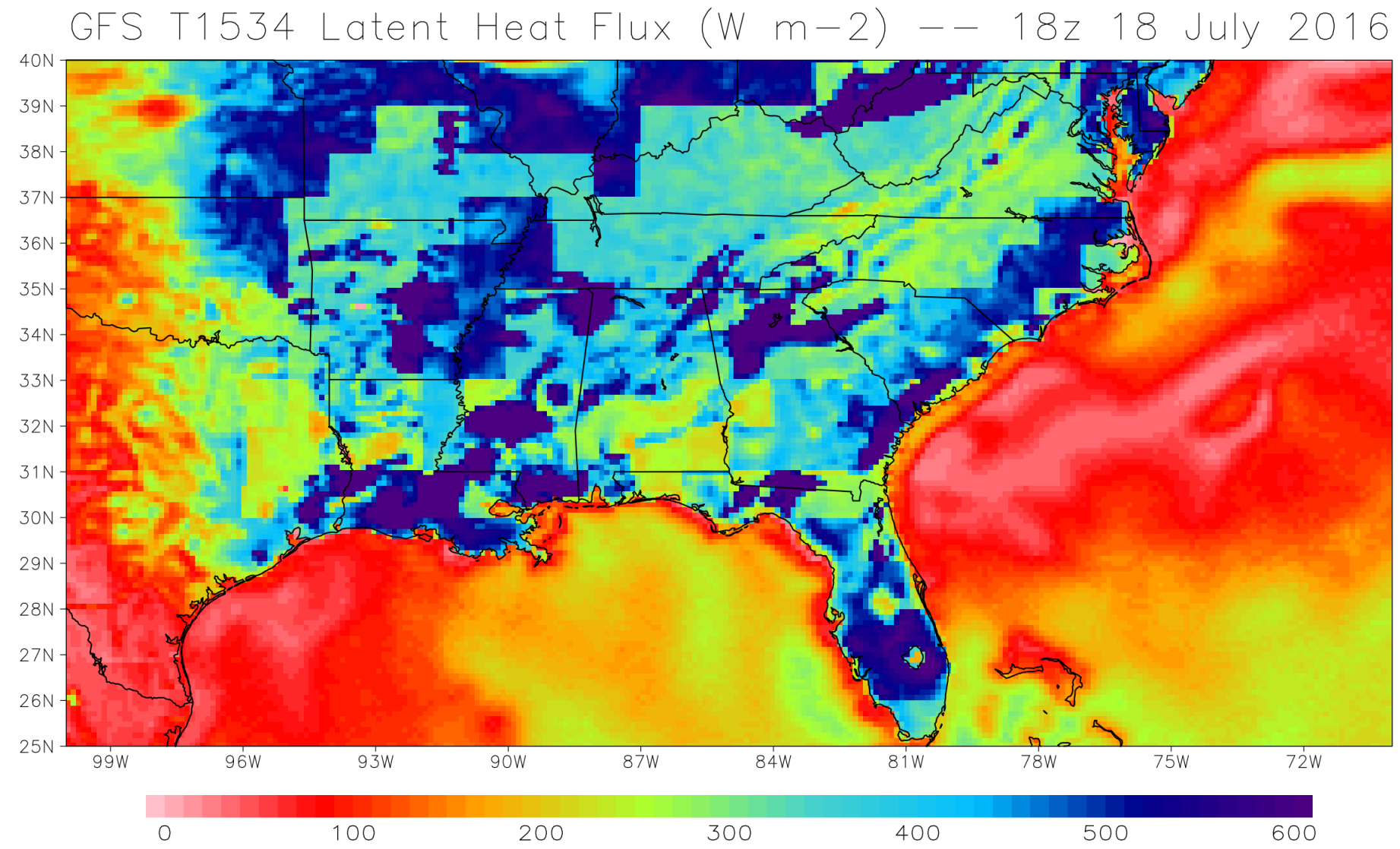
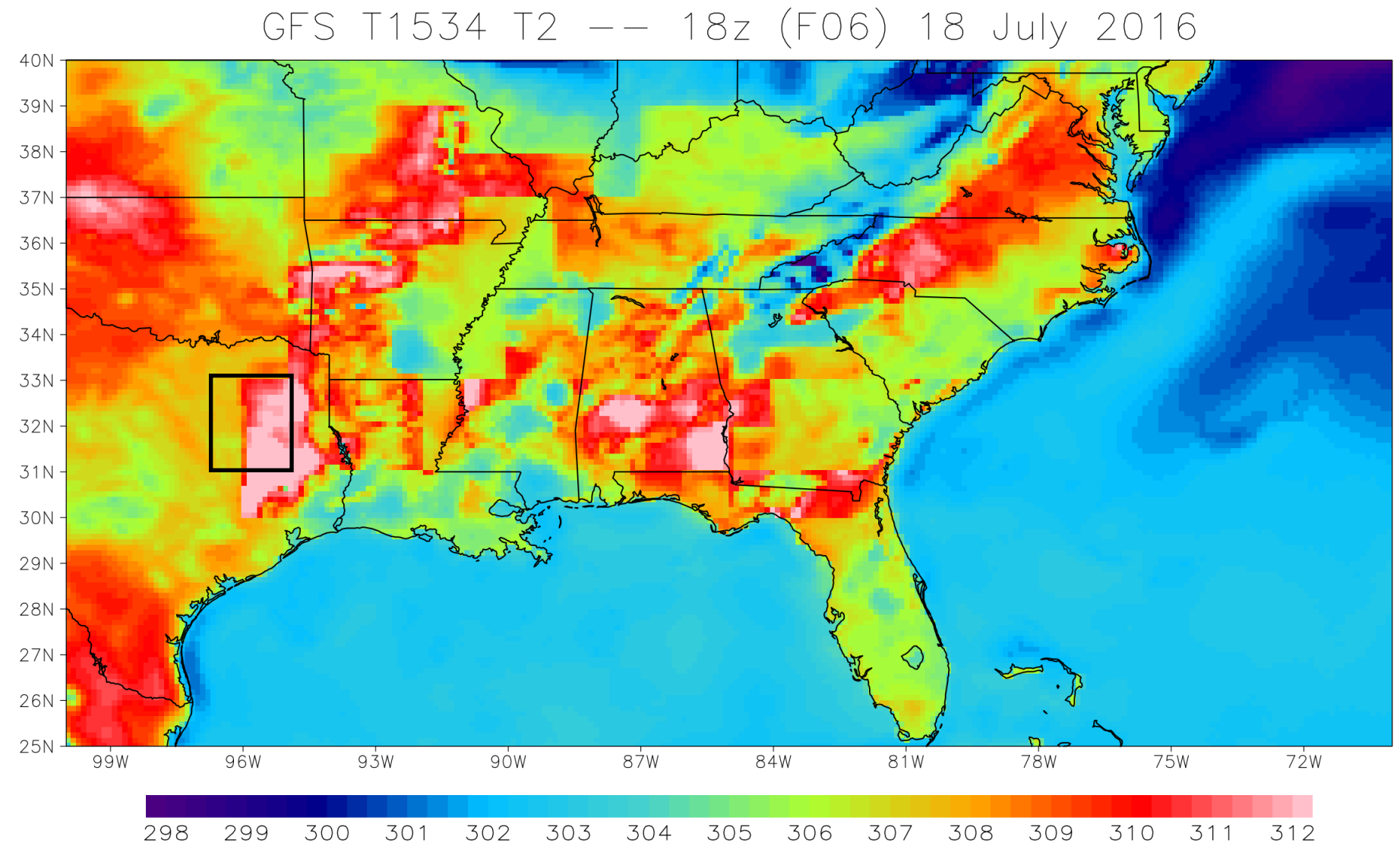
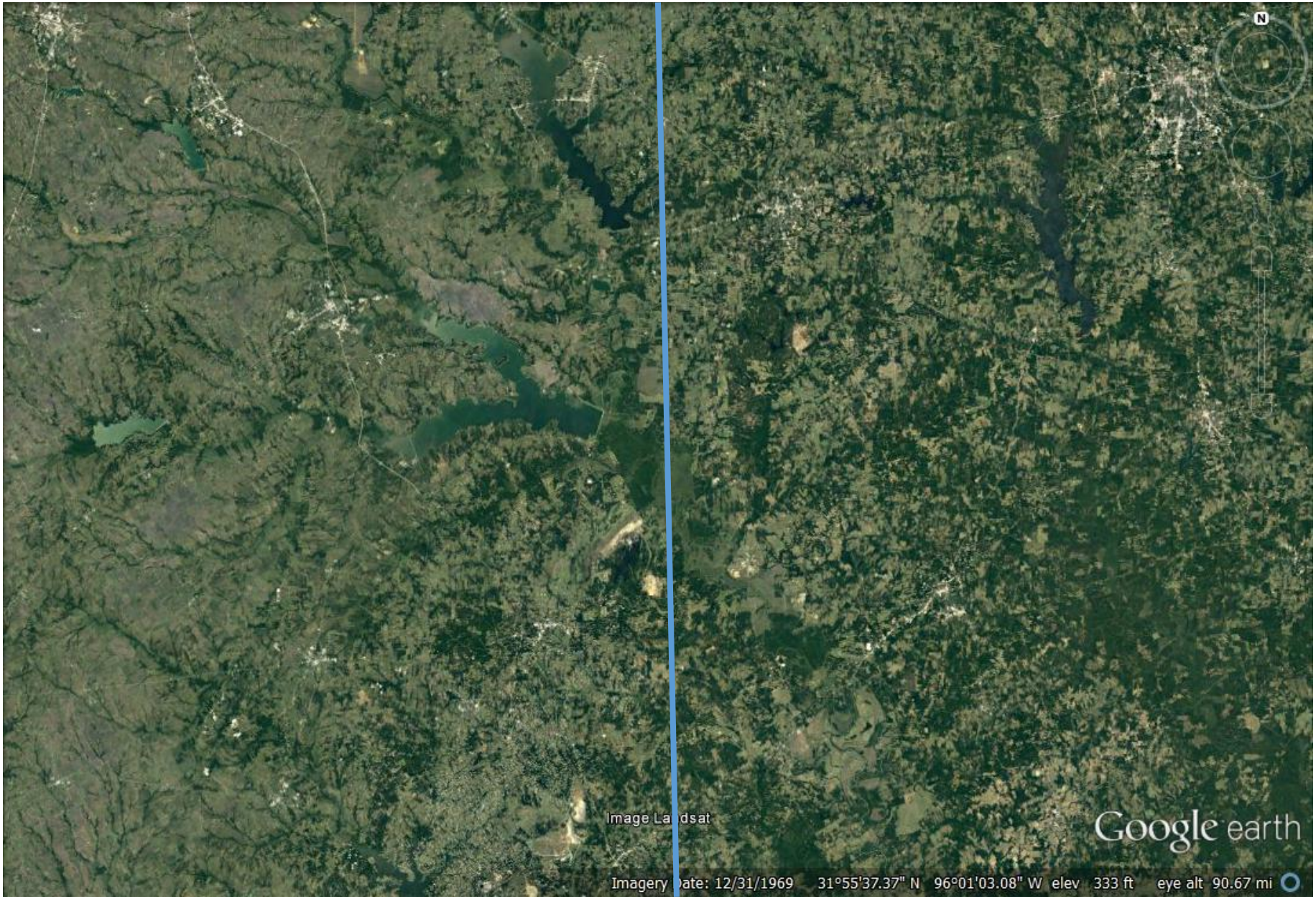


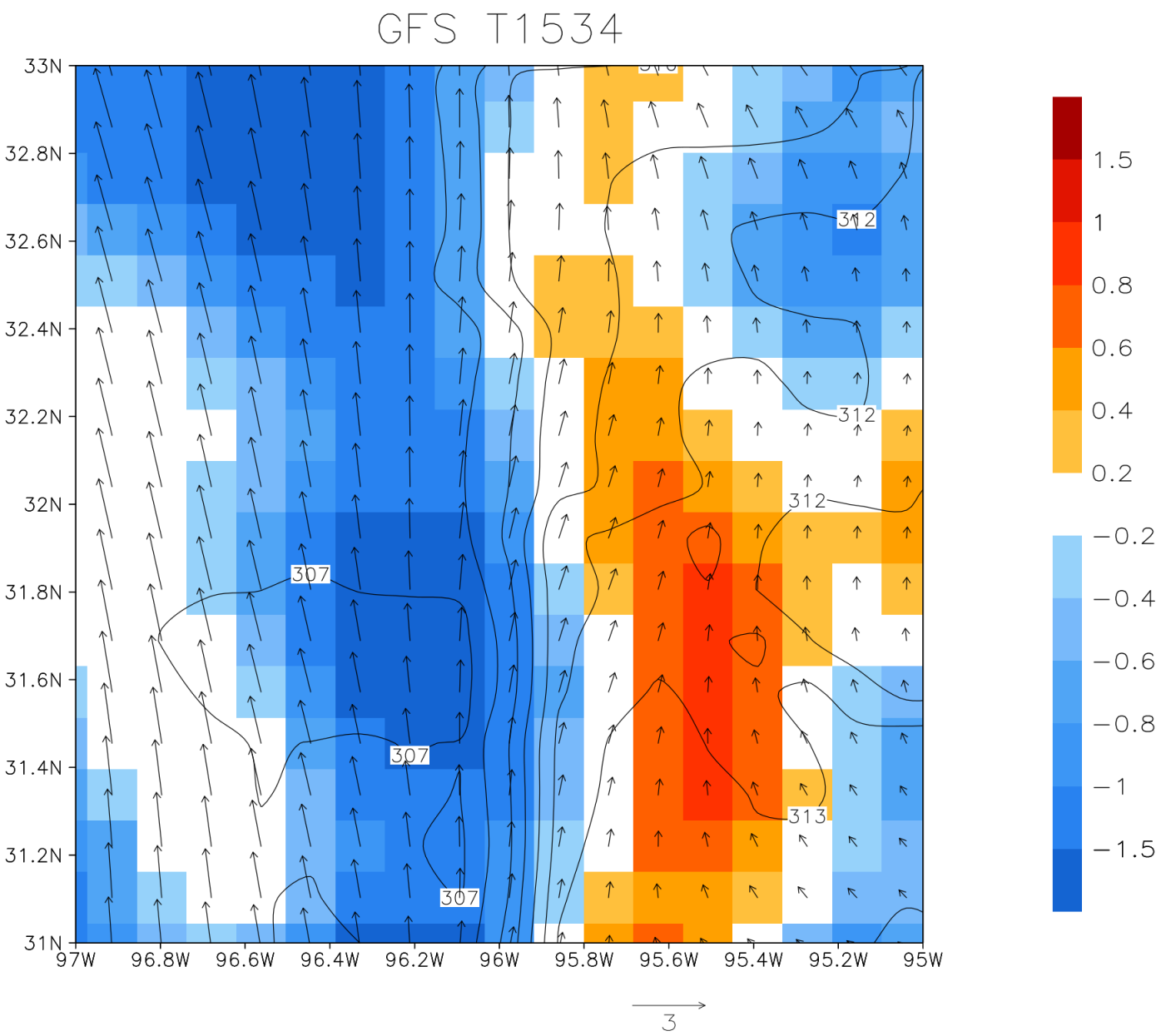
Land Data Initialization – An Operational Prospective



Land Data Initialization – An Operational Prospective



Land Data Initialization – An Operational Prospective



Land Data Initialization – An Operational Prospective

Proposed state variables/parameters/diagnostic information that can be updated with remote sensing datasets:

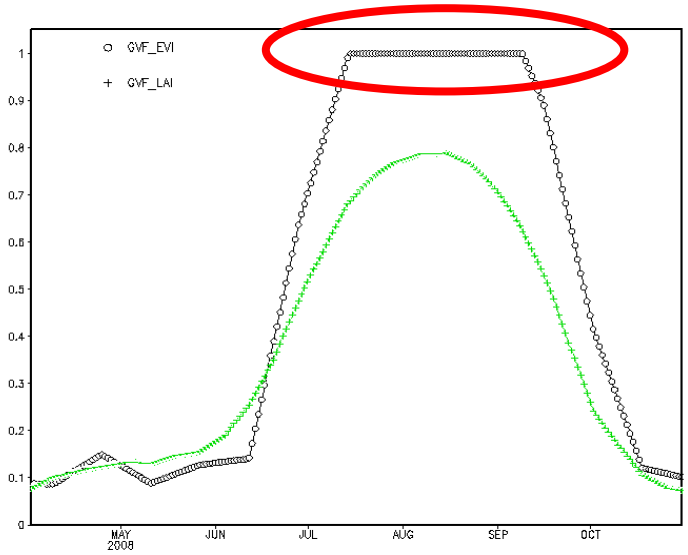
- Fraction of green vegetation (MODIS/VIIRS)
- Soil Moisture (SMOPS MW [AMSR2; SMAP; SMOS; ASCAT])
- Land Surface Temperature (Geo/MODIS/VIIRS)
- Vegetation Type / Land use Classification (MODIS/VIIRS)
- Surface Albedo (MODIS/VIIRS)
- Evapotranspiration (Geo/MODIS/VIIRS)

The specification of the GVF is used to partition energy between the soil/vegetation surface.

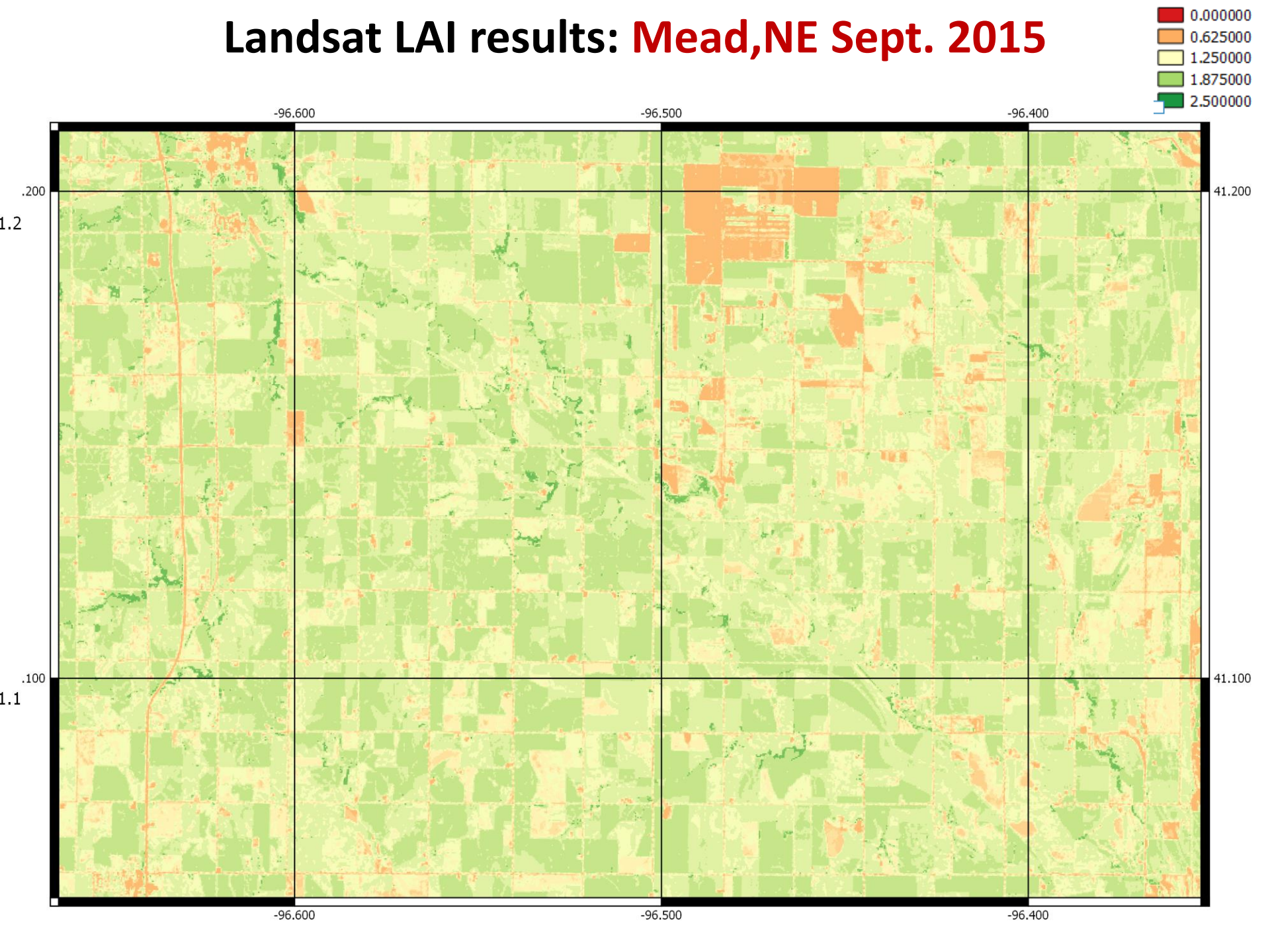
Variability in GVF can occur due to a number of reasons: (1) anomalously wet/dry condition and that impact on biomass; (2) early or late emergence/senescence; or (3) changes in land use/vegetation type.

a) <u>NDVI/EVI-based fraction of green vegetation</u>
   - Issues with saturation over moderate/dense vegetation
   - Tends to overestimate GVF over agricultural regions

b) <u>LAI-based fraction of green vegetation</u>
   - No NOAA VIIRS LAI product (future NASA product will be available early 2017)

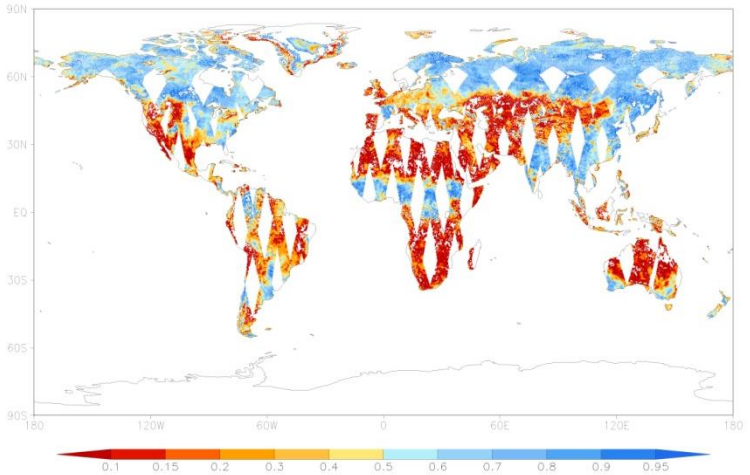


Landsat LAI results: Mead,NE Sept. 2015

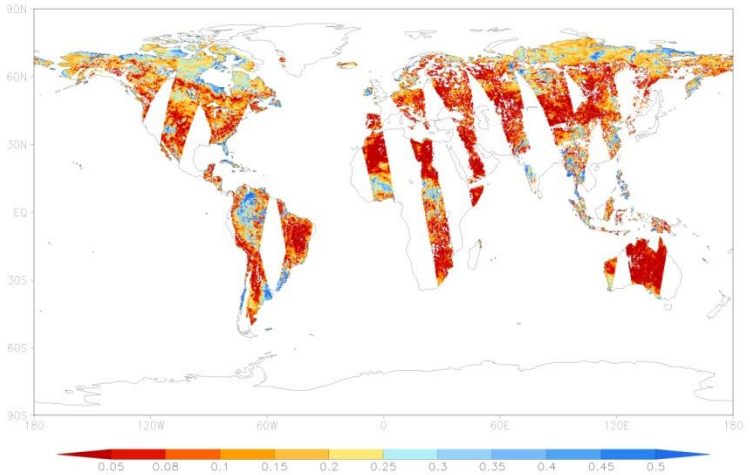


Operational MW Soil Moisture at NOAA (SMOPS)

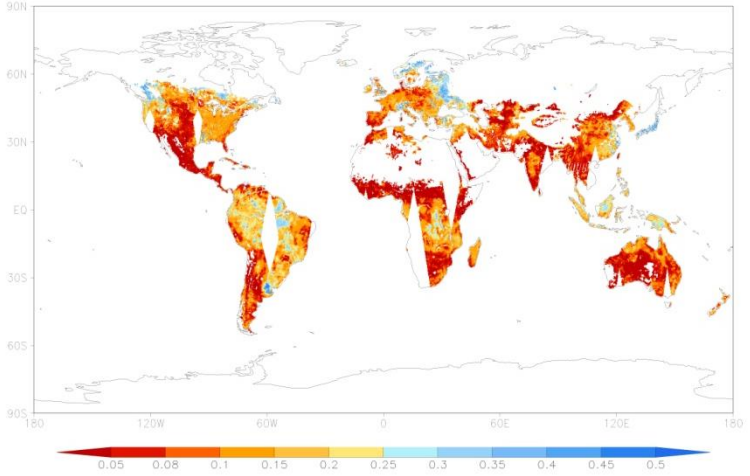
8 August 2015: ASCAT



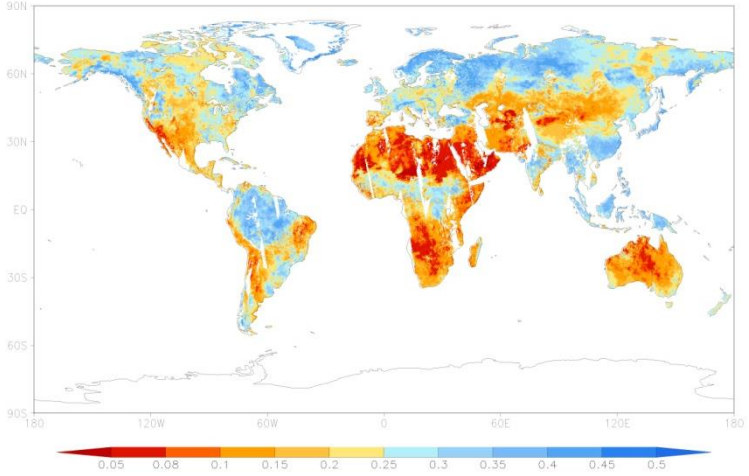
8 August 2015: SMOS



8 August 2015: AMSR2

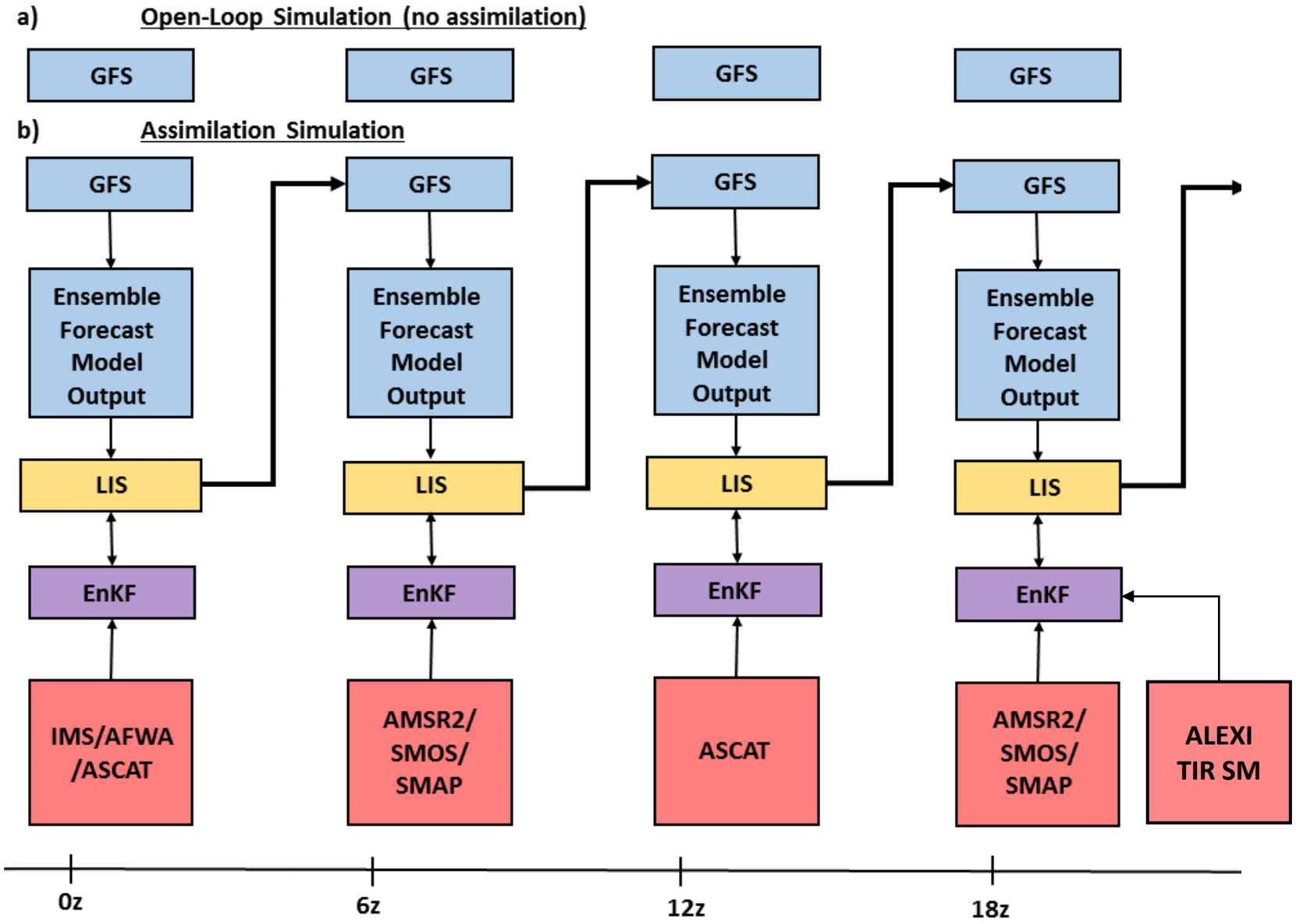


8 August 2015: SMOPS Merged



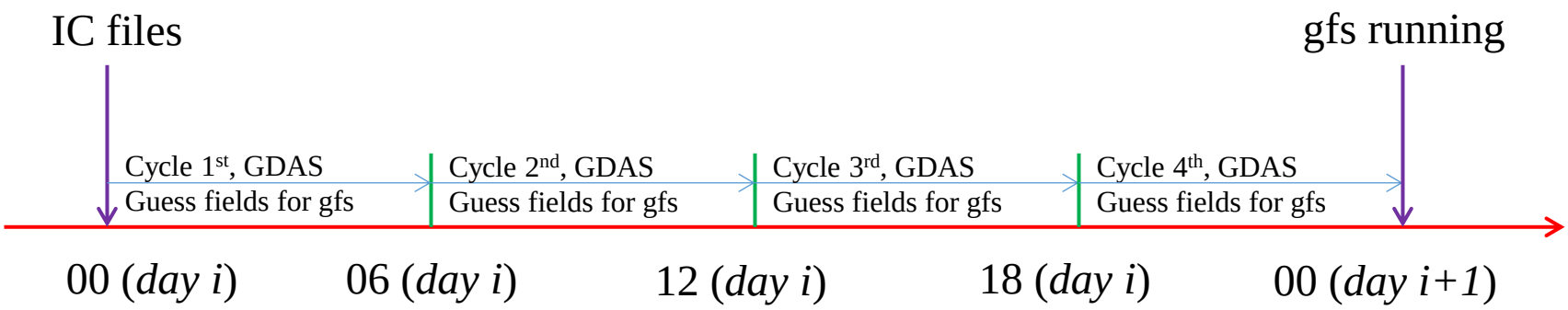
Example of global ASCAT, SMOS, AMSR-2 and SMOPS soil moisture products at 25 km resolution on August 8, 2015.

Semi-coupled GFS/LIS Assimilation System

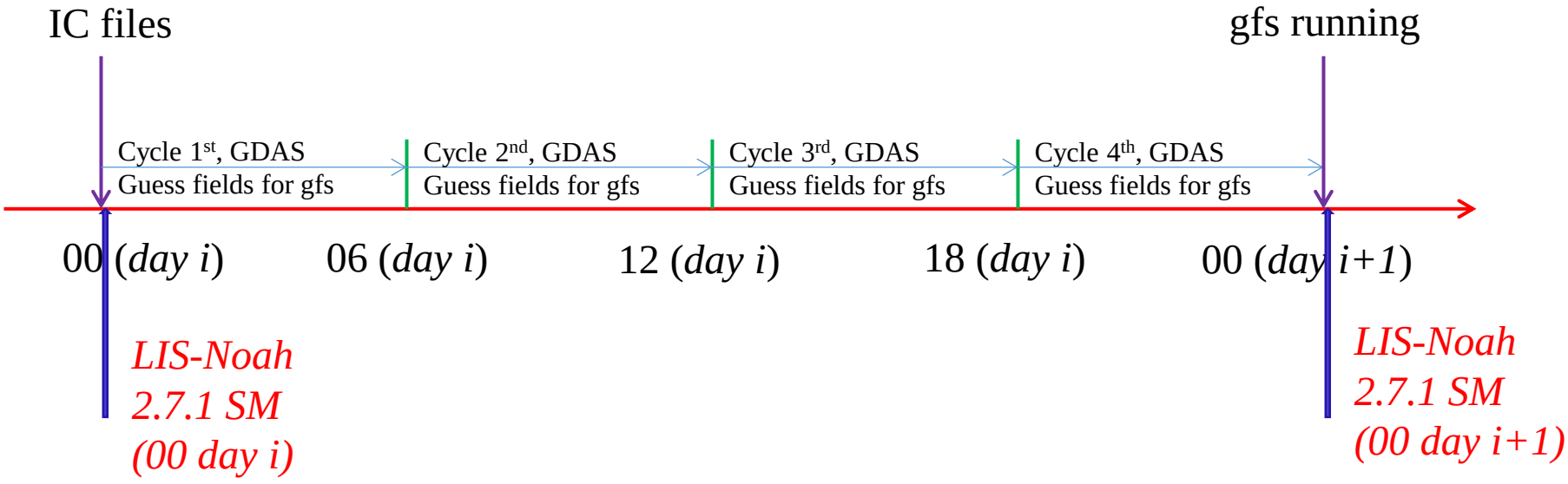


Semi-coupled GFS/LIS Assimilation System

NCEP-GFS model



Semi-coupled system of GFS and LIS



Semi-coupled GFS/LIS Assimilation System

Initial Validation Period: 26 April to 9 May 2015

LIS Noah LSM Spin-up from Cold Start : 1 Jan2000 to 26 Apr 2015 (cycled 3 times)

Current Progress:

1) GFS T1534 grid set up in LIS
2) LIS Spin-up completed
3) All SMOPS MW SM observation re-mapped to T1534 grid
4) GFS T1534 successfully compiled and running on S4
5) Developed semi-coupling between GFS and LIS – LIS state variables are used to update GFS states variables
6) Control run (no DA) GFS T1534 ran from 26 April to 9 May 2015

In Progress:

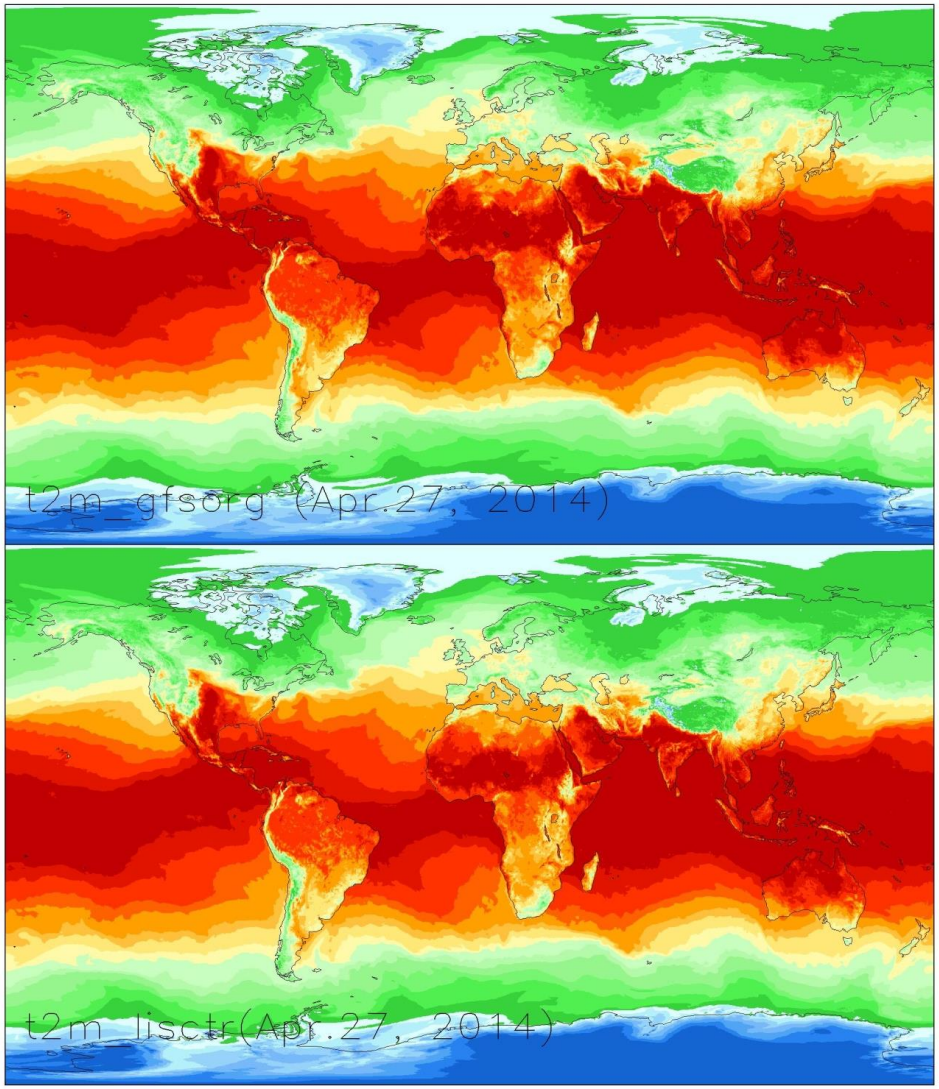
7) GFS T1534 DA run with SMOPS MW SM from 26 April to 9 May 2016

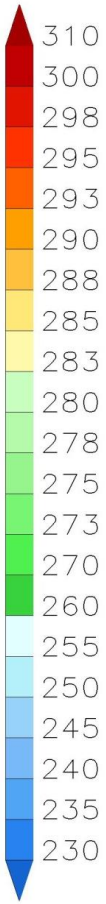
To be Completed:

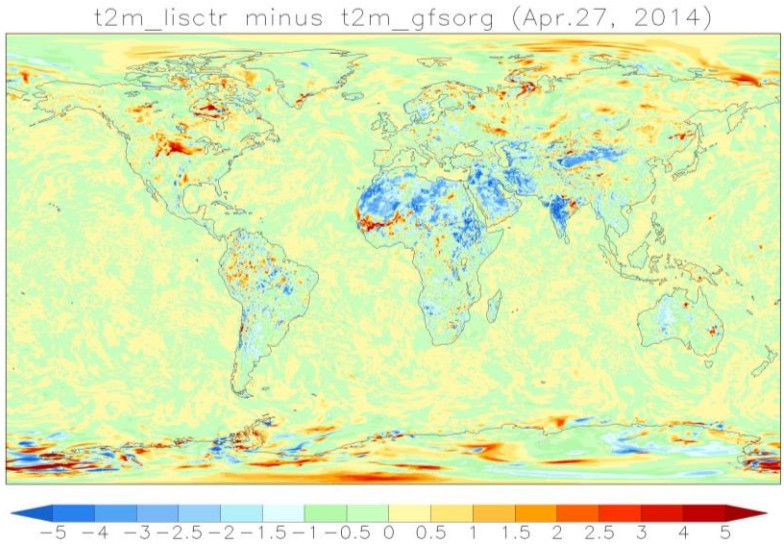
8) Validation and sensitivity analysis
9) Repeat simulations using updated Vegetation Type dataset

Semi-coupled GFS/LIS Assimilation System

GFS (T1534) model-based 2-mr temperature with/without LIS-Noah 2.7.1 SM and their differences.

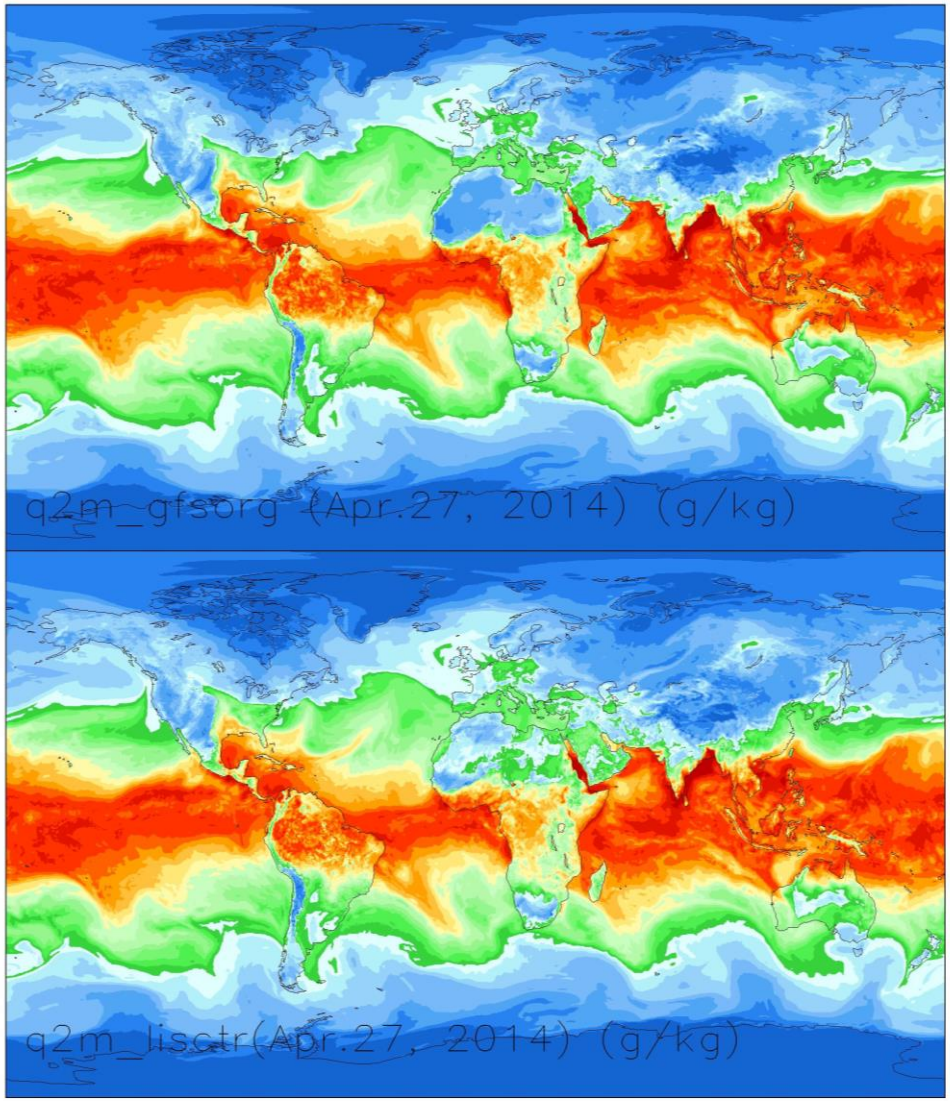


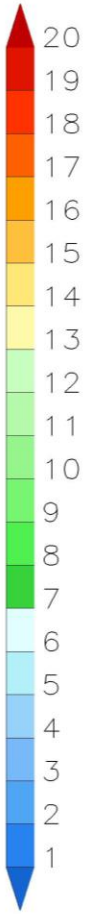


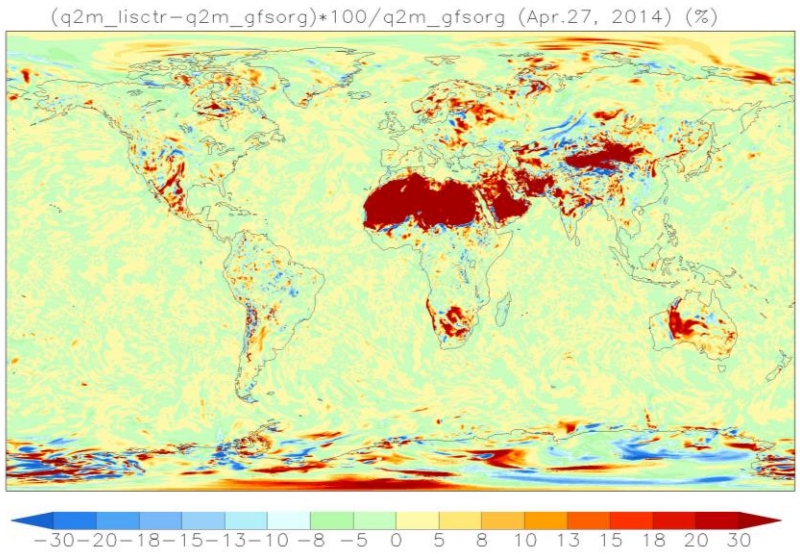


Semi-coupled GFS/LIS Assimilation System

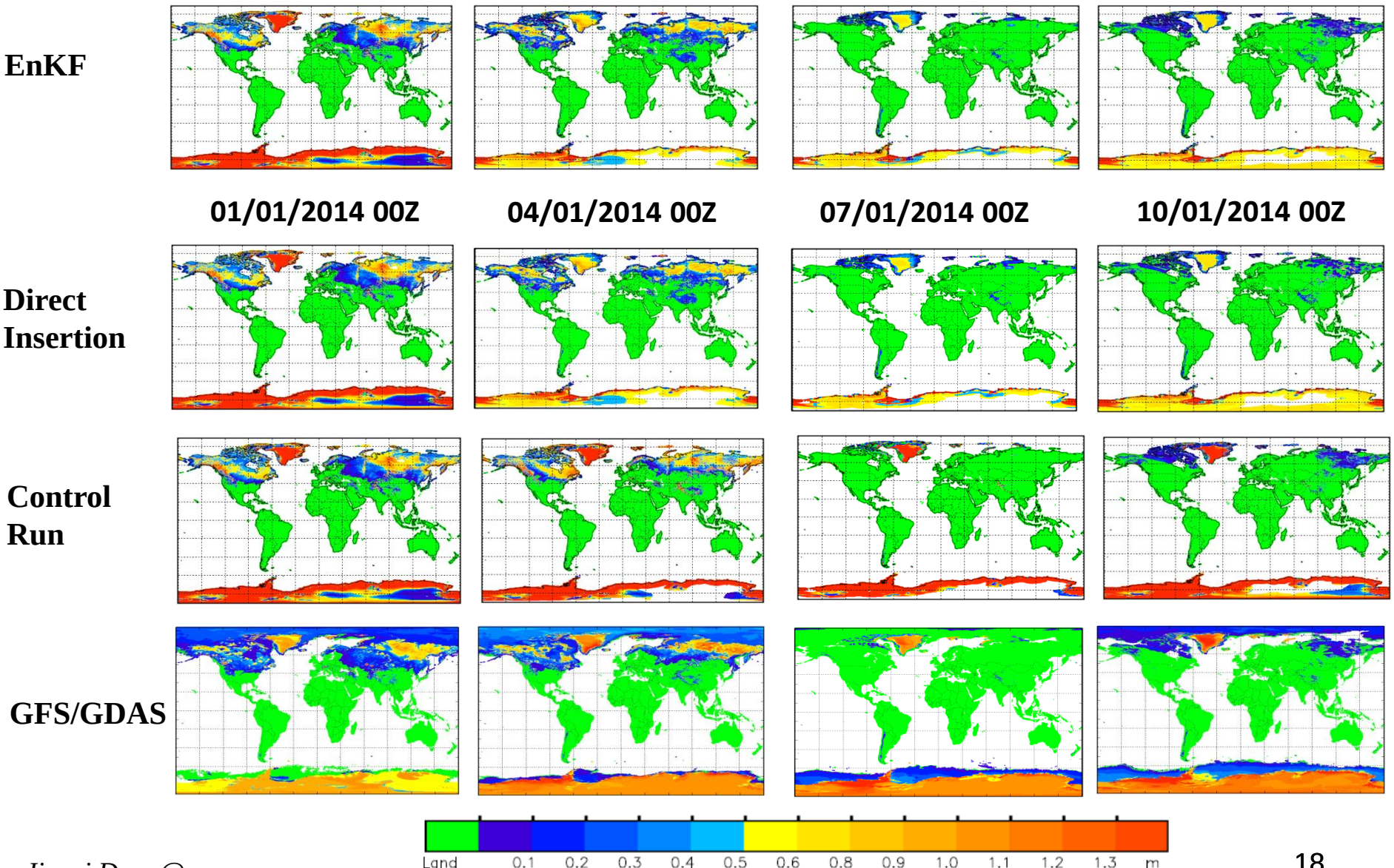
GFS (T1534) model-based 2-m specific humidity with/without LIS-Noah 2.7.1 SM and their differences.







Demonstration of LIS land data assimilation of AFWA Snow Depth



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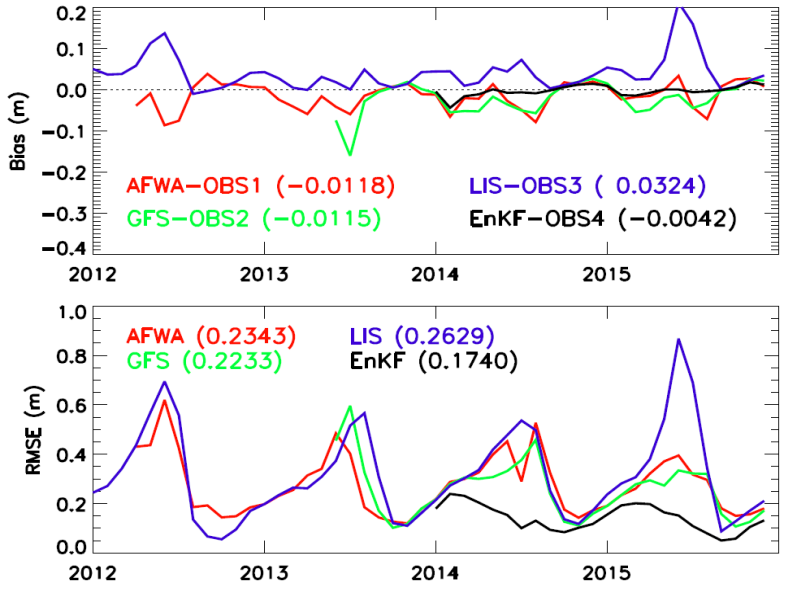
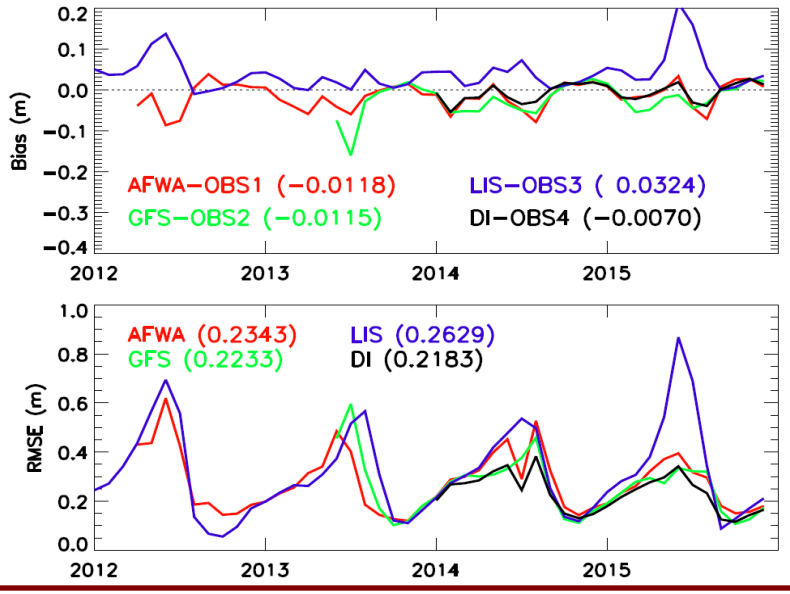
Verification of SNOW DA

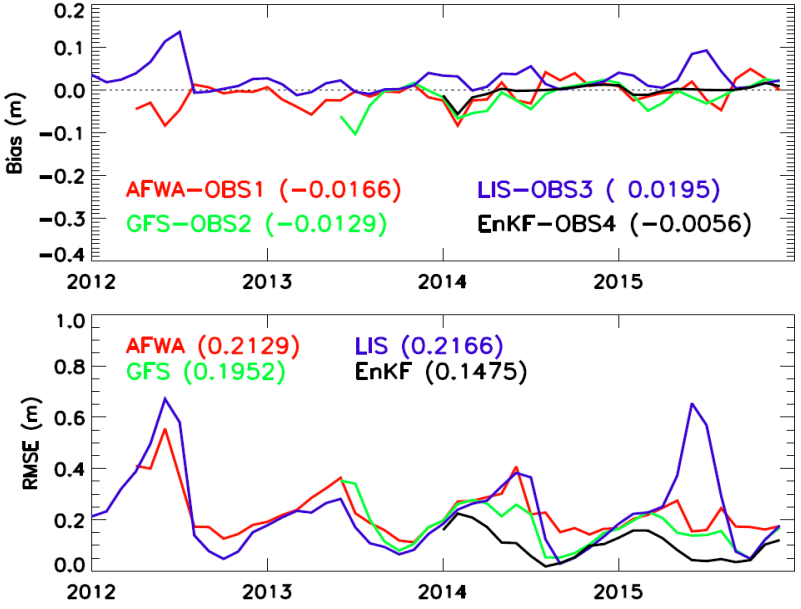
EnKF in Global



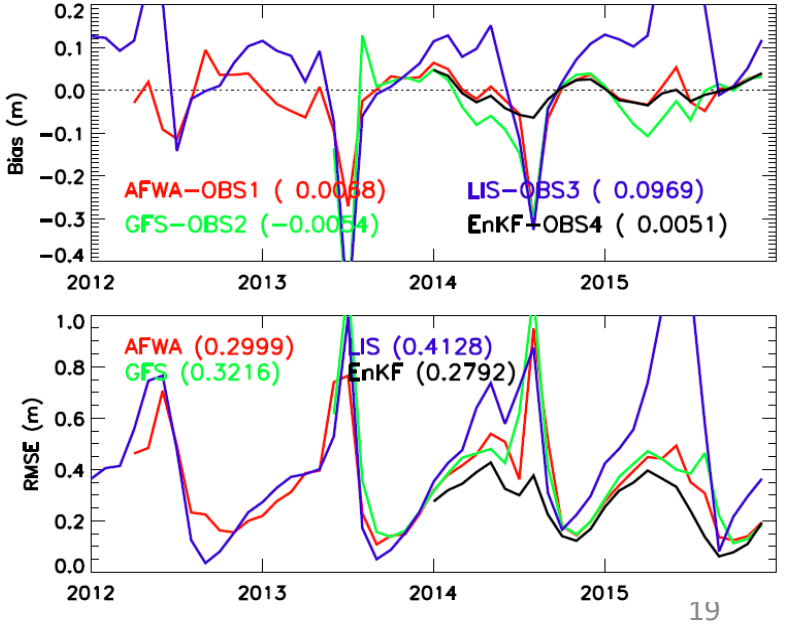
Direct Insertion in Global



EnKF in North America



EnKF in Eurasia



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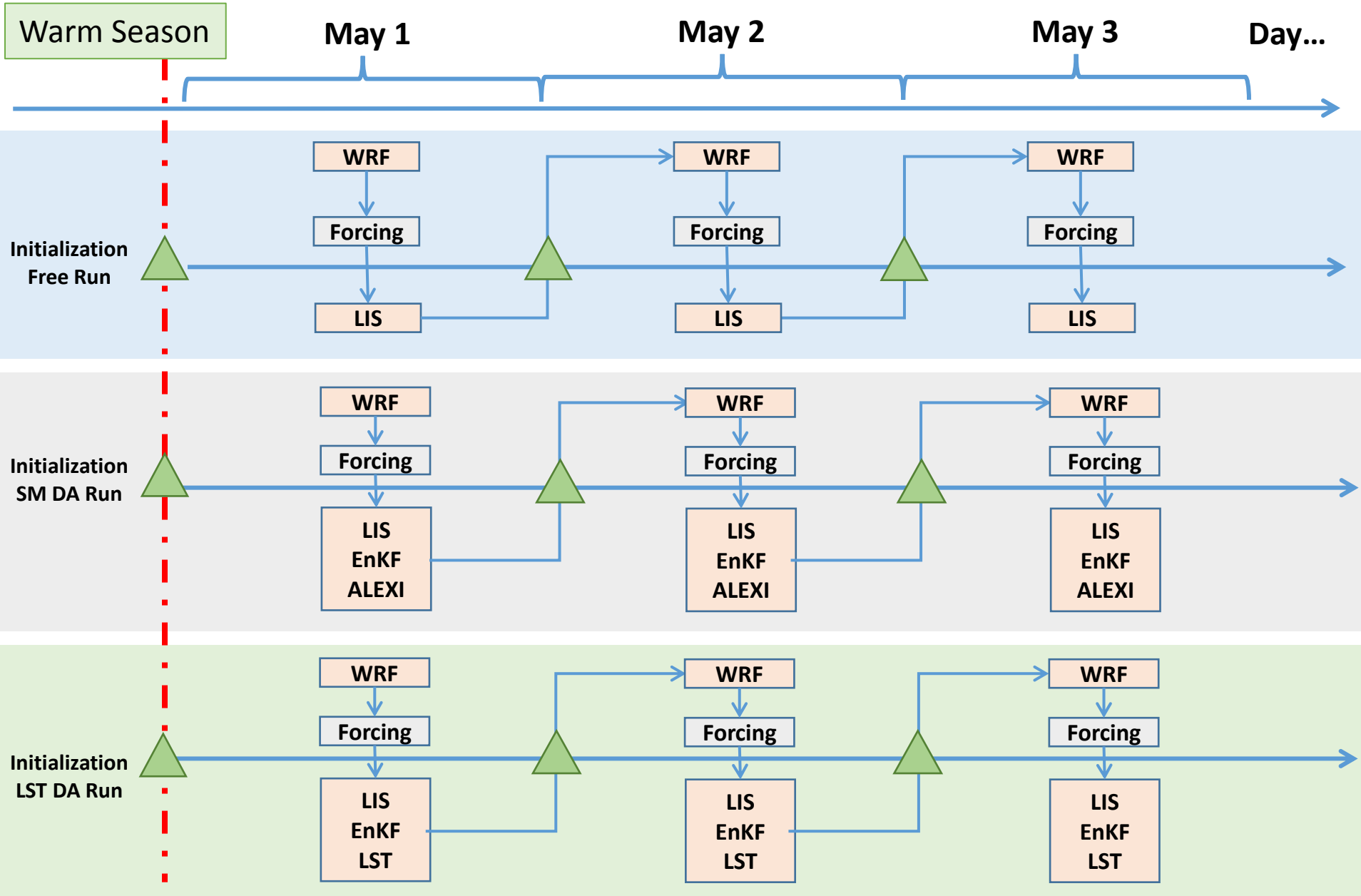
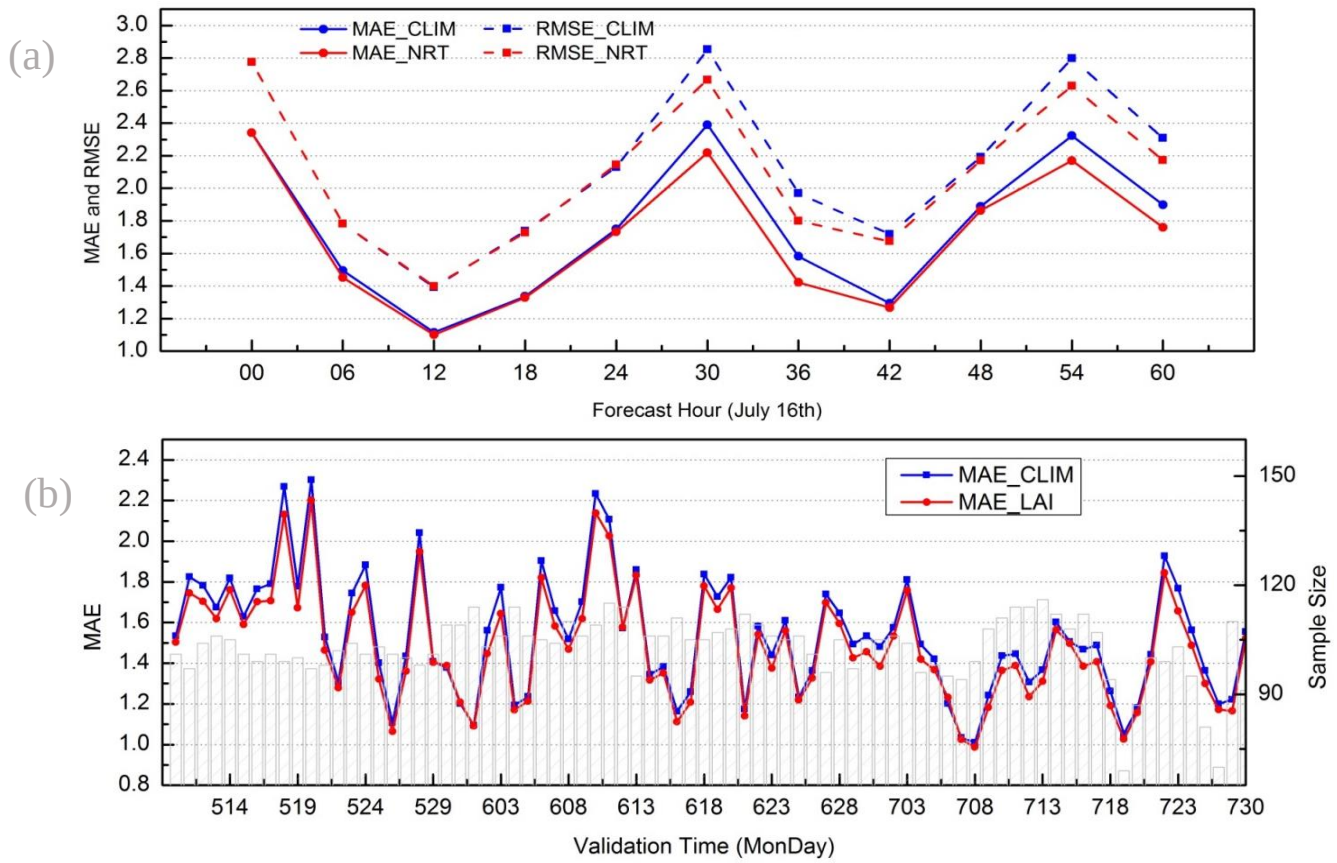
Computational demands of the GFS T1534 limits the number of DA sensitivity tests. Therefore, we developed the same identical semi-coupling of LIS (Noah 3.3) with WRF (v3.6; Noah 3.3) to evaluate the impact of additional land observations over the CONUS.



Regional Semi-coupled WRF/LIS Assimilation System

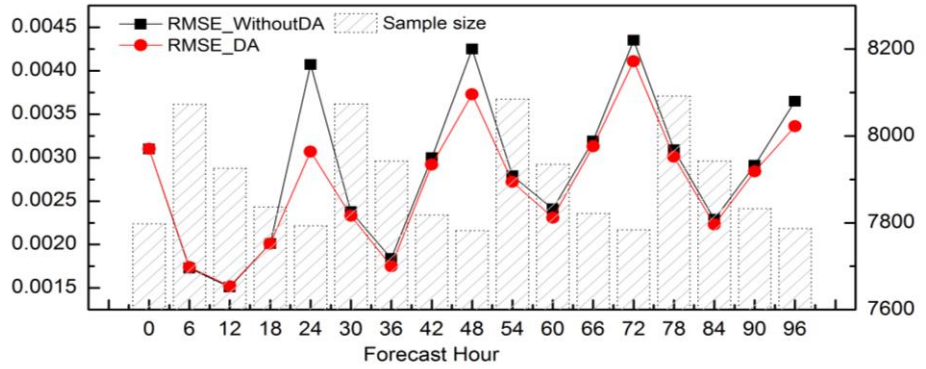
- CONUS Evaluation – Impact of Near-realtime GVF



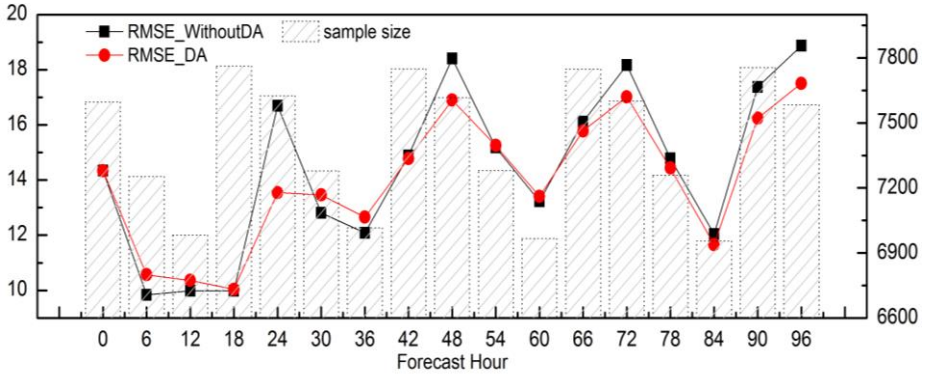
MAE and RMSE in 2 m surface temperature for CONUS region
(a) for 60h forecast on July 16th; (b) over the period of May to July

MW SM assimilation in WRF

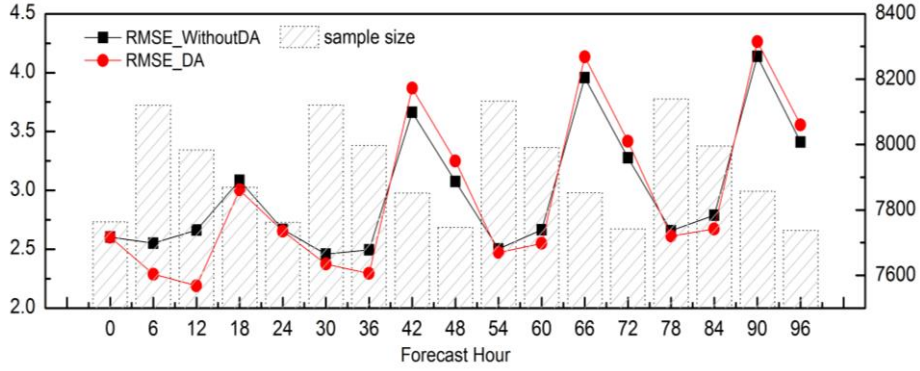
2-m specific humidity (kg/kg)



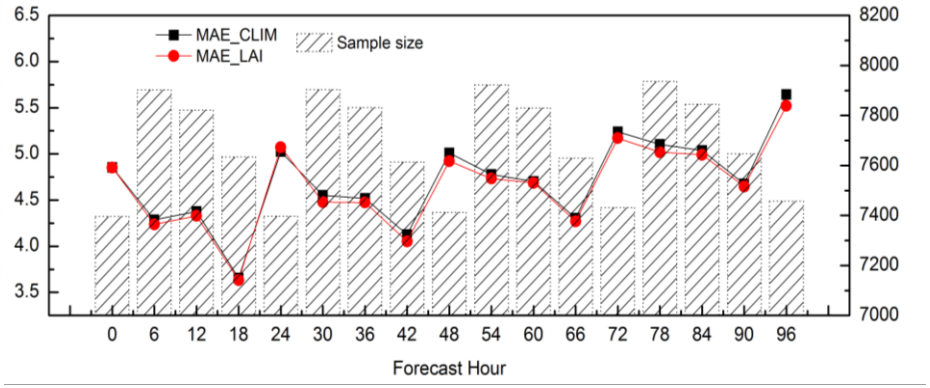
2-m relative humidity



2-m above ground temperature (K)



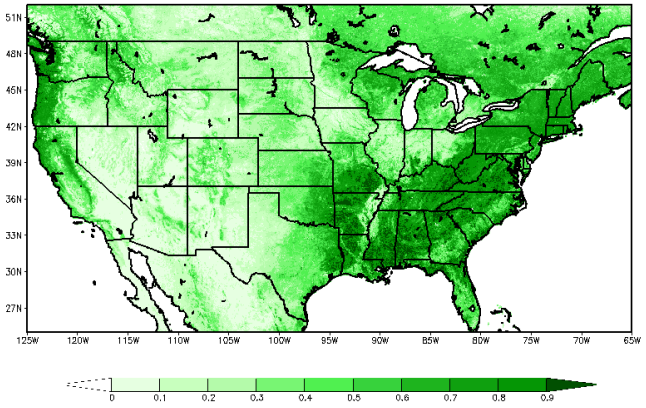
2-m dew point temperature (K)

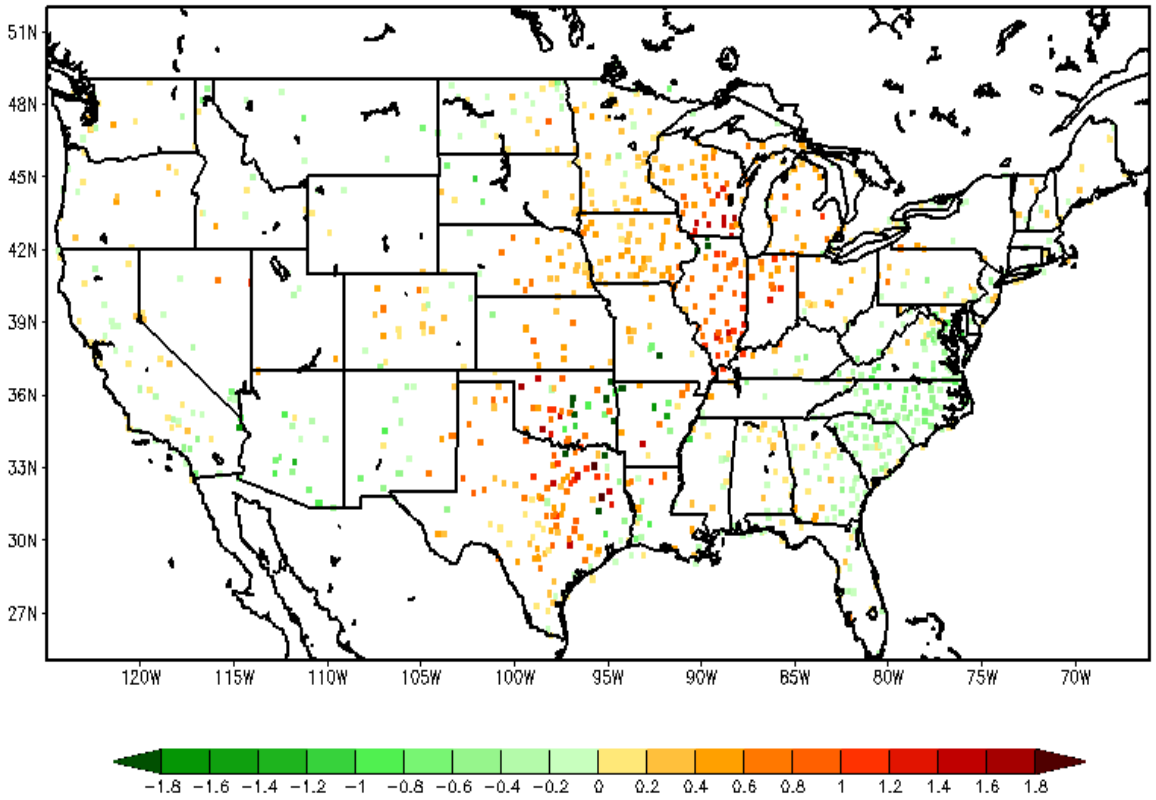


Average RMSE of NUWRF forecast with and without CCI SM assimilation over 96 forecast hours for 2 m specific humility, 2 m temperature, 2 m relative humility and 2 m dew point temperature

MW SM assimilation in WRF

- The pattern of the RMSE difference map (right) matches well with the average surface vegetation fraction map (bottom)
- Greater impact is shown over the regions with low vegetation cover

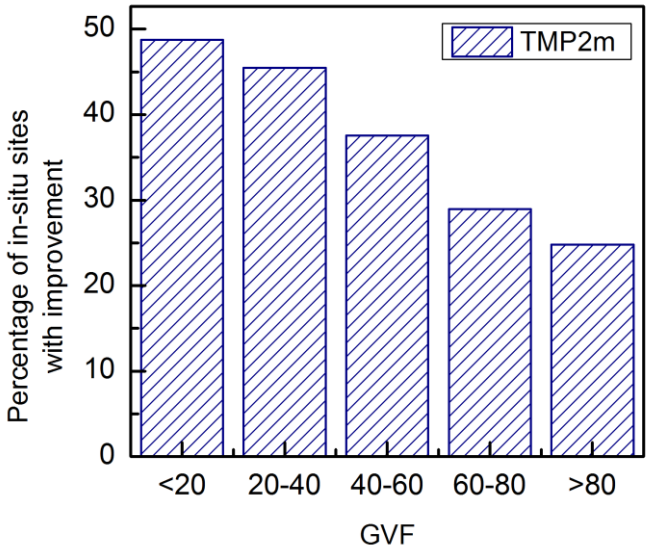




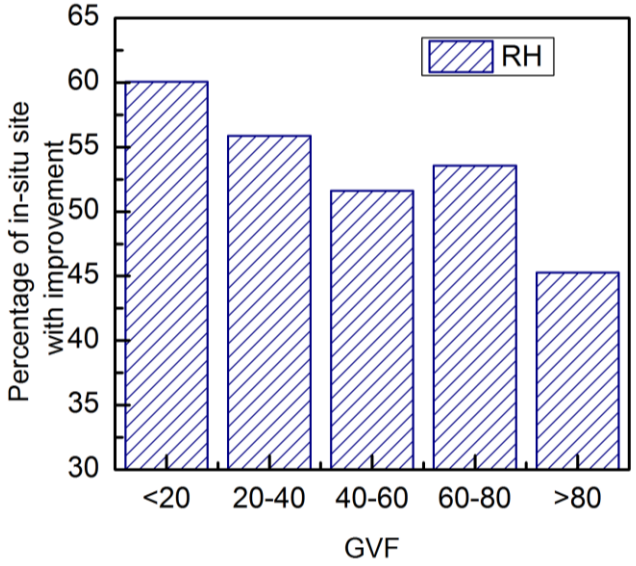
Spatial distribution of RMSE difference in 2 m RH (forecast without DA minus forecast with CCI SM data assimilation)
er the period of May 10th to May 19th

MW SM assimilation in WRF

- The impact of assimilating SM product on validated variables steadily decreases as surface vegetation cover grows
- Higher vegetation cover reduces the quality of MW sensing of soil moisture

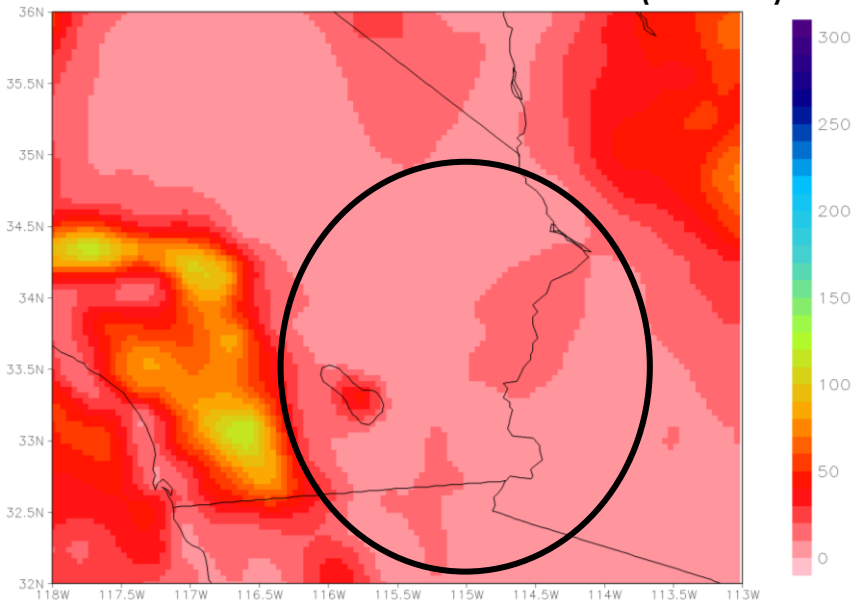


GVF_bin	Total Sample	RH Improvement (%)	DPT Improvement (%)	SH Improvement (%)	TMP2m Improvement (%)
<20	162	60.06	65.28	62.61	48.77
20-40	297	55.88	66.31	69.44	45.45
40-60	237	51.61	58.63	64.27	37.55
60-80	214	53.57	51.86	53.59	28.97
>80	137	45.29	41.06	43.95	24.82

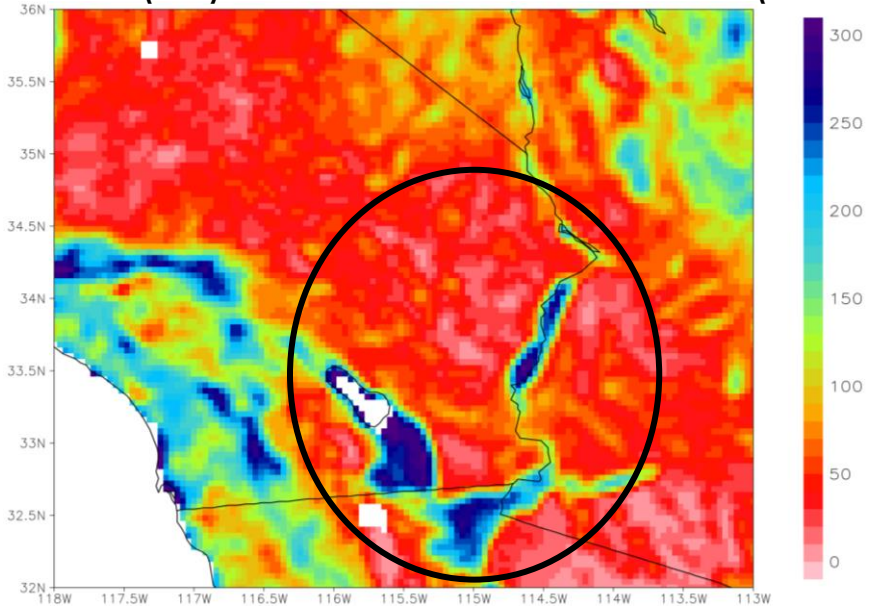


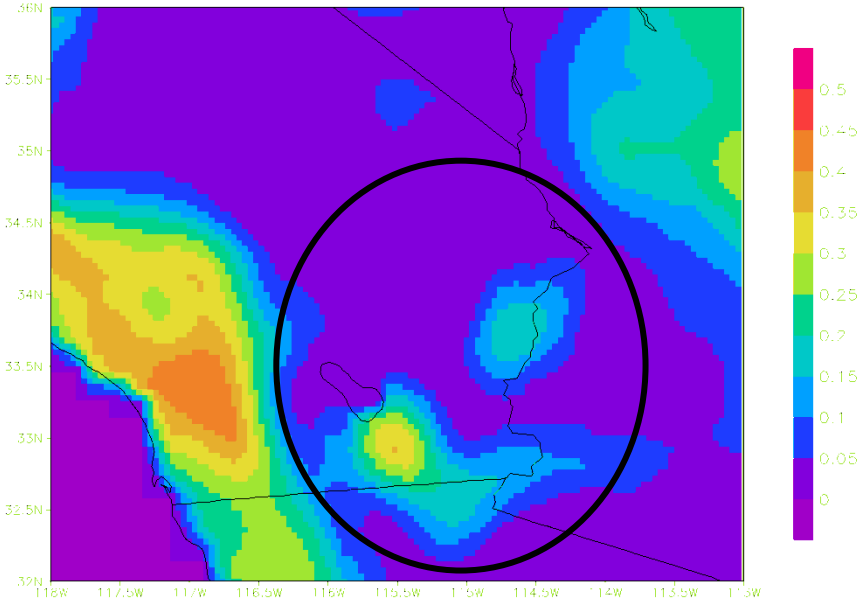
Using Diagnostic RS in Model Evaluation

NAM 4-km Latent Heat Flux (Wm^{-2})



ALEXI (RS) 4-km Latent Heat Flux (Wm^{-2})





NAM GVF (%)