Using the Weak Temperature Gradient Approximation to Develop and Evaluate Convective Parametrization Schemes

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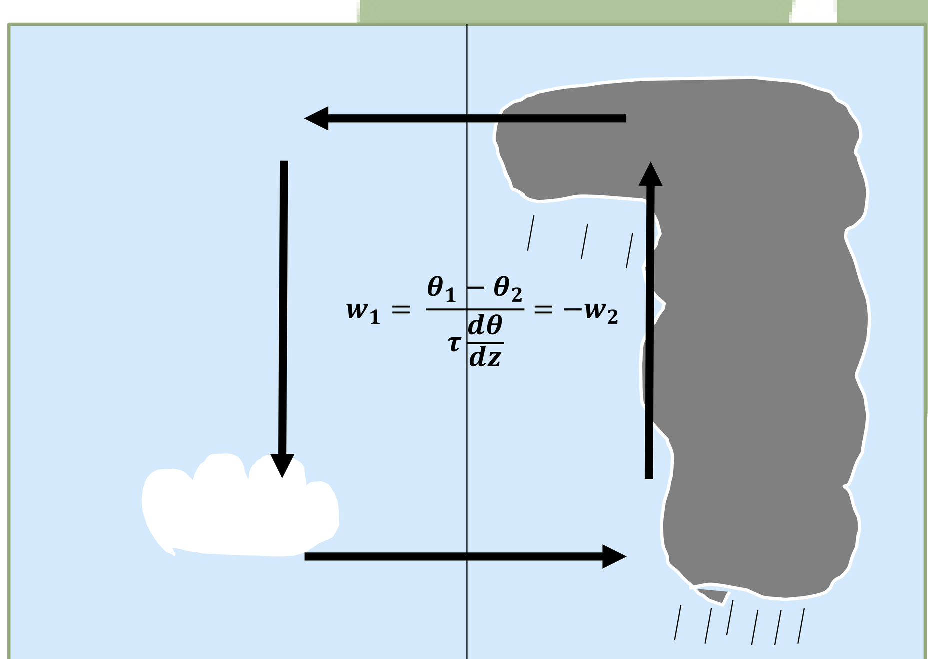
The representation of convection remains a major source of uncertainty in our weather and climate models. The coupling between the convection and the large-scale circulation is a fundamental aspect of the tropical circulation but traditional single column methods for developing and evaluating parametrization schemes cannot capture this interaction. The Weak Temperature Gradient Approximation can provide a framework for developing parametrization schemes in which the coupling between convection and the large-scale circulation is represented.

1. Parametrizing the Large-Scale Circulation

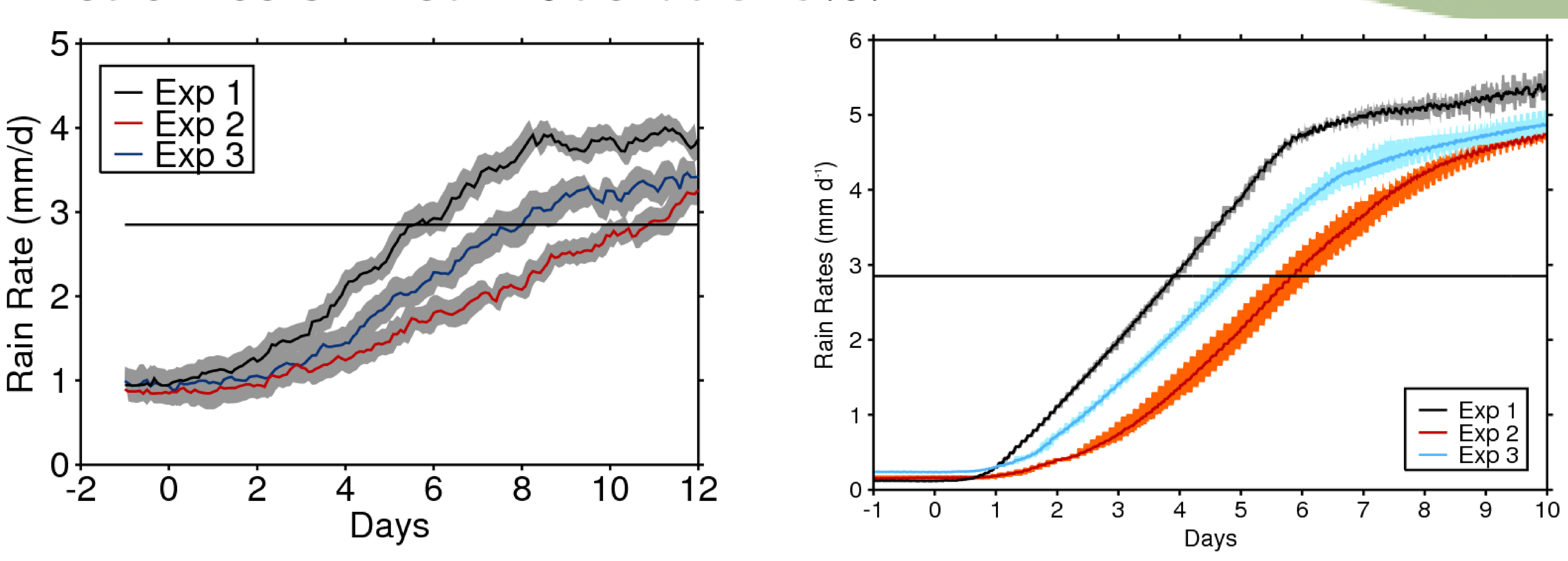
The weak temperature gradient (WTG) approximation has been used to develop a framework for parametrizing the large-scale tropical circulation in single column models (SCMs) and cloud resolving models (CRMs) of the tropical atmosphere (e.g. Sobel and Bretherton, 2000). Daleu et al. (2012) extend this framework to couple two columns.



A large-scale vertical velocity is diagnosed which acts to reduce the temperature difference between the two columns and this large-scale circulation is used to derive temperature and humidity tendencies for each column.

2. The transition from suppressed to active convection.

Daleu et al. (2015a) simulate the transition from active to suppressed convection in 2 CRMs coupled by a WTG derived large-scale circulation. The initial state is from the two column system with a prescribed SST difference of 2K. The transition from suppressed to active convection is forced by either increasing the SST in the cold column to that of the warm column (local forcing) or reducing the SST in the warm column to that of the cold column (remote forcing). In a third experiment the SSTs are equilibrated by changing each by 1K (local and remote forcing). We repeat these experiments replacing the CRMs with SCM versions of the Met Office Unified Model at GA3.0.

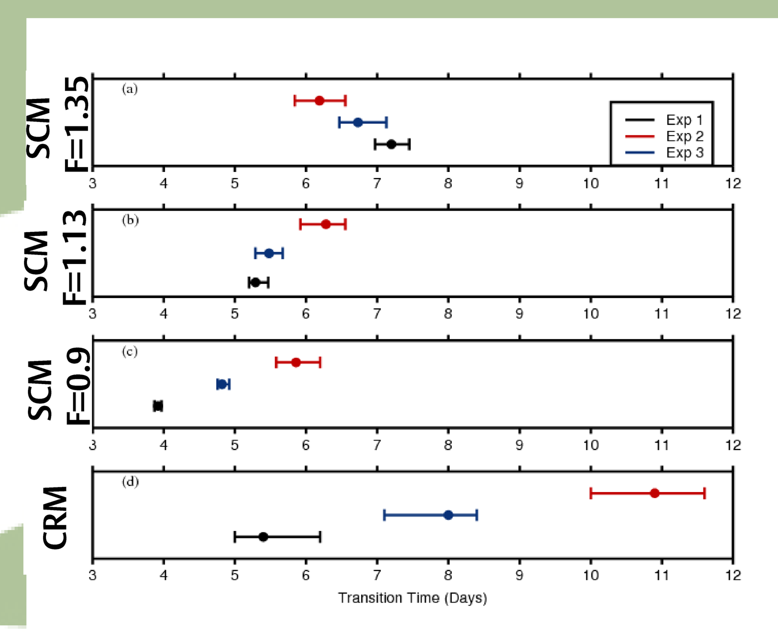


Simulated Transition from deep to active convection in the locally, (black), remotely (red), and locally and remotely (blue) forced transitions in the CRM (left) and SCM (right).

- In each model the locally forced transition occurs more rapidly than the remotely forced transition.
- The transitions occur more rapidly in the SCM than in the CRM

3. The sensitivity to convective mixing

We then explore the sensitivity of the simulated transition in the SCM to the parameter (F) which scales the fractional mixing entrainment and detrainment rate in the deep and mid-level convection scheme.

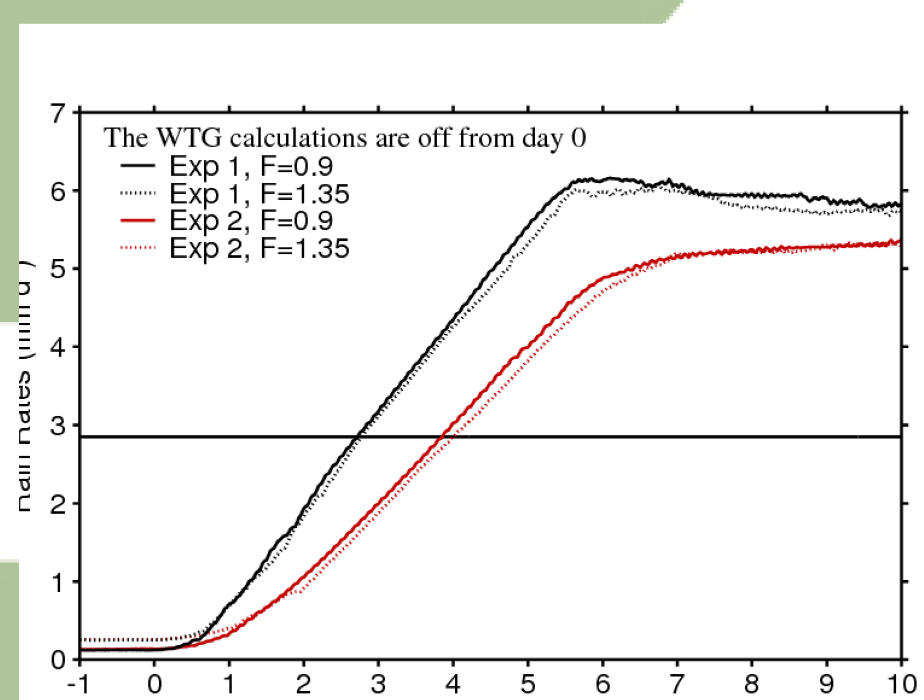


The transition time (at which the precipitation reaches half its equilibrium value), in the locally (black), remotely (red) and locally and remotely (blue) forced experiments for he CRM and the SCM with F=0.9 (control), F=1.13, F=1.35

- For the control value F=0.9, the ordering of the transition times is as for the CRM
- The remotely forced transition is relatively insensitive to F, but the locally forced transition occurs more slowly as the entrainment rate increases
- At high entrainment rates the order the transition times is reverse

4. The role of the large-scale circulation

To explore the role of the large-scale circulation in the simulated transition we perform two simulations in which the large-scale circulation is instantaneously removed. One in which the SST is unchanged and one in which the SST is increased by 2K as in the locally forced experiment



The simulated transition from suppressed to active convection in the SCM with F=0.9 (solid) and F=1.35 (dotted) when the large-scale circulation is removed and the SST is increased by 2K (black) and the large-scale circulation is removed without any change in SST.

- The transition is largely insensitive to the entrainment rate in the absence of the feedback from the large-scale circulation
- The transitions occur more quickly in the absence of the large-scale circulation

Summary

- **The Weak Temperature Gradient Approach provides a simple framework for evaluating convection schemes in the presence of feedbacks from the large-scale circulation.**
- **In an example of the transition from suppressed to active convection this framework highlights a sensitivity to the entrainment rate that was not apparent in the absence of these feedbacks**
- **The feedback from the large-scale circulation is critical to the sensitivity of the transition to the entrainment rate in these experiments**

Sobel and Bretherton, 2000: Modelling tropical precipitation in single column, *J. Clim.*; Daleu et al., 2012: Cloud-resolving model simulations with one and two-way coupling via the weak temperature gradient approximation, *J. Atmos. Sci.*; Daleu et al., 2015: Transition from suppressed to active convection modulated by a weak temperature gradient derived large-scale circulation. *J. Atmos. Sci.*