Reply to reviewer comments amt-2021-104-RC1

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.

We are grateful to the reviewer for the positive and constructive comments and suggestions, which are all considered in the revised paper to improve quality and clarity.

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.

Agree with the reviewer and replaced the ambiguous term with the expression "power-law exponent k" throughout the text.

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.

This is a very good suggestion, it is totally true that the choice of the threshold on the ice fraction (γ) could result in a misclassification. We followed this suggestion to reclassify our cases using a cut off of 0.2 as done by Turner 2003 together with the condition that the absolute difference between the retrieved γ and the cut off must be larger than the retrieval error ($\Delta\gamma$) to identify the case as pure water, this in order to avoid any possible misclassification, namely:

water case if : $\gamma < 0.2$ & $|\gamma - 0.2| > \Delta\gamma \rightarrow$ otherwise mixed or ice

so that in this case we are sure that γ is below the threshold regardless of the retrieval error. In this way all previous cases classified as water turn out to be classifiable as mixed.

Figure 3-5-6-7 were modified accordingly. Particularly, in Figure 5 the RMS for mixed clouds was recalculated considering the corrected dataset and the water one was removed. Finally, the text was corrected accordingly to the adjustments.

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).

Actually, the optical depth shows a strong spectral dependence only in the infrared spectrum and not at the visible frequencies. The OD in the FIR is related to the OD at visible frequencies through Eq. (4) with the extinction efficiency, which can be assumed equal to 2 in the visibile range because of the large size parameter (Eq. (11)). Following this approach, the OD in the visible (specifically at 532 nm) retrieved from the lidar signal can be directly compared with the OD determined from the spectral measurements in the FIR. Therefore, the causes that produce the differences in the comparison of Figure 4 are mainly due to the not perfect co-location of the instrument (in particular the lidar is installed at a lower height of 300 m and 600 m horizontally) and, the different field of view (FOV) of the two instruments are different, in particular FIRMOS has a 22.4 mrad FOV, which corresponds at 5 km above the instrument (where usually cirrus occur) to a region of about 100 m of diameter, whereas for the lidar is much smaller.

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…"

Corrected in the text.

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?

16 measured spectra from the total of 261 were removed regardless of the type of clouds because of inconsistency between the FIRMOS measurements with lidar ones. In fact, in these cases, as you can see from the examples in the figures below (backscattering in the left panels), while the lidar signal decreases the FIRMOS signal increases. These cases denote that the two instruments are clearly observing different scenarios, so they were excluded from the analysis.
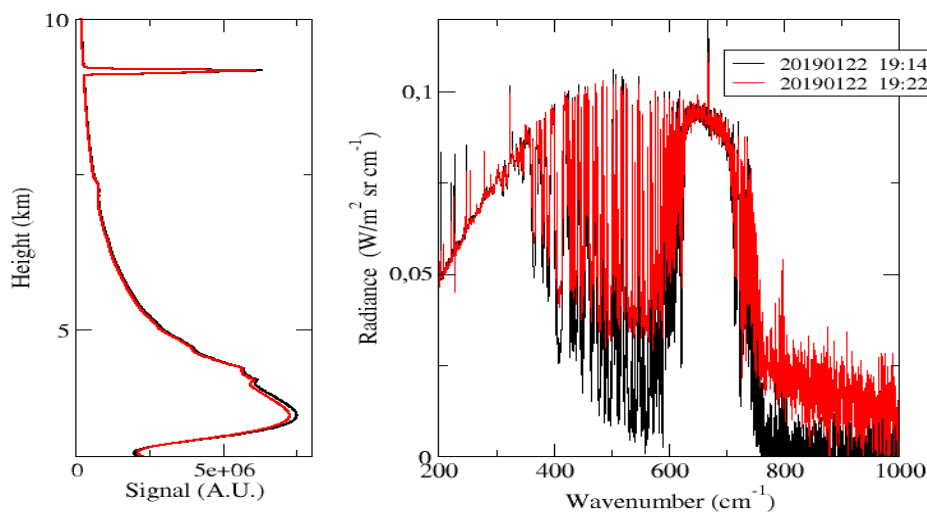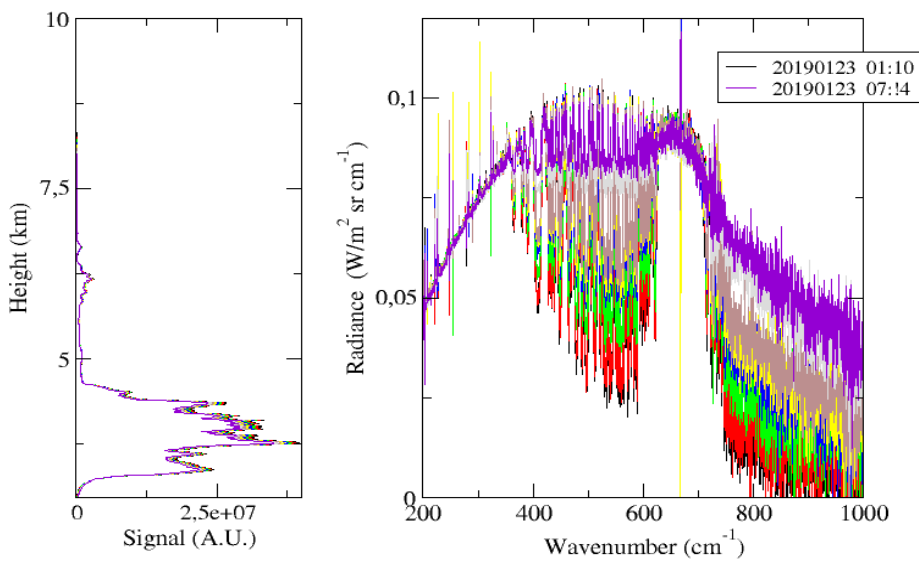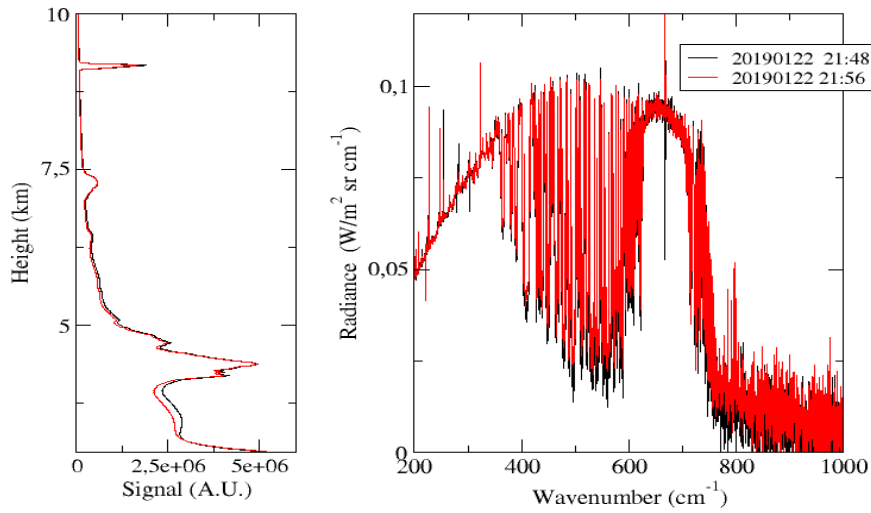
Correct. This sentence was also added to the revised text.

We thank the reviewer for this advise, we also added the curves of k = 1.0 in both panels of Figure 6.