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Interactive comment on “What controls the vertical distribution of aerosol? Relationships between process sensitivity in HadGEM3–UKCA and inter-model variation from AeroCom Phase II” by Z. Kipling et al.

Anonymous Referee #3

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This manuscript examines the influence of a set of processes on the vertical profile of aerosol in the model HadGEM3-UKCA. As well, consideration is given to the variation in aerosol vertical profiles among a suite of global models participating in the AeroCom Phase II control experiment. The basic methodology is to turn off one of about 20 processes in the HadGEM3-UKCA model for each of the about 20 sensitivity simulations and to compare aerosol vertical profiles among this set of simulations. The overall concept is scientifically interesting, but certainly very model specific. The authors need to be careful in their presentation about the limitations of the conclusions reached in

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using this approach. The manuscript does attempt to acknowledge these limitations, but could be improved along these lines. There are some related comments below. As well, below are some comments and questions about how we can connect this analysis with the suite of AeroCom profiles that is presented. There are also a few other general questions below. Prior to publication I would suggest that the following specific concerns should be addressed.

Specific Comments:

- 1) P 25935, L11-12: The abstract indicates that the HadGEM3-UKCA sensitivity simulations replicate the AeroCom diversity in the both the vertical profile and vertical position metric, but the discussions in the text seem to indicate the position metric diversity is not well replicated by the sensitivity simulations. Should this be clarified in the abstract?
- 2) P 25935, L13-14: Consider identifying more explicitly what is meant by 'structural differences'. Does this relate to process parameterizations, meteorology, model resolution, whether the model allows feedbacks between the aerosols and meteorology, or otherwise?
- 3) P25942: Are these emissions the same as used for the AeroCom Phase II simulations?
- 4) P 25943, L12: What was the technical problem that caused a different model configuration to be used? Are you able to comment on the influence of model vertical resolution on your results?
- 5) P 25944, L1-2: Are there any other issues related to emissions that can affect the vertical distribution, other than the altitude of injection and the assumed size distribution? What about the magnitude of the emissions or feedbacks between primary emissions and the meteorology?
- 6) P 25949, L1: Figure 2 is introduced here and there appears to be only one sentence

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of discussion. Please consider adding to the discussion here, or is this figure needed?

7) P 25949, L10-15: The text suggests that the ‘variations in the processes we have considered can largely replicate the model diversity’. I am having some trouble making this connection. Could you also replicate this diversity by changing some of model structural aspects as related to the ‘structural differences’ that you mentioned between models? Then, could this agreement between the AeroCom inter-model diversity and the within-HadGEM3-UKCA-sensitivity-simulations diversity be for the wrong reasons?

8) The sensitivity studies consider the change after reduction of a given process to a negligible influence – are you suggesting then that certain of the models have these processes parameterized with varying degrees of efficiency at affecting the vertical profile? Related to this, within the HADGEM3-UKCA, if a process is parameterized with a relatively low efficiency at affecting the vertical profile, then shutting it off, will appear to have less impact than it would in another model where the base simulation had a more vigorous parameterization for that same process. This makes these results very model specific. I would like to see a bit more discussion in the text about the aspects of the methodology of this study that make the conclusions fairly model specific.

9) P 25949, L 25: Are you able to comment on why the model has the vertically uniform sulphate profile, unlike most of the AeroCom models?

10) Figure 3: The text discusses the vertical position metric for the AeroCom models and then comments that none of the sensitivity simulations can reproduce the U shape seen for the AeroCom models (except NO_WETOX for dust and sulphate, whereas most are flatter and with smaller vertical range). How then do we interpret this result relative to the result from the discussion of Fig. 1 that indicated the model was replicating the global mean profile diversity of the AeroCom models?

11) P 25952, L10-11. The discussion of Table 3 is only one line. Consider introducing the table earlier.

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12) P 25954, L6: Consider starting the paragraph with the most important effect as opposed to placing as the last sentence of the paragraph. There are numerous effects discussed in this section and it would be helpful to have the main points about what we are learning from the figure placed more towards the start of the discussion or at least start of each paragraph.

13) P 25954, L13: The most important effect is imbedded in the paragraph but could be moved earlier.

14) P 25955, L3: The authors comment that the sensitivity tests are not physically realistic and lead to large changes in aerosol loading. It would be instructive to have some indication about how physically realistic these simulations are in comparison to observations. Is this possible to evaluate with the global profiles or have you some indications from examining more regional scales?

15) P 25955, L18-23: What can we learn from this indication that the HadGEM3-UKCA simulations have a similar diversity to the AeroCom vertical profiles, but not for the zonal vertical position metrics?

16) The basic conclusions about the process sensitivity in HadGEM3-UKCA are very model specific, consider discussing this more explicitly in the discussion.

17) P 25957, L5: Please clarify what is meant by ‘Arctic processes’.

18) P 25957, L14-15: The start of the paragraph suggests a shift towards more accumulation-mode particles might contribute to this U shape. However turning off the nucleation did not have this effect. Are the authors able to offer any insights on any other possible contributions to this U shape?

19) Consider explaining more clearly, if possible, what we can learn from the comparison between the set of sensitivity studies and the AeroCom ensemble. It is interesting to check if the HadGEM-UKCA sensitivity simulation diversity agrees with the AeroCom diversity, but are you able to help make the connection between the two any more

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meaningful? Despite having the same diversity, it is difficult to understand whether or not this is agreement for the wrong reasons – it seems very difficult to rule out the possibility that the ‘structural differences’ could contribute strongly to the AeroCom diversity. As a result it is difficult to interpret these results without knowing the extent of this influence. The discussion at the end of P25957 and beginning of P 25958 does indicate these issues, but I am still left wondering how to interpret these comparisons between the AeroCom ensemble and the HadGEM-UKCA sensitivity simulations.

20) P 25959, L 20-25: This is a good point that the study can not determine if the processes identified in this study as being important in controlling the vertical aerosol profile are universally the most important in all models. Thus, the authors suggest that the same study be conducted with other models. Based on this study’s methodology, if the same results for what controls aerosol vertical profiles were obtained after conducting this same study among a set of other models (i.e. shutting off the processes one by one), would this then imply that there would be less diversity in the vertical profiles within that model set, considering the set of simulations with all the processes left intact in those models? In other words, does an agreement on what controls the vertical profiles under this methodology imply not much diversity between modeled vertical profiles?

Technical Corrections:

- 1) P25942, L21: Could ‘model levels 2-12’ be removed since the subsequent altitude range is more meaningful to most readers?
- 2) P 25943, L3: Should the year be added for the Diehl et al. reference?
- 3) P 25946, L4: Add ‘with diameters’ before ‘greater than 3, 30,100...’

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