Remote Sensing of Environment 207 (2018) 65–70

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

An assessment of the differences between spatial resolution and grid size for the SMAP enhanced soil moisture product over homogeneous sites

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ARTICLE INFO

Keywords:
SMAP
Soil moisture
Spatial resolution
In situ

ABSTRACT

Satellite-based passive microwave remote sensing typically involves a scanning antenna that makes measurements at irregularly spaced locations. These locations can change on a day to day basis. Soil moisture products derived from satellite-based passive microwave remote sensing are usually resampled to a fixed Earth grid that facilitates their use in applications. In many cases the grid size is finer than the actual spatial resolution of the observation, and often this difference is not well understood by the user. Here, this issue was examined for the Soil Moisture Active Passive (SMAP) enhanced version of the passive-based soil moisture product, which has a grid size of 9-km and a nominal spatial resolution of 33-km. *In situ* observations from core validation sites were used to compute comparison metrics. For sites that satisfied the established reliability and scaling criteria, the impact of validating the 9-km grid product with *in situ* data collected over a 9-km *versus* a 33-km domain was very small for the sites studied (0.039 m^3/m^3 unbiased root mean square difference for the 9-km case *versus* 0.037 m^3/m^3 for the 33-km case). This result does not mean that the resolution of the product is 9-km but that for the conditions studied here the soil moisture estimated from *in situ* observations over 9-km is a close approximation of the soil moisture estimated from *in situ* observations over the 33-km resolution. The implication is that using the enhanced SMAP product at its grid resolution of 9-km should not introduce large errors in most applications.

1. Introduction

Most surface soil moisture remote sensing products based on passive microwave radiometry involve observations that have spatial resolutions (defined as the 3 dB beamwidth, which is also referred to as the footprint) of 30 km or greater. In the process of providing users with

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https://doi.org/10.1016/j.rse.2018.02.006
Received 14 September 2017; Received in revised form 29 January 2018; Accepted 8 February 2018

standardized products that facilitate applications, data assimilation and modeling, the observations are usually resampled to a fixed Earth grid. In the context of this paper, the spatial resolution is defined as the spatial domain that contributes to the 3 dB footprint of the sensor and grid size is the spatial interval used in the sampling of the sensor measurements. The above is true for the Soil Moisture Active Passive (SMAP) (Chan et al., 2018), Soil Moisture Ocean Salinity (SMOS) (SMOS L3 Product at Centre Aval de Traitement des Données SMOS (CATDS), 2016), and Advanced Microwave Scanning Radiometer 2 (AMSR2) missions (Descriptions of GCOM-W1 AMSR2 Level 1R and Level 2 Algorithms, 2013). In the case of SMAP, which is the focus of this paper, the standard radiometer-based product (L2SMP) has a grid size of 36-km, which is close to the nominal spatial resolution of the sensor (Chan et al., 2016a). In such cases, the terms spatial resolution and grid size have been used interchangeably.

All of the missions noted above now provide products that have been resampled to grid sizes (9 to 25 km) that are significantly finer than the nominal spatial resolutions of the sensor. The actual spatial domain that these grid products represent may not be clear to the user.

For SMAP, there is considerable overlap of footprints across a scan. This is exploited through an interpolation approach to create an enhanced SMAP brightness temperature (TB) product with a grid size of 9-km that is the basis for the 9-km enhanced soil moisture product (L2SMP_E) with a grid size of 9-km (Chan et al., 2018). Although it is stated in supporting documents that the actual contributing domain is larger than 9-km, the reality is that many users will utilize the data as if its spatial resolution was the same as the grid size. When interpreted in this manner, the user implicitly assumes that the actual soil moisture for the 9-km grid cell domain is not much different than the retrieval value, which is based on a TB and ancillary data for the nominal spatial resolution (the nominal spatial resolution specified for the L2SMP_E is 33-km; a full description of this will be provided in a following section). It is reasonable to think that soil moisture at 9-km and 33-km would be correlated; however, it should be recognized that meteorological variability and geophysical heterogeneity over the domains may influence this relationship.

In this investigation we examine the magnitude of the difference between soil moisture estimates made using *in situ* observations over 9 and 33-km domains and also compare these to L2SMP_E retrievals to assess the likely impact of assuming that grid size equals spatial resolution. Analyses presented in this study are based on satellite and *in situ* soil moisture data collected over the SMAP core validation sites (CVS) (Colliander et al., 2017). While there have been no systematic studies that have directly addressed this issue for remotely sensed soil moisture, Dumedah et al. (2014) assessed the SMOS brightness temperature products that were resampled from a 42 km spatial resolution to a 15 km grid size using high resolution aircraft measurements and found that the differences could be < 4 K in some cases, which corresponds to only about 0.01 m^3/m^3 soil moisture over bare surfaces at horizontal polarization (*e.g.*, Njoku and Entekhabi, 1996).

2. Data

2.1. The SMAP level 2 soil moisture passive enhanced (L2SMP_E) product

The L2SMP_E is made possible by an enhanced interpolation of the SMAP Level 1B Brightness Temperature Product (L1BTB) (Chaubell et al., 2016; Peng et al., 2017). The approach is based on the Backus-Gilbert (BG) optimal interpolation technique (Poe, 1990) applied to the original standard TB data, where the objective of the BG interpolation, as implemented by SMAP, is to achieve optimal data estimates at unsampled locations as if observations were actually made with the original sensor at those same locations. This interpolation provides an improvement over the standard SMAP Level 1C Gridded Brightness Temperature Product (L1CTB) (Chan et al., 2016b; Piepmeier et al., 2017; Peng et al., 2017), in that it makes explicit use of antenna pattern information and finer grid size to more fully capture the information of the oversampled radiometer measurements in the along-scan direction. It is important to note that this recovery of high frequency sampling information as implemented in the BG approach comes primarily from interpolation rather than resolution enhancement. Thus, the native resolution of the interpolated data remains similar to the spatial extent covered by the 3 dB beamwidth of the radiometer (~40 km). The resulting interpolated data, known as the SMAP Enhanced Level 1 Gridded Brightness Temperature Product (L1CTB_E), are provided on the 9-km EASE Grid 2.0 projection. The product is used as the primary input to subsequent geophysical inversion to produce the SMAP L2SMP_E. The soil moisture algorithm, the Single Channel Algorithm-V Polarization (SCA-V), is the same as that used in the standard product (O'Neill et al., 2016); several alternative algorithms were included in the assessments in previous reports (Chan et al., 2016a, 2018). Since these comparisons have consistently shown that the SCA-V has the best performance metrics, this study only examines the SCA-V.

Because after BG interpolation the native resolution of the L1CTB_E remains approximately the same as the 3 dB spatial resolution of the SMAP radiometer, as noted above, it is important in the subsequent soil moisture inversion process that a proper contributing domain is chosen to accurately reflect the actual spatial extent observed by the radiometer. The relationship between grid size and contributing domain is illustrated in Fig. 1 using a typical core validation site. As described in Chan et al. (2018), in order to facilitate processing (considering the resolution of ancillary data and the structure of the EASE grid) a contributing domain of 33-km was chosen to approximate the spatial extent covered by the radiometer (spatial resolution). Chan et al. (2018) noted that a change in contributing domain from 36-km to 33-km had almost no impact on the validation metrics.

2.2. Core validation sites

The primary validation for the L2SMP_E soil moisture product is based on a comparison of SMAP retrievals with ground-based observations that have been verified as being capable of providing an estimate of the soil moisture over the same spatial domain (33-km) and depth (5 cm). The locations that provide these validation observations are called CVS (Colliander et al., 2017). The validation comparisons provide error estimates and a basis for modifying algorithms and/or

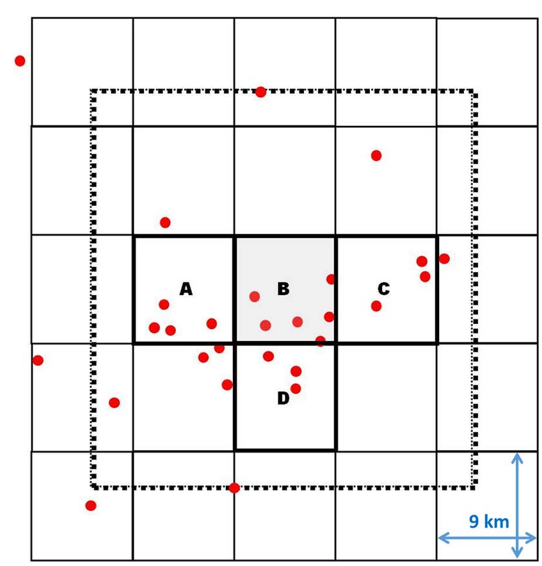

Fig. 1. Example of the SMAP L2SMP_E grid over a core validation site (Walnut Gulch). The solid black lines indicate the borders of the 9-km grid cells. The circles are the locations of *in situ* stations. The CVS 9-km grid cell is chosen (the heavier black line grid cell "B") so that its actual contributing domain of 33-km (the dashed black line centered on grid cell "B") best captures the data from the local network of stations.