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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Role of climate model dynamics in estimated climate responses to anthropogenic aerosols" *by* Kalle Nordling et al.

Anonymous Referee #1

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The discrepancies in projected climate features among current climate models have recently been related to the differences in representing the processes of aerosol and aerosol-cloud interaction in these models. This study addresses this issue by investigating whether arbitrarily eliminating the differences in models' aerosol forcing strength and distribution could limit the above-mentioned discrepancies. For such a purpose, the authors have designed two sets of equilibrium-climate simulations: firstly to use two climate models (NorESM and ECHAM6) driven by their own slab-ocean modules while masked with the same prescribed direct and first-indirect radiative effects of aerosols (MACv2-SP), and secondly to force one of these two models, NorESM to adopt derived aerosol forcing field from the other model, ECHAM6. Certainly, the results are not entirely a surprise that the two models even with largely the same aerosol forc-

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ing distribution and strength would still produce different climate responses particularly over regional scale, for example as reflected from modeled precipitation. The comparison involving the two sets of runs lead the authors to a conclusion that the discrepancy between the two models appears to be largely resulted from the differences in model components beyond that of aerosol.

The model simulations were designed straightforwardly and supportive to addressing the science issue of the study. The paper is well organized, and the result is clearly presented. The content of the paper is perfect for the readers of ACP. Nevertheless, there are a few issues the authors should adequately address before the paper could be accepted for publication.

The authors have drawn one of their major conclusions that "further improvements in the model aerosol descriptions can be expected to have limited value in improving our understanding. . .". Such a statement does not make any logical sense based on the results of the paper. Firstly, simply making any two models to have a nearly exact radiative effects of aerosols does not necessarily mean that they both had already been equipped with an improved representation of aerosol and aerosol-cloud interaction. Furthermore, we perhaps all agree that such representations in our current climate models are far from being ideal and in fact, even unable to correctly simulate some of the key physical processes. Therefore, no one could predict the outcome in terms of modeled climate features should an ideal aerosol module be eventually produced and included. Secondly, per the current modeling efforts in this study, the applied constraint of aerosol forcing does not even include that on cloud response to aerosol perturbation through precipitation and other critical cloud features – as indicated by the authors, not mentioning that on aerosol resuspension through activation-dissolution-evaporation. Even putting aside these comments relating to rather specific processes, giving the well-known status of our current climate models, logically and realistically, the same conclusion made by the authors to the improvement of aerosols could be applied to any other major model components or aspects. Therefore, the above-commented

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statement, especially presented as a major one for the paper, is not logically meaningful and adequate, in addition, it does not accurately reflect the nature and science meaning of this very study.

In order to make a statement as strong as “differences in aerosol descriptions among different models are not the main cause of variation in the regional distributions of climate response among different models”, one needs to compare the results produced by the versions of the two adopted models with their own intrinsic aerosol module without arbitrary constraints on forcing. Such a comparison would serve as a good reference to evaluate the real effect by eliminating aerosol forcing discrepancies.

The use of the term “aerosol-cloud interaction” seems quite casual in certain places. Giving the nature of this study that dealing primarily with direct radiative effect alongside the so-called first indirect effect of aerosol, when discussing the context of the study itself, the authors should stay closely within the proper scope of their topic.

The authors borrowed the results presented in Samset et al. (2018) in their discussions. It does tell us that Samset et al. indeed derived a much larger discrepancy among models with intrinsic aerosol scheme. On the other hand, one needs to realize that Samset et al. did not include the same models that are adopted in this study, and the simulation design in that work (with fully-coupled ocean models and most importantly, based on preindustrial era only with perturbations adopted from current climate) are quite different. The performance of climate models with fully coupled ocean component would be different than that of the models with slab ocean module, e.g., likely occurring over high latitudes as discussed in many previous works. The authors should discuss the limitations of such a comparison.

Some specific comments:

Pg. 4, Ln 2: remove “of” before “are based on”.

Pg. 4, Ln 5” “between aerosol optical depth and CDNC. . .” this seems implying that

the modeled AOD rather than aerosol concentration is the primary input for applying MAC-SP constraint? Or, in fact CDNC itself has been prescribed based on MODIS AOD independent to the model predicted aerosol properties?

Section 2.3: The description of NorESM-EF is not very clear. When masking the aerosol forcings of NorESM using ECHAM6 derived values, how did the cloud fields produced in NorESM be considered, for instance, what to do with non-zero first-indirect effect from ECHAM6 in a no-cloud grid in NorESM, or, how to mask direct forcing into cloud fields in NorESM? Could these details be the reason behind the discussed difference between NorESM-EF and ECHAM6-MACSP?

Pg. 12, Line 28: "identical anthropogenic aerosol representations in the models" is inaccurate.

Pg. 14, Ln 1: please correct "essentially equally".

Figure 1, 2, &4: the results of NorESM-EF run should be presented.

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