GPM for atmospheric water cycle and climate change: Trends in tropical rainfall characteristics

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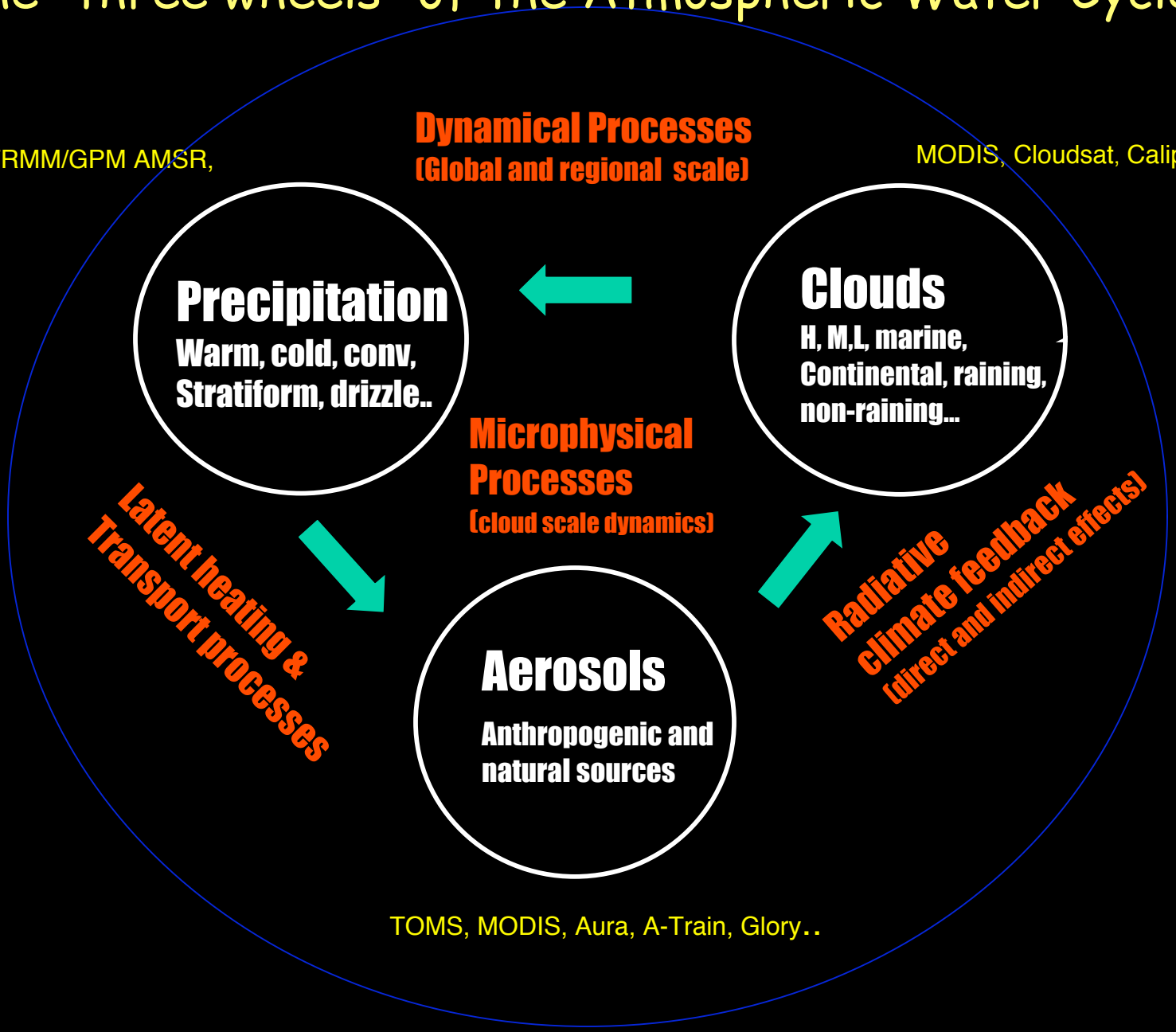
GPM/TRMM will help to answer the top level science question:

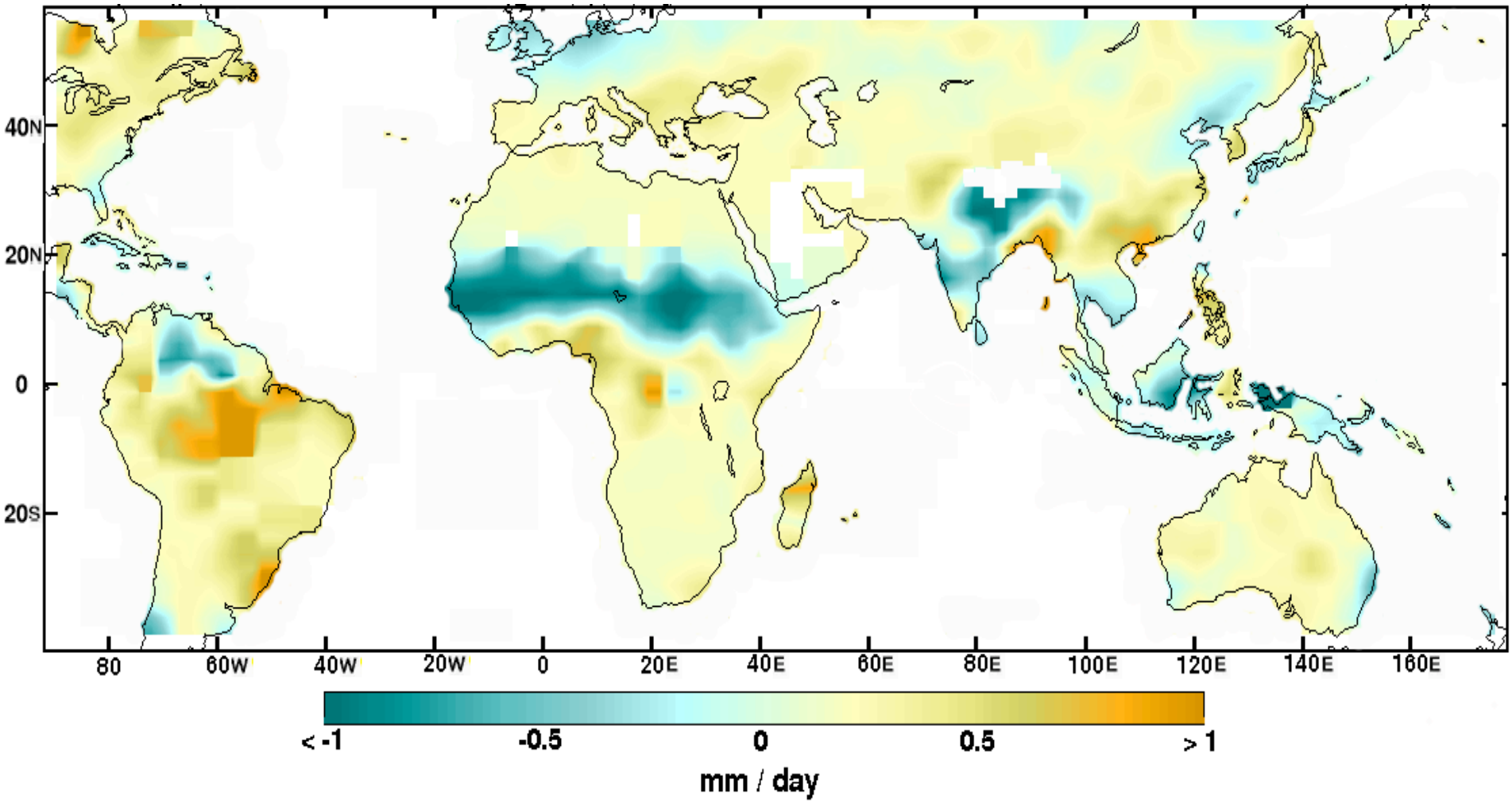
- What is the response of the atmospheric water cycle to climate change?

The "three wheels" of the Atmospheric Water Cycle



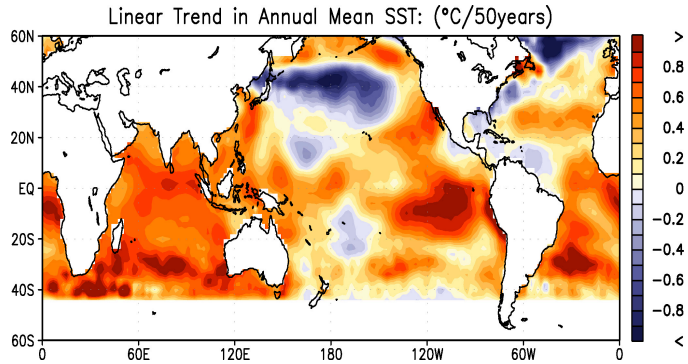
July/August Precipitation Trend

(1967-98) – (1948-66)



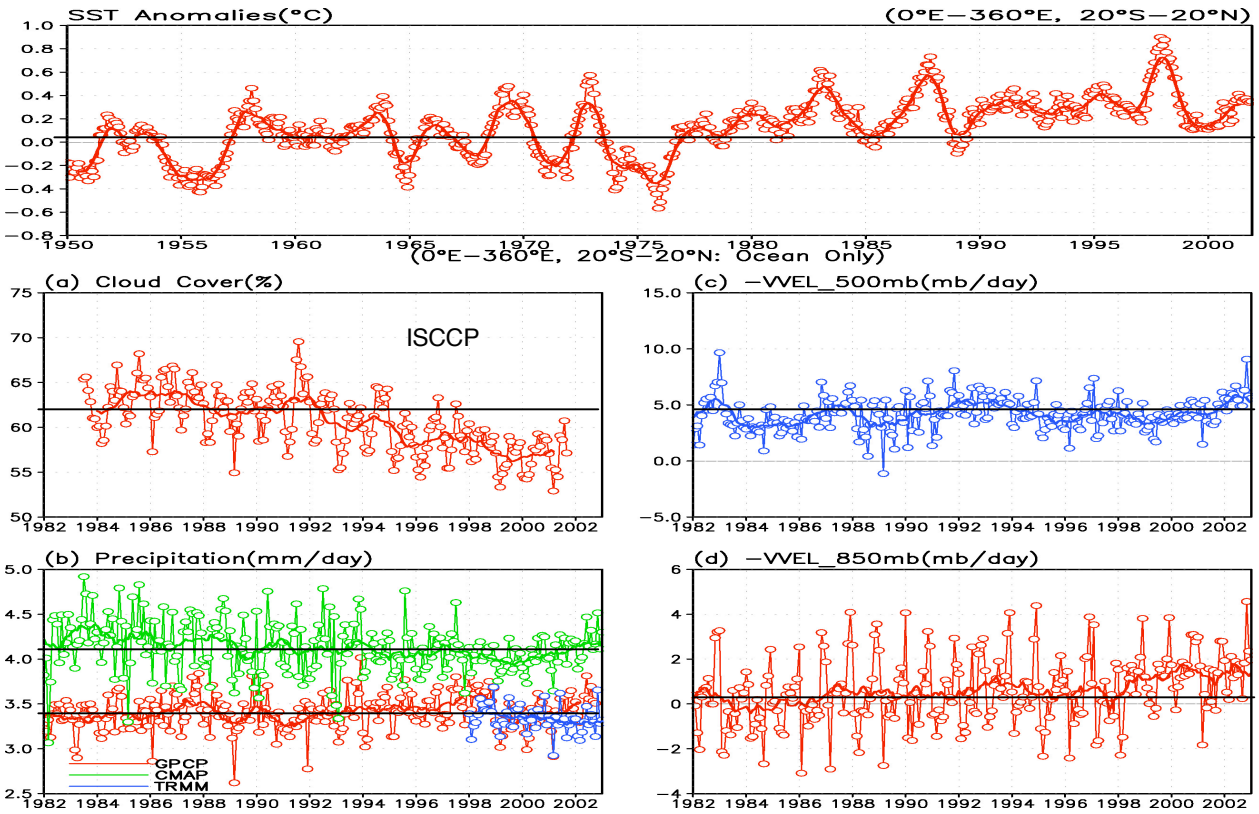
Hulme et al. 1998, Geophys. Res. Letts., **25**, 3379-3382.

Surface historical data: 2.5° latitude by 3.75° longitude

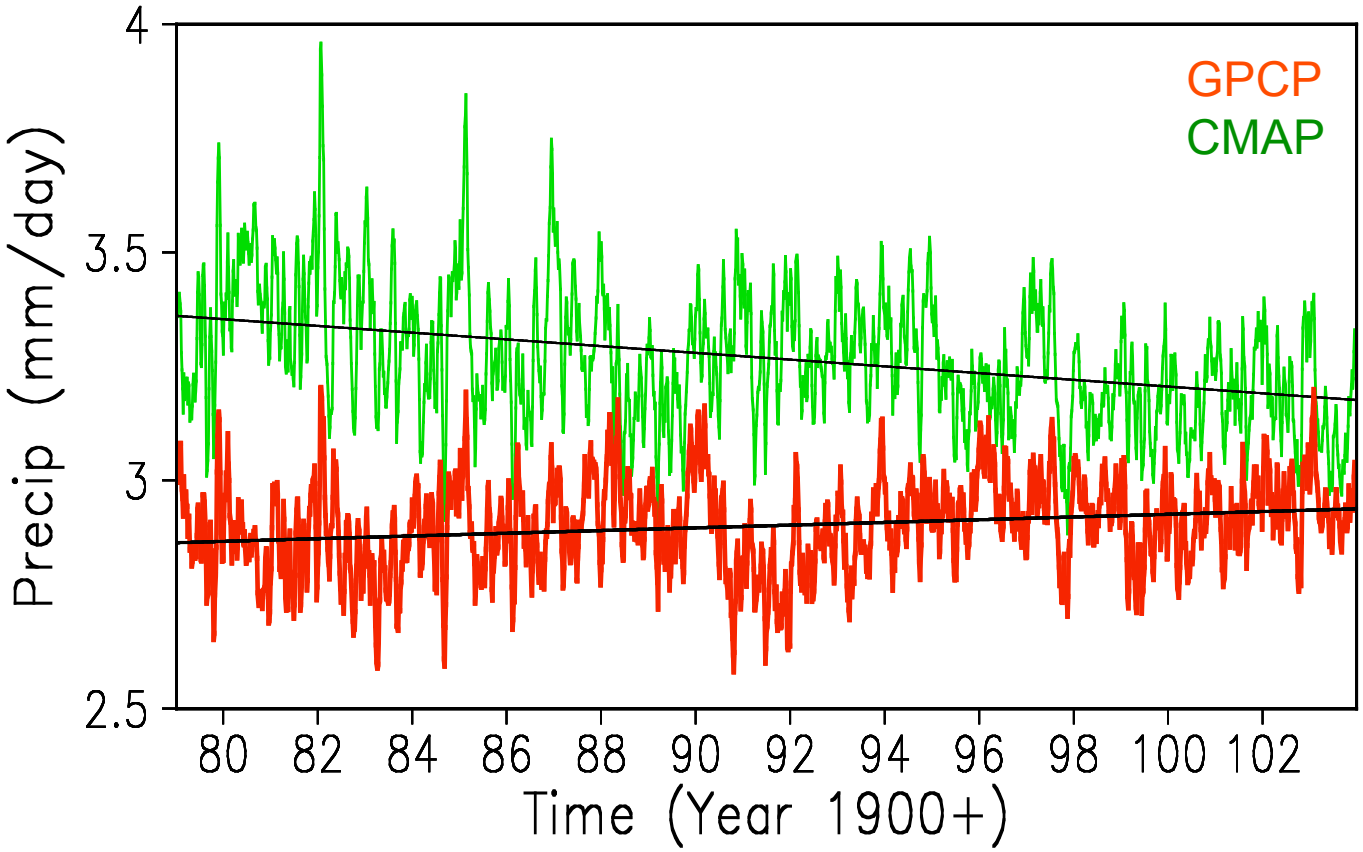


- increasing trend in tropical SST
- Increased OLR, decreasing tropical cloudiness (Weilicki et al. 2005)
- no "apparent trend" in total rainfall, but….
- increasing uplifting at lower troposphere , but not at mid-troposphere

WHY?

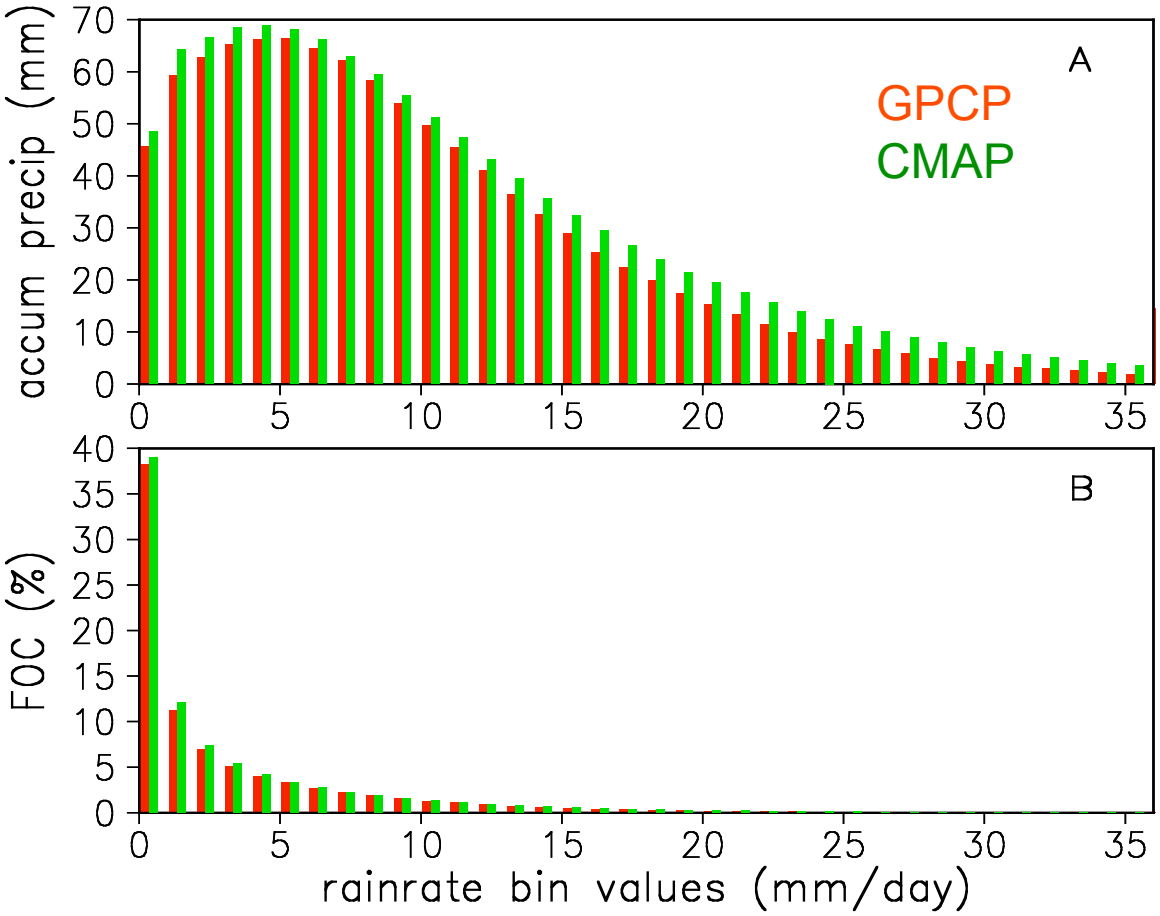


Uncertainty in the total tropical rainfall estimate



Conventional wisdom: No "apparent" long-term trend in total tropical rainfall

1979-2003 tropical rainfall PDF from 5-day mean data

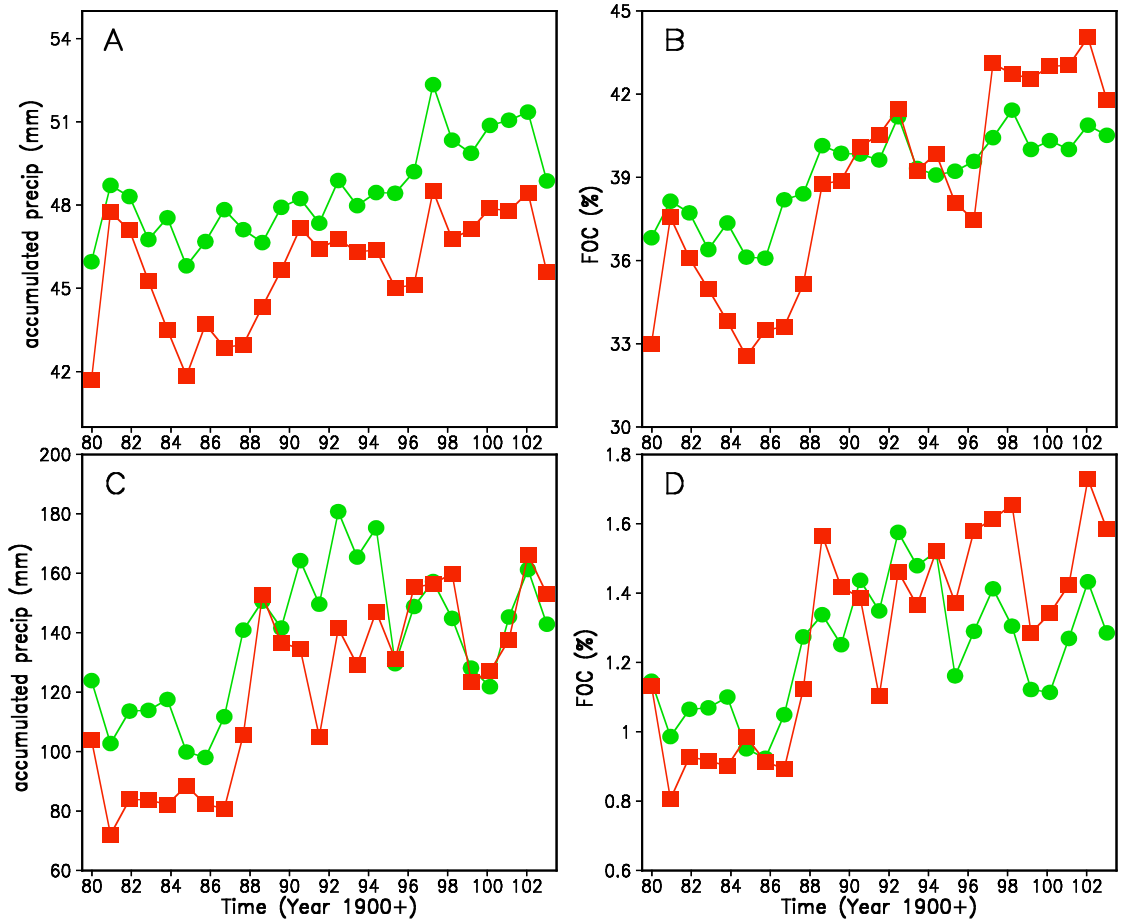


Lau and Wu (2006, I. J. Climatology, in press)

Time series of the amount and FOC for B5 and T10

B5

T10

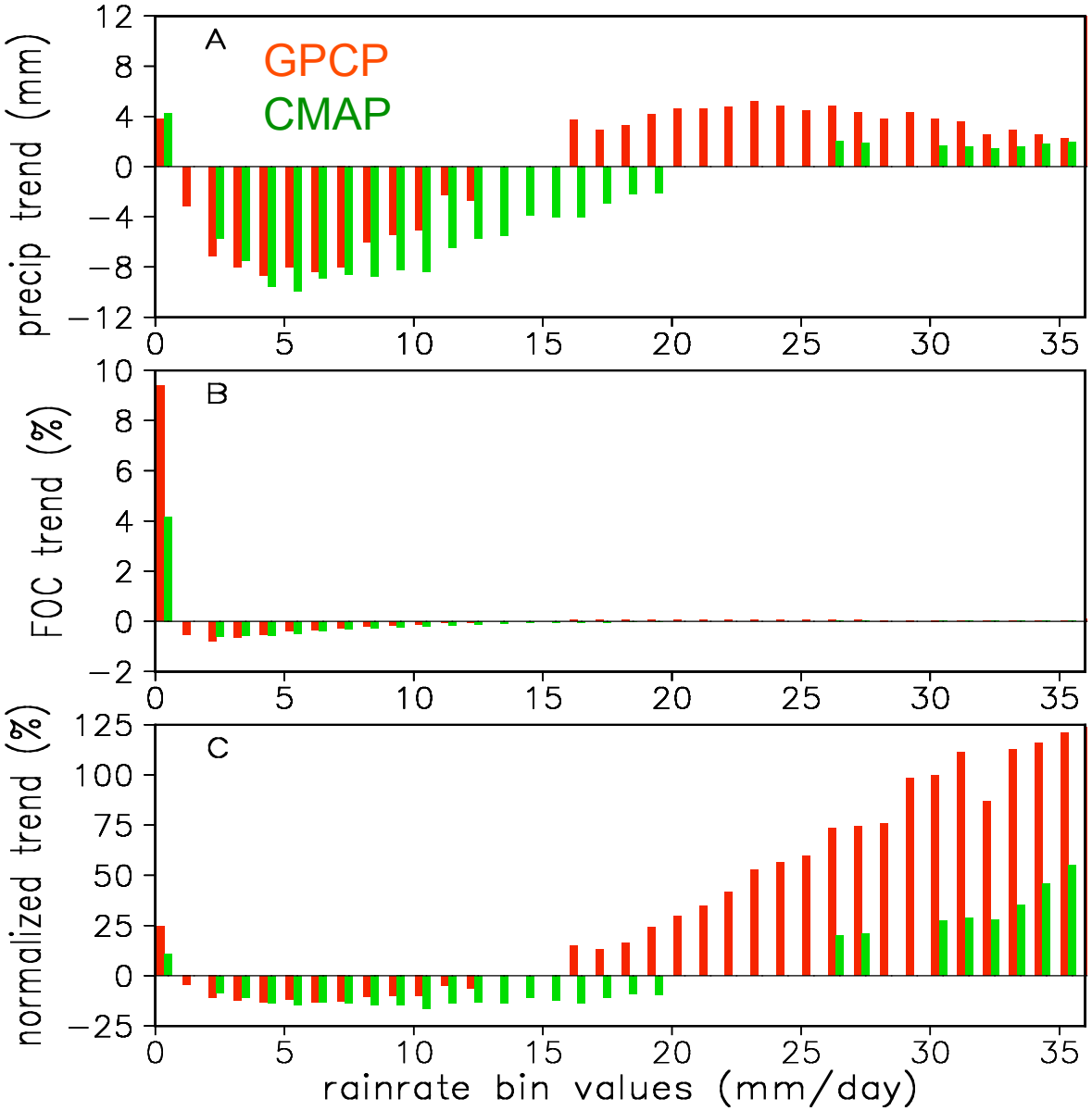


GPCP
CMAP

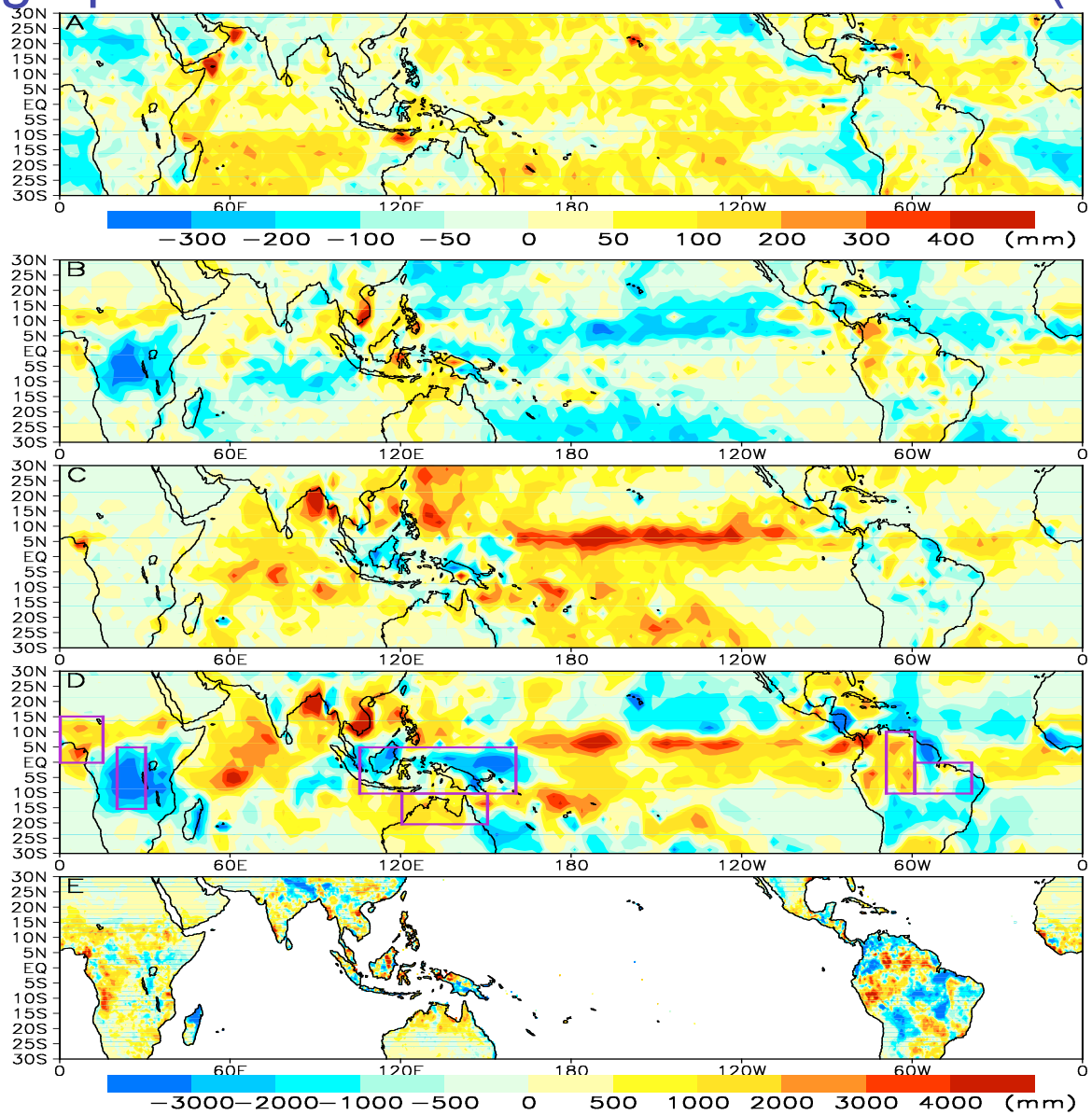
Annual Accumulation

FOC

Significant linear trend



Geographic redistribution of the rain events (GPCP)



B5

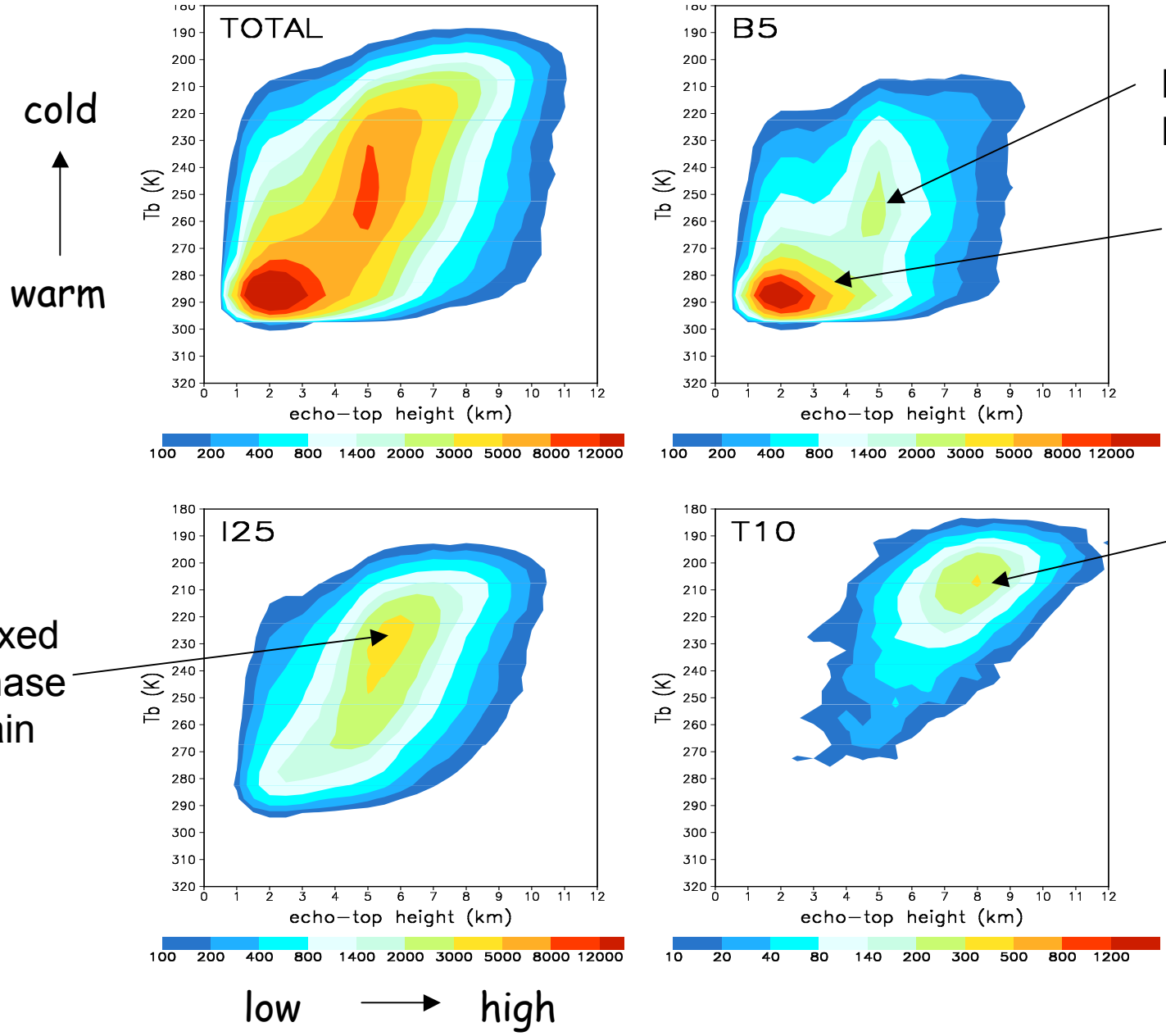
I25

T10

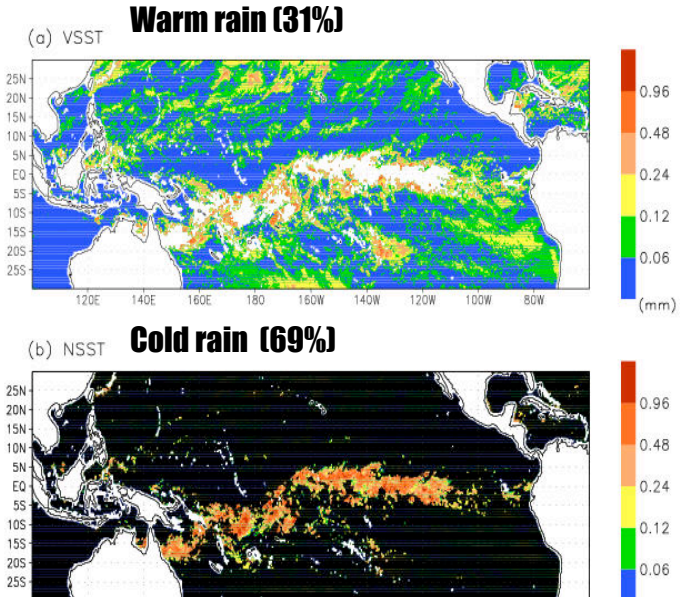
Total

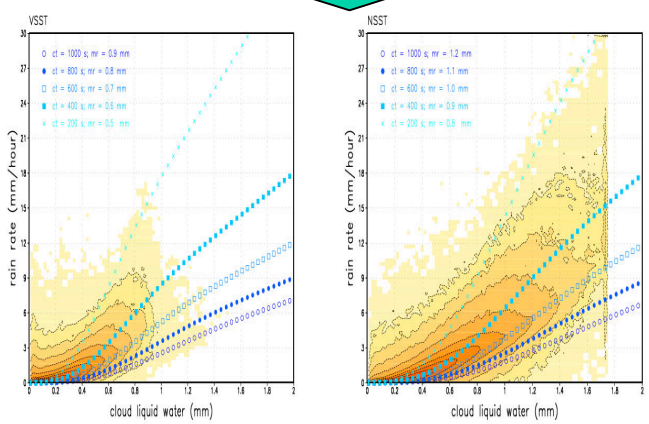
CRU total

Rainfall/cloud structures from TRMM



Increased warm rain efficiency as SST rises: results from TRMM data analysis



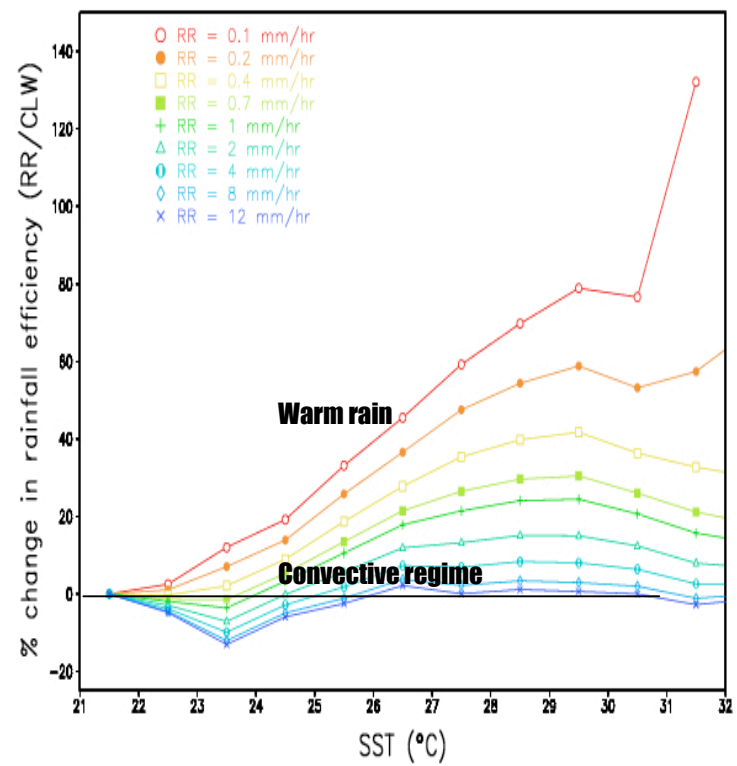


- Autoconversion rate
- threshold cloud water content

$$P = \frac{m}{\tau_0}[1 - \exp(-(m/m_c)^2)]$$

Sundqvist (1988)

Sensitivity of rainfall efficiency to SST

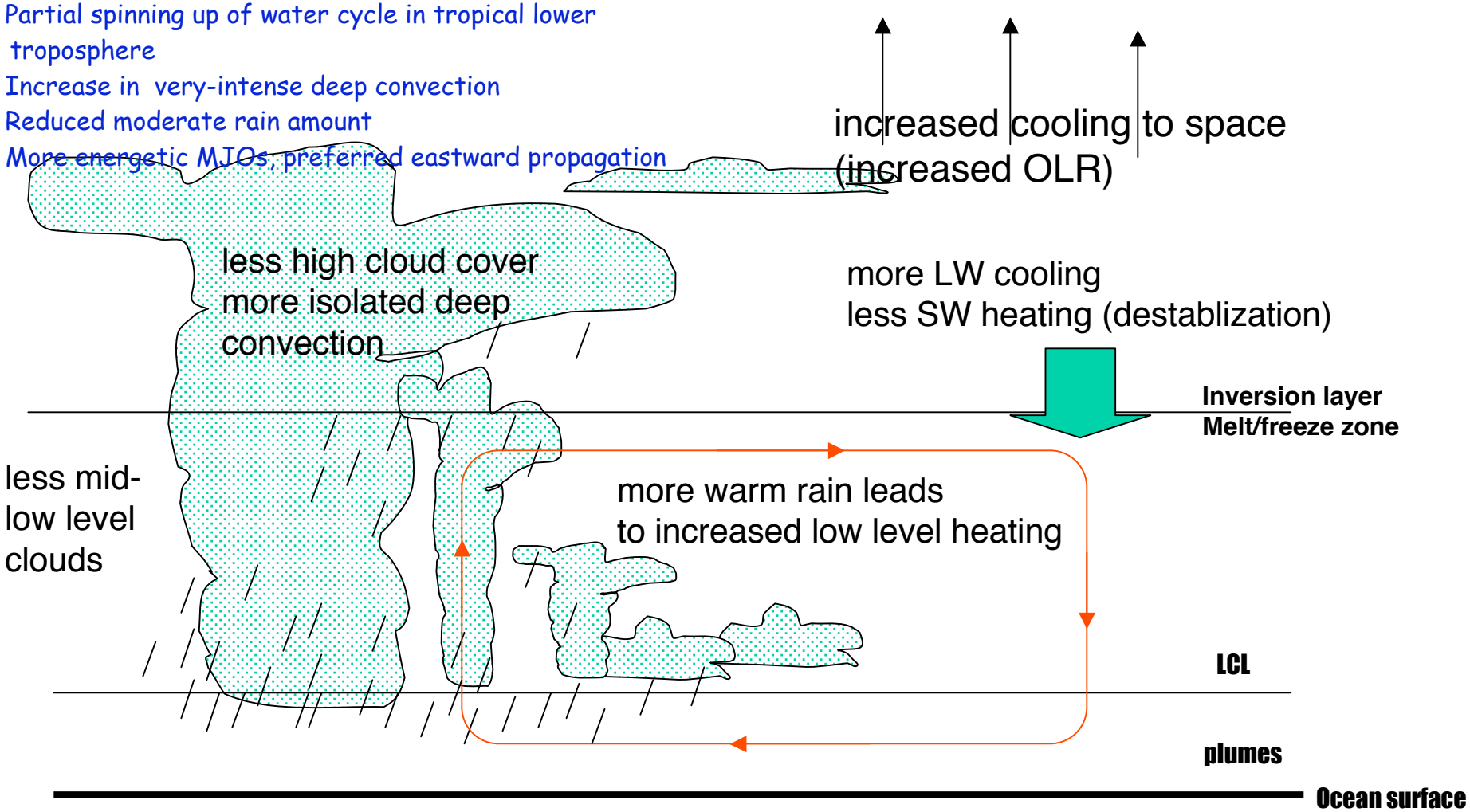


For warm drizzles, precipitation efficiency increases by 8-10% per degree rise in SST. For convective regime, precipitation efficiency is less sensitive to SST

Lau and Wu (2003, GRL)

A scenario of tropical water cycle response to global warming: Results from NASA GEOS model

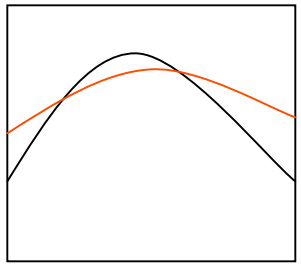
- Increase in warm rain efficiency, less clouds in the tropics
- Partial spinning up of water cycle in tropical lower troposphere
- Increase in very-intense deep convection
- Reduced moderate rain amount
- More energetic MJOs, preferred eastward propagation



Lau et al 2005, J. Climate

There are significant trends in tropical rainfall characteristics:

- A positive trend in light (warm, low, liquid phase) rain
- A positive trend in extreme heavy (cold, high, ice-phase) rain
- A negative trend in moderate (mixed phase) rain



Suggesting changes in:

- Structures in cloud/precipitation systems (different mix of rain)
- Geographic redistribution of total rain
- Large scale ascending/descending motions, including secondary circulations

Lau and Wu (2006, Int. J. Climatology, in press)

To better understand the interactions of aerosol-clouds-precipitation and global change, we need:

A unified approach to study the impacts of suspended particles in the atmosphere as a continuum from aerosol nucleation , growth of cloud droplets to rain drops

GPM/TRMM is the centerpiece of atmospheric water cycle (precipitation, clouds and aerosols), and climate change research and applications

There is increasing evidence that :

- Tropical mean rainfall may be resilient to climate change, because of large compensations, and redistribution; but changes in rain-cloud types and structure, and extremes may be more detectable than the total accumulation.
- Microphysics (autoconversion, CCN, liquid and ice phase nucleation) may be the first responder to climate change through thermodynamics and aerosol effects;
- Tropics (convection-dominant) and extratropics (dynamics-dominant) may respond differently to climate change
- Large societal impacts occur on human scale, e.g hurricanes, Sahel drought

GPM strategy for atmospheric water cycle and climate change studies:

- GPM/TRMM will provide continuity of long-term, high-quality, high resolution (spatial and temporal) rainfall and related datasets to serve as the community standard, and bases for error estimates.

- GPM (increased sampling, HF channel) will enable the identification of structural changes of tropical and extratropical rain/clouds structures, including light rain and ice-phase precipitation

- GPM will provide better definition and understanding of physical processes underlying long-term shift in PDF, particularly light rain, and solid precipitation.

- Detection and attributions of causes of trends (>decades) in water cycle should not depend on a single observable, but rather on multiple observables from other sources e,g, Cloudsat-Calipso, MODIS, water vapor etc., subject to constraints from fundamental physical principles,