

Earth Syst. Sci. Data Discuss., author comment AC1
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Reply on RC1

Muchu Lesi et al.

Author comment on "Landsat and Sentinel-derived glacial lake dataset in the China-Pakistan Economic Corridor from 1990 to 2020" by Muchu Lesi et al., Earth Syst. Sci. Data Discuss., <https://doi.org/10.5194/essd-2021-468-AC1>, 2022

Overall comment:

This manuscript is in good shape. But there are two issues that MUST have attention given to them. (i) Terminology..the classes of lakes are not named at all well. I have suggested what to do. (ii) Argument of why we need to detect small lakes.; I am totally unconvinced by the GLOF angle...rather I suggest thinking about the effects of lakes on glaciers and the fact that many of these newly-formed small lakes will become larger with ongoing glacier mass loss. I have offered a coitation to start these thoughts but really a whole paragraph needs adding. Else the abstract needs a complete overhaul too.

[Response] Thank you for your encouragement and constructive comments, which have helped us to improve the quality of this article. We respond to the comments point by point as follows.

Regarding the terminology of lake classification systems, we have revised it as suggested. Now, in the first glacial lake classification system, glacial lakes were classified into four types based on their spatial relationship to upstream glaciers: supraglacial, ice-contact, unconnected-glacier-fed lakes, and non-glacier-fed lakes. In the second glacial lake classification system, glacial lakes were classified into five categories (herein named GLCS2) modified based on Yao's classification system (2018): supraglacial, end-moraine-dammed, lateral-moraine-dammed, glacial-erosion lakes and ice-dammed lakes.

Regarding small lakes, we agree that small lakes have little or no hazardous impact due to their limited water release. The focus of this study is to generate a new glacial lake dataset for the CPEC, using 5 pixels as the mapping threshold for both Landsat and Sentinel images. We had to map all the glacial lakes, including small ones. If users want to conduct GLOF hazard risk studies, they have the flexibility to set a minimum threshold, such as greater than 0.05 km², to eliminate smaller lakes from our dataset. In addition, we argue that small lakes, such as supraglacial lakes, play an important role in glacier and lake evolutions, and affect cryosphere-hydrological changes. Thus our dataset has

potential to be widely applied in studies on glacial lake-related hazards, glacier-lake interactions and cryospheric hydrology. We have made some changes in the Abstract and main text, and responded to the query of Line32.

We have also cited the recommended references and revised the abstract.

Specific comments:

Line 19: suggest rewording to ...'one of a number of flagship projects...'

[Response] Revised as `...one of the flagship projects...'

Line 22, suggest delete `critical parameters' and state `...parameters X and Y and Z...' (list them out) Are these ALL glacial lakes? Or just ice-marginal ones? Supraglacial? Subglacial? Please specify. Add this specification into your methods.

[Response] Considering the dataset with 17 attributes, it is not suitable to list all of them here. So we decided to list three parameters for example, and revised this sentence to be: `An up-to-date, high-quality glacial lake dataset with parameters such as lake type, acquisition date and area, which is fundamental to flood risk assessments and predicting glacier-lake evolutions and cryosphere-hydrological changes...'

This study defines a glacial lake as one that formed as a result of modern or ancient glaciation. All glacial lakes in the study area were mapped according to our definition without any distance limit between lakes and glaciers. So it is not just ice-marginal glacial lakes. The dataset includes supraglacial lakes; however, it does not include subglacial lakes that are not detectable from optical satellite sensors. See section 4.1 and 4.3 for detailed description.

Line 24. I suggest to put the resolution(s) after the dataset type. Split sentence into two. One for lakes, one for glaciers, for clarity (because as written it is not clear if OI was for lakes or glaciers or both).

[Response] Following the suggestion, we have revised this sentence to be: `This dataset includes (1) a glacial lake inventory for the year 2020 at 10 m resolution produced from Sentinel spectral images, and (2) multi-temporal inventories for 1990, 2000, and 2020 produced from 30 m resolution Landsat images...'

Line 30...is this 5 pixel threshold for both Landsat and Sentinel? Please clarify the thresholds for BOTH datasets.

[Response] Yes, the 5-pixel threshold is for both Landsat and Sentinel images. See

'Landsat derived 2234 glacial lakes in 2020, covering a total area of $86.31 \pm 14.98 \text{ km}^2$ with a minimum mapping **unit of 5 pixels (4500 m²)**, whereas Sentinel derived 7560 glacial lakes in 2020 with a total area of $103.70 \pm 8.45 \text{ km}^2$ with a minimum mapping unit of **5 pixels (500 m²)**.'

Line 31...I'm not sure this is 'discrepancy', rather simply a result that can be interpreted to be due to many small lakes.

[Response] We agree that the discrepancy cannot be simply interpreted by the differences in total number and area of both Landsat-derived and Sentinel-derived lake dataset. Hence, we performed a comparison between Sentinel-2 and Landsat derived products in section 6.1 and interpreted the discrepancy. It reads:

'Glacial lakes from Landsat and Sentinel images have a high consistency in number and area with overlap rates from 85.7% to 94.26% for all lakes greater than about 0.0045 km^2 (Table 5), implying a good potential for coordinated utility with Landsat archived observation (Figure 11). Lake extents extracted from Landsat and Sentinel images match well for various lake types and sizes (Table 4). The best consistency rate reaches 94% for the glacial lakes between 0.1 km^2 and 0.2 km^2 . The difference in area of glacial lakes extracted from Landsat and Sentinel images generally lies within the uncertainty ranges.'

Also, 'Spatial resolution of satellite images plays a primary role in the discrepancies in count and area of glacial lakes extracted from Landsat (30 m) and Sentinel (10 m) observations. Due to a finer spatial resolution, Sentinel images can extract more glacial lakes and more accurate extents than those from Landsat images. We set the same 5 pixels as the minimum mapping unit for both Landsat and Sentinel images, which corresponds to a minimum area of 0.0045 km^2 and 0.0005 km^2 , respectively. The minimum mapping area results in generating nearly 5000 more lakes from Sentinel images than from Landsat images, causing the greatest discrepancy in number of the two glacial lake products (Table 5), such as Figure 12a. '

Line 32. Are (very) small lakes important? For hazards/GLOFs? Why? I think you need to discuss/show this...in the main text of the manuscript as well as here in the abstract...else the whole premise of your work is not represented/defended/argued (?!).

[Response] We agree that small lakes have little or no hazardous impact due to their limited water release. The focus of this study is to generate a new glacial lake dataset based on Landsat and Sentinel images in the CPEC, using 5 pixels as mapping threshold for both Landsat and Sentinel images. We had to map all the glacial lakes, including small ones. If users want to conduct GLOF hazard risk studies, they can set a minimum threshold, such as greater than 0.05 km^2 , to select a subset of lakes from our dataset to eliminate the impact of small lakes. Small lakes, such as supraglacial lakes play an important role in glacier and lake evolutions, and affect cryosphere-hydrological changes. Thus our dataset has potential to be widely applied in studies on glacial lake-related hazards, glacier-lake interactions and cryospheric hydrology. We have made some changes in the Abstract and main text. It now reads:

'An up-to-date high-quality glacial lake dataset with parameters such as lake type, acquisition date and area, which is fundamental to flood risk assessments and predicting glacier-lake evolutions and cryosphere-hydrological changes...'

'This comprehensive glacial lake dataset has potential to be widely applied in studies on glacial lake-related hazards, glacier-lake interactions and cryospheric hydrology...'

'Small lakes such as supraglacial lakes play an important role in understanding meltwater runoff and supraglacial drainage systems (Liu and Mayer, 2015; Miles et al., 2018). Our dataset can be used not only for GLOFs evaluation, but also for glacial lake evolution simulation and glacio-hydrological prediction. '

Line 36...would be more useful to state the types of lakes please. And state the two

classifications systems please. Be explicit (!). what is the improved equation?! Name it!

[Response] The two classifications systems contain a total of nine types of glacial lakes, so specifying all types in the abstract will take up too much space. To keep the abstract concise and present improved equation, we changed this sentence to: ' A range of critical attributes have been generated in the dataset, including lake types and mapping uncertainty estimated by an improved Hanshaw's equation'

Line 37. Potentials is not plural. Remove the 's'.

[Response] We have changed this sentence to 'This comprehensive glacial lake dataset has potential to be widely applied in studies on glacial lake-related hazards, glacier-lake interactions and cryospheric hydrology...'

Line 48. You really must have to cite Carrivick and Tweed (2016) <https://www.sciencedirect.com/science/article/pii/S0921818116301023?via%3DiHub> please! here. Furthermore, if you read that paper, the size of lakes producing hazardous GLOFs is reported. Small lakes (like the ones detected by your sentinel analysis v landsat) are not hazardous (!).

[Response] We agree and cited the reference from Carrivick and Tweed (2016). It now reads:

'...glaciers and impacting downstream ecosystem services, agriculture, hydropower and other socioeconomic values (Carrivick and Tweed, 2016; Nie et al., 2021).'

About small lakes, we have responded to the previous inquiries.

Line 97. Please explain 'type' is this glacier terminus environment? Is it lake dam type? Is it lake position (supraglacial or ice-marginal for example?).

[Response] As suggested, we have revised this to be: 'Dam type classification of glacial lakes provides a crucial attribute for glacier-lake interactions and risk assessment...'

Line 173. A glacial lake is one that receives meltwater from a glacier. Of these most are proglacial (beyond the glacier) and can be attached (ice-marginal or ice-contact) or detached from the edge of the glacier. PLEASE correct this terminology. Then say what you do (which means you need to evaluate what sort of lakes you are actually analysing!).

[Response] We agree to divide proglacial lakes into ice-contact and unconnected-glacier-fed (detached) lakes in this study. We revised the classification system of glacial lakes. See the section 4.3.

We consider a glacial lake as one that formed as a result of modern or ancient glaciation. In this study, all glacial lakes were mapped according to this definition and are attributed using the two classification systems.

Line 186 'without any distance limit'...oh come on there must have been some limit?! The catchment or study area boundary at least?! Please evaluate what you have done and report it carefully.

[Response] Thank you for this comment. Our dataset is indeed limited by the study area boundary. To avoid any misunderstanding, this sentence was changed to 'All glacial lakes in the study area were mapped according to our definition regardless of the distance to glaciers.'

Line 207 this info. on mapping units needs to be accurately represented in the abstract.

[Response] We agree, and have revised this sentence to be: 'The results show that Landsat derived 2234 glacial lakes in 2020, covering a total area of $86.31 \pm 14.98 \text{ km}^2$ with a minimum mapping unit of 5 pixels (4500 m^2), whereas Sentinel derived 7560 glacial lakes in 2020 with a total area of $103.70 \pm 8.45 \text{ km}^2$ with a minimum mapping unit of 5 pixels (500 m^2).'

Line 233. This spatial relationship needs to be explicitly named above in the manuscript where I have already queried it. I dislike this classification. See Carrivick and Tweed (2013) <https://www.sciencedirect.com/science/article/pii/S027737911300293X> for definition of proglacial lakes (my comment for line 173). Supraglacial is a distinct group so that is OK. Proglacial and unconnected are the same/overlap...you need 'ice-marginal' and 'other proglacial' I think, then 'other lakes' as your classes/types.

[Response] Thank you for this valuable suggestion. As we responded earlier, we agree to divide proglacial lakes into ice-contact and unconnected-glacier-fed (detached) lakes. We have revised this consistently throughout the main text, figures, tables and attribute of

our glacial lake dataset.

This sentence was changed to ‘...glacial lakes were classified into four types based on their spatial relationship to upstream glaciers: supraglacial, ice-contact, unconnected-glacier-fed lakes, and non-glacier-fed lakes according to Gardelle et al. (2011) and Carrivick et al. (2013).’

Line 238. The terminology again is wrong here and confusing because mixes position and dam type. See Carrivick and Tweed (2013) <https://www.sciencedirect.com/science/article/pii/S027737911300293X> . You should have supraglacial, terminus moraine-dammed, lateral moraine dammed, ice-dammed and bedrock-dammed I suggest.

[Response] Considering the formation mechanism and dam properties of glacial lakes, the second glacial lake classification system was established via modifying Yao’s classification system (2018). According to your suggestion, we have revised the terminology of the classification system to ice-dammed, end-moraine-dammed, lateral-moraine-dammed and supraglacial lakes. Glacial-erosion lakes contain both bedrock-dominated dam and top-moraine-mixed dam, so we prefer to use glacial-erosion lakes instead of bedrock-dammed lakes. It now reads:

‘Alternatively, combining the formation mechanism of glacial lakes and the properties of natural dam features, glacial lakes were classified into five categories (herein named GLCS2) modified from Yao’s classification system (2018): supraglacial, end-moraine-dammed, lateral-moraine-dammed, glacial-erosion lakes and ice-dammed lakes.’

Line 318 to 326. I suggest to compare to (and cite) Carrivick and Quincey (2014) who also consider uncertainty v lake area. <https://www.sciencedirect.com/science/article/pii/S092181811400054X?via%3Dihub>

[Response] We cited the reference from Carrivick and Quincey (2014). It now reads ‘Lake perimeter and displacement error are widely used to estimate the uncertainty of glacier and lake mapping from satellite observation (Carrivick and Quincey, 2014; Hanshaw and Bookhagen, 2014; Wang et al., 2020).’

The difference in uncertainty estimation between Carrivick’s and Hanshaw’s methods is that Carrivick assumes an uncertainty of ± 1 pixel, while Hanshaw assumes an uncertainty of ± 0.5 pixels and counts the number of edge pixels. In this study, we discovered and solved the problem of repeatedly calculated edge pixels. Considering that the mean lake size in the study area is smaller than that in the Greenland, we prefer to choose the improved Hanshaw’s equation to estimate the mapping uncertainty.

Line 453...so do we need Sentinel images for lake mapping?? If Landsat is doing a good job v sentinel (detection as well as accuracy) then why do we need the extra resolution?

What importance do the numerous small lakes have? They are not important volumetrically? Are they important for hazards/GLOFs? (I don't think so!). I really think the 'promoted capacity of GLOF risk assessment' (line 543) needs further elaboration.

[Response] We believe Sentinel images do offer their unique benefits in mapping glacier lakes, owing to their finer spatial resolution, increasing capacity of revisit observation and accurately depicting lake boundaries with a lower uncertainty. We further clarified these as: 'Due to a finer spatial resolution, Sentinel images can extract more glacial lakes and more accurate extents than those from Landsat images....Meanwhile, Sentinel images are able to depict boundaries of glacial lake with a lower uncertainty (Figure 12b-d). For example, some small islands and narrow channels (Figure 12b and c) were mapped from Sentinel imagery that were unable to be detected in Landsat imagery.'

Regarding small lakes, we have responded to a similar query earlier:

'Small lakes such as supraglacial lakes play an important role in understanding meltwater runoff and supraglacial drainage systems (Liu and Mayer, 2015; Miles et al., 2018). Our dataset can be used not only for GLOFs evaluation, but also for glacial lake evolution simulation and glacio-hydrological prediction.'

About 'promoted capacity of GLOF risk assessment' (line 543), we revised this sentence to be 'Herein, we provide an up-to-date glacial lake dataset derived from both Landsat and Sentinel observations, which further increased the availability of glacial lake datasets for GLOFs risk assessment, predicting glacier evolutions and understanding cryosphere-hydrological changes in the context of climate change.'

In contrast, I think a utility of your dataset and indeed your sentinel-based detection of many small lakes is that those small lakes could be the onset of fast-developing proglacial landscapes...and they will likely grow as glaciers diminish further and affect glacier dynamics (see Carrivick et al., 2020 for example <https://www.frontiersin.org/articles/10.3389/feart.2020.577068/full>)

[Response] Thank you for your affirmation and encouragement. The Sentinel-derived lake dataset has a wider potential than Landsat-derived dataset to be used in studies on proglacial landscape change and glacier dynamic assessment. The recommended reference is important and cited in the main text.

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