



# A relationship between the vertical structure of convection and tropical precipitation climatology in CMIP6 simulations

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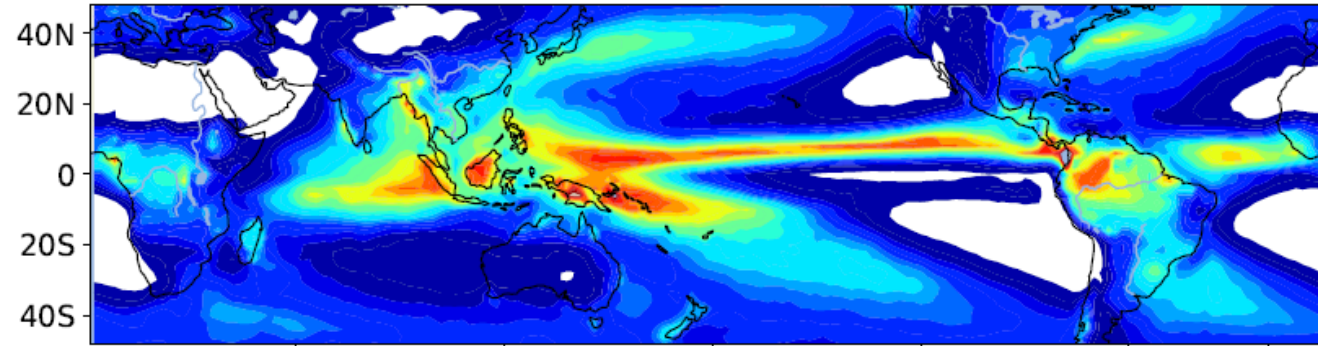


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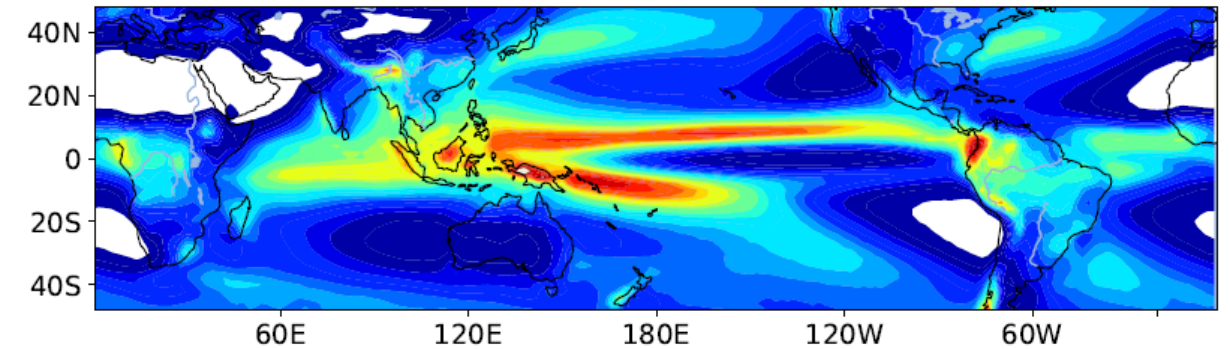


# Motivation

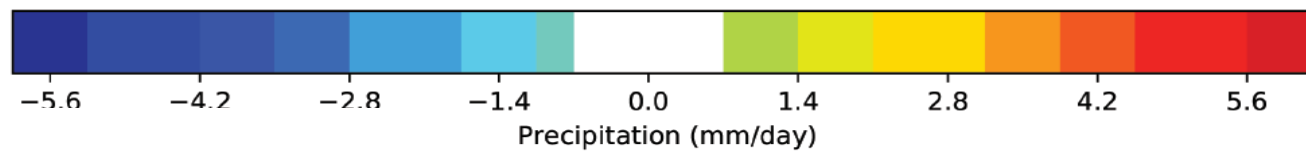
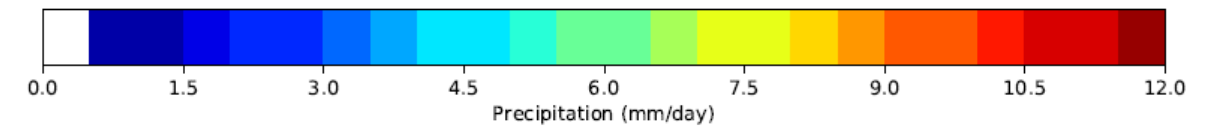
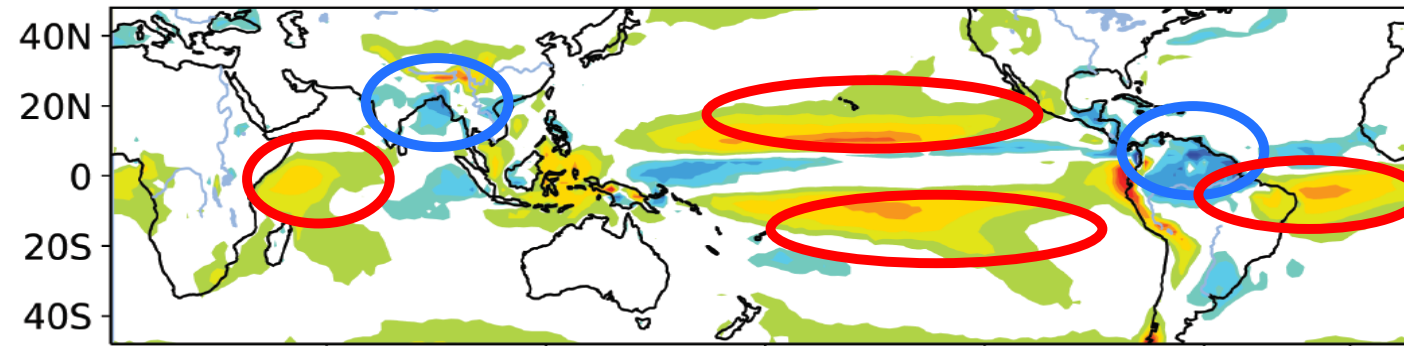
Observations



CMIP6 models



CMIP6 models minus Observations



► The CMIP6 multi-model mean suffers from biases already documented in previous generations of CMIPs. These include:

- Excess precipitation over the tropical oceans off equator
- Dry bias over land masses (South Asia and Amazon)

## Questions

► What are the origins of these biases?

# Representation of P-pw relationship

Two limits of  $P = \frac{E_0}{(1-(pw_n-pw_{nc}))}$

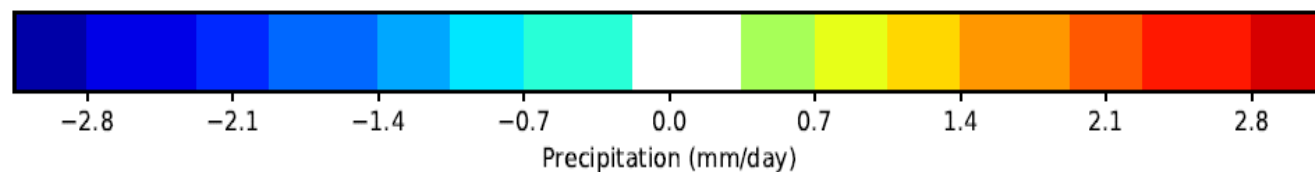
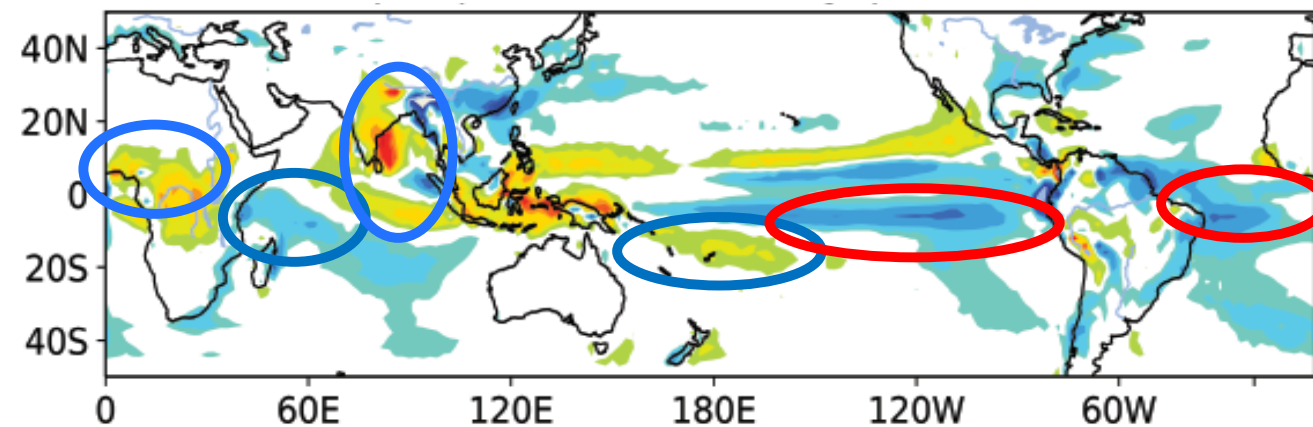
► Regime 1  $pw_n \ll pw_{nc}$   $\rightarrow P \rightarrow \frac{E_0}{(1+pw_{nc})}$

► Regime 2  $pw_n \rightarrow 1.0 + pw_{nc}$   $\rightarrow P \rightarrow \infty$

Wide-spread drizzle controlled by local evaporation independent of PW.

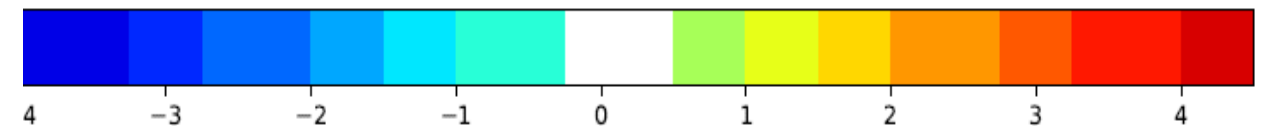
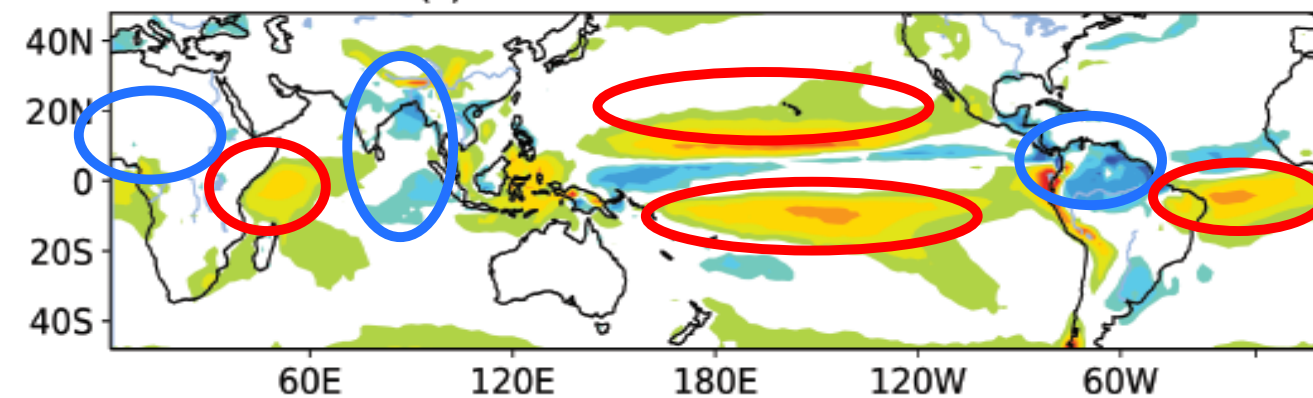
Intense precipitation controlled by moisture convergence concentrated over high PW regions

Precipitation climatology from models with low  $pw_{nc}$  minus that from high  $pw_{nc}$



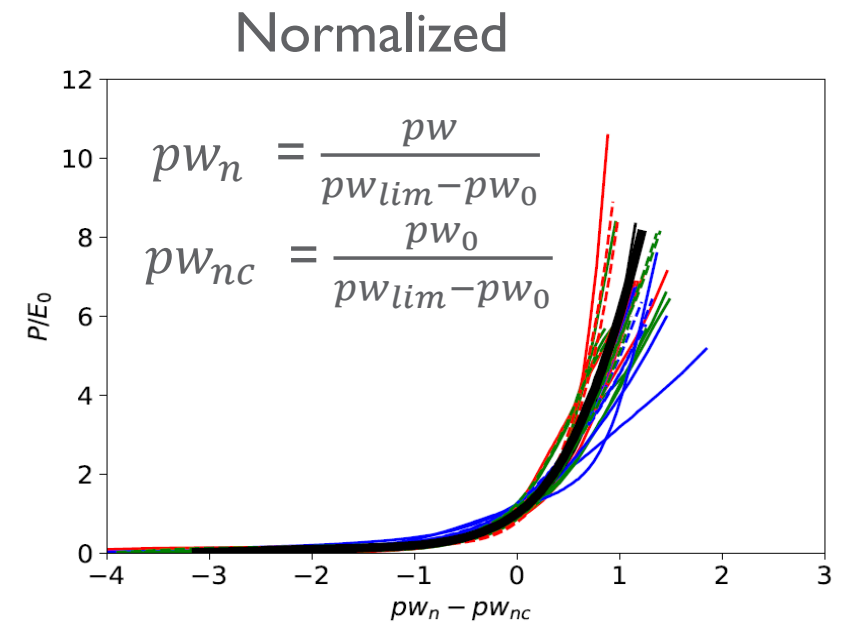
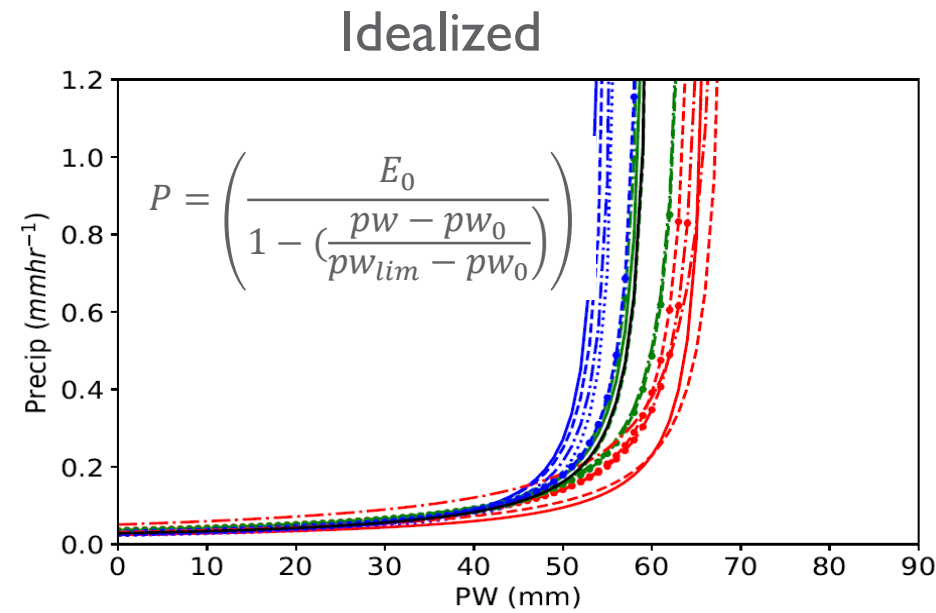
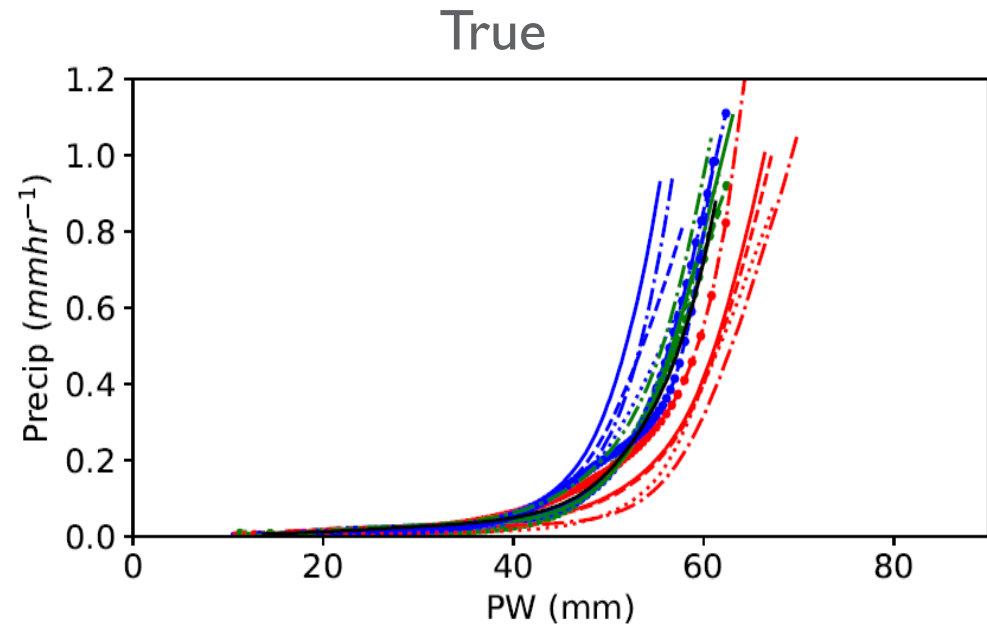
## CMIP6 models minus Observations

(c) CMIP6MMM minus Observations



► CMIP6 models in general and particularly those with larger  $pw_{nc}$  are in Regime I more often.

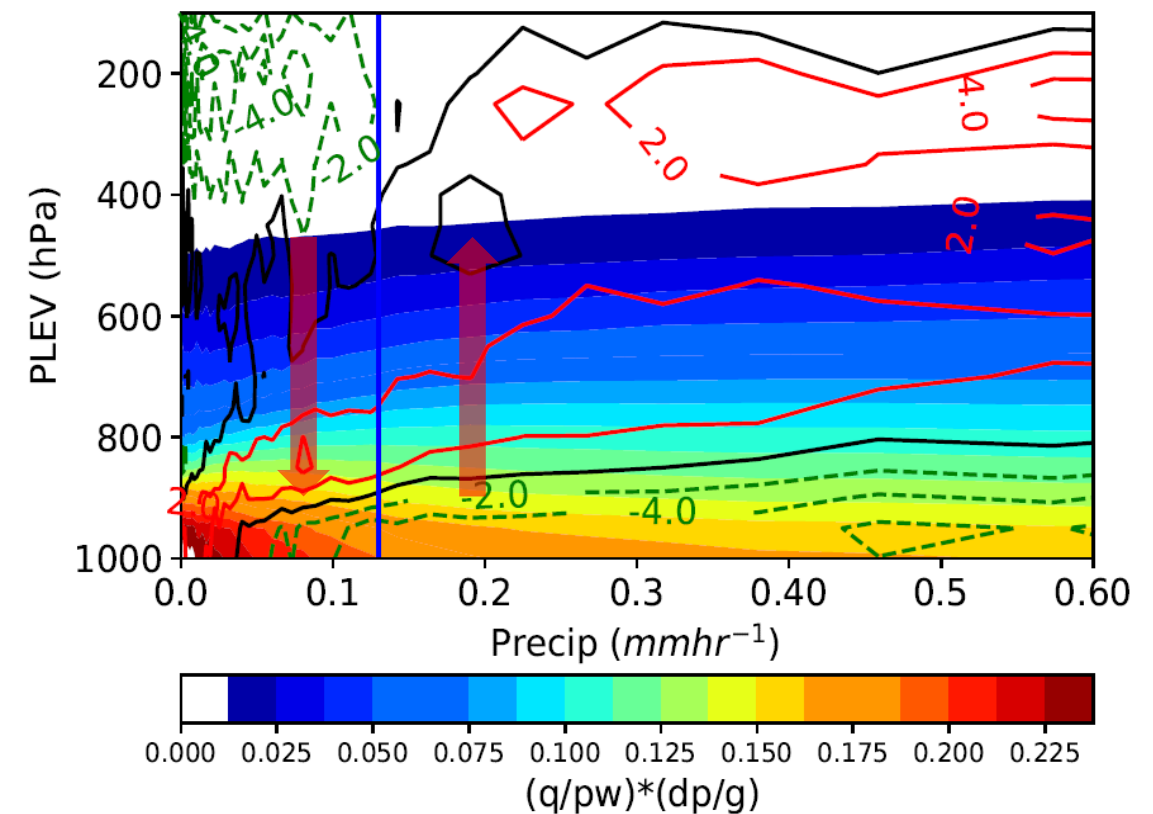
# Relationship between precipitation and column integrated precipitable water



The physical meanings of  $pw_{lim}$ ,  $E_0$  and  $pw_0$

- ▶  $pw_{lim}$ : The point where **moisture convergence and precipitation are balanced** such that pw and precipitation are independent.
- ▶  $E_0$  and  $pw_0$ : The mean value of evaporation and pw where convergence is zero. i.e. **Evaporation and precipitation are balanced.**

Profiles of wind divergence (contours) and water vapor (shadings)





## Research needs and opportunities

- ▶ In this work it is shown that the vertical structure of convection is linked to the tropical precipitation climatology through mass, moisture and energy constraints.
- ▶ **In the next 3 to 5 years** climate models should aim to accurately represent **cloud populations** (from isolated shallow clouds to MCSs) along with the environmental conditions and precipitation associated with them. Not only their bulk effect but also their statistics so model representation and prediction of frequency of extremes can lay on solid foundation.
- ▶ **In the next 5 to 10 years** earth system **predictability and model prediction skills** and how they are affected by model biases should systematically investigated.