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Modeling and hazard mapping of complex cascading mass movement processes: the case of glacier lake 513, Carhuaz, Peru

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The Cordilleras in Peru are especially vulnerable to, and affected by impacts from climate change. Local communities and cities often exist directly within the reach of major hazard potentials such as lake outburst floods (aluviones), mud[U+2010]/debris flows (huaycos) or large rock[U+2010]/ice avalanches. They have been repeatedly and strongly affected these regions over the last decades and since the last century, and thousands of people have been killed.

One of the most recent events in the Cordillera Blanca occurred on 11 April 2010, when a rock/ice avalanche from the top of Hualcán mountain, NE of the town of Carhuaz impacted the glacier lake 513 (Laguna 513), caused displacement waves and triggered an outburst flood wave. The flow repeatedly transformed from debris flow to hyperconcentrated flow and eventually caused significant damage in Carhuaz.

This event was motivation to start early warning and prevention efforts to reduce risks related to ice/rock avalanches and glacier lake outburst floods (GLOF). One of the basic components of an early warning system is the assessment, understanding and communication of relevant hazards and risks. Here we report on the methodology and results of generating GLOF related hazard maps for Carhuaz based on numerical modeling and field work. This exercise required an advanced concept and implementation of different mass movement models. Specifically, numerical models were applied for simulating avalanche flow, avalanche lake impact, displacement wave generation and lake overtopping, and eventually flow propagation of the outburst flood with changing rheology between debris flow and hyperconcentrated flows.

We adopted a hazard mapping procedure slightly adjusted adjusted from guidelines developed in Switzerland and in the Andes region. A methodology has thereby been developed to translate results from numerical mass movement modeling into hazard maps. The resulting hazard map was verified and adjusted during field work. This study shows that complex cascades of mass movement processes can realistically be modeled using different models and model parameters. The method to semi-automatically produce hazard maps is promising and should be applied in other case studies. Verification of model based results in the field remains an important requirement. Results from this study are important for the GLOF early warning system that is currently in an implementation phase, and for risk reduction efforts in general.