Referee #2: Braakmann-Folgmann, Anne

The research article "A Six-year circum-Antarctic icebergs dataset (2018-2023)" presents a novel and valuable dataset of iceberg population, distribution and area estimates for October in six consecutive years covering the whole Southern Ocean south of 55 deg (wherever Sentinel 1 EW data is available). It is the first study to include icebergs of all sizes with a minimum of 0.04 km2 and covering both open water and sea ice. Therefore, I consider this study novel, innovative and valuable for many downstream applications and future studies and recommend publication after some minor revisions listed below:

Thank you for your recognition of our study, and we are also very grateful for your detailed comments and valuable suggestions. Below are our point-by-point responses to each of your comments:

General: On zenodo, where the data is published, there is one section specifically for iceberg detection code and the iceberg sample set, but not for the iceberg vector outlines, which are the main dataset. I would suggest adding a paragraph on them explaining what the data contains and what units each variable comes in! Ideally, the units should also be added to the header within the dataset (e.g. area [km^2] rather than just area) or there should be a readme file with the same information added to the iceberg vector outlines zip file for ease of use.

We sincerely thank the reviewer for their valuable suggestion. We have noted that the current Zenodo page lacks detailed textual descriptions of the iceberg vector outlines files. In the updated Zenodo page (https://doi.org/10.5281/zenodo.16913262), we have added a relevant section providing explanations of the vector data, clearly defining the physical meaning of each variable and its corresponding units, in order to enhance the readability and usability of the dataset.

L9/10: You don't mention mass as a geometric attribute, but that there is an uncertainty estimate for mass. As mass is not directly derived from the data, I would either leave it out or explain that mass is derived using a constant thickness and density.

To provide a comprehensive overview of the dataset in the abstract, we have adopted your second suggestion in the revised manuscript and now explicitly state that the mass is derived from the Volume/Area scaling parameterization of Iceberg Classes Model in Stern et al. (2016) under fixed-density assumptions (L10/11).

L12: The statement that this is related to A68 is not clearly backed up by your analysis or discussed in the paper. Either leave out or add more discussion

We thank the referee for the correction. We recognize that mentioning specific icebergs (such as A68) in the discussion of the overall Antarctic iceberg number change appears abrupt and lacks sufficient analytical support. Therefore, we have removed this part from the revised manuscript.

Table 1: I would suggest adding the studies by Wesche and Dierking and Barbat to the table

We sincerely thank the referee for the valuable suggestion. Our original intention was to summarize long-term iceberg distribution databases or data products, while the studies by Wesche & Dierking (2015) and Barbat et al. (2016), focus more on technical advances in iceberg detection methods. However, to make our review of existing iceberg databases more comprehensive and complete, we have incorporated these studies into Table 1 in the revised manuscript as per your suggestion. Once again, we appreciate your thorough review and constructive comments.

Figure 1: This is a nice plot and clearly motivates why you picked October. However, did you just pick one location (indicated by the coordinates in the legend) for each surface type? And did e.g. the iceberg not move? From the text it is not clear at all whether this analysis was based on 1 pixel, 1 area or how many samples (area and number of images, locations) were used. Please explain.

We thank the referee for the detailed question. Yes, for the analysis in Figure 1, we selected a representative location for each surface type and indicated its specific coordinates in the legend. The iceberg sample was chosen as one that remained grounded without significant drift during the study period to ensure consistency in the time series analysis. This analysis was conducted based on a single pixel with precise latitude and longitude positioning, and we have added relevant explanations in the revised manuscript (L73–78) to improve clarity and reproducibility.

Figure 2: How does the iceberg classification result impact your iceberg thickness calculation? Isn't it solely based on altiberg? And the area/perimeter is independent of thickness?! So, I would suggest two parallel processing chains and merging them only for the mass (if I understand correctly).

Thank you for your suggestion. Initially, to simplify the workflow, we directly merged the two datasets and processed them either separately or jointly as needed in subsequent steps. In fact, the iceberg classification results do not affect thickness calculations, and the extraction of iceberg area and perimeter does not rely on the Altiberg data. Therefore, our original approach may have caused some misunderstanding. In the revised version, we have updated the method for calculating iceberg thickness (L206–213), with thickness derived from iceberg area using the Volume/Area scaling parameterization of Iceberg Classes Model in Stern et al. (2016). Accordingly, Figure 2 has been modified to reflect this change.

L93: I assume most places are covered by several Sentinel 1 scenes within 1 month. How do you select which scenes to use and how do you ensure that icebergs are not missed or counted twice when they drift between scenes that are up to 30 days apart?

We sincerely thank the referee for this pertinent question. In our workflow, all Sentinel-1 HH-polarized scenes acquired within each 5° × 5° tile during the month were arranged chronologically and mosaicked in sequence, with later scenes replacing valid pixels from earlier ones. This procedure ensures that the composite image for each tile represents the most up-to-date spatial coverage while minimizing temporal gaps.

In practice, the temporal separation between images used for a given tile is short. For example, in 2021 over 91 % of all valid Antarctic tiles had a maximum acquisition-date span of no more than 10 days, and more than half had spans of 5 days or less in iceberg-dense regions (65–80° S) (Fig S1). Considering the low drift rates of most icebergs (< 0.2 km day^{-1}; Koo et al., 2023) (Fig S2), such short intervals mean that the likelihood of a single iceberg being detected twice within the same month is very small.

In addition, we accounted for the uncommon situation where rapidly drifting small icebergs might appear in images from adjacent acquisition dates. As clarified in the revised manuscript (L198/199), such duplicate detections were identified and removed through manual inspection. For instance, in the two representative cases shown in Fig S3, icebergs were observed drifting in relatively stable clusters under the combined influence of wind and currents; in these cases, we retained only the set with the most complete outlines (e.g., those highlighted in the red box of Sample Area 1 and the yellow box of Sample Area 2). The few small icebergs that were inadvertently counted twice due to fast drift have an insignificant effect on the overall Antarctic iceberg count and area estimates, and thus can be disregarded.

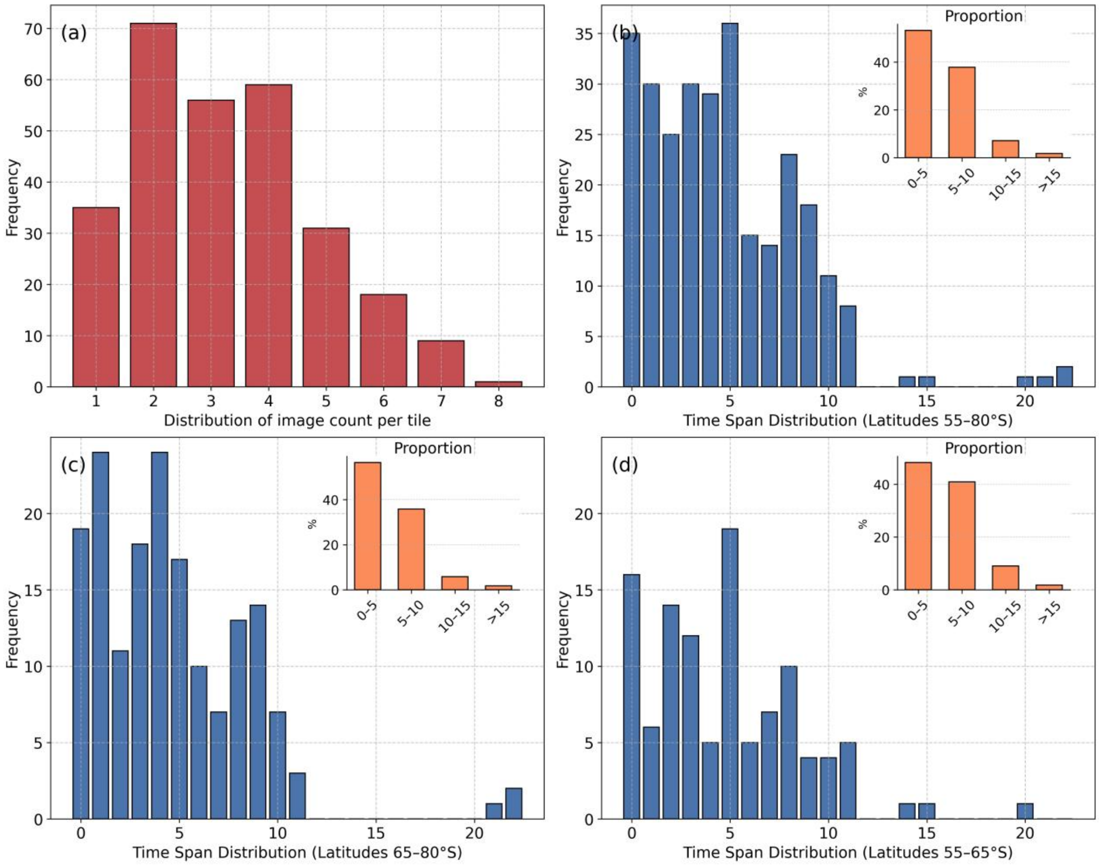

Figure S1. Panel (a) distribution of the number of Sentinel-1 images per tile. Panels (b–d) histograms of the time span between acquisition dates for tiles in different latitude bands (55°S–80°S, 55°S–65°S and 65°S–80°S).

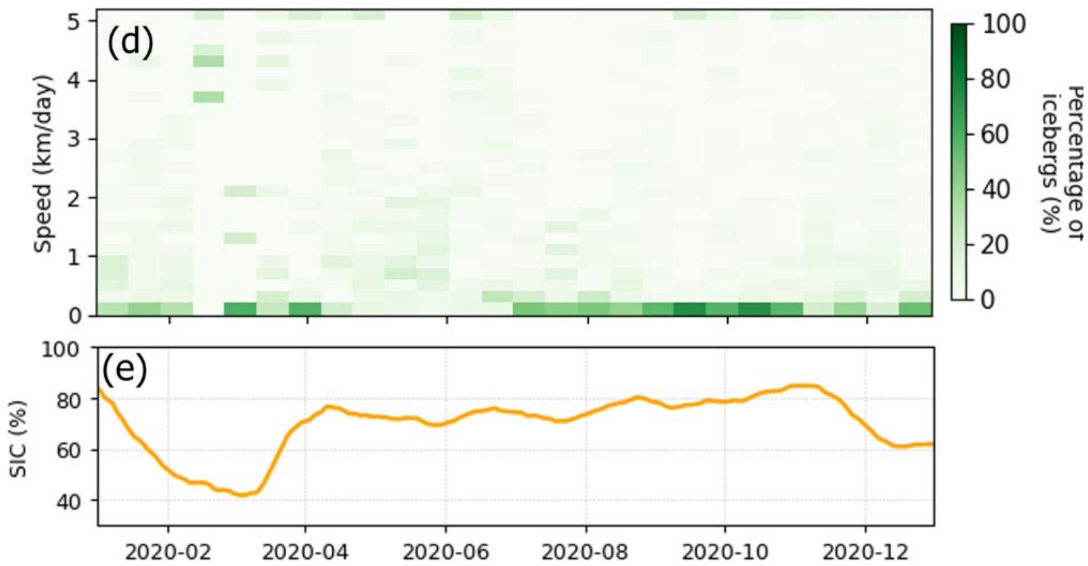

Figure S2. Drift speed distribution (biweekly average): most icebergs drift at speeds below 0.2 km/day, indicating relatively slow short-term movement (Koo et al., 2023).

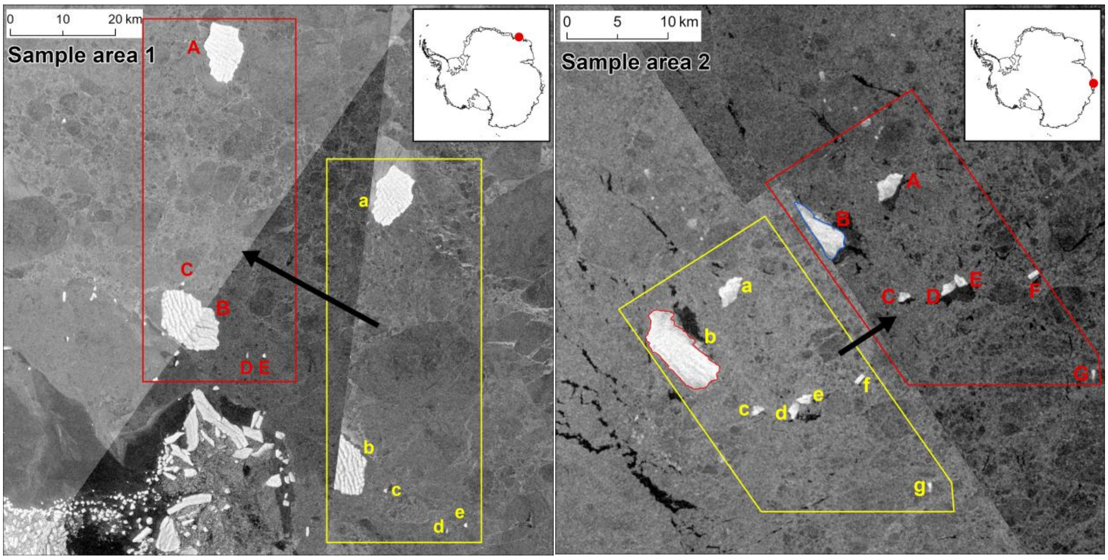

Figure S3. Examples of fast-moving icebergs appearing twice in the mosaic imagery of the same tile.

I am missing an explanation somewhere in your methods how you define each iceberg object. My understanding is that you classify each superpixel into iceberg or not and then do a manual correction. When do you merge neighbouring superpixels that were classified as iceberg into one iceberg? And have you tested how far apart two icebergs need to be to separate them? Or does each superpixel need manual redrawing of the outline anyway before it becomes an iceberg?

Thank you for raising this valuable question. In our methodology, the classification results—i.e., the superpixels identified as icebergs—are first converted into a binary mask. After hole-filling and denoising, we directly apply connected-component labeling to the binary image. This step automatically merges all adjacent iceberg-classified superpixels into a single iceberg object. Two icebergs are recognized as separate objects only if there is at least one non-iceberg superpixel between them, and no additional distance threshold is applied for segmentation. On this basis, we perform only necessary manual corrections to the merged iceberg boundaries to address false detections, omissions, or boundary deviations, rather than redrawing the outline of each superpixel individually. Therefore, the aggregation or separation of iceberg objects is entirely determined by pixel-level connectivity. We have added this clarification in the revised manuscript (L189–192) to enhance the transparency and reproducibility of the methodology.

L145: What do you mean by sample points here? Are these the superpixels derived by SLIC? Or individual pixels? Or merged icebergs?

We thank the referee for the question. Here, the term "sample points" refers to the superpixels extracted from Sentinel-1 imagery using the SLIC algorithm, and we have added a corresponding clarification in the revised manuscript (L153/154).

L178/179: How do you identify which icebergs are counted twice? Most have rather generic shapes or can rotate and break up in between.

We thank the referee for this question. As noted above, because the mosaics are constructed from Sentinel-1 scenes arranged in chronological order and Antarctic icebergs generally drift slowly over short time intervals, the likelihood of the same iceberg appearing in two adjacent scenes and being double-counted is very low (Fig S1-3). The potential counting errors caused by such cases are far smaller than those arising from misclassification or omission during the detection process.

In our workflow, we therefore focus on identifying clusters of icebergs that move together as a group under the combined influence of winds and currents. For these clusters, we manually remove repeated instances of the same iceberg, prioritizing the version with the most complete and accurate outline. In contrast, very small icebergs with atypical texture or shape features—particularly those that drift rapidly—are not targeted for individual de-duplication, as their contribution to total counts and areas is negligible.

L182: As you use a constant thickness and density for all icebergs, I think it would be better to just assign those parameters to individual icebergs that are actually derived from the data (i.e. area, perimeter, axes, coordinates) and only use the thickness and density to calculate the overall mass of icebergs in each year. For this application your assumptions seem fair and some of the uncertainty will average out, whereas the smaller bergs will certainly be thinner than you assume and some giant bergs will be thicker, so assigning the average thickness to each berg seems like an unnecessary stretch.

Thank you for your valuable suggestion! We acknowledge that assuming a constant thickness is meaningful for estimating the overall Antarctic iceberg mass but often introduces large biases at the individual iceberg scale. In the revised version, we applied the Iceberg Classes Model to estimate both the mass of individual icebergs and the annual total iceberg mass across the circumpolar region (Gladstone et al.,2001; Stern et al., 2016). Following the parameterization scheme of Nong et al. (2025), the model provides an area-volume power-law relationship, with iceberg thickness constrained to a maximum of 250 m. This constraint implies that an iceberg with a thickness of 250 m corresponds to an area of 0.67 km2. For icebergs smaller than this threshold, volume is calculated directly from the power-law relationship ($V_{iceberg}=7.64A^{1.26}$), whereas for larger icebergs, volume is derived by multiplying the area by the fixed thickness of 250 m. Assuming an average density of 850 kg/m3(Silva et al., 2006), the mass of each iceberg and the circumpolar total are then obtained accordingly.

In addition, we compared the impacts of two methods on estimating the total Antarctic iceberg mass: the fixed-thickness method (232 m) and the segmented method (using the power-law relationship for icebergs with an area < 0.67 km², and a fixed thickness of 250 m for those with an area ≥ 0.67 km²). The results show that (Figure S4), compared with the fixed-thickness method, the segmented method yields smaller masses for small icebergs (area < 0.67 km²) but larger masses for large icebergs (area ≥ 0.67 km²), indicating that the new approach avoids pulling the two ends toward the middle and instead enlarges the mass contrast between small and large icebergs. Moreover, the total Antarctic iceberg mass estimated by the segmented method is greater than that from the fixed-thickness method, and the variation in large-iceberg mass closely follows that of the total mass, further demonstrating that large icebergs dominate the overall Antarctic iceberg mass.

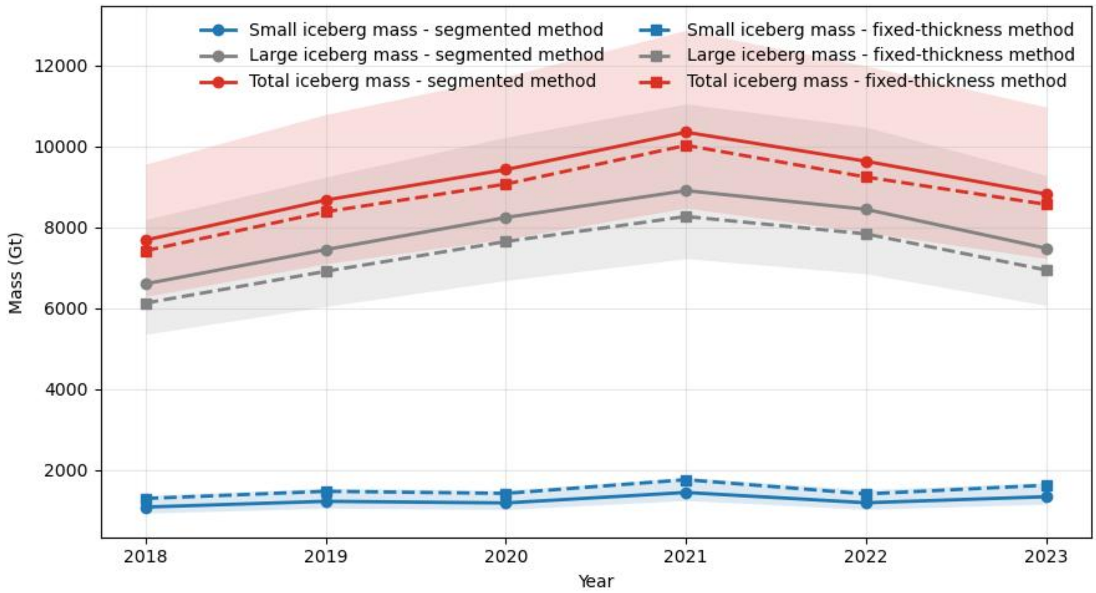

Figure S4. Comparison of Antarctic iceberg mass estimation methods: fixed-thickness method and segmented method, with shaded area representing the uncertainty range of the segmented method.

L301-303: I am surprised that BYU/NIC miss so many icebergs. Are most of the ones missing from their database around the threshold of 5 km? Or are you sure you weren't counting some double? Or accidentally merged two smaller bergs into one bigger one?

We thank the referee for this question. To address the possibility of double counting or incorrect merging, we manually cross-checked all icebergs in our database with a major axis greater than 5 km against the original Sentinel-1 mosaicked images for October 2021. This verification confirmed that no duplicate counts or erroneous mergers occurred. Furthermore, our one-by-one comparison with the BYU/NIC Statistical Database (v7.1) shows that the large number of icebergs absent from BYU/NIC is not concentrated around the 5 km threshold (Fig S5-6). Instead, these undetected icebergs span a range of sizes, with most having major axes of 5-9 km and areas of 0-20 km^2. Many of them are located in front of ice shelves where dense sea ice cover can obscure detection by passive microwave or scatterometer sensors. As discussed by Budge and Long (2018), such coarse-resolution sensors and the challenging coastal environment can cause even large icebergs to be missed. Therefore, the discrepancies between the two datasets primarily reflect limitations in BYU/NIC's detection capability rather than over-counting or merging errors in ours.

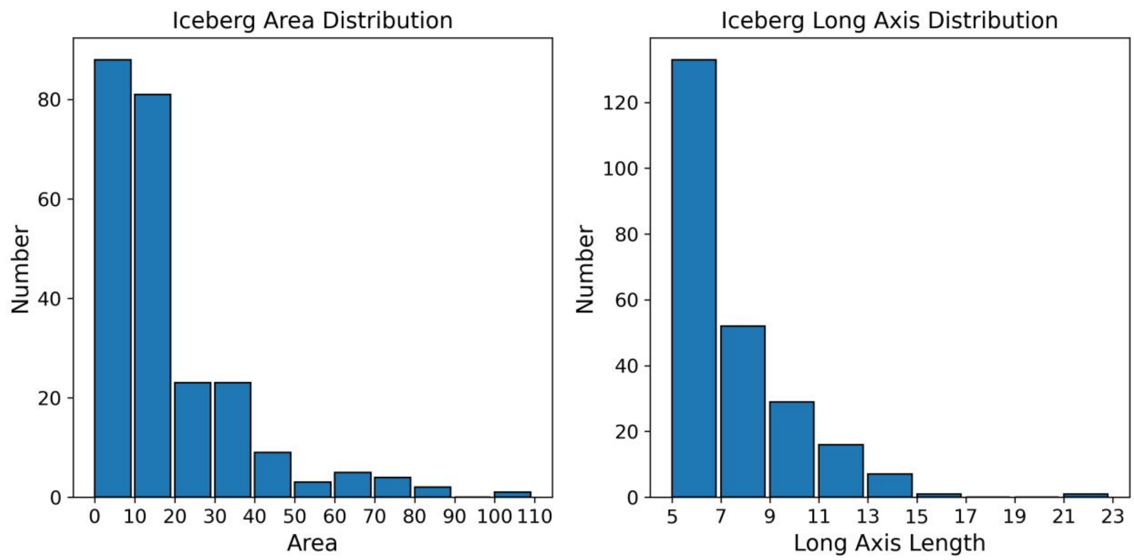

Figure S5. Histogram distribution of the area and major axis length of icebergs (>5 km) missed by the BYU/NIC dataset.

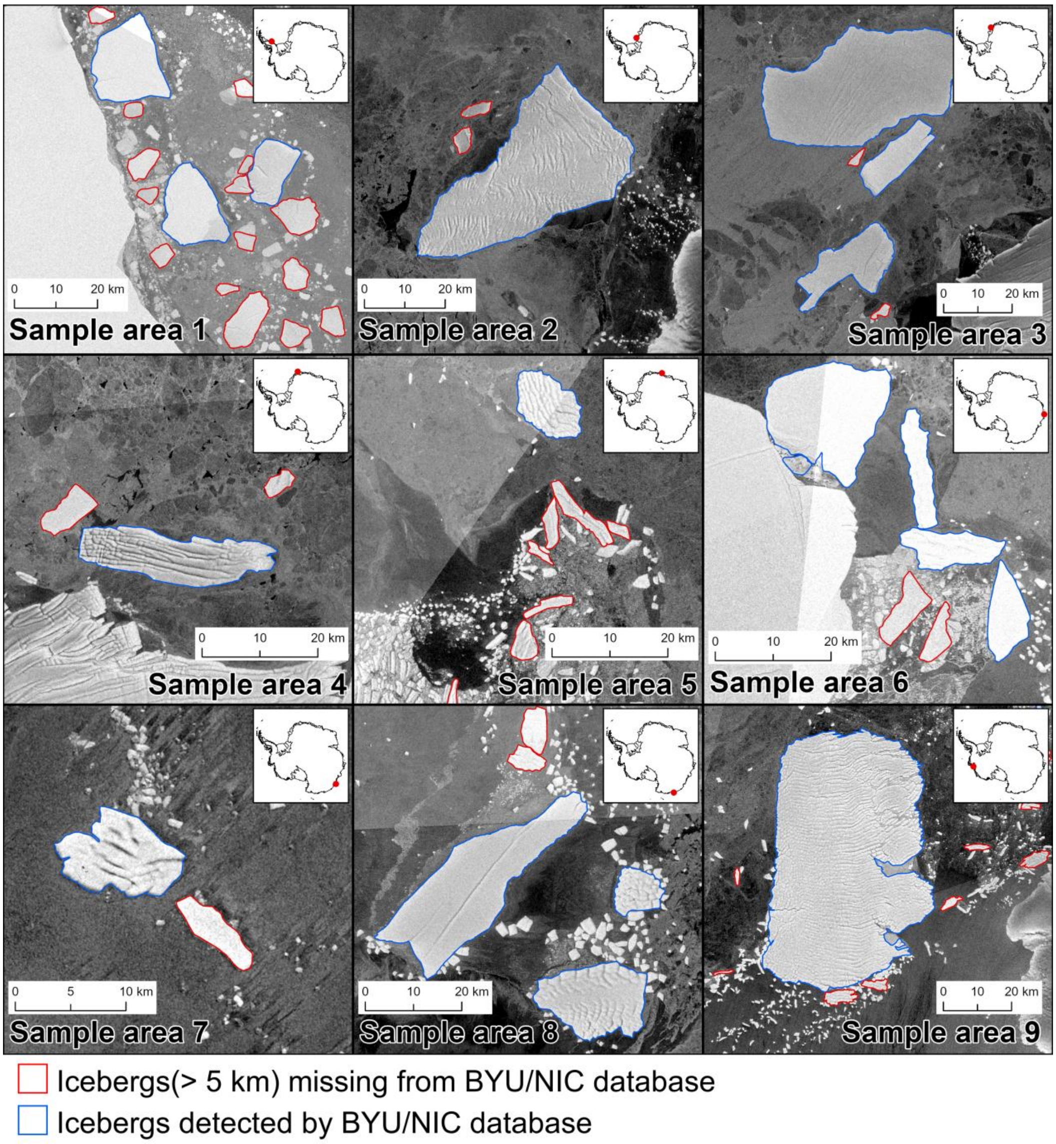

Figure S6. Examples of icebergs (>5 km) detected (blue) and missed (red) by the BYU/NIC dataset, with Sentinel-1 mosaics as background.

L332 Small icebergs are more influenced by wind, not by currents.

We sincerely thank the referee for the correction. As small icebergs are relatively small in size, their movement is more influenced by wind than by ocean currents. We have revised the manuscript accordingly, replacing "coastal currents" with "wind and coastal currents" to more accurately describe the drift mechanism of small icebergs.

L350-352: It does not make sense to analyse trends in mass if your thickness and densities are constant. You can analyse trends in area, but the mass is just a multiple of your area, so just leave this section out.

Thank you for your comment. We acknowledge that analyzing mass trends lacks practical significance when both iceberg thickness and density are held constant. However, in the revised manuscript, we have updated the method for calculating mass and no longer use a fixed thickness. Therefore, we have retained the analysis of mass trends in the revised version.

Figure 8: Very nice figure!

We thank the referee for the positive feedback on Fig. 8.

L417 Thickness and density will also depend on the calving location/mother ice shelf (Dowdeswell and Bamber, 2007 and Ligtenberg et al. 2011).

We thank the referee for the correction. We have added this point in the revised manuscript (L421/422).

Figure 10: Add a comment that the y axis in c starts at 80 % - it's easy to miss

We thank the referee for the suggestion. We have added the caption for Fig 10 in the revised manuscript.

References

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