Nat. Hazards Earth Syst. Sci. Discuss., 2, C3727–C3733, 2015
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Natural Hazards and Earth System Sciences
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2, C3727–C3733, 2015

Interactive Comment

Interactive comment on "Periodic Glacial Lake Outburst Floods threatening the oldest Buddhist monastery in north-west Nepal" *by* J. Kropáček et al.

J. Kropáček et al.

jan.kropacek@uni-tuebingen.de

Received and published: 8 May 2015

General comment 1: With all due respect to the authors, crucial input data (flood hydrograph and peak discharge) seem speculative and even wrong. Answer: Considering the peak discharge, we used the empirical 'Clague & Matthews' approach which is well documented in the literature and widely used i.e. Haeberli (1983), Clarke & Mathews (1981), Ny & Björnson (2003) and Carrivick & Jonathan (2007). For the first part of the question regarding the outflow hydrograph see the next paragraph.

Changes in manuscript: 1. A sentence in the discussion was adjusted to make clear

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Interactive Discussion

Discussion Paper

that the modelled flood extent was generated under the assumption of three concrete values of the lake discharge: ‘The simulation of the flooded area assuming three values of maximum discharge from the lake did not result in a flooding of the village’ 2. Further we emphasized the empirical nature of the Clague-Mathews formula and detail about its validity were added.

General comment 2: Firstly, I fundamentaly disagree with the approximation of outflow hydrograph with the Gaussian normal distribution in this case study. Considering the likely mechanism of the flood (lake drainage through the subglacial tunnel), Gaussian normal distribution-like hydrograph is not related to reality anyhow. Such hydrograph should be characterised by steep rising limb and slightly decreasing falling limb reflecting decreasing hydrostatic pressure (see Fig. 1).

Answer: The hydrograph described by the reviewer applies for a basin with basal drainage of constant cross-section, where discharge is mainly influenced by hydrostatic pressure. For glacial lake tunnel drainage the situation is different because drainage is mainly governed by the enlargement of the ice tunnel during the event. Walder & Costa (1996, p. 702) describe a hydrograph with a slowly rising limb (hours to days) and a steep falling limb (see Fig. 2a).

Fig. 2: Idealized hydrographs (Walder & Costa 1996) To model the hydrograph on the lake outflow we used a reversed lognormal distribution curve with sigma parameter equal to 0.5 in the corrected version of the manuscript. This mathematical curve represents an approximation of the idealized curves described by Haeberli (1983) and Walder & Costa (1996).

Changes in manuscript: 1. The sentence ‘To approximate an outflow hydrograph for the scenarios, a Gaussian normal distribution was fitted to the outflow volumes and associated peak flows Q max.’ vas replaced by ‘To approximate an outflow hydrograph for the scenarios, a lognormal distribution curve with sigma value of 0.5 was fitted to the outflow volumes and associated peak flows Q max.’ 2. The following sentence was added to the paragraph: ‘This mathematical curve represents an approximation of the idealized curves described by Haeberli (1983) and Walder & Costa (1996).’ 3. The hydrological modelling was carried out with the new input hydrographs under six scenarios taking into account three different filling levels and two roughness values which resulted in new hydrographs at the profiles and flooded extents. The figures 9 and 10 were modified to reflect the new results.

General comment 3: In addition, please explain, why authors did not use the only relevant field data describing potential flood hydrograph: “The stream level in the village rose early in the afternoon and stayed high for several hours.“ Modelled hydrographs do not reflect this description. I strongly suggest considering the change of input hydrographs for flood modelling in order to get more reliable results. Answer: We agree in this point. After adjustments, the new hydrographs used for the modelling fit the observation. For instance the discharge modelled by the curve of the lake outflow for the 100% lake filling stays around 4 hours above the level of 50% of the maximum discharge. Also for the profiles near the village the level stays high for several hours. General comment 4: Secondly, if the authors had the opportunity to see 2011 GLOF in the field, I see many ways, how to estimate the peak discharge much more precisely (even retrospectively), rather than using the empirical equation developed by Clague and Mathews (1973), e.g., by measuring cross profile across the river, marking the water level during the flood. Compared to highly precision approach, which is used to estimate the volume of the supraglacial basin (which also likely changed significantly since 2011) and 1 m resolution DEM, this may distort resulted modelled flood considerably.

Answer: An estimation of the peak discharge during the 2011 flood as suggested by the referee is hardly possible because the flow velocity is unknown and can only be estimated with very high uncertainty. Mean flow velocity however is crucial to calculate peak discharge (e.g. using the Manning-Strickler formula). Moreover, no marking of water level was done during the flood in 2011 as no hydrologist was present in the village.

General comment 5: I suggest to compare obtained results (flow depth at measured profiles) with the field evidences in order to verify the modelling results, or even to calibrate the model.

Answer: Comparing obtained results with field observations would generally support the reliability of the results. However, as the flood in 2011 came unexpected after no flood occurred in 2010, no measurements could be done during the flood. No hydrologist was present in the village and the due to the remoteness of Limi Valley the regional authorities could not react immediately. Anyhow, the plausibility of the obtained results was checked according to the available data from the field (estimates of flood extents and flow depths from photographs which were taken during the flood, max. sediment particle size to estimate max. flow velocities). This assessment was added to chapter 4.3 in the manuscript.

Change in manuscript: (4.3 Flow discharge and flood extent)

The following text has been added after the sentence "Accordingly, [...] lower than in the higher roughness scenarios (1-3)." :

"As the flood in 2011 came unexpected after no flood occurred in 2010, there were no measurements possible in the field. Anyhow, we could assess the modelled flow velocities, travel time and discharge using the available field data. Several photographs were taken during the flood. This allowed us to validate our results assuming that the modelled scenario with 100% of the lake volume approximates the 2011 flood. Regarding flood depths, it can be stated that the calculated maximum flow depth of 2.5 m for profile 4 in the village corresponds to the photos taken during the flood, albeit actual flow depths might have been slightly higher than modelled flow depths. The same applies for the simulated flood extent which corresponds to the photographs of the 2011 flood. According to the model results under all six scenarios as well as during the 2011 flood, the water stayed in the channel in the vicinity of the village. Modelled

NHESSD

2, C3727–C3733, 2015

flow velocities of up to 9 m/s at the narrow sections of the channel for the scenario S2 seem plausible. According to the empirical Hjulström-Sundborg Diagram (Sundborg 1956), which represents the relationship between flow velocity and sediment particle size, this flow velocity would be high enough to erode blocks of up to 100 cm diameter. Transported and sedimented blocks up to that size could be found downstream these narrow sections."

Sundborg, A. (1956). The river klarälven: A study of fluvial processes. Geografiska Annaler, 38(2), 125–237.

General comment 6: To be honest, I have some doubts about the suitability of the usage of a given flood model itself for this case study. According to the Figure 1, the distance between the lake and the village is about 5 km with vertical difference of 1 500 m (mean slope cca 17°). If I understand well to the Figure 8, it is seen, that escaped water from the lake has occurred at Profile 5 more than 2 hours later, resulting in mean velocity of the flow less than 0,7 m/s. According to my experience, this is unrealistically low, especially for extraordinary events even transformed into the debris flows. Also flow captured on Figure 5a seems to have higher velocity. Calculated travel time 3 hours also seems unrealistic to me.

Answer: We agree that travel time is too long and that a mean flow velocity of less than 1 m/s is unrealistic. We found out that the problem was caused by the DEM used in the modelling. As the DEM is derived using stereo-processing based on feature matching, it contains some noise and artifacts. The low pass filter with 3 x 3 pixels kernel size which has been applied prior to the first modelling to eliminate noise was not effective in removing the noise. This caused additional turbulence-like flow in the raster based model which adds to the roughness already inherent in the Strickler roughness coefficient. This slowed down mean flow velocities and resulted in unrealistic travel times. To overcome the problem, the DTM was resampled to 2 m resolution in the new version and a 3 x 3 low pass filter was applied (see Fig. 3). Also, instead of roughness coefficients of 15 and 20 m1/3 s-1 the values 20 and 30 m1/3 s-1 were used in the scenarios to obtain more realistic flow velocities. Figure 9c shows that the travel time of the flood wave peak from profile 1 to profile 4 takes 30 minutes in the scenario S2 (100 % lake volume, kSt = 20 m1/3 s-1). Given a flow distance of 5700 m between profile 1 and 4, mean flow velocity is 3.2 m/s. For scenario S4, travel time is about 15 minutes and mean flow velocity is 6.4 m/s. General comment 7: The authors should at least give more detailed description of the model in methodological section to justify these highly questionable results." Answer: In the new version, a more detailed description of the model was provided.

Changes in the manuscript: The section 'Hydrodynamic modelling of flood scenarios' was reworked completely.

General comment 8: I also need the authors to relate obtained results to the broader hydrological context of Halji river (mean discharge of the river, ratio of peak discharge to mean discharge, . . .).

Answer: Unfortunately, there is no hydrological data available for Halji River.

General comment 9: I would appreciate more photos from the field (or larger photos than 6 in 1). The final version of the paper will contain some more and larger photos.

Answer: A photo showing the sediments forming the river bank in Halji was added. The images were rearranged into two figures. If enlarged to the full width of the page in the typesetting process they will be sufficiently large.

Some specific comments: P6937: I suggest to use word "Repeated" rather than "Periodic"; described GLOFs are not periodic in a strict sense Answer: Changed accordingly.

P6940L14: (a.s.l.) replaced by Fig. ?? Answer: corrected

P6941L20: the magnitude of recent event often seems higher then magnitude of earlier events, especially for unexperienced observers Answer: The event in 2011 was objectively the most disastrous.

NHESSD
2, C3727–C3733, 2015

P6941L13: Please, rearrange the description within the entire section chronologically Answer: The sentence was changed based on a comment of the referee 1.

P6948L15-20: this part seems to me not to be a result Reply: This section was changed completely.

P6949L1: interesting paragraph, please, indicate (discuss) some (future) hazard implications Answer: The development of the basin for the period from 2000 to 2013 was documented by subset image in the fig. 5. The decline of the basin was roughly estimated to 30 years.

P6951L12: I suggest to use the term "hazard" or "threat" rather than "risk", which is not the subject of the article Answer: Changed accordingly.

P6962: Please, omit minus value on the precipitation axis Answer: Changed accordingly.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 6937, 2014.