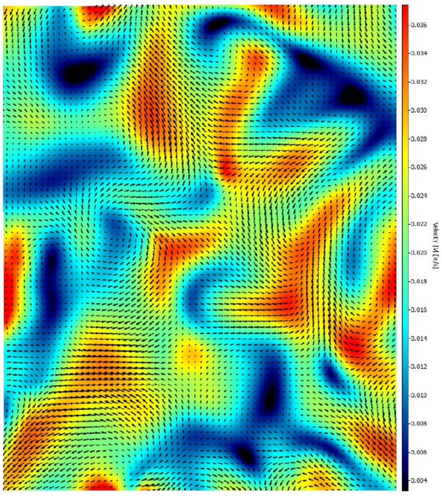
Experimental investigations on the small-scale structures in turbulent Rayleigh-Bénard convection

Wind storms, hurricanes, and heat waves, are atmospheric extreme events with a huge societal impact and significant economic costs. Extreme atmospheric convection events are characterized by large local amplitudes of the rate at which turbulent kinetic energy is dissipated, a central quantity that cannot be predicted from the highly nonlinear mathematical equations of fluid motion. This project aims at understanding the formation and predicting such extreme events of energy dissipation in Rayleigh-Bénard convection (RBC), a paradigm for atmospheric motion. Advanced measurements of the small-scale velocity field and its gradients will therefore be performed in a pressurized convection chamber at TU Ilmenau which allows to downscale turbulence and to use Particle Image Velocimetry for flows at Rayleigh numbers up to a million or higher. By combination of measured kinetic energy dissipation rate in the bulk and wall shear stresses in the boundary layer, we will identify the advection patterns that generate the extreme dissipation events. The present experimental analysis will be complemented by existing training data records of high-resolution direct numerical simulations of the same flows. They serve to develop data-driven methods and algorithms, such as recurrent neural networks, to predict such extreme events in experimental analyses. The goal of this project is to advance our understanding of the dynamic evolution of such extreme events in a RBC flow and to develop reliable tools to predict the events. This research objective will be reached in a multidisciplinary way by a combination of high-resolution optical flow measurements with the data-driven modeling and data analytics by machine learning.



Snapshot of velocity field from stereo-PIV at Ra = 2 × 10^4 in air, on a horizontal section of size 4*H* × 4.3*H* at the midplane of the cell. (*H*: height of the cell).