Building stochastic representation of uncertainty into physical parametrizations

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A key distinction not made sufficiently is between model error and model uncertainty

Model error:

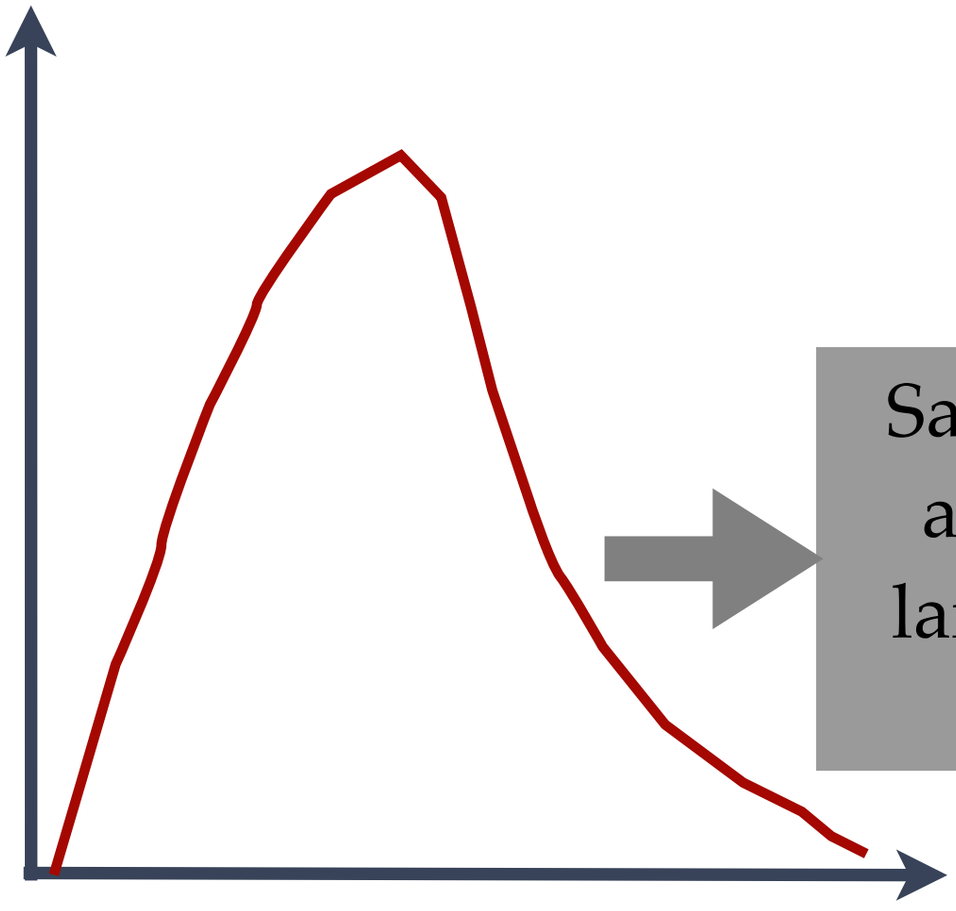
We have built the built the best model we can and we acknowledge that it has errors. We would like to represent the effect of these errors. To do this properly, we ideally must analyse the error characteristics and build a statistical model of them.

Model uncertainty:

We know a priori that some of the relationships we exploit in our models, in particular in the parametrizations, are uncertain. This could be parameter uncertainty or it could be that non-deterministic elements in the relationship allow for more than one outcome. Both should be represented in the parametrizations themselves, the former through drawing parameters from pdfs, the latter by building stochastic elements into the parametrizations.

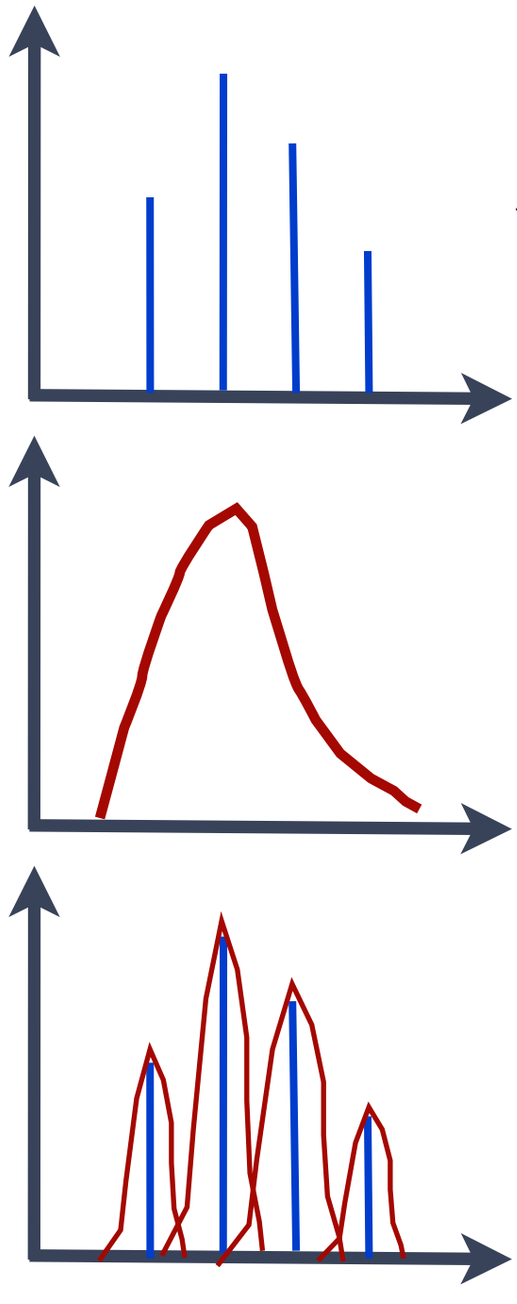
This talk is about the latter point!

What do we mean by stochastic relationships in parametrization?

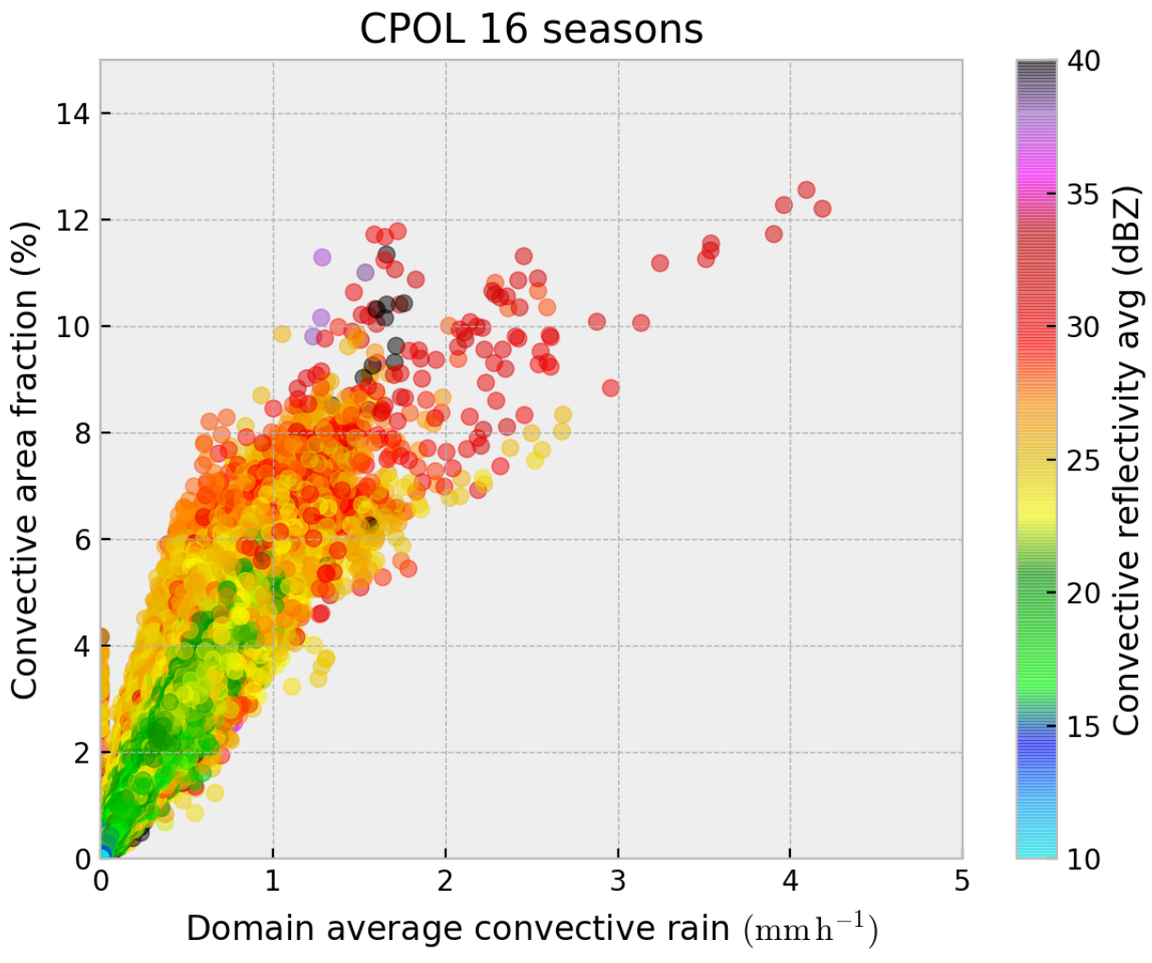


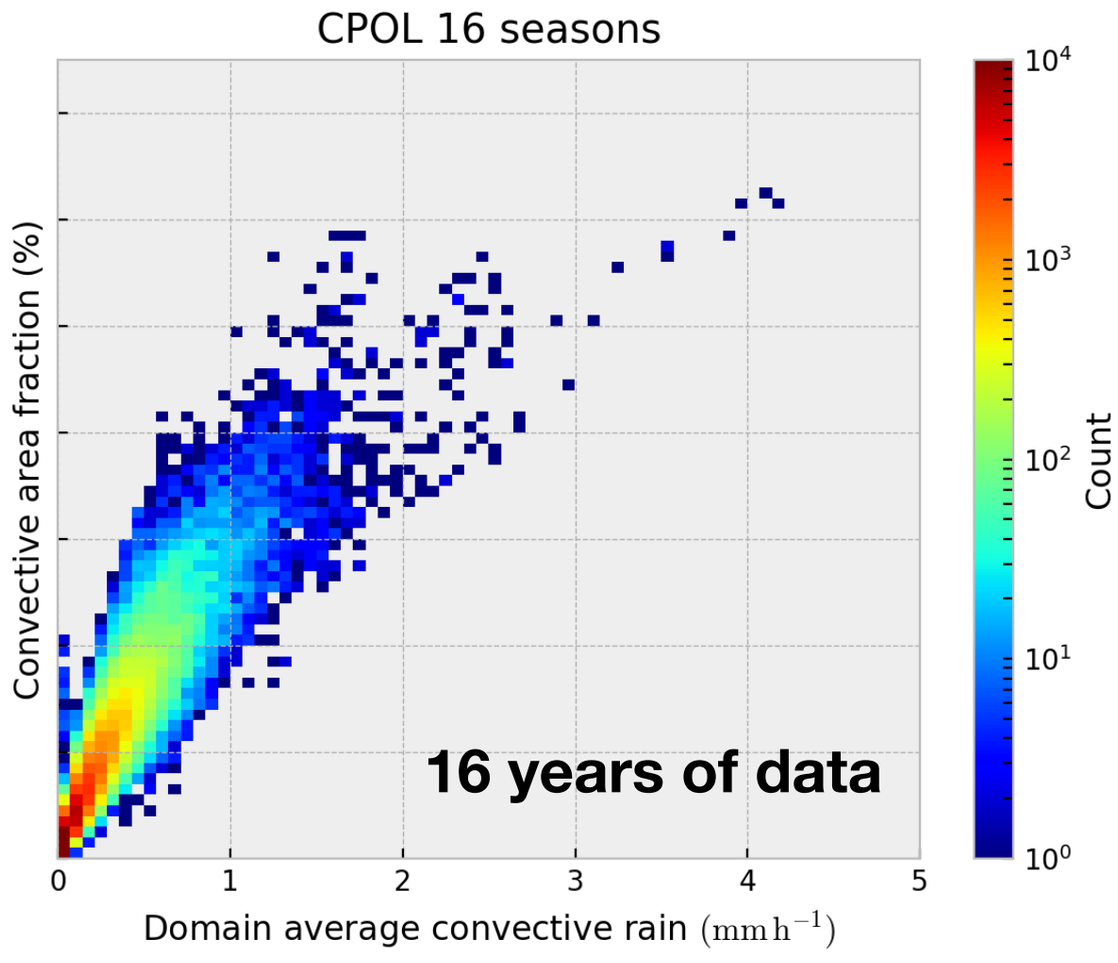
Heating/Precipitation PDF

Sample for arbitrary large-scale states



Can we learn about such relationships from observations?



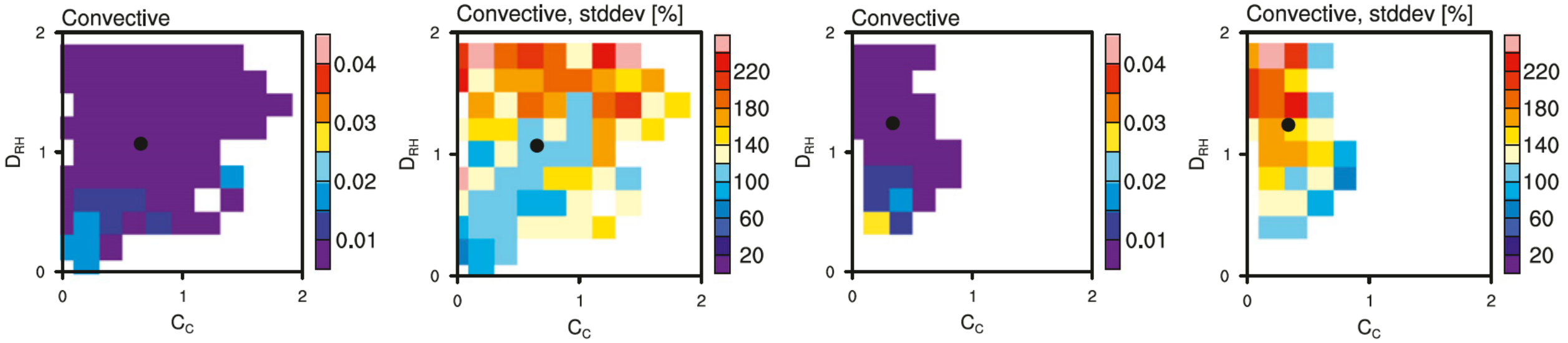


Beware: The degree of “stochasticity” can be a strong function of the model and predictors we choose!

Darwin

CAPE

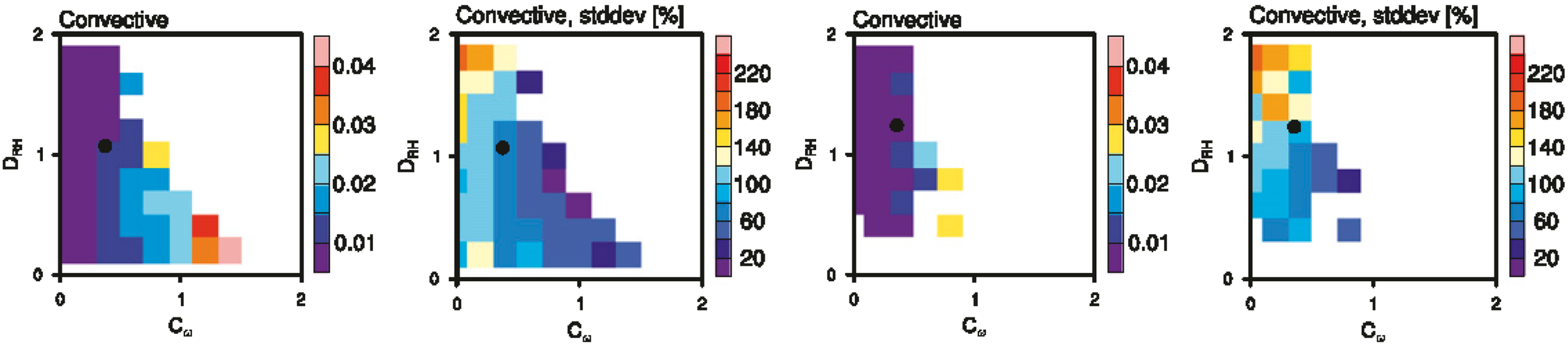
Kwajalein



Darwin

Vertical motion

Kwajalein

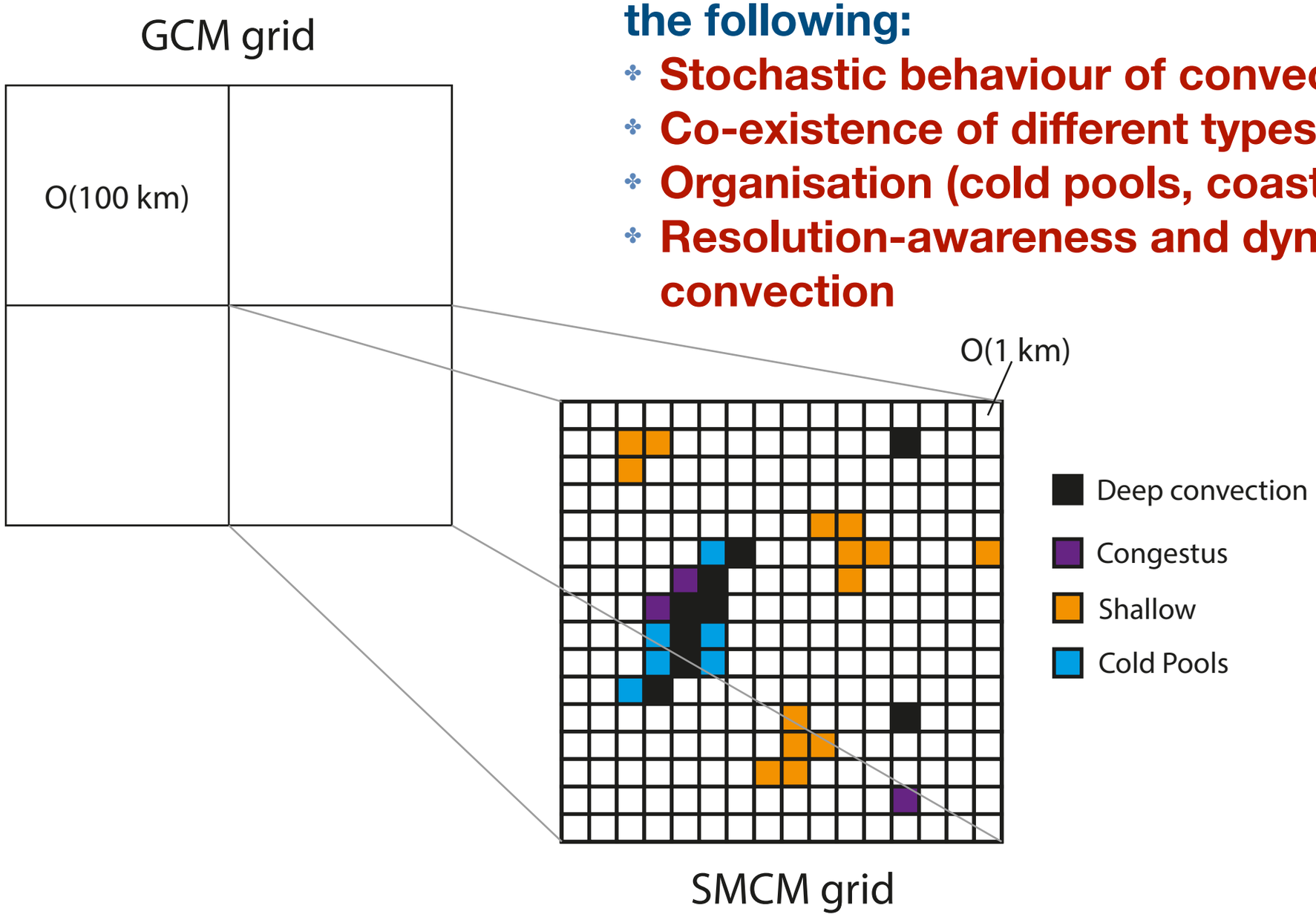


Peters et al., 2013, JAS

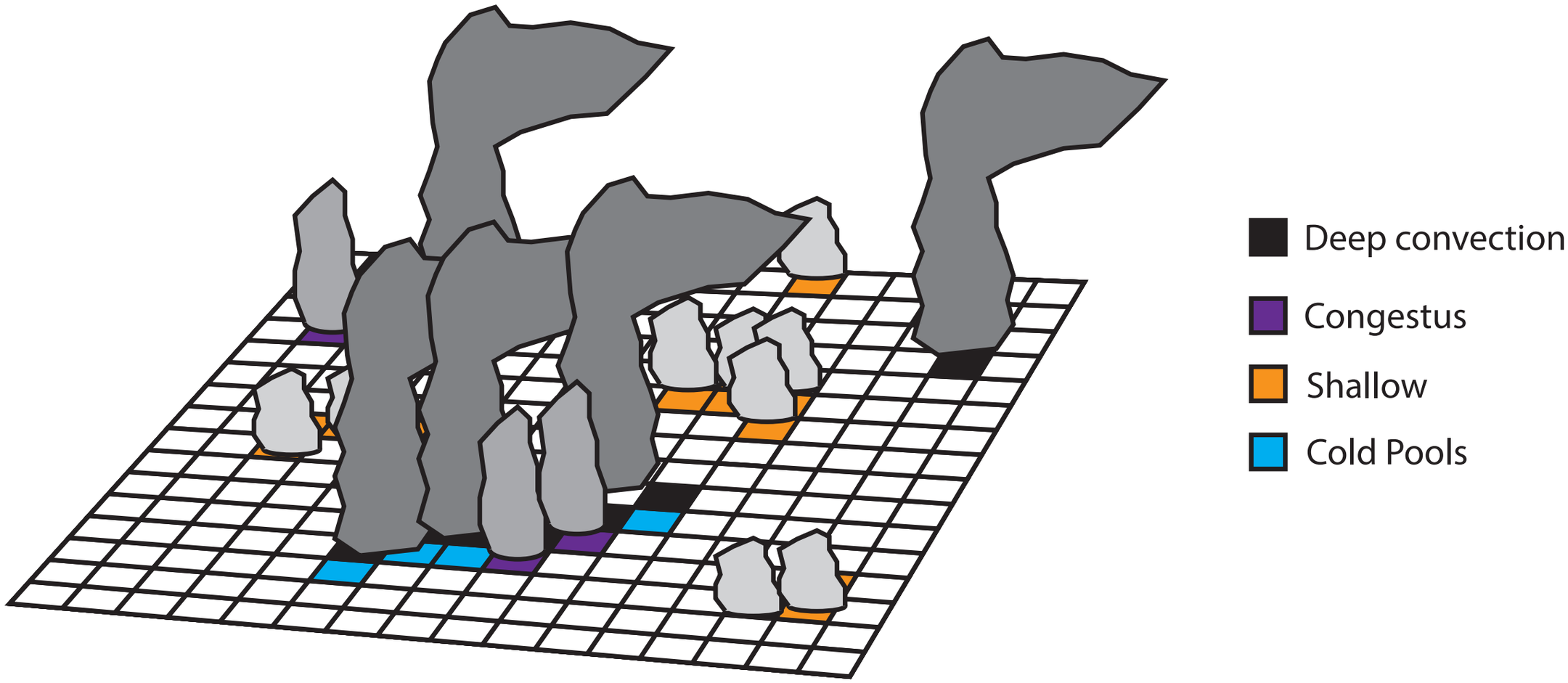
We can apply this information, including the stochastic behaviour directly in parametrizations through statistical models.

We apply a Markov-Chain model to predict area fractions. The model can in principle deal with all of the following:

- **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**

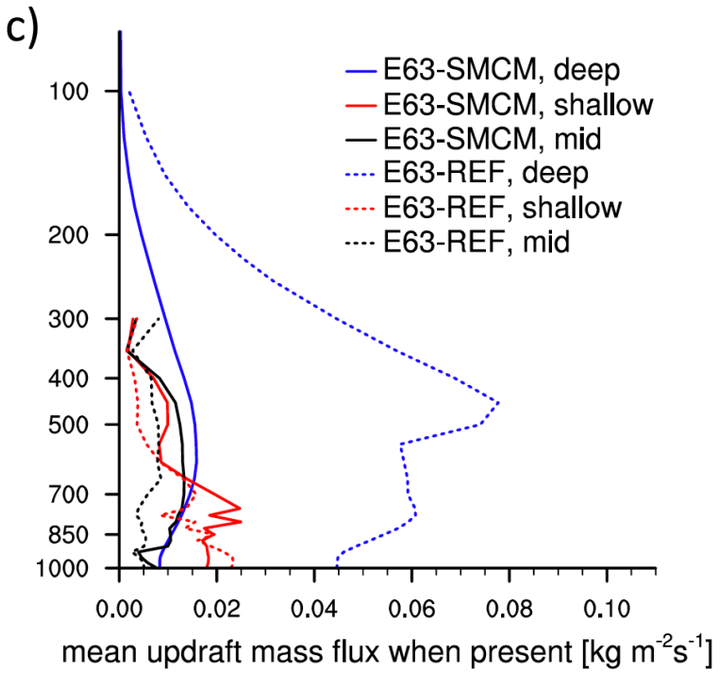


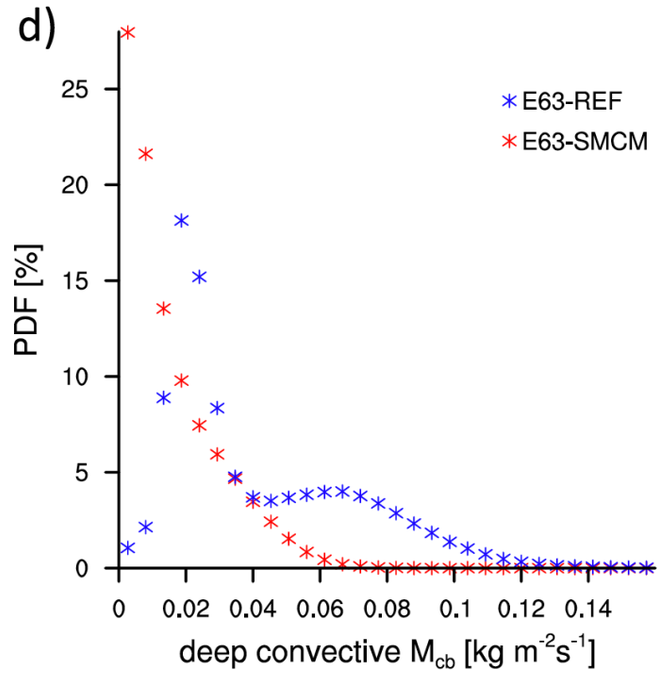
We combine the statistical model with physical models, e.g., mass-flux models for updrafts.

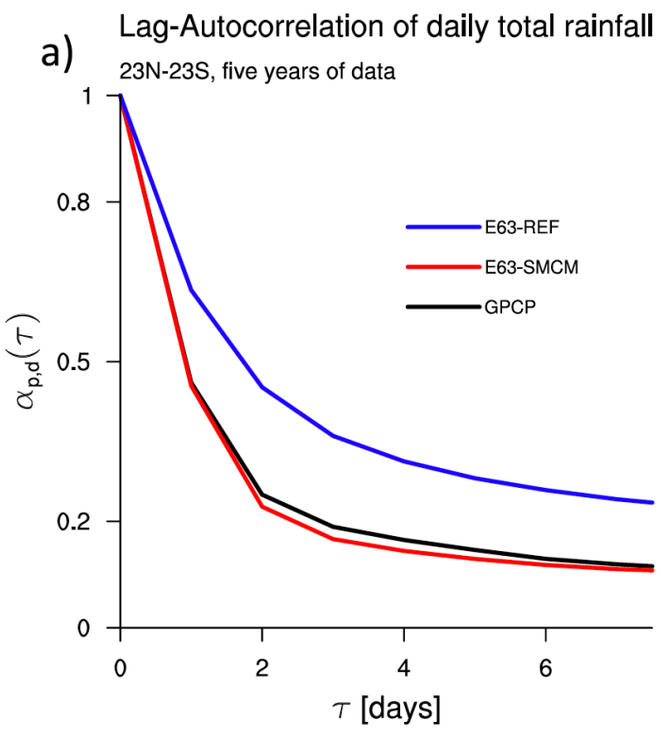


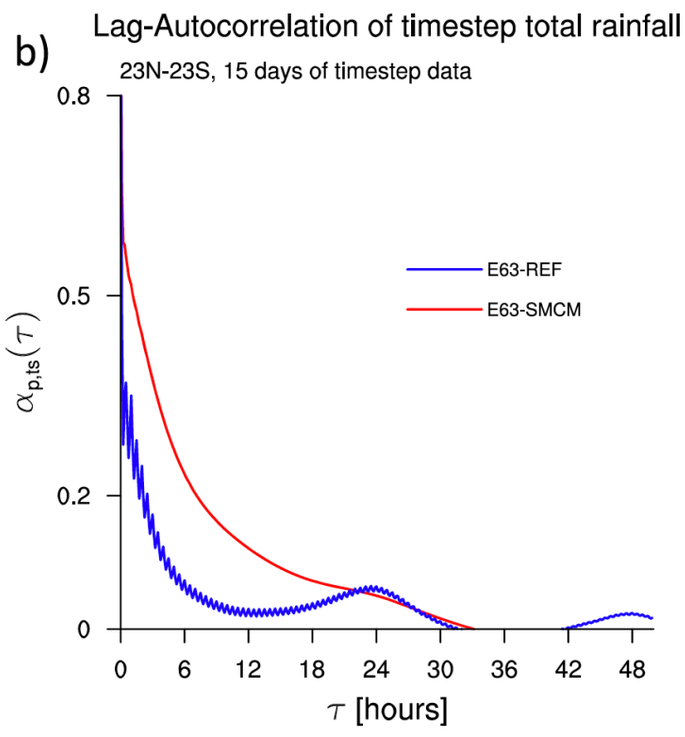
A simple first implementation of this idea in the MPI model gives very promising and interesting results.

Peters et al., JAMES, 2017









- Very large reduction in mass-flux when present
- Complete change in the pdf of deep convective mass-flux
- Strong improvement in the autocorrelation of daily rainfall
- Smoother autocorrelation of time step rainfall

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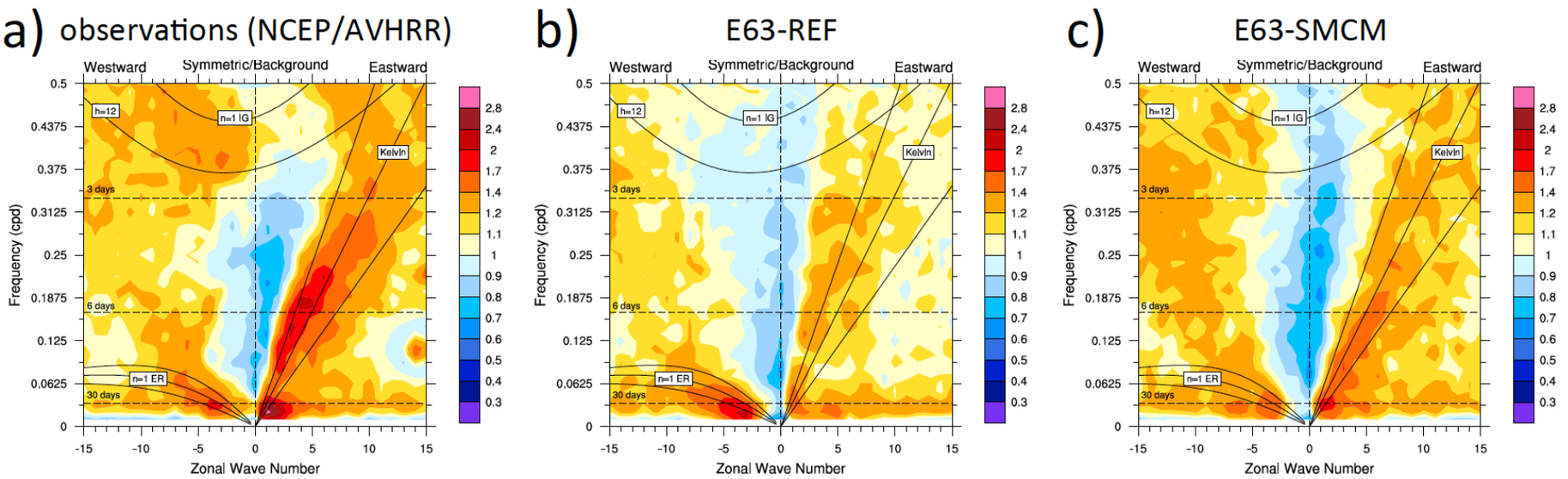
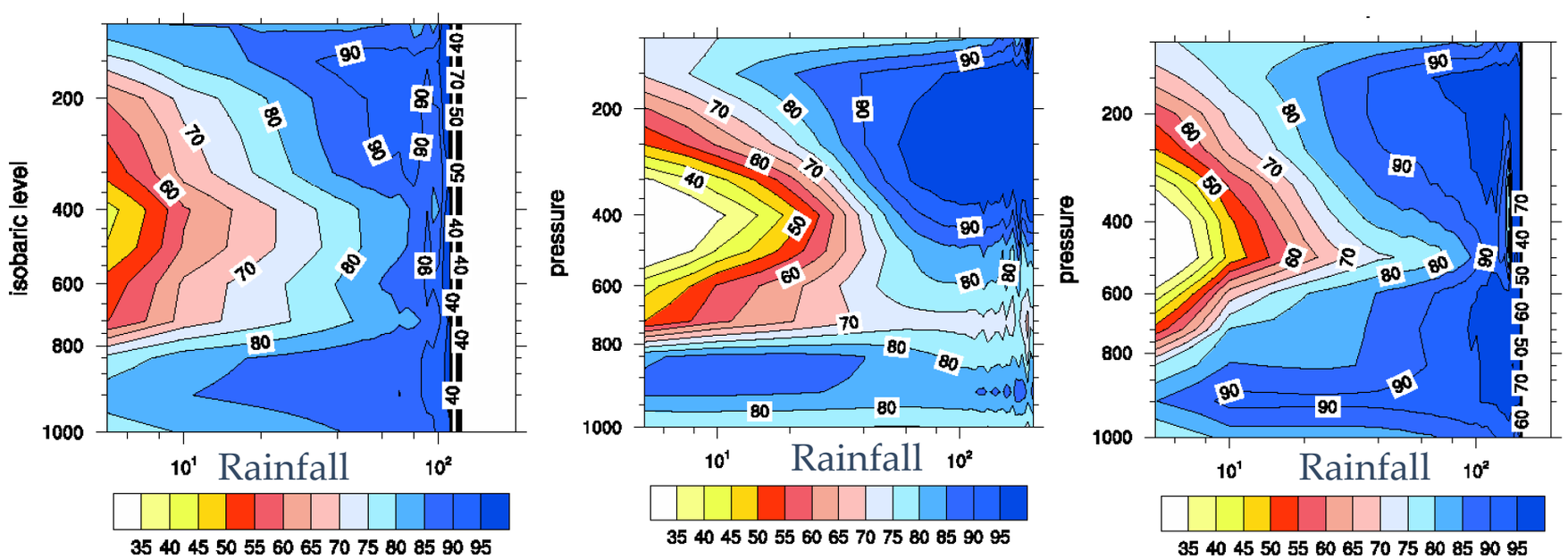
Peters et al., JAMES, 2017



Wave spectra

RH(p) vs Rainfall



Conclusions

- We must be clearer in distinguishing between model error and model uncertainty.

- This is important, as representing the two requires different approaches!

- Model uncertainty that is the result of non-deterministic relationships can be represented directly in the model's formulation.

- Ideally, the models/parametrizations required to do so are

    1. Informed by observations

    2. Contain statistical elements where equations are not known, and physical elements where they are!