

Review of: Glacier Mass Balance and Its Response to Heatwaves for Kangxiwa Glacier in the Eastern Pamir: Insights from Time-Lapse Photography and In-situ Measurements

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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). 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.

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.

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.

Specific comments:

1. Title: consider adding the ERA5 reanalysis data, as this is also a big contribution to the manuscript.
2. L43: Kunlun, the Pamir and Karakoram ranges are a part of the Tibetan Plateau, right? Please state this in the text.
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
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.
5. L48: in this paragraph, it is not clear if it is about the Tibetan Plateau or extreme events worldwide. Please clarify.
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.
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.
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.

9. L71-73: is this data representative for the Kangxiwa Glacier? Why is only the mean summer temperature mentioned?
10. L79: for what period is this shrinkage rate?
11. Figure 1: please add scale bars to Figures 1b and 1d.
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.
13. L92: add a reference to the 900 kg m⁻³. For example, Huss 2013 and reference therewithin.
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.
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?
16. L139 and onwards: this paragraph is already part of the results section.
17. L40: for the reader, it is not directly clear what the difference is between in situ stake observations and manually calculated results. Please clarify.
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.
19. L144: broader applications? Multiple elevations? What do you mean? Please give examples.
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).
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.
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?
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.
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?
25. L158: I find those standard deviations relatively high and it is concluded that the camera approach is reliable. Please elaborate on this.
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.
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.
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?
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?
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?

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.
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 ablation 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.
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.
34. L198: substantial, please quantify this.
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 in the current Fig. 6e now.
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.
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).
38. Figure 7: this figure is unnecessary in my opinion. Especially if adaptations are made to Fig 6 (see comment 36).
39. L229-231: this line would fit better in the discussion section.
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.
41. L236: from Fig. 3c 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".
42. L239: do you refer to air temperature data here? Please clarify.
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.
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 of this AWS is for Kangxiwa Glacier. Please elaborate.
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.
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.
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!
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.
49. L316: less mass loss? Less than? Please rephrase. I think a near-equilibrium state is meant.
50. L320: less mass loss? See 49.

51. L329: the reference to Oliver et al. (2018) is about marine heatwaves and not relevant here. See comment 6.
52. L334: what is a 'center of a heatwave'?
53. L336: an equilibrium cannot be positive. Rephrase to: 'glaciers were previously considered in equilibrium or having a positive glacier mass balance', or similar.
54. L358: what are Rossby wave trains? Please add references to this statement.
55. L360-362: this statement is more appropriate for the introduction.

Grammar and typos:

56. L18: remove 'the' before heatwaves
57. L20: typo 2019/2000
58. L20: consider using 'and' instead of 'but'. When using 'but', you would expect mass gain for the other 2 years.
59. L23: heatwaves
60. L24: Glacier Loss Day, remove mass
61. L25: wakened → weakened
62. L27: remove 'the' before heatwaves
63. L32: occurred → observed
64. L34: Hewit → Hewitt
65. L35: maybe be → might
66. L37: are 'a' critical component
67. L41: 'the' Tibetan Plateau
68. L55: Traditional glaciological method and geodetic survey → The glaciological method and geodetic mass balance method
69. L56: dynamics → differences
70. L60: add 'and' before terrestrial laser scanning
71. L61: remove 'the' before extreme melt events
72. L63: developed → introduced
73. L106, 107, 144, 148-151, 195: hight → height, but this actually needs to be the melt out length of the stake.
74. L118: S channel → S-channel
75. L145: dynamics → changes.
76. L158: glacial → glacier
77. L177: Fig 1 → fig 1b
78. L207: "which own significant mass loss". Please clarify/rewrite.
79. L239: the corresponding grid → add "point"
80. L252: add a reference to Fig. 8b after the radiation values.
81. L317: analysis → analyses
82. L319: remove ground.
83. L320: Ata regions → region.
84. L328: remove the extra point after region.
85. L330: replace dynamics with response.
86. L352-354: repetition of the previous sentence. Also, see comment 45.
87. L365: abbreviation TP is not introduced before. Tibetan Plateau, right?
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?

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.
90. L383: replace deficit by loss.

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
- Huss M (2013) Density assumptions for converting geodetic glacier volume change to mass change. *The Cryosphere*, 7(3), 877-887 (doi: 10.5194/tc-7-877-2013)