A 1/8th Degree Global Ocean Simulation Using the Parallel Ocean Program

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LONG-TERM GOALS

Our long-term goal is to perform an eddy-resolving global ocean simulation using the Parallel Ocean Program (POP) that will provide a high fidelity ocean model state for use as an initial condition in a global ocean/atmosphere/ice prediction system. In addition, the global model state may be used to specify boundary conditions for regional circulation models.

OBJECTIVES

Our primary objective is to spin up a 1/10th degree, 40 level, fully global (including the Arctic Ocean) POP model for several decades using realistic surface forcing. Once the spin-up is complete and validated against observations and other models, the resulting state can be used to address the long-term goals.

APPROACH

The Parallel Ocean Program (POP) is a primitive equation, z-level ocean general circulation model that has been used successfully for both high resolution global (Maltrud *et al.*, 1998) and North Atlantic (Smith *et al.*, 2000) ocean simulations. The model has a range of appropriate physical parameterizations that can be used to improve solution fidelity and has been designed to take advantage of current supercomputer technology, making it a viable choice for such a huge task.

Previous studies focused on processes and features of importance to the Navy using a 1/10th degree North Atlantic version of POP (*e.g.*, McClean *et al.*, 2000) clearly show the importance of very high resolution in producing realistic results. As a result of these analyses, as well as receiving further information on the availability of DoD computational resources, it was decided that the target resolution of this global simulation should be 1/10th degree, instead of 1/8th as specified in the original proposal.

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14. ABSTRACT
Our long-term goal is to perform an eddy-resolving global ocean simulation using the Parallel Ocean Program (POP) that will provide a high fidelity ocean model state for use as an initial condition in a global ocean/atmosphere/ice prediction system. In addition, the global model state may be used to specify boundary conditions for regional circulation models.

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WORK COMPLETED

Most of the model configuration and testing were performed in FY00, including generation and modification of the model bathymetry, lower resolution studies, and full model studies with simplified forcing. In FY01, a significant amount of time was spent generating and validating the daily atmospheric state fields necessary for computing wind stress and surface heat flux, and in testing a variety of possible initial conditions. The first attempt at a production run began at the end of FY00 (as reported in the FY00 progress report). After running two model years, the run was stopped for preliminary analysis, and several problems were noted and corrected, with one exception. It was noticed that the outflow from the Mediterranean Sea was not reaching 1000m depth. Much time was put into trying to understand this problem, but with no satisfactory solution. In the end it was decided to restore the solution in the outflow region to climatology for the spin-up phase of the calculation, and to perform more research on this problem in parallel with the run in hopes of finding an acceptable solution. The most likely path is the introduction of a bottom boundary layer scheme. The current production simulation started in February, 2001 and was run for 6 model years on 500 processors of the IBM SP ("Habu") at Stennis Space Center. At that point, the run was stopped for analysis since it is believed that this is enough time for eddy processes to become close to fully developed.

RESULTS

Assuming that the eddy field has reached a significant fraction of its steady state value, we will use sea surface height (SSH) variability as the primary model field for analysis using two metrics: comparison with other model runs and comparison with satellite altimetry data. Figures 1 and 2 show the SSH variability of the current run for the Southern and north Pacific oceans, respectively, compared with the variability from a lower resolution POP simulation (0.28º, 20 levels, Maltrud *et al.*, 1998) and from a blended TOPEX-ERS1 satellite data set (Le Traon *et al.*, 1998). In all areas of vigorous eddy activity, the new 0.1º model is a clear improvement over the earlier 0.28º model. For the Southern ocean, almost the entire Antarctic Circumpolar Current is essentially indistinguishable from the data, including the Agulhas Retroflection. There is also substantial improvement in the East Australia Current and the Leeuwin Current. For the north Pacific, the variability associated with the Kuroshio Current is substantially improved. The separation point has moved much closer to the observed location, though may still be a bit too far north. However, the extension of the variability across the basin to the Date Line is quite realistic.

Unfortunately, the results in the north Atlantic are not as satisfactory as in the rest of the ocean (figure 3). Although the solution is better than the 0.28º run, it is not as good as the 0.1º north Atlantic basin simulation of Smith *et al.* (2000). The model Gulf Stream hugs the coast too far north most of the time, and the North Atlantic Current extends too zonally across the basin instead of turning northwestward around the Grand Banks. Also of note is the relatively low variability in open ocean regions that is evident in all basins. We are in the process of studying the Gulf Stream-North Atlantic Current issue with the north Atlantic basin subset of the full model, and will continue with the full global simulation once this issue has been resolved. Results from the model spin-up including movie loops can be seen at http://www.oc.nps.navy.mil/navypop .

IMPACT/APPLICATIONS

This simulation represents the state of the art in primitive equation global ocean circulation modeling and should provide a very realistic ocean state for use by Fleet Numerical Meteorology and

Oceanography Center (FNMOC) for use in global forecasting. In addition, detailed analysis of the model should provide new insights into the dynamics of ocean circulation and how this affects processes of importance to the Navy.

TRANSITIONS

Once the spin-up is complete, numerous model states will be given to FNMOC to be used operationally in global forecasts. Model fields will also be made available to NRL-Stennis for use as boundary conditions for regional models. Subsets of the model data will be made available to the oceanographic community in general for analysis.

RELATED PROJECTS

The project most closely related to this work is “Evaluations of the POP Model For Navy Forecasting Use” (McClean et al., ONR award number #N0001400WR20169) which involves feasibility and validation studies using POP. Based on the positive results of these studies, it was decided that using POP with 1/10th degree resolution would be necessary for achieving the stated long-term goals.

Other related projects include efforts to couple POP to the NOGAPS atmospheric model, and the development of a global multivariate Optimal Interpolation (MVOI) system compatible with POP. Both of these efforts are occurring at NRL-Monterey and will take advantage of the results from the 1/10th degree simulation.

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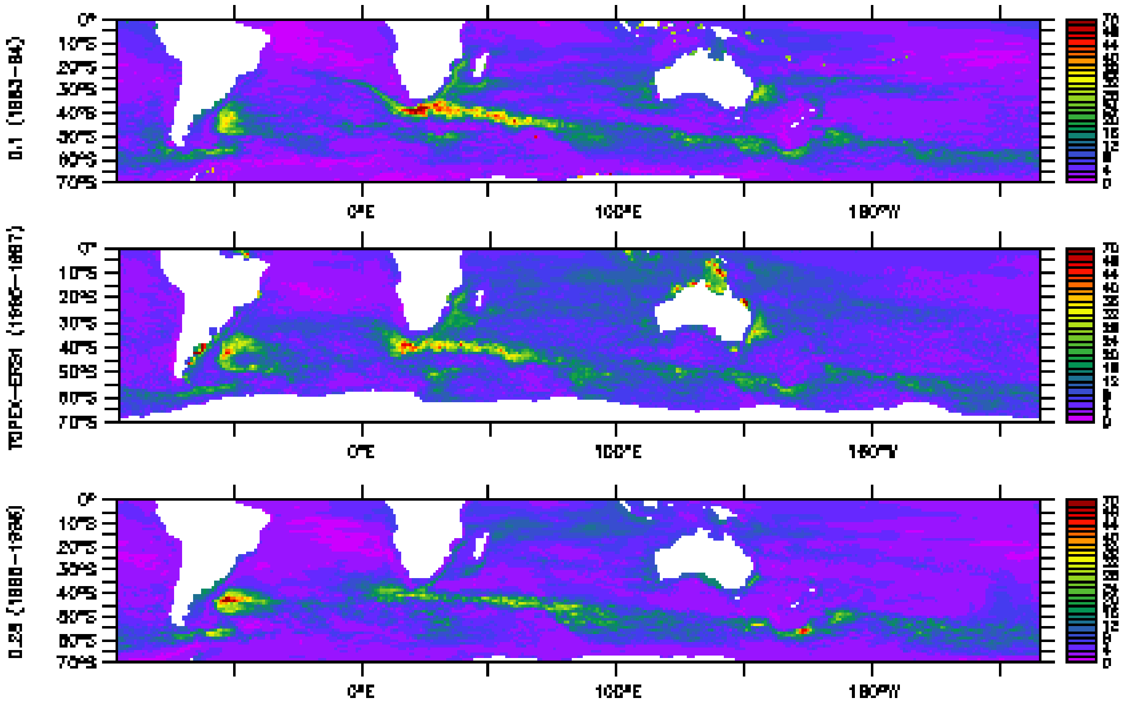

Figure 1. Sea Surface Height variability (in cm) for the Southern Ocean from the 0.1° global simulation (top), blended TOPEX-ERS1 satellite data (middle), and the 0.28° global simulation (bottom). [Color plots show up to 70+ cm of variability in eddy-active regions, such as the Agulhas Retroflection and the Brazil-Malvinas Confluence.]

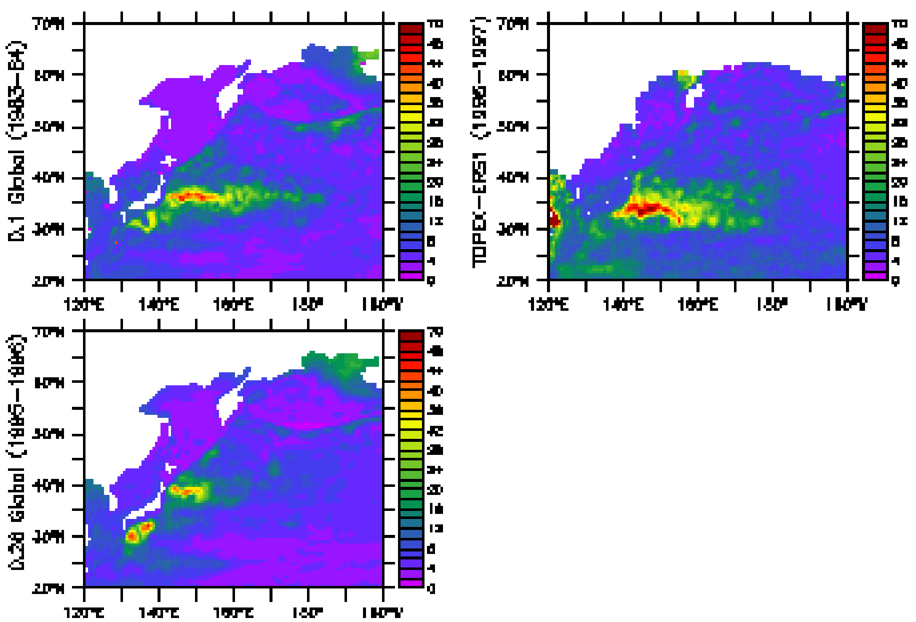

Figure 2. Sea Surface Height variability (in cm) for the northwestern Pacific Ocean from the 0.1° global simulation (top, left), blended TOPEX-ERS1 satellite data (top, right), and the 0.28° global simulation (bottom, left). [Color plots show up to 70+ cm of variability in eddy-active regions in the Kuroshio Current and Extension.]

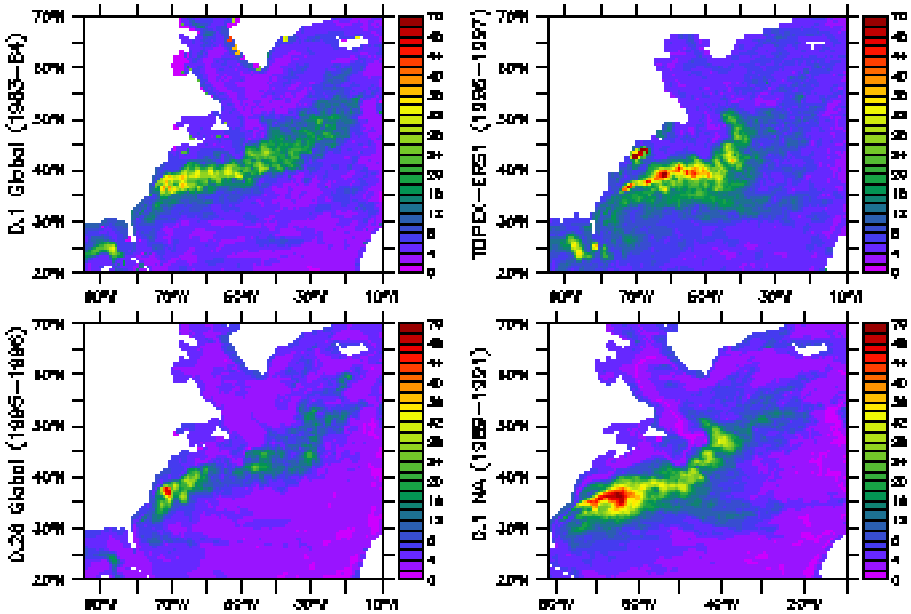

Figure 3. Sea Surface Height variability (in cm) for the northern Atlantic Ocean from the 0.1º global simulation (top, left), blended TOPEX-ERS1 satellite data (top, right), the 0.28º global simulation (bottom, left), and the 0.1º north Atlantic basin simulation (bottom, right). [Color plots show up to 70+ cm of variability in eddy-active regions in the Gulf Stream and North Atlantic Current.]