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Reply to reviewer comments on

“The importance of cloud properties when assessing surface melting in an offline coupled firn model over Ross Ice shelf, West Antarctica”

by

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Dear Referee #1 and Editor,

Thanks for these follow-up comments. We very much appreciate the expertise and time that has been spent on this task, and sincerely believe that your efforts have resulted in a considerably improved manuscript. We are also very glad that you liked our responses to the first round of comments. We have again implemented your suggested changes / comments as best we can, and very much hope that you now find the manuscript acceptable for publication. In the following, we provide a point-by-point reply to each of these.

Yours sincerely,

Nicolaj Hansen

- I would like to thank the authors for their revision of the article, which addresses many of my comments.
  Thank you for the positive feedback.

- A said in my previous review, this study demonstrates that either (1) properties other than ice-to-liquid partitioning of cloud water influence the radiative effects of the clouds, or that (2) melt extent from passive microwave might be wrong.
  Point (1) was well taken into account in the answers. I find the new wording of the Discussion very clear and convincing.
  Thank you for the positive feedback.

- However, I think it is important for the authors to explore further point (2), namely that the extent of microwave melting could be wrong on 17 (and 18) January 2016:
We also agree that this should be explored further in the manuscript. Please see the response to the individual points below for details of how we have gone about this.

- The author should add information on the strength and limitation of microwave-based melt extent in the method section, including under which conditions it is robust or not.
We very much agree with this comment given the importance of the satellite-based melt results. We have therefore substantially strengthened our description of this in section 2.2, and especially cite a number of publications that confirm that this approach is well suited for detecting surface melting. The revised text now states: *"Microwave remote sensing is particularly suited to detecting surface meltwater over ice shelves because (a) the appearance of liquid water causes an abrupt increase in brightness temperatures and (b) the observations can be acquired during day and nighttime and clear and cloudy conditions (Picard et al., 2007; Nicolas et al., 2017; Johnson et al., 2020, 2022; Mousavi et al., 2022; de Roda Husman et al., 2024). Here, we use a gridded daily surface melting dataset based on Special Sensor Microwave Imager Sounder (SSMIS) satellite-based observations, which uses horizontally polarized brightness temperatures at 19 GHz to identify surface melt. See Nicolas et al. (2017) for further details on the melt detection method. This dataset is available at a spatial resolution of 25 × 25 km, with each grid point classified as either 1(meaning melt was detected during the corresponding day) or 0 (melt not detected)."*

- The authors should discuss how does the choice of the melt threshold (3 mm) affects the comparison with model outputs
We selected a threshold of 3 mm because this has been used in previous studies to compare satellite-based and model-based melt patterns (e.g., Lenaerts et al. , 2017; Deb et al., 2018; Donat-Magnin et al., 2020). However, we also conducted an initial sensitivity analysis examining how the simulated melt patterns varied depending on whether a melt threshold of 1, 3 or 5 mm was chosen (see Figures 1-3 below). This analysis actually shows that the patterns of melt extent were largely insensitive to the threshold chosen. To address the comment in the manuscript, the text in section 2.1 was revised to state: *"Note that we found that the modelled patterns of daily melt extent were broadly similar for melt thresholds of 1, 3, and 5 mm per day (not shown), but selected 3 mm per day as this is the same threshold used by Lenaerts et al. (2017b); Deb et al. (2018); Donat-Magnin et al. (2020)."*

- The authors should discuss the robustness of model-data comparison for the 17th and 18th of January, with respect to the 2 points above and the comparison with other datasets. Notably, the 17th of January, all other datasets seem to point to surface melt: high temperature (Figure 4, weather stations, T° > -2) and high liquid water path (Figure 10, CALIPSO track and Figure 12, CERES). The 18th of January, observed surface temperature is bellow -2°C, we don't have a CALIPSO track (?), and the microwaved-based melt-free area seems more extended, so all dataset seem more in phase.
We very much agree with this comment, and that the manuscript would benefit from better integration of the satellite-based melt results with the other results (e.g., AWS

temperatures, CALISPO). To achieve this, we have made the following modifications to the manuscript.

Firstly, section 3 (surface melting) has been revised to state: *"The AWS-measured near-surface air temperatures from the 13th to 18th of January (Fig. 4) are consistent with the satellite-based melt patterns (Fig. 3). For example, Sabrina AWS and Elaine AWS both show temperatures above the -2◦C threshold for melt during this period, consistent with both sites being located in a region where the satellite-based measurements show melting. By contrast, Schwerdtfeger AWS and Marilyn AWS show temperatures that are either around or below this threshold, consistent with both sites being located in the western sector of the RIS that the satellite-based measurements identify as being melt-free during this period. Moreover, the erroneous regions of melt over the western RIS simulated by the firn model during this period are consistent with near-surface air temperatures simulated by HIRHAM5 and MetUM being higher than the temperatures observed by Schwerdtfeger AWS and Marilyn AWS (Fig. 4). In particular, at these two stations the HIRHAM5 near-surface temperatures are consistently above -2◦C from the 16th to 18th."*

Secondly, section 5 (cloud properties) now states: "*Additionally, the occurrence of liquid-based clouds on the 14th and 17th of January in the CALIPSO observations over the eastern and central sectors of the RIS is consistent with the satellite-based measurements showing melting here (Fig. 3).*"

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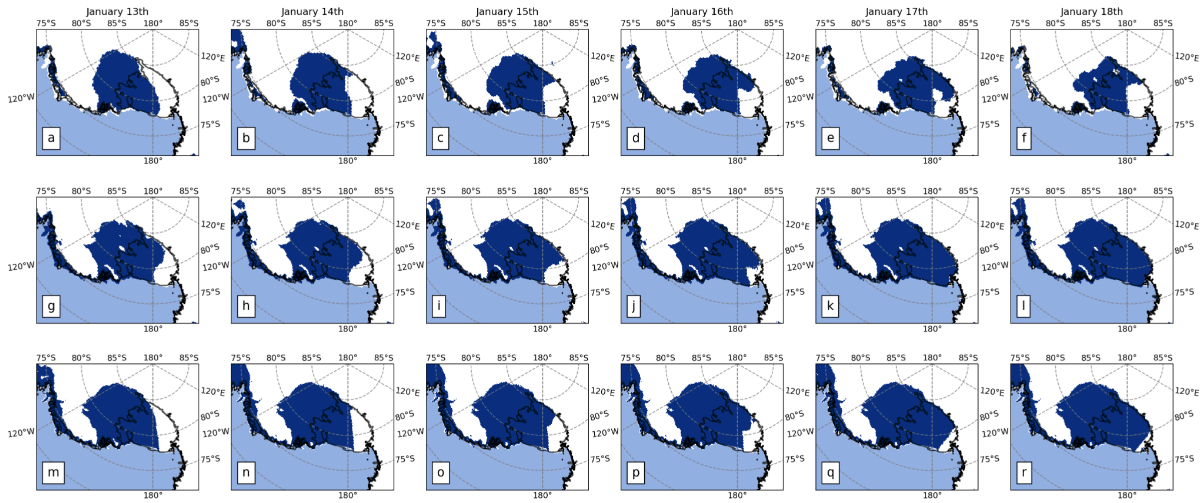

Figure 1: 1mm per day threshold, Maps of West Antarctica showing the daily melt area from the 13th to 18th (from left to right) of January 2016 from (top row; a-f) satellite passive microwave measurements, (middle row; g-l) the offline coupled firn model forced by HIRHAM5 output, and (bottom row; m-r) the offline coupled firn model forced by MetUM output. Melt areas are indicated by the dark shading, while melt-free regions are shown as white.

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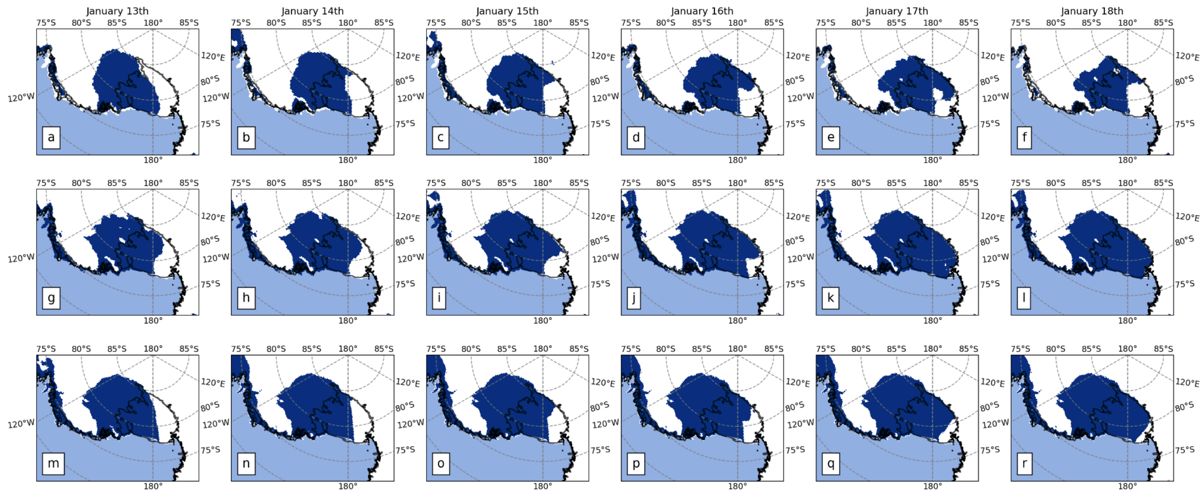

Figure 2: 3 mm per day threshold (as in the paper), Maps of West Antarctica showing the daily melt area from the 13th to 18th (from left to right) of January 2016 from (top row; a-f) satellite passive microwave measurements, (middle row; g-l) the offline coupled firn model forced by HIRHAM5 output, and (bottom row; m-r) the offline coupled firn model forced by MetUM output. Melt areas are indicated by the dark shading, while melt-free regions are shown as white.

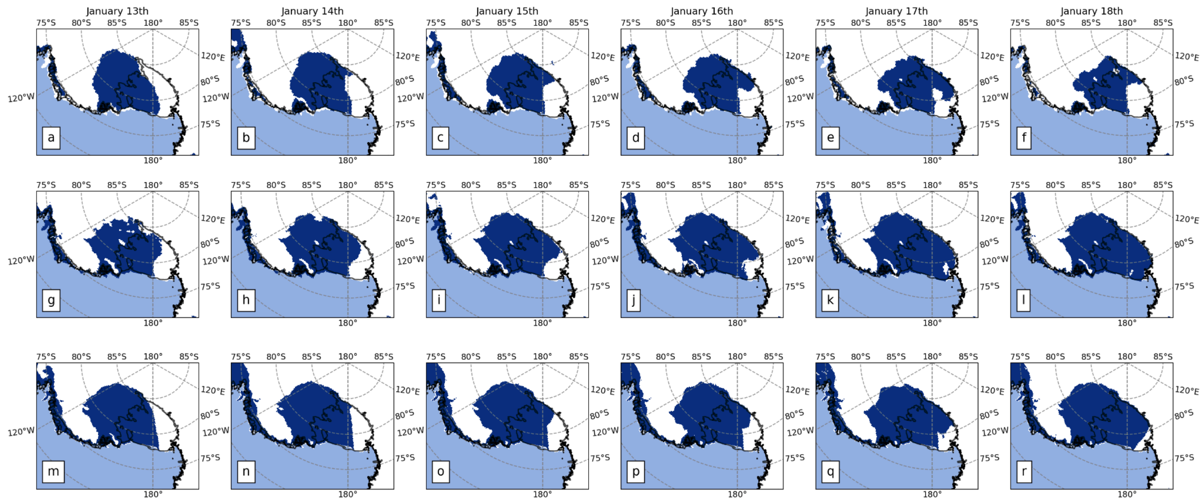

Figure 3: 5 mm per day threshold, Maps of West Antarctica showing the daily melt area from the 13th to 18th (from left to right) of January 2016 from (top row; a-f) satellite passive microwave measurements, (middle row; g-l) the offline coupled firn model forced by HIRHAM5 output, and (bottom row; m-r) the offline coupled firn model forced by MetUM output. Melt areas are indicated by the dark shading, while melt-free regions are shown as white.