

**Can high resolution climate simulations
with the Community Atmospheric Model (CAM)
offer a new perspective on 21st century scenarios ?**

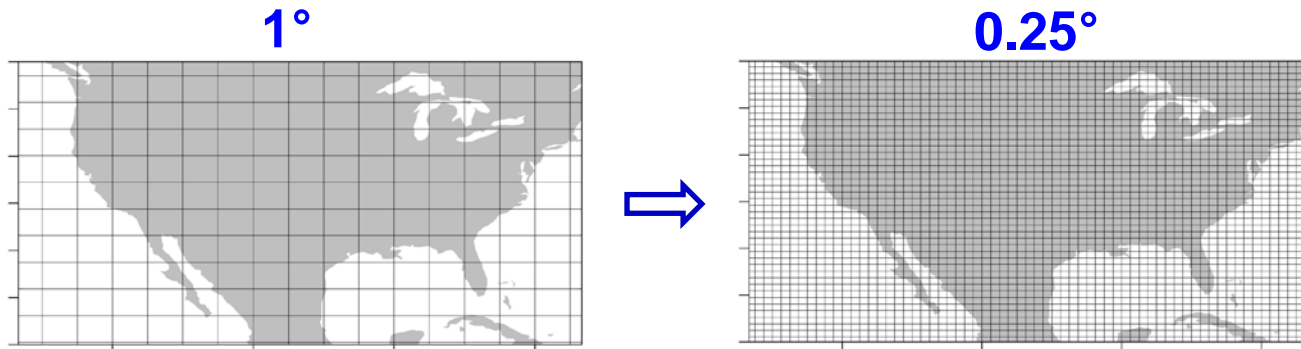
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John Truesdale, Kevin Reed, and Andrew Gettelman.**

National Center for Atmospheric Research, Boulder

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 (CAM5)

CAM standalone with prescribed SSTs

Horizontal resolutions: 1° and 0.25°

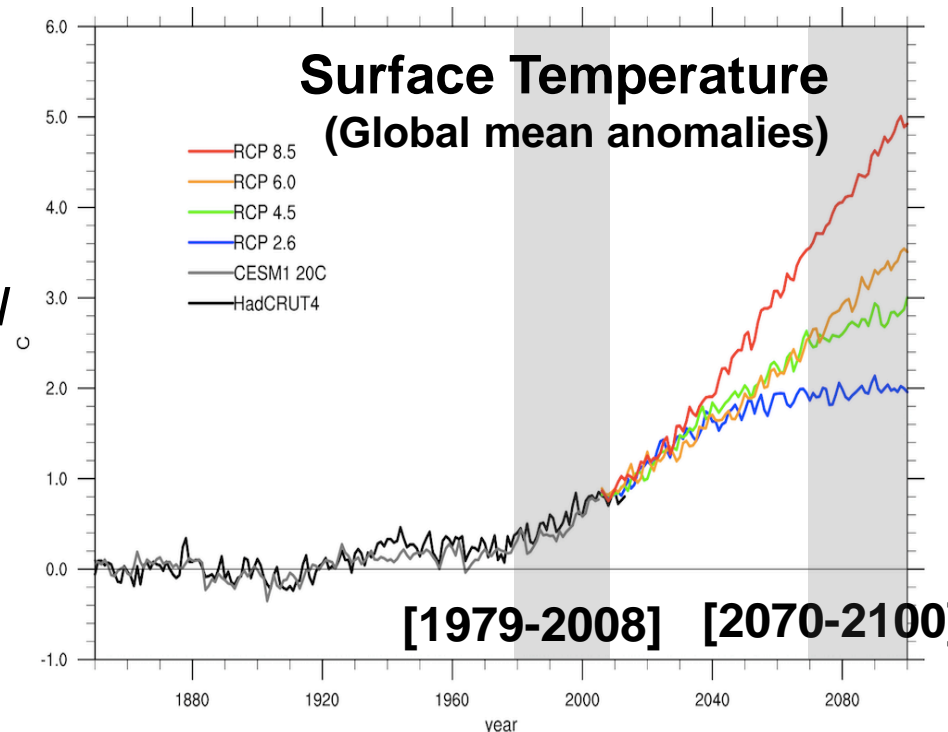
Time-slice experiments

- **Present-day conditions**

Observed SSTs: Merged Hadley-OI

- **Future conditions**

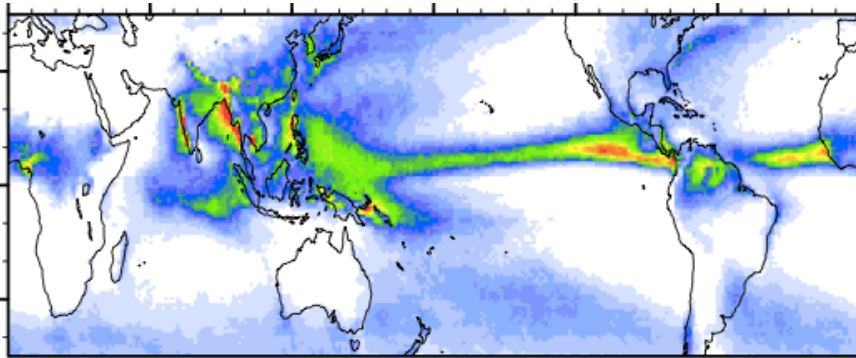
CESM SSTs: RCP4.5 & RCP8.5



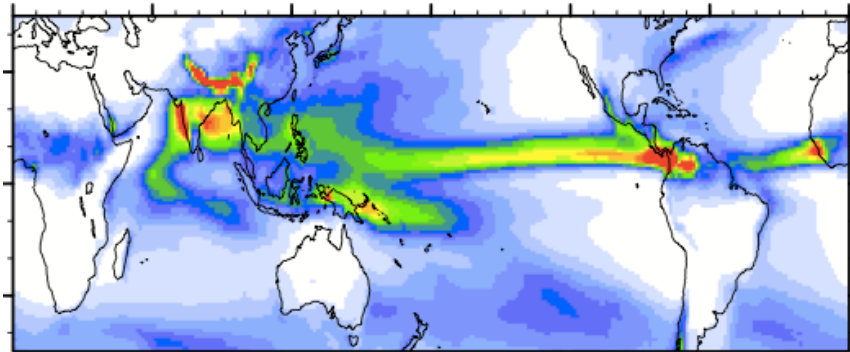
Analysis focuses on **precipitation** and **tropical cyclones**

Precipitation, JJA

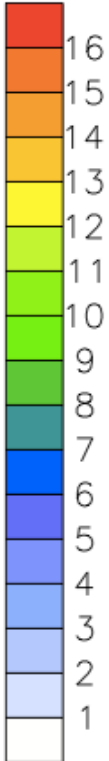
Observations: TRMM



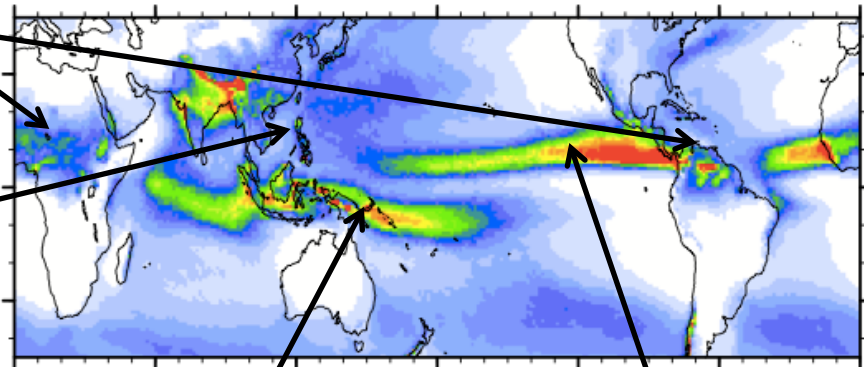
CAM5: 1 degree



mm/day



CAM5: 0.25 degree



Increased precipitation over
Africa and South America

Dry bias
over Micronesia

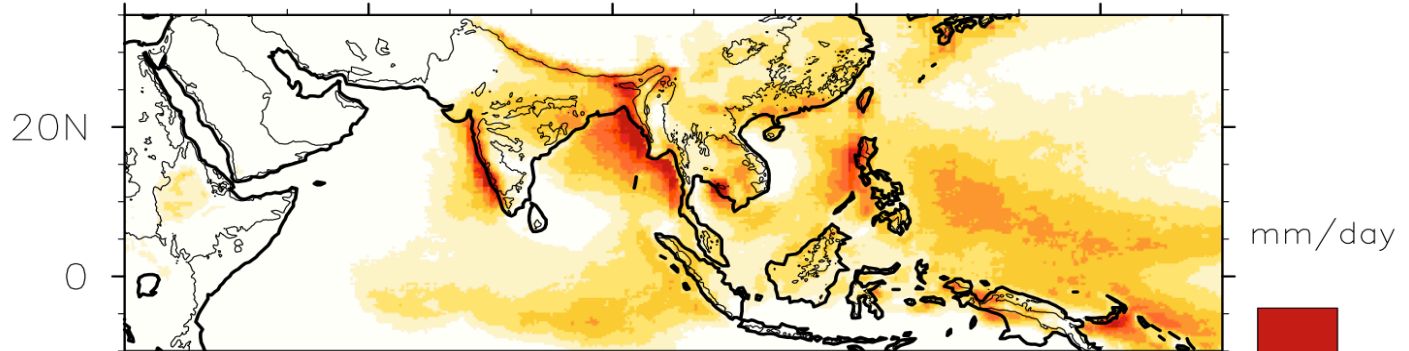
Exacerbated double ITCZ

Increased wet bias in northern ITCZ

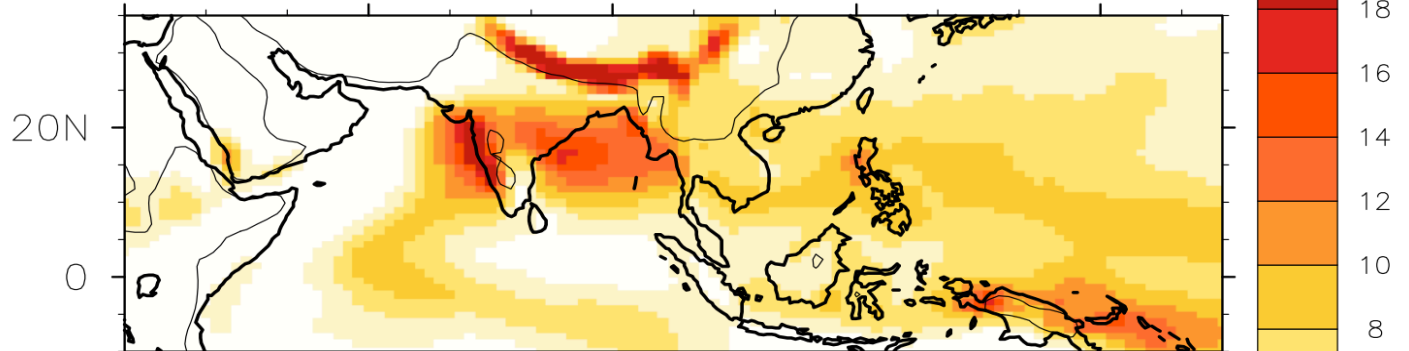
Asian Monsoon, JJA

Precipitation (color). Topography (contour line = 500m level)

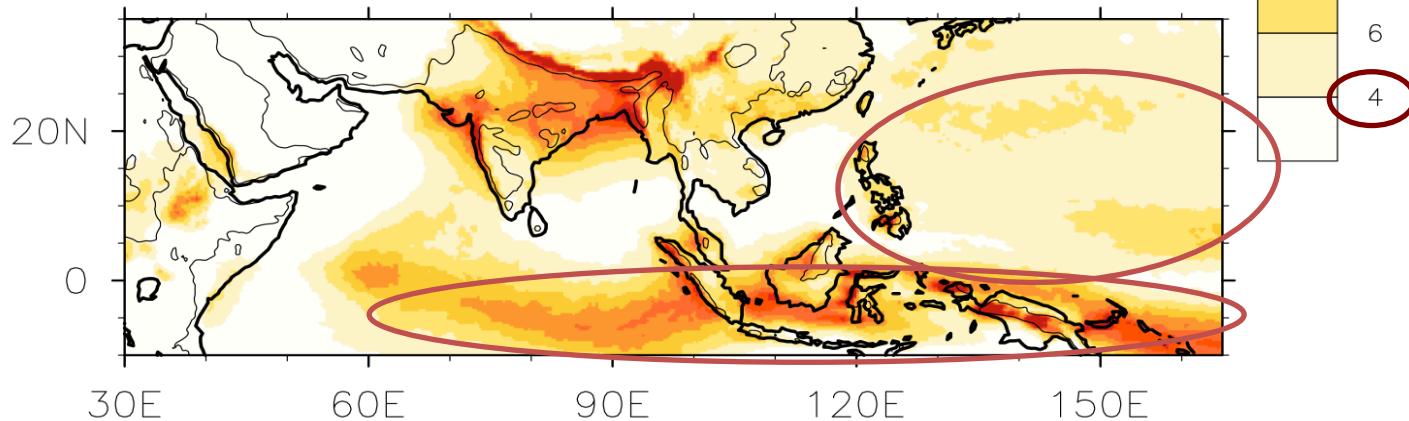
TRMM



CAM5 (1°)

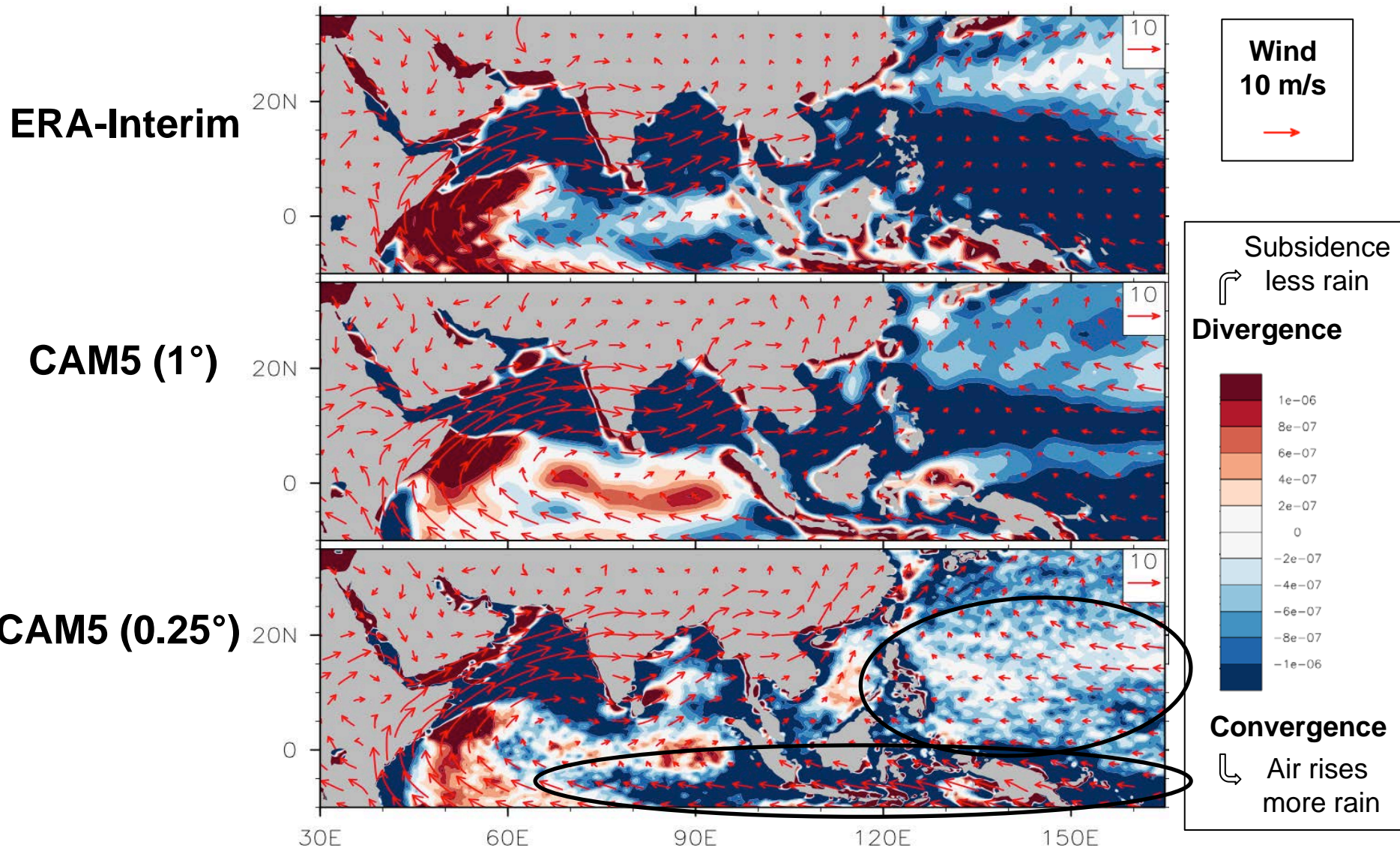


CAM5 (0.25°)



Asian Monsoon, JJA

Red vector: Winds at 850 mb; Contour: Wind divergence



Seasonal pattern ⇔ High frequency data (daily)

- Seasonal pattern of precipitation 
 - Precipitation frequency
 - Precipitation intensity

- How often does it rain ?

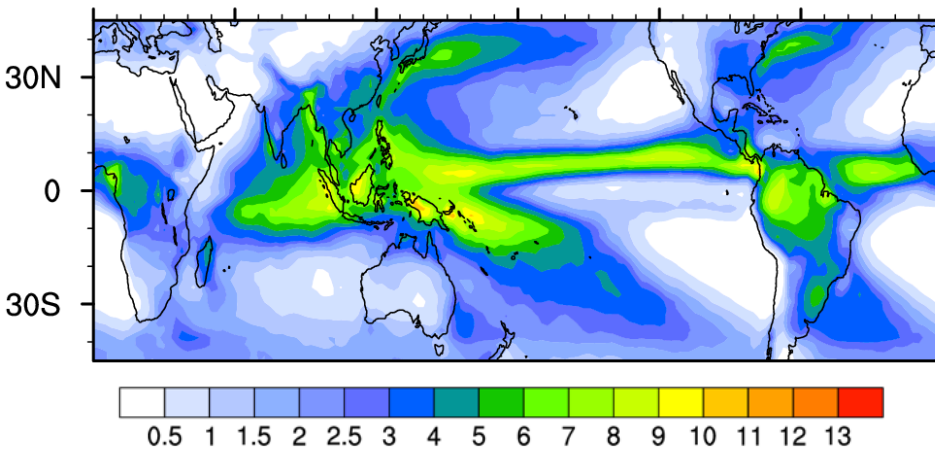
$$\text{Precipitation frequency (\%)} = \frac{\text{Number of rainy days (> 1 mm/day)}}{\text{Total number of days}}$$

- How hard does it rain?

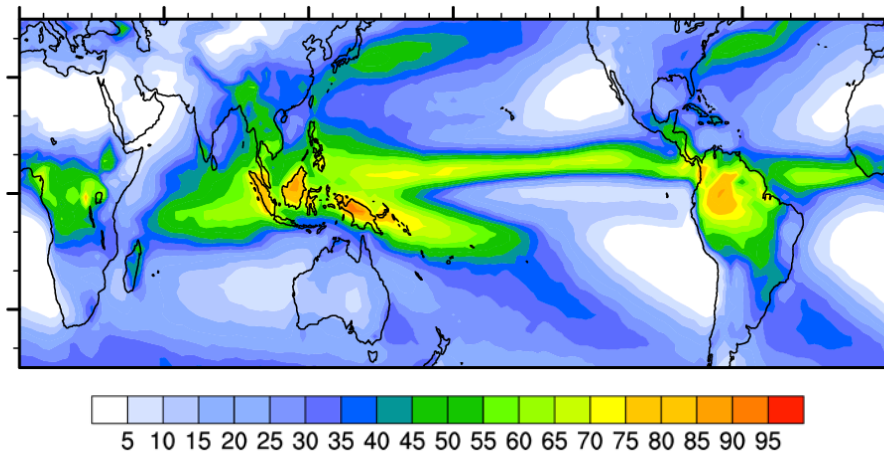
$$\text{Precipitation intensity (mm/day)} = \frac{\text{Total amount of precipitation}}{\text{Number of rainy days (> 1 mm/day)}}$$

TRMM: Precipitation intensity and frequency (ANN)

Precip amount (mm/day)

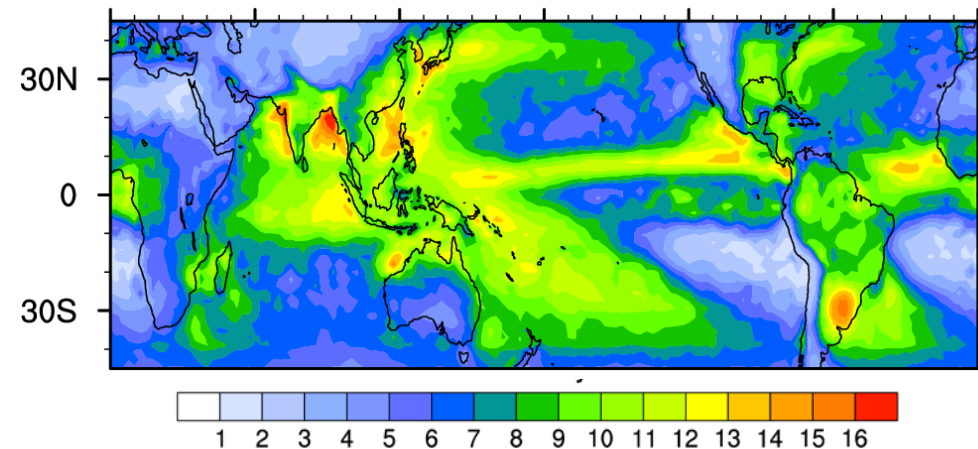


Precip frequency (%)



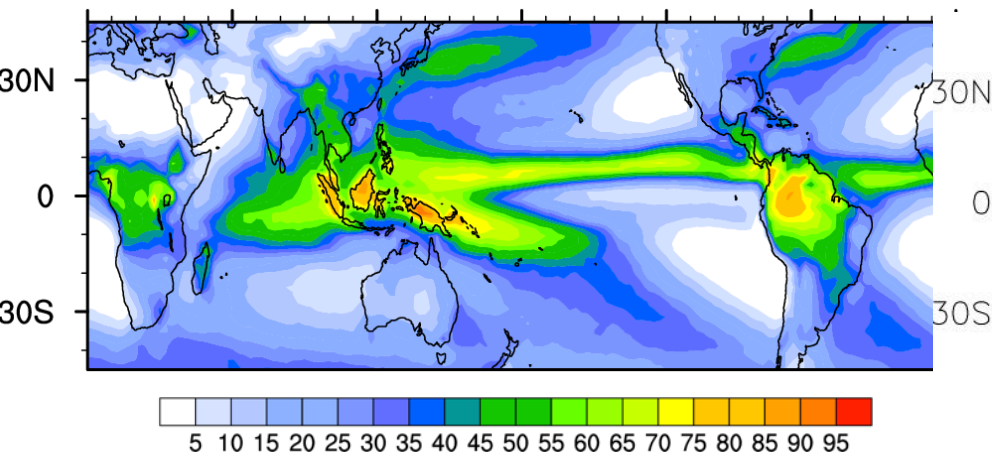
In observations, precipitation amount is mainly determined by the **precipitation frequency**

Precip intensity (mm/day)

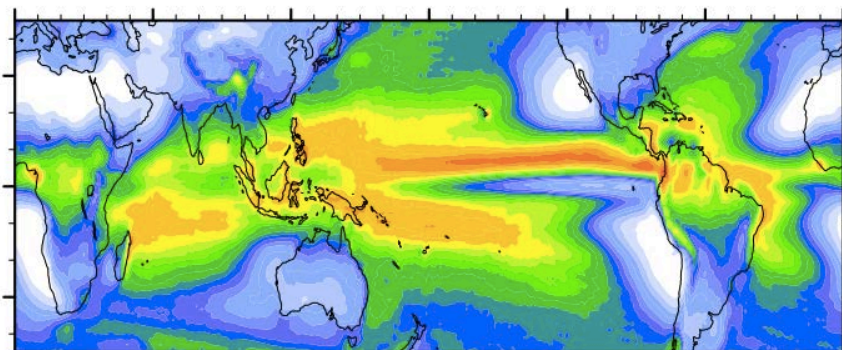


Intensity and frequency: CAM (1°) versus obs

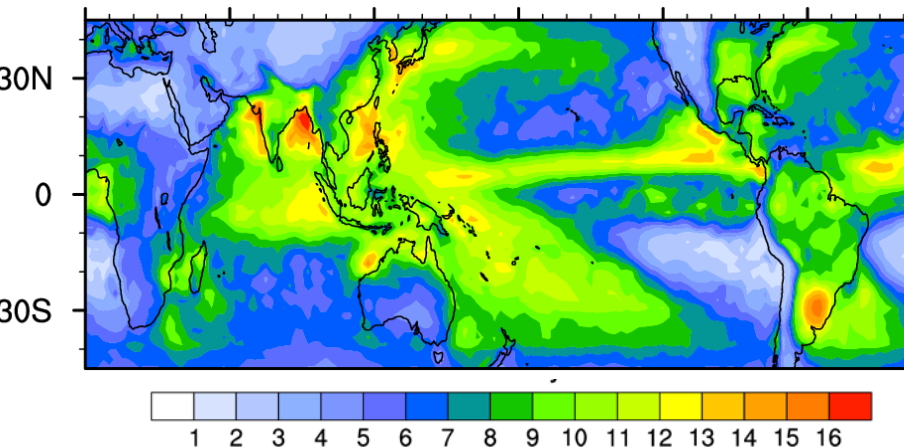
TRMM: Precip frequency (%)



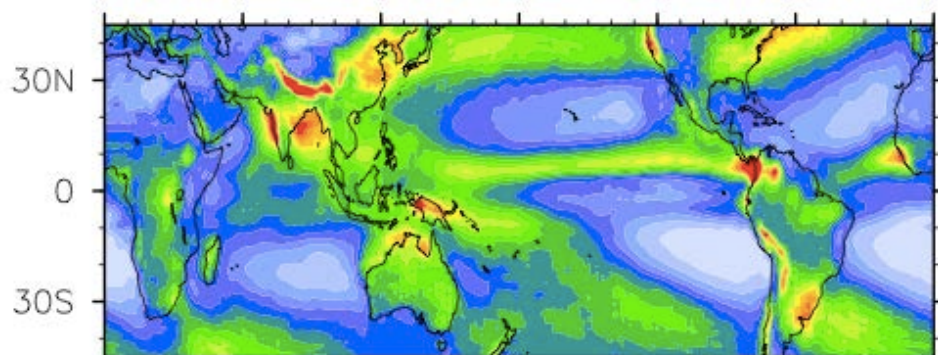
CAM (1°) => rains too often



TRMM: Precip intensity (mm/day)

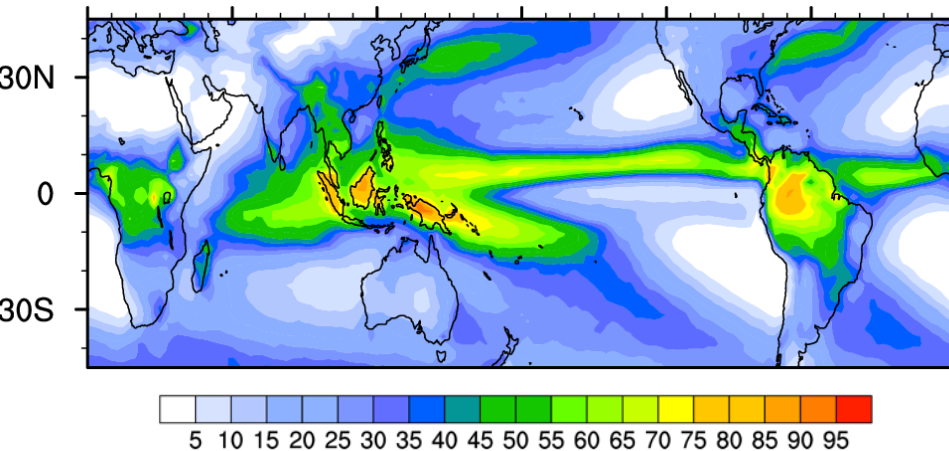


CAM (1°) but not hard enough

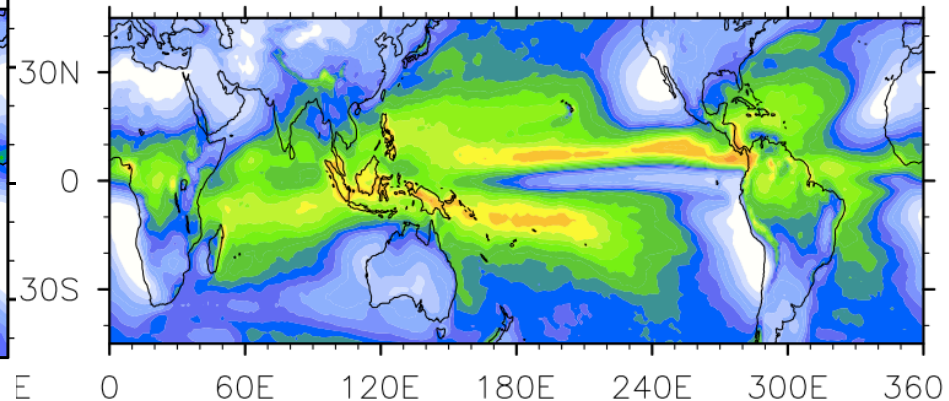


Intensity and frequency: CAM (0.25°) vs obs

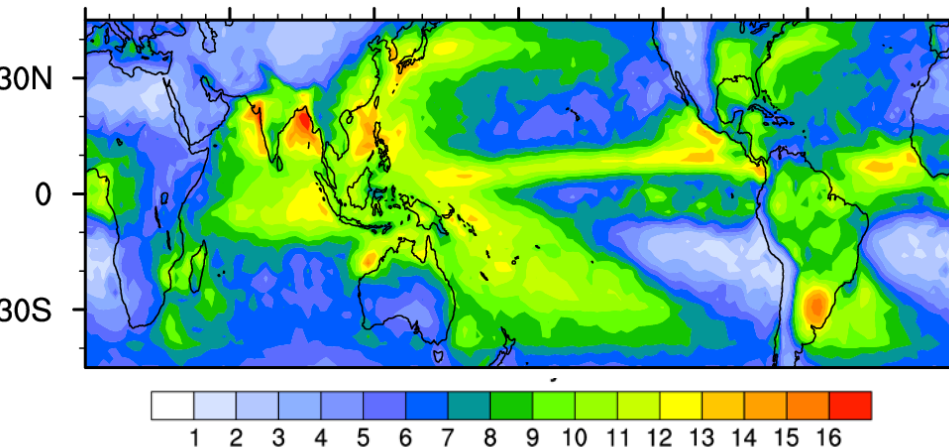
TRMM: Precip frequency (%)



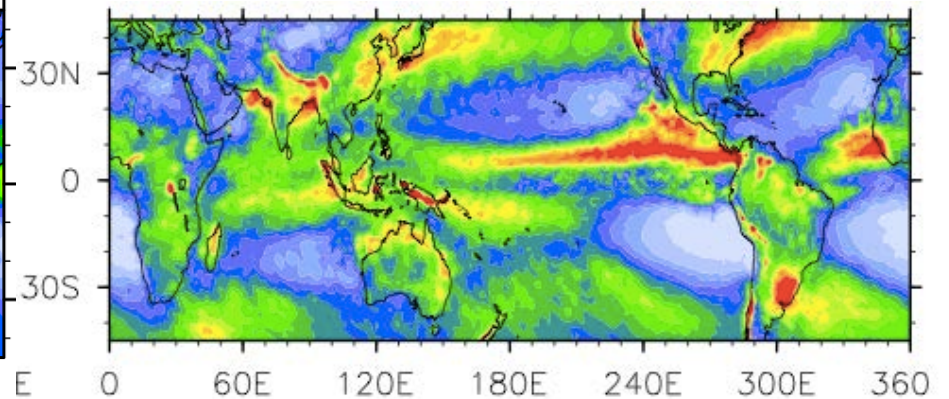
CAM (0.25°) => improved frequency



TRMM: Precip intensity (mm/day)



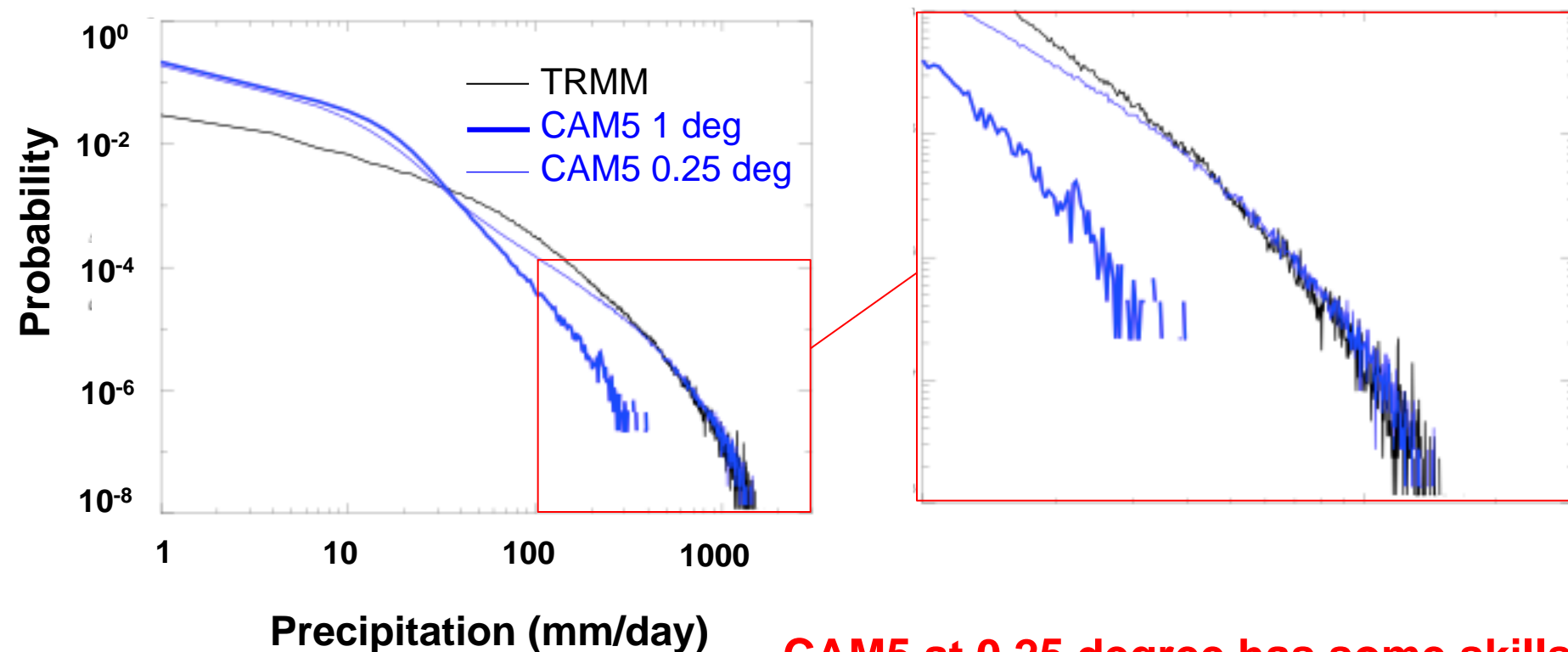
CAM (0.25°) => mixed result



Problem persists at higher resolution (despite some improvements) !

Extreme precipitation

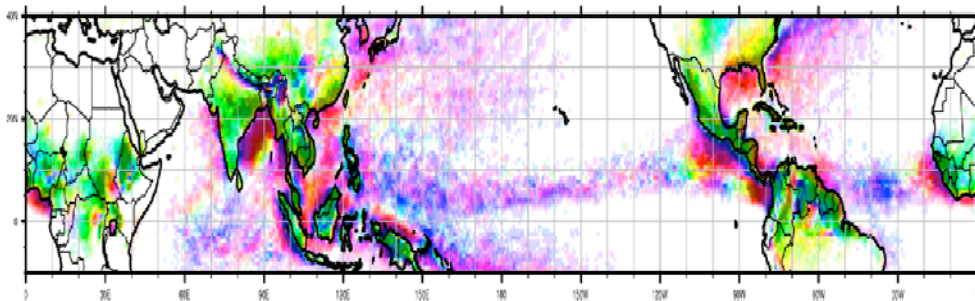
PDFs of precipitation (August 2005)



Diurnal cycle of rainfall (JJA)



TRMM

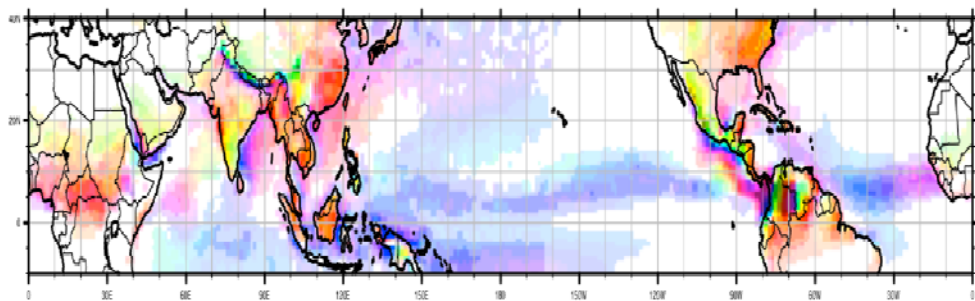


In observations:

Land: evening max

Ocean: early morning max

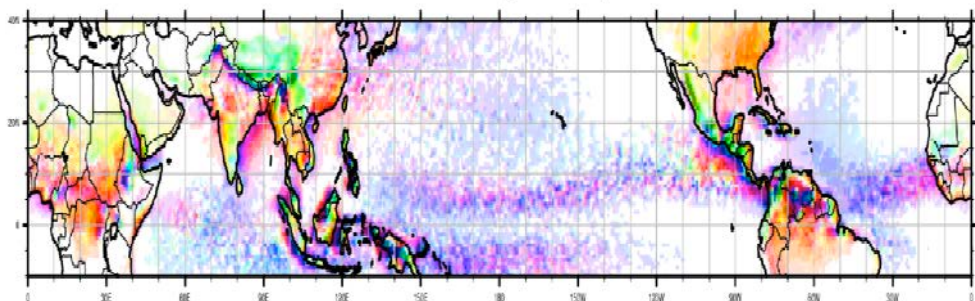
1 deg



At **coarse resolution**,

- Rains **too early** especially over land
- Diurnal cycle amplitude **too weak**

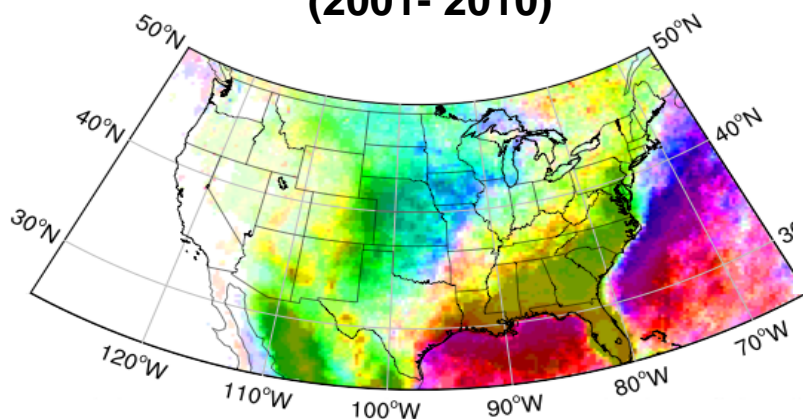
0.25 deg



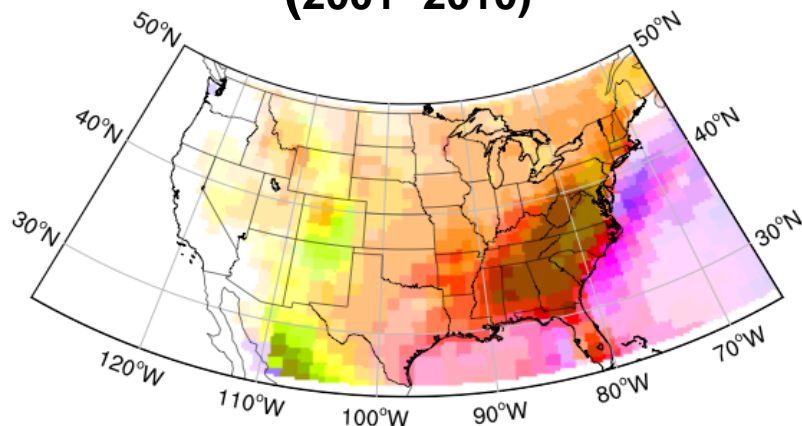
Diurnal cycle **improves** at **higher resolution**

Diurnal cycle of rainfall (JJA)

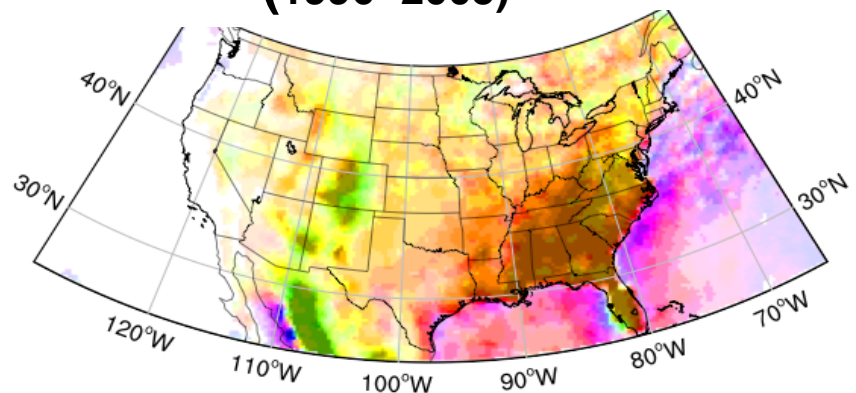
**TRMM 0.25°
(2001- 2010)**



**CAM5 1°
(2001- 2010)**

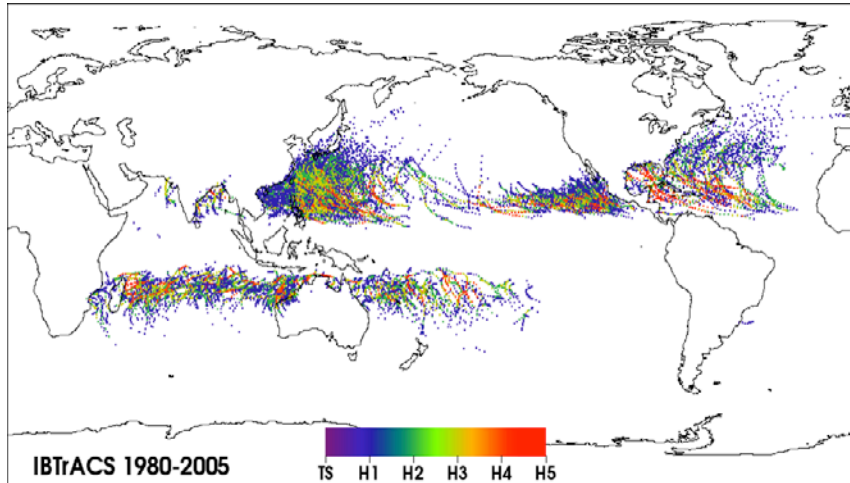


**CAM5: 0.25°
(1996- 2005)**



Tropical Cyclone Tracks

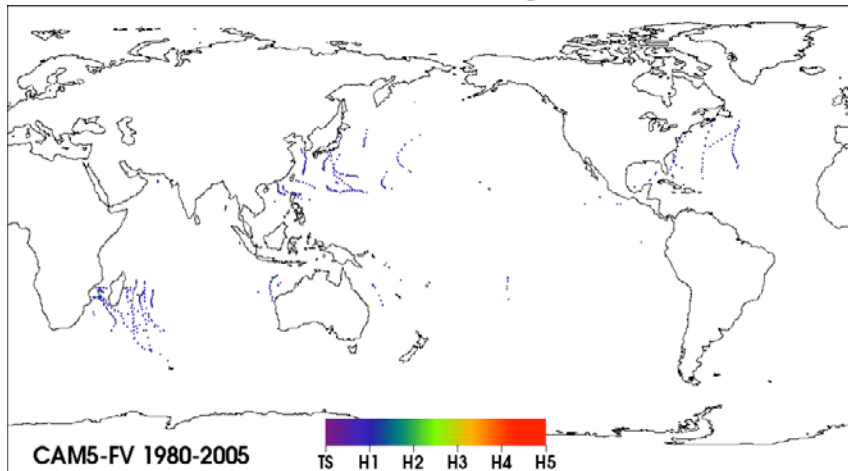
Observations: IBTrACS



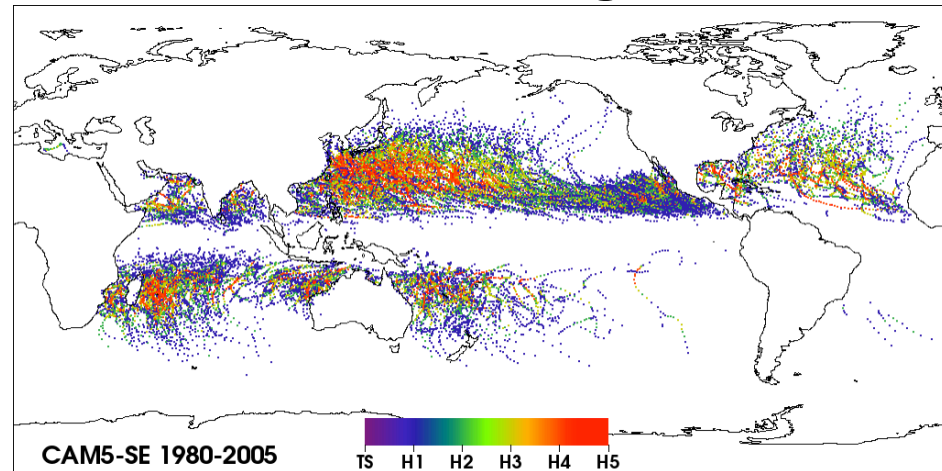
- Tropical cyclone tracks identified by GFDL tracking algorithm

- CAM5 at 0.25 degree has some skills to simulate tropical cyclones

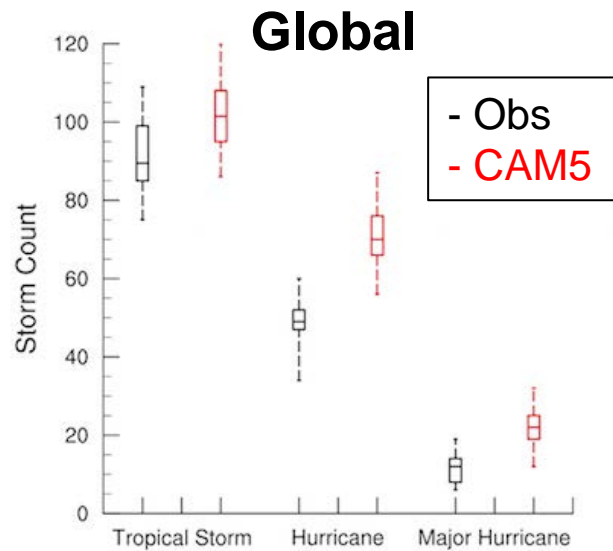
CAM5: 1 degree



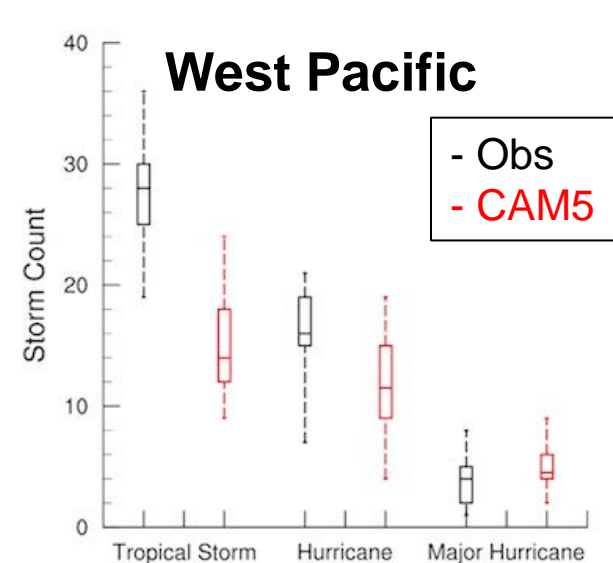
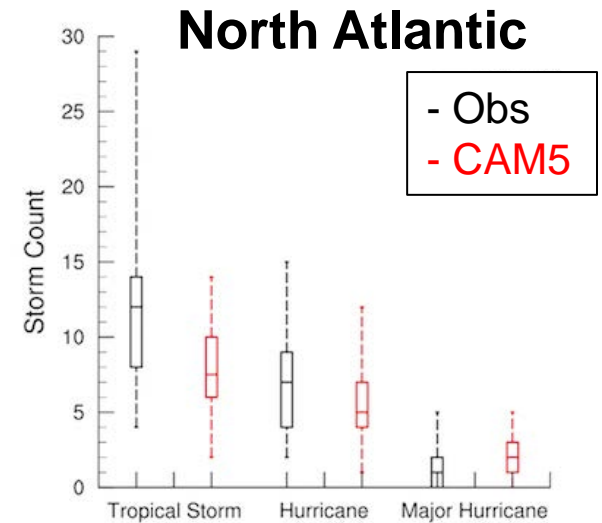
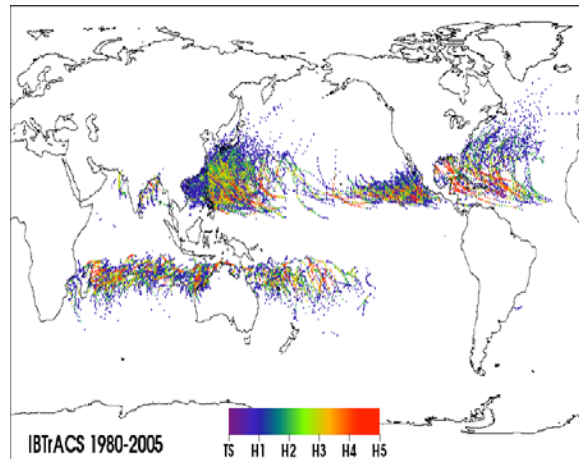
CAM5: 0.25 degree



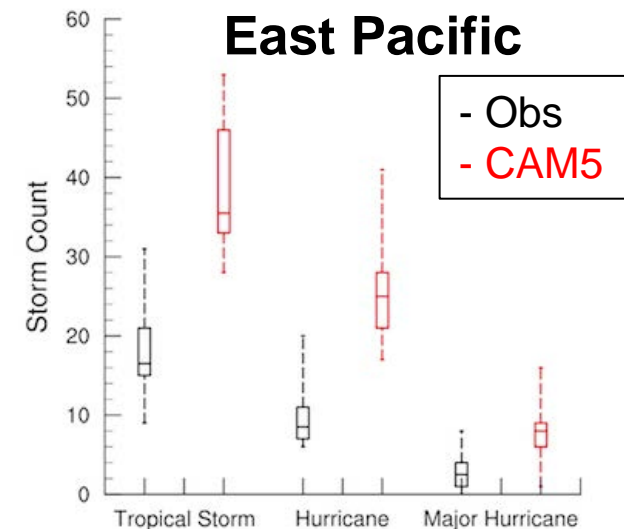
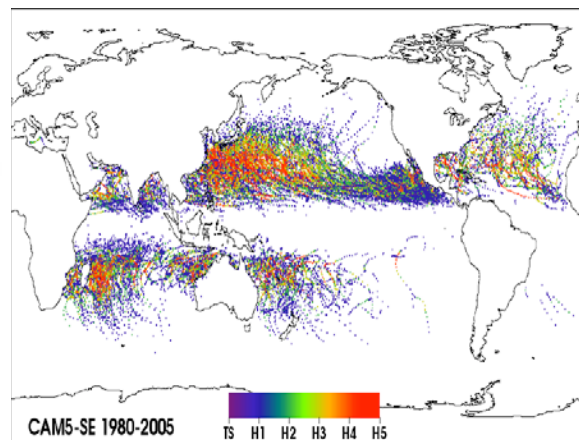
Storm Count: Tropical Storm, Hurricane, Major Hurricane.



Observations: IBTrACS



CAM5: 0.25 degree



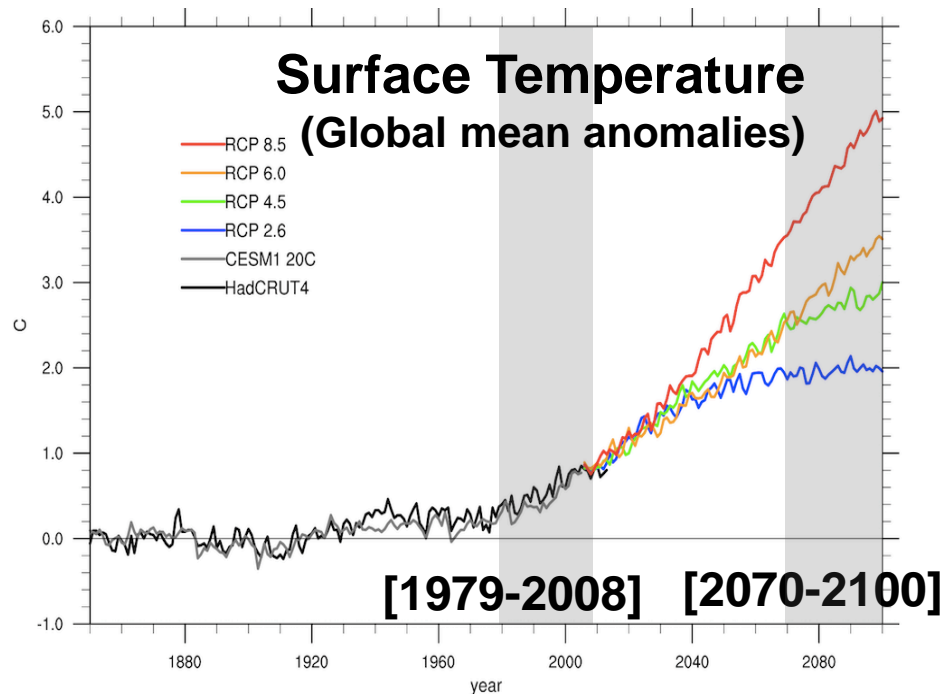
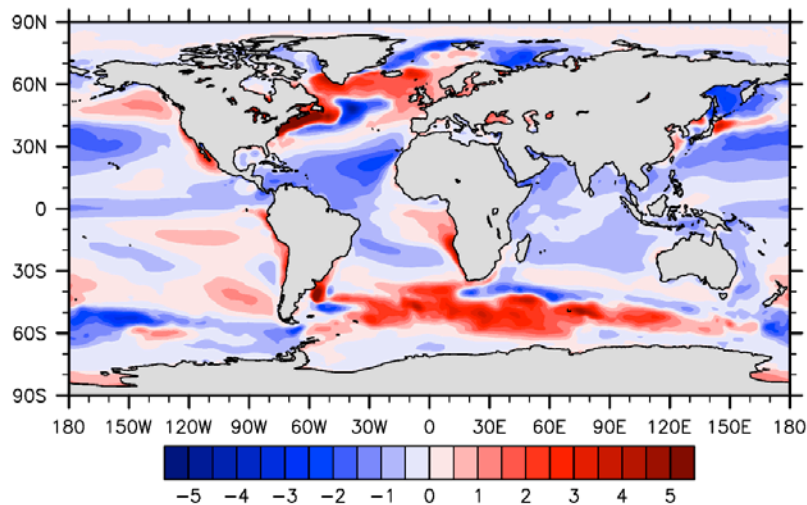
Courtesy: Kevin Reed [See also: Wehner et al. 2014, JAMES]

What is the impact of resolution for future projections ?

Time-slice experiments

- **Present-day conditions**
Observed SSTs: Merged Hadley-OI
- **Future conditions**
CESM SSTs: RCP4.5 & RCP8.5

+ bias correction

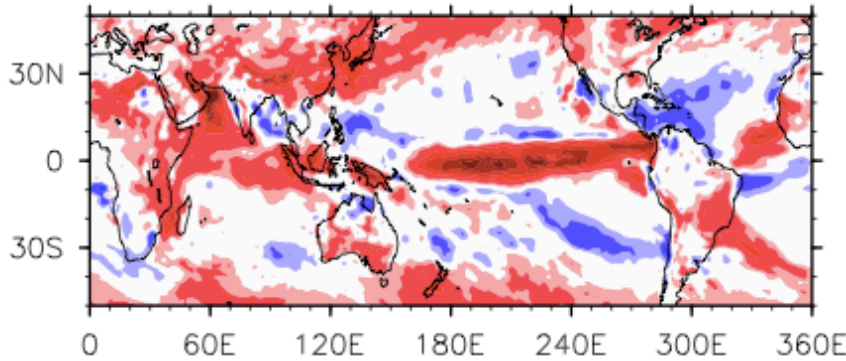


We use the **present-day SSTs bias** as a **correction** for RCP SSTs (Use 12-month cycle correction).

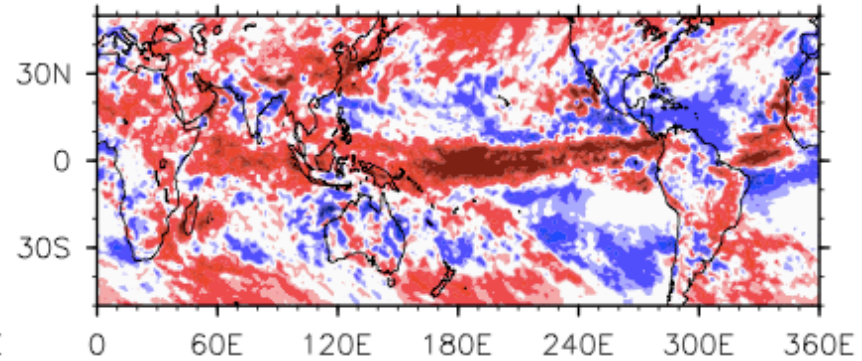
Changes in precipitation intensity/frequency

Precipitation intensity

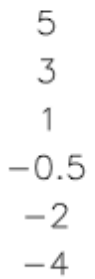
CAM5 (1°)



CAM5 (0.25°)

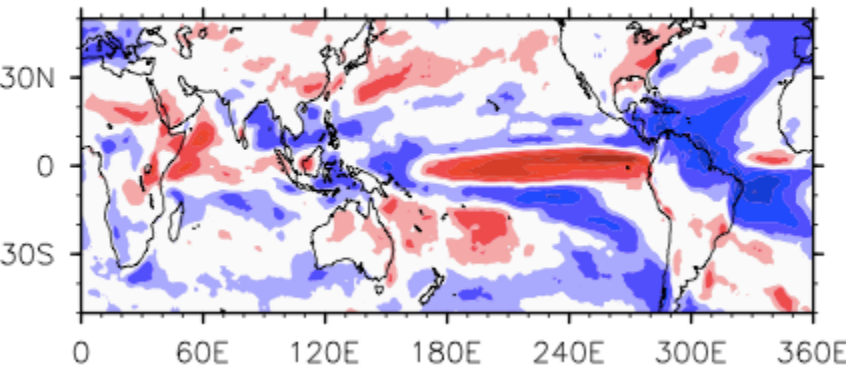


mm/day

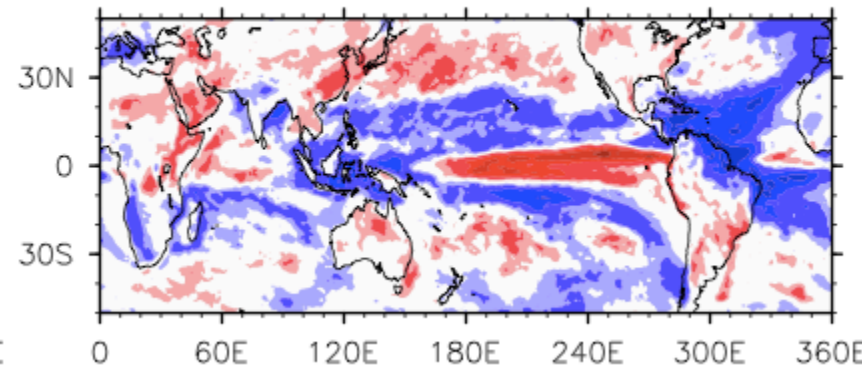


Precipitation frequency

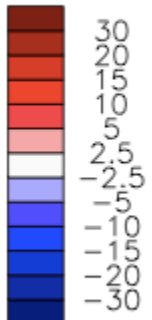
CAM5 (1°)



CAM5 (0.25°)



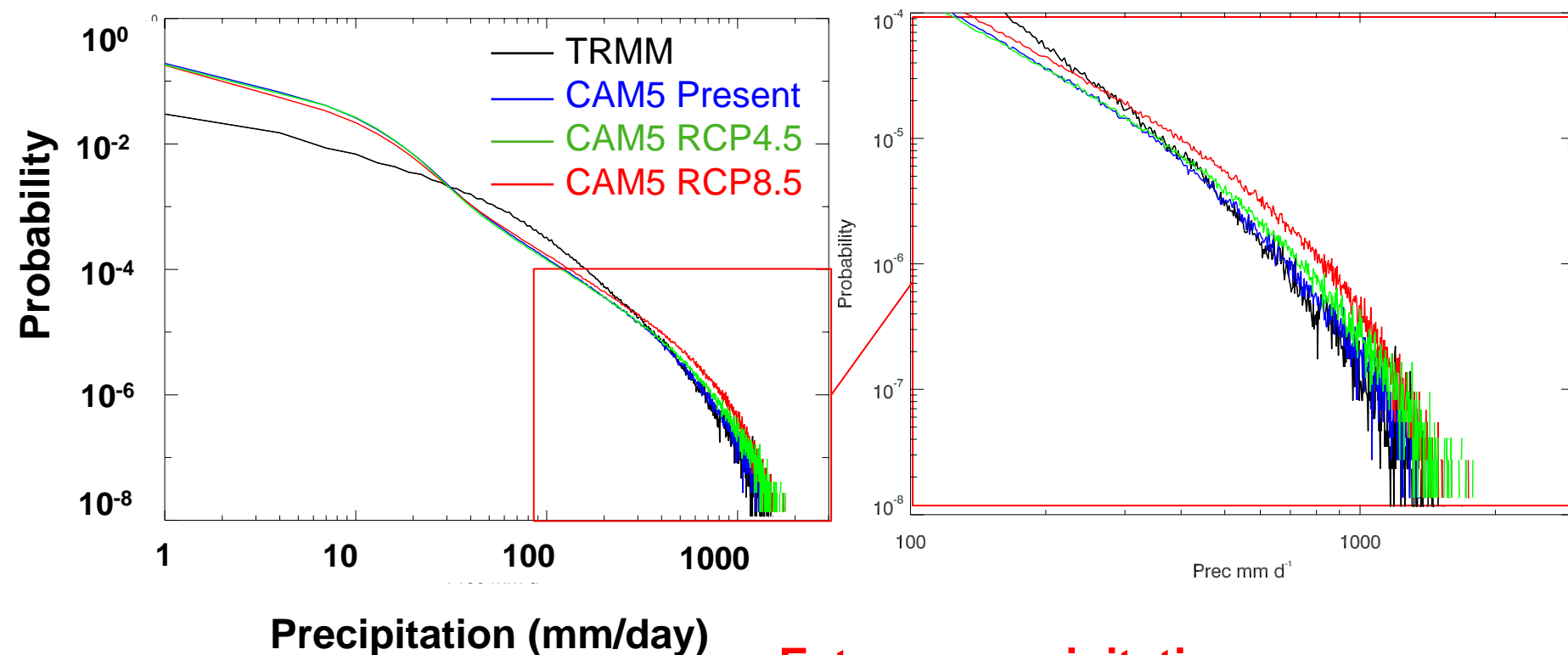
%



In **warmer** climate: it rains **harder** but **less frequently**
(Consistent with Trenberth et al. 2003)

Extreme precipitation in warmer climate

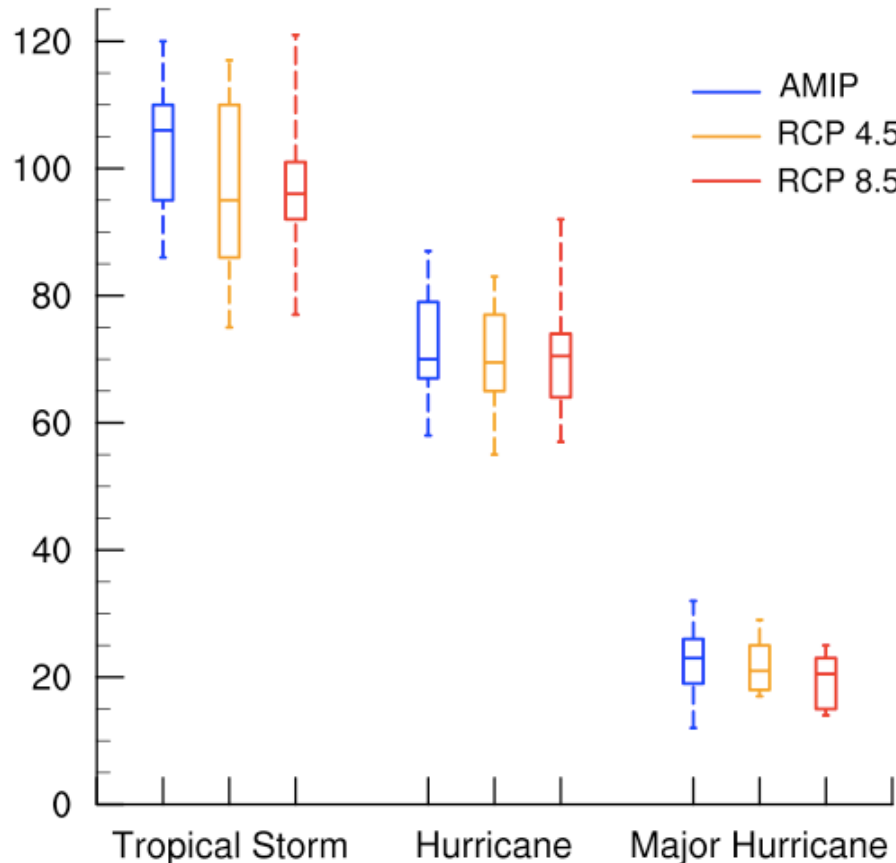
PDFs of precipitation at 0.25 degree (August)



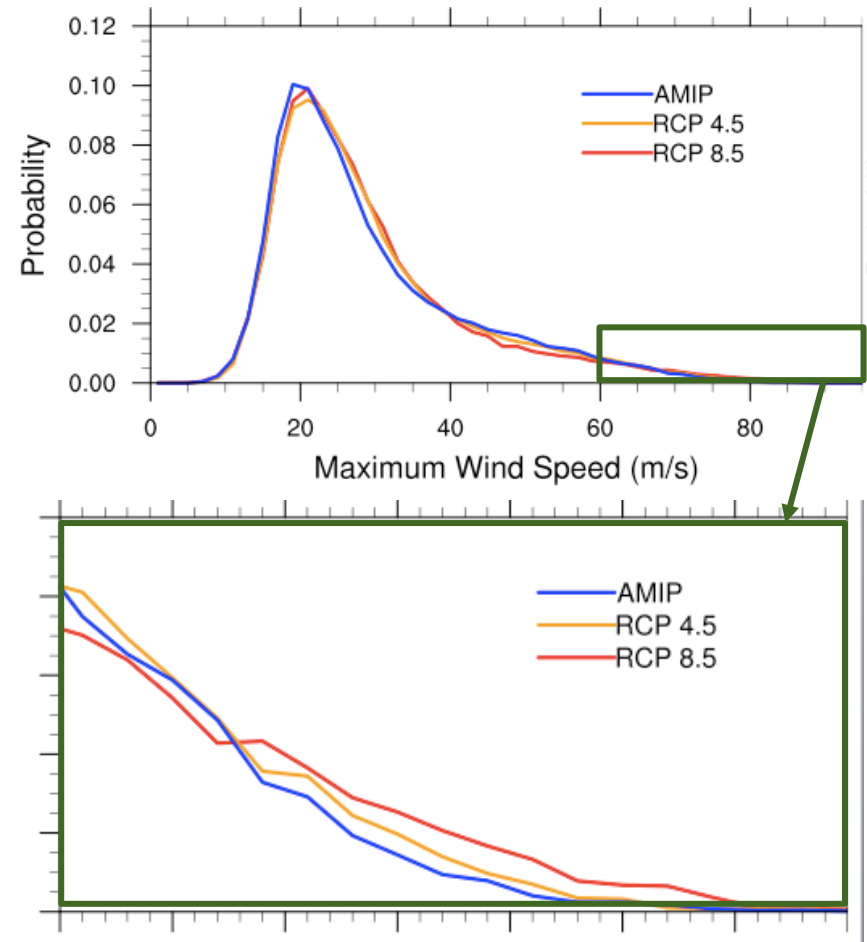
Extreme precipitation are more intense in a warmer climate

Tropical Cyclone count and intensity in warmer climate

Storm Count



Maximum Wind Speed



In warmer climate:

number of tropical cyclones **decreases**

But the **most intense storms** become **more intense**.

Conclusions

Mean climate:

- Mean precipitation bias is **not** much **improved at higher resolution**.
- Some biases even get **worse** (dry Micronesia bias, double ITCZ...)

Daily data:

- In CAM5: **rains too often** but **not hard enough**.

Despite some **improvements**, the problem **persists** at higher resolution.

Diurnal cycle

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**

Extreme events

CAM at 0.25 degree has some **skills** to reproduce **extreme precipitation** and **tropical cyclones**

Conclusions

In a warmer climate:

- It rains **harder** but **less frequently**
- **Extreme** precipitation are **more intense**
- The **number** of tropical cyclones **decreases** but the **most intense storms** become **more intense**.

Thanks !