Response for: "Evaluation of Asian summer precipitation in different configurations of a high-resolution GCM at a range of decision-relevant spatial scales"

Mark R. Muetzelfeldt, Reinhard Schiemann, Andrew G. Turner,
Nicholas P. Klingaman, Pier Luigi Vidale, and Malcolm J. Roberts

9 July, 2021

Response from authors to reviewer 1

Many thanks for your anonymous review. We have addressed each point in turn below – our responses are in blue. We hope that these satisfy you and we expect that the suggested changes to our manuscript below would improve its structure and its connection to the wider literature.

Reviewer 1

(a) Muetzelfeldt et al's manuscript evaluates high-resolution (grid-spacing ca. 14 km) GCM simulations with parameterized convection, with only shallow and mid-level convection parameterized, and explicit convection (i.e. without any convection parameterization) over a South and East Asian area in the months June, July, August. The results are interesting as the challenge of simulating the diurnal cycle of precipitation and its characteristics with parameterized convection is well known. Therefore, the models are pushed to higher and higher resolutions into the convection-permitting regime where deep-convection parameterization can safely, and also shallow and mid-level convection are often switched off. The convection-permitting regime is usually assumed to be at grid-spacing below about 4 km. But, as the authors discuss, this has been relaxed recently (e.g. as in Vergara-Temprado et al. 2020). It might be interesting for the potential reader to note that already Bougeault and Geleyn (1989) did experiments with and without deep convection paramaterization using grid spacing of 10 km in the, as they call it, resolvable domain.

> Bougeault and Geleyn (1989) is very interesting, many thanks for bringing this to our attention. Many of the issues and improvements of convection parametrization schemes they raise are still applicable today: scale-awareness, grey-zone (their so-called "critical domain"), grid-point storms, and intermittency problems. The use of a 10-km resolution model without a convection scheme is certainly relevant; we will add an appropriate citation. Likewise, in their Sect. 3.3 they hint at the timing problem of convection occurring too early when using a parametrization scheme that we see in our Sects. 3.3–3.4; we will mention this in the revised paper. As an aside, the fact that they performed their experiments over a limited domain for 2 days for NWP makes the point of how far computational power has progressed, as we have performed comparable experiments globally for multiple years.

(b) What I missed are figures for the entire investigation domain showing frequency and intensity for all three variants (explicit, hybrid, and parameterized). As Figs. S3 and S4 show for south-eastern China in comparison with Figs. 9 and 10, the hybrid did the diurnal cycles as good as the explicit, and the frequencies and intensities look comparably better. This is what I expected, given the applied grid-spacing very far from resolving shallow convection. Thus, I am not sure that the explicit variant performs better overall than the hybrid one, as the authors imply.

> We would like to have included all of this information in the main manuscript, rather than relegating some of it to the supplement. We will check that we can include figures with 12 panels (we believed that the limit

was 10 but have already included Fig. 6 with 12), and if we are permitted by the Editor we will include N1280-HC in the main manuscript. This will facilitate a greater discussion of the hybrid simulation.

Our expectation was similar to yours: that the hybrid parametrization should perform well for the diurnal cycle. For amount, it does (see Fig. 6). However, it does not produce similar fields for amount and frequency (Figs. 6 and S4), whereas CMORPH does (Fig. 6). For amount, frequency and intensity, the phase of the diurnal cycle is better represented in N1280-EC than N1280-HC (Fig. 8). Taken together, we believe this justifies our assertion that the explicit simulation performs better than the hybrid, although we accept that this is perhaps more marginal than we imply. We will modify our statements to point out that the hybrid simulation performs almost as well.

Regarding the detailed comparison over China, we wanted to make the comparison with Li et al. (2018) as easy as possible (see our response to comment (d)). Thus, we did not include the hybrid simulations in Figs. 9 and 10, and we think these should stay in the supplement, with a brief description of the hybrid simulation in the main manuscript.

(c) Sec. 2.3: Given the definition, the amount A is a rate. This wording is a bit confusing given the usually different units of precipitation amount and precipitation intensity. It is also a bit confusing that some of the figs. show precipitation and some show amount, which is almost the same, but the reader might have to think twice.

We have defined amount, frequency and intensity as in other papers (e.g. Li et al., 2018), where frequency is a ratio (which we have expressed as a percentage). Thus, amount and intensity have equivalent units of mm day^{-1} and mm hr^{-1} respectively (i.e. amount is not a cumulative quantity; it is a rate). We take the point that there is a subtle distinction between amount and mean precipitation – we do point this out in Sect. 2.3 but it does require the reader to bear this in mind. The only figure where we use mean precipitation is Fig. 3; we suggest that we will make it clear in the caption that, in that instance, we are using mean precipitation.

(d) Why the special section 4 on precipitation over China and no special section for the other areas?

By focusing on China, we could perform a detailed comparison with Li et al. (2018), who had used similar UM simulations with both parametrized and explicit convection and compared against CMORPH. This allowed us to draw conclusions about the reasons for the differences between the sets of simulations, and make the case that the parametrization scheme being active or disabled was important despite changes in the horizontal resolution of the two explicit simulations (our global N1280-EC at 14 km and their regional 4.4-km CPM 4p4 experiment in Li et al. (2018)). Indeed, we find similar patterns in amount, frequency and intensity for our observations and simulations, despite the aforementioned differences, which indicates that these results are robust for the UM. Furthermore, the COSMIC project was funded through a research grant from the CSSP China project, and so opportunities for discussion collaboration with Chinese colleagues could be pursued.

(e) The discussion Sec. 5 misses a discussion on the simulation variants and their representation of the different processes and process scales. This discussion might help the reader to understand better the shown results.

This is a fair point – a discussion of this nature is certainly warranted. We would be happy to add a short discussion in this vein, including topics such as how removal of convective instability when using parametrization might lead to upscale changes, and how these might be affected when the instability is only removed at lower levels (as in the hybrid scheme). However, a full, process-based analysis is probably required to fully address this (see also our response to comment (f) below), and in our study we were mainly aiming at a description of what the most substantial differences between the different configurations were at different scales (defined by catchment basins), hence this discussion will be kept short.

(f) The conclusions lack a conclusion on how to proceed in very high-resolution GCMs. What was learnt? Shall GCMs at O(10km) run without any convection parameterization? Should consistent PBL, shallow convection models be further developed?

This are important questions, and we would certainly like to at least raise them. We can respond to "What was learnt?", and we can offer our thoughts and observations on the other two. This discussion will include topics such as:

- longer simulations (these will allow for a better characterization of the climatology of the simulations. Needless to say these are more computationally demanding. They will be run for multiple decades and with three ensemble members, thanks to improvements in performance and more powerful supercomputers);

- process-based analysis, such as the ability of the simulations to represent MCSs; and
- intraseasonal drivers of variability of the EASM, such as oscillations in the subtropical westerly jet and the summertime BSISO.

We note that this is an exploratory study of the use of high-resolution GCMs with a variety of different configurations. From this, we cannot make definitive statements about their utility, but we can start to answer questions about their viability for future studies and the merit in pursuing their development further. Further studies comparing multiple models (c.f. Stevens et al., 2019) with multiple configurations and more tuning will be required before their full potential can be properly assessed.

Fig S3 refers to Fig. 9 not 10.

Will change.

Line 440: of convection -> of precipitation?

Will change to "convective precipitation".

Line 444: "Fig. ??"

Will fix this.

Figure 7: Amount of precipitation -> The diurnal cycle of .... ?

Will fix this.

Bougeault, P., & Geleyn, J. F. (1989). Some problems of closure assumption and scale dependency in the parameterization of moist deep convection for numerical weather prediction. Meteorology and Atmospheric Physics, 40(1–3), 123–135. https://doi.org/10.1007/BF01027471

Vergara-Temprado, J., Ban, N., Panosetti, D., Schlemmer, L., & Schär, C. (2020). Climate Models Permit Convection at Much Coarser Resolutions Than Previously Considered. Journal of Climate, 33(5), 1915–1933. https://doi.org/10.1175/JCLI-D-19-0286.1

References

Bougeault, Ph and JF Geleyn (1989). "Some problems of closure assumption and scale dependency in the parameterization of moist deep convection for numerical weather prediction". In: *Meteorology and Atmospheric Physics* 40.1, pp. 123–135.

Li, Puxi et al. (2018). "The diurnal cycle of East Asian summer monsoon precipitation simulated by the Met Office Unified Model at convection-permitting scales". In: *Climate Dynamics*, pp. 1–21. DOI: 10.1007/s00382-018-4368-z.

Stevens, Bjorn et al. (2019). "DYAMOND: the DYnamics of the Atmospheric General Circulation Modeled On Non-hydrostatic Domains". In: *Progress in Earth and Planetary Science* 6.61, pp. 1–17.