Combined Assimilation of GEOSAT, TOPEX/Poseidon and tide gauge reconstruction data into a global OGCM

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Introduction

The global sea level is exceedingly reacting on variations of the climate. A warming of the world ocean or the melting of large continental icesheets for example would lead to a sea level rise that would affect directly a large part of mankind. These effects are reasonable well understood on the global scale but they are still uncertain on regional or even local scale. For the period of the TOPEX/Poseidon altimetric measurements Wenzel and Schröter (2006, 2007) showed that the sea level trends vary substantially in space and time and that they are closely associated to heat and salt anomalies in the ocean. But longer time-series of the global distribution of sea level variability are needed to confirm these results because the climate-induced decadal and secular sea level changes may be concealed by seasonal, annual and interannual variations, which may act as noise masking long-term trends. One step in this direction is to utilize data from the GEOSAT altimetric mission (1987-1989) in combination with the TOPEX/Poseidon data (1993-2000). Both datasets will be assimilated into the global ocean circulation model. Additionally informations from a global sea level reconstruction from tide gauges are employed to overcome the problem with the unknown reference for the GEOSAT data.

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Model / Data

For our purpose we use the Hamburg Large Scale Geostrophic model (LSG, Maier-Reimer and Mikolajewicz 1991). In conjunction with its adjoint this model has been used successfully for ocean state estimation (e.g. Wenzel and Schröter 2006, 2007). It has 2x2 degree horizontal resolution, 23 vertical layers (varying from 20m thickness for the top layer to 750m for the deepest ones) and the implicit formulation in time allows for a time step of ten days. The utilized global OGCM has a free surface, i.e. it conserves mass rather than volume, and it has the steric effects (thermal expansion, haline contraction) included. This offers the possibility to combine altimeric measurements with hydrographic data in a dynamically consistent manner.

	Data used for assimilation	GETO	GETORC
SSHA	TOPEX/Poseidon (Jan.1993-Dec.2000; GfZ)	X	X
	GEOSAT (Jan.1987 - Sep.1989; GfZ)	X	X
	reconstruct from tide gauges (1987-2000; AWI,C+W)		X
MSSH	SHOM98.2 (CLS) rel. EIGEN-GRACE01S geoid	X	X
	!! constrains the period 1993-2000 only !!		
SST	Reynolds SST (1987-2000)	X	X
T/S (mean)	WOCE Global Hydrographic Climatology	X	X
	Gouretski und Koltermann (2004)		
T/S (monthly anomalies)	WOA01	X	X
mean transports	heat, freshwater, mass	X	X
	from Siedler et al (edt.): Ocean Circulation and Climate		
section data	Ross Sea, Weddell Sea from BRIOS model runs	X	X
	Assmann and Timmermann (2005), Schodlok et al. (2002)		

Sea Level: model vs. data

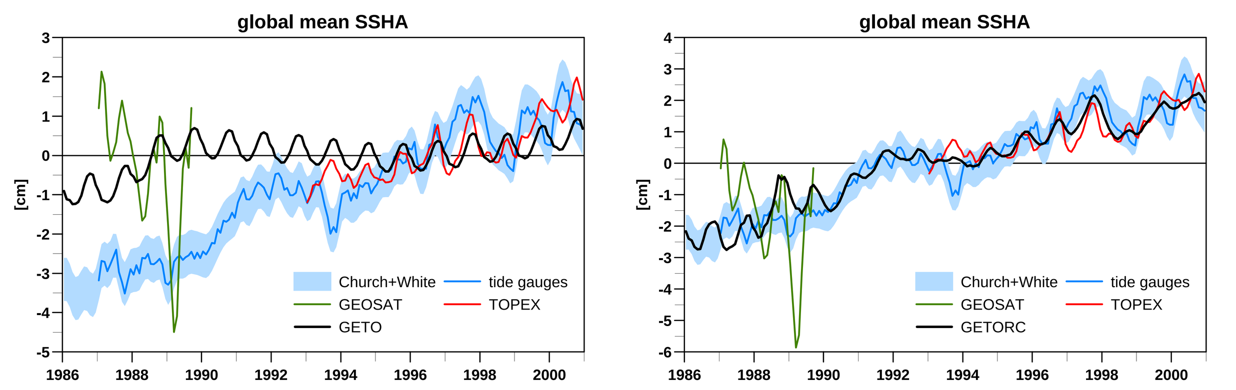

Fig. 1: *Global mean sea level anomaly of the experiments* **GETO** *(left) and* **GETORC** *(right) compared to the different data sets. The* GEOSAT *data are adjusted to meet the corresponding model mean.*

Figure 1 shows that in both experiments, **GETO** (left) and **GETORC** (right), the model reproduces the global mean sea level data from the TOPEX data well. For the period of the GEOSAT data the model gives a positive trend consistent with the data from tide gauge reconstruction but contradicting the negative trend given by the GEOSAT data. Furthermore the assimilation procedure sees no need for a continuous sea level rise without the tide gauge data. Even the spatial RMS of the difference between model and SSH data is improved using this additional information from tide gauges (Fig.2).

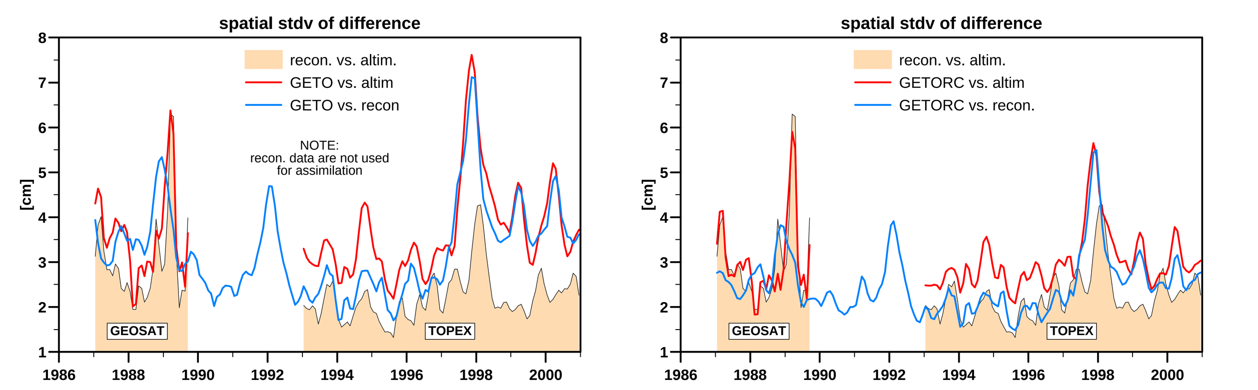

Fig. 2: *Spatial RMS difference between the modelled sea level and the different data sets for experiment* **GETO** *(left) and* **GETORC** *(right). The light red shading gives the corresponding value for the difference between the satellite data and the reconstruction from tide gauges.*

Global Heat Content Anomaly

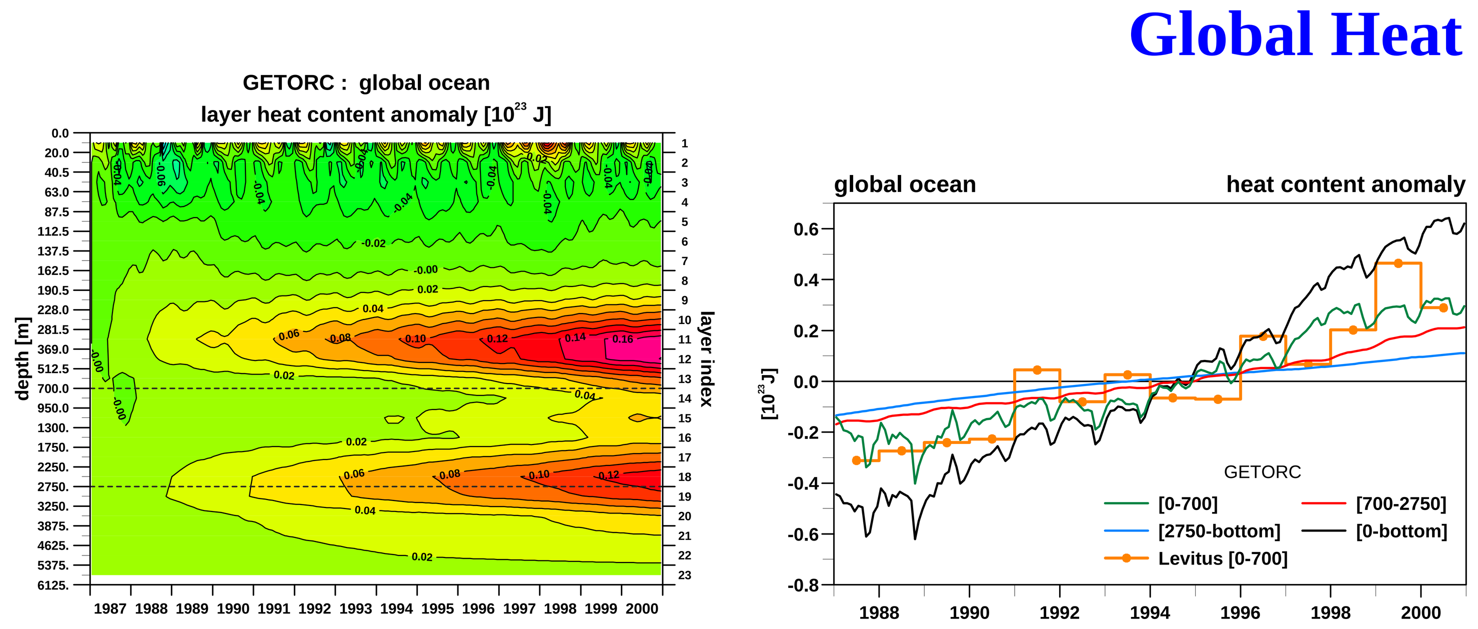

Fig. 3: *Global heat content anomaly from experiment* **GETORC** *given for each layer (left) and summerized for the depth ranges [top 700m], [700m-2750m] and [below 2750m] (right). The right graph also includes the heat content anomaly for the top 700m derived from the Levitus et al (2005) data.* NOTE: *there are different references in the figures: the first timestep for the left one and the temporal mean for the right!*

Within the top 100m the modelled global heat content anomaly shows a pronounced annual cycle (Fig.3,left part), while in the deeper ocean two distinct depth ranges, [150-700m] and [below 1700m], can be found that show significant warming and will contribute to the global sea level rise via thermal expansion. Summing over the top 700m (Fig.3 right) this warming trend is consistent with the data from Levitus et al. (2005).

Sea Level Trends

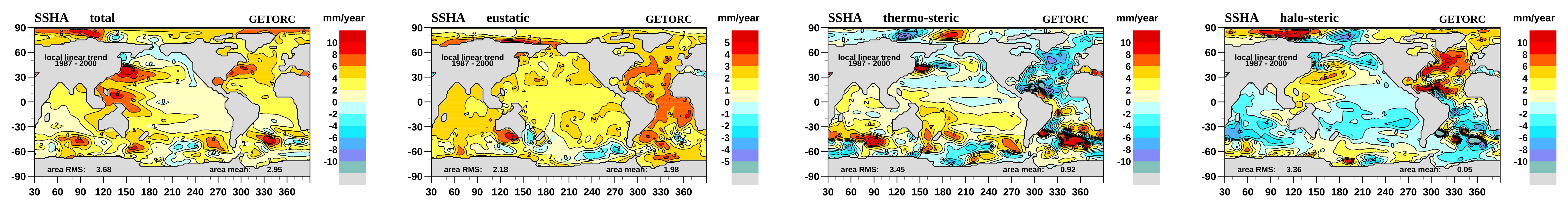

Fig. 4: *from left to right: (a) Modeled local sea level trends from* **GETORC** *and its (b) eustatic, (c) thermosteric and (d) halosteric component. The contour intervalls are 2 mm/year in (a),(c) (d) and 1 mm/year in (b)*

Global Mean Sea Level Trends [mm/year] 1987 – 2000

	1^{st}guess	GETO	GETORC	C+W
thermosteric	+0.28	+0.64	+0.92	
halosteric	–.003	+.001	+0.05	
total steric	+0.28	+0.64	+0.97	
eustatic	–0.06	+0.09	+1.98	
total	+0.22	+0.73	+2.95	+3.27

In Fig.4 the modelled total local sea level trend is splitted into its eustatic, thermosteric and halosteric part. Compared to the thermo- and halo-steric trends the eustatic trend varies on very large scales. There is net eustatic sea level rise nearly everywhere and it is highest in the Atlantic ($\sim$3mm/year compared to $\sim$2.2mm/year global RMS). Both steric components show a higher global RMS ($\sim$3.4mm/year). But in many regions of the world ocean they are opposite in sign thus compensating each other at least by part. This ends up with a total steric sea level rise that is much smoother in space and more comparable in local strength to the eustatic ($\sim$2.6mm/year RMS).

But the total steric trend show large positive and negative regions. Thus for the global mean sea level (Fig.5, Table on the left) we find the main contribution on from the eustatic sea level change, which is about twice as strong as the steric. From comparing experiments **GETO** and **GETORC** (left table) we find that this eustatic trend is induced by the sea level data reconstructed from tide gauges, while the thermosteric trend is already mainly constraint by using the Reynolds SST data. Furthermore, from Fig.5 one also sees that the global eustatic sea level resamples nearly all the 'short term' temporal variability (annual cycle) of the global mean sea level.

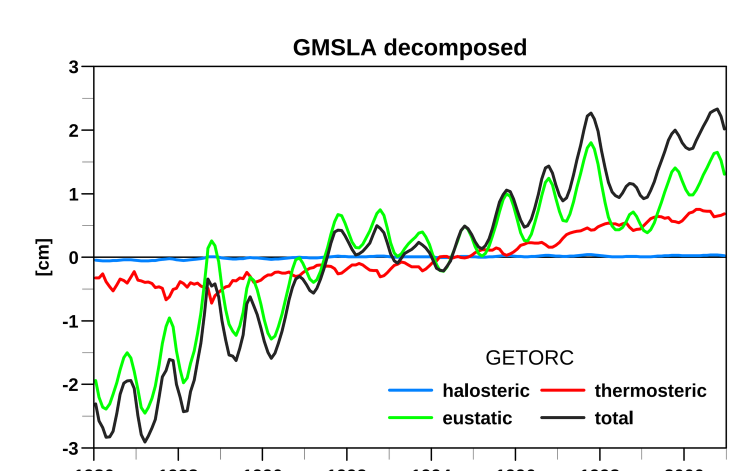

Fig. 5: *Global mean sea level anomaly decomposed into its thermosteric, halosteric and eustatic contribution*