The Atlantic Meridional Overturning Circulation in an eddy-resolving ocean reanalysis

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The Naval Research Laboratory is performing an eddy-resolving 1993-2010 ocean reanalysis using the 1/12° global HYbrid Coordinate Ocean Model (HYCOM) that employs the Navy Coupled Ocean Data Assimilation (NCODA) scheme. A 1/12° global HYCOM/NCODA prediction system has been running in real-time at the Naval Oceanographic Office (NAVOCEANO) since 22 December 2006. It has undergone operational testing and is being recommended for operational use. It is capable of nowcasting and forecasting the oceanic "weather" which includes the 3D ocean temperature, salinity and current structure, the surface mixed layer, and the location of mesoscale features such as eddies, meandering currents and fronts. The system has a mid-latitude resolution of ~7 km and employs 32 hybrid vertical coordinate surfaces. Compared to traditional isopycnal coordinate models, the hybrid vertical coordinate extends the geographic range of applicability toward shallow coastal seas and the unstratified parts of the world ocean. HYCOM contains a built-in thermodynamic ice model, where ice grows and melts due to heat flux and sea surface temperature (SST) changes, but it does not contain advanced rheological physics. The ice edge is constrained by satellite ice concentration. Once per day, NCODA performs a 3D ocean analysis using all available observational data and the 1-day HYCOM forecast as the first guess in a sequential incremental update cycle. Observational data include surface observations from satellites, including sea surface height (SSH) anomalies, SST, and sea ice concentrations, plus *in-situ* SST observations from ships and buoys as well as temperature and salinity profiles from XBTs, CTDs and Argo profiling floats. Surface information is projected downward using synthetic profiles from the Modular Ocean Data Assimilation System (MODAS) at those locations with a predefined SSH anomaly. Unlike previous reanalyses, this ocean reanalysis will be integrated at the same horizontal and vertical resolution as the operational system running at NAVOCEANO.

The system is forced with atmospheric output from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) and the observations listed above. The reanalysis and a non-assimilative twin simulation start in 1993 when the advent of satellite altimeter data provides constraints on the oceanic mesoscale. Significant effort has been put into obtaining and quality controlling all input observational data, with special emphasis on the profile data. The non-assimilative twin simulation is complete through the end of 2009 and the assimilative reanalysis should complete shortly.

The mean MOC at 26.5°N in the non-assimilative simulation is 20.0 +/- 1.0 Sv with a mean depth for the maximum overturning streamfunction of 1195 m. The model MOC strength is not significantly different from the RAPID 2004-2009 mean of 18.8 +/- 2.6 Sv. The seasonal cycle of the RAPID MOC is much larger than the model. The large drop in the strength of the RAPID MOC in 2009-10 is not suggested by the model, although 2010 has not been completed for the model. The model MOC at 30°S in the model is slightly, but not significantly weaker at 19.7 +/- 0.7 Sv. The depth of the maximum overturning streamfunction at 30°S is slightly shallower at 1130 m than 26.5°N. At 50°N, the MOC is weaker with a mean of 16.1 +/- 1.4 Sv, is shallower at 625 m and has decreased significantly over the 17 years at 0.5 Sv/decade. The results are consistent with the climatologically forced HYCOM simulations of Xu et al. (2012) with too shallow MOC with too much Labrador Sea Water compared to RAPID. Similar results are expected for the reanalysis, since NCODA data assimilation has not changed the water mass properties from previous forecasts.