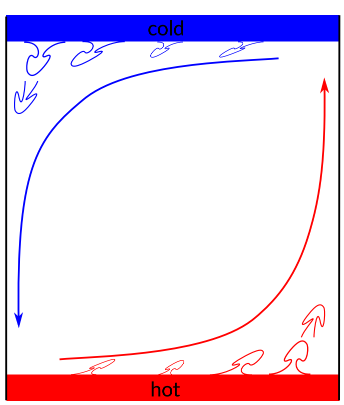
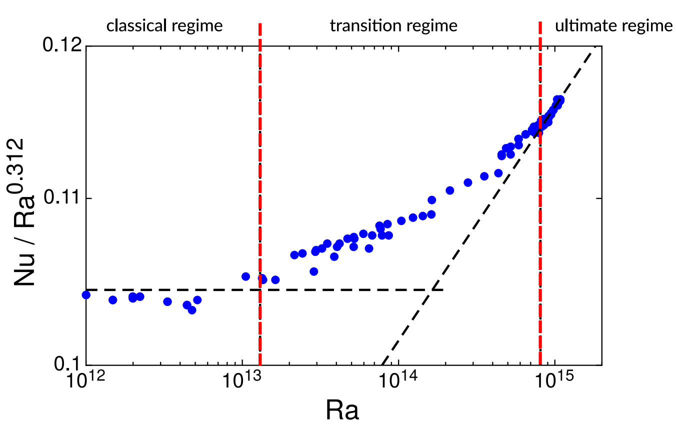
On the influence of the large scale shear flow on the transition to the ultimate regime

Turbulent thermal convection is an important heat transport mechanism and most relevant in many large scale geo- and astrophysical fluid systems. To study thermal convection in the lab or in numerical simulation, significantly smaller systems are considered. The Rayleigh-Bénard convection (RBC) setup consists of a horizontal fluid layer confined between a warm plate from underneath and a colder plate from above. The heat transport in such a system is limited by thermal and viscose boundary layers at the top and the bottom, while the turbulent flow in the bulk self-organises into large scale convection rolls (LSC), i.e., the superstructures of thermal convection. For not to large thermal driving, the shape and the dynamics of these superstructures affect only weakly the heat transport. However, at sufficiently large thermal driving, the LSC is strong enough to render the viscose boundary layers at the bottom and top plate turbulent, resulting in a significant increase of the convective heat transport. While heat transport measurements have found a transition at sufficiently large thermal driving (see figure below), neither the state of the boundary layer nor of the LSC were investigated in detail. In our project we will investigate the interaction of the LSC with the boundary layer and thus its influence on the heat transport in RBC. We are using pressurized sulfur hexafluoride in a 1.10 m high cylinder to maximize the Rayleigh number (i.e., the thermal driving). In this setup we will enhance the strength of the LSC artificially and expect in this way to render the boundary layer turbulent at significantly smaller thermal driving. We furthermore study thermal and viscose boundary layers as they develop in the shear flow above a heated plate. With these experiments we can study in detail the interaction between the temperature and the velocity field during the transition of the latter from the laminar to the turbulent state.



Warm plumes rise on one side of the convection cylinder, while cold plumes sink on the other, causing a coherent large scale convection flow that spans the entire cylinder height.



The rescaled dimensionless heat transport (Nu) as a function of the thermal driving (Ra). A transition is clearly shown, where the effective exponent of $Nu \propto Ra^b$ increases from b=0.312 in the clasical regime to b=0.38 in the ultimate regime of turbulent Rayleigh-Bénard convection.
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