Re.: review, Central Himalayan rivers record the topographic signature of erosion by glacial lake outburst floods, by Dahlquist and West

The manuscript submitted for publication to ESURF by Dahlquist and West investigates the role of glacial lake outburst floods GLOF's on river incision and landscape formation over longer time periods. GLOF's have been recognized for many years now for their tremendous hazard potential and destructive powers. However, the role of these events in landscape formation, river incision and sediment transport has been largely overlooked. The topic is very timely and well suited for publication in ESURF. The authors use three independent methods to identify the topographic signature of GLOF's in mountain landscapes, 1) adjusted normalized channel steepness index, 2) knickpoint distribution and 3) adjusted channel wideness. The results show that rivers draining from glaciated headwaters, thus potentially affected by GLOF's, leave a clear signature on the river channel network, which is a novel finding. The manuscript has now undergone several rounds of reviews and public comments and I acknowledge that the authors have incorporated all the review issues and trimmed the paper to the essential findings. In particular, the authors have cut out the discussion of a bottom-up vs top-down interpretations to only top-down which I think is fair and helps the manuscript to focus on the essential massage. I have only few comments and suggest the paper for publication with very minor revisions.

My main concern is the interpretation and discussion of hanging valleys that might be the result of a more efficient channel erosion due to GLOF's in the trunk rivers, leaving tributaries stranded behind not capable keeping up the incisional pace. The existence of hanging valleys, especially in the very deep incised High Himalayan Range, has been recognized already before (e.g. Goode and Burbank 2009). The interpretation was until now that these tributary knickpoints are formed by pulses of aggradation caused by intense erosion periods or sediment deposition due to climate change or other catastrophic events. Temporary aggradation sets the erosional base level for the tributary higher and leave them hanging once the sediments in the main channel have been cleared out. In this manuscript the interpretation is fundamentally different. I do agree with the interpretation here but it is one of at least tow possibilities. I suggest adding a paragraph to the discussion section on the formation of hanging valleys and possible interpretation.

We thank the reviewer for the supportive comments and the constructive suggestions. Line numbers and a few of the comments seem to relate to the initial version of this manuscript, which we have noted where appropriate.

Minor comments:

Title: the word "record" implies that particular events can be dated or allotted to the topographic signature. Consider to change to "imprint" or similar.

We made a change to the title as suggested.

Abstract: Contains no information about the three methods applied in this study, 1) ksn, 2) knickpoint distribution, 3) channel wideness. Consider to include a sentence on the applied methods.

We added clarification as to the methods applied in the abstract.

Line 24: Add Huber et al. to the citation

Added

Line 80: “from the bottom up” is this this wording still needed here or rather confusing?

We removed this specific wording and reworded the passage to clarify.

Line 90: Is this really poorly understood? The concept that the heavy tail of flood distributions (extreme events) is driving river incision has long been recognized.

We clarified that we mean the specific effect of outburst floods are poorly understood.

Section 2.1: What min area defines 1st order streams in your stream order classification?

2 km^2 - this is explicitly stated in section 2.2

Line 166: This is the TRMM 2B31 dataset, with 4km resolution compiled by Bookhagen and Burbank 2006 & 2010 to mean annual and mean monthly climatology layers. The citation is missing a web ref, journal, doi ….

This citation was specifically for the dataset and doesn't have a doi, though we have added a URL. We have added the Bookhagen and Burbank 2006 and 2010 references as well.

Line 165- 169 and 230 – 234: Has this been calibrated somehow? Should be not so difficult to calibrate with few longtime gauging station datasets. Is the GLEAM correction making any important changes? I understand it makes sense to correct for the orographic gradient of precipitation, however, often global evaporation datasets lead to a negative water balance when compared with TRMM data. Was this observed here?

We added a few references here where the TRMM and GLEAM datasets were verified with field data in similar environments to our field area. We also added clarification about how we dealt with negative water balances in some areas of Tibet. To this comment, the lines 165-169 are no longer relevant, as we changed our k_{sn} analysis to remove the discharge calculation.

Line 170: Water storage variations will be considerable on a seasonal time scale, etc. Add annual variation in water storage … or cut it completely. Might be confusing because it does not matter for your time scale.

We cut this for clarity as suggested.

Line 198: Cite the statement

Added a reference to Kirchner et al. 2011

Section 3.2: Glaciated catchments are not well defined in the manuscript. How do you define this? Using secondary shape dataset, or everything above ELA is named glaciated …? Glacial cover was not determined in the manuscript. Could be easily done but is maybe a bit too much at this stage. Be careful with statements regarding glacial coverage and glaciated catchment if this has not been proper defined.

We have added a sentence in Section 1.2 to clarify that when we say "glaciated catchment" for the purposes of this study we specifically mean any catchment with some drainage area above the LGM ELA.

Line 345: cite statement.

We added a few references here

Discussions in general: Could elaborate more in detail on different processes producing hanging valleys.

We expanded Section 4.2 to include more detail on controls on fluvial hanging valleys, including additional references. We also clarified in this section that we are not necessarily arguing for a fundamentally different mechanism for fluvial hanging valley formation with GLOFs, but rather that in tributaries to mainstem channels with relatively frequent GLOFs, outburst flooding may produce favorable conditions for fluvial hanging valley formation by mechanisms that have been previously identified by others.

Fig. 4: The vertical dashed lines are strangely distributed. It seems not all tick marks have a dashed line associated. Same for the horizontal lines, why three in the upper panel and only one in the lower one? The difference between a and b is not very easy to depict, seems on the first order the same distribution with minor changes on the y-axis. Maybe there is a better way to support the findings?

This comment seems to refer to an older version of the figure, as we have removed the dashed lines from Figure 4 in the most recent version. We hope that the other changes to this figure and the addition of panel c have clarified the points we were trying to make in Figure 4.

We have also changed Figure 5 very slightly due to a typo in the original (the exponents in the equations in panel A were negative and should not have been).