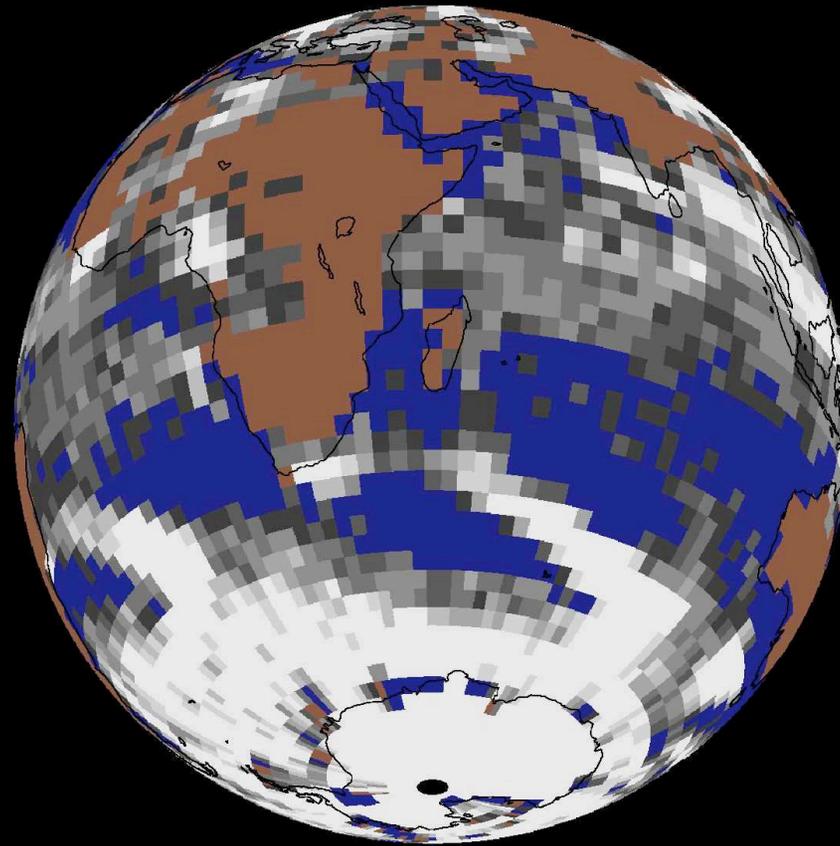




Cloud-Resolving Climate Modeling

Marat Khairoutdinov

Colorado State University



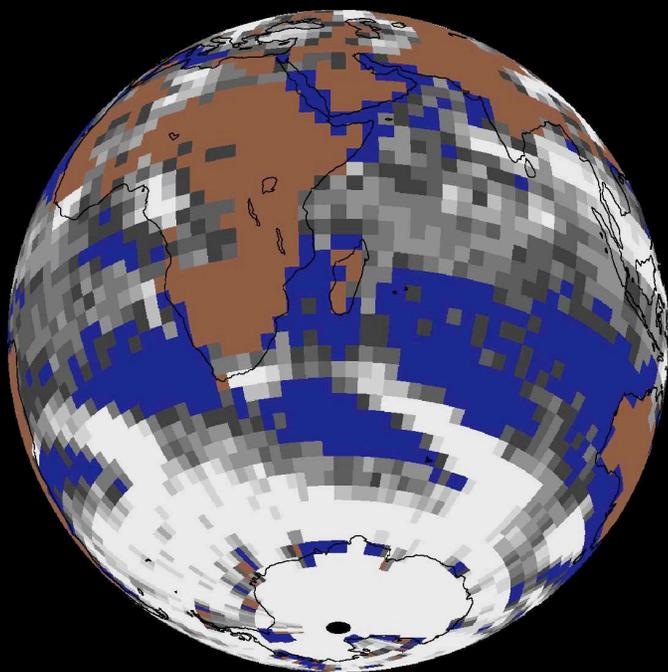
Typical Global Climate Model (GCM) Resolution
~ 200-300 km at the equator.

Lots of clouds can pack over the area 200 miles across!

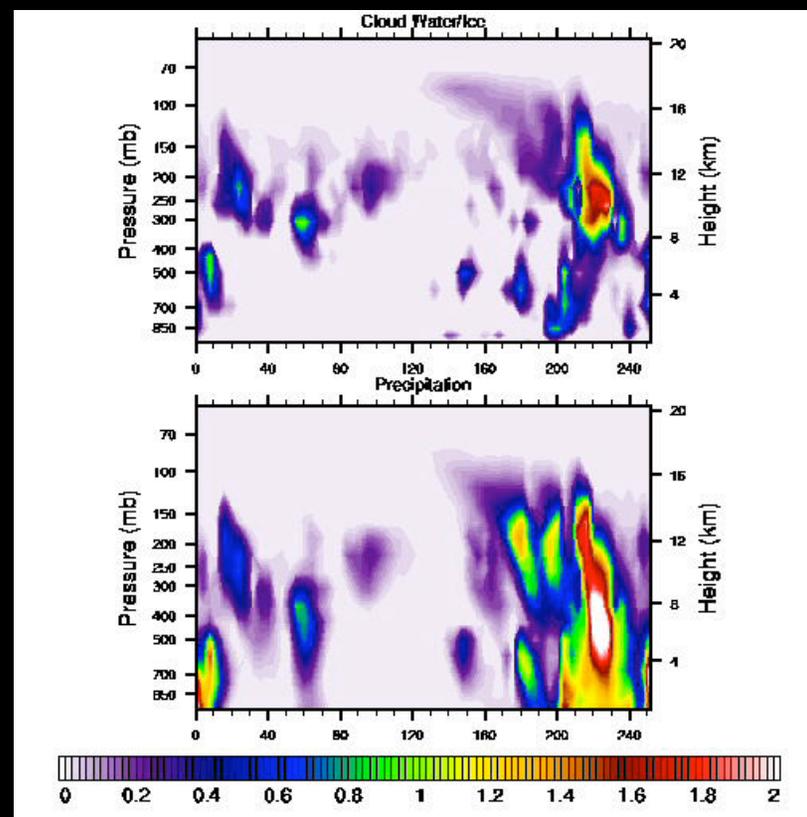


Multiscale Modeling Framework (MMAF)

Inject Cloud-Resolving Model (“super-parameterization”)
into each column of a **GCM**



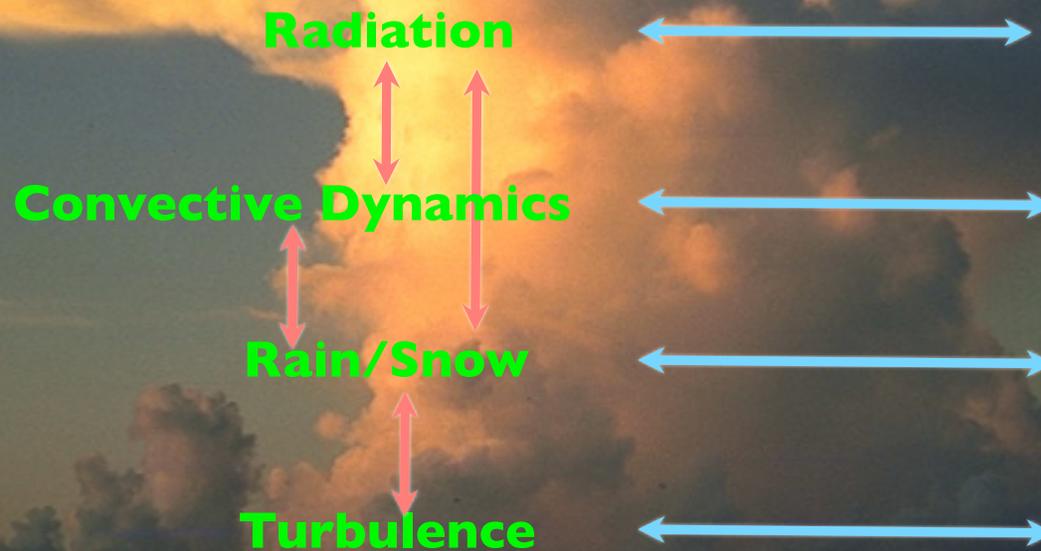
Each column of this has this



In GCMs, processes interact through the large-scale state.



In MMF processes interact on cloud scales as in Nature.

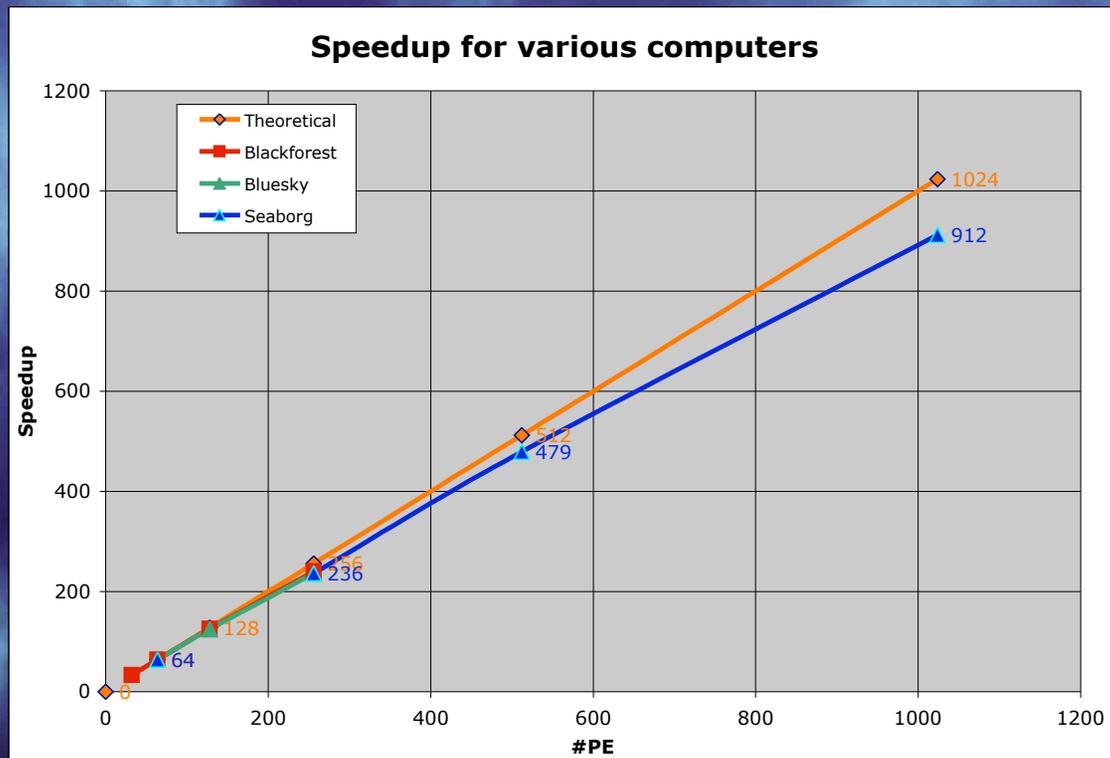


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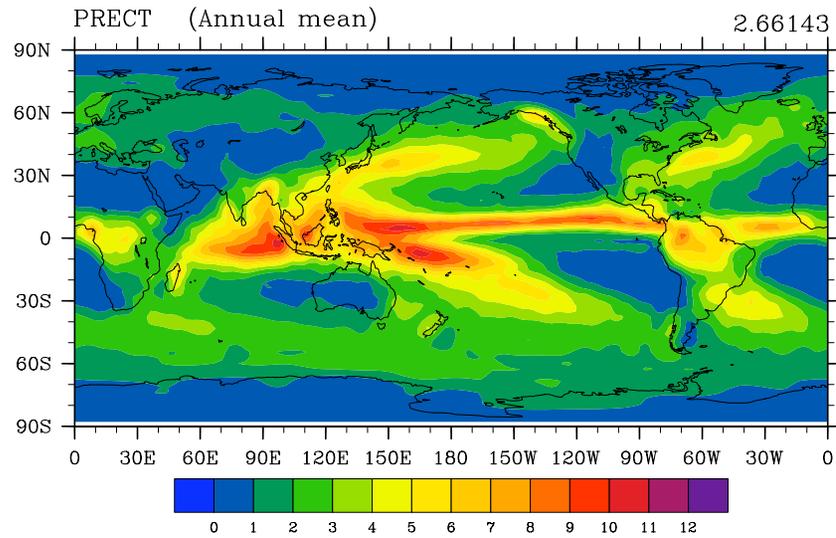
AMIP-style experiment

- ◆ Prescribed monthly-mean observed SST and ice
- ◆ September 1985 to August 2004 (19 years)
- ▲ 10 simulated months per a wall-clock day (DOE Seaborg)

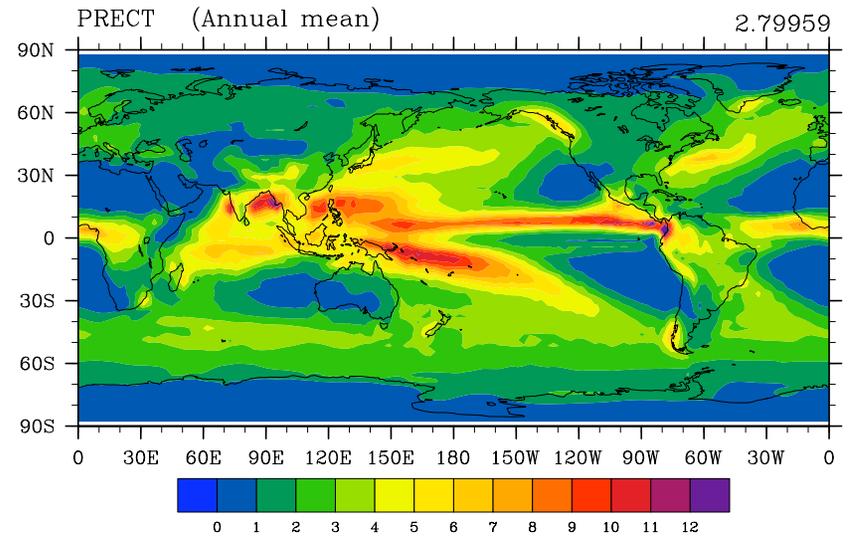


Annual Precipitation

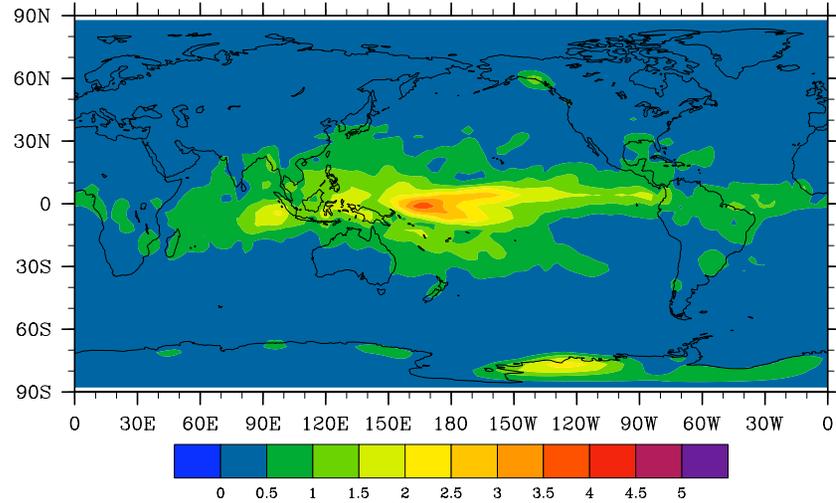
CMAF (1986-2000)



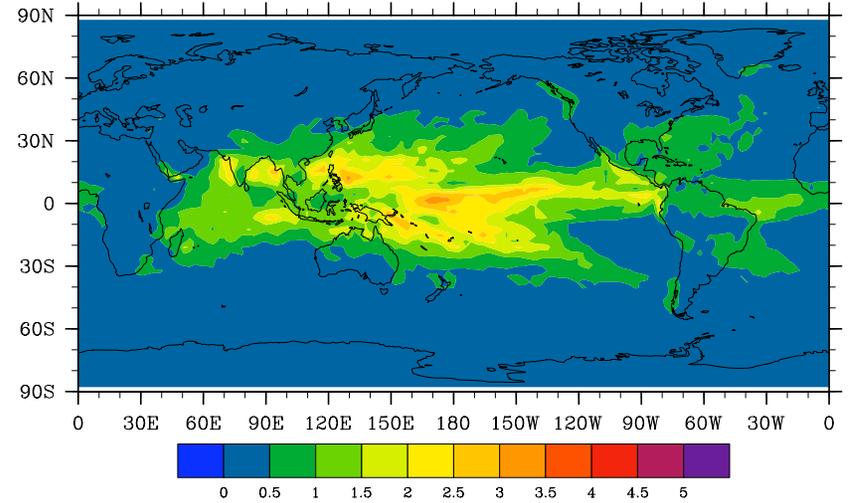
MMF (1986-2000)



PRECT (Interannual Standard Deviation) 0.459513

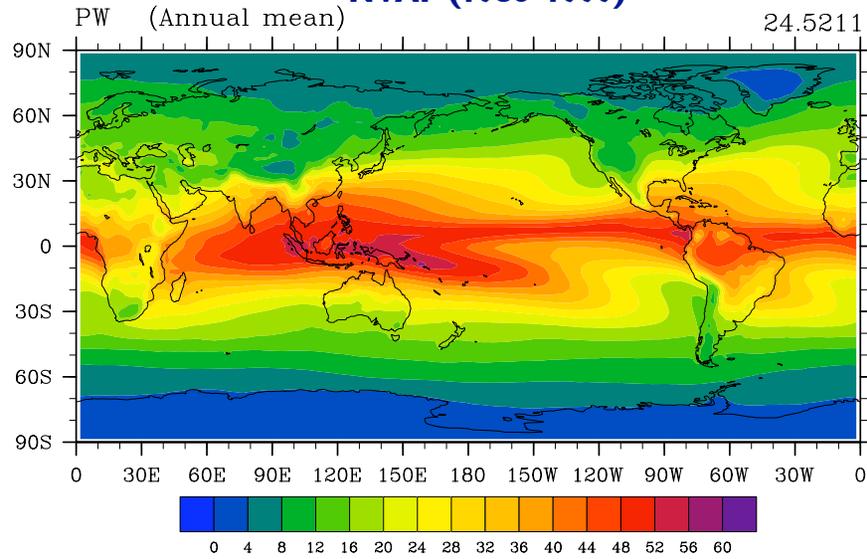


PRECT (Interannual Standard Deviation) 0.607562

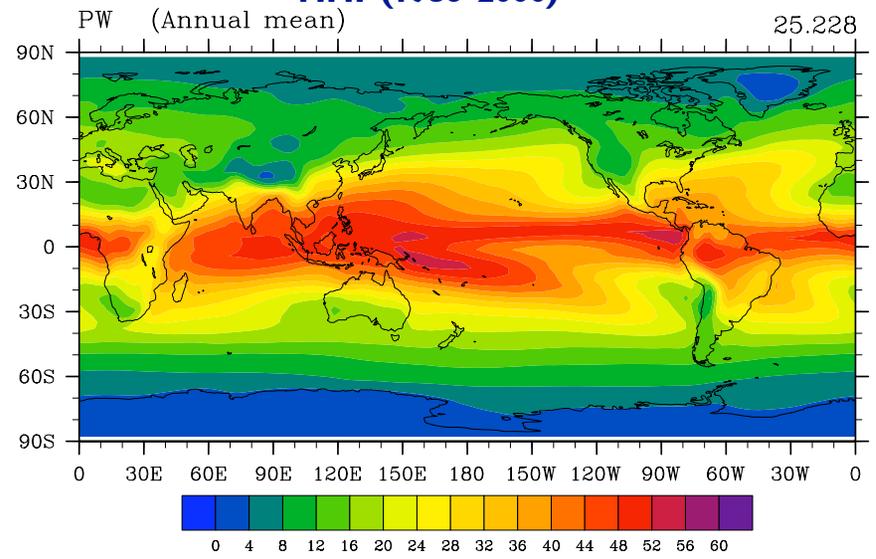


Annual Column Water Vapor

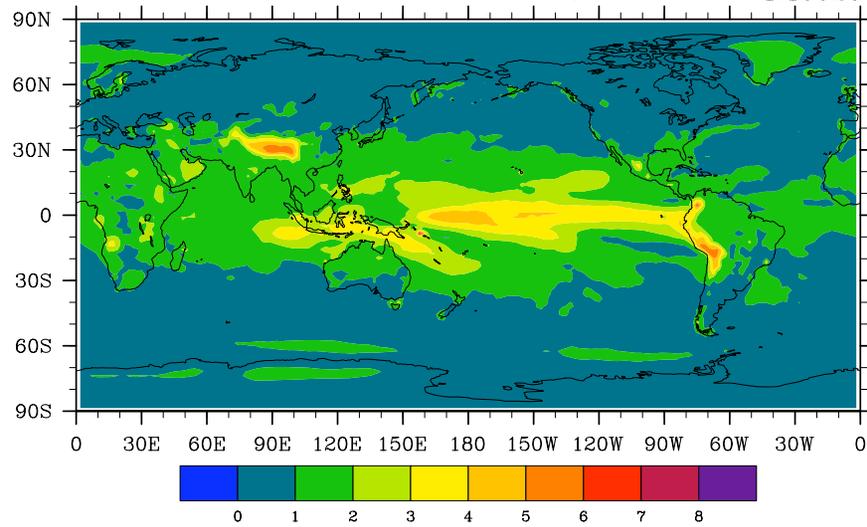
NVAP (1986-1999)



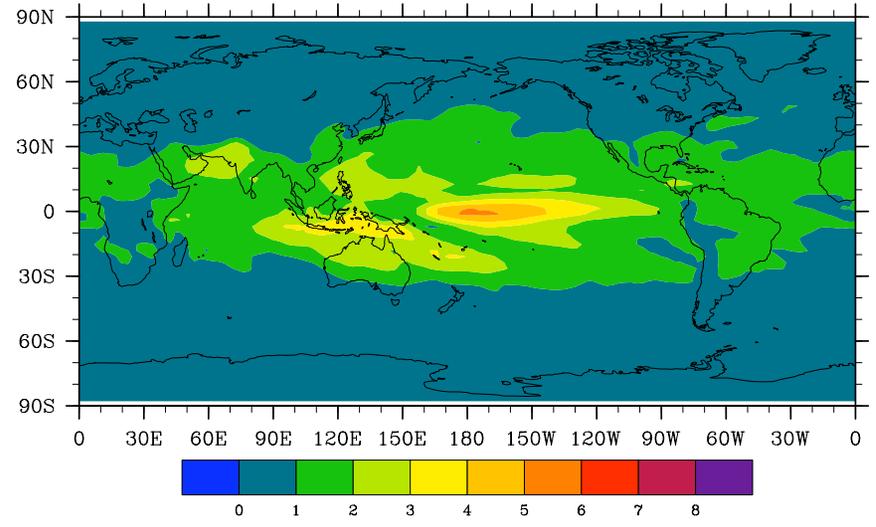
MMF (1986-2000)



PW (Interannual Standard Deviation)



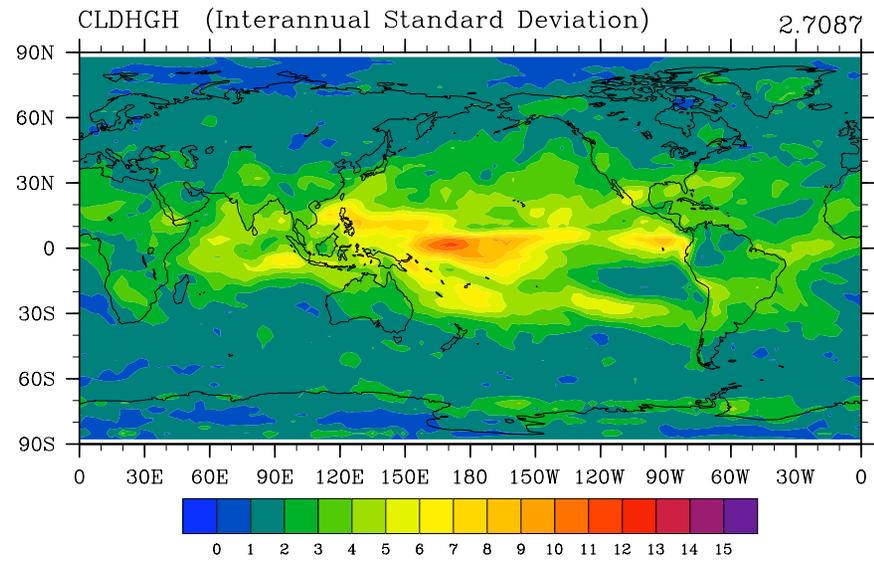
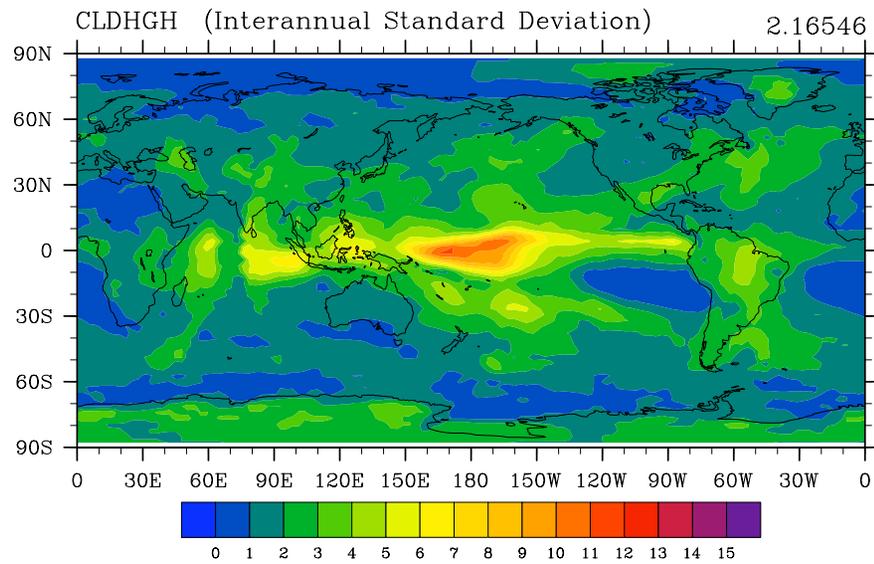
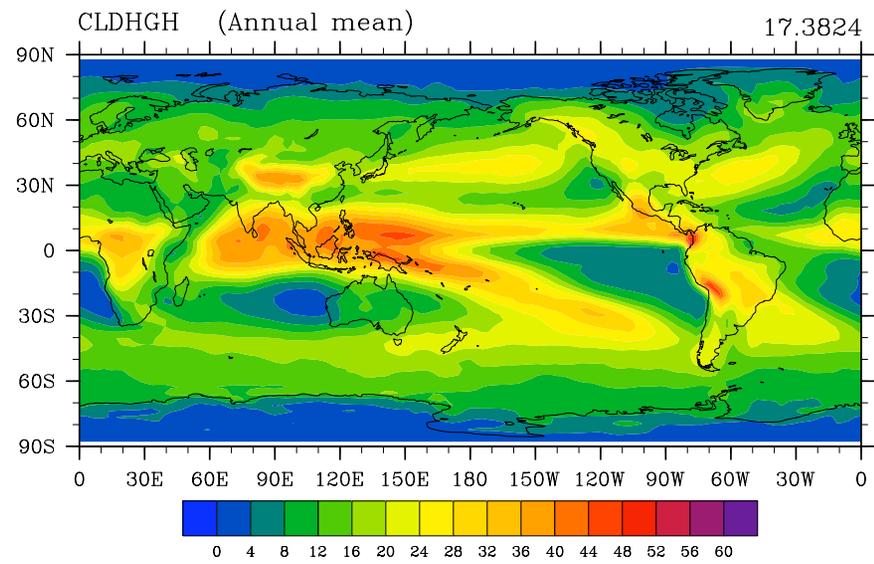
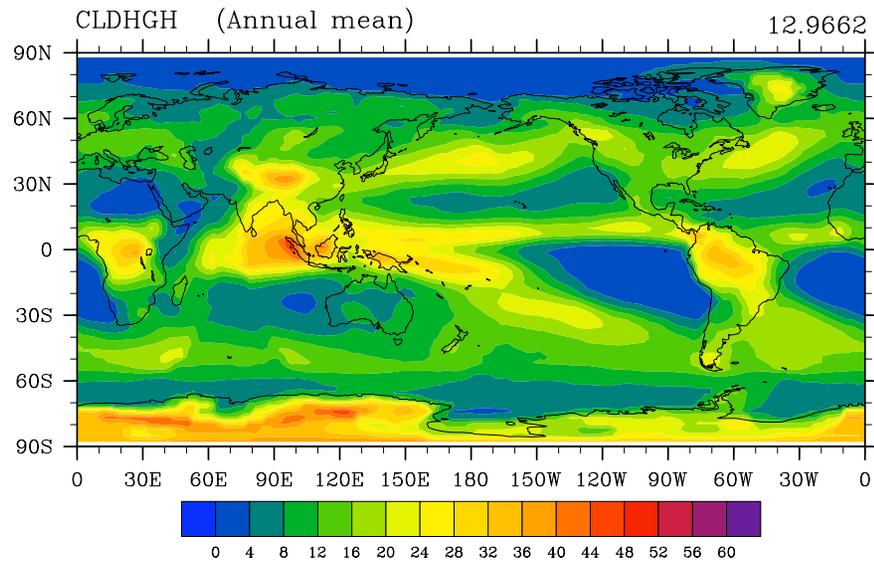
PW (Interannual Standard Deviation)



High Clouds

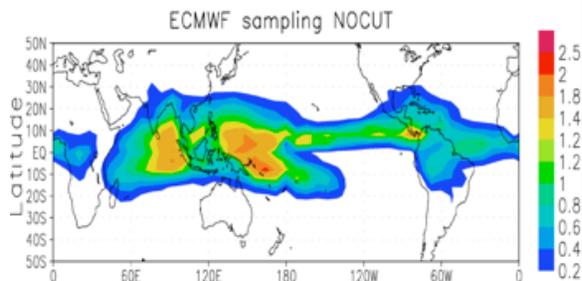
ISCCP (1986-2000)

MMF (1986-2000)

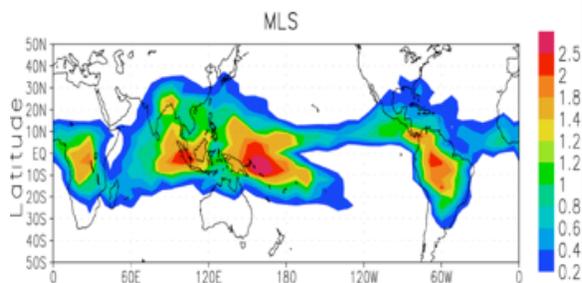


CSUMMF IWC (15 years mean) @147 hPa

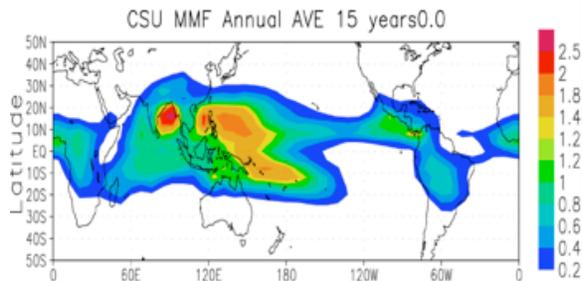
ANNUAL
1-12- Mean 0.0 IWC at 147 hPa
ECMWF



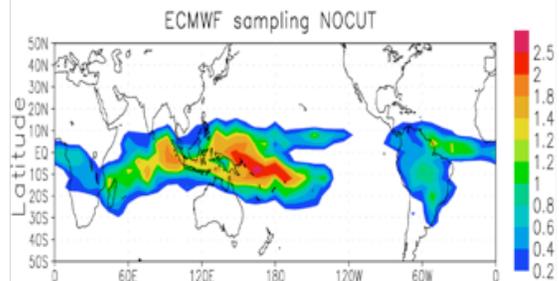
MLS



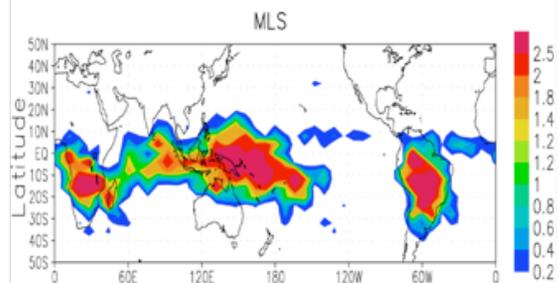
CSUMMF



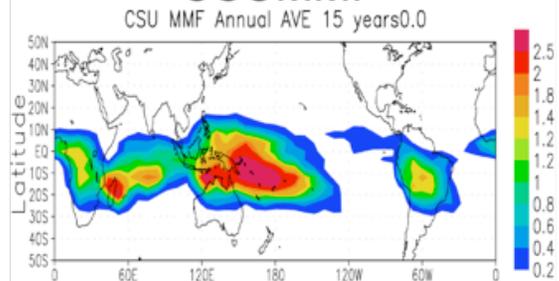
JAN
6-6- Mean 0.0 IWC at 147 hPa
ECMWF



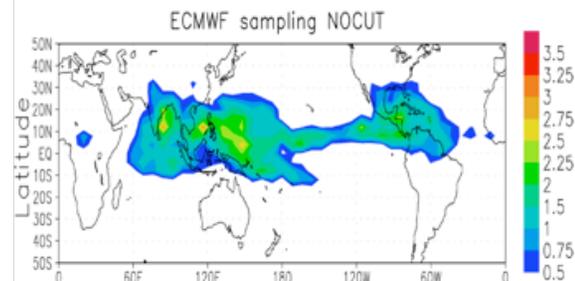
MLS



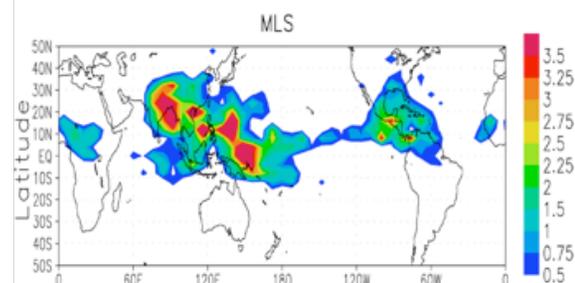
CSUMMF



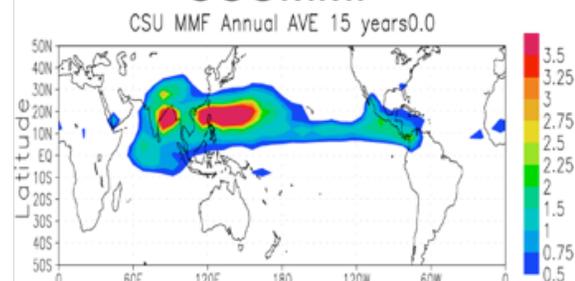
JUL
12-12- Mean 0.0 IWC at 147 hPa
ECMWF



MLS

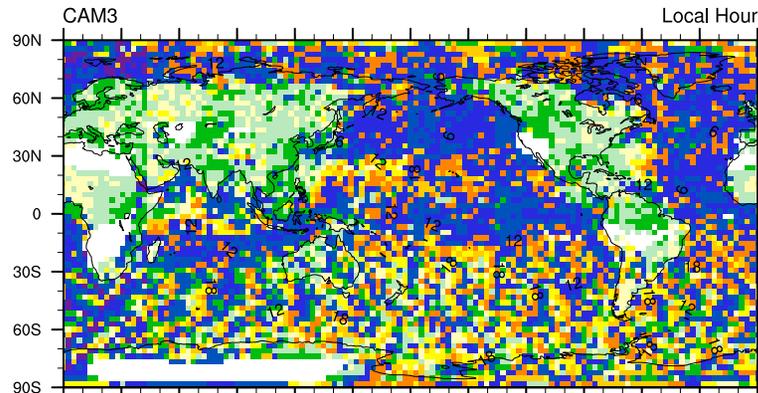


CSUMMF

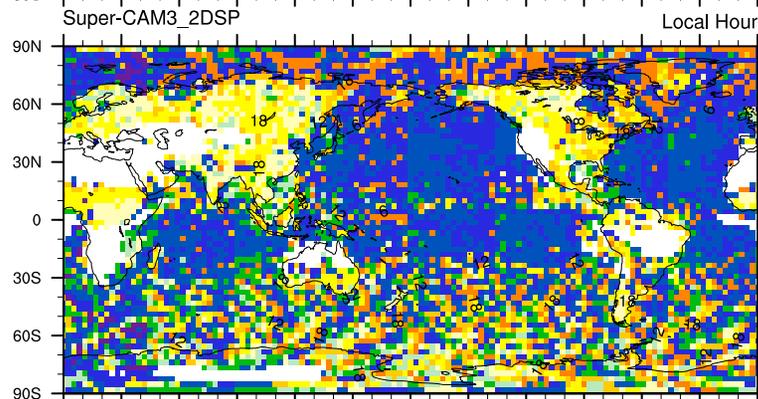


JJA Local time of Precipitation-Frequency Maximum

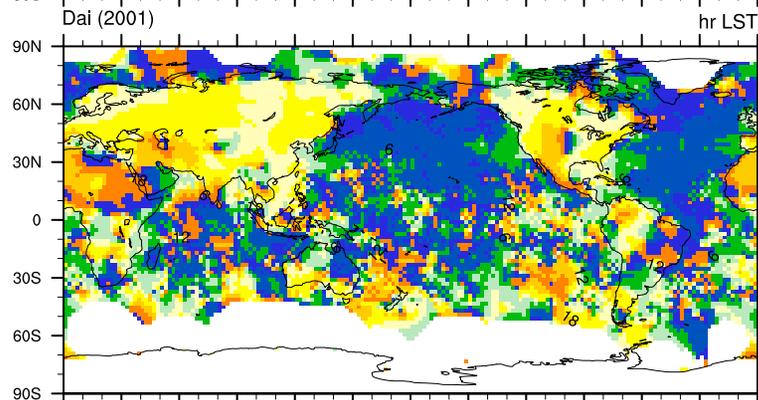
Climatological SST
500 days



CAM3

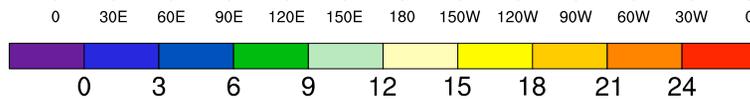


MMF



Obs

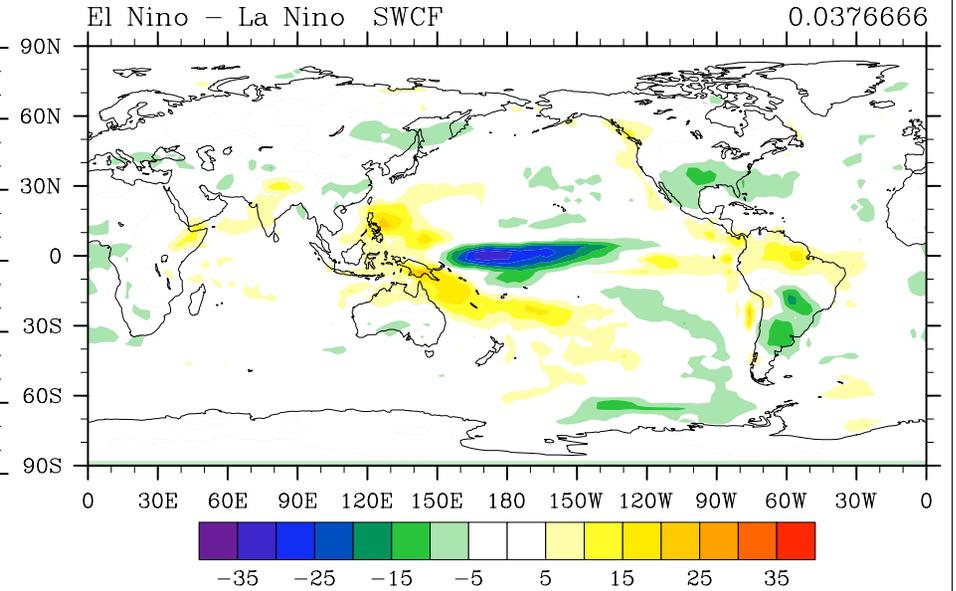
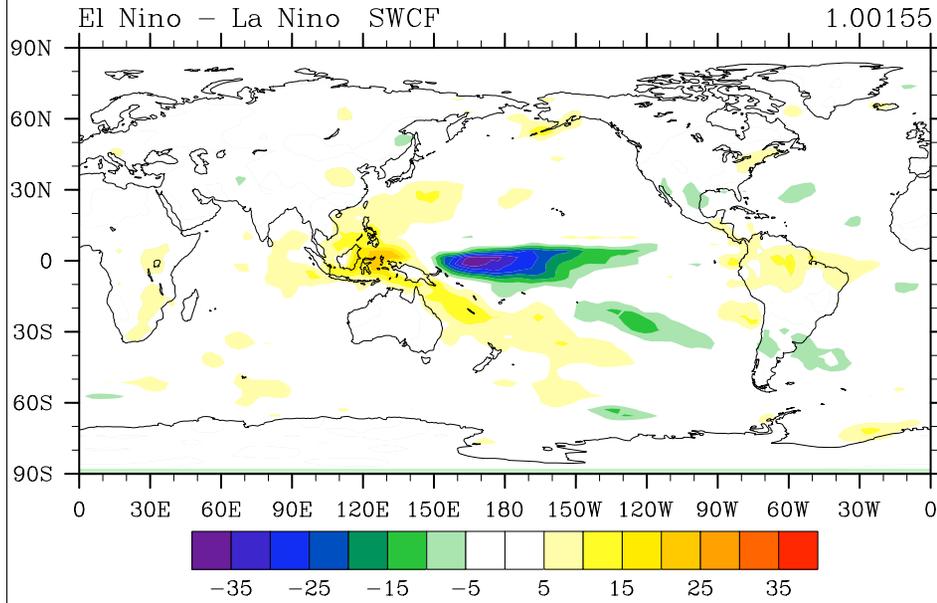
Prec > 0.1 mm/day



EN-LN Shortwave Cloud Effect

ISCCP-FD

MMF



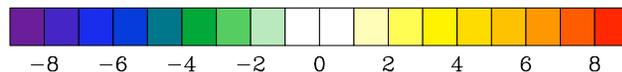
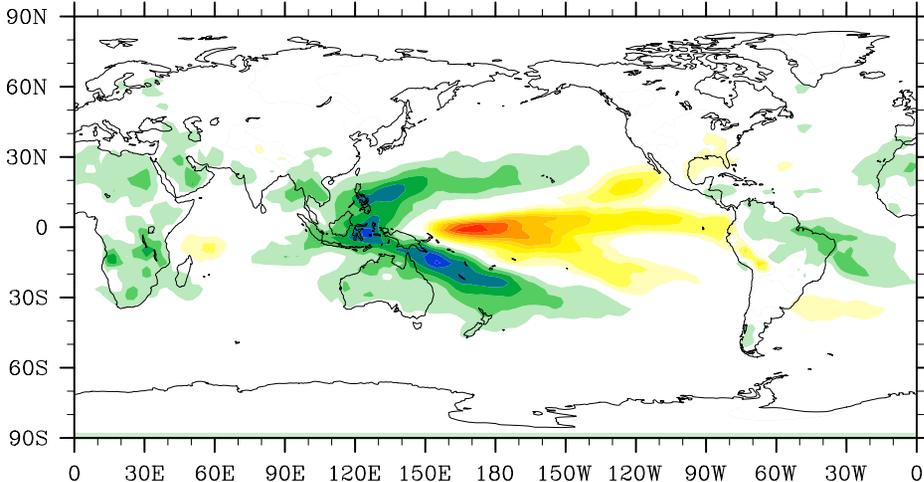
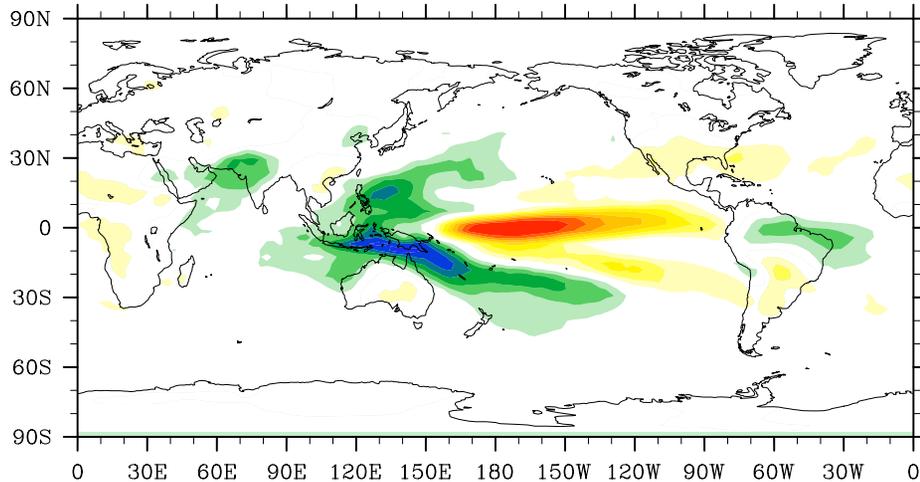
EN-LN Column Water Vapor

NVAP

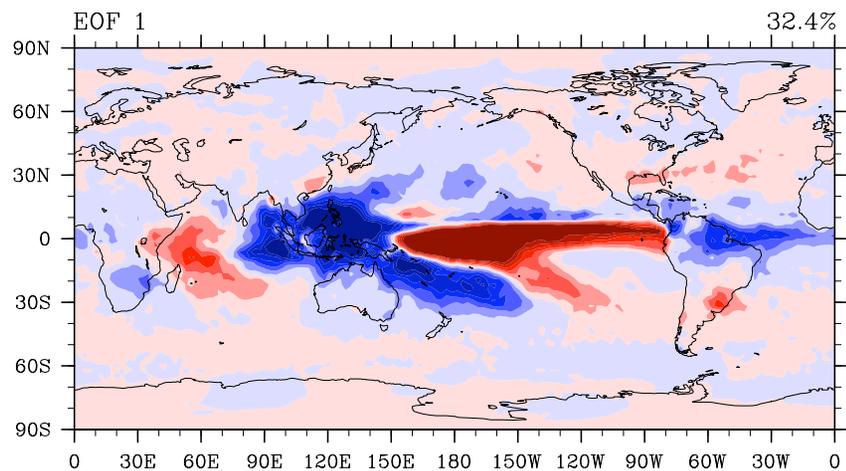
MMF

El Nino - La Nino TMQ 0.0534683

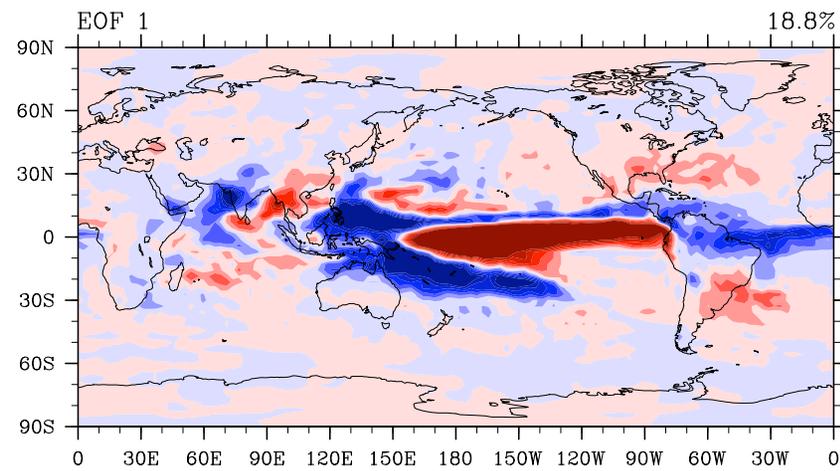
El Nino - La Nino PWAT -0.279011



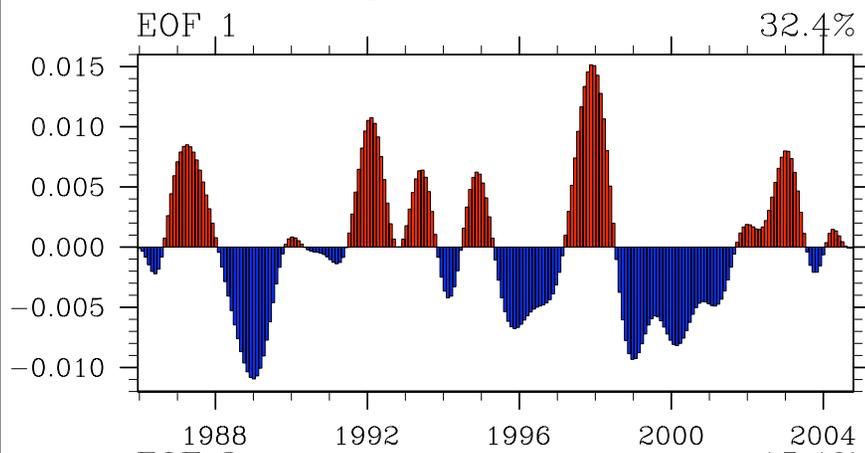
CMAP Precip



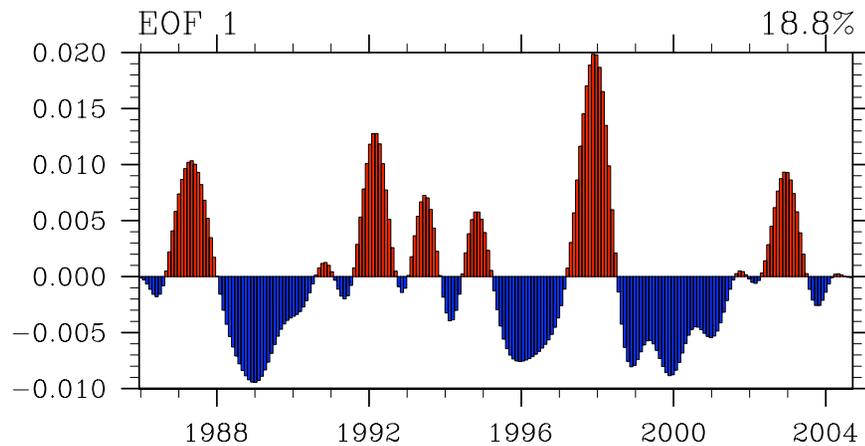
MMF Precip



CMAP Precip EOF time coefs



MMF Precip EOF time coefs



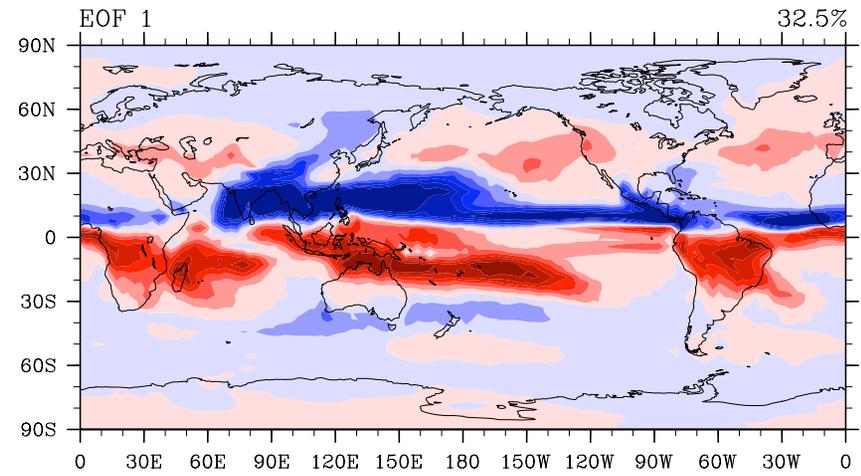
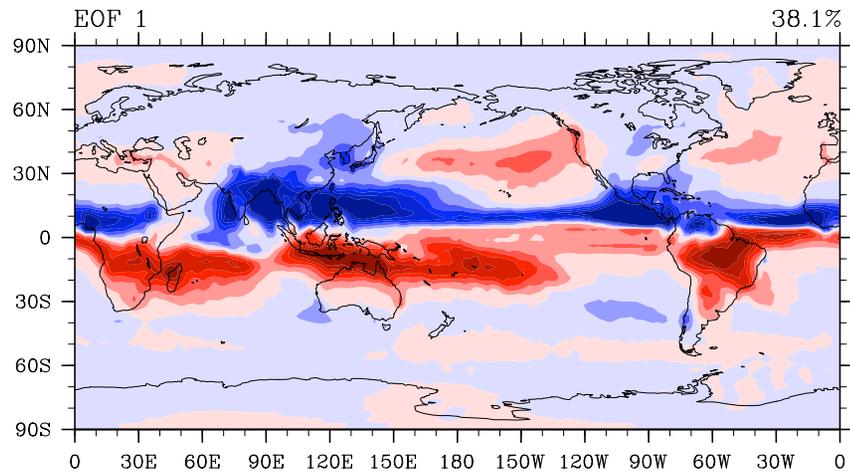
Precipitation EOF Time Coefficients

CMAP (obs)

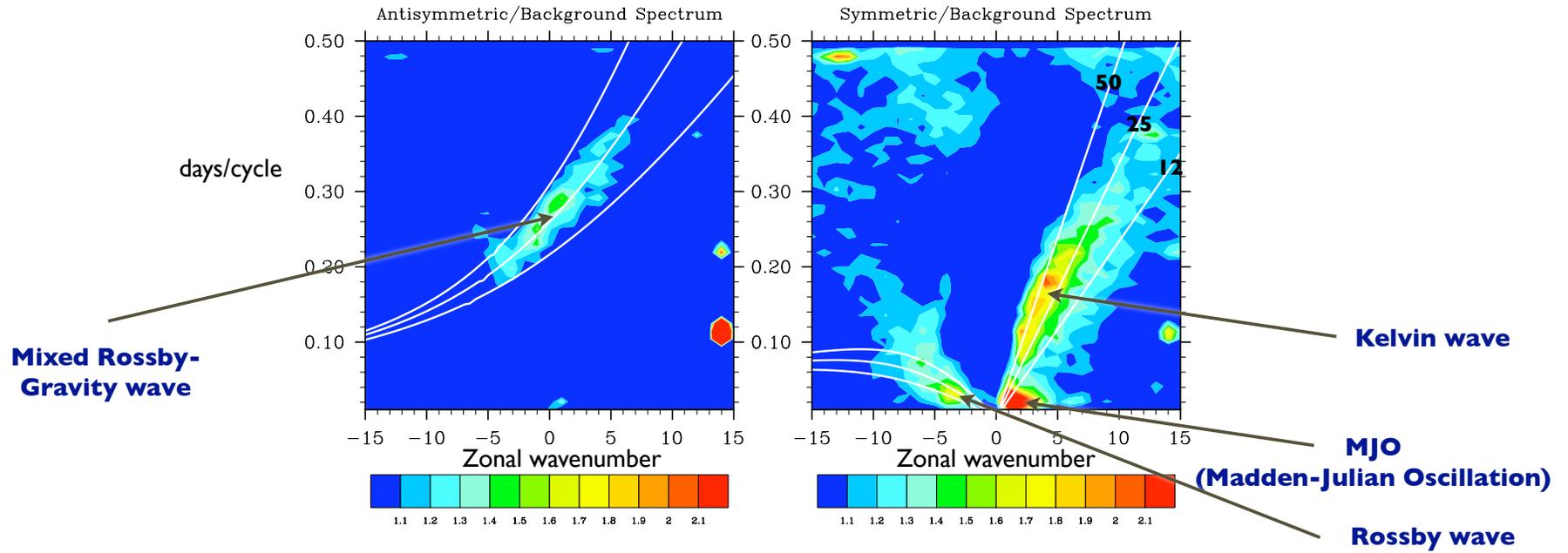
MMF

CMAP Precip

MMF Precip



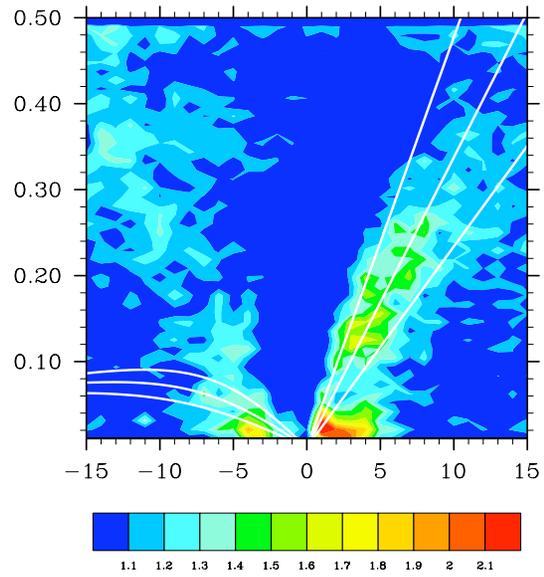
NOAA Outgoing Longwave (Thermal or IR) Radiation (1974-2004)



Outgoing Longwave Radiation

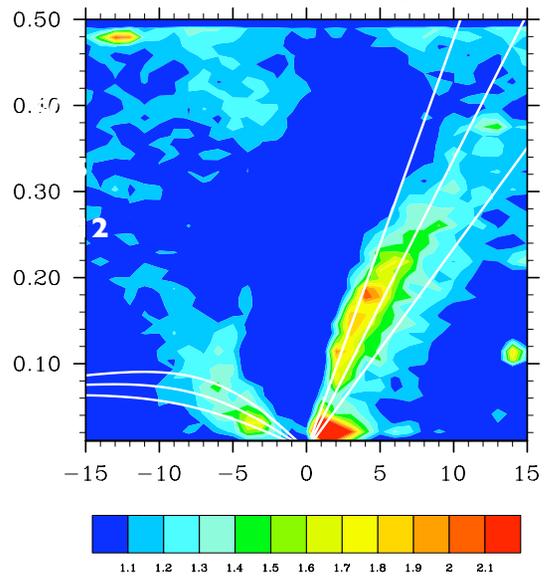
MMF

Symmetric/Background Spectrum



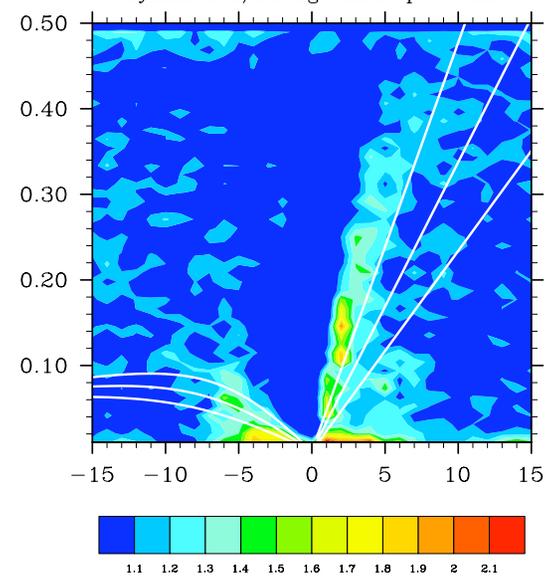
NOAA

Symmetric/Background Spectrum

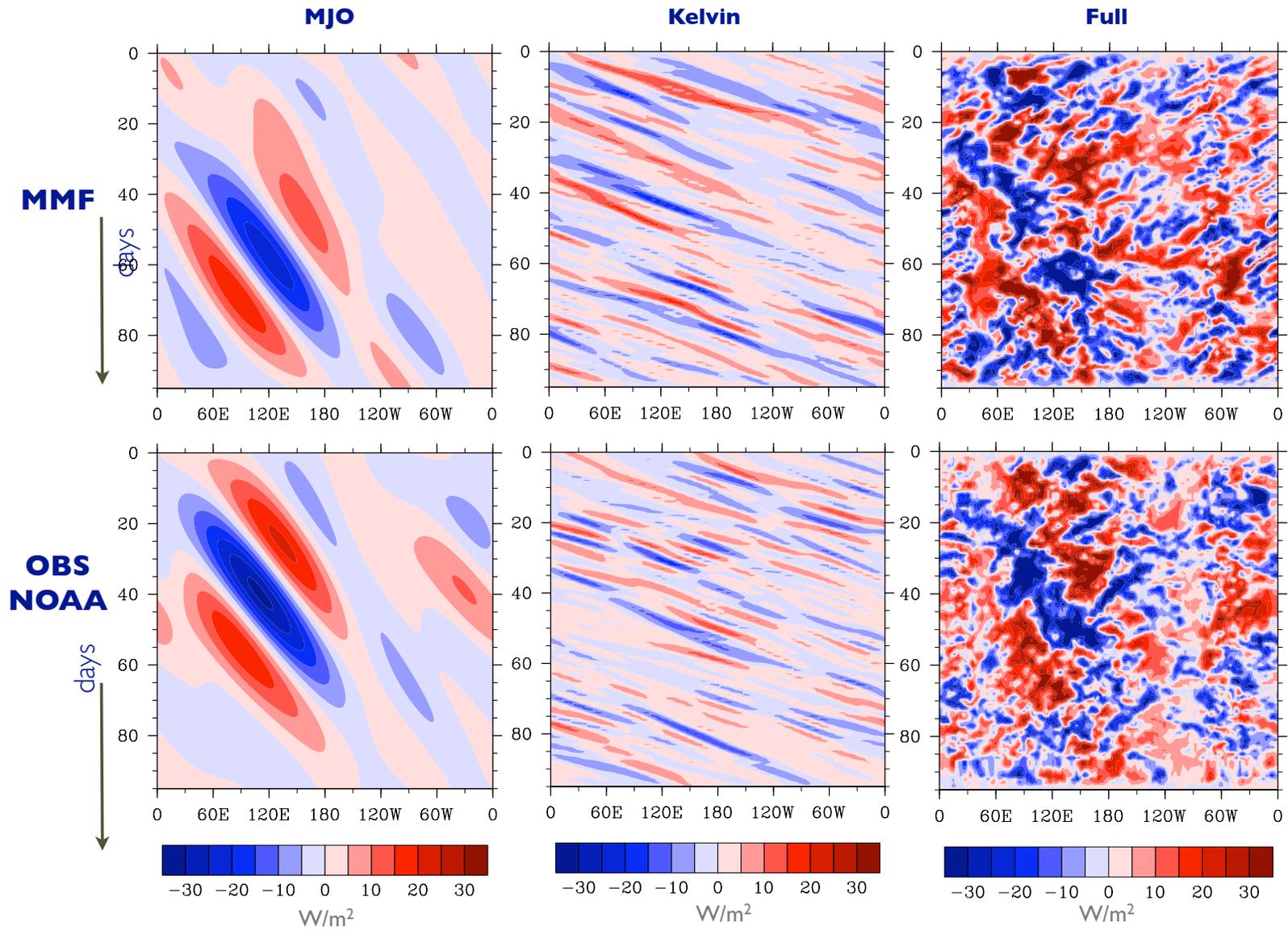


CAM3

Symmetric/Background Spectrum



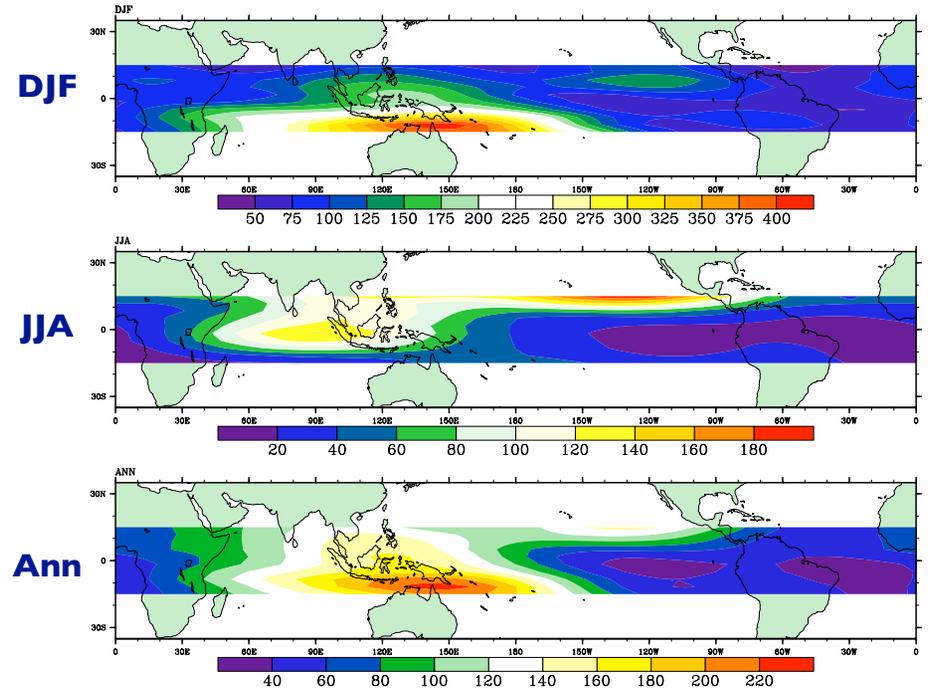
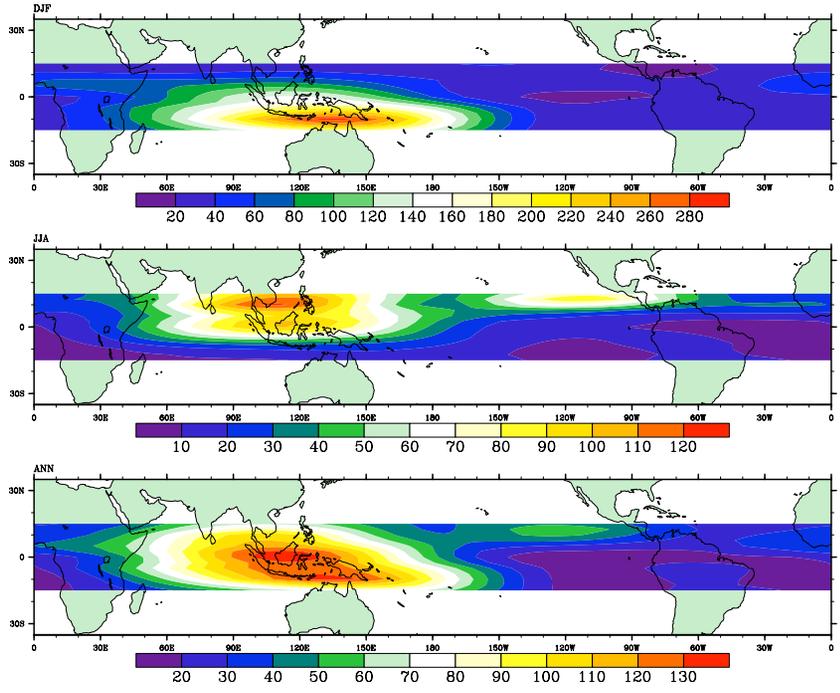
Outgoing Longwave Radiation



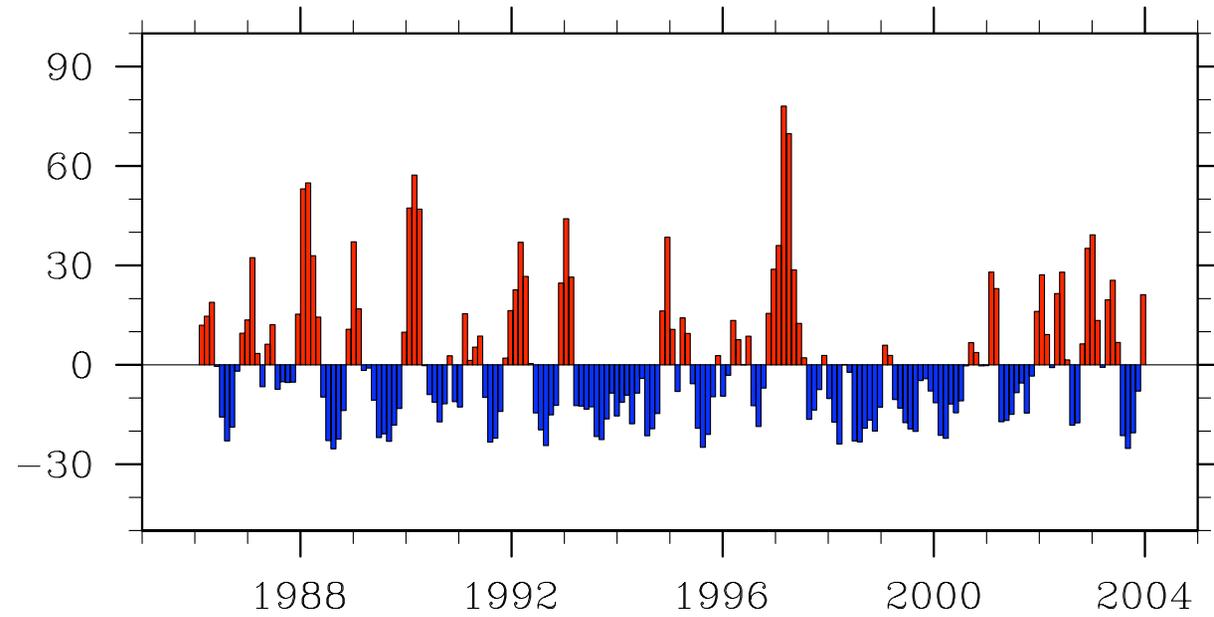
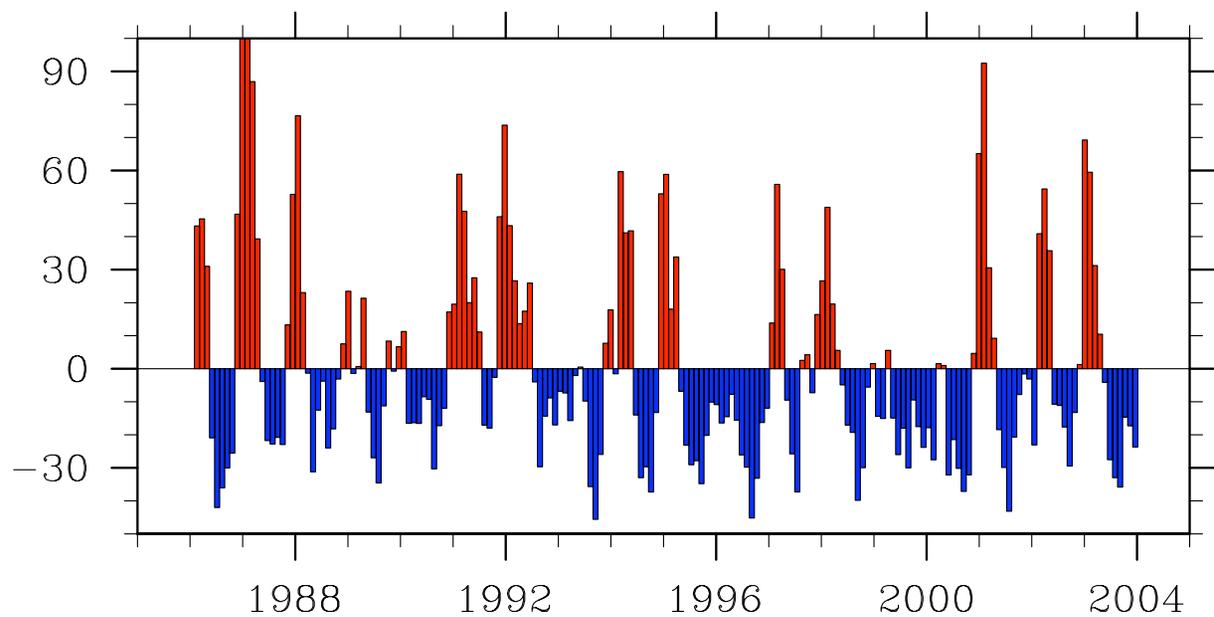
MJO Variance

NOAA

MMF



50% higher than observed



Many Issues...



Prototype MMF has many issues to resolve like 2-dimensionality and periodicity of the domain, deficit of shallow clouds, etc.

But many problems will be solved using more advanced approaches that the STC MMAP will develop, for example, Quasi-3D MMF, embedded LES, etc.