AQUARIUS RADIOMETER RFI DETECTION, MITIGATION AND IMPACT ASSESSMENT

Christopher Ruf[1], David Chen[1], David Le Vine[2], Paolo de Matthaeis[2], Jeffrey Piepmeier[2]

[1]University of Michigan, Ann Arbor, MI USA

[2] NASA Goddard Space Flight Center, Greenbelt, MD USA

ABSTRACT

Performance of the Radio Frequency Interference (RFI) detection and mitigation algorithms used by the Aquarius microwave radiometer is demonstrated on orbit. The detection algorithm makes use of the radiometer's high over-sampling rate to identify short, pulsed increases in power that are characteristic of radar operating nearby in the microwave spectrum. The over-sampled data are downlinked to the ground, which allows the detection algorithm to be implemented in ground processing. Access to over-sampled data on the ground also enables the mitigation algorithm, which removes samples with detected RFI from subsequent averaging. The mitigation algorithm is shown to remove nearly all detected RFI. The algorithm can also be used to characterize the RFI itself – in particular the probability distribution of its strength and its geolocation. A first look at both characteristics of the RFI are also presented here. As expected, the prevalence and strength of the RFI is found to be much greater over land than ocean. Certain regions of the globe –*e.g.* in and around Western Europe and Eastern and Southern Asia– have stronger and more frequent RFI.

Index Terms— *Radio Frequency Interference*

1. INTRODUCTION

The Aquarius/SAC-D satellite was launched on 10 June 2011 into a sun-synchronous polar orbit and the Aquarius microwave radiometers [1] became operational on 25 August 2011. Since that time, they have been measuring brightness temperatures at 1.4 GHz with vertical, horizontal and 3rd Stokes polarizations . Beginning well before the launch, there has been concern that Radio Frequency Interference (RFI) could have an appreciable presence. This concern was initiated by, among other things, its prevalence in both early [2] and more recent [3,4] aircraft field experiments using 1.4 GHz radiometers, as well as by the strong RFI environment encountered during the recent ESA SMOS mission, also at 1.4 GHz [5]. As a result, a number of methods for RFI detection and mitigation have been developed and tested. One in particular, "glitch detection" and "pulse blanking" mitigation has been adapted for use by Aquarius [6, 7]. The early on-orbit performance of the Aquarius RFI detection and mitigation algorithm is presented here, together with an assessment of the global RFI environment at 1.4 GHz which can be derived from the Aquarius measurements.

2. DETECTION AND MITIGATION ALGORITHM

The measurement sampling rate of the radiometer is significantly higher than the Nyquist spatial sample rate dictated by its antenna beam width in order to enhance its ability to detect and mitigate anticipated forms of RFI [7]. When RFI is not present, these short subsamples are averaged together to reduce radiometric noise. When RFI is detected in some of the subsamples, they are removed from the average in ground processing. Oversampling in this way is believed to be especially helpful for overcoming pulsed RFI such as is are produced by large air traffic control and early warning radars. Ground processing of the Aquarius data detects the presence of RFI by examining the variance of the subsamples and flagging those which deviate from their neighbors more than can be confidently explained by normal radiometric noise statistics [8]. This approach to RFI detection and mitigation has been validated previously in ground-based and airborne campaigns [3].

3. FIRST DETECTION AND MITIGATION RESULTS

Histograms of the H-pol brightness temperature before (designed TA) and after (designed TF) the mitigation algorithm is applied are shown on the left in Fig. 1 for land-only observations and in Fig. 2 for ocean-only observations. Histograms of the difference between the two (i.e. TA – TF) are shown for the land-only and ocean-only observations on the right. Fig. 1 (left) illustrates the very high probability of occurrence of RFI-contaminated measurements over land (the blue TA bars), which is consistent with the environment experienced by SMOS. It also shows that, the mitigation algorithm has successfully removed almost all of the non-physically high brightness temperature values.

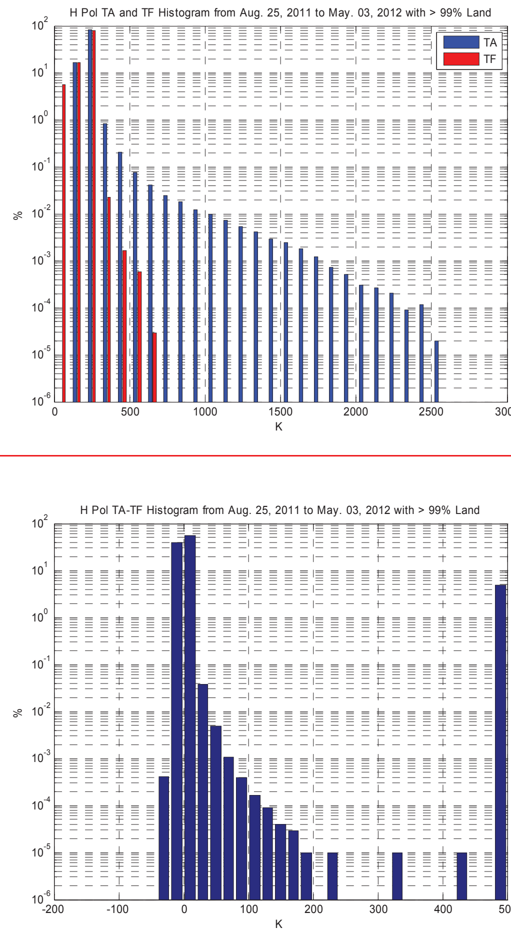


Figure 1: (top) Histograms of measured H-pol brightness temperature (TA, blue) and brightness temperature after RFI mitigation (TF, red) for over-land observations. (bottom) Histogram of the difference (TA – TF) shows the RFI environment at high values and the probability of occurrence of false alarms at low values. Values greater than 500 K are included in the 500 K bin.

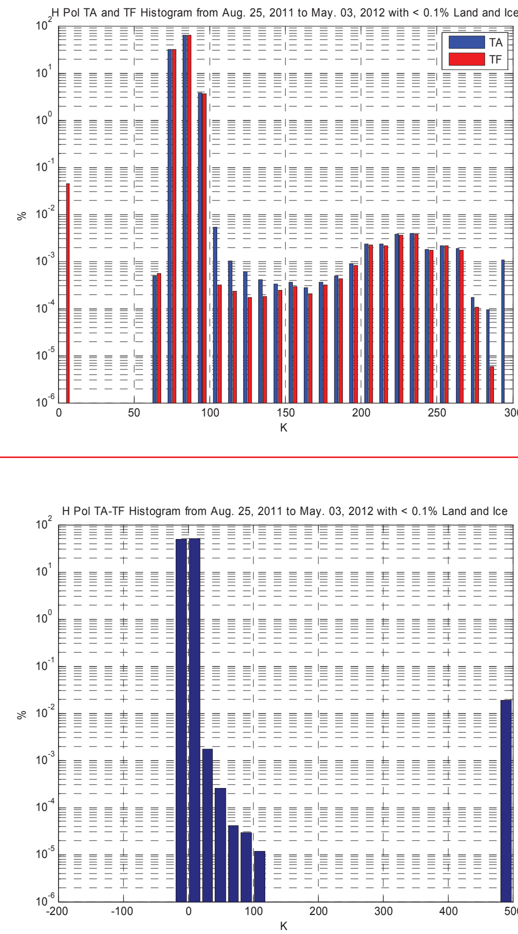


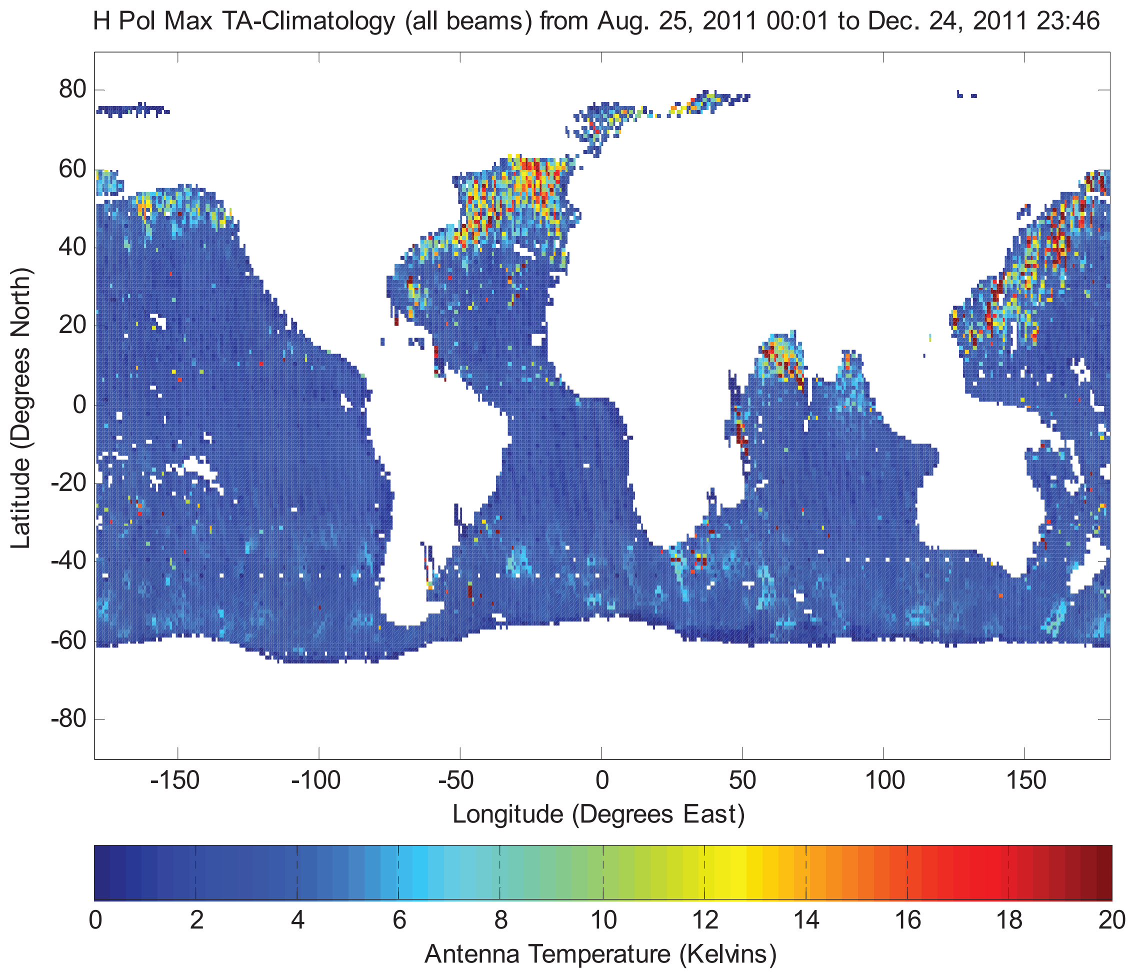
Figure 2: Similar plots as in Fig. 1 for the over-ocean observations. In the top panel, TF values below ~60 K indicate problems with the mitigation algorithm. They happen infrequently and are flagged and removed at a later processing stage.

The histogram of the difference (TA – TF) shown on the right in Fig. 1 illustrates both the RFI and the “false alarm” occurrences of clean measurements that were mistakenly identified as RFI-contaminated. The high probability of (TA – TF) values near zero is likely due primarily to those false alarms. Higher values are likely due to RFI.

Fig. 2 shows data over the ocean in the same format as Fig 1. Comparison with Fig 1 shows that, as expected, there is much less RFI over ocean. However, it is not entirely absent (e.g. values greater than 100K in the left panel). The occurrences of TF with values below ~ 60K on the left panel illustrate occasional problems with the mitigation algorithm, as such values are physically unrealizable over the ocean. This happens only infrequently and the occurrences are flagged and removed at a later processing stage. However, the problem is currently being studied and will be corrected. Work is underway to tune the algorithm to reduce the false alarm rate, especially over the ocean, and to remove problems such as the low values (Fig 2, top) and residual large values (Fig 1, top) which suggest undetected RFI.

4. FIRST RFI CHARACTERIZATION RESULTS

The geographic distribution of prevalent RFI over the ocean is illustrated in Fig. 3 (top), which shows a “peak hold” RFI map for 25 Aug – 24 Dec 2011. To create this map, a climatology of the average RFI-free brightness temperature is first derived by averaging over all observations for which TA (raw observations) and TF (RFI mitigated observations) are the same. The deviation of TA from the climatological average is then noted for every observation over a period of time, and the largest deviation is plotted in the peak hold map. A histogram of the values in the peak hold map is



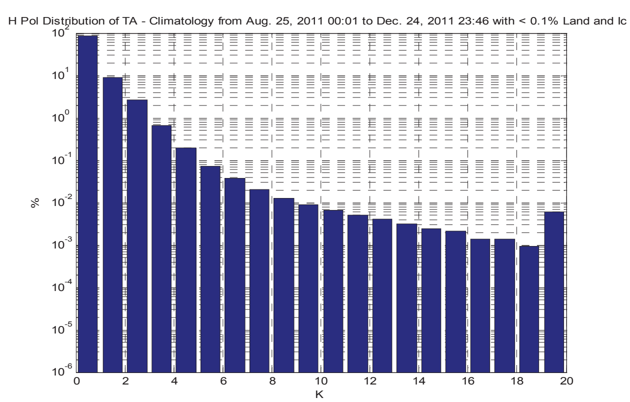


Figure 3: (large top) Peak hold RFI map of the largest deviation of brightness temperature from the average RFI-free value over the period 25 Aug – 24 Dec 2011 highlights the regions of prevalent RFI over the ocean. (small bottom) Histogram of the samples in Fig. 3-top. The largest (20 K bin) accounts for all samples at or above 20 K.

shown in the lower panel in Fig. 3. It illustrates the probability of occurrence of RFI over the ocean as a function of the strength of the RFI.

As Fig. 3 shows, the oceanic regions of most concern for salinity retrievals are the North Atlantic and the coastal regions near Alaska, the Indian subcontinent and eastern China. The actual locations of the RFI sources are likely not where they appear to be in the figure, but rather on the land nearby. Shifts in the apparent location between ascending and descending nodes of the satellite orbit (Fig. 4) indicate that the RFI is entering the Aquarius radiometer antenna through a sidelobe pointed toward land while the antenna boresight is pointing at the apparent location of the RFI.

The strength of the RFI shown in Fig. 3 extends over the full 0-20 K range of the histogram, with the likelihood growing as the strength decreases. At some sufficiently low level, the RFI strength will drop below the detectability threshold of the detection algorithm and can then bias the salinity retrieval. To address this possibility, the detection threshold can be adjusted to a lower level in the regions of most prevalent RFI. This will necessarily increase the probability of false alarms when RFI is not present and so may not be as appropriate in regions where RFI is not typically found. The

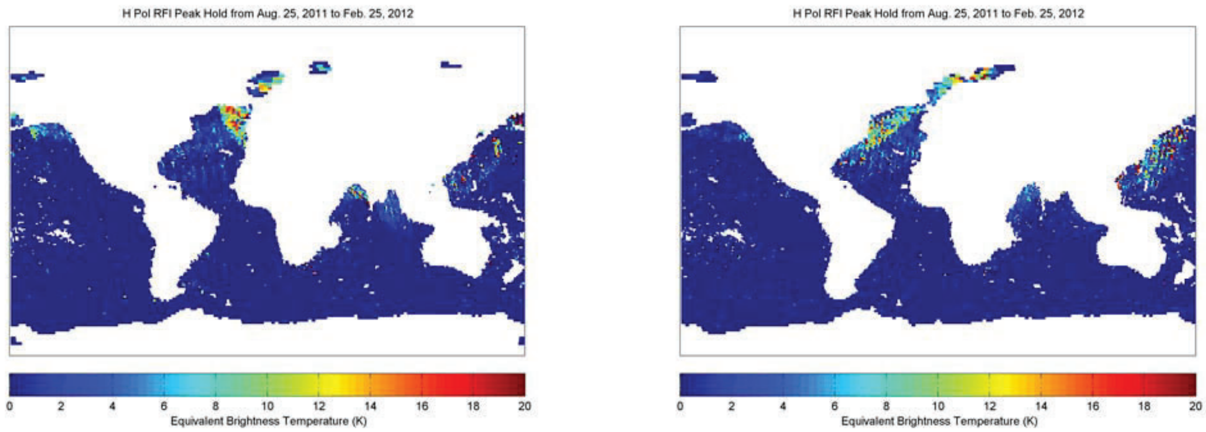


Figure 4: Peak hold RFI maps for the (left) ascending node and (right) descending node portions of the orbit. Note the east/west shift in the apparent location of the predominant regions of RFI in the North Atlantic. This strongly suggests that the RFI sources are located on land and are entering the Aquarius antenna through one of its sidelobes, as opposed to the mean beam boresight direction on which the georeferencing of the image is based.

geographical adjustment of the RFI detection threshold is a topic of ongoing investigation.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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