North Atlantic Modeling with Multi-Layer Primitive Equation Models: DAMEE-NAB

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LONG-TERM GOALS

To perform a realistic, fully eddy-resolving, wind- and buoyancy-forced numerical simulation of the North Atlantic basin with the Miami Isopycnic Coordinate Ocean Model (MICOM) (Bleck and Chassignet, 1994) with data assimilation capabilities.

OBJECTIVES

a) To evaluate the model's performance in reproducing the oceanic circulation, with a special focus on the coastal regions;

b) To evaluate the model's forecast skills and usefulness in providing boundary conditions for regional models.

APPROACH

A series of numerical models of increasing complexity and resolution is used to (a) evaluate the model's forecast skills and (b) develop an understanding of the interaction between the ocean interior and the coastal regions.

WORK COMPLETED

a) Analysis of the medium-resolution (1/2^o) North Atlantic subtropical gyre experiments performed in the context of DAMEE-NAB (Paiva *et al*., 1998a)

b) 15-year integration of the high resolution (1/12^o, mesh size on the order of 6 km) North Atlantic DAMEE-NAB (Data Assimilation and Model Evaluation Experiment - North Atlantic Basin) experiment (Chassignet *et al*., 1998; Garraffo *et al*., 1998; Paiva *et al*., 1998b; http://www.rsmas.miami.edu/groups/micom.html)

c) Data assimilation capabilities for MICOM (Chin *et al*., 1998)

d) Several process studies on boundary current separation and gyre dynamics (Özgökmen *et al*., 1997; Özgökmen and Chassignet, 1998; Stern and Chassignet, 1998)

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RESULTS

First, a series of simulations (Paiva *et al*., 1998a) were carried out to explore MICOM's abilities to reproduce the wind- and thermohaline-driven circulations in the North Atlantic subtropical gyre and to evaluate the model's usefulness in providing boundary conditions for regional models. The constraints imposed on the simulations by the domain size and by the position of the ocean lateral boundaries were addressed in comparisons between simulations performed in a large domain (28^oS to 65^oN) and in a smaller domain (6^oN to 50^oN). In the former configuration, the flow into the subtropics is related to the model circulation in the subpolar and equatorial regions, but in the latter this flow depends solely on the interaction between the circulation in the subtropics and the restoring forcing at the boundaries. Despite the fact that the boundaries in the small domain are located adjacent to the region of interest, and that these boundaries intersect strong meridional surface flows in the western basin (in contrast to the situation in the large domain), the restoring force is able to generate appropriate inflow and outflow conditions without significantly disrupting the circulation in the subtropical gyre (Figure 1). Increasing the model horizontal resolution from medium to eddy-permitting reveals a more complex picture of the surface circulation, in which the broad flows of the coarser simulations are replaced by narrower surface jets. In particular, the increased resolution within the Gulf of Càdiz buffer zone leads to an enhancement of the circulation in the gulf and induces an Azores Current with realistic path and transport (~10 *Sv*).

Second, given that a strong focus of the research performed at the University of Miami is real-time forecasting of both Eulerian fields, such as temperature and velocity, and Lagrangian trajectories, data assimilation methods are being developed and evaluated. The five primary components of this effort are (i) MICOM, the Miami Isopycnic Coordinate Ocean Model, (ii) satellite-derived sea surface temperature and height fields and data from Lagrangian drifters, (iii) an Extended Kalman Filter (EKF) with a second-order Gauss-Markov Random Field (GMRF) model for spatial covariances, (iv) a random flight turbulence model for Lagrangian trajectory prediction, and (v) contour-based parameter estimation and assimilation techniques. Most of the research activites are focused on the North Atlantic Ocean in the framework of DAMEE-NAB. Assimilation of satellite-derived sea-surface temperature (SST) (36 km mesh size, 4 day composite) was performed by using the satellite-derived SST (instead of the climatological ship-observed SST) in the heat flux surface boundary condition of the medium resolution ($1/2^o$) DAMEE North Atlantic simulation (see Paiva *et al*., 1998a). These experiments yielded very encouraging results such as improved Gulf Stream separation. The first assimilation experiment was a twin-experiment, four layer, 100 x 100 horizontal grid points, wind-driven and highly nonlinear, double-gyre MICOM simulation for one year. Our EKF using a 2nd-order GMRF model was stable for one year with an exponential decrease in forecast error and was able to recover from a worst-case flat-ocean initial condition with 6 months of simulated Topex/Poseidon data (Chin *et al*., 1998). The second assimilation experiment is underway with the $1/2^o$ DAMEE North Atlantic configuration. The ultimate goal is near-real time assimilation in the fine-resolution DAMEE run. Coupling of the model to coastal (see annual report by R. Bleck), atmospheric, ice, and biological models has also been initiated.

IMPACT/APPLICATIONS

This research has potential for providing large scale information needed as boundary conditions for regional models as well as forecasting skills.

TRANSITIONS

The data from the 1/12^{o} run are presently being analyzed in collaboration with observationalist W. Johns.

RELATED PROJECTS

Collaborations are active with DAMEE-NAB participants as well as with ONR sponsored PIs: R. Bleck, M. Chin, A. Griffa, W. Johns and A. Mariano.

REFERENCES

Bleck, R., and E.P. Chassignet, 1994: Simulating the oceanic circulation with isopycnic coordinate models. *The Oceans: Physiochemical Dynamics and Resources*. The Pennsylvania Academy of Science, 17-39.

http://www.rsmas.miami.edu/groups/micom.html MICOM home page; click on ``Very-high-resolution (1/12 deg.) North Atlantic MPP simulation" for the DAMEE-NAB results.

PUBLICATIONS

Chassignet, E.P., Z.D. Garraffo, and A.M. Paiva, 1998: Fine-mesh (1/12^{o}) numerical simulation of the North Atlantic: The meridional overturning circulation and associated water mass transformations, *EOS*, 1998 Ocean Sciences Meeting.

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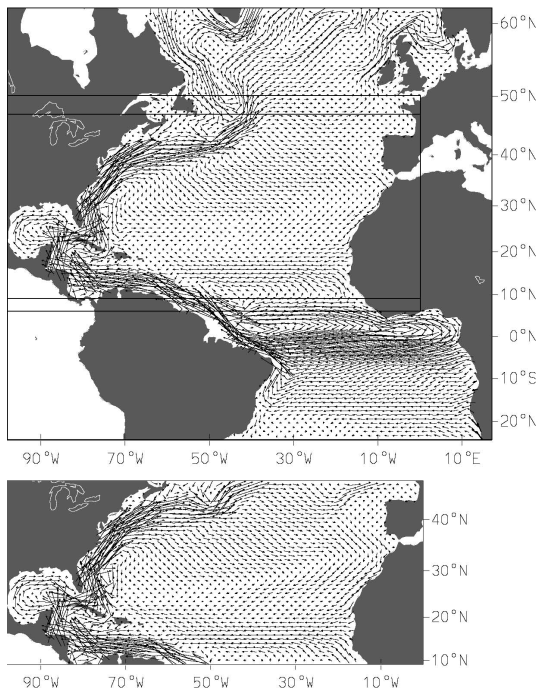

Figure 1: Model surface velocity climatology: Large domain (upper panel) and small domain (lower middle panel). The model domain and buffer zones in the small domain experiment are also shown in the upper panel, to facilitate the comparison between the two experiments.