STABILITY OF THE VICARIOUS COLD CALIBRATION STATISTIC FOR THE GPM CONSTELLATION

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When water vapor condenses and forms precipitation, latent heat is released into the atmosphere, and this heat is a major driving force behind large scale motions in the atmosphere. It is difficult to quantify the latent heat from precipitation due to current limitations on the temporal resolution of global precipitation measurements. NASA's Global Precipitation Measurement (GPM) mission will aid in improving this temporal resolution. In order to perform the precipitation measurements, a constellation of satellite-borne microwave radiometers will be utilized. However, a problem arises when using several different radiometers because each radiometer has unique instrumental and orbital characteristics. The radiometers must be inter-calibrated to account for these differences. The objective of the GPM Inter-Calibration Working Group (ICWG) is to characterize and correct for the differences in the radiometers. The University of Michigan members of the ICWG are approaching this problem using a vicarious calibration technique which provides both cold [1] and warm [2] reference brightness temperatures to calibrate the radiometers.

In order to test the calibration methods that are being developed, the ICWG has been studying a common one year data set that consists of continuous observations by TMI, WindSat, SSM/I F13, and SSM/I F14 from July 2005 to June 2006. Summary descriptions of the operating characteristics of the instruments, including their frequencies, polarizations, Earth incidence angle (EIA), and orbit, are given in Table 1.

Table 1: Characteristics of instruments used in the ICWG study [3, 4, 5].

Instrument	**Channels** (center frequency and polarization: V = vertical, H = horizontal)	**Earth Incidence Angles**(degrees)	**Orbit Properties**
TMI	10.7V, 10.7H, 19.4V, 19.4H, 22.3V, 37.0V, 37.0H*	53.35	350 km altitude, non-sun synchronous, 35° inclination angle
WindSat	6.8V, 6.8H, 10.7V, 10.7H, 18.7V, 18.7H, 23.8V, 23.8H, 37.0V, 37.0H	49.91 – 53.53 (depending on channel)	830 km altitude, sun synchronous, 98.7° inclination angle
SSM/I	19.35V, 19.35H, 22.235V, 37.0V, 37.0H*	53.1	833 km altitude, sun synchronous, , 98.8° inclination angle

*Low Resolution channels only

The theory behind the vicarious cold calibration is that for a given frequency, polarization, and EIA, there is a sea surface temperature (SST) where the brightness temperature (TB) is at a minimum. To calculate the vicarious cold cal TB point, a polynomial is fit to an inverse cumulative distribution function (CDF) of the measured TBs and extrapolated down to the minimum observed TB. This is done because the conditions that produce the precise theoretical coldest possible TB value may not be present in any particular population and because noise in the data broadens the distribution about this minimum TB. To minimize the effect of this noise, the CDF is fit in a region near but higher than the expected vicarious cold cal TB (e.g., 2%-10%) and extrapolated down to 0%.

Since the vicarious cold cal TB is dependent on SST for varying frequency, polarization, and EIA, the location on the globe where the vicarious cold cal TB occurs varies. Figure 1 shows this dependence, where the location of the vicarious cold cal TB is shown on the globe for a given frequency, polarization, and EIA. The plot uses a 19 GHz H-pol channel and an EIA of 53°. [6]

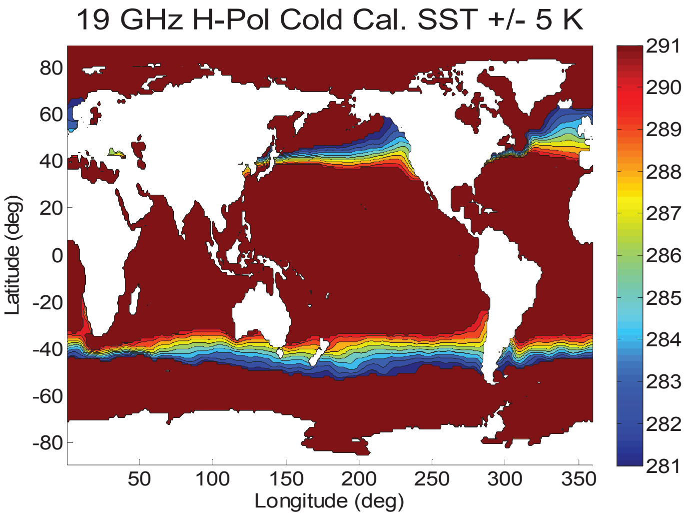

Figure 1: Location of the vicarious cold calibration TB for 19 GHz H-pol at 53° EIA. Vicarious cold cal SST is located at approximately 286 K.

Since the vicarious cold cal TB occurs at different latitudes for different frequencies and polarizations, this becomes a problem when calibrating satellites with low orbit inclination angles. At the lower frequencies, where the vicarious cold cal TB occurs at higher latitudes, the data from these satellites does not include the population of TB samples needed to derive the vicarious cold cal TB. This problem has been analyzed and a solution has been proposed by using Global Data Assimilation System (GDAS) data to estimate what brightness temperatures would be observed by the satellite in lower inclination orbits and using those values to derive the vicarious cold cal TB. Figure 2 shows some sample data from comparing TMI data to GDAS. As the figure shows, the GDAS predicted brightness temperatures and the TMI brightness temperatures are very close. Therefore, this solution was found to be a very effective method when applied to TMI data giving stable results. We would like to examine in detail the quality of this proposed solution by expanding this idea to other datasets and varying parameters in these datasets to see if a stationary vicarious cold cal point can still be reached.

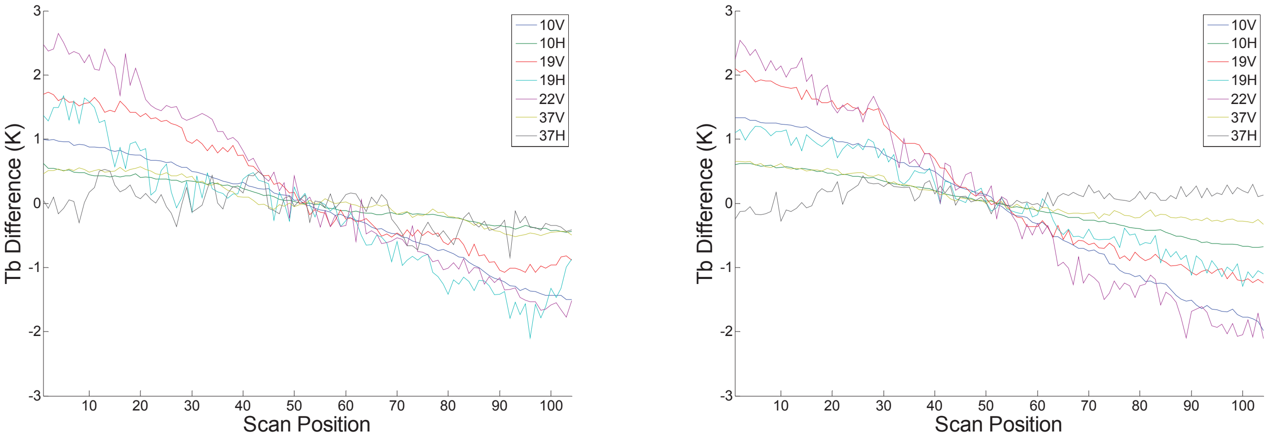

Figure 2: The vicarious cold cal TB difference with respect to the center of scan position for TMI (left) and GDAS predicted (right).

The stability of the cold calibration statistic will be analyzed by using WindSat data and breaking up the earth into latitude bands. Using the population of TBs from just one latitude band, we are going to estimate what brightness would be observed using GDAS and then calculate the vicarious cold cal TB from those estimated TBs. The problem to be explored here is to see how stationary the statistic is when the SSTs that produce the coldest TBs are not present in the population of TBs. The extent to which the statistic is stationary for a population of TBs can be shown by changing model parameters. One of the model parameters that can be changed is the size of the latitude bands and seeing what effect this change has on producing a vicarious cold cal point that is stationary. The sensitivity of the statistic can also be analyzed when there are varying weather conditions on the globe. We would like to show that the statistic is stable regardless of seasonal or year-to-year variations in weather, as well as characterizing the sensitivity (if any) of the vicarious cold calibration point to the climate. For instance, this would include examining whether the calibration point will change due to rising SSTs or to changes in the joint probability of occurrence of particular SSTs and water vapor burden values over the years.

The application of this statistical analysis to WindSat data will show whether this solution is a good method to use for shallow orbit satellites that need to be calibrated in the GPM constellation or for radiometers like WindSat that experience a slight change in incidence angle as a function of azimuth scan and orbit positions. Due to these complications, the vicarious calibration method must be capable of performing over restricted, regional, latitude bands in order to be able to detect and characterize this problem.

References

[1] Ruf, C.S., “Characterization and Correction of a Drift in Calibration of the TOPEX Microwave Radiometer”, *IEEE Trans. Geosci. Remote Sens.*, 40(2), 509-511, 2002.

[2] Brown, S., and C. Ruf, “Determination of a Hot Blackbody Reference Target over the Amazon Rainforest for the On-orbit Calibration of Microwave Radiometers,” *AMS J. Oceanic Atmos. Tech.*, 22(9), 1340-1352, 2005.

[3] Simpson, J., C. Kummerow, W.-K. Tao, and R. F. Adler, “On the Tropical Rainfall Measuring Mission (TRMM),” *Meteor. Atmos. Phys.,* 60, 19-36, 1996.

[4] Gaiser, P.W., et. al., “The WindSat Spaceborne Polarimetric Microwave Radiometer: Sensor Description and Early Orbit Performance,” *IEEE Trans. Geosci. Remote Sens.*, 42(11), 2347-2361, 2004.

[5] Hollinger, J.P., J.L. Peirce, and G.A. Poe, “SSM/I Instrument Evaluation,” *IEEE Trans. Geosci. Remote Sens.*, 28(5), 781-790, 1990.

[6] Reynolds, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey, and M. G. Schlax, “Daily high-resolution blended analyses for sea surface temperature,” *J. Climate*, 20, 5473-5496, 2007.