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Integration of satellite radar interferometry into a GLOF early warning system: a pilot study from the Andes of Peru

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Glacier lake outburst floods (GLOF) have killed thousands of people in the Andes of Peru and in many other high-mountain regions of the world. The last years have seen progress in the integrative assessment of related hazards, through combined focus on the glacier lake, its dam properties, and processes in the lake surrounding, including the position and fluctuations of the glacier tongue and potential displacements and thermal conditions of adjacent slopes. Only a transient perspective on these factors allows anticipating potential future developments.

For a very limited number of cases worldwide, where GLOF hazards and risks have been recognized, early warning systems (EWS) have been developed and implemented. Lake 513 in the Cordillera Blanca of Peru is one of those. Structural GLOF mitigation measures (tunnels to lower the lake level) have been undertaken in the 1990s and could successfully reduce, but not fully prevent, impacts of a GLOF such as that of April 2010 triggered by a rock/ice avalanche from Mount Hualcán. The EWS was implemented during recent years and disposes of automatic cameras, geophones, river run-off measurements, a meteorological station, and real-time communication with the municipality of Carhuaz and the communities in the catchment.

An EWS is by definition limited in its concept and Earth Observation (EO) data offer a promising possibility to complement the assessment of the current hazard. In particular, the monitoring and early detection of slope instabilities in ice, rock and sediments that could impact the lake and trigger a GLOF is still a major challenge. Therefore, the potential of optical and SAR satellite data is currently tested for integration into the EWS within the project S:GLA:MO (Slope stability and Glacier LAke MOnitoring) project, funded by the European Space Agency (ESA) in collaboration with the GLACIARES project supported by the Swiss Agency for Development and Cooperation.

EO data (optical and SAR) are considered for the production of up-to-date Digital Elevation Models (DEM), for the monitoring of glaciers (extent and velocity fields), glacier lakes (area), and for the compilation of a landslide inventory and slope activity map. DEMs are produced either from TanDEM-X image pairs or very-high resolution optical stereo pairs. Landsat-8 images are used to derive glacier and lake outlines, the latter complemented by TerraSAR-X and Radarsat-2 very high-resolution image pairs. Very-high resolution SAR data are also used to derive glacier flow velocities, indicating high flow velocities of up to 200 m/a for many glaciers of the Cordillera Blanca. Advanced SAR interferometric (InSAR) processing with a series of sensors (ERS-1/2, ENVISAT, ALOS PALSAR, TerraSAR-X and Radarsat-2) is considered for the monitoring of slope instabilities.

Our results for the pilot study indicate no major slope displacements around Lake 513 for the period 1995-2014, confirming related field investigations. Current limitations of the EO data analyses are related to difficulties of detecting slope displacements in steep areas (steeper than about 40°), and timely acquisition and processing of the data. Rather than serving a real-time warning purpose, the potential of InSAR-derived information for GLOF EWS lies therefore in the regular and repeated monitoring of slope deformation and instabilities, independent of meteorological conditions and over large areas, in order to facilitate the decision if and where ground-based instruments should be installed. In addition to the investigation of slope instabilities around Lake 531, many instable slopes were detected based on the InSAR data on a regional scale on both sides of the Rio Santa Valley in the Ancash region.