Lagrangian aspects of turbulent superstructures: numerical analysis of long-term dynamics and transport properties

Turbulent fluid flows often exhibit large-scale, long-lived coherent structures, termed turbulent superstructures. In turbulent shear flows superstructures are characterized by elongated regions of streamwise velocity fluctuations, whereas in turbulent convection they are identified as patterns in the time-averaged velocity or temperature fields.

While clearly observable in the Eulerian frame of reference, the origin and dynamics of these superstructures and their impact on turbulent flow properties and transport processes are far from being understood. To this end, there is a need for mathematical descriptions of turbulent superstructures beyond the Eulerian specifications.

In the first funding period, trajectory-based methods have been developed for the study of coherent behavior in the Lagrangian frame of reference, using concepts from dynamical systems and ergodic theory as well as data science.

In the second phase of the project, we will continue to develop and apply computational approaches to approximate and characterize Lagrangian superstructures in 3D turbulent flows. Our focus will be on (i) the analysis of the long-term dynamics of superstructures including the prediction of bifurcations, (ii) attempting a systematic understanding of the relation between Eulerian and Lagrangian superstructures, and (iii) a characterization of their transport properties.

In cooperation with our interdisciplinary project partners within the Priority Programme, we will study the Lagrangian aspects of turbulent superstructures both in Rayleigh-Bénard convection and in turbulent shear flows.

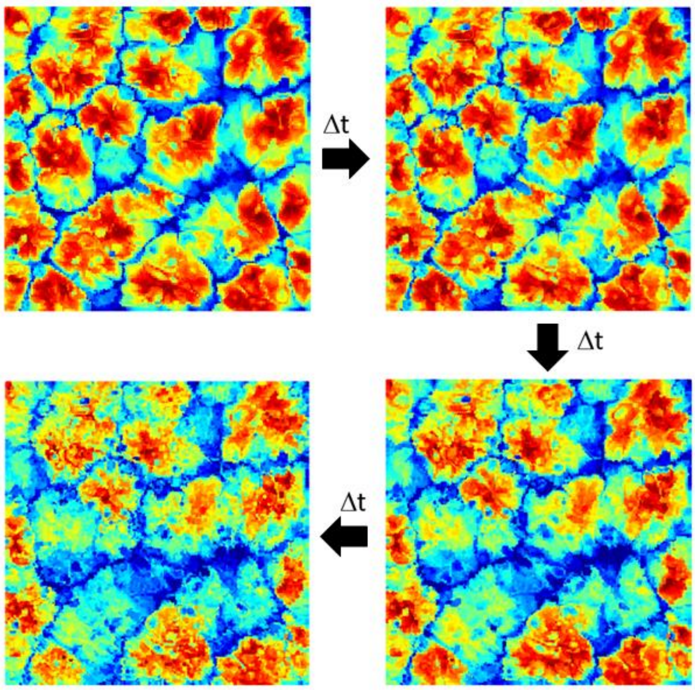

Figure: Temporal evolution of Lagrangian coherent sets in turbulent Rayleigh-Bénard convection.