We thank the reviewer for the careful and thoughtful review. Our responses are outlined in bold and italics below.

My only major comment is that the retrieval results are not evaluated sufficiently. The authors applied their method to data of probably the best-observed measurements site in the Arctic. Only a comparison of the retrieved LWP to MWR data is provided, whereas independent estimates of the other retrieval products are very likely available in the ARM database. In my opinion, this paper needs to provide a more adequately evaluation of the new method before it can be accepted.

We agree with the reviewer's comments and have now included an intercomparison with a retrieval method by Dong and Mace (2003). We have added a figure (Figure 13) illustrating the intercomparison. The accompanying text reads

The final comparison is between the infrared-based retrieval approach described here and an independent retrieval approach that has been applied to the same time period and location by Dong and Mace (2003). The Dong and Mace method is based on ground pyrometer measurements of solar shortwave cloud transmissivity and MWR retrievals of liquid water path. Combined with the solar zenith angle and measurements of surface albedo, Dong and Mace applied their technique to retrieve liquid cloud optical depth, cloud droplet effective radius, and with assumptions about the droplet size distribution, cloud droplet number concentration.

The infrared method described here begins to saturate for liquid water paths greater than 40 g m^{-2} whereas the Dong and Mace method, being based on MWR measurements, is less well suited for liquid water paths below 40 g m^{-2}. This means that the two methods could ultimately be used in a complementary fashion.

For the sake of intercomparison, we examined how well microphysics retrievals agreed for an intermediate regime between 20 g m^{-2} and 40 g m^{-2}, as shown in Fig. 13. For a period between May and September, the average LWP within this range was 29.26 g m^{-2} for the infrared method and 29.62 g m^{-2} and Dong and Mace method.

Overall, both techniques give very similar retrievals, at least in trends if not always in absolute values. Both approaches reveal a transition in liquid cloud r_e between late spring and summer from approximately 5 μm to 10 μm along with a commensurate relative decline in optical depth. However, in late spring, the Dong and Mace retrievals of r_e tend to be about one to two micrometers smaller, and this lends itself to as much as a factor of three discrepancy in retrievals of droplet number concentration. Nonetheless the transition to higher droplet concentrations between spring and summer is reproduced by both methods. In summer, the differences between both approaches are in general very small.

My other general comment is that in the way described in the present manuscript the method seems rather complicated and uses a lot of auxiliary data other than interferometer measurements. In my view, this considerably limits the applicability of the method.

The necessity of the auxiliary data is not (adequately) mentioned in the abstract, introduction and conclusions. Please list all auxiliary data needed for the method in the introduction, abstract and conclusions to make its limitations clear.

The conclusions have been rewritten to state
The primary limitations of the thermal IR approach discussed here are twofold. First, it requires a fairly extensive grouping of measurements to achieve its stated level of accuracy. Second, it requires that clouds cannot approximate blackbodies.

A similar statement is in the introduction. Table 1 has been modified by including all datasets used by the retrieval algorithm

Specific comments:
*Section 2.1:
Page 8657: Line 9: Mie theory is used throughout the paper for both liquid and ice. This is probably fine for the wavelengths considered, but a brief discussion and possibly a relevant reference would be informative.

To clarify this point, we have amended the text to read
"The retrieval algorithm described here is based on retrievals of a cloud particle ``effective radius" r_e and optical depth in the geometric-optics limit at visible wavelengths (τ). Here, r_e is proportional to the ratio of the bulk ice or liquid volume to the scattering cross-section of the particle, as introduced by Hansen and Travis (1974). The original definition r_e can be applied equally to all shapes, independent of whether they are spherical droplets or hexagonal ice crystals (Foot, 1988). However, because ice crystals are not spherical, the concept of effective radius does not relate directly to the ice crystal geometric size. Rather, it is a length scale used to calculate how efficiently ice crystal mass corresponds to radiative extinction. That said, at the infrared wavelengths considered here, the size parameter $2\pi r/\lambda$ of cloud ice crystals is sufficiently small to lie below the geometric optics regime where the details of shape become important. "

Line 12: Figures 3 and 9 are swapped. The x-axis in the figure is effective radius, although radius r is used in the text. Please make this consistent. Are the Mie calculations integrated over a size distribution? Please mention this in the text.

No, the Mie calculation is for a series of cloud droplet effective radii, and this has been corrected in the figure.

Figure 4: Please use the same y-axis scale on all figures for easy comparison.
Fixed

Figure 5: The caption mentions 'percent difference', but the right figure seems to give the fractional difference. Also the caption mentions dashed lines, but it is unclear to me in the left figure which lines correspond to 5 and 10 micron effective radius. In both

plots there are '5 micron' labels, and in the right there is a '50 micron' label, but it is unclear where they point to.

The figures have been adjusted slightly, and the caption now reads:
Range of re (dashed: 5 and 10 μm) and τ (solid: 0.5, 1, 2, 4, 8, 16) associated with the split-window difference ε_b - ε_e, depending on whether a cloud is assumed to be liquid or ice. The dotted line represents 1:1 perfect correspondence.
For example, a re = 5 μm liquid droplet in a cloud with an optical depth of 1 has a split-window difference that is lower than an equivalent cloud composed of ice crystals. Right: The difference in transmissivity within the ozone band associated with cloud phase assumption as a function of ozone band transmissivity t_{ozone} and cloud r_e.

Figure 6: please explain in the text how the boundaries are determined. In the text the quantity Chi is given, which is used later in the results discussion. I suggest changing the figure to show this ratio since in the results of the case study also Chi values are shown.

This point is clarified in the figure as suggested. The caption now reads
The unity ratio of the axes $\chi=1$ is shown by the dashed black line

The clouds for which the phase cannot be determined are labeled 'uncertain' here. In the rest of the paper, the authors sometimes speak of 'mixed-phase clouds'. Are the clouds labeled 'uncertain' the same as 'mixed-phase clouds'? Please clarify and be consistent throughout the paper.

With regards to mixed-phased clouds, we have modified the text to read
Clouds that are more spectrally flat, or in between ice and liquid, are not amenable to phase discrimination and are labelled ``uncertain''. In reality, many of these cases may be clouds that are in fact ``mixed-phased'', however the ambiguity in the retrieval prohibits us from identifying such clouds with certainty. Nonetheless, as will be shown, retrievals of cloud properties are relatively insensitive to an a priori *assessment of cloud phase, so retrievals of cloud properties are still performed where possible.*

*Section 2.3:
Equation 3: Where are the required N and Delta_Z obtained from? Please clarify in the text.

The text currently reads
To address this possibility, we first estimate a characteristic precipitation particle radius and number concentration using a precipitation retrieval method we previously developed in Zhao and Garrett (2008). This technique retrieves precipitation microphysical properties as a function of radar reflectivity and Doppler velocity.

*Section 2.4:

To me it is unclear why the transmittances in the P and R branches are calculated, but not in the Q branch. Moreover, I would assume it is only necessary to calculate the transmittance in the micro window that is used. This procedure seems to be overly complicated and needs to be clarified.

The text has been rewritten to clarify the method. It now reads
In order to constrain estimates of cloud emissivity, it helps to have an estimate of cloud transmissivity t since, to first order, $\varepsilon = 1 - t$. Cloud transmissivity is often estimated using the sun as a direct source. The drawback is that the sun can be absent for long stretches of time in the Arctic.

Here we estimate cloud transmissivity from the degree to which a cloud attenuates strato-spheric ozone emission within a 1038 cm^{-1} to 1042 cm^{-1} microwindow. Because ground based measurements of downwelling radiation include both cloudy emission and ozone transmission, cloudy emission must first be subtracted to obtain the ozone signal. Transmissivity can then be obtained if atmospheric ozone, temperature and moisture profiles are known.

The procedure for estimating cloud transmissivity within the 1038 cm^{-1} to 1042 cm^{-1} microwindow follows a series of steps illustrated in Fig. 8. In the first step, surface radiance measurements Imeas(ν) are corrected for precipitation emission to give

$I_{sky}(\nu)=I_{meas}(\nu)-\varepsilon P(\nu)B(T_P,\nu)$ (7)

In the second step, a wavelength dependent brightness temperature T_{cb} representative of cloud base is estimated from the relation $I_{sky}(\nu) = B(T_{cb},\nu)$. Intensity measurements are evaluated in two ranges, between 960 cm^{-1} and 975 cm^{-1} and between 1070 cm^{-1} and 1085 cm^{-1}. These spectral bands lie within the atmospheric window, but just outside the P and R branches of ozone emission.

In the third step, the prior estimates of brightness temperature from outside the ozone band are used to evaluate values of T_{cb} within the P and R branches associated with ozone emission. This is done using simple linear interpolation. The calculated value of T_{cb} within the ozone band is used to estimate the background radiance from all other sources than ozone and precipitation, $I_{bkg}(\nu)$, including clouds, water vapor and other greenhouse gases.

Fourth, cloud transmissivity t is calculated within the P and R branches of ozone emission. The calculated background emission I_{bkg} is subtracted from measurements of downwelling emission Isky withing the P and R branches. The difference is divided by calculated values of the clear sky downwelling radiance I_{clear} in the P and R branches that would be associated with an atmosphere without precipitation or clouds

$t(\nu)=I_{cloudy}(\nu)/I_{clear}(\nu)=(I_{sky}(\nu)-I_{bkg}(\nu))/I_{clear}(\nu)$ (8)

Values of I_{clear} are estimated using the LBLRTM radiative transfer model and measured profiles of atmospheric ozone, temperature and moisture.

Fifth, values of t that are calculated in two narrower spectral bands – 1020 cm^{-1} to 1040 cm^{-1} in the P branch and 1048 cm^{-1} to 1065 cm^{-1} in the R branch – are then used to interpolate values of t in the Q branch between 1040 cm^{-1} and 1048 cm^{-1}, thereby completing estimates of t within the ozone band. Interpolation is used because ozone emission is weak within the Q branch.

Finally, the desired values of t_{ozone} are obtained from a subset of these ozone transmissivity values, evaluated within a microwindow between 1038 cm^{-1} and 1042 cm^{-1}. This microwindow is chosen because water vapor absorption is particularly small in this band.

Figure 8: Please separate the two top "panels" for clarity.
This figure has been changed accordingly

Page 8662, line 2: "Other sources than ozone..." Please give examples here.
Page 8662, line 4: This first sentence is incomplete.
See modifications above.

*Section 2.5:
Equation 9: Probably the absolute difference is meant here. Please add absolute brackets or such.

True. We mean absolute difference. This has been added.

Page 8663, line 17: Please change "droplet size distribution" to "particle size distribution"

Changed.

Table 1: Change "ROSE-GOME" to "ERS-GOME"

Changed

*Section 3.2:
Page 8666, line 5-7: The Burrows et al. reference is a reference for the GOME instrument, not for the ozone profiles. Please move it forward, just after "ERS-GOME". Is the Lapaolo et al. reference the correct reference for the GOME dataset used here? Then please add it where the Burrows et al. reference is currently. I also suggest adding the source where this data was obtained from in the acknowledgements.

The GOME retrievals we used are the assimilated 3D ozone distributions from the World Data Center for Remote Sensing of the Atmosphere, WDC-RSAT (Hildenbrand et al. 2003). We have cited this reference and acknowleged this data source.

Line 10: I am surprised that the time resolution mentioned for the GOME retrievals is 6 hours since it is polar orbiting. Is this because the target is in the far North and orbit swaths overlap? Moreover, as far as I know, no retrievals are possible in the local winter, since there is little light (extreme solar zenith angles). The authors do give results for the whole year. Please clarify this.

The GOME retrievals we used are the assimulated 3D ozone distributions from the World Data Center for Remote Sensing of the Atmosphere, WDC-RSAT (Hildenbrand et al. 2003). In this dataset, the ozone profiles are derived by assimilating GOME ozone measurements into the 3D-NCAR-ROSE (NCAR Research on Ozone in the Stratosphere and its Evolution) chemical transport model. This dataset has 6-hour temporal resolution for all year period. However, we do find time that ozone profiles do not exist, for which monthly averaged ozone profile has been used instead. These points are now clarified.

Page 8666, line 24: For clarity add 'temperature' in front of 'profiles'

"temperature" has been added.

Line 26: For clarity I suggest changing "Other trace gases" to "Trace gases other than ozone"
Modified.

Page 8667, line 1: "Associated uncertainties". Please clarify which uncertainties you refer to (i.e. in which quantities).

The text now reads
Associated uncertainties in cloud property retrievals are less than 1% and not considered in detail

*Section 4:
Figure 10: The caption of the figure should be more informative. It was unclear to me what the contours and colors in this figure mean. I guess the labels indicate percent differences as I make up out of the text. Also, the contours seem to end at tau=14 for no apparent reason.

The caption has been rewritten to read
"Calculated uncertainties in retrievals of liquid cloud re, LWP and N that are associated only with the look-up table method outlined in Section 4, separate from any errors associated with uncertainties in measurements. Errors (contours) are expressed in percent within a space of re and τ for a cloud with fixed boundaries and a specified atmospheric profile."

Page 8668, line 4: "Sect. 4" should be "Sect. 3" if I'm correct. Line 27: remove the "and" before "38%"
Corrected

*Section 5.1:
Figure 11 and 12: It is unclear what the different contours indicate.
The captions now make clear that these are linear probability density distributions

Page 8670, line 3: Please add "additional" before "uncertainties".
Done

*Section 5.2:
Figure 13: In the caption of this figure it says that only the 14% with differences above 0.1 micron are plotted. This is probably a typo since in the figure itself and in the text this number is 0.01 micron. Please change the last word of the caption ('circles') into 'Symbols'. Please also add to the caption that the symbols indicate PWV. In the legend add hyphens between the range values (e.g., 0.5-1).
The typo is corrected

*Section 5.3:
As indicated in my major comment above, I think this case study should include some independent data to compare the results with.
Figure 13 now shows such a comparison with the accompanying text described previously in this response

Figure 15: I suggest not showing the cloud boundaries on a log scale, but on a linear scale. Also, I suggest using colors to separate ice, liquid and 'uncertain' retrievals, since the diamonds and open circles are hard to distinguish.
We chose a log scale since both low-altitude stratus and high altitude cirrus are in the Figure. Colors have been added.

*Section 5.4:
The results shown in figure 16 appear to be a wonderful, useful dataset. It would be very informative to mention whether the dataset is available or what the future plans are for this dataset.

We are currently unfunded for this research, but the datasets are available on request.

Figure 16: I suggest using more distinct colors than cyan, blue and black.
Changed

In the caption there is a bracket missing after "(liquid... ".
Fixed

Also the y-axis label for number concentration is confusing in this way and can be interpreted as $cm^{-3} l^{-1}$.
This is now changed so that all are in per centimeter cubed.