Simulation of the ARGO Observing System

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Project Summary

The ARGO array currently consists of 3000 instruments that make vertical profiles of temperature and salinity every 10 days over the depth range of 1500 meters. The array is rapidly being brought to full strength, and a comprehensive assessment of the limitations of the ARGO observing system is urgently needed.

The main goal of our study is to examine how well the ARGO observing system determines the state of the global upper ocean. We sample and reconstruct oceanic fields from ocean general circulation models (GCMs), in gradually more realistic sequence of simulations. By quantifying errors in the reconstructed fields, we estimate accuracy of the ARGO observing system, and therefore directly address NOAA's Program Plan for *Building a Sustained Ocean observing System for Climate*.

This project is conducted at the University of Washington, Seattle, Washington.

Accomplishments

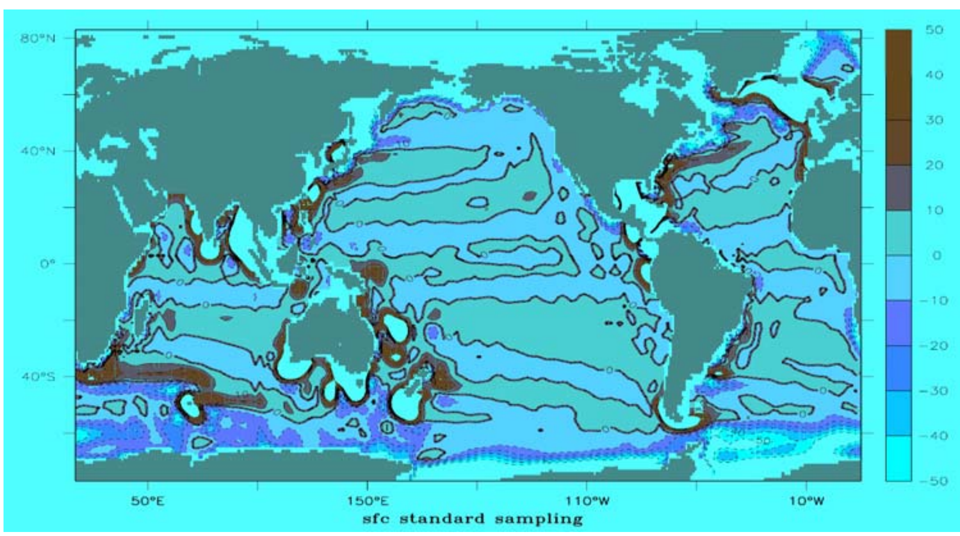
We have (with Drs. Wei Cheng and D.E. Harrison) been looking at the expected performance of the ARGO observing system for the ocean. The main goal of the activities during the FY 2006 was to quantify the effects of oceanic advection on the expected performance of the ARGO system. We analyzed simulation of the ARGO observing system in two models: a global coarse resolution model and a high-resolution model of the North Atlantic. The main objective of the coarse-resolution studies was to quantify effects of the large-scale advection on the expected performance of the ARGO observing system. High-resolution studies addressed the importance of the mesoscale variability.

Coarse-resolution studies

We continued studies with a course resolution, 2^o in both latitude and longitude, global ocean GCM forced by daily atmospheric fluxes. Daily values for the 2-meter air temperature and humidity, 10-meter wind speed, and zonal and meridional components of the wind stress are taken from years 1979-2001 of the NCEP-NCAR reanalysis. Climatological monthly values are used for all other atmospheric variables and freshwater fluxes. In these simulations, 3,000 ARGO floats are advected with the GCM-simulated velocities at 1500m depth during most of the time. Every 10^{th} day, a simulated float surfaces, while taking the temperature and salinity (T/S) profile; it then spends 8 hours at the surface, where the float is advected by the surface currents. A float becomes “lost” if it enters a shallow region. Resulting data are used to reconstruct temperature and salinity of the ocean, using objective analysis.

We analyzed several oceanic quantities, including the temperature, salinity and depth of the thermocline. In this report, we present the results for the integrated heat content in the upper 750 meters of the ocean. The reconstruction errors, calculated as a difference between the reconstructed and the actual GCM-simulated values, are presented in Figure 1a. To estimate the significance of these errors, we convert them to the heat flux units and compare the results to the magnitudes of the 2003-2005 trend in the 750-meter heat content diagnosed from the real ARGO. The observational data are taken from Lyman et al. (2006), who report a significant (> $50 Wm^{-2}$) warming and cooling patterns in North Atlantic, parts of the North Pacific and the Antarctic Circumpolar Current (fig. 1b).

Overall performance of simulated observing system is good, and the reconstructed upper-ocean heat content is very close to the actual GCM-simulated values (fig. 1a). However, there are some significant differences between the reconstructed and actual fields within western boundary systems, such as the Gulf Stream and Kuroshio, and the Antarctic Circumpolar Current (ACC), where the errors exceed the observed 2-year trend (fig. 1b). These reconstruction errors are also noticeably larger than in simulations without float advection (not shown), which demonstrates the role of advection. Since intensity of these swift oceanic currents is underestimated by our coarse-resolution GCM, the deviations of the reconstructed fields from the actual values are expected to be even greater in reality than in our simulation.



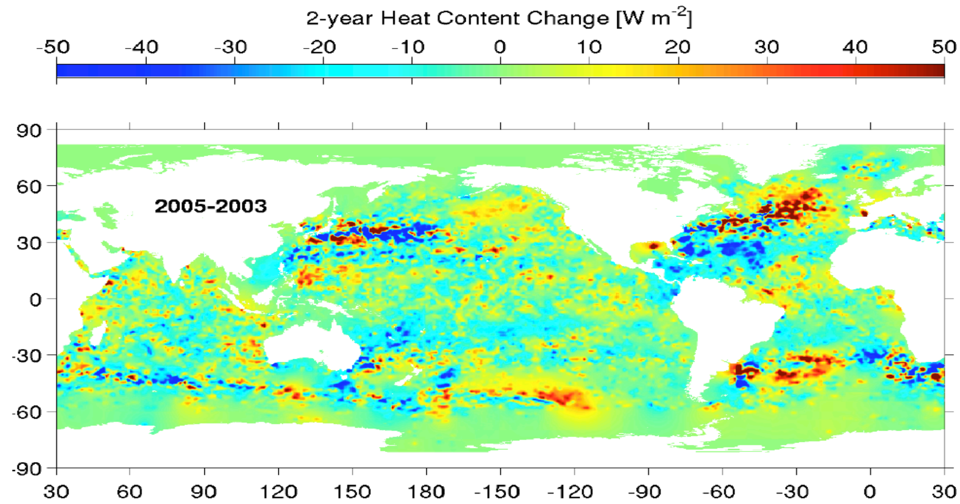


Figure 1 Upper panel: Difference between the reconstructed and GCM-simulated ocean heat content integrated over the upper 750 meters, expressed in flux units (Wm^{-2}); the values are divided by the length of two years to be comparable with the results in Lyman et al. (2006). Lower panel: Figure 2 from Lyman et al. (2006): Map of ocean heat content change ($W\ m^{-2}$) in the upper 750 m from 2003 to 2005.

High-resolution studies in the North Atlantic

Results from the coarse-resolution studies demonstrated sizeable reconstruction errors in the vicinity of fast ocean currents, whose intensity is underestimated by a coarse-resolution model. In addition, the coarse-resolution simulations do not include mesoscale eddies, whose effects can significantly impact the accuracy of the mean-state estimates. To address these issues, we carried our analysis in a regional model of the North Atlantic, whose high resolution permits more accurate simulation the Gulf Stream and mesoscale eddies. The objective is two-fold: (i) to evaluate the expected performance of the ARGO system in the presence of intense oceanic currents; (ii) to analyze the effects of the mesoscale variability on the performance of the ARGO system.

The model has $1/8^{o}$ resolution in both latitude and longitude and 30 levels in the vertical. The topography is realistic on a coarse $1^{o}x1^{o}$ grid; the total depth of the ocean is 3,000 meters. Initially, 250 ARGO floats are evenly distributed in the model domain; the floats are then advected by GCM-simulated currents. We perform three simulations in an off-line mode: (i) a standard case; (ii) a case in which the velocity and T/S fields are time-averaged (no eddies); (iii) a case in which the velocity and T/S fluctuations are amplified (amplified eddies).

Preliminary results indicate that at some locations, in particular in the Gulf Stream vicinity and in the subpolar gyre, the errors in the reconstructed upper ocean heat content (fig.2) are at least as large as the observed two-year trend (fig.1b). Increased intensity of the boundary currents in the high resolution model results in larger reconstruction errors; compare figures 1a and 2a,b. Removal of eddies does not have a significant impact on the size of errors (figs. 2a and 2b). However, if simulated eddies are amplified by a factor of 2.5, which brings the simulated sea-surface height variance closer to the observed values, the errors increase significantly everywhere in the domain (figs 2a,b and 2c).

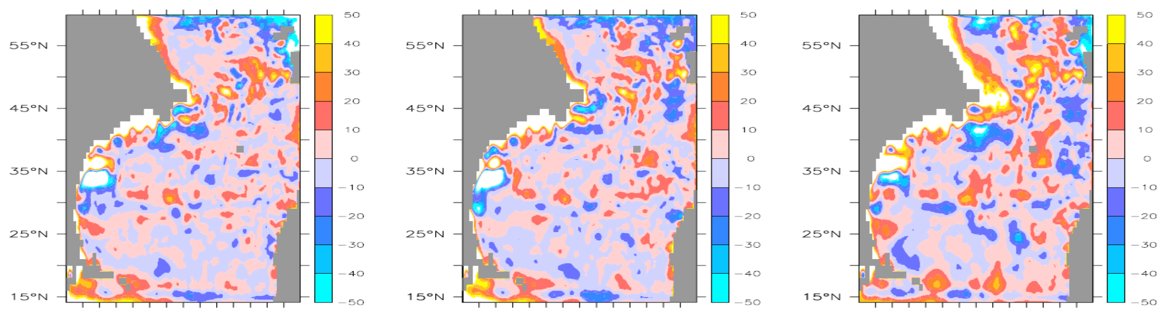


Figure 2 Difference between the reconstructed and GCM-simulated ocean heat content integrated over the upper 750 meters, expressed in flux units (Wm^{-2}): (a) standard case; (b) a case with mesoscale variability removed; (c) a case with mesoscale variability amplified by a factor of 2.5. The errors are comparable to the signal in Lyman et al. (2006) at selected locations; see fig. 1b.

Significance of results

The results clearly demonstrate the importance of oceanic advection in affecting the expected performance of the ARGO observing system. We emphasize the need for additional, dense spatial sampling in the western oceanic boundaries and ACC, as well as in the regions characterized by intense mesoscale variability. It remains unclear, however, whether more frequent sampling can improve performance of the ARGO system (Vecchi and Harrison 2006).

References:

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