Investigating the equilibrium assumption between convection and the forcing

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Definition of equilibrium

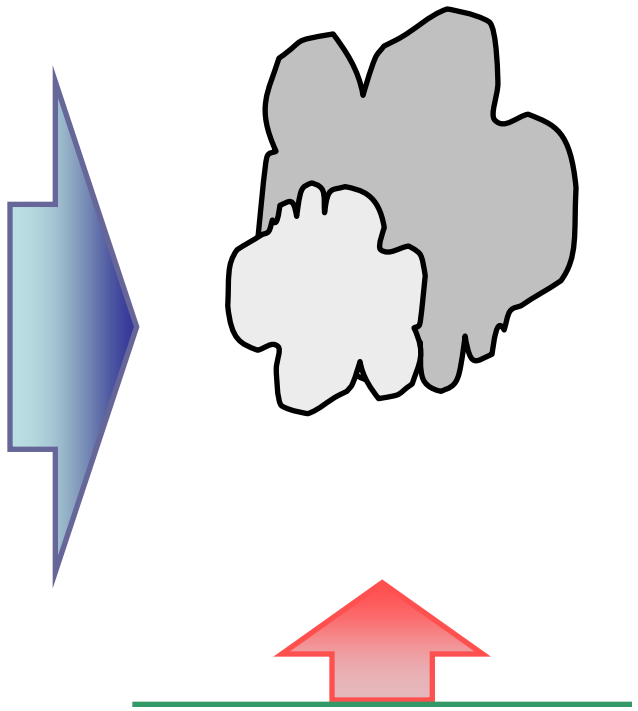
Dictionary definition:

- The condition of equal balance between opposing forces. (Oxford English Dictionary)

Convective system

- In a convective system this is a balance between:

- Surface forcing,
- Large-scale cooling and
- Convection.



- Not considering large-scale subsidence and convergence.

Defining equilibrium (1)

A strict definition

- Balance between these forces.
- However,
  - What about CIN?
  - What about the lifetime of a cloud?

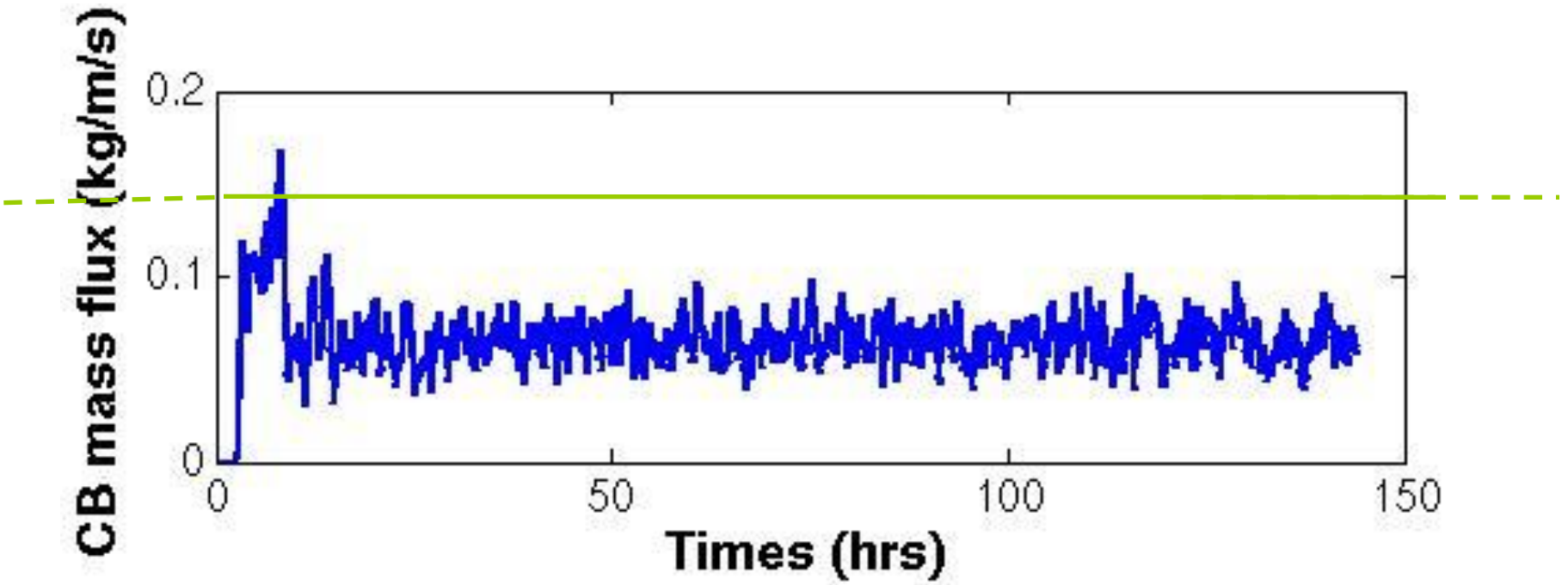
- Can we use a definition of equilibrium and quasi-equilibrium from literature.

- So, how do we define equilibrium?

Defining equilibrium (2)

A working definition

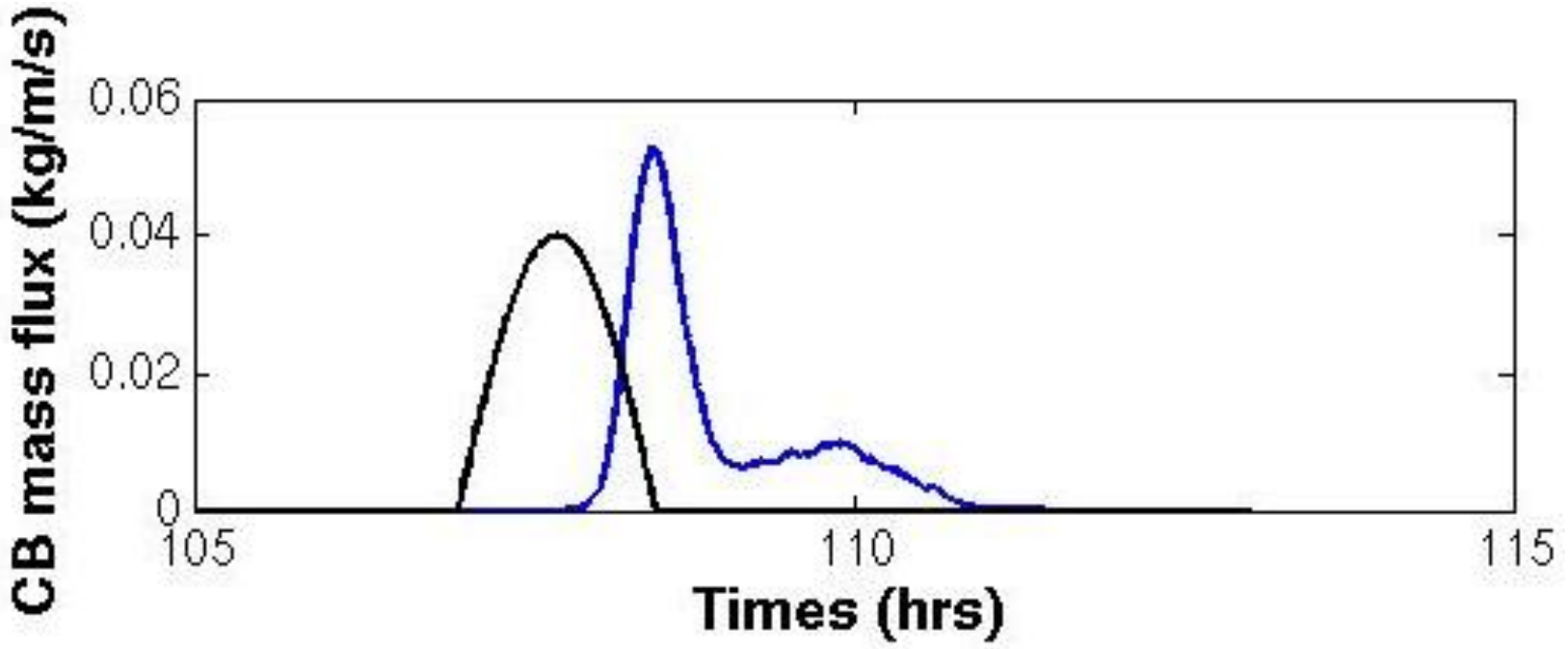
- Consider an infinitely long forcing.
- The system develops a mean amount of convection and achieves equilibrium.



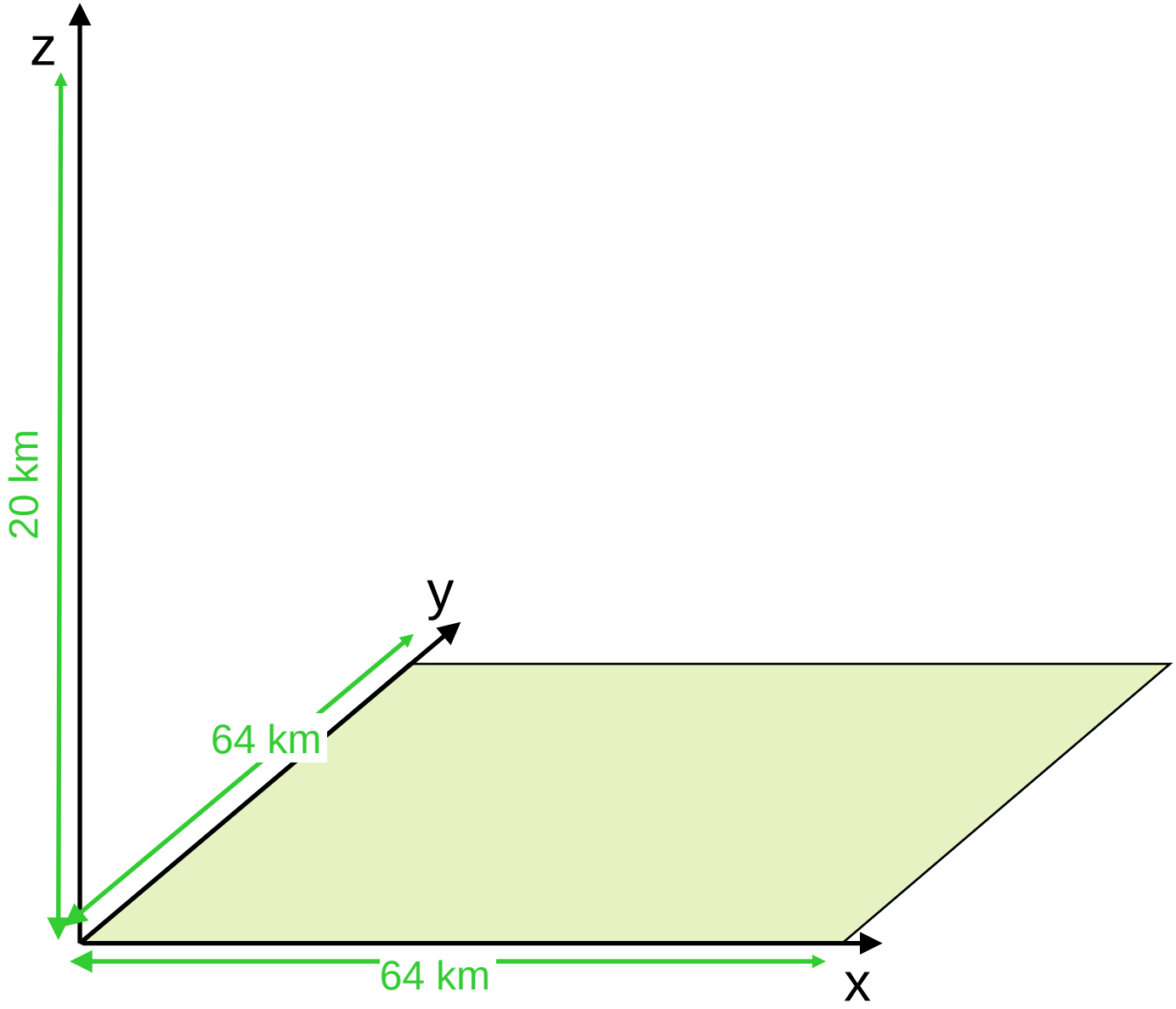
Defining equilibrium (3)

A working definition

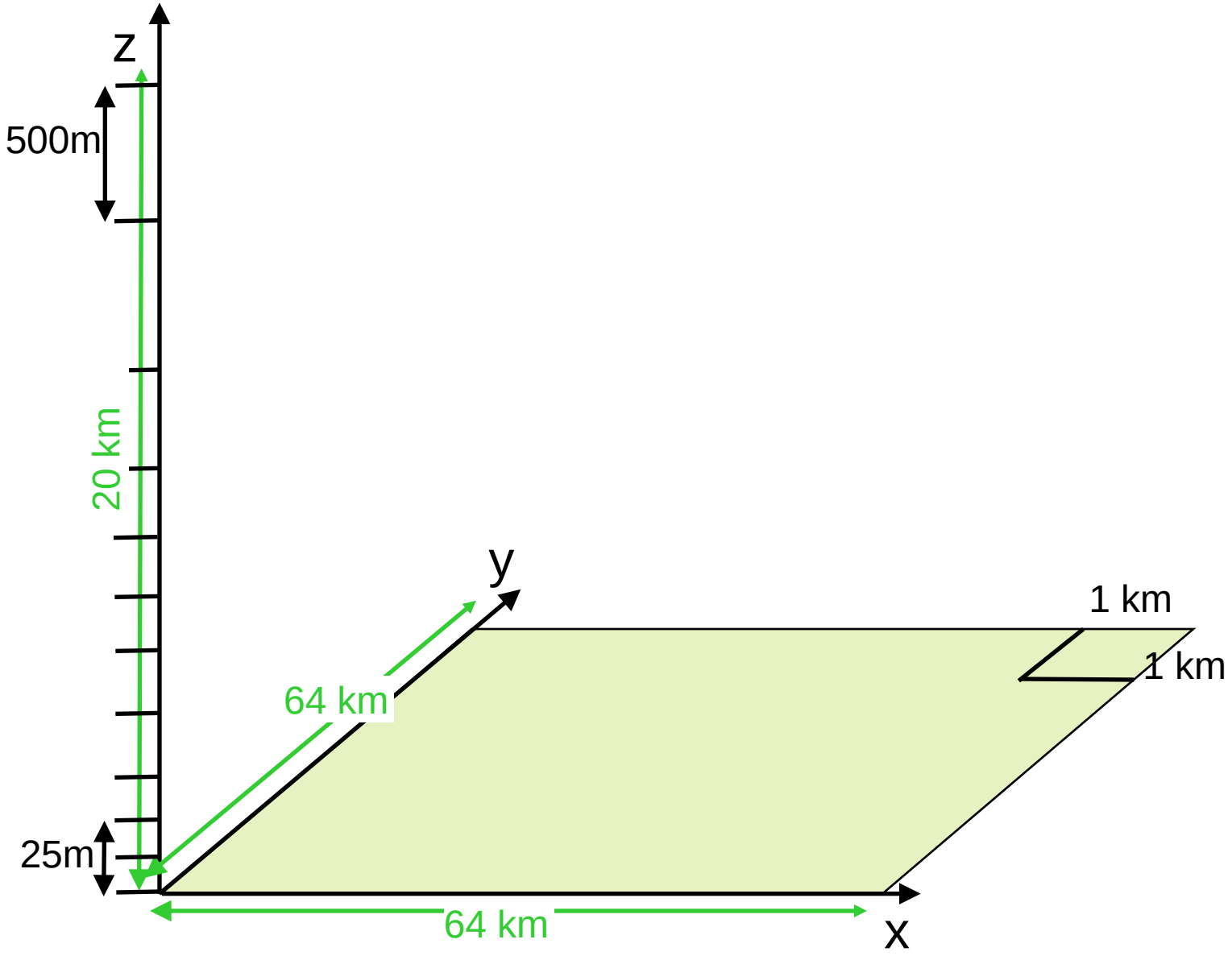
- Now, the system has a finite forcing.
- The total amount of convection is proportional to the amount of forcing.
- Avoids issues of timing and cloud-scale fluctuations.



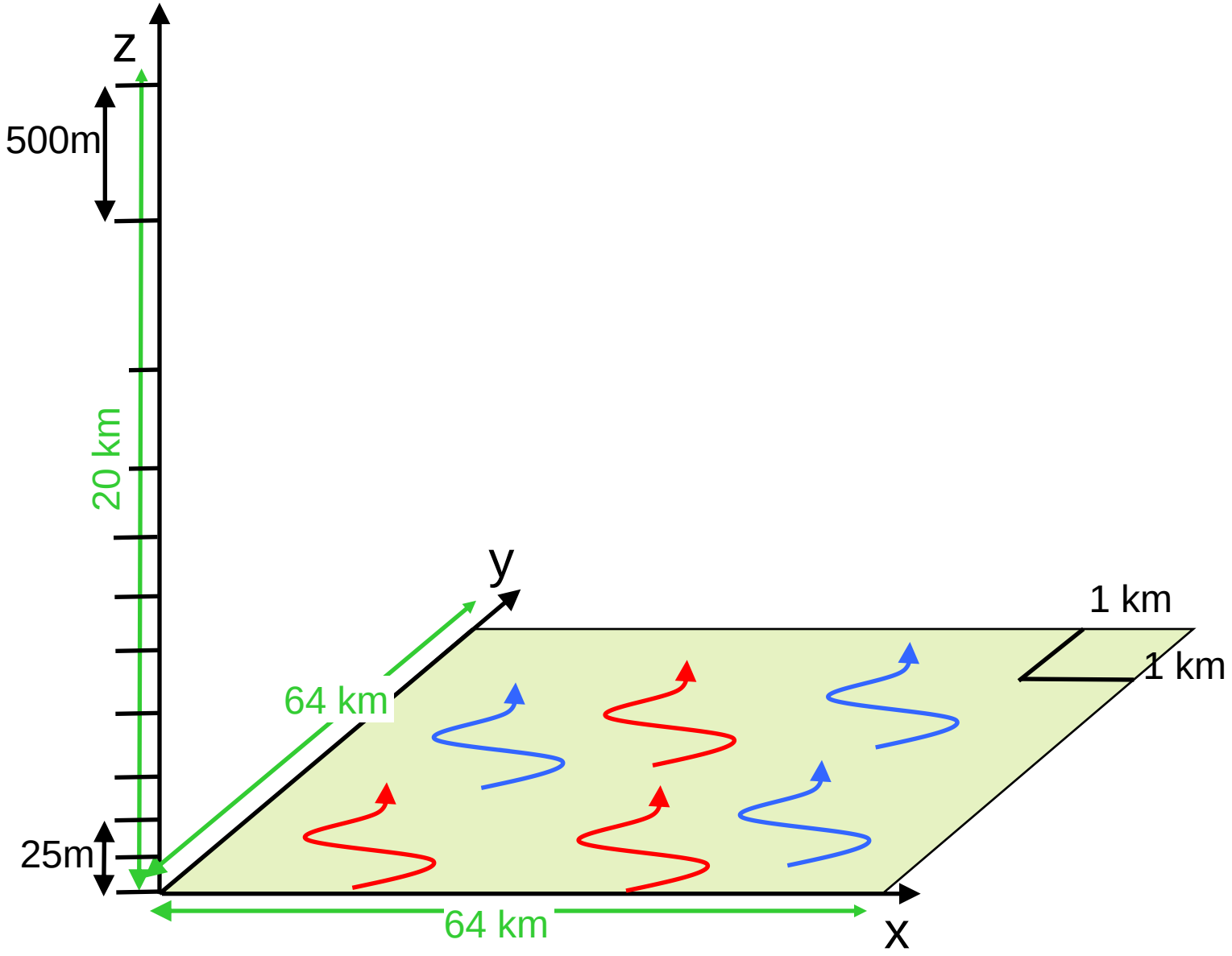
Model setup



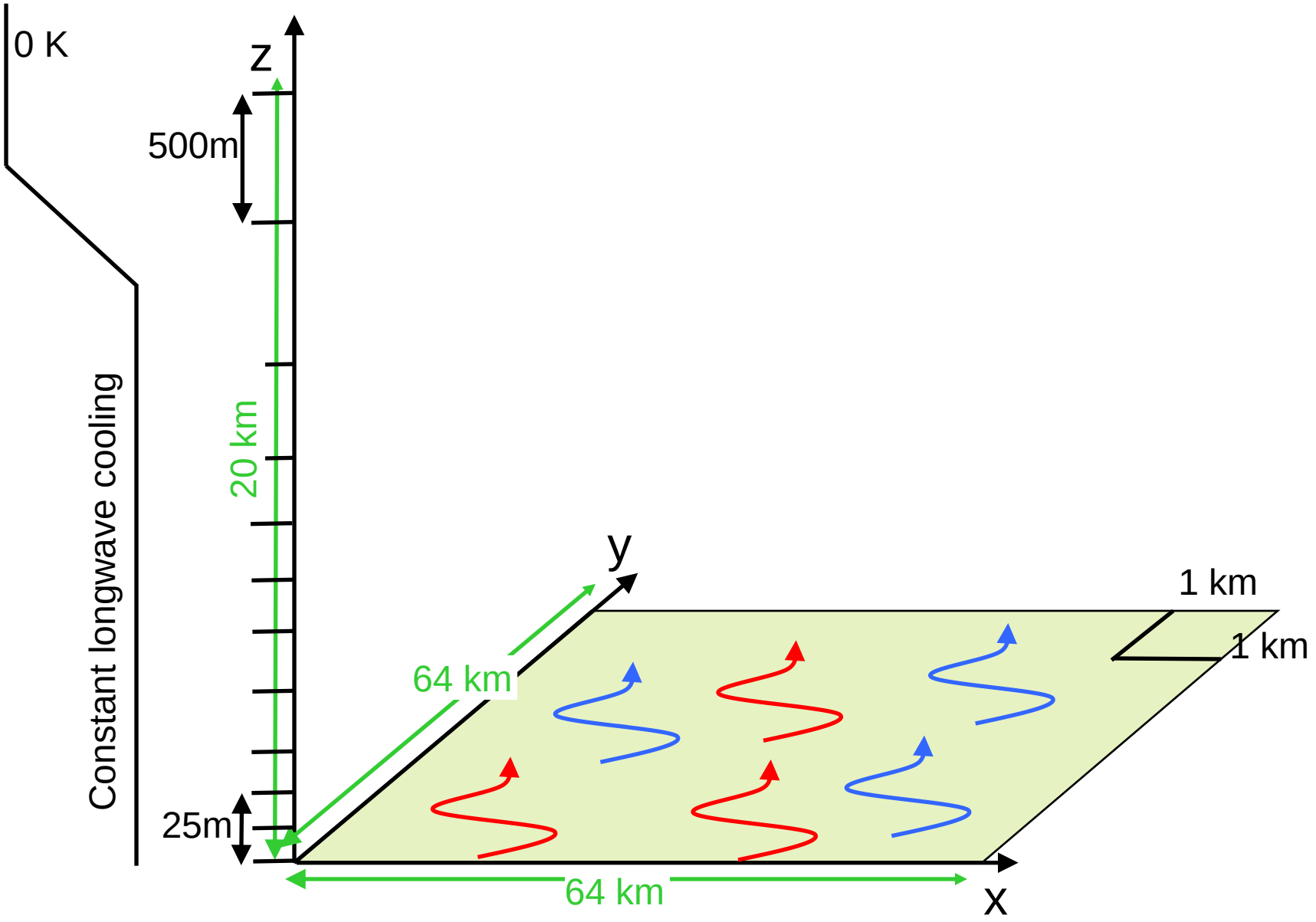
Model setup



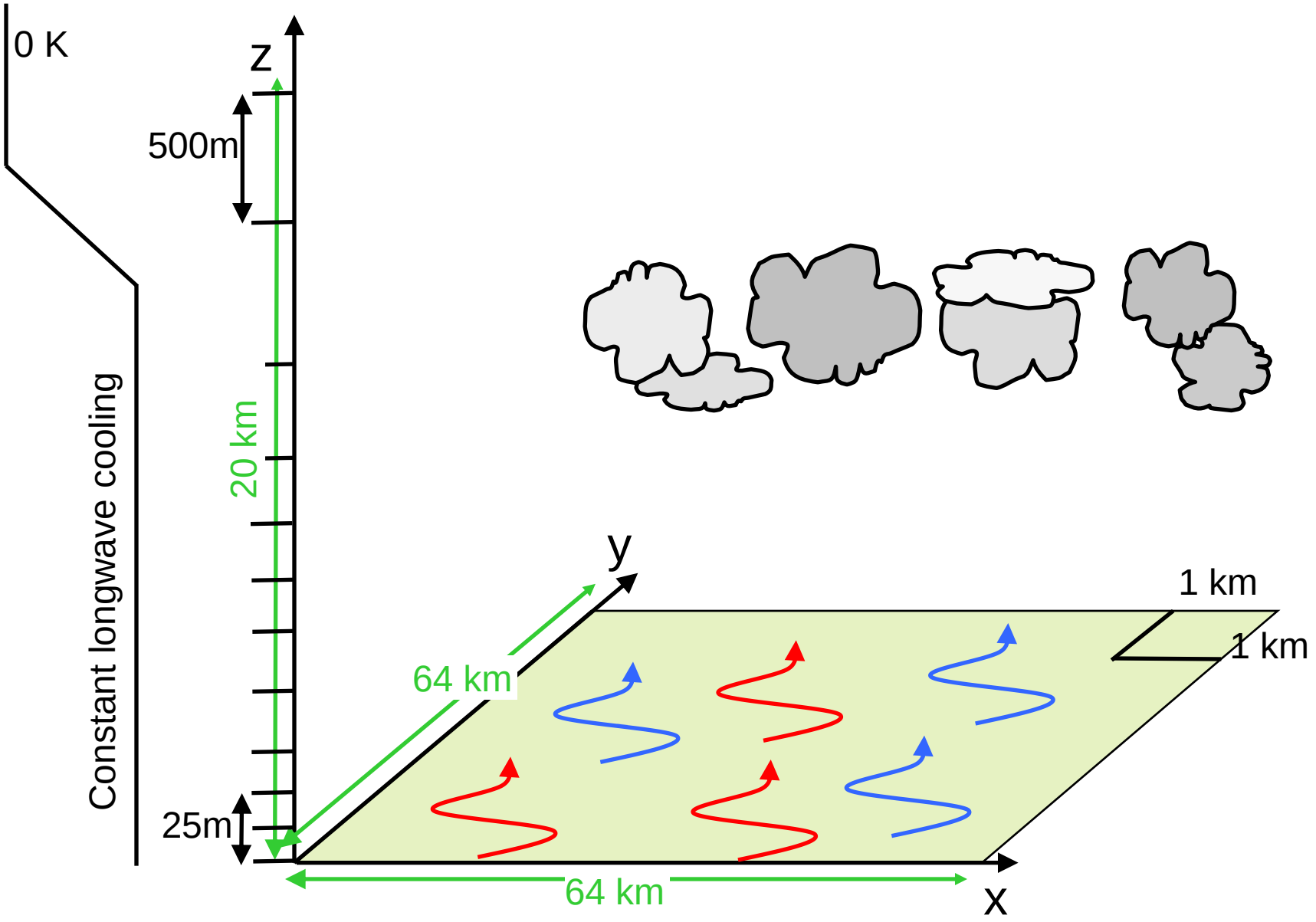
Model setup



Model setup


0 K
z
500m
20 km
Constant longwave cooling
25m
y
64 km
1 km
1 km
64 km
x

Model setup


0 K
z
500m
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y
64 km
1 km
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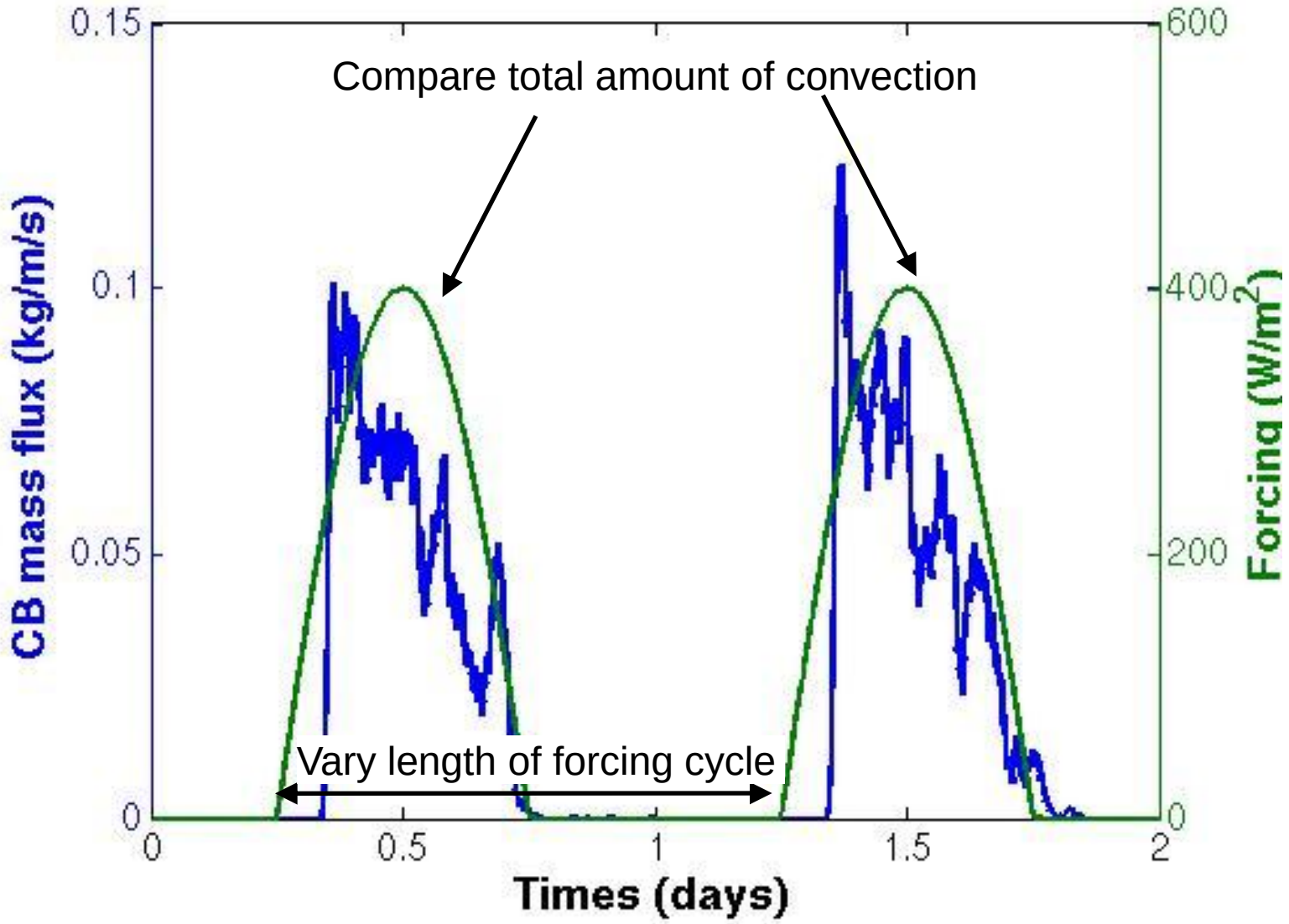
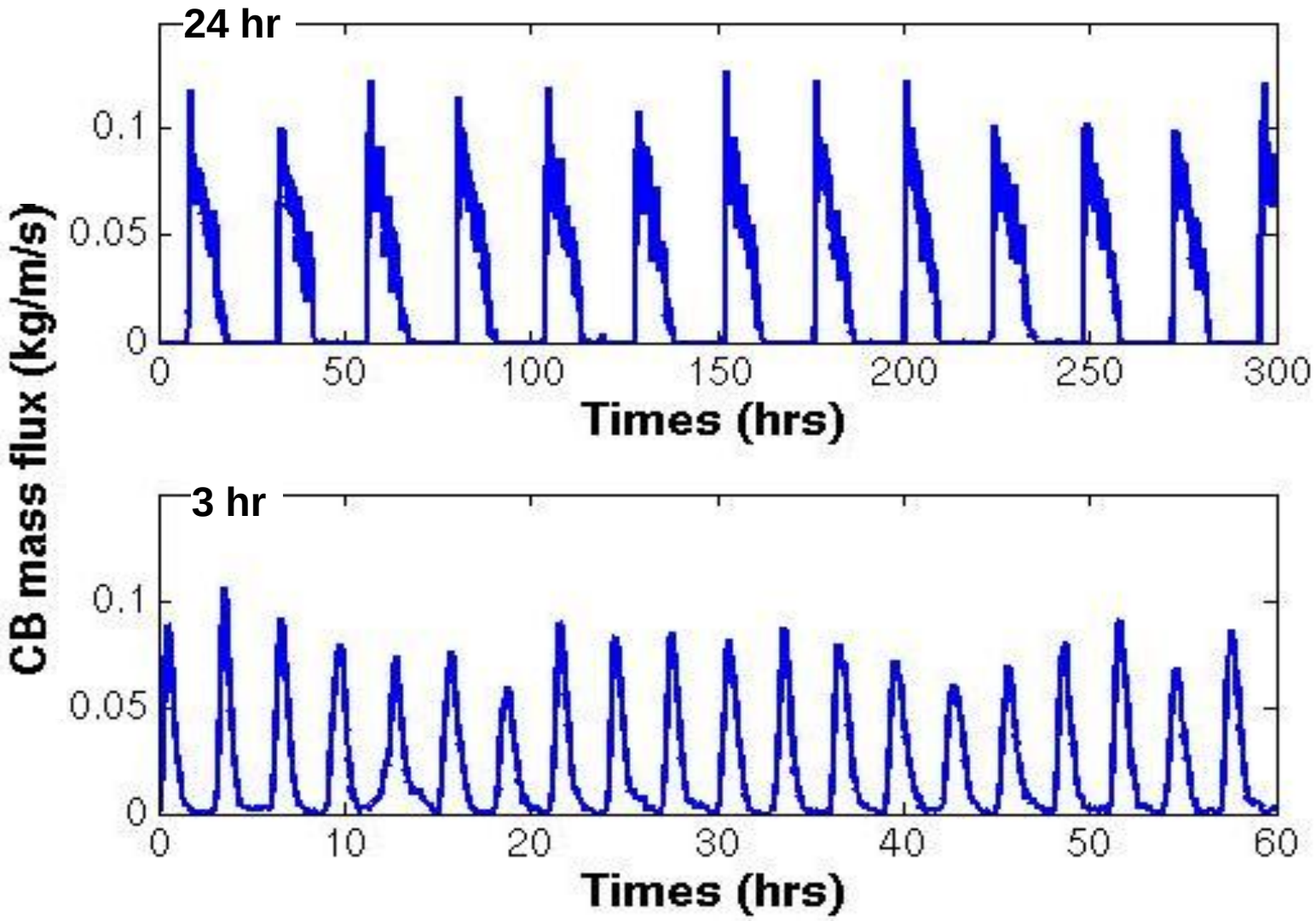
64 km
x

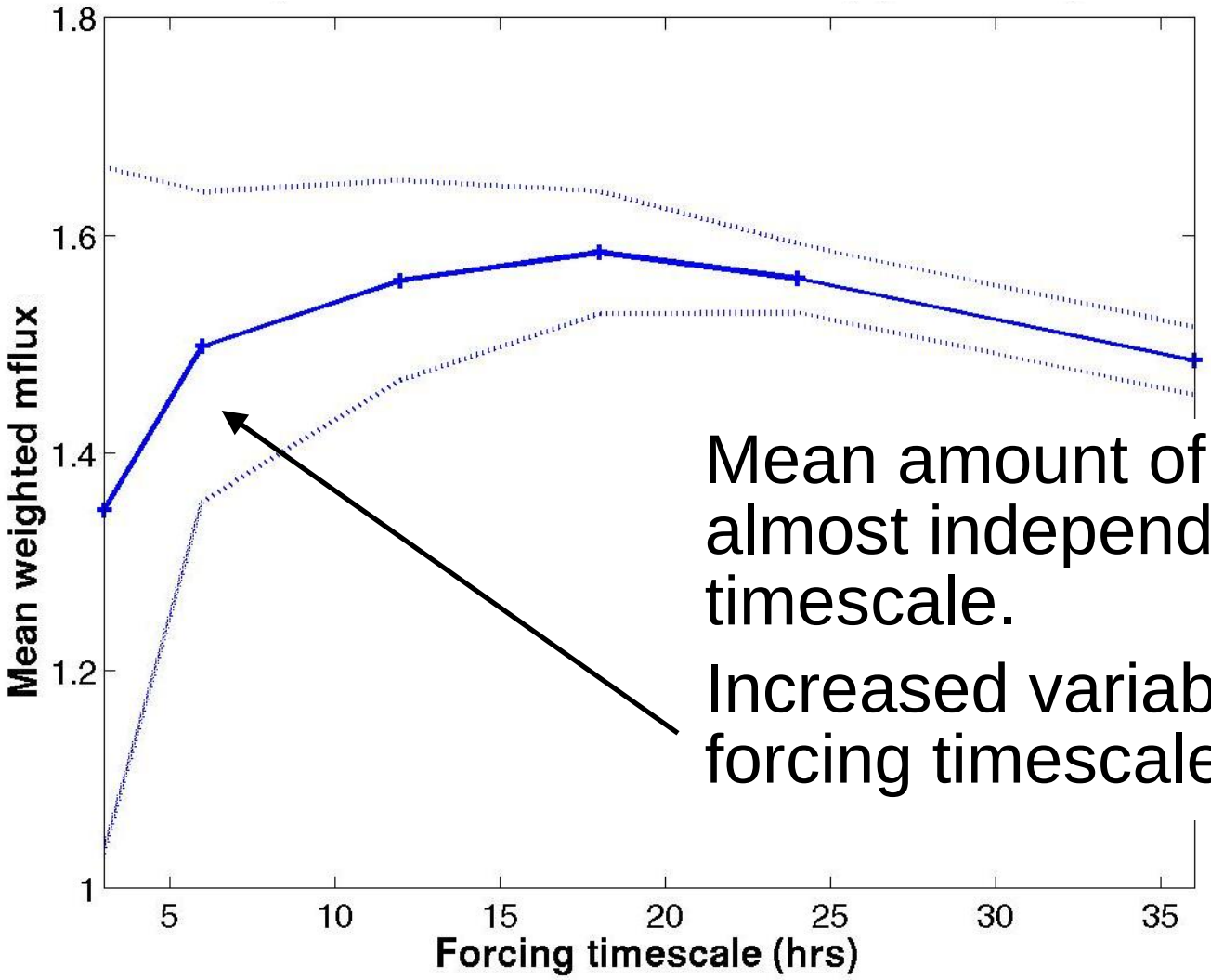
Forcing method



Time evolution



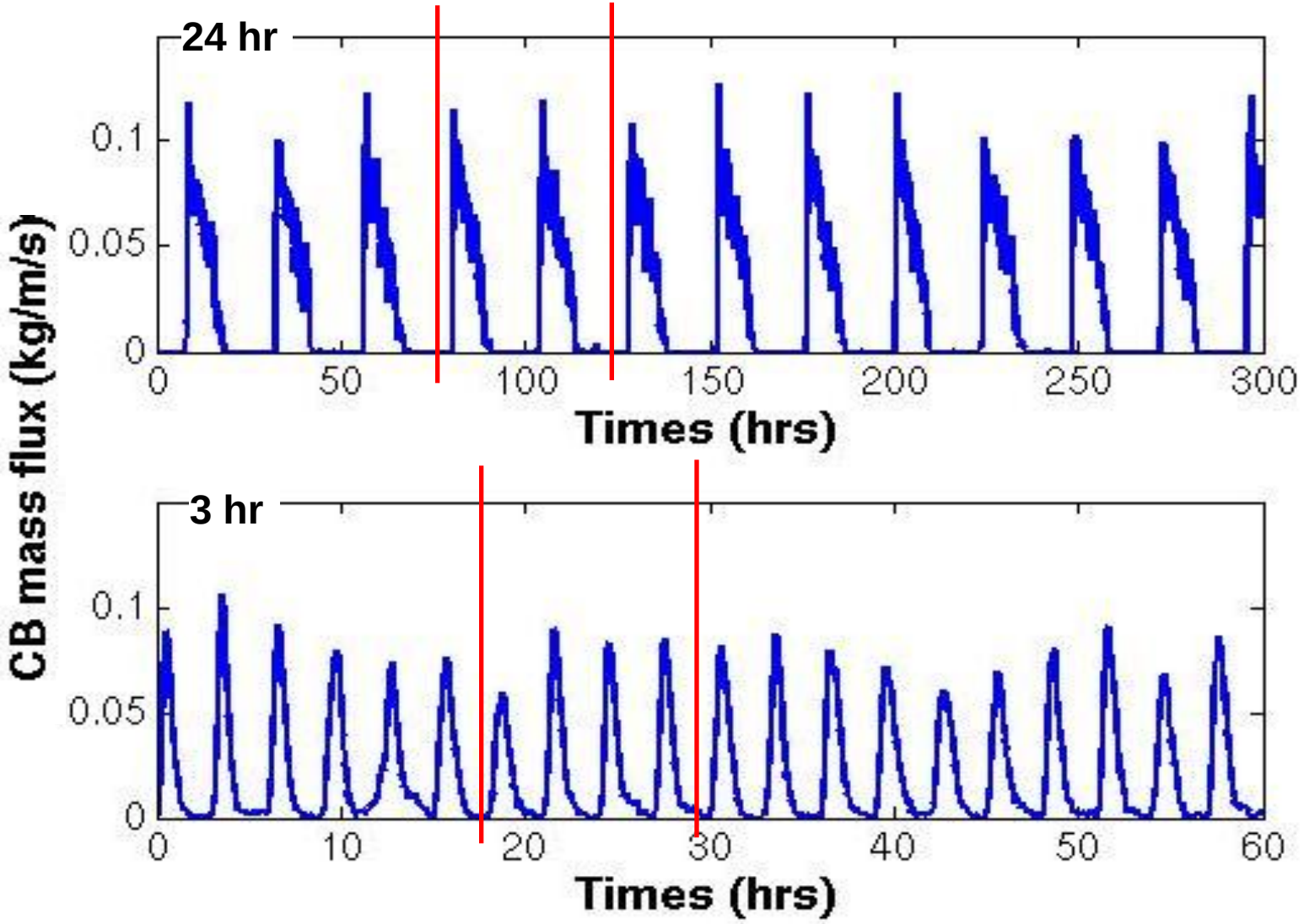
Effect of forcing timescale



Mean amount of convection is almost independent of forcing timescale.

Increased variability at short forcing timescales (< 10 hrs).

Time evolution



Cause of variability

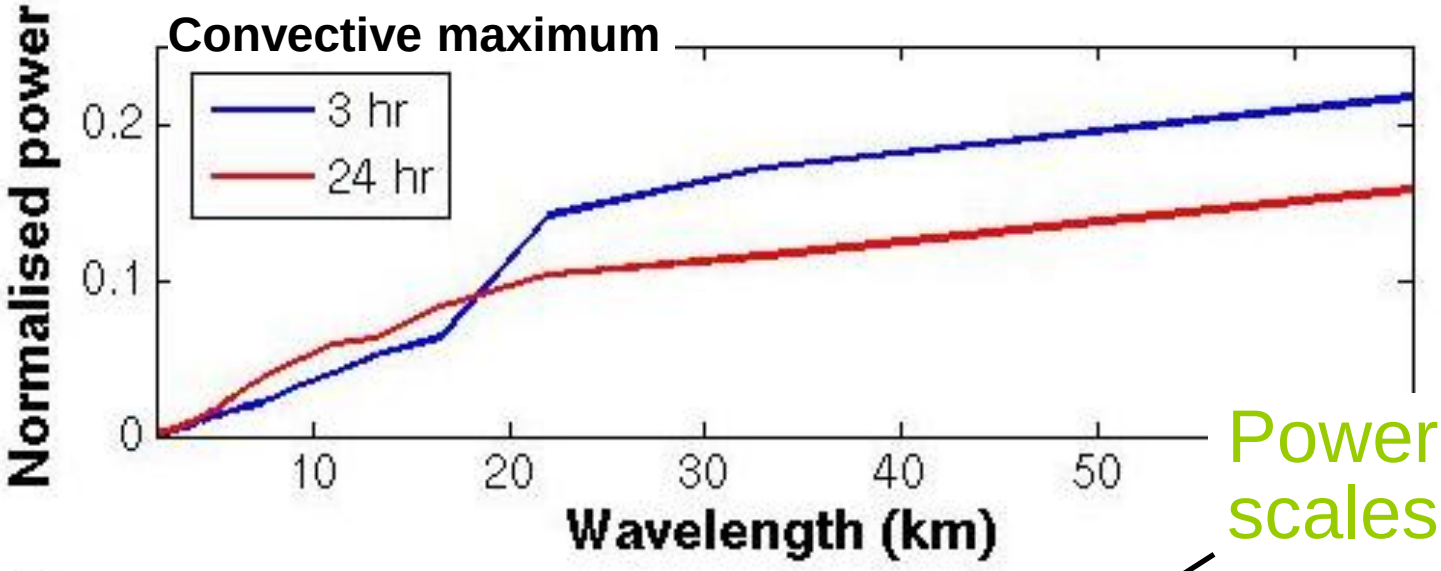
Differences in the mean profiles of θ and q_v?

The mean and variability of the initial profiles of θ and q_v are comparable at different forcing timescales.

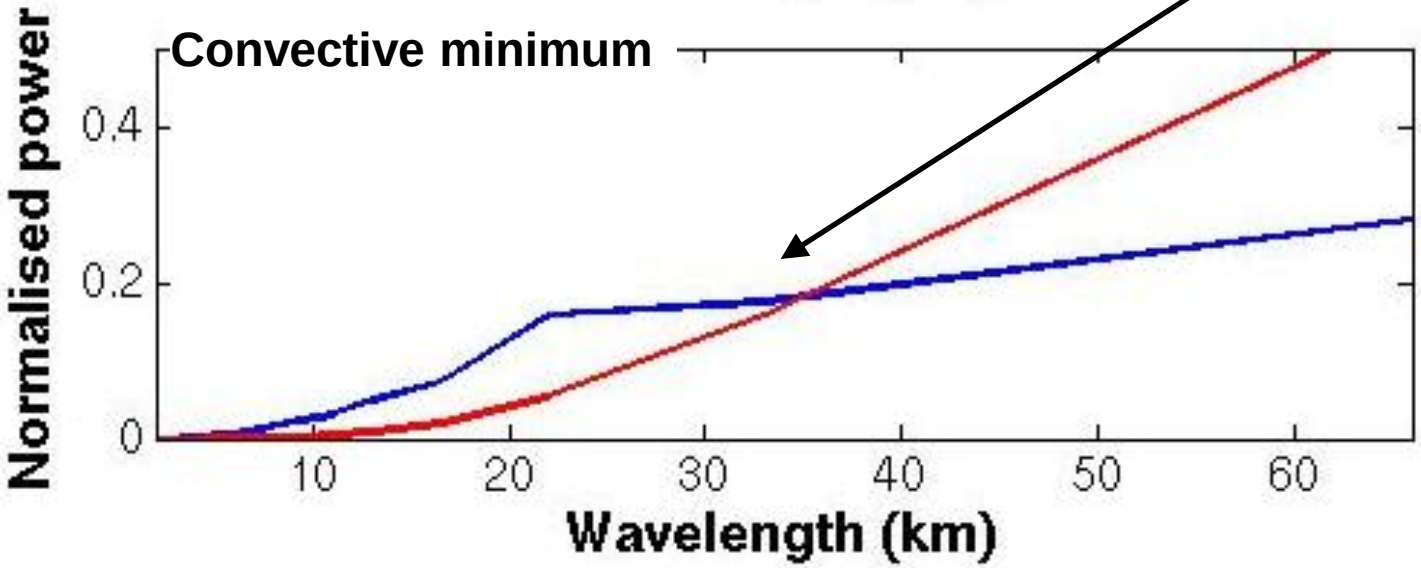
Differences in the spatial variability?

Are there different spatial scales of θ and q_v present initially at different forcing timescales?

Spatial scales of relative humidity



Power persists at scales 10-30 km.

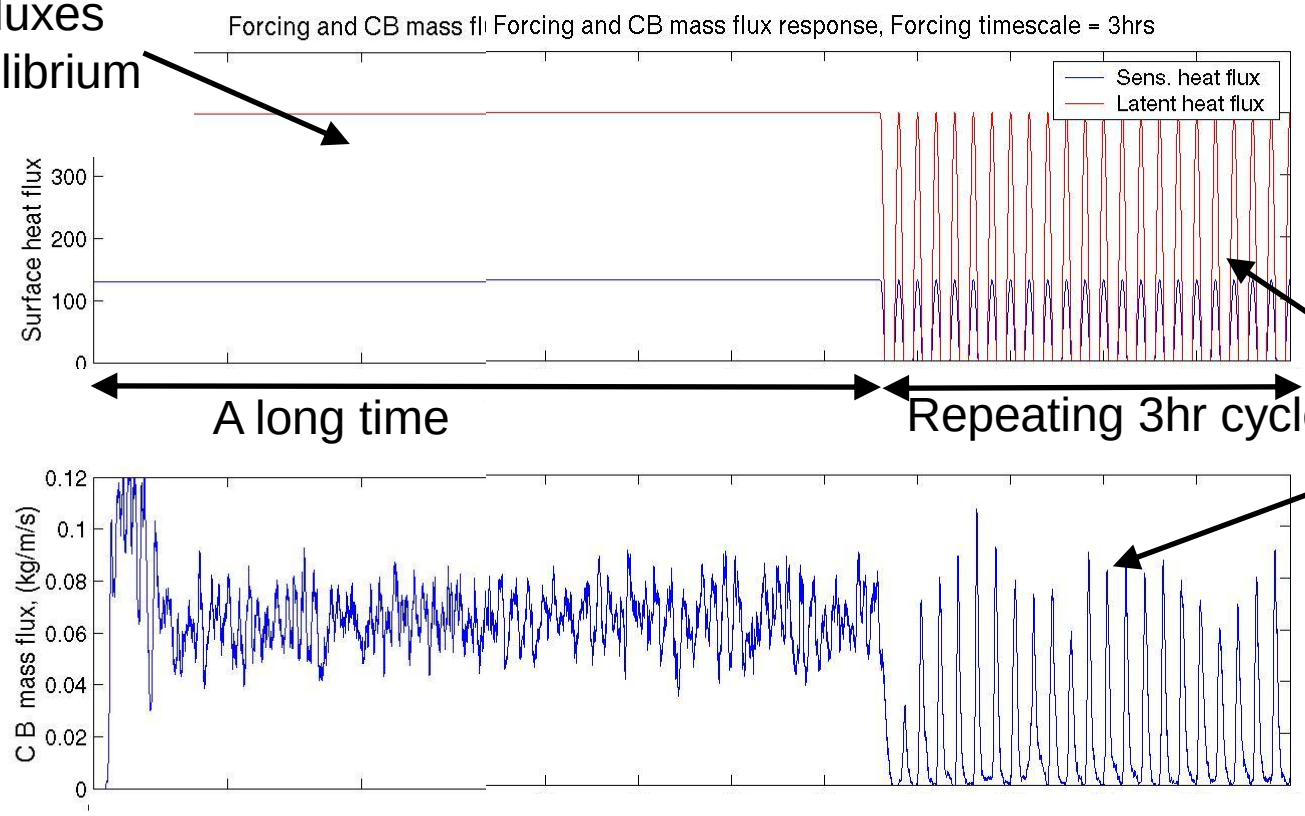


Conclusions

- A definition of equilibrium is proposed which is based on the total amount of convection in the system.
- Using this definition a convective is not in equilibrium when forced on timescales < 10 hrs.
- It was found that the mean initial state could not explain this dis-equilibrium.
- Spatial structures (10-30 km) in the relative humidity field were found to persist when the system was in dis-equilibrium.
- These structures may be important in explaining the memory within a convective system.

Control run

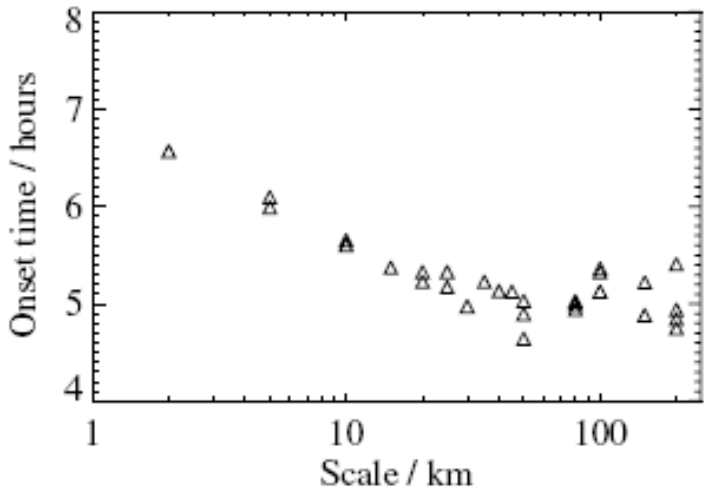
Control run:
Applying constant surface fluxes until equilibrium achieved



Time-varying portion of run

Stirling and Petch (2004)

Sine moisture perturbation in lowest 500m



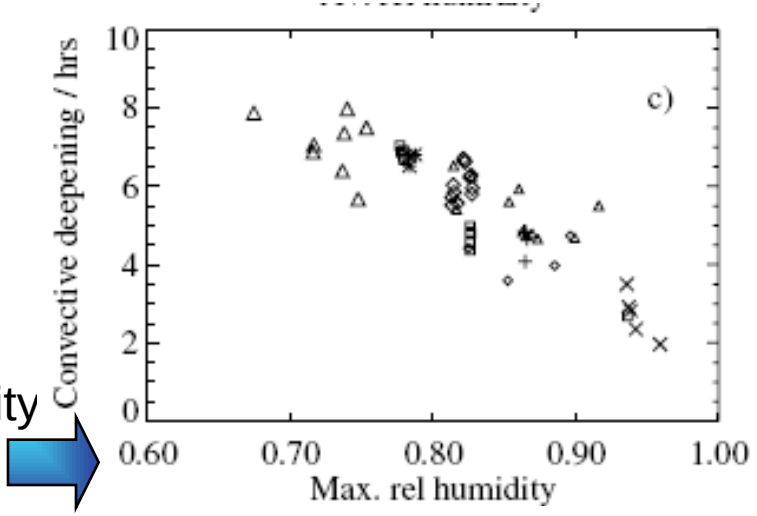
Cloud top height > 3 km & w_{max}> 5 m/s.

Found onset of convection brought forward by **moisture** perturbations on scales **greater than 10 km.**

Figure 9. The deep-convective onset time as it varies with the scale of initial moisture perturbation.

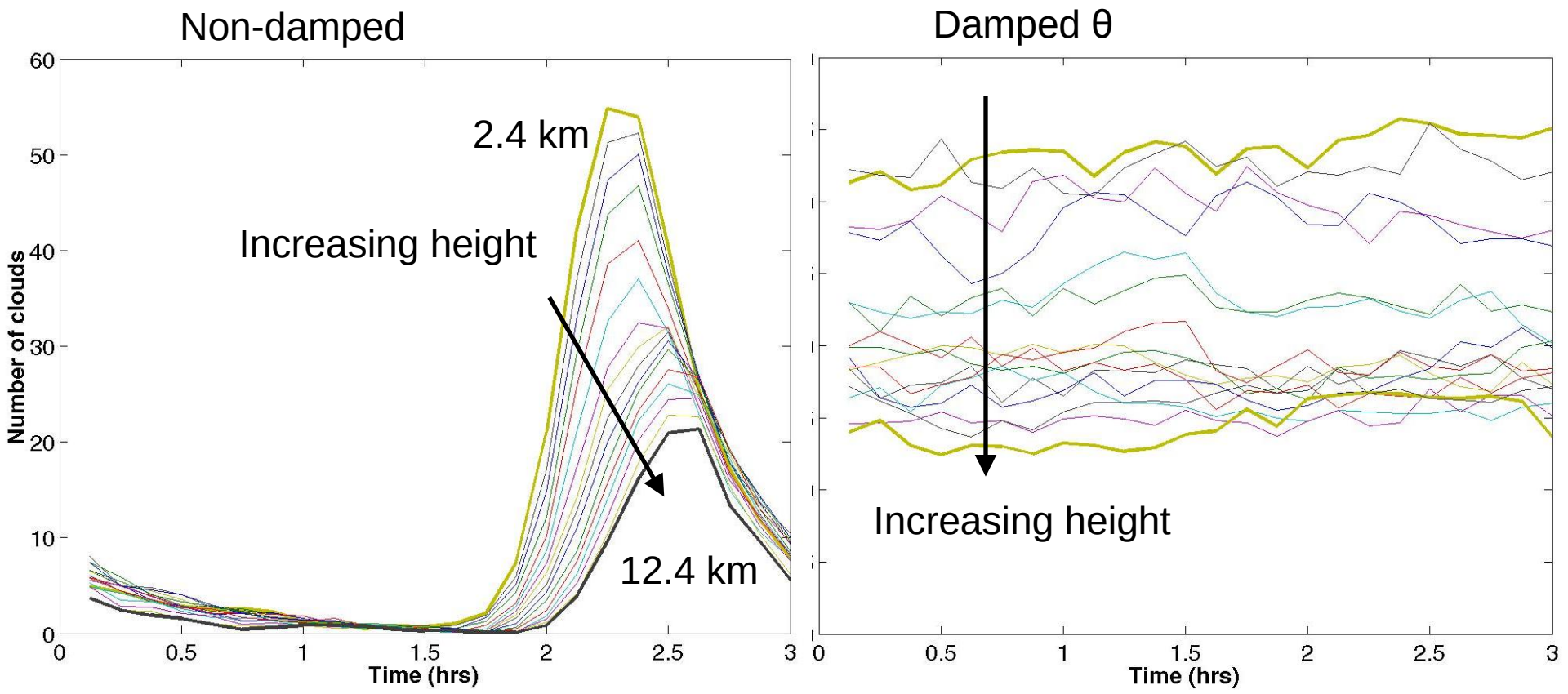
Rainfall increase by 20–70 % with convectively generated variability

Maximum boundary layer relative humidity at dawn

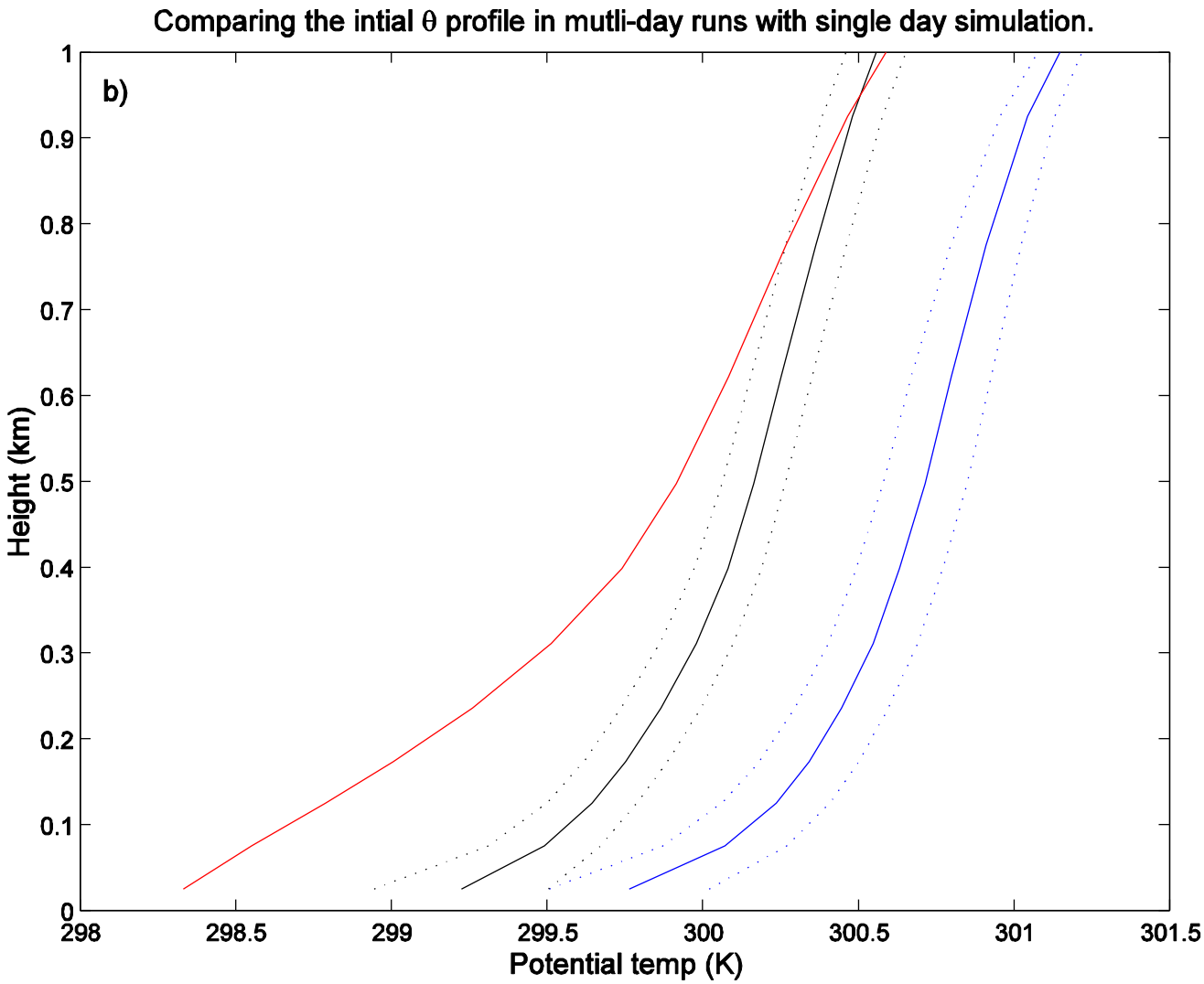


Cloud distribution

Mean number of clouds

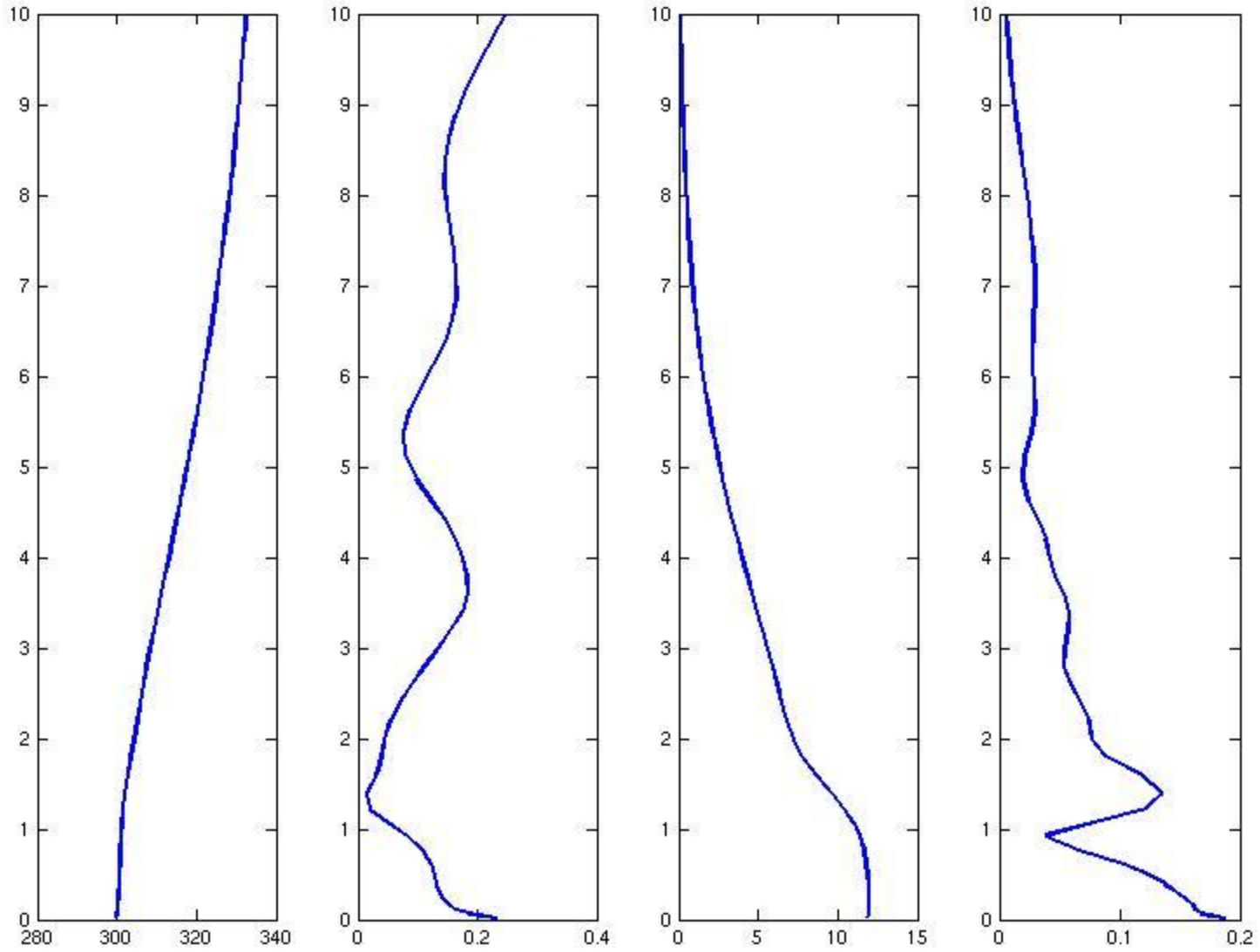


Clouds defined as buoyant, moist and upward moving


Comparing the intial θ profile in mutli-day runs with single day simulation.
b)
Height (km)
Potential temp (K)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
298
298.5
299
299.5
300
300.5
301
301.5

Mean profiles

3 hrs



Mean profiles

24 hrs