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## Identifying past rockfall trajectories and runout distances from detailed 3D terrain model: The case of the Mel de la Niva mountain, Switzerland.

François Noël<sup>1</sup>, Synnøve Flugekvam Nordang<sup>2</sup>, Michel Jaboyedoff<sup>1</sup>, and Marc-Henri Derron<sup>1</sup>

<sup>1</sup>Risk Analysis Group, Institute of Earth Sciences, University of Lausanne, Switzerland (francois.noel@unil.ch)

<sup>2</sup>Engineering geology and slides, Rambøll, Trondheim, Norway AS

When planning for the implantation of transport infrastructures or buildings, it is necessary to identify the land zones that can be reached by rockfalls. These zones should then be avoided if possible, or stabilisation and risk mitigation measures must be considered. 3D preliminary rockfall simulations can be used to help finding the areas where inspections should be prioritised. Using orthophotos, a detailed shaded representation of the terrain and field work, geologists can then note the position of the deposited blocks and sources from past events, among other things. Collecting this information can however be complex, and the blocks can sometimes be mistaken for glacial deposits.

To increase the accuracy of this inspection task, the land can be analysed using a 3D detailed terrain model with artificial colors based on its aspect orientation and slope steepness and artificial shadows based on the ambient occlusion and eye dome lighting methods. Scars left by past rockfall events are then highlighted and some trajectories can be reconstituted. This method can help isolating identified rockfall deposited boulders from erratic blocks and help finding where is the source from. It can also draw attention to the location where a block has settled by showing parts of its trajectory. A relative aging can also be attributed based on the sharpness of the scar edges, with older events appearing smoother or partly erased. This can help estimating the activity of the site when no other information is known.

We applied this method to the Mel de la Niva site in Switzerland while analysing the two main rockfalls from the 2015 event. The 3D model used was created from SfM photogrammetry using pictures acquired on the field by manually flying a DJI Phantom 4 drone over the terrain. The method allowed to identify 1 rockfall that followed the main 2015 event and 7 rockfalls that preceded it, which is quite interesting. Indeed, if activity is observed on a site, inspection of the source cliff should be done to try to identify if a larger event is about to occur.

These identified rockfalls trajectories were validated using a time series of available orthophotos from SWISSIMAGE. Two paths were present before the oldest photo from 1983. Three appear on the 1999 photo. They then happened in between the previous photo from 1995 and the 1999 one. One happened in between the 1999 and 2005 photos. One happened in between the 2010 and

2013 photos and one in between the 2016 and 2017 photos.

The 8 identified trajectories combined with the 2 from 2015 also have an interesting shape. They tend to not directly follow the steepest path of the terrain. This behavior seems to be frequent, especially when the blocks are disk-shaped, and it has also been observed and partly quantified from the rockfall experiment we presented here last year (2019). Data from the Mel de la Niva site has been added to our rockfall database and it will be used for the calibration and further developments of our rockfall simulation model.

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