Manuscript number: egusphere-2026-4436
Full title: Morphologically complex ice crystal plate structures in mid-latitude cirrus: combining space-borne lidar, in-situ scattering, and physical optics simulation
Author(s): H. Ballington et al.

This study investigates ice crystal habits in cirrus clouds from airborne in-situ measurements, spaceborne lidar measurements, and numerical simulations of ice crystal scattering properties. Plate-like ice crystals, including their aggregates, are dominant ice crystal habits observed through airborne in-situ stereographic measurements. On top of that, the angular distributions of scattering intensity by ice crystals are measured from the airborne in-situ instruments. Spaceborne HSRL datasets are also explored over the region of interest to investigate the backscattering properties (i.e., lidar and depolarization ratios) of ice clouds. For airborne measurements of the angular scattering intensity and spaceborne lidar measurements, physical optics simulations are performed to explore differences in these scattering properties among ice crystal shapes. While the authors did not draw clear conclusions about the ice crystal habit dependence, the present analyses of airborne scattering data, spaceborne lidar data, and light-scattering simulations of ice crystals are all high quality. The topic and scientific significance of the present paper are suitable for *Atmospheric Chemistry and Physics*. In particular, the comparison of lidar backscattering properties between measurements and light-scattering simulations is still a scientifically premature topic, given the fact that recent advances in the understanding of coherent backscattering by a single particle in geometric optics have made it possible to investigate this subject, and any exploratory research would benefit the scientific community at this stage. I would recommend publication of this manuscript after minor revisions.

One important point that the authors implied but did not strictly highlight in the main text is that any ice particle habits that reproduce given optical measurement signals are merely the representation of the ice crystal population *weighted according to the measurement technique of the optical instrument*. The nature of this weighting depends on the measurement technique. For example, in lidar observations (i.e., ATLID), it can be interpreted as an ice particle habit weighted by the backscattering cross section, whereas in measurements of angular scattered intensity (i.e., PHIPS), it can be interpreted as an ice particle habit weighted by the scattering cross section. I read this as an important conclusion implied in the paper overall. If this is true, I would suggest highlighting this conclusion. In addition, please find the specific comments below for potential improvements to this manuscript.

Minor comments

1. Lines 166-172: Is the habit classification procedure algorithmic or based on manual inspection? Suggest adding a brief description of the habit classification procedure.
2. Lines 200-202 and elsewhere: Some acronyms are not spelled out when introduced. Suggest spelling out all acronyms.
3. Lines 214-221: I would suggest the authors rewrite this part using a paragraph or a schematic illustration rather than rough bullet points.
4. Line 312: What is SO(3)?
5. Line 341: The Muller matrix element S_{11} should first be defined when introduced.
6. Line 360-363, regarding PO: By definition, PO methods (i.e., the wave effect is taken into account for each geometric beam/ray) should account for the coherent backscattering

enhancement (CBE), as the far-field mapping is processed for each beam. I checked the original reference briefly, Ballington and Hesse (2024a), and it was not clear to me whether far-field mapping is performed for the near-field generated by each beam (i.e., PO) or the near-field generated by a bundle of beams (i.e., more like physical optics correction, similar to Muinonen, 1989 and Yang and Liou, 1996; i.e., IGOM). If the latter is true (which I suspect), CBE is not accounted for (as discussed in Saito et al., 2026). Please clarify which one is true.

7. Line 368: I believe that ϵ is not defined.
8. Line 369: The roughness quantity is expressed as X%, which is somewhat confusing with other numerical fractions. I suggest the authors use a symbol rather than % to express roughness degrees.
9. Figure 9a: The variations of lidar and depolarization ratios as a function of roughness are not smooth but rather scattered. Is this due to numerical noise (e.g., Monte Carlo noise) in PO simulations?
10. Figure 9b: What is the difference between Yang and TAMU? There is no clear description of TAMU in the caption.
11. Lines 429-430: What criterion of sun-glint filtering was used? I do not think that this is described in the main text (e.g., Lines 214-221). Please clarify.

References

1. Ballington, H., & Hesse, E. (2024). A light scattering model for large particles with surface roughness. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *323*, 109054.
2. Muinonen, K. (1989). Scattering of light by crystals: a modified Kirchhoff approximation. *Applied optics*, *28*(15), 3044-3050.
3. Saito, M., Yang, P., Tsang, L., Okamoto, H., & Ding, J. (2026). Exploration of coherent backscattering mechanisms for nonspherical particles in geometric optics regime. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 109805.
4. Yang, P., & Liou, K. N. (1996). Geometric-optics–integral-equation method for light scattering by nonspherical ice crystals. *Applied Optics*, *35*(33), 6568-6584.