Reply to Anonymous Referee #1

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We thank referee #1 the helpful and constructive comments. Below please find our response to the review comments.

This technical note on the use of nudging in studies of aerosol impacts on clouds and climate in global climate modeling provides an important methodological refinement with a wide range of applications. The manuscript presents the issues and results clearly. A few minor additions could help provide better context for a broad range of studies:

Comment: *1. The authors apply nudging as the only data assimilation technique, and would benefit from reflecting on the applicability of the findings to other assimilation techniques widely employed in climate and aerosol modeling. Are any of the qualitative findings inherently specific to nudging, or would they be expected to perform similarly for variational assimilation approaches?*

Reply: Our understanding is that most other data assimilation techniques are used in climate and aerosol modeling for the purpose of initializing forecasts/predictions, producing reanalysis, constraining regional downscaling, estimating parameters, etc. In such cases, the goal is to keep the model state as close as possible to the ``truth". In the model intercomparison we discussed in the paper, however, the intention is to expose model biases and inter-model discrepancies, and use nudging to exert a continuous constraint to suppress the impact of natural variability. We think these are two different types of applications with different needs. We've added a clarification on this in the revised manuscript (please also see our reply to comment 2 below).

Comment: *2. Would a similar strategy apply to the investigation of aerosol indirect effects through ice clouds at regional and local scales?*

Reply: We think the answer to this question would depend on the purpose and needs of the investigation.

If, like in the AeroCom intercomparison, the purpose is to characterize model responses, then a similar strategy can be applied, although there is a caveat that in smaller-scale transient simulations where the dynamical responses are an

important component of the aerosol indirect effect, nudging winds may suppress the feedback and change the magnitude of the signal.

If the purpose of using nudging (or other assimilation techniques) is to reduce model biases, then the wind-only nudging might not provide a sufficiently realistic simulation.

A discussion is added to the revised manuscript at the end of the “Conclusions” section:

“As an additional remark we note that nudging, and in a broader sense data assimilation, has been widely used in weather and climate related research and applications. Examples include initialization of weather forecast and climate prediction, boundary control and large-scale steering for downscaling using regional models, and parameter estimation (including reanalysis). The optimal assimilation strategy for an application must be determined according to the specific needs. For example for prediction and downscaling problems where the purpose of data assimilation is to keep the model state as close to the ``truth'' as possible (or in other words, to reduce model errors), constraining only the horizontal winds as discussed here may not be sufficient, especially if the model tends to generate large temperature biases. On the other hand, if the goal is to suppress the influence of natural variability and meanwhile let the model express its own characteristics (i.e., to expose model biases or inter-model discrepancies), like in the case of the AeroCom ice-AIE intercomparison, then our method can be a good option, and may potentially be used for regional modeling as well. In certain applications and regimes where wind differences between the driving data and the simulated values have significant impact on important features of the model results, or when the dynamical responses play an important role, one may need to loosen the constraint on winds as well, for example in certain geographical regions or in the near-surface levels. Again, the optimal experimental design depends on the specific needs of the conceived application.“