

Thanks for your suggestions and comments. Please find our point-to-point response below in blue color.

Response to RC2's Comments:

General comment:

This study presents a statistical analysis of cloud types, their occurrence and macrophysical properties over a Southern Ocean region (and separately its northern and southern parts), based on measurements from the MARCUS campaign. In most cases, presentation of results, discussion and comparison with other studies is adequate. The results are relevant for AMT and can be useful for evaluation studies of satellite retrievals and model simulations. For these reasons, I recommend that this manuscript is accepted for publication after major revisions. These regard mainly structural issues (particularly in Section 2) and several points throughout the text that need to be clarified.

Specific comments:

Section 1:

Lines 97-98: "which in-situ ... this analysis". This part of the sentence is not clear. Do you mean that in-situ measurements from SOCRATES were used here as reference? Please clarify and rephrase.

Yes, we are using SOCRATES measurements as a reference because these two experiments do not have overlapped in the same location but have the overlapped period (Jan-Feb. 2018). The sentence is rephrased to 'In this study, the aircraft in-situ measurements from SOCRATES are used as the reference for the analysis.'

Lines 99-102: while the objectives of the MARCUS campaign are clearly stated in this sentence, it is not clear what the focus of this study is. While it is described in the next paragraph, this sentence needs rephrasing.

We changed the entire sentence to: 'Our study will focus on cloud macrophysical properties and cloud phases along the ship tracks.'

Section 2 general comment: It was difficult for me to follow the text in Section 2. The authors describe data sets, algorithms and methods in an unclear and mixed way. Please provide a more concise description of data sets and methods by considering the following suggestions:

- It would be helpful for the reader if you provide a table with all the cloud parameters measured and analyzed in this study.
- For each cloud parameter, please provide a short description of the instrument and method used for its measurement or retrieval.

We have rearranged the texts in Section 2 to provide better readability and provided a table with a brief description for each instrument, its measurement and uncertainty. More detailed information can be found from Mace et al. (2021).

Mace, G. G., Protat, A., Humphries, R. S., Alexander, S. P., McRobert, I. M., Ward, J., Selleck, P., Keywood, M. and McFarquhar, G. M.: Southern Ocean Cloud Properties Derived From CAPRICORN and MARCUS Data, *J. Geophys. Res. Atmos.*, doi:10.1029/2020JD033368, 2021.

Line 118: please provide a reference or short description for the AMF2 instruments suite. The following references are cited in Section 2.

McFarquhar, G., Bretherton, C., Alexander, S., DeMott, P., Marchand, R., Protat, A., Quinn, P., Siems, S., Weller, R., Wood, R.: Measurements of Aerosols, Radiation, and Clouds over Sothern Ocean (MARCUS) Science Plan, DOE ARM Climate Research Facility., DOE/SC-ARM-16-011, available at: <http://arm.gov/publications/programdocs/doe-sc-arm-16-011.pdf>, 2016.

McFarquhar and coauthors, 2021: Observations of Clouds, Aerosols, Precipitation, and Surface Radiation over the Southern Ocean: An Overview of CAPRICORN, MARCUS, MICRE, and SOCRATES, BAMS, <https://doi.org/10.1175/BAMS-D-20-0132.2>.

Lines 135-136: the occurrence frequency estimation, as you describe it here, should refer to all clouds, instead of each type of cloud separately. Please clarify.

For each 5-min sample, we can only determine one type of cloud (low, mid, high, etc) and thus the column cloud fraction of that classified type of cloud within 5 min. Thus, we can further estimate the occurrence frequency of each type of cloud separately. We have also clarified this statement in the revised manuscript.

Lines 140-142: what are these “brightness temperature biases”? What is the reference value? And what is the extra step to determine the uncertainties that you propose?

Since the retrieved LWP and PWV are based on the MWR measured brightness temperatures at two frequencies, any biases on the brightness temperatures will affect these retrievals. Therefore, we propose an extra step to determine the LWP uncertainty during MARCUS. Based on the sounding temperature profiles, we can identify clouds that are not likely to contain liquid (e.g., pure ice-cloud), then we can estimate the LWP uncertainty based on their corresponding retrieved LWP values. From the PDF analysis, the LWP uncertainty is estimated as 10 g m^{-2} during MARCUS IOP.

Lines 150-151: how did you calculate LTS and EIS? How did you use them in your analysis?

The lower tropospheric stability (LTS) is calculated from the potential temperature difference between the surface and 700 hPa based on the ERA-Interim reanalysis to assess the boundary-layer stabilities when the low-level clouds appeared along the ship tracks. We did not use EIS so it was removed.

The following statements are in Section 3:

By analyzing the ERA-Interim reanalysis (not shown), the 850 hPa geopotential heights show persistent westerlies with slightly higher geopotential heights over the northwest corner of the domain, which may closely relate to the higher Htop over NSO than over SSO. Furthermore, the boundary layer over NSO is relatively more stable than over SSO based on lower troposphere stability (LTS) analysis (12.2-15.32 K over NSO vs. 11.48-13.29 K over SSO).

Lines 152-154: Wasn't the occurrence frequency estimated as described in lines 135-136? Please provide a short description of the method mentioned here.

The radar records measurement every 2-second, which shows the part of the column that is cloudy, so the column cloud fraction can be given by the total cloudy samples divided by 150 samples (assuming all the samples within 5 minutes have valid measurement). The statement is rephrased accordingly.

Section 3 general comment: Results are described consistently and are adequately compared with the literature.)

Thanks.

Line 163: the cloud categorization appears for the first time in Fig. 3. I suggest to move the categories explanation from the caption of Fig. 3 to a separate table, and present it earlier in the paper.

Please refer to Table 1 and Figure 6 in Xi et al., 2010. The detailed description is also added in Section 2.

Lines 188-191: it is a common approach in such cases to use spatial and temporal averaging for a more reasonable comparison. Did the authors try such an approach?

Because CloudSat has difficulty retrieving the clouds below ~1 km, we cannot directly compare these two results via temporal and spatial averaging. We did successfully match the GOES and ground-based measurements in Xi et al., 2010.

In fact, the reviewer 1 has raised the same question. Here is what we response. Figure 1 of Xi et al. (2010) has illustrated the temporal-spatial CF comparison between ARM SGP ground-based and GOES satellite observations. We concluded that the 0.5-hr averaged ARM CFs agreed well with 0.5° GOES observations, while 4-hr averaged ARM CFs matched well with 2° GOES results.

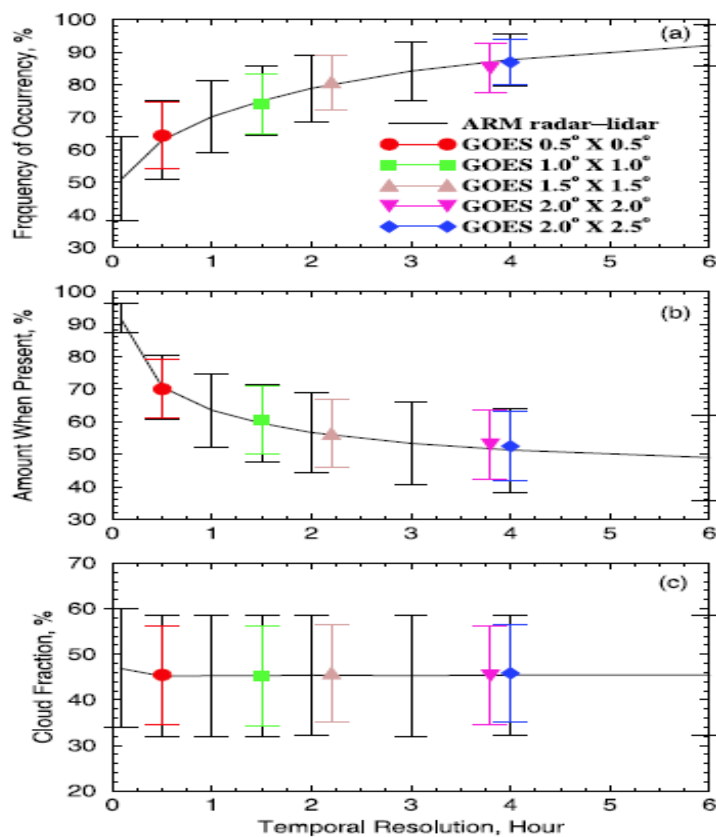


Figure 1. Dependence of (a) cloud frequency of occurrence (FREQ), (b) amount when present (AWP), and (c) cloud fraction (CF) on temporal resolutions of Atmospheric Radiation Measurement Program (ARM) surface radar-lidar observations during the period 1997–2006 and on grid boxes of satellite observations during the period from May 1998 to December 2006 at the ARM Southern Great Plains (SGP) site.

Lines 204-212: Please consider moving this description to Section 2, and adding a table to show this categorization more clearly (see also my comment on line 163).

This description is moved to Section 2.

Line 215: “all types of clouds in SSO are higher...”: do you mean that they occur more frequently?

Yes, we have rephrased the sentence as ‘all types of clouds in SSO have higher frequency of occurrence than those in NSO except HOL.’

Line 248: The information in Table 1 and Figs. 3b, 4a could also be nicely combined in box plots.

We think the mean and standard deviation on top of each bar might be too difficult to read, so we think it is better to keep table 1.

Section 4:

Line 283: In Fig. 5 a LWP threshold of 20 g m^{-2} appears, contrary to the text where a 10 g m^{-2} threshold is mentioned. Please clarify.

Thanks for catching our mistake. It has changed to 10 g m^{-2} .

Line 292: “... WID is greater than 0.4 m s^{-1} and Vd is greater than 0.0 m s^{-1} ...”. This “and” is an “or” in the diagram of Fig. 5. Please clarify.

Thanks for catching our mistake. It has changed.

Line 307: “By changing ... for each range volume”. This sentence is not clear, please rephrase.

Change to ‘integration time’.

Line 308: “statistics of the possibility of the cloud phase that may be detected by cloud radar”. Please consider replacing with “the possible cloud phase partitioning that may be detected by cloud radar”.

Changed, thanks for the suggestion.

Line 347: please replace “e.g.” by “i.e.”.

Changed.

Line 358: please replace “least” by “lowest”.

Changed.

Line 385: “mimics” should be replaced by “follows”.

Changed.

Line 419: Is 73% the percentage of all cloud samples available with a threshold of -50 dBZ? Please clarify.

No, the denominator was always all the measurements. So, by changing the threshold from -40 dBZ to -50 dBZ, we included 17.4% more data. We added the following sentence for clarification “If we used the threshold of -50 dBZ, then we would have 90.4 % cloud samples, which gained 17.4% more samples on top of the -40 dBZ threshold.”

Line 460: please replace “indicating” with “indicative”.

Changed, thanks.

Line 483: the term “such as” should be replaced by “i.e.”. Also, isn’t the LWP for MOL and HOL a full column retrieval? If so, the term “low clouds” should be replaced by “low clouds, including middle and high clouds overlapping cases”. Please clarify.

Rephrased to ‘The mean LWPs for LOW, MID and HOL clouds over NSO, range from ~ 130 to 150 g m^{-2} , while the mean LWPs ($\sim 270 \text{ g m}^{-2}$) for MOL and deep convective clouds (HML), are

much higher than the same types of clouds over SSO'

Section 5:

Line 465: please replace "the northern" with "its northern".

Changed.

Figures:

Figure 1 caption: "Some of the dates have labeled along the shiptracks, which can indicate the direction of the ship traveled". Suggested rephrasing: "Some of the dates are labeled along the shiptracks, indicating the direction of the ship".

Changed, thanks the suggestion.

Figure 6 caption: please replace "shows" with "is shown" or "appears".

Changed.

Figure 11 caption: what is the meaning of IOP (also mentioned in line 465)?

Changed to 'Intensive observational period (IOP)'.