PROJECT INFORMATION:

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Inter-Comparison & Validation of Remote Sensing Satellite Based Soil Moisture Product

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Inter-Comparison and Validation of Remote Sensing Satellite Based Soil Moisture Product

Abstract

A statistical analysis for BLENDED Soil Moisture Operational Product System (SMOPS) soil moisture data was performed by comparing in-situ data from the Soil Climate Analysis Network (SCAN). The primary objective for SMOPS is to retrieve surface soil moisture using low-frequency microwave satellite sensors to assist in decision making within various sectors such as, farming, meteorology, hydrology, water resource management, urban development, and the military. Algorithms developed in the past to increase spatial and temporal coverage of the soil moisture observations were validated and compared with ground data in the United States (Fang et. al. 2016). However, lack of uniformity creates an issue when trying to apply these products in various sectors. SCAN data were from 216 data-collecting weather stations across the United States were implemented to assess the accuracy of BLENDED soil moisture data by recording the bias, mean squared error and linear correlation for a focus time period of January 2015 to its most recent possible measurements (June 2018). Results showed that some products had significant and commendable correlations, proving the accuracy of the satellite data, however, others did not, which can be attributed either to possible ground site discrepancies over the focus time period where surface soil moisture was not being recorded or to computational error.

Introduction

Soil Moisture is widely known for playing a major role in determining precipitation forecasts in weather models. The dynamic between land-atmosphere water and energy exchange processes can carry a significant effect on floods, droughts, harvest season, groundwater supply, etc. (Wagner et al., 1999). Although in-situ soil moisture measurements are often used because of their accuracy, precision, and ease of access, their accessibility is often a luxury of more developed countries while others face challenges in climate and weather prediction. Satellite-based soil moisture monitoring is a promising approach to assist in weather prediction, business models, and even in developing military strategy because soil moisture can be monitored over large spatial areas and over long periods of time.

The most extensively developed soil moisture products are based on passive microwave brightness temperature observations. Currently, several soil moisture products are available from passive microwave satellite systems including: Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-2), Soil Moisture and Ocean Salinity (SMOS) satellite, WindSat, and Advanced Scatterometer (ASCAT). Multiple satellite-based soil moisture products have been developed, but the main challenge has been the calibrating the precision and accuracy among satellite data.

SMOPS is an active system that uses multiple satellite technologies that differ based on its algorithmic and scientific approach as to how it accounts for surface soil moisture data. The Soil Moisture Operational Products System (SMOPS) is a blended soil moisture (SBSM) product, which is a combination of soil moisture products from WindSat, Advanced Scatterometer (ASCAT), and Soil Moisture and Ocean Salinity (SMOS).

SMOPS products have been diversely utilized in the past and will continue to be used for numerical weather predictions at the National Centers for Environmental Protection (NCEP) and the Association of Fish and Wildlife Agencies (AFWA), in determining world crop productivity forecasts at the United States Department of Agriculture (USDA) and to create water predictions at the National Weather Center (Zhan et. al. 2016).

The goal of this NERTO summer internship program was to create a program that would properly match and compare soil moisture readings on the ground and from BLENDED satellite data.

Methodology

The approach for validating soil moisture measurements at all available sites was to first obtain its historical data from the Natural Resources Conservation Service (NRCS) and create tabular data that uniformly displays necessary information, includes: timestamps, surface soil moisture and soil temperature at each respective timestamp. Organization of the data was very necessary due to the fact that surface soil moisture measurements were taken at varying depths beneath the soil, depending on the site location (Majority of measurements were taken at 2 centimeters below, but some were taken at 5 cm or 8 cm). An example of the tabular setup used for validation and processing shown in Figure 1. After this was complete, processing of the satellite data performed for each site. SMOPS BLENDED data were retrieved in a binary file that contains a 720x1440 cell-matrix that contains soil moisture values in a cell depending on its correlation with global geographic coordinates. A sample of the binary file shown in Figure 2. Once the matrix cell matched with the proper SCAN site based on its latitude and longitude, satellite soil moisture measurements were logged with its corresponding SCAN measurement for each particular timestamp.

Results and Discussion

Multiple efforts were made to ensure accuracy in matching the proper SCAN site with its respective satellite soil moisture value for a given timestamp for record purposes and for developing products for statistical analysis. The following statistical parameters were used to determine the validity of the BLENDED soil moisture product: the bias between measurements at a given timestamp, the biased and unbiased root mean square error, and finally the correlation coefficient to determine the overall strength of accuracy between the SCAN and BLENDED data. New inter-comparison graphs were considered plausible when verified with graphs from past publications for the year 2016. For example, Figure 3 (a-d) note the similarities in the data recorded in that year for a previously developed product and the new and improved product.

Overall, there were notable strengths in correlation for many of the sites, which is a positive sign for the idea of integrating BLENDED soil moisture data for various applications. Figures 4-8 show some of the more successfully processed sites. Very few sites may require more research into the accuracy of the weather station, the accuracy of the code used to process the data, and the legitimacy of the measurements taken over time. Areas with low correlation with in-situ soil moisture data need to improve based on statistical analysis provided in this study.

Outputs:

1. **Intern created new system(s) for enhancing functions at host office** *I collected national data offered by the Natural Resource Conservation Services to obtain and process ground data of surface soil moisture. I also developed a program that properly matches ground site measurements with its BLENDED satellite measurements based on latitude and longitude coordinates.*
2. **Intern generated new data for models or products for host office** *The uniformly formatted SCAN data will be useful in the processing of data from other SMOPS satellites (AMSR-2, etc.)*
3. **Intern delivered oral or poster presentation of internship project results** *On the last day of the NERTO internship, I presented all my procedures and results of my work to my project team.*
4. **Intern created new NOAA mission-aligned professional networks** *BLENDED data validation has potential use for the NYC Department of Environmental Protection***.**
5. **Intern Demonstrated new NOAA mission aligned core competencies** *Networking, presenting and biweekly deadlines enhanced my NERTO experience and contributed to achieving core competencies*.

Outcomes:

1. **Intern has new NOAA-mission and skills**
   Yes
2. **Intern demonstrated new/expanded competencies to conduct research and engage in NOAA mission aligned activities**
   Established skills in a new programming language (Python).
3. **Inter contributes to a diverse and highly skilled candidate pool for future workforce and pursues careers in disciplines that support NOAA mission enterprise.**
   Yes.

Acknowledgements

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Figures and Tables

Year	Month	Day	Hour	Precip	SM_2_	SM_4_	SM_8_	SM_20_	SM_40_	ST_2_
2015	1	2	14	-99.9	6.8	6.7	6.7	7.7	12.1	-2.1
2015	1	2	15	-99.9	6.9	6.3	7.2	7.7	12.3	-2
2015	1	2	16	-99.9	6.8	6.4	6.8	7.8	12.4	-1.9
2015	1	2	17	-99.9	7.1	6.5	6.9	7.8	12.3	-1.9
2015	1	2	18	-99.9	6.8	6.5	6.9	7.7	12.2	-1.9
2015	1	2	19	-99.9	7.1	6.6	6.6	7.9	12.3	-1.8
2015	1	2	20	-99.9	6.9	6.6	6.7	7.7	12.1	-1.8
2015	1	2	21	-99.9	6.9	7	7.1	7.6	12.2	-1.8
2015	1	2	22	-99.9	7	6.6	6.9	7.8	12.3	-1.7
2015	1	2	23	-99.9	7.2	6.8	7.3	7.7	12.4	-1.8
2015	1	3	0	-99.9	6.9	6.6	7	7.9	12.3	-2.1
2015	1	3	1	-99.9	6.7	6.6	7.1	7.4	12.2	-2.5
2015	1	3	2	-99.9	6.7	6.7	7.1	7.6	12.3	-2.9
2015	1	3	3	-99.9	6.7	6.1	7.1	8	12.1	-3.3
2015	1	3	4	-99.9	6.3	6.4	6.7	7.3	12.1	-3.6
2015	1	3	5	-99.9	6.7	6.1	7.1	7.6	12.1	-3.9
2015	1	3	6	-99.9	6.4	5.6	6.8	7.5	12.1	-4.2
2015	1	3	7	-99.9	6.4	6	6.9	8.1	12.3	-4.4
2015	1	3	8	-99.9	5.9	5.6	6.8	7.6	12.3	-4.7
2015	1	3	9	-99.9	6.1	5.5	6.7	7.6	12.3	-4.8
2015	1	3	10	-99.9	6.3	5.7	6.9	7.3	12.2	-4.9

Figure 1. Sample table for SCAN site soil characteristics . All SCAN sites are organized with headers, although some may have a different surface soil moisture depth.

dat_out - NumPy array

	671	672	673	674	675	676	677	678	679	680	681	682
293	-999	-999	0.1006	0.0889	0.0751	0.0631	0.0633	0.0685	0.0779	0.076	0.0678	0.0557
294	-999	-999	0.0895	0.0807	0.0674	0.0595	0.0628	0.0732	0.0797	0.0748	0.0664	0.0576
295	-999	-999	0.0782	0.0714	0.062	0.0578	0.062	0.0722	0.0711	0.0652	0.0576	0.0583
296	-999	-999	-999	0.0531	0.0535	0.0554	-999	0.0699	0.0678	0.0579	0.053	0.0536
297	-999	-999	-999	0.0504	0.0542	0.0588	0.0661	0.0643	0.0602	0.0519	0.0476	0.0489
298	-999	-999	-999	0.054	0.0596	0.0638	0.0702	0.0679	0.0686	0.0606	0.0539	0.0473
299	-999	-999	-999	0.0582	0.0658	0.068	0.0733	0.075	0.0805	0.0735	0.0636	0.0532
300	0.1293	-999	-999	-999	0.0753	0.0735	0.0741	0.0831	0.0976	0.0916	0.0816	0.0627
301	-999	-999	-999	-999	0.0847	0.0803	-999	-999	0.1105	0.0997	0.0913	0.0711
302	-999	-999	-999	-999	0.0805	0.0787	0.0811	0.0949	0.1109	0.1008	0.0942	0.0714
303	0.1554	-999	-999	-999	0.074	0.0734	0.0845	0.0952	0.1076	0.0955	0.0868	0.0706
304	-999	-999	0.0932	-999	0.0784	0.0775	0.0865	0.088	0.0913	0.0839	0.0773	0.068
305	-999	-999	0.097	0.0921	-999	0.0846	0.0835	0.0783	0.0772	0.0737	0.0708	0.0707
306	0.1182	0.113	0.1104	0.1121	0.1	0.0944	0.0848	0.0754	0.0731	0.0702	0.0744	0.0743
307	0.1419	0.1332	0.1216	-999	0.1099	0.0964	0.0755	0.0714	0.0746	0.0704	0.0749	0.0872
308	0.1509	0.1472	-999	-999	0.1525	-999	0.0922	0.0746	-999	0.0707	0.075	0.0901
309	0.185	-999	-999	-999	0.2011	0.1559	-999	-999	0.0649	0.064	-999	0.0961

Figure 2. Sample data from a binary file containing satellite based soil moisture measurements. Each cell accounts for a 0.25-degree radius in geographical coordinates.

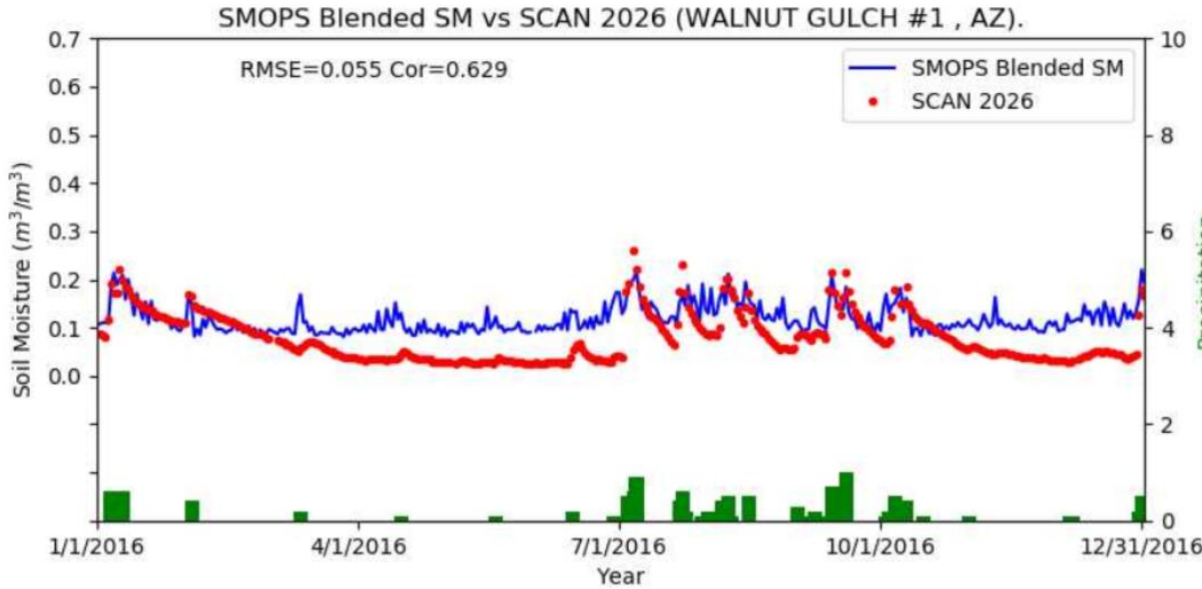

Figure 3a: Blended soil moisture for previously processed data in 2016.

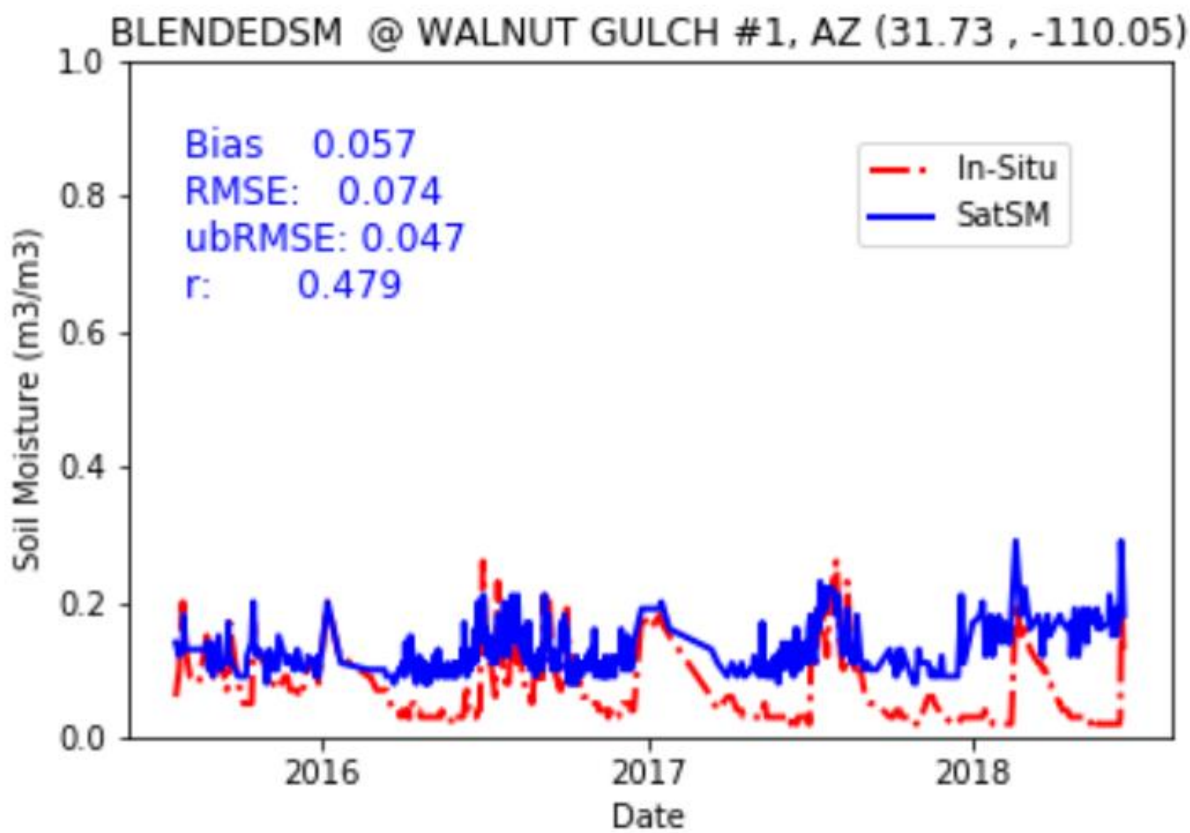

Figure 3b: Blended soil moisture for newly processed data from 2015-2018.

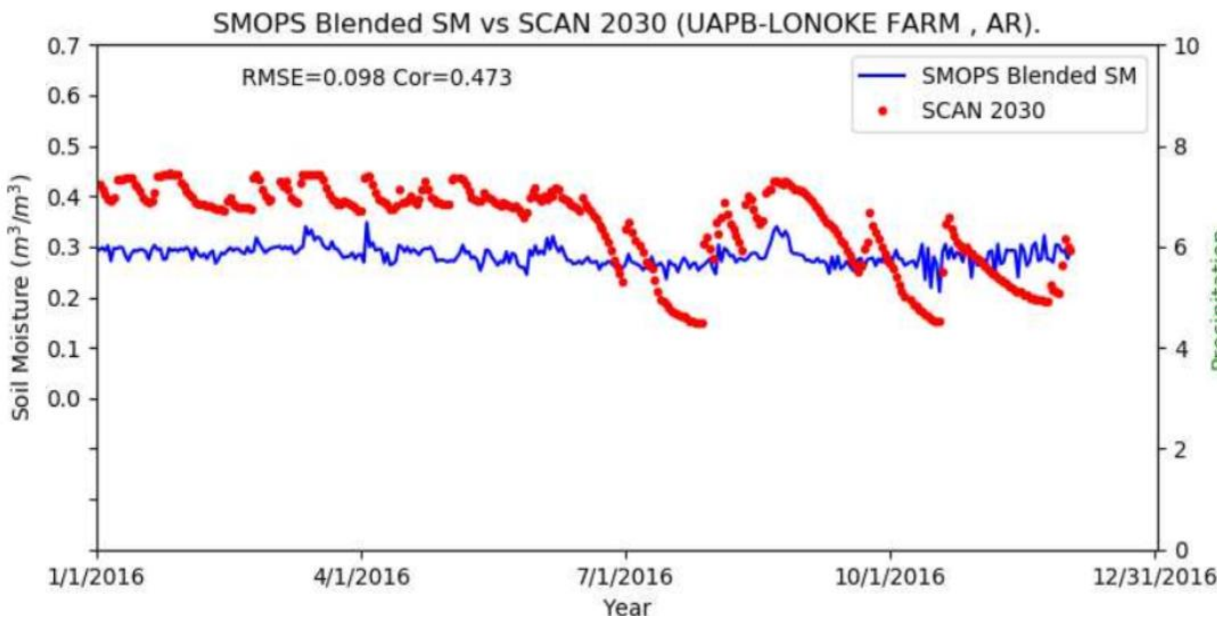

Figure 3c. Blended soil moisture for previously processed data in 2016.

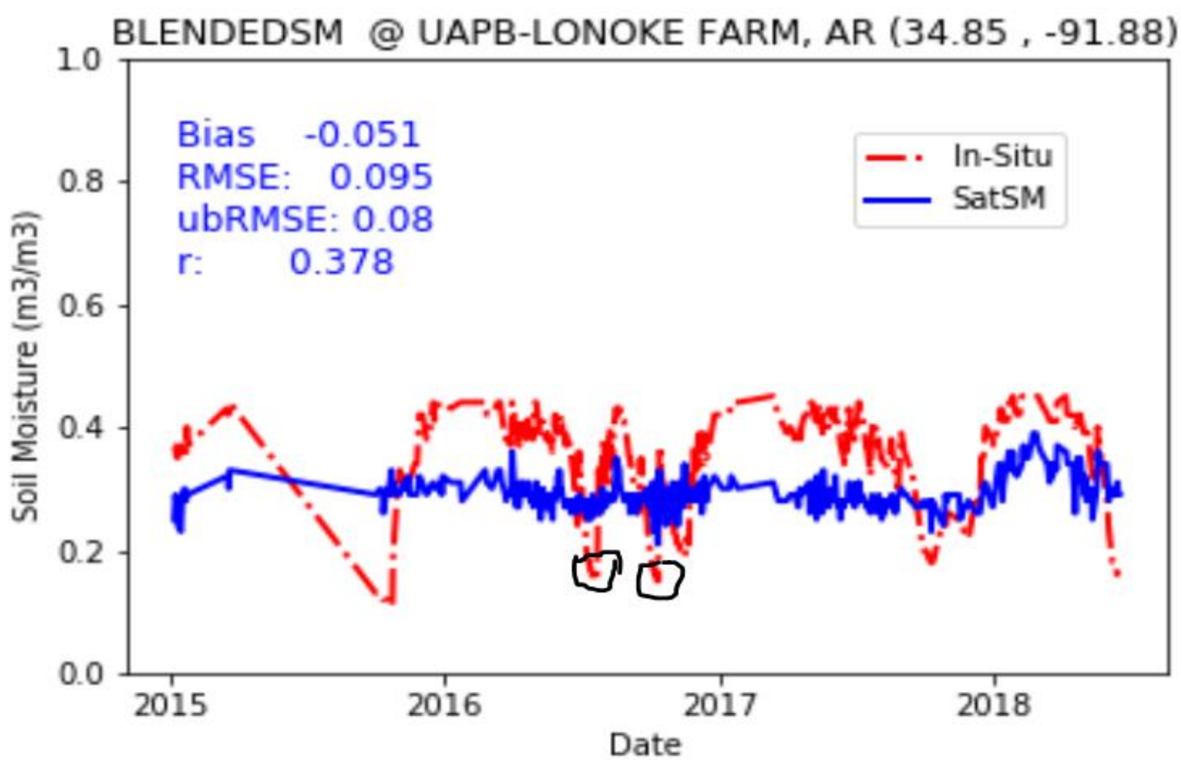

Figure 3d. Blended soil moisture for newly processed data from 2015-2018.

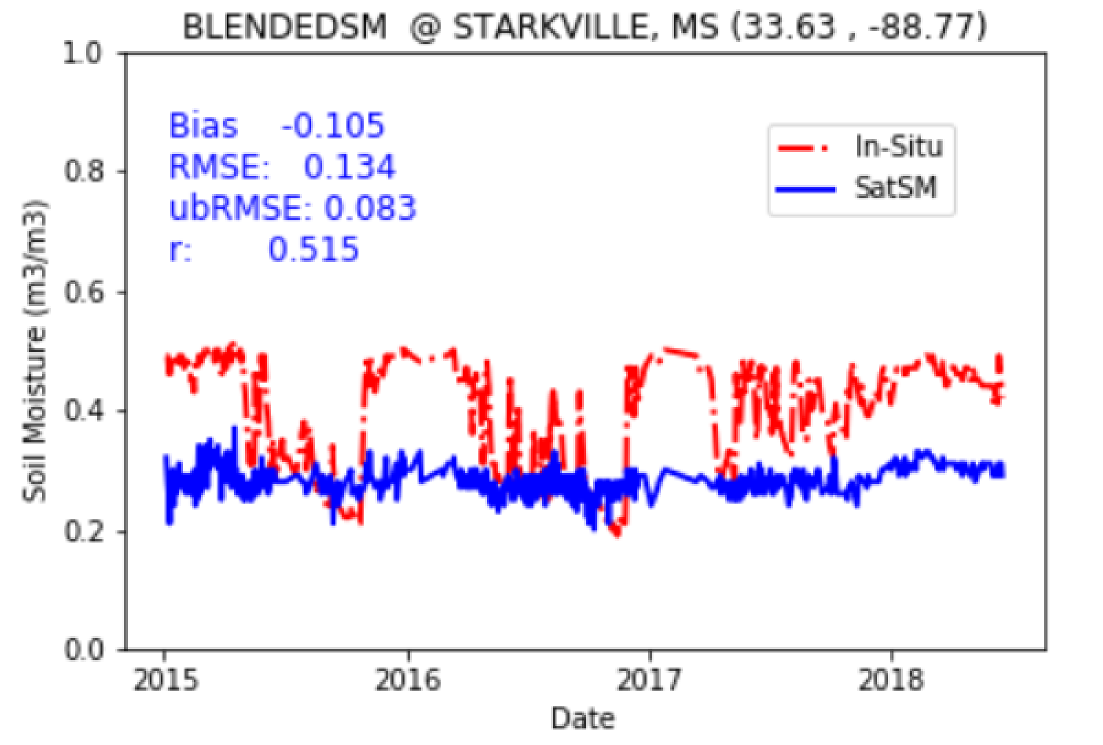

Figure 4. SCAN site data compared with Blended satellite-based data at a site in Mississippi.

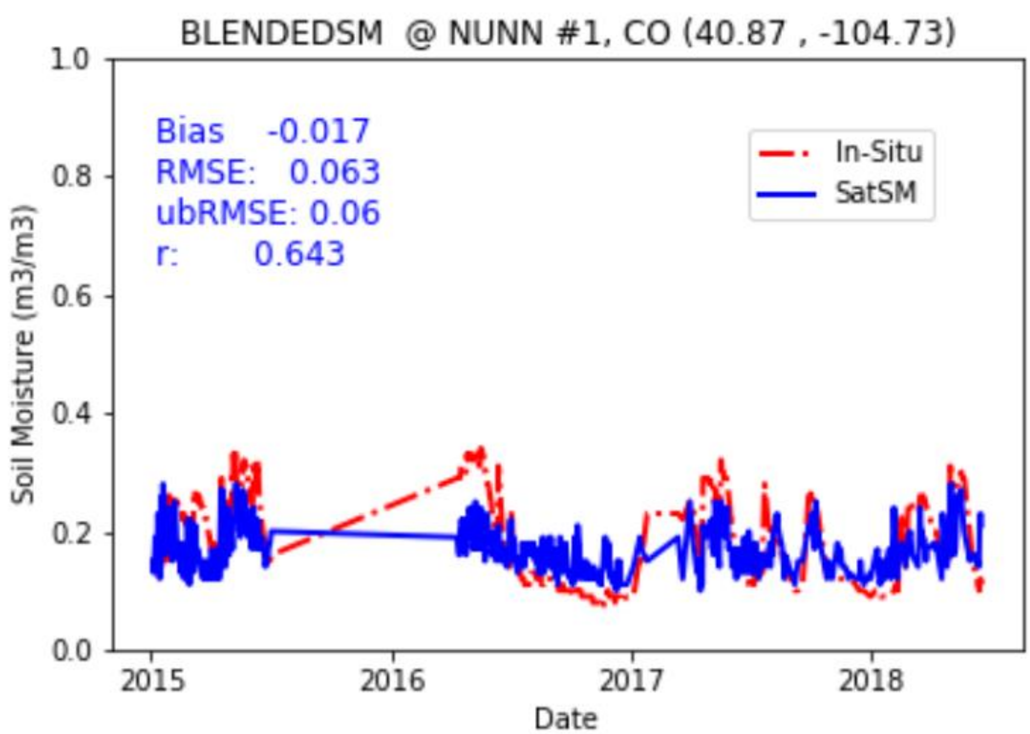

Figure 5. SCAN site data compared with Blended satellite-based data at a site in Colorado

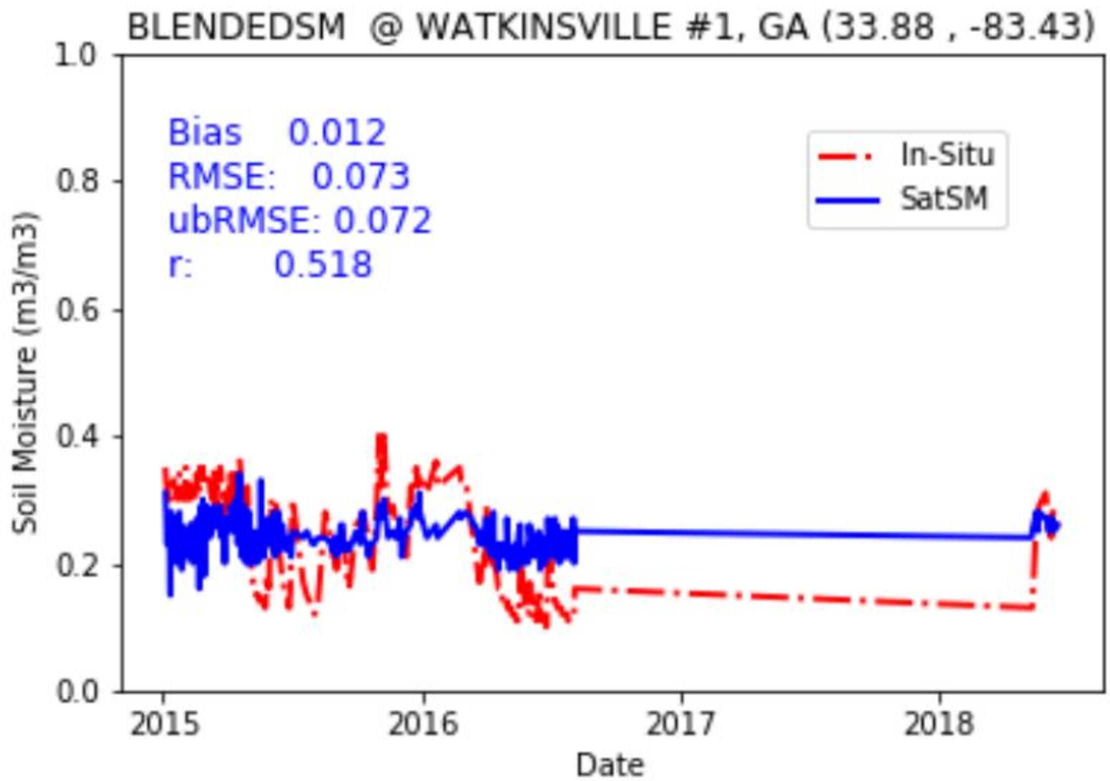

Figure 6. SCAN site data compared with Blended satellite-based data at a site in Georgia

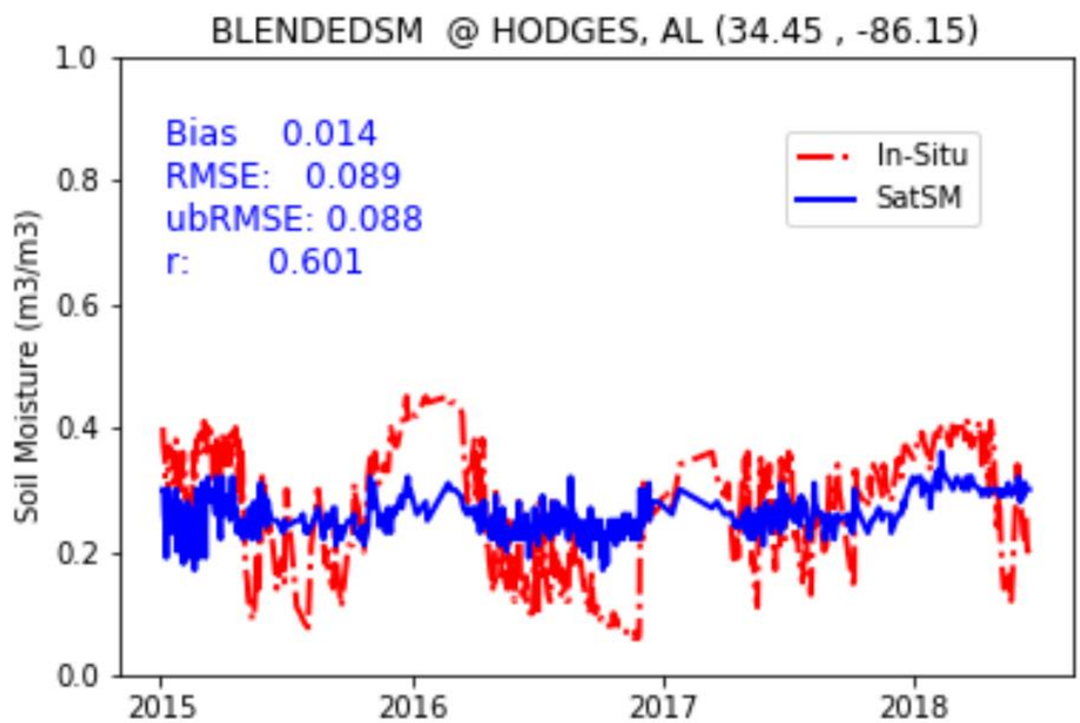

Figure 7. SCAN site data compared with Blended satellite-based data at a site in Alabama

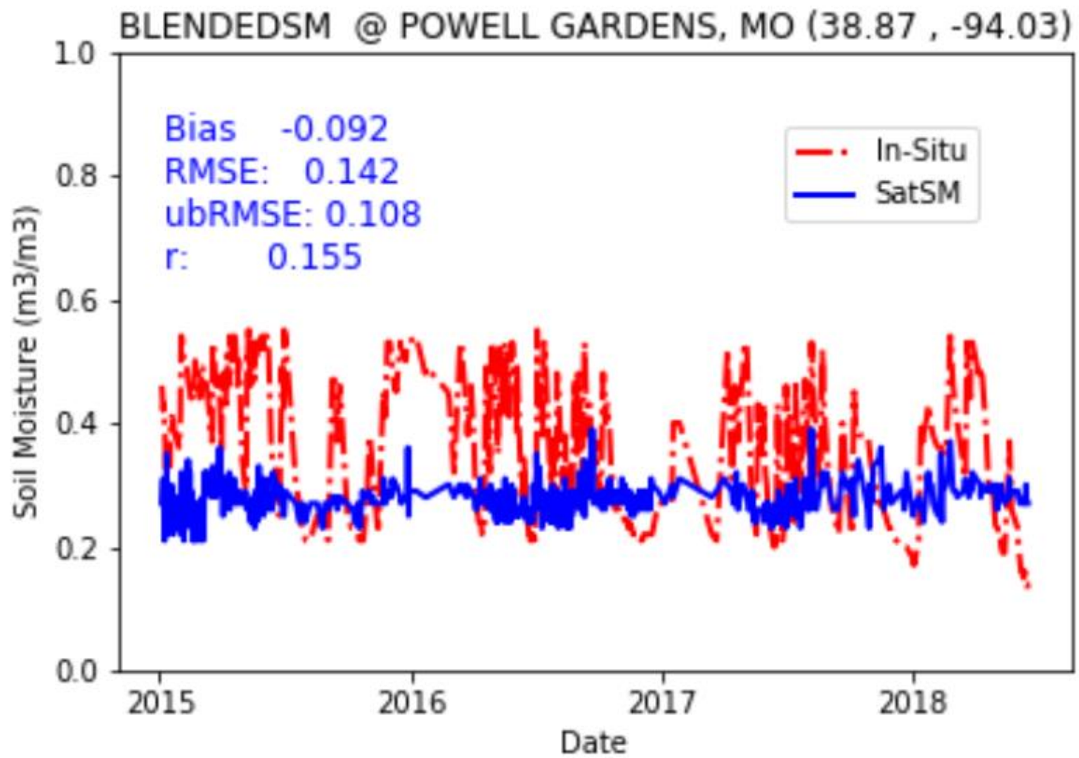

Figure 8. SCAN site data compared with Blended satellite-based data a site in Missouri

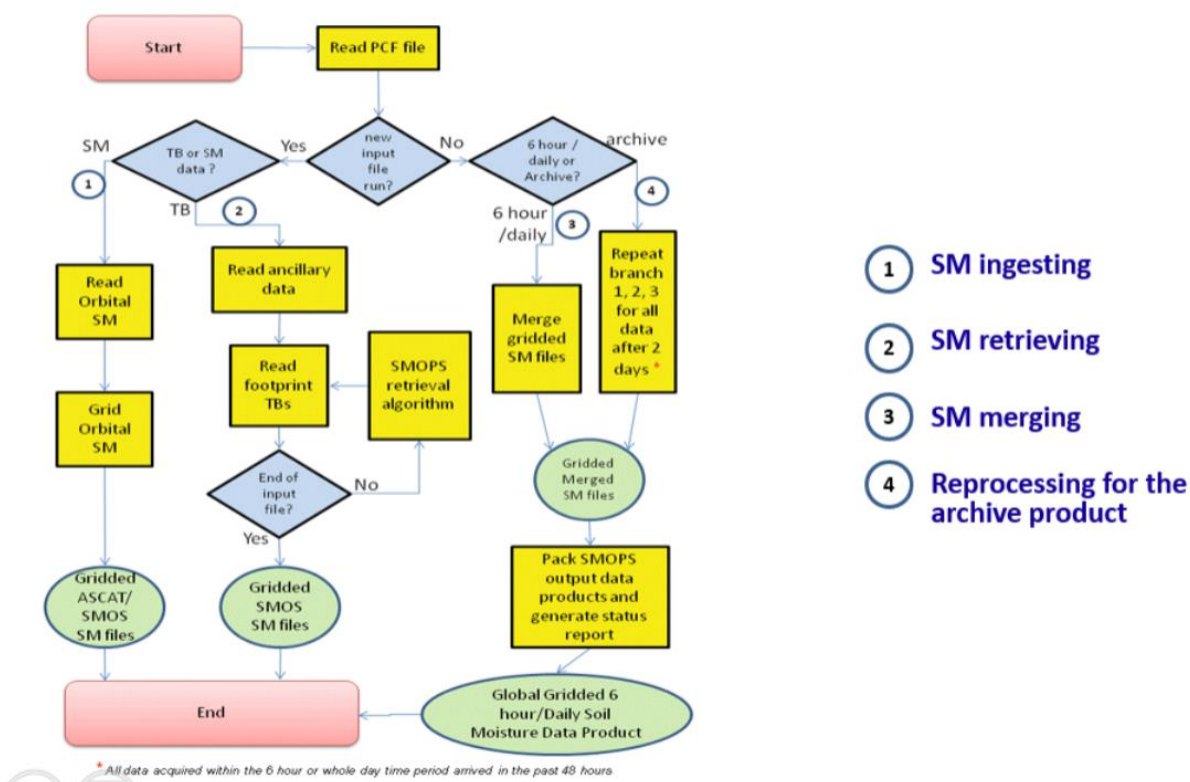

Figure 9. The sequence of processes in SMOPS that generates the various soil moisture products

Table 1. Various soil moisture products in the SMOPMS operational system and its various features.

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)