The Cryosphere Discussions

The Cryosphere Discuss., author comment AC1
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Reply on RC1

Sajid Ghuffar et al.

Author comment on "Brief communication: Glacier mapping and change estimation using very high-resolution declassified Hexagon KH-9 panoramic stereo imagery (1971–1984)" by Sajid Ghuffar et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-203-AC1, 2022

Comments Reviewer 1:

We thank the reviewer for a positive and careful review of the paper. A detailed reply to each comment and the suggested revisions are listed below.

The study by Ghuffar et al. aims at applying a previously published methodology to a different satellite data set. The methodology was developed to generate Digital Elevation Models from film-based declassified satellite images. While the previously published paper was focused on images from the Corona (KH-4) satellite series, this study focuses on the Hexagon panoramic camera images (KH-9 PC). There was apparently no novel methodological development required for this data set, but because the dataset studied here (KH-9PC) has been barely exploited so far, this study is a valuable contribution.

I only have minor comments, mostly intended to clarify the text or provide additional results, before the article can be published.

We appreciate the reviewer's positive comments and we share their opinion about the immense potential of the KH-9 very high resolution panoramic imagery.

Minor comments:

- Preprocessing (section 4.1): I understand that the photogrammetric part follows exactly the method of Ghuffar et al. (2022). However, in that study, there is also an extensive preprocessing part in order to correct for film distortion using edge markers (rail holes, PG stripes...). Here you only mention the stitching of the image part. As for the KH-4 and KH-9 MC images, I would expect that some distortion exist, due to film distortion and due to the scanning. Can you please elaborate a bit more on the preprocessing? If there is no other processing step required, I would explain why as it seems rather surprising. If you applied a preprocessing step, please detail it. Are there any markers on the image that can help identify and correct for film distortion?

The KH-9 PC imagery also contains markers similar to the KH-4B imagery on both edges along the film length. These markers include scan angle marks, stripes, timing marks as well as other titling data. Similar to the Corona KH-4 missions these additional markers show some variation from earlier to later missions e.g. the stripes on the both edges are not available on all images. A thorough evaluation of the film distortions, reconstruction of the panoramic geometry and film bending correction in the KH-9 PC is beyond the scope of this study. In this work, we only clip the exposed image part of the film and align the image axis along the length and width of the film. We will add this information in the revised manuscript for clarification.

- DEM coregistration: at L 102, you mention the use of "coregistered DEMs". You describe the tile-based coregistration used for the KH-9PC DEMs, but it is not clear what coregistration method you used for the other DEMs. Do you apply the same tile-based coregistration or did you use the coregistration method of the previous studies? If so, can you explain here what the method was?

The KH-9 DEMs have been coregistered using the tile-based technique. The earlier DEMs have been coregistered with Nuth and Kääb (2011) coregistration method [1]. We will include this information in the revised text.

[1] Nuth, C. & Kääb, A. Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change. *Cryosphere* **5**, 271–290 (2011).

- Results: In Figure 2, for Passu glacier, there seem to be a 50% difference (-6.2 vs -9.0 m) between the mean elevation change calculated from both datasets (KH-9PC and KH-9MC), but the mass balance values report in Table 1 and later in the text differ by less than 10%. Can you please explain? I believe this might be because the values are on the unfiltered results? In that case, I would suggest in that Figure 2 to also show the results after filtering and gap-filling.

The reviewer is correct in their interpretation that the differences in the mean elevation change values originate from the filtering/gap filling process. The difference is found between the filtered (but not yet gap-filled) dH data. The KH-9MC dH grid has many more gaps over the accumulation area of Passu Glacier following filtering, so the mean value of dH is biased by the substantial thinning seen over the lowermost ~3 km of the glacier. The coverage of the KH-9PC dH grid is much more complete over the upper reaches of the glacier, so the mean dH value is less negative. Following gap-filling, the mean values of dH of the KH-9MC Vs Pleiades and KH-9PC Vs Pleiades dH grids are much closer (-6.06 KH-9MC, -5.44 KH-9PC Vs Pleiades) and so the subsequently derived mass balance estimate are also closer.

We will modify Figure 2 to show the dH data following filtering and gap filling and ensure that the Figure caption highlights the plotted distributions as showing outlier filtered but not gap-filled dH data.

Specific comments:

- L12: Mannerfelt et al. (2022) is not about aerial images. Either rephrase the sentence or use a different citation (e.g., Girod et al. (2018), Geyman et al. (2022))

We will correct this.

- L24: "with high resolution" □ "with the high resolution"

We will correct this.

- Figure 1, caption – two typos: "90º, 90º" should be "90º, 120º" and "with with".

This will be corrected.

- section 4.2: I am amazed by how many different software you are able to leverage!

- L109: "We convert glacier-wide dH to volume change estimates considering the pixel size of the dH grids". Note that for volume calculation, it is more accurate to calculate a mean dH of all pixels, then multiply by the glacier polygon area, rather than using the pixel count and area, which is more discretized. Of course, it does not matter too much in this study since the focus is not on the glaciological interpretation of the results, and since the same method is applied in all cases, they are directly comparable.

We thank the reviewer for highlighting this alternative approach. To check the consistency of our original method, we calculated our mass balance estimates using this mean dH approach described by the reviewer and find only minor differences across the various datasets which are well within the estimated uncertainty. Mass balance estimates are within 0.01 m w.e.a^{-1} at both study sites, apart from the KH-9 mapping camera Vs Pleiades derived mass balance estimate for Passu Glacier, which is 0.04 m w.e.a^{-1} more negative using the mean dH approach (-0.10 Vs -0.14 m w.e.a^{-1}). As these minor differences do not impact our interpretation, we will retain our original results.

- L110: Can you state which error correlation length was used in the Fischer et al formula? Note that this formula tends to largely underestimate uncertainty, and I can only recommend to follow the approach of Hugonnet et al. (2022).

The correlation length we calculated varied between the different dH grids. The correlation length was 605 m in the case of the KH-9PC dH data, and 873 m in the case of the KH-9MC data over the Passu Glacier. Over the Petrov Glacier, the correlation length was 1488 m in the case of the KH-9PC derived dH data and 1220 m for the KH-9MC derived dH data. We will add these values to the revised version of the manuscript. We will investigate the contrast in the calculated uncertainties using the methods of Fischer et al. (2015) compared to Hugonnet et al. (2022). Our main aim here is to illustrate the contrasting uncertainty depending on the underlying data sources (KH-9PC Vs KH-9MC), rather than its overall magnitude, which we believe would be illustrated by both uncertainty methodologies.

- Figure 3: Would you be able to show the approximate footprint of each image on the figure? This would help interpret the small steps in the DEM visible on the left.

We will add the image footprints on the figure in the revised version.

References:

Geyman, E.C., J. J. van Pelt, W., Maloof, A.C., Aas, H.F., Kohler, J., 2022. Historical glacier change on Svalbard predicts doubling of mass loss by 2100. Nature 601, 374–379. https://doi.org/10.1038/s41586-021-04314-4

Girod, L., Nielsen, N.I., Couderette, F., Nuth, C., Kääb, A., 2018. Precise DEM extraction from Svalbard using 1936 high oblique imagery. Geoscientific Instrumentation, Methods and Data Systems 7, 277–288. https://doi.org/10.5194/gi-7-277-2018

Hugonnet, R., Brun, F., Berthier, E., Dehecq, A., Mannerfelt, E.S., Eckert, N., Farinotti, D., 2022. Uncertainty analysis of digital elevation models by spatial inference from stable terrain. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 1–17. https://doi.org/10.1109/JSTARS.2022.3188922

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