RETRIEVING OCEAN SALINITY FROM SMOS MICROWAVE RADIOMETRIC MEASUREMENTS

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Abstract

SMOS (Soil Moisture and Ocean Salinity) is an Earth observation satellite from the European Space Agency launched in November 2009. It is the first satellite mission addressing the challenge of measuring sea surface salinity, never attempted before due to its technical complexity. It uses a microwave interferometric radiometer with aperture synthesis that generates brightness temperature images at 1.4 GHz, from which both geophysical variables are derived using their influence on the dielectric constant of the emitting body, land or ocean. This paper presents the principles of operation of the instrument, the algorithmic approach implemented for the retrieval of salinity from the observations, and the limitations for the use of SMOS products in the Mediterranean Sea.

Keywords: Salinity, Remote Sensing, Surface Waters, Open Sea

In 1999 the European Space Agency (ESA) selected the proposal of a mission to provide for the first time a global and continuous coverage of Soil Moisture and Ocean Salinity with resolution and accuracy adequate for climatic studies and large scale oceanography, as both variables play a key role in the control of the Earth's water cycle and as a consequence in the understanding of the possible climate evolution in the present context of global warming [1]. SMOS (http://www.esa.int/esaLP/LPsmos.html) was launched on November 2, 2009 and is expected to become operational by May 2010.

The measurement principle

All bodies emit electromagnetic radiation in a large range of wavelengths. At low frequencies, including microwaves, the brightness temperature of the body (T_B, the quantity to be measured by a radiometer, and related to the emitted power) is proportional to its physical temperature. The proportionality coefficient, the emissivity, is a function, among other variables, of the dielectric constant and as a consequence of the conductivity, and hence salinity when the emitting body is seawater. For SMOS a frequency of 1.4 GHz was selected, as it is close to the maximum sensitivity of T_B to changes in salinity as well as minimises the impact of other parameters influencing it. In addition, this is a frequency band where human made emissions are forbidden, so the risk of interferences should not be an issue. At this frequency the penetration of the radiation, and then the thickness of the emitting surface layer, is around 1 cm.

The fundamentals of salinity and soil moisture determination by microwave radiometry were sufficiently known, but no satellite mission had been attempted so far to measure these variables. The main reason was that to achieve a reasonable spatial resolution at this low frequency very large scanning antennas were needed, something that appeared not feasible on board a satellite. The solution implemented in SMOS is the use of a large number of small fully polarimetric antennas (up to 69, 20 cm diameter) deployed along three 4 m arms forming a Y shape. Instead of using the T_B recorded by the individual antennas, SMOS takes the correlation of the polarised signals from all pairs of antennas to reconstruct a unique T_B image through a complex process based on interferometry [2]. The result, in the selected configuration (758 km height, antenna plane 32.5º from horizontal), is a curved-hexagonal field of view, almost 1000 km wide, formed by pixels from 30 to 100 km, with varying incidence angle and radiometric resolution.

Fig. 1. The 69 antennas along the SMOS arms (by P. Carril for ESA)

Retrieving salinity values

The approach to determine the salinity of the ocean surface imaged at each SMOS overpass is based on a convergence loop that compares the measured T_B to the T_B theoretically emitted by the surface following a forward model of the ocean emission taking into account the seawater conditions. During the convergence the sea surface salinity (SSS) value is modified from a first guess until reaching an optimal fit with the measured T_B value. The geometrical optics theory provides a model of the flat sea emission, which depends on the temperature, salinity, angle of observation, frequency and polarisation state of the radiation. On top of this we have to introduce the effect of the sea roughness, as the topography of the emitting surface has a strong impact on the viewing geometry and then on the T_B measured by the radiometer. Further modifications are needed before comparing modelled and measured T_B, as the emitted radiation is modified in its path from the surface to the satellite (attenuation by the atmosphere, polarisation mixing in the ionosphere, …), while it is necessary to take into account other sources of radiation at the same frequency that can also reach the radiometer (emission by the atmosphere, galactic radiation scattered on the surface, …). The result is a quite complex algorithm implemented in the SMOS salinity processor [3].

Even the multiangular measurement characteristics allow for a redundant determination of SSS, the noise and other possible errors due to the instrument performance limitations, image reconstruction process, errors on external parameters needed to estimate the sea surface state (provided by numerical weather forecasts), and incomplete forward model formulation are expected to result in an accuracy in retrieved salinity around 1.5. To reduce this noise and reach the mission objectives, further processing is planned to generate global salinity maps by integrating several SMOS orbits in a temporal window of 10-30 days and spatial resolution of 100-200 km, then providing a product similar to present climatologies but including the temporal evolution. The goal is to achieve salinity accuracy close to 0.1.

These spatio-temporal characteristics of the SMOS observations, together with the fact that strong contamination from land radiation is expected in the first 100-200 km from coast, makes the use of these products in the Mediterranean Sea a real challenge. Some validation activities are planned within the Mediterranean Operational Oceanography Network (MOON, http://www.moon-oceanforecasting.eu/) to explore this limitation.

The development of SMOS has been a collective effort coordinated by ESA of many scientists and technologists as well as industrial companies from several countries, especially Spain and France. This paper is a contribution to the SMOS Barcelona Expert Centre and project ESP2007-65667-C04 funded by the Spanish Ministry of Science and Innovation.

References

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