Verification of an ocean general circulation model with time varying GRACE geoid data

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Introduction

A global data assimilation experiment was performed with the goal of a better understanding of sea level rise. For this satellite altimetry referenced to the GRACE geoid is assimilated together with a set of oceanographic data into an ocean general circulation model (OGCM).

The OGCM that is used for this study is based on the Hamburg Large Scale Geostrophic model LSG. The main improvement of the model is the ability to estimate the single contributions to sea level change, the steric (thermosteric, halosteric) and the non-steric effects (local freshwater balance, mass redistribution) seperately.

The model has a $2^o \times 2^o$ horizontal resolution, 23 vertical layers and a ten day timestep. Nine years (1993-2001) of respective TOPEX/Poseidon (T/P) 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

$$\frac{\partial}{\partial t}\zeta =$$

$$\mathbf{P-E} \qquad \text{freshwater flux}$$

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

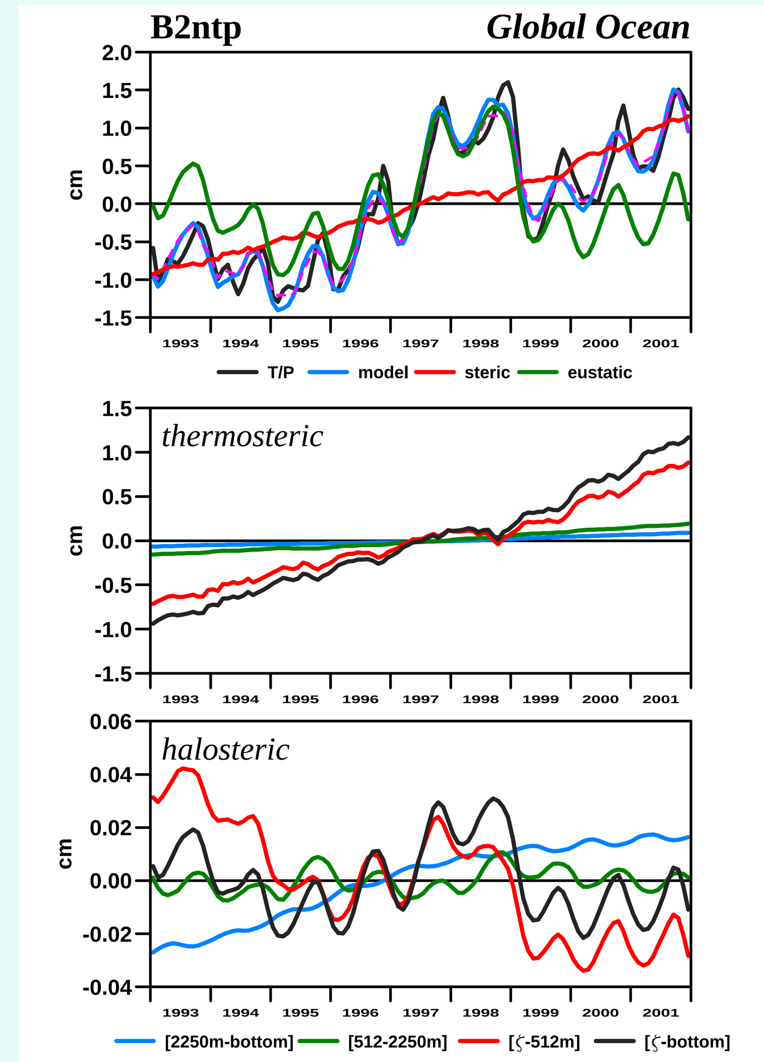
$$+\int_{-H}^{\zeta}\frac{1}{\alpha}\frac{\partial\alpha}{\partial T}\bigg|_{S,p}\frac{\partial}{\partial t}T\,\mathbf{d}z \qquad \text{thermosteric effect}$$

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

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

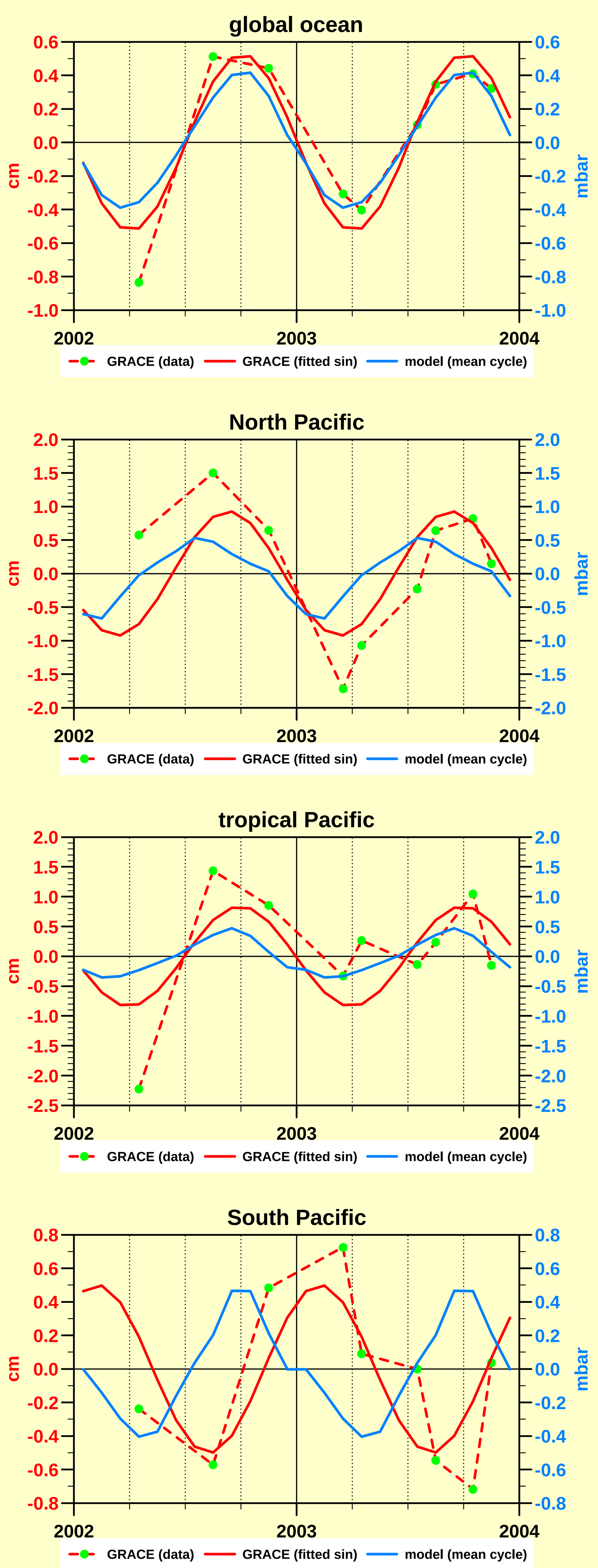
ζ : sea level ; H : depth ; P : precipitation ; E : evaporation
T : temperature ; S : salinity ; p : pressure ; $\alpha = 1/\rho$: specific volume
$\vec{v}$: horizontal velocity ; A_h : diffusion coefficient

Global Mean Sea Level



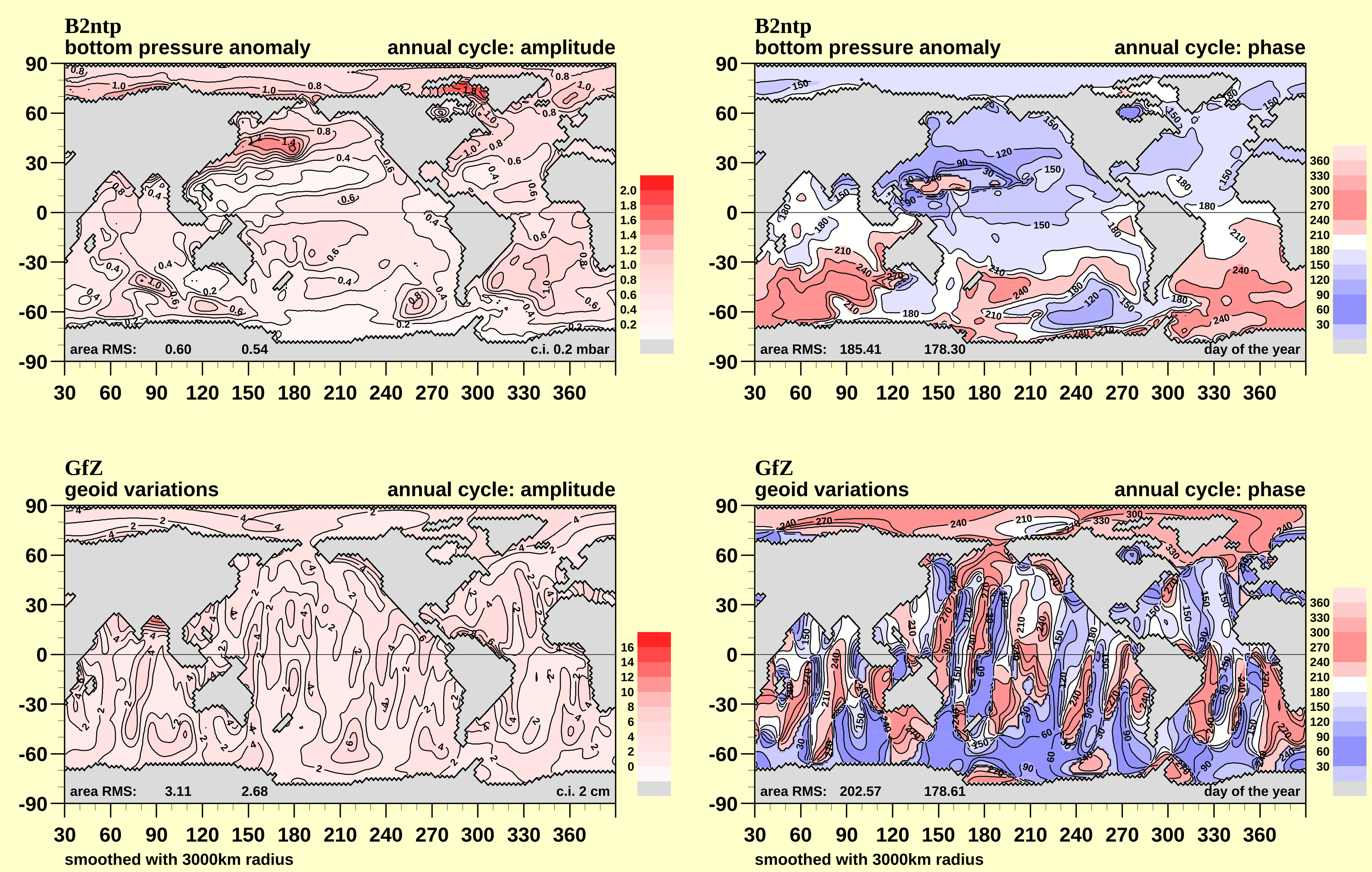
Global mean sea level anomalies: The top graph shows the comparison of the OGCM with the T/P data as well as the models steric and non-steric contributions. The steric components are further decomposed in the graphs below.

Area Mean Comparison



Area mean bottom pressure anomalies (mean annual cycle) as compared to the GRACE geoid variations. Areas shown are (top to bottom): global ocean, North Pacific (20N-60N), tropical Pacific (20S-20N) and South Pacific (58S-20S)

Local Annual Cycle



Global distribution of the amplitude and phase of the mean annual cycle for the models bottom pressure anomalies (top row) as compared to the corresponding estimates for the geoid variations (bottom row, in cm water analog). The annual cycle is estimated locally by fitting a sin-curve to the data. For the model a trend elimination was applied prior to fitting the sin to the nine year timeseries.

Conclusion

- The model reproduces the sea level variations as measured by the TOPEX/Poseidon altimeter well.
- The global ocean mass variations fit well to the GRACE estimates in amplitude and in phase.
- On regional scale the comparison gets worse, especially for the phase on the southern hemisphere.
- Comparing amplitude and phase of the annual cycle on local scale does not give satisfactory results because of obvious deficiencies in the geoid variations on these scales.