Response to RC1

The manuscript by Xie et al aims to investigate how glaciers in the eastern Pamir, specifically the Kangxiwa Glacier, respond to short-term climatic events such as heatwaves, and to better understand the processes driving glacier mass balance variability in this region. To do so, time lapse photography, in situ measurements and ERA5 data are used. The manuscript is interesting and timely, and applies methods recently used in the European Alps to a different region (Tibetan Plateau).

Response: We thank the anonymous reviewer for his/her insightful comments and constructive suggestions. Below are our point-by-point responses in blue.

Major comments:

Before the manuscript is ready for publication, I see a few shortcomings and points that can strengthen the manuscript. First, no clear distinction is made between methods and results. The results of the time lapse cameras are presented in the methods. This needs to be clearly separated.

Response: Following your suggestion, we restructured both the method and results Sections. We have removed all the results of the time lapse cameras, which was presented in the methods in previous version to the Results section in the revised manuscript. And we also added new Section 4.1: The performance of glacier mass balance estimation based on the time-lapse cameras in the Result Section. In this section, we compared the performance of mass balance calculated by both stake method and camera-based method in both point scale and glacier-wide scale.

Second, it is not clear how the mass balance from three time-lapse stakes is interpolated to the daily glacier-wide mass balance (Fig. 6). This needs to be clarified in the method section. This would strengthen the use of the time-lapse photography, which is presented poorly now.

Response: Thanks for pointing out such issues. Glacier-wide mass balance was derived via a weighted average of the three pointing mass balance observations by Cameras and their representative elevation-area. Although there are only three cameras available, their spatial representativeness was carefully considered before the installation near the terminus (5005m asl), middle (5137m asl) and upper region (5300 m asl) of Kangxiwa Glacier. The location of camera 1 at 5005m roughly represents the zone of 5005±60 m in elevations (~4960-5080m asl); Camera2 represents the zonal range of 5137±60 m in elevations (~5080 to ~5200 m asl); Camera3 represents the zonal range of 5300±100 m in elevations (~5200 to ~5390 m asl). Actually, the topography condition of Kangxiwa Glacier is relatively flat and the 10 stake mass balance measurement evidenced that there are linear mass balance gradients (See the following Figure). It allows us to use the weighing method to calculate the glacier-wide mass balance.

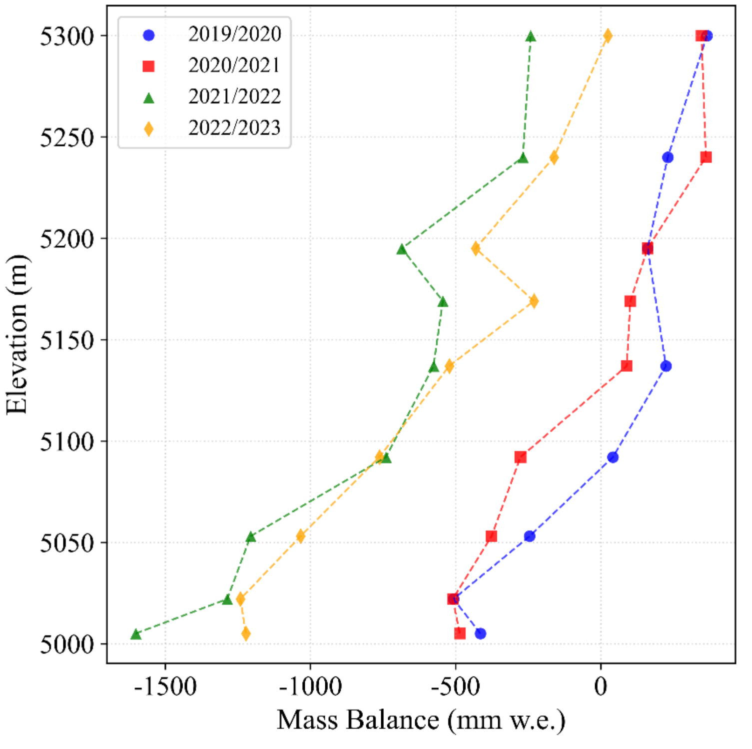

Figure 1R The elevation distribution of point mass balances measured by 10 stakes over 2019/2020-2022/2023 hydrologic years

And we also compared the glacier-wide winter/summer mass balance calculated by using the traditional in-situ ablation method and the time-lapse photography on the Kangxiwa Glacier. The mean difference is within 62 mm w.e. and such comparison evidenced the reliability of the area-weight method by using three mass balance observations. We also added the relevant description to address the process in the Method section and their reliability of both point and wide-glacier mass balance in Result section in the revised manuscript (Figure 4).

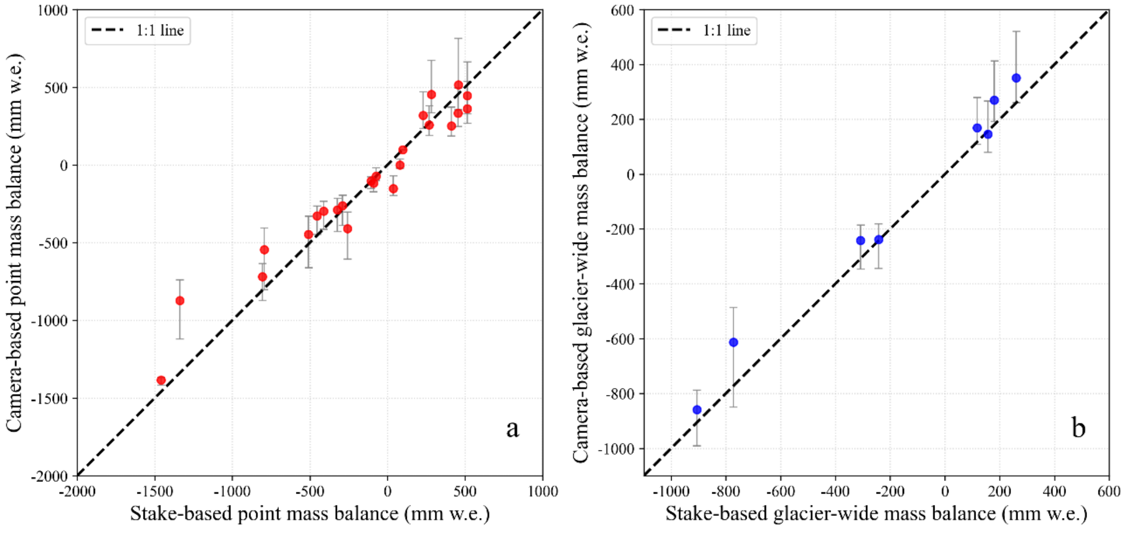

Figure 4 The comparison of pointed mass balance (a) and glacier-wide mass balance (b) measured by using the stake method and the time-lapse photography on the Kangxiwa Glacier.

Last, the manuscript (and supplementary material) contains a lot of figures, that are not all meaningful. For example, Figure 5 is Figure 4 with a factor of snow/ice density, and Figure 7 is Figure 6, but at monthly intervals. Also, Figure 10 is a different representation of Figures 4-7, without showing new data. I will comment more on this in the specific comments.

Response: We have deleted the redundant Figures and new Figures are provided to show the performance of daily mass balance estimation by using time-lapse camera (New Figure 4), the climatic backgrounds from long-periods (New Figure 6). Please see the revised Figures and descriptions.

Specific comments:

1. Title: consider adding the ERA5 reanalysis data, as this is also a big contribution to the manuscript.

Response: The ERA5 reanalysis temperature data is important to this research. We think the camara mass balance data are the core data to the manuscript. We did not therefore add "the ERA5 reanalysis data" in the title. However, following your specific comment 8 and comment 31 and RC2's comment, we further addressed the role of ERA5 reanalysis data in both objectives and methods and the title was revised as "Glacier Mass Balance and Its Response to 2022 Heatwaves for Kangxiwa Glacier in the Eastern Pamir: Insights from Time-Lapse Photography".

2. L43: Kunlun, the Pamir and Karakoram ranges are a part of the Tibetan Plateau, right? Please state this in the text.

Response: The sentence was revised as: *In addition, long-term glaciological measurements are scarce across the western Tibet Plateau, particularly in the western Kunlun, the Pamir and Karakoram ranges (Barandun and Pohl, 2023; Yao et al., 2022; Zemp et al, 2023).*

3. L45/46: the references used here are not correct. References to the glaciological mass balance method can be: Kaser et al, 2003, and Cogley et al, 2011

Response: Thanks for the comment. We changed the reference here and add them to the References.

Kaser G, Fountain A, Jansson P et al. (2003) A manual for monitoring the mass balance of mountain glaciers. UNESCO, Paris

Cogley JG, Hock R, Rasmussen L, Arendt A, Bauder A, Braithwaite R, Jansson P, Kaser G, Möller M, Nicholson L and Zemp M (2011) Glossary of glacier mass balance and related terms. IHP-VII technical documents in hydrology, 86

4. L47: glacier dynamics is used, but glacier mass changes are meant. Dynamics has to do with the movement of the glacier. Replace dynamics with glacier mass changes here and throughout the paper.

Response: We used “glacier mass changes” here and we have unified throughout the paper.

5. L48: in this paragraph, it is not clear if it is about the Tibetan Plateau or extreme events worldwide. Please clarify.

Response: This paragraph is about extreme events worldwide. The sentence was revised as: *Recent extreme events such as heatwaves have caused abnormal high-elevation melting in the world.*

6. L54: The references here deal with marine heatwaves or regional heatwaves. Especially Oliver et al is not relevant. Consider removing and finding references relevant to mountain glaciers.

Response: We have removed Olive et al. in the introduction and discussion. We added two references on heatwave impact on mountain glaciers in Apls and Tibetan Plateau.

Colucci R., Giorgi F., Torma C., Unprecedented heat wave in December 2015 and potential for winter glacier ablation in the eastern Alps, Scientific Report, 7: 7090, DOI:10.1038/s41598-017-07415-1, 2017.

Zhu, F., Zhu, M., Yang, W., Wang, Z., Guo, Y., Yao, T., Drivers of the extreme early spring glacier melt of 2022 on the central Tibetan Plateau. Earth and Space Science, 11, e2023EA003297. https://doi.org/10.1029/2023EA003297, 2024.

7. L58: consider adding 'to monitor ablation' after monitoring techniques to clarify and add that the steel wire is called SmartStake. It derives ablation by rolling the wire up.

Response: The sentence was revised as “*Recent advancements in high-temporal-resolution techniques to monitor ablation, such as the SmartStake deriving the ablation by rolling the steel wire up (A2PS contributors 2021), automated cameras monitoring colour-coded ablation stakes (Landmann et al., 2021; Cremona et al., 2023), and terrestrial laser scanning techniques (Voordendag et al., 2023), have provided new insights into short-term mass balance variations*”

8. L63-66: sharpen the scope of the study and add that also ERA5 reanalysis data are used. My expectation after reading the introduction was, that it would have a focus on the time-lapse photography method, but this expectation was not met after reading the manuscript.

Response: The sentence was changed as: “*Based on these high-resolution daily surface mass balance datasets, this study aims to (1) characterize the contrasting seasonal mass balance patterns of the Kangxiwa Glacier in the eastern Pamir under varying climatic forcing regimes across the 2019/2020 to 2022/2023 balance years; (2) quantify the sensitivity of surface mass balance to the extreme 2022 summer heatwaves; and (3) identify the atmospheric circulation anomalies linked to the 2022 heatwaves using ERA5 reanalysis data, and further elucidate regional glacier response.”*

9. L71-73: is this data representative for the Kangxiwa Glacier? Why is only the mean summer temperature mentioned?

Response: This data was used here to illustrate the regional climate background (Figure 1b), showing that the Kangxiwa Glacier is situated in a cold and dry climate. Given that mean summer temperature was inappropriate for this purpose, it was replaced with mean annual temperature. Also, references about the values were added here following RC2's comment The sentence was changed to "*Data from the Taxkorgan Meteorological Station (3091 m a.s.l., ~50 km south of Muztagh Ata) show a mean annual temperature of 3.7°C and annual precipitation of ~70 mm (Li et al., 2022; Lv et al., 2020).*"

Li Z., Wang N., Chen A., Liang Q., and Yang D., (2022) Slight change of glaciers in the Pamir over the period 2000–2017, Arctic, Antarctic, and Alpine Research, 54(1), 13-24, DOI: 10.1080/15230430.2022.2028475.

Lv M, Quincey DJ, Guo H, King O, Liu G, Yan S, Lu X, Ruan Z (2020). Examining geodetic glacier mass balance in the eastern Pamir transition zone. Journal of Glaciology, 66 (260), 927–937. https://doi.org/ 10.1017/jog.2020.54

10. L79: for what period is this shrinkage rate?

Response: The period of 2000-2017 was added it in the revised manuscript.

11. Figure 1: please add scale bars to Figures 1b and 1d.

Response: We added scale bars to Figure 1b and 1d. The symbol of the studied was changed to triangle.

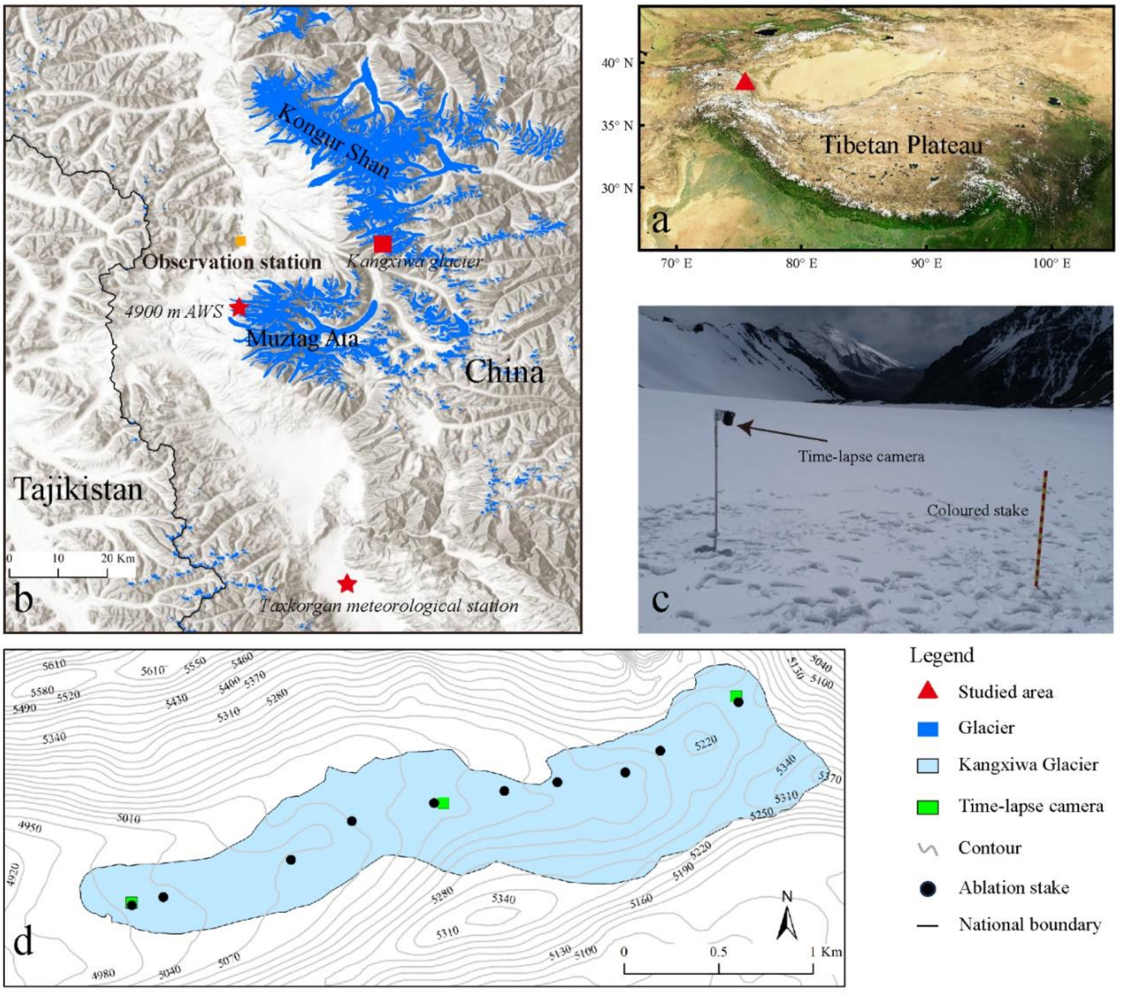

Figure 1. Study region and the distribution of in-situ measurements. (a) Location of the studied area in the eastern Pamir, central Asia; (b) The location of Kangxiwa Glacier (red triangle), Automatic Weather Station (AWS) at the elevation of 4900 m and Taxkorgan meteorologic station (red stars); the World hillshade layer was used as the background (http://www.arcgis.com) and the outline of the glacier was obtained from the Randolph glacier inventory (RGI 7.0; http://www.glims.org/RGI); (c) Photograph of the time-lapse camera and colour-coded stake on the Kangxiwa Glacier (5300 m a.s.l., 20 June, 2020); (d) Topographic map of the Kangxiwa Glacier showing the locations of three time-lapse camera monitoring systems and the ablation stakes/snow pits for in-situ mass balance observations.

12. L90: using Yu et al 2013 gives the impression that this is the paper that describes the well-established glaciological method. Replace by Kaser et al, 2003 and Cogley et al, 2011.

Response: Thanks for the suggestion. We changed the references, added Kaser et al, 2003 and Cogley et al, 2011 to the reference part.

13. L92: add a reference to the 900 kg m-3. For example, Huss 2013 and reference therewithin.

Response: We added the reference.

14. L100: here and at several locations of the paper 'stake height' is used. I think the authors mean to say 'the melt out length of the stake', because the length of the stake itself is not changing. Correct it here and throughout the

paper, e.g. also in L106.

Response: Following your suggestion, we used "the stake melt-out length" in the revised manuscript.

15. S1: this figure is subdivided in 6 to 8 periods per camera location. How are these monitoring periods defined? Would it be possible to make one long period per location?

Response: These monitoring periods at each site were founded on the date of the glacier field investigation. For example, "5005: June 16, 2022–September 25, 2022" indicates that glacier mass balance observations were conducted on June 16 and September 25, 2022 at the 5005 observational site. We replotted all the data at each location as follow.

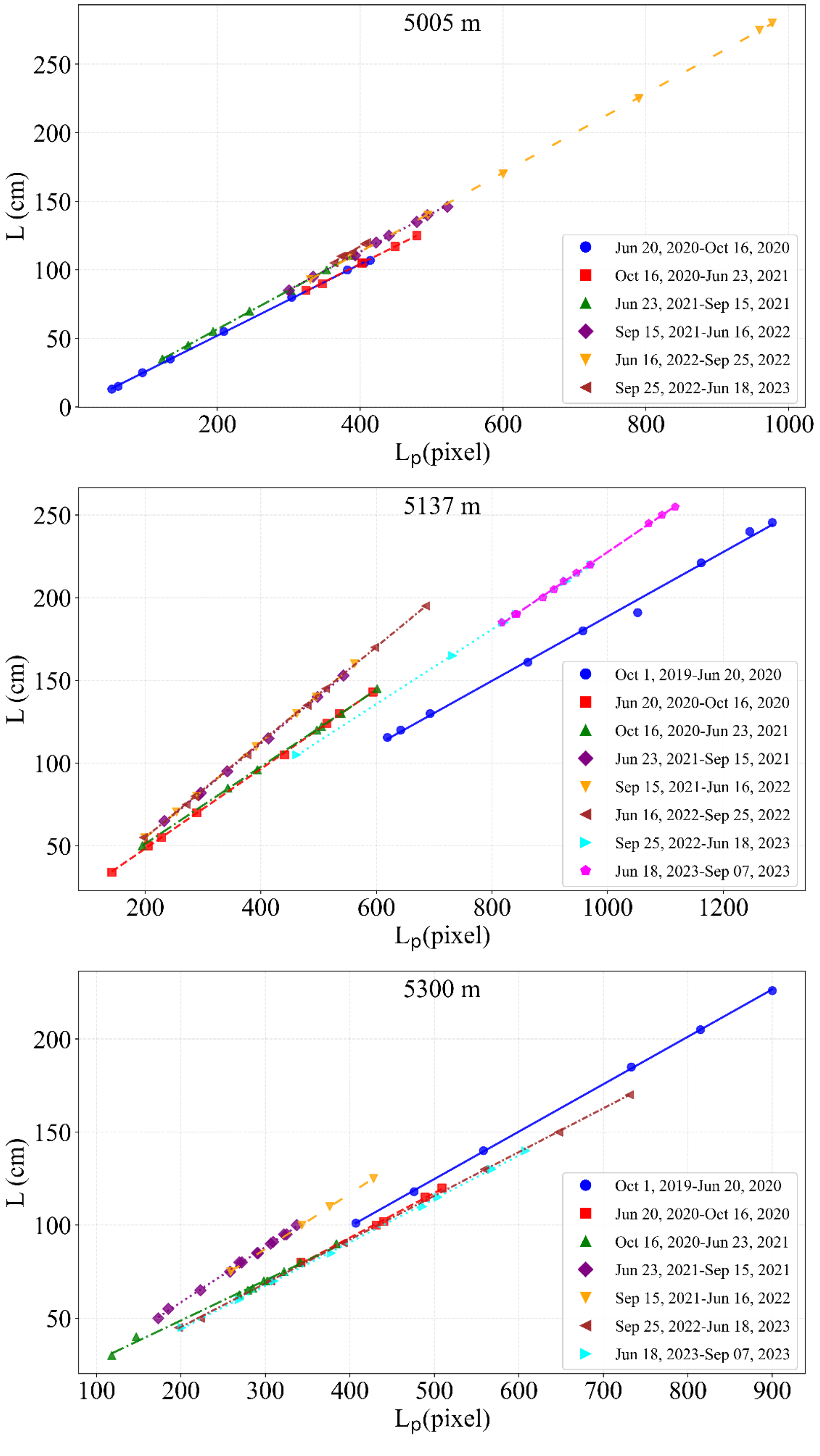

Figure S1 Linear relationship between L_p and L for each monitoring period at each camera site.

16. L139 and onwards: this paragraph is already part of the results section.

Response: Figure 3 was removed to the supplementary material. Figure 4 was deleted according to the major comment.

17. L140: for the reader, it is not directly clear what the difference is between in situ stake observations and manually calculated results. Please clarify.

Response: For clarify, we revised the terms to "field tape measurements" and the "manually photo inspection". We also replotted the Figure 3 for more clarification, and moved it to the supplementary material.

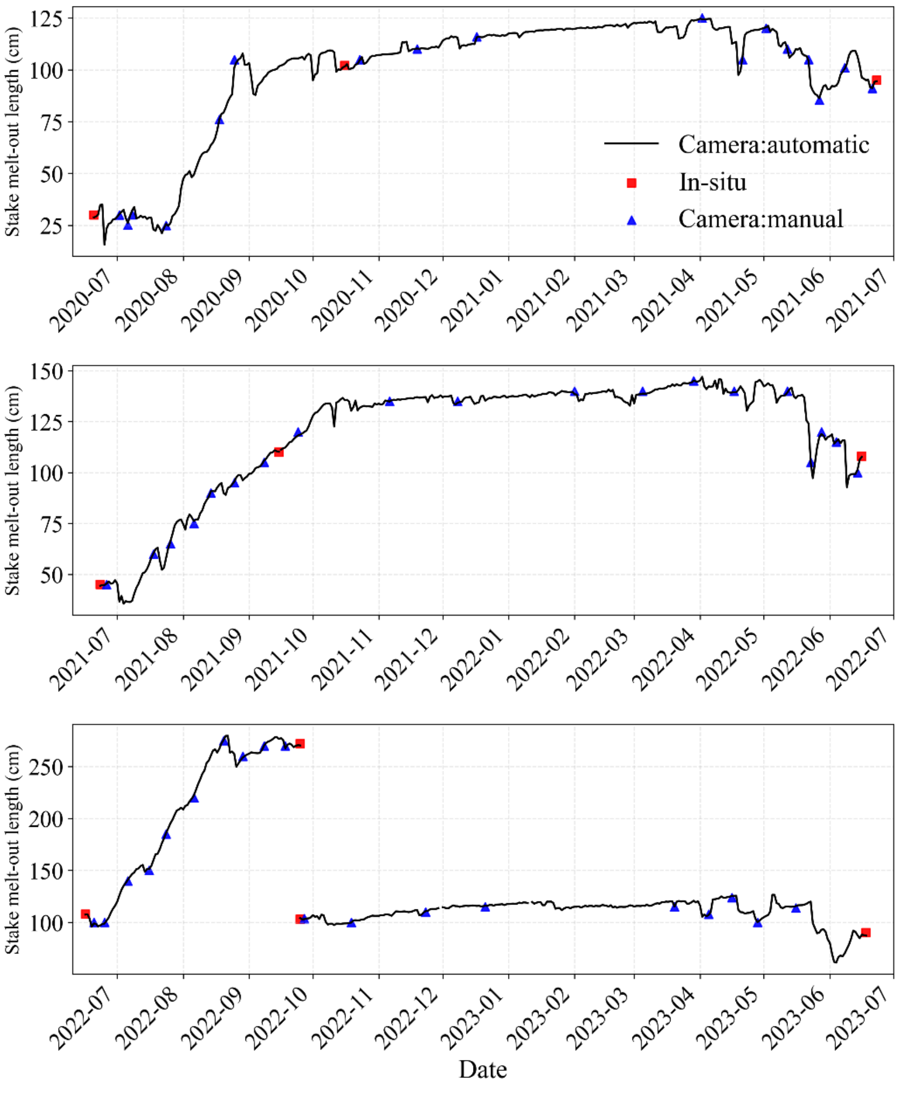

Figure S2 The performance of stake melt-out lengths derived automatically from time-lapse cameras (black line), compared with in-situ observations (red square) and manual inspections (blue triangle) for a stake at the elevation of 5005 m asl. Noted that the camera monitoring systems were maintained in June and September in each year during the period from 2020 to 2023.

18. L142/143: these results seem surprisingly low to me, given the roughness of the glacier surface and the

possibility to read stakes manually. Please elaborate.

Response: We have deleted the relevant description, and only provided the value ranges with centimeter-level precision.

19. L144: broader applications? Multiple elevations? What do you mean? Please give examples.

Response: We did not mention the broader application in the revised manuscript. We only address the robustness of the semi-automatic procedure for deriving stake length changes by time-lapse cameras.

20. Figure 4: What is the white period in this figure? Add this to the caption and the text. Also, the figure is confusing, given negative values above positive values on the y-axis. Consider renaming 'changes in stake height' and mirror the y-axis. Please also explain what happened in the last 2 months of 2022/2023 at location 5005 m. There is a lot of data missing there. In the caption replace 'the stake height was set to 0 cm' by changes relative to the first day of the hydrological year (otherwise positive values are not possible).

Respond: Thanks for point out the incorrect description in figure caption. Regarding the redundant Figures, this Figure has been deleted according to Major comment and another review's comment. The white period was the missing data. Missing data during the last 2 months of 2022/2023 at the 5005 m was caused by that the top part of the stake was out of the camera view. “changes in stake height” was revised to “Stake melt-out length” (comment 14) in figures in the revised version.

21. L152: how are the surface conditions derived? In S2, there is only distinguished between snow and ice, whereas later (L161) also firn is mentioned.

Respond: The surface conditions (ice/snow) were determined via visual interpretation of the captured images. Given the challenge associated with differentiating between snow and firn, we no longer make this distinction in the revised manuscript. We have added the relevant description “*The daily changes in the stake melt-out length recorded by three cameras were converted into changes in mass balance by multiplying by the corresponding density for different surface conditions (snow vs. bare ice) through visual inspection of the photos manually.*”

22. L154: why is the average snow density from June used? Is the representative? What is the variability in snow density over years and over the seasons?

Respond: The density of snow pits was measured during each field mass balance observation on June and September. The average density of snow pits at the three sites in June was 426 kg/m^3, ranging from 286 kg/m^3 to 587 kg/m^3; while that in September was 380 kg/m^3, ranging from 295 kg/m^3 to 536 kg/m^3. The average density from all the snow pits in June and September was 405±69 kg/m^3. In the revised version, we used 405 kg/m^3 as the snow density for calculation.

23. L156: So Figure 5 is derived with interpolated data from the 10 stake locations in Figure 1? Or how can you have daily mass balances? This part of the method really needs to be clarified.

Response: The data in Figure 5 is derived from three camera locations at 5005 m a.s.l., 5137 m a.s.l. and 5300 m a.s.l., respectively. Daily balance was calculated as the product of the daily change in the stake melt-out length and the corresponding density. As response to major Comment 2, we have clarified the description of how glacier-wide mass balance was calculated and the new Figure 4 was provided to show their reliability by comparing with the traditional stake-based glacier-wide mass balance.

24. L157: which differences do you mean? The differences between the camera observations and the in situ measured mass balance? How is this derived? And with 3 points, are the three locations of the cameras meant?

Response: The 3 cameras locations (5005 m, 5137 m and 5300 m) also have the coupling in-situ stake and snow pit measurements (close to the camera). To validate the accuracy of camera-based mass balance observation, we compare the camera-based and stake-based mass balance at three locations. For clarify, this sentence was revised as "*Quantitative comparisons reveal that the mean seasonal mass balance differences between the two datasets at the three monitoring sits are −64, −13, and 2 mm w.e, with corresponding standard deviations of 193, 137 and 104 mm w.e., respectively*"

25. L158: I find those standard deviations relatively high and it is concluded that the camera approach in reliable. Please elaborate on this.

Response: We actually compared the winter and summer mass balance estimated by between camera-based and stake-based methods. Please see the following figure. The standard deviation is relatively small (seasonal average difference was 26±149) if comparing with winter and summer mass balance at different locations. Following your suggestion, we added the relevant description of summer and winter mass balance in the revised manuscript.

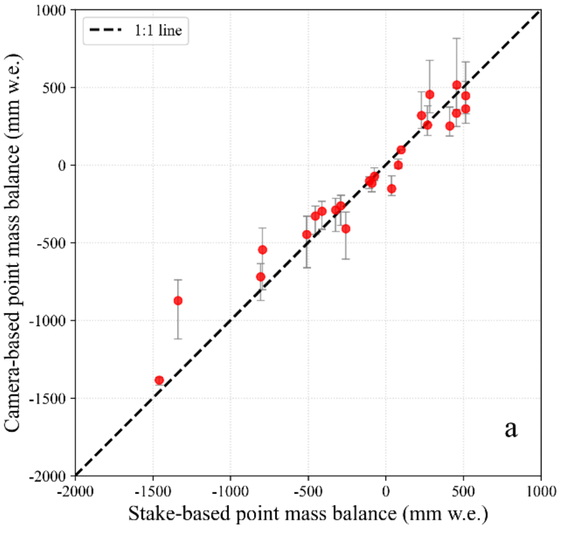

Figure 5a. The comparison of pointed mass balance measured by using the stake method and the time-lapse photography on the Kangxiwa Glacier.

26. L158-163: Why is this text in italics? Again, in this section, it needs to be made clear how you distinguish between snow, ice and firn and how this is derived from the images.

Response: Sorry for the type error. In this manuscript, the glacier surface conditions are divided into two categories:

ice and snow. We manually distinguished between ice and snow by visually inspecting the photos. We added this '*The daily changes in the stake melt-out length recorded by three cameras were converted into changes in mass balance by multiplying by the corresponding density for different surface conditions (snow vs. bare ice) through visual inspection of the photos manually*'

27. L165: the DEM with this resolution is derived from which satellite (mission). What is the temporal resolution of the DEMs? In this paragraph, it is also not clear how and why the DEMs are used. Later, I don't see any results that are derived from the DEMs.

Response: Using the 30 m resolution SRTM DEM, the glacier area at different elevation bans were generated to calculate the glacier-wide mass balance by using camera-based and stake-based method. We add this information in the text as "*A 30-m resolution SRTM DEM was employed to quantify the area distribution with its elevations.*"

28. L170/171: confusion is added, as here it is referred to the cameras again. In which figure can I find results? What does it mean?

Response: L170/L171 was used to describe how to fill the data gaps which were referring to new Figure 3.

29. Figure 5: shorten the extent of the y-axis for the upper two locations. Consider adding all locations to one plot or display it in a similar way as figure 4, grouped over years. This figure also raised the question how the cameras work in winter, do they get snowed in?

Response: We have replotted the Figure 5 following your suggestion. The camera work in winter continuously and thus the changes in stake melt-out length could be detected.

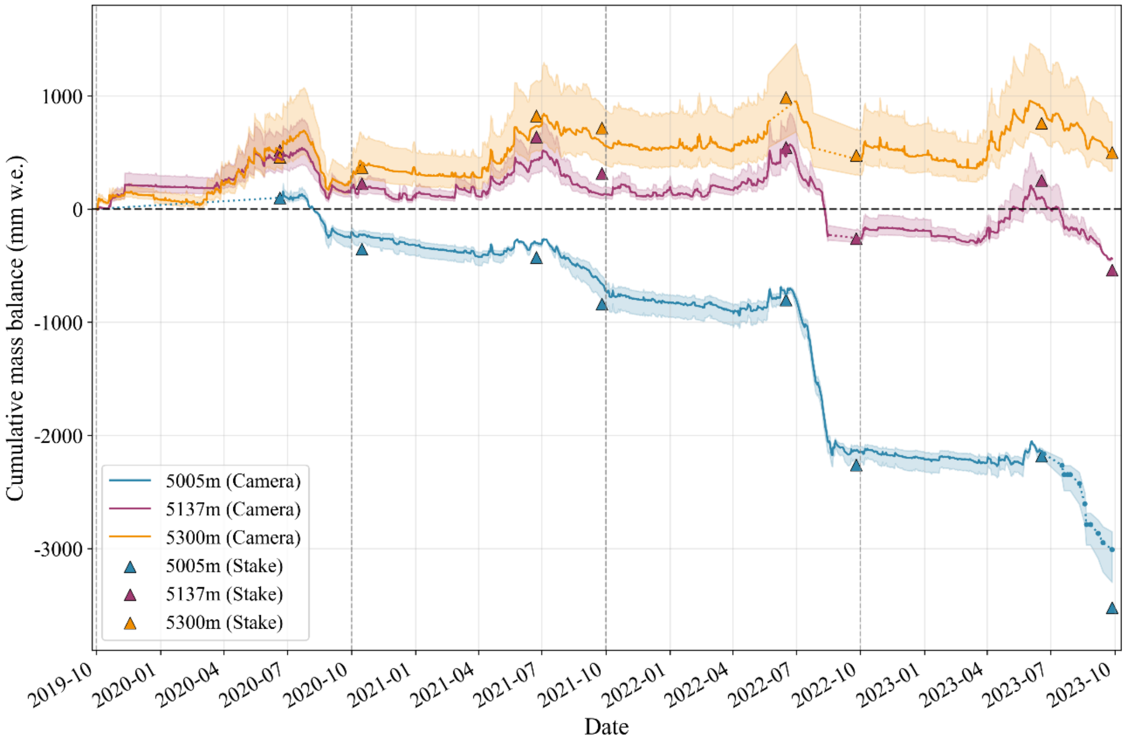

Figure 3. Comparison of the accumulated mass balance estimated using time-lapse cameras (lines) and the glaciological methods (triangles) at the three locations (5005 m, 5137 m and 5300 m) on the Kangxiwa Glacier. The thin dotted lines denote gap-filled data.

30. L178: The AWS was deployed since 2011, but does it cover the entire period until 2023? Are these data representative for the Kangxiwa Glacier?

Response: The 4900AWS data started from Mid-July 2011 and cover the entire period until 2023. This AWS is the only long-term continuous measurement near the Kangxiwa Glacier in high elevation. We thus use this data to investigate their climatic background in the following section.

31. L185-188: elaborate more on how and why ERA5 data is used. This should already have been mentioned in the scope/aim of the study.

Response: We have elaborated the description the usage of ERA data in the revised manuscript. "*To investigate the possible climate mechanism on abnormal glacier mass loss, this study also employed the fifth generation of reanalysis data from the European Centre for Medium-Range Weather Forecasts (ERA5) with 2.5º horizontal resolution, which has been widely used in climate research (Hoffmann et al., 2019; Song et al., 2024) and glacier change analyses (Zhu et al., 2024b). By analysing the spatial anomalies pattern of geopotential height, wind fields, and surface air temperature, we investigated the change of large-scale atmospheric circulation and discussed its possible influences on extreme weather events and the subsequent responses of glacier surface mass balance.*"

32. L191: it is unclear from the text how the glacier-wide mass balance is calculated at such high temporal resolution. Are only the three camera stakes used or also the other ablations stakes, as indicated in Fig. 1d? I cannot imagine it's sufficient to interpolate only from the three stakes. If this is the case, please elaborate why this would be sufficient.

Response: The glacier-wide daily mass balance was calculated based on the three camera's data. We firstly calculated the daily mass change at each point (comment 23), glacier-wide daily mass balance was then derived via a weighted average of the three-point values, with weights assigned by elevation-specific area proportions. The three measurement points represented elevation ranges of 4960–5080 m (weight: 0.33), 5080–5200 m (weight: 0.38), and 5200–5390 m (weight: 0.29). The three cameras are located at the lowest, the middle part, and the highest part of the glacier, respectively. They cover the sites with the lowest, medium, and highest surface mass balance values of the glacier. The in-situ observations at the 10 points (Figure 1d) showed strong liner relationship with elevation (Fig R1), which provides favorable conditions for calculating the mass balance of the entire glacier using the three camera's data. We also used the in-situ seasonal mass balance data to test whether it can be used the three point values to generate the glacier-wide mass change data. The difference between the seasonal three camera-based and ten-stake based mass balance values was 62±54 mm w.e.. The low difference further confirms that using the 3 point mass change values and weighted factor to drive glacier-wide mass balance was a reasonable approach.

33. L196/197: authors claim they have evidence for sublimation or mechanical snow erosion, but abrupt transition of the surface cover is no evidence for this, especially because it's not related to wind velocity and direction and/or

temperature. Additionally, it is not clear how the surface properties were derived, so calling it abrupt is not appropriate here.

Response: Thanks for pointing out this issue. The low air temperature in winter prohibits the surface melting. The time lapse camera evidenced that the snow-cover surface was transferred to exposed ice surface condition, which means the possible surface sublimation or mechanical snow drift in the winter season. Therefore, the sentence was revised as "*The slight surface mass loss during this period was likely caused by sublimation or mechanical snow drift by strong winter wind, which was evidenced by the transition from snow-covered surfaces to exposed bare ice (Fig. S2)*".

34. L198: substantial, please quantify this.

Response: We rephrased it as "*During the accumulation period (mid-April to June/July), the glacier experienced different maximum snow accumulation across the entire glacier ranged from 258 to 445 mm w.e.*"

35. Figure 6: I recommend to make three subplots here in total. a) Figure of the mass balance of all the years, b) cumulative precipitation over all the years in order to get a feeling of the total amount of precipitation over the year (so not the daily bars that are hard to compare), c) CPPD, as it the current Fig. 6e now.

Response: Following your suggestion, we have redrawn following new Figure 5.

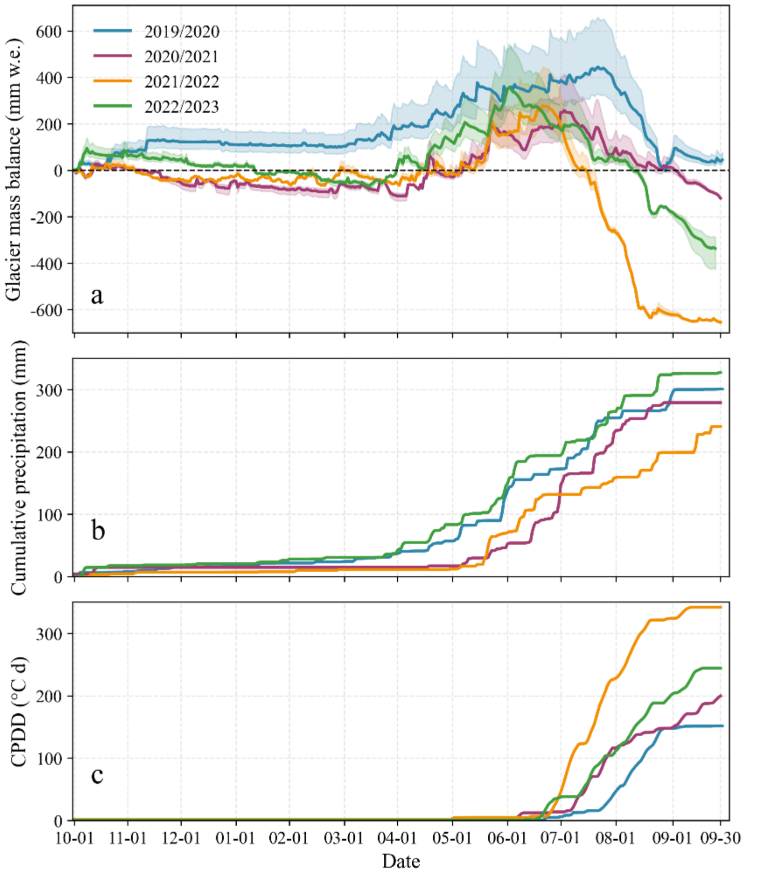

Figure 5. Cumulative glacier-wide mass balance of the Kangxiwa Glacier during the 2019/2020–2022/2023 hydrological years with the uncertainties by shaded area (a). The cumulated precipitation (b) and the cumulated positive

degree day recorded by the AWS4900 (c).

36. L213: from fig 6a, there is no GLD visible in 2019/2020. The fact that a GLD is given in the text, makes me doubt even more about the reliability of (the interpolation of) the glacier-wide mass balance.

Response: Our impression is wrong. The original intention was to use "~ 20 August 2020" to mean that the 2019/2020 hydrologic year almost reach its GLD at 20 August 2020. We revised sentence as: *Concurrently, the GLD-defined as the date when the net mass balance transitions to negative and all winter snow accumulation is depleted (Voordendag et al., 2023)-occurred on around 11 July 2022, approximately one month earlier than in other years (e.g., ~3 September 2021; ~26 August 2023). Notably, no GLD was recorded in the 2019/2020 hydrologic year, a phenomenon attributed to abundant winter-spring snow accumulation coupled with relatively low summer air temperature (Fig. 5b,c).*

37. L214: please also relate the occurrence of the Glacier Loss Day to the total amount of precipitation, like it has been done in the original GLD paper (Voordendag et al., 2023).

Response: We compared the cumulative precipitation before GLD between these hydrologic years, and analyzed the relationship between GLD and the amount of precipitation. The added sentences are: *The earliest GLD in the 2021/2022 hydrologic year was partly caused by the lowest precipitation in the accumulation season. Specifically, the AWS4900 show that the cumulative precipitation for the 2021/2022 hydrologic year was only 131.8 mm until 11 July, while the corresponding values were 195.9 mm, 165.1 mm, and 218.7 mm for the 2019/2020, 2020/2021, and 2022/2023 hydrologic years, respectively.*

38. Figure 7: this figure is unnecessary in my opinion. Especially if adaptations are made to Fig 6 (see comment 36).

Response: Following the comment, Figure 7 was moved to supplementary material.

39. L229-231: this line would fit better in the discussion section.

Response: We use this in the discussion part.

40. L235: "unprecedented" has been used as strong statement by Cremona et al. (2023), but this statement seems too strong here, as we do not see any proof how it has been before. We do not have a long period of observations at Kangxiwa Glacier.

Response: We have removed the "unprecedented" from the subtitle.

41. L236: from Fig. S3c it is not clear to me that the warm summer of 2022 was unprecedented. Please rephrase, for example, "xx % of the time above the 90% percentile".

Response: Thanks for the suggestion, we rephrased these sentences. We also added one new Figure 7 to address the anomalous high air temperature in July of 2022. "*Both ERA reanalysis data and ground-based meteorological station observations revealed an unprecedented summer warming event in 2022 in the east Pamir, with the most pronounced anomaly recorded in July (Fig. 6 and Fig. S5). The ERA5 temperature data confirmed that the corresponding grid point of the Kangxiwa Glacier in July 2022 was the highest recorded between 1981 and 2024 (Fig. 6a). The AWS4900 records evidenced that the average July temperature during 2012-2023 was 2.9°C, while it reached 6.2°C in July 2022, constituting a substantial positive temperature anomaly (Fig. 6b). Additionally, daily maximum temperature recorded at Taxkorgan station during summer 2022 was significantly higher than the long-term mean for 1957-2023 (Fig. S5), with 61% of days in July exceeding the 90th percentile of historical temperatures and satisfying the criteria for an extreme heat event as defined by Lu et al. (2024). This evidence indicates that July 2022 was characterized by significantly elevated temperatures relative to historical baselines. This exceptional climatic event provides a unique opportunity to analyse how glaciers respond to extreme heatwaves in the eastern Pamir.*"

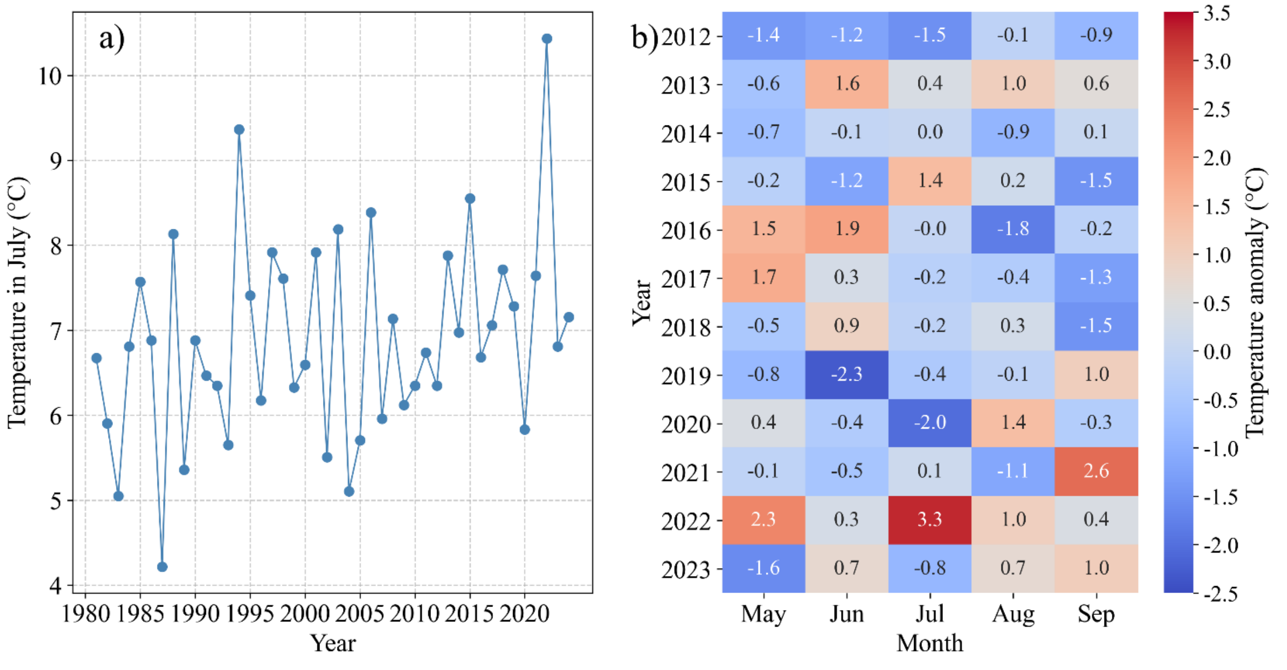

Figure 6. Variation of mean ERA-land air temperature in July at the corresponding point grid of Kangxiwa Glacier during the period from 1981 to 2024 (a) and heatmap of representative monthly air temperature from May to September during 2012-2023 recorded by AWS4900 (b)

42. L239: do you refer to air temperature data here? Please clarify.

Response: Yes, we refer to ERA air temperature. The sentence was revised as: "*The ERA5 temperature data confirmed that the corresponding grid point of the Kangxiwa Glacier in July 2022 was the highest recorded between 1981 and 2024 (Fig. 6a).*".

43. S3: is the slope in Fig. S3b in C/year? Also add "point" to grid in the caption and correct the typo EAR-land.

Response: Thanks. We have added the units °C/year in the legend. Also, we have added “point” to grid and correct the typo as ERA-land. According to comment 41, the subplot showing the July temperature data was removed from the original figure, and the revised version is provided below.

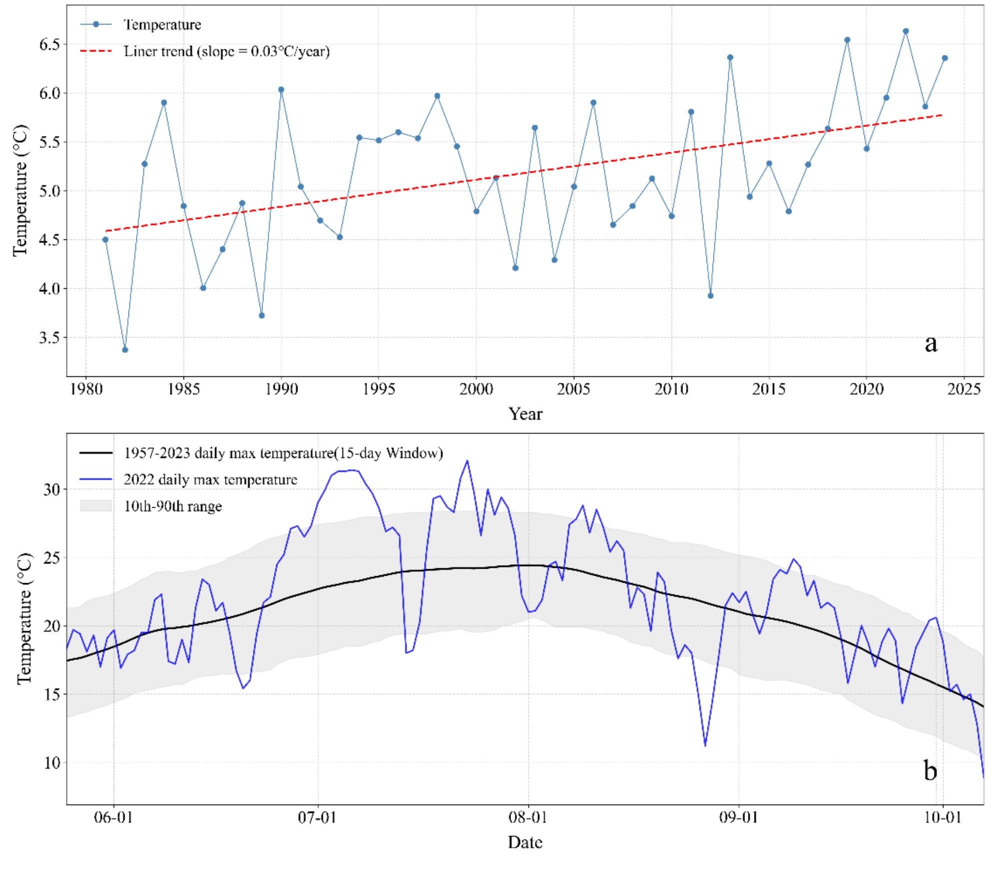

Figure S5 Variation of mean ERA-land air temperature in July (a) and July-September (b) at the corresponding grid point of Kangxiwa Glacier during the period from 1981 to 2024. (c) Comparison of June-September daily max air temperature in 2022 with the 1957-2023 mean at Taxkorgan station.

44. Figure 8: taking an average of 4 years is not very helpful. Is 2022 removed from this average. I suggest plotting all the years in one subplot, without averaging. Also, where are the three heat events based on? What was the threshold (temperature?)? Furthermore, I wonder how representative the location three heat events of this AWS is for Kangxiwa Glacier. Please elaborate.

Response: Precipitation, temperature, radioactive were the average of 2020 2021 and 2023. The three heat events were identified by comparing the air temperature of 2022 with that of 2020, 2021, and 2023 average. The threshold was determined by that the 2022 temperature was higher than that of 2020,2021and 2023 mean. We plotted the variables during the four years in one subplot without averaging (Fig. 2R). However, this figure makes it difficult for readers to distinguish the differences between the variables for 2022 and those for the other three years, so we kept the original figure. Given the short distance between the meteorological station and the glacier, the variation trends of air temperature at the two sites should be consistent; thus, the heatwave events recorded by the AWS4900 can be used to represent the heatwave conditions experienced by the glacier.

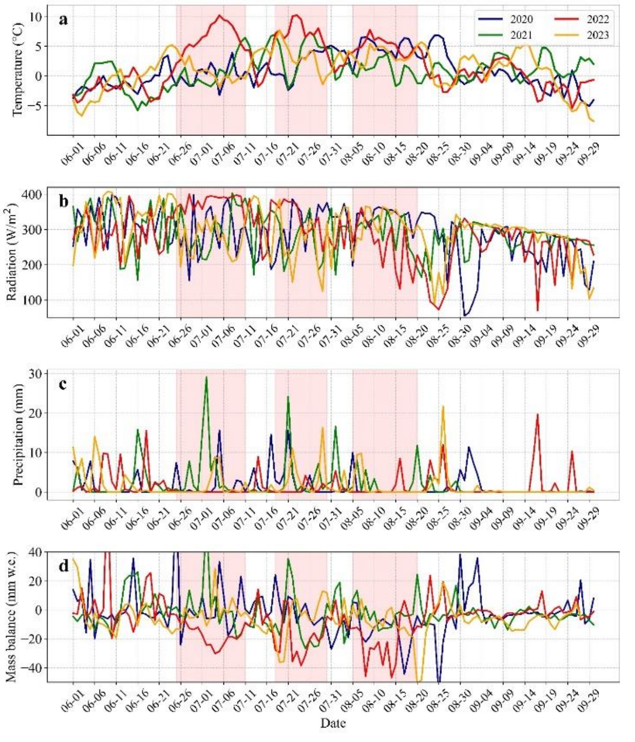

Figure 2R. Comparison of (a) daily air temperature, (b) daily incoming shortwave radiation, (c) daily precipitation and (d) daily glacier-wide mass balance at the Kangxiwa Glacier during the ablation season (June–September), showing the difference between 2022 and the other three years. The grey line shows the average for 2020, 2021 and 2023 with standardized variation (grey shaded area), while the red line shows the records for 2022. Light red rectangles highlight three heat events. The meteorological data was derived from AWS4900.

45. Table 1: calculating anomalies relative to only three other years is not sufficient. To give information about the climate, a longer period is needed. Consider removing Table 1.

Response: Following your suggestion, we have removed the Table 1.

46. Figure 10: this figure is unnecessary. It is visually hard to interpret, and the data has already been displayed in the previous figures. Precipitation and CPDD are not related variables, and it is thus not relevant to plot them against each other.

Response: We have deleted the Figure.

47. L293: the reference to Maussion et al 2012 is not found in the reference list. I might also have missed other references. Please check this!

Response: We have added the missing reference and carefully recheck all references.

48. L302-305: how is this comparative analysis calculated? What is meant with accumulation variability accounts for ~33%? I'd recommend relating the maximum of precipitation and the total ablation to the total mass loss. "Variability in mass loss" is not a clear indicator. Also, refrain from using italics here.

Response: Thanks for point out this. In the revised manuscript, we rephrased it and listed the detailed numbers. "*A comparative analysis between the 2019/2020 and 2021/2022 reveals that less accumulation of 167 mm w.e. in winter season, but more ablation of 494 mm w.e. in summer season in 2021/2022. These results emphasize that interannual variability in the glacier mass balance of Kangxiwa Glacier was predominantly driven by the variability in mass loss during the ablation season.*"

49. L316: less mass loss? Less than? Please rephrase. I think a near-equilibrium state is meant.

Response: The sentence has been corrected as: *Glaciers in the Muztagh Ata have been in a near-equilibrium state since at least the 1970s.*

50. L320: less mass loss? See 49.

Response: it was revised to "near-equilibrium" here.

51. L329: the reference to Oliver et al. (2018) is about marine heatwaves and not relevant here. See comment 6.

Response: We changed the reference as Colucci et al., 2017 and Zhang et al., 2025.

Colucci R., Giorgi F., Torma C., Unprecedented heat wave in December 2015 and potential for winter glacier ablation in the eastern Alps, Scientific Report, 7: 7090, DOI:10.1038/s41598-017-07415-1, 2017.

Zhang, T., Deng, G., Liu, X., He, Y., Shen, Q., and Chen Q.: Heatwave magnitude quantization and impact factors analysis over the Tibetan Plateau. npj Clim. Atmos. Sci., 8, 2, https://doi.org/10.1038/s41612-024-00877-x, 2025.

52. L334: what is a 'center of a heatwave'?

Response: We have rephrased as "*Analysis using ERA reanalysis data indicates that the July heatwave event was mainly located on the Pamir Plateau*"

53. L336: an equilibrium cannot be positive. Rephrase to: 'glaciers were previously considered in equilibrium or having a positive glacier mass balance', or similar.

Response: We clarify the expression following your suggestion.

54. L358: what are Rossby wave trains? Please add references to this statement.

Response: We added Hood et al., 2020 as the reference here.

Hood, L. L., Redman, M. A., Johnson, W. L., and Galarneau, T. J.: Stratospheric Influences on the MJO-Induced

Rossby Wave Train: Effects on Intraseasonal Climate, J. of Climate, 33, 365-627 389, 10.1175/JCLI-D-18-0811.1, 2020

55. L360-362: this statement is more appropriate for the introduction.

Response: It was moved to the introduction.

Grammar and typos:

56. L18: remove 'the' before heatwaves

Response: According to the scope of this study, the sentence was revised to "This study analyzes the characteristics of daily glacier mass balance and their responses to the 2022 heatwaves based on time-lapse photography".

57. L20: typo 2019/2000

Response: Sorry for the mistake. we changed 2019/2000 to 2019/2020

58. L20: consider using 'and' instead of 'but'. When using 'but', you would expect mass gain for the other 2 years.

Response: We changed 'but' to 'and'.

59. L23: heatwaves

Response: Done.

60. L24: Glacier Loss Day, remove mass

Response: according to RC2's comment, the term "Glacier Loss Day" was removed.

61. L25: wakened → weakened

Response : Done.

62. L27: remove 'the' before heatwaves

Response: The original sentence was removed according to RC2's comment.

63. L32: occurred → observed

Response: Done.

64. L34: Hewiit → Hewitt

Response: Done.

65. L35: maybe be → might

Response: Done.

66. L37: are 'a' critical component

Response: Done.

67. L41: 'the' Tibetan Plateau

Response: Done.

68. L55: Traditional glaciological method and geodetic survey → The glaciological method and geodetic mass balance method

Response: Done.

69. L56: dynamics → differences

Response: the sentence was revised to "*However, both approaches face challenges in capturing the high temporal evolution of surface mass balance.*"

70. L60: add 'and' before terrestrial laser scanning

Response: We added "and" before terrestrial laser scanning

71. L61: remove 'the' before extreme melt events

Response: 'the' was removed.

72. L63: developed → introduced

Response: this sentence was revised to "*New indices like the Glacier Loss Day (GLD), which was defined as the day when net mass balance becomes negative and winter snow is exhausted (Voordendag et al., 2023), have provided new insights into short-term mass balance variations.*"

73. L106, 107, 144, 148-151, 195: hight → height, but this actually needs to be the melt out length of the stake.

Response: Thanks for the suggestion, we used "stake melt-out length" in the revised version.

74. L118: S channel → S-channel

Response: "-" was added.

75. L145: dynamics → changes.

Response: the sentence was removed according to comment 19.

76. L158: glacial → glacier

Response: the part was removed.

77. L177: Fig 1 → fig 1b

Response: Done.

78. L207: "which own significant mass loss". Please clarify/rewrite.

Response: According to comment 29, we replotted this figure using different color for each hydrologic year.

79. L239: the corresponding grid → add "point"

Response: Done

80. L252: add a reference to Fig. 8b after the radiation values.

Response: we added "Fig. 7b (new Figure)" after the radiation values.

81. L317: analysis → analyses

Response: Done

82. L319: remove ground.

Response: we removed "ground".

83. L320: Ata regions → region.

Response: we changed "regions" to "region".

84. L328: remove the extra point after region.

Response: we deleted the extra point.

85. L330: replace dynamics with response.

Response: we changed "dynamics" to "changes".

86. L352-354: repetition of the previous sentence. Also, see comment 45.

Response: we deleted the repeated sentences.

87. L365: abbreviation TP is not introduced before. Tibetan Plateau, right?

Response: we changed 'TP' to 'the Tibetan Plateau'.

88. L376: "spring accumulation-summer ablation". Check spelling with hyphens here and make it the same throughout the paper. Is this type invented by the authors or have other glaciers similar behaviour?

Response: Fujita and Ageta (2000) used "winter-accumulation-type" and "summer-accumulation-type". Maussion et al., 2014 used "spring-accumulation type". The hyphen was placed between the seasonal term (e.g., spring/summer) and accumulation/ablation. We revised the sentence as: "generally characterizing glaciers in the eastern Pamir as *"spring-accumulation and summer-ablation"* type.". Previous research (Xu et al., 2017) shows that Urumqi Glacier No. 1 in the eastern Tien Shan has a similar behavior with the Kangxiwa Glacier.

Fujita K and Ageta Y.: Effect of summer accumulation on glacier mass balance on the Tibetan Plateau revealed by mass-balance model, J. Glaciol., 46(153), 244-252, 2000.

Maussion, F., Scherer, D., Mölg, T., Collier, E., Curio, J., and Finkelnburg, R.: Precipitation Seasonality and Variability over the Tibetan Plateau as Resolved by the High Asia Reanalysis, J. Climate, 27, 1910–1927, https://doi.org/10.1175/JCLI-D-13 00282.1, 2014.

Xu, C., Li, Z., Wang, F., Li, H., Wang, W., and Wang, L.: Using an ultra-long-range terrestrial laser scanner to monitor the net mass balance of Urumqi Glacier No. 1, eastern Tien Shan, China, at the monthly scale, J. Glaciol., 63(241), 792-802, 2017.

89. L379: brought forward? Please rephrase. For example, the GLD occurred one month earlier in 2022 compared to the other three years, due to exceptional melting early in the season and/or under average precipitation amounts in winter.

Response: we rephrased this sentence as "*Coupled with below-average winter–spring accumulation, these heatwaves pushed the equilibrium line altitude above the glacier's maximum elevation.*"

90. L383: replace deficit by loss.

Response: According to RC2's comment, the original sentence was revised to "*Our findings clarify their vulnerability to short-term climatic extremes and validate a practical surface mass balance monitoring method for remote mountain regions*"