Effects of anisotropy on the geometry of tracer particle trajectories in turbulent flows

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Using curvature and torsion to describe Lagrangian trajectories gives a full description of these as well as an insight into small and large time scales as temporal derivatives up to order 3 are involved. One might expect that the statistics of these properties depend on the geometry of the flow. Therefore, we calculated curvature and torsion probability density functions (PDFs) of Lagrangian trajectories obtained from experimental data using the Shake-the-Box algorithm[1]. We analyse three datasets, turbulent von Kármán flow, Rayleigh-Bénard convection and a zero-pressure-gradient (ZPG) boundary layer over a flat plate. The results for the von Kármán flow compare well with experimental results for the curvature PDF[2] and numerical simulation of homogeneous and isotropic turbulence for the torsion PDF[3]. For Rayleigh-Bénard convection, the power law tails found agree with those measured for von Kármán flow. Results for the logarithmic layer within the boundary layer differ. To detect and quantify the effect of anisotropy either resulting from a mean flow or large-scale coherent motions on the geometry of tracer particle trajectories, we introduce the curvature vector. We connect its statistics with those of velocity fluctuations and demonstrate that strong large-scale motion in a given spatial direction results in meandering rather than helical trajectories. For the turbulent boundary layer, this is commensurate with the current understanding of turbulent superstructures[4][5].

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