Review of: "Impact of wildfire smoke on Arctic cirrus formation, part 1: analysis of MOSAiC 2019-2020 observations" by Ansmann et al.

Content

The study describes polar lidar obervations of cirrus clouds and aerosols in the time frame between October 2019 and March 2020 during the famos MOSAiC expedition. This manuscript is the first part (observations) of a series of two manuscripts. The lidar observations were combined with radar and in-situ particle observations. 20 cirrus events where analysed and the main findings are the low ice crytstal number concentrations (ICNC) point to heterogeneous ice nucleation, the evidence of elevated smoke pollution levels, and high ice saturation ratios point ot inefficient INPs.

Overall impression and rating

I'm reviewer of both manuscript parts of this paper series. The overall impression of this first part of the manuscripts is very good. In particular, this manuscript is written in a clear way and the important aspects are considered. It is well organized and the analysis and results are clearly structured and communicated. The study is very valuable for the scientific community because it shows rare observations of polar cirrus clouds which are potentially influenced by wildfire aerosols. For this reasons, I recommend publication in ACP after addressing my very few comments and a subsequent very minor manuscript revision.

Main comments/questions:

- Figure 7: ICNC obervations between 01:30 and 02:30 on the 22 January 2020 show high values around 50L-1 while below in the fall streak ICNC are one orders of magnitude lower. This is an indication for mulitple nucleation events and could be an indication of homogeneous nucleation as INPs are already consumed by previous nucleations. So it is hard to tell weather it is homogeneous or heterogeneous nucleation just from the microphysical observations wihtout having information of ICNC in the important nucleation layer above. It could be that most of the cirrus cases where formed via both nucleation pathways. First consuming all INPs and than subsequently homogeneous nucleation kicks in. In the virga you would just see the heterogeneously formed ice particles because of their larger sizes. So the ICNC values in the nucleation layer are more or less speculation as indicated also by your measurements line 358-365. I would recommend, in order to argue as evenly as possible, to mention this possible path in the discussion, because a final answer is not possible only from the observational side.

Specific comments/questions:

- Line 35-36: You list here just lidar observations in the references. However, there are also other observations of wildfire plumes available (e.g. obs. with OMPS by Kloss et al, 2017). I recommend to cite here a little bit more balanced.

- Line 44: "of the order of 500 L^-1 in the case of homogeneous freezing" - It is actually not true that homogeneous freezing is producing always high ICNC. For example under calm (w ~ 1-5cm/s) and warm conditions (e.g. 220K) you could have also much smaller ICNC with homogeneous freezing as can be seen in Fig. 5 of your cited paper Kärcher et al. 2022 or in another paper by Krämer et al. 2016 (Fig. 6). I recommand to just mention here a range of typical ICNC for freezing.
- Line 149: Maybe you can add here how the 1936 lidar profiles are distributed over the half year.
- Line 168: Can you give an estimation to which altitude maybe also realtive to the tropopause it was possible to apply the LIRAS-ice analysis scheme. This would help the reader to estimate how much of the cirrus was missed due to the limitations of the radar. If I understand correclty, you will miss always the nucleation zone directly at/below the tropopause for the microphysical property determination.
- Line 270: The difference might come from the different sites. Espacially at Kupio the influence of mountain waves genertated by the Scandinavian mountains might influence the ICNC and thus also the COT. This could be added as speculation here.
- Line 275-276: As I mentioned before, the simple discrimination between heterogeneous and homogeneous nucleated ice particles just by the number concentration is not always reliable. It is important to look at the cloud air mass history to determine the updraft speed during nucleation to better classify, if the ice partcles are formed heterogeneously and homogeneously (Krämer et al. 2016).

Technical comments/suggestions:

- Line 37: There is a Latex/Bibtex citation missing.
- Figure 2: This is a cool photo !
- Line 441: Reference of PollyNet database is missing in the PDF.

References

- Kärcher, B. (2022). A parameterization of cirrus cloud formation: Revisiting competing ice nucleation. Journal of Geophysical Research: Atmospheres, 127, e2022JD036907. https://doi.org/10.1029/2022JD036907
- Kloss, C., Berthet, G., Sellitto, P., Ploeger, F., Bucci, S., Khaykin, S., Jégou, F., Taha, G., Thomason, L. W., Barret, B., Le Flochmoen, E., von Hobe, M., Bossolasco, A., Bègue, N., and Legras, B.: Transport of the 2017 Canadian wildfire plume to the tropics via the Asian monsoon circulation, Atmos. Chem. Phys., 19, 13547–13567, https://doi.org/10.5194/acp-19-13547-2019, 2019.
- 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.