Soil Moisture Validation in the U.S.

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Outline

- Project Overview
- GCOM-W AMSR2 Brightness Temperature Assessment
  - Comparison to AMSR-E (NASA) climatology at selected sites
    - Stable targets
    - Watershed sites
  - Comparison to AMSR-E 2 rpm
- Research Algorithm and Soil Moisture Validation
  - SCA and long-term watershed sites
  - New sites
  - JAXA AMSR2 product
- NASA Algorithm Improvement Study
  - Summary comments
  - NASA product update

Project Overview

- Passive microwave remote sensing of soil moisture has matured over the past decade as a result of the AMSR program of JAXA.
  - This program has resulted in improved algorithms that have been supported by rigorous validation.
- For soil moisture, GCOM-W (AMSR2) ***continues*** the AMSR-E heritage as well as providing improved capabilities.
- There is a need to ***continue algorithm evaluation through validation***, to revisit some of the basic approaches to exploit new information, and to explore new products that have recently shown promise.
- The objectives of this project are to provide:
  - An alternative soil moisture research algorithm including results of ongoing algorithm inter-comparisons.
  - Soil moisture validation data from U.S. sites
  - Explore a LST product (delayed pending calibration)

GCOM-W AMSR2 Brightness Temperature (TB) Assessment

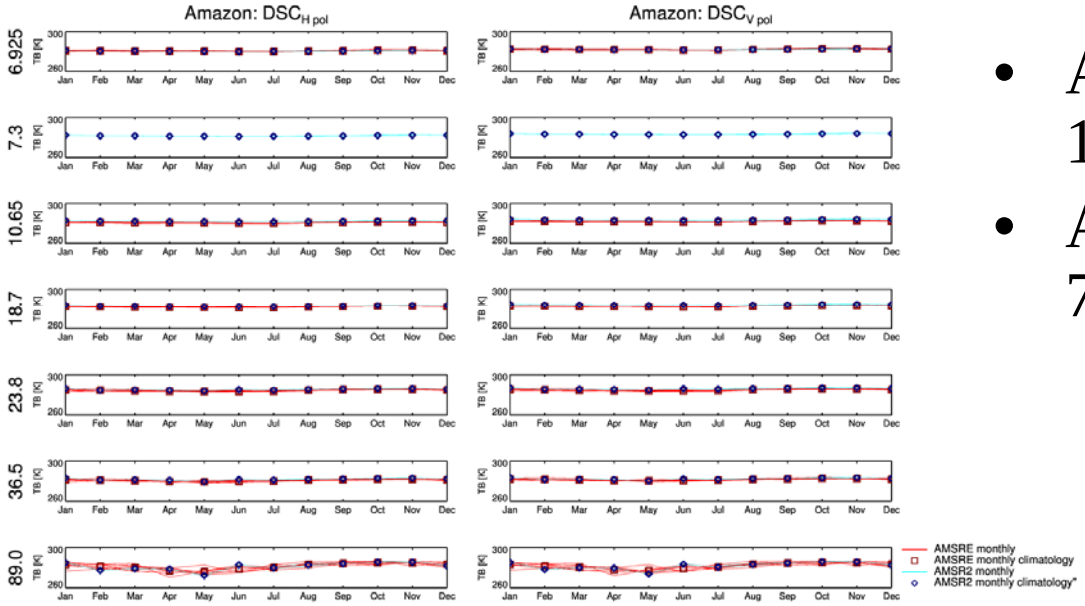
- A primary objective is to provide long-term data sets of Essential Climate Variables (i.e. soil moisture)
  - Requires linking products from multiple satellite sensors (AMSR-E, AMSR2, ….)
- First step is the evaluation of the TB data
  - JAXA has conducted evaluations that indicate adjustments may be necessary
  - Concern with continuity of the NASA TB products from AMSR-E to AMSR2
- Soil moisture involves sensor channels and a TB range that are somewhat different than those of other products.
- Land targets present unique challenges.
  - Heterogeneity
  - Effects of physical temperature, diurnal and seasonal variation
  - .....

GCOM-W AMSR2 TB Assessment: Approach

- (1) Compare AMSR-E (NASA) TB climatology to AMSR2 at selected sites
  - Not concurrent
  - Limited period of record for AMSR2
  - Targets
    - Stable TB
    - Watershed sites
- (2) Compare AMSR-E 2 rpm to AMSR2 globally
  - Concurrent
  - Limited frequency of coverage by AMSR-E 2 rpm
- Interpret carefully
  - Different AMSR-E TB source data used in (1) and (2)
  - Unknown issues with AMSR-E 2 rpm data

AMSR-E (NASA) TB Climatology vs. AMSR2 TB at Selected Sites

- Compute the average TB (of each channel) for the specified domain (stable targets, watersheds, ...)
- Compute the average monthly TB for each month of each year for the period of record (POR)
- Compute the average monthly TB and SD for each month for the POR



- AMSR-E (NASA) 1/2003-12/2010
- AMSR2 7/2012-11/2013

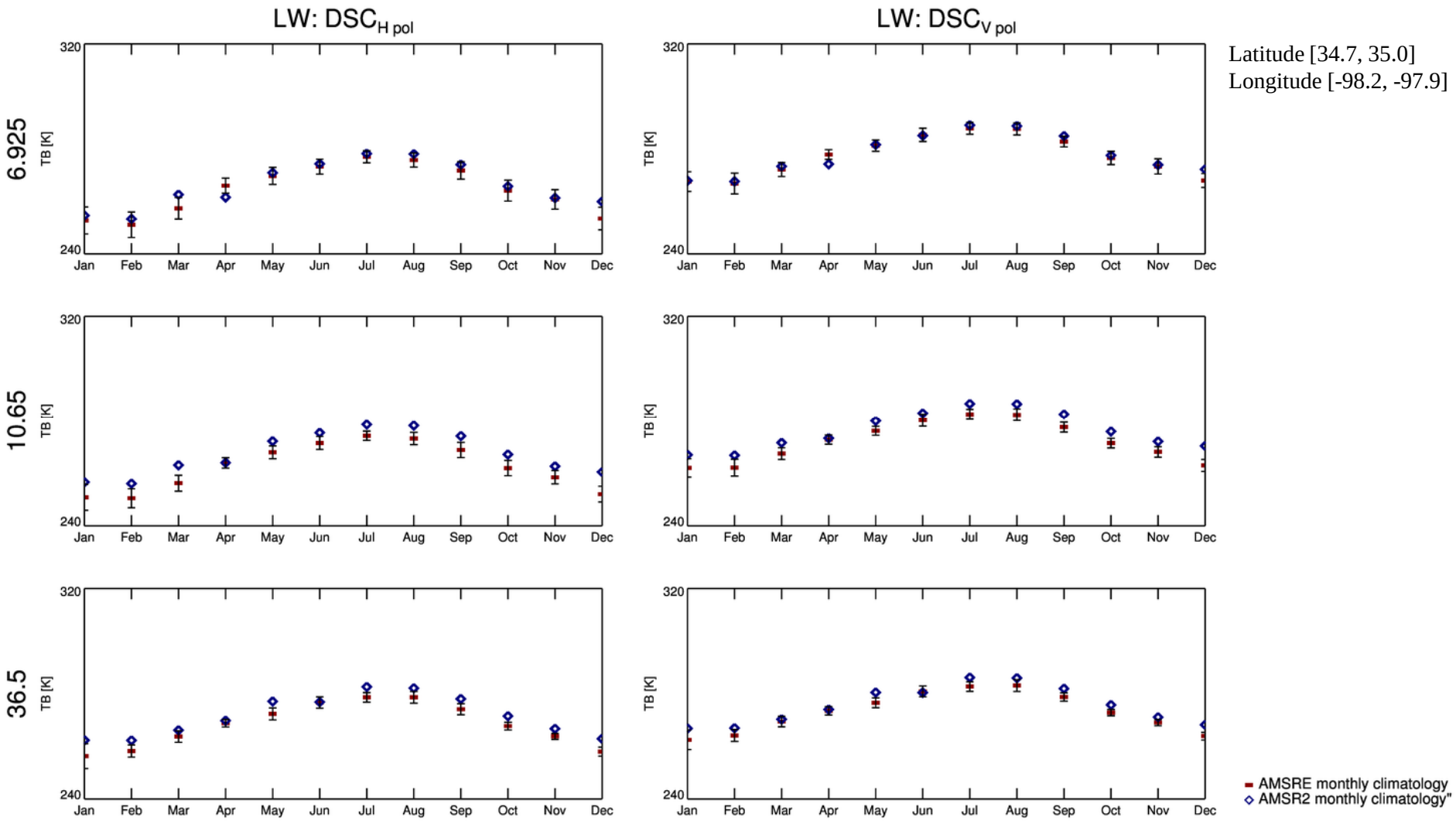
AMSR-E (NASA) Climatology vs. AMSR2 at Selected Sites: Targets

- Amazon
  - High TB values
  - Small month to month changes
  - Low variability between years
- Dome-C
  - Low (Land) TB values
  - Consistent month to month changes associated with seasons
  - Some year to year variability
- Ocean
  - Low TB Values
- Watersheds
  - Range of TB
  - Seasonal effects of temperature and vegetation
  - Targets

AMSR-E (NASA) Climatology vs. AMSR2 at Selected Sites: Evaluations

- Is there much variation year to year for AMSR-E?
  - Low variability would help concluding that any observed difference with AMSR2 is calibration.
- Does the limited AMSR2 data fall within the range based on the AMSR-E SD?
  - If the AMSR2 monthly mean fall outside the SD, it would support concluding that any observed difference with AMSR2 is calibration.
- Are these consistent over all months and sites?
  - The more months and sites that exhibit a consistent pattern, would help concluding that any observed difference with AMSR2 is calibration.
- Specific channels?

AMSR-E (NASA) Climatology vs. AMSR2 at Selected Sites: LW



AMSR-E (NASA) Climatology vs. AMSR2: Watershed Site Bias

	H-pol		V-pol	
f	Asc	Desc	Asc	Desc
6.925	0.75	1.41	-1.12	0.27
10.65	3.92	4.62	2.75	3.67
18.7	1.42	1.48	0.95	1.75
23.8	3.00	3.12	2.24	2.59
36.5	2.15	2.57	1.51	1.93

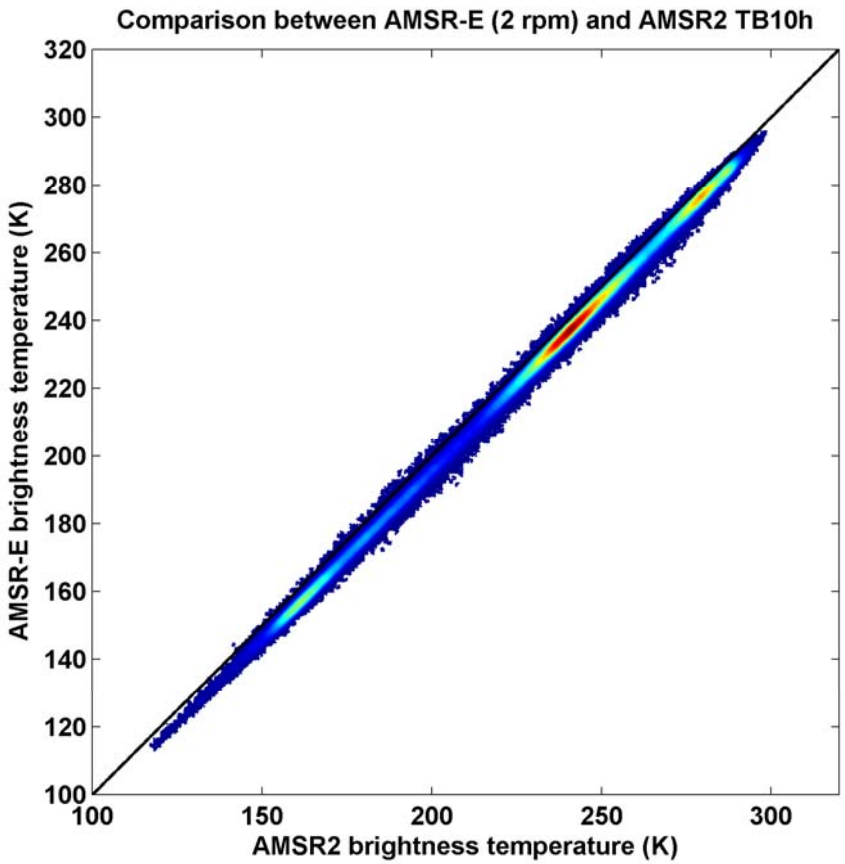
AMSR-E (NASA) Climatology vs. AMSR2 at Selected Sites: Summary

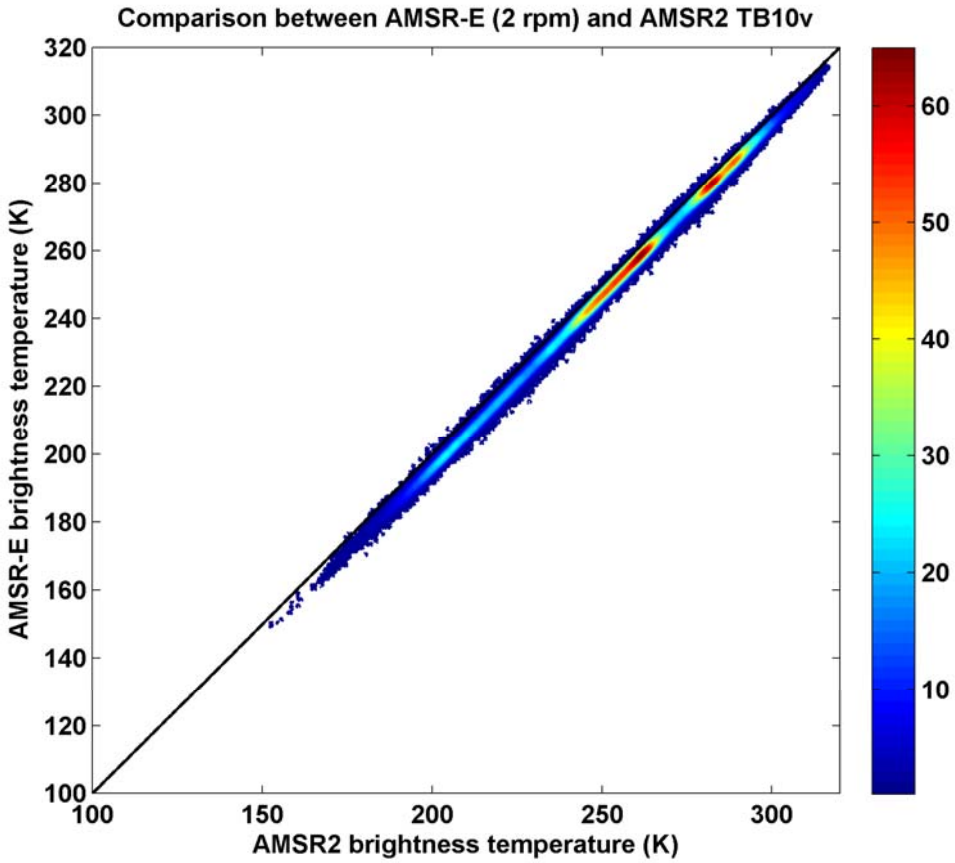
- Overall, there is consistent bias in the AMSR2 versus the AMSR-E (NASA) products
  - 10.65 and 36 GHz appear to have the largest bias. (“Soil Moisture “ Channels)
  - The Amazon has a lower level of bias
  - 6.9 GHz bias appears to be related to TB level (gain)
- Remember that this is a comparison to climatology. The conclusions are based upon
  - The AMSR2 monthly means fall beyond the SD found for AMSR-E (NASA) for a wide range of conditions.
  - Consistent for all months

AMSR-E 2 rpm TB vs. AMSR2 TB Global: Approach

- Two radiometers operating at the same frequency should produce a consistent brightness temperature EDR
- Co-located AMSR-E and AMSR2 observations
  - Spatial distance between footprint boresight of < 500 m: Same location
  - Temporal difference of less than 5 min (Nominal difference between AMSR-E and AMSR2 is 3-4 min): Eliminates changes in surface properties
- AMSR2: L1B dataset
- AMSR-E (2 rpm): L1S dataset
- Period available: 12/2012-2/2013 (3 months)
- Land only and global analyses

Density Plot of Comparison between AMSR-E 2 rpm and AMSR2 (Land-10 GHz)

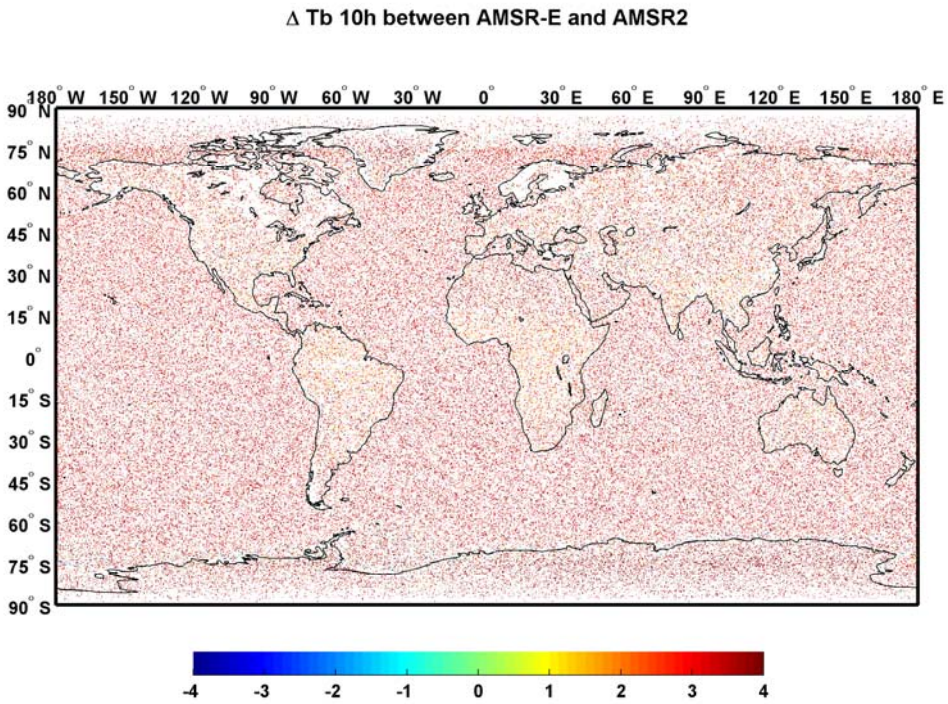


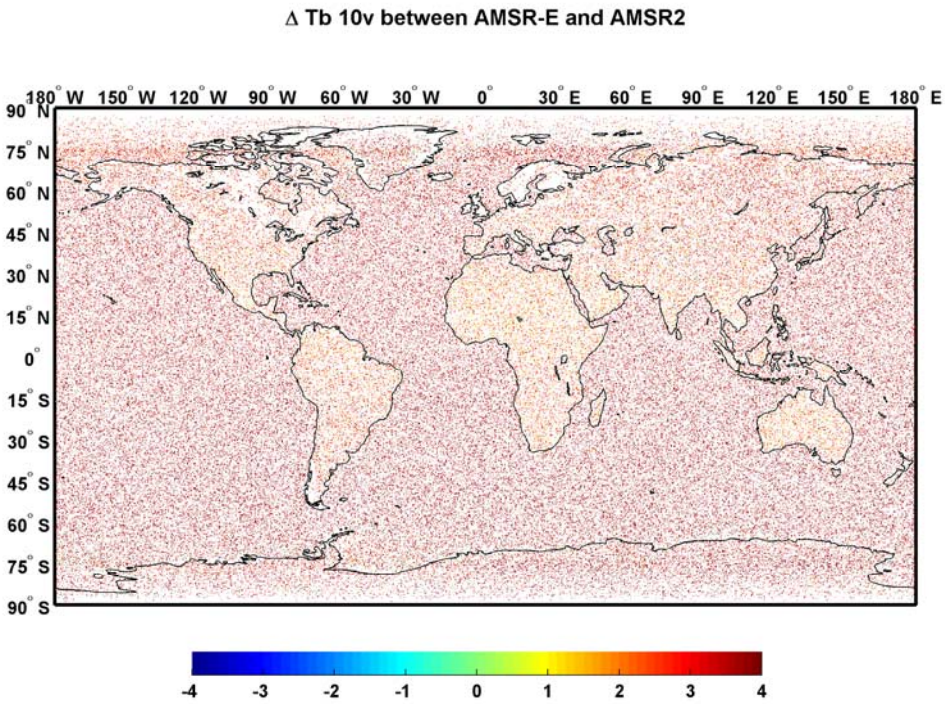


Comparison between AMSR-E 2 rpm and AMSR2 over Land: Summary Statistics

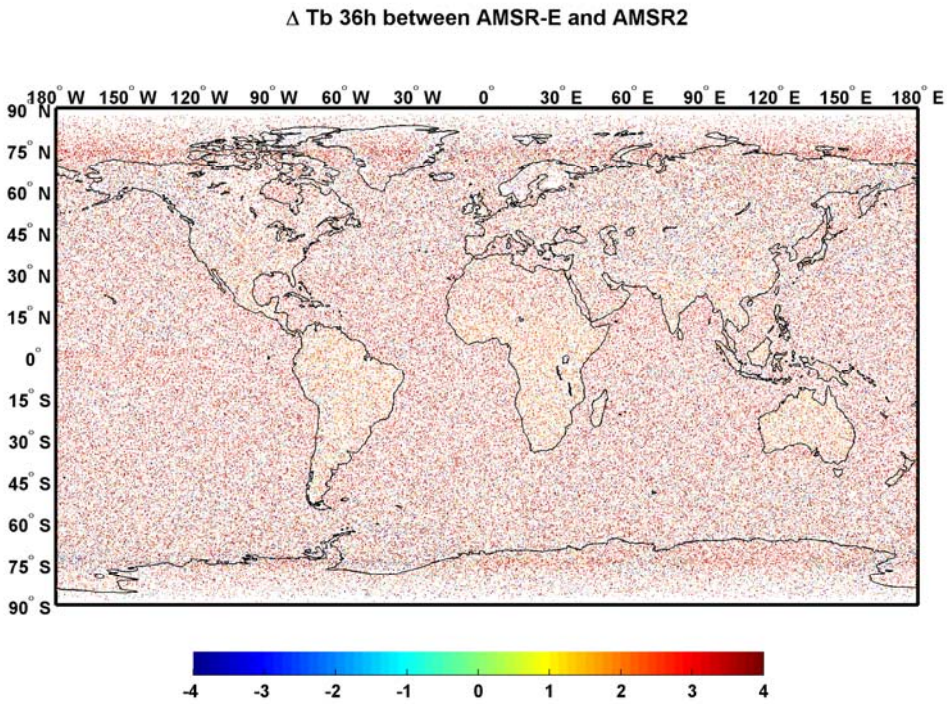
		RMSD (K)	R	Bias [AMSR2-AMSR-E] (K)	N
H pol	6.9 GHz	2.10	0.9992	1.17	545056
	10 GHz	4.11	0.9990	3.67	522519
	18 GHz	2.32	0.9987	0.52	526352
	23 GHz	2.86	0.9988	2.06	551870
	36 GHz	4.35	0.9970	3.13	694179
V pol	6.9 GHz	1.35	0.9991	0.09	547543
	10 GHz	3.55	0.9989	3.20	524774
	18 GHz	2.71	0.9986	1.33	528564
	23 GHz	2.43	0.9988	1.88	553709
	36 GHz	4.10	0.9970	3.17	696657

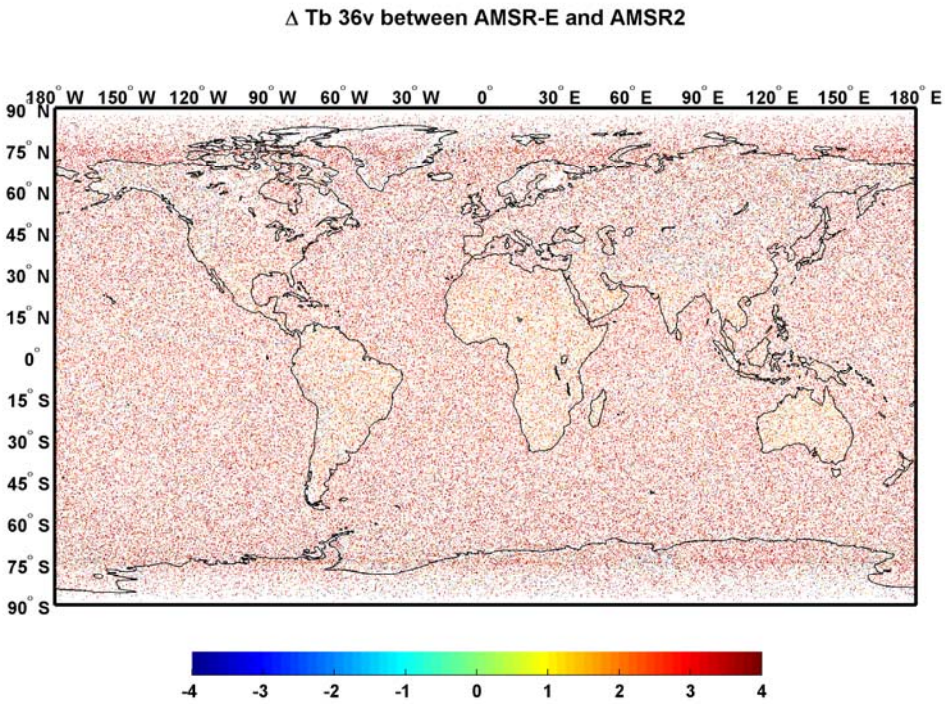
Comparison Between AMSR-E 2 rpm and AMSR2 (Global-10 GHz)





Comparison Between AMSR-E 2 rpm and AMSR2 (Global-36 GHz)





Comparison between AMSR-E 2 rpm and AMSR2: Global Summary Statistics

		RMSD (K)	R	Bias [AMSR2-AMSR-E] (K)	N
H pol	6.9 GHz	2.10	0.9998	1.60	1851075
	10 GHz	3.57	0.9997	3.22	1727369
	18 GHz	2.24	0.9991	0.55	1740091
	23 GHz	3.01	0.9988	2.26	1788184
	36 GHz	4.54	0.9961	2.93	2247598
V pol	6.9 GHz	1.31	0.9997	0.65	1859799
	10 GHz	3.55	0.9994	3.29	1735804
	18 GHz	3.08	0.9986	2.38	1751239
	23 GHz	2.35	0.9985	1.95	1795501
	36 GHz	3.62	0.9946	2.86	2258926

Re-calibration of AMSR2 Using AMSR-E 2 rpm

		Gain (m)	Offset (c)
H pol	6.9 GHz	1.0067	-2.4453
	10 GHz	0.9993	-3.1296
	18 GHz	1.0045	-1.2292
	23 GHz	1.0078	-3.6499
	36 GHz	0.9997	-2.8695
V pol	6.9 GHz	1.0121	-2.8465
	10 GHz	1.0006	-3.2533
	18 GHz	1.0114	-4.5807
	23 GHz	1.0047	-2.9403
	36 GHz	1.0050	-3.9107

- These gain and offset numbers were computed using co-located AMSR-E 2 rpm and AMSR2 observations. Assuming AMSR-E (2 rpm) calibration was correct.
- Best to constrain the low TB end using cold sky calibration from both the sensors. Gain and offset should be re-computed after constraining the low end.

Comparison Between AMSR-E 2 rpm and AMSR2: Summary

- Scatter possibly due to:
  - RFI
  - Heterogeneous footprint
  - Noise in AMSR-E 2 rpm and AMSR2 data
- Very high correlation between AMSR-E 2 rpm and AMSR2
- Consistent warm bias in AMSR2 observations (as compared to AMSR-E 2 rpm)
- Most of the RMSD is due to the systematic bias
- Consistent for both land and ocean observations
- How do cold sky observations for AMSR2 and AMSR-E 2 rpm instruments compare?
- Is the warm bias due to offset or gain+offset error?
- Warm bias may lead to inconsistent CDR across AMSR-E 2rpm and AMSR2 missions
- **Waiting to see what decisions JAXA makes on recalibration.....**

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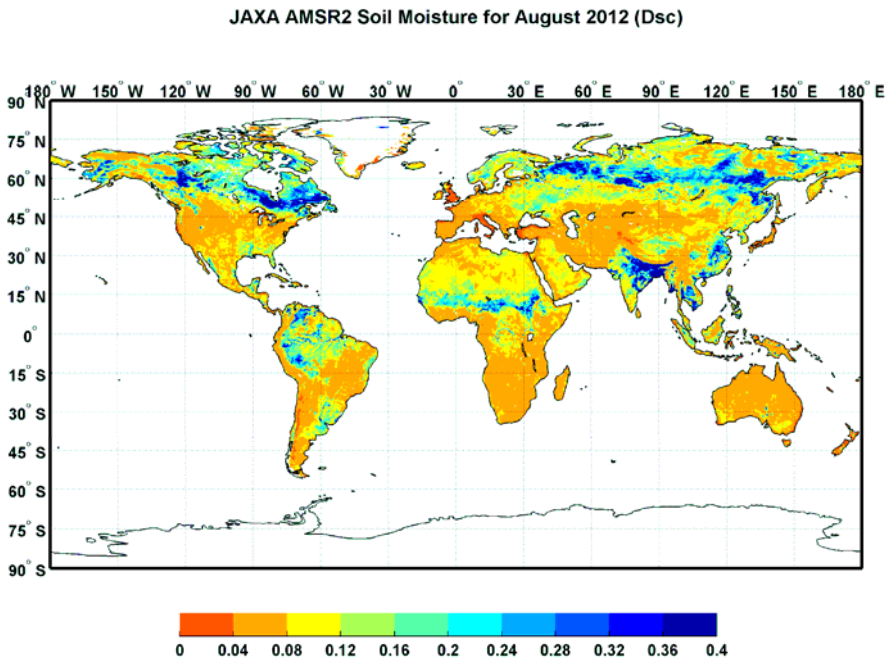
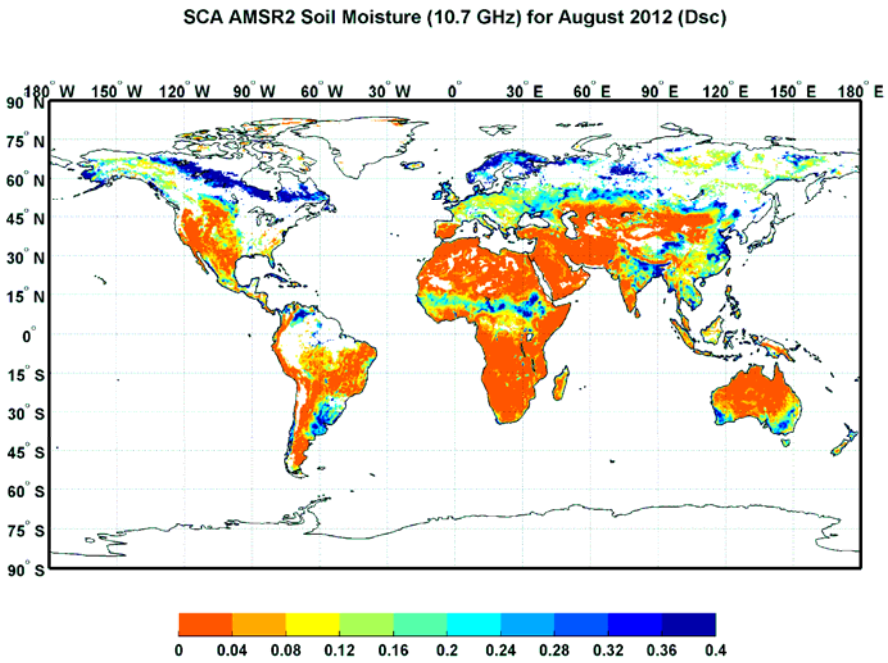
  - SCA and long-term watershed sites
  - New sites
  - JAXA AMSR2 product
- NASA Algorithm Improvement Study
  - Summary comments
  - NASA product update

Research Soil Moisture Algorithm: Single Channel Algorithm (SCA)

- Description: Provides soil moisture using 10 GHz H channel combined with Land surface temperature estimated from 36 GHz V and several static ancillary data inputs.
- Maturity: This is a mature algorithm. Versions have been implemented by NASA for AMSR-E and Aquarius SM products. It is the baseline for the SMAP radiometer-only SM product.
- Implementation: It has been implemented with AMSR2.
  - Additional improvements (including a possible LST product) are on hold until all calibration issues are resolved.
  - Post-launch assessment of the new AMSR2 C-band channels (RFI) does not provide strong support for replacing 10 GHz in algorithm.
- Goal Accuracy: 0.06 m^3/m^3 for regions with vegetation water contents (VWC) < 2 kg/m^2, 0.10 m^3/m^3 for VWC 2-5 kg/m^2.
- Validation
  - Inter-comparisons with Aquarius, SMOS, and SMAP SM products
  - Ongoing using established watershed sites. Adding new sites over the next year.

Global Comparison of SCA and JAXA Standard Soil Moisture Products from AMSR2



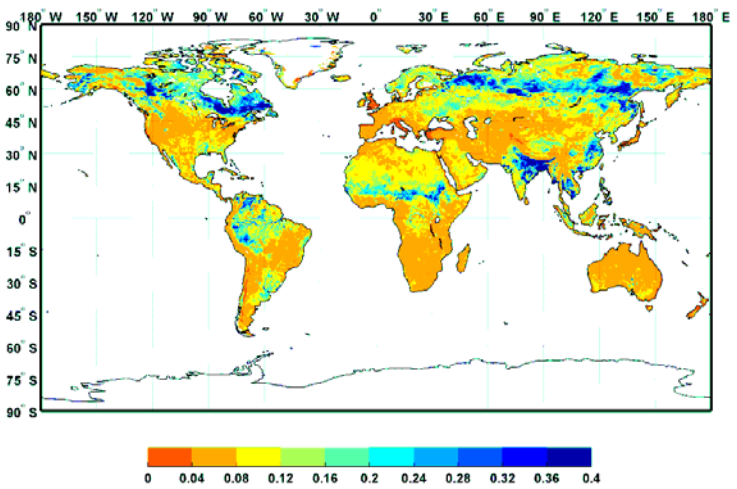


- Overall spatial structure is similar (arid areas are dryer, Northern latitude and forested areas are wetter)
- Arid areas are dryer in SCA retrievals
- Greater range of soil moisture in SCA retrievals

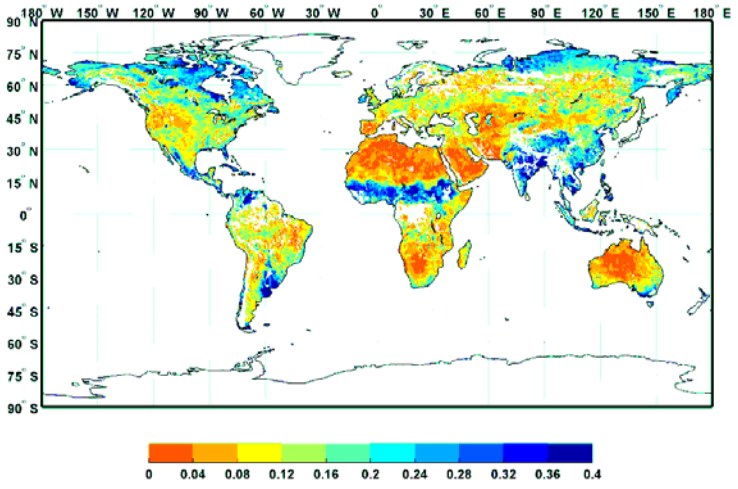
AMSR2, SMOS and Aquarius Soil Moisture Products

Global comparisons to other satellite products indicates consistency in temporal and spatial patterns but differences in levels.

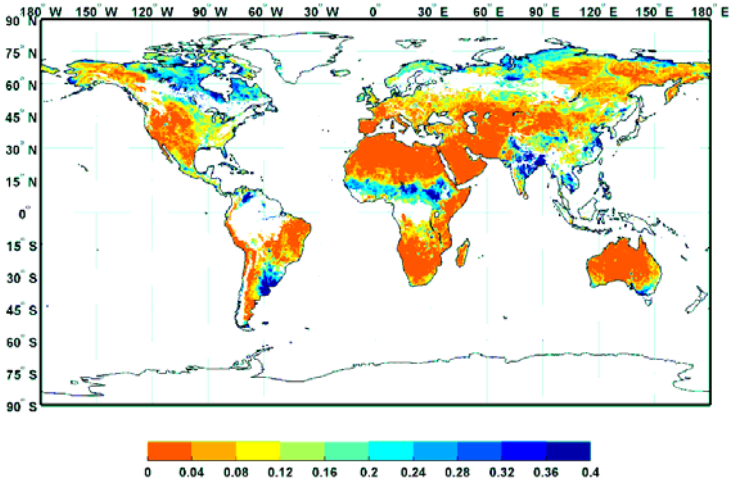
JAXA AMSR2 Soil Moisture for August 2012 (Dsc)



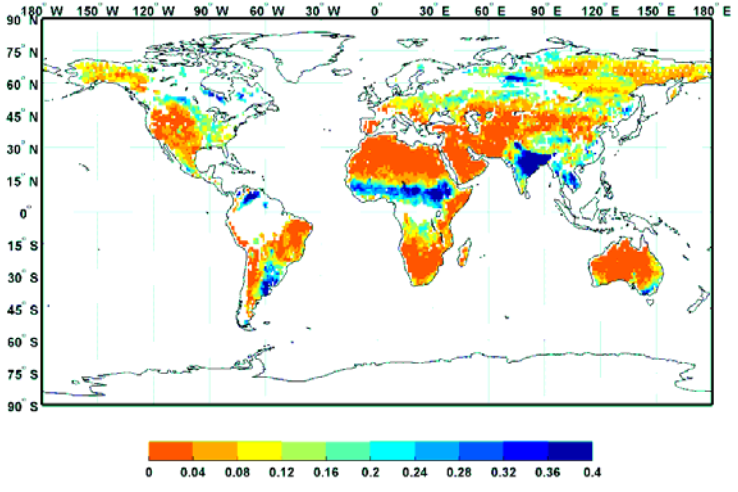
SMOS (ESA) Soil Moisture for August 2012 (Asc)



SMOS (SCA) Soil Moisture for August 2012 (Asc)

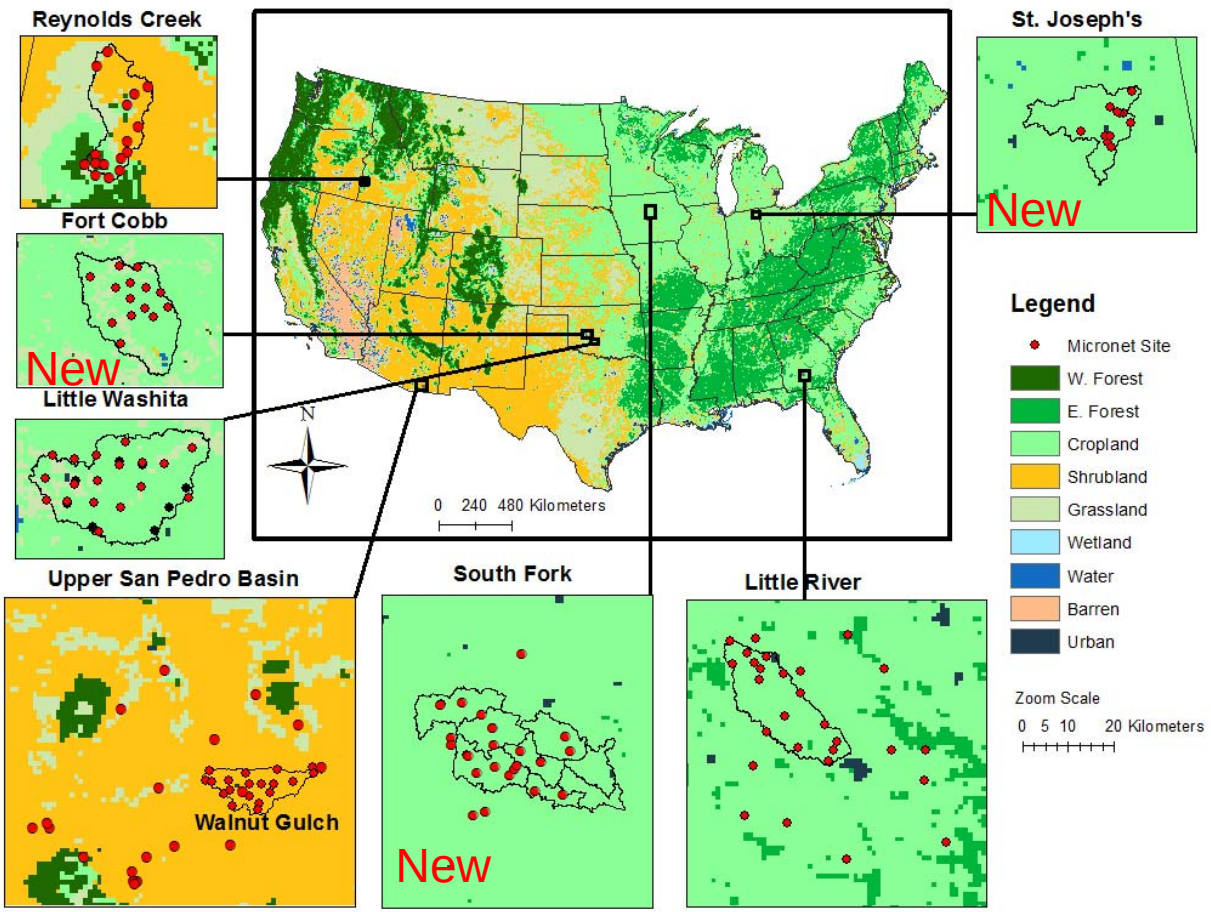


Aquarius (SCA) Soil Moisture for August 2012



Update on USDA ARS Validation Sites

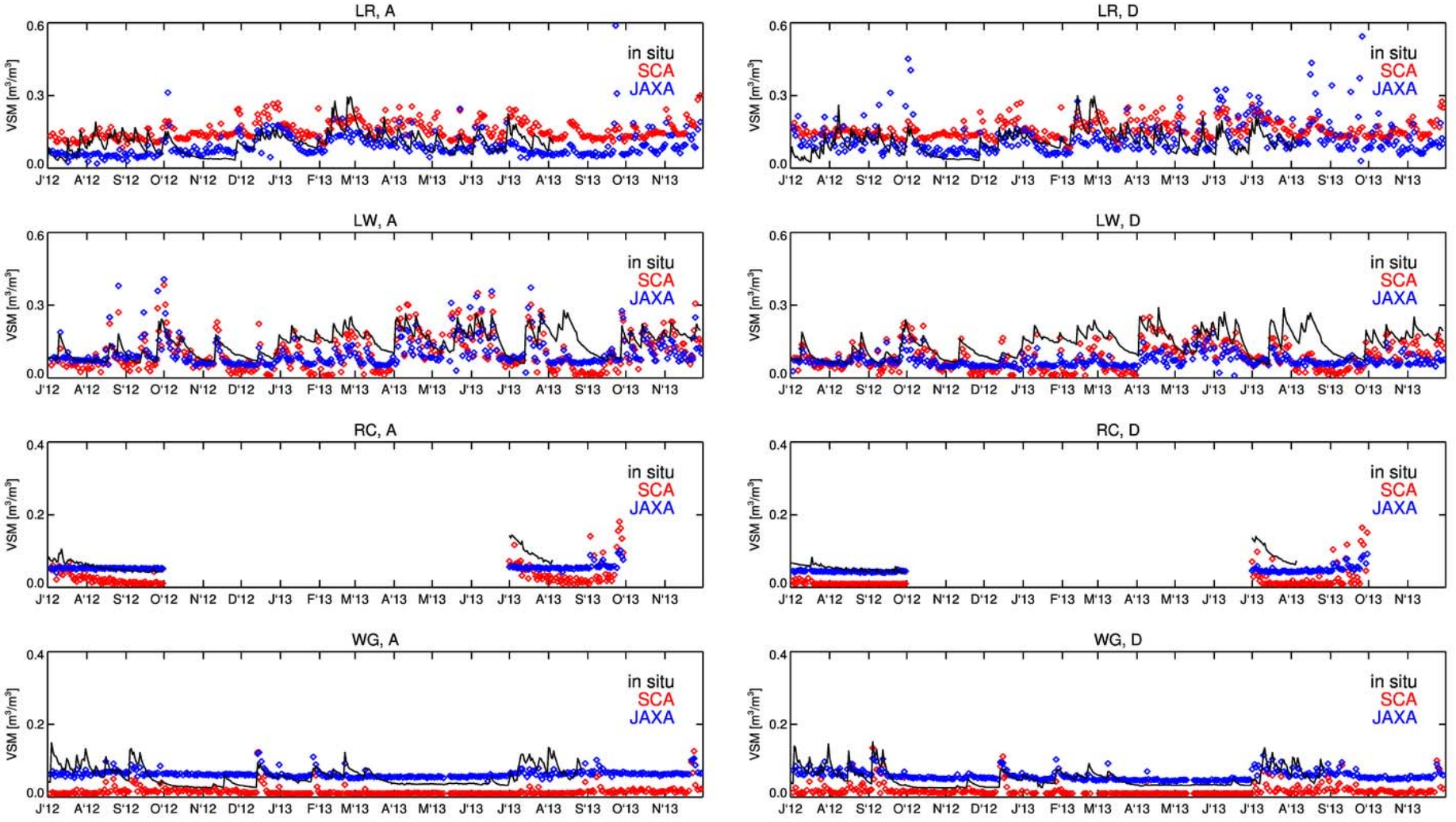
- Continuing record for the *four* USDA ARS sites distributed across the U.S. in different climate regions providing surface soil moisture.
- New sites available that are undergoing quality control (Fort Cobb, OK and St. Joseph, IN).
- Another site is being established (South Fork, Iowa).



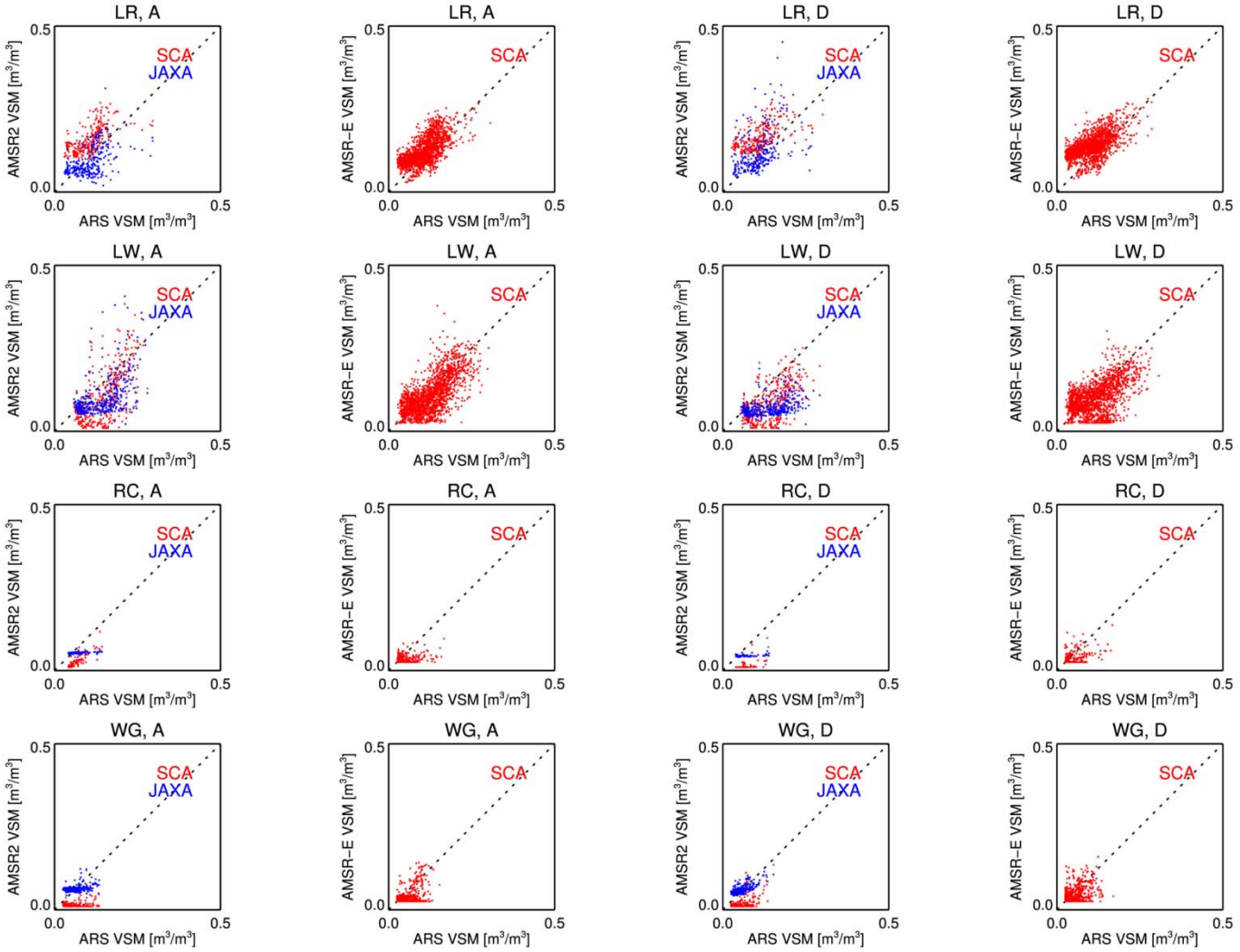
Validation of AMSR2 SCA and JAXA Standard Product

- Data sets used
  - AMSR2: July 2012 - November 2013
  - AMSR-E paper: June 2002 - July 2009
- Time series plots
- Observed versus Estimated plots
- Summary statistics
- Comments

Time Series of AMSR2 SCA and JAXA Standard Product



Estimated vs. Observed AMSR2 SCA and JAXA Standard Product



Summary Statistics for the AMSR2 SCA and JAXA Standard Products

		AMSR2				AMSR-E (*Jackson et al. 2010*)			
		A		D		A		D	
		SCA	JAXA	SCA	JAXA	SCA	JAXA	SCA	JAXA
LR	*R*	0.594	0.501	0.553	0.462	0.590	0.231	0.673	0.332
	RMSE	0.065	0.046	0.068	0.061	0.051	0.088	0.038	0.059
	Bias	0.052	-0.013	0.054	0.014	0.034	0.046	0.018	0.021
LW	*R*	0.634	0.5	0.583	0.423	0.528	0.343	0.676	0.429
	RMSE	0.071	0.07	0.074	0.083	0.053	0.089	0.047	0.090
	Bias	-0.04	-0.041	-0.056	-0.067	-0.017	0.043	-0.015	0.054
RC	*R*	0.829	0.413	0.57	0.408	0.460	0.219	0.406	-0.033
	RMSE	0.042	0.03	0.054	0.031	0.024	0.066	0.026	0.105
	Bias	-0.039	-0.016	-0.05	-0.02	-0.011	0.045	-0.014	0.079
WG	*R*	0.231	0.428	0.553	0.77	0.495	0.717	0.444	0.534
	RMSE	0.051	0.025	0.039	0.018	0.021	0.042	0.026	0.037
	Bias	-0.044	0.004	-0.033	0.008	-0.008	0.033	-0.015	0.030

		AMSR2		AMSR-E (*Jackson et al 2010*)	
		SCA	JAXA	SCA	JAXA
Summary Performance	*R*	0.605	0.499	0.778	0.556
	RMSE	0.062	0.056	0.040	0.073
	Bias	-0.019	-0.020	-0.002	0.040

Summary: Validation of the AMSR2 SCA and JAXA Standard Products

- Be careful until there are a few years of data
- The JAXA Standard product for AMSR2 shows considerable improvement from the AMSR-E version.
  - In particular there is a reduction in the bias contribution to error.
  - RMSE is within the target accuracy range!
- SCA performance indicates a larger bias than AMSR-E.
  - This might be expected because the same algorithm is used for AMSR2 and AMSR-E and there is a TB bias that has not been resolved yet.

Evaluation and Improvement of the NASA Aqua/AMSR-E Soil Moisture Algorithm

- NASA Terra/Aqua project.
- Address known performance issues with the NASA “Standard” product.
- Evaluate the performance of the NASA AMSR-E standard algorithm using ground based measurements, and assess its performance against *alternative algorithms*.
- Identify algorithm improvement options and select.
- Product Continuity to AMSR2.

NOTE: New name! “Standard” is now Normalized Polarization Difference (NPD)

Algorithm Improvement Options

1. Do nothing…
   - Keep the NPD algorithm and the AMSR-E SM database as is.
   - Distribution of a product with limited usefulness for a number of applications.
2. Modify the final product (statistical rescaling)
   - Best results achieved when combining 2 re-scaling techniques: Total Least Squares and Min/Max.
   - Addresses the shortcomings of the current NPD retrievals, however, requires accurate global long-term reference dataset.

★ 3. Modify the NPD algorithm (based on theory)

★ 4. Switch to/Adding an alternative retrieval approach
   - *The SCA will be added as a second SM product.*

SMAP Status
Launch Nov. 5, 2014