EVALUATION OF THE VALIDATED SOIL MOISTURE PRODUCT FROM THE SMAP RADIOMETER

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ABSTRACT

NASA's Soil Moisture Active Passive (SMAP) mission launched on January 31, 2015 into a sun-synchronous 6 am/6 pm orbit with an objective to produce global mapping of high-resolution soil moisture and freeze-thaw state every 2–3 days using an L-band (active) radar and an L-band (passive) radiometer. The SMAP radiometer began acquiring routine science data on March 31, 2015 and continues to operate nominally. SMAP's radiometer-derived soil moisture product (L2_SM_P) provides soil moisture estimates posted on a 36 km fixed Earth grid using brightness temperature observations from descending (6 am) passes and ancillary data. A beta quality version of L2_SM_P was released to the public in September, 2015, with the fully validated L2_SM_P soil moisture data expected to be released in May, 2016. Additional improvements (including optimization of retrieval algorithm parameters and upscaling approaches) and methodology expansions (including increasing the number of core sites, model-based intercomparisons, and results from several intensive field campaigns) are anticipated in moving from accuracy assessment of the beta quality data to an evaluation of the fully validated L2_SM_P data product.

Keywords (Index Terms) *-- soil moisture, passive microwave, SMAP, accuracy assessment, cal/val.*

*USDA, NASA, and JPL are equal opportunity employers.

1. INTRODUCTION

Soil moisture is a critical variable in land surface hydrology, and large-scale mapping of soil moisture based on microwave remote sensing will enable new science and applications of benefit to society. NASA's SMAP (Soil Moisture Active Passive) mission launched on January 31, 2015 with a goal of providing global mapping of soil moisture and freeze/thaw state every 2-3 days using data from an L-band radiometer (40 km resolution) and/or an L-band radar (3 km resolution) [1]. Routine science operations began on March 31 after two months of on-orbit check out. However, after ten weeks of science acquisitions, the SMAP radar stopped transmitting on July 7, 2015. The SMAP radiometer was not affected by the radar malfunction and continues to operate nominally today and produce passive-only estimates of soil moisture. SMAP continues the legacy of soil moisture measurements produced by ESA's ongoing L-band SMOS (Soil Moisture Ocean Salinity) mission. Although differing in the details of their algorithm approaches, passive-only soil moisture retrievals from both SMOS and SMAP are fundamentally based on the same *tau-omega* model [2,3].

Table 1. Key Orbital & Radiometer Specifications

Parameters	Values
Frequency	1.41 GHz
Polarization	H, V, 3rd and 4th Stokes Parameters
Instrument native resolution	38 km × 49 km (3-dB IFOV)
Radiometric uncertainty	1.3 K
Antenna diameter	6 meters (fully deployed)
Antenna rotation rate	14.6 rpm
Beam efficiency	~90%
Incidence angle	~40 degrees (from nadir)
Orbit type	Near-polar, sun-synchronous
Orbit repeat period	8-day exact repeat every 117 orbits
Orbit altitude	685 km
Orbit period	98.5 minutes
Swath width	~1,000 km
Local time des/asc node	6:00 am / 6:00 pm
Complete global coverage	Every 2-3 days (revisit interval)

2. SMAP L2_SM_P SOIL MOISTURE PRODUCT

The SMAP L2_SM_P product represents surface soil moisture in the top 0-5 cm soil layer. It is derived using SMAP L-band radiometer time-ordered observations (L1B_TB product) as its primary input. Table 1 summarizes the key instrument specifications of the SMAP radiometer as well as SMAP orbital parameters. Unlike previous L-band radiometers in space, the SMAP radiometer contains sophisticated digital hardware which enables a significant amount of radio frequency interference (RFI) to be mitigated, thus increasing the amount and spatial coverage of successful soil moisture retrievals.

At the start of the L2_SM_P processing, the Level 1 time-ordered brightness temperatures (TB) are remapped onto a 36-km Earth-fixed grid using Version 2 of the global cylindrical Equal-Area Scalable Earth Grid projection (EASE-Grid2) (SMAP L1C_TB product). A soil moisture retrieval algorithm is then applied to these gridded TBs in order to estimate soil moisture. The baseline L2_SM_P operational production uses observations acquired from SMAP 6:00 am descending passes only. Soil moisture estimates from the 6:00 pm ascending passes are also produced for validation analysis, but are not made available to the public at this time.

In addition to the TBs, a variety of static ancillary data (e.g. water fraction, soil texture, land cover classification, vegetation index climatology) and dynamic ancillary data (e.g. near real-time soil temperature, freeze/thaw state, rainfall intensity) are also ingested [3]. These ancillary datasets provide information necessary for geophysical inversion and also for data flagging that may indicate anomalous issues that may affect product accuracy and usability. The L2_SM_P product contains retrieved soil moisture and TBs along with other fields carrying supplemental geolocation information, quality flags, and ancillary data. Detailed information about the L2_SM_P product can be found in the *SMAP L2_SM_P Product Specification Document* [4]. Figure 1 presents a 3-day global composite of SMAP L2_SM_P data, showing expected global wet and dry patterns (including flooding in Texas/Oklahoma in May, 2015).

At the present time, the SMAP Project is evaluating five soil moisture retrieval algorithms: Single Channel Algorithm-Horizontal (SCA-H), Single Channel Algorithm-Vertical (SCA-V), Dual Channel Algorithm (DCA), Microwave Polarization Ratio Algorithm (MPRA), and Extended Dual Channel Algorithm (E-DCA). A description of these algorithms can be found in the *SMAP L2_SM_P ATBD* [3]. Based on ongoing accuracy assessments and performance evaluations, at any point in time one of these algorithm approaches will be designated as the current baseline algorithm in the operational processing stream, although this designation may change in time as new information becomes available.

3. CALIBRATION/VALIDATION APPROACHES

During SMAP's post-launch cal/val phase, the SMAP L2_SM_P team is focused on (1)

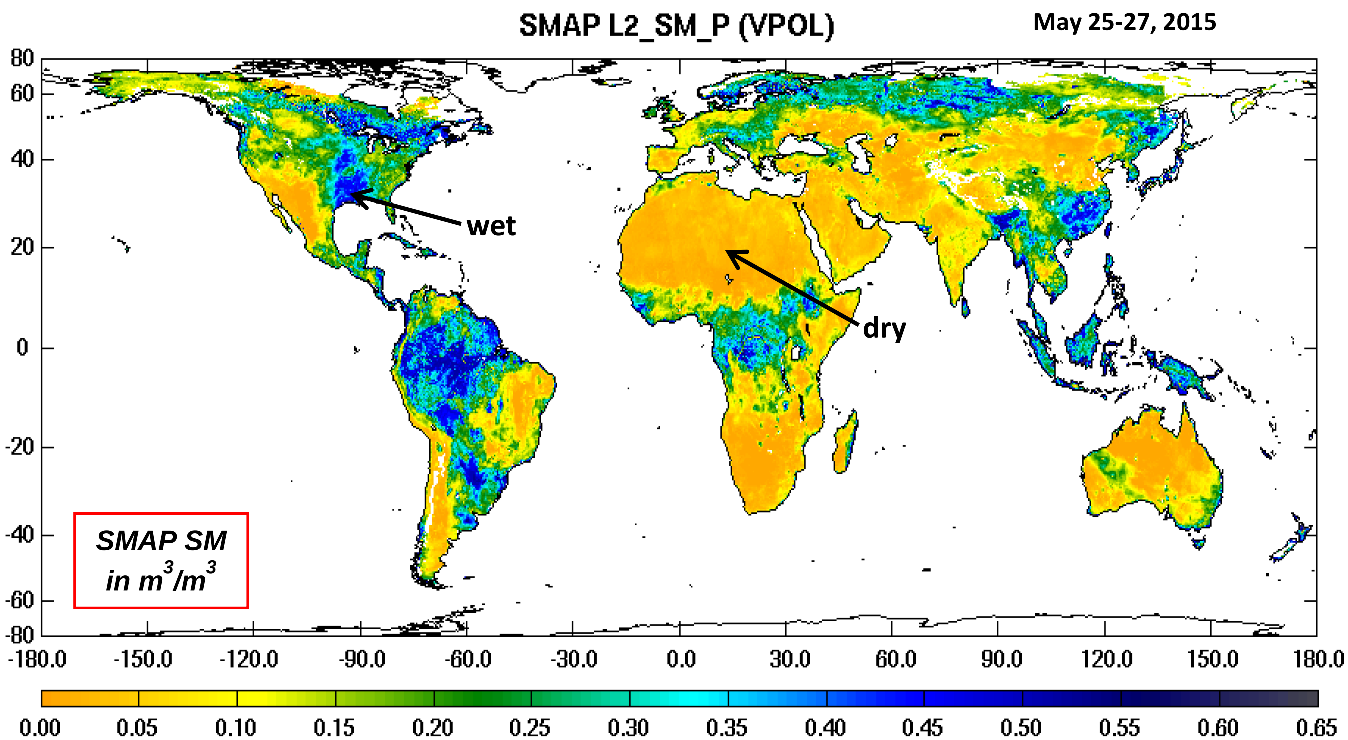

Figure 1 is an example of a 3-day composite of SMAP L2SMP soil moisture data, showing expected global wet and dry patterns (including flooding in Texas/Oklahoma in May, 2015).

calibrating, verifying, and improving the performance of the science algorithms, and (2) validating the accuracies of the L2_SM_P soil moisture product, especially in light of mission accuracy requirements. These assessments are based on a number of different approaches, including comparisons with ground-based *in situ* soil moisture measurements from instrumented sites run by SMAP Cal/Val Partners; *in situ* ground measurements from sparse networks; other satellite-based products, especially SMOS soil moisture; model-based products; and results from dedicated SMAP field campaigns. Although initial cal/val efforts have focused on comparisons with *in situ* data, it is expected that cal/val evaluations and monitoring using all approaches will continue throughout the SMAP mission lifetime.

4. L2_SM_P BETA RESULTS

The SMAP Project released to the public a beta or preliminary science quality version of the Level 2 passive-only soil moisture data in September, 2015. Although these data had not yet undergone full validation, they were judged to be of a sufficient level of maturity and quality to be approved for distribution to and use by the larger science and application communities. The SMAP L2_SM_P data are currently available from the National Snow and Ice Data Center (a NASA Distributed Active Archive Center) [5].

In order to assess the quality of the beta data and to evaluate the performance of the different soil moisture retrieval algorithms, SMAP soil moisture data from March 31 through October 26, 2015 were compared against locally scaled aggregations of *in situ* measurements of soil moisture data from thirteen core cal/val sites in the U.S., Canada, Argentina, Spain, and Australia, and from over 400 stations in sparse networks located in the U.S. (CRN, SCAN, GPS, COSMOS), France (SMOSMania), and Argentina (Pampas) [6]. Agreements between the SMAP L2_SM_P data and the cal/val data sets are reported in unbiased root mean square error (ubRMSE), bias, and time series correlation.

SMAP L2SMP Metrics for March 31-October 26, 2015	ubRMSE (m^3/m^3)			Bias (m^3/m^3)			Correlation			N
	SCAH	**SCAV**	DCA	SCAH	**SCAV**	DCA	SCAH	**SCAV**	DCA	
Overall Mean Metrics from Core CV sites	0.043	0.038	0.044	-0.040	-0.018	0.008	0.748	0.781	0.719	13
Overall Mean Metrics from Sparse Networks	0.049	0.048	0.060	-0.044	-0.016	0.020	0.655	0.654	0.590	416

Figure 2. Comparisons of SMAP L2_SM_P soil moisture with *in situ* soil moisture measurements from SMAP Cal/Val Partner core sites and sparse networks [6].

As shown in Figure 2, results for the beta data release indicated that the Single Channel Algorithm-Vertical polarization (SCA-V) currently delivers the best performance of the retrieval algorithms examined. The accuracy of the soil moisture retrievals averaged over the core validation sites was an ubRMSE of 0.038 m^3/m^3, which meets the SMAP mission accuracy requirements of an ubRMSE < 0.040 m^3/m^3.

5. L2_SM_P VALIDATED RELEASE

Prior to the scheduled release of the validated L2_SM_P data set in May, 2016, a number of additional improvements are anticipated, including optimization of algorithm parameters and upscaling approaches. In addition, methodology expansions, including increasing the number of core sites, performing model-based intercomparisons, and incorporating results from several intensive field campaigns, will be used to expand on the assessments performed for the beta data report. It is expected that the accuracy of the fully-validated SMAP L2_SM_P soil moisture data will meet or exceed the mission requirements, and thus prove to be useful in advancing our understanding of the processes that link together the Earth's water, energy, and carbon cycles.

6. REFERENCES

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