Measured three-dimensional flow structure in turbulents Rayleigh-Bénard convection in slender cylindrical cells

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Abstract

Recent experiments and simulations have sparked growing interest in the study of Rayleigh–Bénard convection in very slender cells. One pivotal inquiry arising from this interest is the elucidation of the flow structure within these very slender cells. Here we employ tomographic particle image velocimetry, for the first time, to capture experimentally the full-field three-dimensional and three-component velocity field in a very slender cylindrical cell with aspect ratio =1/10. The experiments cover a Rayleigh number range 5.0x108 < Ra < 5.0x109 and Prandtl number 5.7. Our experiments reveal that the flow structure in the =1/10 cell is neither in the multiple-roll form nor in the simple helical form; instead, the ascending and descending flows can intersect and cross each other, resulting in the crossing events. These crossing events separate the flow into segments; within each segment, the ascending and descending flows ascend or descend side by side vertically or in the twisting manner, and the twisting is not unidirectional, while the segments near the boundary can also be in the form of a donut like structure. By applying the mode decomposition analyses to the measured three dimensional velocity fields, we identified the crossing events as well as the twisting events for each instantaneous flow field. Statistical analysis of the modes reveals that as Ra increases, the average length of the segments becomes smaller, and the average number of segments increases from 2.5 to 3.9 in the Ra range of our experiments.

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