Decaying turbulence in an active-grid-generated flow and comparisons with large-eddy simulation

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Abstract

Measurements of nearly isotropic turbulence downstream of an active grid in the Corrsin wind tunnel are performed as a high-Reynolds number ($Re_\lambda \approx 720$) update of the Comte-Bellot & Corrsin (1971) data set. Energy spectra at four downstream distances from the grid, ranging from $x/M = 20$ to $x/M = 48$, are measured and documented for subsequent initialization of, and comparison with, Large Eddy Simulations (LES). Data are recorded using an array of four X-wire probes which enables measurement of filtered velocities, filtered in the streamwise (using Taylor's hypothesis) and cross-stream directions. Different filter sizes are considered by varying the separation between the four probes. Higher-order statistics of filtered velocity are quantified by measuring probability density functions, hyper-flatness and skewness coefficients of two-point velocity increments. The data can be used to study the ability of LES to reproduce both spectral and higher-order statistics of the resolved velocity field. In this study, the Smagorinsky, dynamic Smagorinsky, and dynamic mixed nonlinear models are considered. They are implemented in simulations of decaying isotropic turbulence using a pseudospectral code with initial conditions that match the measured energy spectra at $x/M = 20$. Overall, it is found that the various LES models predict accurate low-order statistics of resolved scales in isotropic turbulence during the decay. For the spectral cutoff filter, the dynamic Smagorinsky model simulates the energy spectrum more closely at smaller wavenumber, and the dynamic mixed nonlinear model has closer agreement at large wavenumber. For the graded physical-space (Gaussian) filter, the dynamic mixed nonlinear model provides the best spectral results. The three models considered here underpredict the intermittency of longitudinal velocity increments at small distances. For transverse velocity increments, the models' predictions are closer to the measured values, but differ among themselves with the mixed nonlinear model predicting reduced intermittency. Comparisons of probability density functions of subgrid-scale dissipation and stresses from simulations and experimental data reveal pronounced differences among the different models.