

Author's response:

Dear Dr. Tobias Bolch:

Thanks very much for your kind work and for giving us several opportunities to make revisions. On behalf of my co-authors, we would to express our great appreciation to you and the reviewers again.

We have made significant modifications to the revised manuscript based on their comments. Please find the point-by-point responses to the two reviewers listed below this letter. We sincerely hope that the revised manuscript now meets the requirements of the journal.

Looking forward to hearing from you.

Best regards.

Yours sincerely,

Mengzhen Li

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22 Sep. 2023

Responses to the Reviewer's comments:

TO REVIEWER#1

Specific comment

Line 21: better "occur"

Corrected.

Line 66: labels /b), (c) and (d) seem to be missing on the maps

Corrected.

Line 85: better " ... reaches from - 7-2 to 8.8°C ..."

Corrected.

Line 86: correspondingly: " ... from -3.2 to 4.3°C ..."

Corrected.

Line 124: debris not deris.

Corrected.

Line 145: shear not sheer

Corrected.

Line 184: provide labels (a), (b), (c) and (d) in the corresponding graphs

Corrected.

Line 213: Do the MAGT values relate to the rock glacier fronts? Make clear.

Thank you for your reminder. The calculation of MAGT values include the whole rock glaciers and represent the average level of MAGT within the boundary of a rock glacier. To make it clear, we have corrected here as below:

“The variation in mean altitude of rock glacier distribution with changes in mean annual precipitation for different mean MAGT states.”

Line 282: better "occur"

Corrected.

Line 318: These numbers are difficult to understand: If the amount is 3.5% of 94.66 Gt it cannot be 2.2% of 58.05 GT. Clarify.

Thank you for your reminder. We feel sorry for our carelessness. In our resubmitted manuscript, the mistake is revised.

“These estimates indicate that the amount of water stored in rock glaciers in the GKLRJ is ~2.2% of the total previously-identified rock glacier water reserves globally (94.66 Gt), and ~3.5% of the existing water reserves in rock glaciers on the TP (58.05 Gt) (Jones et al., 2018a; Jones et al., 2018b; Jones et al., 2021).”

Line 360: Better avoid such popular language. The term "climate" is defined as a statistical mean of meteorological conditions and as such cannot "warm". Better use terms like "climate-induced warming", "global

warming", atmospheric temperature rise", etc.

this statement is difficult to understand - provide a physical reason.

Corrected.

“Under the background of global warming, the warming rate of permafrost in the eastern part of the TP is significantly faster than that in the western part (Cheng et al., 2019).”

Line 382: Better and more precise: " ... in subsurface ice of rock glacier permafrost ..."

Corrected.

Line 470: mention in text or eliminate in reference list

Eliminated.

TO REVIEWER#2

General comments

Introduction: The impacts of the climate change on permafrost are numerous and slope instability is only one of them. It would be interesting to describe in a more complete way the different impacts of permafrost degradation (e.g. on the thermal condition of the ground, on ice content, etc.).

Corrected.

“Global climate change may result in permafrost thawing and ice melting in rock glaciers, thus impacting slope stability, runoff patterns and water quality, with possible consequences for periodic landslides, debris flows, floods and other geological disasters (Barsch, 1996; Schoeneich et al., 2015; Blöthe et al., 2019; Hassan et al., 2021; Yao et al., 2022).”

Material and methods: It would be useful to explain in this chapter the different upslope boundary types used for delimitation of rock glaciers and add the reference to figure 2 in the text (it is missing).

Corrected.

“Following the baseline concepts, the rock glacier without any (significant) headwall is classified as the ‘debris-mantled slope-connected’ (Fig. 2a), the rock glacier unit subjacent and connected to a talus slope unit is classified as the ‘talus-connected’ (Fig. 2b), and the rock glacier developed within or from a (formerly) glaciated area is classified as the ‘glacier forefield-connected’ (RGIK, 2022a) (Fig. 2c). In addition, any landform consisting of a single rock glacier unit or multiple spatially connected units is classified as a rock glacier system (RGIK, 2022a) (Fig. 2d). We also provided information on their morphological system and units as well as their upslope connection type in the attribute table (RGIK, 2022a, 2022b).”

Results: This chapter presents several statistics on the distribution of the rock glaciers based mainly on the results of the ANOVA test. However, the

chapter on Material and Methods lacks an explanation of the statistical analyses performed (type of statistical test, dependent and independent variables, control of test assumptions, significance level, etc.). In addition, it would be useful to summarize the results of ANOVA test in a single table in the results.

Thanks for your suggestions. We have added this part in the Material and Methods, and summarized the results in a single table in the results part.

“Furthermore, we applied One Way ANOVA in SPSS27® software based on the F-test method to analyze the differences in some characteristics between different types of rock glaciers. The significance was evaluated at the level $p < 0.05$.”

Table 3: The results of the One Way ANOVA.

Independent variable	Dependent variable	<i>df</i> between groups	<i>df</i> within groups	F-value	<i>p</i>
activity types	mean altitude	2	5,054	544.749	0.000
upper slope connection	mean altitude	2	5,054	102.9	0.000
upper slope connection	mean area	2	5,054	89.814	0.000
sub-regions	mean slope range	2	4,680	81.175	0.000

Tables 2 and 3 are missing in the manuscript.

Corrected.

Specific comment

Line 40: “long term hydrological reserve” instead of “largely inert hydrological reserve”

Corrected.

Line 65: please add in figure 1 letters (b), (c) and (d) associated with the different sub-figures. Also add the references to the sub-figures in the text.

Corrected.

Line 76: orders of magnitude of irrigated agricultural area and population density in this region?

The irrigated agricultural area in GKLRJ is about 283 km² (National Bureau of Statistics of

China, 2018). The population density in this region is about 12 persons/km², but it is very unevenly distributed, with population densities of up to 18 persons/km² in Lhasa and less than 5 persons/km² in Linzhi and Shannan.

Reference: National Bureau of Statistics: Basic data on the cultivated land area in the Tibetan Autonomous Region (1956-2016), 2018.

Lines 91-92: missing spaces in the figure caption: “altitude (ASTER”, “ELA(Liu”, “2012)for”

Corrected.

Lines 174-175: please add the letters (a) and (b) associated with the two subplots in the caption text. Also add the reference to the subplot 3b in the text.

Corrected.

Line 183: please add in figure 4 letters (a), (b), (c) and (d) associated with the different subplots. Also add the references to the sub-figures in the text.

Corrected.

Line 185: missing spaces in the figure caption: “(a)the”, “(b)RA”, “(c)R2” and “(d)R3”

Corrected.

Line 199: “mean area” instead of “mena area”

Corrected.

Line 219: “ (Fig. 6)” instead of (Fig.6)”. Space is missing.

Corrected.

Line 220: please add the references to the sub-figures of figure 7 in the text.

Corrected.

Line 221: “rock glacier activity states” in the figure caption is not correct, as this term is associated with the differentiation between active, transitional and relict rock glaciers. In this case, the rock glaciers are classified according to the upslope boundary type. In addition, it would be desirable to explain in the figure caption the different subplots associated with letters (a), (b), (c) and (d).

Corrected.

Line 237: “km³ (see Table 5)” instead of “km3 (see Table 5)”. Space is missing.

Corrected.

Line 324-326: it would be desirable to move the ANOVA results to chapter 4.

Corrected.

“However, the results obtained based on both methods reflect clear differences in the water storage of the three sub-regions of GKLRJ (ANOVA: F -value =27.930, df within groups = 2, between groups = 3,671, $p \leq 0.001$).”

Lines 342: it would be helpful to briefly explain how the Permafrost Zonation Index was modeled by Gruber (2012), specifically describing the model parameters considered. Also add the references to the sub-figures a) and b) in the text.

Corrected.

“Furthermore, we compared the spatial distribution of rock glaciers in GKLRJ to the Permafrost Zonation Index (PZI) which is based on the model of permafrost extent and mainly related to the MAAT (Gruber, 2012). At the same time, we also compared it to the thermal stability of permafrost which mainly depends on the accumulation of the MAGT measurement data and remote sensing big data (Ran et al., 2020). Overall, it aligns well with the regions of $PZI \geq 0.49$ (Fig. 8a) and the map of the thermal stability of permafrost (Fig. 8b), especially in R2 and the

western part of R3.”

Line 364: “degradation” instead of “thawing”

Corrected.