Evaluation of the Effects of Stochastic Convection Scheme in E3SMv1

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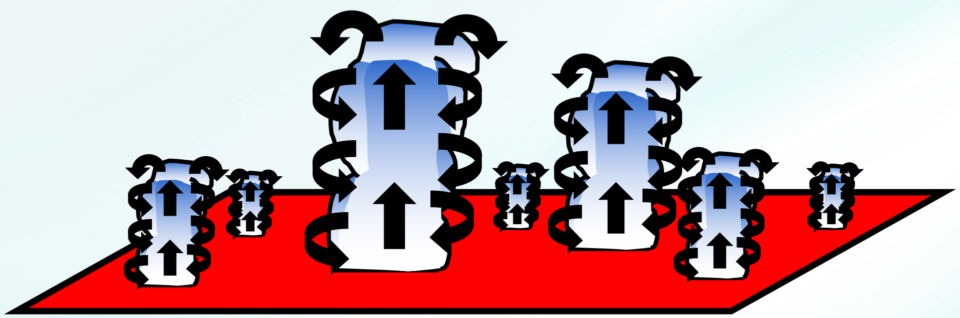
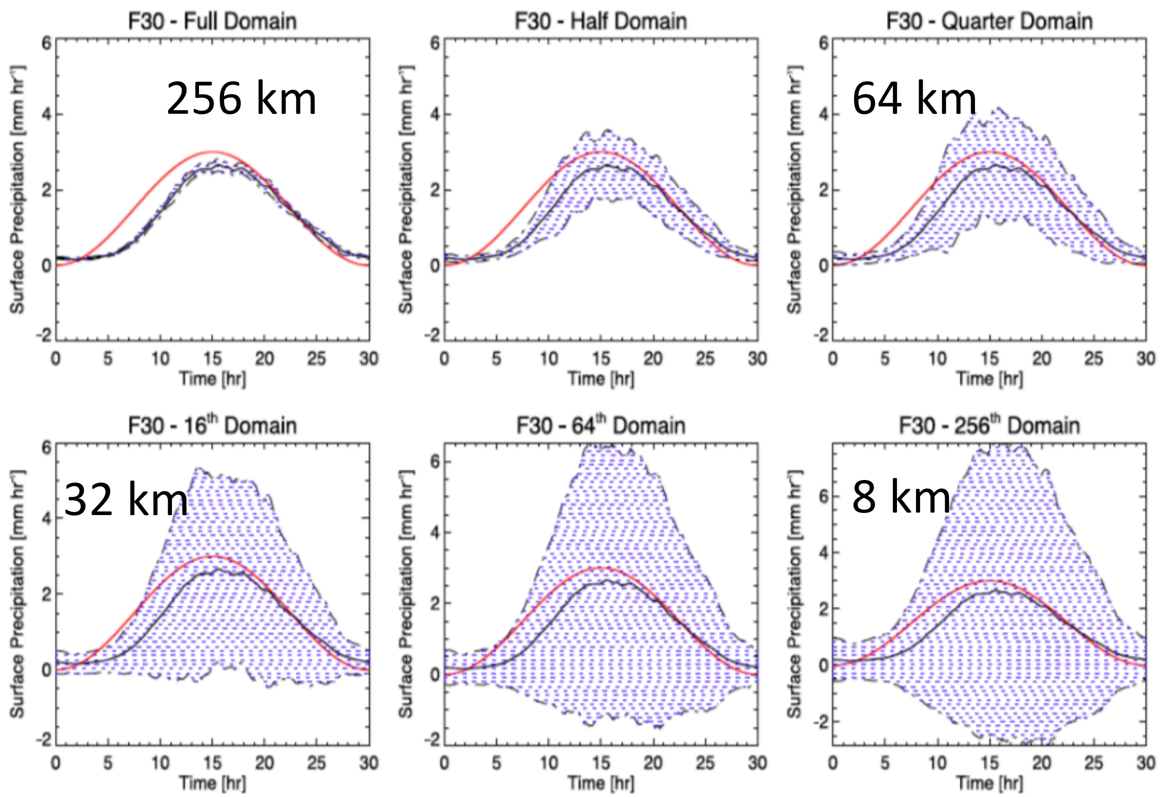
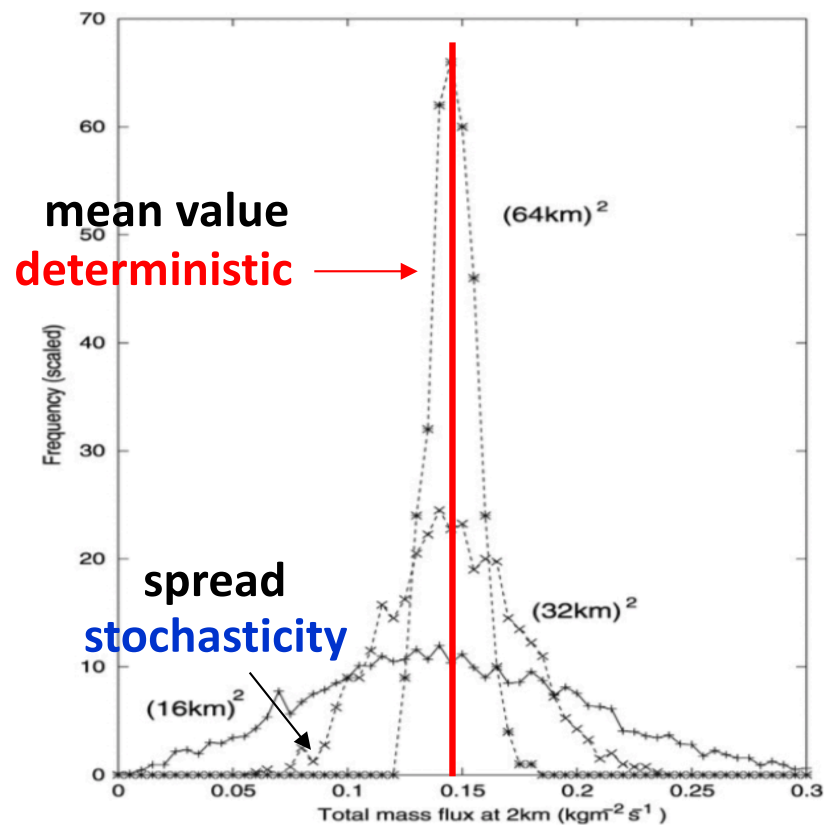
Outline of This Talk

- Why stochastic parameterization?
- Brief outline of parameterization specifics
- Results
- Summary



Stochasticity of Convection





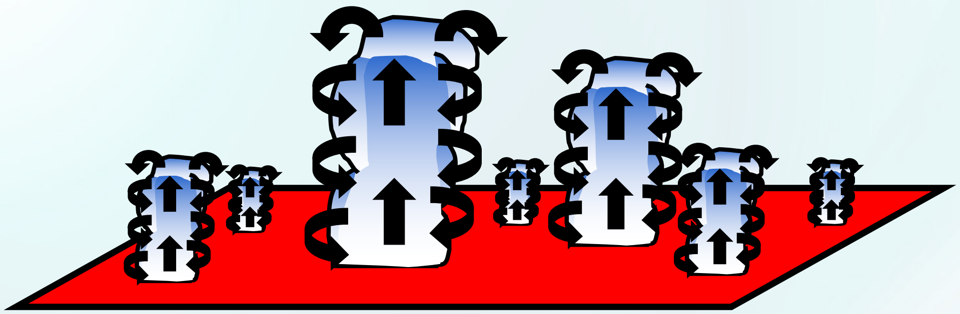
Stochasticity increases with model resolution

Jones and Randall (2011)

Plant and Craig (2008)

A physically based stochastic convection model (Plant and Craig 2008)

Mass flux of a cloud follows Boltzmann distribution



The probability of having n clouds follows Poisson distribution

$$p(m)dm = \frac{1}{<m>} e^{-m/<m>} dm$$

Assume non-interacting clouds:
cloud mass flux follows Boltzmann distribution

$$p_{N_m}(n) = \frac{<N_m>^n e^{-<N_m>}}{n!} \quad \text{for n=0, 1, 2,...}$$

Assume clouds are initiated randomly in space, triggering n clouds follows Poisson distribution

$$p_{d\bar{n}(m)}(n=1) = \frac{<N>}{<m>} e^{-\frac{m}{<m>}} dm$$

- **The probability of triggering one cloud with mass flux between *m* and *m*+d*m***

Coupling PC08 with the ZM deterministic scheme

$$p_{d\bar{n}(m)}(n = 1) = \frac{<N>}{<m>} e^{-\frac{m}{<m>}} dm \qquad where < N > = \frac{<M>}{<m>}$$

- The ensemble-mean mass flux <M> is obtained from the ZM scheme.
- The probability is compared with a random number, generated once every 3 days, to determine whether a cloud with mass flux between m and m+dm is launched.
- The tendencies of T and q from all clouds in a grid-box produced this way are summed to obtain the total convective tendencies.

Model Simulations:

- **AMIP (5 years each) for 1° resolution**
- **AMIP (3 years each) for RRM (1/4 ° in CONUS, and 1° everywhere else**

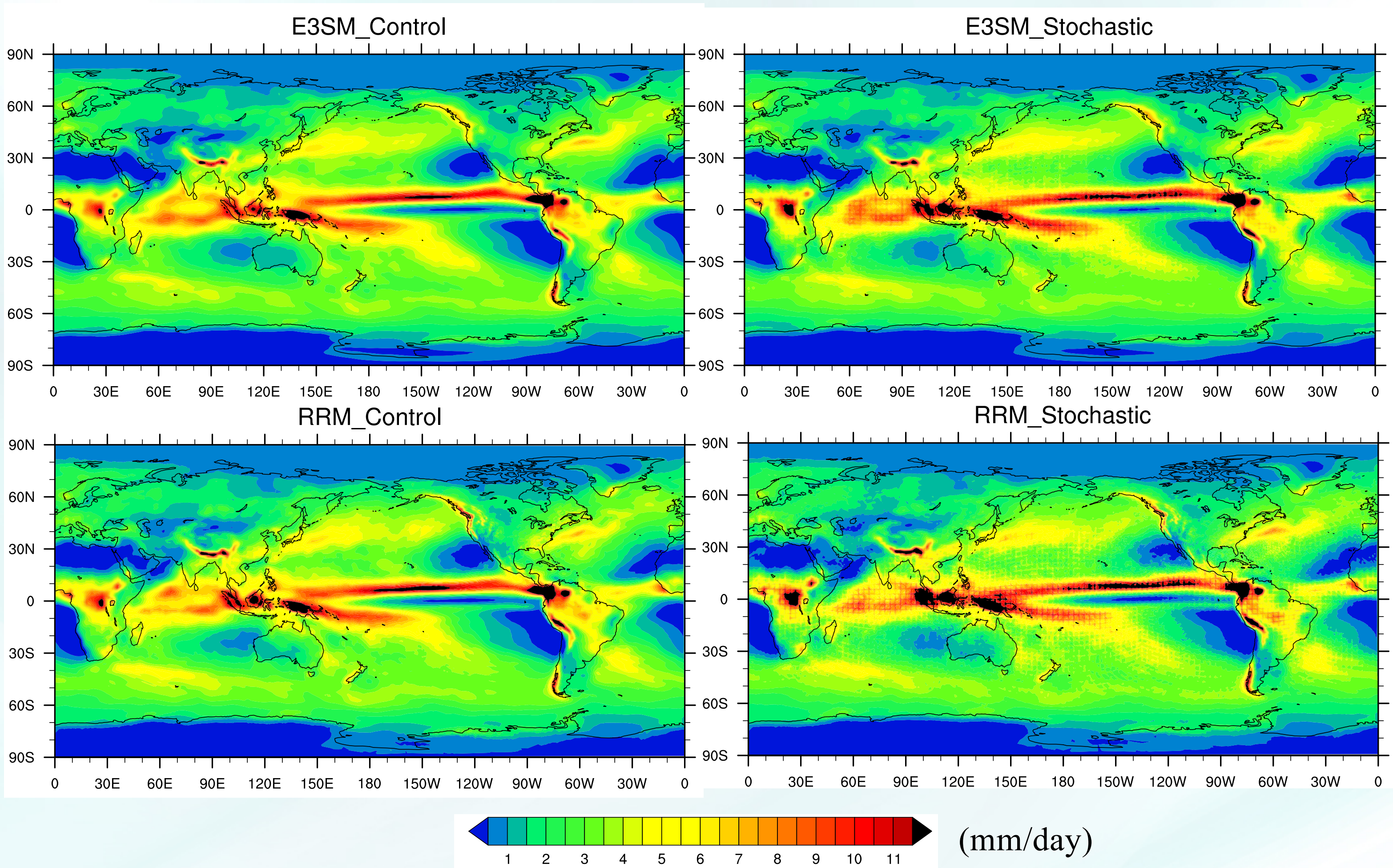
CTL: Standard E3SMv1 Model
Stoch: Stochastic Parameterization

Precipitation

E3SM Control Run | Stochastic Run

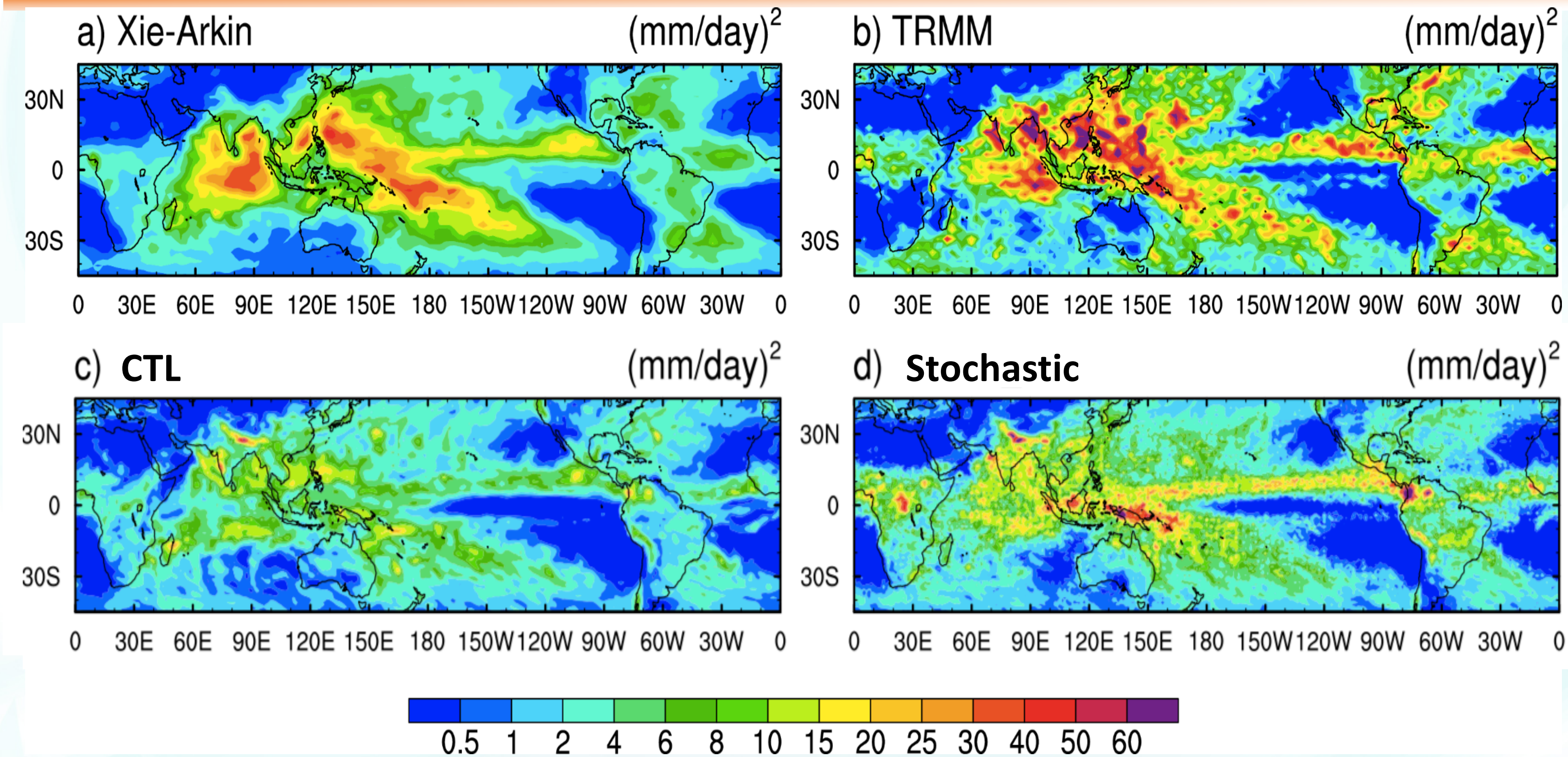
1°

RRM



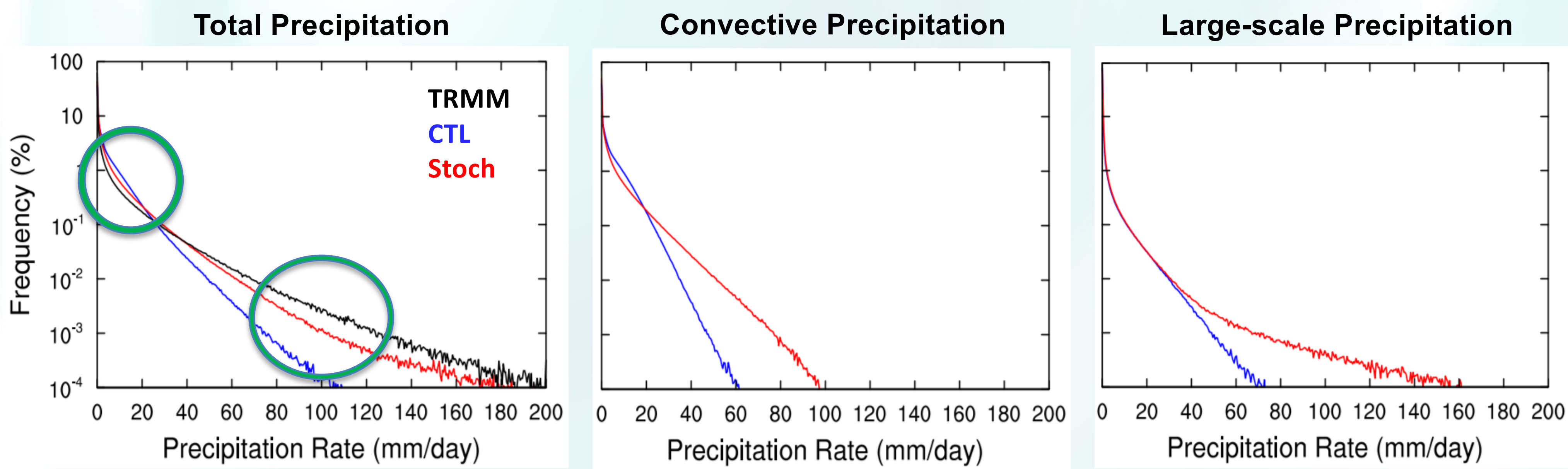
There is not much difference in mean precipitation between stochastic and control simulations in either 1-deg or RRM

Intraseasonal Variability



The intraseasonal variability in the tropics is increased in the stochastic convection simulation

Daily Precipitation PDF in the Tropics

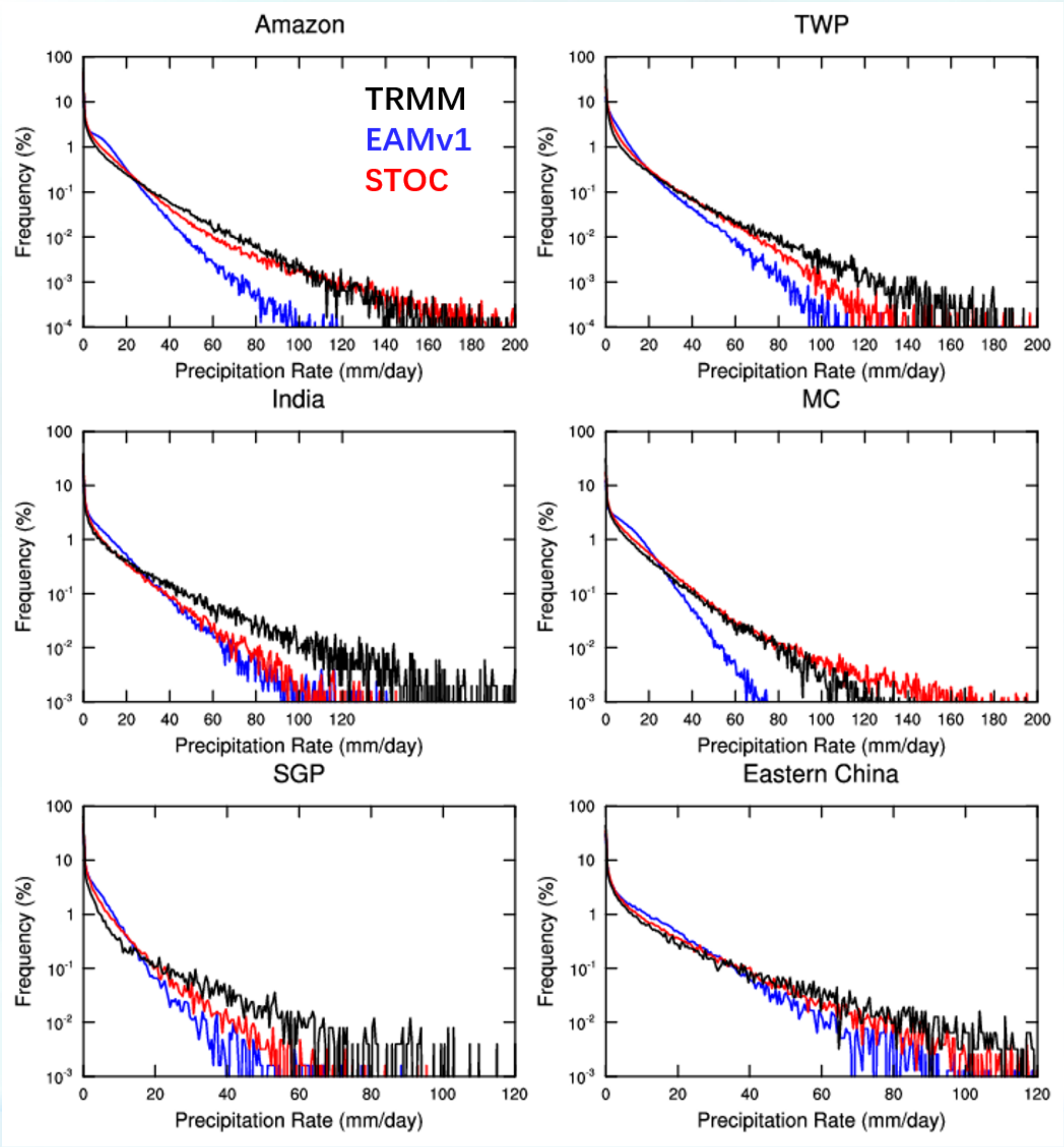


- Light rain frequency is decreased and heavy rain frequency is increased in Stoch
- Convective precipitation changes occur in both light rain and heavy rain
- Large-scale precipitation changes only in heavy precipitation regime

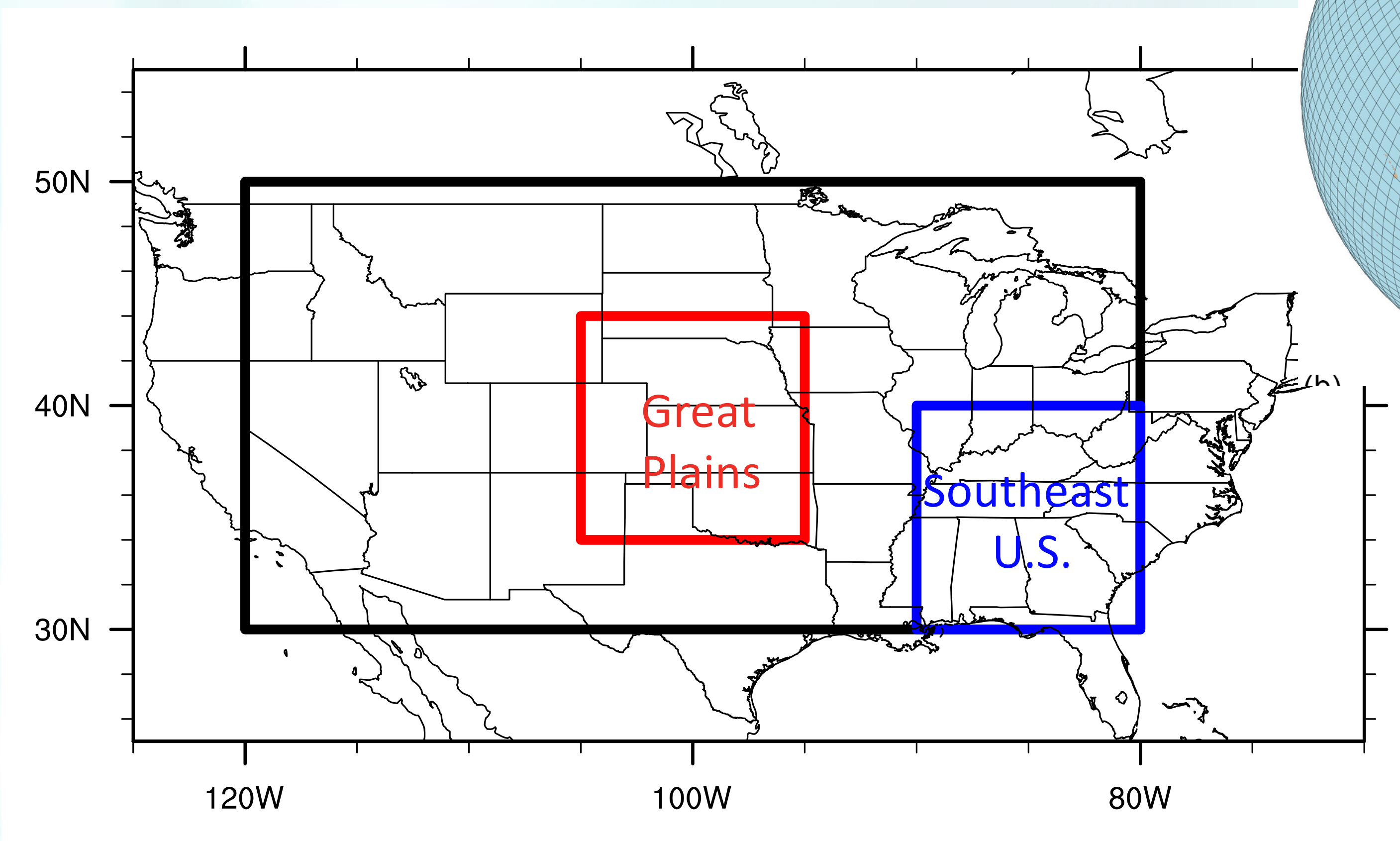
Daily Precipitation PDF in Different Regions

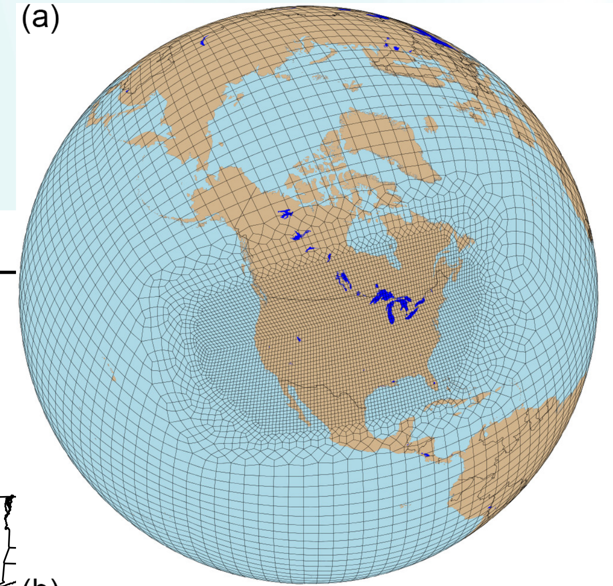
Tropical Regions

Mid-lat Regions



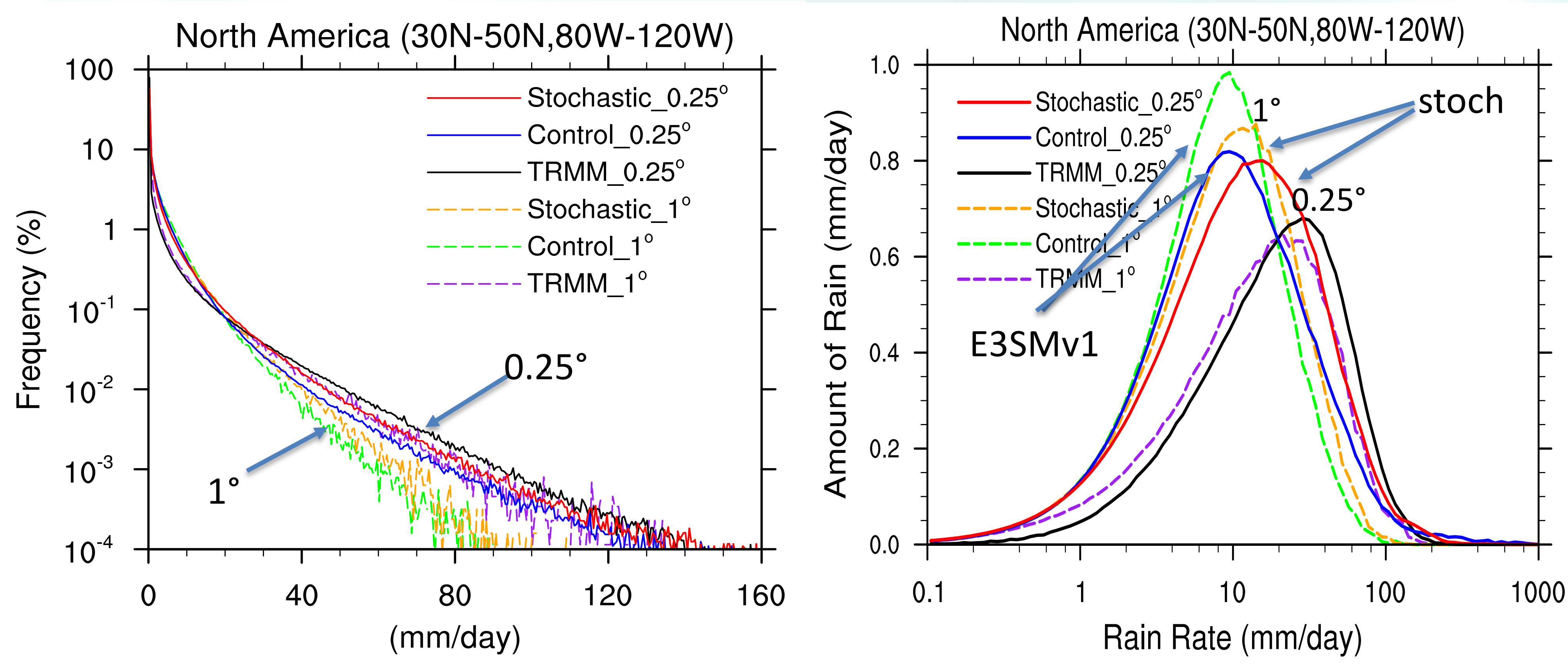
North America





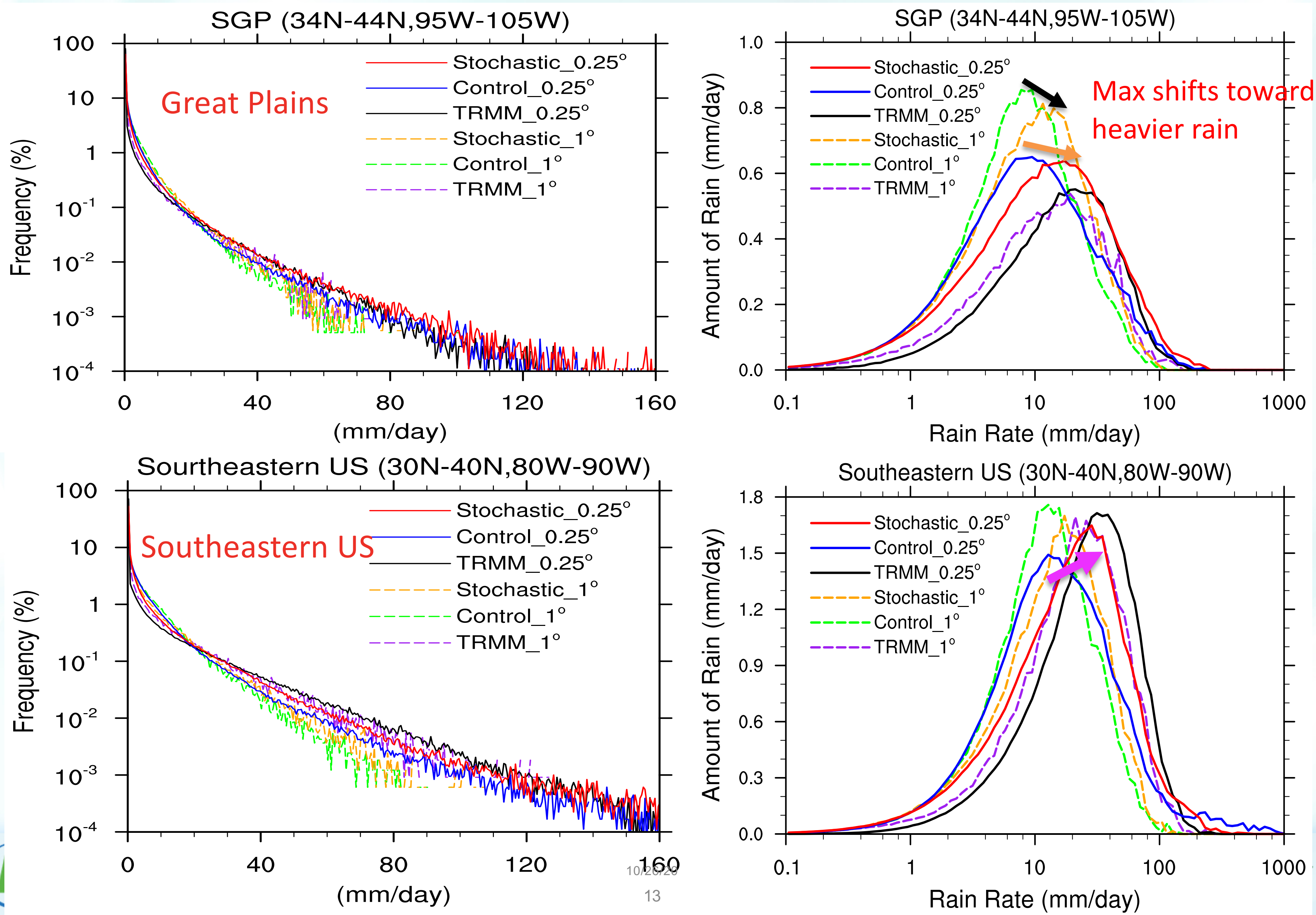
RRM
Qi et al. 2019

Precipitation PDF in NA

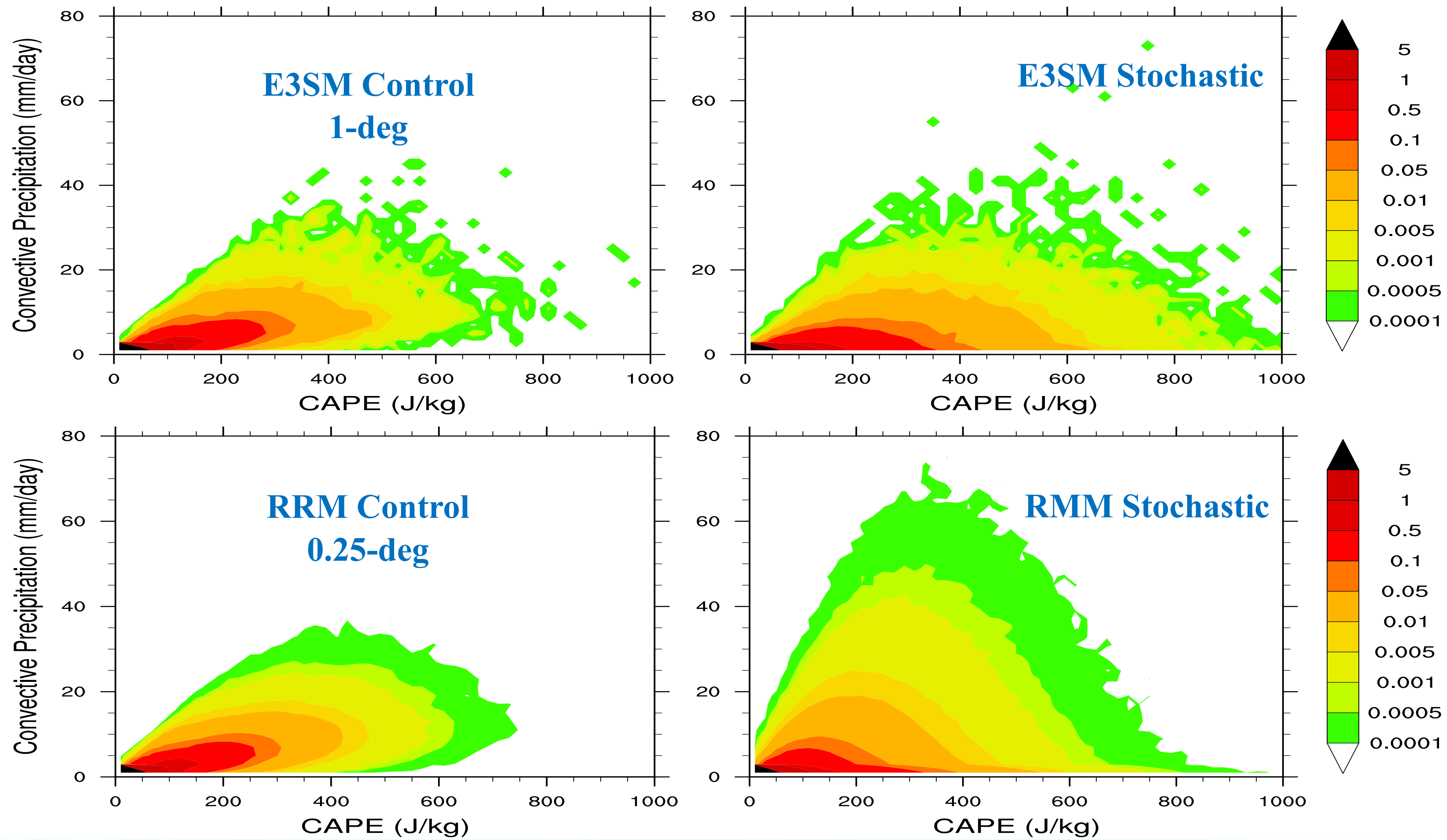


- Precipitation frequency distribution is improved in both 1-deg and 1/4-deg resolutions
- There is a clear shift toward heavy rain in terms of the contribution to the total rainfall for both resolutions as well

Central and SE United States



Joint PDFs of CAPE versus Convective Precipitation over North America (30N-50N, 80W-120W)



There is more stochasticity in 1/4-deg than in 1-deg with the stochastic convection scheme, an indication of scale-awareness

Conclusions

- Incorporating a stochastic convection scheme significantly improves the pdf of precipitation intensity, alleviating the problem of “too much drizzle and too little heavy rain”.
- This improvement appears in both low-res (1-deg) and hi-res (1/4-deg RRM) simulations, more so at hi-res;
- It captures the increased stochasticity as model resolution increases (scale-aware);
- Mean states do not change much, which means less work for retuning when used in E3SM.