Dear Editor,

Please find our point-by-point response letter to your comments below.

Kind regards, Bernhard Hynek

Editor Comment – Author Comment

Before a final decision can be made, some corrections are still needed. In particular, one of the comments of reviewer#2 was not fully addressed, regarding the presence of the 2018 avalanche snow at the surface in 2021. This could also originate from avalanches in winter 2019, 2020 and/or 2021. This may lead to modifications at several instances in the text.

We changed the wording *remnants of avalanches 2018* to *avalanche affected areas* in several instances in the text to make it less specific and added some lines in the discussion section, where we argue, that some of these areas are most likely remnants of 2018.

L2: "High arctic" make the study generic but I feel it would be good to be more precise about the location. An option would be "...mass balance of a peripheral glacier of Greenland" or " a mountain glacier at the periphery of Greenland"

We agree. We suggest to change the title to: *Accumulation by avalanches as significant contributor to the mass balance of a peripheral glacier of Greenland*

L24: This number and its difference to 1.33 m w.e. just above is enigmatic to the reader until he understands, line 160, that a seasonal offset to the end of the melt season is involved and corrected. I would include in parenthesis a very short statement about this seasonal correction.

Thanks for that comment. We changed the phrase to: *After applying a seasonal correction of -0.6 + 0.05 m w.e. the geodetic mass balance over the entire eight-years period (2013/14 - 2020/21) is found to be 0.73 + 0.22 m w.e.*

L24: This point has been raised by reviewer #2 but not really addressed I think. How can the authors be certain that the snow of the 2018 avalanches is visible at the surface? This could also come from avalanches in winter 2019, 2020 and/or 2021.

Thanks for that comment. Off course we cannot be certain about that, and when we made that statement, we were actually referring only to the two big avalanches in the middle of the glacier (green circle in Fig. 11), which originated from opposite sides and travelled almost all the way through the other side of the glacier.

In the case of these two avalanches, we have good reasons to believe, that these are the remnants of 2018 because

- the extent of the snow cover 2021 matches very good the avalanche areas of 2018 based on the GPR survey (we marked that in Fig.10)
- winter accumulation in all 3 years after 2018 was far below average and was therefore very unlikely to produce avalanches of that size
- we have no signs of big avalanches in 2019, 2020 and 2021 there in imagery of the automatic cameras
- we can see signs of small avalanches on top of the big ones (of 2018)

Here, in the abstract, we changed the statement about the surface in 2021 to the following sentence: *Remote sensing data show, that Freya Glacier is prone to avalanches also in other years, but to a lesser spatial extent.*

At several instances in the text, we changed *remnants for the 2018 avalanches* to *avalanche affected areas.*

In the discussion, we added the following text:

The avalanche cycle of 2018 was outstanding in regard to the mass input and the glacier area affected. However, avalanches seem to be a persistent feature on Freya Glacier, as their deposits are visible almost every year. It is difficult to date these avalanches and estimate their frequency, as older avalanche deposits might get covered by new ones. In case of the two big avalanches in the middle of the glacier which originated from opposite sides and travelled almost all the way through the other side of the glacier in 2018 (green circle in Fig. 11), we have strong evidence, that their remnants are still visible in the orthophoto of 2021, more than three years after the incident. On the one hand it takes a few ablation seasons to melt avalanche snow up to 8 meters thick, particularly, if that snowpack is located in a rather flat area on the glacier, where it is more likely to get densified by retention of meltwater. On the other hand, winter mass balances in the following years were below average (Fig. 12) and therefore unlikely to produce avalanches of this size. While avalanche deposits are easy to identify in the ablation area or in rather negative mass balance years, their presence and extent remain equivocal in the upper firn area or less negative years.

L29: add "(burried stakes)" to suggest why high accumulation rates leads to missing years/Gaps.

Thanks for that comment. We added *(buried stakes).*

L44: 11% is not their sea level fraction but contribution to the overall loss of Greenland. So, move this number after "Greenland", otherwise this is ambiguous.

We added that accordingly.

L112: I checked the website 6/9/24 and it seems the webcams were offline since 28 April 2024... Delete the link or provide an explanation.

Yes, the webcams are offline due to a technical problem, but most likely will be online again after the next fieldwork in April 2025. Via the link readers can also use the calendar function to look at images in previous years. So, we would like to leave the link here, but we added the following footnote: *Due to technical problems the webcams are offline since April 2024, but older camera images can still be found here.*

L172: Unclear. Do you address "sampling" here or "material density"? Clarify.

We wanted to say that the spatial coverage of the glacier surface with GPR tracks was comparable in those years. (While in other years we did only snow depth probing, with a far lesser number of observations and a reduced spatial coverage.) We changed the wording to: *Similar GPR snow surveys with comparable spatial coverages have been carried out in spring 2008 and 2017, while in other years a reduced sample network was used.*

L176: Typo glacierwide: here and elsewhere Thanks, we corrected it everywhere in the manuscript!

L177: a reference for this error.

We reference (Pulwicki et al., 2018) here, they found typical winter balance uncertainties ranging from 0.03 to 0.15 m w.e. As our point observation density is very high, we estimated an uncertainty of 0.05 m w.e., which is in the lower range of their estimate.

L198: I guess these values are difficult to back up. But which value did you exactly used? 5 or 10%? Right now, it is not clear enough for the reader why two values are listed. Later in the article I see that this is values for sensitivity tests. Present them this way here also.

Thank you for that comment, that was ill-conceived and inconsistent. We changed the reasoning throughout the paper to the following: We use a 5% increase of snow density within the avalanche deposits (in regard to the undisturbed snow pack) as our best guess to account for compaction due to overburden pressure and avalanche deposition. And we use a 10% increase as an upper boundary, which only appears in the error of the mass balance contribution of 0.35 + 0.04 m w.e. in line 262.

The phrase reads now:

To convert snow heights into snow water equivalent, we used the mean snow density of 385 kg m^{-3} (measured in the snow pit next to the automatic weather station) for areas that are not influenced by avalanches. As snow density typically increases with snow depth and avalanche deposits have higher snow densities than the undisturbed snow pack we used higher snow densities for the avalanche deposits: a 5% increased snow density (404.25 kg m^{-3}) as a best guess and 10% increase (423.5 kg m^{-3}) which we interpret as an upper boundary.

L206: Using the exact same snow height values or using a correction factor to account for the different setting? I can imagine that the snow heights are not exactly the same on these two glaciers. I see this is detail in the supplement. Add a sentence indicating that the AP Olsen ice cap are corrected and refer to the supplement.

We added: *The data gap of 2.5 months was reconstructed using snow height data from the main weather station at A. P. Olsen Ice Cap (Larsen et al., 2023; Greenland Ecosystem Monitoring, 2020a), which has a continuous record in 2018 (see supplement, Fig. S6).*

L225: maybe "sampling" ? We changed that accordingly.

L227 "still" not really needed here (as the 2018 avalanches have not been described yet) Deleted.

L231 This is shown in Figure 6b. Authors should check carefully the figure numbers and make sure they are called sequentially in the text. Make sure all figures are referred to in the text.

Thank you. We corrected that and checked all Figure and Table references to be in the right order.

L231 It seems that a small part close to the glacier front is not covered also.

Yes, we forgot to mention this part. We changed the wording to *… missing only some parts in the upper accumulation zones and a small debris covered area next to the glacier snout.*

L243 You could provide the equivalent annual rate in parenthesis. We added *(0.09 m w.e. a^{-1}).*

L261 See my main comments above (echoing Rev#2 comment). Could be the trace of avalanches in 2019, 2020 or 2021 also.

We deleted the text here and added some lines in the discussion section instead, as stated above.

L262: See my above comment that figures should be numbered sequentially in their order of referencing in the text. Corrected.

L265 The title of the section does not match with the content of the paragraph that discuss the visibility of the avalanche on the glacier surface...

We changed the section title to: *Visibility of avalanches on the glacier surface.*

L267 Authors would need to annotate (circles?) these photos (Fig. 10 and 11) to make it clear to the readers where the deposits are visible. We outlined all visible avalanches in Fig. 10 and added circles to the main avalanche zones within the ablation area in Fig. 11.

L271 No section 4.6 Corrected

L273 Fig 12… Corrected. This reads as if the availability of a DEM would impact the mass balance... To be rewritten.

We changed the sentence to:

Prior to 2013, all annual mass balances were negative, with 2013 having the most negative mass balance on record so far. Higher winter mass balances between 2014 and 2018 can be associated with some positive annual mass balances in that period, while after 2019 drier winters facilitated again negative annual mass balances.

282 How does this sentence relate to the discussion? Clarify the not so obvious link. In fact I had a hard time following the logic of the whole paragraph. Can you try to make this logic more obvious to the reader? Do you want to justify the Huss density assumption? Justify the 5 to 10% higher density?

Thank you for the comment, that this is hard to understand. Yes, we wrote this to justify both the 5 to 10% higher density assumption of the avalanche snow and the Huss density assumption. We changed the wording of the paragraph and hope, that it has become clearer now.

L 297: It is "internal accumulation" if these deep layers are below the last summer horizon. It is what you mean? Clarify

Yes, that is what we meant. We changed the phrase to: *Another likely reason for the bias between the glaciological and geodetic mass balance is the already mentioned unknown magnitude of meltwater retention by refreezing within deeper firn layers.*

L299 I think "necessary" is best here. Thank you. We changed that accordingly.

L316 I miss a clear demonstration that the deposits visible in 2021 are really from 2018 (as said above and noted by rev#2). This point needs to be addressed. See our statement above.

L321 exponent Corrected

L324 I suggest to add: "leading to internal accumulation" Thank you. We changed that accordingly.

505 Typos and grammar Corrected

508 no cap letters Corrected

520 Fig 8c is almost not discussed in the text. I think it is important to back up the statement of a regional phenomenon.

We changed the reference to Fig. 8c in the text to: (L248)

In the winter of 2017/2018, a series of low-pressure systems between the southern tip of Greenland and Iceland transported warm and moist air masses to the East Coast of Greenland with frequent snowfall leading to above average winter precipitation sums along large parts of the East Coast (Fig. 8).

522 Fig 9 caption typo bolt changed to bold

525 Fig 10 See comment in the main text to circled the visible avalanche deposits. We added outlines of visible avalanche

deposits to the figure

L530 Fig 11 See comment in Fig. 10 We added circles to the figure.

L537 maybe clarify that this results from extensive GPR survey? Reader can be surprised by this number.

To clarify this, we added: *The high number of point observations in winter 2017/18 corresponds to 10 m along track mean snow depth values of the extensive GPR survey.*