COMBINED ASSIMILATION OF GEOSAT AND TOPEX/Poseidon DATA

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1. 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. By assimilating the TOPEX/Poseidon measurements into a global ocean circulation model they were able to separate the individual parts contributing to the sea level change (steric effects, oceanic fresh water budget). 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. By doing this the data gap between GEOSAT and TOPEX/Poseidon can be filled in a dynamically consistent manner.

2. MODEL AND 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 2 x 2 degree horizontal resolution, 23 vertical layers (varying from 20 m thickness for the top layer to 750 m 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. The datasets used in the assimilation experiment are:

- monthly sea surface temperatures (SST) for the period 1993-2000 (Reynolds et al. 2002)
- gridded fields of ten day averages of sea surface height anomalies (SSHA) as measured by the TOPEX/Poseidon altimetric mission for the period 1993-2000, provided by Geoforschungszentrum Potsdam (GfZ; S. Esselborn, pers. communication). These anomalies are combined with the SHOM98.2 mean sea surface height (MSSH; available online at the time of writing at: http://www.cls.fr/html/oceano/projets/mss/cls_shom_en.html) referenced to the EIGEN-GRACE01S geoid (available online at the time of writing at: http://www.gfz-potsdam.de/grace/results/grav/g001_eigen-grace01s.html) to give absolute dynamic height values.
- preliminary re-processed gridded fields of ten day averages of sea surface height anomalies (SSHA) as measured by the GEOSAT altimetric mission for the period 1987-1989, provided by Geoforschungszentrum Potsdam (GfZ; T. Schöne, pers. communication). These anomalies are referenced to their own temporal mean.
- temporal mean transports of mass, freshwater and heat as obtained by different authors and as they are summarized e.g. by Bryden and Imawaki (2001) and by Wijffels (2001). Trans-

port constraints are not applied for the Antarctic Circumpolar Current (ACC).

- the climatological mean temperatures and salinities from the WOCE Global Hydrological Climatology (WGHC; Gouretski and Koltermann 2004) in combination with the mean annual cycle from the most recent World Ocean Atlas (WOA01; Conkright et al. 2002). These data are supplied to the assimilation procedure with small weights thus serving only as background information.
- the mean annual cycle of temperatures, salinities and horizontal velocities on two sections in the Weddell Sea area and on four sections in the Ross Sea. These data are taken from high resolution model experiments of the Weddell Sea (Schodlok et al. 2002) and the Ross Sea (Assmann and Timmermann 2005) whose water mass characteristics and circulation are in good agreement with local observations.

3. RESULTS

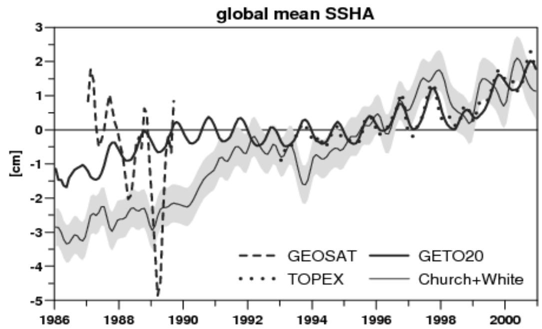

Figure 1: Global mean sea level anomaly (GMSLA) for experiment GETO20 (thick line) as function of time. For comparison the measurements from TOPEX/Poseidon (dotted line) and GEOSAT (dashed) are included. The GEOSAT data are adjusted to the corresponding model mean because of the missing absolute reference. Additionally the data from Church and White (2006) reconstructed from tide gauge measurements are shown (thin line) with their error bars (grey shading).

Figure 1 shows the modeled global mean sea level anomaly (GMSLA) after assimilation in comparison to the above mentioned datasets. While the model (experiment: GETO20) reproduces the GMSLA derived from the TOPEX/Poseidon measurements quite well this is not the case for GEOSAT. Even the trend for the period 1987-1989 is not reproduced. The model prefers a positive trend while the data show a negative one. That the modeled positive trend is more realistic to some extend, one can conclude from the GMSLA reconstructed by Church and White (2006) from tide gauge records, that shows a positive trend throughout the period 1986-2000. Even the spatial structure of the GEOSAT anomalies are not well reproduced by the assimilation procedure while for TOPEX/Poseidon measurements there is good success as can be seen from Fig. 2 and 3. The reason for this behaviour is not well understood yet.

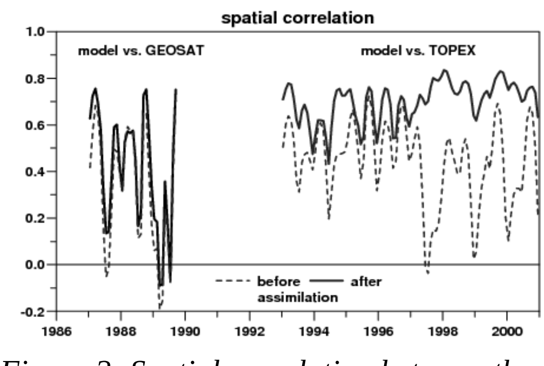

Figure 2: Spatial correlation between the sea level anomalies from the altimetric measurements and the model results without assimilation (dashed lines) and for experiment GETO20.

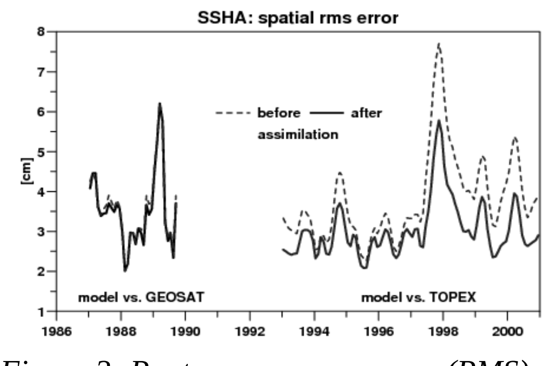

Figure 3: Root mean square error (RMS) between the sea level anomalies from the altimetric measurements and the model results without assimilation (dashed lines) and for experiment GETO20.

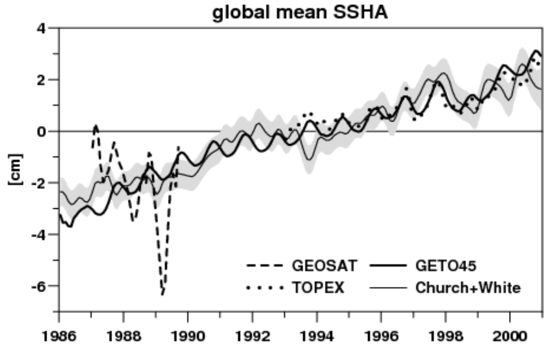

Figure 4: same as Figure 1 but for experiment GETO45

Furthermore, Fig. 1 shows the disadvantage of not having an absolute reference for the GEOSAT data. From hydrographic data alone the assimilation has no reason for producing a sea level rise as large as given e.g. by Church and White (2006). This can be improved when the information about the evolution of the GMSL is applied accordingly as can be seen from Fig. 4 (experiment: GETO45). In this experiment the Church and White (2006) data are supplied additionally as background information. From this we conclude that an absolute reference is needed for the GEOSAT data before reliable statements are possible for the past 20 years. For future work we will utilize time dependent global sea level reconstructions instead that will be made available by GFZ Potsdam. The necessity of this additional information can also be gathered from Fig. 5. In this figure the modeled GMSLA is decomposed into the parts that arise from steric effects (thermal expansion, haline contraction) and from the ocean fresh water budget (eustatic contribution). The latter contributes about twice as much (2.52 mm/year) to the total sea level rise (3.71 mm/year) as the thermosteric part (1.13 mm/year), while the halosteric contribution is neglegible on global scale (0.06 mm/year) but should not be neglegted on regional or even local scale (see e.g. Wenzel and Schröter 2006, 2007). The hydrographic data can sufficiently constrain the thermosteric contribution only. Further inspection of this preliminary result shows that the thermosteric contribution to sea level rise mainly stems from the upper 700m of the water column (Fig. 6). For this depth range we find a global ocean warming, increasing heat content that fits well to the estimates taken from Levitus et al (2005). The contributions from the lower depth ranges (700-2750m and 2750m-bottom) are neglegible and they even partially compensate each other.

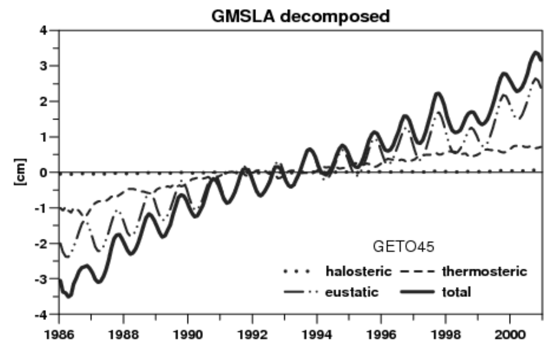

Figure 5: Global mean sea level anomaly (GMSLA) from experiment GETO45 (thick line) broken down to the halosteric (dotted), thermosteric (dashed) and eustatic (dash- dotted) contribution.

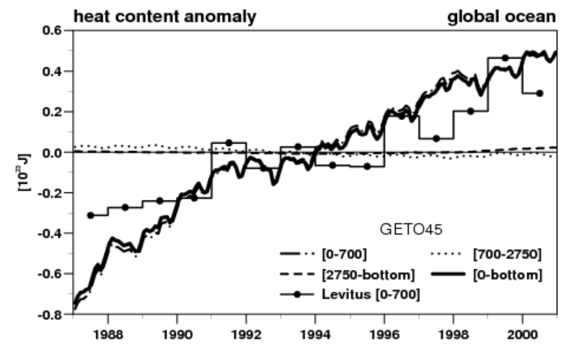

Figure 6: Global ocean heat content anomaly from GETO45 for the total water column (thick line) as well as for the depth ranges [0-700m] (dash-dotted), [700-2750m] (dotted) and [2750m-bottom] (dashed). For comparison the heat content anomalies of the upper 700m from Levitus et al (2005) are included (staircase with dots)

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