Scaling Eddy Parameterizations with Locally Eddy Resolving Models

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The ocean's dominant mesoscale eddy length-scales vary strongly in space and time. Even relatively high resolution global ocean models do not resolve the first baroclinic deformation radius (one possible metric of the eddy length-scales) in high latitudes and coastal regions. Where the eddy scales are not resolved, their effects need to be parameterized.

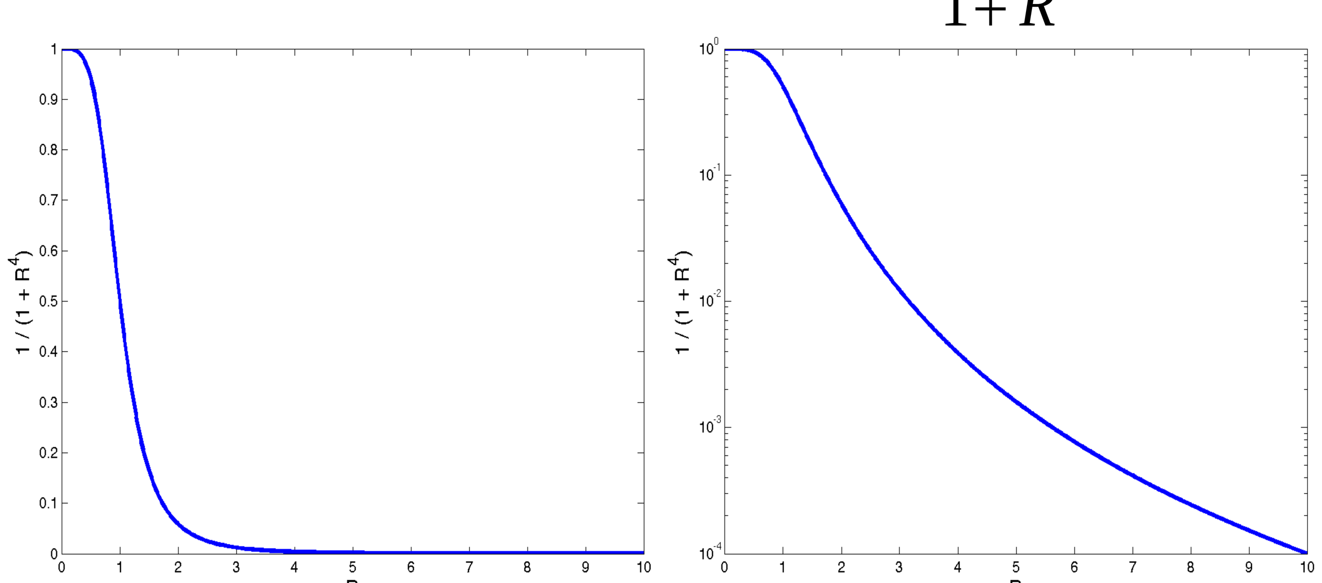
Most parameterizations of eddy effects act to suppress resolved eddies. Where the mesoscale eddies are resolvable, it is highly desirable to avoid their suppression by the parameterization of the eddy effects. To accomplish this, we find that it is useful to scale the interface-height and epipycnal tracer diffusivities and any Laplacian viscosity by a function $F(R)$ of the ratio of the first baroclinic deformation radius (λ_{Def}) to the effective grid spacing ($\tilde{\Delta}$). If c_{g1} is the flat-bottom, rigid-lid, first-mode baroclinic gravity wave speed,

$$\tilde{\Delta} = \sqrt{\Delta x^2 + \Delta y^2}$$

$$R = \lambda_{Def} / \tilde{\Delta}$$

$$\lambda_{Def} = \sqrt{\frac{c_{g1}^{\ 2}}{f^2 + \beta c_{g1}}}$$

A reasonable choice for $F(R)$ is $F(R) = \dfrac{1}{1+R^4}$



This scaling seems to be particularly promising when combined with a parameterization for the intensity of eddy activity based on a two-dimensional diagnostic equation of the Mesoscale Eddy Kinetic Energy (MEKE), E, which takes as its source term some of the energy extracted by the interface height diffusion and/or the lateral viscosity (Adcroft & Marshall, pers. comm.; Eden et al., 2008)

$$\frac{\partial E}{\partial t} = Src - \gamma E - \frac{c_d \left\| u_{bot} \right\|}{H} E + \frac{1}{H} \nabla \cdot \left(H \kappa_E \nabla E \right)$$

$$Src = \frac{1}{H} \sum_{k=1}^{K} g'_k \kappa_{Int} \left\| \nabla \eta_k \right\|^2 - \frac{0.001}{H} \sum_{k=1}^{K} h_k u_k \cdot \nabla \tau_{Visc}$$

In this parameterization, the eddy energy is combined with the grid spacing to give a lateral interface height or tracer diffusivity, here also combined with the resolution scaling defined above.

$$\kappa_{MEKE} = 0.03 \tilde{\Delta} \sqrt{2E}$$

$$\kappa_{Int} = F(R) \left(\kappa_{MEKE} + \kappa_{Background} \right)$$

By suppressing the source of energy for the MEKE equation, the scaling function ensures that the both the MEKE, and especially the parameterized diffusivity, are dramatically reduced where the eddy scales are well resolved, but fully active where the resolution is coarser.

The Common Ocean Reference Experiment (CORE) forced global examples at right both use all the same parameter settings (apart from the time-steps), despite their very different resolutions and levels of resolved eddy activity. These examples use the Generalized Ocean Layered Dynamics (GOLD) ocean model in an isopycnal coordinate configuration; the 1° configuration is similar to that being used as the ocean component of an IPCC-class coupled model (CM2G) at GFDL.