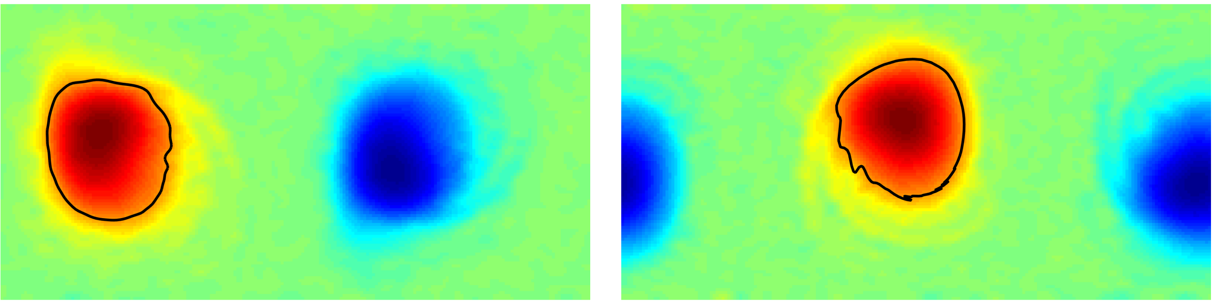
Computational methods for coherent sets

Long living superstructures in turbulent fluids may be characterized as so-called (Lagrangian) coherent sets of the underlying time-dependent velocity field. These sets can be computed elegantly as sublevel sets of eigenfunctions of a certain linear operator. Traditionally, the discretization of this operator has been based on the computation of a large number of Lagrangian trajectories and low order ansatz functions in space, resulting in rather expensive computations for even moderate accuracy and small problems. Recently, techniques have been proposed which use high-order ansatz functions and a direct time integration of the associated Fokker-Planck equation. This approach allows to compute Lagrangian coherent sets without computing Lagrangian trajectories. However, these methods are not yet applicable to 3D turbulent fluid flows which require a high spatial resolution. Within this project, in order to detect superstructures effectively and rapidly, we are going to develop new numerical techniques for a fast and reliable discretization of the operator eigenproblem. This in turn will allow to predict the emergence or bifurcation of superstructures and potentially allow for short-term forecasts of extreme events. We will validate and apply our methods to models and data from simulations and experiments from other projects within the SPP.

This project is part of the joint project „Computational methods for coherent sets and coherent transport"with Daniel Karrasch (TUM).



Eigenfunction (left) of a dynamic Laplace operator and its image (right) under the evolution of some turbulent flow on a cylinder. The black curve is some level set of this eigenfunction which identifies a coherent set, i.e. a set which shows small distortion under the flow and for which the mass transport across its boundary is small.