DATA ANALYTICS TO IMPROVE SMOS CALIBRATION

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The SMOS mission is a joint program led by ESA with participation of CNES in France and CDTI in Spain. SMOS satellite carries a single payload on board, MIRAS, a Microwave Imaging Radiometer with Aperture Synthesis. The satellite has been in-orbit for over 7 years, providing for the first time and for this entire time, the longest record of space-sensed soil moisture and ocean salinity measurement [1], as well as new applications such as measurements of thin ice thickness [2] and surface ocean winds in storms [3].

SMOS payload MIRAS [4] is the first radiometer interferometer to ever flown in space. Calibration of this novel and complex system has been very challenging, but good progress has been made over the past years, enhancing SMOS measurement [5]. A good example of this was the qualitative jump in the data quality between the first and the second mission reprocessing. This qualitative jump was measured with a number of metrics that include instrument stability, spatial bias, polarimetric performance and radiometric accuracy.

On this last second mission reprocessing, the metrics show that the instrument stability has basically no long-term trend (<0.03K/year) and its seasonal variations are smaller than 2 Kelvin peak-to-peak for the entire mission. A good representation of this metric is a Hovmoller plot that compares the SMOS measurement over time and latitude to the expected signal from the Ocean emissivity models. See Figure 1.

Ideally Figure 1 should be flat and close to zero, indicating that the instrument is stable and the measurement in line with the Ocean models. For this analysis, the overall 2K bias has been disregard since the initial target is to remove the seasonal variability. Among the reasons to disregard this overall bias is that slightly different ocean models analyzed provided similar variability maps, but not necessarily the same overall bias. This bias will be re-assessed at a different stage and compared to other references as over ice.

Therefore, the initial objective has been to reduce any temporal deviation from the overall bias (2K), which indicates either an instrument instability, or an error in the geophysical model. The difficulty in trying to improve the calibration lies in differentiating instrument related problems from model errors, and also in understanding what the origin of the instrument instabilities is. Although, some variations are easy to understand for the SMOS calibration team (such as the strong bias early in the mission related to processes during the Commissioning Phase, or the strong bias in northern latitudes in Winter periods, related to the big thermal variation suffered by the satellite following an orbital eclipse of the Sun by the Earth), other variations are subtler, and sometimes even compensating one another. In some cases, the origin of the instability comes from the inaccuracy of a particular calibration parameter, whose accuracy is limited by the inherent error of the SMOS calibration procedures.

In order to improve the instrument stability in view of a third mission reprocessing, the SMOS team has applied a new methodology that uses analytic techniques over a large data record of the satellite-related available information to determine the origin of the instabilities, and then act on each of them.

In a first step, the Hovmoller plots of brightness temperature deviations for Stokes-1, X, Y polarizations and the cross-polarizations, separately for ascending and descending passes (such as Figure 1), were compared to one another and correlated with hundreds of parameters. These parameters included telemetry information, calibration parameters and geophysical information. This step indicated which parameters were more likely to induce biases in the Hovmoller plots. Then, for the analysis, the bias error was considered to be a linear combination of a subset of those hundreds of telemetry parameters. Following an iterative procedure, the bias error was decomposed on this non-orthogonal basis, made of telemetry and geophysical parameters. The stronger error contributors were then removed (linearly) from the overall bias signal. The process followed successive steps until the main error contributors were all removed and the Hovmoller plots were clearly flattened (see Figure 2).

This method determined that SMOS instabilities contributors are mainly 5: A calibration parameter of the SMOS reference radiometer (the amplitude of the noise injection, Tna), the external thermal variability at the skin of SMOS antennas (Tp7) and its gradient, and model errors related to the reflected galactic signal and the total electron content in the atmosphere.

The SMOS team does not use this information to propose an empirical correction based on the numbers derived, but to re-assess the calibration procedures. The investigations conveyed over the past year are introducing new changes in the algorithm to improve SMOS calibration. Use of a fixed value for noise injection of the SMOS reference radiometer, the refinement of the antenna losses values, and a correction to incorporate a thermal delay in one of the thermistor measurements are among the initial tests performed. The first results show that SMOS stability can be qualitatively improved again in a future mission reprocessing. At the time of writing the abstract, the instability of the signal (measured as the RMS for the Hovmoller plot) decreased by 20 to 40% depending on the polarization. Future tests are expected to reduce these figures even further.

This paper describes the methodology used by SMOS calibration team to improve the instrument calibration in view of a third mission reprocessing. The method correlates the estimated errors with a large amount of information related to the satellite in order to determine the strongest contributors to the errors. The results are being used successfully to improve the instrument stability, leading to a never achieved before measurement performance that can benefit the many applications that use SMOS data.

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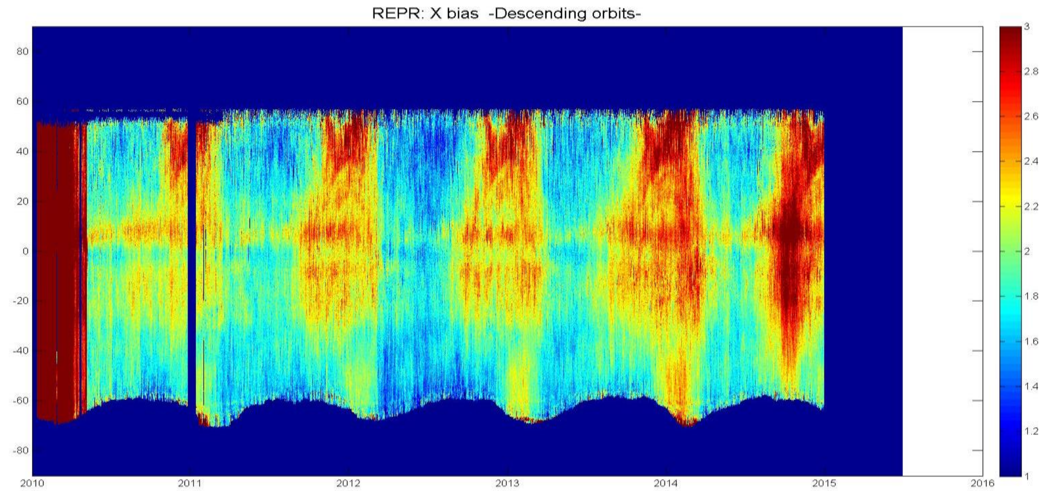

Figure 1: Bias error for Descending orbits on X polarization for the second Mission Reprocessing data

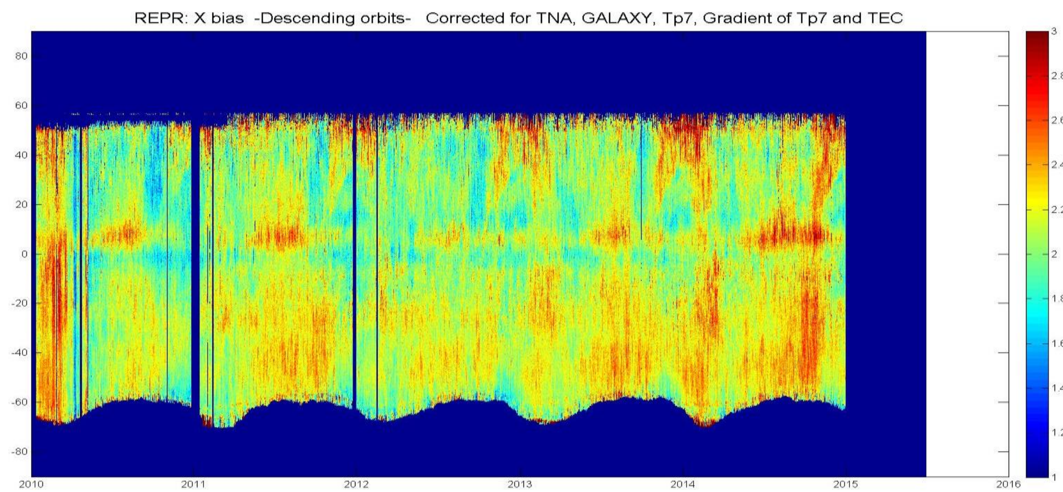

Figure 2: Bias error for Descending orbits on X polarization once certain error contributors have been linearly removed.