

Atmos. Chem. Phys. Discuss., referee comment RC2
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Comment on acp-2022-128

Anonymous Referee #2

Referee comment on "Ice crystal characterization in cirrus clouds III: retrieval of ice crystal shape and roughness from observations of halo displays" by Linda Forster and Bernhard Mayer, Atmos. Chem. Phys. Discuss.,
<https://doi.org/10.5194/acp-2022-128-RC2>, 2022

This paper is the third in a series on the HaloCam observations of cirrus clouds. This part of the series is focussing on interpretation of the HaloCam data and using observations of ice cloud halos to infer information on the crystals. This is an interesting subject suitable for publication in ACP. The paper is generally well written, although some clarifications are needed. Below I list some major comments that need to be addressed before publication followed by detailed minor comments.

Major comments:

- Ice crystal habit, size and smooth crystal fraction (SCF) is inferred from the halo observations by matching the observations at different viewing angles to simulations. However, it is not shown how the halo properties change with habit, size and SCF. I do not believe this is described in the other two parts of the series. I suggest using the LUT to show how the observations vary systematically with habit, size and SCF. I suggest the investigations of sensitivities to size and SCF focus on the plate and column aggregate, as these appear to match the data mostly while yielding quite different results on SCF as seen in Fig 4.
- The retrieval procedure needs to be explained more clearly. Specifically:
 - on page 8 you say that cases with RMSE values below 2-sigma measurement uncertainty are "considered possible solutions", while "the LUT element with the minimum RMSE represents the best match." How are the possible solutions used? Isn't only the best match considered the retrieved parameter set? Are there instances where the lowest RMSE is not lower than the 2-sigma measurement uncertainty and thus the retrieval fails?
 - The RMSE values are not very useful without a reference point, so please give a representative value of this 2-sigma measurement uncertainty. Alternatively or additionally, RMSE values could be normalized by the 2-sigma measurement uncertainty. The range of RMSE values in Fig 3 is quite broad, so is the 2-sigma measurement uncertainty quite large? Maybe I am not interpreting the RMSE values

in Fig 3 correctly and these are not only for the 'best match' cases? If so, please explain in the text.

- Then in Figure 3, the AOD differs between the results for different habits, but it was explained that the AOT is constrained by clearsky observations before or after the cirrus observations, so I do not understand why this varies with habit?
- On page 7, line 13, it is stated that "the LUT was also constrained to SSARA's COT measurements within a 2-sigma confidence interval averaged over a ± 5 min time interval." I am not sure what is meant here. I assume the COT within the LUT that matches most closely to the mean SSARA's COT is used, but it is not clear how the 2-sigma confidence interval is used.
- On page 13, the sensitivity study is described and it is stated that "the LUT was modified by multiplication with a slope". But what specifically was multiplied? And with a slope with respect to what? Please clarify. Also, does the modified LUT also lead to a different SCF?
- In section 3.2 the 46 degree halo is simulated, but it is unclear what the SCF and size is used here, i.e. in Figs 6 and 7.
- The LUT elements "with a 46 degree halo" are excluded, but how is this quantified?

Minor comments:

Page 1, Line 21: add "be" between "to" and "more"

Page 2, line 4: add "to" after "helps"

Page 2, line 21: The papers van Diedenhoven et al. (2012, 2020) are cited referring to RSP data, but both papers use POLDER data. The van Diedenhoven et al. (2013) that is also in the reference list is using RSP data and could be cited here as well. The other two papers could be cited in the previous sentence, although "more recently" does not apply then anymore.

Page 4, line 3-4: "ice crystal orientation also has significant effects on the global radiative budget (Noel and Sassen, 2005)". This is an overstatement and not supported by the cited paper. Other studies, such as Breon and Dubrulle (<https://doi.org/10.1175/JAS-3309.1>) and Zhou et al. (<https://doi.org/10.1175/JAMC-D-11-0265.1>) have concluded that the percentage of oriented plates in the clouds is very low and that "These low fractions imply that the impact of oriented plates on the cloud albedo is insignificant." Please correct the statement in the paper.

Page 5, line 9 and throughout the paper: The 8-element aggregate of columns is named "8-element columns" here, but this is confusing in my view. Please refer to this as an

aggregate throughout the paper. Also correct the naming of the plate aggregates accordingly.

Page 5, line 26: A bias in what? Radiance, retrieved SCF? Please specify.

Page 10, line 3: The grammar of this sentence does not seem to be correct.

Page 10, line 35: Note that the base temperature of -10C is out of the range of your definition of cirrus.

Page 14: figures 6 and 7 are out of order with the text.

Page 16: line 8-10: Would a mixture of habits also be a plausible explanation?

Page 16: line 12: remove the second instance of "results"

Section 4.1: Bullet rosettes are also commonly observed in in situ cirrus. The poor agreement with the haloCam could also be because the aspect ratios in the Yang et al. model are too high, as also suggested by the work of Fridlind et al. (*Atmos. Chem. Phys.*, 16, 7251–7283, 2016, doi:10.5194/acp-16-7251-2016)

Page 17, line 1: While halo displays are not rare, you have shown that 75% of the cirrus do not show them and thicker clouds may be expected to have more complexity in their ice crystals, so recommending using a high SCF globally is probably not appropriate.

Section 4.3: The paper of van Diedenhoven et al. 2020 that is cited concluded that mean roughness decreases with size, which may be consistent with your conclusion that the smooth crystals are generally small.