Review of “Recent contrasting behaviour of mountain glaciers across the European High Arctic revealed by ArcticDEM data” by Jakub Małecki

General comments:

The author uses the high-resolution elevation data from the ArcticDEM dataset to evaluate mass balance on selected glaciers in the European sector of the high Arctic, comprising Svalbard, Franz Josef Land, and Novaya Zemlya. The ice masses in these regions are among the “small” glaciers of the world (i.e. all the ice outside of the Greenland or Antarctic Ice Sheets), that make up relatively little of the overall global ice volume, but whose ongoing melting contributes a significant percentage of the current sea level rise. The analysis presented here restricts itself largely to the smallest of these “small” glaciers, namely land-terminating valley glaciers, with a few exceptions; it does not consider tidewater glaciers or ice caps.

Specific comments:

One aspect of satellite remote sensing is that the data are typically available to all; one can spend a great deal of time and energy analyzing data only to see another paper come out which supersedes one’s own efforts. A recent paper by Hugonnet and others (2021) has seemingly eclipsed all other small glacier elevation change studies by marshalling all available elevation data (ASTER, ArcticDEM and REMA) in a major global analysis, including all glaciers in the three regions of the present study. Some mention is made of this, but it likely came midway during the writing of the present contribution. There are clear differences in the aims of the two studies, but ultimately this manuscript can seem a bit amputated in comparison. It is of course a more focused regional study, but it is not exhaustive since it does not analyze all the glaciers in these regions. It is higher-resolution, working at the original 2-m grid of the ADEMs trips, but this does not necessarily improve the results of the dH analysis, given the relatively large spatial coherence of that signal. Because of the many glitches in the ADEM data, the author has to hand-edit problem areas in the DEMs, even after filtering; this explains at least in part why the present study is restricted to a subset of the entire glacier-covered area, since hand-editing all glaciers would be very time-consuming.

By not considering tidewater glaciers, complications arising from having to account for the dynamic balance (frontal advance and retreat, calving) are side-stepped. Indeed, since surge-type glaciers tend to be mostly tidewater, this problem is also avoided. However, some mountain valley glacier *have* been observed to surge, on Svalbard at any rate, and surging is not mentioned at all. It is likely not an issue, since surging does not seem to generally occur in large clusters of neighboring valley glaciers in the same area.

One of the stated aims is to provide proxy information about the local climate, and in this regard, the paper contributes to our knowledge of these areas, particularly to less well-studied areas in the Russian Arctic. However, it would have been nice to see a more in-depth analysis of the connection between the derived glacier change and the results of mass balance models, rather than just trends in temperature and precipitation. The results of Noel et al. (2020) are considered, briefly, but those of van Pelt et al (2019) are not. The findings of the latter study need to be included, as they show positive balances in the same general area as in this study, in SV-N.

Corrections:

L3: Small land-terminating mountain glaciers are a widespread and important element of the Arctic, influencing local hydrology, microclimate, and ecosystems. Due to their relatively small ice volumes, this class of ice masses is particularly sensitive to the significant ongoing climate warming in the European sector…

L16: …experiences…

L17: …challenge for mass balance models…

L22: …has fundamentally improved our knowledge on the general trends of glacier change in the Arctic, and…

L25: However, these studies have relatively coarse spatial resolution, and thus more limited coverage of smaller glaciers.

L29: … class of glaciers north of the Arctic circle, and are vulnerable to climate warming due to their small ice volumes…

L30: …exhibit low…

L31: …and shallow ice thickness…

L31: …balance, being little modified…

L33: …might not only help predict future fluctuations…

L34: …piece…

L42: …fast rate, and that many…

L44: …disappear in a rapidly…

L45; …islands, and…

L53: The Barents Sea is strongly influenced by warm Atlantic waters (Fig. 1a), particularly to the west (e.g. West Spitsbergen Current) and south (e.g. North Cape Current , making the climate of these two sectors relatively mild (Figs. 1b and 1c) and wet (Fig. 1d). For this reason, waters west of SV and southwest of NZ are free of sea ice, even during the winter (Fig. 1e). During summer, the Barents Sea is typically ice-free, except for around FJ (Fig. 1f), where the Atlantic influence is reduced, making climate there the coolest and driest in the region.

L61: Over the past decades, the Barents Sea region has been experiencing strong ocean and atmospheric changes, the so-called Atlantification of the area (*appropriate reference*).

L67: …has been reported…

L75: The global climate reanalysis ERA5 dataset (Hersbach et al., 2020) shows that these trends prevail over the period of this study (roughly 2011-2017).

L77: …temperatures were…

L80: …and in September north and east of FJ (Fig. 2d). The ERA5 analysis…

L86: …approximately 85% are mountain glaciers, which comprise 14 % of the total ice area. Overall, glaciers of SV are known to have been losing mass over the past decades; the most recent estimate of the climatic mass balance is -8 Gt a-1, or ca. -0.23 m w.e. a-1, for the period 2000-2019 (Schuler et al., 2020). The larger glaciers of SV are typically polythermal, with a temperate base and cold surface layer, whereas the small glaciers…

L99: … that the small…

L103: … mountain glaciers, due to the paucity of studies of such glaciers.

L106: …distinguished (five, two and two, respectively for SV, NZ and FJ).

L109: … analysis, for consistency between the different regions.

L111: …NZ, and small…

L114: Therefore, the glacier…

L122: The basis for the glacier elevation change analysis is the high-resolution (2 m) digital elevation model (DEM) strip dataset downloaded from the ArcticDEM repository (https://www.pgc.umn.edu/data/arcticdem).

L125: …and have been used previously in various…

L127: However, the data suffer…

L128: Besides the usual issues common for glacier…

L130: …ArcticDEMs contain numerous artefacts

132: *Delete sentence* Solutions…section.

L137: …due to the scarcity…

L143: dimensions. To align the DEMs, I used the co-registration technique of Nuth and Kääb (2011); however, this…

L149: moutonées

L155: Artefacts on glacier surfaces were manually removed by inspecting DEM hillshades for suspicious landforms (e.g. steep bumps, hollows, ridges or gullies on otherwise gentle glacier surfaces), and DoDs for unlikely patterns of glacier surface change (e.g. sharply defined areas of abnormally high or low *dh*). In some areas, the resulting data gaps were larger than areas with useful data, leaving some glacier DoDs with limited spatial coverage.

L165: … area, and the surface at an unknown time, but most likely…

L165: The mosaics were downsampled to 20 m with bilinear interpolation and corrected to orthometric heights using the EGM2008 geoid model (Pavlis et al., 2012), which is accurate to within a few meters over the study regions, and is therefore sufficient for plotting the calculated glacier elevation changes against altitude.

L169: … fit to a 20-m grid of the…

L170: All glacier grid-points with dh data were exported with their…

L173 …percentiles, all of which…

L175: The hypsometry for each glacier was calculated from the glacier outlines and the downsampled and orthometrically corrected ArcticDEM mosaic data. Median values of *dh* were calculated for each 50-m elevation bin, since the median is a more robust metric than the average, when there are outliers in the data

L183: … overall $\overline{dh}/dt$, since…

L184: …advised caution when using such a conversion method…

L193: …sites, the empirical scaling of Martín-Español et al. (2015) was used, which is based on…

L198: …were summed to…

L204: …study, there is another important factor.

L216 …lowest or highest…

L216: …had insufficient…

L227: …(Fig. 3a), where all glaciers have been experiencing thinning, and at all elevations.

L229: …by the median…

Table 1: Date of first DEM, Date of last DEM

Table 1: *There is no apostrophe in decadal dates e.g. 2040s, rather than 2040's.*

L239: …the relatively low elevations of the mountain glaciers.

L240: From the available data, there is a northward trend of less negative elevations change.

L245: …the highest elevation ice masses…

L249: In SV-N, mountain glaciers have a contrasting pattern of change; here, glaciers have had positive…

L53: …between the rapid ice loss of…

L254: …with a poleward…

L260: In the subregion NZ-N, all three sites of mountain glaciers showed glacier-wide thinning, with an…

L262: …NZ-S, had higher rates…

L263: …and rapid…

L265: …by low topography and extensive large ice caps, on most islands.

L275: …glaciers and high-elevation…

L281: *The Hugonnet study covers slightly different periods. Calculating trends with even a single year difference in the period can lead to very different results, if that year was remarkable in any way*.

L286: …while losses were…

L287: …values to the ~4600…

L288: …covered by…

L289: …regions; ca. 25%...

L294: …Atlantic…

L298: …SV, with two trends in thinning rates (Fig. 3a). There is an overall trend of less negative $\overline{dh}/dt$ to the north, and another to the interior of SV-C.

L303: …(Fig. S42), and close to zero at ca. 900 m a.s.l. This implies that over much of SV (SV-W, SV-C and SV- E), it is predominantly elevation that controls spatial variability…

L306: … slight trend of reducing thinning rates to the northeast (Figs. 3b and 3c).

L309: As many as 21 of the 29 sites investigated…

L310: …sites, *dh* was negative, even at…

L313: …and the dominant role of surface processes to their…

L314: …glaciers would eventually…

L316: …some sites had losses…

L327: …northeastern…

L339: …ice north of SV…

L340: An increase in snowfall is, however, not evident in the ERA5 reanalysis data (Fig. 2), which shows that while SV-N did experience strong sea ice retreat and a slight increase in winter precipitation, this increase was comparable to other subregions in which there was overall glacier mass loss, e.g. SV-E and NZ- N. Nor do the results of a finer-scale 500 m model by Noël et al. (2020) match the observations reported here, show instead a generally negative trend in B over Sites 16 and 17.

L344: *Higher resolution is not necessarily the answer. As mentioned in my general comments, the 1-km simulations of van Pelt et al. (2019)* <u>*do*</u> *hint at more positive balance in SV-N. The disagreement between model and observation can also lie in how the mass balance model is* *constructed in the first place. Noël et al and van Pelt et al use regional climate model simulations for their forcing, both of which have resolutions of ca. ~10 km. These are then further downscaled in the mass balance model to the reported resolutions of 0.5 and 1 km respectively.*

L357: …even in the present…

L362: …part of SV) experienced…

L363: …the greatest climate warming…

L364: …interactions, even for low-activity ice masses, and…

L366: …this research provides a useful…