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Transition from suppressed to active convection modulated by a weak-temperature gradient derived large-scale circulation

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Abstract

We assessed the influence of the large-scale circulation on the transition from suppressed to active convection. As a model tool, we used a two-column model. It consists of two cloud-resolving models which are coupled via a weak-temperature gradient derived large-scale circulation.

The simulations of the transition are initialized from the simulations over non-uniform sea surface temperature (SST) and the transition is forced within the column with suppressed convection by changing the local and/or remote SST towards uniform SST across the columns.

Direct effects from changing SST wane after few days and the subsequent evolution of the large-scale forcing modulates the transition to active convection. Its contributions are approximately equally divided between the heating and moistening effects. The remotely forced transition is around twice as long compared to a locally forced transition. A locally-and-remotely forced transition produces intermediate transition times.

Model description

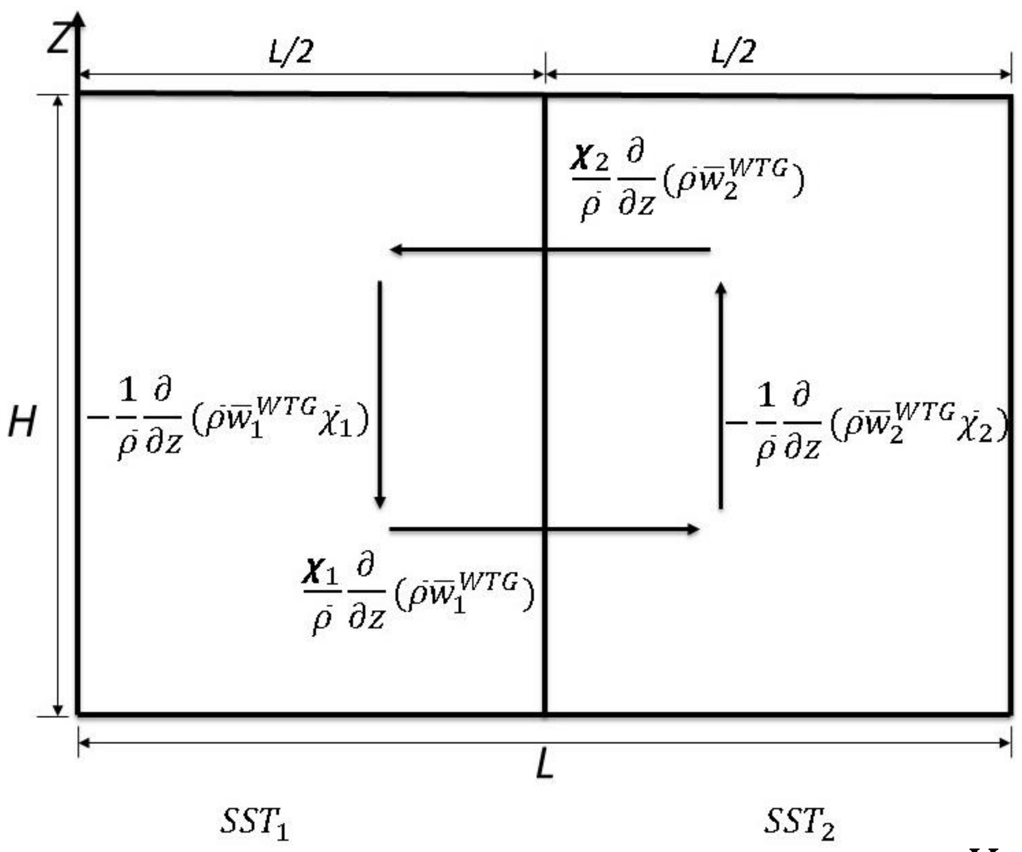

Fig.1: Two-column formulation

$$\bar{w}_2 \frac{\partial \bar{\theta}_2}{\partial z} - \bar{w}_1 \frac{\partial \bar{\theta}_1}{\partial z} = \frac{\bar{\theta}_2 - \bar{\theta}_1}{\tau}$$

$$\bar{w}_1 + \bar{w}_2 = 0.$$

The coupling timescale τ=2h

Properties of each column

Large-Eddy Model at version 2.4 of the UK Met Office run in Cloud-Resolving mode

$Y \times Z = 128 \times 20\ km,\ \Delta Y = 0.5\ km$

ΔZ: variable; finer resolution closer to the surface.

$V = 0\ m/s, U = 5\ m/s$ with a relaxation time scale of 2hours.

Radiative cooling: 1.5 K/d up to 12 km, then decreases linearly to 0 K/d at 15km.

Experimental setup

Initial conditions

Simulations over non-uniform SSTs:

$SST_2 = SST_1 + 2\ K$

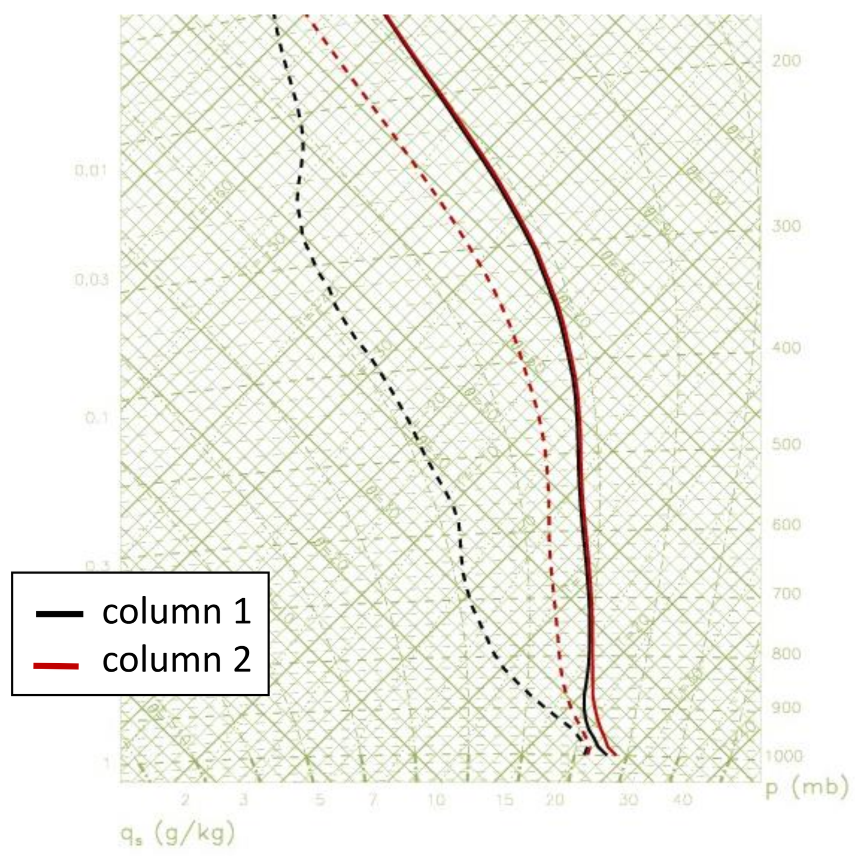

Fig.2: Tephigram of the initial state

Simulations of the transition

Local forcing: the SST in column 1 is increased by 2 K: **L**

Remote forcing: the SST in column 2 is decreased by 2 K: **R**

Local-and-remote forcing: the SST in column 1 is increased by 1 K while the SST in column 2 is decreased by 1 K: **L+R**

References

. Daleu, C., S. Woolnough, and, R. Pant, 2012: Cloud-resolving model simulations with one and two-way couplings via the weak-temperature gradient approximation. *J. Atmos. Sci.*, **69**, 3683-3699

. Daleu, C., S. Woolnough, and, R. Pant, 2014: Transition from suppressed to active convection modulated by a weak-temperature gradient derived large-scale circulation *J. Atmos. Sci.*, (submitted)

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Results

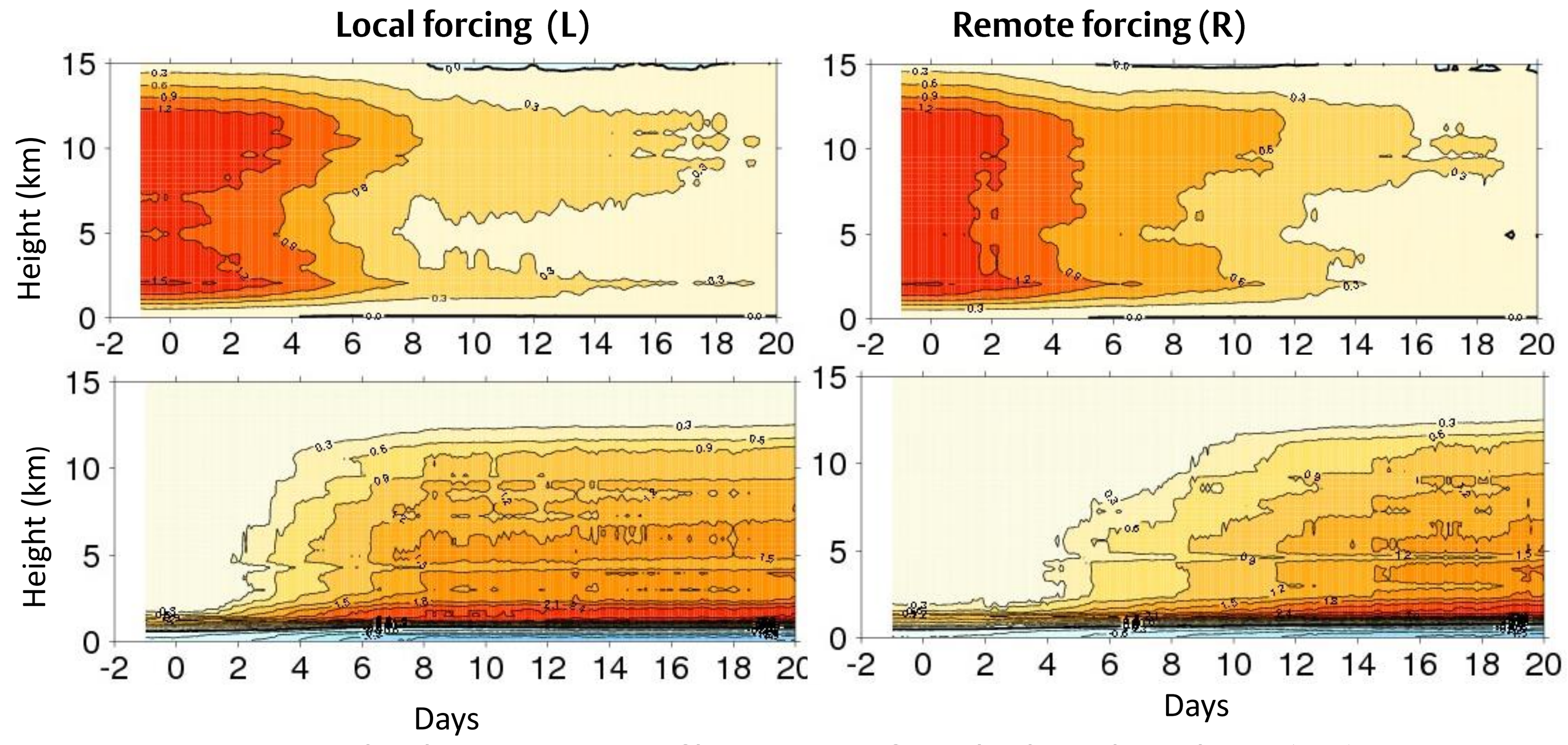

Fig.3: Time-height cross sections of heating rates from the derived circulation (top) and domain –mean heating rates from microphysics (bottom)

The transition time, t^* is the time when the rain rate is half way between the initial and final value.

Exps	L	L+R	R
t^* (days)	5.4 (5.0-6.2)	10.9 (10.0-11.6)	8.0 (7.1-8.4)

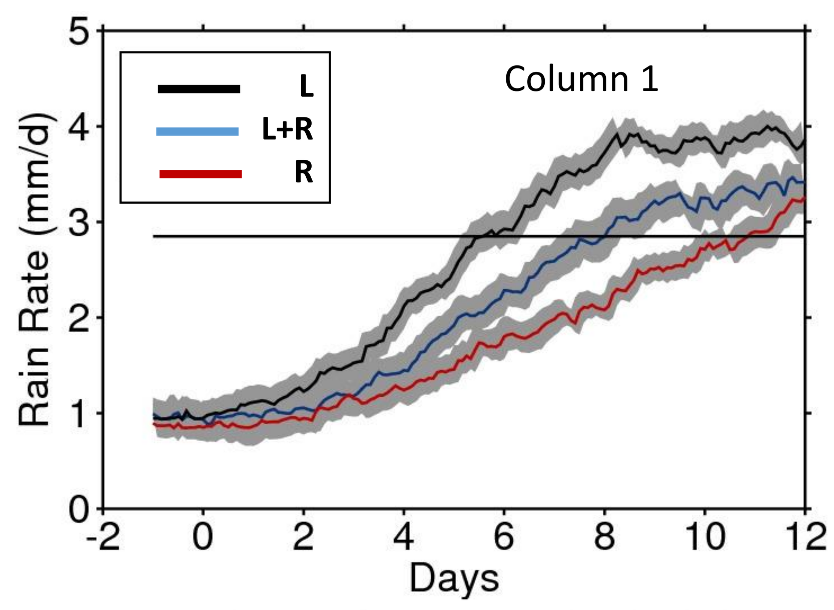

Fig.4: Time evolution of rain rates. The shaded areas represent the range of the five ensemble realizations

The role of surface forcing

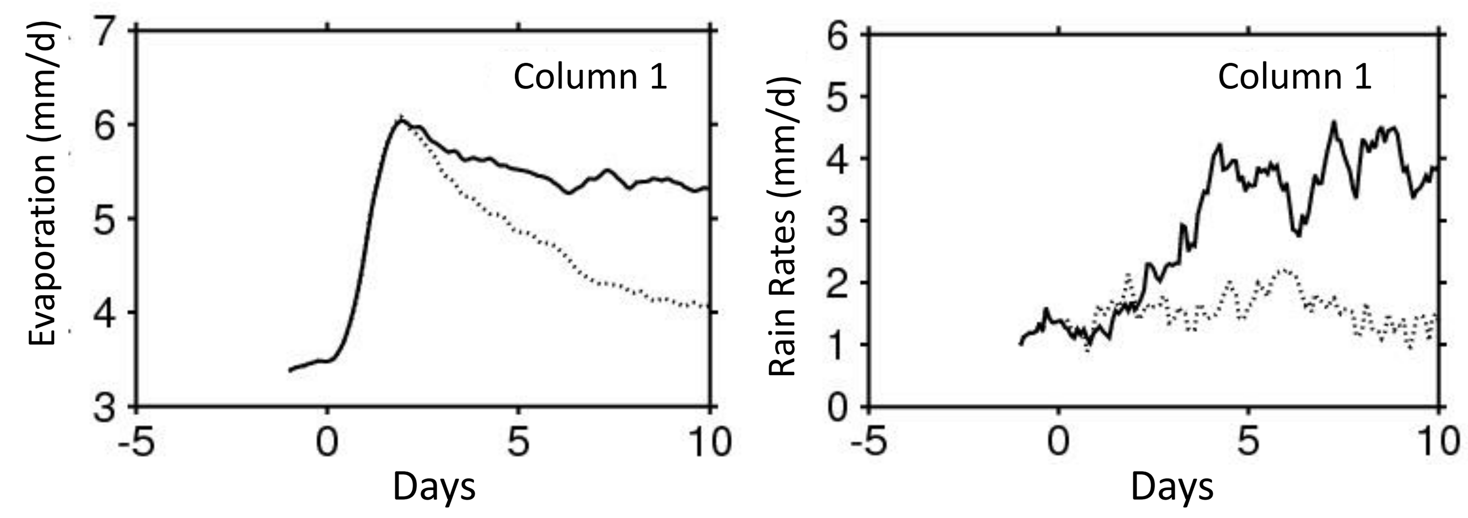

Fig.5: To assess the role of the large-scale circulation we compared experiment L (solid curves) with an experiment in which the large-scale circulation is not allowed to change from the initial state (dotted curves)

The roles of large-scale forcing

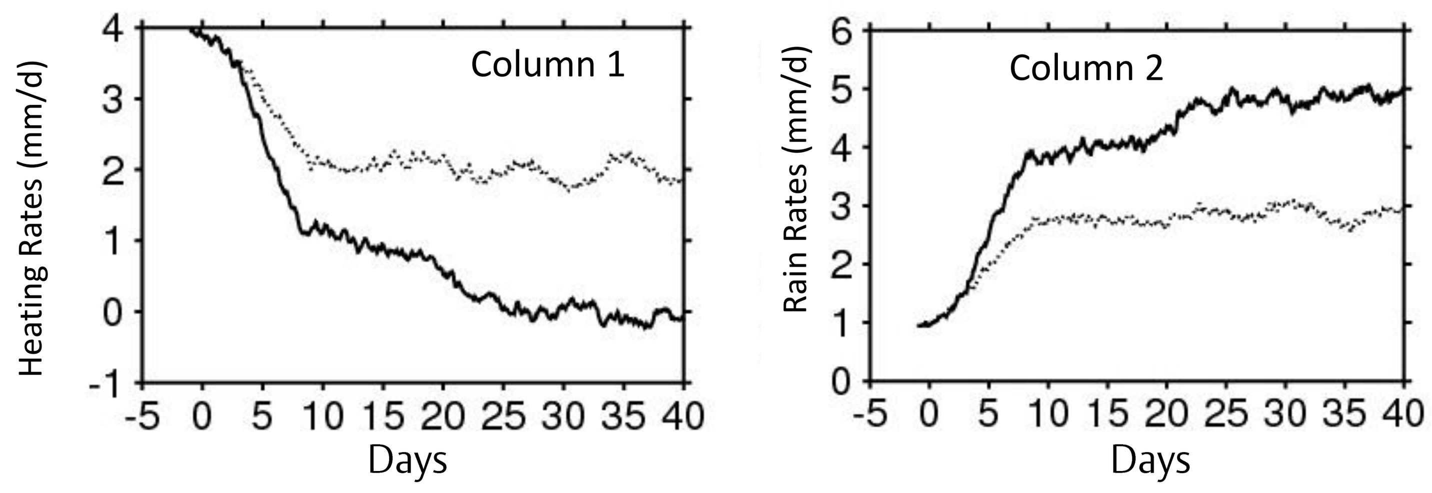

Fig.6: To assess the relative role of the heating and the moistening rates from the large-scale circulation we compared experiment L (solid curves) with an experiment in which the heating rates from the large-scale circulation adjust interactively as in experiment L while the moistening rates are not allowed to change from the initial state (dotted curves).

Summary

- The transition time is around twice as long for a remote forcing compared to a local forcing. A local-and-remote forcing produces intermediate transition times.
- The change of the remote SST drives a weakening of the large-scale forcing. The change of the local SST promotes convective heating which produced the weakening of the large-scale forcing.
- In all three cases, it is the evolution of the large-scale forcing which modulates the transition. Its contributions are approximately equally divided between the heating and the moistening effects.

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