Jason-3 GDR Calibration Stability Enabled by the Cold Sky Maneuvers

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Jason Radiometer Calibration

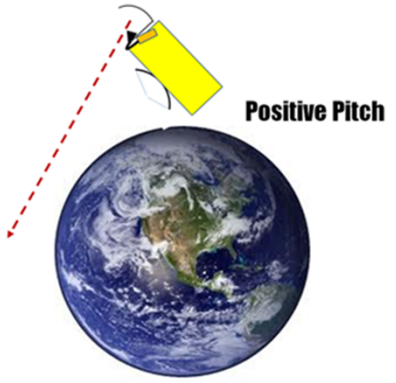
- Radiometer wet path delay drift has been largest component of uncertainty on satellite derived GMSL trend

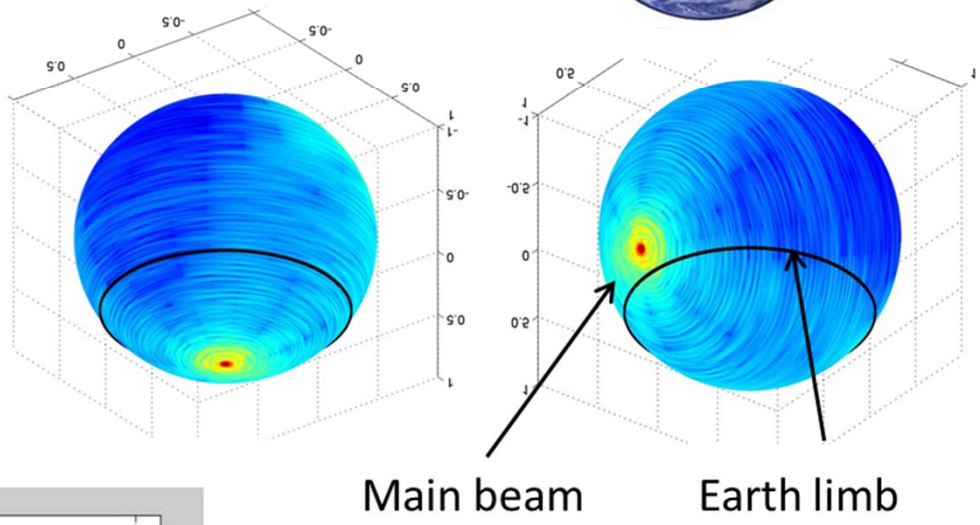
- Jason radiometer requires calibration to external stable sources to meet mm/year path delay stability requirements
  - Vicarious on-Earth calibration targets have been used since no on-board external calibration hardware are included
  - Can lead to uncertainties in climate data record due to potential systematic changes in the vicarious calibration sources

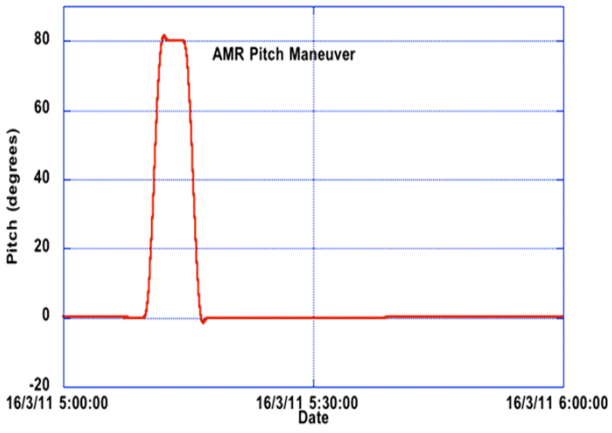
- Jason-3 mission was the first altimeter mission to implement special spacecraft calibration maneuvers for improving the long term climate calibration of the radiometer
  - Jason-2 followed Jason-3 and currently performs routine CSMs

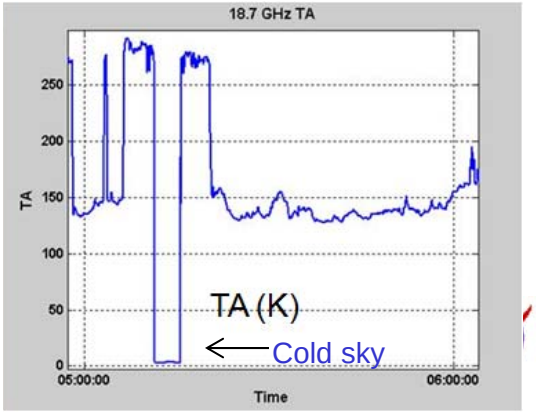
Cold Sky Calibration

- Cold sky calibration performed by rotating the spacecraft which provides a calibration reference through the same path as the Earth scene
- Presents stable 1-point calibration to the radiometer
- 2-stable points required for complete calibration, therefore cold sky maneuver supplemented by on-Earth references

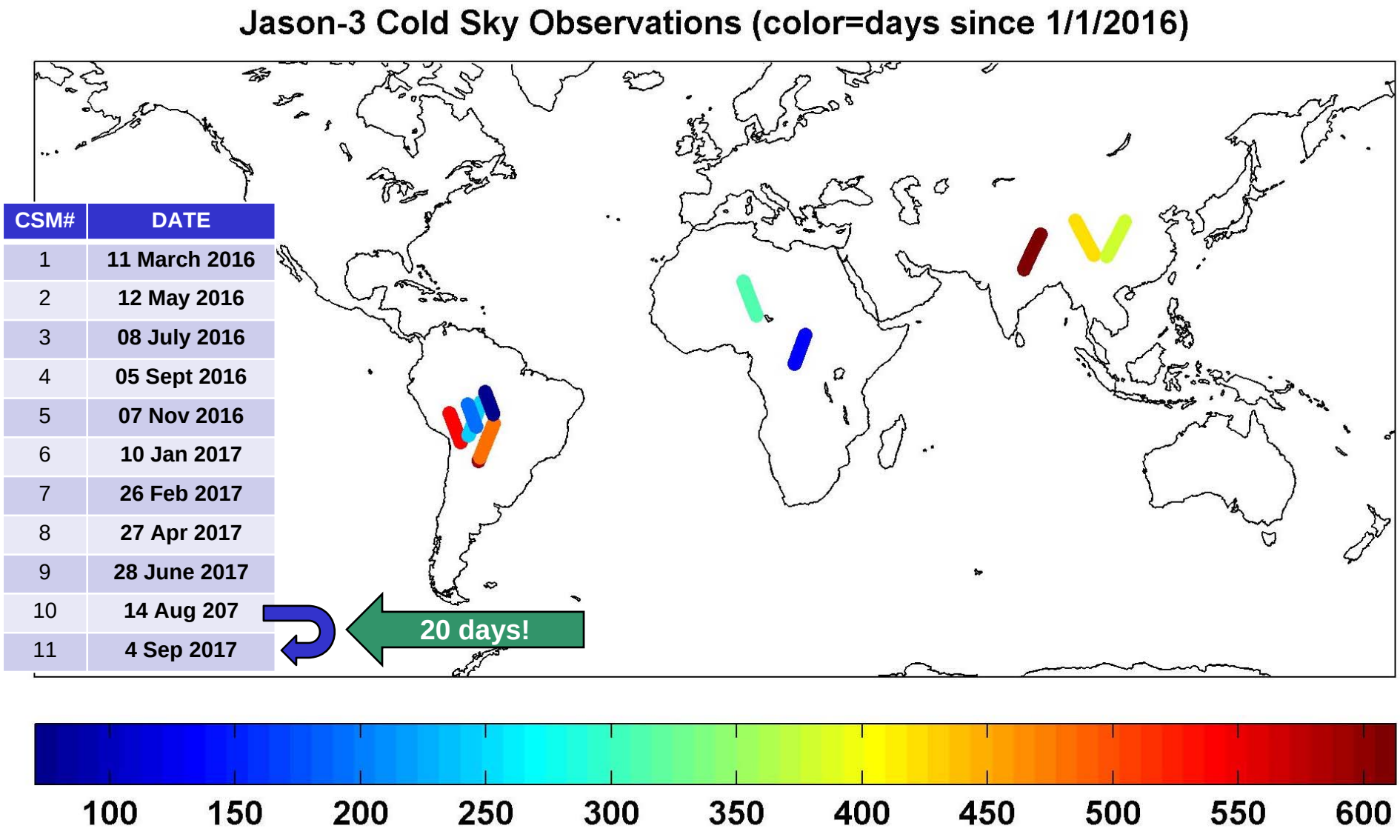








Cold Sky Calibrations to Date

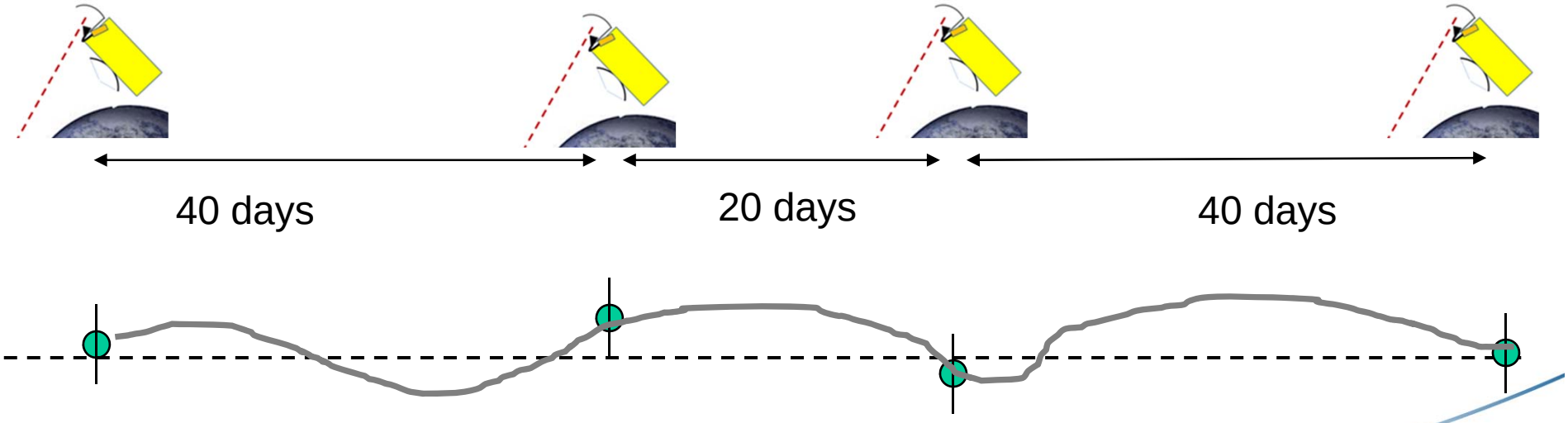


CSM#	DATE
1	11 March 2016
2	12 May 2016
3	08 July 2016
4	05 Sept 2016
5	07 Nov 2016
6	10 Jan 2017
7	26 Feb 2017
8	27 Apr 2017
9	28 June 2017
10	14 Aug 207
11	4 Sep 2017

New Cold Sky Calibration Schedule

- At last OSTST, we agreed to implement a GDR processing schedule based on cold sky calibrations which increased latency to upwards of 90 days

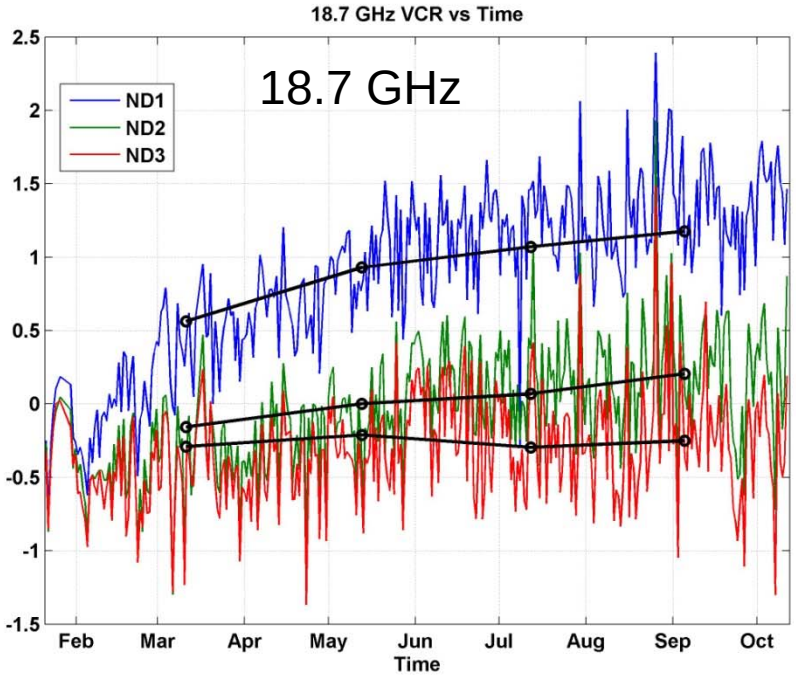
- OSTST also recommended more frequent cold sky calibrations, which was evaluated and recently implemented by CNES
  - Fixed yaw period extended
  - Cold sky calibrations now performed at beginning and end of fixed yaw periods (~20 day latency)
  - Shortens GDR calibration latency overall



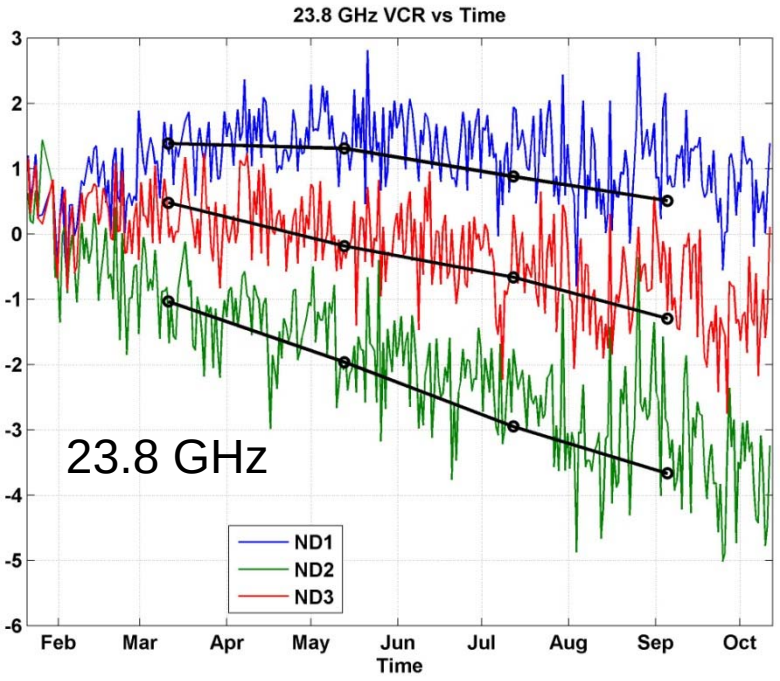
JA3 Drift – VCR and Cold Sky

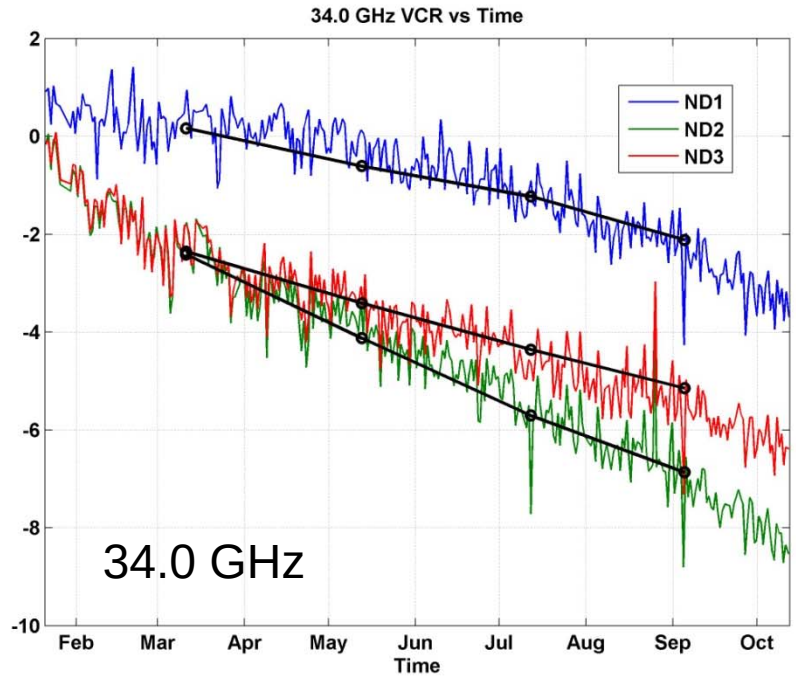
- Since launch, Jason-3 AMR has been drifting
  - Observed in cold sky measurements and vicarious ocean reference
- Percentage drift computed from cold sky measurements consistent with that computed over the ocean
  - Suggests drift is isolated to noise diodes (e.g. gain drift)

$$\frac{\Delta T}{\left(T_{REF} - T_{MODEL}\right)}$$



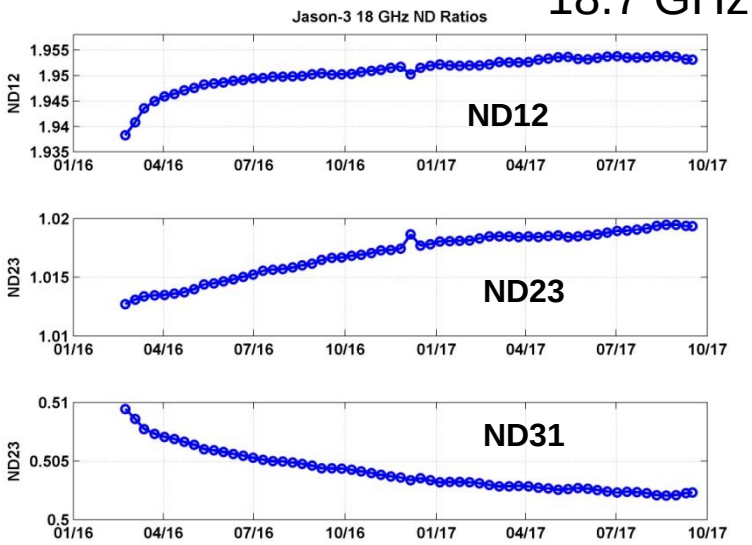
ND1
ND2
ND3



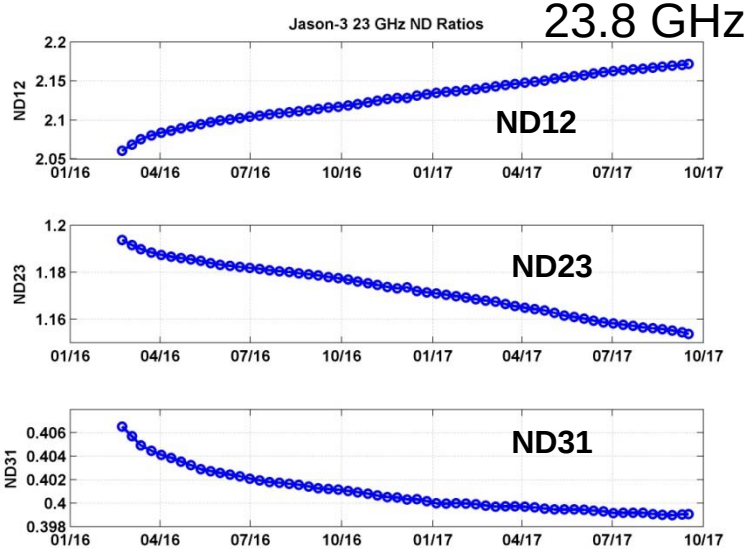


Noise Diode Ratios

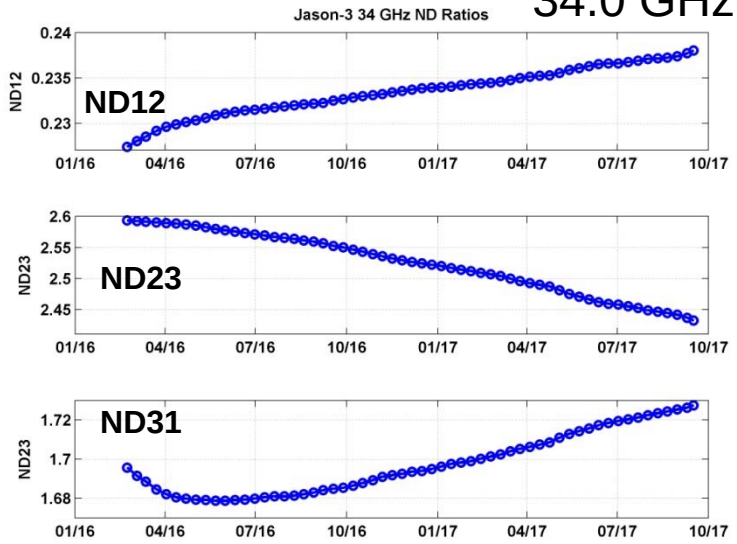
18.7 GHz



23.8 GHz



34.0 GHz

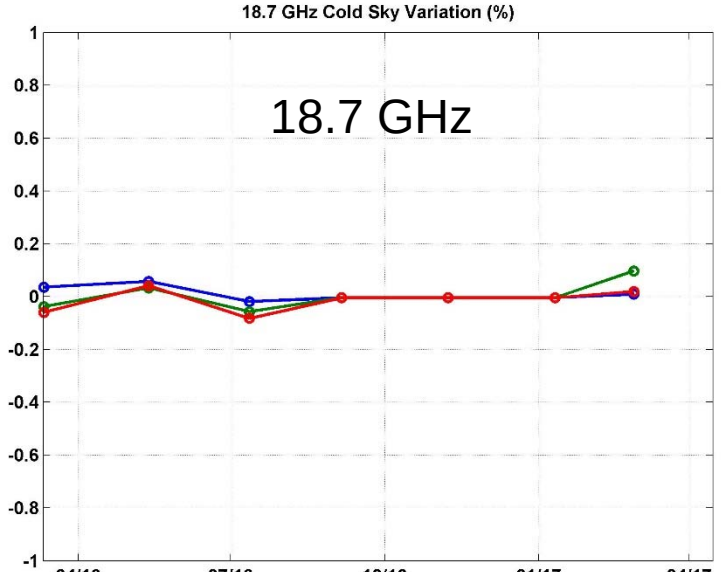


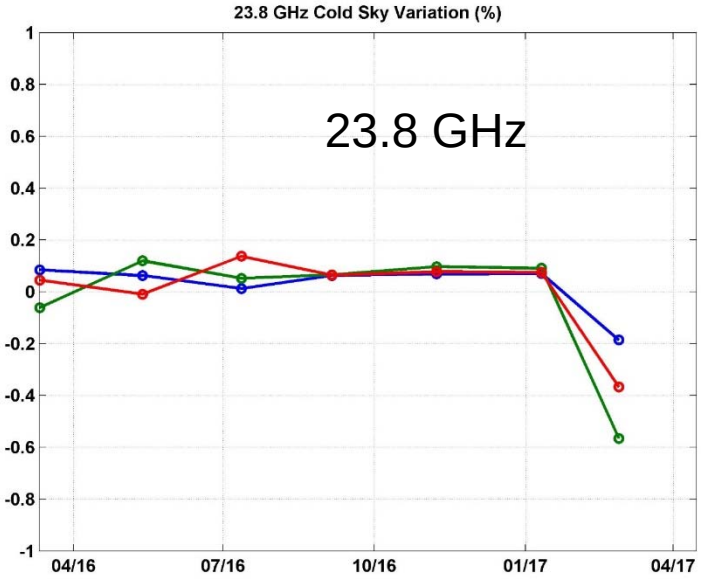
- Ratio of signal between noise diode pairs in the AMR show drifts, giving further evidence of source of drift in TB
- Curves show exponential delay, consistent with out-gassing as an explanation of cause

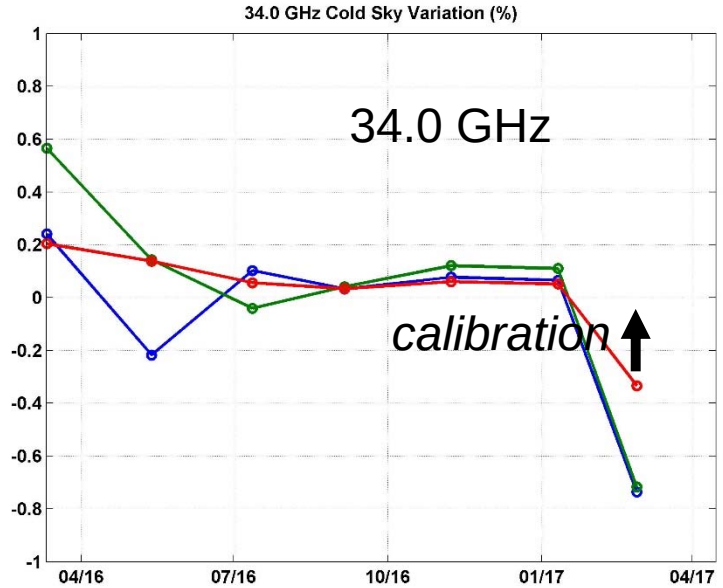
Correction Approach

- New noise diode coefficients are determined for each cold sky calibration
- Linear interpolation performed between 60-day cold sky calibrations
- Coefficients discretized to once per day in coefficient file

$$\Delta T_{ND}(t) = \frac{\partial T_{ND}}{\partial T_{sky}} \left(T_A^{AMR}(t) - T_A^{SKY}(t) \right)$$







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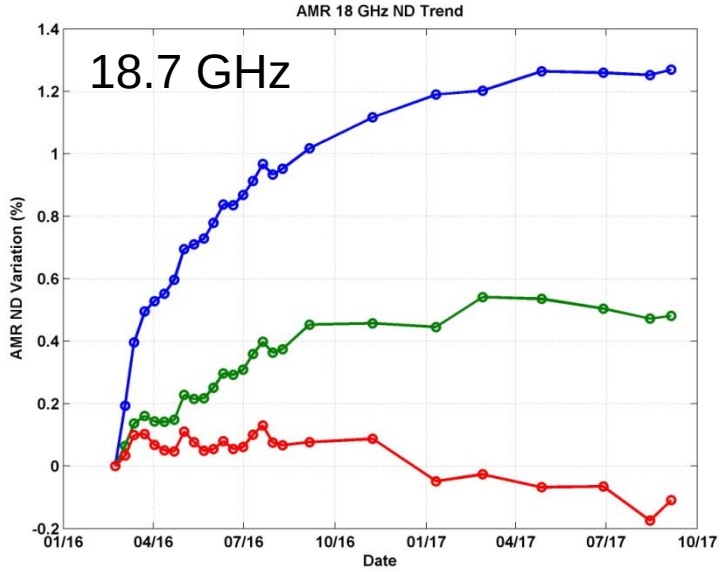
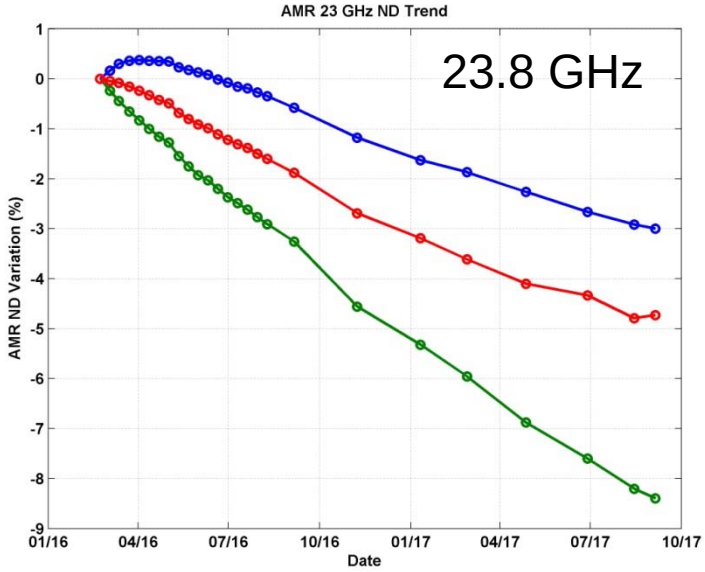
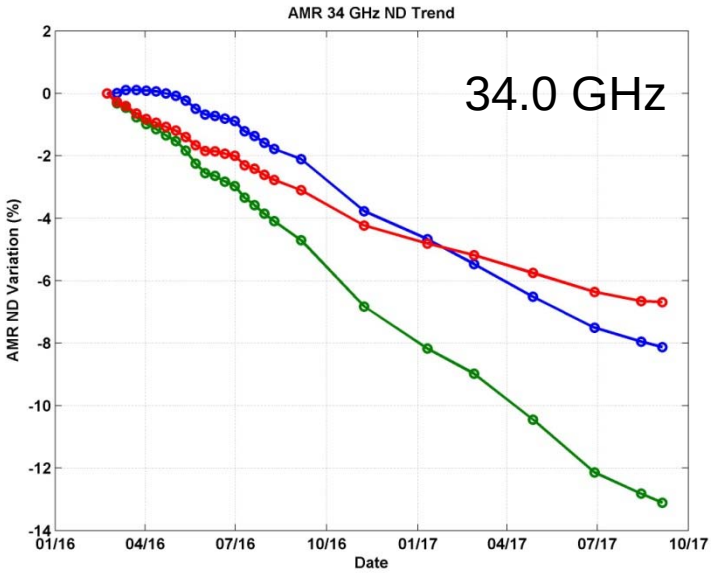
Derived Noise Diode Variation

ND1
ND2
ND3

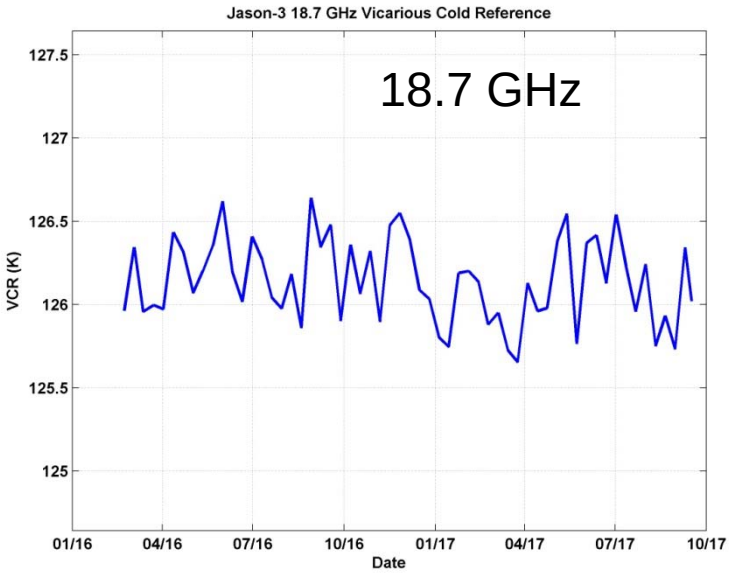


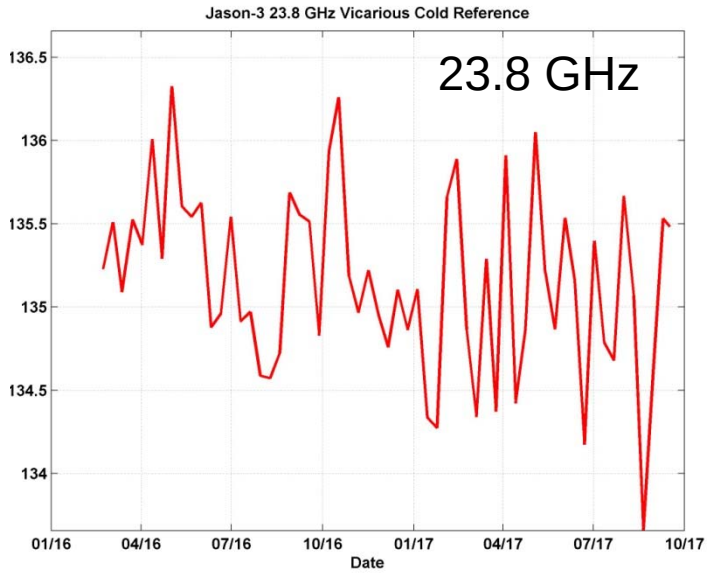




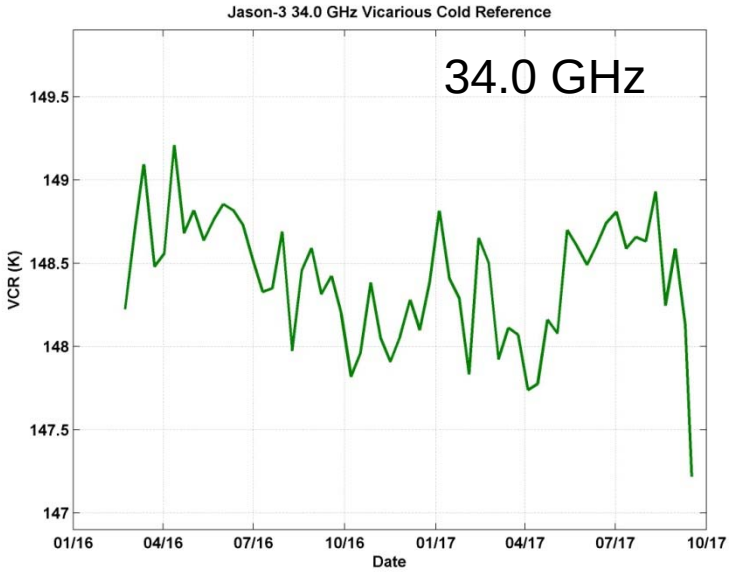
- ND brightness stabilized at 18.7 GHz
- Smooth, monotonic drift remains for 23 and 34 GHz channels
  - Upwards of 13% change at 34 GHz
  - Larger than Jason-1 and Jason-2
- Investigation underway at JPL to understand cause

Vicarious Cold Reference – After GDR Correction



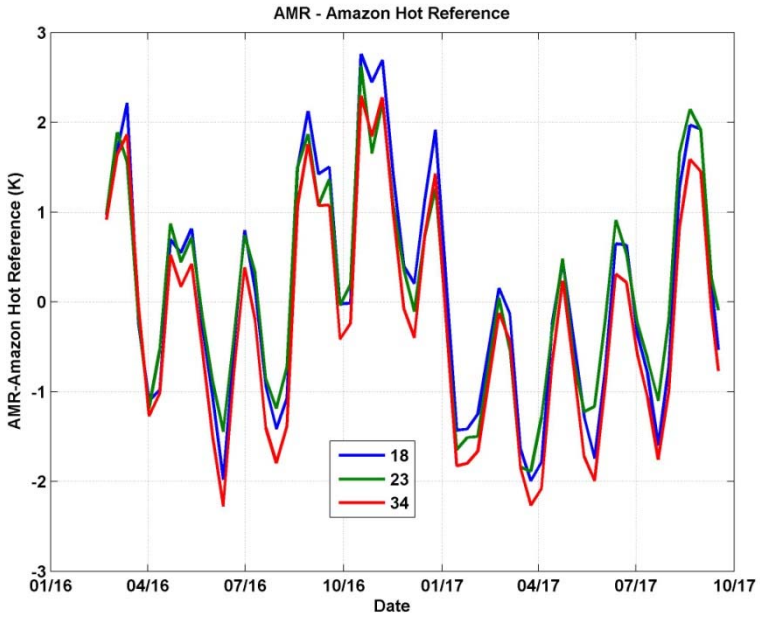


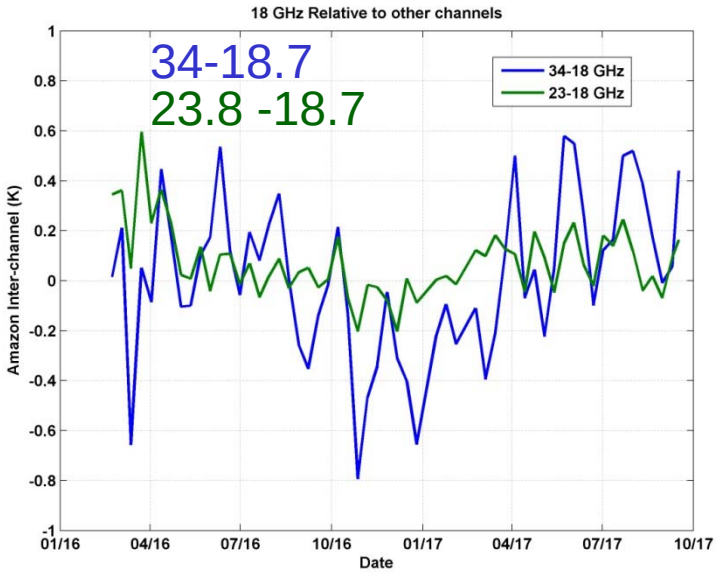
- Vicarious cold ocean reference offers an independent validation of the cold sky drift removal
- No evidence for statistically significant drift in ocean reference in GDR calibration over mission to date

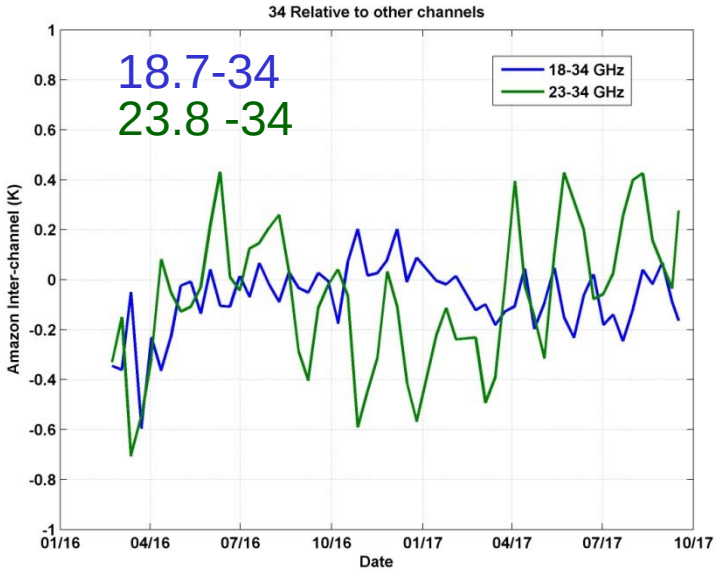


Amazon Hot Reference – After GDR Correction

18.7 GHz
23.8 GHz
34.0 GHz



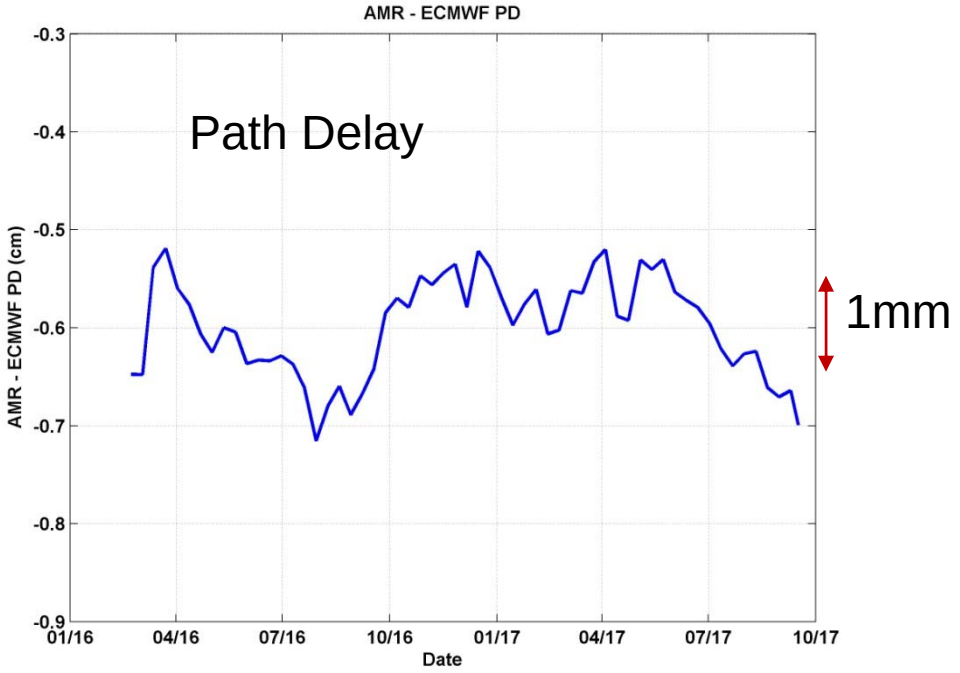


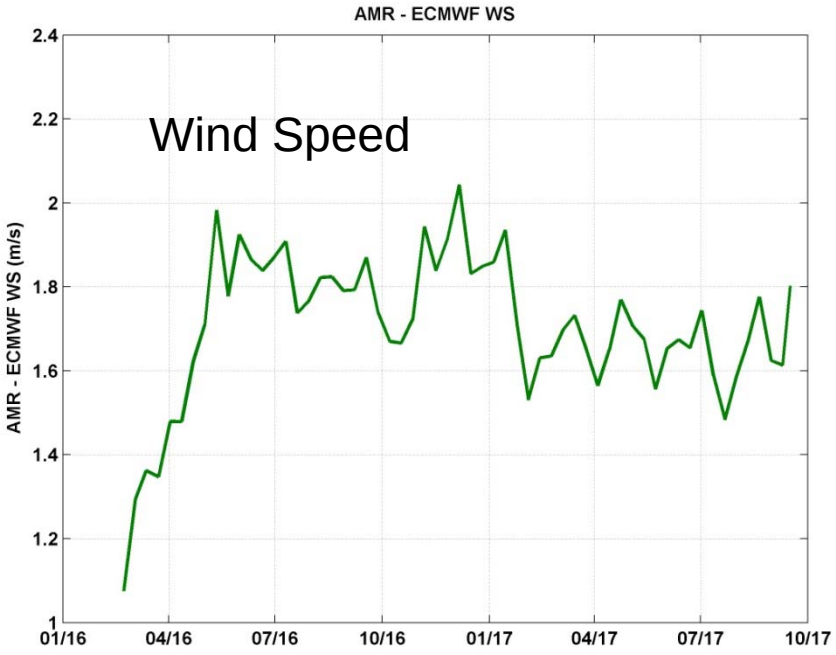


- No evidence for offset calibration drift at hot end of TB spectrum
  - ~1-2K uncertainty in hot TB vs time
- Inter-channel differences provide finer assessment of hot end (offset) stability
  - No evidence for offset drift greater than 0.1K

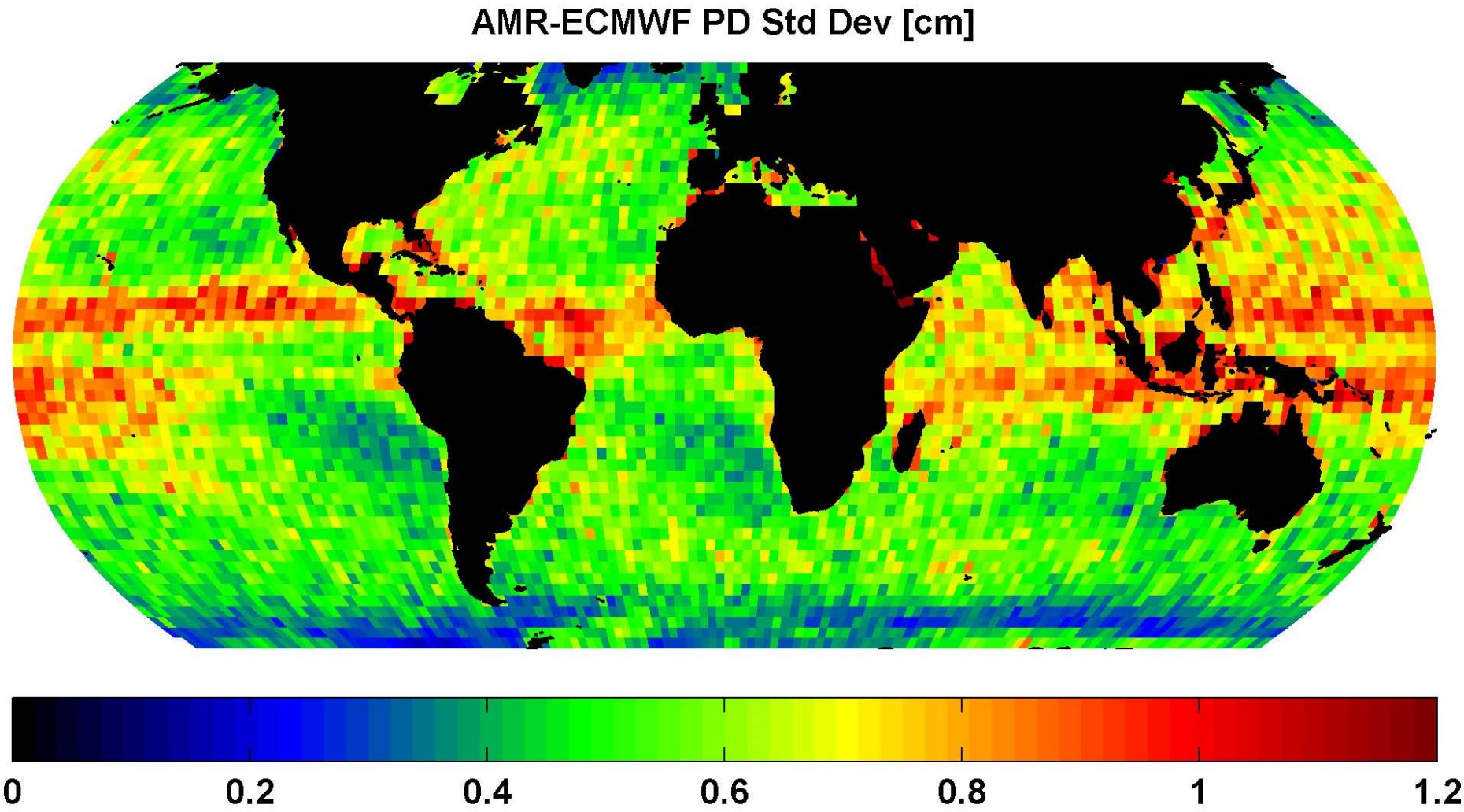
Geophysical Comparisons – GDR Calibration

- J3 AMR PD relative to ECMWF stable to +/- 1mm over mission to date
- Wind speed (which is more sensitive) stable to +/- 0.2 m/s past June 2016
- Both offer independent validation of cold sky calibration

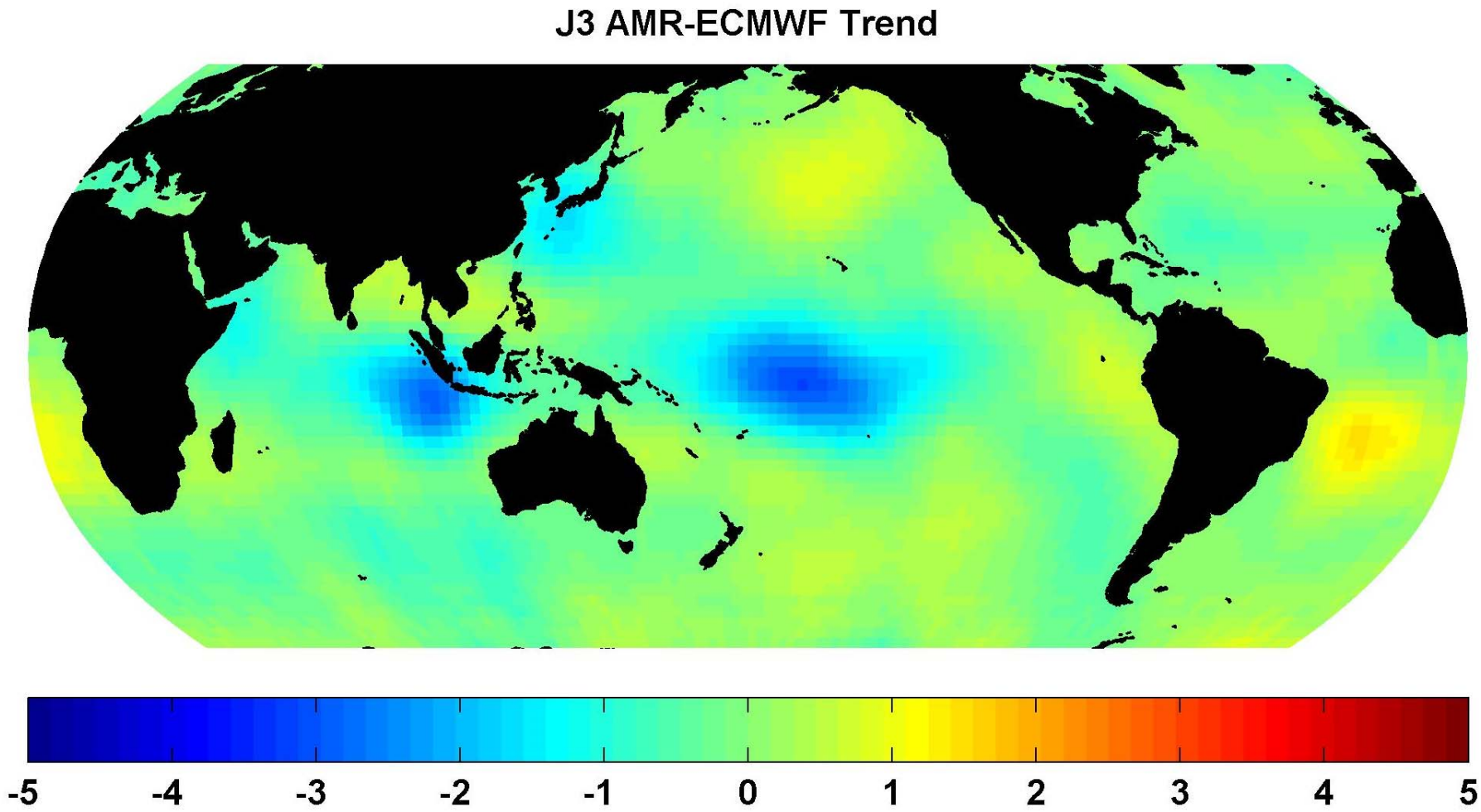




2.5º Cycle Average Standard Deviation



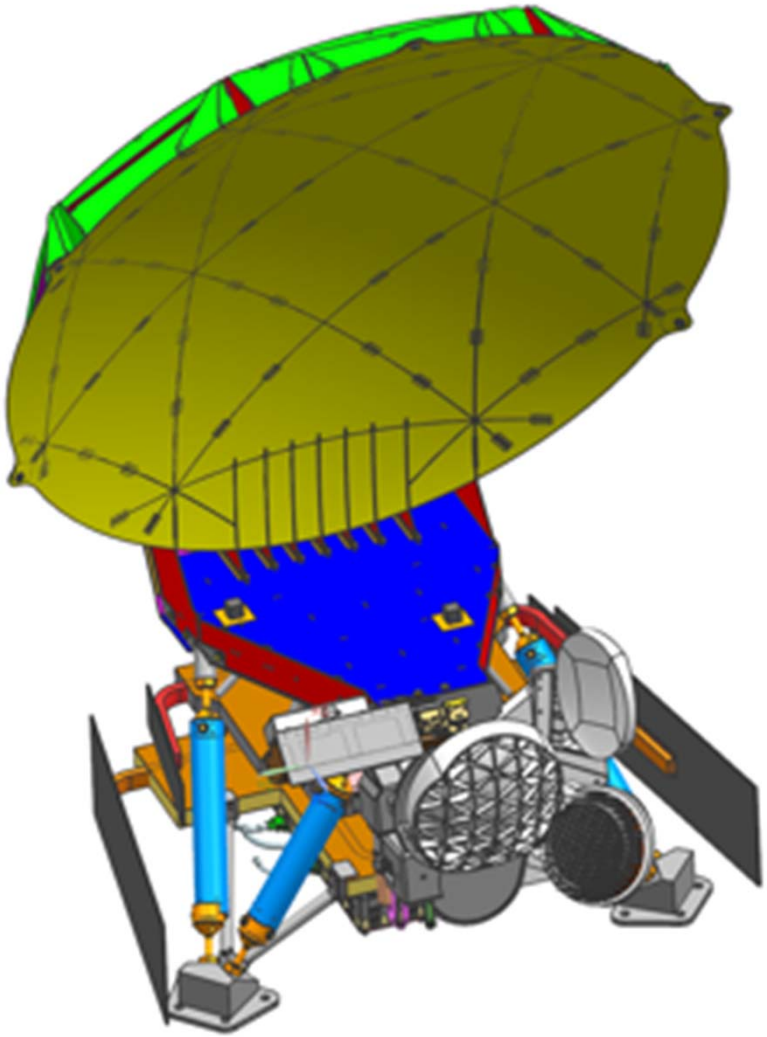
12.5º Linear Trend [mm/yr]



Summary

- Cold sky calibrations are critical to stabilizing Jason-3 AMR
  - CSCs combined with on-Earth ocean and land references suggest drift is isolated to noise diodes
  - Allows single-point calibration using only cold sky data
  - Radiometer is stabilized to ± 0.1K level
- Path delays stabilized to better than ± 1mm over mission
- More frequent calibration schedule implemented by CNES will reduce overall GDR latency
  - 20-day latency achieved after most recent calibrations
  - Makes derived calibration more robust to shorter term radiometer instability

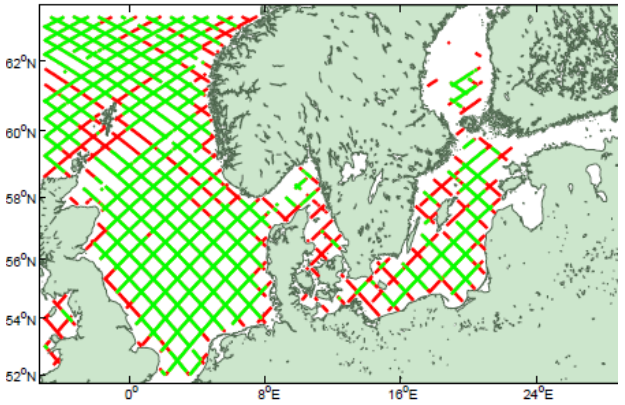
Sentinel-6 / Jason-CS

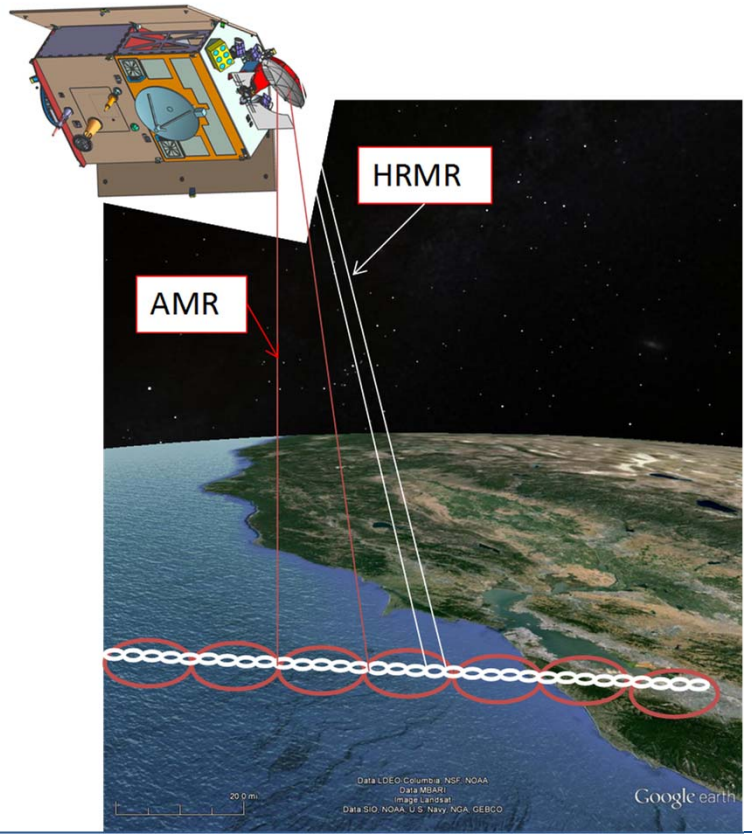


- Sentinel-6 will carry the AMR-C, the first specially designed climate quality microwave radiometer
  - Includes external blackbody calibration targets to stabilize radiometer to < 1 mm/yr
  - Calibration available with < 5-day latency

Sentinel-6 / Jason-CS HRMR - Coastal Altimetry

- The High Resolution Microwave Radiometer was recently baselined for Sentinel-6
  - Three high-frequency channels to improve accuracy of PD retrieval to 5km from land
  - Includes 90, 130 and 166 GHz channels with 2-5km spatial resolution





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