Convergence of Eddy Statistics in Simlations of Baroclinically Driven Flows

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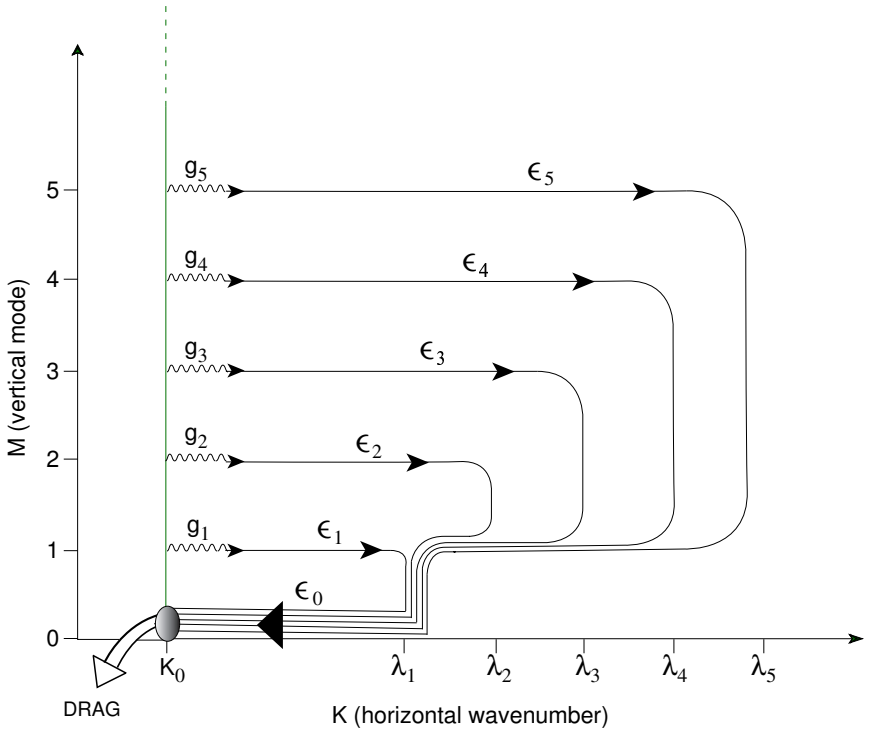
Idea

- 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.



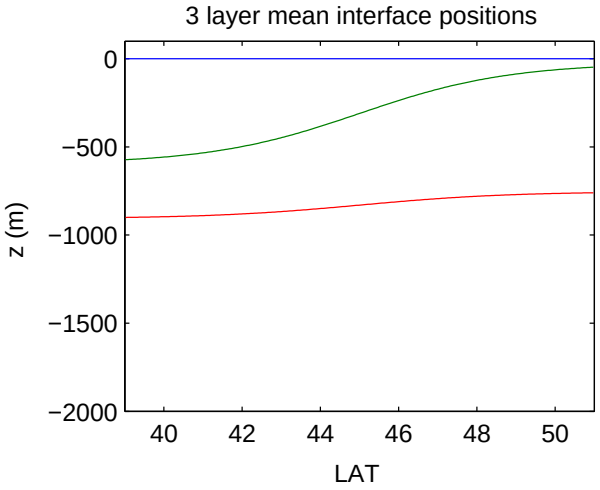
Experimental Design

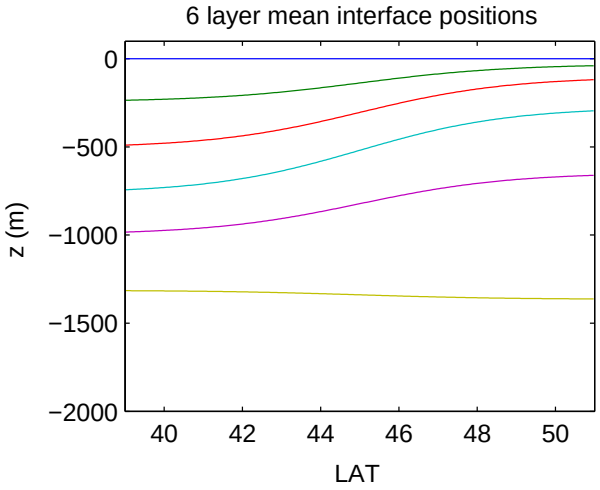
- Idealized flat-bottom channel simulations using HIM
- 3 and 6 layer, $1/5^\circ - 1/80^\circ$, $12^\circ \times 12^\circ$ domain, deformation radii $R_1 = 38$ km, $R_2 = 17$ km at center of channel
- Forced by relaxation of zonal mean interface heights toward initial baroclinically unstable condition

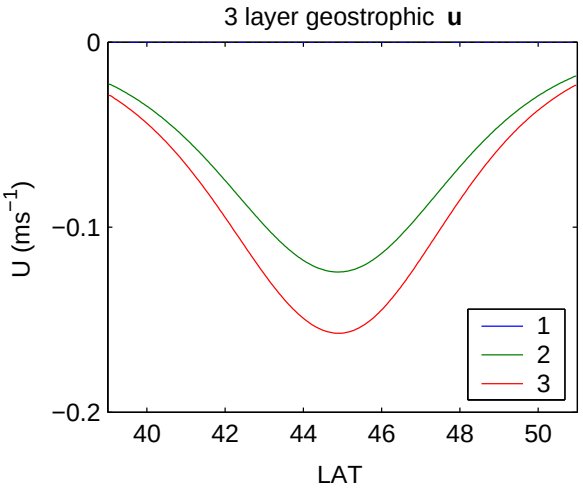
  $\overline{h_i}^x(y, t+\Delta t) = \overline{h_i}^x(y,t) + [\overline{h_i}^x(y,0) - \overline{h_i}^x(y,t)](1 - e^{-\Delta t/t_{\text{relax}}})$

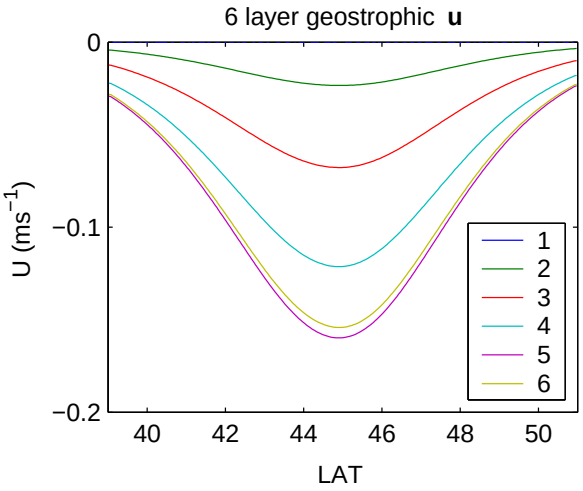
  where $\overline{h_i}^x(y,0) \propto \tanh(\pi y/L)$ (no outcropping, no shear near side-walls)
- Dissipate with linear bottom drag for energy removal and Smagorinsky + small background biharmonic viscosity for enstrophy removal
- Stratification in center of domain is exponential density profile
- Mean 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

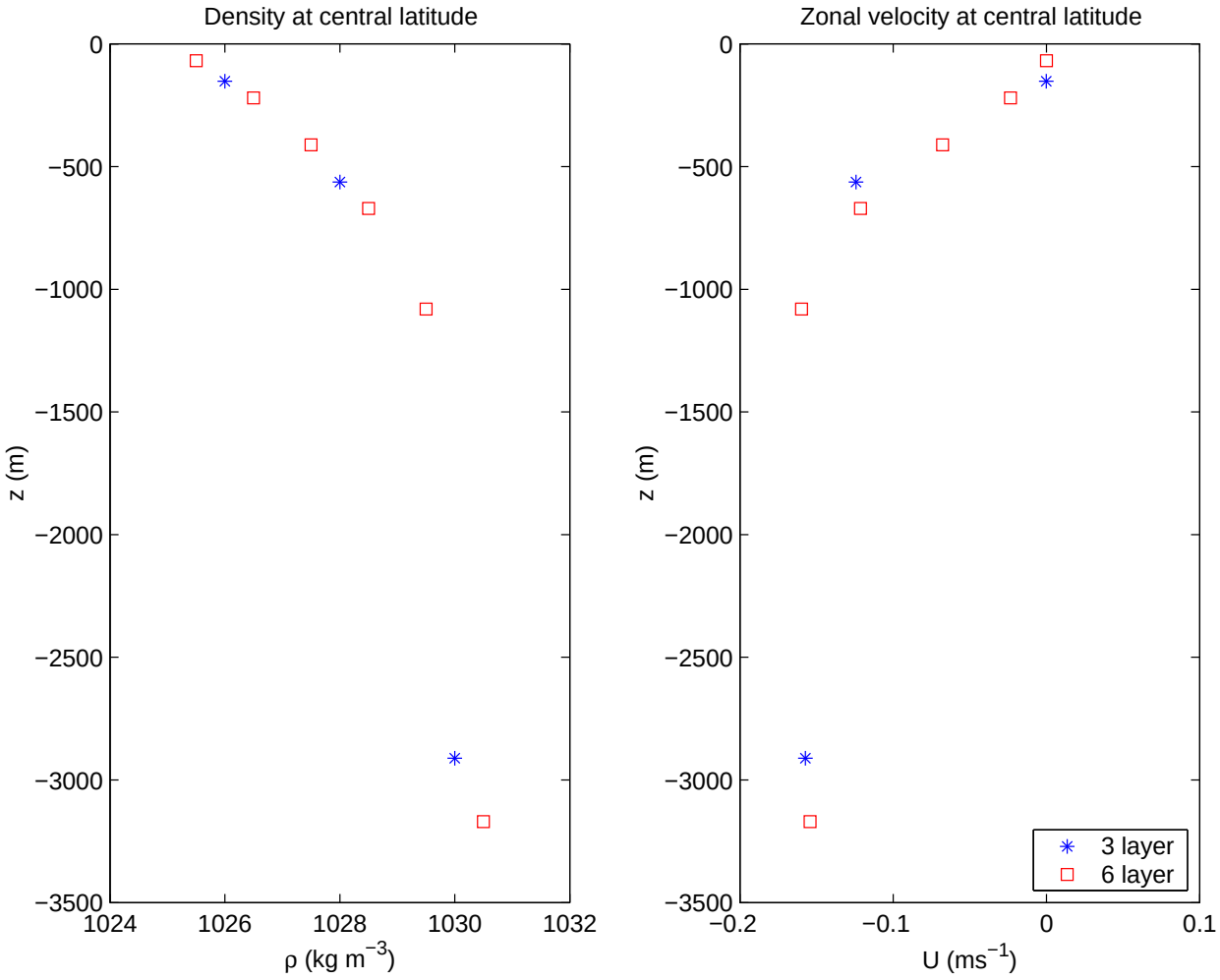




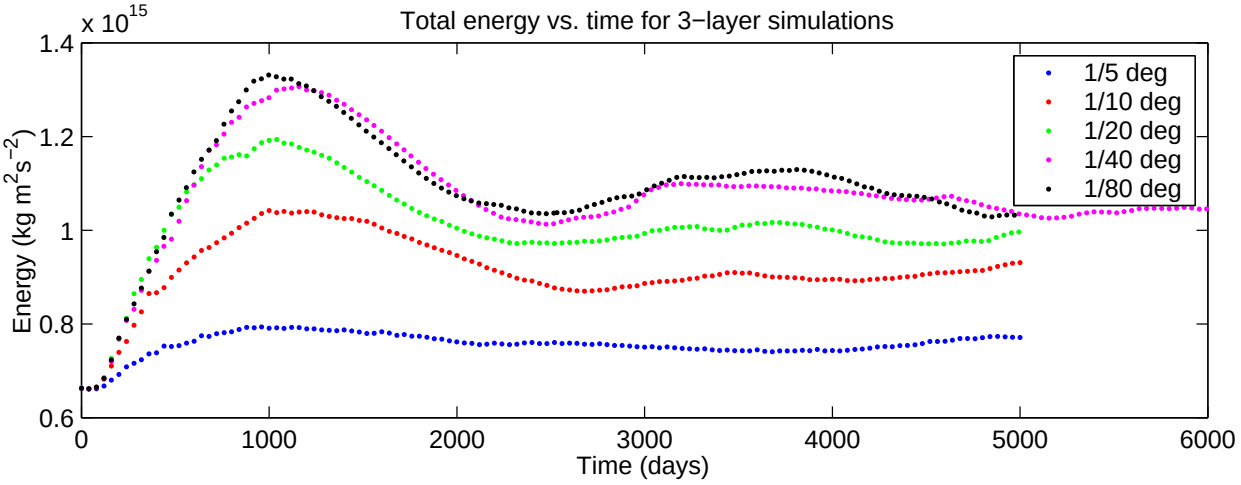


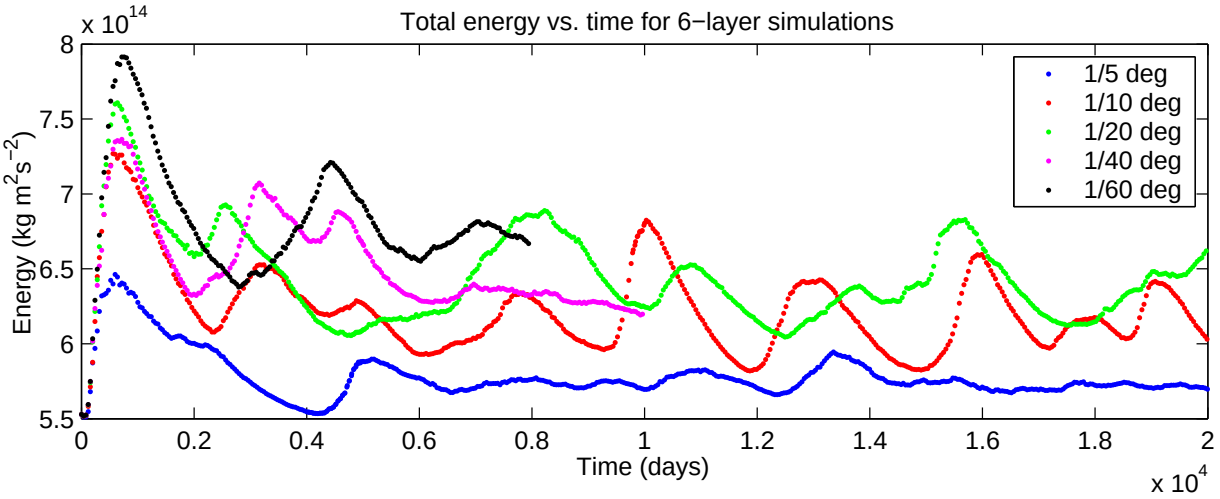


Initial Conditions

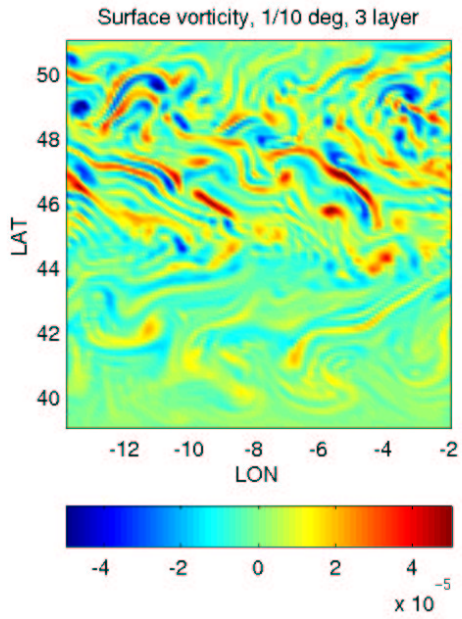


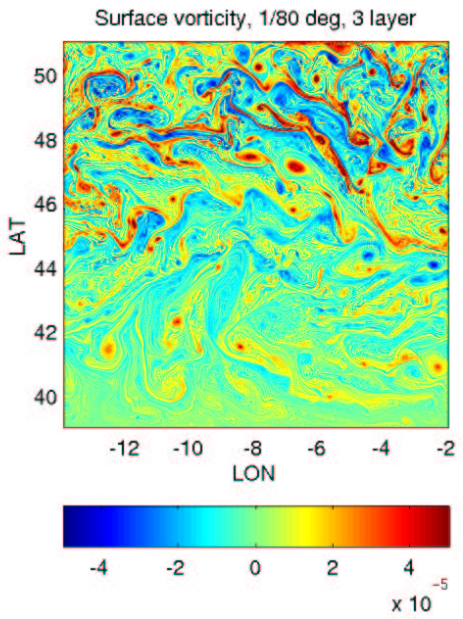
Energy Evolution

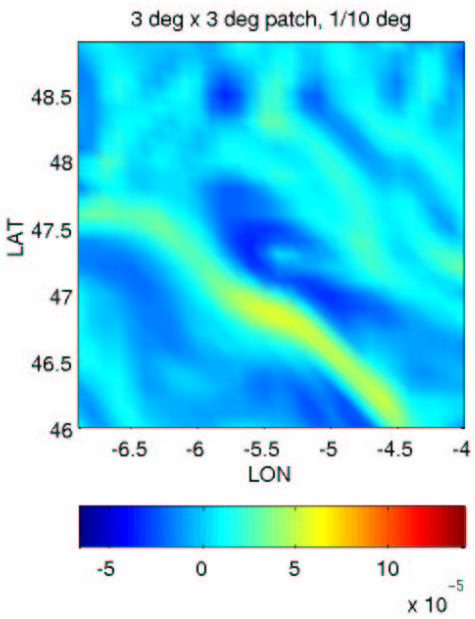


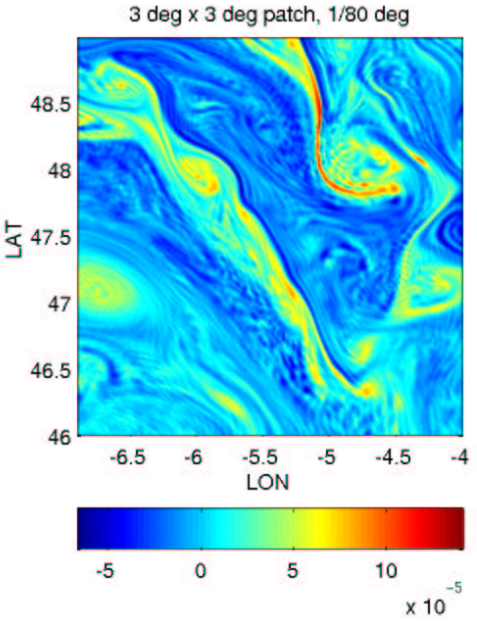


Vorticity

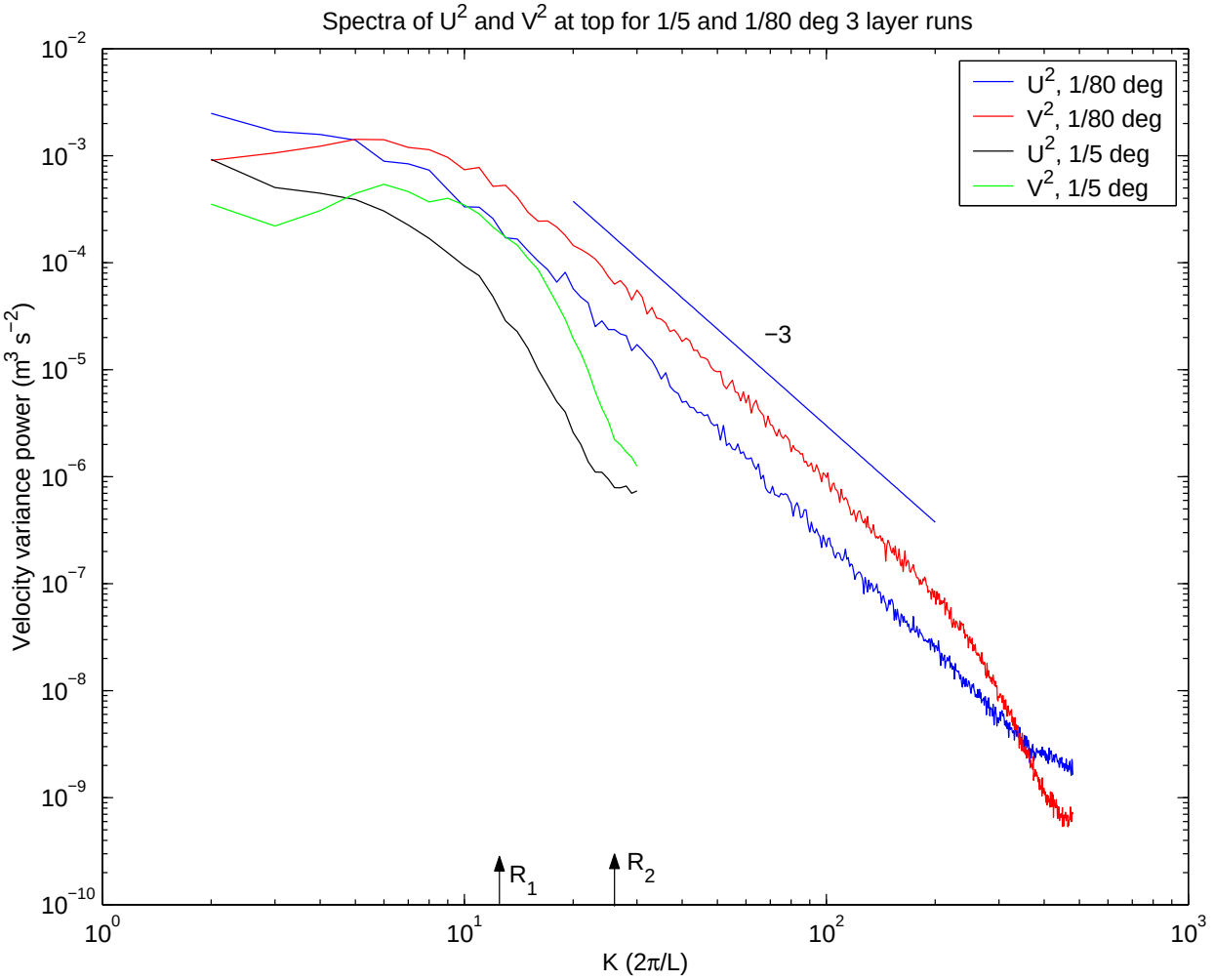

Surface vorticity, 1/10 deg, 3 layer
LAT
LON
x 10^-5


Surface vorticity, 1/80 deg, 3 layer
LAT
LON
x 10^-5


3 deg x 3 deg patch, 1/10 deg
LAT
LON
x 10^-5

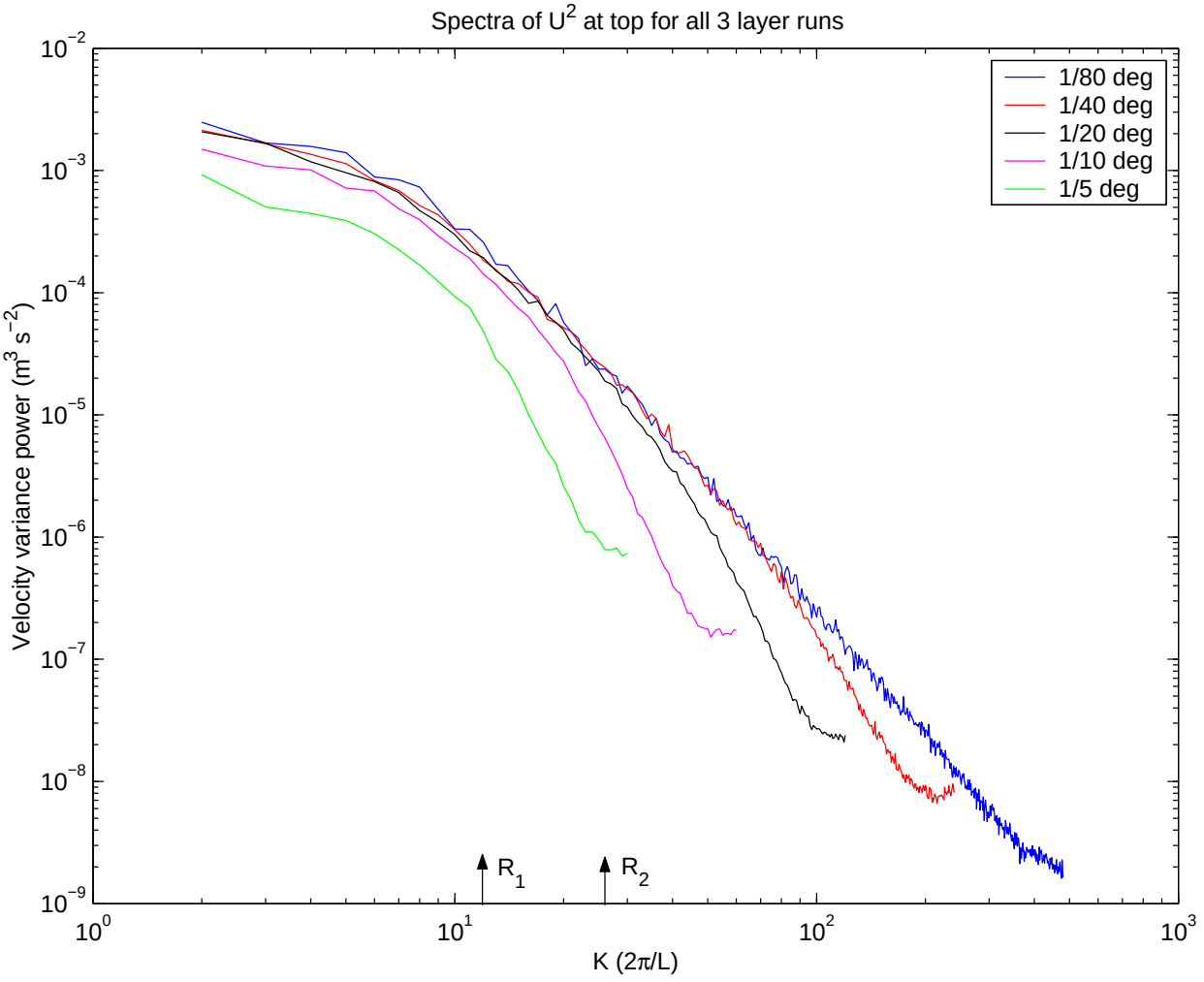

3 deg x 3 deg patch, 1/80 deg
LAT
LON
x 10^-5

Spectra of velocity variance



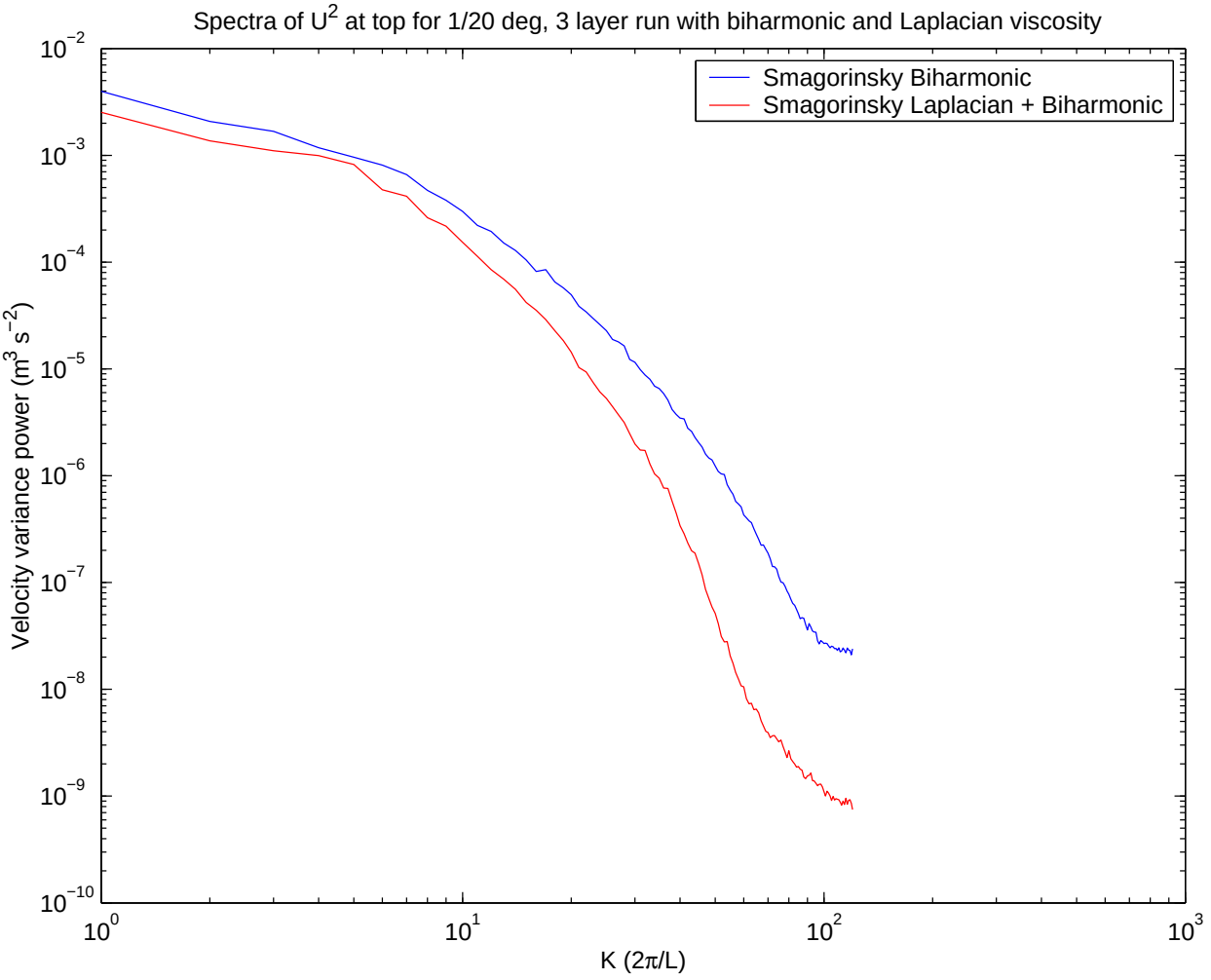
Time averaged zonal spectra of velocity variance in top layer at center of domain for 3-layer runs with 1/10° and 1/80° horizontal resolutions

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 horiziontal 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