Alfred Wegener Institute
for Polar and Marine Research

CAN WE ESTIMATE THE GLOBAL OCEAN MASS BALANCE VIA SEA LEVEL CHANGE?

M.Wenzel and J.Schröter

Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

mwenzel@awi-bremerhaven.de jschroeter@awi-bremerhaven.de

Introduction

The mass budget of the global ocean is studied with a global circulation model that conserves mass instead of volume, i.e. fresh water is exchanged with the atmosphere via precipitation and evaporation and inflow by rivers is taken into account. The mass is redistributed by the ocean circulation. Furthermore, the oceans volume changes by steric expansion with changing temperature and salinity.

Recent volume changes are monitored successfully by altimetry. However, the corresponding mass changes - or bottom pressure variations - can be estimated only using secular changes in the geoid provided e.g. from the **GRACE** mission since 2002. But these data are still not accurate enough. To distinguish between mass variations and steric effects in the measured volume changes of the ocean a global data assimilation experiment was performed. For this satellite altimetry referenced to the **GRACE** geoid is assimilated together with a set of oceanographic data into an OGCM, that offers the ability to estimate the single contributions to sea level change, the steric (thermosteric, halosteric) and the non-steric effects (local fresh water balance, mass redistribution) seperately. The model has a $2^o \times 2^o$ horizontal resolution, 23 vertical layers and a ten day timestep. Eleven years (1993-2003) of respective **TOPEX/Poseidon** sea surface height anomalies are assimilated into the model. In addition the SHOM98.2 mean sea surface relative to the **GRACE** geoid (GFZ) as well as sea surface temperatures and ice cover information from Reynolds (2002) are assimilated into the model. Furthermore background information from the Levitus WOA98 is used.

To adjust the model to the data the adjoint method is employed. The control parameters of this optimization are the models initial temperature and salinity state as well as the forcing fields (windstress, air temperature and surface freshwater flux). For verification the models bottom pressure anomalies are compared to the geoid variations derived from the **GRACE** mission.

Sea Level Evolution

$$\frac{\partial}{\partial t}\zeta = \mathbf{P-E+R} \qquad \text{freshwater flux}$$

$$+\ \nabla\cdot\int_{-H}^{\zeta}\vec{v}\,\mathbf{d}z \qquad \text{divergence}$$

$$+\int_{-H}^{\zeta}\frac{1}{\alpha}\frac{\partial\alpha}{\partial T}\Big|_{S,p}\frac{\partial}{\partial t}T\ \mathbf{d}z \qquad \text{thermosteric effect}$$

$$+\int_{-H}^{\zeta}\frac{1}{\alpha}\frac{\partial\alpha}{\partial S}\Big|_{T,p}\frac{\partial}{\partial t}S\ \mathbf{d}z \qquad \text{halosteric effect}$$

$$+\ A_h\,\Delta\,\zeta \qquad \text{subgrid processes}$$

Sea Level: Model vs. **TOPEX/Poseidon**

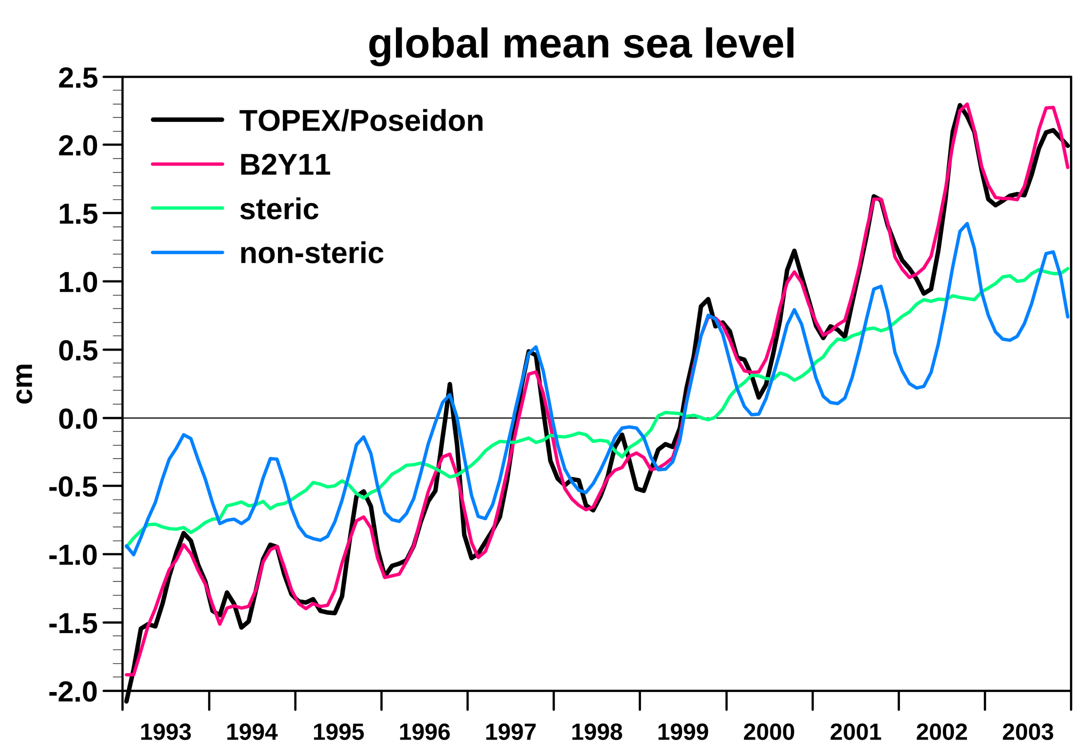

Fig. 1: Global mean sea level anomaly from the assimilation experiment **B2Y11** as compared to the **TOPEX/Poseidon** data. Additionally the modeled steric and non-steric contributions are shown.

Figure 1 shows that the optimized model reproduces the global mean sea level data well. This is true especially for the interannual variabilty, while the amplitude of the annual cycle is slightly underestimated by the model. The latter becomes even more apparent on local scale (not shown) and appears to be a general deficit of the OGCM used. This leads to the maxima in the temporal RMS differences shown in **Fig.2**. The global RMS value, which is the measure of success in the assimilation, is 2.74cm although locally we find higher RMS values (up to 7cm) especially in the tropical Pacific and in the western boundary currents.

Figure 1 also shows that the linear trend in the global sea level change originates equally from the steric and the non-steric contribution. In contrast to that nearly all the 'short term' temporal variability of the global mean sea level is resampled by the non-steric part, while the steric contribution appears more or less as a straight line. Nevertheless we find a small annual cycle in the steric part also, which appears to be in anti-phase with the non-steric.

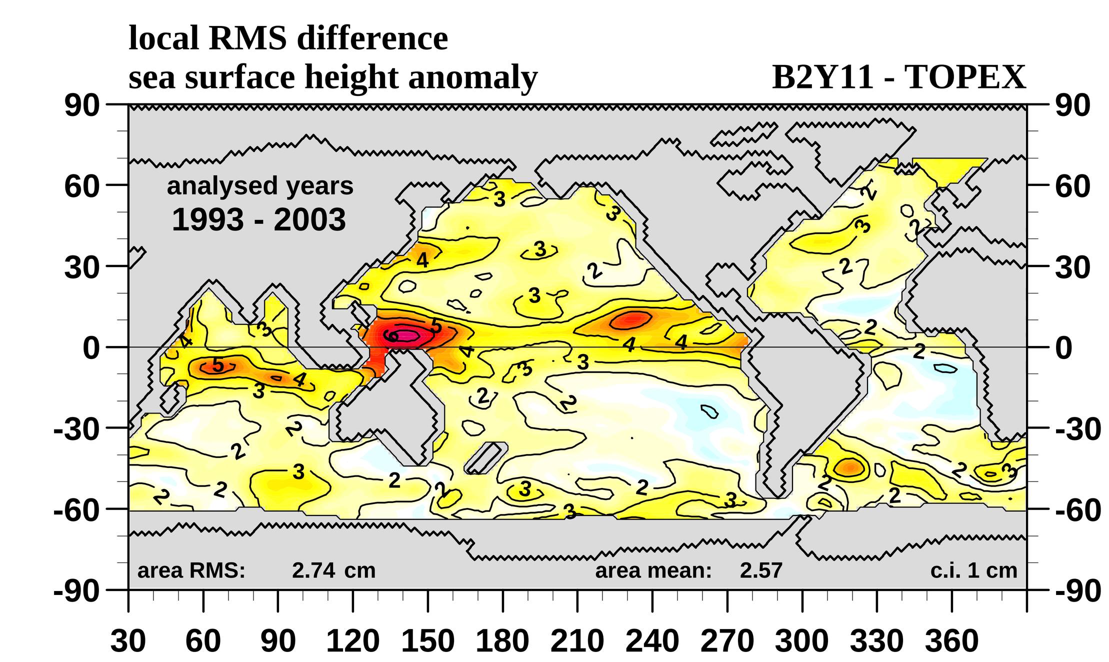

Fig. 2: Local temporal RMS of the modeled SSHA difference between model and the **TOPEX/Poseidon** data. The models coastline is given by the thick black line and the grey shading within the ocean indicate areas with no data

Bottom Pressure: Model vs. **GRACE**

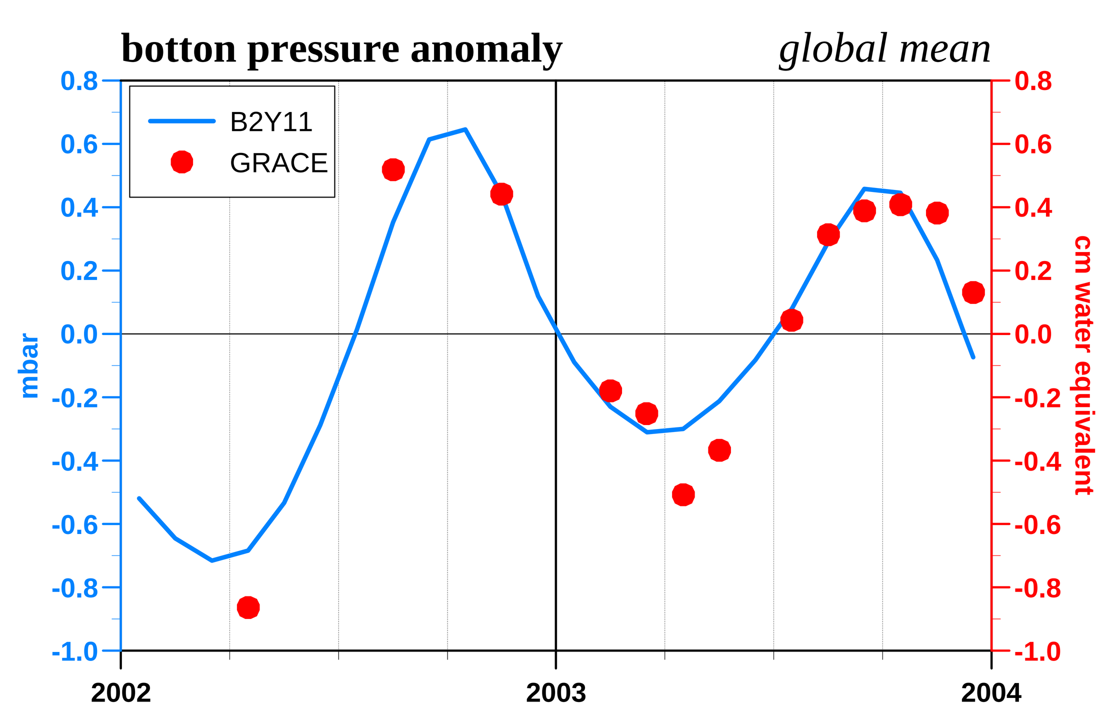

Fig. 3: Global mean bottom pressure anomalies as compared to the **GRACE** geoid variations (given in cm water equivalent).

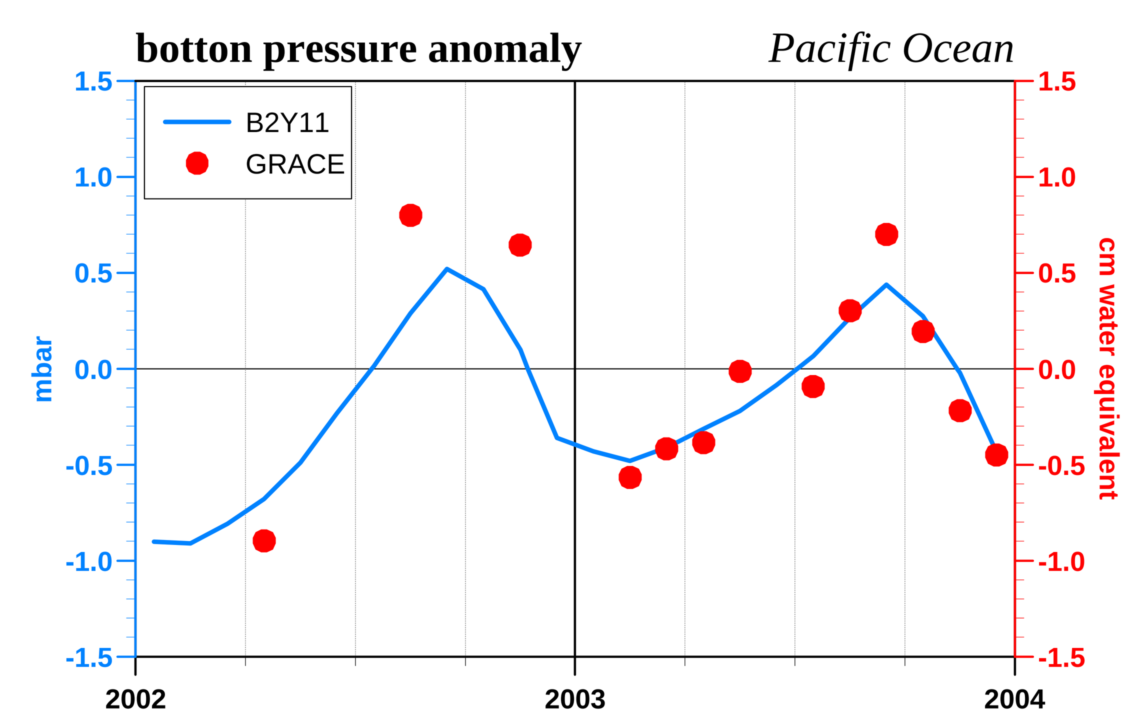

Fig. 4: same as **Fig.3** but for the Pacific Ocean (60S-60N)

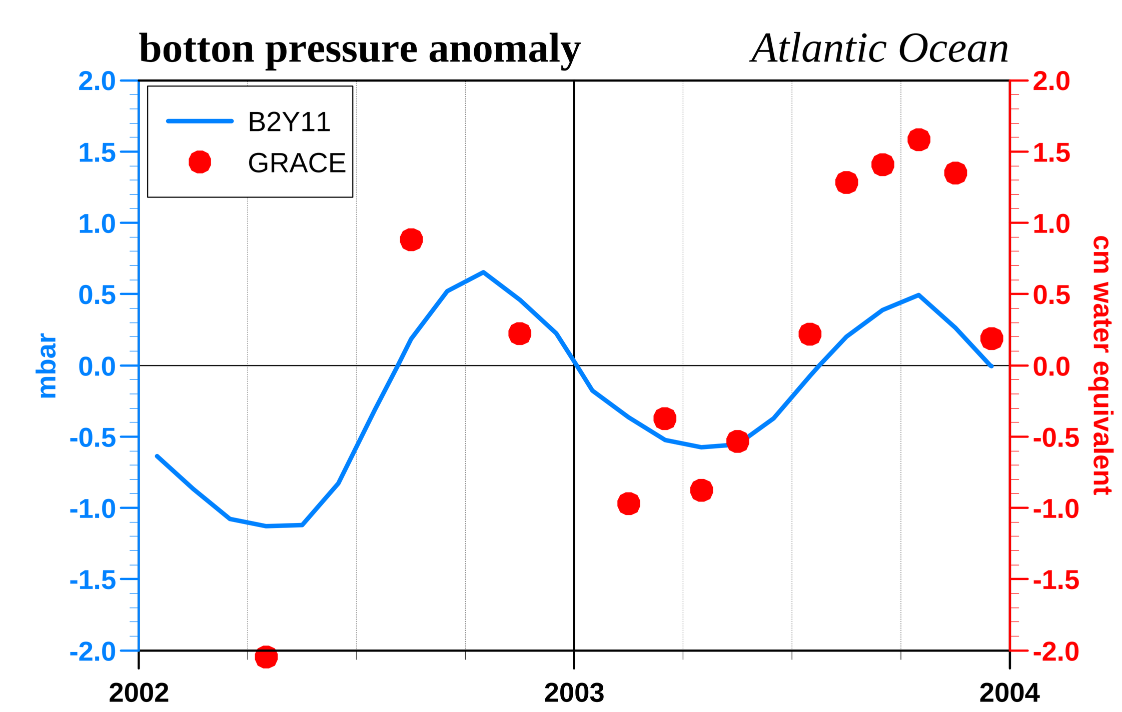

Fig. 5: same as **Fig.3** but for the Atlantic Ocean (60S-60N)

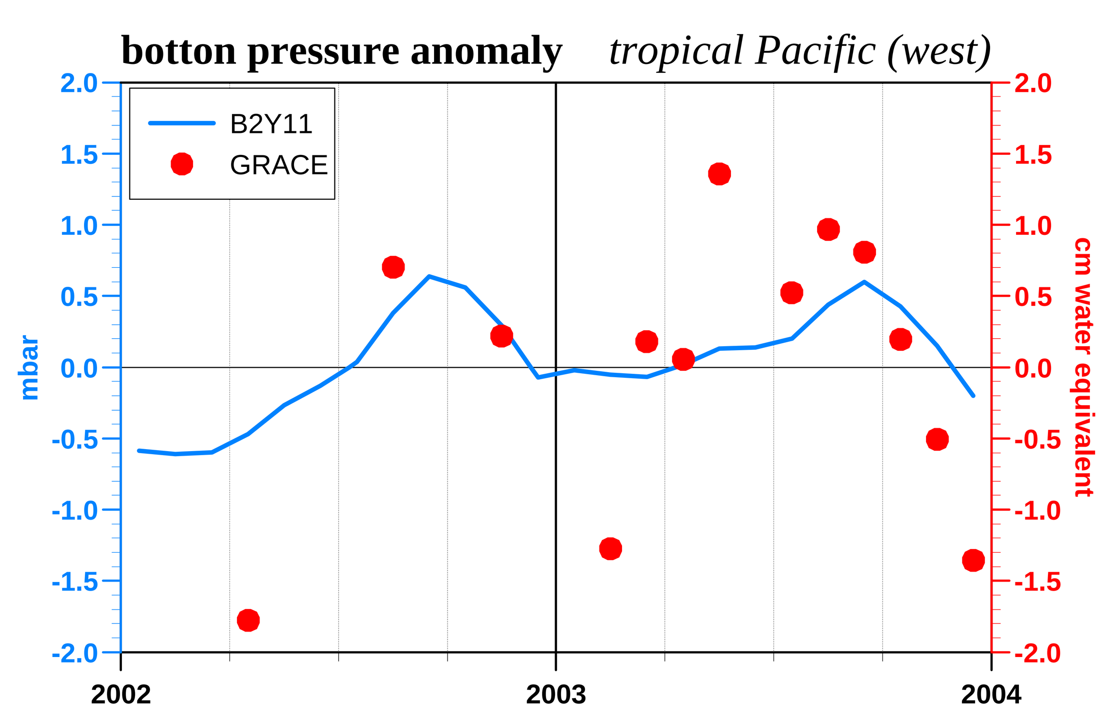

Fig. 6: same as **Fig.3** but for the western part of the tropical Pacific (20S-20N/140E-150W)

The modeled mass variations (non-steric part, blue curve in **Fig.1**) are well represented by the corresponding variations in the bottom pressure field. These variations should be detectable through variations in the geoid estimated e.g. from the **GRACE** mission once the measurements have been fully analysed.

The available **GRACE** data are still rather preliminary and should be treated with caution. Nevertheless we do a first comparison on different scales. Examples are given in **Fig.3** to **6** for: the global ocean, the total Pacific, the total Atlantic and for the western part of the tropical Pacific, respectively. We find good correspondence in amplitude and phase between the modeled bottom pressure variations and the **GRACE** data (given in cm water equivalent) for the global ocean (**Fig.3**). The correspondence diminishes when looking at smaller areas and gets even unacceptable on scales smaller than e.g. the western tropical Pacific (**Fig.6**). This obviously is a still excisting deficiency of the **GRACE** data, which are represented by spherical harmonics and include the much stronger signals from the hydrological cycle of the land surface.

Summary

- The model reproduces the sea level variations as measured by the **TOPEX/Poseidon** altimeter well.
- On the largest scales the ocean mass variations fit well to the **GRACE** estimates in amplitude and in phase.
- Comparing the mass variations on basin wide down to local scales (not shown) does not give satisfactory results because of obvious deficiencies in the geoid variations on these scales.

Acknowledgement

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