Integrated assessment of high mountain hazards, related risk reduction and climate change adaptation strategies in the Peruvian Cordilleras

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ABSTRACT: In the framework of an international 3-year project, called 'Proyecto Glaciares', effects of climate change on glacierized high-mountain hazards and adaptation in Peru are addressed on (1) local, (2) academic, and (3) institutional levels. Within the first nine months, a monitoring and early warning system for flood hazards in Carhuaz, Cordillera Blanca, has been designed and is currently in the implementation phase. Furthermore, the first 3 modules of a postgraduate course in glaciology, climate change, and hazard management were held in the city of Huaraz in June 2012 and will be continued during the next months.

Keywords: high-mountain hazards, glaciology, climate change, early warning system, capacity building

1. INTRODUCTION

The ice-clad Peruvian Cordilleras are often and seriously affected by high mountain hazards such as ice and rock avalanches, glacier lake outbursts, floods and debris flows. In the past, thousands of people have been killed in such disasters (e.g. Carey, 2005; Evans et al., 2009). More recently in 2010, massive floods in the Cusco Region and an outburst flood from glacier lake "Laguna 513" triggered by the impact of an ice-rock avalanche from the steep ice-clad and permafrost slopes of Nevado Hualcán in the Cordillera Blanca (Ancash Region) drew the attention of the public, policy and science (Carey et al., 2012).

In the face of climate change, there is strong concern that warming has a destabilizing effect on perennially frozen bedrock and on steep glaciers in high-mountain flanks, with potentially severe consequences when avalanches impact existing and new glacier lakes and far-reaching glacier lake outburst floods form (Haeberli et al., 2010a; Huggel et al., 2010; 2012a).

Related risks are changing and need to be integratively managed. Laguna 513, where structural measures were implemented in the early 1990s (Reynolds et al., 1998), is an example of successful hazard reduction. Nevertheless, the glacier lake outburst flood on April 11, 2010, has shown that the possible future occurrence of even larger events cannot be excluded and that the risk needs to be further reduced, so that complementary measures are necessary.

As a follow up of the Laguna 513 event in 2010 and corresponding to assessments by international experts (Carey et al., 2012; Haeberli et al., 2010b), an integrative and international project was initiated, which combines three components to sustainably enhance climate change adaptation and reduce high-mountain risks in the Peruvian Cordilleras:

(1) a local level with detailed case studies and the implementation of monitoring and early warning systems,

(2) an academic level, to strengthen local capacities in glaciology (mainly glaciers and permafrost), high mountain process, climate change and risk management, and

(3) an institutional level to strengthen glaciology in Peru on a national and international level.

Monitoring and early warning systems for ice/rock avalanches and glacier lake outburst floods as well as for rain-triggered mass movements will be implemented at two sites, one in the Cordillera Blanca in the downstream path of Laguna 513, and one at Santa Teresa, a site downstream of Machu Picchu, in the Cusco Region of Peru.

2. IMPLEMENTATION OF AN EARLY WARNING SYSTEM IN THE CORDILLERA BLANCA

Early warning systems are considered to be feasible and promising tools to jointly reduce risks and to adapt to impacts and extreme events in relation with climate change. The Andes region, sensitive to climate change, and exposed to a large number of extreme events, has not yet seen a significant number of operational sensor-based early warning systems but some experiences are available and promoted (Huggel et al., 2012b). In this context it is important to consider that early warning systems are highly complex systems. They should, on the one hand, include monitoring sensors, data and voice communication, and on the other hand, establish clear institutional responsibilities and response, and essentially involve local people to ensure that adequate action is taken according to different warning levels. The different elements can be categorized into (i) a technical, (ii) a social and (iii) an institutional level.

For the Laguna 513 case in Carhuaz, Cordillera Blanca, an early warning system has recently been designed and is currently in its implementation phase. Figure 1 shows a sketch of the design of the technical components of this early warning system.

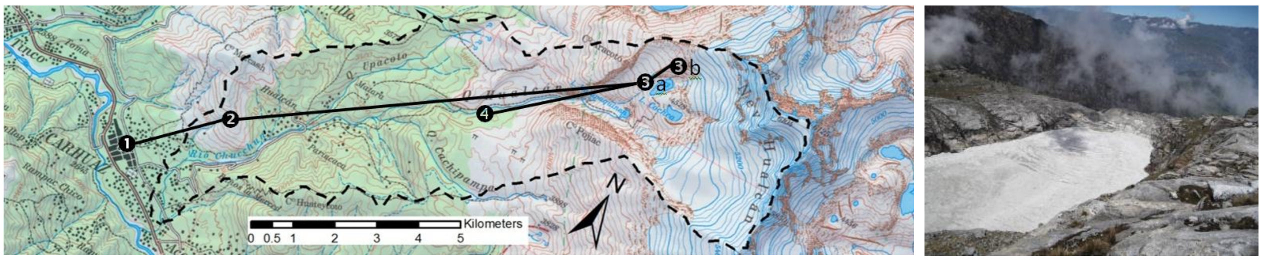

Fig. 1: Left side: Overview of Rio Chucchun catchment above the city of Carhuaz in the Cordillera Blanca (dashed line; area of 50 km^2) with sites of the main components of the basic monitoring and early warning system (left image; Alpenvereinskarte 1:100,000.

❶ Communication and data center at Carhuaz (2641m a.s.l.)
❷ Repeater station 1 (~3189m a.s.l.)
❸ a) Video/photo cameras for visual monitoring and geophones near Laguna 513 (4491m a.s.l.)
❸ b) Geophones near the rock-ice avalanche source area (4752m a.s.l.), connected by cables to station ❸a)
❹ Climate station / camera / geophones / flow discharge monitoring at Pampa Shonquil (3600m a.s.l.)
Right side: Laguna 513 with ice debris cover the day after the rock-ice avalanche of April 11, 2010.

Automatic cameras, geophones, discharge measurement, and a meteorological station are deployed, and data are transmitted to the civil defense center of Carhuaz. Redundancy of the system is ensured by different sensors, and local observers. Dynamic, physically based modeling for (i) avalanche flow, (ii) lake displacement wave and (iii) lake outburst floods permitted to determine the characteristics of past events and future scenarios (cf. Schneider et al., 2010; Worni et al., 2012), and to understand critical warning parameters such as flood travel time and flood inundation height. Based on these results and field mapping, a hazard map for the city of Carhuaz is being elaborated. Parallel to the technical implementation, community based efforts are undertaken to ensure effective response and sustainability.

Within a project of an Non-Governmental Organization (NGO), evacuation routes are currently signed out, and a purely human-based warning system has been set up with radios and acoustic alarms at certain points in the area (without the installation of any sensors). These alarms need to be manually activated and have a very limited reach.

To optimize the benefits of the two approaches (the one within this project and the one of the other NGO), the projects are tightly coordinated. The presented monitoring and early warning system will require a test and calibration phase of 1-2 years, where in case of a detected emergency, the radio and alarm system of the NGO could be of use. In a second phase, it is planned to include automatic acoustic alarms with a wide reach to cover the entire potentially affected region.

3. HAZARD ASSESSMENT FOR SANTA TERESA

For the case of Santa Teresa in the Cusco region, very little is known about the nature, origin and exact dimensions of the extreme events and mass movements, although there are significant disasters on record over the past years. Most of the mass movements that caused disasters have their origin in glaciated catchments draining towards the Santa Teresa village, with catchment sizes between about 100 and 300 km^2, and glacier areas of 6 to 16 km^2 per catchment. It is known that the enormous 1998 debris flow (various surges with an estimated total volume of ca. 25 million m^3) that destroyed the Machu Picchu hydropower plant originated in terrain with large sediment reservoirs. For other events on record, ongoing studies analyze origin, trigger and characteristics.

Satellite-based studies on glacier lakes revealed a significant number of potentially hazardous lakes in the catchments (Figure 2) that need to be integrated in a comprehensive monitoring and early warning system that will take into account the high dynamics of such high-mountain environments under climate change.

Fig. 2: Left image is showing glacier lakes, indicated by arrows, in the upper reach of the Río Sacsara catchment, at the foot of Nevado Sacsarayoc (image from Google Earth, acquired on 19 July 2008). The red arrow indicates the lake on a dead ice body at the northeast of Nevado Sacsarayoc (detailed views on the right side).

4. EFFORTS ON ACADEMIC AND INSTITUTIONAL LEVELS

Further significant efforts of the international collaboration are directed to strengthening the scientific and technical capacities in Peru regarding this field, as part of concerted disaster risk reduction and climate change adaptation (component 2). In June 2012, a new postgraduate course on glaciology and high-mountain research and related aspects of risk reduction and adaptation was initiated, borne by a consortium of three universities in Peru (UNASAM, Huaraz; UNSAAC, Cusco; La Molina, Lima) and the University of Zurich (Figure 3). New capacities and experts are thus formed, which is a critical element to cope with present and future challenges. Parallel to the education program, new high-mountain research projects are initiated within the consortium of universities that will facilitate a much stronger scientific involvement in this field.

Fig. 3: Information brochure (left) and the initiation of the first three modules of the postgraduate course in glaciology, climate change and risk management at UNASAM University, Huaraz (right).

Additionally, a fundamental aspect of risk reduction and climate change adaptation is the institutional level (component 3), including both governmental and non-governmental institutions. Inter-institutional working groups are created to coordinate the activities and resources on a national and international level.

5. STATUS AND PERSPECTIVES

Challenges in terms of the aims of this project are manifold. For the implementation of the monitoring and early warning system, a Peruvian partner had to be found. In Carhuaz, the preparation phase has been finished and technical and logistical problems concerning the implementation of the system in hardly accessible high mountain environments are to be solved. The integration of local authorities and the population concerning responsibilities and the elaboration of efficient alarm chains is advancing but needs to be refined and tested. Currently, the technical implementation phase is starting and new uprising challenges must be addressed.

It needs to be considered that sensor-based automatic early warning systems can be powerful tools, but the higher the level of technical/social/institutional complexity, the higher is the risk of failure. Costs are relatively high, which can rise up questions of comparativeness, especially in developing and threshold countries, where money is a very limiting factor. Furthermore, follow-up costs for maintenance and sensor replacements need to be considered. In terms of a longer term perspective, it can be difficult to keep the interest of the local authorities to maintain the system if no event occurs e.g. within the next 5-10 years, that is well possible and likely. Another challenge within the project is the aversion of certain local people against technical, particularly meteorological and climatological installations. This pilot project will therefore also assess the mentioned aspects by means of tight collaborations and workshops with local authorities, scientists and residents on the different levels (technical/social/institutional) to achieve positive long-term results.

The launch of the postgraduate course in Huaraz was a first success in terms of capacity building. The upcoming modules which will be held in Cusco are now in preparation, while the work on the highly complex institutional level requires more time to be fully developed.

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