Trajectory-based Lagrangian approaches for the extraction and characterization of coherent structures in turbulent convection

Turbulent fluid flows often exhibit large-scale, long-lived dynamical structures that have a crucial impact on global transport and mixing. The origin and dynamics of these superstructures, and their influence on turbulent flow properties are far from being understood. The Priority Programme aims at arriving at a comprehensive characterization and understanding of turbulent superstructures in an interdisciplinary effort. To this end, there is a need for mathematical descriptions of coherent structures in fluid motion and for corresponding efficient and reliable numerical methods for their identification, extraction and tracking, as well as for the quantification of the underlying transport processes. In this project, we will develop mathematically rigorous computational approaches to approximate and characterize coherent structures in turbulent flows. For this, we will make use of concepts from dynamical systems and ergodic theory as well as data mining. In particular, the computational methods will be tailored to directly work with Lagrangian particle trajectories, such as obtained from experiments involving particle tracking or from a particle model in direct numerical simulations. Central tools will be a transfer operator-based framework and spatio-temporal clustering schemes. They will allow us to analyse the emergence and dynamics of superstructures in three-dimensional turbulence. In cooperation with our interdisciplinary project partners within the Priority Programme, we will in particular study coherent behaviour in turbulent convection, but also in other systems.

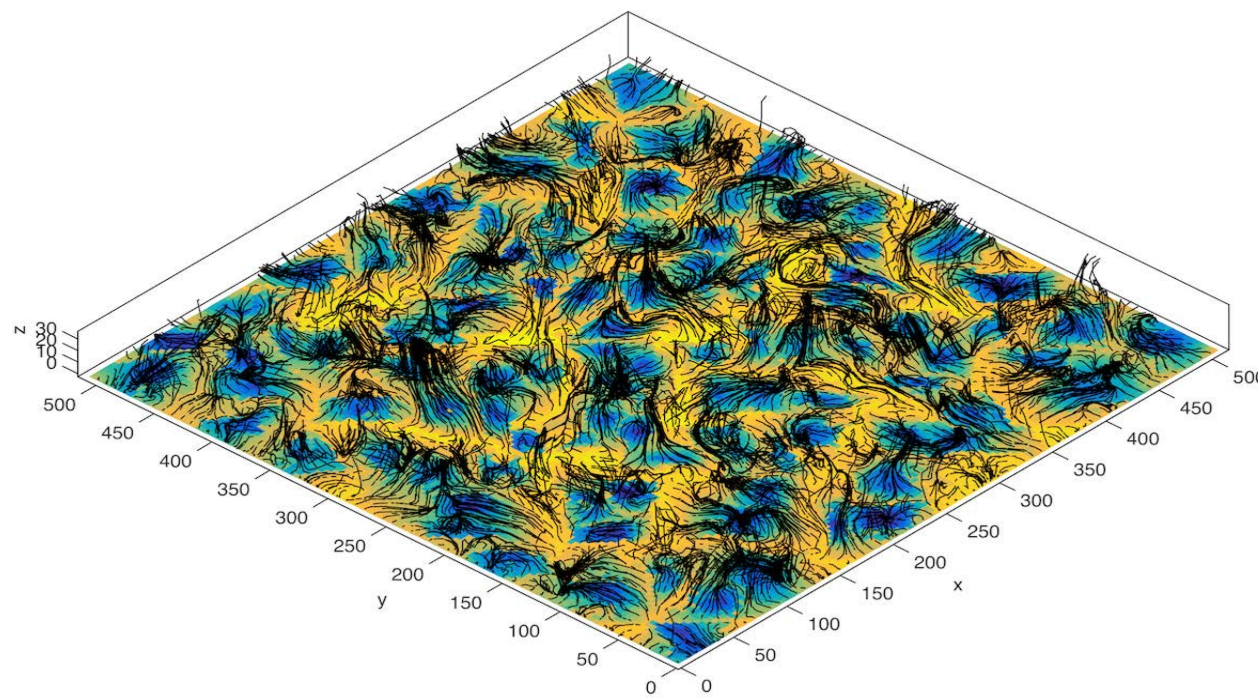

Figure: Preliminary numerical study of Lagrangian trajectories computed from the heat flow in a convection cell. Blue regions indicate initial conditions near the bottom plate that give rise to coherent structures (here obtained via spatio-temporal clustering of trajectory data).