INFLUENCE OF DEEP OCEAN WARMING ON THE INTERPRETATION OF SEA LEVEL RISE

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Introduction

Two global data assimilation experiments, **B0ntp** and **B2ntp**, are performed with the goal of a better understanding of sea level rise. In both cases satellite altimetry referenced to a GRACE geoid is assimilated together with a set of oceanographic data. The experiments differ in the treatment of the Weddell Sea. In the first case, **B0ntp**, climatological hydrography is used for assimilation while in the second experiment, **B2ntp**, hydrographic lines (see **Fig.1**) derived from a detailed shelf-ice/sea-ice/ocean model are used in addition.

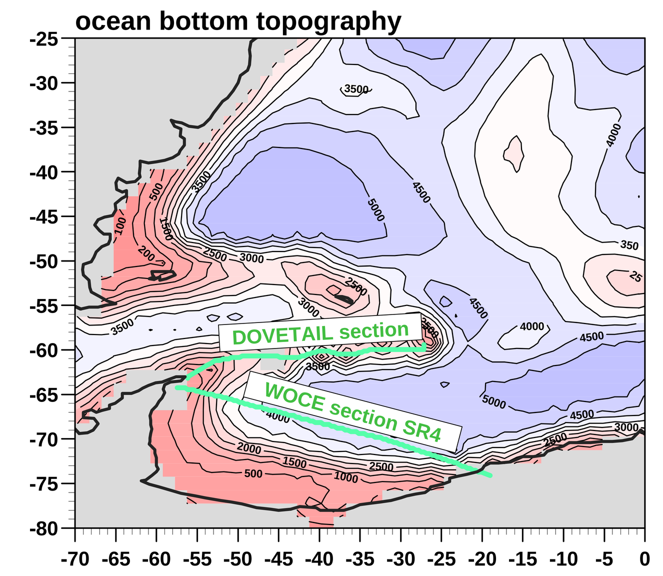

Fig. 1: Weddell Sea sector of the ocean models bottom topography showing the additional data sections across the Wedddel Sea (WOCE section SR4) and along the South Scotia Ridge (DOVETAIL section).

assimilation experiment	Weddell Sea data
B0ntp	NO
B2ntp	YES

The OGCM that is used to study the impact of the different treatment of the Weddell Sea 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) seperately.

The model has a $2^\circ \times 2^\circ$ horizontal resolution, 23 vertical layers and a ten day timestep. Nine years (1993-2001) of TOPEX/Poseidon sea surface height anomalies, provided by GfZ Potsdam, 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). The forcing is optimized via an empirical orthogonal function (EOF) decomposition, with the first guess taken from the NCEP reanalysis.

Both assimilation experiments, **B0ntp** and **B2ntp**, start from the same first guess. They differ only in the additional section data used!

Ocean Model Sea Surface Height vs. Data

Figure 2 shows that in both experiments, **B0ntp** as well as **B2ntp**, the model follows the altimetric anomalies and trend well. This is true especially for the interannual variability, while the amplitude of the annual cycle is underestimated by the models. The spatial distribution of the temporal RMS difference (**Fig.3**) is very simular for both experiments. Also their global mean RMS values, the measure of success in the assimilation, appear to be comparable (2.86cm and 2.81cm respectively). The same good correspondence between the two experiments one finds for the differences between the modeled temporal mean sea level and the SHOM98.2 sea level (**Fig.4**). These also have a comparable spatial RMS (12.24cm and 10.84cm respectively).

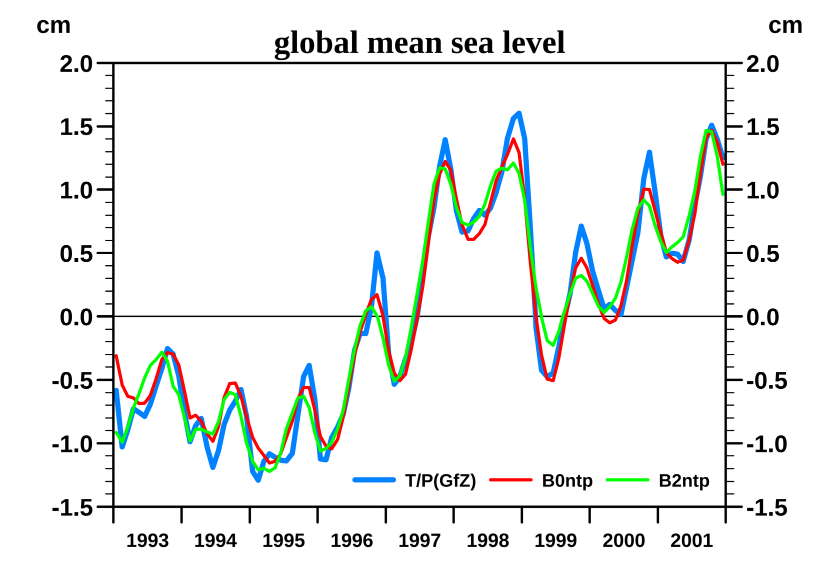

Fig. 2: Global mean sea level anomaly from the two assimilation experiments, **B0ntp** and **B2ntp**, as compared to the TOPEX/Poseidon data

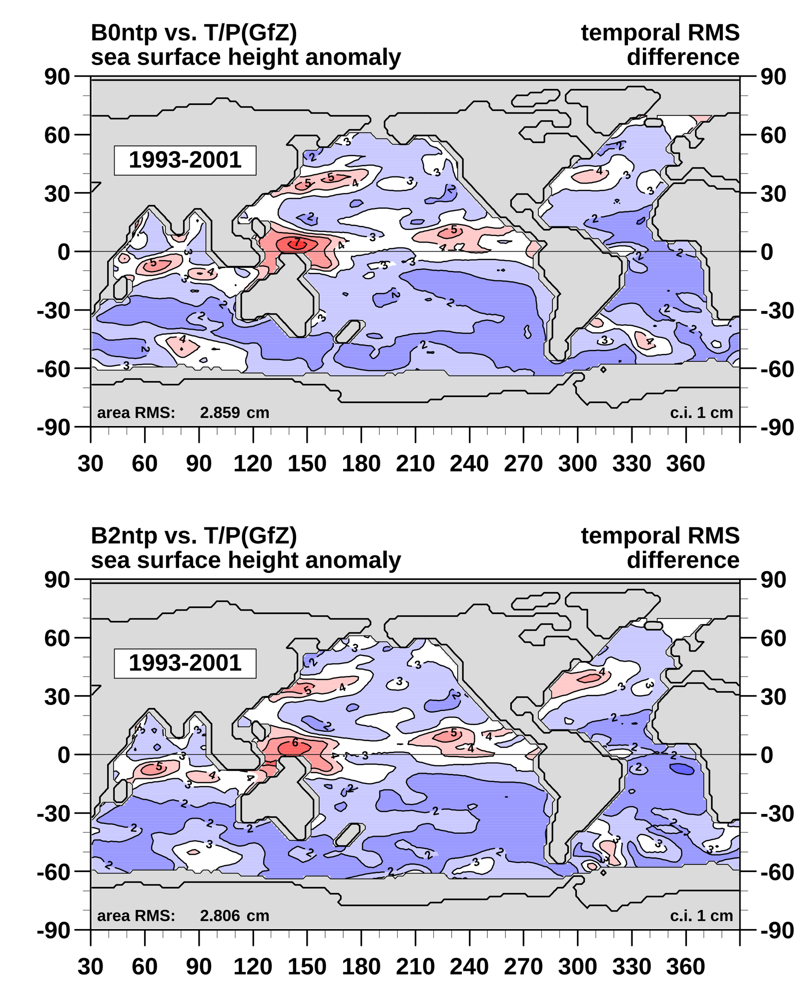

Fig. 3: Local temporal RMS of the modeled SSHA difference between model and TOPEX/Poseidon data, for experiment **B0ntp** (top) and **B2ntp** (bottom).

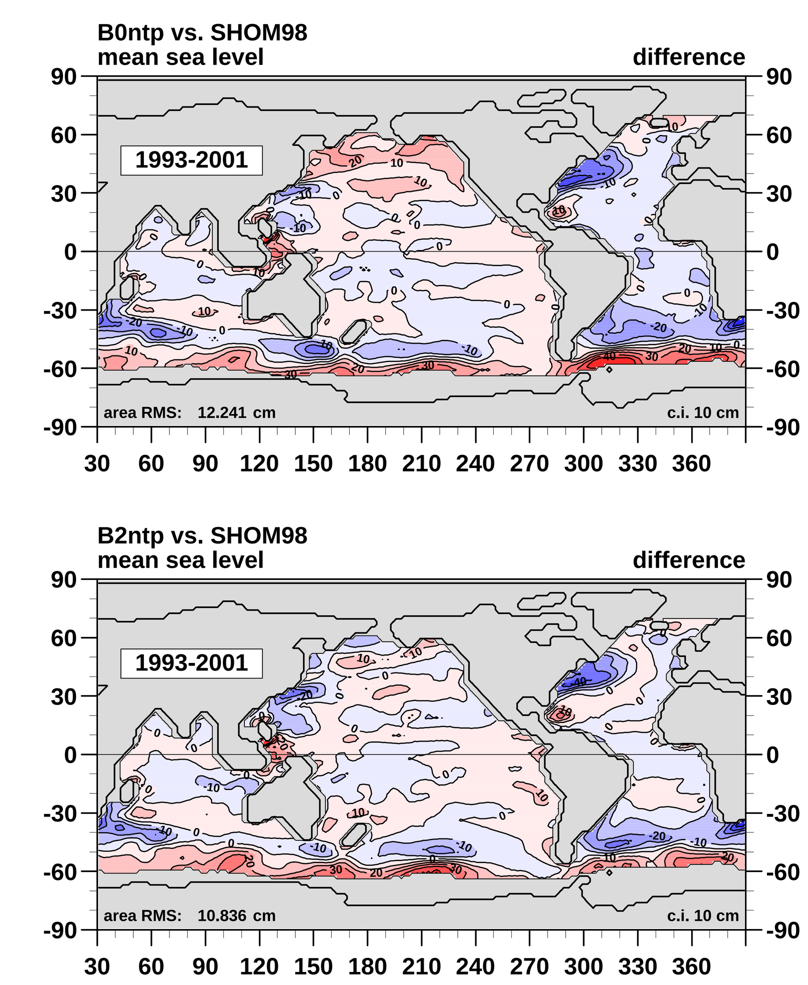

Fig. 4: Temporal mean sea level for the assimilation experiments **B0ntp** (top) and **B2ntp** (bottom) compared to the SHOM98.2 mean sea surface height referenced to the GRACE geoid

Ocean Model Heat Content

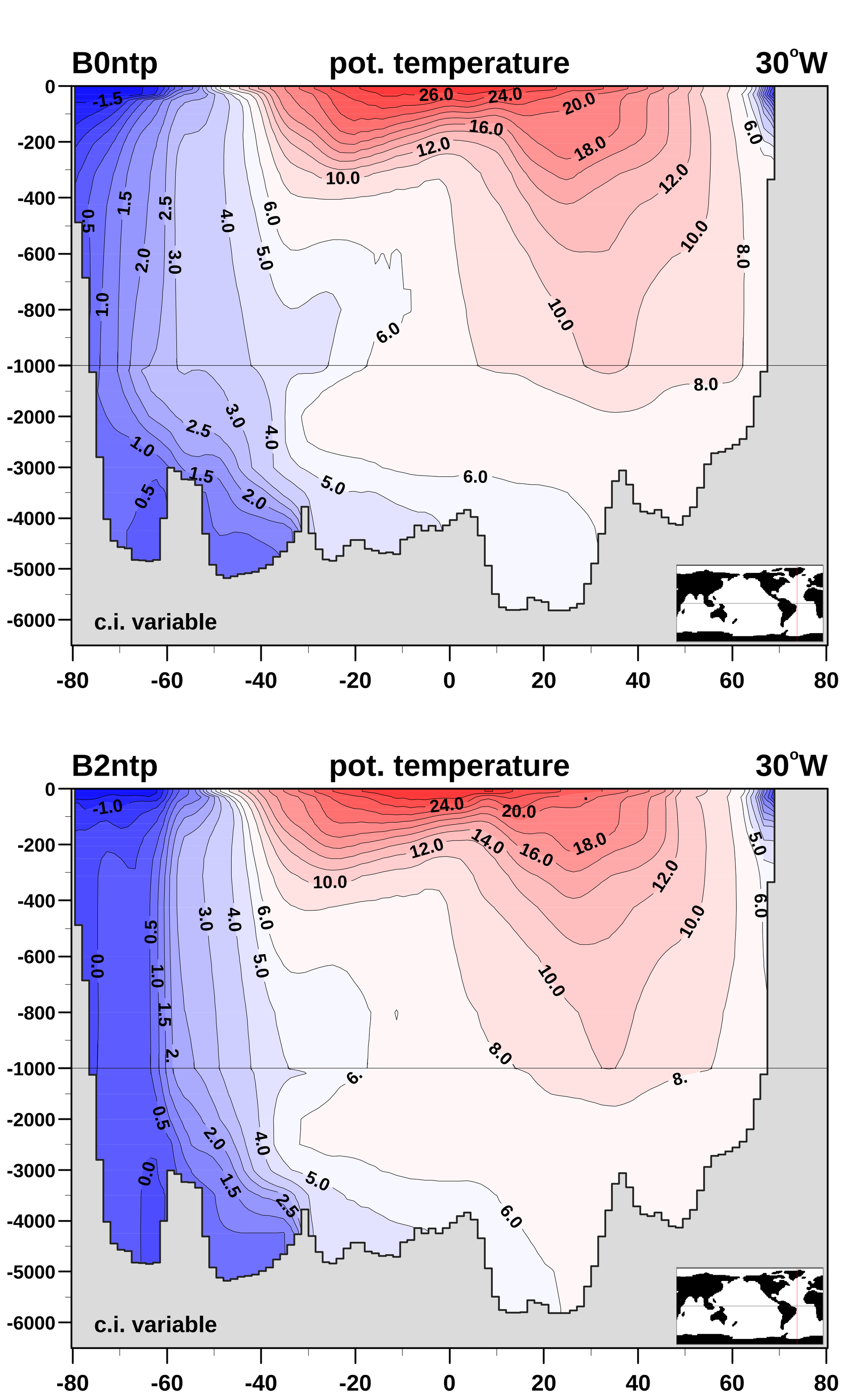

Fig. 5: Mean potential temperature on the N-S section through the Atlantic Ocean at 30°W, for experiment **B0ntp** (top) and **B2ntp** (bottom).

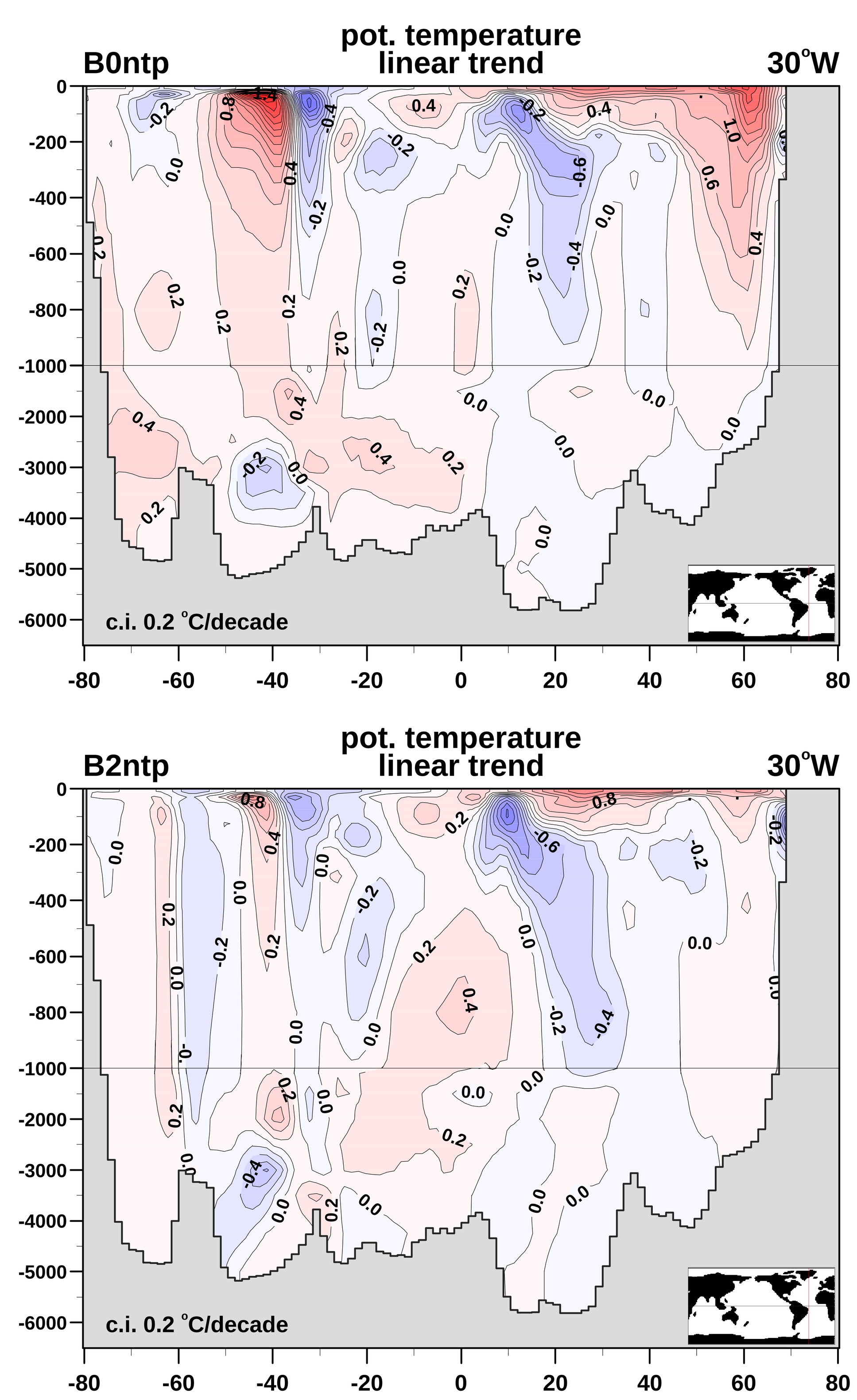

Fig. 6: Corresponding linear temperature trends on the N-S section through the Atlantic Ocean at 30°W, for experiment **B0ntp** (top) and **B2ntp** (bottom).

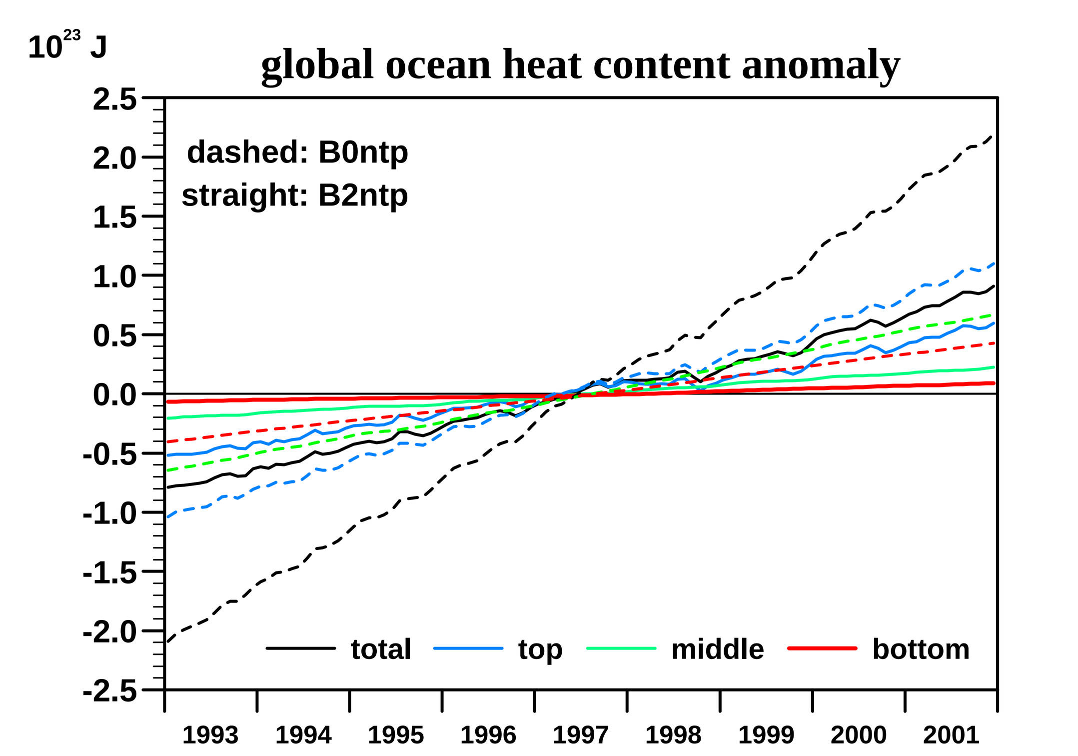

Fig. 7: Global ocean heat content anomaly for the depth ranges: total=[ζ-bottom], top=[ζ-512m], middle=[512m-2250m] and bottom=[2250m-bottom] , for experiment **B0ntp** (dashed lines) and **B2ntp** (straight lines).

Using better information for the Weddell Sea leads to an improvement of the circulation in the South Atlantic. But the assimilation experiments, **B0ntp** and **B2ntp** respectively, do not only end up with a different mean state (e.g. for temperature, **Fig.5**) but exhibit also different trends (**Fig.6**) which are most notable in the convective as well as in the subduction regions. Here the downward transport of relatively warm and saline water is significantly reduced in **B2ntp**. Associated with this is a reduction in the global warming of the ocean (**Fig.7**) especially in the deep layers. This consequently leads to a reduced sea level rise due to steric effects in **B2ntp**.

Comparing Model Sea Level Trends

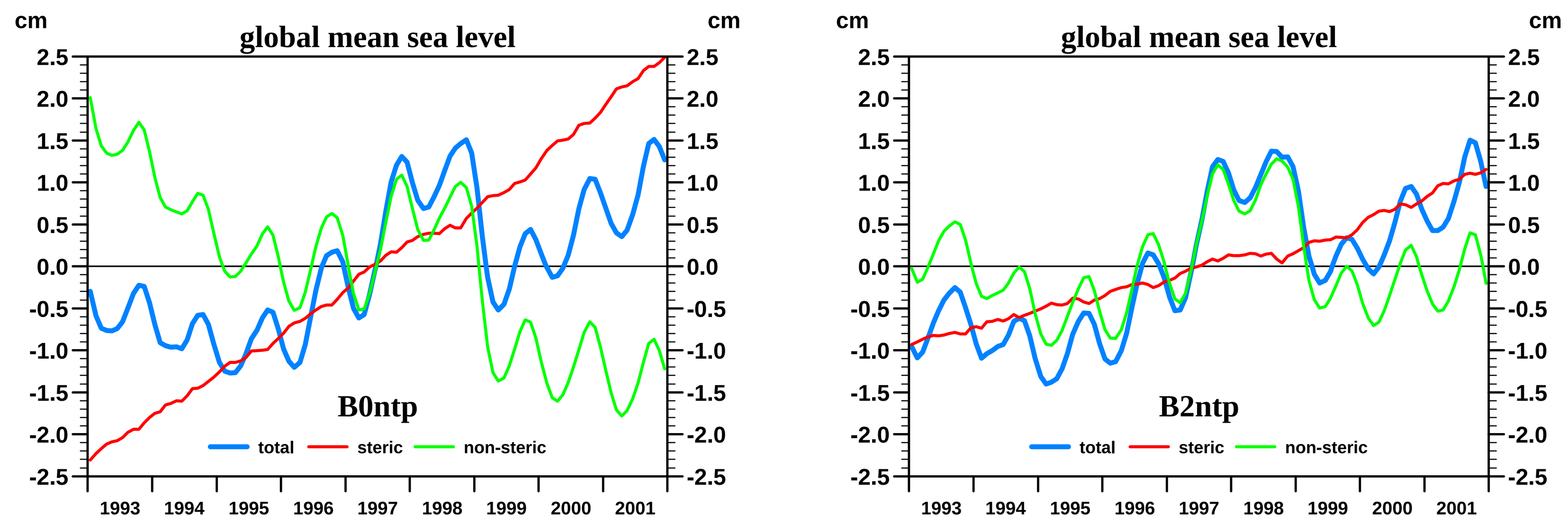

Fig. 8: Temporal evolution of the global mean sea level decomposed into its steric and non-steric part for the model solutions **B0ntp** (left) and **B2ntp** (right).

Figure 8 shows that in both experiments, **B0ntp** and **B2ntp** respectively, 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. The global sea level rise due to thermal expansion is about twice as large for the model solution without the additional hydrographic section data (**B0ntp**) compared to the case utilizing this data (**B2ntp**). Consequently a strong evaporation surplus is needed in **B0ntp** to fit the measured global mean sea level curve (**Fig.2**).

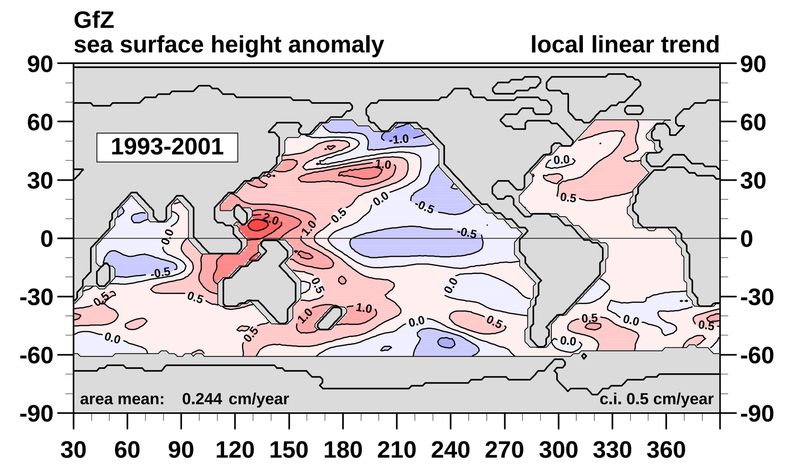

Fig. 9: Local linear trend of the TOPEX/Poseidon (GfZ) sea surface height

Both model solutions, **B0ntp** and **B2ntp** respectively, retrieve the measured local sea level trends to a good quality although the extrema are partly shifted in space (**Figs. 9** and **10a**). The main part of the spatial variability is given by the steric contribution (**Figs.10b**), while the non-steric part (**Figs.10c**) exhibits a much weaker signal. Nevertheless both components show strong differences among the experiments. But while these differences are more or less restricted to the southern hemisphere for the steric one, they are more global for the non-steric part giving a negative trend nearly everywhere in experiment **B0ntp**.

A more detailed comparison of the local steric contribution to sea level rise from the two experiments is given in **Figs. 11** and **12**. In both experiments the main contribution results from the top 500m for the thermosteric as well as for the halosteric part, but the differences appear mainly in the thermosteric in the deeper layers of the circumpolar belt, the South Atlantic and the Southwest Pacific.

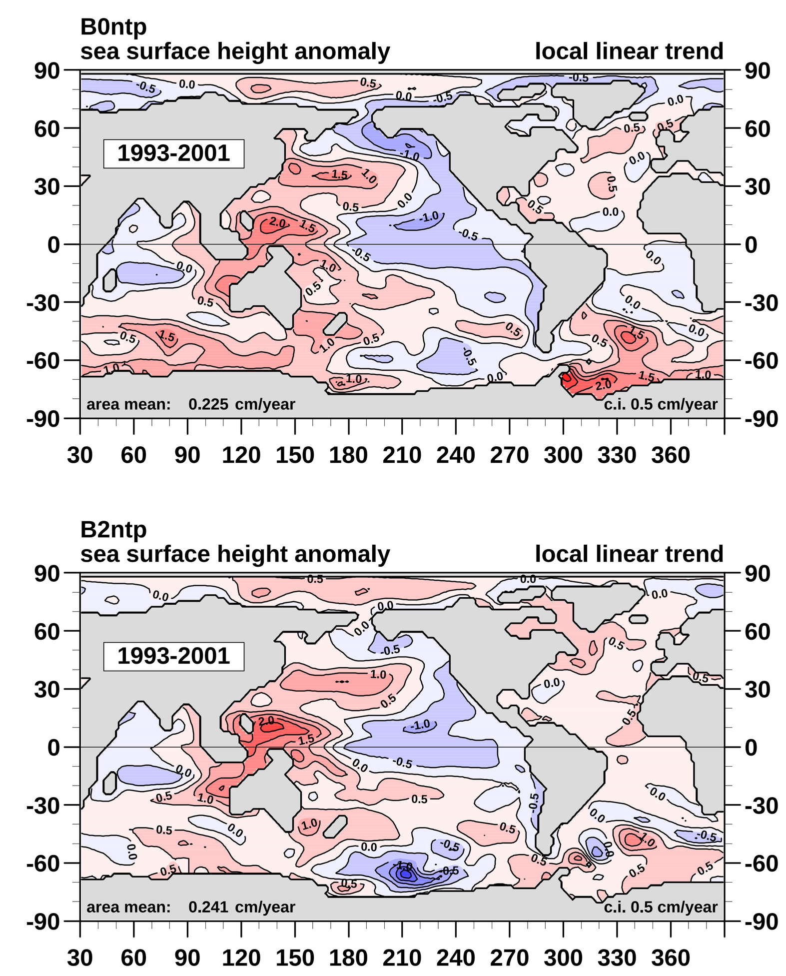

Fig. 10a: Local sea level trend of the model solutions **B0ntp** (upper row) and **B2ntp** (lower row).

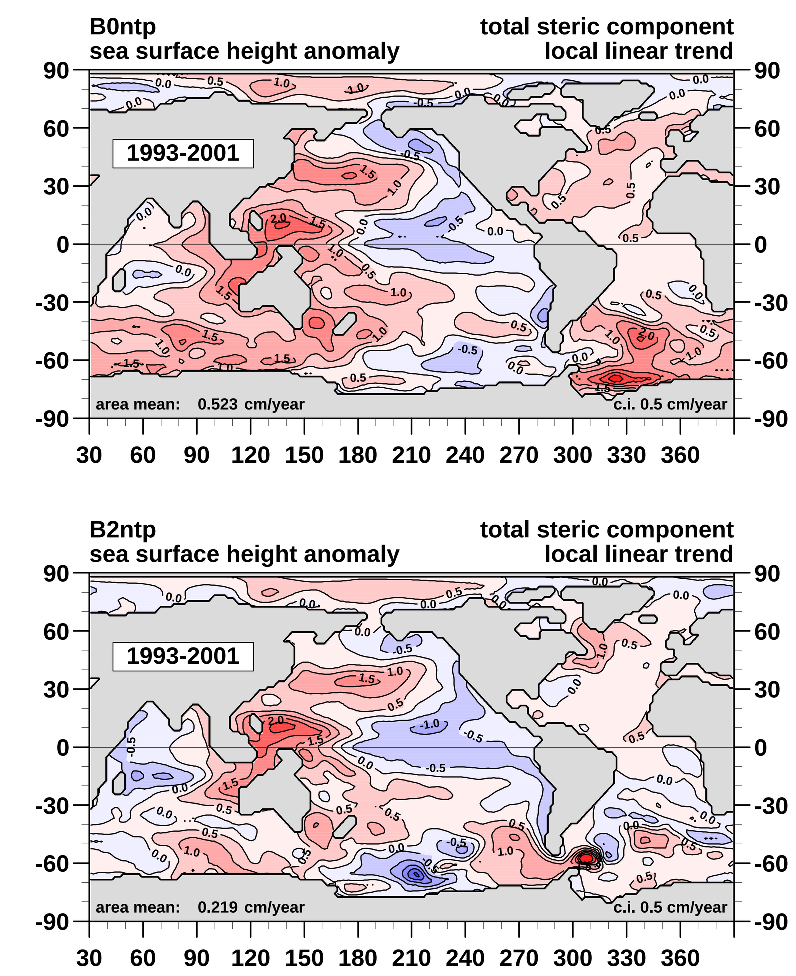

Fig. 10b: same as **Fig.10a** but for the total steric component

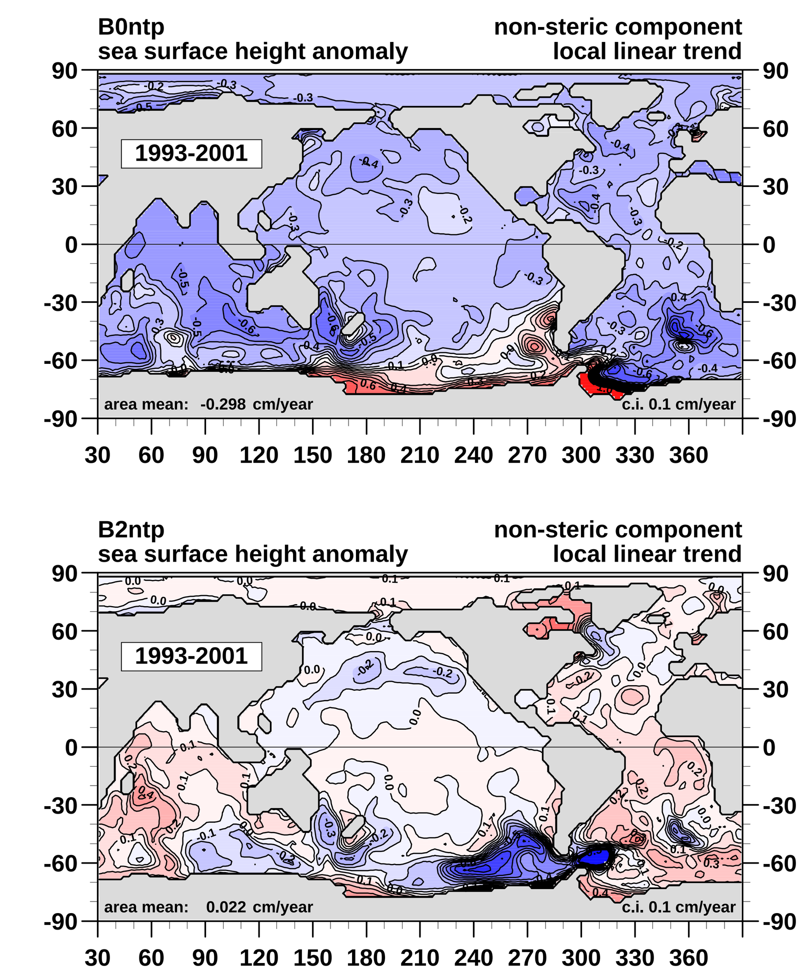

Fig. 10c: same as **Fig.10a** but for the non-steric component

Thermosteric Sea Level Trends

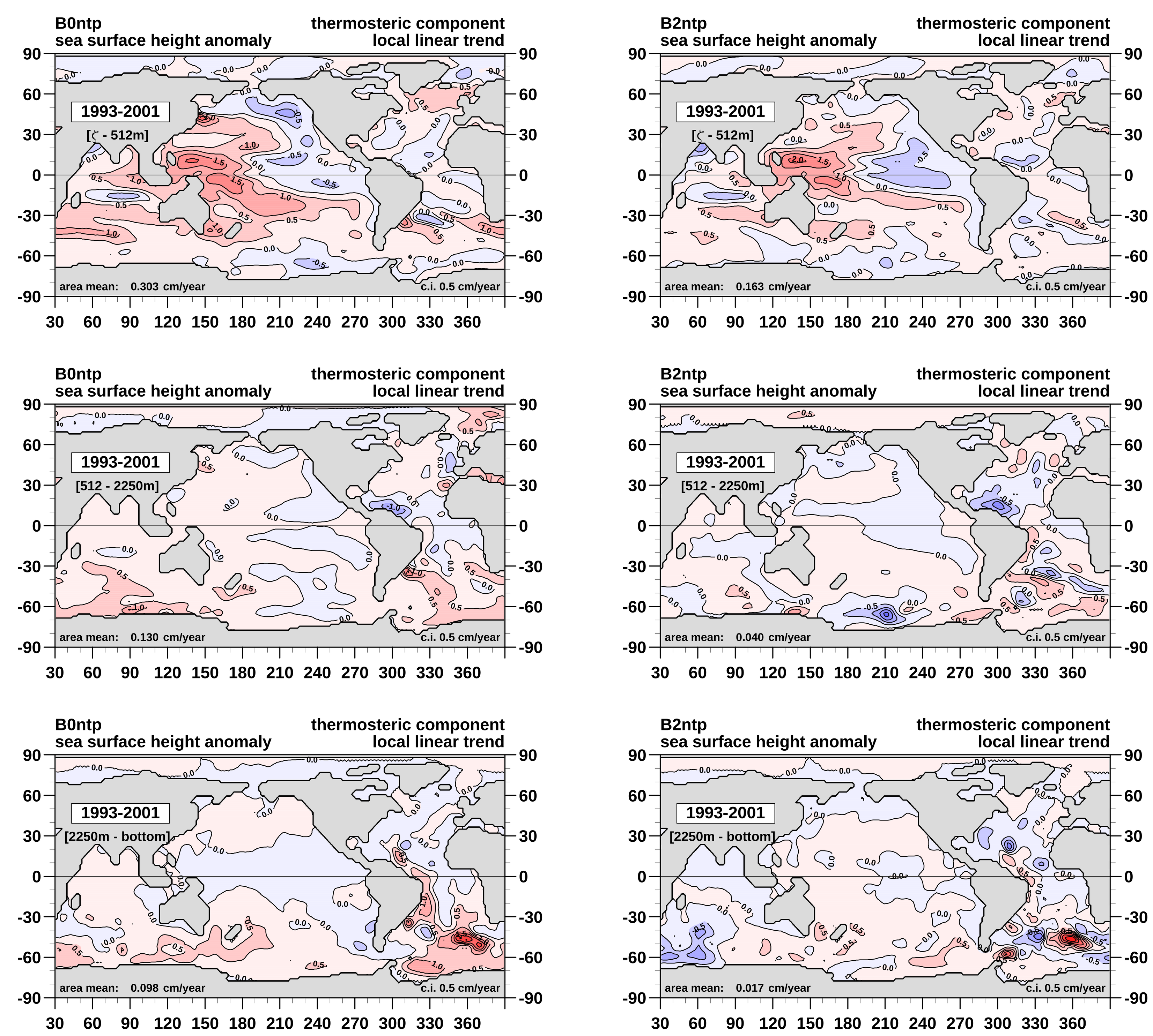

Fig. 11: Thermosteric sea level trends from ocean model solutions **B0ntp** (left column) and **B2ntp** (right column), giving the contribution from the depth ranges (topmost to undermost): [ζ-512m], [512m-2250m] and [2250m-bottom].

Halosteric Sea Level Trends

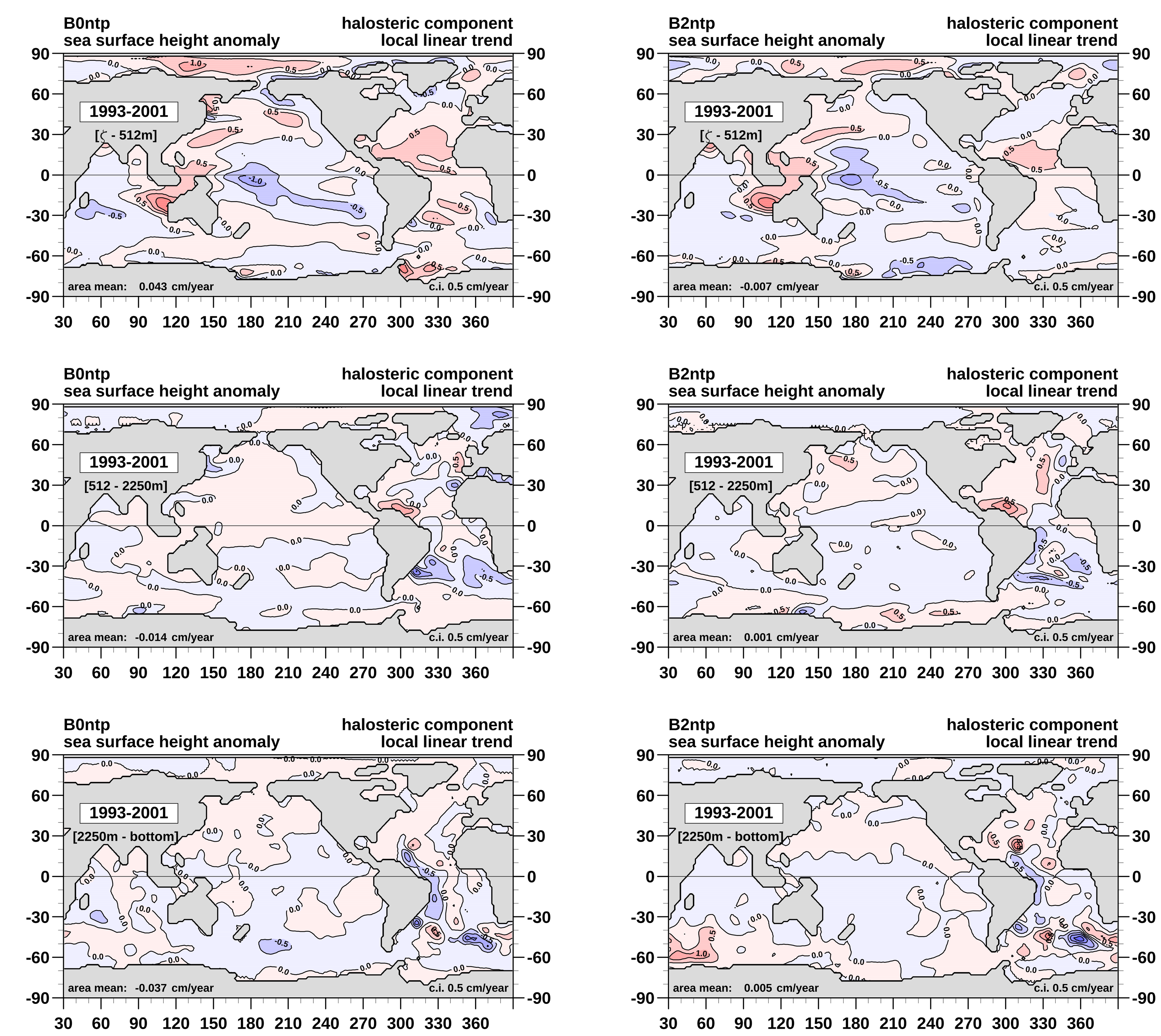

Fig. 12: Halosteric sea level trends from ocean model solutions **B0ntp** (left column) and **B2ntp** (right column), giving the contribution from the depth ranges (topmost to undermost): [ζ-512m], [512m-2250m] and [2250m-bottom].

Summary

- The ocean model fits the altimetric data with equal quality no matter if the additional hydrographic section data are used or not.
- The use of the section data in the Weddell Sea results in a much less warming of the global ocean, approximately half the value, than without these data.
- The resulting difference in the steric global sea level rise of the ocean model solutions is balanced by the non-steric contribution (net global surface freshwater flux).
- On regional scale the differences in the steric part are mainly restricted to the southern hemispere, while the non-steric differences show a distinct global extent.
- Not only the thermosteric sea level change is effected by the additional use of Weddell Sea data, but the halosteric part as well.
- The steric differences are most evident in the deeper ocean layers.

For the **Consequences of using different altimeter products on the interpretation of the sea level change 1993-2001** you are invited to visit the OS18 poster by Wenzel and Schröter on Friday, April 30, board number: P0207.

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