Simulation of the Argo Observing System

Igor Kamenkovich[1]
[1]RSMAS, University of Miami, Miami, FL

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1. Project Summary

The Argo array currently consists of more than 3500 instruments that make vertical profiles of temperature and salinity every 9-10 days over the upper 1500-2000 meters. The array provides the scientific community with a wealth of data that are used in a variety studies aimed at determining the state of the global upper ocean and detecting changes in this state.

The main goal of this study is to employ a suite of Observing System Simulation Experiments (OSSE) in order to assist all users of the real Argo data in interpretation of data and development of analysis techniques, and to provide guidance on the optimal design of the Argo observing systems. For this purpose, the oceanic fields, simulated in ocean general circulation models, are sub-sampled in ways similar to how the real Argo float array samples the ocean, reconstructed and compared with the direct model fields. This procedure leads to quantification of errors in reconstructions of the oceanic state by the actual Argo array and to understanding of factors that control these errors. These reconstruction errors can be used as a convenient metric for the evaluation and development of the analysis techniques, as well as for the optimization of the observing system design. The project directly addresses a long-term goal of the NOAA Strategic Plan of *Climate Adaptation and Mitigation*, and its objectives of "*Improved scientific understanding of the changing climate system and its impacts*" and "*Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions*".

The research is being carried as a part of the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) program. The relevant CIMAS research theme is *Sustained Ocean and Coastal Observation*, which includes "the development and improvement of ocean and coastal observation platforms and instruments that biological, physical, and chemical parameters; studying the optimum configurations for observation networks; modeling, data assimilation, and diagnostic analysis of local, regional, and global data sets; and information product development.".

2. Scientific and Observing System Accomplishments

During the FY2012, simulation of the Argo observing system has been carried out in one of the most comprehensive numerical models of the World Ocean: a high-resolution ($1/12^o$) global Hybrid-Coordinate Ocean Model (HYCOM). HYCOM model has been used extensively at National Research Laboratory (NRL). A list of publications, and on-line presentations, are available at http://www.hycom.org. For this study, a global data-assimilating $1/12^o$ climatological simulation with 32 vertical layers is used. The model is forced with monthly climatological ECMWF (ERA40) forcing fields plus 6-hourly anomalies and includes an "energy loan" ice model. HYCOM $1/12^o$ global simulations without Argo floats have already been carried out and the simulated daily velocity and temperature/salinity/density fields have been archived. The simulated stratification closely resembles observations and the eddy field is sufficiently realistic.

Simulated Argo floats are advected at the depth of 1000 meters for nine days, followed by a 6-hour ascent (during which a profile is taken), 12 hours of surface advection, and a 6-hour descent to the 1000-m depth; the floats continue being advected during their ascent/descent. The differences in float design are not addressed. The deployment sites and times closely match those for the actual Argo.

The float trajectories exhibit strong signature of the mesoscale variability (Fig.1), particularly in such eddy-rich regions as the vicinity of the western boundary currents and the Southern Ocean. In the most of the domain, the eddies help to achieve more uniform spatial coverage, acting to reduce gaps in the spatial coverage (*Kamenkovich et al.* 2011). Identification of regions corresponding to strong eddy dispersion, based on Argo float trajectories, appears to be important, since these will require continuing redeployment of the floats.

The **reconstruction errors** – the differences between the reconstructed (gridded) and actual model-simulated fields – are analyzed next. These errors can be used as a convenient metric for the evaluation and development of the analysis techniques, as well as for the optimization of the observing system design. In particular, they assist in interpretation of such important deliverables of observing systems as the Sea-Surface Temperature (SST) and heat content and transport. In many parts of the domain, improved coverage in the presence of eddies corresponds to reduced reconstruction errors. Gaps in the sampling coverage do not, however, always correspond to elevated reconstruction errors, as demonstrated by the analysis in *Kamenkovich et al.* (2011).

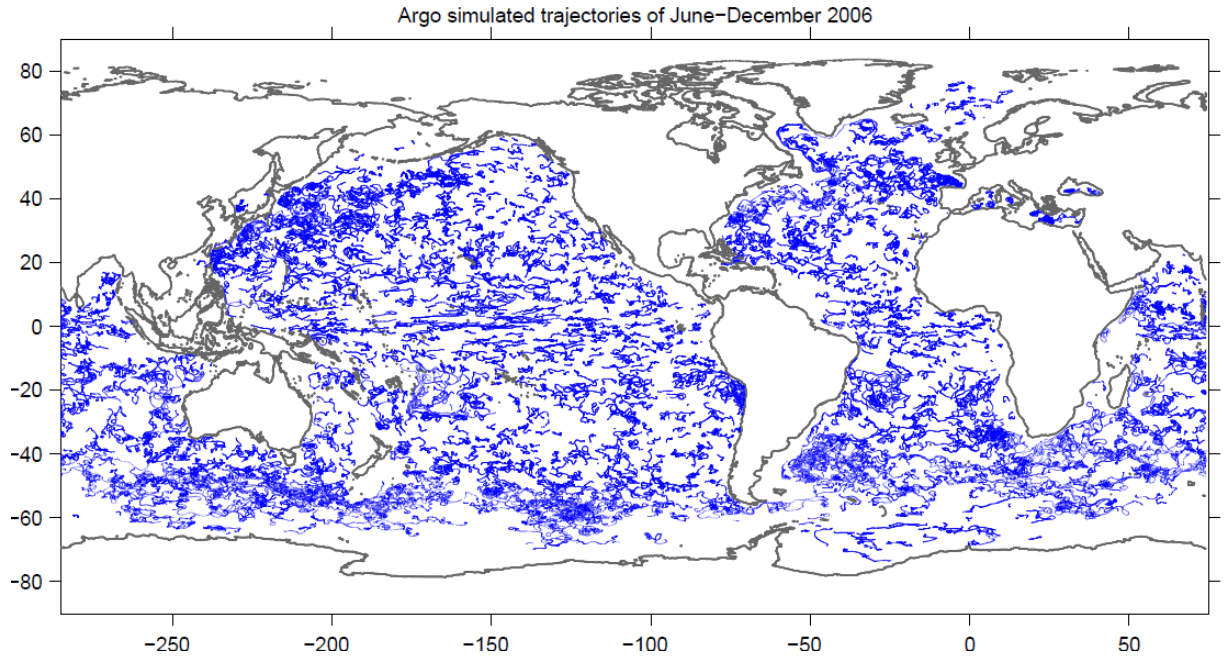

Figure 1: Simulated Argo trajectories during the period of Jun-Dec 2006. Note a strong signature of mesoscale eddies.

The reconstruction errors in several key variables, such as the upper-ocean heat content, SST, sea surface salinity and upper-ocean stratification are small in most of the World Ocean (Figs. 2, 3 and 4b). The errors, however, tend to be significant in several regions characterized by strong oceanic advection and mesoscale variability and insufficient spatial data coverage; see also *Kamenkovich et al.* (2009; 2011).

In particular, the reconstruction errors are large in the northern part of the Southern Ocean, due to sharp meridional gradients in temperature and salinity and fast advection of floats (Fig.3). The depth of the deep mixed layers in this region is also significantly underestimated in the reconstructed fields (Fig.4a).

The reconstruction errors are particularly large in the vicinity of the Gulf Stream, due to the biases in the reconstructed position of the associated sharp front (Figs. 2, 3 and 4c; see also *Kamenkovich et al.* 2009). The reconstruction of this sharp front using a straightforward method of objective mapping employed in this study can, therefore, be expected to be very challenging.

Web Site

Information on this project and a link to synthetic model datasets (in progress) can be found at http://www.rsmas.miami.edu/groups/argo-simulation

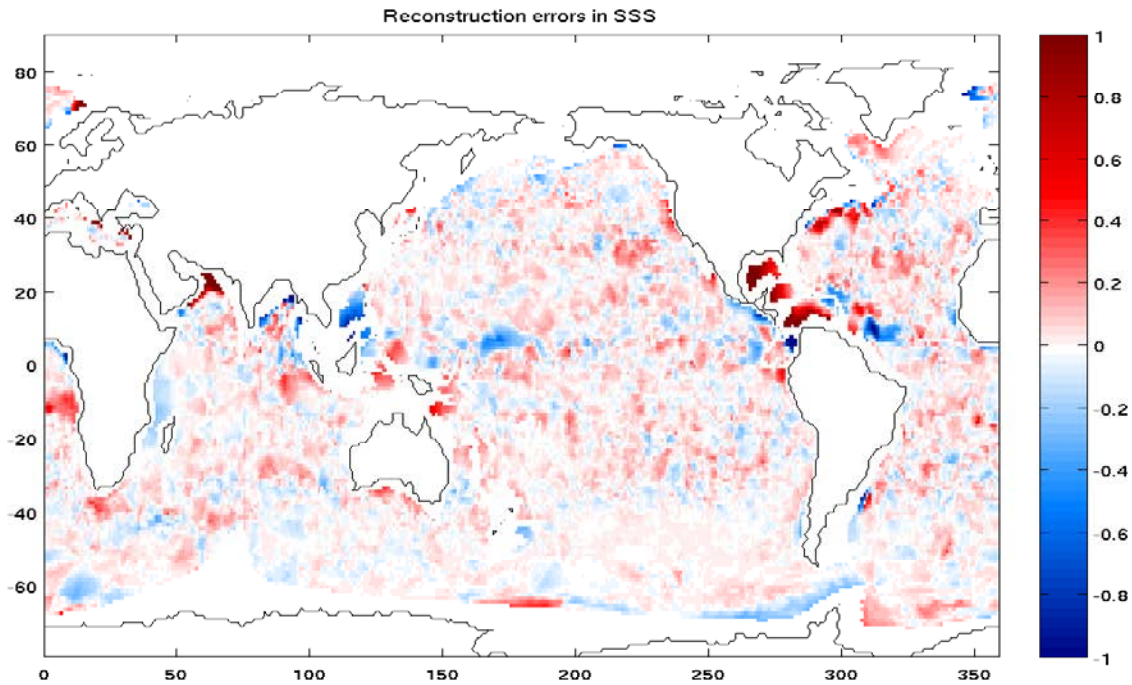

Figure 2: Reconstruction errors in sea-surface salinity (SSS) for October 2006. The units are PSU.

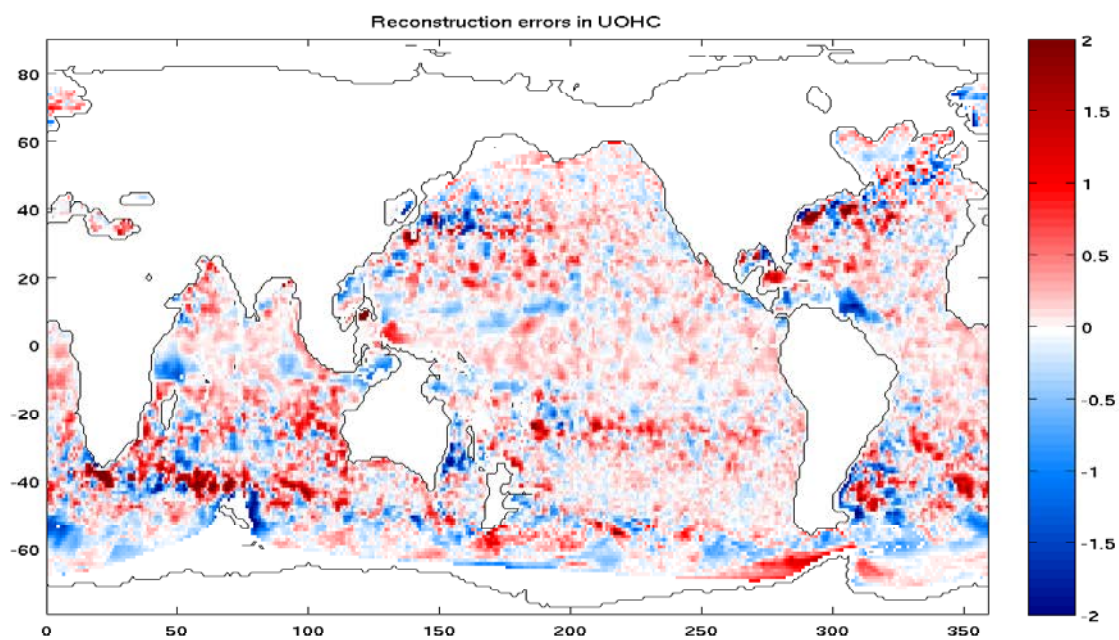

Figure 3: Reconstruction errors in the upper-ocean heat content (UOHC) for October 2006, shown as the depth-averaged (over the upper 1000m) temperature (in K).

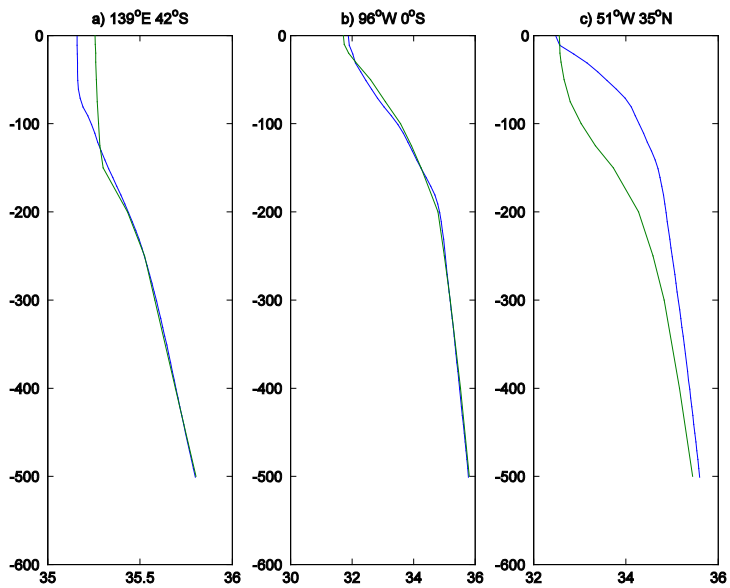

Figure 4: Reconstructed (blue) and actual GCM-simulated (green) density at three locations: a) south of Australia; b) equatorial eastern Pacific; c) North Atlantic (vicinity of the Gulf Stream).

2.1. Outreach and Education

The synthetic model data from this study can be used for educating graduate students on the ways of using the real Argo data as well as on the limitations of corresponding approaches. This activity is planned for the near future, upon the completion of the core analysis.

3. Publications and Reports

3.1. Publications by Principal Investigators

Kamenkovich, I., W. Cheng, E.S. Sarachik, and D.E. Harrison, 2009: Simulation of the Argo observing system in a global ocean model. *J. Geophys. Res.* **114**, C09021, doi:10.1029/2008JC005184

Kamenkovich, I., W. Cheng, C. Schmid, and D.E. Harrison, 2011: Effects of mesoscale variability on the accuracy of the Argo observing system, *J. Geophys. Res.*, **116**, C06003, doi: 10.1029/2010JC006910.

3.2. Other Relevant Publications

van Sebille, E., I. Kamenkovich, and J. Willis, 2011: Quasi-zonal jets in 3D Argo data of the northeast Atlantic, *Geophys. Res. Lett.*, **38**, L02606, doi:10.1029/2010GL046267.