Convergence of Eddy Statistics in Simulations of Baroclinically Driven Flows

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Idea

- Must resolve generation and transfer scales

- Dissipation range must be at sufficiently small horizontal scale to allow enstrophy to cascade away from these scales

- If generation is baroclinic instability, then vertical structure of shear determines highest mode one must resolve

- In other words, increasing vertical structure implies need to resolve smaller horizontal scales.
Experimental Design

- Idealized flat-bottom channel simulations using HIM

- 3 and 6 layer, $1/5^\circ - 1/80^\circ$, $12^\circ \times 12^\circ$ domain, deformation radii $R_1 = 38$ km, $R_2 = 17$ km at center of channel

- Forced by relaxation of zonal mean interface heights toward initial baroclinically unstable condition

$$
\bar{h}_i^x(y, t+\Delta t) = \bar{h}_i^x(y, t) + [\bar{h}_i^x(y, 0) - \bar{h}_i^x(y, t)](1 - e^{-\Delta t/t_{relax}})
$$

where $\bar{h}_i^x(y, 0) \propto \tanh(\pi y/L)$ (no outcropping, no shear near side-walls)

- Dissipate with linear bottom drag for energy removal and Smagorinsky + small background biharmonic viscosity for enstrophy removal

- Stratification in center of domain is exponential density profile

- Mean shear in center of domain projects only onto first two baroclinic modes — there are only two BC modes in 3 layer case, but 6 layer case uses identical stratification and shear.

- Future runs will test more complex vertical shear
Initial Conditions

3 layer mean interface positions

6 layer mean interface positions

3 layer geostrophic $u$

6 layer geostrophic $u$
Initial Conditions

Density at central latitude

Zonal velocity at central latitude

- $\rho$ (kg m$^{-3}$)
- $z$ (m)
- $U$ (ms$^{-1}$)

3 layer
6 layer
Vorticity
Spectra of velocity variance

Time averaged zonal spectra of velocity variance in top layer at center of domain for 3-layer runs with $1/10^\circ$ and $1/80^\circ$ horizontal resolutions
Spectra of zonal velocity variance for all cases

Time averaged zonal spectra of zonal velocity variance in top layer at center of domain for 3-layer runs
The effects of the viscosity operator

Time averaged zonal spectra of zonal velocity variance in top layer at center of domain for 3-layer runs with 1/20° horizontal resolution, one using **Biharmonic Smagorinsky** viscosity and the other using **Laplacian Smagorinsky** viscosity.
Conclusions

- Experiments ambiguous but suggestive that increasing vertical resolution requires higher horizontal resolution for smooth vertical profiles

- Ongoing simulations using QG model are being performed simultaneously to compare results in homogeneous and inhomogeneous domains

- Future studies will examine required resolution with more structure in vertical shears