Rotating Rayleigh–Bénard convection with latitude dependence: the ultimate turbulence

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Short abstract

Convection-driven flows under the influence of rotation are ubiquitous in geophysical and astrophysical environments. Rotating Rayleigh–Bénard (RRB) convection is a classical paradigmatic system to examine the effect of rotation on turbulent convection, receiving extensive attention over the past several decades. In RRB, the flow is heated from below and cooled from above, with a constant background rotation. The focus of the research on the topic is to understand the dimensionless heat transport, defined by the Nusselt number Nu, as a function of the driving forces, namely the dimensionless temperature difference between the heated and cooled plates, i.e. Rayleigh number Ra, the dimensionless intensity of rotation, i.e. Ekman number Ek, and Prandtl number Pr. The scaling relations of the system response Nu upon the control parameters Ra, Ek, and Pr are highly important to determine the various flow regimes and the results can be extrapolated to real situations where these parameters are often extreme. In traditional studies of RRB, the rotation axis is parallel to gravity, however, in real geophysical and astrophysical flows, the most commonly seen geometries are the spheres, and the traditional implementation is only able to mimic the convection in the polar regions. This latitude dependence of the rotation axis and the gravity causes distinctive heat transfer processes and turbulent dynamics. Thus, it is doubtful whether the results from the traditional RRB studies can be directly applied to spherical geometries. By choosing serval simulation cases with different Ra, Ek, and tilted angles, we aim to determine the flow regimes with increasing Ra for the different tilted angles at high rotating rates as well as connecting the flow structures with the scaling behaviors of Nu as a function of Ra and Ek.