Extending the TOPEX/Jason Global Mean Sea Level Time Series with GEOSAT Observation

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Abstract

The rate of global mean sea level rise over the past 15 years determined from TOPEX/Jason satellite altimeter observations is ~3 mm/yr, more than 50% greater than tide gauge-based estimates of sea level rise over the past century. Determining whether the present higher rate is a reflection of decadal variability or long-term change is an important Global Warming issue. Here we extend the length of the altimetric global mean sea level record to 22 years, using tide gauge measurements to connect a new, improved version of GEOSAT observations (1985-1988) with TOPEX observations beginning in 1992. The GEOSAT data set has been enhanced with orbits based on a new GRACE gravity model, resulting in a significant reduction in the rms crossover differences. A statistical analysis showing the day/night effects of the ionosphere on the single frequency GEOSAT observations is presented.

1. The Problem:

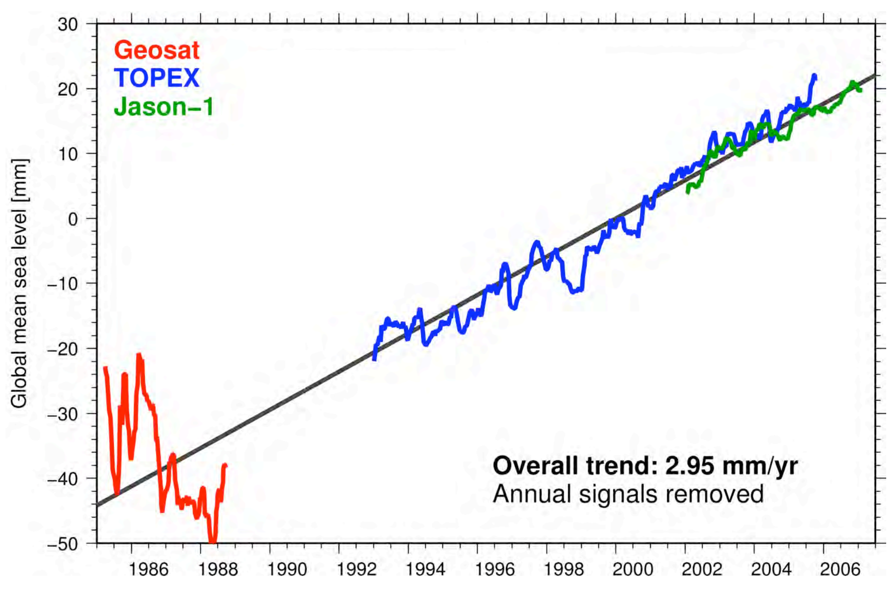


Figure 1. Global mean sea level change from Geosat, TOPEX and Jason-1, based on a simultaneous fit to a single trend and annual function and separate bias estimates for each satellite.

The Geosat Geodetic Mission (GM) data set has recently been upgraded with new orbits computed by F. Lemoine, NASA/Goddard, reducing the rms orbit error from about 10 cm to 5 cm.

Also, each Geosat GM waveform at the full (10 Hz) sampling rate was retracked by a method that eliminates the coupling between SWH errors and SSH errors, similar to what was previously developed for ERS-1 by D T Sandwell & W H F Smith (Geophys J Int (2005) vol 163, pp 79-89).

The retracking eliminates noise resonance and down-track group delay from the on-board alpha-beta tracker, cutting the r.m.s. noise in SSH by 50%.

Using this new data set, Figure 1 shows the global mean sea level record from Geosat, TOPEX, Jason-1, based on a simultaneous fit to a single trend and annual function and separate bias estimates for each satellite. The overall trend is 2.95 mm/yr with bias values of:

geosat = 40.56 mm; topex = 16.58 mm; jason-1 = 143.35 mm

topex - gm = 23.98 mm

Two Issues:

---This fitting process doesn't allow for the possibility of an acceleration between Geosat and TOPEX.

---The downward trend in Geosat, -6.8 mm/yr, is probably wrong, considering the stable upward trends in TOPEX and Jason-1.

2. Methods

Tide Gauge Locations

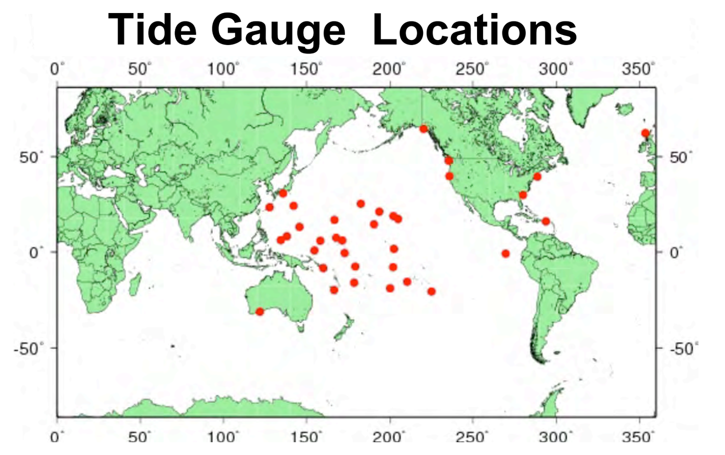


Figure 2. 39 tide gauge records were selected from the PSMSL archive based on the requirement that they each span the Geosat to Jason-1 time period

We approach the problem of independently estimating a Geosat bias and drift by using tide gauge records that span the GM & ERM and the first 2 years of the TOPEX mission to "connect" the two time series

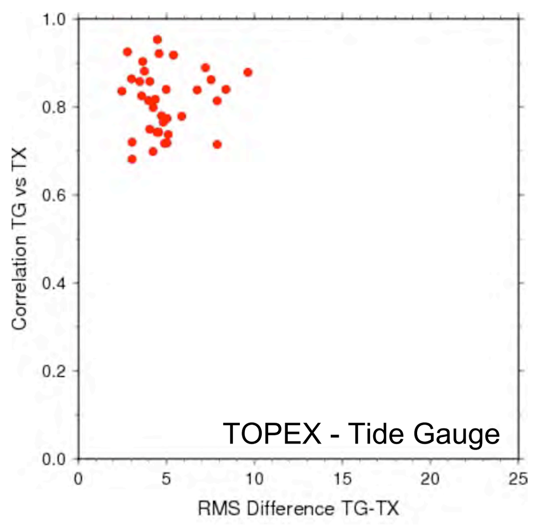
A total of 39 PSMSL gauge records (Figure. 2) were initially selected . Daily means were differenced with respect to along track, tidal corrected altimeter observations, using the following selection and averaging rules:

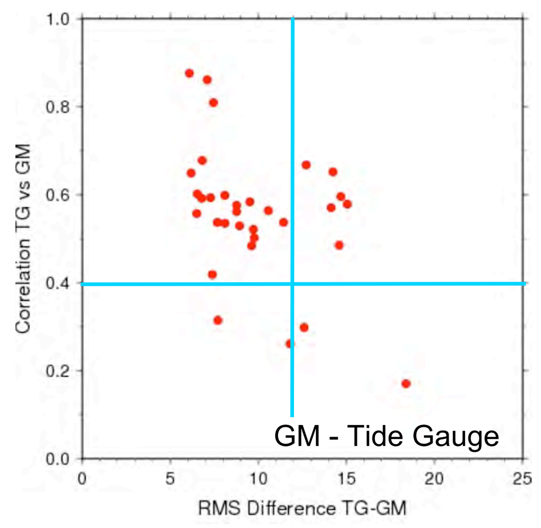
Geosat Geodetic Mission (GM) : all passes falling within +/-0.75° longitude of gauge, averaged over +/-0.5° latitude centered on gauge site.

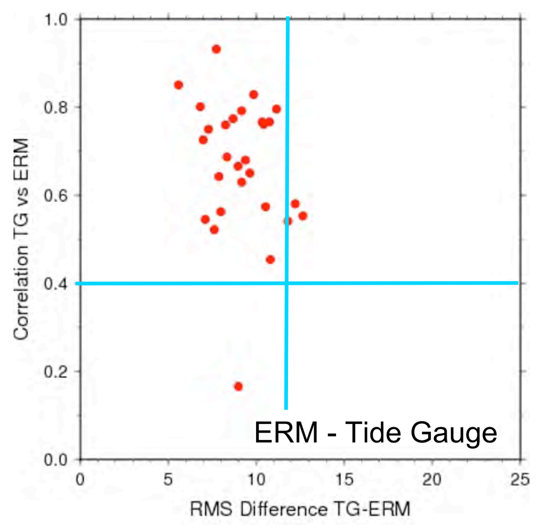
Geosat Exact Repeat Mission (ERM) and TOPEX Mission: nearest ascending and/or descending passes, depending on the correlation wrt to the gauge record; averaged over +/-0.5° latitude centered on the gauge.

3. Correlation vs RMS TG-Alt Difference

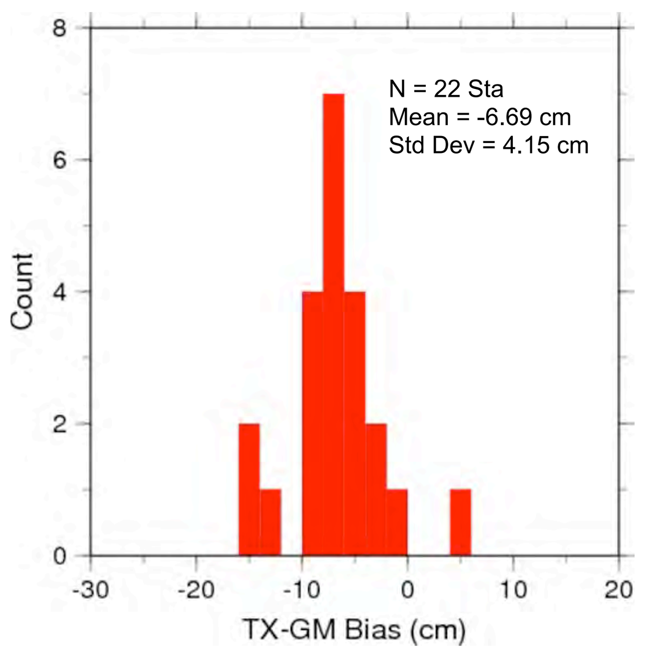
Figure 3a,b,c shows for the 3 separate missions the correlation vs rms difference at each gauge site. Not surprisingly, TX displays the highest r's and lowest rms's, followed by the ERM and then the GM. The relatively poor performance of the GM is probably the result of using a mean sea surface to determine the altimeter deviations, rather than a repeat track mean. Based on these figures, we exclude from subsequent calculations all TG/Alt comparisons which have an RMS > 12 cm or a correlation < 0.4







4. Estimating Geosat Bias Relative to TOPEX



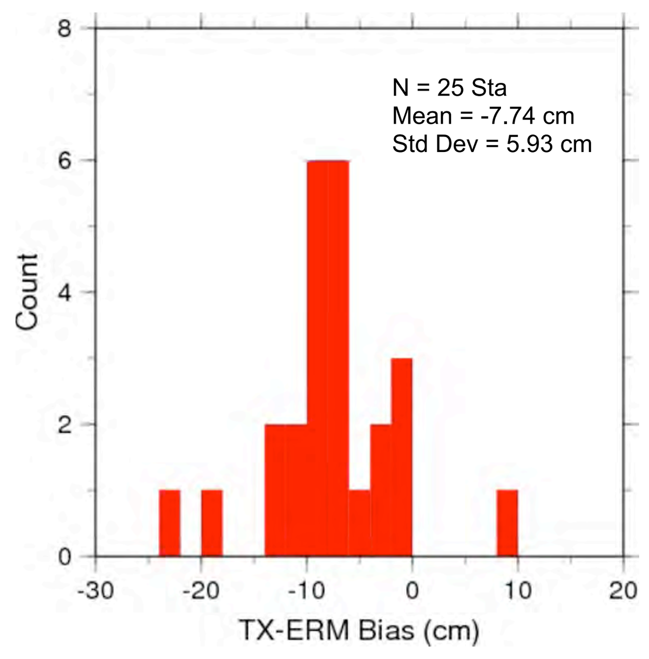


Figure 4a,b. Histograms of TX-GM and TX-ERM Bias

Figure 4a,b. show for each Tide Gauge (TG) station the TG-GM and TG-ERM means relative to the TG-TX mean. The GM and ERM mean biases are quite similar, -6.69 and -7.74 cm, respectively. The GM bias has a lower standard deviation, despite the fact that the GM has lower correlations and higher rms's than the ERM (Figures 3a,b). For comparison with these results, note that an earlier attempt at estimating Geosat biases iusing tide gauges found a GM bias of -7.9+/-2.4 cm and ERM bias of -8.9+/-2.5 cm, based on 8 and 10 stations, repectively (T. Urban, 2000).

5. Estimating Geosat Drift Relative to Tide Gauges

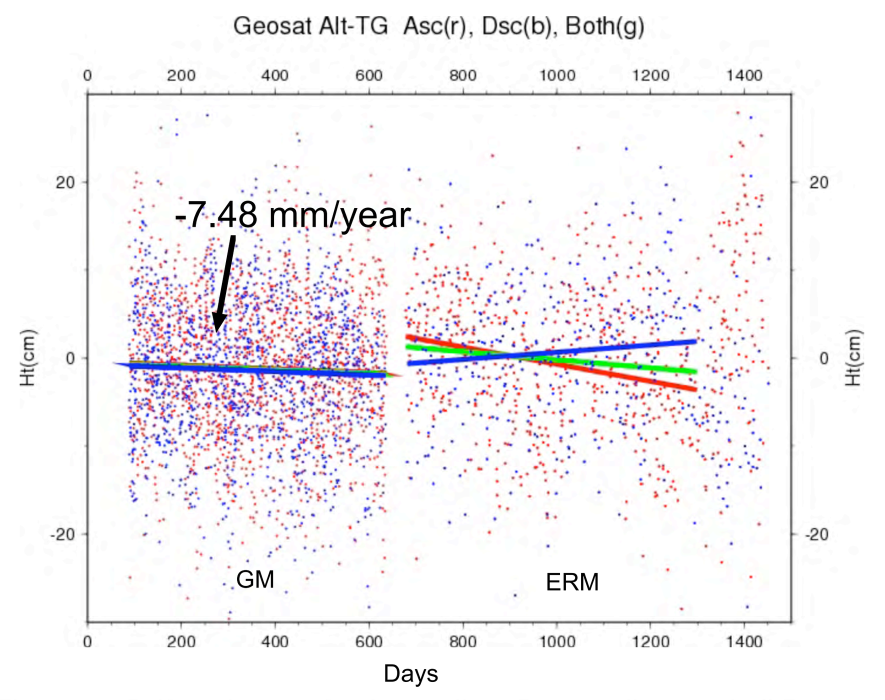


Figure 5a Drift estimates for Ascending, Descending, and all Passes

Figure 5a (left) shows the drift estimates (Geosat -Tide Gauge) computed separately for ascending, descending, and all passes . For the GM, the three curves fall almost exactly on top of each other, with an average of -7.48 mm/yr. The ERM shows diverging estimates, perhaps due to having fewer samples, poorer orbits and greater ionosphere errors.

Figure 5b (right) Illustrates the potential problem caused by the use of model ionosphere corrections. The day time trends are more negative in both the GM and and especially in the ERM, when the ionosphere was most active.

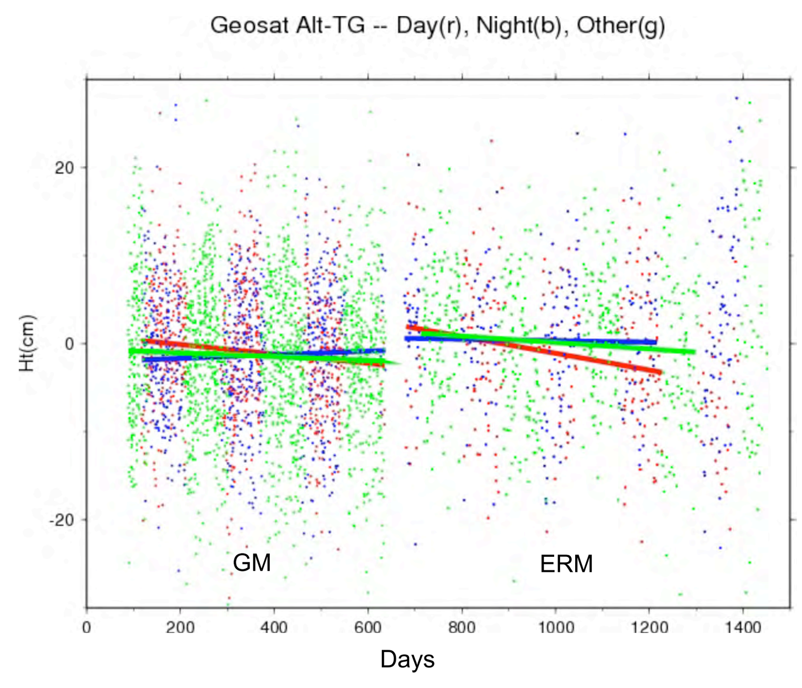


Figure 5b Drift estimates for Day Time, Night Time, and Other

6. Global Mean Sea Level with Drift Corrected Geosat

Although much more work needs to be done, it's instructive to see how the global mean time series shown in Figure 1 is altered by applying a drift correction of 7.48 mm/yr to the Geosat record, prior to simultaneously fitting a trend, annual cycle and separate bias estimates for each satellite. The result, Figure 6, shows Geosat has now flipped from a steep downward trend to a slight upward trend.

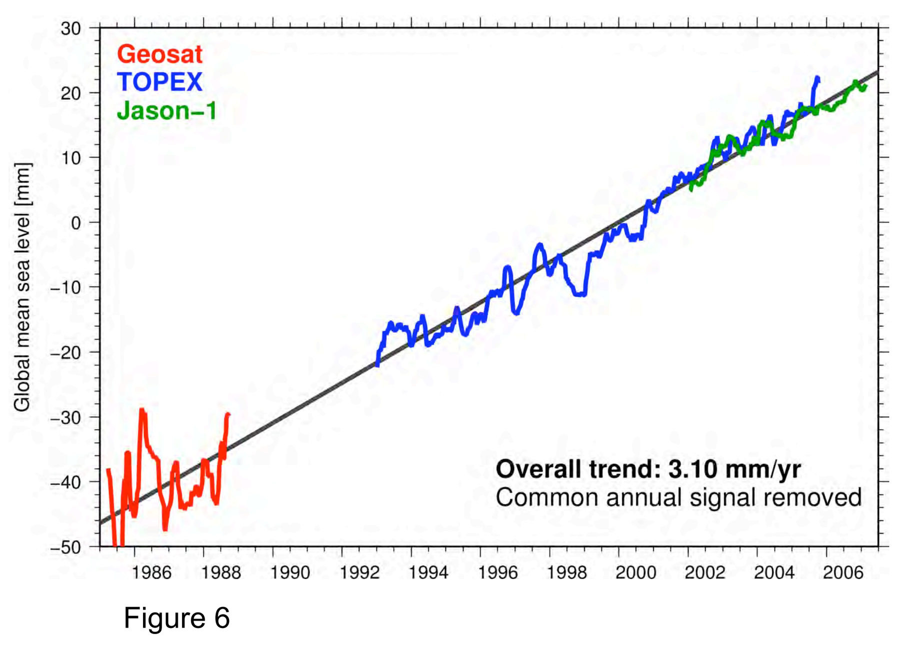


Figure 6

Summary

- **The GM and ERM bias estimates (-6.69 cm and -7.74 cm) are more negative than the least-squares fitted value, -2.38 cm, shown in Figure 1, but not significantly so. More work needs to be done to narrow this discrepancy.**
- **The drift estimates, particularly the GM values in Figure 5a, strongly suggest that the global mean Geosat time series contains a large drift error... large enough to cause the overall trend to switch signs from positive to negative.**
- **This is a very preliminary analysis. Much more work needs to be done to determine the best selection of gauge measurements and either improving the ionosphere model or developing ways of avoiding ionosphere errors. It would certainly help to have the ERM orbits recomputed with the newest gravity model.**