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Computational design of a new unstructured grid model of the world ocean circulation

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There has been considerable interest in the coastal and regional ocean modeling communities in the development of numerical techniques that discretize space using unstructured triangular grids. Such discretizations are very good at representing the geometry of coastlines while also permitting arbitrary spatially varying and adaptive grid resolution, but they require algorithms that are more sophisticated and less well-understood than their counterparts in the context of traditional structured Cartesian grids. We describe the application of unstructured grid methods to a new ocean general circulation model (OGCM), and discuss how key technical issues have been addressed with reference to numerical results.

In OGCM dynamics, relevant physics is incompletely resolved in practice, so it is important that dynamical invariants be well-conserved at the discrete level - i.e., independently of the convergence of solutions with respect to space and time step. Under-resolved low-viscosity flow simulations will diverge with time without true discrete energy conservation, which confines inaccuracies to grid-scale ‘‘noise” whose amplitude is limited by the availability of kinetic energy. Established results pertaining to the conservation properties of Cartesian grid schemes lend credence to established OGCM techniques, although traditional models reflect a number of design choices that compromise their discrete conservation properties. Our approach builds upon recent advances in unstructured staggered mesh, or ‘‘co-volume” methods, which have shown considerable promise in small-scale ocean modeling applications, where the emphasis has been on optimizing the accuracy of advection for the resolution of detailed flow structures. We demonstrate that the co-volume approach can be used to derive viable and robust energy-conserving discretizations of the 3-D hydrostatic Boussinesq system on the sphere. Topics in ongoing work include the extension of the scheme to include generalized vertical coordinates and free-surface dynamics.