TIFR Centre for Interdisciplinary Sciences
21 Brundavan Colony, Narsingi, Hyderabad 500075

Seminar

Studies of Turbulance structure and Turbulent Mixing using direct numerical simulations

Kartik Iyer

Georgia Institute of Technology

A large direct numerical simulation database spanning a wide range of Reynolds and Schmidt number is used to examine fundamental laws governing passive scalar mixing and turbulence structure. This talk focuses on some new results regarding the Kolmogorov small-scale phenomenology at Taylor scale Reynolds numbers as high as 650 with grid-spacing as small as the Kolmogrov length scale.

Turbulent mixing is important in a wide range of fields ranging from combustion to cosmology. Schmidt numbers range from O(1) to O(0.01) in these applications. The Schmidt number dependence of the second-order scalar structure function and the applicability of the so-called Yaglom's relation is examined in isotropic turbulence with a uniform mean scalar gradient. Evaluation of different terms in the scalar structure function budget equation assuming statistical stationarity in time shows that with decreasing Schmidt number, the low-to-moderate Peclet number regime becomes increasingly non-universal.

One of the few exact, non-trivial results in hydrodynamic theory is the so-called Kolmogorov 4/5th law. Agreement for the third order longitudinal structure function with the 4/5 plateau is used to measure the extent of the inertial range, both in experiments and simulations. Direct numerical simulation techniques to obtain the third order structure functions typically use component averaging, combined with time averaging over multiple eddy-turnover times. However, anisotropic large scale effects tend to limit the inertial range with significant variance in the components of the structure functions in the intermediate scale ranges along the Cartesian directions. The net result is that the asymptotic 4/5 plateau is not attained. Motivated by recent theoretical developments, an efficient parallel algorithm to compute spherical averages in a periodic domain has been developed. The spherically averaged third-order structure function is shown to attain the K41 plateau in time-local fashion, which decreases the need for running direct numerical simulations for multiple eddy-turnover times.

It is well known that the intermittent character of the energy dissipation rate leads to discrepancies between experiments and theory in calculating higher order moments of velocity increments. As a correction, the use of three-dimensional local averages has been proposed in the literature. Kolmogorov used the local 3D averaged dissipation rate to propose a refined similarity theory. An algorithm to calculate 3D local averages has been developed which is shown to scale well up to 32k cores. The algorithm, computes local averages over overlapping regions in space for a range of separation distances, resulting in N^3 samples of the locally averaged dissipation for each averaging length. In light of this new calculation, the refined similarity theory of Kolmogorov is examined using the 3D local averages at high Reynolds number and/or high resolution.

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12:00 PM (Tea/Coffee at 11:45 AM)

Seminar Hall, TCIS