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TOWARDS A LONG-TERM DATASET OF ELBARA-II MEASUREMENTS ASSISTING SMOS LEVEL-3 LAND PRODUCT AND ALGORITHM VALIDATION AT THE VALENCIA ANCHOR STATION

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RESUMEN

El presente estudio se refiere a una validación de datos de nivel 3 de SMOS con medidas *in situ* tomadas en la *Valencia Anchor Station* (VAS) para el año 2012. El radiómetro ELBARA-II está situado dentro de la VAS, observando un campo de viñedos que se considera representativo de un *footprint* de SMOS. Las temperaturas de brillo (TB) adquiridas por ELBARA-II se compararon con las observadas por SMOS en las mismas horas y fechas. También se invirtieron mediante el modelo L-MEB con el fin de obtener humedades de suelo (SM) que, posteriormente, se compararon con SMOS.

Palabras clave: contenido en agua de la vegetación, datos de nivel 3 de SMOS, ELBARA-II, espesor óptico de la vegetación, humedad de suelo, L-MEB, SMOS, rugosidad del suelo, temperatura de brillo, *Valencia Anchor Station*.

ABSTRACT

This study is a validation of SMOS level 3 data using in situ measurements from the Valencia Anchor Station (VAS) in 2012. ELBARA-II radiometer is placed in the VAS, observing a vineyard field considered as representative of a SMOS footprint. Brightness temperatures (TB) acquired by ELBARA-II have been compared to those observed by SMOS at the same time and date. They were also inverted using the L-MEB model to provide soil moistures (SM), which later on have also been compared to those provided by SMOS.

Keywords: *brightness temperature, ELBARA-II, L-MEB, SMOS, SMOS level 3 data, soil moisture, soil roughness, Valencia Anchor Station, vegetation optical depth, vegetation water content.*

1. INTRODUCTION

The *Soil Moisture and Ocean Salinity* (SMOS) is the second *European Space Agency* (ESA) *Earth Explorer Mission* launched on 2nd November 2009 with the objective to provide global estimations of soil moisture and sea surface salinity (Kerr *et al.*, 2010).

In the framework of SMOS data and product validation, ESA selected the *Valencia Anchor Station* (VAS) for the installation of one of the ELBARA-II radiometers in September 2009, under the responsibility of the *Climatology from Satellites Group* of the University of Valencia. Since then, the radiometer has been continuously operating except for some interruptions caused by power failures or minor spare parts replacements. This has permitted the acquisition of a robust dataset that has recently been approved to continue for a long-term basis during the lifetime of the mission.

The VAS constitutes an area of about 50 x 50 km², sufficiently large to cover a SMOS *pixel*. It is placed over a large semi-arid plateau at about 80 km west of the city of Valencia. The ELBARA-II radiometer can measure brightness temperatures and is placed at a vineyard field in the “*Finca El Renegado*” (Caudete de las Fuentes, Valencia) which has been named as the MELBEX-III (*Mediterranean Ecosystem L-Band Characterization Experiment*) site (39°31'18, 18°N; 1°17'29,64''W, altitude 800 m). This place is considered as representative of a SMOS *pixel* with respect to the vine land use which accounts for about 65-70% of the whole SMOS *pixel* (Wigneron *et al.*, 2012, Schwank *et al.*, 2012) and the matorral area that represents only about 20% does not change so much along the year (Cano *et al.*, 2010). The interest of this site, apart from its significant homogeneity, is the possibility of studying two totally different land use states since the vine phenological cycle extends from

April to October, leaving the rest of the year the area under bare soil conditions. This study aims at the validation of both brightness temperatures and soil moisture (SM) obtained by SMOS during the year 2012, using the data acquired by the ELBARA-II radiometer and other *in situ* measurements from the VAS area.

2. MATERIALS AND METHODOLOGY

In this study, we used SMOS level 3 data and *in situ* measurements obtained in MELBEX-III.

The main vegetation type present in the VAS 50 x 50 km² area corresponds to vineyards (around 65%), pine trees and scrubs and other Mediterranean ecosystem species such as olive and almond trees. There are also small towns and the topography is relatively flat with small undulations of about 2%. The climate is semi-arid of continental Mediterranean type with temperatures between -15°C and 45°C. Precipitations are scarce (450 mm per year), mainly developing in spring and autumn.

ELBARA-II is a dual polarization L-band microwave radiometer with two measuring channels, namely 1400–1418 MHz and 1409–1427 MHz, that uses a 23.5 dB gain horn antenna that can move changing its inclination. It is mounted on a 15 m height platform to continuously observe brightness temperatures in both polarizations (TB_v, TB_h). The radiometer has a measuring protocol by which every day it takes a sky calibration measurement at 23:55 h with an inclination angle of 150° (relative to nadir). Besides, it also regularly measures every half hour at angles 30°, 35°, 40°, 45°, 50°, 55°, 60°, 65°, 70°, and at 45° every 10 min. The ELBARA-II footprint has been analysed in detail in Schwank *et al.* (2012).

The 30-min TB_v and TB_h values for each inclination angle are obtained by using an ESA Phyton toolbox routine that processes the original ELBARA-II raw data (Voelksch *et al.*, 2011). The routine has also a robust quality control filter to detect RFI (Radiofrequency Interference) measurements and delete them. After the efforts made in 2010 in Spain to switch off microwave systems violating the protected part of the L-Band, RFI has decreased significantly. Very few RFI effects have been detected over the VAS for the period analyzed.

The MELBEX-III site also contains a full DAVIS meteorological station and two Delta-T ML2x soil moisture probes: ThetaProbe #17702, placed close to a vine stump and ThetaProbe #17701, placed in the middle of two vine rows. They measure SM every 10 min. Both of them are close to ELBARA-II.

The transformation of ELBARA-II TB values into soil moisture (SM) and vegetation optical depth (TAU) is carried out by inverting the L-MEB model (Wigneron *et al.*, 2007). The inversion is based on minimizing a cost function (CF) using a least-squares iterative

algorithm which requires some model input parameters, namely SM, TAU, soil temperature T_{GC}, scattering albedo ω_p, roughness parameters -H_R, Q_R, N_{RV}, N_{RH}- and structural vegetation parameters -tt_H, tt_V- (Equation 1).

$$x = \frac{\sum (T_{Bmes} - T_B^*)^2}{\sigma(T_R)^2} - \sum \frac{\sum (P_i^{ini} - P_i^*)^2}{\sigma(P_i)^2} \quad (1)$$

where TB_{mes} is the value given by ELBARA-II, σ(T_B) is the standard deviation associated with the brightness temperature measurements, P_i^{*} (i = 1, ... N) is the value of the retrieved parameter (SM, TAU in our case); P_iⁱⁿⁱ (i = 1, ... N) is the initial value of each parameter in the retrieval process and corresponds to an a priori estimate of the parameter P_i; σ(P_i) is the standard deviation associated with this estimate.

In the cost function, only 30-min TBs for angles smaller or equal to 55° were considered.

The arithmetic mean soil moisture of the two ThetaProbes was used as an input parameter to the model (Wigneron *et al.*, 2012). T_{GC} at 2 cm depth was obtained from a YSI thermistor placed next to the ThetaProbes. Soil roughness and vegetation parameters were considered constant for the whole year 2012. The TAU value was set to 0.05 and the roughness parameters as H_R = 0.25, Q_R = 0.15, N_{RV} = -1.7, N_{RH} = -0.7. Vegetation parameters were set to tt_H = 1, tt_V = 0. These assumptions followed Wigneron *et al.* (2012) previous work. Soil roughness and LAI (*Leaf Area Index*) measurements are now currently and systematically being obtained to better adapt the model to the field conditions along the year, thus improving its performance in obtaining SM and TAU. The values obtained for TB, SM and TAU were compared to SMOS level 3 data, obtaining the root mean square error (RMSE), correlation coefficient (R2) and bias.

The SMOS level 3 products are all resampled to the spatial resolution of 25 km of the EASE Grid (*Equal-Area Scalable Earth Grid*).

The level 3 product chosen for this study is the daily product *One Day Soil Moisture Global Map, P11P*, that is distributed by CATDS (*Centre Aval de Traitement des Données SMOS*). The format of these files is NetCDF. This product contains data that has previously been analyzed and filtered in order to provide the optimum daily SM estimation considering the different satellite re-visits. For the estimation of a specific daily value, CATDS takes into account the values for ascending and descending orbit in the three days before and after. This product also provides TB and TAU, among other parameters.

The level 3 TB (incidence angle of 42.5°), SM and TAU daily data for 2012, together with the exact observation time, have been extracted by means of MatLab routines. For the validation of SMOS TBs, the ELBARA-II TBs used were those with 40° incidence angle. Since the CATDS level 3 data are given

separately for ascending orbit (approximately taken around 5:30 am) and for descending orbit (approximately taken around 6:30 pm), these times were taken into account for the comparisons with the radiometer measurements.

Daily precipitation data were obtained from the Jucar River Basin Authority (*Confederación Hidrográfica del Júcar*) close raingauge of Caudete de las Fuentes.

3. RESULTS

3.1. TB for ELBARA-II and SMOS (level 3)

The evolution of TB measured by the ELBARA-II radiometer at the MELBEX-III site for 2012 has been compared to that estimated by SMOS (considering both ascending and descending orbits data). Figure 1 shows this comparison which also includes daily precipitation data in the area. Before analysing the results, it should also be considered that the SMOS pixel extends over a larger and less homogeneous area than that observed by ELBARA-II over the vineyard field. According to Cognard *et al.* (1995), the justification of less abrupt TB variations on a more heterogeneous area are in the impact produced by the different land cover, roughness, texture and precipitation. Thus, it is justified that ELBARA-II is more sensitive to the periods of rain, in which the decrease in TB is more noticeable. In parallel, the summer months show higher values of TB, and this is due to the absence of rainfall, mainly recorded in the spring and especially autumn months.

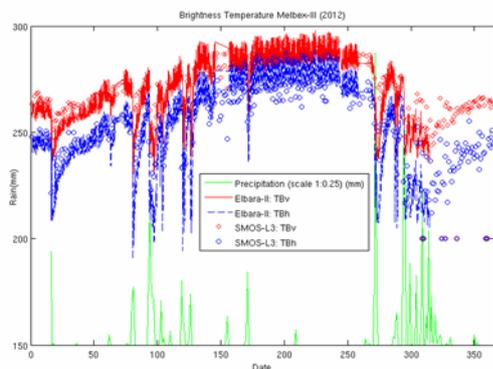


Figure 1. Comparison of ELBARA-II and SMOS L3 TBs

Figure 2 shows the correlation between both sets of measurements using the specific ELBARA-II measurements at SMOS overpassing time. The results are very satisfactory thus confirming the significant correlation of both TBs ($R^2 > 0,87$) for both polarizations. It is also noticeable that in dry conditions (larger TB values) the correlation is even higher.

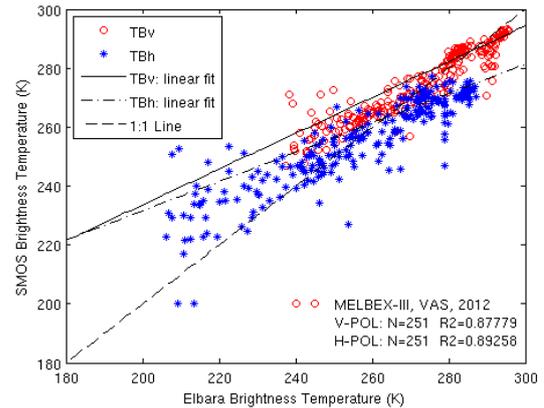


Figure 2. Correlation between ELBARA-II and SMOS L3 TBs

3.2. SM for ELBARA-II and SMOS (level 3)

Figure 3 shows the evolution of SMOS SM in descending orbit (around 6:30 pm) and that obtained by L-MEB inversion of ELBARA-II TBs at the same time. In spite of the difference between the values obtained for SMOS and ELBARA-II, a trend is clearly shown in the SM behaviour in both cases: there exists a significant increase in spring and autumn that is in correspondence with the precipitation periods in the area. It can be seen that SMOS underestimates SM values as compared to ELBARA-II's. This difference can be attributed to the homogeneity of the field observed by ELBARA-II opposite to the greater heterogeneity offering a wider area seen by SMOS. Nevertheless, it should be taken into consideration the character of first approximation of this analysis. The use of better model input parameters in the short future will likely improve the results. For that, LAI (related to optical depth, TAU) and soil roughness are currently been measured.

Table 1 shows a more direct comparison between both SM datasets. The analysis separates ascending (approximately 5:30 am) from descending orbit (approximately 6:30 pm). As shown, the results in descending orbit have a higher correlation ($R^2=0.665$) than the ones in ascending orbit ($R^2=0.591$) and similar RMSE and BIAS.

Table 1. Correlation of SMOS SM (ascending and descending orbits) and ELBARA-II SM

Orbit	no. of data values	BIAS	R ²	RMSE
Ascending	135	-0,074	0,591	0,093
Descending	143	-0,086	0,665	0,100

The L-MEB inversion of TB measurements also allows the extraction of TAU for the whole year 2012. However, the comparison of this result with SMOS estimations provides low correlations and the conclusions are still unclear.

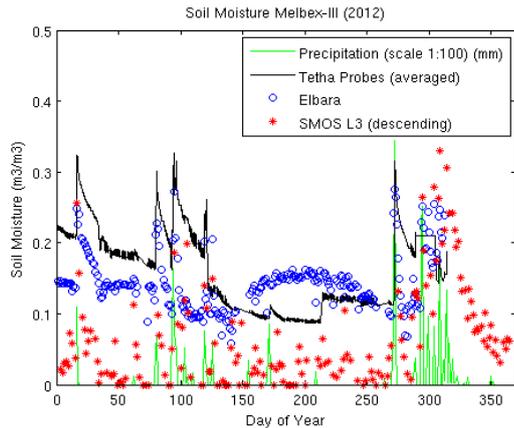


Figure 3. Comparison between SMOS SM (descending orbit) and ELBARA-II SM

4. CONCLUSIONS

The dataset so far obtained by the ELBARA-II radiometer observations over the vine MELBEX-III site at the *Valencia Anchor Station* for more than three years now (2010 - current time) is adequate for the long-term validation of SMOS soil moisture products. The VAS area is also adequate for this validation exercise thanks to the reasonably homogeneous conditions at SMOS scale. Continuous measurements of soil and vegetation parameters are under way to improve the characterization of the significant parameters influencing the validation process.

In this study, for the year 2012, brightness temperatures obtained from the ELBARA-II microwave radiometer over a vineyard field have been compared to those from SMOS level 3 over the Valencia Anchor Station area. The correlation obtained is significantly high ($R^2 > 0,87$) and the comparison follows the precipitation rhythm very well.

The ELBARA-II TB inversion with L-MEB provides estimations of soil moisture and of vegetation optical depth at L band. With respect to SM, the comparisons with the corresponding SMOS estimations show a parallel evolution also following the rhythm of the precipitation events occurred in the area. In spite of this, SMOS still underestimates SM as compared to ELBARA-II. The values of TAU so far obtained still need better interpretations.

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