HIGH-RESOLUTION ENHANCED PRODUCT BASED ON SMAP ACTIVE-PASSIVE APPROACH USING SENTINEL 1A AND 1B SAR DATA

Narendra N. Das1,*, Dara Entekhabi2, Seungbum Kim3, Thomas Jagdhuber1, Scott Dunbar1, Simon Yueh1, P. E. O’Neill4, Andreas Colliander1, Jeffery Walker2, Thomas J. Jackson6

1Jet Propulsion Laboratory, Water and Carbon Cycle Group, Pasadena, USA - Narendra.N.Das@jpl.nasa.gov
2Massachusetts Institute of Technology, Cambridge, MA, USA
3German Aerospace Center, Microwaves and Radar Institute, Oberpfaffenhofen, Germany
4Goddard Space Flight Center, NASA, Greenbelt, MD, USA
5Monash University, Melbourne, Australia
6USDA ARS Hydrology and Remote Sensing Lab, Beltsville, MD, USA

Commission V, SS: Natural Resources Management

KEY WORDS: soil moisture, microwave remote sensing, active-passive algorithm, SMAP, and Sentinel-1A and -1B

ABSTRACT:

SMAP project released a new enhanced high-resolution (3km) soil moisture active-passive product. This product is obtained by combining the SMAP radiometer data and the Sentinel-1A and -1B Synthetic Aperture Radar (SAR) data. The approach used for this product draws heavily from the heritage SMAP active-passive algorithm. Modifications in the SMAP active-passive algorithm are done to accommodate the Copernicus Program’s Sentinel-1A and -1B multi-angular C-band SAR data. Assessment of the SMAP and Sentinel active-passive algorithm has been conducted and results show feasibility of estimating surface soil moisture at high-resolution in regions with low vegetation density (~< 3 kg m⁻²). The beta version of this product is released to public on Nov 1st, 2017. This high resolution (3 km) soil moisture product is useful for agriculture, flood mapping, watershed/rangeland management, and ecological/hydrological applications.

1. INTRODUCTION

The SMAP active-passive soil moisture product (L2SMAP) [1] was discontinued on July 7th, 2015 due to malfunction in the SMAP radar. The active-passive algorithm developed for the SMAP mission is also capable to work with different combinations of coarse resolution passive microwave (L-/C-band radiometer) and high resolution active microwave (L-/C-band SAR) observations, provided they meet certain criteria. This feature of the microwave active-passive algorithm enables us to work on an Enhanced SMAP-Sentinel high resolution soil moisture product. The importance of such high-resolution (3 km) soil moisture product is in many geophysical applications.

2. THE SMAP-SENTINEL HIGH RESOLUTION SOIL MOISTURE PRODUCT

The heritage SMAP single-look angle L-band active-passive algorithm [1] is modified to accommodate the Sentinel multi-angular and higher frequency C-band SAR data. The most important change is in the method to compute two algorithm parameters. In the heritage SMAP active-passive algorithm, a seasonal time series regression was done between the SMAP brightness temperature and the SMAP SAR co-pol observations for computing the algorithm parameter. It is not possible to create such seasonal time series between the SMAP radiometer-based brightness temperature and the temporally sparse Sentinel SAR co-pol observations because the revisit interval of the Sentinel overpass is very coarse (6 to 12 days). Also the Sentinel data have variable look angles. Therefore, we used a snapshot approach [2] to compute the algorithm parameter. This approach does not need a time series and can provide the algorithm parameter whenever there is an overlap (within 24 hours) of the SMAP radiometer brightness temperature and the Sentinel SAR data. The parameters incorporate the effects of changes in look-angle as well. The SMAP-Sentinel active-passive algorithm used in the high resolution product is shown in Eq. 1:

\[ T_{bp}(M_j) = \left[ \frac{T_{bs}(C)}{T_s} + \beta'(C) \cdot \left[ \sigma_{pp}(M_j) - \sigma_{pp}(C) \right] + \Gamma \cdot \left[ \sigma_{pq}(C) - \sigma_{pq}(M_j) \right] \right] \cdot T_s \]  

(1)

where, \( T_s \) [K] is the effective surface temperature of the top ~5 cm of the soil profile. The parameter \( \Gamma [-] \) is estimated the same way as in the heritage SMAP active-passive algorithm, however, in a linear scale. The snapshot \( \beta'(C) \) is shown in Eq. 2:

\[ \beta'(C) = \frac{T_{bs}(C) - (\gamma + 1 - \omega) \left( \frac{1}{\sin \theta} \right) \cdot T_{bp}(M_j) \cdot S_{pp}(M_j)}{S_{pp}(M_j) - S_{pp-pq} \cdot S_{pq}(M_j)} \]  

(2)

where, \( S [-] \) is the effective single scattering albedo, \( \gamma = e^{-1/sin \theta} \) [-] is the vegetation loss term, and \( \theta \) [rad] is the incidence angle. The nadir vegetation opacity \( \bar{\omega} [-] \) is related to the physical characteristics of the vegetation layer, such as the vegetation water content (VWC). \( S_{pp}(M_j) \) is co-polarized backscatter, where

* Corresponding author
The advantage of the SMAP-Sentinel based product is high spatial resolution because unlike the SMAP SAR (~3 km) the Sentinel SAR observations have very high resolution of (~50 meters). For the SMAP-Sentinel combined product, the Sentinel-1A and -1B SAR observations are preprocessed at JPL and aggregated to 1 km resolution that helps to reduce the speckle. It is planned to provide the SMAP-Sentinel product at two different resolutions (3 km and 1 km). Beta assessment of the L2SMSP product shows less variability than the SMAP-only combined product. This is expected because of the higher sensitivity of microwave C-band for the vegetation and roughness as compared to the microwave L-band SAR observations.

3. ASSESSMENT OF THE SMAP-SENTINEL HIGH RESOLUTION SOIL MOISTURE DATA

The assessment and validation of the L2SMSP data is done using two different approaches: a) comparing the disaggregated brightness temperature from (1) against the high resolution brightness temperature acquired during airborne experiments; and b) comparison of the L2SMSP retrieved soil moisture against the in situ soil moisture observations from the core cal/val sites (CVS).

In the first assessments, the L2SMSP algorithm shows significant contributions of the Sentinel 1 SAR data in capturing the finer spatial details that is otherwise not visible in the coarse resolution L2SMP_E product. In the second assessment, the L2SMSP high resolution (3 km) data when compared against the CVS sites shows an unbiased root mean square error (RMSE) of ~0.05 vol./vol. of soil moisture. The CVS sites at 3 km resolution is limited in number, therefore, we used the CVS sites at 9 km resolution. The coinciding nine 3 km retrievals are averaged to obtain 9 km soil moisture from the L2SMSP data and then evaluated against the 9 km CVS sites. The statistics shows an unbiased RMSE of 0.039 vol./vol. of soil moisture, that meets the L1 accuracy standards set for the SMAP mission.

4. DISCUSSION

The beta release of the L2SMSP product was done on Nov 1st, 2017 [3]. The data is hosted in the NASA DAAC at the National Snow
The validated release of the L2SMSP data is expected in May-June 2018 timeframe. Some improvement is expected in the L2SMSP data for the validated release due to following steps: i) We plan to include more recent and current ancillary information and updated tau-omega parameters for different landcovers. This will improve the quality and accuracy of the high resolution soil moisture retrievals in the L2SMSP products; ii) We also plan to conduct more rigorous analysis of the L2SMSP algorithm parameters to understand further its behavior and evolution over variety of geophysical surface conditions and how this understanding can help to improve the accuracy of the parameters in the L2SMSP disaggregation algorithm (2); and iii) With the improved acquisition strategy of the Sentinel 1A and 1B at Interferometric Wide (IW) swath mode in ascending and descending orbits, the global coverage of the Sentinel 1 data is also expected to improve to nearly ~6 days revisit over the select regions of the world.

In the current form, the beta released L2SMSP product shows promise. The high resolution (3 km) features of soil moisture data from the SMAP-Sentinel combined product has capability to improve the performance of many geophysical applications, especially in agriculture and flooding.

REFERENCES