SMAP MISSION STATUS AND PLAN

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ABSTRACT

The prime mission phase of National Aeronautics Space Administration's (NASA's) Soil Moisture Active Passive (SMAP) project was successfully completed in June 2018. The extended phase has been approved by NASA for operation through 2021 (with option to 2023). SMAP data have been well calibrated and have enabled diverse scientific investigations in water, energy and carbon cycle research, terrestrial ecology and ocean science. This paper will provide the highlights of algorithm updates to radiometric calibration and soil moisture retrieval algorithms. A summary of extended phase activities, in particular the SMAPVEX19 campaign, for product enhancements will be provided.

***Index Terms*—** NASA Soil Moisture Active Passive (SMAP), Soil Moisture, Water Cycle

1. INTRODUCTION

NASA's Soil Moisture Active Passive (SMAP) mission [1] now has accumulated measurements from multiple northern hemisphere warm seasons and freeze/thaw cycles. The science products and their assessment reports are distributed through a public archive, the National Snow and Ice Data Center (NSIDC) with significant number of data users for various scientific investigations and applications (Fig. 1). The number of users of SMAP Level 3 gridded soil moisture products (L3SMP) has reached over 7000. The new SMAP-Copernicus Sentinel-1 active-passive soil moisture product (L2SMAP_S) has also been gaining significant attention with more than 1700 users at the end of October 2018.

In addition to the standard products, SMAP project has also produced Near Real Time (NRT) soil moisture products to meet the needs of operational users, such as National Oceanic and Atmospheric Administration (NOAA) and United States Airforce, who require a data latency of no more than three hours for weather forecasts. The NRT products are available directly from the SMAP Science Data System (SDS) at the Jet Propulsion Laboratory.

To further enhance the usage of SMAP data, the project has continued activities to improve the quality of SMAP data. The primary advancements include the improvement in

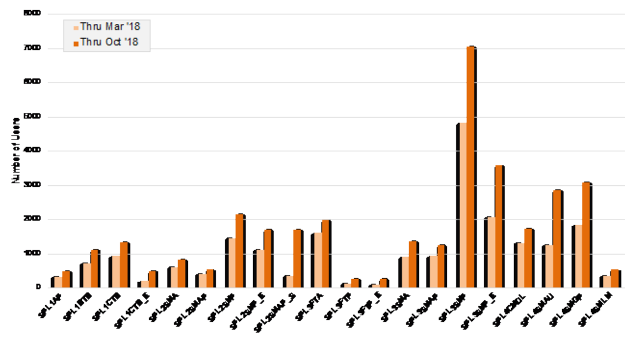

Figure 1: Number of users of SMAP data by product (courtesy of NSIDC).

radiometer calibration, soil moisture retrieval for evening pass, dual-channel algorithm for soil moisture and vegetation opacity retrieval and active-passive algorithms with applications to SMAP radiometer data in conjunction with SMAP L-band radar or Copernicus Sentine-1 C-band radar data. The results of these enhancements will be summarized below.

2. NEW SCIENCE ALGORITHM ENHANCEMENTS

2.1. Radiometric Calibration

We are conducting studies to improve the calibration of radiometer brightness temperatures. The reprocessed radiometer temperature products released at the end of prime mission was determined to have two minor deficiencies. One is the bias between ascending and descending passes by a few tenths of Kelvin. The other one is the excessive brightness temperature over dry warm land surfaces, which requires an ad hoc correction of land surface temperature to reduce soil moisture retrieval bias.

Although the ascending-descending bias of a few tenths of Kelvin has a negligible impact on soil moisture retrieval over land surface, it does impact the usage of brightness temperature data for ocean applications, which require much more stringent calibration accuracy. We have carefully analyzed the SMAP data from ascending and descending passes and determined that the antenna reflectivity emissivity was overly estimated previously. The latest data analyses based on vicarious calibration techniques put the emissivity of reflector mesh at about 0.4 percent, rather than 1 percent estimated earlier. The new estimation is in much closer agreement with the pre-launch measurements and modeling effort. An impact assessment shows that the new reflector emissivity estimation allows the reduction of ascending and descending biases and significantly improves the retrieval of sea surface salinity from SMAP brightness temperature data [2].

The adjusted reflector emissivity for radiometric calibration also found to reduce the brightness temperatures over land surfaces by about 1 to 2 K and appeared to remove the artifact in the overestimation of land surface emissivity from SMAP brightness temperature. The recalibration will be applied to the next reprocessing for updated data release in mid 2019.

2.2. Improved Soil Moisture Retrieval from Afternoon Passes

SMAP SDS uses the land surface temperature from the operational data assimilation system at the Global Modeling and Assimilation Office (GMAO) as ancillary data for retrieval of soil moisture from brightness temperatures. Because the vertical gradient in temperature from the top of vegetation canopy to the upper soil layer is expected to be much more significant in the afternoon (PM) than in the morning (AM), it was not possible to determine an accurate representation of the effective land scape temperature using the GMAO product for soil moisture retrieval before launch. The pre-launch SMAP/GMAO formula is based on the Choudhury effective soil temperature with the coefficient C=0.246 for both AM and PM passes. Comparison with the in-situ soil temperature at the core SMAP calibration/validation sites indicated that the effective temperature of land surface was essentially unbiased against in situ data for AM passes, but had a negative bias of about 3K for PM passes.

Given the substantial time series of SMAP data acquired in the prime mission phase (three years), we determined that the GMAO temperature of the top soil layer is a better representation of the effective land temperature for the PM data; therefore, the Choudhury effective soil temperature coefficient is set to C=1.000 for PM, while the coefficient for AM remains unchanged from the pre-launch model value.

The updated effective land surface temperature significantly reduced the dry bias in the SMAP soil moisture for PM data. The soil moisture from both AM and PM has become very similar (Fig. 2). A quantitative performance assessment using the core Calibration/Validation (Cal/Val) sites data indicates a small bias (0.001 for AM and 0.002 for PM), an averaged unbiased Root-Mean-Square-Difference (ubRMSD) of about 0.038 and a correlation coefficient of great than 0.8 for both AM and PM data (Table 1). The

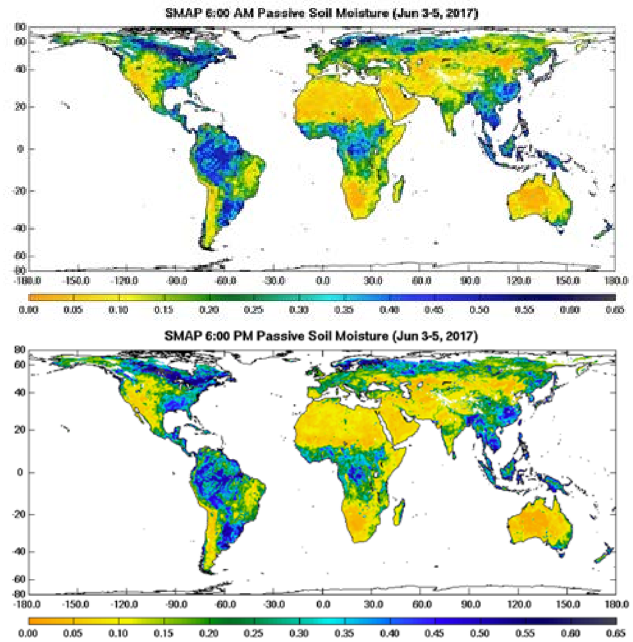

Figure 2: SMAP soil moisture bias between ascending (afternoon) passes and descending (morning) has been removed, leading to a significant improvement in data quality for evening passes.

improved quality of PM data effectively doubles the SMAP data sampling rate for science investigations, leading to about a global coverage of every 1.5 days.

Table 1. Comparison of SMAP baseline (SCA-V: single channel-vertical polarization) passive soil moisture with in situ data from core cal/val sites.

	ubRMSD (m^3/m^3)	Bias (m^3/m^3)	RMSD (m^3/m^3)	R
AM	0.038	-0.001	0.047	0.814
PM	0.036	-0.002	0.045	0.818

2.3. Dual Channel Algorithm

SMAP project has implemented several algorithms for soil moisture retrieval, including the dual-channel algorithm (DCA), which retrieves the soil moisture and vegetation optical depth (VOD) together from dual polarized brightness temperature data. Although the DCA algorithm has the potential to avoid the use of external ancillary vegetation water content, which is derived from the MODIS Normalized Difference Vegetation Index (NDVI) for SMAP, the quality of DCA soil moisture has been marginal. Consequently, SMAP project team members have been investigating ways to realize the potential of DCA. Through the analysis of tau-omega model and retrieval simulations, it is concluded that the change of polarization mixing due to rough surface

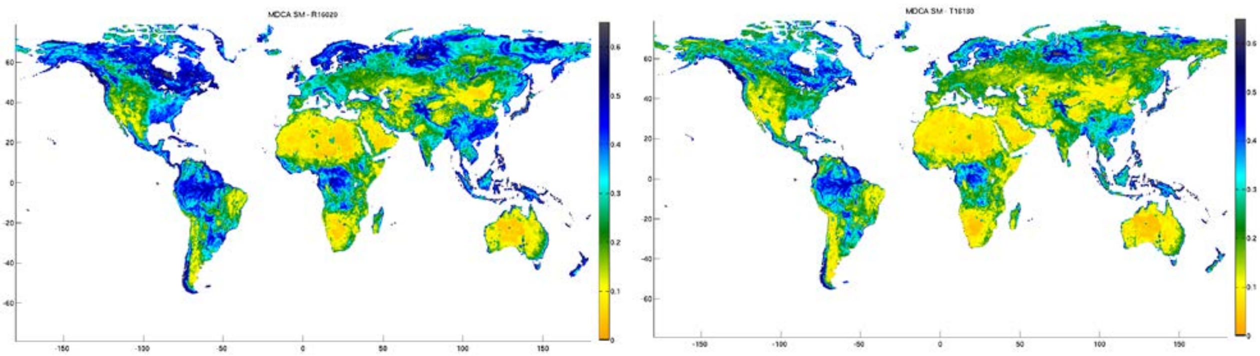

Figure 3: Comparison of current (left) and updated (right) DCA soil moisture products. The patterns are in general quite similar. However, the new DCA in general provides lower soil moisture over regions with higher vegetation water content.

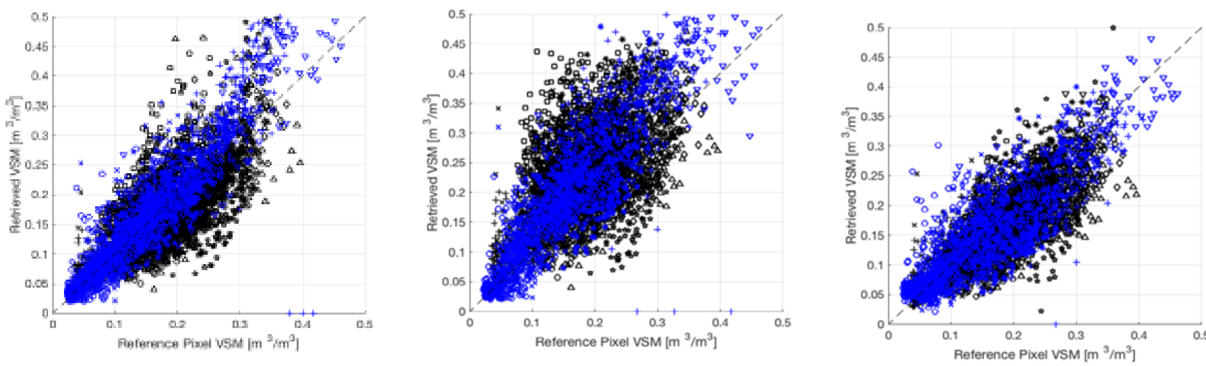

Figure 4: SMAP soil moisture retrievals versus in situ data from core Cal/Val sites. SCA-V (left panel), current DCA (middle panel) and new DCA (right panel). Different symbol represents data from different core Cal/Val site.

scattering has the most significant positive impact and the update of vegetation albedo parameters provides the next level of improvement [3]. As a result, the new DCA soil moisture achieves performance similar to the baseline (SCA-V) product when assessed against the in-situ data acquired at the core Cal/Val sites [3]. Figure 3 indicates the general differences between current and new DCA products. The scatter plots (Fig. 4) shows the improvement of new DCA from current DCA with a tighter scatter and smaller bias. In compraison with the SCA-V, the new DCA appears to have a larger scatter for low soil moisture, but is able to remove some systematic bias in SCA-V for wetter soil (>0.2). The performance of SCA-V and new DCA seems to be complementary to each other. The algorithm details and extensive comparison are provided in [3].

2.4. SMAP Active-Passive High-Resolution Soil Moisture Products

The SMAP mission was designed to acquire high resolution (1 km) L-band synthetic radar data in conjunction with coarse resolution (36 km) passive microwave data to produce disaggregated soil moisture at intermediate resolution (9 km) [1]. Although the radar ceased operation in early July 2015, a total of 84 days of radar data were acquired to test the initial mission requirement. We have updated the SMAP active-passive (AP) algorithm parameters to retrieve soil moisture at two spatial resolutions, 3 km and 9 km. The values of disaggregation parameters were derived from the SMAP radar and radiometer data collected from mid-April to July 7, 2015. More detailed spatial features can be clearly identified in the disaggregated soil moisture images (Fig. 5). The performance of the updated SMAP AP soil moisture has been assessed using the core Cal/Val site data, showing the high quality of retrieval (Table 2). Similar algorithm has been applied to the use of Sentinel-1 C-band SAR data for disaggregation with performance also included in Table 2. In general, the use of SMAP L-band radar data appears to provide a better accuracy. However, it is important to recognize the differences in time and duration. The SMAP data covers a much shorter time window (<3 months) in 2015, while the Sentinel-1 time series is about one year in 2017. In

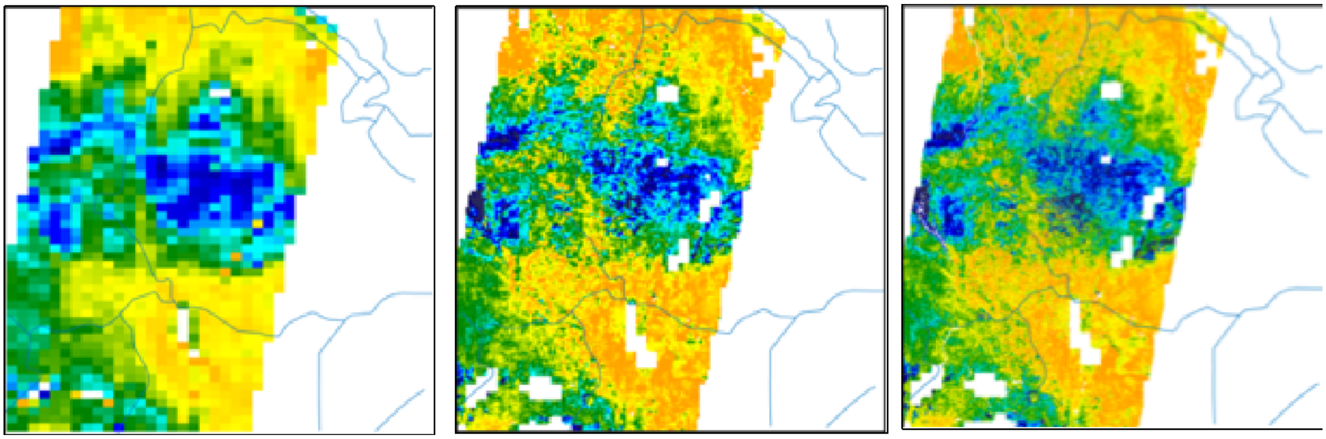

Figure 5: The SMAP Active-Passive soil moisture produced at 9 km resolution (middle panel) and 3 km resolution (right panel) reveal more details than the passive soil moisture at 36 km spatial resolution (left panel) over East Africa.

short, the algorithm updates have led to high quality SMAP AP products for research and applications.

Table 2. Quality of SMAP active-passive soil moisture products at a spatial resolution of 9 km

Configuration	ubRMSD (m^3/m^3)	Bias (m^3/m^3)	RMSD (m^3/m^3)	R
SMAP radar and radiometer	0.034	0.007	0.046	0.692
Sentinel-1 C-band and SMAP radiometer	0.039	-0.008	0.059	0.804

3. EXTENDED-PHASE PLAN

We are planning activities to improve the SMAP data products, including standard and NRT, and to reduce retrieval bias. We expect to release the new DCA products, including soil moisture and vegetation optical depth, in 2019. Through comparison of the retrievals from the single channel and dual channel algorithm options, further insight into the tau-omega model and surface scattering is expected to lead to more accurate parameter values for retrieval.

Our short-term objectives are to extend the algorithm performance for regions with higher vegetation water content (>5 kg/m^2) and to provide extensive data for the evaluation of SMAP-Sentinel-1 algorithm. We've been planning an extensive field program in 2019 (SMAPVEX19), including space (SMAP and Sentinel-1), airborne (JPL Passive Active L-band System), ground-based radiometers and in situ soil moisture and vegetation observations. Two campaign sites located at the Harvard Forest in Massachusetts and Millbrook in New York have been selected. The SMAPVEX19 data will also be used to advance the science investigations relating the soil moisture to vegetation water usage.

4. ACKNOWLEDGEMENT

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