Landslide monitoring in southern Peru – SEG-Geophysicist Without Border project

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Summary

Monitoring active landslides requires comparing different observations including meteorological, hydrological, geodesic and seismic ones. In the framework of the SEG-Geophysicist Without Border "LAMOPE" project (LAndslide MOnitoring in PEru), we designed and installed three observation huts on the active landslide affecting the Maca village in the very touristic and agricultural Colca valley, southern Peru. We compare the evolution of the soil rigidity obtained from ambient seismic noise correlation and the GPS ground deformation to external possible triggering factors such as local and regional earthquakes, volcanic eruptions and seasonal rainfalls. The final goal is to establish a warning procedure for the landslide acceleration impacting the populated Maca village.

General overview

The Colca valley is one of the most touristic valleys of South Peru, with major landslides (see Fig. 1) threatening the security of the village inhabitants, the development of tourism, the irrigation of agricultural fields, and pre-Inca heritages. Those landslides are subject to rapid acceleration due either to the high seismicity of the area or to periods of intense (seasonal) rainfalls. This article focuses on the Maca landslide, the most active of this valley, threatening a village of 900 inhabitants, the agriculture and the tourism of the area.

The Maca landslide is representative of many landslides of the valley, which are developing in lacustrine sediments, with motion mostly controlled by water infiltration, affecting villages and agricultural terraces. Ten of these active landslides were detected in the valley [Lacroix et al., 2015].

The Maca area is well known thanks to a survey that started in 2011, initiated by INGEMMET (Arequipa-Peru) and ISTerre (Grenoble-France). A geological mapping of the main morphological structures and rock types, combined with a geophysical characterization of the sub-surface based on electrical profiles and seismic imagery concluded on the presence of very low consolidated sediment and the possibility of fluidization of the material [Zerathe et al., 2016]. Moreover the presence of rock avalanche deposits of 30 m thick creates a high permeable layer, which favors the water infiltration inside the landslide, mass. A geodetical monitoring of the area was conducted based on a network of twelve markers measured by GPS and deformation measurements based on repeated satellite data. It concluded that the main active area has an extent of 1km². The area is deforming at a rate of 2m/yr over the last 30 years [Bontemps et al., in prep], with a very high yearly variability. The motion is mostly controlled by the yearly rainfall and the river erosion, with a threshold of precipitation above which rapid deformation starts [Zerathe et al., 2016]. The landslide deformation is also controlled by earthquakes that trigger rapid motion followed by a 5 weeks period of relaxation [Lacroix et al., 2014].

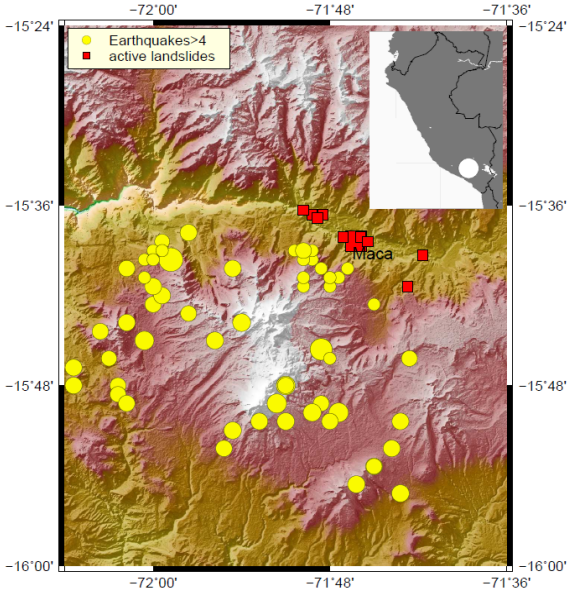

Figure 1: Recent seismicity map (2013-2015) of the study area (earthquakes of Mw>4). The yellow circles scale with the earthquake magnitudes. The red squares represent the locations of the main active landslides in the area [Lacroix et al., in review] including the Maca landslide.

The Maca landslide displayed periods of rapid deformations in 1991, 1995, 2001, 2012, 2013. This activity led the Peruvian government to request a technical report on the site stability [Zavala et al., 2013], based on the previous measurements initiated on the site. This report concluded on the risk of fluidization associated with low consolidated sediments and on the main role of the river erosion on the destabilization. Two options were then proposed: cutting the river meanders or monitoring the evolution of the landslide. Deviation of the river, even if not easy and very costly, can be undertaken but with large