Continuous Dynamic Grid Adaptation in Global Atmospheric Model (CAM-EULAG): Application and Refinement

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CAM-EULAG: An excting jungle!!!

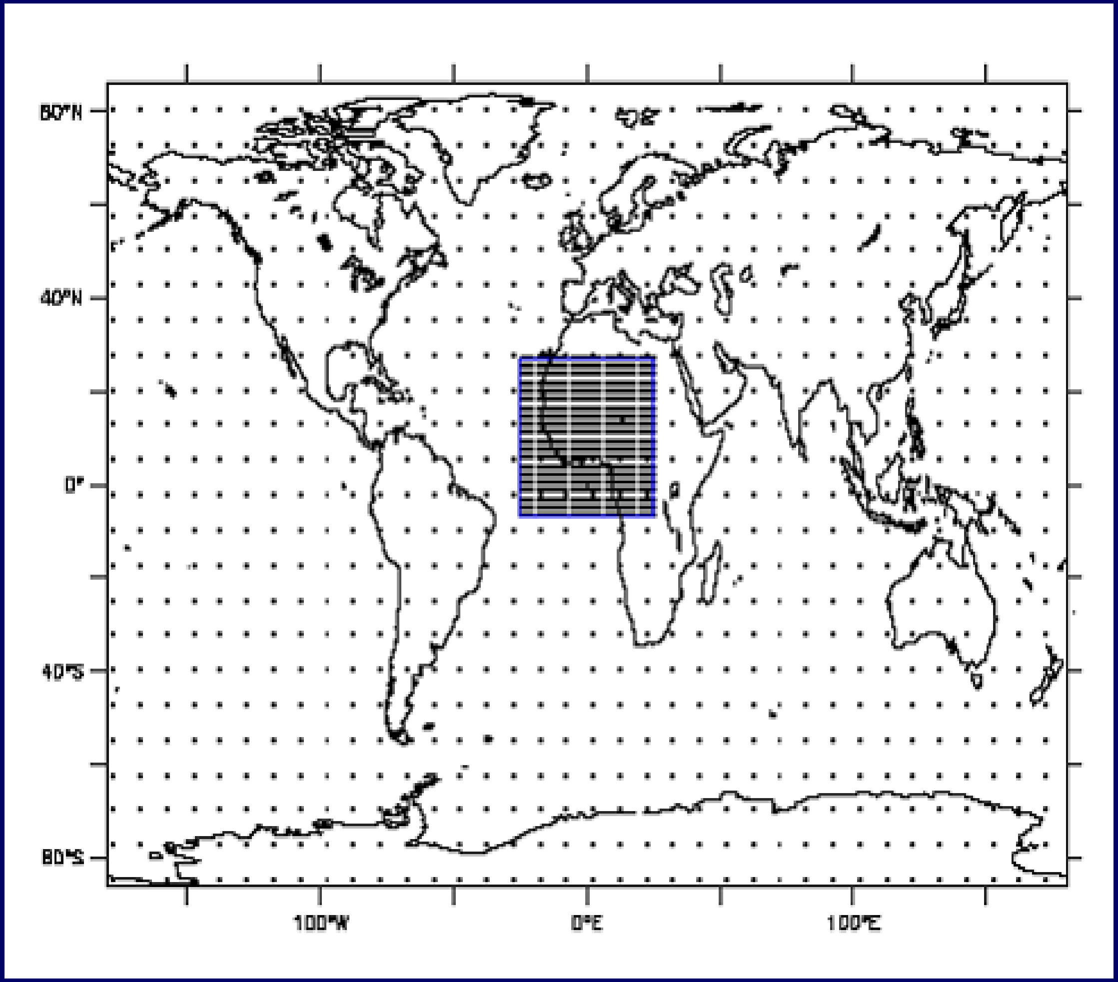
Outline

- Motivation
- Features of CAM-EULAG
- Applications of CAM-EULAG
- Future works and Refinement

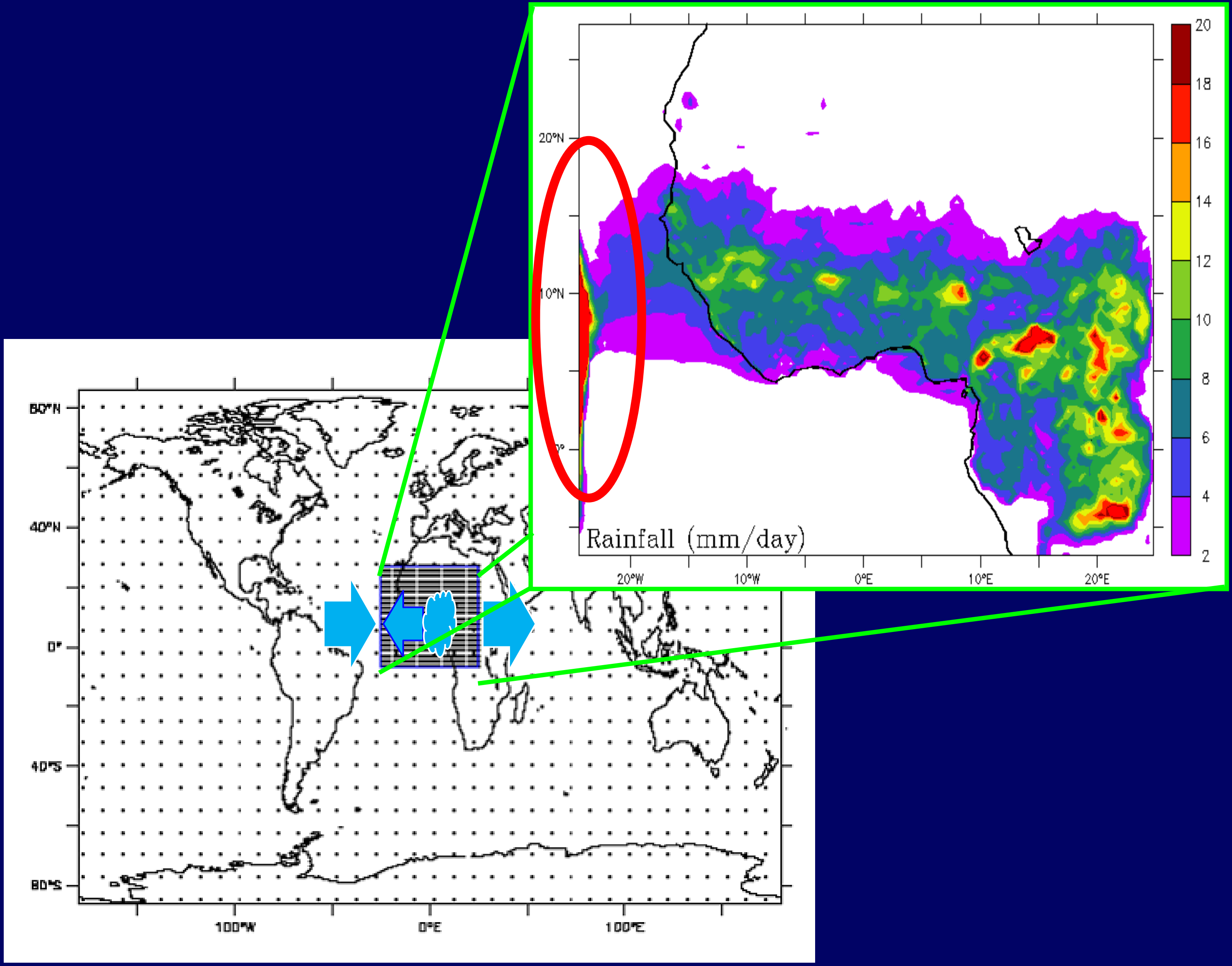
Motivation:
The need to improve Regional Climate Modelling

- **Global Models**
  - Cover the entire globe
  - Simulate the entire atmosphere
  - Low resolution

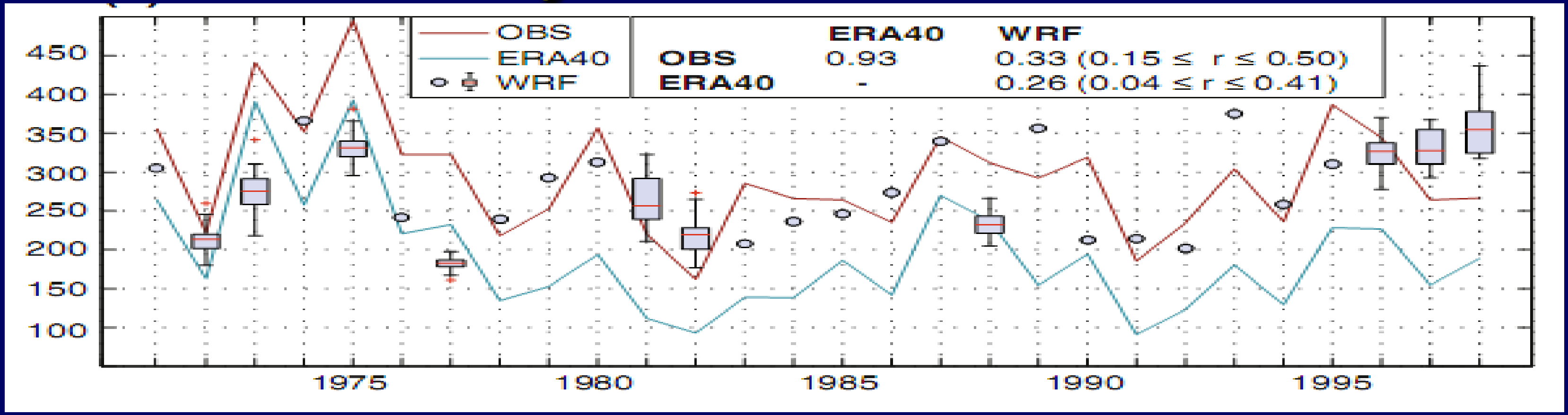
- **Regional/Mesoscale Models**
  - over a limited area of the globe
  - High resolution
  - Boundary problems

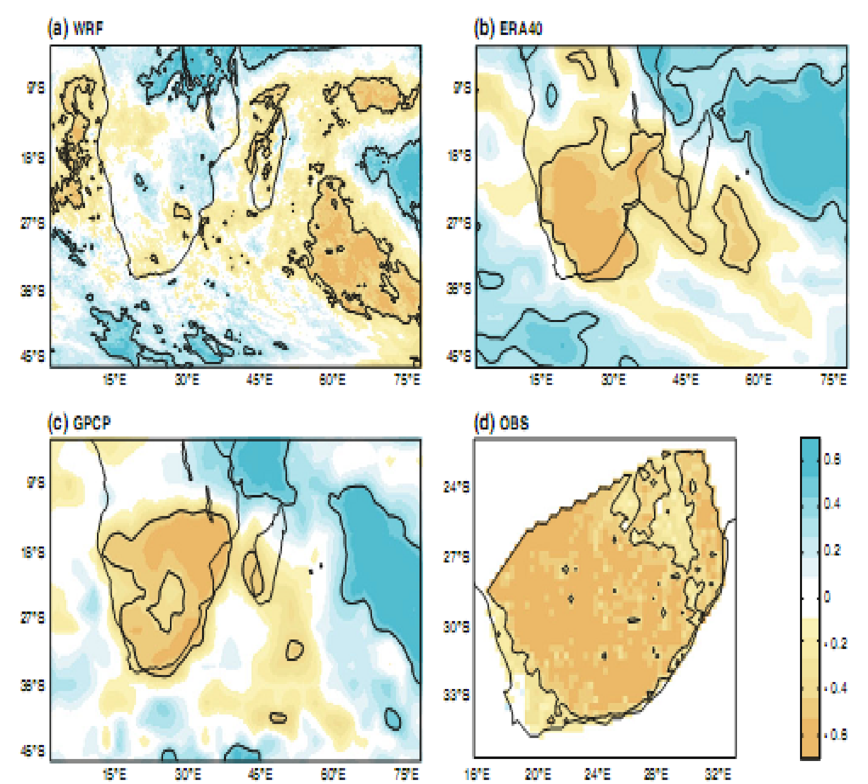


Boundary Condition Problem



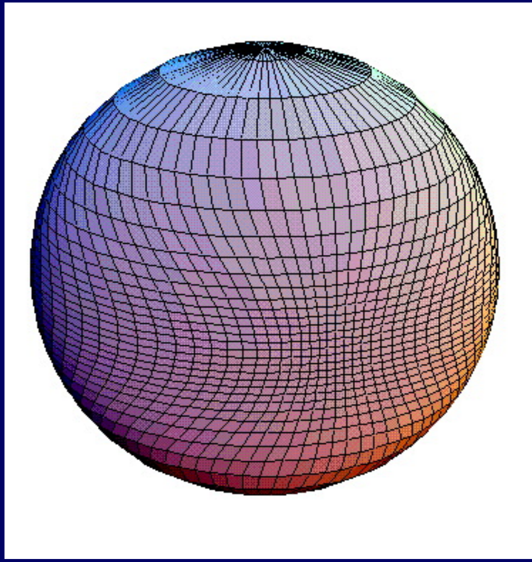
Boundary Condition Problem





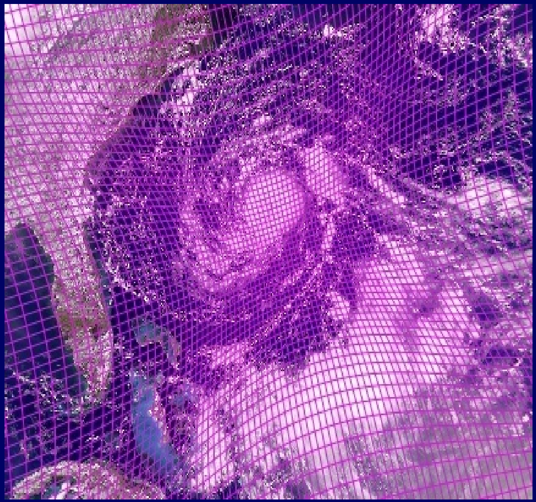
Boulard et al (2012) (Climate Dynamics)

Features of CAM-EULAG



Static GA:
- for areas of interest
- consistent dynamics over high and low resolution areas
- small scale and large scale features are fully coupled

Dynamic GA:
- for features of interest
- storm tracks, hurricanes, squall lines, frontal precipitation, Asian monsoon, tornadoes, convection



The coupling of CAM3 and EULAG

We adopt the process-spilt method in CEU. Consider the general prediction equation for a variable (ψ)

$$\frac{d\psi}{d\bar{t}} = D(\psi) + P(\psi) \qquad (3a)$$

$$\psi^{n+1} = \mathrm{MPDATA}(\tilde{\psi}) + 0.5\Delta t(D_{\psi}^{n+1} + P_{\psi}^{n}) \qquad (3b)$$

where

$$\tilde{\psi} = \psi^{n} + 0.5\Delta t(D_{\psi}^{n} + P_{\psi}^{n}). \qquad (3c)$$

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

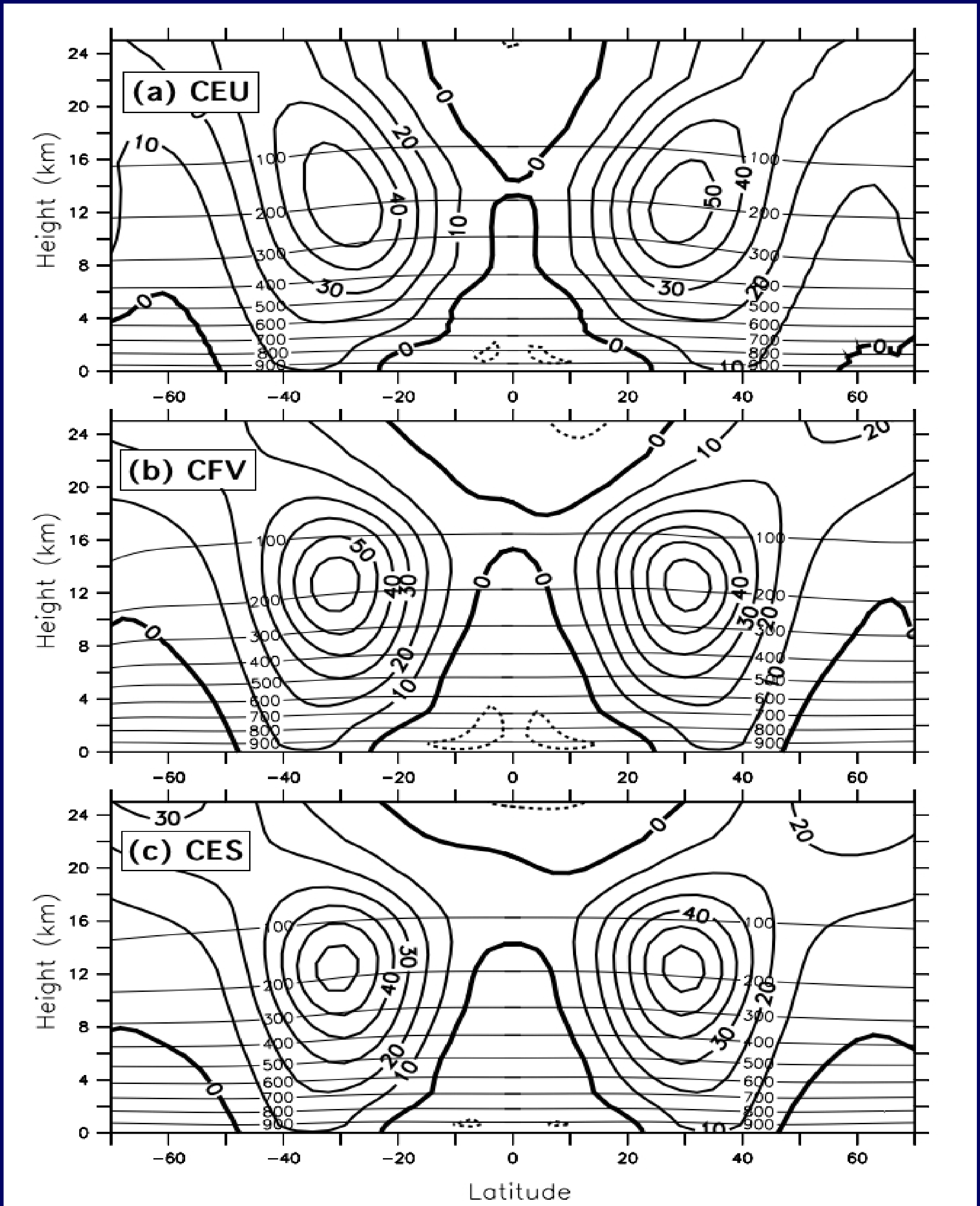
Abiodun et. al (2008a)
(Climate Dynamics)

Aqua-Planet Simulation with CAM-EULAG

- 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

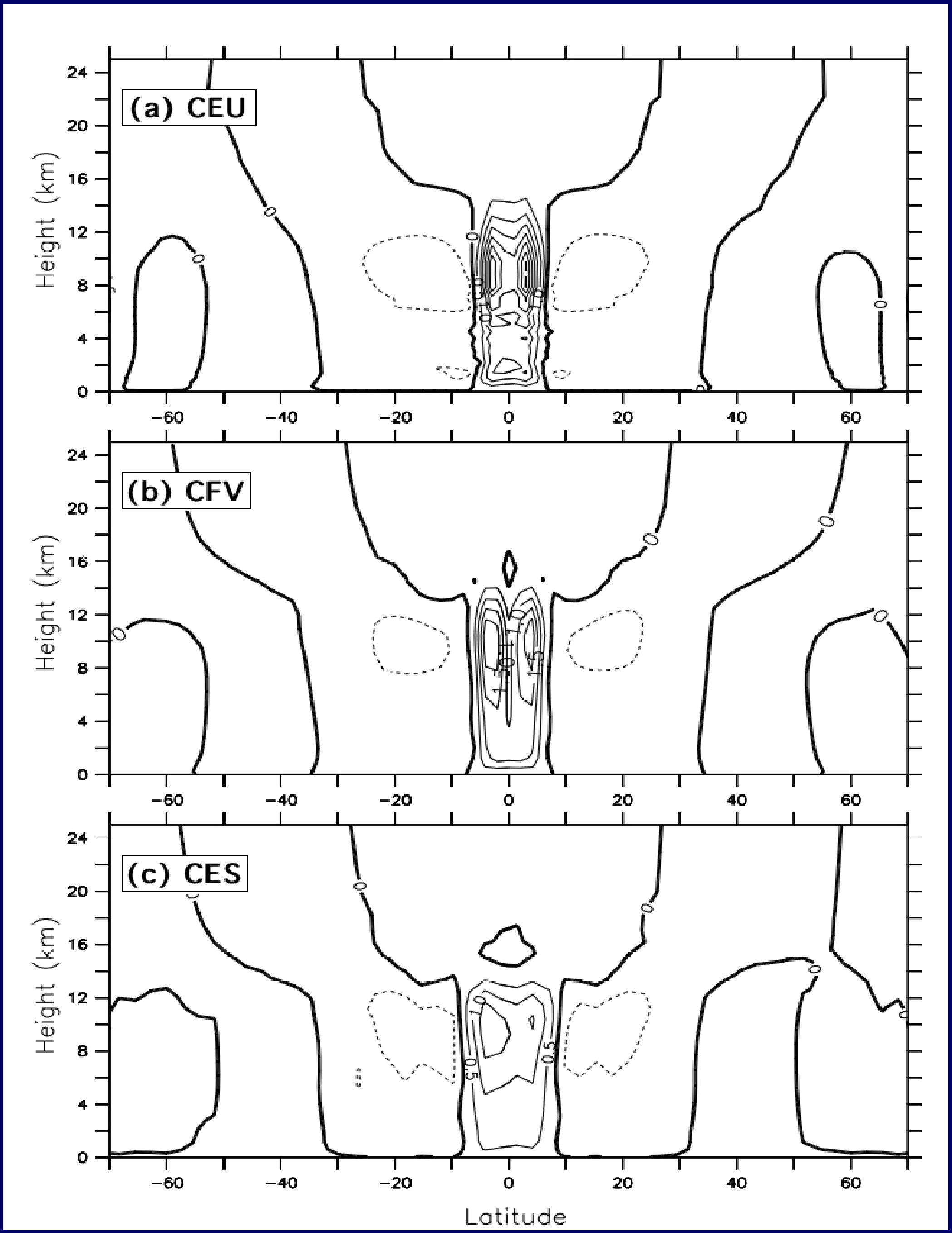
Zonally Averaged Zonal Wind

- 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)

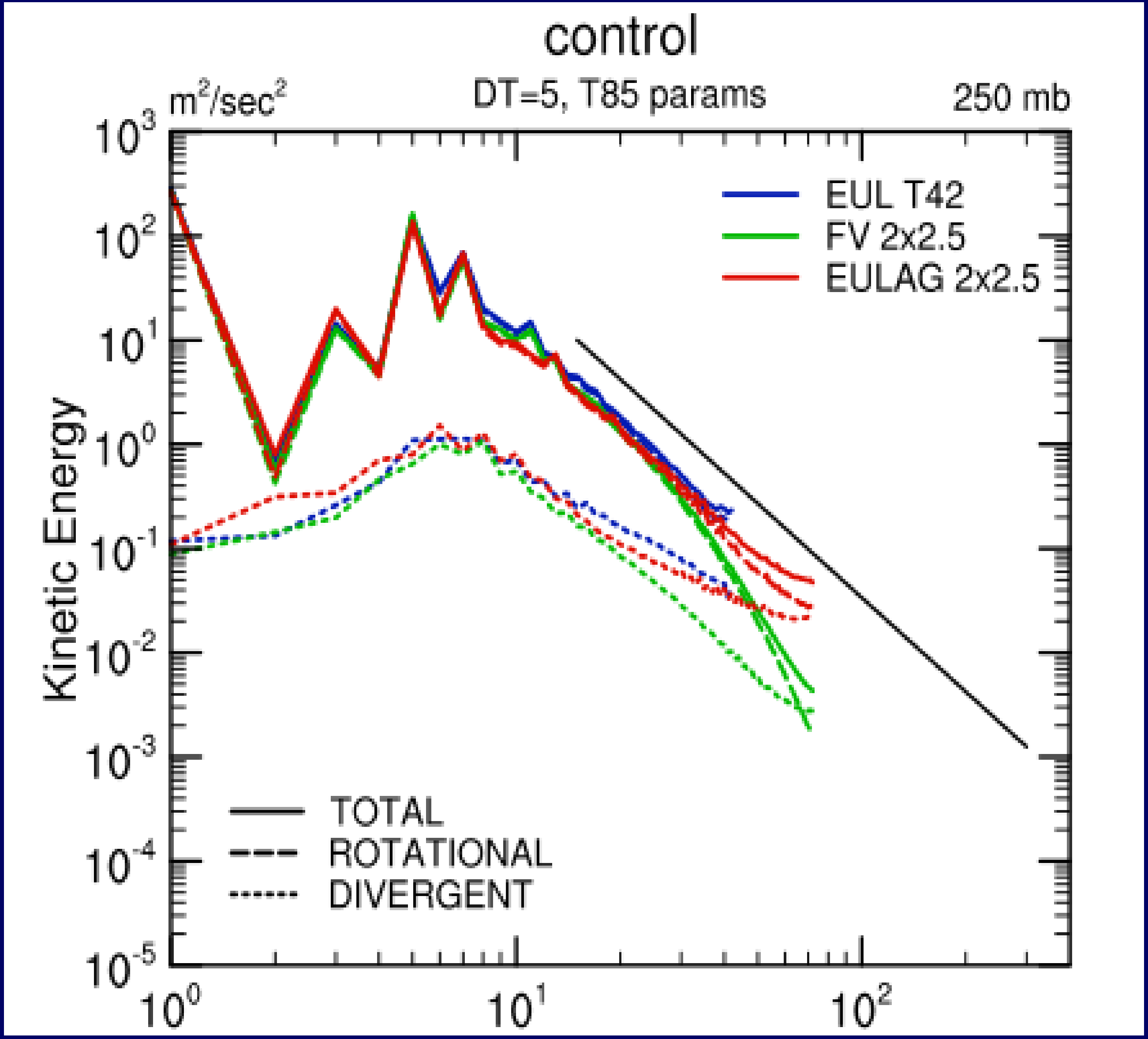


Zonally Averaged Vertical Wind

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



Power Spectra: Kinetic Energy

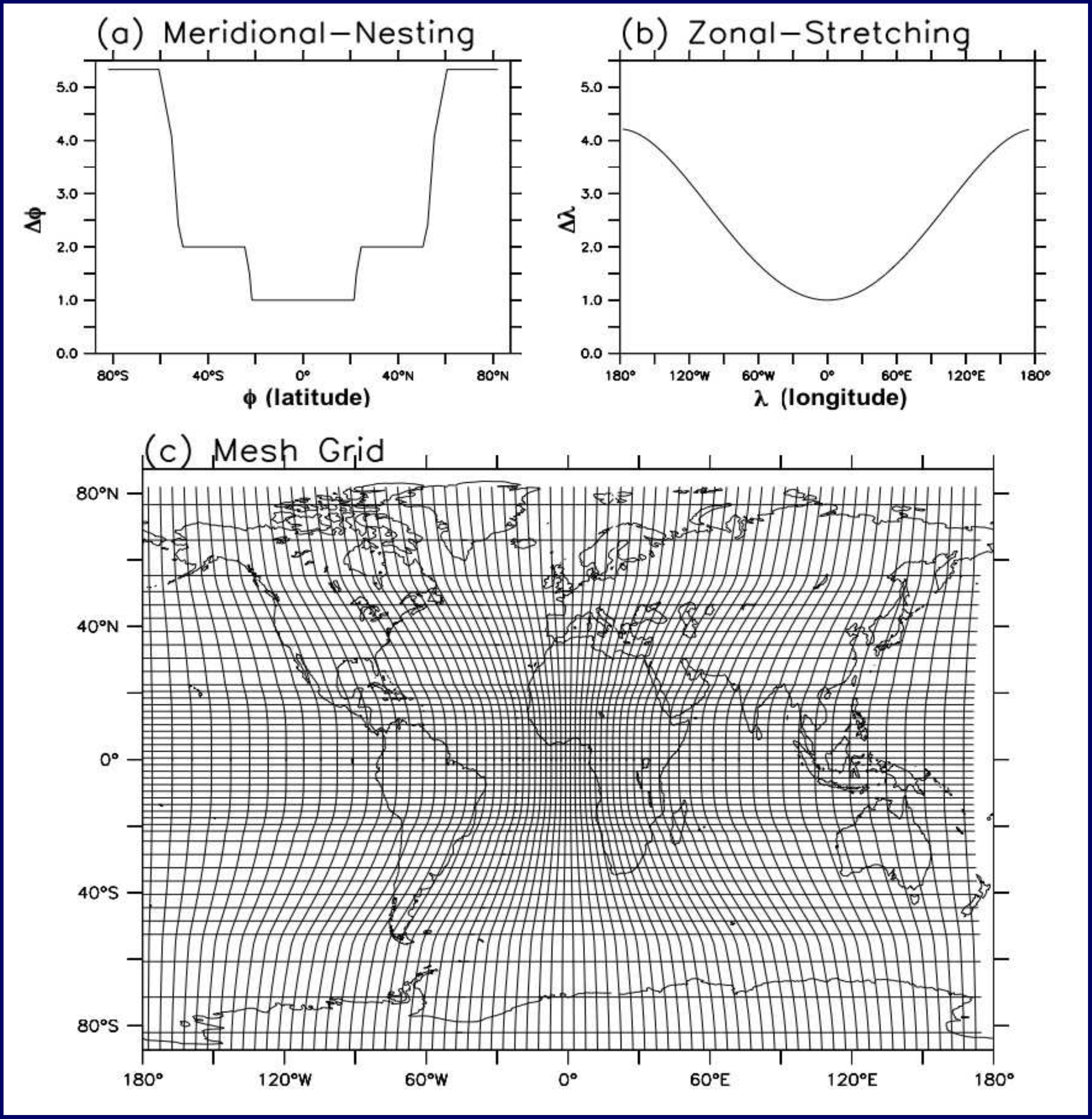


(D. Williamson, NCAR, 2007)

Simulation with Static Stretch: Grids

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

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



Show animation

Simulation with Static Stretch: Tropical Precipitation

Tropical Precipitation

(at the equator)

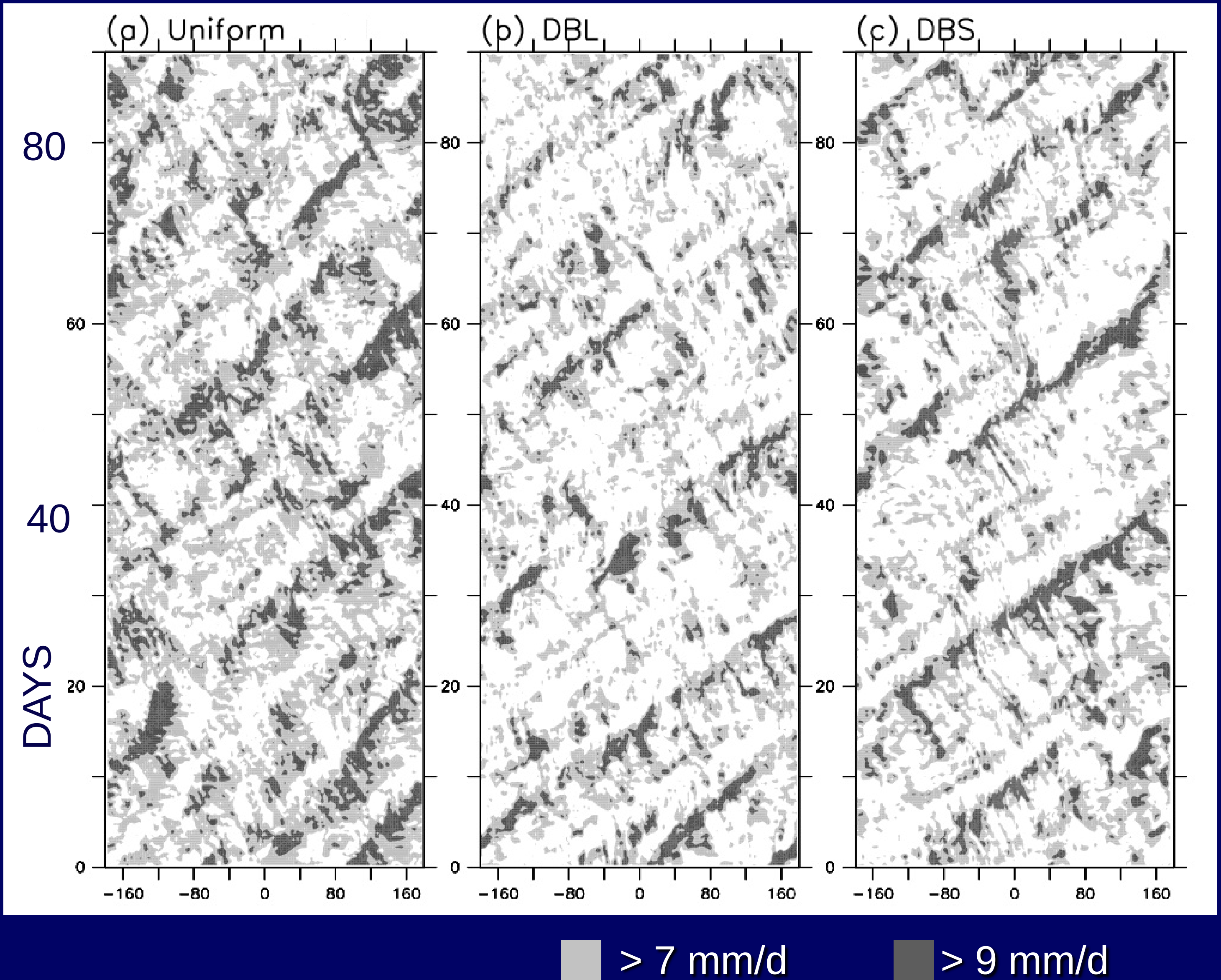
No spurious reflections or abrupt structure changes

<u>Periods</u>

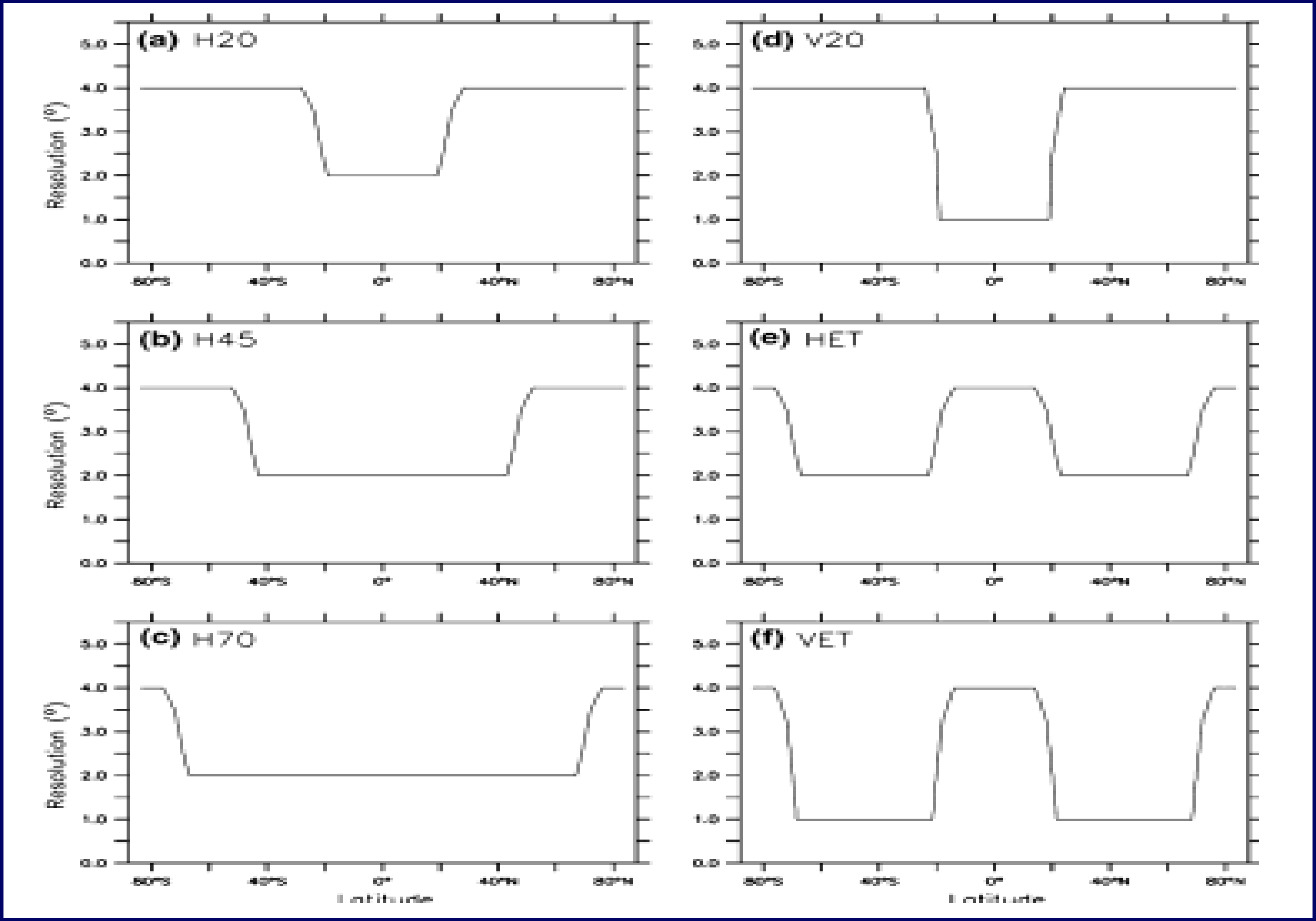
UNIF ~ 30 d

DBL ~ 26 d

DBS ~ 26 d

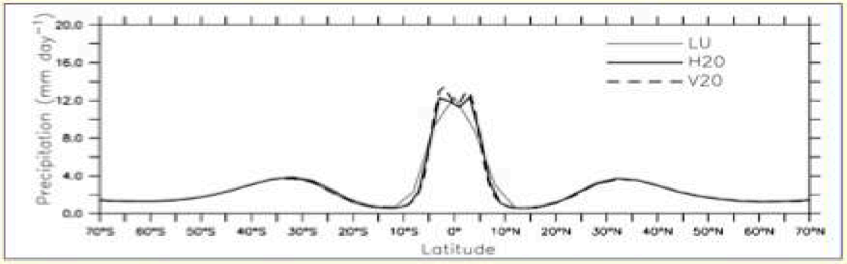


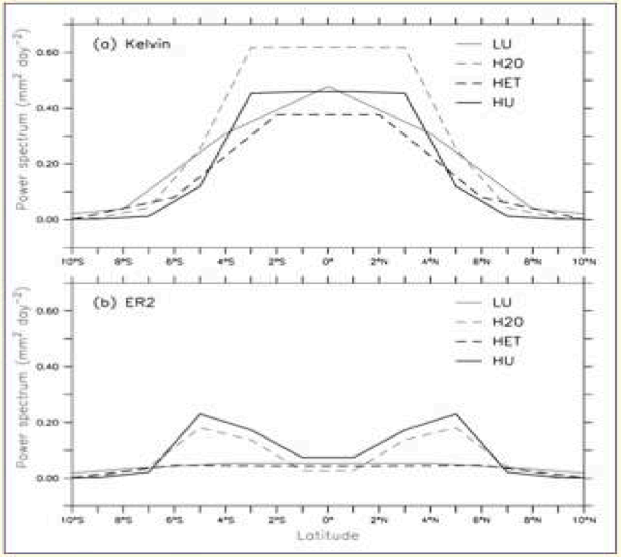
Aqua-Planet Simulations: Double or Single ITCZ?



Aqua-Planet Simulations: Double or Single ITCZ?

Influence of Equatorial Waves on Tropical Convection Morphology

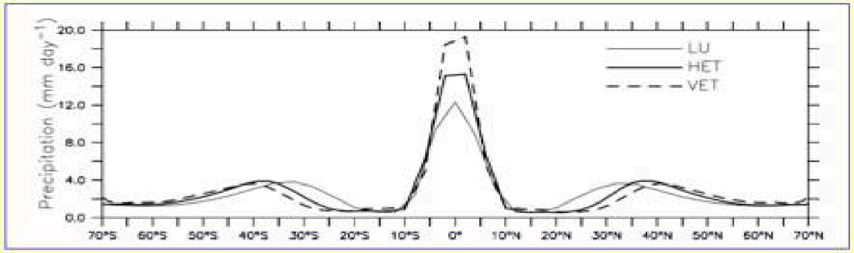




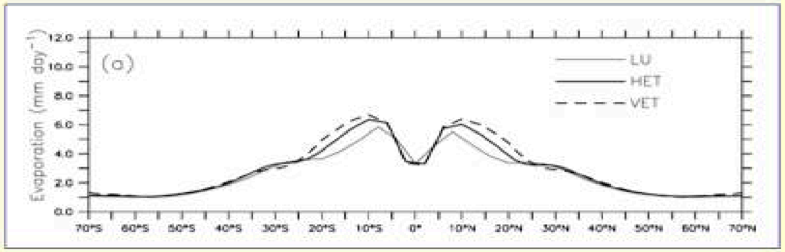
Above: Average precipitation vs. latitude. Increasing tropical resolution yields a double maximum in the ITCZ.

Right: Wave amplitude vs. latitude for (a) Kelvin waves and (b) equatorial Rossby wave, mode 2. Increasing tropical resolution allows equatorial Rossby waves to occur. Convection coupled to these waves yields the off-equator ITCS maxima. Increasing resolutions also gives better definition to Kelvin-wave structure.

Influence Extratropical Waves on Tropical Convection Strength



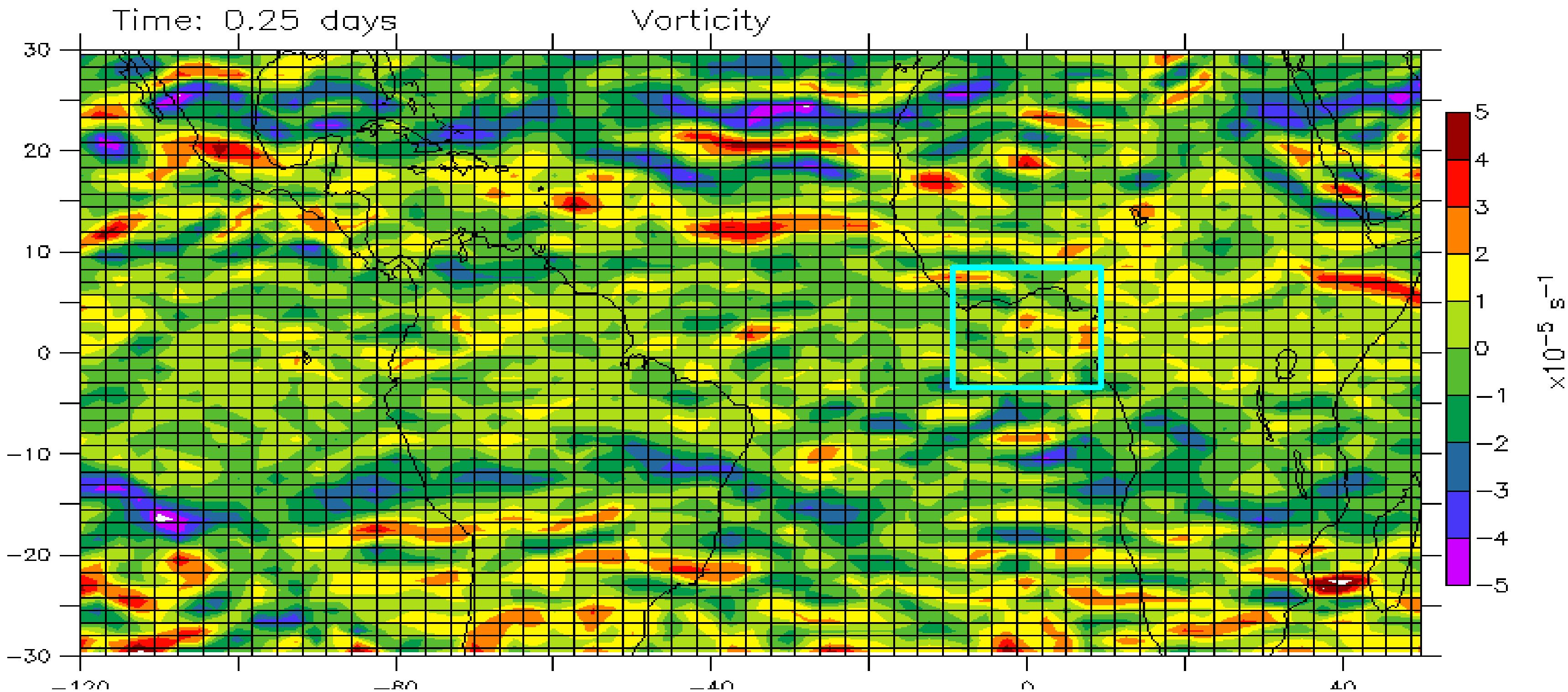
Above: Average precipitation vs. latitude. Increasing extratropical resolution yields a wider and stronger Hadley cell, with more ITCZ precipitation. With low tropical resolution, the ITCZ retains a single maximum.



Above: Average evaporation vs. latitude. The wider, stronger Hadley cell increases the fetch for water imported to the ITCZ, further strengthening tropical precipitation.

Abiodun et. al (2008b; Climate Dynamics)

Dynamic Grid Adaptation in CAM-EULAG



-Initial 2 x 1 (zonal x meridional) degree uniform resolution improved to 1 x 1 degree

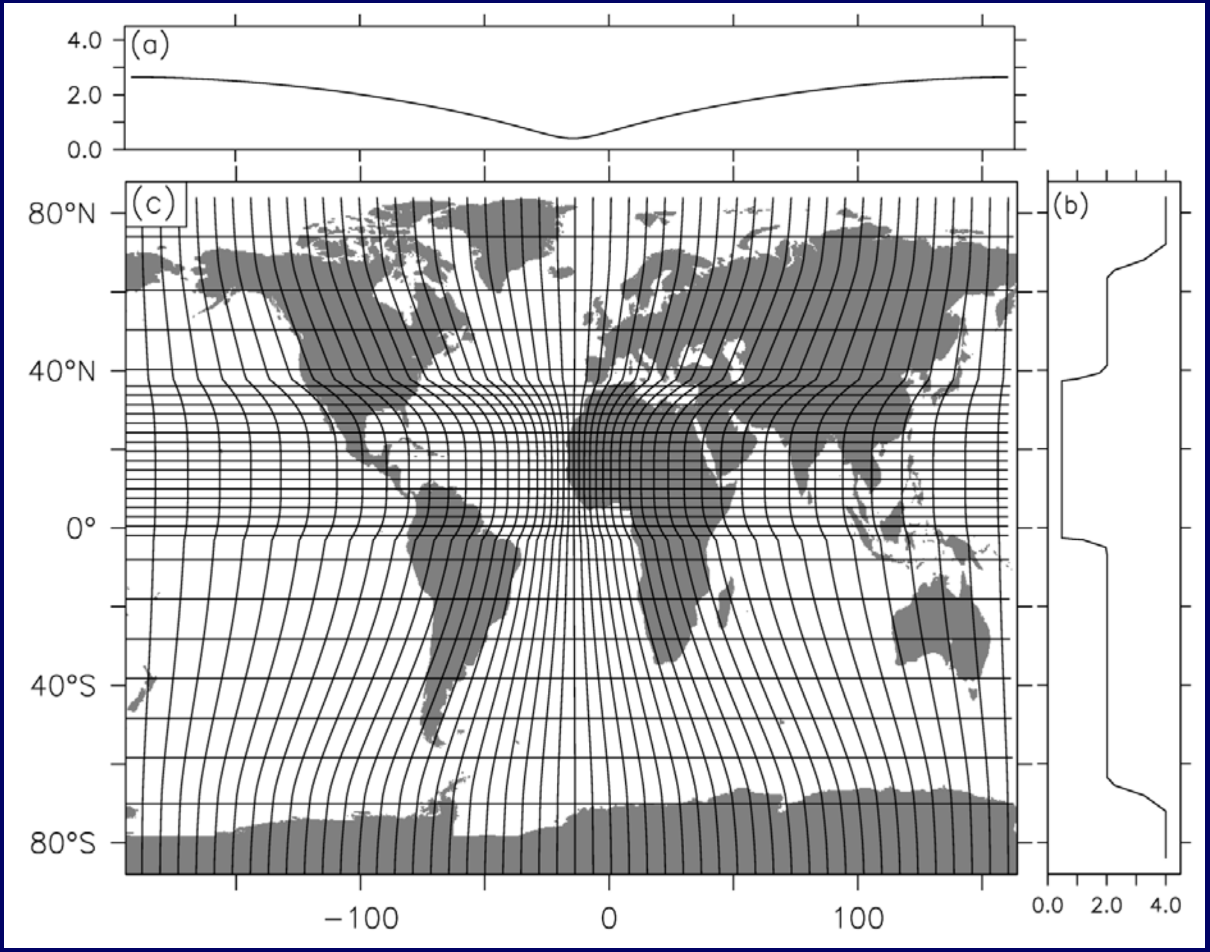
- Blue-green box shows central region of grid adaptation
- Grid tracks first sufficiently strong tropical vortex to enter target region, measured by vorticity $\geq 5.5 \times 10^{-5}\ s^{-1}$

Simulation of West African Monsoon System

-**Real Topography and Land Use Cover**

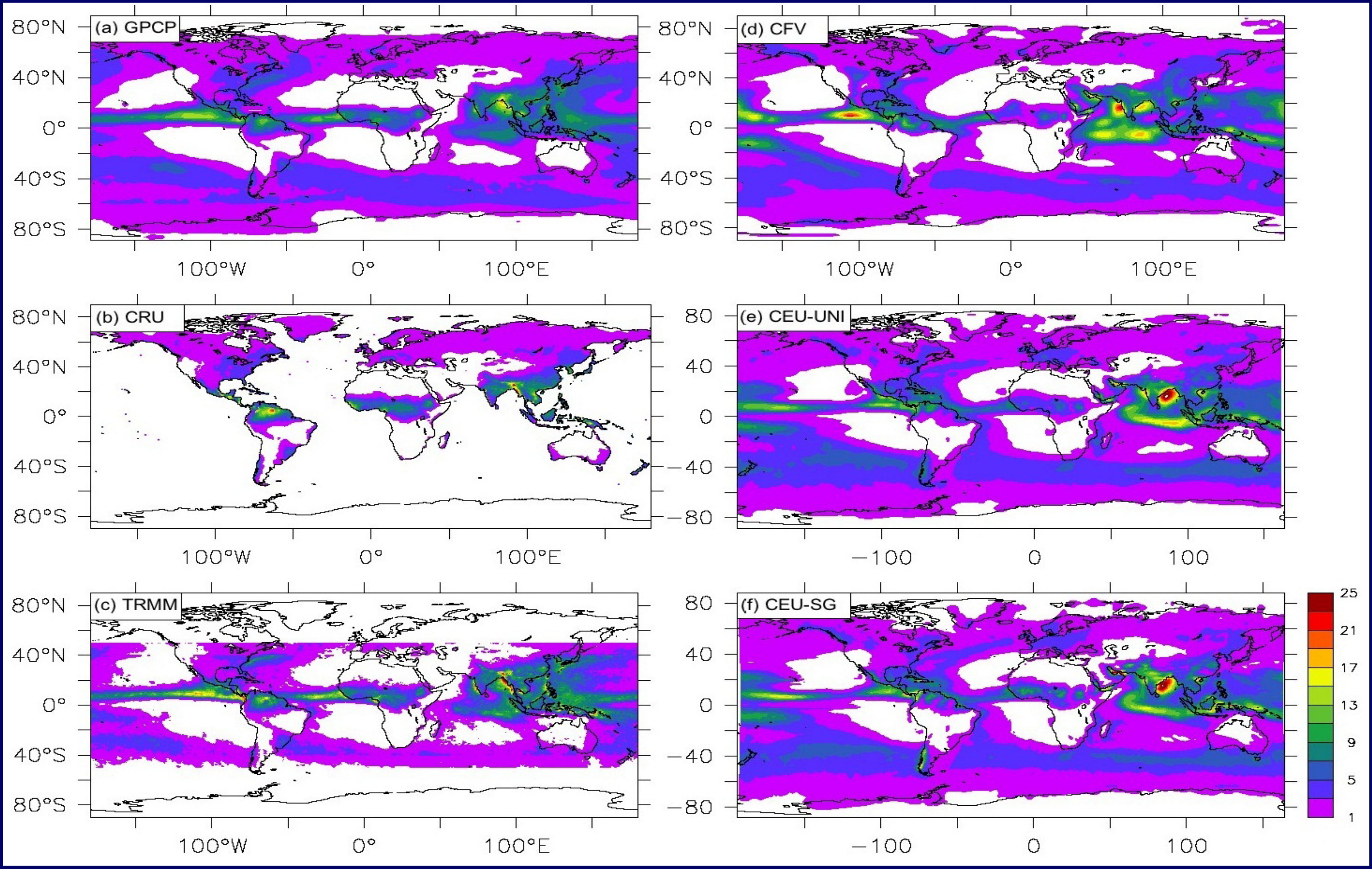
-**Observed Sea Surface Temperature Forcing**

-**Period: 1995 - 2000**

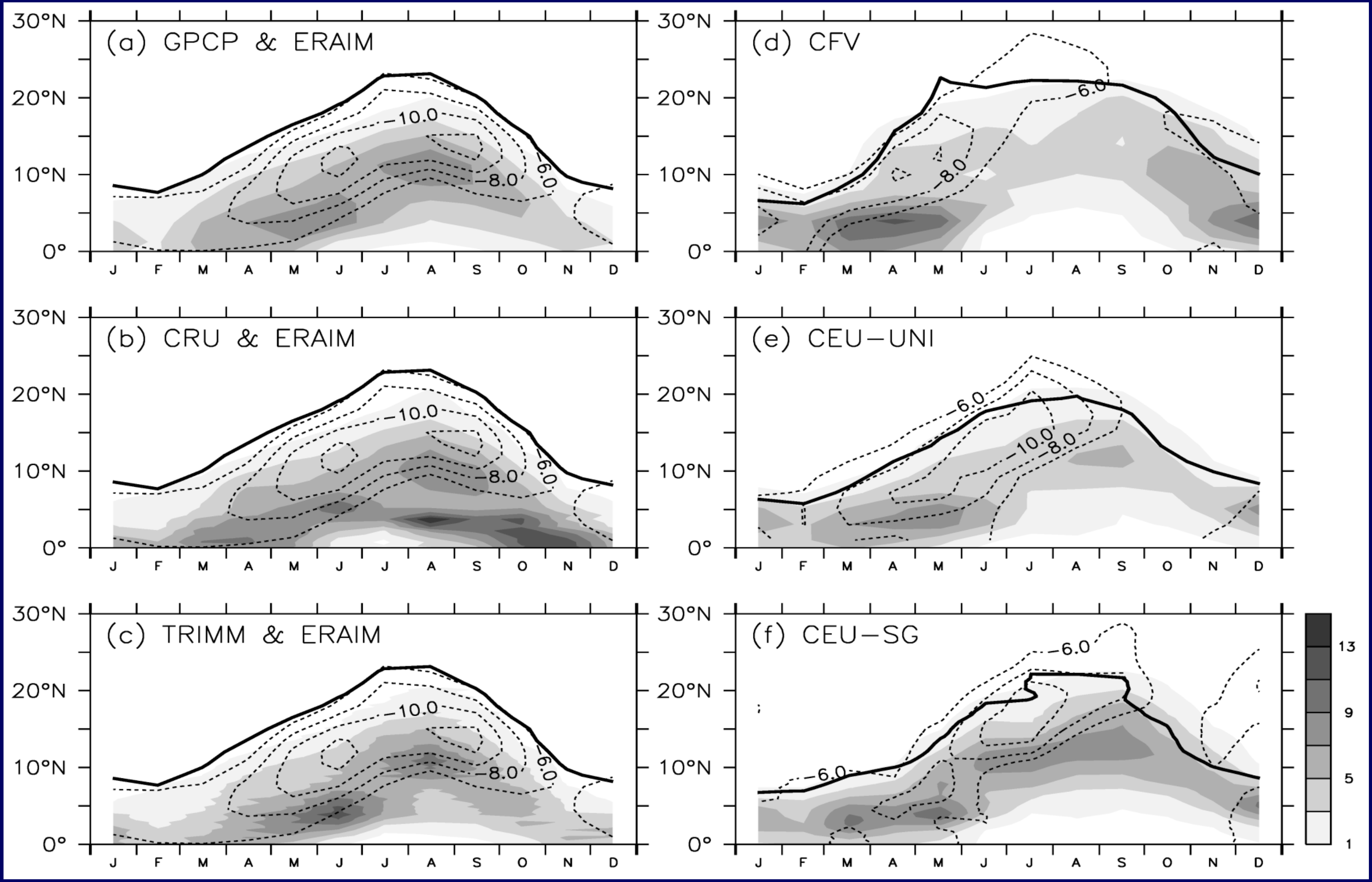


Abiodun et. al (2011; Acta Geophysical)

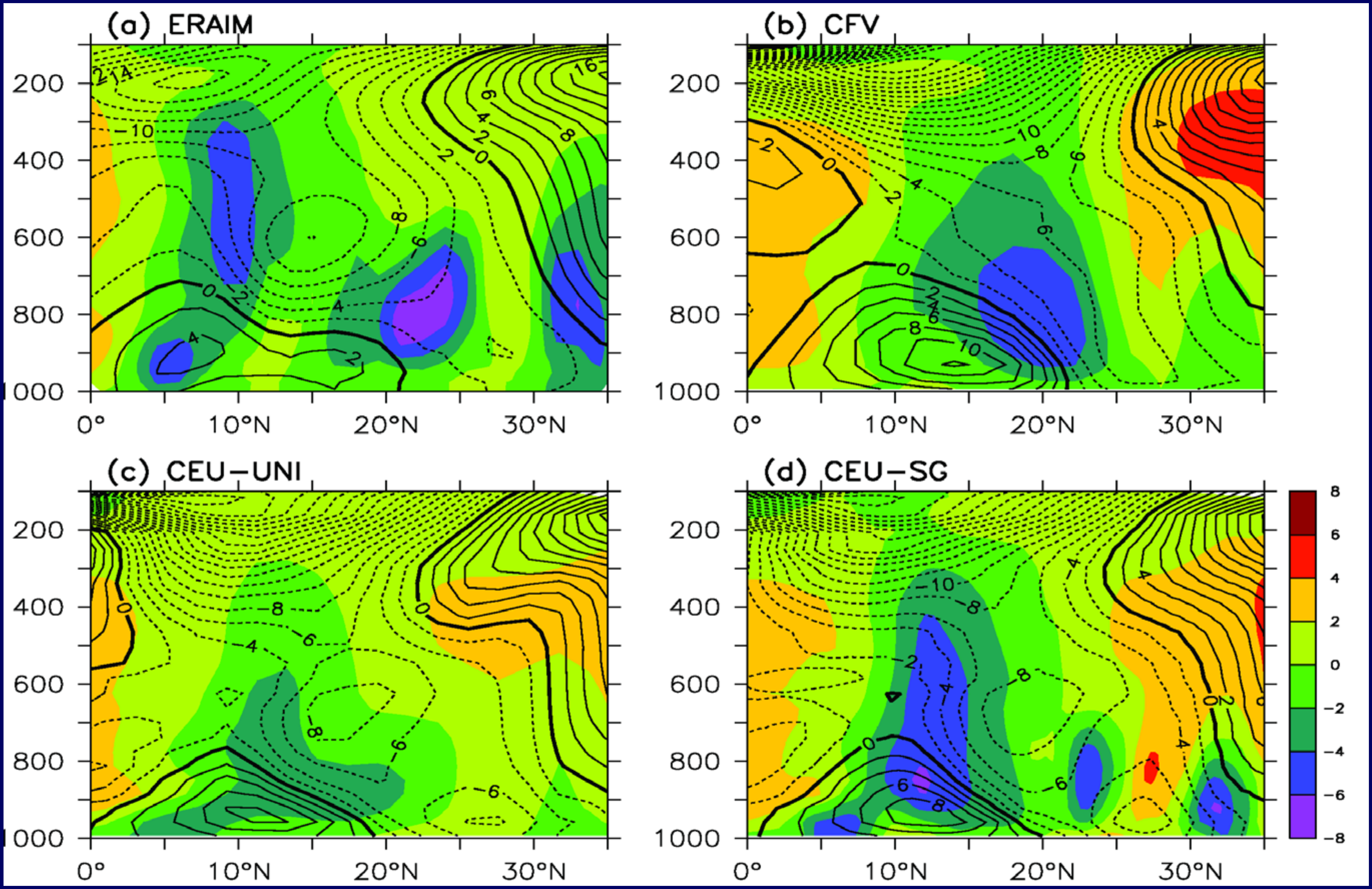
Global Precipitation (mm/day) in June-August



West African Monsoon System



West African Monsoon System (August)

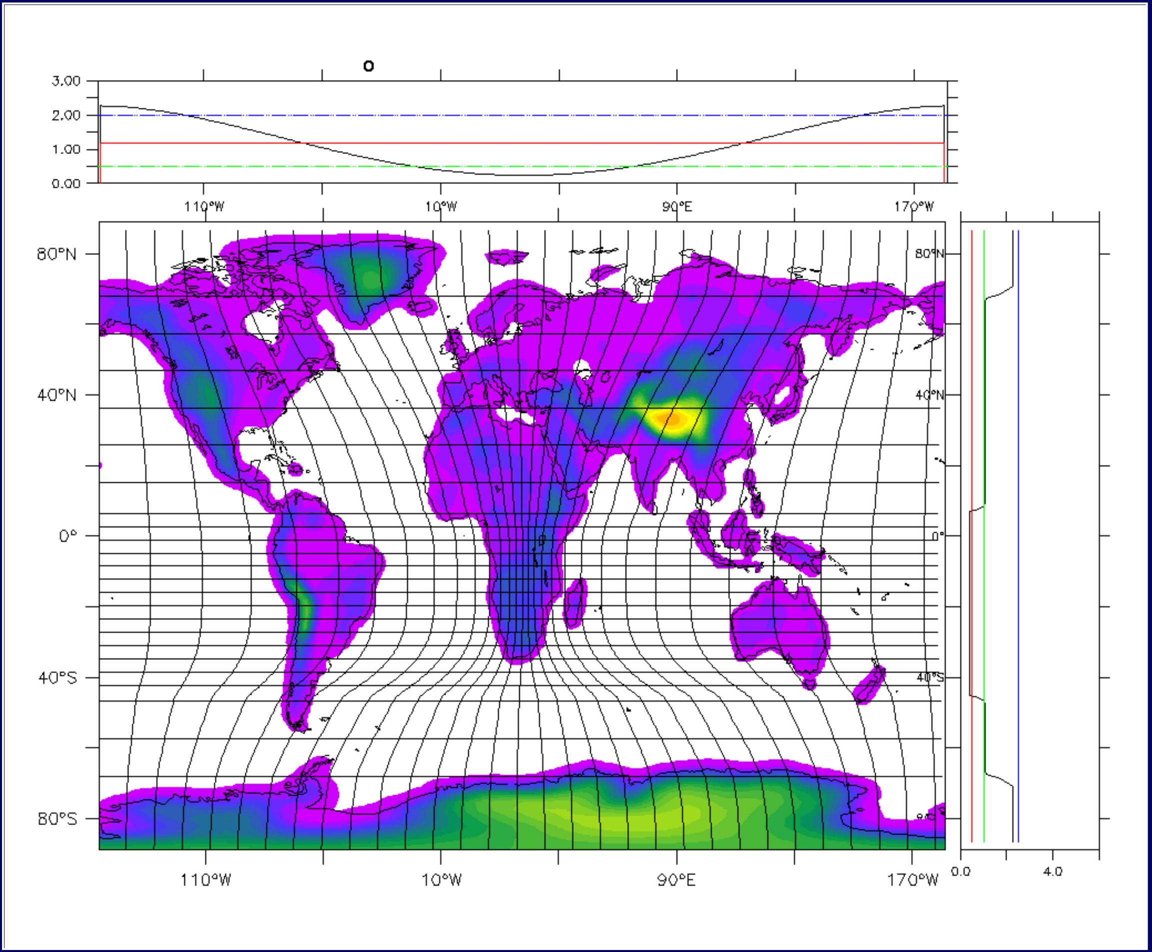


Simulation of Southern African Climate

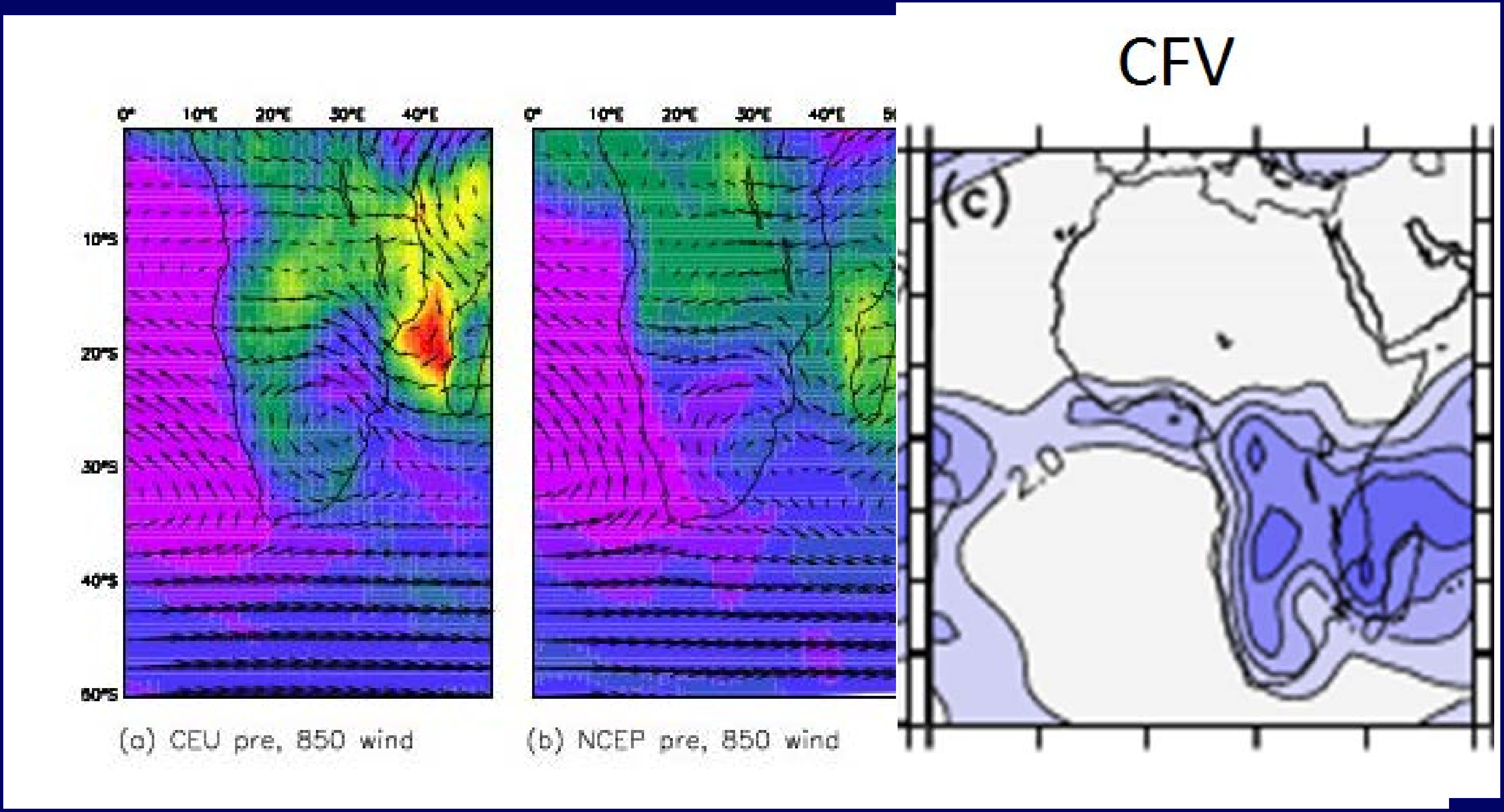
-Real Topography and Land Use Cover

-Observed Sea Surface Temperature Forcing

-Period: 2000 -2002



Precipitation (mm/day) in December-February



Summary

- CAM-EULAG: a non-hydrostatic global atmospheric model with capability for static and dynamic grid adaptation is developed, and the stretching poses no problems
- CAM-EULAG aqua-planet simulation agrees with those from standard CAM3
- CAM-EULAG perform better than CFV in simulating West African climate, even though both models use the same physics parameterizations. This suggests that resolution of dynamics, rather than parameterization, may be a key factor
- Future studies will focus on improving CAM-EULAG simulation over Southern African region, and on comparing the models results with those from Regional Climate Models (RCMs)

Thank you!!!