Evaluating the CoMorph Parameterization using idealised simulations of the two-way coupling between convection and large-scale dynamics

C. Daleu¹ | R. Plant¹ | A. Stirling¹ | M. Whitall²
¹Department of Meteorology | ²UK Met Office

Introduction

We present a new methodology to test the interactions of convection schemes with their larger-scale environment. In this study, a single-column model (SCM) using the new Met Office convection scheme, CoMorph, and the new Met Office NERC Cloud Model (MONC) used as a Cloud-Resolving model (CRM) are coupled to damped-gravity wave (DGW) derived large-scale dynamics. The coupled models are used to investigate convective responses to stimulus forcings under the influence of interactive large-scale dynamics. We show results from the SCM using CoMorph, demonstrating that its behaviour is now very similar to that of the CRM.

Model description

<table>
<thead>
<tr>
<th>Models</th>
<th>MONC</th>
<th>SCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
<td>3D</td>
<td>1D</td>
</tr>
<tr>
<td>Wind</td>
<td>None; ((u, v)) relaxed to (5.0) m/s</td>
<td></td>
</tr>
<tr>
<td>Rad Cool</td>
<td>-1.5 K/d (0-12 km) decreases to 0 (16 km)</td>
<td></td>
</tr>
<tr>
<td>Radiative-Convective Equilibrium (RCE) simulations</td>
<td>(P_{RCE}) (mm/d) 4.22</td>
<td>4.27</td>
</tr>
<tr>
<td></td>
<td>(E_{RCE}) (mm/d) 4.20</td>
<td>4.26</td>
</tr>
</tbody>
</table>

Parameterized large-scale dynamics

A combination of the momentum and thermodynamic equations.

\[
\frac{\delta \omega}{\delta t} = \frac{\delta \delta \omega}{\delta \delta p} + \frac{\omega}{p_{RCE}} \left( \omega - P_{RCE} \right)
\]

\(\omega\) induces source or sink terms to \(\theta\) and \(q\) budgets

\[
\frac{\delta \delta}{\delta t} = \cdots + \delta \omega \frac{\delta \delta}{\delta \delta p} \quad \text{and} \quad \frac{\delta \delta}{\delta t} = \cdots + \omega \frac{\delta q}{\delta p} + \max \left( \frac{\delta q}{\delta p}, 0 \right) \left( q_{RCE} - q \right)
\]

Experimental design

\[
\frac{\delta \delta}{\delta t}_{\text{pert}} = \frac{A_{\delta}}{\tau} \frac{\delta \delta}{\delta n} \left( \frac{z - n/2}{n/2} \right) \quad \text{and} \quad \frac{\delta q}{\delta t}_{\text{pert}} = \frac{A_{\delta}}{\tau} \frac{\delta q}{\delta h} \left( \frac{z - h/2}{h/2} \right) \exp \left[ 2 \left( 1 - \frac{z}{h} \right) \right]
\]

Approach to equilibrium

\[
\frac{\delta P}{\delta \delta} = \frac{A_{\delta}}{\tau} \frac{\delta P}{\delta n} \left( \frac{z - n/2}{n/2} \right) \quad \text{and} \quad \frac{\delta q}{\delta h} \left( \frac{z - h/2}{h/2} \right) \exp \left[ 2 \left( 1 - \frac{z}{h} \right) \right]
\]

Vertical profiles

Response as a function of the strengths of moistening stimuli

Figure 4: Profiles of the large-scale pressure velocity \(\omega\)

Figure 5: Profiles of the sum of heating rates in MONC and the sum of heating rate from parameterized physics in the SCM

Conclusions

- For stimuli acting to enhance convection
  - The SCM adjusts to a new equilibrium with stronger responses
  - The SCM responses are faster, followed by damped oscillations
- For stimuli acting to suppress convection
  - The SCM adjusts to a dry equilibrium that is similar to that in the CRM, but its transient convective responses are markedly too fast (CoMorph parameterized physics are not quite effective in capturing the long-term convective memory found in the CRM simulations)
  - Convective rainfall in the SCM is relatively insensitive to a combination of stimuli acting to enhance and suppress convection simultaneously, in agreement with the CRM.
  - Convective responses in the SCM are very similar to those in the CRM for moistening up to 0.83 mm/d, and above which they are stronger.
- Both models simulate a monotonic increase of precipitation with CRH and correctly capture the observed CRH threshold
- Above the threshold, the increase of precipitation with CRH is more abrupt in the SCM than in the CRM and observations (CoMorph parameterized physics do not appropriately capture the precipitation-CRH relationship as the CRH increases past its threshold)

Reference


Contact information: Department of Meteorology, University of Reading. Email: c.daleu@reading.ac.uk