Evaluating the Impact of Initial Spatial Resolution on Downscaling Soil Moisture Maps

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Abstract

The impact of the initial spatial resolution of soil moisture maps on the quality of downscaled products was investigated in this study. L-band observations are sensitive for estimating soil moisture, however the low frequency (1.4 GHz) limits sensor spatial resolution given a fixed antenna size. Current passive sensors provide resolutions of 30-50 km, while some applications require higher spatial resolutions. Although several downscaling methods have been proposed in the literature to derive high-resolution soil moisture datasets using auxiliary data, the effect of the initial resolution on the quality of downscaled products has not been thoroughly addressed. This research utilizes airborne data from three different campaigns conducted in various climatic regions (NAFE'06, SMAPVEX15, and SMAPVEX16) to assess this impact. Specifically, soil moisture maps obtained from airborne sensors with resolutions ranging from 500 m to 1 km were aggregated to 4-5 km, 8-10 km, 18-20 km, and 36-40 km prior to applying the DISPATCH algorithm to generate 1 km maps. These downscaled maps were compared to the original 1 km maps. The results demonstrate that downscaled maps are 30%-75% more accurate when the initial resolution is in the range of 5-10 km compared to initial resolutions of 36-40 km. This finding is significant for the preparation of future missions such as SMOS-HR.

Keywords: L-Band soil moisture, Passive Radiometry, Spatial downscaling, Soil Moisture and Ocean Salinity satellite

1. Introduction

Soil moisture is critical for the survival of all forms of life on Earth, influencing temperature, precipitation, and various hydrological, biological, and biogeochemical processes. Measuring soil moisture is essential for numerous applications, as it affects both terrestrial and aquatic ecosystems. Gravimetric soil moisture refers to the weight of water in a unit weight of soil, while volumetric soil moisture is defined as the ratio of the volume of water to the unit volume of soil. Given that different soil types exhibit varying saturation and water-holding capacities, accurate global soil moisture measurements are vital. This has led to the use of space-borne instruments to estimate soil moisture on a global scale. Among these, the Soil Moisture and Ocean Salinity (SMOS) satellite employs microwave remote sensing at low L-band frequencies to capture surface soil moisture and ocean salinity (Kerr et al., 2010). However, the low frequency limits the spatial resolution of current L-band sensors to approximately 30-50 km, posing challenges for applications requiring higher resolution data.

To address this limitation, downscaling methods have emerged as valuable tools for estimating soil moisture at higher resolutions by merging low-resolution data with higher-resolution auxiliary datasets, which, although lower, retain some sensitivity to soil moisture. Techniques such as the DISPATCH (Disaggregation based on Physical and Theoretical scale Change) algorithm utilize high-resolution land surface temperature data from MODIS to disaggregate soil moisture observations (Merlin et al., 2012). The initial implementation of DISPATCH was tested with airborne data from the NAFE'06 campaign over Southeast Australia (Merlin et al., 2008).

This study aims to quantitatively assess the impact of initial spatial resolution on soil moisture estimation using downscaling approaches, particularly in the context of preparing for future missions such as SMOS-HR (Rodríguez-Fernández et al., 2019). Airborne data from the NAFE'06, SMAPVEX15, and SMAPVEX16 campaigns were aggregated to various resolutions before applying the DISPATCH algorithm to downscale the data back to 1 km. The results are compared to the original 1 km airborne data to evaluate the importance of the initial resolution on the quality of downscaled products. The remainder of this document is organized as follows: Chapter 2 presents the methodology, followed by a result and discussion in Chapter 3; and finally, conclusion is drawn in Chapter 4.

2. *Methodology*

This study evaluates the performance of the DISPATCH algorithm across three distinct case studies, focusing on regions in the Yanco area of the Murrumbidgee River catchment in Southeastern Australia (Merlin et al., 2008), the USDA Walnut Gulch Experimental Watershed in Arizona, USA (Colliander et al., 2017), and the Red River Watershed in Carman, Manitoba, Canada (Colliander et al., 2019). The MODIS data (AQUA and TERRA) and PLMR (NAFE'06) datasets were initially obtained in vector format and converted into a grid format with 40x40 points. For PALS data from the SMAPVEX campaigns, which was already in grid format but in different geographical coordinate systems, a 1 km resolution was achieved by averaging 4 pixels from the original 500 m EASE 2.0 grid. This data was then reprojected into a UTM coordinate system to obtain appropriate x and y coordinates. The methodology involves initially aggregating airborne data from the PLMR/PALS instrument at a 1 km resolution to four coarser resolutions (5 km, 10 km, 20 km, and 40 km for PLMR; or 4 km, 12 km, 18 km, and 36 km for PALS) by averaging the pixel values. Downscaling to the original 1 km resolution is subsequently performed using the DISPATCH algorithm with MODIS auxiliary data. The outputs are then compared to the original 1 km resolution data, allowing for an evaluation of the downscaling effectiveness.

3. Results and Discussion

The results were analyzed both on a daily basis and as a cumulative overview. A significant enhancement in the quality of downscaled soil moisture estimates was observed as the initial resolution decreased from approximately 36-40 km to around 4-5 km. This improvement was most pronounced at resolutions of 12 km or finer. Specifically, the correlation with the original PLMR data from the NAFE’06 campaign increased by 6% to 15% when transitioning from 10 km to 5 km relative to the 40 km resolution. For the PALS dataset from the SMAPVEX15 campaign, the correlation improvement ranged from 14.5% to 28.99% as the resolution changed from 12 km to 4 km compared to the 36 km resolution. The SMAPVEX16 dataset exhibited even more substantial gains, with correlation values increasing from 35% to 75%. While the availability of additional data may impact these improvements, the findings clearly indicate that higher initial resolutions lead to more accurate soil moisture estimations. The results shown a global improvement of the correlation for all the cases when starting at ∼ 12km or ∼ 5 km, respectively, but it is also interesting to analyze in more detail the daily results.

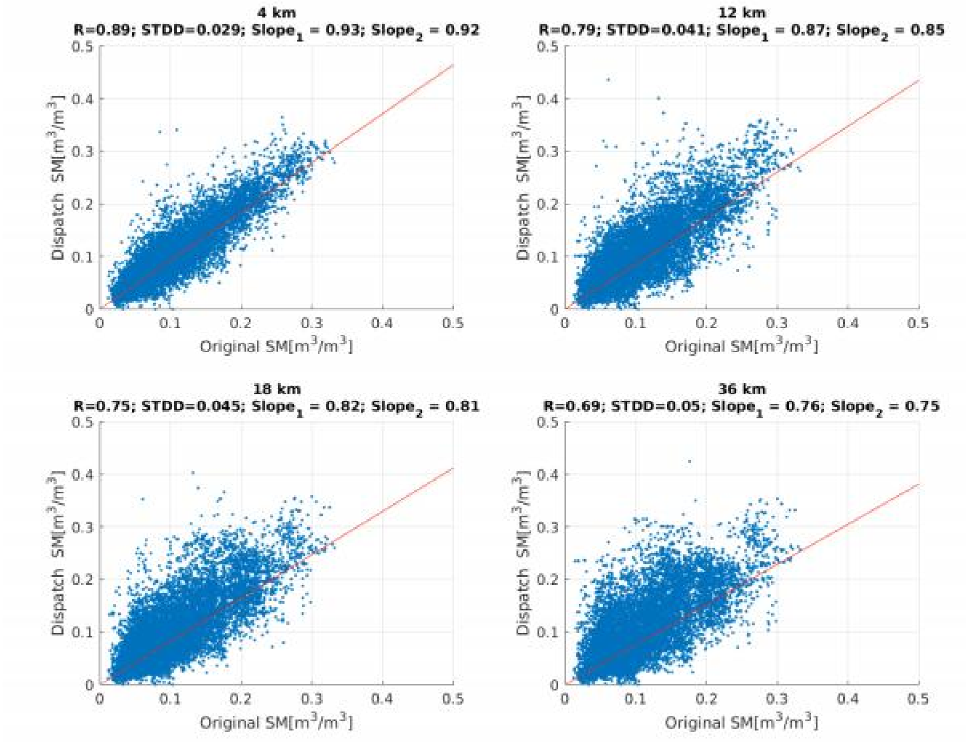

Figure 1 Global scatter plot for all the days and for respective resolutions over the SMAPVEX15 campaign.

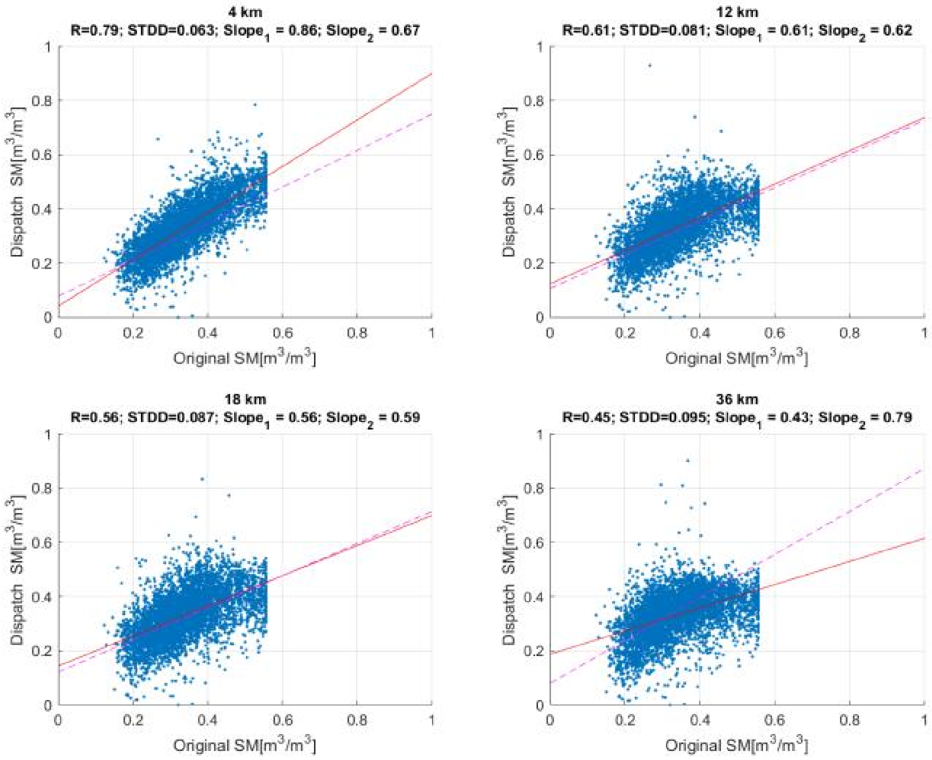

Figure 2 Global scatter plot for all the days and for respective resolutions over the SMAPVEX16 campaign.

4. Conclusion

This study demonstrates that downscaled soil moisture data obtained from sensors with a native resolution of 10 km or finer exhibit significantly improved accuracy compared to those derived from sensors with resolutions ranging from 40-55 km. The extent of quality enhancement associated with higher initial spatial resolutions is contingent upon the specific soil moisture application in question. Utilizing various quality metrics, this research revealed that downscaled maps achieved an accuracy improvement of 30% to 75% when the initial resolution fell within the 5-10 km range, compared to initial resolutions of 36-40 km.

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