Review of "Overview and statistical analysis of boundary layer clouds and precipitation over the western North-Atlantic Ocean" by Kirschler et al. (egusphere-2023-898)

General comments:

This study provides an overview of the in-situ cloud sampling dataset collected during the NASA ACTIVATE mission over the western North-Atlantic Ocean. The ACTIVATE team did a great job of collecting comprehensive observations and the authors have compiled these observations in a way that sets the stage well for further examination. This study compares measurements of cloud and precipitation properties across summer and winter months from three deployment years. The dataset is described with extensive descriptions of cloud probes and their operational characteristics. A merged particle size distribution is created using two data from cloud probes and a hydrometeor number-size phase space is used to classify the observations into aerosol, cloud, and precipitation samples. The methodology is described with great detail, which is appreciated. The discussion of vertical profiles and spatial distribution of cloud/precipitation properties presents findings in line with existing knowledge. The novel aspects of the study include the rich in-situ dataset and a comparison of seasonal trends in cloud properties.

In certain instances, the paper could benefit from better organization or minor clarifications. The introduction focuses on aerosol variability a bit too much given that aerosols are not the focus of the analysis. Some interesting discussions could be added, and conclusions could be rephrased slightly to separate direct observations from inferences made based on these observations. However, these are minor details and I recommend the paper for publication with minor revisions. Specific comments are provided below along with a list of technical edits for the authors' consideration.

Specific comments:

Line 1 and 15: Please specify what "large variability" is referring to?

Line 19: I don't see how the phase space helps understand cloud formation. As I interpreted the discussion, the phase space provided thresholds to separate cloud samples from precipitation/aerosol sampling and to shed light on hydrometeor phase.

Line 25-38: This paragraph has some very old references which can be supplemented with more recent work. For example, quantitative cloud radiative effect estimates could be provided?

Line 39: is there a reference associated with this statement?

Line 40: Please specify what "aerosol variability" is referring to. I find text that might be relevant in lines 49-55 which could be placed with this statement for clarity.

Line 61: There is considerable emphasis on aerosol variability. Aerosol conditions are discussed only to be followed by a statement that updraft speeds predominantly dictate the wintertime cloud properties (or at least number concentration). The paper has little to no analysis or mention of aerosol observations. I suggest the introduction be steered from aerosol variability toward the discussion of cloud processes which are explained later in the sub-sections. The extended discussion of previous knowledge of cloud

processes within the results seems a bit misplaced. Perhaps the aerosol discussion can be moved to a discussion section if the authors still wish to discuss these aspects?

Line 95: If the CAPS system was also available and collecting data, was there a reason to choose FCDP data for this study? Would the results presented in this study be affected if the CAPS data were used instead? Since these probes sample droplets in similar size ranges, these data could be compared. I would assume the conclusions of the study are not sensitive to the choice of the probe but that would be good to confirm and report here.

Line 115: I appreciate the mention and quantification of the measurement uncertainties. Do the uncertainties affect the interpretation of the results? A comment on that would be helpful.

Line 117: The term "The FCDP and 2D-S combination probe" seems strange. I would suggest using a term that highlights that this is a combined dataset instead. As it is presently stated, it seems a new combined probe was created when in fact data from two probes were merged to create a combined size distribution.

Line 143: This information could be placed with "we assume all small particles <100 μ m detected by the FCDP and the 2D-S to be liquid, as there is no other information available". The current organization is confusing as the explanation is placed separately.

Line 149: quantitative estimate in place of "vast majority"?

Figure 2:

1. I'm assuming the axis limits on panels (b) and (c) were chosen for consistency with panel 2a. It could be argued that that is not important. The three panels show three different 2-D phase spaces. The panels would be better interpreted if they have axis limits corresponding to the data plotted within them.
2. I don't see the utility (or any discussion) of the counts presented in panels (b) and (c). I suggest coloring these panels according to N_liquid and/or ED_liquid for the following reasons:
    - The discussion of Fig. 2a argues the 2-D phase space of ED_liquid and N_liquid is necessary to determine the thresholds used to determine in/out of cloud and precipitation samples.
    - Independent thresholds for N_liquid to determine cloud samples and ED_liquid to determine precipitation samples have consistently been used by past studies. These studies have used thresholds with similar values to those determined based on Fig. 2a. (in fact, the current N_liquid threshold is partly influenced by the instrument detection limit).
    - Coloring by N_liquid and/or ED_liquid would likely help reinforce the choice of thresholds.
3. It is not obvious how the threshold of ED_liquid > 60 um was chosen to represent precipitation samples based on Fig. 2a. On first glance, there seem to be no significant differences in N_liquid counts for ED_liquid between 40 um to 60 um.

Line 179: A combination of N_liquid and LWC thresholds to define cloud samples has been used previously. A reference to the past studies and contrasting the current thresholds with past work would be useful (Wood, 2005 (https://doi.org/10.1175/JAS3529.1) or Gupta et al., 2021 (https://doi.org/10.5194/acp-21-4615-2021 - this is a non-exhaustive list).

Line 213: It would be nice to include statistics for ED_liquid in Table 1. That would also allow including these quantities while comparing the dominant particle modes during the three summer deployments.

Line 213: Given the large LWC differences between winter deployments, I'm wondering why winter deployments were not compared similar to comparisons between summer deployments and summer 2020 versus winter 2020.

Line 254: Suggest changing "thus yielding stronger suppression of precipitation during winter as compared to summer" to "thus yielding lower concentrations for droplets larger than __ um during the winter" and referring to figure 6d. This is what was observed based on the measurements instead of observing precipitation suppression directly.

Line 276: "Mixing processes…". Was this observed/explained by Tornow et al., 2022? As currently phrased, it seems this was determined based on current analysis. Suggest the sentence be edited or placed after the next one if explained by Tornow et al. 2022.

Line 281: From Fig. 7h, it seems the ice cloud size distribution exceeds the liquid cloud size distribution after 200 um instead of 100 um. This is probably due to the sample volume of the 2D-S, but I suggest either changing to 200 um or clarifying the selection of 100 um here.

Line 297: The phrasing is confusing. I am assuming you mean something like this - "During summer, the cloud deck is characterized by more cloud-free areas and the width of the clouds is reduced with less frequent cloud measurements compared to the winter seasons."?

Line 299: Figure 8 presents a good case to compare cloud-free areas, but I wouldn't imagine this is a good way to compare seasonal cloud width. For direct comparisons of cloud width, wouldn't it be better to compare the average duration of cloud transects during the seasons?

Figure 10: I don't see a discussion of panels c and f? These panels interesting features and spatial patterns. Maybe I'm missing something, but I'm confused by the observation of higher fractions of mixed-phase precipitation (Fig. 10f) versus the fraction of mixed phase clouds (Fig. 10c)?

Line 349: "In addition, the average cloud encountered per research flight is higher in winter." I find this statement confusing. Do you mean you sampled more clouds during the winter or sampled clouds for a greater duration during the winter? I am assuming the latter.

Line 356: Suggest adding the rationale behind the observation made here.

Line 359: The vertical profiles do not show the onset of WBF process. The onset is inferred based on the observations that are consistent with changes expected in association with the WBF process. Suggest rephrasing. Similar adjustments would be helpful for the following paragraph.

Line 367: "consists of a larger mixed-phase fraction compared to clouds observed in the summer"?

Line 368: "while precipitation coincides less frequently with cloud measurements during summer". This phrasing seems a bit confusing since precipitation would generally be associated with a cloud which was not sampled. The frequency of precipitation was likely higher due to the sampling altitude? Suggest changing this to "frequency of precipitation sampling coincides less frequently with cloud measurements during summer" or clarify if this interpretation is incorrect.

Technical corrections:

Line 21: "products"?

Line 29: “higher cooling rates by low-level clouds”?

Line 53: “show”?

Line 70: “Cloud, aerosol, trace gas”?

Line 140: I believe you mean D_i and N_i in this sentence instead of D and N?

Line 159: It would be useful to explicitly mention the color of each corresponding region within the text.

Line 262: “we assume particles with sizes smaller than 100 μ m to be liquid” reads better.

Figure 8: Suggest changing the color of the symbols to represent liquid or mixed phase. It is nearly impossible to see the difference for the darker blue colors for winters 2021 and 2022. Might also be more informative to include the number of flights or flight seconds for each season in the legend.

Line 346: “cloud properties” instead of “clouds”?

Line 349: “indicates”?

Line 353: “contained”?

Line 362: “size distribution of mixed-phase cloud droplets” unless you mean the size distribution of clouds themselves.

Line 365: promotes “stronger precipitation” instead of “precipitation”?

Line 371: “oriented”

Figure 3,4,5: Please consider adding labels to subplots within these figures.