Atmos. Chem. Phys. Discuss., 7, S376–S381, 2007
www.atmos-chem-phys-discuss.net/7/S376/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observing cirrus halos to constrain in-situ measurements of ice crystal size" *by* T. J. Garrett et al.

Anonymous Referee #3

Received and published: 2 March 2007

Review of "Observing cirrus halos to constrain in-situ measurements of ice crystal size" by Garrett, Kimball, Mace and Baumgardner, submitted for publication in Atmos. Chem. Phys. Discuss.

Recommendation: Accept for publication after revision

Major Comments

The authors attempt to determine the characteristic optical sizes of ice crystals in synoptic cirrus acquired by using observations of ice cloud optical phenomena, and measurements of size-resolved crystal distributions and bulk ice cloud properties obtained during the recent MidCiX experiment. The paper should be published because it uses a unique methodology, based on the existence of ice crystal haloes, to hypothesize

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information on the sizes of ice crystals that are present.

I have a number of questions and suggestions that will help clarify and focus the manuscript that should be accounted for in a revised version of the manuscript:

1) the authors should attempt to explain why haloes are only present for a subset of the observations. It is hard to speculate on reasons for the presence of haloes if they are not able to distinguish differences between ice crystal size distributions when the haloes are and are not present;

2) the authors need to investigate crystal habits that are present when haloes appear and when they do not appear since this may explain the differences between the conditions (the authors should also clarify that haloes would be expected when the particular crystal habits are present);

3) the authors should better explain how they accounted for out-of-focus of hollow crystals that are frequently observed with the CIP, and how they accounted for particles that occur at the edges of the photodiode arrays, and their impacts on the extinction coefficients estimated from the in-situ data;

4) I would like to see a more thorough error analysis in the paper as relates to the contributions of the large and small crystal modes to the haloes. I also think that this discussion could be simplified and more focused than what is present in the current form;

5) the authors should address whether there are any remote sensing observations that can be used to verify that the cirrus were indeed homogeneous;

and 6) I would recommend that the paper remove the section on the parameterization of effective radius and keep a focus on investigating what are typical sizes of ice crystals and whether shattering artificially enhances small crystal concentrations (since the development of a parameterization implies some sort of statistical representativeness that is obviously not present).

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Other Comments

1. 16th line in 1296. The term “the density in air of ice mass” is non-conventional. I assume the authors mean ice water content and would recommend they use this more standard terminology.

2. Equation (1) in 1296. I suspect that this equation is from Francis et al. (1994) and not Foot (1988). Foot’s definition of effective radius is only for graupel or bullet rosette. Following Fu (1996) a definition of effective radius that is proportional to crystal masses divided by extinction or cross-sectional area is most appropriate for describing or parameterizing the radiative properties of ice crystals because it gives better representations of scattering and absorption than definitions relying on equivalent-volume or equivalent-area spheres. The papers of McFarquhar and Heymsfield (1998) and Mitchell (2004) that examine altering definitions of effective radius should be referenced here to help show the different re definitions that are used.

4. Page 1299. Is it true that the refraction can be well-approximated using ray tracing for all the size parameters used in this study? Perhaps the authors can give the range of size parameters that they are considering in this study here.

5. Page 1299. One of the arguments used that haloes are frequently not noted is that many non-pristine crystal habits are present, or because of various rounding or smoothing effects (i.e., distributions of ice crystals, evaporated crystals meaning the edges of the crystals are not smooth, etc.). Perhaps some comments can be made about the range of habits that might support the occurrence of haloes.

6. Page 1301. I would expect that a lot of the columns would not be randomly oriented, but rather would be preferentially oriented. Also, across this paper only column type ice crystals are considered. However, other type of ice crystals, such as a bullet or bullet rosette can contribute diminishment of 46 degree halo intensity.

7. Page 1302. I think the evidence for the maximum equivalent radius for the existence

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of halos is not as complete as the evidence given for the minimum equivalent radius. As noted above, bullet rosettes could also be associated with halos and they do have sizes exceeding 100 micrometers in cirrus. The study of Auriol et al. (2001) is indeed important to reference, but this absence of halo could be caused by other reasons (e.g., different crystal habits) or sampling conditions.

8. 7th line in 1304. How do assumptions in the CIN processing algorithms related to how much energy is in the forward peak affect the results? Furthermore, it is very interesting whether there were halo phenomena during three measurements (i.e., Auriol et al., 2001; Garrett et al., 2001, 2003). Since this paper focuses on the effective radius with halo phenomena, an asymmetry parameter for the scaled optical depth calculation should correspond to the halo phenomena. There is big discrepancy between g from CIN and g from theoretical calculations, even though the theoretical calculations produce halo phenomena.

9. 9th line in 1305. Were there any problems with the appearance of hollow images or out of focus images with the CIP during MidCix, and if so, has the sizing of these images been corrected for? This could have big impacts on the calculated cross-sectional areas. Also, what are the contributions of particles with sizes between 50 and 125 um? The poorly defined sample volume of the 2DC/CIP in this range could induce substantial errors on the concentrations of particles in this size range.

10. 11th line in 1305 and Figure 2 What averaging period is used for the extinction coefficient depicted in this figure?

11. Page 1305. Was the Nevzorov probe also in good agreement with the other bulk water probes? I thought it suffered from an underestimate of the water content.

12. Observations (3.2) and Case study (3.3). Could you specify time period, aircraft flight distance, and sample volume of CAPS during measurements? To know the significance of data used in study would be useful. The Figure 1 in Hallet (2003) is very good example. Hallet, J, 2003: Measurement in the atmosphere. Handbook of Weather, Cli-

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mate and Water: Dynamics, Climate, Physical Meteorology, Weather Systems and Measurements, Ed. T. D. Potter and B. R. Colman, John Wiley & Sons, Inc., 711-720.

13. Page 1306: Values of effective radius, ice water content and extinction coefficient are quoted for when haloes are present and when haloes are not present. Can you do a simple statistical test to determine whether these distributions could be from the same statistical sample?

14. 23rd line in 1310. Since the ice crystal size criteria and optical depth criteria were derived in terms of the equivalent radius and a parameterization of effective radius is calculated in conclusion, it would be better to show a difference between the parameterization of effective radius and of equivalent radius. The effective and equivalent radius should be different especially for the presence of large irregular shape ice crystals.

15. 20th line in 1312. According to the figure 7 in Garret et al. (2001) the large mode cannot be 25 times smaller than the smaller mode. The shaded area is for small mode and the difference between the solid line and shaded area is for large mode. Is it due to different conditions of clouds? Or is there any upgrade in CIN? The FSSP and CAS working principle is the same.

16. Figure 7. The fit in the figure is for halo present case only or all measurements? Could you indicate it?

17. Effective radius parameterization. This study shows a parameterization of effective radius when halo phenomena are present. However, the halo phenomena are rare. Another concern is that there are other degrees of halo beside 22 and 46 degree even though they are very rare. This study only consider column like ice crystal for the ice crystal size and optical depth criteria. Considering these weaknesses and representative it is somewhat ambiguous whether the parameterization of effective radius can be used in large scale models. See also comments above.

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 1295, 2007.

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