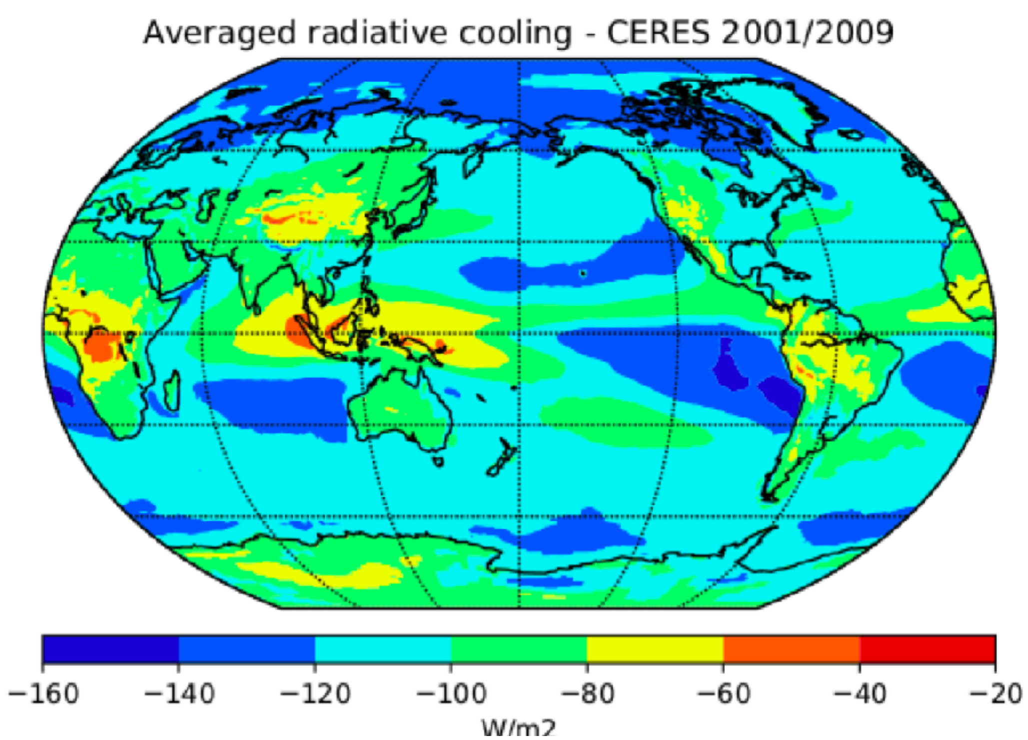
Bringing together observations and models to understand the world and improve predictions of it

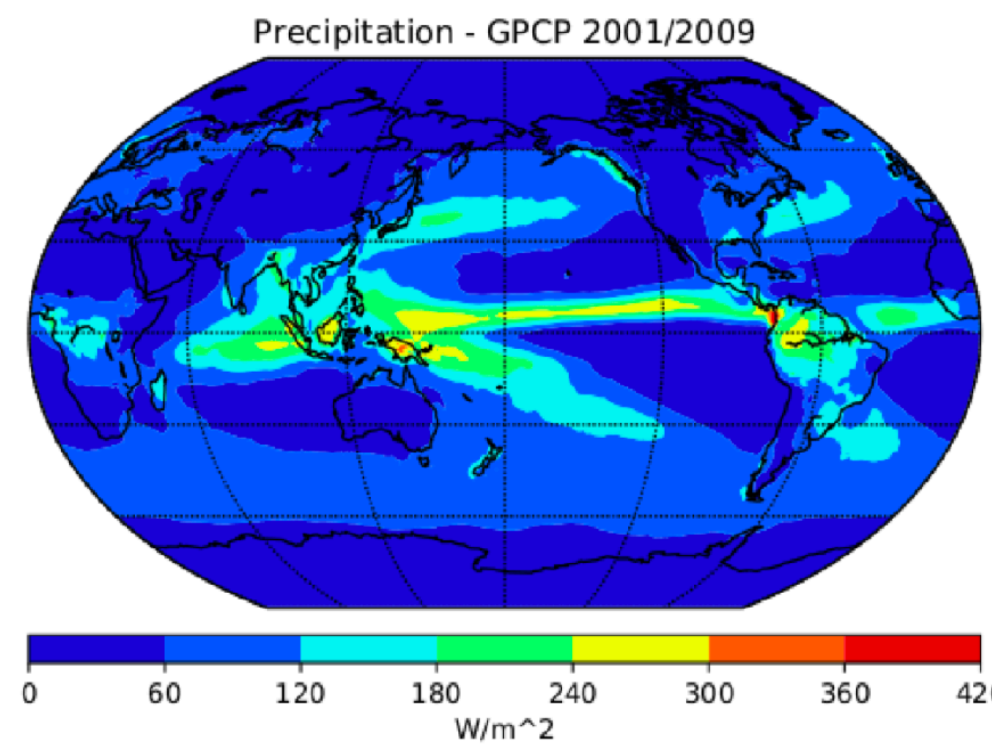
Christian Jakob
Monash University

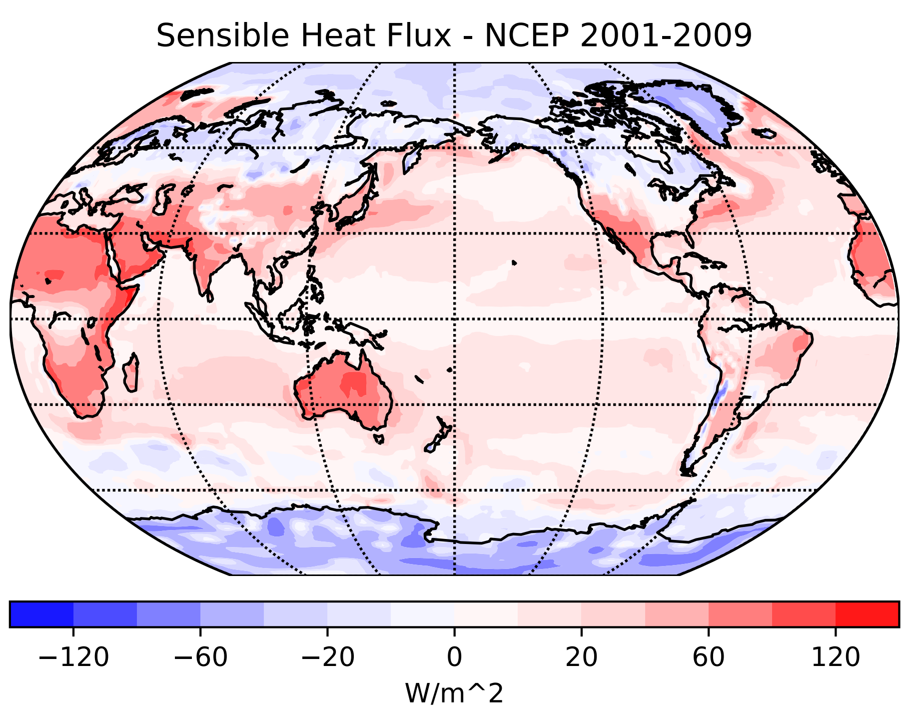
Thank you to lots of people

Global observations set the scene
What is happening?

Climatologically, the “tropics” (30 N to 30 S) are close to Radiative Convective Equilibrium (RCE).







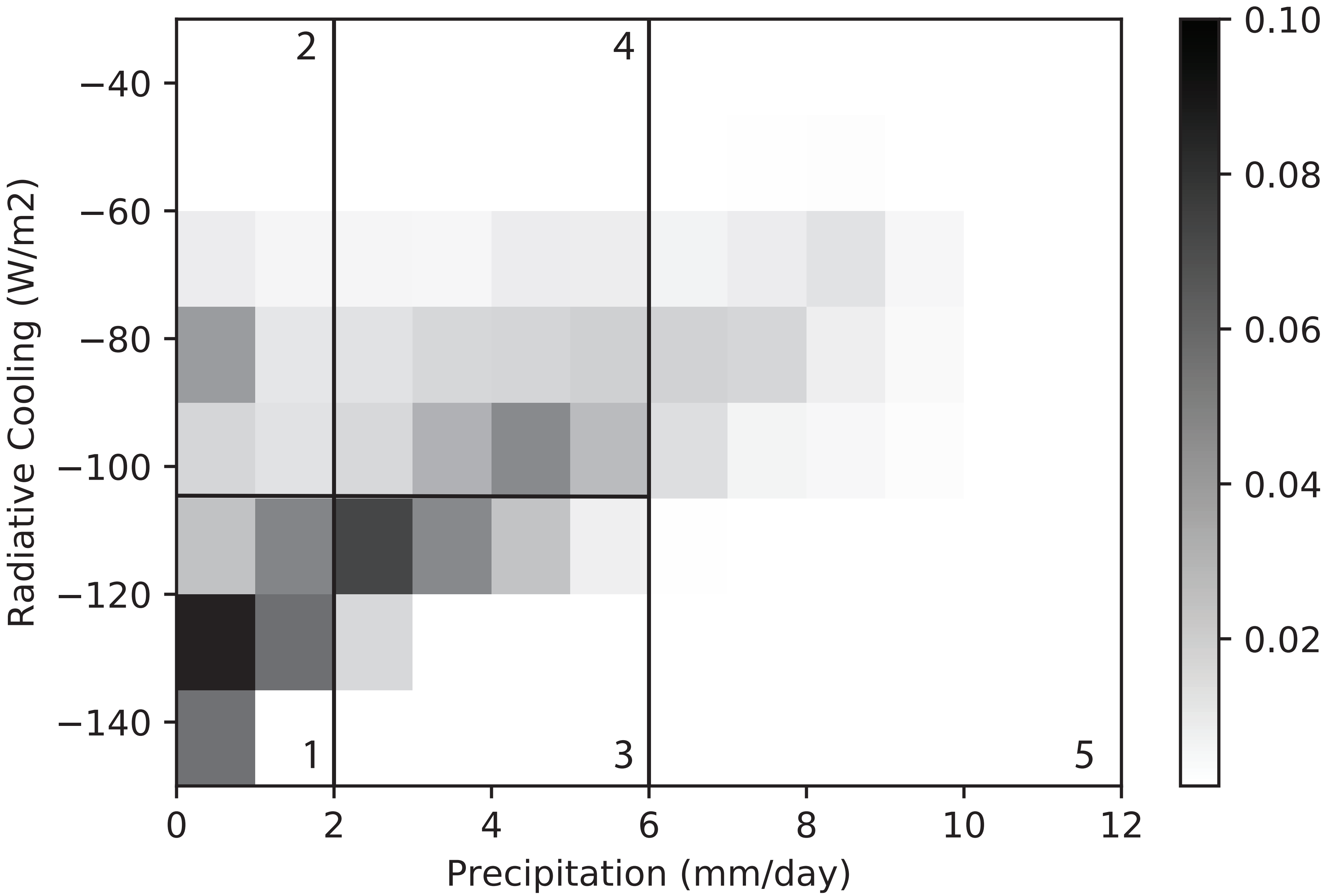
$$< Q_{Rad} > = -104.5 W/m^2$$

$$< P > = 85.2 W/m^2$$

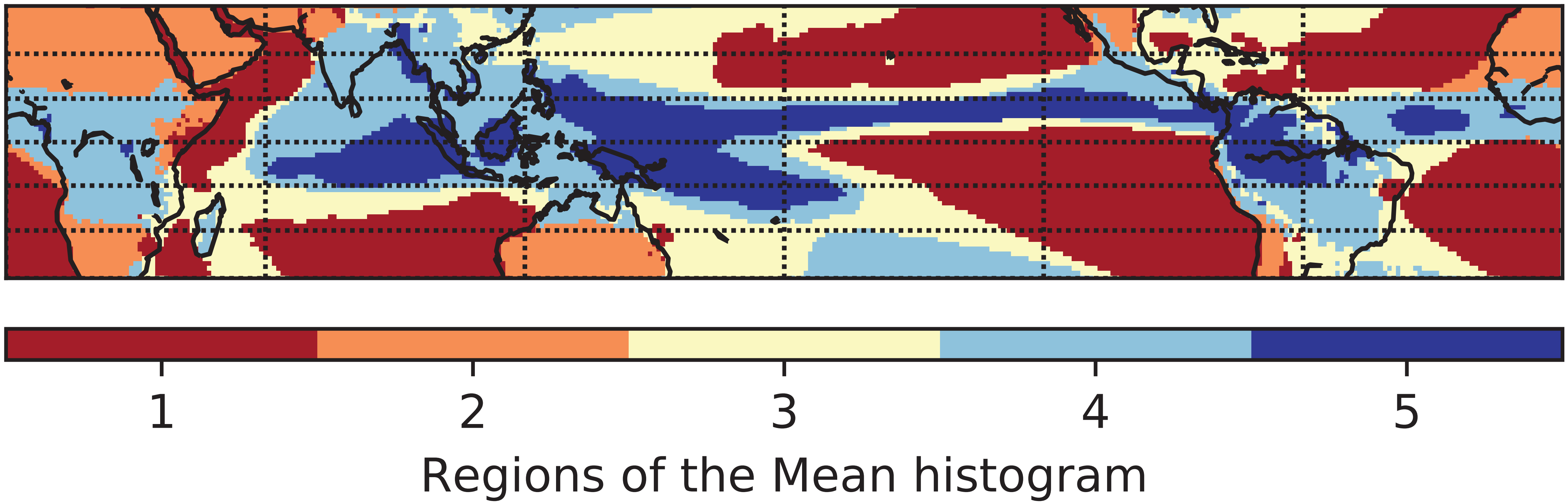
$$< SSHF > = 22.6 W/m^2$$

$$Residual = 3.3 W/m^2$$

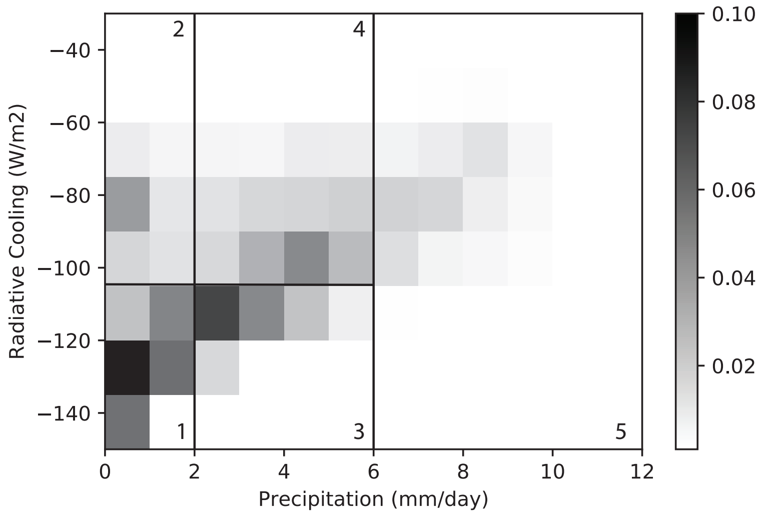
A histogram of the climatological radiative cooling and precipitation in the tropics shows that this is not true locally!



It is clear that the tropical RCE is only established by the "cooperation" of very different regions in the tropics.

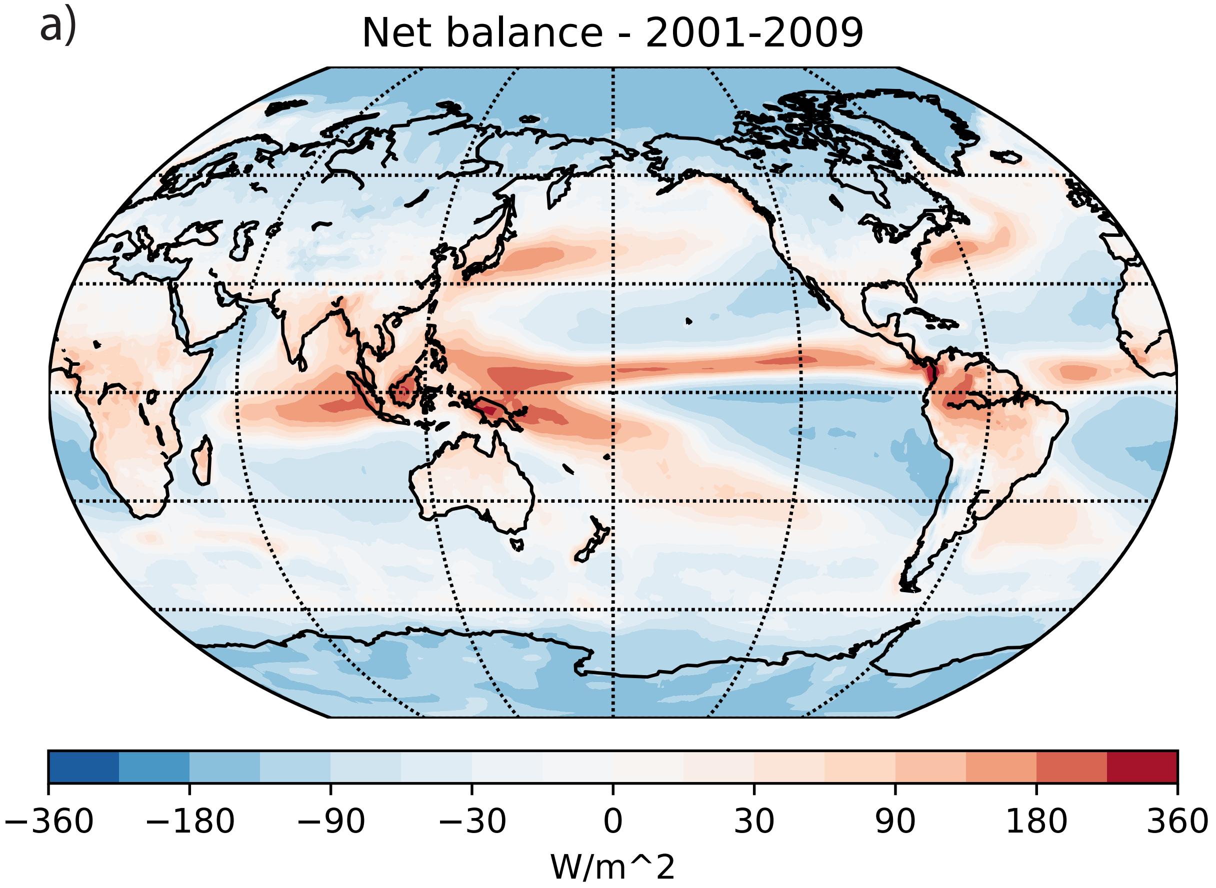


1 = Strong cooling, no rain
2 = Weak cooling, no rain
3 = Strong cooling, medium rain
4 = Weak cooling, medium rain
5 = Strong rain, never cools strongly

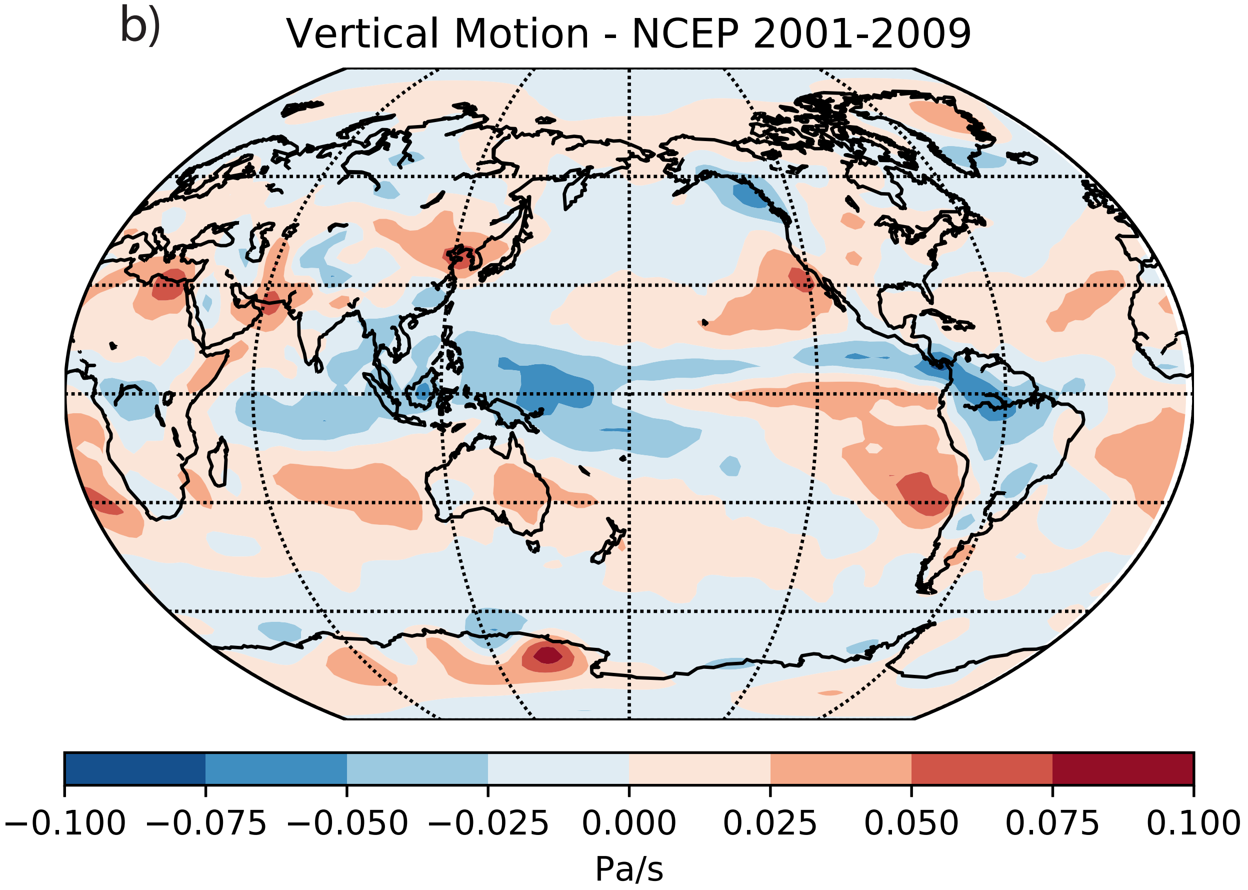


It is the circulation that facilitates the large-scale equilibrium

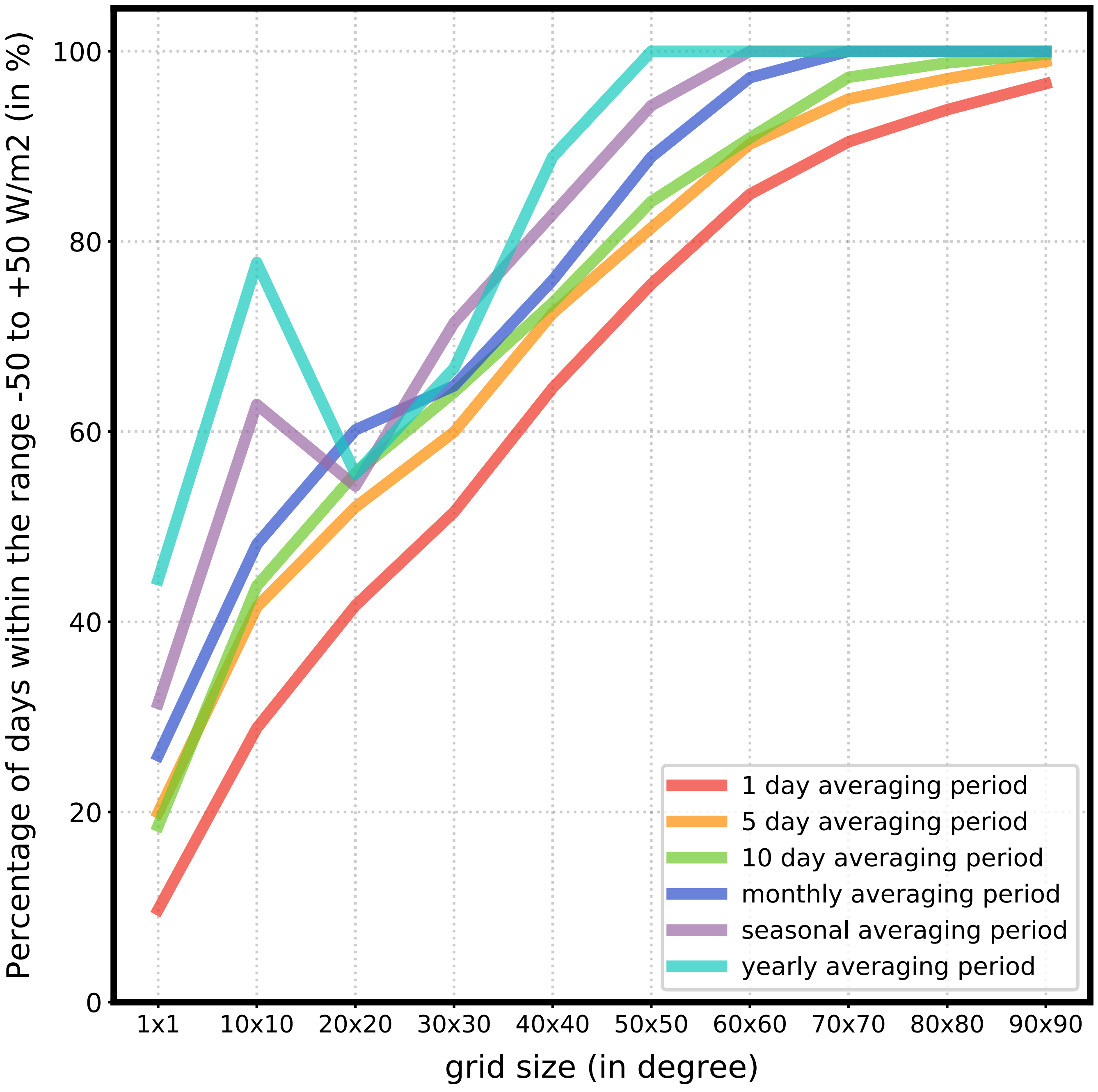
a)



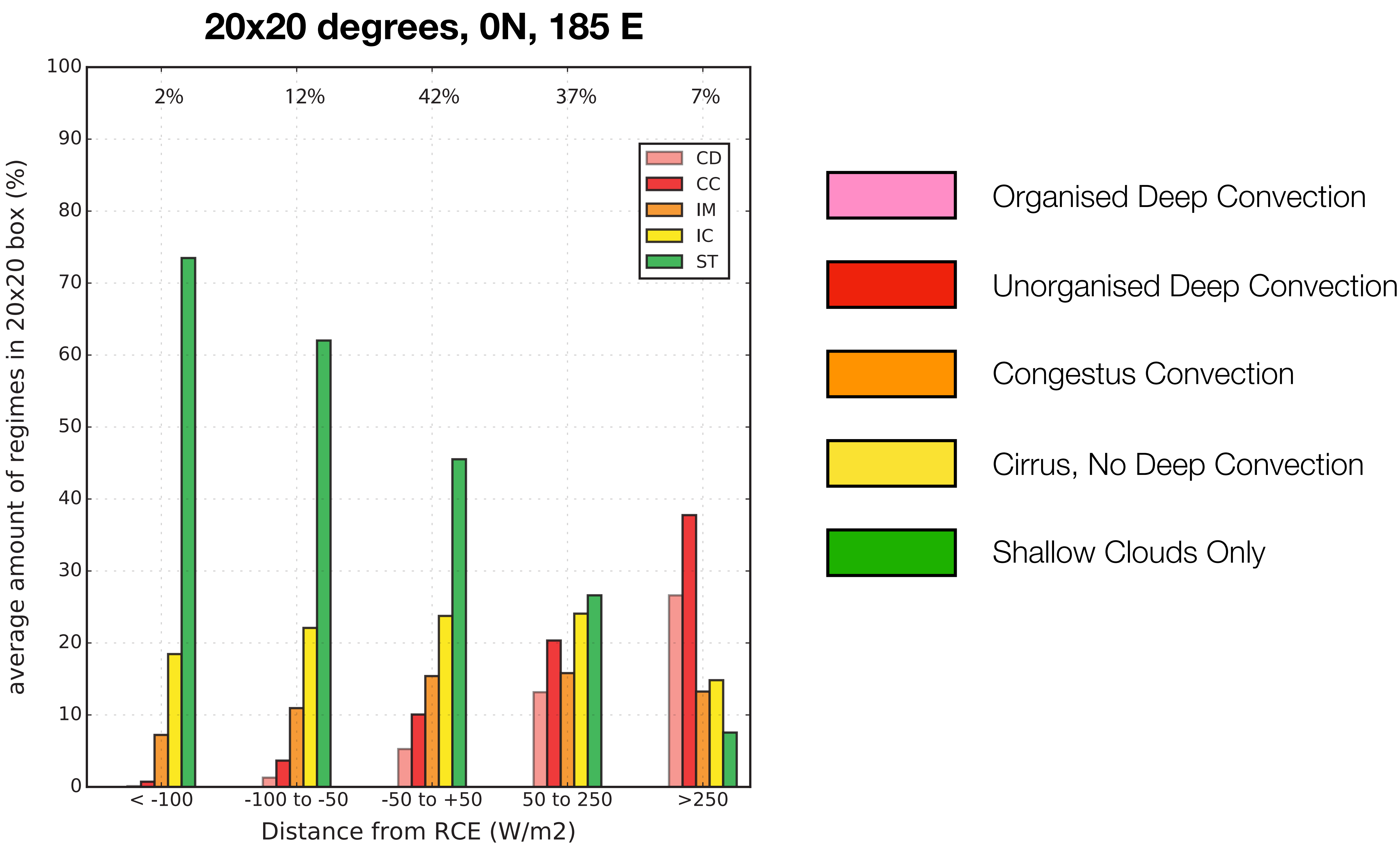
b)



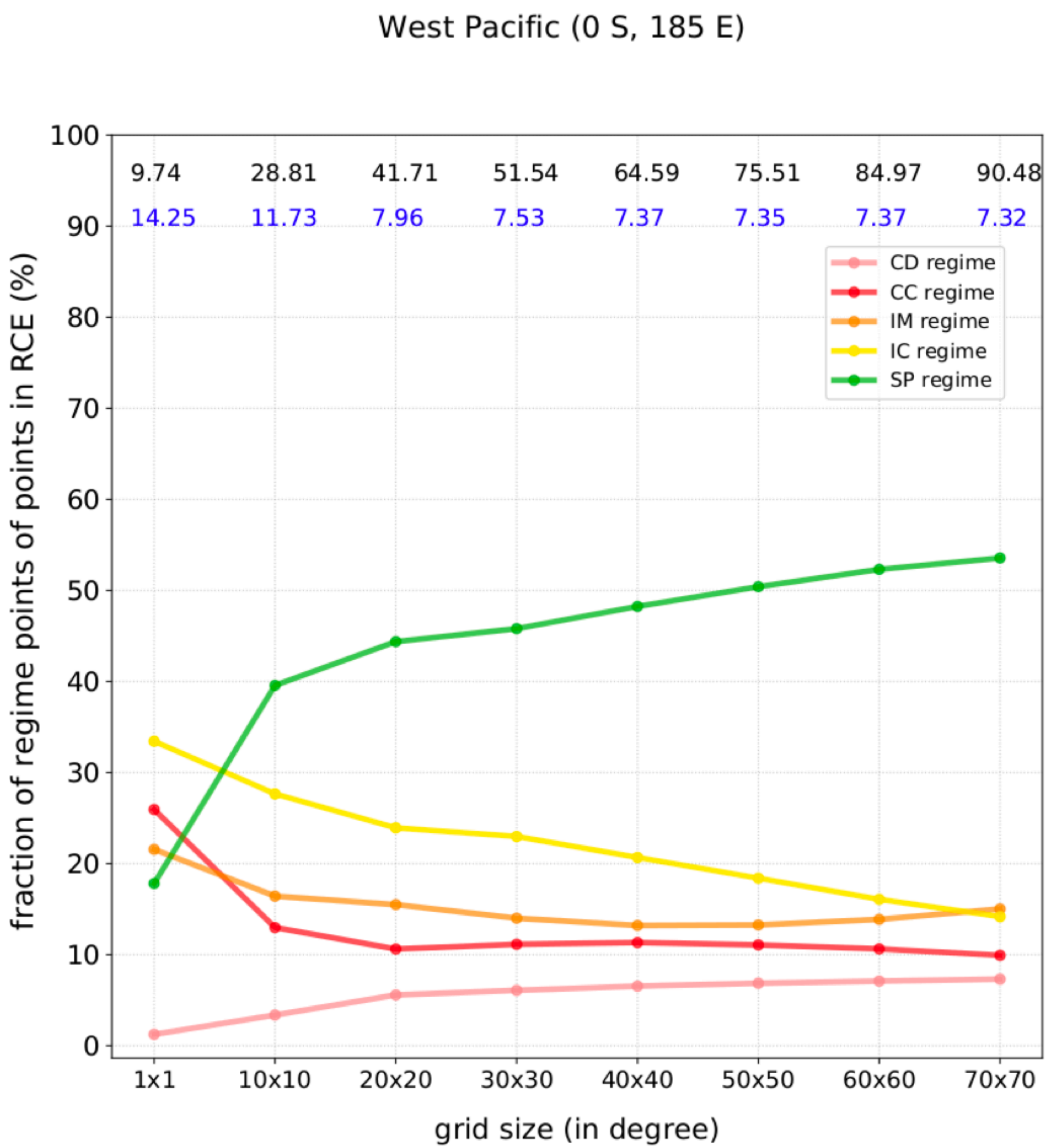
We define a “distance from RCE” as the difference between radiative cooling, sensible heat flux, and precipitation and ask what fractions of days are in RCE (-50 to + 50 W/m2 difference) as a function of spatial and temporal averaging scale.



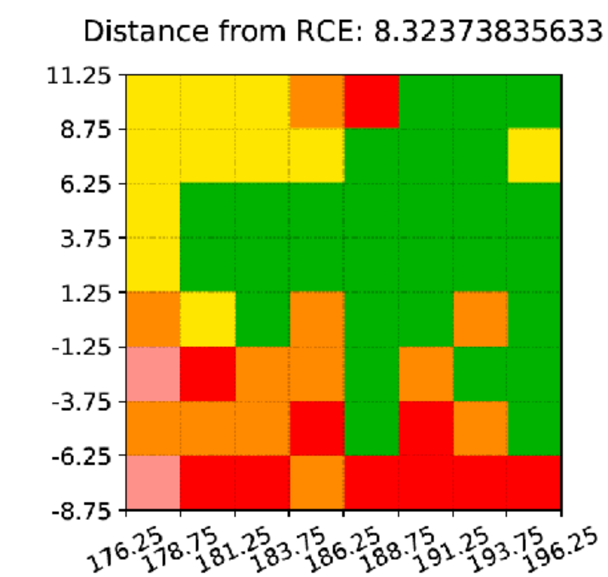
In relating RCE to cloud states, we find that achieving RCE requires the *"right" mix* of deep and organised convection and suppressed conditions.



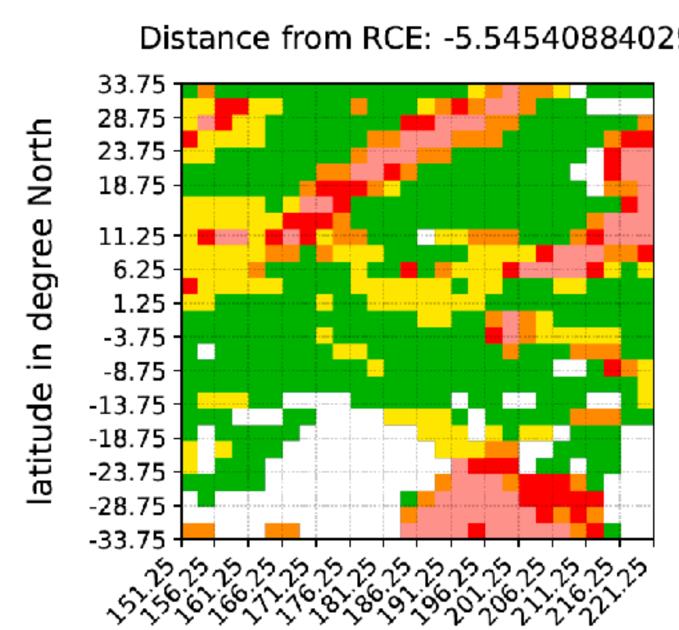
The ratio of active to suppressed conditions appears to be quite scale-invariant.



Snapshots



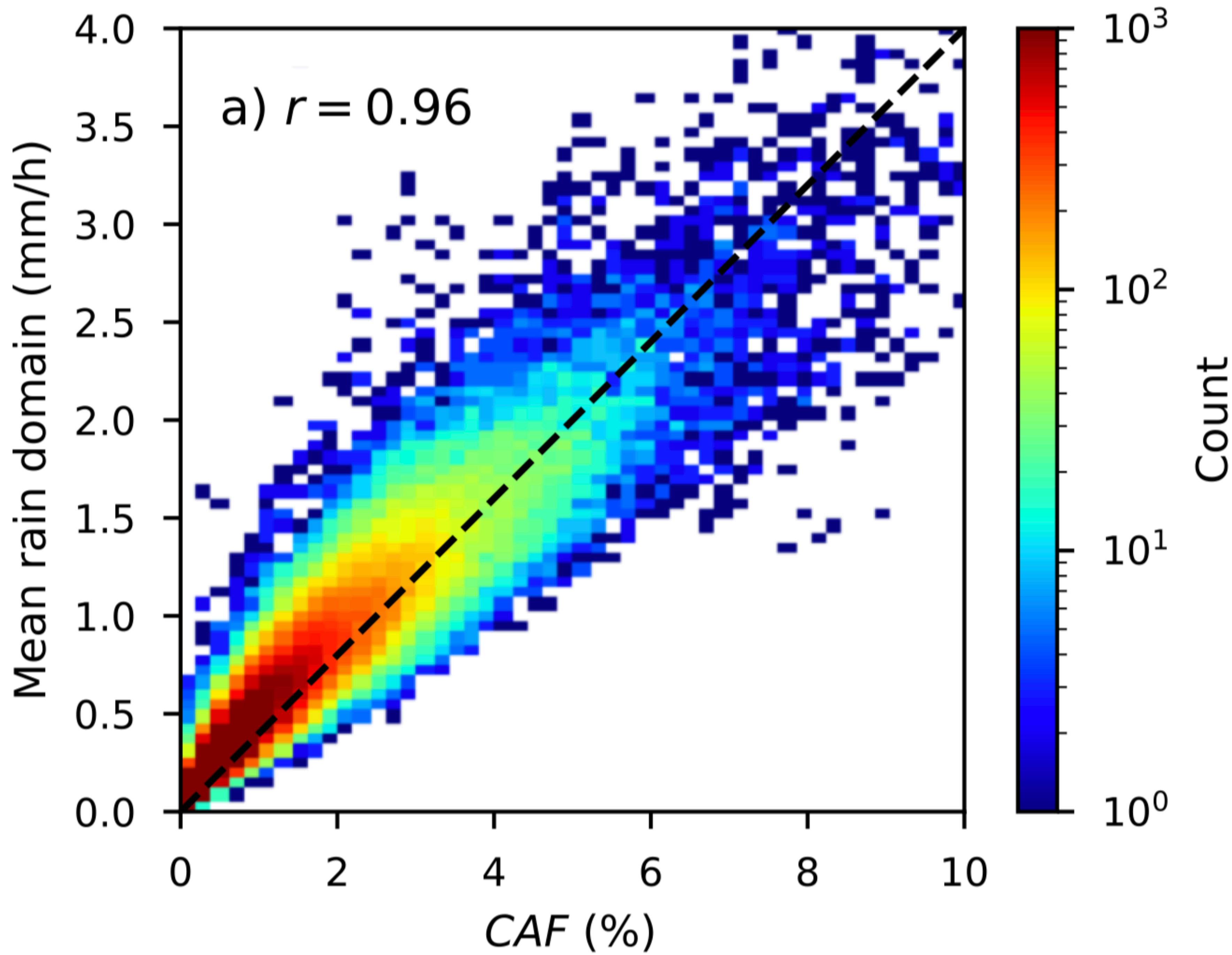
20x20



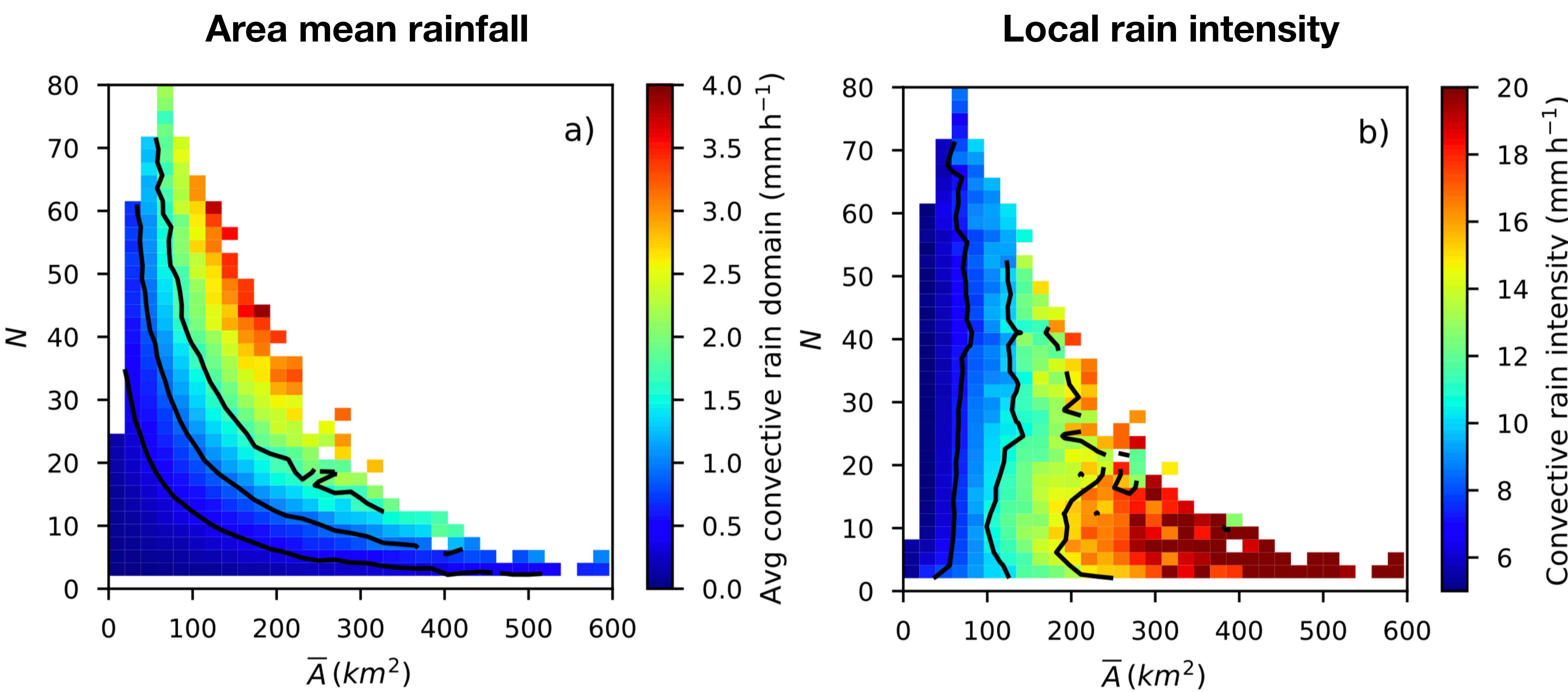
70x70

Local observations
provide process details
How might it work?

Radar observations from Darwin show that area-average rainfall in a convecting environment relates strongly to the area that is raining

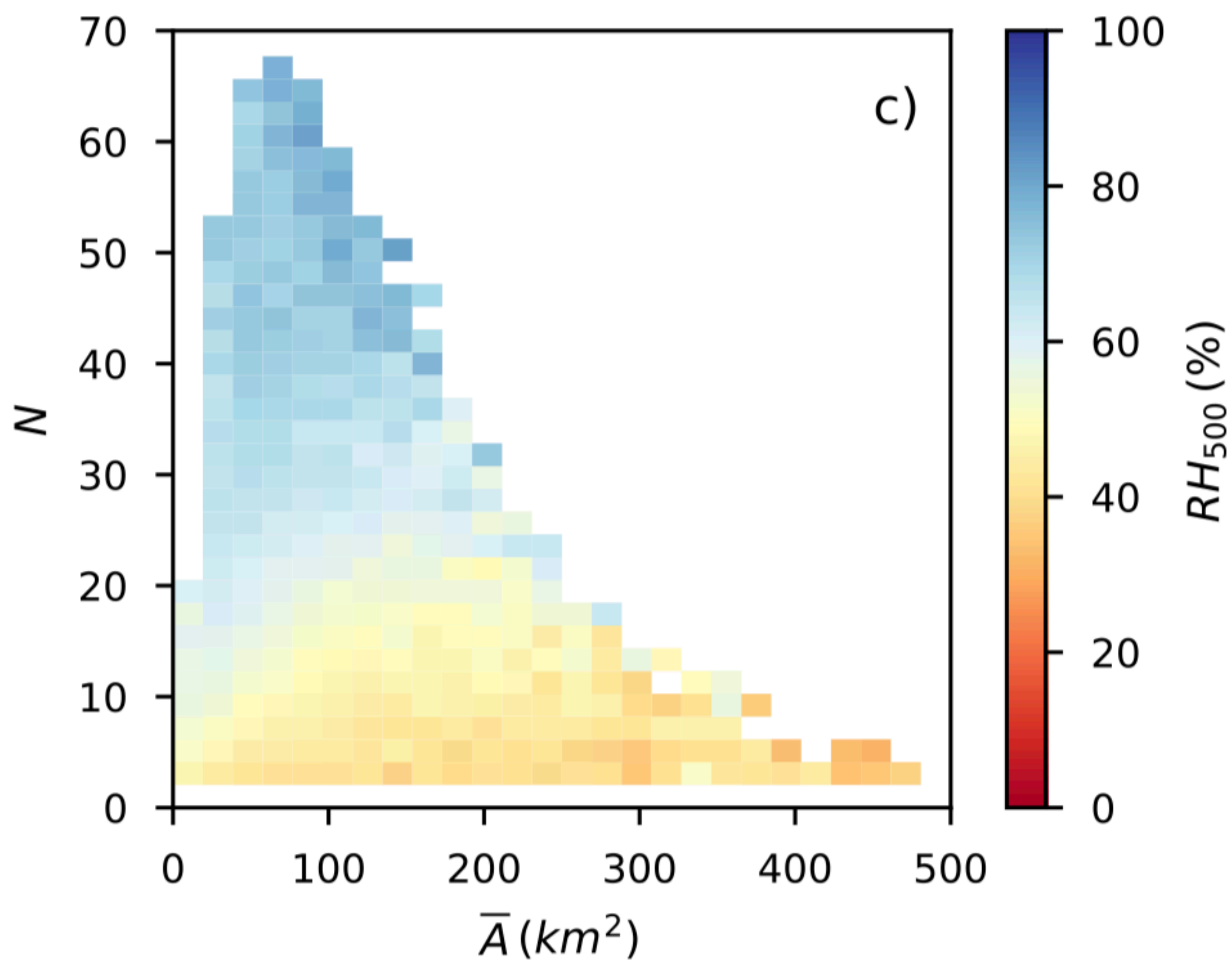


Splitting the area fraction into number of clouds and their size reveals interesting behaviour

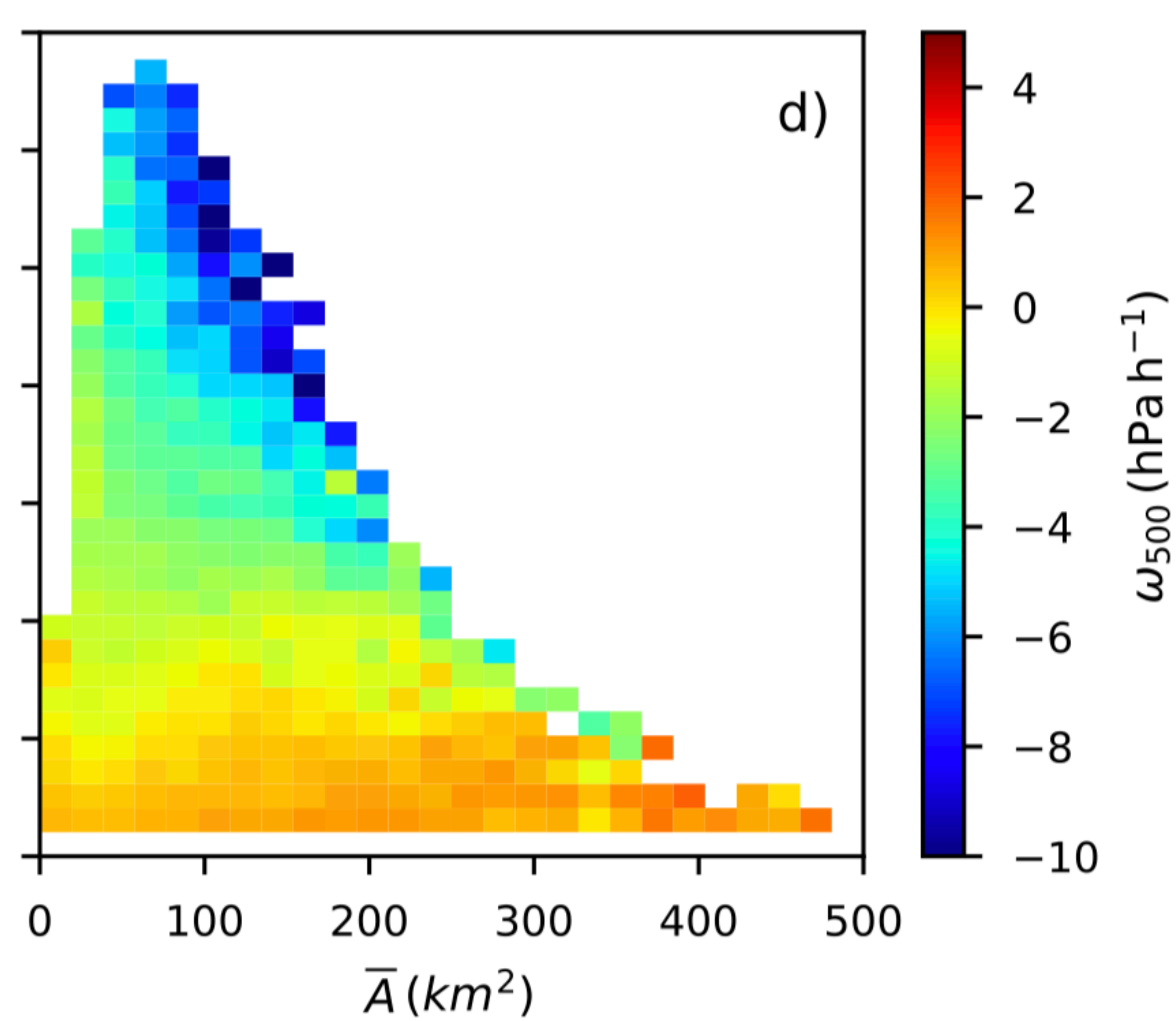


Investigating the relationship of the convective cloud ensembles characteristics to the large scales sets the scene for parametrisation

Mid-tropospheric RH

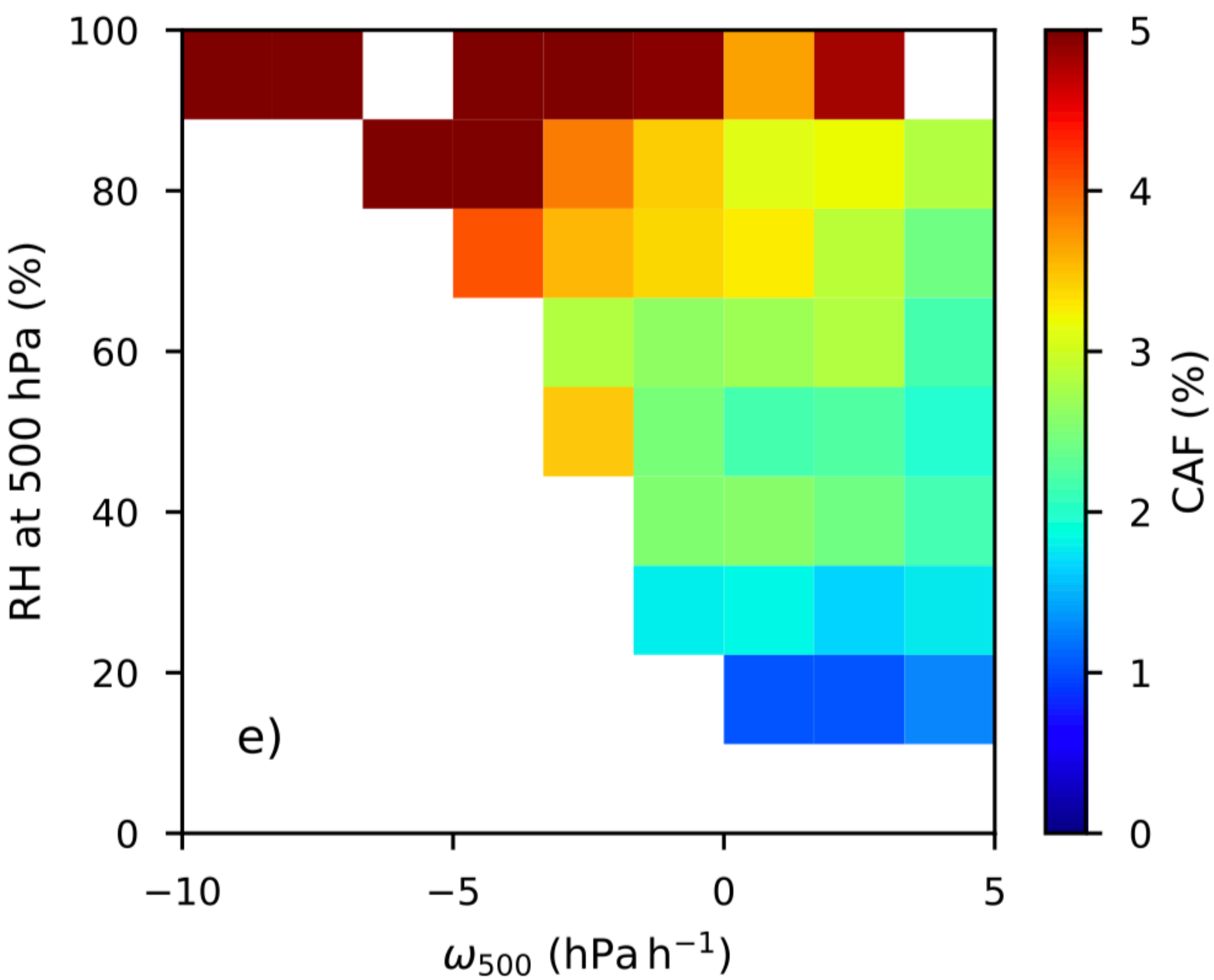


Mid-tropospheric vertical motion

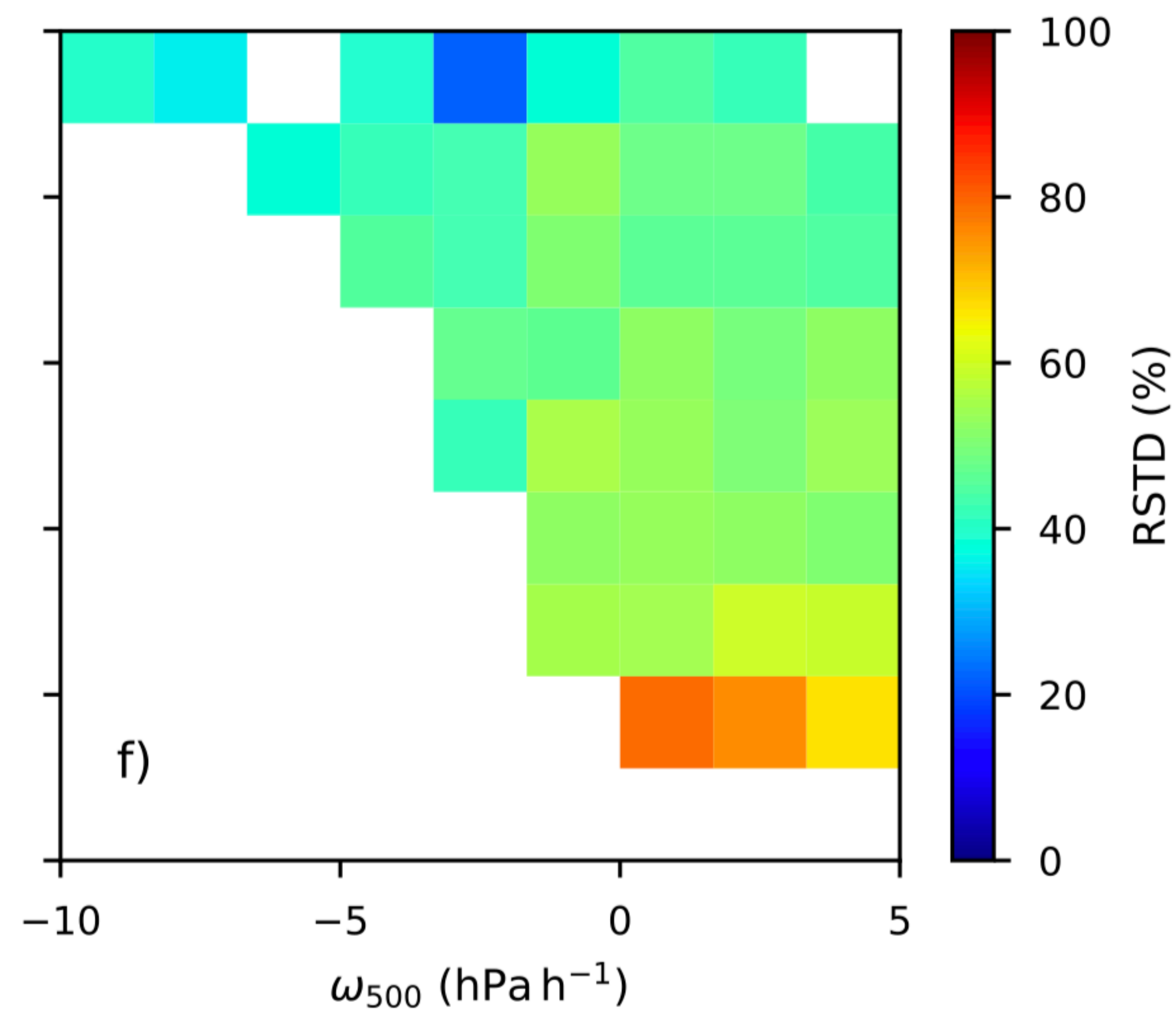


Investigating the relationship of the convective cloud ensembles characteristics to the large scales sets the scene for parametrisation

Cloud area fraction as f(RH, w)



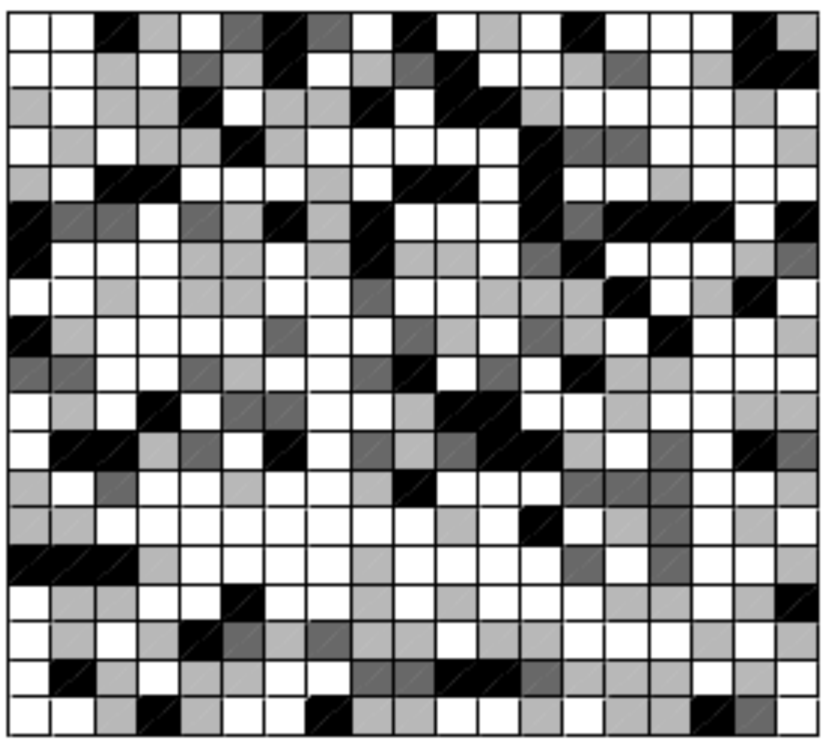
Within-bin standard deviation



Translating what we've learned into models

Based on our findings we divide the mass-flux that models use to describe convection into area and velocity and predict area with a statistical model

$$\rho \overline{w's'} \sim M_c (s_c - \overline{s}) \qquad M_c \approx \rho \sigma_c w_c$$



$$R_{01} = \frac{1}{\tau_{01}} \Gamma(C)\Gamma(D),$$

Clear to congestus

$$R_{02} = \frac{1}{\tau_{02}} \Gamma(C)(1 - \Gamma(D)),$$

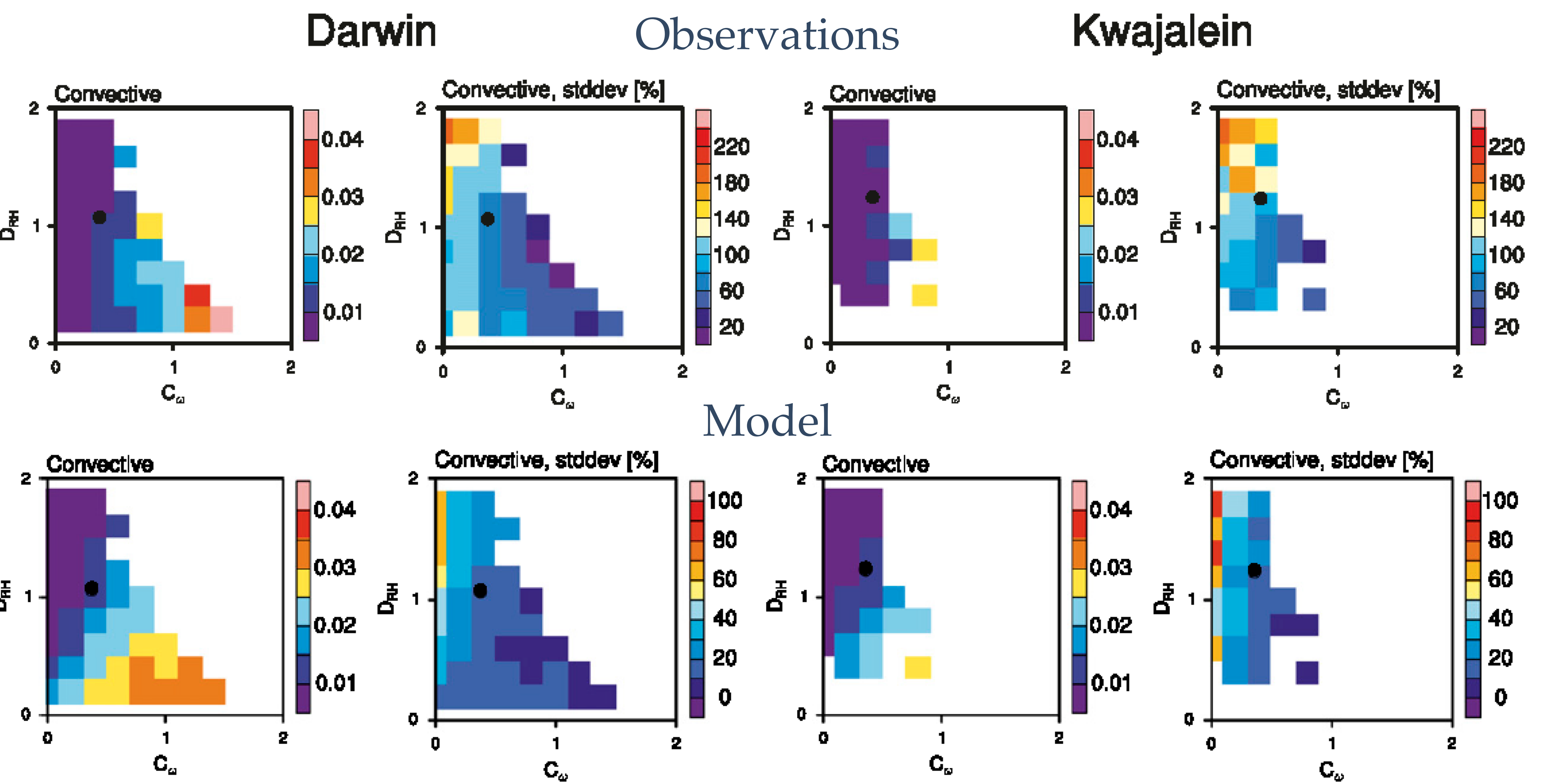
Clear to deep

So large C (ascent) and large D (low RH) favour congestus, while large C and small D (high RH) favour deep convection.

States considered:

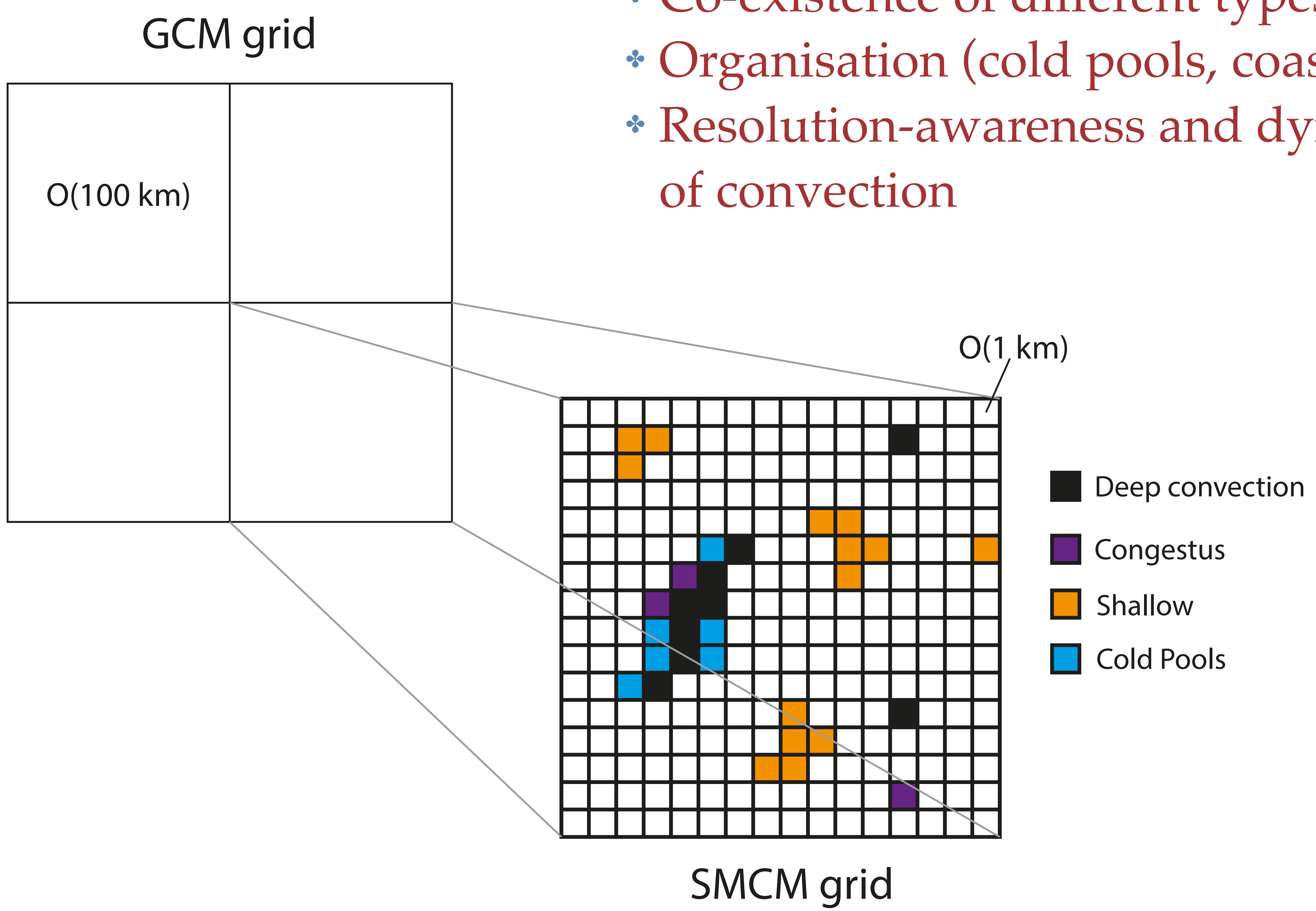
- Clear
- Congestus
- Deep Convection
- Stratiform Clouds

The model captures the the observed behaviour well



The new framework can in principle deal with all issues currently being discussed in the parametrisation community

- Stochastic behaviour of convection
- Co-existence of different types of convection
- Organisation (cold pools, coast lines, other)
- Resolution-awareness and dynamic switching off of convection



The vertical cloud structure will be calculated separately for each cloud type using an entraining plume or any other cloud model