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Interactive comment on "Analysis of variability in divergence and turn-over induced by three idealized convective systems with a 3D cloud resolving model" *by* Edward Groot and Holger Tost

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Author comment to "Analysis of variability in divergence and turn-over induced by three idealized convective systems with a 3D cloud resolving model"

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1 Comments to reviewer #1

We regret, that we could not convince the reviewer of our presented work. Nevertheless, we would like to reply to the review comments, directly indicating that we have to reformulate both the purpose and the details of our study such that the overall gains become more obvious. And hopefully these replies and the overhauled manuscript can convince the reviewer that our presented work is worth publication.

1.0.1

The motivation for our simulations is the analysis of upper tropospheric divergence and the uncertainty that arises from the description of convection in NWP models which affects forecasting uncertainty. For that purpose we aim at understanding the impact of individual processes in the model representation of convection on the upper tropospheric divergence, which as an ageostrophic wind component can substantially impact forecast uncertainty; we used this (and the results given in Baumgart et al.(2019)) as a motivation for our study.

As we concluded that this analysis in a comprehensive NWP model can become even more challenging than in an idealised convective situation, we decided to start this analysis with cloud resolving model simulations. Hence the specific set-up used in our simulations serves as a showcase and will serve as a reference to compare later NWP experiments with. The response of our simulations in CM1 will more closely resemble real-world convection than convection in (parameterized) NWP. The impact of our (un-)physical adjustments in the model code can be compared to what we have found in preliminary analysis of NWP simuations. The real-world variability that obeys all physical laws is of course more accurately described with our ensemble, but physical impacts of adjustments in the model should at least partially resemble each other when using different modelling techniques.

However, we are fully aware, that simulations with parameterised convection such as NWP models operating on the global scale will behave substantially differently. Even (deep) convection permitting simulations will behave differently due to the individual (non-idealised) synoptic situations (and probably another few other modelling choices). To partially resemble a standard set of conditions, we selected three different standard cases for convective activity, namely a supercell, a multi-cellular storm and a convective squall line.

1.0.2

The overall setup of the simulations will be better described in a revised manuscript version. The different horizontal resolutions have been selected to test, whether at a certain resolution our results will (more or less) converge, i.e. whether the scales on which our individual test simulations are impacted by the individual processes are within the limits of NWP (km scale) or whether turbulent processes (sub-km scale) dominate the uncertainty. Of course, we are aware that certain processes such as the gravity waves in the upper troposphere can be only (or at least much better resolved) at very high resolutions. However, the question whether this gravity waves substantially impact the upper tropospheric divergence and therefore the main flow can be analysed by comparing the highest resolution, the reference simulation and the ensemble with the typical NWP resolutions.

1.0.3

We are well aware, that the experimental design in some cases violates conservation laws. However, if we want to estimate the importance of the convective cloud formation for the mean flow (in terms of UT divergence), the change in e.g. latent heating results in a modified temperature redistribution without directly influencing the moisture budget of the atmosphere. Therefore, the individual cell (or plume) development is altered, but the domain mean moisture content is not substantially affected. In our opinion, this allows for estimating the direct impact of the level of detail in microphysical process description in a highly simplified form. Of course, changes in real microphysics modify both the temperature structure (via the latent heat release) and the moisture budget and therefore affect downstream (both spatial and temporal) cloud processes. This makes an analysis of these processes even more difficult. "Piggy-backing" (as described by Grabowski (2019) would be a better approach; however, given our central research question, we had estimated that our simplified approach would be equally feasible. Please note, that we do not aim at tracking sensitivity to microphysics explicitly, but the aim is only to decide whether the convective microphysics or the convective dynamics dominate the changes in the mean flow in the upper troposphere.

We did not analyse the impact of the modification of the latent heating on evaporation, subsequent cold pool development (which also impacts the potential propagation) and subsequent development of the convection in detail. However, we mostly analysed the mature stage of the initial cloud. Effects of propagation and convectively induced feedbacks are still of minor importance during the phase of cloud development.

1.0.4

The conservation issue is also present in the simulations in which we modified the vertical advection of the moist static energy and horizontal momentum. However, we did not reduce (neither stimulate) the vertical velocity in the simulations directly (and in the dynamical core), but only the advection terms (those with a vertical derivative) not to violate the air mass balance. Consequently, we aimed at representing atmospheric conditions in which the vertical mixing by convection is more (less) efficient in case of enhanced (reduced) vertical advection. This can also be seen as the interplay (quantitatively a ratio) between lateral mixing (entrainment) and the convective cloud core. This process in reality is partially controlled by turbulence on scales below the model resolution. Unfortunately, we cannot easily disentangle individual processes (already in the simplified approach), which impact the cloud development. Instead we used an ensemble technique with disturbed initial conditions to tackle parts of the uncertainty due to variability in cloud development.

1.0.5

We are also aware, that some simulations (i.e., those with the strongest artificial modifications) can not be compared with the reference simulation as the convective cloud is substantially changed, i.e. the vertical development is too different and convection becomes unrealistic as a result of the artificial model modifications. These situations should therefore better not be presented in this the study. We decided to test overall strong modifications in the hope that we would get a better response signal to the artificial disturbance which would otherwise be potentially lost in the spread of an ensemble with identical modifications.

However, we also think that not all modifications of the system have to be fully physically consistent to gain insights into the systems behaviour as long as basic conservation of mass and energy are maintained throughout the model domain. This would justify our choice of simulation configurations and experiments. The main purpose of our study is to obtain these insights of the sensitivity of the cloud system to the selected processes.

1.0.6

We will definitely try to improve the language, especially with respect to grammar and wording.

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