Geophysical Research Abstracts
Vol. 17, EGU2015-9936, 2015
EGU General Assembly 2015

Rainfall and snow-melt triggered glacial lake outbursts: a systematic analysis of the Kedarnath (Uttarakhand, India), June 2013 disaster

Simon Allen (1,2), Philipp Rastner (2,3), Manohar Arora (4), Christian Huggel (2), Markus Stoffel (1,5)

(1) Institute for Environmental Sciences, University of Geneva, Switzerland, (2) Department of Geography, University of Zurich, Switzerland, (3) EURAC-Institute Applied Remote Sensing, Bolzano, Italy, (4) National Institute of Hydrology, Roorkee, Uttarakhand, India, (5) Dendrolab.ch, Institute of Geological Sciences, University of Berne, Switzerland

Heavy rainfall in early June 2013 triggered flash flooding and landslides throughout the Indian Himalayan state of Uttarakhand, killing more than 6000 people. The destruction of roads and trekking routes left around 100,000 pilgrims and tourists stranded. Most fatalities and damages resulted directly from a lake outburst and debris flow disaster originating from above the village of Kedarnath on June 16 and 17.

Here we provide a first systematic analysis of the contributing factors leading to the Kedarnath disaster, both in terms of hydro-meteorological triggering (rainfall, snowmelt, and temperature) and topographic predisposition. Specifically, the topographic characteristics of the Charobari lake watershed above Kedarnath are compared with other glacial lakes across the northwestern Indian Himalayan states of Uttarakhand and Himachal Pradesh, and implications for glacier lake outburst hazard assessment in a changing climate are discussed.

Our analysis suggests that the early onset of heavy monsoon rainfall (390 mm, June 10 – 17) immediately following a prolonged four week period of unusually rapid snow cover depletion and elevated streamflow is the crucial hydro-meteorological factor, resulting in slope saturation and significant runoff into the small seasonal glacial lake. Over a four week period the MODIS-derived snow covered area above Kedarnath decreased nearly 50%, from above average coverage in mid-May to well below average coverage by the second week of June. Such a rapid decrease has not been observed in the previous 13-year record, where the average decrease in snow covered area over the same four week window is only 15%. The unusual situation of the lake being dammed in a steep, unstable paraglacial environment, but fed entirely from snow-melt and rainfall within a fluvial dominated watershed is important in the context of this disaster. A simple scheme enabling large-scale recognition of such an unfavorable topographic setting is presented, and on the basis of all assessed watershed parameters, the situation at Charobari lake indicates an anomalous predisposition towards rapid runoff and infilling during enhanced snowmelt or heavy rainfall.

In view of projected 21st century changes in monsoon timing and heavy precipitation in South Asia, more emphasis should be given to potential hydro-meteorological triggering of lake outburst and related debris flow disasters in the Himalayas. The potential for Kedarnath-type lake breaching may further increase as glaciers recede or ultimately disappear, and watersheds become increasingly rainfall dominated. Hence, a long-term perspective to glacier lake outburst hazard assessment and management is required, as the greatest threat from hydro-meteorological triggering of related disasters may only be realized in an ice-free environment.