A Stochastic Parameterization for Deep Convection

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Why Stochastic? In Theory

- A deterministic parameterization gives unique increments due to convection for a given (local) model state

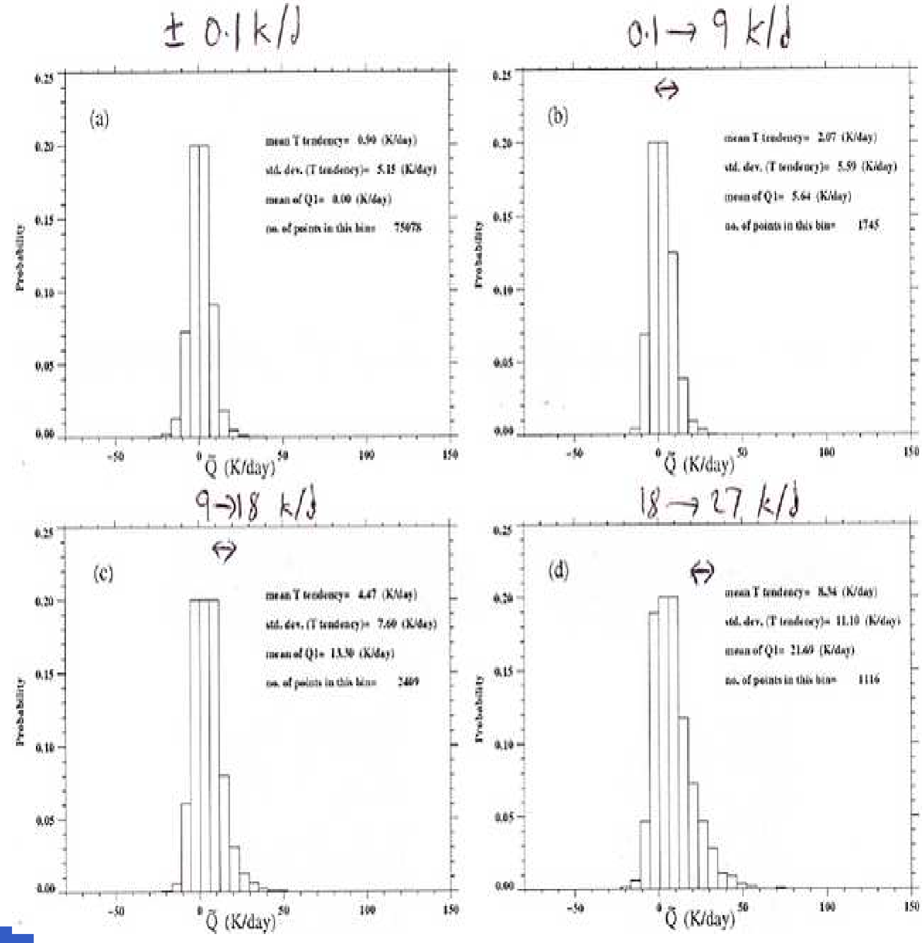
1. This assumes an equilibrium, with the forcing scales being large compared to the intrinsic scales of the convection
2. It also assumes the model grid scale to be large compared to the intrinsic scales

Why Stochastic? In Theory

- If equilibrium breaks down ... see poster!
- If equilibrium holds but the number of cumulus clouds in a grid box is not large then ...
  - ... convection on the grid scale is unpredictable
  - ... but drawn from an equilibrium distribution
  - ... so a stochastic parameterization is required
- Fluctuating component of sub-grid motions may have important interactions with large-scale

Range of Sub-Grid States

The typical number of clouds in a GCM grid box is not enough to give a steady response to a steady forcing

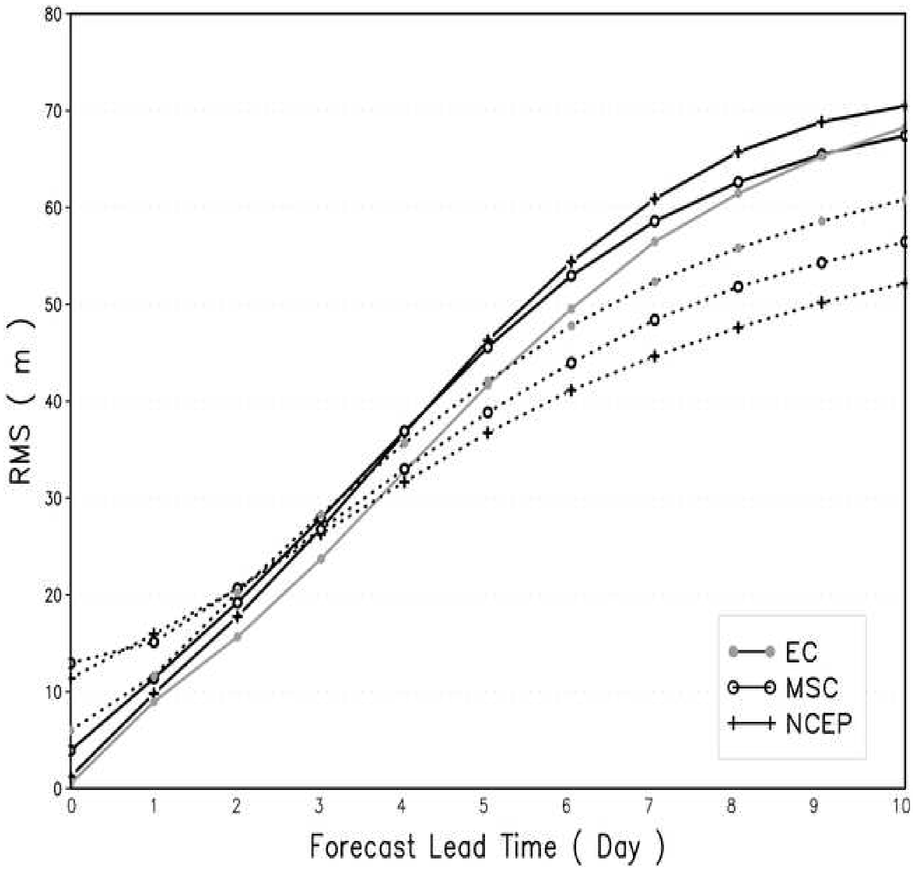


Temperature tendencies for 120km boxes from CRM simulations of tropical convection.

Each plot is for a given range of dT/dt according to Bechtold *et al.* (2001) parameterization.

(From Shutts and Palmer, J. Clim, submitted)

Possible Benefits



Buizza *et al* (2005)

Stochastic parameterizations may solve known problems with current approaches:

- NWP models have insufficient ensemble spread
- GCMs have insufficient variability in tropics

Characteristics of Stochastic Scheme

- Character and strength of the noise should have a physical basis
  - supported/inspired by CRM studies
- The physically-based noise $>>$ numerical noise from scheme
- The noise $\rightarrow 0$ if there are very many clouds
  - in this limit, the scheme should be competitive with current deterministic schemes

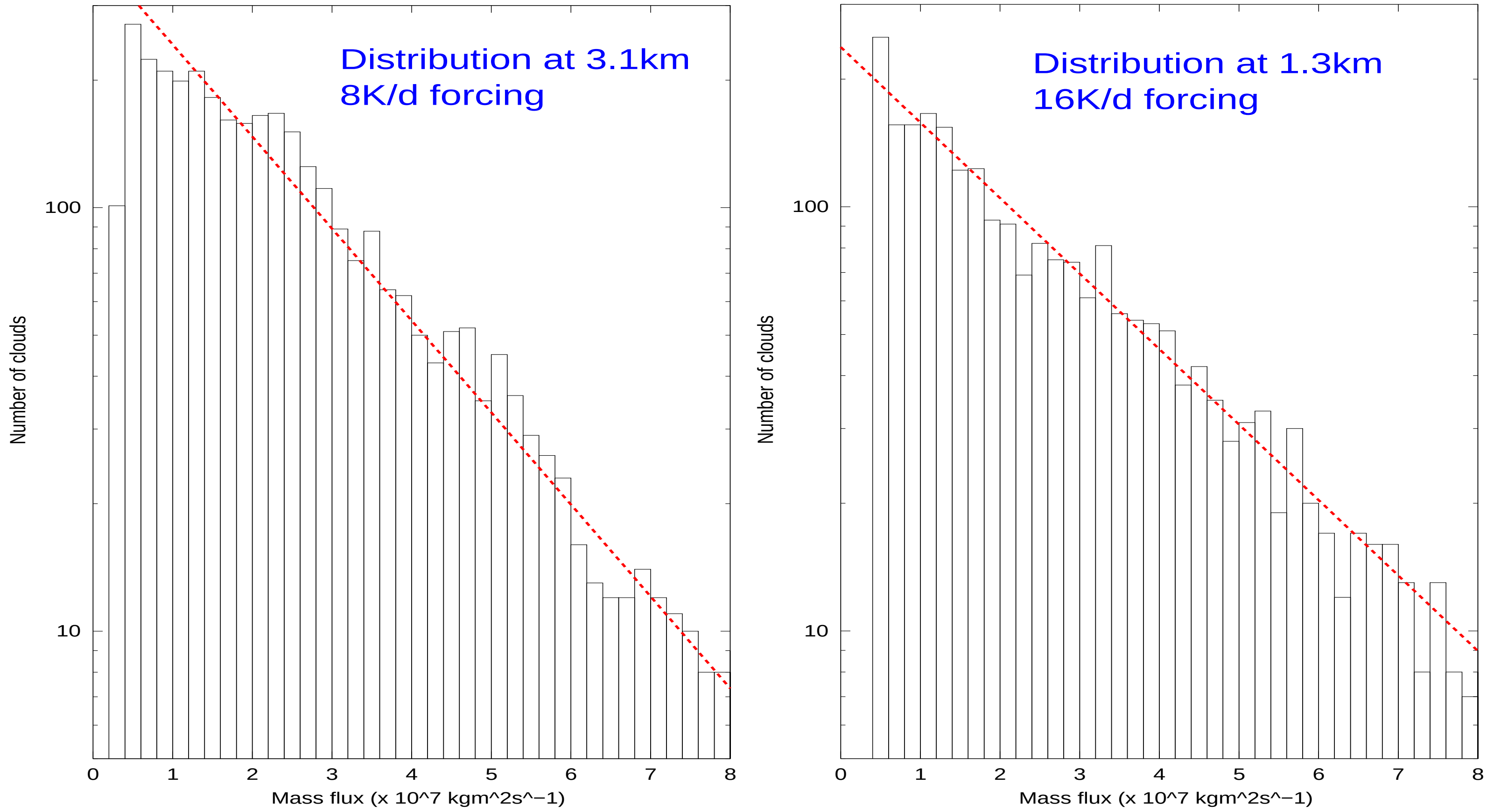
Structure

Mass-flux formalism ...

- No trigger function. Presence of convection dictated by random subgrid variability
- Plumes chosen from known exponential distribution of mass fluxes
- Behaviour of each plume based on modified Kain-Fritsch plume model
- Plumes persist for finite lifetime $\neq$ timestep
- CAPE closure, with timescale that depends on forcing. Based on full spectrum using an averaged (non-local, large-scale) sounding.

Exponential Mass Flux Distributions

From statistical mechanics, and found in CRM with different forcings and at different levels (Cohen and Craig 2006)



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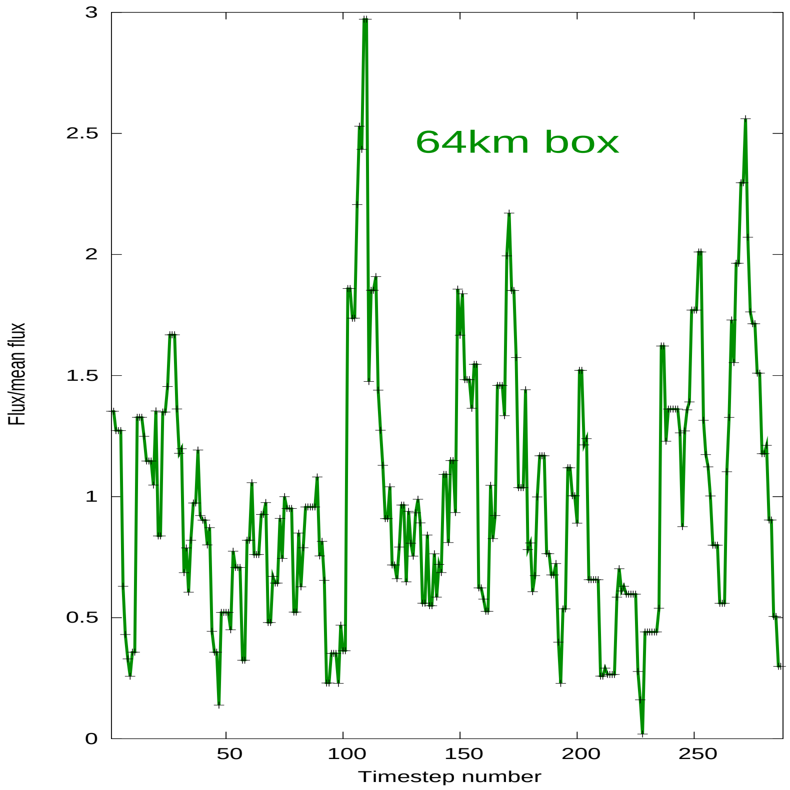
Single Column Tests

Met Office Unified Model – single column version

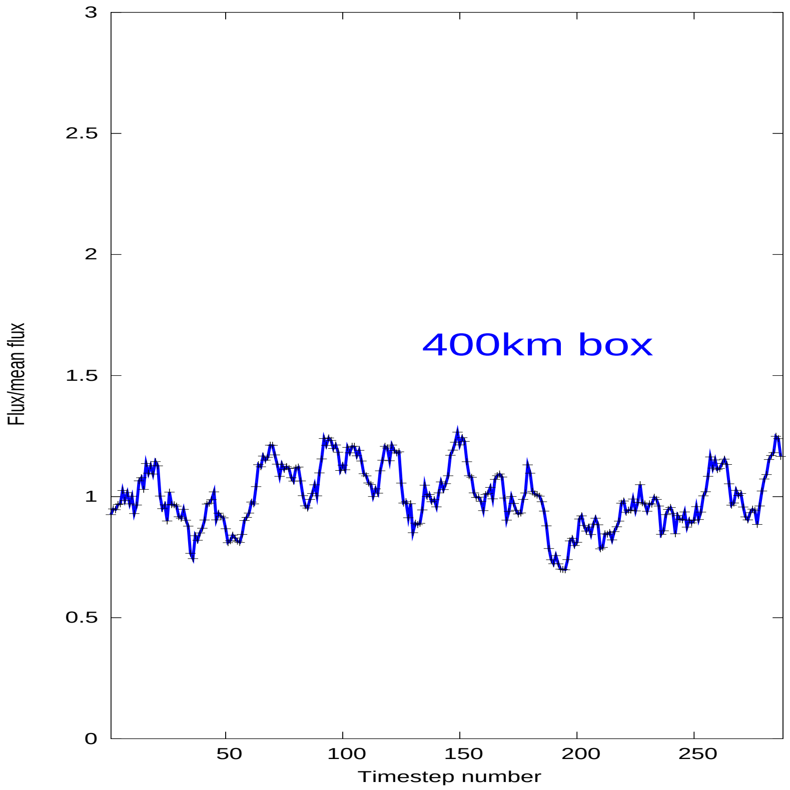
- parameterizations for boundary layer transport, stratiform cloud
- forced as in CRM simulations (fixed tropospheric cooling)
- aim is to replicate mean state and fluctuations of companion CRM simulation

Physical not Numerical Noise

Does a steady forcing give a steady response (in the limit of a large grid box)?



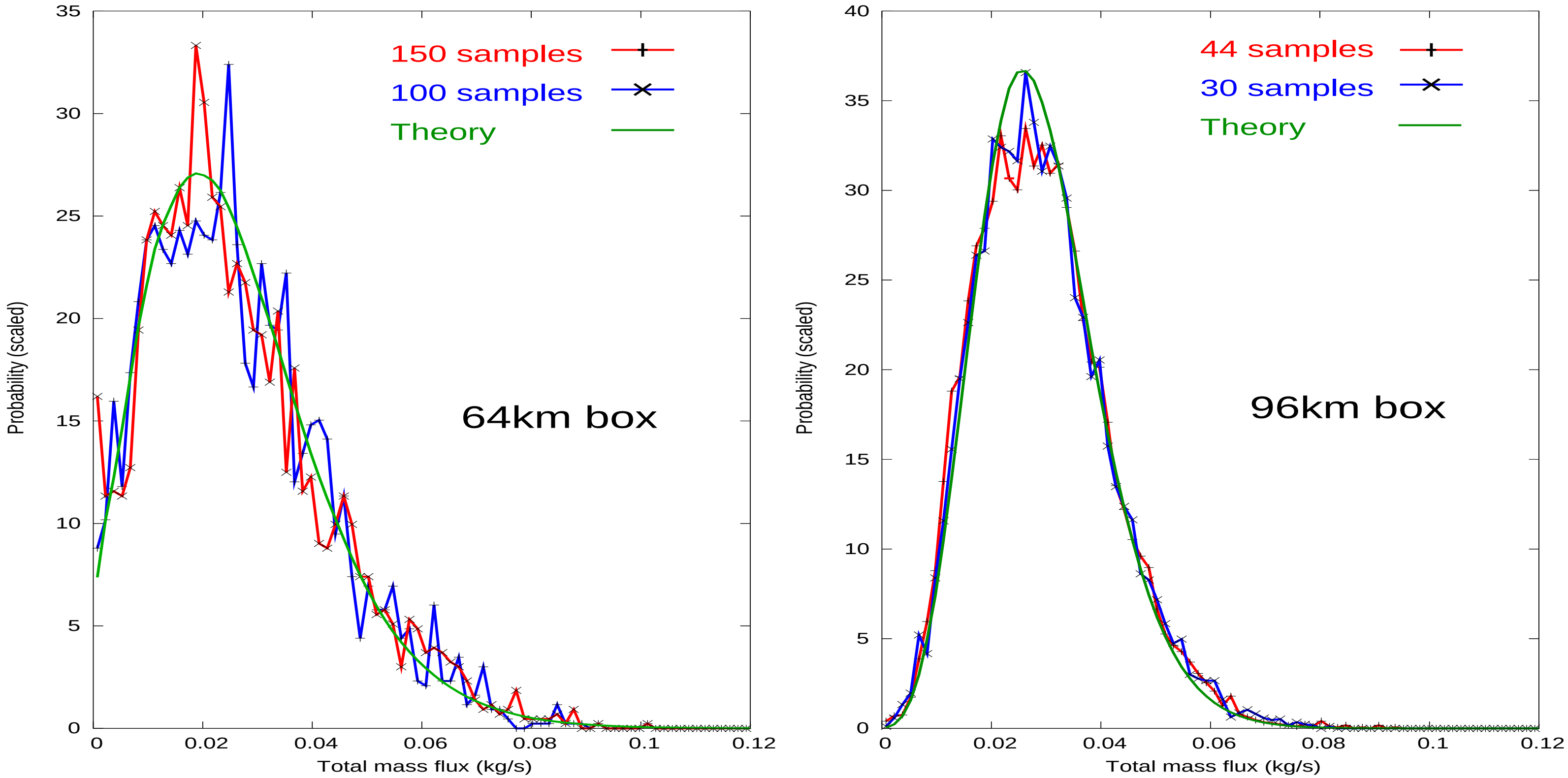
$\sim$ 5 clouds



$\sim$ 200 clouds

Pdf of Total Mass Flux

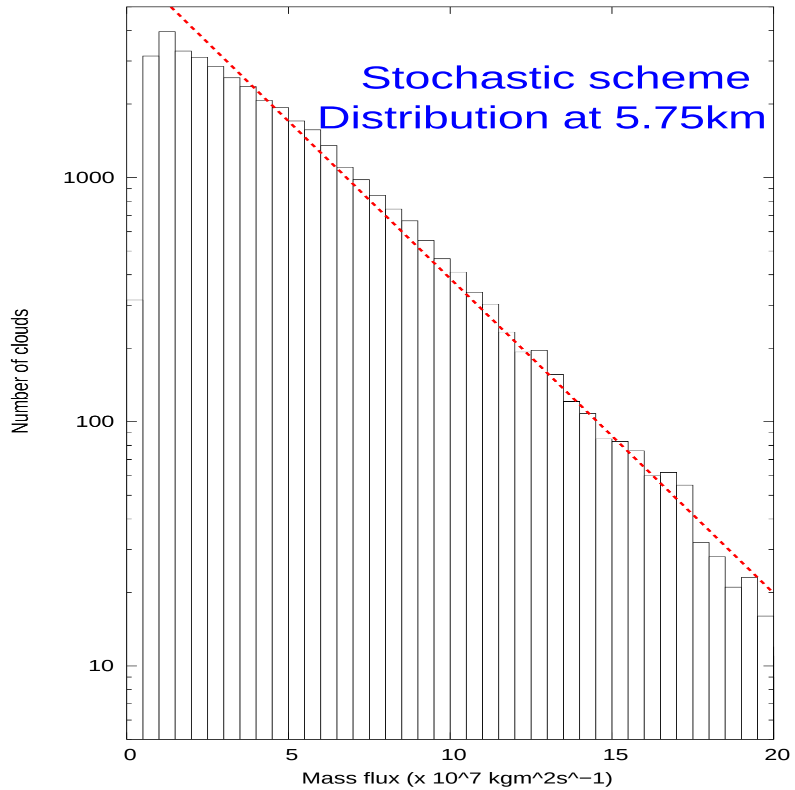
Is the desired distribution of total mass flux reproduced for different-sized areas?



Imposed variability does not feedback onto the closure.

Plume Properties

Are properties of the individual plumes consistent with CRM results?



Exponential distribution achieved well above cloud base.

Current / Near-Future Steps

Test in different configurations:

- Implemented in DWD Lokal Modell for case-study tests in COSMO-LEPS regional ensemble system
- Statistical tests in Met Office short-range ensemble (MOGREPS)
- Test in aqua-planet GCM

Main issues:

- How often, and in what circumstances, does stochastic variability matter?
- On what spatial and temporal scales should the variability be correlated?