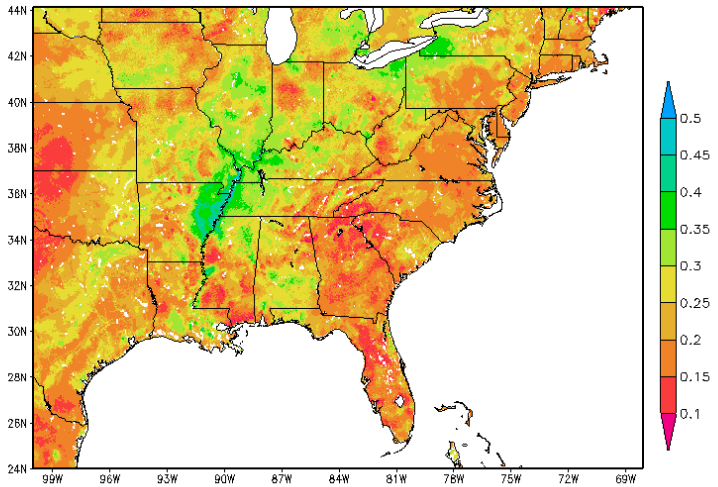
Impacts of Assimilating SMAP Soil Moisture Retrievals in the SPoRT Land Information System



Clay Blankenship *(USRA)*

Jonathan Case *(ENSCO, Inc.)*

William Crosson *(USRA)*

Christopher Hain *(NASA-MSFC)*

Bradley Zavodsky *(NASA-MSFC)*

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Overview of Project

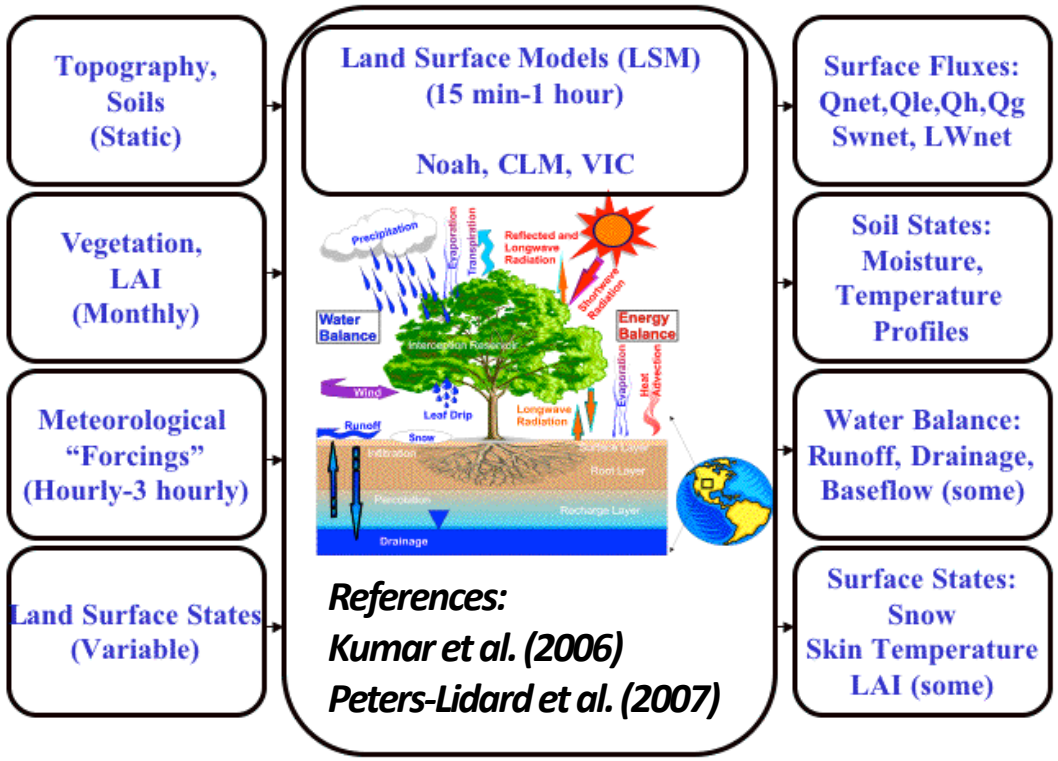
Assimilate SMAP L2 retrievals of soil moisture (9km Enhanced) into the Noah LSM within the Land Information System

- *Data assimilation via Ensemble Kalman Filter*
- *Baseline is existing SPoRT LIS run in CONUS and East Africa*
- *Builds on experience assimilating SMOS*
- *Assess impact of SMAP on soil moisture*

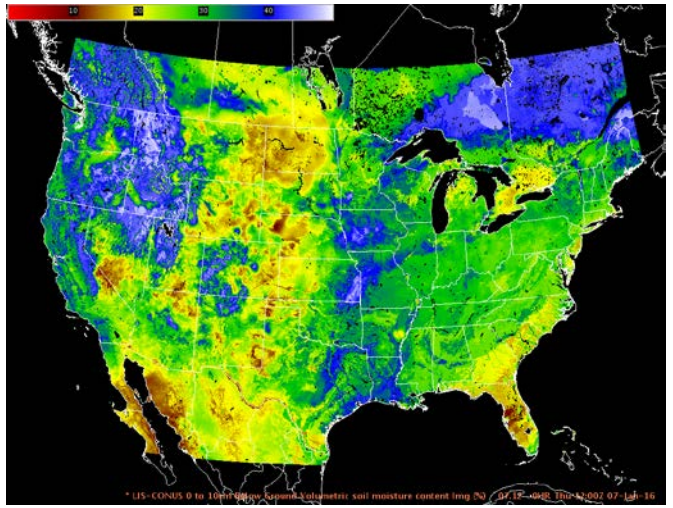
Initialize NWP Forecasts with SPoRT LIS and SMAP LIS

- *Investigate impact of SMAP DA on NWP forecasts*
- *Case studies and statistical verification*

Land Information System (LIS)

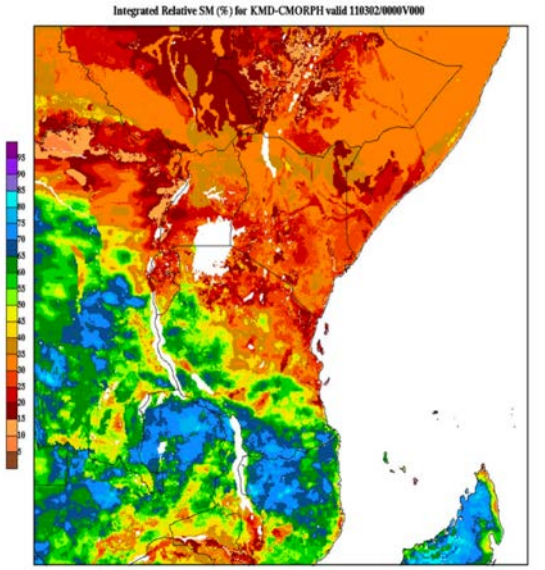


References:
Kumar et al. (2006)
Peters-Lidard et al. (2007)



SPoRT-LIS total column soil moisture displayed in AWIPS II

- 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
  - SE US (3-km), shared with WFO's
  - East Africa, shared with Kenya Meteorological Service (KMS)

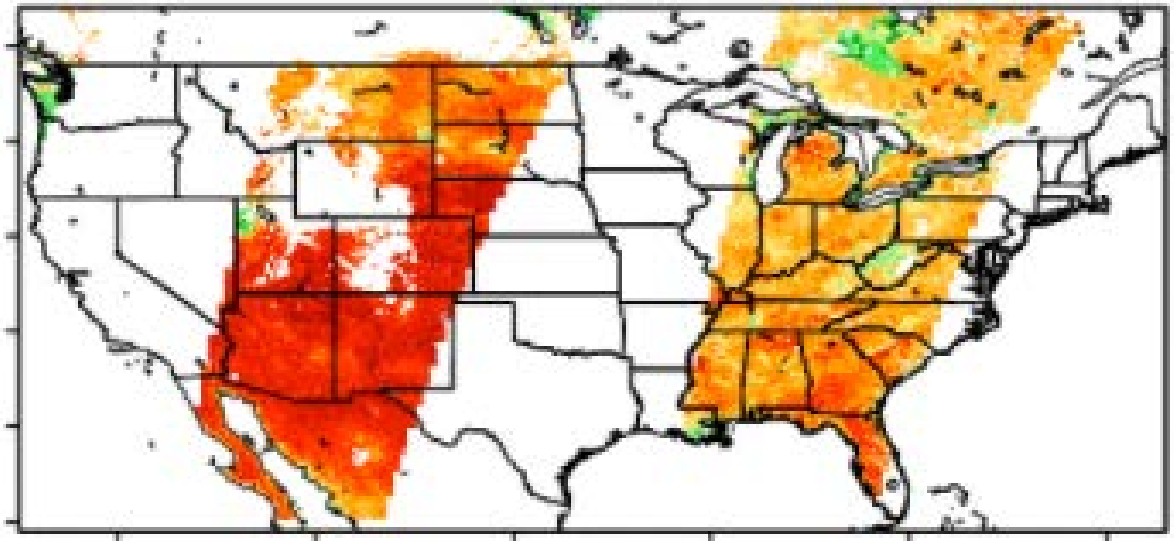


East Africa LIS domain

SMAP L2 Assimilation in SPoRT LIS

LSM is forced by meteorological data (NLDAS-2)
Data assimilation combines model fields with observations (SMAP L2SM) to update model state
Customized LIS to add SMAP L2 soil moisture retrievals
    (half-orbit files)
    Using 9-km “Enhanced” product
3-km CONUS domain based on ongoing SPoRT-LIS run

12 ensemble members
1 month ensemble perturbation spinup



SMAP Surface Soil Moisture
(Observations Assimilated into LIS)

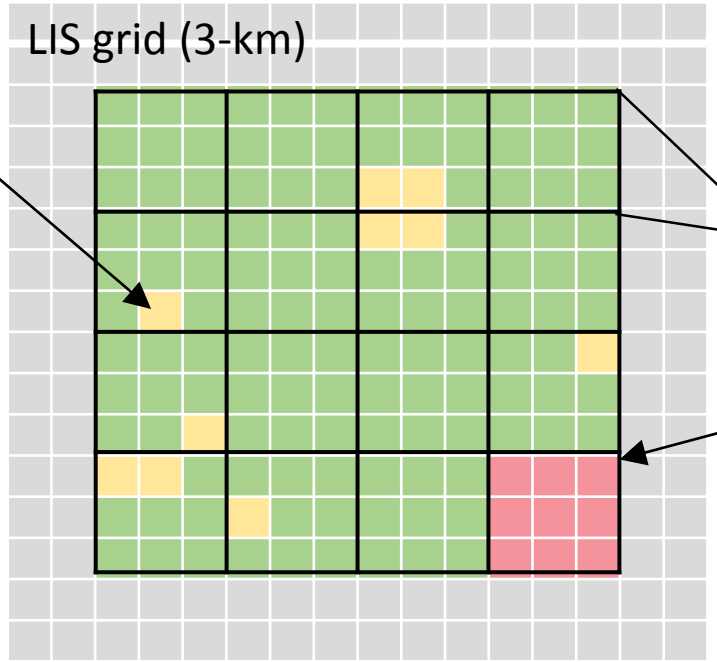
Observation mapping and QC

- Level 2 data are available on 9-km EASE grid
- To take advantage of high resolution geophysical properties (topography, vegetation, soils), running model at 3-km
- SMAP observations are assimilated at each model grid point in their FOV
- Downscaling to preserve background variability implemented

Model-based QC applied on LIS grid

- Precip (changed to 1 mm/hr)
- Frozen ground
- Snow on ground
- GVF>0.7
- Extreme values

Bias correction is applied on LIS grid.



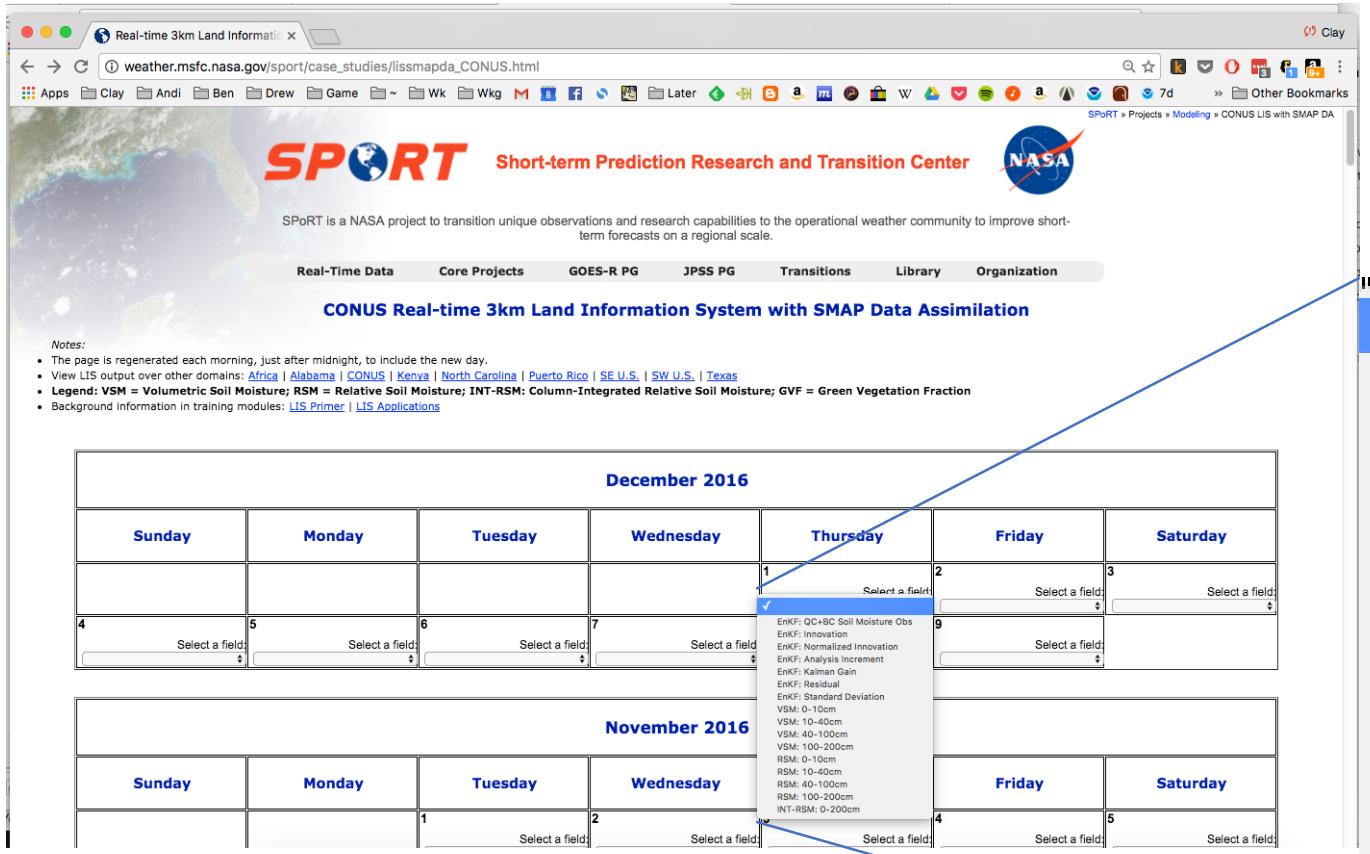
SMAP enhanced (passive) 9-km cell

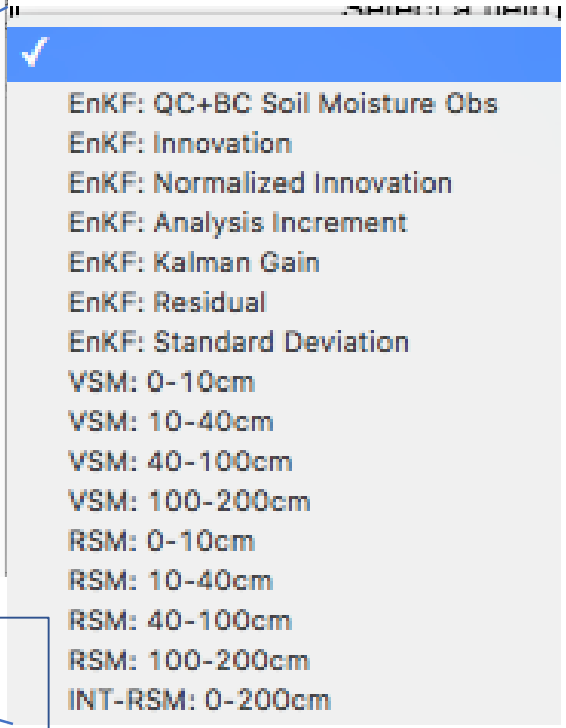
Observation-based QC at 9-km resolution

- RFI
- Retrieval Quality Flag
- Vegetation Water Content
- Frozen Ground Fraction

(In reality, SMAP and LIS grids are not aligned.)

SPoRT LIS Web Interface





https://weather.msfc.nasa.gov/sport

->Realtime Data

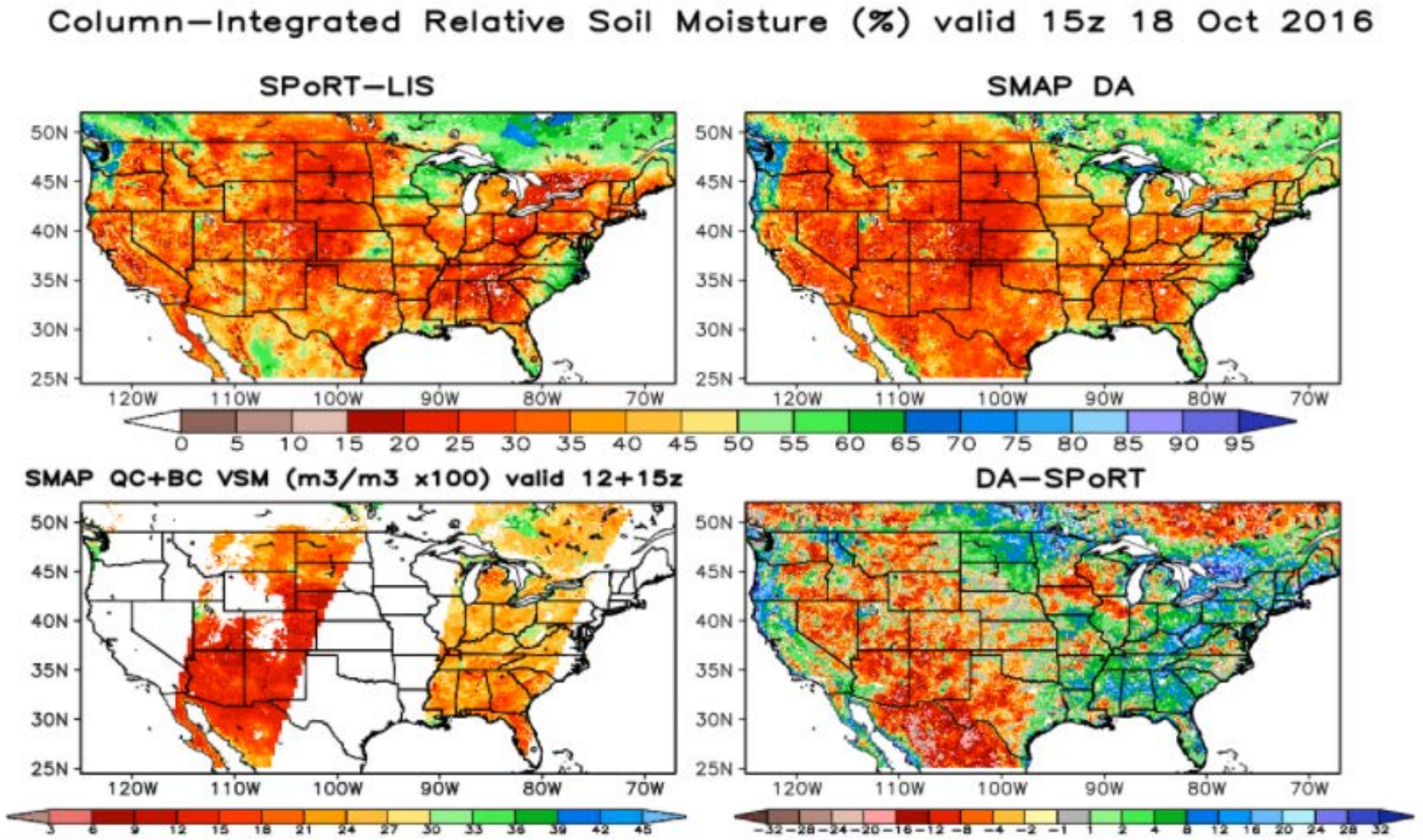
->SMAP Soil Moisture

->Realtime Data

->Land Information System

->SPoRT LIS + SMAP DA

LIS Web Products from SPoRT: SMAP LIS

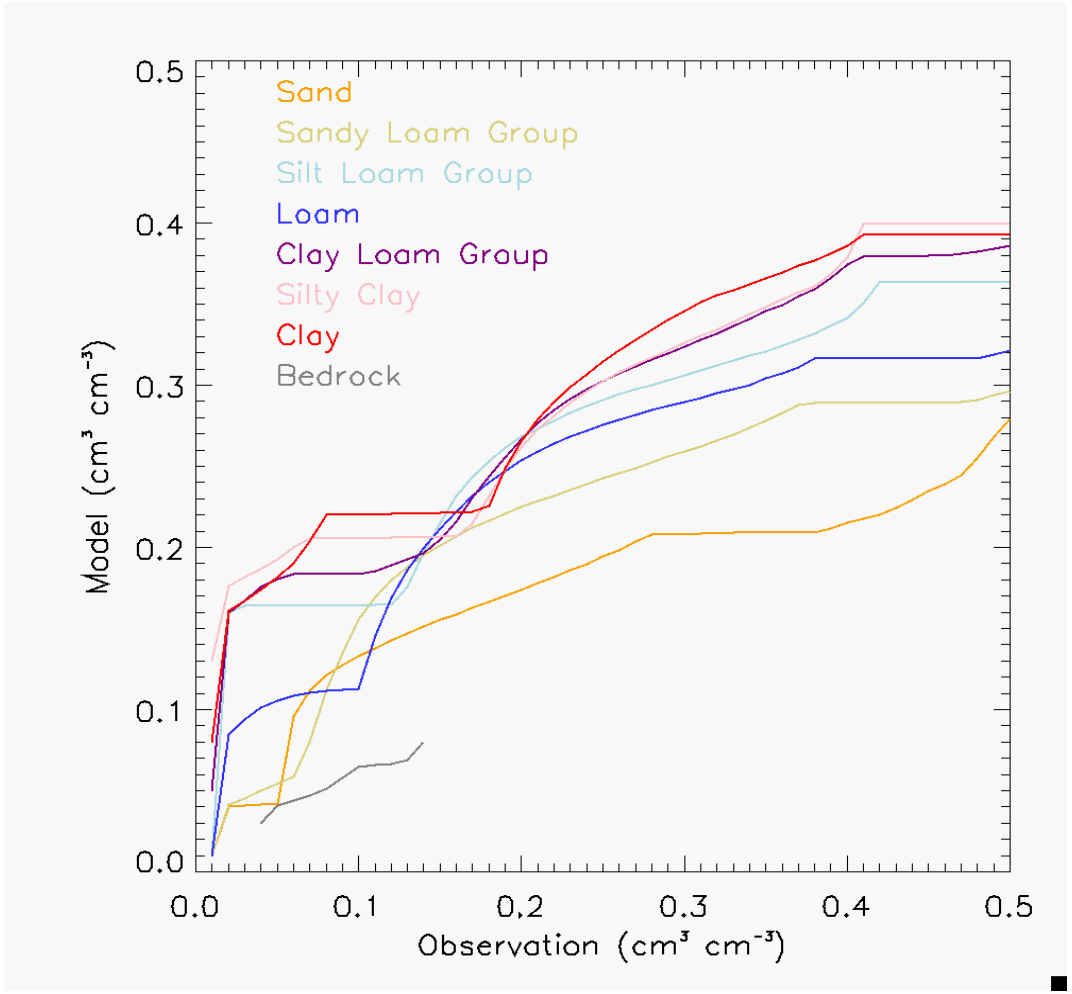


- 0-10 cm model soil moisture

https://weather.msfc.nasa.gov/sport/case_studies/lissmapda_CONUS.html

Bias Correction

- Assimilation systems assume unbiased observations
- LIS can apply point-by-point correction curves. Many implementations generate climatologies of model and obs at each grid point.
- We have implemented CDF matching aggregated by soil type
  - Described for SMOS in Blankenship et al. 2016 (*IEEE TGRS*)
  - Idea is to let the observations influence the model climatology rather than enforcing previous climatology.
- Other methods being explored
  - Point=-by-point
  - Hybrid (matching soil type in neighborhood)
- Using a thinner soil moisture layer may reduce forward operator error and subsequently the magnitude of bias corrections



Correction Curves By Soil Type

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SMAP Assimilation Reduces Errors due to Poor QC in Forcing Data

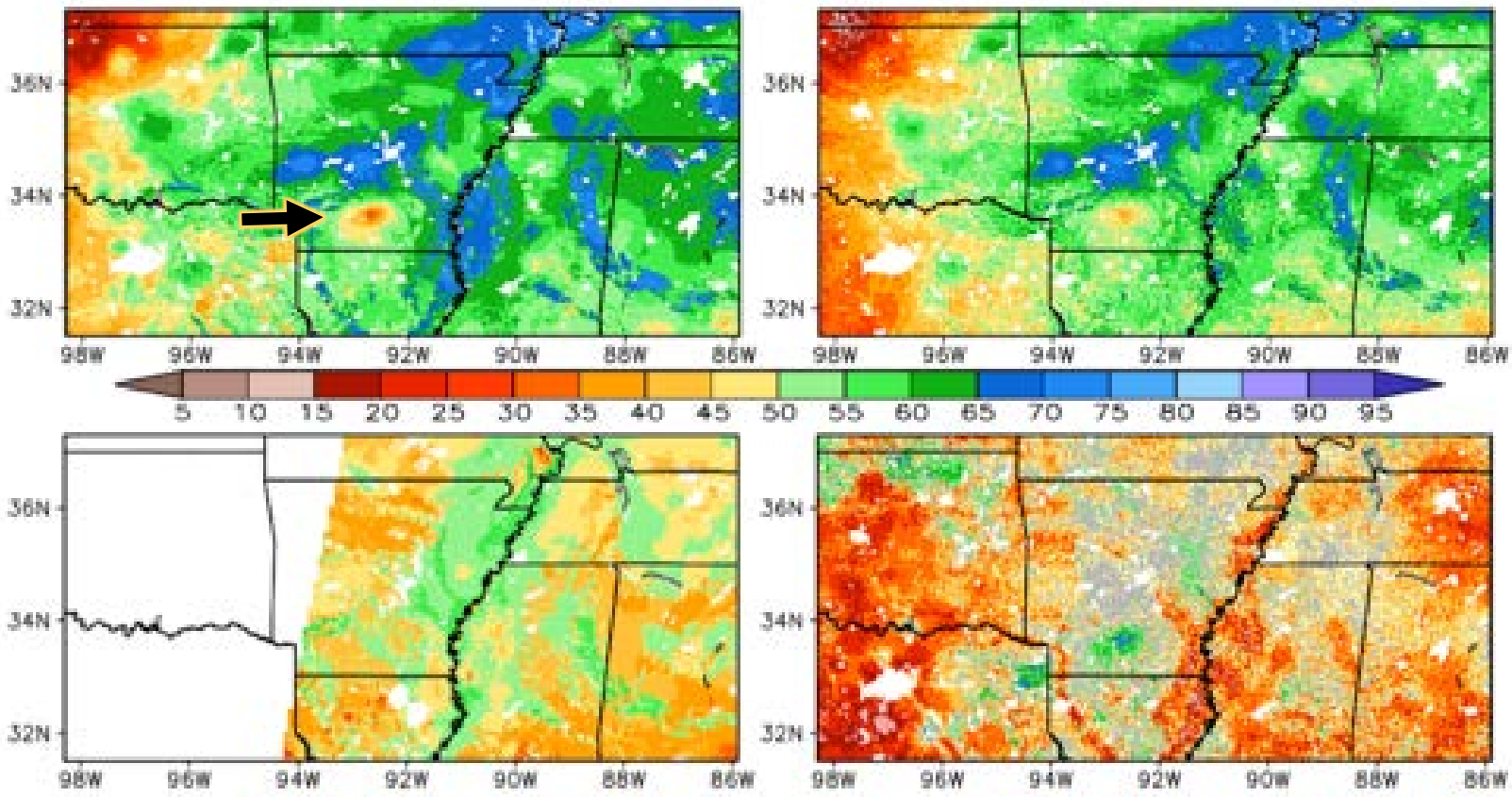
- NLDAS-2 forcing data included data from a bad rain gauge (consistently near zero) in southern Arkansas causing an anomalously dry soil moisture “bullseye” (upper left, arrow).
- Through assimilation of SMAP L2 soil moisture fields, which do not exhibit this feature (lower left), this anomaly is reduced (upper right) to provide a more representative soil moisture field.
  - Snapshot is after first instance of assimilated data at this location.
- This results in a more accurate depiction of local conditions.
- This type of correction is possible due to the non-local bias correction method.

0-10 cm Relative Soil Moisture (%)

12Z 2 Apr 2015

Baseline SPoRT LIS

SPoRT LIS with SMAP DA



SMAP Retrieved Soil Moisture

0-5 cm, volumetric (m^3/m^3 x100)

Non-localized CDF-matching bias correction applied

LIS Difference

(SMAP DA Minus Baseline SPoRT)

Column Integrated RSM (%)

Credit: Youlong Xia, Pingping Xie (NCEP/EMC); David Mocko (NASA/GSFC)

Better Blending of Soil Moisture Across US-Canada Border

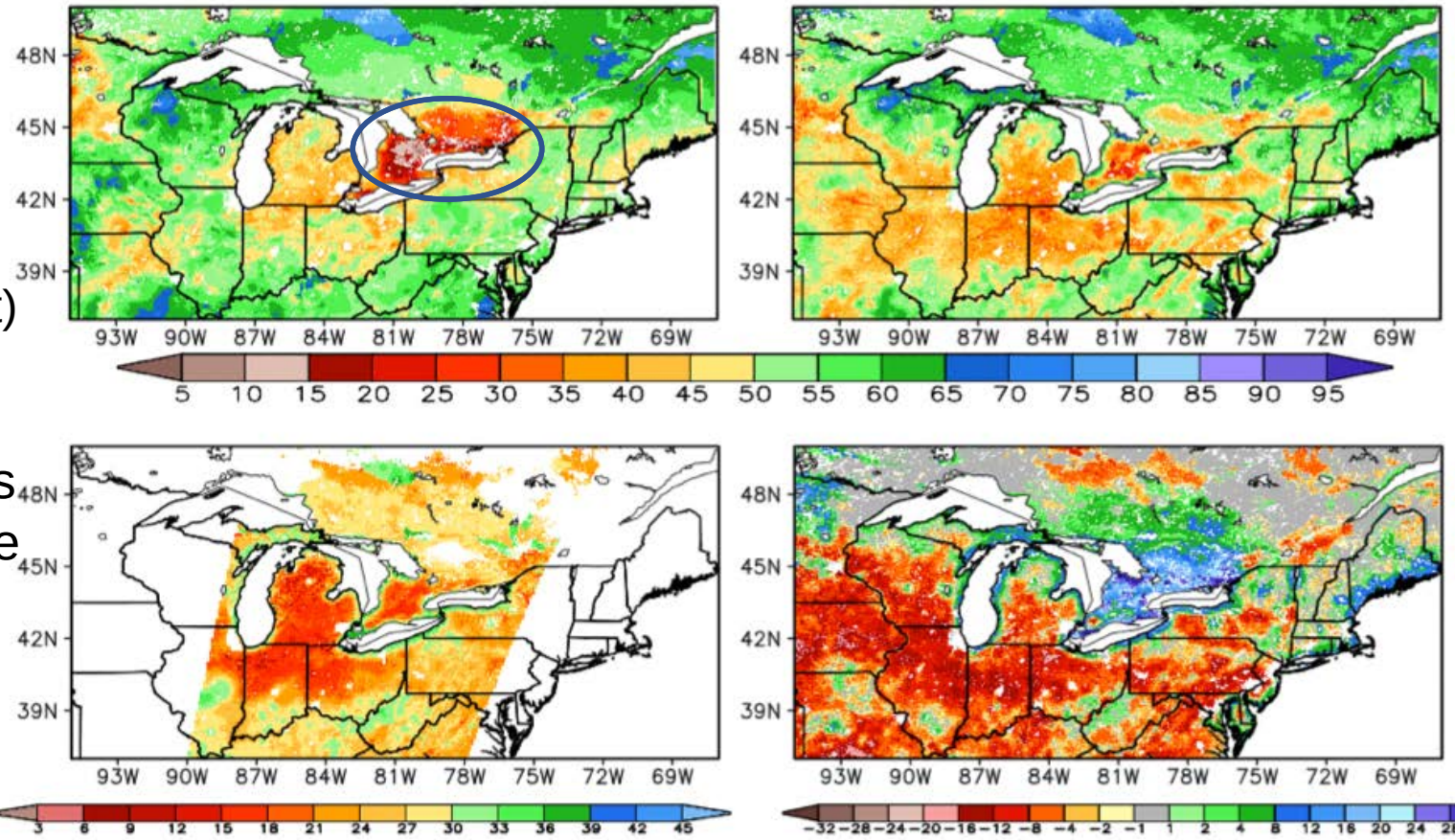
- Soil moisture discontinuities can occur in regions where different precipitation inputs are blended
  - NLDAS-2 uses radar-derived precipitation over U.S. and reanalysis outside of U.S.
  - Results in anomalous dry conditions in southern Ontario (upper left, oval)
  - SMAP retrieved soil moisture (lower left) does not have this feature.
- Through assimilation of SMAP L2 soil moisture fields, this anomaly disappears over time (upper right) to provide a more representative soil moisture field
- This should help forecasters better assess current regional conditions and provide more accurate initialization of NWP models.

0-2 m Column Integrated Relative Soil Moisture (%)

12Z 4 Jun 2016

Baseline SPoRT LIS

SPoRT LIS with SMAP DA



SMAP Retrieved Soil Moisture

0-5 cm, volumetric (m^3/m^3 x100)

Non-localized CDF-matching bias correction applied

LIS Difference

(SMAP DA Minus Baseline SPoRT)

Column Integrated RSM (%)

Credit: Youlong Xia, Pingping Xie (NCEP/EMC); David Mocko (NASA/GSFC)

Validation Results (Elora, ON)

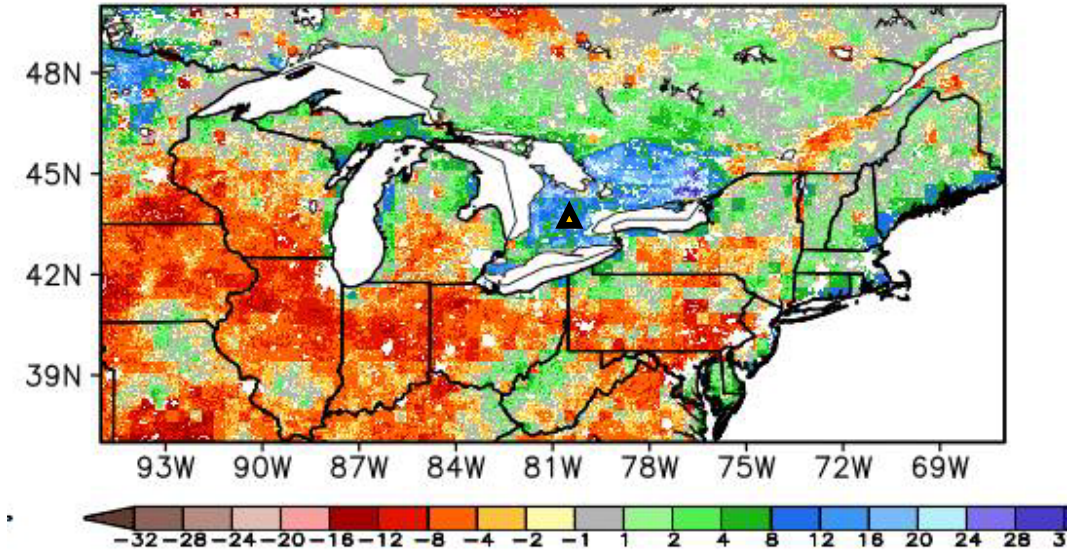
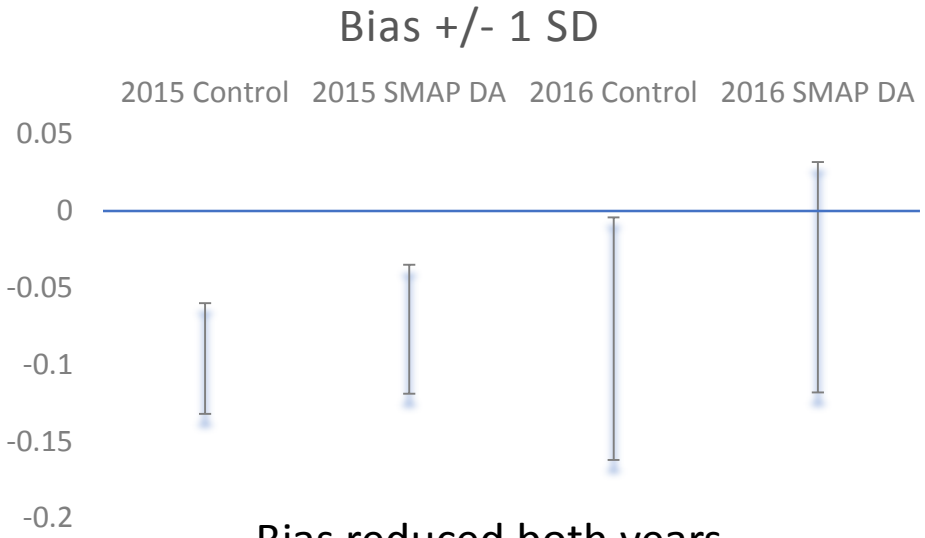


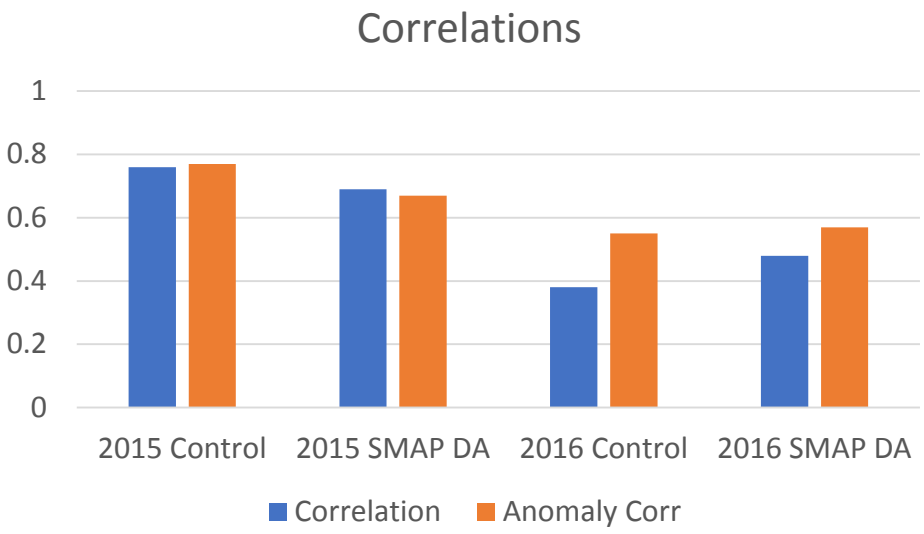
TABLE I
SOIL MOISTURE VALIDATION AT ELORA, ONTARIO

	2015		2016	
Metric	Control	SMAP DA	Control	SMAP DA
Bias	-0.096	**-0.077**	-0.083	**-0.043**
RMSE	0.102	**0.088**	0.115	**0.086**
ubRMSE	**0.036**	0.042	0.079	**0.075**
RCORR	**0.76**	0.69	0.38	**0.48**
ACORR	**0.77**	0.67	0.55	**0.57**

Validation statistics (bias, RMSE, unbiased RMSE, correlation, anomaly correlation) from Elora, Ontario, Canada soil moisture gauge for summer 2015 (30 May-4 Sep) and summer 2016 (2 May-31 Aug). For each pair of measurements, the better value is in bold font.

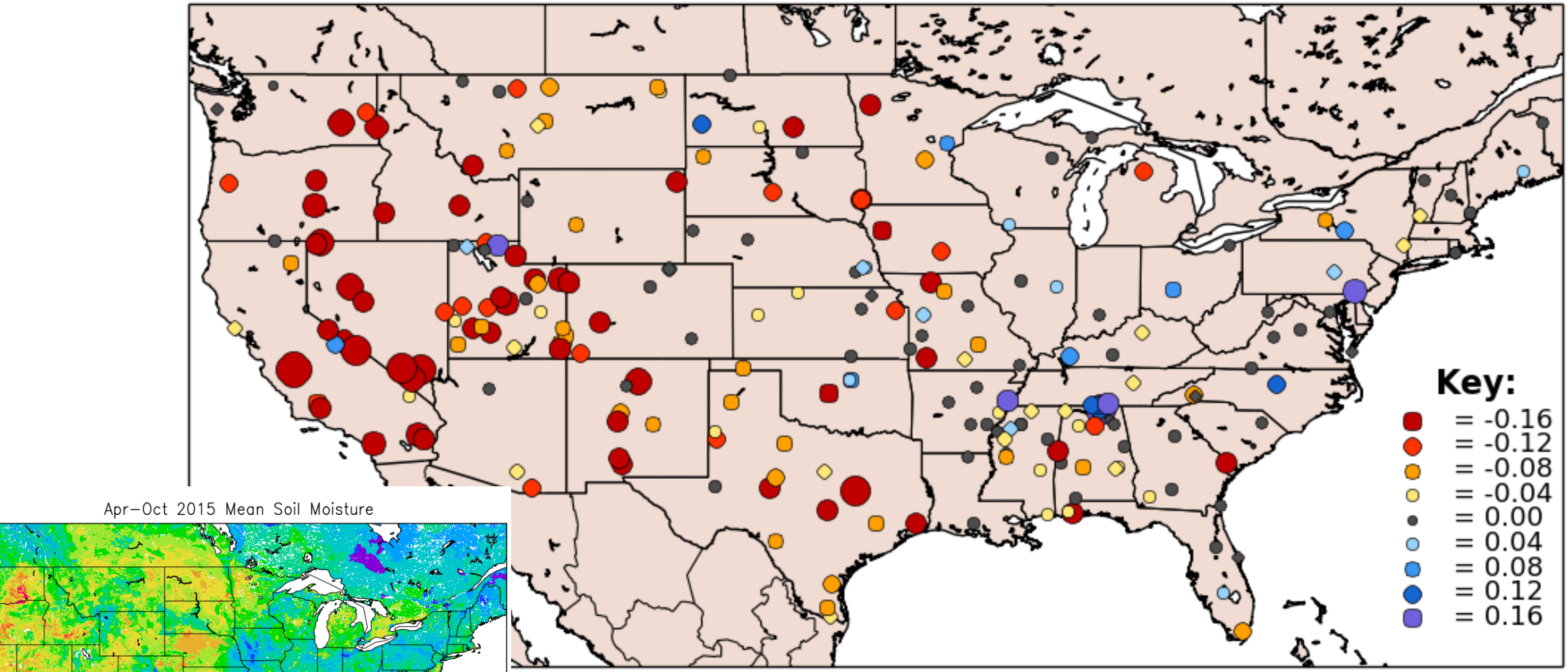


Bias reduced both years.

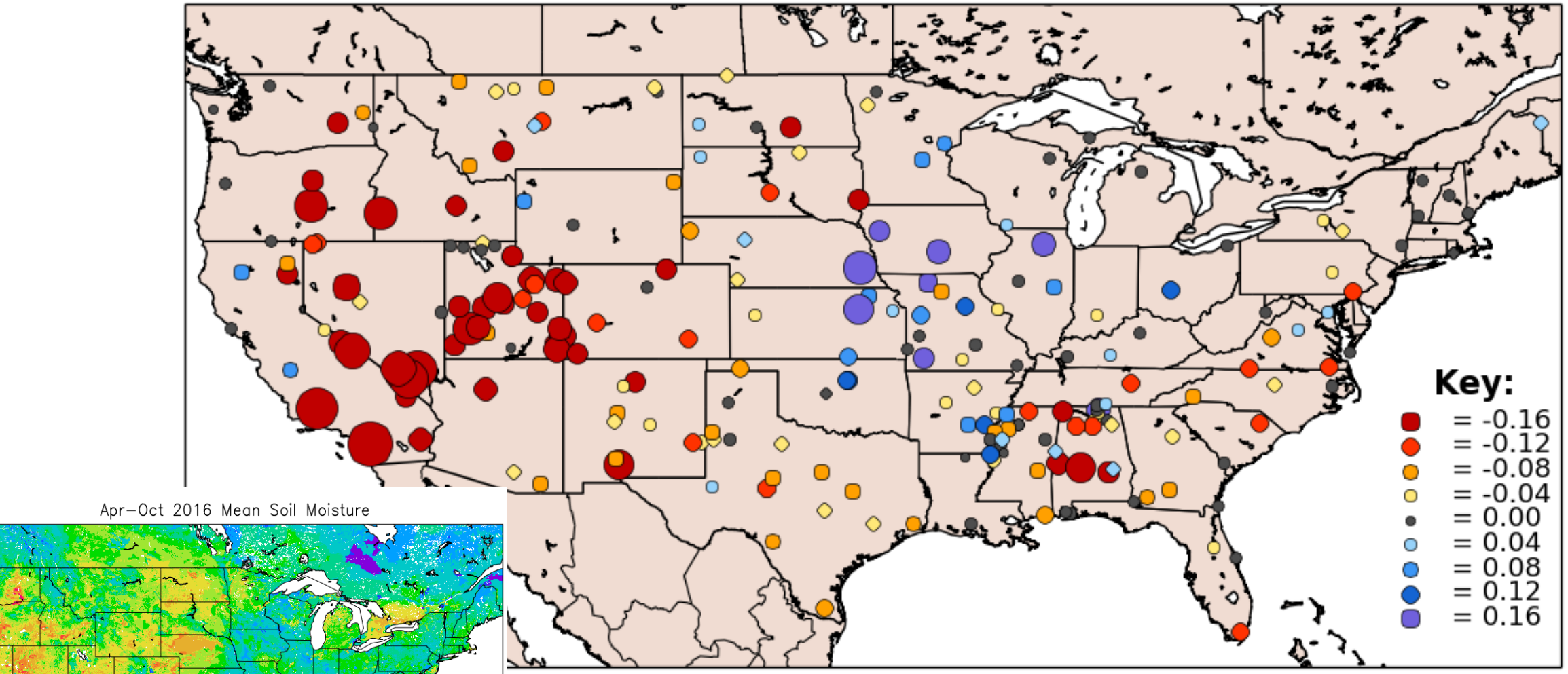


Correlations mixed (2015 worse, 2016 better)

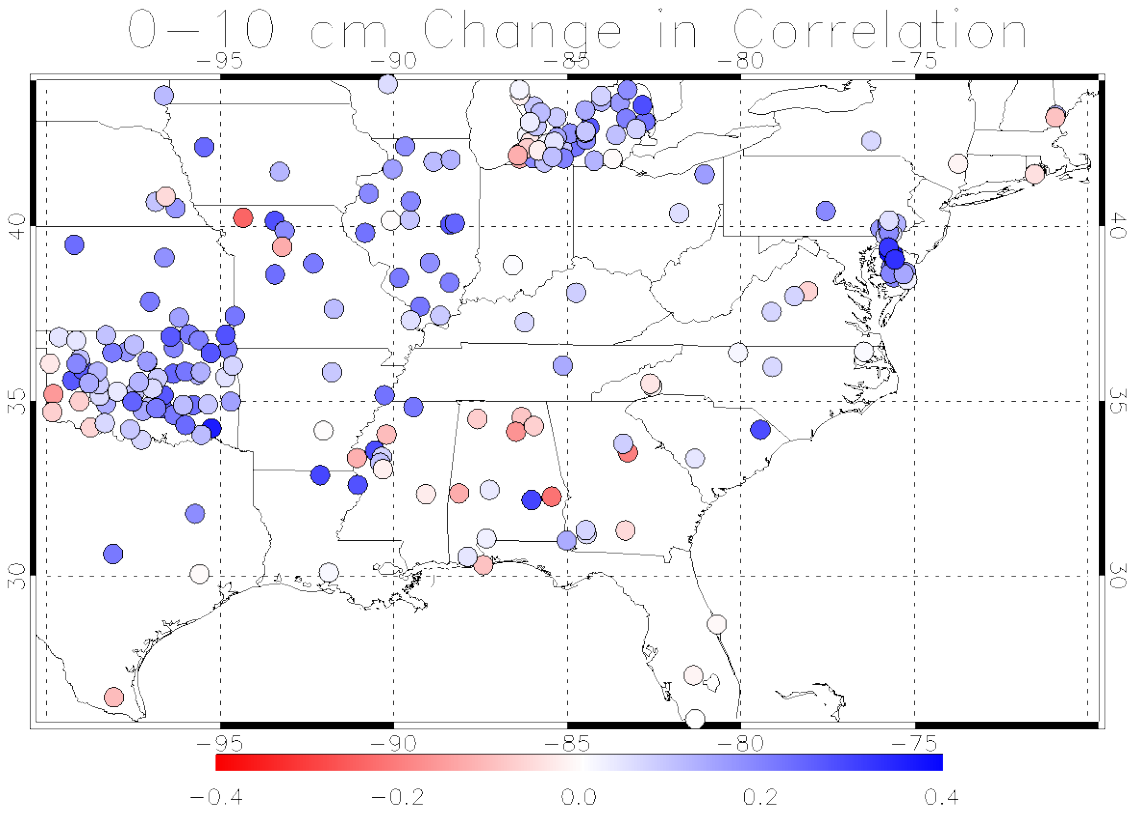
SMAP Correlation change 2015

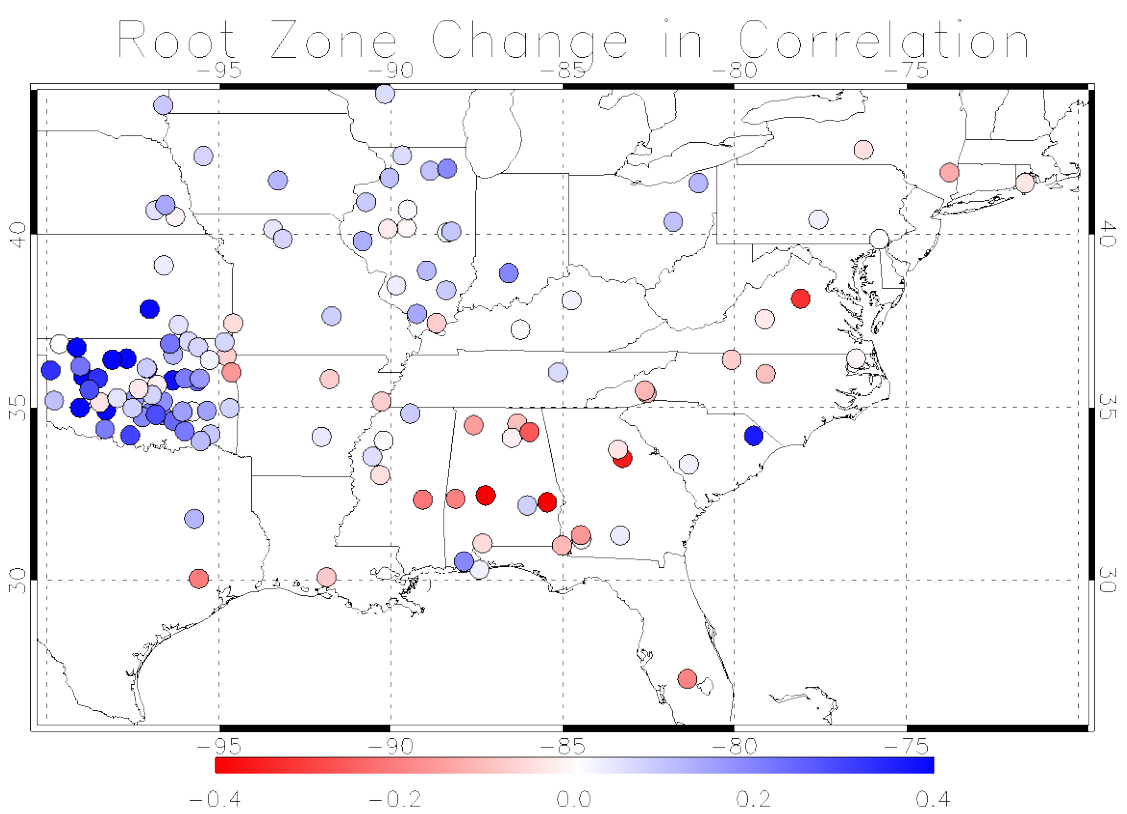


SMAP Correlation change 2016



Previous Validation Results (SMOS DA)

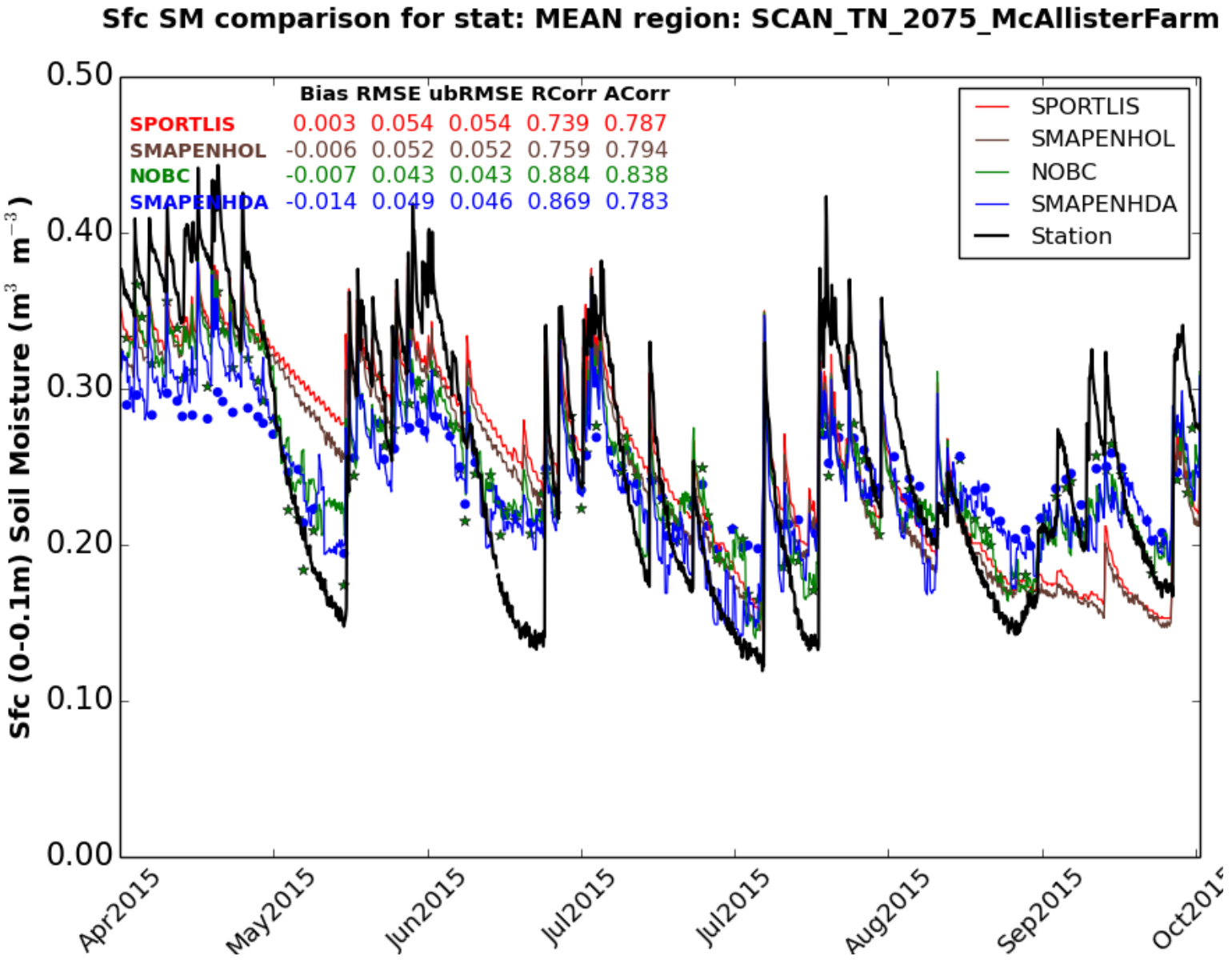


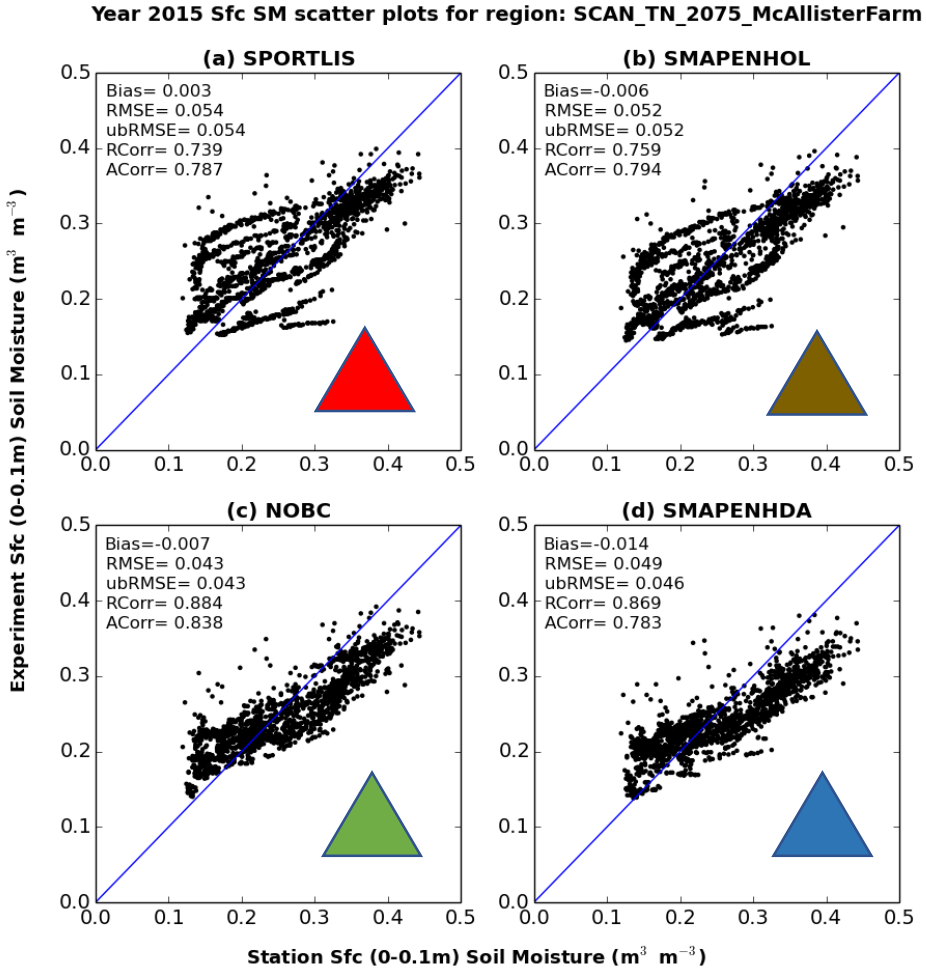


	Near Surface (0-10 cm)			Root Zone (10-100 cm)		
	Bias	Err SD	**Corr.**	Bias	Err SD	**Corr.**
Control	3.6%	23.5%	**0.47**	4.0%	10.6%	**0.61**
SMOS DA	-0.5%	21.8%	**0.57**	10.6%	11.8%	**0.67**

New Validation Results (SMAP DA)

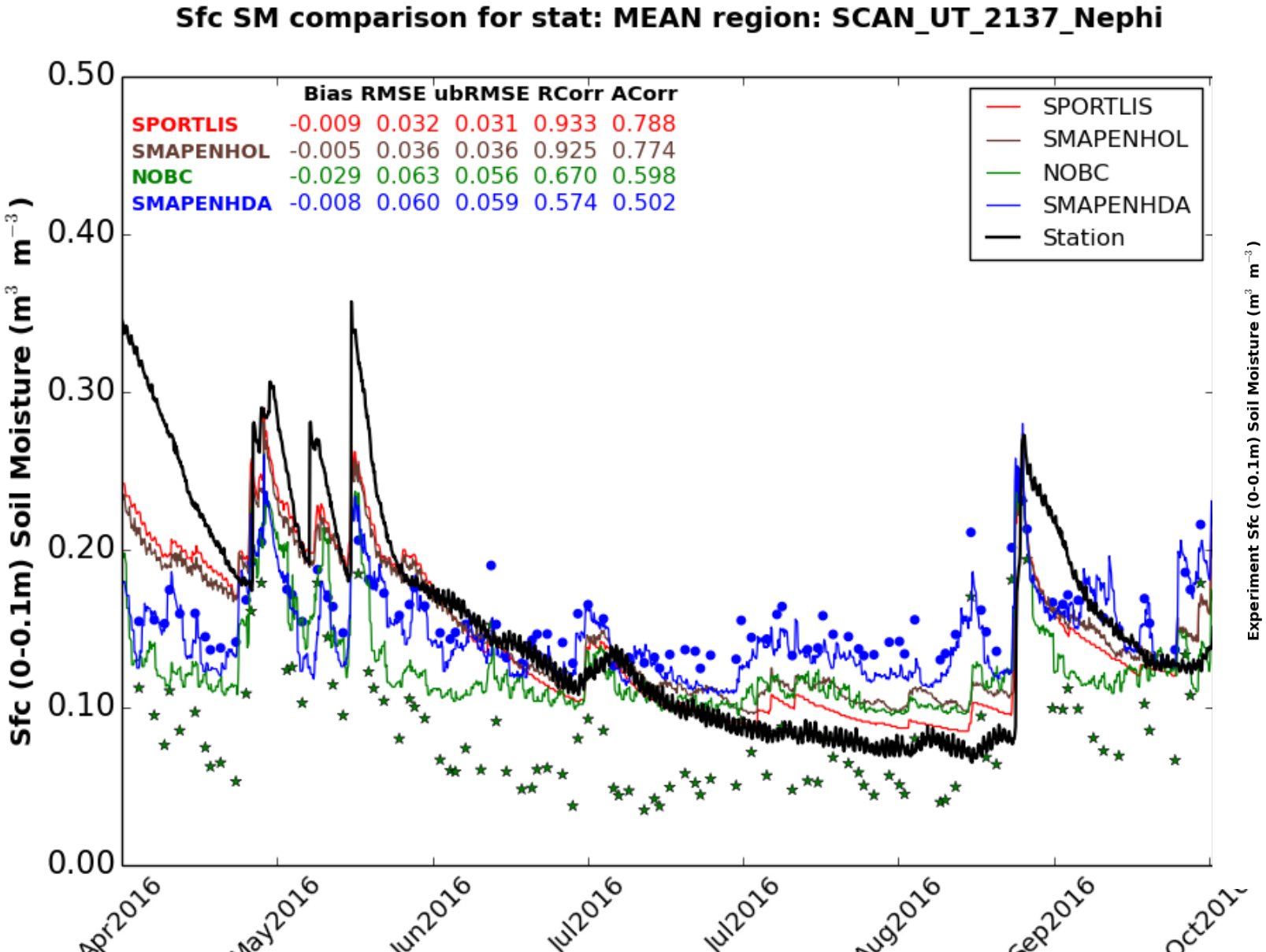
- Corr increases from .79 to .84 (NOBC)
- ubRMSE decreases from .054 to .043

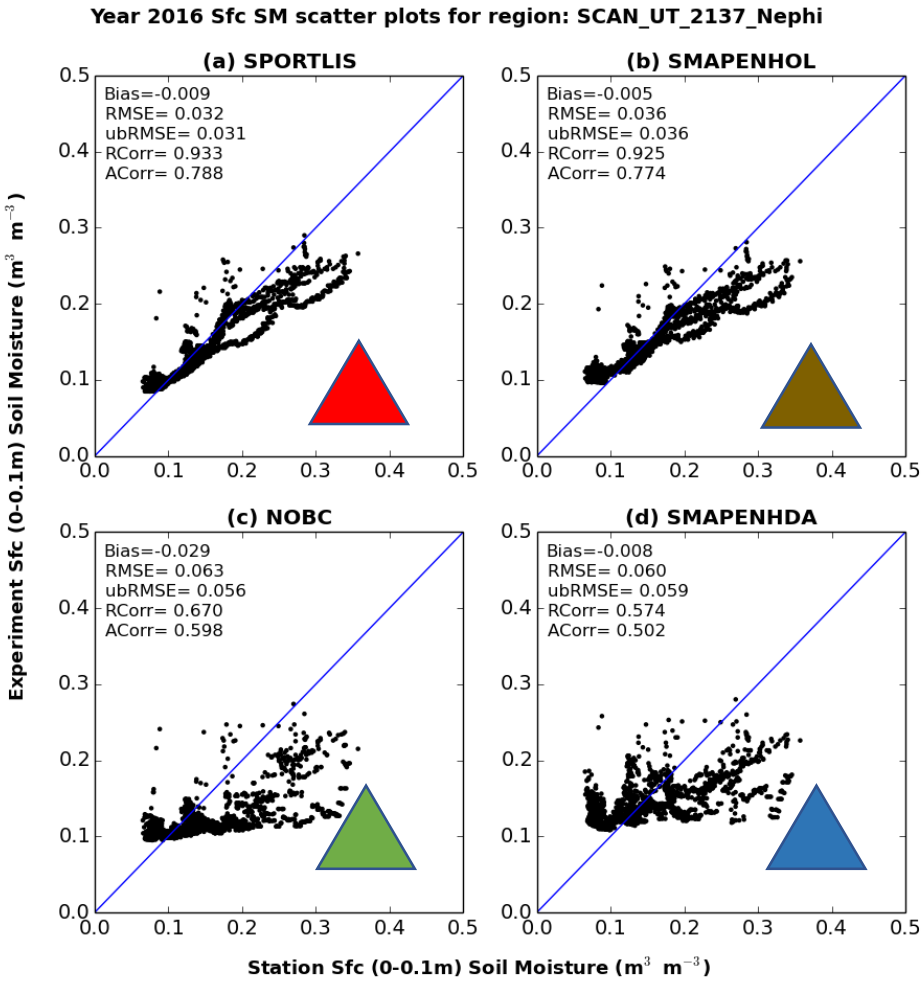




New Validation Results (SMAP DA)

- Corr decreases from .93 to .67 (NOBC)
- ubRMSE increases from .031 to .059





Areas of Investigation

Overall, negative impact on correlation and ubRMSE

- Bias Correction
  - but correlation is insensitive to bias correction
- AM/PM data
  - Validation of retrievals indicates small difference (<10%)
- Representativeness (point vs grid cell, also vertical) of validation data
  - Previously got positive impact (correlations) with SMOS
  - Others getting good impact
- Depth discrepancies
  - (10 cm model layer, 5 cm or less SMAP measurement)
  - Experiment in progress
- Information content of 3-km LSM is too hard to match with 9-km obs?
- But previously got positive impact with SMOS with similar settings.
- Data less useful in western US?

Initial East Africa Results

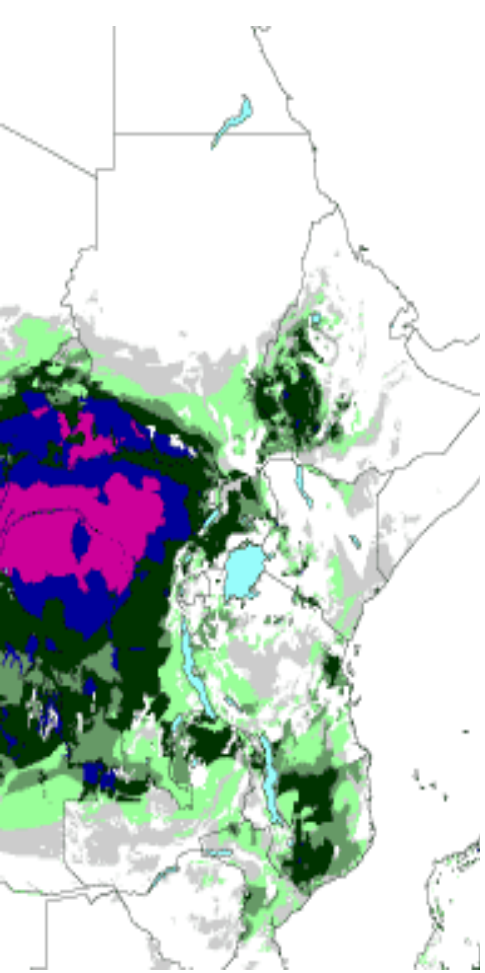
9/1/2015 after 3 months DA

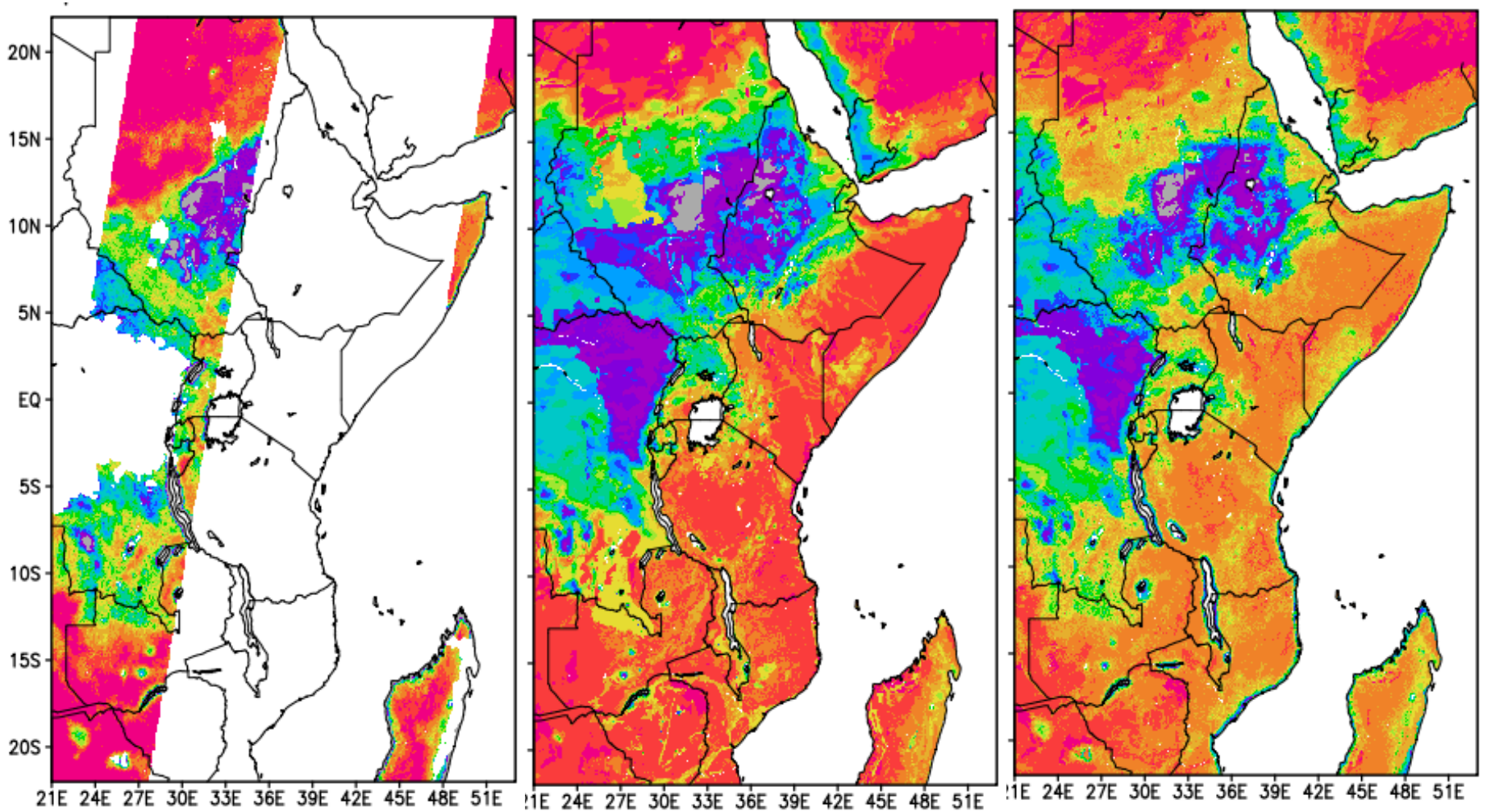
Biomass for Reference

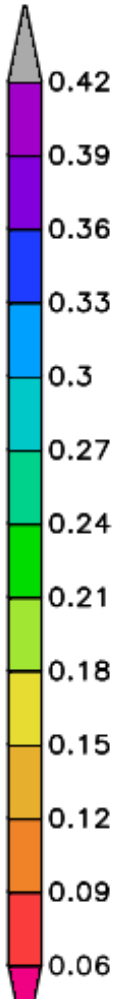
SMAP Retrieval

SPoRT LIS

SMAP DA LIS *(No BC)*

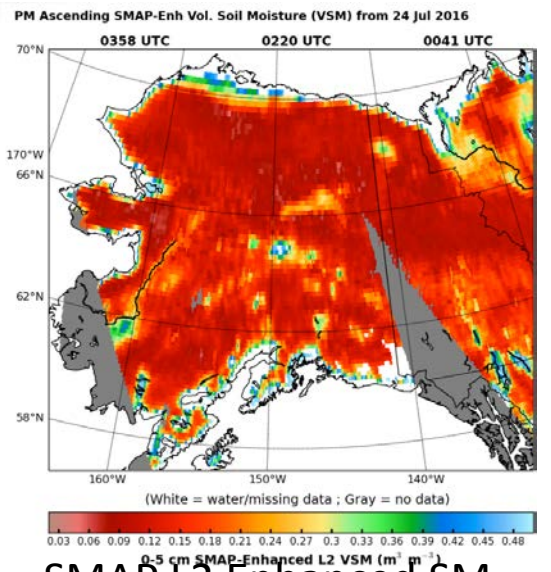




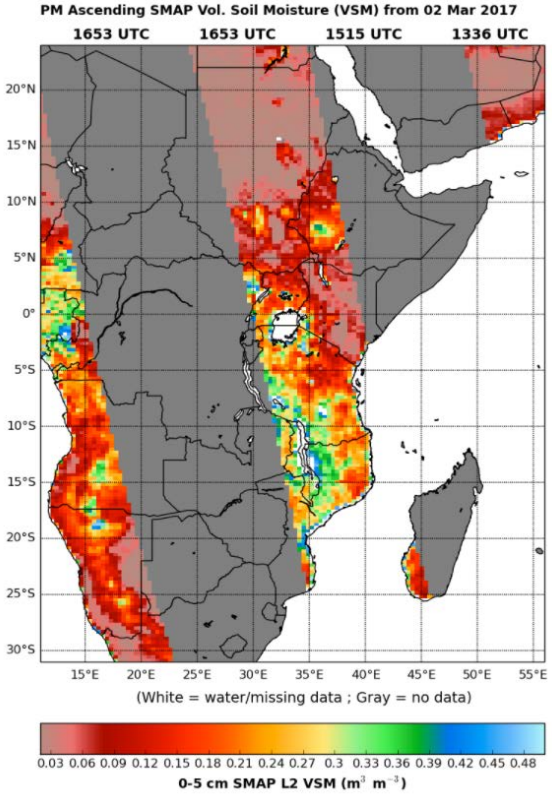


Future Plans

- Soil Moisture
  - Refine methodology (layers, bias corrections)
  - Validation of soil moisture against stations
- NWP Initialization
  - Validation of 48-hr NWP forecasts
    - High-impact case studies
    - Comprehensive seasonal validation
- Africa domain
    - Limited ground validation data
    - Focus on NWP
- Alaska domain (wildfire threat)



SMAP L2 Enhanced SM



Goals and Progress

Domain	CONUS	East Africa
Assimilate SMAP in LIS Implementation Refinement Validation (vs. station measurements)	 ✓ In progress ✓(initial)	 ✓ In progress
Coupled NU-WRF Experiments (LIS+WRF) Case studies Validation (48-h weather forecasts)	 In progress	

Refinement of methodology

- Vertical layers
- Bias correction methods (soil type, pointwise, hybrid)
- Ensemble size, perturbations, weighting

Validation

- Soil: SCAN and USCRN Networks, SMAP core sites
  - 0-10 cm and 10-100 cm
- Weather: surface and upper air observations (MADIS, WMO)
  - Precipitation (MRMS (gauge corrected radar), IMERG)

Acknowledgments

- Land Information System Team (NASA-GSFC)
- SMAP Science Team and Early Adopters Team
- Steven Quiring, Texas A&M University (now @Ohio State U.)
- Brent McRoberts, Texas A&M University
- Funding: NASA Earth Science Division
  (ROSES 2015 Science Utilization of SMAP Mission Program)

Questions and Comments?

clay.blankenship@nasa.gov

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