Review of: "Technical note: Identification of two ice-nucleating regimes for dust- related cirrus clouds based on the relationship between number concentrations of ice-nucleating particles and ice crystals" by He et al.

Content

This manuscript describes an approach to determine the ice crystal number concentration (ICNC) and dust related ice nucleation particle concentration (INPC) from satellite and sun photometer observations. Both quantities are compared to each other to examine the nucleation pathway (homogeneous or heterogeneous) of two single cirrus cloud cases in China.

Overall impression and rating

The overall impression of the manuscript is good in general. The manuscript is mostly written in a clear way and the most important aspects are considered. The presentation quality of the manuscript is besides small details good. It is well organized and the analysis and results are clearly structured and communicated. However, in some minor parts I cannot fully follow the argumentation. Especially, the explanation of the middle cloud part in case 1 where INPC and ICNC disagree is too short and insufficient. For these reasons, I recommend publication in ACP after some minor manuscript revisions.

Specific comments/questions:

- Page 2, lines 41-43, You are right that liquid origin clouds form completely heterogeneously, but at a later stage when reaching higher/colder altitudes additional homogeneous freezing can occur, if the updraft is fast enough. This can happen in convection and warm conveyor belts (WCB, see Kraemer et al. 2016). I recommend to add at the end of sentence: "...altitudes where homogeneous freezing can occur under high updraft conditions in addition to the heterogeneously formed ice crystals."
- Page 5, lines 137-138, What is actually meant by "interestingcirrus clouds" ? Are this cases where your ICNC-INPC closure worked or how do you select the "interesting cases". Maybe you can a little bit more specific in the text.
- Page 5, line 144, I find this sentence confusing. What is meant by "isotherm" in this context ? Cirrus clouds usually occur below -38 °C, but can also as completely frozen mixed-phase clouds above -38 °C. I recommend to rewrite this sentence to make it clearer.
- Page 6, line 168, The date in the headline does not fit to the case you are showing! (29 December 2010 and 15 May 2008). So please correct. Please also capitalize after the colon.
- Page 6, line 173, I do not understand the first part of the sentence: "Dust particles were full of the cloud-free regions". Can you please rephrase it!

- Page 6, lines 182-184, How do you determine the average values ? Just taking your bounding box shown in the figures or did you use the feature mask from Calipso ? Because of the very irregular shape of the cloud, this can have a large influence on the averaged values. The same comment applies for page 8 line 238-289.
- Page 8, lines 221-225, The explanation and discussion of the disagreement in the lower part of the cloud is definitely not sufficient and long enough. You argue with sedimentation of the heterogeneously formed ice crystals from the cloud top level, which can be an explanation. But if the heterogeneously formed ice crystals fall from above they also lower the ice concentration and also the INPC which are consumed by the formation process in the upper part of the cloud. In addition, new ice crystals in the upper part cannot form heterogeneously afterwards anymore because of low INPC values. Or you have to explain where new IN particles should come from. I also do not understand the argument with homogeneous freezing in the lower part of the cloud. Homogenous freezing would need higher vertical updrafts to maintain high supersaturations. Where should the higher vertical updrafts come from and why one could not find them in the top part of the cloud ? I also think that homogeneous freezing can still not be ruled out completely also for the upper part of the cloud especially with the argument of ice crystal sedimentation. I think this point should be discussed in in more detail in this Section of the paper.
- Page 9, lines 277-279, I cannot follow your conclusion that "heterogeneous nucleation would gradually be dominant" in a competition situation. When you uplift an air parcel you will increase relative humidity until a cloud is forming. Of course you would form a cloud heterogeneously first, but with further vertical updraft and thus cooling, relative humidity can increase again reaching homogeneous nucleation threshold even if you are consuming humidity by particle growth of heterogeneously formed ice crystals. Thus, forming heterogeneously and homogeneously exactly at the same time is not possible, but of course one after the other. And than I would be identify the dominance of formation mechanism by the ICNC. Given the high ICNC values in the upper part of the cloud, I would argue that you have a large dominance of homogeneous frozen ice crystals in the cirrus cloud. I suggest to rethink your conclusions and discussion in this point.
- Figure 12: In part (a) of the figure you write T<-38°C, while you write <0°C in the caption. In this case your argumentation about thin clouds (few large crystals) is only valid for in-situ cirrus clouds, I suggest to change the caption to T<-38°C as in the Figure. In part (b) the RHi values stated in the figure are not correct. In a competition case heterogeneous freezing still happens at RHi values 100-140%. Thus I suggest to change the values in the Figure and Caption to 100-170%.

Technical comments/suggestions:

- Page 1, line 27: Better write "~5km up to the tropopause".
- Page 2, line 32: Use the plural form "general circulation models".
- Page 3, line 84: I recommend to include Kraemer et al 2020 as reference in addition to Marinou et al. 2019. The authors also perform a comparison between in-situ and satellite ICNC.
- Page6, line 175: Please change "can be considered dust-related cirrus clouds" to "can be considered as dust-related cirrus clouds".
- Page 7, line 199: "above -35 °C isotherm". I guess you mean colder than -35 ? So please correct the wording.
- Page 7, lines 200-204, Table 2: Please explain what is meant by the parameter Si, because it is not mentioned in the text before or afterwards.
- Page 8, line 221: "ice crystals falling": Better use the common term "ice crystal sedimentation".
- Page 8, line 226: Please capitalize after the colon.

- Figure 2/3/4: I would recommend to zoom a little bit closer to your selected cirrus case by showing only date between e.g. 45-25° latitude. Than all features are better visible.
- Figure 3/4: Please use the same latitudinal projection as in Figure 2 to make the figures better comparable.
- Figure 8/9: Same comment for Figure 3/4 above.

References

- Krämer, M., Rolf, C., Luebke, A., Afchine, A., Spelten, N., Costa, A., Meyer, J., Zöger, M., Smith, J., Herman, R. L., Buchholz, B., Ebert, V., Baumgardner, D., Borrmann, S., Klingebiel, M., and Avallone, L.: A microphysics guide to cirrus clouds – Part 1: Cirrus types, Atmos. Chem. Phys., 16, 3463–3483, https://doi.org/10.5194/acp-16-3463-2016, 2016.