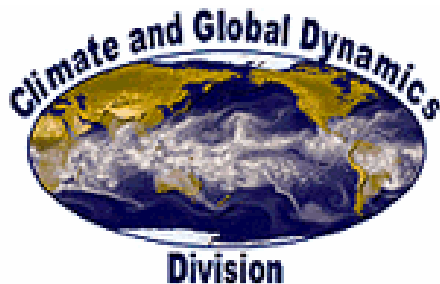


# CAM3.5 Model Changes

**Rich Neale**

***CCSM Workshop  
AMWG Session  
June 2007***



# Modifications CAM3->CAM3.5

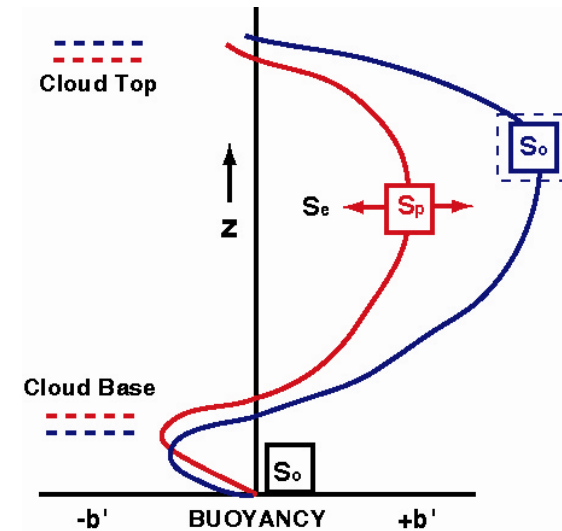
- **Deep Convection**
  - Convective momentum transports (Richter)
  - Dilute instead of undilute plume calculation (Neale)
- **Cloud Fraction**
  - Polar cloud freeze-drying (Vavrus)
  - Calculation update (Park)
- **Land Model Changes**
  - New hydrology, surface datasets, canopy integration
- **Other Changes**
  - New chemistry modules (GHGs, aerosols)

# Deep Convection Changes

Zhang-McFarlane Scheme (1995)

## 1. Change from an Undilute to a Dilute Reference Parcel (DIL, Raymond and Blythe, 1986)

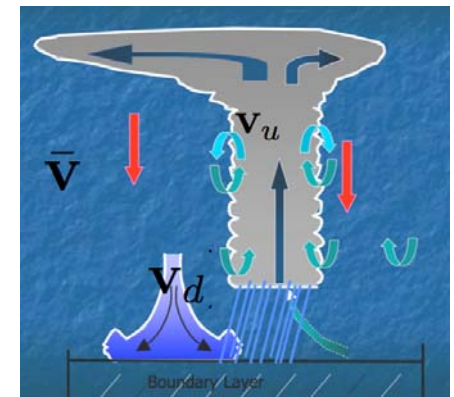
- Improve diurnal cycle over land
- Sensitivity to tropospheric drying



## 2. Introduction of Convective Momentum Transports (CMT, Gregory et al. 1997)

- Include a *missing* process
- Decrease excessive surface trades
- Couple convection and dynamics

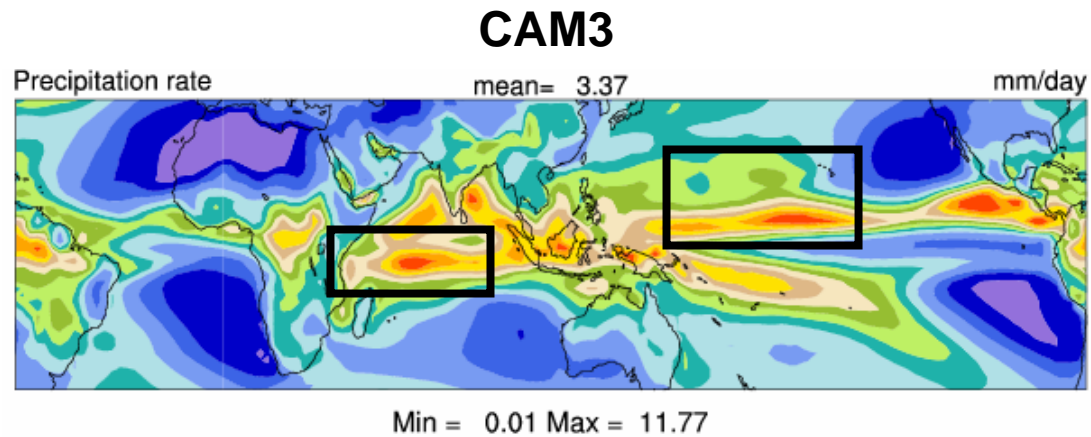
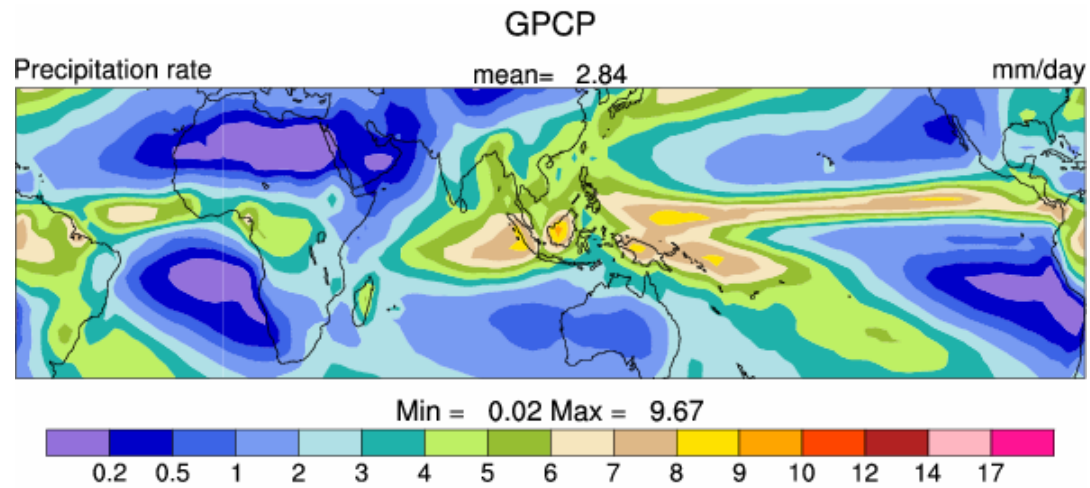
$$d\mathbf{u}/dt = \dots + d[\mathbf{u}'w']/dz$$
$$(dq/dt = \dots + d[q'w']/dz)$$



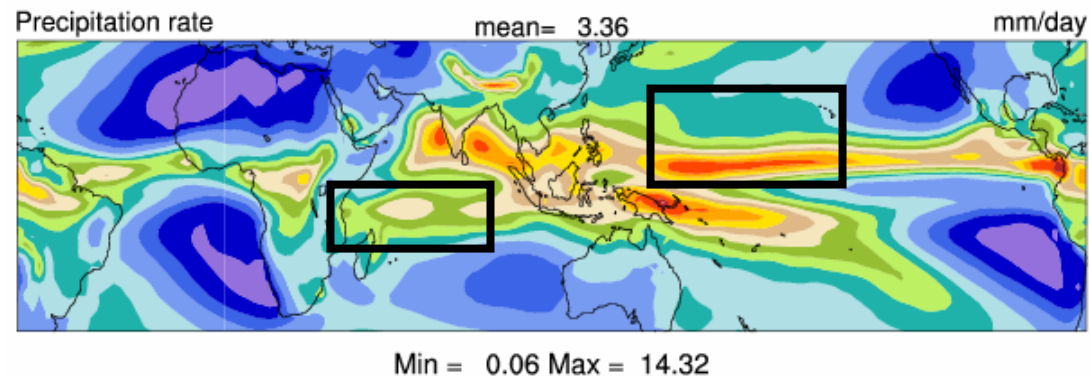
# CAM3.5 Convection Changes Summary

- AMIP-type experiments (1979-2000)
- FV 1.9x2.5 deg / 26 levels

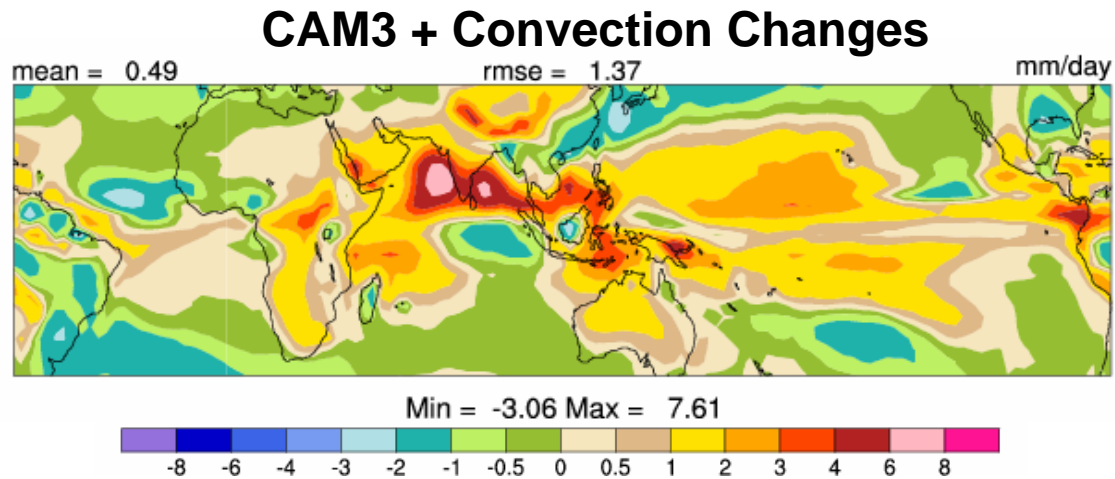
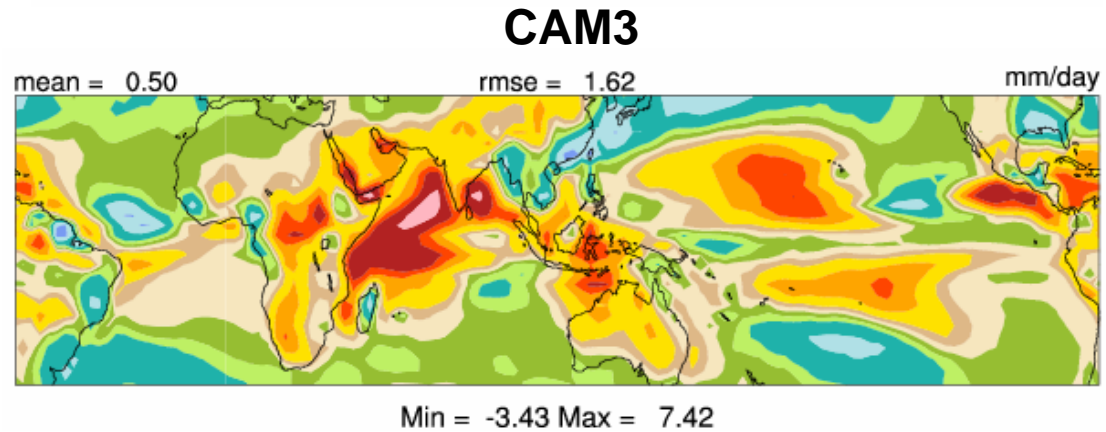
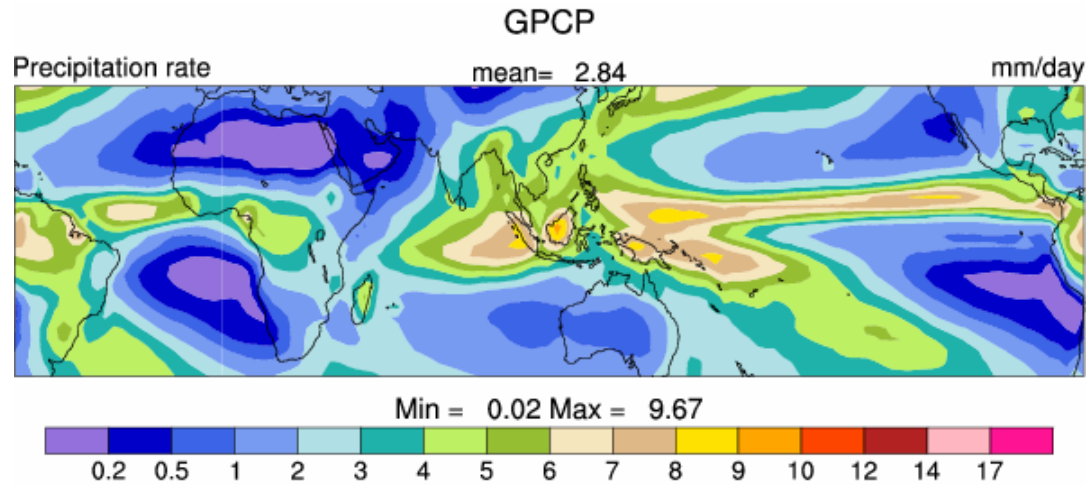
# Annual Rainfall



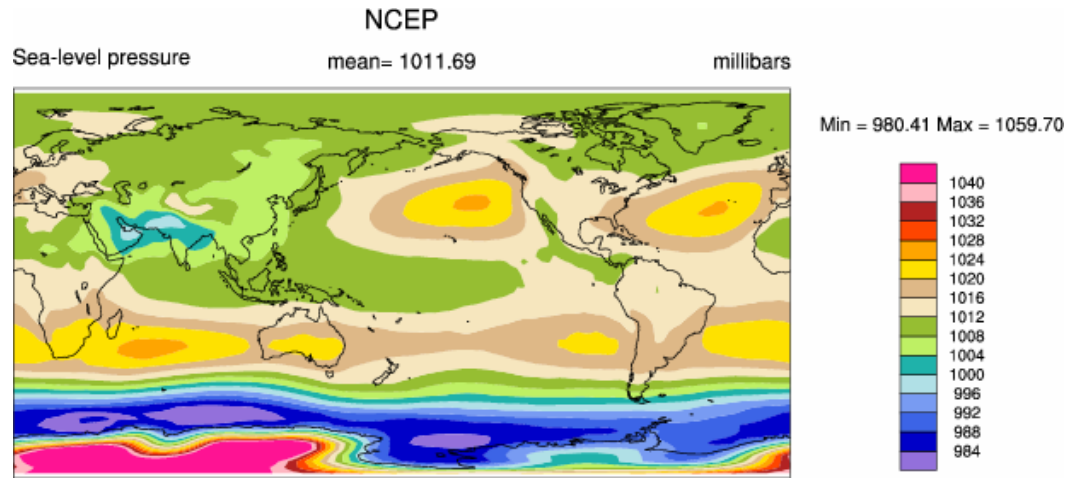
## CAM3 + convection changes



# Annual Rainfall Error

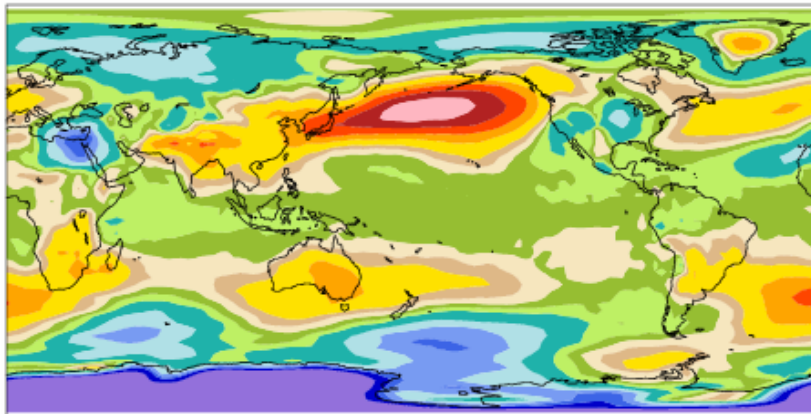


# JJA MSLP Errors



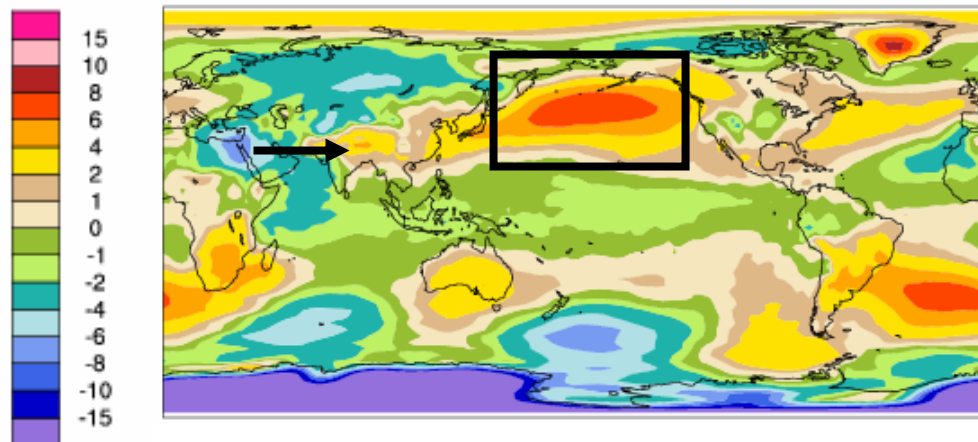
## CAM3

mean = -0.46 rmse = 5.13 millibars

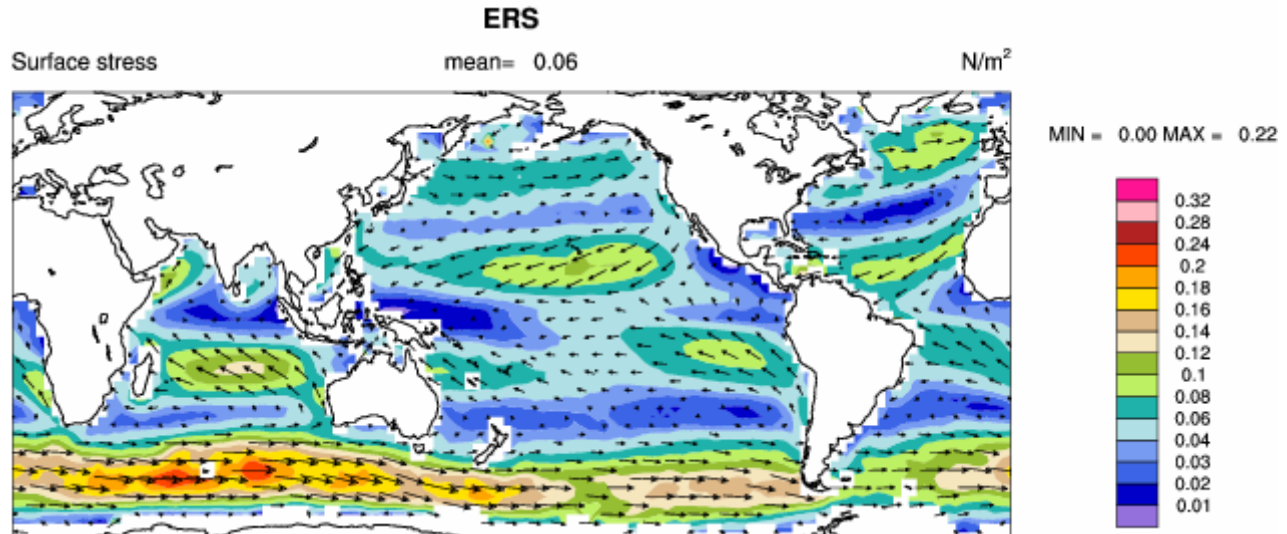


## CAM3 + Convection Changes

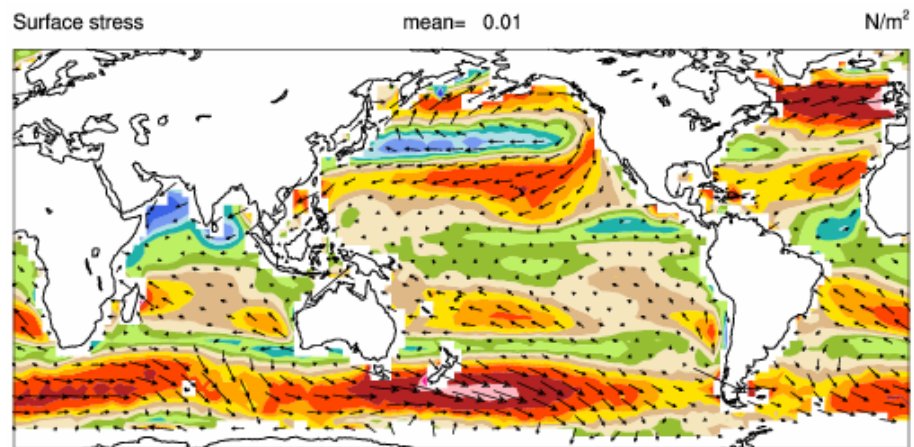
mean = -0.34 rmse = 4.81 millibars



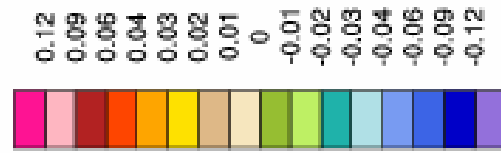
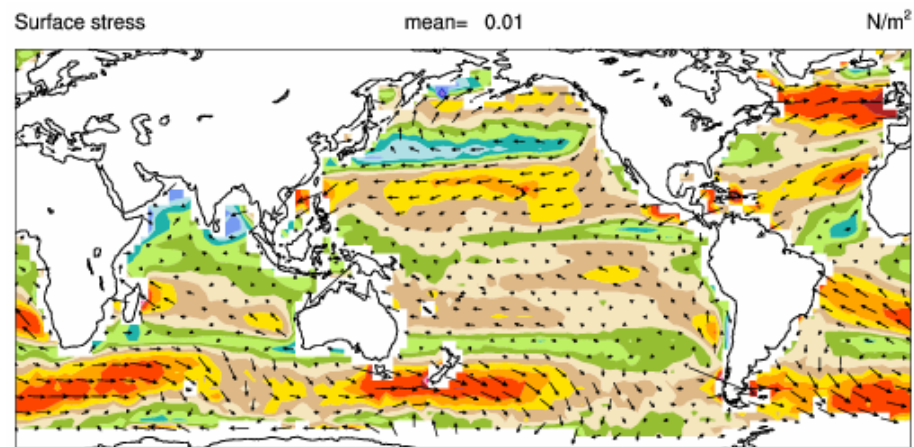
# Annual Surface Stress Error



## CAM3



## CAM3 + Convection Changes

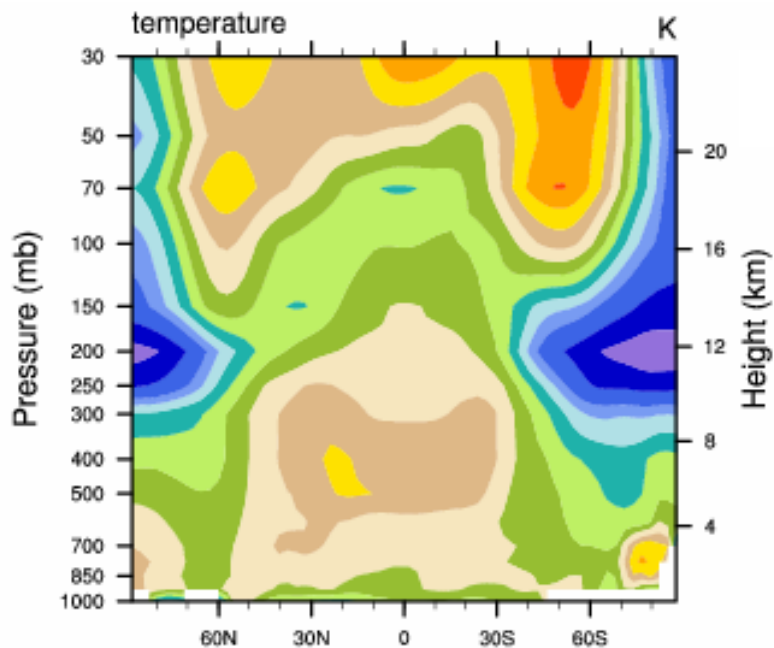




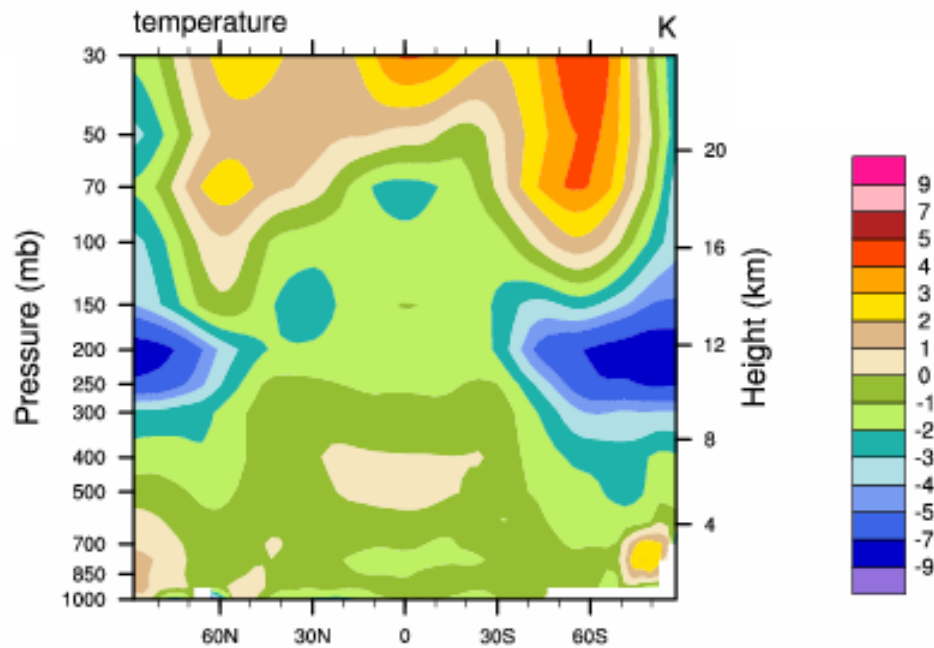
# Temperature Errors

## Warm to Cold Bias (de-stabilization)

**CAM3**



**CAM3 + Convection Changes**

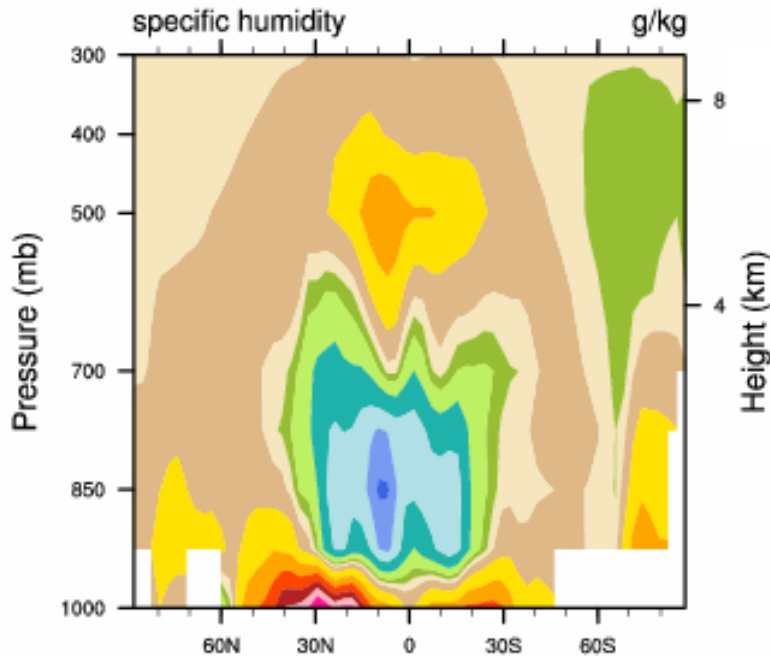


**Annual Means**  
**(ECMWF)**

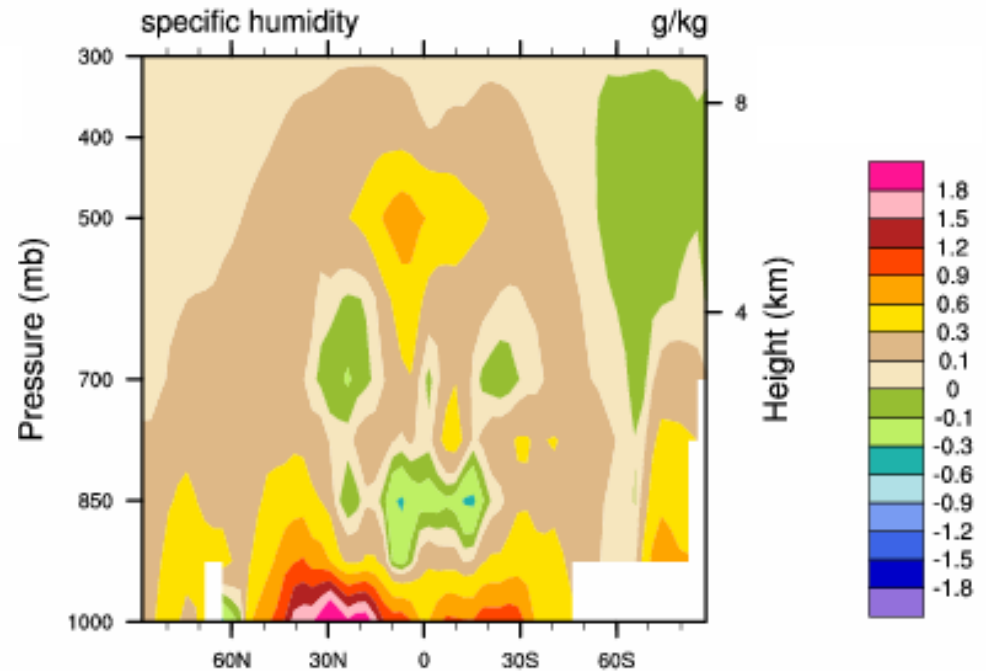
# Humidity Errors

## Moister lower troposphere

**CAM3**



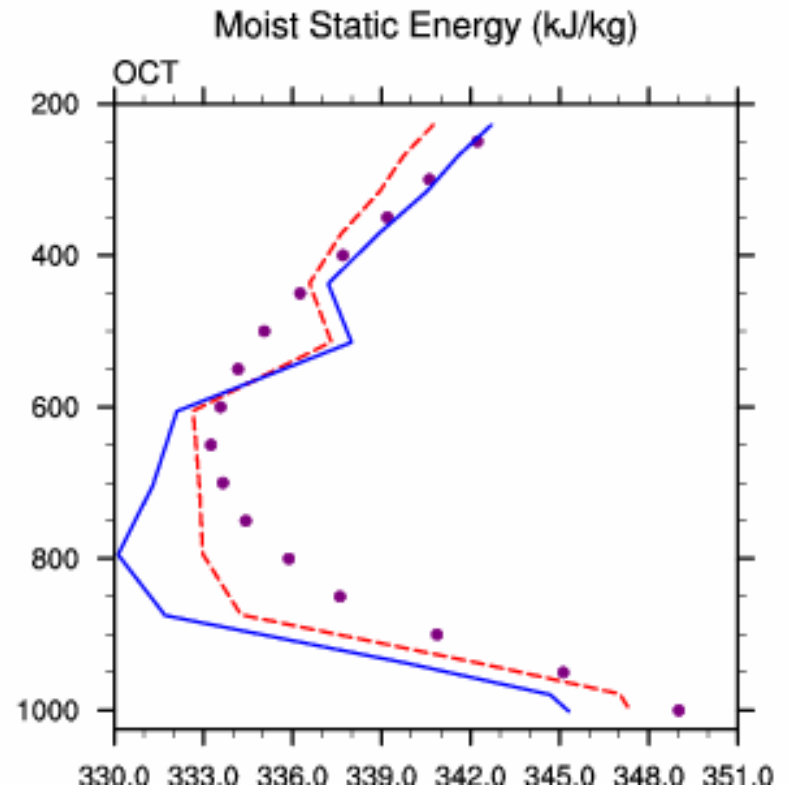
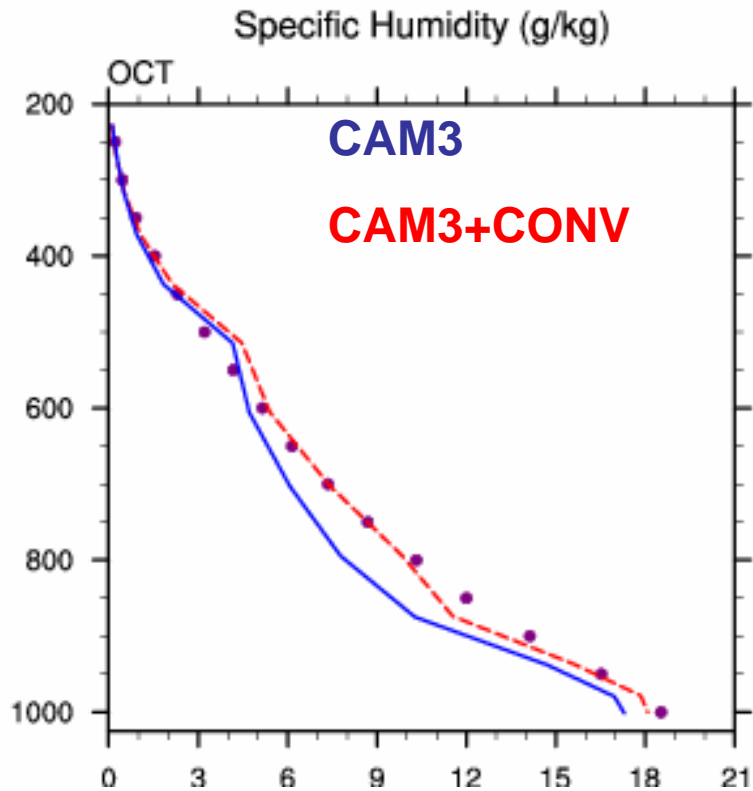
**CAM3 + Convection Changes**



**Annual Means  
(ECMWF)**

# Vertical Humidity Distributions

## Truk Island (W Pacific)

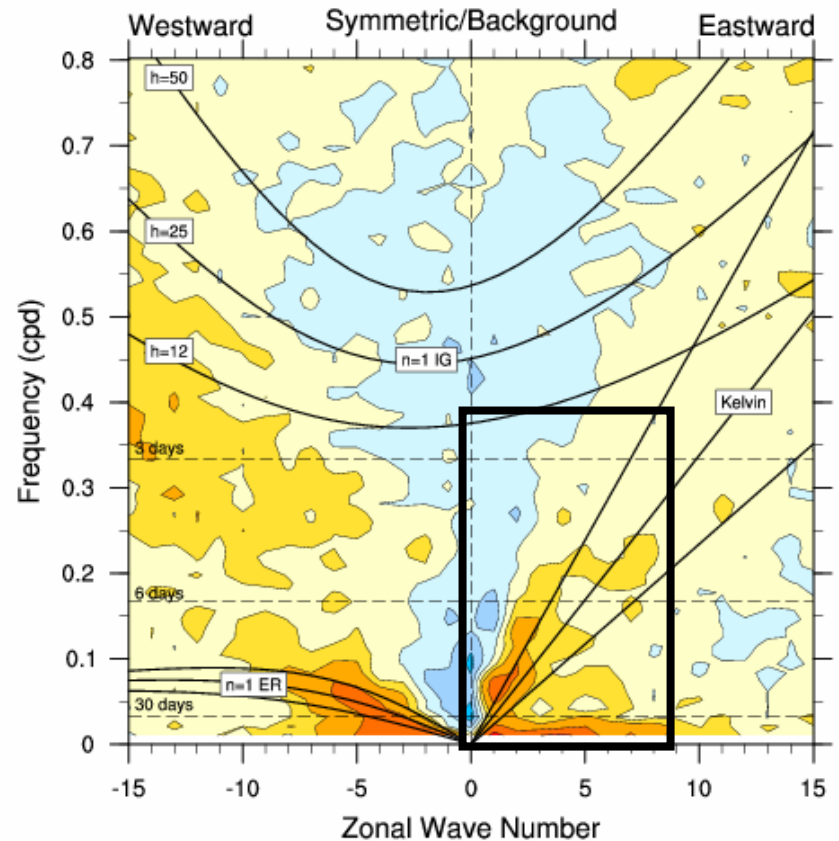
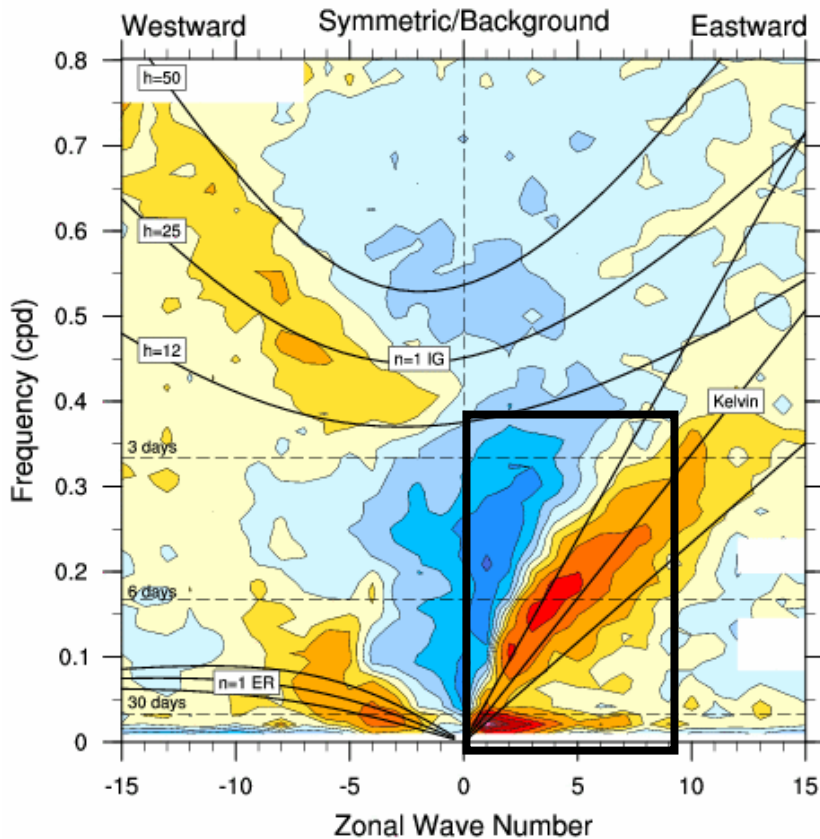


# Intra-Seasonal Variance

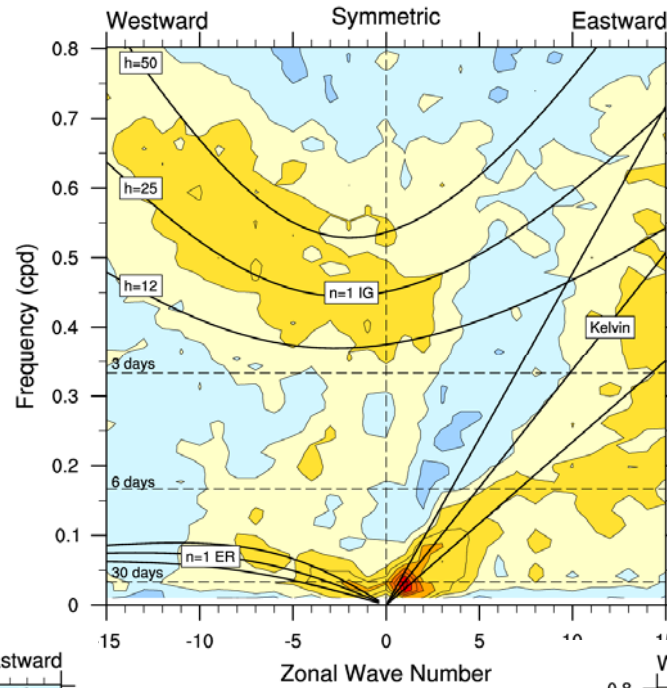
Madden Julian Oscillation (MJO) and Kelvin Waves Deficient  
OLR (15N-15S)

**Observed (NOAA)**

**CAM3**

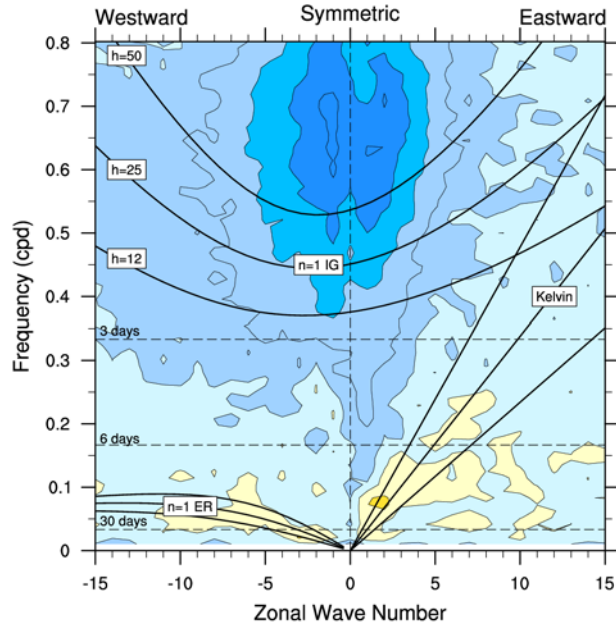


# Intra-Seasonal Variance Improvements



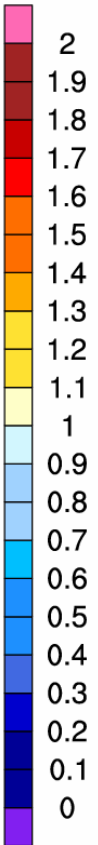
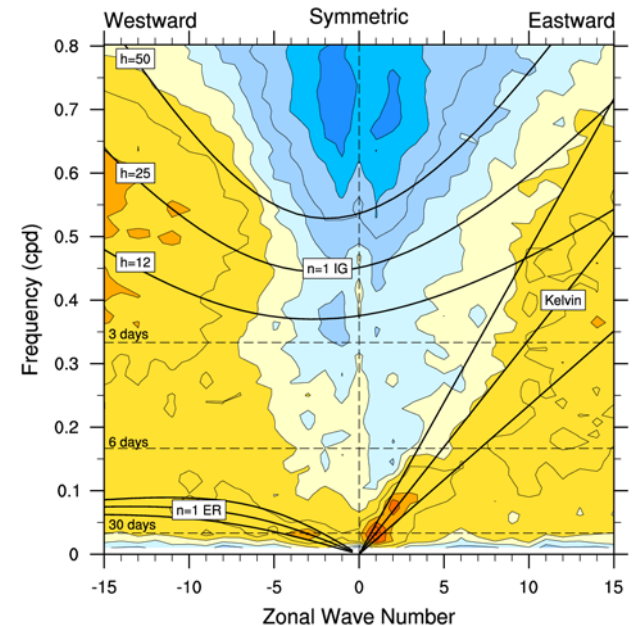
**CAM3+CMT**

**CAM3**



**CAM3+DIL**

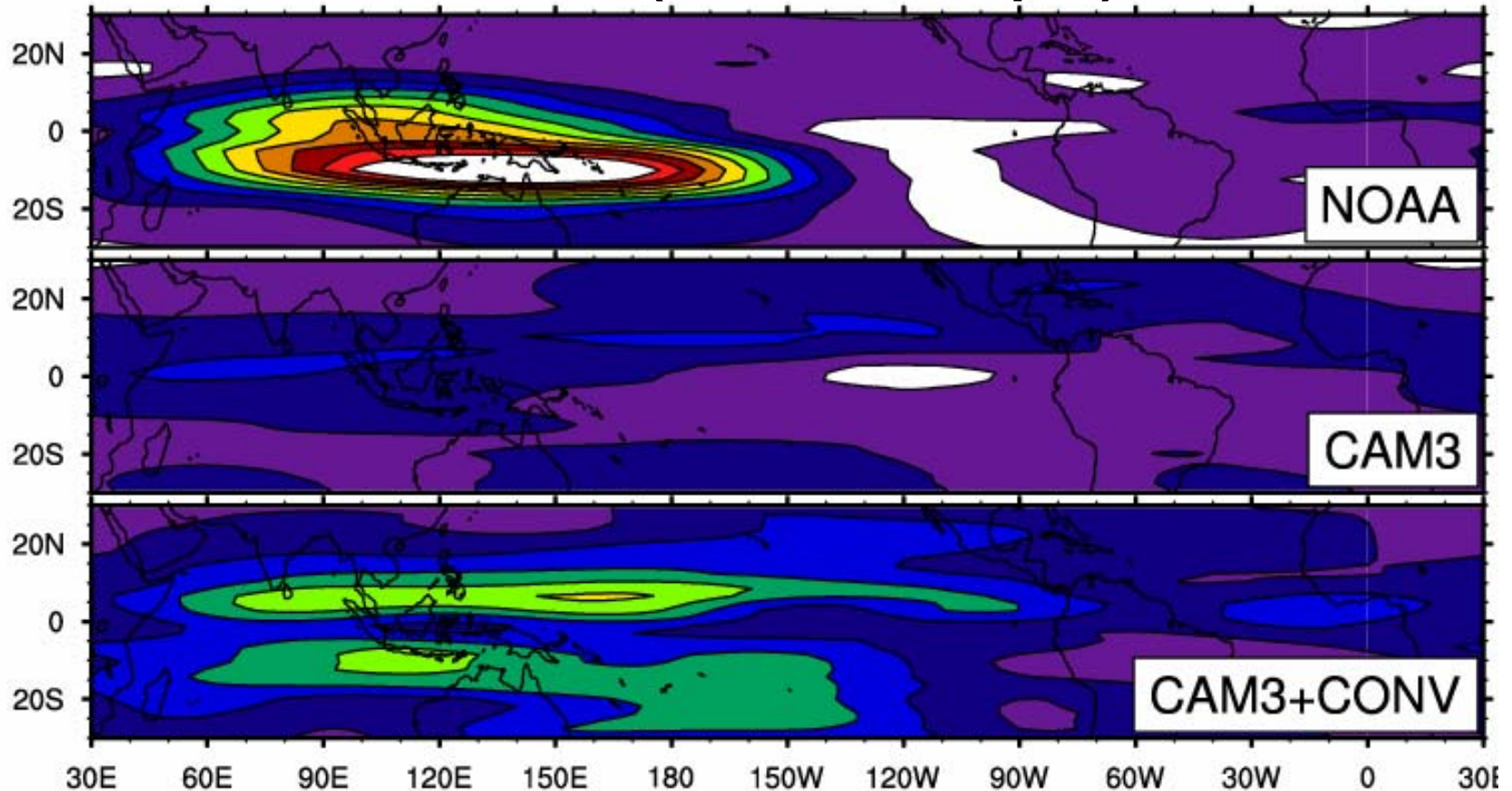
**CAM3**



# MJO Variance

OLR filtered for MJO wavenumbers (1-5) and periods (30-90days)

Winter (November-April)

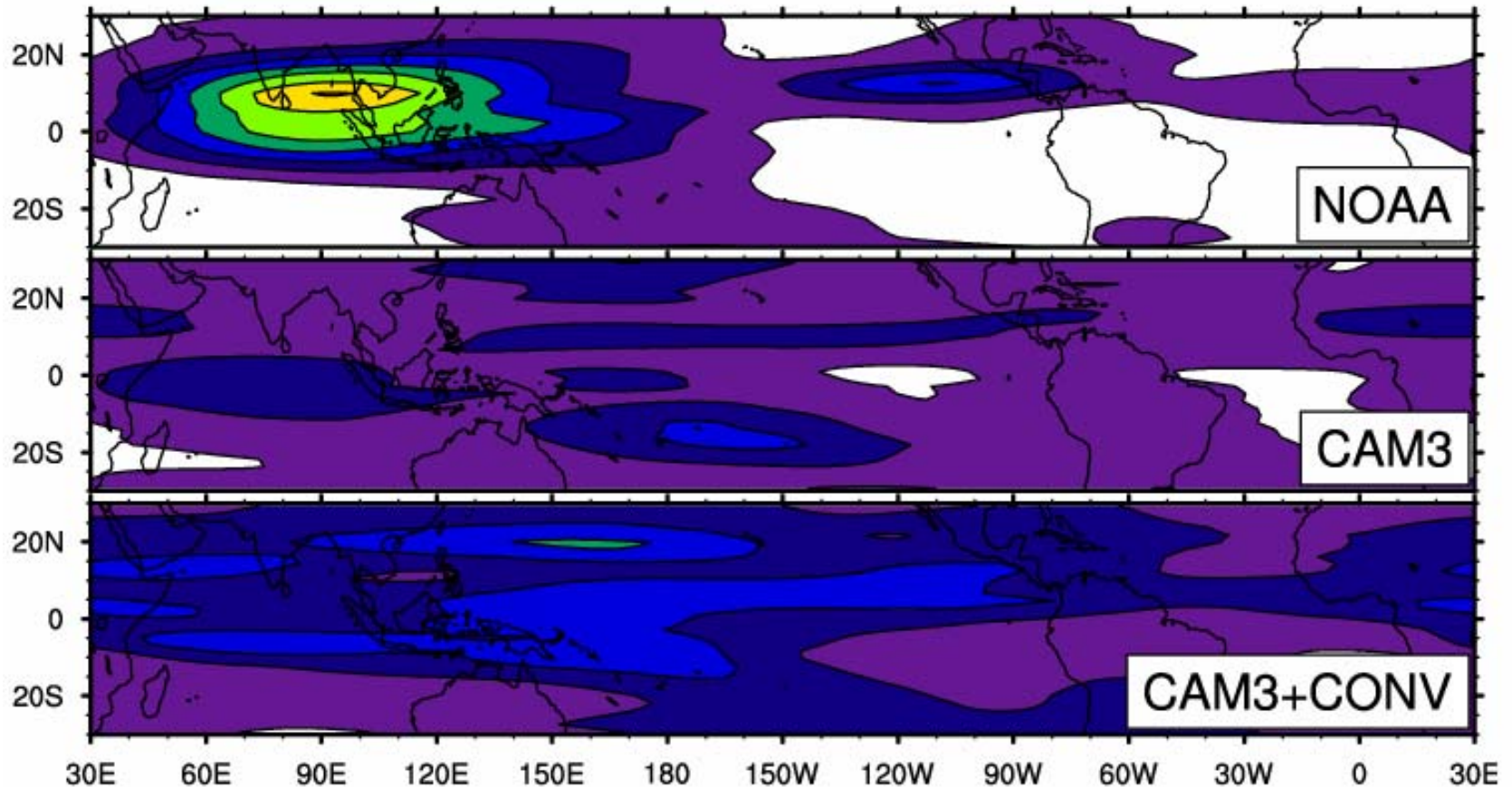


*Contour interval 20 (W/m<sup>2</sup>)<sup>2</sup>*

# MJO Variance

OLR filtered for MJO wavenumbers (1-5) and periods (30-90days)

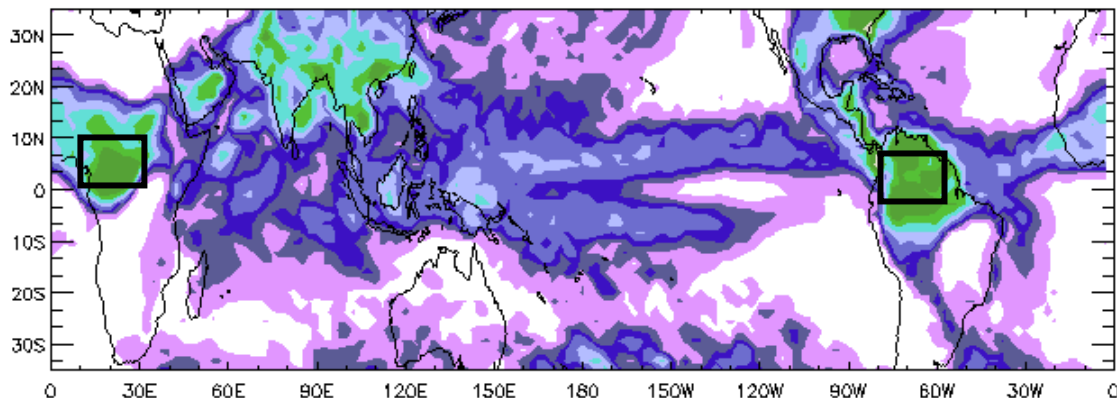
Summer (May-October)



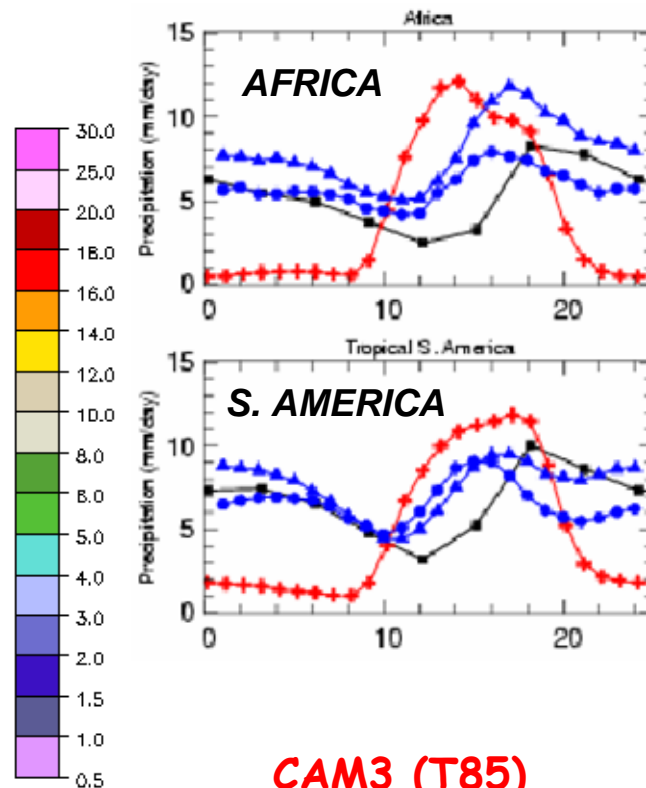
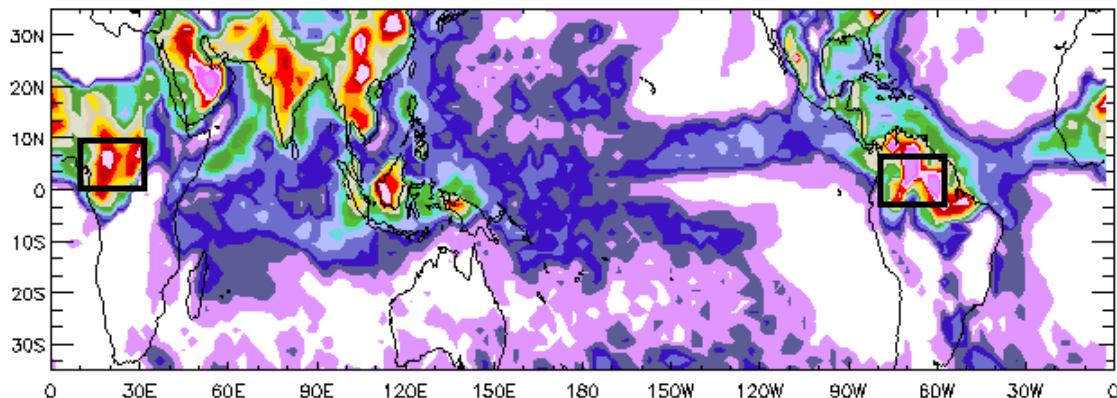
*Contour interval 20 (W/m<sup>2</sup>)<sup>2</sup>*

# Amplitude of Diurnal Cycle (mm/day) (JJA 1984)

## CAM3 + Convection Changes



## CAM3



CAM3 (T85)

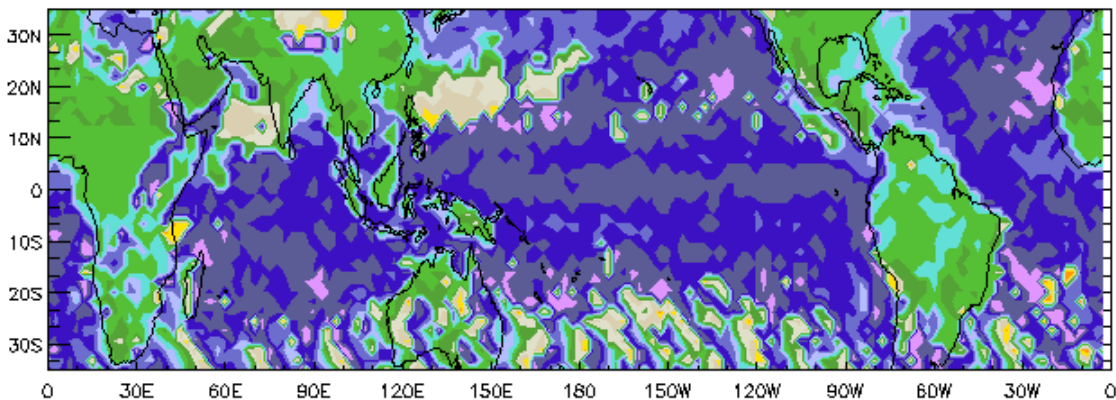
3B42 TRMM

TMI/PR

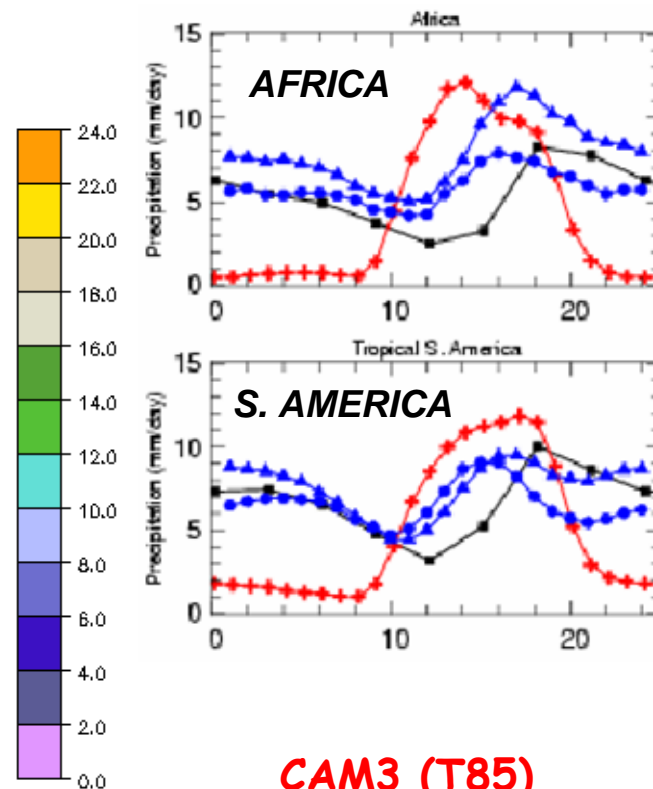
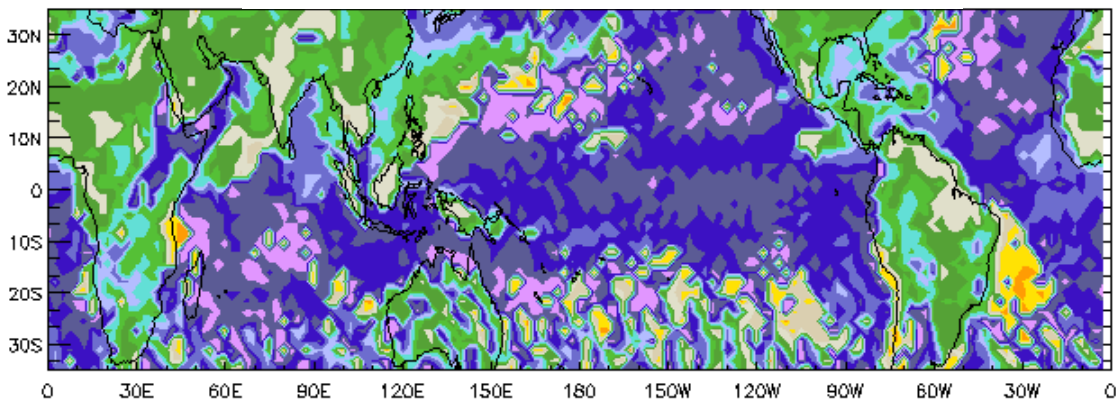


# Local Time of Daily Rainfall Max

## CAM3 + Convection Changes



## CAM3



**CAM3 (T85)**

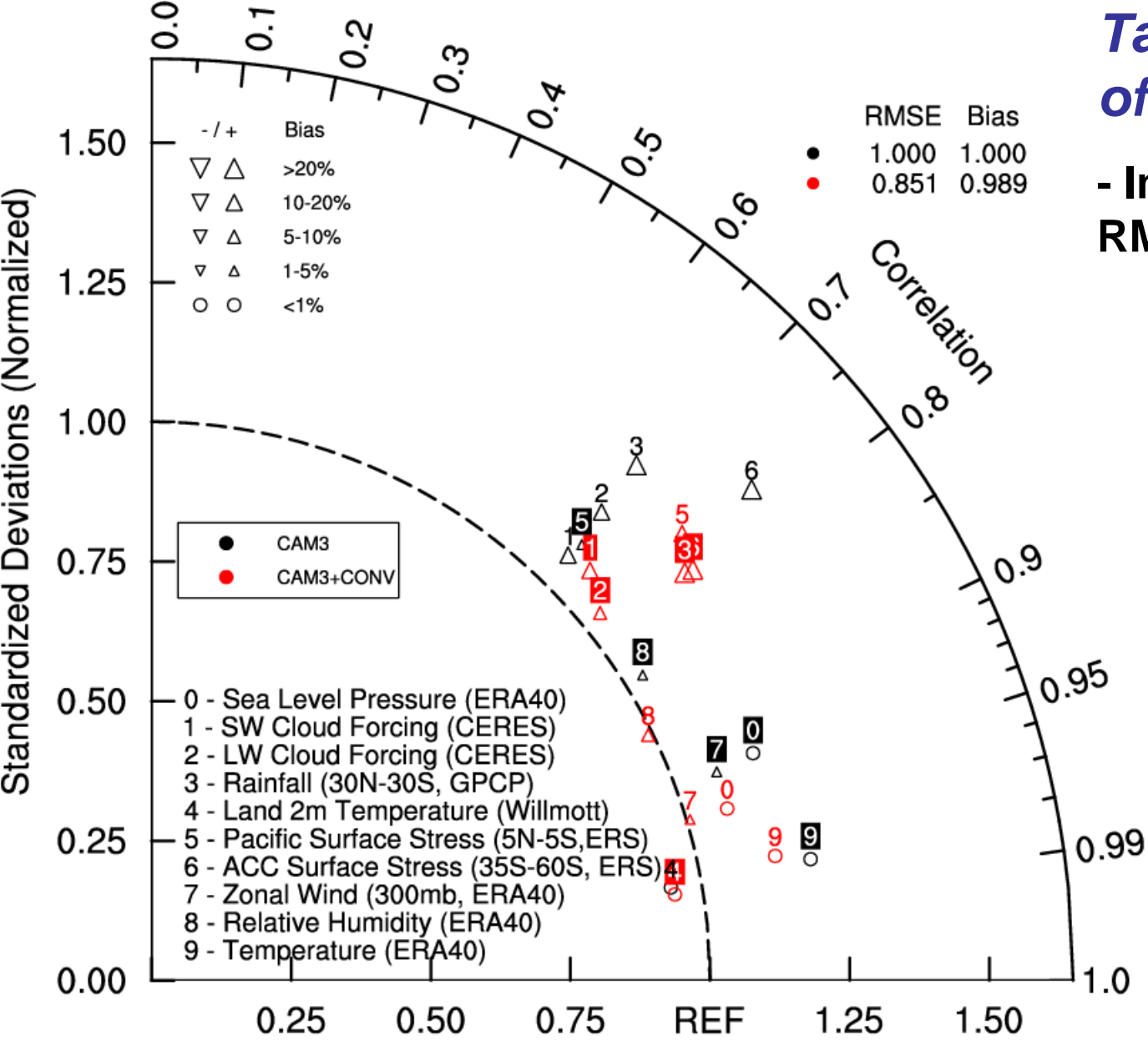
**3B42 TRMM**

**TMI/PR**

# Taylor Diagram of Key Metrics

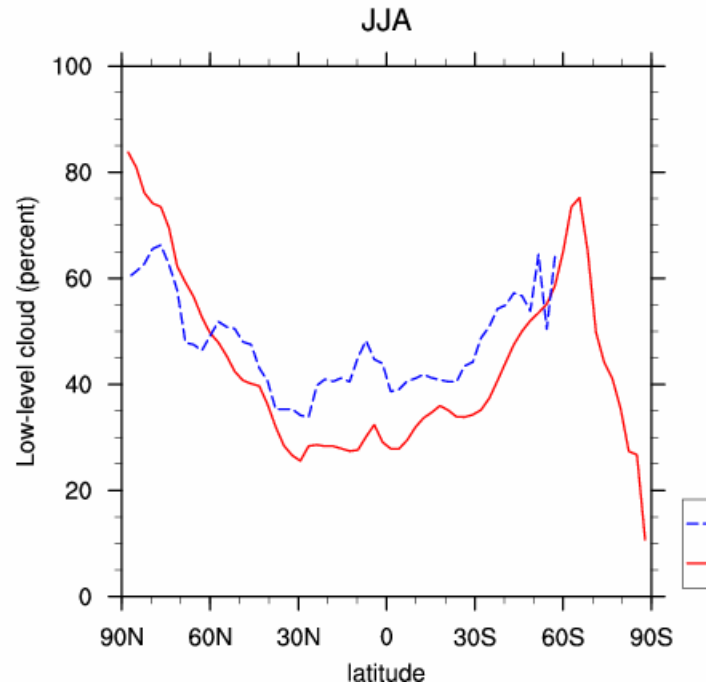
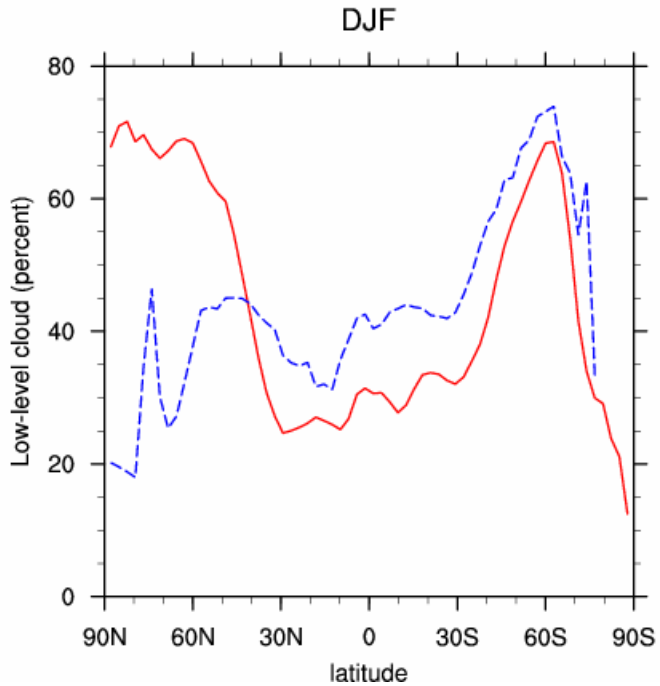
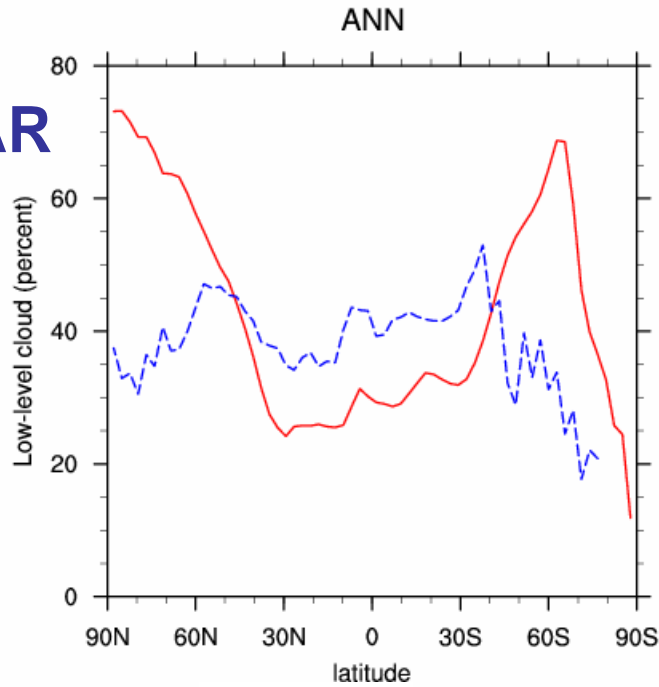
- Improved mean RMSE by 15%

Annual Cycle of Monthly Means



# EXCESSIVE POLAR LOW CLOUD AMOUNT

*Warren Obs.*  
**CAM3**



# Freeze Drying (Steve Vavrus)

- Cloud Fraction – CAM3

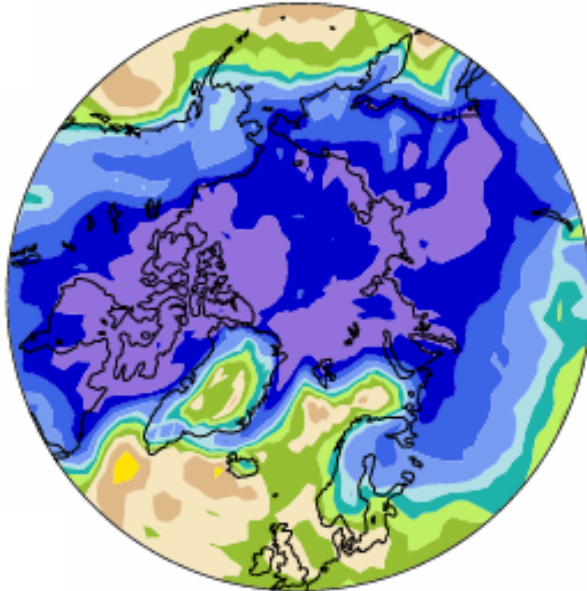
$$- \text{Frac} = [(\text{RH} - \text{RH}_{\min}) / (1 - \text{RH}_{\min})]^2$$

- Cloud Fraction – Freeze Dry

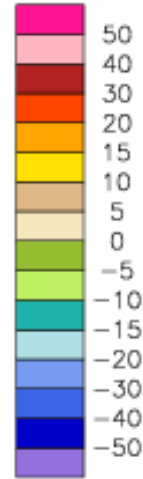
$$- \text{Frac} = \text{Frac} * [\max(0.15, \min(1.0, q_c / 0.003))] ]$$

**Low Cloud  
Changes**

percent



MIN = -77.09 MAX



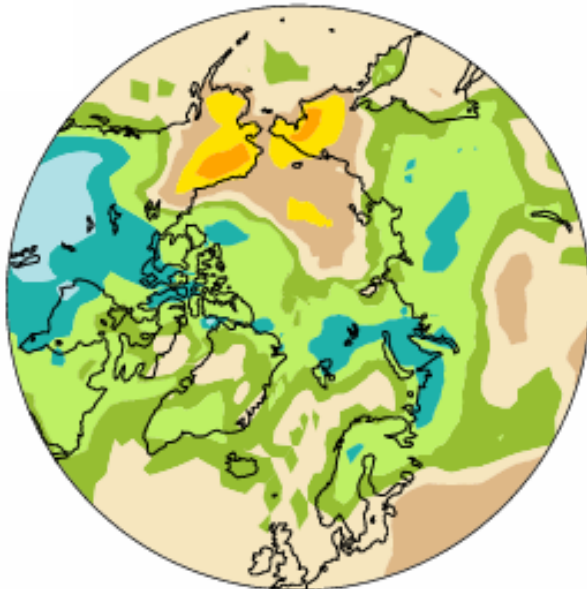
**DJF - Cloud/Ts  
Improvements**

**-Increased LW loss**

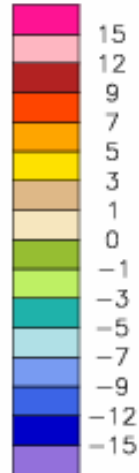
**-Cools surface temp**

**Surface  
Temperature  
Changes**

K



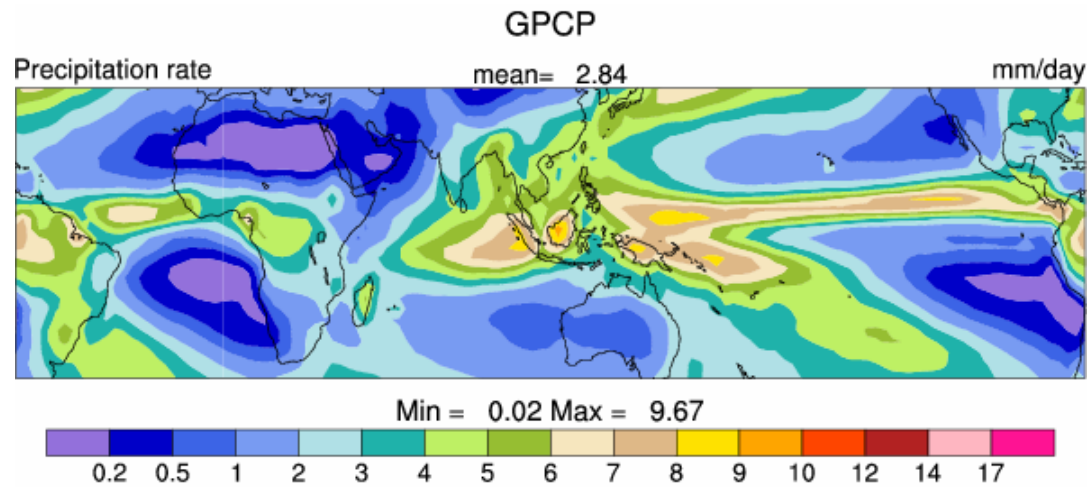
MIN = -6.90 MAX =



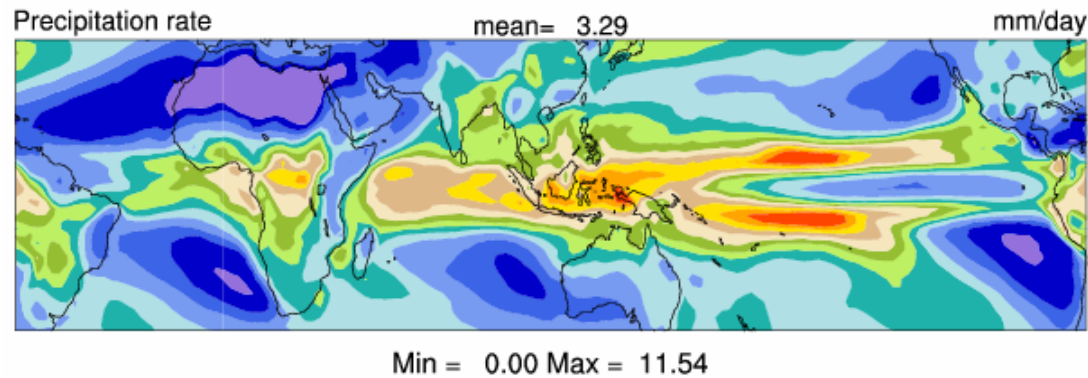
# CCSM3 + Convection Changes

100-year experiments  
80-year averages

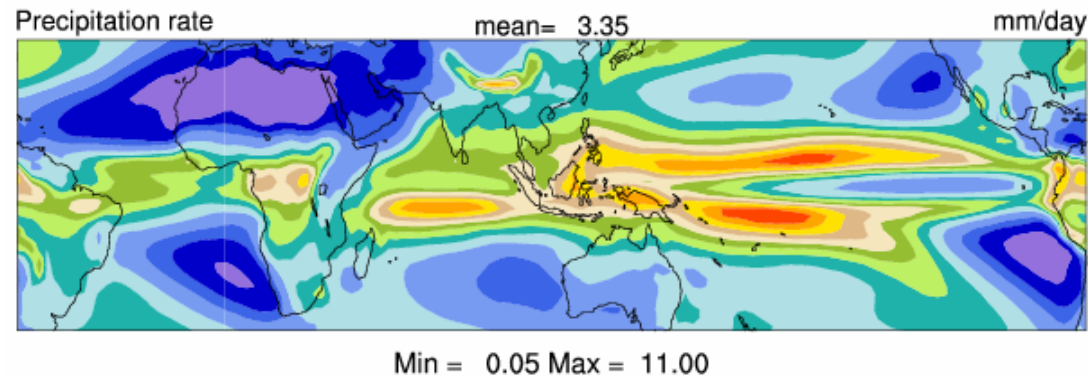
# Annual Rainfall



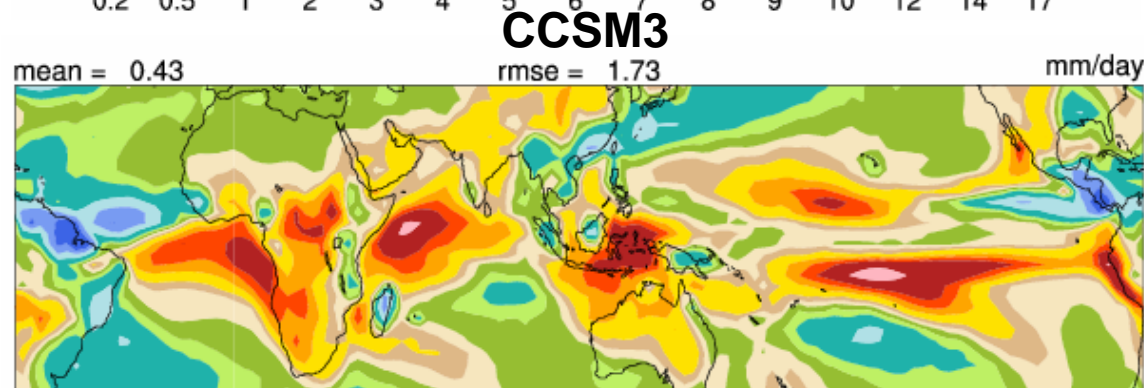
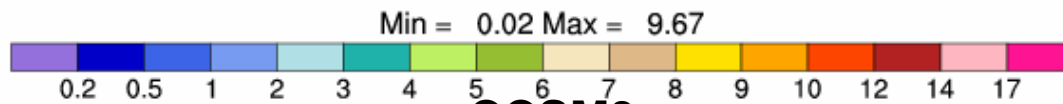
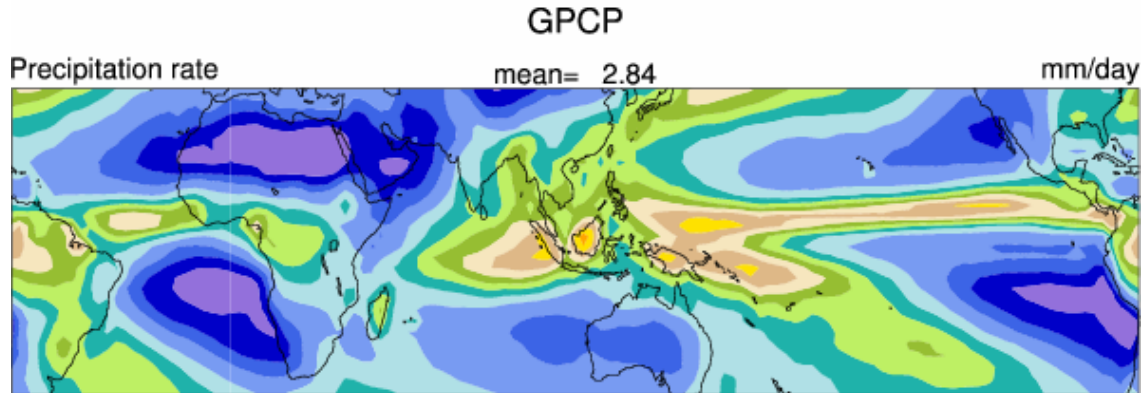
## CCSM3



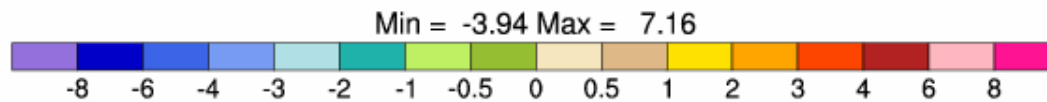
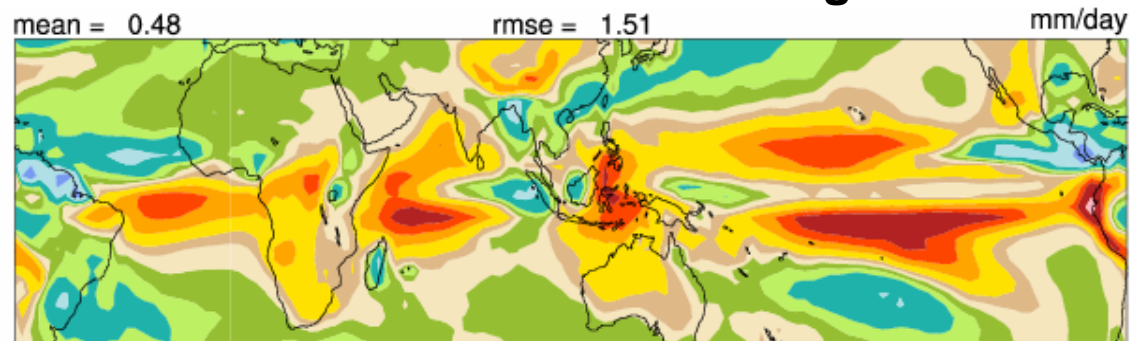
## CCSM3 + Convection Changes



# Annual Rainfall Error



## CCSM3 + Convection Changes





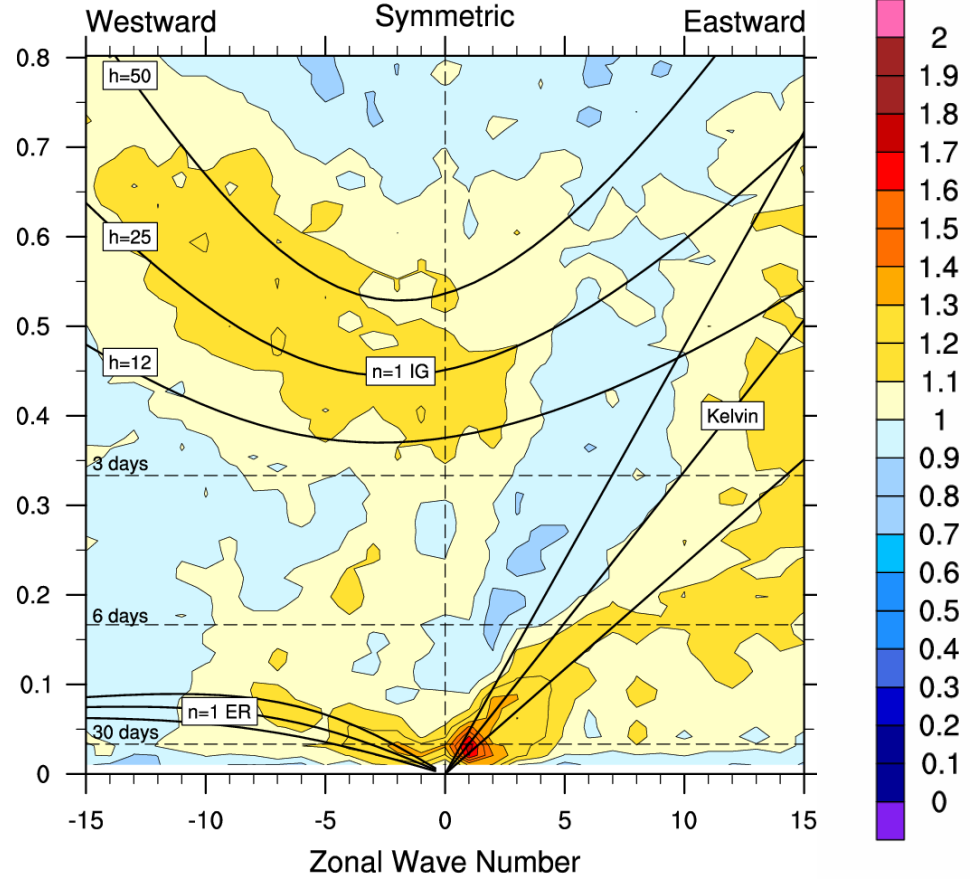
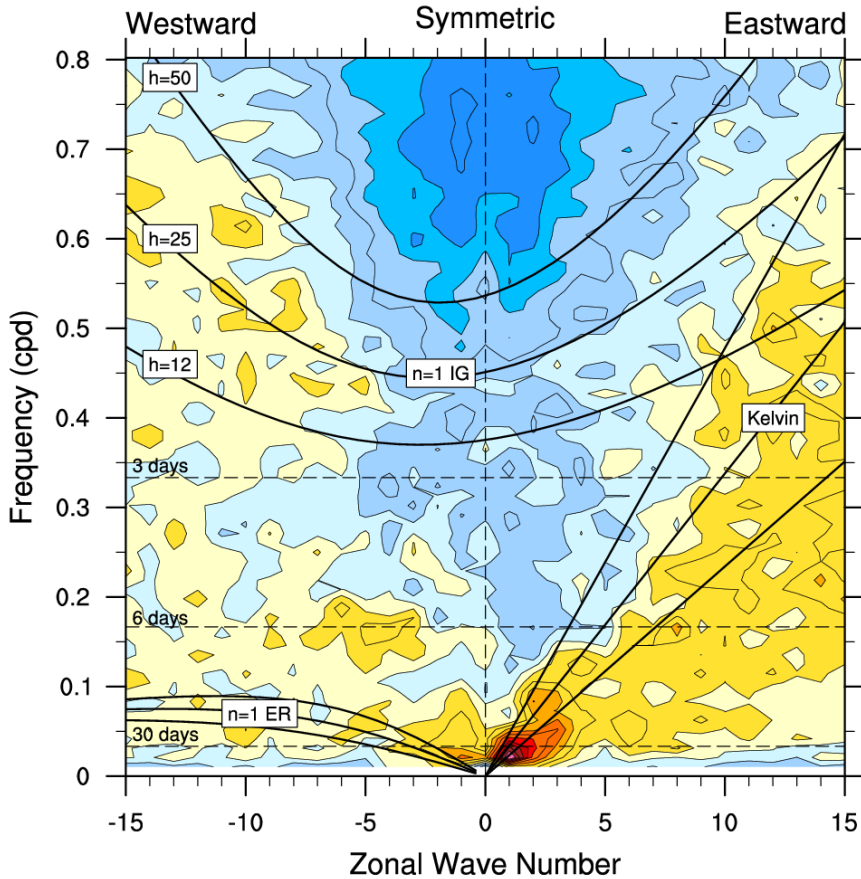
# Intra-Seasonal Variance Improvements

**CCSM3+CONV**

**CCSM3**

**CAM3+CONV**

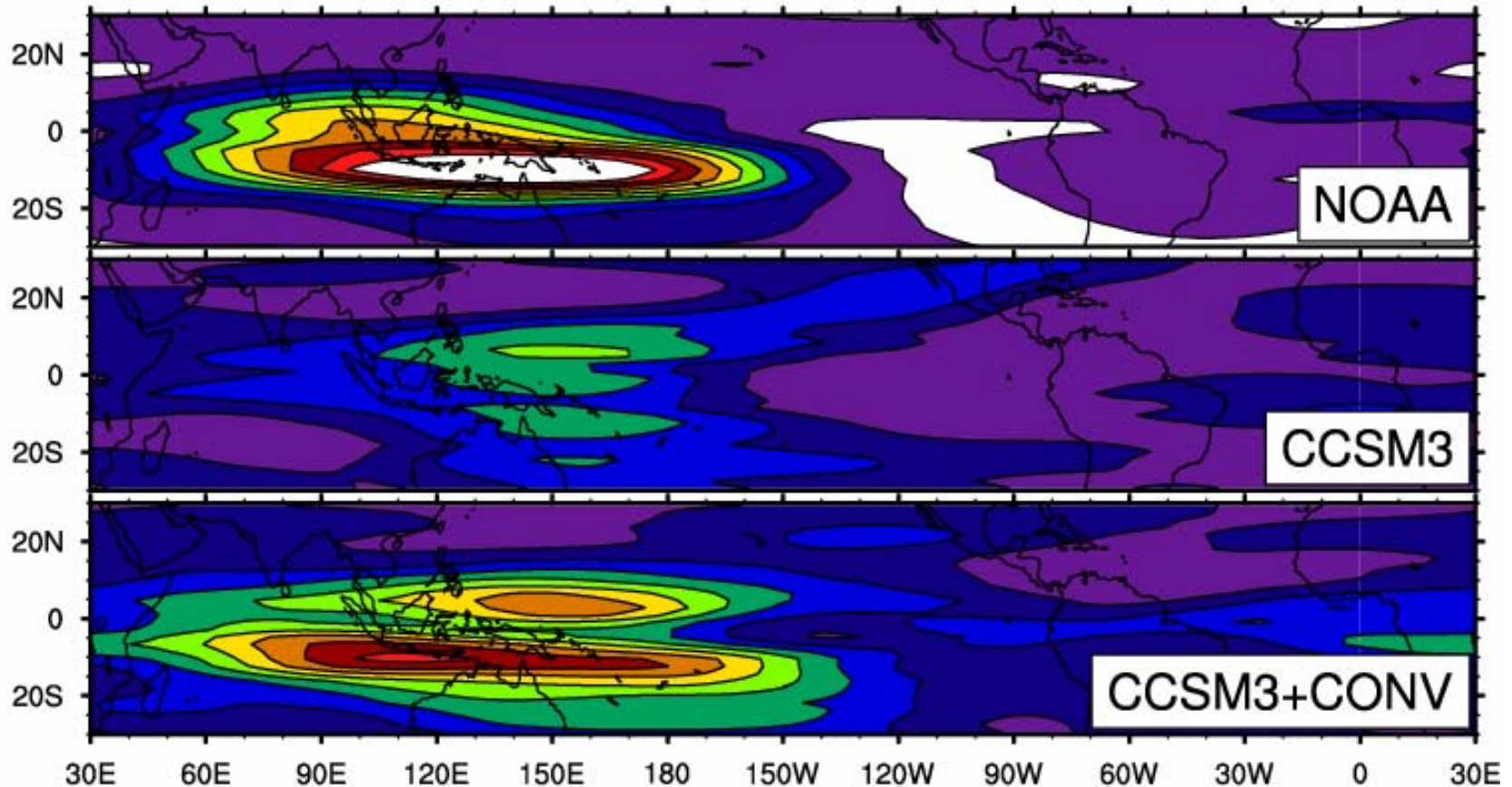
**CAM3**



# MJO Variance

OLR filtered for MJO wavenumbers (1-5) and periods (30-90 days)

Winter (November-April)

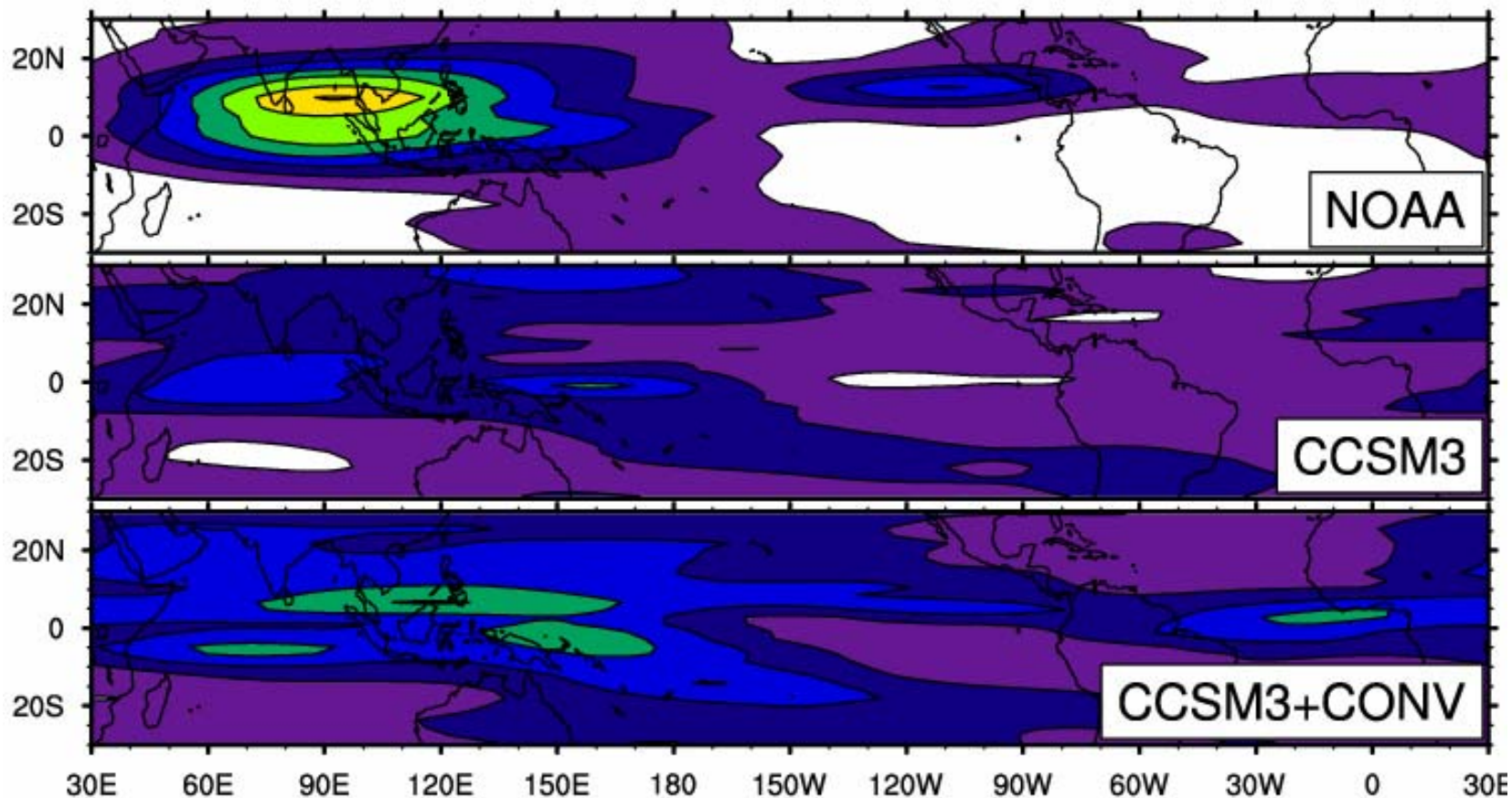


*Contour interval 20  $(W/m^2)^2$*

# MJO Variance

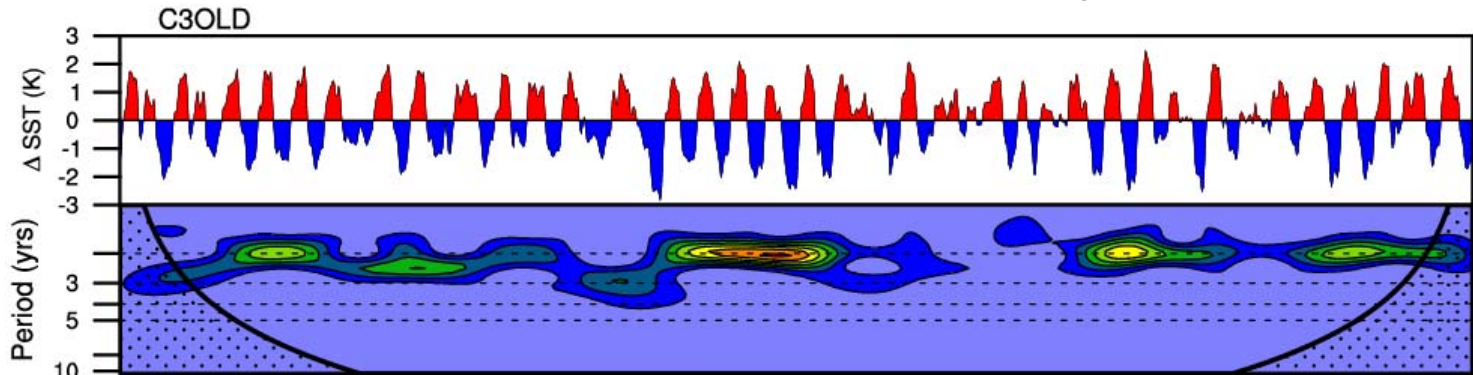
OLR filtered for MJO wavenumbers (1-5) and periods (30-90days)

Summer (May-October)

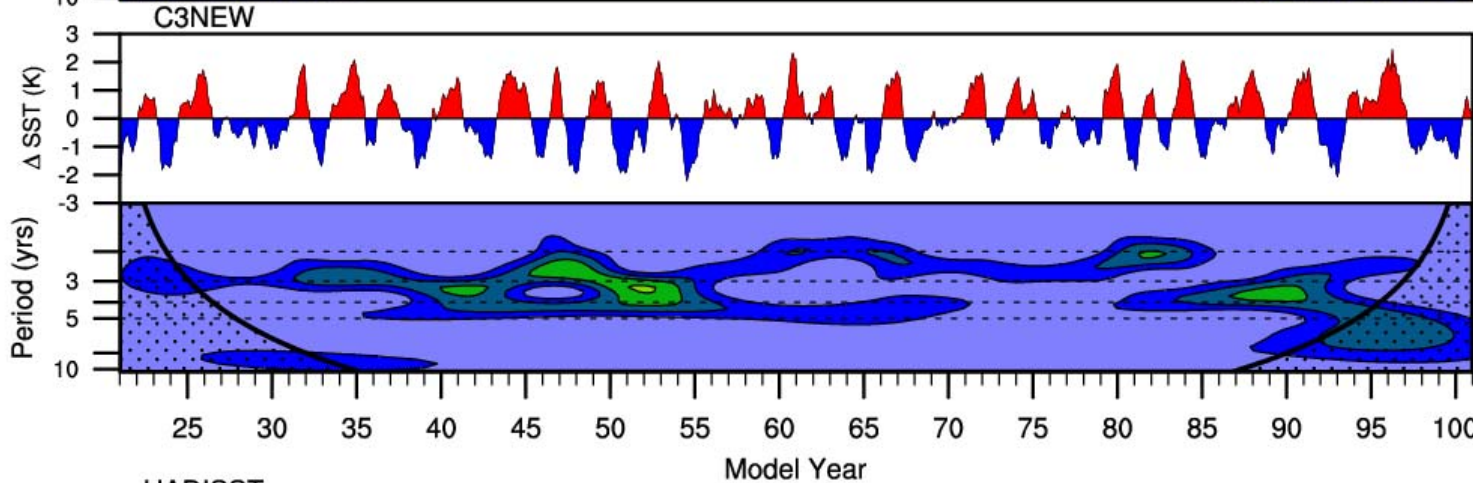
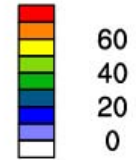


# Nino3.4 SST anomalies (80 years)

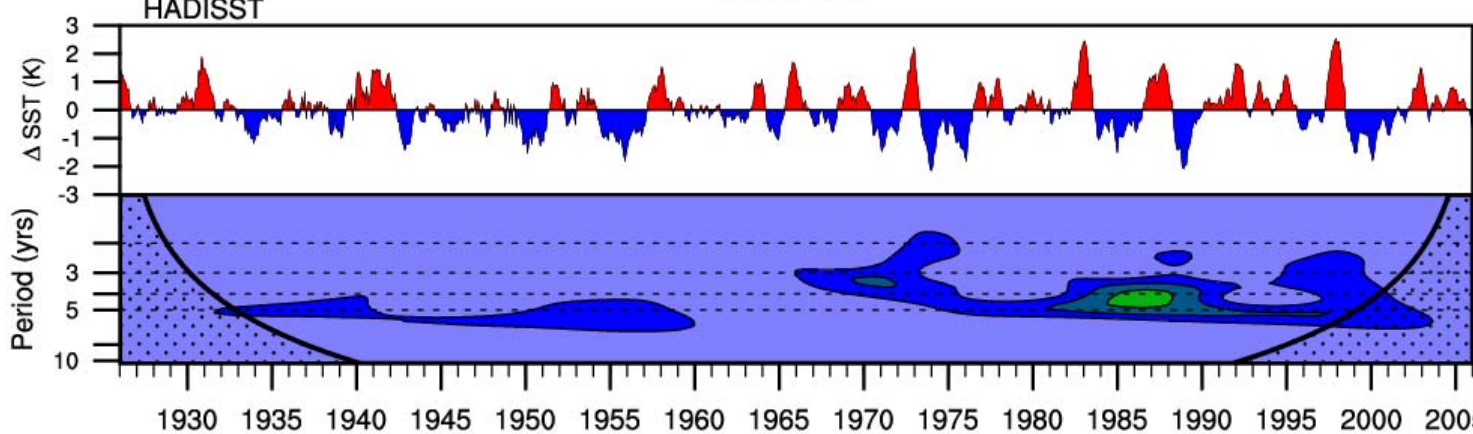
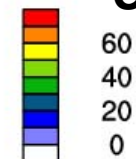
# ENSO



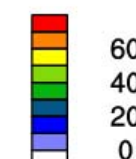
**CCSM3**

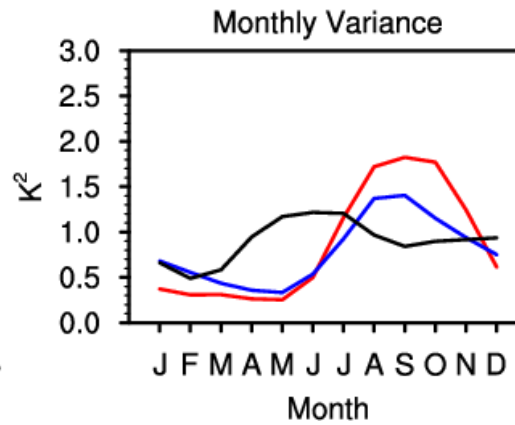
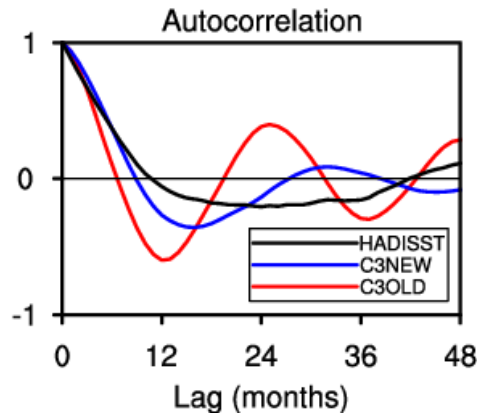
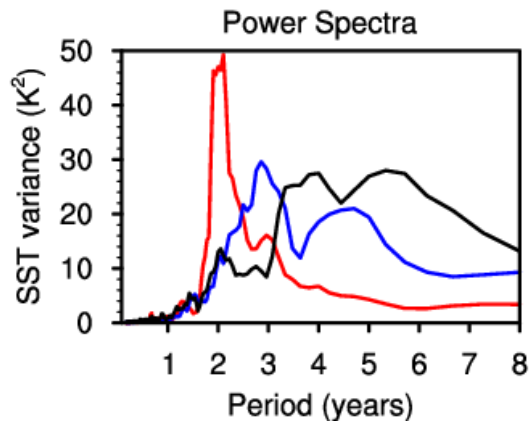


**CCSM3 +  
Convection  
Changes**

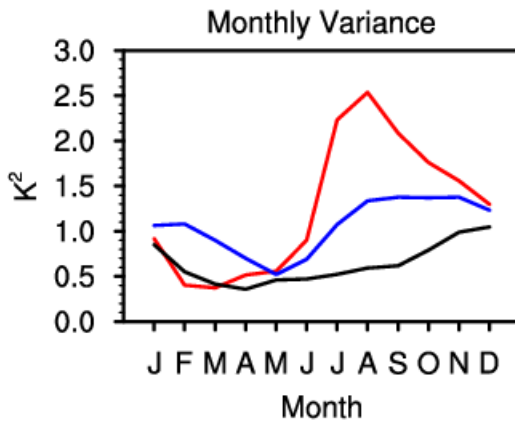
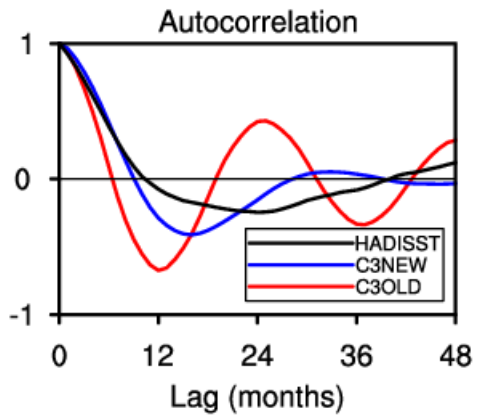
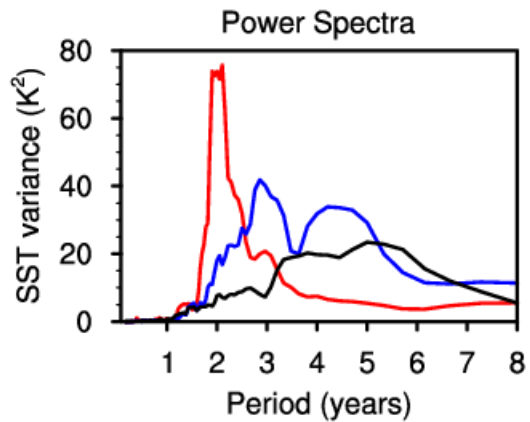


**HadISST**

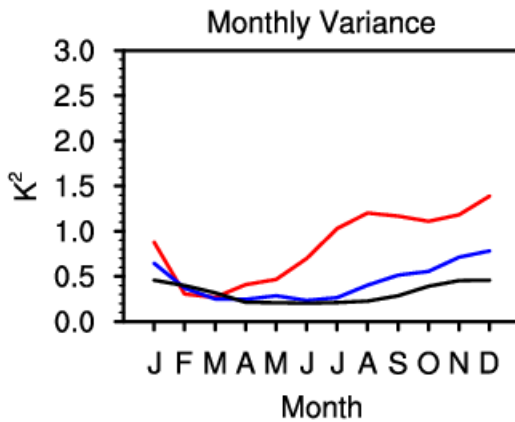
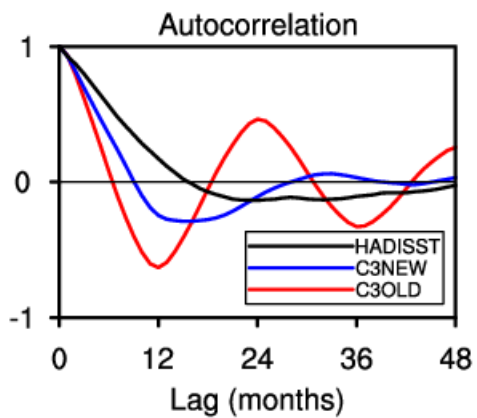
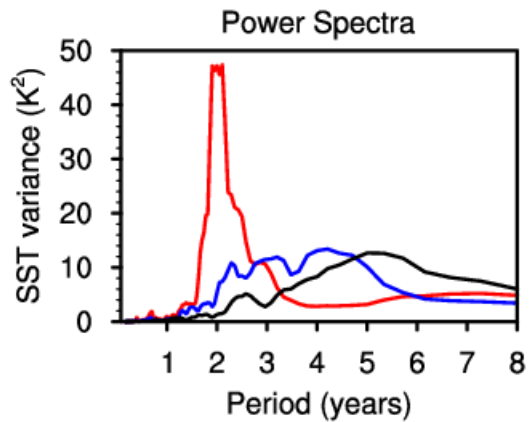




**Nino1+2**

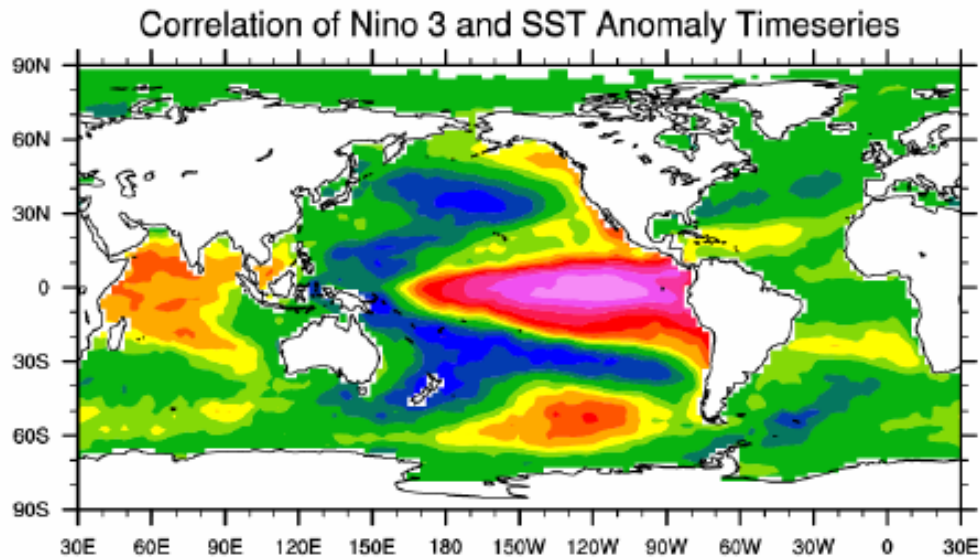


**Nino3**

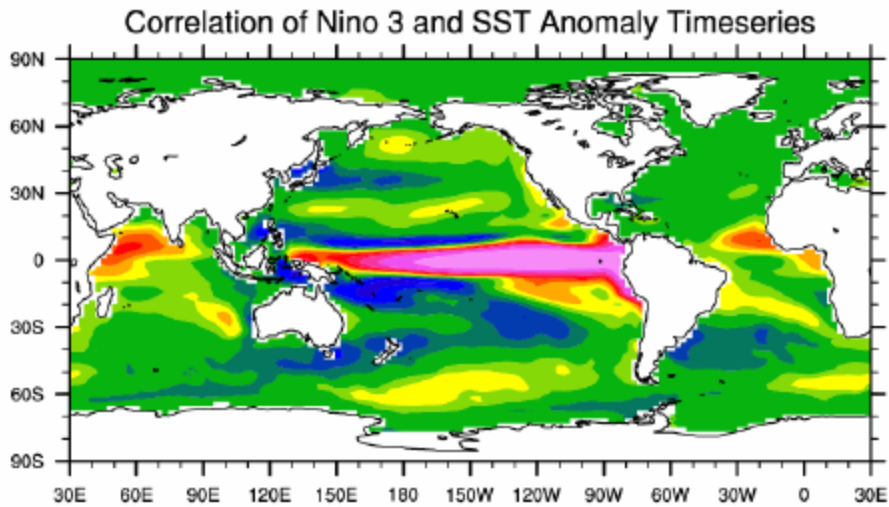


**Nino4**

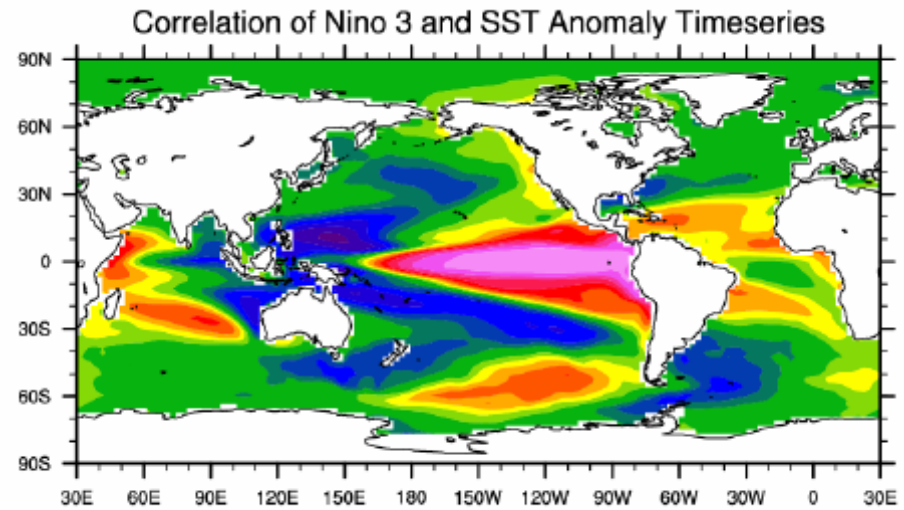
# Lag 0 Nino 3 SST Correlation



## CCSM3

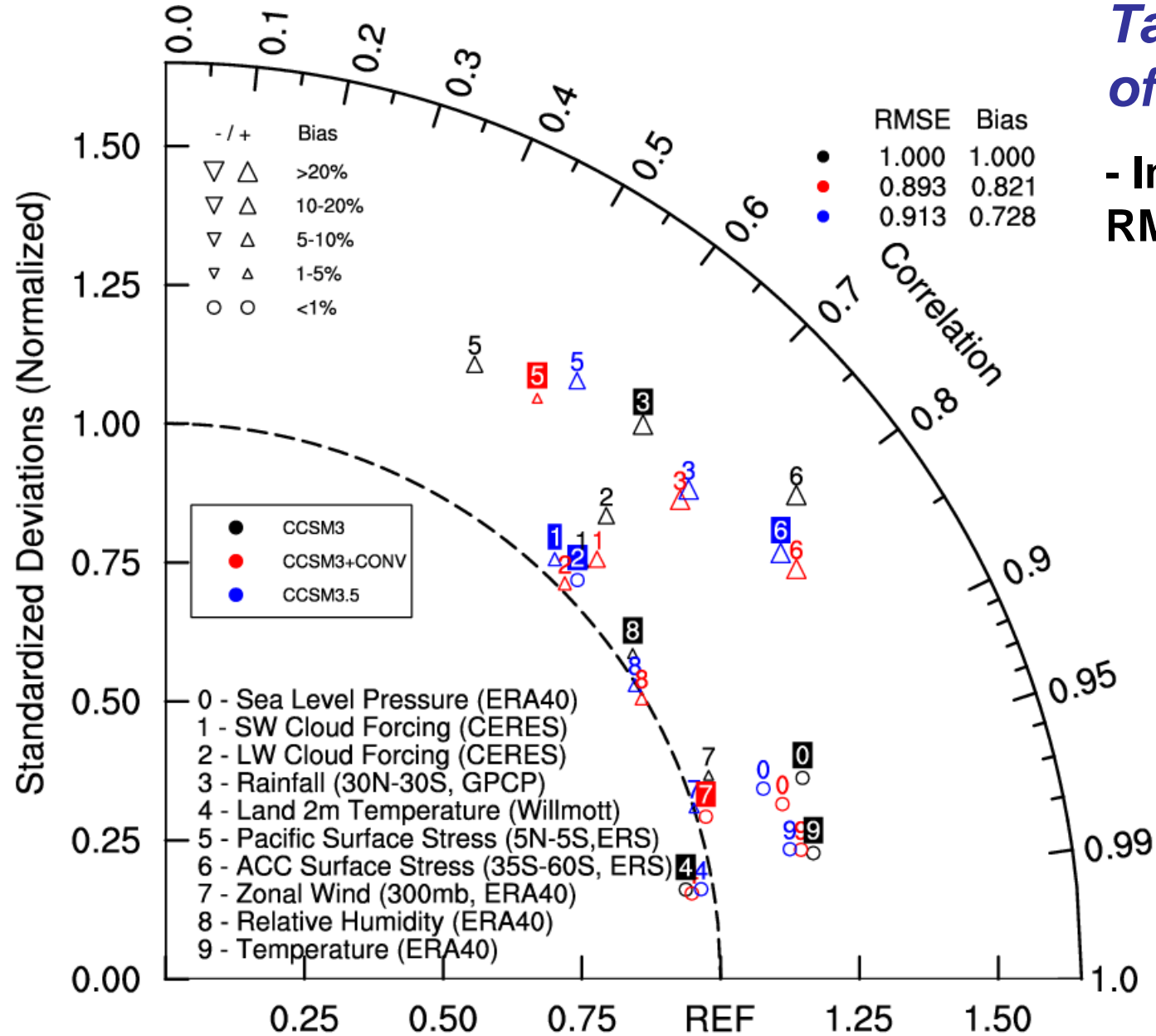


## CCSM3 + Convection Changes



# Taylor Diagram of Key Metrics

- Improved mean RMSE by 10%



# Summary (CAM3.5)

- Improved Indian Ocean rainfall distribution
- Removal of Central Pacific local rainfall maximum
- Reduced North Pacific surface pressure errors
- Reduced excess southern ocean surface stresses
- Reduced excessive trade eastelies
- Improved vertical humidity/temperature structure
- Minor increases in intraseasonal variability (MJO)
- Reduced magnitude in the diurnal cycle over land
- Excessive polar cloud/Ts reduced
- Overall reduction of mean RMSE by 15%



# Summary (CCSM3.5)

- Reduced Central Pacific cold tongue bias
- First annual harmonic of SST dominates in East Pacific
- Reduced Gulf of Guinea excess rainfall
- Reduced excess rainfall over land in DJF
- Twin ITCZ remains
- Substantial improvements in MJO variance
- Improved ENSO variance, period, teleconnections
- Overall reduction in RMSE of 10%