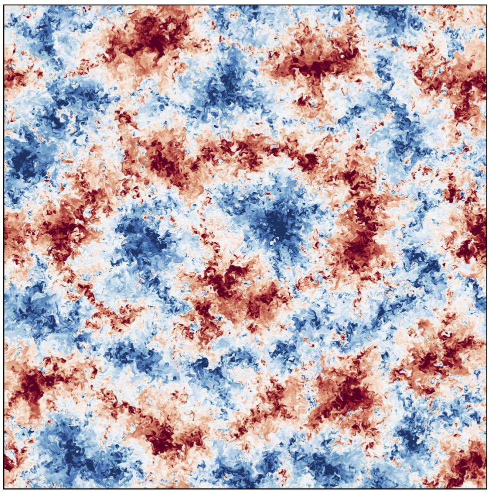
Effective Description of Superstructures in Turbulent Convection and Simple Turbulent Shear Flows



Turbulent superstructures in Rayleigh-Bénard convection at $Ra = 10^8$. The visualization shows the temperature field in the midplane[1].

Turbulent flows are ubiquitous in nature and often show a surprising large-scale order, even though turbulence is associated with small-scale fluctuations and chaotic, irregular motion. These large-scale structures in presence of turbulent fluctuations are one manifestation of turbulent superstructures. Turbulent superstructures occur in a range of prototypical flows, including wall-bounded[2] and shear-driven flows as well as in convective flows[3–6]. Developing a predictive theory of large-scale flow patterns in the turbulent regime leaves many open challenges.

The overarching objective of our research is to establish an effective description of turbulent superstructures in a data-driven theoretical approach. Through extensive DNS investigations, our work from the first funding period has given detailed insights into the role of turbulent fluctuations and boundary layers on the emergence of large-scale flow structures in Rayleigh-Bénard convection[1]. These computational studies were complemented by analytical investigations of a reduced-order model[7], based on which we were able to analytically investigate, for example, the increase of superstructure size with Rayleigh number. In the second funding period, we plan to combine these two complementary approaches. In particular, we will investigate how to systematically connect a coarse-grained description of turbulent convection to reduced-order models.

We additionally aim for identifying potential universal features of turbulent superstructures. To this end, we will investigate turbulent Kolmogorov flow as a prototypical example for a simple shear flow. An analysis of the energetics of the system will provide insights in the role of turbulent fluctuations for the emergence of turbulent superstructures. Building on collaborations within the SPP 1881, we also plan to extend these investigations to a variety of flows such as (atmospheric) boundary layer flows[8] and turbulent Taylor-Couette flow[9].

References

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