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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol effects on ice clouds: can the traditional concept of aerosol indirect effects be applied to aerosol-cloud interactions in cirrus clouds?" *by* S. S. Lee and J. E. Penner

Anonymous Referee #2

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Review of Lee and Penner: Aerosol effects on ice clouds: can the traditional concept of aerosol indirect effects be applied to aerosol-cloud interactions in cirrus?

The influence of cirrus clouds on the radiative budget is an important field of research. Furthermore it is not clear yet how heterogeneous freezing modifies the microphysical and optical properties. The presented paper contributes to our understanding of the processes involved. However there are some points that have to be clarified before publication.

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Major comments:

1) It is not clear to me which aerosol species are considered in your study and how/if they act as cloud IN for immersion/contact and deposition freezing. In section 2.3. you state that for contact and immersion freezing dust and BC is used. For deposition freezing only dust is considered? Why is BC not considered for deposition freezing? On the other hand, in section 3 you describe the background aerosol concentration which you obtain from the CAM-UMICH. Here you say that BC/OM from fossil fuel, BC/OM from biomass, sea salt and dust are considered as well. Are these species also taken into account fort he heterogeneous freezing modes? Please clarify which species are considered and how they can act as IN.

2) In section 4.5 you state that changes in homogeneously frozen ice crystals are the main reason fort he different IWP in the PI and PD simulations. In figure 3 you show the background aerosol number concentration which lies in the range of approx. 10 to 30 cm-3. The simulated CINC shown in figure 6 is approx. two orders of magnitudes lower, in the order of 0.1 cm-3 (if the unit of l-1 is correct here). Normally the number of homogeneously frozen ice crystals is not limited by the available background aerosol concentration as also in the upper troposphere there are enough aerosols available for freezing. Thus, in your PI simulations there are already enough aerosols available and I don't see the reason fort he strong difference between PI and PD. Could you maybe add some explanation?

3) Section 4.6: You describe the influence of the changed IWP on the SW and LW radiation. Besides the IWP/LWP the effective radius of the ice crystals (or ice crystal number concentration) also influences the optical depth of clouds and therefore their radiative impact. Fusina et al, 2007 show that the transition of ice clouds from a cooling to a warming regime strongly depends on the ice crystal number concentration/size of the crystals. As in the PD simulations the IWP and CINC changes it would be interesting to see how the effective radius of the crystals and the corresponding optical depth of the clouds change. Could you maybe add a figure of these essential variables

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for the radiation or give some statements about their changes from PI to PD?

Minor comments:

1) Abstract, line 5: Please add CINC after IWP as the CINC strongly influences the radiation (see Fusina et al, 2007, Zhang 1999).

2) Page 10432, line 19: How are the shape parameters and the characteristic diameter of the distribution chosen? Could you please add some information?

3) Page 10436, line 17 ff. Are the different shapes of the crystals also applied to the radiation code? Could you add some information how many different crystal types are involved?

4) Page 10438, line 15: For which aerosols do you apply a bi –or trimodal log-normal size distribution? Please clarify.

5) Page 10438, line 29: show the time series of the domain averaged total background ..... (remove time before domain).

6) Page 10439, line 5: You write that periodic boundary conditions are used on the horizontal boundaries. I thought that the model is nudged towards the ECMWF – analyses? Could you please explain what you mean here?

7) Page 10439, section 4.1: I'm not sure if it makes sense to show figure 4. It does not contain important information that could not be described in the text. You maybe could remove this figure and just mention the content in the text.

8) Page 10440, equation 7: Should the sedimentation also be a sink of cloud ice or is the budget equation over the whole vertical domain such that even the cloud ice which has sedimented to the ground is still counted?

9) Page 10441, line 10: Could you explain what you mean with this sentence "the absolute value of any variable A is represented by |A|"?

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10) Page 10442, equation (9): Is the crystal shape factor given by Sh=C/D? If so, then Fre=int (C*fRe *fgam(D) dD).

11) Page 10442, line 13: Add space after "and eta ....“

12) Page 10443, line 9-17: In this paragraph you explain the interaction between depositional heating and the intensification of updrafts. Probably, the strength of this interaction depends on the stratification of the atmosphere (the Brunt-Väisälä – frequency). In your case there is a relatively unstable layer between 13.5 and 14.5 km height. Could you please comment on how sensitive your results are to the stratification?

13) Page 10445, line 20: remove "that“ in front of 2%.

14) Page 10446, line 2: You could merge the first two sentences to: " Upward shortwave (SW) and longwave (LW) fluxes at the top ... in table 2: And remove "In table 2, SW and LW represents ....“.

15) Page 10446, line 9-11: Please rewrite this sentence as it is not clear.

16) Page 10446, line 19-23: This findings seem interesting to me as it shows that it is not possible to calculate changes in the radiative properties of clouds without taking changes in the dynamics and following from that the IWP into account. Maybe you could highlight a little bit more this result and the difference to the finding of Penner et al., 2009).

17) Page 10446, section 4.6: Due to the depositional growth latent heat is released which changes the temperature and supersaturation in the cloud layer. The crystal habit is dependent on these variables. Are changes in crystal habit due to these processes calculated and taken into account in the radiation calculation or are these changes way too small?

18) Page 10446, line 25: Please rewrite the sentence to something like " Aerosol-cloud interactions in cirrus clouds developing in an environment with large-scale low vertical motion off the ....“.

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19) Page 10447, lines 16-27: Could you maybe rewrite this paragraph as it is not that clear to me what exactly you want to say.

20) Page 10447, line 28: Rewrite the sentence to something like " The effect of changes in LW radiation on ice clouds caused by increasing ...“.

21) Page 10448, line 1-4: You state that the increase in IWP could enhance the greenhouse effect of ice clouds. However, if the optical depth of the clouds is high enough, the albedo effect (cooling effect) dominates and an additional increase in IWP would then increase this cooling effect. Could you maybe add this dependence on optical depth somewhere?

22) Page 10449, line 23: replace Du2.5 is set at " with "DU2.5 is set to“.

References: These two articles also investigate the Competition of homogeneous and heterogeneous freezing and dynamical infleunces and you may want to cite them:

Spichtinger and Gierens, 2009b, Modelling of cirrus clouds -part 2: Competition of different nucleation mechanisms, Atmos. Chem. Phys., 9(7), 2319-2334.

Kärcher and Ström, 2003, The roles of dynamical variability and aerosols in cirrus cloud formation, Atmos. Chem. Phys., 3. 823-838, 2003.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 10429, 2010.