Author Responses to Anonymous Referee #2

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The authors have developed an algorithm to joint retrieve cloud water path and rain water path, using W-band reflectivity measurements from aircraft-borne radar, radiometric cloud optical depth, and cloud effect radius from Research Scanning Polarimeter during ORACLES.

We thank you very much for taking the time to review our work and provide constructive comments toward improving this manuscript! We have responded to each of your comments in blue text (indented after and below each comment), and hope that each of our comments sufficiently addresses each of your concerns. Updates or changes to the manuscript text are denoted in red text.

Atmospheric Chemistry and Physics (ACP) is a scientific journal dedicated to public discussion of studies investigating the Earth's atmosphere and the underlying chemical and physical processes. In the manuscript, there is no process level discussion. This retrieval algorithm manuscript definitely fits better into the scope of "Atmospheric Measurement Techniques". It is noticed that several retrieval-based papers published in ACP, so a decision would be made by the editor.

We understand the point you are trying to make here. We feel, however, that the content of this manuscript goes beyond the typical scope of an AMT paper – especially the results in Section 6. The manuscript blends algorithm details and analysis that supports cloud & precipitation processes in the aerosol-rich southeast Atlantic environment. Ultimately, this manuscript will be part of an inter-journal ACP/AMT special issue "New Observations and related modeling studies of the aerosol-cloud-climate system in the Southeast Atlantic and Southern Africa regions" and feel that ACP is the more appropriate choice given the scope. Several process-level studies using the dataset presented in this work are planned, and will be the topic of future manuscripts within this special issue.

In short, we feel the submission is justified for ACP but ultimately would respect the editor's decision to either keep the manuscript here in ACP or transfer the manuscript to AMT.

The manuscript is well written overall, but more clarifications are greatly needed especially in the retrieval methodology. How to estimate the cloud effective radius profile is critical in your retrieval. Your assumption for the estimation is not clear. Are you suggesting the cloud top effective radius from RSP is representative of the whole cloud column? Due to cloud-top entrainment, an effective radius at the cloud top can be substantially different from re in the cloud (say, the middle of the cloud layer), see air- craft measurements in Wood (2005). As you will show results for individual cases, it is important to quantify cloud-top entrainment strength and the resulting errors in your retrieval case by case. Otherwise, I see limited values in the retrieval product for detailed case analysis or process analysis. Although the retrievals may be useful for statistic-based study from ORACLES, please prove the values of your retrieval product in process aerosol-cloud interaction study. If these issues are addressed well, the paper might be suitable for publication.

The cloud effective radius assumption, we argue, is not a critical component to our retrieval. This is because the cloud water path (CWP) is a bulk quantity and relies mostly on the cloud top effective radius. We certainly agree and acknowledge that processes such as entrainment, accretion and autocorrelation will vary CWC on a profile-by-profile basis depending on the point in the cloud profile's lifetime. Cloud water content (CWC) through each individual profile is assumed following the Bennartz (2007) method, whereby integrating CWC in each profile will equal the CWP regardless of how effective radius varies through the column. We did not make clear, however, that uncertainty arising from effective radius through the profile is not accounted for, and added the following sentence within Line 6 on Page 10:

"Given this assumption for CWC through the profile, we do account for variability in r_e through the profile and uncertainty that may arise from variable r_e through each profile."

With this in mind, future studies will be addressing in-situ cloud properties (cloud water content, effective radius, etc.) much more rigorously and will provide a basis for further evaluation and improvement of the treatment of CWC in this algorithm. Furthermore, studies covering the effects of entrainment will be explored in future studies. The entire premise of this algorithm is to provide bulk precipitation, CWP and RWP estimates (each constrained by radar and radiometric measurements) for future statistic-based and process-level aerosol-cloud-precipitation interaction studies.

The science behind this specific algorithm is very well established through numerous previous studies, and is the only algorithm (and corresponding data product) available for ORACLES that encapsulates both cloud and precipitation processes using all valid and available W-band radar and polarimetric radiometer data.

Comments:

I did not see the feasibility of the application of the current retrieval algorithm in the manuscript. If there is no direct observations from aircraft or RSP, how would you apply this algorithm? Further clarification is needed.

This algorithm was developed from satellite based (CloudSat + MODIS) algorithm methodologies for retrieving rainfall profiles and cloud properties. This algorithm was certainly optimized for airborne remote sensing observations (APR-3 + RSP), and can be applied to any airborne platform field campaign using radar & radiometers. We perhaps should have clarified in the title that this algorithm is meant for airborne application. We will update the title of the manuscript to specify "Airborne", as in:

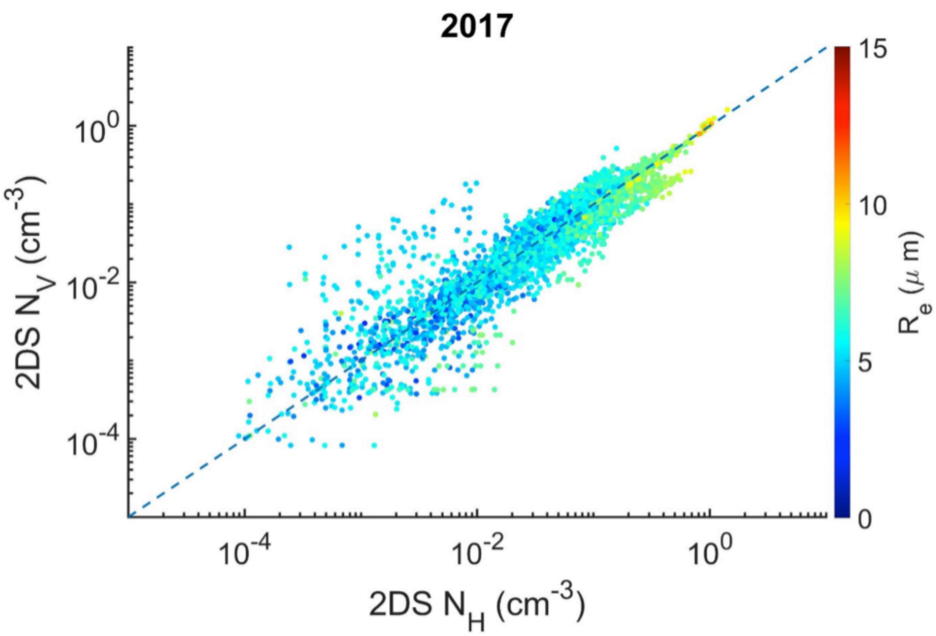
Joint Cloud Water Path and Rain Water Path Retrievals from Airborne ORACLES Observations

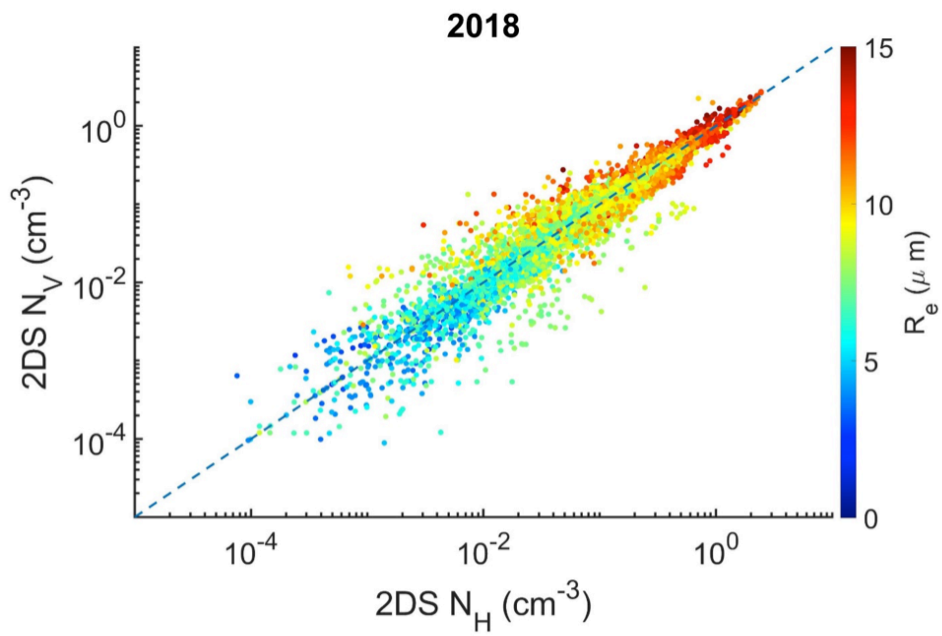
Page 7 lines 1-4: When the V channel data was available, are droplet properties similar from 2DS H and V channels? What are the differences in rain droplet size, concentration, and water content from the two channels?

The figures below compare the droplet concentration sampled by the horizontal (NH) and vertical (NV) channels of the 2-Dimensional Stereo probe (2-DS). Each data point on the figures represents a 1 Hz measurement colored by the effective radius (Re). For the 2017 deployment, NH and NV were compared for 6125 data points from eight research flights. For the 2018 deployment, NH and NV were compared for 9886 data points from twelve research flights. Statistically significant (p = 0) linear fit coefficients were derived using a linear regression model, and NV = 0.91 NH + 0.0033 for 2017, and NV = 0.96 NH - 0.0017 for 2018. NH and NV were well correlated with Pearson's correlation coefficient, R = 0.94 for 2017 and R = 0.98 for 2018.

A more comprehensive analysis of 2-DS precipitation measurements and properties will be the topic of a future paper, and thus we elected not to include the following figures in the text. Instead we elaborated at this point in the text to justify our use of H-channel data only:

"This decision is justified by the fact that available n(D) data between the H and V channels were highly correlated. The Pearson correlation coefficients between the droplet concentration (Nc) were 0.94 (N = 6125) and 0.98 (N = 9886) for 2017 and 2018 respectively."





Page 7 lines 8-12: how do you determine if drizzle presents? 2DS can record valid values even in drizzle free regions.

Droplets larger than 50 μm in diameter were defined as drizzle. The presence of drizzle was determined when 2-DS registered droplets within the size bins corresponding to this size range.

Page 8 line 12: Please briefly describe the parameterization.

This parameterization (Equation 4) is a model for visible optical depth. We did not explicitly state this prior to presenting this equation (but do so later around Line 18). To make this more clear, we added additional context on Line 11:

"... The visible optical depth observed by the RSP includes contributions from CWC and RWC, *and can be modeled as (also see Lebsock and L'Ecuyer, 2011)*:"

Page 10 Eq 10. Should you include the effect of uncertainties of cloud effective radius?

We only included the uncertainty in cloud effective radius following our assumption. There will certainly be variation in cloud effective radius through the column, however, given the nature of our retrieval algorithm there is no need to account for effective radius through the column. The column cloud water content assumption, which also requires the assumed cloud effective radius through the column, will likely be covered in future ORACLES papers and will provide further evaluation of the validity of this assumption.

Will Ka-band see part of the cloud with some overlapping regions from W-band observation? Would the different Ka-W band measurements add more information in your retrieval?

The Ka-band channel is insensitive to cloud size droplets (i.e. less than −15 dBZ), but will usually detect precipitation when it's present. The development of a Ka-W band joint channel retrieval was actually the original idea for retrieval development, however, the W-band + cloud optical depth retrieval was developed because nearly all stratocumulus clouds (with exceptions for trade cumulus and similar cases like the one presented in Fig. 5) were fully detectable by the W-band channel. Ka-band measurements would add much more information in cases such as those similar to Fig. 5, since the Ka-band can penetrate deeper into more heavily precipitating clouds before (if at all) partially or fully attenuating.