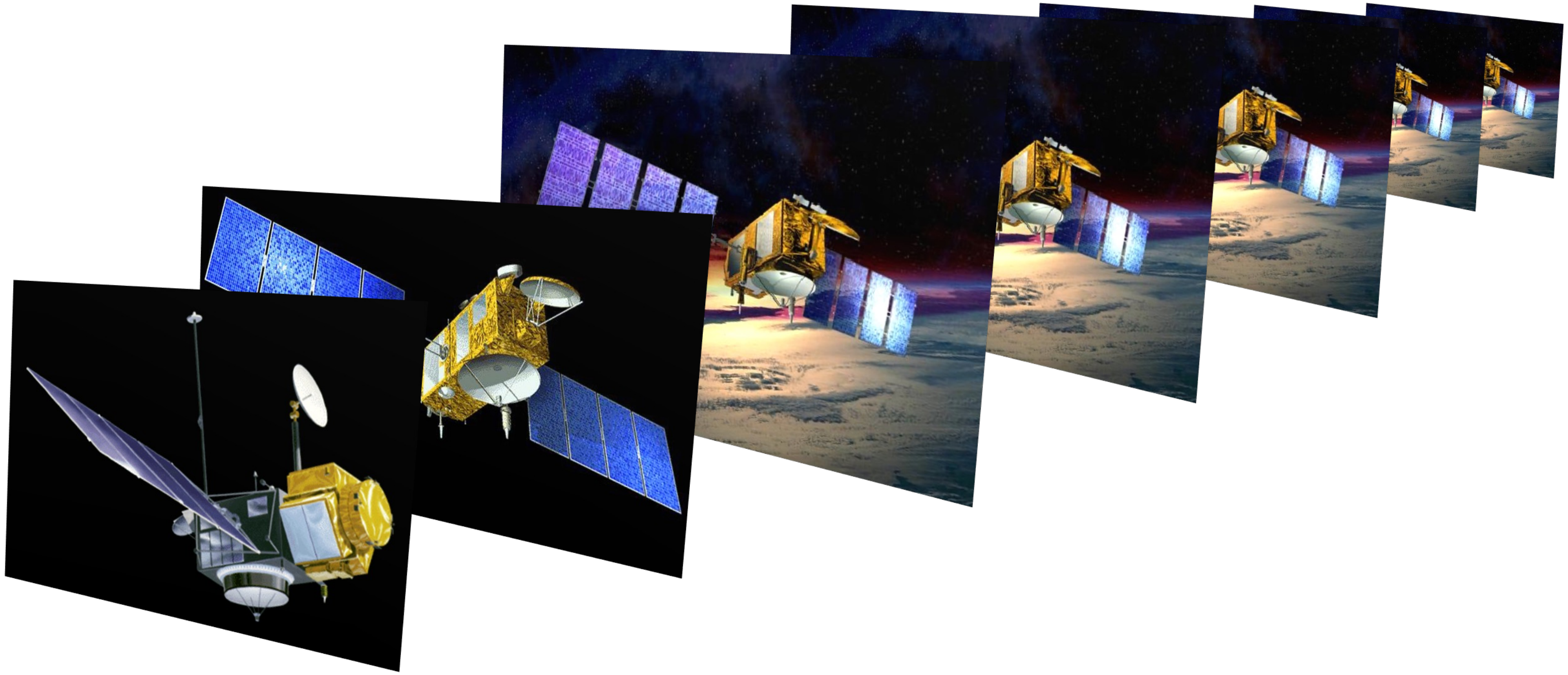

Progress on the Wet Path Delay Correction: Historical, Current and Future

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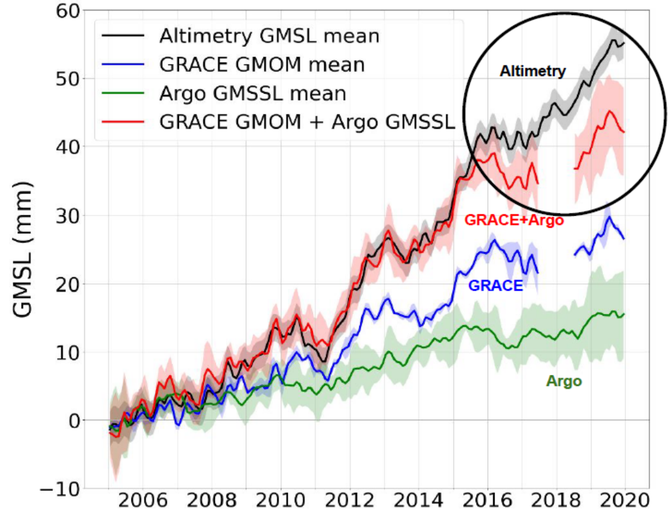
Overview

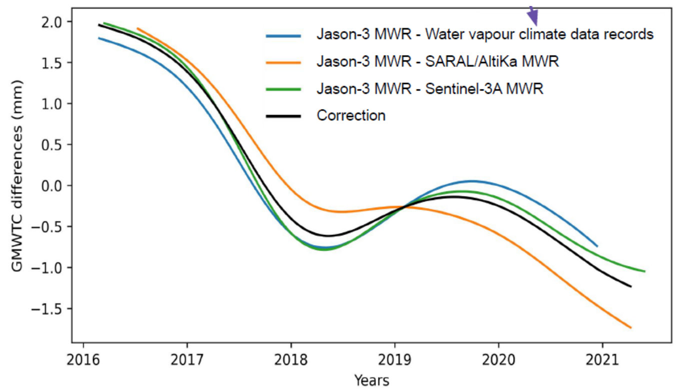
- Updates to Jason-2 and Jason-3 climate calibration
- Sentinel-6A performance
  - Long term stability
  - Coastal performance with HRMR
- Outlook for CRISTAL

JASON-3

Jason-3 Climate Calibration

ΔGMSL = ΔGMSSL + ΔGMOM





From Barnoud et al., (OSTST 2022)

- Sea level budget not able to be closed starting in 2015
- Small drift in Jason-3 AMR wet tropospheric correction suspected contributor (~30%)
- Jason-3 radiometer long term TB stability assessed

Long Term TB Calibration

- Jason-3 radiometer calibration is stabilized using a satellite pitch maneuver to point radiometer to cold space

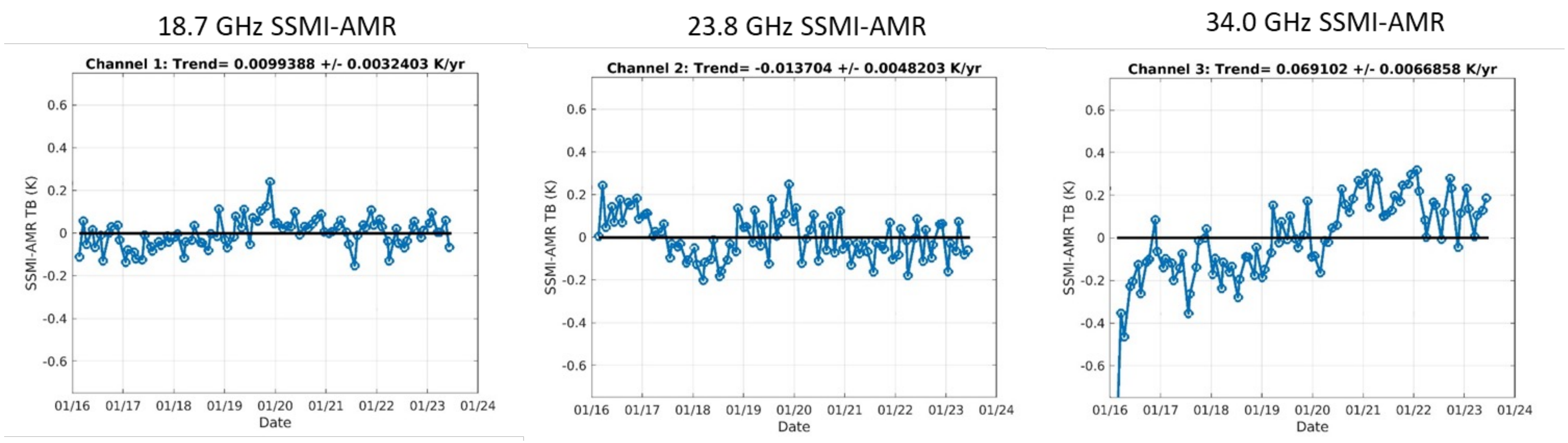
- Cold sky observations alone are not sufficient to remove both gain and offset drifts
  - Potential drift must be assessed using on-Earth references and inter-satellite comparisons

- Jason-3 AMR GDR-F compared to SSMI F16, F17 and F18 FCDR
  - NOAA Climate Data Record (CDR) of SSMIS Microwave Brightness Temperatures, RSS Version 8 (Wentz et al., 2019)
  - Used method described in Brown et al., 2012 to map SSMI TBs to AMR equivalent TBs
  - Removed bias between SSMI equivalent AMR TBs and AMR TBs with respect to latitude for all data prior to computing temporal trends (though found this made little difference)
  - Only considered rain free, mostly clear data (TB18.7 GHz < 160K)

SSMI – J3 AMR Trend Results 2016-2023

- Small inter-satellite trends observed in 23.8 and 34 GHz channels
  - 18.7 GHz channel generally stable in time
  - Largest variation in 23.8 GHz channel between 2016-2018
  - 34 GHz channel has long extended 0.5K drift over 2016-2023 period

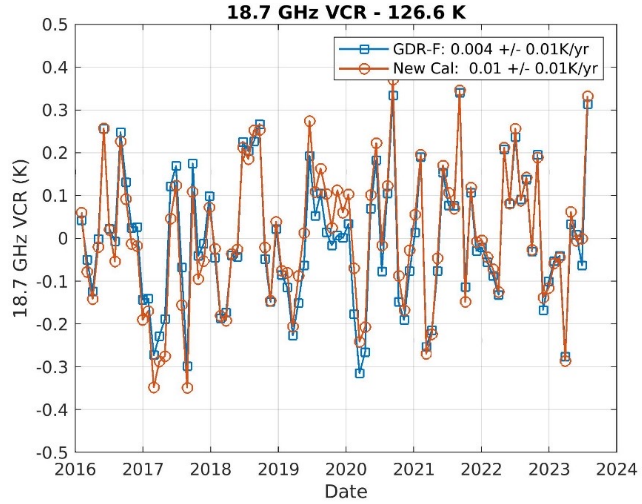
- TB bias correction derived from SSMI for each channel and applied to J3 AMR data
  - New calibration validated using independent references

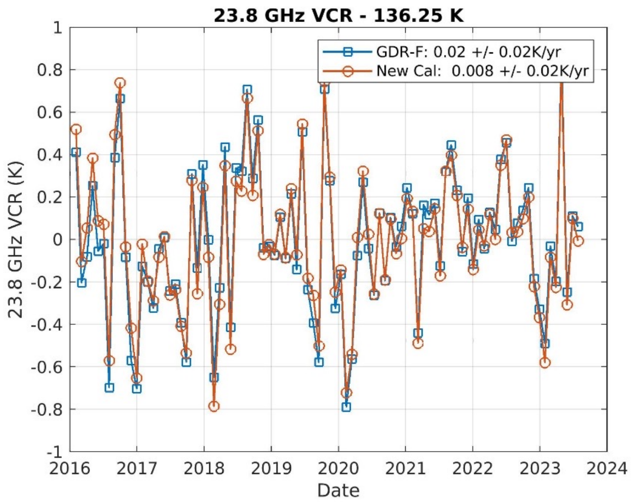


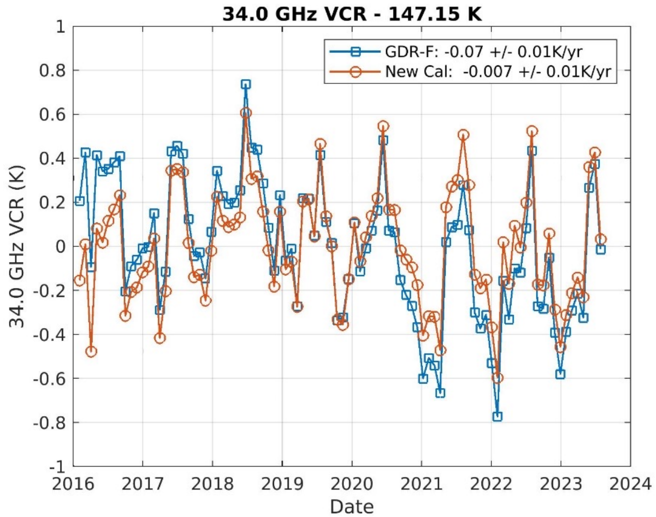
J3 Vicarious Cold Reference

- Vicarious cold reference is an independent ocean calibration source

- In all cases, drift with respect to vicarious cold reference metric statistically insignificant after SSMI correction
  - **18.7 GHz:** 0.01 $\pm$ 0.01 K/yr
  - **23.8 GHz:** 0.008 $\pm$ 0.02 K/yr
  - **34.0 GHz:** -0.007 $\pm$ 0.01 K/yr

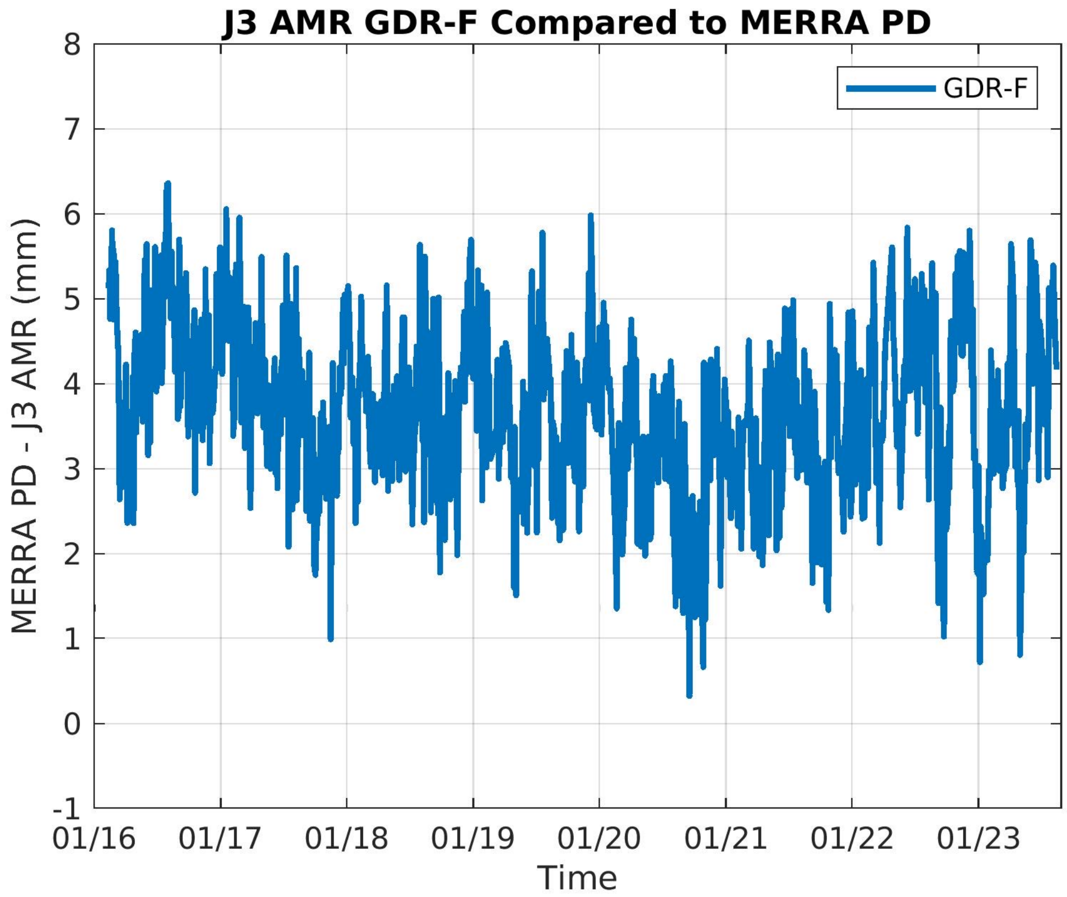






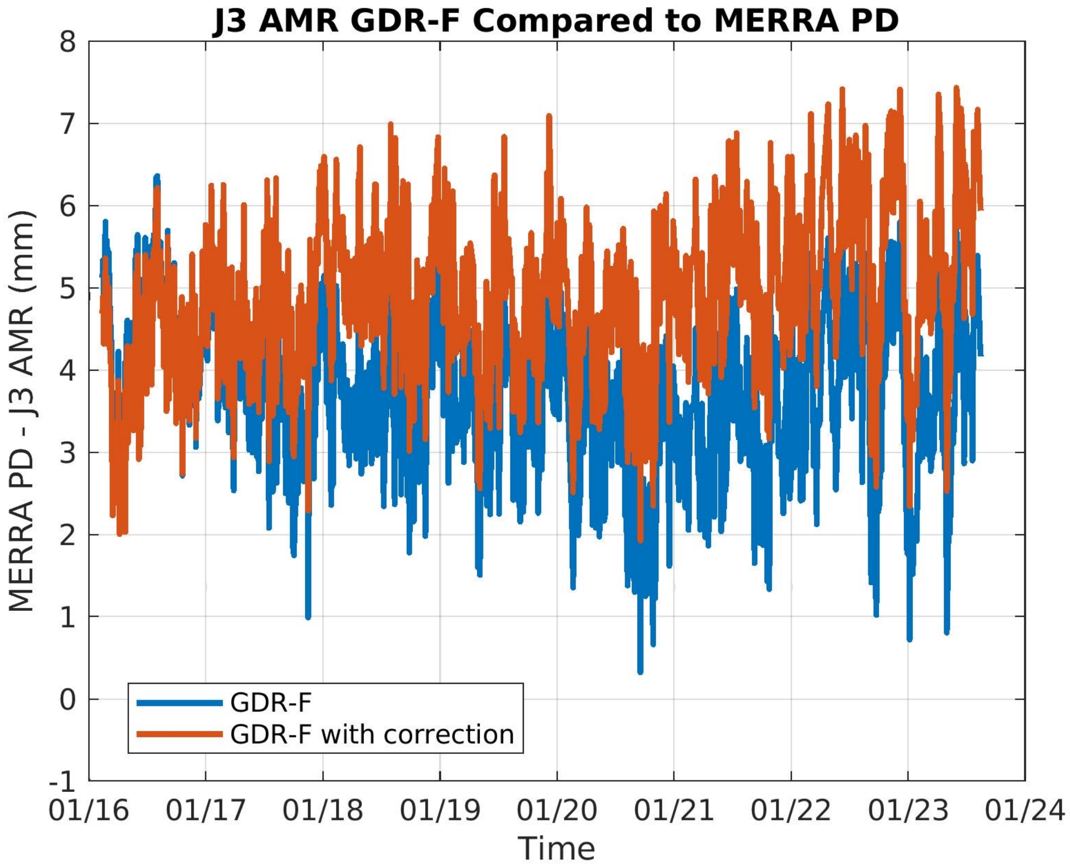
Path Delay Compared to MERRA-2

Path delay computed from MERRA-2 3D temperature and water vapor profiles and matched to Jason-3 observations



Path Delay Compared to MERRA-2

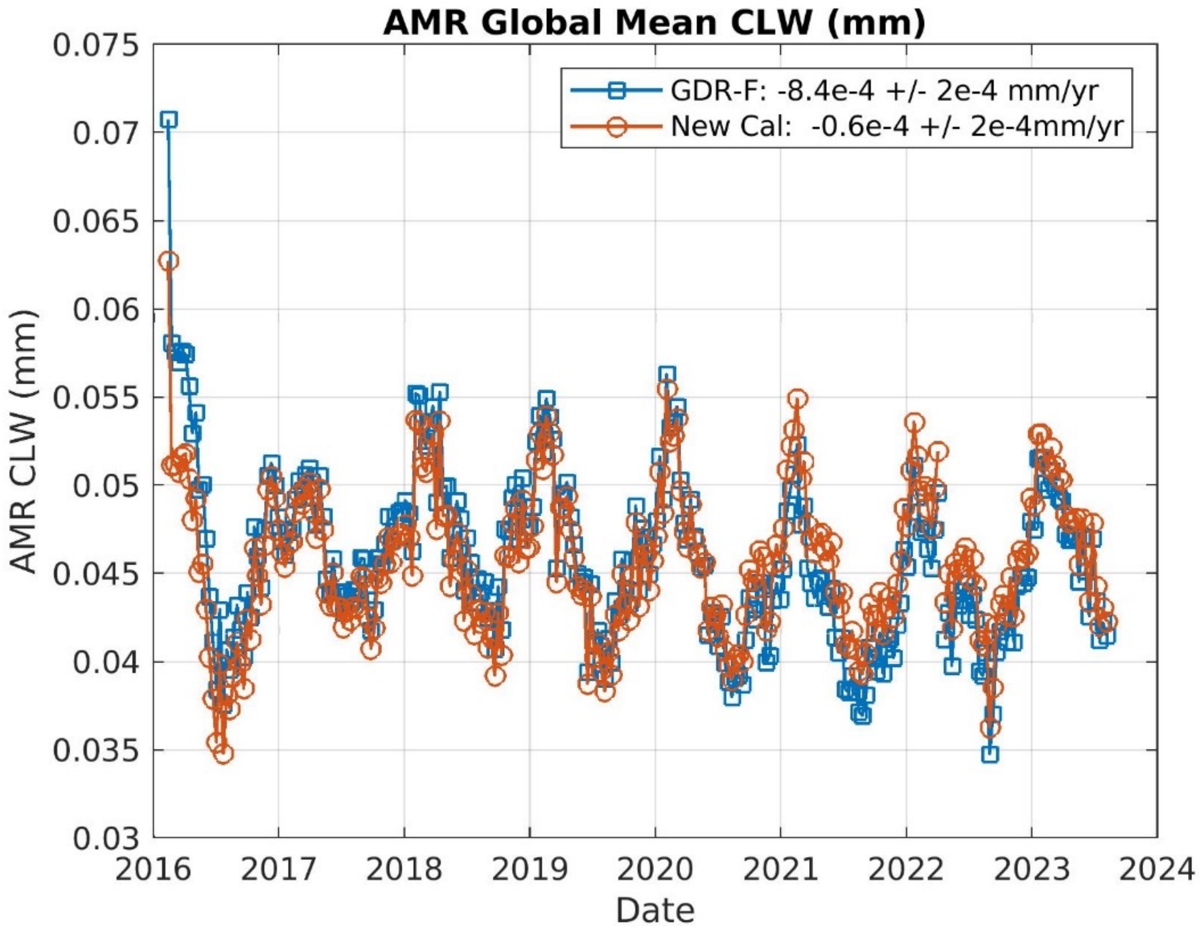
Updated calibration (red) appears more stable over mission, particularly in 2016-2021 time period



Global Mean CLW

- Largest correction is to 34 GHz TB, which most significantly impacts cloud liquid water (CLW) retrieval

- After SSMI based TB correction, global mean CLW signal in 2016-2017 more consistent with long term annual variation and trend is reduced to a statistically insignificant level

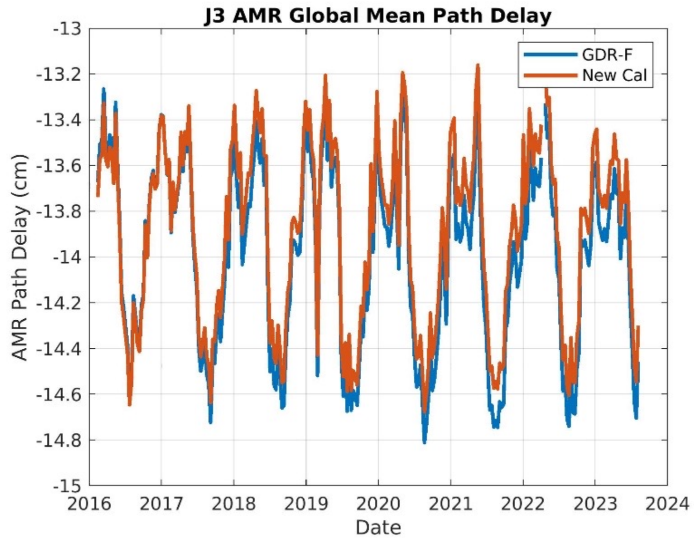


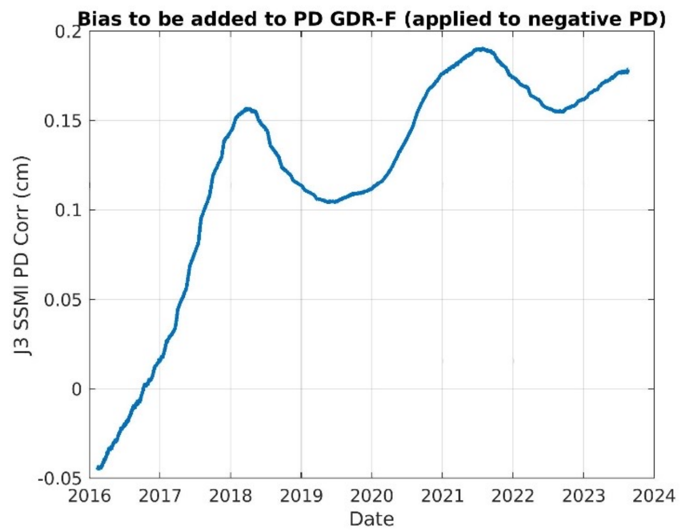
Jason-3 PD Correction

- Resulting PD correction placed in J3_PD_correction_20230925.txt
  - Columns of file are:
    - Cycle
    - Pass
    - UTC time string
    - PD bias to be added to path delay (where path delay is a negative quantity)

- Correction is about 2mm over 8 years (0.25mm/yr)

- Initial results show it improves sea level budget closure (Beckley, personal communication)

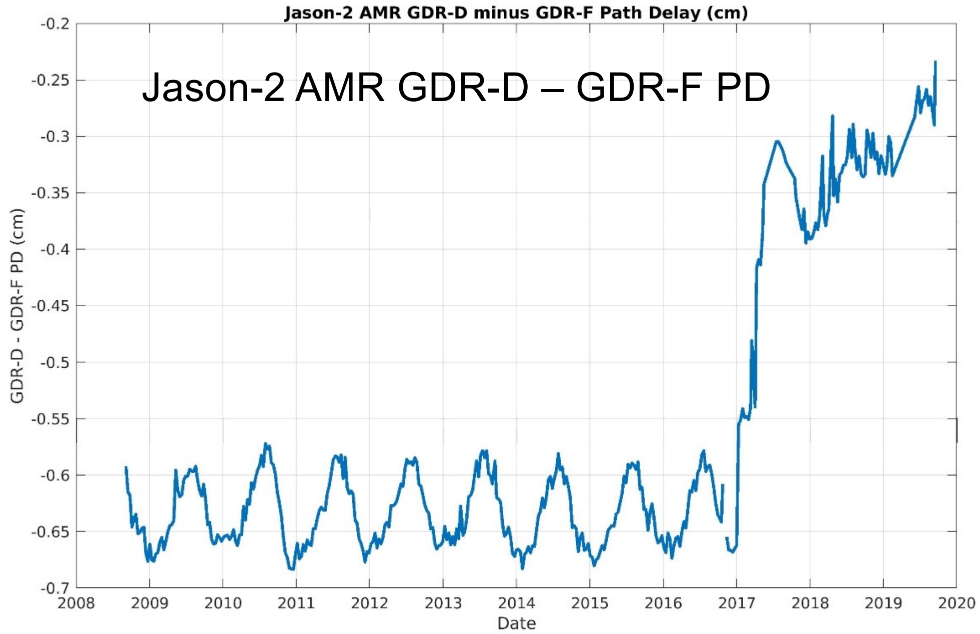


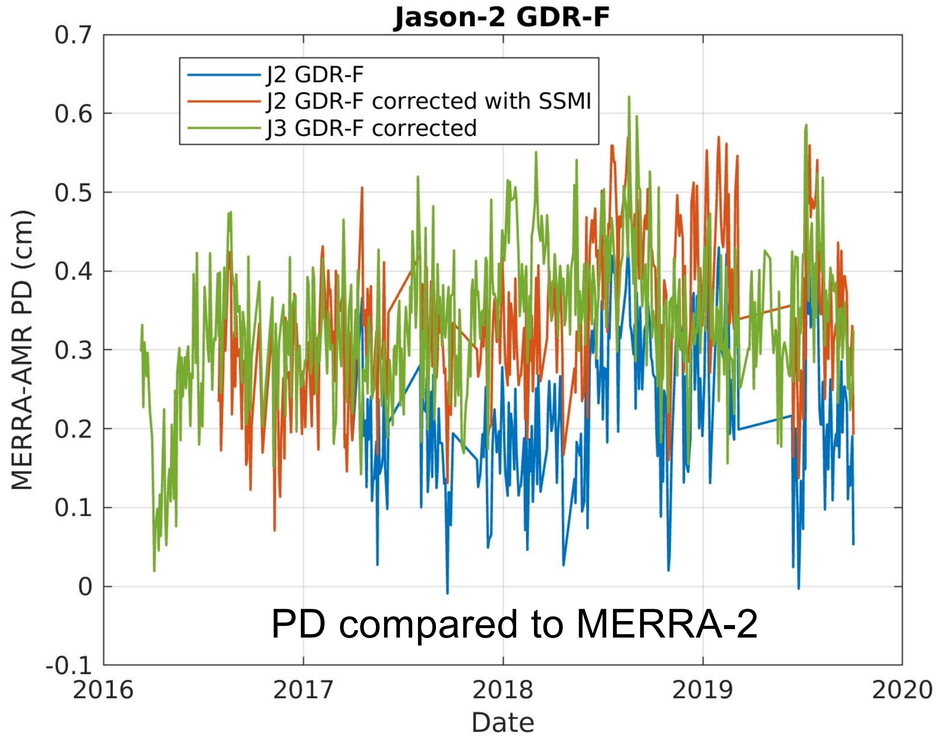


JASON-2

Jason-2 GDR-F

- Recently applied additional correction on top of Jason-2 AMR GDR-F correction to reduce small offsets observed in 18 and 34 GHz calibration after 2017
- Calibration uses same SSMI reference as Jason-3, improving consistency from 2017-end

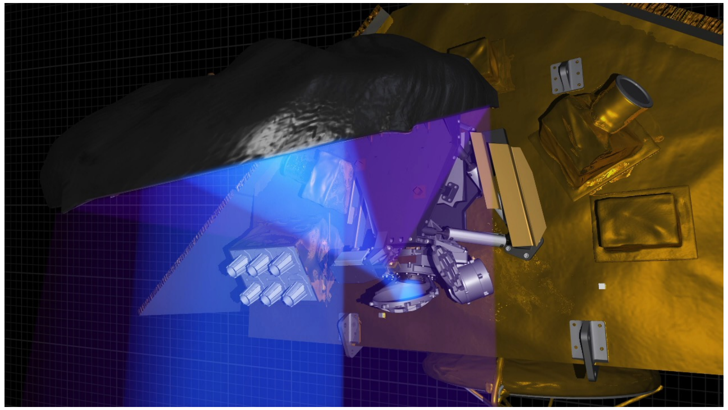




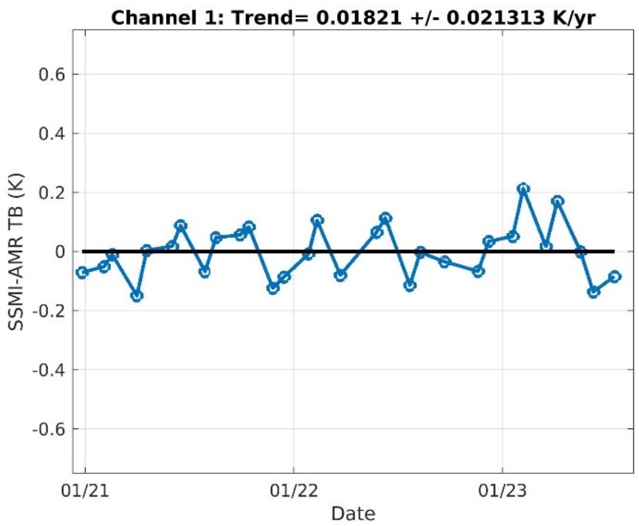
SENTINEL-6A

Sentinel 6A Compared to SSMI TBs

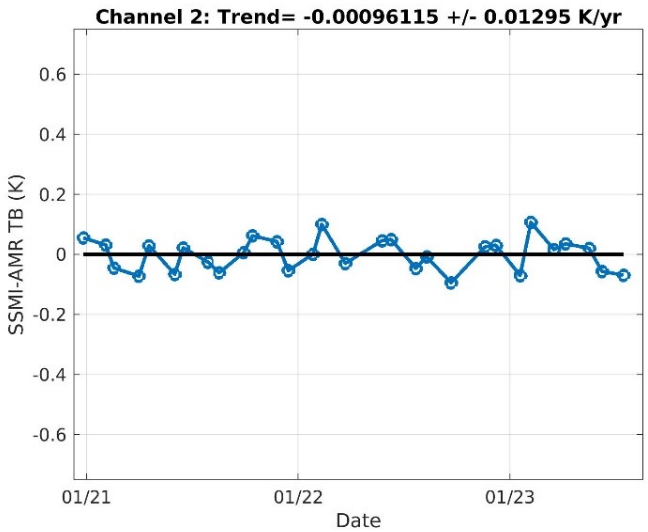
- Sentinel-6A includes an supplemental calibration system (SCS) which stabilizes the long-term calibration to < 0.7mm/yr
- No statistically significant trend in TBs detected over mission to date
  - Relative drifts < 0.02K/yr



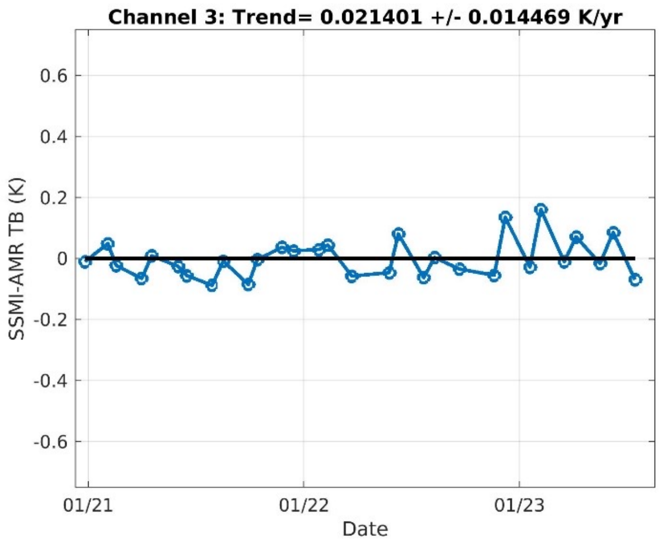
18.7 GHz SSMI-AMR



23.8 GHz SSMI-AMR



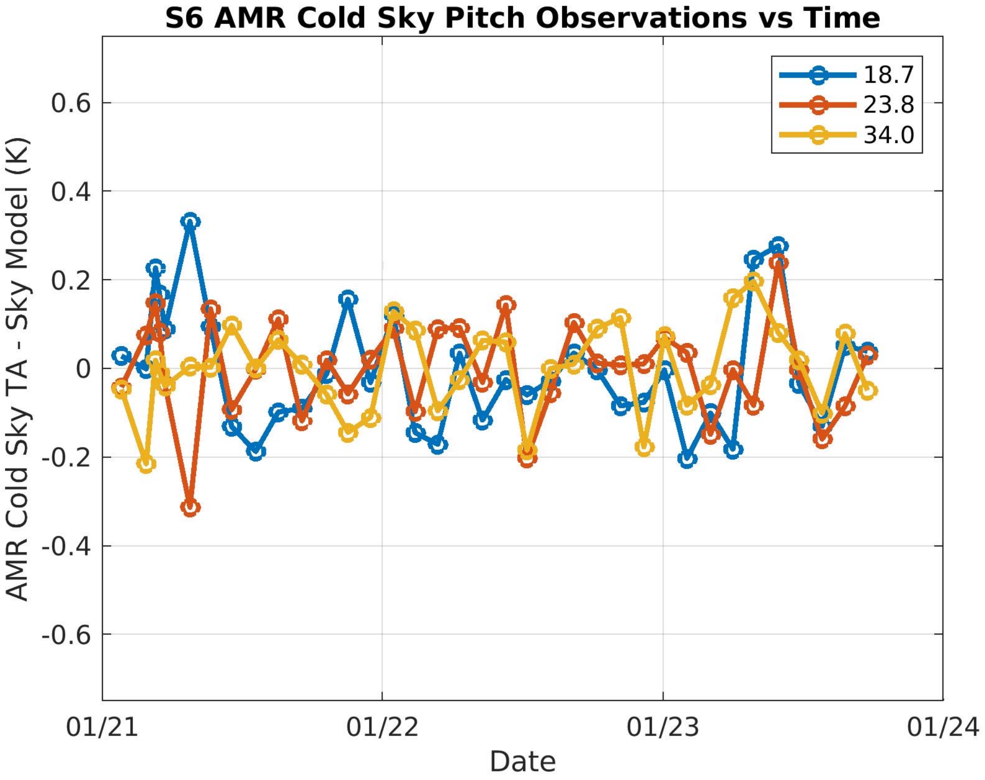
34.0 GHz SSMI-AMR



Sentinel 6A Pitch Calibrations

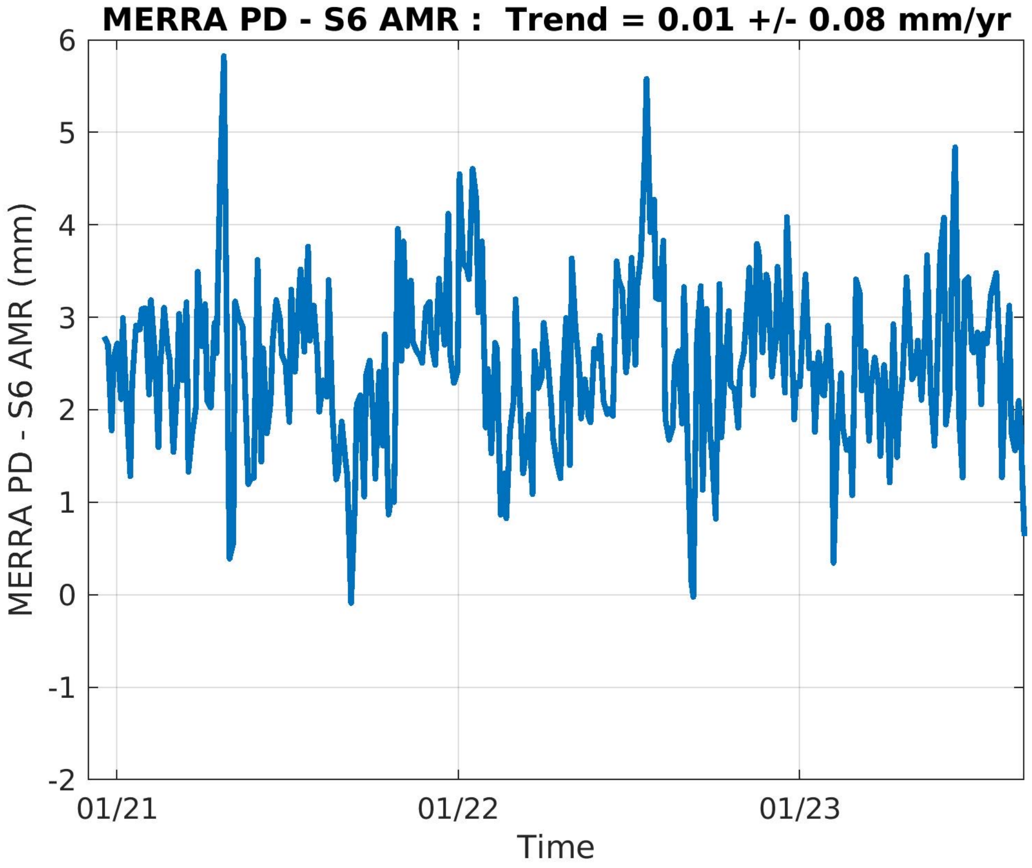
- Like Jason-3, Sentinel-6 performs monthly pitch maneuvers to point radiometer to cold space providing independent view of stable source through main reflector

- **No statistically significant trends observed**



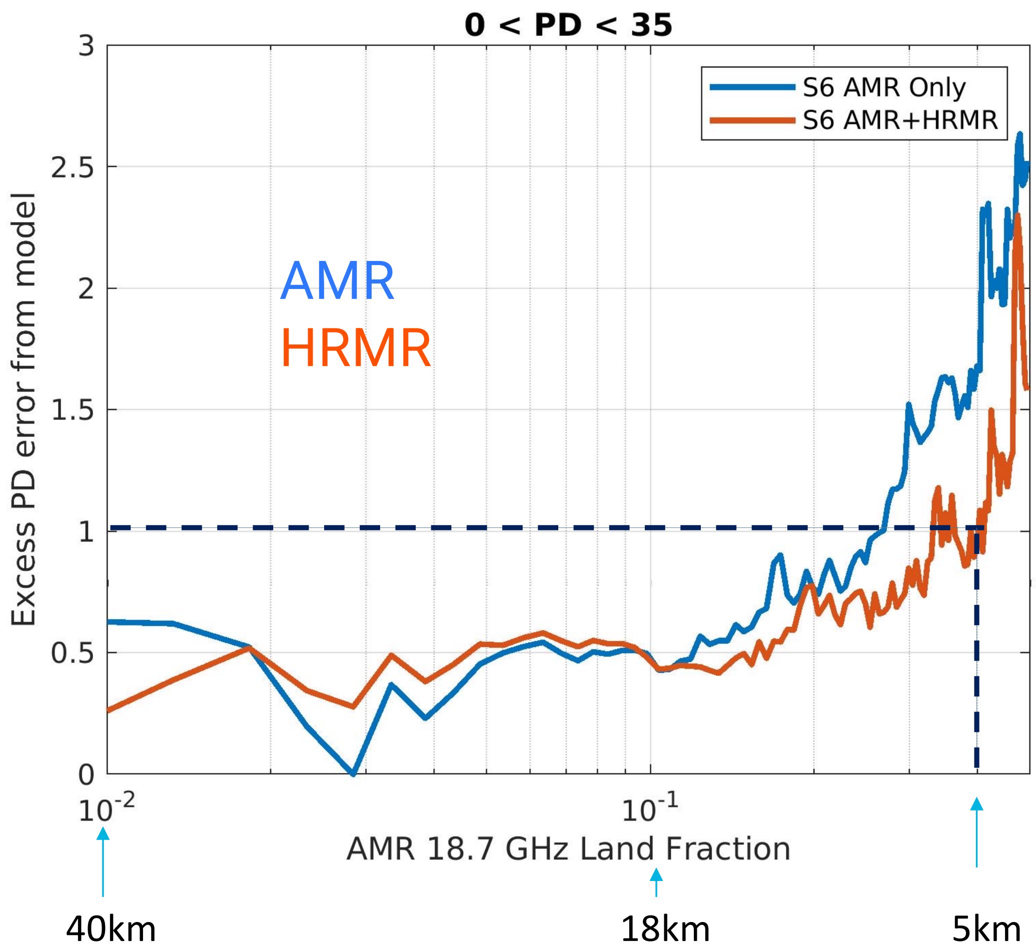
Sentinel 6A Compared to MERRA PDs

Sentinel-6A shows no significant PD drift relative to MERRA-2 PDs over 2021-2023 time period



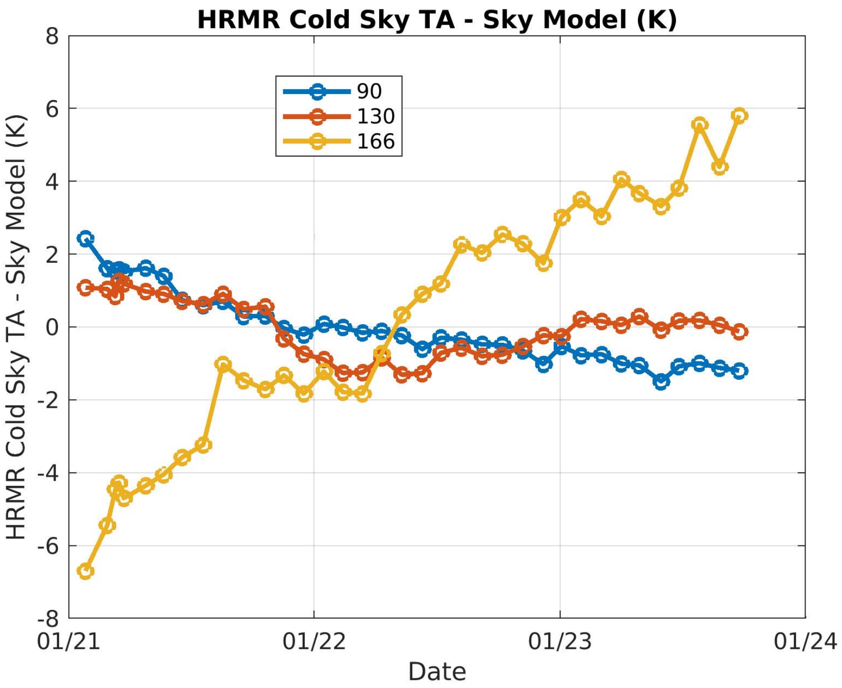
HRMR Coastal Path Delay Performance

- Computed excess error from model relative to open ocean as a function of land fraction (distance to coast)
  - Same validation approach used for AMR coastal algorithm currently in use
- HRMR+AMR has up to 50% reduction in variance from AMR only coastal PD to coast
- HRMR+AMR excess error globally less than 1 cm to 5km from land
- HRMR algorithm currently conservative, will investigate tuning that may offer further performance improvement



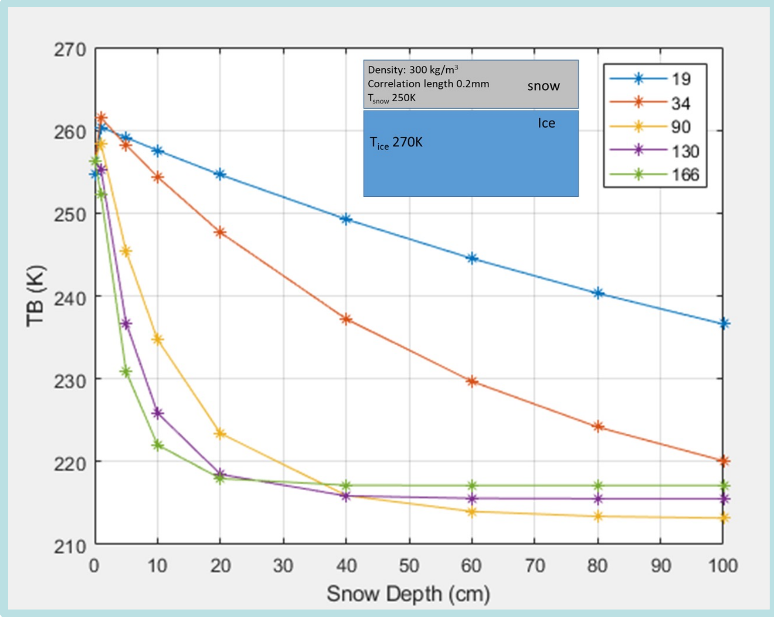
HRMR TB Trends

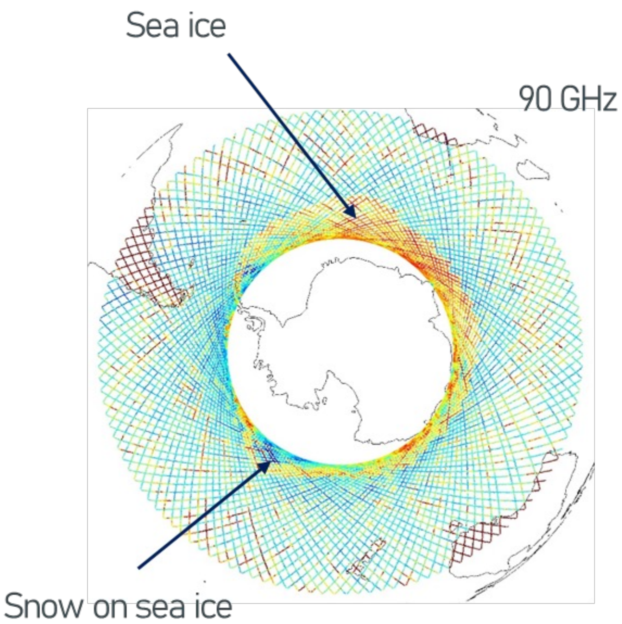
- Drift is evident in HRMR TBs relative cold sky, however appears to be gain drift and is reduces near zero for Earth TBs (which are close in magnitude to reference load)
- Will be addressed in future re-processing, however since only relative signal used from HRMR, it does not impact product quality

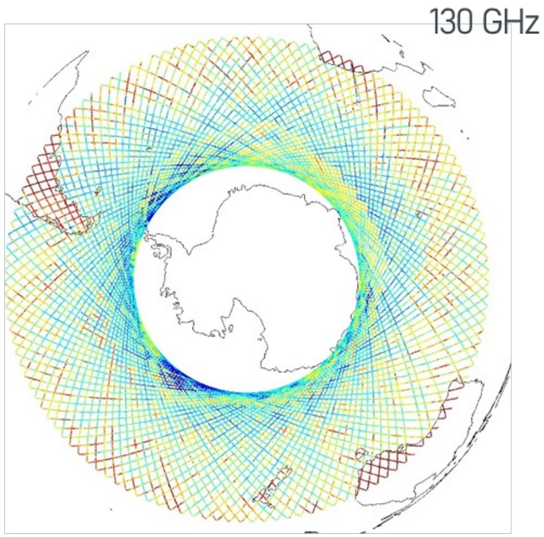


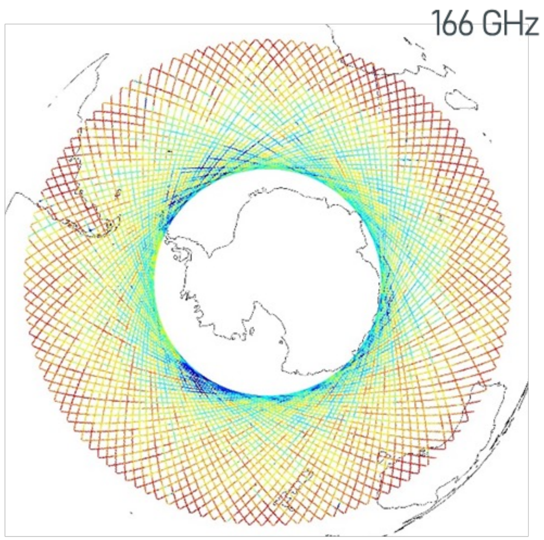
HRMR for Cryosphere

- In context of CRISTAL mission, exploring cryospheric applications of HRMR mm-wave channels
  - HRMR bands sensitive to small amounts of snow (<10cm) on land surfaces and on sea ice









Summary

- Sentinel-6A exhibiting climate quality calibration on NTC product due to new supplemental calibration system
  - No trends observed with uncertainty < 0.08mm/yr over mission to date

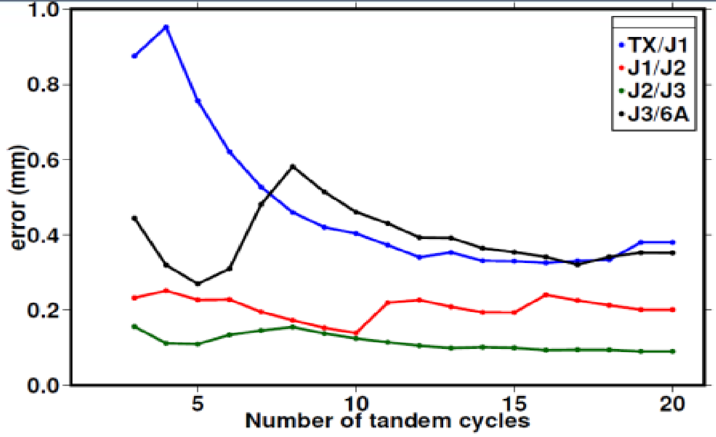
- Jason-3 long-term calibration updated and PD correction product available, appears to improve non-closure of sea level budget

- Jason-2 GDR-F long-term calibration improved over GDR-D after 2017 (un-changed before)

- HRMR working well, shows promise for new applications for cryosphere altimeter missions, including CRISTAL

TOPICS

Climate requirements on reference missions (S6 and S6 Next Gen)



1) Require multiple tandem phases?

Will requiring the tandem phases require future missions to remain in the reference orbit?

2) Change the intermission bias requirement?

The current requirement for S6 is 1 mm, which may be too large for climate science.

3) New system stability (drift) requirements?

Climate science question	Accuracy in GMSL rates ($mm\,yr^{-1}$)	Accuracy in GMSL acceleration ($mm\,yr^{-1}$ per decade)	Accuracy in regional sea-level rates ($mm\,yr^{-1}$)
Closing the sea-level budget	Detection[a,b]: ±0.1 Quantification[a,b]: ±0.02	–	Detection[c,d]: ±0.3 Quantification[c,d]: ±0.07
Detecting and attributing the signal in sea level that is forced by GHG emissions	Detection[b,e]: ±1.5 Quantification[b,e]: ±0.7	–	Detection[d]: ±0.5 Quantification[d]: ±0.1
Estimating the EEI	Detection[d,f]: ±0.1 Quantification[d,f]: ±0.03	Detection[d,g]: ±0.5 Quantification[d,g]: ±0.1	

Meyssignac et al. 2023

Future planning for Jason-3

The current plan for the Jason-3 mission extension includes a 2nd tandem phase in 2025 with Sentinel-6MF to reduce the uncertainty in the mean sea level record, which the OSTST had recommended.

What happens after that?...

In light of the early results from SWOT, should we consider changes to the recommended plan?

- Interleaved phase (April 2022 to early 2025)
- Tandem phase (4-6 months)
- Long-repeat orbit (2 complete cycles, ~2 cycles)
- Final orbit

Future planning for Jason-3

Questions to be discussed:

- Is Long-Repeat Orbit (LRO) still necessary?
- If not, which kind of mission phase (after tandem) will make better return for the communities?

Options:

1. Go to the LRO orbit after the second tandem (current baseline)
2. Return to the interleaved orbit until Sentinel-6 MF joins Jason-3 on the interleaved track in ~2026
   - Should there be a third tandem?
   - And which kind of mission phase after that?
3. Go to another orbit phase after the second tandem
   - Which kind of mission phase is preferred?

Please provide strong arguments for your preferred solution.