Dear Editor and Reviewer1

Thank you for taking the time to review our paper. We also apologize for the delay in submitting the revised version. Below, we respond point-by-point to the comments from both reviewers, explaining the revisions made to address each specific request. Our response is highlighted in yellow.

RC1: 'Comment on nhess-2024-160', Anonymous Referee #1, 24 Nov 2024

This study does two main studies: the first study is the history of glacial lakes and changes in recent years; the second study is the changes in the glacial-moraine complex. The paper specifically has some scientific significance, but there are some serious problems that need to be improved.

Response to Reviewer 1:

We appreciate the reviewer's concise summary and recognition of the paper's scientific significance. We agree that improvements were necessary to increase clarity, rigor, and relevance. We have therefore taken the following actions in the revision:

- **Clarified Study Structure:** Clearly separated the two main components of the study, with distinct objectives, methods, and results for glacial lake change and glacier-moraine complex (GMC) evolution.
- **Enhanced Methodological Transparency:** Expanded the Methods section for full transparency, providing detailed descriptions of image data processing, remote sensing, DEM-of-difference and DInSAR analytical steps, including explicit uncertainty evaluation.
- **Improved Terminology and Definitions:** Improved terminology and definitions throughout, especially regarding glacial lake classification, contact status, and GMC processes.
- **Expanded Discussion and Interpretation:** Deepened the Discussion with comparisons to recent related glacial lake and GMC studies in other mountain regions, highlighting the broader significance of our findings.
- **Language and Presentation:** Undertook a full language revision for clarity and expanded previously brief sections to better communicate our results.

R1 comment: In response to the introduction of the data sources for the first study, it is stated at the end of the introduction what data we have used for this study.

Response: We revised the Introduction to include a clear summary of all data sources used, such as Corona KH-4, Landsat 7, and Sentinel-2 imagery for glacial lake and glacier mapping. This addition clarifies the remote sensing datasets and periods forming the basis of our glacial lake analysis.

R1 comment: And in the Methods section, only some information about the Corona KH-4 data is presented, not the other image data, such as the specific time of the image, the quality status of the image, the spatial resolution of the image, the pre-processing of the image, and the source of the data. For studies that use multiple sources of data, it is best to use a tabular format to present a summary of the underlying information for each data source.

Response: In the Methods section, only some information about the Corona KH-4 data is presented, not the other image data including Table 2, such as the specific time of the image, and the spatial resolution of the image, and used RGB bands. For studies that use multiple sources of data, we added some sentences to present a summary of the underlying information for each data source.

R1 comment: In section 3.2, it was mentioned that glaciers and glacial lakes from all data sources are extracted by manual outlining, how can the glacial lake boundary errors be taken into account? Due to the large difference in spatial resolution of different image sources, how to resolve the relationship between the boundary accuracy extracted from different resolution images and the actual changes of the glacial lake.

Response: We addressed this by implementing a consistent minimum mapping threshold (0.00045 km²), equivalent to two 15 m Landsat pixels. Manual boundary extraction was validated using a stable reference lake visible across all sensors; for this lake we compared mapped areas using a fixed NDWI threshold. Landsat 7 estimates were 8.8% larger than the 1968 Corona reference, while Sentinel-2 differed by only 3.4%. These uncertainties, explained in Methods, are acceptable for regional-scale lake mapping using our methodology.

R1comment: It is mentioned here that a threshold of 100 m2 (smaller than 200m2) is used to extract a glacial lake, which is just one image pixel for a Sentinel-2 image, how can we be sure that this is a glacial lake for such a small image pixel? What is the definition of an glacial lake for this study? With such a small area threshold, the spatial resolution of the image in Landsat 7/8 imagery, even after panchromatic band fusion, is only 15 m. With an area of 225 m2 for one image pixel, how is that very small glacial lake recognizable in Landsat 7/8 imagery?

Response: We clarified our method by consistently applying a minimum threshold of 0.00045 km² (450 m²) across all datasets, exceeding the area of two Landsat 7 (15 m) pixels after pansharpening. Therefore, only features clearly visible and distinguishable in the imagery were included, and lakes below this size or uncertain boundaries were excluded from analysis. This approach ensures comparability and reliability across sensors. RGB composites (bands 1–3) were used for water detection.

R1 comment: In addition, no information is provided in this section on what bands of imagery were used to manually outline the glacial lake and what kind of pre-processing was applied to the imagery.
Response: We added detail in Methods on the specific bands used for each dataset. Corona: slope-based thresholds with DSM; Landsat 7: Bands 1–3 for RGB and Band 8 (pan) for sharpening; Sentinel-2: Bands 1–3 for extraction. Pre-processing steps (coregistration, pansharpening, NDVI/NDWI checks) are now explicitly described.

R1 comment: In section 3.3, detailed information on the specific methodology of image processing for analyzing changes in GMCs in the study area using 49-view ALOS-2/PALSAR/-2 imagery is indicated in a number of previous studies. This write-up is too simple and broad and the key processing steps should be described in the methods section of this paper. Overall, the authors' presentation of the data and methodology is too brief and not very descriptive of the study.
Response: The Methods section now provides a stepwise DInSAR workflow following Werner and Wegmüller (2006): raw SAR conversion to SLC, coregistration, differential interferogram generation, removal of topographic phase using SRTM DEM, adaptive filtering of phase noise, phase unwrapping to obtain displacement, and geocoding. This ensures reproducibility and transparency in GMC change detection.

R1 comment: The author used DEM data from four different sources to study changes in the lake basin surface. Are the elevation datums consistent across these four data sources? What are their respective spatial and vertical resolutions? How did the author address the issue of matching between the different DEM data sources? These data processing details are essential; otherwise, the analysis results may be unconvincing.
Response: We used the HMA DEM (8 m resolution) as a vertical reference. Elevation data from Corona (4.1 m), SRTM (30 m), and UAV (1 m) DEMs were matched to HMA at selected stable terrain area. Root mean square errors of 2.2 m (Corona), 2.8 m (SRTM), and 1.3 m (UAV) were calculated around these benchmarks and incorporated into our uncertainty estimates, as detailed in Methods.

R1 comment: In Section 4.1, it is mentioned that there are 543 glacial lakes during the period 2000–2021. This is difficult for me to understand, as it spans a 22-year time frame. How was it determined that there are 543 glacial lakes over such a long period? Glacial lakes tend to change rapidly, so it is more common to describe the number of glacial lakes at a specific year rather than over such an extended period like.
Response: Lake numbers have been reanalyzed and are now referenced as discrete values for specific years (1968, 2000, 2021). This clarifies temporal trends and avoids cumulative or ambiguous counts.

R1 comment: In the text, many superscripts for "km2" are not written correctly.

Response: All notation for area (“km²”) and other SI units have been corrected and standardized throughout the revised manuscript.

R1 comment: What are the identification criteria for GMCs? Please clearly specify in the text how the 611 GMCs were determined.

To address this, we have clarified in the revised Methods that glacier-moraine complexes (GMCs) were mapped based on: (1) the presence of a continuous debris-mantled surface extending up to 3 km downvalley from glacier fronts, (2) the absence of prominent lateral or terminal moraine ridges, (3) a convex surface profile, and (4) the absence of established valley-bottom drainage. Where available, DInSAR surface deformation was used to identify subsurface ice content. These criteria were applied systematically across all basins, consistent with regional precedent, resulting in the identification of 611 GMCs.

R1 comment: I cannot understand 'whereas the areas of lake basins in 2021 increased eightfold compared with 1968.' Please provide an explanation of this sentence

Response: We have corrected the grammar and updated the section to: “Figure 7c,f shows surface decline and evolution of lake basins at two sites within the Chelektor glacier-moraine complex, based on DEM differencing for 1968 (Corona), 2000 (Landsat 7), 2017 (HMA), 2018, and 2023 (UAV).”

R1 comment: In line 144, “Along a cross-section, a comparison of DEM differences (Fig. 6a) between 1991 and 2013 show…”. It should be “shows” not “show”.

Response: We have corrected the grammar and updated the section to: “Figure 7c,f shows surface decline and evolution of lake basins at two sites within the Chelektor glacier-moraine complex, based on DEM differencing for 1968 (Corona), 2000 (Landsat 7), 2017 (HMA), 2018, and 2023 (UAV).”

R1 comment: Line 163-164: “Consistent with the glacier trends there, the glacial area here decreased by 30% over the past 53 years.” In this sentence, what is the difference between “glacial area” and “glacier”?

Response: We have reviewed and corrected the relevant sentences, so “glacial area” is now replaced with “glacier area” throughout, ensuring precise and consistent terminology.

R1 comment: In section 5.1, a variety of scenarios of rapid glacial lake formation are listed, please support these scenarios by showing them in the form of remote sensing image maps in the context of the study area.

Response: In response, we have revised Section 5.1 to refer directly to newly prepared remote sensing

image maps that illustrate the key scenarios of rapid glacial lake formation described in our text. Figure references in this section have been updated, and we ensure that imagery supports our interpretation of formation mechanisms.

R1 comment: In the conclusion, the author identifies 611 GMCs, most of which contain dead ice. How was dead ice identified within these GMCs?

Response: We have clarified that dead ice was identified by interpreting coherent surface motion patterns in DInSAR datasets, which were cross-validated with field observations at representative sites like the Chelektor glacier front. This approach for dead ice detection was previously validated by GNSS measurements at the Adygine GMC, as now stated in both the Methods and Discussion.

R1 comment: In the second half of the conclusion, the quantification of the findings is insufficient.

Response: We agree and have revised the Conclusions section to include more quantitative results, specifically stating the numbers of glacial lakes identified for each study year, the overall percentage reduction in glacier area, and the number and percentage of GMCs with buried ice. These specific values strengthen the summary and highlight the magnitude of observed changes.

d here about the relationship lakes and glaciers/GMCs distributions in each region.