

Interactive comment on “Incidence of rough and irregular atmospheric ice particles from Small Ice Detector 3 measurements” by Z. Ulanowski et al.

Anonymous Referee #2

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This article describes the first cloud 2-D light scattering pattern measurements performed with the small ice detector (SID-3) during the CONSTRAIN airborne campaign. Ice crystal roughness is retrieved from the SID-3 2-D scattering pattern measurements for three cases of mid latitude cirrus and two cases of mixed phase clouds. While most of the cases were in prevailing oceanic air masses, one cirrus case corresponds to a continental air mass. In this study, no differentiation is made between small scale surface roughness and large-scale crystal complexity. Several features of the 2D patterns for scattering angles ranging from 6° to 25° (such as GCM energy, root mean square brightness, kurtosis..) are used to retrieve the roughness of ice particles. The SID-3 2D patterns are also compared to the ones obtained from a variety of particles (mineral dust grains, ice analogues with rough on complex features) tested in labora-

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tory. It is shown that the majority of cirrus cases are characterized by deeply rough ice crystals with values sometimes higher than the “roughest” test particles. The authors also suggest that this high roughness could be maintained or reinforced by sublimation processes. A slightly weaker roughness was found for cirrus in prevailing continental air masses. My opinion is that the work presented in this paper is a significant contribution to the field of light scattering by irregular particles and more generally to cloud microphysics. The paper is very interesting and deserves to be published. However, the paper requires a substantial number of minor revisions, especially in the way the results are presented, before being published.

General Comments :

I agree with most of the comments made by reviewer 1. I think he made a very good review and his suggestions should be taken into account in order to significantly improve the paper. In addition to his remarks, I would recommend to :

- i) Clarify some aspects of the results and the discussion. This can be easily done by rearranging the discussion part. For example, some of the statement made in the “discussion” part should be transferred to the “results” part. This would really help the reader to follow the reasoning of the authors.
- ii) Independent measurements of cloud microphysical and thermodynamic properties should be presented to understand the possible links between roughness and other parameter such as particle size, temperature. Size of ice crystals can be retrieved from SID-3 measurements, why no information on the size of ice crystal is provided in this paper? Did you experience a relationship between the size of the crystals and the surface roughness? Temperature is also a parameter missing in the interpretation of the results.
- iii) How can the semi-quantitative assessment of the roughness of the crystals proposed by the authors be implemented in light scattering models? For example, is the combined roughness can be linked to the surface roughness parameter used by P.Yang

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et al. or the distortion used by A. Macke et al.?

iv) The frequency distributions of roughness measured by the SID-3 should be analysed more in details in order to establish equivalent shape models (dependent of the type of clouds) that can accurately describe the optical properties of small ice crystals.

Specific Comments :

Abstract :

- P24976 ; Line 19 : There is no clear evidence of a correlation between the halo ratio and the roughness. I think this part should be rephrased. At high surface roughness the 22° halo seems to vanish whereas at low roughness the scattering enhancement at 22° can become significant.

Introduction :

P24977 ; Line 1 : Add a couple of references concerning the uncertainty of cloud feedbacks in climate models.

Line 4-5 : Please be more general and mention that the ice crystal morphology is not the only parameter that impacts the cloud radiative properties (size, IWP, ...).

Line 16 : what do you mean here by indirect in the following sentence : "most of it indirect or from remote sensing" ?

P 24978 line 24978 : it is mentioned in this part of the introduction that "it is possible to recover the shape, size and orientation of small ice particles". Why don't you show in the paper any results concerning the size or the orientation of the ice crystals?

Section 2: Methods

This section seems to be a bit technical. Could it be presented in another way so that the reader does not get lost with so many details? This is just a suggestion, it is not mandatory.

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Line 21: The open geometry of the SID-3 is expected to reduce shattering but can you refer to previous work showing how shattering is reduced. Do you have a quantitative assessment of this reduction?

P24983 line 7 : Could you specify how the equation defining the combined roughness was found, on what physical basis? Is this roughness comparable to other roughness parameter introduced in other light scattering modelling studies ? (IGOM model developed by P. Yang et al for example)

P24984 line 1-6 : Ice particle size is not shown in this paper but mentioned a couple of times in the paper. It should be clearly mentioned that no retrieval of size is performed in this paper or size retrievals should be presented (second option is better). Other microphysical measurements should also be mentioned at that point.

Section 3: Results

I think this section should be rearranged as it is very short and the results should be presented thoroughly. The authors can use some of the key points presented in the discussion part to expand the results. One major result is that the surface roughness can change with environmental conditions and that surface roughness is not uniformly distributed on the surface of the ice crystals. This is shown in laboratory experiment. This also seems to be the case in cirrus clouds depending on the air mass origin. This is an important result and should be emphasized in this section. The interpretation of the results should also be done looking at the HR and the temperature simultaneously. HR accuracy should also be mentioned.

P24984 line 20 : Figure 6 is very important and deserves to be described in details with a more complete analysis. I also think that Figure 7 should be presented before figure 6.

P24985 line 5-20 : Halo ratio : There is no clear correlation between the halo ratio and the roughness parameter. Can you discriminate crystals with an hexagonal geometry

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from more irregular ice crystals? And then look at the variability of the halo ratio for hexagonal ice crystals.

Section 4 : discussion

This part of the paper is very interesting. I think the authors did a very good job. However, this section is too long and must be clarified. I would suggest moving some paragraphs to the result section. For example the discussion on the link between halo ratio and roughness (p24987) should belong to the result section.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 24975, 2013.

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