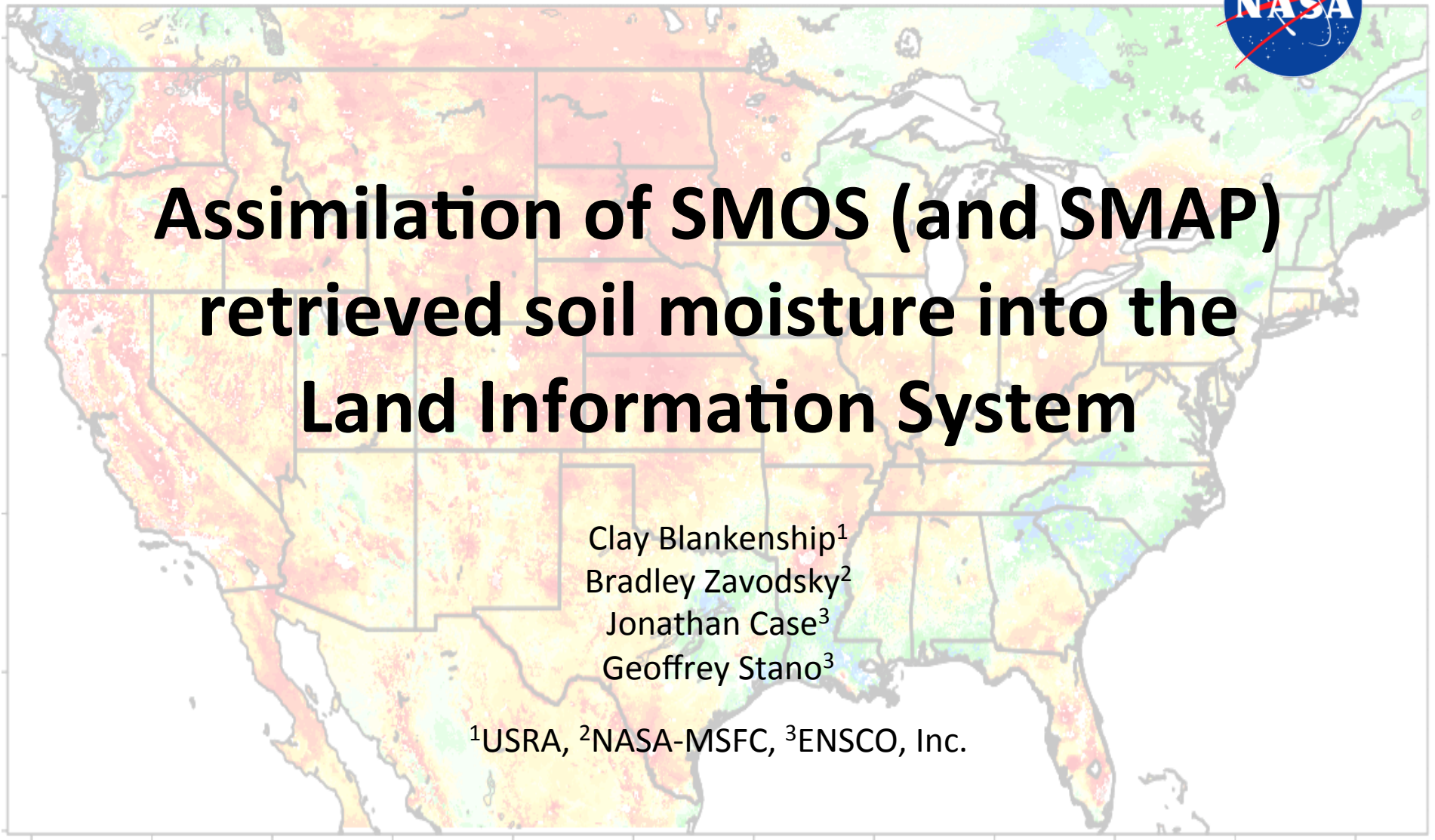


Assimilation of SMOS (and SMAP) retrieved soil moisture into the Land Information System

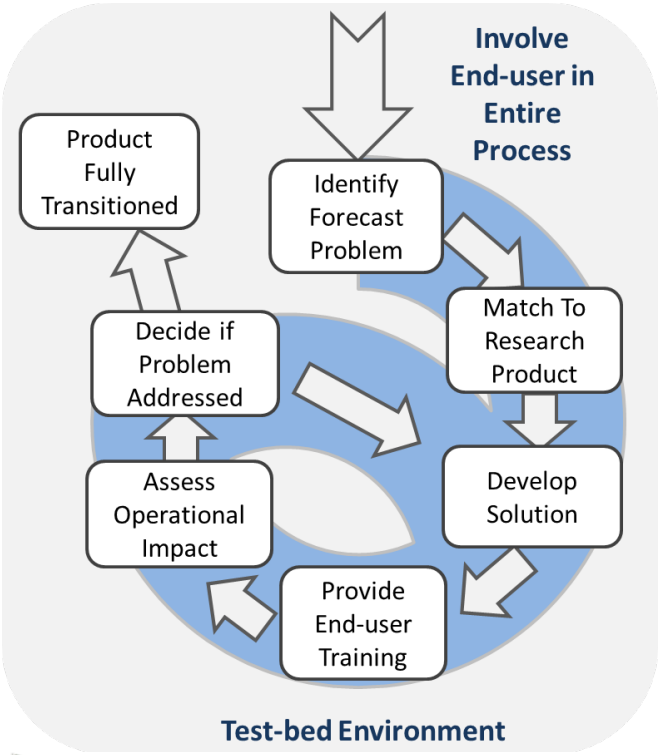
Clay Blankenship[1]
Bradley Zavodsky[2]
Jonathan Case[3]
Geoffrey Stano[3]

[1]USRA, [2]NASA-MSFC, [3]ENSCO, Inc.

NASA/SPoRT Center

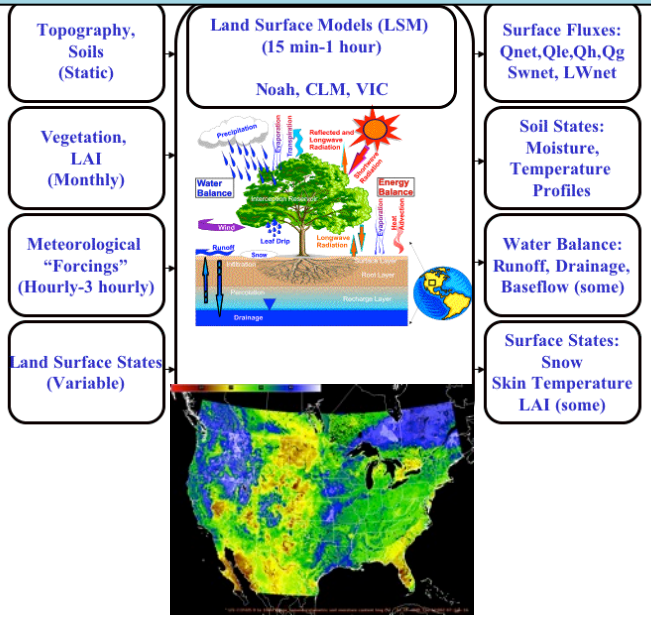
Short-term Prediction Research and Transition (SPoRT)

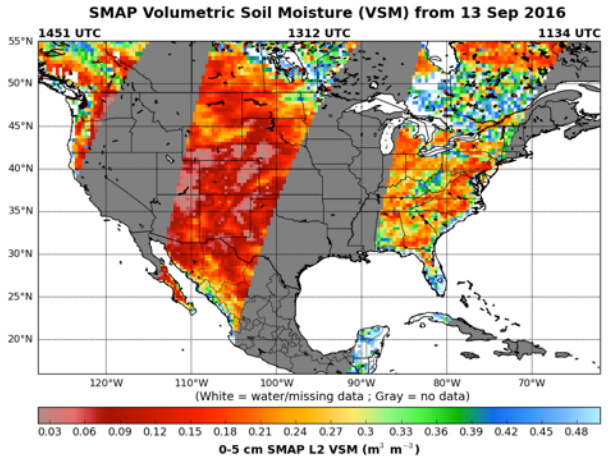
- **Location:** NASA Marshall Space Flight Center in Huntsville, Alabama, USA
- **Mission:** Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on regional and local scales
- ***Proven paradigm for transition of research and experimental data to operations***
- Close collaboration with numerous NWS WFOs across the U.S.
- Began in 2002; co-funded by NOAA since 2009 through "proving ground" activities



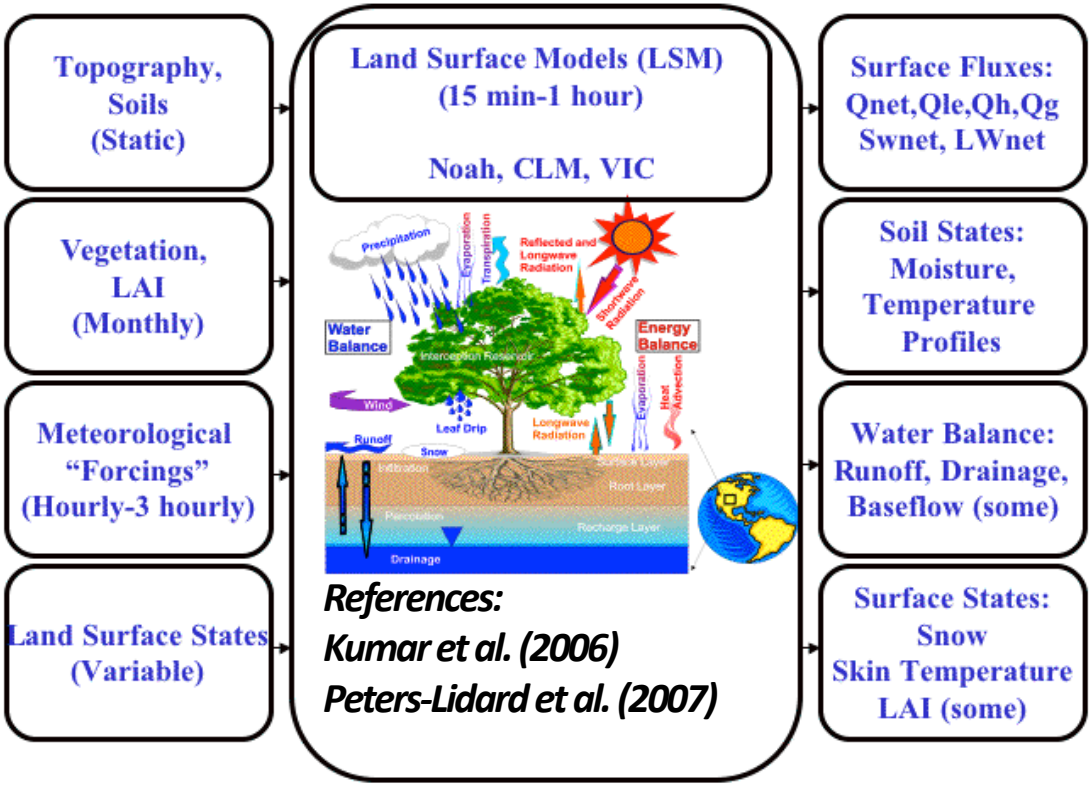
- **Goal: Accurate, high-resolution (~3 km) soil moisture in near-real-time**
  - Situational awareness (drought assessment, flood and fire threat)
  - Local modeling applications (to improve sfc-PBL exchanges)
- **Method: Assimilate satellite soil moisture retrievals into a land surface model**
  - Combines high-resolution geophysical **model** data with latest satellite **observations**

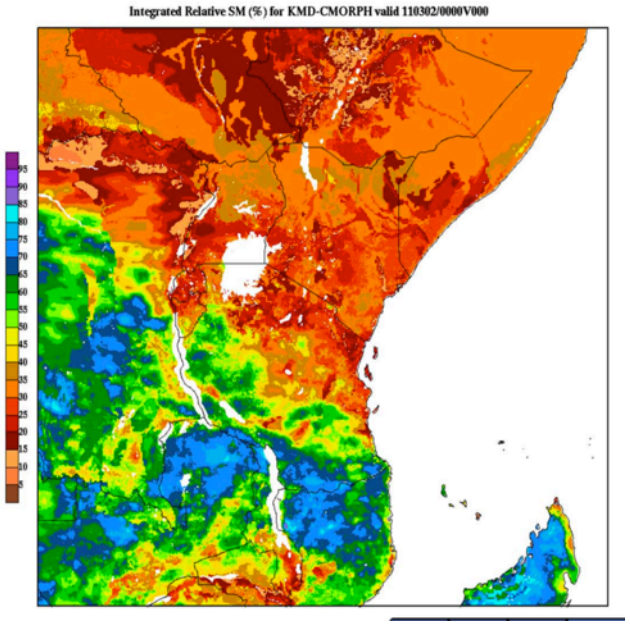
MODEL	**OBSERVATIONS**
Noah LSM in Land Information System ***Driven by meteorological forcing + physics***	***Soil moisture retrievals from SMOS/SMAP***





Tools : Land Information System (LIS)





East Africa LIS domain

- Framework for running LSMs incorporating a wide variety of meteorological forcing data and land surface parameters
  - Developed by NASA-GSFC
  - Includes data assimilation capability.
  - Can be run coupled with Advanced Research WRF.
- Using Noah 3.3 Land Surface Model (LSM) within LIS
- SPoRT maintains near-real-time and experimental LIS runs over the US and East Africa.

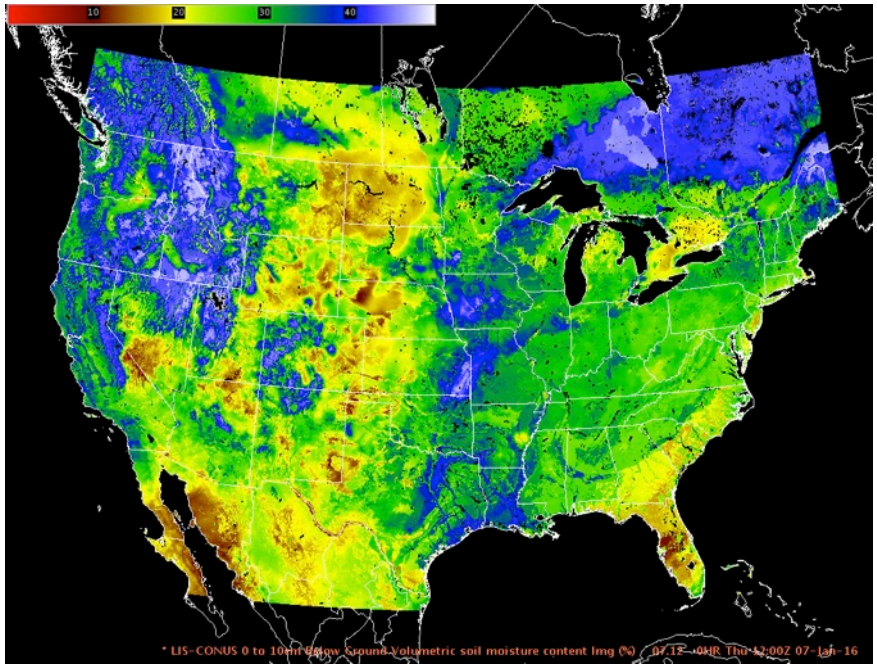
LIS Modeling at SPoRT

Full Continental U.S. (CONUS) domain with 0.03° (lat/lon) grid resolution

Unique characteristics of "SPoRT-LIS":

- Real-time S-NPP/VIIRS Green Vegetation Fraction
- Albedo scaled to input vegetation
- Restart simulation strategy to produce real-time output (timeline below)
- SPoRT-LIS ingested and displayed in AWIPS II at select NOAA/NWS weather forecast offices
- Land surface variables available to initialize modeling applications (WRF and STRC/EMS/UEMS)

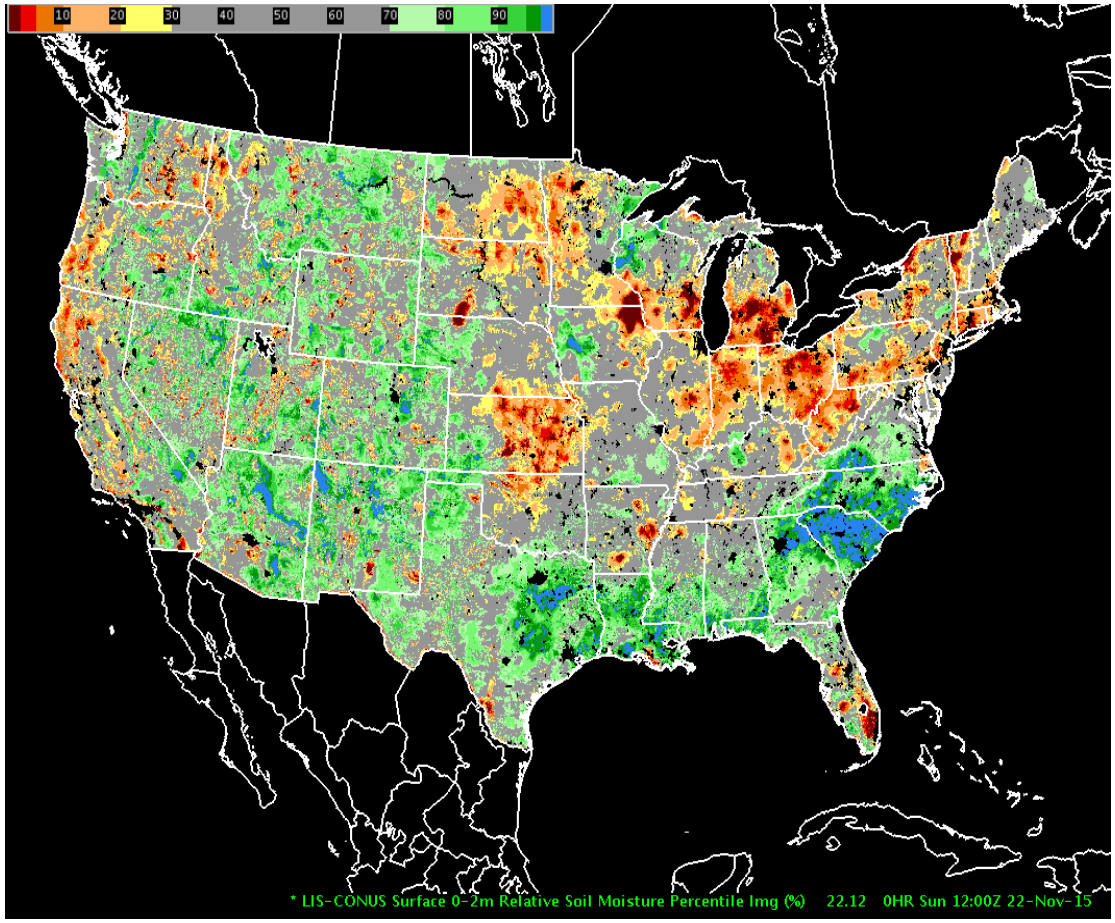
Current SPoRT-LIS CONUS domain running Noah LSM, displayed in AWIPS II



NASA SPORT

Land Surface Modeling Applications:
Soil moisture percentile application

SPoRT-LIS Percentile Product in NWS AWIPS-II decision support system for 22 November 2015



- **Near real-time soil moisture percentiles provide proper climatological context and allow for more thorough, accurate operational analysis**
- **Drought diagnosis especially important during times of "flash drought"**
  - NWS contributes to the USDM and has made sub-county scale modifications based on LIS output
- **Flood threat analysis**
  - Flood guidance provided by RFCs
  - NWS forecast offices issues flood watches and warnings
  - Soil moisture over SC still exceeds 98th percentile over a month after major flooding in early OCT

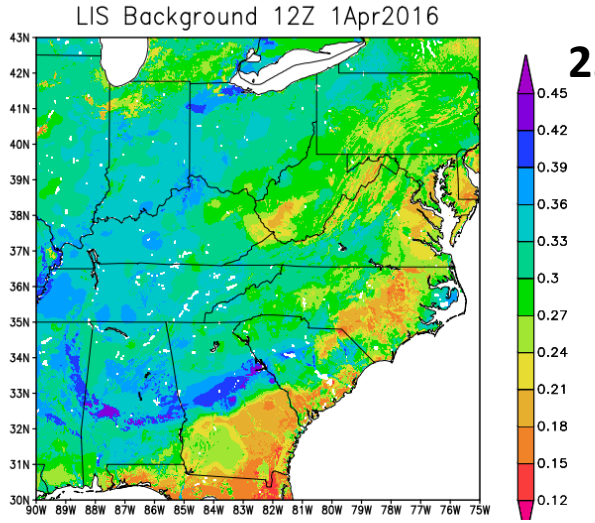
Observing Systems: SMOS and SMAP

- L-band radiometers (and radars) can be used to estimate soil moisture near the surface
  - Compared to previous generation (higher frequency) instruments:
    - See deeper in the soil (up to 5 cm)
    - Better vegetation penetration
    - Higher sensitivity (accuracy)
- Soil Moisture and Ocean Salinity (SMOS) retrievals assimilation tested and validated in LIS 6.
- Currently assimilating Soil Moisture Active/Passive (SMAP) retrievals experimentally in LIS 7
  - SMAP has higher resolution product but due to failure of radar, time period is limited to a few months.

Name	AMSR-E	SMOS	SMAP		
Agency	NASA/ JAXA	ESA	NASA		
Launch	2002	2009	Jan. 2015		
Orbit	Polar	Polar	Polar		
Sensor Type	Passive	Passive *(synthetic aperture)*	Passive	Active (Failed July 2015)	Combined (limited duration)
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**

SMAP Data Assimilation in LIS

1.



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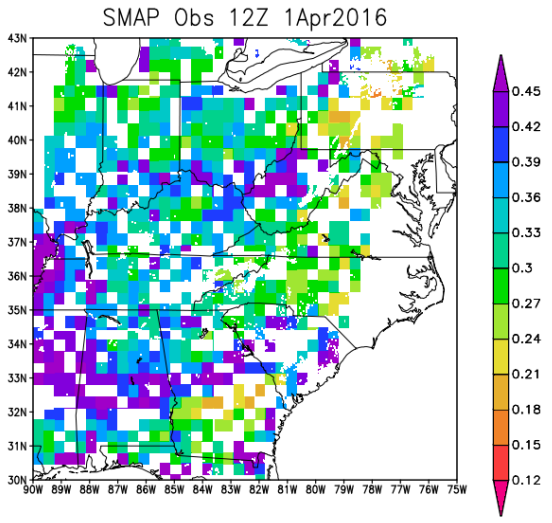

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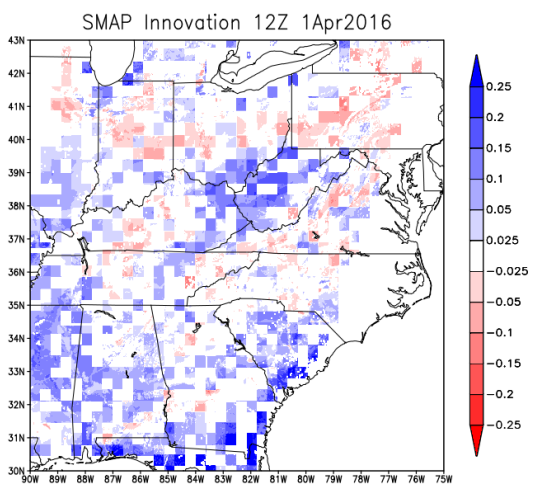

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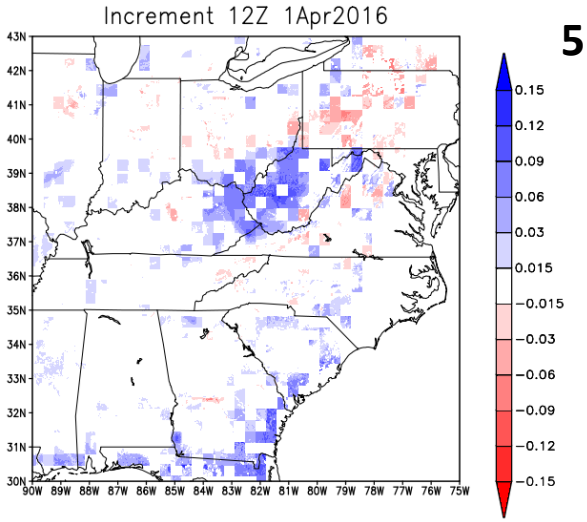

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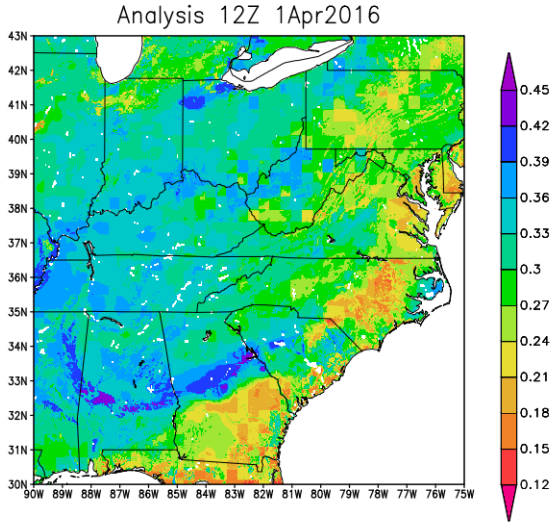
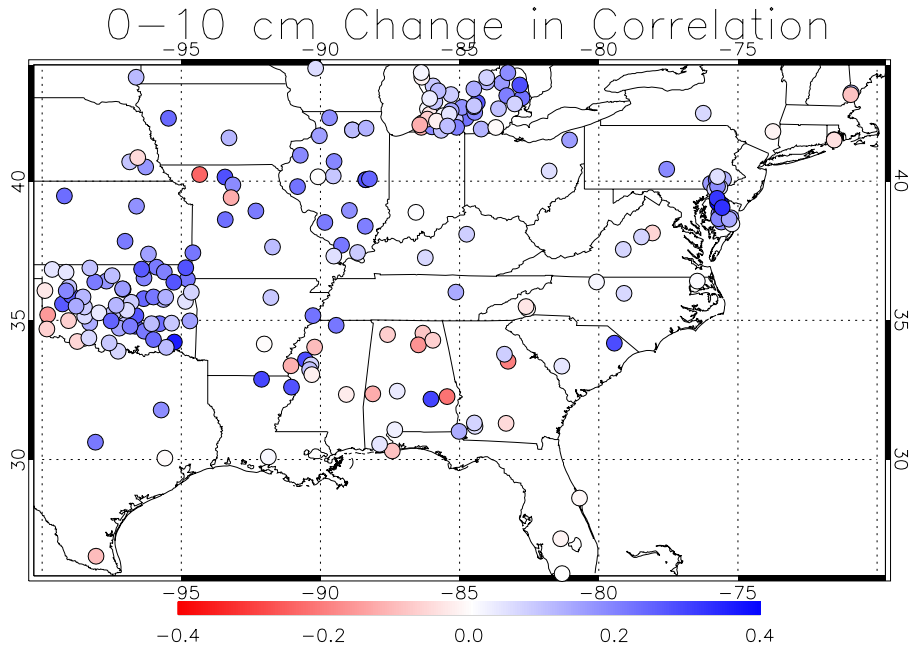
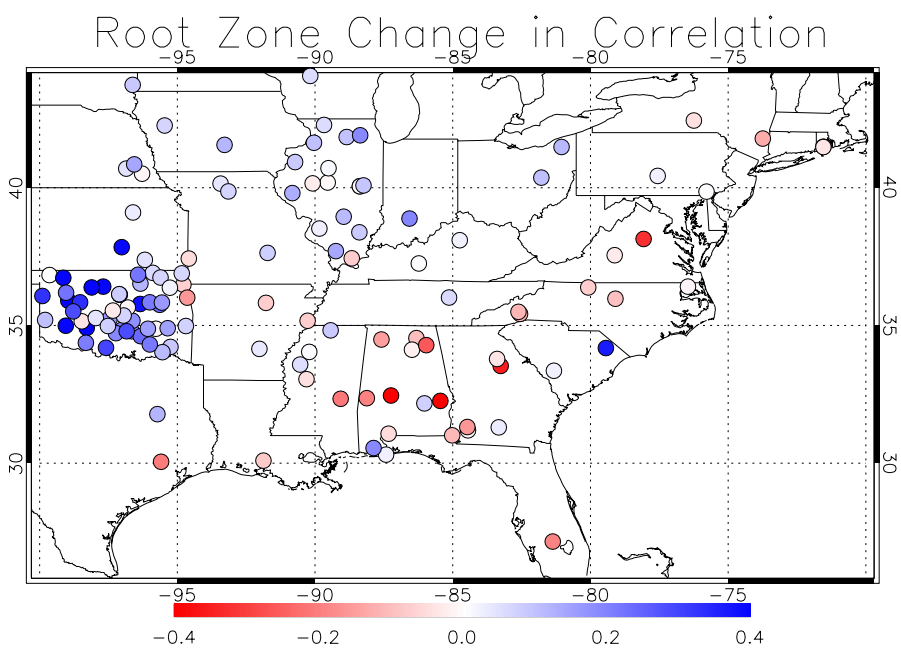


1. LIS Background Soil Moisture (0-10 cm)
2. SMAP Observed SM *(after QC and bias correction)*
3. Innovation *(obs minus BG)*
4. Model Increment
5. Model Analysis *(blending background & obs)*

NASA SPORT

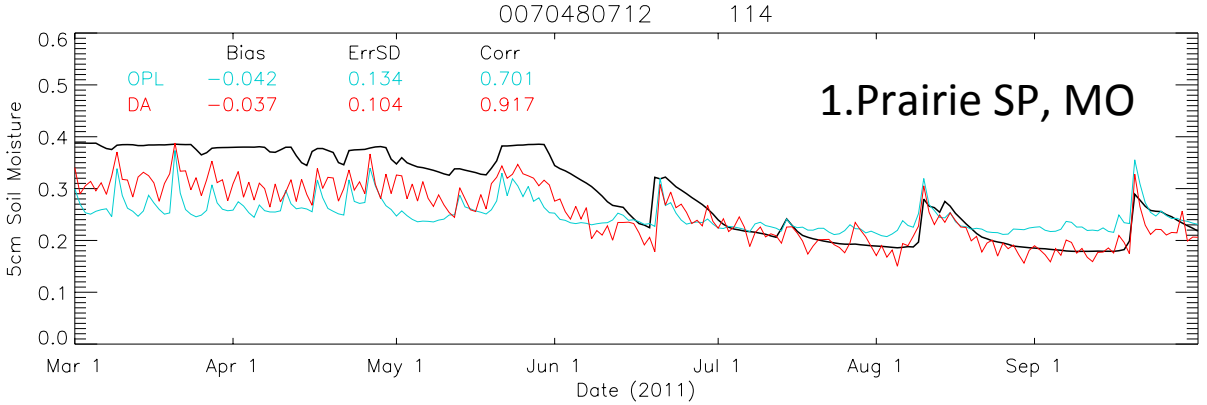
Validation from SMOS Assimilation

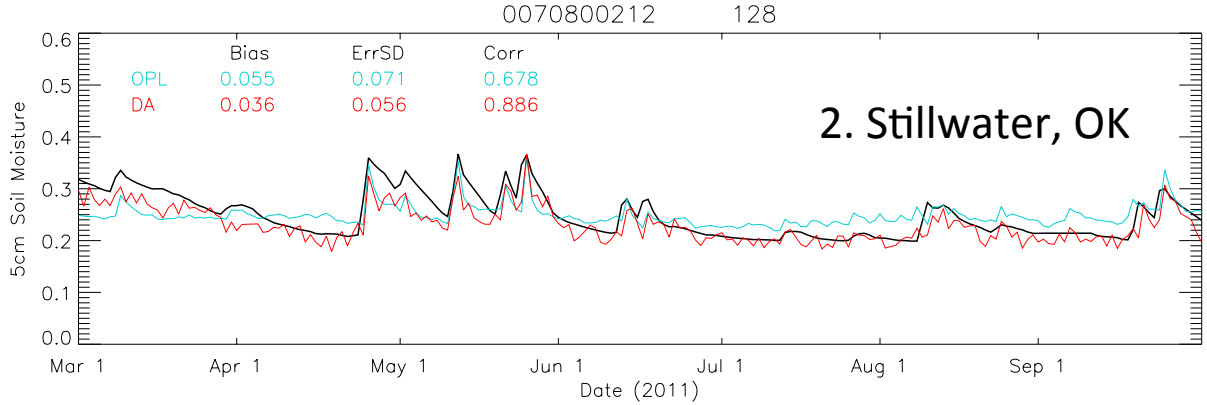


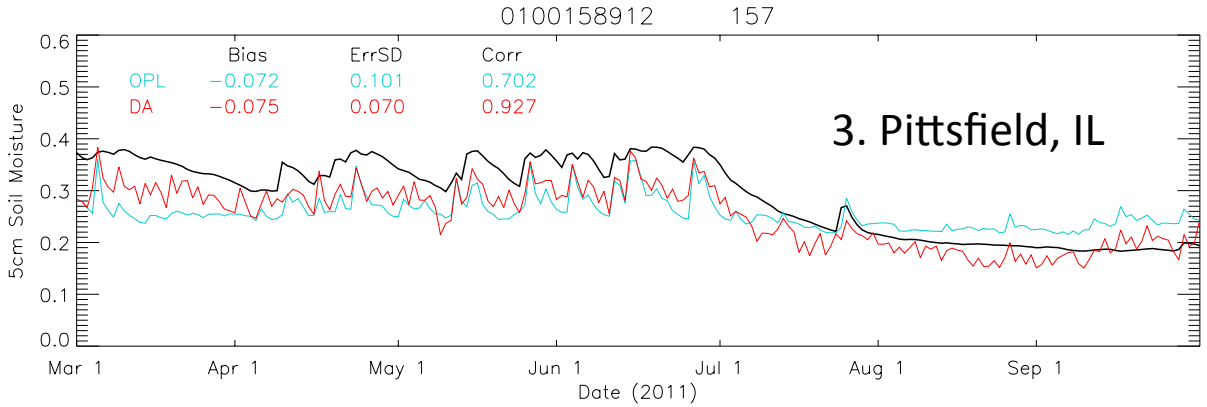


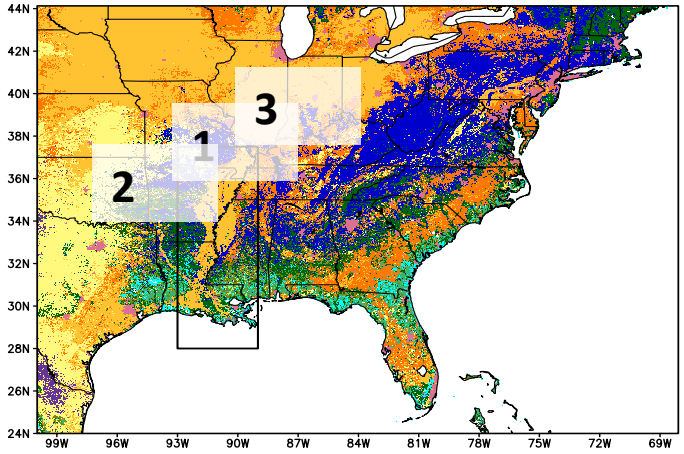
	Near Surface (0-10 cm)			Root Zone (10-100 cm)		
	Bias	Err SD	**Corr.**	Bias	Err SD	**Corr.**
Control	3.6%	23.5%	**0.47**	4.0%	10.6%	**0.61**
SMOS DA	-0.5%	21.8%	**0.57**	10.6%	11.8%	**0.67**

SMOS Data Assimilation Validation (2)







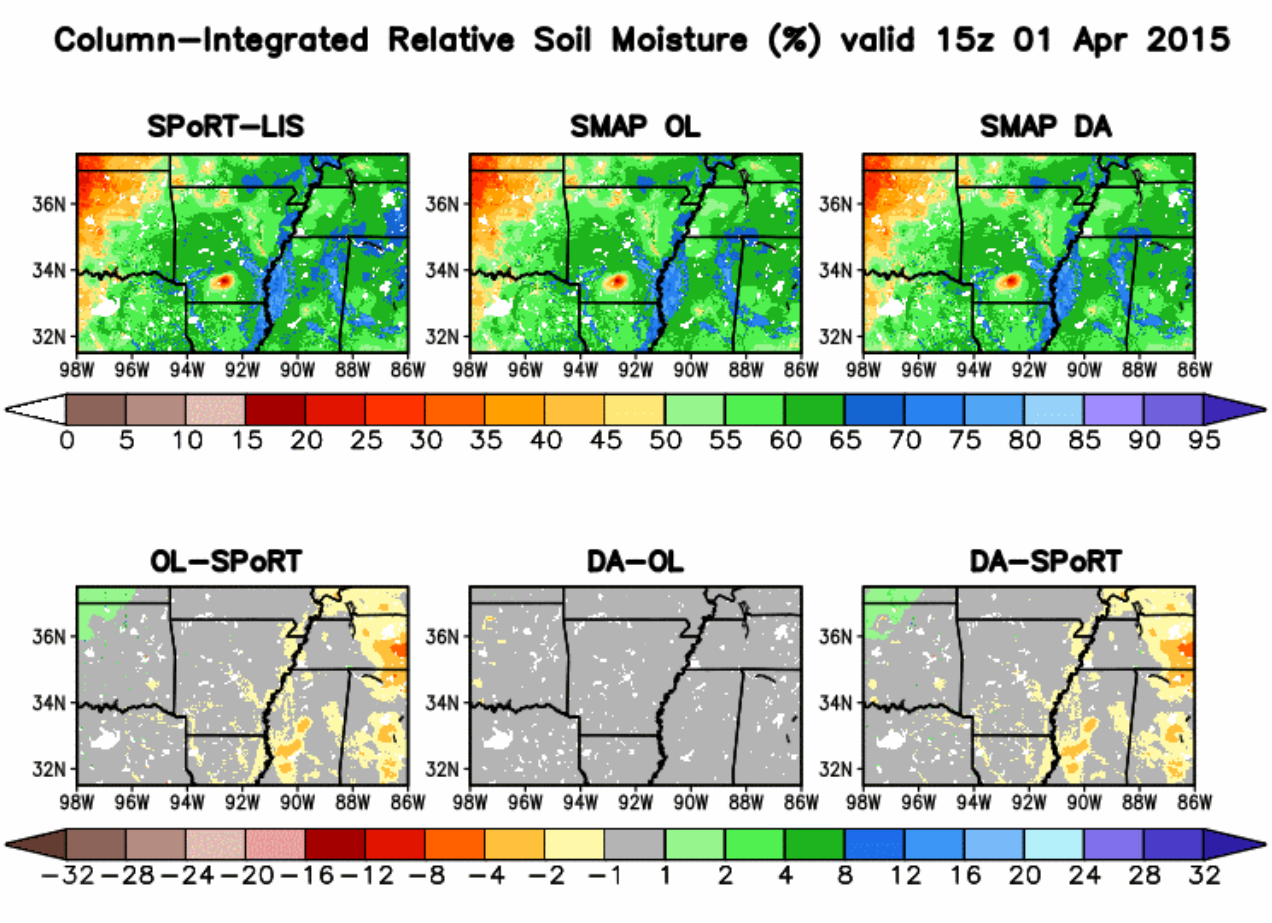


- 0-10 cm model soil moisture
- Compared open loop run to SMOS DA run

Results validated against soil moisture networks in U.S.

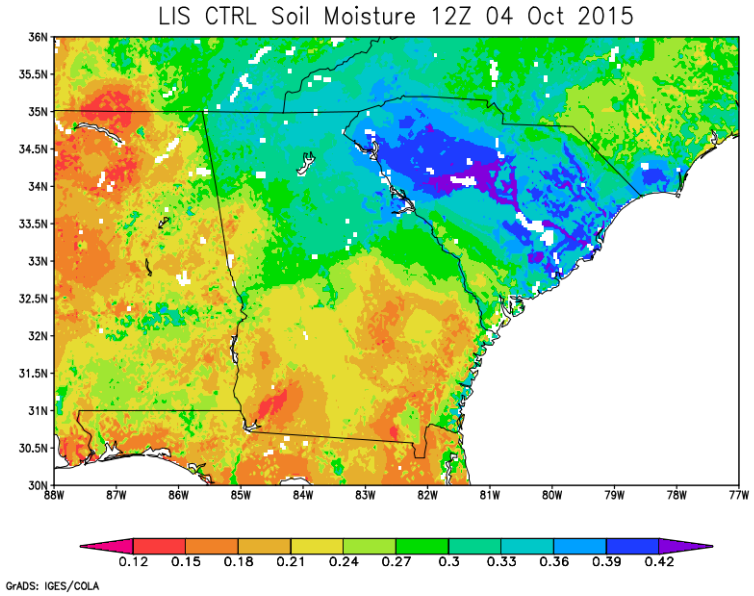
- North America Soil Moisture Database
- Better correlations
- Improved dynamic range

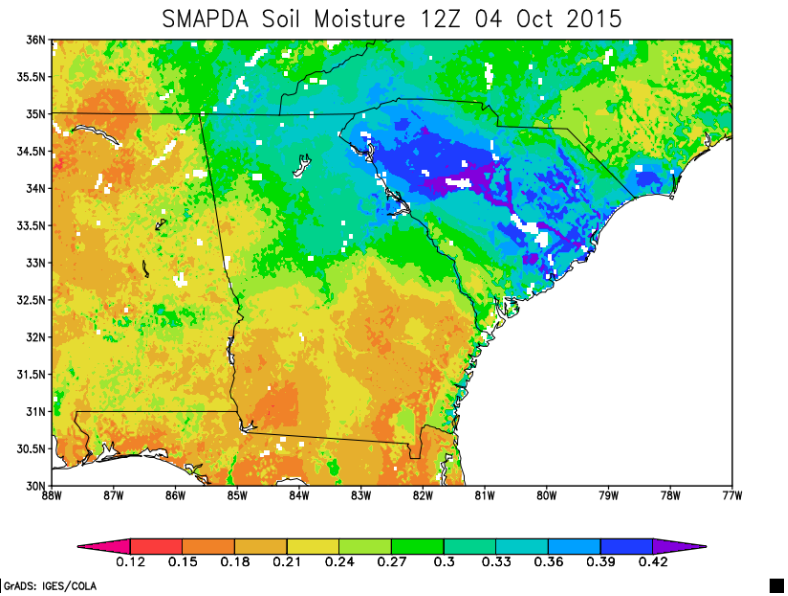
SMAP Data Assimilation Results:
Positive impact on soil moisture artifacts due to poor forcing

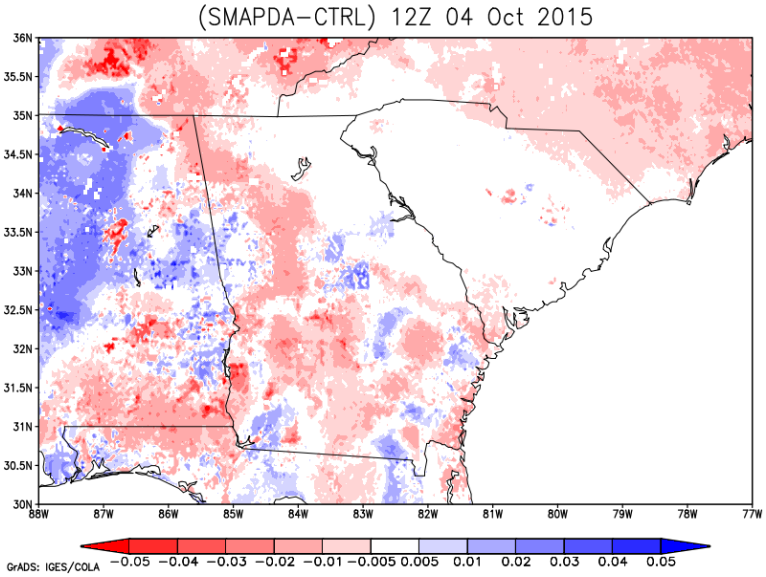


- Problem with gauge QC at NCEP/CPC resulted in dry precip "bulls-eyes" in NLDAS-2 forcing input to SPoRT-LIS during 2015
- Notable dry bulls-eye in southern AR (left)
- Anomaly significantly reduced after first month of SMAP assimilation.
- Location-independent bias correction permits these type of artifacts to be reduced

South Carolina Flooding







Preliminary results—no bias correction

- top left: soil moisture from LIS control run
- top right: soil moisture from SMAP assimilation run, after 3 days assimilation
- bottom left: differences
- Differences are small in flooded area due to extremely strong forcing leading to saturation over a wide area.
- Differences elsewhere illustrate impact of SMAP on LIS products

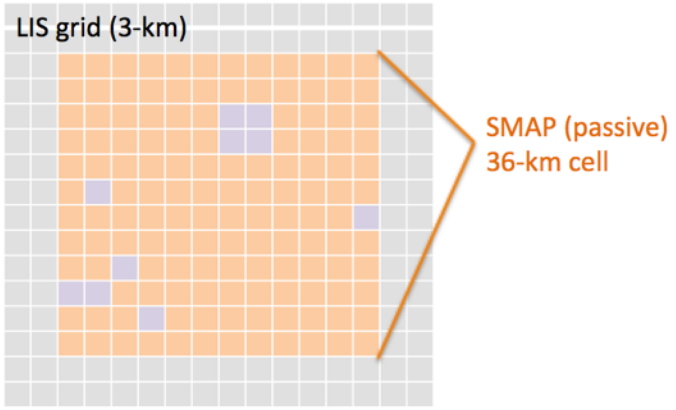
Research Questions

- Does antecedent soil moisture improve flood prediction?
- Does SMOS/SMAP DA help resolve drydown?

Downscaling and higher-resolution data

Challenge

- Model resolution is ~3km, but passive observations are much coarser (~36 km). Currently assimilating one observation over several model grid cells.



Original plan

- Use SMAP Active/Passive product at 3 km (SMAP radar failed after ~3 months)

Possible Future Methods...

Method 1

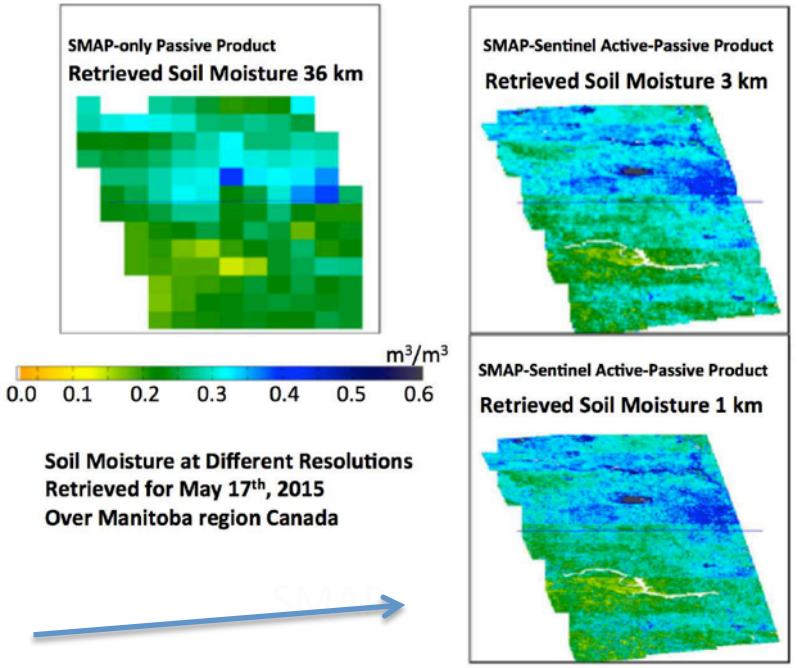
- Downscale SMAP L2 retrievals using model background
- Apply the variability of the background to the observations

Method 2

- Use SMAP Enhanced data at 25 km (coming December 2016) plus downscaling

Method 3

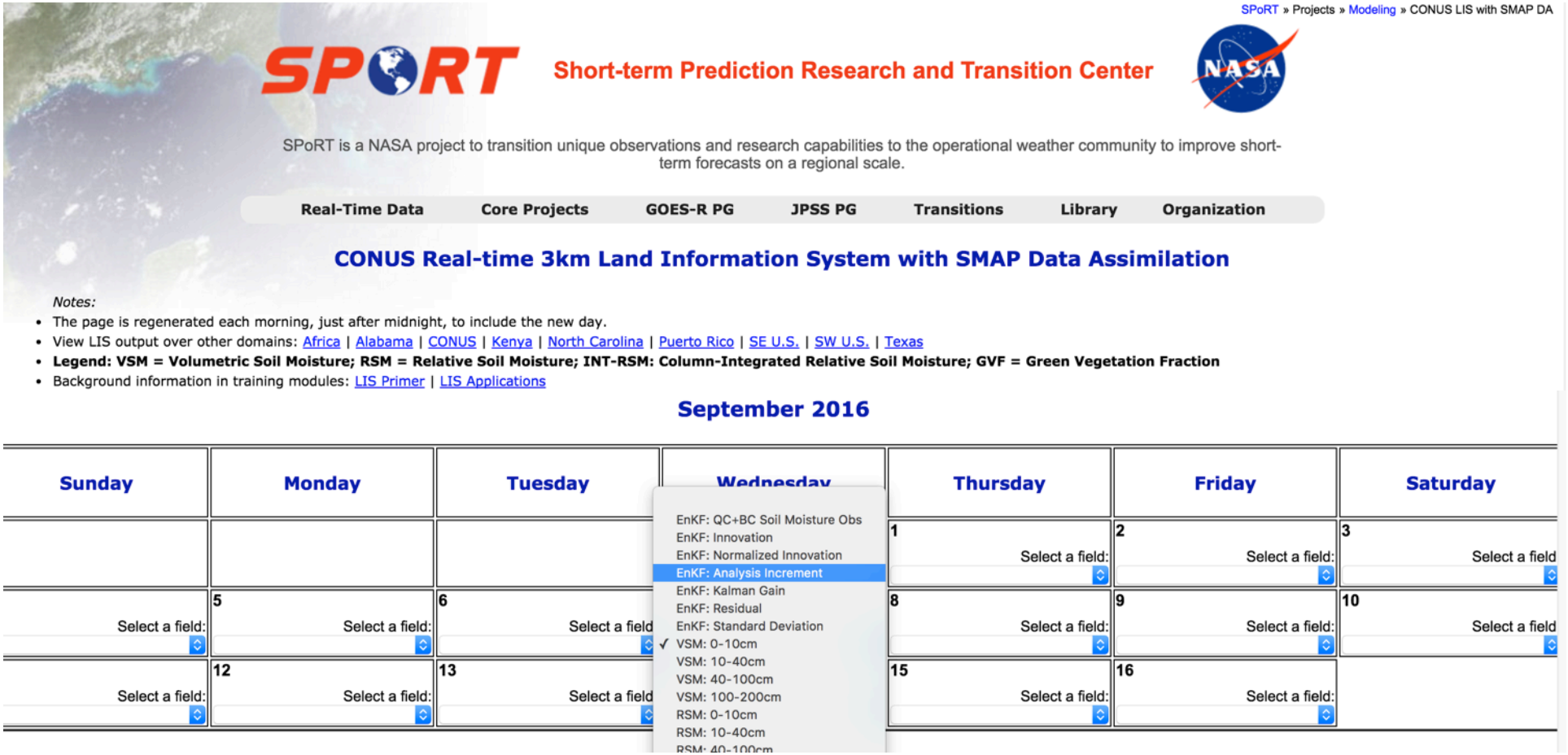
- Use combined active-passive product from SMAP and ESA's Sentinel 1 constellation, coming March 2017. (1-3 km but Sentinel revisit time is several days)



Credit: Narendra Das, SMAP Science Team

SMAP Data Assimilation

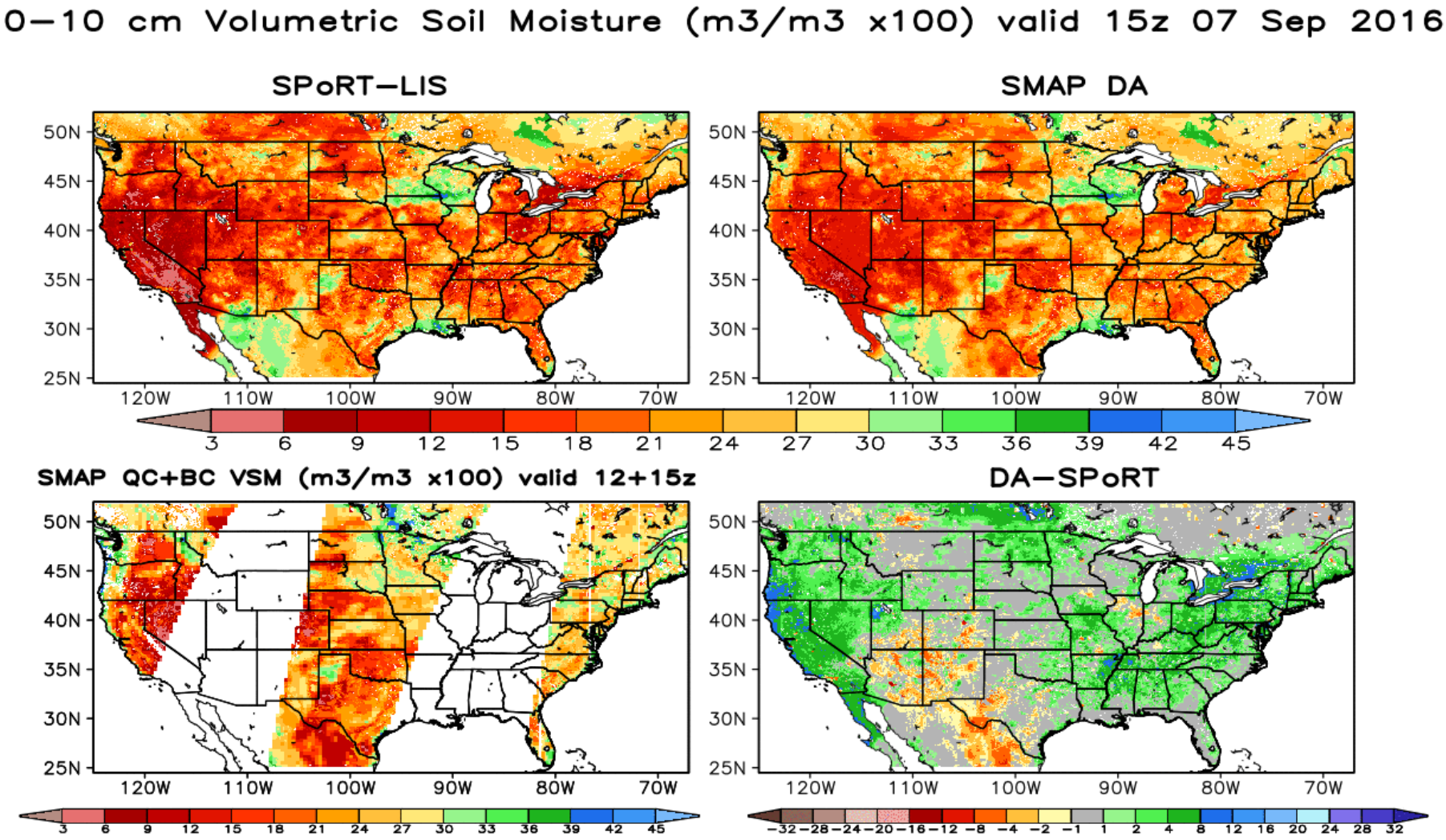
Example Products in Development



Calendar interface with drop-down menu for selecting products and diagnostics.

SMAP Data Assimilation

Example Products in Development



LIS product status at SPoRT

LIS Version	Available*	Evaluating	Developing
Base LIS (No DA)	CONUS Puerto Rico East Africa		
SMAP DA		CONUS (planned Oct) Alaska	
SMAP+SMOS DA			CONUS East Africa (planned Nov)

*Products available at http://weather.msfc.nasa.gov/sport/

For current status, email *clay.blankenship@nasa.gov*.

See Also...

Blankenship et al., 2016: Assimilation of SMOS Retrievals in the Land Information System, *IEEE Trans. Geosci. Rem. Sens.* (in press).

Products at http://weather.msfc.nasa.gov/sport/

Email: clay.blankenship@gmail.com