

What time scales throw convection out of equilibrium?

1. Motivation

Convective systems are a major contributor to global circulations of heat, mass and momentum. However, as convective processes occur on scales smaller than the grid scale parameterisation schemes are used in large scale numerical models.

Current schemes require an equilibrium assumption between the large-scale forcing and the convective response. However, there are many important situations where this assumption may not be valid and significant variations in the convection are a feature of the flow, for example, the diurnal cycle.

We focus on the impact of time-scale of the forcing on convection.

2. Method & model set-up

Comparisons are made between simulations from a Cloud Resolving Model (the Met Office LEM). The model is forced with time-varying surface fluxes. The forcing is realistic in the sense that surface fluxes are imposed which are taken from observations of the diurnal cycle. However, in order to investigate the sensitivity of equilibrium to the forcing timescale, the length of the 'day' is artificially altered.

The model set-up is fundamentally similar to Petch (2004). It is initialised with profiles of θ and q_v and run to equilibrium with constant surface fluxes simulating noon conditions. From this point the run is continued with time-varying forcing. A constant cooling profile is applied to balance the moist static energy over a 'day'.

The simulations presented here are 2D with a 64 km domain and 1km resolution.

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3. Initial setup

Constant surface fluxes were applied to the system to trigger convection and ensure that each subsequent run experienced the same initial conditions (Figure 1). This control was run for 240 hrs to ensure convective equilibrium was achieved.

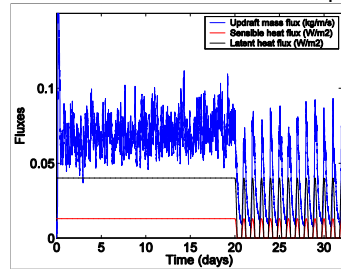


Figure 1 Constant surface fluxes are superseded by time-varying forcings where the timescale can be altered, 24 hrs was used here.

4. First look

Initial analysis of contrasting timeseries (Figure 2) shows:

- Shorter timescales have a smaller range of mass fluxes with lower maxima and higher minima than the larger timescales or with constant forcing (Figure 1). However some days have multiple peaks or convection is suppressed.
- Longer timescales are more predictable in terms of the mass flux values between days. Also, the timing of triggering and the peaks of convection match more closely to the forcing.

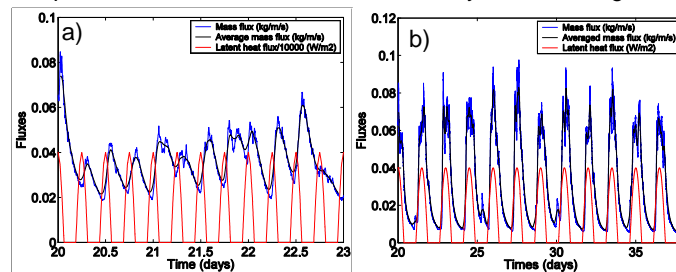


Figure 2 Updraft mass flux with running averages for, a) forcing timescale of 6 hrs and b) forcing timescale 36 hrs. (Averaging less than 10 % of timescale).

5. Effect of timescale on convective response

More detailed analysis (Table 1) of the mass flux timeseries shows triggering occurs closer to 'dawn' and the peak closer to 'noon' for longer timescales than shorter timescales. In all cases there is a larger delay in the triggering after 'dawn' than for the peak after 'noon'. This shows that convective adjustment occurs more rapidly than initiation of convection for all timescales.

Table 1 Mean time of triggering and peak of convection as a percentage of the timescale.

Forcing timescale (hrs)	3	6	12	24	36
Triggering after dawn (% of day)	-	-	24	16	10
Peak after noon (% of day)	20	21	14	2	4

References

Petch, J. (2004). Predictability of deep convection in cloud-resolving simulations over land. Q.J.R. Met. Soc.

6. Equilibrium

Comparing the convective response between one 'day' and the next shows high degrees of correlation when the timescale is longer (Figure 3). For timescales greater than ~24 hrs convection is in equilibrium with the forcing.

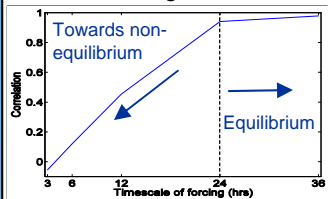


Figure 3 Correlation of mass flux between days.

7. Convective memory

Work by Derbyshire (pers. comm.) (Figure 4) shows that if a convective system has memory the response can be chaotic. Our results suggest that the effects of memory may become important for shorter forcing timescales when the system departs from equilibrium.

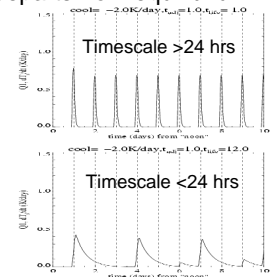


Figure 4 Idealised model results show affect of memory (life time) on convection.

8. Conclusions

The timescale of forcing has a strong effect on convective systems in terms of both triggering and peak mass flux. Short forcing timescales (< 24hrs) produce a less predictable response and do not achieve equilibrium. The convection is chaotic in nature. It is suggested this is due to increased memory effects in these convective systems.

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