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Comment on acp-2021-685

Anonymous Referee #4

Referee comment on "Cirrus cloud thinning using a more physically based ice microphysics scheme in the ECHAM-HAM general circulation model" by Colin Tully et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-685-RC3, 2021

Review for Tully et al. entitled "Cirrus cloud thinning using a more physically-based ice microphysics scheme in the ECHAM-HAM GCM" submitted to ACP

This manuscript documents a sensitivity study on cirrus cloud thinning (CCT) in the ECHAM-HAM model that includes new updates to the treatment of ice cloud macrophysical and microphysical schemes, namely the implementation of different treatment of ice cloud fraction following Dietlicher et al. (2019) (D19) which uses a higher relative humidity (RH) threshold for cirrus cloud fraction and the Morrison & Milbrandt's P3 scheme. The authors also investigate the competition between heterogeneous and homogeneous nucleation in cirrus clouds by increasing the critical ice saturation ratio for cirrus cloud seeds (Si,seed) to 1.35. The main conclusions of the authors are that (i) the increased RH threshold in the D19 scheme reduces the positive forcing in response to overseeding relative to the Sundqvist (1989) (S89) scheme, (ii) the P3 scheme reduces ice sedimentation and produces more and smaller ice crystals thereby prolonging the lifetime of cirrus clouds, (iii) increasing Si,seed to 1.35 can reduce overseeding effects and allow the model to produce cooling responses over a broader range of seeding concentrations. The strengths of the study are that it implements and tests the impacts of updated ice cloud microphysics schemes on CCT and provides potentially useful insights into the direct effects and side effects of CCT. The weaknesses of the study are that there is arbitrariness in the choice of tuning in the simulations, the shortwave effects are not well-assessed and some of the statements don't seem to agree with the figures and some of the results are not fully explained. Overall, I recommend major revisions. Specific comments follow:

- It might be helpful to take a step back and better validate both the shortwave (SW) and longwave (LW) cloud radiative effect (CRE) in the model. After model tuning, it was mentioned on lines 275-277 that the net CRE was too negative and that the 5-year

global LW CRE is weaker than the observed range. What is this "structural issue within the model" on line 276 referring to and why does it cause a presumably more negative SW CRE? What is the cause for the CRE biases? Is it due to differences in cloud fraction, cloud height or cloud optical thickness?

- Although P3 is a more physically-based ice microphysics scheme, does it result in ice removal processes that are more *realistic*? Please include a discussion in the context of snowfall.
- The tuning in the model appears to be quite arbitrary. To reduce the overseeding effect in the model, the authors increased Si,seed to 1.35. Why was this particular value chosen, e.g. why not 1.4 or 1.45?
- I disagree with the statement that the model "agrees remarkably well with the Kramer et al. (2020) measurements for in-situ formed cirrus" (lines 340-341). The discussion comparing the modelled and measured ICNC appears to be only based on the median values. It appears that there is a large discrepancy in the 215 K to 250 K range for relatively low ICNC (bottom right of plot) which is unexplained. Also, did the Karcher et al. in situ measurements account for the ice crystal shattering effects on probes? Lines 452-454 also seem inaccurate because a small cooling effect is not seen for all seeding concentrations other than S89 Seed100 in Table 3--- it is also small and positive for 5 other values too.
- Given the competing effects of CCT on both the SW and LW CRE, I would recommend including the breakdown of these effects (as opposed to only the net CRE) in Table 2, Table 3 and Figure 3.
- Figure 5: Please carefully explain the unexpected result of the heterogeneous change in ICNC.
- Does the intended side effect of CCT on mixed-phase clouds dominate the intended main effect on CCT? The impact on mixed-phase clouds in Figs 7 and 11 seem quite large. Please discuss. I would also recommend adding this result to the Abstract as well.
- What is the reason for the isolated southern hemisphere cooling effect in the summer due to seeding with Si,seed = 1.35 in Fig. 10?

Minor:

- Please include letter labels for every panel of all multi-panel plots.
- Line 302: "cannot not" double negative. I think you mean "cannot"?