INTEGRATION OF SMAP AND SMOS 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° incidence angle. The brightness temperatures from the two missions are not consistent. SMAP observations show a warmer TB bias (about 1.27 K: V pol and 0.62 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 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. Results from the development and validation of the integrated soil moisture product will be presented.

Index Terms**—** SMAP, SMOS, passive microwave, inter-comparison of microwave radiometers

1. INTRODUCTION

Soil moisture observations from the Soil Moisture Active Passive (SMAP) mission [1, 2] and the Soil Moisture and Ocean Salinity (SMOS) missions [3] provide information about an important hydrologic parameter that contributes to understanding the Earth's climate and water cycles. The standard 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 soil moisture observations. Integration of all available (both AM and PM) brightness temperature (TB) observations from multiple L-band satellites (SMAP and SMOS) can potentially reduce the revisit time to about 1 day.

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 [2]. 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.

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 retrieval algorithm that spans multiple L-band missions requires consistent input observations for the development of a long term environmental data record of L-band TB observations. 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 fixed 40° incidence angle product (consistent with the SMAP Level 1 radiometer observations) (referred as the SMOS-SMAP TB product). SMOS-SMAP TB observations were then used in the SMAP radiometer only soil moisture retrieval algorithm with SMAP ancillary data to develop a consistent soil moisture product. This results in the development of a harmonized soil moisture product using the same soil moisture retrieval algorithm.

2. BRIGHTNESS TEMPERATURE INTER-COMPARISON METHODOLOGY

Microwave observations from the SMOS mission were reprocessed to approximate SMAP microwave radiometer observations made at a constant incidence angle of 40.0°. SMOS data version v620 was used for the analysis. 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 observations when the footprint distance was less than 1 km between SMAP and SMOS. 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 correction. 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 40° incidence angle for V- and H-polarizations. This analysis was done using a future version of the SMAP data due to be released in May 2018 (V4.0). A small change in reflector or radome emissivity was introduced in this release [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 1.27 K: V pol and 0.62 K: H 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. These combined results provide strong evidence of the relative calibration of SMAP and SMOS over a wide range of targets. 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

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]. Figure 2 shows the composite image with both SMAP and SMOS H-polarization brightness temperature for June 14-16, 2017 over South America for three overlapping SMAP and SMOS orbits. The SMOS observations were reprocessed at 40° incidence angle and recalibrated to match the SMAP brightness temperatures. There are no significant SMAP or SMOS swath artifacts observed after overlaying the orbits for 6 AM overpass time.

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 SMAP revisit time is about 3 days (using descending orbits only). 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.

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 3 shows the soil moisture estimates using the recalibrated SMOS-SMAP brightness temperature observations for June 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.

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 will be compared directly with SMOS and SMAP only retrievals. The integrated soil moisture product will be also validated with the same set of core and candidate validation in situ observations used for the SMAP radiometer only soil moisture product. Results from the validation analysis 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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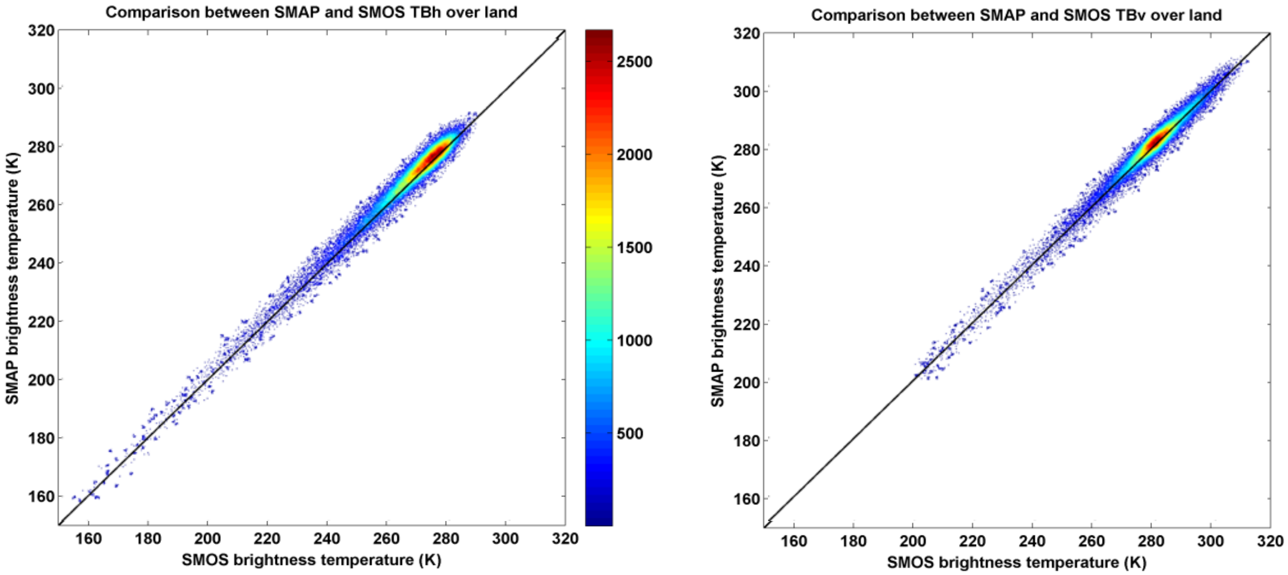

Figure 1. Density plot of the L1 brightness temperature comparison (top of the atmosphere) between SMAP and SMOS observations over land targets for V-pol (left) and H-pol (right).

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	3.40	0.9909	**1.27**	3.15
	Ocean	2.44	0.7061	0.08	2.44
	Overall	2.71	0.9994	0.38	2.68
V pol	Land	2.95	0.9967	**0.62**	2.88
	Ocean	2.52	0.7679	-0.23	2.51
	Overall	2.63	0.9994	-0.02	2.63

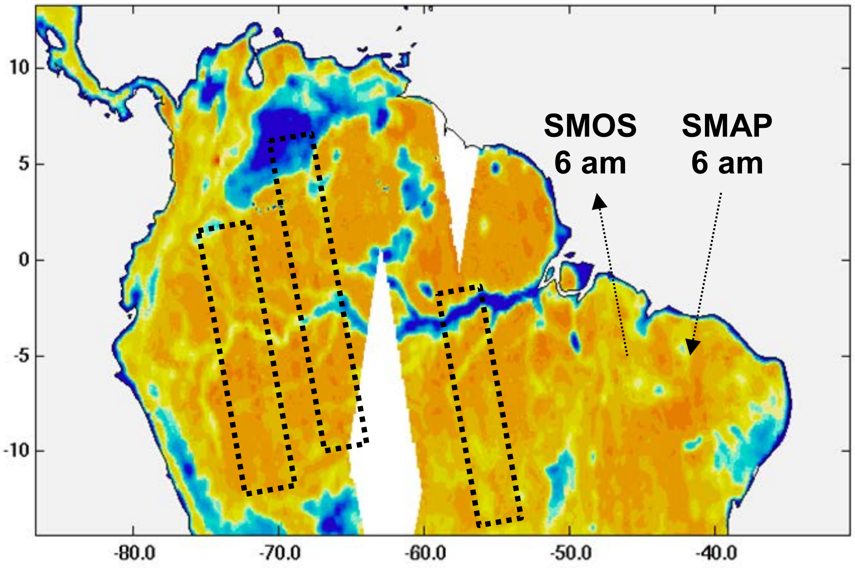

Figure 2. SMAP and SMOS H-pol brightness temperatures overlaid for multiple orbits over South America for June 14-16, 2017. The overlaid brightness temperatures show minimal swath discontinuities after the TB adjustment.

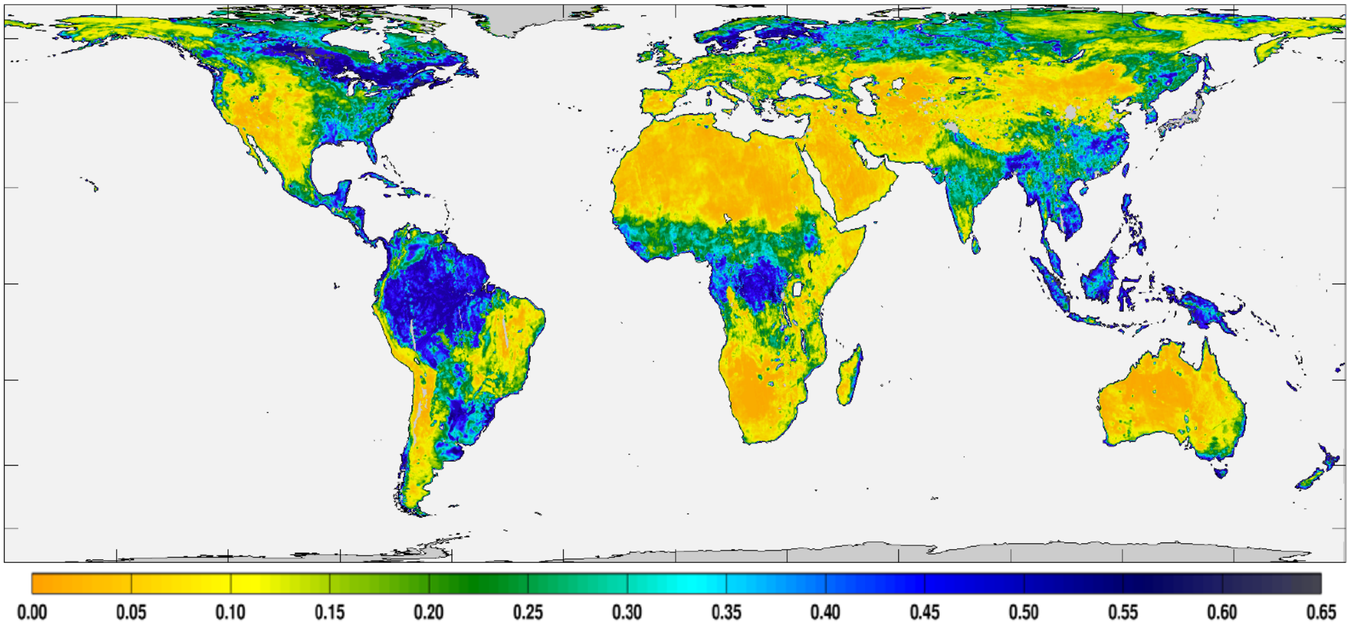

Figure 3. Soil moisture retrievals using the recalibrated SMOS-SMAP brightness temperature and SMAP algorithm and ancillary data for June 2017.