

General comments:

R: This manuscript presents a method for how to digitize and georeference archival maps, and finally evaluates their potential for quantifying changes in glacier geometry on Sørkapp Land, Svalbard. For this exercise, three topographic map sheets from the Institute of Geophysics of the Polish Academy of Sciences (IGF PAN) published in 1987 were used together with a reference dataset from 1990. The 1987 map sheets have contour lines based on aerial photos from 1961 (from the Norwegian Polar Institute; NPI), and the 1990 dataset consists of a 20-m-resolution digital elevation model (DEM) and a glacier outline vector layer (also NPI).

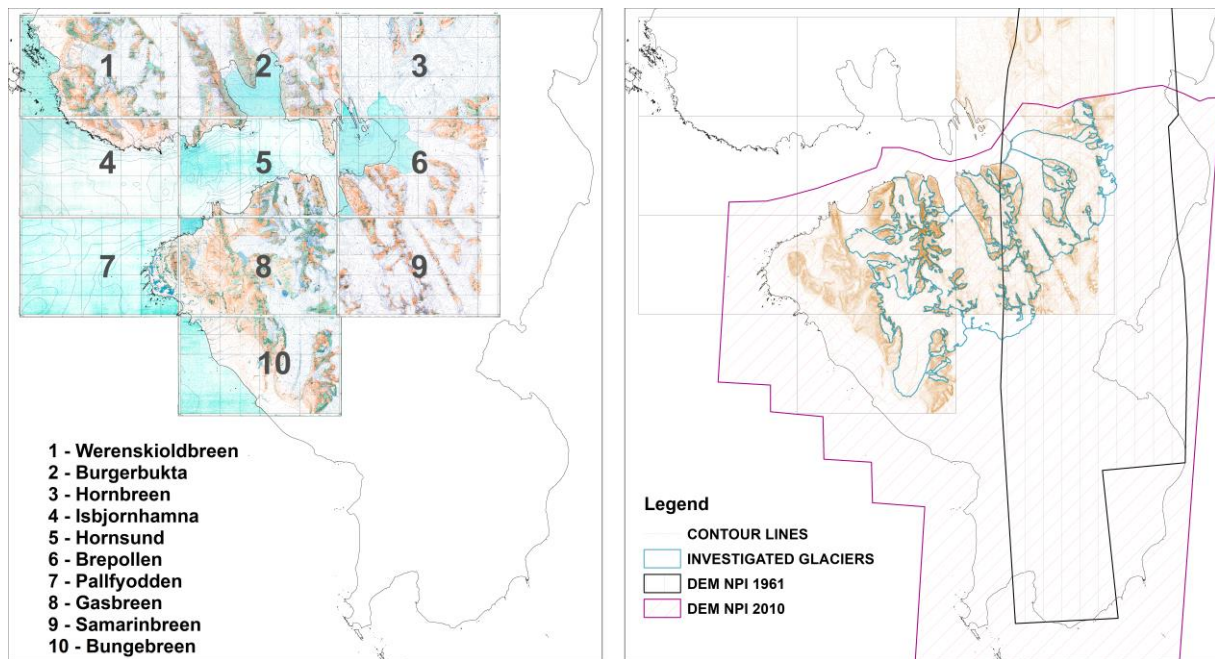
Overall, this is a nice study with clearly described methods, walking us through the different steps of source data processing, verification, and data fitting, as well as presents the final DEM and examines the glacier elevation and areal change. However, there are some issues that need to be addressed, mainly considering the dataset size and the potential for improving the quality of the digitization/georeferencing. I have listed my main concerns and suggestions for improvements in the specific comments below. If these questions are resolved, I think the paper could be a good contribution to the journal.

A: We appreciate your valuable feedback and we corrected our manuscript (the text and figures) according to these suggestions. We believe that they helped substantially to improve the quality of our work. Below we included our answers. Referee text (R) and author responses (A) are indicated.

Specific comments

R: 1. Why did you not digitize all ten IGF PAN map sheets? Digitizing these map sheets is a valuable contribution, but it would be most useful to have all of them compiled. Especially considering the initial confusion with the contour lines (i.e., that they represented the 1961 elevations, without being corrected based on field observation before publication in the 1980's). I strongly recommend digitizing the rest of the map sheets to provide a complete updated dataset with greater areal coverage. If choosing not to, please provide an explanation for why you decided to process only three (you describe this nicely in your response to the editor), as this is not obvious to the reader. To help illustrate that these are the most valuable map sheets (for glaciological research), show all of them in Figure 2 and mark the three you present in the paper.

A: In the initial version of the manuscript we focused on the map sheets of the PAS series that in our opinion presented the highest value for glaciological research. The three sheets we initially have chosen for processing (5, 8, 10) cover the peninsula further inland and present the complete surface of 14 land-based glaciers. The remaining map sheets were already partly covered by the DEM published by NPI (based on original aerial photographs from 1961), presented only frontal parts of the tidewater glacier (updated to the period of 1982-1984, when PAS field measurements took place), or did not present the glaciers. We still believe that this choice was valid, nonetheless, we also agree that it would be better to show larger spatial coverage. For the revised version of our manuscript, we decided to expand our study both spatially and temporally by adding the 2010 data and additional 4 map sheets (as shown in the attached figure). This way we will use all 7 maps produced for Sorkapp Land and overlapping with the data from the latest flight campaign.



R: 2. The method section would benefit from having a figure showing the workflow, describing all the steps. That would provide a good overview of the methodology and make it more user friendly. Also, I am a bit skeptical to whether the method is innovative enough, and whether the final map (Figure 14) is really satisfactory? There are still areas with both large positive and negative dz, suggesting that the georeferencing could still be improved. Have you considered supplementing with other methods? You refer to studies using structure-from-motion to create historical DEMs from aerial imagery (Mertes et al., 2017; Midgley et al., 2017). Why not try that, using the NPI aerial photographs from 1961, to compare to the topographic maps? Another option could be DEM production by digital stereophotogrammetry on the 1961 images. For methods, see e.g., Korsgaard et al. (2016) and references therein.

A: Following the suggestions of both reviewers we improved our methods of data processing and hence the quality of the final maps. Unfortunately, we do not have access to high quality scans of aerial imagery from 1961 that could be used to generate new DEMs using stereophotogrammetry or structure-from-motion methods. We tried to process low quality scans that we possess with Agisoft Photoscan, however the results were not satisfactory. The main focus of the study was a use and recovery of historical maps and not to generate completely new dataset from the source data, to which we do not have access.

R: Why not compare the 1961 and 1990 data to the 2010 data from NPI? The spatial resolution is higher (5 m for the 2010 DEM vs. 20 m for the 1990 DEM), and it would allow you to do a two-step comparison (1961 vs. 1990, and 1990 vs. 2010), to see if the retreat and/or thinning rates have varied between these periods, and whether they have accelerated or not. Further, you could even use the 1936 oblique photos, since from what I can tell from Table 1, the entire peninsula was covered also during that survey? Several studies compare the 1936/38 maps to the 1990 DEM (e.g., Nuth et al., 2007; Girod et al., 2018), so I strongly suggest that you compare more than two years (i.e., by adding 2010 and/or 1936), since that would add something extra to this paper.

A: Good suggestion. We decided to enlarge our study by adding the 2010 DEM (as a reference dataset) to our revised manuscript and compare it to the data from 1961 and 1990.

Overall syntax and structure

R: The structure is generally good, but the readability would benefit from having a native English speaker reading through this manuscript. Sometimes the word choices are not optimal, the sentence structure not correct, or the sentences too long (e.g., line 80-84). This makes it somewhat difficult to understand the message, without re-reading some of the sentences. In the introduction, the paragraphs are very short, often only two sentences each. Merge some of them to get a clearer structure and give the text a better flow. I would remove the word 'glacier' after all of the glacier names, since 'breen' in the end of all names already indicates that those are glaciers (in Norwegian). Abbreviate Norwegian Polar Institute to NPI after the first use.

A: Thank you for these suggestions. We tried to apply changes according to them in our revised version of the manuscript.

Study area

R: Start by introducing Svalbard, the influence of the West Spitsbergen Current, strong climate gradients etc., and how the ice masses vary between different parts of the archipelago. Then move on to the Hornsund area and the glaciers there. You could also show or describe some climate data from Hornsund, to see how the temperature/precipitation have changed from 1961 to 1990. Also introduce the concept of surging glaciers.

A: We added these changes in our manuscript.

Source material

R: You mix present and past tense. Decide on one (I recommend past tense) and stick to it.

A: We changed this section to the past tense.

Line by line comments

R: Line 3: materials -> data

A: Corrected.

R: Line 8: glaciers of -> glaciers on (this is reoccurring in several places)

A: Corrected.

R: Line 9-10: Remove sentence about dataset availability. Enough to have this information in the 'Data Availability' section

A: Corrected.

R: Line 13-15: This sentence needs to be supported by 2-3 references. Also, do you with 'more dynamic' in the first part of the sentence mean faster? Or in terms of ice dynamics? This needs to be clarified. Reference suggestions: Nordli et al. (2014), Isaksen et al. (2016), Schuler et al. (2020)

A: By 'more dynamic' we mean that changes in Spitsbergen (such as progressive disappearance of ice) are occurring faster than in other parts of the European Arctic (and the world). We will rephrase this sentence and add suggested references.

R: Line 19: huge -> crucial

A: Corrected.

R: Line 20: Give some examples of ‘traditional research methods’, e.g., in situ stake mass balance measurements

A: Corrected.

R: Line 23: Support this statement with a couple more references, e.g., Jacob et al. (2012) and Nuth et al. (2013)

A: Corrected.

R: Line 24: Change to ‘The use of remote-sensing has a number of advantages’

A: Corrected.

R: Line 44: Change to ‘the University of Wrocław were held there (Zyszkowski, 1982)’

A: Corrected.

R: Line 47: has -> have

A: Corrected.

R: Line 51-52: Change to ‘including primarily the Gåsbeen area’

A: Corrected.

R: Line 57: Norwegian Polar Institute (NPI)

A: Corrected.

R: Line 59-61: Do you mean that the next map covering the entire peninsula was not published until in the first decade of the 21st century? Also, better to write out the year (2010) instead of ‘the first decade of the 21st century’.

A: Corrected.

R: Line 64: 49 years later -> in 2010. Additional comment: if there are data with the same spatial extent from 2010, why don’t you compare the 1961 and 1990 glacier extents to the 2010 extents as well? It would be interesting to compare the glacier areas, and see if the rate of retreat and thinning have increased or decreased etc.

A: Corrected. Following previous comments, we added dataset from 2010 as well in the revised version of the manuscript.

R: Line 68: add the spatial coverage (XXX km²) of this map

A: Corrected.

R: Line 69: Enough to use the abbreviation (IGF PAN) here

A: Corrected.

R: Line 73: attempts -> aims

A: Corrected.

R: Line 73-73: Change to ‘geometry of glaciers **on the western** Sørkapp Land peninsula’

A: Corrected.

R: Line 78-79: change to ‘It **hosts** 14 land-terminating **and 4 tidewater** glaciers’

A: Corrected.

R: Line 85: Remove 's' in the end of 'Körberbreen glaciers'

A: Corrected.

R: Line 88: 'outflow glaciers' should be 'outlet glaciers'?

A: Corrected.

R: Line 93-94: Change to 'They formerly served as tributary glaciers to Samarinbreen, but as its snout receded, they split from it and today constitute separate calving glaciers'

A: Corrected

R: Line 97: The **IGF PAN** topographic map

A: Corrected

R: Line 98-100: Remove 'These were the following sheets' and put '(No. 5 –Hornsund, No. 8 – Gåsbreen, and No. 10 – Bungbreen; Fig. 2)' in brackets.

A: Corrected

R: Line 102: Change to 'The topographic map sheets presented the relief, permanent and periodic watercourses, ...'

A: Corrected

R: Line 106: colour from orange (**land**) to blue (**glacier**). Additional comment: is it blue or purple?

A: Corrected. The colour of the contour lines indicating the glaciers on the maps is dark blue.

R: Line 111-112: Explain what you mean by 'somewhat non-standard mean' – what was done and in comparison to what (the standard way)? And what do you mean by 'in desk research'?

A: We rephrased this section of the manuscript to make it more clear. The term "desk research" used in our article was directly cited from the map description meaning compilation, analysis, and processing of data and information from existing sources (in this case aerial photographs). By the 'standard way', we mean collecting field information (geodetic measurements) and using it during the aerial data processing. By 'non-standard mean' we consider using the data from the field (collected 2 decades after flight campaign) after the initial processing of the images.

R: Line 116: Change the first 'extent' to 'degree'?

A: Corrected.

R: Line 117: Is "completed in the field" a quote from the map? Otherwise rephrase.

A: Yes it is a quote from the map.

R: Line 123: Remove line break

A: Corrected.

R: Line 124-127: Change to 'These studies were based on photos from NPI's photogrammetric overflight over the west of Sørkapp Land in the summer of 1960 (Table 1) and resulted in a publication that included a map showing the hypsometric variation of Gåsbreen and a hillshade that was valid for 1960 (Schöner and Schöner, 1996).'

A: Corrected.

R: Line 127: Another -> A (since referring to other glaciers)

A: Corrected.

R: Line 136: Add reference to the NPI photos

A: These photos were not published before. We obtained the information by pers. comm. with Harald Faste Aas from NPI over email.

R: Line 142: Add reference to the NPI data after first sentence.

A: Corrected.

R: Line 144: 'slightly less' – Can this be quantified?

A: This is the information provided by the NPI. We didn't process this dataset.

R: Line 145: Divide into 4 Methods, and 4.1 Source data processing and evaluation of output data accuracy

A: Corrected.

R: Line 146: stages -> steps

A: Corrected.

R: Line 153: Does a newer version of R2V allow data to be saved as shapefiles and to be georeferenced? In that case, why did you not use the newer version?

A: We used the version of R2V that was accessible to us at the time of data processing. As for the map sheets which were added to the revised version of the manuscript we used the function of automatic feature generation available in the ArcScan, an extension of ArcGIS. It proved to be a faster method, although required more data editing.

R: Line 154: resultant -> resulting

A: Corrected.

R: Line 161: Remove '(northern hemisphere, zone 33)'

A: Corrected.

R: Line 162: Remove 'later in this work'

A: Corrected.

R: Line 165: GRID -> grid

A: Corrected.

R: Line 168: Remove 'with the working name DEM IGF 1961'

A: Corrected.

R: Line 171: Add reference

A: Corrected.

R: Line 174-186: Make this into one paragraph, and remove the sentence starting 'Work began with the correction of sheet 8...'

A: Corrected.

R: Line 180: Change to ‘the locations of the elevation points **were** assessed’

A: Corrected.

R: Line 180: Remove ‘as many as’ and add ‘elevation points’ after 95

A: Corrected.

R: Line 181: about 50 elevation points? Not exactly 50, which are the same as 50 of the points in the map sheet?

A: Since we added 4 more map sheets, we updated the information and rephrased this sentence in the revised manuscript.

R: Line 187-188: shifted southeastwards by how much? A: As explained before, the shift between two maps was not constant in space. In order to clarify this, we will provide exact value of the mean shift between these sheets.

R: Line 193: (Barna and Warchol, 1987)

A: Corrected.

R: Line 195: Remove ‘because much of it was covered by the Greenland Sea’

A: Corrected.

R: Line 202: fragment -> portion

A: Corrected.

R: Line 205: adding a few **points**

A: Corrected.

R: Line 228: Remove ‘natural’ before ‘processes’

A: Corrected.

R: Line 230: Remove ‘for obvious reasons’

A: Corrected.

R: Line 231: Change to ‘After **considering** the aforementioned criteria, the **part** of the IGF PAN model selected’

A: Corrected

R: Line 247: Change to ‘The measure for examining the **extent** and pattern of glacier **retreat**’

A: Corrected

R: Line 248: The research -> This analysis

A: Corrected

R: Line 251: Change to ‘**During** the study period’

A: Corrected

R: Line 255: most intense -> greatest

A: Corrected

R: Line 256: Change to '**For** these glaciers'

A: Corrected

R: Line 257-258: Rephrase sentence to follow better after the previous one

A: We moved these sentences to the section Discussion.

R: Line 258-261: This comparison to the LIA does not belong in Results, but rather Discussion

A: We moved these sentences to the section Discussion.

R: Line 261-262: Repetition of narrowing of the lowest/lower parts of the glaciers. Rephrase

A: We moved both sentences (lines 257-261) to the discussion section, and therefore this repetition does not occur here in the revised manuscript.

R: Line 268: shrank -> decreased

A: Corrected.

R: Line 268: amounted to -> was

A: Corrected.

R: Line 273: situation -> setting

A: Corrected.

R: Line 281: Change to '**at** their termini'

A: Corrected.

R: Line 286-287 Change to 'the area of Nordfallbreen decreased by only 0.03 km² (3.6%), **which is** among the lowest values in the entire region'

A: Corrected.

R: Line 289: Remove one of the 'However'

A: Corrected.

R: Line 290: Space missing after 'zone'

A: Corrected.

R: Line 292: 'receded by only 120 m' - Is not 120 m in 30 years a lot?

A: It is a lot, but this value is still relatively small among the glaciers in the area, and the smallest if we compare it with the retreat rate for the glaciers of similar size. Nevertheless, since it might be confusing we removed the word 'only'.

R: Line 297: shrinkage -> areal decrease

A: Corrected

R: Line 298: Remove 'though this did vary between glaciers'. Change to '**For** the region's largest glaciers'

A: Corrected

R: Line 299: shrinkage -> decrease

A: Corrected

R: Line 299: leading into -> calving into

A: Corrected

R: Line 300: for the glaciers instead of in the glaciers

A: Corrected

R: Line 309: Could add Nuth et al. (2007, 2013) and Holmlund (2021)

A: Corrected

R: Line 313: Specify which modern methods. Could also cite Girod et al. (2018) and Holmlund (2021).

A: We changed it to “structure-from-motion (SfM) photogrammetry” and added both references.

R: Line 315-316 Change to ‘The accuracy of simulations prognosing changes in glacier volumes based on dynamics models depends largely on **that** those models have been initialised correctly’

A: Corrected

R: Line 323-324: How did the temperature change during this period? Relate this to meteorological data to explain the changes.

A: Following previous suggestions in the revised version of the manuscript we are discussing the changes in the temperature and the precipitation in the section “Study area”. Answering the question: what concerns the data for the period of 1960-90 – in the nearest station (Polish Polar Station) meteorological measurements were not carried out until the 1970s, and therefore we can only refer to the dataset from Longyearbyen airport collected since the beginning of the 20th century (Nordli et al., 2014). According to Førland et. al. (2011) the mean annual temperature at the Svalbard airport in the period of 1966-1988 increased by 0,52°C/decade, and in the following period (1988-2011) this trend continued with an increase of the mean annual temperature to 1,25°C/decade. For Hornsund a similar trend was observed. In the period of 1971-2000, the mean annual temperature was -4,7°C which in the following years (2001-2015) increased by 1,9 °C.

R: Line 325-326: For the same time period (1961-90), or something else?

A: We could not find an estimate for the same period, Błaszczuk et. al. (2009) refers to the period of 2000-2006.

R: Line 331-332: extending upwards to -> reaching.

A: Corrected

R: Line 354-355: Change to ‘Nordfallbreen is adjacent to Nordfallet (824 m a.s.l.) to the south, which shades it against the sun while also providing it additional supply by avalanches’

A: Corrected

R: Line 359: What’s the elevation of the equilibrium line?

A: In the western part of the peninsula (except for the ice-free mountains in the northwest) it was about 300-400 m a.s.l. (Jania, 1988). We added this information to the revised manuscript.

R: Line 367-373: Remove ‘Ignorance of the principles on which they were compiled may lead to conclusions drawn as to the glacier recession rate being erroneous and, consequently, recession being overestimated for the years 1984–90, as the apparent status in 1984 would be contrary to reality. Specifically, the misapprehension lies in the fact that, a’. Instead, start the second sentence ‘Although the IGF PAN field campaign was conducted in the early 1980s, the maps published after the expedition were based on elevation data taken from aerial photos from 1961, upon which only glacier extents were updated (with a change in colour of contours). Crucially, contour lines were not updated in this 1984 edition, and continued to represent the elevations of 1961.’

A: Corrected

R: Line 384-385: Remove last sentence

A: Corrected

Tables

R: Table 1: Add a third column with references to the published works from these overflights (or surveys?). Could also add a map next to the table, showing the coverage for each of the flights?

A: Corrected

Tables 2-5: Add references to IGF PAN and NPI data. In Table 2: Vestre Zdanovfjellet with a capital V

A: Corrected

Table 7: It says land-terminating glaciers instead of calving glaciers in the caption

A: Corrected

Figures

R: Figure 1: Why the red frame in (c)? Make (c) only cover the area of interest or make the text ‘Area of research’ in red and put inside red box. Figure could also benefit from having a map showing Svalbard’s location in the North Atlantic instead of panel (b)? Add all names mentioned in the text.

Figure 2: Label the maps (a), (b), and (c), and provide information on which sheet is which. Consider showing all ten map sheets, to help illustrate why these three are the most valuable (supported by an explanation in the text).

Figure 3: Mark the extent of this figure in Figure 2 or present them (Figures 2 and 3) together.

Figures 5-8. Merge these figures into one (or at least Figures 5, 6 and 8), and increase the letter size. Add info on contour line interval.

Figure 7: Stuppygen -> Stupryggen. This typo reoccurs in several figures and in the text.

Figures 10-12: Merge into one figure, potentially also adding the plot from Figure 13.

Figure 9 and 14: Present these figures together, to make them easier to compare. Could even present them together with Figure 4.

A: Since the revised version of the manuscript concerns much bigger area all figures needed an update, but we introduced also changes according to your suggestions, which we appreciate.