AQUARIUS ENGINEERING PHASE ON-ORBIT T_A CALIBRATION

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ABSTRACT

Aquarius is a passive microwave radiometer operating at L-band that is designed to measure ocean salinity. Launched in June 2011, the instrument has since been the subject of on-orbit calibration to evaluate its performance and characterize its stability. This study addresses external calibration methods, using observed antenna temperatures to characterize instrument behavior by computing the oceanic global average and vicarious cold statistics. Results indicate that a slow drift in antenna temperature is present throughout the mission, as well as shorter time scale variations. Implementation of a noise diode deflection ratio-based correction algorithm mitigates most of the short term variations but the slow drift remains present in both statistics. It is most apparent using the global average statistic. The drift can be largely removed by adjusting the instrument calibration to force agreement between observed and modeled global averages over long time intervals.

1. INTRODUCTION

The Aquarius microwave radiometer is a major part of a new satellite platform designed to remotely measure sea surface salinity from space [1]. However, because the sensitivity of the observed brightness temperature to salinity is small, the instrument must be extremely stable—on the order of 0.1 K over weekly time scales. A number of calibration assessment methods are utilized to validate and characterize the repeatability of the observations. The subject of this paper is the application of external calibration methods using the Aquarius antenna temperatures (T_A).

2. AQUARIUS DATASET

The Level 2 T_As are used for this calibration study, and cover the period 29 August 2011 through 14 May 2012. Three separate sets of T_As are provided by Aquarius' three independent radiometers, all operating at 1.4 GHz. The radiometers are offset, at incidence angles between 29° and 45°, and each provides horizontally and vertically polarized (H- and V-pol) observations as well as observations of the 3rd Stokes parameter. The specific T_As used for the calibration study are restricted to be over the ocean with no radio frequency interference (RFI), and are solely V- and H-pol.

Various methods of drift correction have been applied to the observations throughout version releases, and this paper uses the version 1.3 T_As. This set includes two distinct phases of data. The first phase, which spans the CY 2011 period of operation, includes a long time scale drift correction that was updated weekly but is unable to correct for the short time scale fluctuations in the data. The second phase, throughout CY 2012, also implemented a short time scale drift correction based on internal noise diode deflection ratios, and yields T_As that are significantly more stable on both short and long time scales. In this paper, the first phase of data is referred to as V1.3 and the second phase as V1.3-DR.

3. CALIBRATION TECHNIQUES

Two separate calibration statistics are used to characterize the drift in observed T_As over the mission. The primary technique is the global average, which is an arithmetic mean of all T_As over the ocean [2]. The vicarious cold calibration statistic is a second evaluation tool, and is the coldest theoretical temperature observable by Aquarius [3]. Ideally, both statistics remain stable over time and are relatively insensitive to both external environmental changes and internal instrumental factors. The two statistics are also useful when applied in tandem, as they are sensitive to separate effects. The global average can be influenced by anomalously high wind speeds and the presence of precipitation, while the vicarious cold statistic is primarily affected by changes in the background space brightness.

The statistics are applied to week-long population sets of T_As to account for the Aquarius exact revisit time. The statistics are reported at each day over the mission timespan, but include all observations for 3.5 days before and after the marked time in the calculations.

The two statistics alone provide a general sense of radiometer stability, but provide more detail when used together with the statistics of modeled T_As as well. Each reported Aquarius observation has a corresponding expected T_A, simulated with ancillary wind fields and other physical inputs for the same time period. The modeled T_As provide a theoretical estimate of what the radiometer is expected to observe. For calibration purposes, the global average and vicarious cold statistics are independently applied to the expected T_As as well, and the observed minus expected T_As are computed. Ideally, this single difference technique isolates biases and drifts produced from the instrument hardware alone from those of geophysical origin.

4. RESULTS

The global average statistics for the oceanic H- and V-pol T_As are shown in Figures 1 and 2, respectively. The vicarious cold calibration statistics are likewise plotted for H- and V-pol T_As in Figures 3 and 4. Both statistics reveal the short time scale variations present throughout the V1.3 data, with a clear shift on 4 January 2012 into the smoother V1.3-DR T_As. A slowly changing drift is evident throughout all data, but the inclusion of the noise diode deflection ratio correction largely removes the quickly oscillating effects of the hardware. The results are similar in the bias estimates, shown for the global average in Figure 5 and the vicarious cold statistic in Figure 6. With the geophysical signals isolated from this set, the large T_A fluctuations caused by the drifting noise diodes are made clearer and are removed by the deflection ratio correction in the V1.3-DR data. However, the slow drift in the T_As also remains throughout all observations. With the geophysical signal removed, it is evident that further drifting in the hardware—most likely still caused by the noise diodes—remains.

The hardware bias estimates are further investigated by filtering the T_As in two ways: by

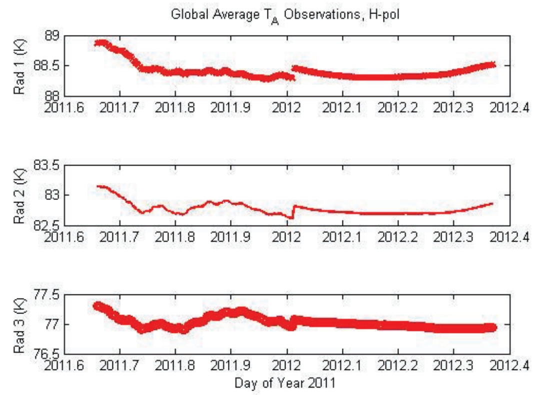

Figure 1. Global average statistic for RFI-free oceanic H-pol T_As, including V1.3 and V1.3-DR data.

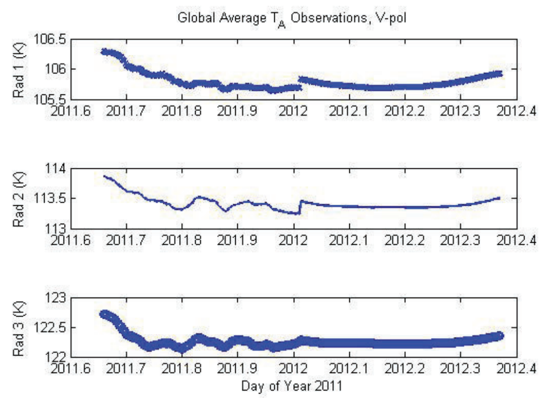

Figure 2. Global average statistic for RFI-free oceanic V-pol T_As, including V1.3 and V1.3-DR data.

Northern and Southern Hemisphere observations, and by ascending and descending passes. The results are similar between the global average and vicarious cold statistics, so only one version is presented here. The vicarious cold observed minus expected T_As are shown for the Northern and Southern Hemispheres in Figures 7 and 8, respectively. The large variations in the V1.3 T_As are present in both hemispheres and make conclusions difficult, but the V1.3-DR T_As provide better insight. The long-term drift is present in both hemispheres at different scales, and appears to be moving in opposite directions between polarizations. Further, the vicarious cold bias estimates for the ascending and descending passes are plotted respectively in Figures 9 and 10. The drifts are likewise present in both sets of data, but are different in scale between pass directions.

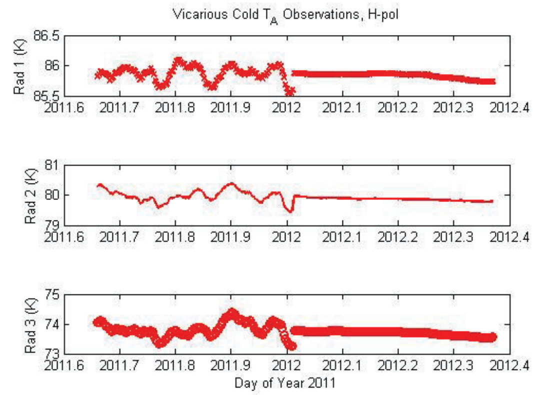

Figure 3. Vicarious cold statistic for RFI-free oceanic H-pol T_As, including V1.3 and V1.3-DR data.

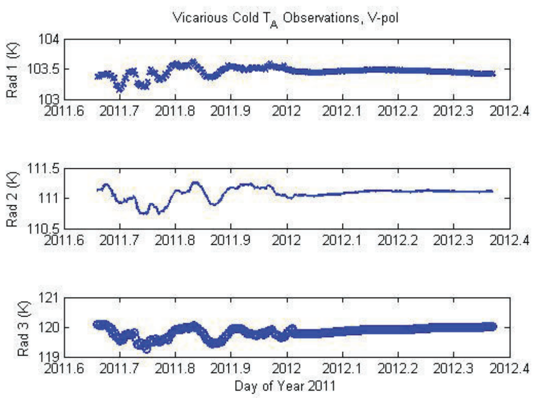

Figure 4. Vicarious cold statistic for RFI-free oceanic V-pol T_As, including V1.3 and V1.3-DR data.

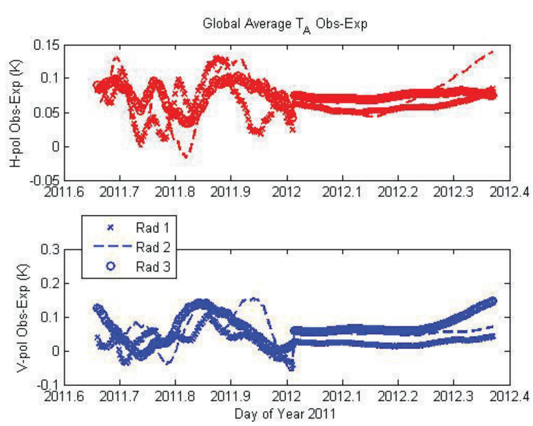

Figure 5. Global average bias estimate (Obs-Exp) oceanic RFI-free T_As, including V1.3 and V1.3-DR data.

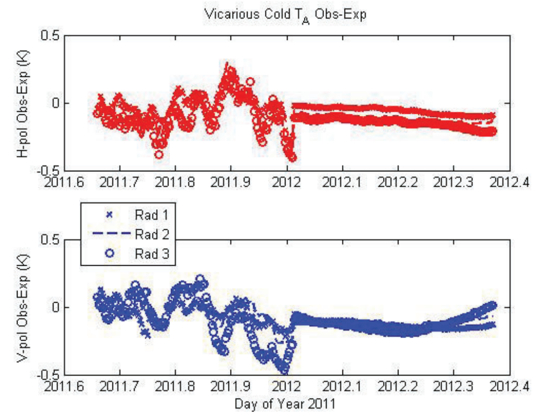

Figure 6. Vicarious cold bias estimate (Obs-Exp) oceanic RFI-free T_As, including V1.3 and V1.3-DR data.

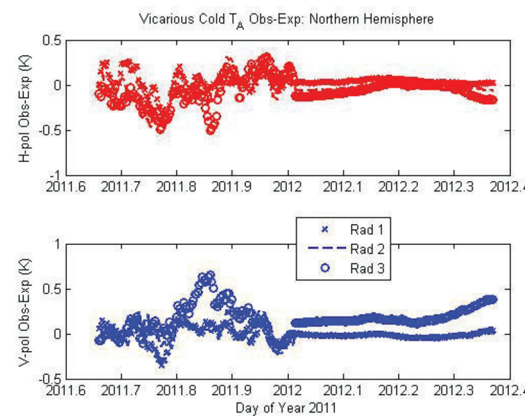

Figure 7. Vicarious cold bias estimate (Obs-Exp) for Northern Hemisphere oceanic RFI-free T_As.

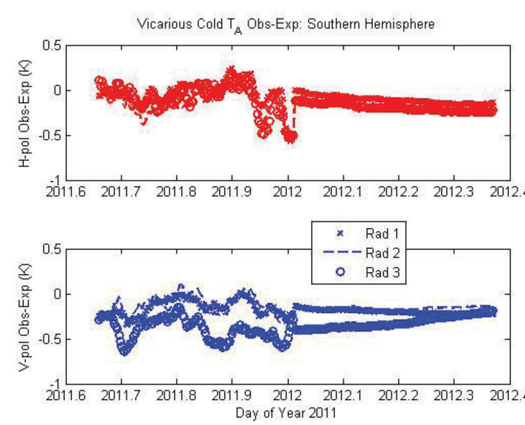

Figure 8. Vicarious cold bias estimate (Obs-Exp) for Southern Hemisphere oceanic RFI-free T_As.

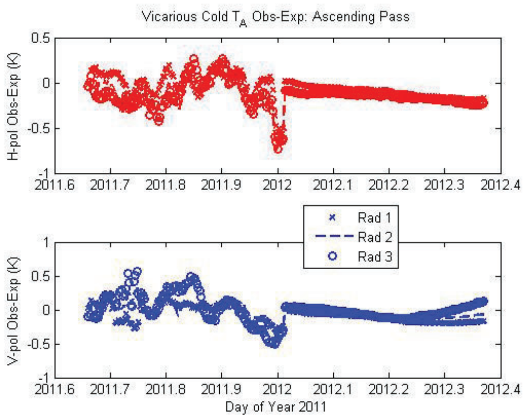

Figure 9. Vicarious cold bias estimate (Obs-Exp) for ascending pass oceanic RFI-free T_As.

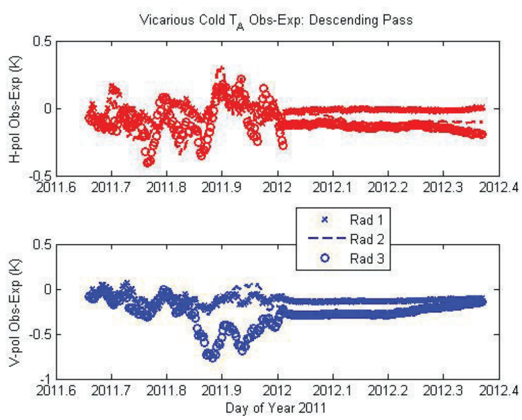

Figure 10. Vicarious cold bias estimate (Obs-Exp) for descending pass oceanic RFI-free T_As.

5. CONCLUSION

On-orbit calibration of the Aquarius observations is an important tool to evaluate and characterize the instrument's performance. As the salinity signal it is designed to retrieve is small, stability and repeatability are immensely important to success.

The external calibration performed in this study utilizes the observed and expected T_As, and uses their single difference to investigate hardware biases and determine their trends. Short time scale variations caused by noise diode fluctuations are addressed using a deflection ratio correction algorithm that greatly improves the stability. However, a slow drift remains in the T_As, suggesting the need for further mitigation of long term problems in the noise diodes.

6. REFERENCES

[1] Lagerloef, G., F.R. Colomb, D. Le Vine, F. Wentz, S. Yueh, C. Ruf, J. Lilly, J. Gunn, Y. Chao, A. Decharon, G. Feldman and C. Swift, The Aquarius/SAC-D mission: Designed to meet the salinity remote-sensing challenge, *Oceanography*, vol. 21, no. 1, p. 68-81, March 2008.

[2] Ruf, C., Detection of calibration drifts in spaceborne microwave radiometers using a vicarious cold reference, *IEEE Trans. Geosci. Remote Sens.*, vol. 38, no. 1, p. 44-52, Jan. 2000.

[3] Ruf, C., Vicarious calibration of an ocean salinity radiometer from low Earth orbit, *Journal of Atmospheric and Oceanic Technology*, vol. 20, p. 1656-1670, Jan. 2003.