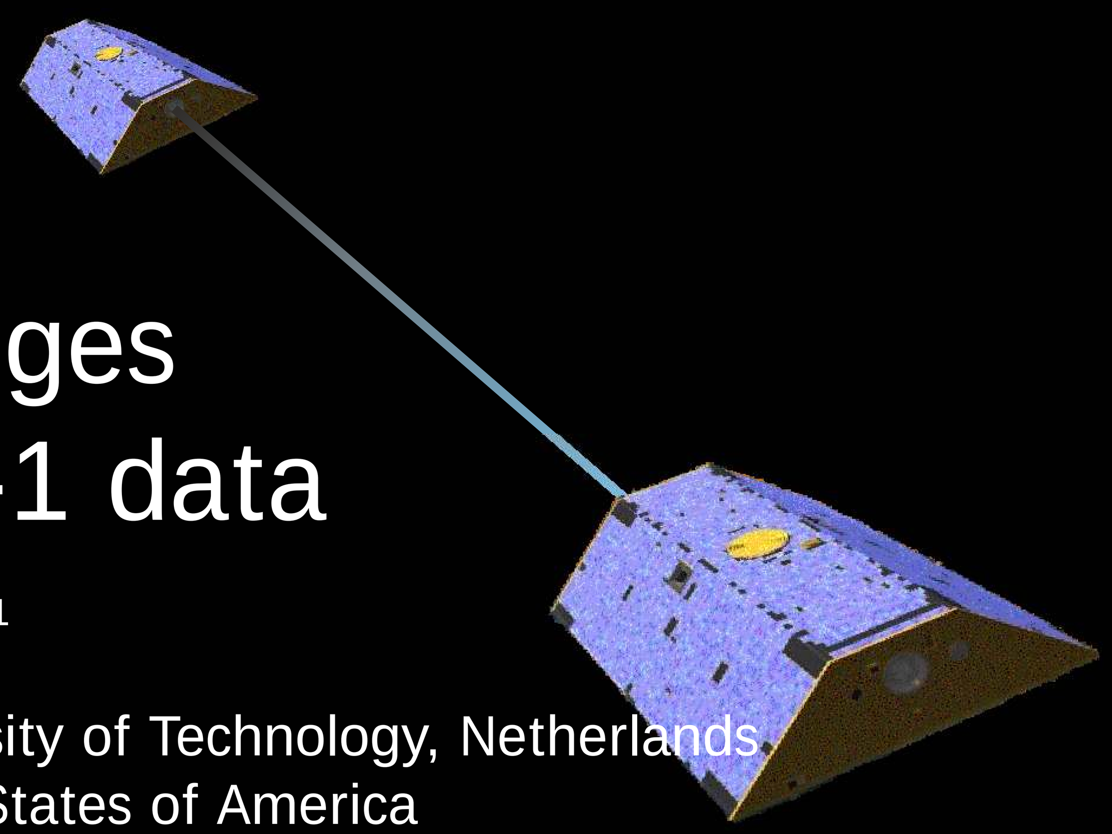

Identification of sea level changes using GRACE, TOPEX and JASON-1 data

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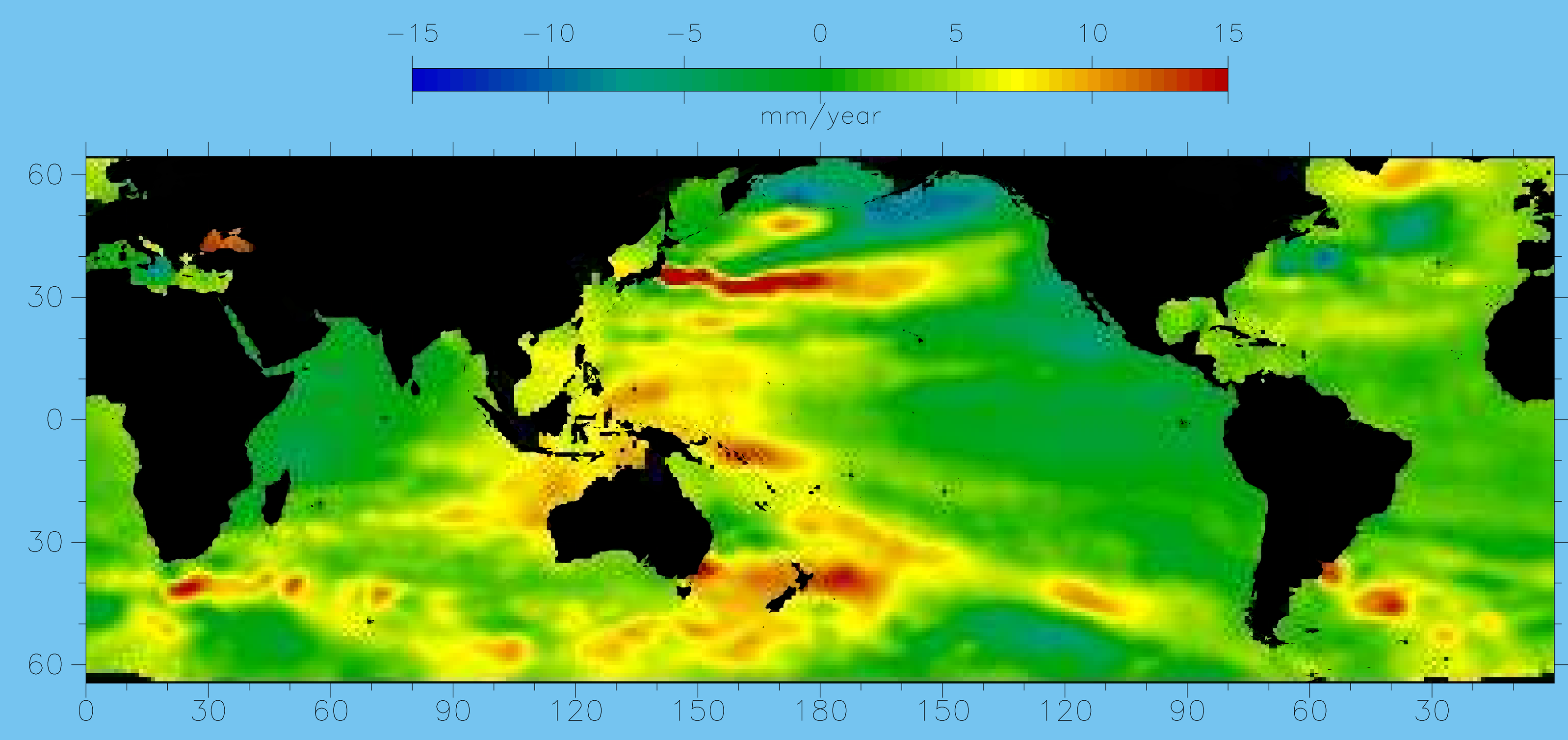
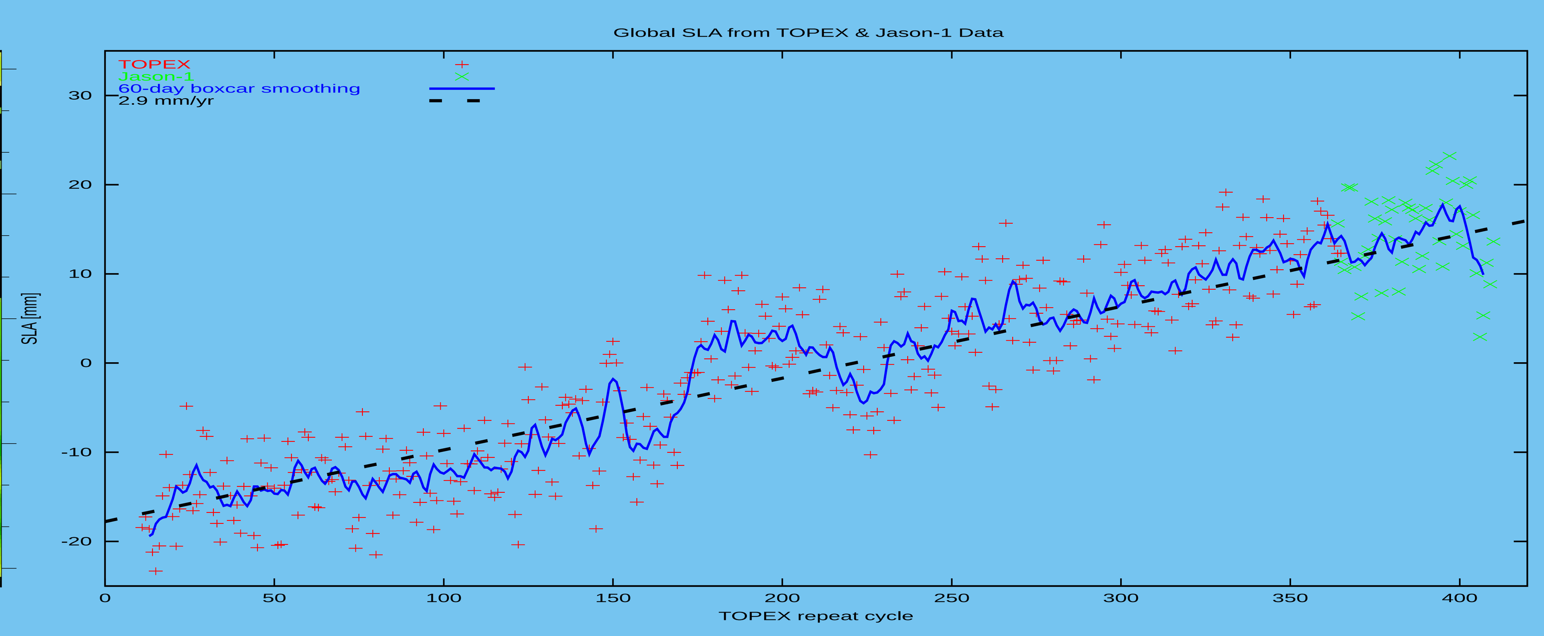
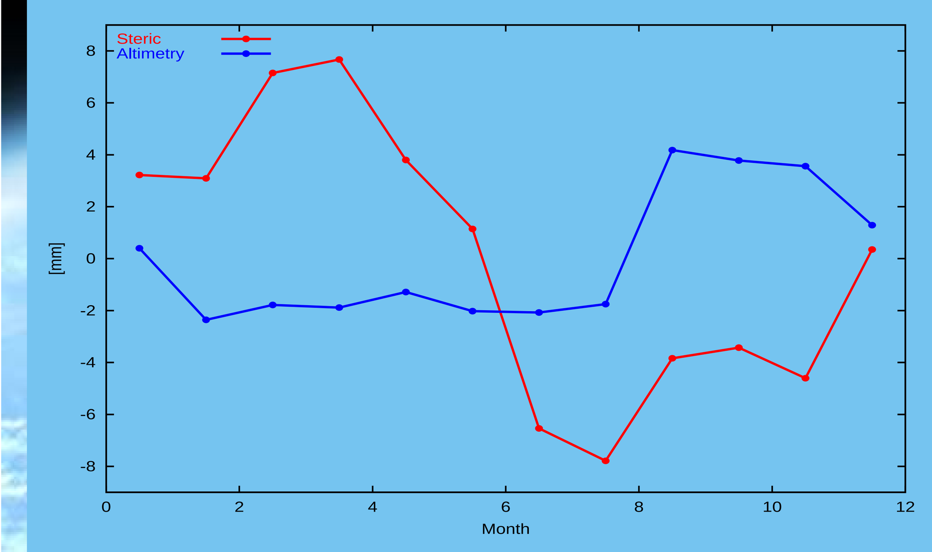
Abstract

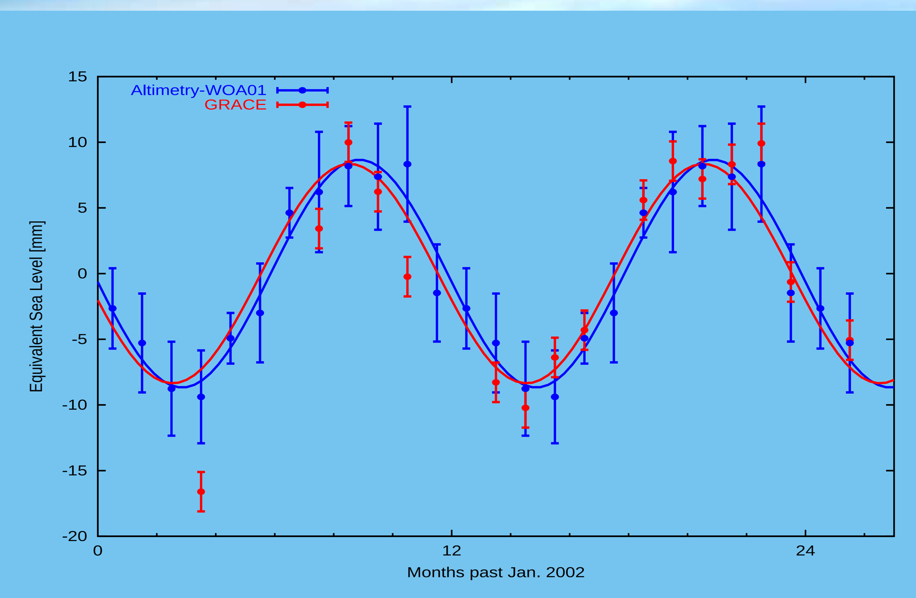
Using 11-year of TOPEX and Jason-1 altimeter data, a trend in the global mean sea level (GMSL) of 2.9 +/- 0.4 mm/yr has been observed over the period 1993-2003. The TOPEX data was corrected for sea state bias using the CSR_A/B model, which raised the estimated trend with respect to the BM4 model (1.9 +/- 0.4 mm/yr).
To estimate the seasonal variations of the global eustatic signal in the oceans, two different approaches were followed. First, the altimeter data was averaged over the 11-yearly months to produce a mean monthly climatology set. These were corrected for the steric contribution using monthly average grids of salinity and temperature from the World Ocean Atlas 2001 (WOA01).
In the second method, the monthly estimates of the Earth's gravity field from the GRACE mission were used to infer mass changes over the oceans, equivalent to the eustatic signal. Both methods give comparable results, with similar estimates for amplitude and phase. The small differences between the two methods could be partly explained by the interannual variations measured by GRACE. To study the accuracy of the two methods at a local scale, the eustatic signal was also estimated in the three major ocean basins. Differences in this area might be attributable to the barotropic model used to correct the GRACE data.



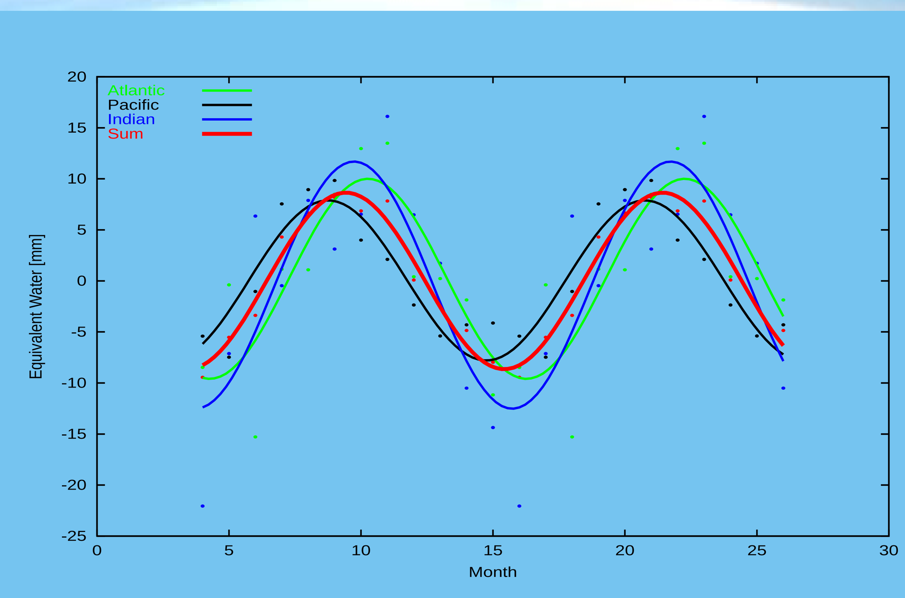


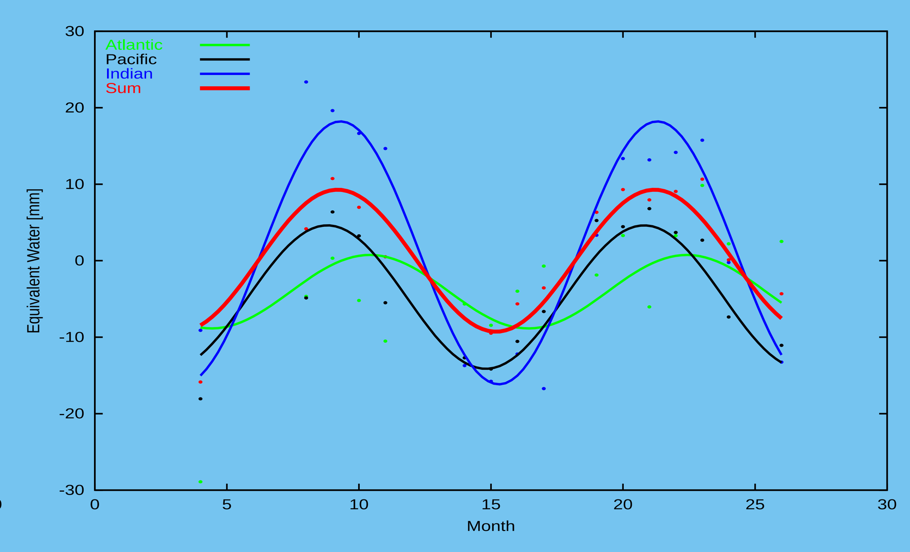
Eleven years of TOPEX and JASON-1 data (cycle 11-415) has been used to construct a time series of the area-weighted GMSL. To reduce aliasing of the tidal M2 and S2 tidal constituents, a 60-day box car filter has been applied. Two different sea state bias models were used, i.e. the BM4 and CSR_A/B model. The results of the latter are presented here (right panel). After removing an annual and semi-annual signal, a linear trend of 2.9+/-0.5 mm/yr was fitted to the time series, a significant increase with respect to the BM4-model (1.9+/-0.5 mm/yr).
The left panel gives an illustration of the local trends of the rise in sea level over the 11-year period. Note the difference between the two hemispheres. The value computed in the Northern Hemisphere 2.2+/-0.5 mm/yr is much closer to the values obtained from tide gauges studies (~1.8 mm/yr), which uses mainly stations located in this region of the Earth. This indicates that part of the difference between the two methods is attributable to the geographical biases of the tide gauge stations.





The TOPEX and JASON-1 data were averaged over the 11-yearly months to obtain monthly climatology sets of the sea level anomaly. The steric sea level has been computed using analyzed monthly temperature and salinity grids from the World Ocean Atlas 2001. The results can be seen in the left panel. To infer the global ocean mass changes, the two obtained climatology sets were differenced, yielding the global mean eustatic sea level signal, to which a cosine with an amplitude of 8.6 ± 0.6 mm and phase of 279° ± 5° was fit (right panel, blue line).
The same eustatic signal was estimated using the first 16 monthly GRACE solutions to which a correction for the geocenter movement was applied. To compensate for the increasing errors in the monthly fields at higher degrees, a Gaussian smoothing filter with an averaging radius of 2000 km has been carried out. A cosine-fit to the GRACE data, excluding the spurious April/May measurement, resulted in an amplitude of 8.4 ± 1.7 mm and a phase of 271°±7.5° (right panel, red line).
The two signals agree very well, considering the fact that the GRACE data is influenced by interannual variations whereas the altimetry-WOA01 data is not. Despite this, the amplitude and phase are consistent, indicating that both observations techniques are measuring the same mass variations and that the GRACE satellites are capable of observing real ocean mass variations, at least globally.





The two figures above show the contributions of the three major ocean basins (i.e. Indian, Pacific and Atlantic Ocean) to the total mean ocean water mass variations as measured by altimetry-WOA01 (left) and GRACE (right). Relative to its size, especially the Indian shows a lot of variability, both in the GRACE and altimetry-WOA01 measurements. The phase estimated from the two measurements agrees within the confidential intervals, but the amplitude shows significant differences. This might be attributable to the barotropic ocean model used in the background processing, which is known to have problems at monthly periods.

Conclusion

This study indicates that GRACE is capable of measuring seasonal mass variations in the ocean on a global scale, and possibly also on local scales. In the near future, the procedure used in this study might lead to direct observations of inter-annual and secular changes in the eustatic sea level, which nowadays relies on scarce temperature and salinity in-situ measurements. In combination with altimetry observations, the changes in sea level due to ocean heating can be inferred. This will improve understanding and modelling of the global climate system.
On local scales the GRACE observations perform relatively well, although the differences with the altimetry-WOA01 climatology suggest that the results are affected by the barotropic ocean model used in the background processing.