Stability Monitoring of the AMR-C on Sentinel-6

National Environmental Satellite, Data, and Information Service

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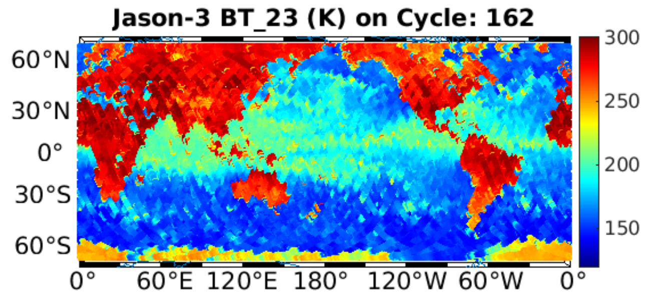
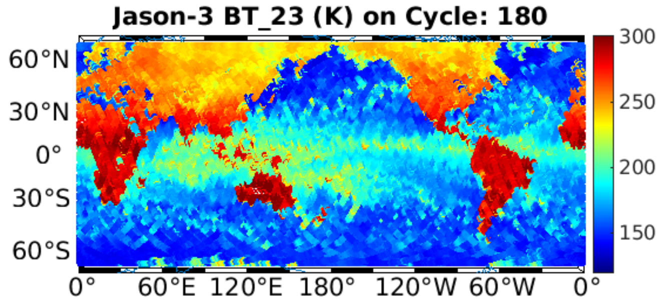
Outline

- Background and Objectives
- Approaches: Cal/Val methods for Sentinel-6 AMR-C
- AMR-C Time series Analysis
- HRMR time series analysis
- Summary and future work

Sentinel-6 AMR-C

- MR measurements are not stable, need frequent post-launch calibration/validation
  - Two points calibration (Dicke switch for internal calibration targets)
  - Onboard warm target with ambient temperature
  - Noise diodes [Cold target] design subject to temperature drift/jumps (J1, J2, J3, S6)
- S6 AMR-C is designed following previous missions but for climate quality water vapor observation
  - Additional Supplemental Calibration System (SCS) [Every 5-10 days].
  - Additional satellite maneuvers to calibrate SCS cold sky mirror.
  - Level-4 instrument requirement: stable to ±0.1K over one year [Kloosterman et al., 2017]
- S6 High Resolution Microwave Radiometer (HRMR) is designed for coastal sea level products improvements
  - Reduced footprints, its stability may affect coast sea level products.
  - No stability requirement



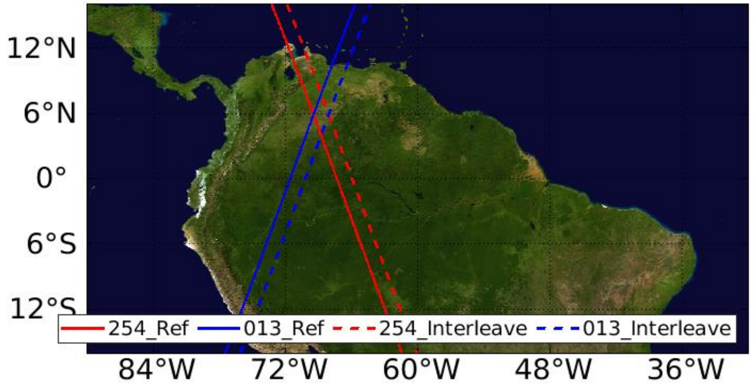


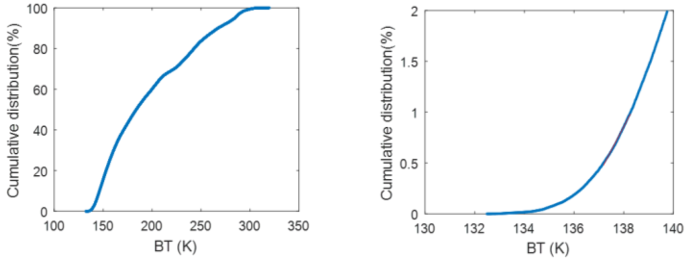
Stability monitoring of WTC and brightness temperature time series of Sentinel-6 AMR-C

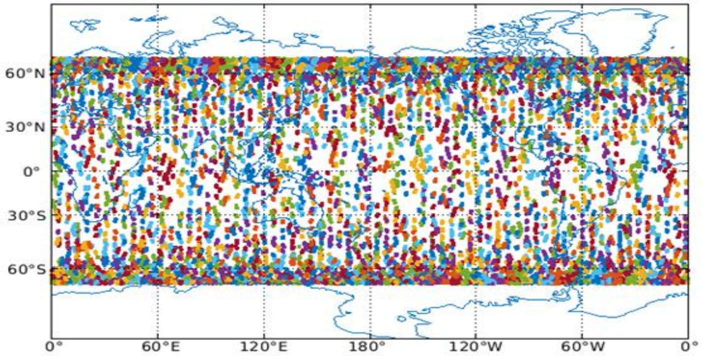
- Research Objectives:
  - Monitoring time series stability of S6 AMR-C brightness temperature and WTCs are essential steps for reducing the errors contributing to the global mean sea level rise rate determination.
    - Short term monitoring for IGDR/STC products, for instant errors in processing and calibration.
    - Long term monitoring for GDR/NTC datasets, for long term drift detection and connecting time series between different missions.
  - Monitoring HRMR stability for coastal sea level products improvement.
    - Retrievals near coastal line

Microwave Radiometers Stability Monitoring Methods

- Amazon Rainforests (Hot Target)
  - Amazon rainforest acts as a natural pseudo blackbody for microwave sensors.
  - Microwave radiometer BTs display strong diurnal cycle but can be predicted.
  - Selected area [5.5S to 4.5S, 64.5W to 67.0 W) [Eymard et al. 2005]
- Coldest ocean brightness temperature (Cold Target)
  - Statically derived “coldest” (driest) brightness temperature over ocean surface.
- Global mean methods
  - Similar to global sea level rise calculation methods, applied to BT and WTC.
  - Compare difference with NWP model (ECMWF/ERA-5).
- Simultaneous Nadir Overpass for inter-mission comparison
  - Among different altimetry missions
  - Tandem phase between Jason-3/Sentinel-6
  - With SNPP Advanced Technology Microwave Sounder (ATMS)
    - Very stable microwave radiometers.
- Website setup for short/long term monitoring for different missions
  - https://www.star.nesdis.noaa.gov/socd/lsa/AMR/realtime.php



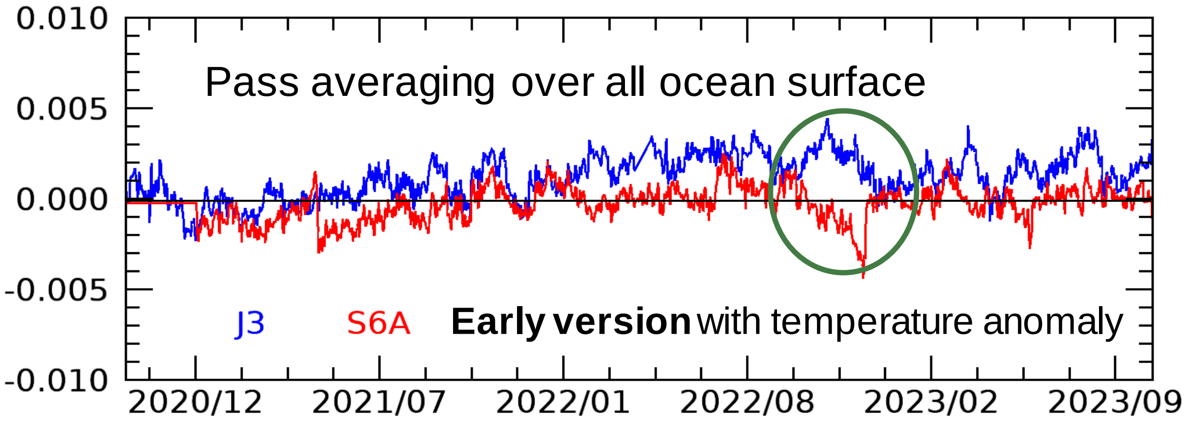


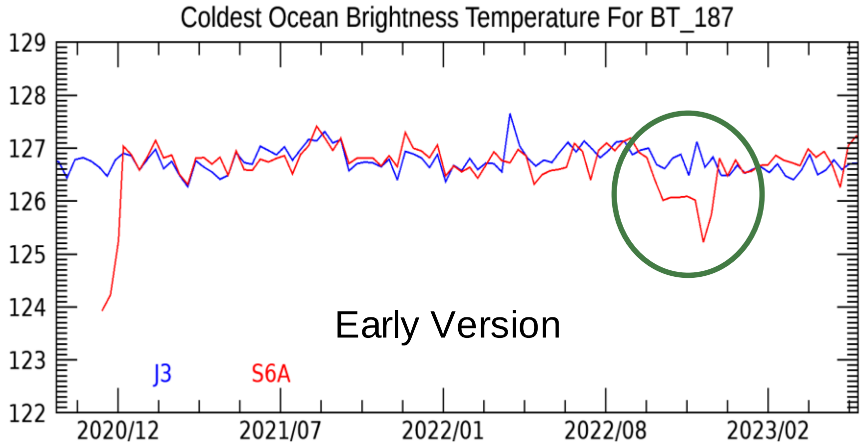


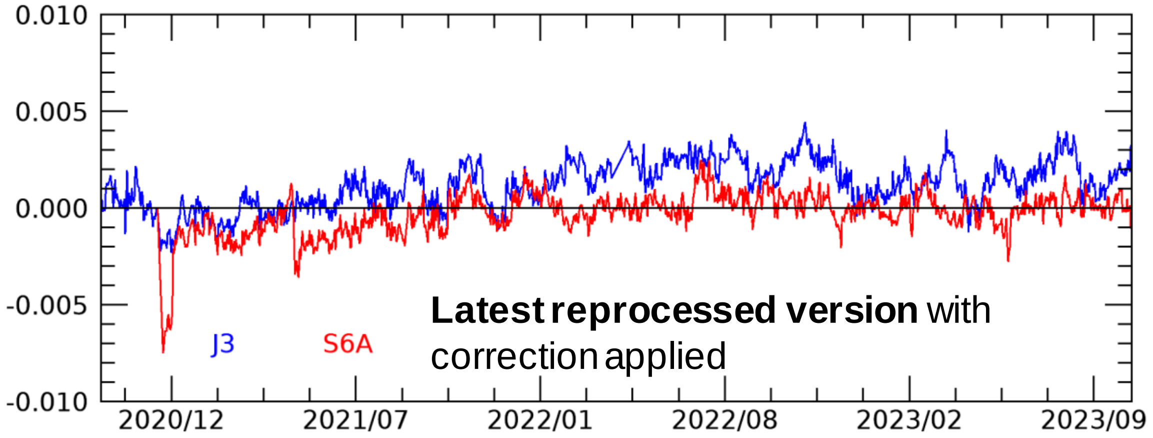
Data Sources

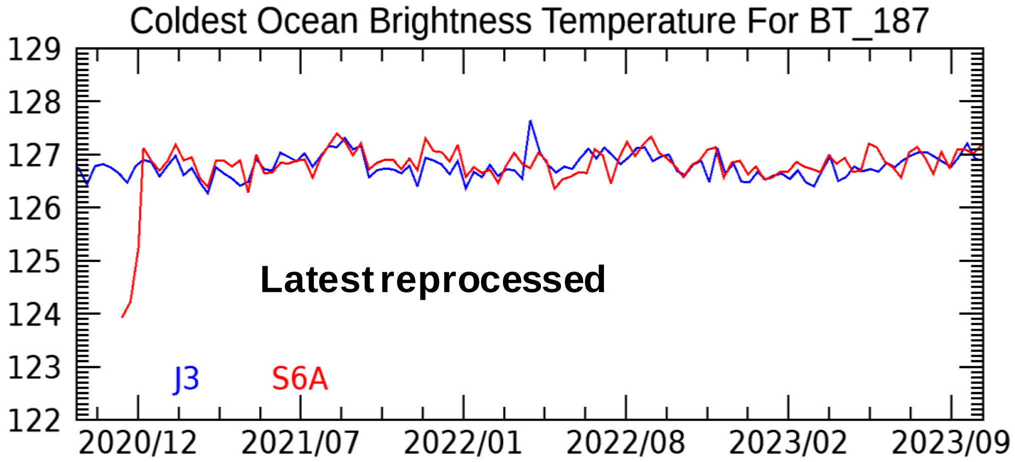
- **Radar Altimeter Database System (RADS)**
  - "The Radar Altimeter Database (RADS) is employed at NESDIS/STAR as an enterprise multi-mission algorithm providing consistent sea level anomaly, waves, and ocean surface wind speed products."
  - It also includes all the geophysical parameters (BTs, WTCs etc) for all altimetry missions.
- SNPP ATMS from NOAA/CLASS
  - Operational datasets with consistent calibration algorithm.
  - High radiometric stability, suitable for climate study [Zou 2021].
  - Ch1 (23.8GHz), Ch2 (31.4GHz) out of 22.
- JPL AMR-C STC/NTC
  - Extract HRMR brightness temperature from different versions of datasets

WTC time series monitoring for Sentinel-6 (Validation against ECMWF)



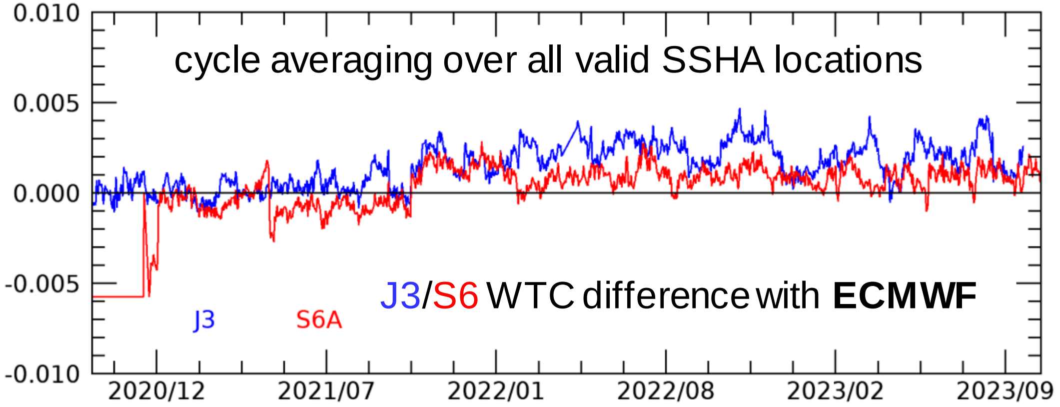


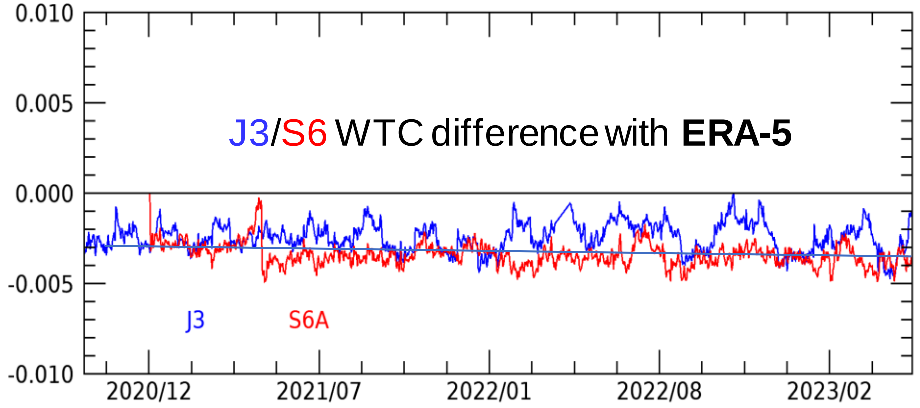




Daily monitoring of WTC with ECMWF can tell large departures in the WTC retrievals, such as those around 10/2022 caused by 18.7GHz temperature large drop. Even in the latest version, inconsistency between Jason-3 and Sentinel-6 exists. But ECMWF has problems itself.

WTC monitoring for Sentinel-6 (Validation against ERA-5)





- Large bias/drift between ECMWF and ERA-5
- General lower bias in S6a than J3.
  - Inconsistency with J3>1mm
- Both significantly lower than ERA-5
- Larger variability after 2022.
- Jason-3 WTC needs correction, so does the Sentinel-6. But S6 WTC is more stable.

Daily monitoring of WTC with ERA-5 can detect the short term anomalies and possible long term time series drifts, given the relative stability of ERA-5. ERA-5 is updated daily with a latency of about 5 days. It may not be used to monitor the latest IGDR/OGDR (STC) datasets.

WTC Sensitivity to Brightness Temperature

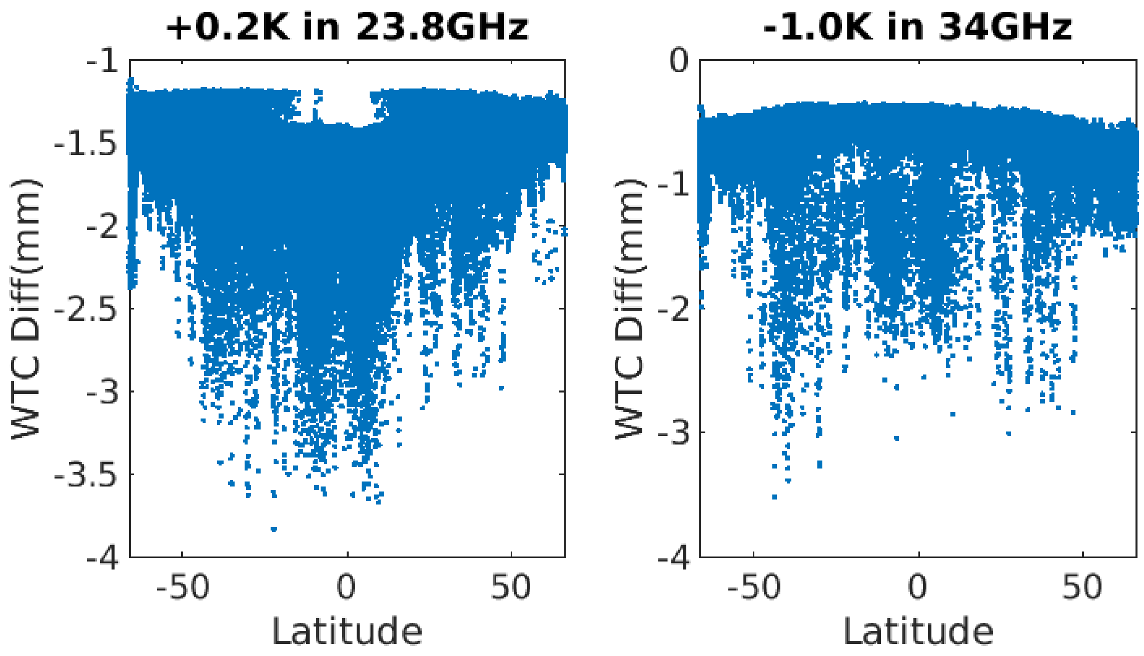
$$PD^{(2)} = B_0^{(2)} + \sum_{i=1}^{3} B^{(2)}(f_i)\ln[280 - T_b(f_i)]$$

References: Sentinel-6 AMR-C ATBD

Using Keihm 1995 TP Coefficient Table and J3 brightness temperature

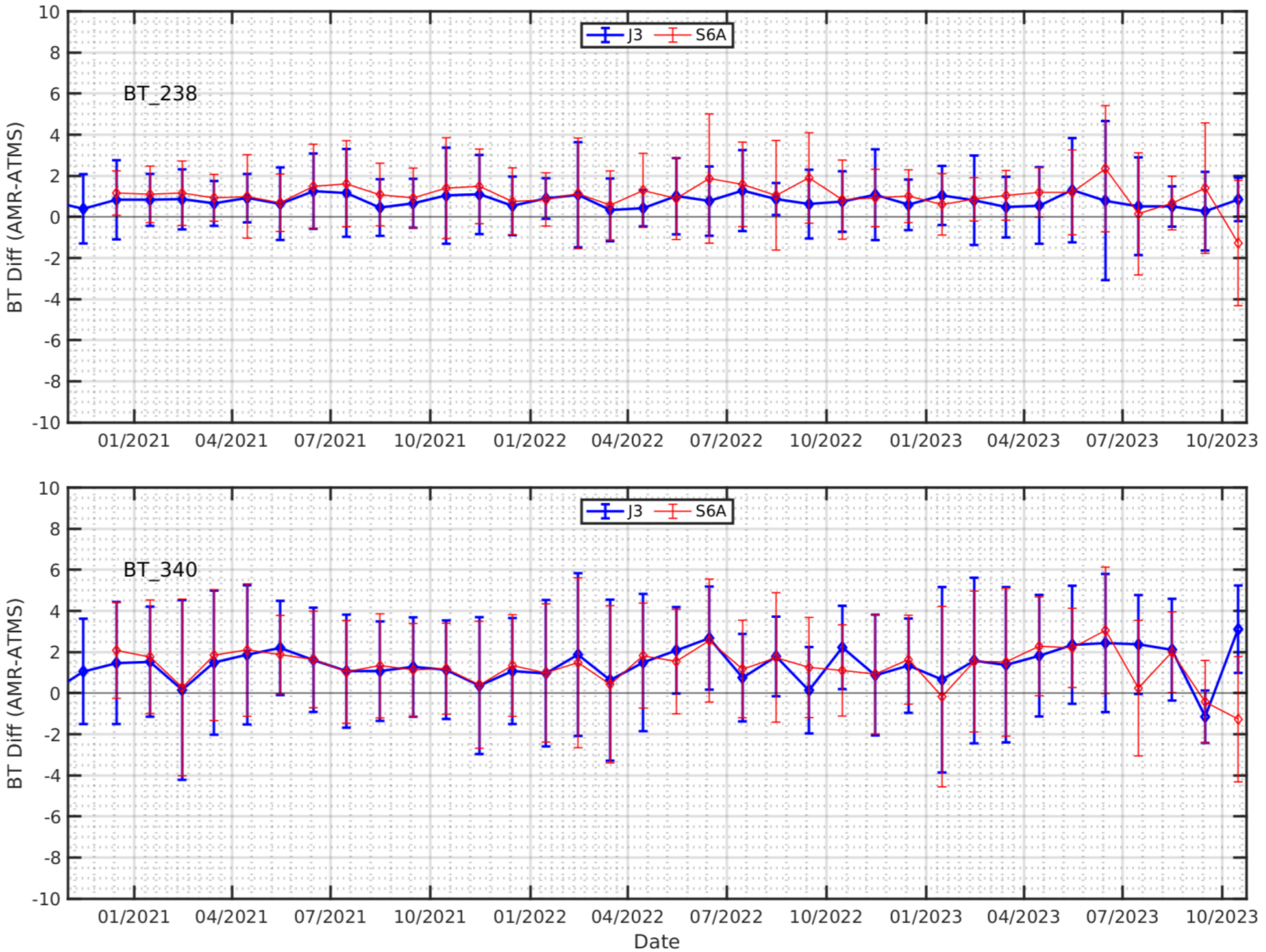
Any drifts in BT can contribute to GSML drift. Weight is latitudinal dependent.

Thus, it is needed to monitor the brightness temperature time series.

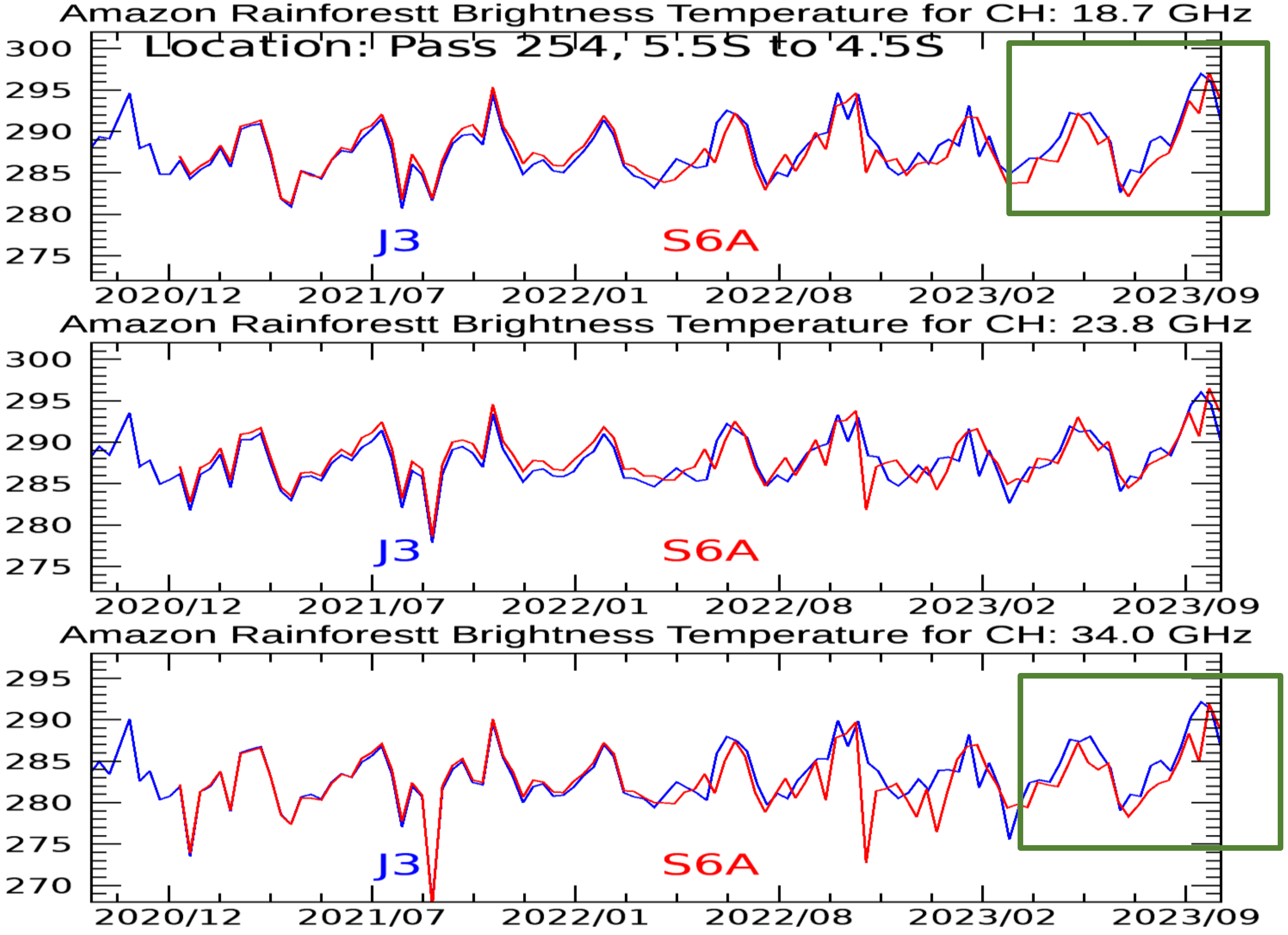


AMR-C brightness temperature monitoring over SNO with SNPP/ATMS (all surface)

- General higher bias in S6A 23.8 GHz than J3.
- More consistent for 34.0 GHz between J3/S6
- Consistent with the lower bias (than J3) in the WTC comparison with model.



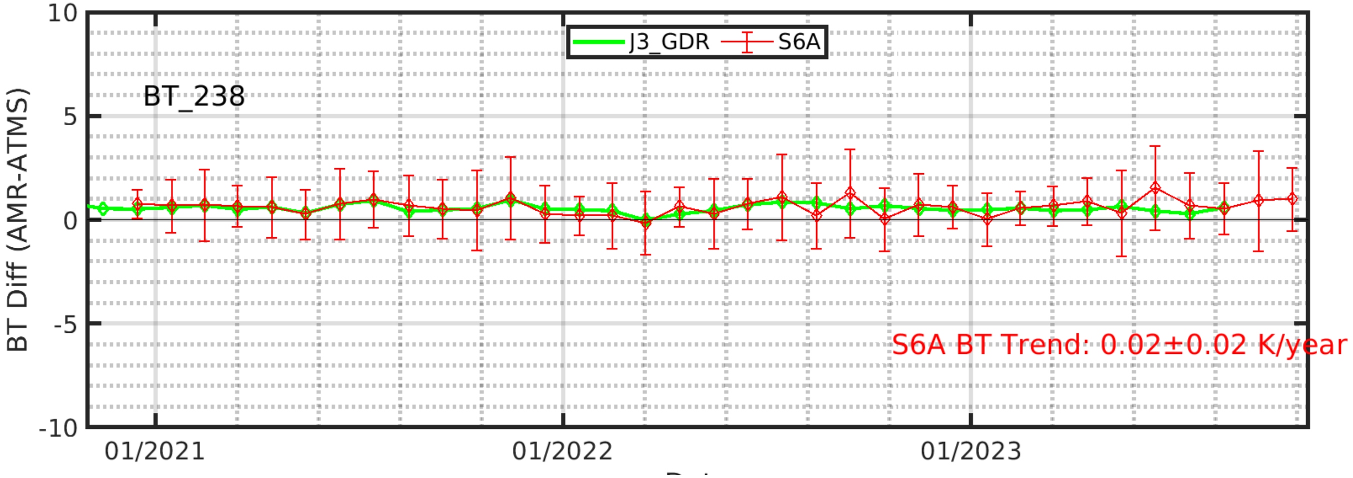
Brightness temperature monitoring at Amazon rainforest

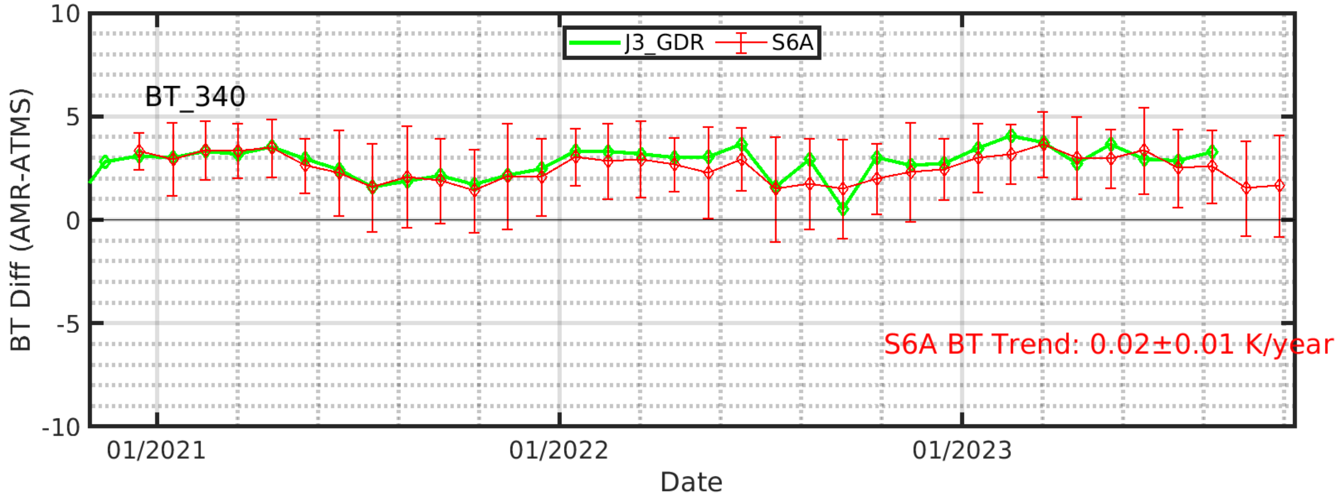


- J3/S6A generally agree well during tandem phase and J3 interleaved phase, but BT of S6A 23.8GHz is slightly higher.
- There is a lower bias of S6A 18.7GHz and 34.0GHz in 2023.
- A lower bias in S6A 34.0GHz 10/2022-01/2023.

AMR-C brightness temperature monitoring over SNO with SNPP/ATMS over ocean

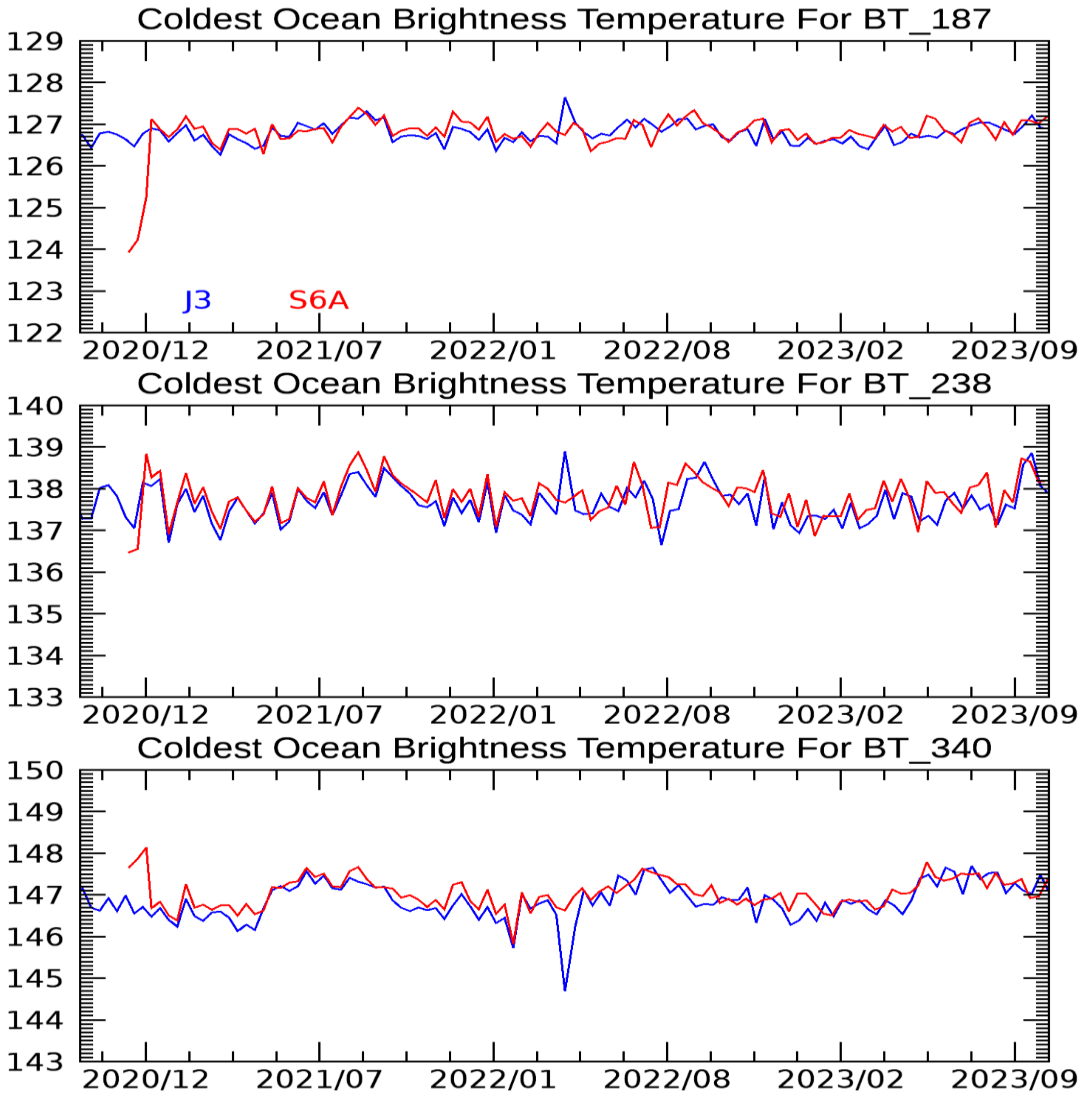
- Statistically stable for both 23.8 GHz and 34.0GHz compared with ATMS over SNO.





Brightness temperature monitoring over coldest ocean

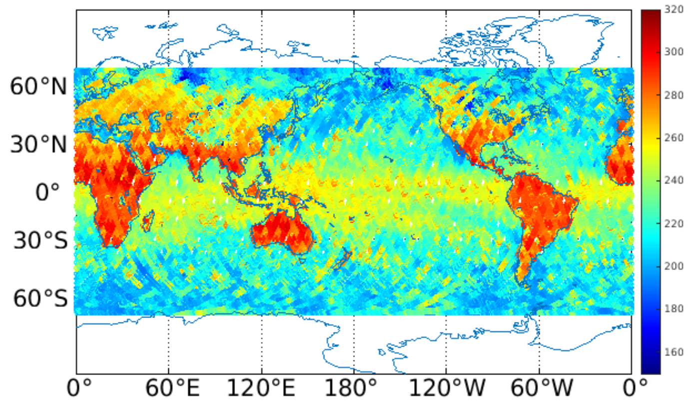
- General higher bias in S6A 23.8 GHz than J3 especially In 2023
- Higher bias in S6A 34.0GHz than J3



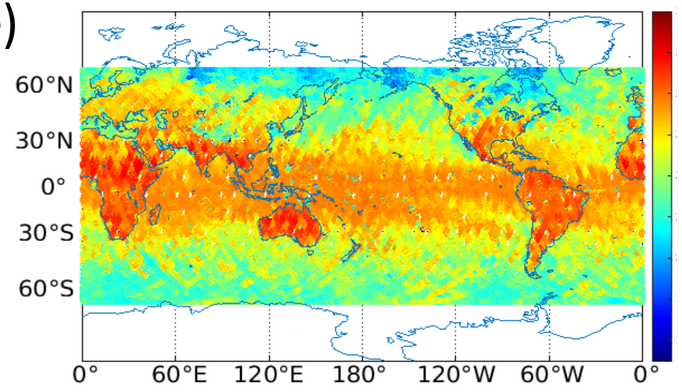
High Resolution Microwave Radiometer

- Improves the sea level retrieval accuracy close to coastal and other surface boundaries.
- Different from AMR-C
  - SCS is only for AMR-C, not for HRMR
  - No stability requirement
  - Smaller footprint
  - Higher frequency
    - 90,133,160 GHz
- Validation with the similar technics.
  - Amazon/Libya sites (beyond the range)
  - Coldest ocean (may not work)
  - Inter-comparison with ATMS
    - **Paired channels: 90/89; 160/163**
    - **No 130 GHz channel on ATMS**

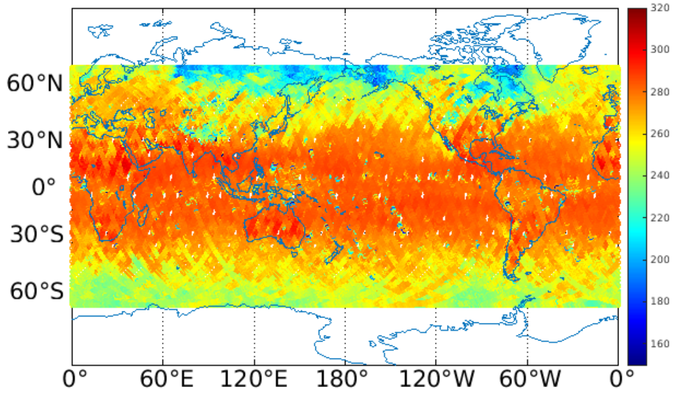
Global BT of C088 for 90GHz



Global BT of C088 for 130GHz

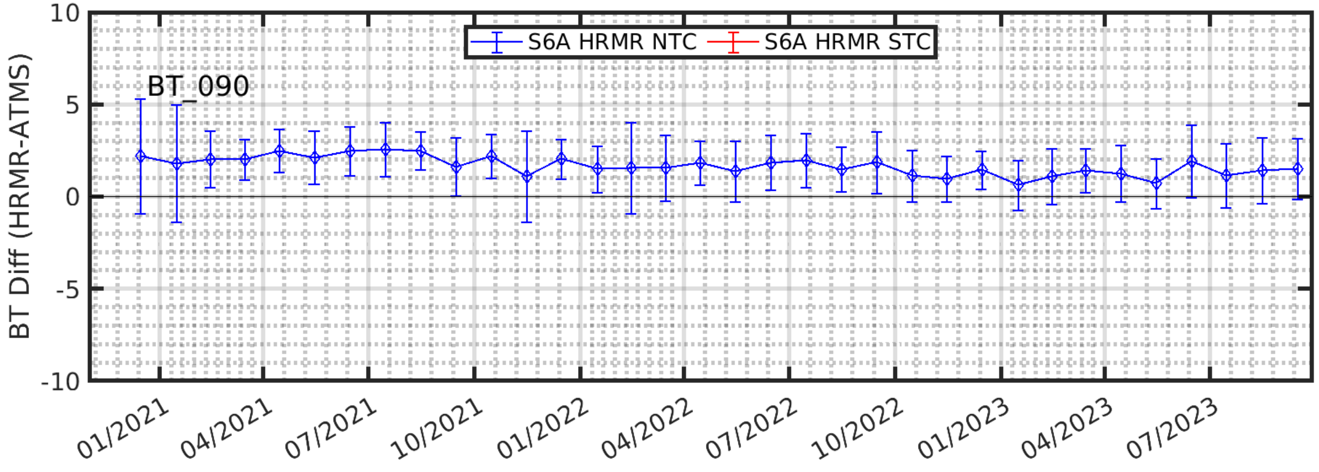


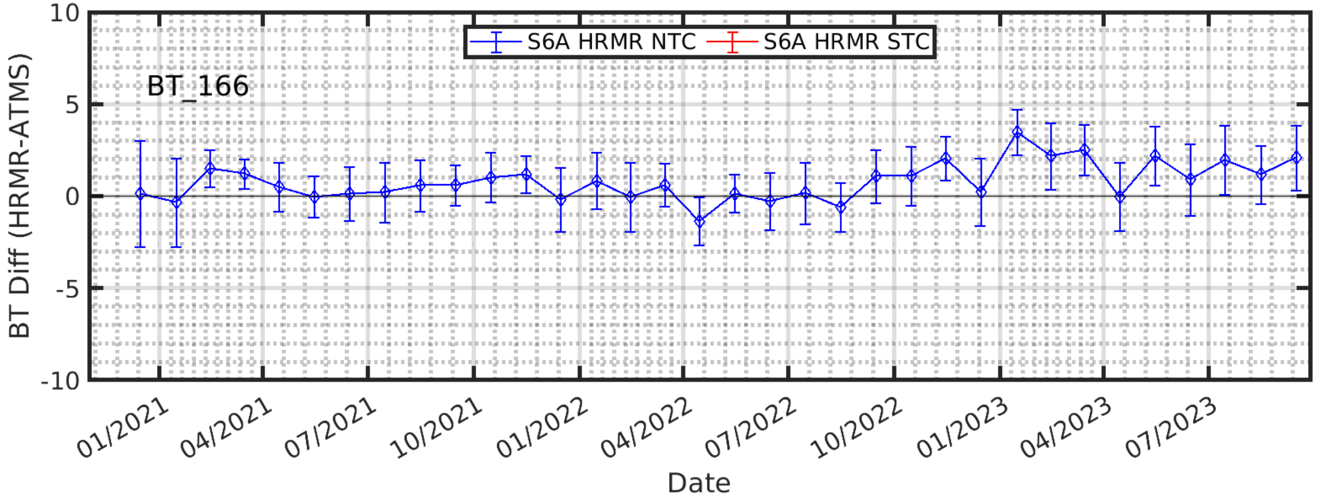
Global BT of C088 for 166GHz



HRMR SNO time series with ATMS

- Same methods applied as the AMR/ATMS SNO.
- Only 90GHz and 166 GHz.
  - ATMS does not have similar channel near 130GHz.





Summary and Conclusion

- Sentinel-6A has achieved stable AMR-C WTC retrievals and brightness temperatures with the latest recalibrated/reprocessed version.
  - Difference exists between Jason-3/S6a WTC and brightness temperature.
  - Jason-3 on the interleaved orbits is less stable than S6.
- Differences in the S6A WTC retrieval and ERA-5 show more than 3 mm bias, but the overall difference is relatively stable.
- S6 HRMR brightness temperatures are also compared with ATMS
  - Channel 90 GHz shows relatively stable time series.
  - Channel 166 GHz shows a larger bias in 2023.
- A microwave radiometer stability monitoring system has been developed at NOAA/STAR for multiple altimetry missions, for short and long-term time using RADS.
  - More altimetry missions will be added
  - More validation for WTC using different methods will be added.
- ATMS, as a highly stable microwave radiometer sensor, through SNO and site time series comparison, is a useful cal/val reference for altimetry microwave radiometers.
  - SNPP, NOAA-20, NOAA-21 and more in the future

Disclaimer and Acknowledgement

- The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.
- Data Sources:
  - HRMR data: Ocean Surface Topography Science Team. 2021. Sentinel-6A MF Jason-CS L2 Advanced Microwave Radiometer (AMR-C) NRT Geophysical Parameters. Ver. F. PO.DAAC, CA, USA. Dataset accessed [2023-10-30] at https://doi.org/10.5067/S6AMW-2NRTF
  - RADS: Scharroo, R., E. W. Leuliette, J. L. Lillibridge, D. Byrne, M. C. Naeije, and G. T. Mitchum, RADS: Consistent multi-mission products, in Proc. of the Symposium on 20 Years of Progress in Radar Altimetry, Venice, 20-28 September 2012, European Space Agency Special Publication, ESA SP-710, p. 4 pp., 2013.
  - ATMS: NOAA CLASS: https://www.avl.class.noaa.gov/saa/products/welcome

Routine Microwave Radiometer Stability Monitoring

- Daily update
  - Based on RADS and NOAA SCDR
- WTC validation
  - Model (ECMWF and ERA-5)
  - Simulation (ATMS)
- Sensor Brightness Temperature validation
  - Sites (Amazon Rainforests)
  - Coldest Ocean
  - SNO
  - more
- Multi missions short and long term
  - SWOT
  - Jason-3, S3A/B
  - Working on other missions.