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Implicit LES using Weighted Compact Nonlinear Scheme

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Numerical Methods for Turbulent Flow

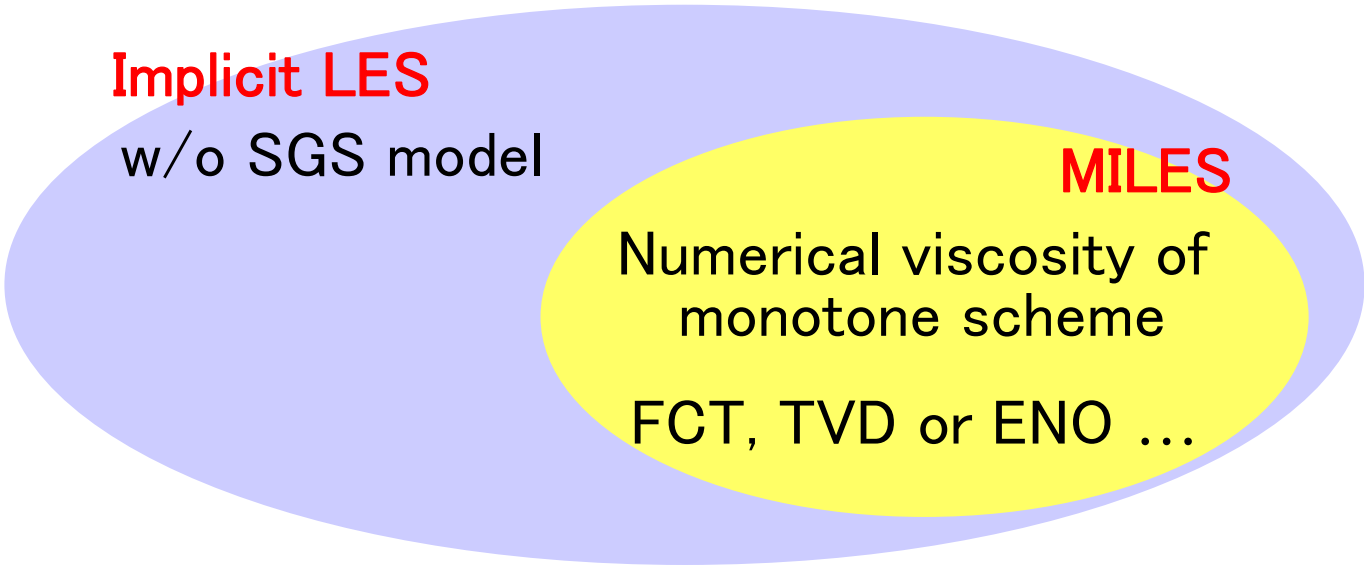
Large Eddy Simulation (LES)

- One of the major techniques
- Needs suitable SGS model
  - ・ Compressible turbulent flowfield involving shock wave

Implicit LES

- Not require SGS model
- Capable of wide application
  - ・ Compressible turbulent flowfield involving shock wave
- Monotonically Integrated LES (MILES) (Boris et al., 1992)
  - ・ Flux-Corrected Transport (FCT)

Implicit LES Using WCNS



Weighted Compact Nonlinear Scheme (WCNS)

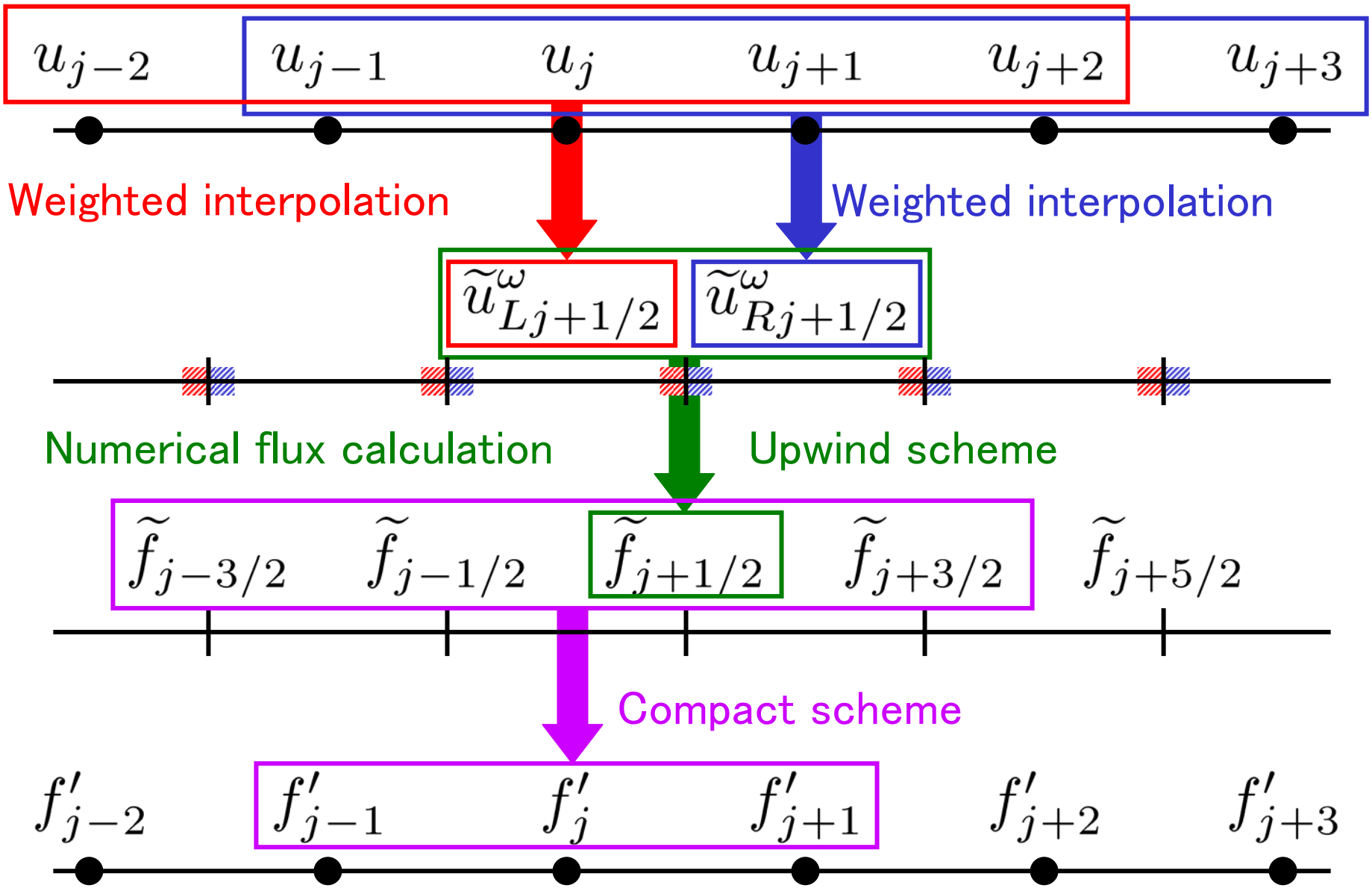
- Monotone scheme in MILES approach
- Shock capturing scheme developed by Deng et al. (2000)
- 5th-order compact scheme
- Weighted ENO like weighted interpolation
- High spatial accuracy even at discontinuities

Objectives

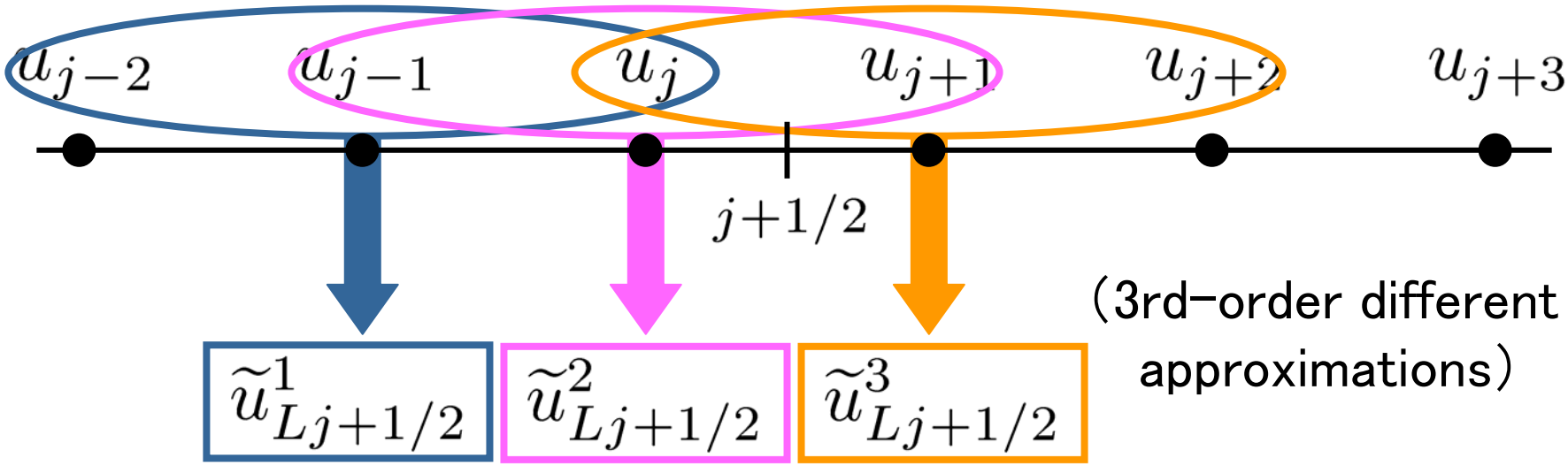
Verifications of implicit LES code using WCNS for typical test problems

- 1D Burgers turbulence
- 2D homogeneous turbulence

Weighted Compact Nonlinear Scheme



Weighted Interpolation

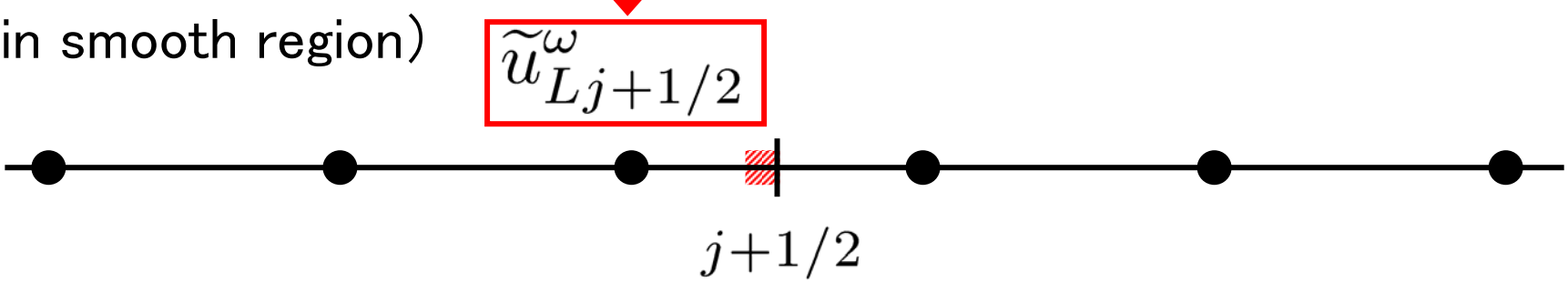


(3rd-order different approximations)

$$\widetilde{u}^{\omega}_{Lj+1/2} = \omega_{L1}\widetilde{u}^1_{Lj+1/2} + \omega_{L2}\widetilde{u}^2_{Lj+1/2} + \omega_{L3}\widetilde{u}^3_{Lj+1/2}$$

ω_{Ll} : Weights
(5th-order accurate in smooth region)

Determined from gradient and curvature at grid point j



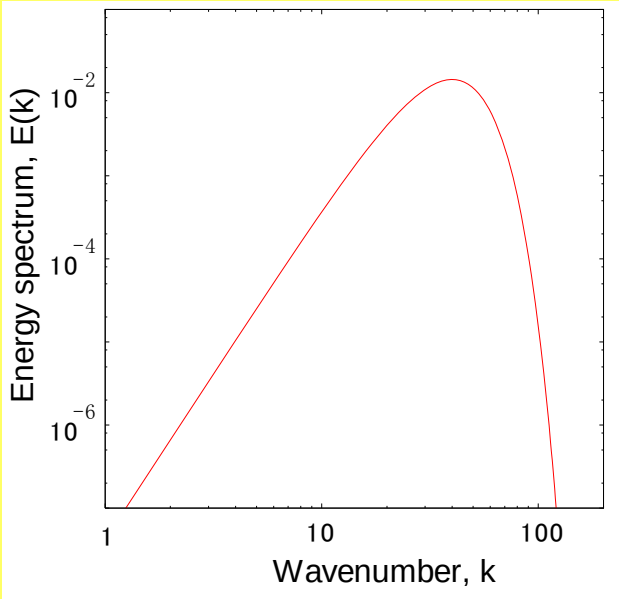
1D Burgers Turbulence

$$\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}\left(\frac{u^2}{2}\right) = \nu \frac{\partial^2 u}{\partial x^2}$$

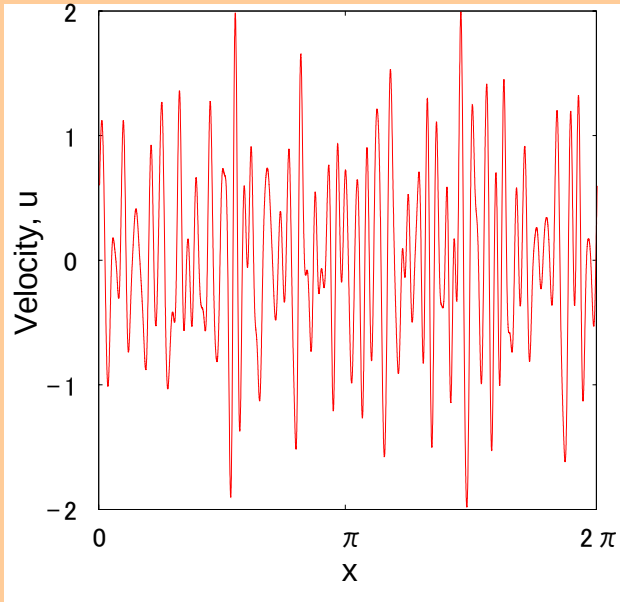
Coefficient of viscosity

$$\nu = 5 \times 10^{-5}$$

Initial energy spectrum



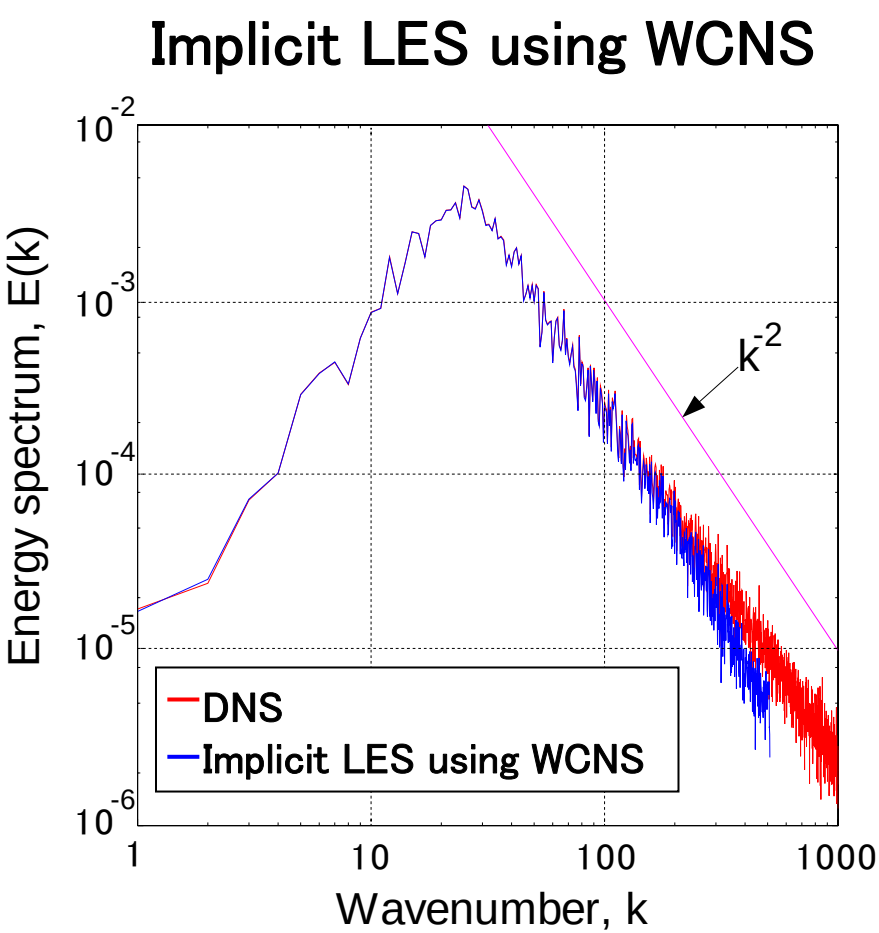
Initial velocity profile

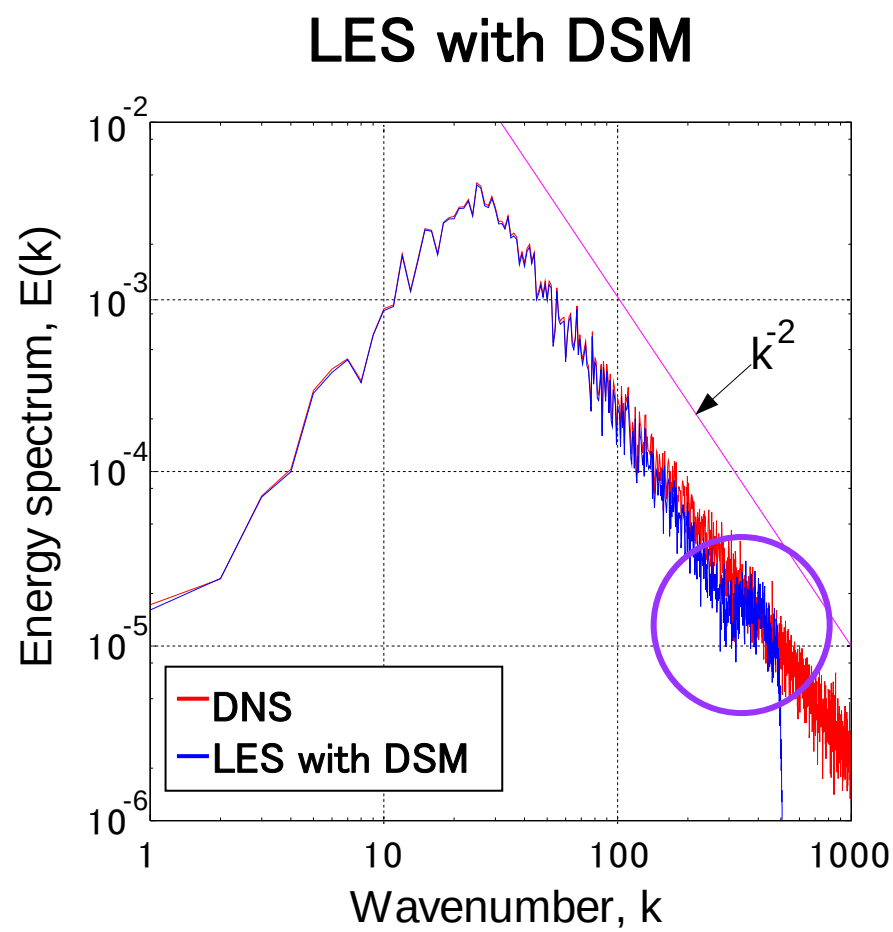


Comparison

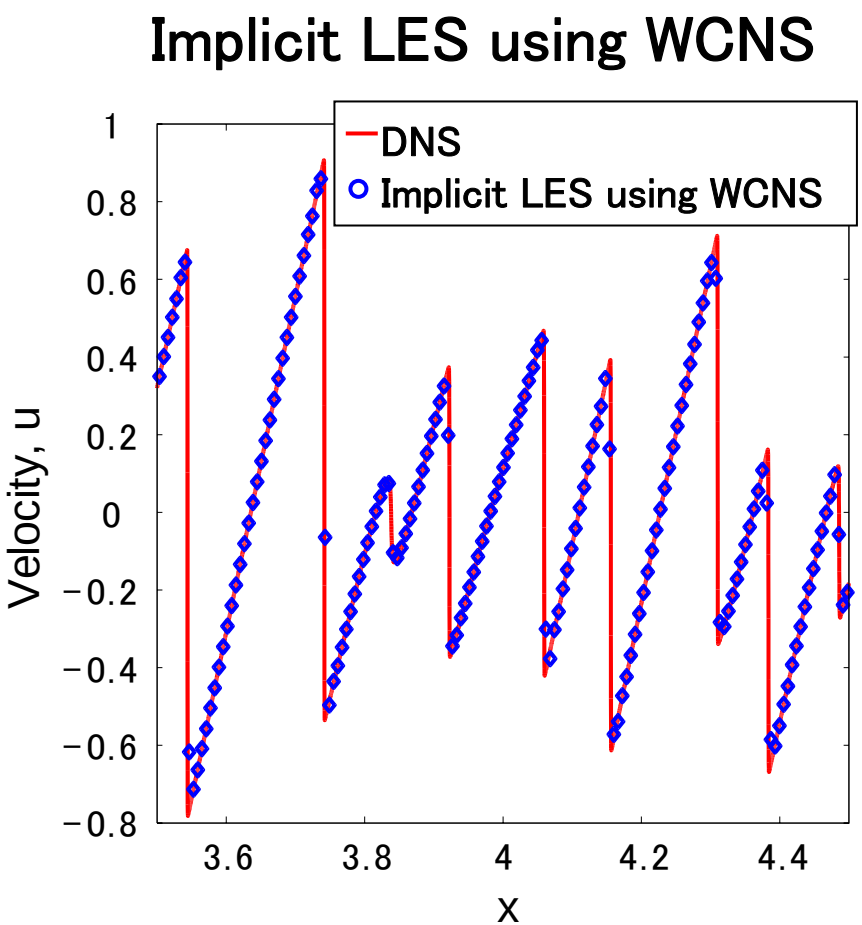
- Implicit LES using WCNS
- LES with Dynamic Smagorinsky Model
- DNS

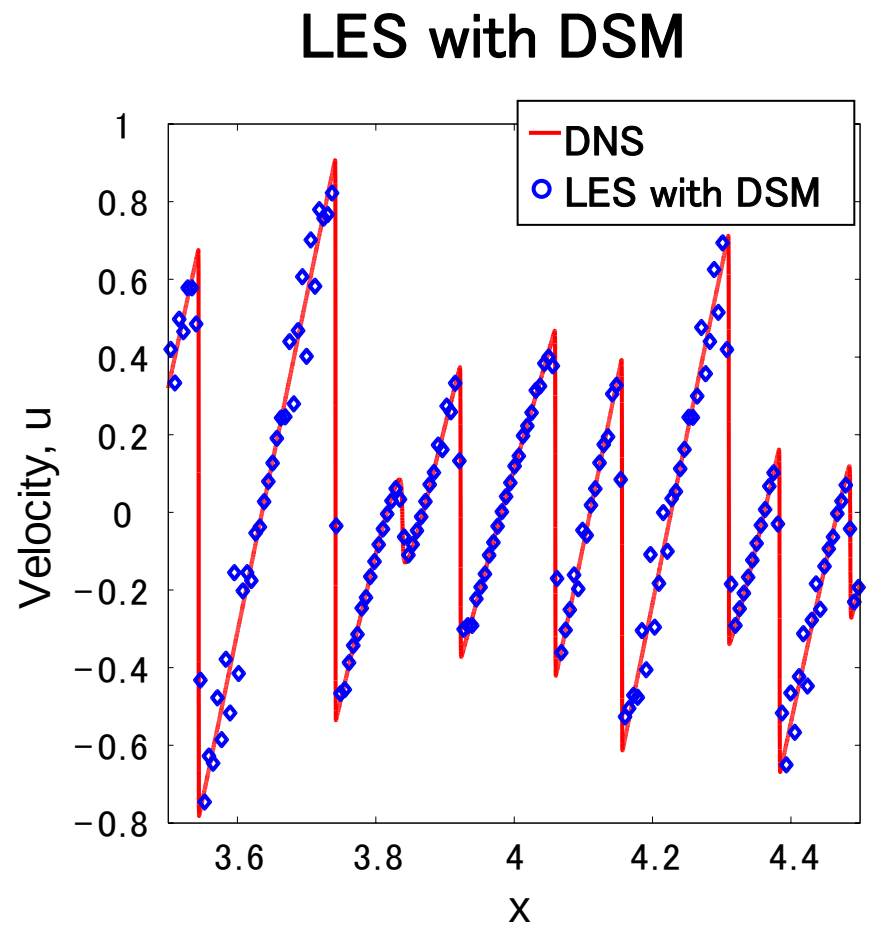
Energy Spectra





Velocity Profiles





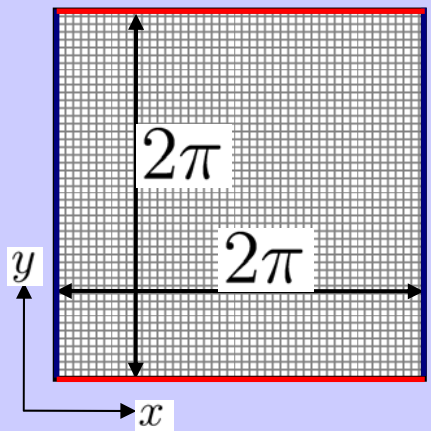
2D Homogeneous Turbulent Flow

$$\begin{cases} \dfrac{\partial \mathbf{u}}{\partial t} + \nabla \cdot (\mathbf{u}\mathbf{u}) = -\nabla p + \nu \nabla^2 \mathbf{u} \\ \nabla \cdot \mathbf{u} = 0 \end{cases}$$

Initial Reynolds number

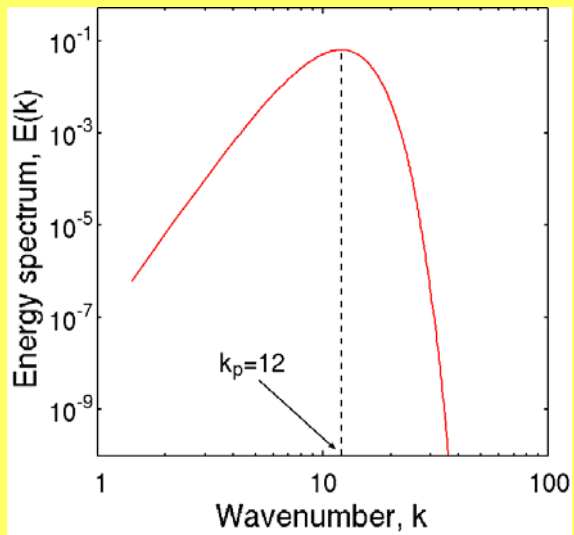
$$R\,(t=0) = 2048$$

Computational domain

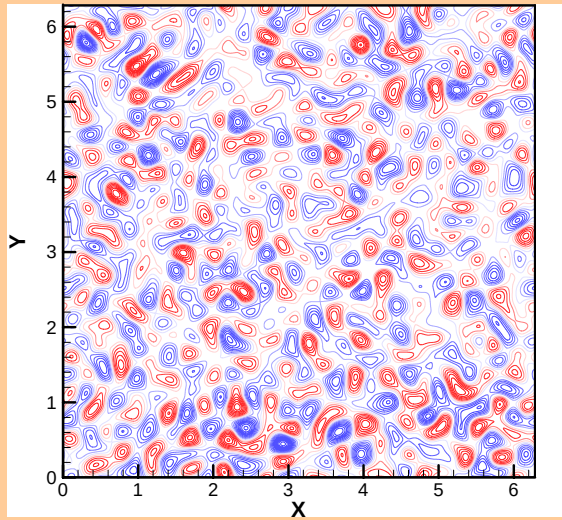


Uniform Cartesian grid with a periodic boundary condition

Initial energy spectrum



Initial vorticity contours



Comparison

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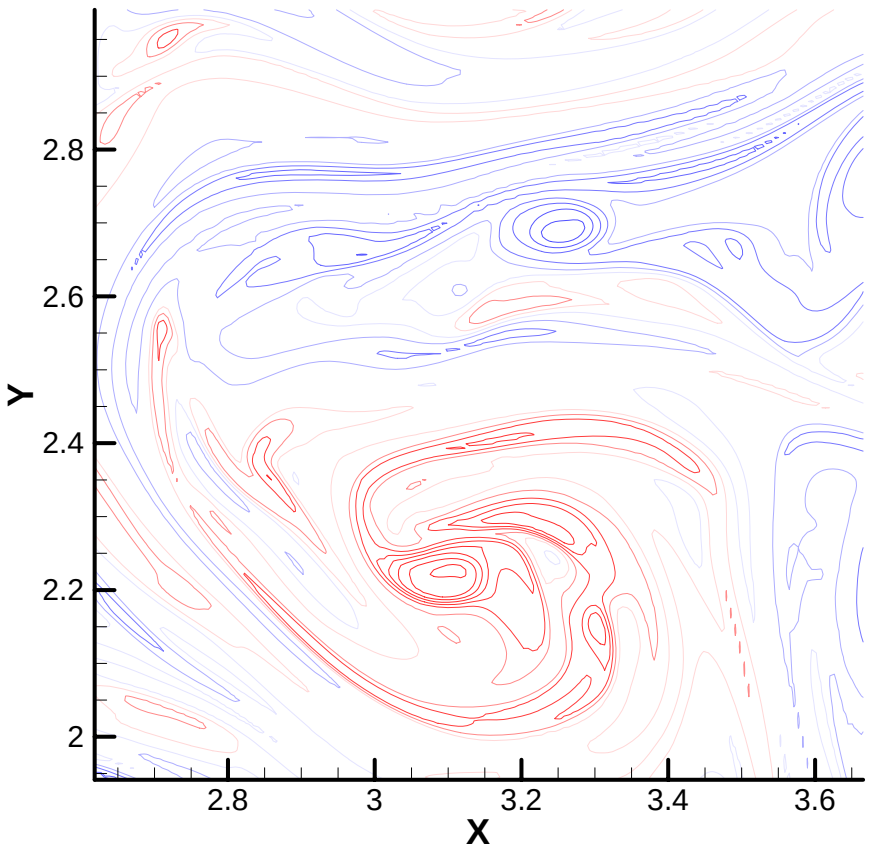
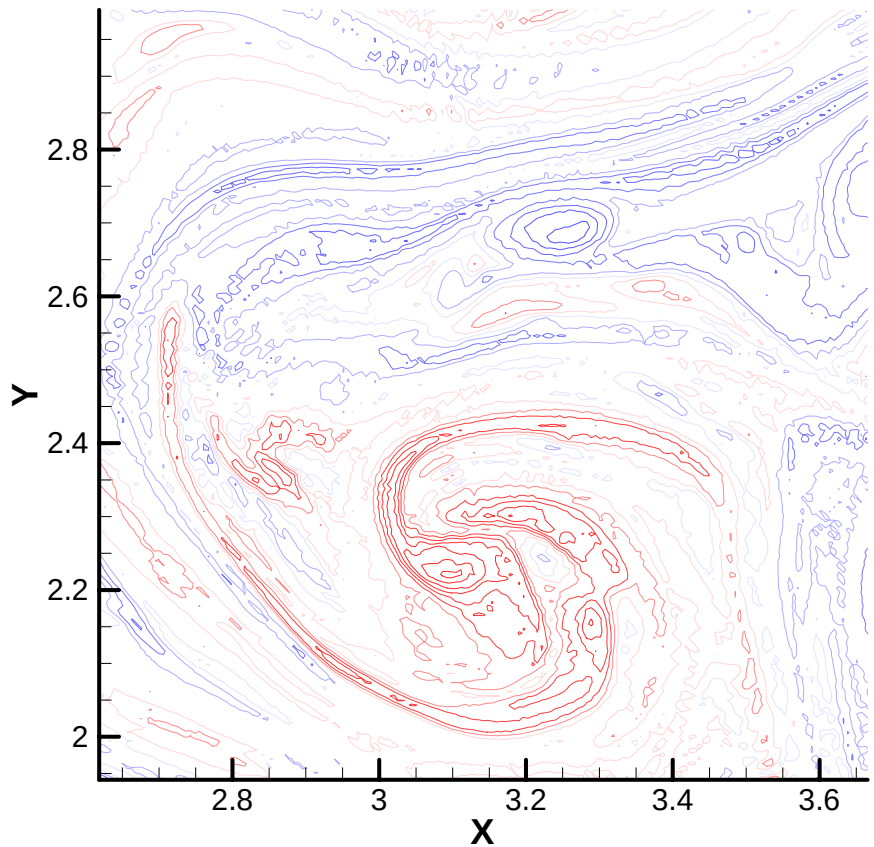
Vorticity Contours (Close up view)

Implicit LES using WCNS



LES with DSM



Conclusions

Verifications of implicit LES code using WCNS for 1D Burgers turbulence and 2D homogeneous turbulence were carried out

- Velocity profiles and vortices are sharply captured without any numerical oscillations

- Computed energy spectrum in inertial range agrees quite well with that obtained by DNS

- Obtained energy spectrum at shortest wave length is shown to be truncated quite naturally

Thank you for your kind attention