GCOM-W1/AMSR2 SOIL MOISTURE

NOAA NESDIS STAR
301-683-3599; Xiwu.Zhan@noaa.gov
X. Zhan, J. Liu, T. King, R. Ferraro, P. Chang

Outline

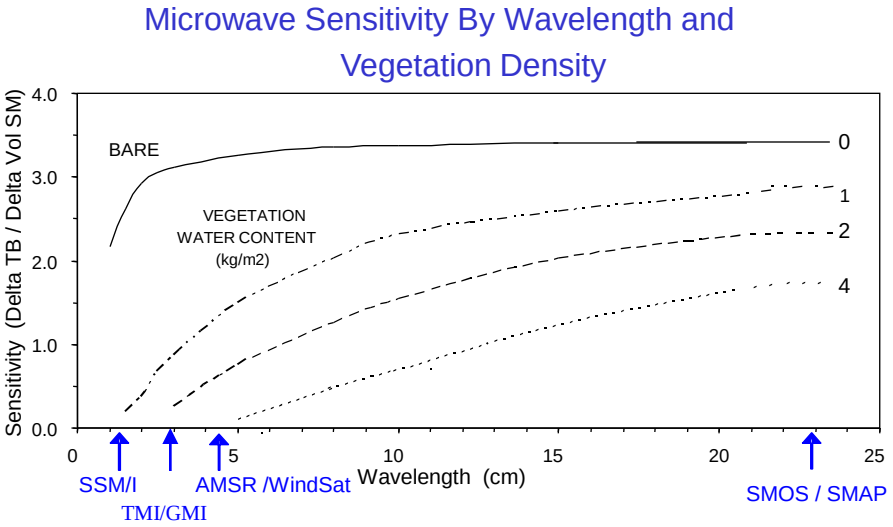
- AMSR2 Soil Moisture EDR Team Members
- Soil Moisture Sensor Overview
- AMSR2 Soil Moisture Algorithm
- AMSR2 Soil Moisture Data Product
- Summary and Path Forward

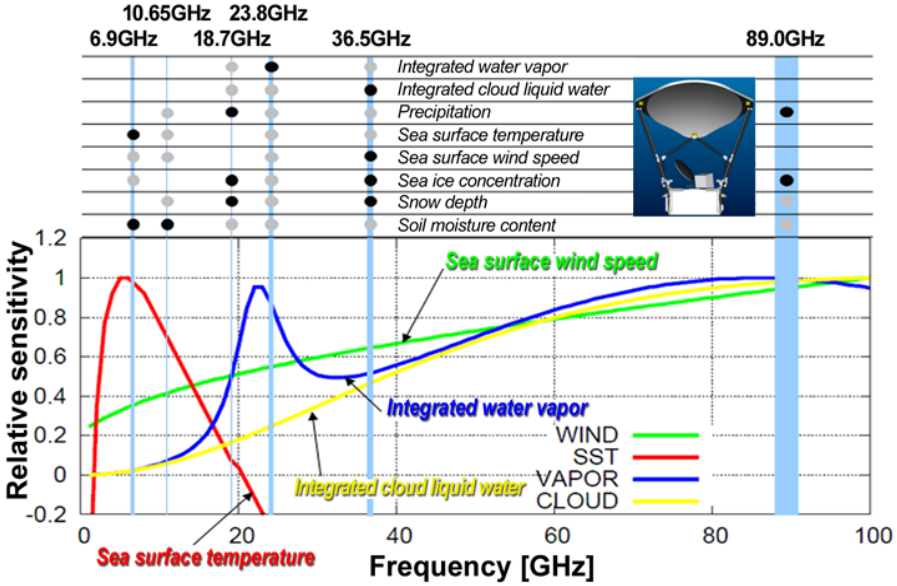
AMSR2 Soil Moisture Team Members

Team Member	Organization	Roles and Responsibilities
Xiwu Zhan	NESDIS-STAR	AMSR2 Soil Moisture Team Lead
Jicheng Liu	UMD-CICS/ NESDIS-STAR	SM Algorithm and Validation Lead
Tom King	IMSG/ NESDIS-STAR	GAASP Development Lead
Zorana Jelenak	UCAR/ NESDIS-STAR	JPSS GCOM-W1 EDR Lead
Ralph Ferraro	NESDIS-STAR	JPSS GCOM-W1 Project Deputy
Paul Chang	NESDIS-STAR	JPSS GCOM-W1 Project Lead

Soil Moisture Sensor Overview

- Soil Moisture remote sensing is based on the sensitivity of L/C/X band microwave emission to soil dielectric constant
- Soil moisture capable passive microwave satellite sensors include: SMMR, SSM/I and SSMIS, AMSR/AMSR-E, WindSat, **SMOS**, **AMSR2**, **GMI** and **SMAP**
- AMSR2 on board of JAXA's GCOM-W1 satellite is currently the **only** **operational passive microwave soil moisture** sensor in NASA-NOAA JPSS program





JPSS Requirements for AMSR-2 Soil Moisture EDR

Table 6.1.10 - GCOM-W Soil Moisture		
EDR Attribute	Threshold	Objective
Applicable conditions	Delivered under “all weather” conditions	Delivered under “all weather” conditions
Sensing depth	Surface to -0.1 cm (skin layer)	Surface to -80 cm
Horizontal cell size	25 km (1)	3 km
Mapping uncertainty, 3 sigma	5 km	1 km
Measurement Uncertainty	6% volumetric RMSE (goal) with VWC < 1.5 kg/m^2 or GVF < 0.5 and < 2 mm/hr precip rate	Surface: 5% 80 cm column: 5%
Measurement range	0 – 50%(2)	0 – 50%
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)(3)	n/s

Note:
(1) Per AMSR-E legacy and user convenience, 25km can be obtained with resampling AMSR-2 footprints to 25km. 3km could be obtained by interpolation with VIIRS optical observations
(2) Absolute soil moisture unit (m^3/m^3 volume %) is preferred by most users of NWP community
(3) This Refresh requirement is consistent with the AMSR-2 Cross-track Swath Width design of 1450 km for a single orbit plane

JPSS Requirements for AMSR-2 Surface Type EDR

Table 6.1.11 - Surface Type (AMSR-2)		
EDR Attribute	Threshold (1)	Objective
Applicable conditions	Delivered under “all weather” conditions	Delivered under “all weather” conditions
a. Horizontal cell size	25 km	1 km
b. Mapping uncertainty, 3σ	5 km	1 km
c. Measurement Range	8 hydrological classes(2)	13 classes of land types listed in Note (3)
d. Measurement Precision	5%	2%
e. Measurement Accuracy	70% for 17 types	80%
f. Refresh	>90% coverage of globe every 20 hrs (4)	n/s

Note:
(1) Satisfied by VIIRS under “probably clear” and “probably cloudy” conditions.
(2) 1) Standing water, 2) Dense veg (jungle), 3) Herb veg, 4) Desert, 5) Snow, 6) Urban, 7) Wetland, 8) Raining area
(3) 1) Standing water/flooded, 2) Dense veg (jungle), 3) Ag/range land, 4) Dry arable soil, 5) Moist soil, 6) Semi-arid surface, 7) Desert, 8) Dry snow, 9) Refrozen snow, 10) Wet snow, 11) Veg/water mix, 12) soil/water mix, 13) Indeterminate.
(4) Consistent with AMSR2 cross-track swath width of 1450km.

Soil Moisture Algorithm Overview

Multi-channel Inversion (MCI) Algorithm

(Njoku & Li, 1999)

$$\min\{\chi^2 = \sum_{i=1}^{6}\left(\frac{T_{B,i}^{obs} - T_{B,i}^{cmp}}{\sigma_i}\right)^2\}$$

$T_{B,i}^{cmp} = T_s \{e_{r,i} \exp(-\tau_i/\cos\theta) + (1-\omega)[1-\exp(-\tau_i/\cos\theta)][1+(1-e_{r,i})\exp(-\tau_i/\cos\theta)]\}$

$\tau_i = b * VWC$

$e_{r,i} = f(e_s, h)$

$e_s = f(\varepsilon)$ -- Fresnel Equation

$\varepsilon = f(SM)$ -- Mixing model (Dobson et al)

$T_{B,i}^{obs} = T_{B06h}, T_{B06v}, T_{B10h}, T_{B10v}, T_{B18h}, T_{B18v}$

Soil Moisture Algorithm Overview

Land Parameter Retrieval Model (LPRM) :

(Owe, de Jeu & Holmes, 2008)

$$\min\{delta = T_{Bh}^{obs} - T_{Bh}^{cmp}\}$$

$T_{Bh}^{cmp} = T_s \{e_{h,r} \exp(-\tau/\cos\theta) + (1 - \omega)[1 - \exp(-\tau/\cos\theta)][1 + (1 - e_{h,r})\exp(-\tau/\cos\theta)]\}$

$\tau = f(MPDI)$, $MPDI = (T_{Bv} - T_{Bh})/(T_{Bv} + T_{Bh})$

$e_h = f(e_s, h, Q)$

$e_s = f(\varepsilon)$ -- Fresnel Equation

$\varepsilon = f(SM)$ -- Mixing model (Wang & Schmugge)

$T_s = f(T_{B37v})$ or T_s^{LSM}

$T_{Bh}^{obs} = T_{B06h}$, T_{B10h} or T_{B18h}

Soil Moisture Algorithm Overview

Single Channel Algorithm (SCA) :

(Jackson, 1993)

$$T_{B10h} = T_s\,[1 - (1-e_r)\exp(-2\tau/\cos\theta)]$$

$$\tau = b * VWC,\ VWC = f(NDVI)$$
$$e_h = f(e_v, h, Q)$$
$$e_s = f(\varepsilon) \quad \text{-- Fresnel Equation}$$
$$\varepsilon = f(SM) \quad \text{-- Mixing model}$$
$$T_s = f(T_{B37v}) \text{ or } T_s^{LSM}$$

AMSR2 Soil Moisture Algorithm

SCA: Inverse tau-omega equation of a TB_h (C/X-band) for *SM* with *tau* from *NDVI* and T_s from TB_{36v}. Used in SMOPS

LPRM: Inverse tau-omega equations of TB_h and TB_v (C/X-band) for *tau* and *SM* with T_s from TB_{36v}

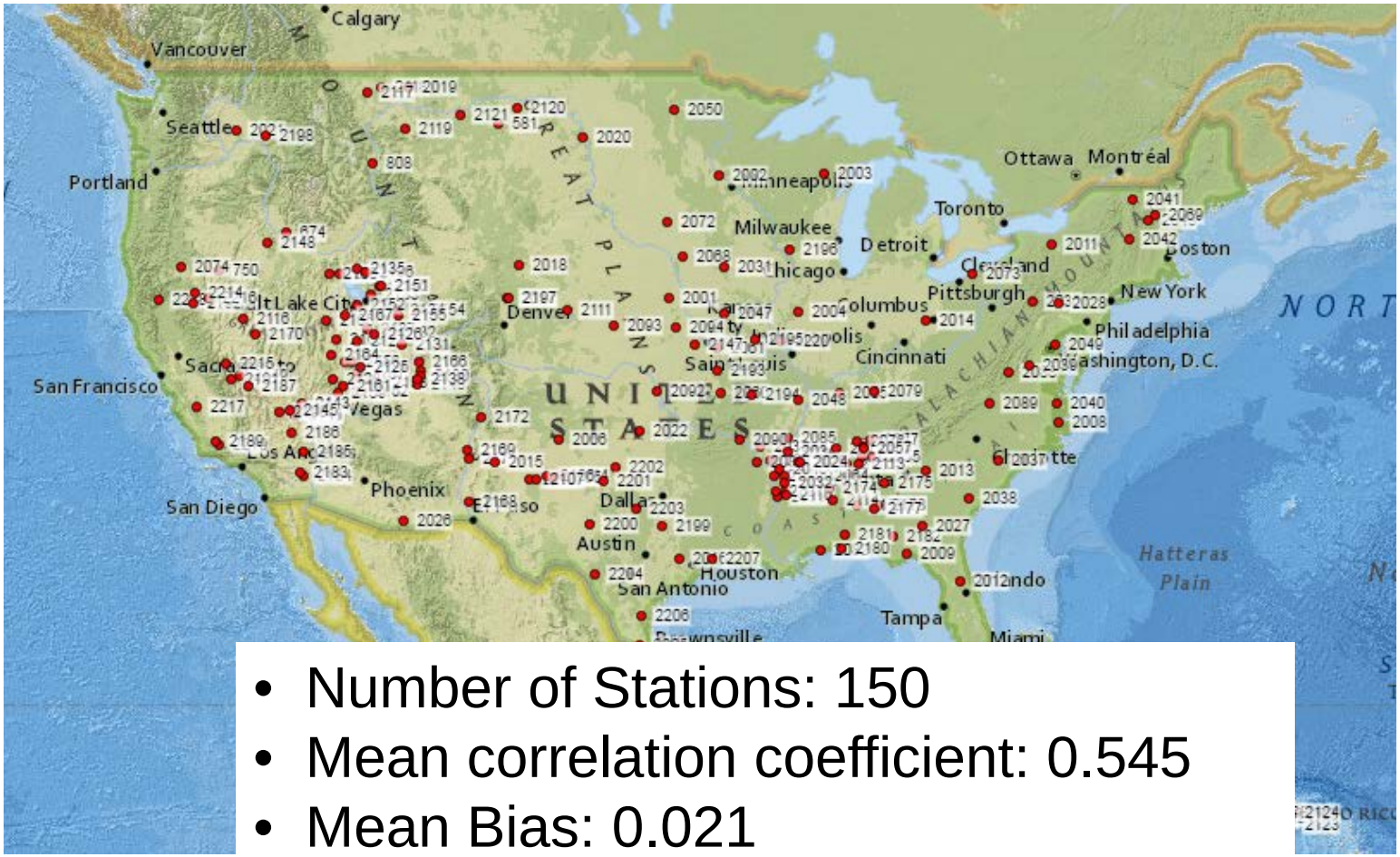
Hybrid: Use LPRM inversed *tau* in SCR for AMSR2 soil moisture EDR

AMSR2 Soil Moisture Products

- AMSR2 soil moisture EDR is generated with the hybrid algorithm implemented in NESDIS GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) using AMSR2 6.9/7.3GHz H-pol TB data, available as Level 2 swath product
- Global 0.25 degree (Level 3) gridded AMSR2 soil moisture data product are made available through NESDIS Global Soil Moisture Operational Product System (SMOPS) in 6 hour or daily NetCDF and GRIB2 files
- Algorithm Readiness Review for the Day 2 EDR of GCOM-W1 products was held in May 2016
- SMOPS update for AMSR2 to provide Level 3 global soil moisture product for users was delivered to OSPO in July and Operation Readiness Review (ORR) of the SMOPS update is arranged later this month

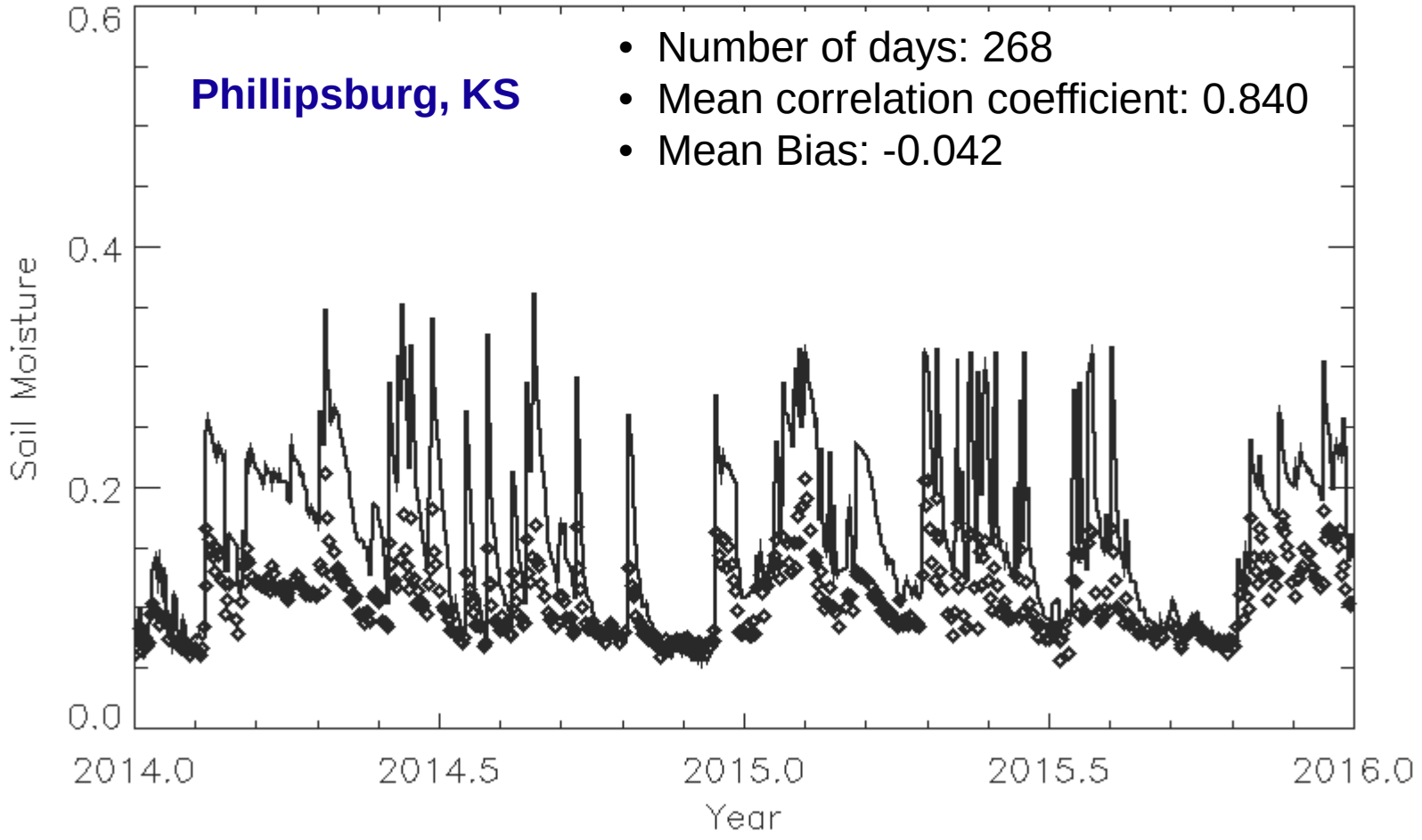
AMSR2 Soil Moisture Performance

Comparison with in situ Measurements of SCAN Sites

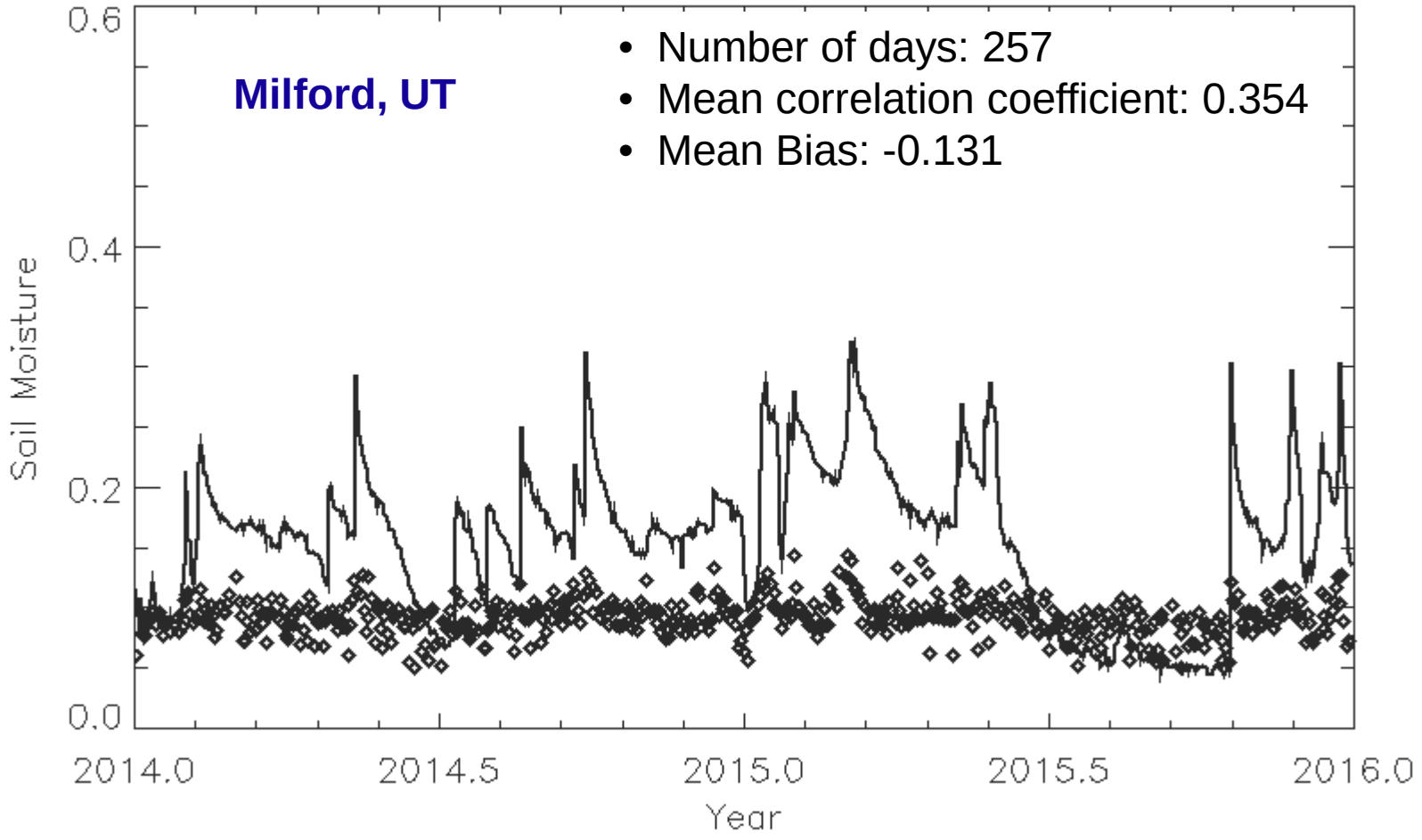


- Number of Stations: 150
- Mean correlation coefficient: 0.545
- Mean Bias: 0.021
- Mean RMSE: 0.038

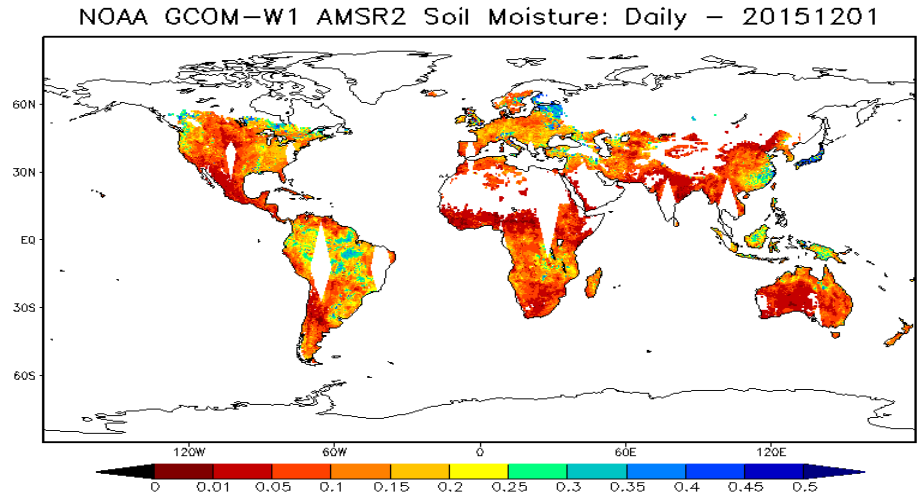
AMSR2 Soil Moisture Performance

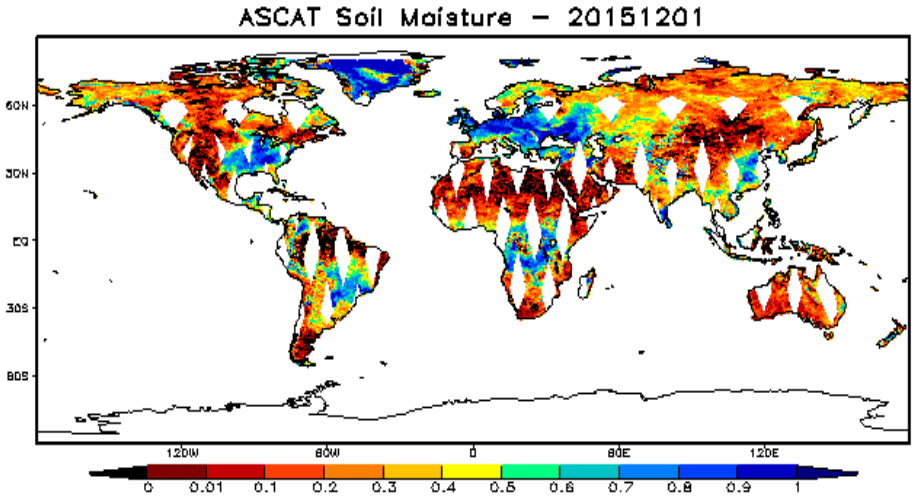


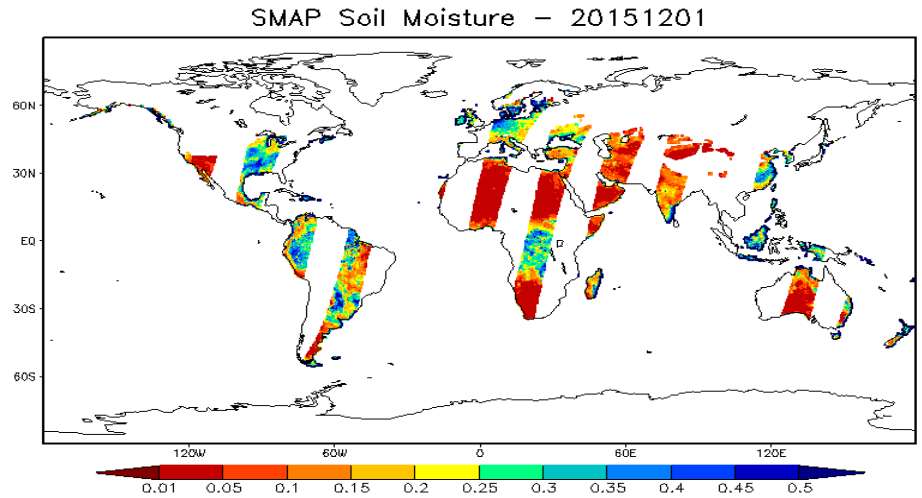
AMSR2 Soil Moisture Performance

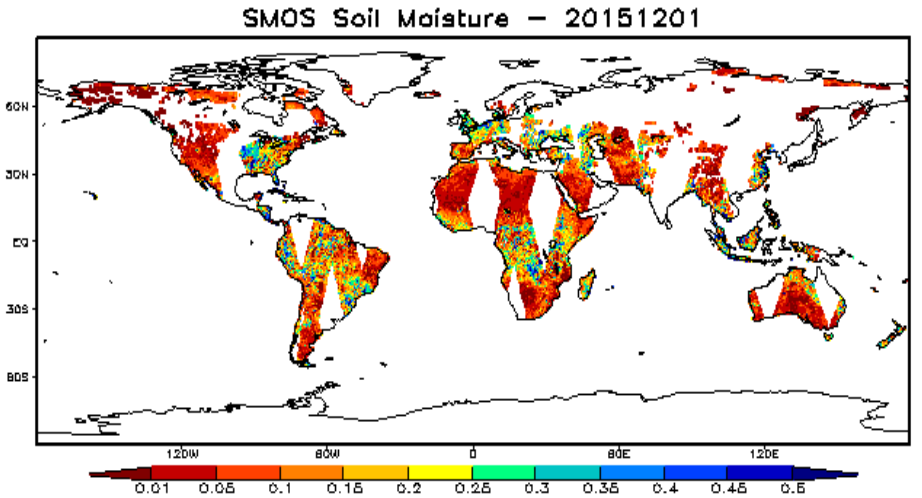


AMSR2 SM vs Other SM Products



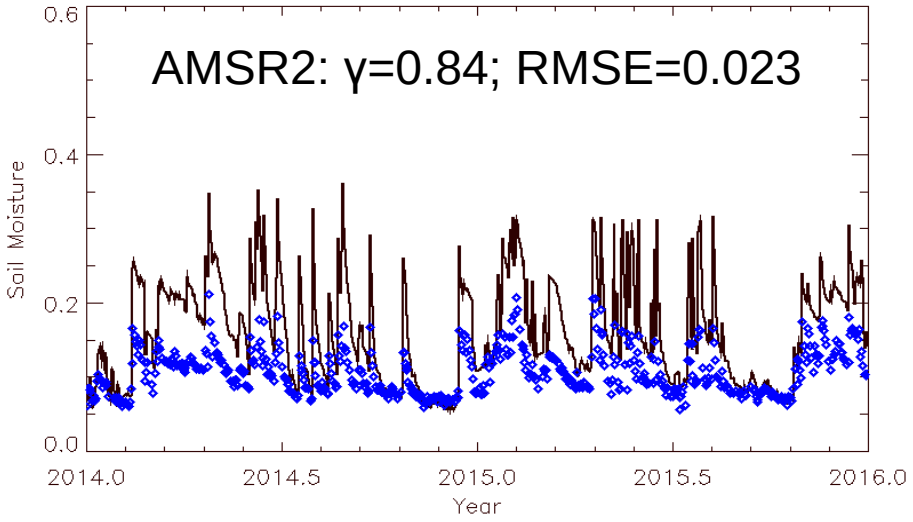


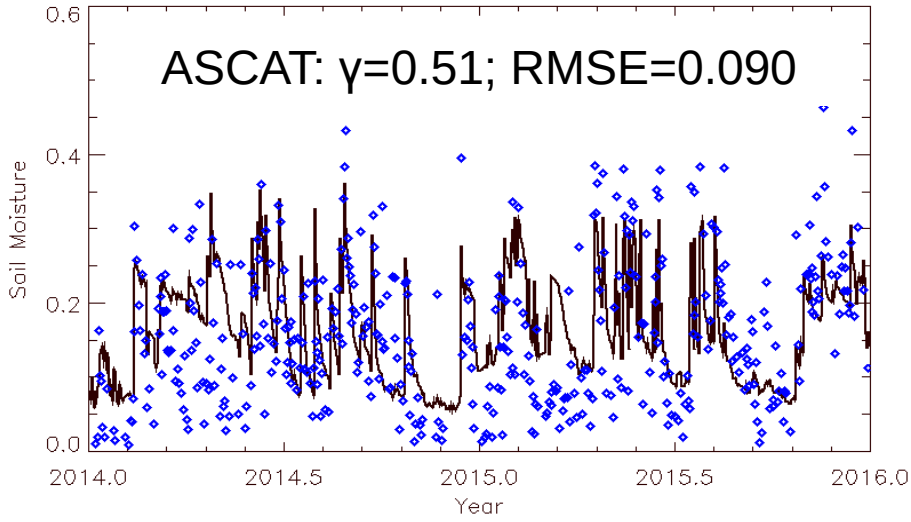


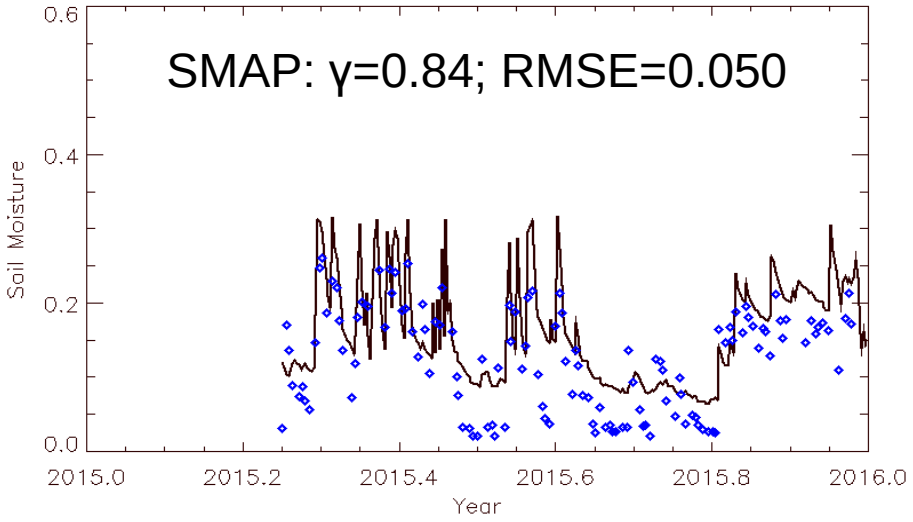


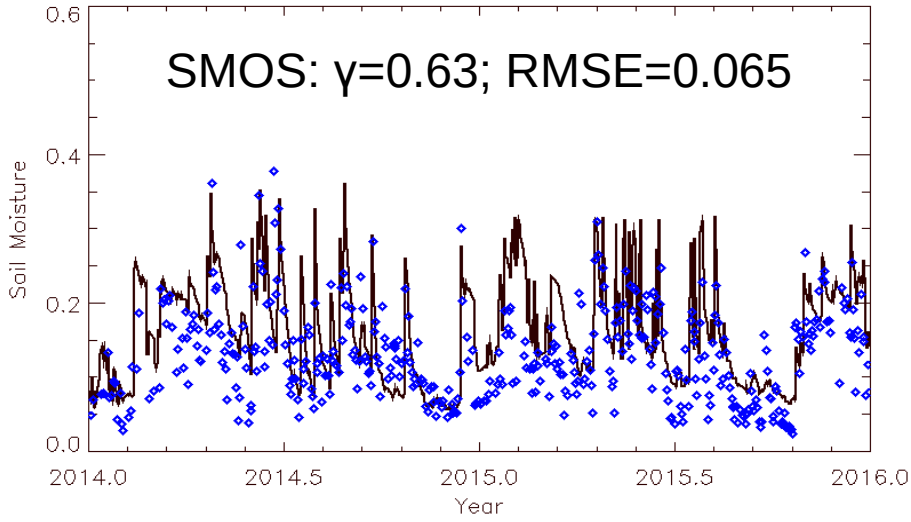
AMSR2 SM vs Other SM Products: Phillipsburg, KS

(γ: correlation coefficient; RMSE: Root Mean Square Error)



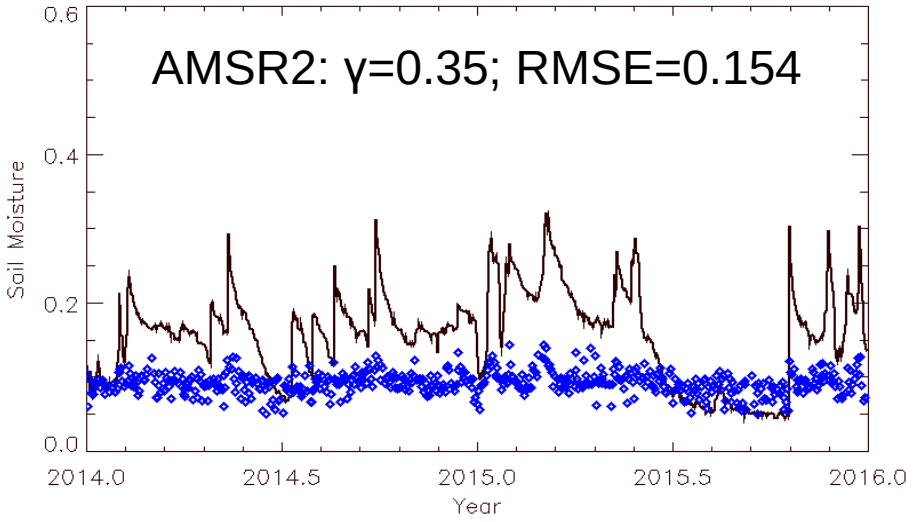


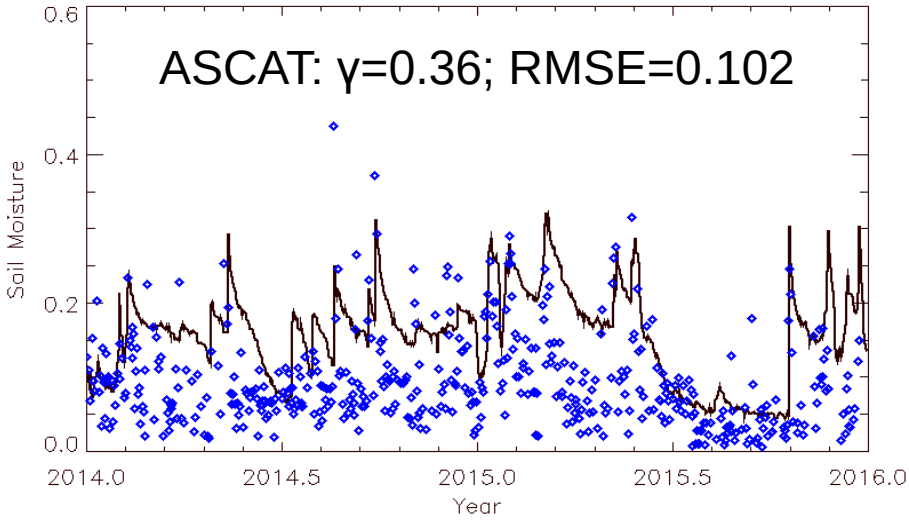


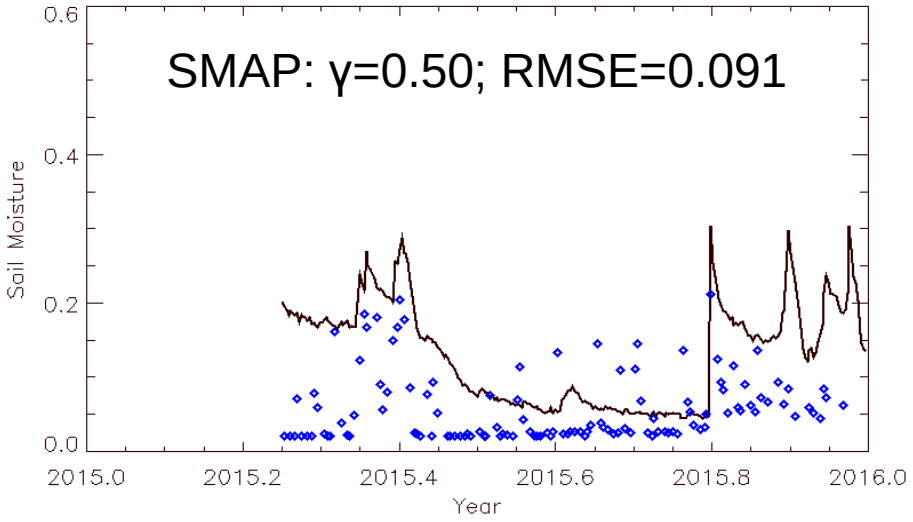


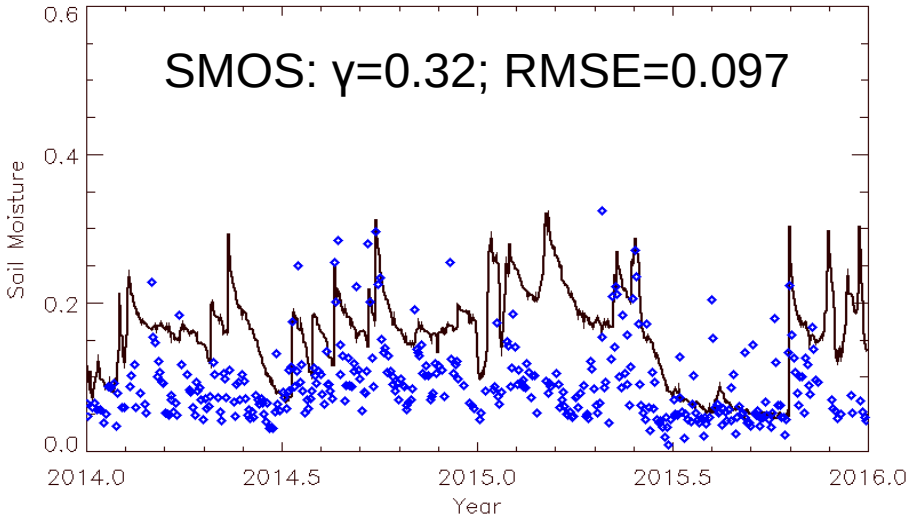
AMSR2 SM vs Other SM Products: Milford, UT

(γ: correlation coefficient; RMSE: Root Mean Square Error)









AMSR2 Soil Moisture EDR Overview

- Performance generally meets requirements
- Reprocessing Plan/Status: in development
- Long Term Monitoring/Website Links:
  - SMOPS website at STAR is in development
    - https://www.star.nesdis.noaa.gov/smcd/emb/soilmoisture/SMOPSMaps.php
  - SMOPS update for AMSR2 at OSPO is ready for review later this month
    - http://www.ospo.noaa.gov/Products/land/smops/smops_loops.html?Imap=6H
- Enterprise Algorithm Status: SMOPS?
- Users Feedback:
  - NCEP use of SMOPS data are in research mode
  - SMOPS products are used in DoD AFWA and USDA FAS operationally
  - SMOPS products are used for Blended Drought Index

Readiness for Follow-on Satellites

- Significant Algorithm changes is planned for GCOM-W2 if any
  - SCA will be calibrated with VIIRS EVI or LAI for better counting of vegetation water content impact
- Pre-launch Characterization
  - N/A
- Post-Launch Cal/Val Plans
  - Data Sets/Planned Field Campaigns : N/A
  - Schedules and Milestones: N/A
- Accomplishments and Highlights Moving forward
  - A NASA funded project may leverage an effort of downscaling AMSR2/3 soil moisture data product for high resolution data need
- Major Risks/Issues/Challenges/ and Mitigation
  - No GCOM-W1 follow-on satellite is approved yet
- Collaboration with Stake Holders/User Agencies
  - Interaction with user community has been frequent

Summary

- GCOM-W1/AMSR2 soil moisture EDR has been generated by NESDIS GAASP as Day 2 product
- AMSR2 soil moisture EDR quality is compatible with other available satellite products and meets JPSS accuracy requirements generally
- NESDIS SMOPS is going to ingest AMSR2 soil moisture EDR and merge it with other global soil moisture data products to provide NCEP and other operational users with 6 hour and daily gridded products from next month

Path Forward

- FY17 Milestones:
  - AMSR2 soil moisture EDR comprehensive validation with global in situ measurement networks and other soil moisture data products
  - Improve user applications by providing more quality control information of products
- Alternate Algorithms and Future Improvements
  - Algorithm refinement and validation with VIIRS EVI replacing NDVI as input
  - Downscaling algorithm development and validation for high resolution data needs
- Preparation for future satellites: n/a

Thanks!