Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-380-AC1, 2020

Atmospheric Measurement Techniques
Discussions

Interactive comment on "Spatial distribution of cloud droplet size properties from Airborne Hyper-Angular Rainbow Polarimeter (AirHARP) measurements" *by* Brent A. McBride et al.

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Received and published: 14 January 2020

The authors thank Anonymous Reviewer #1 (AR #1) for their thorough review of the manuscript. The reviewer's comment will be outlined in quotes and the author response will be given underneath for ease.

AR #1:

"My understanding is that the technique measures up to 3 optical depth, although the majority of the signal comes from the first OD. Is this layer really representative of the cloud depth ? In particular, I wonder how the modeling results that are shown in Figure

8 are integrated over the vertical for comparison with the radiometric estimate."

Author Response:

This layer is not representative of the total cloud depth (except for clouds on the order of COD ∼3), but the sizes retrieved there serve as a tracer for microphysical processes going on toward the cloud top (i.e. condensation) and potential complexity on the cloud periphery. As per AR #1's recommendation, we will be more explicit in the paper about the penetration depth of the polarized signal and how representative it is for the entire cloud depth.

As per AR #1's second point, the "ATEX clean" simulation (Figure 8c) is described in detail in Miller et al. (2018), already takes into account the vertical weighting of the droplet size distribution in each grid box. Miller et al. (2018) do a sensitivity study, shown in Figure 3 of that paper, that compares a radiometric retrieval of CDR and COT on the LES field to the vertically-weighted parameters of the LES simulation and the results are quite good. When a theoretical polarimetric retrieval is applied to the same LES simulation, the correlations between retrieved and vertically-weighted CDR and CDV are again, quite good (Figure 4 in Miller et al. (2018)). This result suggests that vertical weighting techniques can theoretically reproduce both the polarimetric, single-scattering signal at cloud top and the radiometric signal, which comes from multiple scattering throughout the cloud.

We would ideally need a co-incident radiometer with comparable resolution and necessary channels for a data-based study between radiometer and AirHARP estimates of droplet size properties, as discussed in the manuscript. This scenario was not available for this dataset, unfortunately. We anticipate future AirHARP aircraft campaigns with a cloud focus such that we can provide a data-driven study of this kind.

AR #1:

"Also, I wonder why the authors have limited their analysis to the 670 nm band. The polarized radiance of the cloud shows large spectral variations that are sensitive to the droplet size and variance. Thus, it is unfortunate that the authors have not used this piece of information either to derive additional information, or to make a consistency check based on the variability between the various spectral estimates."

Author Response:

The authors did not limit our study to the 670nm band, as AR #1 suggests. In fact, it was the opposite; the HARP instrument was proposed to perform hyper-angular cloud retrievals at up to 60 viewing angles at 670nm, at the pixel-level and across a spatial field. This paper serves as the validation of this new technology. Furthermore, our study shows that a single polarized wavelength, with sufficient viewing angles, is enough to retrieve cloud droplet size properties. There is supporting evidence in the literature (Alexandrov et al. 2016 and other referred papers from this author) and Mie scattering curves at different wavelengths are degenerate for a given CDR and CDV (Figure 1a).

AR #1 suggests that using multiple channels could serve as a consistency check, however, it is possible that the lack of along-track angular coverage in the other three AirHARP channels makes the retrieval less robust than the 670nm hyper-angular method presented in this paper. The other three AirHARP bands are not hyper-angular: at 20 distinct view angles each, they sample the cloudbow at the same pixel three times less frequently than at 670nm. The limited coverage in these other channels may not always capture the cloudbow oscillations, especially for narrow size distributions. Therefore, the non-670nm channels may introduce more uncertainty to a joint retrieval than what already exists in the hyper-angular 670nm retrieval. On the other hand, adding the other channels may provide more information about above-cloud aerosol, Rayleigh scattering, or improve thermodynamic phase or multi-layer cloud discrimination. This complexity requires its own sensitivity study and would distract from the focus of this paper, if included.

As discussed in the manuscript, the joint spectral retrieval can also be done in a completely different way: cross-track, instead of along-track, similar to the method in Xu et al. (2018). This concept alone warrants its own study: while the underlying retrieval method is the same, the way it is done is wholly orthogonal and contains uncertainties different to the method presented in this paper.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-380, 2019.