Numerical analysis of turbulent superstructures in thermal convection: Dynamics and role for turbulent transport

When turbulent convection proceeds in horizontally extended layers large-scale patterns of the time-averaged velocity and temperature fields are formed. These patterns are termed turbulent superstructures and will be in the focus of the present project. More specifically, we want to understand their dynamical origin from the weakly nonlinear regime of convection, the transitions between different large-scale patterns in turbulence and their importance for the turbulent transport, in particular the turbulent heat transport. Our investigations are based on massively parallel three-dimensional direct numerical simulations of turbulent Rayleigh-Bénard convection in flat and closed rectangular cells of aspect ratios of 10 and larger (see figure for a streamline plot). In order to answer some of these questions, we will reduce the vast amount of degrees of freedom of the flow and derive a set of simplified and effective equations that describe the slow and large-scale dynamics of the superstructures, isolated from fast small-scale vortices and plumes. Furthermore, we will apply and extend newly developed Lagrangian set-oriented and trajectory-based methods to our simulation data. The latter methods will reveal the most persistent and longest-living coherent structures in the turbulent convection flow and help to understand the relevance of superstructures for turbulent transport. The work is conducted together with colleagues from Theoretical Physics and Applied Mathematics.