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NESL's Climate & Global Dynamics
CGD

Understanding the Inter-Tropical Convergence Zone (ITCZ) in CCSM/CESM

Richard Neale

CGD/NCAR

With help from **Dani Coleman**

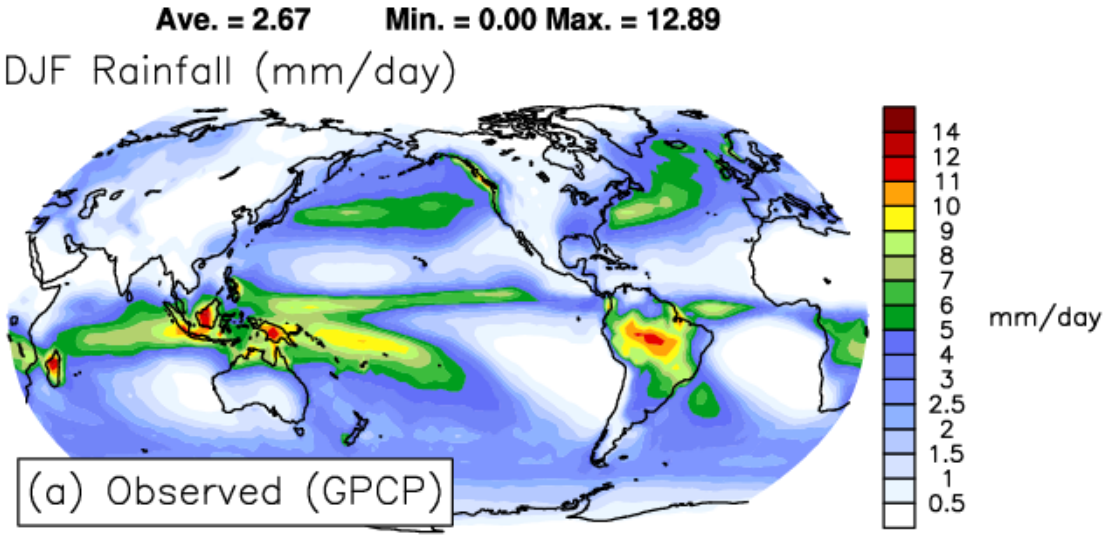
Community Earth System Model
CESM

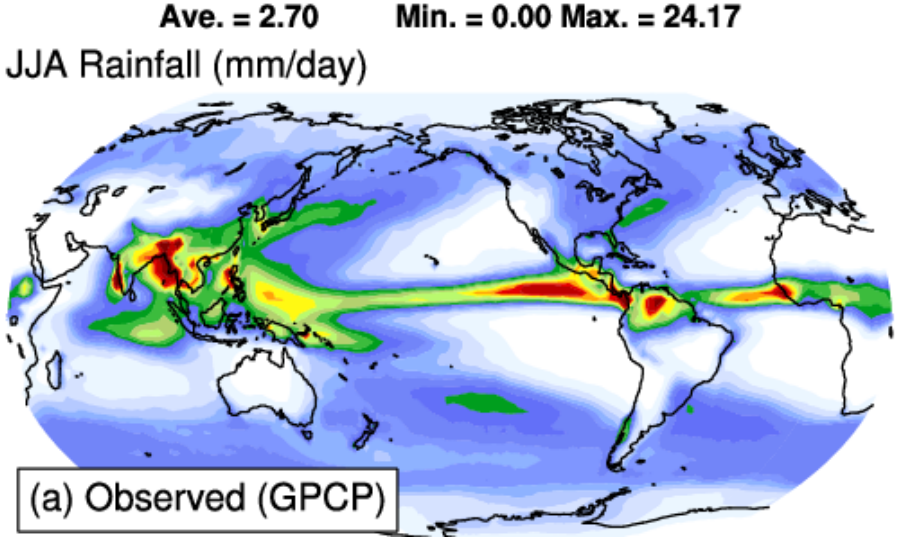
Outline

How robust is the ITCZ?

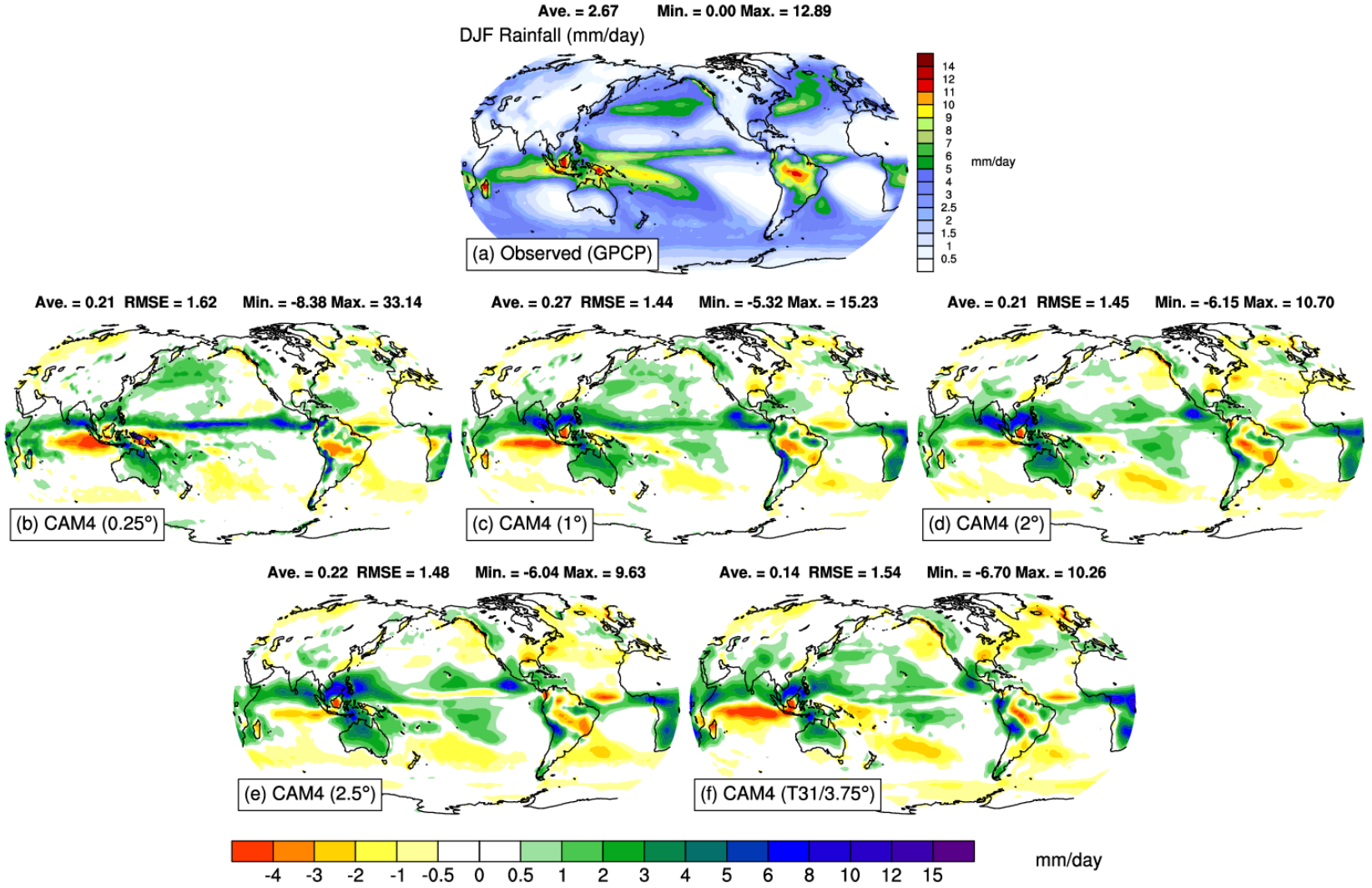
- Observed precipitation maximum
- Effect of resolution
- East Pacific maxium
- High frequency rainfall differences
- Double ITCZ in coupled model
- Sensitivity to convective physics changes
  - Convective **gustiness**
  - Convective **organization**

Observed ITCZ

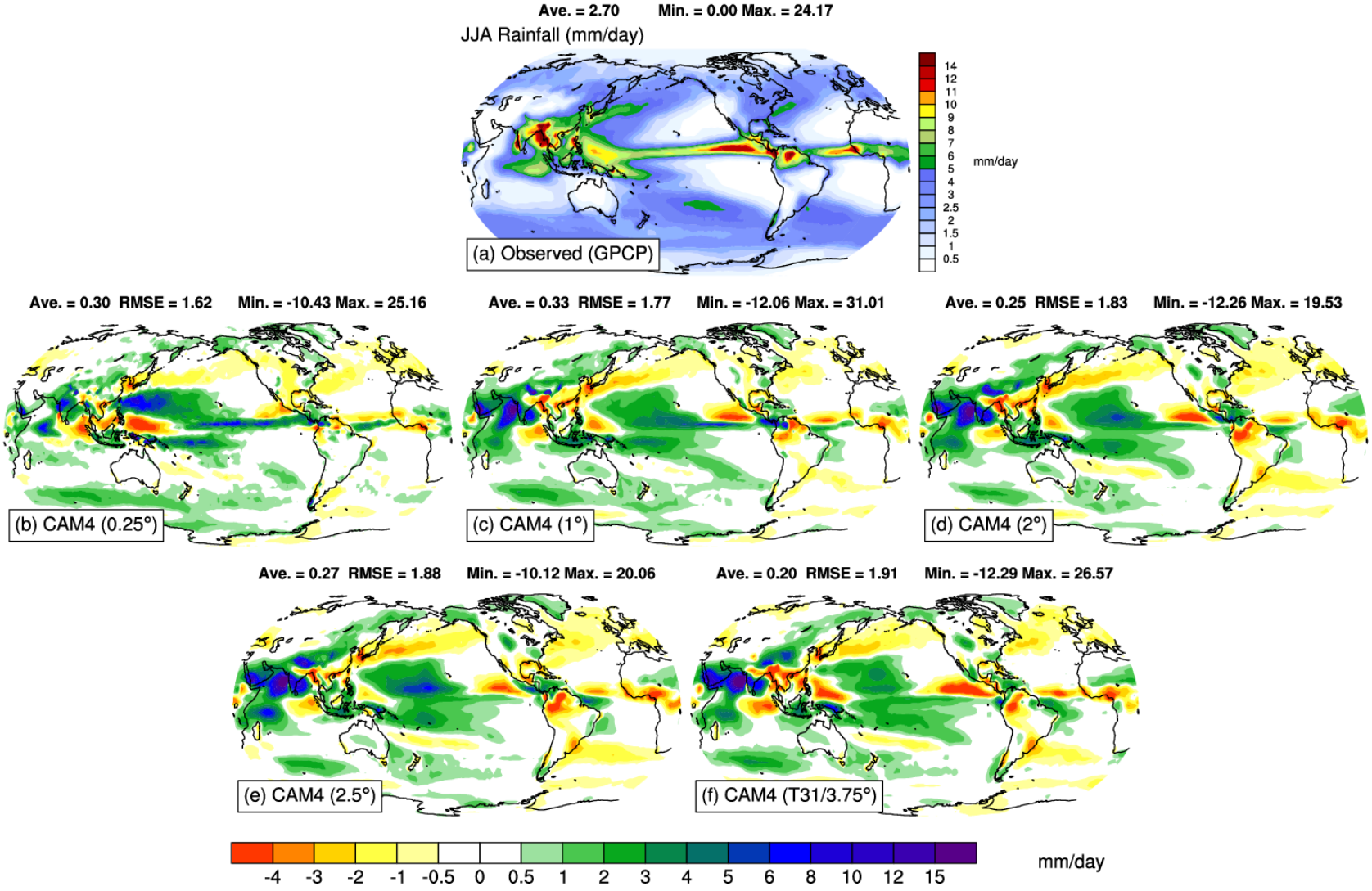




CAM4 Resolution - DJF

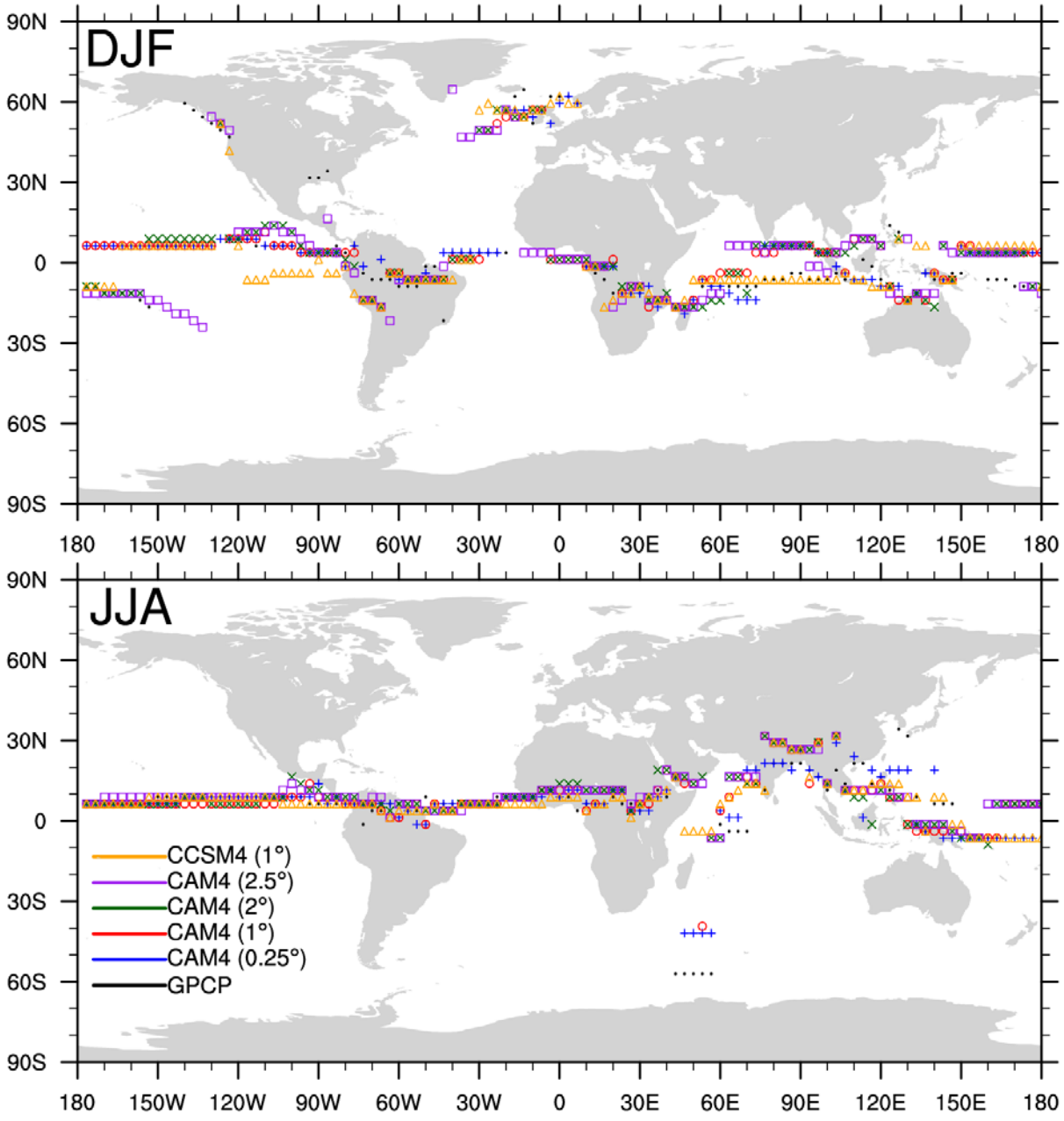


CAM4 Resolution - JJA



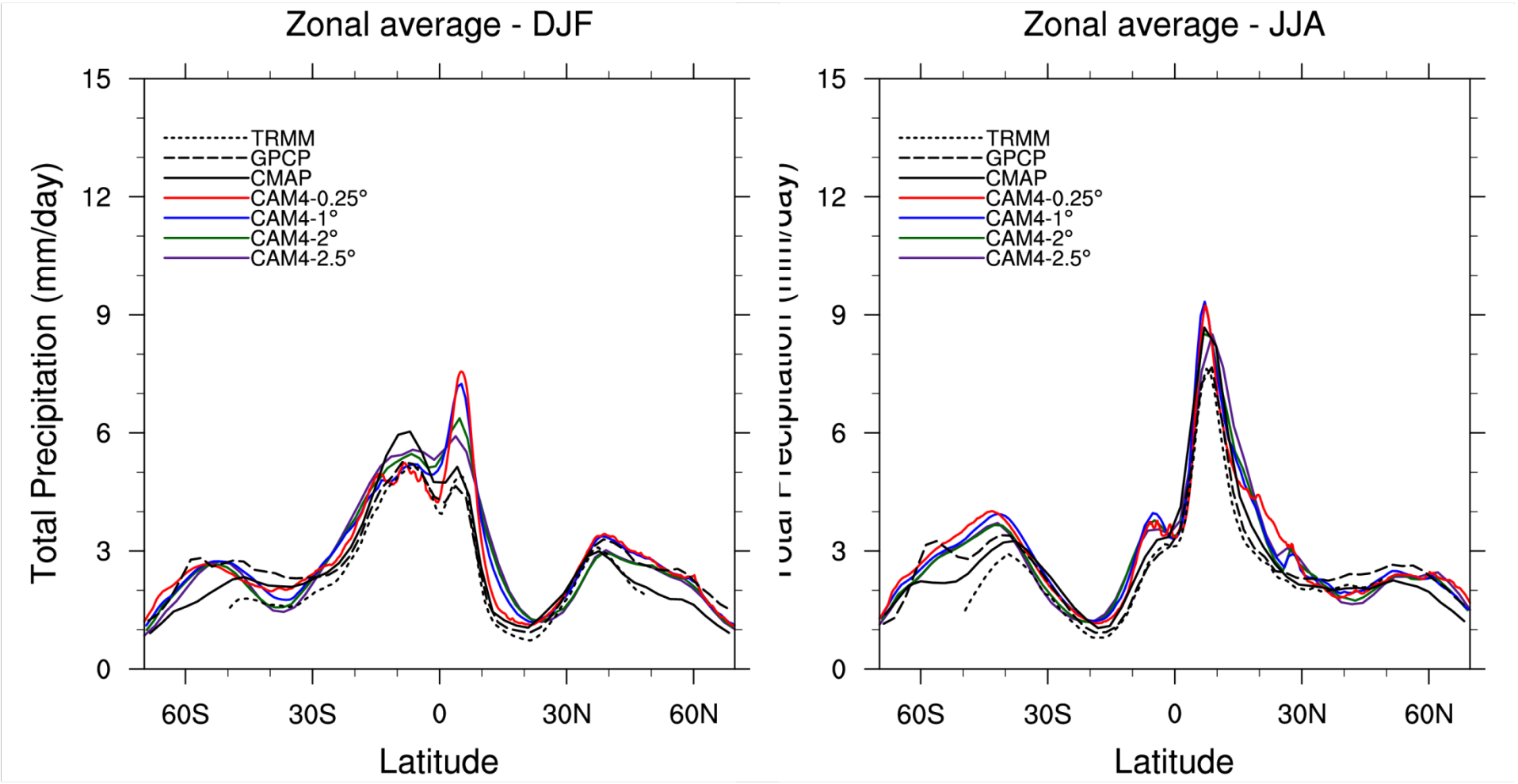
Latitude of Rainfall Maximum

- Generally good agreemen with obs.
- More agreement in JJA
- More agreement in E. Hemisphere
- Maximum not always in the tropics
- Coupled run more often S. of equator
- Summer monsoon can move maximum far from equator
- 0.25 deg resolution not the most accurate



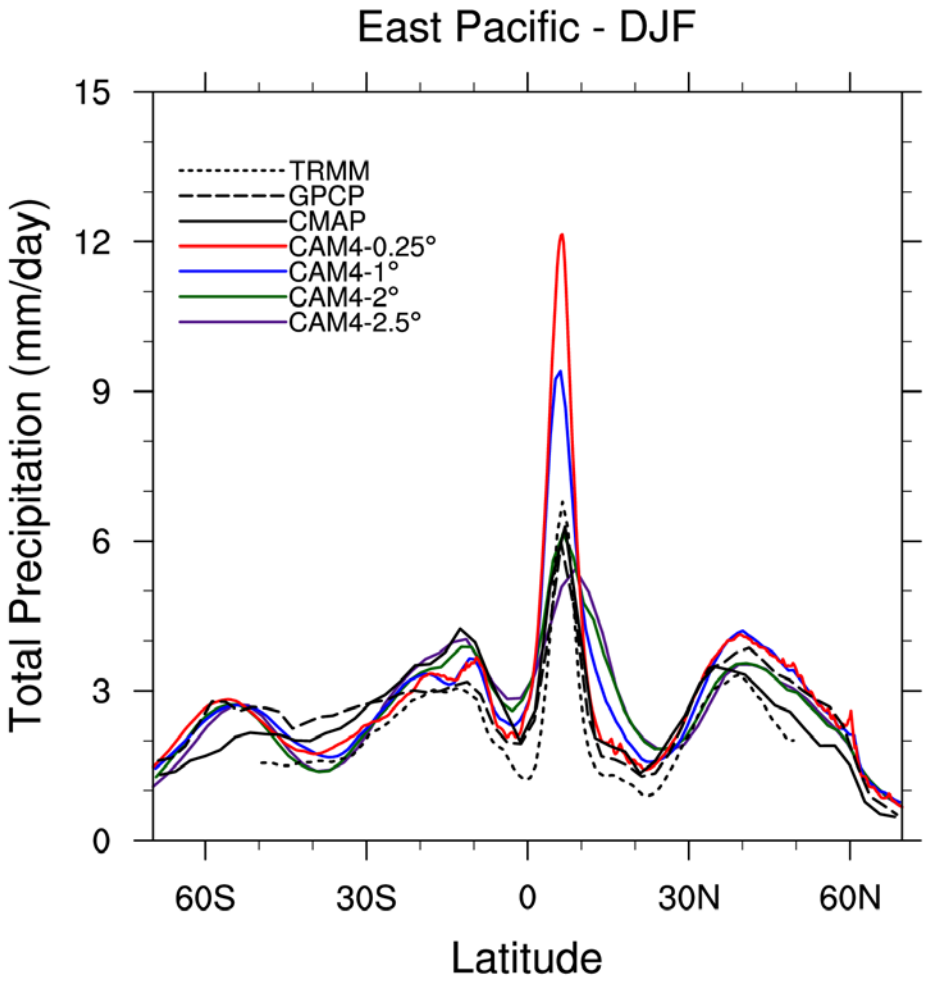
Zonal ITCZ

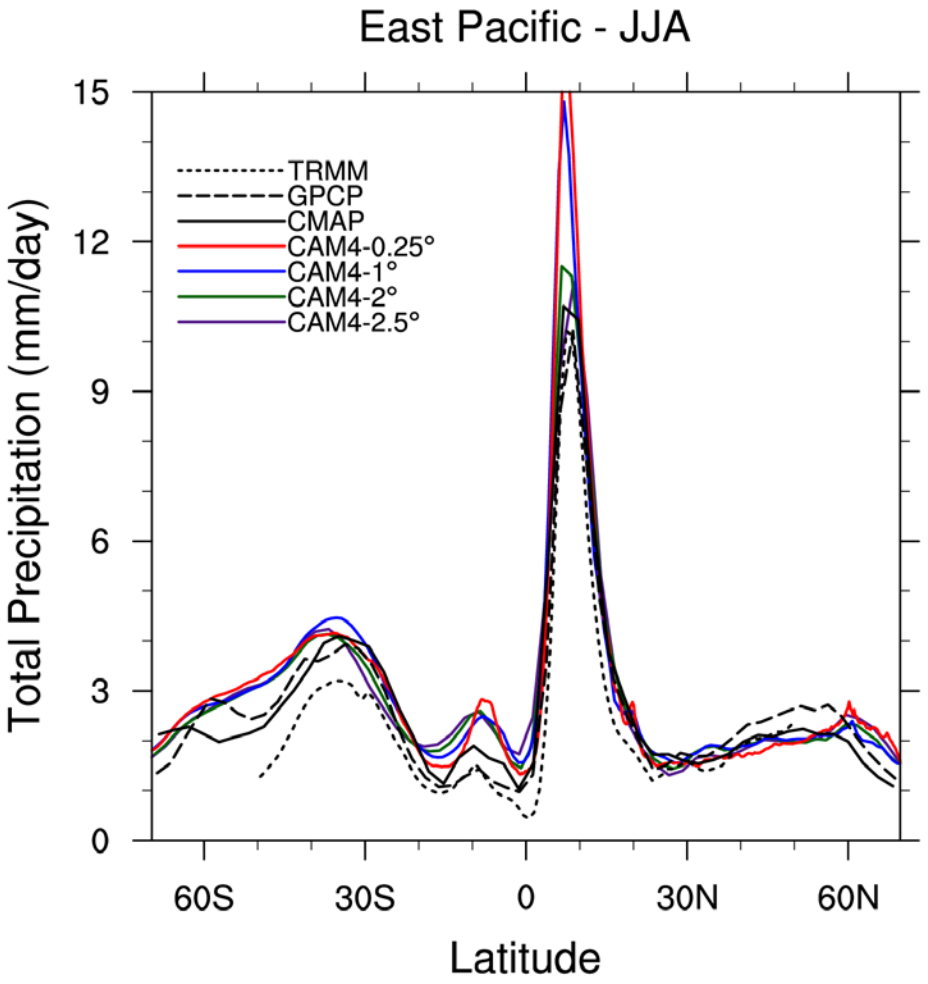
Disagreement between observations



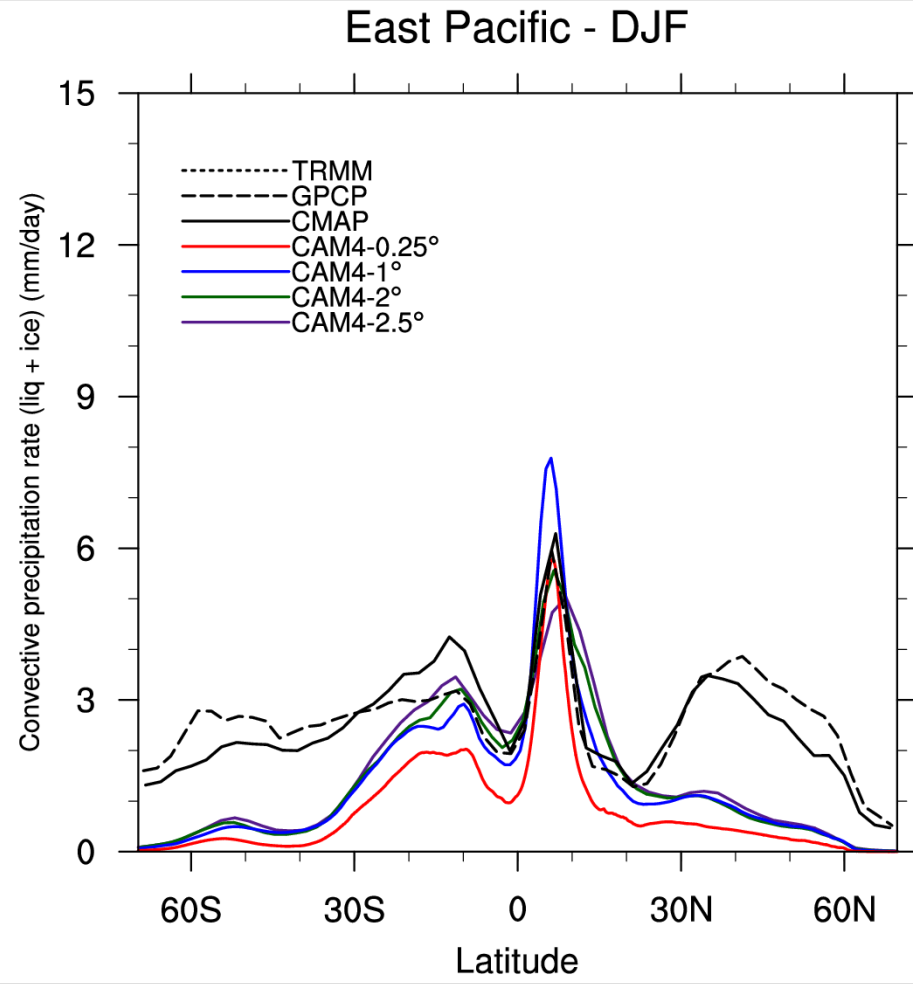
East Pacific ITCZ

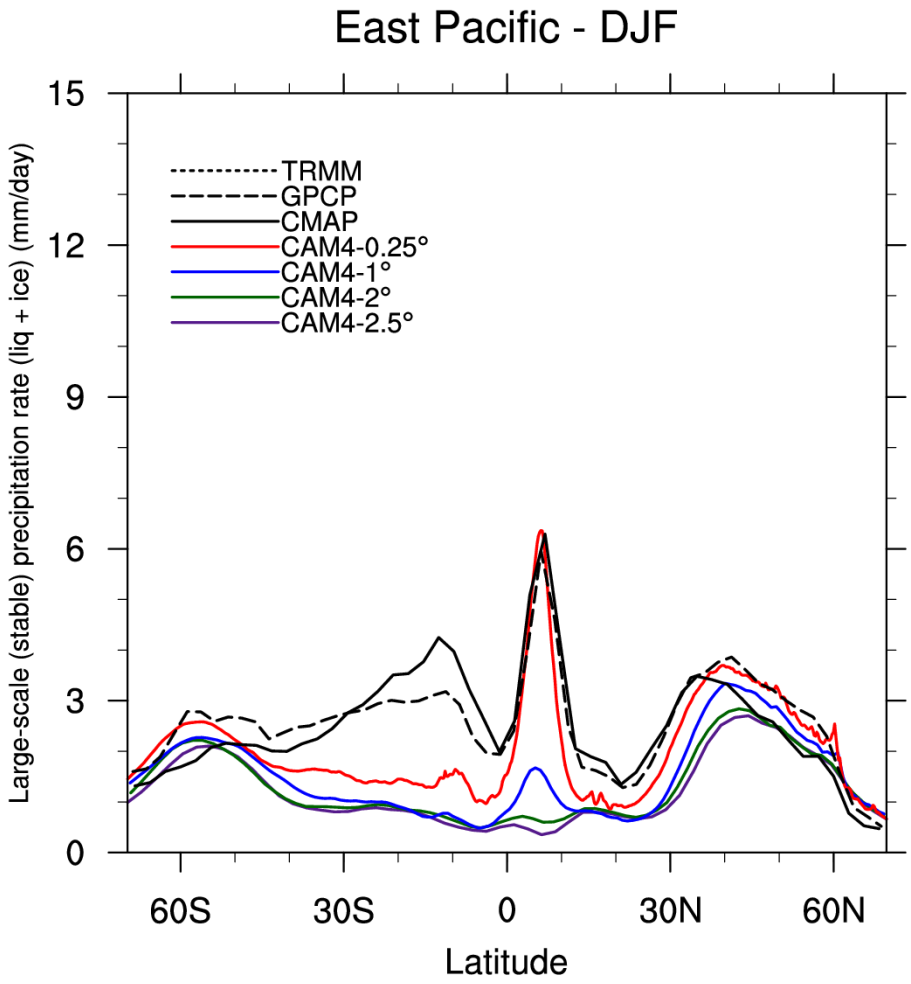
180-285°



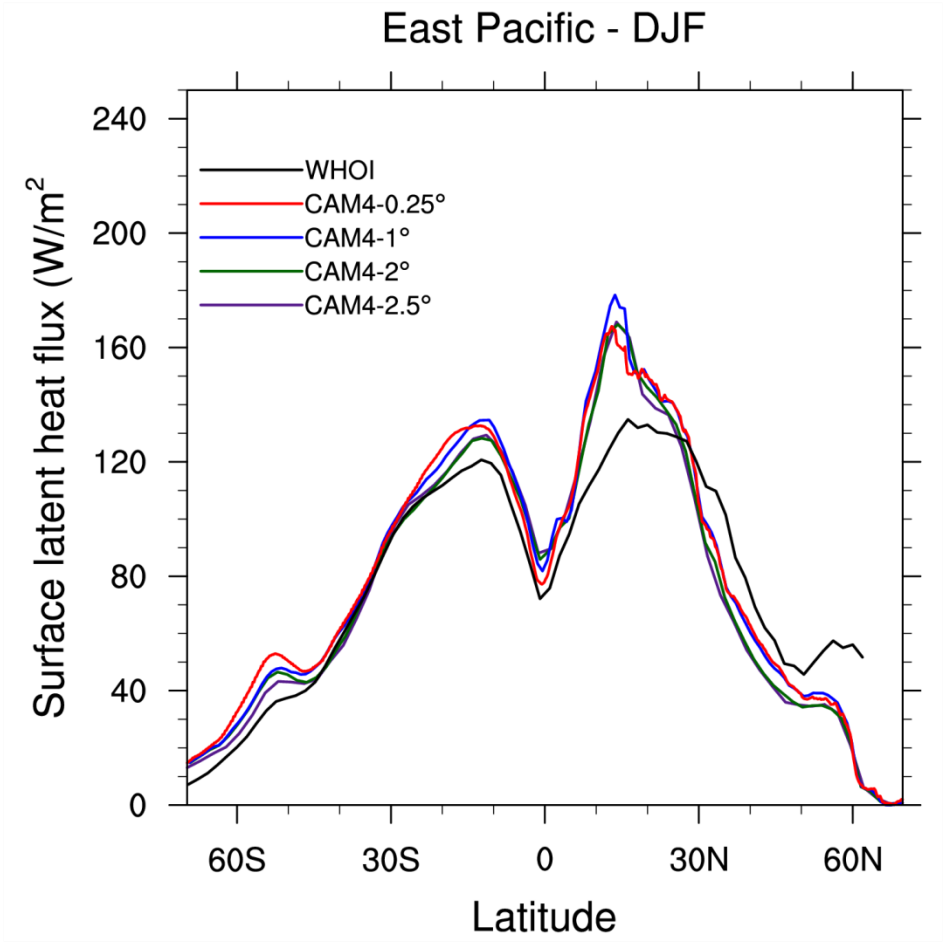


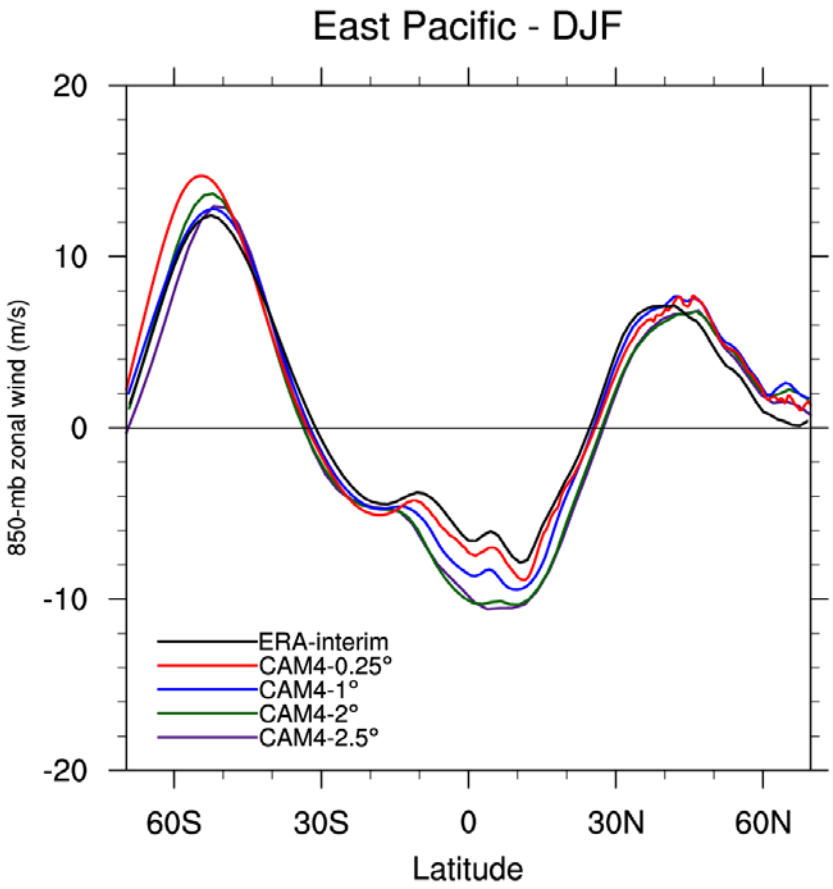
East Pacific ITCZ



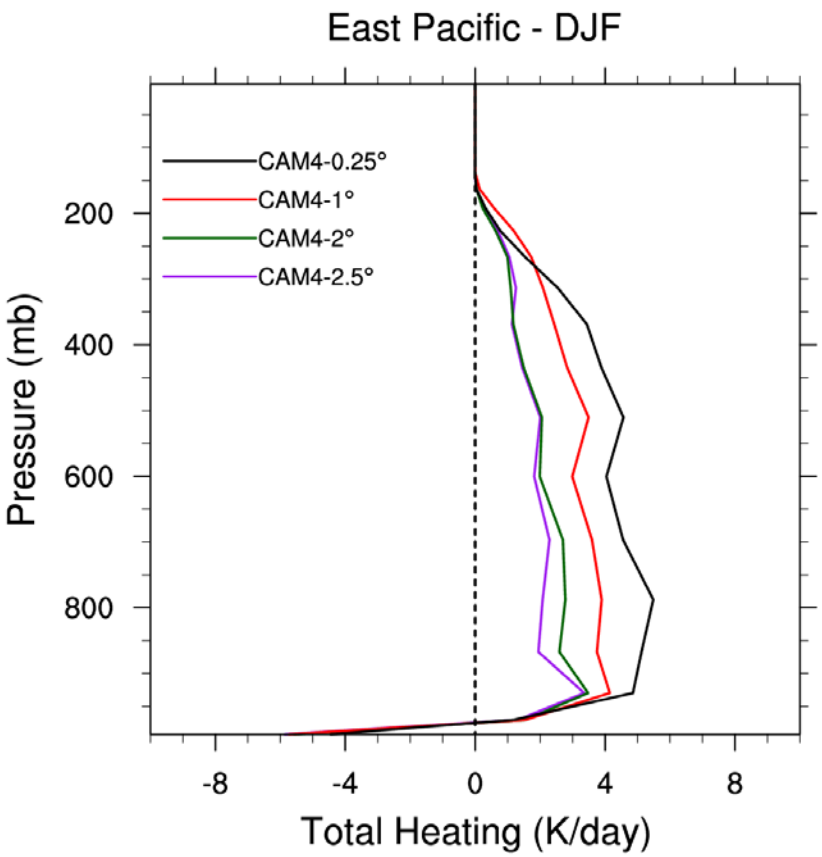


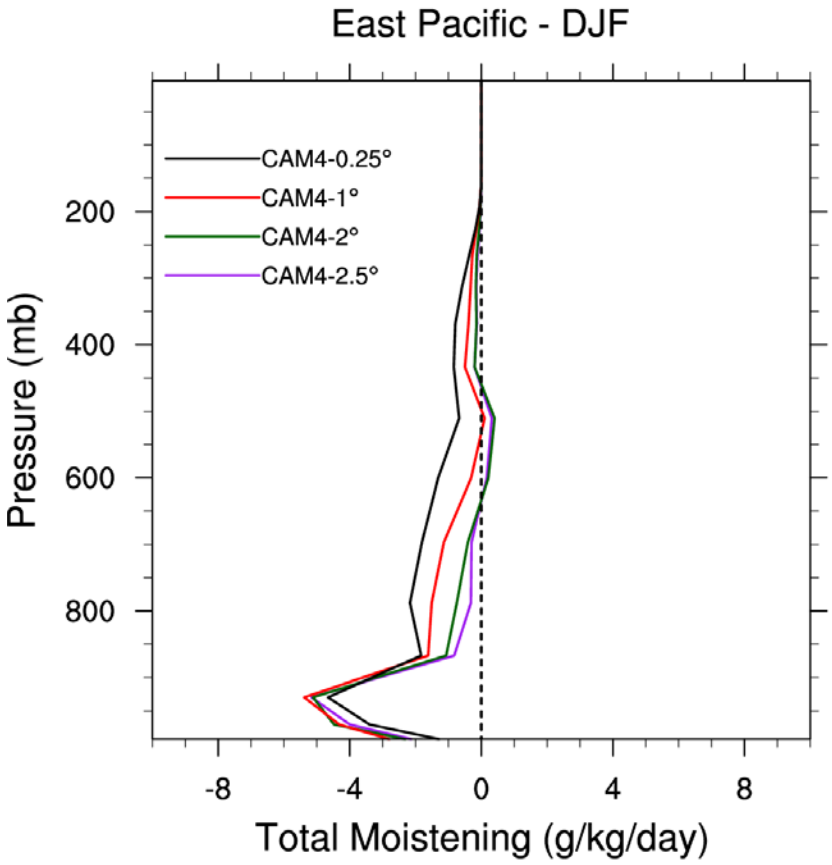
East Pacific ITCZ



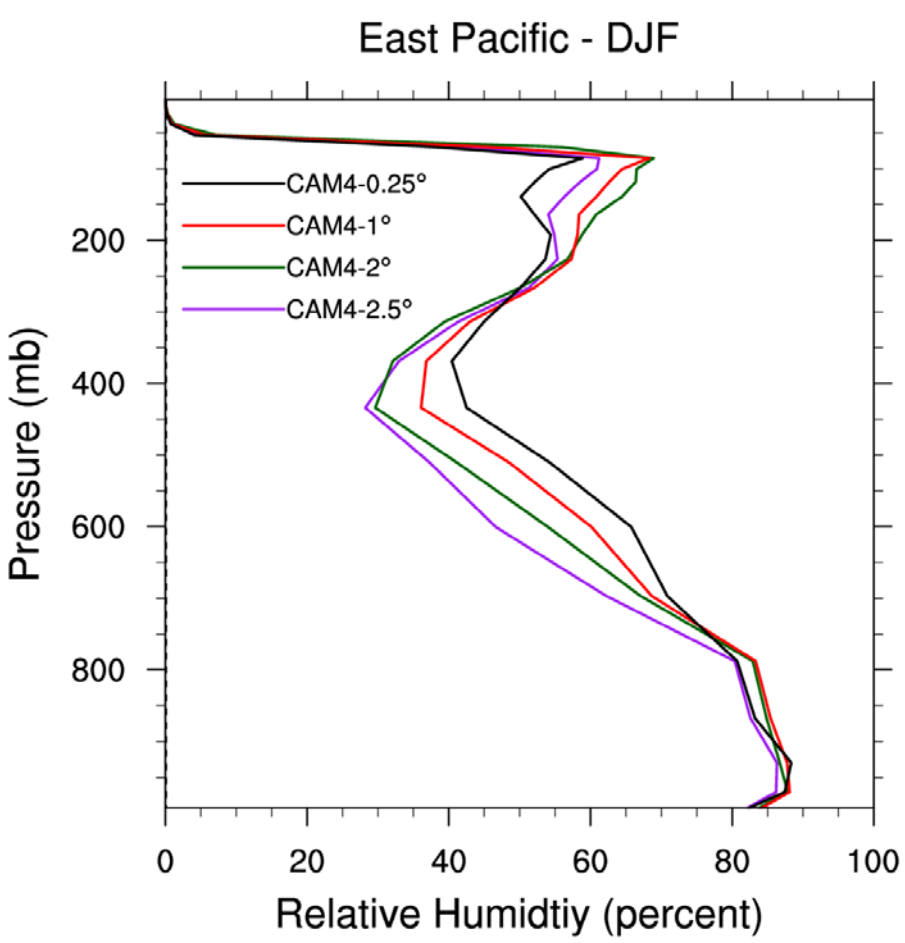


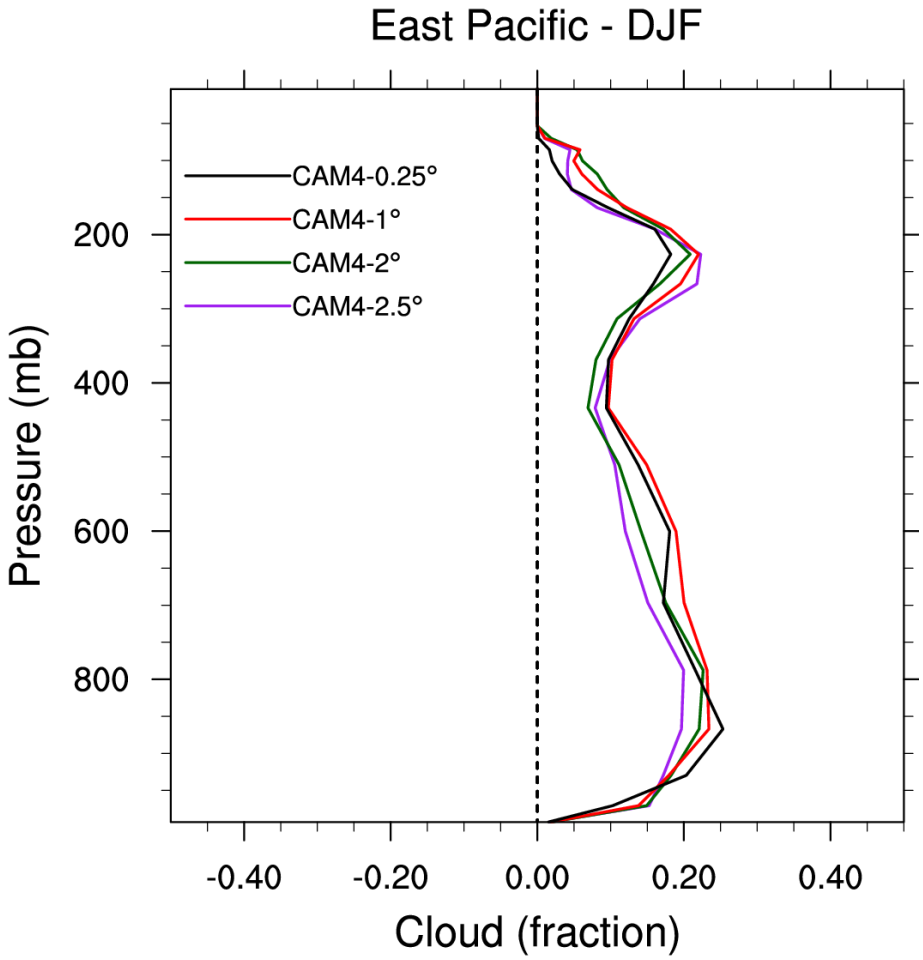
East Pacific ITCZ





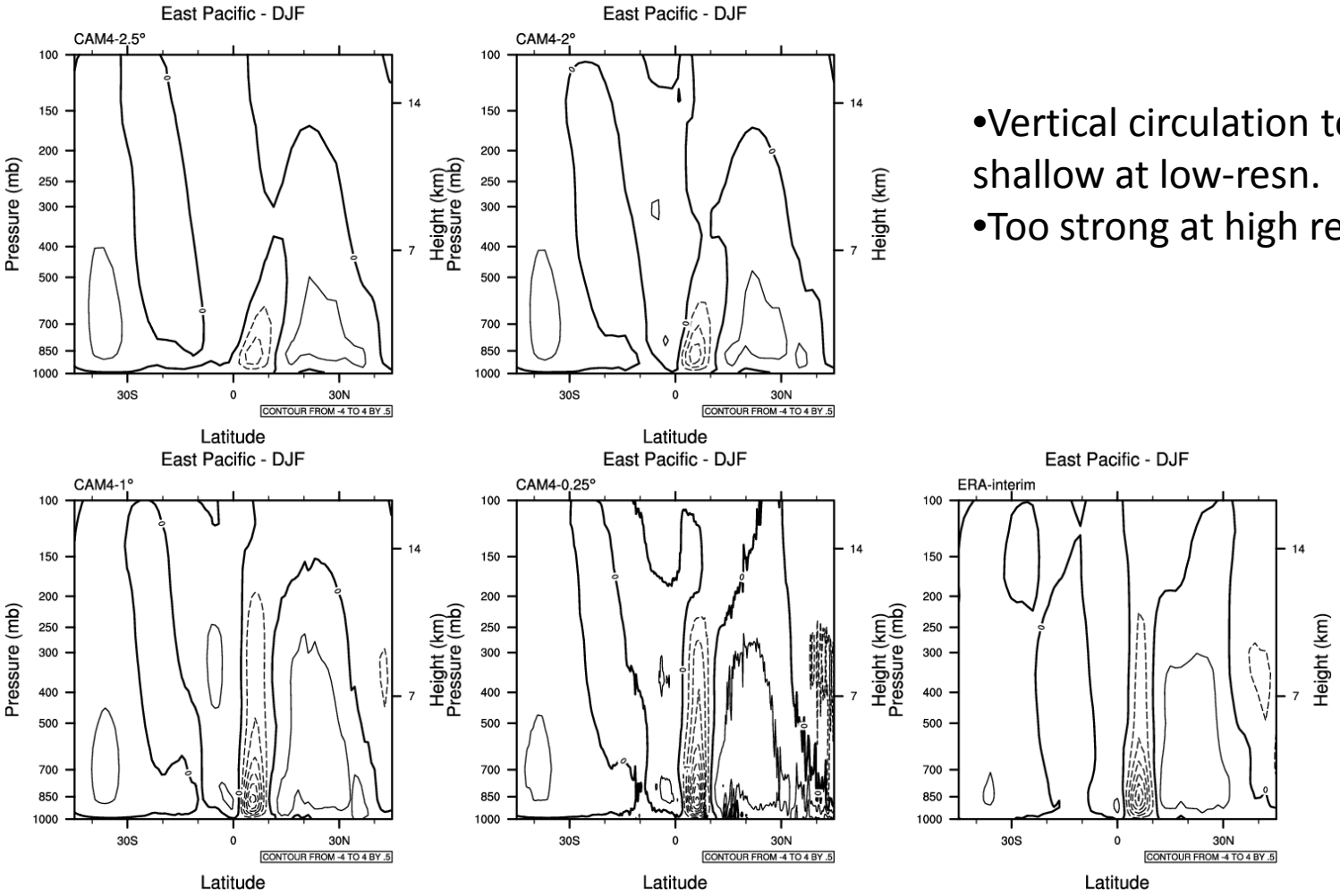
East Pacific ITCZ





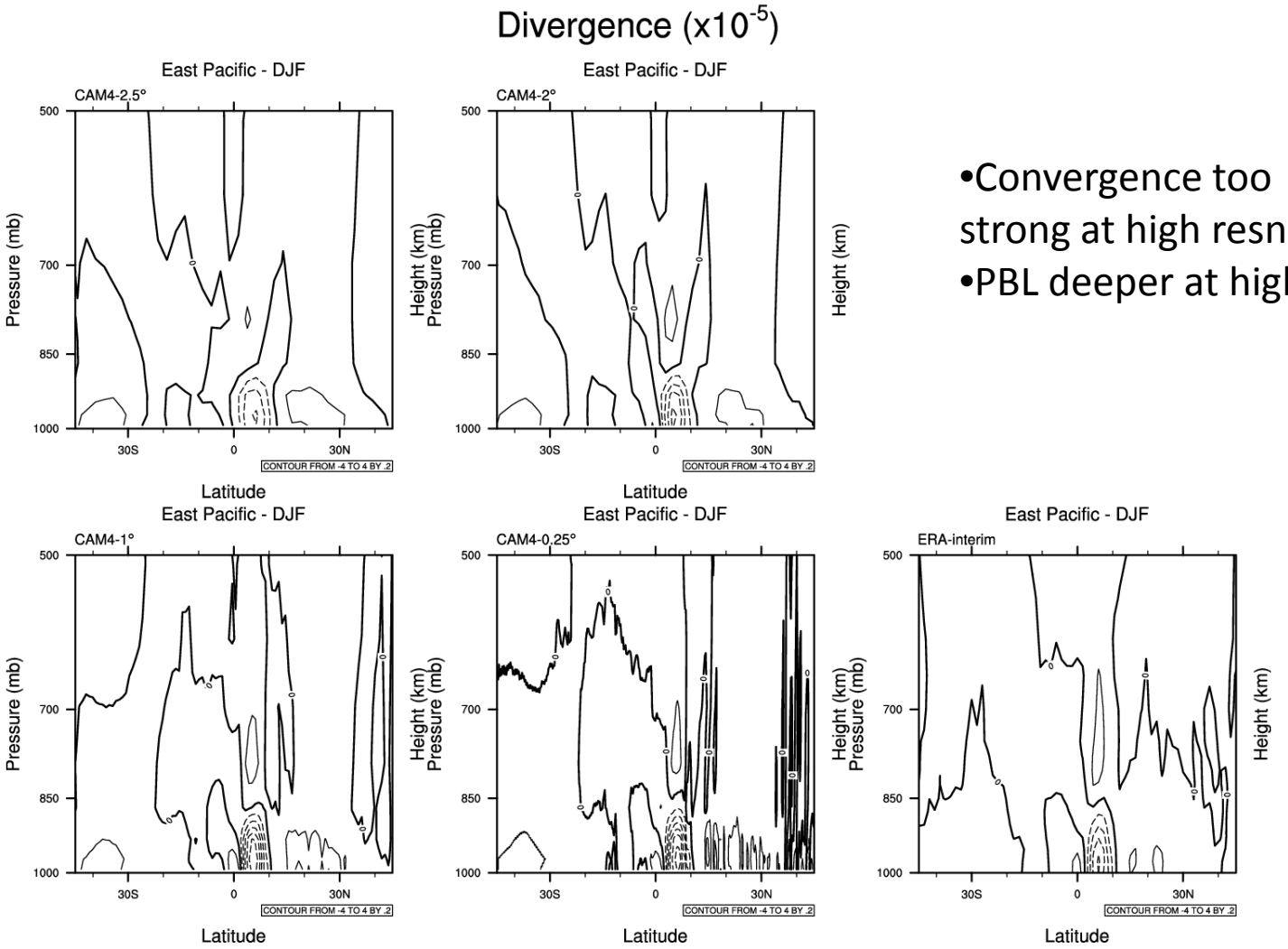
East Pacific ITCZ

Vertical velocity (mb/hr)



- Vertical circulation too shallow at low-resn.
- Too strong at high resn.

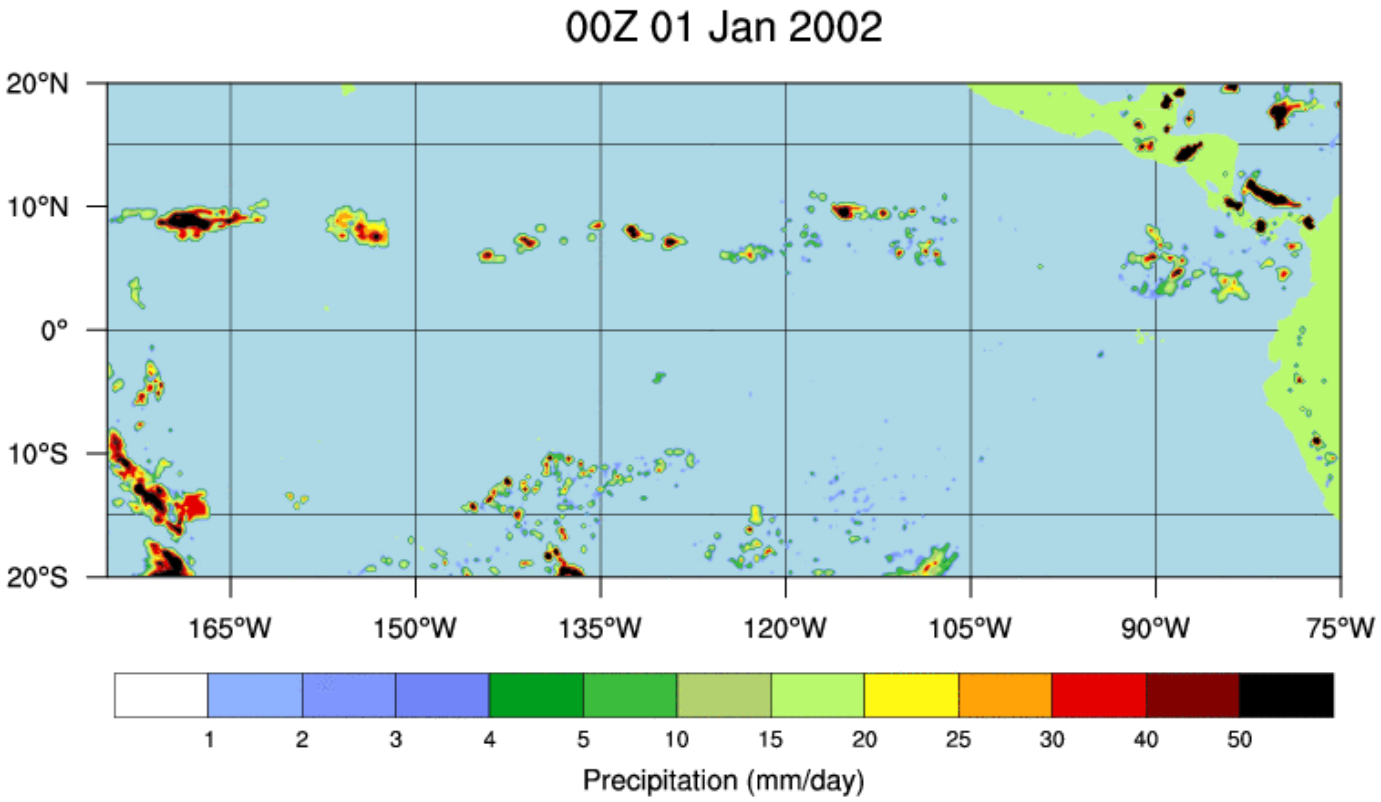
East Pacific ITCZ



- Convergence too strong at high resn.
- PBL deeper at high res.

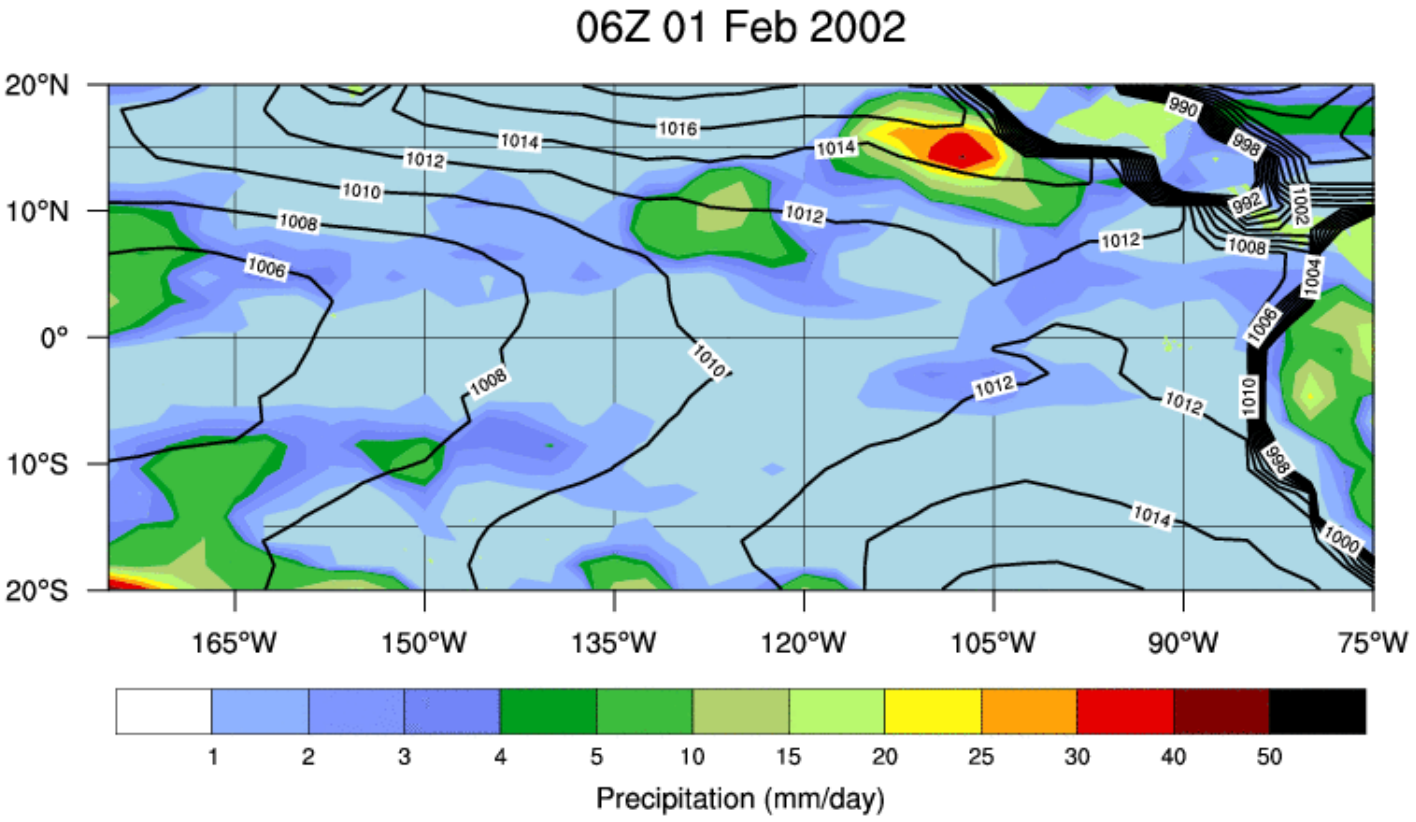
High Frequency Events

TRMM 3-hourly rainfall



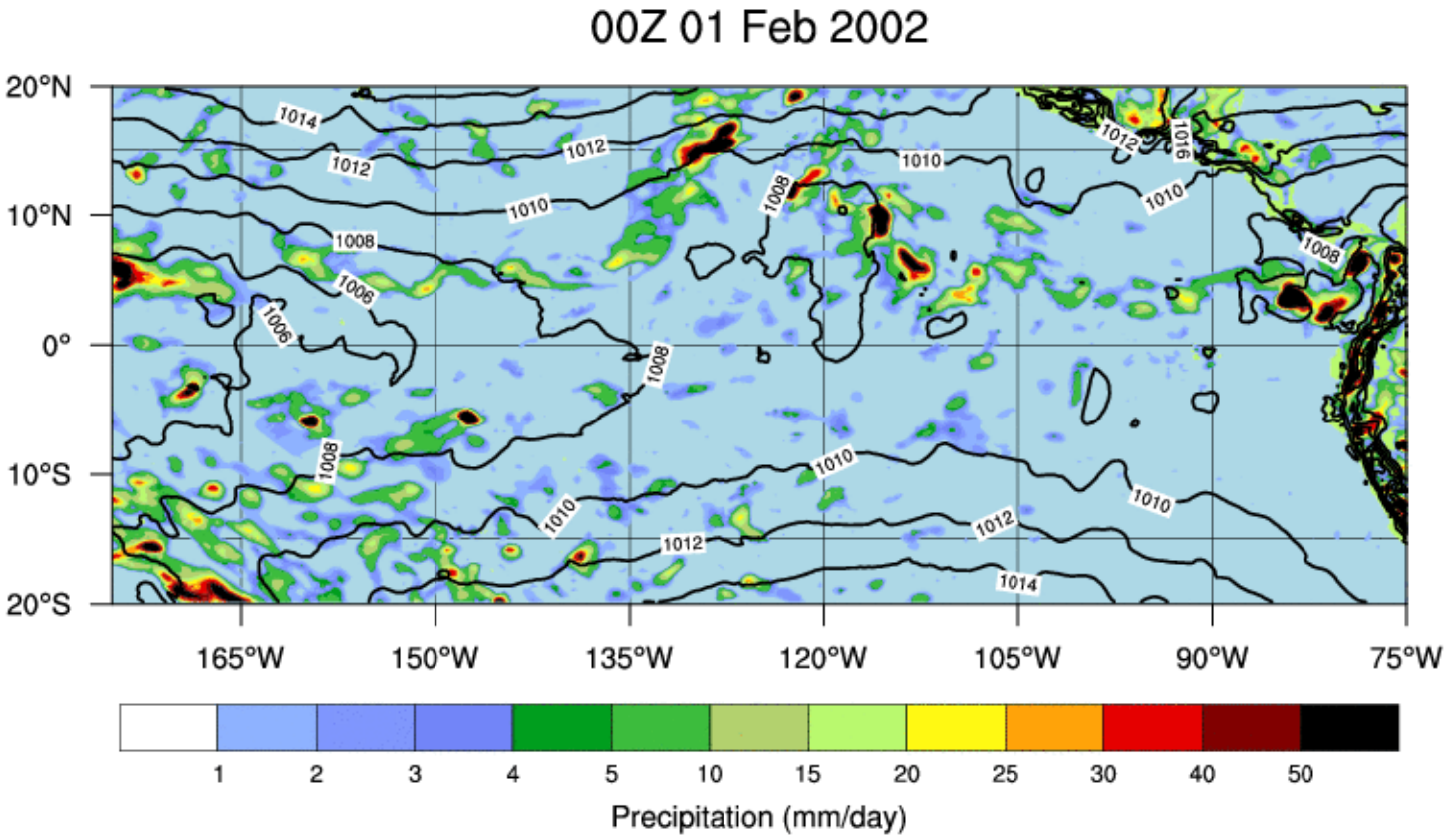
High Frequency Events

CAM4: 2 deg, 3-hourly rainfall

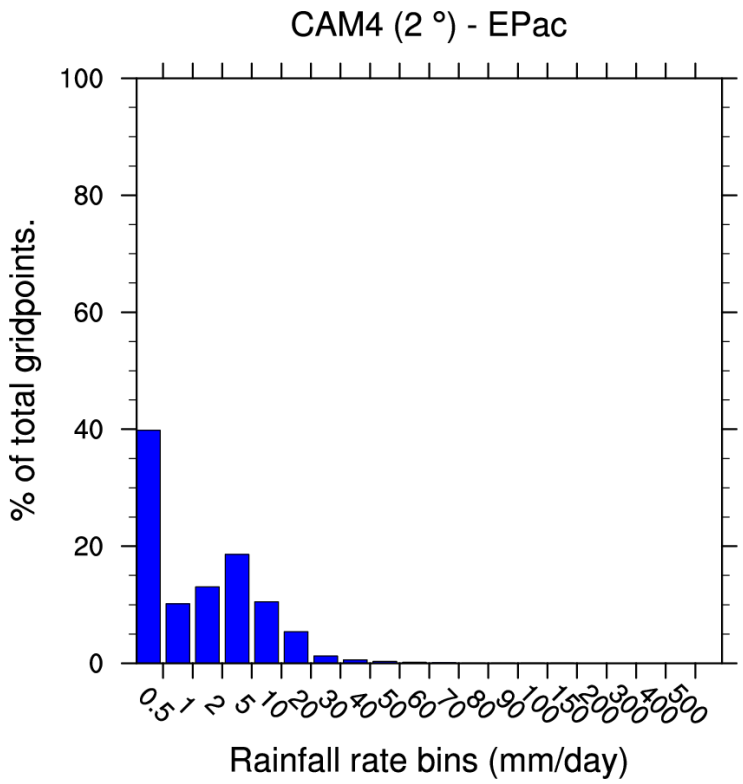


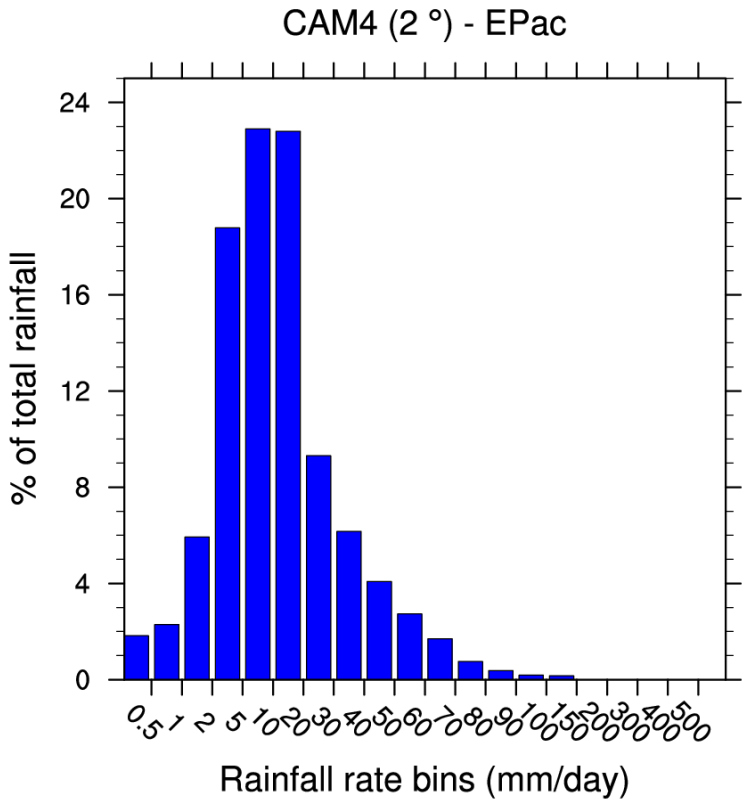
High Frequency Events

CAM4: 0.25 deg, 3-hourly rainfall



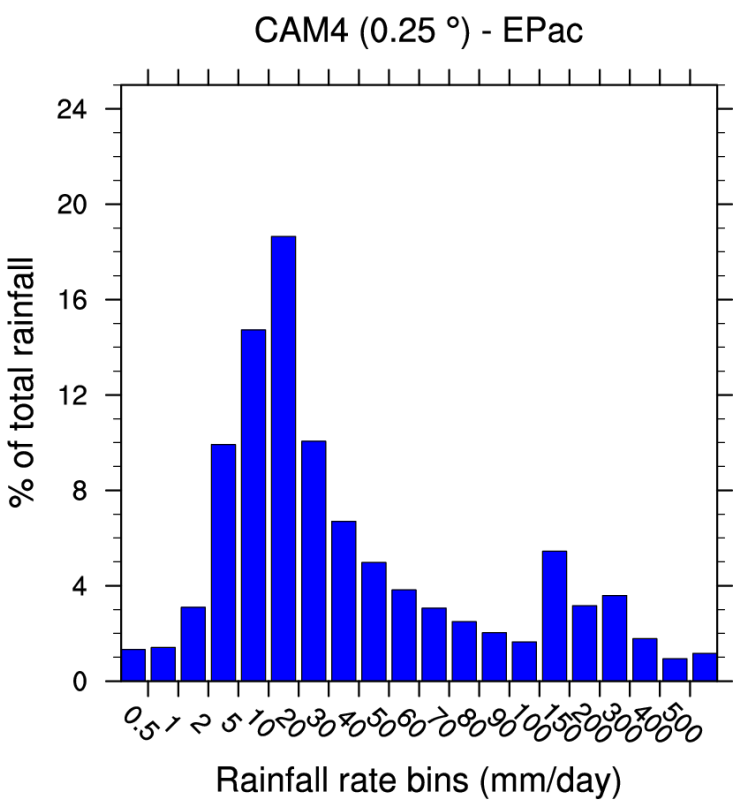
Rainfall Rate Contributions

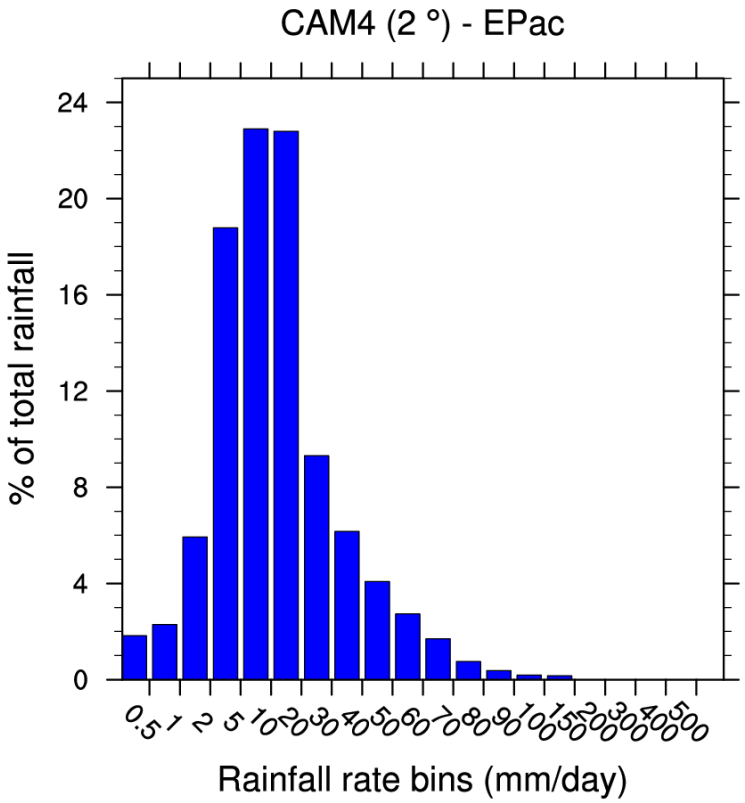




3-hourly mean precipitation from Feb 2002

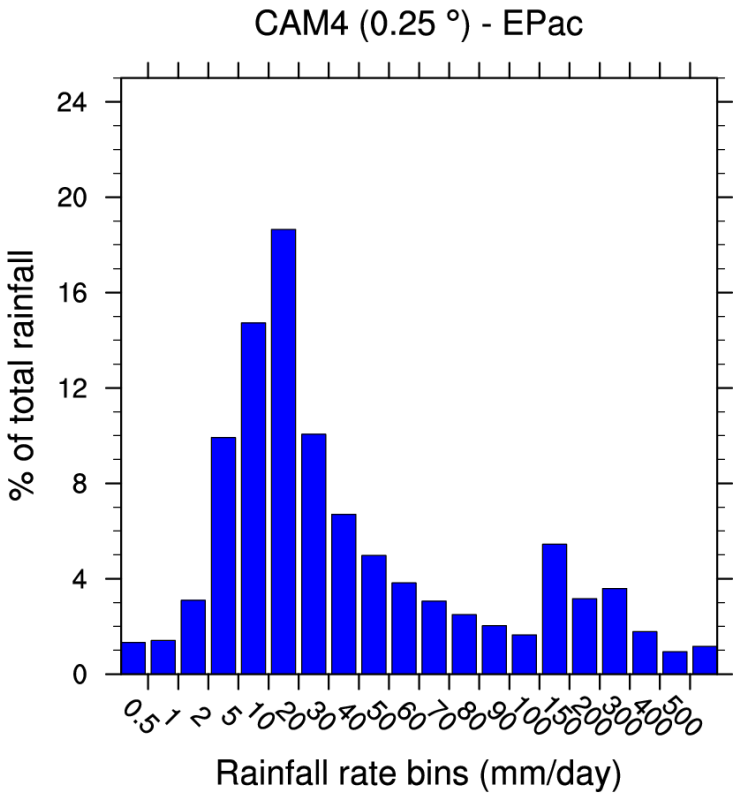
Rainfall Rate Contributions

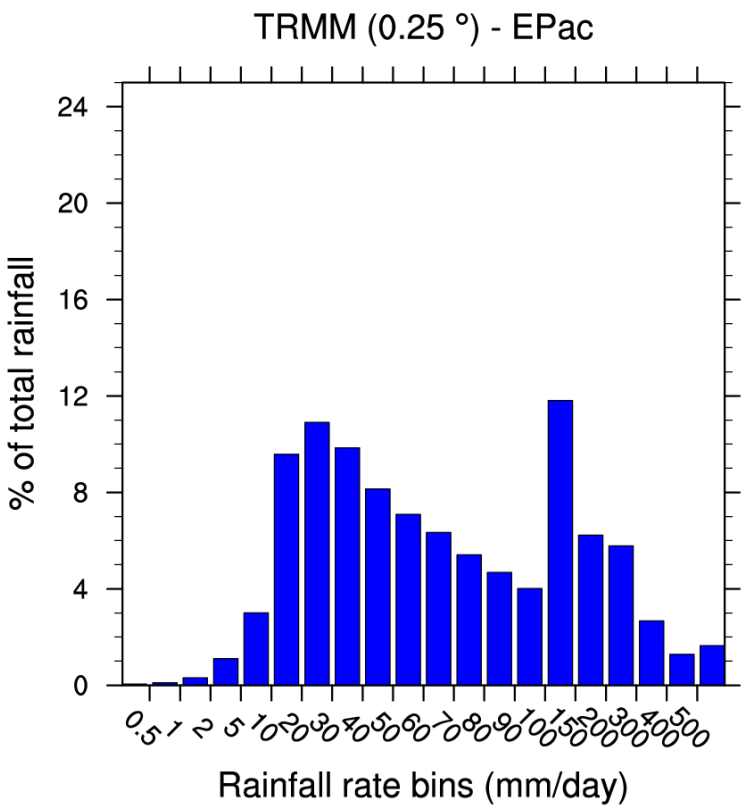




3-hourly mean precipitation from Feb 2002

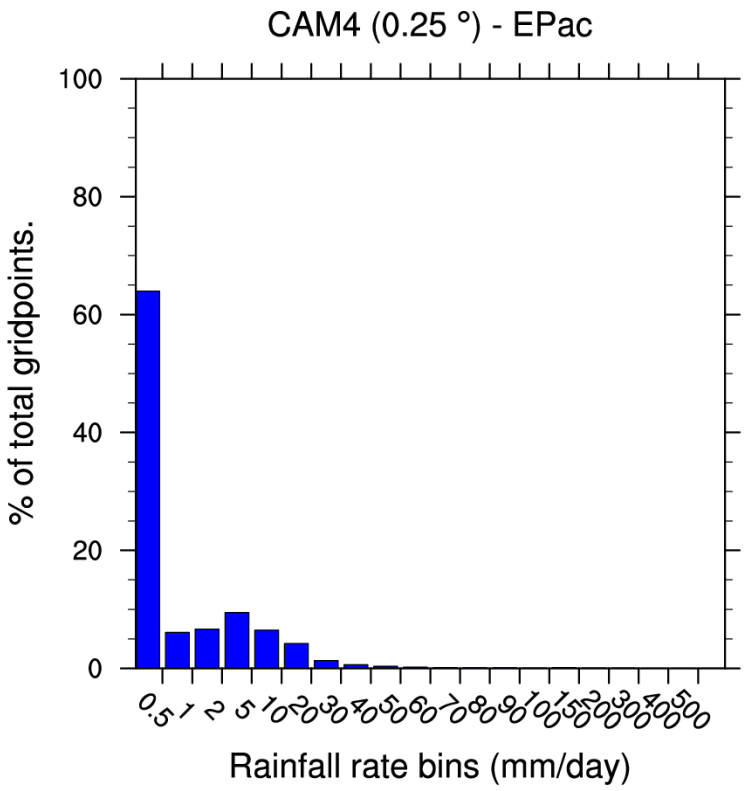
Rainfall Rate Contributions

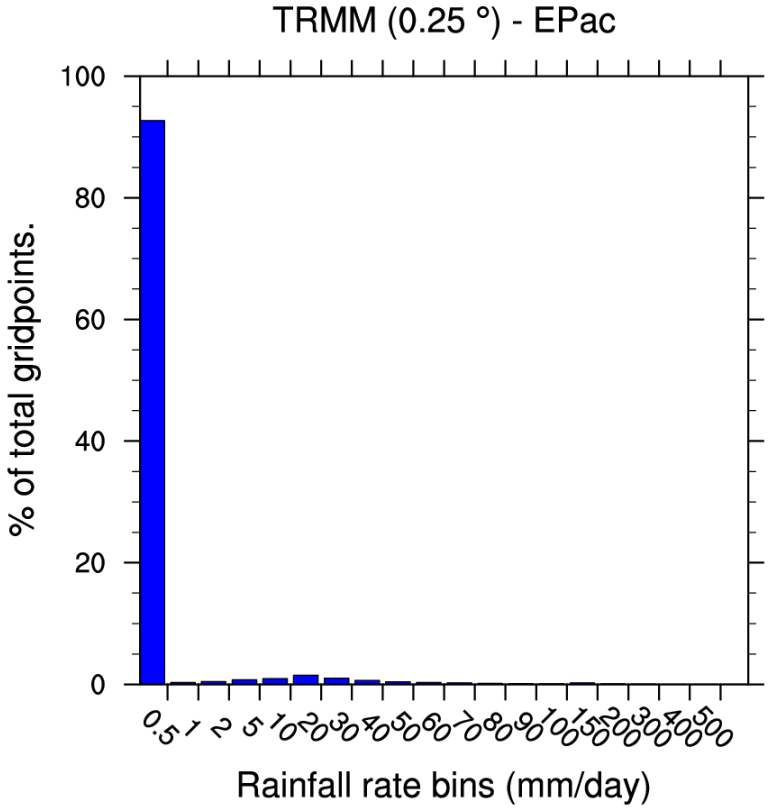




3-hourly mean precipitation from Feb 2002

Rainfall Rate Contributions

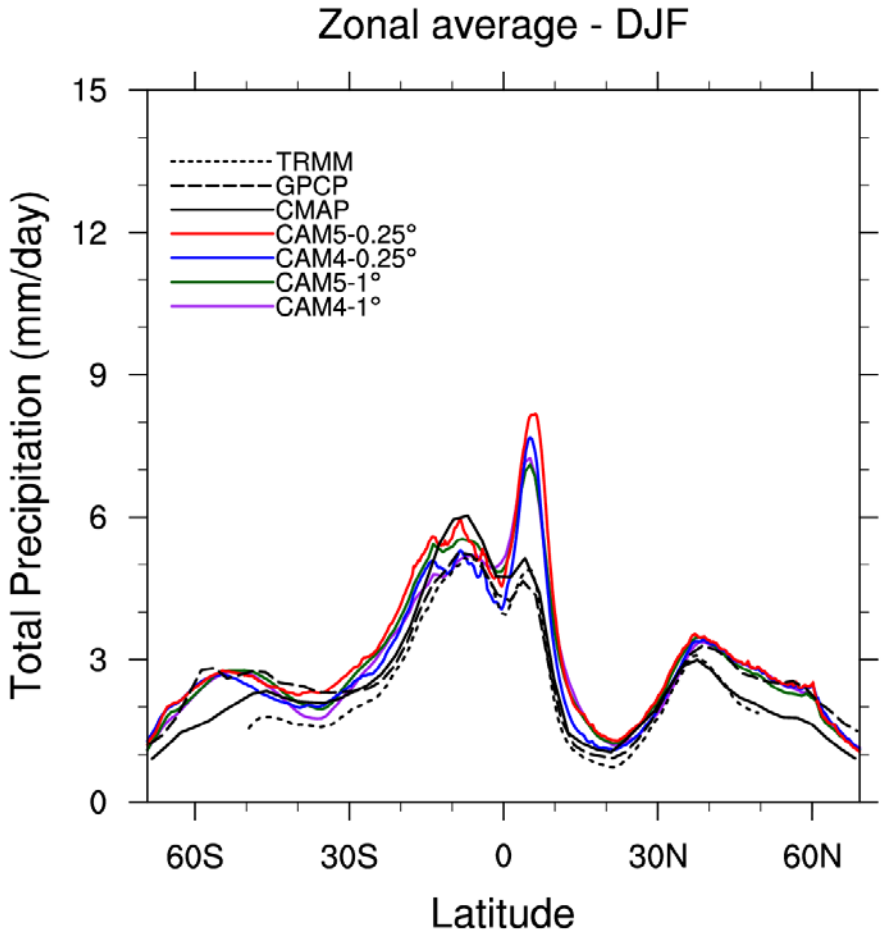


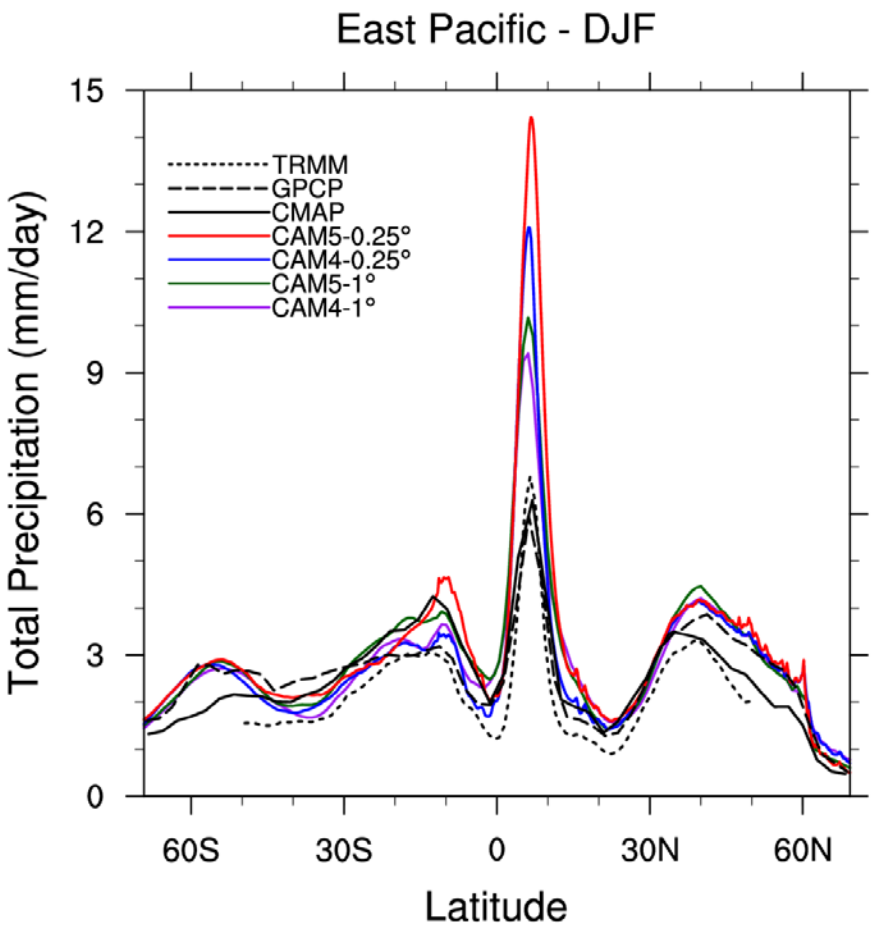


3-hourly mean precipitation from Feb 2002

CAM4 vs. CAM5 ITCZ

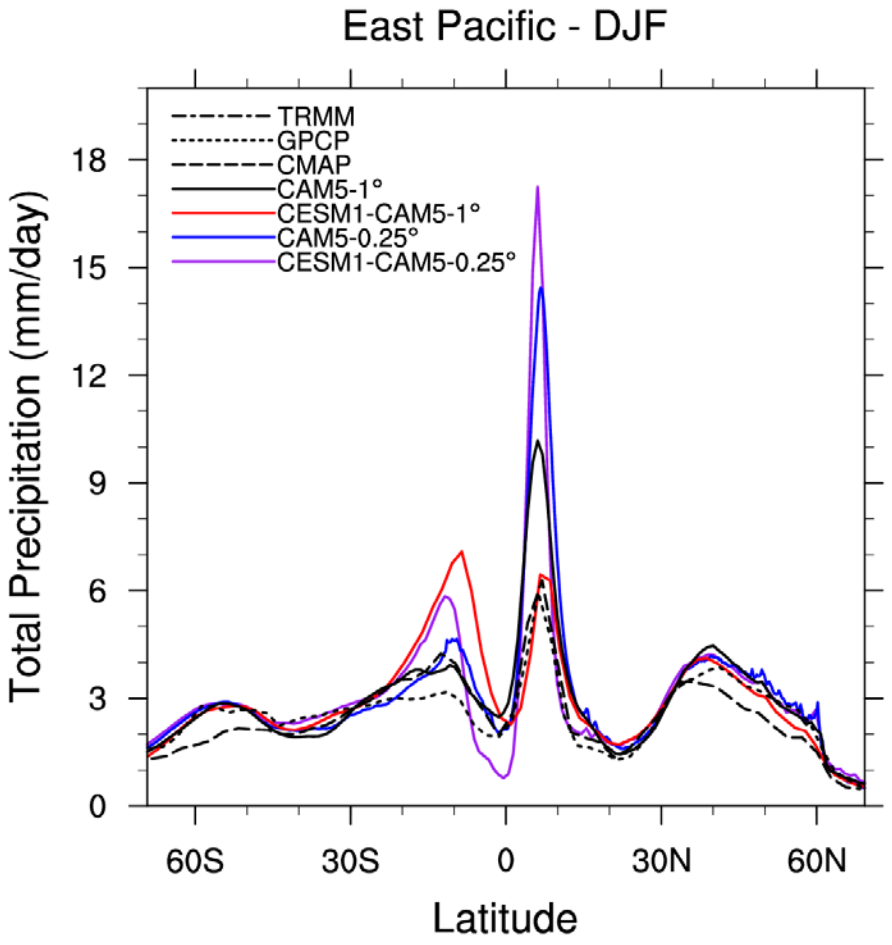
Model versions share many of the same problems

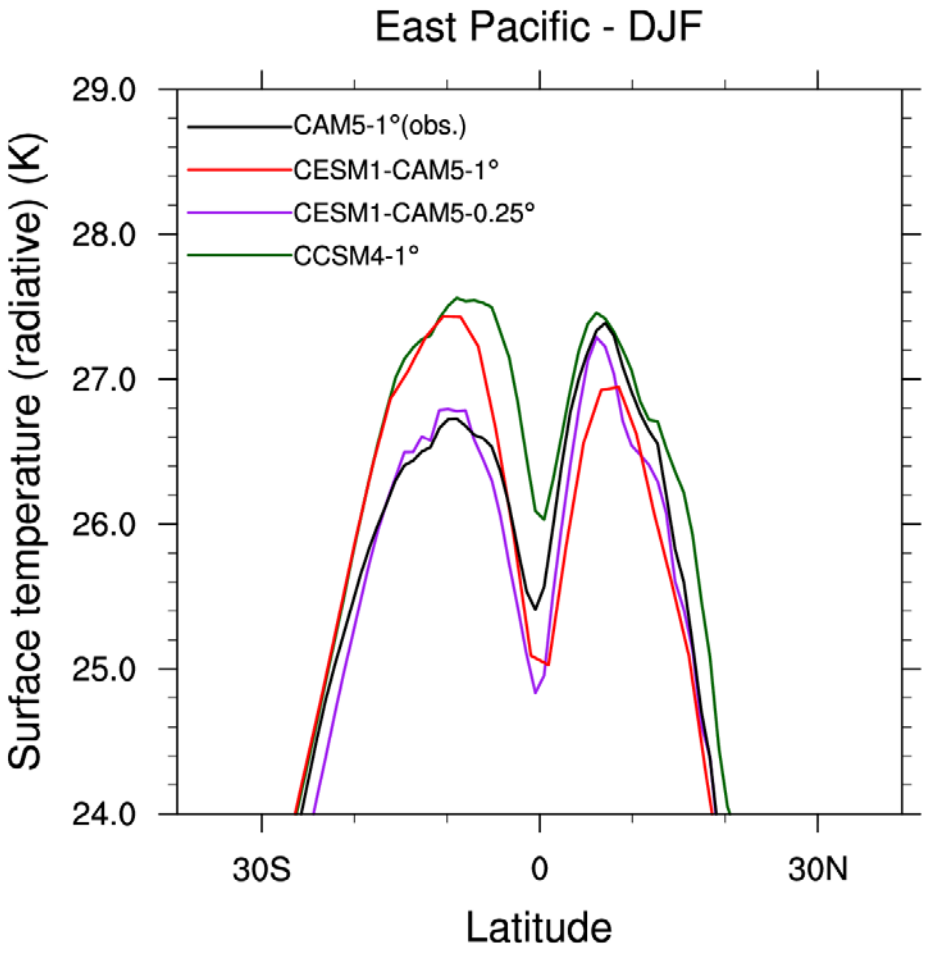




Coupled vs. uncoupled ITCZ

Coupling can worsen excess rainfall and introduces S. Hem ITCZ

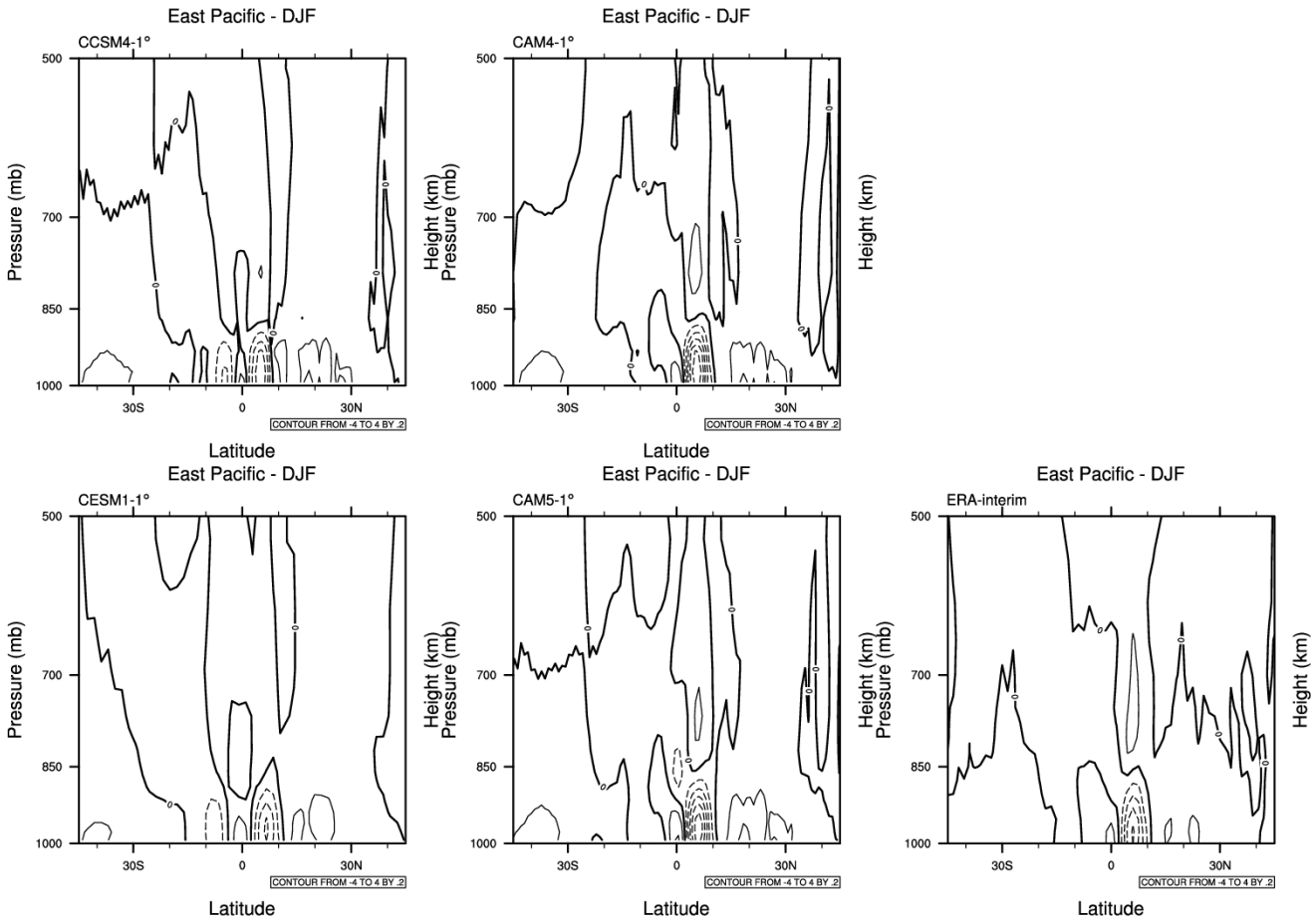




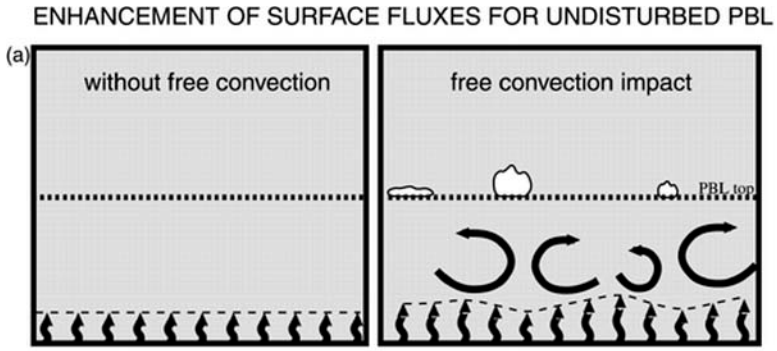
Coupled vs. uncoupled ITCZ

Local area of convergence of south of equator

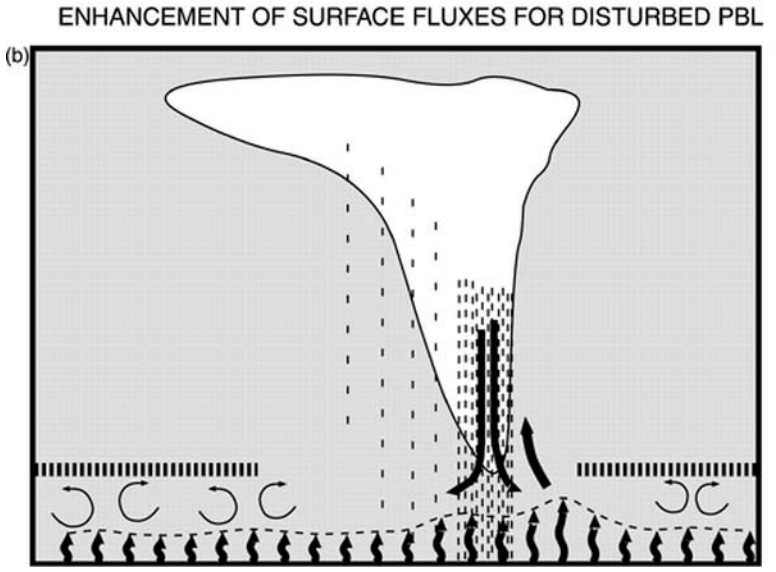
Divergence ($x10^{-5}$)



Surface fluxes in low wind conditions



- Parameterizing surface fluxes in low wind conditions can be problematic
- Model assumes free convection regimes give enhanced surface fluxes

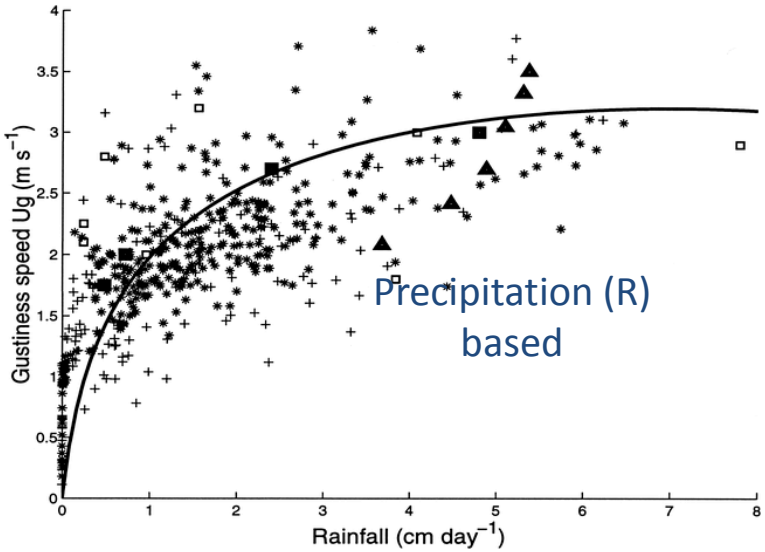


- Lowest mean surface winds are seen in the deep tropics
- Region of strongest deep convection
- Significant multidirectional wind gusts that average to near zero

Convective gustiness relationships

Redelsperger et al. (2000)

Based on CRM simulations of TOGA-COARE periods



$U_g = \log(1.0 + 6.69R - 0.476R^2)$

Added to Zhang McFarlane scheme

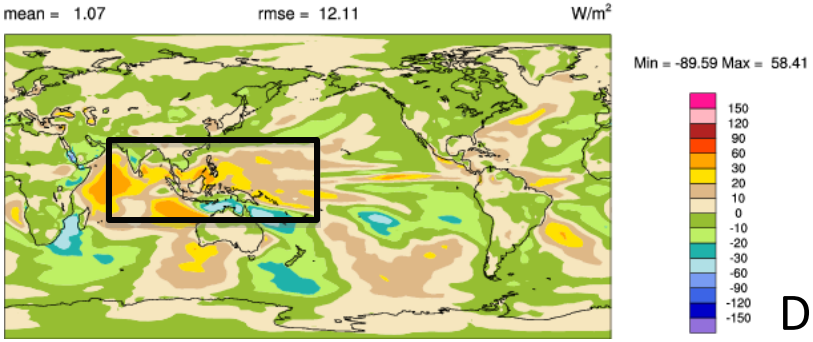
Add wind gust for purposes of surface latent heat flux only

$U^2 = U^2_0 + U^2_g$

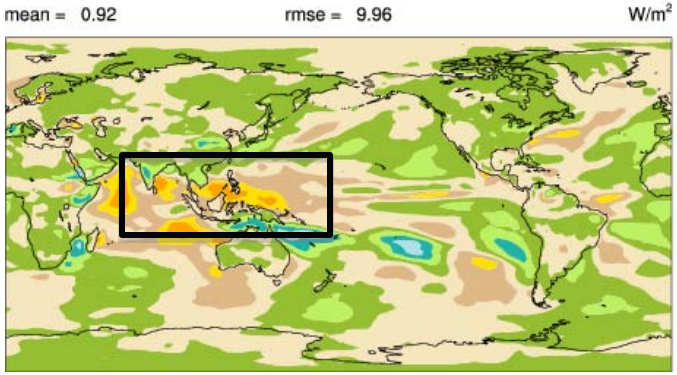
Latent Heat Flux Changes

Differences with convective enhancement of surface fluxes (5-yr runs)

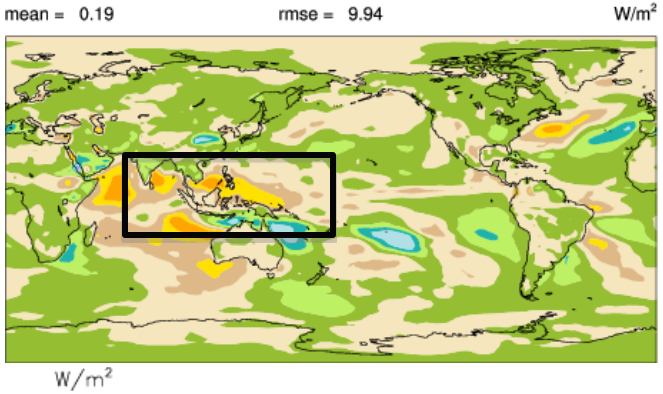
Precipitation based



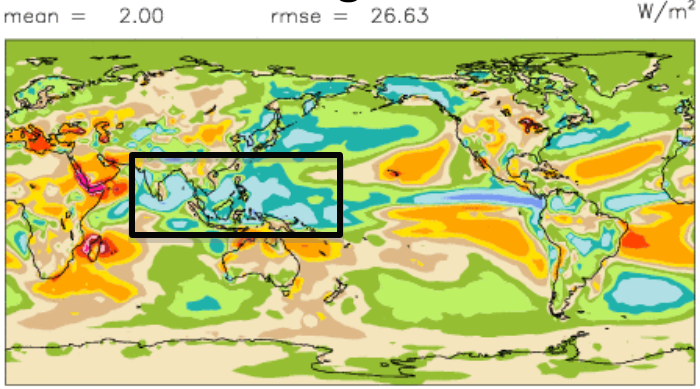
Updraft based



Downdraft based

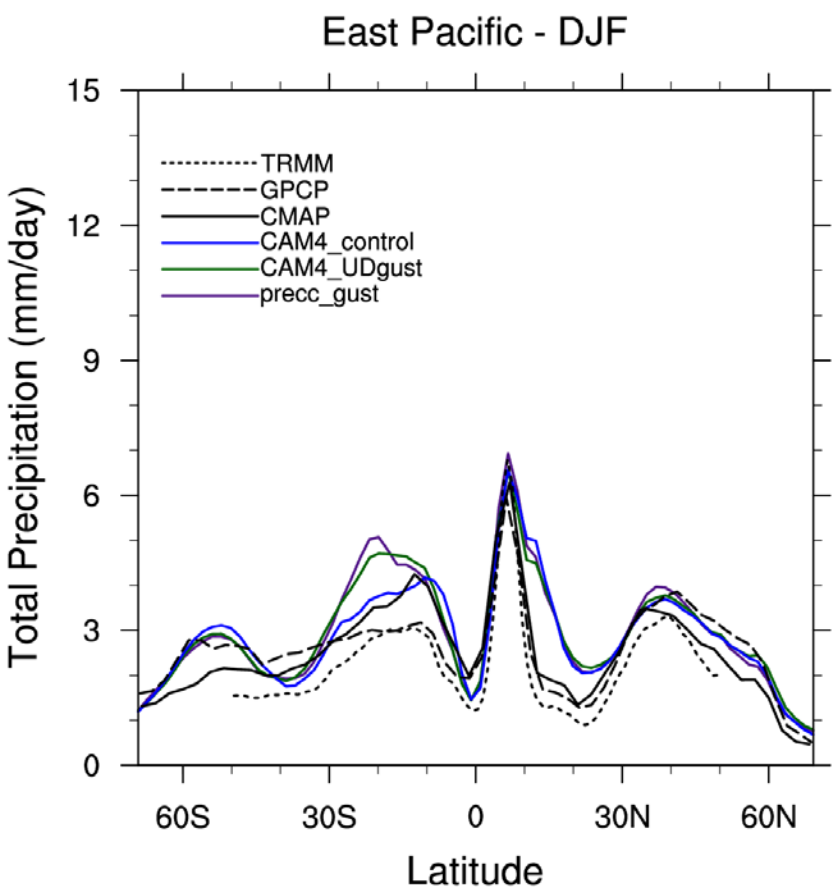


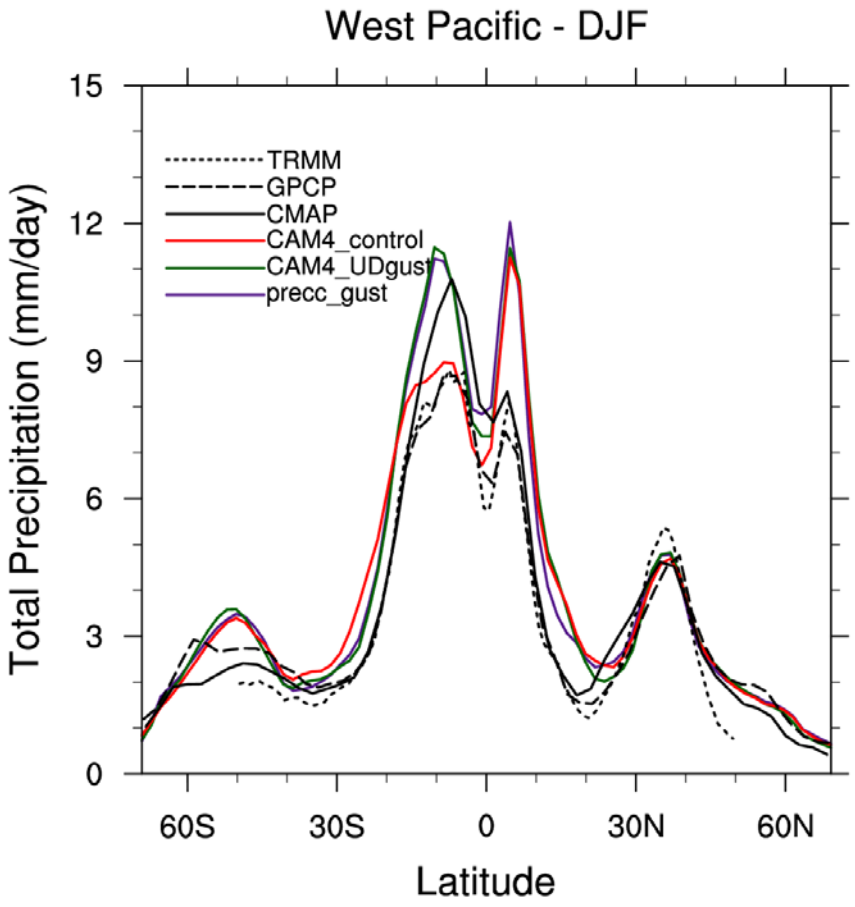
Existing error



Convective Gustiness

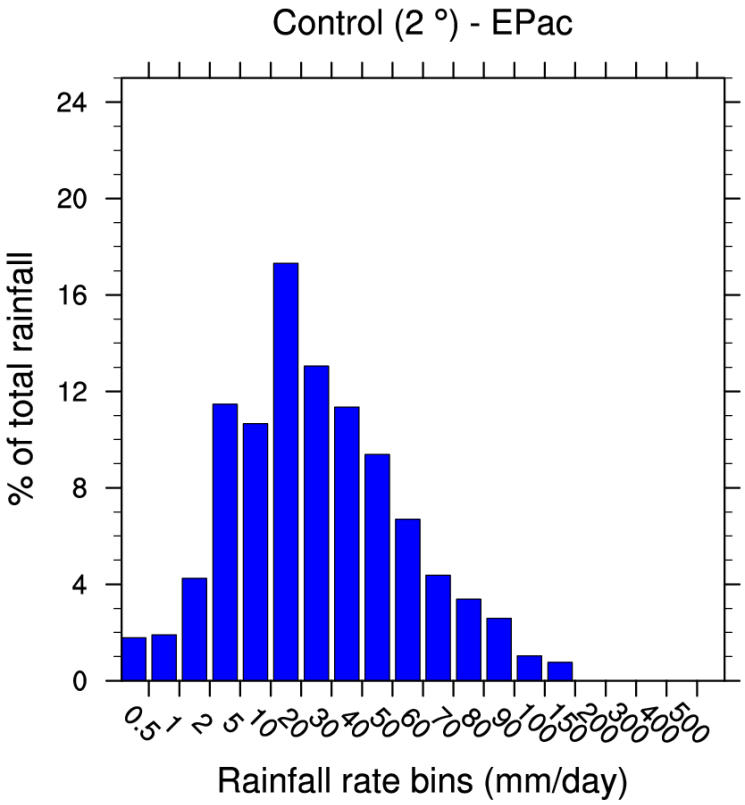
Impact minimal in E Pacific. Greater in W Pacific.

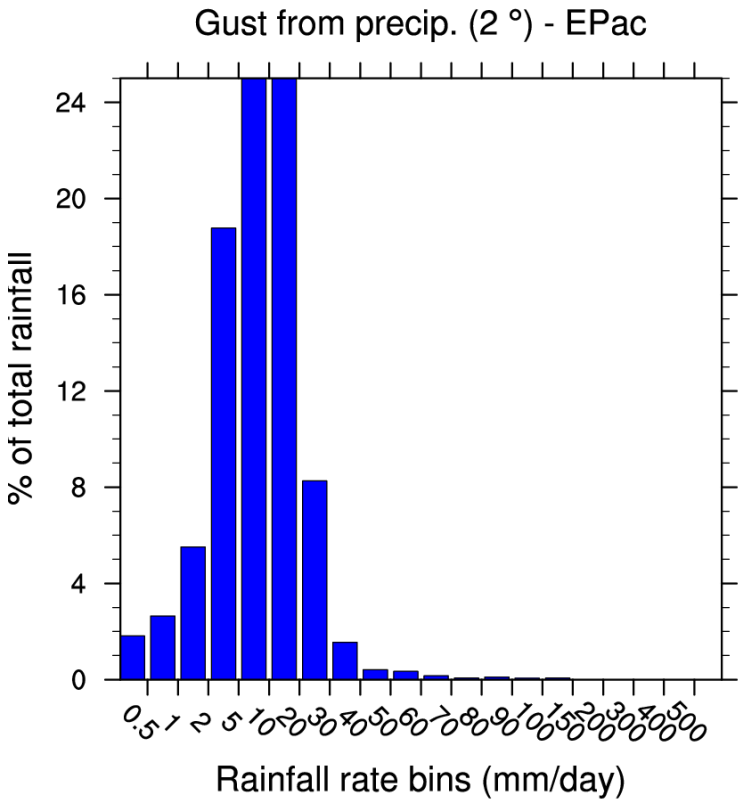




Convective Gustiness

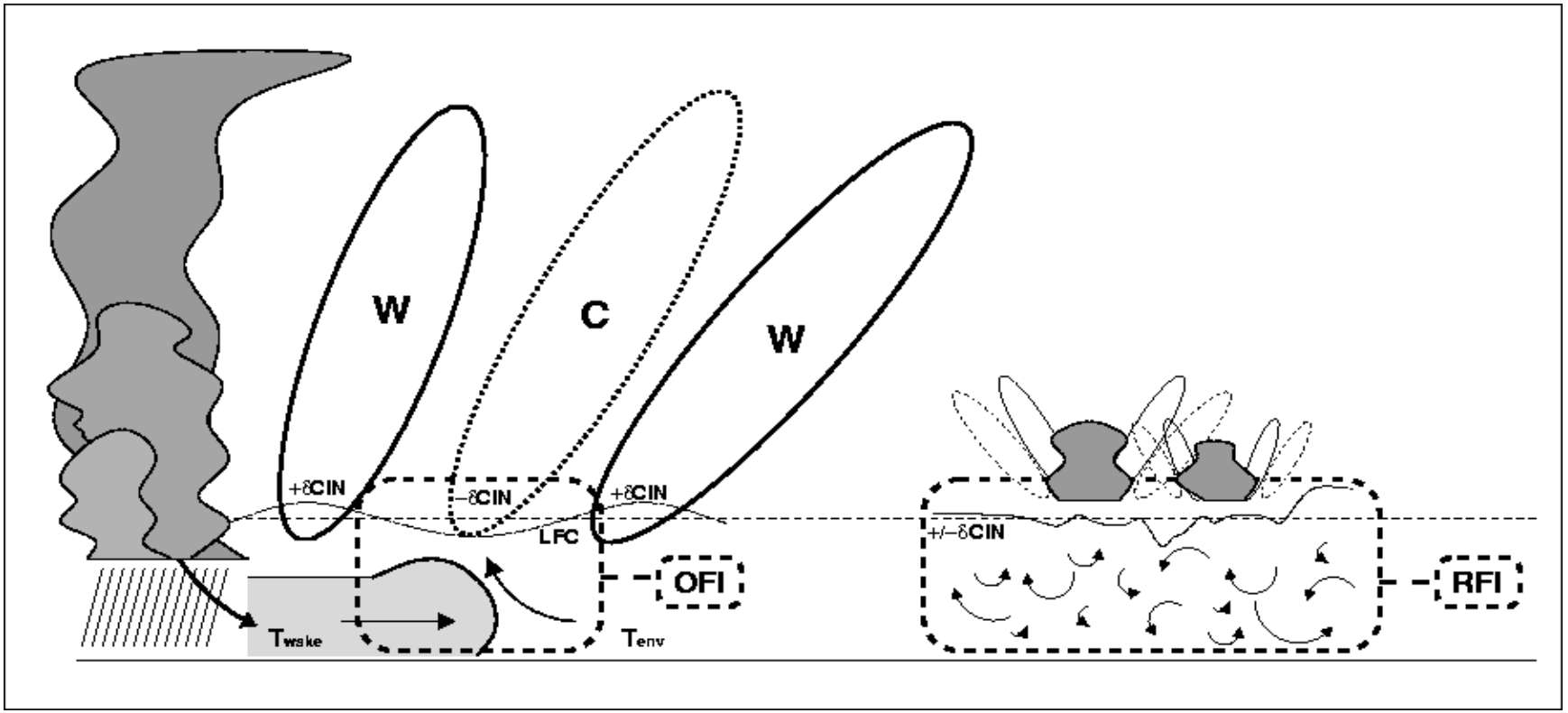
Impact was too much rain from low rainfall events





Organization Enhancement of Deep Convection

Representation of convective organization adds to existing convection



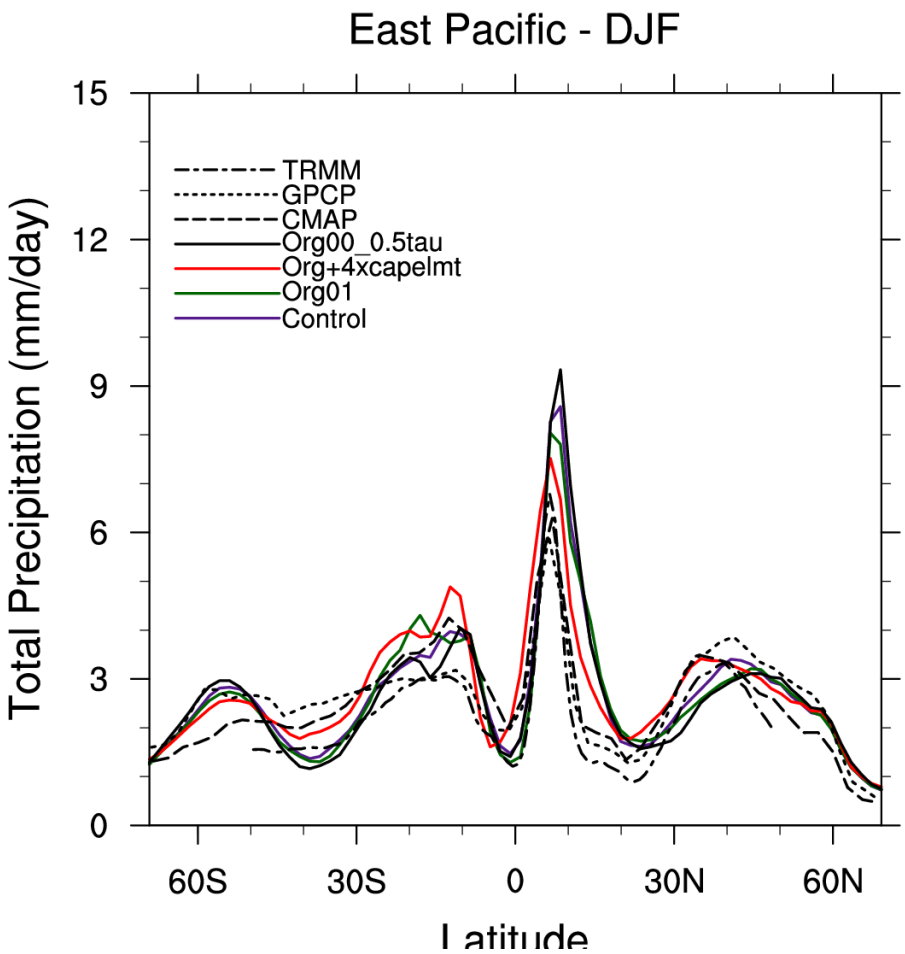
OFI – Organized Fluctuation Intensity

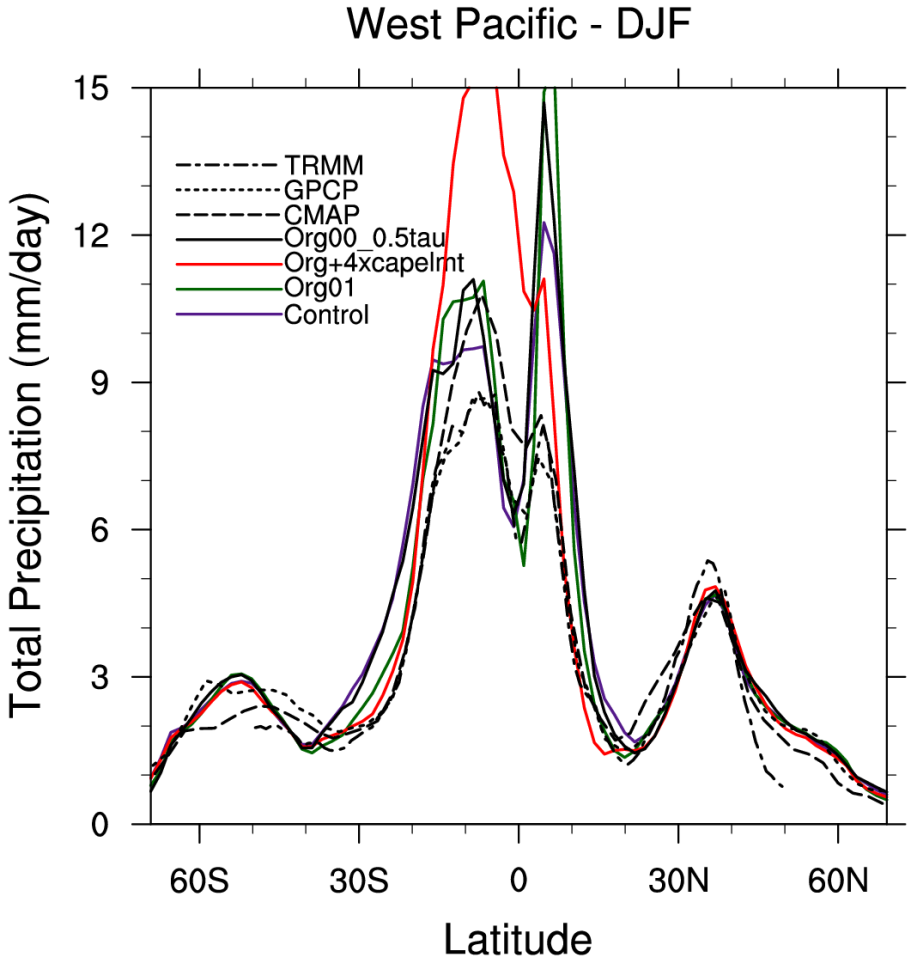
RFI – Random Fluctuation Intensity

Added to Zhang McFarlane scheme

Convective Organization

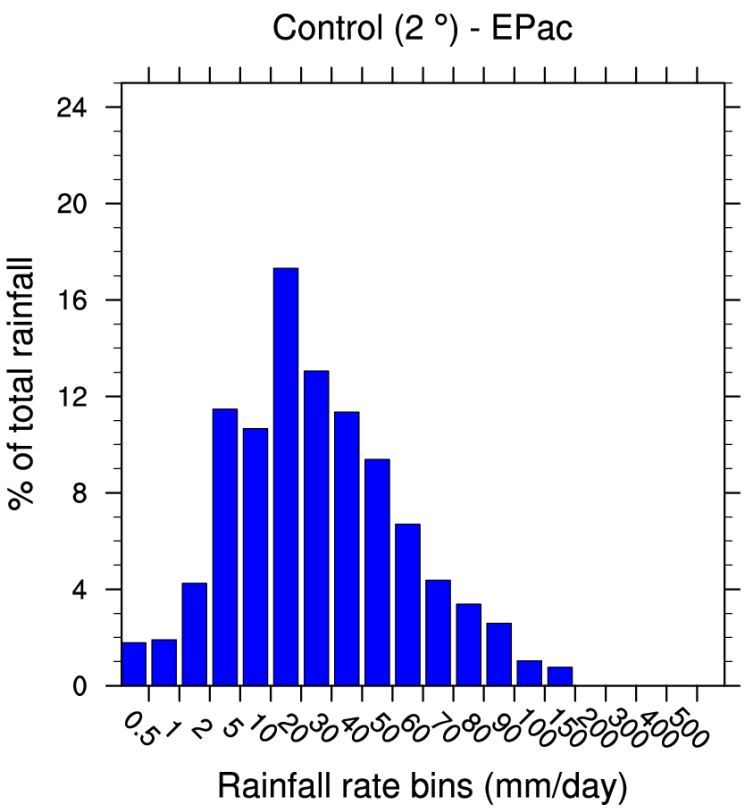
4Capelmt case reduces rainfall in E Pac. But large increase in W. Pacific

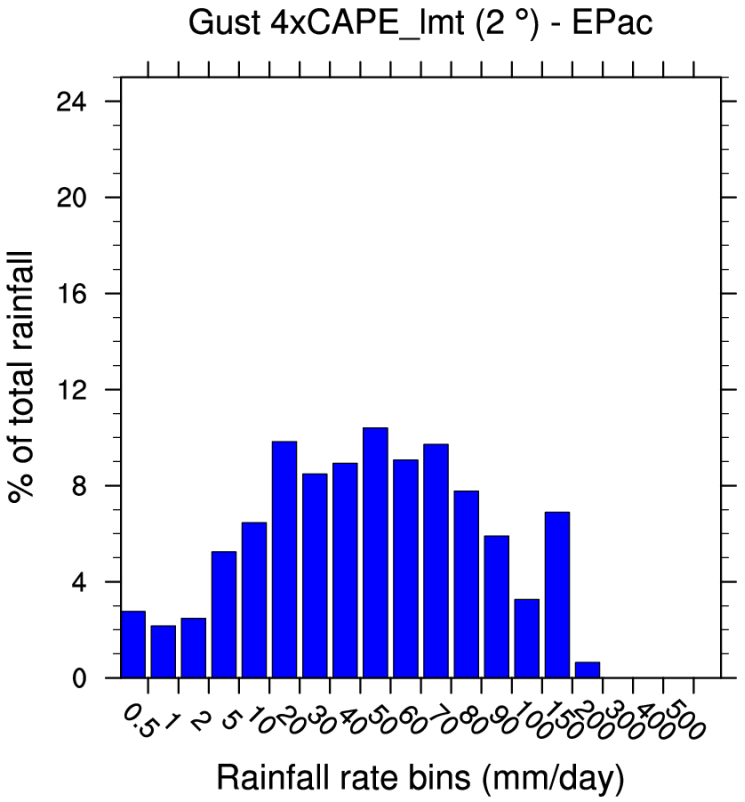




Convective Gustiness

Greater contribution from strong rainfal events





Summary

- ✓ITCZ (strength+position) has a significant dependency on resolution in CAM4
- ✓In E. Pacific higher resolution simulations significantly over-estimate rainfall
- ✓Low resolution CAM4: too much rainfall from weak events
- ✓High resolution CAM4: improved, but still too much rainfall from weak events
- ✓CAM5 does not see a signficant (any?) improvement from CAM4
- ✓Coupling leads to a S. Hem rainfall maximum and excessive equatorial upwelling
- ✓Position of E. Pacific ITCZ more robust than in W. Pacific
- ✓Strong balance between convective heating, divergence and vertical velocity
- ✓Sensitivity to convection changes: Resistant in E. Pacific sensitive in W. Pacific
- ✓Not shown, but timestep and dy-core choices also affect nature of ITCZ

Thanks !