Mitigating the impact of RADCAL beacon contamination on F15 SSM/I ocean retrievals

K. A. Hilburn[1] and F. J. Wentz[1]

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[1] Data from six Special Sensor Microwave/Imagers (SSM/I) have been used to provide a 22-year climate data record of surface wind speed, columnar water vapor, columnar cloud water, and surface rain rate. On 14 August 2006, a radar calibration (RADCAL) beacon was activated on F15, one of the SSM/I. Interference from the beacon caused retrieval biases of roughly −30% for wind and rain and 40% for vapor and cloud. We have developed a simple correction for RADCAL interference, which brings the retrieval biases down to a few percent for cloud and rain, and less than 1% for wind and vapor. The corrected F15 data are of suitable quality for weather research purposes, but we discourage use of F15 retrievals after 14 August 2006 for climate research purposes at present because it appears that RADCAL beacon interference may not be stable in time, but may depend upon the thermal environment of F15. **Citation:** Hilburn, K. A., and F. J. Wentz (2008), Mitigating the impact of RADCAL beacon contamination on F15 SSM/I ocean retrievals, *Geophys. Res. Lett.*, *35*, L18806, doi:10.1029/2008GL034914.

1. Introduction

[2] For the last 22 years (July 1987 to the present) the Special Sensor Microwave/Imager (SSM/I), flying onboard United States Air Force Defense Meteorological Satellite Program (DMSP) spacecrafts, have been providing extremely useful meteorological data for both weather and climate purposes. Over this time period, retrievals from a total of six SSM/I are available: F08, F10, F11, F13, F14, and F15. The SSM/I are passive microwave radiometers that measure brightness temperatures at 19.35, 22.235, 37.0, and 85.5 GHz for both horizontal and vertical polarizations, except for the 22 GHz channel that has only vertical polarization. These data are used to retrieve surface rain rate, columnar cloud water, columnar water vapor, and surface wind speed over the global oceans.

[3] On 14 August 2006, at the direction of the of US Strategic Command and in coordination with the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office Associate Director of Operations for DMSP operations, the satellite operations control center activated the radar calibration (RADCAL) suite on DMSP F15 (B. Hughes, personal communication, 2006). The RADCAL suite consists of pair of 150 MHz and 400 MHz beacons. Prior on-orbit testing conducted in August 2005, confirmed that the transmissions from the RADCAL 150 MHz beacon produced strong interference in the SSM/I 22 GHz vertical polarization (22V) channel. No effect was apparent on the 19 or 37 GHz channels during the testing. A small effect was found for the 85 GHz horizontal polarization channel (http://mrain.atmos.colostate.edu/LEVEL1C/cal/F15.CALT1.R1a_RADCAL.html).

[4] Our inspection of F15 data products since 14 August 2006 show that the RADCAL interference produces a 30% negative bias in retrievals of rain rate and wind speed and a 40% positive bias in retrievals of water vapor and cloud water. These retrieval biases are due to a mean 22V brightness temperature increase of about 10 K with a strong dependence on the cross-track position. We have developed a simple table-based correction for the 22V brightness temperatures. We have not attempted a correction for the 85H brightness temperatures because our retrieval algorithm does not use the 85 GHz channels. Since the on-orbit testing and our own analysis have failed to find an effect on the 19 and 37 GHz channels, and because of the success of our correction, we have not attempted to adjust the 19 or 37 GHz channels.

2. Data

[5] We have used a combination of Level-1A brightness temperatures and gridded daily geophysical retrievals from F14 and F15 SSM/I. All of the data are the Version-6 intercalibration performed by Remote Sensing Systems (RSS), which has a reported accuracy of 0.1 K in brightness temperature [*Wentz et al.*, 2007]. The retrievals of surface rain rate, columnar cloud water, columnar water vapor, and surface wind speed are made by the Unified Microwave Retrieval Algorithm (UMORA), which is described by *Wentz* [1997], *Wentz and Spencer* [1998], *Wentz and Meissner* [2000, 2007], and *Hilburn and Wentz* [2008]. UMORA makes use of the 19.35, 22.235, and 37.0 GHz channels. We note that other SSM/I processing groups, such as the National Environmental Satellite, Data, and Information Service (NESDIS) and Fleet Numerical Meteorology and Oceanography Center (FNMOC), have also developed RADCAL corrections. The results in this paper only apply to the SSM/I brightness temperature record calibrated by Remote Sensing Systems and the geophysical retrievals calculated by Remote Sensing Systems.

3. Method

[6] To isolate the effects of the RADCAL beacon, we developed a simple linear-regression model to predict 22 GHz vertical-polarization brightness temperatures (T_B) using the temperatures of the other channels:

$$T_{B22V} = 0.216\ T_{B19V} + 1.110\ T_{B19H} + 1.194\ T_{B37V} - 0.987\ T_{B37H} - 76.197$$

[1]Remote Sensing Systems, Santa Rosa, California, USA.

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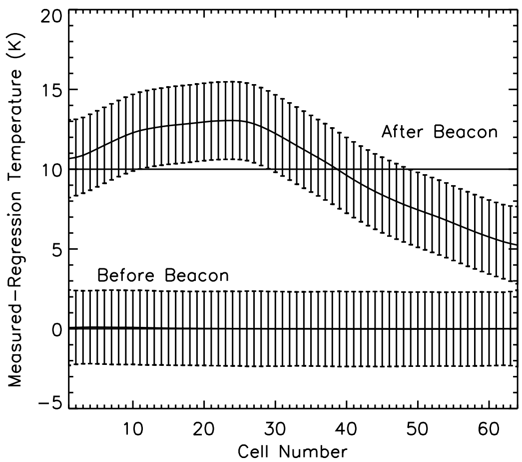

Figure 1. Cell position average difference between the measured and the regression-predicted 22 GHz vertical-polarization brightness temperature before the beacon was turned on (year 2005) and after (year 2007). These averages are for the rain-free ocean equatorward of 60 degrees latitude for the 64 SSM/I footprints along the scan. The "after" curve is our correction.

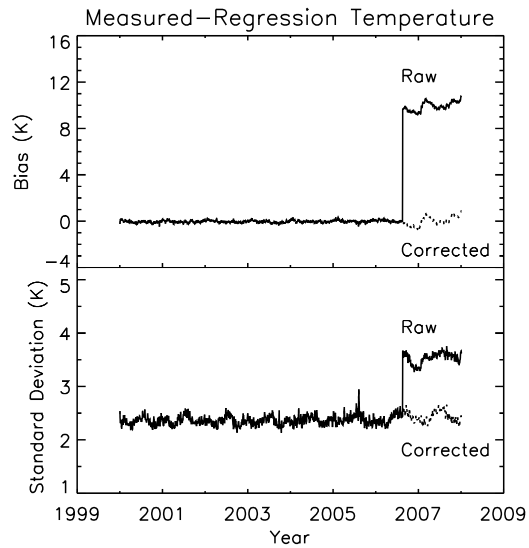

Figure 2. Daily-average time series of the difference between the measured and regression-predicted 22 GHz vertical-polarization brightness temperature for raw F15 data (solid curve) and the corrected F15 data (dotted curve). The (top) bias and (bottom) standard deviation are shown, and the calculations are over the rain-free global-ocean equatorward of 60 degrees latitude.

The coefficients were found using measured 22V during the year 2005 (i.e., before the beacon was turned on) omitting the August test period. The regression is for ocean-only scenes equatorward of 60 degrees latitude. A crude rain filter, T_{B37H} > 200 K, was used to exclude raining observations from our analysis. Figure 1 compares the regression-predicted T_{B22V} with measured T_{B22V} averaged at each cell position. SSM/I has 64 cell positions along the scan. Before the beacon was turned on (year 2005), this relationship fits the measurements with no mean bias and a standard deviation in each cell of 2.33 K. This relationship fits well over the whole range of ocean brightness temperatures. After the beacon was turned on (year 2007), we find a strong mean bias around 10.13 K with a strong 8 K dependence on along-scan cell position. The standard deviation within each cell is nearly the same, 2.39 K. This mean difference between the measured TB_{22V} and the regression-predicted TB_{22V} is our correction – a simple table

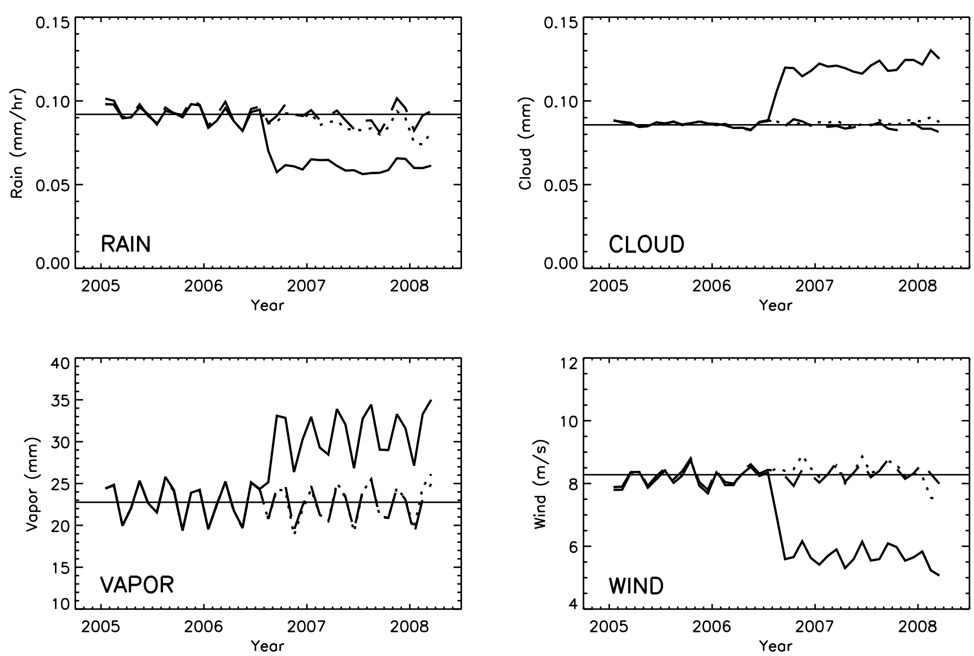

Figure 3. Monthly-average time series for (top left) rain rate, (top right) cloud water, (bottom left) water vapor, and (bottom right) surface wind speed over the global oceans equatorward of 60 degrees latitude from SSM/I on F14 (dashed curve), F15 uncorrected data (solid curve), and corrected F15 (dotted curve).

Table 1. F15–F14 Differences[a]

	Raw F15–F14 (%)	Corrected F15–F14 (%)
Rain	−31	−4.2
Cloud	42	2.2
Vapor	37	−0.21
Wind	−32	0.57

[a]The differences are calculated by $(A - B)/B$, where B is before the beacon was turned on (January 2005–August 2006) and A is after (September 2006–March 2008). Both time periods are 19 months.

of 64 numbers, which are applied after 14 August 2005 (F15 orbit 34478). These values are available online at http://www.remss.com/ssmi/support/f15_radcal_table_22v.txt.

[7] To assess the accuracy of our correction, Figure 2 shows time series of the bias and standard deviation between measured and predicted 22V T_B. For the uncorrected F15 data, the jump in the bias is clear, and the jump in the standard deviation comes from the along scan dependence of the RADCAL interference. Once the adjustment has been applied, both the bias and standard deviation return to pre-RADCAL levels. We note that there is the slight hint of a seasonal oscillation in the bias and perhaps a slight upward trend. We will continue to monitor F15 data very closely in the future to determine if the correction reported here will continue to work.

4. Results and Conclusions

[8] In order to assess the quality of the retrievals made from the corrected F15 data, we have compared it with F14 to serve as a control. Figure 3 shows that the dramatic jump in F15 retrievals of rain rate, cloud water, water vapor, and wind speed are removed when using our simple correction. Table 1 indicates that problems in the wind and vapor retrievals are almost completely eliminated. However, the cloud and rain retrievals still have biases of a few percent. We have examined our retrievals of rain, cloud, vapor, and wind using maps and joint histograms of F14 and F15. These analyses also demonstrate the good quality of the corrected data (see our website, http://www.remss.com, for more information).

[9] The corrected F15 data are of good quality and suitable for weather analysis purposes. We have made these corrected F15 retrievals publicly available on the RSS website. We discourage using the F15 retrievals after 14 August 2006 for climate analysis at present as there is no guarantee that the RADCAL interference will remain stable in time. It appears, in fact, that the RADCAL beacon interference may depend upon the thermal environment of F15, which undergoes significant changes beginning in early 2008 as the orbit drifts. These thermal environment changes are transient and common to other SSM/I, and are normally removed at the calibration stage by target factors. For F15, these changes seem to have an impact not only on calibration, but also on the RADCAL interference as well. To handle this issue, FNMOC has provided a "shadow flag" to identify data from these time periods. We have found that adding the hot load temperature to our RADCAL regression has the potential to remove most of the problem. Since we lack a firm physical understanding of these effects and the period of the new thermal environment is brief, we will continue to monitor F15 retrievals, and plan to reassess our calibration of F15 and the F15 correction when we reprocess our data in the future.

[10] **Acknowledgments.** We are thankful to the Defense Meteorological Satellite Program for making the SSM/I data available to the civilian community. This work has been supported under NASA contract NNG07HW15C, Precipitation Measurement Missions (PMM). We would like to thank George Huffman for encouraging us to work on the F15 RADCAL problem.

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K. A. Hilburn and F. J. Wentz, Remote Sensing Systems, 438 First Street, Suite 200, Santa Rosa, CA 95401, USA.(hilburn@remss.com)