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 analyze the evolution of the glacial lake and its mother glacier in Results section to make the relative complete study and presentation of the research object, but the fact is that the glacial lake has not evolved too drastically. According to your suggestion, we present this part in 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 trigger 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 trigger identified in Section 5.1. What is described in Section 5.1. gives mainly qualitative overview of potential GLOF trigger. 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 aim to assess 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 trigger, following with the generation and propagation of wave in lake, the erosion of the dam by overtopping floods, and the resulting GLOFs in the downstream flow channel. We analyzed the potential GLOFs trigger in section 5.1, i. e. ice avalanches from the tongue of its mother 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 GLOF of Ranzeria Co, a moraine-dammed glacial lake just 10 km away from Bienong Co. And the lateral moraine landslide is the GLOF trigger of Jinwu Co (a moraine-dammed glacial lake), which is only 24 km away from Bienong Co, so in this revision, we took the ice avalanche from mother glacier and the lateral moraine landslide as potential trigger for Bienong Co. 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 crevasse-developed glacier volume with a surface area of 0.19 km^2 as the potentially dangerous ice body of the mother glacier of Bienong Co. To simulate the subsequent process triggered by ice avalanche in different magnitudes, we divided the potentially hazardous ice body into three parts according to the surface elevation range (the dangerous ice body 01, the dangerous ice body 02 and the dangerous ice body 03), representing partial or total collapse of the hazardous ice body and 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 with a surface area of 0.05 km^2 and 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 with a surface area of 0.11 km^2 and the mean height difference of 103 m from the lake surface) is released, which is the moderate-magnitude trigger. In scenario-3, the total crevasse-developed ice body (the dangerous ice body 03 with an area of 0.19 km^2 and the mean height difference of 131 m from the lake surface) is released, which is the extreme-magnitude trigger. For the release depth we 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 base of the ice tongue may be in a dome shape, therefore the avalanche volume of the collapsed ice body would be overestimated. But in the Rapid Mass Movement Simulation (RAMMS) Avalanche module (Bartelt et al., 2013) simulation, the 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 into the lake as set.

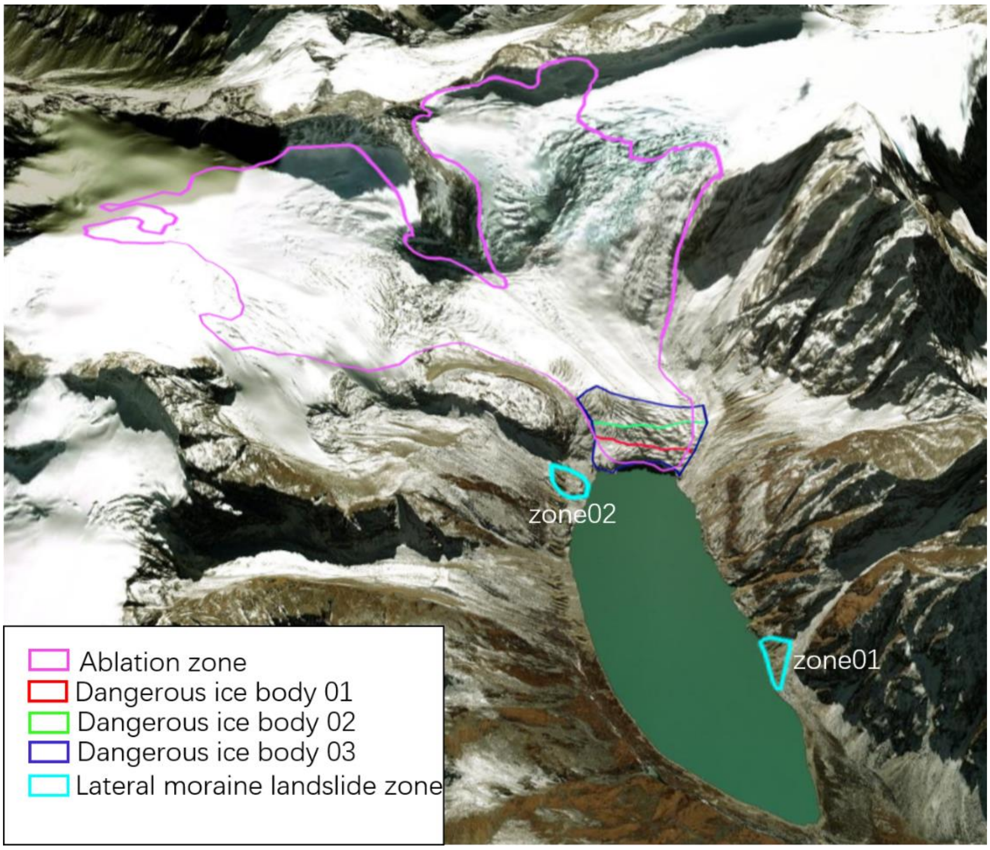


Figure 1. Illustration of setting trigger for potential GLOF in Bienong Co

In addition, we selected lateral moraine landslide as another GLOFs trigger 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 multi locations with lateral moraines around the Bienong Co that fit into this slope range. We selected two potential release zones 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 is to fully consider the impact of trigger 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 trigger 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 trigger should be identified, quantified and treated more in depth in my opinion, feeding the definition of dam breach (GLOF) scenarios.

Reply: Landsat images show that the mother glacier of Bienong Co retreated by about 120 m from 1976-1988 (possibly earlier), after which small changes of the mother glacier's tongue were not identified because of the coarse spatial resolution of the available images. Comparing the image in ArcGIS Earth software (earlier than 2020, but the exact date is not clear) (Figure2-left) with the photos taken during the 2020 field survey (Figure2-right), it's clear that the glacier tongue was in a significantly different state and have collapsed in 2020 compared to the earlier period. The above evidence shows that the glacier tongue is in a changing state, although we did not directly witness one change process during our field survey. Meanwhile, large number of cracks appear on the mother glacier's tongue of Bienong Co, which are clearly visible in both ArcGIS Earth image and field survey photo (Figure 2), that 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 32˚, 26˚, 22˚, 20˚ and respectively, all of which exceed the above threshold, indicating the potential hazard.

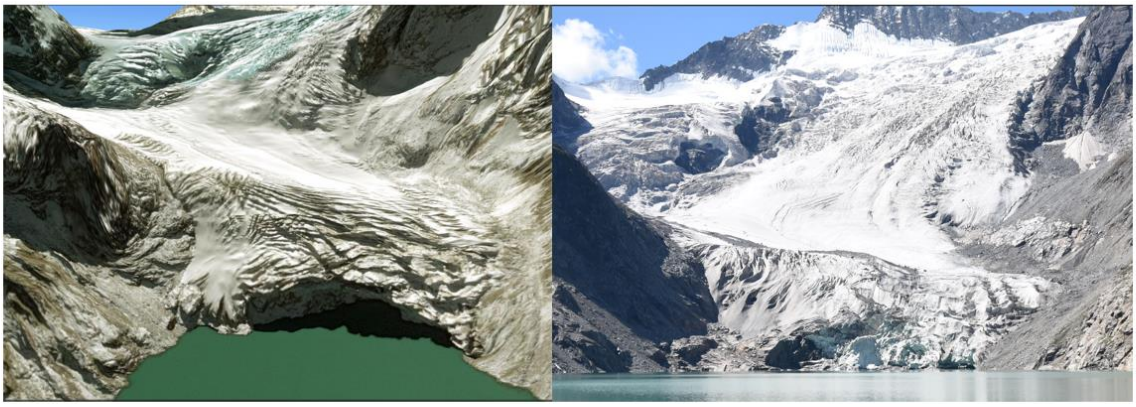


Figure 2. Comparison at the tongue of the mother glacier of Bienong Co in different periods (left: the high-resolution image from ArcGIS Earth software, the date is earlier than 2020, but the exact date is unknown; right: taken in August 2020)

The scenario of the extreme-magnitude GLOF downcutting to the base of moraine dam (72 m) was informed by the hypothesis of Sattar et al. (2021) for Lower Barun Glacial Lake, in which they set the extreme scenario of outburst incision reaching the base of the moraine dam (104 m) due to the initial erosion of the overtopping flood. We assumed that the extreme scenario may be caused by one or more factors such as ice/avalanches, rock falls, landslides, heavy precipitation, or earthquakes. According to your comments, this assumption may be relatively subjective because of the lack of investigations for strong earthquakes and extreme precipitation and temperature events in the region, and the small probability of earthquake-induced GLOFs in the Tibet, China. The probability of GLOFs induced by glacial meltwater and heavy precipitation and their combinations can account for one fifth. For example, the GLOF of Jinwu Co in 2020 was caused by precipitation-induced lateral moraine landslide that destabilized the glacial lake and ultimately led to the GLOF event. In Tibet, China, ice/snow avalanches and landslides and their combinations induced more than 70% of GLOFs events. However, the trigger was not quantitatively simulated in our initial study.

Therefore, in this revision, we first quantified the potential trigger of GLOFs according to your comments, in which ice avalanche and lateral moraine landslide are selected, 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. 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 lake, 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).

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 object 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 are significantly reduced. The flood flows into the cross-section representing Bada village 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 the comment, we fully understand your opinions and for the discussion part, we will work on the glacial lake hazard quantification, evaluation of the published volume estimation relationships and uncertainty analysis 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, and Figure 6 are discarded, so we will reconsider this problem. We appreciate your comment.

I think that especially GLOF trigger 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 process chain, including the initial slope movement, the generation and propagation of wave in the lake, dam breaching and the floods behaviors in the downstream channel starting from quantifying the trigger according to your suggestion. And, 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 the glacial lake hazard quantification, evaluation of the published volume estimation relationships and uncertainty analysis of GLOFs process chain simulation.

We attached reviewer 2's comments and our reply in this paper.

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 trigger 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 GLOFs trigger, 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. Regarding our language, we will look for a native English-speaking editor to help revise the research once it is finalized to ensure the readability of our article.

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 is a representative glacial lake 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 were described in Study area section. But the way it is written does not seem to be clear enough to make you question it. We will improve it 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 glacial lakes. In this study, the Yi'ong Zangbo River Basin in the Southeastern Tibetan Plateau is used as the study area. According to Duan et al. (2020), there were 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 2016, 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) area of mother glacier, (2) distance between lake and glacier terminus, (3) slope between lake and glacier, (4) mean slope of moraine dam, and (5) snout steepness of mother glacier to evaluate the GLOFs potentiality of the 67 glacial lakes, and GLOFs susceptibilities were classified as very high, high, moderate, and low. The results show that there were 10 glacial lakes with a very high GLOFs potentiality, in 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 breached in 2020, with an area of 0.53 km^2 in 2016, and the other is the object of this study, Bienong Co, whose area in 2016 was about 1.12 km^2. GLOFs of relatively small glacial lakes cause limited damage in sparsely populated regions like Tibet, so relatively large lakes tend to be valued more. The area of Bienong Co is nearly twice as large as the area of the already breached Jinwu Co, and given the huge damage caused by Jinwu Co's GLOF to the downstream region, the potential GLOF 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 Ranzeria Co 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 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 GLOFs.

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 GLOFs hazard of glacial lakes. Zhang et al. (2022) systematically summarized the indicators for assessing GLOFs hazard in the Himalayas, 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. Multi 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 GLOFs hazard of a glacial lake from 57 factors by designing experiments: (1) average slope of mother glacier, (2) likelihood of material entering lake, (3) average slope of moraine dam, (4) watershed area, and (5) lake perimeter, corresponding to glacial collapse, rockfall and landslides, dam instability, heavy precipitation or other fluid inflow, and lake characteristics. Considering that ice avalanche and landslide trigger almost more than half of the GLOFs; average slope of mother glacier and likelihood of material entering lake were given higher weights in assessing potential GLOFs of glacial lakes in the Himalayas using the fuzzy consistency matrix method.

The GLOFs hazard of a glacial lake are influenced by multi factors, such as the area and its growth rate, the properties of moraine 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 it's considered to be safe. However, its huge area should be valued. The presence or absence of ice cores in moraine dams is unknown. But, the absence of ice core is only one of the factors representing the stability of moraine dam, dam height, dam texture (consolidated or unconsolidated, bedrock, or other) dam freeboard, mean slope, the present of leakage, et al. are also the important characteristics. The moraine dam of Bienong Co is high and steep, consisting of loose materials. With a freeboard of 0 m, any mass entering the lake could create overtopping flows 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, in terms of moraine dam, Bienong Co is dangerous, because the moraine dams of the two nearby glacial lakes that have breached 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 GLOF, 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 avalanche, meaning the potentiality of the GLOFs. In terms of Bienong Co, slopes of the ablation zone are 20°, which exceed the threshold, indicating the potential hazard. And, the destabilization conditions of lateral moraine that lead to the failure of Jinwu Co also exist around Bienong Co, so it may also be a potential trigger.

Finally, studies show that although ice avalanche into Ranzeria Co and lateral moraine landslide into Jinwu Co are the dominant factors leading to GLOFs, the preceding precipitation and rapid warming still plays a role in the occurrence of ice/avalanche and lateral moraine landslide (Sun et al., 2014; Liu et al., 2021 and Zheng et al., 2021). Bienong Co is in proximity to these two glacial lakes, and the same climatic conditions are likely to act on Bienong Co and cause GLOFs.

Above is the explanation of the potential trigger for GLOFs of Bienong Co. We believe that it is reasonable to study Bienong Co as a glacial lake with potential for GLOFs. Although the exact trigger and timing of its breach 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 of 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 calculation and the GLOFs simulation. Therefore, the work of this study is of great significance for understanding the basin morphology and glacial lake depth, as well as 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 lake, dam erosion and breach, and downstream flood behavior using the

Rapid Mass Movement Simulation (RAMMS) Avalanche module (Bartelt et al., 2013) and the Basic Simulation Environment for Computation of Environmental Flow and Natural Hazard Simulation (BASEMENT) model (Vetsch et al., 2017) are 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.

Reference:

1 *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.*

2 *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.*

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 of a lake can be calculated. In Results section, we simulated the morphology of Bienong Co and estimated its water volume. However, the description of the title does not use “water storage” but “volume”, perhaps the former would be better. Comparisons with other lakes in this region are not covered because few bathymetric data for other glacial lakes in the region are currently available. In addition, the section 5.2 Comparison of morphological characteristics for glacial lakes in continental and maritime glaciation regions in Discussion section is to explain that glacial lakes in the maritime glaciation zone may be deeper and therefore store more water by comparing with lakes of 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 the Yi’ong Zangbo River Basin have both caused serious disasters in the downstream region. The outburst of Ranzeria Co 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 with beautiful scenery and is a representative of the local Tibetan religious beliefs. GLOFs disaster, therefore, is always an extreme concern for the local government, and during our survey, there was local government staff involved. This study could provide some theoretical help to local governments in understanding this glacial lake. For local residents, due to the presence of settlements, infrastructure and farmland, engineering measures such as lowering water levels are most likely to be used to mitigate potential threats based on the potential hazards generated by Bienong Co's GLOF.

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 Chinese 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 zone.

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.

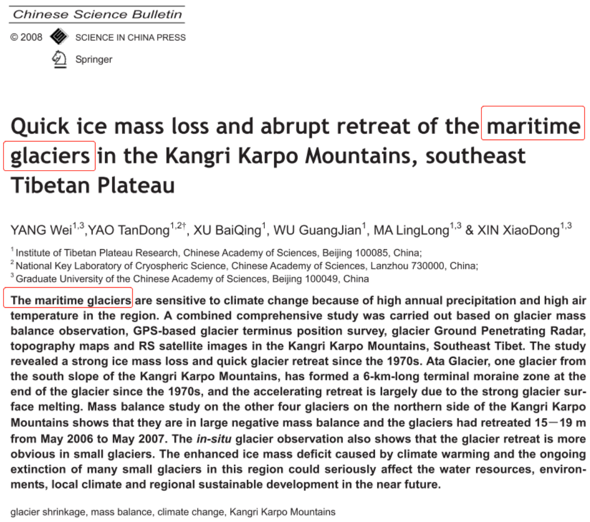
Reply: Thanks a lot for your guidance on our grammar. We will correct this situation throughout the text.

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

YANG Wei[1,3],YAO TanDong[1,2†], XU BaiQing[1], WU GuangJian[1], MA LingLong[1,3] & XIN XiaoDong[1,3]

[1] Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China;
[2] National Key Laboratory of Cryospheric Science, Chinese Academy of Sciences, Lanzhou 730000, China;
[3] Graduate University of the Chinese Academy of Sciences, Beijing 100049, China

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

YAO TanDong[1,2*], LI ZhiGuo[1], YANG Wei[1], GUO XueJun[1], ZHU LiPing[1], KANG ShiChang[1,2], WU YanHong[3] & YU WuSheng[1]

[1] *Key Laboratory of Tibetan Environment Changes & Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China;*
[2] *State Key Laboratory of Cryosphere, Chinese Academy of Sciences, Lanzhou 730000, China;*
[3] *Key Laboratory of Digital Earth Sciences, Center for Earth Observation and Digital Earth, Chinese Academy of Sciences, Beijing 100190, China*

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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 Bienong Co refers that its area remains unchanged. But the surrounding environment, such as the mother glacier, the lateral moraine, and climate are unstable, and they may act on the glacial lake to destroy the original stability, thus may inducing GLOFs. 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 moraine dam was 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 assumed that this event can be caused by one or more factors such as ice/avalanches, rock falls, landslides, heavy precipitation, or earthquakes.

Our assumption is to simulate the impact of an extreme-magnitude GLOF on the downstream region, but the occurring possibility of the scenario is poorly considered. Reviewer I also questioned this assumption. Therefore, we paid enough attention to this situation and improved it. According to reviewer 1's suggestion, we simulated the GLOF process chain starting with detailed quantitative analysis of potential trigger, followed by the generation and propagation of waves in the lake, the erosion of the dam by overtopping floods, and the resulting flood in the downstream region.

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 GLOFs in the downstream channel within the distance of ~53 km from Bienong Co.