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Interactive comment on "Disk and circumsolar radiances in the presence of ice clouds" *by* Päivi Haapanala et al.

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We thank Anonymous Referee #1 for his/her constructive and insightful comments on the manuscript. Below, we respond to these comments and outline changes planned in the revised manuscript.

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COMMENT:

For the most part the paper is technically well written. The authors put their work in reference to previous studies and it is easy to follow which steps they have undertaken in their study. However, what is lacking is a clear formulation of the study goal. Consequently also the presentation of the findings is somewhat vague. Before publication in

Printer-friendly version

Discussion paper

ACP these issues should be addressed.

RESPONSE:

The overarching goal of the research is to understand how ice clouds influence the downwelling solar radiances within a few degrees from the direction of the Sun. This knowledge may be exploited, in future work, for developing schemes to correct measurements of direct solar radiation for the diffuse radiation that is present at the angular range of instruments such as pyrheliometers. Furthermore, it is crucial for understanding the information content in measurements with the relatively new SAM instrument, and for the future development of retrieval algorithms based on SAM data.

As noted by both reviewers, this study is largely divided into two components, both of which contribute to the overarching goal. The goal of the first component (i.e., the sensitivity studies) is to determine what parameters the circumsolar radiance is sensitive to; the goal of the second component is to use case studies to determine if we are able to get a successful match between the observed and simulated radiances. However, while we consider the first component (sensitivity studies) interesting in its own right, it also provides important information for designing and interpreting the comparison with modelled radiances. Specifically, it demonstrates the large sensitivity of circumsolar radiances to ice crystal roughness and small ice particles. This, together the fact that in-situ microphysical measurements yield no information on roughness and only very uncertain information on small ice crystals, motivates the study of how assumptions related to these factors impact the agreement between modelled and measured radiances.

In the revised manuscript, we will clarify the goals of the study in the Introduction. In addition, the links between the sensitivity tests and the comparison between observations (noted above) will be made explicit in a new subsection (section 4.4 in the revised manuscript) summarizing the findings of the sensitivity tests.

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COMMENT:

While for the second part of the study it makes sense to use only the size-shape distributions measured at the same dates as the radiance profiles, it is unclear why the authors have limited themselves to also only using the two size distributions as basis in the first part of the study. Unfortunately, little information is provided on how representative these size distributions are or whether it is sufficient to focus only on these two size distributions when deriving general relations between ice cloud micro-physics and circumsolar radiation. The authors discuss differences in simulated radiance profiles caused by the differences in the two measured particle distributions as well as due to impact of the assumed particle roughness. However, it remains unclear why the authors did not explore the parameter space further – e.g. by using more size-shape distributions from the SPARTACUS campaign or idealized single-shape size distributions in different size variations. Although certainly not easy to quantify, at least some comment on how common/representative the measured size-shape distributions are considered by the authors should be provided.

Overall the study explores the sensitivity of the phase function in regard to particle shape and roughness. The finding is that the surface roughness is the dominating parameter. The third parameter, particle size, is largely neglected, however. While radiance profiles for three different concentrations of "small particles" are compared, little information is provided about the size distribution(s) used for this small particle fraction. Modifications to the size distribution of the large fraction are not performed.

RESPONSE:

In the revised manuscript, sensitivity tests will be added which demonstrate the impact of ice crystal size through the use of idealized (lognormal) size distributions. These tests demonstrate that the impact of ice crystal size arises, to a large part, through its impact on the width of the diffraction peak. In broad terms, the diffuse radiance in the solar disk area increases, and the radiance outside the solar disk decreases with increasing ice crystal size, while at angles of more than a few degrees the effect of ice crystal size is relatively small, especially for rough ice crystals. In addition, in the revised manuscript Figure 2 will also include the measured size distributions of small ice crystals.

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COMMENT:

Following modifications to the script could help to address the above mentioned issues:

The authors should leave no doubt in the introduction as to what the study goals are.

RESPONSE:

The goals will be clarified, as stated in our response to the first general comment.

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COMMENT:

The authors should concisely summarize (if deemed feasible maybe also in tabular form for ease of comprehension) which aspects of the radiance profile are influenced by which of the cloud micro-physics parameters. The authors should also mention which of these aspects were newly identified in this study.

RESPONSE:

In the revised manuscript, a subsection summarizing the main findings of the sensitivity tests, and how they relate to earlier research, will be added (section 4.4).

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COMMENT:

While the authors found that the small particle fraction (Dmax < 100mu) cannot be neglected, the influence of the overall particle size distribution is not very thoroughly explored. I suggest to expand the study in this regard. Alternatively the authors should comment on why they deem the size distribution not to be as important as the particle shape and roughness

RESPONSE:

In the revised manuscript, sensitivity tests will be added which demonstrate the impact of ice crystal size through the use of idealized (lognormal) size distributions (see above).

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COMMENT

While only two dates of the SPARTICUS campaign where usable for a comparison to SAM measurements, the authors should add a paragraph that puts the shape-size distributions measured during those two flights in perspective to what was measured during the rest of the campaign.

RESPONSE:

This will be done in the revised manuscript. Jackson et al. (2015) examined the size and shape distributions sampled by the SPEC Learjet for all 101 missions flown during SPARTICUS, establishing the meteorological context of each cirrus sampled using visible and infrared images from GOES and WSR 88D radar images. Comparing Figure 2 of the manuscript (size-shape distributions of flight A and B) against Figure 10 in Jackson et al. (2015) establishes the degree to which the data from these 2 flights were representative of those observed during other flights: flight A tends to have lower N(D) than the average observed during other flights whereas flight B tends to have larger N(D) than the observed averages. Overall, flights A and B well represent the range of conditions observed during SPARTICUS.

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COMMENT:

The authors should provide the size distribution for the small particle fraction for flights A and B as well as the optical thickness assigned to this particle fraction. The latter could be added to tables 3 and 4.

RESPONSE:

This information will be presented in the revised manuscript.

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COMMENT:

Additional minor suggestions:

In line 24 it is stated that circumsolar radiation is caused by scattering on particles between 1mu and 100mu. However, the study mainly focuses on particles larger 100mu. Please clarify/rephrase.

RESPONSE:

Good point. Indeed, the upper limit is not warranted, because circumsolar radiation is particularly large in the presence of particles much larger than the wavelength. In the revised manuscript, this sentence will be modified as follows: "The radiation arises from near-forward scattering of direct solar radiation by atmospheric particles with sizes comparable to or larger than the wavelength (i.e., larger than about 1 μm)."

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COMMENT:

Should pictures of the cloud scenes (e.g. webcam) for times of comparison between simulations and SAM measurements be available, I suggest to include those.

RESPONSE:

Total Sky Imager (TSI) images for times corresponding to those of SAM measurements used in the comparison with simulations will be included in the revised manuscript.

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COMMENT:

Caption of Figure 5: “Sensitivity of the size and vertically integrated phase functions to the roughness of large ice crystals.”. Potentially remove “the size” from the sentence.

RESPONSE:

In the revised manuscript, the words "the size" will be removed from this sentence and also from the sentence in the caption of Figure 4.

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