Soil Moisture Operational Product System (SMOPS)

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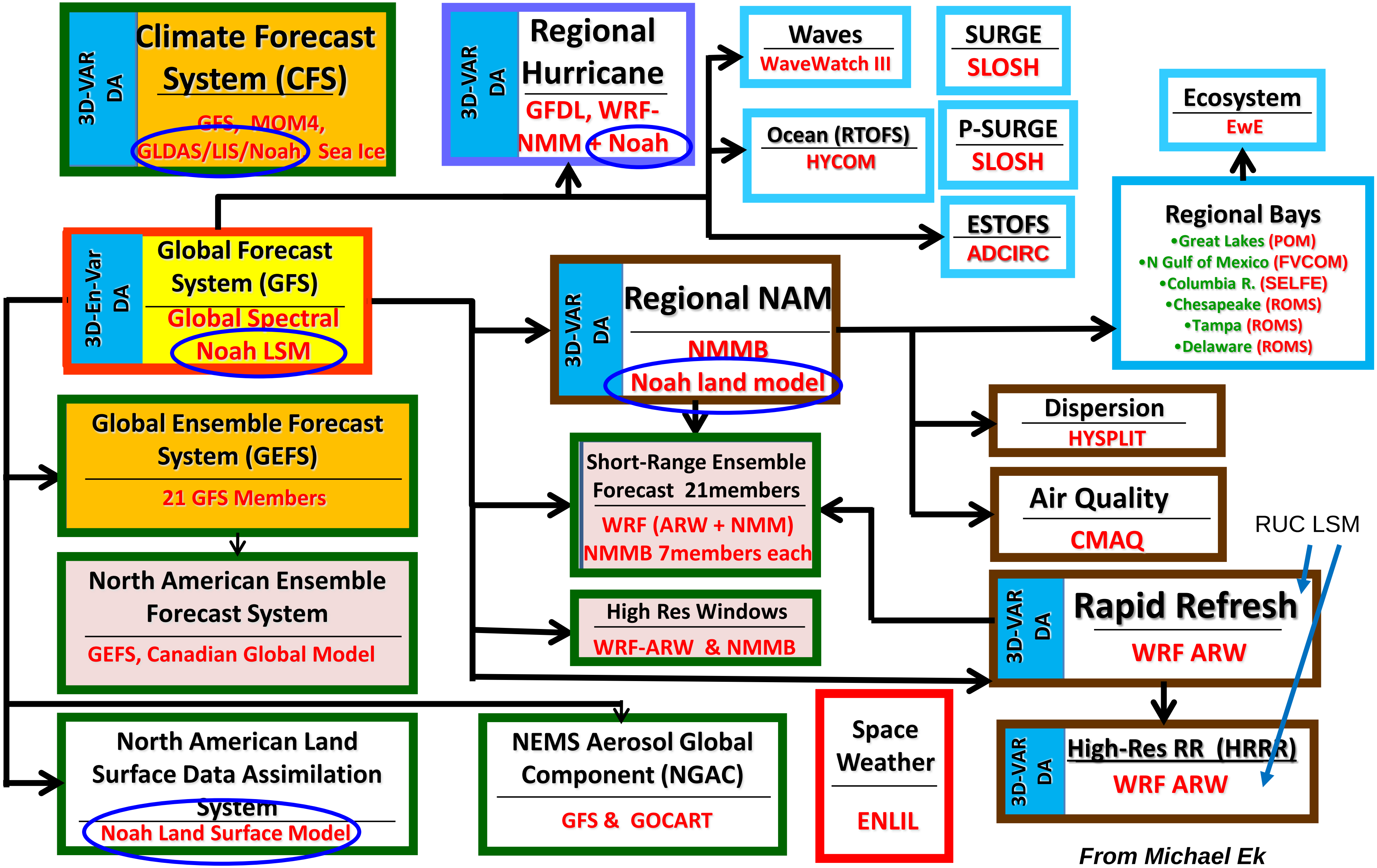
Outline

- Why SMOPS
- System Structure
- Product Validation
- Product Applications

Land Prediction in Weather & Climate Models: NOAA's Operational Numerical Guidance Suite

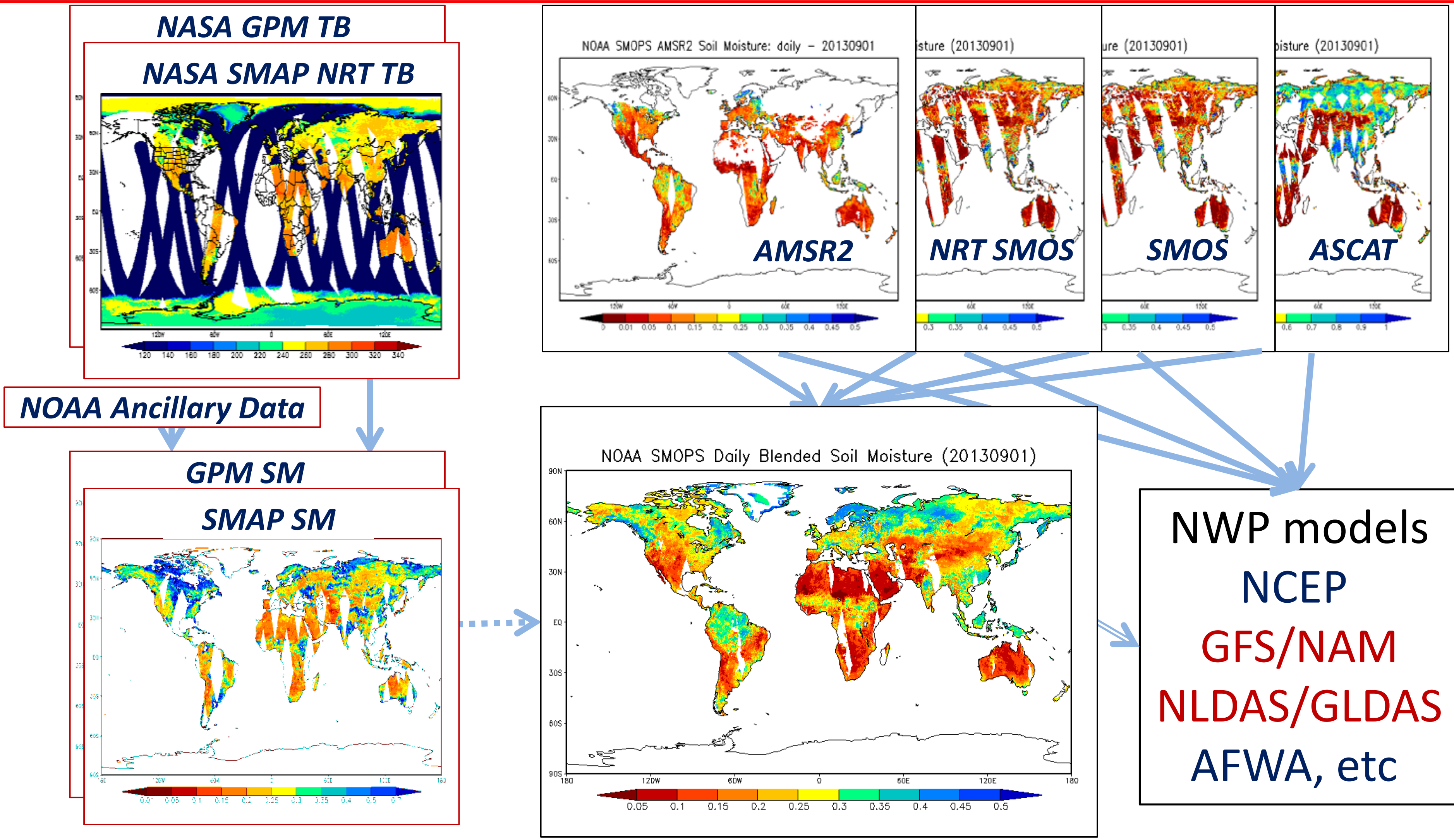


From Michael Ek

Soil Moisture Operational Product System

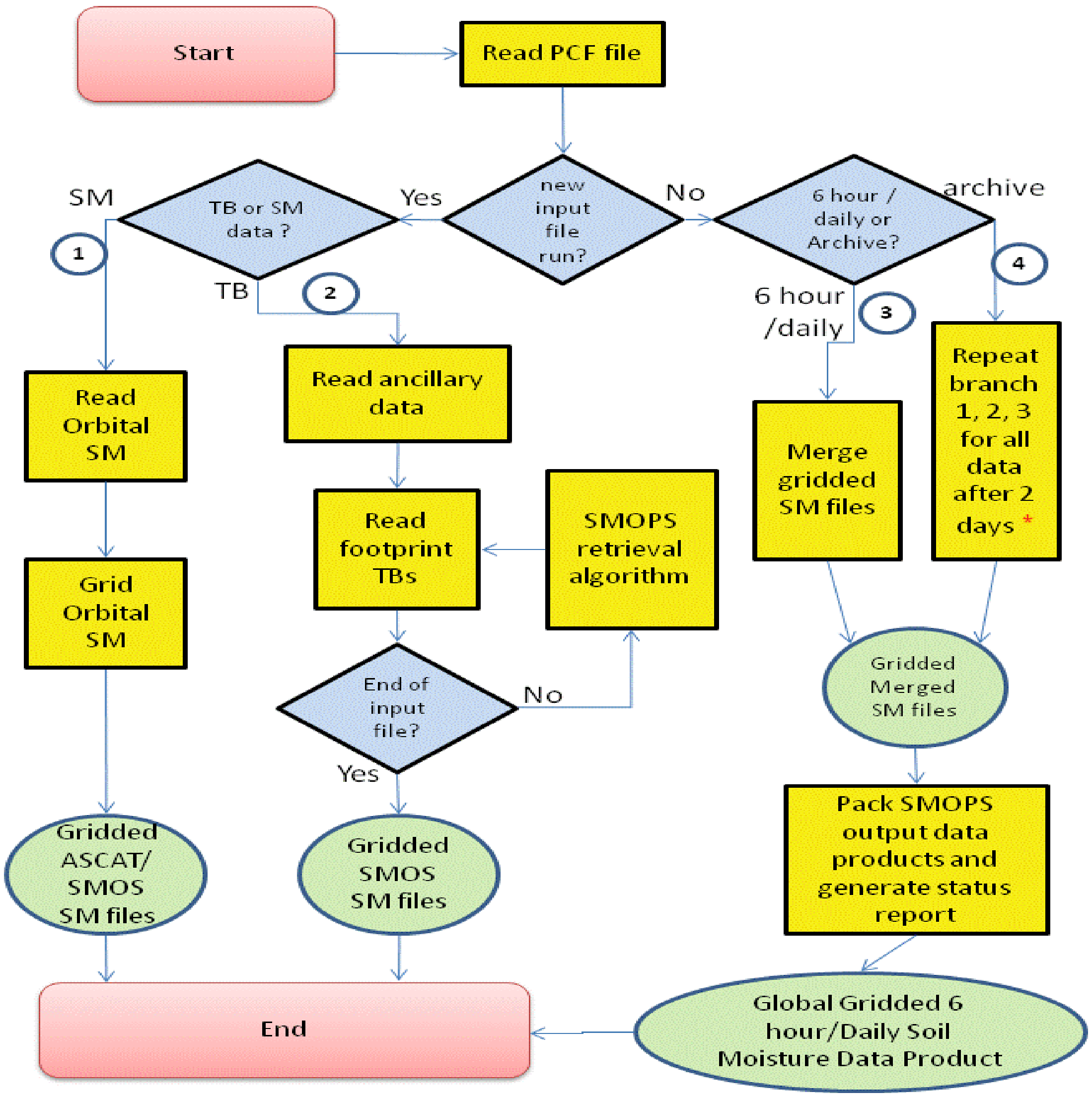
- **Requirements**
  - SPSRB requirement #0707-17, “Soil Moisture Products System”: NCEP GFS requires global soil moisture data products from “NASA's TMI on TRMM and AMSR-E on Aqua, NRL's WindSat, ESA's SMOS, and future soil moisture related missions by NASA and NPOESS ” submitted by Ken Mitchell (Michael Ek’s predecessor) , NCEP/EMC
    - TMI replaced by GMI, AMSR-E replaced by AMSR2
  - JPSS Supplement requirement L1RDS-2260, “The JPSS shall support modifications to ESPC blended products.”
  - JPSS Environmental Satellite Processing Center Requirements Document (JERD) Vol 2 identifies requirement to add GCOM-W1 AMSR2 data to blended soil moisture product
  - Others: USDA FAS needs global soil moisture for world crop forecasts and soil moisture is one of the top three critical EDRs of NPOESS; SMOPS Letter of Support (LoS) from the interagency LIS collaboration, including EMC, 557th www, NASA, UK Met Office, etc.
- **User community**
  - NWS (NCEP, OCWWS, CR), the 557th www, JCSDA, USDA, Universities
- **Benefit to user**
  - More accurate and complete soil moisture data/information as input to prediction models or decision making processes
    - Better land surface fluxes result in better weather, climate and hydrologic forecasts
    - Societal benefits include agricultural crop forecasts, flash flood forecasts, and military mobility
- **NOAA Mission Goal supported:**
  - Weather & Water, Climate, Commerce & Transportation
- **Mission priority:**
  - Critical

Soil Moisture Operational Product System
SMOPS 2.0/3.0



NESDIS SMOPS 3.0 upgraded over the current SMOPS 3.0 Ingest NASA SMAP NRT and GPM TB data to retrieve global soil moisture with NOAA ancillary Data

Soil Moisture Operational Product System Data Processing Functions



* All data acquired within the 6 hour or whole day time period arrived in the past 48 hours

1 **SM ingesting**

2 **SM retrieving**

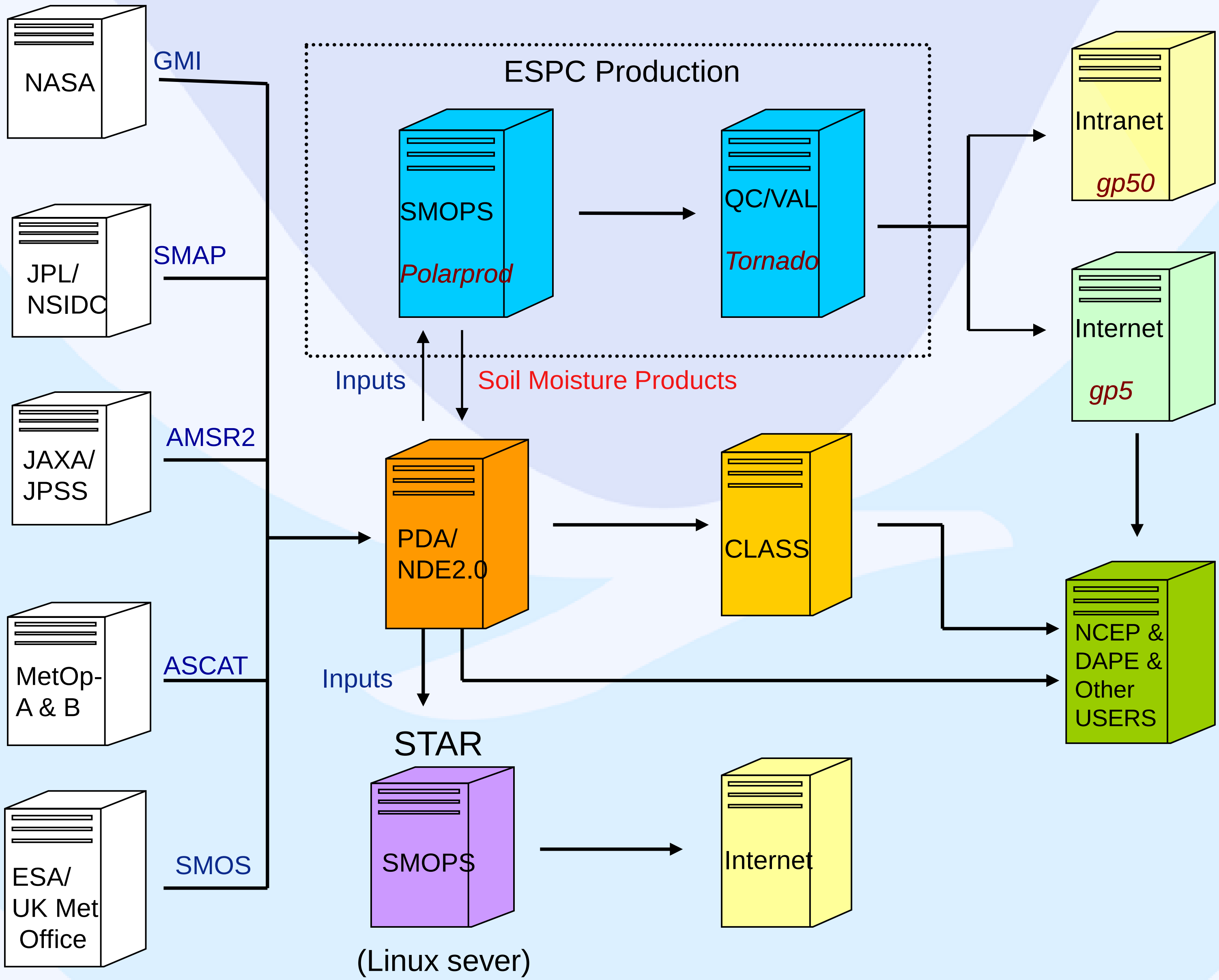
3 **SM merging**

4 **Reprocessing for the archive product**

SMOPS Algorithm

- A single-channel algorithm is used to retrieve soil moisture from x-band brightness temperature observations (Jackson, 1993);
- An regression equation is used to estimate land surface temperature from 37GHz brightness temperature (de Jeu, 2008);
- An empirical equation is used to estimate vegetation optical depth from optical observations of vegetation index (Jackson & Schmugge, 1991);
- A CDF-matching approach is used to merge soil moisture retrievals from difference satellite sensors.

SMOPS Production IT Infrastructure



Input Data: MetOp-A & B ASCAT soil moisture data, and SMOS Level 1B & L2 soil moisture data, AMSR2 L1B & soil moisture, GMI L1C, SMAP SM and VIIRS EVI

SMOPS Output File Data layers

Soil Moisture Product	SMOPS Version 1.3	SMOPS Version 2.0	SMOPS Version 3.0
SMOPS Blended	√ (1)	√ (1)	√ (1)
NOAA AMSR-E	√ (2)	×	×
NOAA NRT SMOS	×	√ (2)	√ (2)
ESA SMOS	√ (3)	√ (3)	√ (3)
EUMETSAT ASCAT-A	√ (4)	√ (4)	√ (4)
EUMETSAT ASCAT-B	√ (5)	√ (5)	√ (5)
NOAA WindSat	√ (6)	×	×
NOAA AMSR2	×	√ (6)	√ (6)
NOAA GMI	×	×	√ (7)
NOAA NRT SMAP	×	×	√ (8)
NASA SMAP	×	×	√ (9)

SMOPS Product Suite

Products	Description	Format	Projection	Spatial Coverage	Spatial Resolution	Main Purpose
SMOPS 6-Hour Product	SMOPS 6-hour Gridded Soil Moisture	GRIB2	Lat/Long	Global	0.25 degree (720x1440)	For operational use
SMOPS Daily Product	SMOPS Daily Gridded Soil Moisture	GRIB2	Lat/Long	Global	0.25 degree (720x1440)	For operational/ research use
SMOPS Archive Product	SMOPS Daily Gridded Soil Moisture	netCDF4	Lat/Long	Global	0.25 degree (720x1440)	For research use

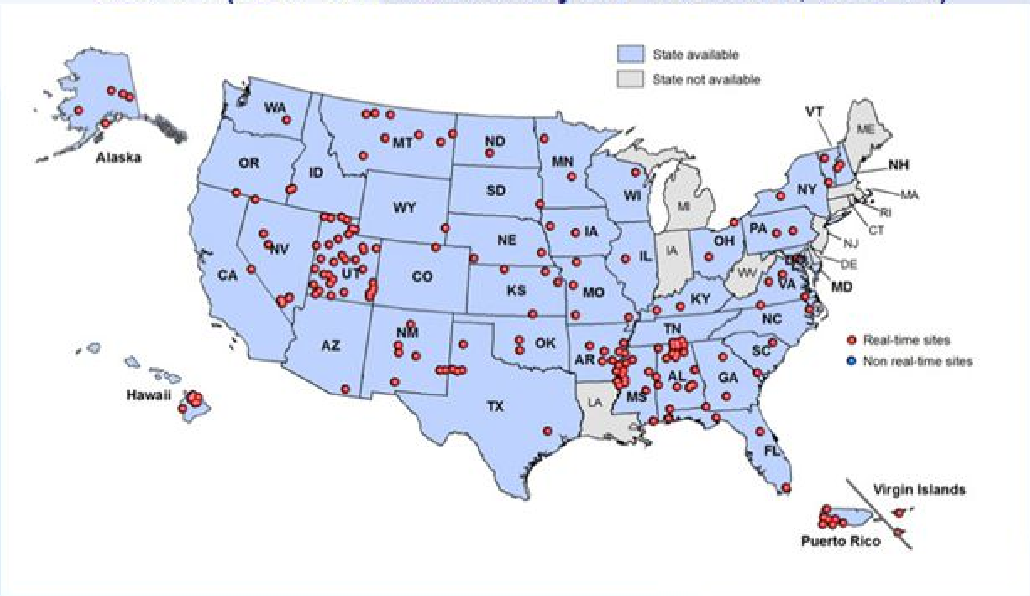
SMOPS Product Validation (1/11)

Comparison with in situ measurements:

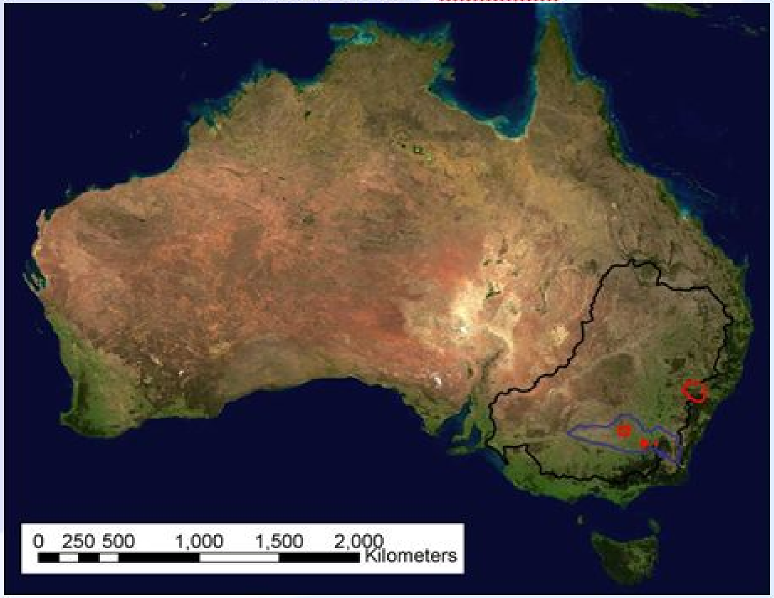
- Field Data Used
  - SCAN (Soil Climate Analysis Network, USDA)
  - USDA-ARS MicroNet
  - Australian OzNet
  - China SMNet
- Data Quality Verified against User Requirements
  - Soil moisture time series for the observation site.
  - Statistical metrics, including mean, standard deviation, RMSE, mean bias, etc.

SMOPS SM Product Validation Data Sets (2/11)

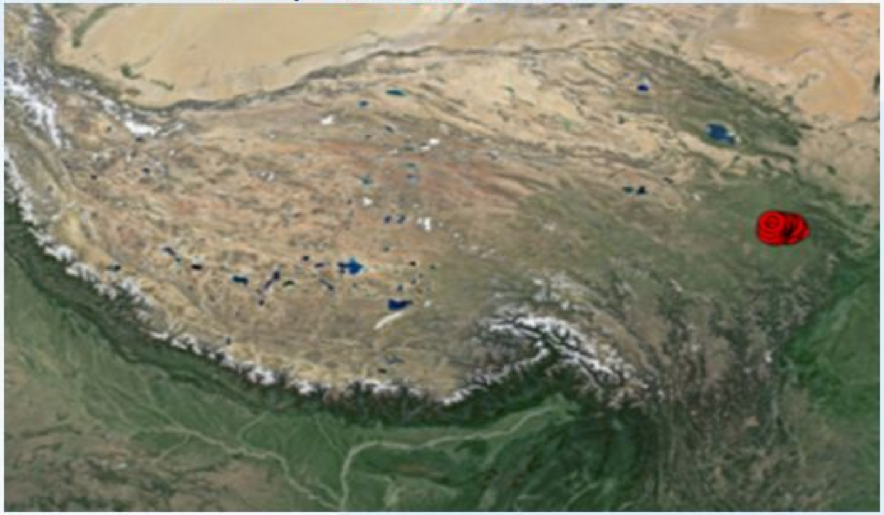
SCAN (Soil Climate Analysis Network, USDA)



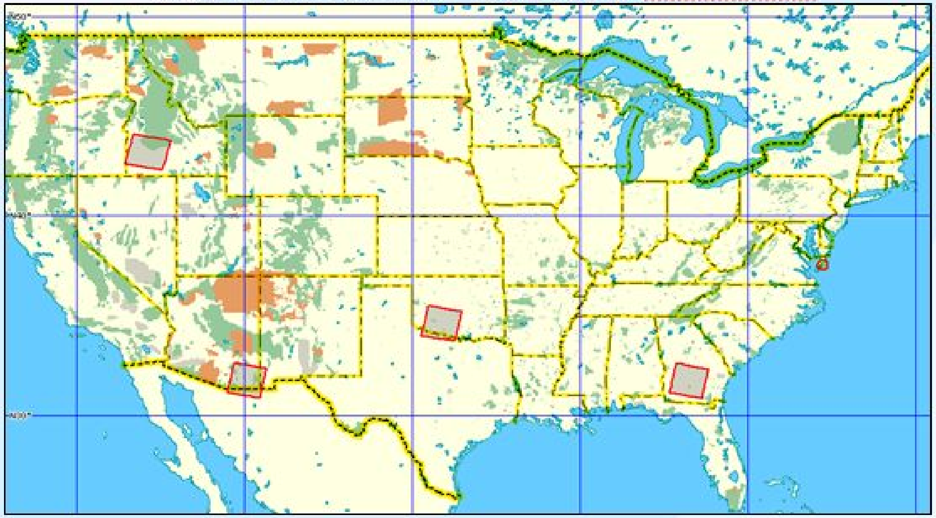
Australian OzNet



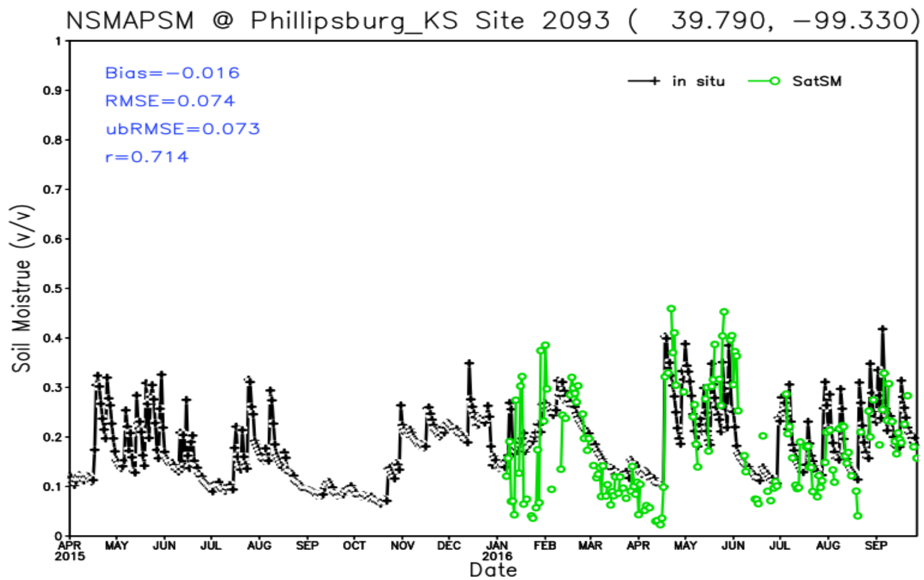
Maqu SMNet of China

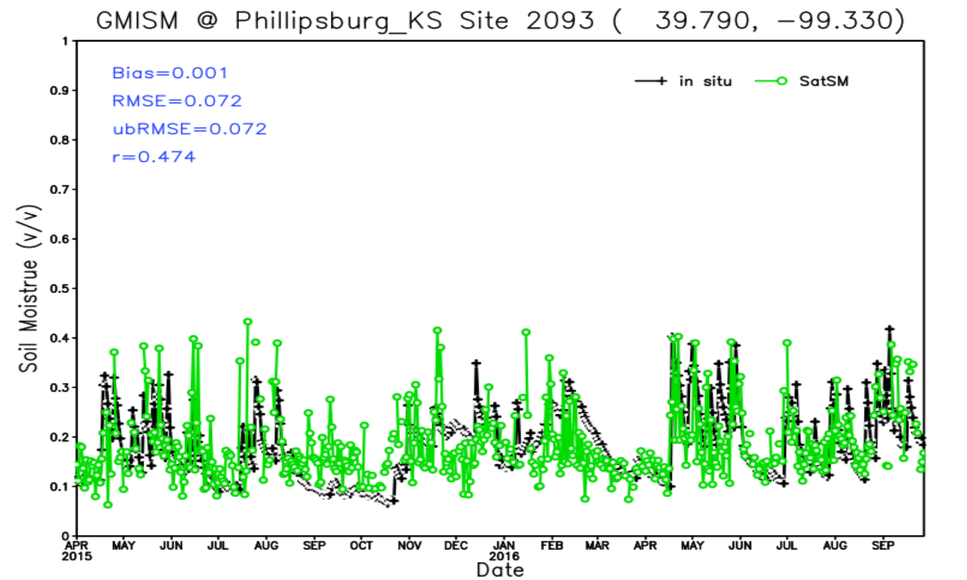


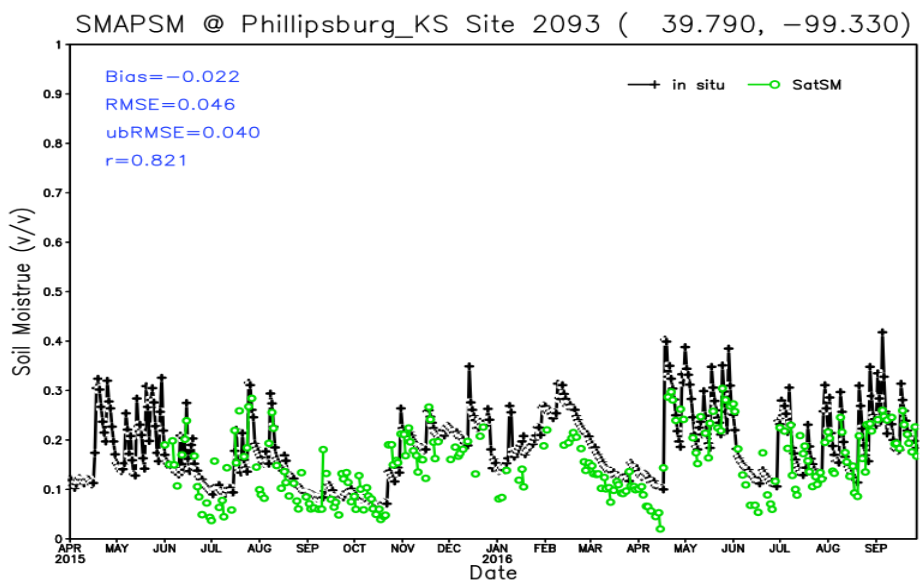
USDA-ARS Soil Moisture MicroNet

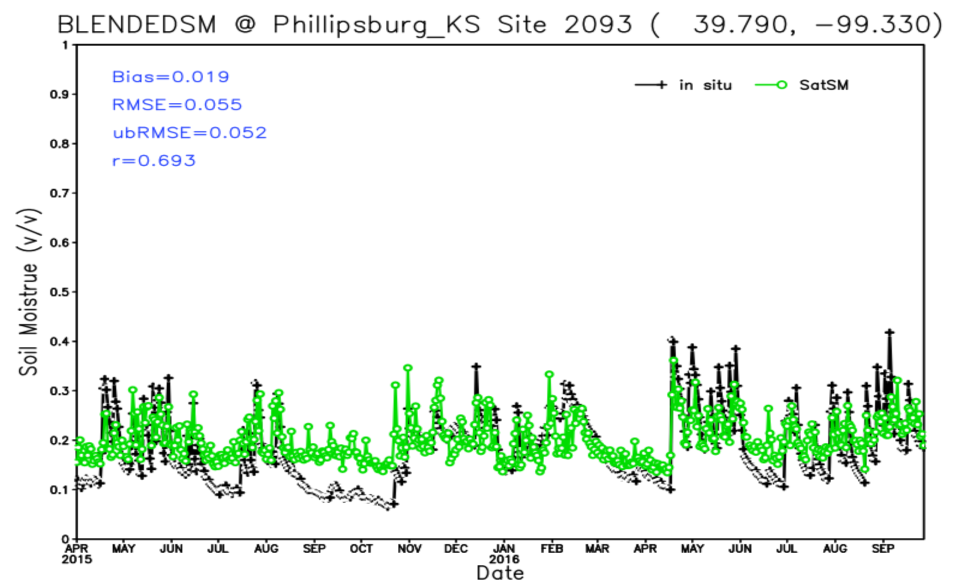


CASE 1: SMOPS SM vs Phillipsburg_KS (3/11)

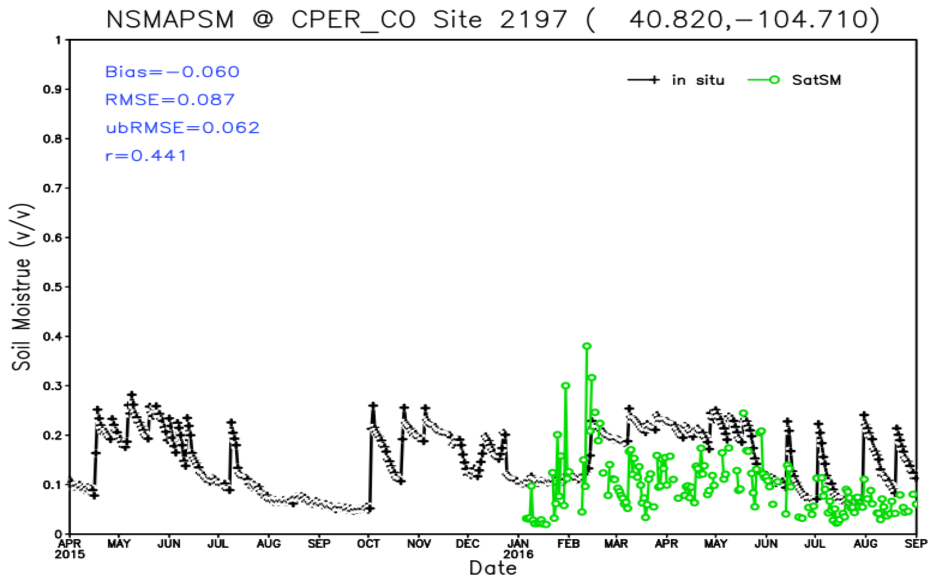


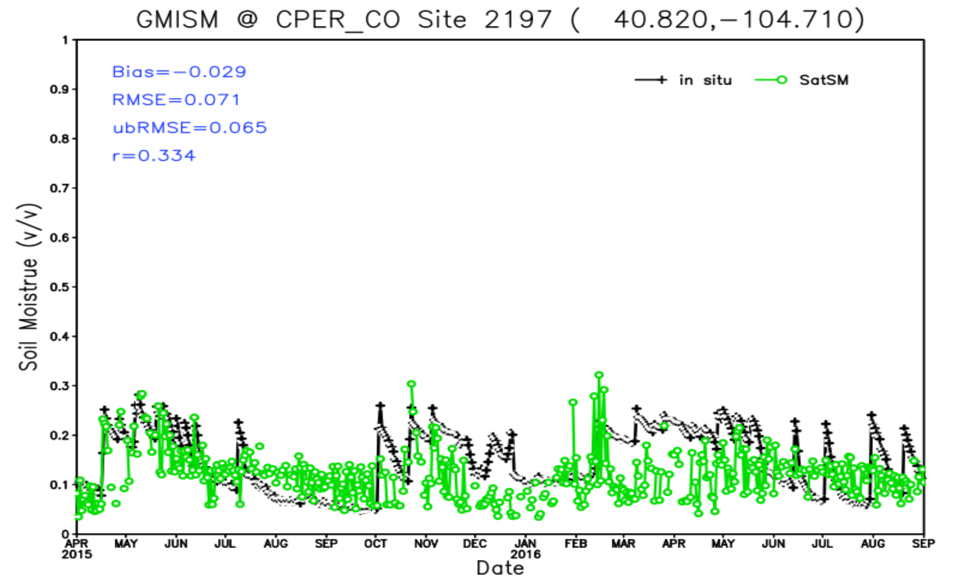


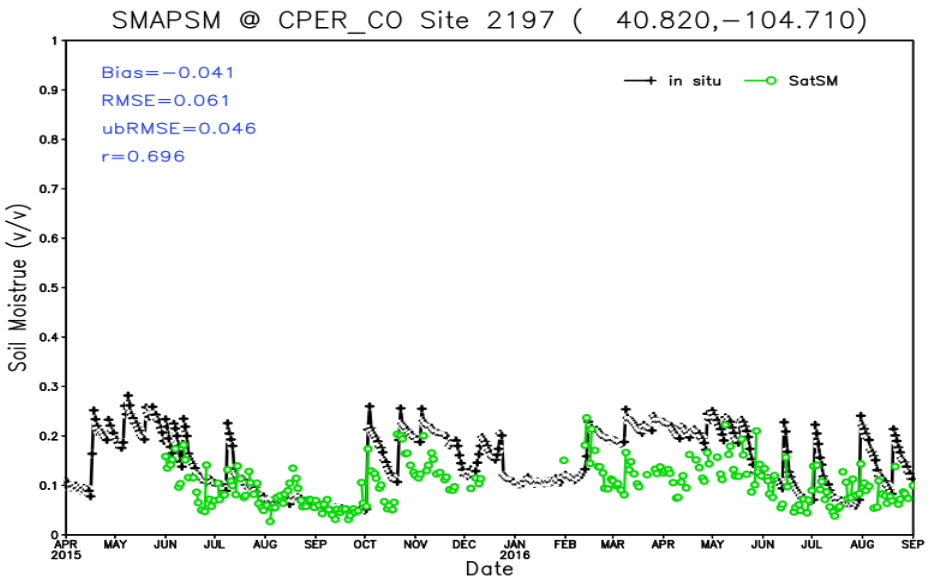


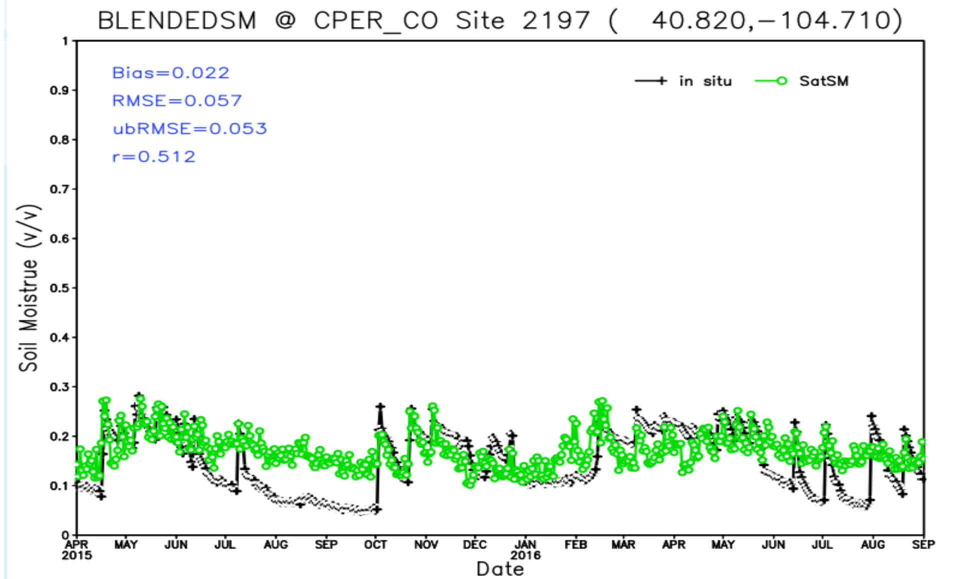


CASE 2: SMOPS SM vs CPER_CO (4/11)

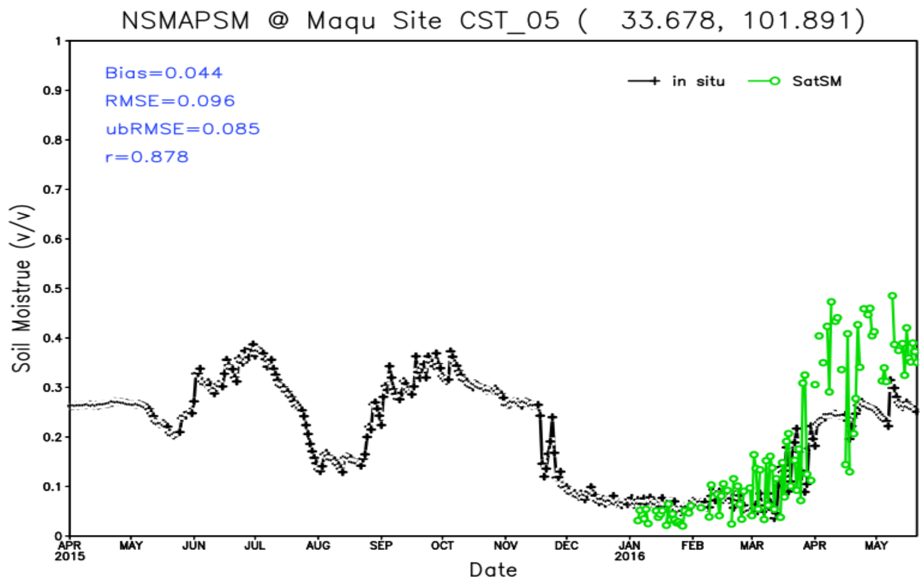


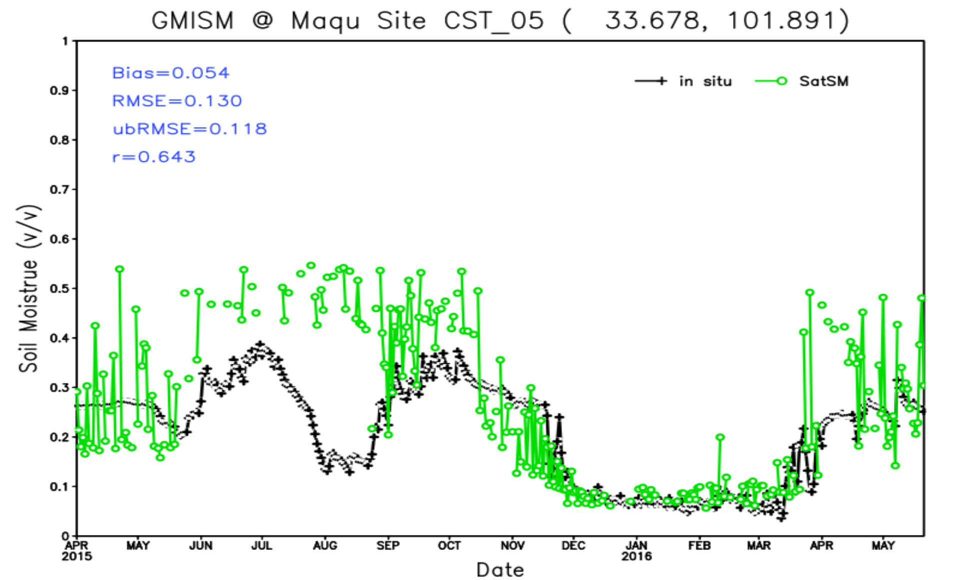


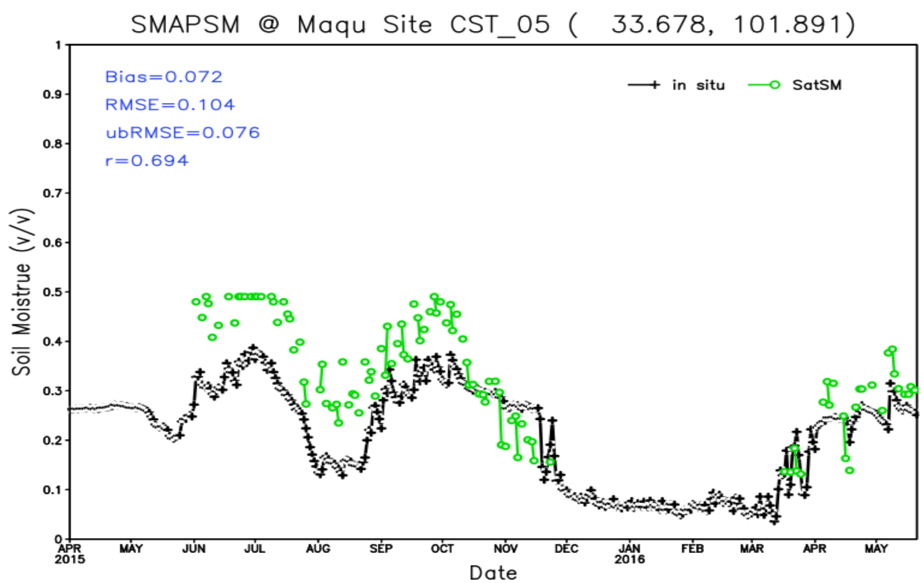


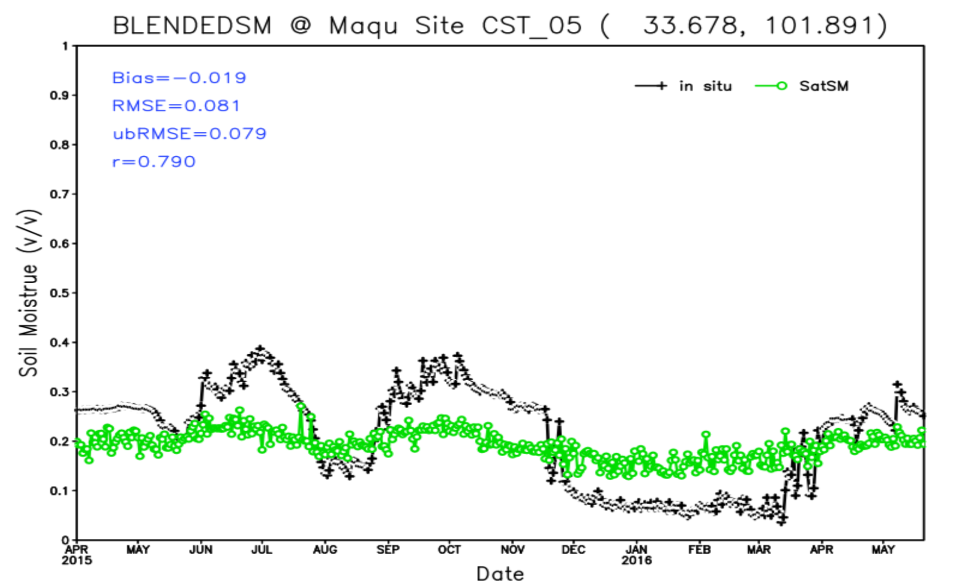


CASE 3: SMOPS SM vs Maqu_CN (5/11)

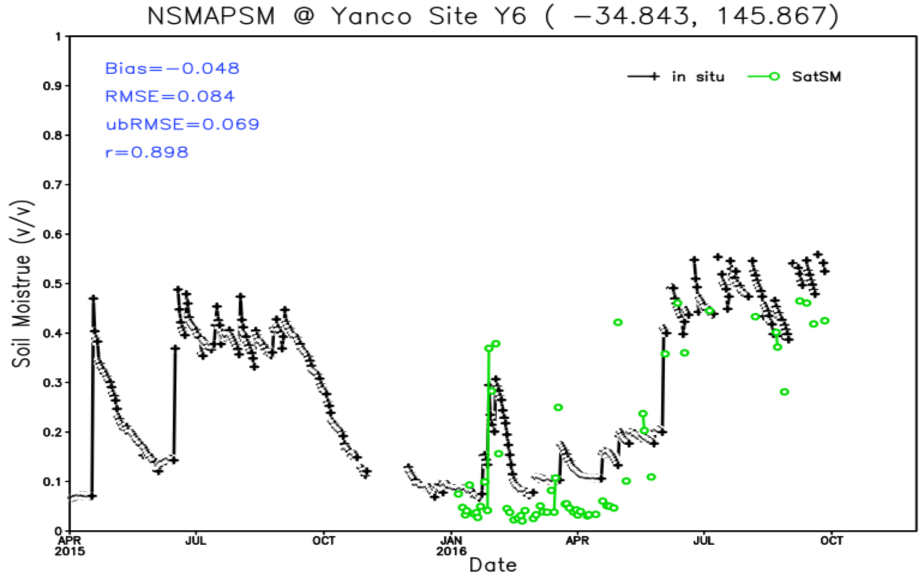


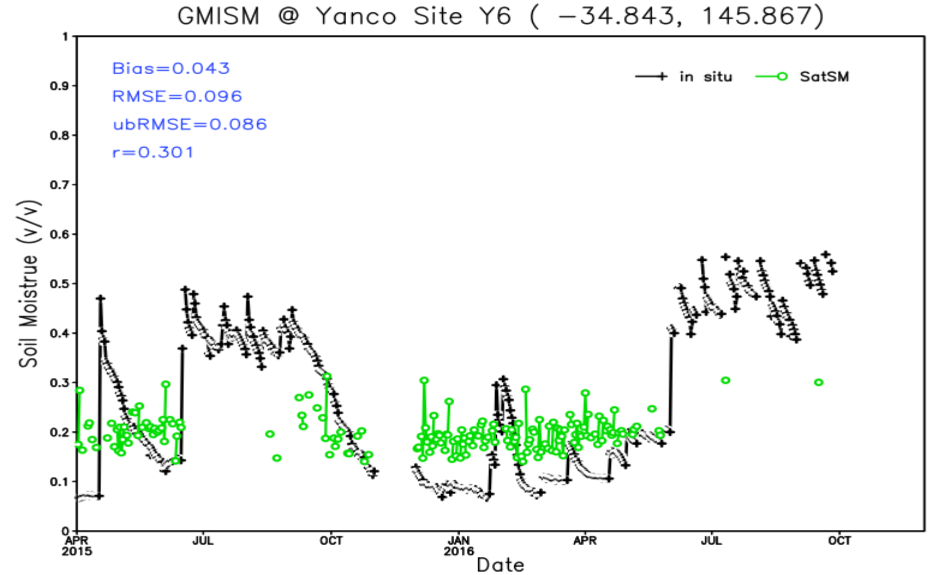


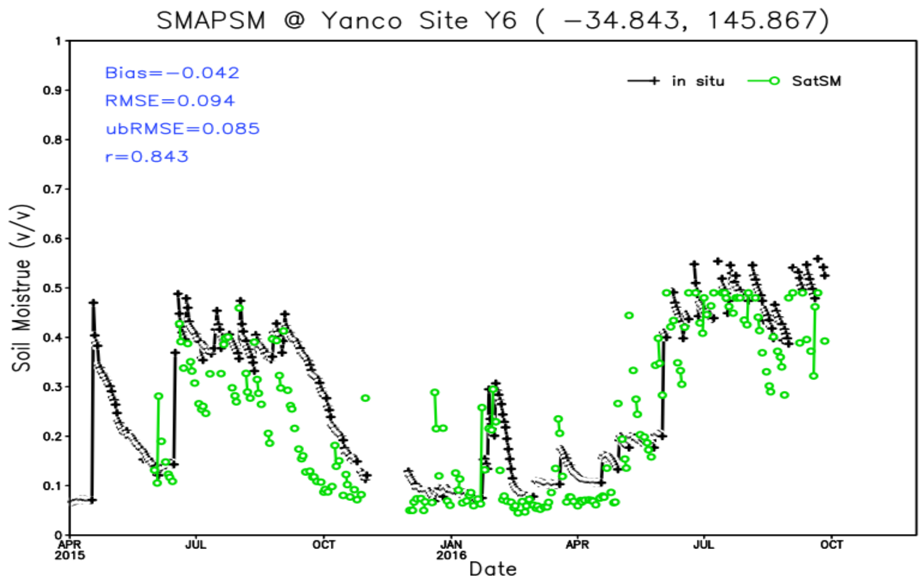


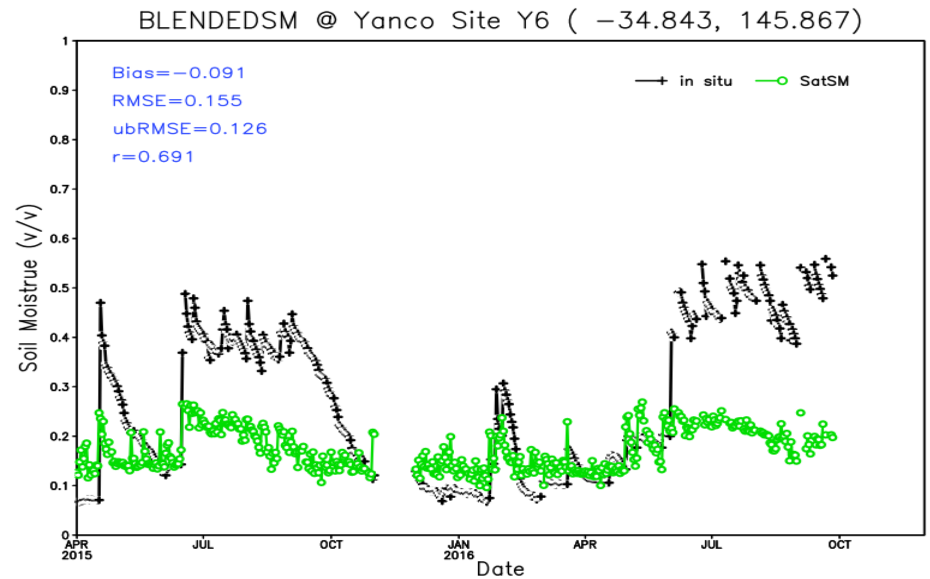


CASE 4: SMOPS SM vs Yanco_OZ (6/11)

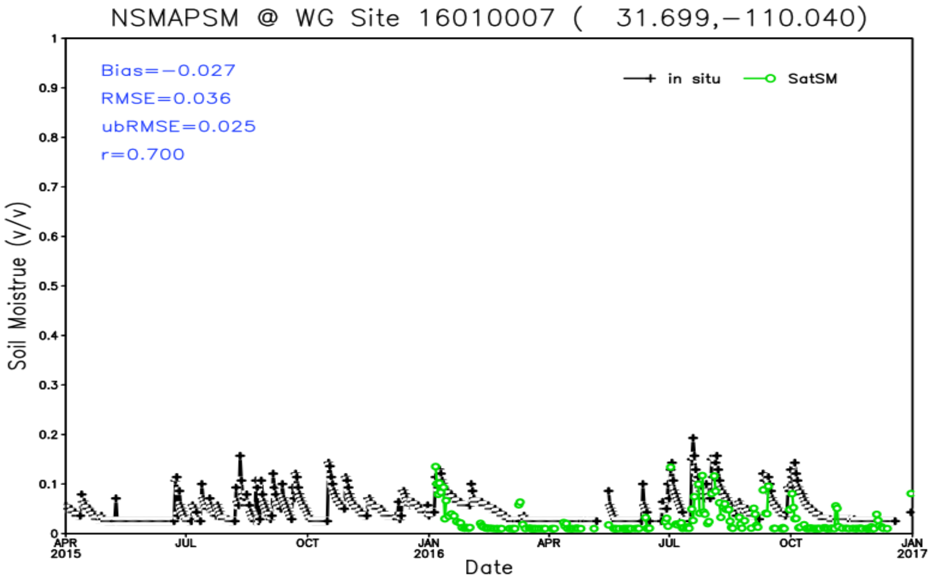


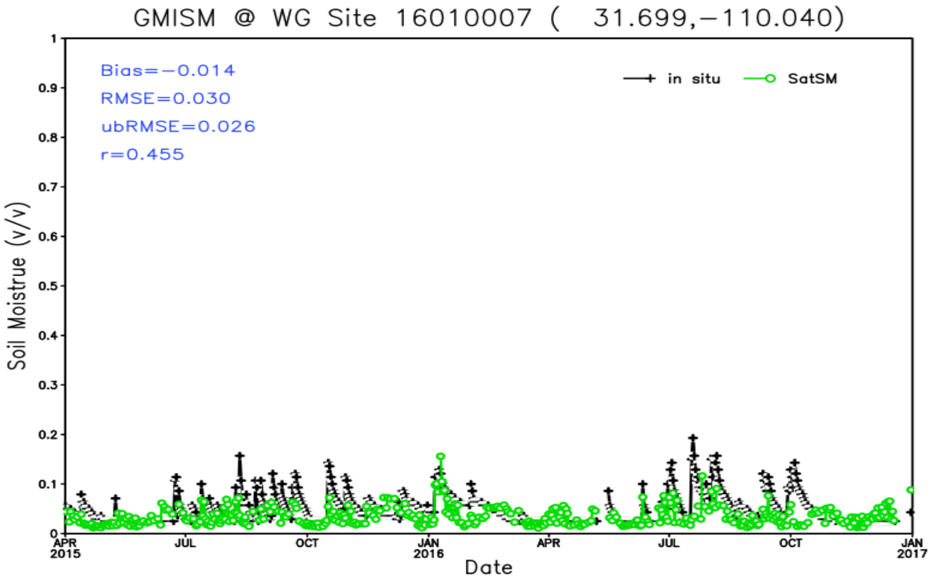


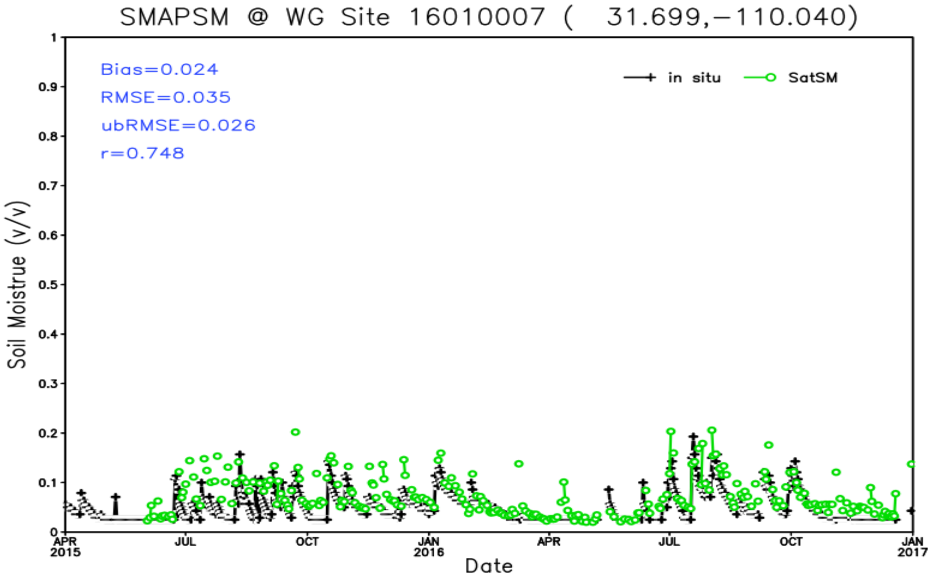


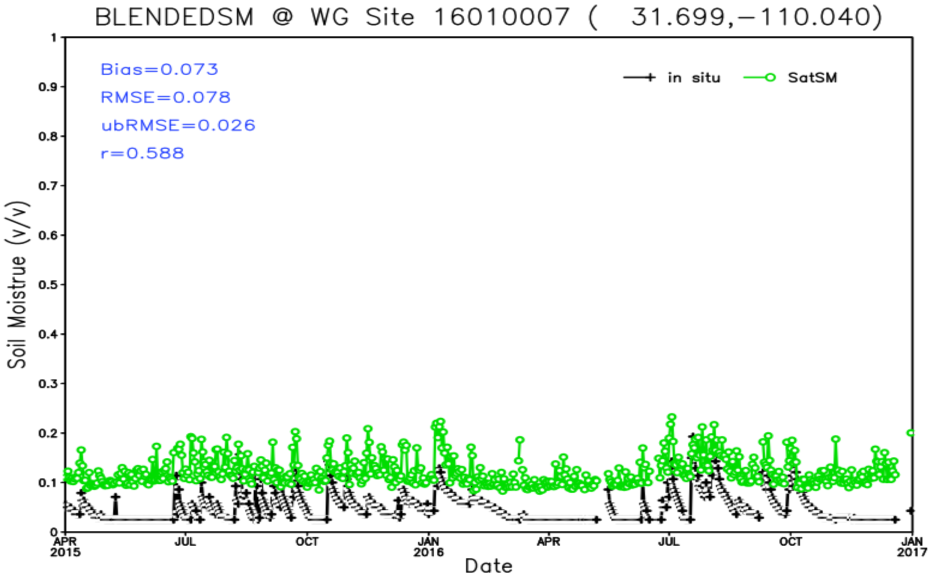


CASE 5: SMOPS SM vs WG_AZ (7/11)

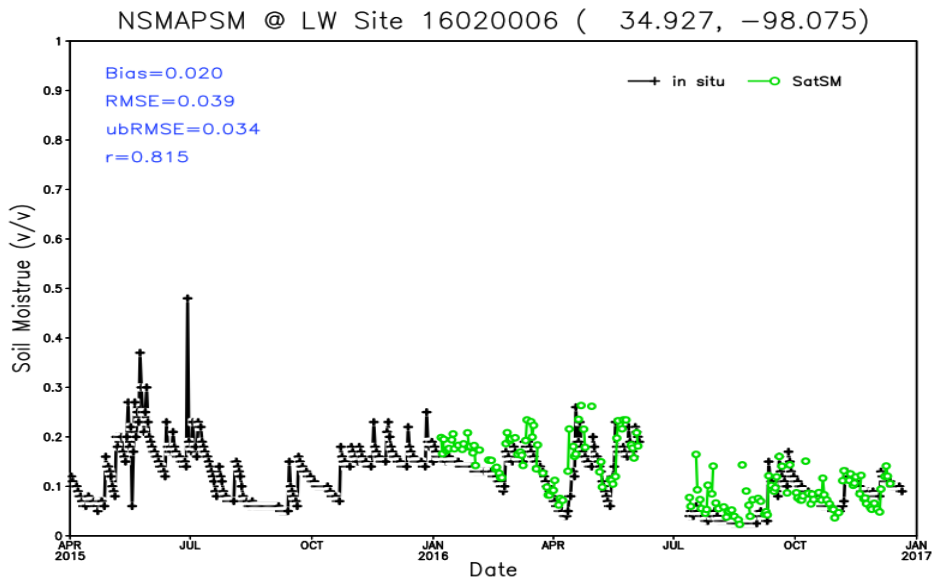


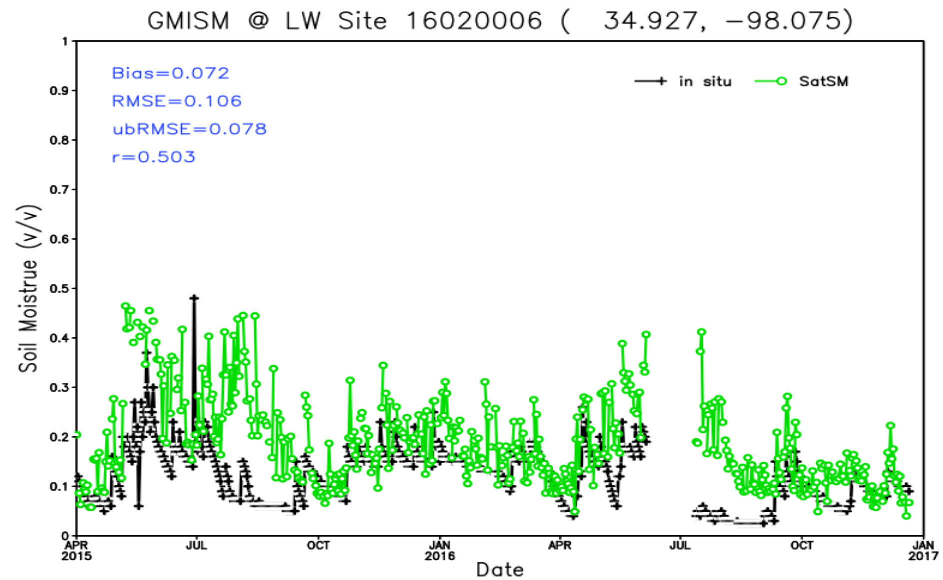


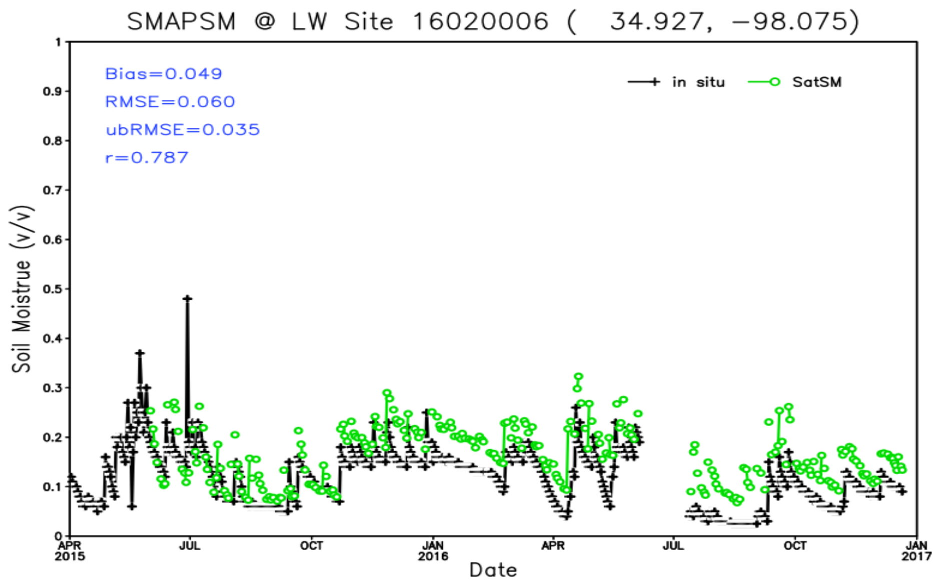


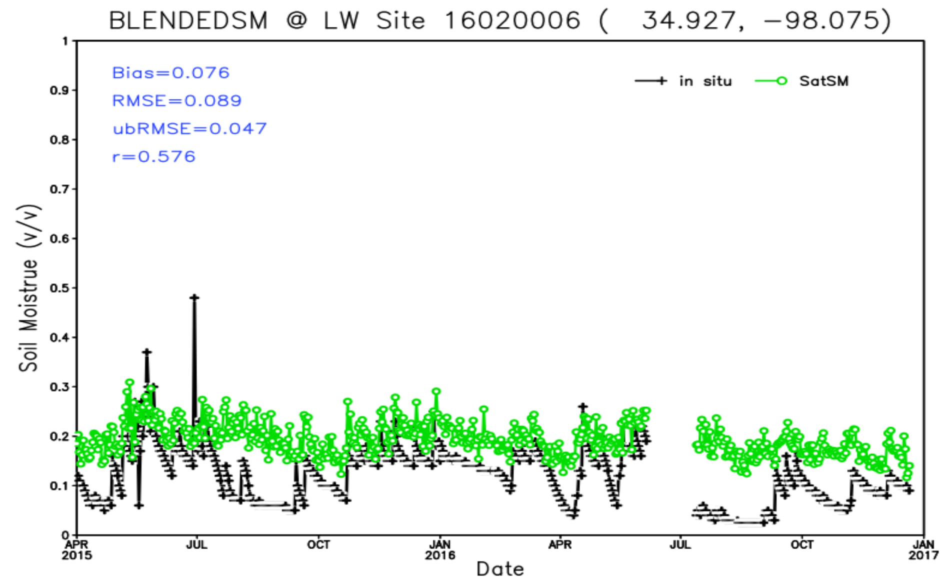


CASE 6: SMOPS SM vs LW_OK (8/11)









SMOPS SM Product Validation (9/11)

In situ Sites	*Correlation Coefficient (r)*			
	GMI	*NSMAP*	*SMAP*	*Blended*
Phillipsburg, KS	0.474	0.714	0.821	0.693
CPER, CO	0.334	0.441	0.696	0.512
Torrington, WY	0.437	0.684	0.711	0.577
Geneva, NY	0.355	0.501	0.779	0.486
Maqu, China	0.643	0.878	0.694	0.790
Yanco, Australia	0.301	0.898	0.843	0.691
WG, AZ	0.455	0.700	0.748	0.588
LW, OK	0.503	0.815	0.787	0.576
Average	**0.438**	**0.704**	**0.760**	**0.614**

- *Different products have different performance, which could be caused by the different heterogeneity feature of in situ site and product accuracy*

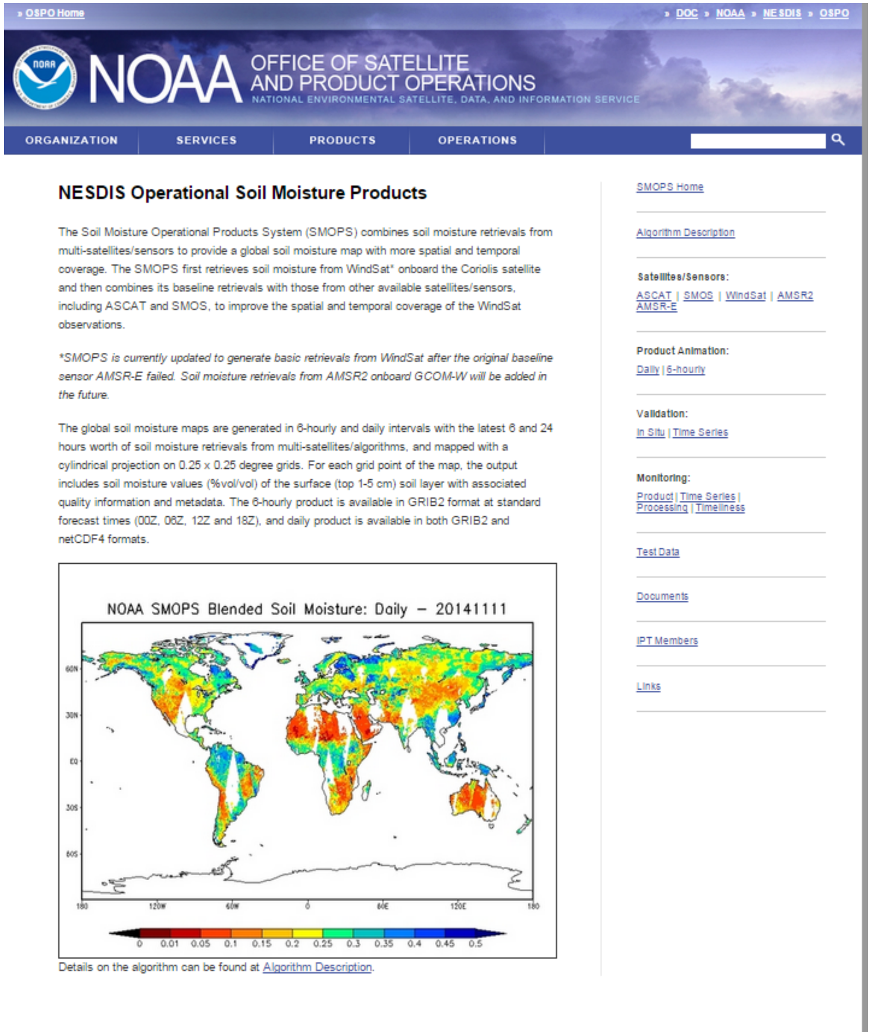
SMOPS SM Product Validation (10/11)

In situ Sites	*Unbiased Root-mean-square-error(ubRMSE)*			
	GMI	*NSMAP*	*SMAP*	*Blended*
Phillipsburg, KS	0.072	0.073	0.040	0.052
CPER, CO	0.065	0.062	0.046	0.053
Torrington, WY	0.047	0.034	0.035	0.040
Geneva, NY	0.064	0.094	0.047	0.066
Maqu, China	0.118	0.085	0.076	0.079
Yanco, Australia	0.086	0.069	0.085	0.126
WG, AZ	0.026	0.025	0.026	0.026
LW, OK	0.078	0.034	0.035	0.047
Average	**0.070**	**0.060**	**0.049**	**0.061**

- *The ubRMSE average **6.1%** [v/v] meets the **4-10%** [v/v] requirement specified in the NCEP user request (SPSRB requirement **#0707-17**).*

Soil Moisture Operational Product System

http://www.ospo.noaa.gov/Products/land/smops/index.html



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NOAA OFFICE OF SATELLITE AND PRODUCT OPERATIONS

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

ORGANIZATION SERVICES PRODUCTS OPERATIONS

NESDIS Operational Soil Moisture Products

The Soil Moisture Operational Products System (SMOPS) combines soil moisture retrievals from multi-satellites/sensors to provide a global soil moisture map with more spatial and temporal coverage. The SMOPS first retrieves soil moisture from WindSat* onboard the Coriolis satellite and then combines its baseline retrievals with those from other available satellites/sensors, including ASCAT and SMOS, to improve the spatial and temporal coverage of the WindSat observations.

**SMOPS is currently updated to generate basic retrievals from WindSat after the original baseline sensor AMSR-E failed. Soil moisture retrievals from AMSR2 onboard GCOM-W will be added in the future.*

The global soil moisture maps are generated in 6-hourly and daily intervals with the latest 6 and 24 hours worth of soil moisture retrievals from multi-satellites/algorithms, and mapped with a cylindrical projection on 0.25 x 0.25 degree grids. For each grid point of the map, the output includes soil moisture values (%vol/vol) of the surface (top 1-5 cm) soil layer with associated quality information and metadata. The 6-hourly product is available in GRIB2 format at standard forecast times (00Z, 06Z, 12Z and 18Z), and daily product is available in both GRIB2 and netCDF4 formats.

Details on the algorithm can be found at Algorithm Description.

SMOPS Home

Algorithm Description

Satellites/Sensors: ASCAT | SMOS | WindSat | AMSR2 AMSR-E

Product Animation: Daily | 6-hourly

Validation: In Situ | Time Series

Monitoring: Product | Time Series | Processing | Timeliness

Test Data

Documents

IPT Members

Links

- **Developed by NOAA/NESDIS/STAR**
- **Operationally running at NOAA/NESDIS/OSPO**

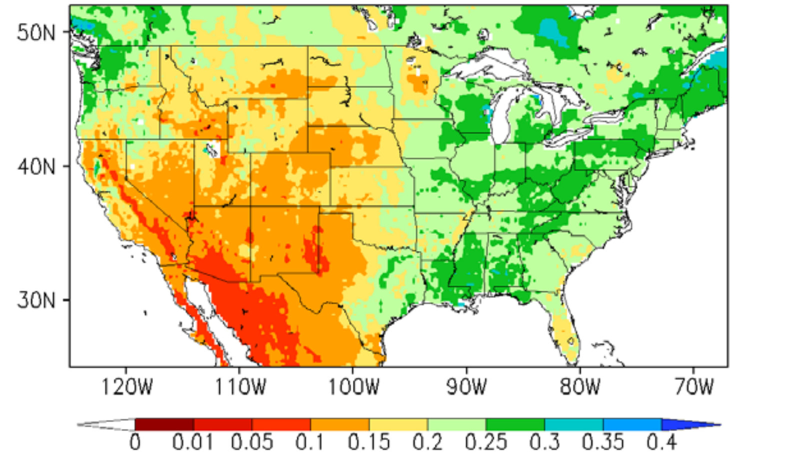
Operational data access contact:
Limin.Zhao@noaa.gov

Science and historical data contact:
Xiwu.Zhan@noaa.gov,
Jicheng.Liu@noaa.gov,

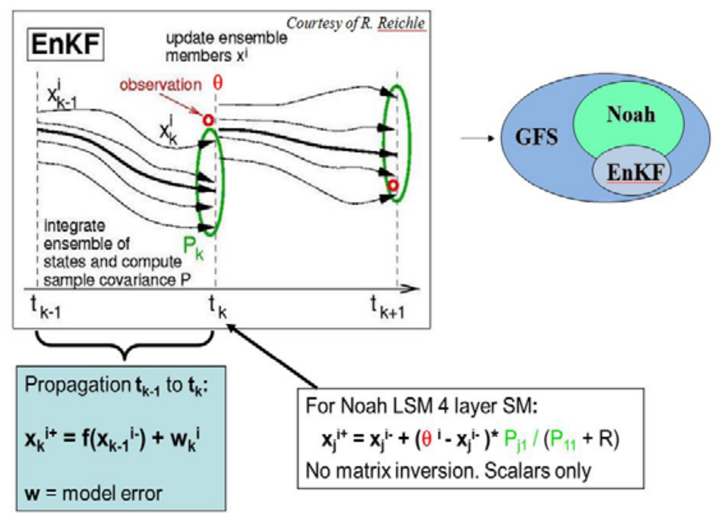
Assimilation of SM in NCEP GFS

- SMOPS combines soil moisture retrievals from multiple satellites sensors to provide a global climatologically consistent soil moisture map with more spatial and temporal coverage.

- Positive impact has been shown on the model performance, particularly for precipitation forecasts by assimilating SMOPS blended product into GFS using a simplified EnKF

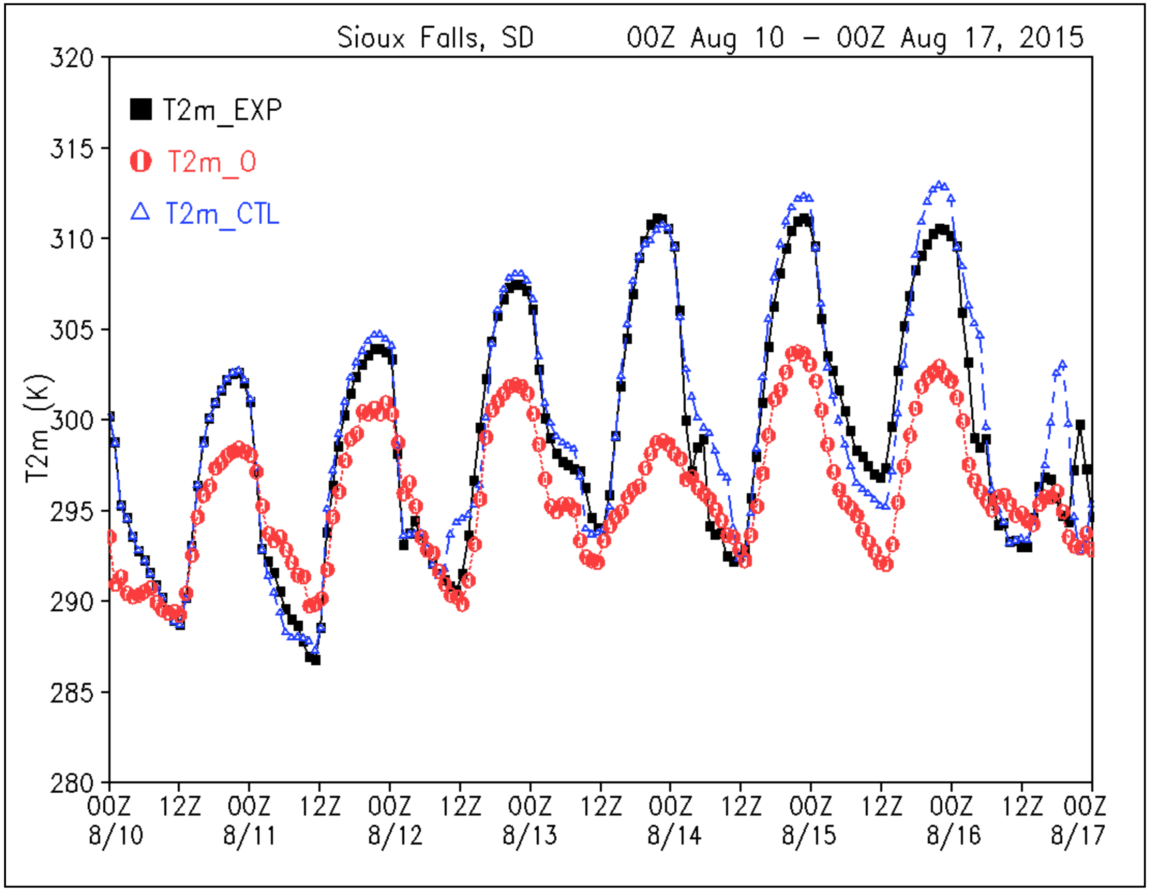


SMOPS blended product over CONUS in Apr 2012



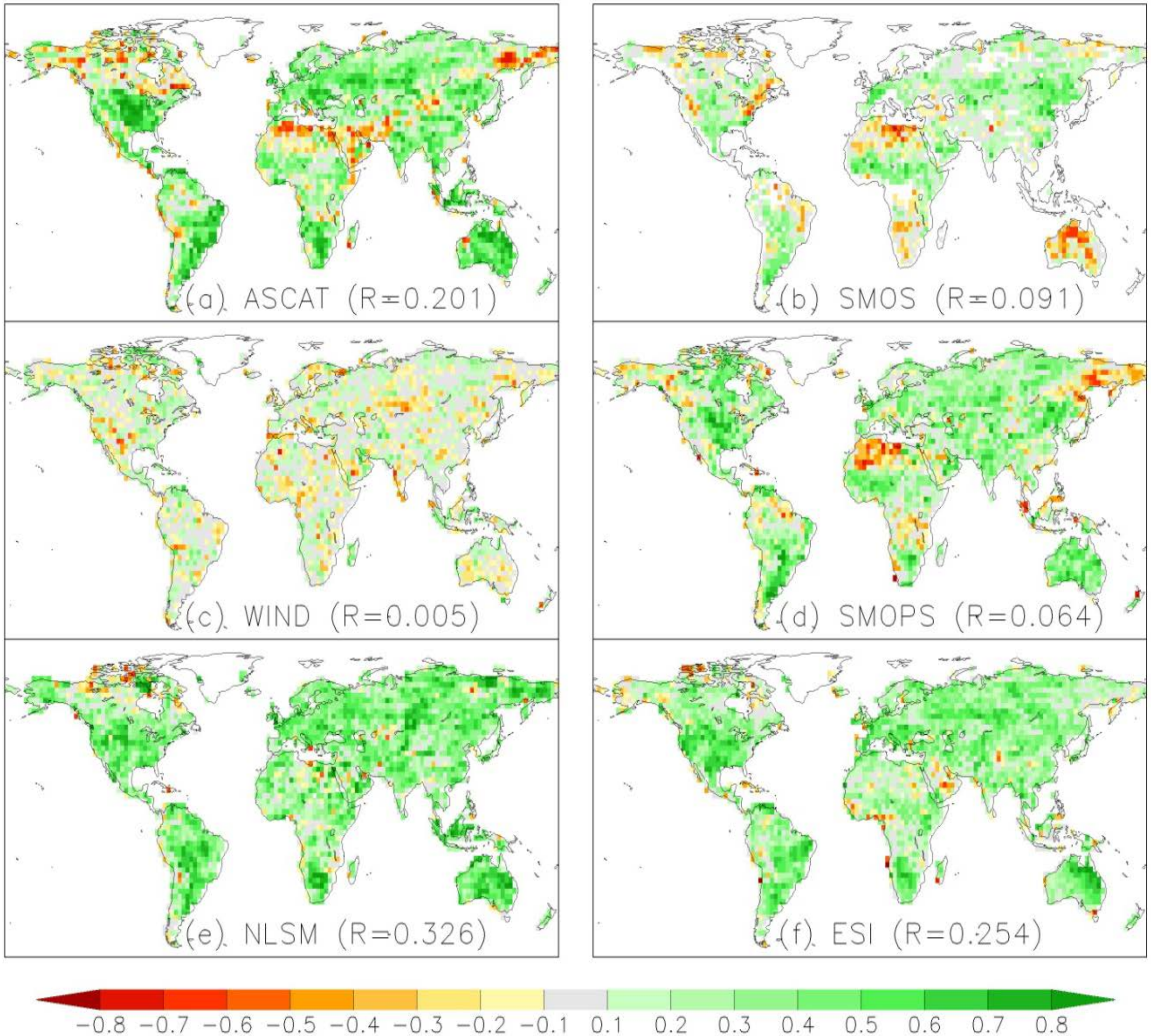
A Simplified EnKF data assimilation utility implemented in NCEP GFS

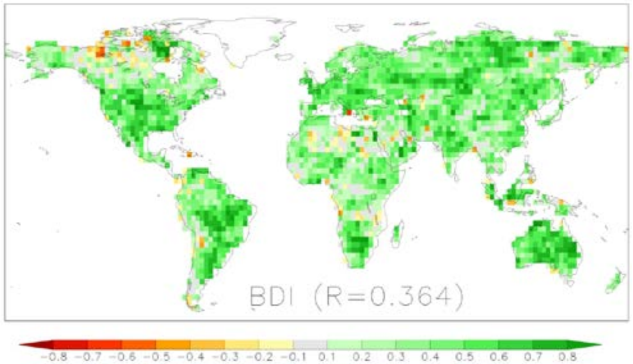
Assimilation of SM in NCEP GFS



Assimilating SMAP SM from 8/1 – 8/10/2015 Reduces the daytime warm biases of NCEP GFS four (4) day forecasts of 2 meter air temperature

Blending Sat SM for Drought Monitoring





Correlation coefficients (R) between PDSI standard anomalies (against 1985-2014 averages) and drought estimations for (a) ASCAT, (b) SMOS, (c) WindSat, (d) SMOPS, (e) NLSM and (f) ESI cases. Grey color indicates insignificant correlation. The Blended Drought Index (BDI) has better correlation than all other data sources

SUMMARY

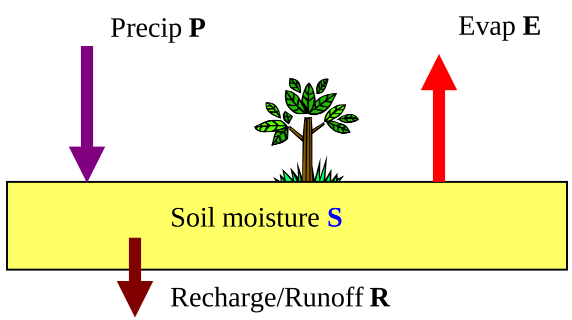
- *Soil moisture is required for NWP model initialization*
- *A soil moisture operational product system (SMOPS) has been developed for providing users with near real time satellite soil moisture products and their blend*
- *Current SMOPS blends soil moisture observations from ASCATs (MetOp-A & MetOp-B), SMOS (ESA & NRT), AMSR2, SMAP (NASA & NRT), GMI*
- *Application of these products in drought monitoring operations and NCEP models are explored*

Thanks for your attention!

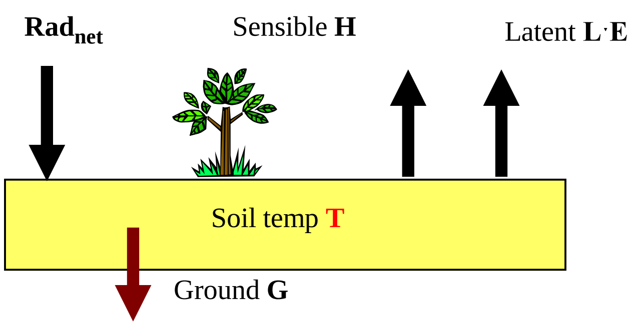
Why Soil Moisture for NOAA

<u>Soil moisture</u> controls land surface **mass** and **energy** partitioning through impacting **<u>evapotranspiration</u>**

Mass balance



Energy balance



$$V \frac{dS}{dt} = P - E(T, S) - R(S)$$

$$c \frac{dT}{dt} = Rad_{net}(T) - H(T) - L \cdot E(T, S)$$

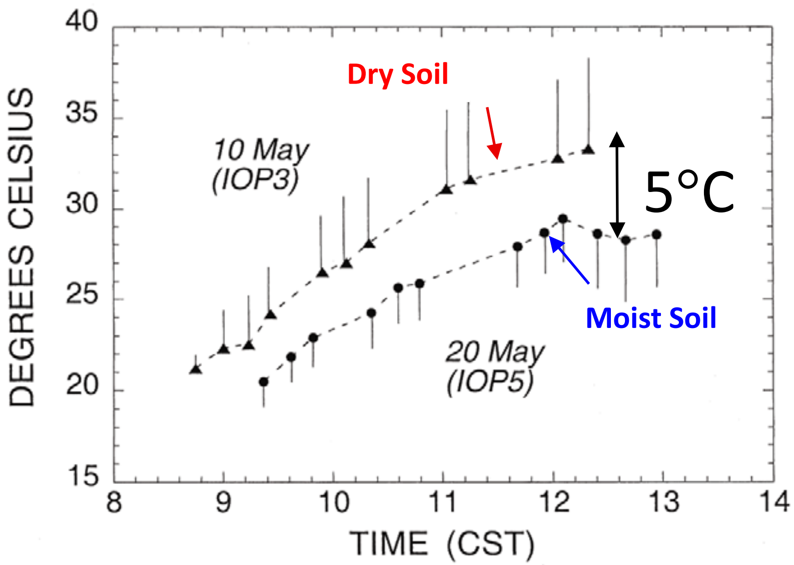
Evaporation & soil moisture **couple mass & energy balances** at land surface

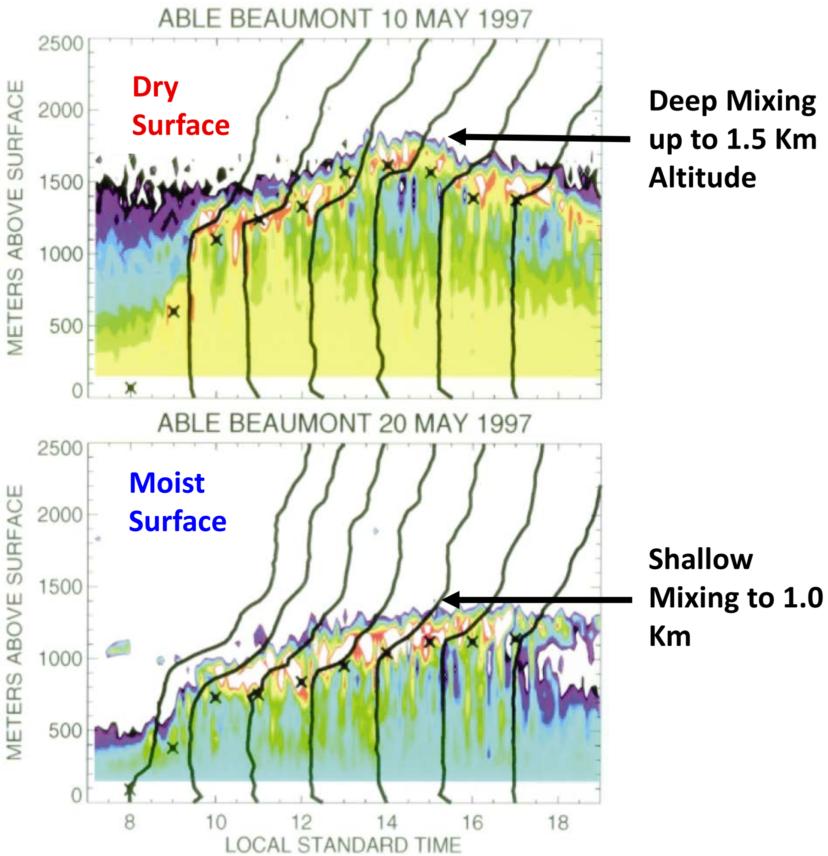
L is the latent heat of vaporization: 2.5×10^6 [J/kg]

Why Soil Moisture for NOAA

Over land actual evapotranspiration depends on both **incident energy** and **soil moisture**.

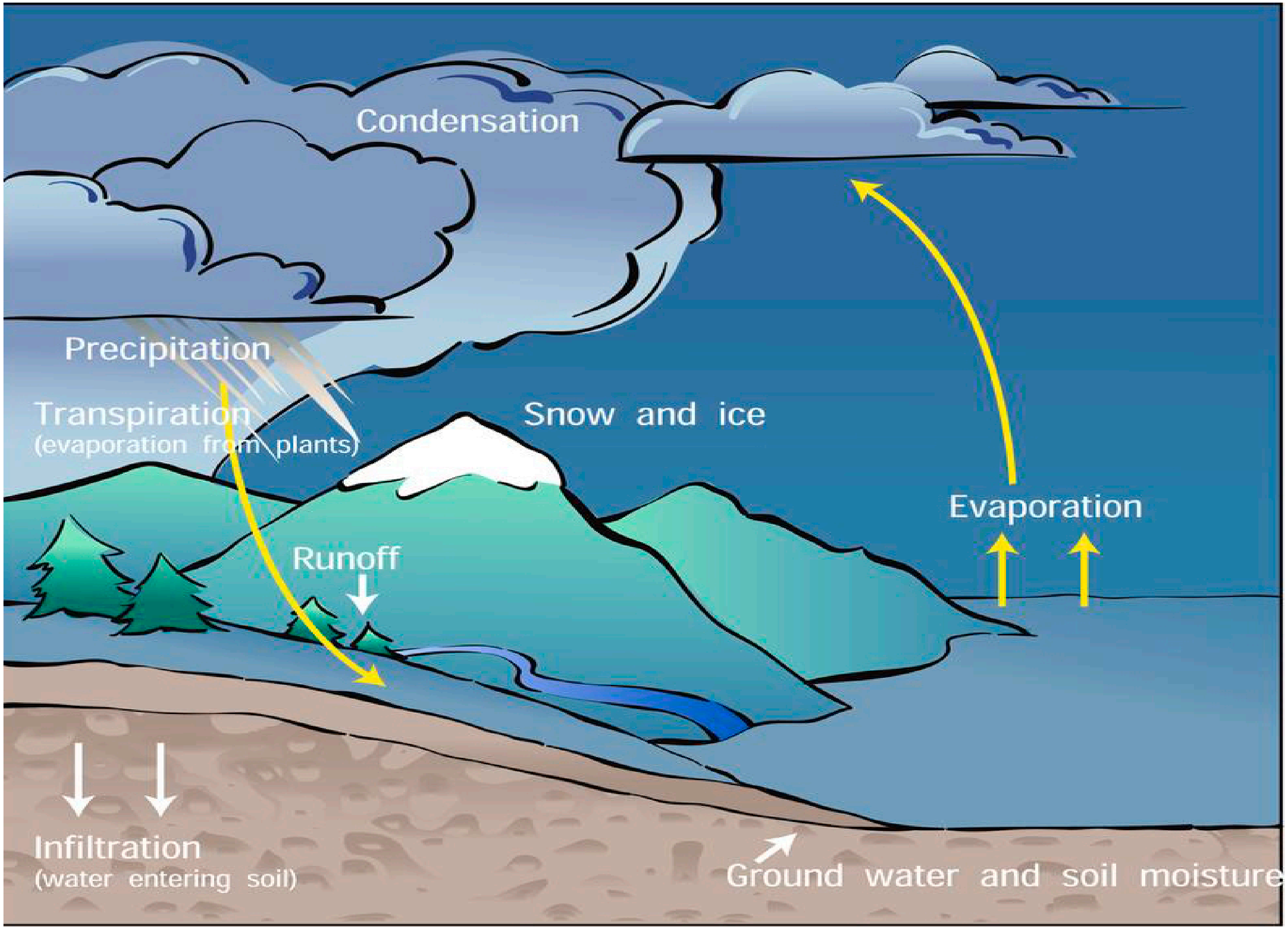
May 10	Dry soil, clear, mild winds. (**LE≈H**)
May 18	90 mm Rain
May 20	Moist soil, clear, mild winds. (**LE>H**)





CASES'97 Field Experiment, *BAMS*, 81(4), 2000.

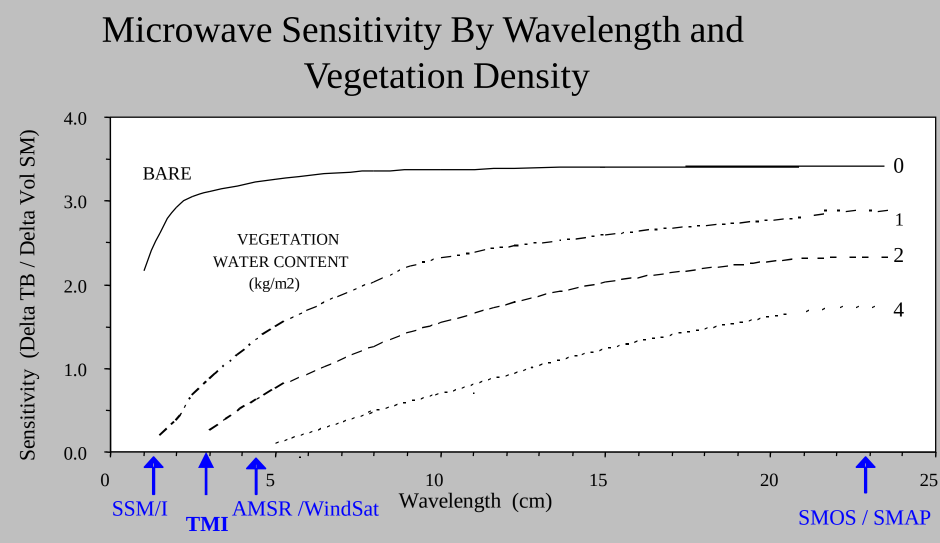
Soil Moisture for Water Cycle Studies

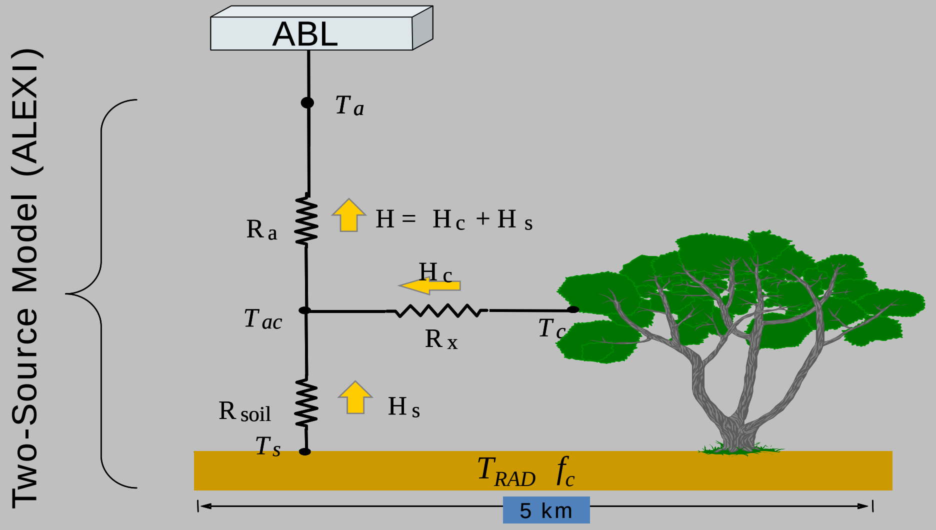


Soil Moisture Remote Sensing Science

Two ways to retrieve soil moisture from satellites:

- **Microwave (MW):** Observed MW brightness temperature depends on soil dielectric constant that is related to soil moisture:
  - **Strength:** higher reliability based on direct physical relationships
  - **Weakness:** antenna technology limits spatial resolution
- **Thermal Infrared (TIR):** Observed surface temperature changes result from surface energy balance that is dependent on soil moisture:
  - **Strength:** TIR sensor could have higher spatial resolution
  - **Weakness:** relies on land surface energy balance model that is prone to input data errors.





MW Soil Moisture Remote Sensing Technology