Response to Professor Frank Paul

We sincerely thank you for agreeing to review our manuscript and for the considerable time and effort you devoted to this work. We greatly appreciate your careful examination of both the manuscript and the 2mKGI dataset, as well as the detailed mapping examples, critical observations, and constructive recommendations you provided. Your comments have been extremely valuable in helping us identify important issues in the original submission and in guiding a thorough revision of both the dataset and the manuscript. We are particularly grateful for the rigor and attention to detail reflected throughout your review. We have carefully considered all of your comments and have made substantial revisions accordingly. Our detailed point-by-point responses are provided below. For clarity, the reviewer's original comments are shown in blue, while our responses are shown in red.

General comments

The study by Yang et al. presents a new glacier inventory for the larger Karakoram mountain range derived from very high (ZiYuan-3) and high (Sentinel-2) resolution optical satellite images acquired in 2020 and 2021. The authors also use Landsat derived surface temperatures and a 4 m resolution DEM derived from ZiYuan-3 (plus the ASTER GDEM) to derive glacier extents automatically from a combined U-Net/CBAM approach and corrected the outlines manually as required. As I do not work with DL/ML and miss the related expertise, I do not comment on this part of the study.

First, I want to acknowledge the large effort by the authors to create this inventory and confirm that an update of the currently available glacier outlines (from around 2000) is indeed required. As (apart from surging glaciers) area changes are small in the Karakoram, a highquality dataset is very helpful to reveal them. I also want to acknowledge that the other investigations (e.g. regarding debris cover and glacier type) are interesting, that the study is well written and that the figures are generally good to illustrate the different points. Last, I want to acknowledge that the authors provided image coordinates and glacier outlines for inspection. The latter show that high resolution does not solve all mapping challenges in this region. Apart from some other points, these challenges are actually the largest problem of the derived dataset. I am aware that the RGI 7.0 dataset for this region is not perfect (e.g. missing or wrong location of ice divides), but overall, I think it is still better than the new one described in the present study. The main problems of the dataset are included seasonal snow, wrongly interpreted debris cover, included glacier forefields and remaining artefacts of the processing. I include at the end six example images to illustrate the various issues. Regarding snow cover, the years 2020 and 2021 were in some regions about ok for glacier mapping, but at the highest elevations snow cover is often hiding the real glacier perimeter (also illustrated in Figs. 6d and 7b). In consequence, many rock outcrops are classified as glaciers or their extent is too small and glaciers have been mapped where no glaciers are. With a focus on the region around Batura Glacier, I also found several glaciers where the lateral moraines from the Little Ice Age (LIA) have been wrongly mapped as glacier extents or debris-covered parts are not or wrongly included. Together, the wrongly included snow cover and LIA extents create too large glacier areas.So, how to proceed in this regard? I assume the authors would prefer to publish a high-quality dataset and improve it where possible. Given that the workload for reworking everything is likely too high, I suggest correcting at least the largest errors:

As a first step, I would compare the outlines of the present dataset (red lines) with those from RGI 7.0 (in blue, on top) and wherever they are much larger (or smaller) in the ablation region (visible red outlines), please check if LIA extents have been mapped or debris-covered tongues are incorrect (the geolocation issue of Shisper Glacier in RGI 7.0 has to be ignored) As this mostly concerns larger glaciers, I think the workload is feasible.

(2) Correcting the too large extents in the accumulation area is more difficult. At best, RGI 7.0 outlines are used as a mask so that the glacier-covered region in the present dataset will not be larger than this. This can be applied automatically and will only be wrong for a few glaciers that advanced or surged. Unfortunately, geolocation shifts between the two datasets will create wrong corrections and the back-correction will be very demanding. Maybe a buffer or ML/DL techniques will help. Please try! In the following I list specific comments to the text that should be considered as well.

Response

We fully agree with the reviewer that the reliability of glacier boundaries is fundamental to the value of the inventory and that very-high-resolution imagery alone does not resolve all mapping difficulties in the Karakoram. After carefully examining the reviewer's comments and the six examples provided, we confirmed that seasonal snow remaining in some of the ZY-3 scenes, particularly in the accumulation areas, had led to erroneous delineation

in a number of locations. We also identified cases where debris-covered glacier margins required further discrimination from LIA moraines, glacier forefields, exposed bedrock, and other debris-covered landforms.
We therefore carried out a comprehensive quality-control and revision of the entire 2mKGI dataset. Every glacier polygon was individually inspected and revised where necessary using the original ZY-3 and Sentinel-2 imagery, together with available topographic and geomorphological information. Particular attention was given to removing seasonal snow, excluding exposed rock within snow-covered accumulation areas, correcting erroneously included LIA moraine extents and glacier forefields, and reassessing debris-covered glacier termini and margins.
Following the reviewer's suggestion, we used the correct RGI 7.0 dataset as an important reference and, where appropriate, as a spatial constraint during the revision. For most glaciers, differences between 2mKGI and RGI 7.0 were used to identify potentially problematic boundaries, which were then re-examined using the original ZY-3 and Sentinel-2 imagery. For some large glaciers whose accumulation areas were heavily affected by seasonal snow and for which the true glacier perimeter could not be reliably identified from the 2020–2021 imagery alone, the RGI 7.0 outlines were partially used as masks to constrain the revised glacier extent and reduce the inclusion of seasonal snow. This masking procedure was not applied uniformly across the inventory. In areas where glacier advance, surging, geometric offsets, or other evidence suggested that the RGI 7.0 boundary might not represent the contemporary glacier extent, the outlines were reassessed manually using the original imagery and available topographic information.
The revision resulted in substantial changes to the inventory statistics. The total mapped glacier area decreased from 21,261.8km^2 in the original submission to 19,582.31km^2 in the revised dataset, corresponding to a reduction of 1,679.49km^2 (7.90%). The mapped debris-covered glacier area decreased from 2,239.9 to 2,055.97 km^2, a reduction of 183.93km^2 (8.21%).
Following completion of the boundary revision, we recalculated all glacier-level attributes, including geometric, topographic, debris-cover, and related statistical variables, and repeated all subsequent regional analyses and comparisons. The corresponding figures, tables, methodological descriptions, results, discussion, and conclusions have also been updated to ensure full consistency with the revised inventory.
We believe that this comprehensive revision has substantially strengthened the reliability and internal consistency of the 2mKGI dataset. The reviewer's detailed inspection and specific examples were particularly valuable in prompting this glacier-by-glacier reassessment and in improving both the dataset and the manuscript.

Specific Comment 1

The perimeter used here for the Karakoram is much larger than usually used. It also includes glaciers in Wakhan region of Afghanistan. I suggest restricting the analysis to the perimeter provided by Bhambri et al. (2022), see doi.org/10.1007/978-3-030-47660-1_8.

Response

Thank you for this important comment. We agree that the perimeter used in the original manuscript extends beyond the geographical extent of the Karakoram as defined by Bhambri et al. (2022), particularly toward the Aghil Mountains, the upper Shyok basin, and the Pamir–Wakhan margin (Bhambri et al., 2022). Referring to the entire study domain simply as the "Karakoram" was therefore imprecise. In the revised manuscript, we have adopted the boundary of Bhambri et al. (2022) to define the Karakoram proper. Rather than discarding the glacier data already mapped outside this boundary, we have revised the geographical framework of the study and now refer to the complete domain as the "Karakoram and adjacent high-mountain regions." The area outside the Karakoram proper mainly includes the Aghil Mountains and the high-mountain areas of the upper Shyok basin, including the Depsang–Chang Chenmo sector, together with a limited extension toward the Pamir–Wakhan margin. We have revised the study-area description and Study area map (Fig.1 in this Document) accordingly to distinguish explicitly between the Karakoram proper and the surrounding high-mountain regions. Where results refer specifically to the Karakoram, the Bhambri et al. (2022) perimeter is used as the geographical reference, while results for the complete inventory domain are explicitly identified as referring to the Karakoram and adjacent high-mountain regions.

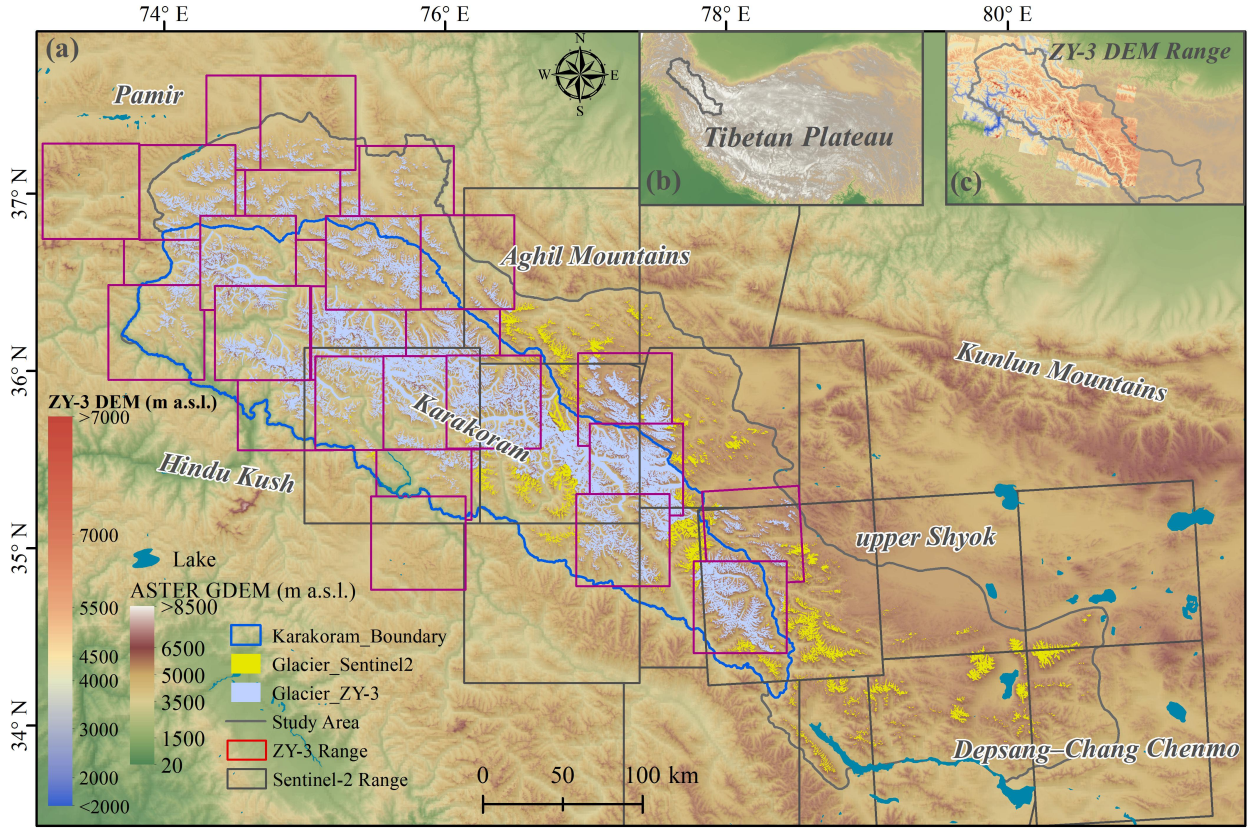


Figure 1. Study area.

Specific Comment 2

The ASTER GDEM v3 and the (void-filled) SRTM DEM have locally quality issues, the latter in particular in the interpolated regions with data voids. It is unclear where these DEMs have been used and how they compare to the ZY-3 DEM. Do these DEMs match seamlessly? I also miss a hillshade of the ZY-3 DEM revealing its topographic quality, e.g. compared to other high-quality DEMs such as the HMA-DEM or the Copernicus DEM. This can all be in the supplement, but it should be there.

Response

The roles and spatial coverage of the different DEM products were not sufficiently clear in the original manuscript, particularly regarding where each DEM was used and whether they were combined for glacier delineation and subdivision. We have therefore revised the data description to clarify the specific role of each DEM and have added the spatial coverage of the ZY-3 DEM to the study-area map.

Specifically, the ZY-3 DEM and ASTER GDEM v3 were used for glacier-level topographic attribute extraction and glacier-unit subdivision. The ZY-3 DEM was used preferentially wherever available because its higher spatial resolution preserves finer ridge morphology and local topographic discontinuities. In areas not covered by the ZY-3 DEM, ASTER GDEM v3 was used as supplementary topographic information. In contrast, the SRTM DEM was not used for glacier-unit subdivision. It was used only in the supplementary comparison between 2mKGI and RGI 7.0, where it served to calculate the glacier area and area fraction within the accumulation zones of RGI glaciers. We have now made this distinction explicit in the revised manuscript.

We have also added comparisons of the ZY-3 DEM (Resampled to 8 metres) with other DEM products, including hillshade representations, to better illustrate differences in topographic detail and terrain representation (Fig. 2 in this Document). These comparisons show that the DEMs do not match completely seamlessly. In particular, ridge positions and small-scale topographic features can differ locally because of differences in spatial resolution, acquisition characteristics, and DEM quality. We have explicitly acknowledged this limitation in the revised manuscript.

Importantly, the ZY-3 DEM and ASTER GDEM v3 were not mosaicked and treated as a single seamless DEM for glacier subdivision. At transitions between the two DEM sources, ridge lines can show local inconsistencies, and in some cases these differences make automatic subdivision unreliable. We therefore manually inspected these transition zones and ambiguous ice divides, with reference to the original optical imagery, surrounding topography, and previously published glacier boundaries, before finalizing the glacier units.
We have clarified these procedures in the revised Methods section and added the corresponding DEM comparison figures to the Supplement. These revisions make the respective roles of SRTM, ASTER GDEM v3, and the ZY-3 DEM, as well as the limitations associated with combining topographic information from different DEM sources, more transparent.

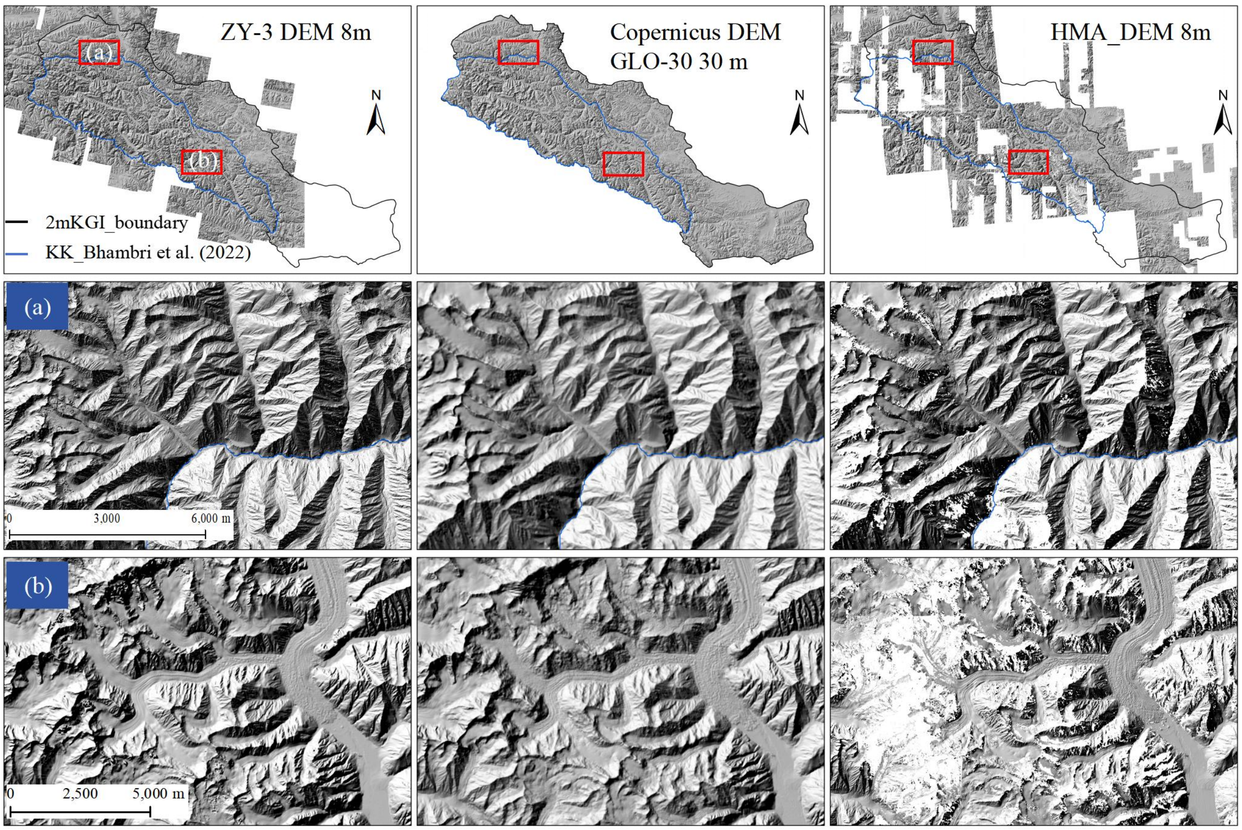


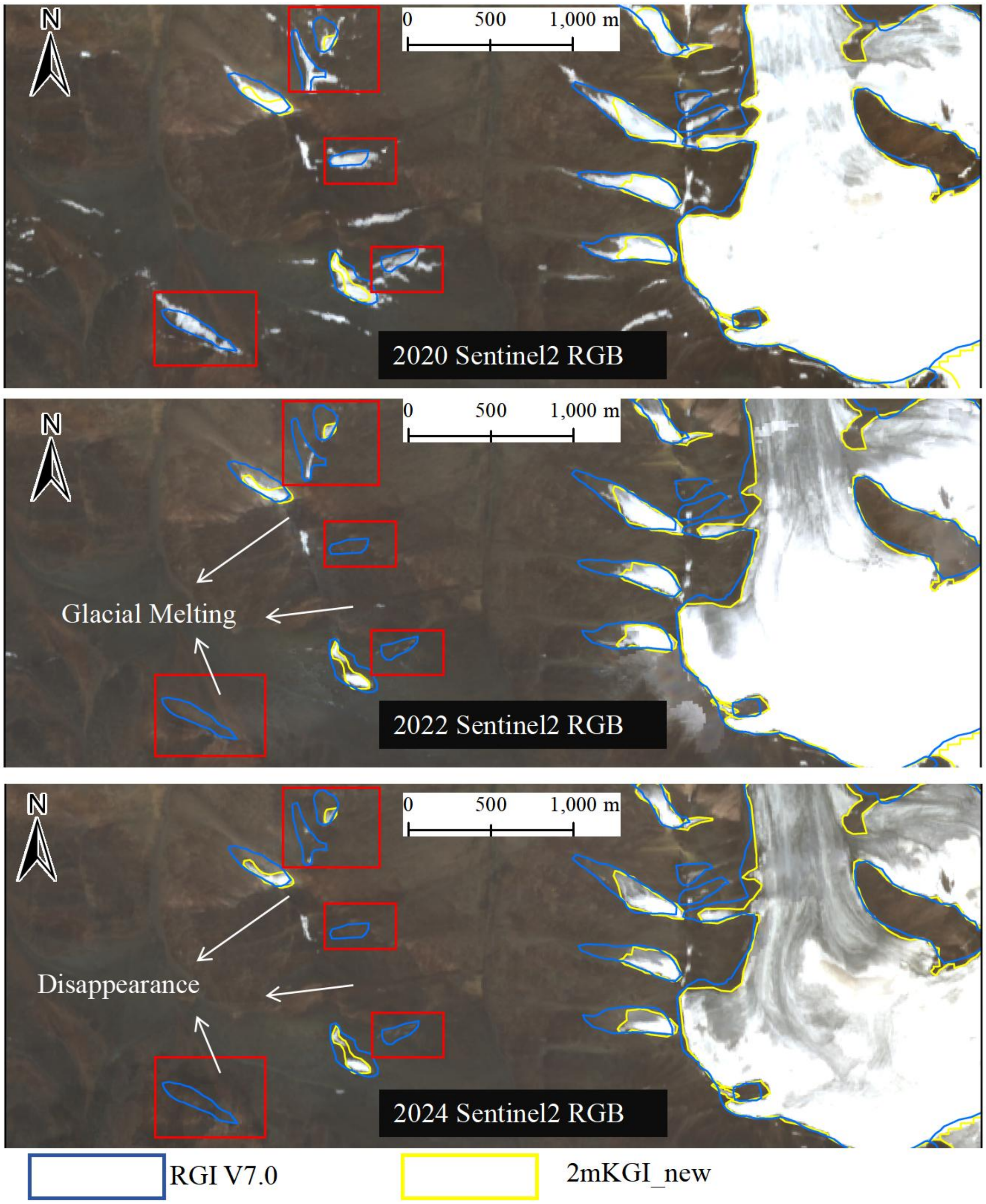
Figure 2. Comparison of shadows on different DEM slopes.

Specific Comment 3

Please check if the correct RGI 7.0 has been used/displayed. The missing glaciers shown in Fig.13a are all there. Also the small glaciers shown in Fig. 7e are in RGI 7.0.

Response

Thank you for pointing this out. After re-examining the RGI data used in the original comparison, we found that an incorrect version had indeed been used in some of the figures. We apologize for this oversight. We have now replaced it with the correct RGI 7.0 dataset (Consortium, 2023) and have systematically rechecked all comparisons involving RGI 7.0. Accordingly, the examples previously shown in Fig. 13a and Fig. 7e have been corrected, and the associated statements in the manuscript have also been revised.
During this re-examination, we still identified a limited number of cases in which differences remain between the revised 2mKGI and RGI 7.0. These cases were individually checked against the original satellite imagery before being retained for discussion. We also found several very small glaciers represented in RGI 7.0 that have undergone substantial shrinkage (Fig. 3 in this Document). The revised figures and text now use the correct RGI 7.0 dataset throughout, and we have removed or modified the previous statements that were based on the incorrect comparison.



RGI_ID:RGI2000-v7.0-G-13-59233, RGI2000-v7.0-G-13-59234, RGI2000-v7.0-G-13-59236

Centre coordinates: lon:79.352291, lat:34.015545; lon:79.357818, lat:34.004421; lon:79.344737, lat:34.001018.

Figure 3. Small glaciers represented in RGI 7.0 that have undergone substantial shrinkage.

Specific Comment 4

There is also a book and dataset about a new glacier inventory for Pakistan from Sentinel-2 scenes acquired in 2022, led by Davide Fugazza (EVK2CNR). It would be worthwhile to also compare results from the present study with the dataset created by the student project.

Response

We thank the reviewer for drawing our attention to the newly available Pakistan glacier inventory derived from Sentinel-2 imagery acquired in 2022 . Following this valuable suggestion, we adopted this inventory for an additional cross-inventory comparison. The complete Pakistan inventory contains 13,031 glacier polygons with a total area of 13,546.93km^2. Within the Karakoram portion directly comparable with our study area, it contains 5,129 glaciers covering 9,407.92km^2. We compared this subset with the corresponding pre-selected part of our 2mKGI inventory, which covers 9,147.58km^2. The Pakistan inventory is therefore 260.34km^2 (2.85%) larger than our inventory in the common comparison area. This small aggregate difference indicates close agreement in regional-scale glacier area, while differences in individual glacier outlines may still arise from image acquisition dates, delineation procedures, and glacier segmentation rules. We have added this comparison to the revised manuscript.

Specific Comment 5

As a general note, for me, medium resolution is MODIS type (100-1000 m) and Sentinel-2, ASTER, Landsat TM (10/15/30 m) is high resolution. 5 m or higher (Planet, ZY-3, etc.) would be very high-resolution. But I am aware that this is not standardized.

Response

The terminology used to describe spatial resolution is not fully standardized, and our previous use of "medium resolution" for Sentinel-2, ASTER, and Landsat imagery could therefore be ambiguous. Following the reviewer's suggestion, we have revised the terminology throughout the manuscript. Sentinel-2, ASTER, and Landsat data at approximately 10–30 m resolution are now referred to as high-resolution data, whereas ZY-3 and other imagery with spatial resolutions of approximately 5 m or finer are referred to as very-high-resolution (VHR) data. We have also checked the relevant statements throughout the manuscript to ensure consistent usage of these terms.

Abstract Comment 6

Please check all statements about previous inventories, e.g. the underestimation of glacier numbers (which is incorrect for RGI 7.0) or the generalization of debris-covered margins (which are also not well captured in the present study, e.g. confused with LIA extents). As the glacier count is a rather arbitrary number, it is maybe not too important to improve it.

Response

Thank you for this important comment. We agree that several statements in the original Abstract concerning previous glacier inventories were too general, particularly the statement that existing inventories underestimate glacier numbers. We also agree that glacier count is strongly influenced by glacier-subdivision rules and should not, by itself, be regarded as an indicator of inventory quality.

Following the reviewer's comments, we first rechecked the RGI comparison using the correct RGI 7.0 dataset and then conducted a comprehensive revision of the entire 2mKGI inventory. Every glacier polygon was individually inspected, with particular attention to seasonal snow contamination, exposed rock in accumulation areas, debris-covered margins, LIA moraines, glacier forefields, and other ice–debris landforms that could lead to erroneous boundary interpretation. The identified errors were corrected, and all glacier-level attributes and regional statistics were subsequently recalculated.

Based on the revised dataset, we have carefully re-evaluated the statements in the Abstract and throughout the manuscript. The generalized claim that RGI 7.0 underestimates glacier numbers has been removed, and differences in glacier counts are now reported only as inventory characteristics rather than as evidence of superior mapping quality. We have also revised the discussion of debris-covered glacier mapping. Rather than attributing improved boundary delineation directly to spatial resolution, we now emphasize that very-high-resolution imagery provides additional geometric and geomorphological information that can assist boundary interpretation when combined with topographic information, explicit mapping rules, and systematic manual quality control.

The revised Abstract therefore focuses on the updated glacier geometry and attributes derived from the comprehensively revised 2mKGI dataset, rather than using glacier number alone as a measure of improvement.

Abstract Comment 7

What is missing here as a motivation is the high impact of wrongly mapped seasonal snow on glacier area (which is also a major reason for area overestimation in this study), ice divides being at the wrong place (mostly due to errors in the SRTM DEM) and the geolocation shifts of outlines in RGI 7.0 derived from former Landsat images that have been corrected now to better match with the Sentinel-2 geometry.

Response

Thank you for this important suggestion. We agree that the original Abstract placed too much emphasis on spatial resolution and did not sufficiently acknowledge other important sources of uncertainty in glacier inventories, particularly seasonal snow, uncertainties in glacier divides, and geometric inconsistencies among glacier outlines derived from different satellite datasets.

We have therefore revised the motivation in the Abstract to explicitly include these issues. In particular, we now emphasize that seasonal snow can obscure the true glacier perimeter and substantially bias mapped glacier area, especially in accumulation areas. We also acknowledge that uncertainties in DEM-derived ice divides and geolocation differences among glacier inventories derived from different generations of satellite imagery can affect glacier geometry and subdivision.

During the revision of the 2mKGI dataset, we used multi-temporal Sentinel-2 imagery from 2020, 2022, and 2024 to distinguish persistent glacier ice from temporary seasonal snow and to revise glacier boundaries where necessary. The comparison of these multi-temporal images was particularly useful in areas where the 2020–2021 ZY-3 imagery alone did not provide sufficient confidence for boundary interpretation. We also re-examined a number of glacier divides using the satellite imagery and manually adjusted them where the image evidence indicated that the original subdivision was inappropriate.

Accordingly, the revised Abstract now presents seasonal snow, glacier-divide uncertainty, and geometric inconsistencies among inventories as important mapping challenges, rather than attributing inventory differences primarily to spatial resolution.

Abstract Comment 8

The statement in L34 is incorrect for the present dataset and shows that higher resolution is not everything. More important is the ruleset applied to distinguish rock glaciers, icecored moraines and other ice-debris-landforms from the debris-covered glaciers to be mapped, largely due to the fact that such features only became visible at very highresolution. As mentioned above, I think the outlines in their present form are not a new benchmark (L37) as RGI 7.0 outlines have overall the better quality. But due to geolocation issues and wrong/missing ice divides, RGI 7.0 outlines should be updated at some point. I hope the authors can improve their dataset to have an alternative.

Response

This is an important distinction. The principal advantage of very-high-resolution imagery is that it reveals additional geomorphological and surface details that are difficult to resolve in coarser imagery, thereby allowing more explicit and consistent mapping criteria to be applied when distinguishing debris-covered glacier ice from surrounding ice–debris landforms.

Following this suggestion, we have revised the corresponding interpretation in the manuscript and further clarified the criteria used for debris-covered glacier delineation, including ice cliffs, glacier meltwater outlets, lateral and terminal moraines, surface morphology, and local slope or topographic breaks. We have added an example figure illustrating these interpretation criteria (Fig. 4 in this Document), showing how very-high-resolution imagery and slope information derived from the ZY-3 DEM provide additional evidence for identifying debris-covered glacier boundaries.

We also applied these clarified criteria during the comprehensive revision of the 2mKGI dataset. All glacier polygons were re-examined, and questionable debris-covered margins were corrected where necessary. Multi-temporal Sentinel-2 imagery was additionally used where temporal information helped distinguish persistent glacier-related features from temporary snow cover or ambiguous surrounding terrain.

We also agree that the term “benchmark” used in the original manuscript was too strong and have therefore removed it. Following the comprehensive revision and systematic quality control, we now present 2mKGI as an updated and independently derived very-high-resolution glacier inventory that can serve as a complementary dataset for glacier studies in the Karakoram. We appreciate this comment, which helped us better articulate both the advantages and limitations of very-high-resolution glacier mapping.

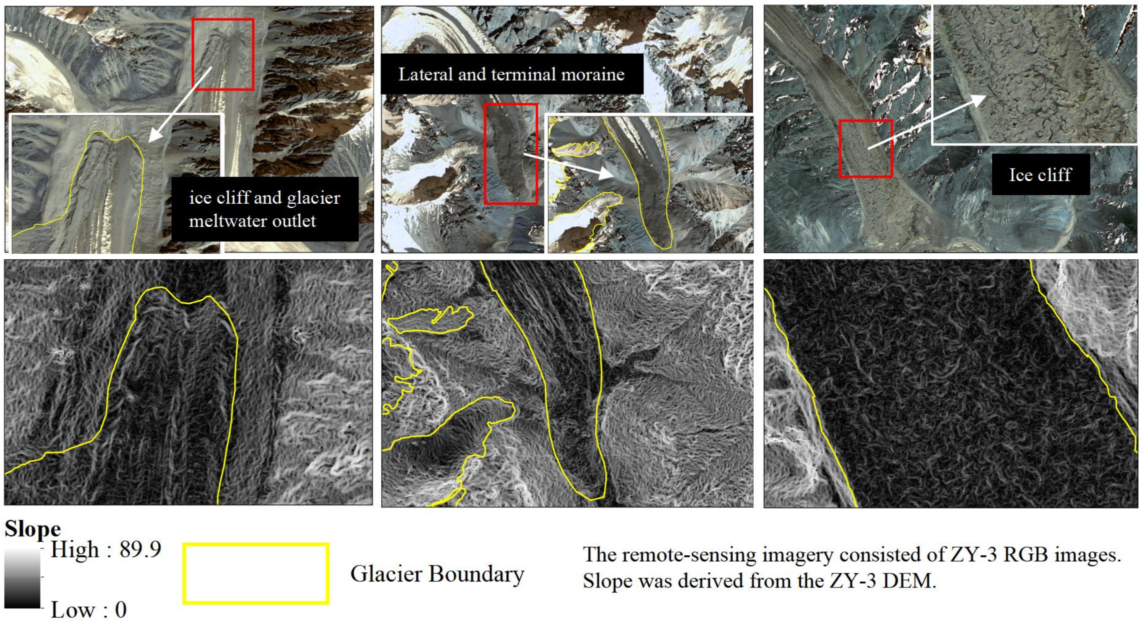


Figure 4. Revision criteria for the boundaries of supraglacial debris.

Specific Comment 9

L58: Please be precise here. The cited references seemingly refer to RGI 6.0 and the first GAMDAM inventory. These are superseded by GAMDAM II (Sakai 2019) and RGI 7.0 (RGI consortium 2023) and should no longer be used for comparison.

Response

Thank you for pointing this out. We agree that the references cited in the original manuscript were outdated for the intended comparison. Following the reviewer's suggestion, we have updated the relevant text and replaced the superseded datasets with GAMDAM II (Sakai, 2019) and RGI 7.0 (Consortium, 2023) where appropriate. We have also updated the corresponding comparison results and citations so that the discussion is based on the latest glacier inventory products.

Specific Comment 10

L67: Please check carefully. As far as I can see it, nothing has been omitted in RGI 7.0.

Response

Thank you for this comment. The original description of these features as "omitted glaciers" was too definitive. We therefore re-examined this issue using the correct and latest RGI 7.0 dataset and revised the corresponding statements in the manuscript accordingly.

During the revision of 2mKGI, we further compared multi-temporal Sentinel-2 imagery from 2020, 2022, and 2024. We found several small snow- or ice-covered features that persist at approximately the same locations across these three observation years but are not represented by glacier polygons in RGI 7.0 (Fig. 5 in this Document). Interestingly, some nearby features with similar appearance and setting are included in RGI 7.0. We therefore consider these cases to represent differences between the two inventories that merit further attention.

However, we cannot completely exclude the possibility that some of these small persistent features represent perennial or long-lasting snow patches rather than independent glaciers. In the revised manuscript, we describe them more cautiously as persistent snow- or ice-covered features identified in the multi-temporal imagery but not represented in RGI 7.0, and we have revised the associated figure and text accordingly.

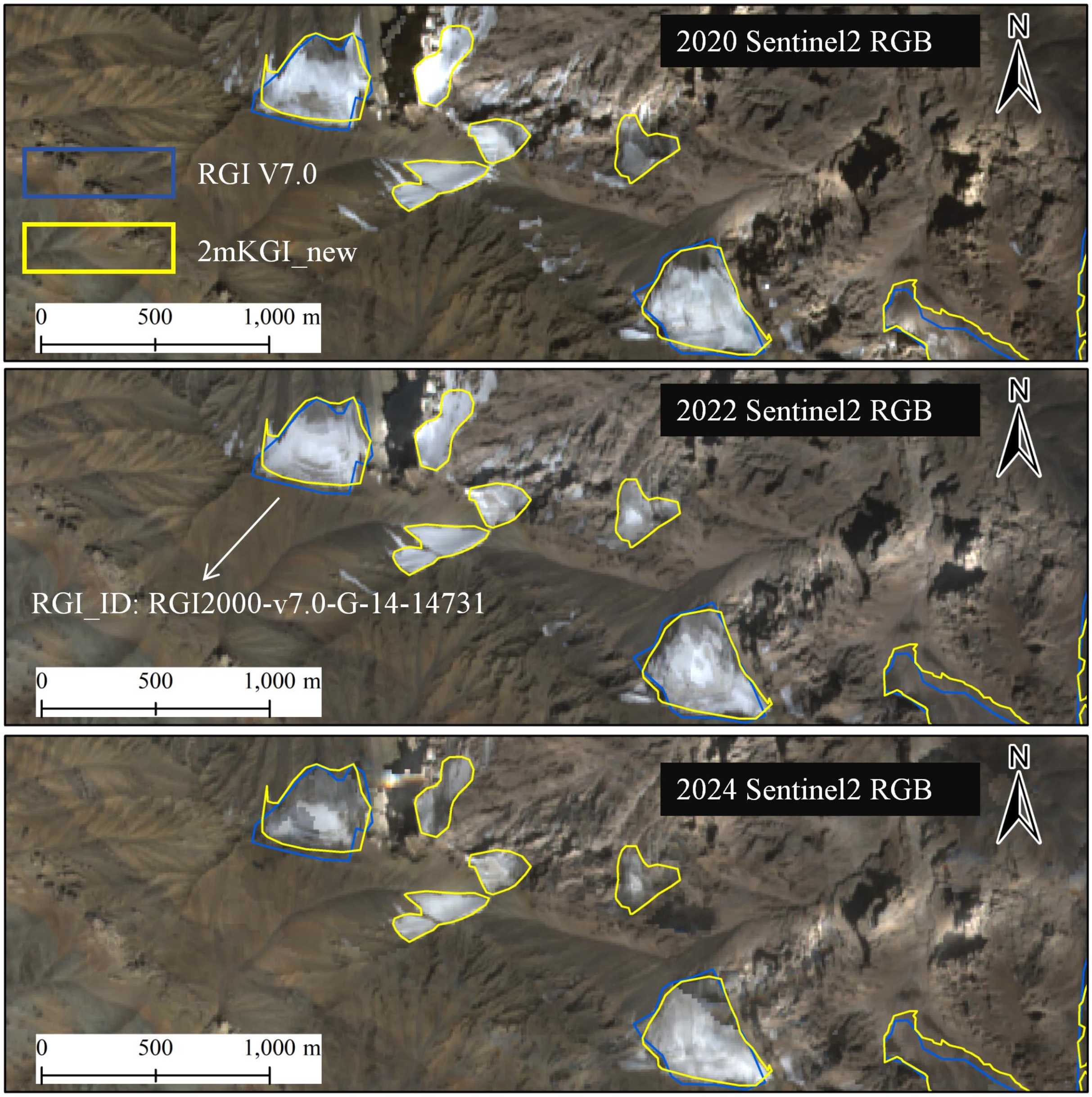


Figure 5. Persistent snow- or ice-covered features in 2mKGI and RGI 7.0: a multi-temporal Sentinel-2 comparison.

Specific Comment 11

L69: Small glaciers do not necessarily have short response times. They must be thin (steep) with strong ablation near the terminus. When they are flat (thick) with limited ablation (e.g. debris-covered tongues) they can also have long response times.

Response

Thank you for this clarification and correction. As you noted, small glaciers do not necessarily have short response times, as glacier response depends not only on size but also on ice thickness, slope, ablation conditions, shading, and debris cover. We have therefore revised the relevant statement and removed the generalized link between small glacier size and rapid response. The revised text now emphasizes that response times can vary substantially among small glaciers depending on their geometry and surface conditions.

Specific Comment 12

L70-78: This is all fine, but the impact of resolution is maybe small compared to factors like wrongly classified seasonal snow (leading also in this study to an overestimation of glacier area). The area difference when digitizing the same glacier at 10 or 2 m resolution might be small as outline deviations have a random distribution. What changes is the ruleset, i.e. at higher resolution different features of a glacier become visible (e.g. icecored moraines) and digitizing guidelines have to be adjusted accordingly.

Response

This is an important distinction. The original text placed too much emphasis on spatial resolution as a primary source of inventory uncertainty. As you pointed out, differences caused solely by digitizing the same glacier at 10–30 m versus metre-scale resolution may be relatively limited because local outline deviations can partly compensate. In contrast, systematic interpretation errors, such as the inclusion of seasonal snow, incorrect delineation of debris-covered margins, or inconsistent treatment of ice-cored moraines and other ice–debris landforms, can have a much larger effect on mapped glacier area.

We have therefore revised this section to distinguish more clearly between the effect of spatial resolution and the effect of mapping rules. In the revised manuscript, we no longer imply that higher spatial resolution alone necessarily produces substantially more accurate glacier areas. Instead, we emphasize that the main advantage of very-high-resolution imagery is that it reveals additional small-scale geomorphological features, such as moraine ridges, ice-cored moraines, ice cliffs, and other surface structures, which can support more informed boundary interpretation but also require appropriately adapted and consistent mapping criteria.

We have also added seasonal-snow contamination as an important source of glacier-area uncertainty. This issue was particularly relevant to the original version of 2mKGI and was addressed during the comprehensive revision of the dataset using multi-temporal Sentinel-2 imagery and systematic glacier-by-glacier inspection. The corresponding discussion has been revised accordingly.

Specific Comment 13

L85: I think this is mostly the case for small glaciers, say <0.1 km^2. Towards larger glaciers and less complex forms (ice caps) resolution has a decreasing impact on outline quality.

Response

Yes, this point is particularly relevant for very small glaciers, especially those smaller than about 0.1 km^2, where metre-scale imagery can substantially improve the visibility of narrow margins, small isolated ice bodies, and complex boundary features. For larger glaciers and morphologically simpler glacier forms, the additional benefit of increasing spatial resolution is generally smaller.

We have revised the corresponding text accordingly and now limit the statement about the value of metre-scale imagery mainly to small glaciers and glaciers with complex or debris-covered margins, rather than applying it uniformly to all glacier types.

Specific Comment 14

L87: I think also for DEMs it is not only resolution that is important. Other factors like the time stamp (everything acquired in the same month), artefacts/data voids, radar penetration or cloud/contrast issues are equally important to obtain high-quality ice divides and topographic information. There is nothing against using the ZY-3 tri-stereo images (but please show a hillshade for comparison with other DEMs), but for the comparably large glaciers in the Karakoram also other DEMs provide reliable glacier morphology.

Response

This is an important point. The ZY-3 DEM used in this study was generated from tri-stereo imagery acquired in 2020 and 2021, primarily between July and October, corresponding to the late ablation season in the Karakoram.

Restricting the source imagery to this seasonal window helps reduce, although not completely eliminate, temporal inconsistencies associated with seasonal snow and surface conditions.

We also recognize that DEM quality depends on factors beyond nominal spatial resolution, including acquisition timing, data voids and artefacts, radar penetration, and image contrast or cloud conditions. To make this more transparent, we have added a hillshade comparison between the ZY-3 DEM, Copernicus GLO-30 DEM, and HMA DEM, including both the regional coverage and two representative local enlargements (Fig. 1). The comparison shows that the three DEMs reproduce the major glacier and valley morphology consistently, while differences are more apparent in local ridge geometry and small-scale topographic detail.

The corresponding description of the ZY-3 DEM and its acquisition period has been clarified in the revised manuscript, and the hillshade comparison has been added to the Supplement.

Specific Comment 15

L90: I am not sure how this separation works when there is no break in slope or surface morphology? Usually, DEM differencing is used to see where ice is below the debris.

Response

Where there are no obvious breaks in slope or surface morphology, a digital elevation model (DEM) alone cannot reliably determine whether glacier ice is present beneath debris. In our mapping procedure, the DEM was therefore used as supplementary topographic information rather than as an independent criterion for identifying buried ice. Debris-covered glacier boundaries were interpreted by jointly considering ZY-3 optical imagery and topographic information, with reference to features such as ice cliffs, meltwater outlets, lateral and terminal moraines, surface texture, flow-compatible morphology, and local slope breaks or topographic discontinuities. Where these indicators were unclear or absent, the boundary was treated as uncertain. We have clarified these interpretation criteria in the revised manuscript and included an illustrative figure to demonstrate their application (Fig. 3).

We recognise that DEM differencing can provide valuable supplementary evidence for identifying ice beneath debris, particularly where surface morphology alone is insufficient for confident interpretation. However, DEM differencing was not systematically applied in this study.

Specific Comment 16

L96: As mentioned above, it seems that the very high resolution has not always helped to identify debris-covered glacier parts, as in several cases moraine crests from the LIA have been mapped. Please carefully check results against RGI 7.0 to improve the dataset.

Response

This issue was addressed through a comprehensive re-examination of the 2mKGI dataset. During the revision, we carefully checked the glacier boundaries using the original ZY-3 imagery together with multi-temporal Sentinel-2 imagery, with particular attention to debris-covered margins and areas where LIA moraine crests could be confused with glacier boundaries. The revised outlines were also systematically compared with the correct RGI 7.0 dataset, and discrepancies were re-evaluated against the satellite imagery before the final boundaries were retained or modified.

These checks led to a number of corrections to the debris-covered glacier boundaries and substantially strengthened the reliability of the revised inventory. In the revised manuscript, we will provide a more detailed comparison between 2mKGI and RGI 7.0 to make the remaining differences and their interpretation more transparent.

Specific Comment 17

I suggest adjusting the extent of the Karakoram to the one by Bhambri et al. (2022).

Response

Thank you for this suggestion. As also addressed in our response to Specific Comment 1, we agree that the Bhambri et al. (2022) perimeter provides a more appropriate geographical definition of the Karakoram. We have therefore adopted this boundary to define the Karakoram proper in the revised manuscript. Because the original 2mKGI domain extends beyond this perimeter, the complete study area is now referred to as the "Karakoram and adjacent high-mountain regions," rather than the Karakoram alone. Study area map and the study-area description have been revised accordingly, while the full inventory is retained to preserve the mapped glacier information outside the strict Karakoram boundary.

Specific Comment 18

Please get ‘Table 1. Data …’ to the next line that it works as a table caption.

Response

Thank you for pointing this out. This was an oversight in the original manuscript. We have corrected the formatting so that “Table 1. Data …” now appears on a separate line as the table caption.

Specific Comment 19

L120: Please add somewhere which spectral bands are covered by the multispectral sensor. I assume it does not have a SWIR band and can thus not be used to calculate the NDSI or other band ratios for (clean ice) glacier mapping? As a note, in most of the image examples in Figs. 4, 6 and 7 the white glacier surfaces have a brownish colour. It looks as if bands 1, 2, 3 rather than 3, 2, 1 have been combined as RGB. If so, please adjust, otherwise I assume the strange colours are an artefact of the pan-band fusion?

Response

This comment helped us clarify both the spectral characteristics of ZY-3 and the source of the spectral indices used in the workflow. We have added the ZY-3 multispectral band configuration to the Data section: blue (B1, 0.45–0.52 μm), green (B2, 0.52–0.59 μm), red (B3, 0.63–0.69 μm), and near-infrared (B4, 0.77–0.89 μm). Because ZY-3 has no SWIR band, the standard NDSI cannot be calculated directly from ZY-3 imagery.

We have therefore clarified that the NDSI and NDWI used in the workflow were derived separately from Sentinel-2 surface-reflectance data in Google Earth Engine, rather than from ZY-3 imagery. ZY-3 was used primarily for high-resolution visual interpretation and boundary delineation, rather than as a source of NDSI-based clean-ice classification.

We also rechecked the image composites. The brownish appearance of glacier surfaces in several panels resulted from an incorrect RGB band assignment, rather than from the pan-sharpening procedure itself. We have regenerated Figs. 4, 6, and 7 using the correct true-colour B3/B2/B1 combination.

Specific Comment 20

L124: Please show where Sentinel-2 derived extents are located, e.g. as a footprint in Fig. 1.

Response

This point has been addressed by revising Study area map (Fig .1). The areas mapped from Sentinel-2 are now shown in gold, while the ZY-3 coverage is shown in blue, so that the spatial distribution of the two data sources is clearly indicated.

Specific Comment 21

L127:Can you also show (in a map) the regions covered by the ASTER GDEM?

Response

Yes, We clarified this issue in the revised Figure 1. The background elevation layer represents the ASTER GDEM coverage across the study area, while the area covered by the ZY-3 DEM is highlighted using a distinct colour scheme.

Specific Comment 22

L142: I am unclear how the 100 m LST info from Landsat could support glacier mapping with ZY-3 at 2 m resolution. Apart from the fact that the thermal sensor measures just something (i.e. requires careful calibration with field data), the resolution mismatch seems to be too large for a meaningful application. Please better explain how this works. In L147 it is written that the LST info was ‘aligned’ to the 2 m ZY-3 grid, but not how and what the impact of the resampling (?) was.

Response

This is an important distinction. We agree that the original wording did not sufficiently distinguish between the 2 m computational grid used for feature stacking and the native spatial support of the Landsat-derived LST data. The LST layer was not intended to provide 2 m thermal information or to delineate glacier boundaries at metre scale.

Instead, it was included as a coarse-resolution auxiliary predictor providing thermal context complementary to the high-resolution spectral and topographic information.

After transformation to the common coordinate reference system, the LST raster was resampled to the 2 m ZY-3 grid using nearest-neighbour resampling and clipped to the corresponding processing extent. Nearest-neighbour resampling was used only to enable spatial co-registration and feature stacking and does not interpolate new temperature values. Therefore, this operation neither sharpens nor downscales the thermal information, and the effective spatial support of the LST feature remains that of the original Landsat thermal observation.

Accordingly, fine-scale glacier-boundary delineation is controlled primarily by the 2 m ZY-3 imagery, whereas LST contributes only broader-scale thermal information that may help distinguish glacier surfaces, particularly debris-covered ice, from surrounding non-glacial terrain. Its contribution was evaluated empirically through the feature-ablation experiments reported in Table S1, rather than inferred from the resampled spatial resolution.

We clarified this issue in the revised Methods section by replacing the ambiguous term "aligned" with an explicit description of the nearest-neighbour resampling procedure and by stating that resampling does not increase the effective spatial resolution of the LST information. We also clarify that LST was used as a relative thermal predictor for classification rather than for quantitative interpretation of absolute glacier-surface temperature.

Specific Comment 23

L201-203: I would remove this sentence as the contents is about the same as in L151-153.

Response

Following this suggestion, we have removed the sentence in Lines 201–203 to eliminate the repetition with the description already provided in Lines 151–153.

Specific Comment 24

L204-299: I do not comment on Section 3.3 as this is not my area of expertise. However, I would like to mention that I find the (standard) uncertainty measures listed in Table 2 not very insightful. They can basically mean anything. None of them tell me if seasonal snow has been included or not. In Figures 6, 7 and 13 several outline overlays are shown, but most of the glaciers are clean (and easy to map) and located in the very north outside the Karakoram. I suggest showing also mapping results for a few more challenging examples of (small) debris-covered glaciers in the south of the Karakoram.

Response

Thank you for this suggestion. The metrics reported in Table 2 are intended to evaluate the predictive performance of the deep-learning model against manually delineated reference labels on the independent test dataset. Specifically, OA, F1 score, and MIoU quantify agreement between the model predictions and the reference labels; they are not intended to diagnose specific mapping errors such as the inclusion of seasonal snow. We have clarified this distinction in the revised manuscript to avoid interpreting these model-performance metrics as a direct assessment of all sources of glacier-boundary uncertainty.

We also agree with the reviewer that the previous examples were dominated by relatively straightforward clean-ice cases and did not sufficiently illustrate the more difficult mapping conditions. Following this suggestion, we have revised the figures to include additional, more challenging examples of small debris-covered glaciers in the southern Karakoram. These examples better illustrate the performance and remaining limitations of the mapping approach in areas where debris-covered ice is difficult to distinguish from surrounding moraines, rock surfaces, and other non-glacial terrain.

Specific Comment 25

L302: How do you know that snow-covered 'glaciers' <0.01 km2 are glaciers? Considering the partly poor snow conditions (Fig. 6d and 7b), is it meaningful to include them?

Response

This is an important point. We agree that very small, completely snow-covered features cannot be reliably identified as glaciers from a single high-resolution image alone. Spatial resolution does not resolve whether glacier ice is present beneath seasonal snow, and the original manuscript did not sufficiently acknowledge this limitation.

We therefore re-examined these very small glacier polygons during the revision using multi-temporal Sentinel-2 imagery from 2020, 2022, and 2024, together with the available ZY-3 imagery. Features that could only be identified as transient snow patches, or for which persistent glacier ice could not be supported by the multi-temporal observations, were removed from the inventory. Glacier boundaries in snow-covered areas were also revised where necessary. During this re-examination, we also found that some of the very small glaciers in the 2020 imagery correspond to glacier units that were larger than 0.1 km² in RGI v7.0 but had subsequently undergone substantial area reduction, leaving residual glacier bodies smaller than 0.01 km². Their inclusion was therefore supported not only by the 2020 imagery but also by their spatial correspondence with previously mapped glacier units and by the multi-temporal image evidence. Accordingly, inclusion of glaciers smaller than 0.01 km² is no longer based solely on their appearance in a single snow-affected ZY-3 scene. We have revised the manuscript to clarify the multi-temporal quality-control procedure.

Specific Comment 26

L310: How do you know that there is no ice underneath the snow? The higher resolution does not reveal it. For example, for the small glacier in the centre of Fig. 7d all the surrounding snow patches have been included.

Response

We acknowledge this limitation and have revised the relevant interpretation accordingly. Compared with coarser-resolution imagery, very-high-resolution imagery contains fewer mixed pixels and provides finer spatial detail for separating exposed glacier ice, rock outcrops, and discontinuous seasonal snow patches. This can help reduce seasonal-snow contamination where the snow cover is sparse or fragmented. However, when seasonal snow is extensive or continuous, the advantage of higher spatial resolution becomes limited because the imagery cannot determine whether glacier ice is present beneath the snow.

We therefore re-examined the snow-affected glacier boundaries, using multi-temporal Sentinel-2 imagery from 2020, 2022, and 2024 together with the available ZY-3 imagery. Snow patches that could not be supported as persistent glacier ice by the multi-temporal observations were excluded, and the corresponding glacier boundaries were revised where necessary.

Specific Comment 27

L313: As seemingly nothing has been omitted in RGI 7.0, please check the statement.

Response

We have revised this statement accordingly. As also addressed in our response to the related comment above, we re-checked the comparison using the correct and latest RGI v7.0 dataset and removed the overly broad statement that small glaciers are generally "omitted" from RGI v7.0.

During this re-examination, however, multi-temporal Sentinel-2 imagery from 2020, 2022, and 2024 revealed several small snow- or ice-covered features that persist at approximately the same locations across all three observation years but are not represented by glacier polygons in RGI v7.0 (Fig. 5 in this Document). Nearby features with similar appearance and topographic setting are included in RGI v7.0, indicating that these cases represent genuine differences between the two inventories.

Nevertheless, because the available imagery cannot unequivocally determine whether all of these very small persistent features are glacier ice rather than perennial or long-lasting snow patches, we no longer describe them as "glaciers omitted in RGI v7.0".

Specific Comment 28

L320 and elsewhere: Please insert an empty line to separate the figure caption from the text.

Response

Thank you for pointing this out. We have adjusted the formatting throughout the manuscript to ensure that figure captions are clearly separated from the main text.

Specific Comment 29

L321: Please exchange Figs. 8a and 8b, to start with the more general graph and a before b.

Response

Following this suggestion, we have exchanged the order of Figs. 8a and 8b (Fig. 6 in this Document) so that the more general overview is presented first. The corresponding figure caption in the main text have been updated accordingly.

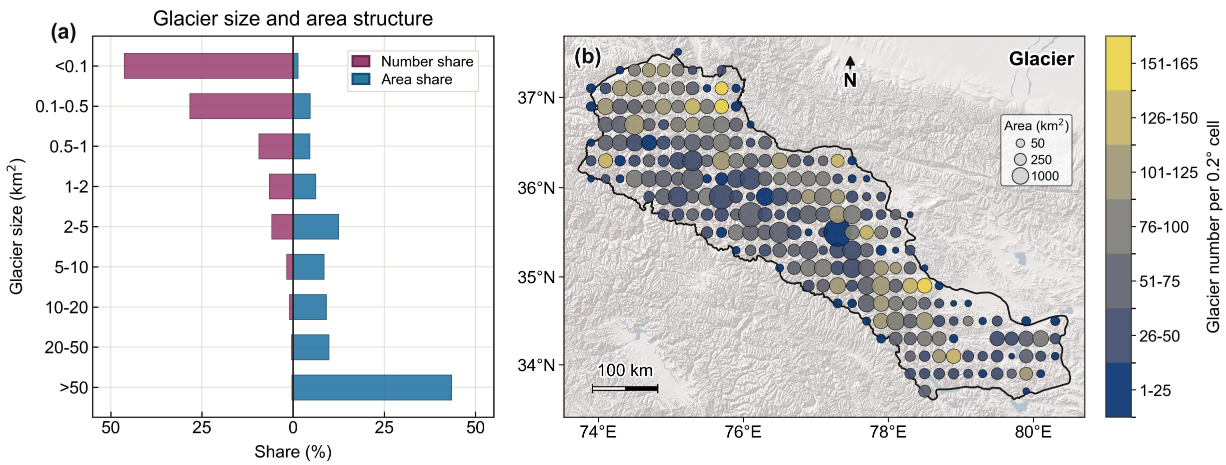


Figure 6. Spatial distribution and size-area structure of glaciers in the Karakoram.

Specific Comment 30

L327: Due to the orange outlier (?) in Fig. 8a (and 11c), there are only small colour differences for the glacier count. Please check values and possibly adjust the legend.

Response

We regenerated the figure using the updated inventory data. The isolated high value in the previous version was confirmed to be an outlier and is no longer present in the revised results. We also adjusted the colour scheme and legend intervals to improve the visual contrast of glacier-count variations (Fig . 6 in this Document).

Specific Comment 31

L341/363: The 2mKGI includes/provides …

Response

Thank you for pointing out this language issue. We have revised the wording accordingly at the indicated locations.

Specific Comment 32

L342: How is mapped debris per glacier defined? Is one pixel enough to name it debriscovered? If not, what is the threshold?

Response

We clarified this definition in the revised manuscript. The degree of debris cover for each glacier is defined as the ratio of mapped supraglacial debris area to the total area of that glacier. A single debris-classified pixel is not sufficient for a glacier to be identified as debris-covered. Instead, the mapped debris must form a spatially coherent area and be supported by recognizable geomorphological characteristics of debris-covered ice.

We did not apply a fixed minimum-area threshold for classifying a glacier as debris-covered. In the revised inventory, the smallest mapped supraglacial debris area is 0.007951 km². This value represents the minimum debris-covered area occurring in the final dataset rather than a predefined classification threshold.

Specific Comment 33

L344: Has 'debris patch number' any glaciological relevance? How is a 'debris patch' defined? Wouldn't it be better to show the percentage of debris cover per grid cell? Before going abstract in Fig. 9, please show what is meant here for a couple of glaciers.

Response

We apologize for the confusion caused by the terminology. The phrase "debris patch number" in the original text was inappropriate and may have suggested that individual debris patches were treated as independent units with glaciological significance. This was not our intention.

In this analysis, we focus on the mapped supraglacial debris itself, including its total area, area-size distribution, and spatial distribution across the Karakoram. The 1,526 glaciers reported in the original manuscript (revised to 1,391 after the inventory update) refer to glaciers containing mapped supraglacial debris. By contrast, Fig. 9 represents only the debris-covered portions of these glaciers; the clean-ice portions of the same glaciers are not included in the statistics shown in this figure.

Following the reviewer's suggestion, we have also revised Fig. 9 (Fig. 7 in this Document) to show the percentage of debris-covered area within each grid cell rather than the number of debris patches. This provides a more intuitive and glaciologically meaningful representation of the spatial concentration of supraglacial debris across the study area.

We have therefore revised the relevant text and the caption of Fig. 9, removed the ambiguous term "debris patch number", and clarified that the figure depicts the spatial distribution and relative coverage of mapped supraglacial debris.

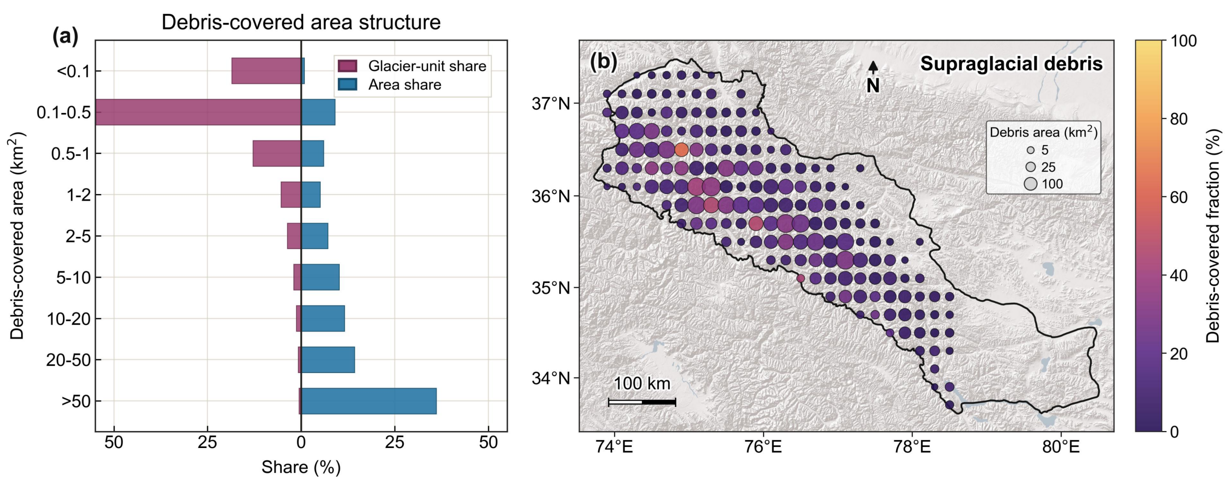


Figure 7. Spatial distribution and size-area structure of supraglacial debris in the study area.

Specific Comment 34

L345: I do not get the relation between debris distribution and 'valley geometry' or 'lowgradient tongue development' from the figure or the text. How is valley geometry or tongue development quantified? What should this relation be? Please explain. Or should this be the conclusion to the sentence following? Then please move it to the end.

Response

We agree that the original placement of this statement was unclear. We have therefore moved it to the end of the sentence as suggested.

Specific Comment 35

L348: That total amounts scale with glacier size is clear, but what is with the percentage of debris cover per glacier? Is it more similar and size independent?

Response

Following this suggestion, we additionally examined the debris-cover fraction at the individual-glacier level. For each of the 1,391 debris-covered glaciers in the revised inventory, the debris-cover fraction was calculated as the supraglacial debris area divided by the total glacier area. We then evaluated its relationship with glacier area using Spearman's rank correlation (Fig . 8 in this Document).

The results show a significant negative relationship between glacier area and debris-cover fraction (Spearman's $\rho = -0.457$, $p < 0.001$). Thus, although larger glaciers contribute disproportionately to the total supraglacial debris area because of their greater size, the relative proportion of their surface covered by debris tends to be lower. Conversely, smaller debris-covered glaciers show a much wider range of debris-cover fractions and can have relatively high proportions of debris cover. Therefore, debris-cover fraction is not size independent.

We have added this analysis and the corresponding scatterplot to the revised manuscript and revised the relevant text to distinguish clearly between absolute debris-covered area and the relative debris-cover fraction of individual glaciers.

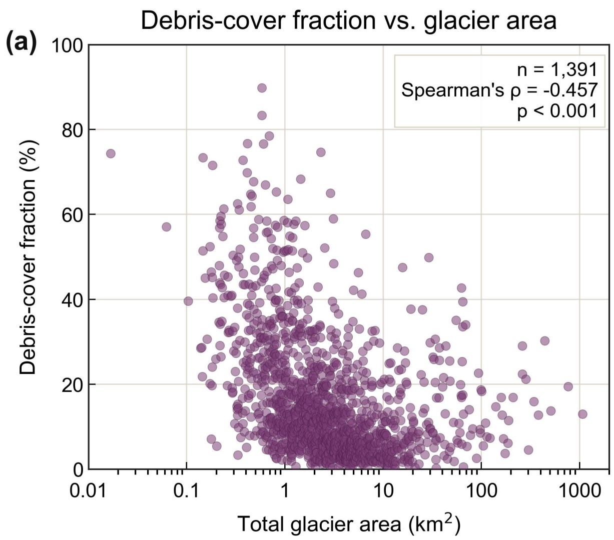


Figure 8. Debris-cover fraction versus glacier area.

Specific Comment 36

L360: See general comments. It seems that in several cases lateral moraines from the LIA have been mapped as boundaries. So, very high-resolution is not everything.

Response

Thank you for highlighting this issue. As addressed in our responses to the related general comments above, we re-examined the affected glacier margins and corrected cases where LIA lateral moraines had been incorrectly included. The corresponding text has also been revised to avoid overstating the ability of very-high-resolution imagery alone to resolve these ambiguities.

Specific Comment 37

L369: I think the maximum is rather broad (5000 to 6000 m).

Response

We agree that the elevation maximum is broader than indicated in the original text. We have therefore revised the description to reflect a broader concentration of glacier area between approximately 5000 and 6000 m, rather than identifying a narrow maximum at 5600–5800 m.

Specific Comment 38

L372: Ok, but that debris usually melts out below the ELA is a consequence of (vertical) glacier flow dynamics and not special for the Karakoram.

Response

We agree with the reviewer that this pattern is not unique to the Karakoram. We have revised the interpretation accordingly. The observed concentration of supraglacial debris at lower elevations is now described as being consistent with the general emergence and accumulation of debris in glacier ablation zones through ice flow and surface melt.

Specific Comment 39

L382: Ok, but this is also well known since a few decades and has actually been used in several studies to map debris-covered glaciers using a slope threshold.

Response

Yes, this pattern is well established and has been recognized for decades, including in previous debris-covered glacier mapping studies that used slope thresholds. We have therefore revised the text to present our result as a quantitative confirmation of this established topographic pattern in the Karakoram, not a novel finding.

Specific Comment 40

L388: Still, the difference to other (northern hemisphere) mountain ranges is remarkable as these usually have most glaciers (and areas) exposed to the north.

Response

Yes, this contrast is noteworthy. We have added a brief statement in the revised manuscript to highlight the difference from the more common north-facing glacier distribution observed in many Northern Hemisphere mountain ranges.

Specific Comment 41

L393: Isn't the snowline be just located somewhere, i.e. depending on the date of image acquisition and snow conditions? Or is the date of the albedo product the same for all glaciers in the sample? Can you demonstrate (in the supplement) that the method works and provides meaningful results?

Response

This is a valid concern, particularly because an instantaneous snowline can vary considerably with image-acquisition date and transient snow conditions. Our original description was therefore not sufficiently precise. The glacier-type classification in this study was not based on a snowline identified from a single satellite image or a single acquisition date.

Instead, we used the published multi-year firn-line product developed by Xie et al., which was derived from melting-season glacier-surface albedo and represents the firn–bare-ice transition at the end of the ablation season (Xie et al., 2025; Xie et al., 2024). The multi-year mean firn-line altitude (FLA) was used as a remote-sensing proxy for the equilibrium-line altitude (ELA), thereby reducing the influence of anomalous snow conditions in any individual year.

Based on this proxy ELA, the accumulation area of each glacier was approximated as the glacier area above the equilibrium line, and the accumulation-area ratio (AAR) was calculated as the accumulation area divided by the total glacier area. The resulting AAR was then used for glacier-type classification. We have revised the description accordingly to clarify that the classification relies on an existing multi-year albedo-derived firn-line product .

Specific Comment 42

L407/431: As a note: Many smaller surge type glaciers can be connected to a larger trunk glacier (that does not surge) after their surge. A large number of surge-type glaciers in the Karakoram are isolated, medium-sized glaciers rather than large valley glacier systems.

Response

This is an important distinction. We agree that our original interpretation at Lines 407 and 431 placed too much emphasis on an association between surge-type glaciers and large valley-glacier systems. Figure 11 shows that surge-type glaciers are concentrated mainly in the central and western Karakoram and partly overlap spatially with Mustagh-type glaciers, but they span a range of glacier sizes and include many medium-sized glaciers.

Similarly, the resemblance between surging and Mustagh-type glaciers in Figure 12 refers only to their aggregated topographic characteristics, particularly the normalized mainline elevation profiles. It should not be interpreted as evidence that individual surge-type glaciers share the same morphological configuration or are necessarily components of large trunk-glacier systems. As the reviewer notes, some smaller surge-type glaciers may become connected to larger non-surging trunk glaciers following an advance, whereas many surge-type glaciers in the Karakoram occur as isolated, medium-sized glaciers.

We have therefore revised the corresponding statements at Lines 407 and 431 and removed the generalization that surge-type behaviour is associated with large valley-glacier systems. The revised interpretation is limited to the observed spatial overlap and similarities in the aggregated topographic profiles.

Specific Comment 43

L418: I would have expected that Alpine-type glaciers have the least extensive areas at low slopes as they are more attached to the topography than the other types.

Response

This is an important point. We re-examined the slope characteristics using the revised inventory (Fig. 9 in this Document). The glacier-type analysis was conducted for glaciers larger than 5 km² in the 2mKGI, which were classified as Alpine-, Mustagh-, and Turkestan-type glaciers according to their accumulation-area ratio (AAR). Recalculation using the revised data confirmed the original pattern, with Alpine-type glaciers showing a comparatively large proportion of glacier surface at slopes below 15°.

To further examine this result, we calculated the low-slope area fraction (<15°) separately for each glacier and plotted it against glacier area (Fig. 10 in this Document). The individual-glacier analysis shows that relatively high low-slope fractions occur widely among Alpine-type glaciers across a broad range of glacier sizes. This indicates that the observed pattern is not simply controlled by differences in the total area of the three glacier groups or by a small number of exceptionally large glaciers.

A possible explanation is that the glacier types used here are defined by AAR rather than by glacier-surface slope. Although Alpine-type glaciers may occur within steep surrounding topography, substantial parts of their glacierized surface, particularly within their accumulation areas, can still have relatively gentle slopes. We have therefore retained the observed result while revising the corresponding interpretation to present this relationship more cautiously.

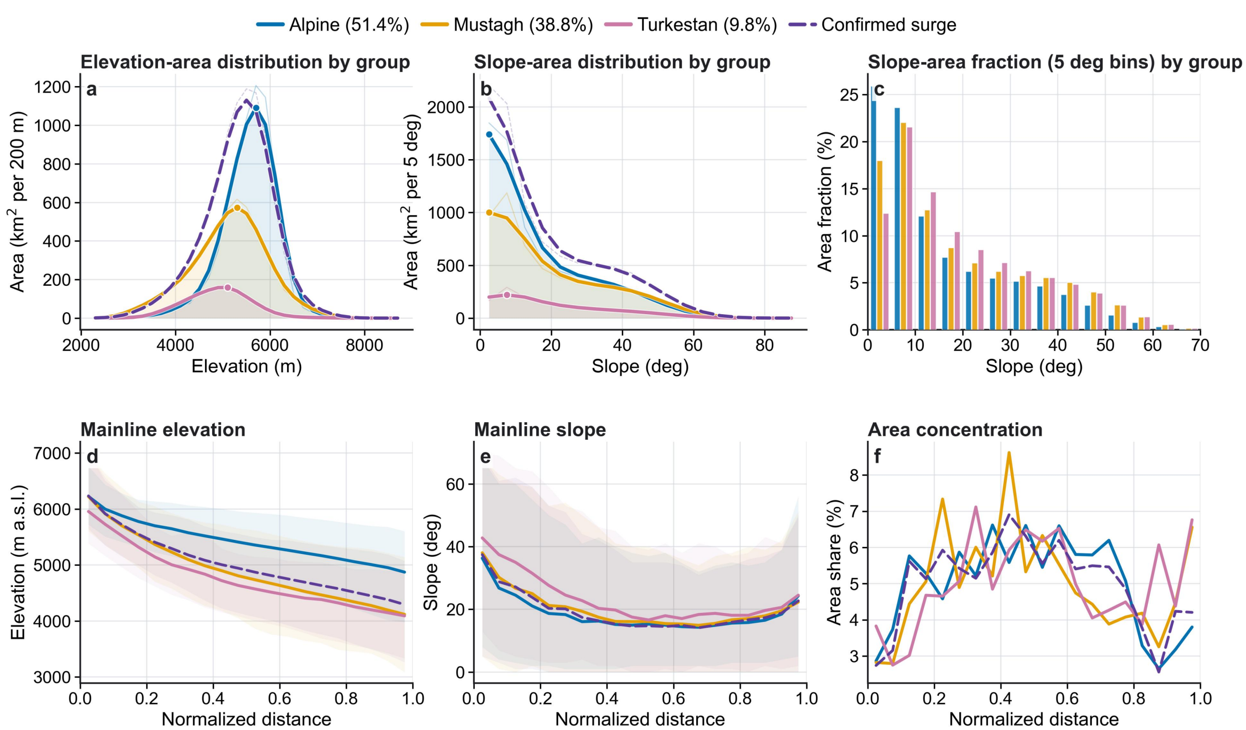


Figure 9. Topographic and longitudinal profiles of glacier types in the study area.

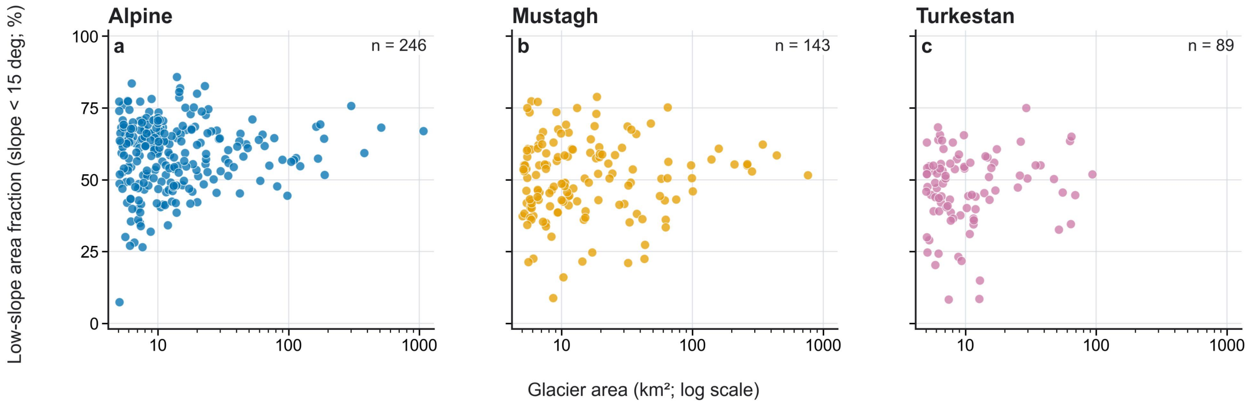


Figure 10. Glacier area versus low-slope area fraction by glacier type.

Specific Comment 44

L428: Should this be Figure 12d and e? Please also cite Fig. 12f (e.g. in L434).

Response

Thank you for pointing this out. We have corrected the figure references accordingly and added the citation to Fig. 12f in the relevant text.

Specific Comment 45

L436: The steep headwalls must at least partly be ice free to provide debris.

Response

Thank you for highlighting this point. We have revised the wording to clarify that debris supply from steep headwalls requires exposed or partly ice-free rock surfaces. The revised interpretation therefore refers specifically to debris supplied from steep, partly ice-free headwalls and adjacent rock faces.

Specific Comment 46

L442: The RGI 7.0 includes the glaciers shown in Fig. 13a as omitted, please check.

Response

Thank you for highlighting this inconsistency. This issue has been addressed together with the related comments above. We re-checked Fig. 13a using the correct and latest RGI v7.0 dataset and confirmed that the glaciers shown there are included in RGI v7.0. We have therefore revised Fig. 13 and the corresponding text and removed the previous interpretation of these glaciers as omitted features.

Specific Comment 47

L445/6: This is what I expected, but it seems the higher resolution has not solved all problems. Please improve your outlines (e.g. as suggested above) to meet this statement.

Response

Thank you for this careful assessment. We fully appreciate the reviewer's concern regarding the quality of the glacier outlines. Following the comments raised above, we conducted a glacier-by-glacier re-examination of the inventory and revised the outlines where necessary, with particular attention to seasonal snow, debris-covered margins, moraine-related ambiguities, and other non-glacial features.

We are committed to providing a high-quality glacier inventory, and the reviewer's detailed inspection has been very helpful in identifying cases that required further correction. We have also moderated the corresponding statement in the manuscript to avoid implying that higher spatial resolution alone resolves all boundary-mapping uncertainties.

Specific Comment 48

L454: The 2mKGI chiefly …

Response

Thank you for pointing this out. We have revised the sentence accordingly.

Specific Comment 49

L456: As stated above, small glaciers do not necessarily have short response times. Those being attached to rock walls at high elevations (cold ice) might not change for decades. Also those being flat (thick) and well shaded or debris-covered might not change much.

Response

We acknowledge this point and have revised the statement accordingly. The original wording overgeneralized the relationship between glacier size and response time. Small glaciers do not necessarily respond rapidly, because their behaviour also depends on factors such as ice thickness, elevation, thermal regime, surface slope, shading, and debris cover. High-elevation cold glaciers or flat, thick, shaded, and debris-covered glaciers may remain relatively stable for extended periods despite their small area.

We have therefore removed the Viewpoint that small glaciers inherently have limited thickness and short adjustment times, and revised the discussion to emphasize their contribution to inventory completeness and the diversity of glacier responses rather than assigning them a uniformly rapid response.

Specific Comment 50

L458: I think this is correct in general, but in the Karakoram? Fragmentation or rapid shrinkage (excluding surging glaciers) has rarely been observed over the past decades.

Response

We agree that the original wording was too broad for the Karakoram. As noted in our previous response, glacier fragmentation and rapid shrinkage are not widespread regional characteristics, particularly when surge-related changes are excluded. Where such changes do occur, they appear to affect some small glaciers rather than represent the general behaviour of Karakoram glaciers.

During revision of the inventory, however, we did identify several such cases. In imagery acquired around 2020, some small glaciers represented in RGI v7.0 had become fragmented, while in other cases small glacier bodies had separated from larger glacier units. These observations indicate that such changes do occur locally, although they are not common across the region. We have revised the text accordingly. We thank the reviewer for drawing our attention to this distinction.

Specific Comment 51

L490-493: Can this be shown with a figure and some numbers? Many glaciers here are >>10 km2 (up to 1000 km2) and it is unclear how the better DEM changes related numbers. I think a 30 m DEM can also be used to create a 'quantitative topographic framework'.

Response

This is an important point. Following the reviewer's suggestion, we quantified the differences between the 4 m ZY-3 DEM and the 30 m DEM using a common sample of 440 glaciers larger than 5 km² with valid coverage in both DEM datasets. This sample spans a wide range of glacier sizes, including 228 glaciers larger than 10 km², 23 glaciers larger than 100 km², and a maximum glacier area of approximately 1075 km².

The comparison shows systematic and measurable differences associated with DEM resolution. Relative to the 30 m DEM, the 4 m DEM yields mean slopes that are higher by 5.9–9.0° and 90th-percentile slopes that are higher by 12.0–17.7° among the three glacier types. Mean 90 m surface roughness is higher by 12.8–14.7 m, and mean 90 m local relief by 70.9–83.5 m. These differences are also evident for the largest glaciers. For the 23 glaciers exceeding 100 km², the corresponding mean differences are +6.9° in mean slope, +15.2° in the 90th-percentile slope, +10.6 m in surface roughness, and +56.5 m in local relief. These results are now shown quantitatively in Fig. 14a–d.

We agree that a 30 m DEM can also be used for quantitative topographic analysis. The original wording therefore overstated the distinction. We have revised the text to describe the resolution-related differences, focusing on how the two DEMs represent slope, surface roughness, and local relief at different spatial scales.

Specific Comment 52

L510: I think this is not unique for the 4 m DEM, other DEMs also allow it.

Response

We agree with this point. As also noted in our response to the related comment above, linking glacier type, debris distribution, and climatic exposure is not unique to the 4 m ZY-3 DEM, and other DEM products can also support such analyses. We have therefore revised the wording to avoid attributing this analytical framework specifically to the 4 m DEM and now describe it simply as the topographic dataset used in the present analysis.

Specific Comment 53

L512-522: This is now all about the benefits of higher resolution, but only some points of the listings have been shown. Neglecting that the outlines are not yet more reliable than those from the RGI 7.0 and that small glaciers have not been omitted, where are the improved 'narrow divides, upper-basin margins, and debris-covered termini' shown? Or how do uncertainty estimates provide a more reliable geometry when snow has been mapped? Please also note that the DEM has to be provided should hypsometric analysis etc. be supported (the DEM is not listed in the data availability statement). Where is the 'finer glacier-unit subdivision' shown? And why should 'compound valley-glacier systems' be separated? All these benefits might be correct, but they are not shown or yet achieved.

Response

Thank you for this detailed comment. We agree that the previous version grouped several potential benefits of the dataset more broadly than was directly demonstrated in the manuscript. Following the reviewer's comments, we re-examined the glacier outlines on a glacier-by-glacier basis and revised the relevant comparisons and interpretations, including the statements concerning RGI v7.0 and small-glacier omission.

We have also revised the wording concerning uncertainty. The uncertainty estimates are intended to quantify the remaining mapping uncertainty; they do not themselves make the glacier geometry more reliable. The corresponding statement has therefore been corrected.

The description of glacier-unit subdivision has also been revised. In this study, drainage-basin-based subdivision is used to define glacier-specific inventory units and to derive attributes such as area, length, elevation range, slope, and hypsometry. This subdivision is not intended to imply that tributaries within compound valley-glacier systems are dynamically independent. We have therefore removed the previous overstatement concerning "finer" subdivision where it was not directly demonstrated.

Because the improvements in narrow divides, upper-basin margins, and debris-covered termini were not systematically demonstrated in the original figures, we have removed the broad statement that 2mKGI generally improves these features and restricted the discussion to aspects directly supported by the analyses presented in the manuscript.

Regarding data availability, the 4 m ZY-3 DEM used in this study cannot be publicly redistributed. We have clarified this limitation in the revised Data Availability statement and revised the discussion so that the availability of the glacier inventory and its derived topographic attributes is distinguished from that of the underlying DEM.

Specific Comment 54

L534/535: The omission is not correct for RGI 7.0 and debris cover is often wrongly determined in this study (see examples at the end). I suggest using other points.

Response

Following this comment, we reconsidered the emphasis of the Conclusion. As addressed in our responses to the related comments above, we have removed the general statement concerning the omission of small glaciers in RGI v7.0 and re-examined the supraglacial debris boundaries throughout the inventory. The corresponding errors identified during this review were corrected.

We have therefore revised the Conclusion and no longer present glacier omission and debris-margin overgeneralization as the two principal findings of the study. Instead, the revised conclusion focuses on results that are directly supported by the updated analyses, including the size structure of the glacier population, the spatial and topographic distribution of supraglacial debris, and the morphometric characteristics derived from the revised inventory. We thank the reviewer for encouraging us to make this distinction more clearly.

Specific Comment 55

L540: Isn't this just because debris reappears below the ELA?

Response

Yes, this is an important distinction. The concentration of supraglacial debris at lower elevations can largely be explained by the emergence and accumulation of debris in the ablation zone below the ELA, where surface melt progressively exposes englacial debris. Our original interpretation placed too much emphasis on additional topographic controls.

We have therefore revised this statement to describe the observed elevational pattern primarily in terms of debris emergence and accumulation below the ELA, while treating factors such as debris supply, ice transport, and local topography as secondary influences on its spatial distribution.

Specific Comment 56

L541-546: As this is the same text as in the discussion, see comments above.

Response

Thank you for pointing this out. We have revised and shortened this part of the Conclusion. The corresponding statements have been updated consistently with the revisions made in response to the related comments above, and the Conclusion now focuses only on the main findings of the study.

Specific Comment 57

L545: This requires knowing where the debris-covered parts are, i.e. a good reference dataset.

Response

Yes, this is an important prerequisite. Automated mapping of debris-covered glaciers requires reliable reference information on the extent of supraglacial debris. As described in our responses above, we have re-examined and revised the debris-covered boundaries throughout the inventory, including the cases highlighted by the reviewer.

We have also revised the wording in the Conclusion to avoid presenting the dataset as an unquestioned reference for automated debris-covered glacier mapping. Instead, we describe the revised supraglacial-debris outlines as a potential reference dataset for the development and evaluation of automated mapping methods, while acknowledging the remaining interpretation uncertainties in complex debris-covered terrain.

Figures and Tables Comment 58

Fig. 1: The region marked as the Karakoram is too large. I suggest restricting it to perimeter provided by Bhambri et al. (2022). It is unclear to me which DEM is from which sensor. Also the dichromatic red-blue colour table seems sub-optimal for a continuous variable. If at all, please use the usual elevation colour table (as in Fig. 2c). But please also check if it makes sense when glaciers on top hide the info. As a note, the glaciers that are described in Fig.13a as 'omitted in RGI' are included here. The caption should describe for panel c) to which place or region the two graphs refer to.

Response

Following this suggestion, we have substantially revised Fig. 1 (Fig. 1 in this Document). The Karakoram boundary has been restricted to the Karakoram perimeter adopted from Bhambri et al. (2022), and the revised extent is shown in Fig. 1a. The coverage of the ZY-3 DEM and Sentinel-2 data is now displayed explicitly, while the ASTER GDEM is used as the regional background elevation dataset. The DEM sources and their respective coverage are clearly distinguished in the revised legend.

We also replaced the previous red–blue elevation scheme with continuous elevation colour tables and adjusted the glacier overlays so that the underlying topographic information remains visible. The glaciers previously described as "omitted in RGI" have been re-checked and the corresponding interpretation has been corrected, as addressed in our responses above. In addition, the caption has been revised to specify the geographic context shown in panel (c).

Figures and Tables Comment 59

Table 1: Please add horizontal lines to better distinguish the three main sections.

Response

Thank you for this suggestion. We have revised Table 1 by adding horizontal lines to clearly separate the three main sections.

Figures and Tables Comment 60

Fig. 2a: To be honest, I do not see a difference in the viewing geometry of the three images in the top row. Can this be adjusted?

Response

Thank you for pointing this out. The three images shown in Fig. 2a are thumbnail representations of the forward-, nadir-, and backward-looking observations. At this reduced scale, the differences in viewing geometry are difficult to distinguish visually from the image content alone.

To clarify the tri-stereo configuration, we have therefore redrawn the ZY-3 three-line-array imaging geometry and provide the schematic below, in which the forward, nadir, and backward viewing directions relative to the same ground target are shown explicitly. This additional schematic is intended to make the viewing-angle differences more intuitive.(Fig. 11 in this Document)

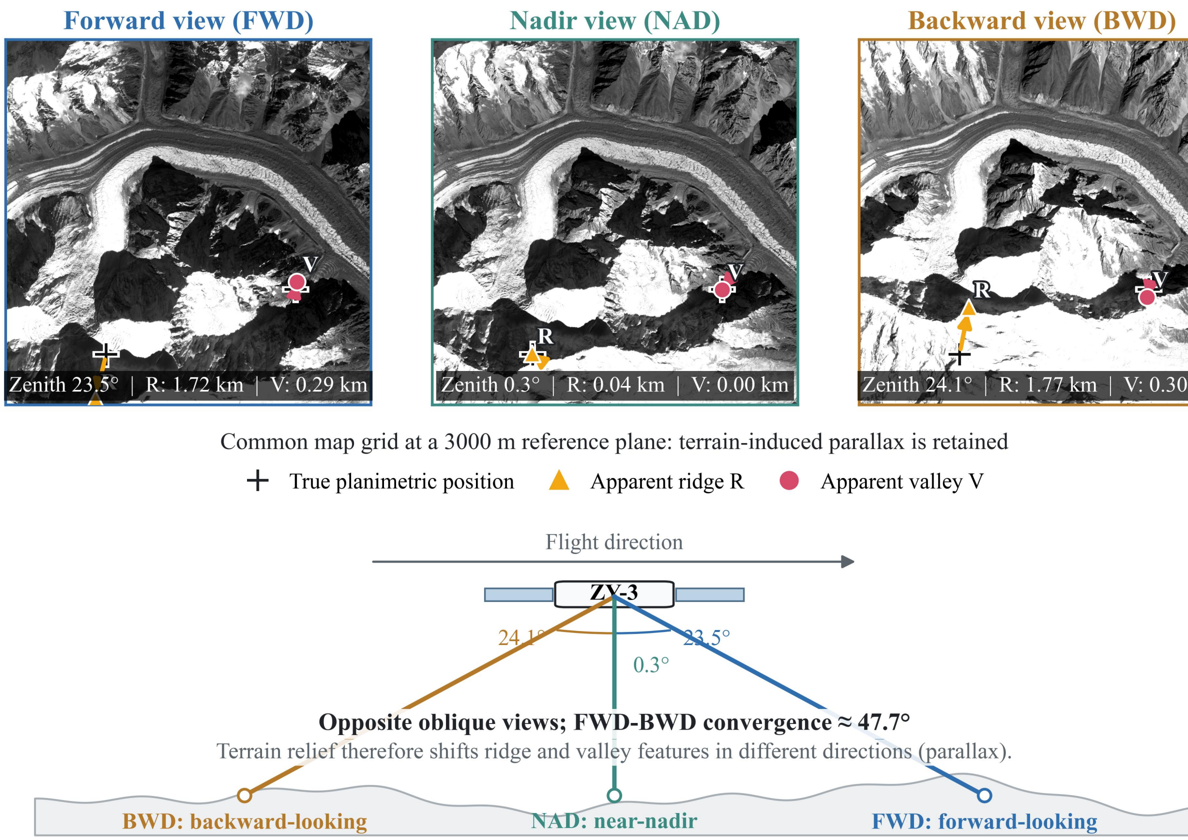


Figure 11. ZY-3 Trilinear Viewing Geometry and Terrain-Induced Parallax

Figures and Tables Comment 61

Fig. 2c: I suggest showing glacier outlines on top. And please explain the white areas (I assume these are data voids?). The supplement could be used to show a close-up comparing a hillshade of the DEM derived here and the ASTER GDEM (and other DEMs).

Response

Following this suggestion, we have added glacier outlines to Fig. 2c and clarified the white areas as DEM data voids (Fig. 12c in this Document). We also added hillshade comparisons in the Supplement, showing the ZY-3 DEM alongside the Copernicus GLO-30 DEM and HMA-DEM at two representative locations (Fig. 2 in this Document).

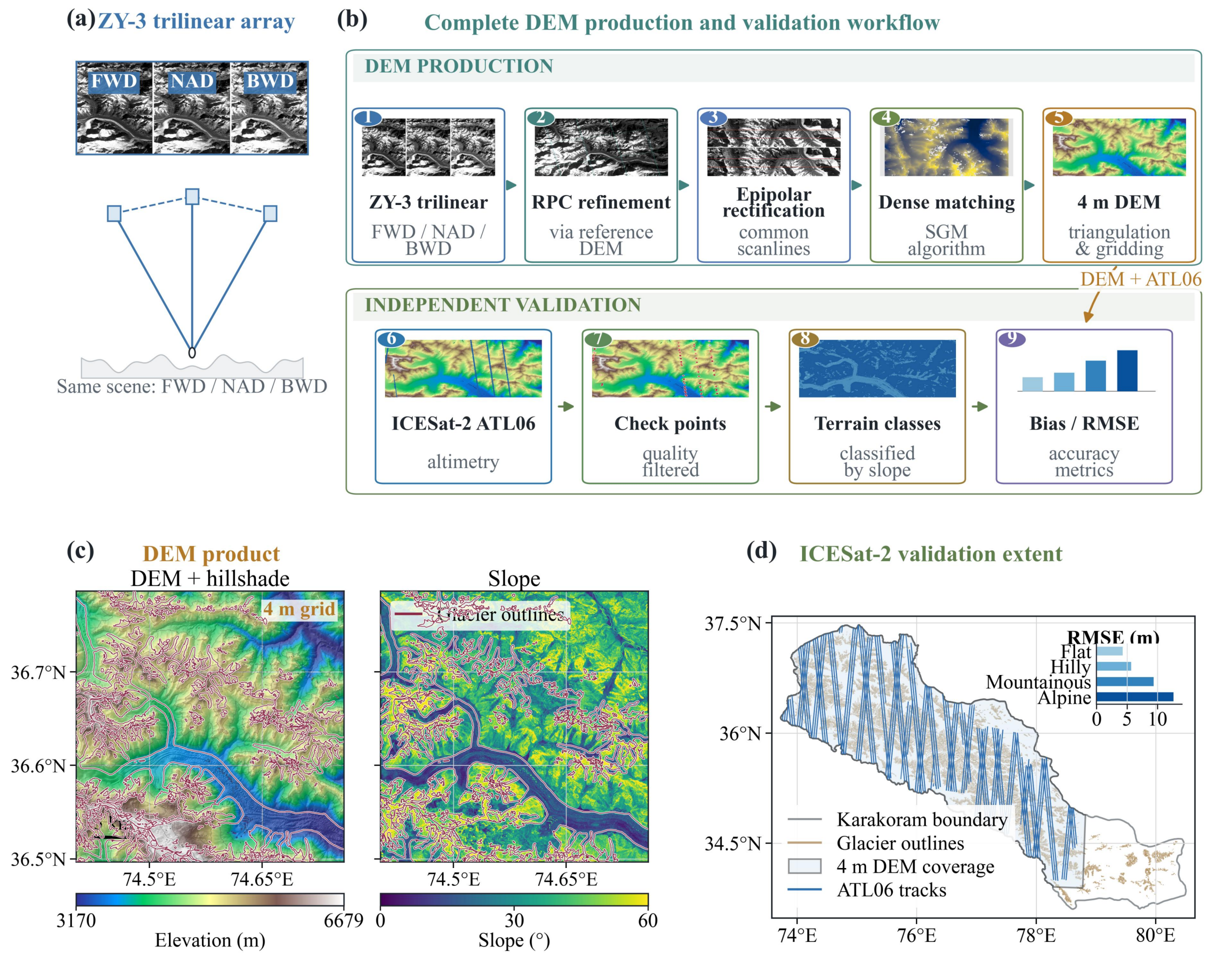


Figure 12. Generation and validation of the 4 m ZY-3 DEM.

Figures and Tables Comment 62

Fig. 2d: I suggest showing glacier outlines in the background for orientation.

Response

Following this suggestion, we have revised Fig. 2d by adding glacier outlines in the background to improve spatial orientation (Fig. 12d in this Document).

Figures and Tables Comment 63

Fig. 4b: The region marked as 'cloud shadow' looks partly more like a cloud.

Response

Thank you for pointing this out. The marked region includes both cloud and cloud-shadow contamination, and the original label was therefore too specific. We have revised the annotation and caption accordingly to distinguish cloud from cloud-shadow effects more accurately.

Figures and Tables Comment 64

Fig. 5: I suggest showing a close-up, there is not much to see at this scale. And please do not show red lines against a brown background, white might work better here.

Response

Thank you for this suggestion. We will update Fig. 5 in the revised manuscript by adding a close-up view to better show the relevant details and by adjusting the line colour to improve contrast against the background.

Figures and Tables Comment 65

Fig. 6a and b: Mapping clean ice is maybe a bit too easy to reveal differences in interpretation. I suggest showing a more challenging example, a debris-covered tongue with a gradual transition to the glacier forefield, i.e. no clear front. The line colours for 'Karakoram' and 2mKGI are nearly the same. Please use colours that are more distinct.

Response

Thank you for this suggestion. We have revised Fig. 6 by replacing the relatively straightforward clean-ice example with a more challenging debris-covered glacier tongue, where the transition from supraglacial debris to the glacier forefield is gradual and the terminus is difficult to identify. This example better illustrates the interpretation uncertainty among different operators. We have also changed the line colours for the outline to make them more clearly distinguishable.

Figures and Tables Comment 66

As a general note, the glacier examples shown In Fig. 7 do not belong to the Karakoram.

Response

We agree with this point. The glacier examples shown in the original Fig. 7 are located within the broader study area used in our initial analysis, but we accept the reviewer's definition of the Karakoram extent. The study-area boundary has therefore been revised accordingly, and the examples are now presented in the context of the updated study region.

Figures and Tables Comment 67

Fig. 7a: As pro-glacial lakes had to be excluded, I think this is not a specific advantage of very high-resolution (VHR) imagery. However, smaller lakes might be detected.

Response

Yes, that is an important distinction. Proglacial lakes should be excluded regardless of image resolution, so this is not a specific advantage of very high-resolution (VHR) imagery. However, as you pointed out, some small lakes and ponds can be difficult to distinguish in lower-resolution imagery. We therefore now emphasize that higher spatial resolution is primarily useful for identifying these smaller features.

Figures and Tables Comment 68

Fig. 7b: I am a bit unclear how VHR images can help to reveal if there is ice under the snow or not? The decision seems to be ok for the region where the arrow points to, but to the left and right of the line from the arrow, several rock outcrops have not been excluded. And as mentioned in the general comments, the scenes used here partly suffer from adverse snow conditions, i.e. seasonal snow was included rather than excluded. I am thus unclear how VHR imagery could help when there is simply too much snow or when the info is not used to exclude rock outcrops?

Response

Yes, this is a significant limitation. High-resolution (VHR) imagery alone cannot determine whether glacial ice is present beneath extensive or continuous snow cover. Its primary advantage is limited to situations where seasonal snow cover is spatially fragmented and where exposed bedrock, glacier margins or other surface features remain clearly visible on a metre-scale. For areas with extensive snow cover, we consider that the best approach is to use multi-temporal imagery for exclusion; alternatively, multi-source data such as radar and topography can be utilised to assist in the assessment.

We have re-examined the entire area covered by the data and corrected the rock outcrops and areas of seasonal snow cover that had previously been erroneously included. Figure 7b and the corresponding text have been revised accordingly.

Figures and Tables Comment 69

Fig. 7c: Ignoring the point that there might still be some ice in the lateral moraine to the right (east) of the glacier, the outline shown here is too large. The boundary to the right runs along the LIA moraine. One can see erosion gullies (Racheln) below which would be destroyed when they were connected to the glacier. Only to the left there is lots of debriscovered ice (extending a bit beyond the end of the clean ice).

Response

Thank you for this professional and detailed guidance. The issue identified in Fig. 7c prompted us to systematically re-examine the entire glacier inventory rather than only this individual example. We reviewed glacier boundaries throughout the dataset and corrected similar problems where identified, including cases involving LIA moraines, debris-covered margins, seasonal snow, and non-glacial terrain. The inventory has therefore been comprehensively revised accordingly.

Figures and Tables Comment 70

Fig. 7d: Also here I am unclear what the VHR offers for mapping ice in terrain/cloud shadow compared to other sensors such as Sentinel-2? Wouldn't it be the spectral resolution and quantization (12 or 14 bits) that help recognizing the ice? Apart from this, it seems that the small glacier in the centre of the image has been connected to the main glacier although the surrounding rock reveals that it is isolated. In RGI 7.0 this glacier is correctly depicted as a separate polygon.

Response

Yes, this example is affected not only by cloud and terrain shadow but also, most likely, by seasonal snow, which contributed to the incorrect delineation. As you noted above, seasonal snow remains a fundamental difficulty in glacier mapping regardless of spatial resolution, and VHR imagery alone cannot resolve this problem when surface conditions obscure the true glacier boundary.

Your comment also made us recognize that some of the glacier outlines in the original inventory may have been more strongly affected by seasonal snow than we initially considered. We therefore re-examined the inventory with particular attention to snow-affected areas and corrected the corresponding boundaries.

Figures and Tables Comment 71

Fig. 7e: Except the yellow outline in the lower left, all these 'small glaciers' are also included in RGI 7.0, i.e. mapped from Landsat. The advantage of the VHR is thus unclear. I would like to see a discussion how these completely snow-covered features can be identified as glaciers? Apart from that, the two larger glaciers to the right are not connected. Again, lateral moraines from the LIA have been wrongly interpreted as glaciers despite the VHR. The moraines could be ice cored, but this does not count for the glacier extent. As a note, we are here deep into the Wakhan National Park, outside the Karakoram.

Response

Thank you for this detailed comment. We re-examined the example shown in Fig. 7e and confirmed that most of the small glaciers illustrated there are already represented in RGI v7.0. We have therefore removed the previous interpretation that these features demonstrate a specific advantage of VHR imagery.

In the revised manuscript, we will instead focus more carefully on the difficulty of delineating glacier boundaries in snow-covered areas, particularly in accumulation zones where seasonal or persistent snow can obscure the actual glacier extent. As noted in our responses above, the combined use of multi-temporal imagery and topographic information provides a more reliable basis for interpretation than relying on a single VHR image.

We also found that our previous interpretation criteria were too permissive in places, which led to some LIA moraine areas being incorrectly included as supraglacial debris or glacier extent. These cases have now been corrected throughout the inventory.

Figures and Tables Comment 72

Fig. 8a: Where does the isolated orange circle come from? Is there really such a strong increase in glacier number in this region?

Response

We regenerated the figure using the updated inventory data. The isolated high value in the previous version was confirmed to be an outlier and is no longer present in the revised results (Fig. 6 in this Document).

Figures and Tables Comment 73

Fig. 8b/9b: Please consider colour-blind people and use colours different for red/green.Fig. 9a: Showing the percentage of debris cover per grid box might be more instructive. Fig. 10: Please use colours that stronger differ from red/green.

Response

Thank you for these suggestions. We have revised the colour schemes in Figs. 8b, 9b (Fig. 6 and Fig. 7 in this Document), and 10 to avoid red–green combinations and improve accessibility for colour-blind readers. In Fig. 9a, we have also replaced the previous representation with the percentage of debris-covered area within each grid cell, as suggested.

Figures and Tables Comment 74

Fig. 10: Please use colours that stronger differ from red/green.

Response

Thank you for this suggestion. We have revised the colour scheme in Fig. 10 and replaced the previous red–green combination with more clearly distinguishable colours (Fig. 13 in this Document).

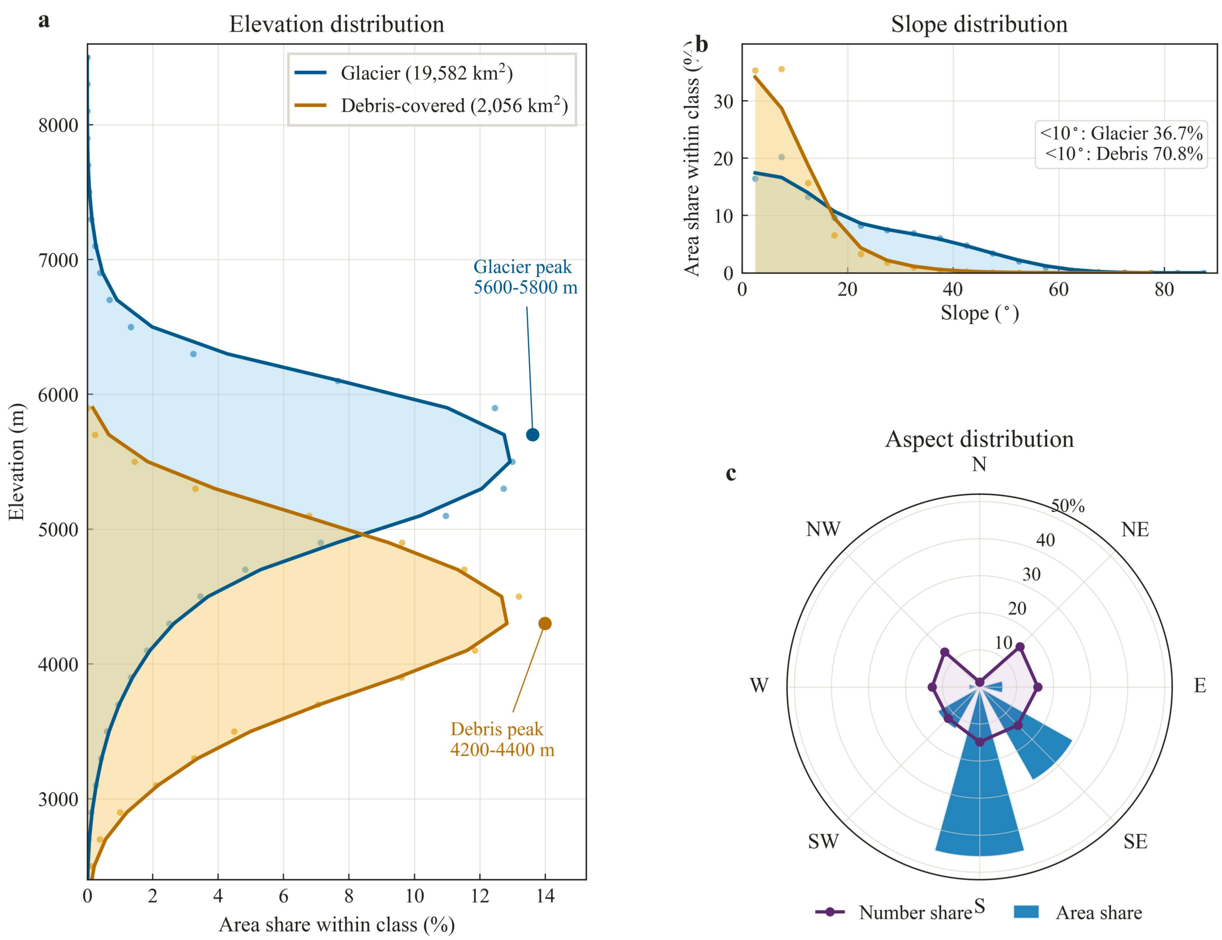


Figure 13. Topographic distributions of glacier area and supraglacial debris in the study area.

Figures and Tables Comment 75

Fig. 11c: Again, here is a single orange circle. Where does it come from? If this is an outlier (?) I suggest making the circle white to make better use of the full range of colours. The differences between the glacier types should be better described in Section 3, including images illustrating the differences (could be in the supplement).

Response

Thank you for raising this point. We rechecked the underlying revised inventory and confirm that the highlighted circle in Fig. 11c is not a data anomaly (Fig. 14c in this Document). It represents a genuine local maximum of 11 Alpine-type glaciers within one 0.2° × 0.2° grid cell (centred at 75.7° E, 36.5° N; combined glacier area: 150.28 km²). The high value arises because the map aggregates the representative points of individual classified glaciers by grid cell, and this particular cell contains a locally dense cluster of Alpine-type glaciers rather than an anomalous individual glacier or an error in the inventory.

To prevent this valid maximum from visually dominating the map, we replaced the former continuous colour scale with discrete, labelled classes (1, 2, 3, 4, 5–6, 7–8, and 9–11 glaciers per 0.2° cell). We therefore retained the cell rather than rendering it white, because a white symbol could be interpreted as missing data or absence of glaciers.

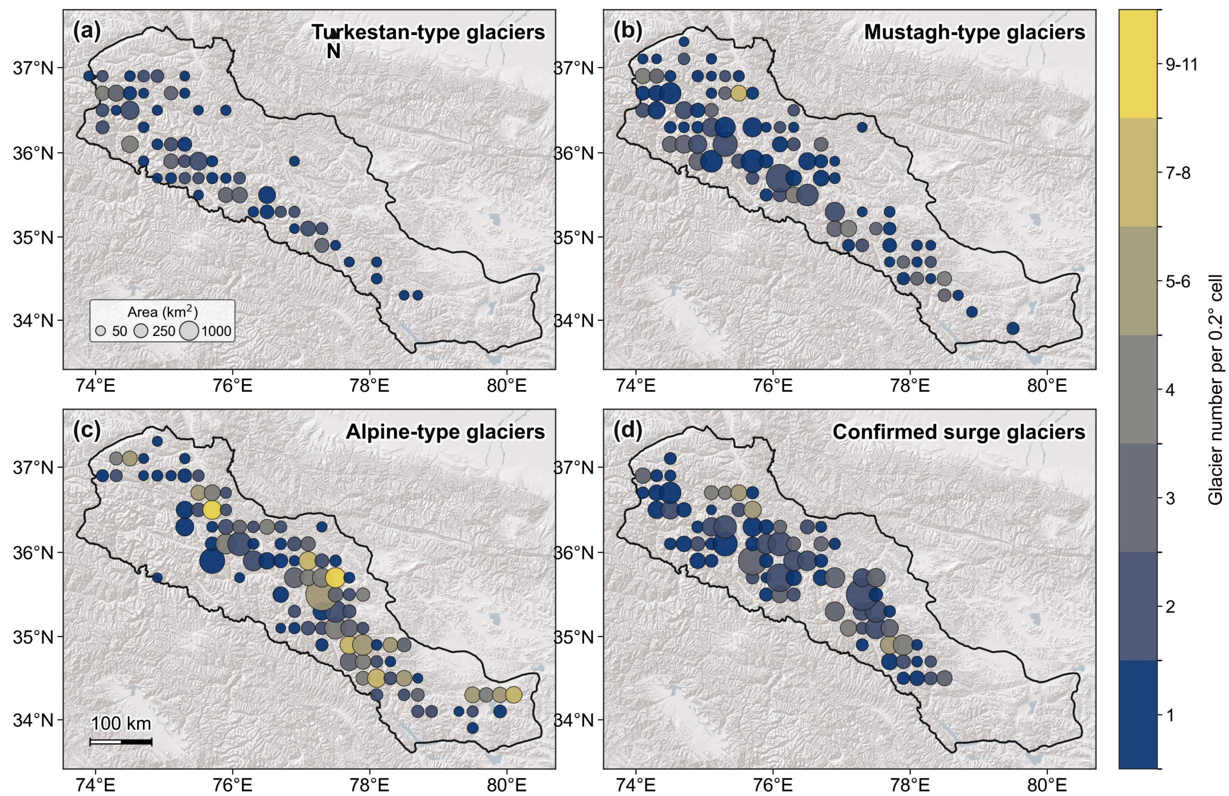


Figure 14. Spatial distribution of glacier-type attributes derived from the 2mKGI.

Figures and Tables Comment 76

Fig. 12: Please avoid using red and green lines in the same plot.

Response

Thank you for this suggestion. We have adjusted the colour scheme in Fig. 12 (Fig. 9 in this Document) to avoid using red and green lines in the same plot and to improve visual distinction between the different glacier types.

Figures and Tables Comment 77

Fig. 13a: The 'RGI' outlines shown here are not those being available in RGI 7.0. The RGI 7.0 includes these glaciers.

Response

Thank you for pointing this out. We acknowledge that the RGI outlines used in the original Fig. 13a were not from the correct/latest RGI v7.0 dataset. We have now replaced them with the latest RGI v7.0 data and will update Fig. 13a and the corresponding interpretation accordingly.

Figures and Tables Comment 78

Fig. 13c: The outlines shown here are derived from a raster file and could thus not be from RGI 7.0 (but likely from RGI 6.0). Please only use RGI 7.0 for comparison.

Response

Thank you for pointing this out. We have corrected Fig. 13c accordingly and now use only the latest RGI v7.0 outlines for the comparison. The figure and corresponding text have been updated to ensure consistency with RGI v7.0 throughout the manuscript.

Figures and Tables Comment 79

Fig. 13d: I suggest adding in the caption that this example from the KGI shows too much seasonal snow being mapped as glaciers (in the inset) and a missed correction for the medial moraine of the glacier in the upper left.

Response

Thank you for this suggestion. We have revised the caption of Fig. 13d to clarify that the KGI example includes excessive seasonal snow mapped as glacier area in the inset, as well as an uncorrected medial-moraine area in the glacier shown in the upper left.

Figures and Tables Comment 80

Fig. 14a-d: These plots are rather abstract and summarized. I am also not sure if glacier typeis a good separator to reveal dependencies. I suggest showing instead scatterplots with glaciers size (logarithmic) vs. the related differences.

Response

Thank you for this constructive suggestion. We agree that the previous glacier-type summaries were overly aggregated and did not directly reveal whether DEM-resolution effects depended on glacier size. We therefore replaced the former type-based plots with glacier-level scatterplots showing glacier area on a logarithmic axis against the 4 m minus 30 m differences in mean slope (Fig. 15 in this Document), 90th-percentile slope, 90 m surface roughness and 90 m local relief. The revised analysis includes 1,781 glaciers $\geq$1 km² with at least 95% valid coverage in both DEMs. Individual glaciers are shown as transparent points, while the red symbols represent size-bin medians and interquartile ranges. Spearman correlations indicate weak positive associations for mean-slope difference ($\rho = 0.14$, $P < 0.001$) and roughness difference ($\rho = 0.10$, $P < 0.001$), but no detectable associations for 90th-percentile slope ($\rho = 0.02$, $P = 0.505$) or local relief ($\rho = 0.02$, $P = 0.455$). These results suggest that the smoothing effect of the 30 m DEM is widespread but is not strongly controlled by glacier size.

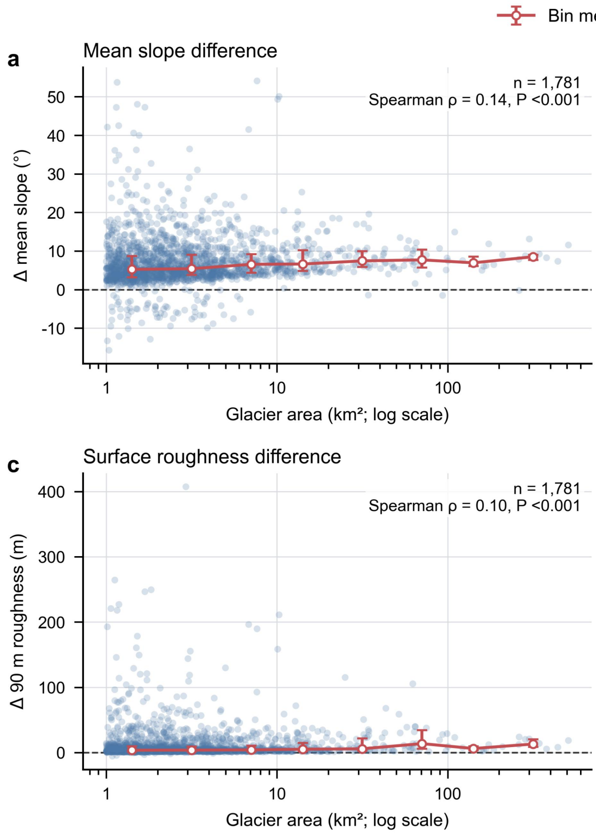


Figure 15. Glacier-size dependence of DEM-resolution effects.

Figures and Tables Comment 81

Fig. 14 e/f: It seems these plots show a completely different topic. To avoid confusion, I suggest showing them in a separate figure.

Response

Thank you for this suggestion. We have revised the figure arrangement accordingly and separated the original Fig. 14e–f into a standalone figure to avoid mixing different topics within the same figure (Fig. 16 in this Document).

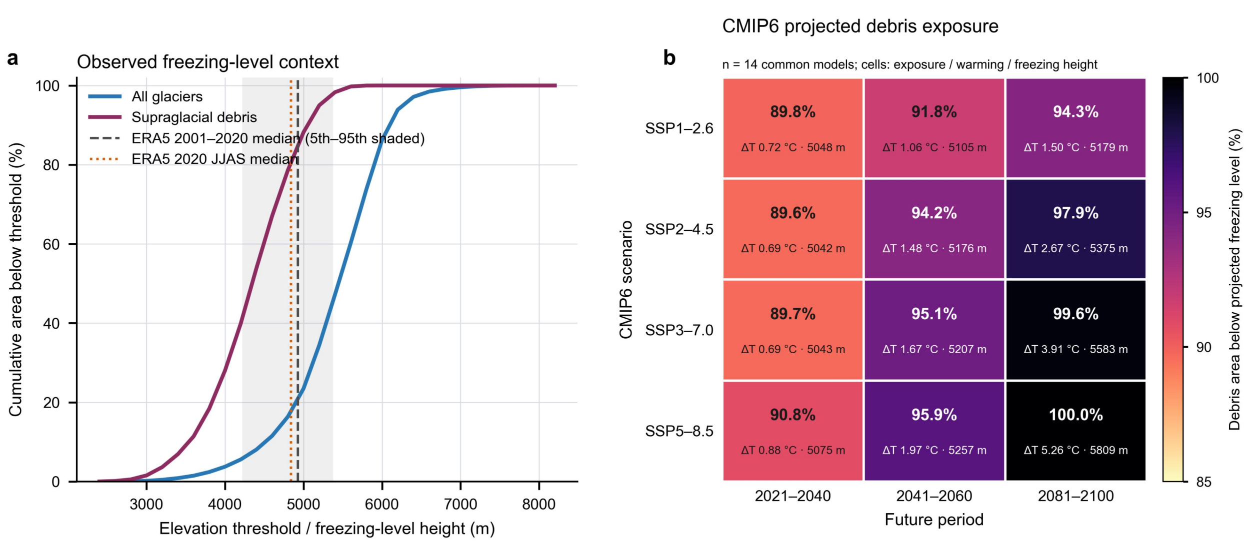


Figure 16. Freezing-level changes and debris-area exposure.

Figures and Tables Comment 82

Fig. S1: To better see the subtle changes, I suggest showing the real or final glacier outlines in a different colour on top.

Response

Thank you for this suggestion. We have revised Fig. S1 by overlaying the final glacier outlines on both the original images and the previously manually delineated labels in a contrasting colour (Fig. 17 in this Document). This makes the subtle differences among the reference labels and the model outputs easier to identify.

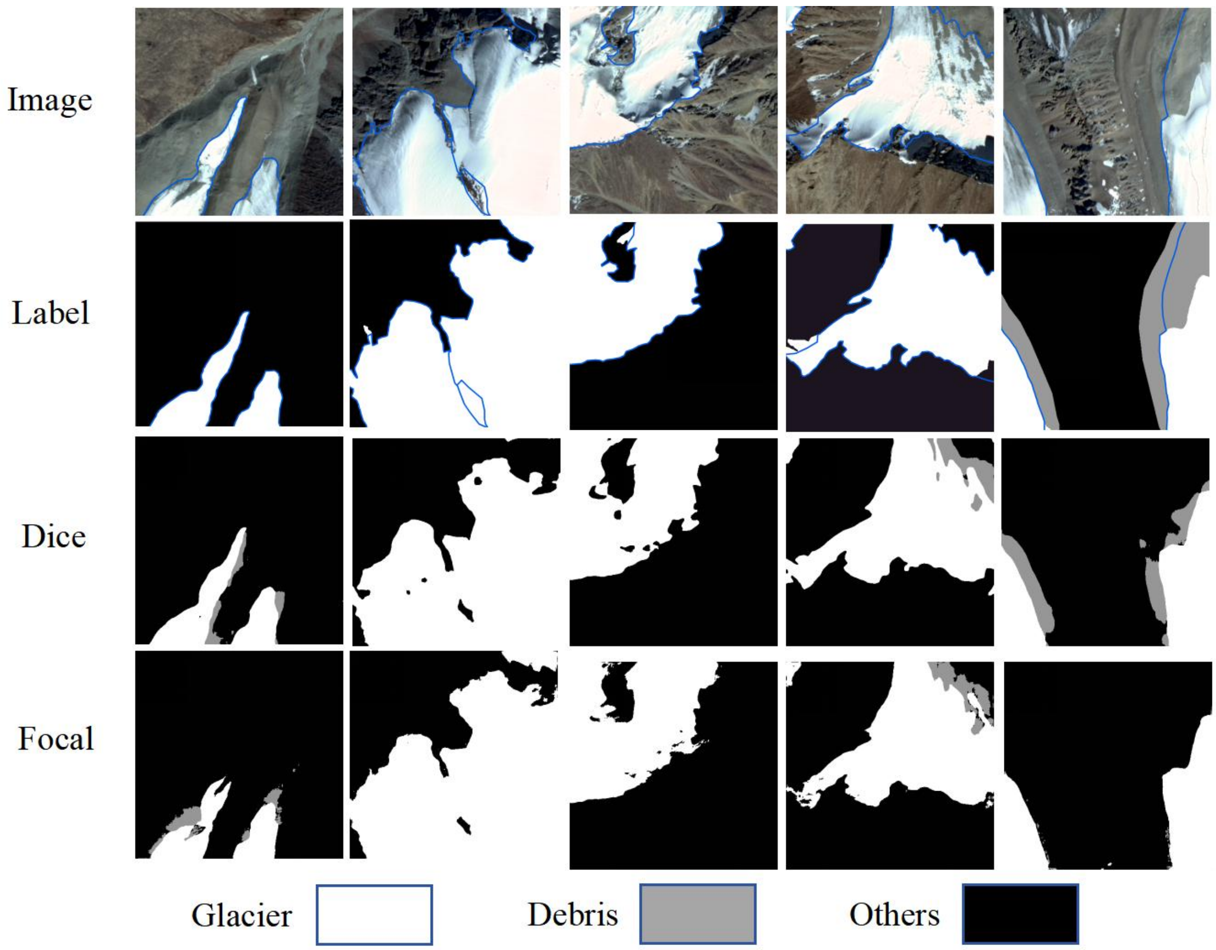


Figure 17. Comparison of extraction results in ZY-3 imagery for Dice loss function and Focal loss function.

Figures and Tables Comment 83

Fig. S3: As this is the supplement (and there is some space) please increase the size of the images and show only two side by side.

Response

We thank the reviewer for this constructive suggestion. In the revised supplementary material, we have enlarged all images in Fig. S3 (Fig. 18 in this Document) and rearranged the layout so that only two panels are displayed side by side per row. This improves clarity and makes full use of the available space in the supplement. The updated figure has been replaced in the revised manuscript.

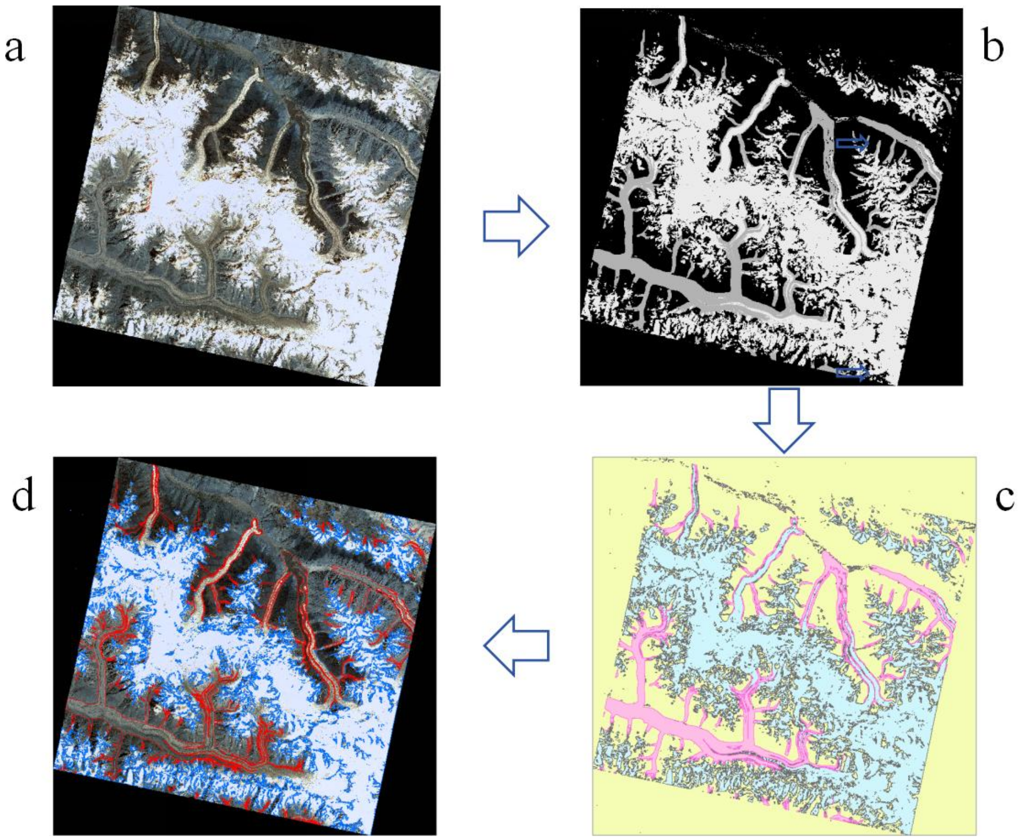


Figure 18. Processing flow for extracting glacier outlines using single-view ZY-3 imagery.

Figures and Tables Comment 84

Figs. S4 and S5: Area changes in km^2 depend on the initial area and are thus incomparable across regions. Please show relative area changes.

Response

Thank you for this important suggestion. In the revised manuscript, we will update Figs. S4 and S5 to show relative area differences (%) rather than absolute changes in km² (Fig. 19 in this Document). For the inventory comparisons in Fig. S4, the differences will be normalized by the corresponding reference-inventory area in each grid cell. We will also extend the comparison to include the recent Pakistan glacier inventory, in addition to RGI v7.0 and KGI-2020s. The glacier-area changes in Fig. S5 will be normalized by the initial glacier area. This will allow a more meaningful comparison among regions with different glacierized areas and among different glacier inventories.

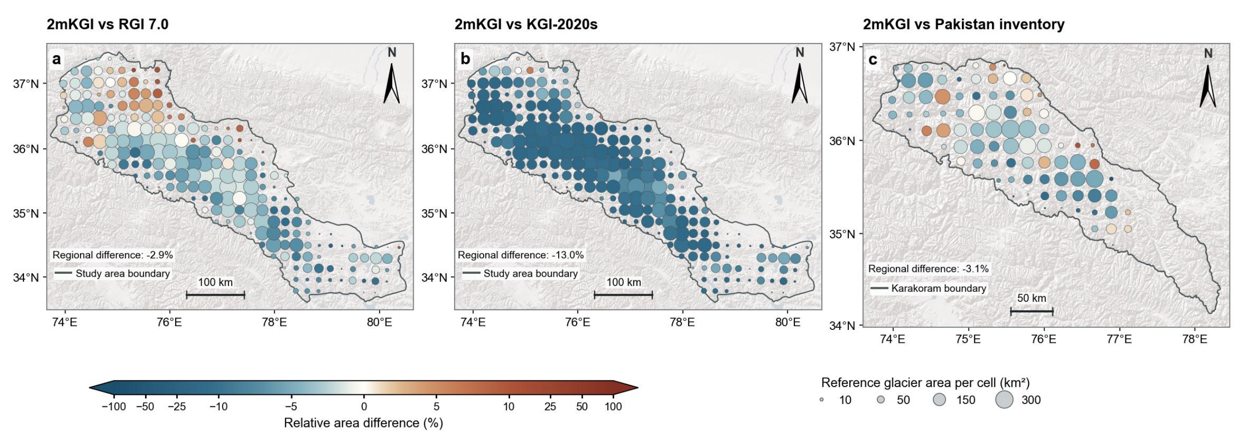


Figure 19. Glacier Inventory Comparison.

Reference

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