Map-based modeling of high-Ra turbulent convection in planar and spherical geometries

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Turbulent convection is important in many technological and geophysical applications. A model problem for such flows is Rayleigh-Bénard (RB) convection. The classical RB setup is a fluid-filled box with a heated bottom and cooled top. For geophysical applications, the spherical geometry of the confinement is sometimes important (e.g. in mantle convection). This is addressed by a spherical annulus configuration in which fluid is confined between an inner hot and an outer cold sphere. In this case, the gravity field is radial and its strength can also vary with the radius.

Numerical simulations of RB convection are challenging because of the high Rayleigh numbers (Ra) observed in applications. 3-D direct simulations have been performed up to $Ra \sim 10^{12}$, but even larger values of Ra are relevant. Hence modeling is needed if one wishes to increase the accessible Rayleigh number limit within the considerable future. The difficulty is that gradient-diffusion approaches do not allow for scale interactions, which can be crucial for the dynamics of the flow and the resulting heat transfer. In order to make such simulations feasible we make use of a different modeling strategy, the so-called One-Dimensional Turbulence (ODT). ODT resolves all scales of the flow along a notional line of sight, but reduces cost by assuming statistical homogeneity of the flow in the off-line directions. Along the line, turbulent advection is modeled by discrete mapping events, which mimic the effect of turbulent stirring. These events are selected stochastically with highest probability where shear and buoyancy yield net extractable energy in analogy to real turbulence.

In the talk we evaluate ODT results against available reference data (e.g. flow statistics, heat transfer) using a new and fully adaptive version of ODT. This new version allows to simulate turbulent convection in spherical geometry. We address this by discussing the effects of radius ratio and radius-dependent gravity.

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