Responses to Reviewer 2

Review of the manuscript titled: “Measurement Report: Differences in cloud optical and microphysical properties in the Arctic and Antarctic derived using thermal infrared spectroscopy”, by Joseph Hung, Penny M. Rowe, Christopher J. Cox, Emily M. McCullough, Liam Kroll, Raia Ottenheimer, Matthew D. Shupe, Von P. Walden, and Kimberly Strong

General Comments:

The Measurement Report compares cloud properties from two ground sites, one in the Arctic and one in Antarctica using AERI instrumentation. The authors constructed a robust retrieval of cloud optical depth, thermodynamic phase and effective radius of liquid and ice particles. This retrieval allowed for the investigation of a long-term record of these cloud properties in Eureka, Canada. In addition, the study provided detailed measurements and analysis of polar cloud properties at two locations, exploring the similarities and differences at these high latitude sites. Ultimately, this study serves as a valuable contribution to the characterization and understanding of mixed-phase and supercooled liquid clouds, which have strong implications for the Earth’s radiation budget.

Novel insights between the differences of the results at Eureka and that of McMurdo were explored in detail, framing the new results within the context of well-referenced studies. In addition, the study considered and described data caveats well, including differences in cloud boundary methodology and discrepancies in the span of the measurements. The writing was clearly presented, and I recommend the manuscript for publication after the following items are addressed.

The authors thank the reviewer for their thorough review and suggestions. Point-by- by-point responses are provided in red to each comment below. Text that has been added and/or changed in the manuscript is given in blue. Line numbers refer to the location of changes in the revised manuscript, unless otherwise noted.

Specific Comments:

Does the CLARRA retrieval report uncertainties? There is little discussion of the retrieved uncertainties and how that factors into the validity of the comparisons throughout the paper.

Being an optimal estimation-based retrieval, CLARRA does provide a retrieval covariance matrix in the standard output product. However, due to the nonlinearity of the inversion problem, this becomes a strict underestimation of the true error (often a very significant underestimation) because it does not capture important sources of error such as cloud inhomogeneity, cloud boundaries, ice crystal habit, and sky scene subsampling. For this reason, we chose not to report the OEM covariance as an uncertainty. Instead, the manuscript discusses several of the aforementioned error sources:

- sensitivity to cloud base (Appendix B)
- uncertainty associated with assumed ice crystal habit (and more generally, the lack of infrared sensitivity to different ice crystal habits)
- reduced sensitivity to thin/thick clouds
- sampling bias from precipitation, humidity, and other quality control filtering

Figure 1: Adding the latitude and longitude of each location in the caption would add clarity to the Figure.

Done

Table 1: Add the radiosonde types to the table for completeness. Also listing the surface meteorology data used would be useful to know (i.e. 2m temperature, 2m RH, . . .).

This info has been added to Table 1

For radiosonde types:

- At Eureka: Vaisala RS92 (2006-2019) and GRAW DFM-09 otherwise.
- At McMurdo: Vaisala RS41

Surface meteorology:

- 2m and 10m temperature

Line 162: Is section 2.1 the correct section to reference? I am not finding the description there in the instrumentation section.

It was not the correct section to reference; line 176 has been updated to "...using temperature, pressure, and trace gas profiles described in the preceding paragraph..."

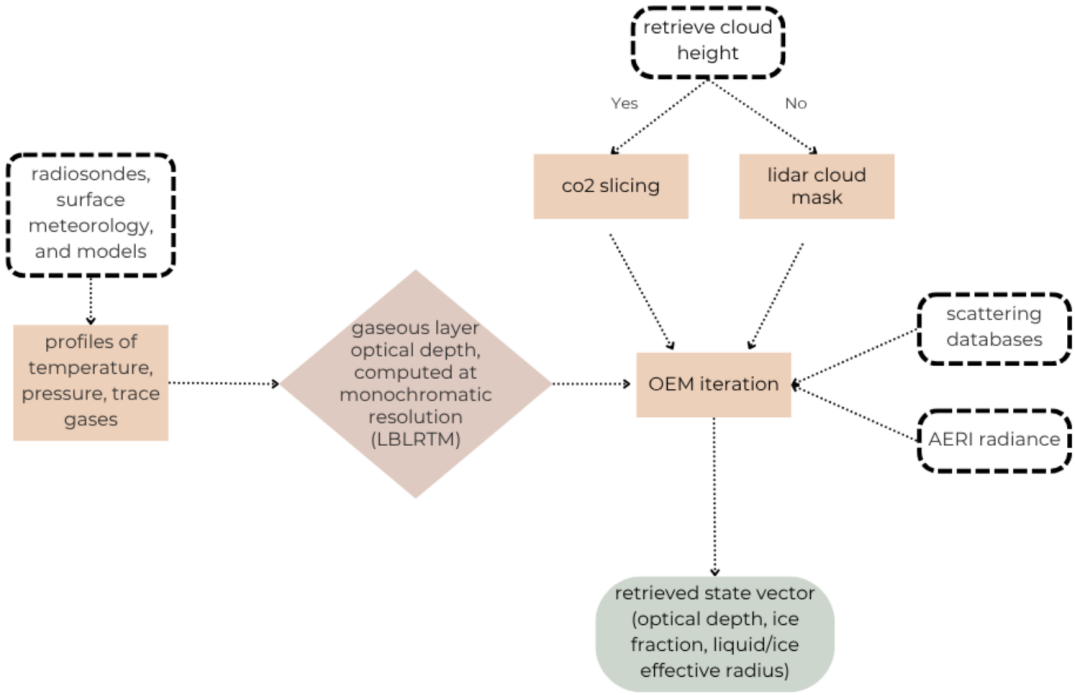
Table 2: Were there any sensitivity studies done on the channel selection? Or what is done completely by inspection of micro windows and based on the previous studies referenced?

No sensitivity studies were performed as part of this work – we rely on the substantial investigation already done in the sensitivity of appropriate spectral regions by the cited works.

Figure 3: Make sure the input to the left side of the figure is complete (list all inputs to the model). For example, does the box of "profiles of temperature, pressure, trace gases" also use surface meteorology as data input to account for reflected upwelling LW? What remote sensing is used as data input?

The left-hand input box has been updated to "radiosondes, surface meteorology, and models", and "scattering databases" has been added as an input to the OEM iteration box. However, reflected upwelling LW was not accounted for in the forward model.

The "remote sensing" input was a holdover from an old version of the retrieval where we had experimented with using surface/satellite measurements for trace gas information and has been removed from the updated version.



Updated Figure 3

Line 183: Is this considered "radiative closure" or "radiative consistency"? This quality control check is a good one.

The text on line 196 has been updated to "… to provide radiative consistency with the best-knowledge thermodynamic state…" rather than "radiative closure" to reflect that this is primarily a quality control measure, and we are only ensuring agreement for narrow windows of the spectrum.

Line 240: Figure 5 does not indicate the mean ice fraction.

The monthly mean ice fraction has been added to Figures 4, 5, and 7.

Last line of the caption in figure 4: suggest changing "monthly mean" to "weighted monthly mean" or change the legend in the bottom panel.

Figure 4 caption has been updated to "weighted monthly mean".

Line 277: Clarify what "this bias" is referring to.

This was a poor choice of wording, and incorrect sentence order. We have reordered the text (on line 292) to say:

"Liquid-only clouds were also almost always supercooled. This may be significant as smaller, supercooled, liquid droplets will generally have larger albedo (at solar wavelengths). Note that references to seasons at McMurdo are offset by 6 months against seasons at Eureka and are referred to hereafter as austral seasons."

Line 297: The previous sentence says there is no seasonality at McMurdo, in contrast to this sentence on line 297. Perhaps reword as "the small seasonal differences".

Done

Lines 363-364: I don't see how the variability of optical depth is similar at both locations. The variability at these two locations looks different in Figure 9.

Line 376 has been updated to:

"The seasonal variability of optical depth is similar at both locations…"

To clarify that the seasonal cycles are similar, but not the magnitude.

Line 378: What is meant by “an annual cycle around 10 um”? Is that the same things as “an annual mean value of 10 um”?

Yes, the text on line 395 has been updated to “… Shupe et al. (2015) considered all clouds and also found an annual cycle centered around 10 um…”

Figure B1 caption: Change “of the CBH error” to “of the CBH difference”.

Done

Technical Corrections:

Line 29: Remove extra semicolon after “hydrometer”.

Line 105: Suggest changing “Earth’s emission spectrum” to “downwelling atmospheric emission spectrum.”

Line 124: Suggest changing “quick-looks of” to “example”.

Line 152: Change to “radiative transfer output”.

Line 185: remove the word “sky”

Line 277: Change “solar” to “shortwave” as the sun emit wavelengths into the infrared.

Line 318: Suggesting changing “to note the extent” to “to note that the extent”

Line 378: space between “10” and “um”

All have been done