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Comment on amt-2021-104

Anonymous Referee #1

Referee comment on "Comparison of mid-latitude single- and mixed-phase cloud optical depth from co-located infrared spectrometer and backscatter lidar measurements" by Gianluca Di Natale et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-104-RC1, 2021

Overview: Spectral measurements of downwelling longwave radiation from the Far-Infrared Radiation Mobile Observation System (FIRMOS) spectrometer at the Alpine observatory on the summit of Mount Zugspitze are compared to simultaneous lidar measurements of optical depth. The FIRMOS measurements can be used to retrieve cloud optical and microphysical properties such as the effective diameters of ice crystals and liquid water droplets, liquid and ice water paths, and the ice fraction. Based on the assumed power law relationship between backscatter and extinction, minimization of the root-mean-square differences between the FIRMOS and lidar optical depth retrievals are used to determine the value of the constant, *k*, for ice, liquid, and mixed phase clouds.

General Comments: The manuscript is well written and clearly understood. The scientific approach is valid, and the authors present some interesting results. For example, the power law relationship between ice water path and optical depth are in reasonable agreement with previous studies. Furthermore, the values for the exponent, *k*, which is often assumed as unity is relevant for the inversion of lidar data. Measurements of clouds in the far-infrared are needed in advance of satellite missions like the Far infrared Outgoing Radiation for Monitoring and Understanding (FORUM). However, there are some minor suggestions/corrections that should be considered before this work is published. For instance, the use of backscatter-extinction coefficient ratio to identify the exponent, *k*, could be an unnecessary cause of confusion. The small sample of liquid water clouds (only 10 cases) is not very convincing. At the very least, it should be noted that there is the potential that these may be misclassified from mixed phase cases. However, the strong results from the ice phase/cirrus cloud cases supersedes any weaknesses elsewhere, and this manuscript should be published after minor revisions.

Detailed Comments:
Page 1, Line 8: Though the term is used by Chan 2010, backscatter-extinction coefficient ratio does not appear to be widely accepted to describe the power law exponent, *k*, in most literature. In fact, it can be confused with the more commonly used backscatter-to-extinction ratio (or it's inverse, the extinction-to-backscatter ratio) which is used to solve the lidar equation. My suggestion is to avoid using this potentially confusing term

throughout the manuscript.

Page 6, Line 147: The choice of ice water fraction, $\gamma < 0.3$, to identify water clouds may result in misiclassification of mixed phase. For example, Turner 2003 uses a cutoff of 0.2 which includes a majority of the 10 liquid water clouds in the sample judging by Figure 3. However, as noted by the authors, without the availability of depolarization measurements it is difficult to determine the vertical distribution of thermodynamic phase. It should be noted, though, that the majority of the liquid water phase is indistinguishable from mixed phase in Figure 3 (OD, LWP, effective diameter, and temperature), with the exception of ice water fraction.

Page 10, Line 189: Could the differences in wavelength (532 nm vs. FIR) also contribute to the differences in optical depth? If so, how does that affect the other results of the study (e.g. *k* retrieval).

Page 10, Line 193: The sentence beginning with, "In order to check whether the habit choice does not affect the OD retrieval…" could be more clearly expressed as, "In order to check whether the habit choice affects the OD retrieval…"

Page 11, Line 231: How many cases are removed in order to determine the optimal value of *k*? And are such removals necessary for ice, liquid, and mixed phase clouds?

Page 12, Lines 243 – 244: The high liquid water optical depths likely fully attenuate the lidar signal which is why it is not reproducible using the Klett inversion.

Figures 6 and 7: Because *k* is often assumed to have a value of unity, it would be instructive to see how that value compares to the optimal value determined from this study.

References:

Chan, P.W.: Determination of Backscatter-Extinction Coefficient Ratio for LIDAR-Retrieved Aerosol Optical Depth Based on Sunphotometer Data, Remote. Sens., 2, 2127–2135, 2010.

Turner, D. D.: Microphysical properties of single and mixed-phase Arctic clouds derived from ground-based AERI observations, Ph.D. thesis, University of Wisconsin–Madison, 35, 1–167, 2003.