Calibration of the TOPEX and Jason-1 altimeter microwave radiometers using VLBI and GPS derived tropospheric delays

D. Mac Millan [1], Y. Bock [2], P. Fang [2], B. Beckley [3], C. Ma [4]
[1] (NVI, Inc., USA)
[2] (Scripps Institution of Oceanography, USA)
[3] (Raytheon ITSS, USA)
[4] (NASA/GSFC, USA)

Long-term drift calibration of the altimeter radiometer data is essential for removing any systematic radiometer drift behavior as well as for monitoring the continuity of Jason-1 and TOPEX/POSEIDON data. We are using the independent estimates of wet tropospheric path delay from VLBI (very long baseline interferometry) and GPS (global positioning system) to monitor the drift of the wet delay measured by the TOPEX altimeter microwave radiometers and will continue this effort for the Jason-1 radiometer.

Introduction

One of the contributions to the measured altimetric delay is the wet path delay caused by tropospheric water vapor in the altimetric signal path. The wet path delay is the additional time that it takes for the signal to pass through the water vapor. If this contribution is not subtracted from the measured altimetric delay, this additional time will introduce error to the measured sea surface height. A downward-looking water vapor radiometer onboard the TOPEX/POSEIDON (T/P) altimeter satellite measures microwave radiation at several different frequencies, 18 GHz, 21 GHz, and 37 GHz.
These frequencies were chosen because radiances at these frequencies are sensitive to atmospheric water vapor and liquid water.

Over the lifetime of the T/P mission, the radiometer performance has degraded with age so that radiance measurement error has increased with time. This has caused an error of about -1 mm/yr in the wet path delay derived from the radiances. Several studies [for example Ruf, 2000 or Keihm et al, 2000] have indicated that the measurements made by the T/P radiometer have drifted since the launch in 1992. This error translates directly into our estimates of the rate of change of sea surface height. This level of error is significant because global climate change analysis is sensitive to variations of the global mean sea level of 1 to 2 mm/year. Historical records of tide gauge measurements indicate that the global average sea level is rising by 1.8 mm/yr [Douglas, 1991]. To detect a signal of this size requires that one carefully calibrate all the systematic errors in the altimeter data.

The objective of our investigation is to monitor the long term drift of altimeter radiometers. Specifically, we will be monitoring the Jason-1 microwave radiometer (JMR) and are continuing to monitor the TOPEX microwave radiometer (TMR). In our investigation, we determine the drift of a radiometer using estimates of the wet zenith delay from very long baseline interferometry (VLBI) and the global positioning system (GPS) measurements. GPS and VLBI are space geodetic techniques that each provide a long and continued series of independent measurements of wet tropospheric delay measurements. Comparisons between VLBI and GPS estimates at collocated sites typically yield rms differences of 5-12 mm. This is about the same level of agreement that has been found between the geodetic techniques and ground-based water vapor radiometer measurements.

Approach

To determine the long term TMR drift, we use wet zenith tropospheric delay estimates made during altimeter overpasses at a globally distributed set of GPS and VLBI calibration sites. Currently, we are

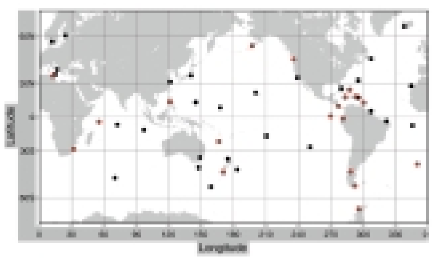

Figure 1: Map showing the location of TMR calibration sites (black circles), where permanent GPS antennas are located. VLBI antennas are collocated with GPS antennas at seven of these sites. Locations of likely new GPS calibration sites that recently began operation are indicated by the red circles.

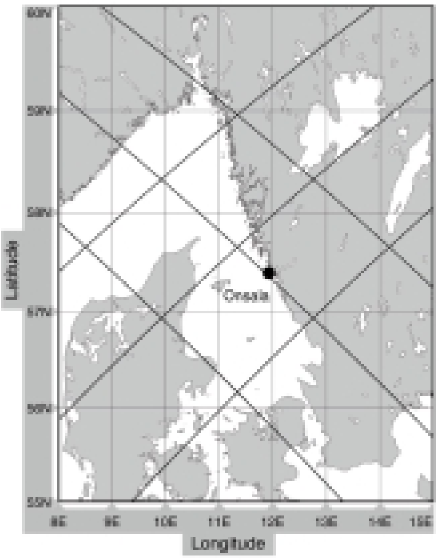

Figure 2: Calibration site at Onsala, Sweden showing the nearest TOPEX altimeter tracks.

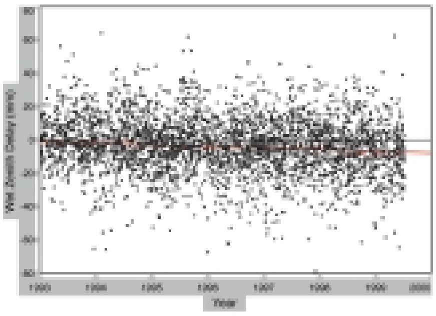

Figure 3: Differences (TMR-GPS) between the TMR and GPS wet path delay for 8 GPS sites and the implied linear drift error (red line) of -0.9 ± 0.2 mm/yr.

analyzing data from about 25 coastal and island sites. A TOPEX orbit track typically lies within 20-100 km for most of these sites. For future monitoring of the JMR in the upcoming Jason mission, additional sites will be used when they become operational. The map in figure 1 shows our current calibration sites as well as new possible sites that have recently begun operation.

The TOPEX and Jason altimeter satellites orbit the earth so that the orbit track on Earth's surface below the satellite repeats itself about every 10 days. At the equator, the ground tracks are spaced about 300 km apart. The coastal geometry near a site determines the feasibility of using a particular ground track near a site. TMR measures an average radiance over a ground footprint, which has a diameter of about 20-40 km depending on the microwave frequency. It is desirable to choose a calibration point along the track that is as near as possible to the calibration site while minimizing the effect of land on the TMR measurements. The map in figure 2 shows our calibration site at Onsala, Sweden and the nearest TOPEX groundtracks.

TOPEX Results

At the time of each altimeter pass near a given calibration site, the difference between the TMR wet path delay and the GPS or VLBI wet zenith delay was computed.
These differences are shown in figure 3 for a set of 8 GPS sites with 15 site/track pairs. For this plot, site biases were removed. Based on these sites, the mean TMR drift rate from 1993.0 to 1999.5 is -0.9 ± 0.2 mm/yr. For the period before 1997.0, the rate is -1.3 ± 0.3 mm/yr. This is consistent with analysis by [Ruf et al., 2000], which indicates that the TMR wet path delay drift is due to a drift in the TMR 18 GHz channel that produced a wet path delay drift of -1.3 mm/yr. This drift ended after the end of 1996. Similar analysis with VLBI wet zenith delay estimates from 4 calibration yielded a TMR drift rate estimate from 1992-1999.5 of -1.1 ± 0.5 mm/yr.

References

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Corresponding author:
Dan MacMillan
NVI, Inc./NASA GSFC
Code 926
Greenbelt, MD 20771 - USA
E-mail: dsm@leo.gsfc.nasa.gov