Implementation of a Non-Hydrostatic, Adaptive-Grid Dynamics Core in the NCAR Community Atmospheric Model

William J. Gutowski, Jr.[1]
Babatunde J. Abiodun[2]
Joseph M. Prusa[3]
Piotr Smolarkiewicz[4]

[1]Iowa State University, Ames, IA
[2]University of Cape Town, South Africa
[3]Teraflux Corp., Boca Raton, FL
[4]National Center for Atmospheric Research, Boulder, CO

Outline

- Features of EULAG Dynamics Core
- EULAG Baroclinic Wave Test
- CAM-EULAG Aqua-Planet

EULAG Features

- Nonoscillatory, Forward in Time (NFT) model integration algorithm, with optional semi-Lagrangian and fully conservative Eulerian variants.

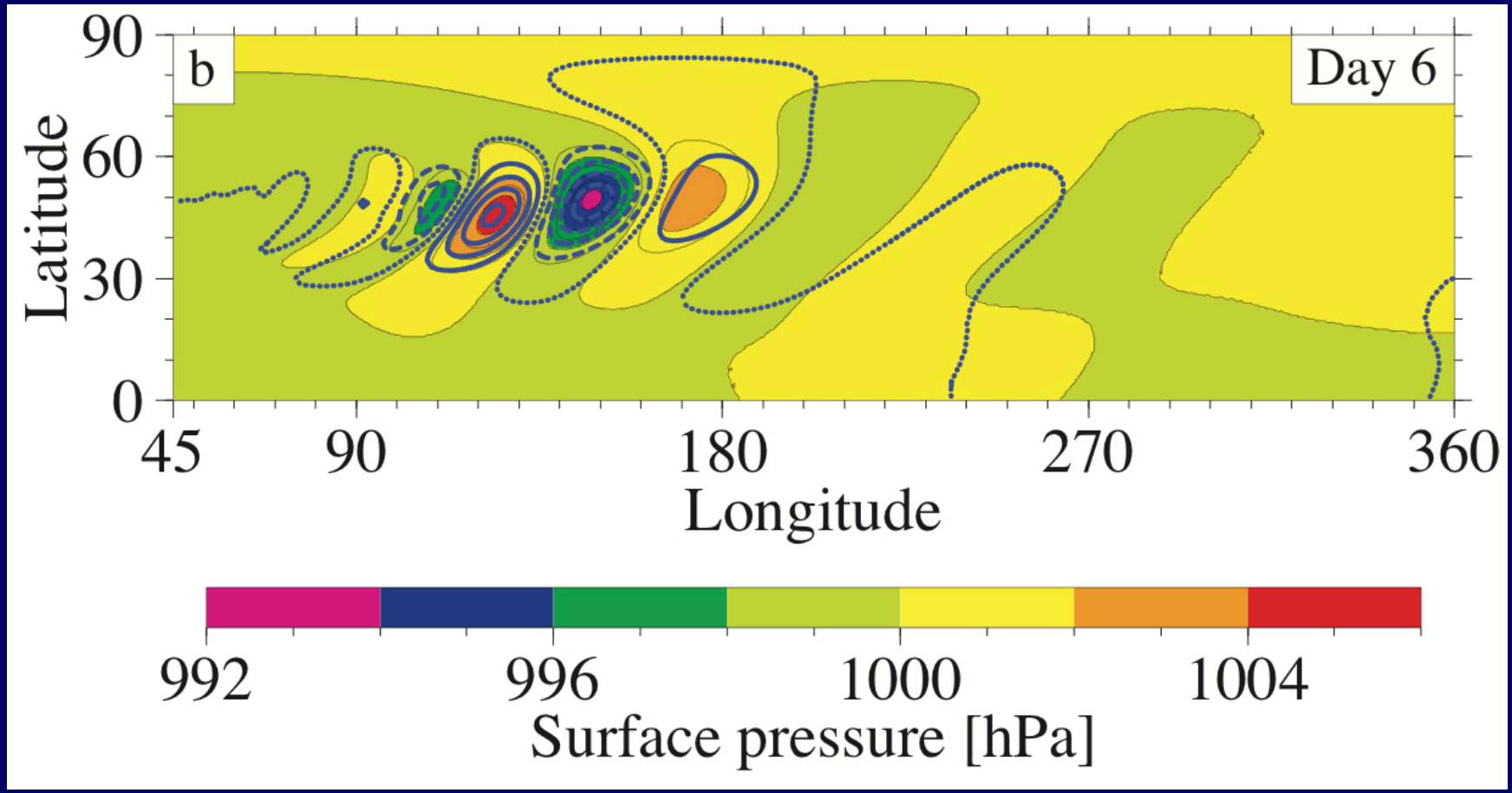
- Tensor formalism underlies numerical model, enabling static and dynamic grid stretching with uniformly 2^{nd} order accuracy.

- Robust preconditioned, non-symmetric Krylov solver for pressure: inverts stiff full elliptic problems to a round-off error (viz. exact projection).

EULAG Features

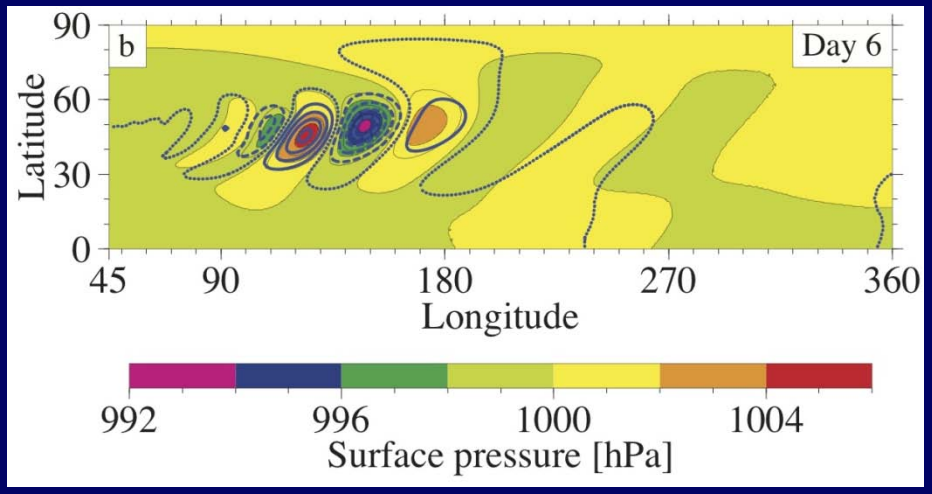
- Trapezoidal-rule integrals for gravity-rotation and condensation amplify accuracy for well defined physics.
- Monotone, positive-definite advection (MPDATA)
- Continuous (t,x)-refinement without degrading MPP
- DNS, LES, and ILES turbulence models as options
- Default nonhydrostatic, deep moist anelastic approximation; a variety of gov. equations available for dynamics (dry), including Eulerian conservation laws for high-speed flows.

Baroclinic Wave Test – Day 6

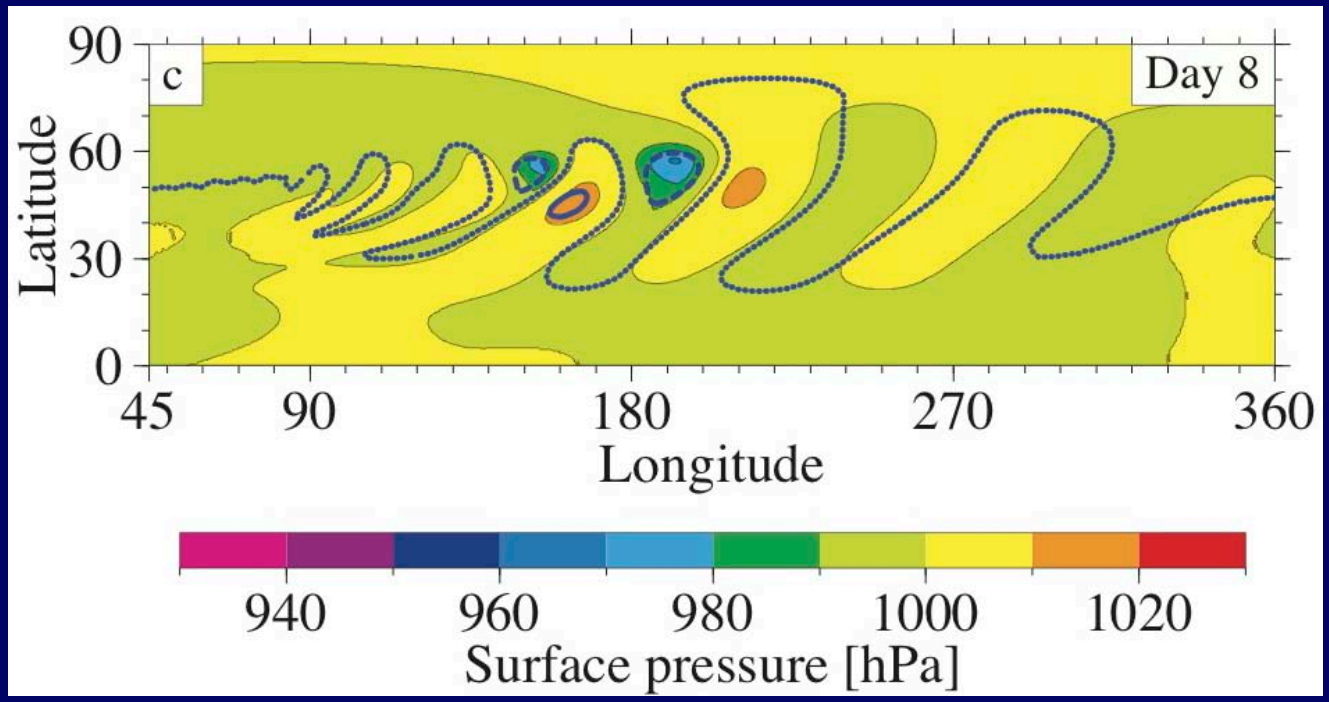


- Color: Jablonowski & Williamson (2006)
- Lines: EULAG simulation

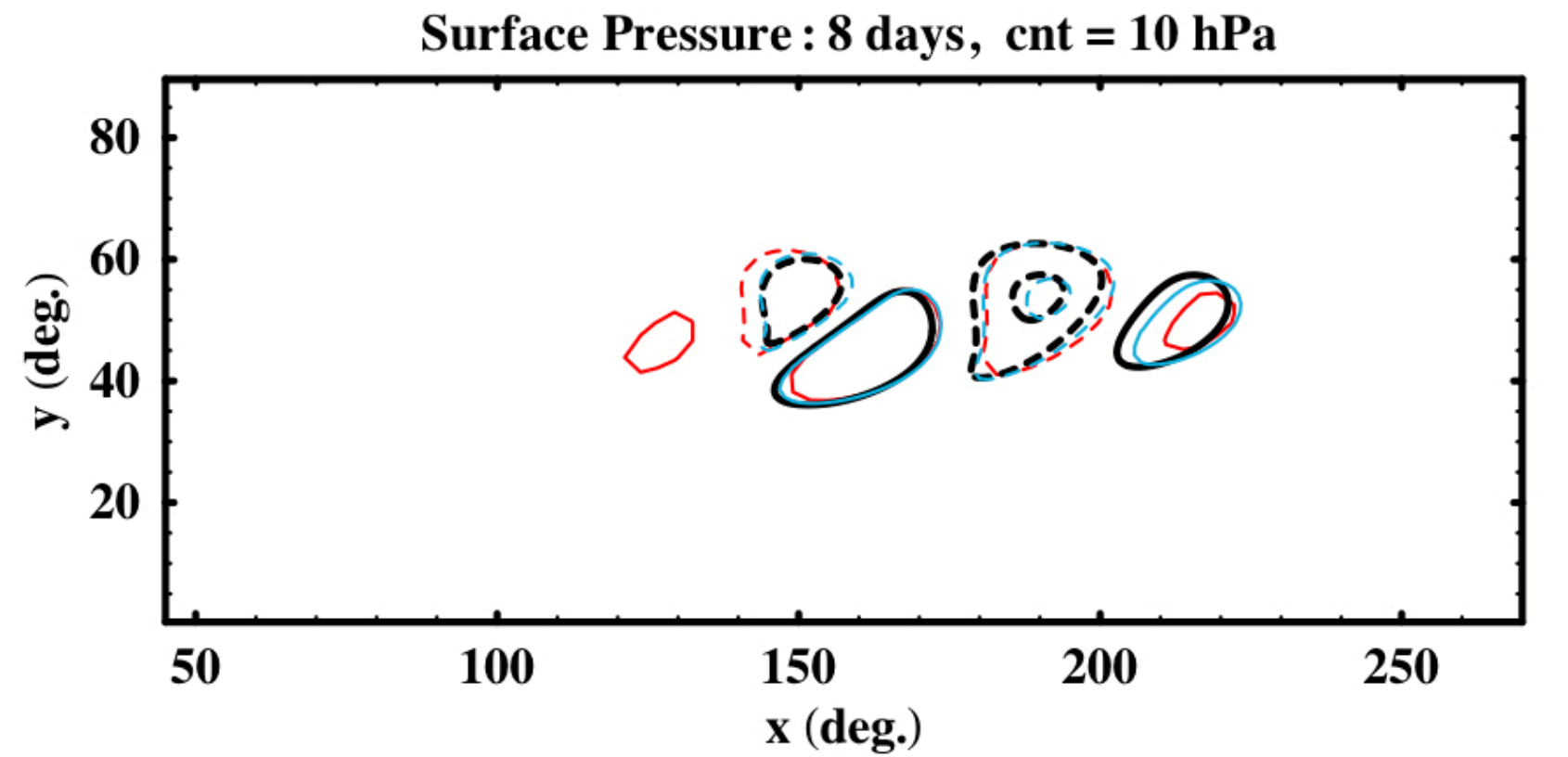
Baroclinic Wave Test



- Color: Jablonowski & Williamson (2006)
- Lines: EULAG simulation



Baroclinic Wave Test



Convergence with resolution:

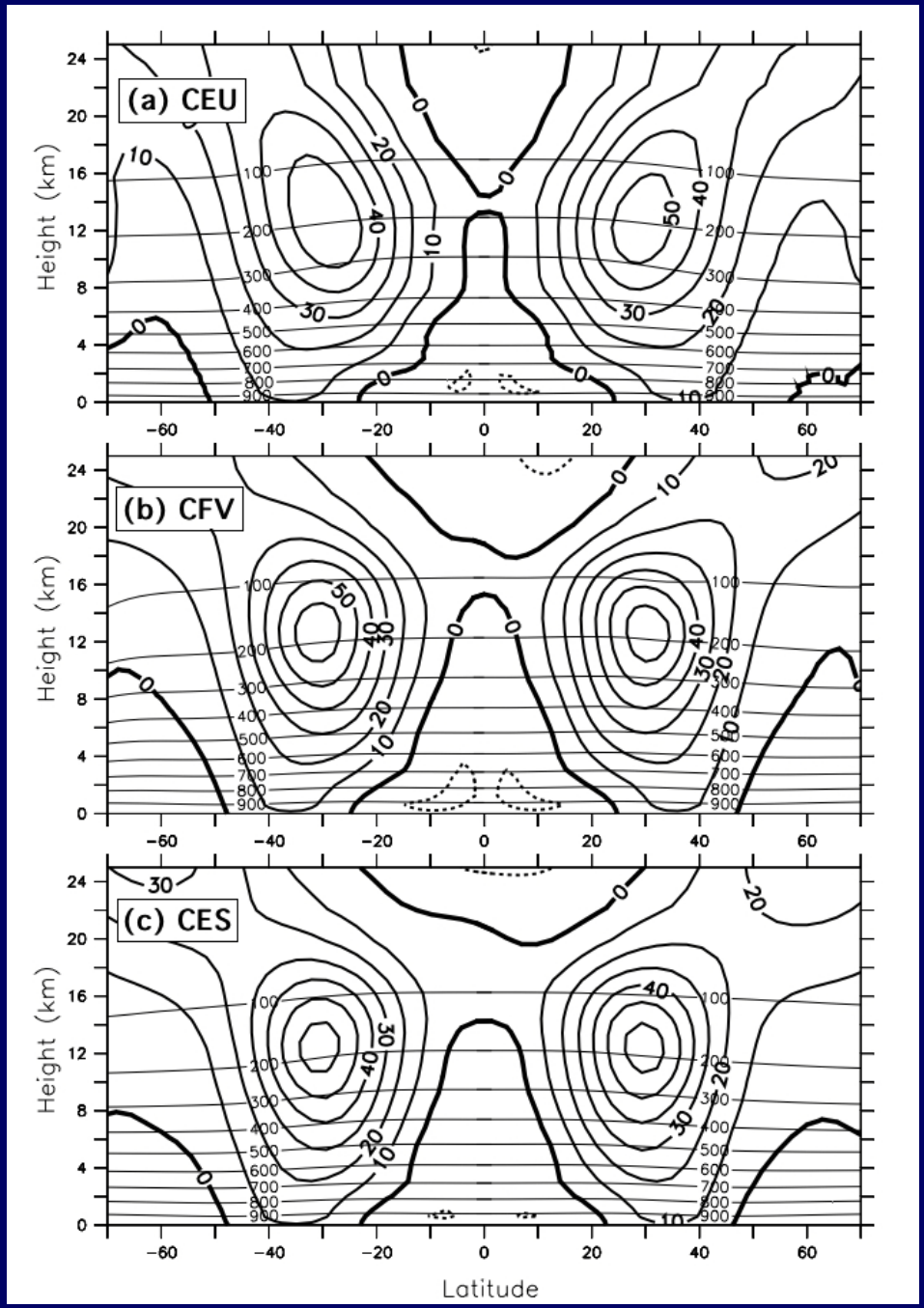
- Red – 2.8˚
- Blue – 1.4˚
- Black – 0.7˚

Aqua-Planet Simulation

- Cores: EULAG, FV and ESP
- Experiment: Aqua-planet
- Forcing: Idealized, zonally symmetric SST
- Horizontal resolutions : 2˚x2.5˚ [EULAG, FV] and T42 [ESP]
- Vertical grid: 26 levels
- Time step: 600s (EULAG), 900s (FV and ESP)
- Initialization: Eulag started from rest, FV and ESP from their standard initial conditions

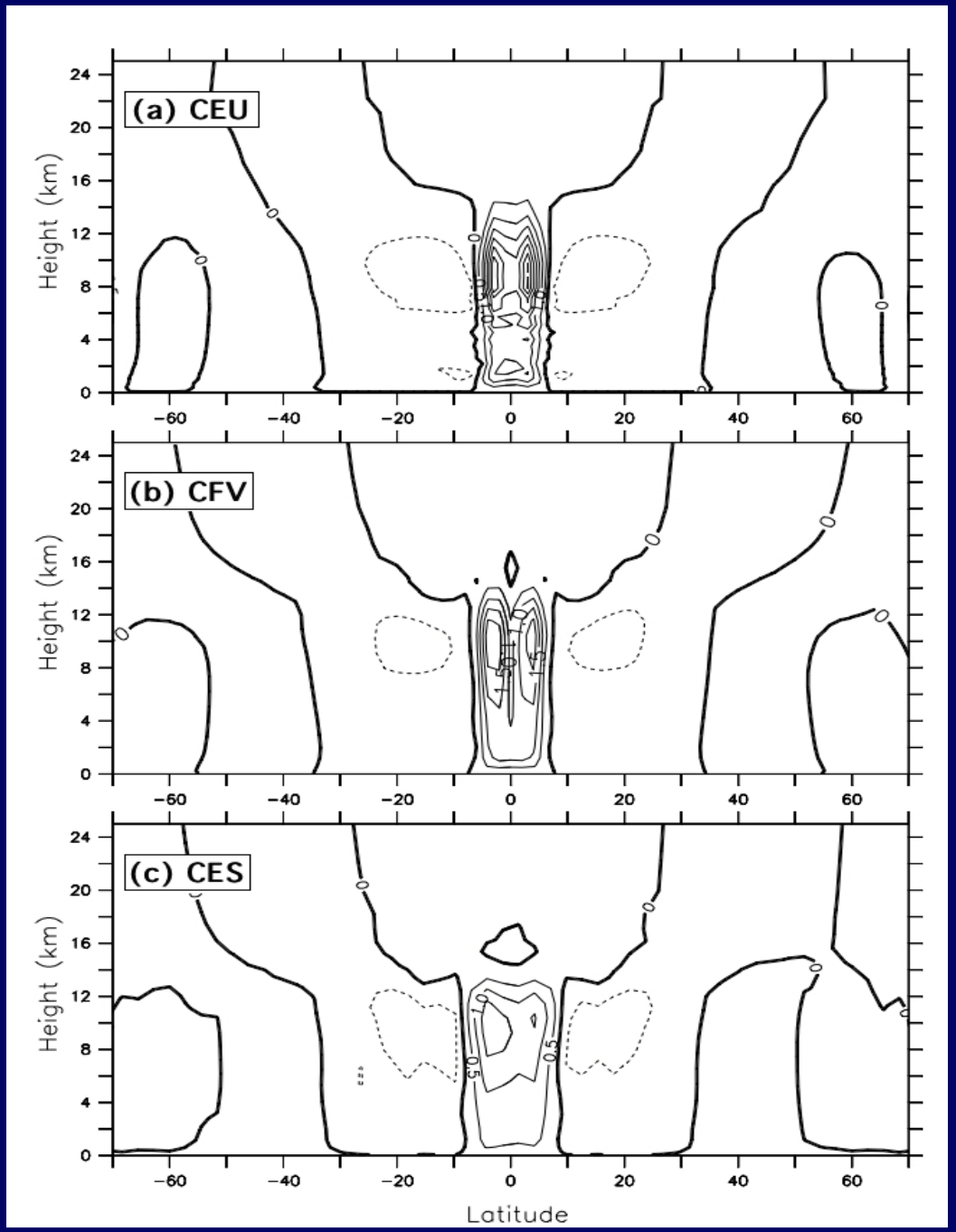
Zonally Averaged Zonal Wind

- **Westerly Jet cores:**
  - **EULAG (55 m/s)**
  - **FV (65 m/s)**
  - **ESP (60 m/s)**
- **Easterly peaks:**
  - **EULAG (10 m/s)**
  - **FV (10 m/s)**
  - **ESP (10 m/s)**

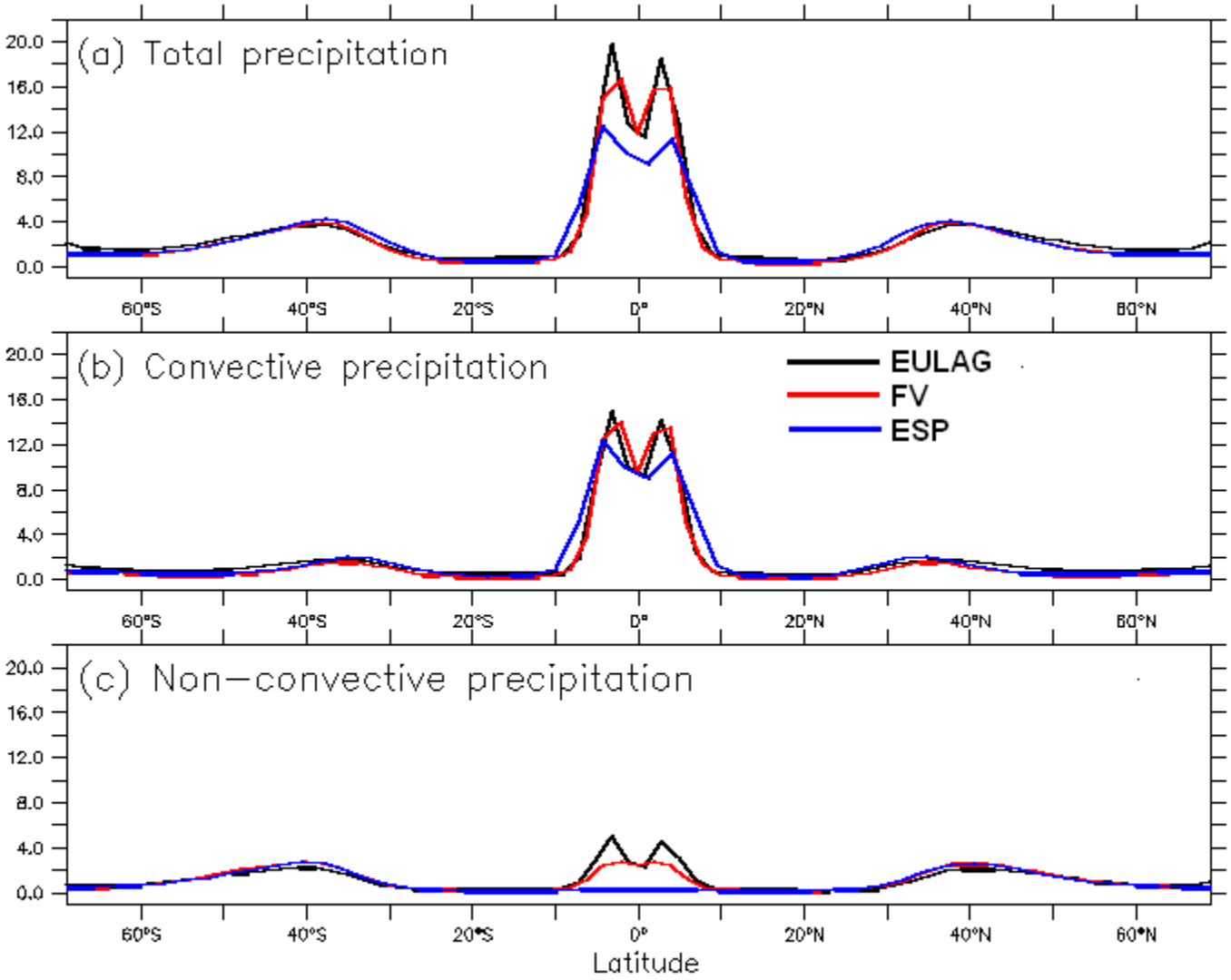


Zonally Averaged Vertical Wind

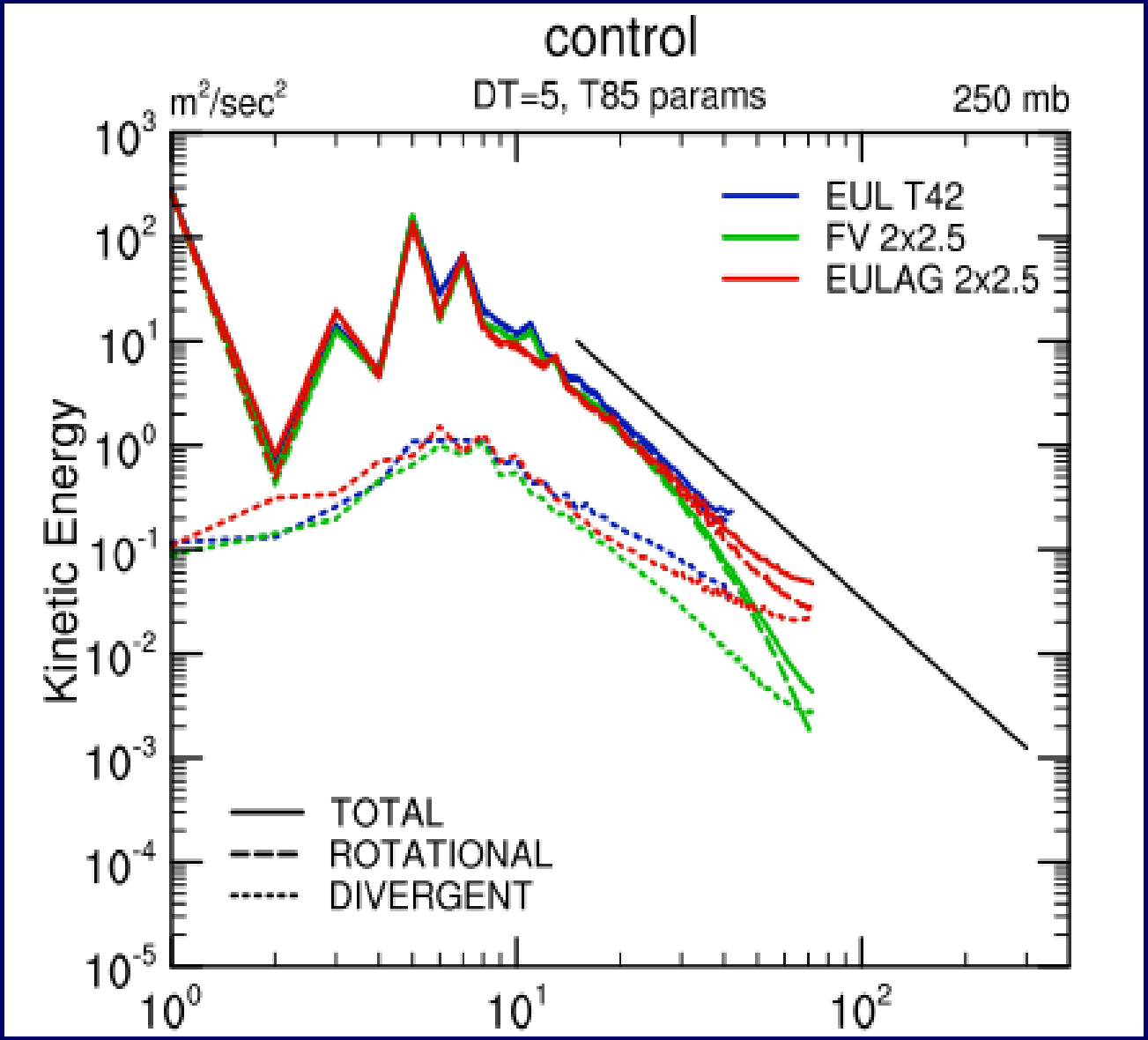
- Maximum updrafts:
  - EULAG (4.0 cm/s)
  - FV (2.2 cm/s)
  - ESP (1.8 cm/s)
- Updraft locations:
  - ~ ± 3˚ off equator



Precipitation



Power Spectra: Kinetic Energy

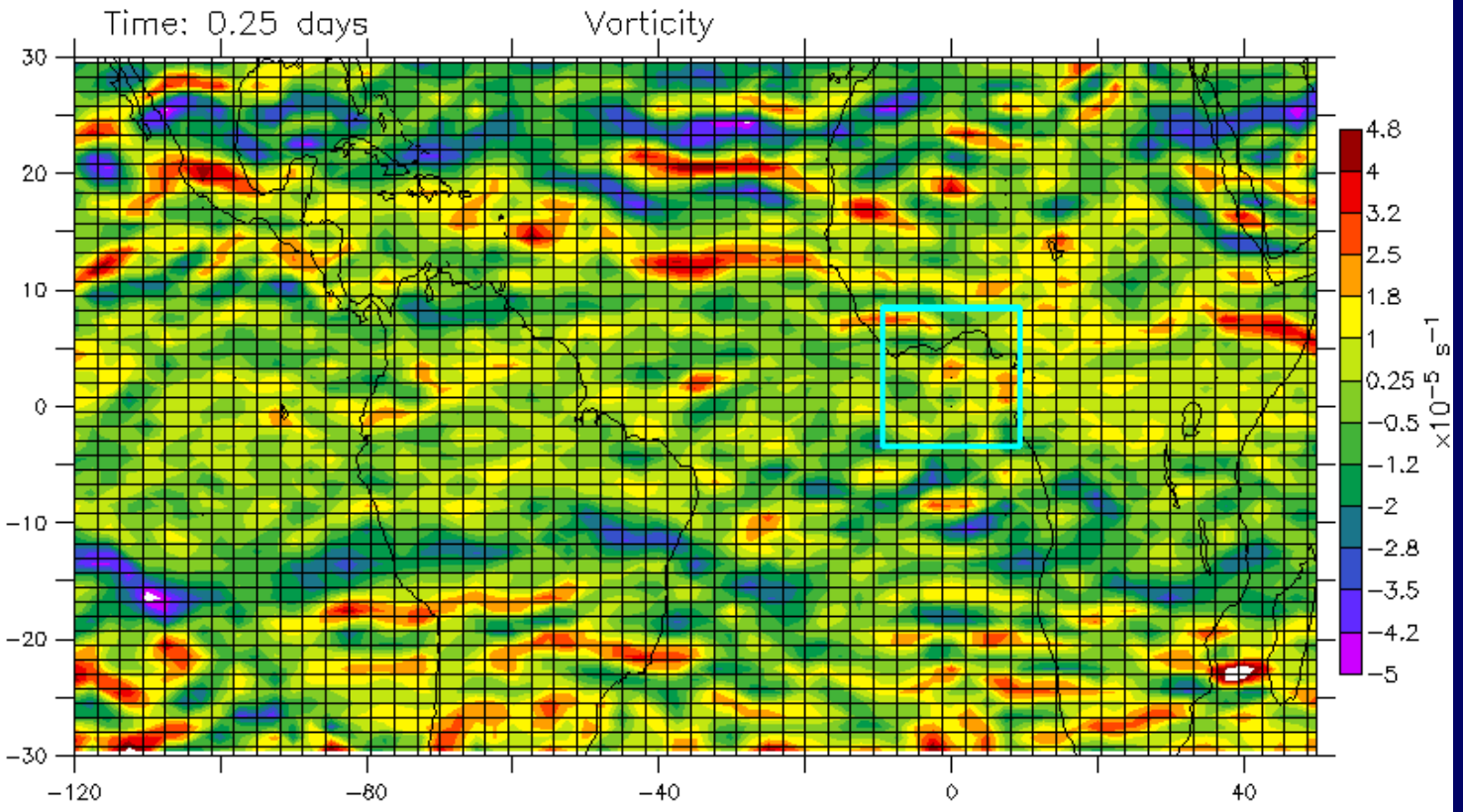


(D. Williamson, NCAR, 2007)

Summary

- CAM3 coupled to a non-hydrostatic dynamic core with capability for dynamic (& static) grid adaptation (EULAG)
- EULAG baroclinic wave simulation agrees with standard hydrostatic CAM
- CAM-EULAG aqua-planet simulation agrees with standard CAM3

Thank you!


Time: 0.25 days
Vorticity
30
20
10
0
−10
−20
−30
−120
−80
−40
0
40
4.8
4
3.2
2.5
1.8
1
0.25
−0.5
−1.2
−2
−2.8
−3.5
−4.2
−5
×10−5 s−1