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

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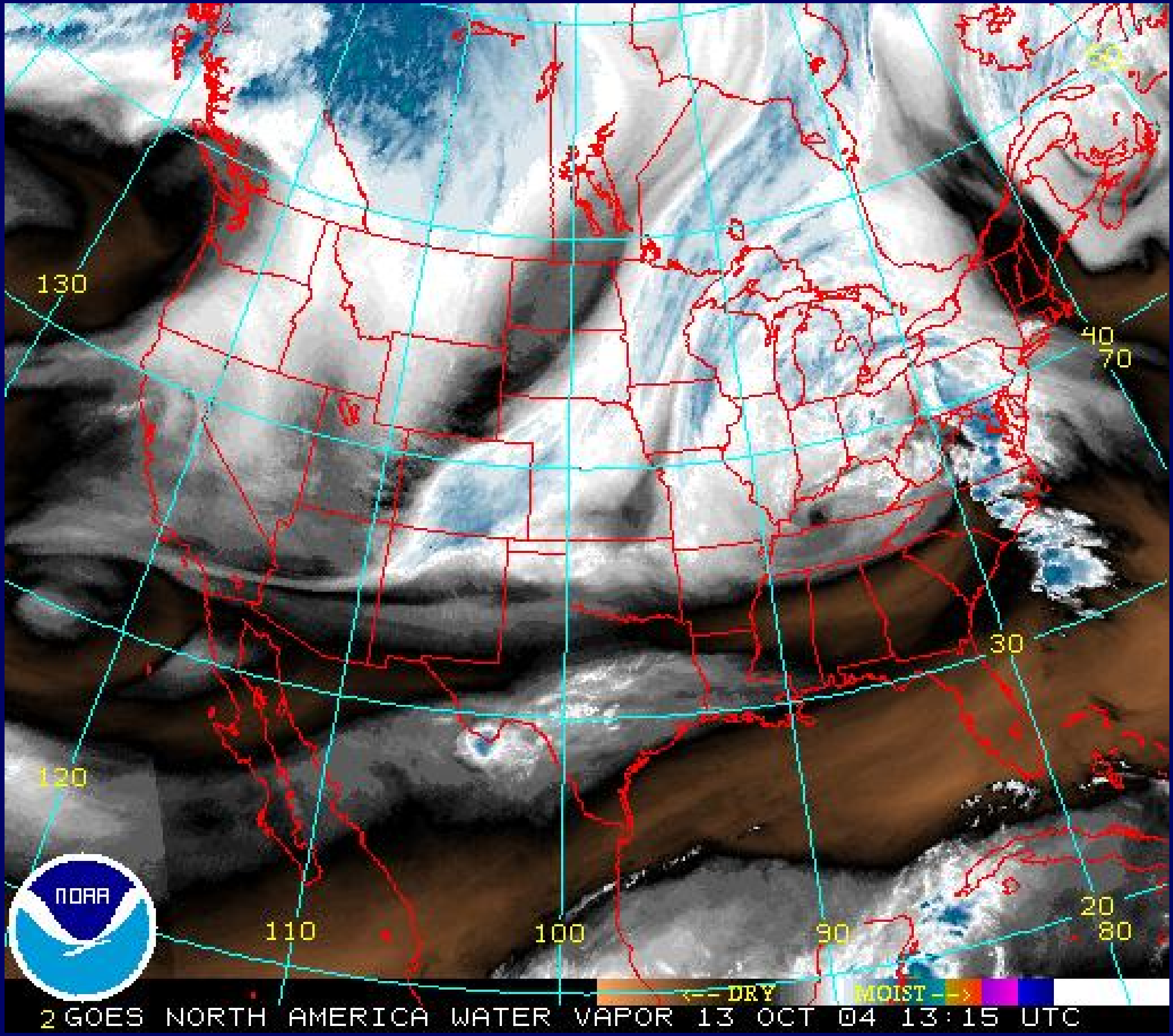
Outline

- Motivation
- Model development (CAM-EULAG)
- CAM-EULAG vs. Existing Dynamics Cores
- Applications

Motivation

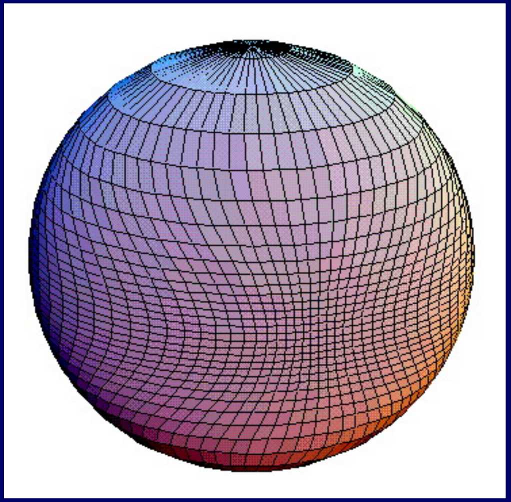
Motivation: Scale Issues

Regional features in global climate simulation often need accurate simulation encompassing a range of scales.



Grid Adaptation

One approach is to use grid adaptation (GA) in global models

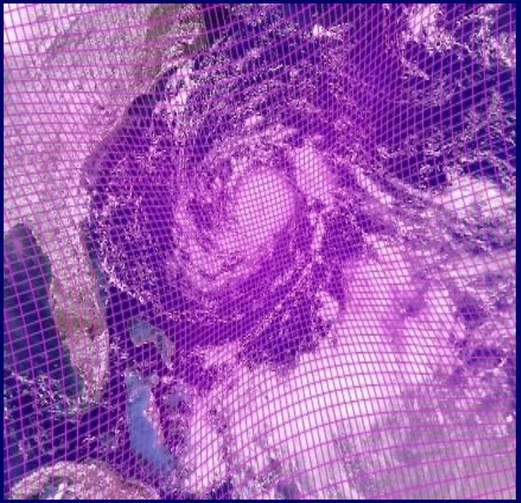


(1) Static GA: <u>for areas of interest</u>

alternative to nested grid regional models

advantages:

- consistent dynamics over high & low resolution areas
- small scale & large scale features fully coupled



(2) Dynamic GA: <u>for features of interest</u>

- storm tracks
- hurricanes
- squall lines
- convection
- tornadoes
- …

Model Development: CAM-EULAG

Coupled Model: CAM-EULAG

Combines the numerical and mathematical rigor of the advanced dynamics core EULAG (Smolarkiewicz et al.) …

… with the climate-system physics of the U.S. National Center for Atmospheric Research (NCAR) Community Atmospheric Model, v3 (CAM3)

CAM3

- The physics package includes radiation, boundary-layer, convection and cloud-physics routines.

- Standard model has three hydrostatic dynamic cores: Finite Volume (FV), Eulerian Spectral (ES) and Lagrangian Spectral (LS)

- For details see Collins et al. (2004).

CAM-EULAG: Coupling

- Thermodynamic pressure and temperature

$$p_{phy} = p_r \left(\frac{\rho_b R_d \theta_e}{p_r} \right)^{1/(1-\kappa)} + 2\rho_b \pi' / \Delta\bar{t} - \rho_b W' / \rho_b (\bar{z} = 0)$$

$$T_{phy} = \theta (p_{phy} / p_r)^{\kappa}$$

- CAM vertical pressure velocity

$$\omega = \frac{dp_{phy}}{d\bar{t}} = \bar{v}_*^i \frac{\partial p_{phy}}{\partial \bar{x}^i}$$

- CAM tendencies: process-split coupling

$$\psi^{n+1} = MPDATA(\tilde{\psi}) + 0.5\Delta t (D_\psi^{n+1} + P_\psi^{n})$$

$$\tilde{\psi} = \psi^n + 0.5\Delta t (D_\psi^{n} + P_\psi^{n})$$

- Parallel coding

CAM-EULAG: Baseline Simulation Tests

- **Aqua-planet (Neale & Hoskins, 2001)**
  - Ensure dynamic core and physics suites are well coupled.
  - Compare results with current dynamic cores in CAM
  - Further test static and dynamic GA
- **AMIP II: Full surface-atmospheric physics**
  - Fine tune CAM physics for EULAG dynamic core
  - Compare results with observation and other models

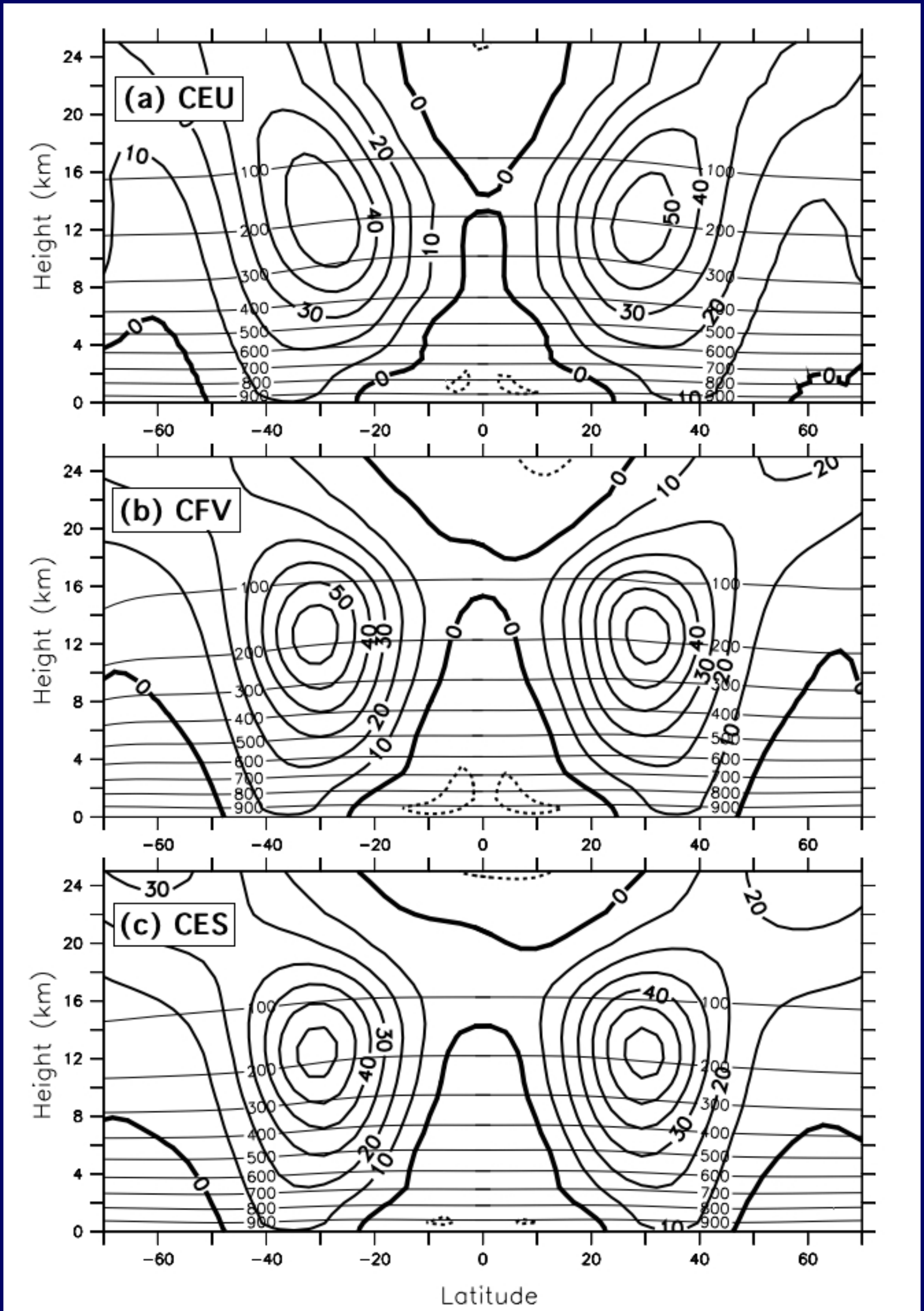
Comparison of Dynamics Cores

Comparison of dynamic cores

- Cores: EULAG, FV and ESP
- Experiment: Aqua-planet
- Forcing: Idealized, zonally symmetric SST
- Horizontal resolutions : 2°x2.5° [EULAG and 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

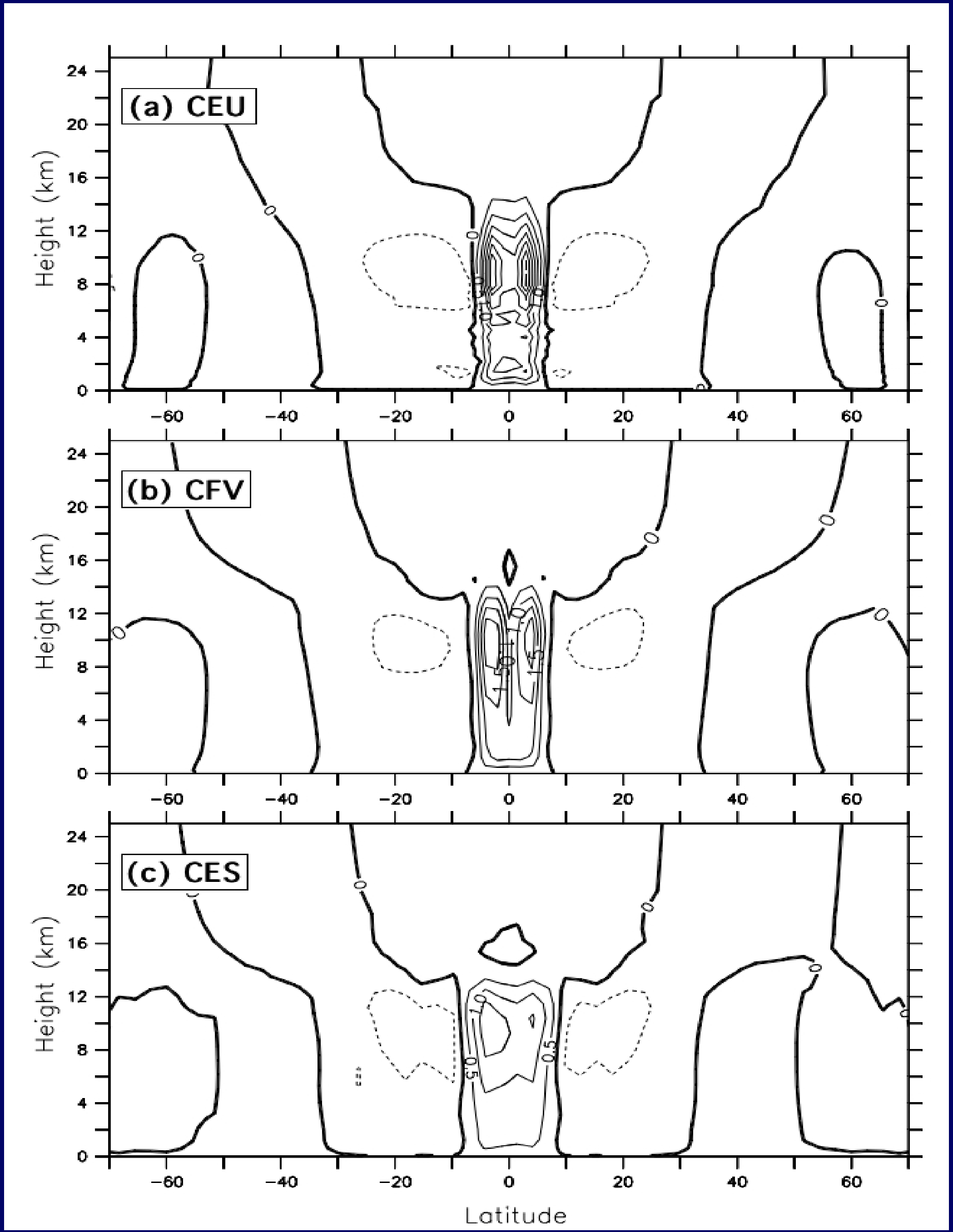
Zonally Averaged Zonal Wind

- 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)

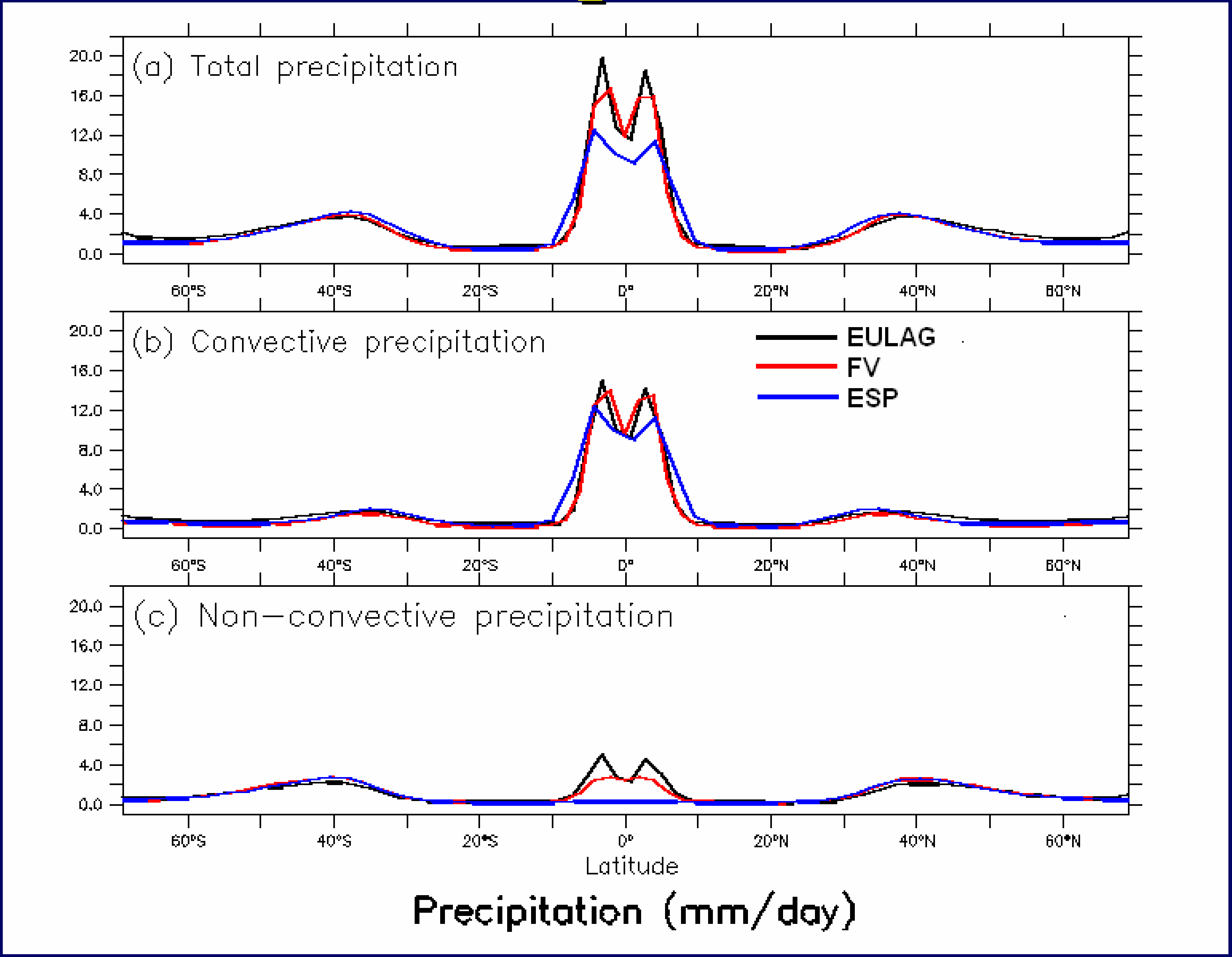


Zonally Averaged Vertical Wind

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



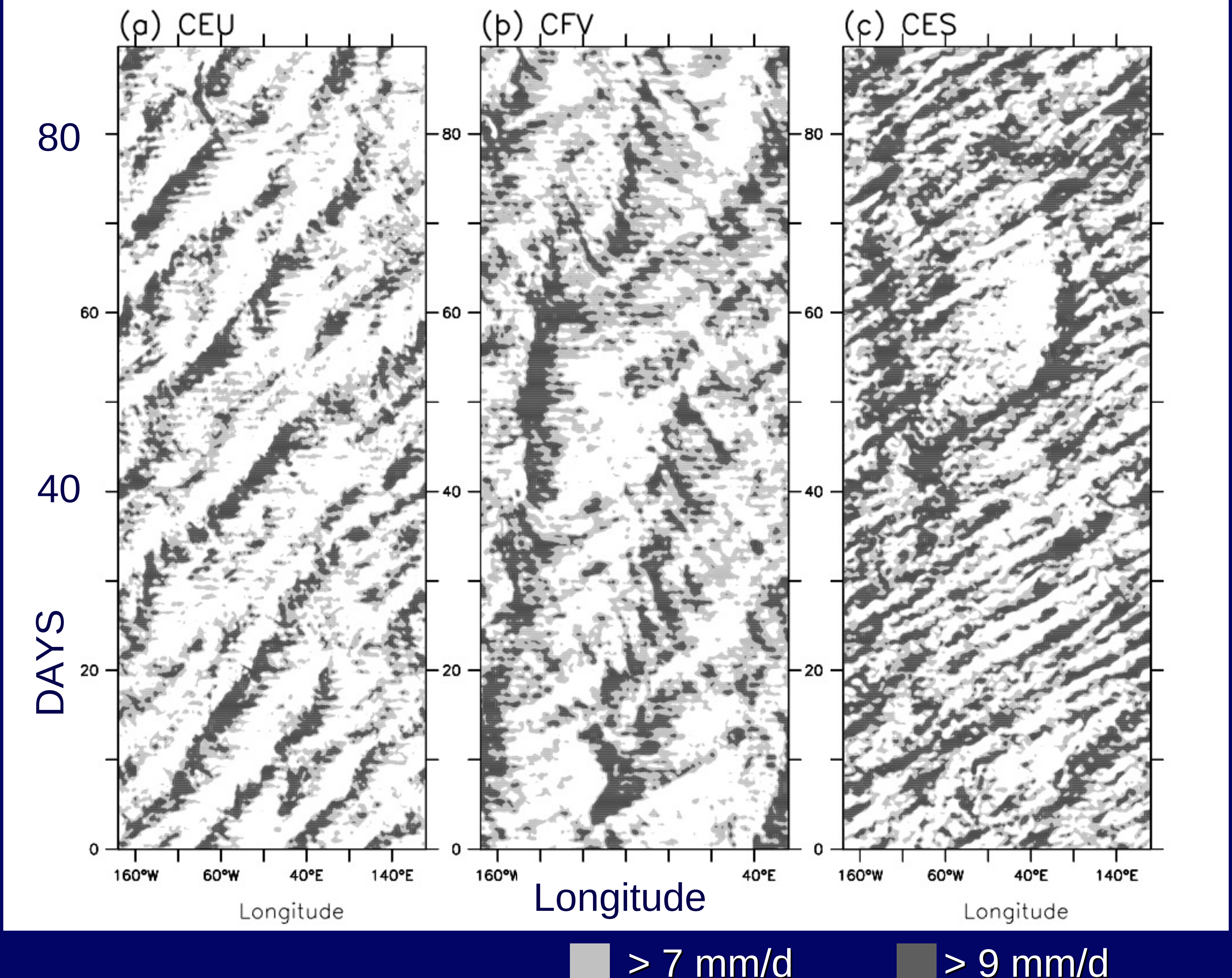
Precipitation



Tropical Precipitation vs. Time/Longitude

Tropical Precipitation

(averaged over 10˚ S - 10˚ N)



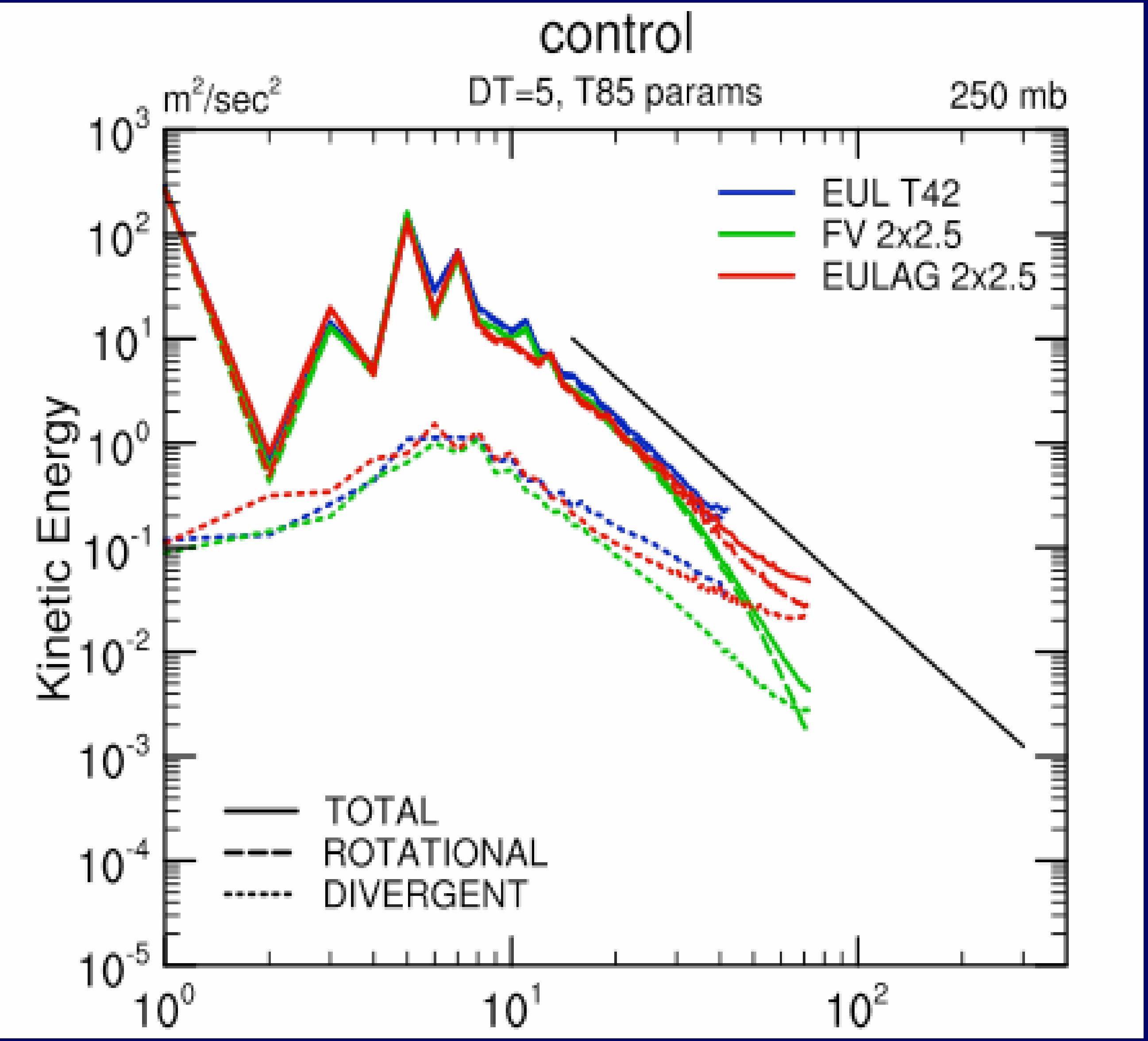
Periods

EUL ~ 30 d

FV > 45 d

ESP ~ 22 d

Power Spectra: Kinetic Energy



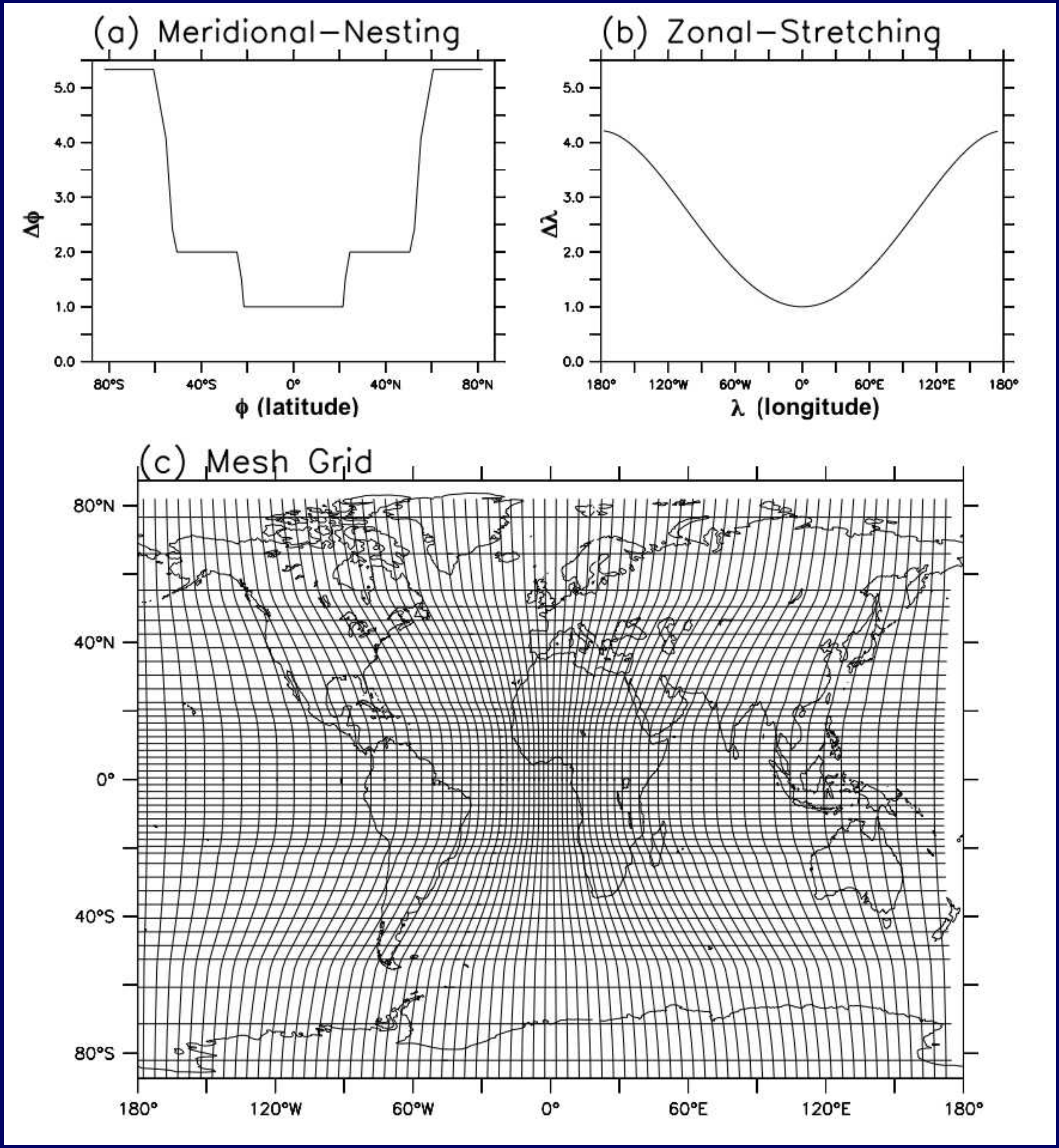
(D. Williamson, NCAR, 2007)

Applications

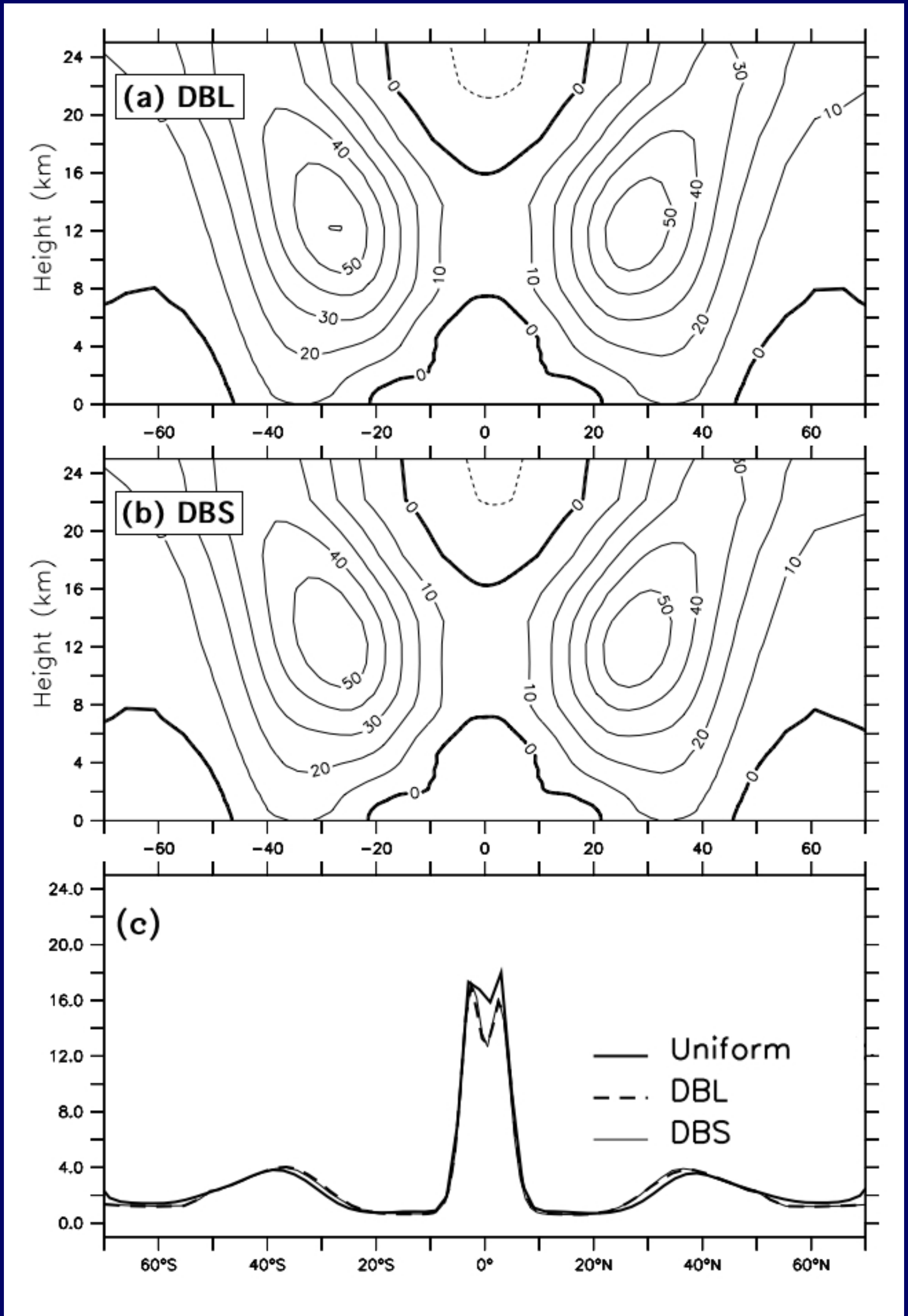
Simulation with Static GA: Grids

<u>90 (lat) x 144 (lon)</u>

1. Uniform (2°)
2. Meridional Double Nest (DBL)
3. Zonal Stretch + Meridional Double Nest (DBS)



Simulation with Static GA: Zonal Flow & Precipitation

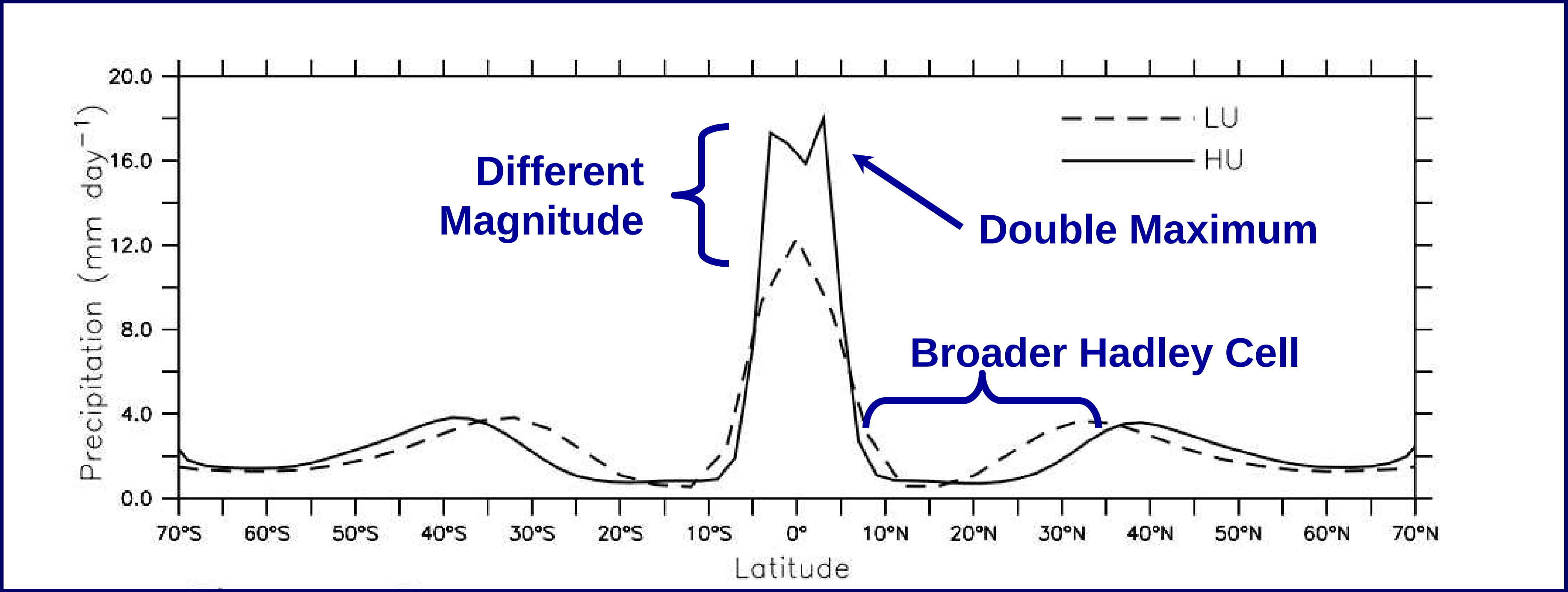


Versus Uniform

1. Jets about 1° closer to equator
2. DBL jet stronger by about 5 m/s
3. Layer of equatorial westerly flow
4. Precipitation slightly weaker

No abrupt changes in structure

Precipitation vs. Latitude: Uniform Grids



Resolutions:

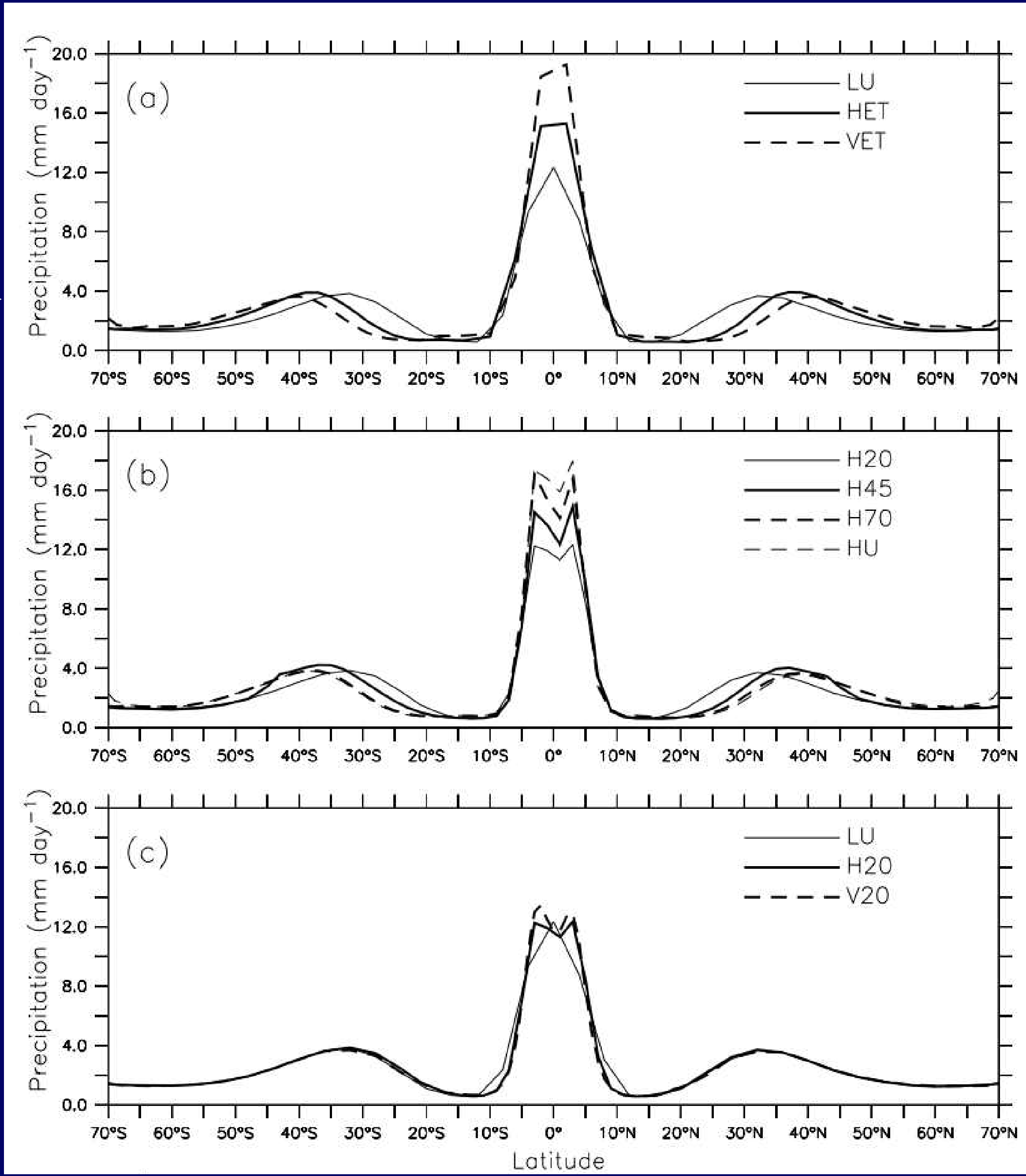
- LU = 4° meridional (2° zonal)
- HU = 2° meridional (2° zonal)

Precipitation vs. Latitude

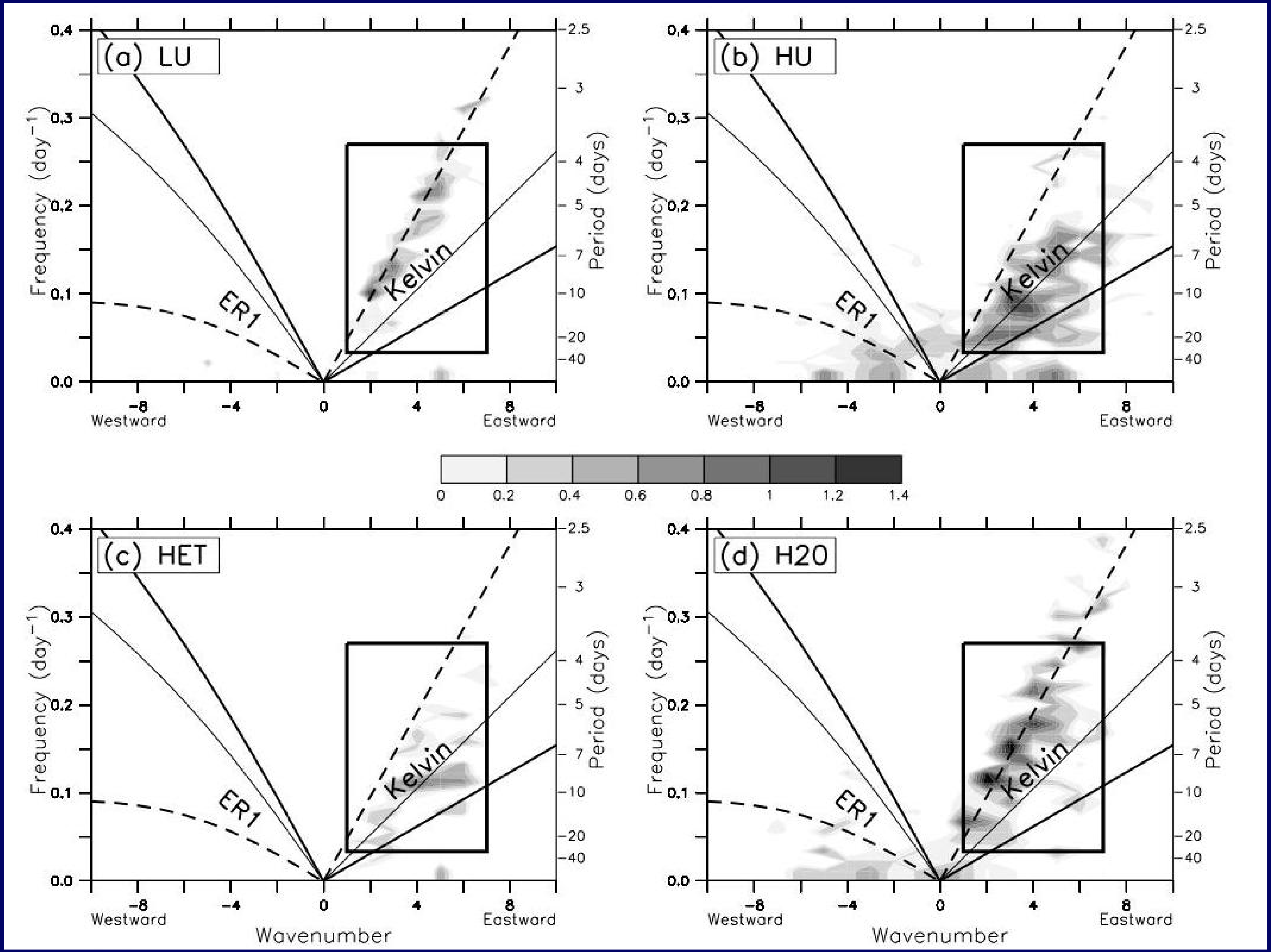
Extratropical changes in resolution

Expand width of tropical high resolution region

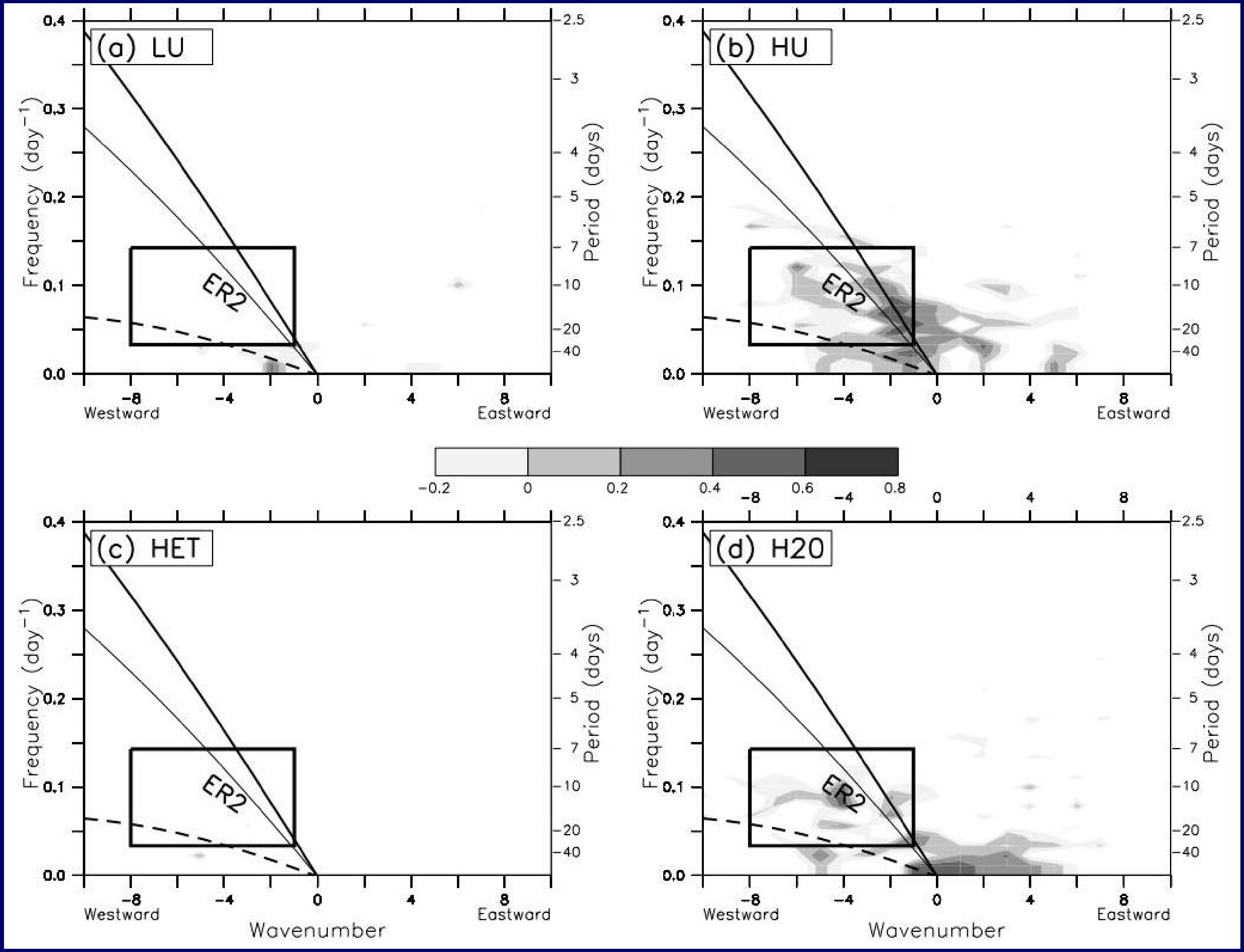
Tropical changes in resolution



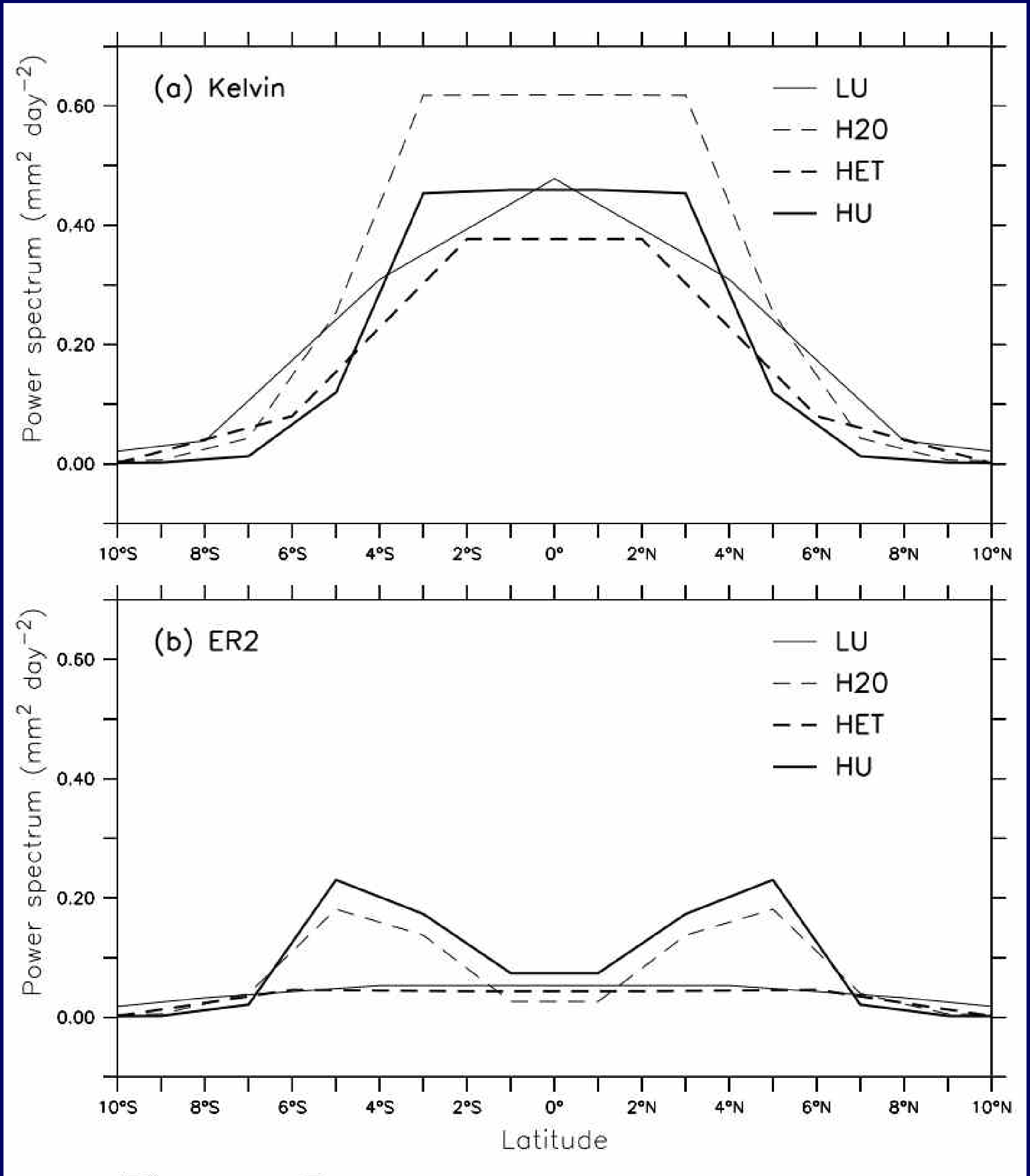
Precip. Power Spectra: Symmetric Waves



Precip. Power Spectra: Anti-symmetric Waves

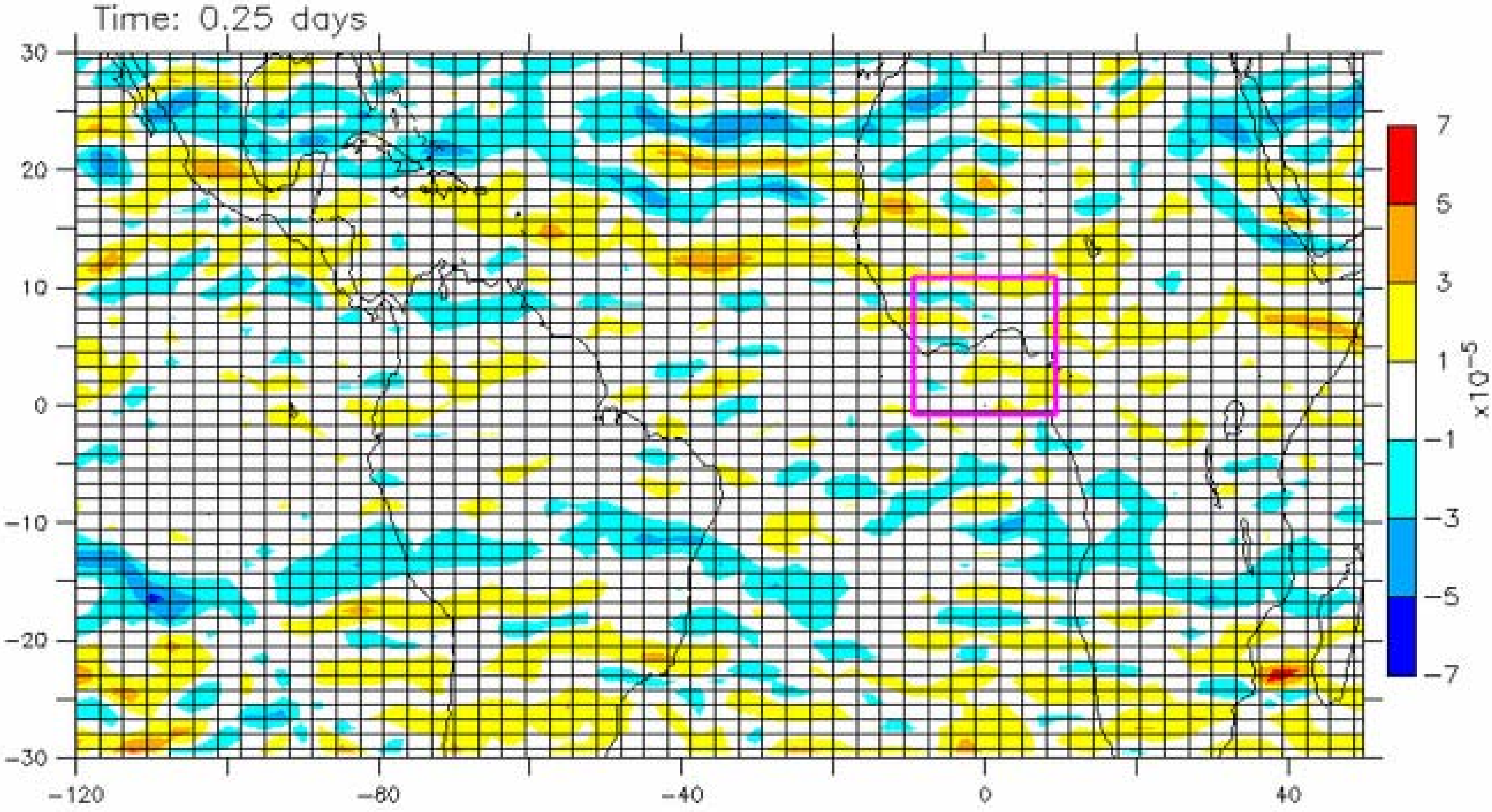


Resolution of Tropical Waves
(Power vs. Latitude)

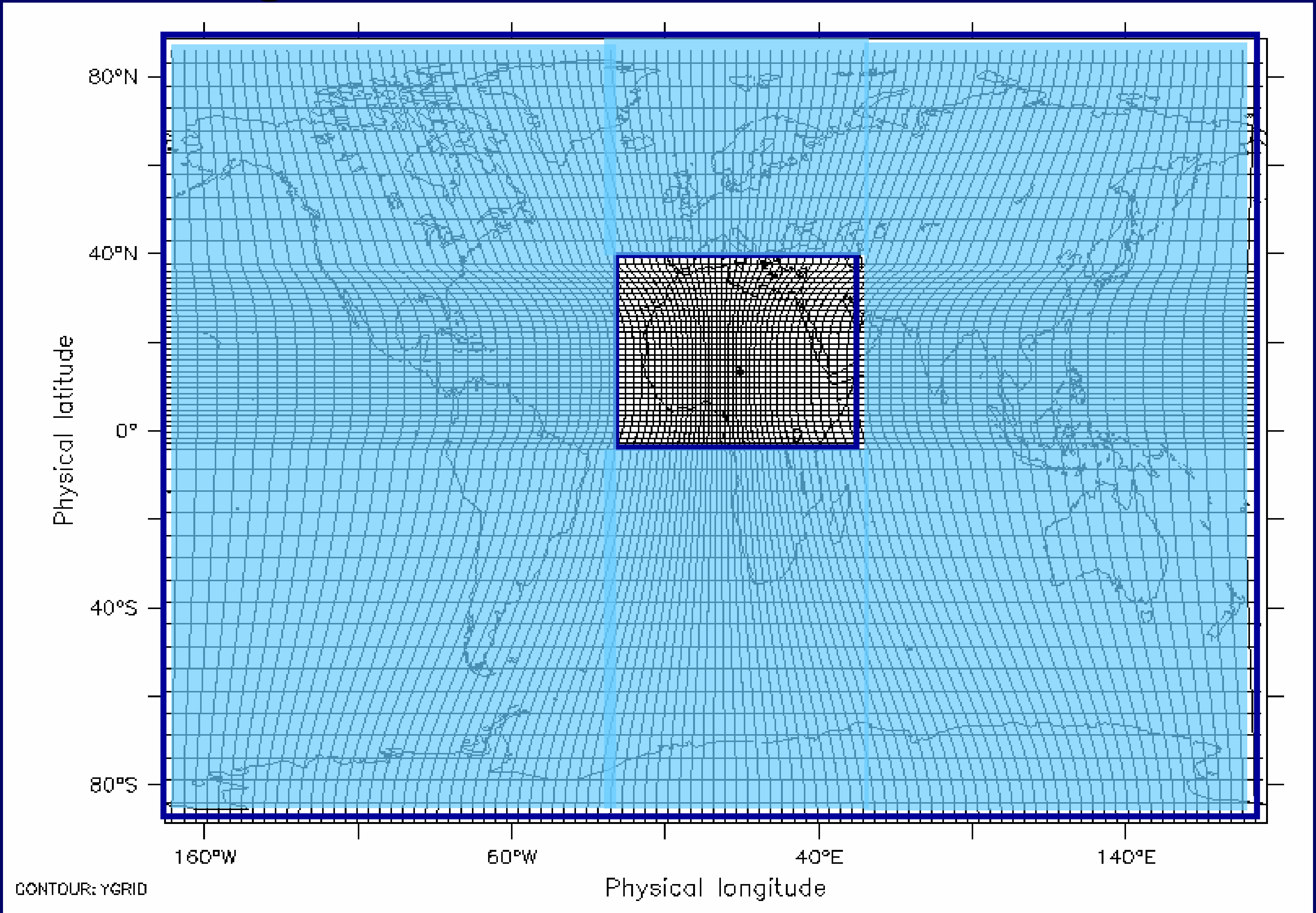


Additional Simulations

Dynamic GA: Tracking a Tropical Vortex



High Resolution Grid over West Africa



Summary

- CAM3 coupled to a non-hydrostatic dynamic core with capability for both static and dynamic grid adaptation (EULAG)
- CAM-EULAG aqua-planet simulation agrees well with standard CAM3
- ICTZ features linked to resolving tropical and extratropical waves

Thank you!

Abiodun, B.J., J.M. Prusa and W.J. Gutowski, 2008: Implementation of a Non-hydrostatic, Adaptive-Grid Dynamics Core in CAM3. Part I: Comparison of Dynamics Cores in Aqua-Planet Simulations. *Clim. Dynamics* [DOI 10.1007/s00382-008-0381-y].

Abiodun, B.J., W.J. Gutowski and J.M. Prusa, 2008: Implementation of a Non-hydrostatic, Adaptive-Grid Dynamics Core in CAM3. Part II: Dynamical Influences on ITCZ Behavior and Tropical Precipitation. *Clim. Dynamics* [DOI 10.1007/s00382-008-0382-x].