NCAR

Timeslice Experiments at High Resolution. What does the resolution buy us ?

Cécile Hannay, Rich Neale, Julio Bacmeister

National Center for Atmospheric Research, Boulder

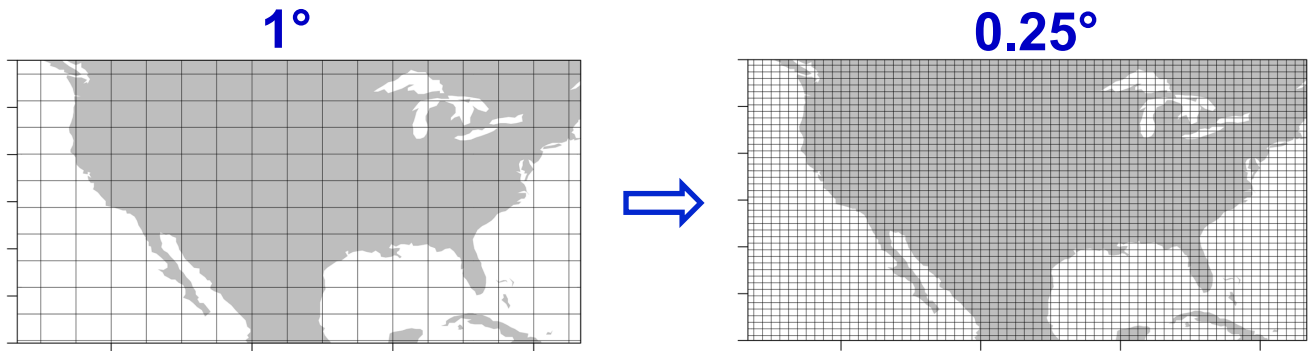
Thanks to DOE for providing allocation on jaguar

AMWG Meeting, Boulder, 1 - 3 February

Motivation

Common wisdom

“The expectation is that increasing spatial resolution will generally cause the simulation to improve because of a more accurate topography, and a better large-scale circulation”



What does the high resolution buy us ?
What is the impact for future projections ?

At a glance

Model

- Community Atmospheric Model (CAM4)
- CAM standalone with prescribed SSTs
- Horizontal resolutions: 2°, 1°, 0.25°

Time-slice experiments

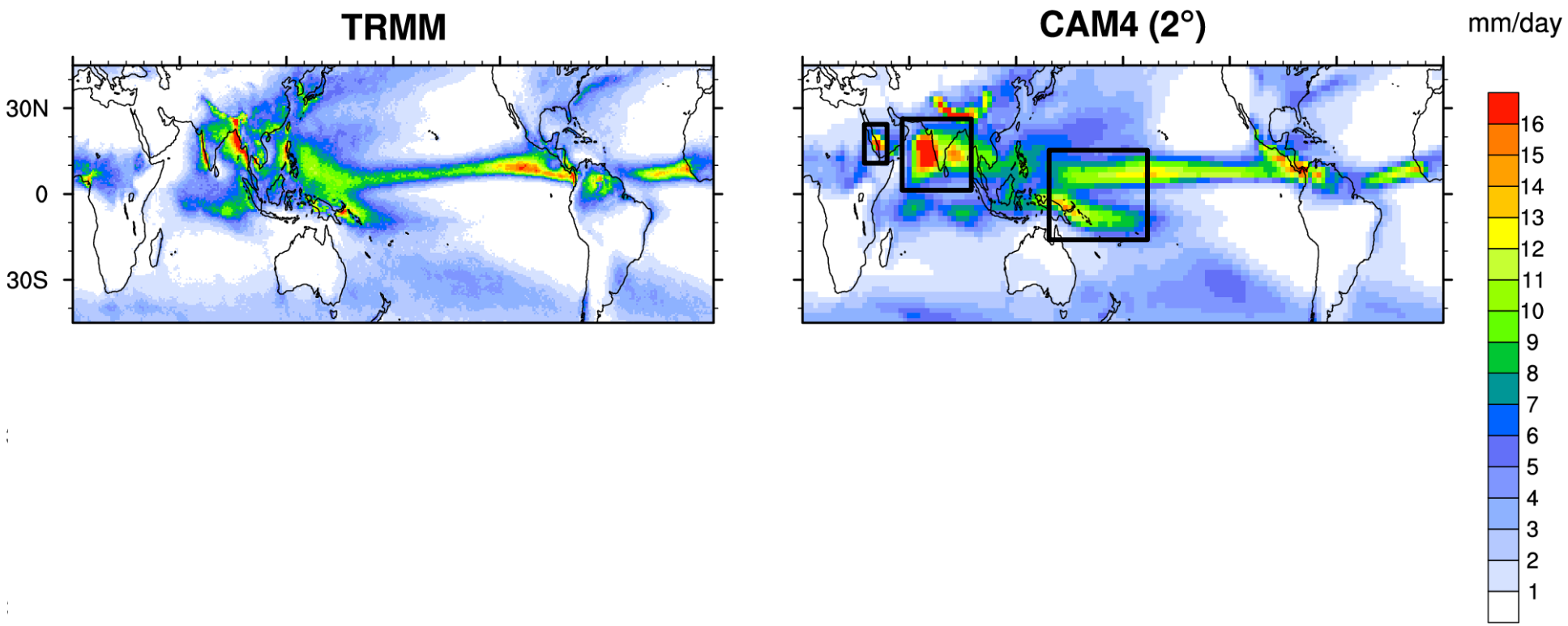
- present-day conditions (1981-2000)
- future conditions (2081-2000)

Analysis focuses on **precipitation** (Model ⇔ TRMM)

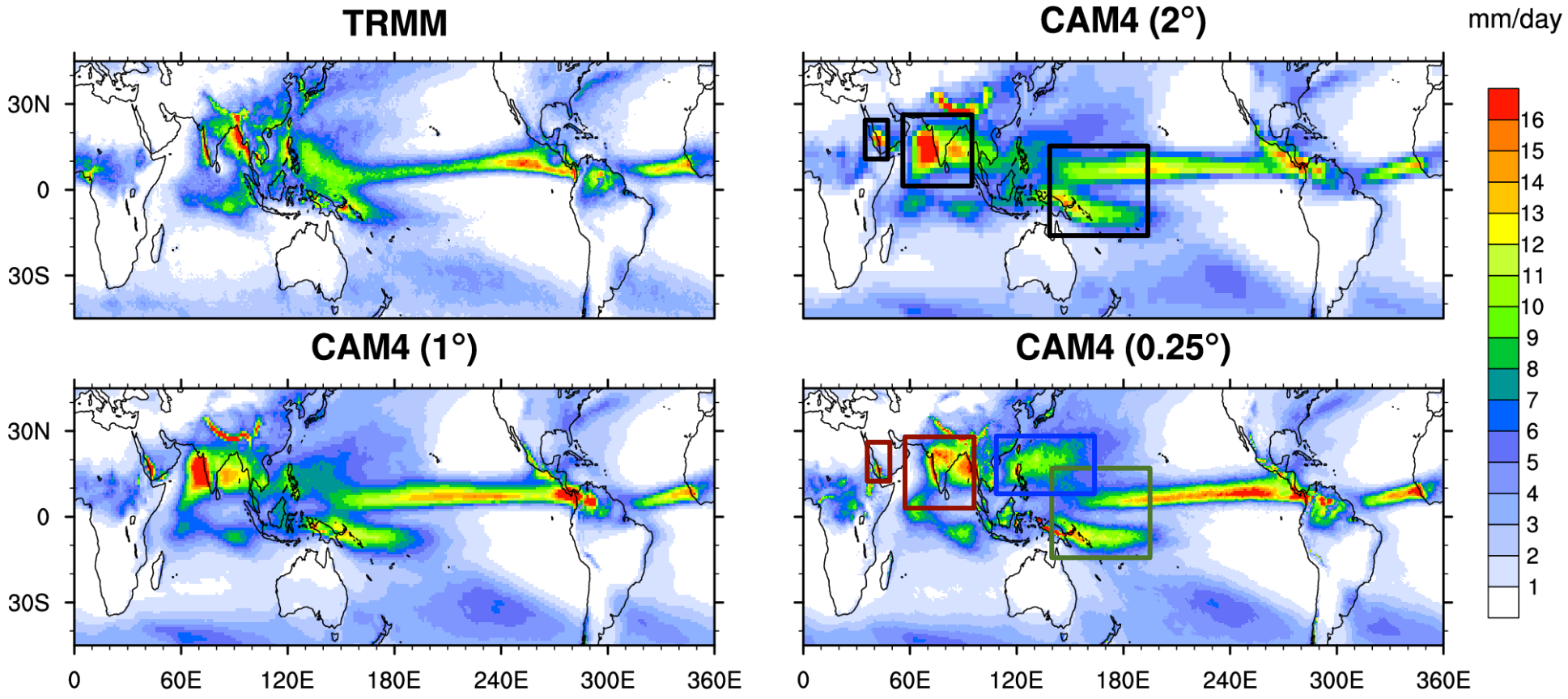
Impact of horizontal resolution on:

Mean climate: seasonal means, daily means, diurnal cycle

Precipitation, JJA



Precipitation, JJA

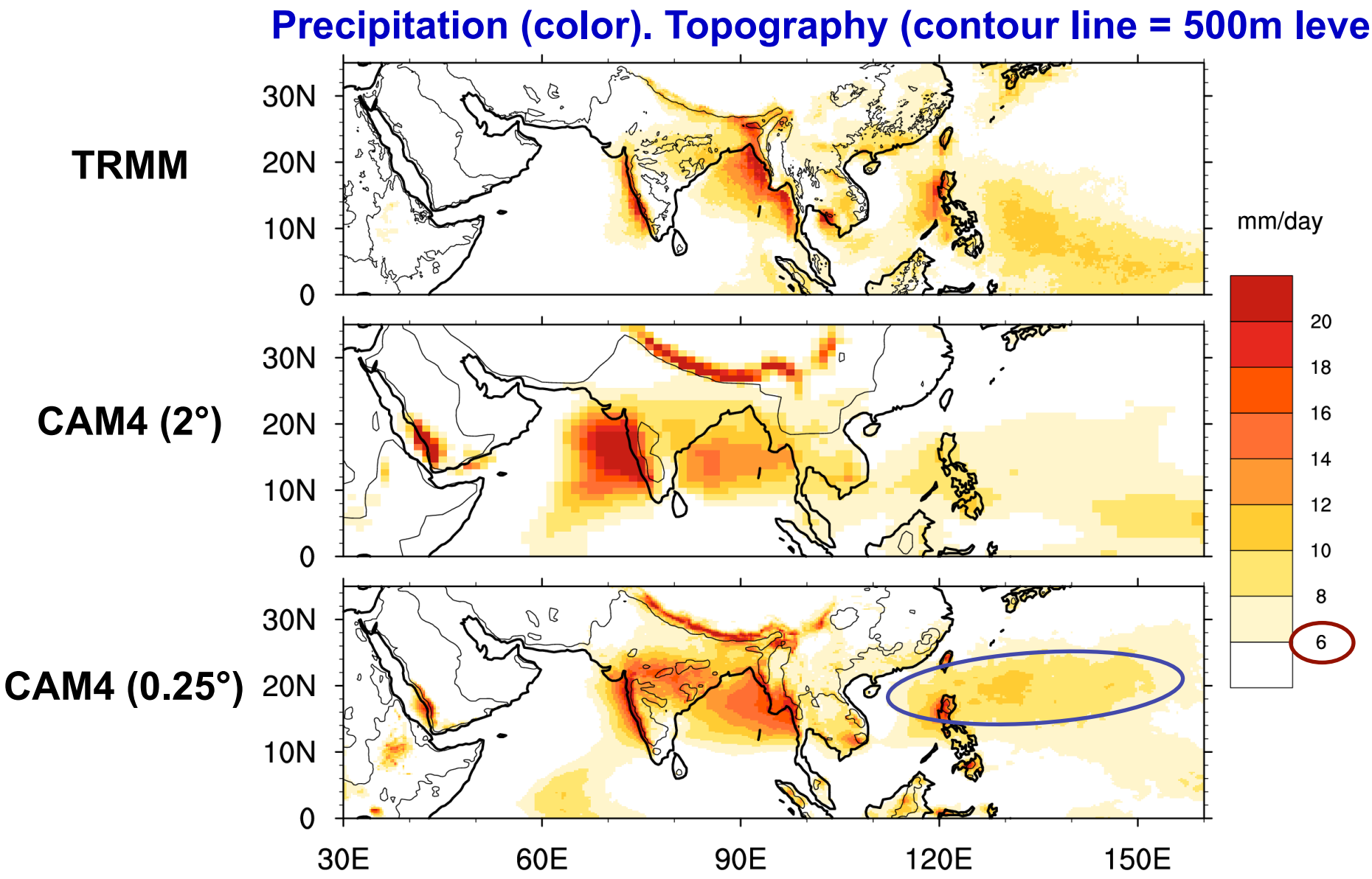


Improves: Asian monsoon and Saudi Arabia wet bias

Remains the same: double ITCZ

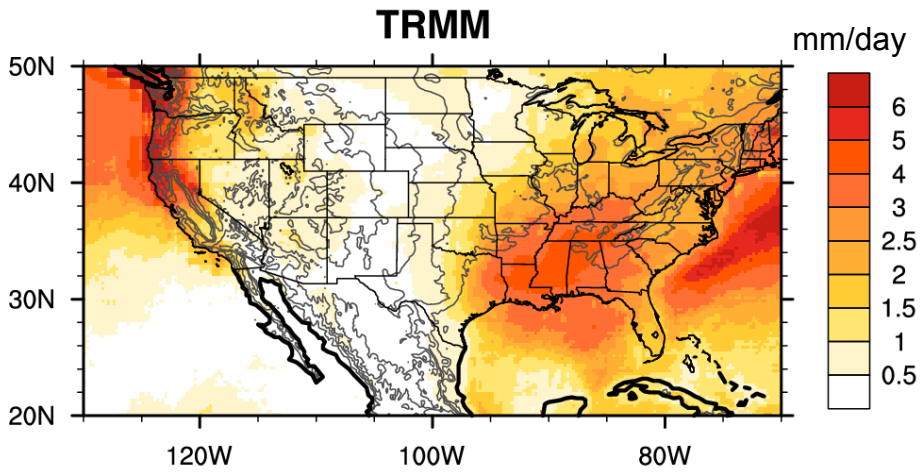
Gets worse: extension of Asian monsoon

Asian Monsoon, JJA

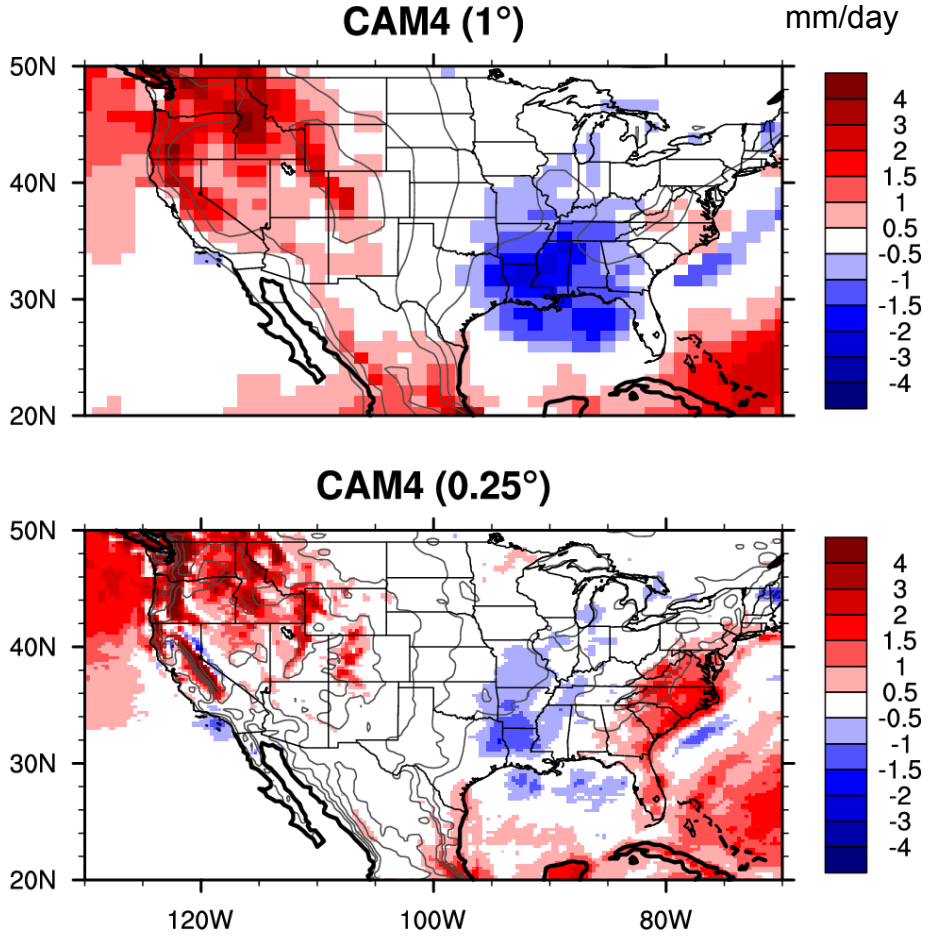


Precipitation over the US, DJF

Observed precipitation (color) Topography (line)



Precipitation Error (color) Topography (line)

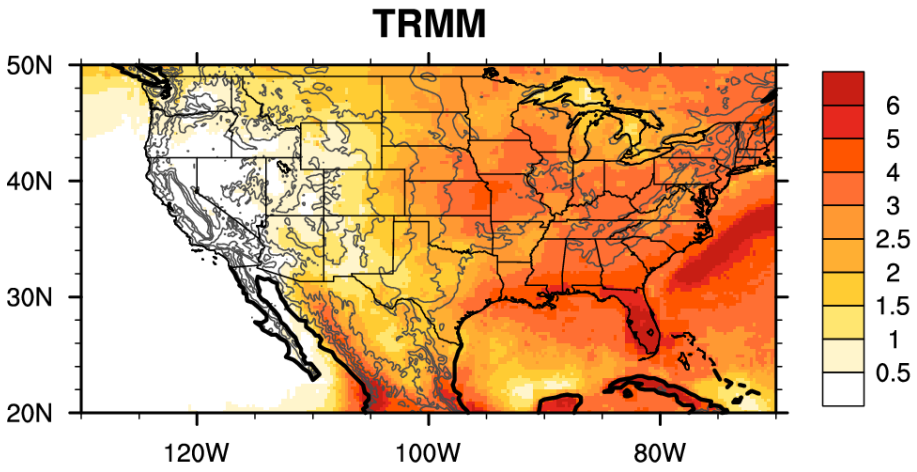


- Dry bias over Southeast (reduced due to better resolved orography)

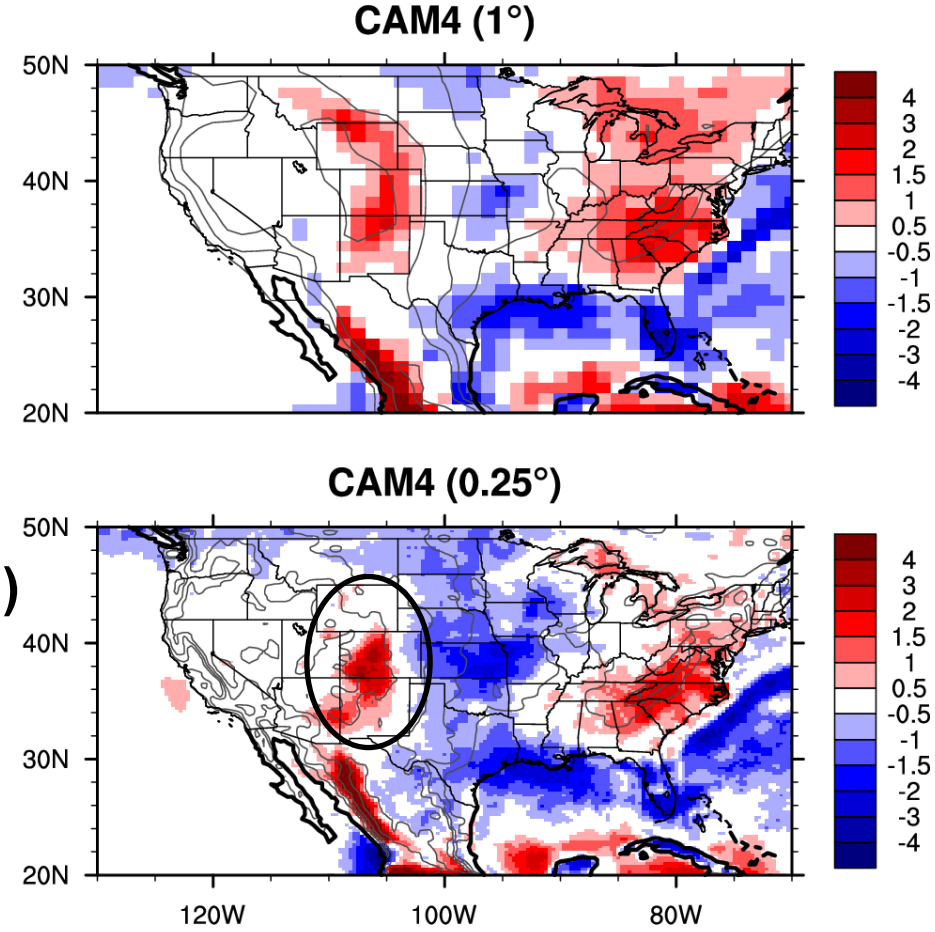
- Wet bias over Northwest (remains)

Precipitation over the US, JJA

Observed precipitation (color)
Topography (line)



Precipitation Error (color)
Topography (line)



Wet bias over Colorado ("Red Spot")

- remains with new physics (CAM5) and at higher vertical resolution

- recent research:
"Red Spot" disappears with rougher orography

Seasonal pattern ⇔ High frequency data (daily)

- Seasonal pattern of precipitation
  - Precipitation **frequency**
  - Precipitation **intensity**

- How often does it rain ?

$$\text{Precipitation frequency (\%)} = \frac{\text{Number of rainy days (>1 mm/day)}}{\text{Total number of days}}$$

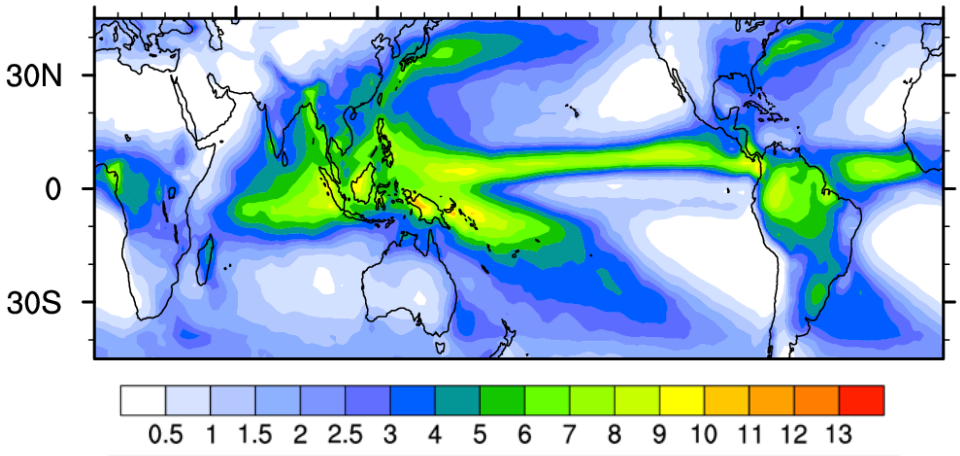
- How hard does it rain?

$$\text{Precipitation intensity (mm/day)} = \frac{\text{Total amount of precipitation}}{\text{Number of rainy days (>1 mm/day)}}$$

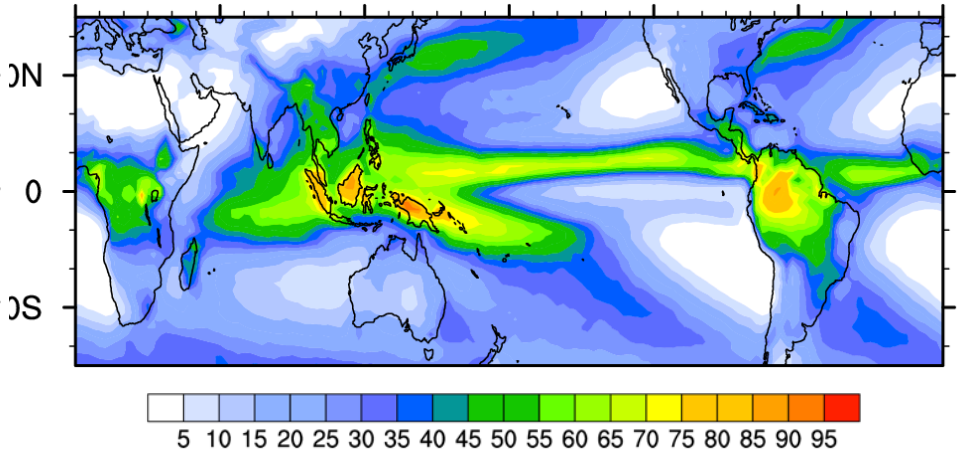
Dai et al. (2007)

TRMM: Precipitation intensity and frequency (ANN)

Precip amount (mm/day)

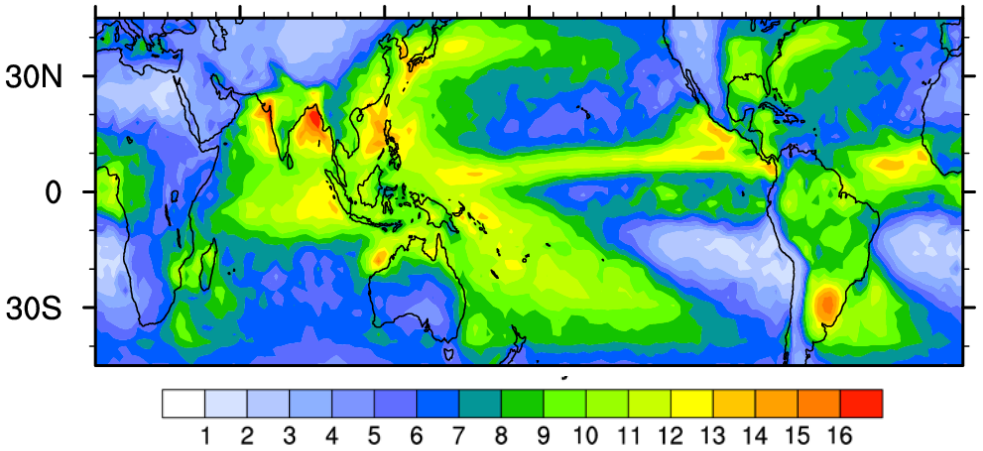


Precip frequency (%)



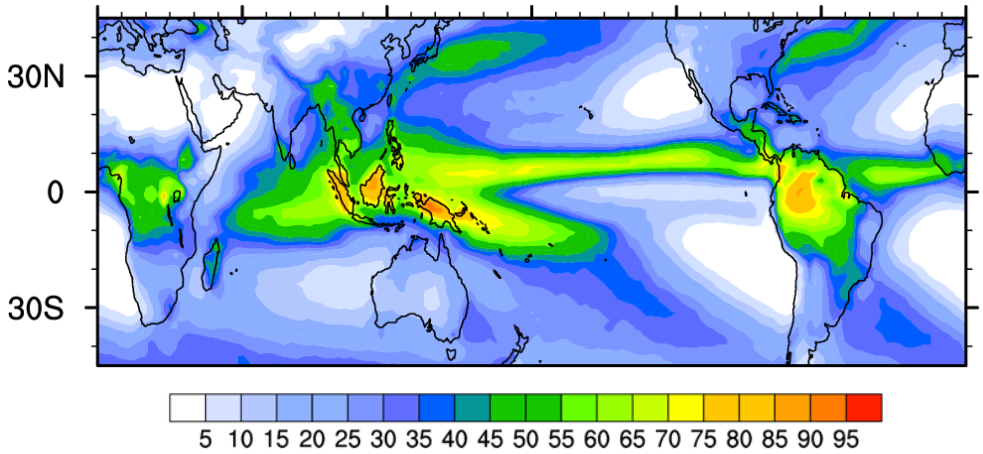
In observations, precipitation amount is mainly determined by the precipitation frequency

Precip intensity (mm/day)

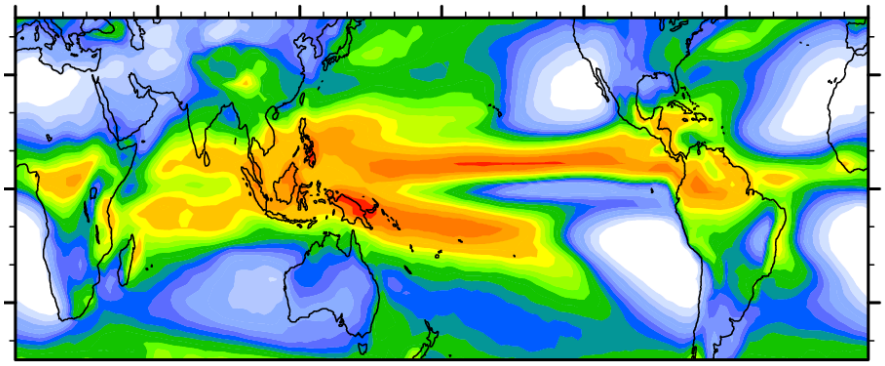


Intensity and frequency: CAM (2°) vs obs

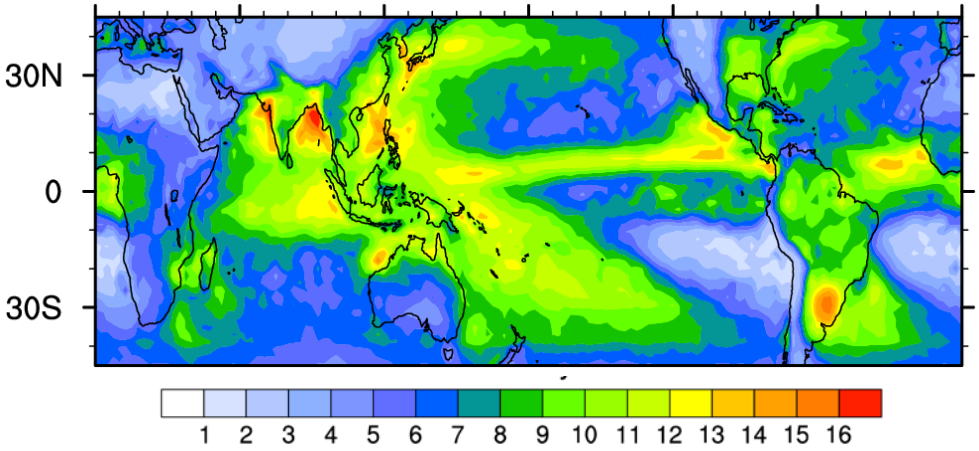
TRMM: Precip frequency (%)



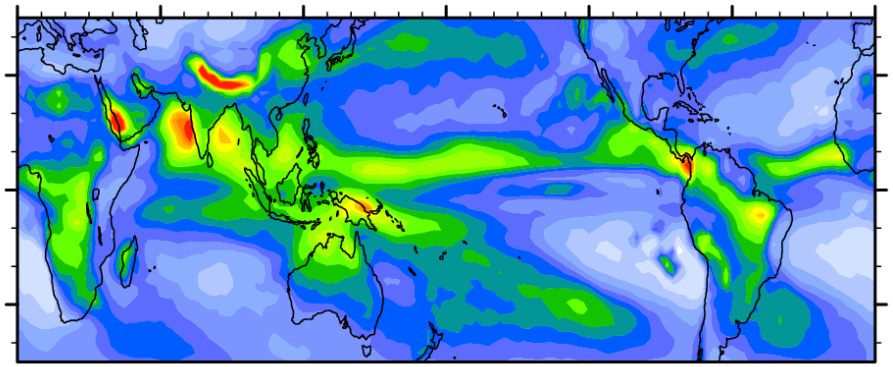
CAM (2°) => rains too often



TRMM: Precip intensity (mm/day)

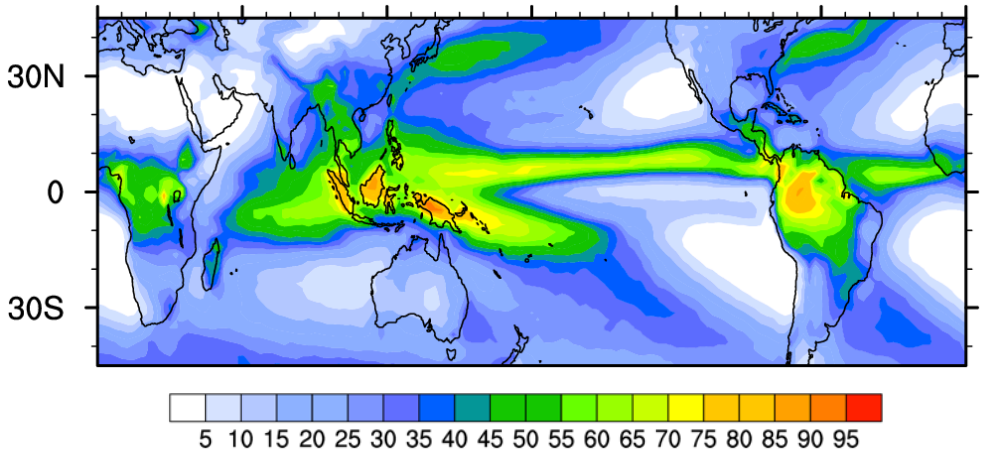


CAM (2°) and not hard enough

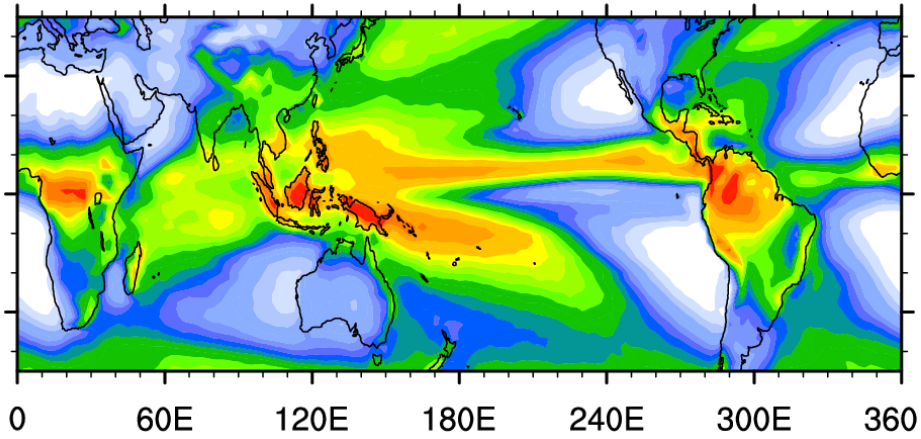


Intensity and frequency: CAM (025°) vs obs

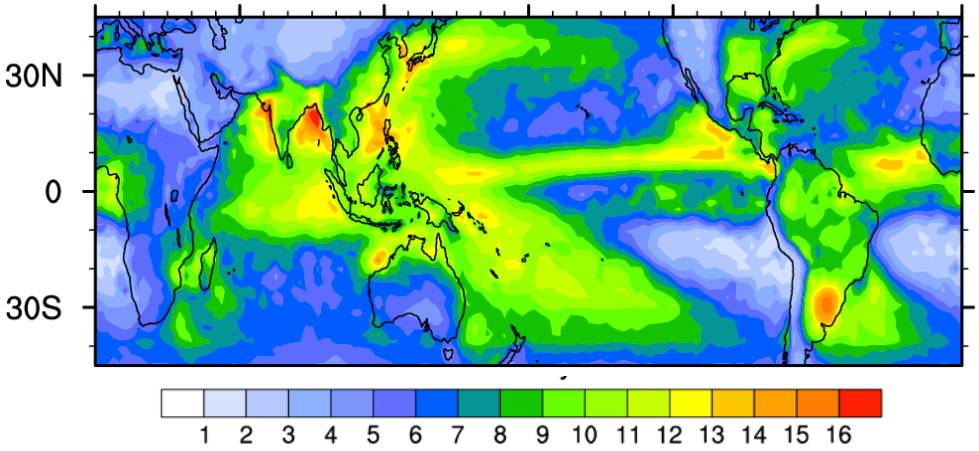
TRMM: Precip frequency (%)



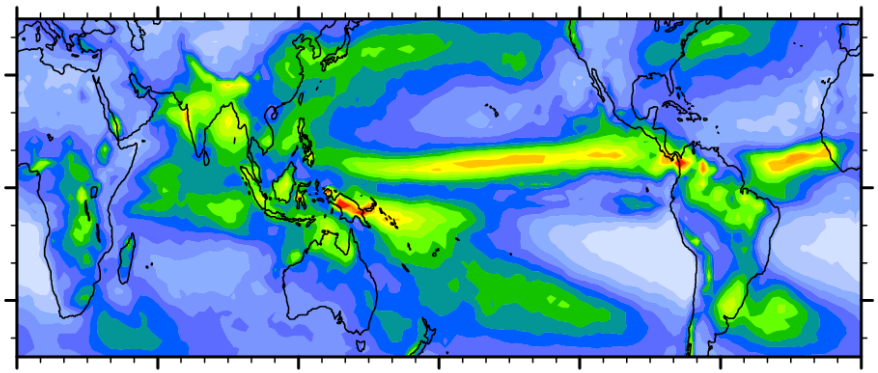
CAM (0.25°) => improved frequency



TRMM: Precip intensity (mm/day)

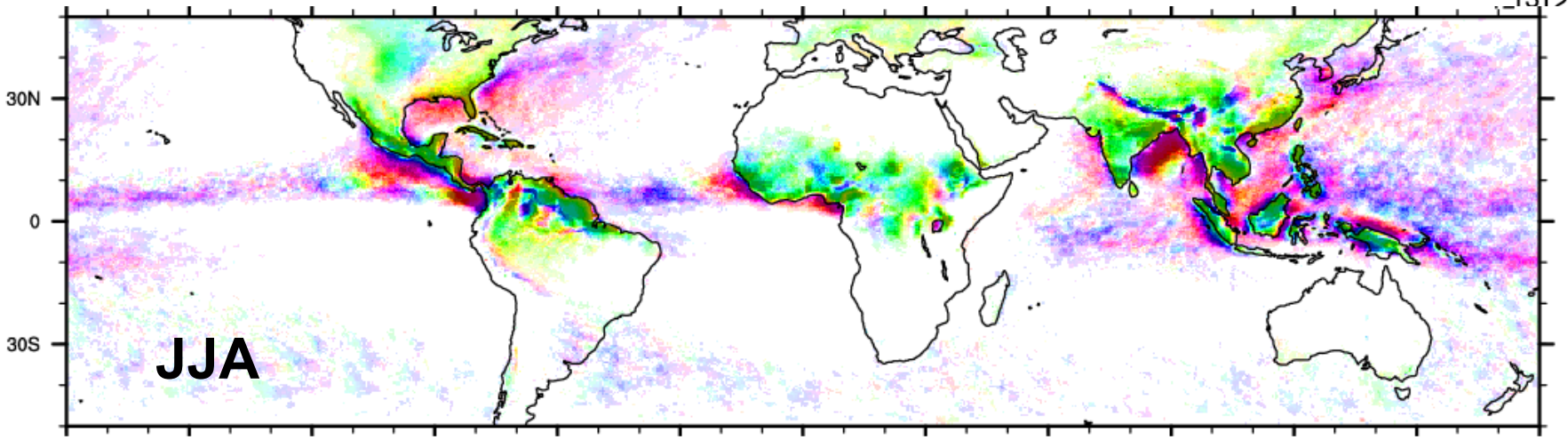


CAM (0.25°) => improved intensity

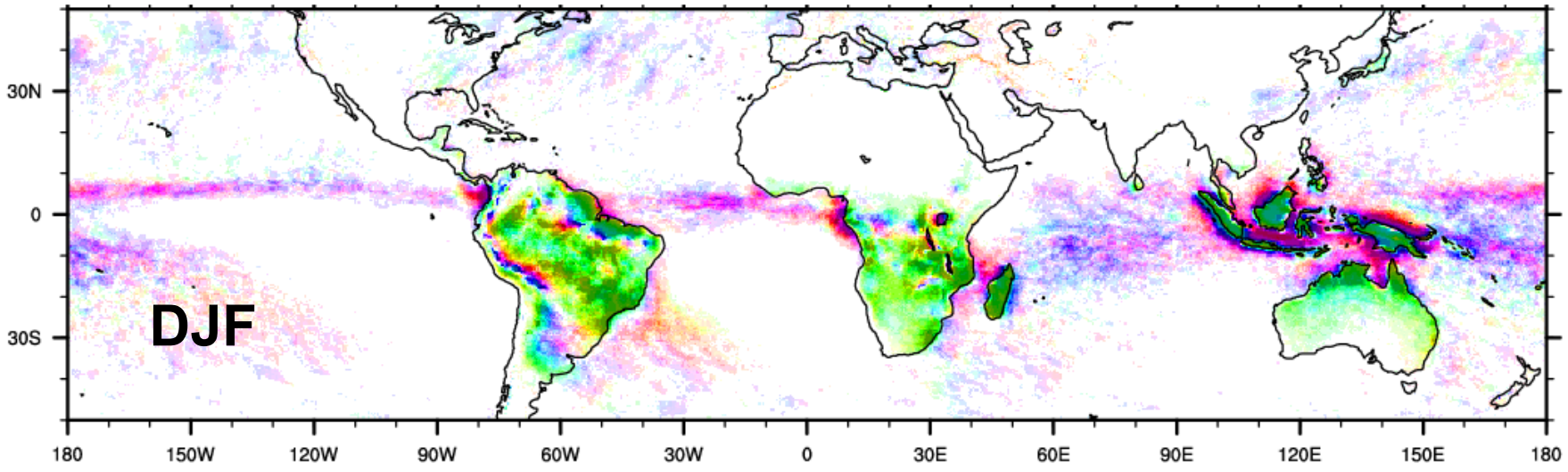


Problem persists at higher resolution (despite some improvements) !

Diurnal cycle of rainfall: TRMM (3-hourly data)



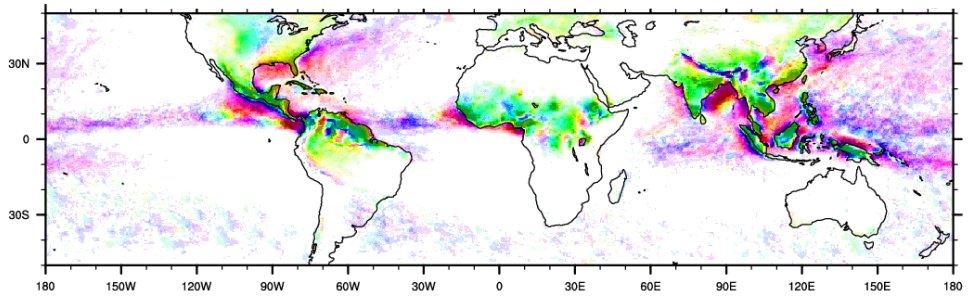
Land: afternoon/evening max **Ocean: early morning max**



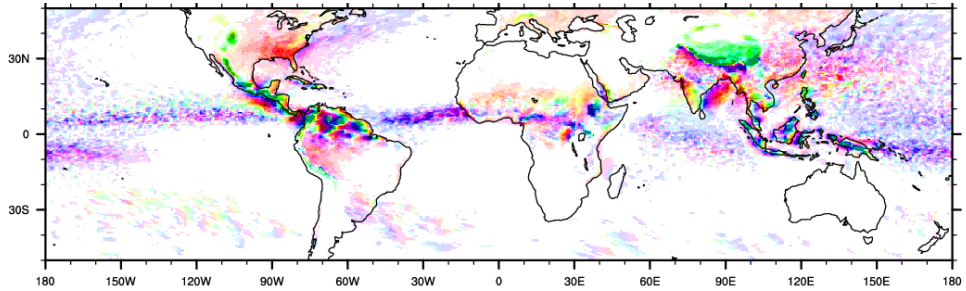
Courtesy Rich Neale

Diurnal cycle of rainfall (JJA)

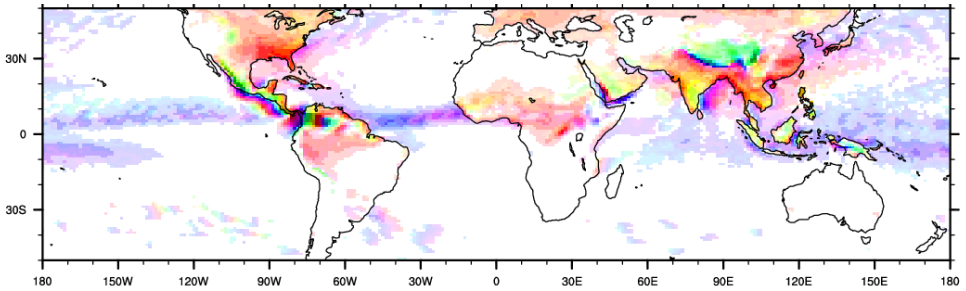
TRMM



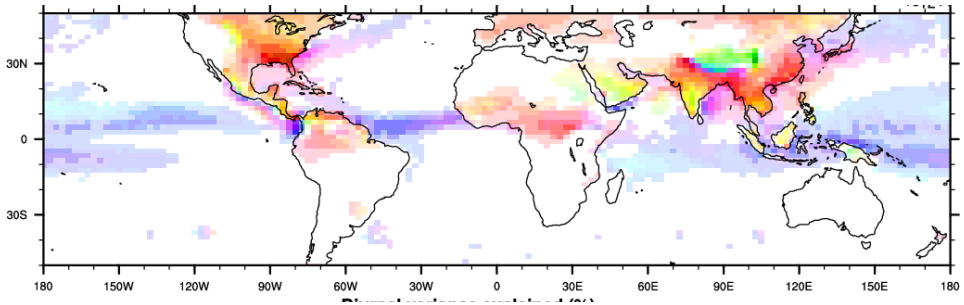
0.25 deg



1 deg



2 deg



- At **coarse resolution**, CAM fails to reproduce observed diurnal cycle

- Rains **too early** especially over land

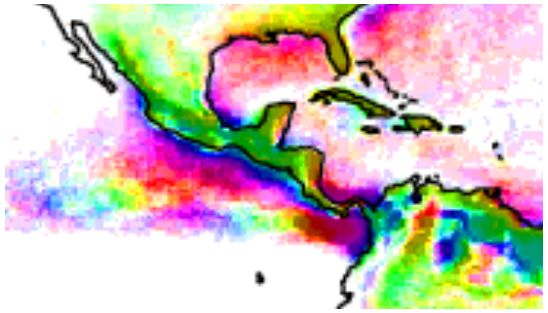
- Diurnal cycle amplitude **too weak**

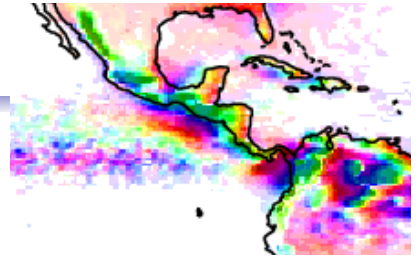
- Diurnal cycle **improves** at **higher resolution**

Courtesy Rich Neale

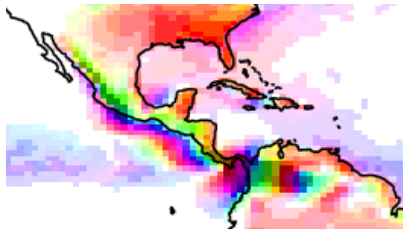
Diurnal cycle of rainfall (JJA)

TRMM (0.25º)

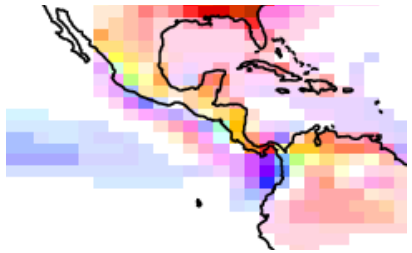




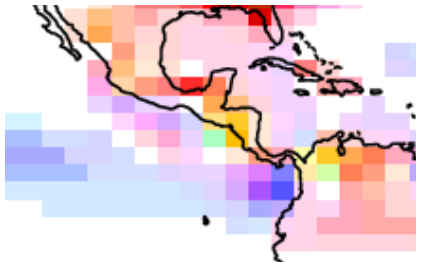
0.25º



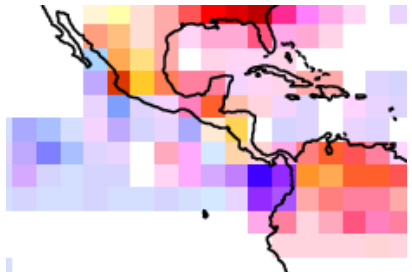
1º



2.



2.5º



T31
(3.8º)

Courtesy Rich Neale

What is the impact of resolution for future projections ?

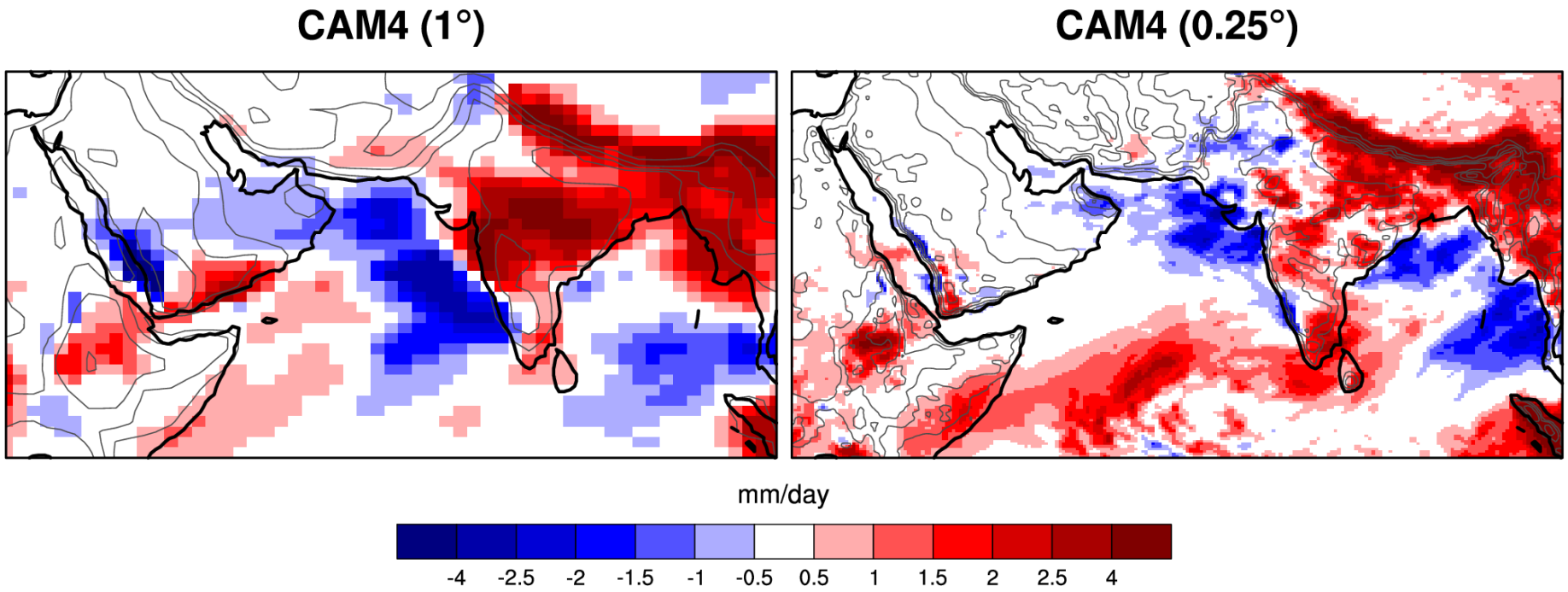
- **Present-day time-slice: Observed SSTs**

- **Future time-slice: SSTs from RCP8.5**
  + use correction for CESM SST bias
  + use correction for sea-ice cover (Hurrell *et al*, 2008)

- **Precipitation change = Prec[2081-2100] – Prec[1981-2000]**

Asian monsoon, JJA

Precipitation change by the end of the 21th century

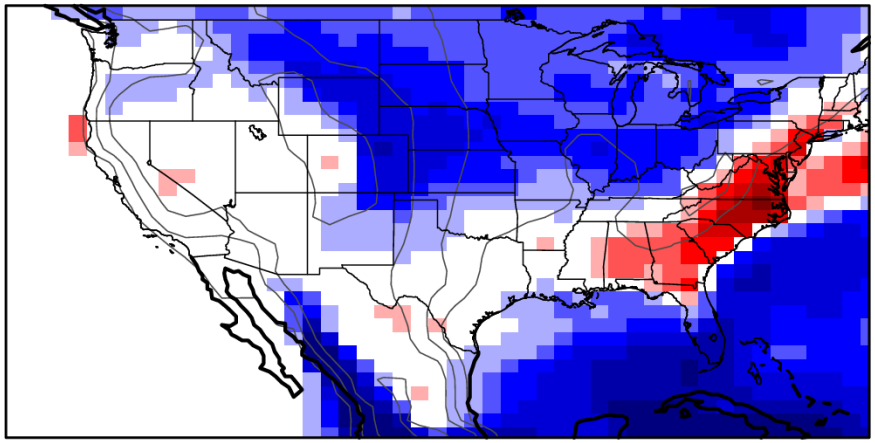


=> Precipitation extremes are reduced at 0.25°

Change in precipitation over the US

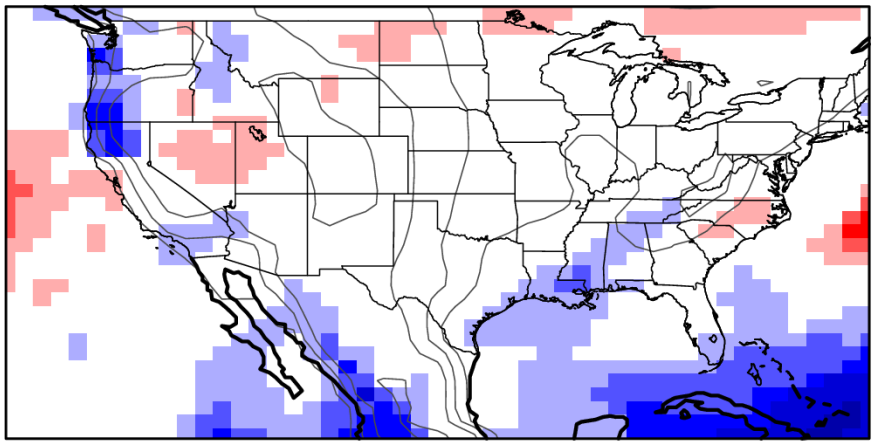
CAM4 (1°)

J J A

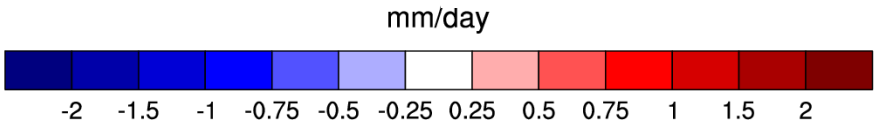


Summer drought

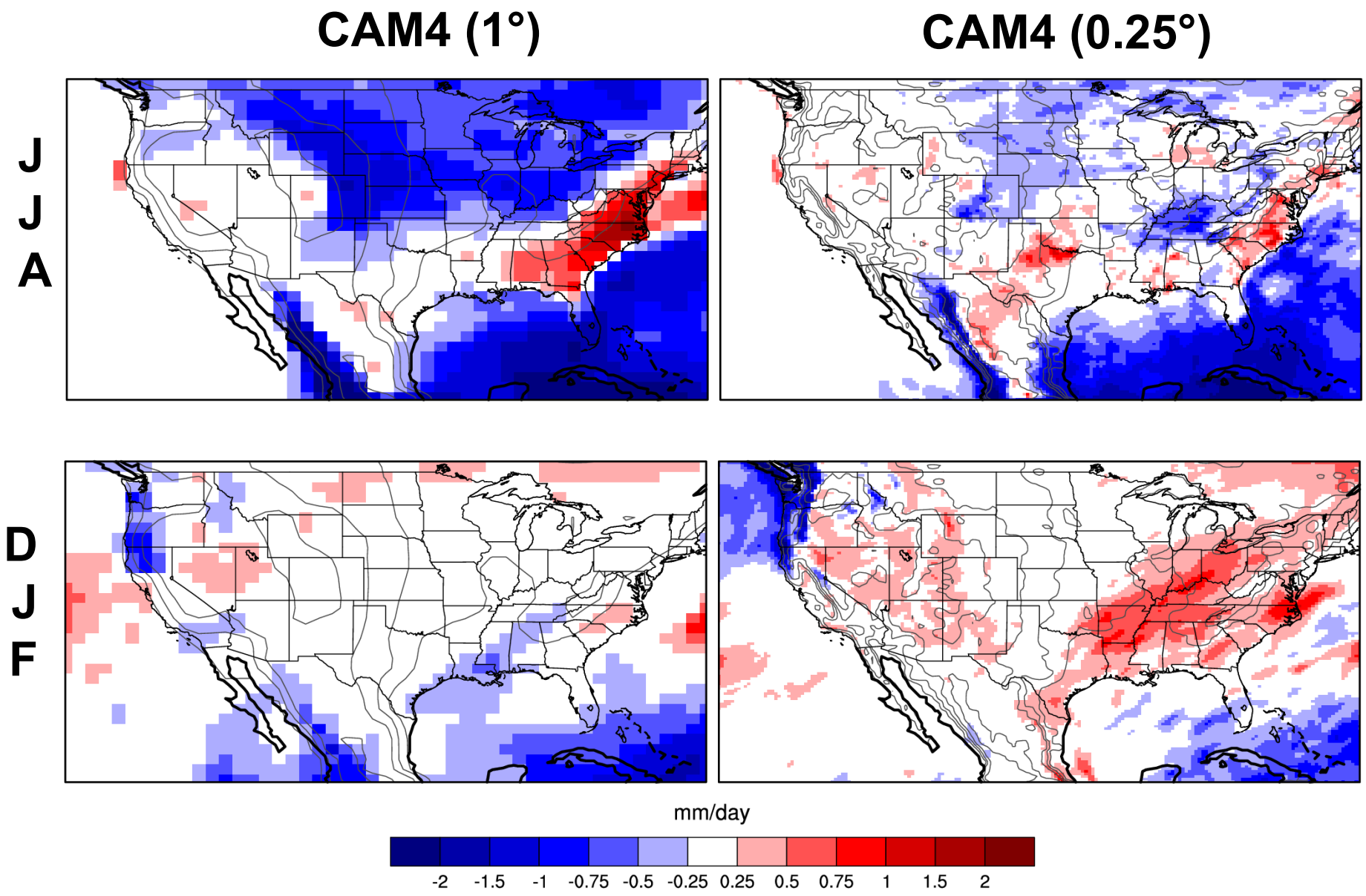
D J F



Changes are less dramatic in winter

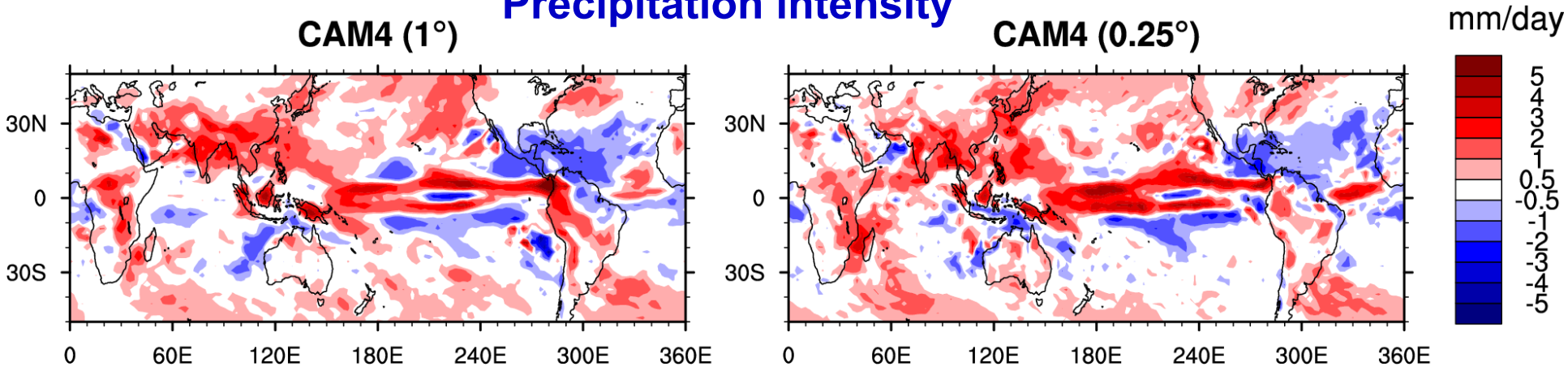


Change in precipitation over the US

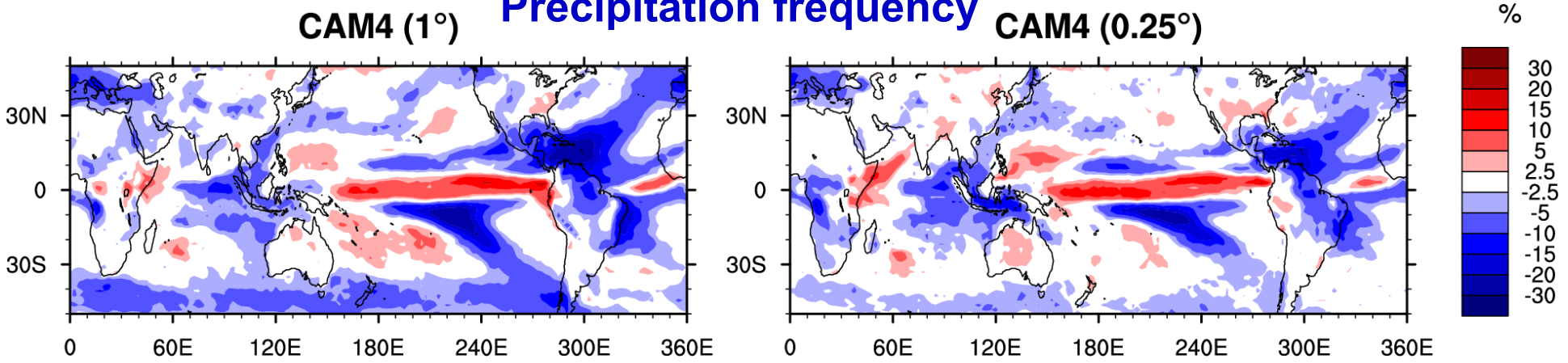


Change in precip intensity/frequency

Precipitation intensity



Precipitation frequency



In warmer climate: it rains harder but less frequently

(Trenberth et al. 2003)

Conclusions

Mean climate:

- Improvements at higher resolution due to more accurate representation of the topography and a better simulation of the large-scale circulation (Asian monsoon, Saudi Arabia wet bias, Southwest US dry bias)

- But … some biases remain (double ITCZ, Colorado "Red Spot") or even get worse (extension of the Asia Monsoon into the Philippine Sea)

Daily data:

- In observations: distribution of precipitation amount is mainly determined by the precipitation frequency

- In CAM4: rains too often but not hard enough.
Despite some improvements, the problem persists at higher resolution.

Conclusions

Diurnal cycle

Observed diurnal cycle:
- Land: afternoon/evening maximum
- Ocean: early morning maximum

At coarse resolution, CAM fails to reproduce observed diurnal cycle
- Rains too early especially over land
- Diurnal cycle amplitude too weak

- Diurnal cycle improves at higher resolution but some bias remains

Change in precipitation by the end of the 21th
- Resolution has an impact on the climate change signal:
JJA drought over US is reduced at 0.25°
- In warmer climate: it rains harder but less frequently

Thanks !