Vertical Resolution Requirements in Atmospheric Simulation

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We examine the role of vertical mesh spacing in the convergence of full-physics global atmospheric model solutions for synoptic, mesoscale and cloud-scale horizontal resolutions. Using the MPAS-Atmosphere model, convergence is evaluated for three solution metrics; the horizontal kinetic energy spectrum, the Richardson-number probability density function, and resolved flow features. All three metrics exhibit convergence in the free atmosphere for a 15 km horizontal mesh when the vertical grid spacing is less than or equal to 200 meters. Non-convergence is accompanied by noise, spurious structures (e.g. see figure 1 below), reduced levels of mesoscale kinetic energy, and reduced Richardson number peak frequencies. Coarser horizontal mesh solutions converge in a similar manner but contain much less noise than the 15 km solutions for coarse vertical resolution. For convective-scale resolution simulations with 3 km cell spacing on a variable-resolution mesh, solution convergence is almost attained with a vertical mesh spacing of 200 meters. The boundary layer scheme is the dominant source of vertical filtering in the free atmosphere. Although the increased vertical mixing at coarser vertical mesh spacing depresses the kinetic energy spectra and Richardson number convergence, it does not produce sufficient dissipation to effectively halt scale collapse. These results confirm and extend the results from a number of previous studies, and further emphasize the sensitivity of the energetics to the vertical mixing formulations in models.

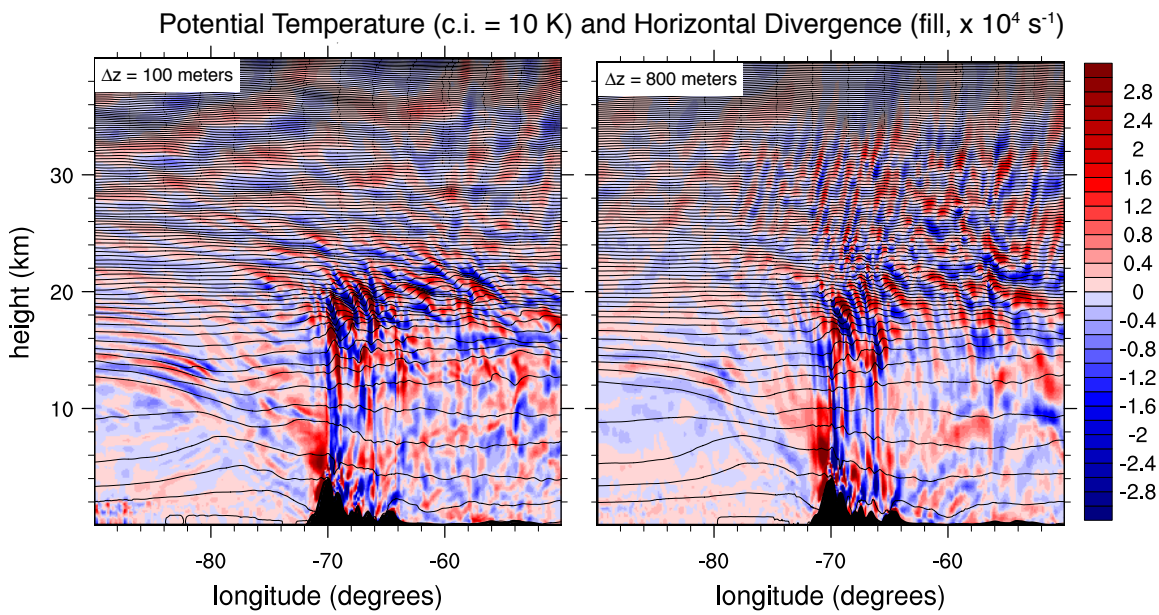

Figure 1: Flow over the Andes at forecast day 6 in the 15 km mesh simulations using 100 and 800 meter vertical mesh spacing in the free atmosphere. Strong mountain waves are generated, and spurious waves and noise appear in the 800 m solutions.