Implicit Turbulence Modeling

(The Magic of Nonoscillatory Finite Volume Approximation)

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Nonoscillatory Finite Volume Approximation

1) Finite Volume Approximations
- AKA flux form differencing, conservative differencing.
- Solves equations in integral form.
- Ref: Leveque, Finite Volume Methods

2) Nonoscillatory Methods
- Preserve monotonicity, positivity
- Ensure the 2^{nd} Law locally
- Examples: FCT, PPM, Godunov, WENO, MPDATA

3) Mimetic Methods
- Discrete calculus

Advantages of NFV Methods

- **Nonlinearly stable (N)**
- **Exactly conserves mass, momentum, energy (FV)**
- **Implicit turbulence modeling (NFV)**
- **Spatially unsplit**
- **Discrete calculus**
- **Efficient on MPP platforms**

Implicit Turbulence Modeling

- **First pioneered by Boris for plasmas (MILES) late 1980s** *very controversial*

- **Early results:**

  Youngs, fluid instabilities
  Woodward, astrophysical jets
  Margolin & Smolarkiewicz, atmospheric physics

- **Justification: Finite Scale theory, Margolin & Rider (2002)**

- **Book: Implicit Large Eddy Simulation, Grinstein, Margolin, & Rider (2007)**

Finite Scale Theory

Question: If every point in a volume (e.g., computational cell) obeys Navier-Stokes equations, what equations do the *averages* of mass, energy, momentum obey?

Answer: Finite scale equations – Navier-Stokes plus new terms representing the noncommutativity of averaging and nonlinearity.

The derivation (M&R 2002) is based on a novel combination of renormalization and inductive reasoning.

Modified equation analysis shows that NFV schemes simulate the finite scale equations.

Energy/Dissipation for Decaying Turbulence

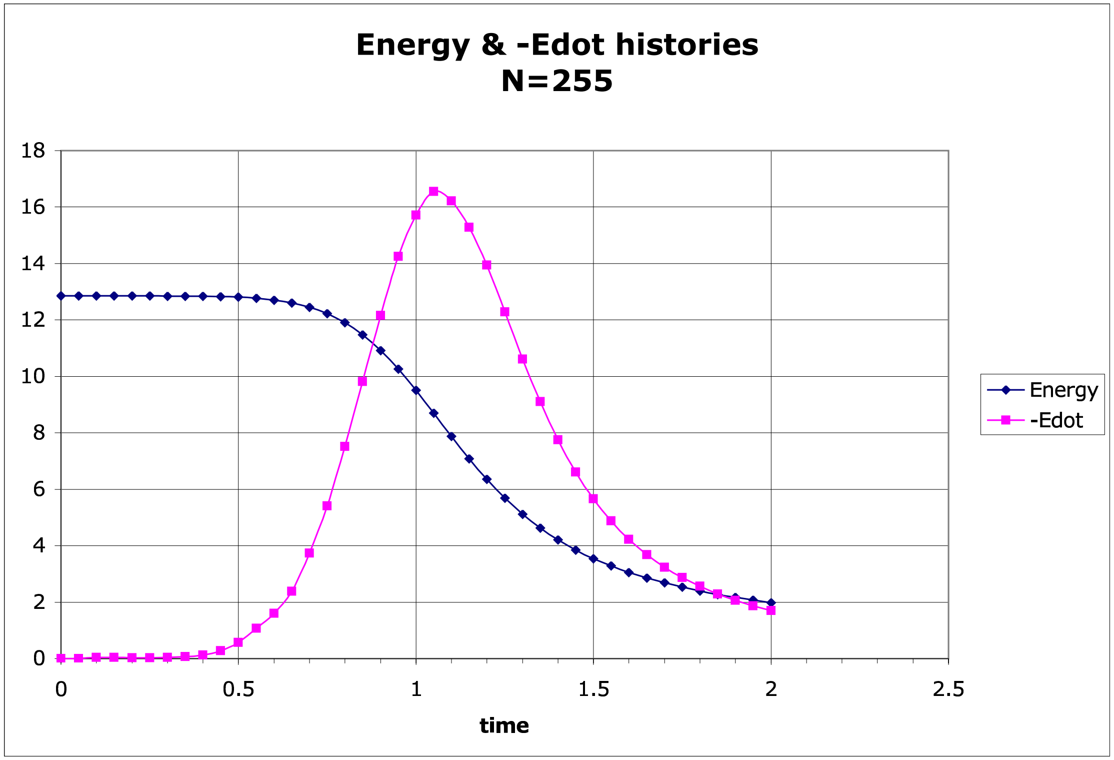

Figure 1: MPDATA simulation, N=255

Kolmogorov's $4/5^{th}$ Law

Shows that the energy dissipation rate is independent of physical viscosity, but is determined by the large scales of the flow.

$$3 < u_x^3 >= -\frac{4}{5}\frac{\epsilon}{\Delta x^2}$$

where

$$\epsilon = \frac{\partial}{\partial t}\left(u^2 + v^2 + w^2\right)$$

time	1.00	1.25	1.50	1.75	2.00
$-15 < u_x^3 > \delta x^2/(4\epsilon)$	0.785	0.933	1.028	1.054	1.019

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Potential Drawbacks

1) Scientific: Finite scale equations for MHD have not been derived. (No reason to believe it couldn't be done.)

Reverse Engineering: Margolin & Rider, 2004.

2) Practical: Important members of the classical turbulence modeling community are still skeptical.

Fortifying quotes

”Progress always involves risks. You can’t steal second base and keep your foot on first. ” **Frederick B. Wilcox**

”At every crossroads to the future there are a thousand self-appointed guardians of the past.” **Betty MacQuitty**

”Science progresses, funeral by funeral.” **Niels Bohr**


FRAUD!
SWINDLER!
TAKE YOUR ENLIGHTENMENT VALUES SOMEWHERE ELSE!
ELECTRICITY'S A HOAX!
NEXT HE'LL START PRESCRIBING SOME KIND OF LIGHTNING PROTECTION SYSTEM!
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