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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Improved simulation of clouds over the Southern Ocean in a General Circulation Model" *by* Vidya Varma et al.

Anonymous Referee #1

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Summary:

Varma et al. describe the impact of changing the capacitance in the vapor deposition growth equation of ice crystals and changing the temperature that determines ice formation in the mixed-phase temperature regime for stratiform and convective clouds separately in a recent version of the Met Office's Unified Model. Their chosen capacitance is based on observations of a tropical anvil cloud and theoretical considerations. They analyze the impact of these sensitivity studies on radiative fluxes and ice as well as liquid water path. The focus of their analysis is on shortwave (SW) radiative fluxes in the Southern Hemisphere (SH) (50° S to 70° S).They find that the common bias of a too strong SW cloud radiative effect (CRE) in global climate models (GCMs) in this region is reduced in their sensitivity experiments.

General comment:

While the impact of changing the ice formation temperature on the Southern Ocean SW radiation bias has been shown in other studies, the idea to analyze the impact of changing the capacitance in the vapor deposition growth equation of ice crystals on the Southern Ocean SW radiation bias is novel and within the scope of Atmospheric Chemistry and Physics (ACP). But while the manuscript does show that changing the capacitance has an impact on the simulated SW radiation bias in the SH, the impact on longwave (LW) radiation and the Northern Hemisphere (NH) are not sufficiently considered (the latter is only shown in the supplementary material and not discussed), although the agreement with observations decreases. Furthermore, the properties of ice containing clouds will depend on further uncertain processes in a GCM like aggregation (efficiency). Even without cloud ice forming in mixed-phase temperature regime the SW radiation bias in the SH is not fully removed (exp2). It remains therefore unclear whether the claimed improved simulation of clouds over the Southern Ocean still holds when other aspects are considered. Therefore publication in ACP cannot be recommended unless these issues are addressed.

Specific comments:

P1L4: Is it more realistic to use the capacitance of Field et al. (2008) everywhere? In mixed-phase clouds (which occur frequently in the Southern ocean) riming can be important, hence more spherical ice particles can be present in these clouds.

P1L9: The reduction of the bias of ∼4 Wm-2 should be put into context of the strength of the bias in the model. Also this reduction in SW bias is accompanied by an increase in the LW bias.

P1L10-11: This is what Vergara-Temprado et al. (2018) have shown. What is your original contribution? In the conclusions it is written that INP's are not represented in the model, this can be mentioned in the abstract as well.

P1L19: You mean in the Southern Ocean. These studies include for example Williams et al. (2013) and Lohmann and Neubauer (2018).

P2L20: For which years is the sea-surface temperature climatology computed? Is Schuddeboom et al. (2019) the right citation for AMIP simulations?

P2L21: fig. 1 and further references to figures in the text: follow the manuscript preparation guidelines for authors of ACP.

P2L32: Why is the ventilation factor not considered in eq. (1)?

P3L7: For a sphere the capacitance is 0.5 x (maximum particle dimension).

P3L9: Morrison and Grabowski (2008) use the capacitance of a sphere for small spherical ice and 0.48 times the capacitance for a sphere for unrimed nonspherical crystals, and a linear interpolation in between for partially rimed crystals. Morrison and Milbrandt (2015) use the same in the predicted particle properties (P3) scheme. This is an even more realistic representation of ice crystal capacitance. Could this be implemented in the Unified Model?

P3L10-17: How is heterogeneous nucleation of ice represented in the model? Does it depend in ice nucleating particles (INP) concentrations or is it just a function of temperature (and if the latter, which function)? Not enough information is provided how heterogeneous and homogeneous freezing is implemented in the GA7.1*. What is the difference between the start-ice temperature and the all-ice temperature?

P3L20-21: Since this is not a model version that has been already described in another publication, it needs to be mentioned whether the experiment setup is similar to another study, otherwise details need to be given here. Why is 12 hourly output used? This means that the diurnal cycle is not well represented in the simulations. CERES-EBAF provides a diurnally complete representation of Earth's radiation budget (Loeb et al., 2018).

P3L22: ERA5 is a re-analysis dataset not an observational dataset.

P3L28-29: What was the reason to choose ERA5 as a reference for IWP given the large differences of IWP between different datasets (Duncan and Eriksson, 2018)? An uncertainty range for IWP should be added.

P3L31-32: Why are IWP/LWP shown only for these clouds? Shallow cumulus clouds may be interesting as well (Forbes et al., 2016).

P4L1-2: Why is the analysis split into this boundary layer types? Either provide a motivation and discussion for the different boundary layer types or remove this split.

P4L8 and all following occurrences: "w. r. t.": follow the manuscript preparation guidelines for authors of ACP.

P4L8-9: Why? Why does changing nucleation temperature not also impact LWP?

P5L6: What does "... at surface well" mean? Rephrase.

P5L13-14: That's an uncommon definition of SW CRE for model simulations. Typically two calls to the radiation routine are done, one with clouds and one without clouds. From these SW CRE is computed, taking into account cloud cover. How is SW CRE computed in partly cloudy gridboxes?

P5L16-18: Why do exp1 and exp3 show a stronger reduction in SW CRE than exp2. In exp2 the least cloud ice should be present in the mixed-phase clouds so why is the SW CRE larger in exp2?

P5L31-32: Why (see previous comment)?

P5L33: What are "eastern sects"?

P6L1: Provide references for this statement.

P6L10: Why are low INP concentrations relevant? Are INP's used in any of the experiments?

P6L11: "temperatures between the homogeneous and the heterogeneous freezing points"; rewrite, it's unclear what is meant

P6L17: 0.5 x d is used above

P6L19-20: Why are these then shown?

P6L22: This is not discussed anywhere. Either a discussion is added or the respective experiment and its results should be removed.

P6L29-30: Is there an explanation why the capacitance change has no significant impact in the tropics?

P6L29-30: Why does the capacitance change not significantly change or even decrease SW CRE in the tropics? Is this model dependent?

P7L9: There's no discussion why these temperature thresholds have been chosen for the sensitivity experiments. Are this thresholds considered to be realistic?

P7L20-21: As these changes are not described in the literature or publicly accessible, they need to be described here.

P7L25: The link is not publicly accessible.

Table 1: The experiments could have more meaningful names which indicate what has been changed. Why is the all-ice temperature 1° C larger than the start-ice temperature?

Fig. 1: the sensitivity experiments should be added to this figure. ERA5 is a re-analysis dataset not an observational dataset.

Fig. 3 and all similar figures: a vertical line at 0 Wm-2 is missing. Also these figures make it hard to compare different experiments. One panel should rather show anomalies for one variable but for all experiments and observations. Where do the sensible and latent heat observations come from?

Fig. S8b shows that exp2 still has a SW top-of-the-atmosphere (TOA) bias although

no more ice is present in the mixed-phase temperature range. This indicates that the SW TOA bias is not only due to the wrong phase of mixed-phase clouds in GA7.1* but that there are biases also in other clouds.

Fig. S8 shows that the SW TOA bias in the NH increases in exp1 compared to ctrl. Also from 50° S to 60° S the SW TOA bias increases in exp1 compared to ctrl. Is changing the capacitance really improving the agreement with observations? The root-mean-square error and correlation coefficient with respect to CERES would show if the experiments are an improvement globally.

References:

Duncan, D. I. and Eriksson, P.: An update on global atmospheric ice estimates from satellite observations and reanalyses, Atmos. Chem. Phys., 18, 11205–11219, https://doi.org/10.5194/acp-18-11205-2018, 2018.

Forbes, R, Geer, AJ, Lonitz, K, Ahlgrimm, M.: Reducing systematic errors in cold-air outbreaks, ECMWF Newsletter 146, https://doi.org/ 10.21957/s41h7q7l, 2016.

Lohmann, U. and Neubauer, D.: The importance of mixed-phase and ice clouds for climate sensitivity in the global aerosol–climate model ECHAM6-HAM2, Atmos. Chem. Phys., 18, 8807–8828, https://doi.org/10.5194/acp-18-8807-2018, 2018.

Morrison, H. and Grabowski, W. W.: A novel approach for representing ice microphysics in models: Description and tests using a kinematic framework. J. Atmos. Sci., 65, 1528–1548, doi:10.1175/ 2007JAS2491.1, 2008.

Morrison, H. and Milbrandt, J. A.: Parameterization of Cloud Microphysics Based on the Prediction of Bulk Ice Particle Properties, Part I: Scheme Description and Idealized Tests, J. Atmos. Sci., 72, 287–311, https://doi.org/10.1175/JAS-D-14-0065.1, 2015.

Williams, K. D., Bodas-Salcedo, A., Déqué, M., Fermepin, S., Medeiros, B., Watanabe, M., Jakob, C., Klein, S. A., Senior, C. A., and Williamson, D. L.: The Transpose-AMIP II Experiment and Its Application to the Understanding of Southern Ocean Cloud Biases in Climate Models, J. Climate, 26, 3258–3274, 2013.

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