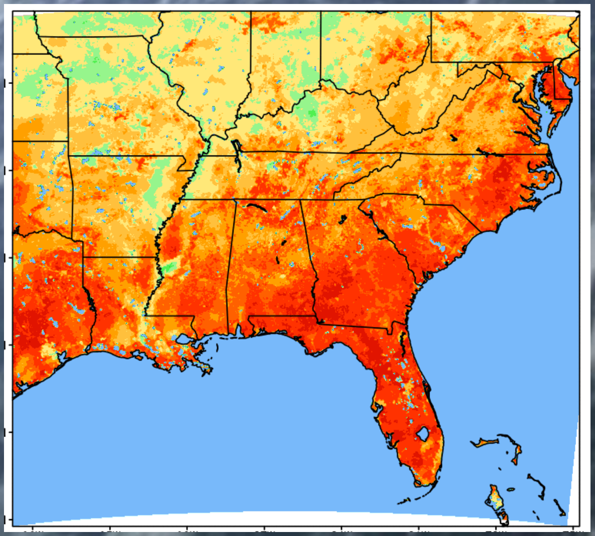
Improved NWP Forecasts from Soil Moisture Assimilation

Results from SMOS, Plans for SMAP



Clay Blankenship
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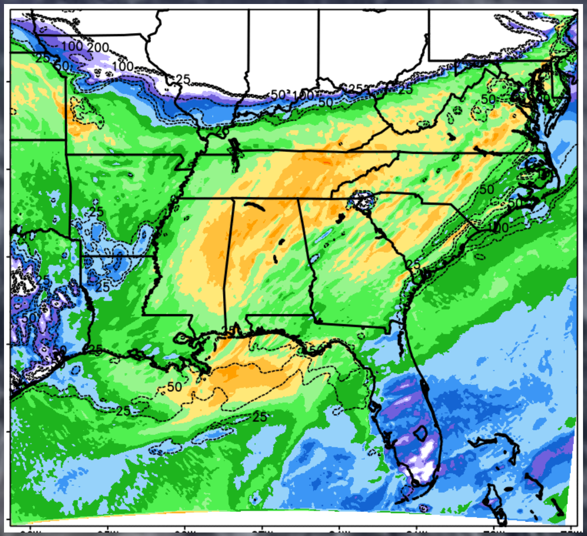
NASA-MSFC SPoRT



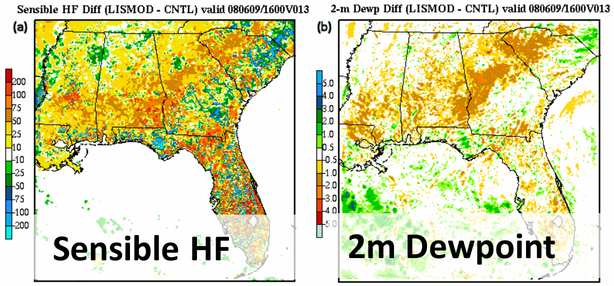
Overview and Motivation

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 numerical weather forecasts using coupled NWP/LSM
  - Available moisture affects humidity, sensible/latent heating, diurnal heating rate, and convection.



Short-term Prediction Research and Transition (SPoRT)

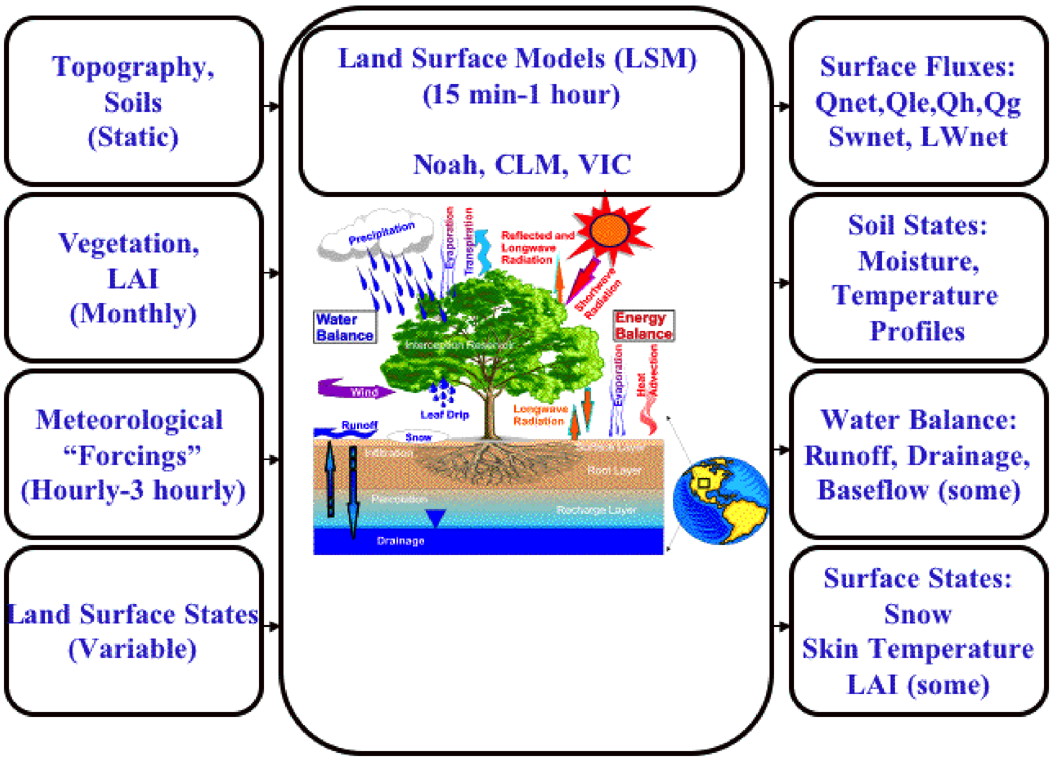
Mission: Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

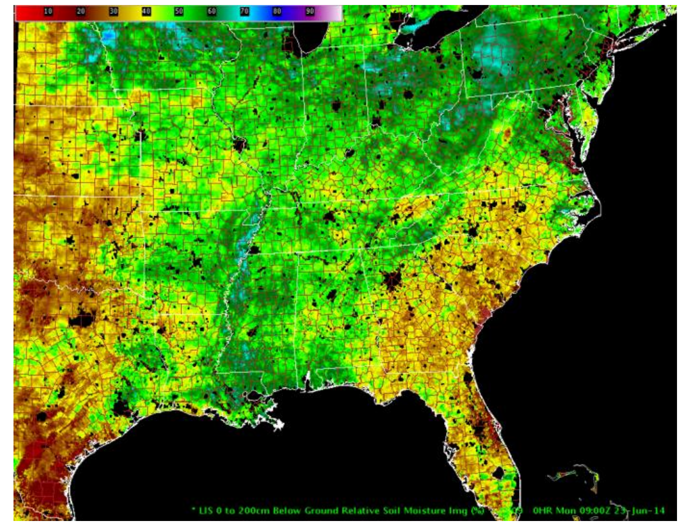
- Close collaboration with numerous WFOs and National Centers across the country
- SPoRT activities began in 2002, first products to AWIPS in 2003
- Co-funded by NOAA since 2009 through "proving ground" activities
- Proven paradigm for transition of research and experimental data to "operations"

Benefit:

- Demonstrate capability of NASA and NOAA experimental products to weather applications and societal benefit
- Take satellite instruments with climate missions and apply data to solve shorter-term weather problems

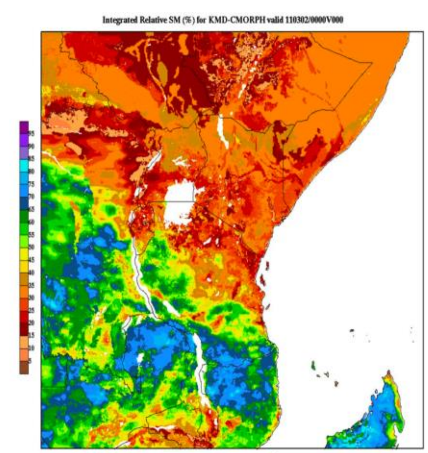
Land Information System (LIS)





SPoRT-LIS total column soil moisture displayed in AWIPS II

- Land Information System (LIS) from GSFC
  - Framework for running LSMs incorporating a wide variety of meteorological forcing data and land surface parameters
  - Includes data assimilation capability
- 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



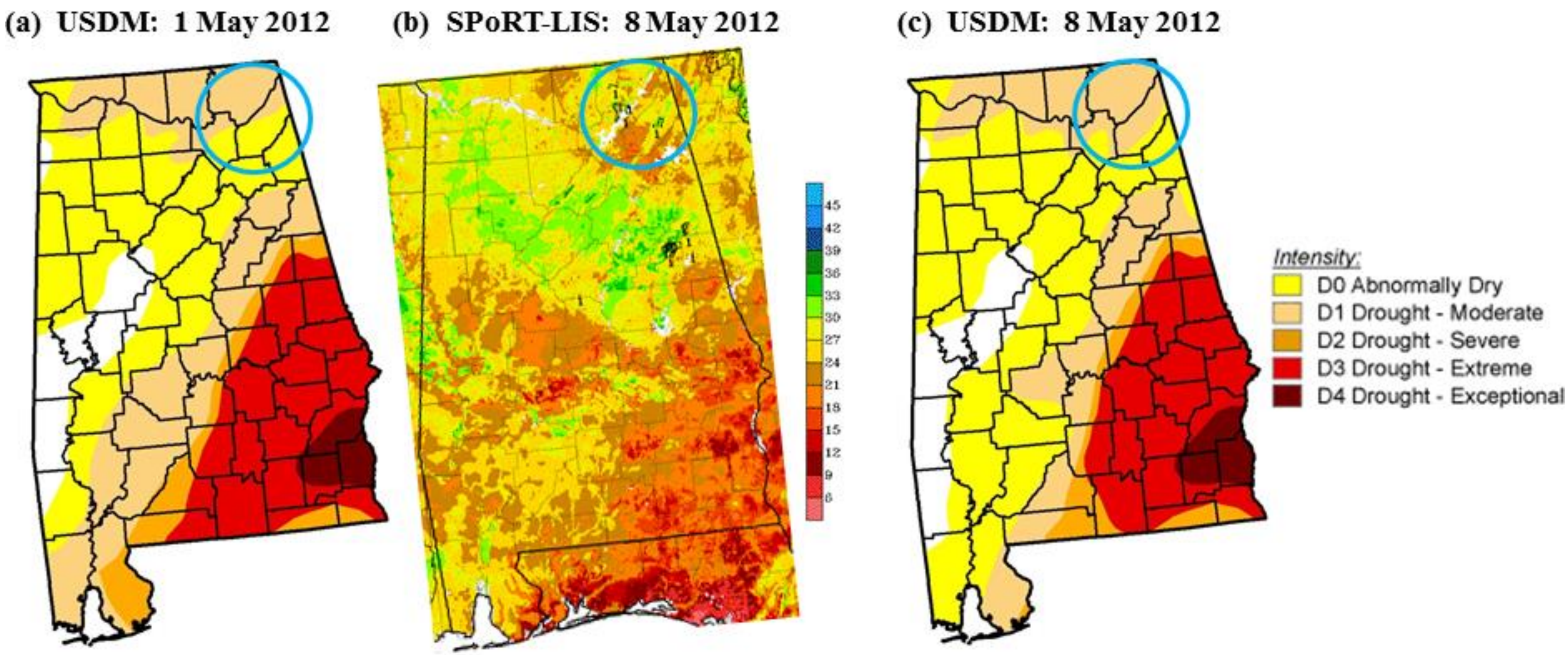
LIS domain over East Africa

Soil Moisture Instruments

- L-band (1.4 GHz) radiometers (and radars) can be used to estimate soil moisture in the top layer (~5 cm) of soil
  - sees deeper in the soil
  - performs better in dense vegetation than higher frequency instruments
- Assimilating retrievals from Soil Moisture and Ocean Salinity (SMOS) satellite
- Preparing for assimilation of NASA Soil Moisture Active/Passive (SMAP) retrievals
  - combined (radar/radiometer) product available at a higher resolution (9 km)
  - SMAP Early Adopters team

Name	AMSR-E	SMOS	SMAP		
Agency	NASA/JAXA	ESA	NASA		
Launch	2002	2009	Jan. 2015		
Orbit	Polar	Polar	Polar		
Sensor Type	Passive	Passive	Passive	Active	Combined
Frequency	6.9 GHz (C-band)	1.4 GHz (L-band)	1.41 GHz	1.2 GHz	
Resolution	56 km	35-50 km	36 km	**3 km**	9 km
Accuracy	6 cm^3/cm^3	**4 cm^3/cm^3**	**4 cm^3/cm^3**	6 cm^3/cm^3	**4 cm^3/cm^3**

Applications: Drought Monitoring

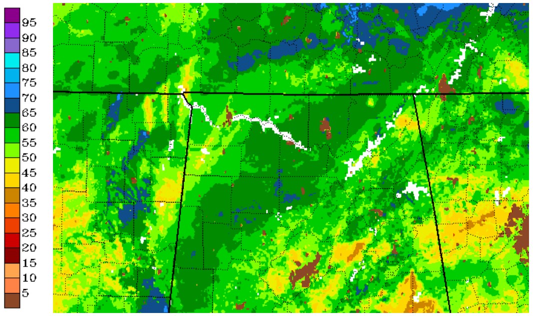


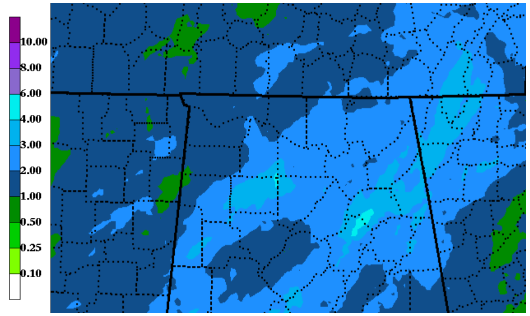
- **Soil moisture from SPoRT LIS has been used by NWS forecasters to refine drought indices on the county scale**
- **Soil moisture and GVF output from LIS could also be applied to situational awareness and forecasts of red flag warnings and potential for fires**

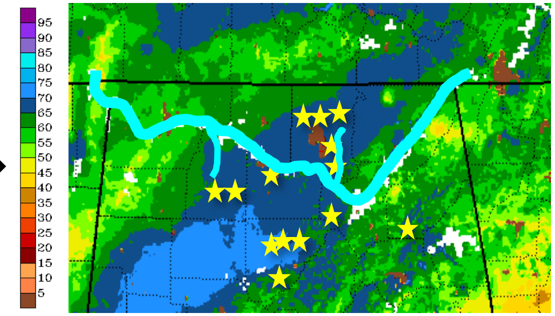
Applications: Flood Potential

March – moderate antecedent soil moisture, moderate rain

- Moderate river flooding and numerous flooding

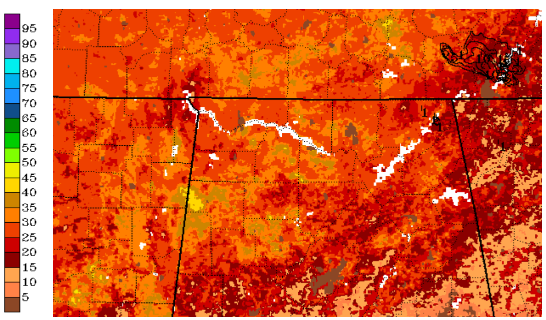


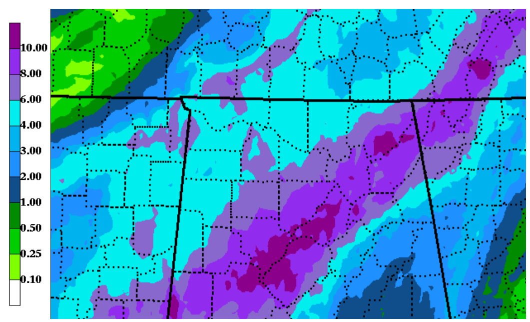


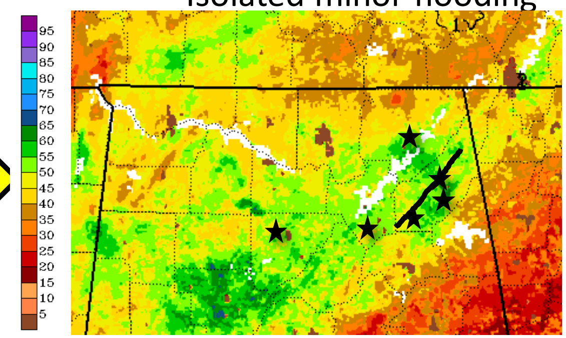


September - low antecedent soil moisture case

- Heavy precipitation
- Isolated minor flooding



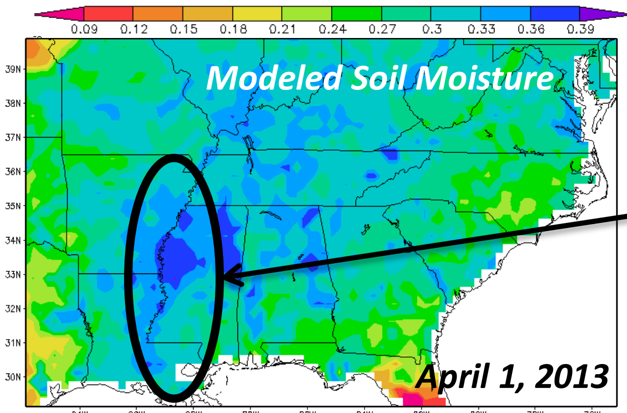




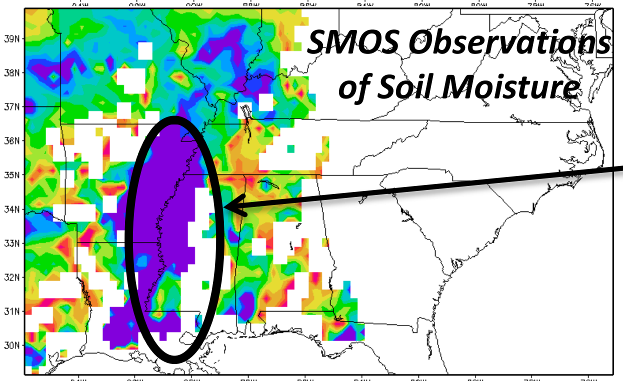
Contrasting antecedent soil moisture likely played a strong role in the different outcomes

Analysis of several events suggests typical moderate-heavy synoptic rainfall events over deep-layer relative soil moisture values exceeding 55-60% will lead to more substantial moderate or heavier flooding events

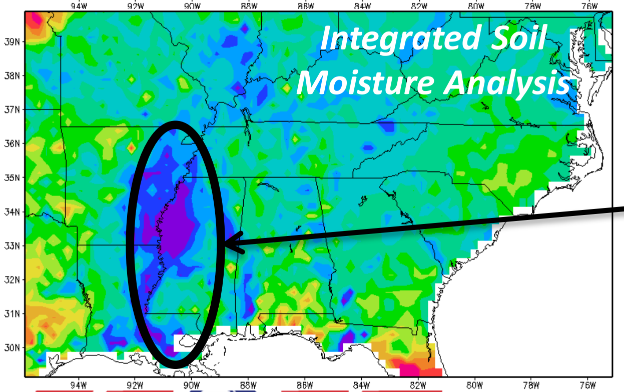
Example DA (rice irrigation)



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

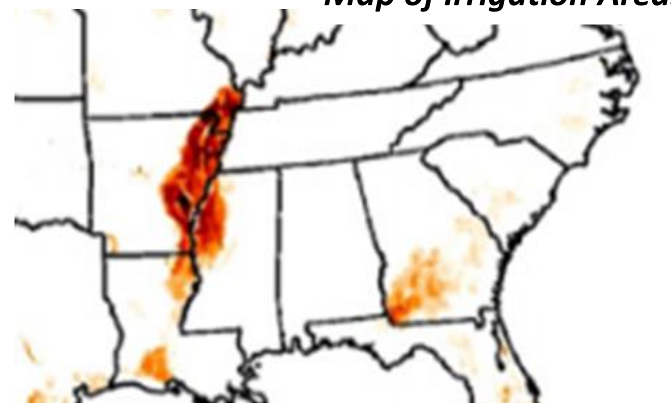


SMOS observes irrigated fields



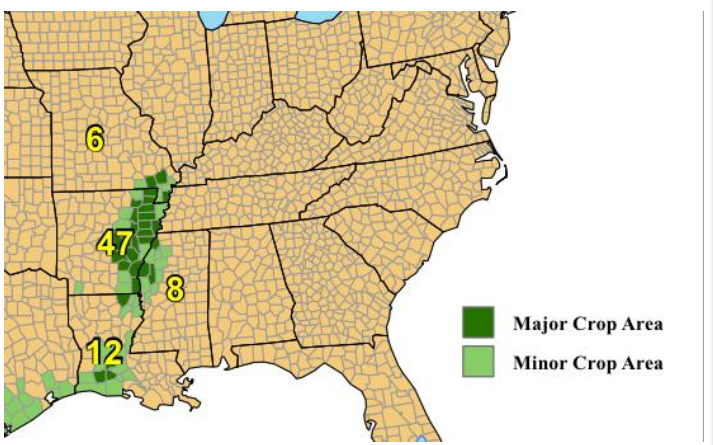
Blended analysis of model and observations better represent irrigated area and should result in improved weather and hydrologic modeling

Map of Irrigation Areas



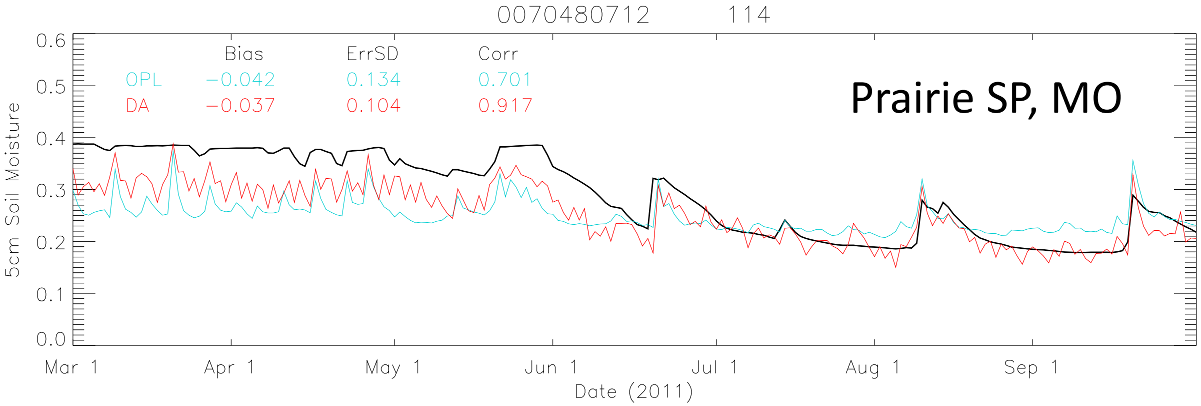
From U. of Frankfurt-FAO (Ozdogan 2001)

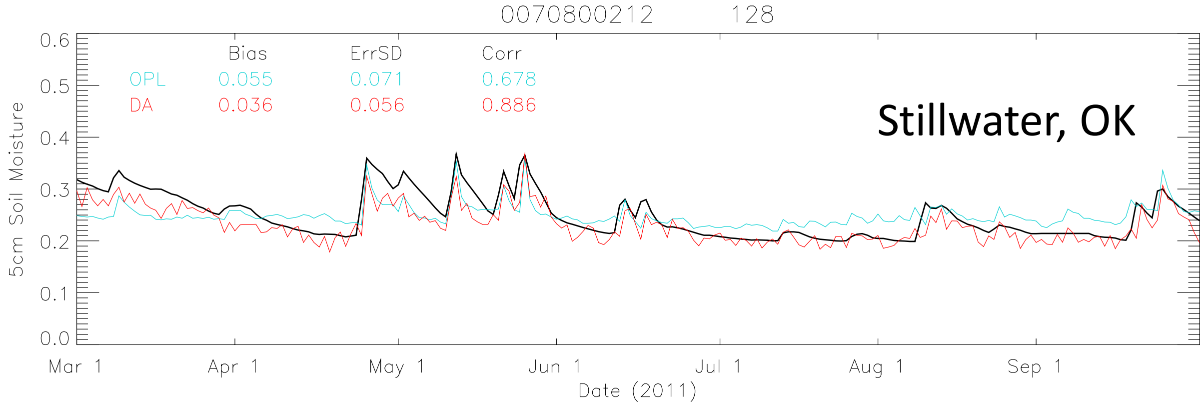
Rice growing areas

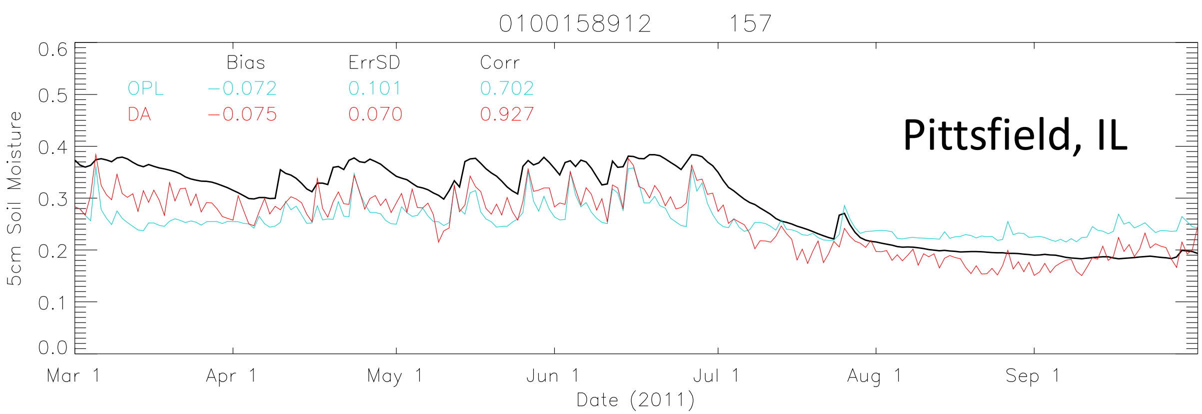


Yellow numbers indicate percentage of national crop yield due to each state.

SMOS DA Validation





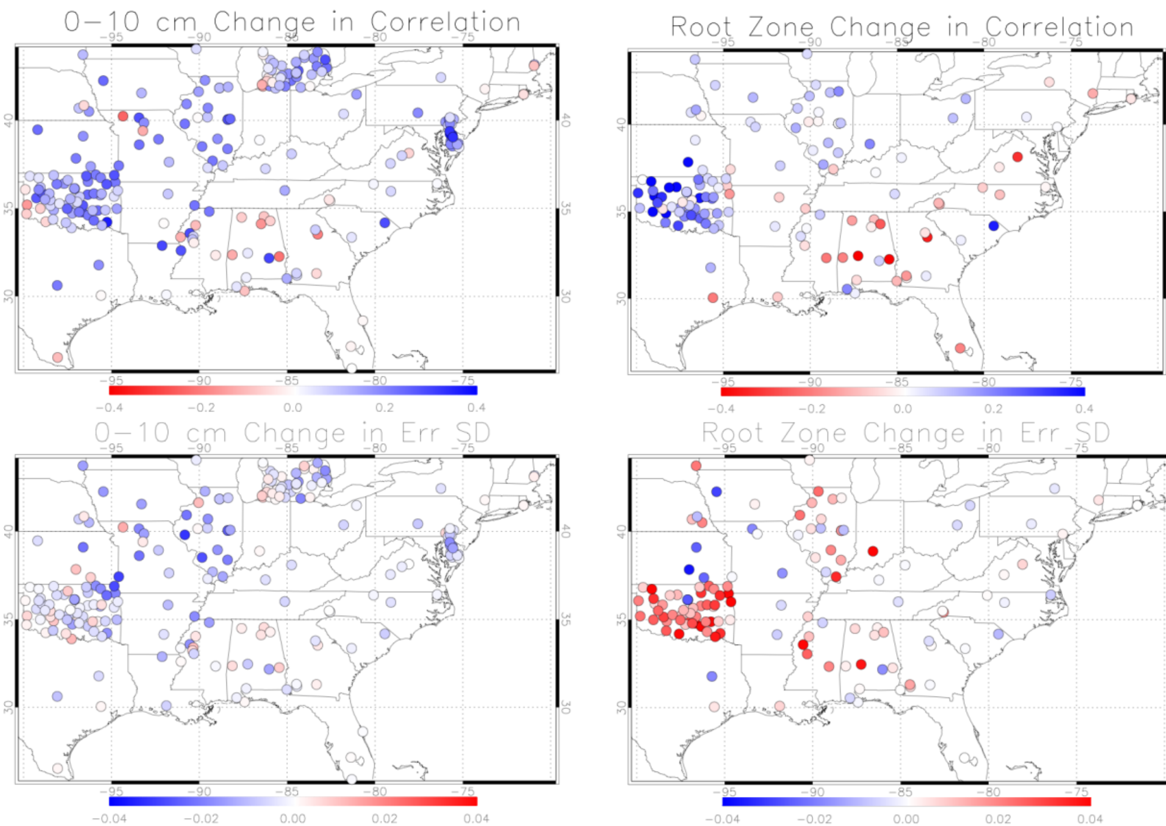


0-10 cm model soil moisture

Results from validation against soil moisture networks in US (North American Soil Moisture Database)

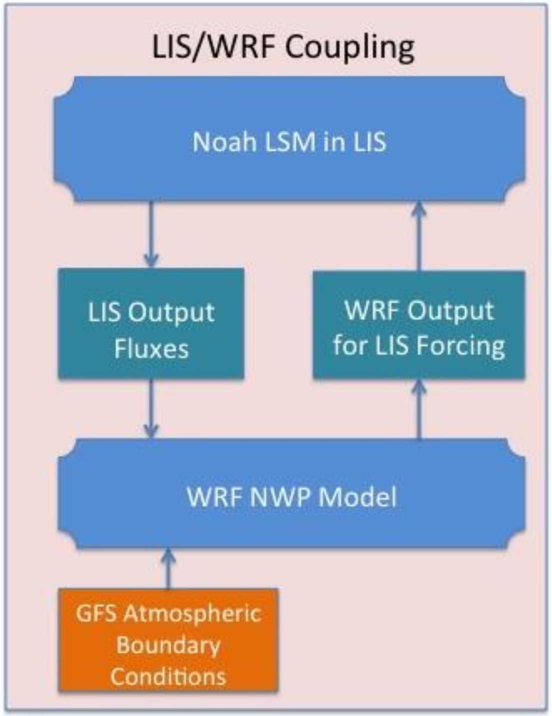
- Better correlations
- Improved dynamic range

SMOS DA Validation



	Near Surface (0-10 cm)			Root Zone (10-100 cm)		
	Bias	Err SD	**Corr.**	Bias	Err SD	**Corr.**
Control	3.6%	23.5%	**0.47**	4.0%	10.6%	**0.61**
SMOS DA	-0.5%	21.8%	**0.57**	10.6%	11.8%	**0.67**

WRF impact tests

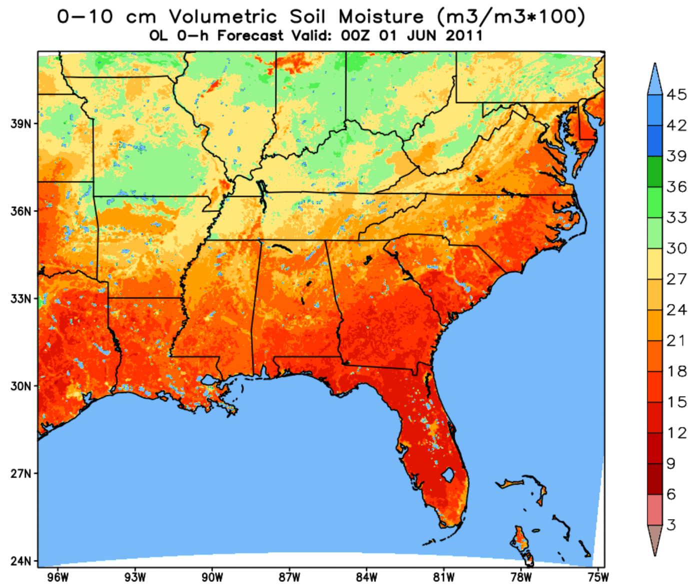


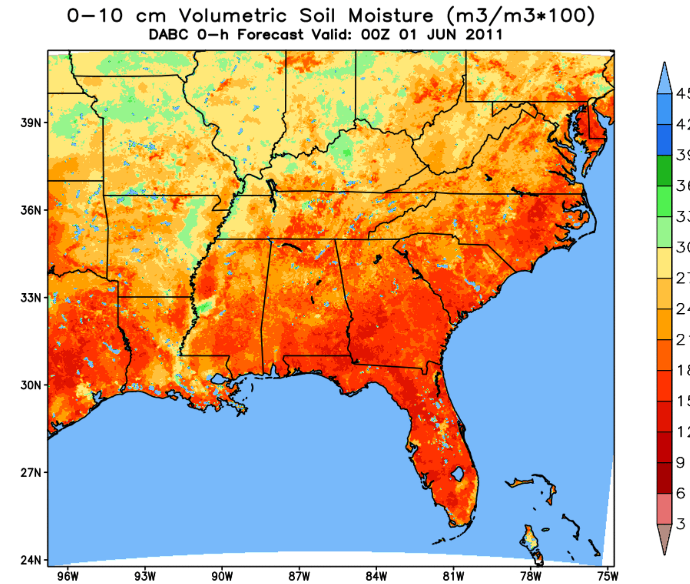
- Test impact of SMAP DA on coupled LIS-WRF runs
  - Verify NWP forecasts against surface obs, soundings, and precipitation analyses
  - Examine impact on significant events
- Applications
  - Weather: improved forecasts
    - Moisture
    - Diurnal heating
    - Convection
  - Regional climate modeling
    - Study impacts of changing land-use, precipitation patterns

SMOS NWP Impact Study

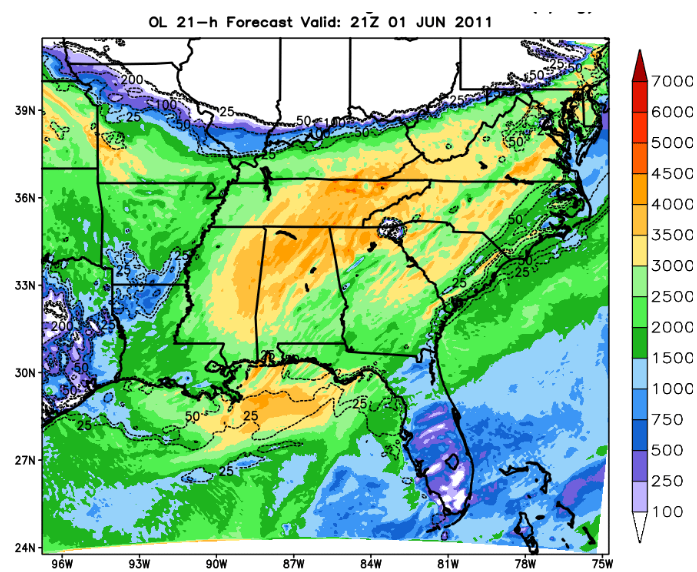
Open Loop | SMOS DA

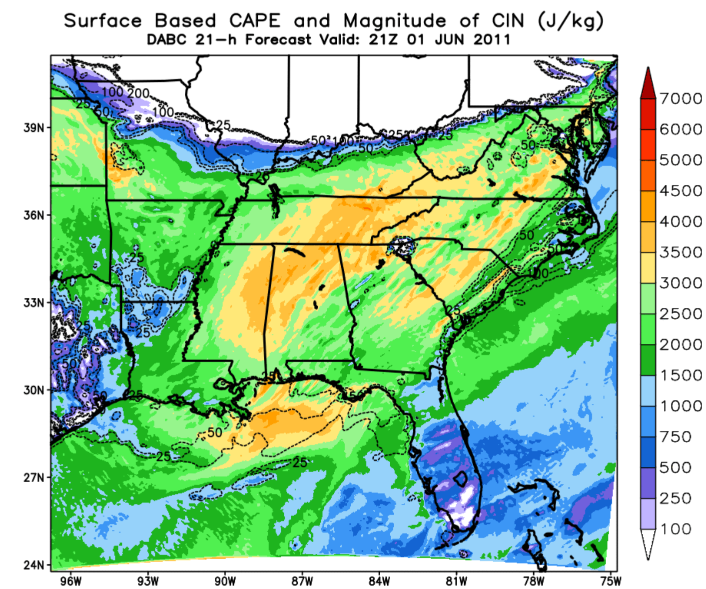
Initial Soil Moisture





CAPE (48-h Fcst)





Future Plans

- Assimilate SMAP L2 Active-Passive Retrieval (9-km) product
  - Validate Soil Moisture Analyses
- Test impact on NWP using coupled LIS-WRF (NU-WRF)
  - Validate against soundings and surface measurements
  - Examine forecasts of convection for significant events
  - US and international domains
- Implement SMAP DA in SPoRT near-real time LIS run
  - Improved resolution should provide a better representation of surface conditions
  - Will be shared with WFOs