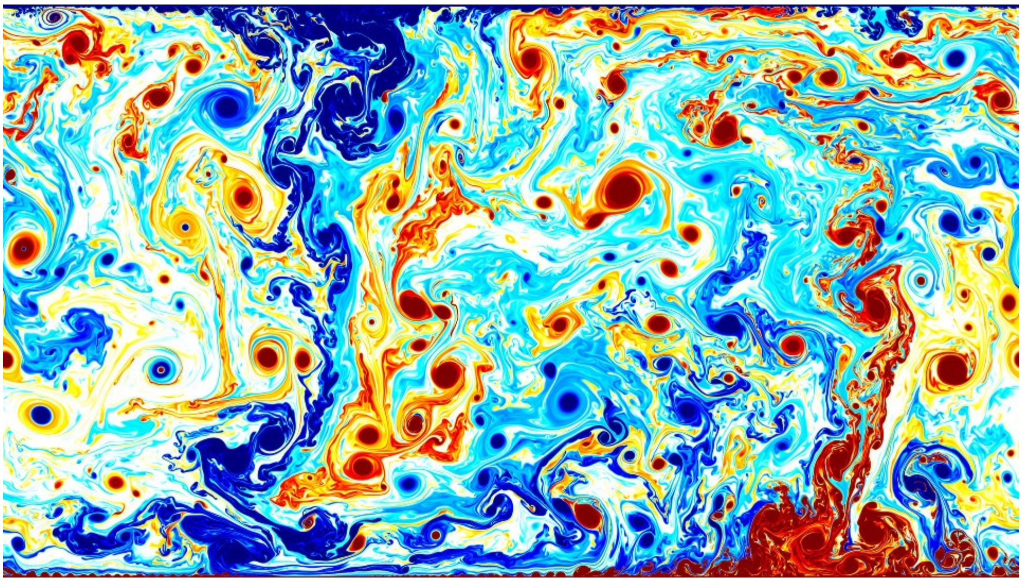
Effective Description of Superstructures in Turbulent Convection

Coherent large-scale flow patterns arise in wall-bounded convective flows right above the onset of convection. Such flow patterns are theoretically well understood in terms of linear and weakly nonlinear analysis. Far beyond onset, turbulence starts to emerge, leading to a complex behavior in space and time. In this regime, turbulent fluctuations call for a statistical treatment. Interestingly, long-lived large-scale flow patterns, reminiscent of the ones just above threshold, are also observed in the turbulent regime. The large-scale wind in turbulent Rayleigh-Bénard convection may serve as an example for this phenomenon.

It remains an open question whether these turbulent superstructures are remnants from linear instability, or whether their explanation requires entirely different mechanisms. For example, it is largely unexplored and unexplained how superstructures trigger smaller-scale turbulence and, conversely, how turbulence supports or inhibits superstructures.

The goal of this project is to investigate turbulent superstructures in a range of convective systems, including two- and three-dimensional Rayleigh-Bénard convection as well as convective planetary boundary layers. The numerical and analytical study will be conducted in close collaboration with colleagues from Mechanical Engineering and the Atmospheric Sciences. From highly-resolved numerical simulations, we will determine the impact of small-scale turbulent fluctuations and large-scale superstructures on the turbulent dynamics using a filtering approach. Based on these results we will then explore the development of reduced models by establishing effective large-scale equations.



Temperature field from a simulation of two-dimensional Rayleigh-Bénard convection. The dynamics is driven by small-scale thermal plumes which conspire to form a large scale wind. Visualization courtesy of J. Lülff (2015).