Title: High-Resolution Enhanced Product based on SMAP Active-Passive Approach using Sentinel 1A and 1B SAR Data

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ABSTRACT

SMAP project is working on a new and enhanced high-resolution (3km and 1km) soil moisture product. This product will combine SMAP radiometer data and Sentinel-1A and -1B data, and it will use the heritage SMAP active-passive approach. However, modifications in the SMAP active-passive algorithm are done to accommodate the Sentinel-1A and -1B C-band SAR data. Tests of the SMAP and Sentinel active-passive algorithm has been conducted and results show great promise for the high-resolution soil moisture data. The beta version of this product will be released to public in end of the March, 2017. This high-resolution (1 km and 3 km) soil moisture product will be useful for agriculture, flooding, watershed and rangeland management, and ecological and hydrological applications. Specific examples of interest will be shown from the proposed product for the above mention geophysical applications.

Index Terms— soil moisture, microwave covariation, active-passive microwave sensing, SMAP, Sentinel-1A and -1B, soil moisture application

INTRODUCTION

The SMAP active-passive soil moisture product (L2SMAP) (Das et al., 2016) 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 of working 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 heritage SMAP Active Passive Algorithm is shown in Eq. 1.

$$T_{B_p}(M) = T_{B_p}(C) + \beta(C) \cdot \{ [\sigma_{pp}(M) - \sigma_{pp}(C)] - \Gamma(C) \cdot [\sigma_{pq}(M) - \sigma_{pq}(C)] \} \quad (1)$$

The parameter $\beta(C)$ in Eq. 1 for any given 36 km EASE grid cell of the SMAP coarse grid was derived using the time series of $T_B(C)$ and σ_{pp} data pairs that were acquired by almost simultanous observations from the SMAP radiometer and radar instriments, respectively, at ~2-3 days intervals. However, this approach of determining the algorithm parameter (β) cannot be implemented when using SMAP and Sentinal data. Computing the parameter (β) using traditional long time series is not possible due to low revisit interval of Sentinel and time mismatch of swath overlap of SMAP and Sentinel. Therefore, a snapshot approach developed to retrieve Beta parameter (Jagduber et al., 2016) from the radar and radiometer observastions is used. Another important change that is warranted using Eq. 1 is the disaggragtion of emmissivity instead of the brightness temperature. This is essential because the retrieved Beta parameter has a unit of [emmissivity/(-)]. Equation (2) is the current implementation of the Active-Passive algorithm for the SMAP and Sentinel high-resolution soil moisture data.

$$T_{B_p}(M) = \left[\frac{T_{B_p}(C)}{Ts} + \beta(C) \cdot \{ [\sigma_{pp}(M) - \sigma_{pp}(C)] - \Gamma(C) \cdot [\sigma_{pq}(M) - \sigma_{pq}(C)] \} \right] \cdot Ts \quad (2)$$

RESULTS AND DISCUSSION

We used 2.5 months (April 20th, 2015 to July 7th, 2015) of SMAP L2SMAP product and compared with the SMAP-Sentinel combined product, the initial results show promise. To further investigate and develop the methodology and algorithm parameters, more Sentinel-1A data at a regular time series is desired. Such long time-series of Sentinel data at regular interval is only available on the European continent because unlike other parts of the world the

Sentinel C-band SAR consistently observes most of the European continent. Figure 1 illustrates the retrieved Beta parameter over Europe using the SMAP and Sentinel 1A data for a 2.5 months period. As expected the Beta parameter shows dependence on landcovers (Fig. 2). The incidence angles of the Sentinel observations over its swath also vary from 30 deg to 50 deg. The retrieved Beta parameters also show dependence on the incidence angle (Fig. 2).

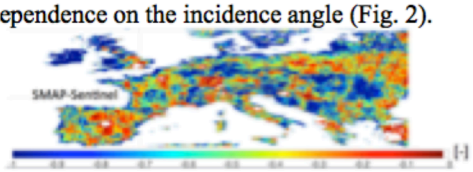

Figure 1: Retrieved Beta parameter over Europe using 2.5 months of SMAP (L-band) radiometer and Sentinel (C-band) radar data. The spatial pattern shows influence of landcovers on the Beta parameter evolution.

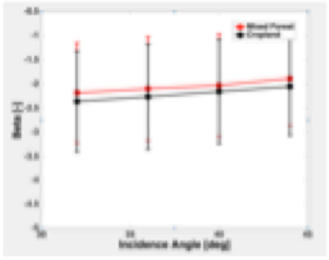

Figure 2: Dependence of Beta parameter on incidence angle.

With the launch of Sentinel 1B, the prospect of getting more C-band SAR acquisitions has increased. The global coverage using SMAP and Sentinel 1A and 1B data from active and passive algorithm is shown in Fig. 3. However, it is expected that the global coverage with further improve with more acquisitions from Sentinel 1B as convey by the European Space Agency.

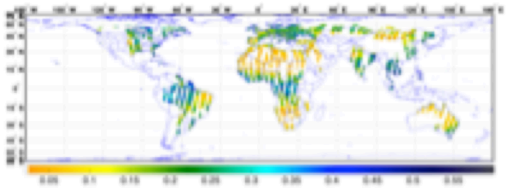

Figure 3: Soil moisture retrievals at 3 km spatial resolution from the SMAP and Sentinel 1A and 1B data between 9th Oct and 16th Oct, 2016.

The SMAP-Sentinel combined product cannot match the spatial coverage and revisit interval of the SMAP-only combined product, however, the spatial resolution obtained from the SMAP-Sentinel combined product is higher. Figure 4 shows the comparison of SMAP-only and SMAP-Sentinel combination.

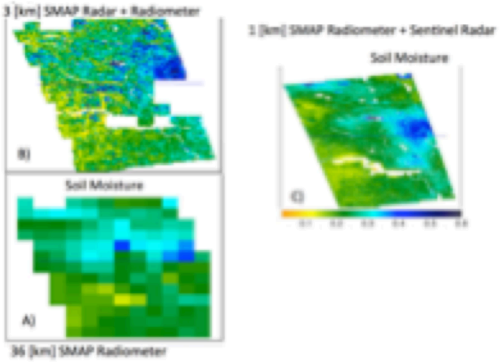

Figure 4: Example of soil moisture products from the SMAP mission. A) SMAP radiometer-based 36 km soil moisture product; B) SMAP based active-passive product at 3 km; and C) SMAP-Sentinel based active-passive product at 1 km spatial resolution.

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 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). Initial assessment of the SMAP-Sentinel soil moisture 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. However, this drawback is compensated by the SMAP-Sentinel soil moisture data because of its capability to capture high-resolution features as shown in Fig. 5.

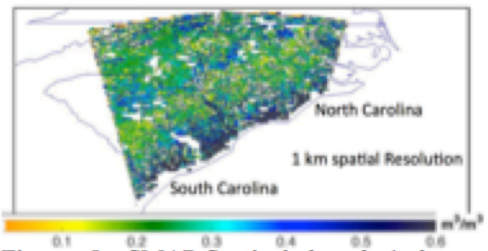

Figure 5: SMAP-Sentinel based 1 km soil moisture aftermath of the hurricane Matthew in the Carolinas of the United States.

For calibration and validation (Cal/Val), we selected a site in Spain to evaluate the SMAP-

Sentinel active-passive combined product. This site has vegetation (not very dense with Vegetation Water Content of <2 kg/m^2) and suitable for optimally Cal/Val the SMAP-Sentinel active-passive combined product. Figure 6, illustrated the statistics and time series comparison. Over this site the soil moisture RMSE meets the SMAP mission requirements. More such sites are under consideration for rigorous Cal/Val of the SMAP-Sentinel Combined product.

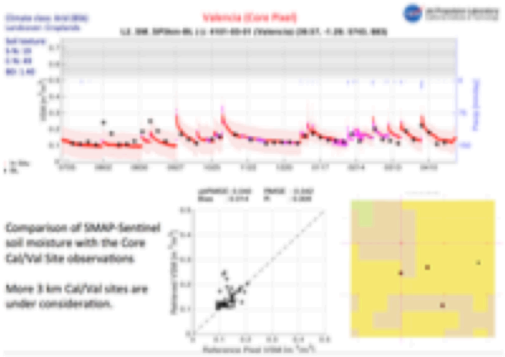

Figure 6. Cal/Val statistics and time series comparison of the SMAP-Sentinel soil moisture product with the Valencia (Spain) Core Site in situ soil moisture observations.

CONCLUSION

The SMAP-Sentinel combined product shows promise. The soil moisture data at 1 km from the SMAP-Sentinel combined product has capability to capture very high-resolution features important for many geophysical applications. With the Sentinel 1A and 1B ascending and descending data the global coverage is also expected to improve to nearly ~8 days revisit over the select regions of the world. The initial Cal/Val of the SMAP-Sentinel data over one Core Site meets the SMAP L1 requirement. However, more such site will be used in future for rigorous Cal/Val of the product. The SMAP project is expect to release the beta version by March 31st, 2017.

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