The Nonlinear LES (nLES) Method:
A fundamental paradigm shift in turbulence modeling

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The talk will discuss the fundamental shift in turbulence-modeling paradigm represented by the Nonlinear LES (nLES) method. The method represents a "return-to-first-principles" in turbulence simulation, in that the artificial-viscosity paradigm, used by most turbulence models of the past half-century, is replaced by direct solution of the nonlinear terms in the original filtered Navier-Stokes and advection-diffusion equations. By solving $\overline{u_i u_j}$ and $\overline{u_j \phi}$ in their original forms, as *nonlinear advective* stresses rather than *linear viscous* stresses, the nLES method more closely reproduces the advective mechanism governing most momentum and energy exchange in real high Reynolds-number hydrodynamic turbulence. The talk will also outline the adaptive backscatter limiter that is used in the nLES approach to control numerical errors arising during an actual simulation. Finally, the talk will highlight two profound consequences of this paradigm shift. First, the nLES method is the only method that can reproduce, almost exactly, the local structure of momentum and energy transfer between the resolved and subgrid scales, with correlations exceeding $\rho > 0.99$, making the method particularly suited to combustion models that are parameterized by local values of the total scalar dissipation and/or total scalar variance. Second, the nLES method has demonstrated the first-ever capability of simulating high Schmidt-number turbulent mixing, providing in the process the first LES confirmation of k^{-1} scaling in scalar power spectra, originally predicted by G. K. Batchelor nearly 50 years ago.

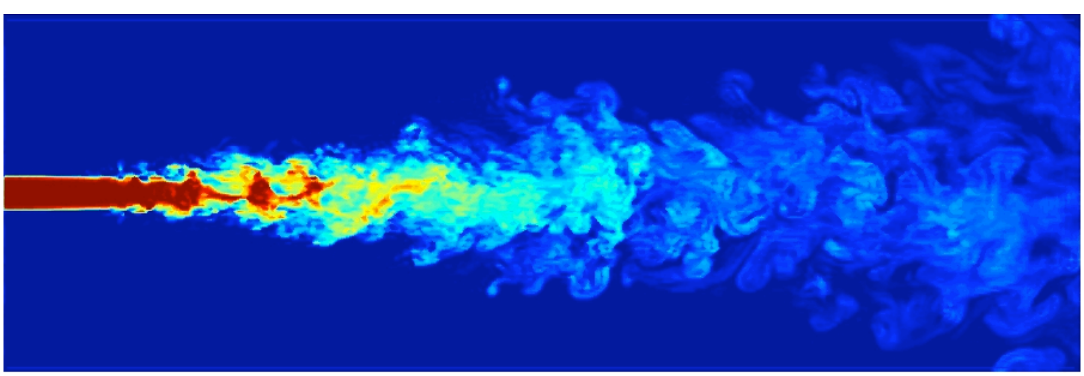

Figure 1: First-ever large-eddy simulation of high Schmidt-number turbulent mixing at $Re_D = 2000$ and $Sc = 1024$ using the nLES method, showing scalar-field cross-section.