DEVELOPMENT OF COUPLED LES/ODT TURBULENCE SIMULATION MODELS

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A relatively recent innovation in turbulence modeling is the one-dimensional turbulence (ODT) model of Kerstein [1]. ODT models simulate, with full spatial and temporal resolution, the turbulent transport and dynamic fluctuations in velocity and fluid properties that one might measure along a one-dimensional (1D) line of sight through an actual 3D turbulent flow. The fields defined on the 1D domain evolve by two mechanisms: (1) molecular diffusion, and (2) a sequence of instantaneous transformations, denoted `eddy events,' which represent turbulent stirring. Eddy events are a probabilistic function of the current instantaneous 1D velocity profiles, but each event in turn modifies these profiles. The resulting two-way coupling leads to complex behavior that emulates both the gross structure and the fine-grained intermittency of the 3D turbulent cascade. In particular, the phenomenology identified by Volker *et al.* [2] as being important for accurate LES subgrid closure is represented by the model.

Here we describe the development of coupled LES/ODT modeling approaches for turbulent flows. The LES/ODT coupling is a multi-scale bi-directional interaction where ODT functions as a complete, albeit simplified model for the small scale fluctuating velocities, while the LES captures the large-scale 3D features of the flow. The first successful application of these ideas has been as a near-wall closure model for LES of wall-bounded turbulent flows [3]. This formulation involves finely resolved wall-normal ODT lines that are embedded within each wall-adjacent LES cell, but which couple through the effect of eddy events with all LES cells that lie within approximately one LES filter width of the wall. Results are presented for calculations of turbulent channel flow at Reynolds numbers based on friction velocity ranging from 395 to 10,000. Recent efforts have focused on developing a more general LES/ODT modeling approach applicable in all regions of a turbulent flow, and several alternative formulations are being investigated. In one approach, all components of both the viscous and the LES subgrid stress tensor are computed directly from a 3-component ODT model that evolves during sub-LES-time step intervals. Coupling from LES to ODT occurs through an ODT reconstruction step that impresses the LES resolved velocity field onto the ODT domains without modifying the small-scale ODT substructure. In addition to describing the current LES/ODT modeling approaches, coupled LES/ODT simulations for the problem of isotropic turbulence decay are presented, discussed and compared to experimental data, and the direction of future research discussed.

References

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