



## **Spurious Rayleigh-Bénard effects in under-resolved simulation of atmospheric convection**

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Intrigued by the regularity of convective structures observed in simulations of mesoscale flow past realistic topography, we take a deeper look into computational aspects of a classical problem of the flow over a heated plane. We found that the numerical solutions are sensitive to viscosity, either incorporated a priori or effectively realized in computational models. In particular, anisotropic viscosity can lead to regular convective structures that mimic naturally occurring Rayleigh-Bénard (RB) cells but that are spurious for the problem at hand. We have extended the classical linear theory to anisotropic viscosity at moderately supercritical Rayleigh numbers, realized effectively in under-resolved convection simulations. It follows that anisotropic viscosity modifies the range of unstable RB modes, such that for an effective viscosity much larger in the horizontal than in the vertical unphysically broad RB cells may be observed. The latter is relevant to “cloud resolving” global models with relatively fine (for numerical weather prediction) horizontal resolution  $\delta x \sim \mathcal{O}(10^3)$  m. At such a resolution the simulated convection is still under-resolved and strongly influenced by numerical filtering.

To better assess the impact of an effective model viscosity on the structure of convective fields, we have conducted a large series of simulations of thermal convection, with various degrees of idealization, using the computational model EULAG. We performed an extensive convergence study and documented differences between the well resolved (viz. realistic) cellular convection and spurious structures. Comparing various means of enhancing the effective viscosity in the horizontal, we demonstrated that details of filtering are inessential. The common denominator of the scale selection is consistent with the linear theory.

On the practical side we found that some numerical approaches may be preferable when the resolution is inadequate to capture the realism of convective fields. While control of effective viscosity is certainly the key to the quality results, resorting to non-dissipative numerics is not a cure. We found that implicit large-eddy simulation (ILES) approach based on non-oscillatory forward-in-time numerics minimizes numerical viscosity and its anisotropy, and produces results superior compared to more standard LES models.