Public database-enabled analysis of Lagrangian time correlations in isotropic turbulence

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The advent of increasingly powerful supercomputers has presented both opportunities and challenges for high-fidelity direct numerical simulation of turbulence in recently years. It makes it possible to glean fundamental physical insight into fine-grained turbulence, whereas the generated massive datasets create serious new hard challenges and hamper practical numerical experiments due to the shortage of easy access to the vast amounts of data generated. In this talk, we briefly describe the new public database approach. One of its hallmarks is a Web services interface that allows a client to access data in a user-friendly fashion while allowing maximum flexibility to execute desired analysis tasks. We then present numerical experiments on Lagrangian temporal auto correlations in isotropic turbulence, based on the DNS data with $Re_\lambda=433$.

Using the web-based turbulence database, we track a large number of fluid particles (> 10,000) without expensive computational cost. 3D Particle trajectories visualize the complex turbulent motion. First, we focus on the Lagrangian time correlations of different turbulence properties including rate-of-strain, rate-of-rotation, pressure Hessian, velocity gradient, etc., which have been recognized as important statistics in the study of small-scale turbulent. We find that rotation rate has a significantly longer time correlation than strain rate, and meanwhile, velocity gradient is between strain rate and rotation rate. We also find that the diagonal pressure Hessian elements have longer time correlations than the off-diagonal pressure Hessian terms. Secondly, the so-called finite-time Cauchy-Green tensor is a key ingredient in a new model of the pressure and velocity Hessians required to close Lagrangian velocity gradient evolution equation (Chevillard & Meneveau, Phys. Rev. Lett. 2006). This model has been proven quite accurate for relatively low Reynolds numbers. However at high Re, significant discrepancies between model and DNS shows the need for more in-depth analysis of the various terms needed in the modeling.

Finally, we report on an extension of the database where we have recently included the forcing term in the equation to the database. We present an analysis of the various terms on the Navier-Stokes equations and show that addition of the force is important to consider at large scales, as expected.