Oceanic State During 1993-1999 Determined by 4-D VAR Data Assimilation

J. Staneva, M. Wenzel and J. Schröter

Alfred Wegener Institute for Polar and Marine Research
Bussestr. 24, D-27570 Bremerhaven, Germany e-mail: jstaneva@awi-bremerhaven.de

We study here the variability of sea level and oceanic state during 1993 - 1999 using 4D VAR data assimilation. The ocean data assimilation is directed to the combined used of ocean and data to obtain a time dependent oceanic state. The recent progress in understanding the ocean circulation depends upon the availability of ocean observations. Hydrography data however are sparse in space and time. TOPEX/POSEIDON satellite altimetry measures the sea level variability at global scales every 10 days with an accuracy of the anomaly less than 5 cm (Cheney et al., 1994). The variability of the sea surface height gives an integral measure of the three-dimensional ocean circulation. Here we use the Hamburg LSG model to study the state of the ocean. It is a coarse resolution OGCM (3.5^o *x* 3.5^o horizontal and 11 vertical levels) originally designed for climate studies. The implicit formulation in time of the LSG allows for a time step of one month. To combine the model and data we use the adjoint method. As control parameters we use the model initial temperature and salinity state and the mean annual cycle of wind stress, air temperature and freshwater flux. The additional temporal variability of the forcing is taken from the NCEP reanalyses from 1992 to 1999. Additionally we utilise the same data sets as in Wenzel et al. (2001), but with reduced weights. The initial state is taken from its optimised climatological annual cycle obtained by Wenzel et al. (2001). As a reference for our purpose the LSG model is forced subsequently with monthly data from the NCEP reanalysis project for 1950-1999. The first guess initial model state and forcing fields are taken from the oceanic state in January 1992. Seven years (1993-1999) of TOPEX/POSEIDON (T/P) sea surface height relative to the EGM96 geoid model are also assimilated into the model.

First we compare the variability of the simulated sea surface height from the model with the variability of T/P data (figure 1). The horizontal patterns of the variability of the Sea Surface Anomaly (SSA) of T/P altimetry data is quite similar to that obtained by the constrained model. The largest differences between the variability of the altimetry data and model simulations are observed in the equatorial Pacific and Indian oceans. The deviations of the SSA variability obtained by the constrained model from that of the T/P anomalies are better pronounced in the regions of the strong currentsion.

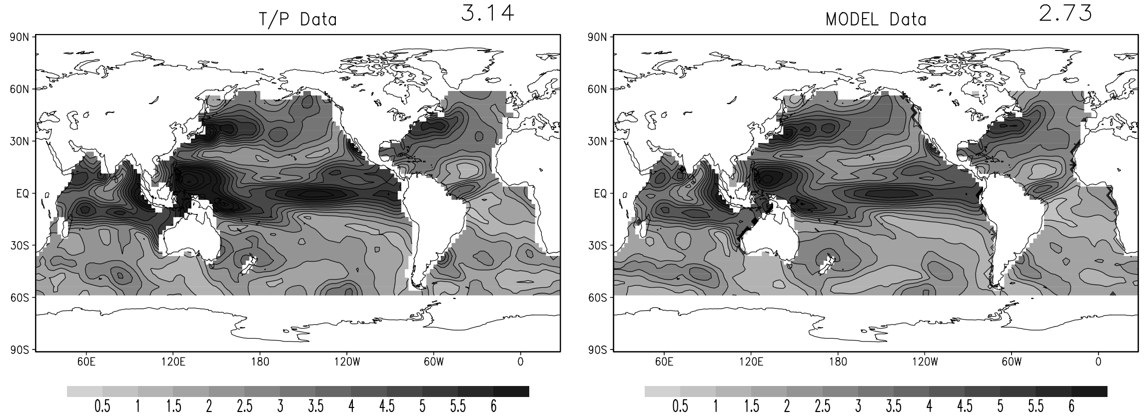

Figure 1: RMS variability of sea surface height [cm] from the T/P data (left) and optimised model (right) averaged from 1993 to 1999.

The area mean variability of SSA (see figure 2) in constrained solution (dashed line) from 1993 to 1999 is closer to that of the T/P data (full line). Some deviations of the model solutions from the T/P data are observed at the end of integration period.

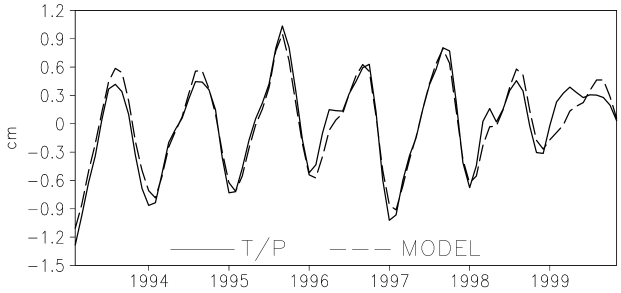

Figure 2: Area mean sea surface anomaly [cm] as a function of time (c): full line-T/P data, dashed line - optimised model data.

The temperature and salinity of the model are constrained using Levitus monthly mean climatological fields (Levitus, 1994). Below we will compare the model simulations with this climatology as well as with independent data set taken from WOCE hydrography. The differences between the temperature estimated by the constrained model and the temperature taken from the Levitus climatology and WOCE data are shown in figure 3 across the central Pacific depth-longitude section (32.5 °S). The temperature from the model simulations and climatological data is time averaged from May to July. The WOCE hydrology and Levitus data are interpolated to the model grid, therefore all small scale structures related to the eddies in the WOCE hydrography are eliminated. The large- scale structures simulated by the model are with visually good agreement with the the data. The temperature differences are mainly pronounced in the upper 1000 m. The sub-surface temperature obtained by the constrained model exceeds that of the data, indicating the model deficits due to its coarse horizontal resolution. It is clearly seen from the vertical sections that the temperature of the assimilation experiment compares better to the independent temperature of the WOCE section than to the Levitus climatology, indicating that the model stratification tends to be closer to the real hydrological data rather than to climatological one. Giving most weight to the constraints on sea surface height improves the density of the model to a structure more realistic than climatology.

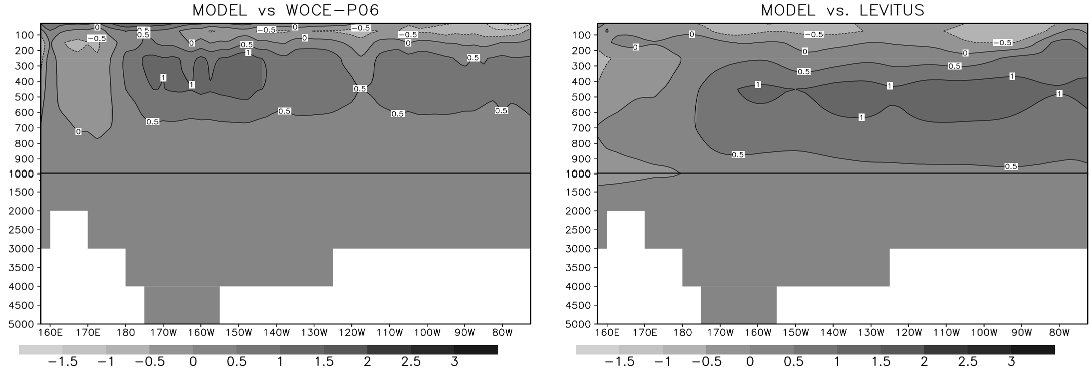

Figure 3: A comparison of depth-longitude section of temperature (^{o} C) taken at 32.5 ^{o}E across Pacific and time averaged between May and July for: (left) model simulations *vs.* WOCE data. and (right) model simulations *vs.* Levitus data

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