PRELIMINARY CROSS-VALIDATION OF THE SMOS MEASUREMENTS AGAINST MODELED BRIGHTNESS TEMPERATURES AND EXTERNAL SALINITY DATA

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ABSTRACT

Preliminary results obtained during the commissioning phase of the Soil Moisture and Ocean Salinity (SMOS) mission are described, devoting special attention to the characterization of the systematic errors found in the measurements and the corresponding impact in the retrieved salinity product. The identified issues and objectives to consolidate and improve the processing chain are also described.

1. ESA SMOS MISSION

The European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) satellite mission has been launched in November 2009 (Fig. 1a) to provide, over the oceans, synoptic sea surface salinity (SSS) measurements with frequent temporal coverage [1]. The single payload onboard SMOS is the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS), a novel L-band radiometer which measures the brightness temperature (\(T_B\)) by means of 2-D aperture synthesis interferometry [2].

To allow proper SSS retrievals from the multi-angular \(T_B\)s measured by MIRAS, a comprehensive inversion scheme has been defined [3], despite several issues remain critical. Spatio-temporal averaging of the retrieved SSS has to be properly performed so as to reduce the noise of the measurements. To meet the challenging mission requirements, retrieved SSS needs to accomplish an accuracy of 0.1 psu (practical salinity unit) after averaging in a 10- or 30-day period and 2\(\times\)2\(^\circ\) or 1\(\times\)1\(^\circ\) spatial boxes, respectively (the so-called Level 3 SSS products).

The SMOS satellite has recently undergone the In-Orbit Commissioning Phase (IOCp), the customary 6-month post-launch calibration and checkout period. The activities covered during the IOCp dealt with the consolidation of the calibration strategy, the assessment of the image reconstruction algorithm needed to produce \(T_B\) maps (Fig. 1b), the analyses of the various processing configurations and a first evaluation of the performance of the geophysical parameter inversion scheme.

Fig. 1 a) SMOS launch on November 2\(^{nd}\), 2009, from the Russian cosmodrome of Plesetsk and b) first officially-released ESA \(T_B\) image (credits: ESA)

2. SYSTEMATIC \(T_B\) PATTERNS DETECTION

One of the issues already identified in the pre-launch simulations studies was the presence of systematic instrumental patterns in the SMOS measurements. To tackle these biases, several mitigation techniques have been proposed in recent years [4, 5].

Currently, great attention is devoted to the bias mitigation technique known as Ocean Target Transformation (OTT) [6, 7], which computes the average instrumental spatial pattern in the SMOS field of view. Namely, the OTT is calculated as the average misfit between the SMOS and modeled \(T_B\)s along a whole satellite half-orbit. The resulting spatial pattern, obtained in satellite antenna coordinates, is subtracted from the SMOS measurements prior to SSS retrieval. In Fig. 2, it is shown an OTT for X and Y polarization calculated with and ascending half-orbit over the Pacific Ocean.
Ongoing research activity focuses on the characterization of the OTT to ensure its stability and to further remove its dependency on modeling errors. Furthermore, the calculation of an aggregate OTT by using up to one week of filtered $T_b$ misfit has been performed, with the aim of getting a more homogeneous geophysical parameter distribution in each pixel, and therefore removing this error source in the OTT computation. Remarkable differences of aggregate weekly OTTs can be noticed with respect to a standard single-orbit OTT, especially in some part of the field of view (Fig. 3).

Besides the OTT, further efforts are devoted to ensure that the computed spatial patterns are only related to the instrumental systematic offsets. In order to do so, a model-independent bias mitigation technique has been devised [8]. Relevant features of this technique are the collection of large ensemble of data, a tight data filtering strategy, the removal of angular dependency of the measurements and a sub-selection of data to further homogenize the geophysical parameters distributions in each location in the antenna frame.

The performances of the various bias mitigation techniques and processing configurations have to be assessed in the salinity retrieved products. This has been carried out in two frameworks: on one hand, the L2 SSS operationally computed at the SMOS Data Processing ground Segment (DPGS) have been spatio-temporally averaged as a matter of diagnostic of the retrieved products accuracy. On the other hand, SSS products obtained through a simplified linear retrieval have been analyzed to underline the effect of the various bias mitigation techniques mentioned above.

3. SALINITY RETRIEVAL BIAS MITIGATION ASSESSMENT: DPGS SSS

Concerning the DPGS-derived salinity, a first assessment of the retrieved SSS accuracy using or not an OTT and having the satellite in dual- or full-pol mode is performed by computing a L3-like SSS product. This is obtained by averaging one week (almost 100 half-orbits) of L2 SSS, and selecting only the satellite ascending tracks. L2 SSS measurements have been filtered to be both far off the coastline, and also according to some flags giving indications of poor performances of the retrieval algorithm (Fig. 4). Measurements have also been weighted to take into account the different accuracy of each single L2 measurement.

Figure 5 shows the weighted mean retrieved SSS in 2ºx2º boxes in three different weekly SSS products, obtained by using different version of L2 SSS processor; that is, including or not the OTT bias mitigation in dual-pol mode (Fig. 5a and 5b), and including the OTT in full-pol mode (Fig. 5c).
Moreover, Fig. 6 shows the standard deviation of the L2 retrieved SSS within each specific spatial box for each of the cases described above. By comparing Fig. 6a and 6b, it is shown how the OTT correction ensures a better performance in terms of the accuracy of the retrieved product. By comparing Fig. 6b and 6c, it is highlighted the accuracy degradation of the full-pol mode with respect to the dual-pol mode. The ratios full-pol/dual-pol of the standard deviations calculated over selected geographical area are consistent with the expected theoretical degradation.

This diagnostic should help in devise an improved filtering strategy and thresholds characterization to perform an adequate quality control of the retrieved product and fine-tuning the settings of the retrieval algorithm.

4. SALINITY RETRIEVAL BIAS MITIGATION ASSESSMENT: LINEAR RETRIEVAL SSS

A simplified linear salinity retrieval method [9] allows an evaluation of the impact of the various bias mitigation techniques previously described in terms of global distributions of Level 3 salinity departures from climatology.

A weekly product at 30 Km grid spacing (ISEA4H8) in the month of March 2010 in full-pol mode for ascending tracks is provided in the various processing configurations. Figure 7 shows the salinity anomaly (misfit between the retrieved SSS and a monthly climatology) for the case of using an OTT derived from a single ascending half-orbit.
In Fig. 8 it is shown the SSS anomaly when the processing is performed by using an aggregate weekly OTT instead of the single half-orbit OTT.

In Fig. 9, in turn, the SSS anomaly is computed once the previously mentioned model-independent bias mitigation technique has been applied to the measurements. Salinity anomalies at the high latitudes provide in this case more reasonable values.

To better compare the performances of these methods, the histograms of the various SSS anomalies global distributions are plotted (Fig. 10).

With the single half-orbit OTT (blue curve), the anomaly distribution is characterized by a positive-values peak and a strong asymmetry. The introduction of an aggregate OTT essentially decreases the offset of the distribution peak (black curve); a further homogenization of the geophysical condition distributions cancels such offset (cyan curve). Inhomogeneities of the geophysical conditions observed at different locations in the antenna frame (much more evident in the half-orbit OTT) clearly introduce systematic errors in the retrieved salinities. The model-independent bias estimation technique, while removing dependency on the forward models, does not introduce significant bias, having negligible offset in the location of the distribution peak (red curve).

In general, shifting towards a model-independent bias mitigation technique progressively shows a more accurate and unbiased retrieval, also accompanied by an increasingly symmetric shape of the anomalies distributions. The same kind of analysis will be repeated using the L2 SSS processor to confirm evidence of these features, towards a future implementation of the most adequate method in the official retrieval chain.

5. ISSUES, OBJECTIVES AND FURTHER WORK

Several activities at different levels of the salinity retrieval processing chain have been identified and already constitute matter of ongoing research. These activities refer to both the validation of the products and the consolidation/improvement of the salinity retrieval procedure itself, and will be carried out by performing specific comparisons against modeled brightness temperatures or external salinity data sources. They will support the choice of an optimal data selection strategy in regard to the existing trade-off, for instance the Ascending/Descending tracks selection and the AF-FOV/EAF-FOV (Alias-Free Field Of View/Extended Alias-Free Field Of View) areas selection. Moreover, they will help in the definition of a reliable bias mitigation strategy and an optimal processing configuration (separated polarization versus first Stokes parameter).
Concerning SSS, in turn, the proposed activities will involve inter-comparisons with various external salinity sources. As a further classification, external sources can be distinguished into data coming from models and data collected in-situ. Specific comparisons with in-situ data coming from oceanographic cruises transects and from VOS (Voluntary Observatory Ships) are foreseen, as well as against moored buoys, profilers, and drifters. These data will be arranged in specific match-up datasets, to properly organize the spatio-temporal collocation of the SMOS and in-situ measurements. The possibility of using model solutions for validation will also be considered. Model data are obtained from available prediction systems. Concerning the salinity retrieval inversion scheme, efforts will be devoted to the optimization of both the GMF (Geophysical Model Function) and the minimization cost function. With the increase of data availability, the semi-empirical GMF in the ocean salinity Level 2 operational processor will be improved, in particular the roughness-dependent $T_B$ term. The prospective approach is to develop, at a later stage, a fully empirical GMF derived ad-hoc for the specific SMOS problem. Finally, the need for a comprehensive balancing of the different terms included in the inversion cost function is also stressed by recent studies [10]. The relative contribution of each of the observational and background terms will be quantified.

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7. REFERENCES


