THREE-DIMENSIONAL FLOW TOPOLOGY EVOLUTION IN TURBULENT RAYLEIGH-BÉNARD CONVECTION

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Small-scale dynamics is the spirit of turbulence physics. It delivers complex mechanisms when turbulence is purely sustained by buoyancy. This takes place in Rayleigh-Bénard convection (RBC). Most of the existing RBC dynamics is ruled by hard turbulent regime and a deep understanding of small scale dynamics with its relevant nonlinearities, is still unsatisfied. To do so, the 2D evolution of $Q_G = -1/2tr(G^2)$ and $R_G = -1/3tr(G^3)$, invariants of the velocity gradient tensor, $G = \nabla u$, are studied and reported in Dabbagh et al. [1] using DNS of RBC. In the present work, we expand the 2D $\{Q_G, R_G\}$ evolution to three dimensions by decomposing $R_G$ into its strain production $R_S = -1/3tr(S^3)$ and enstrophy production $tr(\Omega^2S) = R_S - R_G$ terms, where $S$ and $\Omega$ are the rate-of-strain and rate-of-rotation tensors, respectively. In the $\{Q_G, R_S, R_S - R_G\}$ space, the flow topology in a Lagrangian evolution is changing by the conditional mean trajectories (CMTs) $\{DQ_G/Dt, DR_S/Dt, D(R_S - R_G)/Dt\}$. Using the dataset in [1], and from Figure 1: An identified cyclical start of trajectories is distinguished in areas of vortex-stretching $R_S - R_G > 0$ and $R_S > 0$ in the strain dominated slots ($Q_G < 0$), which becomes stronger and longer expanded at Rayleigh number $Ra = 10^{10}$. Afterwards, the trajectories move downwards ($Q_G << 0$) in areas of vortex-compression $R_S - R_G < 0$ and $R_S > 0$, that also become more diverging at $Ra = 10^{11}$ as a result of the self-amplified straining [1]. This is followed by rising trajectories upwards ($Q_G > 0$) to continue performing the typical planner $\{Q_G, R_G\}$ cyclical behaviour [1], next to $R_S = 0$, and decaying towards the origin. DNS at $Ra = 10^{11}$ is currently being computed on the MareNostrum supercomputer [2]. Results will be presented during the conference.

**Figure 1:** CMTs of the evolution of $G$ in $\{Q_G, R_S, R_S - R_G\}$ space through the bulk region of turbulent RBC at $Ra = 10^8$ (left) and $10^{10}$ (right). The surface $D_G = (27/4)R_G^2 + Q_G^2 = 0$ is shown as a gray wire mesh.

**References**