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Full title: An algorithm to retrieve ice water content profiles in cirrus clouds from the synergy of ground-based lidar and thermal infrared radiometer measurements
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This paper demonstrates an algorithm for ice water content profile retrievals from ground-based lidar and thermal infrared radiometer measurements on an optimal estimation framework. The bulk optical properties rely on a parameterization that links the optical properties with the ice water content and temperature. At first, the shortcoming of the retrieval method based on lidar alone measurements focusing on the uncertainty in the lidar ratio is demonstrated. Then, the authors show that the combined retrieval method based on lidar and thermal infrared measurements benefits the ice water content profile retrievals by reducing the uncertainty due to the lidar ratio. The computed optical thickness from retrieved ice water content profile generally similar for optimally moderately thick clouds and is underestimated compared to the counterparts based on the two-way transmissivity approach.

Overall, this paper is well written and well organized. The methods are sound. The topic presented in this paper is suitable to Atmospheric Measurement Techniques. I recommend the paper for publication, once the several points below have been taken care of.

General comments

The current manuscript contains several grammatical errors and redundant descriptions. I recommend the authors to proofread the manuscript again and encourage to make the redundant descriptions shorter. These treatments may help readers understand the contents.

Minor comments

1. Pages 4–5: The authors should specify the following the instrumental characteristics: (1) The lidar pointing zenith angle; and (2) the FOV of the thermal infrared radiometer. If the FOV is not small enough, does the inhomogeneity of the

response function along with viewing zenith angles affects the uncertainty in thermal infrared radiometric signals?

2. Pages 7–8 “These two parameters are obtained for each cloud…”: These two paragraphs are confusing. The first paragraph mentions that the single scattering albedo and the phase function are obtained from the ice model introduced by Baran and Labonnote (2007). However, the second paragraph mentions that Vidot et al. (2015) parameterization is used to link the ice water content with several parameters including the extinction coefficient, single scattering albedo, and asymmetry parameter based on Baran et al. (2001), which is inconsistent with Baran and Labonnote (2007). I’m not sure if I understand these two paragraphs correctly. The inconsistent optical properties may arise an uncertainty, and the authors should clarify this. In addition, please make the first paragraph shorter. In the paragraph, although the authors introduce many parameterizations regarding ice properties, the paper only use the BV2015 parameterization.

3. Page 9, Equation 8: Should “<<” be “≤” or “<”?

4. Page 10: Please add the descriptions about the Jacobian K if it is the case that opaque cirrus clouds (lidar signals cannot reach to cloud top) are present. You may not have $\partial F_{\mathrm{j\_top}}/\partial \mathrm{IWC}_{\mathrm{j\_top}}$.

5. Page 19, Line 4 “*the COT decreases and with it the simulated radiances*”: Does this include a typo? Could you rephrase it?

6. Page 27 Figure 12 (e): Could you please reconsider the colors for the measurements? It is hard to recognize these plots.

7. Page 28, Lines 7–19: It is unfair to compare different qualities (i.e., COT and an effective COT). Since the author assumes the multiple scattering factor to be 0.75 for ice clouds throughout the paper, you can compare COT from the combined method with COT converted from an effective COT. In Figure 12c, although the effective COT is smaller than actual COT by 33% (if the multiple scattering factor =

0.75), I notice that the uncertainty due to multiple scattering factor cannot fully explain the underestimated COT from the combined method, particularly during UTC 16–17. The estimated lidar ratios are in the reasonable range (i.e., 20–40 sr) during the period. However, the effective COT from the two-way method is larger than the COT from the combined method by a factor of 2–3, and the multiple scattering factor of 0.3–0.5, which would compensate for the large effective COT, is unrealistic for ground-based lidar measurements. Therefore, I suggest the authors to add discussions in the paragraph regarding other potential sources that cause underestimated COT from the combined method. It may be good to mention a potential bias in the thermal infrared radiometer due to temperature.