Geophysical Research Abstracts
Vol. 19, EGU2017-14505, 2017
EGU General Assembly 2017

Integrated satellite InSAR and slope stability modeling to support hazard assessment at the Safuna Alta glacial lake, Peru

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The Safuna glacial lakes (77˚37' W, 08˚50' S) are located in the headwater of the Tayapampa catchment, in the northernmost part of the Cordillera Blanca, Peru. The upper lake, Laguna Safuna Alta at 4354 m asl has formed in the 1960s behind a terminal moraine of the retreating Pucajirca Glacier, named after the peak south of the lakes. Safuna Alta currently has a volume of 15 x 10^6 m^3.

In 2002 a rock fall of several million m^3 from the proximal left lateral moraine hit the Safuna Alta lake and triggered an impact wave which overtopped the moraine dam and passed into the lower lake, Laguna Safuna Baja, which absorbed most of the outburst flood from the upper lake, but nevertheless causing loss in cattle, degradation of agricultural land downstream and damages to a hydroelectric power station in Quitaracsa gorge. Event reconstructions showed that the impact wave in the Safuna Alta lake had a runup height of 100 m or more, and weakened the moraine dam of Safuna Alta. This fact, in combination with the large lake volumes and the continued possibility for landslides from the left proximal moraine pose a considerable risk for the downstream settlements as well as the recently completed Quitaracsa hydroelectric power plant.

In the framework of a project funded by the European Space Agency (ESA), the hazard situation at the Safuna Alta lake is assessed by a combination of satellite radar data analysis, field investigations, and slope stability modeling. Interferometric analyses of the Synthetic Aperture Radar (InSAR) of ALOS-1 Palsar-1, ALOS-2 Palsar-2 and Sentinel-1 data from 2016 reveal terrain displacements of 2 cm y^{-1} in the detachment zone of the 2002 rock avalanche. More detailed insights into the characteristics of these terrain deformations are gained by repeat surveys with differential GPS (DGPS) and tachymetric measurements. A drone flight provides the information for the generation of a high-resolution digital elevation model (DEM), which is used for the modeling of the geomechanical slope stability using the W/Slope and UDEC models. Model application, however, is limited due to data scarcity regarding geotechnical slope properties, which needed to be estimated.

The combination of these data products, measurements and model results provide important information for the estimation of potential source areas for future slope collapses and involved volumes. Eventually, such information can be used for the definition of possible rock avalanche scenarios and related chain reactions in order to elaborate a hazard map for resulting lake outburst floods. At the same time, the potential for an operational slope stability monitoring system at this site will be evaluated.