Lagrangian and Eulerian analysis of superstructures in turbulent flows based on large-scale, time-resolved and volumetric measurements using Shake-The-Box

A great potential for minimizing fuel consumption is the reduction of total drag, consisting to a large extent of aerodynamic drag caused by turbulent boundary layers (TBL) along the entire surface of e.g. aircrafts. The understanding of the formation and the dynamics of very-large coherent structures or superstructures within TBLs and their influence on the drag producing wall shear stress is therefore an important research topic in aerodynamic flows at high Reynolds numbers not attainable by DNS. Another turbulent flow regime of high interest is Rayleigh-Bénard-Convection (RBC) as an archetype of thermal convection, where a buoyancy-driven turbulent flow develops between a hot bottom plate and a cold top plate. In RBC turbulent thermal plumes cluster and drive a global circulation, the large scale circulation (LSC). A further examination of the formation and evolution of such superstructures in their fully temporal and spatial extension is therefore of major interest for a better understanding of turbulent (wall bounded) flows in general. Shake-The-Box (STB) is a novel time-resolved 3D Lagrangian particle tracking method for densely seeded flows developed at DLR and is of particular use for such large scale investigations. STB overcomes the ill-posed reconstruction problem for 3D particle distributions at high seeding densities present for each *single* time-step (as known for tomo-PIV and PTV) by pre-solving the problem for each *predicted* time-step in a cascade of reduced complexity along a time series of images. As a result STB delivers accurate and dense 3D Lagrangian track data in large volumes. The velocity and acceleration information at the track positions can be used for a Navier-Stokes-regularized interpolation method (FlowFit) resulting in high resolution time-resolved 3D velocity gradient tensor information on a regular grid enabling combined Eulerian and Lagrangian investigations.

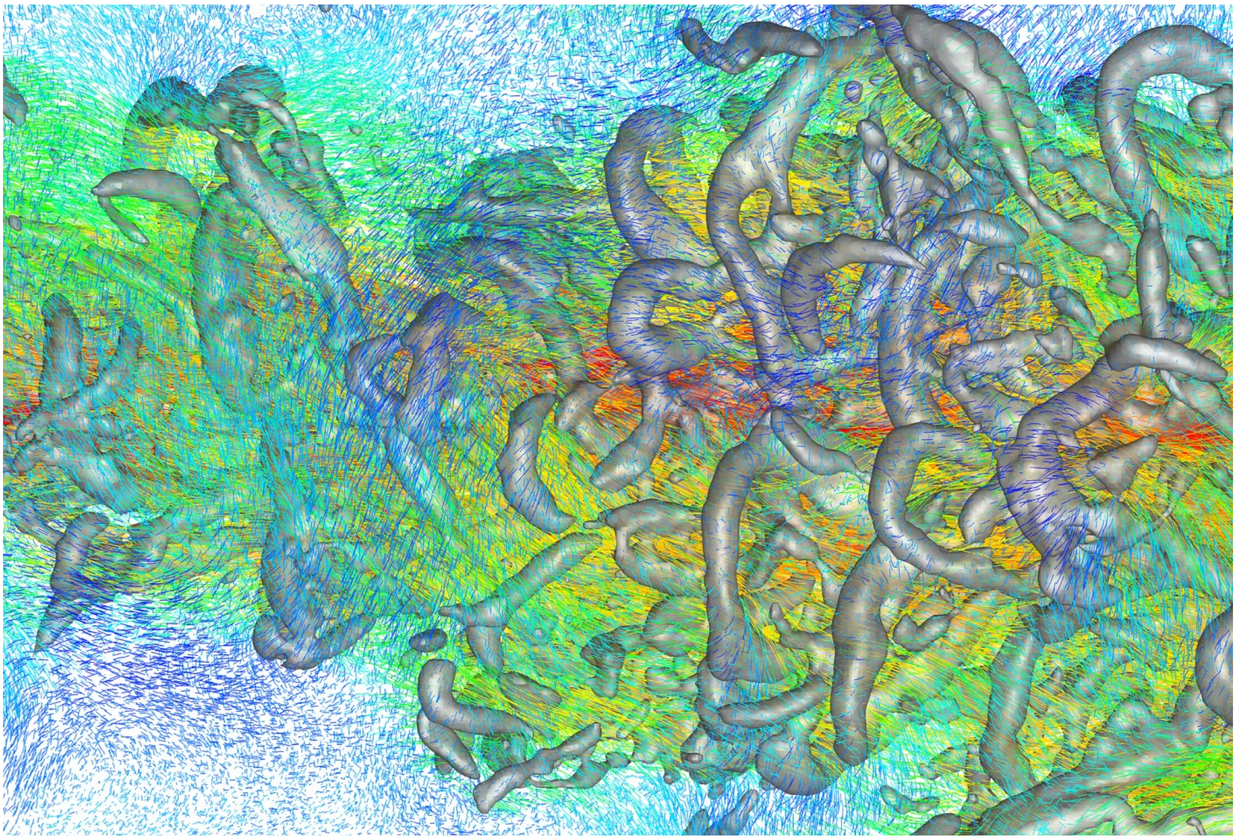

Figure: Thermal plume (tilted by 90°) with Lagrangian tracks of ~300,000 particles in a 0.6 m³ volume, color coded with vertical velocity. Isosurfaces of Q-criterion show vortical structures.