Global and local organization of the convective heat flux in turbulent Rayleigh-Bénard convection

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We investigate the global and local organization of the convective heat flux in a cubic Rayleigh-Bénard cell for Rayleigh numbers in the range $[10^6, 10^8]$. Two data-driven techniques, Proper Orthogonal Decomposition and Latent Dirichlet Allocation (Frihat et al., JFM 2021), are applied to a collection of snapshots consisting of 2D vertical and horizontal cross-sections. Latent Dirichlet Allocation is a soft clustering technique that provides a decomposition into motifs, which are characterized by their spatial distribution on the grid cells (see figure 1) as well as their prevalence in the snapshots. We first establish that the technique shows some robustness with respect to user-defined hyperparameters. We show that Latent Dirichlet Allocation can be used to generate a synthetic database, the statistics of which are in good agreement with the original snapshots. We then examine how the motifs evolve with the Rayleigh number. We find that the general spatial distribution of the motifs does not change, but that it is influenced by the boundary layer thickness and that the size of the motifs decrease with the Rayleigh number. We then investigate the connection between small-scale heat flux variations and the intermittent reorientations of the large-scale circulation. Using a simple model, we show that the time scale of the reorientations can be related with the prevalence of the dominant motifs. The model can be used to estimate reorientation rates from local time series over short periods much smaller than the average time between reorientations.

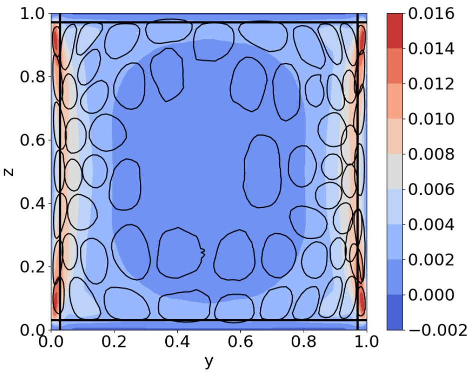

Figure 1: Spatial distribution of the dominant motifs in the vertical mid-plane at $Ra = 10^7$. The lines correspond to the iso-values of the distribution. The color contours correspond to the average heat flux.

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