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Superparmeterization in ocean modeling using general multiscale techniques - a deep-convection case study.

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Multiscale approaches allow explicit modeling of the many different phenomena that are present in real ocean dynamics. We present results from a novel, multiscale, approach to the parameterization of non-hydrostatic deep-convection in coarse, hydrostatic, ocean simulations. In our approach, a two-dimensional (vertical slice), non-hydrostatic, prognostic, process model is embedded in each grid cell of a large-scale, three-dimensional, hydrostatic model. Consistency of the time evolving property budgets in the embedded and large-scale models is achieved by ensuring that domain extents of the embedded model are coincident with cell boundaries in the large-scale model mesh. Double accounting of forcing and internal dynamics for the overset models is avoided by detailed analysis of the terms solved in each part of the system.

We measure the impact of this approach, in terms of both improved numerical accuracy and computational cost, by comparing quantitative metrics with respect to, on the one hand, a fully resolved, three-dimensional, non-hydrostatic ”ground-truth” simulation and on the other hand a purely hydrostatic, coarse-resolution numerical experiment. The time evolving state and statistics of the multiscale system are found to be significantly closer to the ground-truth model solution. For example, in the embedded simulation, the slanting of convective plumes due to large scale flow vertical shear is reproduced and higher order statistics, such as the variance and skewness of the model fields, are all much closer to the ground-truth model solution.

The improved accuracy of the multi-scale model is achieved for a computational cost far less than that of a fully resolved non-hydrostatic model. By exploiting parallelism amongst the embedded models, we can achieve a wall-clock time to solution that is a small multiple of a pure hydrostatic simulation.

The approach we have taken is by no means limited to deep-convection parameterization and can be generalized fairly broadly. For example mixed-layer processes, biogeochemical processes, eddy flux coefficients could all be estimated by appropriate local, prognostic sub-models that are then coupled to a larger scale model, provided the factors and analysis we described are appropriately considered.