

## Response to Editor

Dear Dr. Hauck,

Thank you for the positive feedback and for the opportunity to submit this revised version of our manuscript (No. egosphere-2025-3628).

We are encouraged by the reviewers' recognition that the manuscript is close to acceptance. In this version, we have addressed all remaining comments point-by-point. Specifically, we have updated the relevant figures to enhance visual clarity and refined the corresponding textual descriptions to eliminate potential ambiguities and ensure terminological rigor. We have also carefully rephrased the discussions regarding different methods and datasets to ensure a more objective and balanced comparison. These targeted adjustments ensure that our classification framework is consistent and strictly aligned with the improvements requested, particularly addressing the concerns raised by Referee #2.

We believe these revisions have fully addressed the outstanding points. We hope that the manuscript now meets the standards for publication in *The Cryosphere*.

Thank you again for your efficient handling of our work.

Best regards,

Jinhao Xu, on behalf of all authors

## Response to Referee #1

I thank the authors for their detailed and considerate responses to my comments and revisions made to the manuscript.

**Response:** Thank you very much for your positive and encouraging comments. We sincerely appreciate your recognition of our revisions and your careful re-examination of the manuscript. Your final remark is very helpful and has prompted us to further clarify the relevant description in the revised version.

There is only one final remark regarding the revisions to my original remark about Section 3.1: The authors clarified their application of the mIoU, also by adding the excellent Figure 4 to the manuscript. However, this metric is only applied to the validation region CEH, and not to the STPG region, where the accuracy is only assessed at the lake-object level. I think this is what caused a little bit of confusion for me in the first place. I expect the reason for evaluating mIoU only in CEH is that the authors do not have fully digitized lake shapes available for the STPG region (understandably so considering the effort to produce these). I feel this distinction in data availability could be made a little bit clearer in Section 2.5.

**Response:** Thank you for this helpful comment. We agree that the distinction between the CEH validation and the STPG application assessment was not sufficiently clear in the manuscript.

In this study, mIoU was calculated only for the CEH validation dataset, which served as the independent pixel-level evaluation of segmentation performance based on manually digitized lake masks. In contrast, the STPG analysis was intended to assess regional application results in a large-area mapping scenario. For lake segmentation in the STPG, object-based statistics, including detected lakes, missed lakes, and non-lake artifacts, were used instead of pixel-level mIoU. This is because, compared with minor differences in lake-outline details, the more important considerations for regional inventory generation are the completeness of lake detection and the avoidance of false positives. In addition, the finalized STPG inventory was generated through correction and completion based on the integrated outputs of multiple models rather than fully independent manual delineation, and is therefore not suitable for unbiased IoU calculation.

We have revised the relevant text to clarify this distinction more explicitly (**Lines: 315-336**).

## Response to Referee #2

Note: For improved clarity and to avoid redundancy, we have grouped related comments together where they address the same conceptual or terminological issues. All original remarks are addressed in full.

The authors acknowledged and responded to the reviewers' comments and improved the manuscript widely. I think in combination with RC1's comments and the modifications made, the methods section has greatly improved and is ok for me. To conclude, I think the approach is a valuable contribution and represents an improvement for glacial lake mapping. But the terminological issues still need to be resolved. Thus, I think another minor revision is required before publication.

**Response:** Thank you very much for your positive and encouraging assessment. We are pleased that the revisions to the Methods section have met your approval. In response to your constructive comments, we have made further revisions to enhance the overall quality of the manuscript and to meet the requirements for publication.

Details comments:

However, I still see the issue of terminology with the distinction between glacial and non-glacial lakes not resolved fully. I added some more comments below.

I am sorry to say, but I am still not 100% convinced with your application of the glacial lake terminology, which mainly based on the reference by Yao et al. 2018 (L 38-40). Yao et al.'s review paper highlights the various views on glacier lake terminology and formation but also has some weaknesses. Most of all, it does not provide one single definition, which is ok for a review. Your mentioned new definition now includes the the expression "depression of glacial moraines", which to me appears confusing and incorrect. As clearly demonstrated by Yao et al. (2018) glacial lakes form in bedrock depressions or behind dams of moraine deposits or ice. A "depression of glacial moraines" sounds like a combination of both and does not hit the spot. Additionally, I don't think that you really clarified your distinct classification enough. In line 45 you add the term "active glacial moraine" to your definition to exclude "non-glacial lakes". What is your definition of an "active moraine"? From my perspective, moraines can be considered "active" when they are still in formation, thus receive material from the process of formation in this case the glacier, dumping material or pushing sediment to form a moraine.

I still believe that you can only overcome this shortcoming of a clear definition by adding either a temporal dimension to your classification or a distance condition. Lakes fed mainly by

existing glaciers, lakes that formed within the recent past (20yrs, 50yrs), lakes in contact with ice or lakes within the contemporary proglacial zone. I acknowledge that this information is not always available (especially the time). But it should be somehow anticipated to make this clearer and less unambiguous. This becomes apparent in your results section, when you try to relate lake position to formation (see below).

L 38-40 please modify according to your new definition

**Response:** Thank you for this important comment. We agree that the previous version did not sufficiently distinguish between a conceptual definition of glacial lakes and the operational classification used in our study, which indeed caused ambiguity in the terminology. In particular, the earlier wording in the Introduction could give the impression that we were proposing our own definition of glacial and non-glacial lakes, while at the same time adapting terminology from Yao et al. (2018). We agree that this was not sufficiently clear.

In the revised manuscript, we have therefore removed the definitional wording from the Introduction and no longer present our study as introducing or modifying a universal definition of glacial versus non-glacial lakes. Instead, we added a **new Section 2.2, “Classification framework”**, to clarify that our study uses an operational binary classification framework for remote-sensing-based interpretation. This framework is constructed from the remote-sensing interpretation characteristics summarized for glacial lake types in Yao et al. (2018), rather than from our own reformulation of their verbal definition. Within this framework, lakes showing glacier-related interpretation features consistent with the retained classes of the Yao et al. system are treated as glacial lakes, whereas the remaining mapped lakes are treated as non-glacial lakes in the binary classification scheme adopted in this study. We also clarified that subglacial lakes were excluded because they cannot be reliably identified from conventional satellite imagery, and that other glacial lakes were not treated as an explicit interpretation category because recognizable landslide- or debris-flow dams alone are insufficient to robustly determine glacier-related origin from static remote-sensing imagery.

We appreciate your suggestion that a temporal dimension or a distance condition may help clarify the classification in some contexts. However, we did not adopt either of them as defining criteria in this study, because our objective was to establish an operational image-based classification framework at regional scale. A temporal criterion would require consistent historical information on lake emergence or development, which is beyond the scope of this study and not available in a uniform way for all lakes. Likewise, a distance condition cannot reliably capture the complex geomorphic and hydrological relationships between lakes and glaciers in alpine periglacial environments. We therefore revised the manuscript to clarify that the glacial/non-glacial distinction adopted here is an operational remote-sensing classification framework rather than a universal conceptual definition.

L124-125 As a goal of the study you state: "...thereby supporting more consistent mapping and characterization of periglacial landforms and related cryospheric features" – This is confusing. How can mapping of lakes support mapping of periglacial landforms? What are related cryospheric features. Please explain in more detail.

**Response:** We agree that the previous wording was too broad and could be misleading, as our study does not aim to map periglacial landforms or other cryospheric features directly. We have therefore revised this sentence to better reflect the actual contribution of the study. The revised wording (**Lines 116-118**) emphasizes that our method is intended to support more complete and reliable lake inventories in alpine periglacial environments, particularly by improving the detection of small lakes and the differentiation of glacial and non-glacial lakes.

L394-398 Your weak definition of glacial lakes becomes most apparent in chapter 3.3 where you try to differentiate between your results. You detect lakes mainly in the regions with current glacier occurrence, which is positive. But your conclusions are again not convincing here:

You state a) : "aligned with the glacier systems ... .. , reflecting the primary role of glacial activity in their formation.", and b) "Non-glacial lakes, conversely, are concentrated in non-glaciated regions, ... , indicating distinct geomorphological controls on their distribution".

As mentioned in my previous review, almost all of the lakes in the periglacial region of STPG have been formed by glacial processes. This includes both your glacial and non-glacial lakes. Thus, except for other processes like landsliding, glacial processes have been the dominant "geomorphological control". Your statement on non-glacial lakes thus needs to be rephrased with more precision. You can avoid all of these following my remarks on your classification above.

**Response:** We agree that the previous wording in Section 3.3 was overly interpretive and could imply a stronger inference about lake genesis than is justified by our classification framework. In the revised manuscript, we rephrased this part to describe the observed spatial patterns more neutrally, without directly attributing them to long-term formation history or distinct geomorphological controls. Specifically, we now state that glacial lakes are broadly consistent with the present glacier distribution, while non-glacial lakes are more concentrated in non-glaciated regions but are also common in glacier-proximal areas. This revision is consistent with **the new Section 2.2**, where the glacial/non-glacial distinction is clarified as an operational remote-sensing classification framework rather than a universal conceptual definition.

Chapter 4.2 and Table 8: I acknowledge your comparison with other inventories here, which have been mapped and classified manually. The performance of your approach seems to be notable, especially with respect to small lakes. However, looking at table, 8 one question remains: On what basis did you classify TP, TN, FP, FN and F1 for the ViT-based data? What was used for comparison/validation here? Is this the score for the test area?

**Response:** We agree that this point was not sufficiently clear in the previous version. In the revised manuscript, we clarified in Section 2.6 that the STPG inventory was finalized through comprehensive manual checking and correction, with model outputs used only as initial references during post-processing. We also revised Section 4.2 to clarify the basis of Table 8: for lake objects in the published inventories that matched those in our STPG inventory, label correctness followed the manually checked STPG results established during post-processing, whereas lake objects with no direct match were further resolved through additional manual interpretation. In both cases, the final judgment was based on manual interpretation.

Chapter 4.2. continued: I appreciate that you give a high-resolution example for your classification and comparison. This adds much more information than just Figure 6. I suggest improving this detailed example but adding your result to this overview. However, I have a general comment on this example: Here you give what to show a potential misclassification by of the pure application of the distance-based approach. You applied a 10km distance buffer around the mapped glaciers, in accordance to other inventory approaches like for example Zhang et al. (2024b, following your reference list). I have some doubts that this comparison is performed correctly here. For example, Zhang et al. (2024b) applied a manual mapping approach using this definition for glacial lakes: “In this study, glacial lakes were defined as water bodies primarily fed by contemporary glacier meltwater within a 10 km glacier buffer zone” (Zhang et al. 2024, Methods). Using this definition and approach, I would assume that only lakes with a hydrological connection to the glacier are mapped and classified as glacial lakes. Your example shows an unspecific buffer around the glacier polygons without reference to the meltwater runoff pathways. Thus, most of your “misclassified” lakes would not have been classified as glacial lakes by a manual approach following Zhang et al. 2024b. Please reconsider this example and try to improve it.

**Response:** We agree that the previous wording could incorrectly suggest that Zhang et al. (2024b) was treated as a simple 10 km distance-threshold approach in our comparison. This was not accurate. Zhang et al. (2024b) also considered glacier meltwater connection in their manual interpretation, and we have therefore revised the manuscript to avoid presenting that inventory as equivalent to a pure glacier-distance rule. In the revised text, Table 8 is now framed more clearly as containing two different types of comparison: first, direct comparison with the existing published inventories to evaluate the improvement of our results; and second, separate

tests of pure 1 km and 10 km glacier-distance thresholds applied to the lakes mapped in this study, in order to assess the effect of distance criteria under a unified basis. We consider this separation methodologically fairer and clearer.

We also clarified that Figure 9 is unrelated to the comparison with the published inventories in Table 8. Its purpose is only to visually illustrate the limitation of glacier-distance thresholds, rather than to reproduce the manual mapping procedure of Zhang et al. (2024b) or any other published inventory.

Accordingly, we revised the relevant text in Section 4.2, Table 8, and the caption and description of Figure 9 to make these distinctions explicit. Specifically, we removed wording that linked Zhang et al. (2024b) to a pure 10 km threshold, clarified that the published inventories are compared as existing inventory results under a unified manually verified basis, and stated that Figure 9 serves only as an illustrative example of the limitation of glacier-distance thresholds.

Figure 2: Please add at least one place on each map for orientation

**Response:** In the revised Figure 2, we added place labels to improve geographic orientation in the main map panels, with Kathmandu shown in panel (a) and Nyingchi shown in panel (b). These additions were intended to provide clear reference locations for the two study areas.

Though the methodology is more convincing now, I suggest adding additional visual information on the performance of the approach. The only visual result is figure 6, which is very small, making it hard to really see the visual performance of the approach. I suggest adding another figure depicting an example from the test regions/calibration approach and examples from STPG.

Figure 6: Increase point size in legend. Add at least 1-2 locations / towns for orientation.

**Response:** We acknowledge that the previous manuscript did not provide sufficiently clear visual examples of the mapping results. In the revised manuscript, we improved the visual presentation in several aspects. In Figure 2, place labels were added to improve geographic orientation in the main map panels. In Figure 6, the size of the lake symbols was increased and four representative local examples were added below the regional distribution map to provide more direct visual illustration of the mapped results. We also clarified that Figure 8 presents representative result examples from the STPG, showing the differences between the ViT-based and CNN-based models in lake-boundary detection and artifact suppression. Because the source and purpose of these examples were not sufficiently explained in the previous version, we revised the caption of Figure 8 accordingly. Together, these revisions provide a clearer regional

overview together with more explicit local visual evidence of the performance of the proposed approach. As the CEH was used primarily for quantitative calibration/validation, we did not add separate CEH visual examples, and instead focused the revised visual examples on the STPG regional application results.

This should be also implemented in figure 9, the example between your approach and the pure distance approach (see comments below).

Figure 9: Visibility of red and blue on the background of satellite imagery is low. Please improve with more bright colors. Include lake boundaries also on the close-ups.

**Response:** We acknowledge that the previous version of Figure 9 was not sufficiently clear. In the revised figure, we improved the visual presentation in several aspects. The lake outlines were thickened to increase visibility, and lake boundaries were also added to the close-up panels. In addition, the glacial-lake color was changed from blue to cyan and the glacier extents were changed to yellow to improve contrast against the satellite imagery background. We also revised the caption to clarify that Figure 9 is intended as an example illustrating the limitation of glacier-distance thresholds, using a 10 km buffer as a specific instance. These revisions were made to make the comparison more visually explicit and easier to interpret.