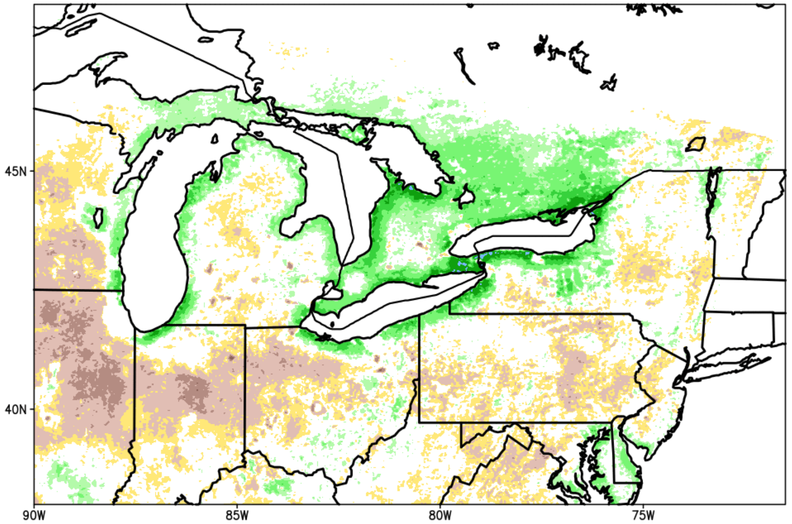
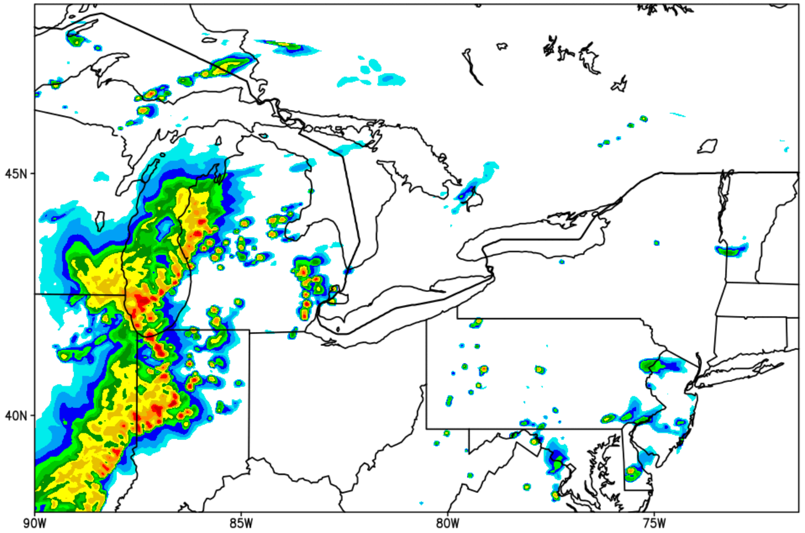
Impact of SMAP Soil Moisture Assimilation on NWP



Clay Blankenship
Jonathan Case
Christopher Hain

NASA SPoRT



SPoRT Short-term Prediction Research and Transition Center

SPoRT is a NASA project to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale.

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)

Topography, Soils (Static)

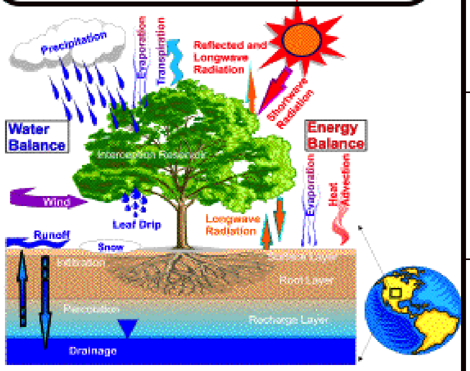
Vegetation, LAI (Monthly)

Meteorological "Forcings" (Hourly-3 hourly)

Land Surface States (Variable)

Land Surface Models (LSM) (15 min-1 hour)

Noah, CLM, VIC



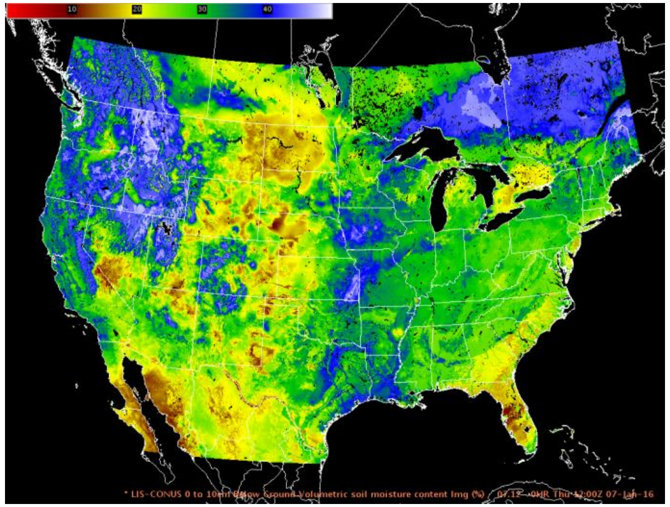
References:
Kumar et al. (2006)
Peters-Lidard et al. (2007)

Surface Fluxes: Qnet,Qle,Qh,Qg Swnet, LWnet

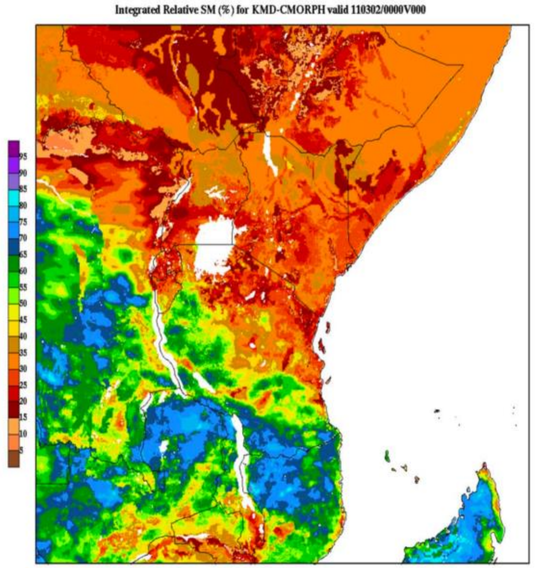
Soil States: Moisture, Temperature Profiles

Water Balance: Runoff, Drainage, Baseflow (some)

Surface States: Snow Skin Temperature LAI (some)



SPoRT-LIS total column soil moisture displayed in AWIPS II



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

Updates

- New Validation Datasets (COSMIC, OK and WTx mesonets)
- Experimented with bias corrections and perturbations
- Tested additional LSM layer
- Started NWP runs for CONUS
- Implemented Alaska domain for fire threat assessment

Algorithm Refinement

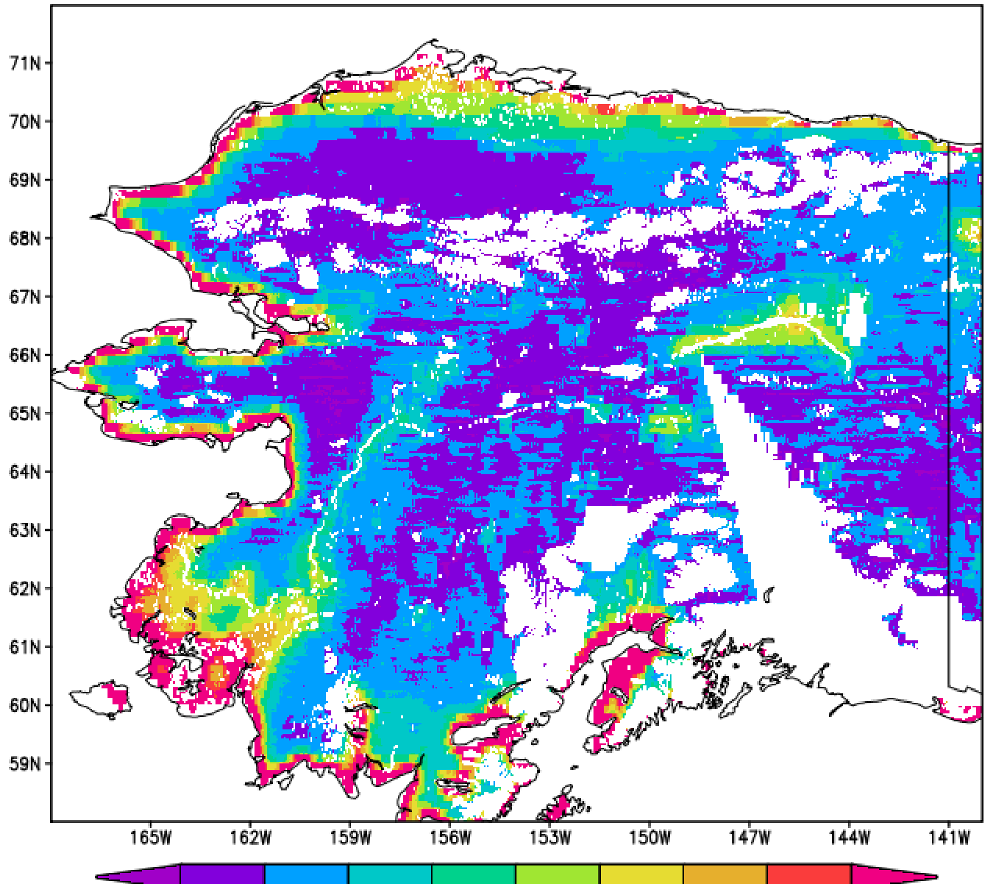
Modeling/DA settings examined

- Depth of first layer
- Number of ensemble members
- Magnitude of ensemble perturbations
- Autocorrelation length of perturbations
- Data version
- Bias Correction

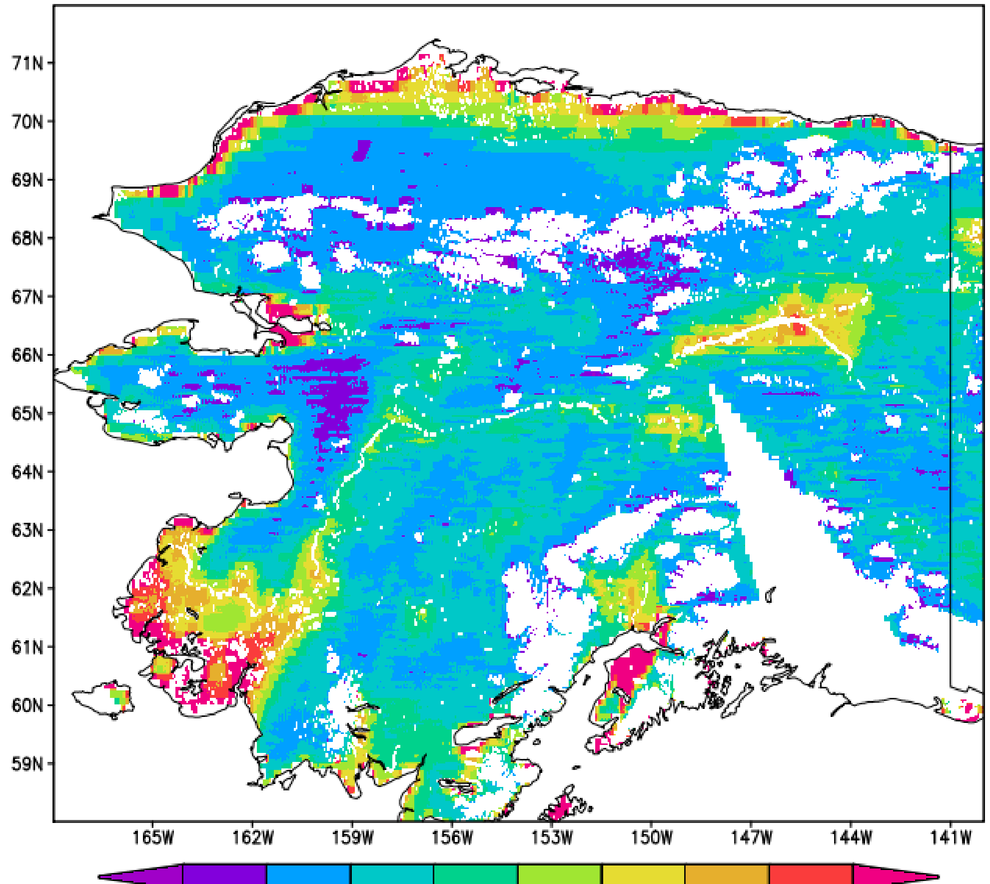
Version 2 of Level 2 Enhanced SMAP Retrievals
Removes/Reduces Striping on Coastlines

SMAP Retrievals 3Z 10 Jun 2015

Version 1



Version 2



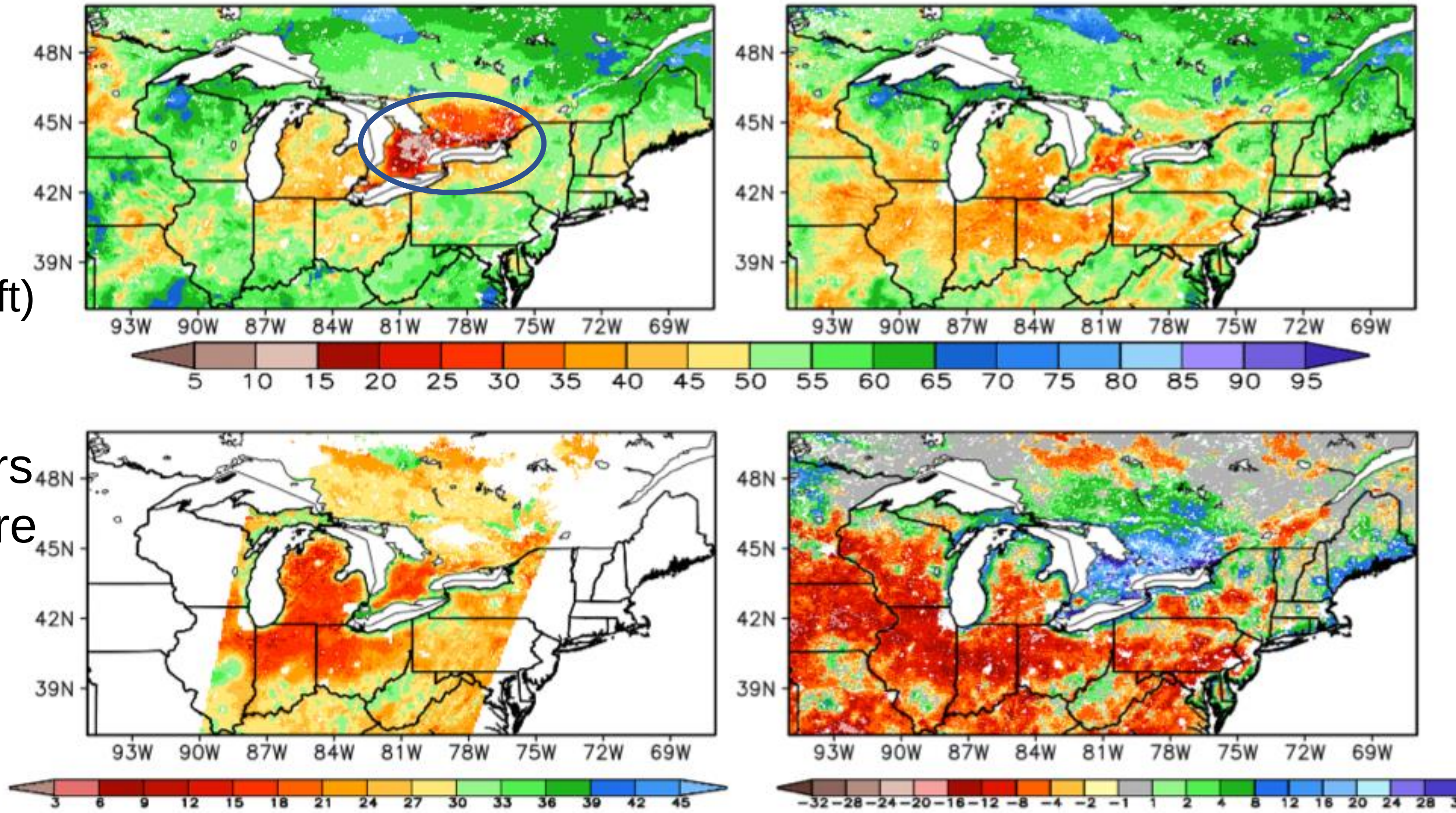
Better Blending of Soil Moisture Across US-Canada Border

- 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

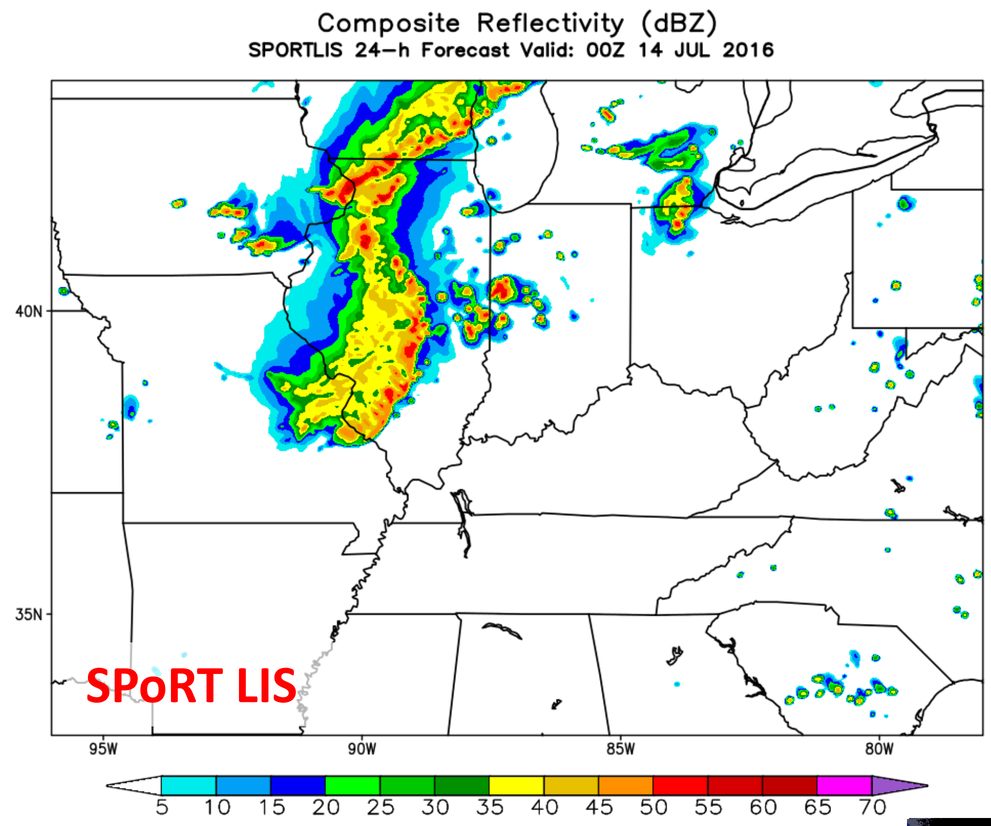
Baseline SPoRT LIS | **SPoRT LIS with SMAP DA**

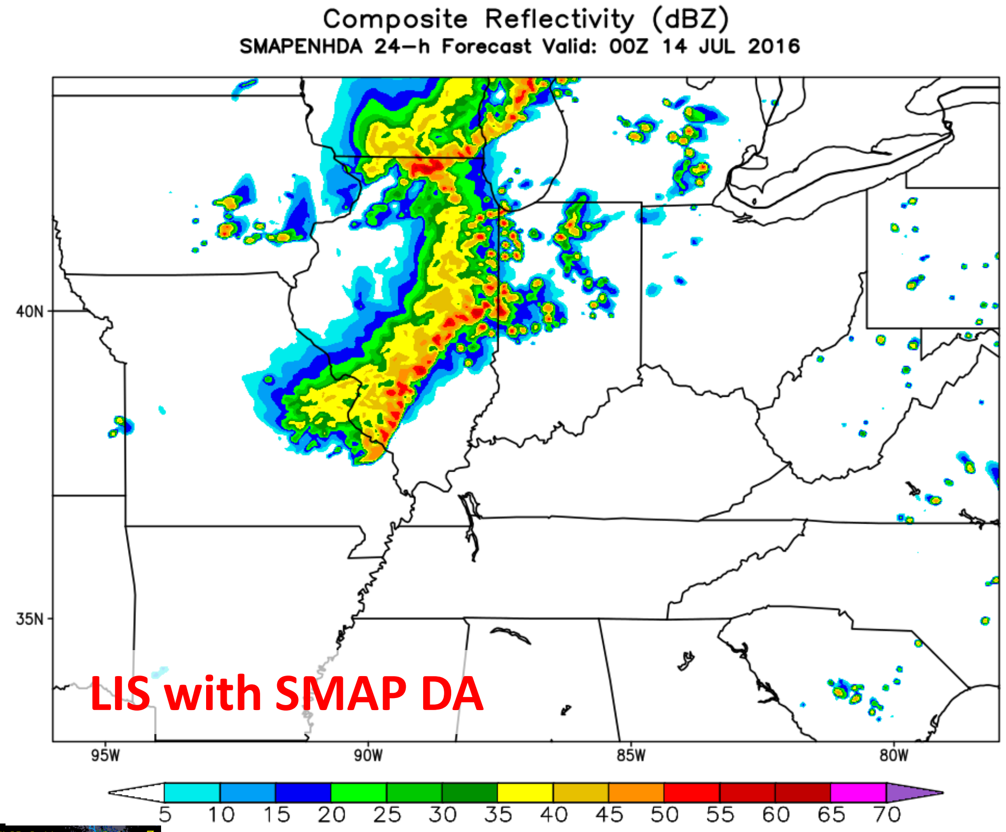


SMAP Retrieved Soil Moisture
0-5 cm, volumetric (m^3/m^3 x100)
Non-localized CDF-matching bias correction applied

LIS Difference
(SMAP DA Minus Baseline SPoRT)
Column Integrated RSM (%)

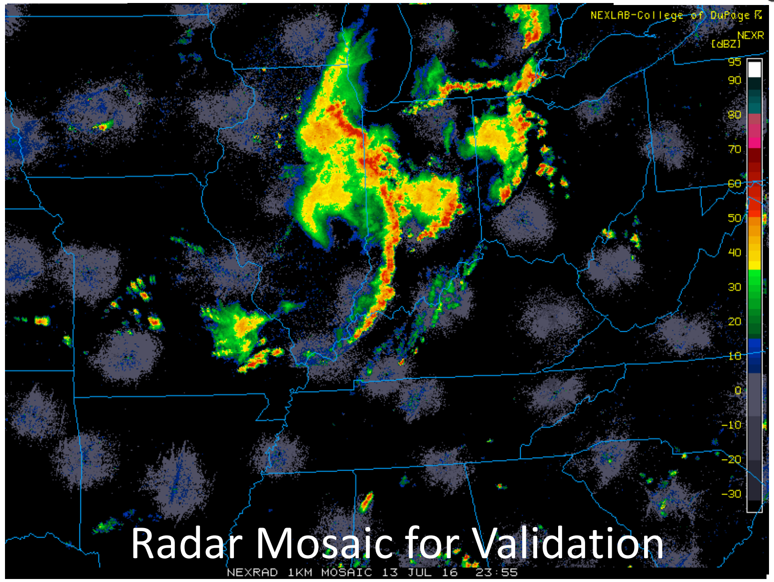
Credit: Youlong Xia, Pingping Xie (NCEP/EMC); David Mocko (NASA/GSFC)





Impact of SMAP Assimilation in LIS for Numerical Weather Prediction

- Running LIS without and with SMAP soil moisture assimilation
- Use LIS output to initialize WRF 48-h forecast (NU-WRF)
- Validate forecast reflectivity against radar observations

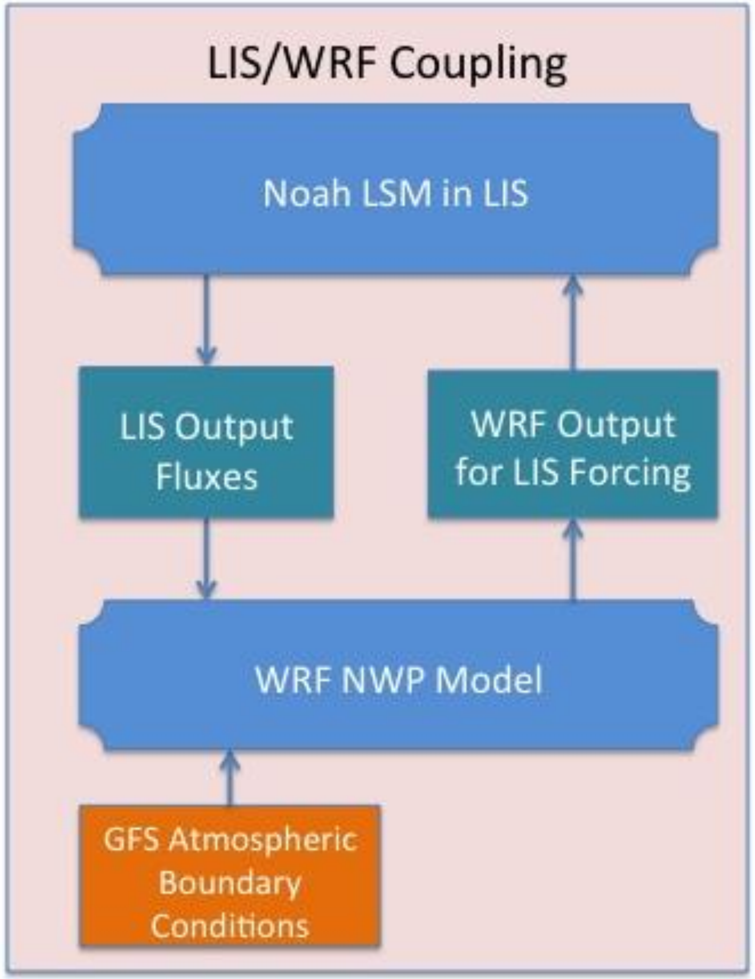


- SMAP assimilation improves timing and shape of forecast squall line
- Quantitative validation planned over 2 warm seasons in CONUS
- East Africa domain experiments to follow
- Future work can investigate impact of CYGNSS, NISAR, etc.

Verification Plan for SMAP DA NWP Impact Simulations

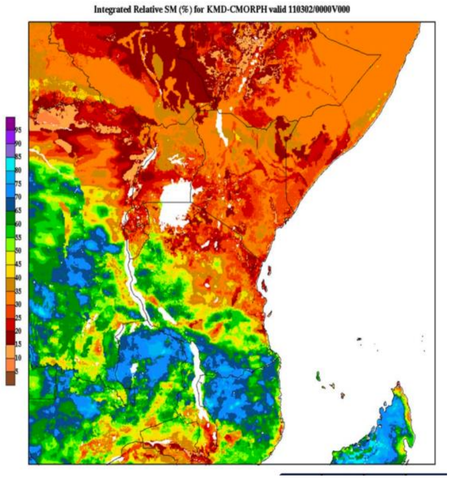
CONUS and East Africa Control- and SMAPENHDA-initialized NU-WRF model runs

WRF impact tests (Planned)



- Coupled LIS/WRF runs within NASA Unified WRF (NU-WRF)
  - NWP provides forcing for LSM
  - LSM provides fluxes and surface conditions to NWP model
- Assess impact of SMAP DA on NWP for coupled runs
  - Verify NWP forecasts against surface obs, soundings, and precipitation analyses
  - Examine impact on significant events
  - Evaluate in CONUS and East Africa

Validation Datasets		
Domain	**T, q, wind**	**Precipitation**
CONUS	MADIS	MRMS
East Africa	WMO network	GPM IMERG



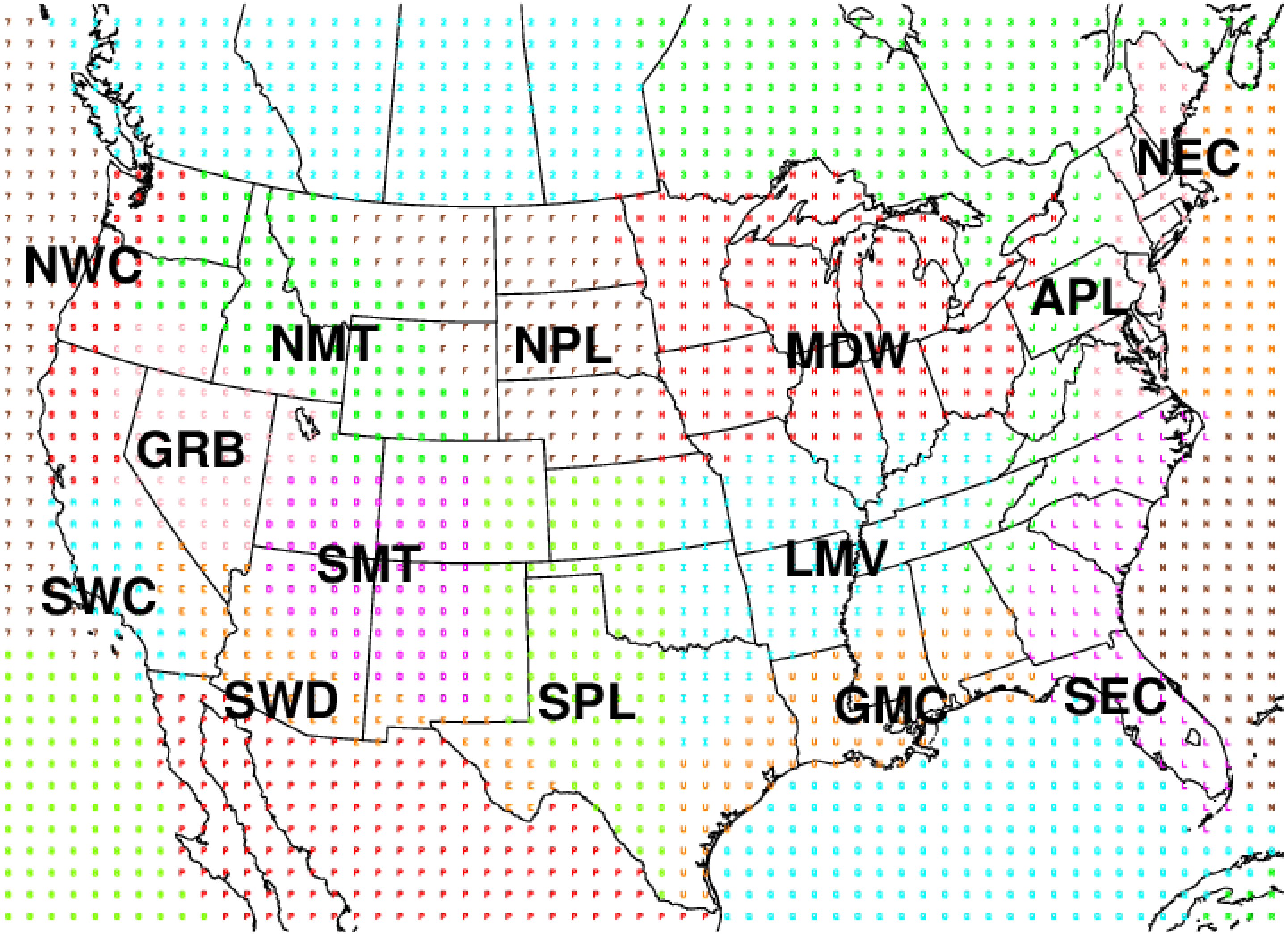
CONUS NU-WRF Simulation Verification

- Point Forecast Verification (T, Td, winds)
  - Data source: NCEP Meteorological Assimilation Data Ingest System (MADIS) surface, upper-air, and cooperative mesonet observations
  - Run through NCAR/NCEP Model Evaluation Tools (MET) using SPoRT-MET python scripting package
    - ✓ Interpolate NU-WRF 9-km/3-km model grid forecast data to point locations
    - ✓ Generate statistics on model grids and mask by 14 NCEP/EMC verification regions
- Gridded Precipitation Verification (1, 3, 6, 12, 24h accumulation intervals)
  - Data source: Multi-Radar Multi-Sensor (MRMS) radar+gauge-corrected hourly precipitation analyses
  - Run through MET using SPoRT-MET scripting package
    - ✓ Upscale MRMS precipitation to 9-km and 3-km model grids
    - ✓ Generate statistics by grid point, and in neighborhood windows of $\pm$ 9km and $\pm$ 27km
    - ✓ Neighborhood verification determines how accurately the model can predict accumulated precipitation thresholds within a certain distance of a point

East Africa NU-WRF Simulation Verification

- Point Forecast Verification (T, Td, winds)
  - Data source: Global Data Assimilation System (GDAS) PREPBUFR files containing surface and upper-air observations
  - Run through NCAR/NCEP Model Evaluation Tools (MET) using SPoRT-MET python scripting package
    - ✓ Interpolate NU-WRF 9-km/3-km model grid forecast data to point locations
    - ✓ Generate statistics on model grids and mask by country
- Gridded Precipitation Verification (1, 3, 6, 12, 24h accumulation intervals)
  - Data source: GPM/IMERG-Final half-hourly precipitation rates, converted to hourly accumulations, sub-set over East Africa region, and output in GRIB2 format
  - Run through MET using SPoRT-MET scripting package
    - ✓ Upscale model accumulated precipitation grids to IMERG 0.1-deg subset grid
    - ✓ Generate statistics by grid point, and in neighborhood windows of $\pm$ 0.1-deg and $\pm$ 0.3-deg
    - ✓ Neighborhood verification determines how accurately the model can predict accumulated precipitation thresholds within a certain distance of a point

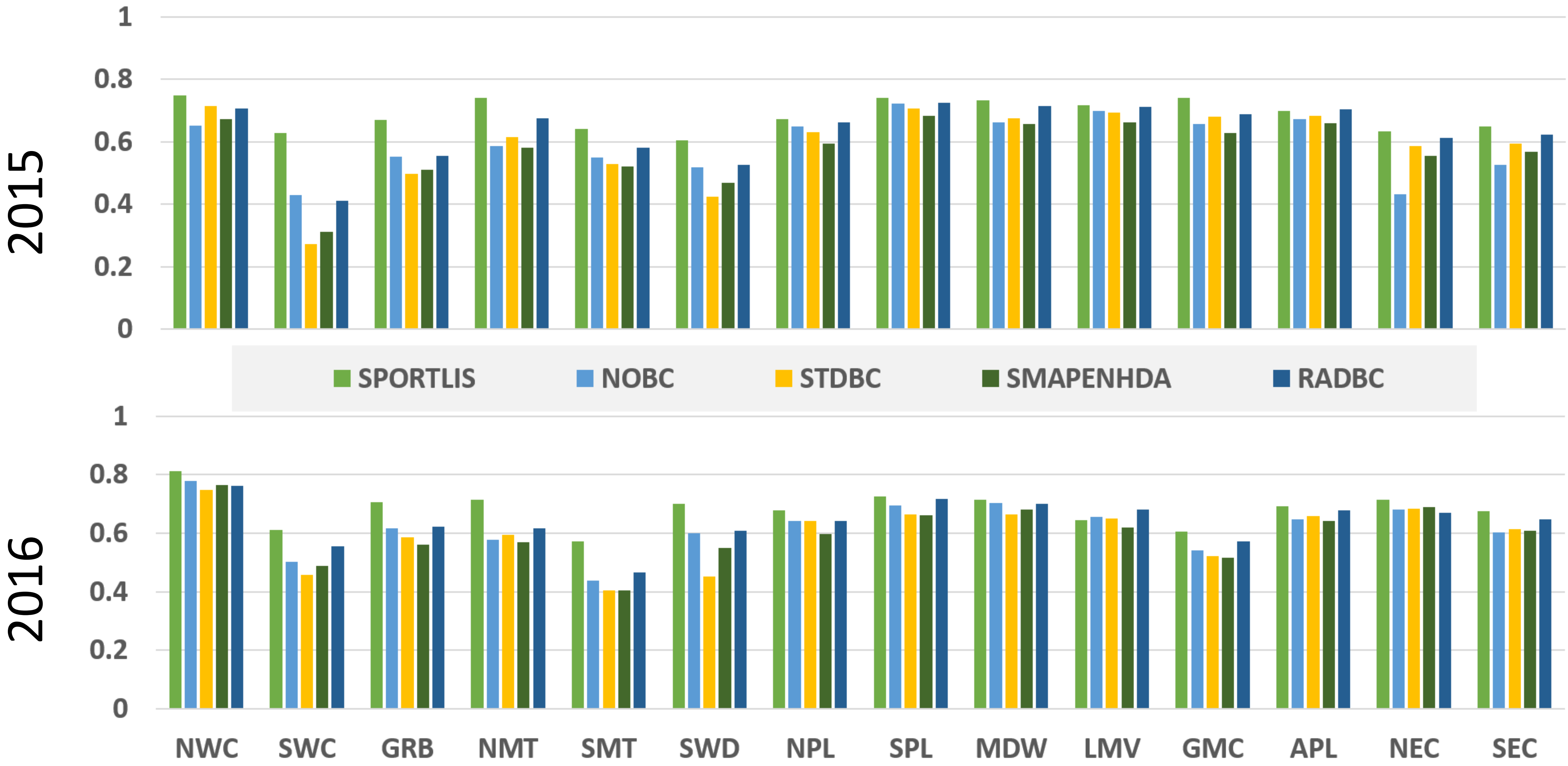
NCEP/EMC 14 Verification Regions over CONUS



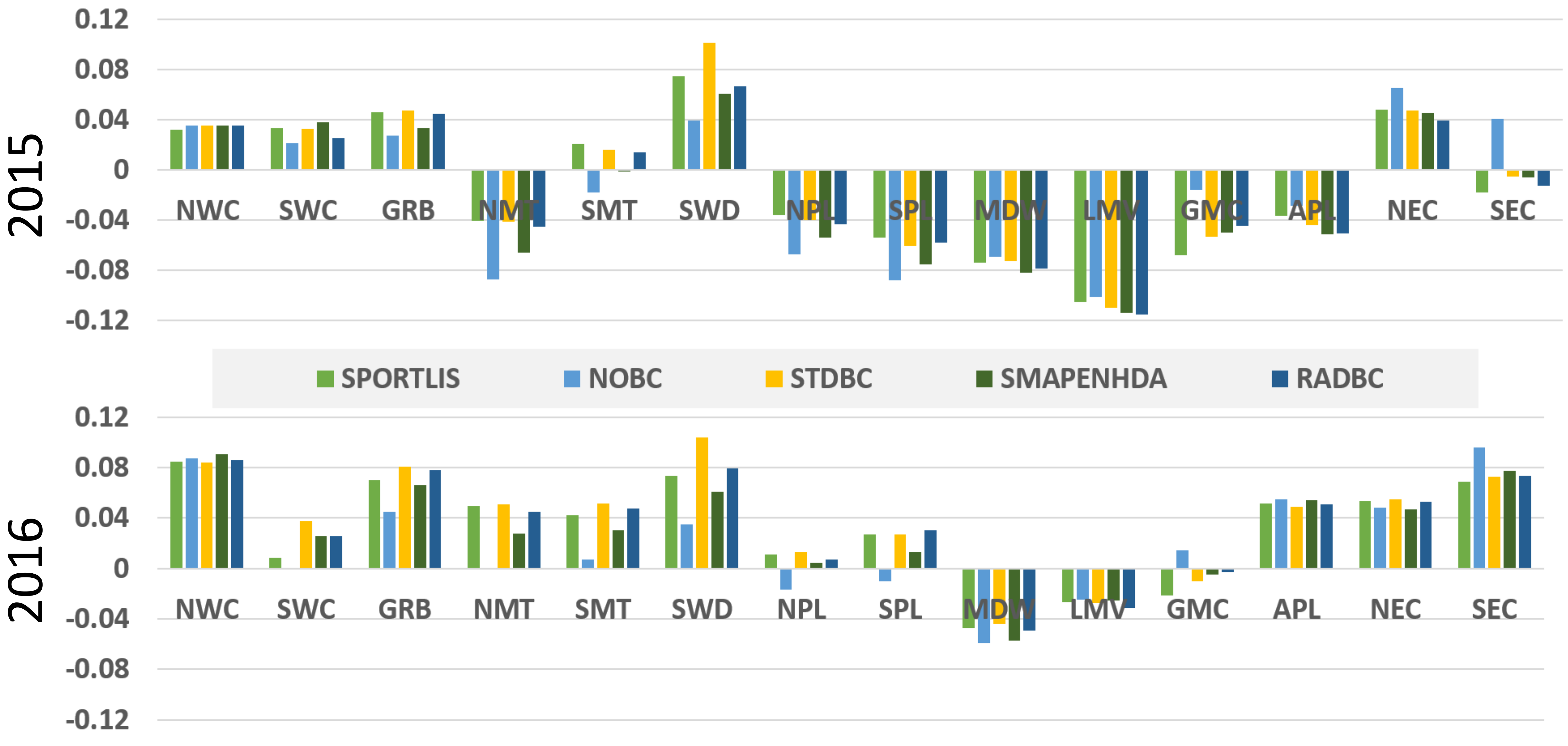
Summary of Experiments

- April 2015-October 2016 (two warm seasons)
  - Initialized from existing SPoRT LIS run (many years spinup)
  - One-month ensemble perturbations to start data assimilation ensembles
- Validation April-October 2015/2016 for SCAN/USCRN sites
- Compare model run assimilating SMAP L2 Enhanced Retrievals to control run (No DA)
- Also intercompare bias correction methods
- Experiments
  - SPoRT-LIS (control)
  - DA with No Bias Correction
  - Soil-type Bias Correction
  - Standard (point by point CDF matching)
  - Radius-limited (300 km) soil type correction
- Validation is vs. *in situ* stations, which have representativeness error and possible bias due to depth of measurement

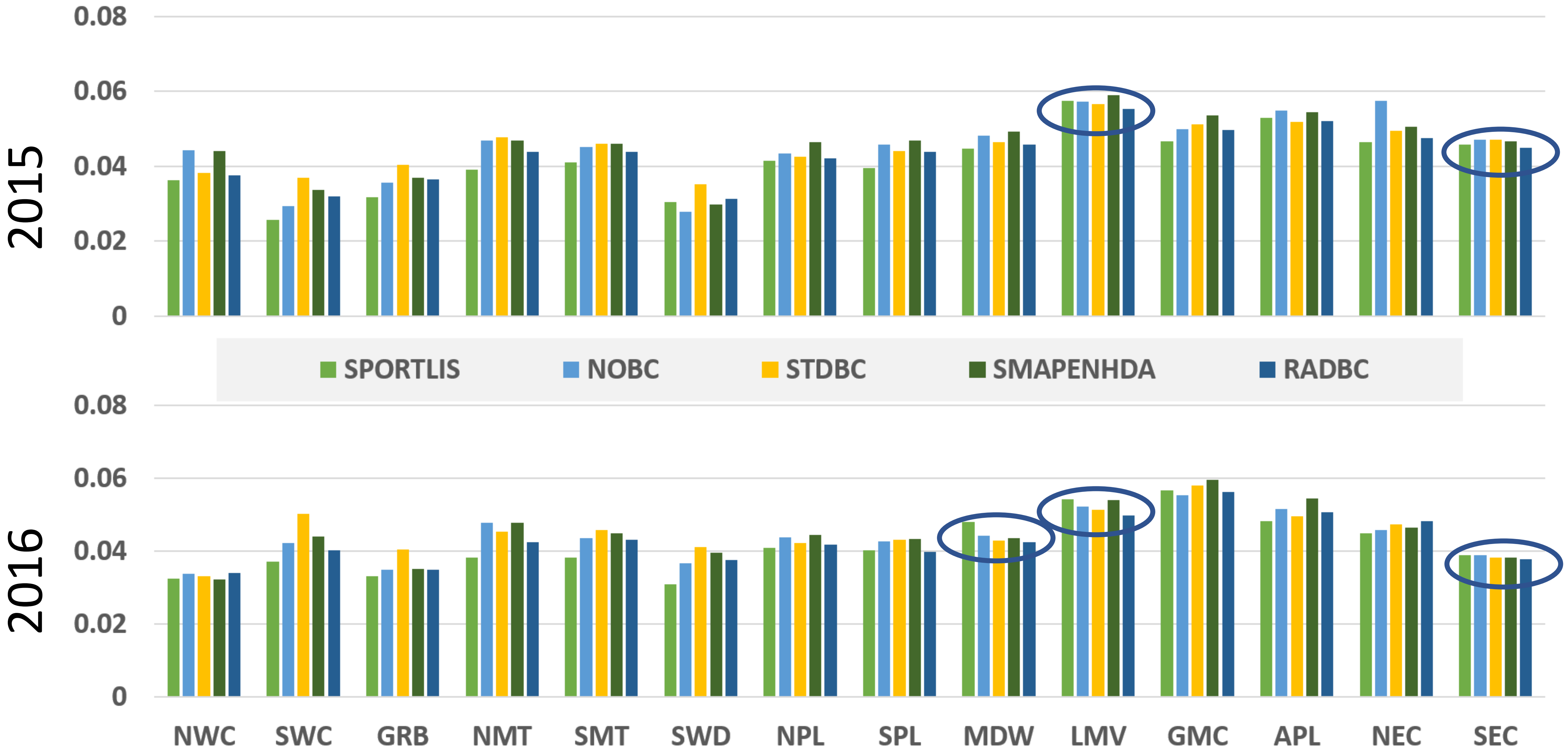
Surface Layer Anomaly Correlation by Region



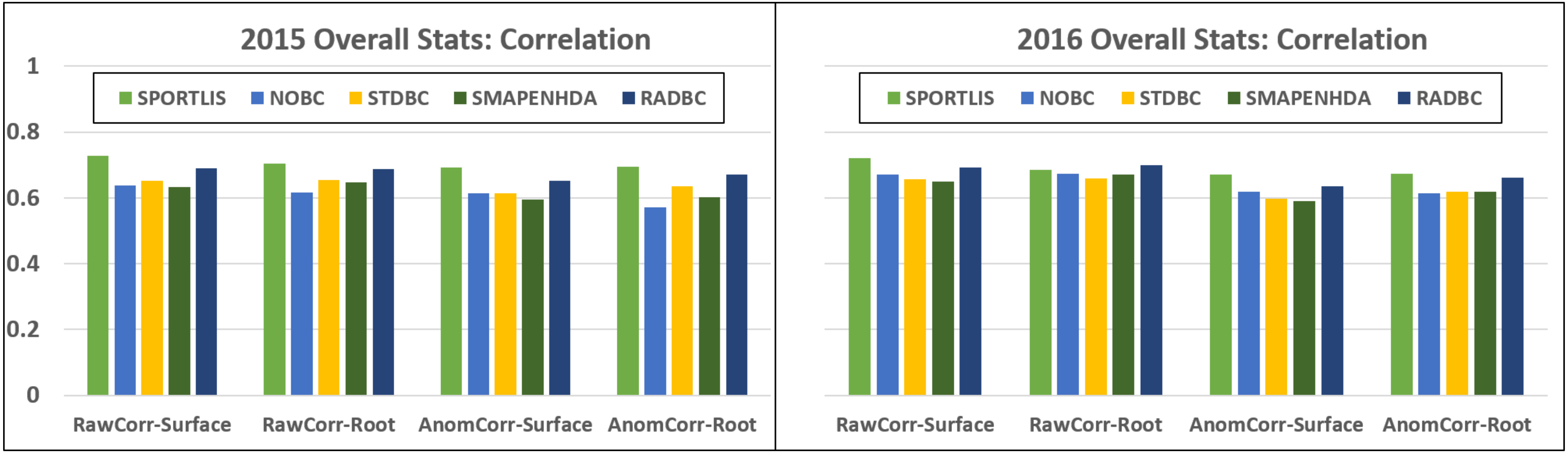
Surface Layer Bias by Region



Surface Layer ubRMSE by Region

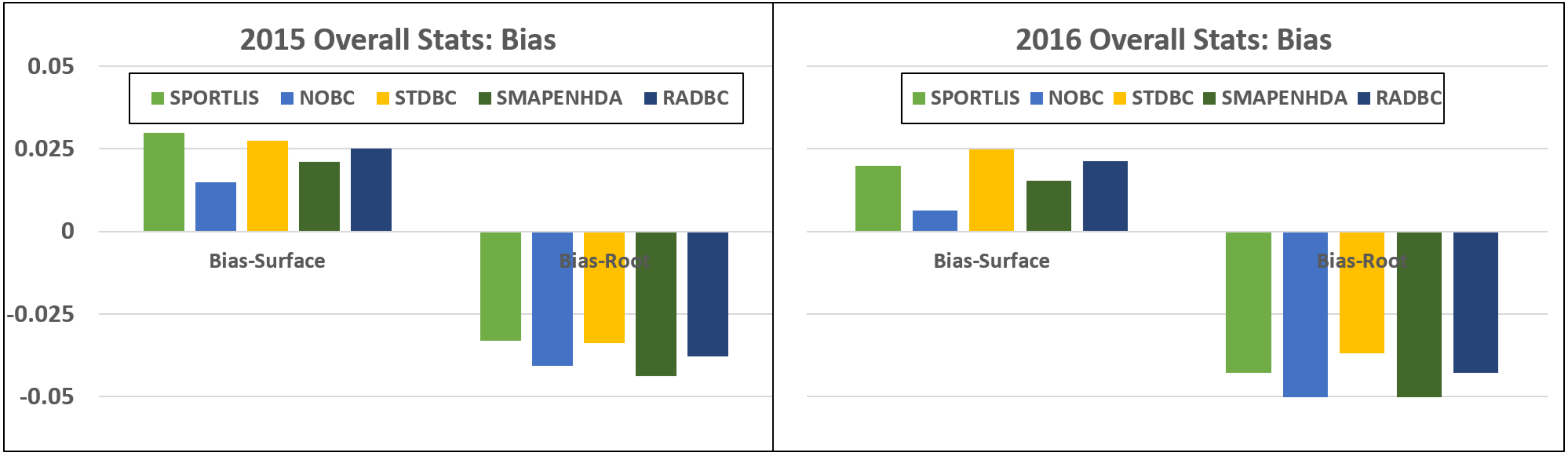


Overall Summary Error Statistics: Correlation



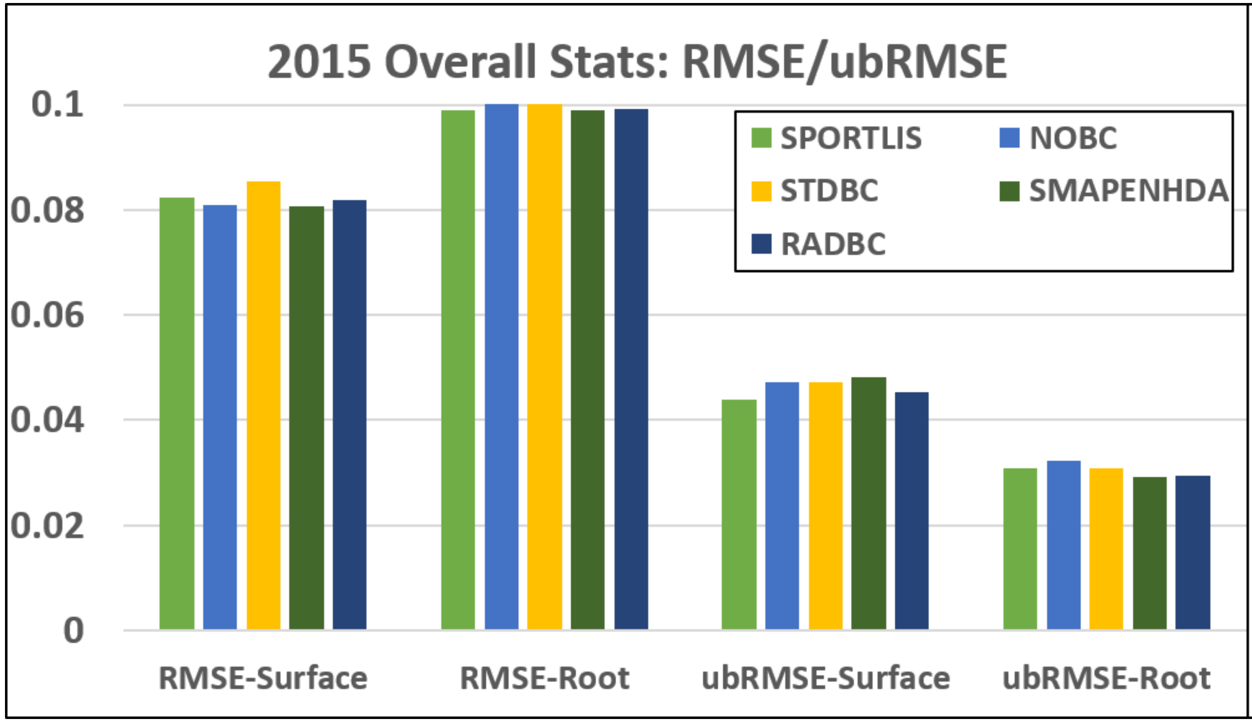
- Generally negative impact from DA
- Need to adjust perturbations to reduce gain (weighting of observations)?
- Radius-limited soil type bias correction (RADBC) performs best among DA methods.

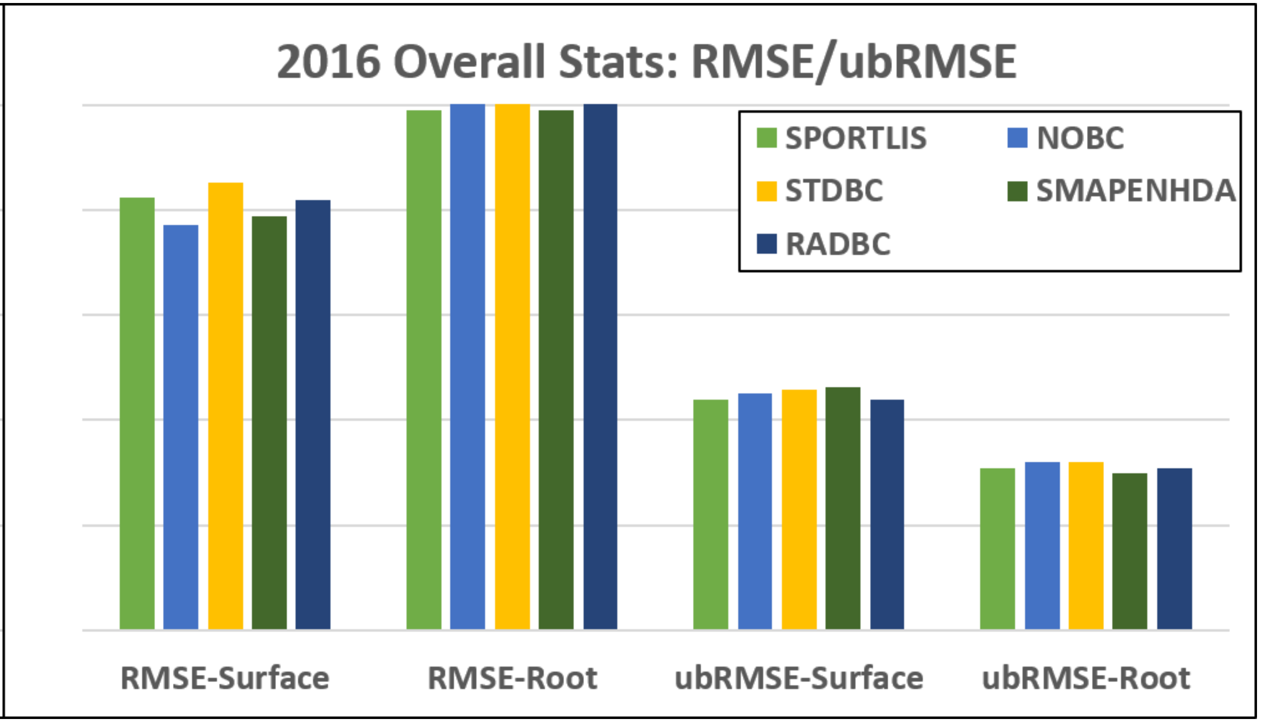
Overall Summary Error Statistics: Bias



- Correction is to the model climatology rather than the *in situ* observations, explaining why the “No BC” run can have lower bias.
- Further experiments show reduced bias when the top soil layer is split in two (0-2.5, 2.5-10 cm).

Overall Summary Error Statistics: RMSE/ubRMSE

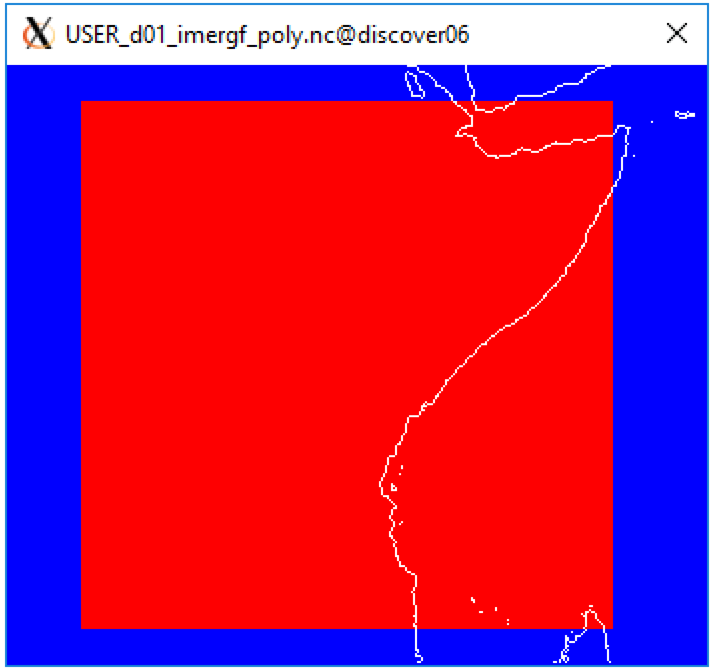




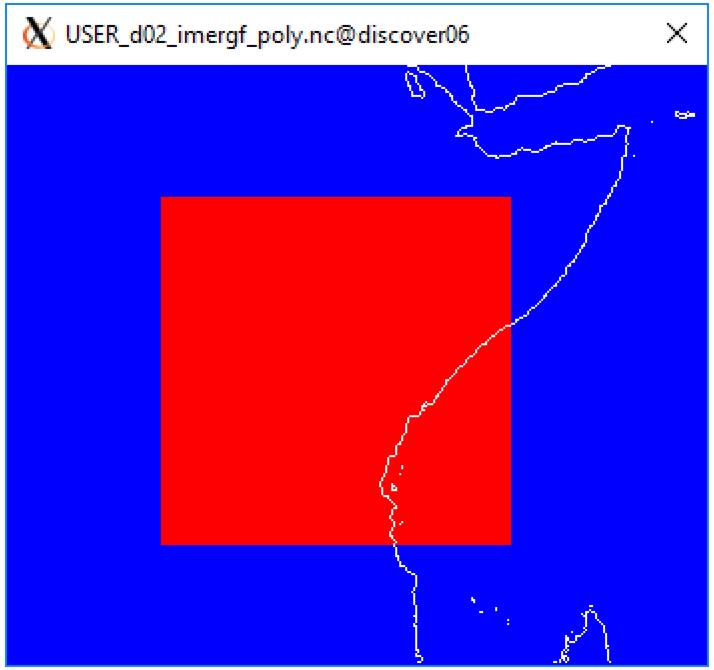
- Generally small changes from DA.
- Radius-limited soil-type correction (RADBC) best DA run for ubRMSE of surface layer.

East Africa Verification Regions

Domain 1 (9 km)



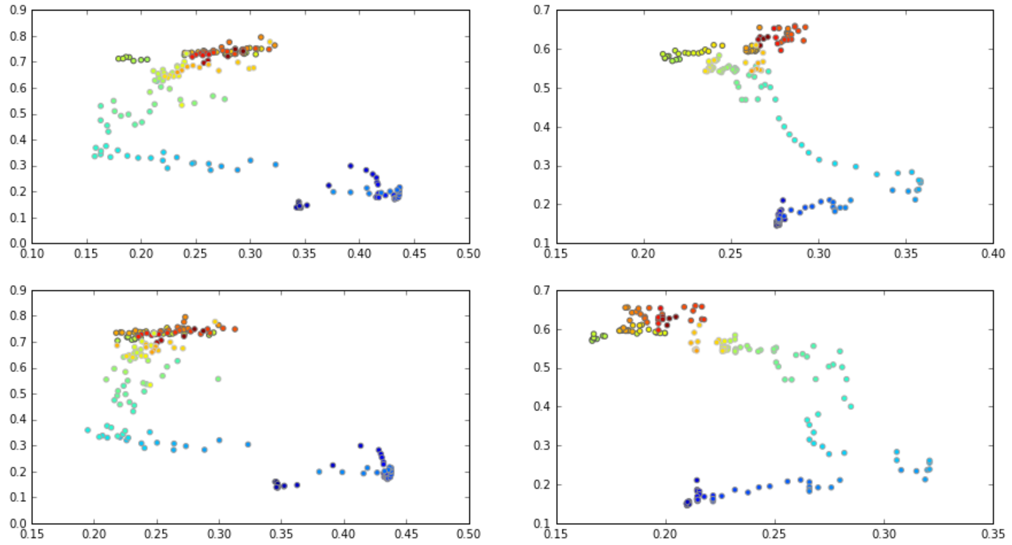
Nested domain 2 (3 km)



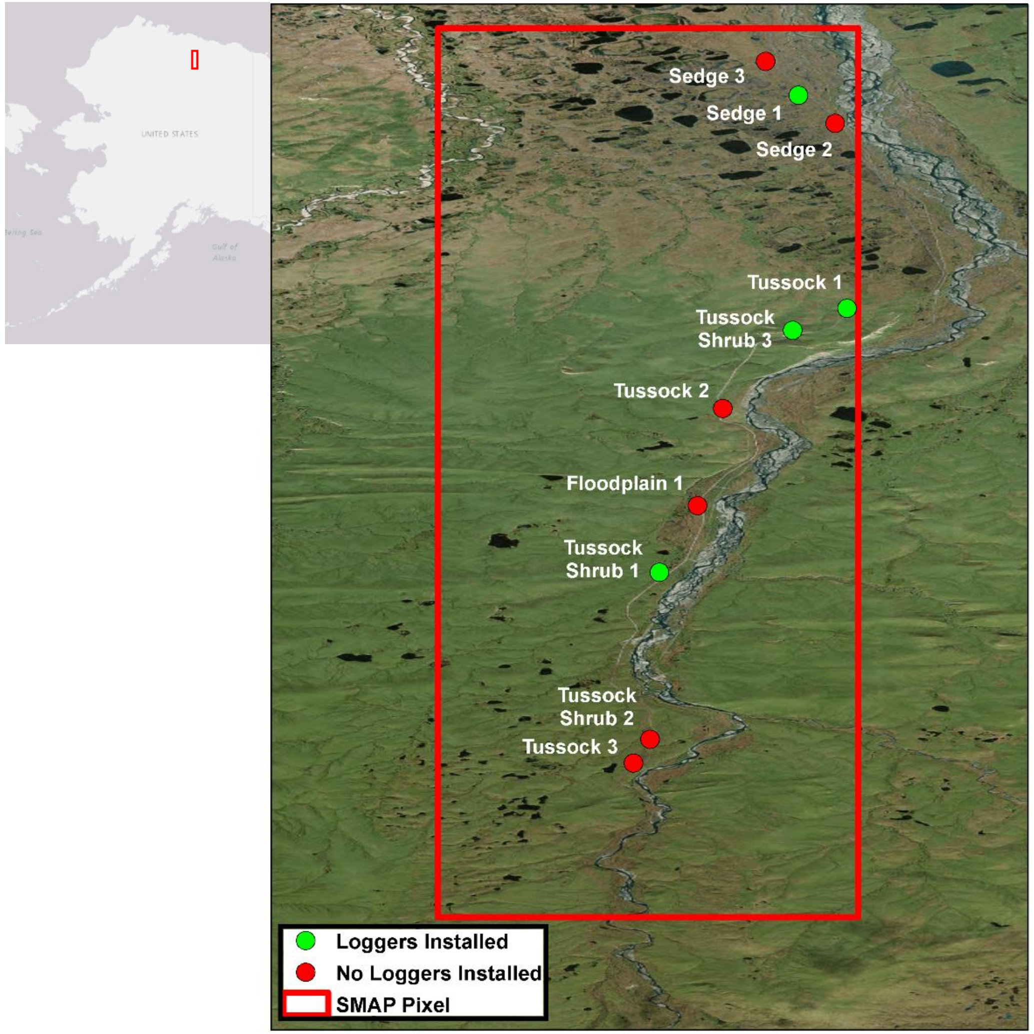
And masked by country

Alaska soil moisture modeling

- Collaboration with Michigan Tech (Laura Bourgeau-Chavez)
- Other potential partners interested in fire risk (BLM, U of Alaska, NPS)
- Modeled SM shows correlation with in situ measurements
- Organic soil type characteristic of upper layers in northern latitudes not well represented in soil-type database used in model.
- In situ measurements show up to 80% VWC while model stops at ~50%



Site Map


Sedge 3
Sedge 1
Sedge 2
Tussock 1
Tussock
Shrub 3
Tussock 2
Floodplain 1
Tussock
Shrub 1
Tussock
Shrub 2
Tussock 3
Loggers Installed
No Loggers Installed
SMAP Pixel

In situ observations vs LIS soil moisture

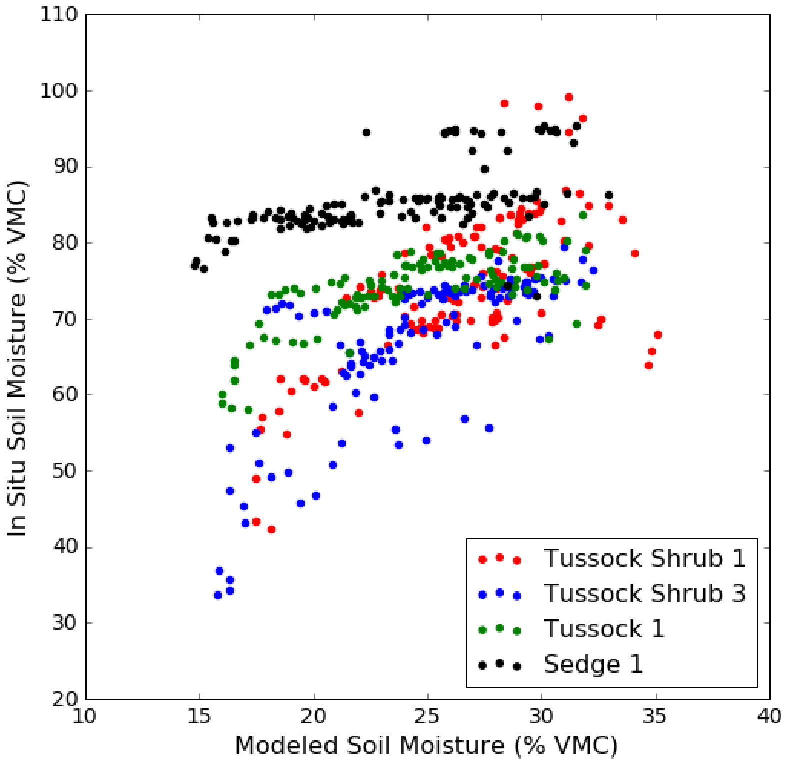
Control model

Tussock Shrub 1: r = 0.668

Tussock Shrub 3: r = 0.747

Tussock 1: r = 0.709

Sedge 1: r = 0.584



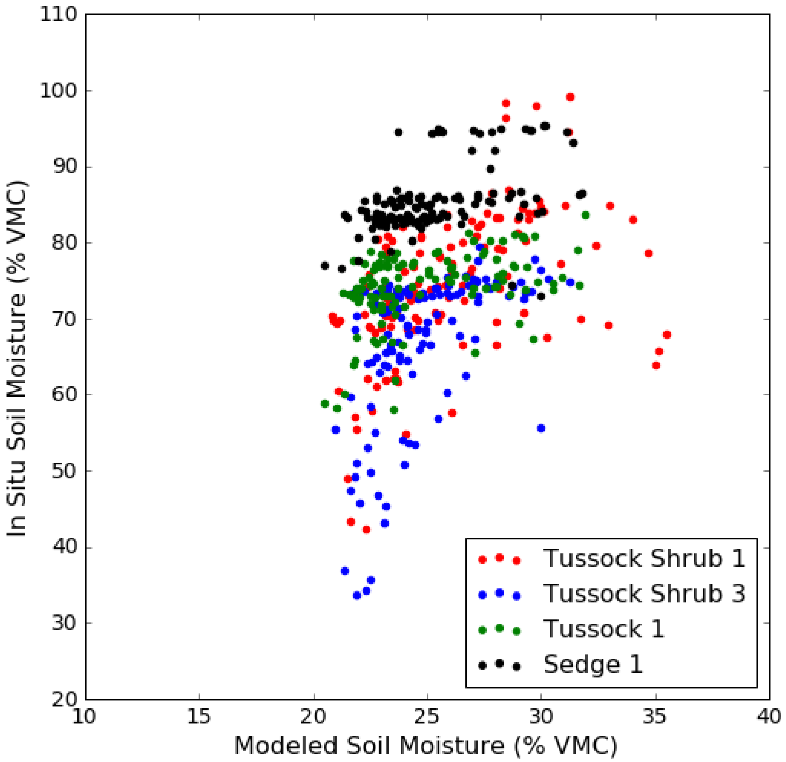
With SMAP data assimilated

Tussock Shrub 1: r = 0.474

Tussock Shrub 3: r = 0.514

Tussock 1: r = 0.410

Sedge 1: r = 0.462



Other details

- Soil moisture loggers were deployed by MTRI in Alaska in July of 2017
  - Measurements taken every hour
  - Powered by solar panels
  - Loggers taking measurements at depths of 6 cm, 10 cm, and 18 cm
  - Raw logger data was calibrated based on the soil profile identified during deployment
  - Daily logger values were calculated by averaging together any data within 3 hours of 6am (the SMAP descending flyover time)
- Data comparisons only use data from 10 cm probe between July 1 and October 31 in years 2017 and 2018
- MTRI work funded by NASA SMAP grant #NNX16AN09G

Acknowledgments

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

Questions and Comments?

clay.blankenship@nasa.gov

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

Facebook: NASA.SPoRT

Twitter: @NASA_SPoRT