# Development of a 20-year Climate Quality Wet Tropospheric Correction from Altimeter Radiometers

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## Abstract

This year will mark the 20th anniversary of the start of the modern record of global mean sea level (GMSL) from satellite altimetry. Over the past two decades, the GMSL has risen by approximately 6cm while under the watchful eye of eight altimeter measurement systems. However, precisely monitoring the rise of the GMSL would not be possible without the careful calibration of the instruments that are a part of the altimeter measurement system. In particular, the microwave radiometers on the altimeter satellites have been shown to be one of the largest sources of error in the long term stability of the GMSL measurement. Microwave radiometers have flown on all ocean altimeter missions over the past 20 years to provide a correction for the delay of the radar signal (relative to the speed in a vacuum) due the refractivity of water vapor in the troposphere. Over the years, the radiometer instrumentation has steadily improved as well as the algorithms used to retrieve wet path delay (PD) from the radiometer's brightness temperature (TB) measurements and we have correspondingly seen a reduction in the radiometer derived PD error, particularly the geographically and temporally correlated components of the error. But, the effort that has gone into ensuring a stable long term PD record, free from drift, is among the most important.

Here, results are presented from the climate calibration effort for the Jason series radiometers. The GDR-D calibration for the Jason-2 AMR was derived using a new inter-satellite calibration approach (Brown, 2012). The resulting drift in the PD record is estimated to be less than 1mm/yr with no regional component. The GDR-C calibration for the JMR has shown a recent decrease in PD due to a small drift in the 23.8 GHz channel. A n updated calibration is being developed and tested in preparation for an end-of-prime mission calibration. These climate quality calibrations join the end-of-mission climate calibration produced for the Topex Microwave Radiometer (Brown et al., 2009) to enable a 20-year climate data record of GMSL.

## AMR Calibration for GDR-D

- Inter-sensor calibration approach applied to calibration AMR TBs using AMSR-E, SSMI and TMI (Brown, 2012, TGRS)
- Transfers long term calibration from other stable reference sensors to AMR
- Uncertainty in calibration estimated to be ~0.3K per month
- Corrected > 3cm of drift in AMR PD since launch

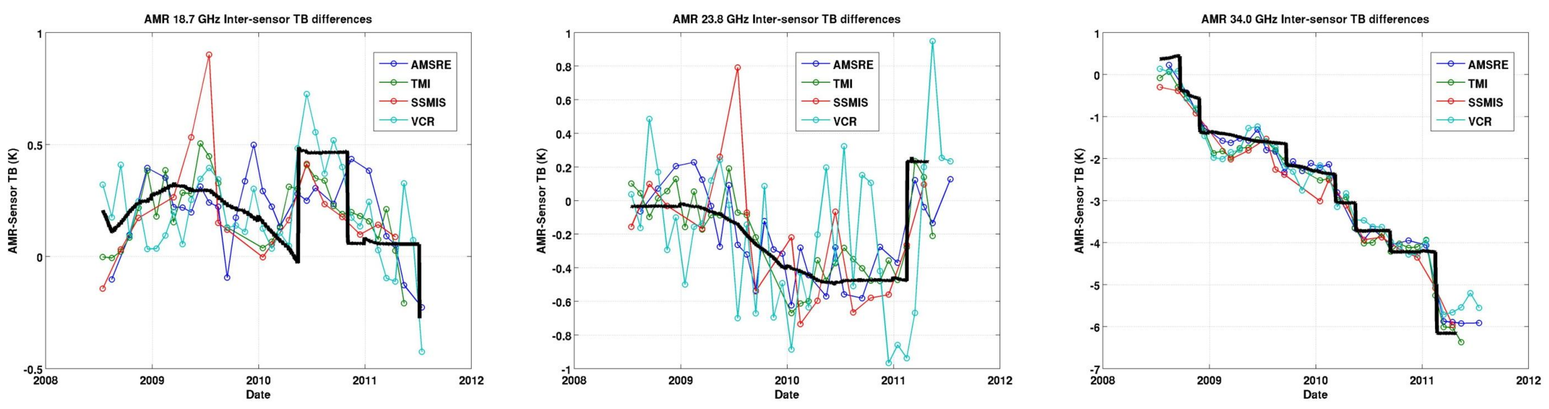
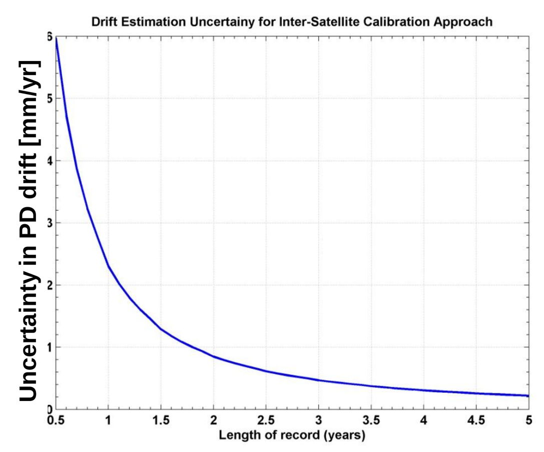



**Figure 1. Calibration corrections applied to AMR 18.7 (left), 23.8 (middle) and 34.0 (right) GHz TBs for GDR-D based on inter-satellite comparisons**




- 0.3 K TB uncertainty translates to 2.5mm PD uncertainty per month
- If errors are uncorrelated month to month, the uncertainty in the PD drift is estimated to be <0.5 mm/yr for a three year record length

## Validation

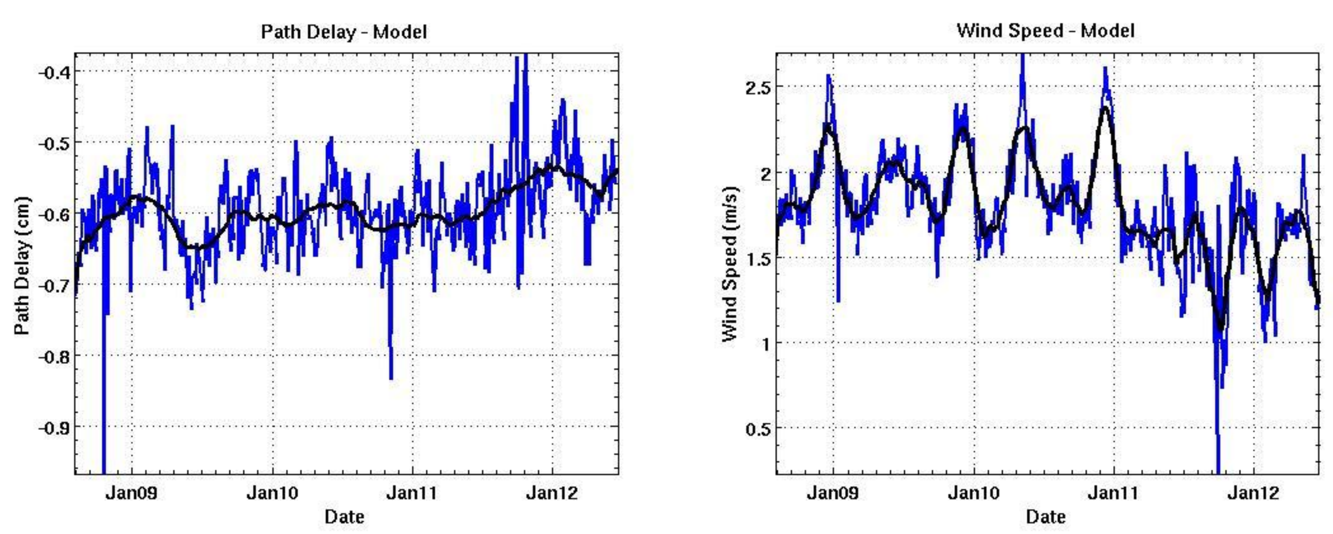



**Figure 2. AMR PD (left) and wind speed (right) compared to ECMWF. No significant drift is evident in either comparison.**

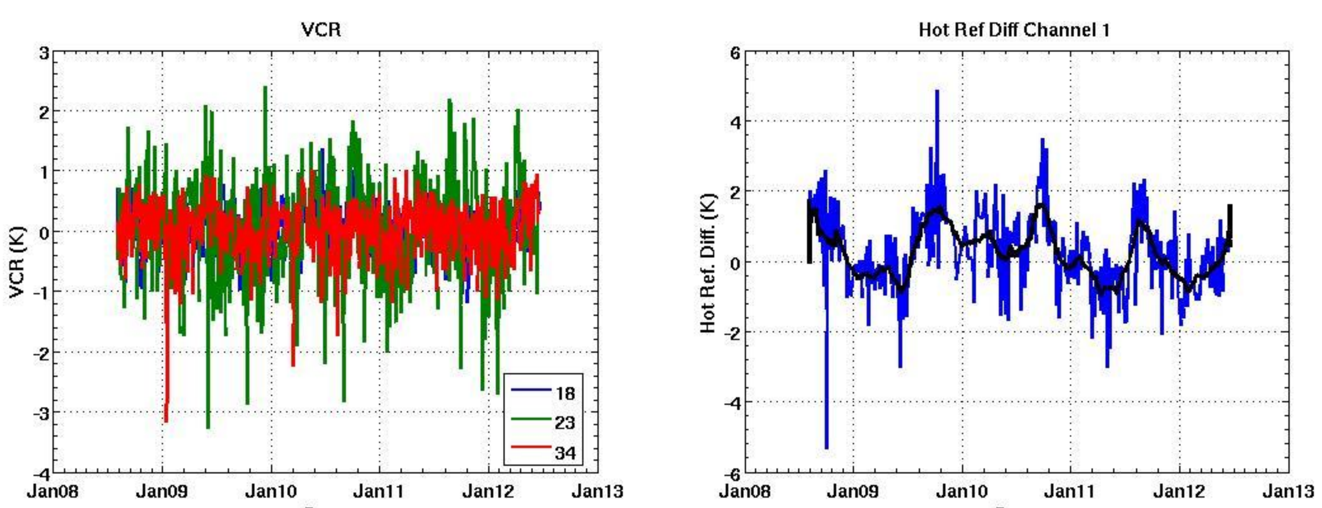
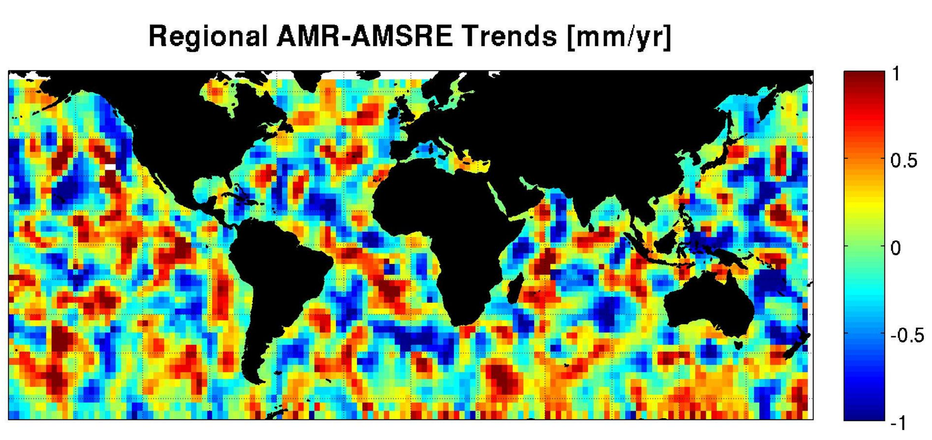
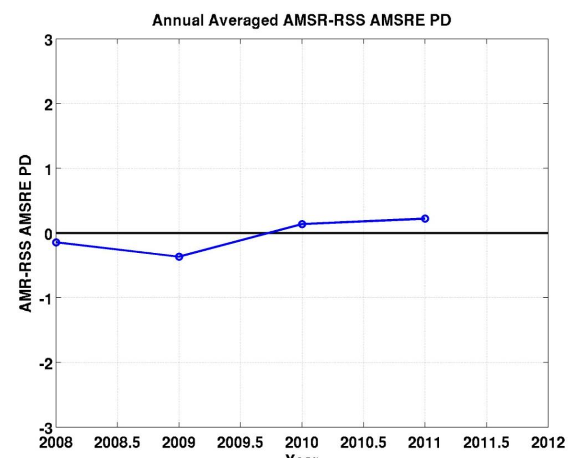



**Figure 3. AMR vicarious cold reference statistic (left) and comparison to Amazon hot reference model at 18.7 GHz (right). The derived calibration is stable relative to these natural TB references.**




- AMR PDs are compared to PDs derived from the integrated water vapor product produced by Remote Sensing Systems from AMSRE and SSMI data
- No significant regional drifts are observed with an uncertainty of approximately 0.5mm/yr
- No trend in global average PD compared to AMSR-E PD is observed




## JMR Mission Calibration

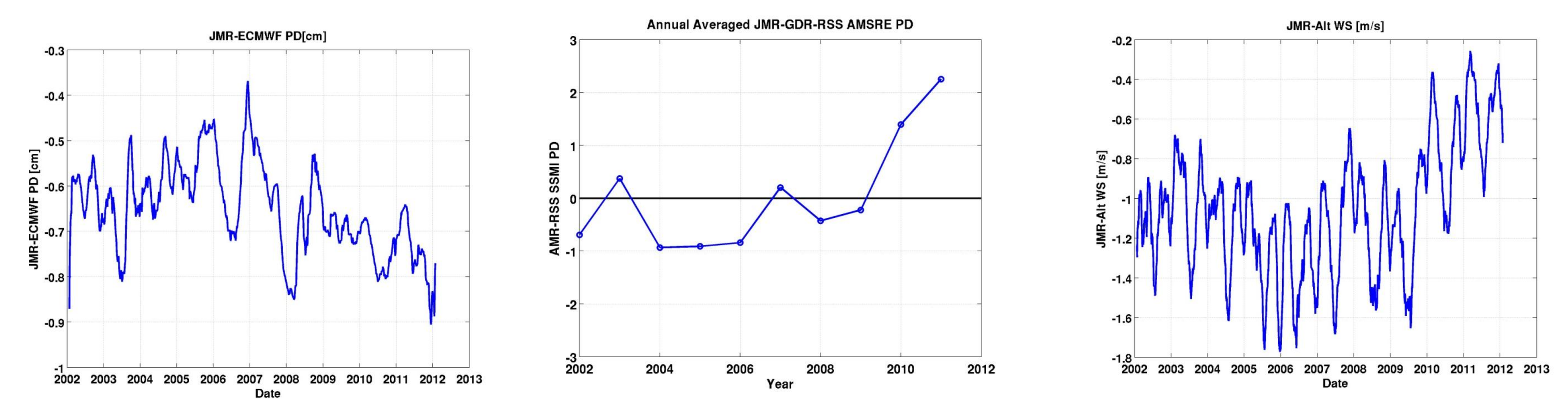
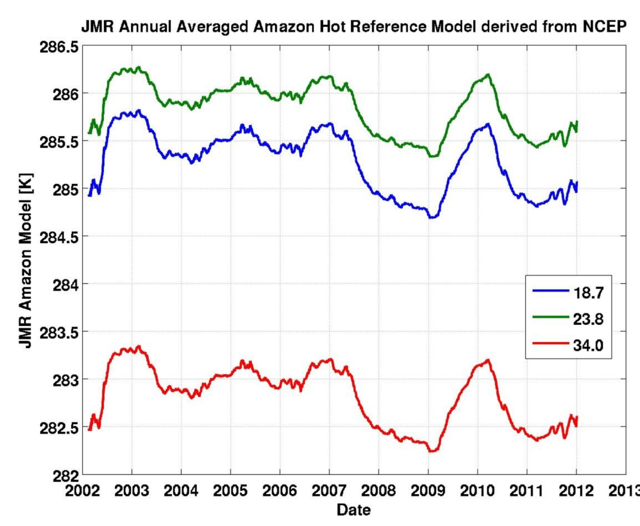



**Figure 4. JMR GDR PD compared to ECMWF (left), JMR PD compared to AMSRE PD from RSS (middle) and JMR wind speed (right) compared to the altimeter (right) .**

- Last update to JMR calibration for prime mission was in 2009
- ~2mm PD drift observed since then
- JMR WS compared with altimeter also shows ~0.5m/s drift after 2010




- JMR TBs are compared to natural hot and cold references
- Dynamic model for Amazon TBs developed for TMR end-of-mission calibration implemented for JMR,
  - Driven by NCEP re-analysis fields to estimate time variability in hot reference

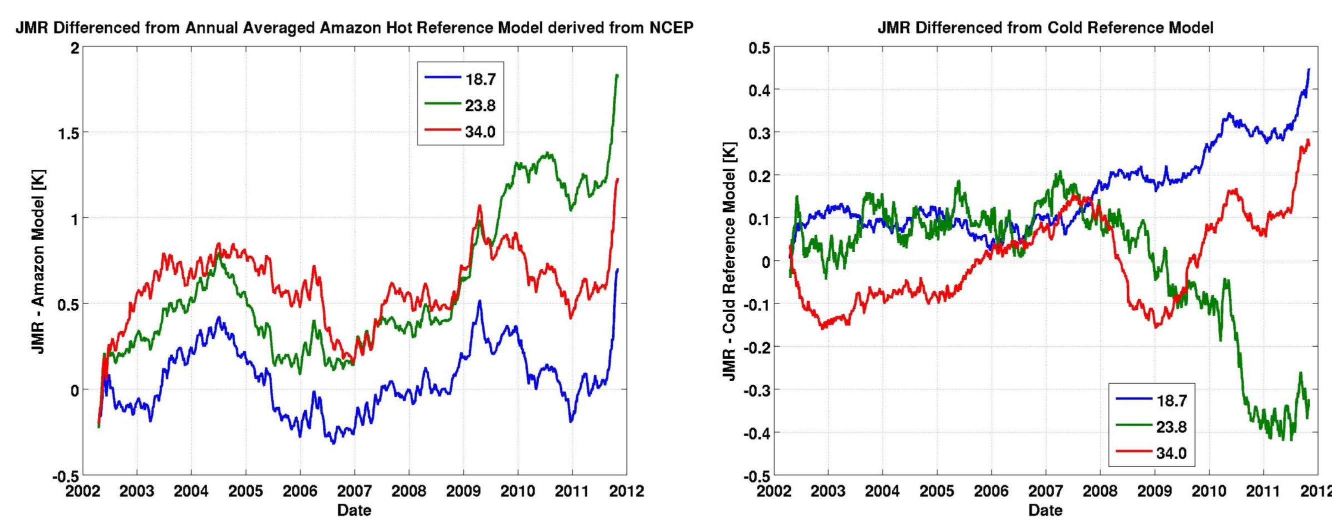



**Figure 5. JMR dynamic hot reference model derived using NCEP re-analysis fields (top), JMR GDR TBs compared to hot reference model (bottom left) and JMR GDR TBs compared to cold reference model (bottom right).**

- Calibration shift observed to occur in July 2010
- Largest shift in the 23.8 GHz channel
- Time variable gain and offset corrections developed and applied to JMR data

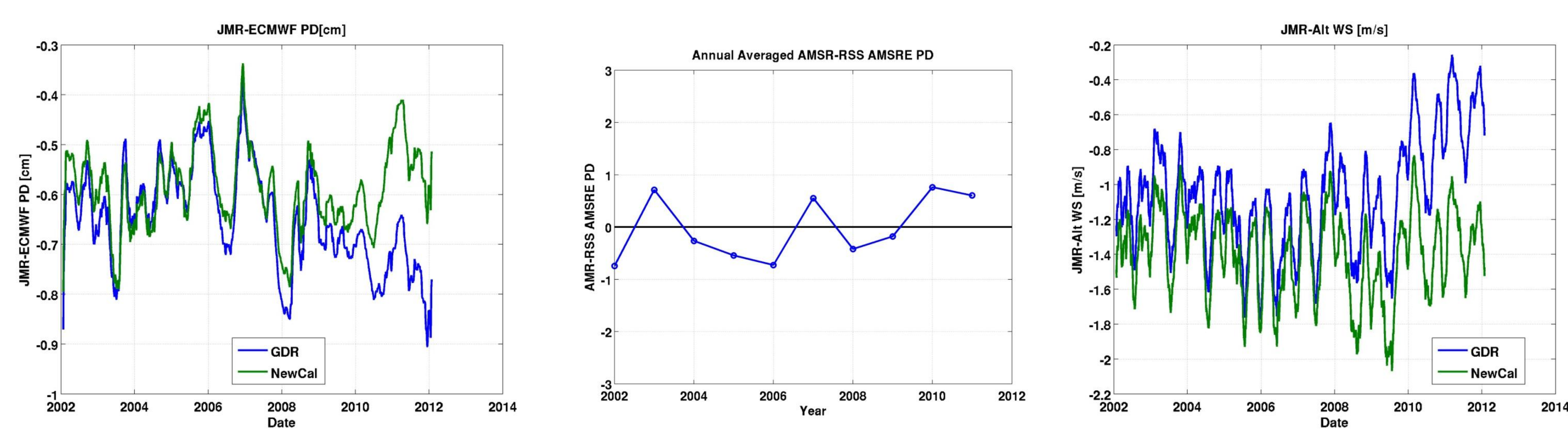



**Figure 6. JMR PD compared to ECMWF (left), JMR PD compared to AMSRE PD from RSS (middle) and JMR wind speed (right) compared to the altimeter (right) after applying time variable TB correction. The PD and wind speed drifts are significantly reduced after July 2010.**

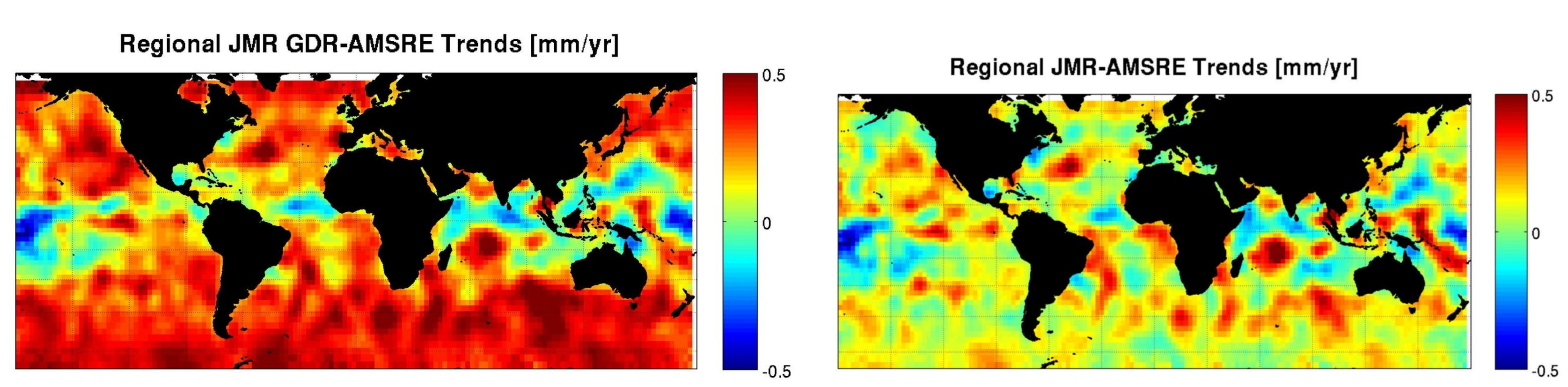



**Figure 7. JMR regional PD drift from AMSR-E for 2002-2011 for GDR calibration (left) and updated calibration (right). The regional drift is reduced to << 0.5mm/yr with the updated calibration.**

- **Mission calibration for JMR data in reference orbit in preparation**
- **Preliminary TB calibration based on natural references removes ~2mm PD shift since July 2010**
- **Inter-sensor TB calibration approach planned for final JMR mission calibration**