Abstract View

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Intercomparison of Quasi-Geostrophic Simulations of the Western North Atlantic Circulation with Primitive Equation Results

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ABSTRACT

The purpose of this paper is to compare two numerical models of vastly different complexity and computational requirements, which have been used recently in a number of midlatitude ocean simulations. Specifically, the two-layer quasi-geostrophic (QG) model of Holland (1978) is compared with the five-level primitive equation (PE) model of Semtner and Mintz (1977) for a wind-driven multi-gyre ocean, with effects of bottom topography and thermal forcing included. The dominant feature of the circulation predicted in the previous PE calculations is a strong free jet, with intense mesoscale transients which are maintained by baroclinic instability.

The configuration of the QG experiment is designed to approximate closely that of the PE experiment, while retaining as much of the simplicity of the Holland (1978) model as possible. The QG model spins up to a state of statistical equilibrium, which is characterized by a meandering jet and by mid-ocean mesoscale eddies with periods and wavelengths much like those in the PE experiment. The time-mean circulations and the distributions of eddy energy in both models are very similar. An energy analysis shows that the free jet in the QG model is more barotropically unstable than in the PE model; however, by reducing the QG upper layer depth to be closer to the thickness of the free jet in the PE model (200 m), this discrepancy disappears. Excellent agreement is also obtained between the volume-integrated energetics of the two models, provided one uses the same lateral diffusion coefficients for momentum and heat in both models.

To gain more insight into physical processes, the computational speed of the QG model is exploited to make additional experiments on the influences of bottom topography, thermal forcing and increased vertical resolution. Bottom topography is found to intensify the upper layer jet and to change substantially the pattern of the deep mean flow. While the presence or absence of topography does not alter the degree of baroclinic versus barotropic instability when the upper layer is 500 m thick, topography does cause a greater proportion of baroclinic instability when the upper layer is thinner. Thermal forcing strengthens the flow in both layers. The use of a three-layer QG model removes the arbitrariness associated with the choice of upper layer thickness: the dominant baroclinic instability of the free jet remains and is concentrated at the interface of the upper two layers.

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The results of the present intercomparison suggest that QG simulations will produce the same basic dynamics as PE models in the type of problem considered, using a fraction of the computer time. The saying in computer resources can be profitably applied to understanding the important effects of parameter variations on the oceanic general circulation.

top ▲

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