Consequences of Using Different Altimeter Products on the Interpretation of the Sea Level Change 1993-2001

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Introduction

In principle sea level changes can be measured accurately by satellite altimetry, but the processing of the data includes many corrections. At this step the choice of the algorithms and the additional correction data is free to subjective preferences to a certain extent. For sure each choice has its own justification, but this finally leads to differences in the products that are delivered to the end user. As example Fig.1 shows the temporal evolution of the global mean sea level as estimated by four different groups.

From the end users point of view it is interesting to see what are the consequences of using different products e.g. in ocean state estimation. For that reason we performed two assimilation experiments utilizing the sea level anomaly maps from the NASA/GSFC Ocean Pathfinder Project (NASA/GSFC) and from the Geoforschungszentrum Potsdam (GfZ) respectively covering the years 1993 to 2001.

Comparing TOPEX Data Products: GfZ vs. NASA/GSFC

Fig. 2: (left) Temporal evolution of area mean differences between the NASA/GSFC and the GfZ dataset. For the single oceans only the excess to the global difference is shown! (center) Temporal RMS of the local differences and (right) the local correlation.

Comparing Model Sea Surface Height to Data

Figure 4 shows that the optimized models reproduce their corresponding global mean sea level data well. This is true especially for the interannual variability, while the amplitude of the annual cycle is underestimated by the models. The latter appears to be a general deficit of the OGCM used and leads to the maxima in the temporal RMS differences shown in Fig.5. The spatial distribution of the RMS is very similar for both experiments and reaches values of up to 7cm especially in the tropics and in the western boundary currents. Also their global mean RMS values, which are the measure of success in the assimilation, appear to be comparable (2.83cm and 2.81cm respectively).

The same good correspondence between the two experiments one also finds for the differences between the modeled temporal mean sea level and the SHOM98.2 sea level (Fig.6). In most of the world ocean the differences are below 10cm. Larger values are found only in the circumpolar belt, where the model produces a much broader Circumpolar Current than expected from the data. The same holds for the western boundary currents, while the strong deviations near the Indonesian Throughflow and in the Caribbean may be explained by deficits in the grid. The spatial RMS value of these difference fields are again comparable (10.58cm and 10.84cm respectively).

The strong similarity in the fit of the model to the data encourages to look at the effect of the differences in the data on the ocean state.

Method

The OGCM that is used to study the impact of the different sea level anomaly products on the ocean state 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) separately.

The model has a $2\times2\times10$ horizontal resolution, 23 vertical layers and a ten day timestep. Nine years (1993-2001) of respective TOPEX/Posidon (T/P) sea surface height anomalies are assimilated into the model. In addition the SHOM98.2 mean sea surface relative to the GRACE geoid (GZ) 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). The forcing is optimized via an empirical orthogonal function (EOF) decomposition, with the first guess taken from the NCEP reanalysis.
Comparing Model Sea Surface Height

For both experiments, BRIO2C and B2ntp respectively, the main contribution to global sea level rise is given by the linear trend of the thermocline component, which is slightly higher using the GIZ data (experiment B2ntp) than in the results obtained when utilizing the NASA/GSFC data. The main differences in the mean sea level is explained by the non-steric component, which reflects the annual to interannual variability (Fig.7a).

Only about 60% of the thermosteric sea level rise originates from the upper 512m of the ocean. Thus the thermal trend in the deeper layers contribute an essential part (Fig.7b).

Figure 8a shows the local sea level trends resulting from the two models BRIO2C and B2ntp that should be compared to the corresponding data shown in Fig.3. Decomposing the sea level trends into its thermosteric, halosteric and non-steric components (Fig.8b-d) shows that even on local scale the main contribution to sea level change is given by the thermosteric part. But the halosteric one cannot be neglected! There are large regions where it is of the same size as the thermosteric.

Differences between the models appear mainly in the non-steric part of the trends. In contrast to the differences in the corresponding data trends Fig.3 right these differences are of opposite sign in the North and the South Pacific. In the thermosteric as well as in the halosteric part differences are found mainly in the Atlantic and in the circumpolar belt.

Indo-Pacific Heat Transport

The meridional heat transport in the two model solutions, BRIO2C and B2ntp respectively, differ mainly in the equatorial belt between 5° and 15°N. Only the transport in the Indo-Pacific is shown here, but this holds for all of the global ocean. The differences mainly appear in the amplitude of the annual cycle which is altered by about 0.5 PW, while the temporal means, given in the right graphs of Fig.12, stay approximately the same.

Outside the equatorial band the differences stay well below 0.04 PW as indicated by the additional dashed lines in the lower left plot.

Summary

- The sea level anomalies, as derived by different groups from the TOPEX/Poseidon altimeter measurements exhibit strong differences related to the respective correction algorithms / data chosen.
- The ocean model can be fitted to the different datasets with equal quality.
- The assimilated model solutions exhibit equal steric contributions to sea level change. The differences in the datasets are mainly reflected in the non-steric part.
- Nevertheless the differences in the sea level datasets project into the oceanic circulation. This can be seen especially in the mass transports, while for the heat transports essential differences are found only in the equatorial belt (5°S - 15°N) in the amplitude of the annual cycle.

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