Japan (East) Sea Dynamics Using Numerical Models With 1/8° to 1/64° Resolution

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LONG-TERM GOALS.

Investigate Japan/East Sea circulation dynamics with a hybrid isopycnal/sigma (generalized) coordinate ocean model, and to verify numerical results via model-data comparisons.

OBJECTIVES

Investigate Japan/East Sea circulation dynamics in a systematic and progressive fashion using a sequence of increasingly complex ocean models and model-data comparisons. Investigate the impact of upper ocean - topographical coupling and isopycnal outcropping on the mean pathways of the major current systems. Also, to assess the impact of different wind forcing on the JES circulation, with emphasis on the branching of the Tsushima Warm Current (TWC). Interannual simulations with multiple realizations differing only in their initial states are used to investigate interannual variability and deterministic vs. nondeterministic (flow instabilities) responses to daily wind forcing.

APPROACH

During the first year an extensive and systematic study of Japan/East Sea dynamics that exploits the dynamical modularity and efficiency of the NRL Layered Ocean Model (NLOM), which is mainly isopycnal in design. The study begins with linear 1.5 layer reduced gravity simulations with wind and/or straits forcing. All use realistic geometry and realistic (rather than idealized) wind forcing. These simulations provide a benchmark for simulations which have added some or all of the features like nonlinearity, bottom topography, multiple vertical modes, flow instabilities, isopycnal outcropping, diapycnal mixing, overturning cells in the vertical, thermodynamics, and thermal forcing. The horizontal resolution ranges from 1/8° (14 km) to 1/64° (1.7 km) for each variable and 2 to 4 Lagrangian layers in the vertical. Continue dynamical studies with the MICOM isopycnal coordinate ocean model, which allows interfaces to intersect the bottom topography to investigate shelf dynamics with low vertical resolution.

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Develop a hybrid isopycnal/sigma coordinate ocean model (joint with University of Miami) that will have high vertical resolution over the shelf and in the mixed layer everywhere (about 20 isopycnals/levels).

WORK COMPLETED

Numerous fully equilibrated simulations have performed at 1/32° (3.5 km) resolution, a resolution not achieved outside of this effort. These include simulations driven by several different monthly atmospheric climatologies, including Hellerman-Rosenstein (1983), FNMOC, ECMWF 10m and 1000 mb, NCEP reanalysis, and COADS. Several simulations have also been driven by 12 hourly 1979-1994 ECMWF 10 m reanalysis winds. A paper was submitted to the Journal of Physical Oceanography that investigated the circulation dynamics in the Japan/East Sea using the NLOM with 1/8° to 1/64° resolution. The paper highlights the importance of horizontal grid resolution, flow instabilities, bottom topography, and isopycnal outcropping for realistically simulating the JES circulation. Six interannual simulations forced with the 12 hourly 1979-1993 ECMWF 10 m reanalysis winds were performed. The simulations differ only in their initial state, thereby distinguishing between deterministic and non-deterministic responses to the atmospheric forcing.

RESULTS

High horizontal grid resolution, baroclinic instability, bottom topography, and isopycnal outcropping are crucial for realistically simulating the mean circulation and eddy field in the JES. As the horizontal resolution is increased in the simulations, the increasing widespread ability of topographic features to steer upper ocean currents becomes apparent, particularly with respect to the separation latitude of the EKWC (Figure 1). This upper ocean topographic coupling occurs via baroclinic instability and requires that mesoscale eddies be very well resolved in order to maintain sufficient coupling (Figure 2) (Hurlburt et al., 1996; Hurlburt and Metzger, 1998). This fundamental and major topographic effect is largely missed at 1/8° resolution and leads to false conclusions about the role of bottom topography and unexplained errors in the pathways of current systems. For example, when Hellerman-Rosenstein (1983) wind forcing is used, 1/32° resolution is required to get a realistic separation latitude for the East Korea Warm Current (EKWC). Many other features of the flow field are strongly influenced by the bottom topography at 1/32° resolution (but not at 1/8° and 1/16°), including features of the mean flow. Isopycnal outcropping is another process that plays important roles (a) in maintaining a boundary current along the west coast of Honshu (the Nearshore Branch of the TWC), (b) in the circulation in the northern Japan/East Sea, and (c) in creating vertical overturning cells. The rate of overturning in the model gave a residence time of 130 years for the JES proper water (abyssal layer of the model), a value consistent with observations. The atmospheric forcing from different wind products also shows varying impact on the separation latitude of the EKWC and the strength of the Nearshore Branch along the coast of Honshu. In particular, the ECMWF, NCEP, FNMOC, and Na climatologies give a realistic separation latitude for the EKWC at 1/8° resolution because of strong positive wind stress curl over the northwest JES, but Hellerman-Rosenstein and COADS do not. A series of simulations forced by the 12 hourly 1979-1993 ECMWF 10 m reanalysis winds that differ only in their initial state indicate that most of the variability in the JES is non-deterministic due to flow instabilities except for a boundary wave guide around the periphery of the basin.

IMPLICATIONS

This research describes the process by which the surface circulation can be influenced by the abyssal circulation through mesoscale flow instabilities. The mechanism by which this occurs, known as upper ocean - topographical coupling, requires that mesoscale eddies be very well resolved as well as the presence of realistic bottom topography. Well resolved eddies are needed to generate strong enough flow instabilities to obtain sufficient coupling. The bottom topography serves to regulate the strength and location of the flow instabilities and steer upper ocean currents. In numerical ocean models, the coupling requires high horizontal grid resolution, at least 1/32° in the JES. Thus the role of upper ocean - topographical coupling is missed in coarser resolution models, which can lead to false conclusions about the role of the bottom topography and unexplained errors in the mean pathways of current systems. The research also addresses the issue of simulation convergence. For instance, the progression from 1/8° to 1/32° showed major impact on the simulations with each increase in resolution (Figure 1). However, the increase from 1/32° to 1/64° yielded relatively modest changes in the mean and variability. This is the first time simulation convergence for mesoscale variability has been demonstrated in a realistic eddy-resolving ocean model.

TRANSITIONS

NRL has funded 6.2 (ONR) and 6.4 (SPAWAR) projects to develop a 1/16° Pacific nowcast/forecast system north of 20°S using NLOM coupled to a 1/12° Asian marginal seas model using the Princeton Ocean Model. However, the results presented in the submitted journal article suggest that neither of these will have adequate horizontal resolution in the JES. Therefore, the 1/32° JES model based on NLOM could be transitioned as the JES component of this system.

RELATED PROJECTS:

Matching funds provided by NRL base 6.1 LLWBC during FY98, matching funds provided by 6.1 LINKS in future fiscal years. Participation in ONR JES DRI.
Interaction with multi-national CREAMS II project.

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PUBLICATIONS

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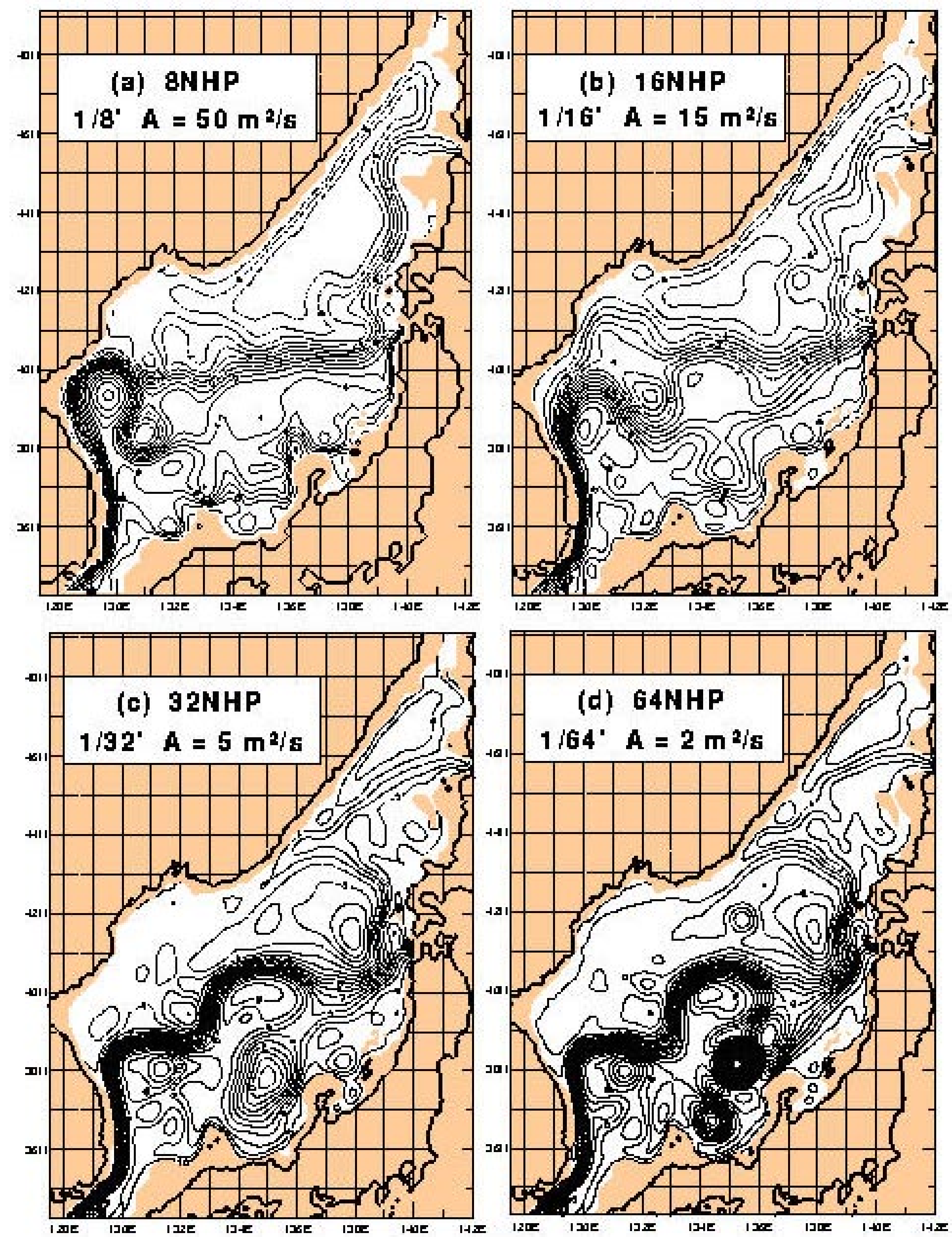

Upper Ocean - Topographic Coupling