Augmenting Long-term Microwave Radiometer Data Quality Assessment Robustness with COSMIC-2 Atmospheric Soundings

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Outline

- Using Global Navigation Satellite System (GNSS) Radio-Occultation (RO) temperature and water vapor soundings and the Community Radiative Transfer Model (CRTM) to monitor NOAA operational microwave sounder data quality
  - Method synopsis
  - Recent data augmentation
  - Data analysis pre-processing
- Pre- and Post-COSMIC-2 data integration results
- Summary

O-B Ta Bias Method Synopsis (1 of 2)

- The CRTM simulated background (B) MW sounder Tb values can be subtracted from collocated observed (O) instrument Ta/Tb values to form O-B Ta bias estimates.
- CRTM input soundings may have their own bias, but that bias must be stable to be able to isolate instrument quality changes over time.
- The GNSS RO soundings are a relatively stable sounding source that can be used to monitor MW sounder data quality.*

* Iacovazzi, Robbie; Lin, Lin; Sun, Ninghai; Liu, Quanhua. 2020. "NOAA Operational Microwave Sounding Radiometer Data Quality Monitoring and Anomaly Assessment Using COSMIC GNSS Radio-Occultation Soundings" Remote Sens. 12, no. 5: 828. https://doi.org/10.3390/rs12050828

O-B Ta Bias Method Synopsis (2 of 2)

ECMWF Era-5 Soundings

GNSS-RO Data
- COSMIC-1* (Oct. '12 – Apr. '20)
- KOMPSAT-5 (Jul '17 – Curr)
- COSMIC-2 (Oct. '19 - Curr)

Microwave Sounder Observed (O) Ta Data
- ATMS Chs 2-3, 5-15: S-NPP (Jan '15 - Curr) and NOAA-20 (Dec '17 – Curr)
- AMSU-A Chs 2-14: NOAA-18, NOAA-19, Metop-A, Metop-B (Jan '12 – Curr) , and Metop-C (Nov '18 – Curr)

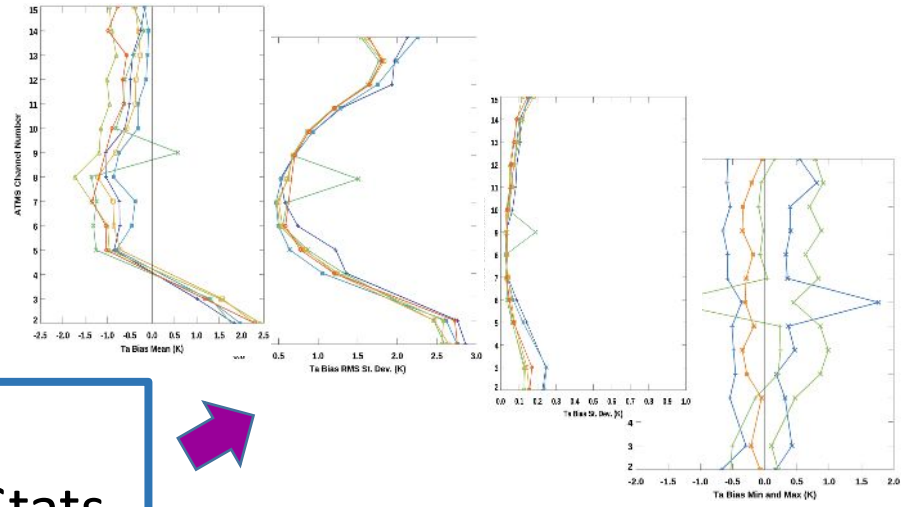
RO Sounding Gap Filling

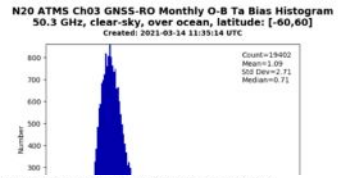
Collocate Data Pairs, Screen and Simulate Background (B) Tb

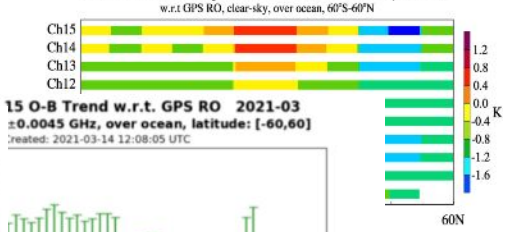
Compute O-B Ta Biases (1 Day)

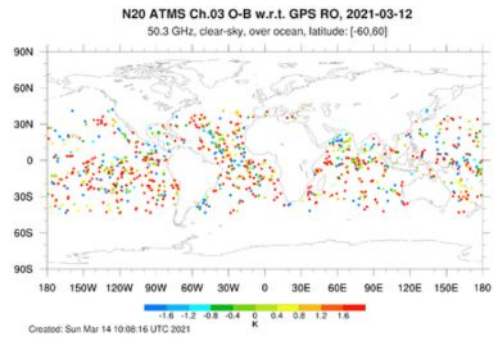
O-B Ta Bias Monthly Stats

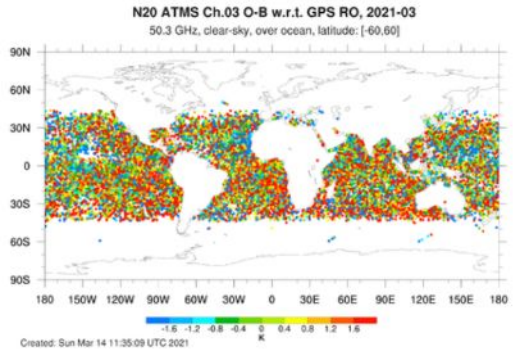
O-B Ta Bias Time-Series Stats

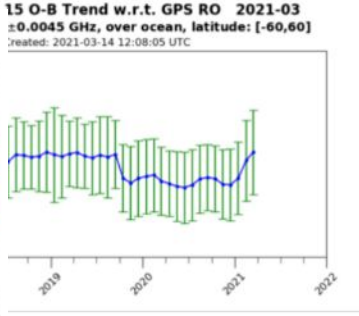












*Sounding Quality: Temperature uncertainty is on average about 0.6 K between 8 km and 30 km. (Kishor et. al., 2008, Atmos. Chem. Phys. Discuss.), and quality degrades below 8 km and above 30 km.

GNSS-RO Data Augmentation

Integrated Near Real-Time wetPf2 COSMIC-2 GNSS-RO Data from CDAAC from 1 October 2019

Characteristic	COSMIC-1	KOMPSAT-5	COSMIC-2
Sounding Elevation Min/Max (km)	0.5-1.0 : 40	0.5-1.0 : 40	0.5-1.0 : 60
Number of Soundings Per Month ($X10^3$)	1 - 5	1 - 5	14 - 40

Implemented GNSS-RO Sounding Gap Filling

- Integrate ECMWF ERA-5 NWP soundings below and above the valid GNSS RO sounding elevations. This enables analysis expansion to ATMS window and upper sounding channels below 60 GHz.

Added Microwave Radiometer Channels

- Previous analysis included ATMS (AMSU-A) Channels 5-13 (4-12*)
- Augmented analysis adds ATMS (AMSU-A) Channels 2, 3, 14, and 15 (2, 3, 13, and 14)

*Note that the ATMS and AMSU-A channel frequencies match.

Data Analysis Pre-processing: Screening Techniques Continuing with No Change

- ATMS/AMSU data and GNSS-RO soundings limited to cloud-free regions equatorward of 60^{o} latitude.
- GNSS-RO soundings accepted if …
  - Collocated with respect to microwave radiometer data with a time (space) difference of less than 3 hours (50 km)
  - Vertical geolocation variation is less than 300km
  - Over ocean regions for ATMS Chs 5-13 and AMSU Chs 4-12
- Cloud screening over ocean using Weng, F. et al. (2003, *Radio Sci.,* 38, 8,086-8,096)

Data Analysis Pre-processing: Updated Sounding Screening

Analysis Extended to Land Regions

- GNSS-RO soundings over land regions with elevation below 2km are now used for the ATMS (AMSU-A) Ch 7-15 (6-14) analysis.
- Cloud clearing over land performed with Grody et.al. (2001: *JGR*, 106, D3, 2943-2953.)

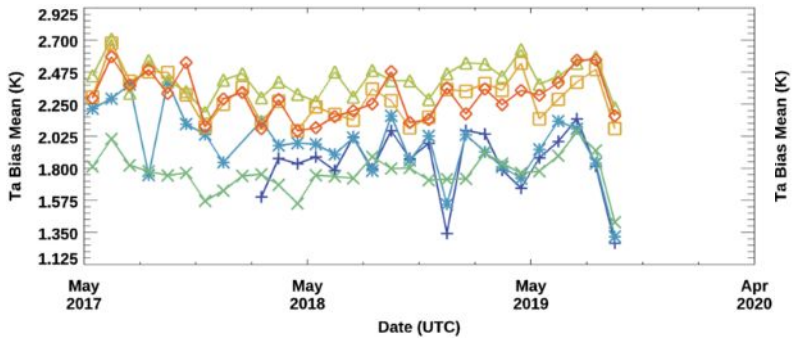
Implemented GNSS-RO Sounding Robustness Screening

Ensure GNSS-RO soundings have adequate depth for CRTM simulations. For a given MW sounder channel, if the Earth surface radiation transmitted to the sensor comprises:

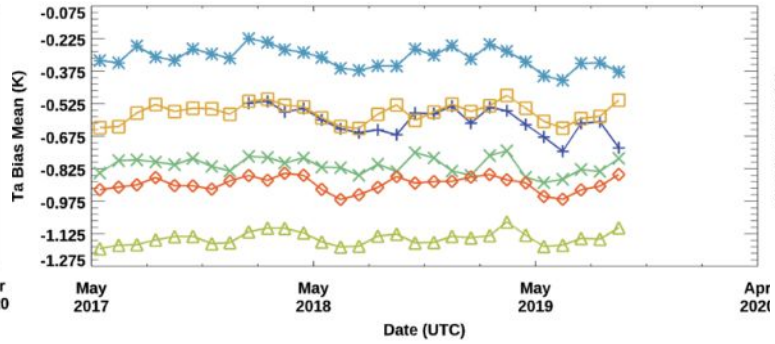
- >5% of total received radiation
  - If elevation ≤ 0 km, the sounding max pressure level must be greater than 1000 hPa.
  - If elevation > 0 km, the sounding must penetrate to within 1.0 km of the surface.
- <5% of total received radiation
  - Sounding data must penetrate at least to an elevation where only 5% of the emission can be transmitted to the satellite.

Monthly-mean O-B Ta Bias Time Series: Pre- and Post-COSMIC-2 Integration

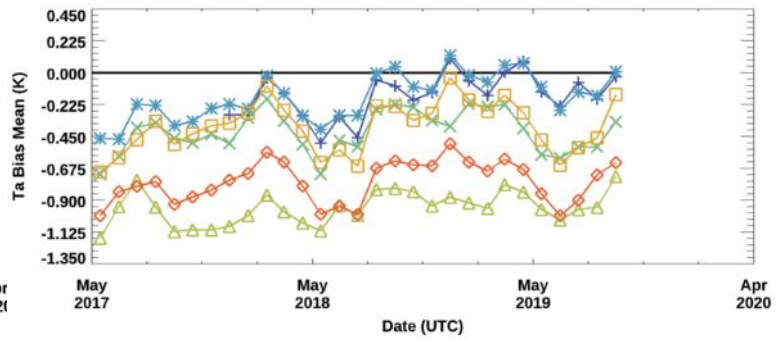
ATMS/AMSU-A Ch 2



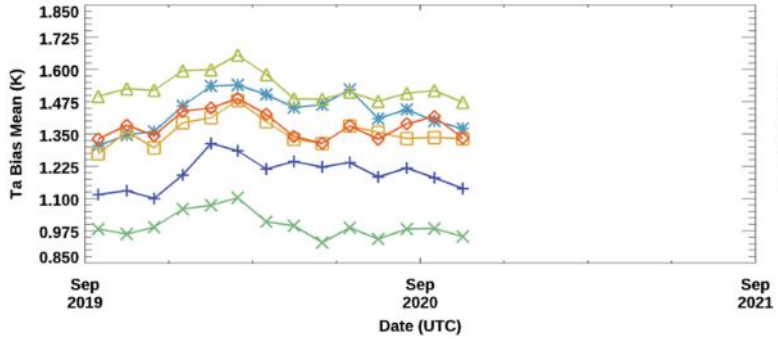
ATMS Ch 10/AMSU-A Ch 9

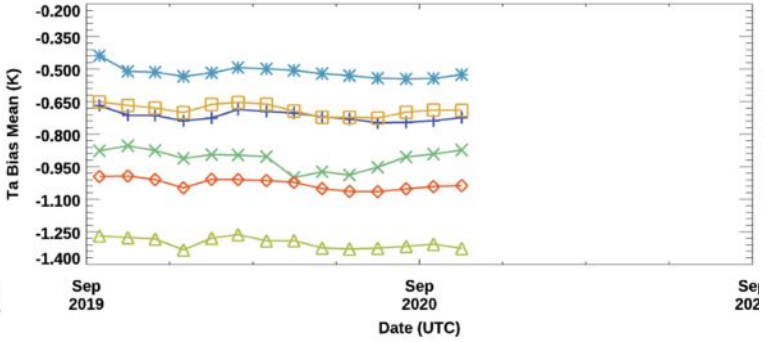


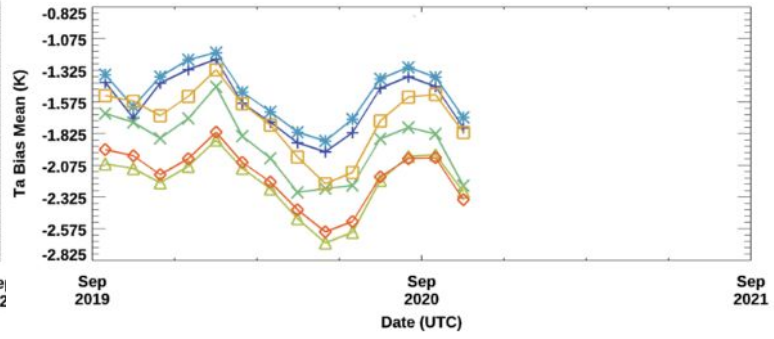
ATMS Ch 15/AMSU-A Ch 14



Pre-COSMIC-2 Integration (1MAY2017 – 30SEP2019)







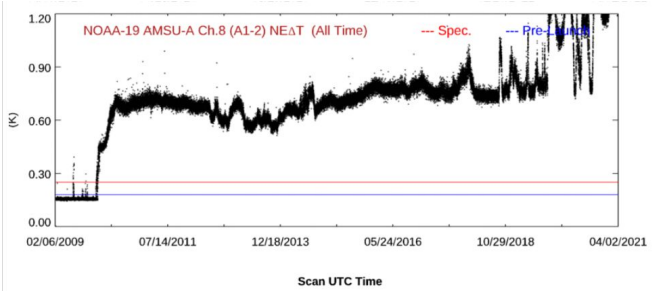
NOTE – Y-axis ranges vary.

Post-COSMIC-2 Integration (1OCT2019 – 30NOV2020)

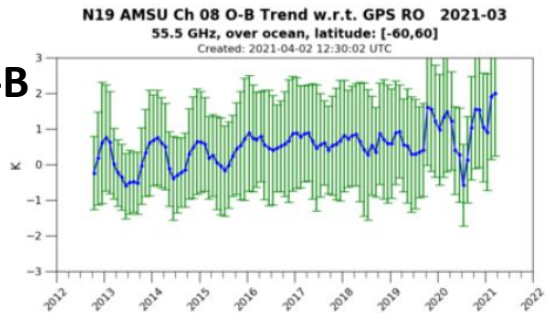
After addition of COSMIC-2: Monthly-mean O-B Ta Bias is often more stable, but a seasonal variability arose for ATMS Ch 15 and AMSU-A Ch 14 that is not understood.

Time Series Mean O-B Ta Bias: Pre- and Post-COSMIC-2 Integration

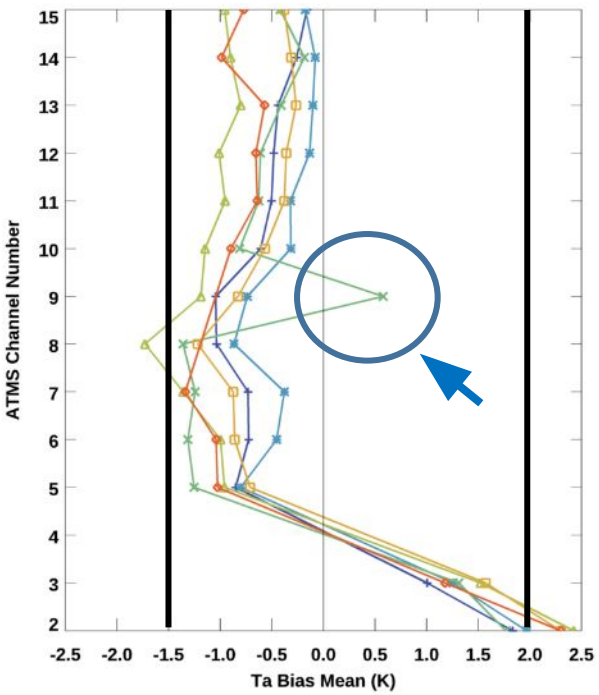
NOTE –
For Y-axis Values > 4,
N18, N19, MEA, MEB, and MEC
AMSU-A Ch # = (Y-axis Value -1)



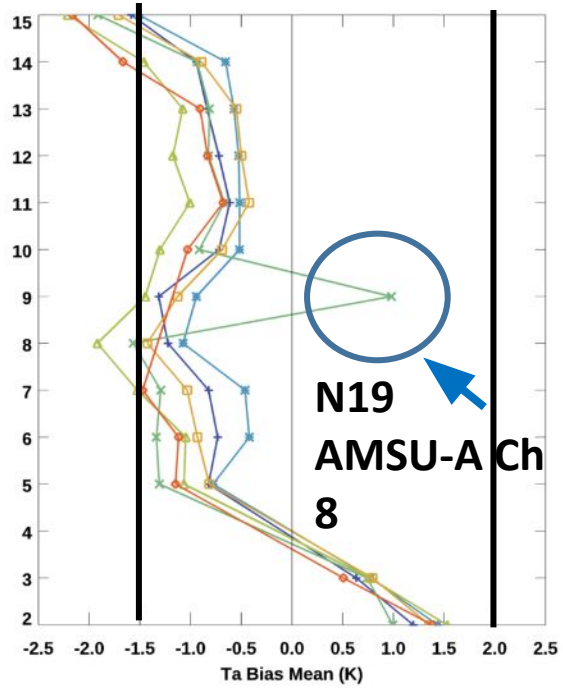
N19 AMSU-A Ch 8 NEDT (top) and O-B Ta Bias (bottom)



Time Series Mean O-B Ta Bias



Pre-COSMIC-2 Integration
(1MAY2017 – 30SEP2019)



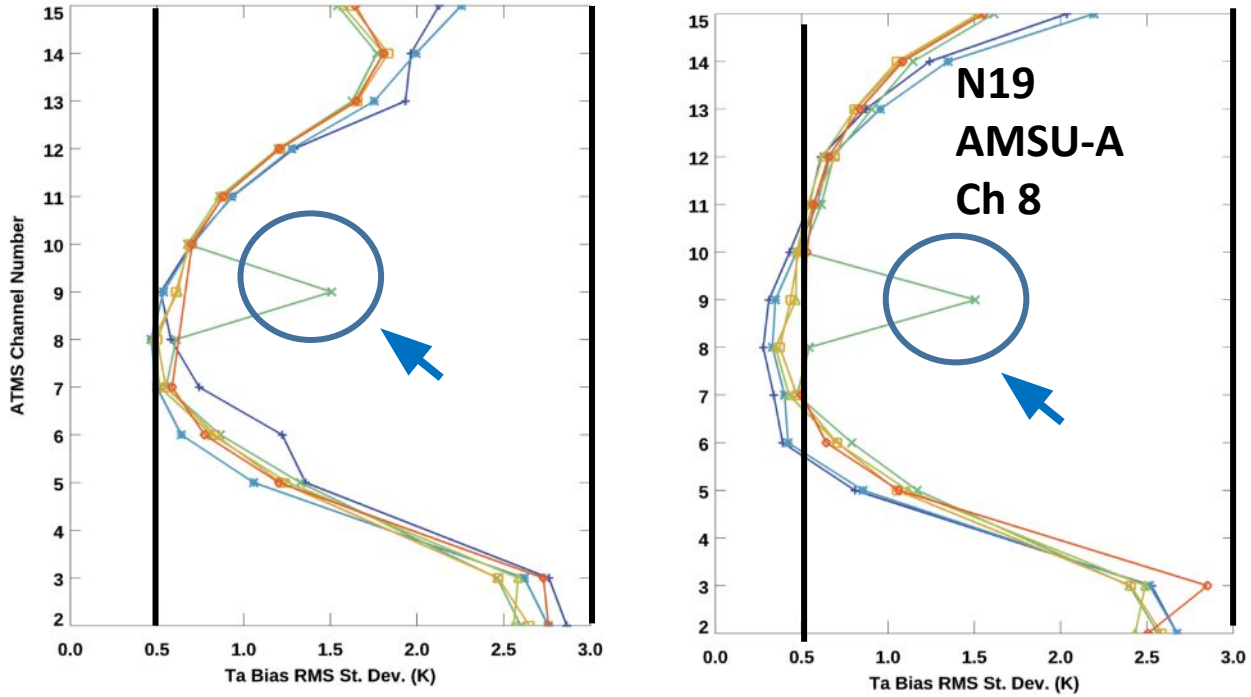
Post-COSMIC-2 Integration
(1OCT2019 – 30NOV2020)

After addition of COSMIC-2: Time series O-B Ta Bias mean shows little change for MW channels with max sensitivity in the mid-troposphere to the lower stratosphere (ATMS Ch 5-10), and while others are negatively shifted.

Time Series RMS Monthly Standard Deviation O-B Ta Bias: Pre- and Post-COSMIC-2 Integration

NOTE –
For Y-axis Values > 4,
N18, N19, MEA, MEB, and MEC
AMSU-A Ch # = (Y-axis Value -1)

Time Series RMS Monthly Standard Deviation O-B Ta Bias



Pre-COSMIC-2 Integration
(1MAY2017 – 30SEP2019)

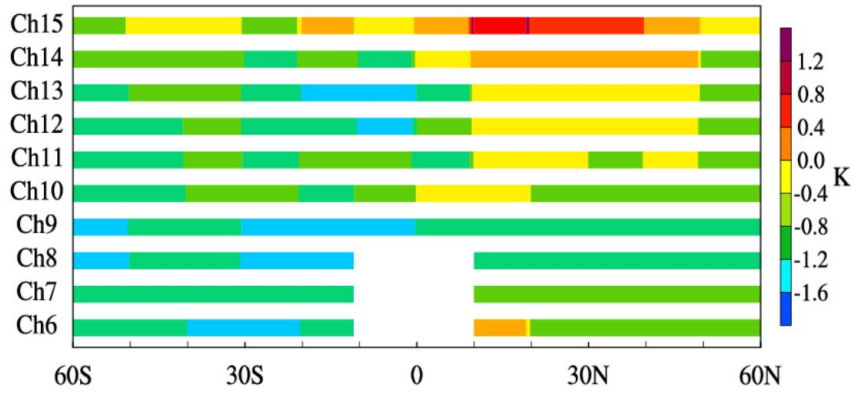
Post-COSMIC-2 Integration
(1OCT2019 – 30NOV2020)

+ N20 ✳ NPP × N19 △ N18 □ MEB ◇ MEA

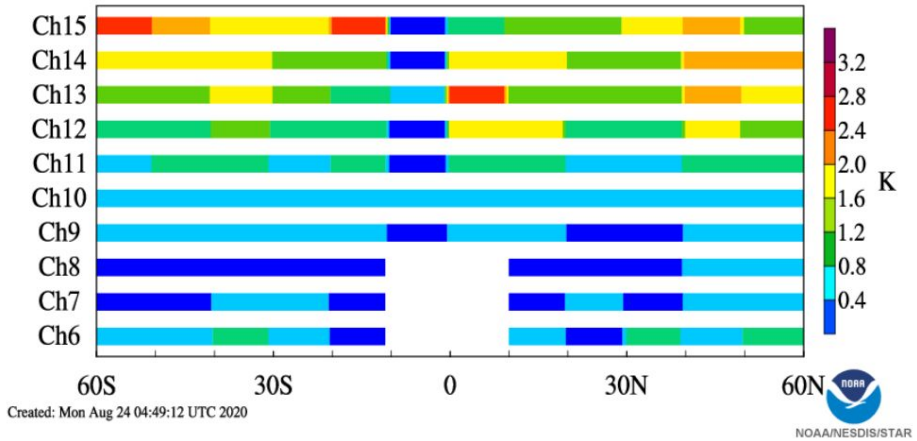
After addition of COSMIC-2: Time series O-B Ta Bias for the most part has smaller RMS variability.

Latitudinal Monthly-mean and Standard Deviation O-B Ta Bias: Pre- and Post-COSMIC-2 Integration

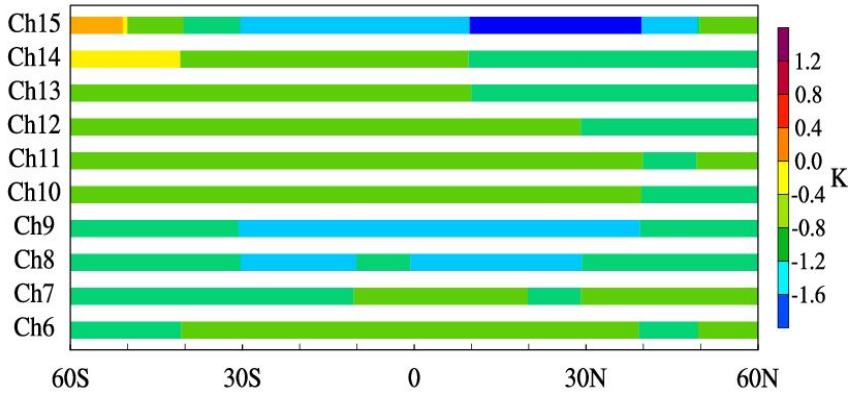
Latitudinal Monthly Mean O-B Ta Bias

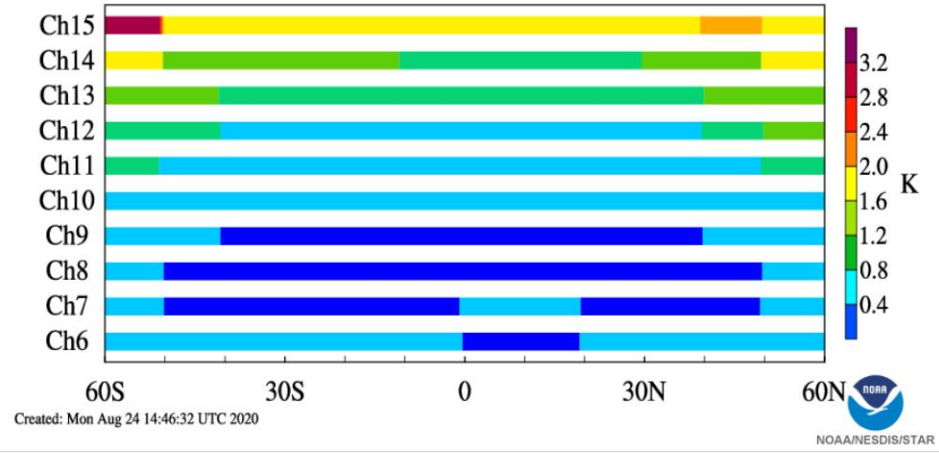


Latitudinal Monthly Standard Deviation O-B Ta Bias



Pre-COSMIC-2 Integration (30SEP2019)

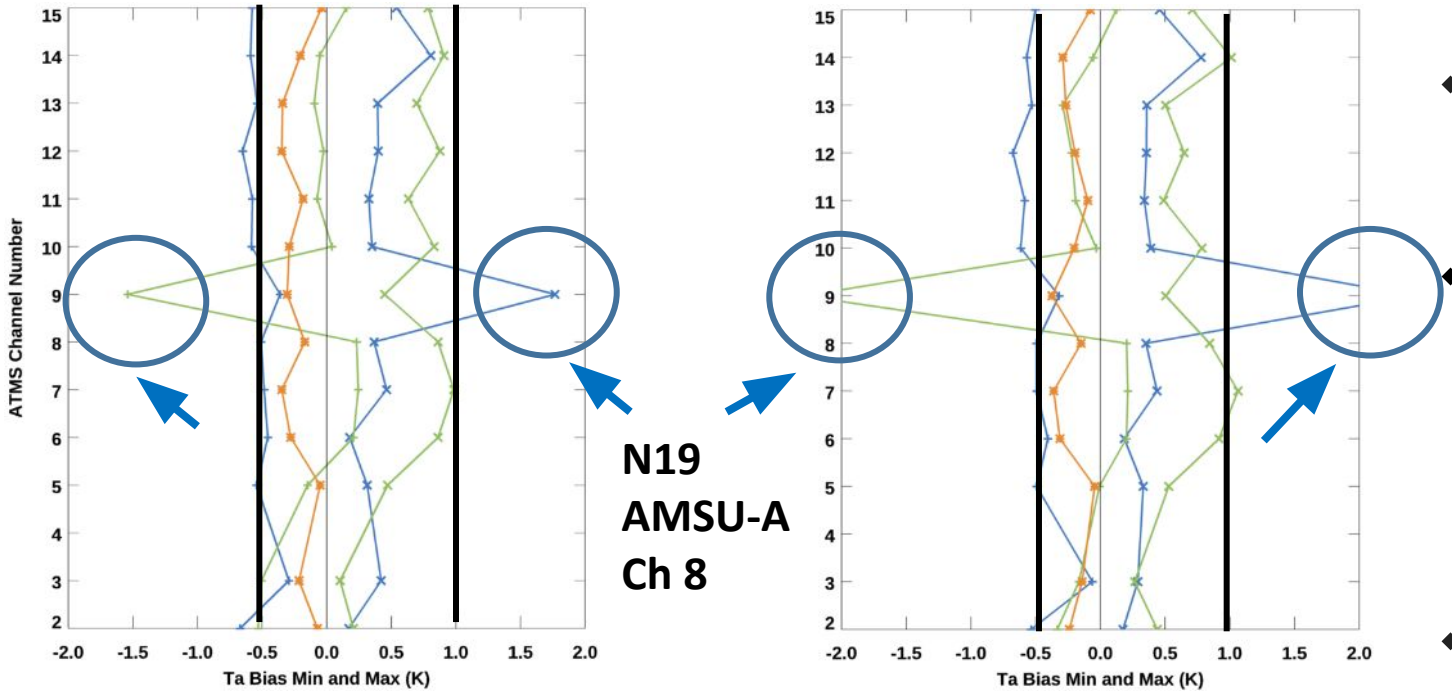




Post-COSMIC-2 Integration (31OCT2019)

After addition of COSMIC-2: For V-Band channels, latitudinal O-B Ta bias monthly mean is more uniform, while the standard deviation is more uniform and often smaller.

Min/Max Double Difference: Pre- and Post-COSMIC-2 Integration



Pre-COSMIC-2 Integration
(1MAY2017 – 30SEP2019)

Post-COSMIC-2 Integration
(1OCT2019 – 30NOV2020)

+ AMSU-AMSU MIN	× AMSU-AMSU MAX
+ ATMS-AMSU MIN	× ATMS-AMSU MAX
+ ATMS-ATMS MIN	× ATMS-ATMS MAX

- Double-difference between O-B Ta biases can be computed during operational overlap period.
- For N18, N19, MEA, MEB, and MEC AMSU-A and NPP and N20 ATMS, there are:
  - *10 AMSU-A to AMSU-A pairs*
  - *10 ATMS to AMSU-A pairs*
  - *1 ATMS to ATMS pair*
- Each pair produces double-difference monthly-mean Ta biases.
- Mission-life minimum and maximum double difference can be used to illustrate Ta bias ranges.

After addition of COSMIC-2: O-B Ta Bias Double Difference Max/Min are largely unchanged except for ATMS-AMSU-A, which shifted for some channels by about 0.25K.

Summary

- The GNSS RO atmospheric and moisture soundings are critical to supporting NOAA operational satellite microwave sounder data quality assessments.
- The monitoring method that utilizes the GNSS RO sounding has been update in the past year or so to include
  - Increased number of radiometer channels
  - Improved screening
  - Sounding gap filling
  - Addition of COSMIC-2 data
- COSMIC-2 soundings have proven to be a stable sounding source that NOAA can use to continue its microwave sounder monitoring activities

Thank you!

Near-real time results can be found at the NOAA/NESDIS/STAR Integrated Cal/Val System (ICVS) web site at https://www.star.nesdis.noaa.gov/icvs/