Review#1

This study aims at estimating lake volume and modelling potential GLOF from the Lake Bienong, SE Tibet Plateau. In general, I'm convinced that such studies are needed and are logical step following region-wide GLOF susceptibility assessments. The outcomes might be of interest for research community as well as DRR practitioners. The authors of this study employ broadly used data (Landsat images, ALSO PALSAR DEM, …) and methods (bathymetric surveying, empirical equations for deriving breach parameters, MIKE11 modelling tool) in new geographical context. As such, this study brings only limited novelty in terms of methodological development and to some extent only replicates the workflows of previous GLOF modelling studies of different lakes. I would maybe expect more novelty in leading journals such as the Cryosphere. Below I provide my comments to individual parts of this study:

The section about lake evolution actually presents no evolution and can be omitted or summarized in one sentence in the Introduction or Study area section in my opinion.

Reply: We present the evolution of the glacial lake and its mother glacier in Results section to make the relative complete study and presentation of the research objective, but the fact is that the glacial lake has not evolved too drastically. Based on your suggestion, we present this part in the Study area section.

The authors defined 4 moraine dam breach (GLOF) scenarios which are then modelled in the MIKE11 and MIKE21 software. However, the moraine dam breach is not the beginning of the process chain, but a consequence of certain triggering event. Considering that this is detailed case study of only one lake, I would expect the authors to analyze the whole process chain in as much detail as possible, i.e. starting with detailed quantitative analysis of potential GLOF triggers which would help to define and justify dam breach scenarios.

However, this is not met in the current version of the manuscript. My major concern is that the breach scenarios are defined subjectively and are not linked to possible GLOF triggers identified in Section 5.1. What is described in Section 5.1. gives mainly qualitative overview of potential GLOF triggers. This is perhaps true for many lakes in the region, but there is no link to considered breach depth scenarios. And this is the major drawback of this study in my opinion.

Reply: In this study, with the objective of assessing the possible risk to downstream areas from potential GLOFs in different magnitudes, we assumed four scenarios based on different break heights of the moraine dam. We appreciate your valuable and constructive comments on this study. According to your suggestion, we analyzed the whole process chain of GLOFs starting with detailed quantitative analysis of potential GLOFs triggers, following with the generation and propagation of waves in the lake caused by potential triggers, the erosion of the dam by overtopping floods, and the resulting GLOFs in the downstream. We analyze the potential GLOF triggers in Section 5.1, i. e. ice avalanches from the tongue of its parent glacier and steep lateral moraine landslides on both sides. Considering that the ice avalanches are the most common GLOFs trigger in the Tibet, China, which induced the outburst of Rangze Glacial Lake, just 10 km away from Bienong Co. And the lateral moraine landslide is the GLOFs trigger of Jinwu Co, which is only 24 km away from Bienong Co, so in this revision, we took the two potential triggers for analysis. Wang et al., (2012) defined the volume of dangerous glacier (VDG) as the glacier volume from the location of abrupt change in the slope to the glacier terminus or the volume of terminal glacier where ice cracks are well developed. We adopted the latter, i.e., the glacier volume with a surface area of 0.19 km^2

for crevasse development, as the potentially dangerous ice body of the parent glacier of Bienong Co. To simulate the subsequent effects triggered by ice avalanche material in different magnitude, we divided the potentially hazardous ice body into three parts based on the surface elevation range, representing partial or total collapse of the hazardous ice body, the dangerous ice body 01, the dangerous ice body 02, and the dangerous ice body 03, simulating three scenarios of low-, medium- and high- magnitude (Figure1). In scenario-1, ice body at elevation below 4844 m (the dangerous ice body 01) yields a release area of 0.05 km^2 with the mean height difference of 76 m from the lake surface, which is the low-magnitude trigger. In scenario-2, ice body at elevation below 4889 m (the dangerous ice body 02) yields a release area of 0.11 km^2 with the mean height difference of 103 m from the lake surface, which is the moderate-magnitude trigger. In scenario-3, the total ice body of crevasse with an area of 0.19 km^2 (the dangerous ice body 03) that is below the elevation range of 4896-4900 m and has the mean height difference of 131 m from the lake surface, which is the extreme-magnitude trigger. For the release depth we still adopted a hypothetical approach because there is no reliable reference data available. The release depth of the ice avalanche in each scenario is assumed to be its mean height difference from the lake surface, i.e., all of the ice body above the lake surface falls off. This is a very extreme case because the subglacial topography is unknown and the lower part of the ice tongue may be in the shape of a dome that would overestimate the avalanche volume of the collapsed ice body. But in the Rapid Mass Movement Simulation (RAMMS) Avalanche module (Bartelt et al., 2013) simulation, the real ice body falling into the glacial lake is reduced, and the model will make a judgment based on the topography instead of dumping the entire ice body we set into the lake.

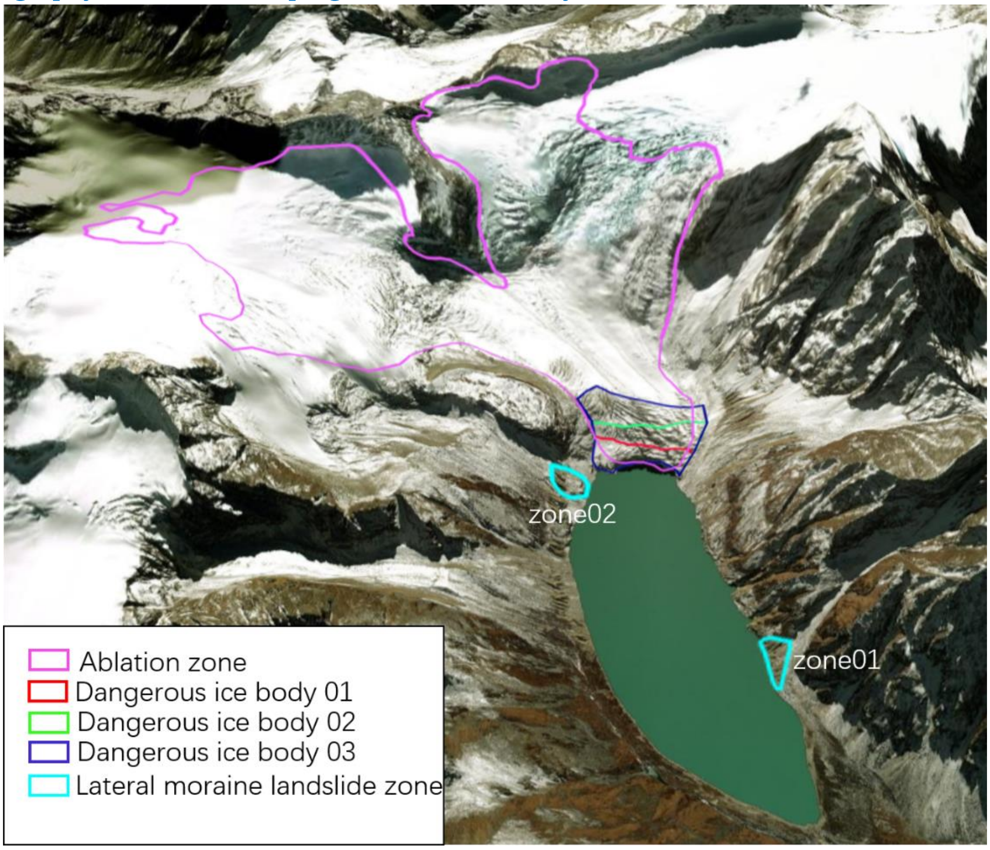


Figure 1. Illustration of setting triggers for potential GLOFs in Bienong Co

In addition, we selected lateral moraine landslides as another GLOF triggers for Bienong Co, which is not common on the Tibetan Plateau, but the 2020 GLOF of Jinwu Co was caused by a lateral moraine landslide (Liu et al., 2021; Zheng et al., 2021). The slope of the lateral moraine where the landslides occurred in Jinwu Co is between 30˚-45˚, and there are several lateral moraines around the Bienong Co that fit into this slope range. We selected two release areas of lateral moraine landslide, one is located on the right bank of Bienong Co facing the mother glacier, near the moraine dam with an area of 0.015 km^2 (lateral moraine landslide zone 01), another is located on the left bank of Bienong Co facing the mother glacier, near the mother glacier with an area of 0.024 km^2 (lateral moraine landslide zone 02). Two sites are at different distances from the moraine dam and further, we set three different release depths of 2 m (scenario-1, low-magnitude), 5 m (scenario-2, moderate-magnitude), and 10 m (scenario-3, extreme-magnitude) for each zone. The above settings fully consider the impact of triggers on Bienong Co under different scenarios, and the results are used as the input for the subsequent disaster chain.

Reference:

1. *Wang X, Liu S, Ding Y, et al. An approach for estimating the breach probabilities of moraine-dammed lakes in the Chinese Himalayas using remote-sensing data. Natural Hazards and Earth System Sciences, 2012, 12(10): 3109-3122.*
2. *Bartelt, P., Buehler, Y., Christen, M., Deubelbeiss, Y., Graf, C., McArdell, B., Sals, M., and Schneider, M.: RAMMS: Rapid Mass Movement Simulation: A numerical model for debris flows in research and practice, User Manual v1.5 – Debris Flow, Swiss Institute for Snow and Avalanche Research SLF, Birmensdorf, 2013.*
3. *Liu, J. K., Zhou, L. X., Zhang, J. J., and Zhao, W. Y.: Characteristics of Jiwencuo GLOF, Lhari county, Tibet. Geological Review, 67: 17–18. https://doi.org/10.16509/j.georeview.2021.s1.007, 2021.*
4. *Zheng, G. X., Mergili, M., Emmer, A., Allen, S., and Stoffel, M.: The 2020 glacial lake outburst flood at Jinwuco, Tibet: causes, impacts, and implications for hazard and risk assessment, The Cryosphere, 15, 3159–3180, https://doi.org/10.5194/tc-2020-379, 2021.*

For instance, I wonder what would need to be the magnitude of triggering slope movement to initiate 72 m deep breach? Is there any evidence that such slope movement could occur in the lake's surrounding? Landslide zones identified in Figure 11 don't seem to be releasing large mass volumes into the lake. Ideally, the initial slope movement, displacement wave propagation in the lake as well as dam breaching would be modelled, not only the GLOF. Critical questions regarding potential GLOF triggers are: Is there any evidence of mass movements entering the lake in the past? Have you observed any evidence from your analysis of remote sensing images and DEMs? Is there any evidence of potential future mass movements (displaced blocks, surface ruptures, opening crevasses, etc.)? Any evidence from your field work? Did any strong earthquake hit the region in the past? Did the lake experience any precipitation / temperature extremes? Do you expect them to change in the future? Considering the scope of the study (case study of one lake), individual triggers should be identified, quantified and treated more in depth in my opinion, feeding the definition of dam breach (GLOF) scenarios.

Reply: The Landsat image series shows a ~120 m retreat at the Bienong Co's ice tongue from 1976-1988 (maybe earlier), after which small changes were not identified because of the coarse spatial resolution of the available images. Comparing the image in ArcGIS Earth softwaer (earlier than 2020, but the exact date is not known) (Figure2-left) with the photos taken during the 2020 field survey (Figure2-right), it is clear that the glacier tongue was in a significantly different state and have collapsed in 2020 compared to the earlier period. It is clear from the above evidence that the glacier tongue is in a changing state, although we did not directly witness one such change process during our field survey. Meanwhile, a large number of cracks appear on the mother glacier's tongue of in

Bienong Co, clearly visible in both remotely sensed images and real photographs (Figure 2), which is the basis of a potential ice avalanche into the lake. In addition, Lv et al., (1999) proposed that a slope of the mother glacier' tongue greater than 8˚ is conducive to the occurrence of ice avalanches, meaning the potentiality of the GLOFs. In terms of Bienong Co, slopes of the dangerous ice body01, dangerous ice body02, dangerous ice body03 and ablation zone are 20˚, 22˚, 26˚ and 32˚, respectively, all of which exceed the above threshold, indicating the potential hazard.

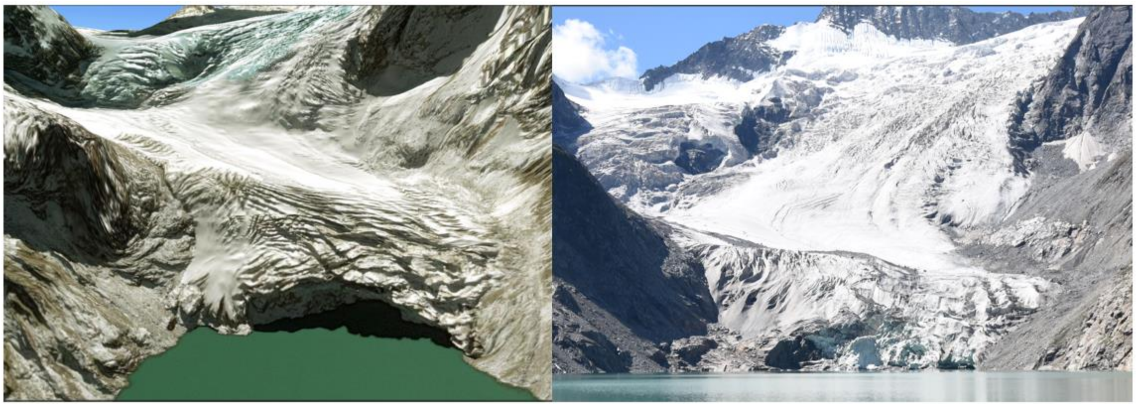


Figure 2. Comparison at the tongue of the mother glacier of the glacial lake in different periods (left: the high-resolution image from ArcGIS Earth software, the date is earlier than 2020, but the exact date is not known; right: taken in August 2020)

The scenario for the extreme-magnitude of GLOFs that downcutting to the base of the moraine dam (72 m) is informed by the hypothesis of Sattar et al. (2021) for Lower Barun Glacial Lake, for which they set the extreme scenario of the outburst incision reaching the bottom of the moraine (104 m) due to the initial erosion of the overtopping floods. We assume that this event may be caused by one or a combination of factors such as ice/avalanches, rock falls, landslides, heavy precipitation, or earthquakes. According to your comments, this assumption may be relatively subjective because of our lack of investigation of strong earthquakes and extreme precipitation and temperature events in the region and the small probability of GLOFs due to earthquakes in the Tibet, China. The probability of glacial meltwater and heavy precipitation and its related combination induced GLOFs event can account for one-fifth, such as the GLOF of Jinwu Co in 2020 was caused by precipitation-induced lateral moraine landslides to make the glacial lake destabilization, and finally GLOF event. In Tibet, China, the ice avalanche/ice landslide and its related combination of factors induced by the GLOFs event accounts for more than seventy percent. However, quantitative simulations of dam breach erosion due to such a trigger mechanism were not performed in our study.

Therefore, in this revision, we first quantified the potential GLOF triggers based on your comments, in which two types of ice avalanches and lateral moraine landslides were set, and the details of the quantification are described in the previous reply. Then, we simulated the initial slope motion, the propagation of displacement waves in the lake, and the dam failure in the ideal case you mentioned. The initial slope motion is modeled by the Rapid Mass Movement Simulation (RAMMS) Avalanche module (Bartelt et al., 2013), and the subsequent propagation of displacement waves in the lake, climbing, moraine dam erosion, dam failure and downstream flood propagation are simulated by the Basic Simulation Environment for Computation of Environmental Flow and Natural Hazard

Simulation (BASEMENT) model ((Vetsch et al., 2017). the Rapid Mass Movement Simulation (RAMMS) Debris Flow module (Bartelt et al., 2013).

Reference:

1. *Lv, R. R., Tang, X. B., and Li, D. J.: Glacial lake outburst mudslide in Tibet, Chengdu University of Science and Technology Press, Chengdu, 69–105, 1999.*
2. *Sattar, A., Haritashya, U. K., Kargel, J. S., Leonard, G. J., and Chase, D. V.: Modeling Lake Outburst and Downstream Hazard Assessment of the Lower Barun Glacial Lake, Nepal Himalaya, J. Hydrol., 598, 126208, https://doi.org/10.1016/j.jhydrol.2021.126208, 2021.*
3. *Bartelt, P., Buehler, Y., Christen, M., Deubelbeiss, Y., Graf, C., McArdell, B., Sals, M., and Schneider, M.: RAMMS: Rapid Mass Movement Simulation: A numerical model for debris flows in research and practice, User Manual v1.5 – Debris Flow, Swiss Institute for Snow and Avalanche Research SLF, Birmensdorf, 2013.*
4. *Vetsch, D., Siviglia, A., Ehrbar, D., Facchini, M., Kammerer, S., Koch, A., Peter, S., Vonwiller, L., Gerber, M., Volz, C., Farshi, D., Mueller, R., Rousselot, P., Veprek, R., and Faeh, R.: System Manuals ofBASEMENT, Version 2.7. Laboratory of Hydraulics, Glaciology and Hydrology (VAW), ETH Zurich, available at: http://www.basement.ethz.ch, last access: 3 November 2017.*

For the modelling part (Section 4.3, Table 3, Figures 7 to 10), flow velocities and peak discharge drop in Bada to 0.26 m/s (2,260 m^3/s) in the most extreme scenario, after which it again speeds up to 18.47 m/s (22,992 m^3/s) in Zongri is contra-intuitive and should be discussed / explained. In Figure 10, you even have negative peak discharge in Bada (?). Also the flow velocities of Scenario-1 (S1 to Jiawu; 44 to 65 m/s) seem unrealistically high considering it is supposed to originate from moraine dam breach.

Reply: The Bada village should not have been the subject of analysis because it is not located directly in the downstream channel of Bienong Co, but in another channel that intersects with the downstream channel of Bienong Co. However, in the extreme-magnitude scenario originally simulated, the Bada village was also affected by the huge flood. Therefore, the impact of flooding on it was analyzed. Because the Bada village is relatively far from the main channel of the flood, the flow and velocity here are significantly reduced. The flood flows into the cross-section representing this region and then flows out in the opposite direction, i.e., exited the region, which is the reason for the negative value of the flow in the later period. But this situation will be improved in this modeling. Again, thank you very much for your valuable comments.

Finally, the authors invested a lot of effort in comparing lake volumes (Section 5.2) and lake volume estimates (Section 5.3), but the implications of these comparisons are nebulous to me and the statistical treatment is incorrect. Considering the bathymetry done by the authors, it is clear that: (i) they have the best possible lake volume estimate for their study; (ii) their one bathymetry can hardly be used to validate or evaluate existing area-volume relationships. Strikingly, bathymetric data used to develop the new area-volume relationship (Table 5, Figure 12) are then used for the performance assessment (Tabel 7, Figure 14), which is statistically not correct. Moreover, some of the existing equations (e.g. Fujita's equation developed specifically for Himalayan lakes) are not considered in this comparison. Further, the number of lakes listed in Table 5 is too low to generate any meaningful conclusions about a difference between lakes associated with continental and maritime glaciers. In addition, it seems that simply larger lakes are deeper as you only have one lake > 1 km^2 associated with continental glacier in your dataset while all lakes associated with maritime glaciers are > 1km^2. This makes the Discussion section overall weak.

Reply: Thank you for your comment, we fully understand your opinions and for the discussion part, we will work on the glacial lake hazard quantification, evaluation of the existing glacial lake volume estimation relationships and uncertainty study of GLOFs process chain simulation.

Table 4: if the lake has a surface outflow, dam freeboard = 0m.

Reply: Thank you for your tips.

Mean breach (Eq. 3) is used as max. breach in Figure 6; please check

Reply: In this revision, the dam-break process will be re-simulated with the BASEMENT model, and Equation 3, which calculates the average breach depth, and Figure 6, which represents the shape of the breach, are discarded, so we will reconsider this problem. We appreciate your comment.

I think that especially GLOF triggers need to be addressed in more detailed and quantitative way first, resulting in re-definition and justification of dam breach scenarios. Also the Discussion section should be re-worked substantially in my opinion. To sum up, I recommend major revisions of this manuscript.

Reply: In this revision, we have simulated the GLOFs processes, including the initial slope movement, generation and propagation of wave in the lake, dam breaching and the floods behaviors in the downstream channel starting from quantifying the triggers of according to your suggestion. The above is the first aspect of the major revisions. Second, for the discussion section, in this revision, we will not attempt to update the existing volume estimation formulae using bathymetry data of Bienong Co because sample size is too small. The discussion will focus on a deeper investigation of the danger of the glacial lake, the risk of glacial lake outburst floods to the downstream region, the evaluation of existing glacial lake volume estimation relationships, the evaluation of GLOFs simulations, etc.

We attached reviewer 2's comments on this paper, as well as our response.

Review#2

This is an interesting paper that investigates a glacial lake and conducts analyses aiming to assess its evolution, basin morphology, estimate its water volume, analyses some possible outburst triggers analysis, and conducts simulations of likely inundation under GLOF scenarios. In general, the paper does a good job of developing these themes and forms a comprehensive case study that could be published given some reasonably substantial changes. I list these here and also some more specific issues with the paper.

1 The paper is often written in a rather vague and imprecise way. In addition, there is often an incorrect use of English. I sympathise with the authors in this; it is difficult for non-English speakers to write precisely and accurately in English but this paper would benefit enormously from careful editing and rewriting by a native English speaker.

The literature review is generally comprehensive although there are some papers that should have been referenced and I highlight some of these later. The rationale for the study is clear and appropriate.

Reply: We appreciate your valuable comments on this manuscript and your full understanding of our language issues. Combining Reviewer 1's and your comments, we will make significant changes to the manuscript. Reviewer 1 suggests that we analyze the whole process chain in as much detail as possible, i.e. starting with detailed quantitative analysis of potential GLOF triggers, we did the above in this revision. And, as you suggested, we will provide a more detailed explanation and analysis of the typicality and dangers of the glacial lakes we have studied in this revision.

3 The sampling strategy and methodology is not clearly discussed. Explain why this lake was chosen. Is this lake representative of others in the region? If so, why and how do you know this? If the lake is not representative, then the authors need to explain its significance.

Reply: In fact, Bienong Co Glacial Lake is representative of the region (the Yi'ong Zangbo river basin in the southeastern Tibetan Plateau) in which it is located, and the characteristics of the Yi'ong Zangbo river basin and Bienong Co are described in our Study area section. But the way it is written does not seem to be clear enough to make you question it. We will improve this in this revision.

The southeastern Tibetan Plateau, with high mountains and deep valleys and under the influence of the Indian monsoon, has developed numerous maritime glaciers and moraine-dammed and other types of glacial lakes. In this study, the Yi'ong Zangbo river basin in the southeastern Tibetan Plateau was used as the study area, and according to Duan et al. (2020), there are 105 moraine-dammed glacial lakes (the main lake type for GLOFs occurring in the Himalaya and southeastern Tibetan Plateau) within the basin with a total area of 16.87 km^2, in which, 67 lakes have an area larger than 0.02 km^2. Based on the characteristics of the breached glacial lakes in the southeastern Tibetan Plateau, Duan et al. (2020) selected five indicators of (1) the area of the mother glacier, (2) distance between the lake and glacier terminus, (3) slope between the lake and glacier, (4) mean slope of the moraine dam, and (5) snout steepness of the mother glacier to evaluate the GLOFs potentiality of the 67 glacial lakes, and GLOFs susceptibility was classified as very high, high, medium and low. The results show that there were 10 glacial lakes with a very GLOFs potentiality, of which seven lakes had an area larger than 0.1 km^2, five had an area larger than 0.2 km^2, and only two lakes had the area larger than 0.5 km^2, one is Jinwu Co, which has already breached, with an area of 0.53 km^2 before the failure (2016), and the other is the subject of this study, Bienong Co, whose area in 2016 is about 1.12 km^2. GLOFS of smaller glacial lakes cause limited damage in sparsely populated regions like Tibet, so larger lakes tend to be valued more. The area of Bienong Co is nearly twice as large as the area of the already collapsed Jinwu Co, and given the huge damage caused by the outburst flood of Jinwu Co to the downstream region, the potential GLOFs hazard of Bienong Co cannot be ignored.

Secondly, three GLOFs have occurred in the Yi'ong Zangbo river basin, the Jinwu Co that breached in June 2020 is 24 km away from Bienong Co in a straight line, and the Ranze Glacial Lake that breached in July 2013 is only 10 km away Bienong Co in a straight line. Considering the similar geological and climatic environment due to the proximity, and Bienong Co was also assessed as a very high dangerous glacial lake in previous study, we believe that it is necessary and meaningful to select Bienong Co for GLOFs process chain simulation.

Reference:

1. *Duan H, Yao X, Zhang D, et al. Glacial lake changes and identification of potentially dangerous glacial lakes in the Yi'ong Zangbo River Basin. Water, 2020, 12(2): 538.*

4 The methodologies used are explained and justified well, and you have used an appropriate range of techniques

to explore the geomorphology, characteristics and evolution of the lake and its future behaviour.

Reply: Thank you very much for your affirmation of the method adopted in this study. However, according to the comments of reviewer 1, the simulation of this study still has some shortcomings. We will adopt more detailed models and methods to simulate the process chain of glacial lake outburst flood.

5 I am interested in why Bienong Co is regarded as a dangerous lake (lines 100 and 239)? The paper demonstrates that the lake has remained stable for some time, and that it cannot expand further. It also argues that the moraine dam does not contain an ice core. So the description of the lake as 'dangerous' requires much more discussion and evidence. This is important because there is always the temptation to describe any moraine - dammed lake as being 'dangerous' even when the evidence for this is lacking. I know of one well-known reviewer of similar papers who regularly rejects all papers who make this assertion without clear evidence!

Reply: There are many indicators that can be used to assess the hazard of glacial lakes. Zhang et al. (2022) systematically summarized the indicators for assessing glacial lake's hazard in the Himalayan, including six main categories: (1) ice avalanches, glacier collapse, (2) rock fall, landslide, or other solid mass movement, (3) dam instability, (4) heavy precipitation, various liquid inflows, (5) characteristic of lake, (6) influence to downstream area. Many specific indicators are included in each category for a total of 57. Zhang et al. (2022) selected the best combination of five factors for assessing the potential hazard of a glacial lake from 57 factors by designing experiments: (1) the average slope of the mother glacier, (2) the likelihood of material entering the lake, (3) the average slope of the moraine dam, (4) the watershed area, and (5) lake perimeter, GLOF triggers corresponding to glacial collapse, rockfall and landslides, dam instability, heavy precipitation or other fluid inflow, and lake characteristics. Considering that ice avalanches and landslides trigger almost more than half of the GLOF (Emmer and Cochachin, 2013); the average slope of the mother glacier and the likelihood of material entering the lake were given higher weights in assessing the GLOF potential of glacial lakes in the Himalayan using the fuzzy consistency matrix method.

The hazards of a glacial lake are influenced by multi factors, such as the area and its growth rate, the properties of the dam and the slope of the surrounding environment. In terms of Bienong Co, its area has remained essentially stable over the last 30 years, which is the main reason why it is considered to be of low risk. However, its huge size is a danger in itself. Whether its moraine dam contains ice cores is currently unknown. But, the present of ice core is only one of the factors representing the stability of moraine dams, dam height, dam texture (consolidated or unconsolidated, bedrock, or other) dam freeboard, mean slope, the present of ice core, the present of leakage, et al. are also the important characteristics. The moraine dams of Bienong Co are high and steep, consisting of loose materials. With a freeboard of 0 m, any mass entering the lake will create an overtopping flow that may erode the moraine dam and make the breach larger, thus releasing a large amount of water from the lake. Sattar et al. (2021) even hypothesized the situation where the moraine dam collapses to the bottom (104 m) due to the overtopping flow. Therefore, from the viewpoint of moraine dam, Bienong Co is dangerous, because the moraine dams of the two nearby glacial lakes that have broken both have such characteristics.

Furthermore, based on the genesis of breached glacial lakes on the Tibetan Plateau, ice avalanches and landslides appear to trigger more than half of the GLOFs, and it is reasonable to assign a higher weight to the possibility of ice avalanches and landslides entering glacial lakes in studies related to glacial lake hazard assessment.

Lv et al., (1999) proposed that a slope of the mother glacier' tongue greater than 8° is conducive to the occurrence of ice avalanches, meaning the potentiality of the GLOFs. In terms of Bienong Co, slopes of the ablation zone are 20°, which exceed the above threshold, indicating the potential hazard. And, the moraine slope destabilization conditions that lead to the failure of the Jinwu Co also exist around the Bienong Co, so it may also become a potential trigger.

Finally, studies show that (Sun et al., 2014; Liu et al., 2021 and Zheng et al., 2021) the Ji Weng wrong and Ran Zerzhong A wrong collapse although the avalanche and ice avalanche into the lake and side moraine landslide into the lake is the most important factor, but in the early sustained precipitation and the rapid recovery of temperature still on the ice / avalanche and side moraine landslide has a certain role.

Finally, studies show that although avalanche and ice avalanche into the lake and lateral moraine landslide into the lake were the dominant factors in the GLOFs of Jinwu Co and Ranze Lake, the preceding precipitation and rapid warming still played a role in the occurrence of ice/avalanche and lateral moraine landslide. Bienong Co is in such close proximity to these two glacial lakes that the same climatic conditions are likely to act on Bienong Co and cause GLOFs to occur.

In summary is the explanation of the potential hazards of Bienong Co. We believe that it is reasonable to evaluate Bienong Co as a glacial lake with the GLOFs possibility, and although the exact trigger and timing of its break cannot be determined, our study at least provides a prediction and assessment of the potential hazards of this glacial lake.

Reference:

1 *Zhang T, Wang W, Gao T, et al. An integrative method for identifying potentially dangerous glacial lakes in the Himalayas[J]. Science of The Total Environment, 2022, 806:150442.*

2. *Sattar, A., Haritashya, U. K., Kargel, J. S., Leonard, G. J., and Chase, D. V.: Modeling Lake Outburst and Downstream Hazard Assessment of the Lower Barun Glacial Lake, Nepal Himalaya, J. Hydrol., 598, 126208, https://doi.org/10.1016/j.jhydrol.2021.126208, 2021.*

3. *Lv, R. R., Tang, X. B., and Li, D. J.: Glacial lake outburst mudslide in Tibet, Chengdu University of Science and Technology Press, Chengdu, 69–105, 1999.*

4. *Sun, M. P., Liu, S. Y., Yao, X. J., and Li, L.: The cause and potential hazard of glacial lake outburst flood occurred on July 5, 2013 in Jiali County, Tibet, Journal of Glaciology and Geocryology, 36, 158–165, https://doi.org/158-165,10.7522/j.issn.1000-0240.2014.0020, 2014.*

5. *Liu, J. K., Zhou, L. X., Zhang, J. J., and Zhao, W. Y.: Characteristics of Jiwencuo GLOF, Lhari county, Tibet. Geological Review, 67: 17–18. https://doi.org/10.16509/j.georeview.2021.s1.007, 2021.*

6. *Zheng, G. X., Mergili, M., Emmer, A., Allen, S., and Stoffel, M.: The 2020 glacial lake outburst flood at Jinwuco, Tibet: causes, impacts, and implications for hazard and risk assessment, The Cryosphere, 15, 3159–3180, https://doi.org/10.5194/tc-2020-379, 2021.*

6 The paper forms a detailed and comprehensive assessment of the site and models some plausible GLOF inundation scenarios. But this is essentially a paper about one lake and therefore could be criticised as being a bit parochial. What does this say about moraine-dammed lakes more generally? Why is this paper significant enough to be published in a mainstream journal like The Cryosphere? It therefore needs much more wider context,

and some sense of why the techniques you used are an advance on other similar work, or why you have provided new insights. Otherwise you have just provided an interesting case study.

Reply: At present, most of the studies on glacial lakes in the maritime glaciation zone of the southeastern Tibetan Plateau focus on the analysis of glacial lake changes and identification of potentially dangerous glacial lakes, etc. There are few or no published studies on glacial lake depth measurements, lake basin simulations, water volume estimation and the outburst flood simulations. Therefore, the work done in this study is of great importance for understanding the basin morphology and glacial lake depth, as well as estimating the water storage of the terminal moraine-dammed lake in the maritime glaciation zone. In addition, the simulation of GLOFs from ice avalanche and lateral moraine landslide to wave generation and propagation in the lake, dam erosion and breach, and downstream flood behavior based on the numerical models RAMMS and BASEMENT is carried out in this revision, and this whole process chain is implemented with a view to providing a research paradigm and reference for the simulation of other glacial lake breaches in the region in the future.

7 The title mentions water storage, but little is made of this in the paper. How does it compare with other lakes in the region?

Reply: Bathymetry data accurately reflects the basin morphology of the glacial lake, based on which the water storage capacity of the lake can be accurately calculated. In the first part of the results, we simulated the morphology of the glacial lake and estimated its water volume. However, the description of the title does not apply "water storage" but "volume", perhaps the former would be better. Comparisons with other lakes in the region are not covered because few actual bathymetric data for other glacial lakes in the region are currently publicly available. In addition, the section 5.2 Comparison of morphological characteristics for glacial lakes in continental and maritime glaciation regions in the Discussion is to explain that glacial lakes in the maritime glaciation zone may be deeper and therefore store more water by comparing with lakes with similar area in the continental glaciation zone.

8 Under the modelling scenarios presented here, some villages downstream will be completely inundated by the largest GLOF. What are the ethical issues that derive from such an analysis. I agree that we should prepare such assessments but the local inhabitants will be rightly concerned. I'm interested in their views of such analyses.

Reply: The two GLOFs that have occurred in this basin have both caused a serious disaster in the downstream region. For example, the outburst of Ranze Lake in July 2013 resulted in missing persons, destroyed houses, and serious damage to bridges, roads and other infrastructure, with direct economic losses of up to 270 million yuan. The outburst of Jinwu Co in June 2020 caused no casualties, but did cause significant damage to infrastructure (such as roads and bridges) and property damage in downstream areas. In addition, Bienong Co is a combination of glacier and glacial lake, the surrounding scenery is beautiful, and in the hearts of the local residents have some kind of religious beliefs representative. GLOFs disaster, therefore, is always an extreme concern for the local government, and during our survey, there were local government staff involved. And for the results of this study, it is a reference for the local government with a view to provide them with some theoretical help. For the local population, because of the presence of settlements, infrastructure and agricultural fields, based on the potential hazards generated by Bienong Co's GLOFS, they are most likely to use engineering measures such as lowering the water level to mitigate the potential threat.

Fig 8. Difficult to differentiate colours in depth assessments.

Reply: We changed this expression in this revision.

Specific issues.

Line 9. Omit 'the' after 'hazard to'

Reply: We are sorry for this grammar error and thank you for the tip.

Line 10 Insert 'the' before 'potential'.

Reply: We are sorry for this grammar error and thank you for the tip.

Line 11 Explain the typology of 'maritime'. These glaciers aren't maritime (meaning close to the sea).

Reply: Glaciers are a product of climate, and China has the largest amount of mountain glaciers in the world at low-and middle-latitude regions. Based on the development conditions and physical properties, glaciers in China are divided into continental glaciers and maritime glaciers. Continental glaciers are distributed from the Altai Mountains in the north, to the Northern Slope of the middle Himalayas in the south, from the Pamirs in the west, and to the Lenglongling and Anyemaqen Mountains in the east. They are characterized by low recharge, weak ablation, high snow line, low temperature, slow movement speed, and weak geological and geomorphological effects. According to the Second Chines Glacier Inventory, the glacier number (37,770) and area (46,200 km^2) account for 81. 4% and 77.8% of the total number and area in China, respectively. Maritime glaciers are mainly located in the eastern and southern slopes of the Himalayas, the eastern and middle sections of the Nyingchi Tanggula Range, and the Hengduan Mountains on the southeastern Tibetan Plateau. They are characterized by abundant recharge, strong ablation, low snowline distribution, high temperature, fast movement, and strong geological and geomorphological effects. The number of glaciers (8,607) and area (13,203 km^2) account for 18.6% and 22.2% of the number and area of glaciers in China respectively. Maritime glaciers are not distributed on the seashore, but their development and changes are controlled by the Indian monsoon. Table 1 shows the main features of continental glacier and maritime glacier in China. In this study, the Yi'ong Zangbo River Basin is located in the southeastern Tibetan Plateau and therefore is a maritime glaciation region.

Table 1 The main features of continental glacier and temperate glacier in China (Shi et al., 1964; Yang 1991; Su et al., 2000; Ding 2012)

Glacier type	Climate	Average annual precipitation/ mm	Average annual temperature/ °C	Average summer temperature/ °C	Ice-forming effect	Ice temper-ature	Motion speed/ (m a^{-1})
maritime glaciers	Indian Monsoonal circulation climate	1000~3000	>-6	1~5	Warm soaking-Recrystallization	-1~0	>100
continental glaciers	Highland monsoon and continental climate	200~1000	<-6	<3	Soaking-Freezing	<-1	10~100

References:

1 *Ding Yihui. Environmental Characteristic of West China and Its Evolution. Beijing: Science Press. 2002: 166-173.*

2 *Shi Yafeng, Xie Zichu. The characteris- tics of existing glaciers in China. Acta Geographica Sinica. 1964. 30(3): 183-208.*

3 Su Zhen. Shi Yafeng. Response of monsoonal temperate glaciers in China to global warming since the little ice age. Journal of Glaciolgy and Geocryology. 2000. 22(3): 223-229.

4 Yang Zhenniang. Glacier Water Resources in China. Lanzhou: Gansu Science and Technology Press, 1991.

Line 12 Cite: Harrison, S., Kargel, J.S., Huggel, C., Reynolds, J., Shugar, D.H., Betts, R.A., Emmer, A., Glasser, N., Haritashya, U.K., Klimeš, J. and Reinhardt, L., 2018. Climate change and the global pattern of moraine-dammed glacial lake outburst floods. The Cryosphere, 12(4), pp.1195-1209.

Reply: Thank you for recommending this paper to us and we will make citations where appropriate.

Line 13 'such as the ice and/or rock avalanches'. There is no need for the definite article (ie 'the) when the noun is plural. This rule applies throughout this paper.

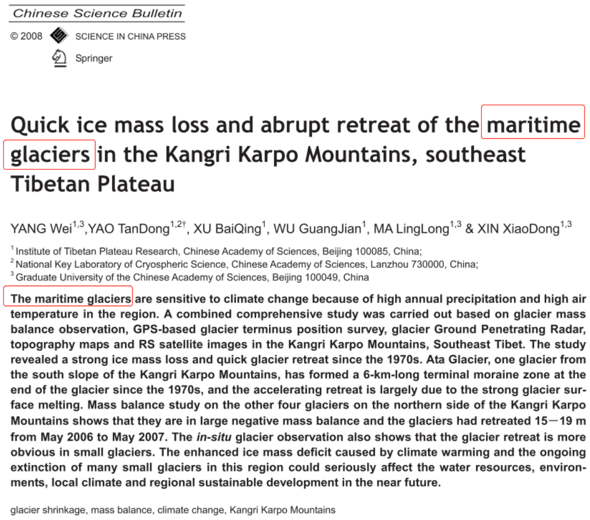
Reply: Thanks a lot for your guidance on our grammar. We will correct this situation throughout the text.

Line 14 Sentence starting 'Study shows…'. This sentence requires rewriting. It is ambiguous and vague. This is also an hypothesis and presupposes that we understand the link between climate change, glacier recession and GLOF incidence.

Reply: Unfortunately, our description of this sentence was so succinct that it confused the reader, and we will be rewriting the sentence.

Line 48 Re 'maritime glaciers'. Reword this sentence. Maritime is the wrong description of these glaciers. This means close to the sea.

Reply: Literally, maritime means close to the sea, and the glacier in the study is not near the sea. However, this writing style was adopted in published papers (such as the following two papers), so we used this writing style.



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Quick ice mass loss and abrupt retreat of the maritime glaciers in the Kangri Karpo Mountains, southeast Tibetan Plateau

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The maritime glaciers are sensitive to climate change because of high annual precipitation and high air temperature in the region. A combined comprehensive study was carried out based on glacier mass balance observation, GPS-based glacier terminus position survey, glacier Ground Penetrating Radar, topography maps and RS satellite images in the Kangri Karpo Mountains, Southeast Tibet. The study revealed a strong ice mass loss and quick glacier retreat since the 1970s. Ata Glacier, one glacier from the south slope of the Kangri Karpo Mountains, has formed a 6-km-long terminal moraine zone at the end of the glacier since the 1970s, and the accelerating retreat is largely due to the strong glacier surface melting. Mass balance study on the other four glaciers on the northern side of the Kangri Karpo Mountains shows that they are in large negative mass balance and the glaciers had retreated 15—19 m from May 2006 to May 2007. The *in-situ* glacier observation also shows that the glacier retreat is more obvious in small glaciers. The enhanced ice mass deficit caused by climate warming and the ongoing extinction of many small glaciers in this region could seriously affect the water resources, environments, local climate and regional sustainable development in the near future.

glacier shrinkage, mass balance, climate change, Kangri Karpo Mountains

Articles — Chinese Science Bulletin

SPECIAL TOPIC
Glacial Retreat and Its Impact on Lakes in Tibetan Plateau

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Glacial distribution and mass balance in the Yarlung Zangbo River and its influence on lakes

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Glaciers in the Yarlung Zangbo River witness severe glacial retreat nowadays, which gives important influence on lake processes in the region. We have studied glacial distribution, glacial mass balance and found large deficit in glacial mass and its impact in the region. Our study also integrated the variation in glacial-fed lakes of the Nam Co and Ranwu Lake, and presented an initial assessment of the impact of glacial mass balance on lakes. The study has shown a significant contribution of glacial melting to recent lake expansion and lake level rising.

Yarlung Zangbo River, glacial distribution, glacial mass balance, lake variation

Line 51 Sentence starting 'Therefore'. I completely understand what you are trying to say here....but the use of language is incorrect.

Reply: Unfortunately, our description of this sentence was so succinct that it confused the reader, and we will be rewriting the sentence.

Line 71 Delete 'Whereas'.

Reply: Thank you for your tips, we have corrected it.

Line 82 I don't agree with this. USV are used quite a lot. Lots of other examples. Cite: Wilson, R., Harrison, S., Reynolds, J., Hubbard, A., Glasser, N.F., Wündrich, O., Anacona, P.I., Mao, L. and Shannon, S., 2019. The 2015 Chileno Valley glacial lake outburst flood, Patagonia. Geomorphology, 332, pp.51-65. Also papers therein.

Reply: This is a reference from other people's research, and if you disagree with this statement, we can remove this statement.

Line 149 the data acquisition module, the data acquisition module. This is repeated.

Reply: Sorry for our carelessness, here is a small mistake that it should be the data acquisition module, the data transmission module.

Line 239 Why is the lake described as 'dangerous' if it is stable?

Reply: Here we may not have described it clearly enough. The stability of a glacial lake means that its area remains unchanged, which is an indication of its stability. But the surrounding factors of the glacial lake, such as the mother glacier, the surrounding moraine, and the climate change are unstable, and they may act on the glacial lake to cause the original stability of the glacial lake to be destroyed, thus inducing glacial lake outburst flood. To avoid ambiguity, it might be better to write *constant area* here.

Line 273 Where is the evidence that strong earthquakes can produce a full-depth incision in a terminal moraine?

Reply: A full-depth incision in a terminal moraine is informed by the hypothesis of Sattar et al. (2021) for Lower Barun Glacial Lake, for which they set the extreme scenario of the outburst incision reaching the bottom of the moraine (104 m) due to the initial erosion of the overtopping floods. We assume that this event may be caused by one or a combination of factors such as ice/avalanches, rock falls, landslides, heavy precipitation, or earthquakes.

Our assumption is designed to simulate the impact of an extreme-magnitude scenario glacial lake outburst flooding on the downstream region, but the possibility of such scenarios occurring is poorly considered. Reviewer I also questioned this issue. Therefore, we have paid enough attention to this situation and improved it. According to review 1's suggestion, we analyzed the whole process chain of GLOFs starting with detailed quantitative analysis of potential GLOFs triggers, following with the generation and propagation of waves in the lake caused by potential triggers, the erosion of the dam by overtopping floods, and the resulting GLOFs in the downstream.

1 *Sattar, A., Haritashya, U. K., Kargel, J. S., Leonard, G. J., and Chase, D. V.: Modeling Lake Outburst and Downstream Hazard Assessment of the Lower Barun Glacial Lake, Nepal Himalaya, J. Hydrol., 598, 126208, https://doi.org/10.1016/j.jhydrol.2021.126208, 2021.*

Line 296 the ~52.98 km downstream. Explain this.

Reply: We only study the impact of flooding in the downstream channel at a distance of about 53 km from Bienong Co.