Using Radio Occultation Profiles to Detect Microwave Sensor Bias for Climate Studies

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Abstract

Radio Occultation (RO) utilizes the LEO satellite measurements of the GNSS signal path delay to perform inversion of the atmospheric temperature profiles. The GNSS RO-derived bending angle data have been used in operational Numerical Weather Prediction (NWP) models to correct temperature bias. The long-term stability of RO temperature profile retrievals makes them ideal datasets for climate study. RO observations have been used to correct the inter-satellite radiometric bias and brightness temperature jumps due to calibration algorithm changes for Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit (AMSU) measurements to construct climate data records. For the Advanced Technology Microwave Sounder (ATMS) onboard JPSS satellites SNPP and NOAA-20, there has been a few updates in the calibration algorithm in the operational ATMS data production. To maintain long term consistency, the SNPP ATMS data were reprocessed with consistent calibration algorithm by NOAA/STAR. With the recent release of reprocessed RO CDR/ICDR dataset for multiple RO missions by ROM SAF, we have an opportunity to carry out inter-comparison between the reprocessed RO data and the reprocessed/operational ATMS data. We carry out collocation analysis between the GPS RO observations and ATMS observations, and use CRTM to model the ATMS channels brightness temperature from the RO wet temperature profiles. In this study, the ATMS channel 10 is used to characterize the lower stratosphere temperature. The mean bias and trend of the brightness temperature difference between the CRTM simulation using RO data and SNPP ATMS observation will be evaluated. NOAA-20 ATMS data are analyzed similarly to derive the bias between SNPP and NOAA-20 ATMS. Comparison between RO and ATMS observation can help extend the long term CDR of microwave observations from AMSU to ATMS.

1. Data and Methods

- Data set
  - ROM SAF RO CDR/ICDR (copyright (2019) EUMETSAT)
    - CDR from 2012-2016, ICDR from 2017-2019 are used.
    - Wet Profiles including Temperature, Water Vapor and Pressure
  - SNPP Reprocessed ATMS SDR datasets with consistent calibration algorithm from 2012 to 2019
  - NOAA-20 Operational ATMS SDR from 11/2017 to 2019.
  - Channel 10 of ATMS Weighting Function (Fig.1) is mainly distributed between 10-30 km above sea level, while RO errors (comparison between different RO missions) usually are smallest in this layer.
- Collocation Criteria
  - 50km distance interval, 3 hours time window, Land/Sea masks from ETOPO5
  - Extract longitude/latitude, sensor/Sun azimuth/zenith angles, RO profiles (as input to CRTM)
- Community Radiative Transfer Model (CRTM)
  - Using RO profiles to derive simulated ATMS Brightness Temperature

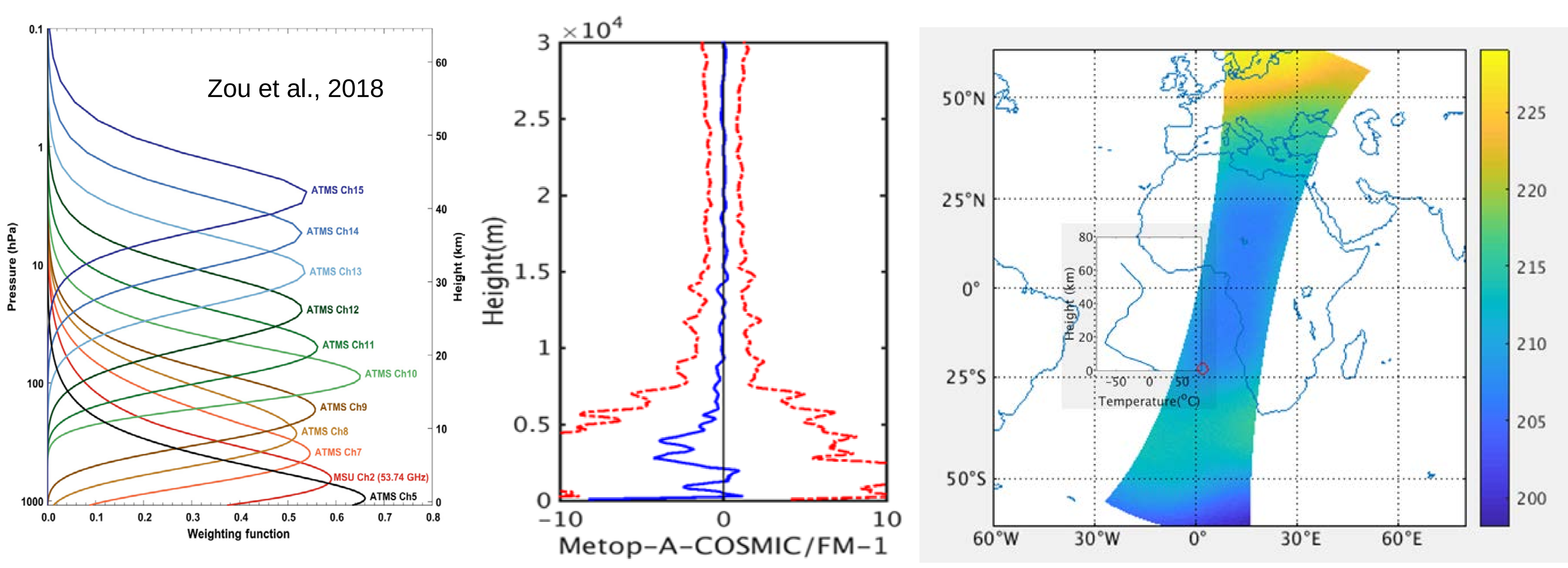

Fig. 1 ATMS channel weighting function distribution along pressure level and sea surface height (left) and the RO bending angle comparison among Metop-A and COSMIC FM-1 (Middle) and the SNPP ATMS CH10 brightness temperature overlapped with RO profiles (right).

2. Collocated RO Profile Distribution

- Distribution of RO profiles
  - Only collocated pixels over ocean are selected.
  - Collocated Data after 2016 are fewer than previous times due to degradation of COSMIC after 2016, and the ICDR dataset does not include the COSMIC dataset yet, only Metop A/B data are included.

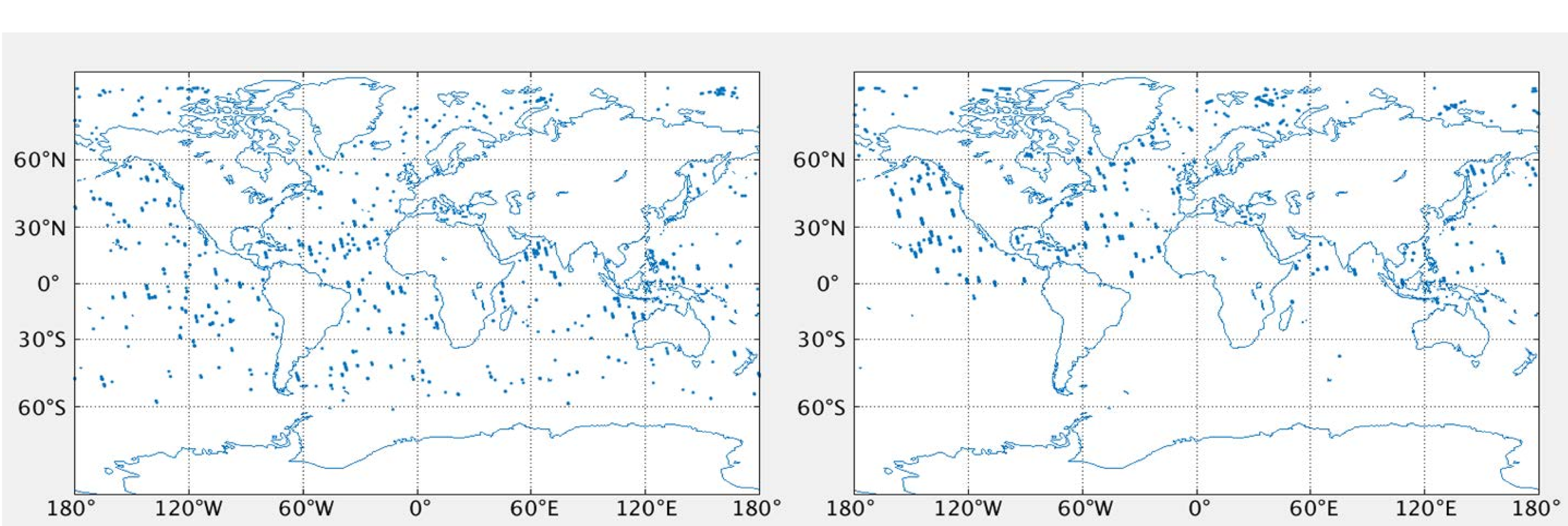

Fig. 2 RO Collocations with SNPP/ATMS (Left on 07/2015) and with NOAA-20/ATMS(Right on 07/2018)

3. ATMS SDR CH10 Brightness Temperature Comparison with RO (I)CDR

- Very stable SNPP ATMS time series with a mean bias of -0.65±0.05K, a trend of -0.086K/dec
- Small annual variations for SNPP bias can be seen. The variation after 2017 is slightly larger. The collocated RO profile numbers are significantly decreased after 2016, which may explain larger variation there.
- Operational NOAA-20 ATMS CH10 BT bias changes dramatically during the first two month since launch, from 1.7K to around -0.4k. Since 2018, its mean bias is -0.48±0.12K.
- Double differencing shows the ATMS bias (NOAA20-SNPP) changed from 2.4K to 0.4k after first two months of NOAA-20 launch, and then gradually reduced to 0.1K-0.2K in 2019.

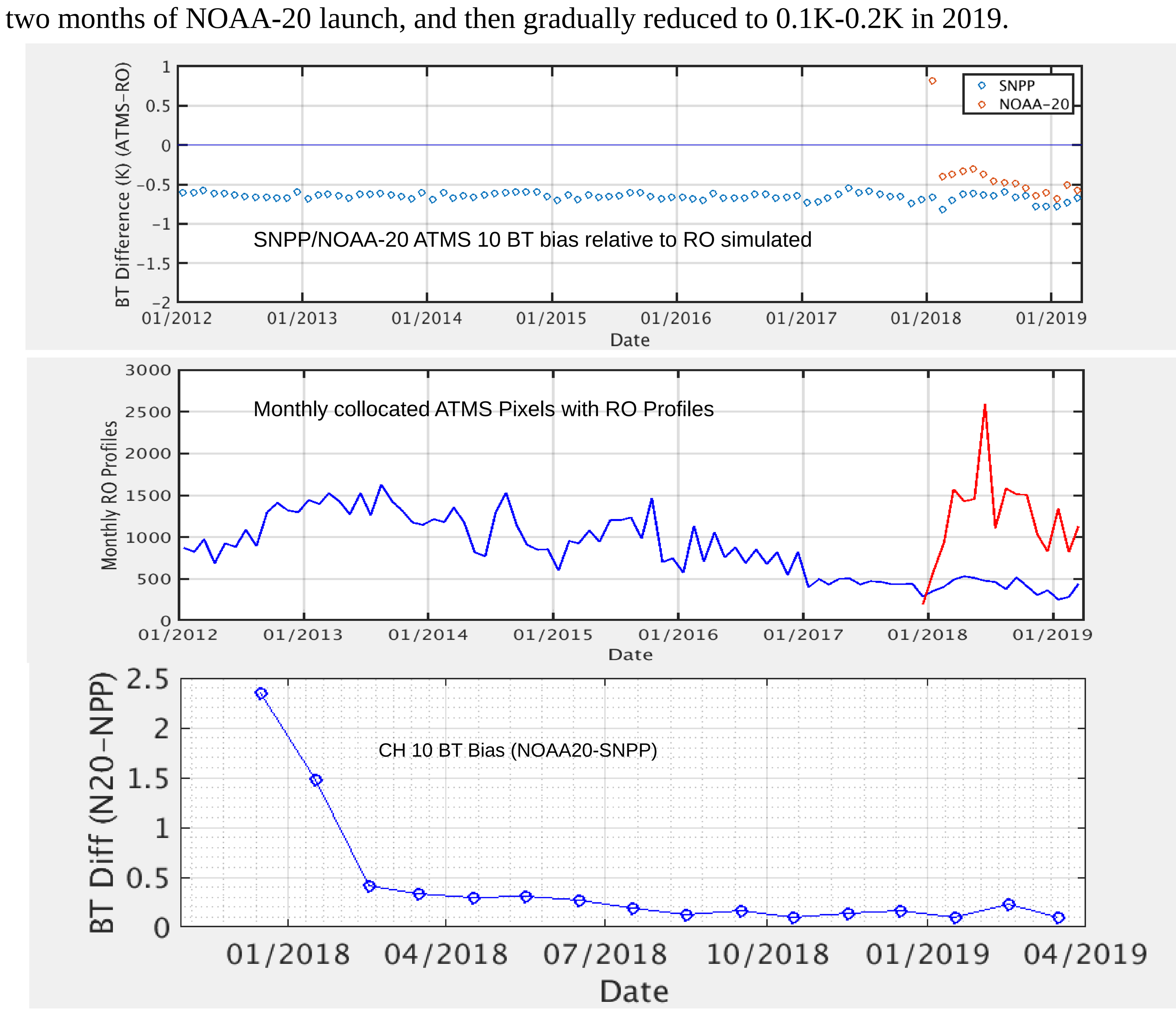

Fig. 3 Time series of ATMS CH10 BT bias relative to CRTM derived BT from RO (I)CDR (upper), the monthly collocated pixel numbers (middle) and BT bias from the double differencing between SNPP and NOAA20 (NOAA20-SNPP).

4. SNPP ATMS CH10 BT Bias Latitude Dependency

- The bias of each latitude zone from [-30,75] with an interval of 15 degree are calculated.
- There is slightly a latitude dependency of the Brightness Temperature Bias. The BT bias is smaller near tropical area than high latitude area. The amplitude is about the 0.16K.

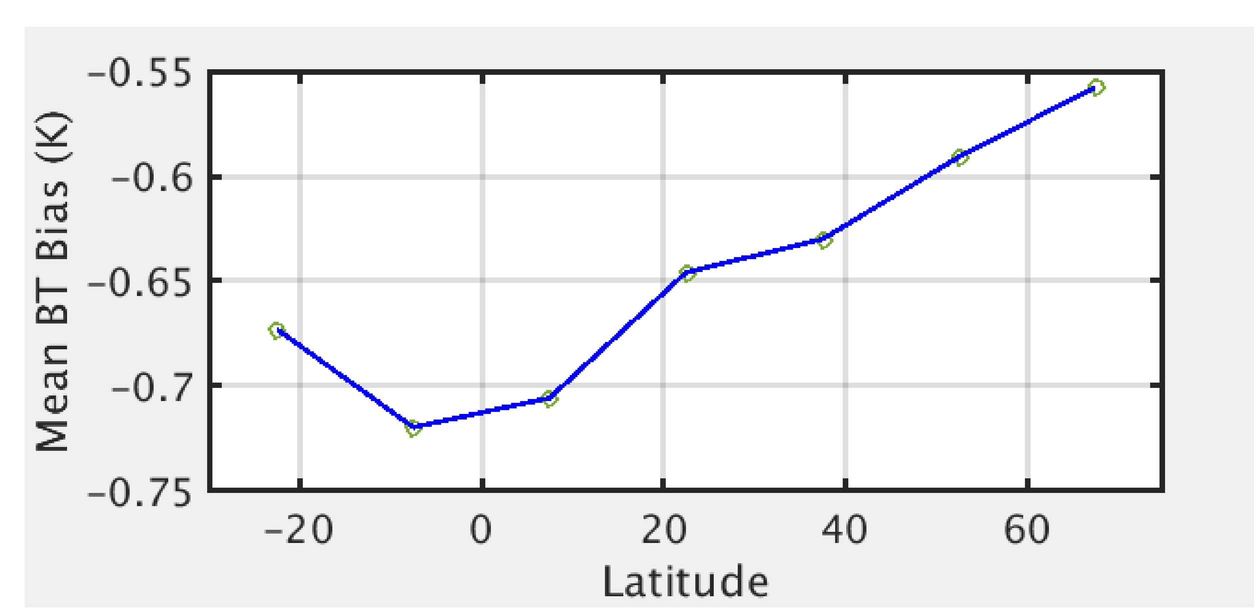

Fig. 4 SNPP ATMS CH10 BT Bias (relative to RO) has a slight latitude-dependency

5. Summary and Conclusion

- Reprocessed ATMS data from NOAA/STAR has very stable bias around -0.65±0.05K and a small trend of -0.0086K/year, indicating very stable time series. The BT bias has a slight latitude dependency with amplitude of 0.16K.
- Operational NOAA-20 ATMS bias (respect to RO) has a bias from -0.48±0.12K, with larger variation indicating calibration changes in post-launch early orbit data. .
- Double differencing between SNPP and N20 indicates the initial bias is more than 1 K in Dec. 2017 and gradually reduced toward 0.1k currently.
- Monthly number of collocation RO profiles likely affects the errors in the monthly bias time series.

6. Future Work

- Bridging AMSU/ATMS with extension to other channels using RO observations as bias anchor .
- Recalibrate ATMS/AMSU to remove inter-satellite bias and orbital drift , and extend the CDR of lower stratosphere (and upper troposphere) (Ho et al., 2016) with ATMS observations.

7. References:

- Ho, Shu-peng; Liang, Peng (2016): NOAA Climate Data Record for Mean Layer Temperature (Lower Stratosphere) from UCAR, Version 2. NOAA National Centers for Environmental Information. doi:10.7289/V5XP72XZ
- Zou, Cheng-zhi, M. Goldberg and X. Hao (2018): New generation of U.S. satellite microwave sounder achieves high radiometric stability performance for reliable climate change detection, Science Advances, 17 Oct 2018 : EAAU0049