CMMAP Team Meeting, July 2009

Ft. Collins, CO

Taking a closer look at the daily rainfall cycle in the CMMAP Multi-scale Modeling Framework

Mike Pritchard

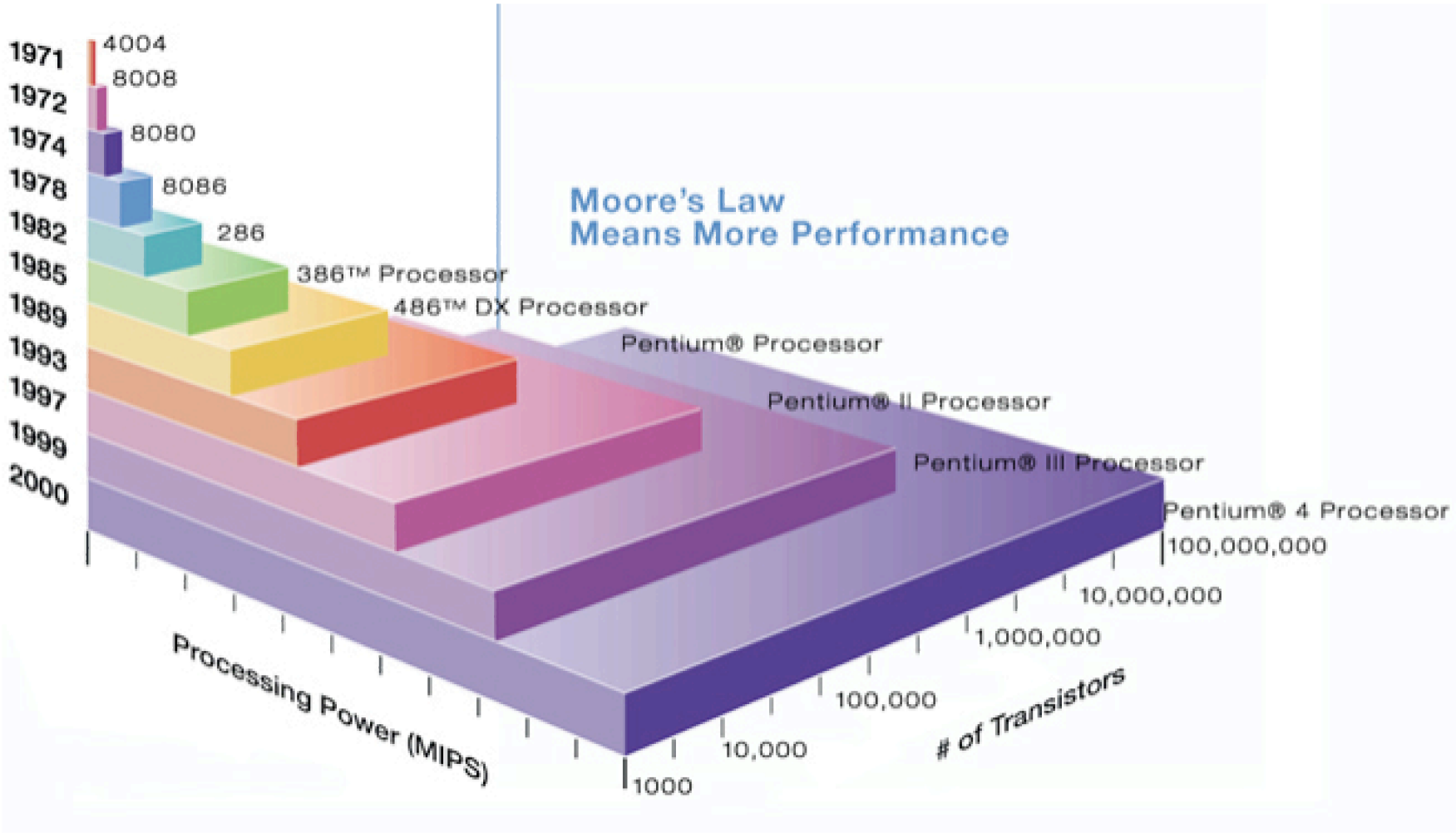
Richard Somerville

Scripps Institution of Oceanography

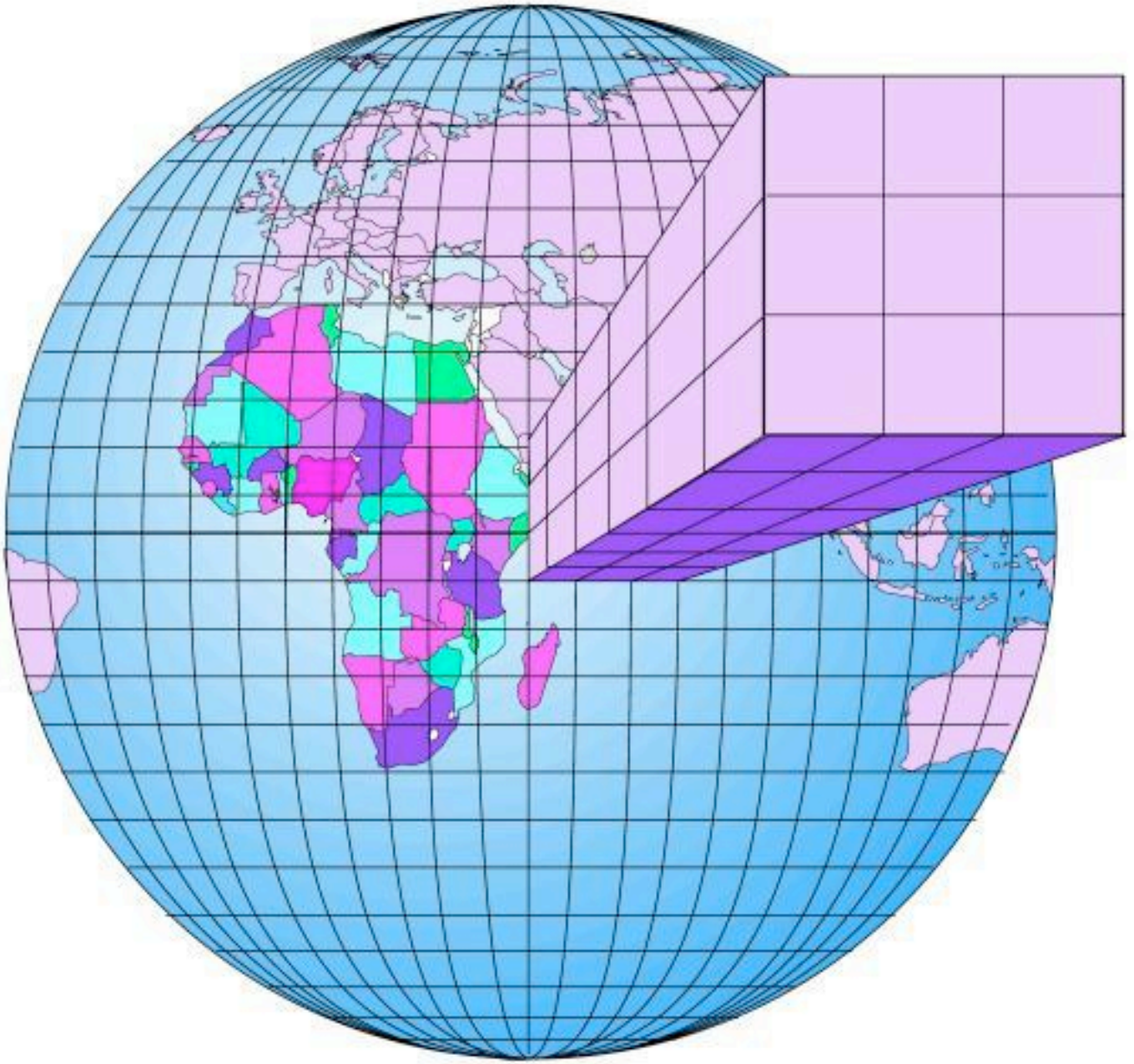
University of California, San Diego

Outline

- Background
  - Context of multi-scale modeling
  - Why study the daily cycle of rainfall?
- Comparing the diurnal cycle of rainfall in:
  - Satellite observations
  - A conventional global climate model
  - The CMMAP multi-scale model framework
- Why does superparameterization improve the daily rainfall cycle?



http://www.developers.net/storyImages/062404/inteldemystifying1.jpg



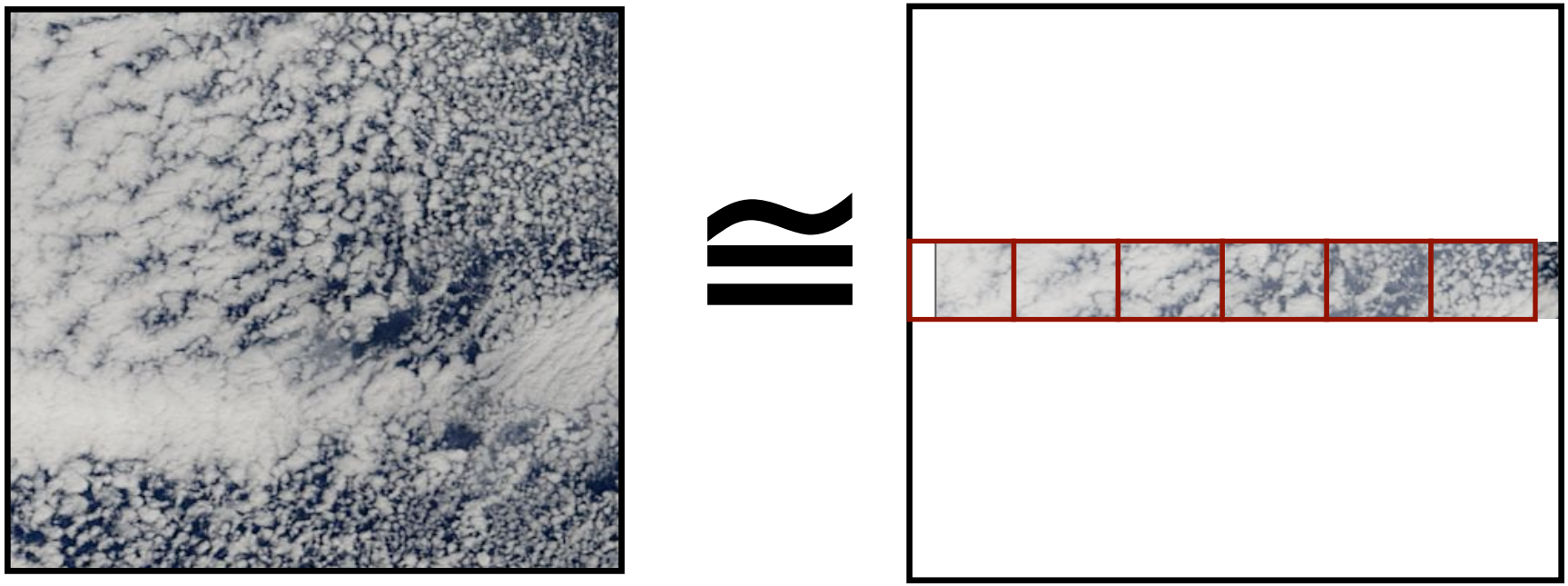
GCM: [conventional] Global Climate Model

http://www.developers.net/storyImages/062404/inteldemystifying1.jpg

“Superparameterization”

a.k.a.

multi-scale climate modeling

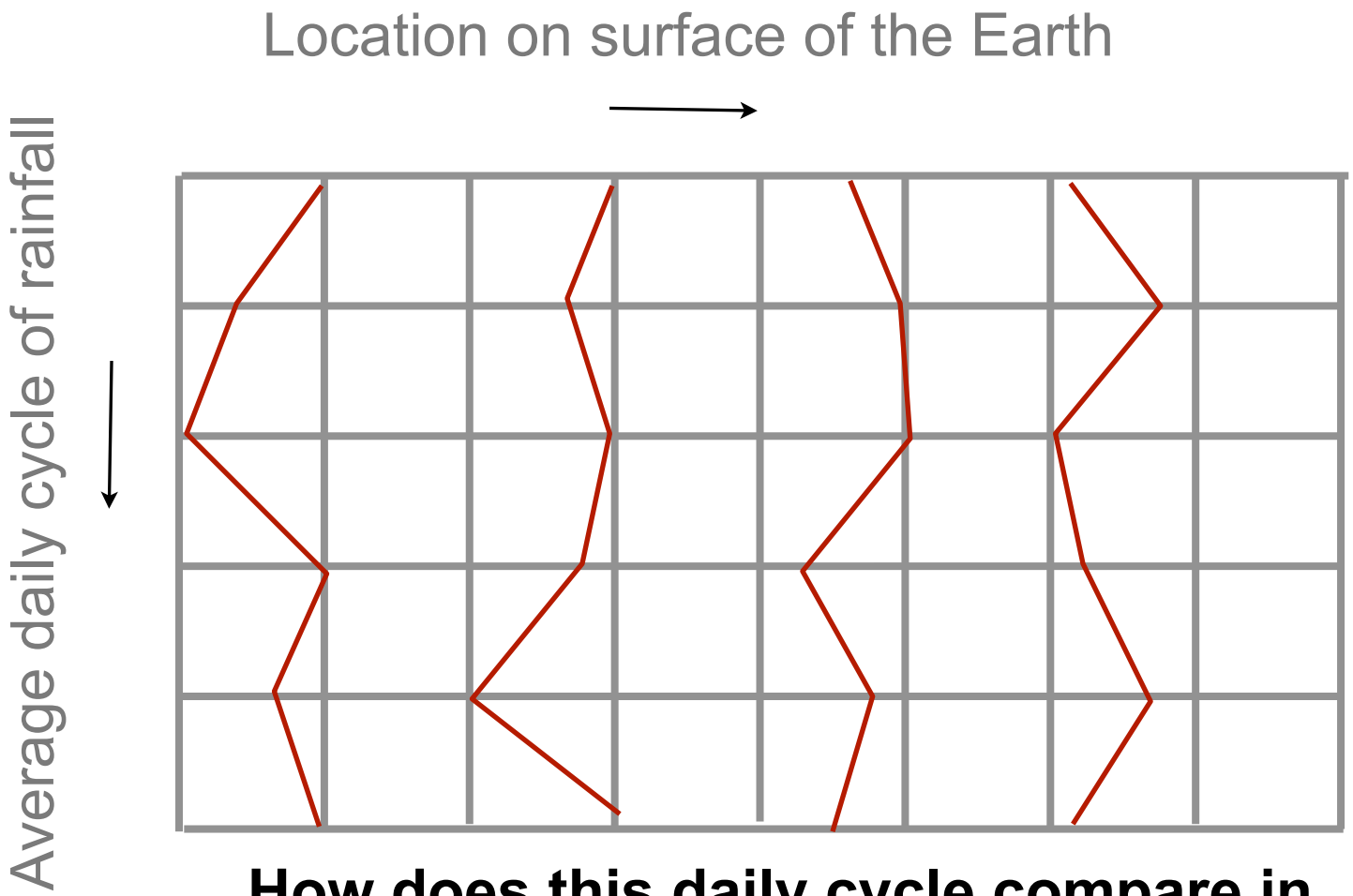


MMF: Multiscale Modeling Framework

Why study the diurnal rainfall cycle?

- Rich and regionally varied convective dynamics
- Well observed with instruments
- Cheap to simulate in models
- Sensitive to cumulus parameterization and “super-parameterization”.

The composite seasonal day



How does this daily cycle compare in a GCM, an MMF and OBS?

Comparing models to observations

GCM

Global Climate Model
clouds etc. “parameterized”

MMF

Multiscale Modeling Framework
clouds etc. “super-parameterized”

OBS

A best estimate of rainfall from many space-based radiation sensors and radars[9]

Fitting a 24 hour sine wave to the daily cycle

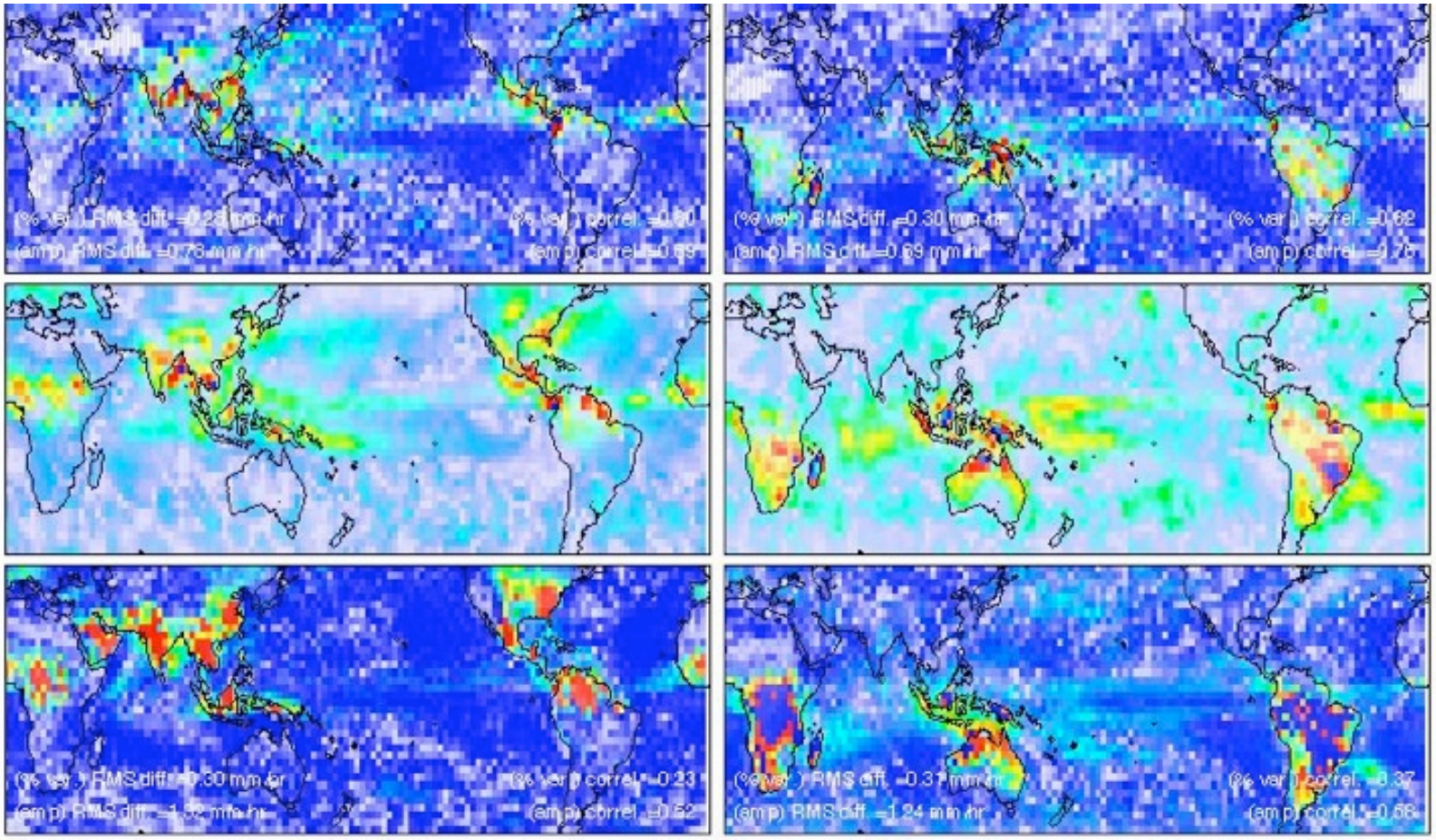
JJA

DJF

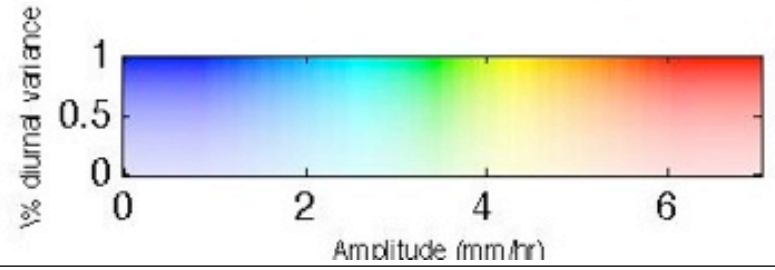
MMF

OBS

GCM

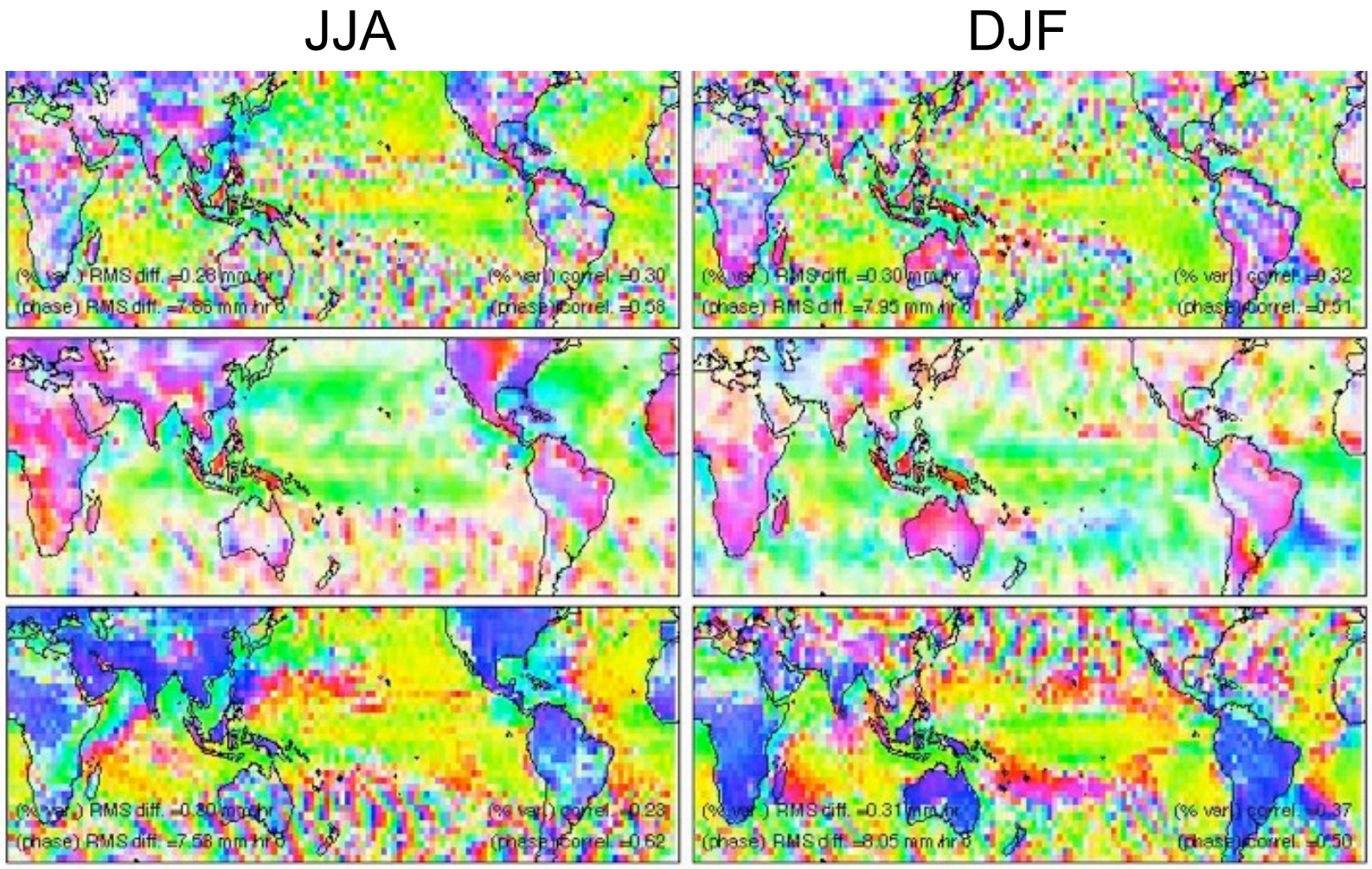


Color hue
(amplitude of 24-hr wave)

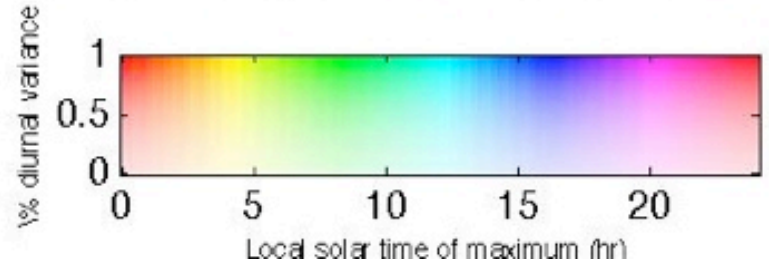


Color saturation
(% variance explained by
fitted 24-hr wave)

Fitting a 24 hour sine wave to the daily cycle

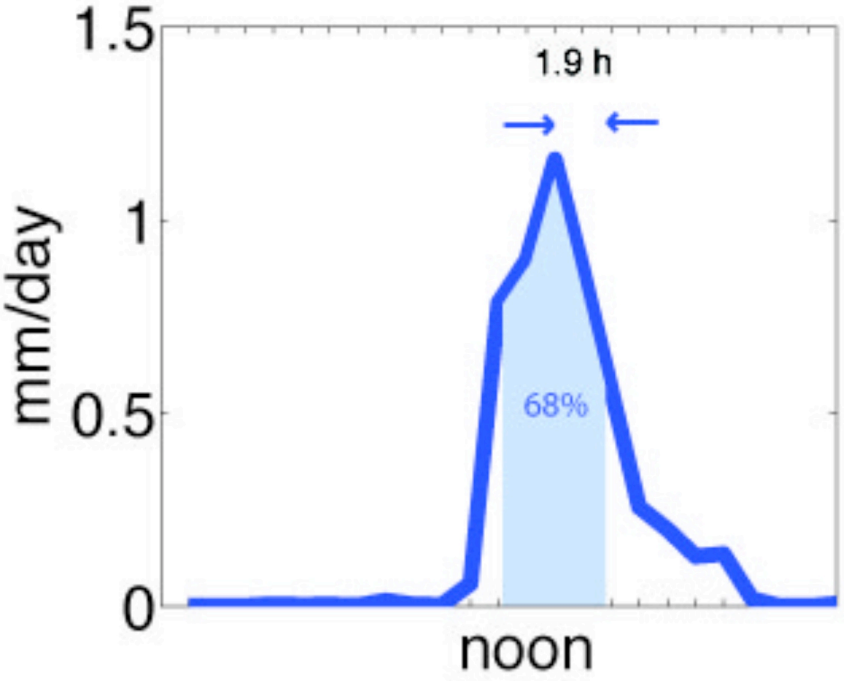


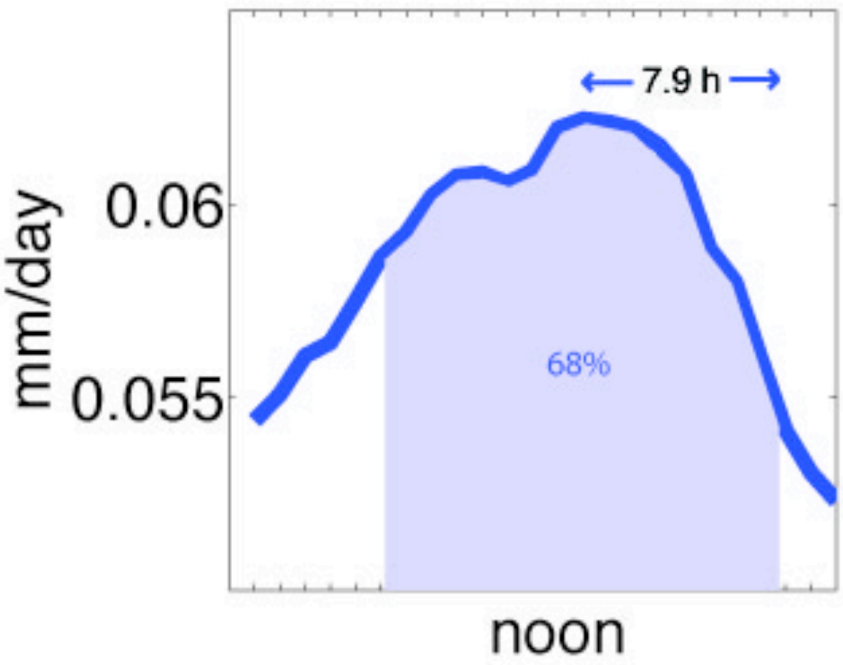
Color hue
(phase of 24-hr wave)



Color saturation
(% variance explained by
fitted 24-hr wave)

Broadness of the daily maximum





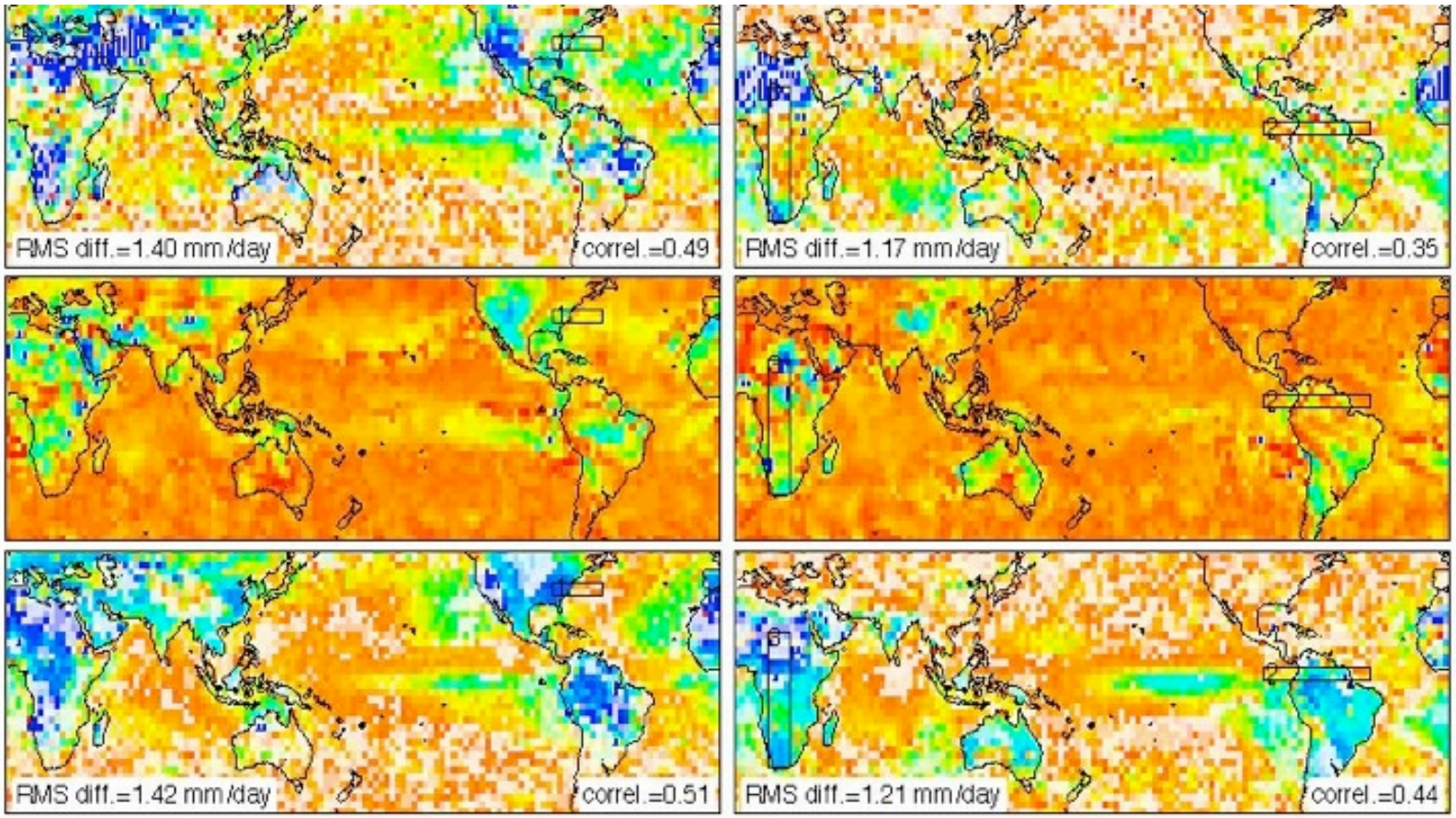
Broadness of the daily maximum

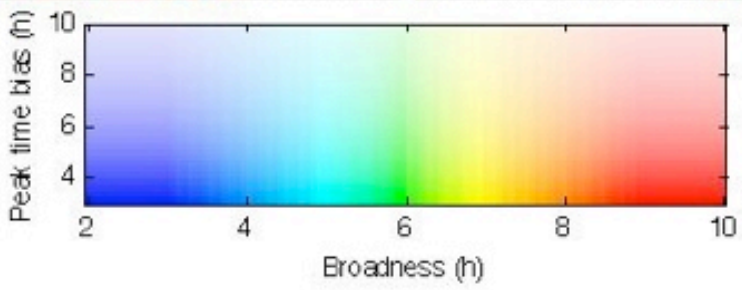
JJA DJF

MMF

OBS

GCM





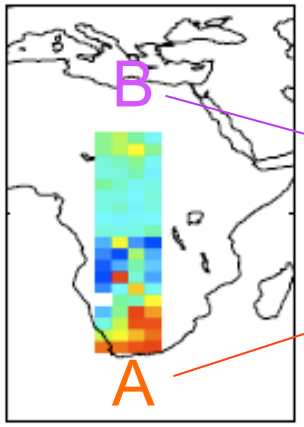
Color hue
(broadness of diurnal peak)

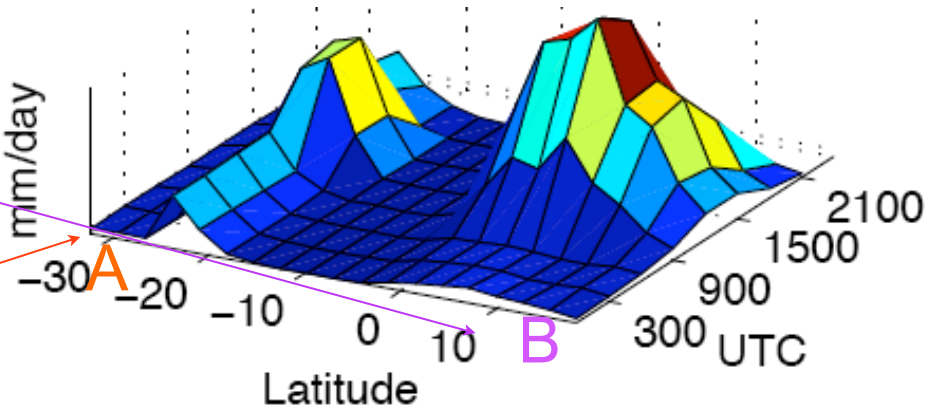
Color saturation
(bias in peak timing)

Broadness

Reduced transect diurnal cycle

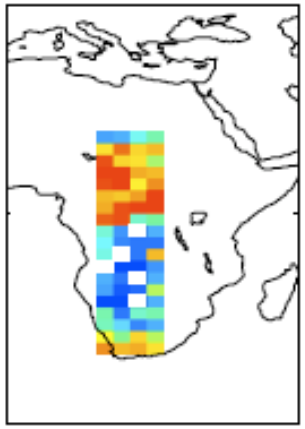
GCM

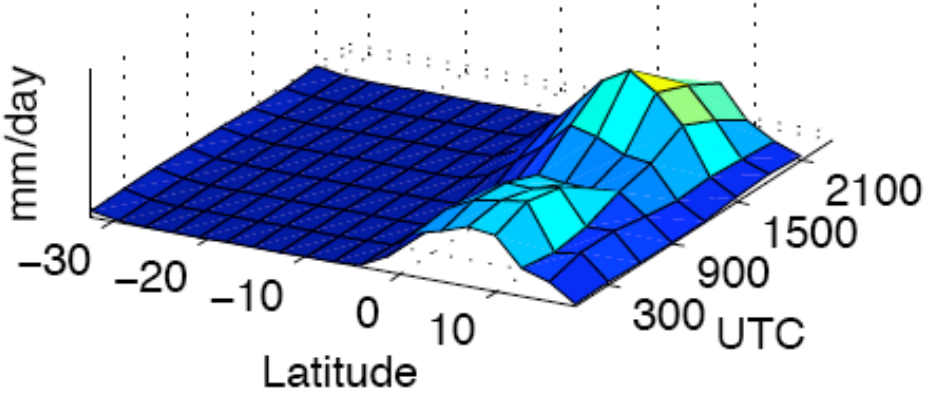




GCM

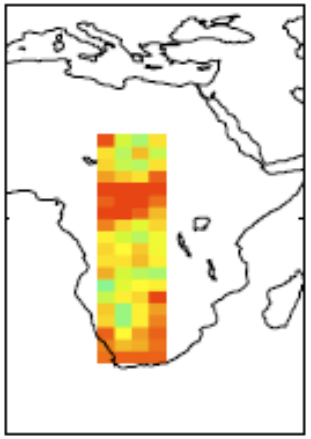
MMF

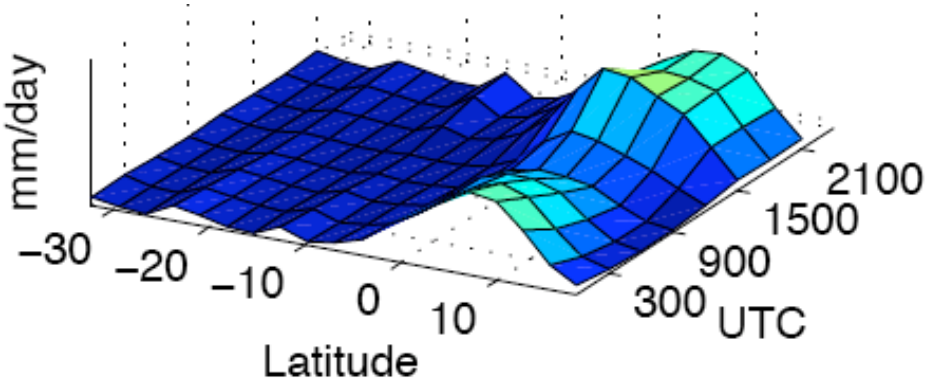




MMF

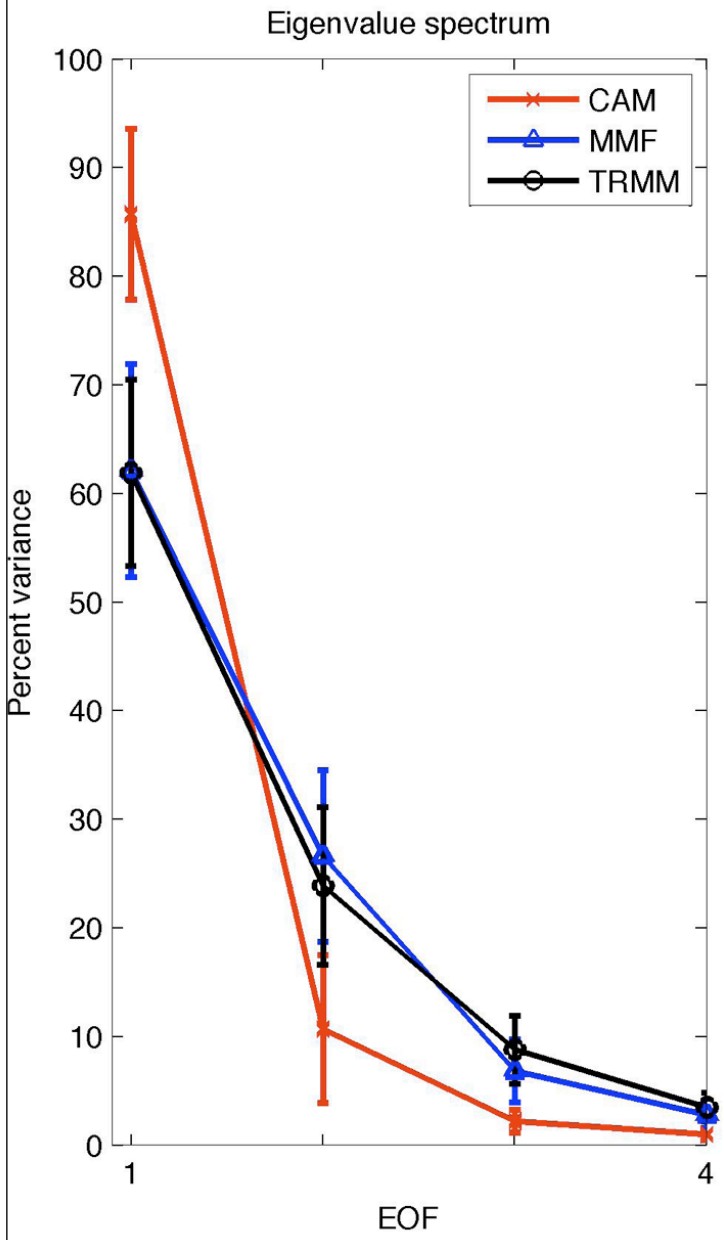
OBS





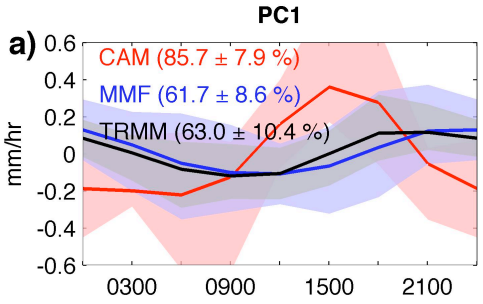
OBS

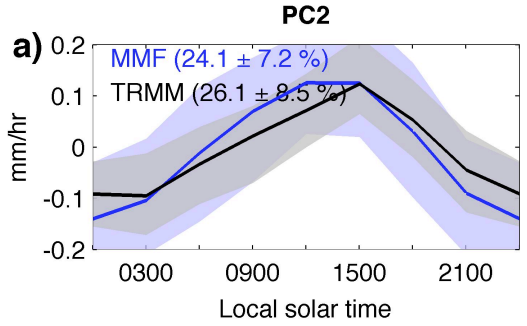
A compact statistical perspective



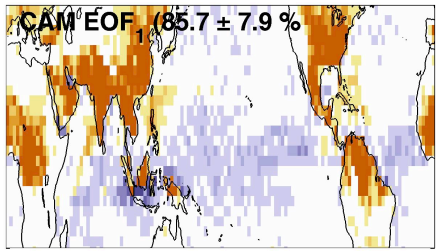
Leading mode

Secondary mode

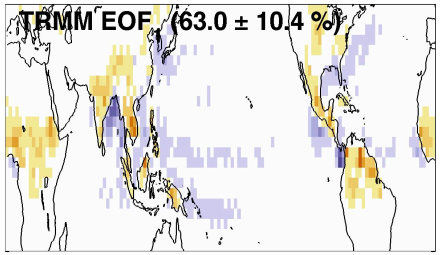


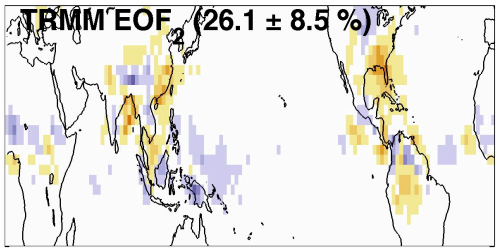


GCM

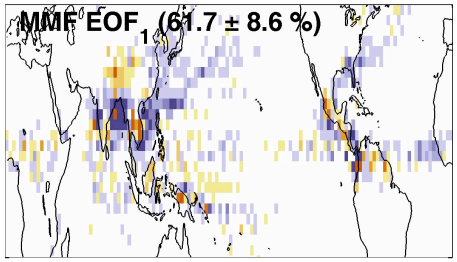


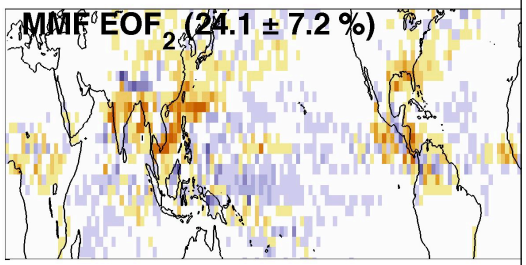
OBS





MMF





Preliminary conclusinos

- Diurnal cycle improvements due to super-parameterization of clouds in the MMF:
  - Less locked to 24-hour sinusoid / single EOF
  - Structure of cross-coastal land-sea contrast
  - Increased horizontal inhomogeneity
  - U.S. eastern seaboard, western Atlantic
- Statistical eigenmode analysis as a compact litmus test for diurnal performance.

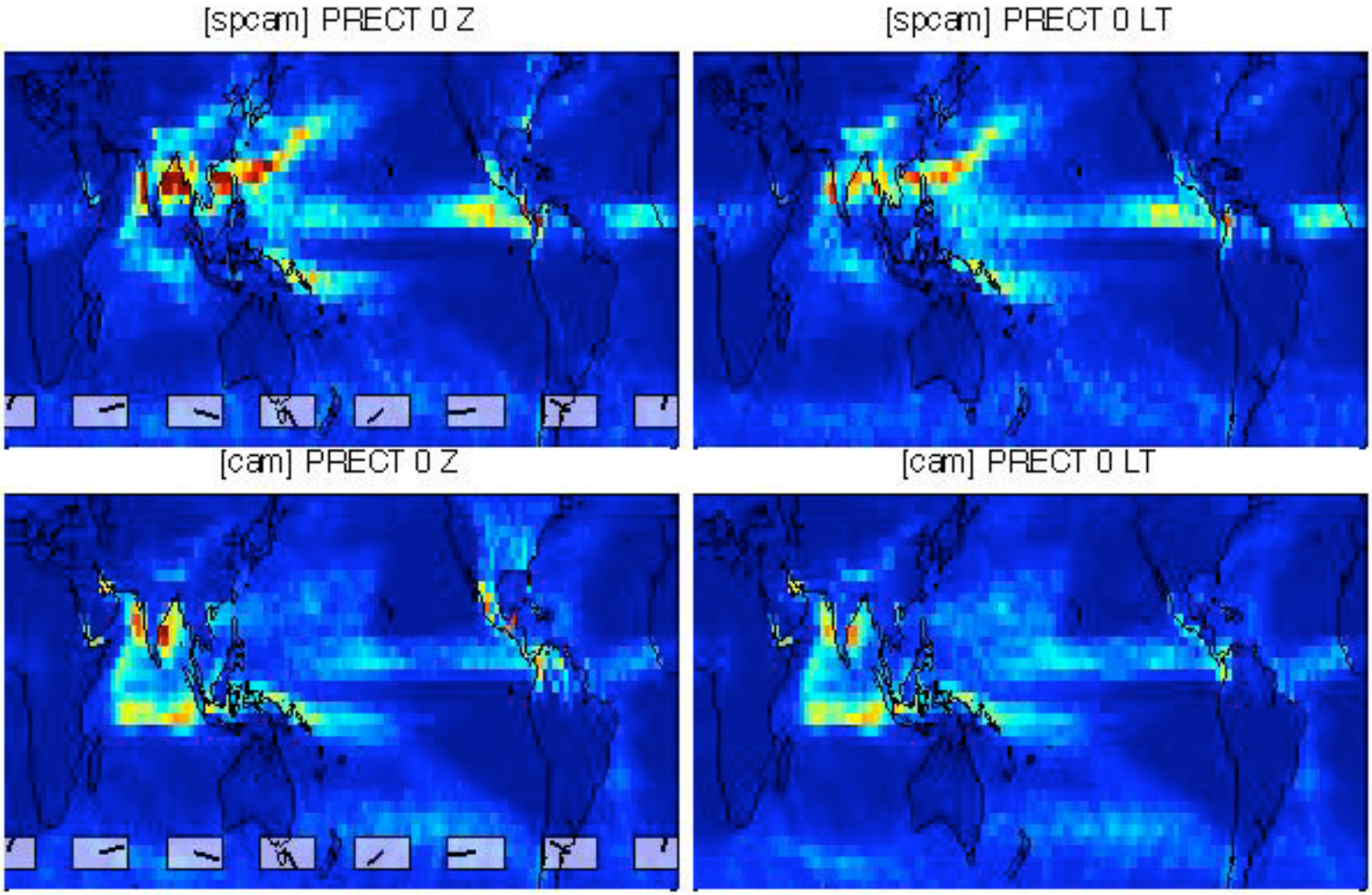
Why does super-parameterization of clouds improve the diurnal cycle of rainfall in the MMF?

JJA precipitation

Cool colors (less rain) warm colors (more rain)

MMF

GCM



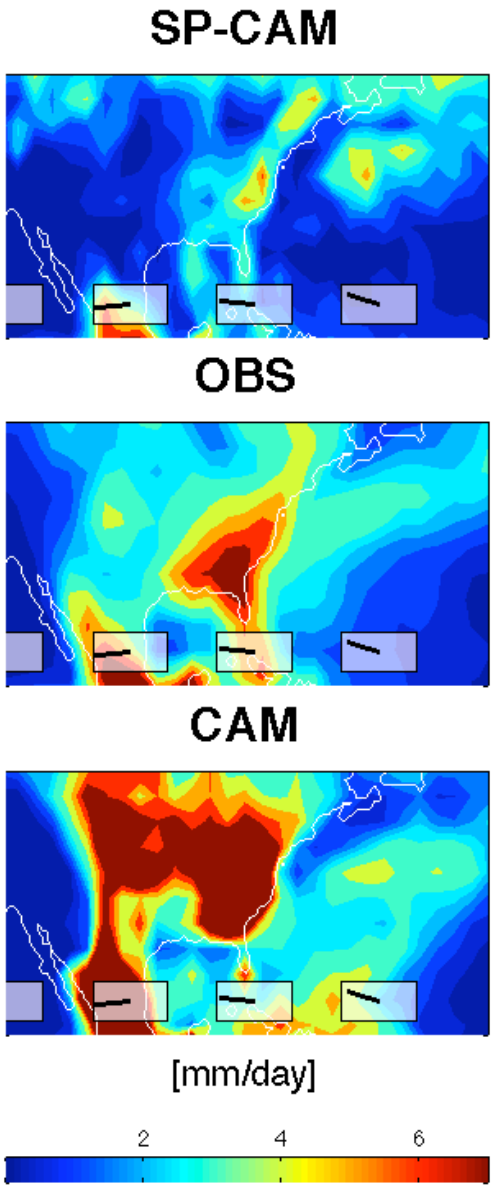
Universal time

Local time

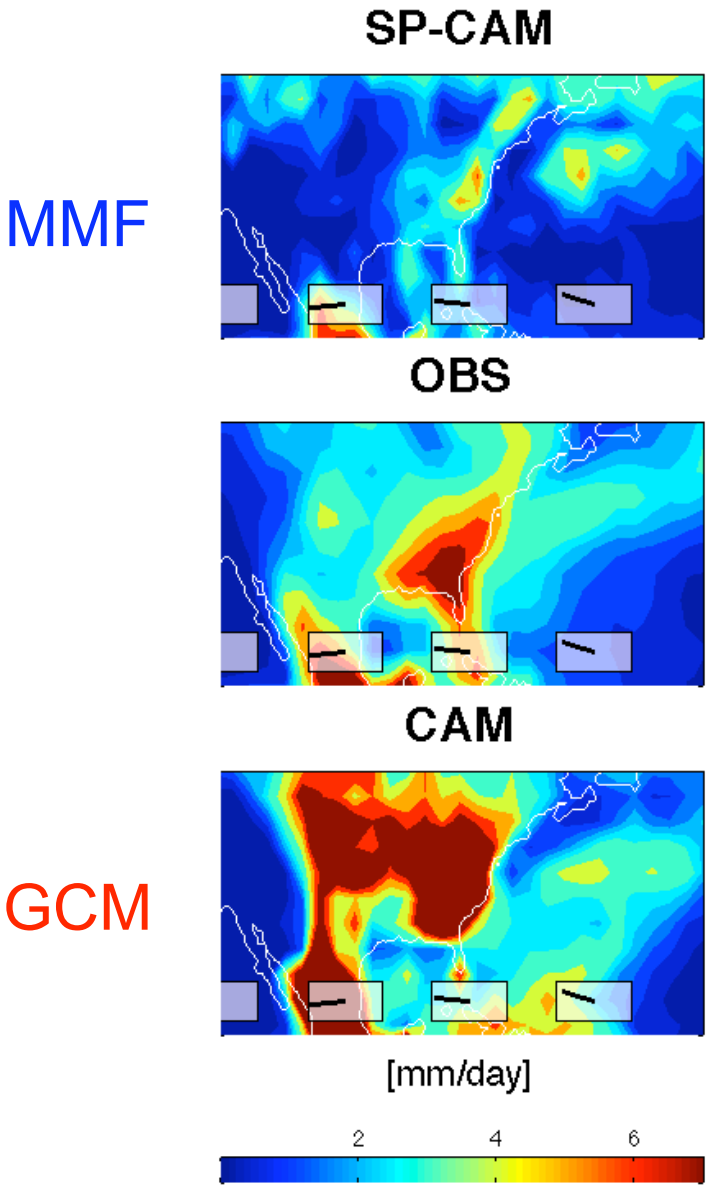
Rainfall

MMF

GCM



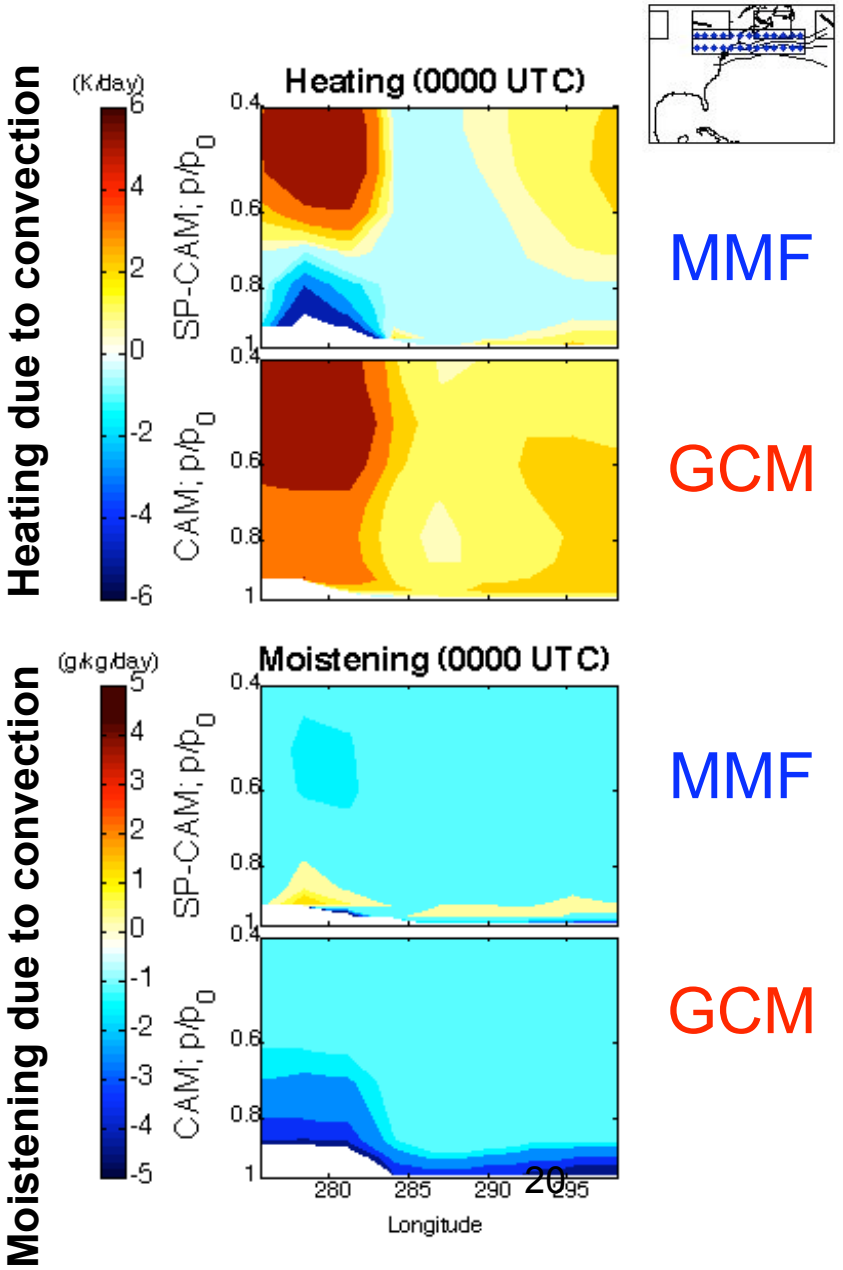
Rainfall



MMF

GCM

Convective tendencies



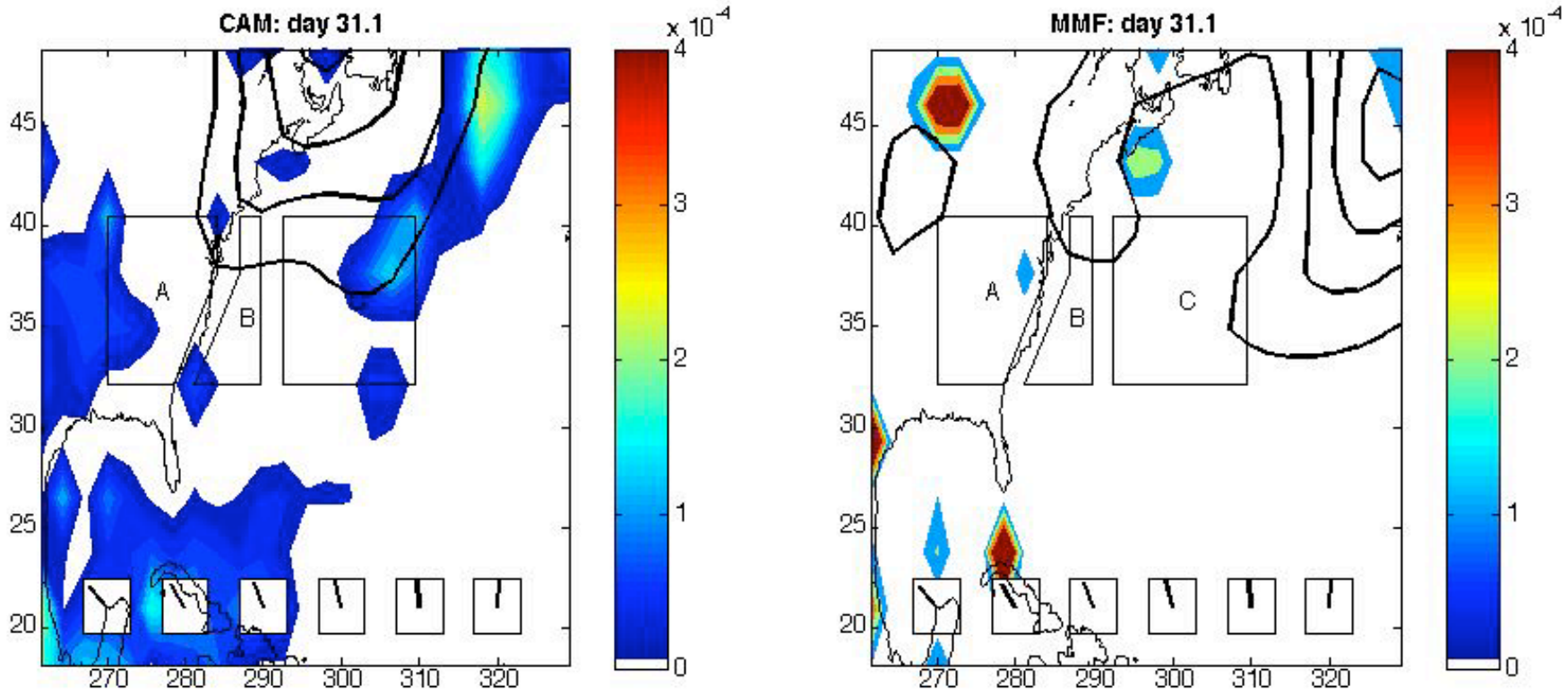
MMF

GCM

MMF

GCM

Unravelling the diurnal composite



Precipitation as a piece of the vertically integrated water budget

$$\underbrace{-\int \frac{\partial q}{\partial t} dz}_{\text{–DQDT}} \underbrace{-\int \nabla \cdot (q\mathbf{v})}_{\text{QCONV}} \underbrace{- PREC}_{\text{-PREC}} + \underbrace{QFLX}_{\text{QFLX}} = 0$$

–DQDT	QCONV	-PREC	QFLX
depletion of stored vapor and cloud	convergence due to advection	removal by precipitation	addition by evapotranspiration

In English,

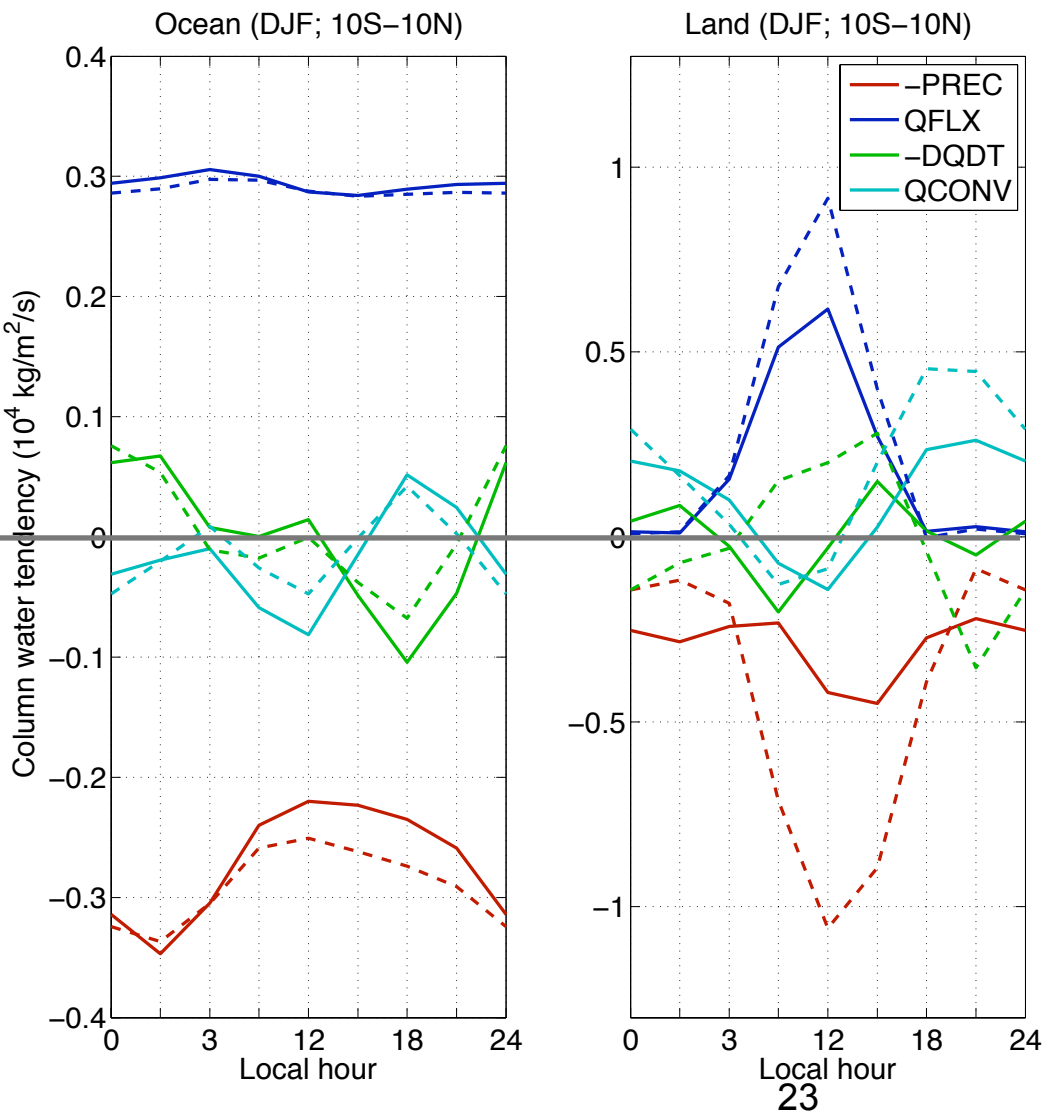
NET GROWTH = DEPOSITS - WITHDRAWALS

Diurnal water budget analysis

Water being withdrawn
Evaporation adding water
Converging winds adding water

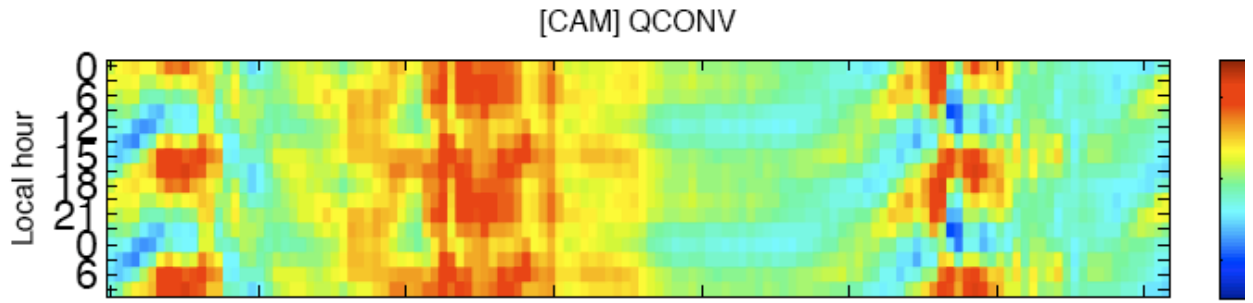
GCM ----
MMF ——

Water being added
Diverging winds removing water
Rainfall removing water



Conservation of water (10S-10N)

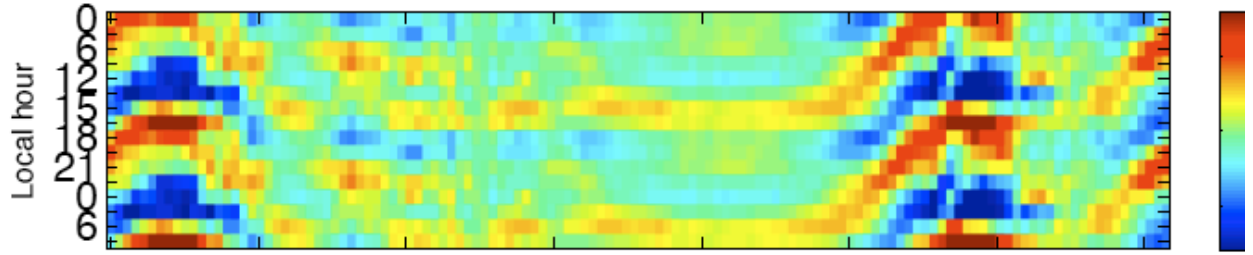
$$\int \nabla \cdot (q\mathbf{v})$$



GCM

water convergence

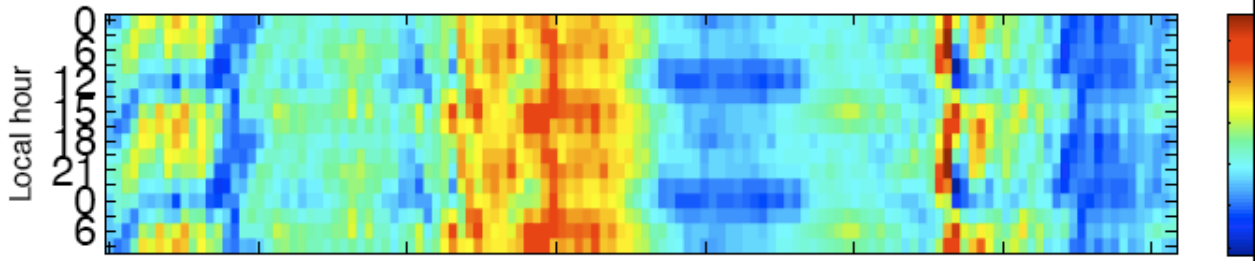
$$\int \frac{\partial q}{\partial t} dz$$



GCM

moisture storage

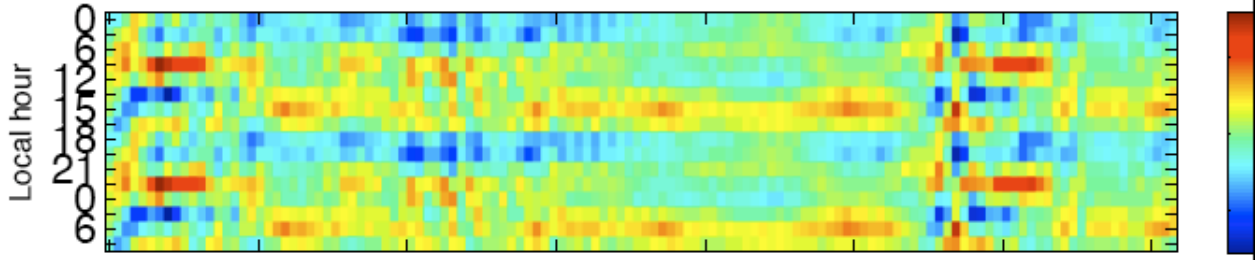
$$\int \nabla \cdot (q\mathbf{v})$$



MMF

water convergence

$$\int \frac{\partial q}{\partial t} dz$$

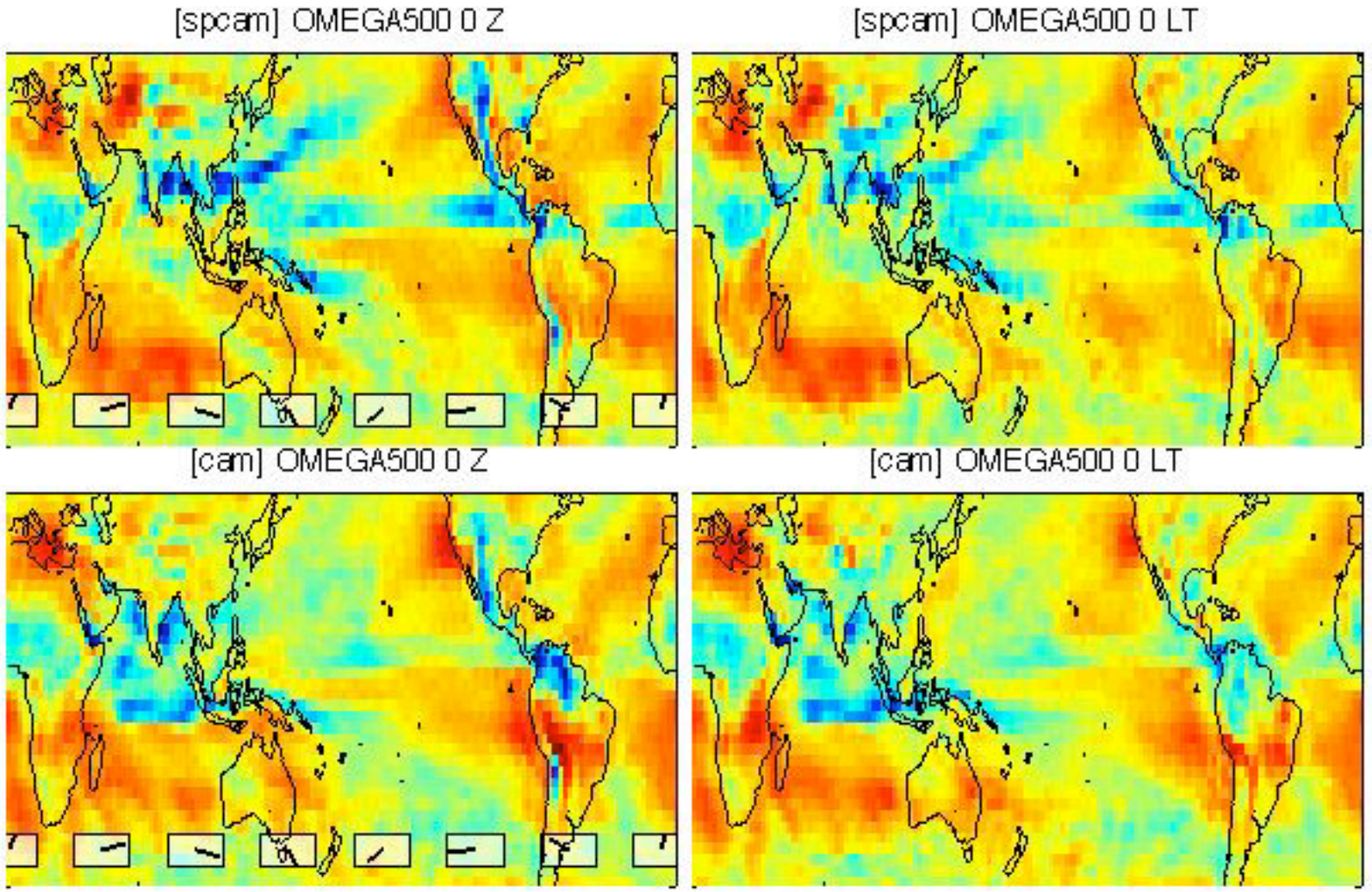


MMF

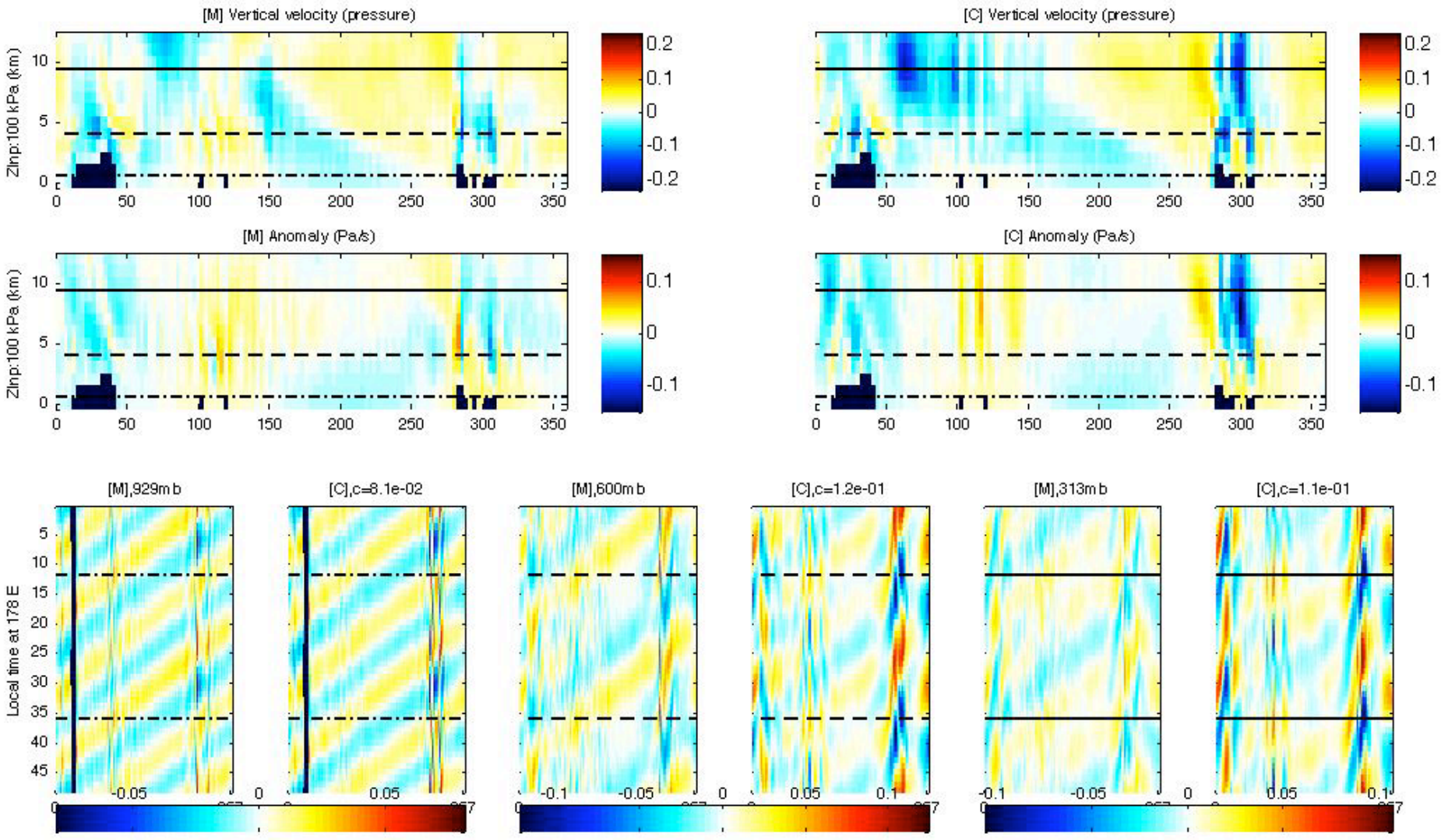
moisture storage

JJA vertical velocity at 500 hPa

Cool colors (upward) ; warm colors (downward)



Why does super-parameterization of clouds improve the diurnal cycle of rainfall in the MMF?


[M] Vertical velocity (pressure)
[C] Vertical velocity (pressure)
[M] Anomaly (Pa/s)
[C] Anomaly (Pa/s)
Zlnp:100 kPa (km)
[M],929mb
[C],c=8.1e-02
[M],600mb
[C],c=1.2e-01
[M],313mb
[C],c=1.1e-01
Local time at 178 E