Exploring nearest-neighbour interaction in a parametrization of deep convection

Tobias Göcke

Convective organisation is a blind spot in most parametrizations of deep convection. Sub grid scale motions of plumes happen independently in each column. In the ICON model [1] at 13km grid point distance the Bechtold convection scheme [2] tends to suppress convective organisation like e.g. squall lines. Inspired by the findings of [3], that a simple 2D lattice model might describe aspects of convective organisation, we investigate whether a nearest-neighbour interaction within the convection scheme might be able to allow for a sustained squall line within an idealized setup.

Setup/Overview:
- Double periodic domain (2000 x 400 km), Temperature and humidity profiles according to [5]. Initial cold pool and wind shear similar to [6]. Wind is zero at surface and about 30 m/s at 2500m. Initial cold pool: 4500m height, \( \Delta \theta = 5K \) at surface decreasing linearly. Cold pool covers leftmost 40% of the domain. In addition random perturbations are added at the cold pool edge.
- Simulations at 1km and 10km grid point distance. Low Resolution runs with convection, without convection and several modifications of the convection scheme.
- Two moment micro physics

Conclusions/Outlook:
- Reduced trigger in convection scheme allows squall line to form, but double squall line structure emerges that moves too slow. Low precipitation intensity.
- Nearest neighbour triggering in convection scheme allows single squall line that propagates at the correct speed. Precipitation intensity still too low.
- Squall line can propagate without any large scale dynamics, the physical process is reproduced qualitatively via the interplay of cold pool and nearest neighbour trigger. Propagation speed is much too low. Propagation speed independent of wind strength or direction.
- We have to take into account the wind in the convection scheme and achieve a proper propagation speed of the squall line in the case without large scale dynamics. This might help to improve the still too low precipitation. Also the strong convection in the initial phase has to be reduced.

The mechanism
Cold pool diagnostics within convection scheme (after [4], implemented by D. Klocke (DWD)):
- cold pool area \([m^2]\): \( A_{cp} = \sum_{\Delta t} \Delta A \)
- cold pool intensity \([m/s]\): \( I = f(\Delta \theta, \Delta t) \)
- \( \Delta t \): convective time step
- \( \Delta \theta \): height of downdraft origin
- effect area from neighbours: \( A_{eff} = \frac{1}{\beta^2} \sum_{\Delta x} A_{\Delta x} \)
- \( \beta \): dilution factor
- effective temperature perturbation: \( \Delta T_{eff} = \sum_{\Delta x} \Delta T_{\Delta x} \)

If \( a_{eff} > 1 \) and wind at 800hPa inward apply: \( \Delta T_{eff} \) in test parcel ascent (trigger)

Anatomy of the triggering mechanism across the squall line
Diagnostics and trigger seem to mimic physical mechanism correctly (qualitatively)!
Cold pool triggers convection \( \rightarrow \) convection creates new cold pool

Quantitative domain average perspective

<table>
<thead>
<tr>
<th>Conclusions/Outlook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced trigger in convection scheme allows squall line to form, but double squall line structure emerges that moves too slow. Low precipitation intensity.</td>
</tr>
<tr>
<td>Nearest neighbour triggering in convection scheme allows single squall line that propagates at the correct speed. Precipitation intensity still too low.</td>
</tr>
<tr>
<td>Squall line can propagate without any large scale dynamics, the physical process is reproduced qualitatively via the interplay of cold pool and nearest neighbour trigger. Propagation speed is much too low. Propagation speed independent of wind strength or direction.</td>
</tr>
<tr>
<td>We have to take into account the wind in the convection scheme and achieve a proper propagation speed of the squall line in the case without large scale dynamics. This might help to improve the still too low precipitation. Also the strong convection in the initial phase has to be reduced.</td>
</tr>
</tbody>
</table>
