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Variational and Multiscale Methods in Turbulence with Particular Emphasis on Large Eddy Simulation

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We present a review of progress in applying the Variational Multiscale Formulation to turbulent flows. We begin with a description of the type of engineering applications we are interested in and follow with a critical evaluation of the conventional approach to Large Eddy Simulation based upon the filtered equations. We then discuss modeling and consider the classic Smagorinsky model (inspired by Von Neumann). According to the analysis of Lilly, by discretizing into the inertial subrange, assuming a Kolmogorov spectrum, and equating model and turbulent dissipation, the parameters of the Smagorinsky model are determined. However, we argue that the effect is to dissipate too much energy from the large scales. The anatomy of the model is further elucidated by considering the Spectral Eddy Viscosity concept of Heisenberg. With this background, we argue that numerical analysis considerations suggest a multiscale framework for modeling. We then describe the Variational Multiscale Formulation, which obviates many of the shortcomings of the filtered equations and possesses enhanced potential for modeling. We demonstrate numerically that the simplest instantiations of the idea lead to significantly improved performance on homogeneous flows, and equilibrium and non-equilibrium turbulent channel flows. We mention in closing the results of some other investigators who have also obtained very good results with various implementations of the approach and we describe current research activities.

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