Observations for Climate: The Use of Numerical Models for Ocean Observing System Evaluation and Design

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Abstract

Our use of ocean general circulation models to evaluate existing ocean climate observing systems and design new systems involves two research thrusts: (1) model sampling experiments, and (2) the use of Observing System Experiments (OSEs) to evaluate existing observing systems and Observing System Simulation Experiments (OSSEs) to evaluate new observing systems. Model sampling experiments have been used test the ability of in situ geostrophic velocity measurement systems supplemented by bottom velocity and wind information to test observing strategies for the Meridional Overturning Circulation (MOC) and meridional heat transport (MHT) in the extratropical South Atlantic. For example, an array of approximately 20 instruments deployed along 34.5°S was found to reproduce the temporal evolution and vertical structure of the MOC and MHT and thus represents a potentially realistic strategy for monitoring these climate parameters at that latitude. Given that there is important mesoscale variability in the South Atlantic, analysis of the mooring data will need to be interpreted in concert with other existing observing systems with better zonal resolution but coarser temporal resolution (e.g., altimetry, cross-basin XBT transects, and Argo). Results are summarized in Figures 1 and 2.

We have developed a prototype OSE/OSSE system at AOML with the goal of executing rigorous ocean observing system evaluation and design studies for a broad range of regional-to-global oceanographic problems. An OSSE is being set up to evaluate observing strategies for the Atlantic MOC (AMOC) throughout the Atlantic basin. This "fraternal twin" system uses two substantially different configurations of the same ocean model as the nature run (NR) model and the data-assimilation (DA) system. The NR is provided by a global HYCOM run on a Mercator grid with 0.72-degree resolution at the Equator blended with an Arctic pole patch that was forced by the NCEP reanalysis from 1948 through 2010. The DA system uses a coarser (1.44-degree nominal) resolution Atlantic HYCOM domain and employs four different DA methods, This allows OSSEs to be used to evaluate the different DA methods and enables the sensitivity of OSE and OSSE results to the chosen DA method to be determined. The OSE/OSSE system setup is further illustrated in Figures 3 and 4. The DA system is now undergoing final tests. The initial AMOC OSSE run is designed to quantify the impact of extending Argo profiles into the deep ocean. Subsequent experiments will assess the impact of existing systems (e.g., repeat XBT transects) and new systems (e.g., new zonal monitoring sections).

Model Sampling Experiments

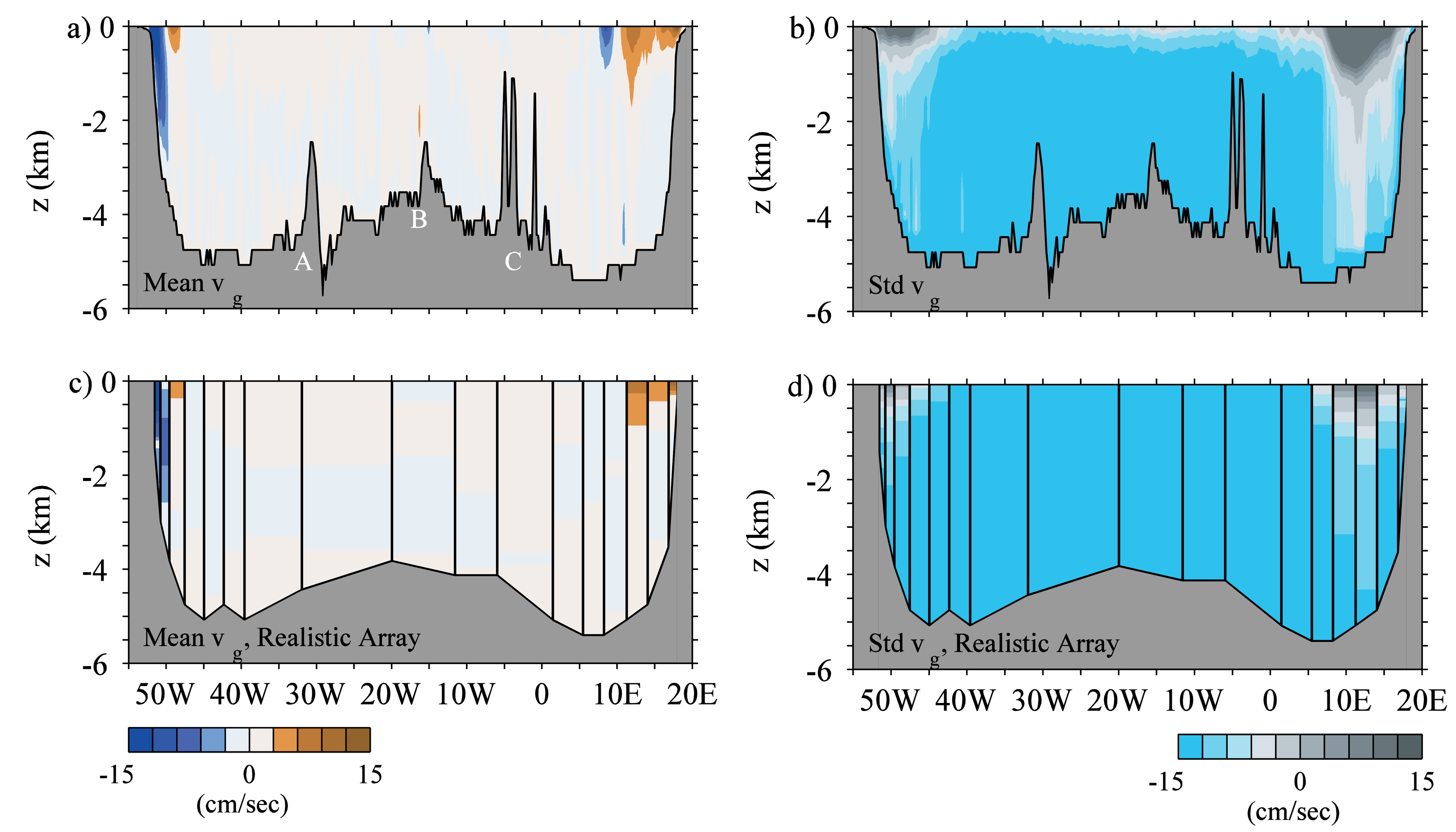

Figure 1. Mean and standard deviation of bottom-referenced geostrophic velocity obtained using density profiles for a-b) the full resolution of the OGCM For the Earth Simulator (OFES) model and c-d) a realistically-sized array of 19 sites deployed within OFES along 34.5ºS. Topographic features such as the Rio Grande Rise and the Mid-Atlantic and Walvis Ridges are identified in panel a) by the labels A, B, and C, respectively.

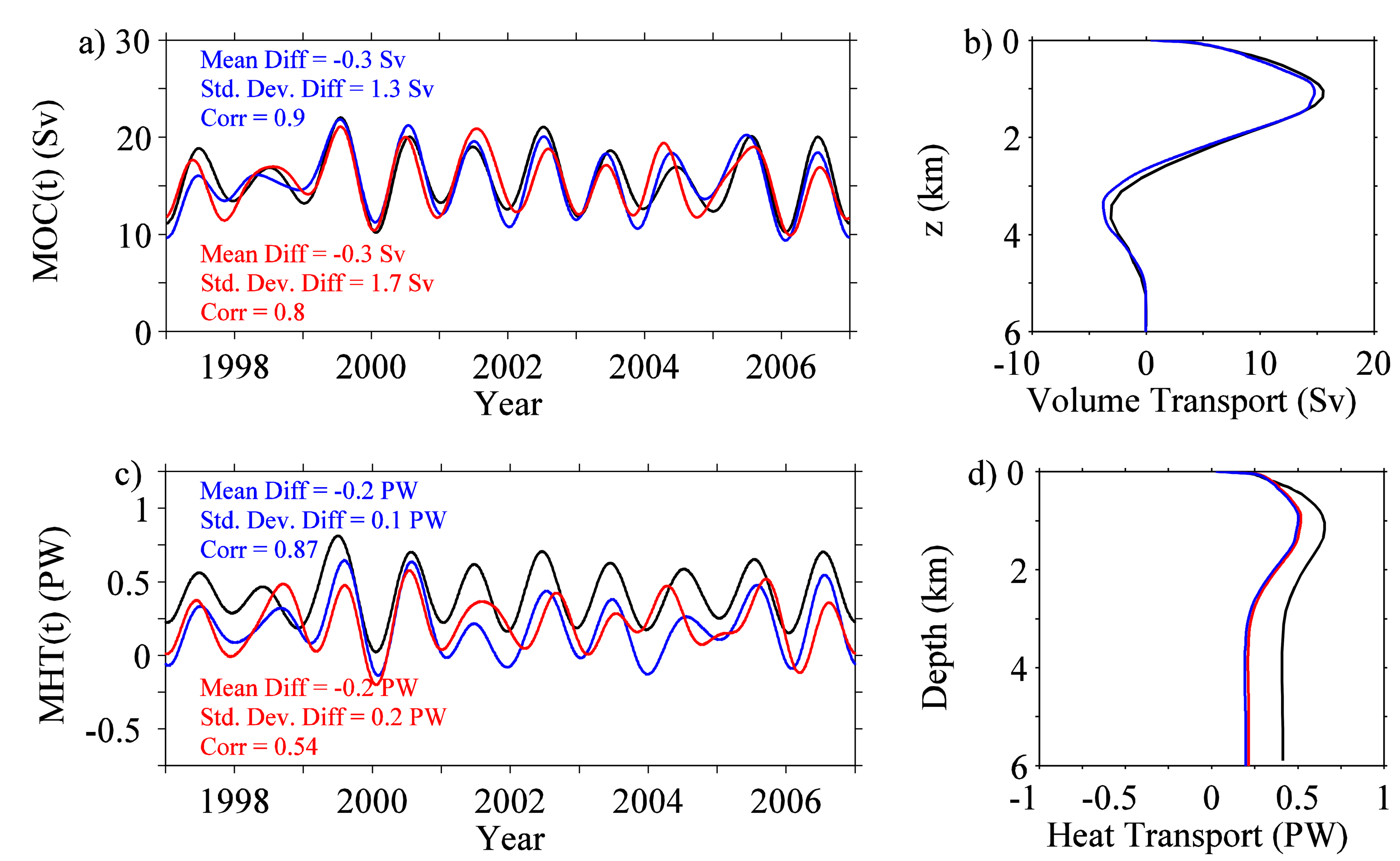

Figure 2. OFES a) MOC and c) MHT time series along 34.5ºS (black lines), with estimates of the MOC and MHT based on geostrophic velocity measurement systems deployed in OFES at the 19 sites in Figure 1. Two methods of estimating geostrophic velocities are tested, simulating dynamic height moorings (blue lines) and current and pressure recording inverted echo sounders (red lines). Time scales shorter than 9 months have been removed. Mean vertically-integrated b) volume and d) heat transport. Reconstruction statistics are listed in panels a) and b).

OSE/OSSE Experiments

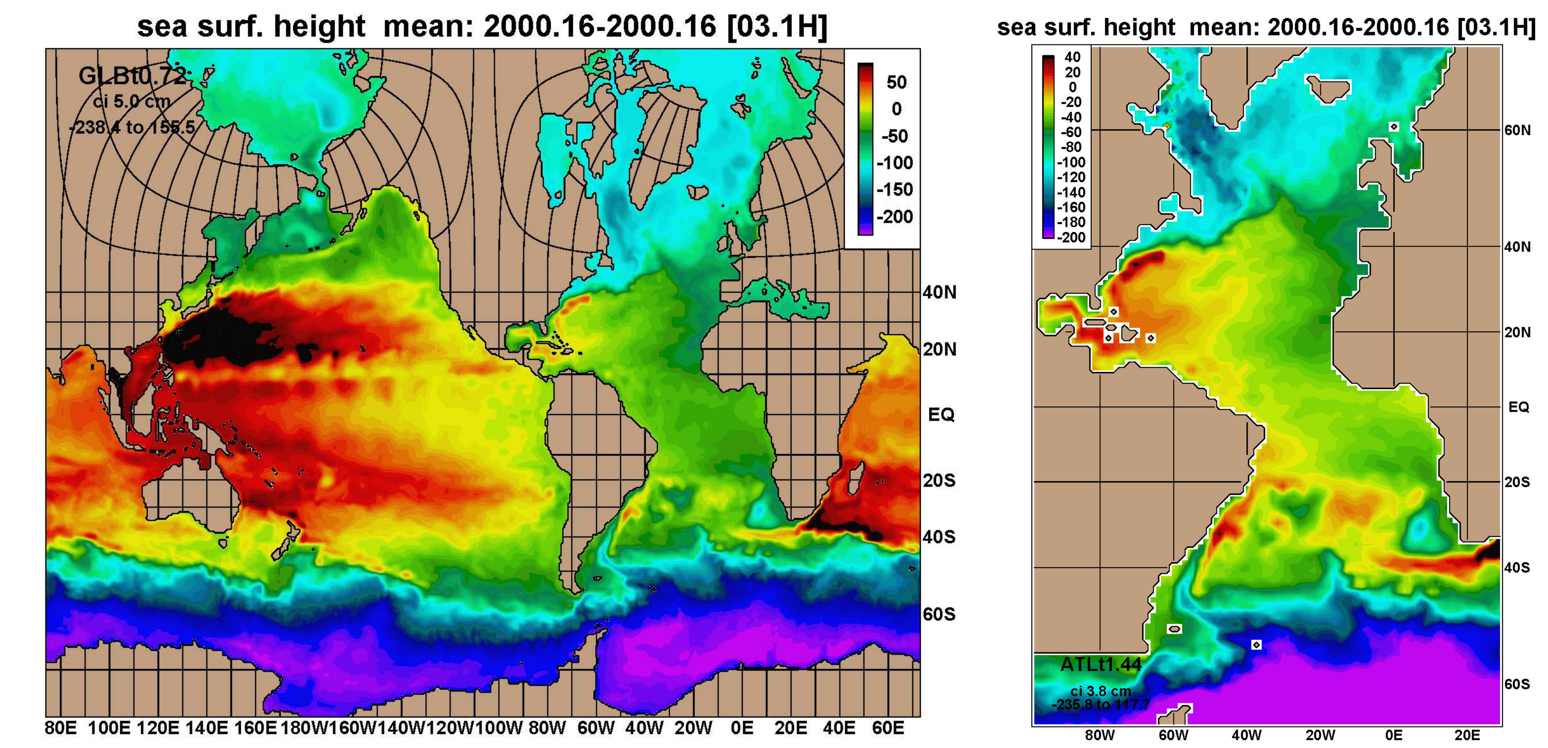

Figure 3. Sea surface height maps for 28 Feb. 2000 obtained from the global 1948-2010 NR model run (left) and the Atlantic DA model run (right), the latter nested within global model fields. OSSEs will be performed by sampling synthetic observing systems from the global NR and assimilating these observations into the Atlantic DA system. The impact of selected observing systems with respect to monitoring the AMOC is quantified by calculating the reduction of errors in the DA model (e.g. of AMOC transport and meridional heat flux) with respect to the NR model simulation.

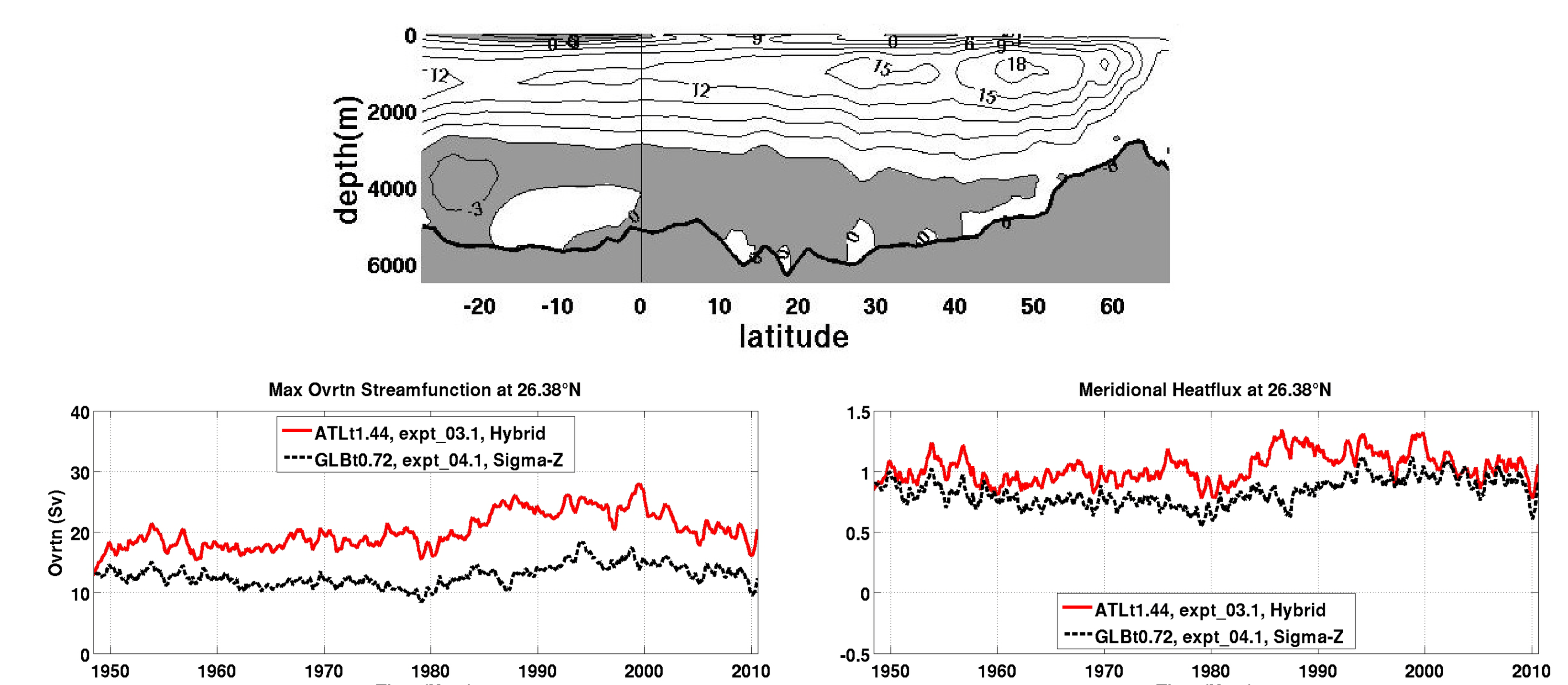

Figure 4. AMOC streamfunction averaged over 1948-2010 from the NR simulation (top) and time series of maximum streamfunction at 26.38ºN (bottom left) and meridional heat flux at 26.38ºN (bottom right) from the global NR simulation (black line) and a non-assimilative simulation run performed with the Atlantic model. Substantial differences exist in how these two models represent the transport and heat flux associated with the AMOC. OSSEs are being performed by sampling synthetic observations from the NR and assimilating them into the Atlantic model. The degree to which errors and biases between the Atlantic and NR models are reduced by assimilating the synthetic observations is a quantitative measure of the impact of these observations on our capability of monitoring changes in the AMOC and the associated meridional heat flux.