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Atmospheric Measurement Techniques Discussions

Interactive comment on "Toward autonomous surface-based infrared remote sensing of polar clouds: Retrievals of cloud microphysical properties" *by* Penny M. Rowe et al.

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Reply to Referee 2. We indicate a referee comment with "Referee" and our response with "Authors".

Referee: The methodology is clearly stated, adequate references are made to work by earlier studies although more recent articles may be available, and the analyses are straight-forward. I am glad to see that the software is being made available to the community as described in Section 7. My view is that the paper is suitable for publication pending relatively minor revisions that address the comments that follow.

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Discussion paper

If there is one primary suggestion to offer, it would be to compare the cloud properties obtained by this method to those obtained from CALIPSO, where new Version4 products are now available (or to a coincident ground-based lidar if possible). Of particular note is that the V4 products have significant improvements in calibration and cloud/aerosol properties. There will be differences between satellite- and surface-based products that will bear further investigation, but this may be outside the scope of this particular study. CALIPSO cloud products have been used heavily in the development and testing phase of many satellite-based cloud retrieval efforts, especially with the discrimination of cloud thermodynamic phase which is a critical component of the current study. As noted in Section 5.4, imperfect cloud phase discrimination can greatly increase the retrieval errors (lines 500-505).

Authors: This is a good suggestion but is unfortunately beyond this scope of this work. We will compare cloud property retrievals using CLARRA to CALIPSO in future work and thank the referee for this suggestion.

Referee: General comments: Lines 58-62: Two points to suggest here: 1. The authors point out the need for portable, low-cost, autonomous IR spectrometers that can make continuous measurements. But these measurements complement those from polar-orbiting IR spectrometers including IASI (on Metop-A/B/C), AIRS, and CrIS. It would be useful to provide an example where the surface measurements fill the gaps between satellite overpasses. 2. Additionally, a primary benefit to surface-based measurements is that the boundary layer is much better characterized than with profiles inferred from a satellite-based spectrometer. In particular, my impression is that the boundary layer profiles are much improved when temperature inversions are present, and this will impact the cloud properties if the layer is at/below the inversion.

Authors: This is a good point. We will add text such as the following to the introduction:

“Such measurements would be beneficial in a number of ways. They could be used to fill gaps in satellite measurements. For example, cloud properties were retrieved at

Eureka from 2006 to 2009 from AERI measurements made nearly-continuously every ∼40 seconds (Cox et al 2014). By contrast, satellite overpasses are typically twice per day. They can also be used to compare to satellite-based measurements. Finally, surface-based instruments are better at characterizing clouds in the boundary layer."

Referee: Section 3: This is a long section (over 6 pages) that discusses the Cloud and Atmo-spheric Radiation Retrieval Algorithm (CLARRA) in quite a bit of detail. Cloud height was discussed in great detail in Rowe et al. (2016) and is not repeated herein. Perhaps the readability would be improved by moving much of the theoretical development into an Appendix.

Authors: We have moved the theoretical development from Section 3.1 to the Appendix (almost 3 pages). To further improve readability, we have reorganized subsections in Section 3 and included the most important information in introductory paragraphs, making clear that the remainder of each section provides additional detail (which can be skipped).

Referee: Minor comments: Line 19: please define exactly what is meant by "mixed phase" - is it a homogeneous mixture of ice and liquid particles or something else?

Authors: Yes. We have clarified this: "Mixed-phase clouds were simulated as an external, homogeneous mixture of liquid and ice particles."

Referee: The word "infrared" appears 26 times in the paper - could contract to IR

Line 47: include more up-to-date L'Ecuyer papers, e.g., "Reassessing the effect of cloud type on Earth's energy balance in the age of active spaceborne observations. Part I: Top-of-atmosphere and surface", by TS L'Ecuyer, Y Hang, AV Matus, Z Wang, in Journal of Climate, 2019. There is also a Part 2 manuscript in review.

Lines 293-294: Radiances are selected in two bands: 400 to 600 cm-1 and from 750to 1300 cm-1. As the method is using selected wavenumbers for each chosen spectral resolution, it would be useful to state them in this paper rather than in the supplemental.

Lines 340; 352; 557: suggest changing “in order to” to “to”

Line 356: change “found such error” to “found such errors”

Authors: Thank you - all of the above changes have been made.

Referee: Lines 503-505: Cloud height: is CO2 slicing used for both water and ice clouds? If so .... might want to change this so it’s used primarily for ice clouds and use 11-μm for optically thick clouds.

Authors: This is an interesting point but is beyond the scope of this work, which focuses more on the microphysical retrievals than the cloud height retrievals (discussed in Rowe et al 2016). We will investigate using 11 micron for cloud height retrievals in future work, and thank the reviewer for this suggestion.

Referee:

Line 536: Polar Regions does not have to be capitalized.

Line 561: suggest changing “correctable” to “mitigated”

Authors: We have made the above changes.

In addition to these changes and changes in response to the other reviewer, we have added a new figure (Fig. 4) and made a number of edits for grammar and clarity. We also made small changes in the retrievals (e.g. standardized number of streams to 16, removed radiance error threshold); resulting differences are minor and do not affect our conclusions.

We thank the reviewer for these helpful suggestions that have improved our paper.

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