A Continuous Record of Long-Term Sea Level Change from TOPEX/Poseidon and Jason

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Abstract

Jason-1 radar altimeter data have been used to extend the TOPEX/POSEIDON (T/P) sea level change measurements in a seamless fashion. We discuss the numerous tests and comparisons we have done to develop and validate the combined time series, including results from using the global tide gauge network to calibrate each mission. Analysis of the combined time series suggests we can have increasing confidence that the observed changes represent true long-term variations, although the possibility of decadal variations still can not be entirely ruled out. We discuss the changes we have observed in an EOF decomposition of the combined time series, versus what was observed from the T/P mission alone.

Correction differences mapped into mean sea level

Immediately following the calibration phase of Jason-1, several studies evaluated the global along-track residuals of the corrections provided on the initial Jason-1 IGDRs as compared to the T/P MGDRs [e.g. Nerem et al., 2002, Chambers et al., 2002]. We revisit this analysis using the Jason-1 GDRs. Estimates of three corrections are dependent in part on measurements from each altimeter: the dual-frequency ionosphere path delay, the radiometer wet troposphere path delay, and the sea state bias. The relative bias (Jason-1 – T/P) for the ionosphere path delay ranges from 3–4 mm. This is not unexpected as the TOPEX ionosphere correction on the MGDRs has not been recomputed to account the errors in the TOPEX-B sea-state bias (SSB) correction found by Chambers et al. [2003]. The rms difference between the Jason-1 TOPEX ionosphere path delay is roughly 14 mm for all cycles. Note that T/P cycle 361 was a POSEIDON cycle and had no dual-frequency ionosphere correction. Both the bias and the rms of the difference exhibit drifts over the calibration phase, with the rms doubling from about 3 to 6 mm. Comparisons of global means of the T/P and Jason wet troposphere path delays show significant differences during the tandem phase (Figure 1). Drifts in the Jason path delay could potentially cause drifts in sea level at the 1–2 mm/yr level. A drift is also present between near-coincident measurements from the Jason and TMI radiometers [V. Zlotnicki, personal communication].

Several SSB models for both T/P and Jason-1 have become available since the calibration phase. We have evaluated three T/P models and two Jason models. The TOPEX models are the model on the MGDRs, which was derived from TOPEX-A data, and two models based on TOPEX-B data: non-parametric model from CLS the parametric model T-CSR. The two Jason models are the non-parametric model included on the GDRs and the parametric model J-CSR. Note that the SSB is a composite correction. It includes both the electromagnetic bias, which is assumed to be frequency-dependent and hence identical when altimeters measure an identical sea state, and a tracker bias. Global along-track residuals of cross-comparisons of each of these SSB models leads to different relative biases, which in turn will affect the relative bias estimation in SSH. The largest relative bias (~8 cm) is produced by using the SSB models on the respective (M)GDRs. Use of the T-CSR model with either the J-CSR model or the Jason GDR model produces the smallest biases (±5 mm). The smallest rms differences (~15 mm) are found in the residuals of these same two combinations (figure 2). In the remaining results in this study, we evaluate the combination with the lowest rms, T-CSR and Jason GDR.

We have tested the effect of using JPL Jason orbits [B. Haines, personal communication]. Global mean sea level differ (Figure 4). The tide gauge calibration of sea level computed using these orbits shows a significantly lower drift than the GDR orbits (Figure 4).

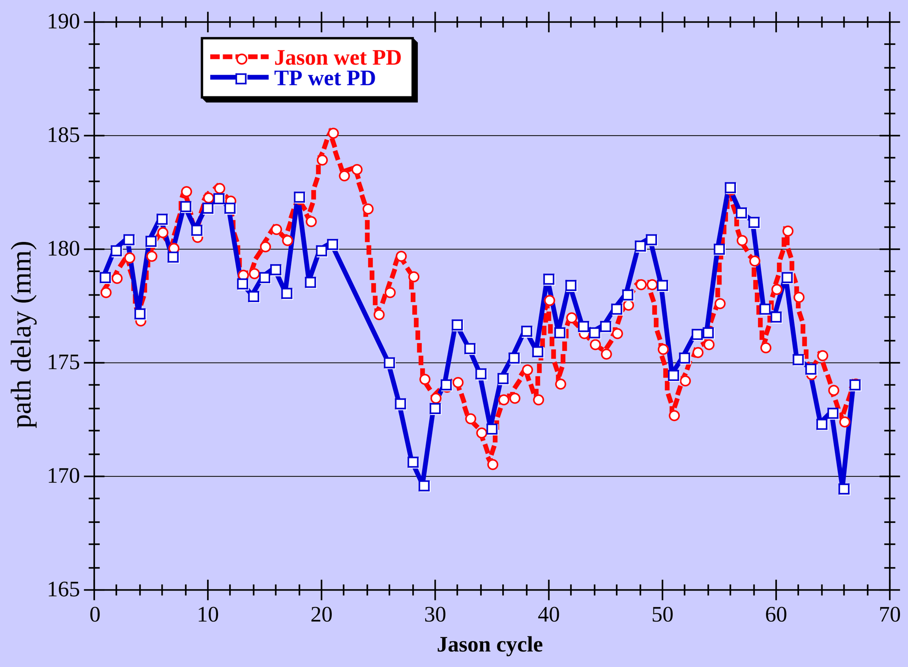


Figure 1. Wet troposphere path delay from Jason-1 and T/P. The TOPEX path delays have been corrected for yaw-related bias and a constant bias.

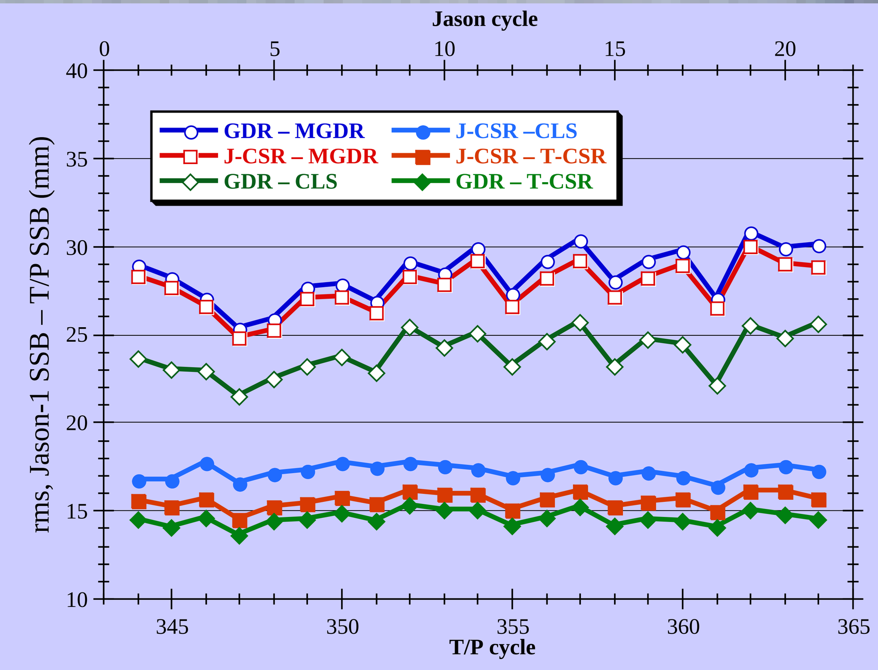


Figure 2. Root mean square of the difference in the global mean sea state bias corrections from T/P and Jason-1 during the calibration phase.

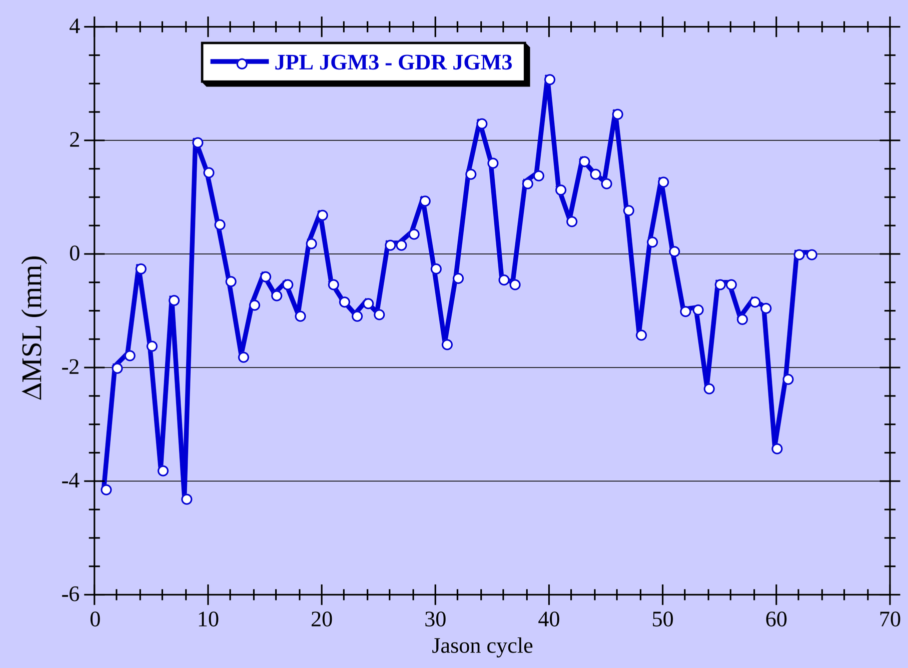


Figure 3. Global mean differences from sea level computed using the Jason GDR orbits and JPL orbits.

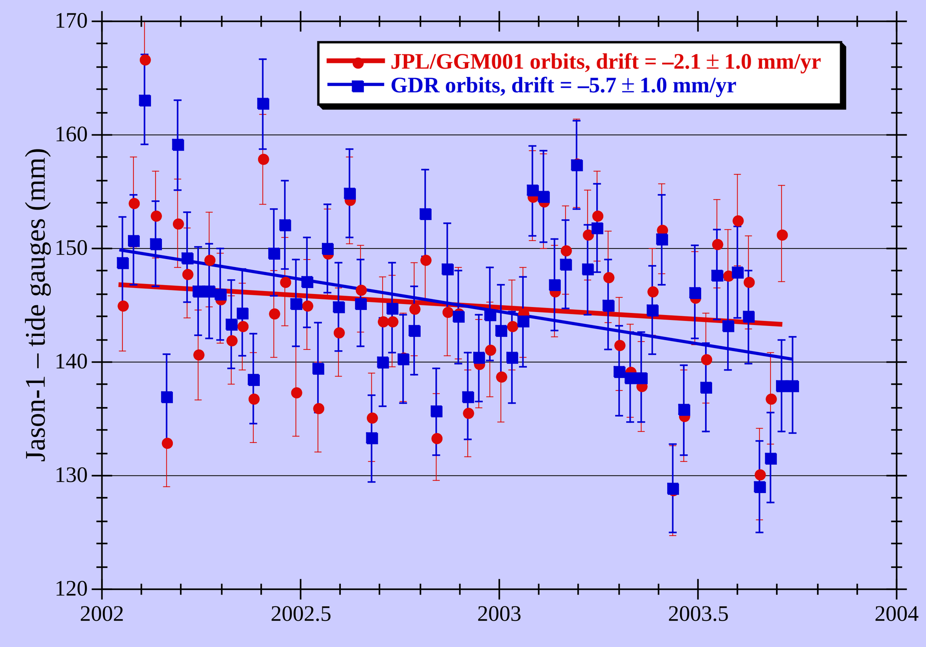


Figure 4. Tide gauge calibration of mean sea level computed using the Jason GDR orbits and JPL orbits.

Continuous record of sea level

A variety of models for the serial correlation were used to calculate the scale factor in the trend error estimate due to the scatter. This random error is estimated to be ±0.2 mm/yr. Even though we have not used the tide gauge calibration to "correct" mean sea level, the calibration can estimate how much of the trend is linear drift error in the altimeters, which is a bias error in the trend estimate. At present, the gauges indicate that the drift error is consistent with zero, but only to a precision of about 0.4 mm/yr. Hence, the estimated bias error due to the altimeter drift is 0.0 ± 0.4 mm/yr. Combining the bias error with the random error produces a final trend error of $(0.4^2 + 0.2^2)^{0.5}$ = 0.4 mm/yr.

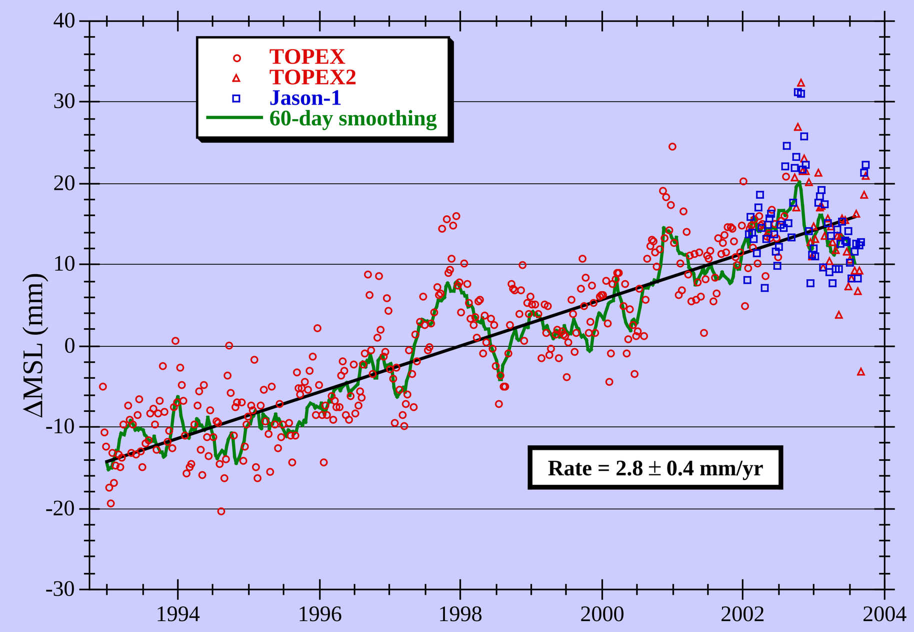
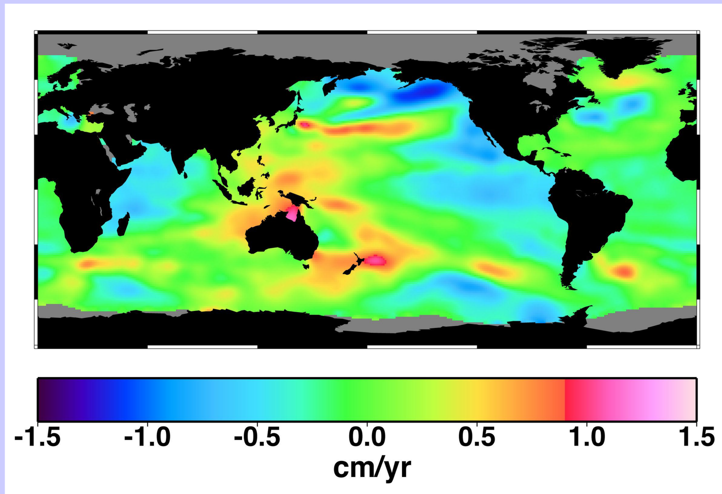
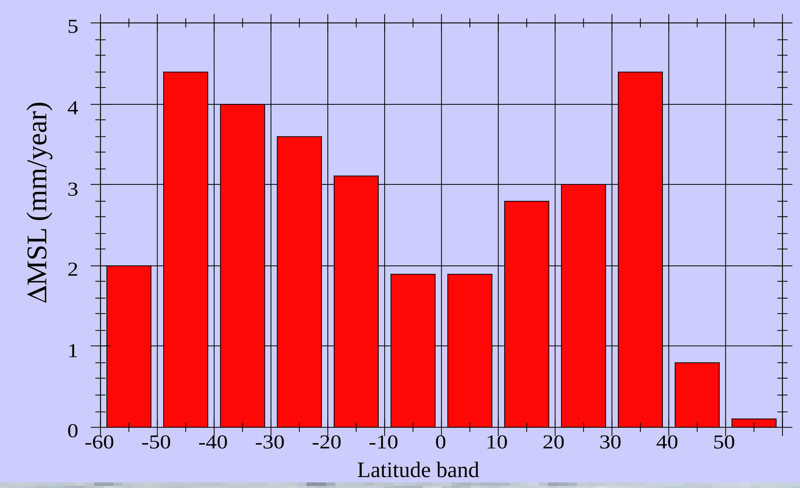


Figure 11. Global 10-day mean sea level variations from TOPEX/POSEIDON and Jason-1. No tide gauge calibration has been applied. No inverted barometer correction has been applied to the series.

Local trends in sea level



Latitude dependence of sea level change



Intersatellite calibration

During the calibration phase, sea level measurements estimated from Jason GDRs and corrected T/P MGDRs agree with a rms difference of 1.6 mm (Figure 5). The rms difference during the tandem phase (Jason cycles 29–63) is 3.2 mm (Figure 6). We modify the T/P MGDRs to use the CSR SSB model, GOT99b tides, a TMR drift correction, and the GCP-C wet troposphere yaw-bias

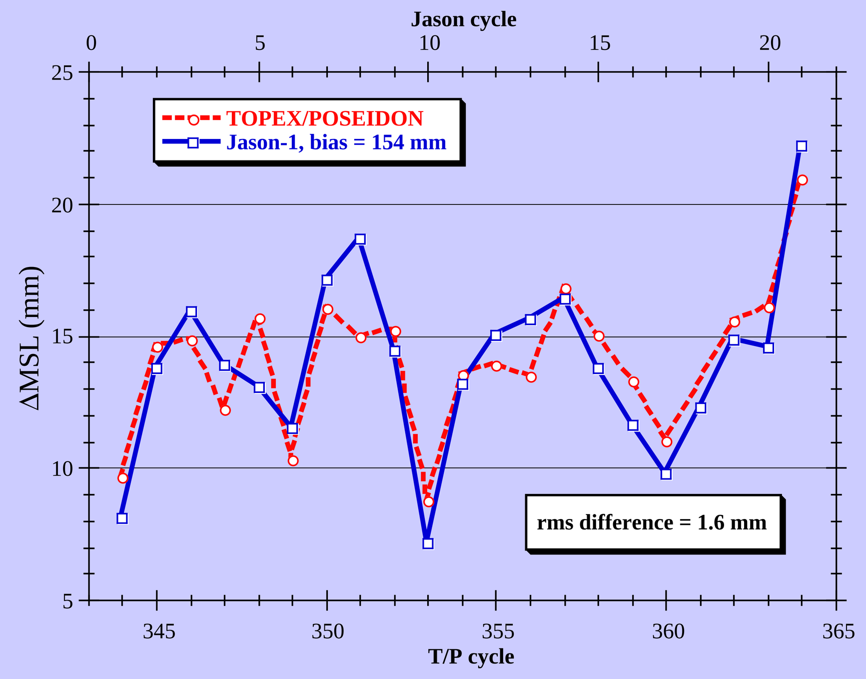


Figure 5. Ten-day global mean sea level estimates from T/P and Jason-1 during the calibration phase. A 154 mm bias has been removed from Jason-1. The zero level of the time series is the mean sea level during the original T/P mission.

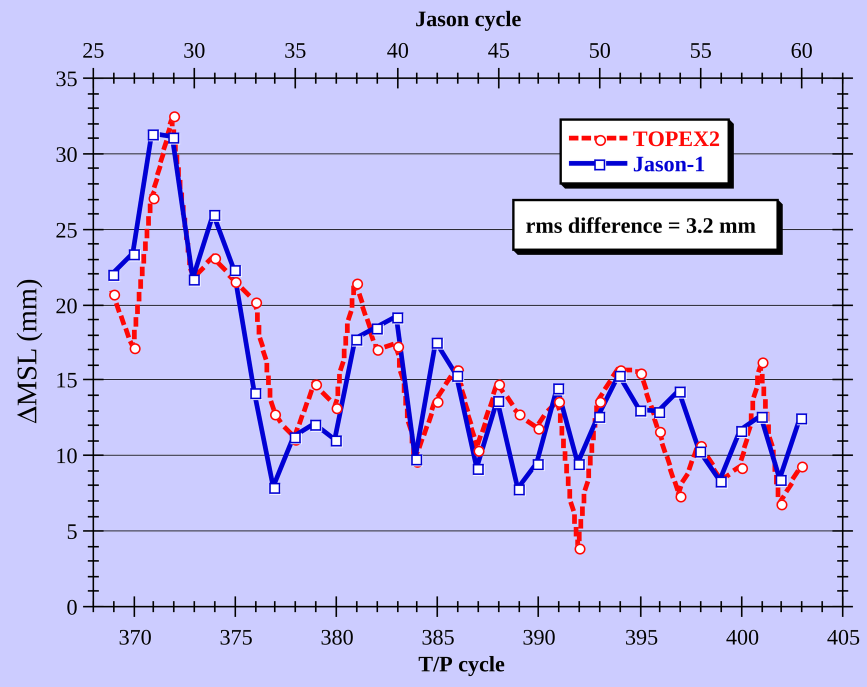


Figure 6. Same as Figure 5, except that the period is the tandem mission, where T/P is in an interleaving orbit with Jason-1.

Tide gauge calibration

The tide gauge calibration has been useful in detecting instrument drifts and algorithm errors [Mitchum, 1998] and is crucial for developing a continuous record of sea level. It provides an independent calibration when switching between instruments (e.g. TOPEX-A to TOPEX-B and T/P to Jason-1). Tide gauges have to be corrected for land motion, possibly introducing some systematic errors.

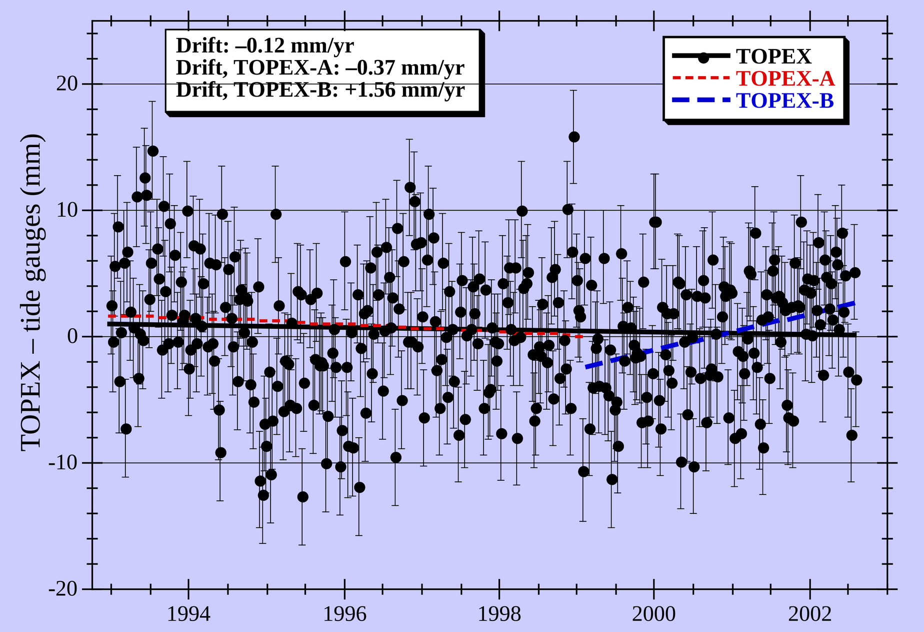


Figure 7. The present estimate of the TOPEX drift computed from the global tide gauge analysis. The solid dots and error bars are the estimates that are computed independently for each cycle of the TOPEX data, and the solid line is the result of fitting a linear trend to the data.

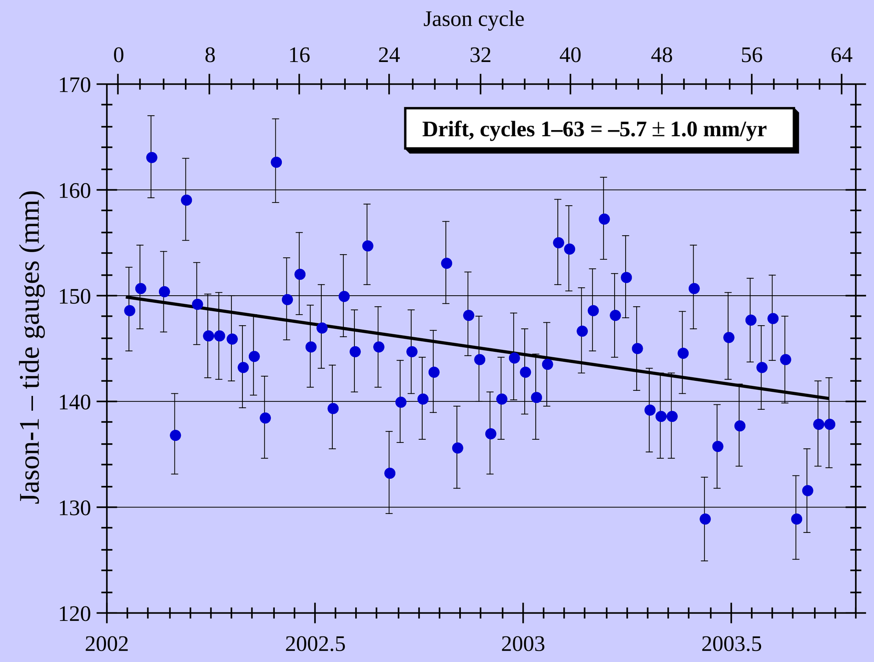
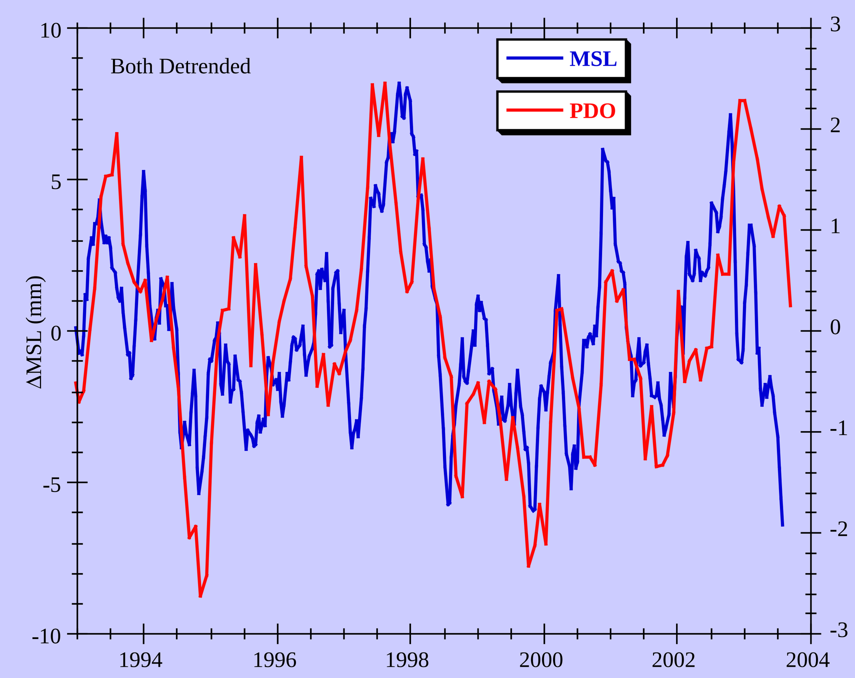


Figure 8. Same as Figure 7, except for Jason-1.

Pacific Decadal Oscillation vs. sea level



Mean sea level in empirical orthogonal functions

An empirical orthogonal function analysis of the present combined T/P and Jason-1 sea level data has a single mode that is highly correlated with the mean sea level curve (Figure 12). The spatial pattern associated with this mode suggests that as much of the mean sea level variation is related to signals in the southern hemisphere as well as the tropics. More altimetry data are required to verify that this mode remains stationary.

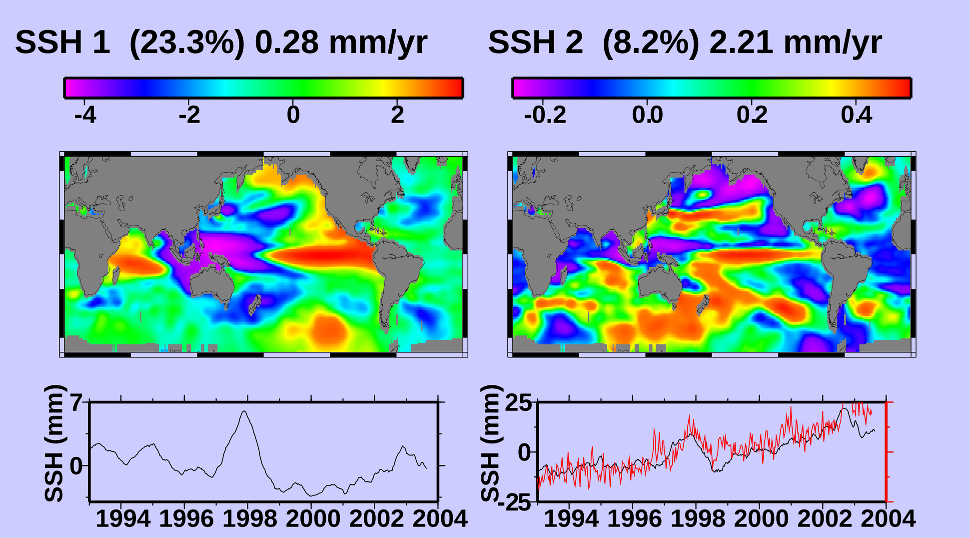


Figure 12. Leading sea level EOFs for T/P and Jason. Mode 2 shows significant correlation with global mean sea level (red). Seasonal terms have been removed.

References

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