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A Recalibration of the AVHRR data record to provide an accurate and well parameterized FCDR

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<th>Task Leader</th>
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BACKGROUND
The Advanced Very High Resolution Radiometer (AVHRR) is a critical instrument for climate change studies because different versions of the AVHRR sensors have been available continuously for over 30 years and continue to be used to the present day. To use the AVHRR for climate change studies, however, accurate and stable radiances are required, or at the very least the biases and trends have to be well understood. Unfortunately these are not available with the current operational calibration, and work done by us and others has already shown significant biases and errors of up to > 0.5K. Further, analysis done by the University of Miami as part of the Pathfinder project shows that for at least one AVHRR (NOAA-16) significant time varying calibration problems are producing large time variable SST biases (see Figure 2). These issues of both large biases and time variable calibration problems will severely limit the use of the AVHRR for climate change studies if left uncorrected.

In order to address the problems with the current AVHRR calibration we have developed a completely new physically based calibration methodology which has been able to find and highlight the complex sources of bias and error in both the pre-launch and in-orbit data for the AVHRR. By including effects such as stray light and instrument temperature drifts we have shown that it is possible to remove much of the source of error seen in AVHRR radiances and under certain circumstances provide a nearly zero bias pre-launch calibration. We have also shown that the new calibration also has the capability of predicting instrument gain during times when the onboard calibration data are affected by solar and/or Earthshine contamination - solar contamination has been a significant problem for many NOAA platforms as their equator crossing times drift. The baseline for this new calibration are matches with the (A)ATSR series and we have developed new match code which deals with variations in observed instrument footprints. We have also derived a correction for the biased 12µm channel on the AATSR. We are currently in the process of moving through the AVHRR series starting with the more modern AVHRRs to derive a new calibration scheme to the complete historic AVHRR data record to fix calibration biases and contamination effects and therefore provide an accurate and clean AVHRR FCDR.

ACCOMPLISHMENTS
This year a significant amount of time has been spent setting up software to accurately match different satellites together such as the AVHRR and (A)ATSR making sure that the different footprints/point spread functions of the different instruments have been taken into account. Much of this work has been done by a new hire, Manik Bali. Now that this software is in place we have begun systematically analyzing data from different AVHRRs to derive new calibrations to create a database of AVHRR/ATSR matched data to be used in determining the new AVHRR calibration.
As a necessary sub-project (which was not part of the original proposal) we have also used the matching software to match IASI with the AATSR so we can estimate and diagnose the known issues with the AATSR 12µm channel. To do this we have matched one months worth of IASI data with the AATSR, convolving the IASI spectrum with the AATSR 11 and 12µm channels spectral response functions to derive equivalent brightness temperatures. Figure 1 shows preliminary results from this analysis and shows that while the 11µm channel has a simple and small (0.06K) bias between IASI and the AATSR, the 12µm channel shows a strong and large (>0.2K) trend as a function of scene temperature. Note that this trend must be due to errors in the AATSR since both the 11 and 12µm channels are covered by a single IASI band and if IASI were at fault a trend would have been seen in both the 11 and 12µm channels. This is the first time to our knowledge that such a trend in the bias has been reported in the AATSR and we are in the process of contacting the AATSR calibration team to work on a solution. While more work (and more data) needs to be analyzed, we have used this result to correct the 12µm AATSR data when doing our AVHRR recalibration.

Using the correction to the AATSR 12µm channel defined above we have currently derived new calibrations for three AVHRRs, NOAA-16, NOAA-17 and NOAA-18. For NOAA-16 we have had to do extra work involving a significant amount of research and data analysis due to large time dependent biases. Figure 2 shows examples of the correlation between the radiance bias and the blackbody temperature for NOAA-16 and shows that the bias is, to first order, linearly correlated with the BB temperature. However the plot also shows that the radiance bias is not a simple function of temperature – the red data points are for the period 2004 – 2007 and the black points are for the period 2008- 2011. These two periods correspond to different behaviors in the thermal state of the instrument and show that the radiance bias behavior seen in NOAA-16 is complex.

At the moment the full solution to the behavior of the radiance bias with respect to the thermal state has not been completed. However, as the lower plot of Figure 2 shows, even a simple correction can significantly help in the retrieval of geophysical parameters from NOAA-16 and we are close to arriving at a solution to the problem.
Figure 1: Comparison between the AATSR and IASI where the IASI spectrum has been integrated over the 11 and 12 µm AATSR spectral response functions. The 11µm bias can be characterized as a simple offset of 0.062K with no obvious trend and may be due to either an offset in IASI or in the AATSR or both. The 12 micron channel, however, shows a significant trend as a function of the observed scene temperature which must be due to biases in the AATSR data since a single IASI band covers both the 11 and 12µm channels. The solid line is a cubic model fitted to the data and can be used to removed the 12µm bias from the AVHRR/AATSR matches.
2: Top two panels show the correlation between instrument temperature and radiance bias (relative to the AATSR) for the AVHRR on-board NOAA-16 for the 11 and 12μm channels. The red data points correspond to data over the time period 2004-2007 and the black data points correspond to the time period 2008-2011 and show that the bias time dependence changed in 2008. The lower panel shows an example of the SST bias caused by not correcting for the time dependent bias (based on Pathfinder V6.0 data, Evans (private communication)) together with an estimate of the expected SST bias based on a simple time dependent radiance bias model. The agreement shows that the radiance bias for NOAA-16 is indeed related to the instrument temperature.

PLANNED WORK

Now that we have matchup software that is fully tested and verified we will continue to generate new calibrations not just for the AVHRR/3 sensors but for earlier sensors as well. We will use the (A)ATSR series to go back to 1991 (to NOAA-11) and will start working on even earlier satellites. As part of this we will redo the pre-launch calibration for the AVHRR/2 sensors and will also start using RTM radiances as well as HIRS radiances to redo the calibration of the AVHRR sensors pre-1991. Finally we will begin using SST as a reference to validate the new calibration. Work has already begun on this (e.g. “Calibration of NOAA satellites and its impact on SST retrievals”, a talk given at the GHRSSST Workshop on Tropical Warm Pool and High Latitude SST Issues held in Melbourne, Australia 2012). We also intend to provide public access to the new calibration for the AVHRR/3 sensors by the summer of 2012.
PUBLICATIONS


PRESENTATIONS