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Efficient WENOCU4 scheme with three different adaptive switches

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Key words:

WENOCU4; shock-capturing schemes; adaptive switch; numerical robustness; dissipation

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Objectives

1. Providing the reference value of parameter C for WENOCU4.
2. Providing the reference values of adaptive parameters Cmin and Cmax for the optimized EWENOCU4.
3. Systematically evaluating the comprehensive performance of three different switches which are used for dynamically adjusting parameter C.

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Methodology

- Three adaptive switches
  - Binary (CUT)

$$C=(1-\psi)\times(C\max-C\min)+C\min \qquad \psi=\begin{cases}1, & if\ \ \theta>\xi\\ 0, & \text{otherwise}\end{cases},\quad \xi=0.7$$

  - Continuous (CONT)

$$C=(1-\theta)\times(C\max-C\min)+C\min$$

  - Hyperbolic tangent (TANH)

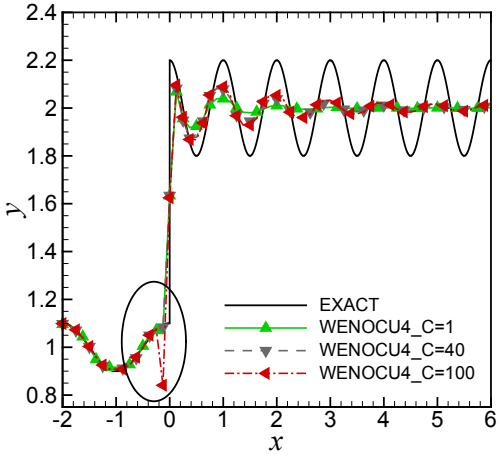
$$C=-\left(\frac{1}{2}\frac{\tanh(r_c\frac{\theta-r_d}{\max(\theta,|\theta-r_d|)})}{\tanh(r_c)}-\frac{1}{2}\right)\times(C\max-C\min)+C\min,\quad r_c=3,\quad r_d=0.5$$

- New shock sensor

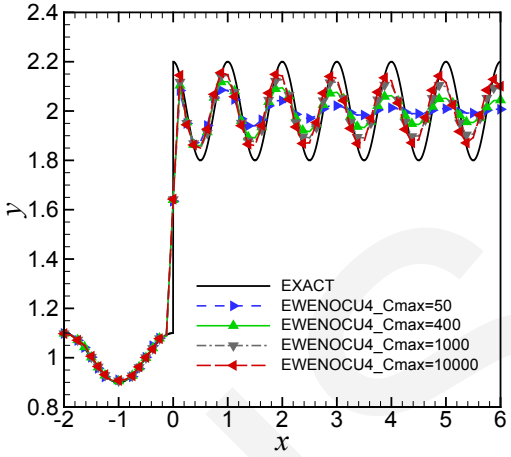
$$\theta=\frac{\sum_{l=0}^{\gamma-1}\left|\frac{\omega_\ell}{d_\ell}-1\right|^n}{\left|\frac{1}{\min_m d_m}-1\right|^n+(\gamma-1)}\ell,\quad m=0,\ldots,\gamma-1,$$

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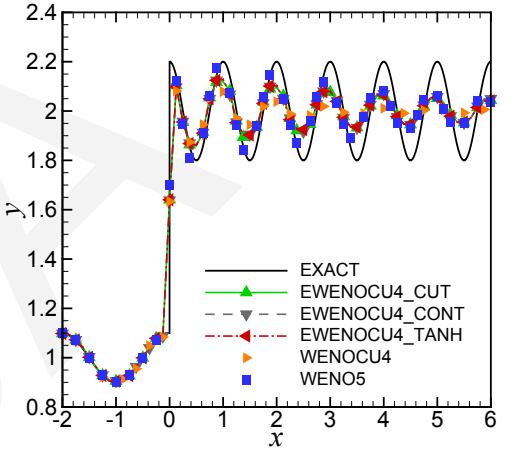
Results



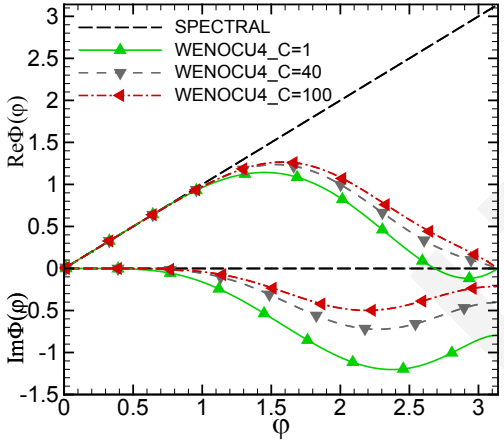
WENOCU4_1/40/100



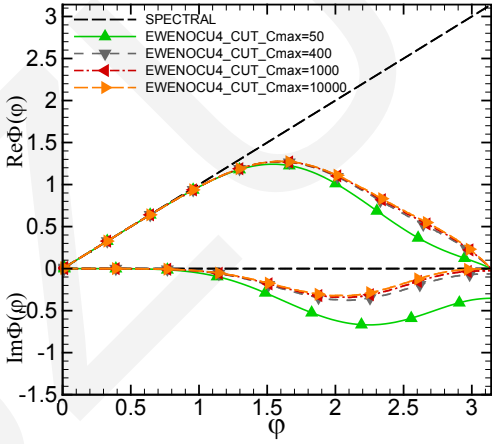
EWENOCU4_50/400/1000/10000



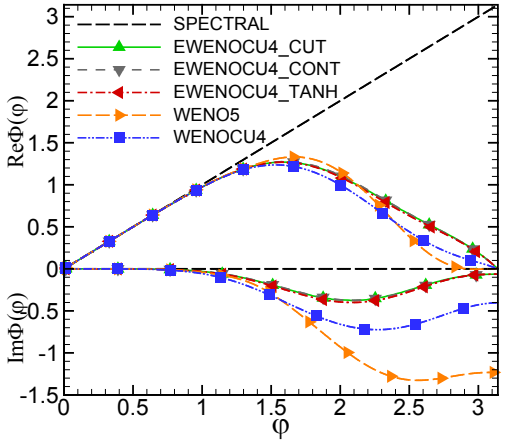
WENO5/WENOCU4/EWENOCU4



WENOCU4_1/40/100



EWENOCU4_50/400/1000/10000



WENO5/WENOCU4/EWENOCU4

Table 1 Estimated CPU time per grid point per time step for various schemes

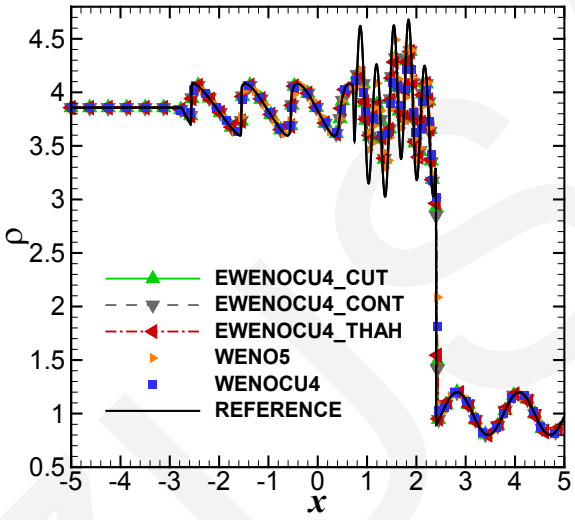
WENO5	WENOCU4	EWENOCU4_CUT	EWENOCU4_CONT	EWENOCU4_TANH
1	1.011	2.893	2.930	3.462

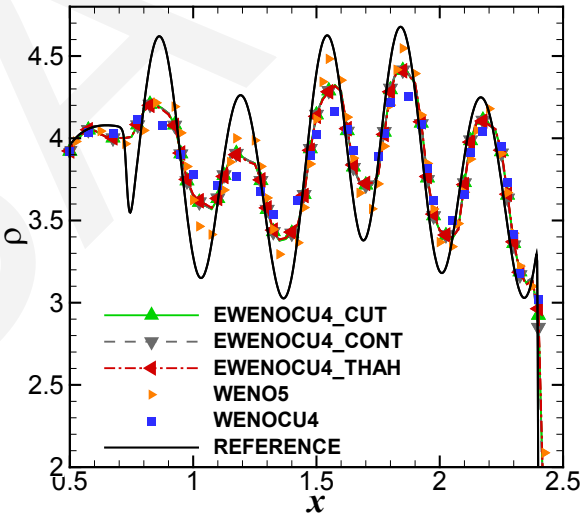
Results

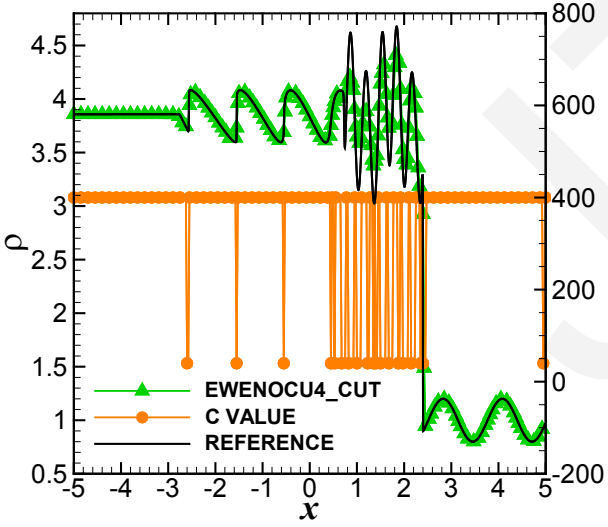
- 1-D Shock/entropy wave interaction Mesh:400

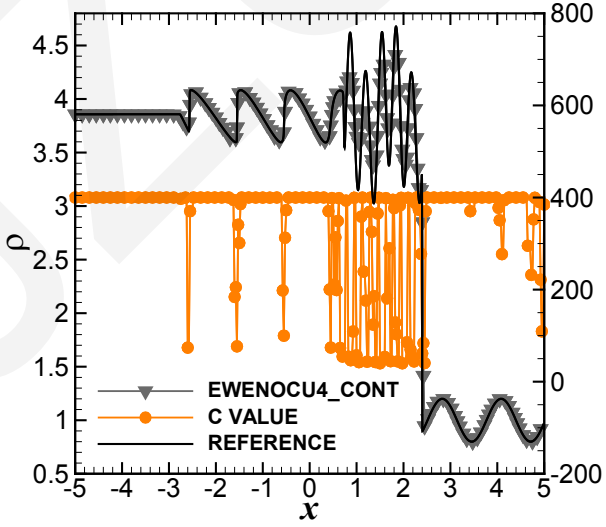
$C = C_{min} = 40$

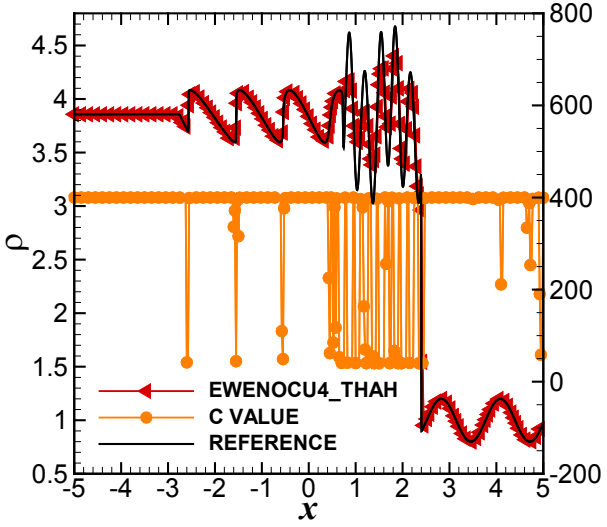
$C_{max} = 400$





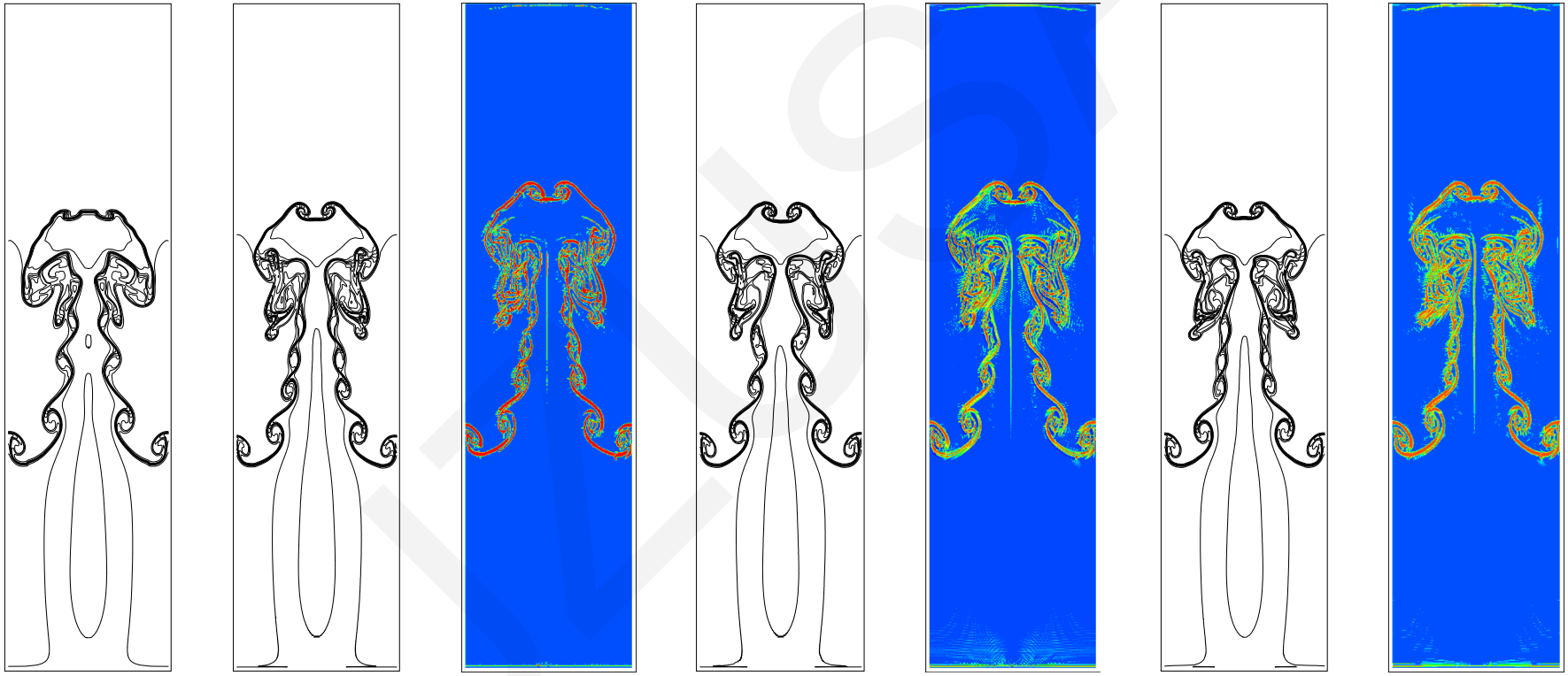






Results

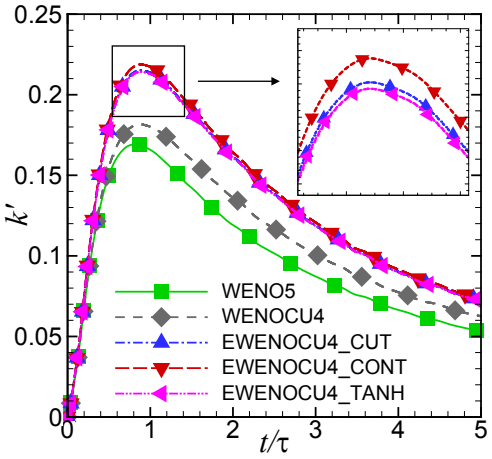
- 2-D Rayleigh-Taylor instability Mesh:240×960



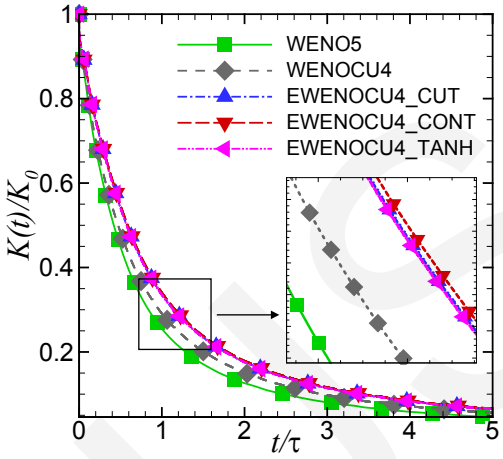
WENOCU4 EWENOCU4_CUT EWENOCU4_CONT EWENOCU4_THAH

Results

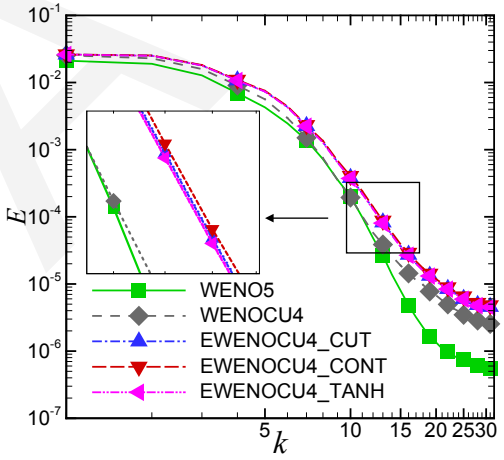
- 3-D Compressible Isotropic Turbulence Decay Mesh:64^3



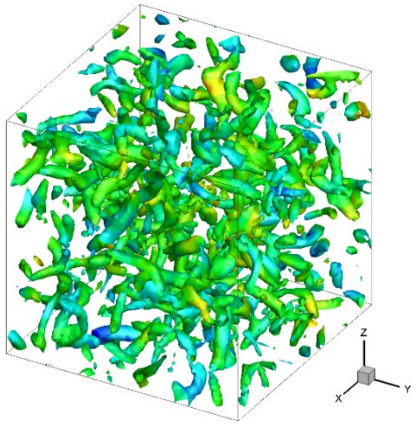
Time evolution of fluctuations.



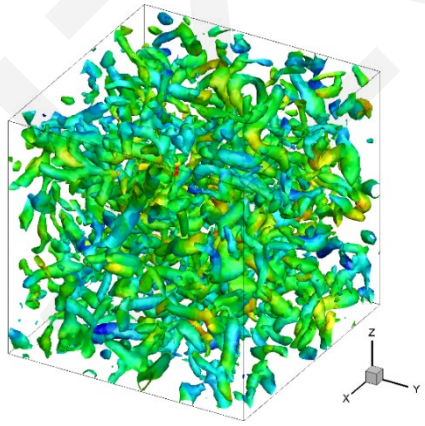
Time history of normalized average kinetic energy.



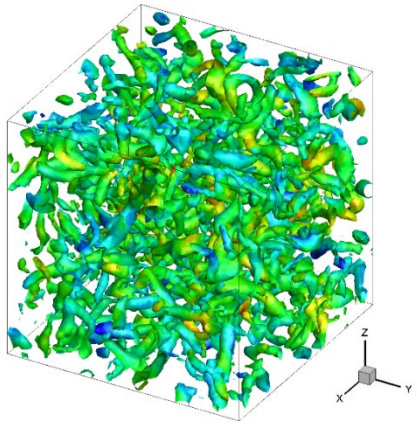
Wavenumber spectrum.



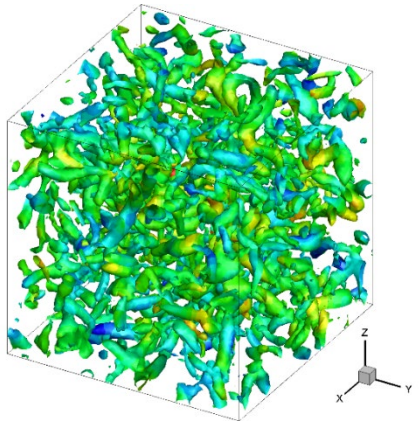
WENOCU4



EWENOCU4_CUT



EWENOCU4_CONT



EWENOCU4_THAH

Conclusions

1. C = 40 is a reasonable value for WENOCU4.

2. Cmax = 400 is a suitable value for adaptive switches.

3. EWENOCU4 with any type of adaptive switch exhibits obvious superiority compared to WENOCU4 and WENO5.

4. Employing the binary switch is a more cost-effective choice.

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