Quantifying Numerical Dissipation and Dispersion in Simulations of Turbulent Flows

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Results of numerical simulations of fluid flows are always contaminated by truncation errors introduced by the discretization of governing differential equations. Truncation errors are only negligible if all physical scales are well resolved by a given mesh and time-step size. For insufficient temporal or spatial resolutions, however, truncation errors can be of a similar magnitude as physical effects and can significantly affect interpretation of simulation results. This situation is most frequently encountered in numerical simulations of turbulent flows at high Reynolds numbers. Simulating such flows usually requires modeling contributions of unresolved scales by various turbulence modeling procedures, leading to Reynolds-Averaged Navier–Stokes (RANS) simulations or Large Eddy Simulations (LES). Recently it has become increasingly clear that the role of the truncation errors rarely can be ignored while using LES. The main effect of the truncation errors is dissipative and inhibits the predictive capabilities of LES because for typical Finite Difference and Finite Volume CFD codes it is of the same order of magnitude or larger than the physical subgrid-scale (SGS) dissipation. However, despite its importance in CFD there are no established methods to compute the numerical dissipation in general. In this talk we will present a procedure for estimating the numerical dissipation rate and the numerical viscosity acting in an arbitrary sub-domain of the computational domain for a general CFD code. Subsequently, we will demonstrate how the knowledge of the numerical dissipation can be used to improve DNS and LES predictions for several flows of increasing complexity, from unsteady flow around a sphere, to isotropic turbulence and a separation bubble flow containing laminar, transitional, and turbulent regions. Finally, we will describe how the original method can be generalized to estimate both numerical dissipation and dispersion errors in numerical solutions of a generic partial differential equation.