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On the internal pressure gradient errors in sigma-coordinate ocean models

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Sigma coordinate ocean models, or models based on more generalised topography following coordinate systems, are presently widely used in oceanographic studies. Terrain following models are attractive because of their abilities to resolve the surface and bottom layers. However, the internal pressure gradient estimation is problematic in such models, and artificial pressure gradients may create artificial flow.

In fine resolution studies where topography and stratification is well resolved, the artificial flow due to erroneous pressure gradients is small because the errors typically converge to zero with the square of the grid size. In coarse resolution studies, however, there may still be large erroneous pressure gradients that may create strong artificial flow.

In recent literature several methods for reducing the errors in the estimated internal pressure gradients are suggested. A basin with a seamount in the middle has often been applied as a test case, and numerical experiments are run over periods up to 180 days. In the present paper the focus is on the time and space scales of the flow generated by the internal pressure gradient errors. It is shown that on a short time scale, shorter spatial modes may dominate and over this time scale one may benefit from applying recent methods for estimation of the pressure gradients. On a longer time scale, basin scale modes gradually become dominating, and the results from the present study indicate that both newer methods and the usual second order method may fail in suppressing the growth of these large scale erroneous flow. Furthermore, even with large values of viscosity, the basin scale modes may continue to grow over at least two years for the seamount case.

The model has also been implemented for an extended Norwegian Sea, and the effects of internal pressure errors on velocities and transports are investigated. It is shown that the artificial transports may be substantial compared to the observed volume flux estimates from this area.