Manuscript egusphere-2023-1665 – Replies to Reviewers

The reviewers have made some valuable suggestions and corrections to significantly improve the quality of the manuscript. All of these suggestions are straightforward to implement, and we look forward to preparing a stronger paper in response to these reviews.

Replies to Reviewer #1:

This paper uses basic radiometric measurements to calculate cloud optical depths and cloud transmissions and infer the presence of ice or mixed phase clouds. The cloud optical depth calculated using wavelength 870 is not affected by ice clouds whereas broadband shortwave transmission is because of ice bands in the near-infrared. In other words cloud radars, lidars, and other sophisticated equipment are not necessary to obtain fundamentally useful data that can distinguish ice and mixed phase clouds from water clouds.

I think the authors demonstrate their point that fairly fundamental radiation measurements can be used at sites in the Antarctic. However, I am not sure that the measurements that they suggest can detect the 10 W/m^2 changes in the net surface radiation (lines 56-58) that could induce ice melt or retention.

We are grateful that the reviewer endorses our conclusion that these kinds of radiation measurements can be made in the Antarctic environment. The revised manuscript will clarify the context about application to studies of ice melt or retention, and will further discuss the sampling requirements to reach conclusions involving changes of order 10 W/m^2.

Line 70: indicates about six weeks of measurements; is that correct?

Yes, that is correct.

Line 150: "... one describes with a unique large-scale circulation pattern." Is this correctly stated?

This sentence will be clarified in the revision.

A map with labels of the geographic sites discussed in these paragraphs would help for those not familiar with Antarctic geography.

The revision will provide a map as requested, for a new “Figure 1.”

Reviewer #2:

Review of the research article entitled “Broadband and filter radiometers at Ross Island, Antarctica: Detection of cloud ice phase versus liquid water influences on shortwave and longwave radiation” by Kristopher Scarci et al.. (MS No.: egusphere-2023-1665)

The authors present a study examining the impact of cloud phase and properties on the surface energy budget based on ground-based radiometric instruments, supported by reanalysis and satellite observations. Their primary objective is to establish a connection between flux measurements and cloud properties using basic instruments deployable in remote locations. This holds particular relevance in Antarctica, where even small changes in the net surface budget could initiate melting processes.

The study is well-written, carefully argued and gives important insights into the role of the meteorological patterns and cloud properties on the radiative budget. However, their method is applied to a limited dataset without really enlightening our comprehension of the Antarctica atmospheric system and surface energy balance. As it stands, the research appears more as a proof of concept, aligning more closely with a technical journal such as AMT. To align with the scope and standards of ACP, the study requires a more in-depth analysis to better integrate with the current state-of-the-art research and contribute to a broader understanding of how cloud microphysical properties influence the surface energy budget. Before publication in ACP, several key points need addressing to elevate the study to meet the journal's standards.

We thank the reviewer for these several suggestions to improve the manuscript, and we are grateful that the reviewer finds the paper to be well-written and carefully argued. We note that we first submitted this manuscript to AMT, whose editor recommended that it would be more suitable for ACP.

Major comments:

1. Scientific significance for the ACP community

The authors leverage data from the AWARE campaign (2015-2016) to scrutinize the impact of atmospheric regimes and cloud properties on the surface radiative budget. However, the study encounters limitations arising from the relatively sparse number of samples, both spatially and temporally (e.g., regime 3 was observed on only 8 days), prompting questions about its representativeness or applicability to Antarctica's meteorological patterns. Notably, the AWARE campaign coincided with a period of high global-average temperatures during an El Niño event, further raising considerations about the broader context of the study.

To enhance the paper's scope, it is imperative to contextualize the analyses and conclusions within the current state-of-the-art research. This approach not only amplifies the scientific significance but also extends the benefits to a broader community. In this regard, I make a couple of suggestions, non exhaustive, that could help enhancing the generalizability of the conclusions:

- *The identification of the meteorological regimes could be put in the context of the paper from Scott et al., 2019. How the four clusters identified in this paper relate to the nine they found, and to the trends they identified.*

We can provide this context as suggested, (a) with reference to Scott et al. 2019 (the k-means clustering method is essentially the same, and (b) earlier work specific to McMurdo (Scott & Lubin 2014, JGR; and Silber et al. 2019, JGR).

- *The cloud properties retrieved in this study could be compared with the literature you cited. For example, the histogram of cloud optical depth (Figure 5) could be compared with the exponential fit of Fitzpatrick and Warren (2005).*

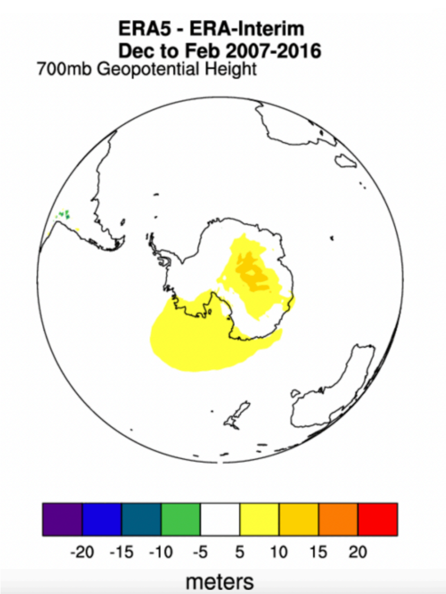
Fitzpatrick and Warren (2005), and two other papers in that series, are indeed excellent studies for comparison with this work, and will provide these comparisons in the revised manuscript.

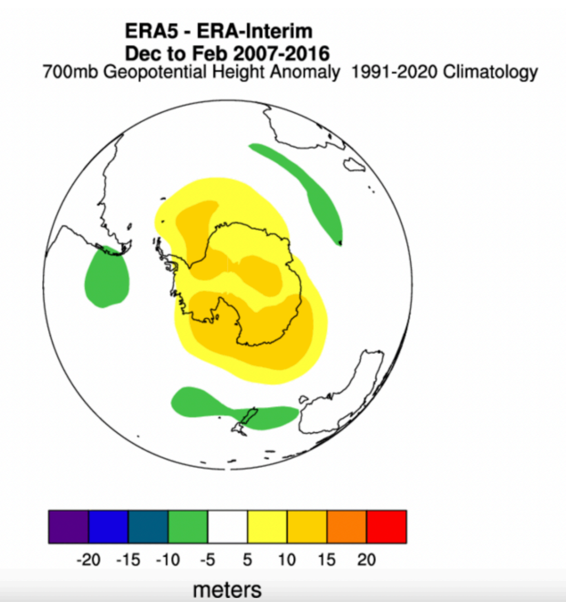
2. Up-to-date reanalysis data set

ERA-5 replaced ERA-Interim in 2019, with improved vertical and spatial resolutions, and a newer Integrated Forecasting System. The ECMWF reanalyses are still experiencing warm biases for 2 m air temperature in polar regions, when compared with ground-based observations, with significant differences between ERA-Interim and ERA5 (see, for example, Jonassen et al., 2019; King et al., 2022; Zhu et al., 2021; Wang et al., 2019).

In the manuscript, you wrote "For the purposes of this work ERA5 reanalyses are essentially identical to ERA-Interim.", but I would like to understand what the expected implications are on the identification of the meteorological regimes. I understand that updating the reanalysis data set would require a lot of work, but could you justify why it is not necessary, and if it is supported by the AWARE observations.

This is a very good point regarding use of an older generation of reanalysis data. We will address it by providing new figures comparing the specific meteorological variables used for the k-means clustering in both ERA5 and ERA-Interim. The differences are small as shown in the following preliminary sketches:





3. Geographical components

The paper is missing a map locating the ARM sites and the regions mentioned in the manuscript. It is important for the readers that are not very familiar with those regions, to better understand the links with the meteorological regimes. See for example the figure 1 in Scott et al., 2019, or the figure 1 in Silber et al., 2019.

Also, the Figure 1 shall contain latitudes and longitudes.

As also requested by Referee #1, a map with these details will be provided.

4. Relevance of the MODIS cloud products for this study

In this paper, MODIS is used to assess the cloud phase and cloud top height over McMurdo station during the summer 2015-2016. As mentioned in the manuscript, some improvements have been made in polar regions (Frey, 2008), but inconsistencies still exist for cloud occurrence (e.g., Cossich et al., 2021; Marchant et al., 2016) and cloud properties (e.g., Wilson et al., 2018).

The impact of uncertainties in MODIS products on the analysis is an important consideration, especially in the presence of multi-layer clouds or potential omissions of certain clouds. The authors should explicitly address how these uncertainties might affect their findings, particularly in scenarios where the MODIS data might misrepresent the actual cloud conditions.

The revised manuscript will include more extensive discussion about MODIS cloud retrieval uncertainties at high latitudes and how they bear on this work's conclusions.

My other comment is why the authors didn't use ground-based observations (radar, lidar, ARM VAP, …) acquired during AWARE to do their analysis or at least assess the cloud properties retrieved by MODIS (see Minor comment below on Figures 2 and 3).

The revised manuscript will use at least two of the ARM Value Added Products (VAPs) to assess the cloud phase retrieved by MODIS, and also to independently verify our conclusions related to cloud phase. Such useful VAPs include the Active Remote Sensing of Cloud Locations (ARSCL) and the THERMOCLDPHASE.

***Minor comments**:*

Page 4, Line 123: In the past, maintaining the measurement quality of some radiometers has been a challenge when used in polar environment, for example when icing appears on the optics (Cox et al., 2021). Could you comment on how feasible it would be to have the suite of instruments you suggest in unattended remote location?

There have been some broadband radiometers occasionally deployed with Antarctic Automatic Weather Stations, and similar net radiation measurements have been made in East Antarctica.

These will be reviewed in the revised manuscript, with emphasis on the potential or limitations involved with unattended operations.

Page 8, Table 1: The date January 26, 2016, appears 2 times.

The table will be corrected.

Pages 8 and 9, Figure 2a and 3: Could you comment on the differences between MODIS clear sky and TSI cloud cover. For example, MODIS identified clear sky during 15%, while TSI observed clear sky for more than 25 %.

This is ultimately related to differences in field of view between space-based and surface-based sensors, and this will be discussed in the revision.

Page 12, Figure 6: The figure may be easier to read using a log-scale.

This change will be made.

Page 13, Line 306: Particle size could be another important parameter influencing the emissivity of optically thin clouds.

This will be mentioned in the revision.

Pages 14 and 16: Figures 7 (b, d, f) and 8 (b, d, f): It would be easier to read with the dashed line crossing 0 on both y-axes, and a legend for the red bars and black line.

These changes will be made in the revision.