

## The cases and frequency of glacier lake outburst in the Bhutan Himalayas

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In order to keep accurate preparedness for and attention on the GLOF hazard mitigation, explorations of past cases of outburst are necessary. The frequency of the GLOF occurrence is still unknown, because major outbursts which caused significant damage on downstream are rare and the recorded period is only several decades. We have to collect data on past outburst events as much as possible including unpublished and unknown incidents. As is obvious in the trace of the GLOF, the outburst event leaves typical topographical and sedimentological features, i.e. 1) v-shaped trench, 2) huge debris fan deposition and 3) subsequent devastated river bed. Hence, these features can be used as the proof of past outburst events. As for the most recent case of GLOF, the 2009 Tshojo flood was studied. The flood which was initiated by lake water leaking, and water splash to the surface via a en-/sub- glacier, shows the potentially dangerous hazard. Attention to such outburst events from invisible source will be required in the future.

As for the evaluation of the frequency of the GLOF incident, besides the reported 6 cases in the previous study, we revealed a total of 15 outburst cases in the Bhutan Himalayas using field survey data, and Corona KH-4A, Hxagon KH9-9, Landsat7/ETM+, and ALOS/PRISM satellite data and the images in Google Earth. These 21 cases were found in the Kuri Chu Tibetan branch, Chamkhar Chu, Pho Chu, Mo Chu and Soe Chu. Ten cases of them, the lake outburst on the foot of cliffs with a hanging glacier is the most frequent cases. Seventeen of 21 cases occurred before the 1970's, while 4 cases are counted during from the 1970's to 2010. Hence, the current frequency of outburst occurrences does not seem to have increased. In order to the Further research which covers the minor outburst events has to be broadened at least the Sikkim and Nepal Himalayas.

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