IMPACT OF MICROWAVE SOUNDER CALIBRATION ON PRECIPITATION FOR THE GLOBAL PRECIPITATION MEASUREMENT MISSION

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ABSTRACT

Cross-track microwave sounders make up a significant percentage of the radiometers included in the Global Precipitation Measurement (GPM) constellation. Therefore, it is important to properly assess the calibration of each sounder instrument and to understand the impact of the calibration on the derived precipitation rates. This ensures an accurate precipitation product is produced for the entire constellation. This paper will use data from past and current microwave sounders to show how offsets in the calibration can impact the precipitation using the GPM Level 2 GPROF algorithm. Potential improvements to the instrument calibration will be assessed by analyzing how they would positively impact the precipitation trends and agreement among the constellation sensors.

Index Terms— Calibration, GPM, Intercalibration, Microwave radiometry, Precipitation

1. INTRODUCTION

The Global Precipitation Measurement (GPM) mission uses a constellation of microwave radiometers on various satellite platforms to measure global precipitation with high temporal and spatial resolution [1]. To obtain consistent precipitation estimates among the constellation, the radiometers are intercalibrated to a common reference standard, the GPM Microwave Imager (GMI) on the GPM Core Observatory. The intercalibration algorithms are developed and applied by the GPM Intercalibration Working Group (XCAL) and make use of the well-known double difference method of intercalibration [2].

Recently, radiometers prior to the launch of GPM Core in February 2014 were incorporated into the constellation, dating back to the launch of the Tropical Rainfall Measuring Mission (TRMM) in November 1997. This GPM/TRMM constellation is comprised of both imagers (conical scanners) and sounders (cross-track scanners). Sounders make up a significant portion of the GPM/TRMM constellation; therefore, characterizing the calibration of these instruments and the impact on precipitation is important for generating an accurate long-term data record of radiometer observations and retrieved precipitation.

The sounders included in the GPM/TRMM constellation include three Advanced Microwave Sounding Units (AMSU-B) from the TRMM-era, four Microwave Humidity Sounders (MHS) launched during the TRMM-era with three still in operation, and two Advanced Technology Microwave Sounders (ATMS) which are currently in operation. This paper seeks to understand how the calibration of the constellation sounders impacts the precipitation derived using the GPM GPROF algorithm. This presentation will analyze the calibration of the AMSU-B, MHS, and ATMS instruments and show what impact errors in the calibration may have on the precipitation. Precipitation trends will be shown and an analysis of how well the precipitation agrees among the sounders will be presented.

2. DATA

The GPM constellation currently contains three MHS instruments onboard the NOAA19, METOP-A, and METOP-B platforms, and two ATMS instruments onboard the NPP and NOAA20 platforms. AMSU-B onboard NOAA15, NOAA16, and NOAA17, and MHS onboard NOAA18 are no longer operating but are incorporated in the GPM/TRMM combined constellation to create a long-term data record. Fig. 1 shows the local observing time of the ascending node for each of the sounders and Fig. 2 shows the XCAL derived calibration offsets by channel for each of the sounders intercalibrated to GMI. Positive (negative) offsets mean that the instrument is colder (warmer) than GMI. The offsets are generally within +/- 1 K of GMI, with some exceptions for AMSU-B and NPP ATMS.

To derive the constants shown in Fig. 2, the XCAL team first analyzes the calibration of each radiometer individually and determines if there are any improvements needed before it can be intercalibrated into the constellation (e.g. cross-track scan biases, calibration drifts over time, etc.). Since the double difference method used in intercalibration incorporates simulated brightness temperatures (TB) from a radiative transfer model (RTM), the intercalibration constants are subject to potential uncertainties in the RTM

[3]. These uncertainties impact the intercalibration and in turn impact the precipitation estimates, so it is useful to quantify the change in precipitation that occurs as a result of a Kelvin in TB calibration adjustment. This gives an understanding of what is an acceptable limit for calibration uncertainty so that it does not negatively affect the precipitation. The results of this analysis are shown in the following section.

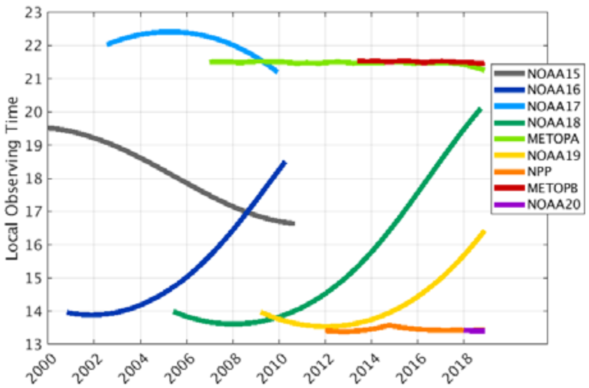

Fig. 1: Local observing time of AMSU-B, MHS, and ATMS instrument platforms included in the GPM constellation.

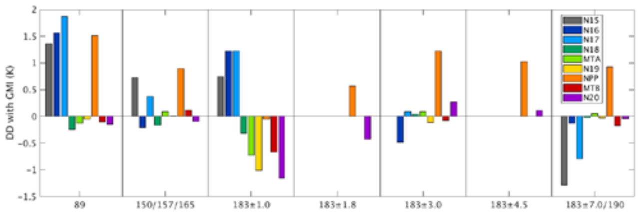

Fig. 2: Intercalibration constants of AMSU-B, MHS, and ATMS instruments compared with GMI by channel. Positive (negative) means instrument is colder (warmer) than GMI.

3. RESULTS

The latest GPROF version [4] is used to analyze the impact of sounder calibration on the precipitation estimates. Figs. 3 and 4 show the mean over-ocean precipitation rate difference over time for AMSU-B and MHS compared with NOAA17 AMSU-B (Fig. 3) and MHS and ATMS compared with METOP-A MHS (Fig. 4). The monthly average (lighter colored lines) and yearly average (darker colored lines) are shown to observe any trends. Only over-ocean observations are shown here to minimize impact of the diurnal cycle due to the differences in local observing time. There are some initial observations that can be made from these figures that require further analysis to determine if the differences are real or due to calibration. The NOAA15 and NOAA16 AMSU-B instruments show higher precipitation rates compared to NOAA17, while the MHS instruments tend to retrieve lower or similar rates to NOAA17. The NOAA15 and NOAA16 AMSU-B instruments have been analyzed in the past and shown to have significant calibration issues, especially in the 183 GHz channels [5-6], so this may be a partial explanation for why NOAA15 and NOAA16 show such high precipitation rate differences from NOAA17.

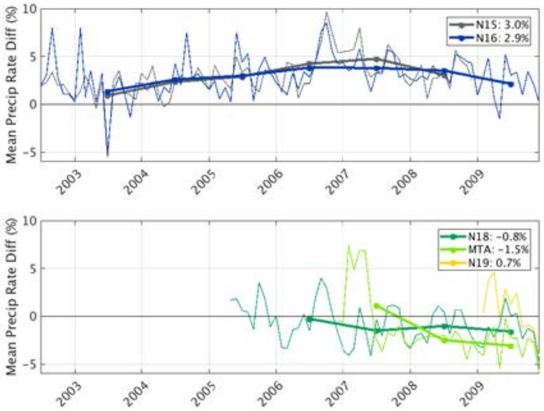

Fig. 3: GPROF precipitation rates of AMSU-B (top) and MHS (bottom) sensors compared with NOAA17 AMSU-B. The lighter colored lines are monthly values and the darker colored lines are the yearly average to show the overall trend.

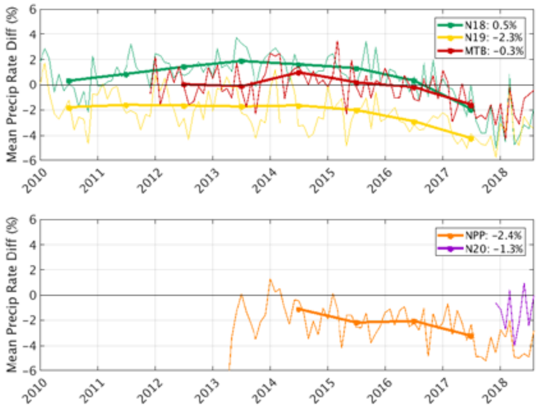

Fig. 4: GPROF precipitation rates of MHS (top) and ATMS (bottom) sensors compared with METOP-A MHS. The lighter colored lines are monthly values and the darker colored lines are the yearly average to show the overall trend.

Fig. 5 shows the results of adjusting the TB calibration by 1 Kelvin on the mean precipitation rate over ocean, vegetated, and snow surfaces. NOAA16 AMSU-B data are used as an example. The results in Fig. 5 show that a 1 K change in the 89 GHz calibration has a much more significant impact on the overall precipitation versus a 1 K change in the 150 or 183 GHz channels.

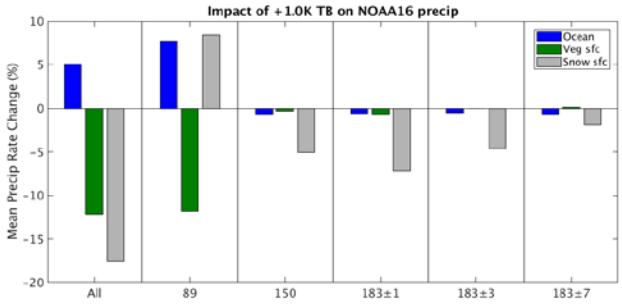

Fig. 5: Impact of an increase in 1 Kelvin calibration for all channels (far left) and each channel individually for ocean (blue), vegetated (green), and snow (grey) surfaces using the NOAA16 AMSU-B GPROF algorithm.

Future analysis will use the results shown here to look at improving the calibration of the individual instruments and the intercalibration constants with GMI to positively impact the precipitation. Since 89 GHz is shown to play such a significant role in impacting the mean precipitation rate in the GPROF algorithm, a primary focus should be on making improvements to the 89 GHz instrument calibration and to the intercalibration algorithm for that channel. However, if the 183 GHz channels have several Kelvins of error, as has been seen with the NOAA15 and NOAA16 AMSU-B instruments [5-6], these should also be targeted for improvements. On the other hand, Fig. 5 shows that trying to improve the calibration of the 183 GHz channels beyond 1 K, as the XCAL team has done with other instruments, is not worth the effort when concerned with deriving precipitation for the GPM mission. Instead, more effort should be placed on improving the 89 GHz calibration of the sounders.

4. SUMMARY

This paper presented preliminary results from an analysis to determine the impact of calibration on precipitation for the microwave sounders in the GPM constellation. Precipitation rates were compared for the AMSU-B, MHS, and ATMS instruments and shown that they agree within a few percentage points. These differences could be a result of varying observing times or due to calibration inconsistencies. It was shown that by adjusting the calibration of the 89 GHz channel by 1 K, the precipitation rate changed by several percentage points, whereas a change of 1 K for the 150-183 GHz channels did not make as significant an impact. Future work will focus on assessing ways to improve the precipitation agreement among the sounders by improving the calibration, such as by applying cross-track scan biases where necessary and determining uncertainties in the RTM used for intercalibration.

5. REFERENCES

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