Sea Surface Salinity Retrieval within the ESA *Soil Moisture and Ocean Salinity* (SMOS) Mission

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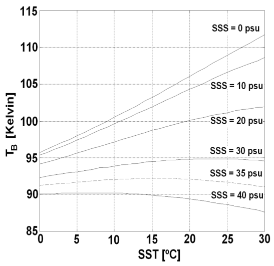
***Abstract* – The SMOS (Soil Moisture and Ocean Salinity) mission will provide from 2007 onwards global maps of soil moisture over land and sea surface salinity over ocean. The radiometry group of the Technical University of Catalonia (UPC) in Barcelona has been involved either in the definition of the SMOS single payload, MIRAS (Microwave Imaging Radiometer by Aperture Synthesis), or in the organization of field campaigns devoted to the comprehension of different parameters affecting the brightness temperature at L-band. At present, many efforts are focused on the issues relevant to the salinity and soil moisture retrieval procedures. In this paper the work related to the ocean salinity is summarized.**

I Introduction

The SMOS (Soil Moisture and Ocean Salinity) mission was selected by ESA to provide soil moisture (SM) and sea surface salinity (SSS) global maps with three days revisit time [1]. Despite SSS is a key parameter regulating the ocean dynamics and thus climate, up to now it has not been monitored on a synoptic basis, considering that over most of the global ocean there is a lack of in situ time series on salinity.

Passive radiometric measurements at L-band, within the protected band of 1400-1427 MHz, furnish the suitable technology for salinity estimation, according to a compromise among the brightness temperature sensitivity to salinity, small atmospheric interferences and reasonable pixel resolution (Fig.1).

Salinity, as mentioned, is a crucial climatic parameter, whose variations are mainly regulated by the evaporation-precipitation (E-P) difference, by the seawater freezing and melting, and by freshwater run-off. Even with a narrow variability range, salinity fluctuations are able to clearly characterize different water bodies and to force a vertical circulation known as thermohaline circulation, crucial in the heat transport. Nevertheless, nowadays oceanographic models already rely on satellite data with respect to sea surface temperature (SST) and sea surface height, but are still referring to climatologic values of salinities [2].



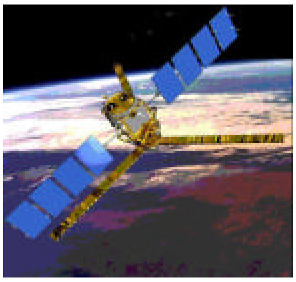


Fig. 1 (Left): L-band nadir dependence of the brightness temperature with sea surface temperature, plotted at different salinities, obtained considering specular reflection and Klein-Swift permittivity model
Fig. 2 (Right): The Y-shaped SMOS configuration

II Technical specifications

SMOS' single payload is the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS), the first spaceborne interferometric radiometer, with full-polarimetric capabilities. Its orbit is sun-synchronous, placed at 755 km height, with a 6 am ascending Equator crossing time, which turns out in a revisit time of less than 3 days. The currently scheduled launch date is March 2007.

MIRAS embodies 69 small receiver antennas uniformly arranged in a Y-shaped array, each of the arms having 21 antennas, plus 2 spares (Fig.2). To avoid aliasing in the Fourier imaging process, a minimum antenna spacing of 0.57 wavelengths is necessary. Nevertheless, antenna size and a limited swath led to an antenna spacing of 0.88 wavelengths. Due to the non-compliance of Nyquist criterion, the reconstructed images present aliasing, and the instrument alias-free field of view (FOV) has a distorted hexagonal shape. The total arm length is about 4.5 m with an angular resolution of approximately 2°.

Each pixel is observed at different incidence angles, covering the range 0º-65º, with varying spatial resolution (from 30 Km to 60 Km). Radiometric accuracy and sensitivity depend on the position of the pixel in the field of view. A snapshot brightness temperature map of the FOV is obtained every 1.2 s (integration time for each polarization).

III Dedicated measurements campaigns

In spite of the maximum sensitivity relevant band, sea surface salinity signature is still fairly small; therefore, SST, wind speed and others geophysical parameters must be accurately measured.

In order to provide ground-truth measurements, several field campaigns have been undertaken by UPC. Since brightness temperature dependence from geophysical parameters has to be assessed, semi-empirical models were developed once *in situ* data were mined. Measurements were carried out with the full-polarimetric L-band AUtomatic RAdiometer (LAURA) developed by UPC (Fig. 3). WISE (WInd and Salinity Experiment) 2000 and 2001 campaigns (Fig. 4) were devoted to the understanding of the angular dependence of the emissivity of the wind-roughened sea, which mainly affects polarimetric brightness temperature estimations [3] [4], In these campaigns, LAURA was settled on the Casablanca oil rig (40 Km offshore Catalonia coast). Simultaneously, oceanographic buoys were measuring SST, SSS, wind field and sea surface spectrum.

Fig. 3 (Left): LAURA (L-band AUtomatic Radiometer)
Fig. 4 (Right): Casablanca oil rig, location of the WISE campaigns

FROG (Foam, Rain, Oil and GPS-reflectometry) 2003 campaign was, in turn, meant to estimate the emission of foam and rain-induced roughness, beside the effects of thin oil film pouring (Figs. 5, 6). Namely, foam emissivity was evaluated in relation with the distribution, size and characteristics of the bubbles. A semi-empirical model which relates the effect of the foam with salinity, foam thickness, incidence angle and polarization, was developed [5].

Fig. 5 (Left): Pond with the foam diffusers switched on in the FROG 2003 experiment

Fig. 6 (Right): Rain generator mounted at 13 m in the FROG 2003 experiment

IV Salinity retrieval issues

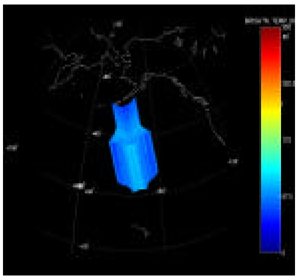
In order to properly assess the instrument characteristics, a complex SMOS End-to-end Performance Simulator (SEPS) has been developed mainly by UPC [6]. Its capabilities are among others: orbit propagation, generation of L-band brightness temperature (relevant to input geophysical parameters), calibration, error analysis and image reconstruction. SEPS is currently being used either in the technical design trade-off of the instrument, or in the test of multi-angular algorithms for SM and SSS retrieval. At present, brightness temperature data for each snapshot are at disposal for any simulated scenario (Fig. 7); the aim is, relying on this software package, to readily shift to the so-called Level-2 (L2) data, i.e. retrieved geophysical parameters.

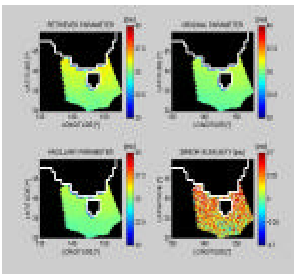
A recently released SEPS “light” version has been implemented in order to provide a considerable amount of simulated brightness temperature data with a shorter computation time. A proto ocean salinity L2 processor is currently in the testing phase, with the aim of generating salinity retrieval error maps. Such a processor is plugged with the output brightness temperature data of SEPS and yields sea surface salinity maps (Fig. 8), once the whole minimization procedure has been applied.

The inversion scheme is actually the crucial and challenging point, being the requested salinity retrieval accuracy of 0.1 psu (practical salinity units).

At present, several optimization/minimization algorithms are under study and comparison, in order to select the most suitable one, which should be able to infer the geophysical parameter from the “measured” brightness temperature. A reliable iterative algorithm based on the Levenberg-Marquardt method is currently in use, while other numerical methods (iterative and empirical) are likely to be exploited. In this context, even the choice of an adequate and robust forward model, and its related permittivity model, can influence the efficiency of the retrieval procedure. Due to the complexity of the payload and of the image reconstruction, a so-called vicarious calibration is crucial in order to deaden the instrumental bias.

Some studies highlighted that the accuracy in a single-step retrieval is about 1 psu (Fig. 9). However, SSS temporal averages in blocks of 10 or 30 days have already envisaged to accomplish the geophysical requirement of 0.1 psu, producing Level-3 data [7]. The improvement relevant to spatial averaging is still under study.





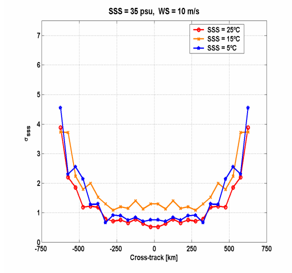


Fig. 7: Brightness temperature for each snapshot in a Pacific Ocean scenario simulated by SEPS Light

Fig. 8: Salinity retrieval error maps using L2 processor

Fig. 9: Retrieved SSS error for a single pass (e.g. salinity 35 psu; wind speed 10 m/s; 5ºC, 15ºC and 25ºC)

The ancillary data plugged as a first guess in the retrieval algorithm, like SST and sea state among others, is crucial for having input forcing parameters, and the gathering ranges from different sources: *in situ* temporal series (oceanographic cruises, moored buoys, drifters) or other spaceborne sensors.

Data fusion topic will be in the next future the final assessment of the pre-launch feasibility study of the SMOS mission. For a consolidated global SST product major sources will be IR and microwave radiometers. Indeed, active instruments like altimeters, scatterometers and SAR might furnish suitable data for sea state correction, besides classical climatology wind information [8].

V Conclusions and future works

A brief summary of the pre-launch studies of the SMOS mission has been sketched. Dedicated field campaigns have been conducted to evaluate the magnitude and sensitivity of some parameters on brightness temperature variation. In order to infer the geophysical parameter with the required accuracy for oceanographic and climatologic purposes, a salinity retrieval procedure has to be accurately pointed out.

An assimilation scheme for mandatory auxiliary data will be developed for an optimized SSS data product.

In the next future, synergetic and complementary aspects of combined ESA-*SMOS* and NASA-*Aquarius* missions will be emphasized, considering the expected performances and principles of each instrument.

From 2007 onwards, post-launch refining and re-iteration procedures will be performed.

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