Investigating the effect of memory on a convective system

NATURAL ENVIRONMENT RESEARCH COUNCIL
Email: l.davies@rdg.ac.uk
L. Davies*, R. Plant* and S. Derbyshire+
*Department of Meteorology, University of Reading, UK. +Met Office, Exeter, UK.
Met Office

Poster available at www.met.rdg.ac.uk/~swr04ld

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, parameterisation schemes are used in large scale numerical models.

Current parameterisations require a statement of equilibrium between the large-scale forcing and the convective response. However, there may be important situations where the equilibrium assumption is not valid, and significant variations in the convection are an important feature of the flow. The diurnal cycle is one possible example.

We focus on the impact of the forcing timescale on the resulting convection.

2. Method & model set-up

A Cloud Resolving Model (the Met Office LEM) is forced with time-varying surface fluxes, based on observations of the diurnal cycle over land. However, in order to investigate the sensitivity of equilibrium to the forcing timescale, runs are compared in which the length of the 'day' has been artificially altered (varying from 3 to 36h).

The model set-up is similar to Stirling and Petch (2004). It is first run to equilibrium with constant surface fluxes simulating noon conditions. The run is continued for a further 12 days with time-varying forcing. A constant tropospheric cooling is applied to balance the moist static energy.

The simulations presented here are 3D with 1km resolution in a 64km^2 domain.

3. Equilibrium and non-equilibrium

Analysis of composite timeseries (Figure 1) shows that for shorter timescales of forcing:

- The phase shift between forcing and response becomes relatively larger. In absolute terms, convection is established 1-2h after the start of the forcing.
- The convection does not switch off: there is almost always some activity.
- The convection develops more gradually, without overshooting.
- There is considerable variability in the amplitude but not the evolution of the convection.

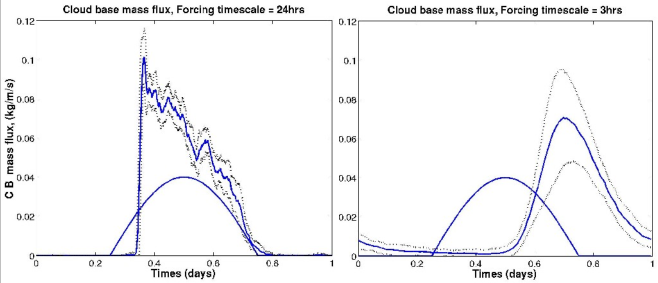


Figure 1 11-day composites (with standard deviations) of the cloud base mass flux for (a) 24h and (b) 3h forcing timescales. For reference the surface latent heat forcing is shown (scaled).

4. Achieving equilibrium

Figure 2 confirms that at longer forcing timescales (>18h) the convective response is highly correlated with the forcing. These timescales have small day-to-day variability, and the system may be considered as close to equilibrium. Figure 3 shows that the overall strength of the convection is almost independent of timescale, but that for shorter timescales, the response on a particular day is much more variable. The convection becomes chaotic, with the response on one day depending on that of previous days. Thus, it exhibits an element of memory.

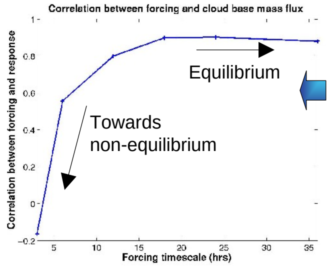
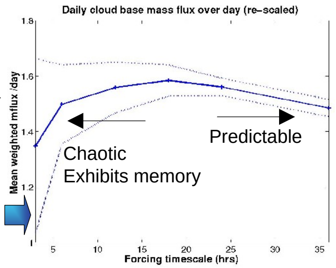


Figure 2 Correlation between mass flux and forcing as a function of forcing timescale.

Figure 3 Mean and standard deviation of the daily-averaged mass flux, as a function of forcing timescale.



5. Convective memory

Let T represent a tropospheric temperature which evolves as

$$\frac{dT}{dt} = COOL + Q_1$$

where COOL is a (radiative and/or advective) cooling rate and Q_1 is the convective heating. It does not respond instantly to a change of forcing but approaches a rate R consistent with the current forcing over a memory timescale t_{mem},

$$\frac{dQ_1}{dt} = \frac{R - Q_1}{t_{mem}}$$

In the spirit of a conventional CAPE closure, we assume that if all forcing were removed, R would achieve a convectively neutral temperature T_n with a closure timescale t_{close},

$$R = \frac{T_n - T}{t_{close}}$$

T_n follows a diurnal cycle. Figure 4 shows that if the system has memory (t_{mem} is relatively long) then the response is chaotic. We are currently using the LEM to investigate appropriate values for the timescales, in order to assess whether a simple model of this type can explain the results above for varying forcing timescales.

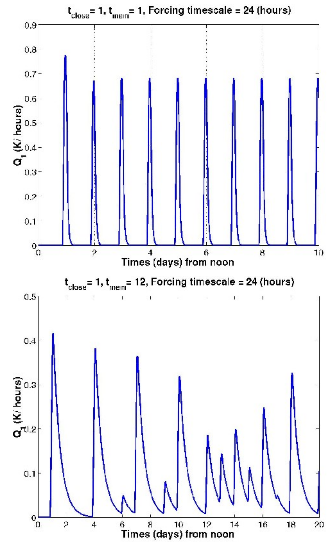


Figure 4 Results from simple model showing the effects of a memory timescale on convection.

6. Conclusions

The timescale of forcing has a strong effect on convective systems in terms of both the evolution and variability of the response. Short timescales produce a less predictable response and do not achieve equilibrium. It is suggested this is due to the increased importance of memory.

Acknowledgements

LD is supported by NERC CASE award NER/S/A/2004/12408

References

Stirling, AJ and Petch, JC. 2004. The impacts of spatial variability on the development of convection. *Quart. J. Roy. Met. Soc.* **130**, 3189-3216.