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Ocean kinetic energy backscatter on unstructured grids

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At eddy permitting ocean grid resolution, i.e. around 1/4° to 1/10°, classical viscosity closures tend to excessively dissipate kinetic energy. While some of the larger eddies may potentially be explicitly resolved, high viscosities lead to reduced eddy kinetic energy and weakened eddy induced transports. Erroneous eddy-mean flow interactions deteriorate simulations of the mean flow and of mean kinetic energy. However, part of the motivation for such viscosity closures arises from considerations of numerical stability.
To address this problem in ocean models, the concept of kinetic energy backscatter was proposed in recent years. It allows to reinject part of the excessively dissipated energy back into the flow using an additional negative viscosity term in the momentum equation. A prognostic equation for sub-grid kinetic energy keeps track of the dissipated energy that leaves the resolved flow. This sub-grid energy is then available for reinjection and defines the amplitude of the backscatter term. The backscatter is designed to act on larger scales than the dissipation, which in turn guarantees that model stability is not compromised.
We present results of a backscatter parametrization in the finite volume model FESOM2 that supports unstructured grid configurations. Our setup is a periodic mid-latitude channel with northern and southern boundaries and 24 vertical layers. Resolution can be constant throughout the channel or it can be increased locally. We investigate the impact of different energy backscatter implementations in combination with different viscosity parametrizations for structured grids of various resolutions. The new backscatter implementations lead to strongly increased eddy kinetic energy, corresponding to simulations with much higher, eddy resolving resolution. Other flow statistics such as mean kinetic energy or variability in vertical velocities are also considerably improved. Moreover, computational costs for the backscatter parametrization are substantially lower compared to a resolution increase.
Additionally, we analyze an unstructured grid configuration with a mixed resolution channel. Part of the domain is eddy resolving while the rest is only eddy permitting, with narrow transition regions in between. The backscatter parametrization leads to much more uniform flow statistics across the channel. It substantially reduces negative impacts of the grid coarsening, both in the transition zones and in the coarse grid domain. We conclude with a discussion of future perspectives and applications in global ocean grid configurations.