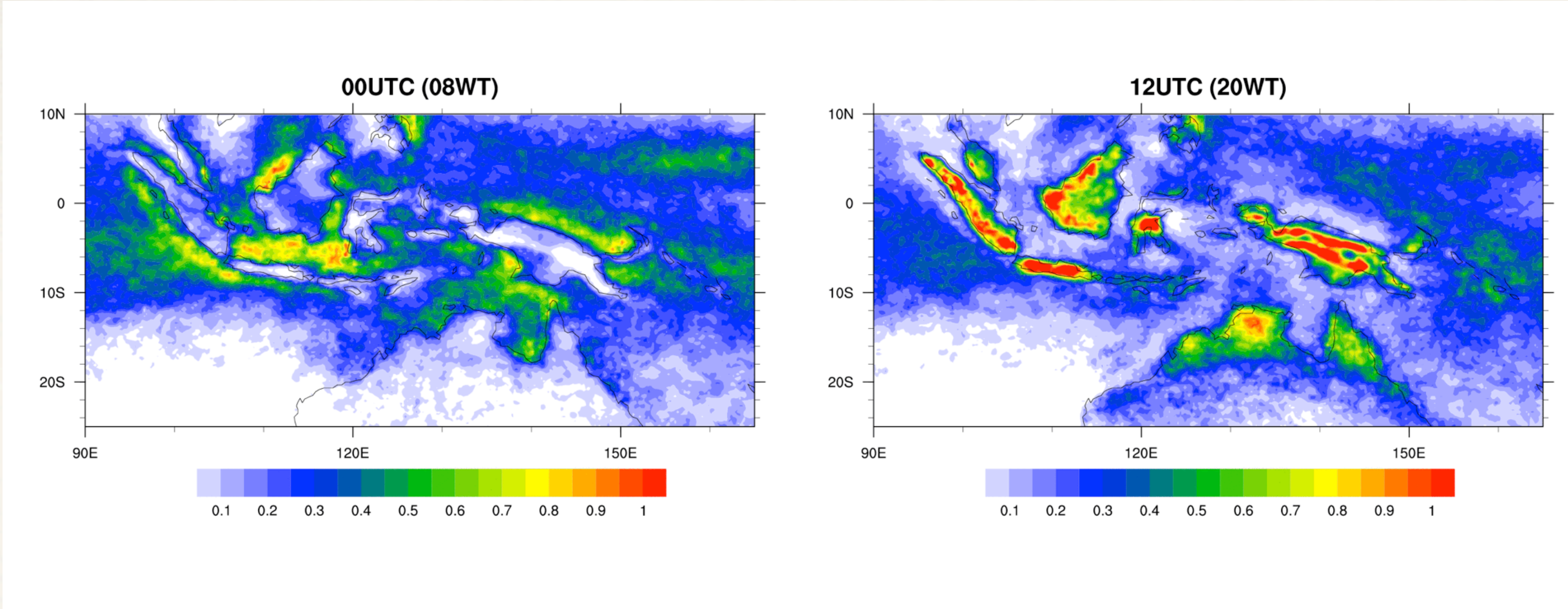
ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

MONASH University Science



Representing convection in models - How stochastic does is need to be?

Christian Jakob and Laura Davies
School of Mathematical Sciences, Monash University, Melbourne, Australia

20 June 2011

Convection in large-scale models

$$\frac{\partial(\overline{\rho}\overline{s})}{\partial t} = -\frac{\partial(\overline{\rho}\overline{u}\overline{s})}{\partial x} - \frac{\partial(\overline{\rho}\overline{v}\overline{s})}{\partial y} - \frac{\partial(\overline{\rho}\overline{w}\overline{s})}{\partial z} - \frac{\partial(\overline{\rho}\overline{u's'})}{\partial x} - \frac{\partial(\overline{\rho}\overline{v's'})}{\partial y} - \frac{\partial(\overline{\rho}\overline{w's'})}{\partial z} + \overline{\rho}Q$$

resolved terms

sub-grid horizontal fluxes

sub-grid vertical flux

sources

To parametrize:

$$-\frac{\partial(\overline{\rho}\overline{w's'})}{\partial z}$$

sub-grid vertical flux

$$+\overline{\rho}Q = +\overline{\rho}(Q_{rad} + C + E)$$

sources

radiation

evaporation

condensation

Surrogate for convective heating:

$$Q_1 = Q_{rad} + L(c - e) - \frac{1}{\overline{\rho}}\frac{\partial(\overline{\rho}\overline{w's'})}{\partial z}$$

Apparent heat source

Convection in large-scale models

Decide on existence and type (e.g., deep vs. shallow) of convection

→ Trigger model

Predict vertical distribution of heating, moistening and momentum changes

→ Cloud model

Predict the overall amount of the energy release

→ Closure

Real data to explore the problem

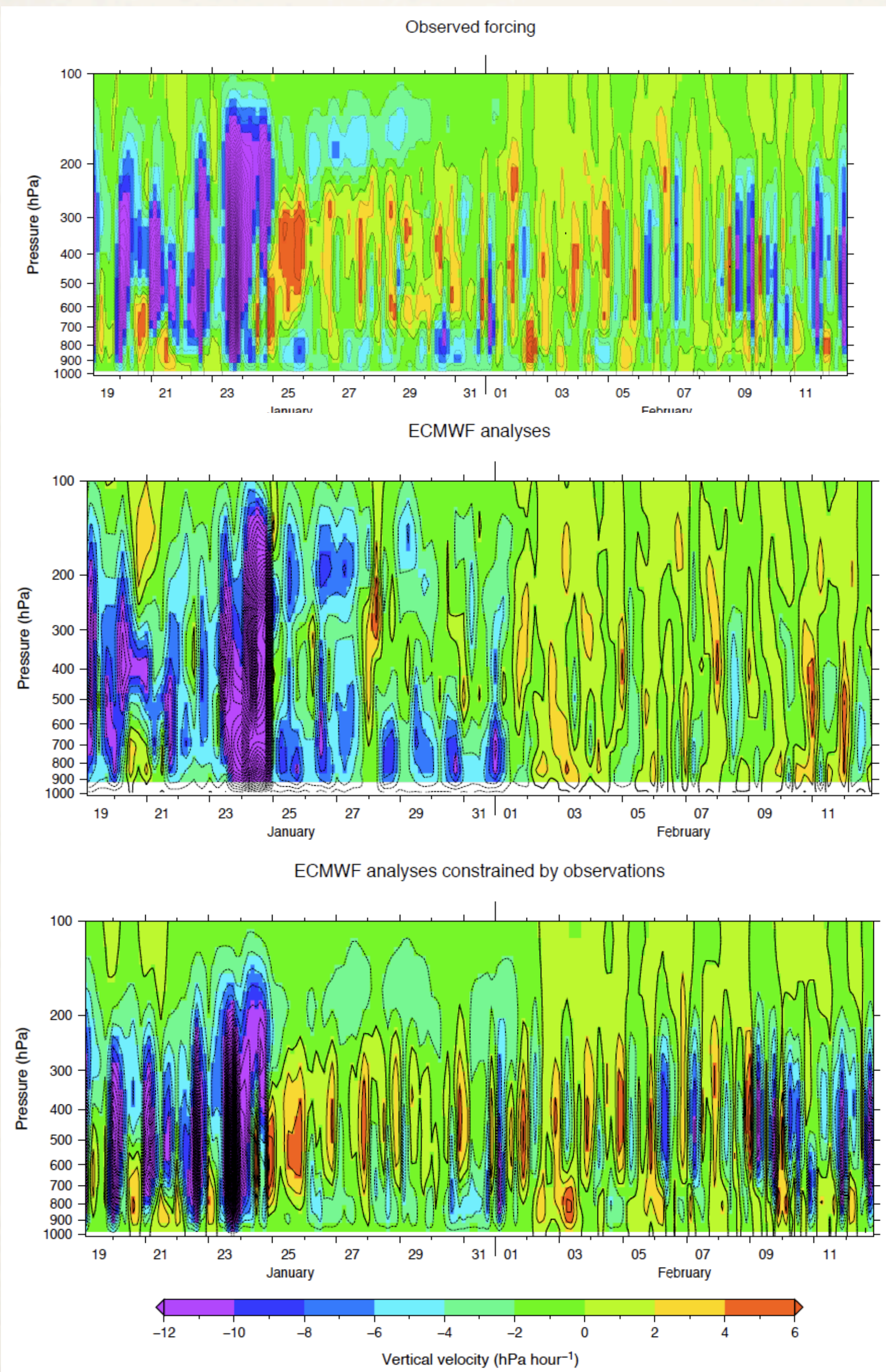
- Most if not all the research into the stochasticity of convection has relied on the use of models
- While justifiable to some extent, ultimately it is the real world we wish to represent
- It is timely to explore observations and make them useful to the discussion
- To do so requires frequent concurrent observations of the large and small scales in a convecting atmosphere

ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

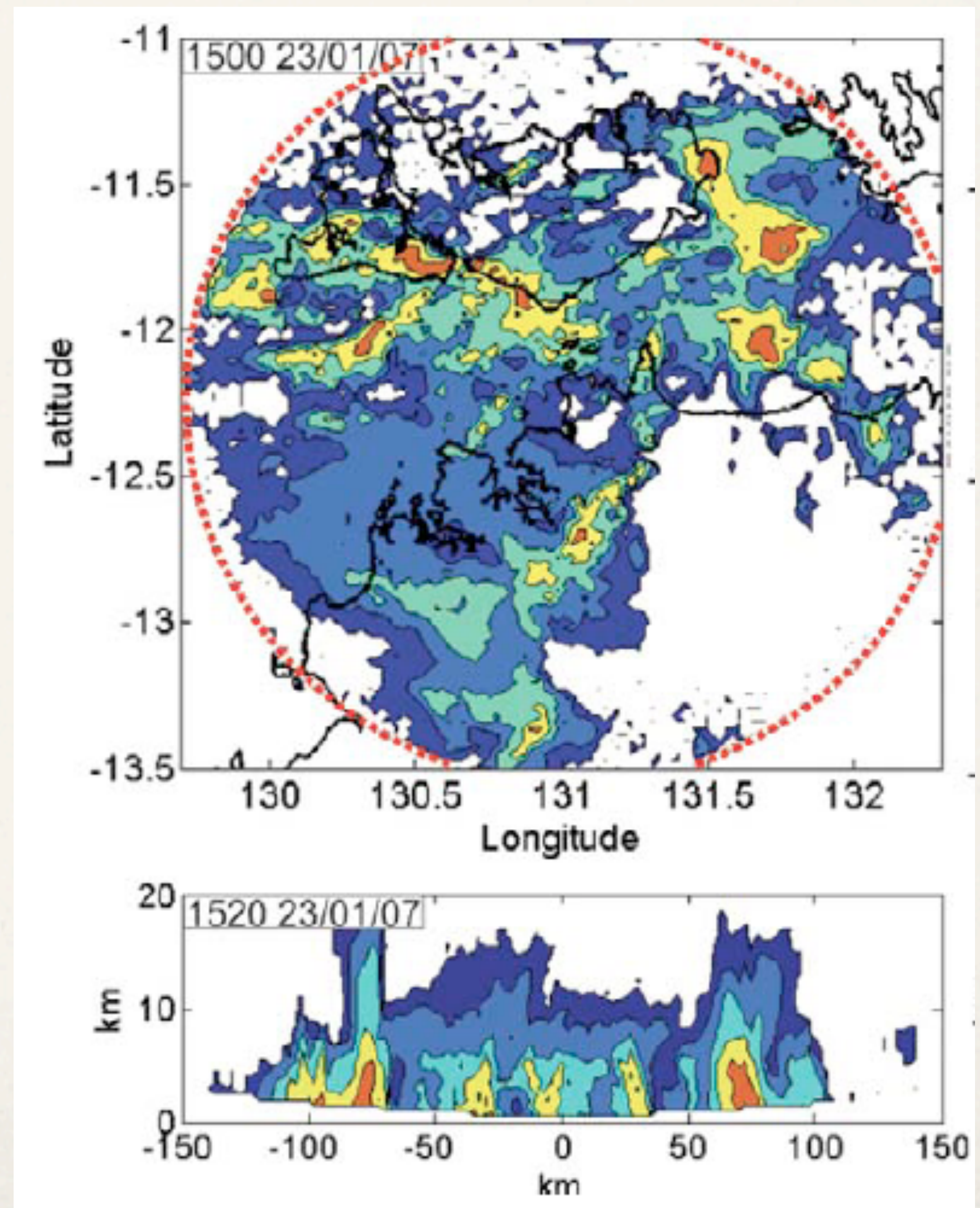
MONASH University Science

The data set - Construction

Large Scales



Small Scales



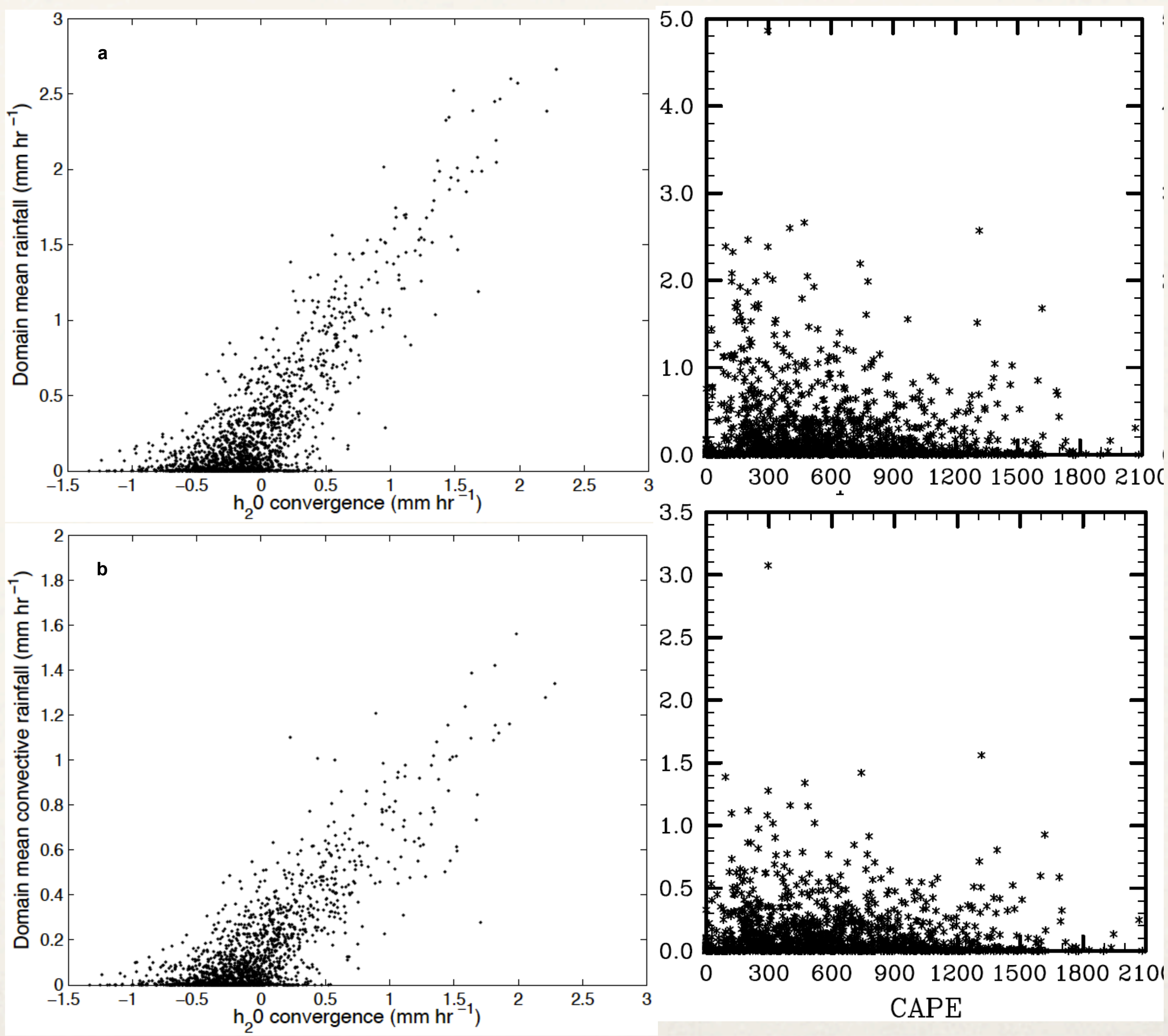
ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

MONASH University Science

Some basic relationships

Total rainfall

Convective rainfall

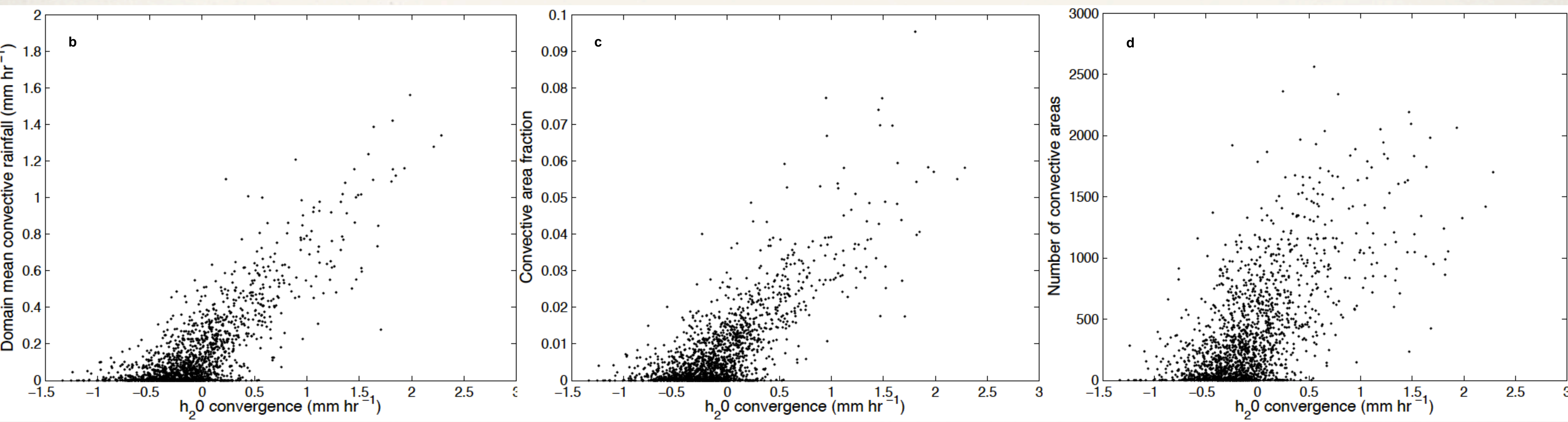


Large-scale q-convergence

CAPE

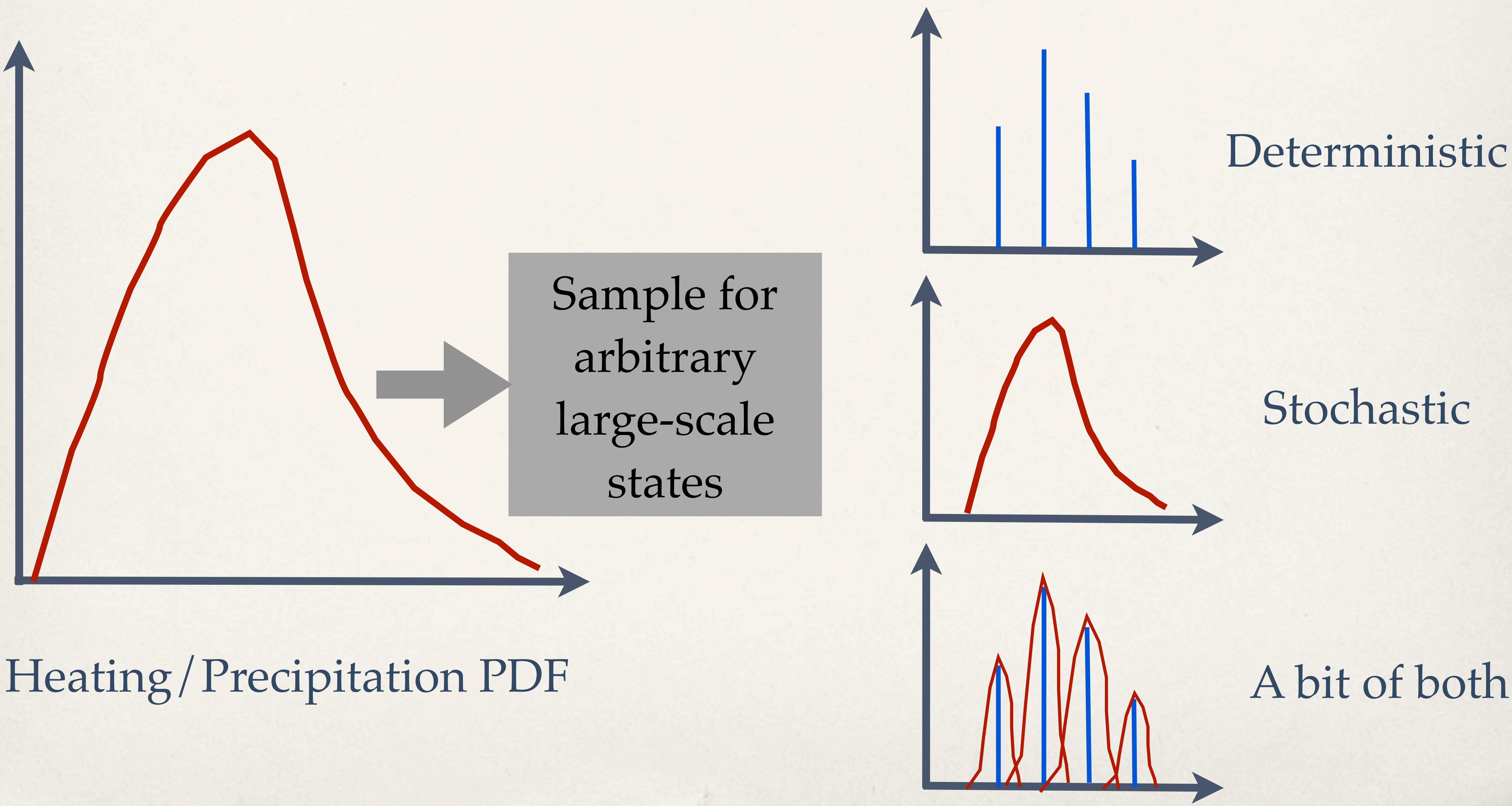
Some basic relationships

Relationship to large-scale q-convergence



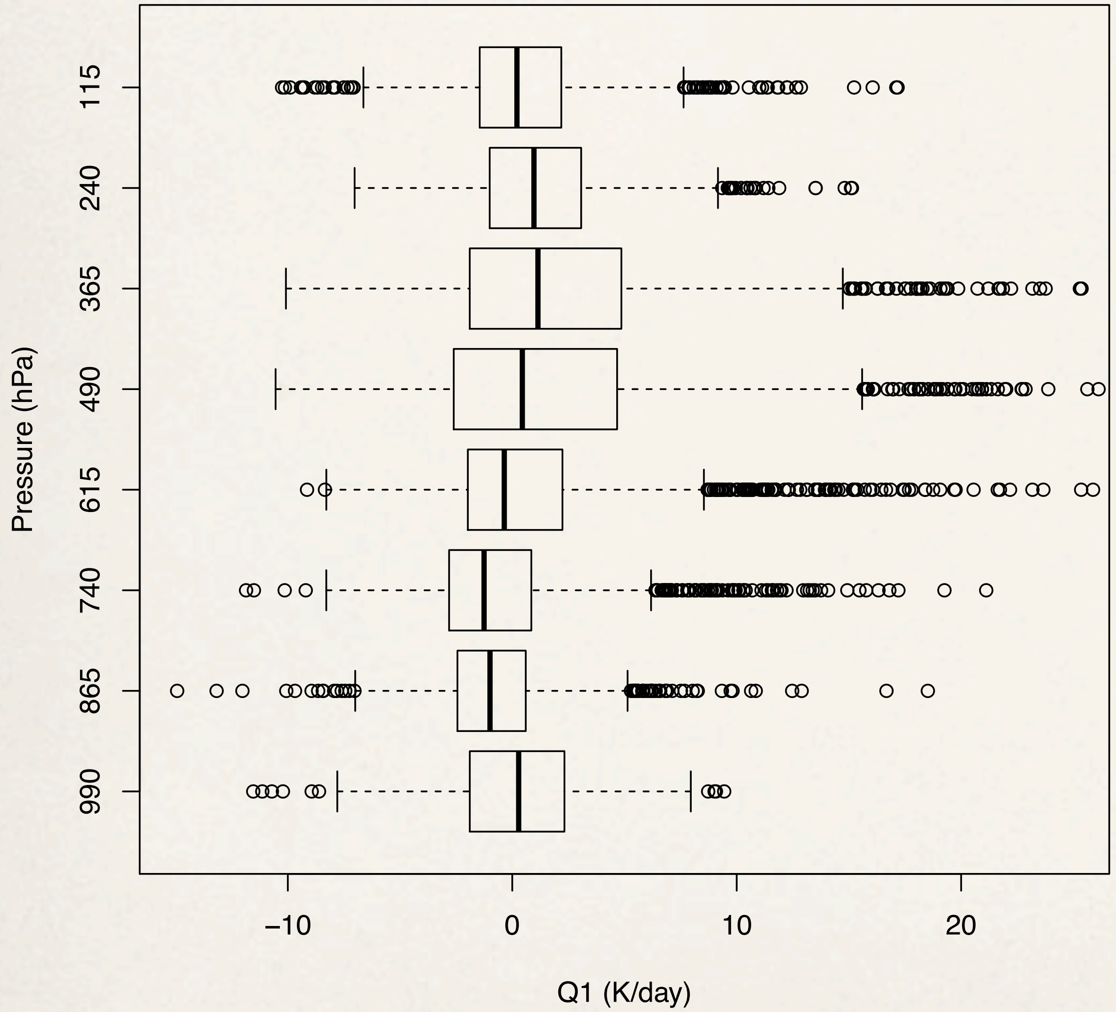
Domain-mean convective rainfall | Convective area fraction | Number of convective cells

What do we mean by "stochastic"?

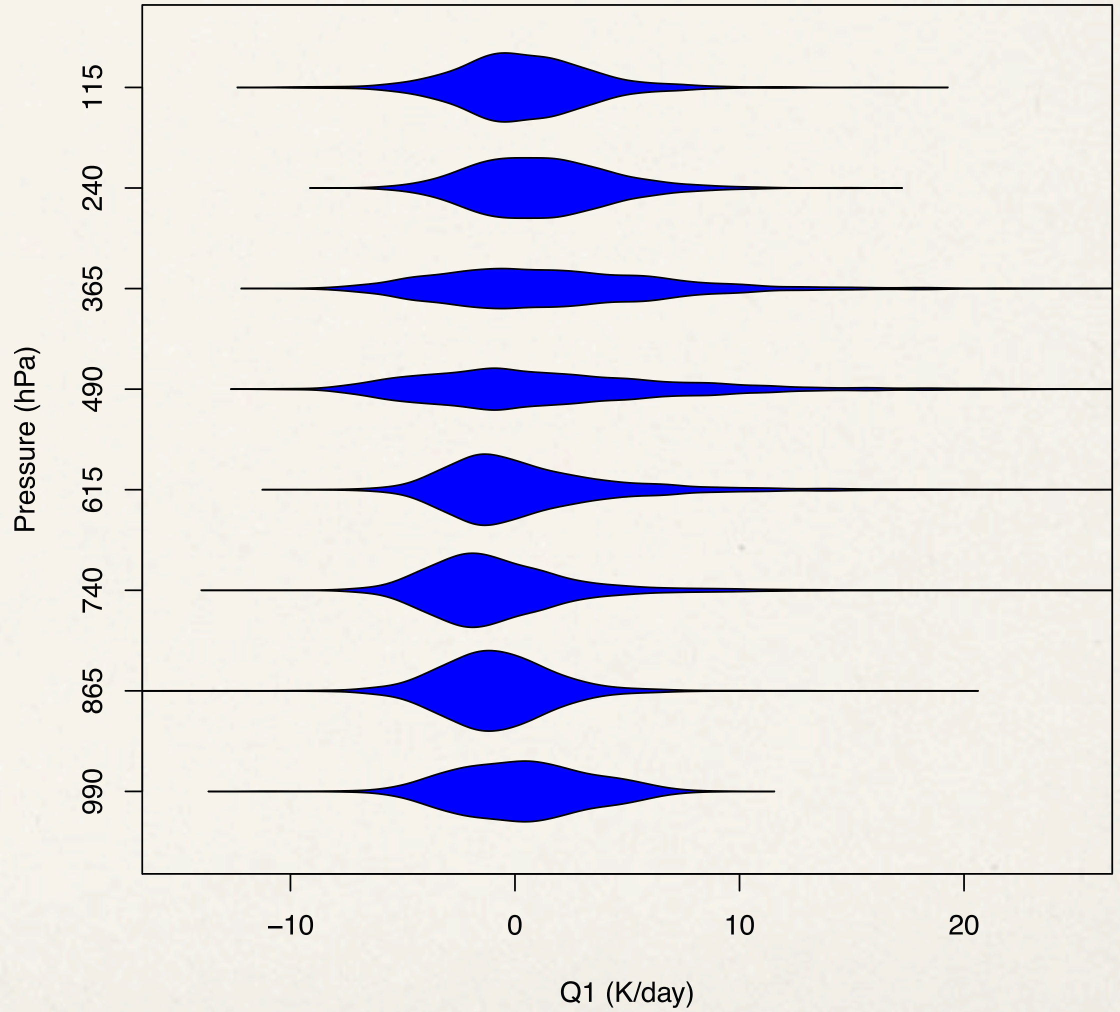


A “new” kind of plot

Distribution of Q1 for the entire data set

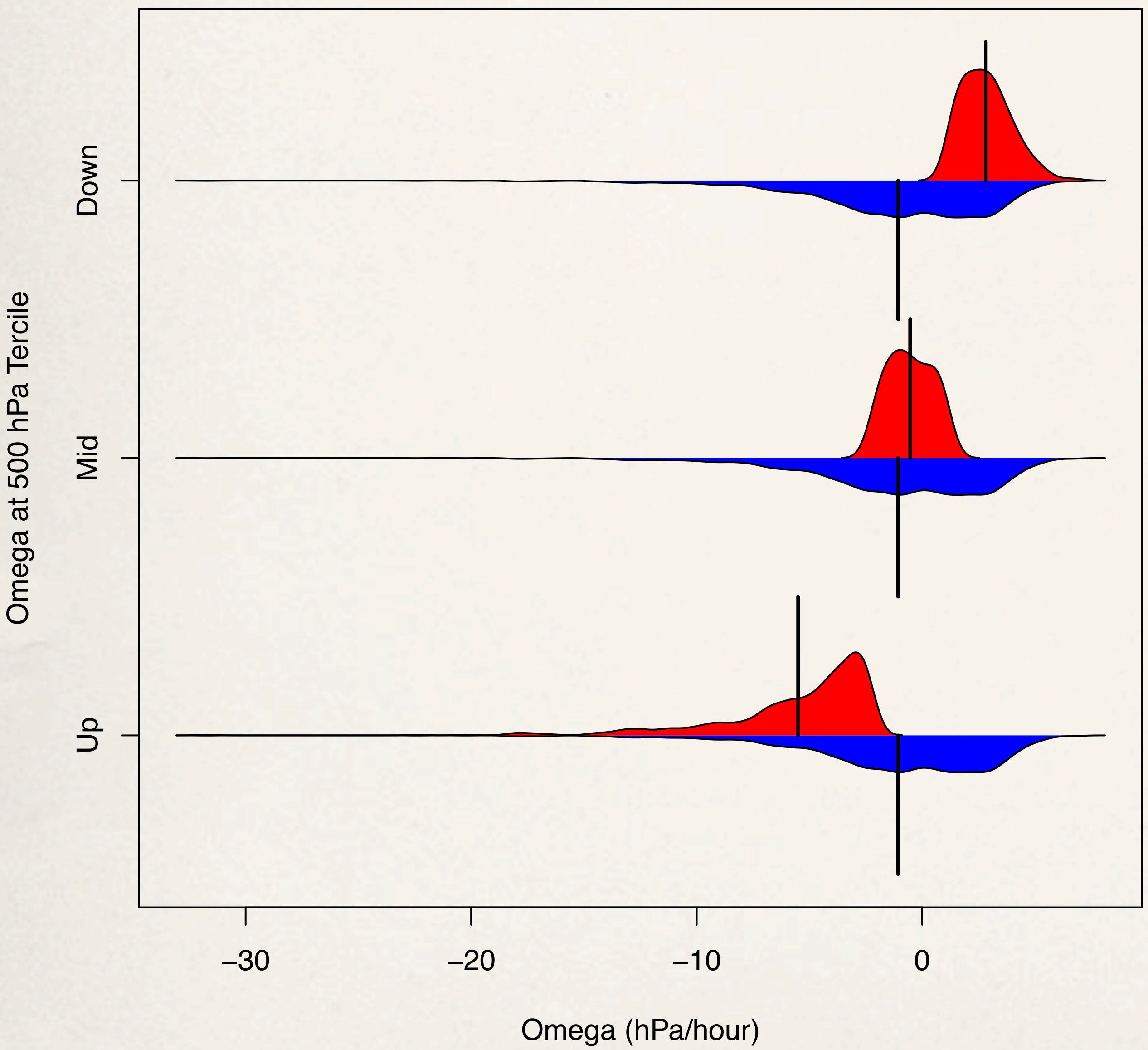


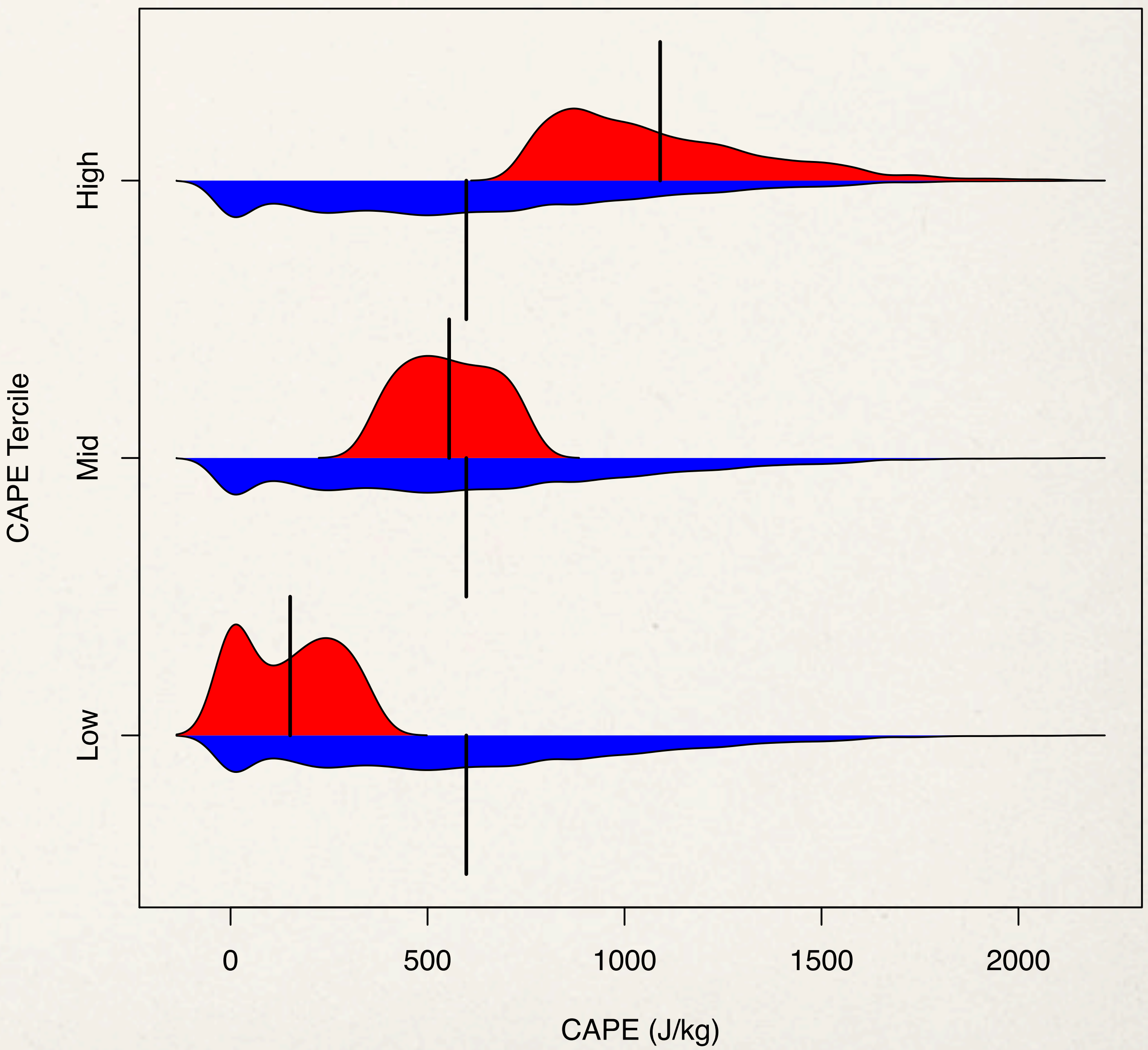
Box Plot



Bean Plot

A “new” kind of plot

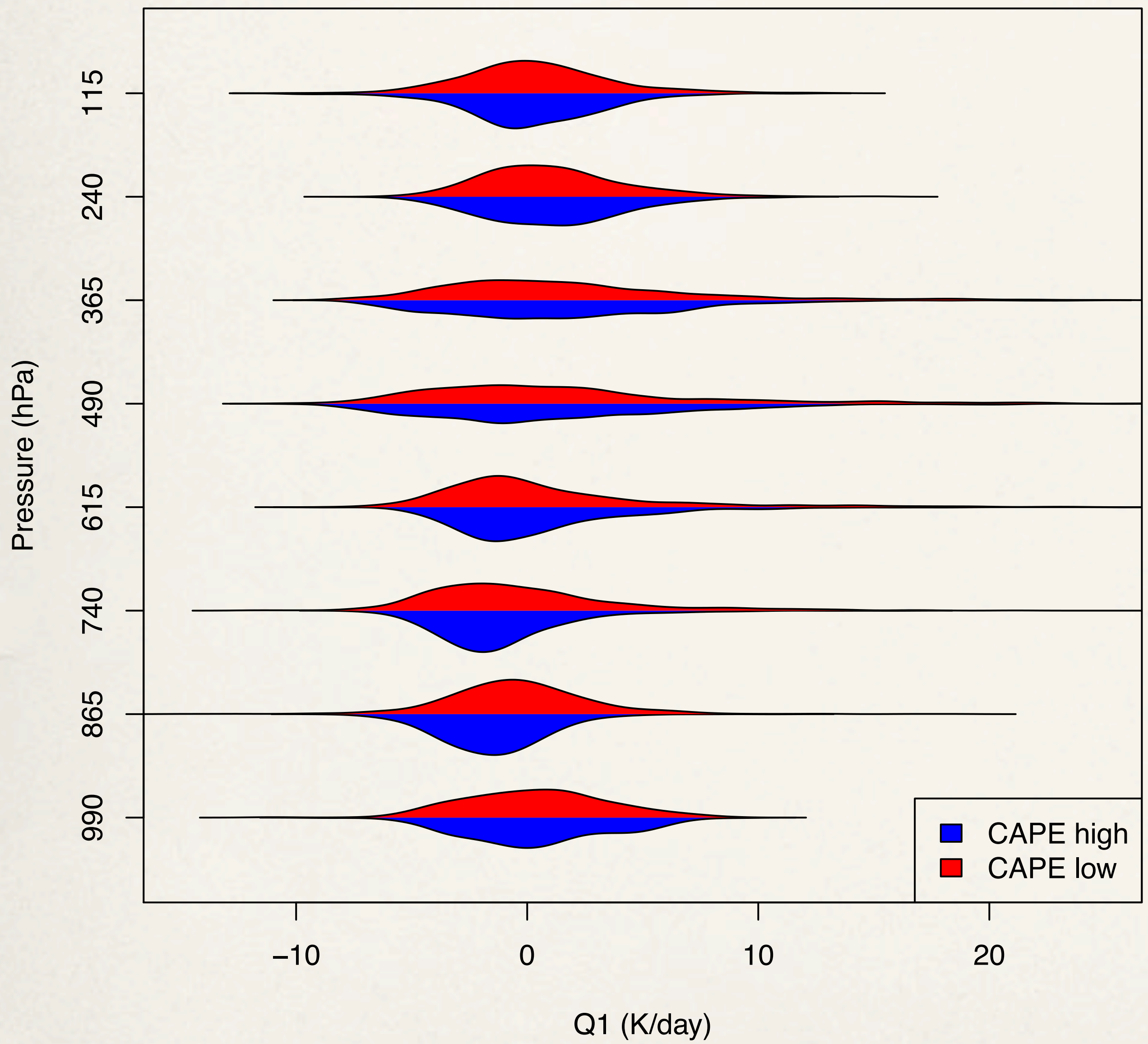




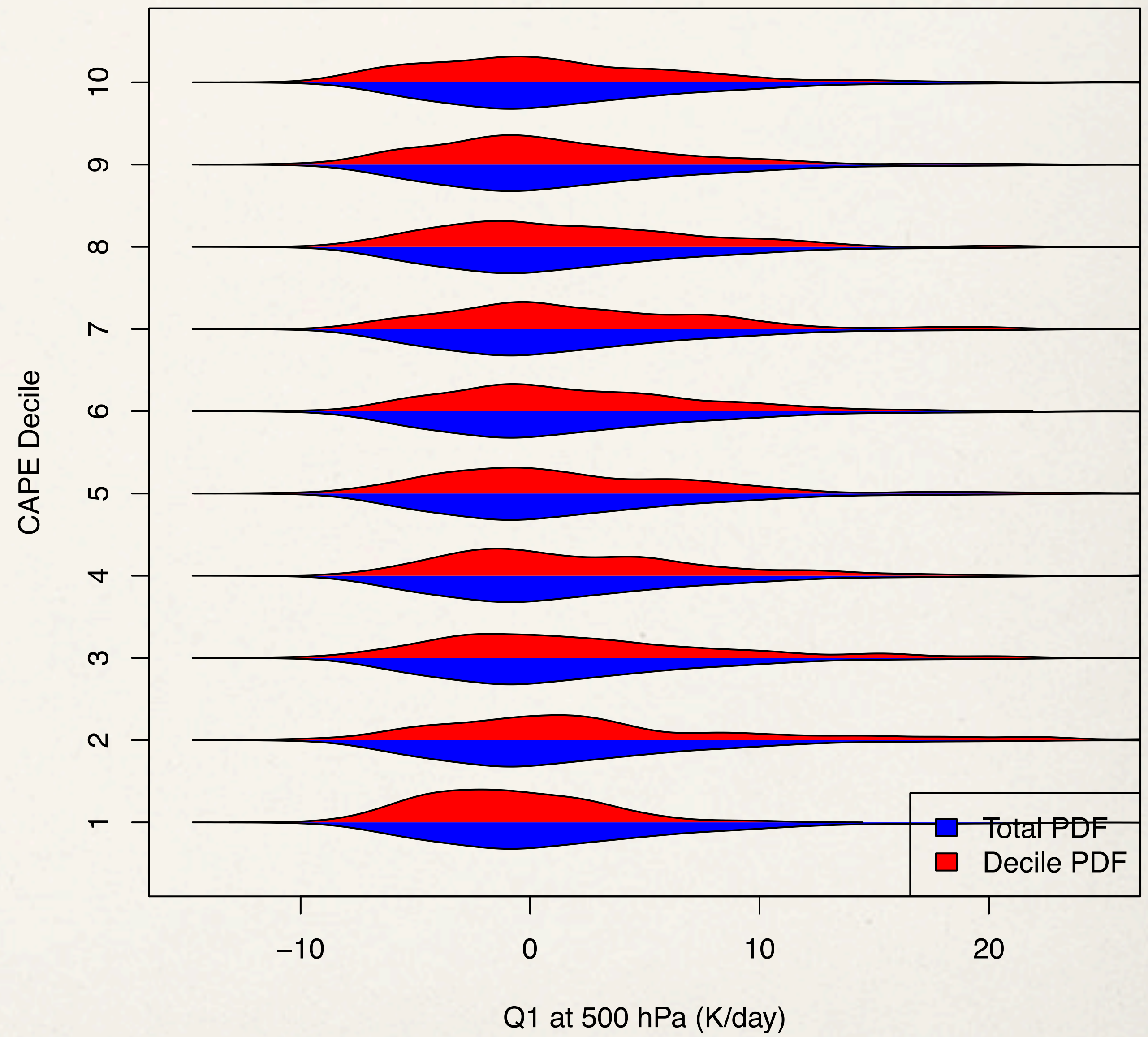
Omega at 500 hPa Terciles

CAPE Terciles

How stochastic is it? - Lets wear CAPEs

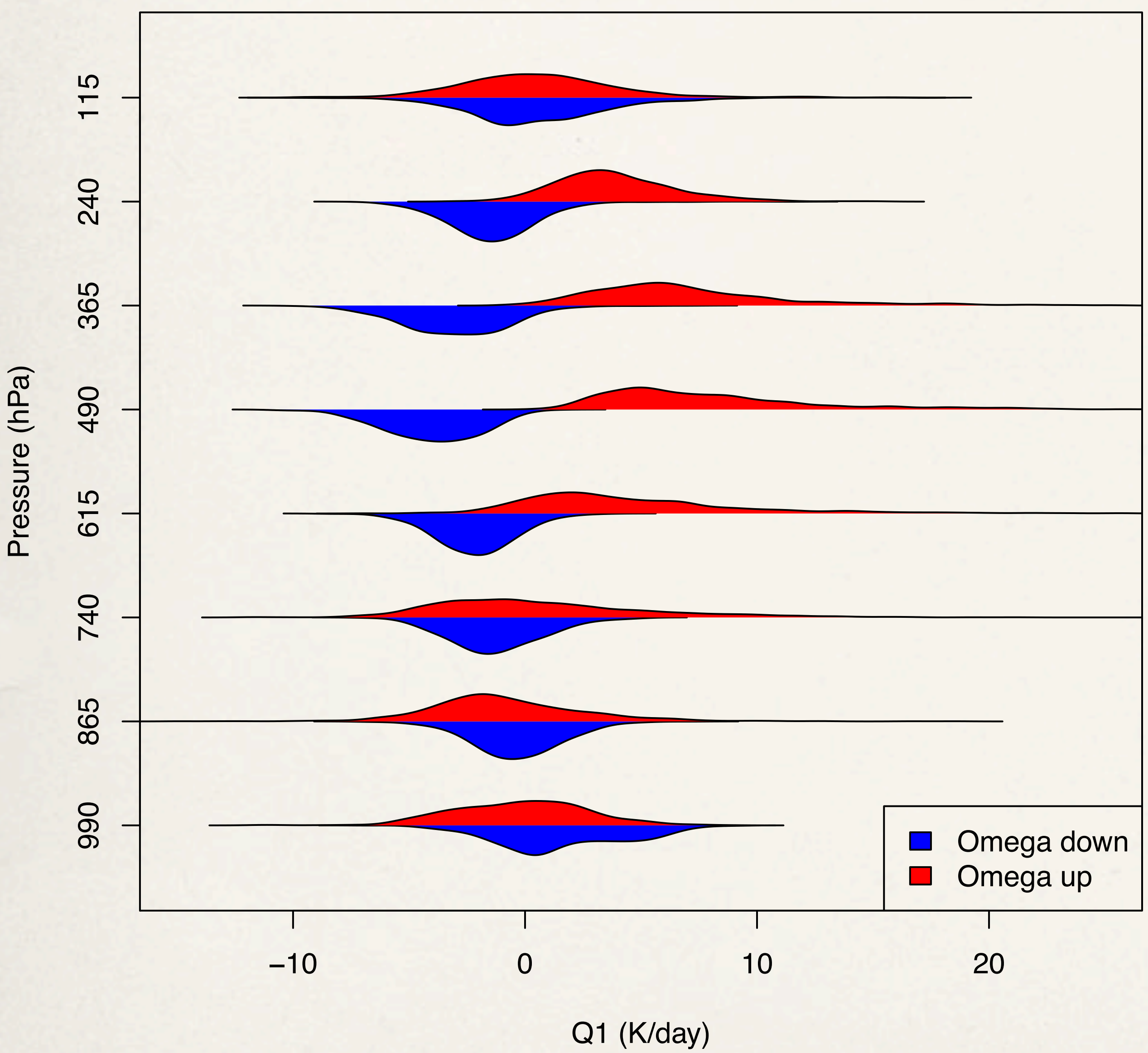


Q1 vs pressure for high/low CAPE

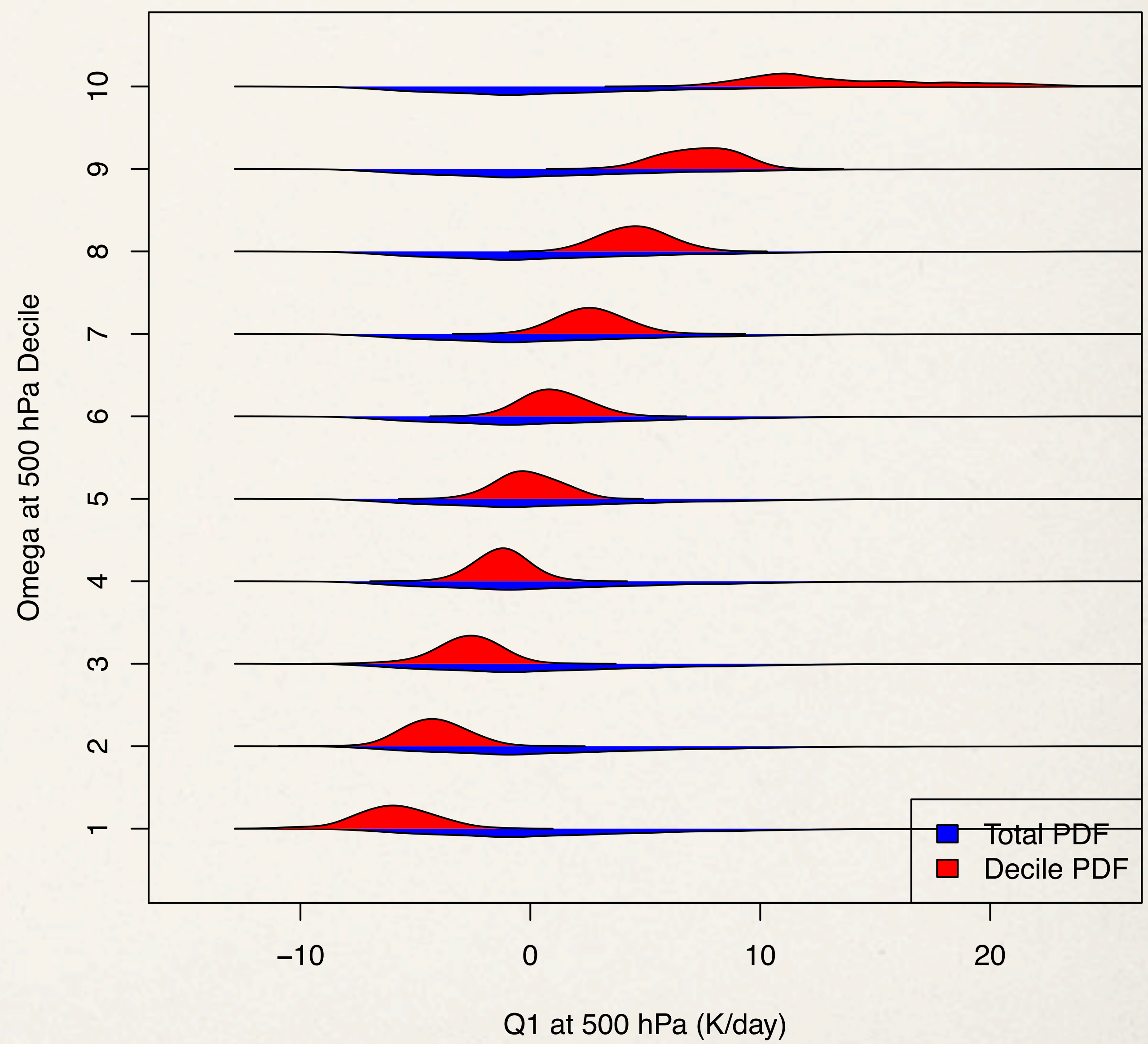


Q1 at 500 hPa by CAPE deciles

How stochastic is it? - A converging view

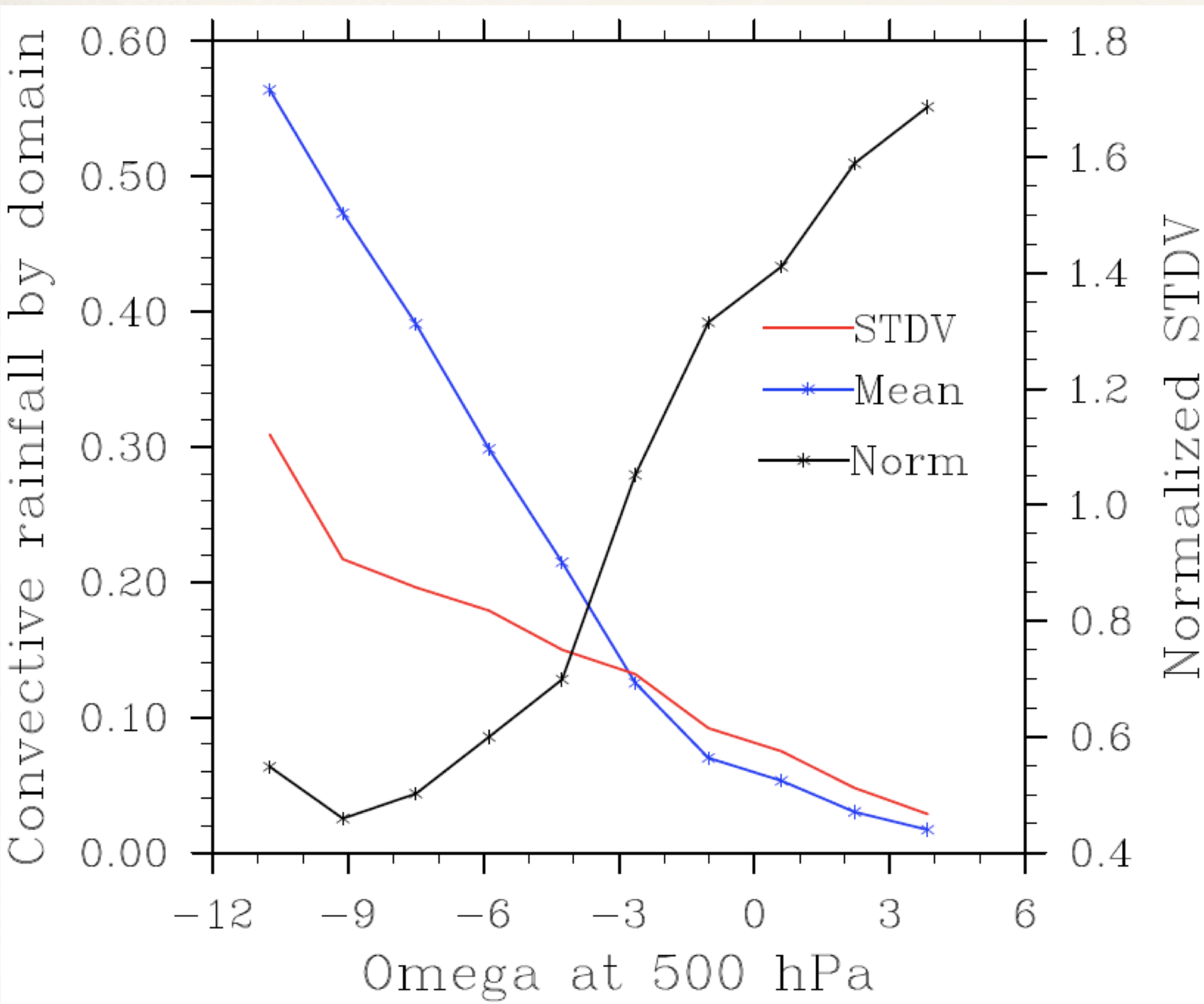


Q1 vs pressure for ω up and down



Q1 at 500 hPa by ω at 500 deciles

How stochastic is it? - A converging view



* Both mean and standard deviation increase with large-scale "forcing".
* However, the signal to noise ratio decreases.
* Hence, overall convective behaviour becomes more "predictable" as the "forcing" increases.
* This is contrary to some implementations of "stochastic" convection.

Next Steps

- Extend to more sites
- Study domain size dependence
- Forced modelling
- Large domain modelling

Conclusions

- Data sets of with frequent concurrent observations of large and small scales in a convecting atmosphere can be constructed at least at some sites using a combination of NWP analyses and radar data.
- Early results indicate poor relationships between stability-based measures and the small scales but much stronger links between convergence based variables and convective heating. C&E!?
- As a consequence, the degree of stochastic behaviour is a strong function of the “model” chosen to link the scales - all the more reason to build uncertainty estimates straight into the parametrizations..
- Naturally, poor models can look very stochastic, better models less so.

ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

MONASH University Science

Conclusions

- How do we know when we have a bad model and when the problem is truly stochastic?
- Efforts on all sides of parametrization are required and the well-balanced application of data, theory and models is required in finding the answers!
- This workshop should contribute to a programme to do this better!