3D experiments with a stochastic convective parameterisation scheme

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Outline

- Introduction to the Plant-Craig stochastic convection parameterisation scheme.
- Experiments in an idealised UM setup.
- A simple ensemble case study.

Plant-Craig scheme: methodology

- Obtain the large-scale state by averaging resolved flow variables over both space and time.
- Obtain $\langle M \rangle$ from CAPE closure and define the equilibrium distribution of m (Cohen-Craig theory).
- Draw randomly from this distribution to obtain cumulus properties in each grid box.
- Compute tendencies of grid-scale variables from the cumulus properties.

PC scheme: probability distribution

Assuming a statistical equilibrium leads to an exponential distribution of mass fluxes per cloud:

$$p(m)\mathrm{d}m = \frac{1}{\langle m \rangle} \exp\left(\frac{-m}{\langle m \rangle}\right) \mathrm{d}m.$$

So if $m \sim r^2$ then the probability of initiating a plume of radius r in a timestep $\mathrm{d}t$ is

$$\frac{\langle M \rangle 2r}{\langle m \rangle \langle r^2 \rangle} \exp\left(\frac{-r^2}{\langle r^2 \rangle}\right) \mathrm{d}r \frac{\mathrm{d}t}{T}.$$

PDF of total mass flux

Assuming that clouds are non-interacting, this can be combined with a Poisson distribution for cloud number,

$$p(N) = \frac{\langle N \rangle^N \mathrm{e}^{-\langle N \rangle}}{N!},$$

leading to the following distribution for total mass flux:

$$p(M) = \left(\frac{\langle N \rangle}{\langle m \rangle} \right)^{1/2} \mathrm{e}^{-(\langle N \rangle + M/\langle m \rangle)} M^{-1/2} I_1 \left(2 \sqrt{\frac{\langle N \rangle}{\langle m \rangle} M} \right).$$

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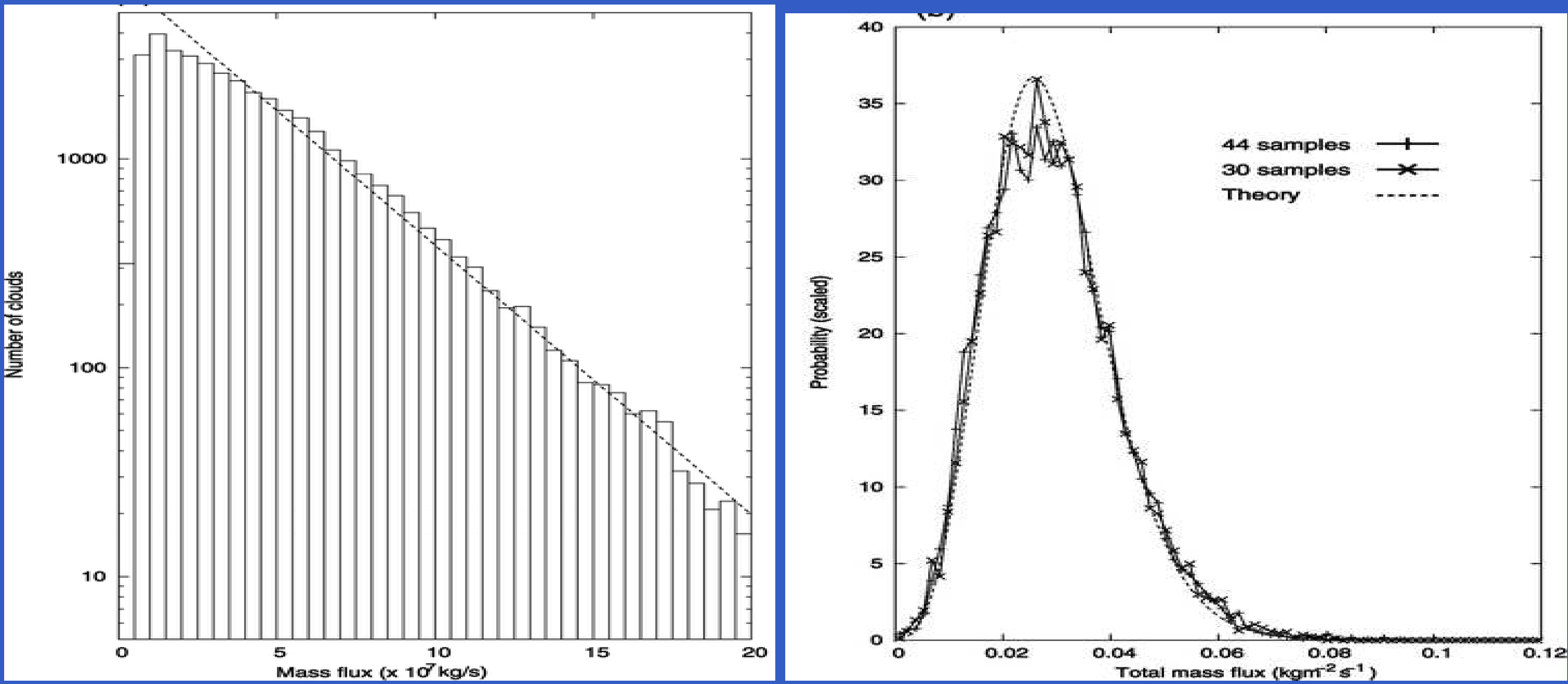
PDFs of mass flux in an SCM

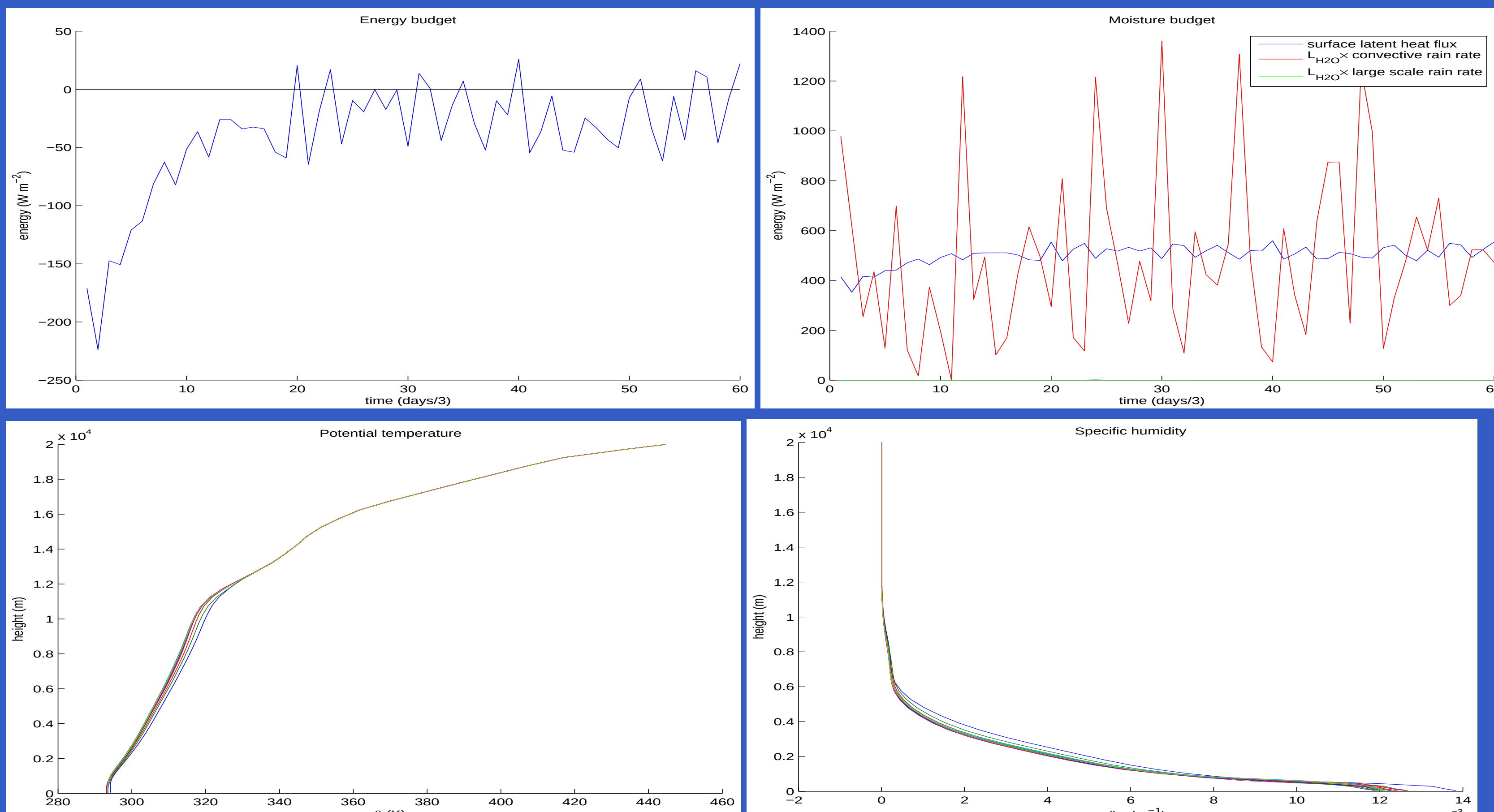


- Plant & Craig, JAS, 2008

3D Idealised UM setup

- Radiation is represented by a uniform cooling.
- Convection, large scale precipitation and the boundary layer are parameterised.
- The domain is square, with bicyclic boundary conditions.
- The surface is flat and entirely ocean, with a constant surface temperature imposed.
- Horizontal diffusion, vertical diffusion of θ and targeted diffusion of moisture are applied.

Energy and moisture balance



- Held et. al., JAS, 2007.

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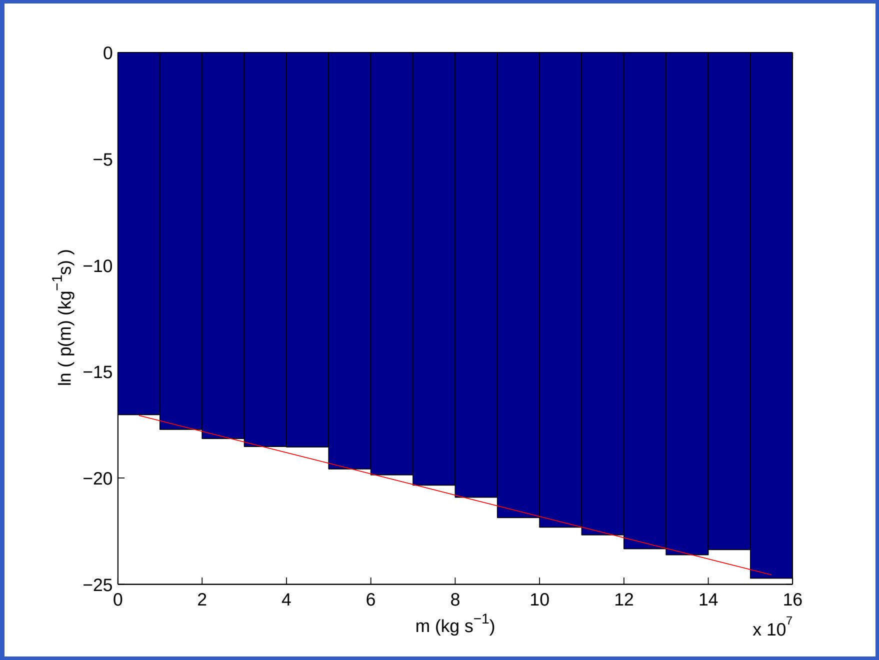
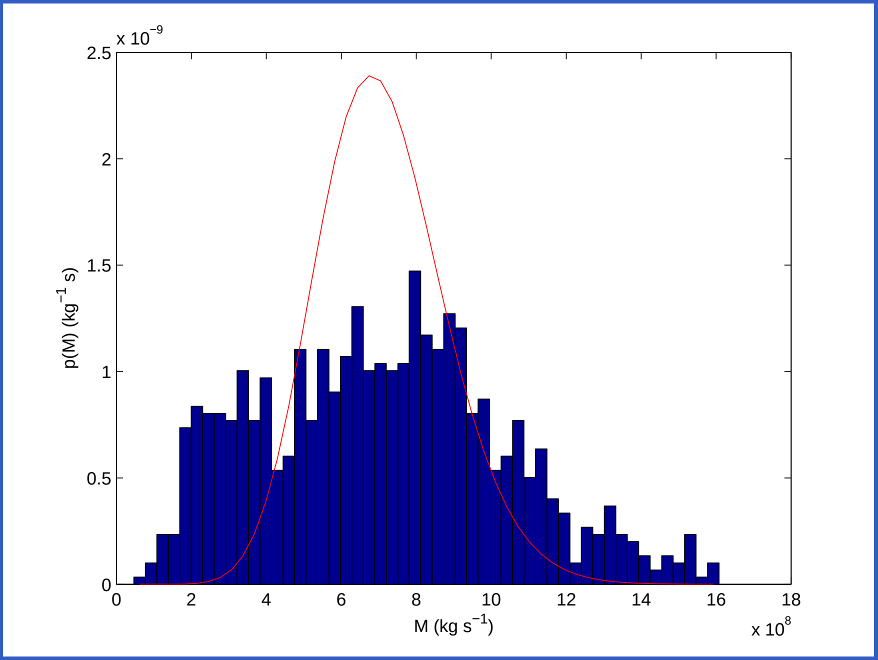
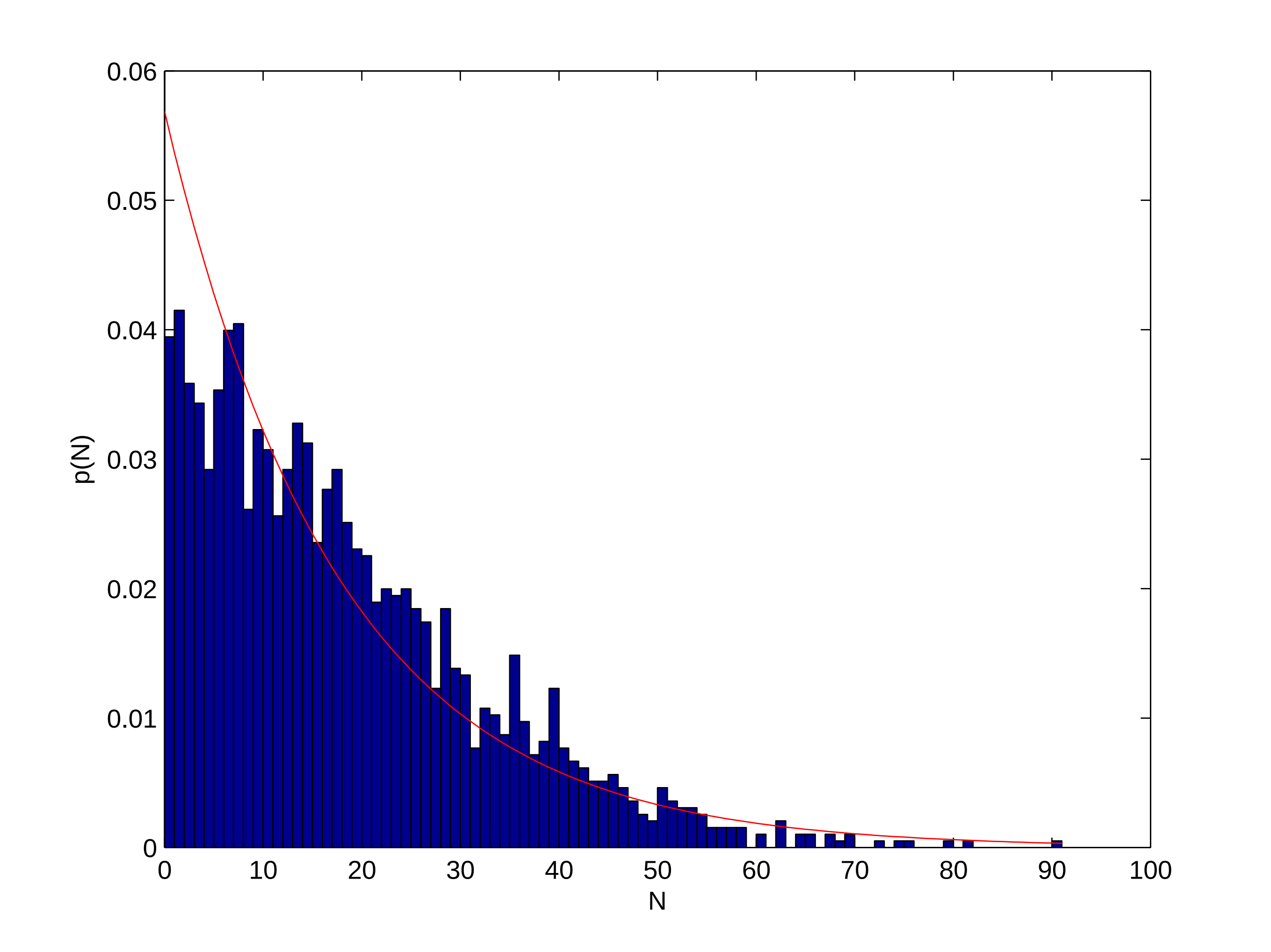
PDFs of mass fluxes



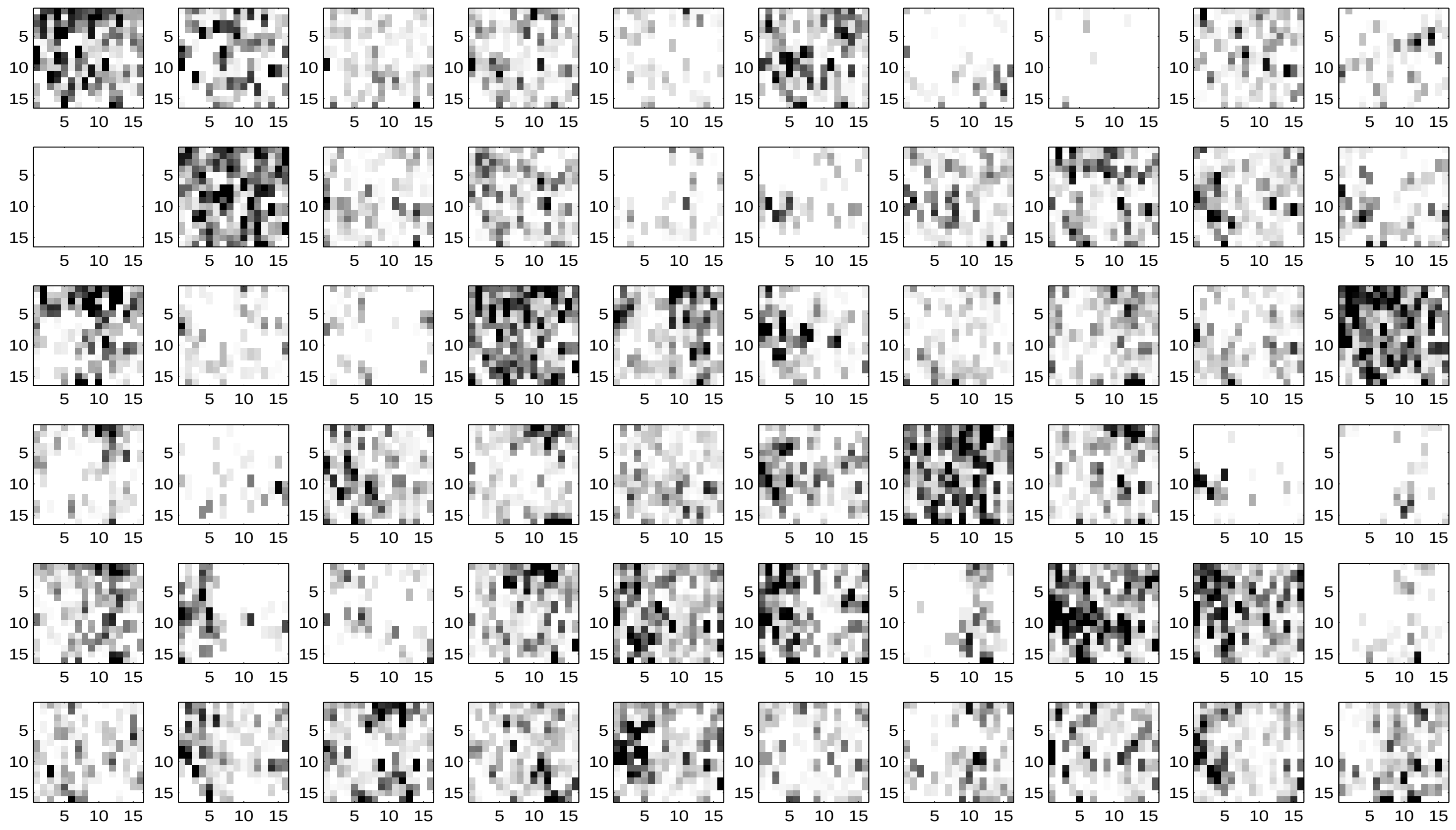


PDF of number of clouds

This seems to follow $p(N) = \exp(-N/\langle N \rangle)/\langle N \rangle$

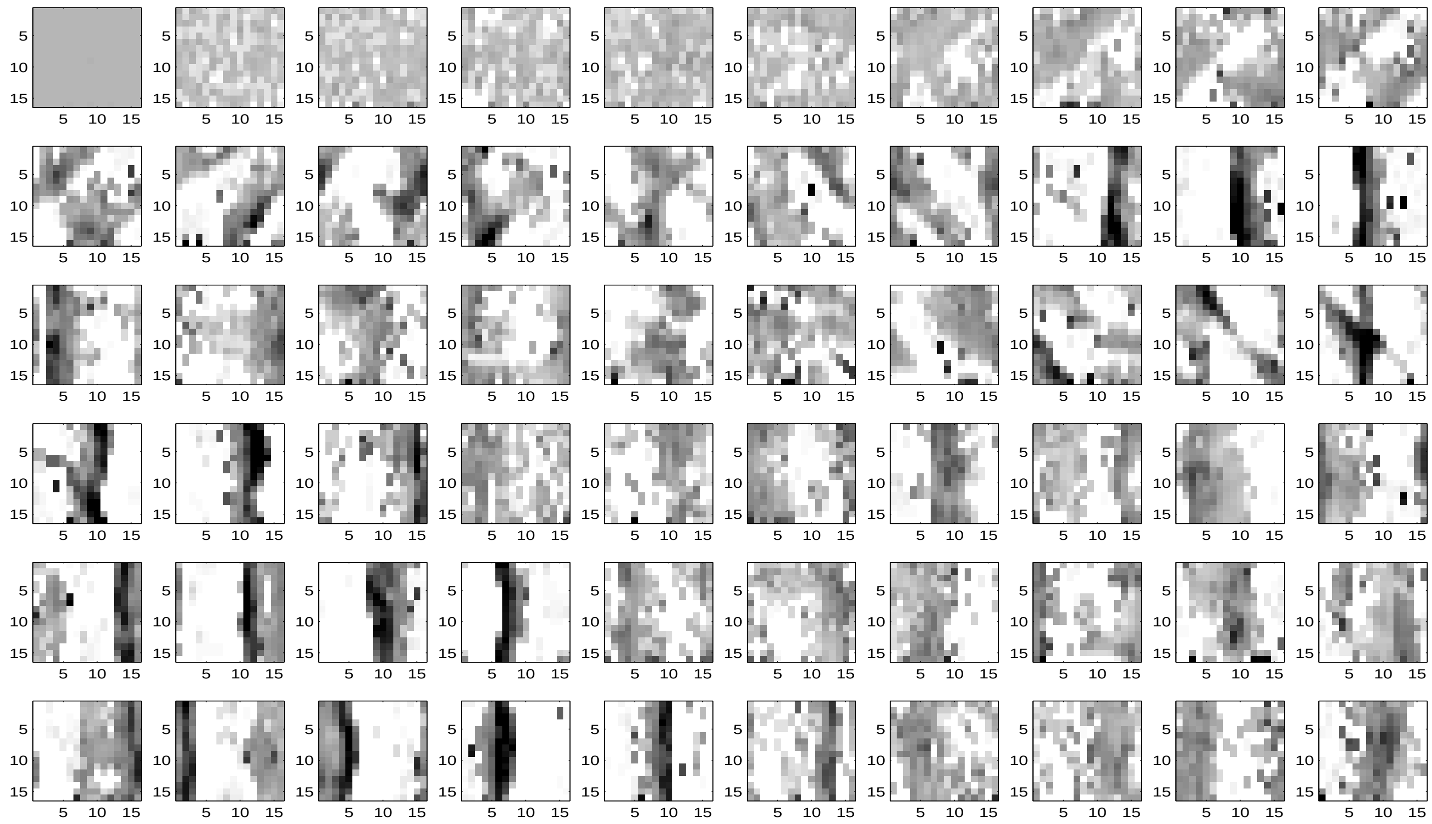


Organisation in rainfall pattern?



animation

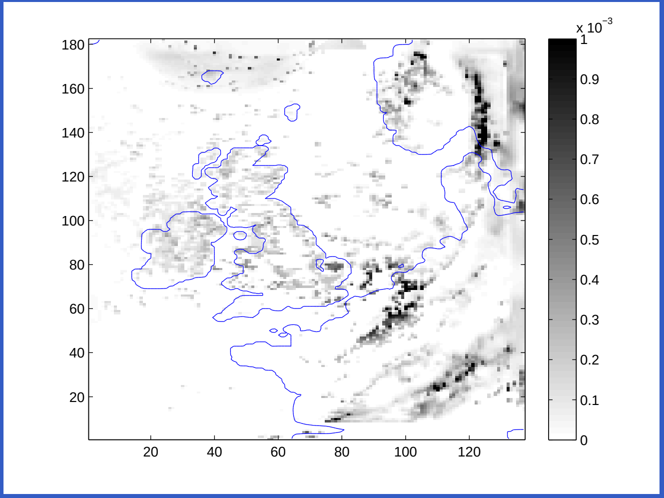
Organisation in rainfall pattern? GR



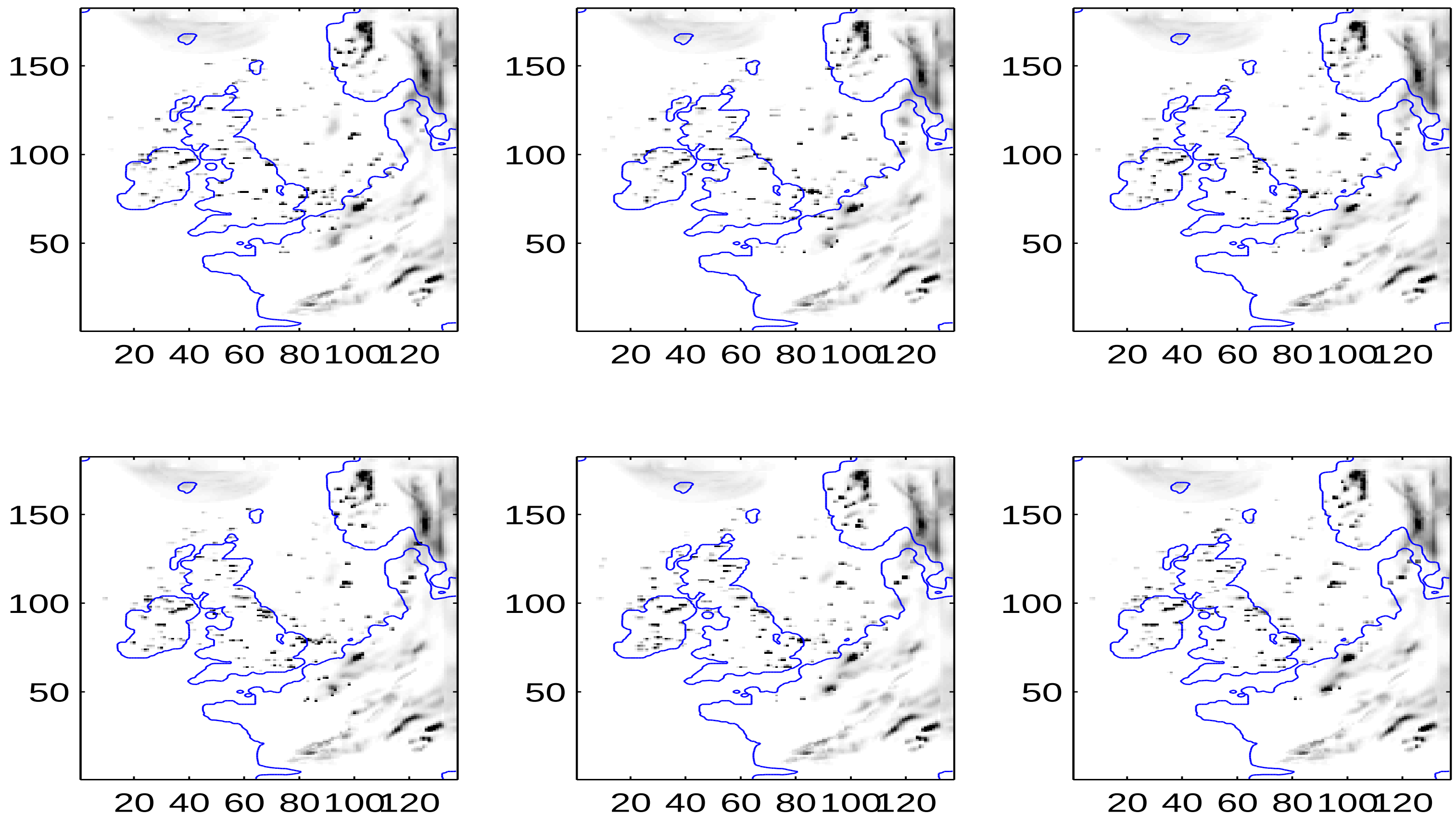
animation

Case study: CSIP IOP18

- Starts at 25th August 2005, 07:00.
- 12 km grid with 146×182 grid points.
- Diffusion as in idealised experiments.

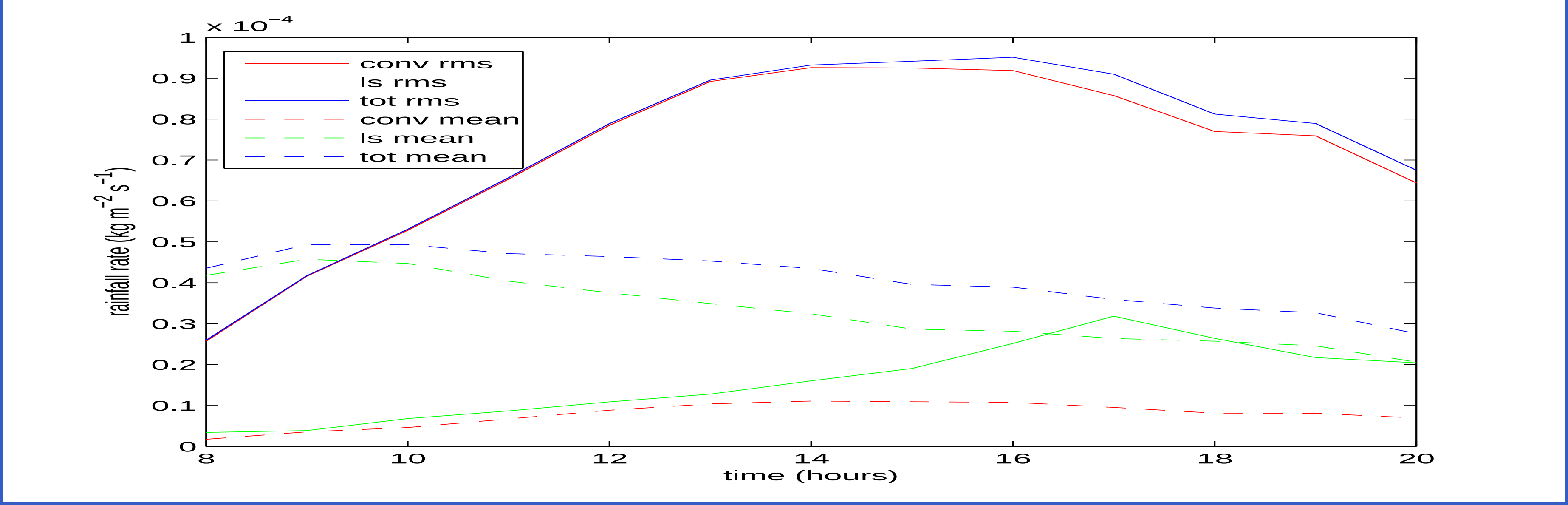


Ensemble of 6 runs using PC scheme



RMS deviation from ensemble mean

- The RMS deviation of total rain is accounted for mostly by the convective rain, even though the mean value of total rainfall is accounted for mostly by the large-scale rain.



Comparison with Gregory-Rowntree

- The PC scheme produces 19% of its rain as convective rain, whereas the figure for the GR scheme is 67%.
- The difference in rainfall reduces as the models ‘spin up’.
- The difference between the PC ensemble runs is smaller than the difference between the two schemes.

Conclusions

- The scheme yields the correct distribution of individual cloud mass flux.
- The distribution of total mass flux is not as according to non-interacting theory, suggesting that there is some organisation of cloud structure in the scheme; however, this is less the case than in the GR scheme.
- The scheme yields considerable convective variability in the simple ensemble case study. This seems to be due to variation in the locations of storms, rather than variation in their intensities.
- The scheme produces less convective rain than the GR scheme, although the convective rainfall behaviour is sensible.