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Interactive comment

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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The authors thank Gerard van Harten (GvH) for his thoughtful review, encouraging recommendations, and public comment on this manuscript. His review greatly enhances our ability to make this paper the best it can be. The authors response will be underneath a reproduced version of the reviewer's comments for ease.

— GvH:—

AirHARP's native pixel size is 50x50 m2. However, data and retrievals presented in the paper are from 200x200 m2 superpixels. I encourage the authors to reconsider

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Discussion paper

showing retrievals at 50m resolution, given the specific attention in the paper to the impact of spatial resolution on droplet size retrievals, and statements such as:

“Our retrievals from this dataset show that cloud DSD heterogeneity can occur at the 200m scale, much smaller than the 1-2km resolution of most spaceborne sensors. This heterogeneity at the subpixel level can create artificial broadening of the DSD in retrievals made at resolutions on the order of 0.5 to 1 km.” (P1_31)

The motivation for binning to 200m is “to increase SNR and mitigate other potential artifacts in the data. These artifacts will be discussed in Section 6” (P10_21). However, it is not clear to me from Section 6 what exactly is the problem at 50m resolution, and the positive results at 200m rise the question if 50m could still be usable for the paper:

Section 6 (P14_21): “Conservative cloud identification and binning pixels to 200m (4x4) resolution further mitigates the error introduced by using this mean height. . . . all retrievals shown successfully fit the RMSE threshold defined above. Therefore, we believe errors in our geolocation do not contribute significantly to the results of our study.“

Author’s Response:

The authors were excited to see GvH’s encouraging recommendation and perspective here. We will explain why this idea was initially considered for the paper but ultimately not done.

First, this paper wears several hats. It is the debut of the HARP instrument concept in the peer-reviewed literature, and so must (1) introduce the instrument, (2) provide the rationale for existing alone and alongside other modern cloud-measuring instruments, (3) make a firm case that these cloud measurements will and/or will not translate to space-borne platforms, and (4) ensure quality-assurance of the results, and (5) create a focused and concise story. These five major points, especially (3) and (4), are what contributed to cutting this study from the paper.

It is important to note that we can perform the cloud retrieval at 50m on this AirHARP dataset. In fact, we did during the testing and evaluation of the retrieval, and we encourage the community to explore AirHARP data at this resolution. There are several factors that led us to using 200m retrievals in this story:

(1) Is it useful to show 50m retrievals in a paper that uses AirHARP measurements as a proxy for HARP CubeSat and HARP2? These two instruments will not achieve 50m ground resolution from orbit; they are expected to see 400 and 700m native pixel resolution at nadir (and will continue bin for SNR and data storage). Therefore, we chose to show the retrievals at 200m: we can highlight the unprecedented, co-located resolution of HARP for this kind of retrieval and stay comparable to the pixel sizes of these other space-borne sensors with minimal binning. We can also extend this comparison to radiometric data. Our retrieval resolution is on the same order as today's operational L2 cloud products (i.e. MODIS, VIIRS, ABI).

We also felt that adding this study either together with the 200m retrievals or alone would put a larger focus on AirHARP, rather than framing the AirHARP results shown here as a proxy for HARP CubeSat and HARP2. The authors are concerned that this would detract from the overall message of the paper. We will change the paper text to make this message more obvious:

P1, L34: "This AirHARP study demonstrates 35 the viability of the HARP concept to make cloud measurements at scales of individual clouds with global coverage, and all in a low-cost, compact CubeSat-size payload." was changed to "This study, which uses the AirHARP instrument and its data as a proxy for upcoming HARP CubeSat and HARP2 spaceborne instruments, demonstrates the viability of the HARP concept to make cloud measurements at scales of individual clouds, with global coverage, and in a low-cost, compact CubeSat-size payload."

P5, L6: "In this paper, we will first describe the HARP concept, with a focus on the AirHARP instrument and its data as a proxy for upcoming HARP CubeSat and HARP2 space instruments." was changed to "In this paper, we will first describe the HARP concept, and frame the AirHARP instrument and its data as a proxy for upcoming HARP CubeSat and HARP2 space instruments throughout the rest of the work."

(2) We estimate our error in geolocating the cloud deck altitude at +-50m in the vertical, as mentioned in Section 6. Doing retrievals at the same scale may not maintain the quality of those done at larger superpixel sizes. In this direction, the larger 200m (and even 600m) superpixel size increases measurement SNR, mitigates geolocation errors, and allows us to use superpixel standard deviation to evaluate our retrieval fits (x2red). We will change the paper text to make this more obvious:

P14, L31: "Therefore, we believe errors in our geolocation do not contribute significantly to the results of our study." was changed to "Therefore, we believe errors in our geolocation do not contribute significantly to the results of our study shown at 200m or 600m resolutions."

The authors ultimately decided to keep the paper concise and focused, without sacrificing information content. There are many opportunities to expand this work in the future, especially with new AirHARP campaigns that specifically target clouds with other comparable instruments and as our data correction algorithms mature. We again thank GvH for his recommendations.

— GvH: —

- P2_15: "clouds would not exist at the scale we see them today": vague

- P3_21: "Reidi" -> "Riedi"

- P4_22: "fourier" -> "Fourier"

- P4_35: "modeled correlations" -> "image-specific empirical correlations"

Author Response:

All minor corrections will be changed as noted.

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P2,L15: “These particles seed both liquid water and ice clouds in our atmosphere in a process that is so important to cloud development that without aerosols, clouds would not exist at the scale we see them today.” was removed. Instead, P2, L12: “Aerosols drop the energy barrier required for condensation, serving as cloud condensation nuclei (Petters and Kreidenweis 2007).” was changed to “Aerosols drop the energy barrier required for condensation, serving as condensation nuclei for liquid water and ice clouds in our atmosphere (Petters and Kreidenweis 2007).”

— GvH: —

- P9_11: “These diagnostics . . . of the LUT”: hard to read

Author Response:

P9, L14: “These diagnostics also account for artifacts from rotating into the scattering plane 15 on Qsca and Usca and retrievals that poorly converge to CDR and CDV values at the very edge of the LUT.” was changed to “These diagnostics also account for any artifacts that arise from rotating our reference frame of polarization into the scattering plane. Retrievals that converge artificially to the edges of the LUT are also screened by the RMSE and x2red.”

— GvH: —

- P11_24: “. . . retrieved on the periphery”: Point out that reduced cloud fraction should not impact polarimetric retrieval (see Eg. (4))

Author Response:

This is noted explicitly when describing the retrieval process itself on P8, L13. We will change P8, L11 from “Corrective factors for aerosol above cloud, cirrus, sun glint, molecular scattering, and surface reflectance signals comprise weak functions of scattering angle, with the parameter [alpha] related to cloud fraction (Breon and Goloub 1998, Diner et al. 2013, Alexandrov et al. 2015).” to “Corrective factors for aerosol above cloud, cirrus, sun glint, molecular scattering, and surface reflectance signals comprise weak functions of scattering angle (Diner et al. 2013, Alexandrov et al. 2015). The parameter [alpha] is related to cloud fraction (Breon and Goloub 1998), and therefore, is also accounted for by Eq. (4)."

— GvH: —

- P12_38: "consistent with current research and theories of cloud microphysics": Similar finding with AirMSPI (Fig. 13 in Xu et al. (2018))

- P13_24: "fourier" -> "Fourier"

Author Response:

Minor corrections are changed as noted. As this sentence (P12, L38) is a summary sentence that is meant to close the paragraph and reference the research mentioned in the paragraph above, we will not add any references at the end. Xu et al. (2018) is heavily sourced in the text in other sections.

— GvH: —

- Figure 5: Indicate flight direction, because it is perpendicular to Fig. 4b

- Figure 5, caption: What is the image size?

- Figure 6, caption: "150m superpixels", whereas: P10_18: "Figure 6 shows several examples of an AirHARP 200m superpixel retrieval" Fig. 6: text inside plots "200m grd.res."

- Figure 9: Units missing for Intensity and Effective Radius

Author response:

All recommendations are valid and changes will be made as noted. The image size of Figure 5 is approximately 37km by 5km and will be added to the figure caption.

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