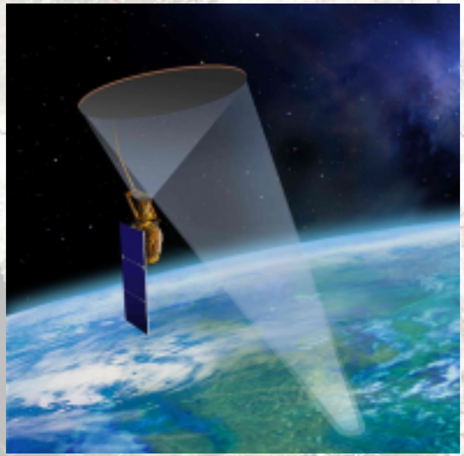
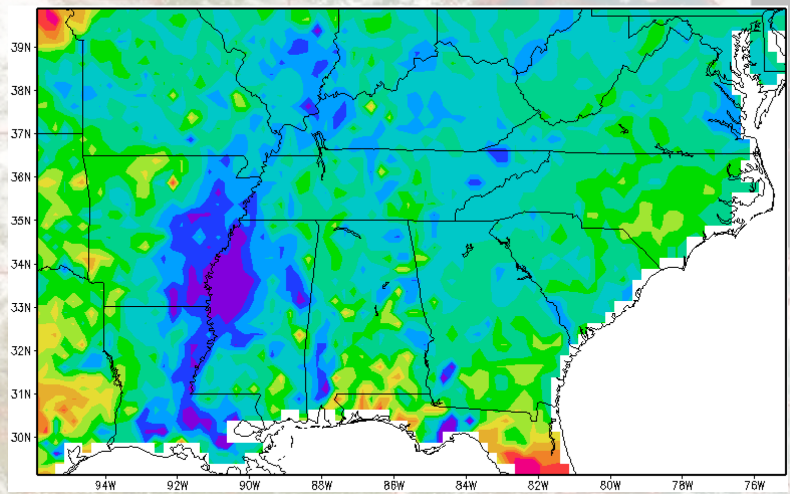
SMOS soil moisture data assimilation in the NASA Land Information System:

Impact on LSM states and NWP forecasts





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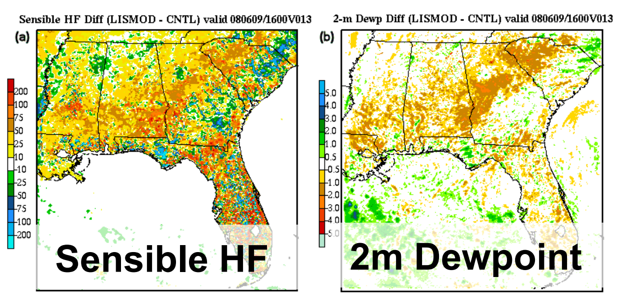
Overview and Motivation

Goal: Assimilate SMOS satellite retrievals of soil moisture into a land surface model

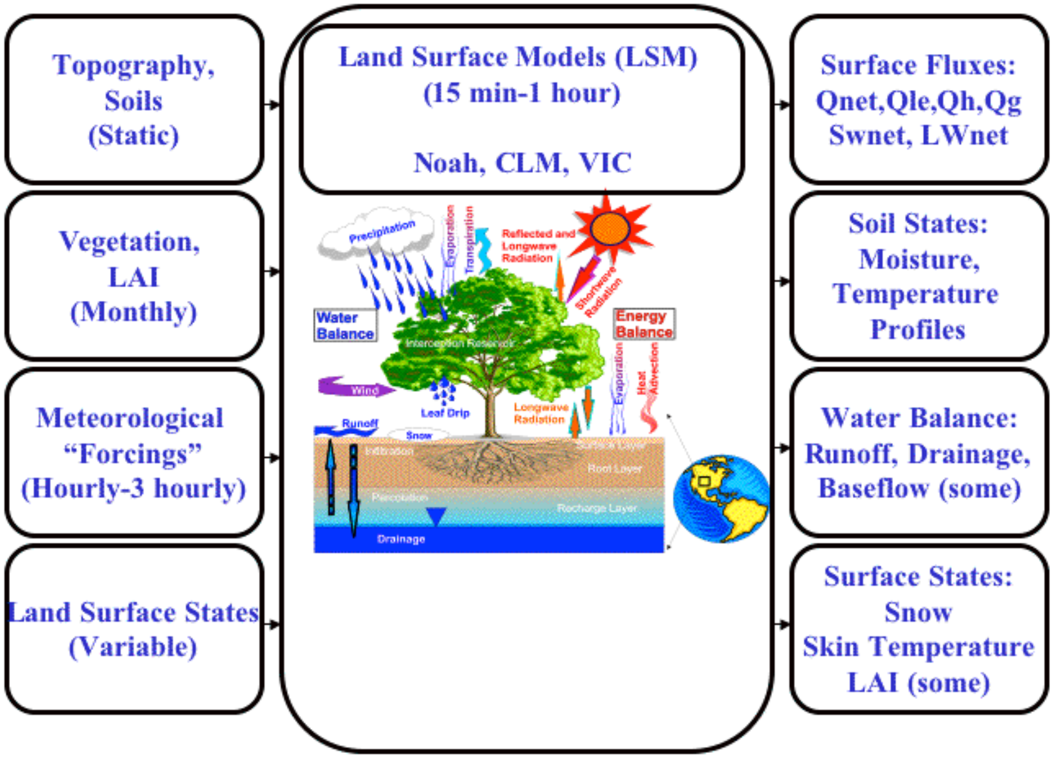
- Improve model depiction of soil moisture and related variables
  - Impacts include drought monitoring, situational awareness for flood forecasting, agriculture, public health

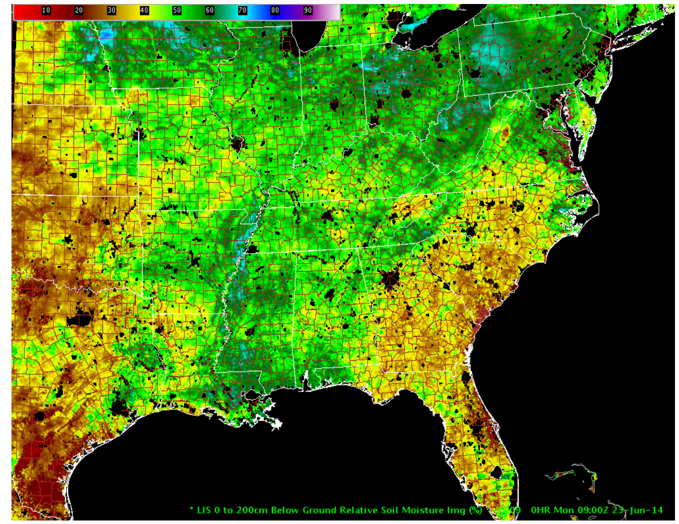



- Better initialization of numerical weather forecasts
  - Available moisture affects humidity, sensible/latent heating, diurnal heating rate, and convection.



Land Information System (LIS)

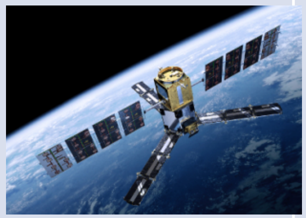
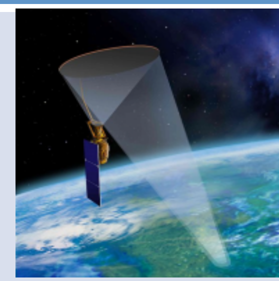




SPoRT-LIS total column soil moisture displayed in AWIPS II

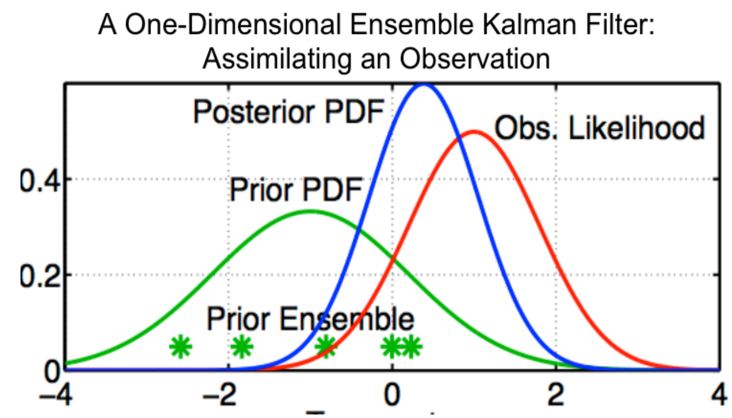
- Land Information System (LIS) developed at GSFC
  - Framework for running LSMs incorporating a wide variety of meteorological forcing data and land surface parameters
- Experiments done in Noah 3.2 Land Surface Model (LSM) within LIS
- NASA SPoRT (Short-term prediction Research and Transition Center) maintains a near-real-time 3-km LIS run, shared with WFO's

Soil Moisture Instruments

Name	SMOS Soil Moisture and Ocean Salinity	SMAP Soil Moisture Active/Passive		
				
Agency	ESA	NASA		
Launch	2009	Jan. 29, 2015		
Orbit	Polar	Polar		
Sensor Type	Passive (synthetic aperture)	Passive	Active	Combined
Frequency	1.4 GHz (L-band)	1.41 GHz	1.2 GHz	
Resolution	35-50 km	36 km	**3 km**	9 km
Accuracy	**4 cm^3/cm^3**	**4 cm^3/cm^3**	6 cm^3/cm^3	**4 cm^3/cm^3**

Data Assimilation in LIS

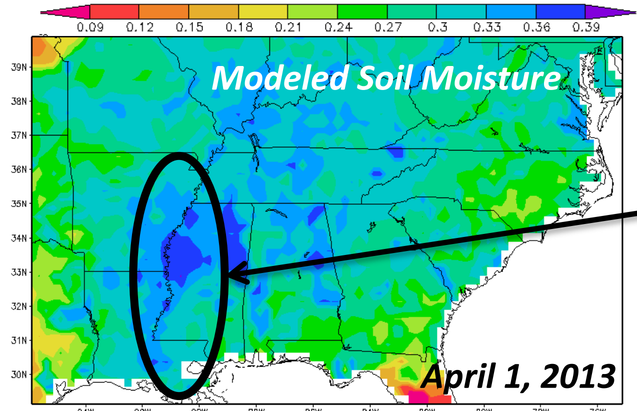
- Use Ensemble Kalman Filter within LIS to assimilate satellite soil moisture retrievals into the Noah 3.2 LSM
- EnKF combines the model **background** and **observations** to make **analyses**
  - Relative weighting is controlled by the specified **observation error** and by the **ensemble spread**
- Implemented EnKF assimilation of SMOS L2 data
  - Assimilating retrievals (rather than radiances) lets us use established methodology
  - QC based on model state and data flags for precipitation, RFI, data quality, frozen soil, snow cover, and high vegetation
  - Empirically tuned run-time settings including perturbations, number of ensemble members



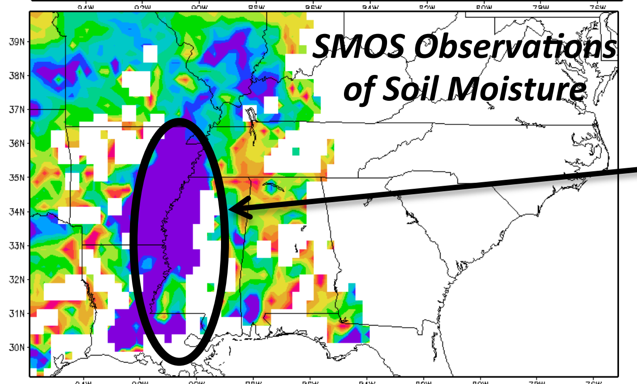
- Assimilation is 1-D (each grid cell independent). Observations can be spread over several grid cells for high-resolution model runs.

Figure from J. Anderson, NCAR.

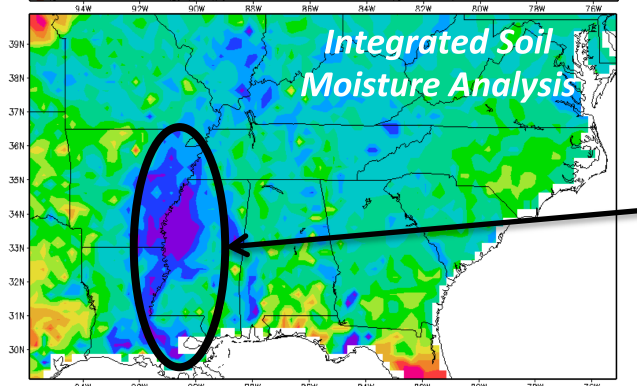
Example DA (rice irrigation)



Model soil moisture concentration forced only by precipitation and misses magnitude of irrigation-saturated MS Valley

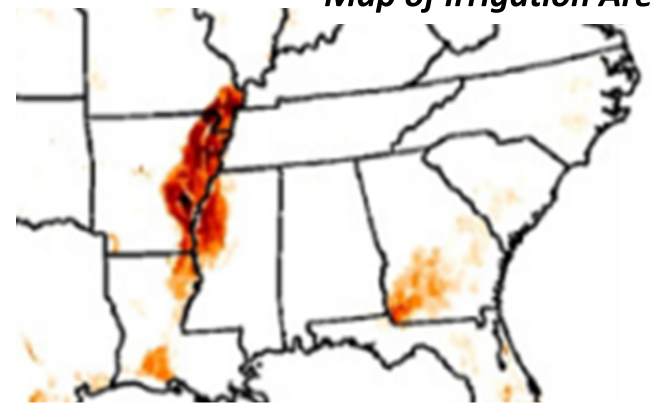


SMOS observes irrigated fields



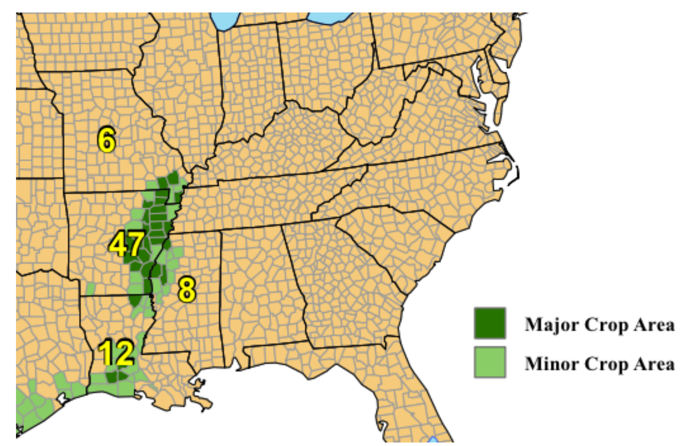
Blended analysis of model and observations better represent irrigated area and should result in improved weather and hydrologic modeling

Map of Irrigation Areas



From U. of Frankfurt-FAO (Ozdogan 2001)

Rice growing areas



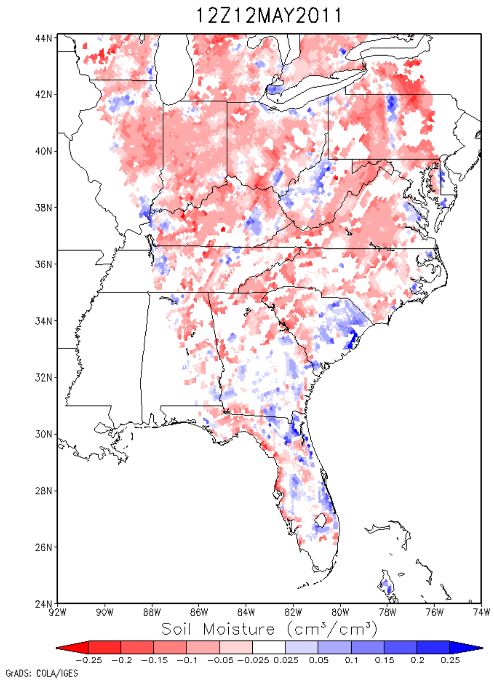
Yellow numbers indicate percentage of national crop yield due to each state.

SPoRT

Bias Correction

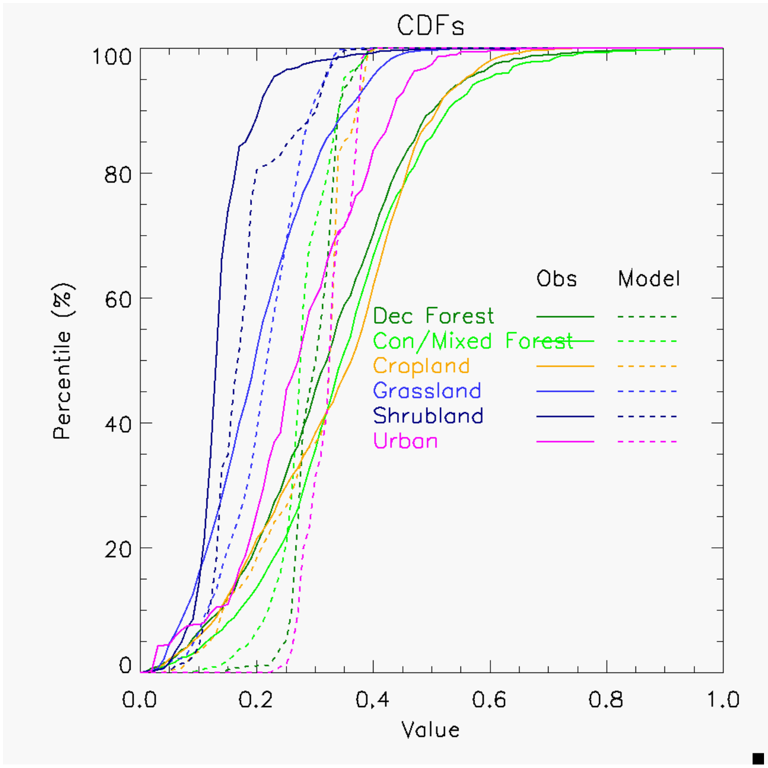
- Initial tests had large dry bias in observations, so that only extreme rain events had correct sign.
- Discussions with other researchers confirmed need for bias correction

Innovations (Ob-Bk)
(Uncorrected)

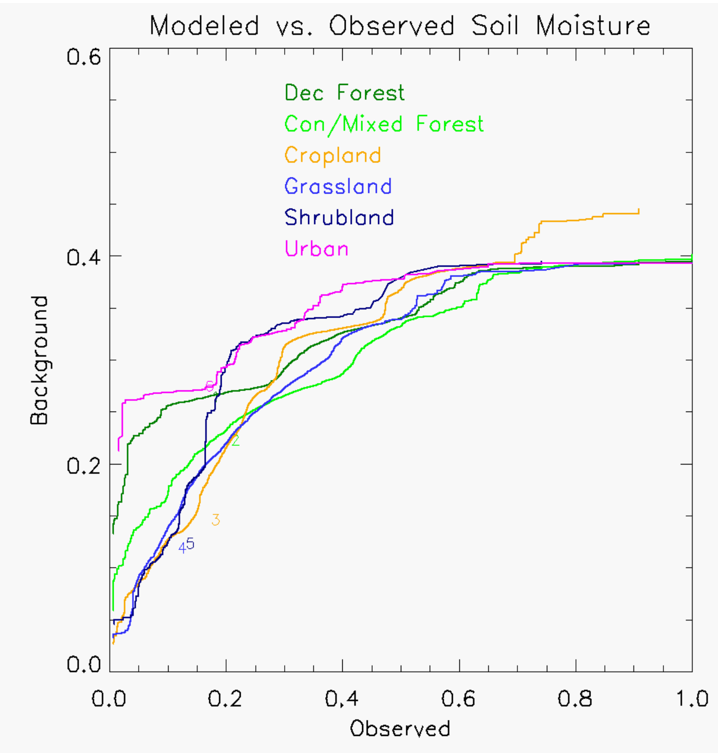


Bias Correction

CDFs of Soil Moisture Observations



Correction Curves

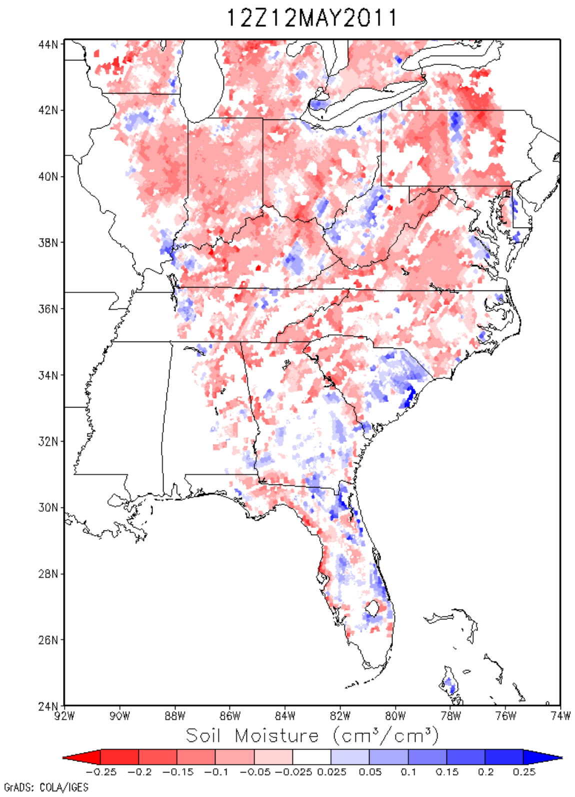


- **LIS can apply point-by-point correction curves. To increase the background dataset size, we are aggregating points by landcover type. We will also explore correction at each point and aggregating by soil type.**
- **In general, observations are drier than the model but have a higher dynamic range.**

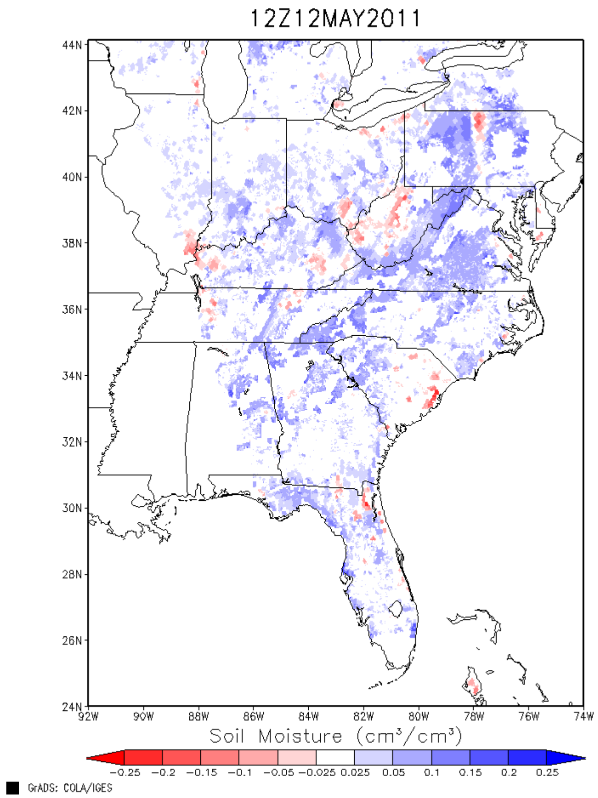
Bias Correction

- Implemented landcover-based CDF matching correction for SMOS retrievals.

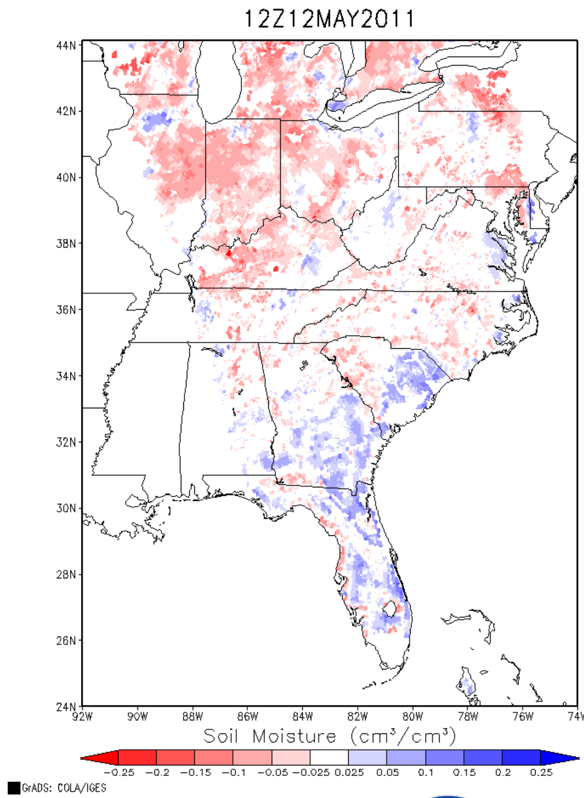
Innovations (Ob-Bk) (Uncorrected)



Bias Correction

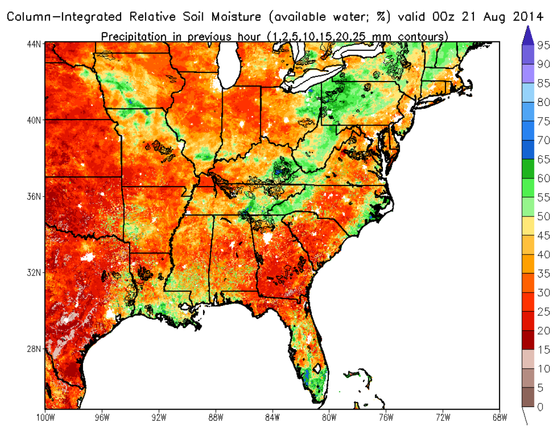


Innovations (Corrected)



Experiment Overview

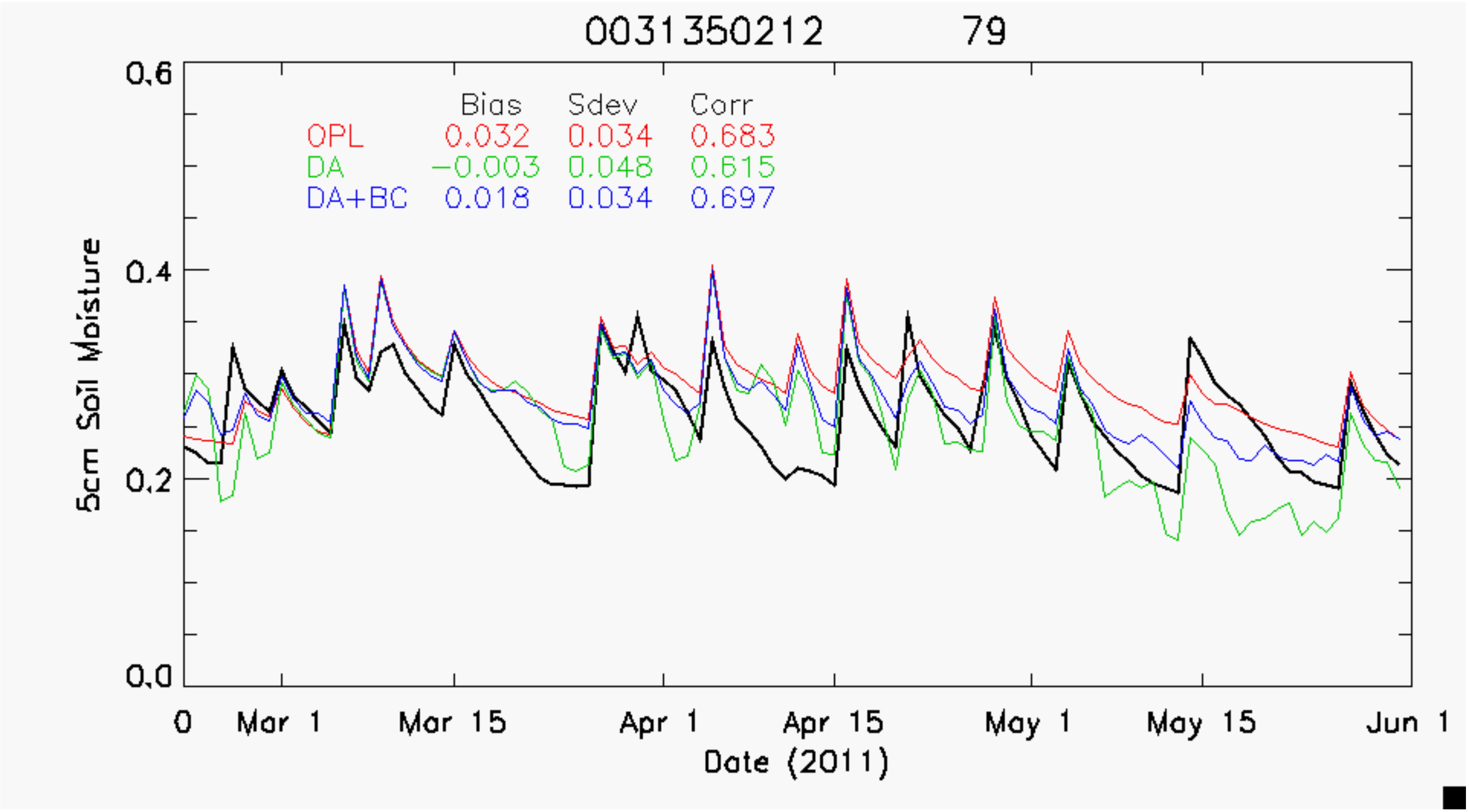
- SE US domain, 2/1/2011-6/1/2011
  - 1 year soil moisture spinup
  - 1 month perturbation spinup
  - Forcing from NLDAS-2 analysis
  - Real-time MODIS GVF



- 3 Model runs
  - OPL: Open loop
    (ensemble run with perturbations, no DA)
  - DA: Data assimilation only
  - DABC: Data assimilation and bias correction

Validation

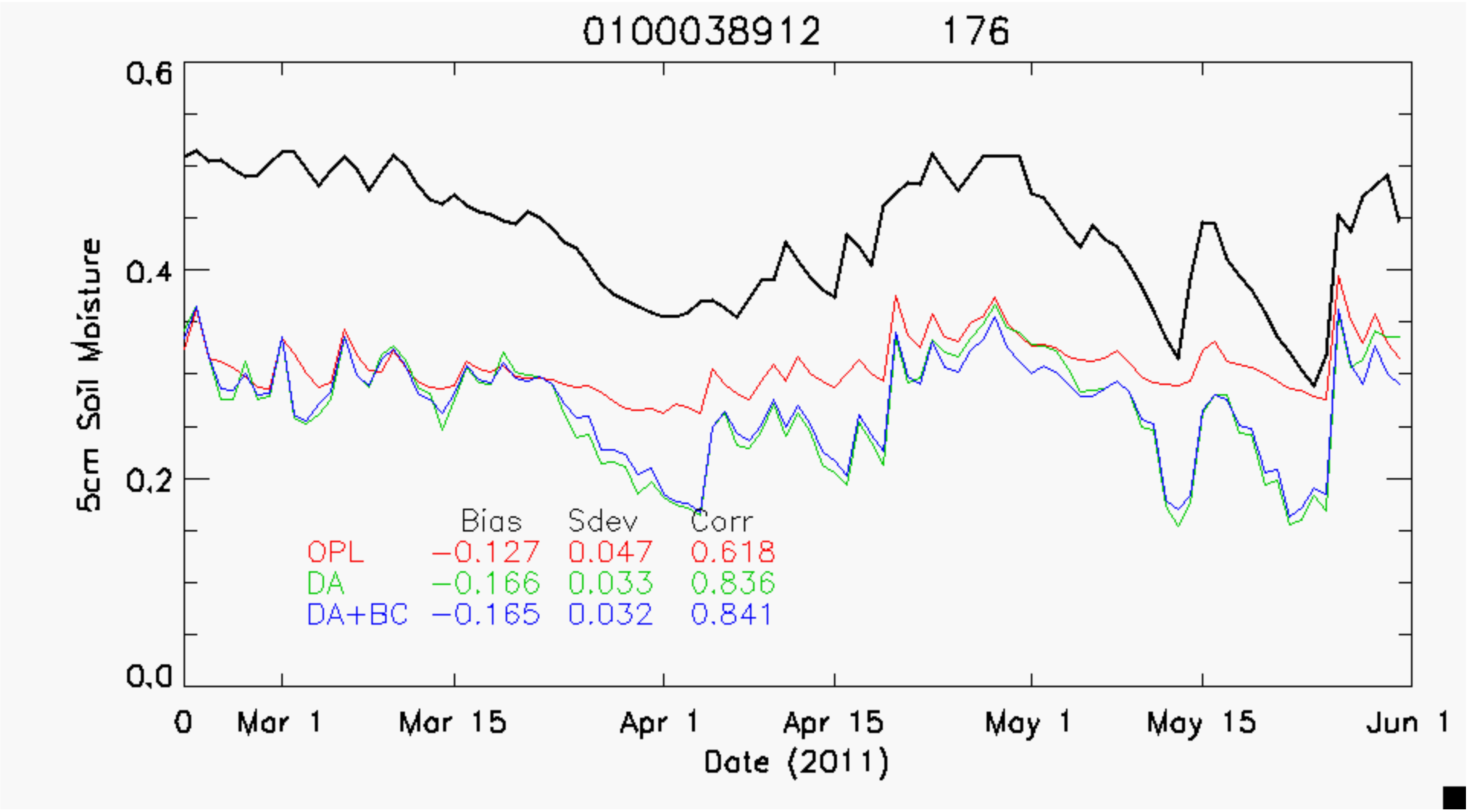
New Hope, AL



In situ validation data from TAMU North American Soil Moisture Database.

Validation

Champaign, IL



Validation statistics from Noah LSM

112 stations, Feb to May 2011

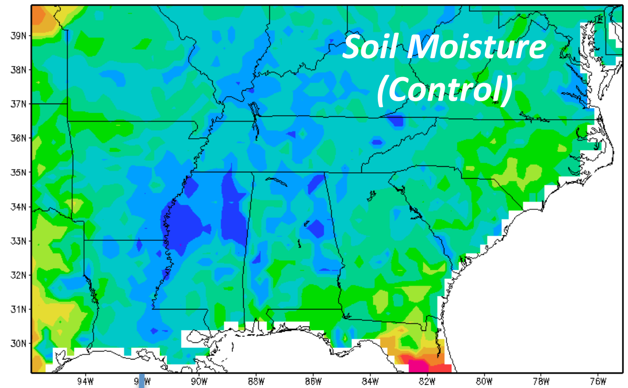
Experiment	Open Loop	DA	DA+BC
Bias	-2.2%	-3.3%	-2.8%
Err. Std. Dev.	9.0%	9.2%	9.0%
Stationwise Correlation*	0.59	0.62	0.63

**Mean of Pearson correlation coefficient at each station*

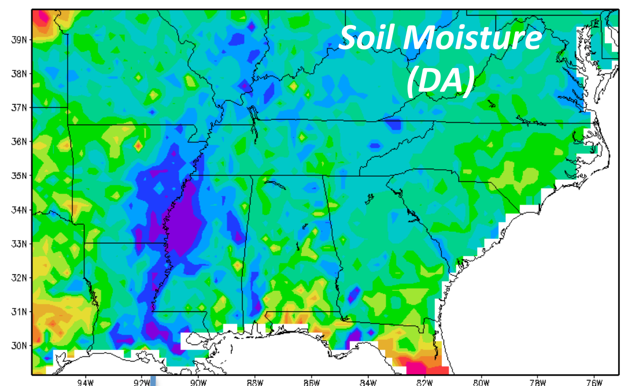
Results

- Both DA runs have worse bias, but bias varies widely depending on soil properties (e.g. porosity) varying between grid cell and site
- Error standard deviation slightly worse for DA run
- Stationwise correlation shows some improvement for DA and BC

WRF impact tests



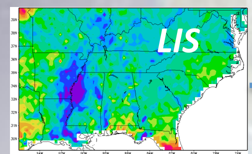
WRF → Forecast Fields



WRF → Forecast Fields

- Hypothesis: extensive flood irrigation in Missisippi Valley may have significant impacts on weather
  - E.g. on diurnal heating, or convective initiation
  - Control run does not include irrigation
- Test impact on NWP using LIS to intialize WRF
  - Validate soil moisture values
  - Examine impact on NWP
  - Verify NWP forecasts
- Implications for regional climate modeling
  - Impacts of changing land-use, precipitation patterns

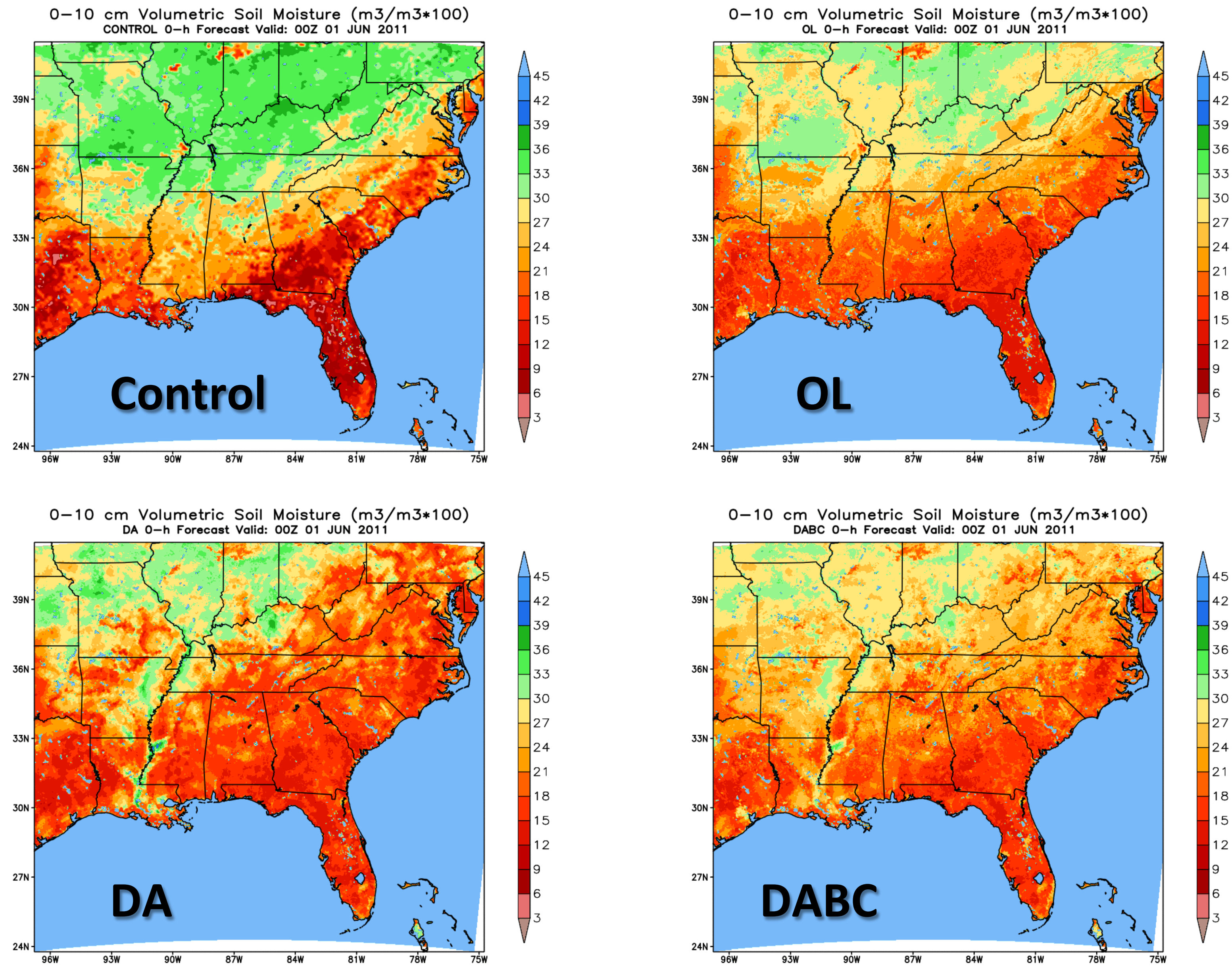
WRF Sensitivity Runs: 1 June 2011



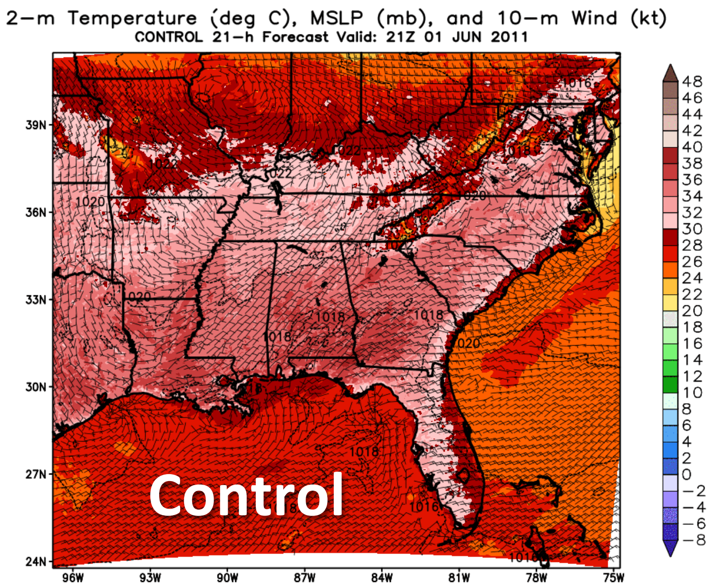
→ WRF 48 hr fcst → Forecast Fields

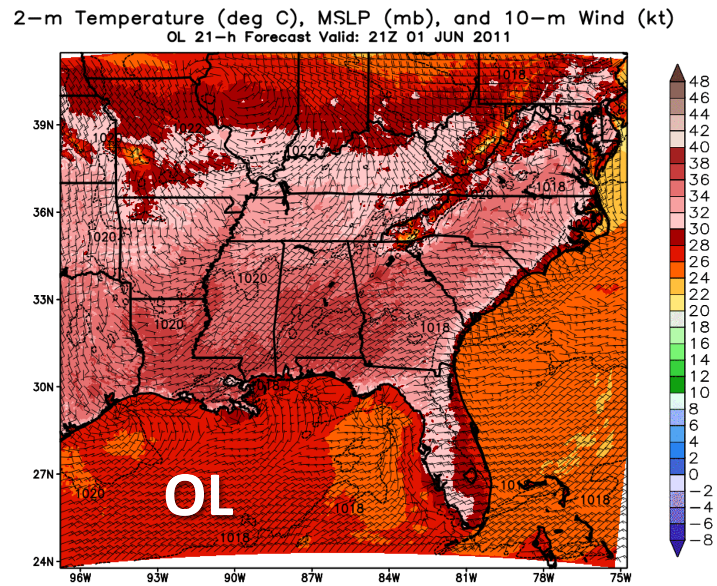
- Model software / physics / grid setup:
  - Advanced Research WRF dynamical core within NASA Unified-WRF (NU-WRF) model, based on community WRF v3.5.1
  - NASA/GSFC SM microphysics-graupel and short-/longwave radiation, Noah LSM, MYJ PBL scheme, no cumulus convection
  - SE CONUS domain at 3-km grid spacing and 61 vertical levels
- Model run sensitivity details:
  - Initialized on 0000 UTC 1 June 2011
  - Integrated 48 hours (out to 0000 UTC 3 June)
  - Initial/boundary conditions: NCEP NAM 0-48 hour forecasts
  - Experiments with varied soil/land surface initial conditions:
    - **Control**: NAM soil/land surface
    - **Open loop (OL)**: LIS open-loop (no data assimilation)
    - **Data Assimilation (DA)**: LIS run with SMOS DA (no bias correction)
    - **DA+Bias Correction (DABC)**: LIS run with SMOS DA with bias correction

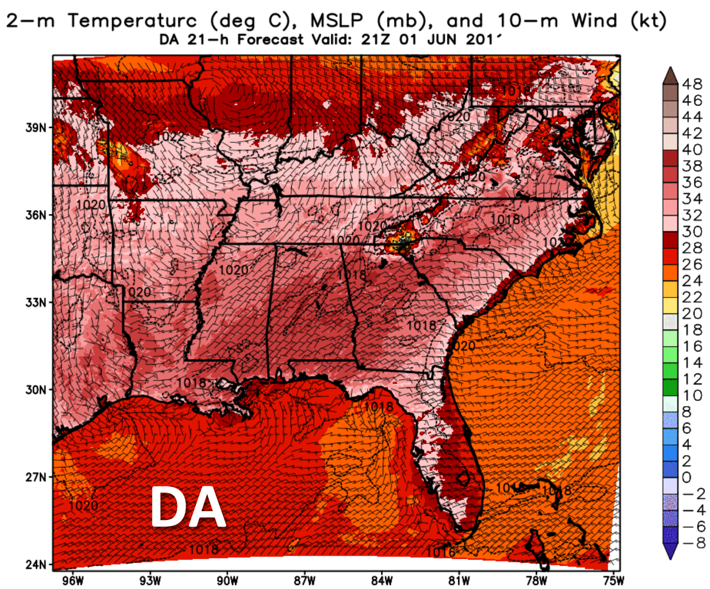
0-10 cm Volumetric Soil Moisture ICs

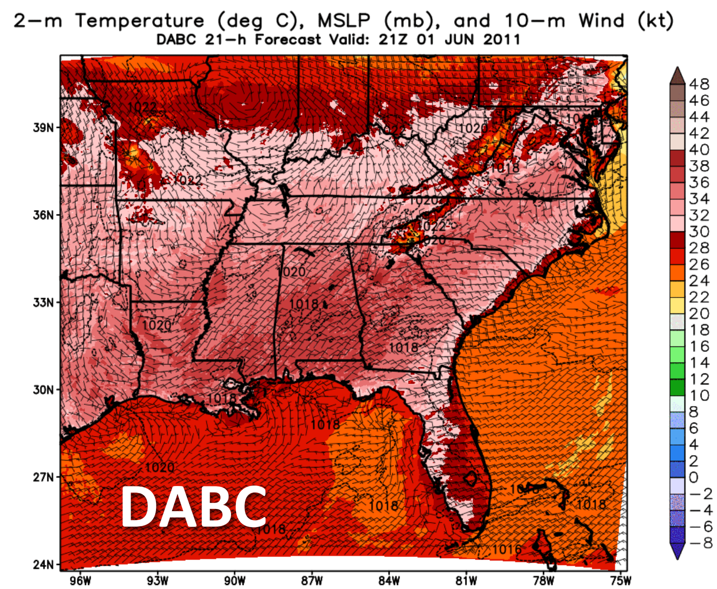


21-h Simulated 2-m Temperature

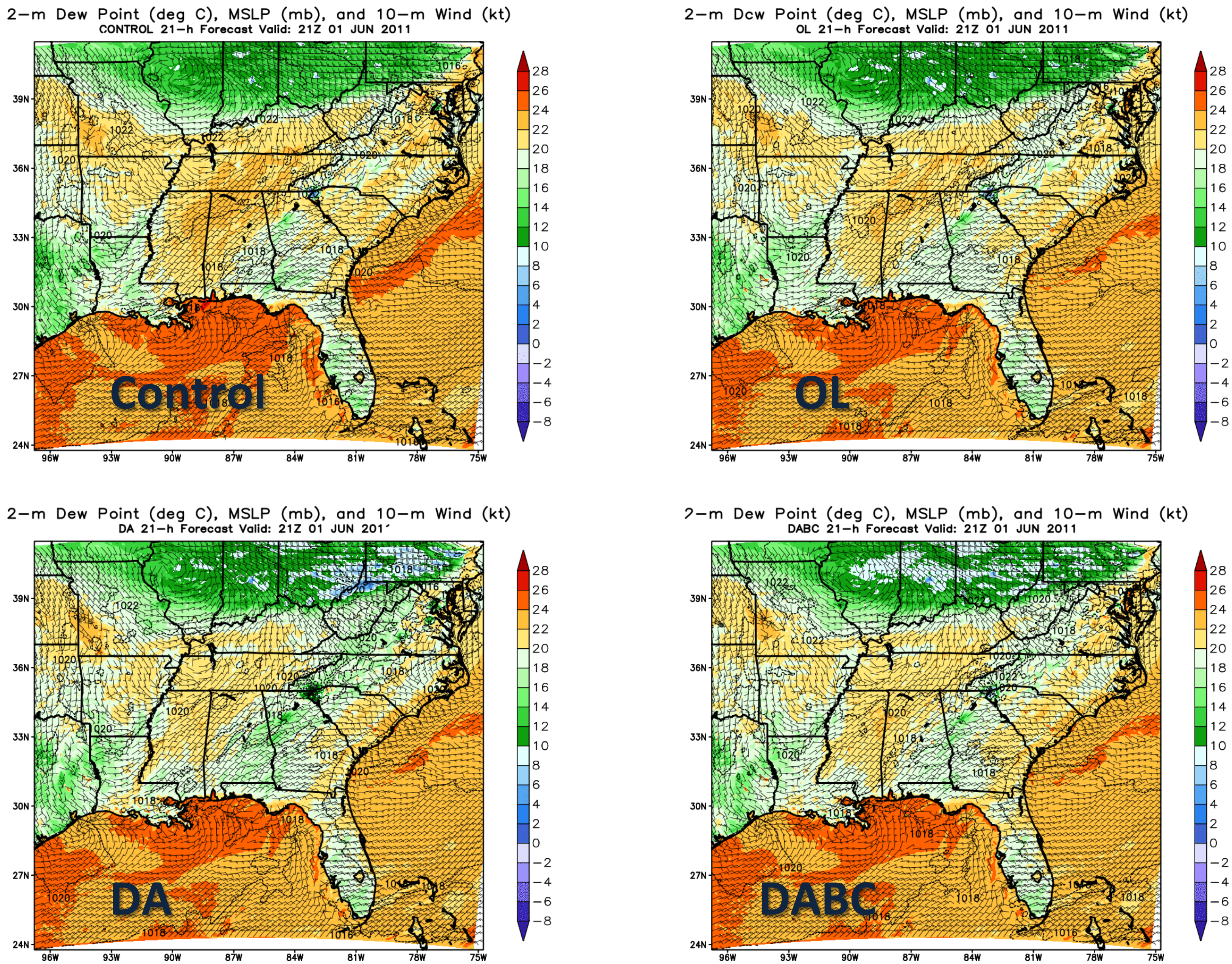




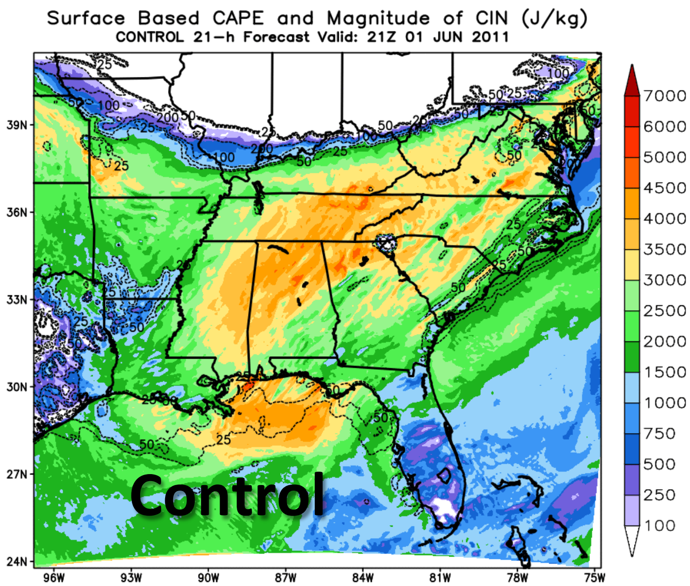


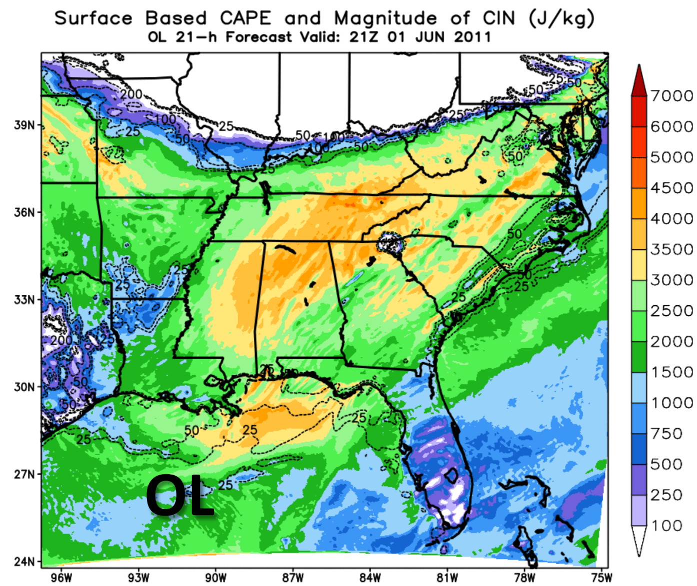


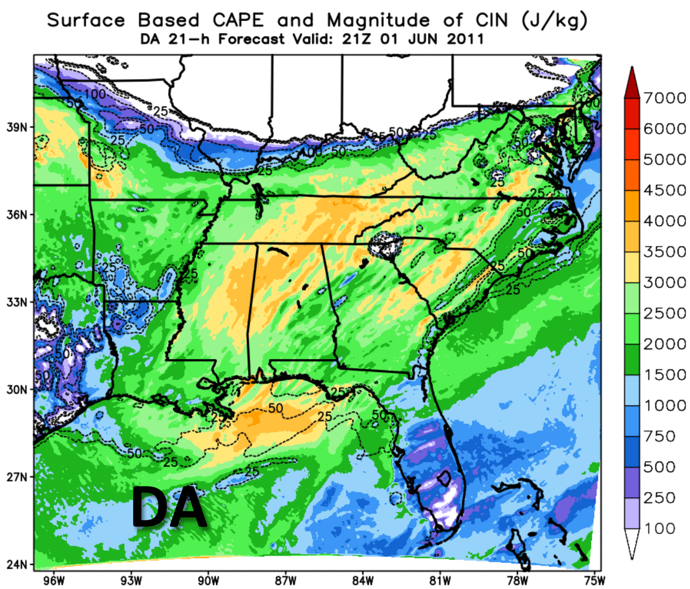
21-h Simulated 2-m Dew Point Temperature

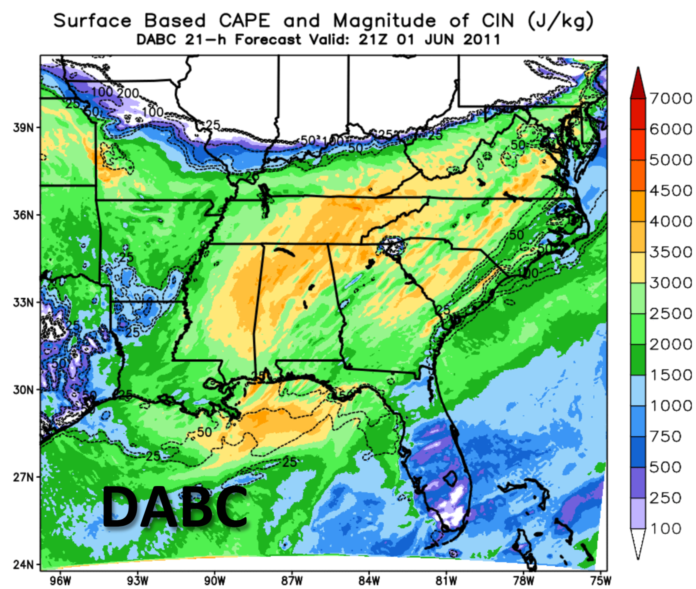


21-h Simulated CAPE/CIN









Current and future plans

- Validate analyses
  - TAMU North American Soil Moisture Database
  - QC and statistics
- Impact of SMOS assimilation using LIS-initialized WRF
  - Look at both sensitivity and forecast accuracy
  - Impact on boundary layer for a quiescent day
  - Active convection case
  - Validation over a longer time period
- After validation, implement in SPoRT near-real time LIS run
  - Will be shared with WFOs
- Assimilate active/passive blended product from SMAP; higher spatial resolution (9 km) should improve local-scale processes

Related Presentations

- 4.4: Development of a 30-Year Soil Moisture Climatology for Situational Awareness and Public Health Applications (Jonathan Case) @ 2:15 in 127ABC
- Poster 520: Operational assessment of 3-km Land Information System Soil Moisture Data for Drought Monitoring and Hydrologic Applications (Kris White) on Thursday

Questions?