Decadal Causes of Sea Level Changes during the TOPEX Period

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Summary

Among the unprecedented measurements of the TOPEX/POSEIDON mission are the measurements of sea level drift, regionally and global. While many studies investigate how much sea level is changing over the last decade, non is able to identify the physical processes that ead to the observed rate of change.

We investigate here the question: What drives the SSH trend observed over the last decade?

For that purpose the ECCO (Consortium for Estimating the Circulation and Climate of the Ocean) adjoint model framework is being used to estimate possible causes for observed changes in sea level over the last decade. An aditional optimization was performed that minimizes (removes) the realistic sea level trend over the period 1992 through 2002 in the existing SIO/ECCO solution.

Model parameters that were adjusted during the optimization, include the initial conditions of temperature and salinity, net surface heat and freshwater fluxes as well as wind stress. The rational behind this experiment is the idea that causes for the observed changes in sea level can be identified through the adjustment in the control parameter required to prevent sea level to drift: With the changes in each of the control parameters specific physical processes are associated that account for different relative contributions to changes in the sea level trend.

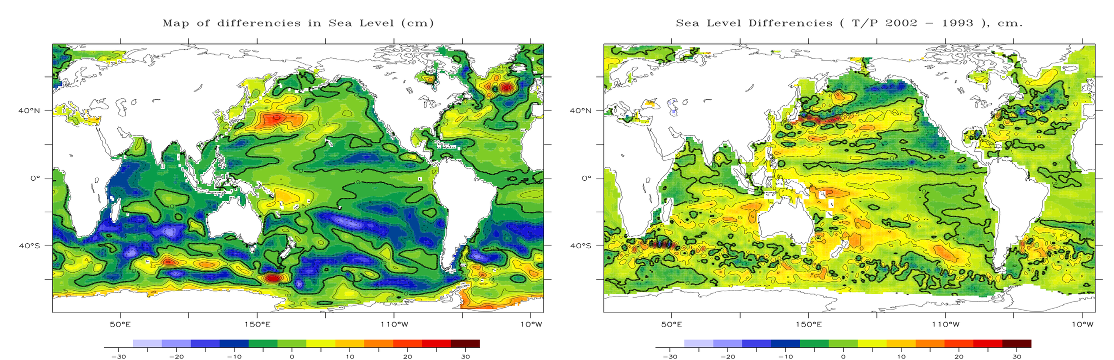

Fig. 1: Map of the SSH trend represented by the difference 2002-1992 from the model (left panel) in comparison to the estimation from TOPEX/POSEIDON (T/P) data (right panel).

Optimization

The optimization starts from the results of the 11 year SIO/ECCO global estimation described in detail by Köhl et al (2006). The initial temperature and salinity conditions as well as the time-dependent surface fluxes of momentum, heat and freshwater are adjusted by the adjoint method in order to minimize the SSH trend of a global 1^o global model over the period 1992 through 2002. The costfuction contains contributions only from the SSH trend and from changes in the control parameter. In all cases, the SSH trend is represented by the differences of the annual SSH means of 2002 - 1992. Illustrated in Fig. 1 is the reduction of the costfunction over the performed 15 iterations.

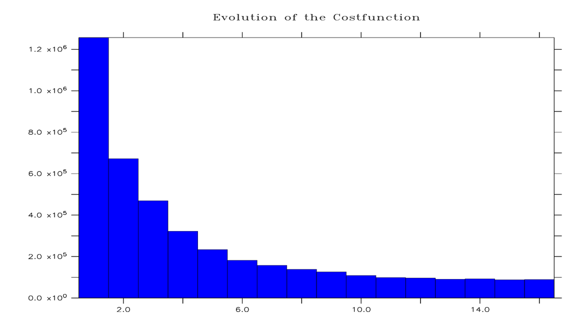

Fig. 2: Reduction of the costfunction as a function of iterations. An overall reduction by a factor of ten has been achieved.

Results from the optimization demonstrate the effectiveness of the adjoint model to remove the SSH trend by adjusting control parameters in reasonable amounts (within uncertainties): After 15 iterations, the SSH trend has been reduced to less than 10%-20 % of the original value, except over a region in the western tropical Pacific (see Fig. 3). All further results are taken from iteration 15.

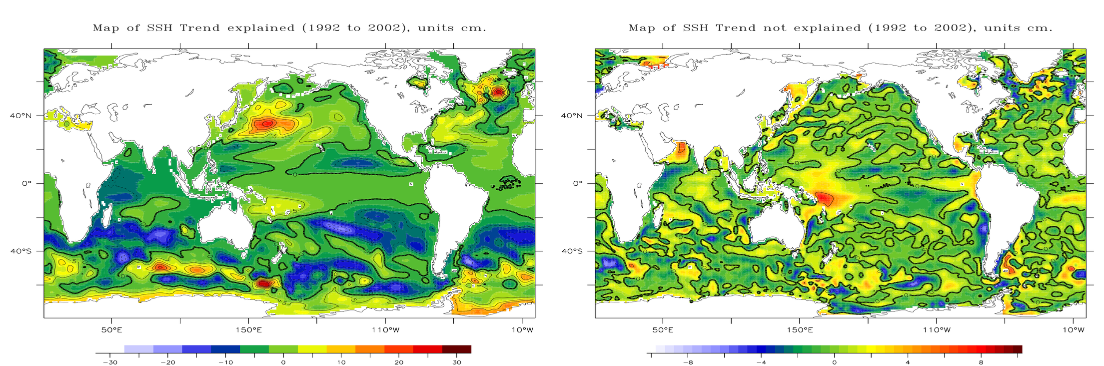

Fig. 3: Part of the SSH trend that could be explained by the estimated adjustments (left) and the residuals that were not explained (right)

Adjustments

Estimated adjustments of the initial potential temperature (θ) and salinity (S) fields, as well as twice-daily averages of surface forcing fields over the full 11 years, required to reduce the models SSH to drift, are shown below.

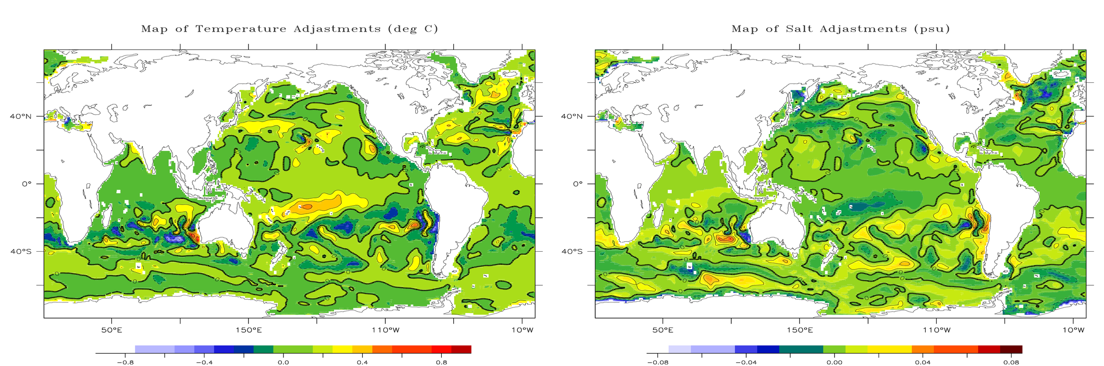

Fig. 4: Adjustments to the initial temperature and salinity in 222.5 m depth.

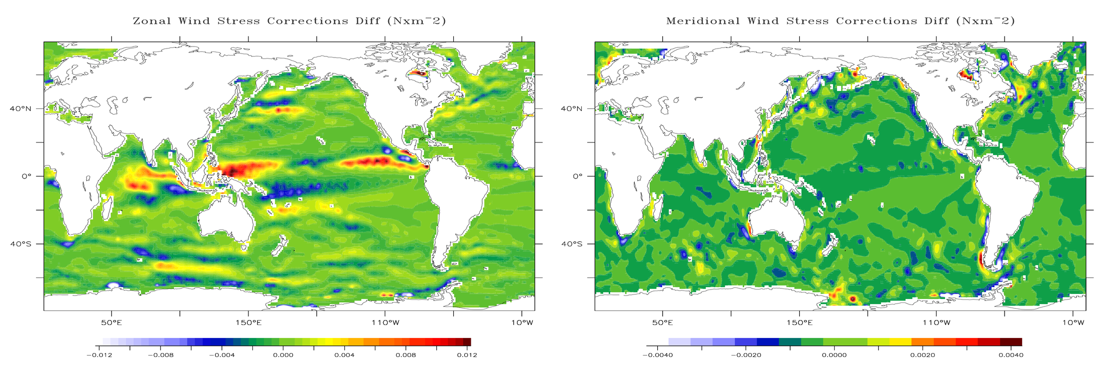

Fig. 5: Differences (last year minus first year mean) of the zonal (left) and meridional (right) wind stress adjustments.

Mechanisms

Next, the above adjustment of control variables are analyzed to identify mechanism leading to changes in sea level and to investigate which mechanism is most effective in changing sea level. For this purpose we decompose the total SSH trend into four individual components, arising from *initial conditions (θ, S), wind, heat flux, fresh water flux.* In order to obtain a quantitative measure of the relative importance of each of the respective contribution to SSH trends and to investigate their geographical distribution, we perform four additional forward experiments with only one control parameter being changed at a time. Results reveal that the steric SSH change,arising from anomalies in the initial conditions is by far the largest contribution to the overall SSH trend.

A. Initial conditions (θ, S)

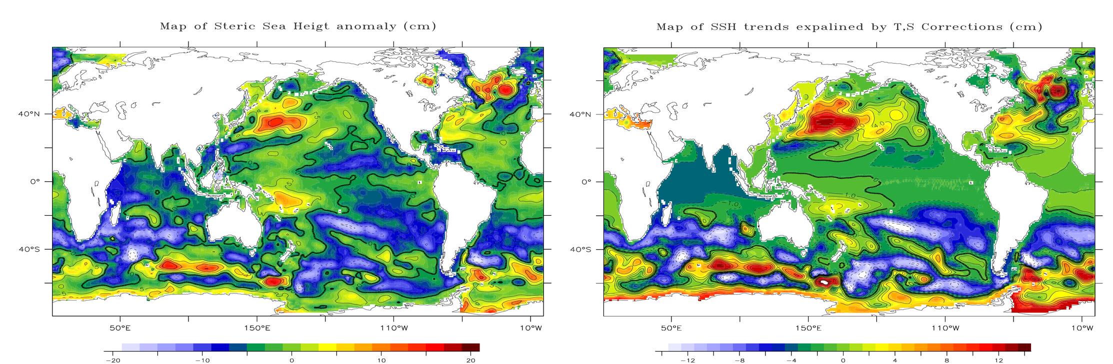

Fig. 6: Difference of the steric height (2002 - 1992) from the model (left). SSH trend explained by the adjustments in the initial conditions, compare with Fig. 3 – overall SSH trend explained (right).

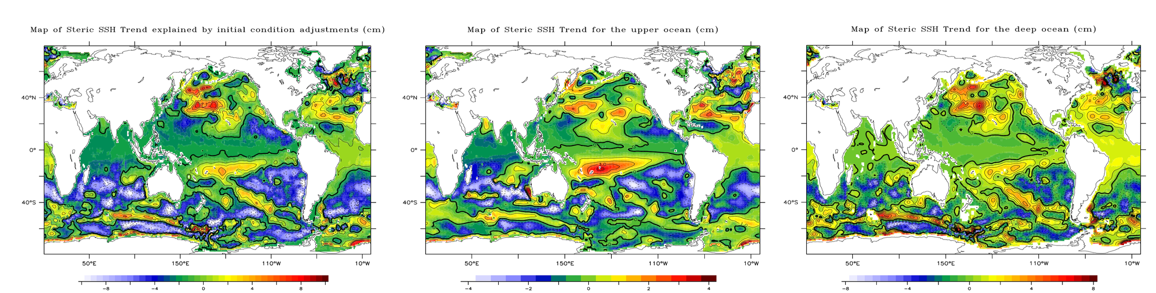

Fig. 7: Steric SSH anomaly explained by the adjustments in the initial temperature and salinity (left). Components of the steric SSH anomaly explained by the adjustments in the initial conditions as resulting from the upper (0-800m, middle) and the deep ocean (800-3500m, right).

B. Wind

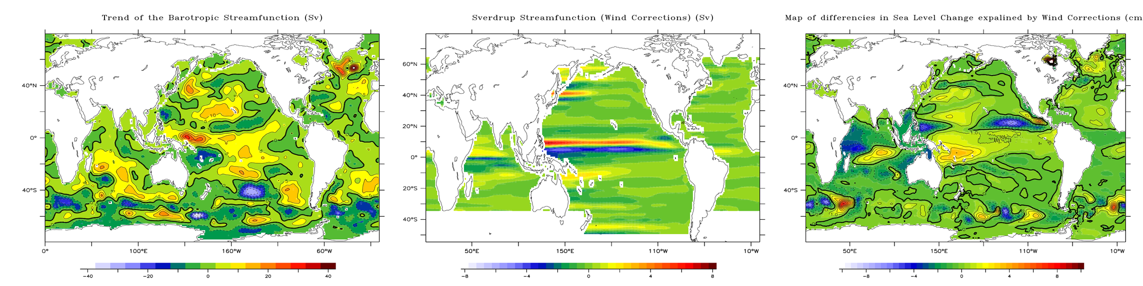

Fig. 8: Barotropic streamfunction trend (in Sv) calculated from the difference 2002 - 1992 (left). Barotropic streamfunction trend (in Sv) calculated according to the Sverdrup relation from the difference (2001 - 1992) of the adjustments of the wind stress curl (middle). SSH trend explained by wind stress adjustments (right).

C. Buoyancy fluxes (heat, salt)

It seems that the components of the SSH trend explained by the Buoyancy fluxes are insignificant almost every where except for the polar regions (Antarctic Circumpolar Current and subpolar gyre in the North Atlantic).

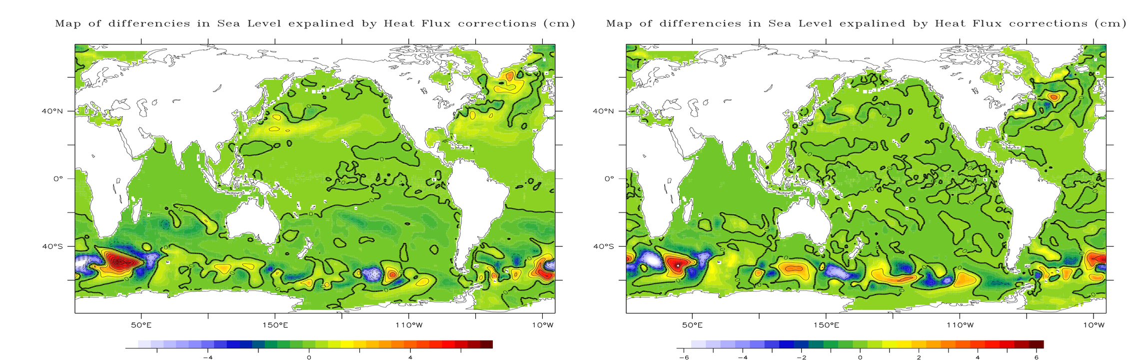

Fig. 9: SSH trend calculated from the model by using only the heat flux adjustments (left). SSH trend calculated from the model by using only the freshwater flux adjustments (right).

Conclusions

Based on the estimated changes in initial conditions, surface wind stress and surface buyancy forcing, physical causes for sea level changes and their relative importance were inferred. From the results it appears that:

- the most important contribution to the observed SSH trend comes from the adjustments to the initial conditions (almost 50% of the whole SSH trend).
- the contribution from the adjustments to the wind stress are important – especialy in the equatorial regions– but more moderate. They can explain about 20-25% of the SSH trend.
- the adjustments to heat and freshwater fluxes have a minor contribution to the SSH trend with the exception of the polar regions. Their contribution is about 10% each.

References

A. Koehl, D. Stammer and B. Cornuelle, *Interannual to Decadal Changes in the ECCO Global WOCE Synthesis,* J. Phys. Oceanogr., 2006 (in press).