Satellite View of Quasi-Equilibrium States in Tropical Convection and Precipitation Microphysics

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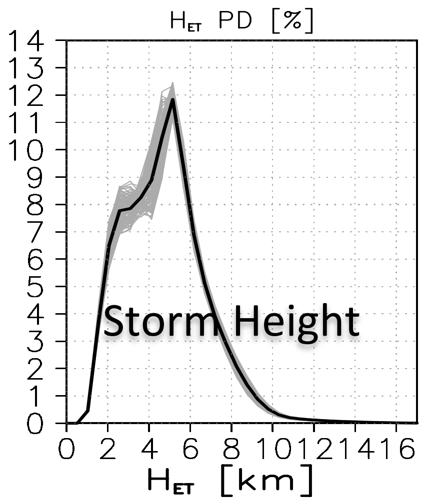
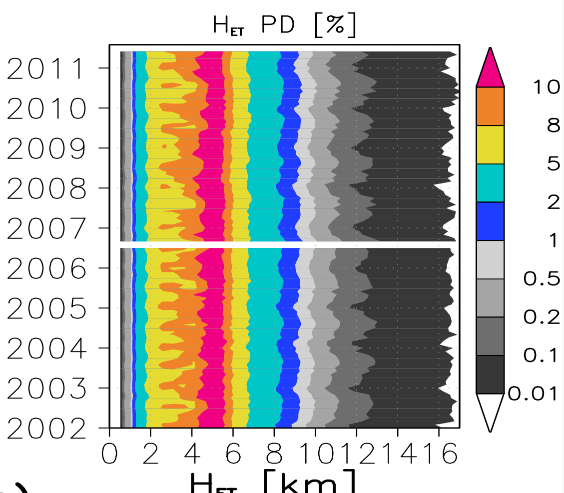
Quasi-Equilibrium State of TRMM Precipitation Signals



a)



b)

Precip Intensitiy & Microphysics

Precip Ice

Precipitation Intensity Spectrum

PR MP: Apply MP PSD into PR climatology

Marshal-Palmer (MP) PSD

$$N(D) = N_o \exp[-\Lambda D],$$

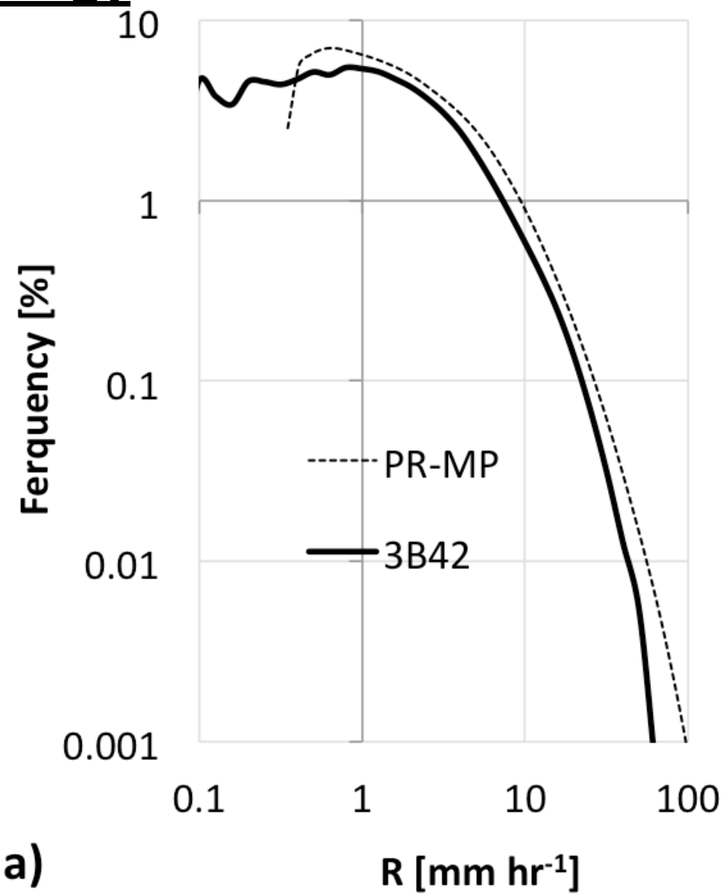
$$Z = \int D^6 N(D) dD = aR^b,$$

where

$$a = \Gamma(7)\left[\frac{\pi}{6}\alpha\Gamma(4+\beta)\right]^{\frac{-7}{4+\beta}} N_o^{\frac{-(3-\beta)}{4+\beta}}$$

$$b = \frac{7}{4+\beta},$$

where coefficients a and b are 296 and 1.47,

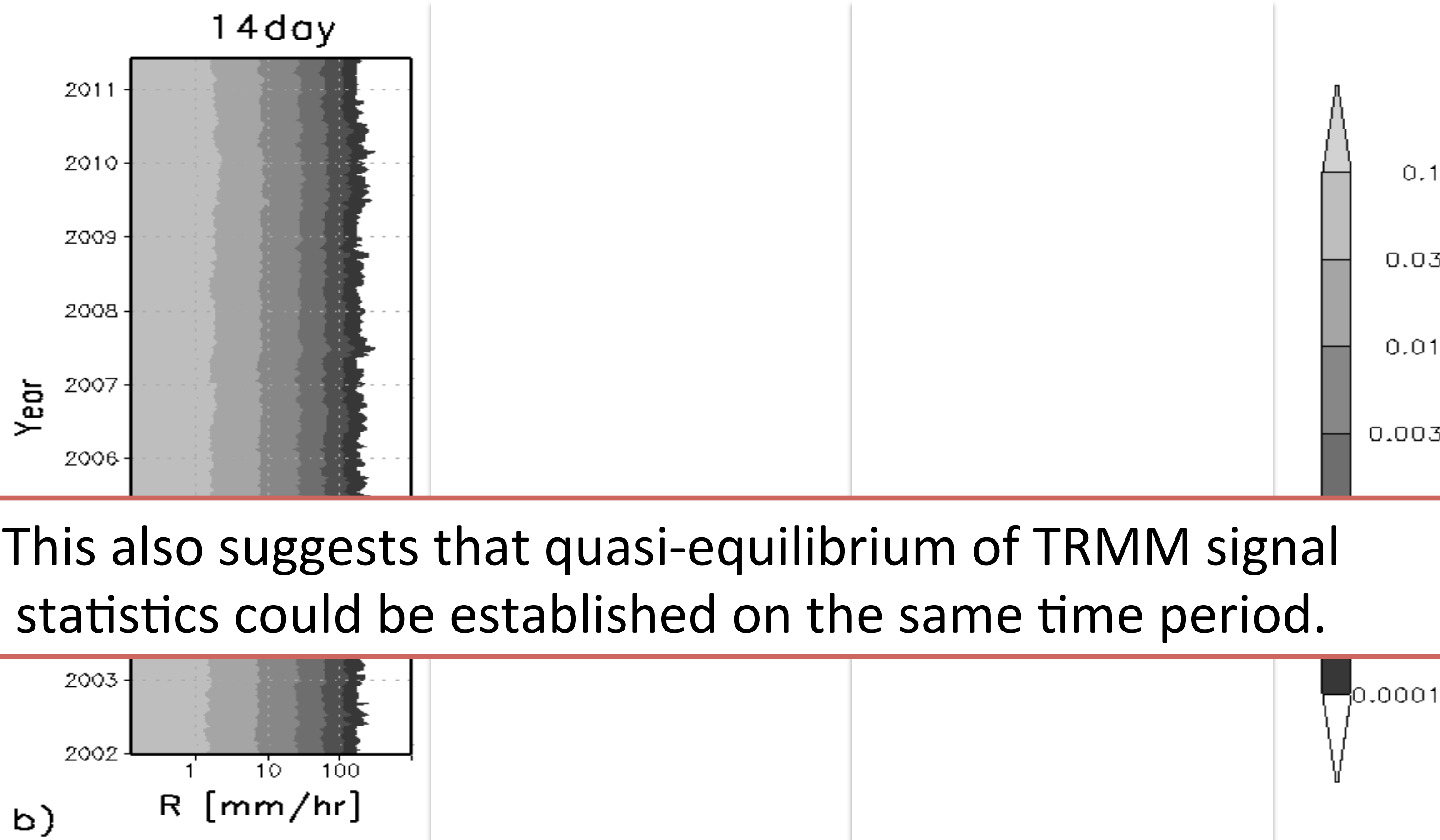


a)

3B42: TRMM Merged Precipitation

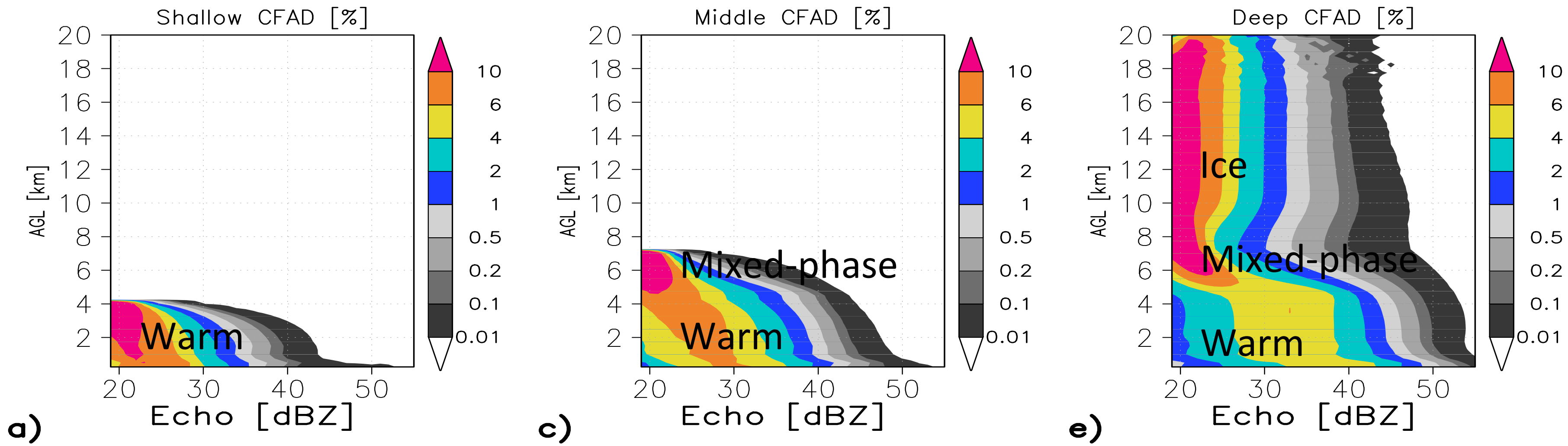
Time Scale of Adjustment

Quasi-equilibrium state of precipitation intensity distribution could be established down to at least **a one-day time period**.



This also suggests that quasi-equilibrium of TRMM signal statistics could be established on the same time period.

Time-Invariant PR *CFAD*|$_{tropics}$



Tropical precipitation microphysics is in a quasi-equilibrium state.

Microphysics Quasi-Equilibrium (MQE)

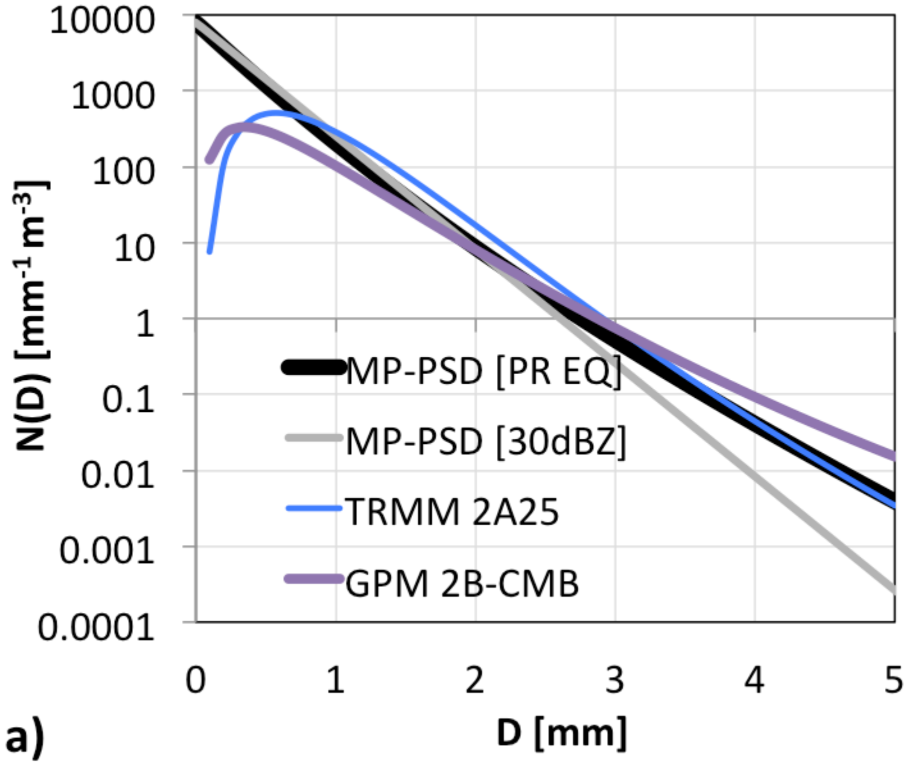
Tropics Integrated Precipitation Microphysics

PS−PSD: Marshal-Palmer (MP) PSD

$$N(D) = N_o \exp[-\Lambda D],$$

$$N(D,Z) = N_o exp\left[-4.1\left(\frac{Z}{a}\right)^{0.12/b} D\right]$$

$$N(D)|_{tropics} = \int N(D,Z)\, pd(Z)\, dZ$$



a)

TRMM 2A25

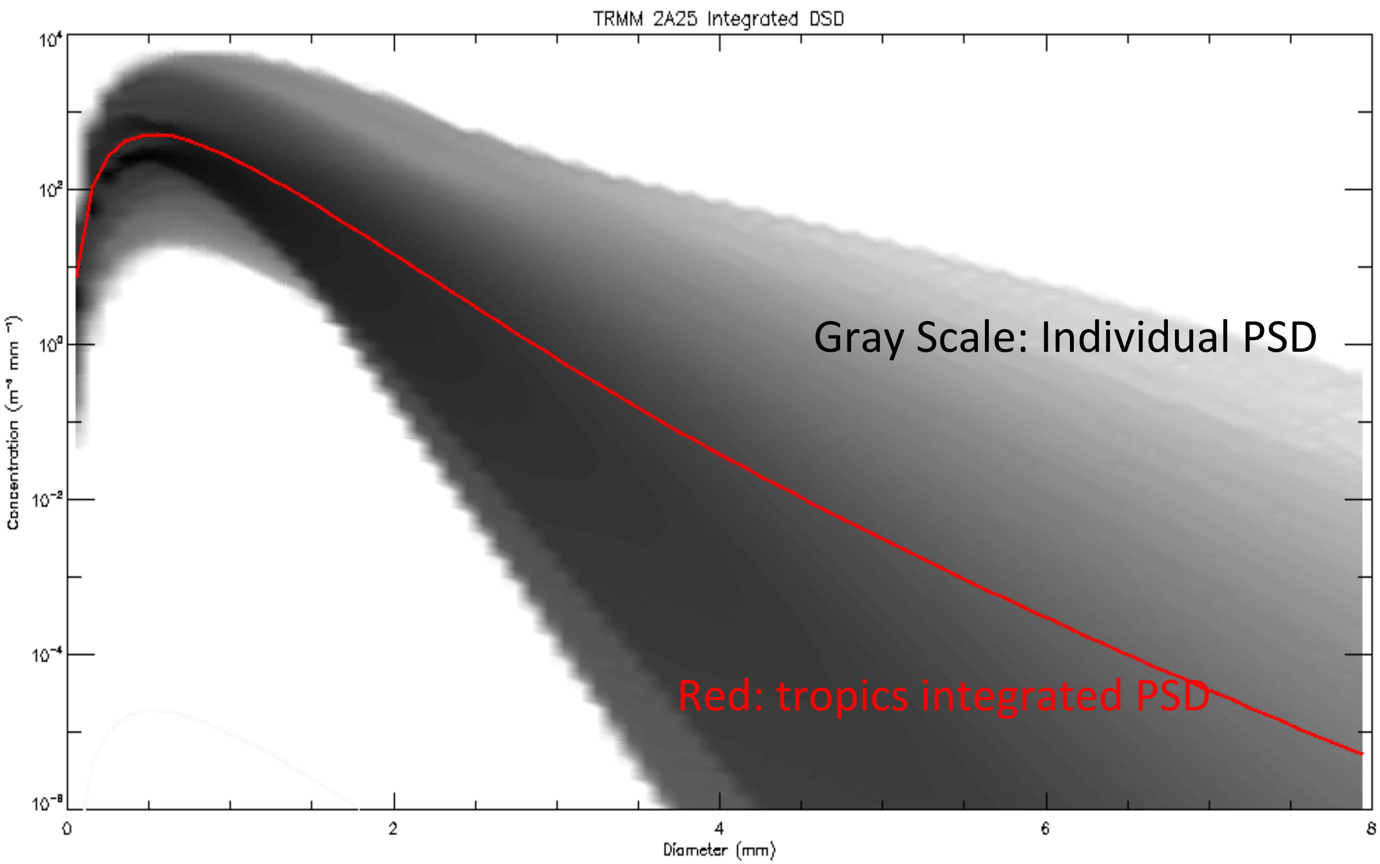
Gamma PSD

GPM 2B-CMB

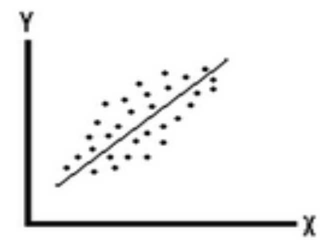
Gamma PSD:
On-nadir only

$$N(D) = N_0 D^{-\mu} \exp[-\Lambda D]$$

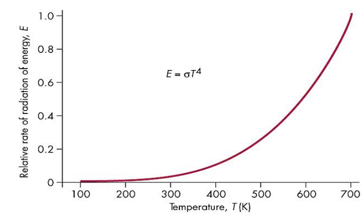
Spectrum of 2A25 PSD



Parameterization



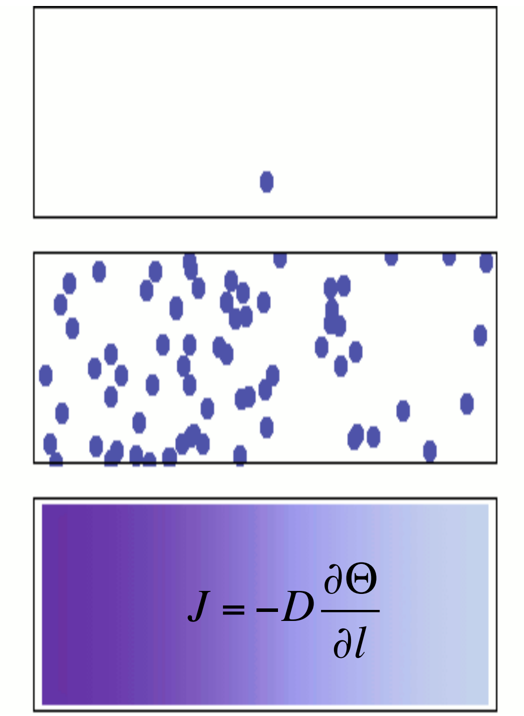
Physics Law



Law of Large Numbers

Law of Large Numbers

Laws of Diffusion



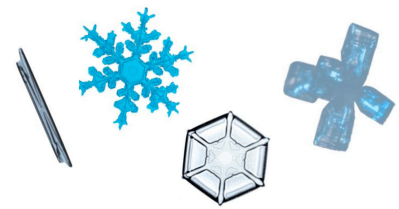
2.69 x 10^{19} cm^{-3} for STP

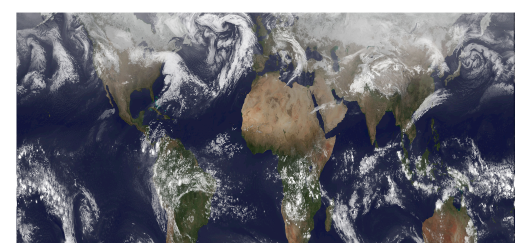
Randomness of single particle

Some deterministic some randomness

Deterministic macroscopic phenomenon

Microphysics





TRMM PR sample ≈ 6.6 x 10^6 / mon
Precip Particle → ~3.3 x 10^{20} / mon

Near-Constant Precipitation and Latent Heat

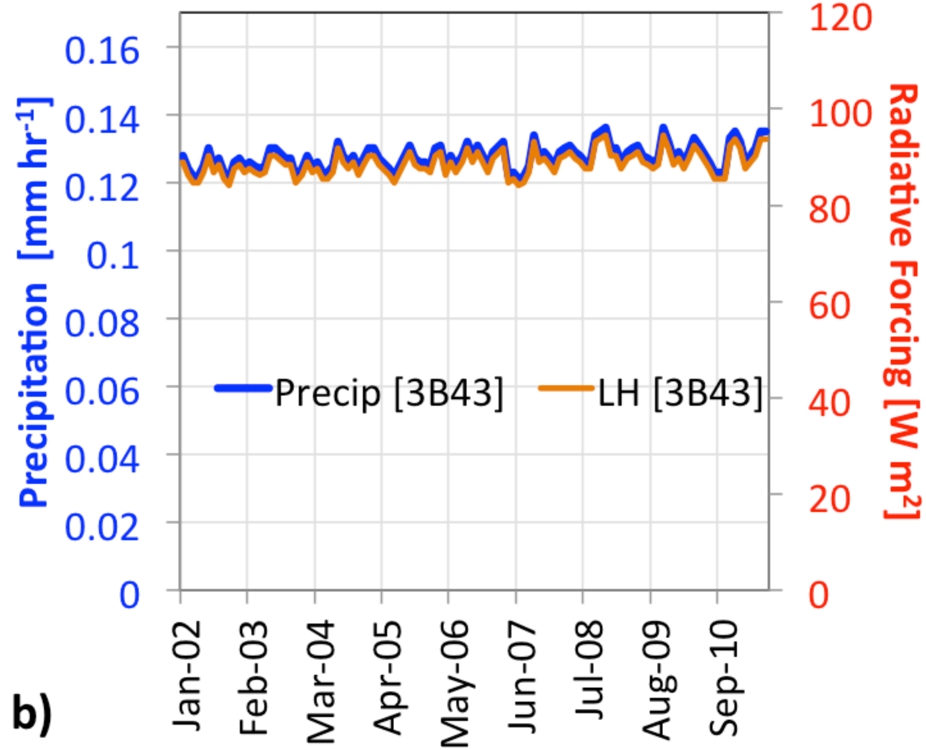
$$R|_{tropics} = \int \rho_l \frac{\pi}{6} D^3 \, V_t(D) \, N(D)|_{tropics} dD$$

MQE: $$\frac{\partial N(D)|_{tropics}}{\partial t} \approx 0$$

$$R|_{tropics} \approx const$$

$$LH = \frac{L_v}{C_p} \frac{M_{cond-evap}}{M_{air}} = \frac{L_v}{C_p} \frac{R}{M_{air}}$$

$$LH|_{tropics} = \frac{L_v}{C_p M_{air}} R|_{tropics} \approx const$$

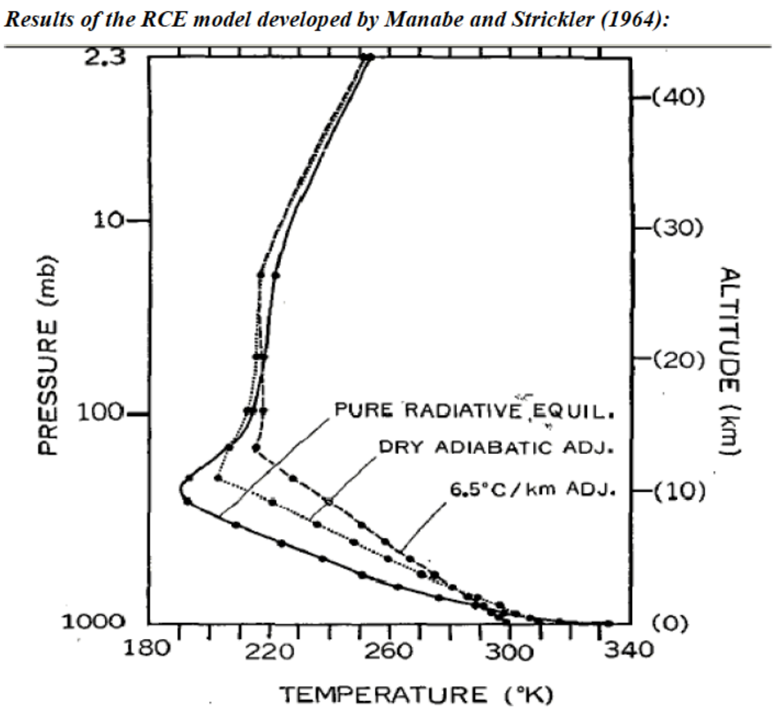


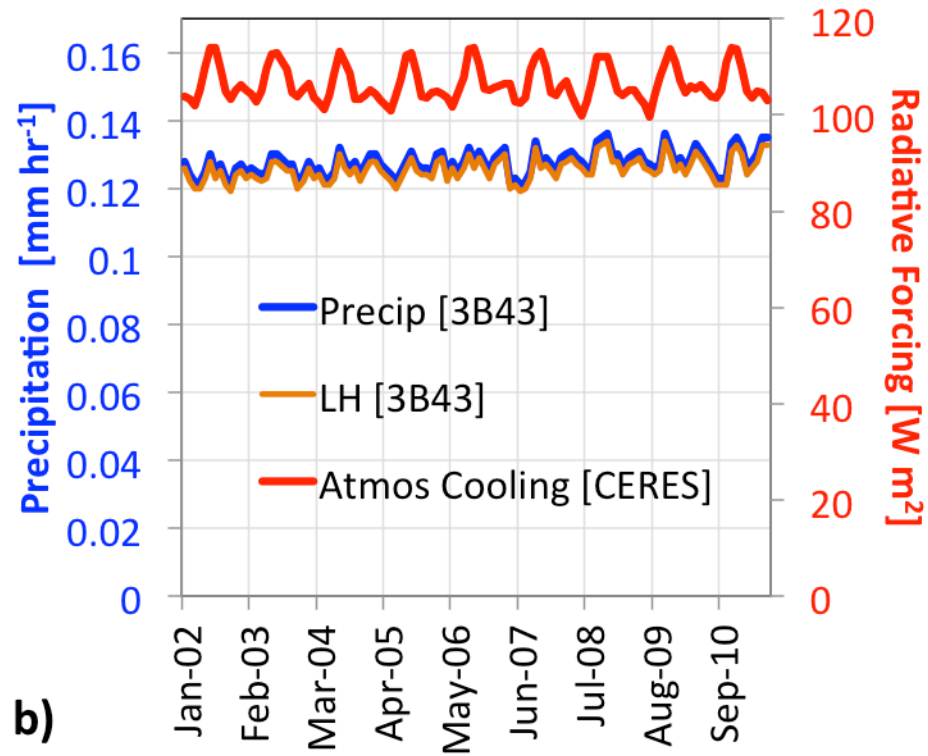
b)

i) dry air specific heat C_p (1004.67 J kg^{-1} K^{-1}), ii) tropical surface pressure ($P_s|_{tropics}$=994 mb) to estimate M_{air} (=10132 kg m^{-2}).

MQE hypothesis does not conflict with the satellite observational record of nearly constant precipitation rate

Latent Heat and Radiative Cooling





Radiative Equilibrium (i.e., atmospheric cooling rate), is adjusted by convection (i.e., LH + SH). → RCE

Nearly constant LH rate is closely balanced with atmospheric radiative cooling rate (r=0.44).

Convective-Microphysics Quasi Equilibrium (CMQE)

- CMQE → planetary-scale convection and microphysics spectrum equilibrium, including tropical dynamics (e.g., ENSO, MJO, waves, etc.).

- Precipitating Radiative Convective Equilibrium (PRCE) is the equilibirum state w/o circulation.

- Ok, what's deal?

Convective-Microphysics Quasi Equilibrium (CMQE)
Importance of Single-Day Convergence:
Sanity Check of GCRM & MMF Quality

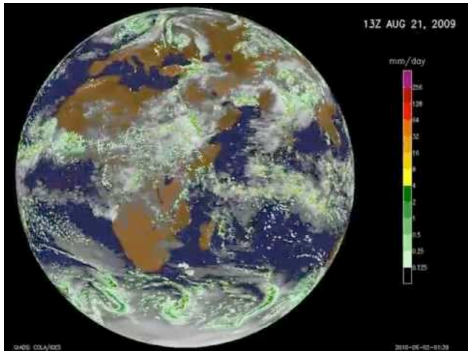
Single-Day Sample of simulated CMQE from global models.

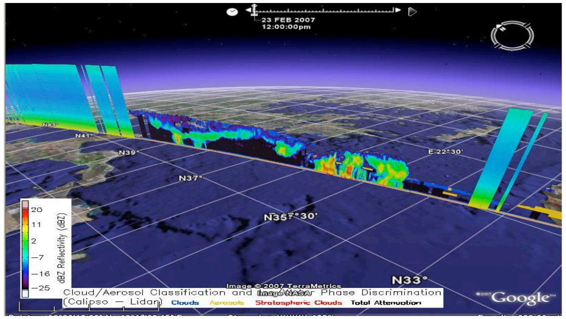
≈

Satellite-derived global CMQE climatology.

Run global CRM / MMF on 1day (after spin-up). That's enough for evaluating convection and microphysics spectrum.

Even if swath is limited (e.g., active sensor), sampled over large area and long-term until statistics converge, satellite data is still useful information for model evaluation.





Summary

Conclusion

- As long as sampled over the entire tropics, precipitation signals and characteristics are in quasi-equilibrium state.
- Convective -microphysics quasi-equilibrium (CMQE) is established.

Next Steps

- Re-examine CMQE in GPM data.
- Examine perturbation of CMQE via +2K SST and aerosols in NASA MMF and NICAM.
- Develop rigorous theoretical framework to describe CMQE.