Heat transport in sheared turbulent thermal convection

Rayleigh-Bénard (RB) flow, the flow in a box heated from below and cooled from above, is one of the paradigmatic systems in physics of fluids. For strong thermal driving (i.e., large enough Rayleigh number), the bulk of the flow becomes turbulent. For even stronger thermal driving, beyond some critical Rayleigh number $Ra_c \sim 10^{14}$, also the boundary layers become of turbulent nature. This is the so-called ultimate regime, which had been seen in experiments, but not yet in numerical simulations, therefore hindering a full understanding of this regime and the transition towards it.

The objective of this project is to numerically reach the ultimate regime of RB turbulence by *shearing* the flow, i.e., by imposing mechanical driving in addition to the thermal one, thus lowering the onset Rayleigh number Ra_c for the ultimate regime. In this way we will achieve mixed convection, which can be tuned at will, with the thermal and mechanical driving strengths as independent parameters. In this way we want to better understand the onset of ultimate turbulence and the way how the flow organises itself in the ultimate regime. The questions we want to answer are: How exactly does the onset of the ultimate regime Ra_c depend on the mechanical driving strength and type? How is the large-scale convection roll ('superstructure') known from pure RB flow modified by the imposed mechanical driving? How does the heat flux (i.e., the Nusselt number) depend on the strength of the combined thermal and mechanical driving? How are above two issues interconnected? I.e., what is the relation between large-scale flow organisation and transport properties of the system? In the presence of shear, what is the role of the thermal plumes (which detach from the thermal boundary layers) in driving the large-scale wind of turbulence? What are the features of the boundary layers in the ultimate regime, in particular, how do the velocity and temperature profiles emerge? Does the strong correlation between plume emission and a logarithmic profile found in standard RB persist?

To answer these questions, we will employ two types of mechanical driving to the RB system: First, mechanical driving of Couette-type, where we shear the upper plate with respect to the lower one. Second, mechanical driving of Poiseuille-type, i.e., applying a lateral pressure gradient which causes the shear flow.

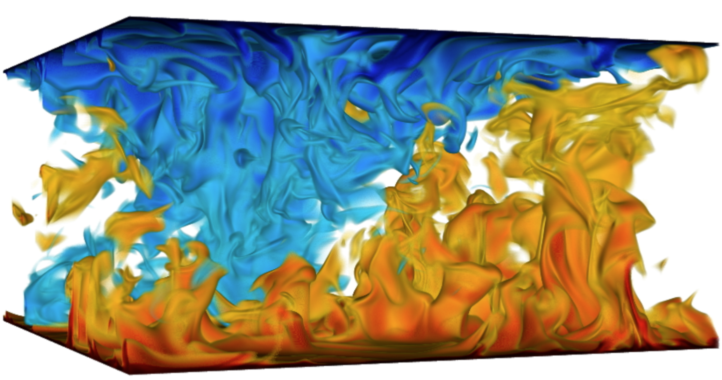

Figure 1: *Snapshots from our DNS: RB flow for $Ra = 10^8$, $Pr = 1$ and $\Gamma = 2$ in Cartesian coordinates. The horizontal directions are periodic and the plates are subjected to a no-slip and isothermal boundary condition. Red/orange indicates hot fluid, while blue indicates cold fluid. Both the small heat carrying structures ('thermal plumes') and the large scale circulation ('wind of turbulence') can be seen in the visualization. In this project we will shear this configuration and analyse whether the onset of the ultimate regime can be triggered by such a shear.*