Mesoscale eddies on unstructured meshes

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Mesoscale eddies contribute to the dynamics of ocean circulation in many important ways. Resolving them in the context of global ocean simulations still present a challenge because the Rossby radius of deformation is highly variable and can be as small as several km at high latitudes. Models formulated on unstructured meshes provide a possibility of locally eddy resolving approach. However, a question arises on how to select the resolution, and how mesh variability may affect the eddy dynamics. We discuss a set of questions related to this topic showing that (i) the observed variability and the information on the behavior of the Rossby radius can be one of the criteria helping in mesh design and that (ii) there might be a delayed turbulence development downstream into a high-resolution domain.

The latter means that the size of refined patches has to be sufficiently large to simulate the unbiased eddy dynamics.

As resolution is increasing, the resolved eddy dynamics may contain a substantial ageostrophic component which may lead to a noisy signal in the vertical velocity on the mesh patches where the resolution is varied. The appearance of this noise depends on the details of discretization. Variable resolution also leads to a question how to combine the locally resolved eddy dynamics with the parameterized one over the coarse part.

In a more broad context, even locally eddy-resolving global meshes are already large and approach in size the eddy-permitting and eddy-resolving meshes of global regular models (from 1/4 degree or finer, or 1M or more surface vertices), which implies massively parallel implementations. Our experience with FESOM1.4 shows that because of good parallel scalability the throughput (simulated model years/per day) reached on large meshes is very competitive to(not worse than) that shown by regular-mesh models, with only a moderately increased demand on computational resources. This in a way changes the message to the community on the numerical efficiency of unstructured-mesh models for global ocean applications:these models, especially the new finite-volume developments (MPAS, FESOM2, ICON), can be nearly as fast as the regular-mesh models in terms of their throughput.