The Hydrostatic and Nonhydrostatic Limits of Ocean Models \as Tested on Buoyancy-Driven Plows

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Coastal ocean models are tested on two classical fluid problems to ascertain the limits of their usual hydrostatic (H) approximation (pressure determined only by the weight of the overlying fluid, no vertical momentum equation). One is the classic lock-exchange problem (light and dense fluids separated by a wall which is then removed), the other is convection driven by surface cooling. Beside hydrostatic models, we also examine the so-called quasi-hydrostatic (QH) models which have a vertical momentum equation, but the vertical velocity and pressure are determined by an iteration procedure; and fully nonhydrostatic (NH) models in which the pressure is determined from an elliptic equation that results from the divergence of the momentum equations.

In general, for vertical to horizontal grid ratios $r = dz/dx > .20$, the hydrostatic approximation is shown to fail. Both NH and QH models behave like hydrostatic models for $r < .10$. The spreading rate of the plumes in the lock-exchange problem is fastest for the hydrostatic approximation, and about the same for the NH and QH models. Preliminary results indicate that only the NH models exhibit the full spectrum and amplitude of the Kelvin-Helmholtz instabilities that grow on the plume - ambient fluid interface.