

Interactive comment on “Cloud thermodynamic phase detection with polarimetrically sensitive passive sky radiometers” by K. Knobelspiesse et al.

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We are very grateful for the referee's thoughtful and considerate review.

The referee raises an important point regarding the choice of validation scenes (Figures 11 and 13). The scenes we selected are indeed complicated and potentially subject to cloud heterogeneity, which would contribute to Q variability and thus difficulty determining thermodynamic phase. Since Figures 11 and 13 illustrate a single day alone, the true test of our method, however, is the scatterplots in figures 12 and 14. Our goal was to showcase a single day as an example of what appears to be a realistic Q response

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to thermodynamic phase (or rather our proxy for it, cloud base height), even in difficult situations. Specifically, we searched for data where there was a transition from high clouds to low clouds so that we could show the value of Q responding accordingly (from negative to positive values). What we failed to do was to fully consider and discuss the impact that multi layered and multi phase clouds have on the observations. In fact, Figure 9 shows how an ice cloud above a water cloud has a surprisingly large impact in the observed value of Q . Since we chose scenes with a low cloud arriving under an existing high cloud, we should consider the very real possibility that this is the case. We have therefore significantly modified the text regarding these figures to better explain our motives for displaying them, and to emphasize that the scatterplots (Figures 12 and 14), are the best overall test of cloud phase determination ability. In addition, we checked with the validation (cloud base height) data to see if there were any indications of multiple cloud layers for the data presented in Figures 11 and 13. With the exception of a small portion near UTC noon in Figure 11, we did not find this to be the case (the cloud phase for this section was 'unidentified' for the smoothed Cimel data). This means that for most of these scenes, there were either no multiple layers, or the lower cloud was optically thick enough that the validation instruments (LD-40 Ceilometer and Micropulse Lidar) did not detect an upper cloud base. Additional screening to remove multiple cloud layers did not affect the scatterplots in Figures 12 and 14 in any noticeable manner. In light of the suggestions to provide instrument details earlier in the paper, we provided brief information about AERONET Cimel properties in the introduction.

Sequential comments: P11992, L15: "quantity" of polarization is somewhat unspecific. How about "contrast" between liquid/ice for the second element of the Stokes vector

A good point. We used "fraction of linearly polarized to total light"

P11992, L24: "comprise" or rather "constitute"? Something seems wrong with this sentence.

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Thanks. Modified to "compose".

P11992, L26/L27: "For this reason, we had no information..." From the abstract alone, one cannot see the logic connection here. The uncertainty aspect is an important part of the manuscript and should be mentioned here, but perhaps a little bit more detail would help.

Agreed. We added a sentence and changed some things around to hopefully make this better.

P11993, L27: "Since this uncertainty. . ." Not enough detail is given here - what uncertainty are we talking about - is this statement needed? If so, a better description of DRAGON and its relevance for this paper is needed.

Agree that more details are needed. We included a link to the DRAGON white paper, and rephrased to show that this is an example of how things can go wrong without phase information, and their significance in terms of COD retrievals.

P11994, L1: ". . .our ability to improve climate models. . ." This is a "broad-brush" statement which should either be made more specific or omitted (the manuscript does not seem to need this kind of motivation).

Agree that this is too broad brush, and it has been omitted.

P11995, L9: "To correspond with AERONET instrument spectral sensitivity..." What does the spectral sensitivity have to do with the selection of channels? Also, CIMELs are not spectrometers, so "radiometric response" would be more appropriate than "spectral sensitivity".

Changed "spectral sensitivity" to "spectral channels"

Figure 2: Add a line at viewing angle of 0deg?

Done.

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Figure 2/3: The "crossover" point of Q_{liq} and Q_{ice} at about 30deg in Fig 2 is interesting, but not sufficiently explained in the text. Is it related to the crossover shown at 15deg in Figure 3b?

This is indeed very interesting! We did not consider this prior to submitting the article, but have now re-examined our simulation results. The "crossover" (neutral) point in Figure 2 does correspond to the P12 sign change in Figure 3 (both are at scattering angles of roughly 15-18 degrees). This angle persists, with minor variation, for all the cloud scenes we simulated. Unlike neutral points in a cloudless sky (which do not originate in Rayleigh single scattering), this point persists from single to multiple scattering. We added a few sentences describing this – than you for pointing it out!

Figure 4: This is a very nice Figure, almost the "paper at a glance", which explains very nicely why using Q is superior to DoLP (or $abs(Q)$ in this case, since $U > 0$).

Thanks! We feel the same way, this is perhaps the most important figure in the paper.

P11998, L5: "at left" → "on the left"

changed

P11998, L17: Fix "The optical depth. . .occurs at. . ." (this sentence does not work, use "value. . ." ". . .at which" instead?)

Changed the wording of this sentence somewhat

P11998, L18: "converge to zero for $COD > 13$ " is clear, but could be formulated better, perhaps using something like e-folding value of COD or something similar?

See above

P11999, L20: "Since cloud chamber, in situ and remote sensing..." please remove comma, otherwise sentence becomes incomprehensible. Alternatively, omit "since" and break up the sentence in two, starting a new one as "Therefore, we have performed. . ."

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We split this into two sentences as suggested.

P12000,L1: "measurementperspective" -> "measurement perspective"

Somehow this has happened during typesetting, we'll confirm that it is removed.

P12000,L5: "totally" -> "completely" (totally sounds too colloquial)

done

P12001, L12-15: This overview paragraph may be more appropriate earlier on in the manuscript (introduction). Also, I think that the authors are too modest in their assessment that their method is not as powerful as others. Rather, the various different methods complement one another and have their specific advantages/disadvantages.

We attempted to reduce our 'modesty' and clarify a bit this paragraph, but kept it in the same location as a conclusion of the Simulation section of the paper.

P12002, L7: Is the 1640nm channel used in this study? It is not shown in Figure 7 and would be interesting to include.

Our original simulations were performed in anticipation of comparison to the older, single polarimetrically sensitive channel, AERONET Cimel instruments. 1020nm was included so that standard "cloud mode" AERONET retrievals could be performed. When we became aware of multispectral polarimetric data from the newer instruments, we considered updating our simulations. However, we had difficulty determining the polarimetric reference frame of the 1640nm channel on the Cimel (as in Figure 10), which seemed inconsistent with other channels. Considering that we already had several channels available for analysis, we did not redo our simulations. This will happen in subsequent research.

Figure 11 and discussion: I wonder why the authors chose such a complicated scene for initial algorithm tests (see also major comment above).

Yes, please see our response above.

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Figure 11+13 are hard to read, enlarge?—Figure 11: Add Q=0 line horizontal line?—Figure 12: What is the range of dates that was used to generate this figure?

In our submitted manuscript (in "printer-friendly" format), these figures are bigger, presumably they would be so in a printer friendly version of the final document. We did not add a Q=0 line because there are already three horizontal lines, and the Q based color tagging of phase type indicates position with respect to Q. We added the date range for Figure 12 in the caption.

P12004,L27: What kind of noise? And how does the Figure show this? Can the deviations (Q up to +0.2 and -0.2) explained with the uncertainty analysis performed in the appendix, and be traced back to random noise, or do they exceed these values? Is it possible that there is also another physical explanation for this (see major comment above).

We respond to this above as well. However, it is important to note that the uncertainty analysis in the appendix is our best estimate of measurement uncertainty, and may omit other sources.

P12005, Figure14. This is good because the negative correlation of cloud base height and Q is what we want to see! Maybe this should be emphasized more because Figure 12 does NOT show it.

Agreed. We mention a weak correlation in the conclusion. This provides hope that the multispectral Cimel instruments could be used operationally for this purpose if we get a better understanding of polarization reference frame, measurement protocol, and other factors. This paper is motivation for making the effort to do so.

Additional changes: We modified an incorrect acronym usage (MPLnet to MPLNET) and changed the Acknowledgements section to properly thank the MPLNET team.