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Hazard mapping and an early warning system for lake outburst floods in the Cordillera Blanca, Peru

Schneider Demian[1], Cochachin Alejo[2], Frey Holger[1], García Javier[3], Giráldez Claudia[1], Gómez Jesús[2], Haeberli Wilfried[1], Huggel Christian[1], Ludeña Sebastián[4], Price Karen[5], Rohrer Mario[6] & Salzmann Nadine[1]

[1]*Department of Geography, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich (demian.schneider@geo.uzh.ch)*
[2]*Unidad de Glaciología y Recursos Hídricos, PE-Huaraz*
[3]*Centre de recherche sur l'environnement alpin, CREALP, Rue de l'Industrie 45, CH-1951 Sion*
[4]*Laboratoire de Constructions Hydrauliques (LCH), EPFL, Station 18, CH-1015 Lausanne*
[5]*CARE Peru, Av. General Santa Cruz 659, PE-Lima 11*
[6]*Meteodat GmbH, Technoparkstr. 1, CH-8005 Zurich*

The Peruvian Cordillera Blanca is strongly affected by climate change impacts, like many other high mountain regions around the world. The combination of a high population density in close vicinity to steep slopes and retreating glaciers has led to some of the most devastating glacier-related mass movement disasters where thousands of people were killed during various events over the past decades (Carey, 2005). The main hazards include ice/rock avalanches, debris flows and glacier lake outburst floods (GLOFs), which are often parts of complex process chains. There are strong concerns that climate change favors such mass movements by destabilizing perennially frozen bedrock and steep glaciers, and that the frequency and magnitude of these events might increase in future (Huggel et al., 2010).

To prevent such disasters, an early warning system is currently being implemented in the Río Chucchún catchment above the city of Carhuaz (~9000 residents). At this site, successful prevention measures took place in the early 1990's, when the water level of the proglacial rock-dammed Lake 513 has been lowered by 20m (Reynolds et al, 1998). However, the changing thermal conditions in the steep and glacierized rockwalls above the lake is a probable trigger of a huge rock-ice avalanche, which occurred on April 11, 2010. Its impact wave in Lake 513 overtopped the freeboard and led to a debris flow and flood which reached down to the alluvial fan of Carhuaz. Fortunately, no victims were claimed, but a lot of agricultural land and several bridges have been destroyed. According to the current state of the glaciers, larger avalanches with more serious consequences cannot be excluded.

In a first step, the hazards have been analyzed and the hazard map elaborated by the 'Instituto Nacional de Defensa Civil' in 2004 has been updated (Figure 1). This has been done by applying an avalanche model (RAMMS::avalanche) for different scenarios, a lake impact and flood wave simulation model (IBER), and by using segment-wise varying frictional rheologies for a debris flow model (RAMMS::DEBRIS FLOW) to account for the complex flow transformations.

As a second step, a technical early warning system is currently being implemented in the field. It is composed by two main measurement stations, a repeater station to transmit the signal, and a communication and data center in the town of Carhuaz (Figure 1). The stations cover two aspects: (I) a long-term perspective that includes high quality climatic and discharge measurements by a new station at 3600m a.s.l., and automatic multi-temporal daily photographic monitoring of the steep glacierized flanks of Nevado Hualcán. This will enable to better characterize the local climatic characteristics, the water balance of the catchment, and to detect changes in the stability of the hanging glaciers. The system further comprises (II) a real-time early warning system for rock-ice avalanches and debris flows. It is based on 4 geophones near the avalanche source area at 4491 and 4752m a.s.l., which activate two cameras in the case of an event. To reduce the risk of false alarms the civil defence needs to verify the alarm based on the video images, and the event needs to be confirmed by other geophones and the discharge measurement sensor at the lower station at 3600m a.s.l. Despite of the redundancy of the sensors, an intense testing and calibration phase will be particularly needed for the geophones to achieve a high level of confidence in the system.

The next steps include instructing the responsible authorities, establishing the alarm chains, informing the population about the hazards, and finally the implementation of acoustic alarms at some sites within the flood path and the alluvial fan to alert the population in time in case of a hazardous event.

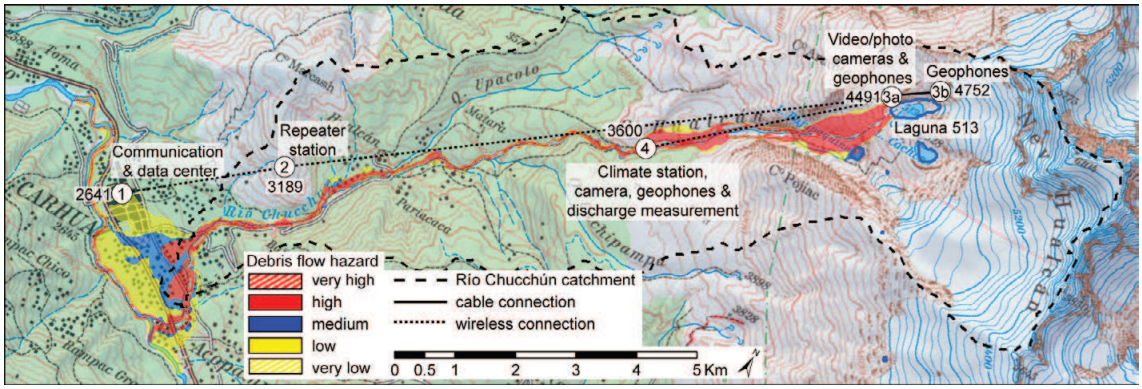

Figure 1. Río Chucchún catchment above the city of Carhuaz with the updated hazard map and the stations of the monitoring and early warning system (background: Alpenvereinskarte 1:100,000).

REFERENCES

Carey, M., Huggel, C., Bury, J., Portocarrero, C. & Haeberli, W., 2012: An integrated socio-environmental framework for glacier hazard management and climate change adaptation: lessons from Lake 513, Cordillera Blanca, Peru. Climatic Change, 112(3): 733-767.

Huggel, C., Salzmann, N., Allen, S., Caplan-Auerbach, J., Fischer, L., Haeberli, W., Larsen, C., Schneider, D. & Wessels, R., 2010: Recent and future warm extreme events and high-mountain slope stability. Philosophical Transactions of the Royal Society A, 368, 2435-2459.

Reynolds, J.M., Dolecki, A. & Portocarrero, C. 1998: The construction of a drainage tunnel as part of glacial lake hazard mitigation at Hualcán, Cordillera Blanca, Peru. Geological Society, London, Engineering Geology Special Publications, 15, 41-48.