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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Surface roughness during depositional growth and sublimation of ice crystals" *by* Cedric Chou et al.

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Response to Referee #3

This unique laboratory study combines a laminar flow tube with a laboratory version SID-3 instrument, where flows from a "dry" and a "wet" laminar flow tube are mixed to control the supersaturation characterizing ice crystal growth at the flow tube outlet where SID-3 measurements are made (including microscope imagery). The methodology is adequately explained while the results are well explained, and the paper is well organized. The results advance our knowledge of the dependence of ice particle optical properties on ice growth/sublimation processes. I did not find much to criticize

in this study.

We thank the Referee for the positive comments and suggestions. Below we list our response to the two main comments.

Specific Comments:

1. Page 5, line 2 regarding Fig. 4: The measurements agree well with the Fluent calculations except at -40°C at low flow rates. Please suggest reasons for these differences.

We think that the reason for the deviation between measurements and simulations at low temperatures and (especially) low flow rates are caused by the measurement technique. Accurate temperature measurement in a gas flow under a small flow tube at low flow temperature and flow speed is not trivial. The temperature sensor, which was positioned in the optical measuring volume of LISA several millimeters below the tube outlet, might not give accurate values if the flow velocity is too small, especially at low temperatures. We spent a lot of time using different types of sensors (various Pt100 and thermocouple sensors) to find out which one gives the best results for our application. In conclusion, even if the sensor is precisely calibrated in an ethanol bath against a reference Pt100 sensor, the difference between measurements and simulation results is probably due to technical measurement issues.

2. Page 9, lines 15-16: "these observations indicate that the more growth-sublimation cycles are performed, the rougher the crystal can become." Figure 11 does not seem to support this. Rather, the 3rd maximum in surface roughness in Fig. 11 (corresponding to the 3rd growth cycle) is slightly lower on average than the 2nd maximum in Fig. 11 (although both maximums are comparable). Therefore, it appears possible that a limiting roughness threshold exists that would not be exceeded in subsequent growth-sublimation cycles. This possibility should be acknowledged. Such a possibility

seems consistent with our theoretical understanding of ice crystal surface kinetics and growth processes. Moreover, future work should explore this possibility by analyzing 3 or more continuous growth-sublimation cycles in multiple experiments at various wall temperatures. If a laboratory roughness threshold were established (possibly being supersaturation- and temperature-dependent), then the next logical step would be to look for evidence of this in natural cirrus clouds. Quantifying and bounding the degree of ice crystal surface roughness is needed to reduce uncertainty in the cirrus cloud radiative effect (CRE) in climate models.

We stopped the experiments after a few growth-sublimation cycles because the gross shape of the ice crystals often slightly changes with each cycle. Here, we didn't wish to mix the effects of surface roughness and larger irregularities and therefore stopped when the ice crystal started to develop significantly different morphology. So we generally agree with the Reviewer's point that there appears to be an upper limit of the (combined) roughness value, but higher values could be reached in principle during longer experiments. We consider this suggestion and will try to address this point in future investigations.

Technical Comments:

1. Page 3, line 23: space between "the" and "central".

2. Page 16, lines 19-21: Reference cited incorrectly. Title should be "Cloud chamber experiments on the origin of ice crystal complexity in cirrus clouds", and the year of publication should be 2016. I have not checked other references; the authors should check these too.

3. Figure 3: In lower panels, the y-axis labels should be changed from "ration" to "ratio". Regarding saturation profile panel "b", should %5 l/min be 5 l/min?

4. Figure 4: Flow units are in "dl/min"; should this be l/min? If not, define dl.

We improve the Figs. as suggested and have rechecked the references.

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