SMAP MISSION STATUS, NEW PRODUCTS AND EXTENDED-PHASE GOALS

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ABSTRACT

NASA's Soil Moisture Active Passive (SMAP) Project now has completed its prime-phase (three years) mission and has entered a new five-year extended phase. The global L-band radiometry from SMAP has enabled diverse scientific investigations in water, energy and carbon cycle research, terrestrial ecology and ocean science. These include eliciting the role of soil moisture control on the evaporation regime and vegetation gross primary productivity, observing soil-vegetation continuum water relations, analysis of flood and droughts, climate modeling and weather prediction, detecting ocean high-winds during tropical storms, and observing fresh-water outflow in coastal oceans. This paper highlights the recent enhancements to the SMAP suite of science products (from instrument level-1 to geophysical retrievals level-2 and level-3).

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 (NSIDC). The global L-band radiometry from SMAP has enabled investigations in and between water, energy and carbon cycle research, terrestrial ecology, and ocean science. These include eliciting the role of soil moisture control on the evaporation regime and vegetation gross primary productivity, observing soil-vegetation continuum water relationships, analysis of floods and droughts, climate modeling and weather prediction, detecting ocean surface salinity [2,3], high winds during tropical storms [2,4], and observing freshwater outflow into coastal oceans. The SMAP instruments have been calibrated using data from other satellites and external stable target such as locations in central Antarctica, tropical oceans and dense forests. The calibration of SMAP radiometer's noise diode was achieved using ocean targets and cold sky. Cross-comparison with the European Space Agency's Soil Moisture and Ocean Salinity (SMOS) radiometer data over land and ocean surfaces indicates in good agreement. This paper outlines the changes to the data processing (L1 brightness temperature and L2 geophysical products) as a result of the observed global L-band radiometry. Recently the project added enhanced radiometry products based on Backus Gilbert optimum interpolation [2] that take advantage of the oversampling characteristics of the SMAP radiometer. The data are gridded so that aliasing effects are reduced. A new approach is also adopted to improve the unmixing of land and water contributions to the surface brightness temperature. A second new product type investigates the disaggregation of the SMAP L-band radiometer data using the Copernicus Sentinel-1A and Sentinel-1B C-band synthetic aperture radar (SAR) data to obtain soil moisture products at about 1 to 3 km resolution. Finally, the SMAP suite of science products includes Near-Real-Time (NRT) instrument (level-1) and geophysical (level-2) data products that are available with about 2.5 hours (median) latency from the time of data acquisition.

2. NEW SCIENCE PRODUCTS AND ALGORITHM ENHANCEMENTS

2.1. Enhanced Radiometer Product Using Backus-Gilbert Optimal Interpolation

The enhanced radiometer product was introduced in 2017 as part of the suite of science products available from the SMAP mission. The L1C_TB_E or enhanced radiometer product is now available along with heritage SMAP science products. The goal of the product is to obtain maximum value from the SMAP radiometer data given its measurement and sampling approach. This radiometer product is termed Enhanced relative to the Baseline version, in that sense. The Baseline SMAP L1B_TB contains global surface brightness temperature estimates over a 36km regular global grid. The aim of enhanced L1C_TB_E product is to provide an optimal interpolation of the radiometer measurements onto a global 9 km grid. The SMAP sampling pattern results in overlapping measurements which, together with Backus-Gilbert optimal interpolation [5], results in a more representative estimation

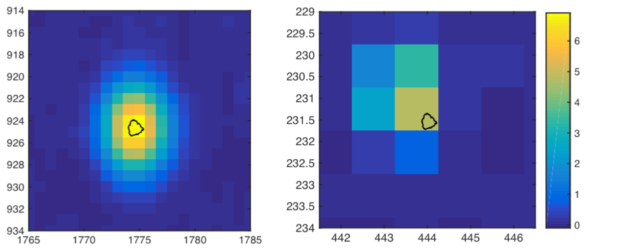

Figure 1: Annually-averaged brightness temperature across Ascension Island in the L1C_TB_E enhanced product posted at 9 km (left) and in the Baseline L1C_TB. The ocean background brightness temperature is removed. The Backus-Gilbert optimal interpolation product has less spatial smoothing and aliasing.

of brightness temperature (Fig. 1). The BG optimal interpolation uses overlapping footprints and the antenna pattern to form an estimate of the surface brightness temperature at a point (in this case grid-points that are 9 km apart) as if the antenna bore-sight was pointed at that point. The estimate is optimal in the least-squares sense. Such optimal interpolation using the antenna pattern generates the most representative estimate of surface brightness temperature.

2.2. Improved Inland Water-Body and Coastal Correction

The SMAP level-2 geophysical science data products such as surface soil moisture and freeze/thaw classification are based on estimates of the land brightness temperature. The land brightness temperature is estimated from the surface brightness temperature after an un-mixing model is applied to remove the in-land water-body and coastal waters contributions to brightness temperature (Fig. 2). In the new release of the SMAP L1C_TB_E, the antenna pattern, estimates of water-body fraction in the field-of-view and water brightness temperature are used to improve the water-body correction over the Baseline approach. The earlier or Baseline approach applied a linear un-mixing model to the gridded brightness temperature at 36 km gridding. Since water-body contamination is a major source of uncertainty and error for estimates of land brightness temperature, it is anticipated that the new approach will significantly enhance the geophysical retrievals.

2.3. Near-Real-Time Geophysical Products

The SMAP science products suite includes the NRT brightness temperature which is available within 3 hours from acquisition for 85 percent of data. This NRT capability is achieved by using model predictions of spacecraft attitude and position for L1 brightness temperature data processing. The baseline sometimes with longer latency waits for the spacecraft engineering information, which might be missing

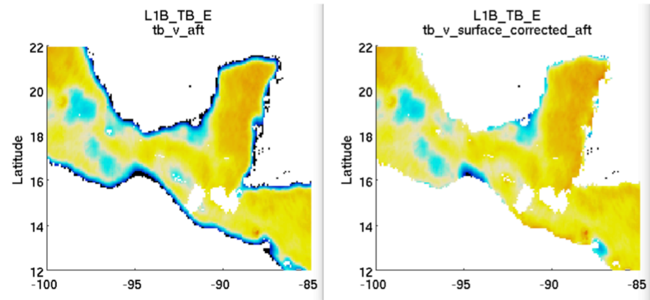

Figure 2: Example of uncorrected (left) and corrected) land brightness temperature across the Yucatan Peninsula. Water-body correction removes coastal water contamination of land brightness temperatures.

from some S-band downlink passes, that is distinct from the complete X-band data downlink for science telemetry. Using orbit or attitude predicts for the missing part of half orbit science data allows the entire half orbit of science data to be processed without additional wait time for the next S-band downlink pass. The project now also produces a level-2 or geophysical NRT product with minimal increases over the brightness temperature NRT product. The processing is identical to the Baseline product except for use of atmospheric model forecasts of dynamic ancillary data

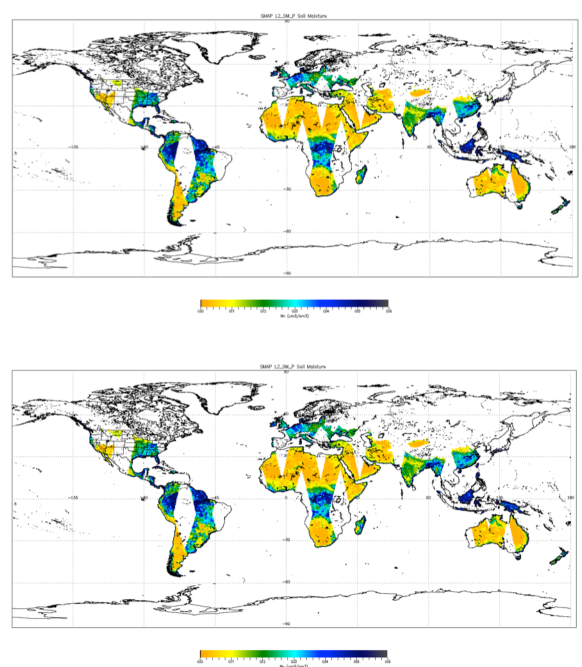

Figure 3: Example of L2 standard (top) and NRT (bottom) soil moisture products on December 14, 2017. The two are almost identical. A careful inspection shows some differences due to snow-cover flag. Otherwise the global mean bias is negligible, and the RMS difference is <0.1%. White color either indicates either data gap or snow-covered areas.

fields (notably surface physical temperature for soil moisture retrievals, snow cover and precipitation forecasts for flags). The baseline product uses the best available forecasts, while the current NRT processing uses the prior day of surface temperature and snow cover data. The reduction of wait time for ancillary data allows the L2 NRT soil moisture to be produced in 3 hours for more than 80 percent of data. The L2 NRT data will help the United States Air Force to meet the 2011 Army Weather Statement of requirements.

Note that there will another difference between the standard and NRT L2 soil moisture products. A suboptimal version of the water body correction algorithm will be implemented for the NRT processing to minimize the impact on processing time.

2.4. SMAP-Sentinel 1A/B High-Resolution Soil Moisture Product

The active-passive brightness temperature downscaling algorithm developed for the SMAP mission has been adapted to work with L-band (SMAP radiometer passive) and C-band (Copernicus Sentinel 1A and 1B active) measurements. The downscaled brightness temperatures at 3 km (1 km experimental) are then used as input to the same surface soil moisture retrieval algorithm as the SMAP Baseline passive-radiometer (Fig. 4). The near-global surface soil moisture fields have a refresh-rate ranging from almost twice-weekly over Europe and some other regions to at least every 12 days globally. The algorithm has the capability of using the Copernicus Sentinel data at the varied look-angle without empirical angular correction. The SMAP-Sentinel L2SMSP product captures features at resolutions finer than the SMAP radiometer. However, because the active measurements inputs are at C-band, areas with dense vegetation show less resolution improvements.

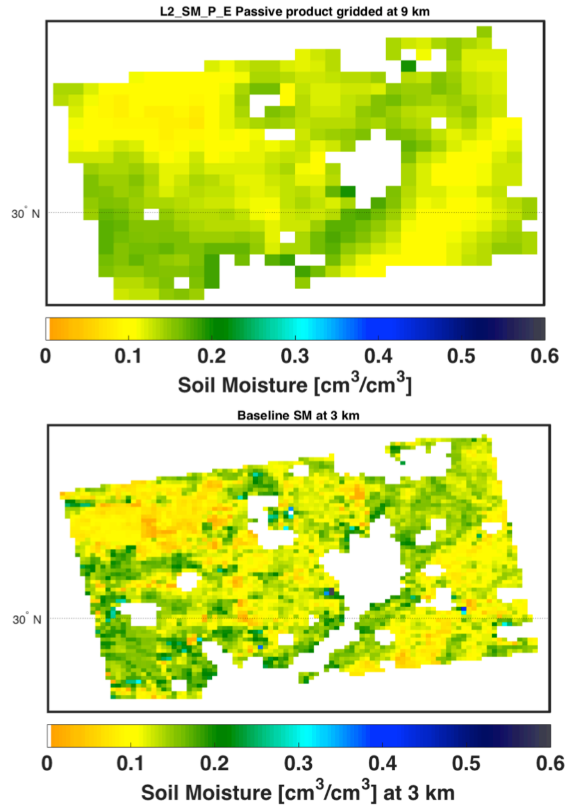

Figure 4: A retrieved soil moisture field example in Texas encompassing the region surrounding the TxSON Core Cal/Val site. In the top panel the passive-only L2_SM_P_E is shown with 9 km posting. In the bottom the SMAP-Sentinel L2SMSP field for the same region and time is shown. The active-passive product captures more detailed spatial features and has higher dynamic range (less spatial averaging). Blank regions cover the urban areas.

2.5 SMAP in the NASA Land Information System (LIS)

The NASA Land Information System (LIS) is a land surface modeling and data assimilation software environment developed at NASA Goddard Space Flight Center [6]. It allows the integration of land surface model and observations in both a simulation and state estimation framework. The NASA LIS is now capable of using SMAP science products in a data assimilation mode.

3. EXTENDED-PHASE GOALS

The SMAP prime three-year mission concludes during June 2018. NASA has approved the SMAP Project to continue data acquisition and science data production for a five-year extended-phase period through 2023. During an extended operations phase, SMAP algorithm and validation teams will refine SMAP algorithms that can produce reliable soil moisture information in woody vegetation and dense crop regions. The improved algorithms will account for the effects of multiple scattering that significantly alter the radiometric signal in denser vegetated surfaces. A robust validation program is a crucial component of this activity. The validation program during an extended operations phase will include airborne campaigns with ground-truth data collection in forested landscapes which have not been a part of the SMAP primary mission. New in situ measurements need to be collected on soils and vegetation to validate the retrievals in these landscapes.

4. REFERENCES

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