

**Review by Mauro Fischer (Glaciologist at the Institute of Geography, University of Bern, Switzerland, mauro.fischer@giub.unibe.ch) of the revised manuscript**

**«Formation, evolution and drainage of short-lived glacial lakes in permafrost environments of the northern Teskey Range, Central Asia»**

**By Mirlan Daiyrov and Chiyuki Narama**

### **General Comments**

Dear authors, dear editor, I appreciate the authors' efforts made concerning corrections and improvements of the first submitted version of their manuscript. In general, implementations of reviewers' comments to the first submitted version of the manuscript are good. The paper is now much clearer, easier to read, very nicely illustrated, and of interest to the scientific community.

On behalf of the editor, I reviewed the second submitted version of the manuscript again in detail. I would ask the authors to consider my comments on specific content/scientific and technical issues listed below and implement these comments as much as possible for their next version of the paper. This should be quite easy and won't take so much time again as for the first submitted version of the manuscript.

My main point of criticism to the second version of the paper is that interpretation/discussion/findings of/from the analysis of the other 160 short-lived glacial lakes in the Teskey Range detected using satellite imagery is still rather (if not too) speculative, even if I can totally follow your rationale here and also guess that you're not that wrong... It mainly concerns chapters 4.4, 5.1 (Lns 252-259) and some corresponding remarks in the conclusions. I think it does make sense that you use the well-studied formation and drainage processes of Korumdu lake (and of the four other lakes) as an analogy for other short-lived glacial lakes of the same type... but I argue that you would need to investigate the other 160 short-lived glacial lakes a bit in more detail to say, for instance, if really 73% are of the same type as Korumdu, how they form and drain etc.... It makes sense to me that you take appearance dates to estimate which of the different possible formation processes belong to the lakes detected using satellite imagery. – But, in my opinion, you should be able to “give some more hard facts rather than only educated guesses” here... For instance, you could try to analyse based on the satellite imagery whether the other lakes have a (visible) surface or subsurface (outlet ice-tunnel) drainage channel (at least from the imagery with highest resolution) or not, how the geomorphological setting of the short-lived lake is (i.e. are there ice-cored moraine complexes visible or not), etc. etc.... this would give you valuable additional information to check if you're right with your statement that  $\frac{3}{4}$  of the other short-lived glacial lakes show similar formation processes as for instance Korumdu lake... I hope you see my point here...

In my opinion, the manuscript now is subject to minor revisions, but can be accepted for publication after implementation of these issues by the authors. Many thanks and all the best, kind regards

### **Abstract**

Add reason how formation of short-lived glacial lakes due to closure of outlet ice-debris tunnel can be detected from satellite imagery

Ln 23: “...in rates...” → “...in discharge rates...”

Lns 23f: “...outlet ice tunnels.” → “...outlet ice-tunnels.”

Lns 24f: “For the 160 other short-lived glacial lakes, we argue that 117 formed mainly due to tunnel closure from deposition of ice ice-debris mixture, though increased glacial melt also likely contributed.” → delete one “ice” (“...ice ice-debris...”); add “...to lake formation.” at the end of the sentence?; moreover, I would appreciate if you could add some words here in this sentence about the reason(s) why you argue that 117 of the detected short-lived glacial lakes formed mainly due to tunnel closure (how did you do that/how could you define that based on the satellite imagery?)

### **Introduction**

Short-lived proglacial lakes? Unterscheidung zu anderen Gruppen von “glacial lakes» nicht immer klar, überall überprüfen

Ln 41: “Most short-lived glacial lake fill ...” → “...glacial lakes fill...”

Ln 44: “...because they appears suddenly...” → “...because they appear suddenly...”

Lns 44f: “Such an outburst (outburst mechanism and damage potential differs from those that are caused by...” → I would delete “such an outburst” at the beginning of the sentence here, much clearer in my opinion to just write: “Outburst mechanism and damage potential of short-lived glacial lakes in the northern Tien Shan differ from those that are caused by...”

Ln 47: “... a mass-movement trigger is the main cause of dam failures of the glacial lakes in the Himalayas and Andes...” → I think the wording “mass-movement trigger” is misleading here, what do you exactly mean? – be precise and rephrase accordingly...

Ln 53: “Several studies reported the formation and drainage supraglacial lakes are related to...” → “Several studies reported that formation and drainage of supraglacial lakes are related to...”

Ln 55: “...of the short-lived glacial lakes...” → be precise what glacial lakes you are referring to here, I would write: “...of short-lived glacial lakes in northern Tien Shan...”

Ln 56: “Short-lived glacial lakes appear...” → again, I would define which glacial lakes you are referring to here (seems important to me to be very clear on that in the introduction already), thus I would write: “Short-lived glacial lakes in northern Tien Shan appear...”

Ln 56: “...when glacier recedes...” → “...when a glacier retreats...”?

Lns 58f: “...and on a surging glacier (Richardson and Reynolds, 2000; Käab et al., 2004).” → I would argue that it might be clearer or less misleading here if you’d delete this subordinate clause because as far as I know surging glaciers (or short-lived glacial lakes formed by glacier surges) are not really frequent in the northern Teskey Range, in northern Tien Shan (contrary to for example the Pamir), right? And in this paragraph you really focus on short-lived glacial lakes in northern Tien Shan or on short-lived glacial lakes in permafrost environment, i.e. the type of short-lived glacial lakes your paper is all about...

Ln 60: “...water supply on an...” → “water supply to/towards an...”?

Ln 66: “...but also to above three conditions in the glacier forefield as described above.” → “...but also to the three conditions in the glacier forefield described above.” (otherwise there is a repetition in this sentence...)

Lns 67f: “They can change over large areas and volumes in a short period of time...” → I think what you mean here is: “They can change in area and volume over a short period of time...”, please change accordingly

Ln 74: I would delete the “flood” here, as lake discharge also occurs if there isn’t a flood...

Ln 75: “...store and drain water...” → clearer to write “...form and drain...”?

Lns 78f: “Findings from our study are relevant for glacier-related hazard mitigation.” → In my opinion, this sentence is “a bit lost” or “out of context” here... I think your study is first about process understanding of the formation and drainage of short-lived glacial lakes in permafrost environments of the Teskey Range, and in a second step it may serve as valuable information/resource for mitigating hazards related to rapid drainage of such lakes.... But your study is not really dealing with how to mitigate such hazards directly... I would consider if it’s not clearer to delete this sentence here and add something on that point to the discussion of the paper...

## Study area

In this section, but also in the whole manuscript, I would maybe use “m a.s.l” instead of just “m” for information or numbers related to altitude

Lns 86f: One cannot really compare the mean annual air temperature data between the western, central and eastern part of the Teskey Range based on the data you give here (recorded time periods, length of recorded periods, and elevation of the three stations are significantly different), the same actually also applies to some extent for mean annual precipitation, as there is more precipitation for higher elevations and the three stations are not at the same altitude at all (Lns 83ff)... Maybe it would be more clear to compare climatic data over the same time period and for an equal elevation to describe climatic differences between the western, central and eastern part of the Teskey Range...

Lns 87f: *“The western part of the range had less glacier shrinkage than that in the eastern part...”* → do you refer to absolute or relative values here? (as the glaciers in the eastern Teskey Range are generally larger I guess you mean “...showed less relative glacier shrinkage than the eastern part...”? → please check and implement accordingly...

Lns 92f: *“...due to ice and debris stagnated by several glacier advances during the glacier shrinkage process...”* → not very well and not very much understandably written... please rephrase in order to be clear what you exactly mean here

Ln 95: *“...satellite image in 2019...”* → “...satellite image of 2019...”

Lns 97f: *“We selected this lake for research because...”* → “We selected this lake for field surveys because...”

Lns 100f: *“...drainage from Korumdu lake is the flood-wave type in the downstream region because the water stream flows on a gentle slope.”* → In my opinion, the reason if drainage of a glacial lake occurs as a flood wave (with a clear “front”, i.e. rapidly increasing discharge) or if drainage of a glacial lake takes place by steadily (but more slowly) increasing discharge does not depend on the slope downstream of the lake but on the outburst or discharge processes (sudden outburst vs. steadily increasing channels)! → Please correct and rephrase accordingly...

Ln 102: *“Supplemental Table 1”* → “Supplementary Table 1”

## Methods

Lns 119f: *“For the water volume at the lake bottom...”* → You should delete “at the lake bottom” here because “at the lake bottom” there is no “water volume”, and it becomes clear what you mean from the following subordinate clause...

Ln 121: "...an *in situ* water level logger data..." → delete "an" here (as data is plural); "*in situ*" → "in-situ"?

Ln 123: "...and combined UAV-derived DSMs." → clearer: "...and therefore combined UAV-derived DSMs with satellite imagery."!?

Lns 123ff: "*For example, we confirmed the position of the water level by comparing a UAV orthorectify image and satellite data on 1-m counter lines extracted by the combined UAV-derived DSMs.*" → I don't really understand this sentence, cannot really follow how you did this... Rephrase in order to be clearer or delete this sentence?

Ln 125: "...water area..." → "...lake area..."

Ln 126: "...between August 4 and 31..." → of which year(s)? not very clear to me...

Ln 127: "...after our last visit..." → "...after our last field survey..."

Ln 131: "...during in 2015-2019..." → delete the "in" here

Ln 134: "*Supplemental Table 1*" → "Supplementary Table 1"

Section 3.2: It is not very clear to me from this paragraph if, based on the numerous satellite data (Supplementary Table 1) you mapped/digitized short-lived glacial lakes only once or several times during summer months (i.e. if you were also looking at area changes of detected short-lived glacial lakes during summer months of the individual years or not...) → if yes please add something on that here...

## Results

Ln 145: I would add "...in recent years." after "...that formed during the retreat of the glacier..."; "*The UAV ortho-images in 2019...*" → "The UAV ortho-images of 2019..."

Ln 151: "...we observed melt draining..." → "...we observed melt water draining..."

Ln 152: "...but not in 12 August 2016..." → "...but not on 12 August 2016..."

Ln 154: "..., the lake area did not appear." → "..., the lake did not form."

Ln 155: "...we had more images of the area..." → "...more images of the area could be acquired..."

Lns 155f: “...a more precise sequence of changes in lake size is shown with a sequence of PlanetScope satellite images...” → repetition “sequence of”, I would rephrase as: “...a more detailed evolution of changes in lake size is shown with a sequence of PlanetScope satellite images...”

Lns 160ff: “In addition, we checked Landsat-8/OLI data in 2014, finding that the lake existed on 5 May, 27 June, and 10 September in 2014. Thus, the satellite data demonstrate that the lake is a short-lived glacial lake.” → ok, all fine, but I have two remarks here: i) I totally agree with you that Korumdu lake is a short-lived glacial lake, no doubt about that, but if you refer to three points in time when the lake is visible from satellite imagery it does, in sensu stricto not imply that the lake is a short-lived one (to “prove” your statement in the second sentence here you’d also have needed satellite imagery on which the lake basin is empty (not filled with melt water)), so my comment here relates to the logic of the sentences...; ii) you also detected the lake on 5 May 2014, rather early to the reported timing of lake appearance in other years... do you have any explanation why the lake already existed on 5 May 2014 (did it possibly not drain in summer 2013 and therefore still existed in spring 2014?)... would be interesting to add something on that here...

Chapter 4.2 is mainly written in present tense; shouldn't it be written in past tense?

Ln 165: “Consider the trends in Korumdu lake during the three summers of 2017–2019.” → “Changes in water level, area, volume and discharge of Korumdu lake were studied in detail during the three summers of 2017–2019.”

Ln 170: “...the net outflow is relatively smooth.” → do you mean “low” here instead of “smooth”? – I would change that accordingly...

Ln 171: “The temperature fluctuates more...” → “The water temperature fluctuates more...”

Ln 173: “The same figures show the cases for 2018 and 2019.” → I would delete this entire sentence here (it is clear from what you write afterwards and like this you can circumvent the issue of the rather fuzzy formulation of “...show the cases for...”)...

Lns 179f: “...shows a local maximum...” → why “local”? – the whole chapter 4.2 is about very local processes... I would delete “local” here...

Ln 196: Replace “visit” by “field survey”!?

Ln 202f: “...are consistent with closure in the outlet ice-tunnel **during being duet to surface motion and ice-debris deposition.**” → there is something wrong here (words in bold) but I don’t know during which period you mean, please correct and rephrase in order that it corresponds clearly to what you mean...

Lns 203f: *“During our fieldwork in 2016, we observed the entrance of an ice-tunnel and water flow to its entrance. After two or three hours, the lake level increased (Fig. 7), consistent with the cause being closure of the ice-tunnel.”* → In the first sentence, there is a repetition of “entrance”. The subordinate clause of the second sentence here is not clear yet, please rephrase and change accordingly in order that one can easily understand what is meant here...

Lns 212f: *“To help determine when other short-lived glacial lakes form, we used satellite images during 2013–2018 to identify and examined 160 such short-lived glacial lakes in the northern Teskey Range.”* → “To determine when other short-lived glacial lakes in the northern Teskey Range formed, we used satellite images of 2013–2018 (cf. Supplementary Table 1). Based on the satellite imagery, a total of 160 short-lived glacial lakes could be identified.”

Lns 216f: *“Such variability has been argued to be related to geomorphological conditions such as drainage through ice tunnel inside of ice-cored moraine complex (Daiyrov et al., 2018).”* → Ok, but this does not directly or not clear enough relate to the detected variability in lake formation (number of lakes in different years) and appearance date (proportion of lakes forming during snow-melt period vs. during ice-melt period). You have to clarify and rephrase here and write exactly what you mean in order to be clear...

Ln 220: *“...likely has...”* → *“...likely have...”*

## **Discussion**

Ln 227: Why not add years of appearance for the four glacial lakes in addition to the months here? – or did they reappear several times? – not very clear (one would have to go into the paper you refer to here)...

Ln 235: *“...supports...”* → *“...support...”*

Lns 241ff: This paragraph about the Toguz-Bulak glacial lake is very interesting, but, as you also write, the process of lake drainage and main drivers of lake formation is (very) different compared to the short-lived glacial lakes forming through blockage of a subsurface outlet ice-tunnel... Indeed, water level and lake volume in such cases (lakes with surface drainage channel) is predominantly influenced by the morphology of the lake depression and the elevation of the surface drainage channel, as well as by the glacier mass balance. In my opinion you're talking about an existing and well interpreted but other type of short-lived glacial lakes here... and the last sentence of the paragraph (*“Thus, in addition to the closure of deposition, the lake-area changes during summer is also likely influenced by changes in the rate of incoming meltwater.”*) is not really appropriate here (as short-lived glacial lakes are rather of the one type (with surface drainage channel) or the other (with subsurface drainage and temporal blockage of the outlet ice-tunnel). Thus, what you write is not wrong but in my

opinion you should more clearly differentiate between these lake types and maybe write: “Thus, as for short-lived glacial lakes with surface drainage channels like Toguz-Bulak, the evolution of the glacier mass balance during summer (amount of snow and ice melt flowing into the lake) also plays an important role for the formation and evolution of short-lived glacial lakes having a subsurface outlet ice-tunnel.”

Ln 245: You’re talking about Korumdu lake again here → write: “In 2017, there were two trends in water volume of Korumdu lake...”

Ln 251: “...and deposition condition of tunnel-closure point.” → I can guess what you mean here but I think it would be worth adding some key words in parentheses at the end of this sentence to clarify what you exactly mean here...

Ln 266: “...emptied at the higher discharge rate...” → “...emptied at a higher discharge rate...”

Ln 270: “...which we argued...” → “...which we argue...”

Ln 273: “...yet the discharge rates were nearly the same every year...” → From figure 6 I wouldn’t say that they were “nearly the same”, maybe write “...yet discharge rates were in the same order of magnitude every year...”

Ln 278: “If these apply...” → “If these conditions and evolution also apply...”

## Conclusions

Ln 283: I would add the years of field surveys here and some specifications about the location of Korumdu lake in parentheses

Ln 284: “argued” → “argue”

Ln 287: “we were able to estimate daily lake discharge and approximate the tunnel dimensions at much less...” → “...we were able to study the temporal evolution (lake area, volume) and daily lake discharge and approximate the tunnel dimensions to much less...”

Ln 288: Delete “...were...”

Ln 289: “Kromudu” → “Korumdu”

Ln 293: “...flood via...” → «...drain through...»

Ln 294: Delete “...can be...” (or replace “are” with “can be” in Ln 293)



## Acknowledgements

Ln 303: *"Thanks to an editor Margreth Keiler and two revisers (M. Fisher and anonymous)..."*  
→ "Thanks to the editor (Margreth Keiler) and two reviewers (Mauro Fischer and anonymous)..." ; please spell my name correctly ;- ) but many thanks for the acknowledgement, I appreciate that!

## Figures

Figure 1: In the legend of figure 1 (right of the green square with check) you have to change *"Large drainage of short-live lake"* into *"Large drainage of short-lived lake"* (a "d" is missing)

Figure 3: figure caption: *"The width at the lake middle is about 85 m (left image) and 40 m (right)." → "Maximum lake width is about 85 m (left image) and 40 m (right image)."*; maybe you could add this directly in the figure (similar as you have done in Figure 12 b for the outlet ice-tunnel height and width)...

Figure 5: figure caption: *"Korumdu lake during 2017–2019 from on time-lapse camera images acquired in the field." → "Korumdu lake during 2017–2019 from on-site time-lapse camera images acquired in the field."*

Figure 6: figure caption: *"Water levels of Korumdu lake in 2017–2019. (a) and air/water temperature in 2017. (b) Lake volume. (c) Lake surface area. (d) Inflow–outflow rate." → "(a) Water levels and air/water temperature, (b) lake volume, (c) lake area, and (d) inflow-outflow rate of Korumdu lake during summer months of 2017–2019."*; moreover, I don't really understand why you write *"air/water temperature"*... As this is not the same... is this because the temperature logger is first above the water level and then later in summer below (i.e. in the water)?... or are you really just showing water temperature data here (in Fig. 6a (as also explained in chapter 4.2)? should you therefore delete *"air/"* in the figure caption here? please clarify and add something on that here or in the text...

Figure 7: I would suggest to delete the *"small"* in the figure caption but add the amount of lake level increase (in centimeters or decimeters) directly in Fig. 7a) and 7c) (with arrows showing the lake level difference and numbers indicating the amount of lake level changes)...

Figure 8: I would delete *"...on the listed dates"* in the figure caption as this becomes clear right after...; in the figure I would add somewhere (a), (b), (c) or (d) to which date the *"basin line"* corresponds (and I would change *"basin line"* into *"lake level on XX.XX.20XX"*)...

Figure 9: In figure 9 a) and b), the red lines refer to feature positions in 2015, and the blue lines to the new position of the same features in 2016. In figure 9 c), blue is taken for the 2015

surface and red for the 2016 surface. – This is misleading. – I would switch the colours in figure 9 c) in order to be consistent with figure 9 a) and b) and increase clarity...