Review of "Microphysical and thermodynamic phase analyses of Arctic low-level clouds measured above the sea ice and the open ocean in spring and summer", by Manuel Moser, Christiane Voigt, Tina Jurkat-Witschas, Valerian Hahn, Guillaume Mioche, Olivier Jourdan, Régis Dupuy, Christophe Gourbeyre, Alfons Schwarzenboeck, Johannes Lucke, Yvonne Boose, Mario Mech, Stephan Borrmann, André Ehrlich, Andreas Herber, Christof Lüpkes, and Manfred Wendisch, acp-2023-44.

Response to reviewer 2

Dear reviewer,
We are very grateful for your valuable feedback and suggestions which helped us to improve the manuscript. The manuscript has been thoroughly revised and point-by-point responses have been prepared. Please find below our replies, highlighted in blue, along with your suggestions. The revised manuscript is also provided with tracked-changes for clarity.

Comments:

1. The main comment from the reviewer is about how Figures 4 and 5 and Table 3 are not separated into different cloud phases or different types of cloud hydrometeors. The reviewer recommends adding figure sub-panels similar to the original Figure 4 and 5, but separately plot the distributions of the 3 types of cloud thermodynamic phases (ice, mixed and liquid) as identified by the group number 1, 2 and 3 in Figure 6, respectively. This way the readers can see if the vertical distributions of these three cloud phases change between summer and spring, and between over ocean and sea ice. In addition, for table 3, more rows can be added to compare N, Deff, CWC, d_cloud_mean that are calculated for each of the 3 cloud phases separately.

Thank you for your comment. Figure 4 is intended to provide an overview of the collected cloud data and its distribution in altitude. For absolute values of the microphysical variables, Fig. 5 and Table 3 are much more suitable. We have created additional Figures and Tables similar to Fig. 5 and Table 3 with data from the ice, liquid, and water regimes, and have included them in the manuscript's appendix. Additionally, we have added new rows to Table 3, which give the cloud parameters calculated for small particles (<50µm, assumed to be water) and large particles (>50µm, assumed to be ice).

2. This is a related question to comment 1, can the authors separate each instrument measurement into liquid or ice hydrometeor? In Figure 6, the Deff and N values seem to use the combined measurements of multiple probes. It would be helpful to trace back how these ice, mixed and liquid phase 1-Hz measurements are contributed by individual probes. For example, the authors can add sub-panels to this Figure 6, using CAS, CDP, CIP and PIP, individually, and then calculate just the Deff and N for that probe alone (in a limited size range), and show how their own Deff vs N would look, color code where the 1-Hz samples of ice, mixed and liquid exist in that probe's measurement space. This way one can understand how individual probes contribute to the groups 1, 2 and 3 of cloud phases in the combined Deff vs N plot.

Another suggestion is, if the authors can separate the ice and liquid hydrometeors within one second, then the authors can calculate the N, Deff, CWC just for liquid or just for ice hydrometeors. Note that this type of calculation wouldn't have the mixed phase because it is based on the type of hydrometeors, not the type of cloud segment. The reviewer would like to point to some previous methods of defining ice and liquid from CDP, 2DC and 2DS probes in the following papers. These probes have some similar size range to the ones used in this study.

Yang, C.A., M. Diao, A. Gettelman, K. Zhang, J. Sun, W. Wu, G. McFarquhar, Ice and Supercooled Liquid Water Distributions over the Southern Ocean based on In Situ Observations and Climate Model Simulations, Journal of Geophysical Research: Atmosphere, 126, e2021JD036045. https://doi.org/10.1029/2021JD036045, 2021.

D'Alessandro, J., M. Diao, C. Wu, X. Liu, B. Stephens, and J.B. Jensen, "Cloud phase and relative humidity distributions over the Southern Ocean in austral summer based on in-situ observations and CAM5 simulations", J. Climate, doi:10.1175/JCLI-D-18-0232.1, 2019.

Regarding the first part of comment 2: To demonstrate how each individual cloud probe contributes to the regimes in the D_{eff} - N space, we have included a Figure in the appendix, similar to Fig. 6, but now display the D_{eff} and N values calculated for CDP/CAS, CIP, and PIP, respectively. Moreover, we show how the previously defined regimes are measured by the individual probes and determine the proportion of the detected values compared to the combined values in Fig. 6.

Regarding the second part of comment 2: The two references cited demonstrate a very effective method for differentiating between ice and liquid water within a second. Although we appreciate these works and methods, within one second we now differentiate between ice and water based on the particle sizes, as doing otherwise would be beyond the scope of our study. We have added additional columns to Table 3, as mentioned in our response to comment 1. However, we will address the proposed methods in future publications. We are also happy to contribute on an individual basis, if an analysis using the mentioned method is requested.
The given papers are now cited in the manuscript for referring to a different method in order to distinguishing between liquid and ice.

3. Because the Deff and N currently used in Section 3.1 seems to be a combined value of both ice and liquid, the reviewer suggests the description of higher or lower Deff not be directly referring to liquid droplets. Line 280, the author said "also during summer a decrease of Deff of the liquid droplets is observed". This is more likely because there are more liquid droplets in summer which tend to be smaller than ice, not because these liquid droplets in summer are smaller than the liquid droplets in spring.

In the new manuscript we are not directly referring to liquid droplets anymore but changed the sentence to: "Also during summer when clouds are most likely in a liquid state a decrease of D_{eff} with altitude is observed."
As we have additionally separated the microphysical properties in Table 3 into liquid and ice, the interpretation should now be facilitated.

4. Comparisons between summer and spring and between ocean and sea ice need some more statistical significance tests. For instance, the analysis in Figure 4, the whiskers represent 97.5 and 2.5th percentile, and Table 3 has 75 and 25th But it would be helpful to provide a t-test to check if the two groups of data (summer vs spring, or ocean vs sea ice) are significantly different statistically.

Thank you very much for your suggestion to test the differences in the data using significance tests. We have checked interesting combinations for the significance of the differences in each row in Table 3: We used the t-test only for the mean cloud extend. For the other microphysical cloud data,

we used the Wilcoxon test since we compare median values and the data are not normally distributed.
With the conducted tests, we found that the horizontal mean cloud extend does not change significantly for all combinations in different environmental conditions.
However, the tests reveal the total difference for both seasons is still valid.
We also discovered a non-significant difference in the variable N through the tests. Specifically, we found that in the summer season, the difference in N over ice and ocean is not significant.
The tests were also performed on the variables for cloud data calculated from liquid and ice particles only, which are added to Table 3, as well for similar Tables added to the Appendix. However here the increased number concentration of particles in the liquid regime over the sea ice compared to the ocean in summer is statistically significant. We have incorporated these new findings into the manuscript.

5. Minor typos. Line 376, We observe lager (should be larger) ice…

Adapted.

6. Line 394, typo Figures have been design (should be designed).

Adapted.

7. In data availability, there is currently no description about where the AMSR2 satellite data for sea ice coverage during the AFLUX and MOSAIC-ACA campaigns are stored. It would be helpful for follow-up studies if the authors can provide other data used in this analysis, such as satellite and HYSPLIT back trajectory data.

The AMSR2 derived sea ice coverage is available from the University of Bremen (https://seaice.uni-bremen.de/). However, extracted sea ice coverage along the flight path of Polar 5 is available via the python package ac3airborne.
We extended line 392 in the data availability section by the sentence. "The data ac3airborne package provides as well access to sea ice coverage along the flight path extracted from data available at University of Bremen (https://seaice.uni-bremen.de/)."

The HYSPLIT model is an online tool that does not require any specific input data by the user. The user just needs to specify time, position, atmospheric model and starting altitude. It is freely available at https://www.ready.noaa.gov/HYSPLIT.php.
We added to the data availability section "The HYSPLIT model is a freely accessible online tool available at https://www.ready.noaa.gov/HYSPLIT.php."