Spectral scaling of velocity and temperature in the Rayleigh-Bènard Convection at Pr $= 7$

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In buoyancy-driven flows, mechanical energy enters the system through density differences caused by temperature distribution and a two-way coupling is realized between the velocity and the temperature fields. Rayleigh-Bènard convection is the most simple case in terms of geometry and boundary conditions where buoyancy-driven turbulence is investigated and the literature on the topic is extensive.

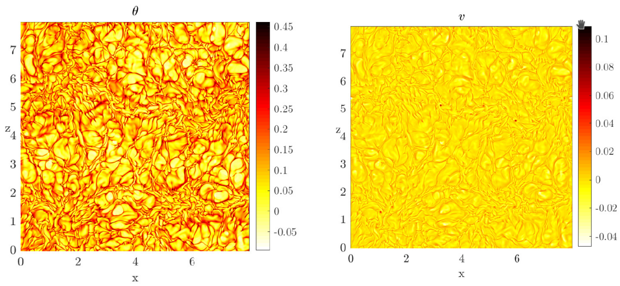

Figure 1: Representation of the temperature and vertical velocity component.

This work reports a discussion on well-resolved Direct Numerical Simulation data obtained on the Rayleigh-Bènard case at a Rayleigh number of Ra $= 3.5 \times 10^8$ and a Prandtl number, Pr $= 7$. The focus is on the scaling properties of spectra of the velocity and temperature field.

In the passive scalar case and for Pr > 1, a viscous-convective range is predicted by Batchelor[1], where fluctuations appear in the temperature field at length scales smaller that the Kolmogorov scale. The viscous-convective range is observed in the present results and discussed here.

In the inertial range of the turbulent kinetic energy, a -11/5 scaling is predicted by the Bolgiano[2]-Obukov[3] theory. This scaling can be observed at comparatively high Rayleigh numbers, when the local Bolgiano scale is as small as to fall in the inertial range. We report horizontal spectra of velocity fluctuations, at the same height as the thermal boundary-layer thickness. Bolgiano-Obukhov scalings are observed in our data. High resolution Direct Numerical Simulation results of Rayleigh-Bènard convection allows for a detailed view of spatial spectra of the velocity and the temperature fields.

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[1]Batchelor, G. (1959). Small-scale variation of convected quantities like temperature in turbulent fluid Part 1. General discussion and the case of small conductivity. J. Fluid Mech., 5(1), 113-133.

[2]Bolgiano, R. 1959 Turbulent spectra in a stably stratified atmosphere. J. Geophys. Res. 64, 2226–2229

[3]Obukhov, A.M. 1959 On influence of buoyancy forces on the structure of temperature field in a turbulent flow. Dokl. Akad. Nauk SSSR 125, 1246–1248.