INTEGRATED SMAP AND SMOS SOIL MOISTURE OBSERVATIONS

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ABSTRACT

Soil Moisture Active Passive (SMAP) mission and the Soil Moisture and Ocean Salinity (SMOS) missions provide brightness temperature and soil moisture estimates every 2-3 days. SMAP brightness temperature observations were compared with SMOS observations at 40^o incidence angle. The brightness temperatures from the two missions are close to each other but SMAP observations show a warmer TB bias (about 0.64 K: V pol and 1.14 K: H pol) as compared to SMOS. SMAP and SMOS missions use different retrieval algorithms and ancillary datasets which result in further inconsistencies between their soil moisture products. The reprocessed constant-angle SMOS brightness temperatures (SMOS-SMAP) were used in the SMAP soil moisture retrieval algorithm to develop a consistent multi-satellite product. The integrated product has an increased global revisit frequency (1 day) and period of record that is unattainable by either one of the satellites alone. The SMOS-SMAP soil moisture retrievals compared with in situ observations show a retrieval accuracy of less than 0.04 m^3/m^3. Results from the development and validation of the integrated soil moisture product will be presented.

Index Terms— SMAP, SMOS, soil moisture, inter-comparison of microwave radiometers

1. INTRODUCTION

Soil moisture observations from the Soil Moisture and Ocean Salinity (SMOS) [1] and Soil Moisture Active Passive (SMAP) missions [2, 3] contribute to understanding Earth's water and climate cycles. SMOS and SMAP soil moisture products currently have a revisit frequency of about 3 days. The value and range of applications for the SMAP soil moisture product is dependent on the revisit frequency of the observations. Integration brightness temperature (TB) observations (both AM and PM) from both L-band satellites (SMAP and SMOS) can potentially reduce the revisit time to about 1 day. SMOS and SMAP both have a spatial resolution of ~40 km with a local overpass time of 6 AM/PM.

The SMOS and SMAP missions use different algorithms and ancillary datasets to estimate soil moisture, the choices are dependent on the instrument configuration. The SMOS soil moisture algorithm exploits its multi-angle observations [1]. This algorithm cannot be applied to SMAP TB observations that are acquired at a fixed incidence angle. Moreover, there are several differences in the ancillary data sources (for example: SMAP uses the GMAO GEOS-5 model estimates for surface temperature and SMOS uses the ECMWF surface temperature estimates). These differences result in discrepancies in the soil moisture retrievals between the two products. As a result, it is not possible to develop a consistent soil moisture climate data record by just merging the soil moisture products from the two missions.

Additionally, SMOS and SMAP missions use different approaches for brightness temperature calibration. Difference in the calibration approach can result in differences in land brightness temperature. The first step in the development of the integrated product requires that the TBs from the two missions are consistent with each other. A physically-based soil moisture retrieval algorithm that spans multiple L-band missions requires consistent input TB observations for the development of a long term environmental data record. Availability of consistent TB observations from SMOS and SMAP satellites allows the development of a consistent long term soil moisture data record.

SMOS TB observations were reprocessed to develop a SMAP-like fixed 40^o incidence angle product (referred as the SMOS-SMAP TB product). SMOS-SMAP TB observations were then used in the SMAP soil moisture retrieval algorithm with SMAP ancillary data. This results in the development of a harmonized soil moisture product using the same soil moisture retrieval algorithm.

2. BRIGHTNESS TEMPERATURE INTER-COMPARISON METHODOLOGY

L-band observations are a function of land surface conditions (e.g., soil moisture, surface temperature, vegetation), which vary both in space and time. Although vegetation conditions do not rapidly change in time, soil moisture and soil temperature can vary significantly over a short period. In order to minimize inter-comparison errors associated with temporal changes in soil moisture and temperature, a maximum time window between the two satellite observations of 30 min was used. Both SMAP and SMOS have an average 3-dB footprint size of 40 km. Spatial variations in the contributing area were minimized by only using footprints that have a boresight distance of less than 1 km. Brightness temperatures at the top of the atmosphere (TOA) from both missions were used in the inter-comparison. Comparisons were made with brightness temperature without reflected galaxy correction, ionosphere or atmospheric corrections. RFI flags from both the missions were used in the analysis. Only brightness temperature observations when both the missions indicated no significant RFI were used in the match-up analysis. The azimuth angle of the observations was ignored during the analysis. This analysis was done for both the horizontal (H) and vertical (V) polarizations.

3. BRIGHTNESS TEMPERATURE INTER-COMPARISON RESULTS

Figure 1 (a-b) shows the density plot of the brightness temperature (top of the atmosphere) comparison between SMOS and SMAP over land targets 40º incidence angle for V- and H-polarizations. This analysis was done using the latest version of the SMAP data (V4.0) [4]. This L1B radiometer data was compared with the most recent SMOS L1B data (version 620) for this analysis. Statistical analysis results are summarized in Table 1. The SMAP brightness temperatures show a very strong correlation with the SMOS observations and most of the observations fall along the 1:1 line. The scatter is greater for H polarization observations, which are more sensitive to changes in land surface conditions (soil moisture and surface temperature). Some of the scatter in the inter-comparison is likely due to the presence of residual RFI in either or both of the SMAP or SMOS observations. Land surface heterogeneity of the footprint can also result in some scatter.

SMAP observations show a warmer TB bias (about 1.14 K: H pol and 0.64 K: V pol) as compared to SMOS. Most of the RMSD can be attributed to the bias between the two satellites. In addition, we extracted the equivalent data set over oceans. Global average brightness temperature comparisons over ocean areas with SMOS are quite favorable, indicating less than 0.08-0.23 K mean bias at top of the atmosphere. The observations over the ocean target have a small dynamic range (5 K) but lie along the 1:1 line with no significant bias. The correlation coefficient for just the ocean observations is due to the small dynamic range. Efforts will be made to address these differences in TB calibration over land and to develop a consistent L-band brightness temperature dataset between SMOS and SMAP missions.

4. CONSISTENT L-BAND DATA PRODUCT

SMOS and SMAP both have the same local overpass time of 6 AM/PM. The SMOS and SMAP orbits are opposite to each other (one will be ascending when the other is descending) and the two satellites cross each other at the equator at 6 AM and 6 PM (SMAP is 6 AM descending orbit whereas SMOS is 6 AM ascending orbit). SMAP has a swath width of about 1000 km. SMOS also has a swath width of about 1000 km. The addition of both SMAP and SMOS observations greatly increases the spatial coverage for a single day. The use of both satellites and both ascending and descending orbits results in near complete global coverage within a single day. Moreover, large portions of the globe would have coverage at both 6 AM and 6 PM local time.

A linear adjustment over land was made to recalibrate the brightness temperatures for the two polarizations to develop a consistent brightness temperature data record [5]. The SMOS observations reprocessed at 40º incidence angle (SMOS-SMAP) were recalibrated to match the SMAP brightness temperatures. No significant SMAP or SMOS swath artifacts were observed after overlaying the orbits for 6 AM overpass time.

SMOS-SMAP TB observations were then used in the SMAP radiometer only soil moisture retrieval algorithm with SMAP ancillary data to develop a soil moisture product. Figure 2a shows the soil moisture estimates using the recalibrated SMOS-SMAP TB observations for July 2017. Major arid areas (northern Africa, Middle-east, Central Australia, Western US) are dry as expected. The soil moisture estimates over these areas are in the range of 0.02 m^3/m^3 - 0.10 m^3/m^3. The northern latitude and the forested areas (Amazon and Central Africa) have higher soil moisture. The onset on the monsoon can be seen over the Indian sub-continent and over south-east Asia. Figure 2b shows the soil moisture estimates using SMAP TB observations for July 2017. Soil moisture retrievals using the two TB datasets do not should any climatological differences and are consistent with each other. The use of consistent brightness temperature and the same algorithm and ancillary data resulted in a SMOS soil moisture that is consistent with the SMAP product. The use of this methodology allows the development of a longer-term climatological dataset of both brightness temperature and soil moisture estimates that can be used in various water cycle applications.

The soil moisture retrievals using SMOS-SMAP TB observations was validated using *in situ* observations from the SMAP cal/val sites. The assessment results based on one year (2017) of data show an accuracy of less than 0.04 m^3/m^3. The 6 AM retrievals perform better than the 6 PM retrievals. Both the 6 AM and PM retrievals have a low bias and high correlation compared to in situ observations. This assessment is comparable to the SMAP radiometer soil moisture results [3]. Results from the validation analysis over a longer time period will be presented. This work will help in the development of a consistent multi-satellite soil moisture product using observations from SMOS and SMAP missions.

5. REFERENCES

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Table 1. Summary statistics of the brightness temperature comparison between SMOS and SMAP.

		RMSD (K)	**R**	**Bias [SMAP-SMOS] (K)**	**ubRMSD (K)**
H pol	Land	3.59	0.9915	**1.14**	3.17
	Ocean	2.44	0.7336	0.08	2.44
	Overall	2.71	0.9995	0.36	2.68
V pol	Land	2.97	0.9895	**0.64**	2.88
	Ocean	2.52	0.7713	-0.23	2.51
	Overall	2.63	0.9995	-0.02	2.63

Table 2. Summary assessment of the SMOS-SMAP soil moisture over SMAP cal/val sites for 2017.

Algorithm	**Ascending (6 AM)**				**Descending (6 PM)**			
	ubRMSE	Bias	R	N	ubRMSE	Bias	R	N
SCA-V	**0.038**	-0.001	0.768	534	**0.040**	-0.002	0.754	491
SCA-H	0.040	-0.003	0.783	534	0.042	-0.004	0.724	491
DCA	0.044	-0.002	0.678	528	0.052	0.004	0.636	351
ubRMSE (unbiased Root mean square error), and Bias are in m^3/m^3. R=Linear correlation coefficient, N=Number of samples								

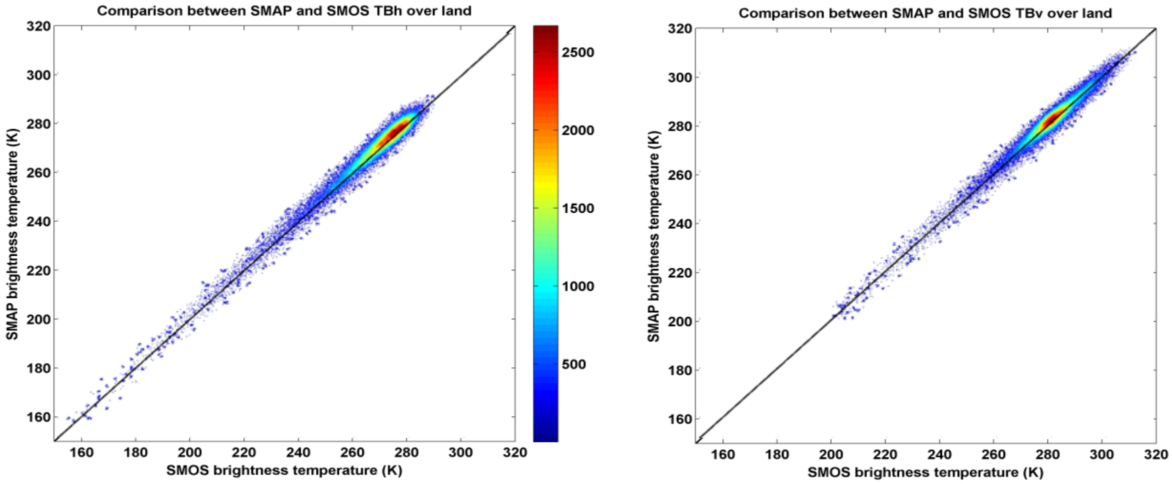

Figure 1. Density plot of the L1 brightness temperature comparison (top of the atmosphere) between SMAP and SMOS observations over land targets for V-pol (left) and H-pol (right).

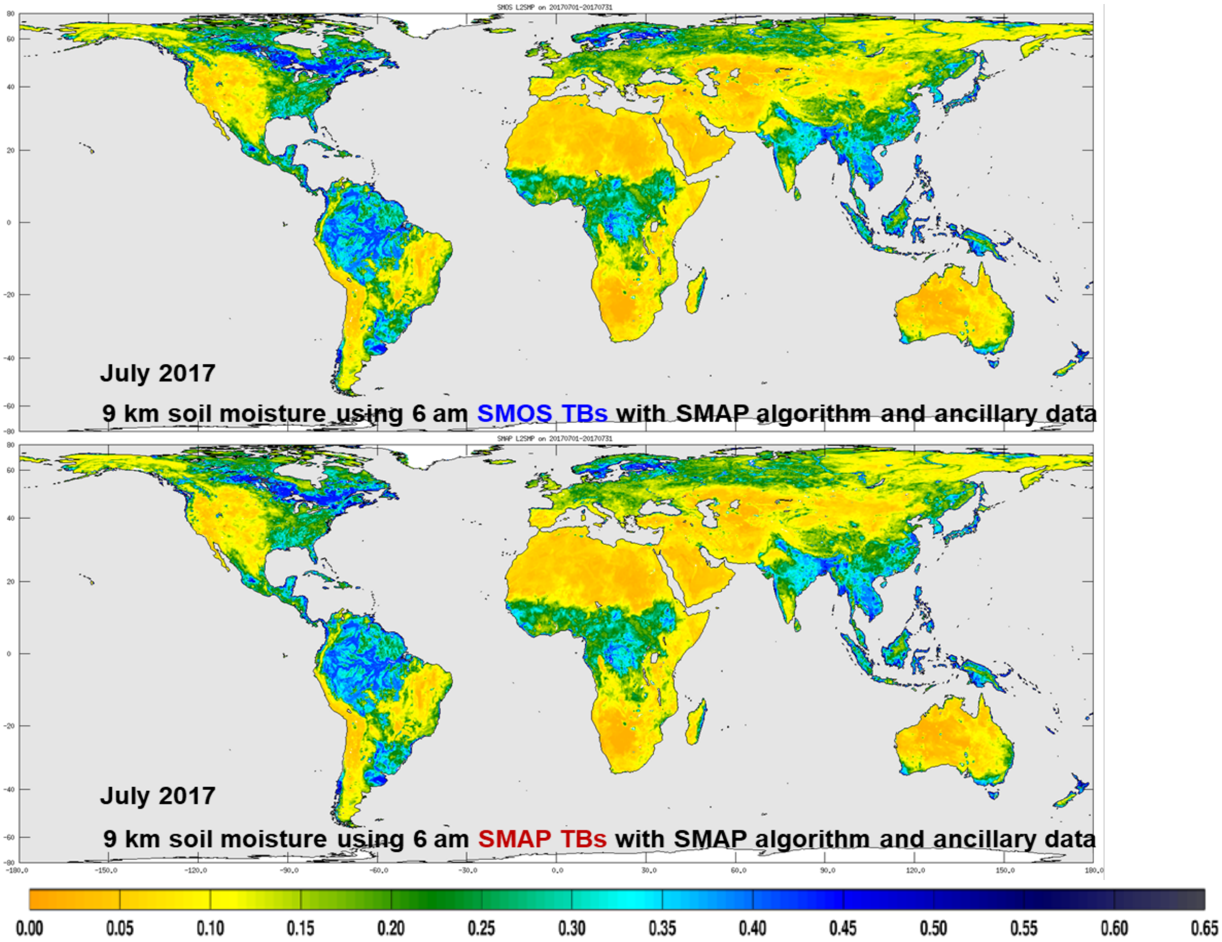

Figure 2. Soil moisture retrievals using the (a) recalibrated SMOS-SMAP TB with SMAP algorithm and ancillary data and (b) SMAP TB with SMAP algorithm and ancillary data for June 2017.