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Reply on RC1

Wentao Yang et al.

Author comment on "Landslide-lake outburst floods accelerate downstream hillslope slippage" by Wentao Yang et al., Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2021-14-AC1, 2021

- Line 18-27: The opening of the manuscript gives general context for the study area. A similar section is found at the beginning of the Material and Methods section (lines 48-53). I'd recommend combining these sections, it is a little strange why further study area context information is provided in the Materials and Methods section.

Response: We deleted the paragraph at the beginning of the Material and Methods.

- Line 28: 'extremely large flux' – it's not clear if this refers to sediment flux or water flux. Please clarify
- Line 28: 'significant social impacts' – such as? Can you give specific examples from these references? It will help justify your study
- Line 30: 'from failed dams and along its routes' is poor English – rephrase to something like 'many large boulders are often entrained by LLFs, sourced from the landslide dam themselves and along the course of flood route.'

Responses to 2-4: We made changes according to these detailed suggestions.

- Line 32: I'm not sure these references are correctly used. The Baynes study explores primarily the impact of extreme flood events (triggered by glacial outbursts, not landslide dams) on bedrock erosion in Iceland, and doesn't mention a comparison with monsoon flood events. There is assumption here that monsoon-flood events do not have high sediment loads of coarse material, and I'm not sure the references cited support this claim. I'd recommend further engagement and appropriate use of literature throughout the manuscript to help support your claims.

Response: As we re-organized part of the introduction part, this sentence has been removed. In addition, we also checked throughout the work to ensure the correct use of the literature.

- Line 40: 'ongoing' may be a better word to use than 'persistent'

Response: The suggestion has been accepted.

- Line 41: This sentence doesn't quite follow on from the previous one – I'd recommend moving the part about not having the direct and ongoing observations of LLF impacts on hillslope instability to after the statement saying they may also disturb upper hillslopes adjacent to the collapsed banks over longer periods. This part of the introduction is crucial for justifying the work, as you're identifying a knowledge gap that we don't have ongoing observations of hillslope displacement after the initial post-flood assessment. This is what makes your study interesting, but I think you could do a clearer job of justifying this knowledge gap as it's a little unclear at present.

Response: We re-organized this part of the introduction by changing the order of these sentences. Now, the revised paragraph are more clear to introduce the research gap:

"Besides flooding havocs, LLFs have long been recognized as important geomorphic drivers on fluvial systems. Most works on geomorphic impacts of LLFs have been focused on their efficiency in sediment transportation and channel erosion (Cook et al., 2018a; Turzewski et al., 2019). Bank undercutting and parallel retreat are the most-frequently reported consequences of LLF's lateral erosion (Korup and Tweed, 2007). Landslides related to bank undercutting along flood routes are regarded as instantaneous impacts of LLFs, which are often recognized by retrospective field reconnaissance or postevent image interpretations (Cook et al., 2018a; Higaki and Sato, 2012). Intersecting with the LLF routes, these already occurred landslides are easy to recognize (Cook et al., 2018a). In addition to these instantaneous landslides, LLFs may also disturb upper hillslopes that adjacent to the river channel over longer periods, which are more difficult to recognize and often overlooked. However, there is a lack of observations on LLFs' impacts on these ongoing slope slippages."

- Line 45: Give the exact dates of the floods, not just 'late October' and 'late November'.
- Line 45: add 'ongoing' to 'the impacts of LLF hillslope stability', as this emphasises the novelty of your study

Responses to 8-9: These suggestions have been accepted.

- Line 49-74: Material and Methods section. I note that the first part of your Material and Methods section neither mentions either materials or methods. All of this first section is more context material that should be moved to the introduction section.

Response: This part is the same as the beginning of the Introduction and has been deleted.

- Line 76-91: More detail is required here about the measurements that you actually made. Can you explain some more of the method behind the COSI-Corr method? Is this a pixel matching method, or some other form of image analysis? Additionally, how was the active channel width measured? Manually? Automatically? Can you give an estimation of the uncertainty associated with these measurements? This is important information that is required to support your conclusions.

Response: The COSI-Corr method is a pixel matching method. To detect surface deformation, the method uses two images at a time, an earlier reference image and a later target image. Both images are transformed from the spatial domain to the frequency domain using the Fourier transformation (Leprince et al., 2007). Sub-pixel changes are detected by using phase changes in the frequency domain. Uncertainties in this method are often estimated by selecting a stable zone (Yang et al., 2020). Although previous works demonstrated the capability of using a similar method to detect surface deformation of up to 1/20 pixel size (Leprince et al., 2007; Stumpf et al., 2016), the smallest reliable displacements are 1/5 of the image pixel size (Yang, 2020).

Similar to the method used by Cook et al. (2018), we measured active river channel by manually interpreting active river channels from false colour composite Sentinel-2 images. Fresh bare land near river banks is major features to interpret active river channel. Topographic information from Google Earth is also used as ancillary data during interpretation. The uncertainty of manually interpret the active channel is the one-pixel size of the used optical imagery (10 m in this work).

- Line 120: See last point, where do these error bars come from? Over what length reach are the channel width measurements taken? Is 96.33 ± 10 m the average width across the whole 100km study area? Can you break this down to reflect different reaches downstream of the initial landslide location?

Response: We checked this sentence and found these two error bars should be deleted. The sentence has been changed from "The successive LLFs increased the mean width of the active channel from 96.33+/- 10 m to 148.56 +/- 10 m." to "The successive LLFs increased the mean width of the active channel from 96.33 m to 148.56 m." The width of active channels before and after the floods are shown in Figure 6 of the revised manuscript.

- Line 121: you state here that there may be a link between the lateral erosion (channel widening) and the ongoing hillslope displacement. At the locations where hillslopes are actively destabilising, it would be good to see a plot of the width increase for the channel at the corresponding location.

Response: According to these suggestions, we made a plot between the increase (rate) of the channel and the maximum measured displacements as shown in Response Figure 1. There seem no relations between both variables. This is because slope stability is determined by the integrity of bedrocks as the first order (Gallen et al., 2015). Therefore, we only showed the location of the landslides on the figure of the river-width increase (Response Figure 2 also Figure 6 of the revised manuscript).

Response Figure 1. The relation between measured maximum slope displacements and river width increase (a) and river width increase rate (b).

Response Figure 2(also as Figure 6 in the revised manuscript). River widths before and after the Baige floods. The gray shadow indicates an uncertainty of ±1 pixel in the Sentinel-2 imagery.

- Line 125: So the areas are different, what about their displacement? Did the concurrent landslides move a larger distance than the ongoing landslides have done since the event? They may be inactive now, but how does the mobilisation of sediment compare between these two types of landslide?

Response: In this work, concurrent landslides are those that already occurred during the floods. It is not possible for us to measure displacements for these landslides.

- Line 127: See previous point on Line 121 – make a figure showing width increase against landslide displacement (either concurrent or ongoing rate)

Response: Please refer to the response to comment 13.

- Line 133-145: Discussion section. This first section of the discussion section should be in the results section. There is nothing 'discussion' about this, it's more analysis providing new results that we haven't seen yet.

Response: This part has been moved to the results section.

- Line 136: Why are these estimates smaller than the flood discharges that we've already been told about on lines 62 and 67?

Response: These estimates are made at the Batang hydrological station for the peak discharge during both Baige floods, whereas the values on lines 62 and 67 are made on the Baige landslide dam. We added a few words to clarify this in the revised manuscript.

- Line 143-144: This sentence is not required, it's a repeat of information in the previous Sentence

Response: This sentence has been removed and the paragraph has been changed to the Results part.

- Line 153: 'tens of hundreds of kilometres away' – I think this should be 'tens of kilometres away'

Response: This suggestion has been accepted.

- Line 154: General point about the Discussion – I think you could do more to place your work in the wider context, to help show the implications of the work beyond this narrow case study. You make a speculative comment here about the feedback cycle of 'landslide-LLF-landslide' hazard chains, which needs to be supported with further reference to relevant literature (and data). How likely is that the ongoing hillslope displacements will lead to large landslides that will form dams? You don't present any evidence that this is likely to happen? Later on, you go on to discuss the seismic control on the hillslope stability – how important are the seismic controls for the 'landslide-LLF-landslide' hazard cycle? Can you have the landslide-LLF-landslide hazard cycle without an underlying seismic control? Further development of these implications, with reference to literature, is required to really help this manuscript make some robust and strong conclusions.

Response: We made responses in the following two parts.

How likely is the ongoing hillslope displacements dam river:

There is few work that documented the 'landslide-LLF-landslide' hazard chains phenomenon, which is a major new finding in this work. This work clearly demonstrated that the MD-2 is activated by the floods related to the 2018 Baige landslides. As the topography from the Baige to the Mindu is similar, we could estimate the possibility of the future landslide dams by adding the following sentences:

"For example, Yang et al. (2020b) found the size of the moving MD-2 slope is larger than the Baige landslide, whereas the river channel under the MD-2 is much smaller than the later one, indicating high risk of blocking the channel once the landslide occur."

The control of earthquake for the 'landslide-LLF-landslide' hazard cycle:

In our study area, we found all slopes with tensile cracks have deformations after the Baige floods. We assume that historic tectonic activities, such as earthquakes, are one type of possible reasons to cause these tensile cracks because earthquake-related landslide dams have been frequently recorded (Dai et al., 2005; Fan et al., 2012a; Ling and Evans, 2014; Wu et al., 2016) and earthquakes can also leave irreversible damage to bedrocks (Hovius et al., 2011; Parker, 2013). The Tibetan Plateau is a tectonically active region and often experience mega-earthquakes such as the Mw 8.6 1950 Assam-Tibet earthquake (Reddy et al., 2009) and the Ms 7.8 west Sichuan earthquake (Qi et al., 2011).

New references:

Qi, W., Xuejun, Q., Qigui, L. et al. Rupture of deep faults in the 2008 Wenchuan earthquake and uplift of the Longmen Shan. Nature Geosci., 4, 634–640, 2011.

Reddy, D.V., Nagabhushanam, P., Kumar, D., et al. The great 1950 Assam Earthquake revisited: Field evidences of liquefaction and search for paleoseismic events. Tectonophysics, 474, 463-472, 2009.

Parker, Robert. Hillslope memory and spatial and temporal distributions of earthquake-induced landslides. Doctoral thesis, Durham University, 2013.

- Line 156: This is the first time that you mention the implications for the infrastructure. You could mention this also in the introduction, to help justify your study – i.e., you need to understand the complete view of hazards associated with LLFs.

Response: We added a few sentences to mention the damages to infrastructures by the LLFs in the introduction part:

"For example, in A.D. 2000, a large rock avalanche dammed the Yigong River with an estimated maximum impoundment of >2 km3. The resulting flood led to record river level rise at gauging stations ~500 km from the landslide and caused major damage to infrastructures (such as roads and bridges) and losses of lives in India (Delaney and Evans, 2015) … Recently, the Tangjiashan landslide dammed lake after the 2008 Wenchuan earthquake posed serious threats to the Mianyang city inhabited by millions of people (Fan et al., 2012a).”

- Line 165: Do you know when strong earthquakes (or extreme precipitation) may have occurred in this study area? I think this is important context for your results, and it helps to show whether the landslide-LFF-landslide hazard chain is an phenomenon that could occur in all landscapes, or is it just likely to occur in landscapes that have been weakened by a recent seismic event.

Response: We searched all earthquakes with magnitude >4.5 and <500km from the Mindu-1, MD-2 and MD-3 landslides in the last hundred years. There are 1026 earthquakes that occurred with the largest magnitude of Mw8.6. The magnitudes of 54 earthquakes are ≥6.0.

The finding that all slopes with tensile cracks have deformations after the floods indicates to form the “landslide-LLF-landslide” hazard chain, weak riverbank hillslope may be an important prerequisite. Tectonic activities such as earthquakes can usually weaken the strength of hillslopes.

Response Figure 3. Historic earthquakes with magnitudes >4.5, within 500km from the MD-1, MD-2 and MD-3 landslides.

- Line 174: ‘our findings are proofs to the theory’ is incorrect grammar. Rephrase to something like ‘our findings support the theory…’

Response: This comment has been accepted.

- Line186-187: There are several references that you could highlight here to support this statement. See Lamb and Fonstad (2010; Nature Geoscience); Lamb et al. (2014; PNAS); Baynes et al. (2015; PNAS); Cook et al. 2018a (Science) and others. This is an example where further engagement with the literature will help to elevate your manuscript to place your work in the wider context of extreme events in landscape evolution

Response: Thanks for your suggestions and the great example for us to improve the discussion part. We read and added these and other references in similar places.

- Figure 2: Can you change the colour scheme for the colour bar. A spectrum from red to green is hard for colour-blind readers to interpret, so I’d suggest using an alternative colour scheme. What does the small red circle inside the black square on the bottom of panels d1 and d2 indicate?

Response: We changed the spectrum of red-green to dark red-blue. Red circles indicate concurrent landslides and black squares are slope slippages. Please find the explanations for the red circles and black squares in the caption of Figure 1.

- Figure 3: See previous point about the colour scheme. What happened to the eastern hillslope in January 06 2019? In this panel only, there is widespread displacement on the hillslope – do you have an explanation for this? Perhaps a rainfall event?

Response: We made the colour scheme. Please find the revised manuscript. Those detected surface movements on January 06 2019 are background noises. We checked the base and target images and found they are probably caused by changes in mountain shadows as shown in Response Figure 4.

Response Figure 4. Background noises in the detected surface movements (a) and the base and target images used to derive the result. These background noises may be caused by changes of mountain shadows.

- Figure 4: Why is the orange line not plotted between ~March 2019 and Jan 2020, when the blue line is plotted across this period?

Response: There are missing measures between March 2019 and Jan. 2020. These missing points may be due to low image quality.

- Figure 5: I think it would be good to see an additional figure showing the width increase against the hillslope displacement. If the hillslopes that have higher displacement correspond to section of the channel that widened more extensively, this would help support your conclusions about the long term impact of LFFs on landscapes.

Response: Please refer to the response to comment 13.

- Also Figure 5: What does the y-axis represent? Would plotting actual channel width be easier to interpret?

Response: We changed the y-axis title to "active channel width". The blue and black curves are measured actual channel width before and after the floods.

- Figure 7: In the caption, it would be good to explain why there are so many data gaps in the flow records. Were the gauging stations not operational? How likely is it that during these periods of missing data, there may have been floods of higher magnitude that have been missed?

Response: The data for these years are not available. We do not know the reasons for these unavailable data, but we are certain that peak annual discharge of water would be less than their maximum value in 1954. The Jinsha River, the upper reaches of the Yangtze River, is the most important and populated rivers in China. Any discharges than the 1954 havoc would be well documented.