SMOS: First in flight results

Y.H. Kerr, F. Cabot, P. Richaume, P. Waldteufel, J.P. Wigneron, A. Hahne, S. Mecklenburg

CESBIO, Toulouse, France
Corresponding author: Yann.Kerr@cesbio.cnes.fr

ABSTRACT

The SMOS mission aims at allowing a frequent and global monitoring of two geophysical parameters: Soil Moisture and sea surface Salinity. These two quantities are key variables for climate studies, weather forecast and water resources management. To achieve this goal, a two dimensional interferometer operating at L band was developed and eventually launched on November 2 2009. The SMOS mission aims at providing a global frequent coverage of the globe with a spatial resolution of 43 km on average (27 km max).

1 Introduction

It is now well understood that soil moisture and sea surface salinity are required to improve meteorological and climatic predictions. There are also key elements for assessing and forecasting extreme events (floods, droughts) and, obviously for improving water resources managemen. These two quantities are not yet available globally and with an adequate temporal sampling. So as to cover this data gap, it has been recognized that, provided it is possible to accommodate a suitable antenna on board a satellite, L Band radiometry was most probably the most promising way to fulfil this gap [1]. It is within this framework that the European Space Agency (ESA)'s selected the second Earth Explorer Opportunity Mission, namely the Soil Moisture and Ocean Salinity (SMOS) mission [2]. The SMOS mission a joint program lead by ESA with the CNES in France and the CDTI in Spain. SMOS carries a single payload, an L band 2D interferometric radiometer in the 1400-1427 MHz protected band [3] as depicted on Figure 2. This wavelength penetrates well through the vegetation and the atmosphere is almost transparent. Consequently, the instrument probes the Earth surface emissivity without much hindrance. Surface emissivity can then be related to the moisture content in the first few centimetres of soil over land, and, after some surface roughness and temperature corrections, spatio-temporal aggregation, to the sea surface salinity over oceans. It must be noted that the design of the instrument is so that either Dual polarisation of full polarisation modes can be operated. But most striking feature of SMOS is it capacity to retrieve the angular brightness temperature signatures of the target, enabling hence to separate the different contributions to the signal (Soil and vegetation layer).

2 Context and specifications

SMOS is an ESA Earth Explorer mission with significant national contributions provided by the French and Spanish Space Agencies, the Centre National d'Etudes Spatiales (CNES) and the Centro para el Desarrollo Technologico Industrial (CDTI). The payload consists of a passive microwave 2-D interferometric radiometer, operating in L-Band (1.4GHz, 21cm), comprising a central structure and 3 deployable

Figure 1: SMOS launch in Plesetzk

Figure 2: Artist view of the SMOS satellite

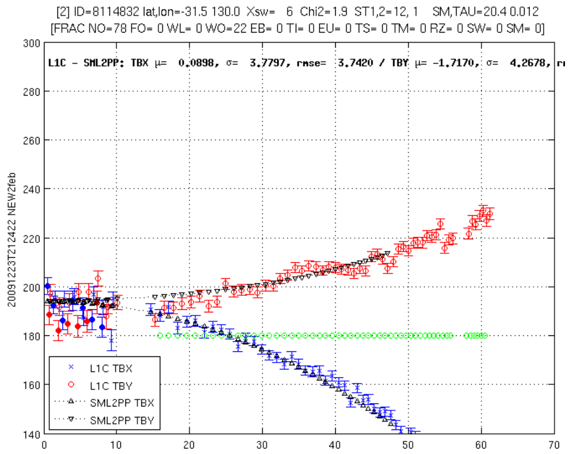

Figure 3: Surface angular signature

arms holding the equally distributed 69 antenna elements. SMOS measures the brightness temperature emitted from the Earth at L-band [6, 3] over a range of incidence angles (0 to 55º) across a swath of approximately 1000km with a spatial resolution of 35 to 50 km. SMOS was launched on November 2 2009 (fig. 1).

The orbit is sun-synchronous at 763km altitude with mean local solar time at ascending node equal to 6:00 hours am The field of view (FOV) has an hexagonal shape and the spatial resolution is of 35km at centre of FOV while the temporal resolution is of 3 days (at the Equator for ascending passes). The operational mode can be either full or dual polarisation with a radiometric accuracy(dual pol) of respectively 1.8 K (at 180K) and 2.2 K (at 220K). Data will be made available in Near Real time by the end ofthe commissioning phase.

3 Scientific objectives

Soil moisture and ocean salinity are key variables in the water cycle and global observations of these two values will enhance our ability to predict changes in the Earth System, in particular the climate [3]. Soil moisture observations will further our knowledge about processes in the water and energy fluxes at the land surface – atmosphere interface and will provide information on storage of water (surface and root zone), water uptake by vegetation (root zone), fluxes at the interface (evaporation) and the effect of these on run-off. This knowledge is important to improve meteorological and hydrological modelling and forecasting, water resource management, the monitoring of plant growth, and contributes to the forecasting of hazardous events such as floods. Ocean salinity measurements will aid the characterisation of global ocean circulation and its seasonal and inter-annual variability and are thus an important constraint in ocean (-atmosphere) models. SMOS observations will improve seasonal to inter-annual (ENSO) climate predictions and the estimates of ocean rainfall and thus the global hydrologic budgets. They will also aid the monitoring of large-scale salinity events and improve monitoring of sea-surface salinity variability. The latter is needed to better understand and characterise the distribution of bio-geochemical parameters in the ocean's surface and upper layers. SMOS observations will also provide information on the characterisation of ice and snow covered surfaces and the sea ice effect on ocean-atmosphere heat fluxes and dynamics, which affects large-scale processes of the Earth's climate system.

4 Mission requirements

Moisture and salinity influence the respective emission characteristics of soil and seawater and thus the emitted microwave radiation of the Earth's surface. Measurements of soil moisture at L-Band are based on the fact that emissions from the Earth show a large contrast between water and land due to the large difference between the dielectric constants of water and dry soil. The attenuation of the emitted radiation due to vegetation is moderate at L-Band for vegetated areas with a biomass < 5 kg m^{-2}, which applies for 65% of the Earth's land surface. The retrieval of soil moisture from emitted radiation, expressed in brightness temperatures TB, has to consider a variety of instrument parameters (radiometric sensitivity and accuracy, calibration stability, interferometric image reconstruction), surface characteristics (soil surface roughness and texture, land cover, surface heterogeneity, dew, intercept, snow, topography, litter effect, surface water) and radiofrequency interference [8]. Soil moisture is a measure of the amount of water within a given volume of soil and is expressed as a percentage on a volumetric basis (m^3/m^3). From space, the SMOS instrument is aimed at providing measurements of the soil moisture of the first few centimetres with a accuracy better than $0.04m^3/m^3$. The requirements for soil moisture measurements are: accuracy of $0.04m^3/m^3$ volumetric soil moisture; spatial resolution 35-50 km; revisit time 1-3 days.

5 SMOS data products

The following SMOS data products will be available [7] at the end of the commissioning phase: 1.Level 1 (A, B, C); 2.Level 2 for soil moisture and ocean salinity according to surface type; 3.Near-real time product. Level 3 (global, single instrument) and level 4 (global, multi-instrument) data is being developed and available through the French national programme CATDS.

5.1 Level 1

The Level 1A product comprises calibrated visibilities between receivers prior to applying image reconstruction. Level 1A products are physically consolidated in pole-to-pole time-based segments. The Level 1B product is the output of the image reconstruction of the observations and comprises the Fourier component of the brightness temperature in the antenna polarisation reference frame. The Level 1C product are multi-angular brightness temperatures at the top of the atmosphere, geolocated in an equal-area grid system (ISEA 4H9 - Icosahedral Snyder Equal Area projection). Two different Level 1C products are generated according to the surface type: one containing only sea and the other only containing land pixels. Two sets of information are available: pixel-wise and snapshot-wise. For each Level 1C product there is also a browse product containing brightness temperatures for an incidence angle of 42.5°(see fig. 4).

5.2 Level 2

The Level 2 soil moisture product contains not only the soil moisture retrieved, but also a series of ancillary data derived from the processing (nadir optical thickness, surface temperature, roughness parameter, dielectric constant and brightness temperature retrieved at top of atmosphere and on the surface) with the corresponding uncertainties[8]. As for the Level 1C, the product is geolocated on the ISEA grid.

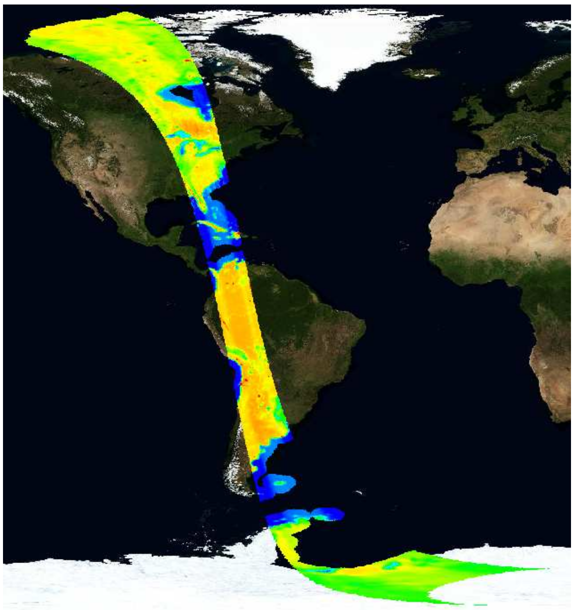

Figure 4: Example of Brightness temperatures over the Americas (Level 1c data December 12, 2009)

5.3 Near-real time product

The near-real time product, similar to the Level 1C product but adjusted to requirements of operational meteorological agencies such as ECMWF and MeteoFrance, will be available less than 3 hours from sensing. It contains brightness temperatures at the top of the atmosphere on an ISEA grid with reduced spatial resolution.

5.4 Cal val activities

A variety of campaigns, such as DOMEX, CoSMOS, WISE, LOSAC, EUROSTARRS, FROG have been (and will be) performed to investigate uncertainties in the soil moisture and ocean salinity retrieval. The major aspects to investigate with regard to soil moisture are the influence of the various types of vegetation and their seasonal variability, as well as the influence of surface roughness. Over oceans, the impact of sea-surface state on the polarimetric radiometric signal is the main issue. The DOMEX campaigns will provide information for vicarious calibration(Fig. 5).

6 Conclusion

The mission requirements are to retrieve soil moisture globally for all the nominal surfaces with an accuracy of 0.0 $4m^3/m^3$ every 3 days at most and with a spatial resolution better than 50 km, Vegetation water content with same spatial resolution but every 7 day and sea surface salinity with a 200 km spatial resolution every 10 to 30 days and an accuracy of 0.1 psu. It is also expected to soon be able to infer root zone soil moisture using assimilation schemes.The current activities cover mainly science research. The mission is new by several aspects: i) measurements (L band emission from space) does not have a long track record to say the list and, ii) there are no real measurements of surface soil moisture [4] or sea surface salinity to date to infer or test algorithms and assumptions; moreover, iii) the technique used here to break the spatial resolution frontier is very novel and relies on a almost never tested from space technique: the 2D interferometry. So the wealth of scientific studies and related technological

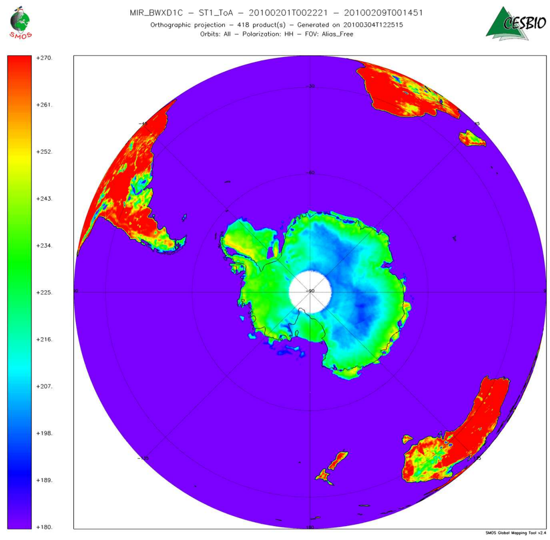

Figure 5: Acquisitions over Antarctica (first week of February 2010)

challenges are very high. On the Science part the different teams (from all over Europe, from the US, Canada, Japan, China, India, Australia, South America and Africa (and even Antarctica!) are addressing the different issues still to be tackled so as to provide the most appropriate and efficient set of retrieval algorithms from the current state of the art. The activities are several folds. Intensive basic research work is still currently underway [5], while the Cal Val programme has started being implemented. To address all these, a number of collaborative studies are underway. For instance, so as to cover the gap linked to the novelty of the approach and of the measurements, simulations and generation of synthetic data sets to build test data sets a performed. The results are also used to assess retrieval algorithms. Large field campaigns either on the long time scale or very intensive over specific targets have been carried out over Land and sea to address the specific issues related to retrieval with perturbing factors. In parallel intensive efforts are devoted to the basics of interferometry, be it the optimization of image reconstruction or devising the most efficient calibration scheme. The second fold of the research activities is in the direction of the step forward. To be even more useful for hydrology and water resources, a higher spatial resolution is sought for. A number of studies show now the possibility to dis-aggregate SMOS data to a few kilometres using external data and models. Finally some efforts are also being devoted to external but important issues such as Galactic contribution to the signal, Sun's emission variation monitoring or radio frequency interferences. Obviously, as with any very innovative approach, we were all anxious to get the first real data to touch and feel the real brightness temperature sat L Band. the most dispointing piece of news was the large amount of Radio frequency interferences (RFI) encountered, especially over Europe (see figure 6). nevertheless, it is expected that with actual data we will be able to significantly improve our understanding of the processes and hence our science, leading to better applications. Looking ahead into the future a brief introduction one may see that both the science community and the end users are confident in the science return for SMOS as a potential operational SMOS follow on system (SMOSops) is already on the table, for which technology development is about to start.

7 Acknowledgements

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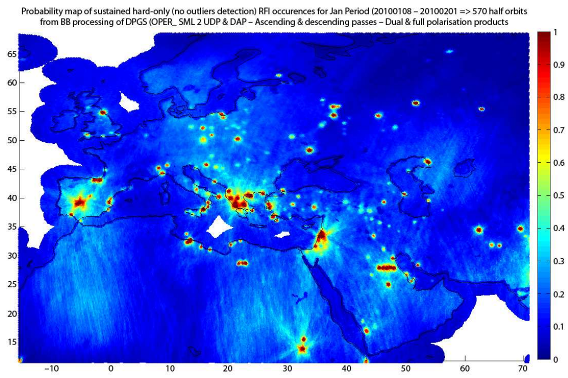

Figure 6: RFI probability over Europe as measured by the level 2 soil moisture processor

expected.

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