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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Understanding cirrus ice crystal number variability for different heterogeneous ice nucleation spectra" *by* S. C. Sullivan et al.

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We thank the reviewer for the positive feedback and the constructive comments. Responses to comments are provided in italics below.

This is an interesting study of the sensitivities of different ice crystal parameterizations used in global models to their input parameters. The paper is clearly within ACP's subject area, and provides interesting information. I suggest that the authors consider the following comments while revising the paper.

1. The experimental envelope shown in Fig. 2 looks very different from what is shown

in Krämer et al. (2009), and it took me a while to figure out why. Looking at Krämer's Fig. 9, it appears to me that if one wants to plot some kind of central number for N(ice) as a function of temperature, it should probably increase quite monotonously. The wiggles up and down shown in Fig. 2 of the present paper are most probably artefacts due to unequal sampling from different geographic areas. I suggest replotting, using some smoothing method.

These points are well taken. In response, we have now completely revised the evaluation with data from the more recent MACPEX and SPARTICUS campaigns. In the comparison, the concentration of the smallest crystals are used to approximate nucleated ice crystal number that correspond to in-cloud average values at the appropriate altitude and scale (45 s averages). We also switched to comparing probability distributions of these ICNCs, rather than their temperature dependence because of uneven sampling size. The new comparison is discussed in Section 3.1.

2. Why is there no model data below about 202 K in Fig.2?

This panel has been removed, but there was no model data below 202 K before because the ICNC traces and corresponding temperatures were from annually-averaged fields. The annually-averaged input temperature was not lower than 202 K for any grid cell.

3. What do the upper and lower limits of the model envelopes represent in Fig. 2? Would comparing the envelope widths between model and data provide any additional information beside the comparison of the central number?

This panel has been removed, but the envelope, as described in the figure caption, represented the first and third quartile of the distribution of ICNC values in each 0.5 K bin. That is, ICNC in the annually-averaged grid had been sorted by input temperature and then binned for every 0.5 K, starting at the lower bound of about 202 K. Then the central trace was the median ICNC value and the envelope was the first and third quartiles for each temperature bin.

4. Regarding the low temperature sensitivity regime discussed on p. 21692-21693. Hoose and Möhler refer to data that show constant activated fractions in lab experiments. These experiments should (at least in principle) give threshold supersaturations that do not depend on vapor diffusivity or on latent heat of sublimation. Furthermore, there are no solution droplets to nucleate homogeneously in the experiments. I think that the low temperature sensitivities seen in the lab and in the model are coincidental, and most probably due to different reasons.

Thank you for pointing this out. Opposing temperature dependencies of thermodynamic properties in the parameterization - even omitting those relevant only for homogeneous nucleation like the homogeneous nucleation rate coefficient – lower its temperature sensitivity. Water vapor mass transfer rate limitations may further desensitize the parameterization to temperature. We suggest that this could provide an explanation for the intermediate, temperature-independent regime, observed in the experiments compiled by Hoose and Möhler 2012. This discussion is clarified in the manuscript.

5. It is not clear from the summaries of the different parameterizations to what extent do they include deposition nucleation and to what extent immersion freezing. Some discussion would be welcome.

At the high altitude and cold temperatures which we are simulating, the system remains sub-saturated with respect to water, so immersion freezing is rather unlikely. All nucleation spectra are used only to describe deposition nucleation. This point is made in the introduction: "This study uses the three aforementioned spectra to describe deposition nucleation."

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 21671, 2015.