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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 #2 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:

. . . In general, the paper is well written and is well describing of the various methods and sensitivity analysis conducted. However, the connection between the sensitivity studies and observations and to the goal of the study is largely missing from the text. Please try to add more content reminding the reader in each of the sections of why and

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how the results of the sensitivity studies would be important for solar measurements and for the aerosol/ice cloud retrieval community.

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. Regarding, the last suggestion ("add more content reminding the reader in each of the sections of why and how the results of the sensitivity studies would be important for solar measure-

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ments and for the aerosol/ice cloud retrieval community"), we think this discussion is best added to the new subsection summarizing the sensitivity tests, rather than in each subsection separately.

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COMMENT:

There are some areas where additional physical explanation or delineation might have been useful. For example, in Fig. 5 and Fig. 9 is it not entirely clear from the text why does the MR crystals result in a much larger bias from CS when compared to the SR particles. One might think that it should result in discrepancies that lie between CS and SR (in magnitude). This might be due to the contradicting effects of the direct and diffuse components, which might create this deflection point, but this is not entirely clear from the text.

RESPONSE:

This was already explained in the original manuscript (lines 307-316) in connection to phase functions, but apparently, the explanation was not sufficiently clear. This issue is related to how the treatment of ice crystal roughness impacts the paths of rays transmitted through parallel crystal faces. In the case of completely smooth crystals, such ray paths results in (near-) delta-transmission, increasing the phase function at scattering angles very close to zero. However, in the case of "rough" crystals, the ice crystal surface slopes are distorted randomly for each incident ray. In effect, this eliminates ray paths that pass through exactly parallel faces. This is why for both moderately rough (MR) and severely rough (SR) crystals, the phase function is lower than that for completely smooth crystals in very-near-forward scattering directions. Moreover, since virtually all such ray paths are eliminated both in the case of MR and SR crystals, the phase function for MR and SR crystals is nearly identical at angles smaller than about 0.3° in Fig. 5. That is, the same amount of energy is removed from the very-near-forward scattering for both MR and SR crystals, and added at larger scattering angles.

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In the case of MR crystals, most of this energy is distributed within a few degrees from the forward direction, while for the SR crystals, it is distributed over a larger range of scattering angles. Therefore, in the case of MR crystals, the phase function is larger than for SR crystals at relatively small scattering angles (up to about 6°), and smaller at larger scattering angles. Of course, these arguments also apply to the radiances.

We will try to make this issue "crystal clear" in the revised manuscript.

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COMMENT:

In Fig. 11 and 12 it is unclear why some of the SAM measurements (dashed grey lines-hp) are discontinued and showing a drop in radiance intensity around 0.27, while the hn are not. Also, please add the acronym of hp and hn to the figures captions (in Fig.11 and 12), to help the reader.

RESPONSE:

The vertical drop in hp lines in Figures 11 and 12 is present because of the gaps between the measurements from the solar disk and the solar aureole cameras in the SAM instrument. The inner edge of the solar aureole imagery in the SAM 300 model in use at the ARM SGP site during SPARTACUS is at about 0.6° from the centre of the solar disk. When the optical depth is below some value, which depends upon the degree of forward directivity of the scattering phase functions, the outer edge of the aureole in the solar disk camera falls below its intensity threshold and creates a gap when the two images are merged (as seen in Figures 11 and 12). These gaps should exist in both the positive and negative, horizontal and vertical profiles, unless the optical thickness along the line of sight has attenuated the disk radiance sufficiently that both the disk and aureole portions of the radiance in the gap are within the intensity measurement ranges of the respective cameras. In the SAM data shown in Figures 11 and 12 the gap is present in all hn and hp lines even it is hard to distinguish from the

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figures. For example in the rightmost panels of Figures 11 and 12 (θ=38.6°; τ=2.1 and θ=44.3°; τ=2.3) the gap is at 0.36°−0.52° and 0.46°−0.52° from the centre of the Sun, respectively. In the revised manuscript the meaning of acronyms hp and hn will be stated more clearly in the figure captions of Figures 11 and 12. In addition, we will remove the unphysical parts of the hp lines (i.e. the near-vertical drop/increase) from the shown SAM measurements and explain in the plain text the reason for the gap in the SAM measurements.

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