# An End-of-Mission Climate Quality Calibration for the JMR – Inter-satellite Calibration with the SSM/I Fundamental Climate Data Record

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# Overview

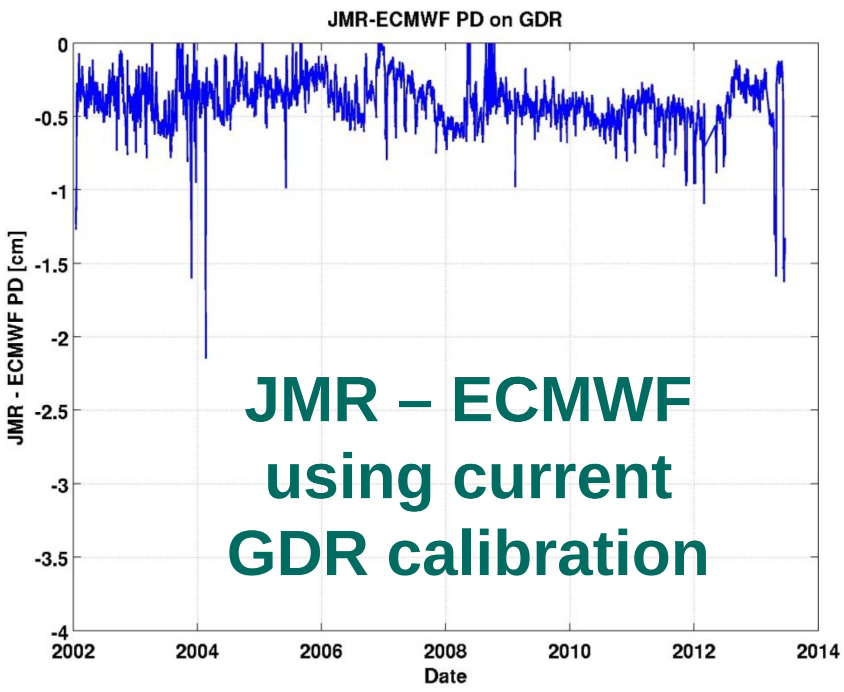
- Current status of the JMR calibration
- End-of-mission recalibration approach
- Initial comparison with the SSMI FCDR

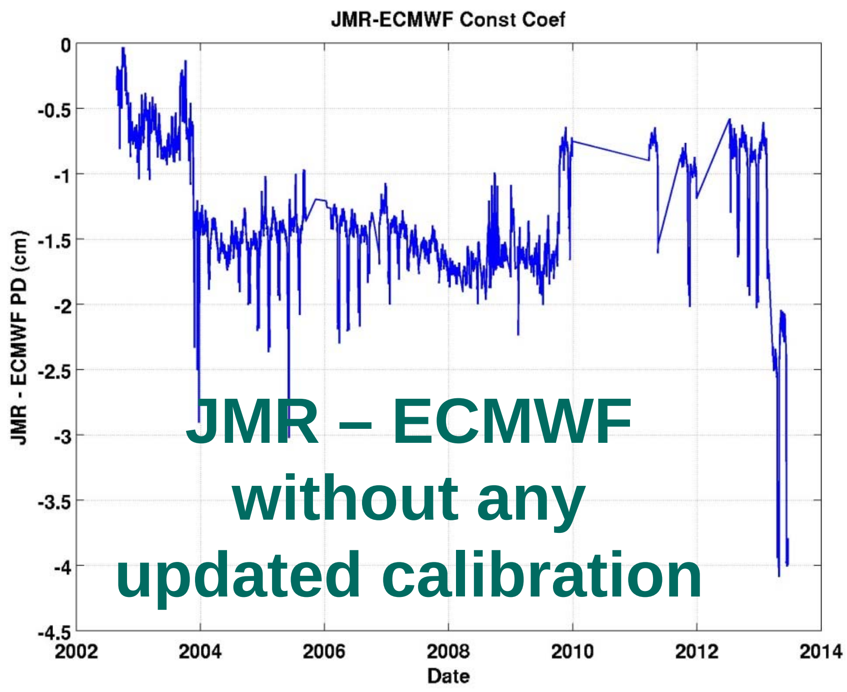
# Jason-1 Jason Microwave Radiometer (JMR) 2002 - 2013

- **Jason-1 JMR maintained same measurement requirements as TMR**
  - 1.2 cm RMS error for PD measurement
  - No requirement for long term stability
- **JMR used noise diodes for calibration to eliminate the need for a cold sky horn**
  - First spaceborne radiometer to use NDs
  - Paved way for Aquarius, SMOS, SMAP and of course AMR
  - JMR ND implementation and thermal environment presents calibration challenges
- **Maintained same antenna design as TMR with partial blockage from struts**
  - Results in larger sidelobes (creates geographically correlated errors)

# Overview of JMR Calibrations to Date

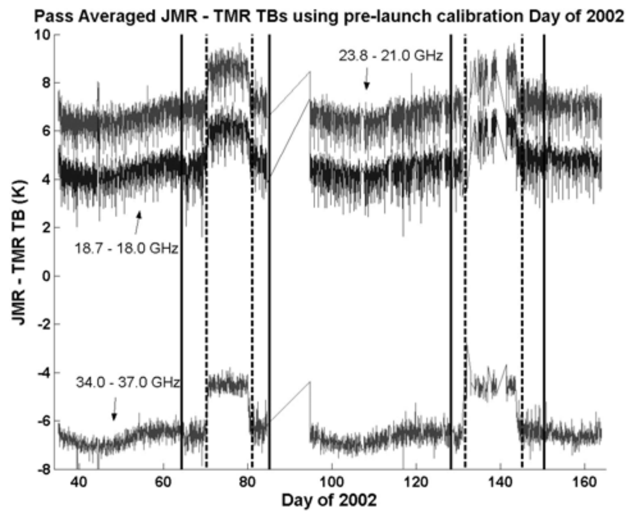
- JMR calibration updated several times during the mission to remove calibration shifts
- 2-4 cm change in PD over mission would be present if nothing had been done



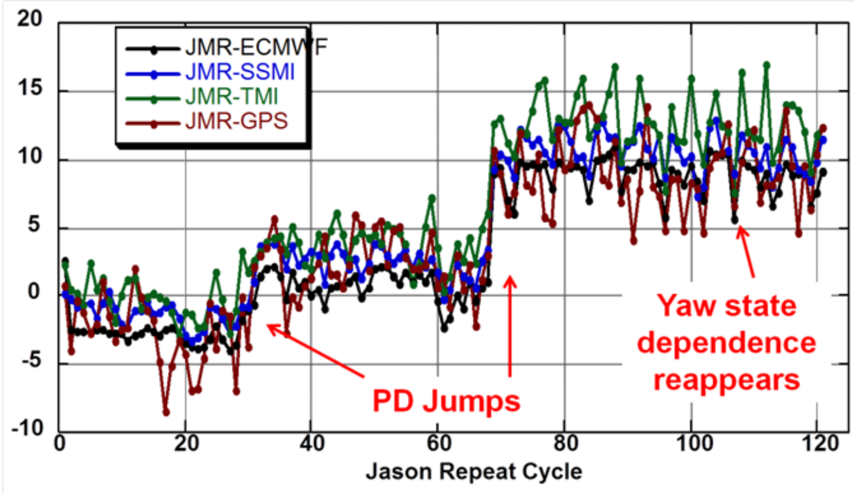



# Overview of JMR Calibrations To Date

- **July 2002 - GDR-A**
  - Pre-launch calibration updated after cal/val phase to remove biases relative to TMR and remove "yaw state" dependence



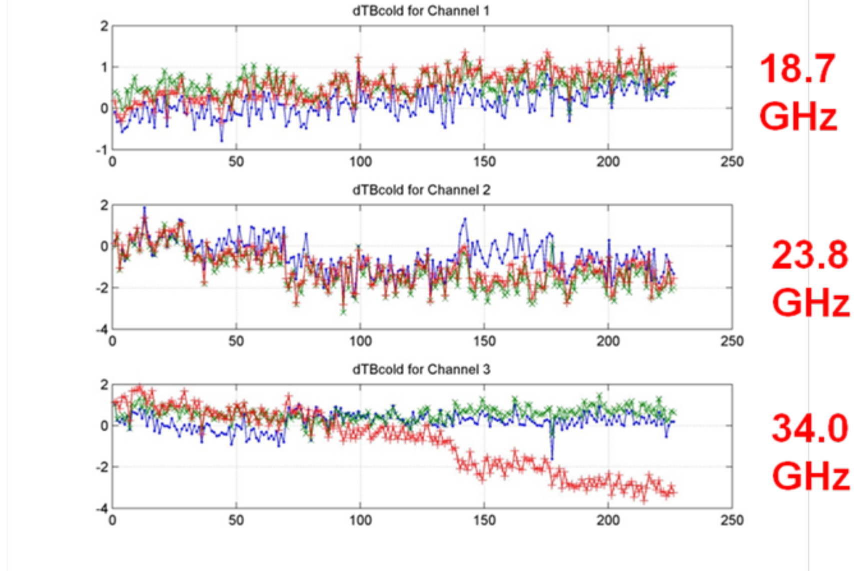

- **September 2005 - GDR-B**
  - Corrected calibration shifts after cycle 30 and cycle 69 using three sets of calibration coefficients.
    - Cycles 1-30, 31-69, 70-present.
  - Updated APC algorithm to mitigate geographically correlated errors ~200-500 km from land

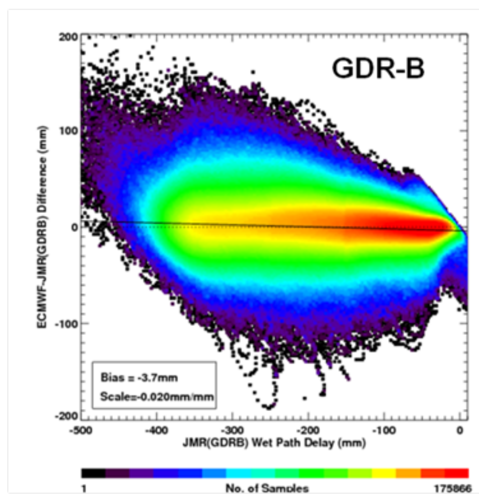


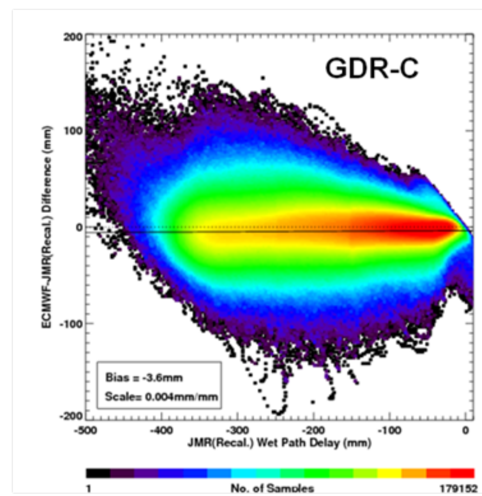
# Overview of JMR Calibrations To Date

- **April 2008 - GDR-C**
  - Implemented time-variable calibration coefficients with new coefficients once per cycle.
    - Once per cycle coefficients derived from moving 30-day data window.
  - Adjusted path delay algorithm coefficients to remove scale error
    - Error in coefficients carried over from an error in the post-launch calibration of the TMR.

**JMR TB Drift Before Calibration**



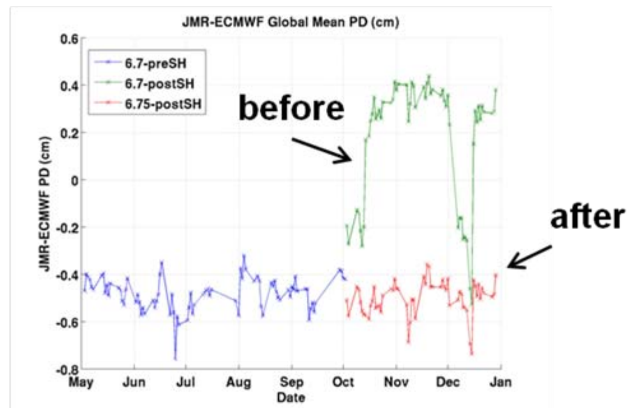



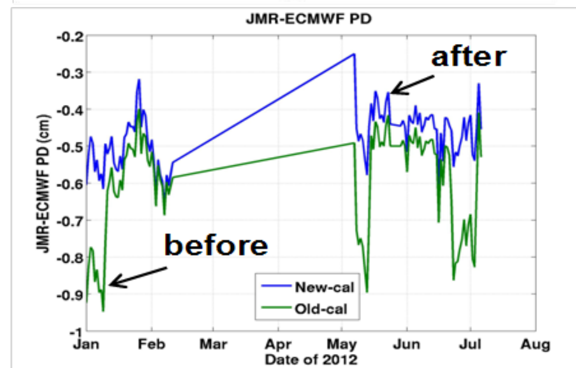



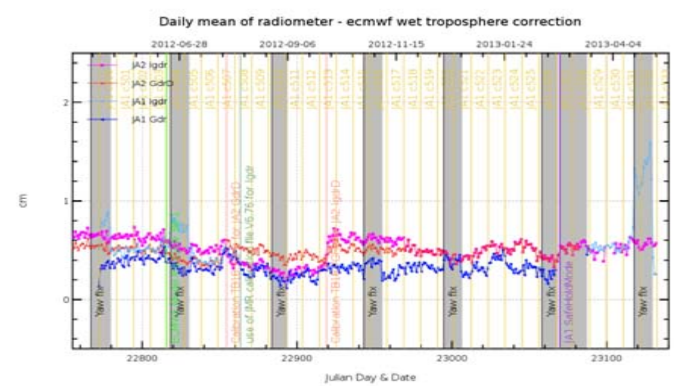
# Overview of JMR Calibrations To Date

- **January 2010**
  - ~1cm path delay jump observed after September 2009 safehold event
  - 23.8 GHz TB calibration corrected prior to GDR processing
- **July 2012**
  - Corrected 23.8 GHz calibration after Feb/March 2012 safehold event to remove ~4mm yaw state dependence
- **July 2013**
  - Adjusted calibration after February 2013 safehold to remove 7mm yaw state bias

**PD Error**

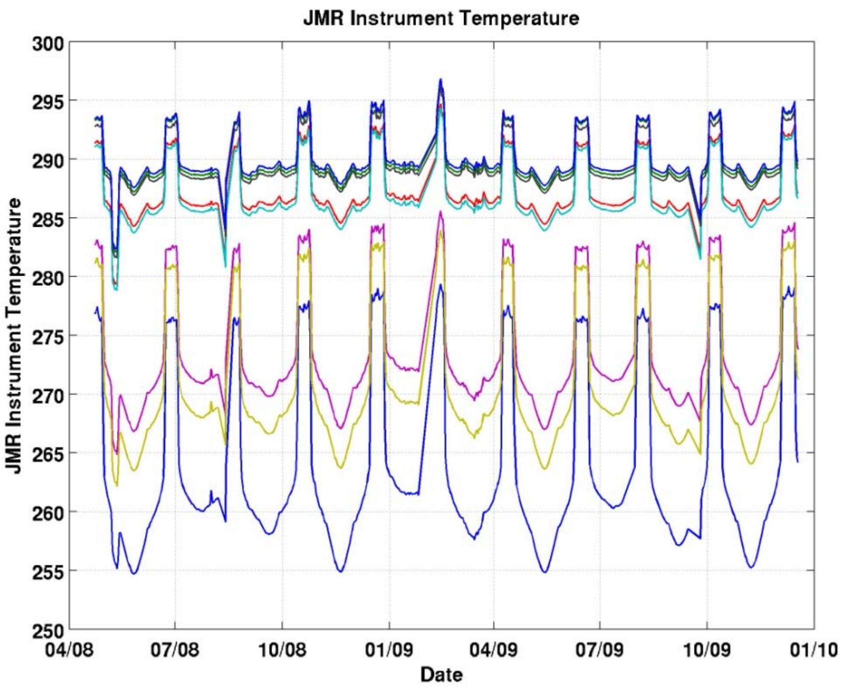


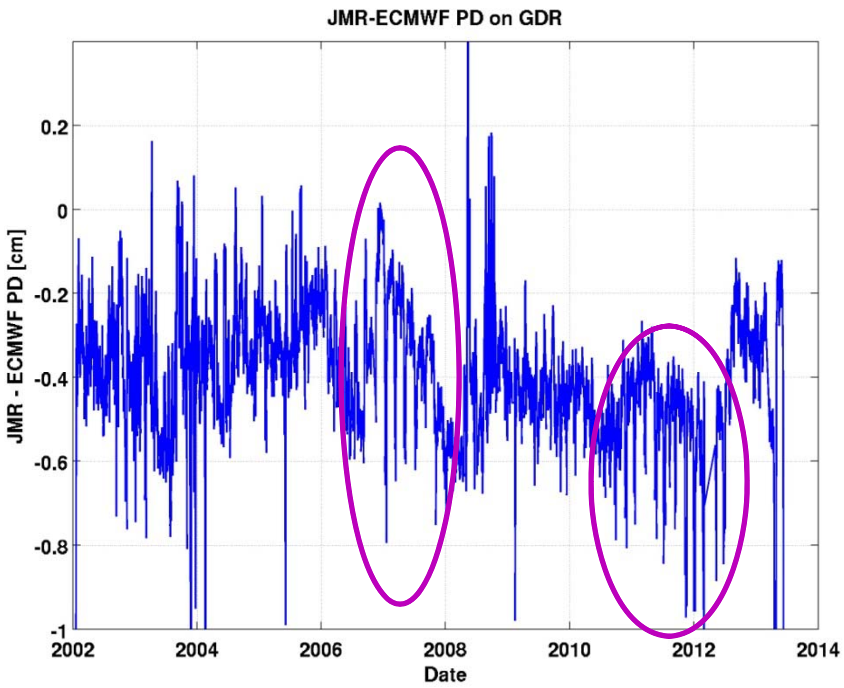



# End-of-Mission Calibration

- **No reprocessing has taken place since April 2008**
  - Calibrations after safehold events not intended to address long term calibration, only to remove pre-/post-safehold bias
- -0.4 mm/yr PD drift evident after 2008
- “Yaw-state” dependence periodically resurfaces (creates 60-day signal)
- Need to address both short term and long term calibration instability



# End-of-Mission Calibration Plan

- Previous calibration relied upon on-Earth hot and cold $T_B$ references
  - Vicarious Cold Reference *(Ruf, 2000, TGARS)*
  - Amazon pseudo-blackbody regions *(Brown and Ruf, 2005, JTECH)*
  - On-orbit references sensitive to climate variability; require corrections; risk of aliasing geophysical signals

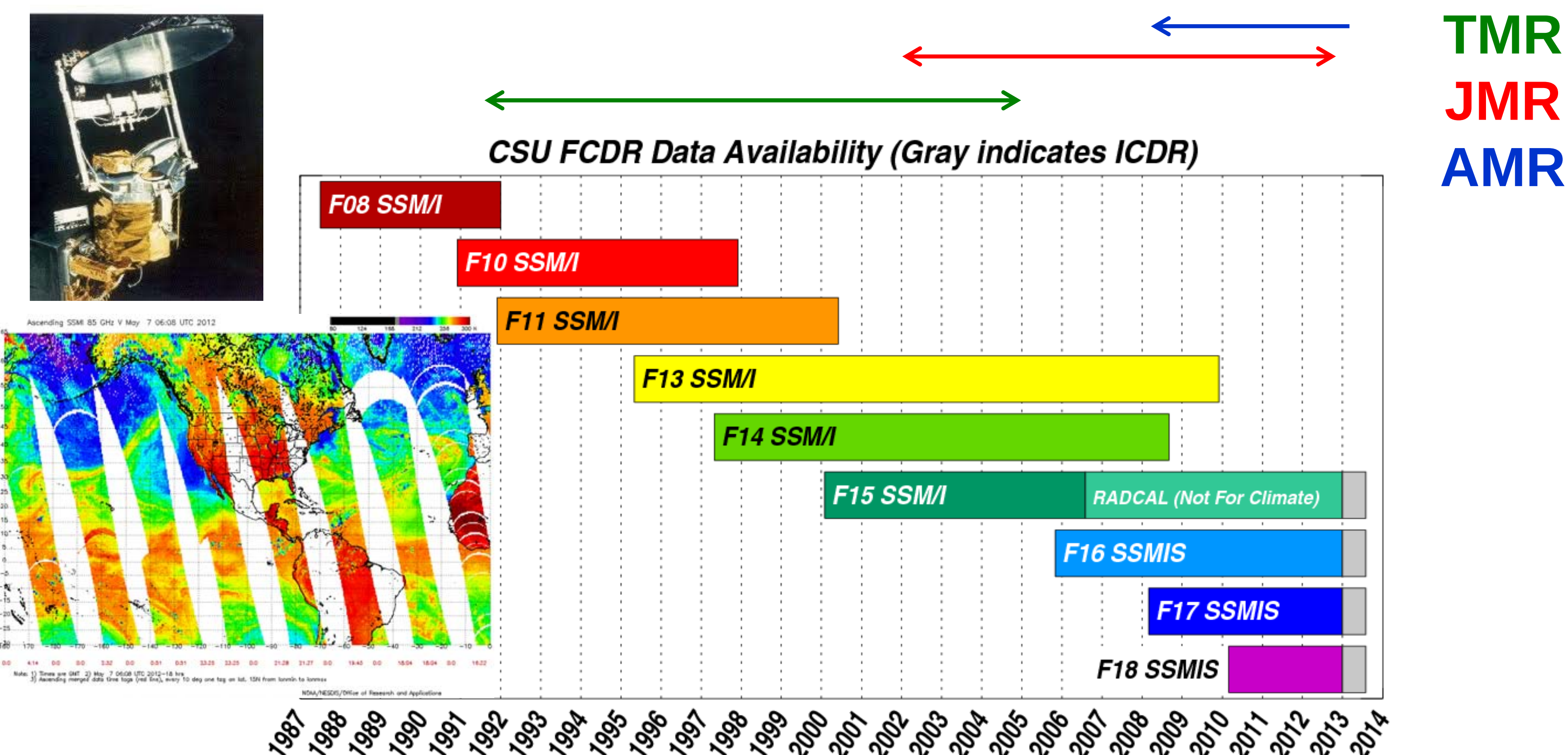
- Complementary inter-sensor TB calibration approach recently developed and applied to AMR (Brown, 2012, TGRS)
  - Uses polynomial regression to transfer one sensor's measurement to another
  - Requires stability of other systems
  - Presents independent means to monitor the long term TB calibration

- Compare geophysical retrievals to in-situ measurements, models and other sensors
  - Dependent on long term stability of other sensors/models
  - Need to use re-analysis products from models to ensure a consistent long term record

- Demonstrated consistency between independent methods ensures a "climate-quality" long term calibration
  - the agreement, or lack thereof, between the different references provides a means to assess the uncertainty of the long term calibration

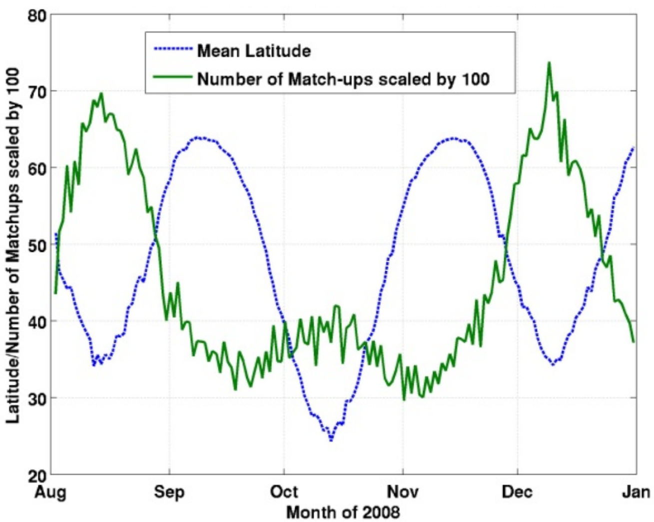
# SSM/I FCDR

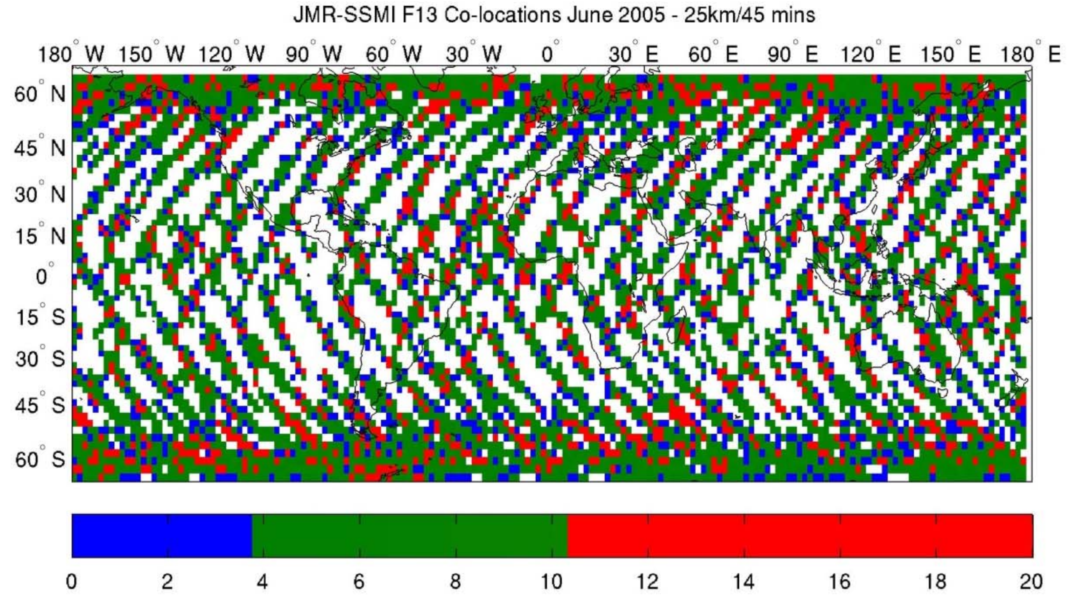
- The SSM/I series of radiometers have operated since 1987, spanning the Topex/Jason altimeter record
- A newly released SSM/I Fundamental Climate Data Record is a reprocessed well inter-calibrated record of brightness temperature ideal for inter-satellite calibration with JMR
- SSMI F13, F14 and F17 used in this analysis



# Match-up Process

- A database of co-locations is generated by finding JMR and SSMI observations that occur within 25 km and 45 minutes of each other
- The match-ups cluster between high and low latitudes as a function of time



# JMR Equivalent TBs from SSMI

- Polynominal regression used to transfer SSM/I TBs to JMR equivalent TBs
  - Uses 19, 22 and 37 GHz TBs from SSMI

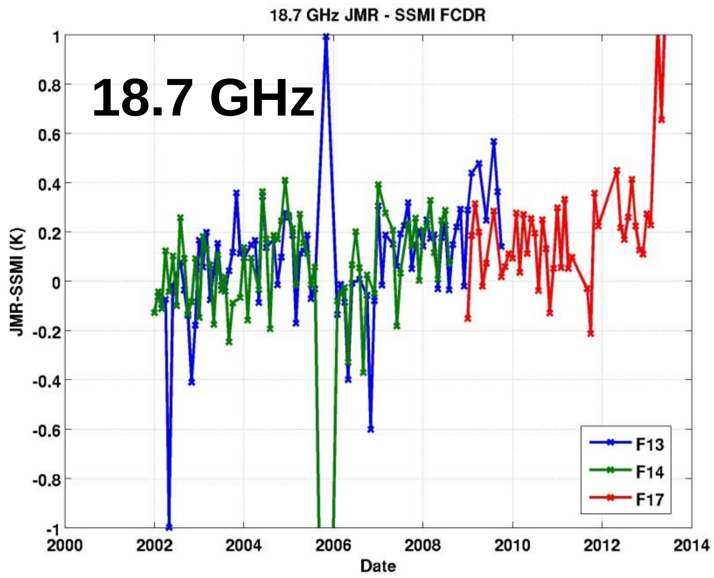
- Coefficients derived from AMR used in this analysis
  - Ensures consistent cross-calibration between AMR and JMR

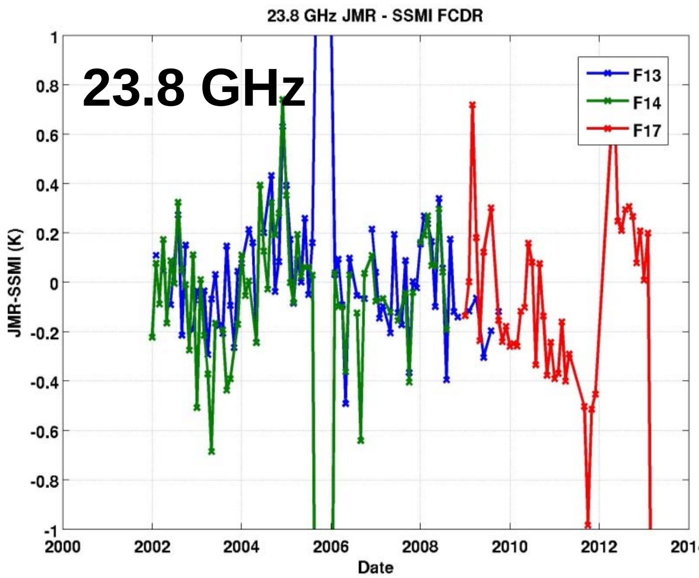
$$T_{B\_ocean}^{AMR} = c_0 + c_1 T_B^{19V} + c_2 T_B^{19H} + c_3 T_B^{22/24V} + c_4 \left(T_B^{22/24V}\right)^2 + c_5 T_B^{37V} + c_6 T_B^{37H}$$

- JMR-SSMI biases correlated with latitude are removed to ensure no signals due to the sampling are aliased into the trend
  - Biases with latitude computed using the entire record

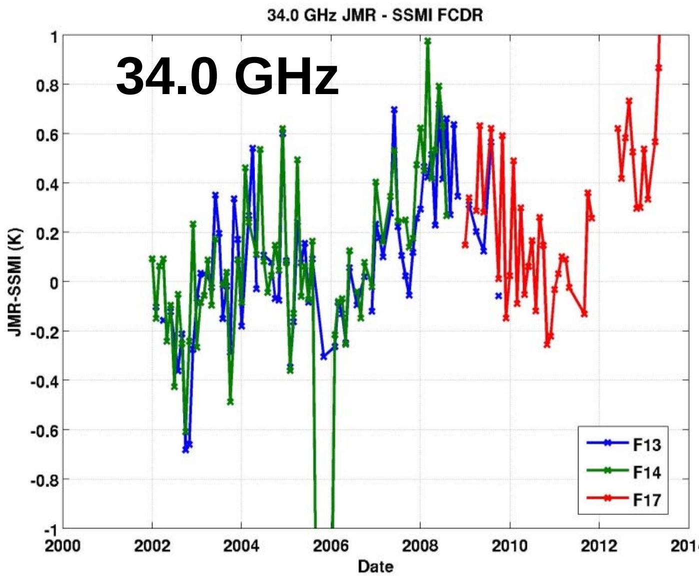
- JMR-SSMI TB differences greater than 8K (5-sigma) were removed from the match-up database

# JMR-SSMI TBs



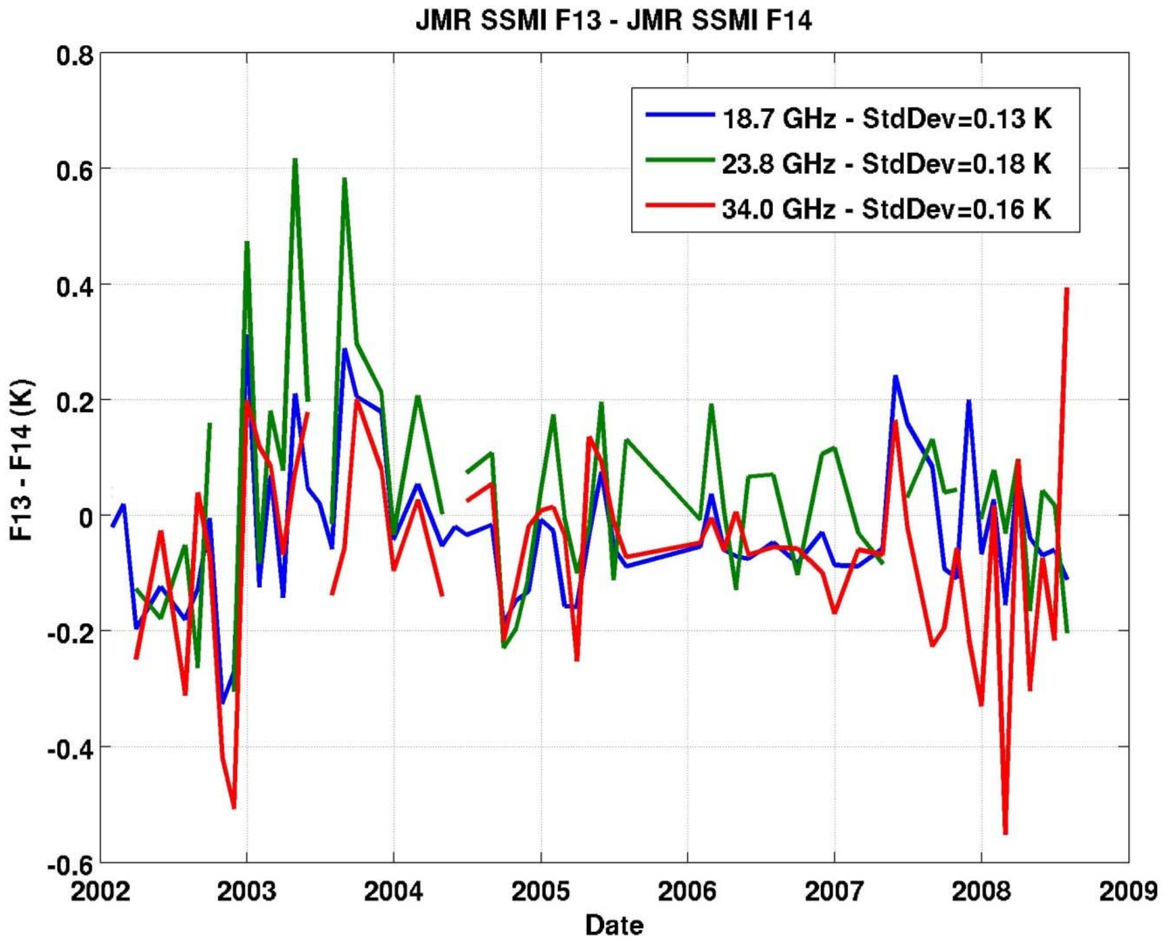




- Computed monthly averages of the JMR - SSMI TB bias for each channel
- Overall excellent consistency between SSMI F13 and F14
- **Small, but statistically significant, residual instability evident in all channels (< 0.5 K)**

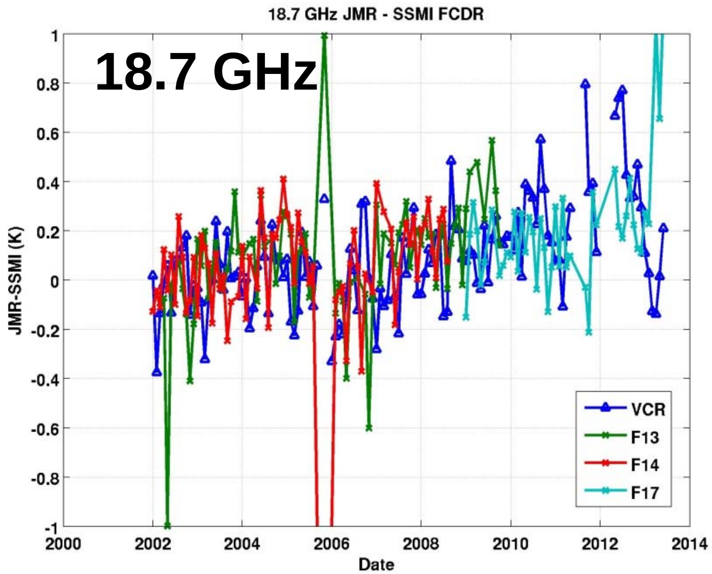


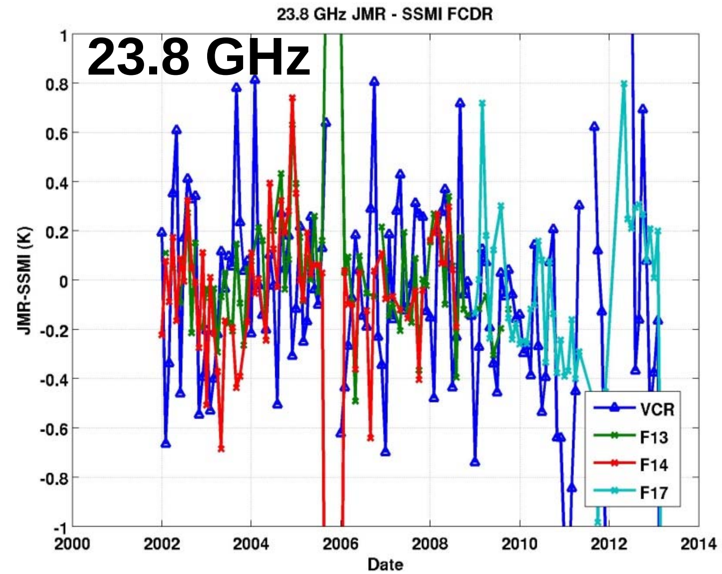
# Monthly Consistency

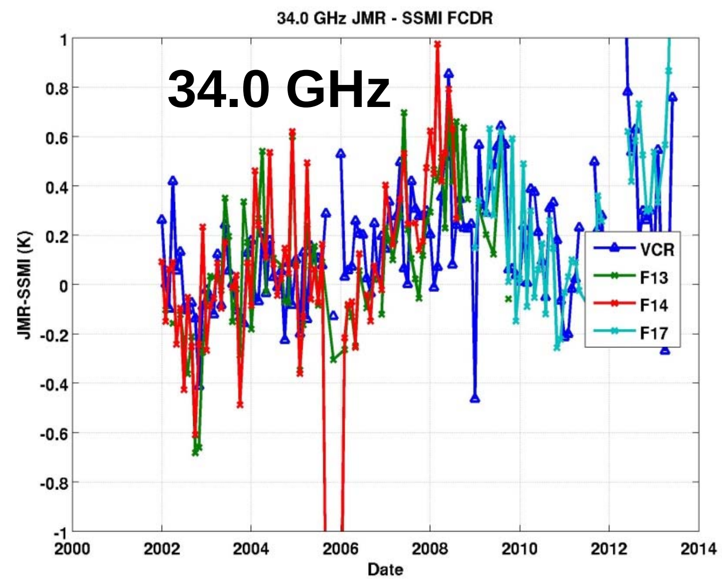
- < 0.2K standard deviation of monthly JMR biases computed from SSMI F13 and F14 with no discernible trend



# Comparison with Ocean Reference

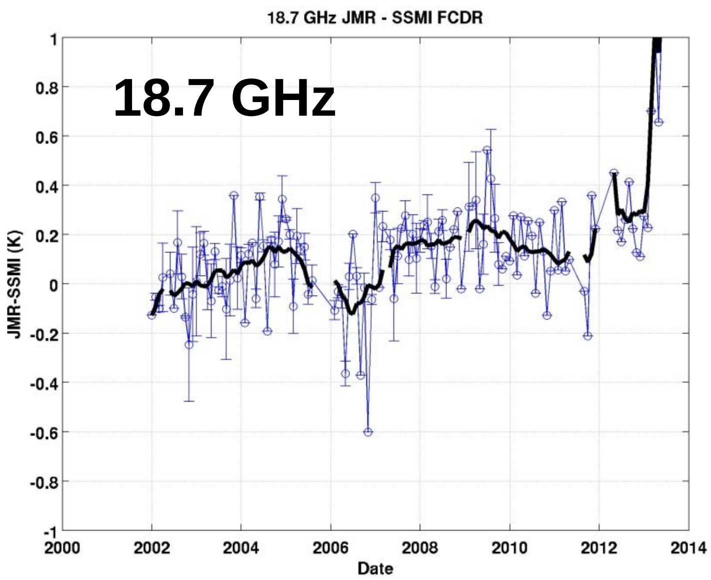


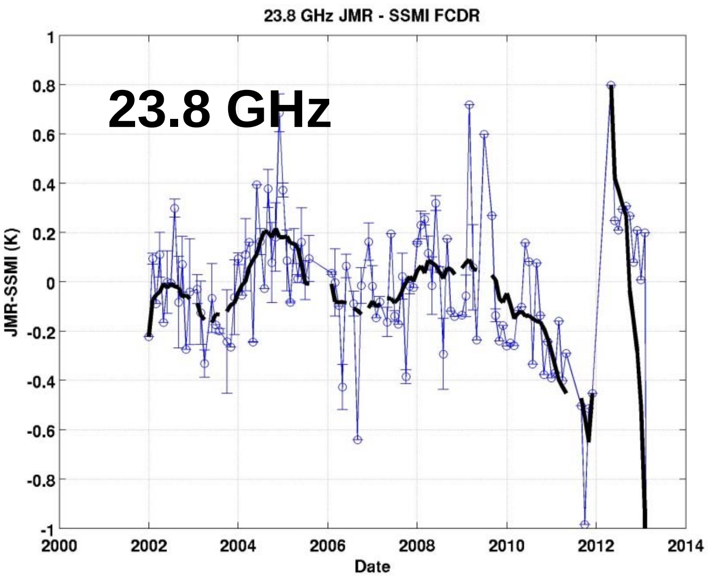



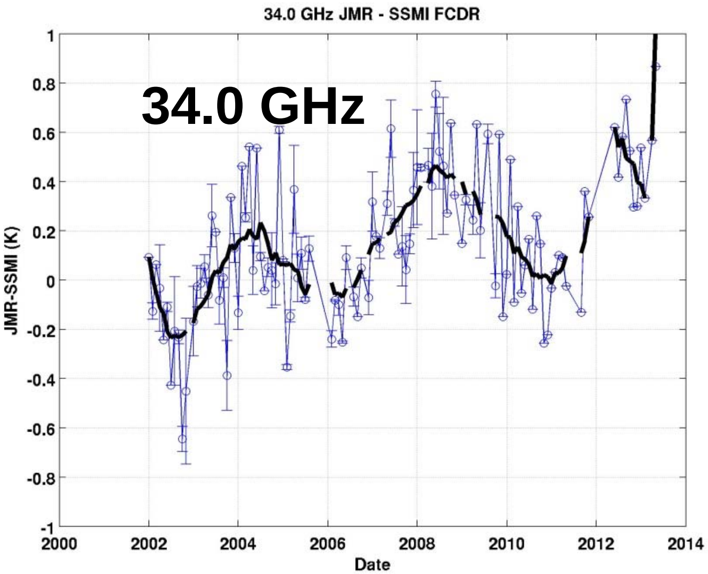

- Dark blue line shows monthly averaged vicarious cold reference with biases from SSMI
- Consistency observed between these independent references increasing confidence in the long term trends

# Consensus TB Calibration



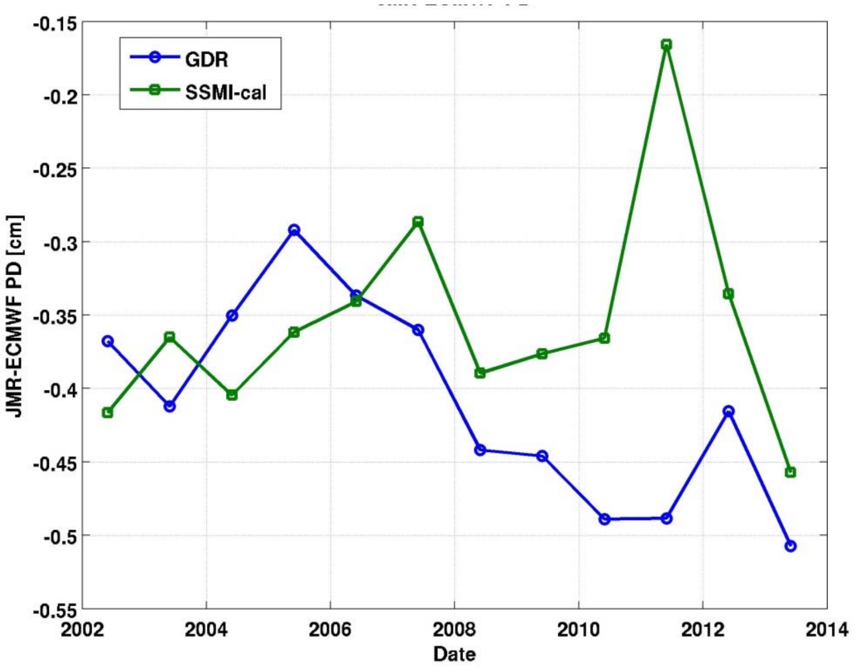

- For each month, computed average JMR calibration bias using SSMI and the cold reference
- Applied 12-month running average to isolate long term component



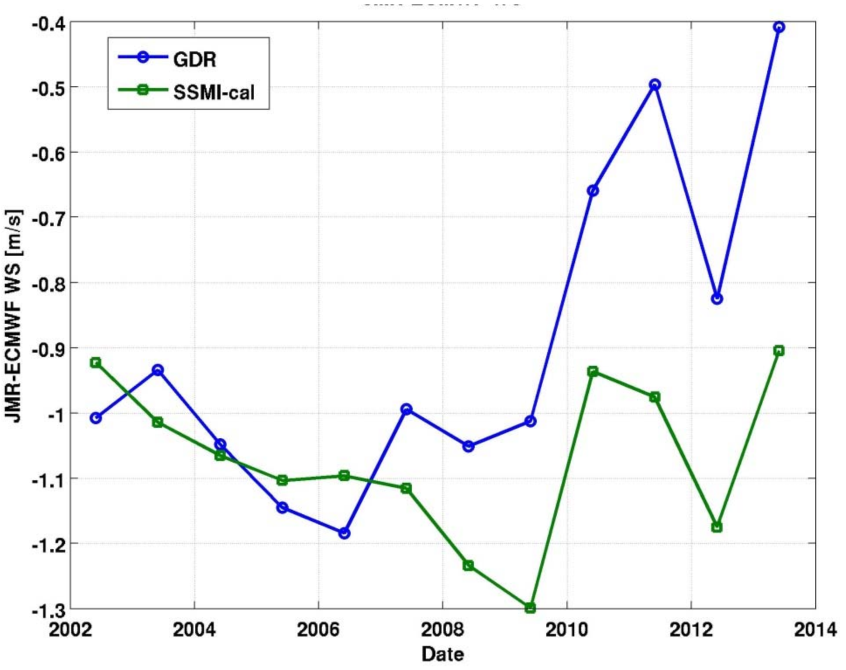
# Resultant PD Time Series

- New calibration applied to the JMR data
- Drift in PD relative to ECMWF and wind speed relative to the altimeter reduced
- **Overall impact of new calibration is to increase the PDs by about +0.4 mm/yr from 2008 to 2012**

## JMR-ECMWF PD [cm]

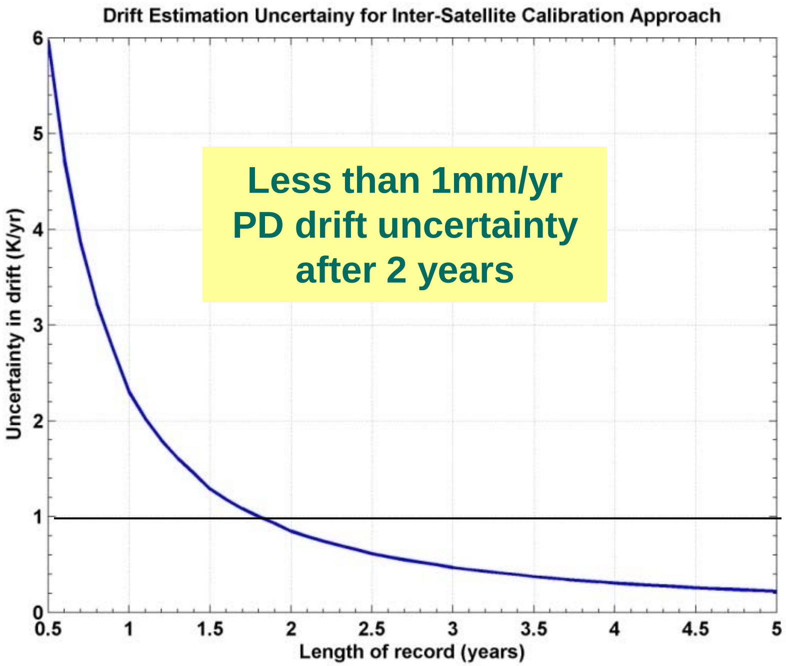



## JMR-Altimeter WS [m/s]



# JMR PD Trend Uncertainty

- Month-to-month calibration uncertainty about 0.2K (~2mm in PD)
- Trend error can be computed as a function of record length
  - 2 mm/yr uncertainty for any 1 year
  - < 1 mm/yr uncertainty for time spans greater than 2 years
  - << 1 mm/yr for mission



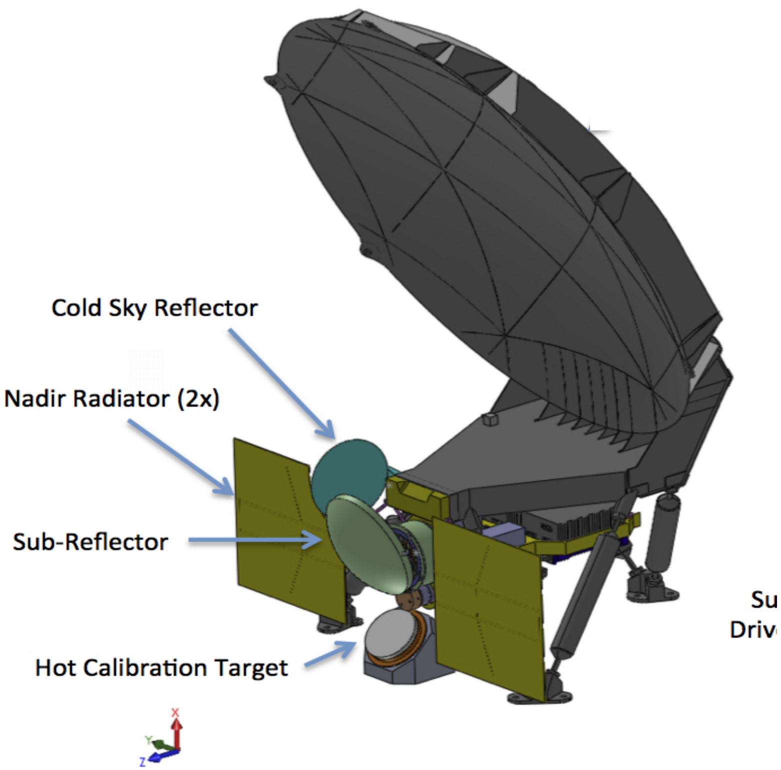
# Summary

- JMR end-of-mission re-calibration effort underway
- Long term calibration to be constrained by inter-satellite calibration to the SSM/I FCDR and on-Earth references
- Other planned updates:
  - Update to antenna pattern correction coefficients using AMR as a reference during tandem mission
  - Verification of negligible scale error compared to radiosondes
  - Incorporate coastal PD algorithm, all weather sigma-0 algorithm and new flagging algorithms into GDR processing

# Backup

# Looking toward the Future

- AMR-C concept includes secondary reflector to perform end-to-end calibration using stable blackbody calibration targets similar to SSM/I, AMSR-E, AMSU, etc.
- Wet PD long term stability estimated to be better than 0.3mm for any one year period and eliminates reliance on ancillary data sources for calibration




**Wet PD Drift Uncertainty vs Time Span**