Pressure fluctuations and small-scale intermittency in DNS at high resolution

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Abstract

Pressure fluctuations in turbulence are closely related to local flow structure as well as (through the gradients) to the statistics of acceleration which is highly intermittent. However, in part because of the Reynolds number requirements, detailed investigations of asymptotic scaling regimes (Batchelor 1951) have been difficult to achieve. In this talk we present results from direct numerical simulations of forced isotropic turbulence with 4096^3 grid points, and Taylor-scale Reynolds numbers (R_λ) up to about 1000. Data from R_λ above about 400 show gradual development of the $k^{-7/3}$ inertial range behavior in the pressure spectrum, consistent with experiments (Tsuji & Ishihara 2003). Our present interest is primarily to understand the nature of local flow conditions that correspond to large, negative pressure fluctuations (i.e. low-pressure regions) which characterize the negatively skewed probability density function (PDF). In particular, conditional expectations for given magnitude of pressure fluctuation show that low pressure is associated with more kinetic energy, and larger enstrophy as well as dissipation, i.e. events of strong intermittency which also make accurate sampling of the negative tails of the pressure PDF difficult. By contrast, high pressure is associated with conditions of near-stagnation with strong strain rate but little vorticity. We also observe that the conditionally-averaged dissipation for given pressure also shows much stronger Reynolds number dependence than conditional enstrophy. This is consistent with recent work (Donzis, Yeung & Sreenivasan 2008) which showed that, as the Reynolds number increases, the PDFs of dissipation and enstrophy become closer to each other. These results differ in most respects from the purely kinematic results for a Gaussian random field even when its energy spectrum is matched with that observed for the turbulent velocity.

The present investigation illustrates the potential of a number of large DNS datasets. These datasets have been made possible through deployment of massive computational resources and are available to other researchers on request. More details will be provided at the Conference.

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