Author's Response – "On the representation of aerosol activation and its influence on model-derived estimates of the aerosol indirect effect"

We would like to thank the reviewer for their helpful suggestions and feedback on our manuscript. To streamline the comment/dialogue process, we have reproduced the comments from the reviewer and added responses inline, using blue text.

Reviewer #1

General Comments

In "On the representation of aerosol activation and its influence on model-derived estimates of the aerosol indirect effect", Rothenberg et al. integrated multiple droplet activation schemes into the Community Earth System Model (CESM) with a well-established, more-detailed aerosol module to quantify the influence of these parameterizations on the calculated aerosol indirect effect (AIE). The aerosol module tracks the evolution of number and mass for lognormally-distributed sulfate (three modes), black carbon, organic carbon, mixed modes, dust, and sea salt. The aerosol and droplets are coupled with radiative transfer and cloud microphysics, which are representative of stratiform clouds. The authors integrate three activation schemes as well as derivations of each scheme that employ a heuristic for more quickly calculating activation based on the dominant mode. They evaluate the predicted cloud droplet number concentration (CDNC) against in situ and satellite-based observations and demonstrate that these observations are insufficient for identifying a singular scheme as successful. Then, they comprehensively and clearly assess the AIE, in which they find a doubling of the strongest compared with the weakest result, and the parameters influencing AIE. Comparing the dependence of the change in cloud radiative effect (CRE) on other parameters and the degree of spread in the AIE in these simulations to the range of AeroCom and IPCC, the choice of activation scheme is shown to produce a similar degree of variability as previous inter-model comparisons. The model results were consistent with the idea in the literature that the CDNC in the pre-industrial run will more strongly influence the AIE than the activation scheme itself.

The authors contextualize the specific aim of this paper in an ongoing effort to quantify the AIE and uncertainty in the calculation of it. The comparison of the AIE from these three schemes as well as the heuristic for each is novel. The evaluations of model performance against measurements as well as inter-model experiments are very strong aspects of the manuscript. One limitation that the authors could more fully address is that CDNC are consistently underpredicted by MARC; although noted, the implications of this characteristic of the aerosol and activation schemes are not conveyed…

We acknowledge this limitation and have added a paragraph in the Discussion and Conclusions section of the manuscript contextualizing this. We defer a more complete discussion of this topic to a follow-up work comparing a rigorous comparsion of MARC to CESM/MAM3 and CESM/MAM7, which is currently in the final stages of preparation before submission to for peer review.

… Another area that could be strengthened is the introduction of and discussion about the minimum-maximum supersaturation heuristic. although the value of it as a simple scheme to introduce more variability in the activation schemes is noted, discussion about how distinct the results are for the comprehensive and heuristic Abdul-Razzak and Ghan and Morales Betancourt and Nenes schemes is lacking…

In response to one of the specific comments below, we added some additional details on the motivation and mechanics of the minimum-maximum supersaturation heuristic. We have also added a bit more discussion on this topic in the manuscript (towards the end of Section 3.3 and in the Discussion and Conclusions), particularly focused on a result best illustrated by Figures 6b and 8, which show that for both the *ARG* and *nenes* schemes, the *_min_smax* heuristic tends to increase the change in CDNC from PI to PD, but the associated change in SW radiative forcing goes in opposite directions.

… I recommend this manuscript for publication in Atmospheric Chemistry and Physics with only minor changes including responses to the issues noted above and addressing the specific comments below.

Specific Comments

- P. 3, L. 27-33: The chemical constituents may need to have subscription of the numbers unless the variable names representing these compounds are being used. These also occur elsewhere (e.g., p. 5, l. 8), so please change throughout the manuscript.

  We appreciate catching these errors; these are a mistake from our conversion of the LaTeX source of the manuscript to comply with ACP's technical restrictions. The entire manuscript was reviewed to find and correct this common mistake, as well as related ones involving incorrect superscripts with units.

- P. 4, L. 28-29: Please elaborate on the minimum-maximum supersaturation approach, note the description in Appendix A4, and state the motivation for implementing it.

  We have modified the paragraph to include an explicit reference to the appendix and additional discussion of the motivation and mechanics, based on results from Rothenberg and Wang (2017).

- P. 5, L. 8-9: Please cite the default CESM inventory.

We've added a reference to (Lamarque et al., 2010).

- P. 5, L. 20: Please cite "maximum-random overlap hypothesis" or explain it more thoroughly.

  We've added a short explanation of this hypothesis, as well as a citation to literature which more completely explains how the assumption is formulated (Morcrette, 1991).

- P. 6, L. 3: Please communicate whether bias may be introduced through the regridding required of the CERES dataset.

  We have added an acknowledgement that re-gridding in this case, which involves *downsampling* to the CESM/MARC grid, will tend to suppress or average out regional variability, which will introduce some biases in the CERES data.

- P. 10, L. 11: Please identify the particular model result when referencing a result by its qualities (and again at p. 13, l. 14).

  We've re-phrased the sentences to identify specific models/simulations in both of these cases.

- P. 10, L. 14: "CCN" is likely intended to be "CCN."

  Fixed.

- P. 11, L. 16: "change PI and PD" is likely intended to be "change in PI and PD".

  Fixed.

- P. 11, L. 28: "couplings, and therefore different" would be better as "couplings and, therefore, different"

  Adopted the recommended punctuation.

References

Lamarque, J.-F., Bond, T. C., Eyring, V., Granier, C., Heil, A., Klimont, Z., Lee, D., Liousse, C., Mieville, A., Owen, B., Schultz, M. G., Shindell, D., Smith, S. J., Stehfest, E., Van Aardenne, J., Cooper, O. R., Kainuma, M., Mahowald, N., McConnell, J. R., Naik, V., Riahi, K. and van Vuuren, D. P.: Historical (1850–2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application, Atmos. Chem. Phys., 10(15), 7017–7039, doi:10.5194/acp-10-7017-2010, 2010.

Rothenberg, D. and Wang, C.: An aerosol activation metamodel of v1.2.0 of the pyrcel cloud parcel model: Development and offline assessment for use in an aerosol-climate model, Geosci. Model Dev. Discuss., 1–35, doi:10.5194/gmd-2016-228, 2016.