Coupling Stochastic Convection Parameterization with ZM in E3SM

Guang Zhang[1], Yong Wang[2], Shaocheng Xie[3]

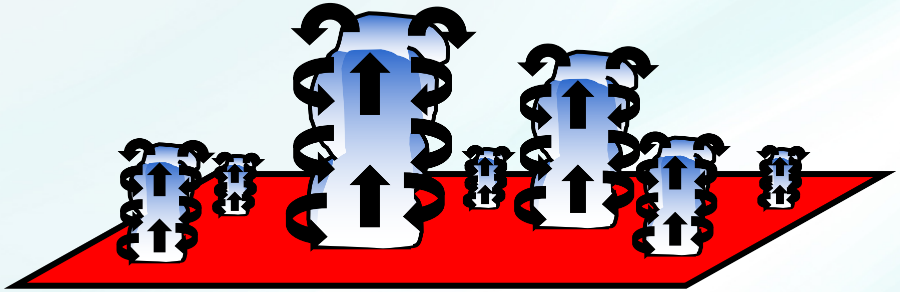
1 Scripps Institution of Oceanography, UCSD

2 Dept. of Earth System Science, Tsinghua University

3 Lawrence Livermore National Laboratory

Outline

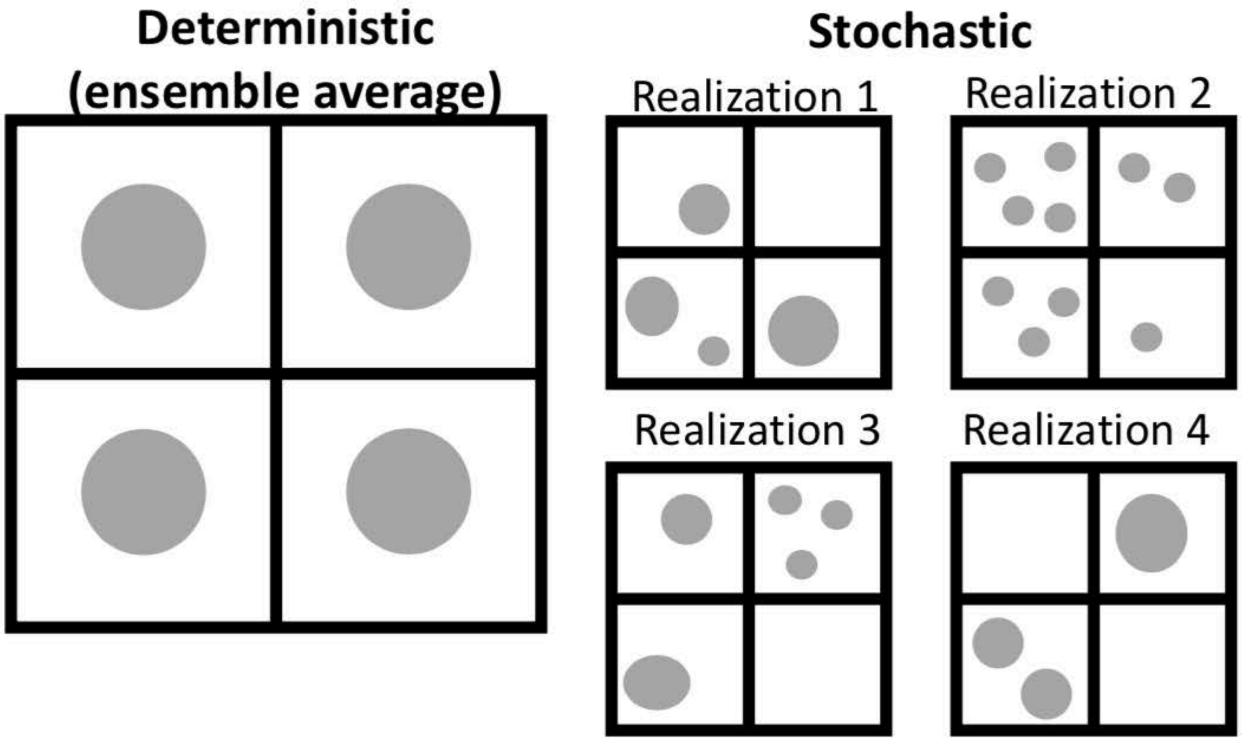
- Why stochastic parameterization?
- Parameterization specifics
- Results
- Summary



Stochasticity of Convection

- **As GCM resolution increases …**

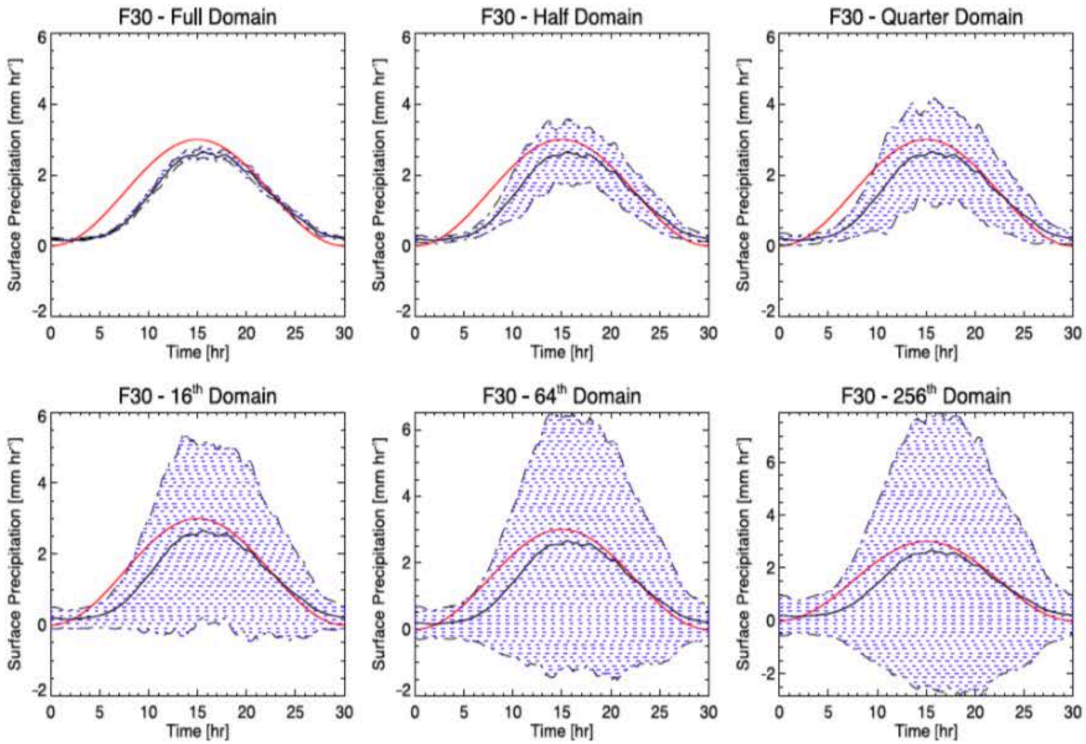
  The quasi-equilibrium hypothesis in conventional deterministic deep convection schemes likely will not be valid anymore.

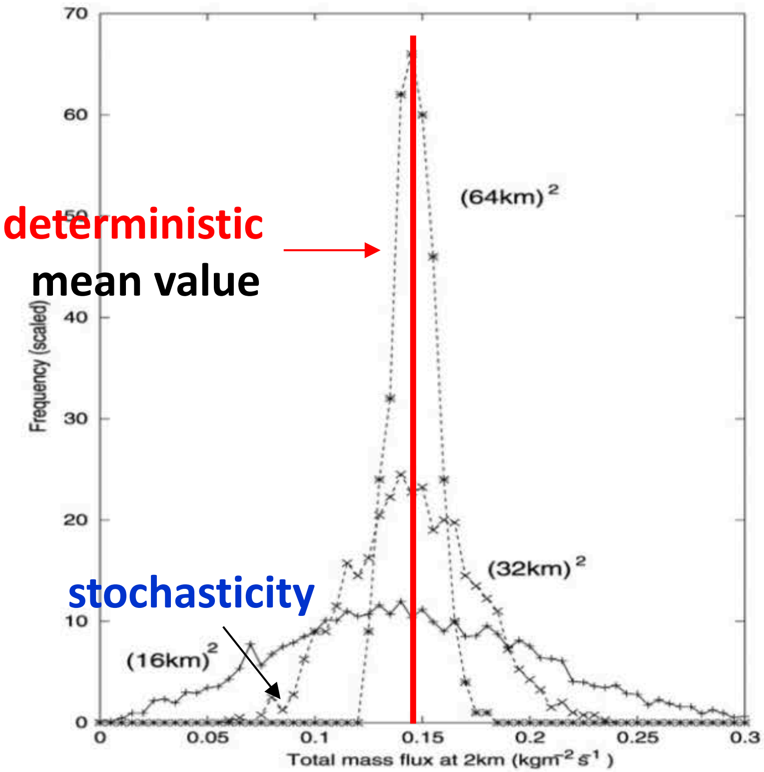


Deterministic: represents the mean of convective ensemble

Stochastic: represents an individual realization of a PDF

Stochasticity of Convection

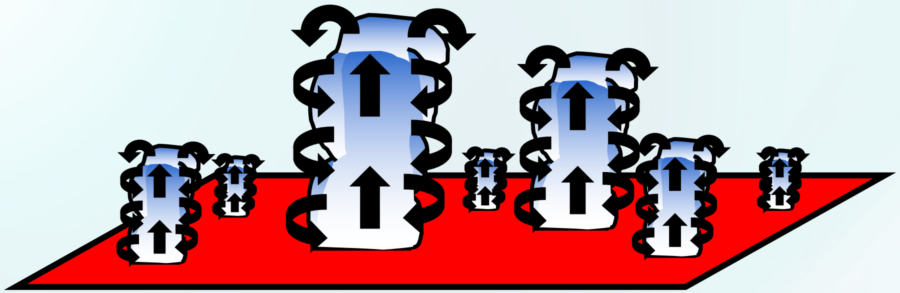




Jones and Randall (2011)

Plant and Craig (2008)

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



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

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

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

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

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

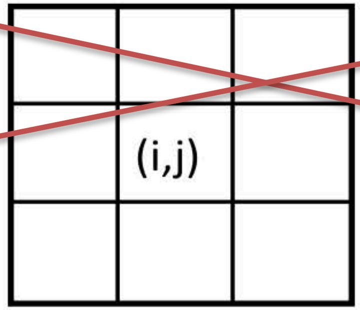
- **The probability of triggering one cloud with mass flux between *m* and *m*+d*m***

Coupling PC08 with the ZM deterministic scheme

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

<N> = <M>/<m>

1. ~~The large-scale state is obtained by performing spatial (over 9 neighboring grid boxes) and temporal averaging (over preceding 3 hours at each time step) of grid-scale variables.~~



The averaged variables are used in closure only to compute *<M>* !

2. The mean total mass flux *<M>* is obtained from the Zhang-McFarlane closure and used to scale the Boltzmann distribution for *m*.

3. The probability is compared with a random number to determine whether a cloud with mass flux (*m*, *m*+*dm*) is generated.

4. Tendencies of grid-scale variables are computed by summing up all clouds launched this way.

Model: EAMv1

Configuration: AMIP (6 years each)

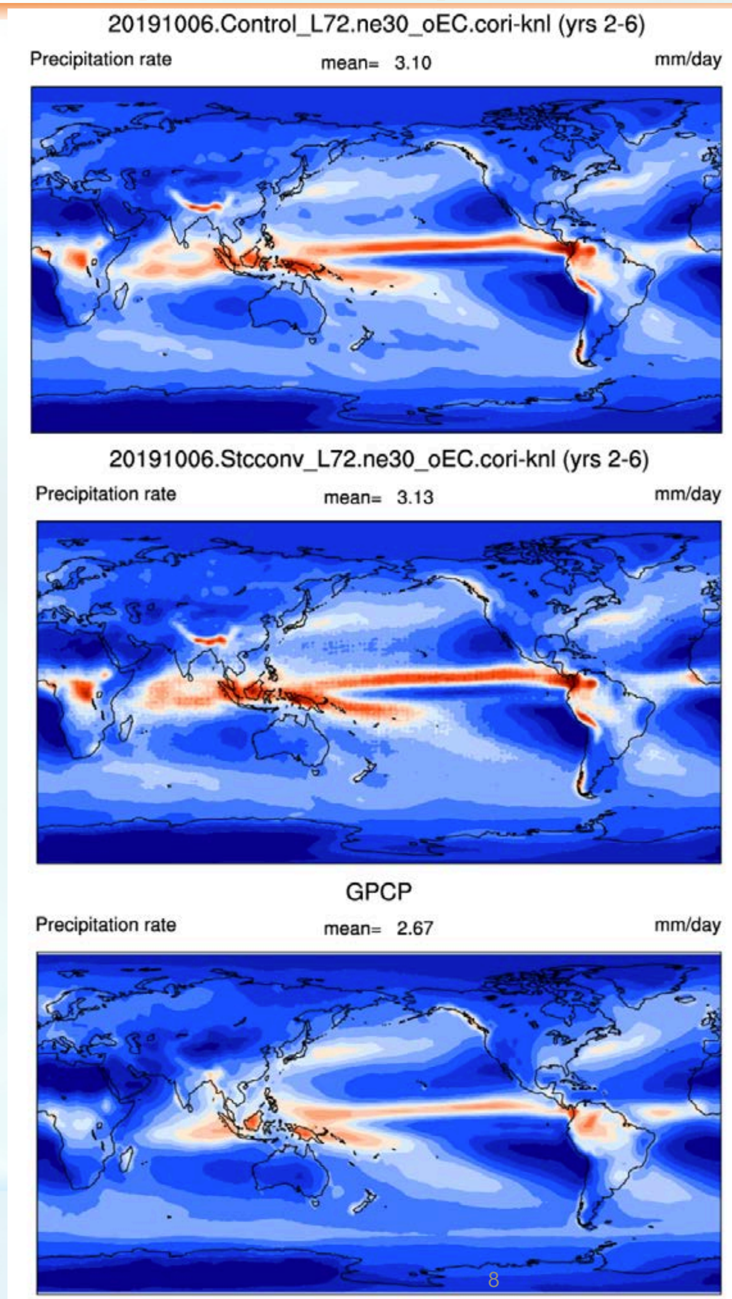
- CTL: Standard Model
- EXP: Stochastic Parameterization

Precipitation (EAMv1)

CTL

EXP

GPCP

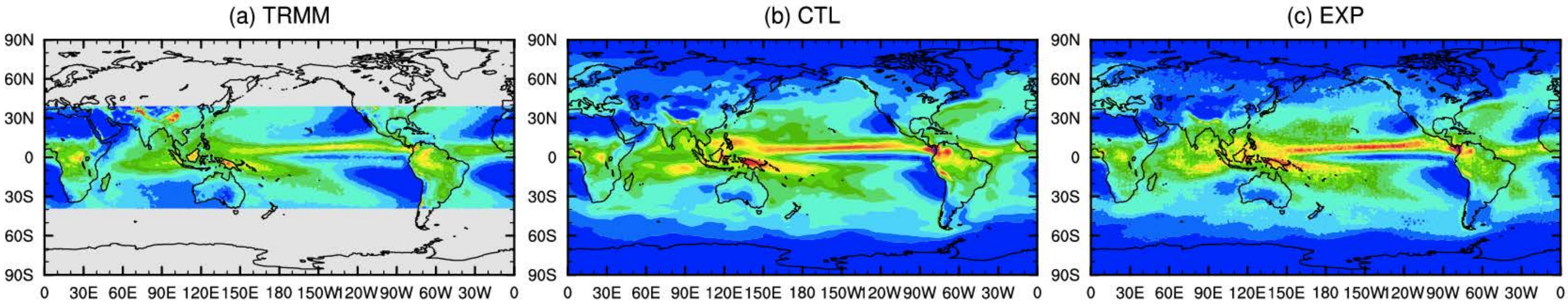


E3SM Energy Exascale Earth System Model

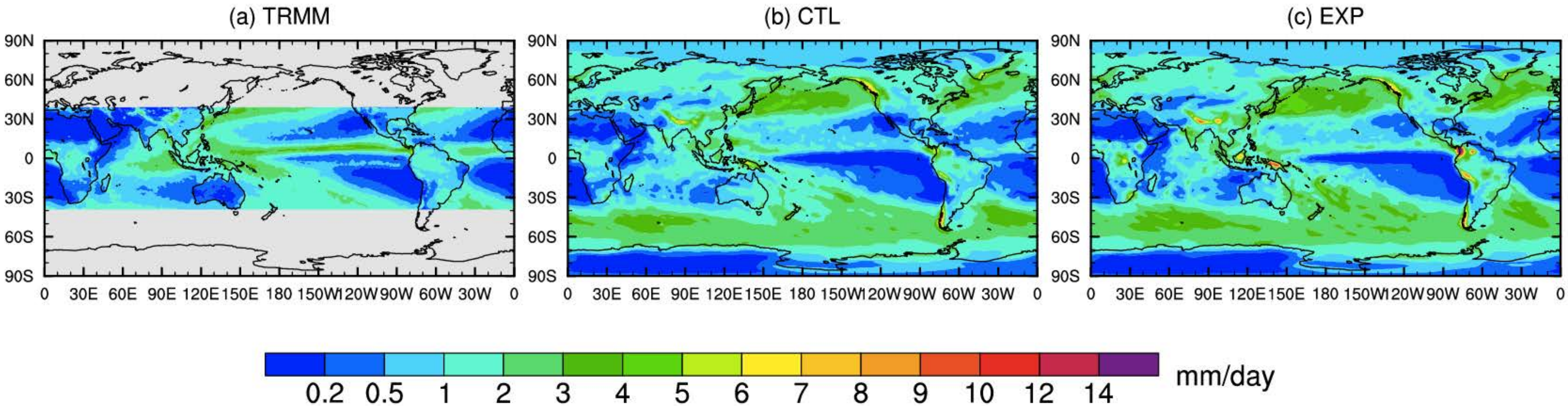
U.S. DEPARTMENT OF ENERGY

Convective & Large-scale precipitation

Convective



Large-scale

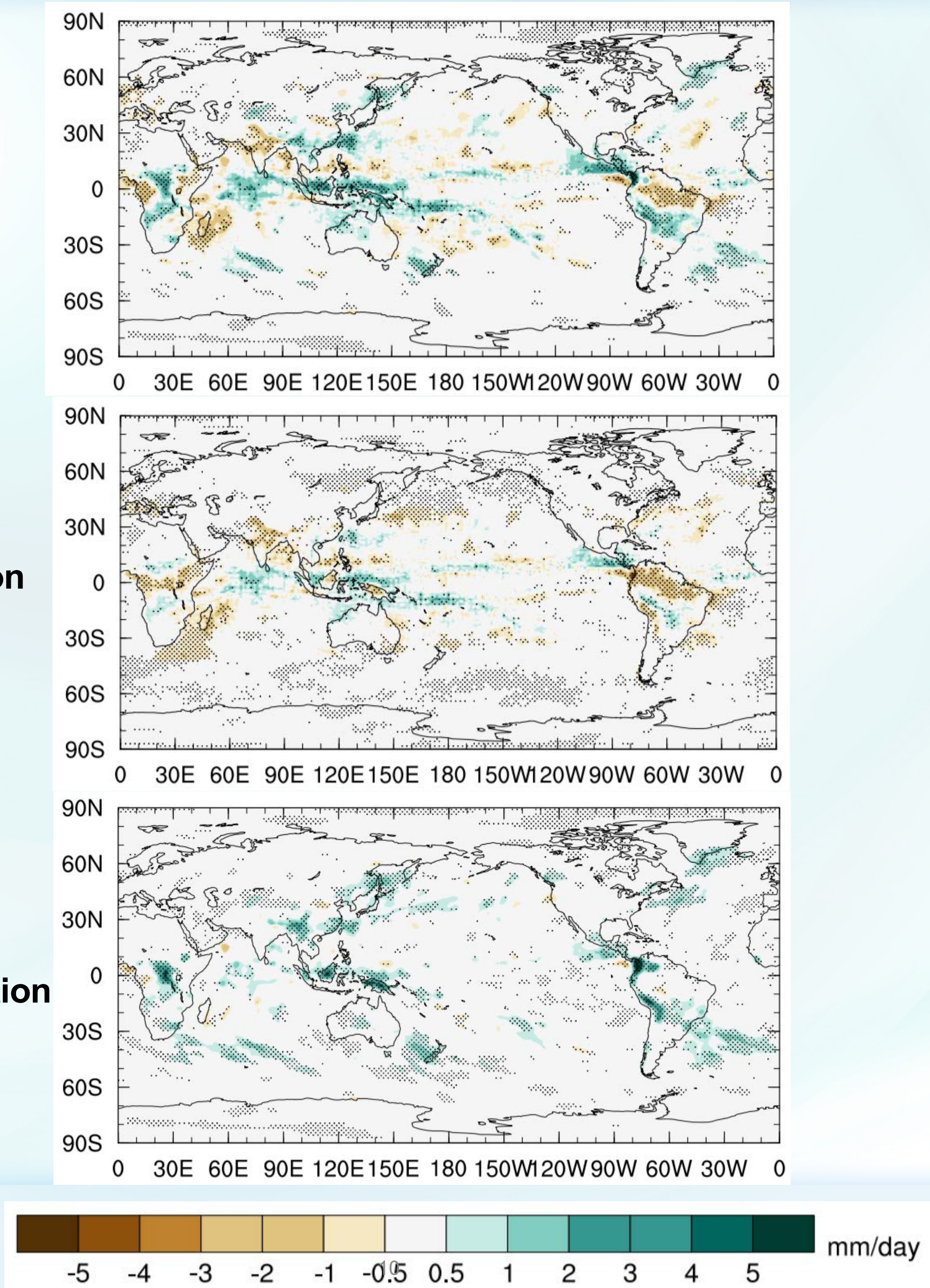


EXP – CTL

Total Precipitation

Convective Precipitation

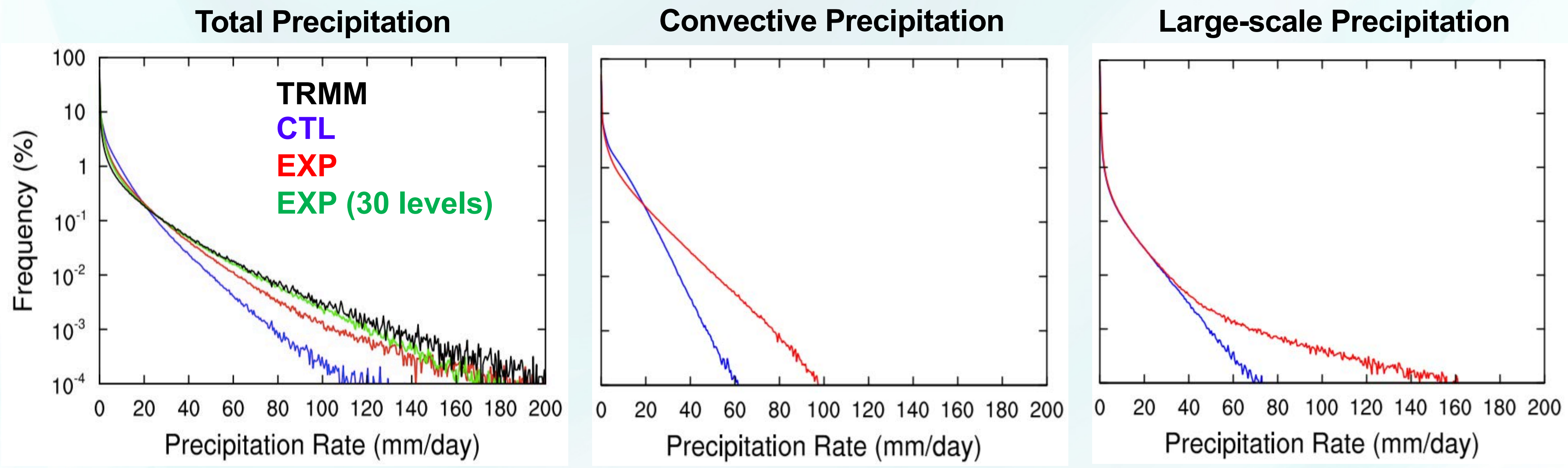
Large-scale Precipitation



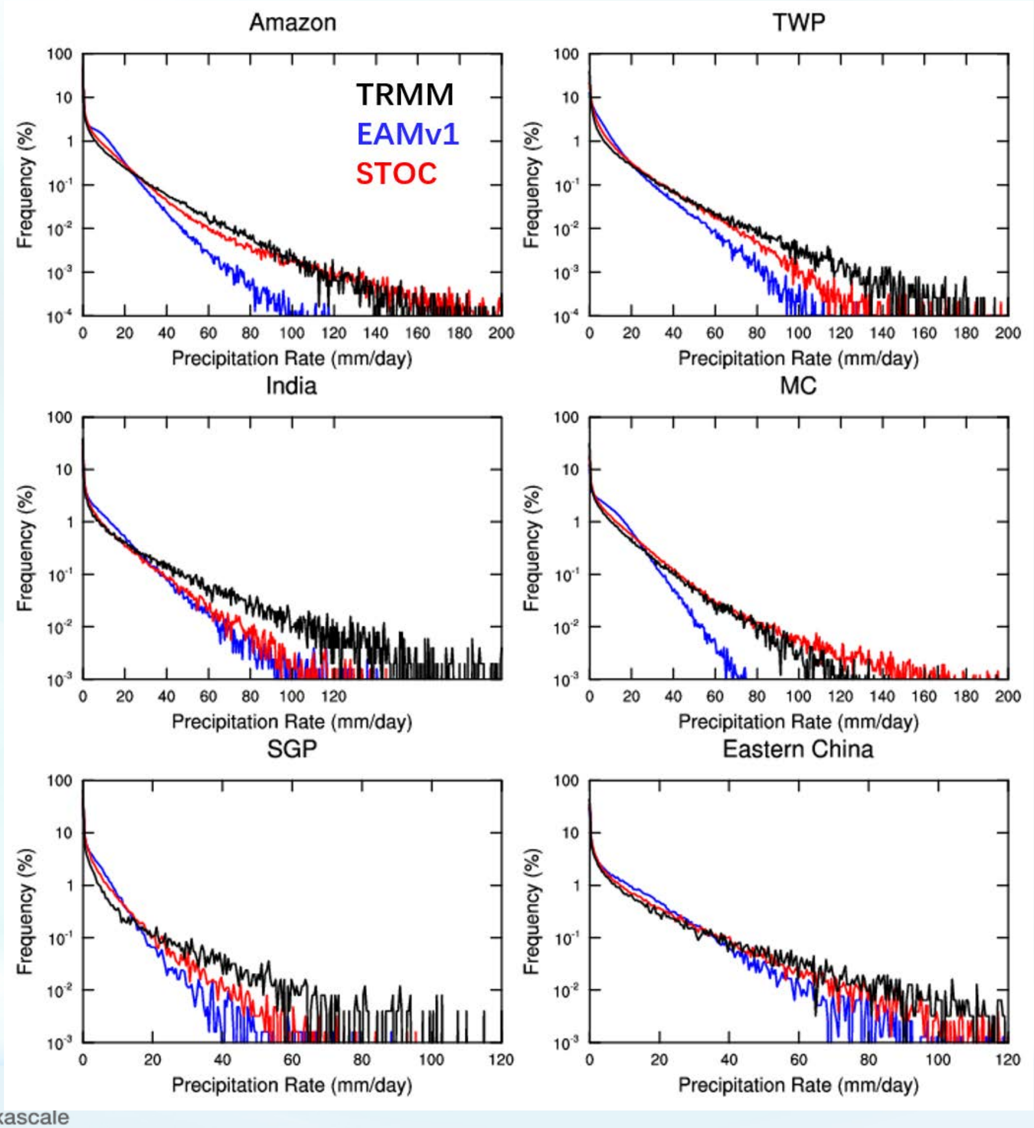
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

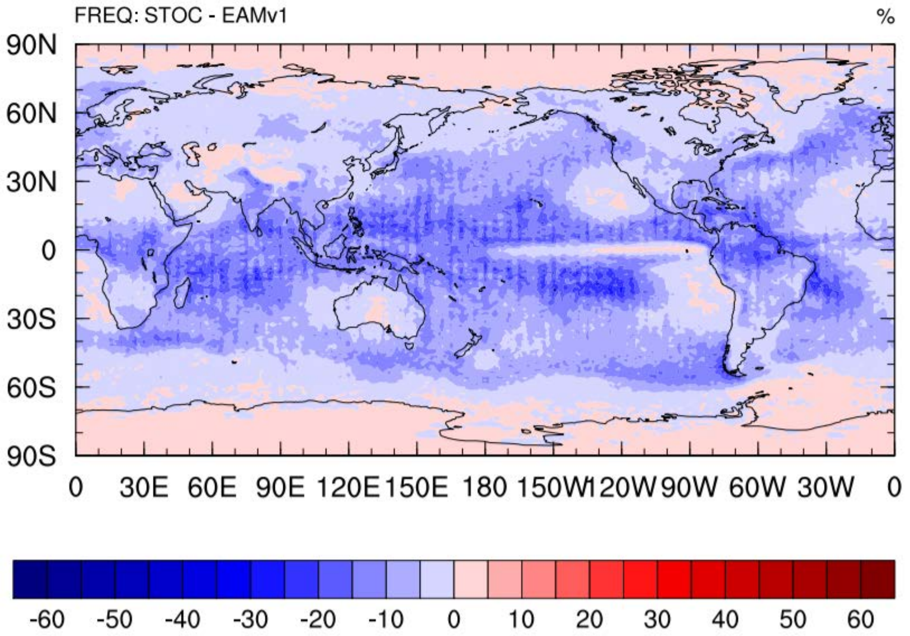
PDF of Daily Precipitation (Tropics)



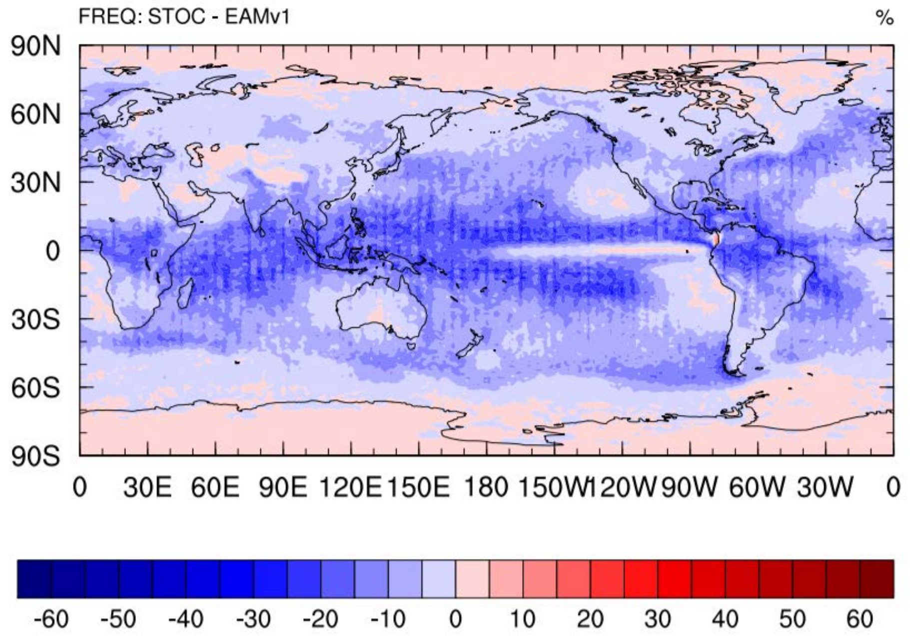
PDF of Daily Precipitation (Tropics)



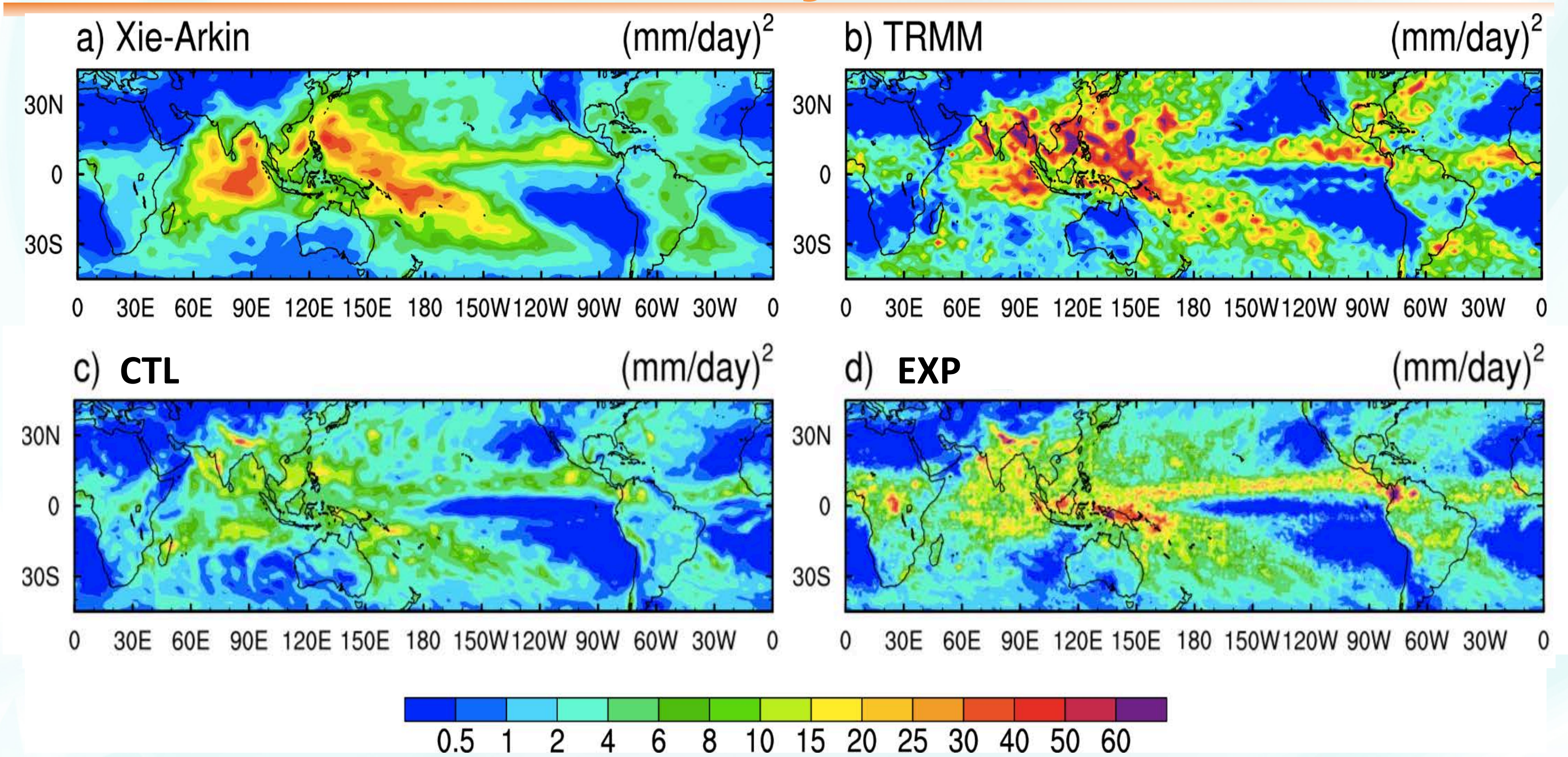
Frequency of Convective Precipitation EXP-CTL



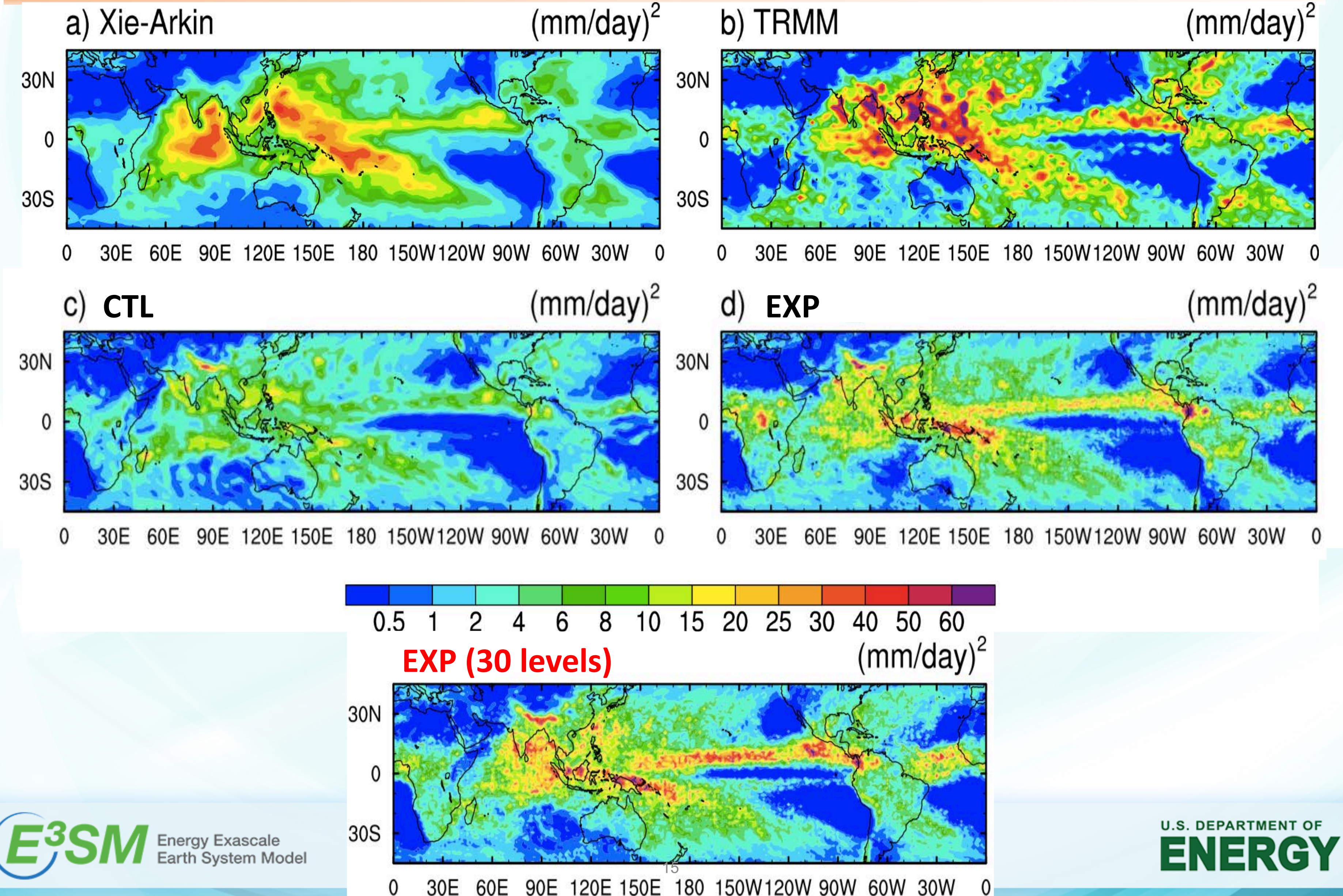
Frequency of Convective Precipitation < 20 mm/day EXP-CTL



Intraseasonal Variability



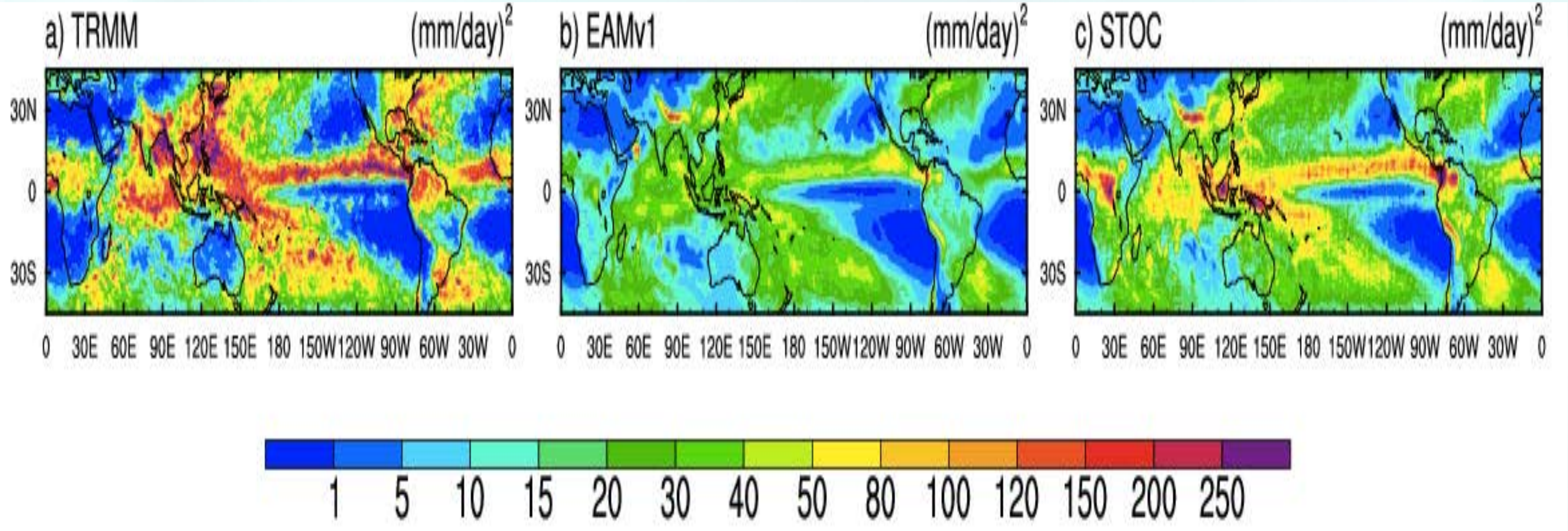
Intraseasonal Variability



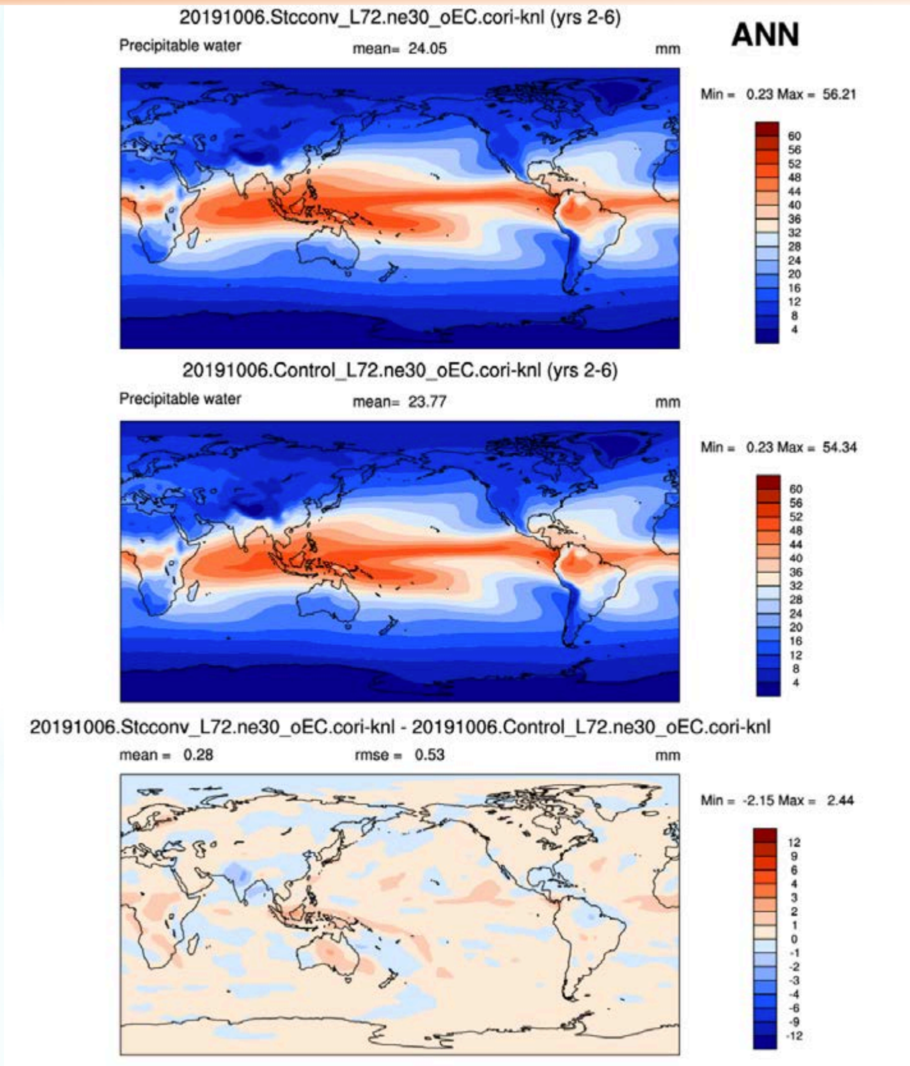
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

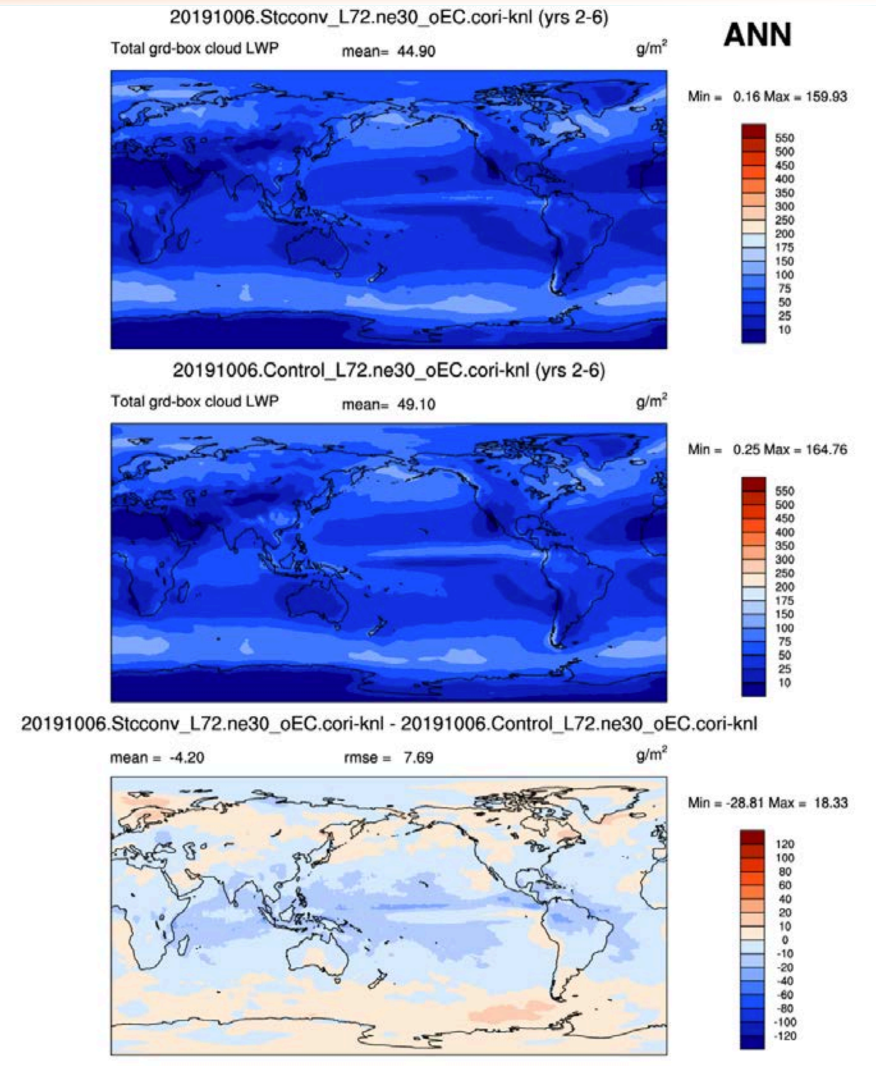
Synoptic-scale Variance



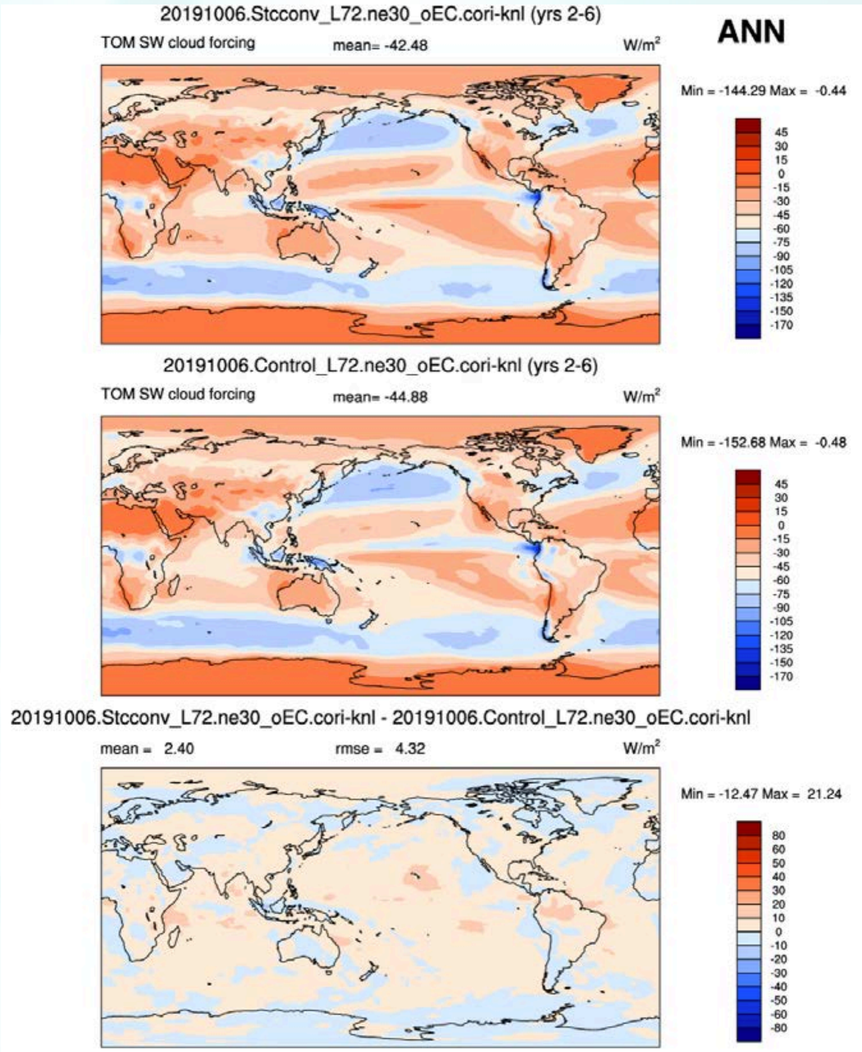
Column water vapor



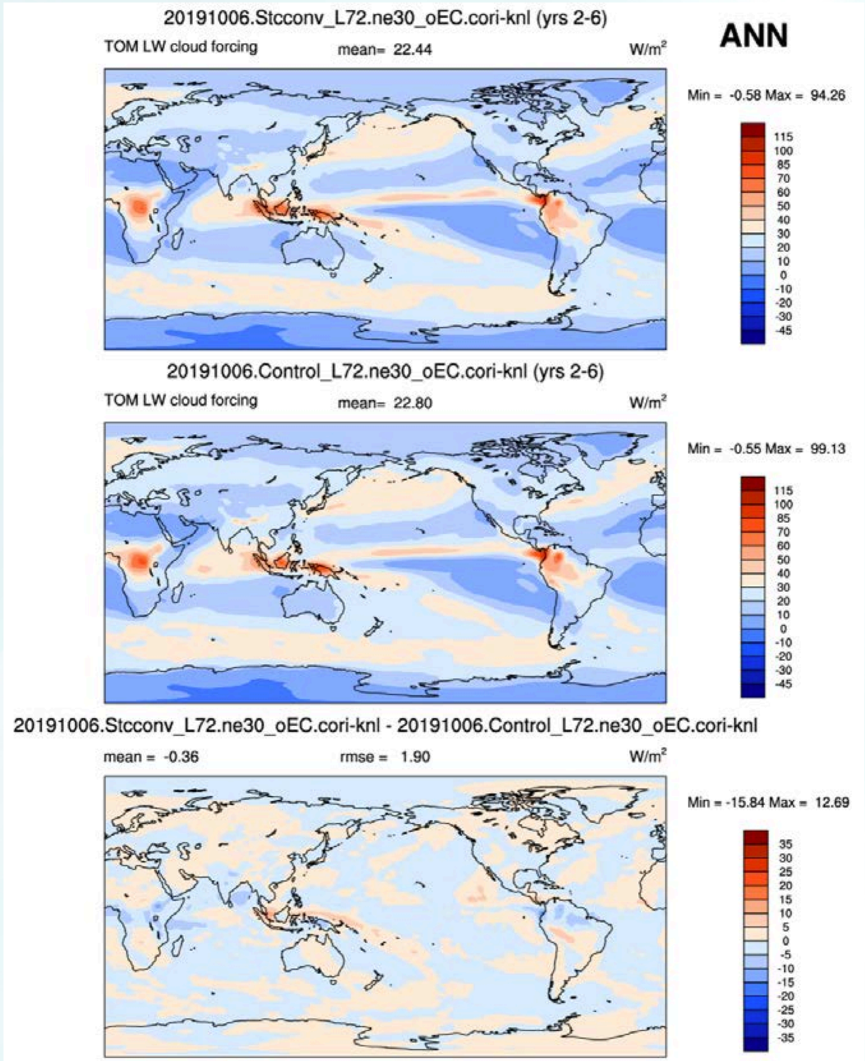
Liquid water path



Shortwave CRF

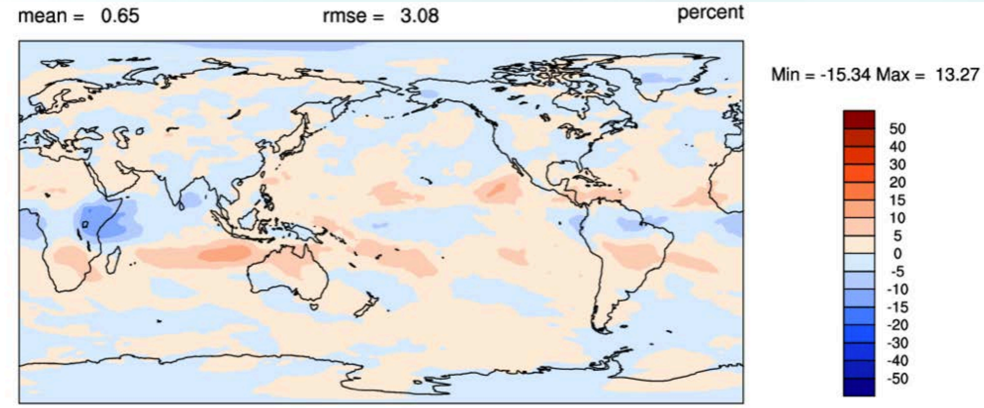


Longwave CRF

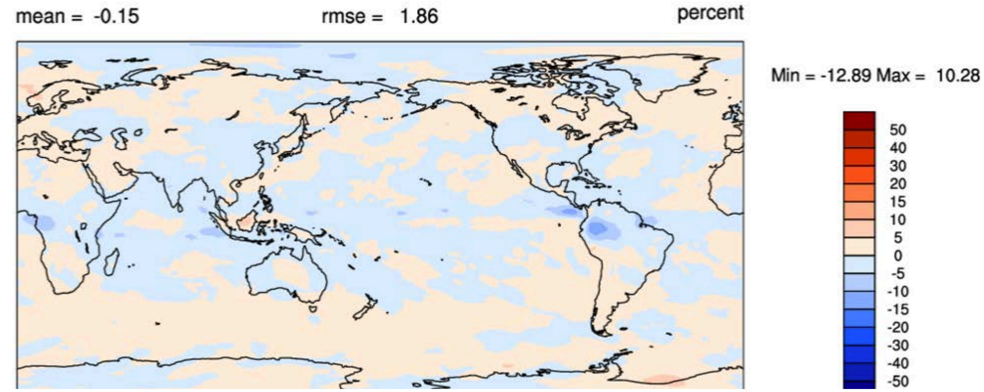


Clouds: EXP - CTL

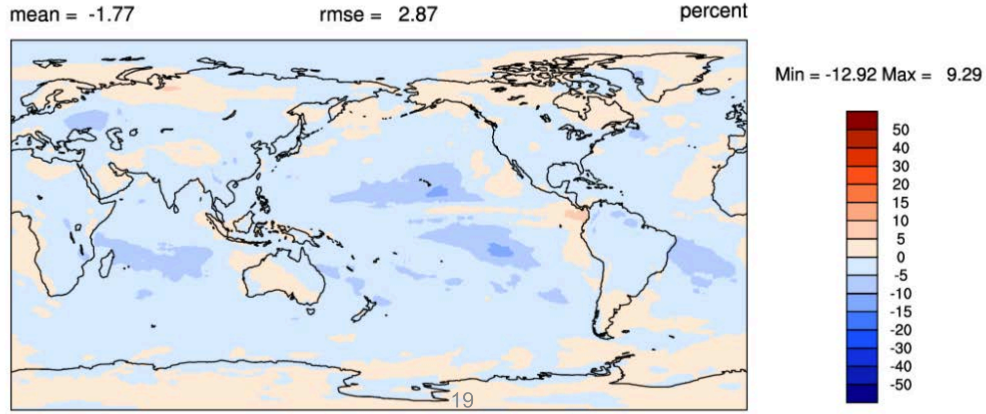
High



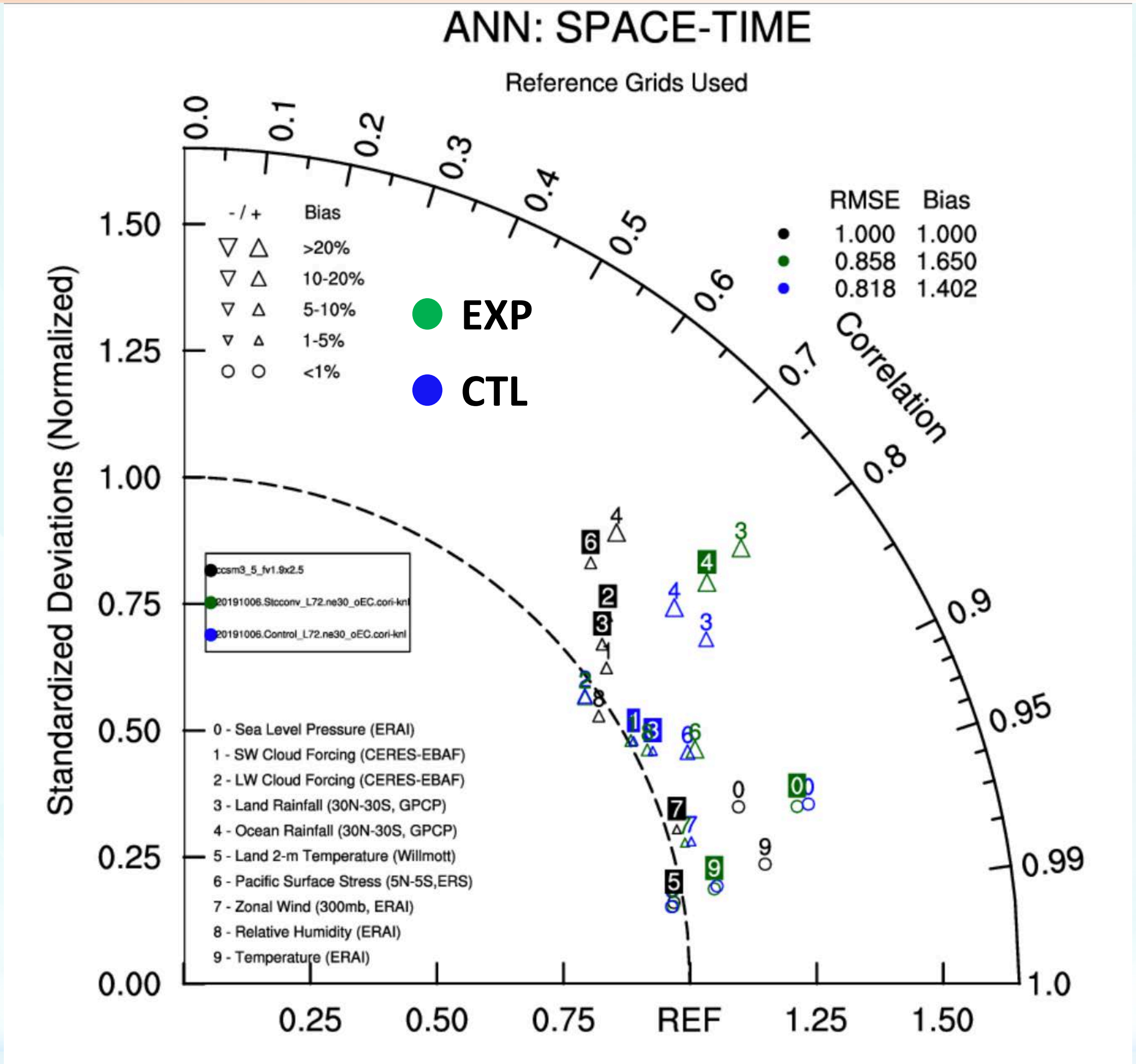
Middle



Low



Taylor diagram (EAMv1)



Conclusions

- Incorporating a stochastic convection scheme significantly improves the pdf of precipitation intensity, alleviating the problem of “too much drizzle and too little intense rain”.
- Frequency of convection with low precipitation intensity is reduced globally.
- Intraseasonal and synoptic-scale variances are also improved.
- Mean states do not change much, which means less work for retuning if/when used in E3SM.