The ESA SMOS Mission: Validation Activities at the Valencia Anchor Station

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SUMMARY

Since 2001, the *Valencia Anchor Station* (VAS) is being used for validation activities in the context of low spatial resolution Earth Observation Missions such as CERES (*Clouds and the Earth's Radiant Energy System*), GERB (*Geostationary Earth Radiation Budget*), EPS (EUMETSAT Polar System), and is also being prepared for SMOS (*Soil Moisture and Ocean Salinity*). These missions have in common the low spatial resolution of their respective footprints (~50x50 km^2) and the necessity of a well characterised and instrumented large scale area. The VAS has been selected as a primary validation site by the SMOS Mission. The reasonable homogeneous characteristics of the area make this site appropriate to undertake the validation of SMOS Level 2 land products (soil moisture (SM) and vegetation water content) during the *Mission Commissioning Phase*. A control area of 10x10 km^2 was chosen to develop a network of ground SM measuring stations based on the definition of homogeneous physio-hydrological units attending to climatic, soil type, lithology, elevation, slope and vegetation cover conditions. The stations are linked via a wireless communication system to a central post accessible via internet. Area SM estimations are presently being compared to modelling products from ISBA – SURFEX. This paper shows the validation activities currently carried out at the VAS, especially the ESA *SMOS Validation Rehearsal Campaign* and the CNES *CAROLS Scientific Airborne Campaign*.

Key words: SMOS (*Soil Moisture and Ocean Salinity*), Soil Moisture, *Valencia Anchor Station*, Validation of satellite products

INTRODUCTION

A better understanding of environmental processes, requires good quantification of SM. Environmental quantities and parameters depend direct or indirectly on SM to provide a more

representative hydrological and energy transfer budget, where water and energy fluxes are significantly affected. SM participates in these fluxes, as latent heat is determined by surface water content, also influencing surface run-off. Through the improvements on these budgets, weather and climate predictions are expected to improve their forecasts and simulations.

L-band passive microwave radiometry is a very useful tool for SM monitoring because it allows nearly all weather observation, surface vegetation cover information, etc. From brightness temperature measured from satellites, SM retrieval is possible by using suitable algorithms to investigate the dependence of the signal on sensor configuration geometry (polarisation and incidence angle), interferometric aspects, types of vegetation cover, topography, heterogeneity within the same pixel, etc. Up to now, significant advances have already been achieved in these issues and the time is reaching now to validate these algorithms and those concerning the assimilation of these products into numerical models.

The SMOS Mission, a joint Earth Observation mission of ESA, France and Spain, is the second *Earth Explorer Opportunity Mission* within ESA's *Living Planet Program*. The *Microwave Imaging Radiometer with Aperture Synthesis* (MIRAS) radiometer, main instrument onboard SMOS, is a 2-D Y-shaped interferometric radiometer made up of 69 antenna elements equally distributed on three 4.5-m arms. It will observe the emitted brightness temperature of the Earth at L-band (1.4–1.427 GHz) with a resolution of ~40 km.

From the beginning of SMOS, the VAS area is being studied from different viewpoints through field activities, many of them related to the preparation of SMOS. ESA accepted a proposal prepared by an international team of SMOS scientists coordinated by the *Climatology from Satellites Group* (GCS) to develop specific land product validation activities at the VAS*,* taking into account the special characteristics of this area of reasonable homogeneity of climate, topography, soil types, land uses, etc. The Project addresses the "*Validation of SMOS Products over Mediterranean Ecosystem Vegetation at the Valencia Anchor Station Reference Area*" (SMOS Cal/Val AO I.D. no. 3252). Its main objectives are (i) development of the VAS site as a large reference area, sufficiently equipped with ground SM probes and characterised, to contribute to SMOS land product validation, (ii) development of L-band emission models for typical Mediterranean ecosystem natural low-cover vegetation species and vineyards to be able estimate surface properties in the whole VAS area.

Basically, the Project methodology consists of the development of a strategically designed ground-based SM measuring network defined over a reference control area and the use of remote sensing techniques and reliable models to extrapolate these ground measurements to an area of about the size of a SMOS pixel. The Project Team is strongly interested in developing and testing different approaches for SMOS data and product validation as well as developing L-band surface emission models characteristic of the Mediterranean ecosystem, not significantly been studied so far. They are organising a significant number of complex activities in which context, an SM measuring network has been deployed in a fairly homogeneous area of 10x10 km^2 which will allow the independent elaboration of SM maps as reference for those that will be obtained from aircraft L-band radiometer data. Besides, and in order to characterise shrubs and vineyards, ground based L-band radiometry experiments (*Mediterranean Ecosystem L-Band characterization Experiment* (MELBEX-1 and MELBEX-2)) have been developed to fully account for all geometry observation conditions, different SM conditions and different vegetation growth development stages.

THE SMOS VALIDATION REHEARSAL CAMPAIGN

Over land, the main objectives of campaigns are the observations of the influence of various vegetation canopies, seasonal cycle, surface roughness, dew and frost using long-term ground-based observations (de Rosnay et al., 2006, Lopez-Baeza et al., 2006). The analysis

of complex surfaces and the mixed pixel issue are addressed with aircraft observations. SM validation is performed by combining results from different approaches. Field measurements will be scaled to SMOS scales with the help of SVAT models and meteorological networks. ESA focuses its validation effort on two key sites: the VAS (east of Spain) and the Upper Danube watershed (south of Germany) (Delwart et al., 2008).

The general purpose of the *SMOS Validation Rehearsal Campaign* (SVRC) is to repeat the *Commissioning Phase* execution with all centers, tools, participants, structures, data available, assuming all tools and structures are ready and trying to produce as close as possible post-launch conditions. The aim is to test the readiness, the ensemble coordination and the speed of operations, and to avoid as far as possible any unexpected deficiencies of the plan and procedure during the real *Commissioning Phase* campaigns (Bouzinac et al., 2008). A specific added-value objective of the VAS Team is to validate the ground sampling strategy defined for this campaign (10x10 km^2) by comparing the ground area-estimated products to the aircraft area-integrated measurements to be able to extend the methodology to the larger SMOS footprint representative area (50x50 km^2). The scientific framework for these objectives is monitoring soil drying after a significant rainfall in the study area.

Airborne Operations during the *SMOS Validation Rehearsal Campaign*
Aircraft measurements were performed using the *Helsinki University of Technology* (TKK) Short Skyvan research aircraft. The payload consisted of: (i) L-band radiometer EMIRAD (*Technical University of Denmark,* TUD), (ii) HUT-2D L-band imaging interferometric radiometer (TKK) (iii) PARIS GPS reflectrometry system (*Institute for Space Studies of Catalonia,* IEEC), and (iv) IR sensor (*Finnish Institute of Maritime Research,* FIMR). The campaign started on 19th April 2008. The conditions for the flight were optimum because a rainfall event determined the first flight on 22nd April. The following flights were performed on 24th, 28th April and 2nd May allowing for an optimum monitoring of the soil drying process. The flights were performed before sunrise to avoid the influence of evaporation. The area was crossed diagonally (NW to SE) and along 5 separate North/Southbound parallel lines displaced by 2 km relative to each other.

Ground Measurements during Aircraft Operations
Ground measurements were carried out by 20 teams of about 5 people each, distributed throughout the entire area (4 teams for the diagonal flight, 4 teams for the harder soil shrub NW part of the area, and 3 teams per each flight line remaining). Depending on soil properties and hardiness, each group took between 140-150 cylinder volumetric samples and an average of 250 (replicated 3 times) volumetric probe measurements every flight night.

The information obtained from SVRC will be very rich for the VAS general characteristics. The selection of the automatic sampling measurements, necessarily reduced, is being done so that it is representative of the larger area, hoping to be able to extrapolate it to wider zones. The team wants to test this by taking advantage of aircraft measurements, that with the defined network based on about 12 automatic measuring stations located over different physio-hydrological units, it will be sufficient to cover this study area of 10x10 km^2. The next step should be to extrapolate this methodology to the larger areas of 50x50 km^2 and 125x125 km^2 by using remote sensing techniques and modeling work.

THE CAROLS/VALENCIA ANCHOR STATION SCIENTIFIC CAMPAIGN

The objectives of the CAROLS (*Combined Airborne Radio-instruments for Ocean and Land Studies*) campaign in the context of the VAS validation activities are the following:
• **Soil moisture validation studies**. Extension of the homogeneous units approach to a larger area, this time supported by a proportionally smaller number of SM measurements in selected areas determined by the analysis of 2008 data.

• **Radiometric characterization**. The 10x10 km^2 previously studied is part of a larger area of ~30 km x 50 km within the VAS SMOS validation reference pixel. The flights performed over this larger area were planned to examine the radiometric signature of other surfaces that were not present in the 10x10 km^2 area examined in 2008 (mostly dense forests, matorral, and nonflat surfaces). SM sampling was mainly oriented to provide relative changes in the SM content for comparison with the radiometric data.
• **Radiometric characterization of 'Los Monegros'** salt pans near Zaragoza to estimate their emissivity at L-band.

Airborne Operations during the CAROLS/Valencia Anchor Station Scientific Campaign
CAROLS flights (L-band, passive) took place in spring 2009 on days 27th April, 14th and 28th May. CAROLS flights were performed in a continuous transect taking off and landing in France. The duration of each of these flights was 4.75 h, including the transect from France. Regarding passive microwave data, CAROLS provides measurements near nadir and about 33 degrees towards the right of the aircraft, with an aperture of ~37 degrees at -3dB.

Ground Measurements during Aircraft Operations
Ground measurements were performed between 10:00 and 16:30 UTC. The aircraft measurements took place during the central part of this time interval. 20 sampling teams were established with different sampling strategies. In general, each sampling plot was about 20x20 m^2 and volumetric SM measurements were performed by means of soil cylinders of known volume and of ThetaProbe Delta-T capacity probes.

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