Response to RC2

The manuscript is reasonably well written and the figures are clear and generally informative, if not a bit redundant at times. The work is of sound scientific quality for the most part, but I struggle to find clearly-driven or stated research questions and support for a few statements in the manuscript. I believe that the relevance of the work needs to be more strongly supported in relation to the past research in the region. Moreover, a clearer presentation and discussion of the magnitude of summer heatwave events during the last decades is required, especially in the context of its role during the anomalous periods of stable or positive mass balance years. A sensitivity to an extreme heatwave year (2021-2022) alone is not suggestive of a termination of the Karakoram-Pamir anomaly as the authors state in their abstract. In several places, there are also unclear statements or those that are not clearly backed by robust tests (e.g. the relative role of precipitation and accumulation on the glacier compared to melt events). Ultimately, the relevance of the presented work needs to be placed better into the context of the broader mass balance patterns and changes over the last decades and considering the role of precipitation and snowfall/albedo. The authors should also work hard to improve the clarity of the text and spelling in several places. Based upon my comments below, I suggest major revisions before the manuscript could be accepted by the journal.

Response: Thank you for your time and constructive comments on the manuscript. We considered each comment carefully and incorporated practically all of them in the revised manuscript. In terms of research motivation and objective, we have added detailed descriptions of the research objectives into the last paragraph of the Introduction. And we also added the past research in the region, in particular the regional mass balance in the discussion Section. Following your suggestion, we did not mention the termination of the Karakoram-Pamir anomaly in the revised manuscript. We added an analysis of the impacts of precipitation variability on glacier ablation intensity to the Result and Discussion section, in particular the precipitation phase. Incorporating the community comment, we compared the mass balance variations of adjacent glaciers and added relevant discussion. We revised the spelling errors and unclear expression. Below are our point-by-point responses (blue color) and the changes we've made to the paper (in italic).

Major comments

1. Research Questions: The manuscript provides no clearly stated research questions that help to direct the main goal of the analysis and its context. The title indicates that heatwaves form the main focus of the paper and timelapse imagery is the tool by which it is evaluated, but the focus falls upon a single extreme year with no historical context regarding heatwave occurrence (or inference from reanalysis etc). While most of the material to frame this is available in the introduction, the goals (or even hypotheses) of the manuscript need to be clearly motivated and established at the end of the introduction.

Response: We sincerely appreciate this insightful suggestion. We have reclarified the research objectives of this study at the end part of the Introduction. We highlight the critical the knowledge gap regarding glacier responses to extreme heatwaves and address the advantages of time-lapse camera-based daily mass balance observations for high-resolution investigations of glacier response. We also revised the three main goals of our study, which include: (1) characterizing the contrasting seasonal mass balance patterns of the Kangxiwa Glacier in the eastern Pamir across the 2019/2020 to 2022/2023 balance years under varying climatic forcing regimes; (2) quantifying the sensitivity of surface mass balance to the extreme 2022 summer heatwaves; and (3) identifying the atmospheric circulation anomalies linked to the 2022 heatwaves using ERA5 reanalysis data, and further elucidate regional glacier response heterogeneity. Please see the following description and more details in the introduction.

"In the summer of 2022, heatwaves swept across many parts of the Northern Hemisphere, causing extreme heat events in North America, Europe, and the Yangtze River in China (Lu et al., 2022). However, the processes and mechanisms through which these heatwaves impact glaciers in the Eastern Pamir—long considered climatically stable—remain poorly constrained. To address this critical knowledge gap, this study prioritizes time-lapse camera observations to capture daily surface mass balance, complemented by in-situ stake measurements for cross-validation, and integrates ground-based meteorological station records and reanalysis datasets to interpret the associated climatic contexts and underlying mechanisms. 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 across the 2019/2020 to 2022/2023 balance years under varying climatic forcing regimes; (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 heterogeneity."

2. Relevance and context within an anomalous region: The authors present some new understanding in a relatively under-studied region of anomalous glacier behaviour, but focus largely upon the role of temperature during summer heatwaves in one year toward affecting mass balance. Nevertheless, in such a region where winter and spring accumulation regimes dominate, the role of antecedent precipitation, accumulation and surface conditions will also have a strong impact on the annual mass balance. The variability of precipitation is one of the suggested mechanisms that was driving the mass balance anomaly for the region (e.g. Farinotti et al., 2020; de Kok et al., 2018) that has now likely ended (e.g. Hugonnet et al., 2021; Jouberton et al., 2025). However the authors present an unclear case for the role of precipitation variability in the winter and spring and, again, provide little broader context related to historical changes. Additional discussion and reframing of the manuscript are needed to provide a more valuable insight for the reader.

Response: We also appreciate this insightful suggestion. We acknowledge that precipitation constitutes another critical factor influencing regional glacier mass balance, particularly the cascading feedback effects of antecedent precipitation, which modulates the albedo feedback mechanism during the summer season. Quantitative assessment of this relationship via sophisticated modeling approaches lies beyond the scope of the present study. We have supplemented an analysis of its impacts on summer glacier mass balance in the Results section, noting that the intense ablation observed in the summer of 2022 was also linked to the variations in the timing of heatwave occurrence and the combination with seasonal distribution of precipitation. The present study focuses specifically on the impacts of summer extreme high temperatures on 2022 glacier ablation, with a comparative analysis against the other three reference years to underscore this core research focus. Please see the details in Discussion 5.1.

3. **Uncertainties:** The estimation of uncertainties and use of the additional mass balance stake observations (i.e. not at the timelapse camera locations - Figure 1) needs more clarification and justification in the study. The glacier-wide mass balance is computed from a weighted average of the three-point mass balance derived at the location of the timelapse cameras, based on their elevation and the hypsometry of the glacier. I do not understand if and how the 10 mass balance stakes are used to help constrain the extrapolation to the whole glacier, especially the 7 stakes which are not located near the cameras. I do not see anywhere that reports the mass balance derived from all of the stakes, which are presented in the map of the study site (Fig. 1d). The differences in mass balance retrieved at the three cameras, shown in Figure 6, highlight the large mass balance variability with elevation, which is not necessarily linear. Therefore, I am wondering how this simplified extrapolation affects the glacier-wide mass balance results and the results of the study in general. The three locations will have different sensitivity to the heatwaves, depending on the baseline temperature and its proximity to the freezing point. The relevance of avalanches and other re-distribution processes is not mentioned or discussed and the authors do not subsequently consider any of the uncertainties in their main results when citing key numbers.

Response: All three reviewers have highlighted this critical issue. In response, we have supplemented the relevant descriptions in the Methods section and added a new subsection (**4.1 Performance of glacier mass balance estimation based on time-lapse camera observations**) to the Results chapter of the revised manuscript. 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. Please see the details in the revised manuscript in Method.

Glacier-wide daily mass balance was then derived by area-weighted sum of point-scale mass balance estimates from the three cameras. A 30-m resolution SRTM DEM was employed to quantify the area distribution with its elevations. The cameras were deployed near the terminus, middle and upper region of Kangxiwa Glacier, allowing the entire glacier to be partitioned into three distinct zones centered approximately on each camera's installation site. These three zones corresponded to the elevation ranges of 4960–5080 m (area weighting factor: 0.33), 5080–5200 m (area weighting factor: 0.38), and 5200–5390 m (area weighting factor: 0.29). Notably, each zone aligns with one camera deployment location and accounts for roughly one-third of Kangxiwa Glacier's total area. Kangxiwa Glacier features relatively flat topography (Fig. 1), and mass balance measurements from 10 ablation stakes further confirmed a linear elevation-dependent mass balance. These characteristics justified the extrapolation of glacier-wide mass balance from the limited set of point observations. Finally, the camera-derived mass balance estimates were validated against results obtained via traditional glaciological methods based on the 10 ablation stakes across the glacier.

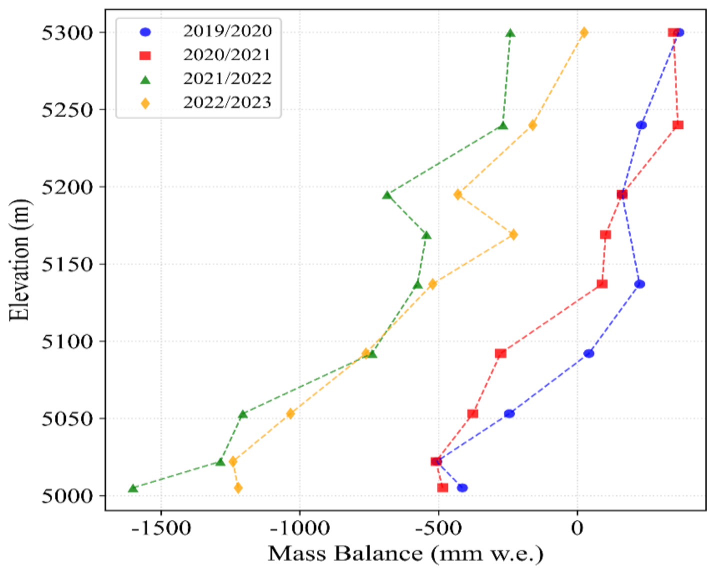

Figure R1 The elevation distribution of point mass balances measured by 10 stakes over 2019/2020-2022/2023 hydrologic years

We have also included a new Figure 4 (see below) to illustrate comparisons between the field stake method and camera-based mass balance observations at both point and glacier-wide scales. These comparisons demonstrate the robustness of daily glacier mass balance calculations derived from three camera-based observation systems, which cover the lower, middle, and upper reaches of the glacierized area.

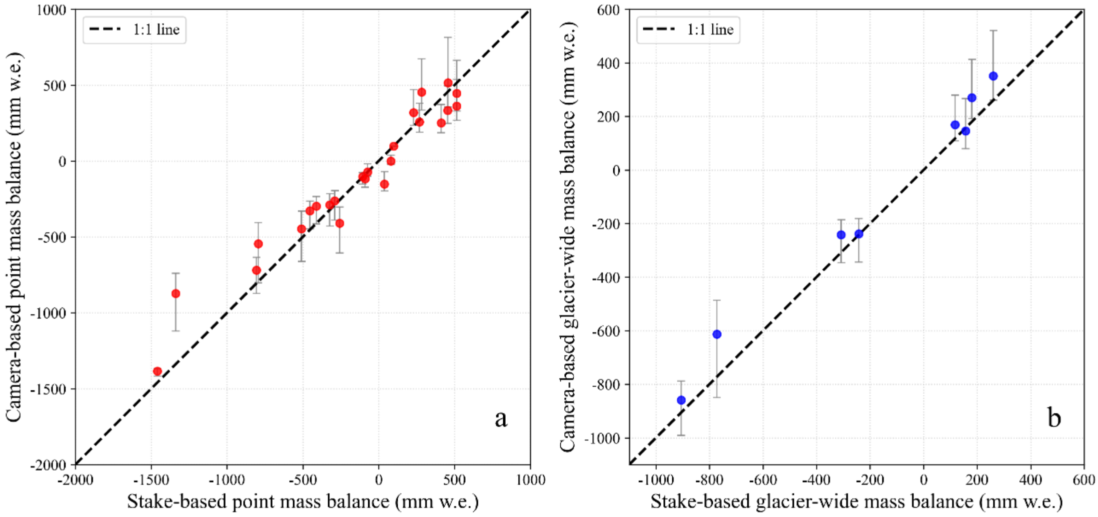

Figure 4 The comparison of pointed mass balance (a) and glacier-wide mass balance (b) measured by using the stake method and the Time-lapse photography on the Kangxiwa Glacier.

4.1 Performance of glacier mass balance estimation based on time-lapse camera observations

Figure 3 shows a comparison of the cumulative point mass balance estimates derived from the time-lapse cameras and the glaciological method at the three camera sites (5005 m, 5137 m and 5300 m) on the Kangxiwa Glacier during the period from 2019/2020 to 2022/2023 balance years. Figure 4a further presents the seasonal comparative performance of point-scale mass balance (winter and summer). 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. Over the entire observation period, the mean discrepancies between the two datasets across three points yield an overall mean of 26 ± 149 mm w.e.

At the glacier-wide scale (Fig. 4b), the camera-based seasonal mass balance data exhibit a robust linear correlation with the stake-based counterparts (e.g., R^2 = 0.98), with almost all in-situ stake-based values falling well within the uncertainty bounds of the camera-based estimates. The mean discrepancy between the two datasets is 62 ± 54 mm w.e., indicating high consistency between the camera-based approach and the glaciological method. This robust agreement not only validates the reliability of time-lapse camera observations for quantifying glacier mass balance but also establishes a solid foundation for investigating temporal evolution characteristics of glacier-wide mass changes for the Kangxiwa Glacier.

4. The role of precipitation phase and surface albedo changes in glacier mass balance sensitivity is neglected: Figure 6 shows the derived daily glacier-wide mass balance and the time series of precipitation recorded at the nearby automatic weather station. The agreement in timing between precipitation events and increases in glacier mass balance can be clearly seen from the figure. However, it is unfortunate that little attention is paid in the manuscript to precipitation type, especially considering that snowfall replenishment and albedo reset are suggested to play a key role in glacier mass losses (e.g. lines 278-281). Summer snowfall will be a function of precipitation and air temperature, and I expect substantial differences along the altitudinal gradient of the glacier, which is not apparent, as most of the latter analyses in the manuscript focus on glacier-wide mass balances. I would suggest that the authors look at precipitation phase types, leveraging their meteorological observations and applying simple phase partitioning schemes such as dual-temperature thresholds or wet-bulb based parametrizations (Ding et al. 2014), to look at the amount of seasonal snowfall for each hydrological year and per elevation, and include this as part of the discussion on the inter-annual variability of glacier mass balance and sensitivity to heatwaves. The authors highlight the role of surface albedo on ablation rates, with the example of the 3rd period of heatwave in 2022 experiencing similar melt rates as earlier heatwaves despite lower air temperatures, likely due to darker surface conditions. With daily photos available for the three sites, it could be worthwhile examining the number of days per summer with bare-ice/darker albedo conditions, and linking this, even qualitatively, to ablation rates.

Response: Following your suggestion, we quantified the rainfall and snowfall contributions at the three camera sites using the method proposed by Ding et al. (2014), coupled with meteorological observations from AWS4900 and the AWS at the Muztagh Ata observation station (3650 m asl). The air temperature and pressure lapse rates were set at 0.6 °C per 100 m and 7.6 Pa m^{-1}, respectively; additionally, the annual precipitation elevation gradient was 11.2 mm per 100 m, and the relative humidity lapse rate was 1.3% per 100 m. Figure R2 below presents the seasonal snowfall and rainfall totals for each hydrological year across the three camera locations. Results indicate that precipitation in the glacierized area is dominated by snowfall. This explains the strong temporal consistency between precipitation events and increases in glacier mass balance in original Figure 6. Even during the exceptionally warm summer of 2022, snowfall accounted for 93.7% of total precipitation at the glacier terminus (5050 m asl), 95.7% at 5137 m asl, and 99.1% at 5300 m asl. The scarcity of rainfall in the glacierized area confirms that precipitation phase transitions likely exert only a minor influence on the surface energy–mass balance. We have added the relevant description in the Results 4.2.

As noted in Major Comment 2, in regions dominated by winter–spring accumulation regimes, antecedent precipitation, accumulation dynamics, and surface conditions also exert a substantial impact on annual mass balance. This contributes to the modulation of surface albedo and, in turn, ablation rates, as exemplified by the third heatwave event of 2022. This event exhibited comparable melt rates to earlier heatwave episodes despite lower ambient air temperatures, a pattern likely attributable to reduced surface albedo (darker surface conditions). We also further address such mechanisms in the Result Section when we explain the possible reason why the third heatwave contribute to the intensive melting. Please see the Result Section 3.3 in the revised manuscript.

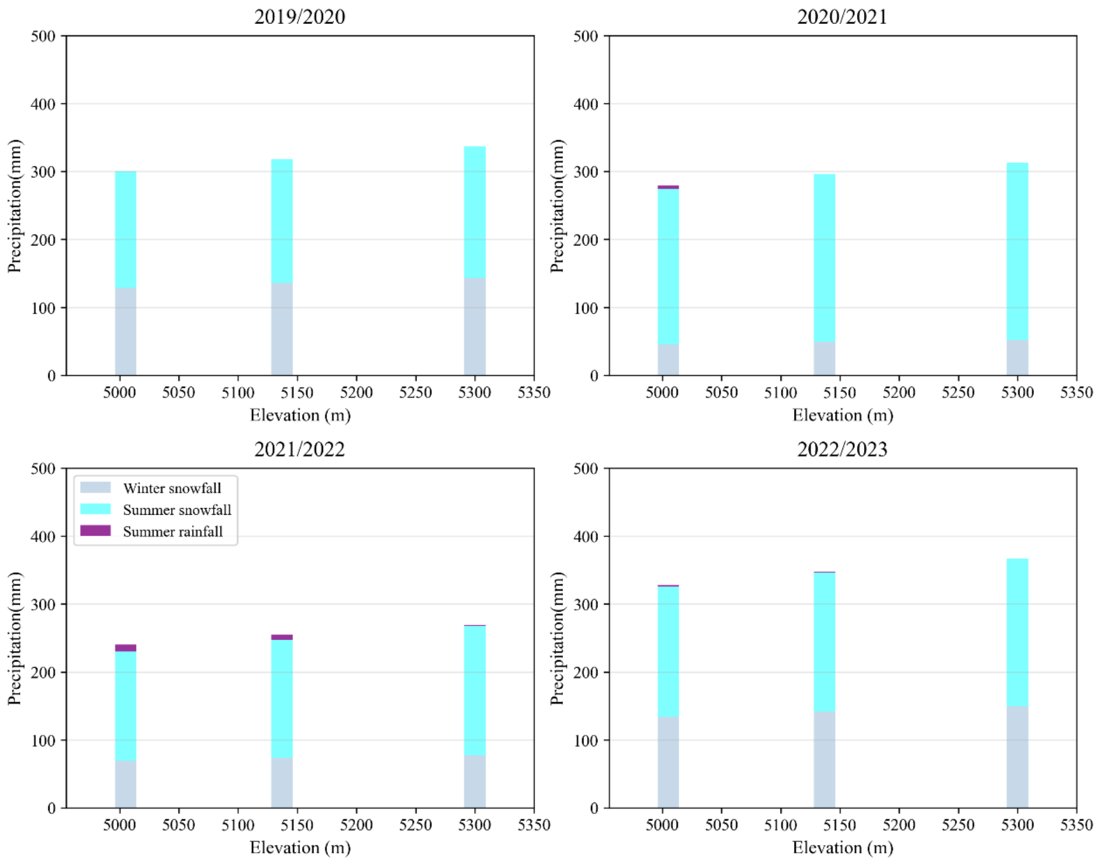

Figure R2. Seasonal snowfall and rainfall totals for each hydrological year across the three camera locations.

Additionally, we compared the number of bare ice days and summer mass balance at the 5005 m and 5137 m sites over the 2019/2020 to 2022/2023 hydrological years (Figure R3). There exists a certain negative correlation between the number of bare ice days and summer (June-September) mass balance. However, due to the limited number of data points, this study cannot perform a reliable statistical quantitative analysis of the relationship between these two variables.

In the revised manuscript, we highlighted in the Results section that the significant increase in bare ice days during the summer of 2022 contributed to substantial mass loss, attributable to the lower albedo of bare ice compared to snow. We have added the following sentences: "*At the 5005 m site, the number of bare ice days from June to September reached 42 in 2021/2022, compared to 4, 23, and 13 days for the 2019/2020, 2020/2021, and 2022/2023 hydrologic years, respectively. This marked increase in bare ice days enhances glacier surface energy absorption, which partly explained the substantial mass loss in the summer of 2022.*"

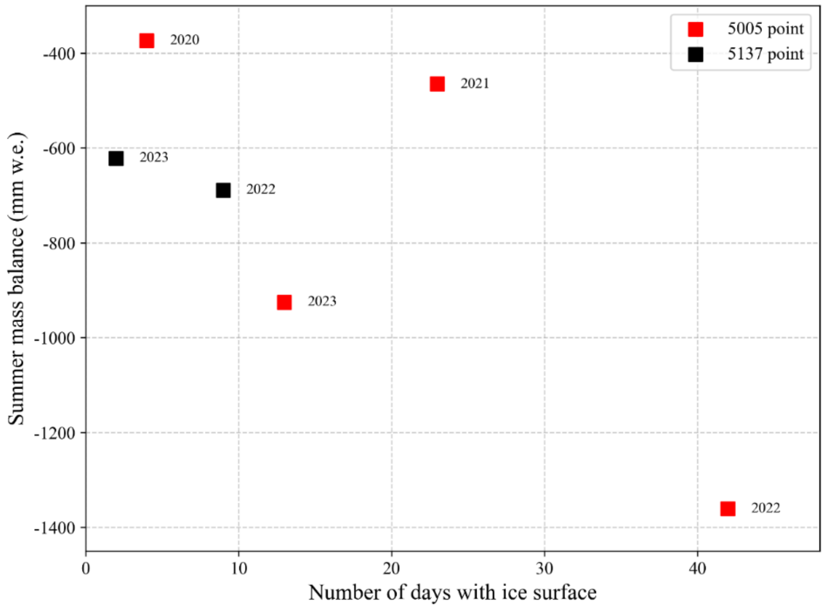

Fig. R3 Relationship between the number of days with bare ice surface and summer balance at the 5005 m and 5137 m points

5. Redundancy and lack of clarity in figures: Figure 2 presents the methodology of the automatic extraction of height changes from time-lapse photography, but could be completed with a scheme or additional indications to help the reader visualize the different lengths introduced in the methods (L, Lp, Lpv, Lpa), making this section easier to follow. Figures 3 to 6 are somewhat redundant, showing the daily evolution of surface changes at the cameras' locations in various ways and units. I do not think Figure 4 adds much to the manuscript; it is mostly an overlay of Figure 3's content, and the inter-annual differences can already be seen clearly in Figure 6.

Response: Following the reviewers' recommendations, we have added relevant annotations to the original Figure 2, deleted Figure 4, and provided the revised figures below. Corresponding revisions have been made to the subsequent Methods section in line with the updates to Figure 2. In response to Reviewer Comment 1, the original Figure 6 has also been revised and the original Figure 7 was moved to the supplementary material. Additionally, we have included two new figures: one illustrating the performance of glacier mass balance estimation based on time-lapse camera observations, and another depicting the unprecedented summer warming event in 2022 in the eastern Pamir. Please refer to all updated figures in the revised manuscript.

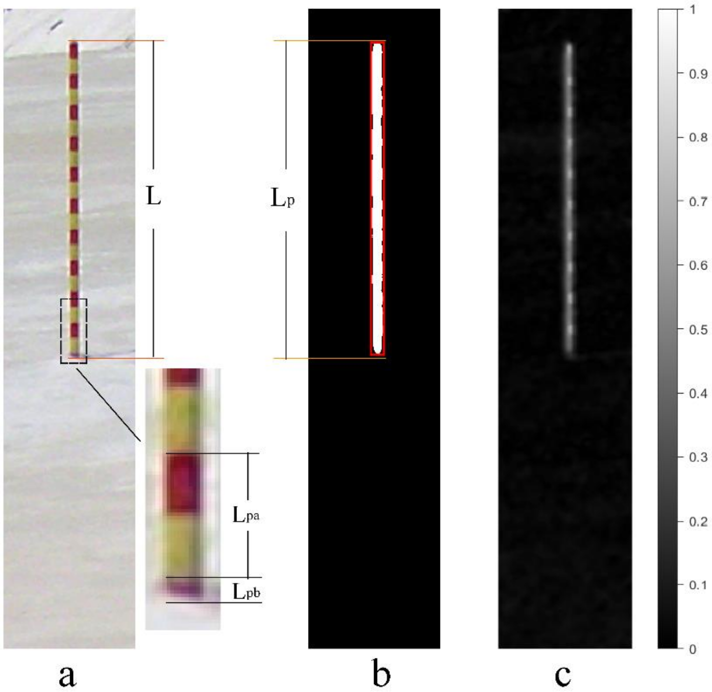

Figure 2. Illustration of image processing. (a) The original image with a frame. The bottom part of the stake is shown in a magnified view. (b) the contour of the scale stake with the minimum bounding rectangle in red; (c) the grayscale representation of the S- channel.

6. Clarity of the structure of the manuscript: A substantial part of the manuscript introduces the set-up used to monitor glacier mass balances. The daily mass changes derived from time-lapse imagery are presented in the methods, but they could equally be shown in the results section. While both options would probably be fine, an outline of the paper's structure could be given at the end of the introduction, which is commonly done to guide the reader through the paper.

Response: We have revised the methodology section and relocated certain descriptive content to the results section. Additionally, we have explicitly addressed the knowledge gaps and core objectives of this study in the introduction. To comply with the guidelines of The Cryosphere, we have omitted the outline of the paper structure in the revised manuscript. Furthermore, both the title and key research objectives have been refined to center on the 2022 heatwave event, rather than long-term heatwave.

Minor comments

1. Title: "In-situ Measurements" is quite broad, especially since Time-lapse photography can be considered as one of the in-situ measurements. Consider replacing it with something more specific (e.g., meteorological observations) or remove.

Response: We removed "In-situ Measurements" from the title. Regarding the key method of Time-lapse photography for high-resolution daily mass balance estimation, the revised title was changed as "*Glacier Mass Balance and Its Response to the 2022 Heatwaves for Kangxiwa Glacier in the Eastern Pamir: Insights from Time-Lapse Photography*".

2. Line 15: "anomalous less changes" is unclear and should be re-formulated. Anomalously less negative mass balances?

Response: We revised as "*anomalously less negative mass balances*".

3. Line 17: scarcity of high resolution observations of what? What resolution? Please clarify and state more specifically.

Response: we mean temporal resolution. It was revised to "scarcity of high temporal resolution of mass change observations".

4. Line 18: "the heatwaves", remove "the" if you do not specify which heatwaves are referred to here.

Response: It was specified as "the 2022 heatwaves".

5. Line 20: "2019-2000" is probably a typo.

Response: Sorry, we changed "2019/2000" to "2019/2020".

6. Line 19: there are no meteorological observations at the glacier itself. Rephrase.

Response: we added "nearby" to the sentence. The revised sentence is "*This study analyzes the characteristics of daily glacier mass balance and their responses to the 2022 heatwaves based on time-lapse photography, ablation stake/snow pit measurements and nearby meteorological record collected at the Kangxiwa Glacier in the eastern Pamir.*".

7. Line 21: "Observations evidence" -> "Observations show"

Response: Done

8. Line 24: The concept of the glacier loss day is not yet a widely-adopted term and should be avoided for the abstract and rather be clearly stated what it means.

Response: Following your suggestion, we deleted the glacier loss day in the Abstract.

9. Line 25: spelling ("wakened" -> "weakened").

Response: Done

10. Line 27: Are there any glaciers not sensitive to heatwaves?

Response: We deleted the sentence.

11. Line 27-28: A strong mass balance response to a single year with heatwaves cannot be used alone to suggest the end of the regional anomaly that is decadal or multi-decadal. Please remove or rephrase to be precise about what it can show/suggest.

Response: We revised it as "*Our finding revealed that short-term heatwaves can trigger substantial glacier mass loss in the Easter Pamir, once considered climate-resilient, suggesting that "Pamir–Karakorum" anomaly is being challenged by the rising frequency of extreme heat events.*"

12. Line 46-47: Specify "in this region".

Response: We added "*in this region*" at the end of the sentence.

13. Line 50: remove "s" from "for examples".

Response: Done

14. Line 54: The Oliver et al. reference describes marine heatwaves and is not really appropriate (also in the discussion). The authors should try and provide some numbers for heatwaves in High Mountain Asia. Here they describe extreme events in general, but this can also be precipitation extremes, snow accumulation extremes or others that can affect glaciers. Please be specific regarding the characterisation of heatwaves in the region, or clarify that no such data/studies are available if that is the case.

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. Following your suggestion, we only address the impact of heatwaves, rather than extreme events due to few such data and studies in the High Mountains.

Ref:

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.

15. Line 63: Remove "d" from "Characterized".

Response: the sentence was revised as: "*Recent advancements in high-temporal-resolution monitoring techniques to monitor ablation, such as the SmartStake 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, including their response to extreme melt events (Cremona et al., 2023).*".

16. Line 65-66: State clearly the research questions/hypotheses of the study here.

Response: We stated the research questions. *(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 explore regional glacier response.*

17. Line 67: "Study regions" -> "Study region".

Response: Done.

18. Line 73: Any reference for this value of 70 mm of annual precipitation? From the AWS? It seems quite low (under-catch corrected?) and appears wholly inconsistent when compared to the accumulation values given later on in the manuscript.

Response: The mean value is from the Taxkorgan meteorological station (~3091 m a.s.l.) ~50 km south of Muztagh Ata), during 1960-2015. We also added the references in the revised manuscript.

Ref:

Li, Z., Wang, N., Chen, A., Zhang, L., and Zhang, Y.: Slight change of glaciers in the Pamir over the period 2000–2017, Arct. Antarct. Alp. Res., 54, 13–24, https://doi.org/10.1080/15230430.2022.2039766, 2022.

Lv, M., Quincey, D., Guo, H., King, O., Liu, G., Yan, S., Lu, X., and Ruan, Z.: Examining geodetic glacier mass balance in the eastern Pamir transition zone. J. Glaciol., 66, 260, 927-937. https://doi.org/ 10.1017/jog.2020.54, 2020.

19. Line 77: Are there no geodetic estimates of Hugonnet et al. (2021) for the specific glacier?

Response: We have added in the text "*Geodetic estimates indicate that the average mass balance of Kangxiwa Glacier was -0.13±0.99 m water equivalent (w.e.)*"

20. Line 84: You could specify the date and time at which the photo was taken

Response: We added the date of 20 June, 2020 in the caption.

21. Line 92: "900 kg/m^3", any justification or citation for this value? Why not follow the common values of the literature with uncertainty ranges?

Response: Following the suggestion and RC1'S comment, we added reference of Huss (2013) here.

Ref:

Huss, M.: Density assumptions for converting geodetic glacier volume change to mass change, The Cryosphere, 7, 877–887, 2013

22. Line 96-105: Can the authors provide information about the distance to the stake from the camera and the resultant pixel resolution?

Response: The distance between the cameras and the stakes was estimated to approximately 6-10 meters. We have added this information in the text. Unfortunately, the camera manual does not provide the information of focal length, so it is difficult to calculate the pixel resolution.

23. Line 106: spelling mistake ("height, not "hight"). Here and in several places (Line 150 etc). Please revise and check carefully throughout the manuscript.

Response: Sorry for the spelling mistake. We have corrected them in the whole text.

24. Line 143: "0.18 cm" reads like a very precise number. Make sure that you don't give numbers with a number of digits that goes beyond the precision achieved by your detection method.

Response: We have revised all the numbers and their precise. We did not mention this value in the revised manuscript. Centimetre-level precision was used for calculation.

25. Line 152: How was the surface condition classified (snow vs ice)?

Response: The surface conditions were derived through visual inspection of the photos manually (snow/ice). This information was added in the revised text.

26. Line 155: Do you have any justifications for the upper and lower bounds of snow density assumed? Could fresh snow fallen during very cold temperatures not have a density lower than 300 kg/m^3?

Response: The upper and lower bounds of snow density were adopted by in situ measurements of snowpack. The minimum and maximum snow density at the three sites during the four balance year were 286 kg/m^3 and 587 kg/m^3 respectively. We added the relevant information in the revised manuscript.

27. Line 159: Can you be more explicit regarding what "lower" glacier mass changes mean here? Does it mean less negative, more negative, or less positive?

Response: It means less negative here.

28. Line 160: "-409.02 mm w.e.", cf. comment above, I do not think the precision of your mass changes derived from the camera is higher than 1 mm. Consider changing to "-409 mm w.e."

Response: Thanks for pointing out this issue. We have rounded all the data in the revised manuscript.

29. Line 165: I am not sure if a website link is acceptable, do you have a proper reference for the digital elevation model used?

Response: The SRTM DEM was used to calculate the area distribution of Kangwure Glacier. We did not provide the website in the revised manuscript.

30. Line 166: What about avalanches? Are they common on this glacier? Are these stakes really representative of those entire elevation bands? Following the major comment above, this needs to be critically considered when deriving uncertainties and at the very least, be discussed

Response: The topography condition of Kangxiwa Glacier is relatively flat (Figure 1) and the 10 stake mass balance measurement evidenced that there are linear mass balance gradients. There are no avalanches in the upper regions. We also compared both pointed and glacier-wide winter/summer mass balance calculated by using the traditional in-situ ablation method and the time-lapse photography on the Kangxiwa Glacier. 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 glacier-wide mass balance in Result section in the revised manuscript (new Figure 4).

31. Line 167-168: Please clarify how the gaps were filled, as it is not clear from the description here in the manuscript.

Response: We have rephrased the description more clearly. The data gap was filled by using the interpolation method. And we have added this in the Section 3.2.3

Limited data gaps were interpolated using adjacent measured values. The data gap at the 5005 m site from 1 October 2019 to 20 June 2020 was filled via daily mean mass balance value derived from the corresponding stake measurements.

32. Line 180: Are these solid and liquid precipitation, or only liquid precipitation?

Response: It is all weather precipitation measured by T200B. We have added the information.

33. Line 196: How can the authors assert the role of sublimation from camera data alone at such a temporal resolution? Estimating sublimation requires specific measurements and modelling to characterize well.

Response: 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. S3)*".

34. Line 199: Explain what the ranges of value refer to. Are these the minimum and maximum annual values?

Response: We did not mention the detailed numbers any more in the revised manuscript. They mean maximum accumulation.

35. Line 209-210: Unclear. There are losses from the surface earlier in the season than the start of June (cf. Figure 6).

Response: Thank you for this comment. In the revised manuscript, we have clarified the onset of significant mass loss since the maximum net accumulation.

36. Line 213: specify the years corresponding to each value of the range "-400 to 957 mm" given.

Response: the sentence was revised as "*Another interannual variability lies in the magnitude of annual surface mass loss, with values of -414, -334, -907 and -694 mm w.e. in the 2019/2020, 2020/2021, 2021/2022 and 2022/2023 hydrologic years, respectively.*"

37. Line 219: "thermal conditions" -> "air temperature". To avoid confusion with the ice temperature.

Response: we used air temperature in the revised version.

38. Line 231: How does this interpolation compare to the additional stake data that do not have cameras (see major comment)? Is this the same evaluation that is described earlier in the manuscript (lines 140-145)?

Response: This part was revised as: "*Meanwhile, linear altitudinal interpolation of two complementary datasets- camera-based point mass balances from three elevations and stake-based measurement from 10 ablation stakes- enabled for the quantification of the equilibrium line altitude (ELA) over the study period. The ELAs displayed significant interannual fluctuations: the highest ELA surpassed the glacier summit during 2021/2022 balance year, whereas the lowest ELA (5079~5086 m a.s.l.) occurred in 2019/2020.*"

39. Line 240: The highest what? Be specific.

Response: It means the highest air temperature. The revised sentence was "*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*".

40. Line 267-268: "Mass loss intensity […] was even greater than those during the two July heatwaves" -> This does not seem to be consistent with the numbers given in the last column of Table 1, please check this.

Response: The Table 1 present daily anomalies of mass balance during the three heatwave periods in 2022 relative to the corresponding 2020–2021–2023 average. The value "23.3" is the average daily mass balance for the period of August 5–17, 2022. According to RC1'suggestion, the table was removed.

41. Line 269: Spelling error for "Given".

Response: We corrected the spelling error.

42. Line 269: What is meant by "reduced atmospheric radiations?" Shortwave? Clarify and write clearly and precisely.

Response: It means shortwave. The sentence was revised to "*Given the limited magnitude of warming and the reduced shortwave radiations*"

43. Line 269-271: Figure S2 actually shows fewer ice exposures during this year compared to 2022/2023. How can the authors reconcile this with their suggestion of albedo being the main driver (cf. line 279-281)?

Response: We apologize for the graphical errors. Specifically, we failed to use the latest data for graphing, and the inappropriate plotting method employed in Python, resulted in incorrect visualization of ice/snow cover. According to the revised graph, the duration of bare ice in the summer of 2023 was shorter than that in 2022.

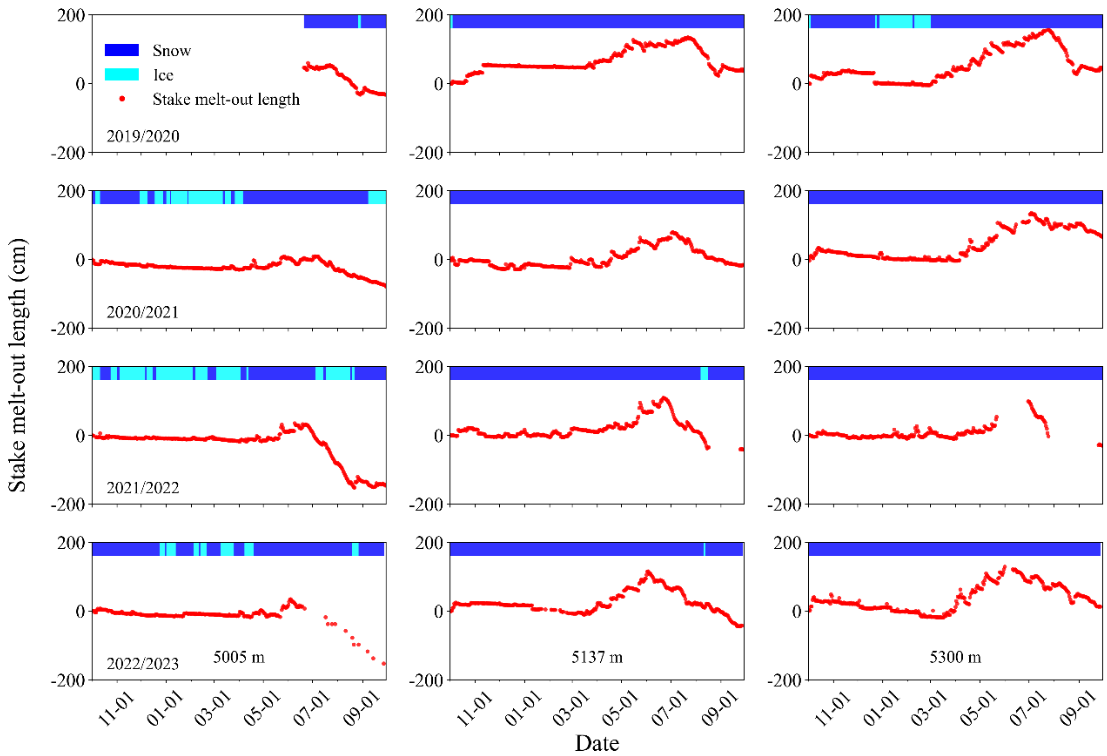

Figure S3 Changes in stake melt-out length derived by subtracting all data from the baseline values recorded on the first day of each hydrologic year on the Kangxiwa Glacier and evolutions of snow and bare ice surface conditions over the hydrological years 2019/2020 to 2022/2023.

44. Line 277: A range of 100 mm is substantial for the region, but again this number and the range is notably larger than the value reported earlier in the manuscript. Please clarify those differences.

Response: Precipitation amount (70 mm) in the "Study region" refers to data from low-elevation Taxkorgan (at an elevation of 3091 m a.s.l.) and serves to demonstrate the dry climate background of the eastern Pamir. The precipitation data utilized to analyze climate condition of the Kangxiwa glacier was monitored by the AWS at 4900 m a.s.l., with precipitation for the 2019/2020, 2020/2021 and 2022/2023 hydrological years around 300 mm. This discrepancy could be attributed to the increase in precipitation with elevations.

45. Line 278: How can the precipitation amounts not explain the differences? How specifically was this tested? Do the authors simply refer to the relationship in Figure 10? What about antecedent conditions and precipitation in the month prior? Once more, the focus falls on heatwaves, but one year and ~3 months of the analysis see heatwaves, whereas the discussion of the paper talks more broadly about the anomalous glacier region and how this might support the end of the anomaly. Ultimately, more care is required in assessing the related role of precipitation and snowfall.

Response: As reply to Major Comments, we revised this paragraph as follows.

Glacier surface melting is critically linked to the energy supply and the surface conditions. The precipitation phrase may greatly influence the snow accumulation and the surface albedo condition (Jouberton et al., 2022). Seasonal snowfall and rainfall amount at each camera-monitored site for each hydrological year were estimated using the method proposed by Ding et al. (2014), combined with meteorological data from AWS4900 and the Muztagh Ata observation station (3650 m a.s.l.). Snowfall accounted for 94% of total precipitation at the glacier terminus (5050 m a.s.l.), 96% at the mid-glacier site (5137 m a.s.l.), and 99% at the upper-glacier site (5300 m a.s.l.) in the warmest 2022. The scarcity of rainfall in summer season across the glacierized area indicates that precipitation phase transitions likely played a limited role in modulating the surface energy–mass balance. At the 5005 m site, the number of bare ice days from June to September reached 42 in 2021/2022, compared to 4, 23, and 13 days for the 2019/2020, 2020/2021, and 2022/2023 hydrologic years, respectively. This marked increase in bare ice days enhances glacier surface energy absorption, which partly explained the substantial mass loss in the summer of 2022. Given the moderate temperature anomaly and reduced shortwave radiation during the August heatwave, the intensive mass loss could be primarily attributed to the exceptionally low surface albedo of exposed ice (Fig. 8), which amplified solar radiation absorption and subsequent melt processes (Mölg et al., 2014).

46. Line 304-305. This is a key statement, but make sure you keep here the link between accumulation variability during the accumulation period and the mass losses in the ablation season. The surface albedo changes will be a function of the seasonal snowpack height, such that the ablation rates are also linked to differences in accumulation (again related to the previous point and the major comment). Also, how have these contribution percentages been calculated?

Response: The original contribution percentages were calculated based on the mass change values and were removed. The relevant statement was incorporated into the Discussion section as following:

Furthermore, variations in the timing of heatwave occurrence and their combination with seasonal distribution of precipitation can also contribute to substantial disparities in the response of glacier surface mass balance to climatic conditions. As illustrated in Figures 5, the mass loss in 2019/2020 was concentrated in August (-346 mm), following a period of high accumulation (+445 mm). In contrast, the 2022 mass balance process featured low spring accumulation and extremely *strong summer ablation driven by heatwaves in July and August. While the ablation periods in 2021 and 2023 were significantly longer than in other years, the average summer ablation intensity was moderate. Unlike the stable mass accumulation observed in June across the other three years, the Kangxiwa Glacier experienced early ablation (-107 mm w.e.) in June 2023, followed by the highest ablation in September over the four-year period. Cumulative mass loss from June onward reached -628 mm w.e. in 2023, which was slightly less than the maximum loss in 2022. These divergent patterns of mass balance evolution not only underscore the complexity of glacier responses to climate change in this region but also highlight the critical importance of continuous, high-temporal-resolution monitoring of glacier surface mass changes to inform future model-based explanations (Barandun and Pohl, 2023).*

47. Line 290: How do glaciers initiate snow accumulation? Please reword.

Response: We rephase as "Barandum et al. (2018) found that glaciers in the West Pamir region received snow accumulation at the start of the hydrologic year and accumulated over 1 m w.e. of snow accumulation during the winter season."

48. Lines 306-313. This reads like a result sentence; consider moving to the result section.

Response: This part was used to discuss the complexity of precipitation/glacier mass balance seasonality and their climate response characteristics and was kept here.

49. Lien 317: Spelling - "stereo" - "analyse"

Response: We corrected the typos.

50. Line 319: 2022 was a positive year from the results of Falaschi? This is then in disagreement with the strong negative mass balances reported by this study therefore? Please clarify how the studies compare and elaborate on the reasoning for any strong contrasts.

Response: Sorry for the mistake. The number was incorrect. It is a negative number -0.17±0.22.

51. Line 342: The high glacier mass loss during the 2022 heatwave was also reported further west in the Pamirs (Jouberton et al. 2025).

Response: Thanks for the suggestion. We added one sentence in the manuscript as follow: "*Latest research (Jouberton et al., 2025) reported that enhanced glacier mass loss linked to the 2022 heatwave in the Northwestern Pamirs*".

52. Line 364: Anticyclone "development"

Response: we changed "developed" to "development".

53. Line 376: What are "regional glaciers"? Please rewrite.

Response: we revised "regional glaciers" to "eastern Pamir glaciers".

54. Line 377: Again what is the role of accumulation regimes within this context of heatwaves and how does this compare with other studies on the sensitivity of glaciers in the region to temperature vs. precipitation? The summer of 2022 also followed a period of anomalously low snow accumulation (April 2022), similar to the European winter of 2021/2022. How much influence did that have?

Response: We rectified the expression to "*Notably, short-term heatwaves could greatly enhance the mass loss and then dominate annual surface mass balance in this region. Three heatwaves in July–August 2022 induced over 800 mm w.e. of mass loss within 40 days. Coupled with below-average winter–spring accumulation, these heatwaves pushed the equilibrium line altitude above the glacier's maximum elevation*."

55. Line 378: What is extreme sensitivity? Relative to what? How/when are glaciers not sensitive to heatwaves? The authors need to be more precise and more scientific in their writing.

Response: we removed the sentence.

56. Line 381-383: This is clearer than what is written in the abstract, but still requires more substantiation in the manuscript. Where do we see evidence of increasing frequency of extreme weather in the East Pamir in the manuscript? Extreme in what sense? Only in heatwaves? Where is the evidence of this and are there any longer term mass balance data that can aid this interpretation of temperature changes and extremes driving this "transition"?

Response: We don't mention transition or the end of the "Pamir–Karakorum" anomaly in the revised version. We highlighted that glaciers in this region may undergo substantial mass loss in response to future extreme high-temperature events.

Figures

Figure 1: Consider replacing the studied area symbol by a more visible marker like a star or a triangle. It is a bit difficult to see in Figure 1a.

Response: A triangle was used as the studied area symbol. Following is the revised figure.

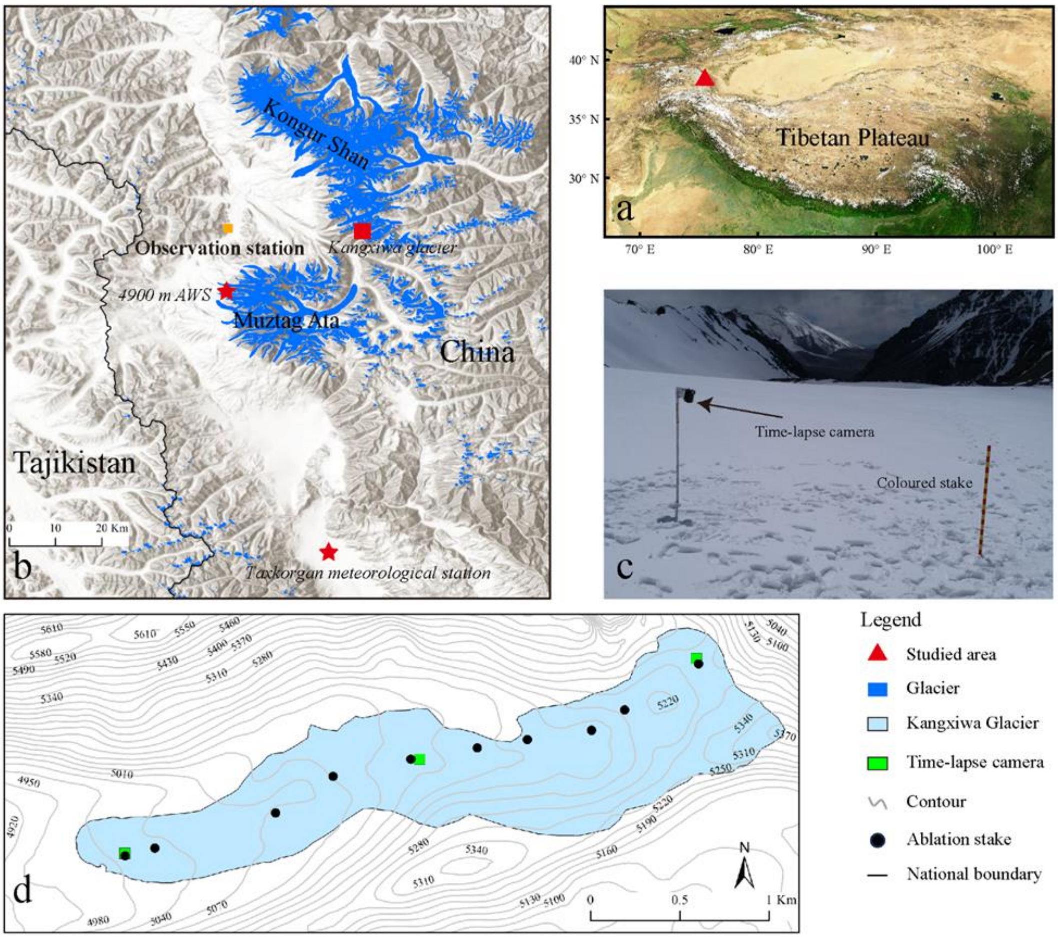

Figure 3: The legend could be misleading, as “manual” could be mistaken as a measurement done by a person physically on-site. Consider expanding the legend as “camera: automatic”, “camera: manual”, or similar.

Response: The legend was revised following the suggestion.

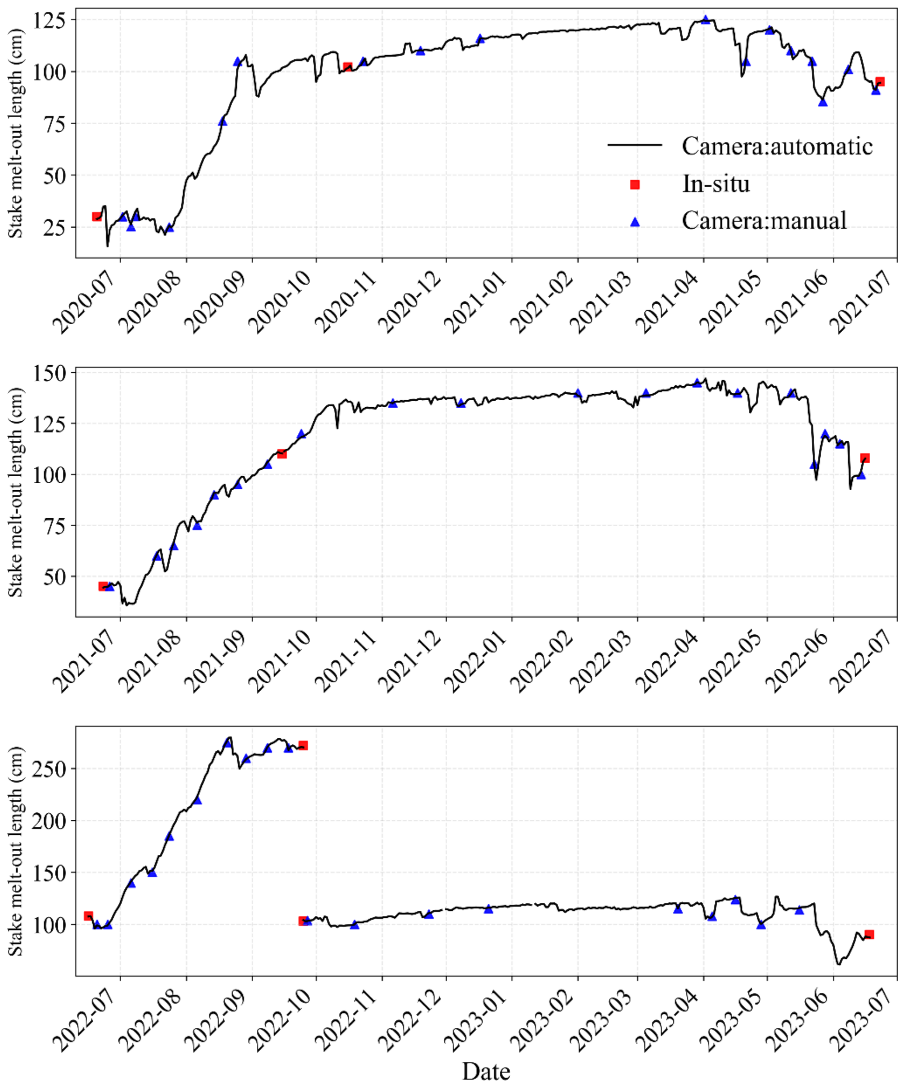

Figure 4: missing a legend for the shaded areas in the figure background.

Response: In the original figure, shaded aeras indicate three phases of glacier mass change: slightly mass change (October to mid-April), mass accumulation (mid-April to June), and ablation (June to September). According to Major comment 4 and RC1's comment, we deleted the figure.

Figure 5: Consider using different scales for the three sub-panels to increase the readability of daily accumulations in the upper two panels. Alternatively, have you perhaps tried to overlay the three curves with different colors in a single panel?

Response: The three curves were replotted in one panel with different colors. Additionally, the filling data of the data gaps were shown with dotted line.

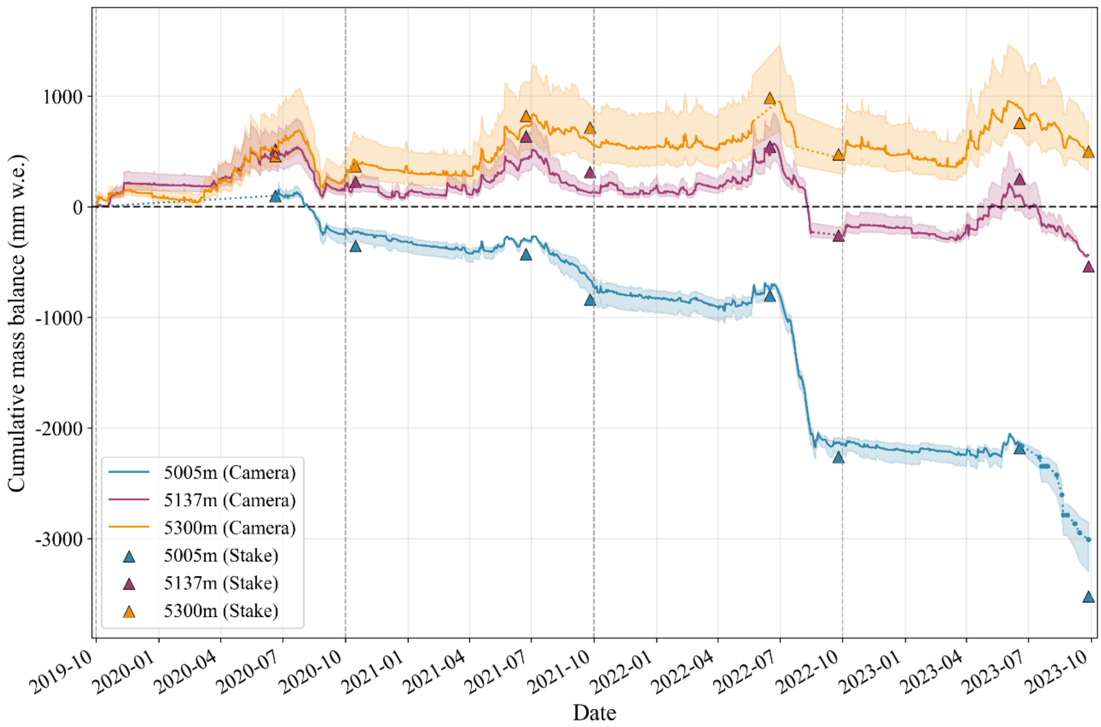

Figure 3. Comparison of the accumulated mass balance estimated using time-lapse cameras (lines) and the glaciological methods (triangles) at the three locations (5005 m, 5137 m and 5300 m) on the Kangxiwa Glacier. Dotted lines denote gap-filled data.

Figure 6: Write in the legend the meaning of the shaded areas around the mass balance lines.

Response: This figure has been redrawn according to RC1's suggestion. We used shaded area to present the mass change uncertain in the new figure below. The meaning of the shaded areas was included in the caption.

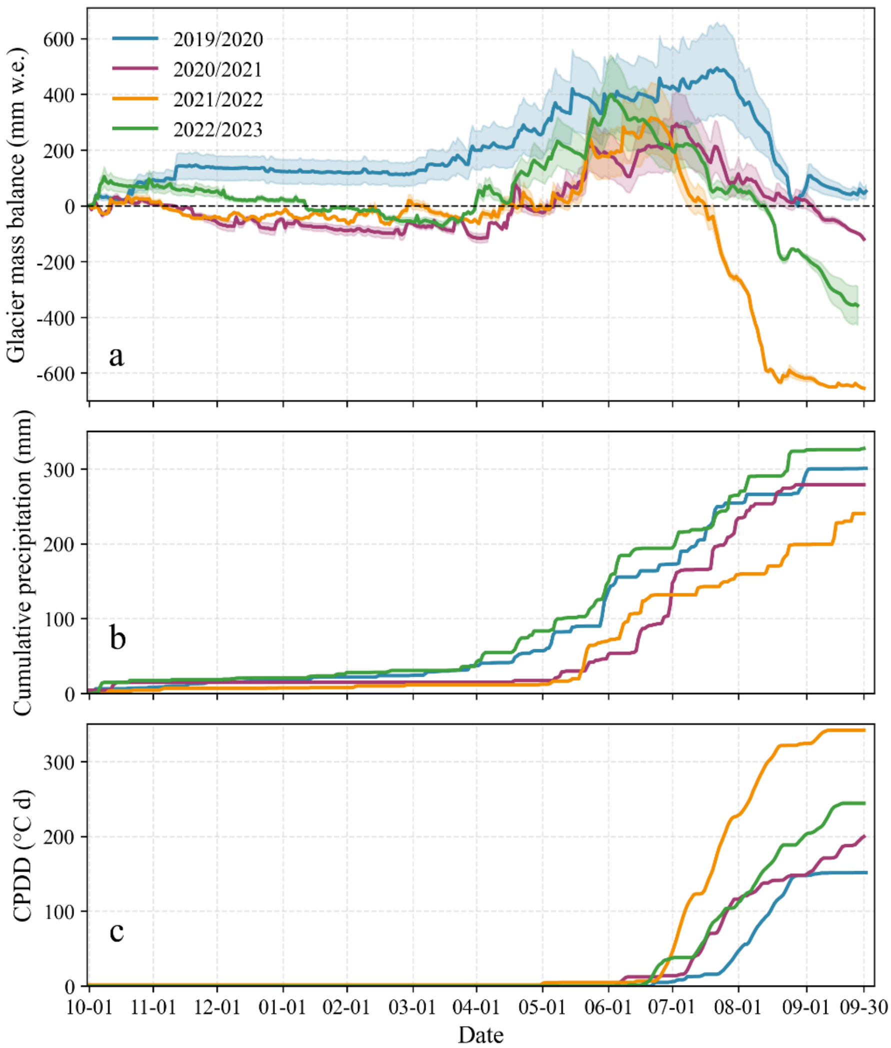

Figure 5. Cumulative glacier-wide mass balance of the Kangxiwa Glacier during the 2019/2020–2022/2023 hydrological years with the uncertainties by shaded area (a). The cumulated precipitation (b) and the cumulated positive degree day recorded by the AWS4900 (c).

Figure 8: In the caption, precisely state that the data shown in panels a-c comes from the AWS.

Response: We added one sentence "The meteorological data was derived from the AWS4900" in the caption (new Figure 7) "AWS4900" was abbreviation for Automatic weather station at 4900 m a.s.l. (section 3.3).

Figure 10: Any reason why the y-axis corresponding to precipitation is reversed? It might be more intuitive to have it the other way around.

Response: This figure was removed according RC1's suggestion.

Figure 11. This is a nice addition to your locally derived results, but it is unclear what the anomaly is relative to. Please clarify. I would recommend swapping the colorbar of Panel d, such that the red

colors correspond to higher melt conditions, as in the other three panels. Legend: Please specify the sources of the black outlines.

Response: The anomalies of meteorological variables and atmospheric circulations in July 2022 relative to the 1991-2020 mean and it was added to the caption. The color bar of Panel d has been swapped. Black lines represent the domain of the Tibetan Plateau

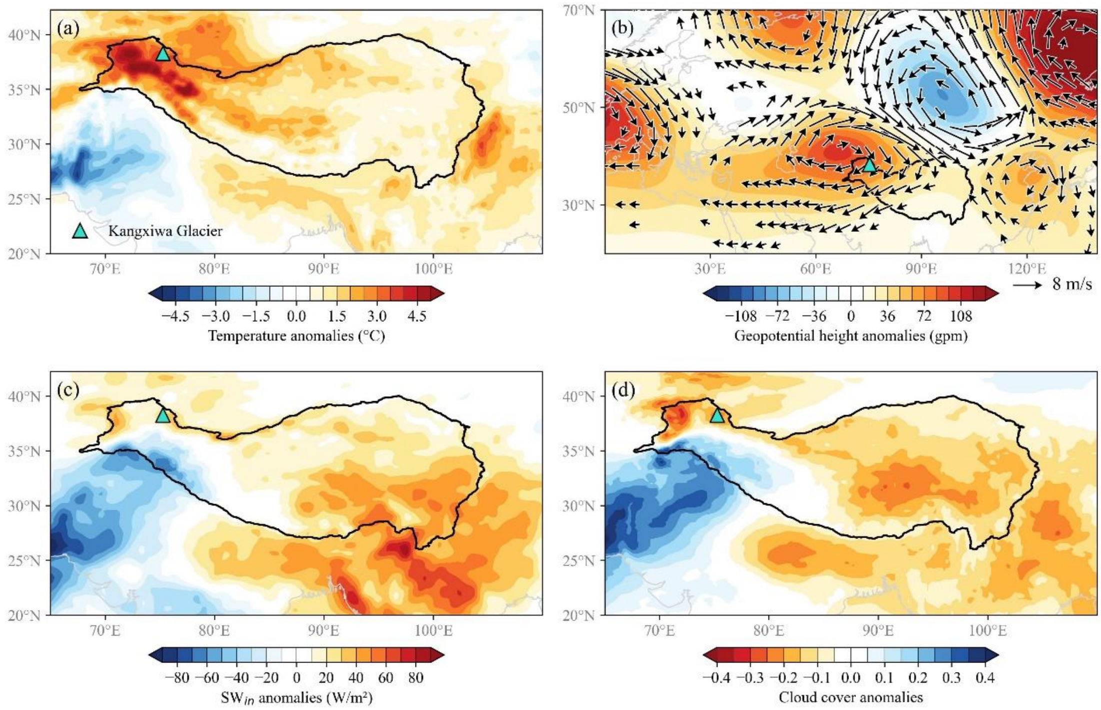

Figure 9. The anomalies of meteorological variables and atmospheric circulations in July 2022 compared with climatological (1991-2020) average. (a) Air temperature; (b) Geopotential height (unit: gpm) and wind field anomalies at 200 hpa; (c) Shortwave incoming radiation (SWin, unit: W/m2) anomaly; (d) Cloud cover fraction anomaly. Black lines represent the domain of the Tibetan Plateau (Zhang et al., 2021).

Ref:

Zhang, Y., Li, B., Liu, L., and Zheng, D.: Redetermine the region and boundaries of Tibetan Plateau, Geogr. Res., 40(6), 1543-1553, doi:10.11821/dlyj020210138 cstr:32071.14.dlyj020210138, 2021 (in Chinese with English abstract).