Review of: **"Recent contrasting behaviour of mountain glaciers across the European High Arctic revealed by ArcticDEM"**, by *J. Malecki* and submitted to *The Cryosphere*.

The author uses high-resolution data from the ArcticDEM to estimate recent elevation changes (2011-2017) over a set of mountain glacier sites located in the Svalbard archipelago (SV), Novaya Zemlya (NZ) and Franz Josef Land (FJ) in the Russian Arctic. Elevation change at these sites is further used to estimate total volume and mass balance changes of all mountain glaciers covering these three regions. The author finds that most glaciers have undergone thinning since 2011. At the current mass loss rate, they could melt away by the end of the 22nd century. In contrast, two glacier sites in North Svalbard (SV-N) have recently experienced thickening, potentially linked to accumulation increase following regional sea-ice decline. The author also discusses spatial gradients in mass loss decreasing from the warmer South to the colder North, and from the low-lying margins to the elevated glacier interior.

This is a well-written and interesting study estimating elevation/mass change of small mountain glaciers in the Arctic. While these results will be of interest for the community, the reviewer has some concerns that are listed below as general, specific and stylistic comments. The reviewer deems that **major** revisions are required before publication in TC.

<u>General comments</u>

1. While estimation of uncertainties is well described in the manuscript, uncertainties in elevation/volume/mass change can be large for different glacier sites. For instance, these uncertainties in elevation/mass balance can sometimes be equal to or double the absolute change for a given elevation bin (see Supplementary Tables). In addition, the spatial coverage of surveyed glacier can be as low as ~20%, with large data gap in given elevation bins (see the hypsometry graphs in the Supplementary Figures). The authors should elaborate on how these local uncertainties impact the results estimated for the different glacier sites, as well as how low spatial coverage affects the elevation change estimates. To address this issue, a sensitivity experiment exploring the impact of low spatial coverage on the elevation change estimates could be conducted by reducing the spatial coverage of a well-surveyed site (e.g. > 90% coverage). It is important to have more insight on how much spatial coverage of glacier sites is required to provide reliable estimates.
2. The selected glacier sites only cover 1373 km^2, which represents ~20% of the total mountain glacier area of the three regions (L287-288), and 2% of the total ice-covered area in SV, NZ and FJ. Out of these glacier sites, 804 km^2 (59% of the studied area) can be used to estimate elevation/mass changes. The reviewer questions whether a 15-20% coverage of these mountain glaciers is sufficient to draw firm conclusions, notably the sharp regional contrast between site 1 and sites 16-17. For instance, are these two small glacier sites in North Svalbard representative of the surrounding northern region? The authors should elaborate on this topic.
3. Recent publications are omitted in the literature review, in particular the author claims that the spatial resolution in previous studies was not sufficient to provide reliable estimates of mass change over small mountain glaciers (L25-27). However previous studies in Svalbard, e.g., using an energy balance model (EBM) (Van Pelt et al., 2019) or statistical downscaling of a regional climate model (Noël et al., 2020) yield surface mass change components at 1 km or 500 m spatial resolution. In addition, the author claims that the impact of recent warming on the glacier mass balance in Svalbard and the Russian Arctic remains poorly known. While the Russian Arctic has not been extensively studied in the literature, previous works including, e.g., Lang et al. (2015), Van Pelt et al. (2019), Noël et al. (2020) discussed the recent mass change in Svalbard and associated driving processes. Furthermore, in a recent TC preprint, Sommer et al. (2020) discussed the recent mass change in the Russian Arctic, including the NZ and FJ regions. The author should consider mentioning these previous studies in the Introduction.

<u>Specific comments</u>

L15-16: The author should discuss how representative the selected northern glacier sites are with respect to the larger northern Svalbard region.

L16-18: While the reviewer agrees that climate models with grids ranging from 5-20 km spatial resolution may fail to represent small mountain glaciers, recent techniques including high-resolution EBM (Van Pelt et al., 2019) or statistical downscaling (Noël et al., 2020) allow refining climate model outputs to much higher spatial resolutions (sub-kilometer). The author could elaborate on this in L25-27. See also General comment #3.
L44-46: The authors could mention previous studies that discussed the drivers of recent mass change in Svalbard and Russian Arctic. See General comment #3.
L63: The concept of "Atlantification" is used here and in L296. Could the author clarify what is meant by "Atlantification" and refer the reader to a publication that further details this concept?
L102-103: How does the author distinguish between mountain glaciers and other ice masses in e.g. Svalbard? Could the author elaborate on the technique used.
L110: The author should mention that the selected mountain glaciers only cover ~2% of the total glacier area, and ~20% of the total mountain glacier area of the three studied regions. Are these selected glaciers representative of the whole mountain glacier area in SV, NZ and FJ? This issue should be discussed in the manuscript. See also General comment #2.
L159: The author could mention that spatial coverage can be as low as 23% (e.g. site 15, Table 1). What is the impact of very low spatial coverage on the resulting elevation change estimates? See General comment #1.
L178-180: The author could also use elevation changes (and uncertainties) in the different bins to estimate site-wide elevation change. Instead, the author used the site-wide volume change and glacier site area, why did the author choose to proceed this way? Does this affect the elevation change and uncertainty estimates?
L183: Does the author refer to the process of "firn compaction" when stating "cancels the dynamic component of elevation changes of glaciers."? Please, clarify.
L206-207: What is the impact of low spatial coverage on the elevation/mass change estimates?
See also General comment #1.
L240-270: The author should consider mentioning the associated sites when referring to elevation changes across the Results section. For instance, in L229: "(from -1.58 m a^{-1} at site 3 to -0.87 m a^{-1} at site 5)". This holds for sections 4.1 to 4.3.
L246, L250 and 255: Fig. 4 should be split in two subpanels, i.e., a) Svalbard hypsometry and b) Russian Arctic hypsometry. The caption should be modified accordingly, and the author should refer to Fig. 4a after "ca. 900 m a.s.l.", "ca. 225-360 m a.s.l." and "ca. 480-600 m a.s.l.".
L247: Does the author mean -0.72 m a^{-1} instead of -0.78 m a^{-1} (see site 11 in Table 1)?
L263 and L270: The author should refer to Fig. 4b.
L305: Could the author add a regression line in Fig. 5 including SV-W, SV-C and SV-E glacier sites. Could the author mention the R^2 of the latter regression in the text?
L328-329: At sites 16 and 17, 57% and 62% of the glacier area is covered. It would be worth mentioning how this may impact the trends observed. For instance, if low-lying/rapidly thinning regions are not well captured, how does this translate in the estimated trends? In addition, Van Pelt et al. (2019) also found a positive surface mass balance trend in northern Svalbard.
L343-346: Is this statement supported by model data? Did the author compare the mass change from Noël et al. (2020) to their extrapolated estimates over mountain glaciers? Looking at figures in Noël et al. (2020) or Van Pelt et al. (2019), spatial patterns of surface mass balance at 500 m and 1 km resolution generally match quite well the elevation changes over the mountain glaciers shown by the author in the Supplementary Figures S30-S37. It is also important to note that all these techniques (including the current study) suffer from large (local) uncertainties. See also General comments #1 and #2. In brief, unless the author has formally evaluated/compared modelled data (e.g. from Noël et al. (2020) or Van Pelt et al. (2019)) against independent observations, L343-346 are insubstantial and could be removed.
L361-362: Are these two small glacier sites in North Svalbard representative of the larger northern ice-covered region? The author should further elaborate on this before drawing regional conclusions. See also General comment #2.

Stylistic comments

As a general comment, the author could consider using a capital letter for "Arctic" across the manuscript. The same comment holds for "Atlantic".

L77: The reviewer suggests: “air temperature in the period 2011-2017 was higher by … compared to the reference period 1981-2020 (Fig. 2a).”
L80: “whereas in September, it is most visible to the northeast of FJ (Fig. 2d).”
L106-107: The reviewer suggests: “were distinguished in SV (5), NZ (2) and FJ (2) respectively (Fig. 3). Overall, mountain glaciers were analysed at 29 sites: 19 in SV, 6 in NZ and 4 in FJ.”
L117: “data suggested considerable differences.”
L127: “these data suffer”
L131: “and incomplete temporal coverage”
L159: “part of the investigated glaciers”
L162: “glacier hypsometry, i.e., the area altitude distribution. To obtain … general glacier, 10-metre”

Figures & Tables

As a general comment, the author should consider adding extra tick marks on the color scales. This would enable a better visualization and interpretation of all figures.
Fig. 1d: Does the author mean “mm w.e. per year”?
Fig2: Sea ice extent is generally defined as the area showing > 15% of sea ice concentration, see for instance the sea ice products supplied by NSIDC.

References

Van Pelt et al. (2019): https://tc.copernicus.org/articles/13/2259/2019/
Lang et al. (2015): https://tc.copernicus.org/articles/9/83/2015/tc-9-83-2015.html
Noël et al. (2020): https://www.nature.com/articles/s41467-020-18356-1
Sommer et al. (2020): https://tc.copernicus.org/preprints/tc-2020-358/