SMOS LAND VALIDATION ACTIVITIES AT THE VALENCIA ANCHOR STATION

Lopez-Baeza, E.[1], C. Antolin[2], F. Belda[3], E. Carbo[2], A. Coll[1], T. Estrela[4], R. Fernández[1], A. Fidalgo[4], O. Gabaldo[4], S. Juglea[5], Y. Kerr[5], H. Lawrence[1], M. Miernecki[1,6], C. Millan[2], Christophe Moisy[6], N. Novello[6], P. Salgado-Hernanz[1], M. Schwank[7], J. Tamayo[3], J.-P. Wigneron[6], M. Zribi[5]

[1] University of Valencia. Faculty of Physics. Dept. of Earth Physics & Thermodynamics. Climatology from Satellites Group. Calle Dr Moliner, 50, Burjassot. 46100 Valencia. Tel: 963544048, Fax: 963543385.
E-mail: Ernesto.Lopez@uv.es
[2] University of Valencia. Center for Desertification Research (CIDE).
[3] Spanish State Agency for Meteorology (Agencia Estatal de Meteorología, AEMet).
[4] Jucar River Basin Authority (Confederación Hidrográfica del Júcar, CHJ).
[5] CESBIO, CNES/CNRS/IRD/UPS, UMR 5126, 18 Avenue Edouard Belin, Toulouse, France.
[6] INRA, UR1263 EPHYSE, F-33140 Villenave d'Ornon, Centre INRA Bordeaux Aquitaine, France.
[7] Swiss Federal Research Institute WSL, Birmensdorf, Switzerland.

RESUMEN

Este trabajo presenta un resumen de la extensa e intensa actividad desarrollada en la zona de la *Valencia Anchor Station* (VAS) para contribuir a la validación de productos de tierra de la misión SMOS (*Soil Moisture and Ocean Salinity*). Se dedica especial atención a los diversos experimentos de radiometría de microondas desarrollados en dicha zona a diferentes escalas espaciales, desde medidas puntuales a la escala regional (hasta 50 km), obtenidas en superficie, con sensores aerotransportados y de los productos SMOS.

Palabras clave: contenido en agua de la vegetación, ELBARA-II, experimentos de radiometría en banda L, humedad del suelo, SMOS, *Valencia Anchor Station*

ABSTRACT

This paper presents an overview of the extensive and intensive activity carried out at the Valencia Anchor Station (VAS) *site to contribute to SMOS* (*Soil Moisture and Ocean Salinity*) *land products validation. Special attention is dedicated to the various radiometry experiments hosted at the VAS that were performed at different spatial scales, from the plot scale to the regional scale (up to 50 km), using ground-based measurements airborne-based observations and SMOS products.*

Keywords: *ELBARA-II, L-band radiometry experiments, SMOS, soil moisture, Valencia Anchor Station, vegetation water content*

1. INTRODUCTION

The main goal of ESA's SMOS (*Soil Moisture and Ocean Salinity*) mission is to deliver global maps of surface soil moisture (SM) and sea surface salinity, with enough resolution to be used in numerical weather prediction and global climate models, using L-band (1.4 GHz) microwave radiometry (Kerr *et al*., 2010). The VAS area, in Spain, was chosen as one of the preferential test sites for SMOS Cal/Val activities (Delwart *et al*., 2008, Mecklenburg *et al*., 2009).

The VAS is located about 80 km west of Valencia, natural region of *Utiel-Requena Plateau*. It is a reasonably homogeneous area of about 50 x 50 km^2, mainly dedicated to vineyards (75%) and other Mediterranean species (shrubs, olive and almond trees and pine forests). Topography is generally plain, slope <2%, slightly undulated (8%-15%). Temperatures range from -15ºC in winter to 45ºC in summer, and annual mean temperature of 14ºC. Annual precipitation is about 450 mm with peaks in spring and autumn (Figure 1).

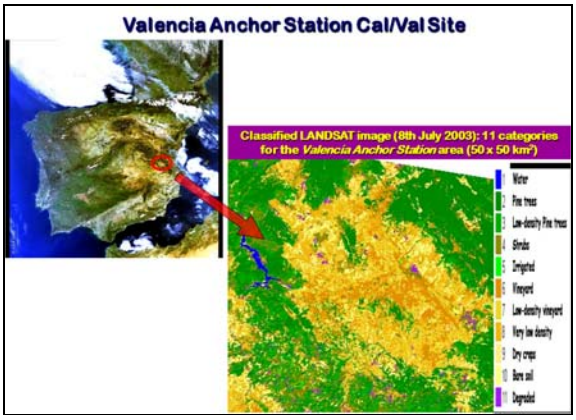
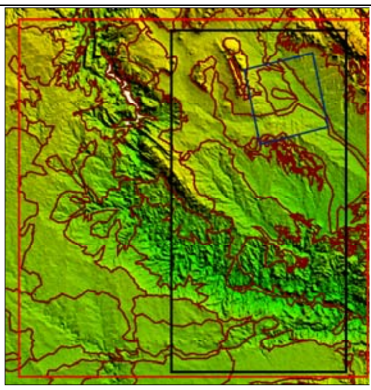


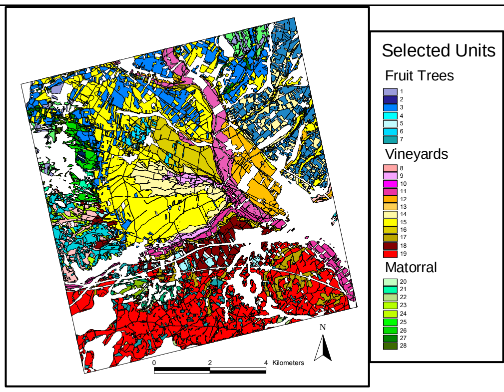
Figure 1. Situation of the *Valencia Anchor Station* Cal/Val Site in the *Utiel-Requena Plateau*. Landsat classification of the area (50 km x 50 km)

2. SOIL MOISURE CHARACTERIZATION OF THE *VALENCIA ANCHOR STATION*

Over continental surfaces, SM validation requires a realistic estimation of surface SM in different areas within a SMOS footprint. SM variability depends on soil intrinsic and extrinsic factors. It is necessary to have a sampling strategy that integrates the relationships between hydrological variables, particularly SM, and the parameters of the landscape at different spatial scales. The VAS strategy and sampling methodology was to subdivide the landscape into environmental units related to the spatial variability of SM (Figure 2). These units are heterogeneously structured entities which present a certain degree of internal uniformity of hydrological parameters according to climate, soil type, topography, vegetation cover conditions, lithology and elevation, and therefore, they are considered to have similar SM levels. Intensive SM sampling has been carried out in the area at different scales in the framework of different campaigns, both at ground level and from aircraft, to support the definition of the homogeneous land units as well as the distribution of SM based on SVAT modeling, explained below, with the final aim of achieving the full characterization of SM at the scale of a SMOS pixel (~ 50 km).

Before launch, numerous field experiments were conducted in order to tune-in the SMOS Level 2 processor for soil moisture retrieval, based on L-MEB (*L-band Microwave Emission of the Biosphere*) model (Wigneron *et al*., 2007), a forward emission model that is valid for different surfaces provided that appropriate parameterizations are used. L-MEB parameterizations represent semi-empirical adjustments of the radiative transfer equations that describe the propagation of L-band radiation in natural media. They describe, for instance, the attenuation properties of different canopies, or the effects of soil roughness on surface emission (Peinado *et al*., 2013).





Unit	Color	Vegetation Class	Soil Type (FAO-UNESCO, '88)	Lithology	Physiography	Geology	Area (km2)
1		Olive & Almond Trees	Haplic Calcisol/Petric Calcisol	Limestones and Marls	Rolling (8-15%)/Undulating (2-8%)	Terciary/Upper middle Miocene/Quaternary: Glacis/Cretacic: Turoniens	0,766
2		Olive & Almond Trees	Haplic Calcisol/Petric Calcisol	Stones, gravels and silts	Rolling (8-15%)/Undulating (2-8%)	Terciary and Quaternary	7,781
3		Olive & Almond Trees	Haplic Calcisol/Petric Calcisol	Conglomerates	Rolling (8-15%)	Quaternary/Pleistocene/Fluvial terraces and Glacis	4,282
4		Olive & Almond Trees	Haplic Calcisol/Petric Calcisol	Silts, gravels and stones	Undulating (2-8%)	Terciary/Upper middle Miocene/Cuaternary: Glacis	0,624
5		Olive & Almond Trees	Haplic Calcisol/Petric Calcisol	Marls and sandstones	Undulating (2-8%)	Terciary/Miocene/Vindoboniense	0,785
6		Olive & Almond Trees	Haplic Calcisol/Calcaric Cambisol	Marls and sandstones	Rolling (8-15%)/Undulating (2-8%)	Quaternary/Pleistocene/Fluvial terraces and Glacis	1,952
7		Olive & Almond Trees	Calcaric Cambisol/Haplic Calcisol	Marls and sandstones	Undulating (2-8%)	Terciary/Miocene/Vindoboniense	1,484
8		Vineyard	Haplic Calcisol/Calcaric Cambisol	Marls and sandstones	Rolling (8-15%)/Undulating (2-8%)	Quaternary/Pleistocene/Fluvial terraces and Glacis	1,573
9		Vineyard	Calcaric Fluvisol	Silts and sands	Flat (<2 %)	Quaternary/Valley floors, fluvial terraces and alluvium cones	0,813
10		Vineyard	Haplic Calcisol/Calcaric Cambisol	Silts, gravels and stones	Flat (<2 %)	Quaternary/Valley floors, fluvial terraces and alluvium cones	2,652
11		Vineyard	Calcaric Fluvisol	Silts, gravels and stones	Flat (<2 %)	Cuaternary/Holocene Valley floors	2,036
12		Vineyard	Haplic Calcisol/Calcaric Cambisol	Stones, gravels and silts	Flat (<2 %)	Cuaternary/Holocene	3,004
13		Vineyard	Haplic Calcisol/Petric Calcisol	Conglomerates	Undulating (2-8%)/Rolling (8-15%)	Terciary/Upper middle Miocene/Cuaternary: Glacis	2,412
14		Vineyard	Haplic Calcisol/Petric Calcisol	Silts and sands	Plano (<2 %)	Quaternary/Valley floors, fluvial terraces and alluvium cones	2,386
15		Vineyard	Haplic Calcisol/Petric Calcisol	Stones, gravels and silts	Plano (<2 %)	Quaternary/Pleistocene	15,054
16		Vineyard	Haplic Calcisol/Petric Calcisol	Silts, gravels and stones	Plano (<2 %)	Terciary/Miocene/Vindoboniense	3,946
17		Vineyard	Calcaric Cambisol/Haplic Calcisol	Silts	Undulating (2-8%)	Terciary/Upper middle Miocene/Cuaternary: Glacis	1,861
18		Vineyard	Haplic Calcisol/Petric Calcisol	Marls and sandstones	Plano (<2 %)	Terciario/Mioceno/Vindoboniense	2,438
19		Vineyard	Calcaric Cambisol/Haplic Calcisol	Marls and sandstones	Undulating (2-8%)/Rolling (8-15%)	Terciary/Upper middle Miocene	13,681
20		Matorral	Haplic Calcisol/Petric Calcisol	Calcarenites	Rolling (8-15%)	Jurasic: Malm/Lower Cretacic	0,239
21		Matorral	Eutric Leptosol/Haplic Calcisol	Marls and sandstones	Rolling (8-15%)	Terciary/Upper middle Miocene	0,430
22		Matorral	Calcaric Cambisol/Haplic Calcisol	Marls and sandstones	Undulating (2-8%)/Rolling (8-15%)	Terciary/Upper middle Miocene	0,816
23		Matorral	Haplic Calcisol/Calcaric Cambisol	Marls and sandstones	Rolling (8-15%)	Quaternary/Pleistocene/Fluvial terraces and Glacis	0,867
24		Matorral	Eutric Leptosol/Haplic Calcisol	Limestones	Rolling (8-15%)	Terciary/Upper middle Miocene	0,226
25		Matorral	Haplic Calcisol/Petric Calcisol	Limestones and Marls	Rolling (8-15%)	Quaternary/Pleistocene/Fluvial terraces and Glacis	1,007
26		Matorral	Haplic Calcisol/Petric Calcisol	Dolomites	Rolling (8-15%)	Upper Cretacic	1,006
27		Matorral	Haplic Calcisol/Petric Calcisol	Stones, gravels and silts	Rolling (8-15%)	Upper Cretacic	0,933
28		Matorral	Haplic Calcisol/Petric Calcisol	Sands and clays	Rolling (8-15%)	Jurasic: Malm/Lower Cretacic	0,185
		Other					31,296
		Área Total					106,535

Figure 2. Top left: homogeneous physio-hydrological units (dark red or brown) within the VAS site. i) 50 km x 50 km (red) VAS SMOS validation pixel, ii) ~30 km x 50 km area observed during the CNES CAROLS 2009 Campaign (black), iii) 10 km x 10 km control area observed during the *SMOS Validation Rehearsal Campaign* flights (blue). Top right: definition of higher resolution physio-hydrological units within the 10 km x 10 km control area. Bottom: Information on each physio-hydrological unit

3. GROUND-BASED RADIOMETRY EXPERIMENTS

In the framework of SMOS, the VAS hosted various radiometry experiments that were performed at different scales, from the plot scale to the regional scale (up to 50 km), using ground- and airborne-based radiometry.

MELBEX-I (*Mediterranean Ecosystem L-Band characterisation Experiment*) was a ground-radiometry experiment run in 2005 using the L-band radiometer EMIRAD (from the *Technical University of Denmark*) over a plot of shrub land. The results highlighted the small effect of Mediterranean shrub land at L-band and investigated the role of exposed rocks in the surface emission (Cano *et al*., 2010). They were also useful to calibrate L-MEB for shrub.

MELBEX-II was a ground-radiometry experiment run in 2007 using again the EMIRAD L-band radiometer over a plot of vineyards throughout its whole vegetation cycle. Vineyards are the main land use at the VAS site, therefore vineyard parameterizations are crucial for the validation of SMOS data at the VAS. MELBEX-II continued with MELBEX-III, the third ground-based radiometry experiment of this series which started in September 2009 using the ESA L-band radiometer ELBARAII-3 mounted on a 17 m tower and fully dedicated to validation activities at the VAS site during SMOS life time. Since then, the instrument has been measuring brightness temperatures at horizontal and vertical polarization from the same vineyard area as in MELBEX-II. Measurements are currently performed automatically at nadir angles between 30° and 70° in steps of 5° every 30 min. At 45°, brightness temperatures are recorded every 10 min. Additional calibration of the radiometer is performed every day around midnight by means of sky brightness measurements at 150°.

The common objective of these experiments, besides retrieving surface SM and vegetation optical depth, τ from the tower-based measurements, was to calibrate the L-MEB model for specific Mediterranean ecosystem species (matorral and shrubs, vineyards, etc.) by characterizing these surfaces for different observation angles, polarization, etc. (Wigneron *et al*., 2012). Schwank *et al*. (2012) carried out a specific experiment with ELBARA-II to accurately and independently measure τ of the vines by covering the soil with a reflecting layer of aluminium foil. An account of the current experiments is given by Fernandez *et al*. (2013) and Salgado *et al*. (2013).

4. AIRBORNE-BASED RADIOMETRY EXPERIMENTS

Airborne measurements at L-band have also been used in the SMOS Mission to improve L-MEB model parameterization in the area and the match between measured SMOS brightness temperatures and simulations from ground SM (Zribi *et al*., 2011).

ESA SMOS Validation Rehearsal Campaign, 2008. A control area of 10 x 10 km^2, mostly dedicated to vineyards (very little developed during the time of the flights) and with significant patches of matorral and shrub land, was flown on four days using the EMIRAD radiometer (Figure 3). SM could be retrieved with good accuracy but only after surface roughness could be estimated for the little developed condition of the vegetation (Saleh *et al*., 2009).

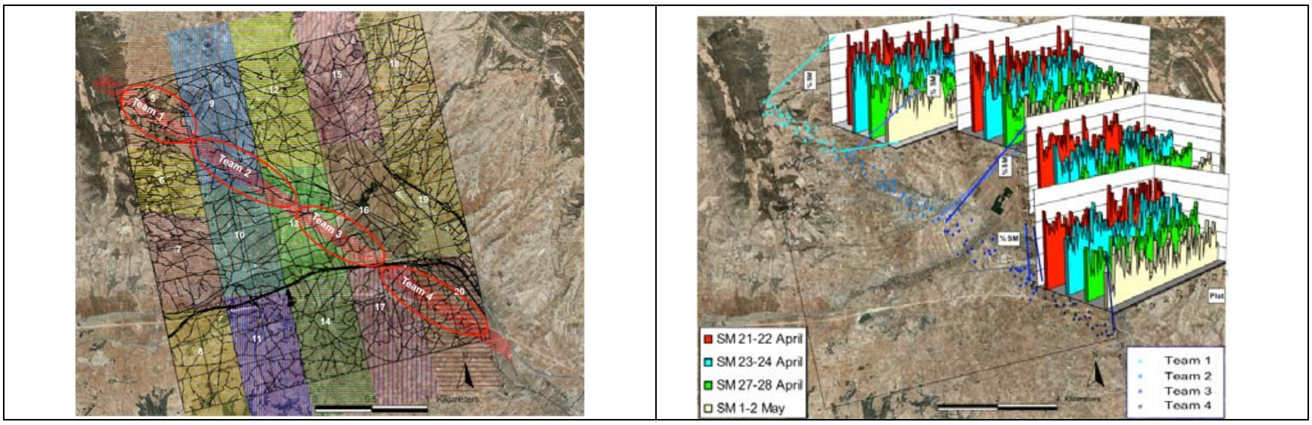


Figure 3. *SMOS Validation Rehearsal Campaign* (SVRT), April - May 2008. Left: aircraft observation flight lines. Right: results of the measurements along the diagonal flight line for the four campaign days and all sampling points

CNES CAROLS (Cooperative Airborne Radiometer for Ocean and Land Studies) Campaign, 2009. The L-band CAROLS radiometer (Zribi *et al*., 2011) developed by CNES, was flown on three occasions over an area of 1500 km^2 (black rectangle of Figure 2 and Figure 4) covering vineyards, shrub land and Mediterranean pine forests during 2009. These flights were performed at 4000 m above the surface. The objectives of the CAROLS campaign at the VAS were to investigate the possibility of extending the VAS physio-hydrological units methodology to the whole 50 km x 50 km area and to examine the radiometric signature of other surfaces that were not present in the 10 km x 10 km control area previously examined in the *SMOS Validation Rehearsal Campaign*, mostly dense forests, matorral, and nonflat surfaces.

ESA-CNES CAROLS Campaign, 2010. The flight plan included, on the one hand, lines performed at approximately 2200 m asl (Figure 5) to be flown in alternate E-W and W-E directions to have multi-angular signatures over the same area, and avoid potential RFI in Spain and, on the other hand, low-altitude flights providing footprints of about 900 m at nadir (-3dB), and 1300 m for the side-looking antenna. The objective of these flights was primarily to validate L-MEB.

5. CONCLUSIONS

This paper shows an overview of the activities carried out at the Valencia Anchor Station for the validation of SMOS. It also provides the framework of other more specific presentations that are referred in the text.

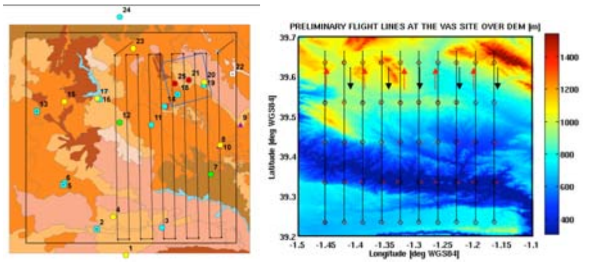


Figure 5. Distribution of the sampling teams over some of the physio-hydrological units (left) and definition of the flight lines for the CNES CAROLS Campaign, 2009

Figure 6. ESA-CNES CAROLS Campaign 2010. Flight lines over the VAS site from East to West in order to map brightness temperatures over almost the whole site

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