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Stratification and energy fluxes in the anelastic convection model

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Convection in the planetary cores is usually connected with the geostrophic state. At the onset of convection, the ratio of horizontal scale to the scale along the axis of rotation is proportional to the cube root of the Ekman number, which characterises the ratio of the viscous forces to the Coriolis force. The Ekman number is extremely small in the liquid cores, which is a source of strong anisotropy. Even if further increase of the heat sources leads to decrease of anisotropy, the final state is still highly anisotropic.

The influence of the rapid rotation on the structure of the flows in the physical space is also manifested by a substantial change of the spectral properties of the turbulence in the core (Reshetnyak and Hejda, 2008; Hejda and Reshetnyak, 2009). If for the non-rotating flow the kinetic energy in the wave space propagates from the large scales to the small dissipative scales (the so-called direct Richardson-Kolmogorov cascade), then in presence of rotation the turbulence degenerates to the quasi two-dimensional state and the inverse cascade of the kinetic energy is observed.

Having in mind that Cartesian and spherical geometries exhibit similar results and reproduce the inverse cascades of the kinetic energy (Reshetnyak and Hejda, 2012), there is an open question how this cascade contributes to the more general energy balance, which includes the heat flux equation. As the heat energy definition in the Boussinesq model is quite questionable, we consider the anelastic model, where the heat fluxes can be compared with the kinetic energy fluxes in the adequate way. Here we consider the spherical geometry model in the shell that limits our study to the cascades in the azimuthal wave-number.

As the self-consistent anelastic model includes new term, the adiabatic cooling, which produces “stratification” in the outer part of the core, we consider its influence on convection in the physical and wave spaces. We show that even small cooling can change the convection substantially, shifting maximum of convection to the inner part of the liquid core. Similar to the Boussinesq model the both direct and inverse cascades of the kinetic energy as well as the direct cascade of the specific entropy in the wave space occur.

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