

Response to Reviewer 2

In this paper, Ramzan and Ghuffar report geodetic mass balance of glaciers located in the eastern Hindu Kush for the period 1979-2002. They find a moderate glacier mass change of -0.13 ± 0.12 m w.e. a⁻¹, which is similar to post 2000 mass changes documented in the literature.

Overall, the authors use state of the art methods to differentiate KH-9 Panoramic and SPOT-5 stereo imagery. It is very nice to see the use of KH-9 Panoramic imagery as described in Ghuffar et al. (2023). It is also great to see a SPOT-5 instead of SRTM reference for circa. 2000 dates. To my knowledge, the study area is on the edge of previous studies, but not covered for the pre 2000 period. Still the glacier area covered is relatively modest (< 1000 km²), and thus the results are not expected to have a major impact.

I recommend publication of the paper after minor corrections.

We thank the reviewer for the positive evaluation of the manuscript and for recognizing the value of using KH-9 panoramic imagery for historical glacier analysis. We appreciate the constructive comments and have addressed them below

Main comments

A- I am surprised to see so few glaciers on figures 1 and 2. I quickly looked at the RGI and there are indeed many missing glaciers (see figure below)! It is not an issue not to calculate the mass balance for each and every glacier, but the criteria for glacier exclusion should be clearly stated, and glaciers without mass balance data should still be plotted on the maps. The authors need to better quantify the total area, the area with valid pixels and the sum of the glacier area with mass balance values. On figure 2, I would like to see the off-glacier elevation changes as well. The figure S3 is clearly not enough to see the quality of the elevation difference map because the color scale is not adapted, I recommend using the same as for figure 2.

We have selected the subset of the glaciers using a 2 km² area threshold on the RGI, as the smaller glaciers have a higher uncertainty in the glacier mass balance estimation. This was the main criterion why all the glaciers in the RGI were not used. Additionally, some glaciers (mainly of smaller size) were excluded because they had significant missing data in the difference DEM. The missing data in the photogrammetric DEMs mainly occurs in the pixel regions with no contrast. Furthermore, the two SPOT-5 stereo pairs have a gap in the coverage producing no data over certain glaciers (as visible in Fig.1 of the paper). The current analysis include glaciers ranging in area from 2 km² to 90 km², whereas the total glacier area of the region is 1200 km²

In the revised paper we will expand our analysis to also include the glaciers with area less than 2 km². so that the results presented in the paper cover majority of the glaciers in the area (barring

the glaciers which are not covered in both the DEMs) and we will report the total glacierized area within the study region, the area with valid elevation-change data, and the total glacier area represented by the analyzed glaciers.

We will also add zoom areas of glacier off surface in separate figure in the supplement.

B- I am missing a short paragraph about the climate context of the region. The stability of the glacier mass balance from 1979 to 2020 should be discussed further.

We will include discussion on climate variability in relation to the stability of glaciers. In the revised manuscript, we will elaborate this using ERA-5 and a nearby weather station. Generally, we have observed a warming trend of 0.33 °C whereas precipitation shows high variability with no significant long-term trend.

We will further discuss the factors behind moderate mass balance of the region in the context of climate.

L11-12: more references are needed, and the description should be a bit more precise at the scale of the High Mountain of Asia. Additional references should include: King et al., 2019; Maurer et al., 2019; Zhou et al., 2017, 2018

Change to historical images have revealed that in the High Mountain Asia that glaciers have been. Here we intend to communicate the usefulness of spy satellites in revealing the state of glaciers in the pre-2000 period. We have further added references from around the world.

L12-13: this statement is too strong, see for instance Gascoin (2024)

We will change this line to: Mountain glaciers are an important freshwater resource which contribute in agriculture, power generation, domestic use and drinking water for the downstream communities.

L29: Additional references should include: Zhou et al., 2017, 2018

We will add these references in the revised manuscript

L62: contradiction with the line above. Why not co-registering KH9 and SPOT5?

Both the KH-9 and SPOT-5 DEMs were co-registered to the SRTM DEM, rather than to each other, because the reference DEM should ideally provide continuous spatial coverage across the entire study area. The KH-9 and SPOT-5 DEMs contain data gaps caused by low image texture, shadows and occlusions. Co-registering these DEMs directly to each other could therefore

propagate local biases into areas lacking valid data in either DEM. Using SRTM as a common reference surface allows systematic errors in both DEMs to be corrected consistently over the entire region.

Equation 1: what is the link with Rolstad? (L84-85)

We do not assert here that Equation 1 is linked with Rolstad. We cite Rolstad et al in line L84 for its association with the equation in line 83 where Rolstad investigated the role of spatial correlation and its scale in calculating the uncertainty for geodetic glacier elevation changes.

I think that the whole error propagation calculation is not very clear.

We will further elaborate this in the revised text, so it's better understandable by the reader

For instance, on L84-85, the mean off glacier elevation difference is used as a systematic error, but it should be zero by construction?

Practically, the mean off glacier elevation difference is not exactly zero, which may arise due to imperfect coregistration and bias effects, therefore it is being incorporated here as systematic error.

I simply don't understand the link between the calculations L83 and equation 2

Line 83-84 refers to calculation of uncertainty in glacier elevation change for individual glaciers combining both random and systematic error. L91 shows the relation between volume uncertainty is related with uncertainty in elevation change, which is further used in equation 2.

Eq. 2: definition of f ??

Here f refers to density of ice, we will also indicate this in the text.

Fig. 2: colorbar not centered on zero + glacier names should be shown somewhere on figure 1 or 2

We will center the colorbar to zero in our revised version. We already tried displaying the glacier names but the figures looked too crowded. Here, most glaciers have names but some are referred to by their RGI IDs. We will add an additional line with figure 1 which refers the reader to fig S1 in the revised manuscript.

L104-105: -0.23 m w.e. is not a large thinning...

-0.23 mwe a⁻¹ is shown here the mass loss of glacier. The thinning here at the glacier terminus is greater than 3 m a⁻¹; we will also add it in this sentence in the revised version.

L101-105: give the dates of known surges

Here, Noroghikun is currently classified as a possible surging glacier. We do not attribute here the retreat of this glacier due to surge activity and did not observed any notable surge during analysis our analysis.

L111: give the area of the glacier

Here, Tirich and Atrak glaciers have respective areas of 82 km² and 90 km². We will also update this in the revised manuscript.

L161-162: I don't understand this sentence

We mention here that the group of debris-covered and debris-free glaciers both show variability in mass balance at individual level, but the total mass balance of debris-covered and debris-free glaciers is nearly the same. We will further elaborate this line in the revised text.

L168-169: different periods so not meaningful

We understand that the studies being compared are of different time periods. Our intention here, was to compare outpre-2000 results with the post-2000 studies.

L170-171: this needs to be better quantified!! Warning, errors are larger for small glaciers than for big ones -> this could explain the discrepancies

We appreciate the reviewer's comment. We will discuss this in relation to glacier uncertainties in the revised text.

L184: "high variability" compared to what??

We refer here to the variability of mass balance among individual glaciers.

L190-191: again there is no reason to agree because periods are different

We will clarify here that our main point was to compare the pre-2000 and post-2000 periods.

Data availability: only DEMs and orthos available -> add the per glacier mass balance data?

We will also publish the data per glacier data.