SMAP CALIBRATION USING COLD SKY OBSERVATIONS

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ABSTRACT

Cold Sky Calibration is an important tool in the calibration of the SMAP radiometer. It is used to assess the absolute calibration and its temporal drift. We will present the results of 7 years of cold sky observations and the latest improvements they provide to the analysis of the SMAP radiometer calibration performances.

***Index Terms*—** L-band, Radiometry, Calibration

1. INTRODUCTION

Cold Sky Calibration (CSC) is an important part of determining the absolute accuracy and long term temporal stability of the L-band (1.4 GHz) radiometer on SMAP [1]. The celestial sky is an excellent calibration reference scene at L-band: it is well-known and is temporally stable and spatially homogeneous over regions large compared to the resolution of the SMAP antenna [2], [3]. Starting in April 2015, CSC maneuvers have been conducted monthly and the data have been used to evaluate and improve the radiometer accuracy and temporal stability. In May 2021 the CSC procedure was revised to include two maneuvers per month, instead of one previously, in order to have both ascending and descending orbit passes sampled every month.

The motivation for the additional CSC came from temporal drift estimates over ocean scenes. Time series of the global average of the difference between observed and simulated antenna temperatures (TA) over oceans showed seasonal swings that varied significantly between ascending and descending passes (Figure 1). The calibration swings occur around the satellite's eclipse season when significant changes in reflector temperature occur along one orbit, with different behavior between ascending and descending orbits. Revisions of the calibration mitigated these swings over the oceans (compare V3 and V4 in Figure 1), but it is not known whether the swings are due to actual calibration drifts (possibly related to eclipse) or deficiencies in the forward model (sea surface emissivity, atmospheric model, reflected Sun, Galaxy, etc …) used to evaluate the drift over the oceans. The CSC data is an ideal tool to assess the origin of the swings as the forward model for the CSC is largely independent of the ocean model. Unfortunately, most of the

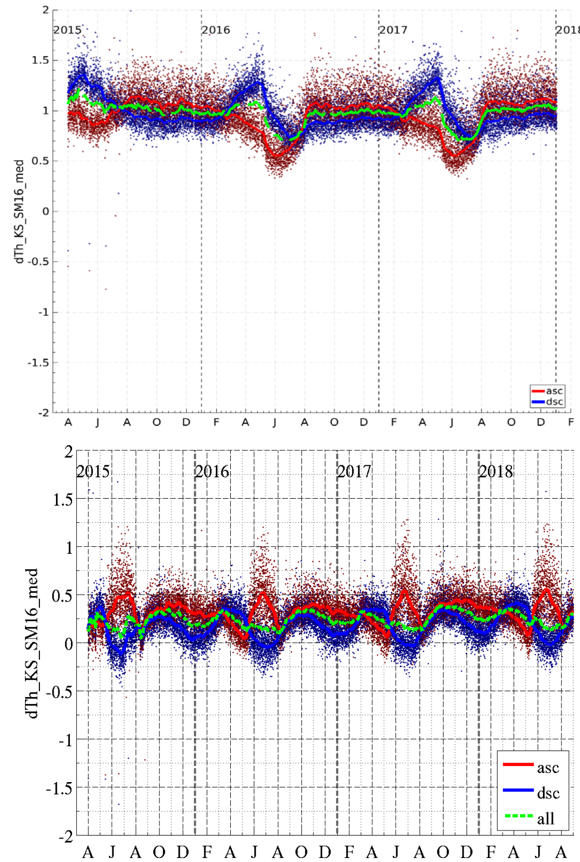

Figure 1 SMAP calibration drift over global ocean for product versions (Top) V3 and (Bottom) V4; biases are for (Red) ascending, (Blue) descending and (Green) all passes combined together.

CSC until April 2021 were for descending orbits, precluding the analysis of the difference in drift between ascending and descending orbits. Starting May 2021, both ascending and descending orbit CSCs occur every month to better characterize the radiometer temporal drift. Also, model improvements are being worked on to increase further the accuracy of the calibration.

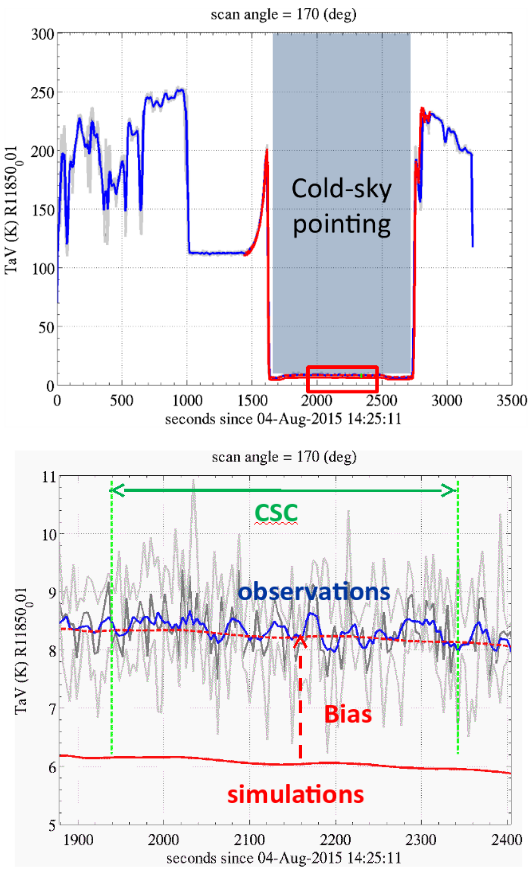

Figure 2 Example of a CSC on Aug 4, 2015. (Top) SMAP (blue) measured TA at V-pol during one orbit for a scan angle of 170° +/- 2.5° and (Red) simulated TA. The red box reports the section shown on the bottom panel. (Bottom) SMAP measured TA: (light grey) min and max for all scan angles in the range 170° +/- 2.5°; (dark grey) averaged over all scan angles in the range 170° +/- 2.5°; (blue) smoothed temporally. (Plain red): simulated TA; (dashed red) simulated TA shifted vertically by a constant offset to minimize the differences with the blue curve: this offset is the estimated bias to be removed in the calibration.

During a CSC, the spacecraft is pitched 110° to point toward the celestial sky, which is accurately known, stable and fairly homogeneous at L-band [2], [4]. The spacecraft is kept inverted for a few minutes, and the difference between observed and simulated TA is averaged over the duration of the CSC to reduce radiometric noise. This TA difference, computed every 5° in scan angle, provides the calibration bias for that particular CSC date. The monthly CSCs allow the assessment of the temporal drift of the calibration, which can be assessed separately for different scan angles. Since May 2021, ascending and descending orbits can be analyzed separately. The data from one CSC are reported in Figure 2 for illustration.

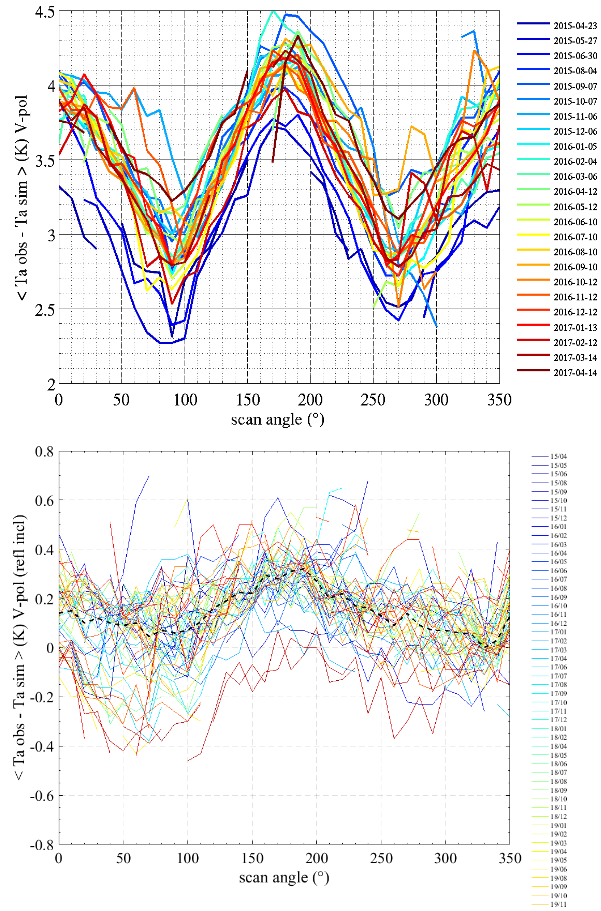

Figure 3 Scan angle dependence of the cold sky bias at various dates, with (top) original antenna pattern model and (bottom) improved model.

The forward model for the CSC configuration is highly accurate (e.g. compared to models for the Earth surface and atmosphere) but improvements are still being made. We will present recent effort in improving further the CSC model. Early work on SMAP CSC showed a significant scan angle dependence in the cold sky bias, of the order of +/-0.75 K peak to peak (Figure 3, top). This was tracked down to an issue in the antenna pattern model. Once the pattern model was corrected, the scan angle dependence was reduced to +/-0.1 K (Figure 3, bottom). Work is being conducted on the antenna pattern model to mitigate further the scan angle dependence of the bias. Another source of uncertainty is the polarized components of the emission from the Sky which has been neglected in the past. Analysis of a special CSC maneuver at 180° pitch showed a likely impact of ~0.2K from the third Stokes emission of the Sky for part of the CSC (Figure 4).

3. RESULTS

Figure 5 reports time series of the CSC bias starting April 2015 (top), and with a focus on the last few months (bottom) to show the differences between ascending and descending

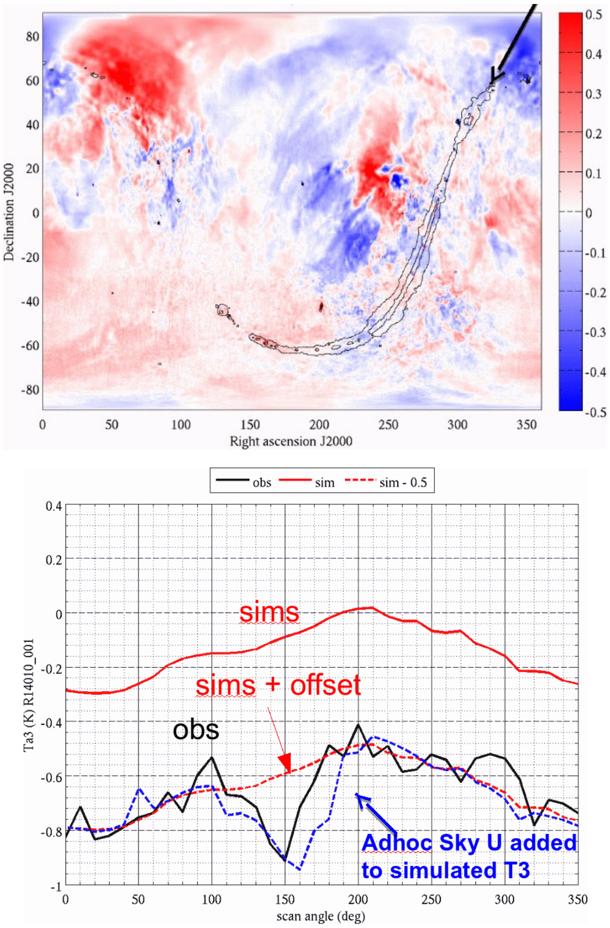

Figure 4 (Top) Map of the third Stokes parameter of the Celestial Sky at L-band as a function of right ascension and declination in the ECI J2000 coordinate system. The black curves report an outline of the galaxy. (Bottom) Third Stokes parameter as a function of scan angle (black) observed by SMAP and (red, plain) simulated assuming unpolarized emission for the Celestial Sky. (Red dashed) simulated third Stokes shifted vertically by a constant offset to account for SMAP calibration error. (Blue dashed) same as the red dashed curve with a contribution to the third Stokes from the sky emission included, derived from the map reported on the top.

orbits. The radiometer stability is within ~0.2K. The black and green curves report the bias without accounting for the reflector emissivity. The reflector emissivity has a significant impact, and including it reduces the bias in vertical and horizontal polarizations by ~2.5K. It also introduces larger seasonal fluctuation with mid-year drops ~ 0.2 K. The results are similar for ascending and descending passes (Figure 5, bottom), both dropping by the same amount mid-year. This is opposite to the results over the oceans which exhibit opposite swings for ascending and descending orbits. There is a small residual bias of 0.2 – 0.5 K (red curves) that is due to uncertainty in antenna pattern spillover normalization. Adjusting this parameter mitigates the scan angle dependence reported in Figure 3 (bottom) and the residual bias, but this is most successful for the horizontal polarization, less so for the vertical polarization.

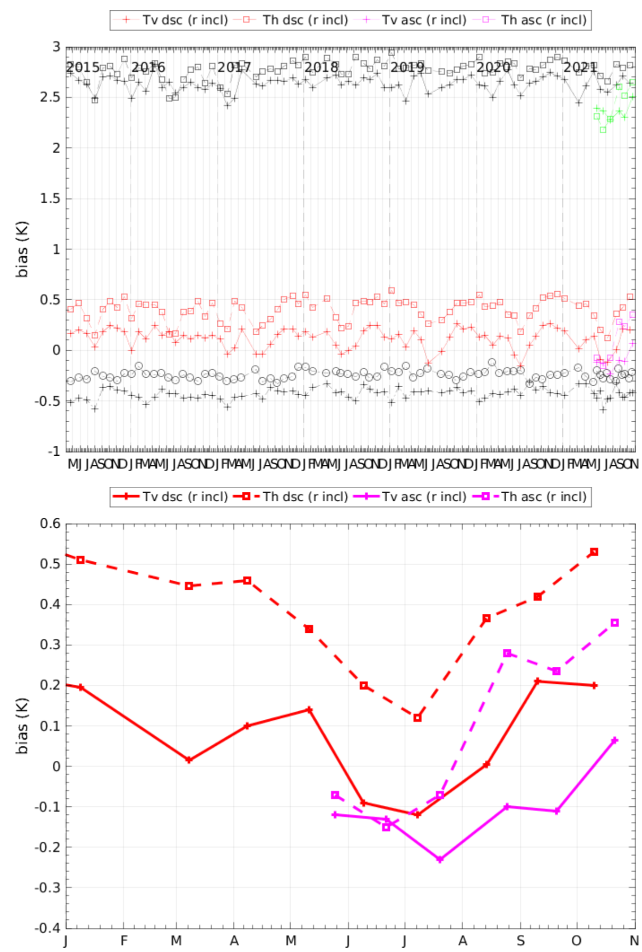

Figure 5 Temporal variation of the bias measured during SMAP cold sky calibration. Top: Bias since the beginning of the mission; black without correction for reflector emissivity, red with correction; green and magenta are newly added ascending orbits; black curves at bottom of top panel are for T3 and T4. Bottom: Data since January 2021 to show the recent data which includes both ascending passes (magenta) and descending passes (red).

4. CONCLUSIONS

CSC for SMAP have been conducted monthly since the beginning of the mission and expanded in May 2021 to include 2 maneuvers per month to sample both ascending and descending passes. They show excellent temporal stability of the calibrated radiometer. Analysis of ascending and descending temporal drift shows different behavior of the bias derived from the cold sky compared to the ocean (Figure

1). More work is needed to understand these differences. Adjusting the antenna gain front/back power ratio enables to mitigate the residual scan angle dependency of the cold sky bias. Significant improvements are found in H-pol and Stokes 3, while V-pol still needs improvements. The correction to the scan angle dependence also brings scan-averaged cold sky bias close to 0 in V- and H-pol.

5. REFERENCES

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