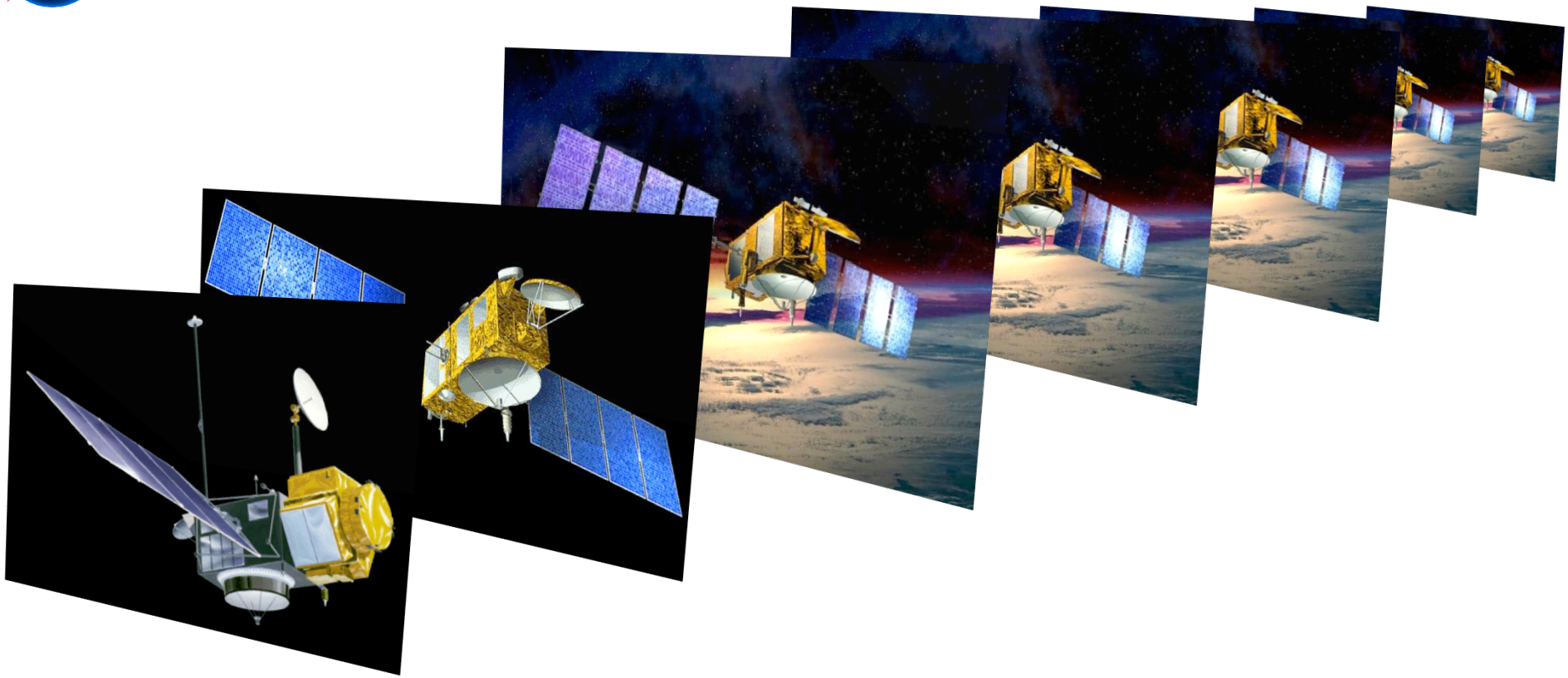

On the Long Term Stability of the Radiometer Wet Tropospheric Path Delay Retrieval: Past, Present and a Proposal for the Future on Jason-3

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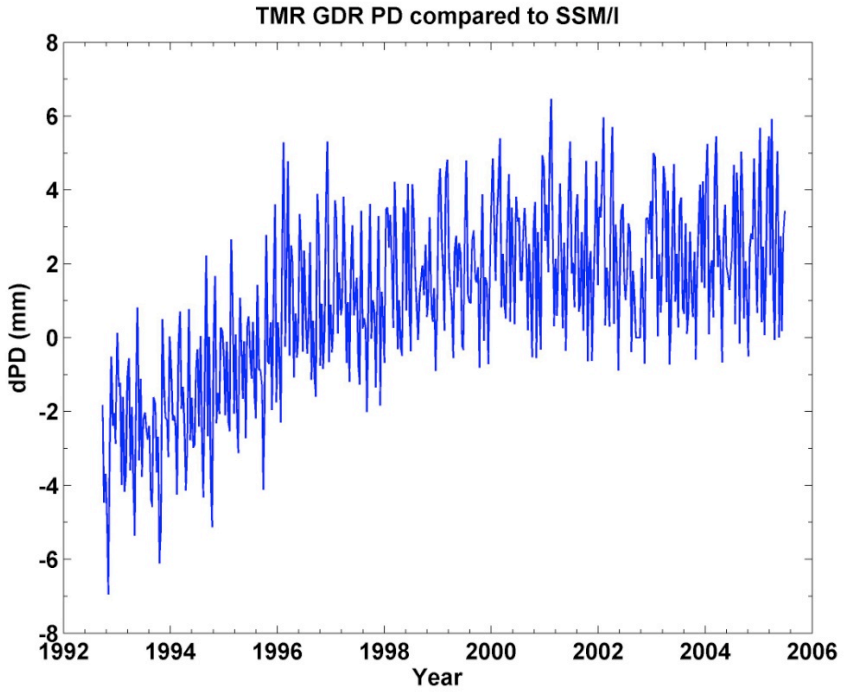
Radiometer Long Term Calibration: Past

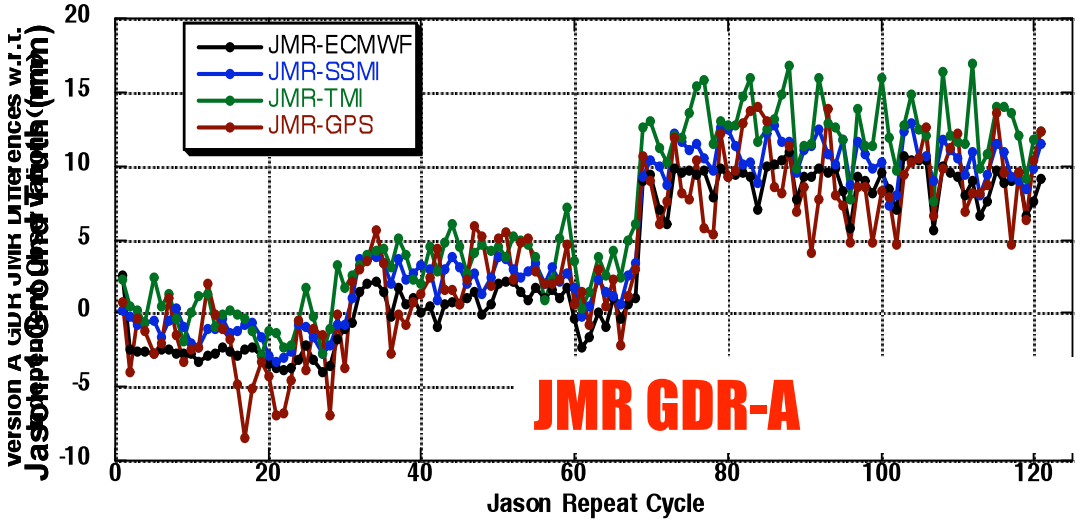
- mm-level long term stability is a demanding requirement for the radiometer
  - < 0.1 K brightness temperature stability
- Radiometers on Topex, Jason-1 and Jason-2 rely on periodic post-launch re-calibration to maintain long term stability
  - Radiometers use internal calibration technique, susceptible to change on-orbit
- On-orbit calibration techniques matured during Topex/Jason-1 era
  - Radiometer calibrated to on-Earth brightness temperatures references
  - Path delays validated against models and other sensors
- Periodic re-calibration performed off-line using multi-year data record
  - Calibration updated on official products infrequently, during GDR re-processing cycles
  - Replacement products made available

Observed TMR and JMR PD Instability



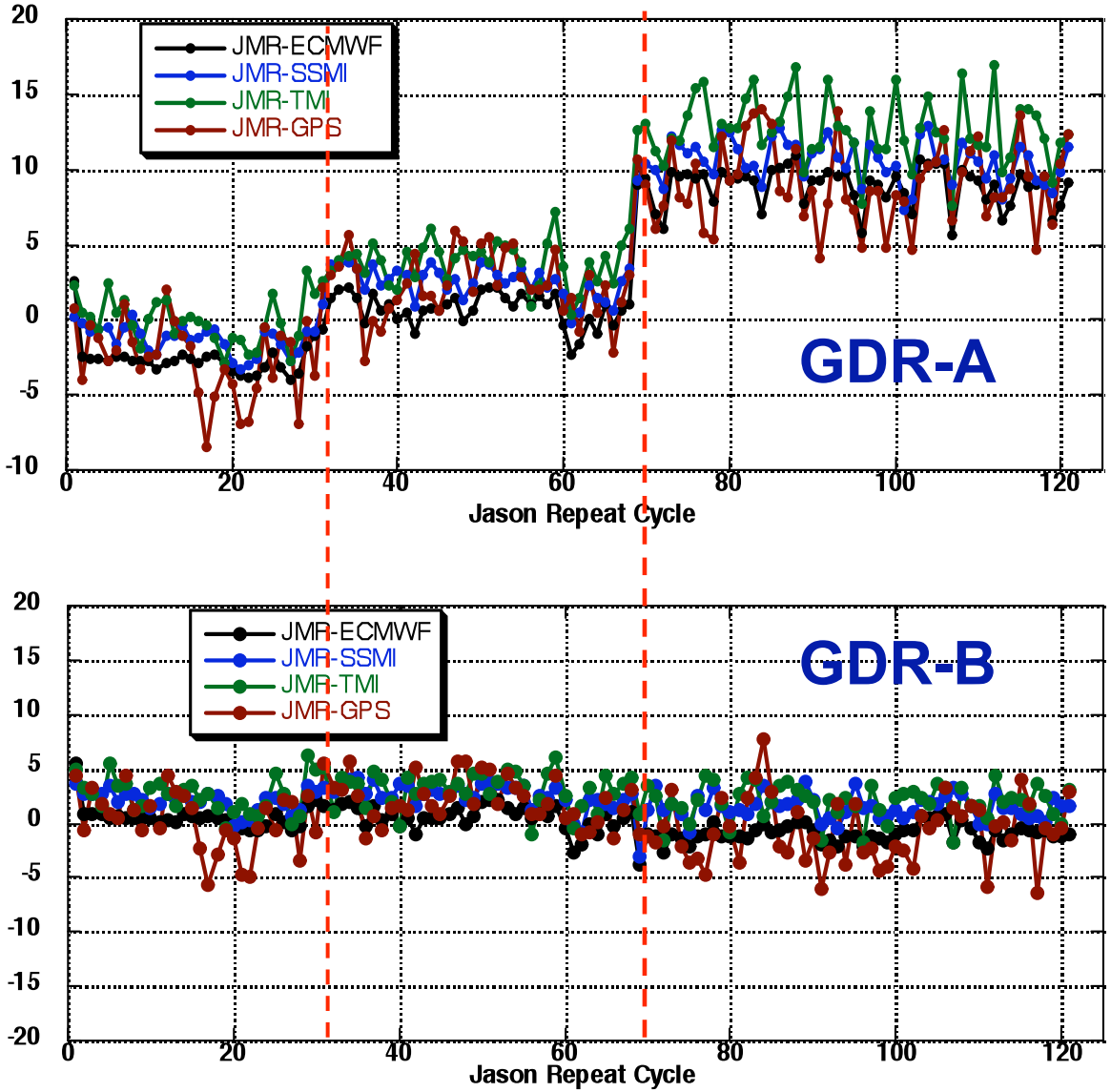
- TMR drifted at a rate of about 1 mm/year over the first 6 years of the mission

Observed instability significant compared to sea level rise signal



- JMR exhibited two jumps of about 5 mm then an additional 8 mm
  - 6mm/year when treated as drift

On-orbit Recalibrated JMR

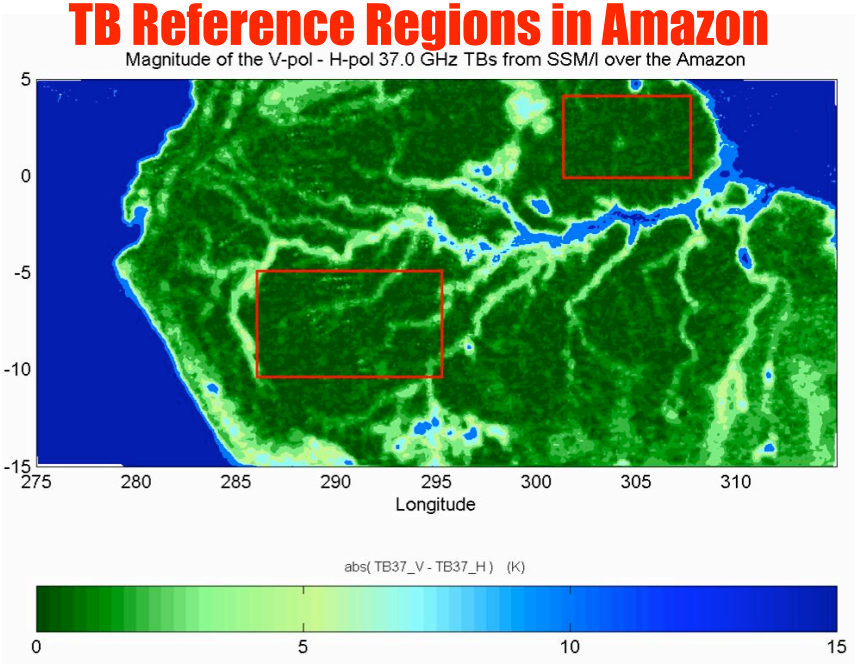


- JMR tuned to on-Earth brightness temperature references for GDR-B
- Eliminates large jumps in PD record

Limitations of On-orbit Recalibration

- **On-orbit references sensitive to climate variability; require corrections; risk of aliasing geophysical signals**
- **Need to acquire sufficient data to reach mm-level**
  - **30+ days of data required to reach 2-4 mm level**
- **Validation of recalibrated product at mm/yr level against other models/sensors challenging**
  - **Uncertainty near ± 1mm/yr level**

TB Reference Regions in Amazon



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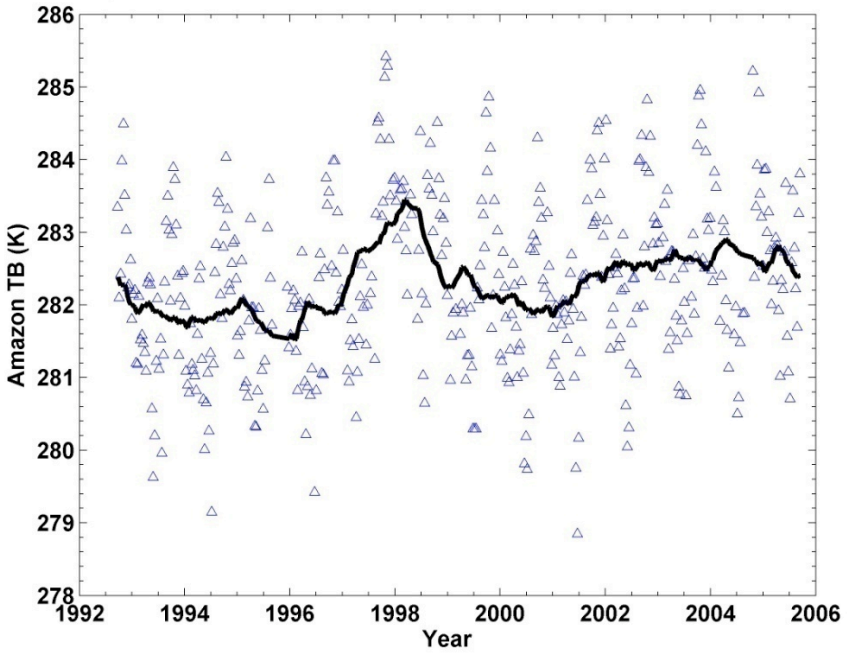
Observed TMR 18.0 GHz Amazon TBs



Radiometer Long Term Calibration: Present

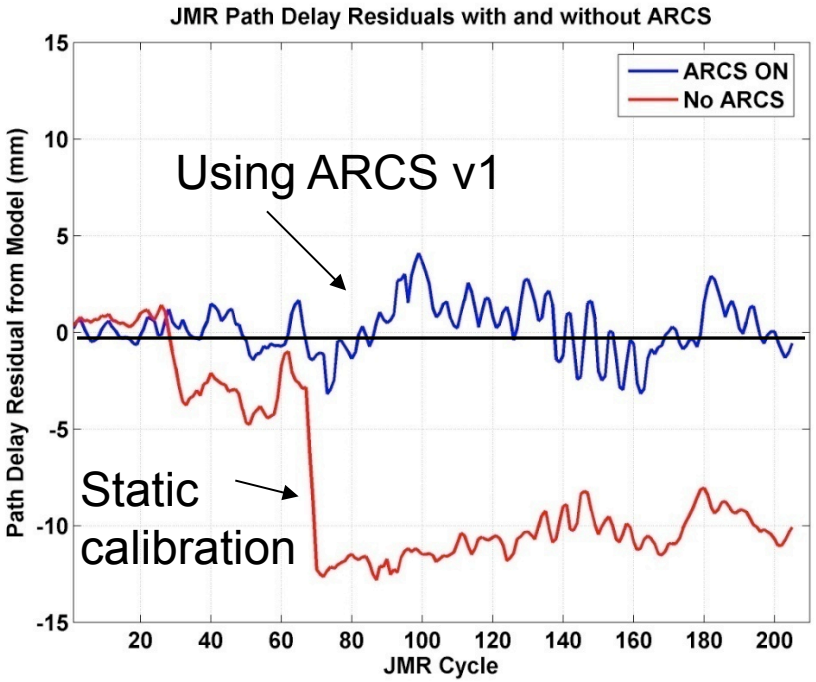
- Significantly improved radiometer design for OSTM
  - Significant advances made with radiometer on OSTM to improve long term stability and to minimize need for on-orbit re-calibration
- To ensure long term calibration for data on GDR, operational on-orbit calibration system developed for OSTM AMR

- Autonomous Radiometer Calibration System (ARCS)
  - Runs in ground processing system at JPL
  - Used to operationally monitor calibration and detect and correct changes prior to GDR production
  - Provides best operational calibration prior to GDR release
  - Fine tuning of calibration using several years of data may still be required for climate data record
  - **Note: same limitations of on-orbit calibration apply, ARCS only improves timeliness**
- ARCS automates on-orbit calibration techniques developed over past 15+ years with TMR and JMR
  - Uses current GDR processing cycle + 2 future cycles (30 day latency)
  - Only uses TBs to recalibrate, PD comparisons used for detection and validation only

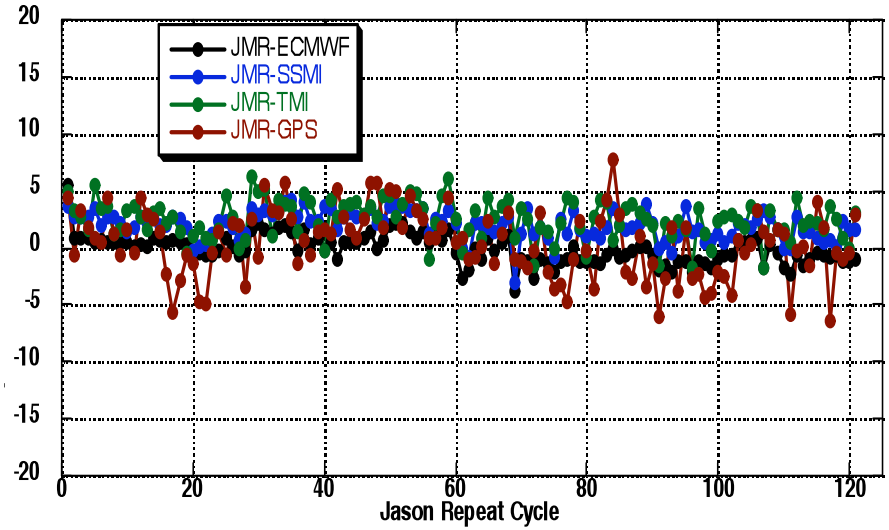
If ARCS Was Used with JMR

- ARCS v1 tested on 6 years of JMR data
  - Recalibrated a total of 26 times out of 206 cycles tested
- Significant improvement observed with ARCS turned on (blue line)
  - Long term drift eliminated with ARCS

Path Delay Residuals from Model

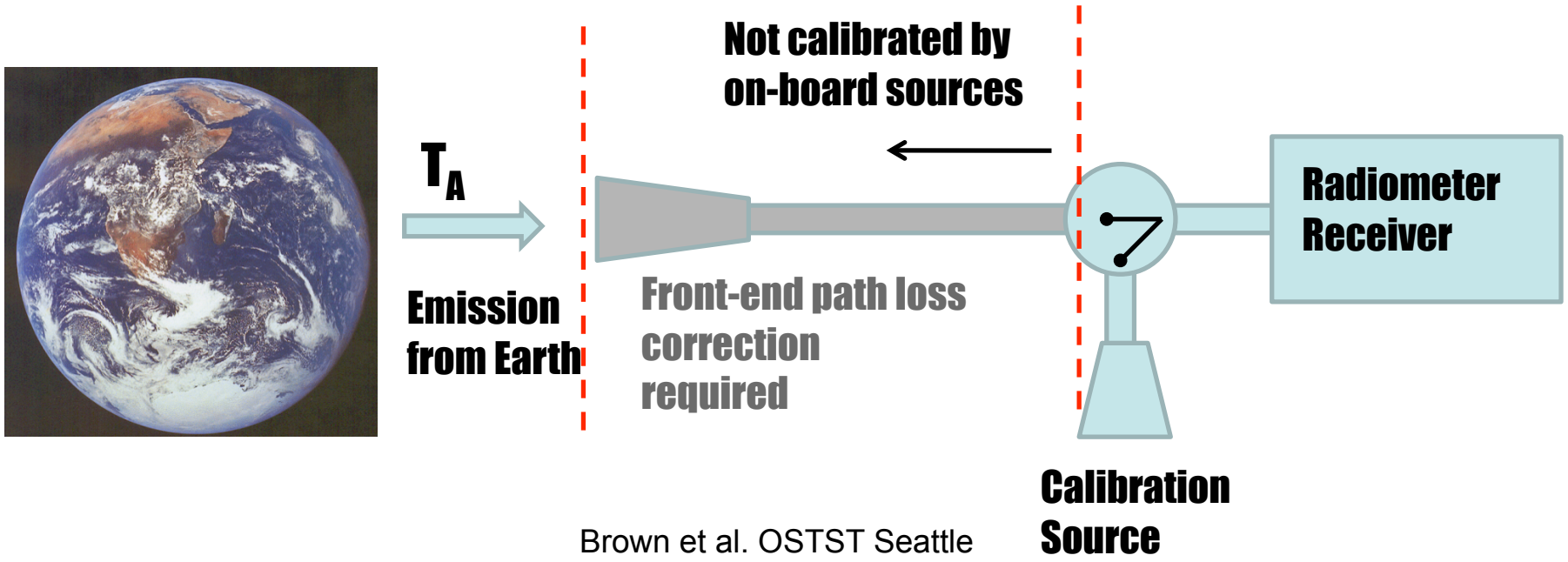


GDR-B



Radiometer Long Term Calibration: Future

- Radiometers on Topex, Jason-1 and Jason-2 all use internal calibration approach
- This design is not optimal for climate applications
  - Advantage: No moving parts
  - Disadvantage: Do not view calibration sources through same path as Earth scene
  - Vulnerable to calibration instability from hardware changes requiring periodic post-launch re-calibration



	Chan. GHz	Techno	Observations on TBs	Correction
ERS1/MWR 1991->1996	23.8 36.5	Dicke / Sky horn	None ?	None
TOPEX/TMR 1992->2005	18 21 37	Dicke / Sky horn	• Drift (mainly 18 GHz) ≅ 0.2K/ year between 1992 and 1996 then stabilization • Yaw maneuvers	Corrected (Ruf 2002, Scharro 2004) Corrected
ERS2/MWR 1995->2003	23.8 36.5	Dicke / Sky horn	• Gain drop at 23.8 GHz in June 1996 • Regular drift of 0.2K/year 23.8 GHz	• Corrected (Eymard et al, 1996) • Corrected (Eymard et al, 2005, Scharroo 2004)
Jason1/JMR 2001->	18.7 23.8 34.0	Noise diode	• Jumps • Drifts • Yaw maneuvers	• Corrected (Brown et al., 2006)
Envisat/MWR 2002->	23.8 36.5	Dicke / Sky horn	• Strong gain drift at 36.5 GHz • low impact on the TBs	• Corrected (Picard et al, 2009)
Jason2/AMR 2008->	18.7 23.8 34.0	Noise diode (new reflector, better thermal control)	• 2 jumps in 34 GHz channel	• Corrected (ARCS) in GDR

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Radiometer Long Term Calibration: Future

- **Proposal for Jason-3: Eliminate reliance on periodic on-orbit recalibration by supplementing internal calibration system with external calibration system**
  - On-board blackbody calibration targets can be added to existing radiometer design
  - Periodic observations of on-board external calibration targets used to maintain the long term stability (e.g. once per pass or cycle over land)
- **Calibration is traceable to known physical quantities that are independent of the climate system and other sensors or models**
- External calibration approach is well established and used scanning Earth observing radiometers
  - MSU, AMSU, SSM/I, TMI on TRMM, WindSat, AMSR-E, SSMIS
- Combination internal/external calibration approach has the potential to produce a long term calibration stability that exceeds that of each system individually
  - **Not unreasonable to expect sub-mm/year inherent stability from such as system**
  - **0.01 K long term TB stability estimated for MSU (Spencer et al., 1990): ~0.1mm/yr**

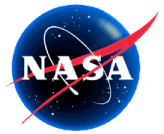
Near Future

- Planning for Jason-3 radiometer started at JPL
  - Current planning assumes instrument is a copy of the AMR

- To improve radiometer long term stability for Jason-3, action is needed from OSTST
  - Modify radiometer path delay stability requirement based on strong science rationale

  AND/OR:

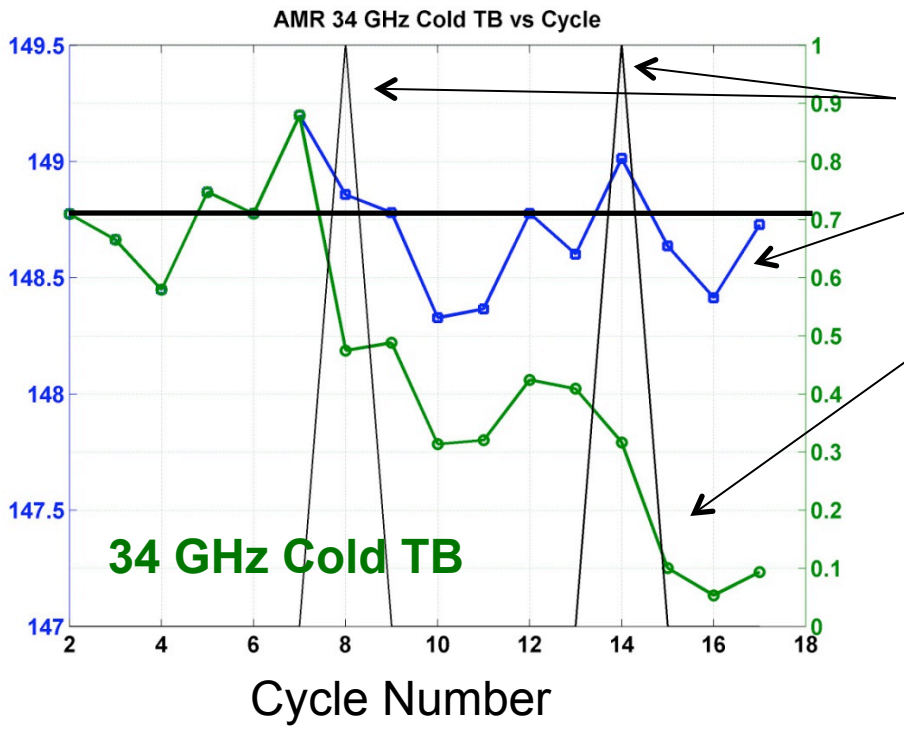
  - Recommend Jason-3 project investigate solutions that improve the long term stability of the path delay measurements and eliminate the need for on-orbit recalibration.



JPL

Backup

OSTM ARCS Performance Assessment

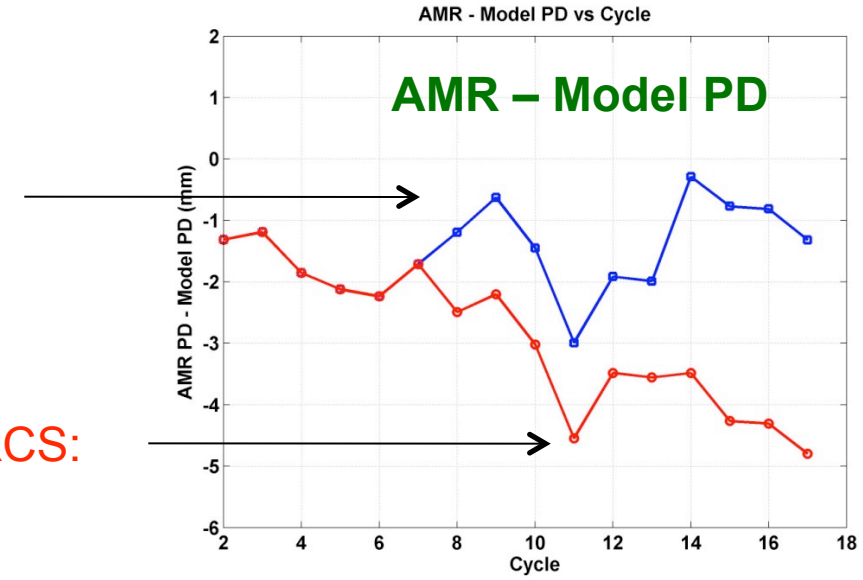


Decision to recalibrate 34 GHz channel

Measured Cold TB with ARCS

Measured Cold TB without ARCS

2 jumps in 34 GHz channel detected and corrected early in mission

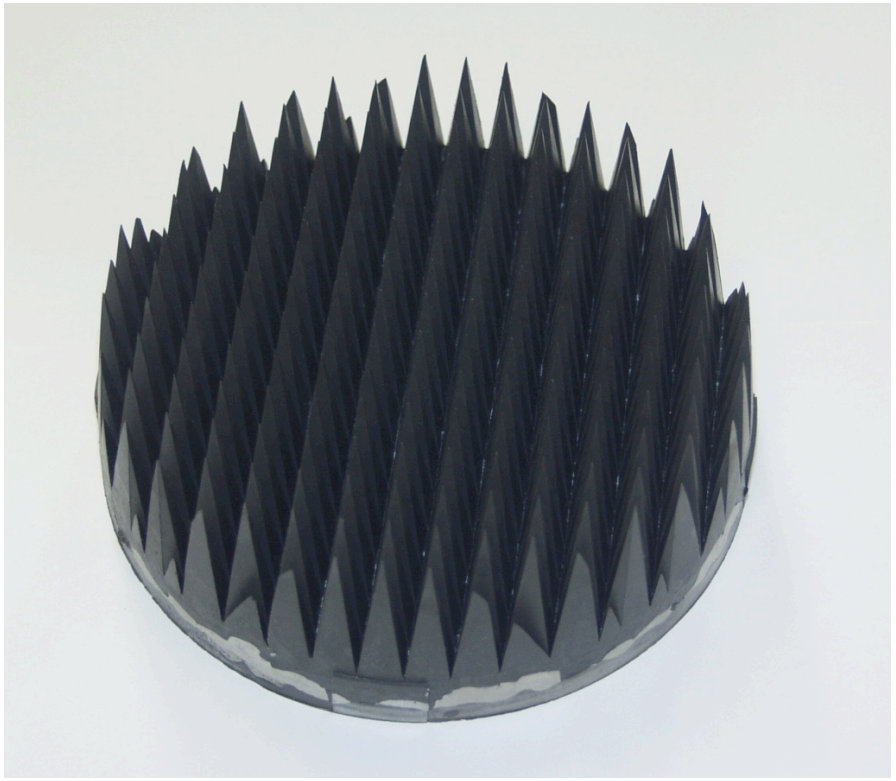


AMR-Model PD with ARCS

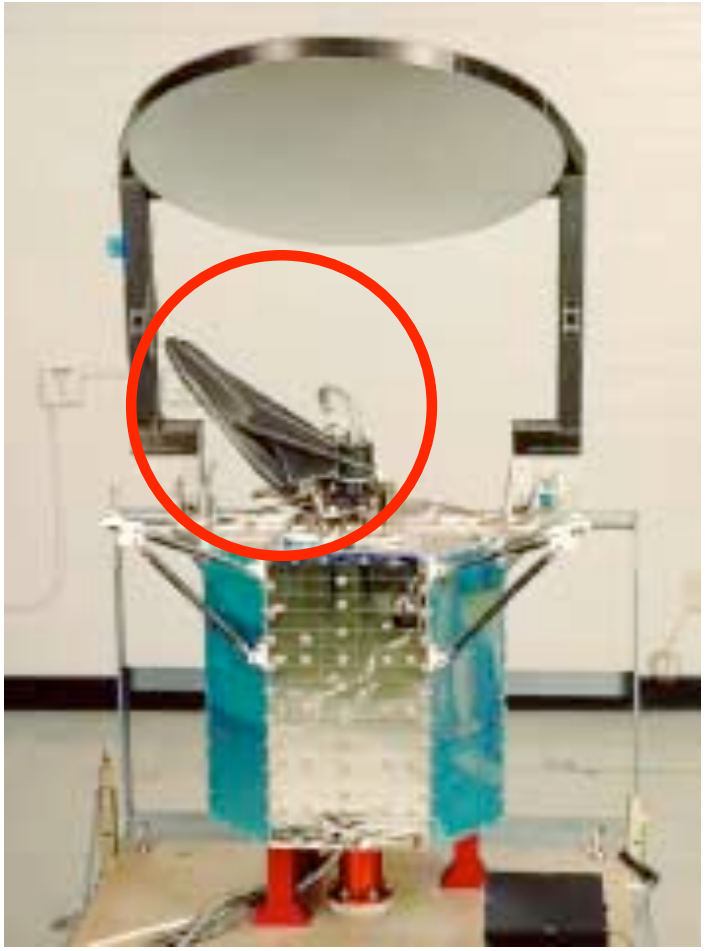
AMR-Model PD without ARCS: apparent 6mm/yr drift

Examples of External Microwave Calibration Targets

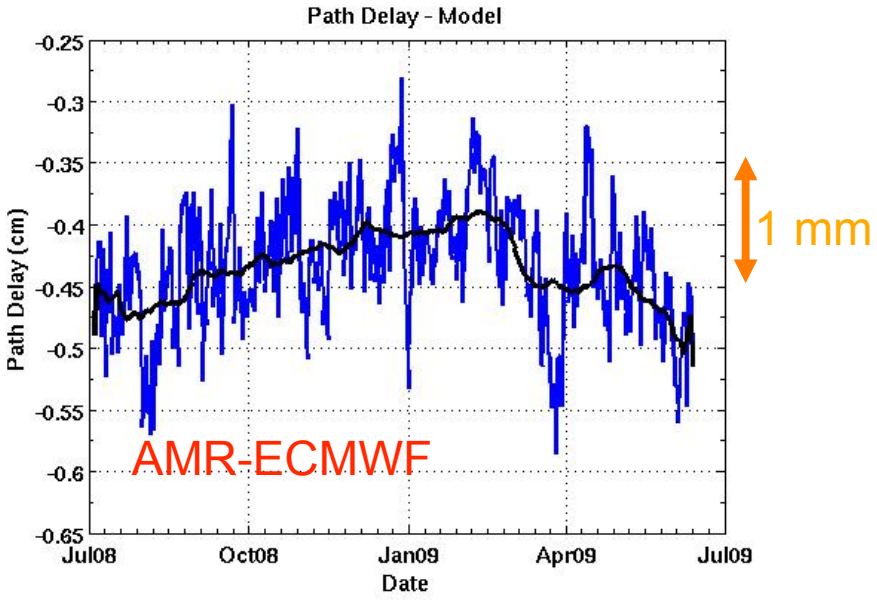
Microwave Blackbody Target

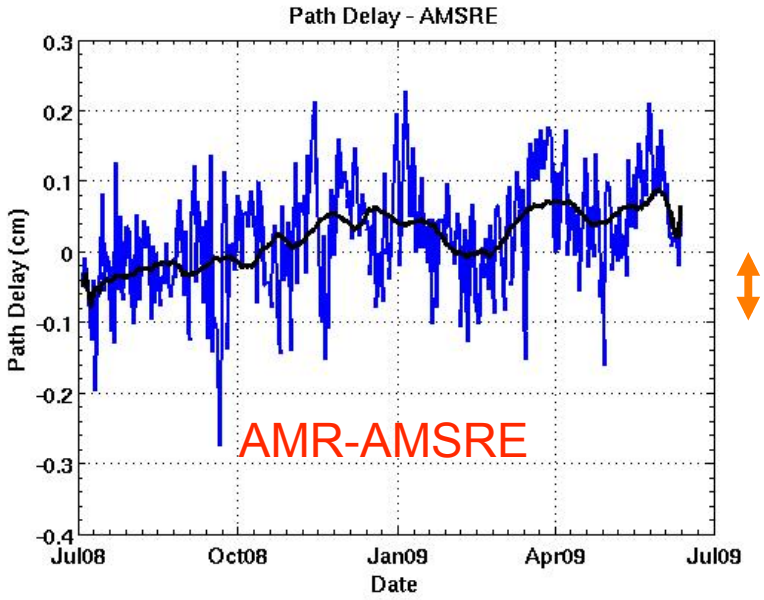


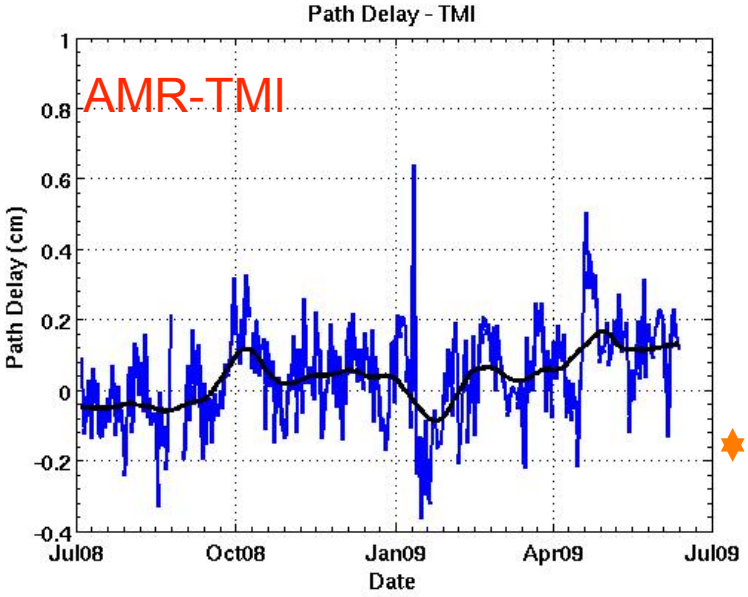
Cold Sky Reflector



AMR PD Stability Assessment







- Comparisons between AMR and model and other radiometers

No conclusive evidence of long term PD instability or drift

Calibration System Concept

- Rotating calibration assembly places target in front of feed horn on command
- Fail safe mechanism to ensure target can not get stuck in front of feed