GLOBAL OCEAN HEAT CONTENT VARIATIONS DERIVED FROM SATELLITE ALTIMETRY AND HYDROGRAPHIC DATA

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Introduction

Sea surface elevations as measured by the satellite altimetry together with a limited set of hydrographic measurements are assimilated into a global OGCM that has a free surface and that conserves mass rather than volume. The combination of both types of measurements appeared to be necessary to get a reasonable estimate of the oceanic circulation. Further improvement in estimating sea level change was achieved by including the steric effects (thermosteric and halosteric) into the modelled sea surface elevation, because local sea level trends vary substantial in space and time. They are closely associated to heat and salt anomalies in the ocean. The resulting heat content variations of the ocean will be analysed and compared to independent estimates like e.g. to the analysis of Willis et al (2004).

The OGCM that is used in this study is based on the Hamburg Large Scale Geostrophic model LSG. The model has a $2^\circ \times 2^\circ$ horizontal resolution, 23 vertical layers and a ten day timestep. Furthermore the model is able to estimate the single contributions to sea level change, the steric (thermosteric, halosteric) and the non-steric effects (local freshwater balance, mass redistribution) seperately.

Eleven years (1993-2003) 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 EIGEN-GRACE01S geoid (GfZ) as well as sea surface temperatures and ice cover information from Reynolds (2002) are assimilated into the model. The WGHC climatology combined with the monthly anomalies from WOA01 is used as background information for temperature and salinity. Furthermore data from high resolution regional model runs are supplied in the Ross Sea and in the Weddell Sea.

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.

Ocean Model Sea Surface Height vs. Data

The temporal RMS differences between the modeled SSHA and the data is shown in Fig.1. The global RMS value, which is the measure of success in the assimilation, is 2.9cm although locally we find higher RMS values (up to 7cm) especially in the tropical Pacific and in the western boundary currents. For the temporal mean SSH the deviations between the model and the data are well below 5cm in most part of the ocean giving a global RMS value of 14cm (Fig.2). As for the anomalies the largest deviations (up to $\sim$ 30cm) are found in the regions with strong currents, i.e. the western boundary currents as well as the Antarctic Circumpolar Current (ACC). Especially the signature in the ACC region implies that these currents are represented too broadly by the model. For the surface temperature the corresponding RMS differences between the model and the data are 0.30K for the temporal mean and 0.51K for the anomalies (not shown).

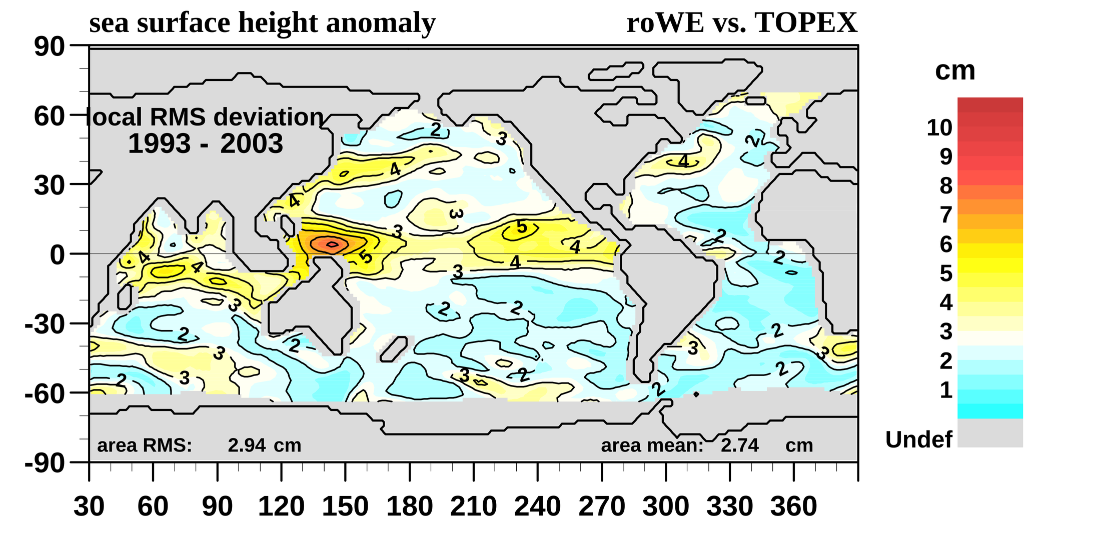

Fig. 1: *Local temporal RMS difference between the modeled SSHA and the TOPEX/Poseidon data.*

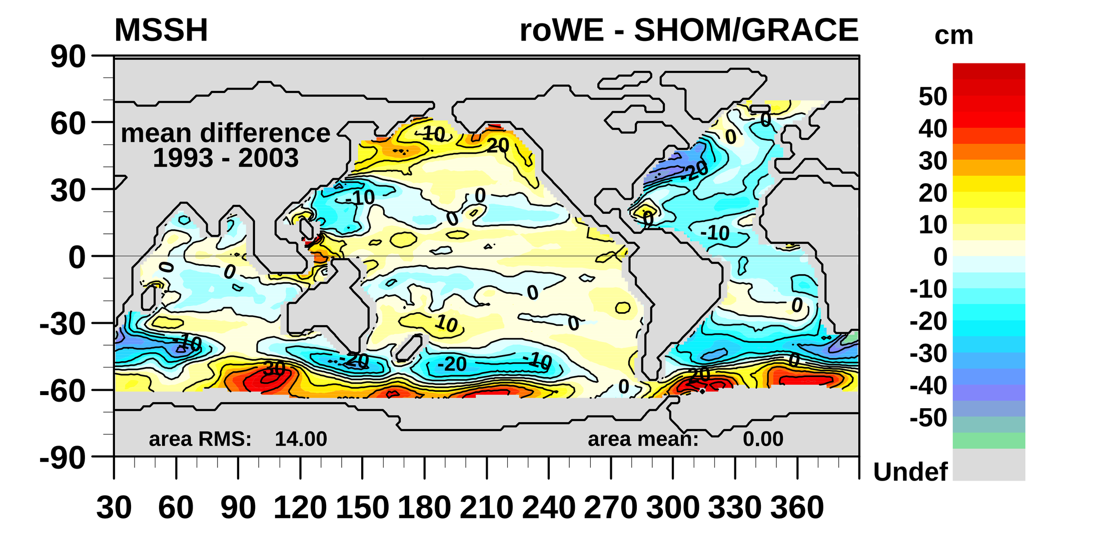

Fig. 2: *Modeled temporal mean sea level compared to the SHOM98.2 mean sea surface height referenced to the GRACE geoid*

Ocean Model Heat Content

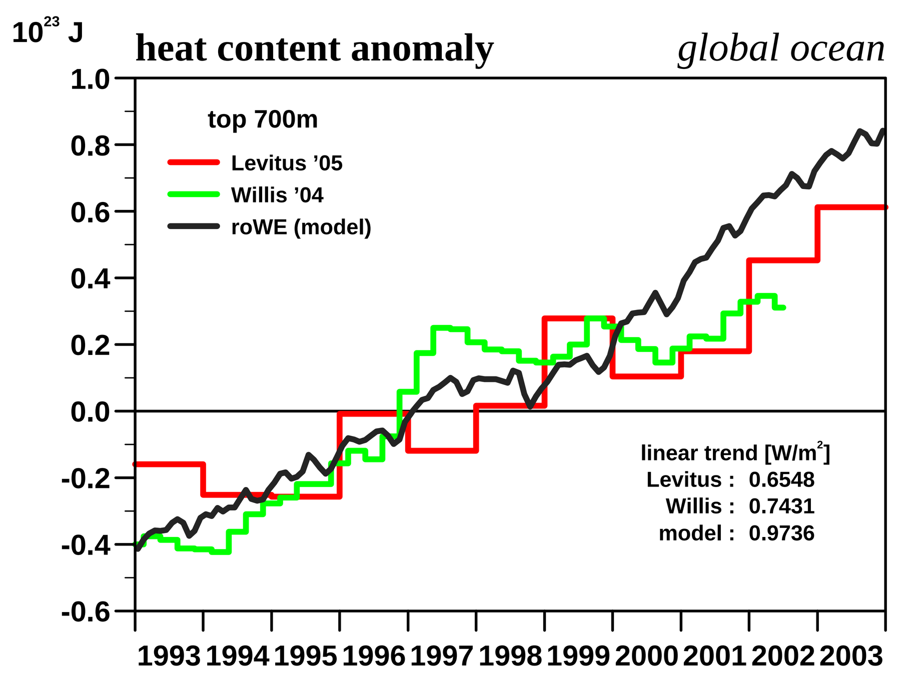

Fig. 3: *Global ocean heat content anomaly for the depth range [ζ-700m] compared to the WOA01 annual anomaly data (Levitus, red line) and to the Willis data (green line).*

Using additional information in the Weddell Sea and the Ross Sea areas leads to a better circulation in these regions and it improves the evolution of the global upper ocean heat content. Its trend now fits well to the estimates derived analysing the WOA01 and the Willis data respectively (Fig. 3). Furthermore the regional distribution of these trends (top panel of Fig.4) compares well to measurements (Fig.5).

Fig.4 also shows that there is net ocean warming in the deeper layers too (middle and bottom panel). Especially in the Atlantic, the South Pacific and the circumpolar belt one finds essential contributions to the overall trend of the total water columns heat content (Fig.6) thus contributing to the thermosteric sea level change.

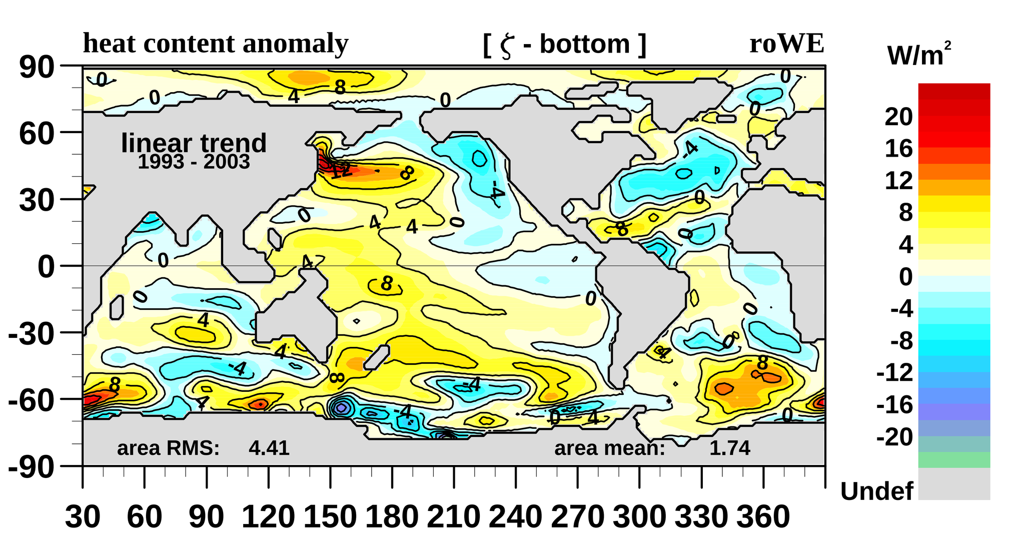

Fig. 6: *Modeled local linear trend of the oceans heat content (total water column).*

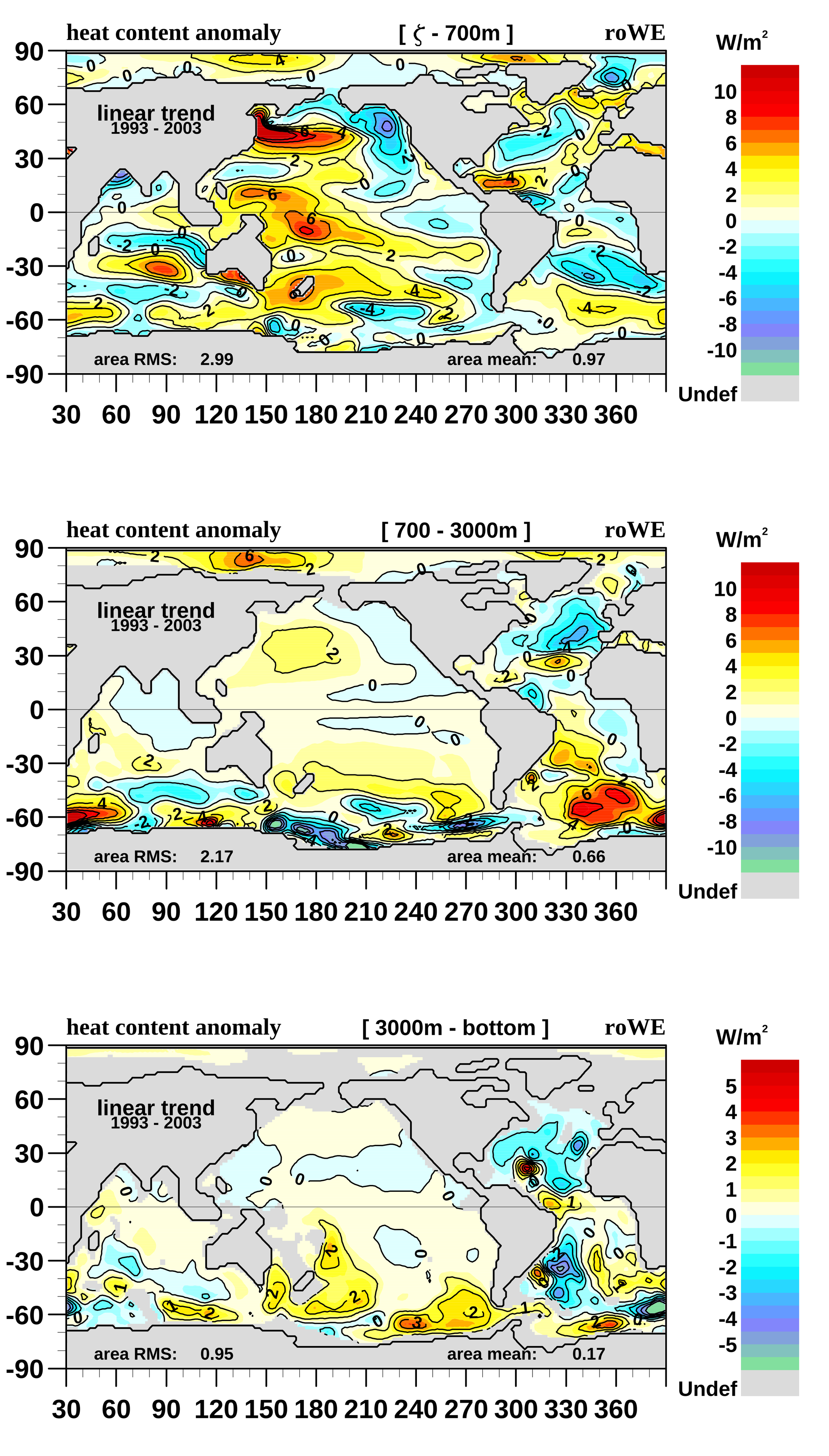

Fig. 4: *Modeled local linear trend of the oceans heat content for the depth ranges: [ζ-700m] = top, [700-3000m] = middle and [3000m-bottom] = bottom panel.*

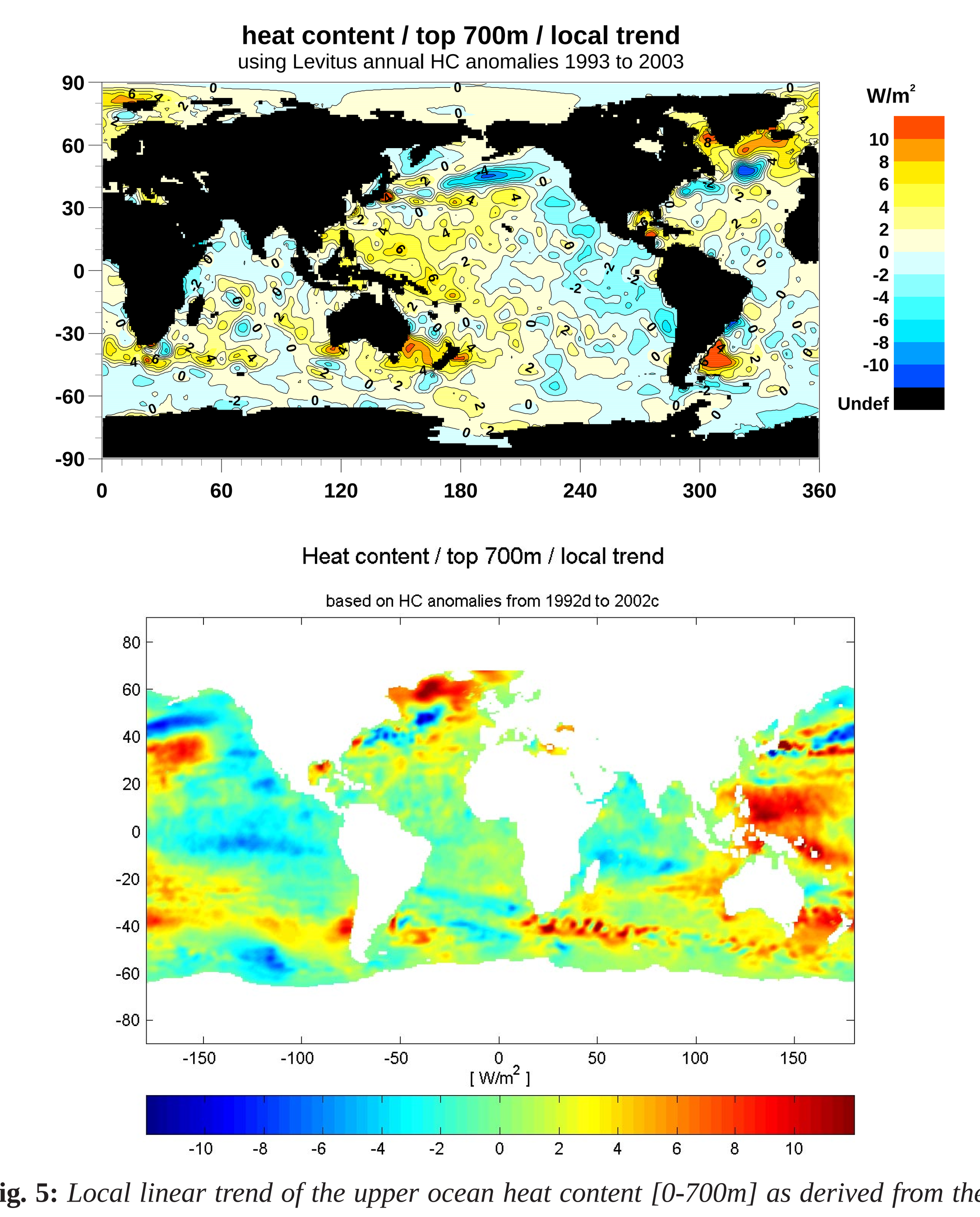

Fig. 5: *Local linear trend of the upper ocean heat content [0-700m] as derived from the WOA01 annual anomalies (top) and from the Willis analysis (bottom).*

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