Remote Sensing of Environment 124 (2012) 26–37

Contents lists available at SciVerse ScienceDirect

Remote Sensing of Environment

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

First evaluation of the simultaneous SMOS and ELBARA-II observations in the Mediterranean region

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ARTICLE INFO

Article history:
Received 13 September 2011
Received in revised form 11 April 2012
Accepted 14 April 2012
Available online 25 May 2012

Keywords:
SMOS
Soil moisture
Optical depth
Retrievals
Mediterranean environment
Level 2 algorithm
Brightness temperature
Vineyards
Soil
NDVI
MODIS
ELBARA

ABSTRACT

The SMOS (Soil Moisture and Ocean Salinity) mission was launched on November 2, 2009. Over the land surfaces, simultaneous retrievals of surface soil moisture (SM) and vegetation characteristics made from the multi-angular and dual polarization SMOS observations are now available from Level-2 (L2) products delivered by the European Space Agency (ESA). Therefore, first analyses evaluating the SMOS observations in terms of Brightness Temperatures (TB) and L2 products (SM and vegetation optical depth TAU) can be carried out over several calibration/validation (cal/val) sites selected by ESA over all continents. This study is based on SMOS observations and in situ measurements carried out in 2010 over one of the main SMOS cal/val sites in Europe: the VAS (Valencia Anchor Station) site in the region of Utiel–Requena, close to Valencia, Spain. The main vegetation types in the region are vineyards, orchards and natural Mediterranean vegetation. The SMOS observations were analyzed in conjunction with those carried out by the L-band ELBARA-II radiometer over a vineyard which is considered as representative of the main land use of the VAS site. Time series of TB and retrievals of SM and TAU based on both the SMOS (L2 products) and the ELBARA-II observations were compared and evaluated against in situ measurements. A good agreement was found between the time variations in TB and in the retrieved SM values computed over the site from the SMOS and ELBARA-II observations (the determination coefficient R^2 was >0.88 for the TB values and $R^2>0.64$ for the retrieved SM values). However, it was found that the SMOS L2 SM products underestimated the SM values retrieved from ELBARA-II by ~0.2 m^3/m^3. It is likely this offset can be partially explained by differences between the observed scenes: while the ELBARA-II footprint includes a single vineyard, the heterogeneous SMOS footprint includes not only a large number of vineyards but also a natural Mediterranean vegetation with persistent leaves overlaying rocky soils. The time variations in TAU retrieved from the ELBARA-II observations were found to be closely related to those of the NDVI (Normalized Difference Vegetation Index) vegetation index obtained from MODIS (Moderate Resolution Imaging Spectroradiometer) ($R^2=0.61$) and revealed the vegetation cycle over the year. Conversely, the time variations in the SMOS Level-2 TAU product did not reveal any trends in relation to the vegetation development over the site.

1. Introduction

SMOS, launched on November 2, 2009, is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme (Kerr et al., 2001, 2012). It aims to improve our understanding of the Earth's water cycle by providing global data of Soil Moisture (SM) over land and salinity over oceans. Over the land

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doi:10.1016/j.rse.2012.04.014

surfaces, the main applications will concern improvements of weather and climate models, agriculture and water resource management. The principle of the SMOS Level-2 (L2) retrieval algorithm is to exploit multi-angular and bi-polarization data in order to simultaneously retrieve two main surface parameters: the surface SM and the vegetation optical depth TAU, which is related to the vegetation biomass. Since the launch of SMOS, during the commissioning phase (November–end of April 2010) and throughout the lifetime of the mission, the scientific team will assess the quality of the data products (Kerr et al., 2012).

First evaluations were based on comparisons between the time series of TB and the L2 products with in-situ data from micro-meteorological stations (precipitation, SM, etc.) and remotely-sensed index of the vegetation development estimated in the optical domain. These evaluations were carried out over several sites representative of some of the most widespread biomes of the globe: semi-arid areas in western Africa (Gruhier et al., submitted for publication), continental US areas using the SCAN/SNOTEL soil moisture monitoring network (Al Bitar et al., 2012), forests (Ferrazzoli et al., 2011), south-eastern Australia (Rüdiger et al., 2011), temperate regions in south western France (Albergel et al., 2011), etc.

The study presented in this paper was carried out in the same assessment framework over one of the main SMOS calibration/validation (cal/val) sites selected by ESA in Europe: the VAS (Valencia Anchor Station), west of the city of Valencia (Spain), within a semi-arid region. The site mainly includes vineyards, other agricultural fields and natural Mediterranean vegetation. In order to facilitate the interpretation of the SMOS TB observations and of the L2 products over the VAS site, a ground-based L-band radiometer (ELBARA-II, Schwank et al., 2010) was installed at the end of 2009 to monitor a representative vineyard within the VAS region from the top of a 17 meter tower. Over this vineyard, referred to as the MELBEX-III or M-III site (Mediterranean Ecosystem L-Band characterisation EXperiment III), automatic and multiangular ELBARA-II observations were carried out continuously every 30 min (Schwank et al., 2012).

The spatial extent of the area monitored by the tower-based and spaceborne sensors is very different: a few square meters within a vineyard field for ELBARA-II, and a large footprint corresponding very roughly to a 40 km diameter circle for SMOS. However, it was considered that ELBARA-II could be very useful in the analysis of the multi-angular SMOS observations, since the general conditions of the SMOS and ELBARA-II observations over the VAS and M-III sites are relatively similar: the M-III vineyard is representative of the main land use of the VAS region, the soil and semi-arid climatic conditions are relatively homogeneous over the large VAS site and no large irrigation systems led to specific soil moisture conditions in most of the agricultural fields. Moreover, to analyze the SMOS observations in this study, we selected a node within the spatial grid including all the L2 products, which is close to the M-III site and which include a very large fraction of vineyards.

First results of the analysis and comparison of the SMOS and ELBARA-II observations in 2010 over, respectively, the VAS area and the M-III vineyard site are presented in this study.

In a first step we will present in detail the experimental set up deployed over the VAS and M-III sites and the L-MEB (L-band Microwave Emission of the Biosphere) forward model. This model was designed to simulate the microwave signatures of the various soil and vegetation types which are present in the mixed SMOS footprint. The simultaneous retrievals of (SM, TAU) made from the SMOS (and provided in the L2 products) and the tower-based ELBARA-II observations are based on the L-MEB inversion (Kerr et al., 2012; Wigneron et al., 2000, 2007).

In a second step we will analyze and compare the time series of the TB observations measured by the ELBARA-II and SMOS sensors over, respectively, the M-III site and the SMOS node, which was selected to be representative of the soil and vegetation conditions prevailing within the M-III vineyard.

In a third step, we present the main results of the (SM, TAU) retrievals over both the M-III site and the SMOS node. Comparisons of the retrieved SM and TAU values are made with *in situ* estimations of SM and precipitation and with the vegetation NDVI index, as measured by the MODIS optical sensor. Finally, direct comparisons between the retrieved SM values from both SMOS and ELBARA-II are evaluated. The results obtained in this study are very useful to evaluate the first results computed from the SMOS Level-1 and Level-2 algorithms. Even if the results are based on a single site, they provide interesting indications of possible issues (in terms of bias and trends) and ways of improvement that will require future studies based on data acquired during longer time periods.

2. Material and method

2.1. The VAS site

The study was based on SMOS observations and in situ measurements carried out in 2010 over the VAS (Valencia Anchor Station) site. This site is one of the main reference areas selected by ESA and the SMOS science team as a validation site for SMOS land products in the Mediterranean region. It is located about 80 km west of the city of Valencia (Spain) on the Utiel-Requena Plateau at ~800 m a.s.l. The landscape is relatively homogeneous over an area of about 50 km × 50 km, which is sufficient to encompass at least a SMOS footprint (~40 km). The main cover type is vineyards and orchards (almond, olive and fruit trees) (65%), followed by natural Mediterranean vegetation (pine trees and shrubs ~30%), and smaller fractions of industrial, and urban areas (Cf Fig. 1). The topography is generally plain (slope<2%) with slightly hilly regions (slope~8%-15%) mainly covered by natural Mediterranean vegetation. The soils are Haplic and Calcic Calcisols and Cambisols. They are deep with accumulation of carbonates and with low organic matter content. The climate is semi-arid, with air temperature ranging from -15 °C in winter to 45 °C in summer (annual mean of ~14 °C) and the mean annual precipitation data are about 450 mm with peaks in spring and autumn.

2.2. The MELBEX-III campaign

2.2.1. ELBARA-II experiment

In order to better evaluate the SMOS observations and to improve the retrieval products over the VAS site, a ground-based L-band radiometer (ELBARA-II) was installed at the end of 2009 at the M-III site within the vineyard "Finca El Renegado", Caudete de las Fuentes (Valencia) Spain (the location of the M-III site is shown in Fig. 1, with coordinates: 39°31′18.18″N, 1°17′29.64″W, altitude = 800 m a.s.l.).

As shown in Fig. 1, the M-III site is located in the central region of the 50 × 50 km^2 VAS site. The ELBARA-II radiometer was set up 17 m above ground to monitor a vineyard which is representative of the main land use of the VAS region. Note that a similar experiment (MELBEX-I) was carried out in the VAS site over a shrub land area in 2005–2006 (Cano et al., 2010). All details concerning the ELBARA-II instrument and the radiometer set up are given in Schwank et al. (2010, 2012) and we will give here only a summary of the main information concerning this experiment. The ELBARA-II was equipped with an elevation tracker that allows the antenna to be oriented automatically for incidence angles θ varying between 30° ≤ θ ≤ 330° where θ = 180° is the zenith direction.

Every 30 min, automatic "observation phases" were carried out. They consist of automatic measurements of TB at horizontal and vertical polarizations at observation angles between θ = 30° and 70° with steps of 5°. Between each observation phase, measurements are made at the incidence angle θ = 45° every 5 min. Once a day, at 24:00 local time, the radiometer is automatically positioned at 150° to carry out sky calibration measurements. The absolute accuracy of the ELBARA-II measurements was estimated to be better than ±1 K