Reviewer 2

In this brief communication the authors present observations of lateral meltwater export from Bach Ice Shelf, and explain this reactivation of export after a 9 year hiatus using regional climate model and reanalysis output.

While this observation would be of interest to the community and lateral movement of meltwater is extremely important for ice shelf stability, there would be major changes needed to this paper for me to recommend it for publication.

Thank you for your review and compliments on the foundations of our case study. We have found your comments to be helpful in further enhancing this Brief Communication, and have made major revisions to the manuscript. We address specific comments and changes in turn below.

The key issue with the paper is it does not present the evidence of the process that is the topic of the paper. The remote sensing evidence found is limited in its presentation, or not shown at all. The meltwater extents are limited to one sub figure and the evidence of the rift extents found from remote sensing are absent. Claims are made about the two main pathways meltwater is exported (line 150), but it is impossible for the reader to see how this conclusion has been made from the evidence presented. Although the total change in melt area is presented in figure 2, actually knowing how the spatial extent changed and how/where it moved laterally is missing from the paper.

Thank you for this feedback, you make some incredibly valid points, we have addressed these in two parts below:

PART 1: "The remote sensing evidence found is limited in its presentation, or not shown at all. The meltwater extents are limited to one sub figure and the evidence of the rift extents found from remote sensing are absent. Claims are made about the two main pathways meltwater is exported (line 150), but it is impossible for the reader to see how this conclusion has been made from the evidence presented."

To present the intersection between surface melt features and the calving front/ rifts we have added Figure 1 (provided below for ease), which clearly shows the intersection of melt features with areas of structural damage and the calving front. Instead of showing these intersections for 2023 alone, we have also provided evidence of these interactions prior to the observed nine-year hiatus. We hope this adds historical context to the study. With regards to the digitised rift extents mentioned in our methods, these are presented in Figure 2, whilst in our new Figure 1 we digitise a historical meltwater fed crevasse to better evidence our findings.

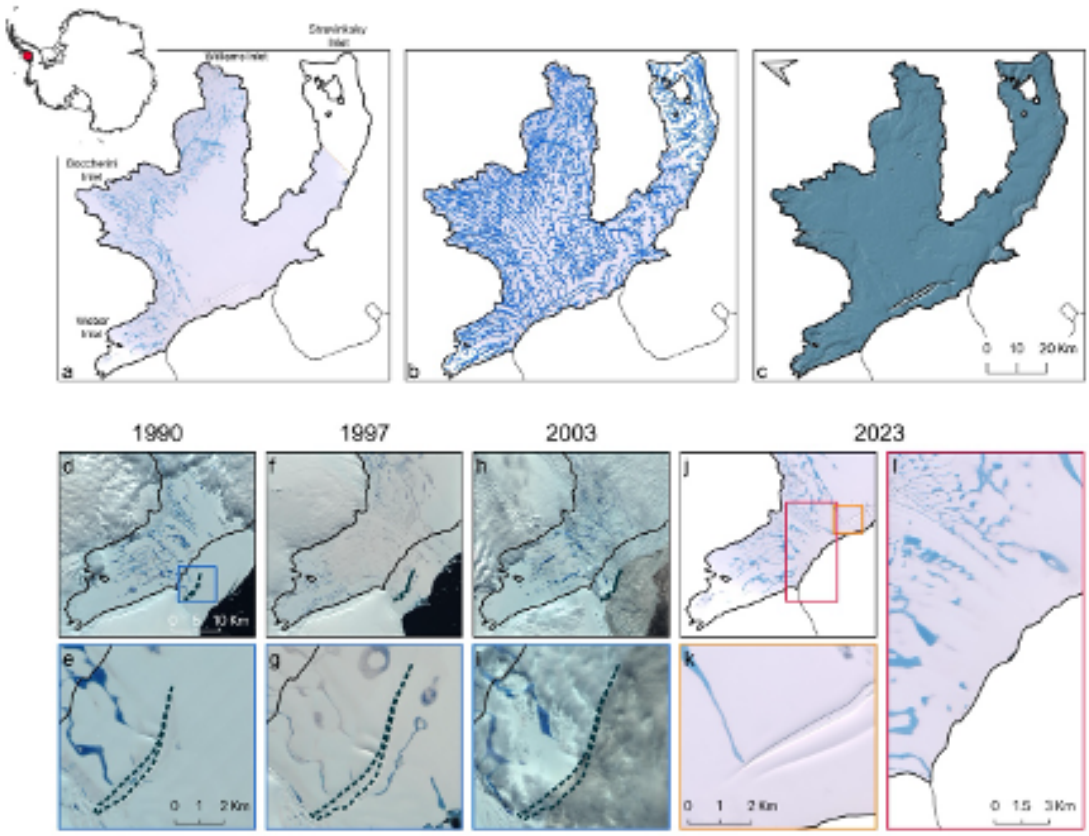

Figure 1: Surface meltwater distribution and the surface topography of Bach Ice Shelf *shown using (a) a Sentinel-2 image mosaic (08/02/2023), (b) the same Sentinel-2 image overlain with meltwater routing pathways, calculated at 8 m resolution (calculated using REMA V2 at 8 m resolution; Howat et al., 2022), and (c) a hillshade visualisation of the 2 m REMA mosaic using a northwest illumination azimuth (315°) and altitude of 60°; a z-factor of 25 was applied to enhance the subtle surface topography of the ice shelf for visual interpretation. Panels d-l provide contextual observations of surface hydrology near Weber Inlet from optical satellite imagery in 1990 (panels a–b; Landsat 4; 1990-01-29), 1997 (panels c–d; Landsat 5; 1997-02-09), 2003 (panels e–f; Landsat 7; 2003-01-17), and 2023 (panels g–i; Sentinel-2; 2023-02-08). Dashed lines in panels a–f delineate the rift extent in 1990 (a–b) and 1997 (c–f), showing that by 2003 the ice shelf had calved along the 1997 rift position. Ice-shelf shapefile data from the SCAR Antarctic Digital Database, 2024 (Gerrish et al., 2024). Inset map (top left) marks Bach Ice Shelf's location within Antarctica.*

PART 2: "Although the total change in melt area is presented in figure 2, actually knowing how the spatial extent changed and how/where it moved laterally is missing from the paper."

With hindsight we completely agree! We have rewritten and restructured large portions of our results to address this (lines 180-239). This re-written section now also benefits from the addition of new Figure 1 (as above), which presents Bach Ice Shelf's meltwater routing pathways alongside a hillshade visualisation of the REMA DEM. Our results now present in far greater detail the distribution of surface meltwater across the ice shelf in the context of its surface topography.

In addition to this major issue I have some minor line by line comments:

Line 23: Surface meltwater *may* pose an instability risk

Amended - thank you (line 27)

While the importance of hydrofracture is well documented here, as this paper covers lateral transport it is important to acknowledge that lateral transport can also stabilise ice shelves e.g. Bell et al. (2017) https://doi.org/10.1038/nature22048

The uncertain role of lateral meltwater movement doesn't diminish from the results of the paper, if anything it highlights the need to understand it more!

This is a good point, which Reviewer 1 also raised, we have now acknowledged this several times within our paper (lines 62-74 and 283-292)

Line 55: The importance of lateral meltwater export isn't really covered as well as the importance of hydrofracture, the flow itself and where it takes the water is also important e.g. Kinglake et al. (2017) https://doi.org/10.1038/nature22049

We have added a paragraph here to provide more commentary on the various ways meltwater may impact ice-shelf (in)stability (lines 62-74).

Line 70: Why is 'adapted from' in italics?

This has now been amended (line 87)

Line 94: Is the lack of runoff not also interesting? In high melt years if there's not much runoff this suggests refreezing and loss of firn air content. Larsen C for example features evidence of lateral movement and ice slab formation e.g. Bevan et al. (2017) https://tc.copernicus.org/articles/11/2743/2017/tc-11-2743-2017.pdf

The lack of runoff in high melt years can point to loss of firn air content, as long as it is not also a high-SMB year, in which case enhanced accumulation may buffer meltwater produced. Firn air content and meltwater production also depend on air temperatures, and with the average increase in air temperature of +0.06°C yr^{-1} over the study period, the regime for runoff generation is changing on Bach.

Given these complexities, and the fact that this is a brief communication focussed on lateral meltwater transport and export, we don't think it is necessary to unpack this more here in the methods. That being said, our results and discussion section does hint at several of these processes. Hopefully this study will motivate future research in modelling firn air content and firn temperatures in the region.

Line 118: Referencing issue (first name shown)

Amended - thank you.

Line 163: The wording of this paragraph is a little odd, as are later references to SMB. The key here is the balance between accumulation and runoff, but it seems SMB is sometimes being used instead of referring directly to accumulation. Melt and accumulation are part of mass balance, SMB doesn't counteract either.

Our reasons for working with SMB rather than accumulation are outlined in methods section 2.4. Here is a summary:

- SMB accounts for multiple processes that control the localized change in surface mass on Bach ice shelf. For example, SMB includes snowfall, sublimation, and drifting snow, which all ultimately influence surface conditions at a given location, whereas accumulation alone may not account for these processes.
- Accumulation dominates SMB, and both rainfall (van Dalum et al., 2024) and runoff (van Dalum et al., 2025) are very small for Bach Ice Shelf.
- We worked with the variables available to us at 2km spatial resolution, as this resolution better represents the processes at play on Bach Ice Shelf.

This section therefore refers to SMB rather than accumulation to allow us to accurately present our results. However, in later discussion sections, we have shifted our wording towards accumulation rather than SMB in response to some of your later comments (e.g. lines 312 and 315).

Line 171: In what way does this pre-condition the ice shelf? (more detail needed).

This would be through a reduction in firn air content, we have adjusted the text to reflect this (lines 256-259).

"This relatively sustained period of elevated melt-to-SMB values likely preconditioned the Bach for widespread ponding events (e.g. 2019/20, 2022/23, and 2024/25) and for the occurrence of lateral surface meltwater export (e.g. 2022/23 and 2024/25) through a reduction in the ice shelf's firn air content (Fig. 2)."

Line 177: The trend (while statistically significant) is much less than the variation in the period that's described as "stable" in line 180- can this short time period really be described as stable?

We agree that the word choice can be improved here - we have revised the text to state temperatures were "consistent" during this period. This puts more emphasis on mean temperatures being similar year-on-year from 2001-2005, without suggesting they are "stable".

Figure 2: A minor point, but these plots don't work in greyscale, particularly the yellow in the third panel and the difference between the pale blue and green.

Thanks for spotting this, we have adjusted the colours and checked this in a colour-blind checker for monochromacy. Note this figure is now Figure 3.

Line 217: There are two dashed lines here (I'd actually describe this more as a dotted line, the trend line is a dashed line).

Amended as below - thank you (lines 307-308)

Line 228: And also the topography of the ice shelf, the firn air content, the firn depth and amount of water that percolates vertically into the snow/firn…

We have added more nuance to this paragraph (below), which should be more all-encompassing (lines 311-319).

Line 230: This is another example of what I was getting at in the earlier paragraph, SMB isn't a buffer, it's the accumulation itself that's the buffer, SMB is the balance between the two.

We have amended this to snowfall.

References

Bell, R. E., Chu, W., Kingslake, J., Das, I., Tedesco, M., Tinto, K. J., Zappa, C. J., Frezzotti, M., Boghosian, A., and Lee, W. S.: Antarctic ice shelf potentially stabilized by export of meltwater in surface river, Nature, https://doi.org/10.1038/nature22048, 2017.

Bevan, S. L., Luckman, A., Hubbard, B., Kulessa, B., Ashmore, D., Kuipers Munneke, P., ... & McGrath, D. Centuries of intense surface melt on Larsen C Ice Shelf. The Cryosphere, 11(6), 2743-2753, 2017

Gerrish, L., Ireland, L., Fretwell, P., & Cooper, P: High resolution vector polygons of the Antarctic coastline (Version 7.10) [Data set]. NERC EDS UK Polar Data Centre. https://doi.org/10.5285/4ecd795d-e038-412f-b430-251b33fc880e, 2024

Howat, I., Porter, C., Noh, M.-J., Husby, E., Khuvis, S., Danish, E., Tomko, K., Gardiner, J., Negrete, A., Yadav, B., Klassen, J., Kelleher, C., Cloutier, M., Bakker, J., Enos, J., Arnold, G., Bauer, G. and Morin, P.: The Reference Elevation Model of Antarctica - Mosaics, Version 2. [Data set]. Harvard Dataverse, V1. https://doi.org/10.7910/DVN/EBW8UC, 2022

Kingslake J, Ely JC, Das I, Bell RE. Widespread movement of meltwater onto and across Antarctic ice shelves. Nature. 544(7650):349-52, 2017

van Dalum, C., van de Berg, W. J., & van den Broeke, M. Monthly RACMO2.4p1 data for Antarctica (11 km) for SMB, SEB and near-surface variables (1979-2023) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.14217232, 2024

van Dalum, C.T., van de Berg, W.J., van den Broeke, M.R. and van Tiggelen, M. The surface mass balance and near-surface climate of the Antarctic ice sheet in RACMO2. 4p1. The Cryosphere, 19(9), pp.4061-4090, 2025

Veldhuijsen, S., Van De Berg, W.J., Kuipers Munneke, P. and Van Den Broeke, M.R.: Firn air content changes on Antarctic ice shelves under three future warming scenarios. The Cryosphere, 18(4), pp.1983-1999, 2024