Reply to Anonymous Referee #2

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We thank referee #2 the helpful and constructive comments. Below please find our response to the review comments.

This manuscript explores different nudging experiments using the Community Atmosphere Model. The manuscript is of significance to the modeling community given the decision to use these results as model guidance for the AeroCom aerosol-climate model intercomparison initiative. The general guidance is to nudge the wind field and not temperature as nudging towards temperature creates issues when trying to estimate aerosol impact on radiation and clouds. The manuscript also provides more general guidance to the modeling community. The manuscript is well written with very well designed experiments to investigate the impact of nudging while retaining estimates of the aerosol impact on the climate. A few minor changes and additions are recommended below.

Comment: *1. The argument that nudging to temperature is a valid argument, but some additional explanations would be helpful. In particular, some of the largest temperature corrections for nudging (mid to high latitudes) do not coincide with the max. mean frequency of occurrence for homogeneous ice nucleation (tropics).*

Reply: The largest temperature biases in Fig. 3 appear in the polar stratosphere, a feature commonly seen in many climate models. Homogeneous ice nucleation rarely happens in these regions in CAM5 because (1) the air is relatively dry, and (2) homogenous nucleation is also inhibited by heterogeneous nucleation, which requires lower relative humidity.

In the revised manuscript we added a masking in Figs. 3 and 7 and only show temperature biases/corrections in regions where the mean ice crystal number concentration exceeds 5 crystals per gram air in the free-running CAM5. There reasoning is, since we want to understand the discrepancy in longwave cloud forcing (LWCF) between the nudged and unconstrained simulations, and the LWCF is mainly associated with ice clouds, we focus on the regions where there is appreciable amount of ice clouds in the CLIM simulation and try to understand what is the impact of nudging there. Regions where ice clouds rarely occur are not very relevant for our investigation.

Comment: *2. Figure 4 needs to be clarified. How is the frequency of occurrence being calculated? Is the frequency from daily model output? Would be helpful to have the color bar as a percent.*

Reply: The caption has been revised. Unit is changed to percent, and we clarify that the frequency of occurrence is calculated using an online nucleation counter, which keeps track whether there is homogeneous ice nucleation happening at each model time step.

Comment: *3. Figure 5 also shows largest sensitivity in the tropics but Figure 6 tries to justify using global average precipitation. It would be helpful to have a separate analysis on the tropics compared to the mid-to-high latitudes.*

Reply: We analyzed the convective precipitation in the tropics and mid-to-high latitudes separately, and found that their responses to nudging are very similar. In the revised manuscript we show the tropical precipitation in Fig. 5b.

Comment: *4. Figure 7: Clarify caption from "5 yr mean zonal mean temperature".*

Reply: It now reads:

"Left column: 5 yr (2006–2010) mean zonally averaged temperature differences between nudged and free-running CAM5 simulations. Right column: same as left column but between nudged CAM5 simulations and the ERA-Interim reanalysis. Simulations shown in the upper and lower rows used the anomaly nudging described in Sect. 2.2 (NDG ERA UVTa) and the wind-only nudging (NDG ERA UV), respectively. Like in Fig. 3, regions with mean ice crystal number concentration lower than 5 g^{-1} are masked out in gray."

Comment: ***5.*** Figure 8: Caption should include (U, V, T, Q, Z3).

Reply: Corrected.

Comment: ***6.*** There are a lot of studies working on regional application of aerosol impacts using limited area models. Should mention this application as it could be a great lead for future studies wanting to understand the impact of nudging of aerosols for regional applications.

Reply: In response to this suggestion and the other referee's comments, we added a paragraph of discussion at the end of the paper:

“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.“