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Full title: Assessment of horizontally-oriented ice crystals with a combination of multiangle polarization lidar and cloud Doppler radar
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The authors proposed and performed a novel retrieval process to infer the horizontally oriented ice crystals (HOIC) using ground-based Doppler radar, zenith-pointing polarimetric lidar, and 15° off-zenith pointing polarimetric lidar. A combination of zenith-pointing and off-zenith-pointing lidars can provide range-resolved detections of HOICs in ice or mixed-phase clouds. The case study demonstrates a distinct relation between the abundance of HOICs and eddy dissipation rates inferred from collocated Doppler radar. In addition, correlations between HOICs and various environmental variables are explored. The present paper shows novel results regarding HOICs and the relationships between HOICs and dynamic and environmental variables and is suitable for *Atmospheric Measurement Techniques (AMT)*. However, the manuscript includes several insufficient descriptions and a lack of validation of some of the retrieval algorithms used in the present study. This manuscript requires major revisions before reconsideration of publication. Please find the comments below for potential improvements to the manuscript.

Major comment

1. Page 1, Line 3 in abstract and elsewhere “pixel”: The terminology “pixel” is often used for a unit of the smallest area in the two-dimensional image data. For example, a satellite pixel indicates the smallest spatial area resolved by spaceborne spectrometers/imagers. It is a bit odd to use the terminology of “pixel” for a measured layer by active-sensor measurements, which is often referred to as a “range”. To avoid any unnecessary confusion, I suggest the authors rephrase “pixel” with “range” throughout the text. In addition, a range-resolved algorithm for HOIC detection is not novel but was achieved by many previous studies (e.g., Noel and Sassen, 2005; Stilwell et al., 2019). It may be the first results based on a combination of zenith-pointing and 15° off-zenith pointing lidars, but it would be too specific to claim the first results. I suggest the authors simply remove the statement “for the first time”.
2. On page 7, Lines 195-199, the authors discuss the horizontal deviation of the off-zenith pointing lidar. The discussions tacitly assume that the wind direction is along the line between the scattering volumes of the zenith-pointing and off-zenith-pointing lidars. This is not often the case in reality. The zenith-pointing lidar and off-zenith-pointing lidar often consistently measure a different portion of ice clouds, and therefore the time average does not justify these lidars observing the same portion of clouds. The authors must assume that clouds are horizontally homogeneous over a certain lateral scale, which is a strong assumption. Please clearly state the tacit assumption and discuss the validity of the assumption.
3. On page 18, the authors discuss the Euclidean distance from supercooled water clouds to ROICs and HOICs. The motivation behind this analysis is a bit questionable. First of all, the authors should separate the horizontal distances and vertical distances in the analyses as many microphysical processes (e.g., gravitational settling, ice aggregations, etc.) are reflected in the vertical distributions of cloud microphysical properties, and those of horizontal distributions may be influenced by a limited number of physical processes (e.g., turbulence, wind shear, etc.). With this in mind, the present analysis compares the distributions of Euclidean distances between HOICs and ROICs, which will unlikely to provide a meaningful interpretation as the distances in the discussion are an order of 10 km in contrast to the scales of physical processes

and scale of turbulence to be generally less than a few km. I suggest the authors remove the entire discussion regarding Euclidean distance.

4. Appendix D: The present analyses use the retrieval of ice crystal diameters as described in Appendix D. However, there are no descriptions of the uncertainty and potential bias in the estimated ice crystal diameters. The algorithm relies on a substantially simplified treatment of ice crystal shapes and orientations and is laid upon several approximations (e.g., aspect ratios). The authors should discuss the accuracy of the retrieval method in Appendix D.

Minor comments

1. Page 2, Lines 31-32 "Mie scattering …": Mie scattering theory applies to spheres and cannot examine the differences in the scattering cross-sections between random orientation and preferential orientations (i.e., particle orientations cannot be defined). Please clarify the point of the statement.
2. Page 3, Line 60: "didn't" should be "did not".
3. Page 3, Lines 71-72: "Westbrook et al. 2010" Suggest the authors add "Sato and Okamoto (2011)."
4. Page 3, Line 72: "Zhou et al., 2012a" Suggest the authors add "Saito et al., (2017)."
5. Page 5, Line 123 "cos(75°)": It would be better to use a unit of steradian inside the cosine. By the way, should this be 15°? Cos(15°) is a very small value.
6. Page 13, Lines 307-309 "… the strong turbulence caused by the latent heat released due to the sublimation…": This statement lacks supporting evidence and is not beyond the speculation level. Please provide sufficient evidence supporting this or clearly state that this is based on the authors' speculation.
7. Page 15, Line 334 "A negative correlation is found …": Is there a hypothesized mechanism for the negative correlation? Also, is this true for ROICs or not?
8. Figure 4 and Page 18, Line 370: I am concerned with the consistency of the scattering volumes between radar and lidars. Between 16:00 and 18:00 in Fig. 4, the liquid layer appears at an altitude of 5-6 km, as evidenced by the strong echoes from both lidars. However, it is not seen from radar. Please discuss the scattering volume consistencies. Perhaps the authors need to discuss the minimum detectable radar reflectivity in Section 2.4.
9. Figure 4 and Page 18, Lines 375–376 "… the signals of both lidar systems were subject to strong attenuation": It is hard to see the attenuation from Fig. 4 which uses a linear scale in the attenuated backscattering coefficients. Suggest the authors use a log scale in this figure.

Reference

Noel, V., & Sassen, K. (2005). Study of planar ice crystal orientations in ice clouds from scanning polarization lidar observations. *Journal of Applied Meteorology*, *44*(5), 653-664.

Saito, M., Iwabuchi, H., Yang, P., Tang, G., King, M. D., & Sekiguchi, M. (2017). Ice particle morphology and microphysical properties of cirrus clouds inferred from combined CALIOP-IIR measurements. *Journal of Geophysical Research: Atmospheres*, *122*(8), 4440-4462.

Sato, K., & Okamoto, H. (2011). Refinement of global ice microphysics using spaceborne active sensors. *Journal of Geophysical Research: Atmospheres*, *116*(D20).

Stillwell, R. A., Neely III, R. R., Thayer, J. P., Walden, V. P., Shupe, M. D., & Miller, N. B. (2019). Radiative influence of horizontally oriented ice crystals over summit, Greenland. *Journal of Geophysical Research: Atmospheres*, *124*(22), 12141-12156.