High-order finite-difference nonlinear filter methods for subsonic turbulence simulation with stochastic forcing

Alexei G. Kritsuk[a,*], Dmitry Kotov[c], Björn Sjögreen[b], Helen C. Yee[c]

[a]*University of California, San Diego*
[b]*Lawrence Livermore National Laboratory*
[c]*NASA Ames Research Center*

Abstract

Numerical stability of high-order filter schemes developed by Yee & Sjögreen is tested on three-dimensional turbulence simulations with stochastic forcing and their performance is compared with that of TVD and WENO schemes. The best-performing filter method employs an eighth-order central base scheme with the Kennedy & Gruber skew-symmetric splitting of the inviscid flux derivative, a wavelet-based local flow sensor, a nonlinear filter utilizing the dissipative portion of seventh-order WENO scheme, and an explicit third- or fourth-order Runge-Kutta time integration. We show that the filter scheme is more computationally efficient and provides a wider spectral bandwidth compared to the seventh-order WENO scheme. The method also demonstrates robust long-time integration for moderately compressible turbulence. In contrast, the the fifth- and seventh-order WENO schemes show non-trivial evolution of the velocity and density power spectra over a few dozen dynamical times, where both TVD and filter schemes recover a solid statistically stationary turbulent state.

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*Corresponding author
Email address: akritsuk@ucsd.edu (Alexei G. Kritsuk)