Use of combined monitoring remote sensing techniques for the study of active fractures in a remote area: Case of Cima Del Simano rockslide

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ABSTRACT: Cima del Simano Mountain (Swiss Alps) presents one main open fracture and several smaller fractures. Satellite InSAR highlights downward movements. This instability is worthy to be studied since it represents a risk for the road and villages located at its foot. Nevertheless, this mountain is challenging to study because of its bad accessibility and the strong atmospheric effects on remote sensing techniques.

The study combines remote sensing techniques to acquire a maximal amount of information on the potential rockfalls sources and slow deep-seated landslides. Those techniques are Lidar, satellite InSAR and Ground-Based InSAR (GB-InSAR). They are aimed at confirming failure scenarios, predicted based on structural analyses and field observations. Small toppling movements are detected as well as more long-term moving areas (few mm/year). We estimate the limits of those instabilities and their corresponding volume by applying the Slope Local Base Level (SLBL) method.

Keywords: Rockslide, InSAR, LiDAR, monitoring, SLBL.

1 CASE STUDY

In the Ticino Canton (Switzerland), landslides and debris flows are recurrent phenomena due to frequent rainfalls and a rugged topography (Pedrozzi, 2004). One of those instabilities is the Cima del Simano Mountain in the Blenio valley, near the commune of Acquarossa. The top, reaching an altitude of 2500 meters, displays several fractures of various length and aperture. Those fractures are mapped in Figure 1.

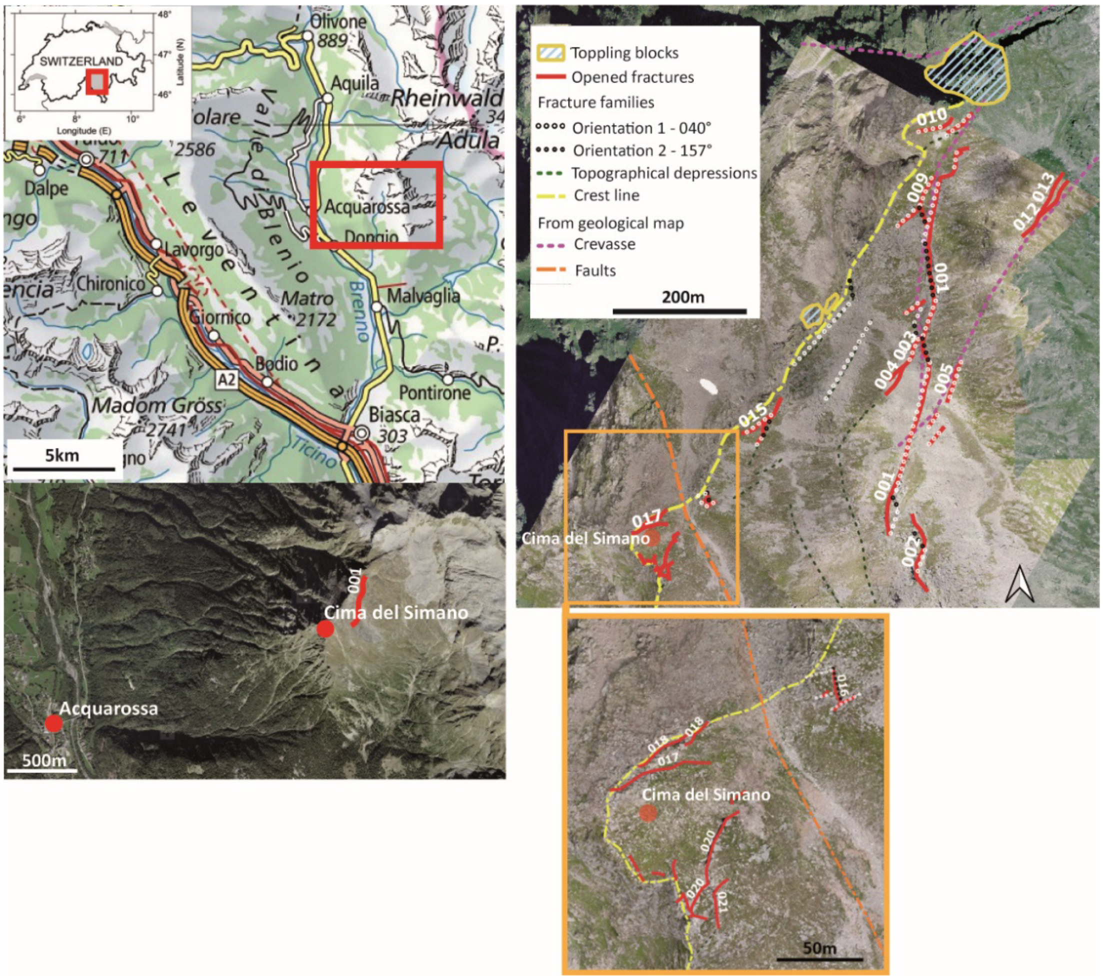

Figure 1. Cima del Simano instability in Ticino Canton (Switzerland). Left: Location of the instability. Right: Mapping on top of the mountain. The fracture 001 corresponds to the major opened fracture.

The largest opened fracture 001 characterized by a 10-meter aperture, seems to be the result of a gravitational movement of the West block moving downwards as shown in Figure 2. In the fracture named “018”, fresh soil was observed in the field, which is a hint of current movement and instability. Furthermore, some blocks are clearly in toppling near the crest.

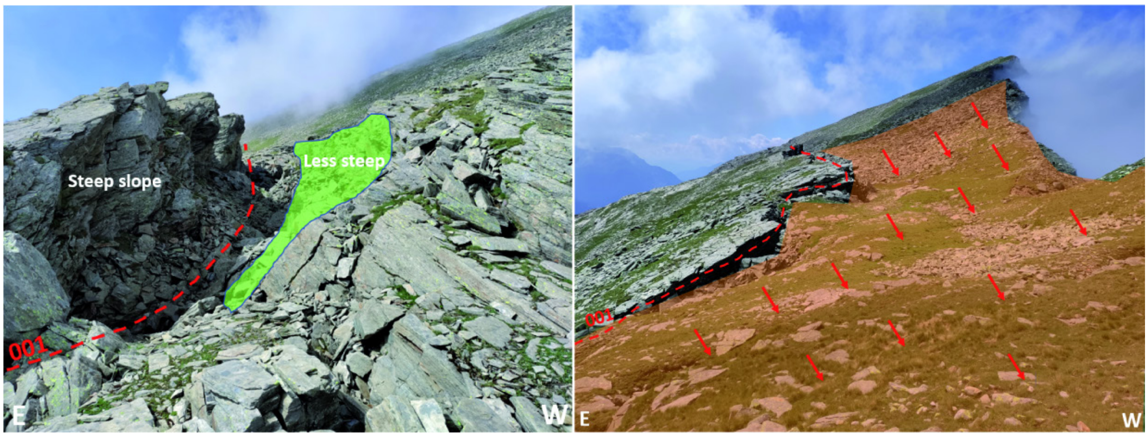

Figure 2. Field views of the main opened fracture 001. Looking South, the fracture seems to correspond to a gravitational movement of the West compartment moving downwards.

2 MATERIAL AND METHODS

Several different remote technique devices were used to carry out the study and detect various movements at different spatial scales.

2.1 Terrestrial Lidar

Using a Riegl 6000, we acquired point clouds (PCs) of the mountain at three different dates over two years. The position of the Lidar at 3.5 km of the bottom of the mountain, the point spacing (30 cm for the upper part), and the total number of points (30 million points) were all kept constant.

Lidar PCs were imported in Cloud Compare and finely aligned. Their relative distance was computed with the Iterative Closest Point-based (ICP) algorithm. Since the point clouds resolution was 30 cm, we decided to extract the areas with displacement above 35 cm (Carrea et al. 2014, Abellán et al. 2014). First, PCs between June 2021 and September 2021 were compared to detect rockfall and toppling events over three months. Then the same procedure was executed for PCs between June 2021 and September 2022 to detect movements over one year.

2.2 InSAR

To detect slow movements, both GB-InSAR and satellite InSAR surveys were used. Sentinel-1 SLC images from 2013 to 2019 were processed by Gamma AG with Interferometric Point Target Analysis (IPTA, Wegnüller et al. 2016) software module using the Persistent Scatterer Interferometry technique (PSI, Rouyet et al. 2021). We installed a Lisalab GB-InSAR in the valley for one month in September 2021 and in July 2022. With satellite InSAR, an average displacement rate per year is obtained, while with the GB-InSAR unwrapped interferograms between two dates with a ten-month interval were computed giving the displacement that occurred between the two dates, 17.09.2021 and 17.07.2022.

It is interesting to combine the two InSAR monitoring technique; indeed, one radar only collects data in the LOS of the devices (Carlà et al. 2019). Combining information from GB- and satellite InSAR provides a better delineation of the instability because the LOS are very different. Since the movement of the large crack seems going down- and westwards, the descendant orbit satellite images were used. Thus, we expect to find negative movement in the LOS of the satellite and positive ones in the LOS of the GB-InSAR, as explained in Figure 3.

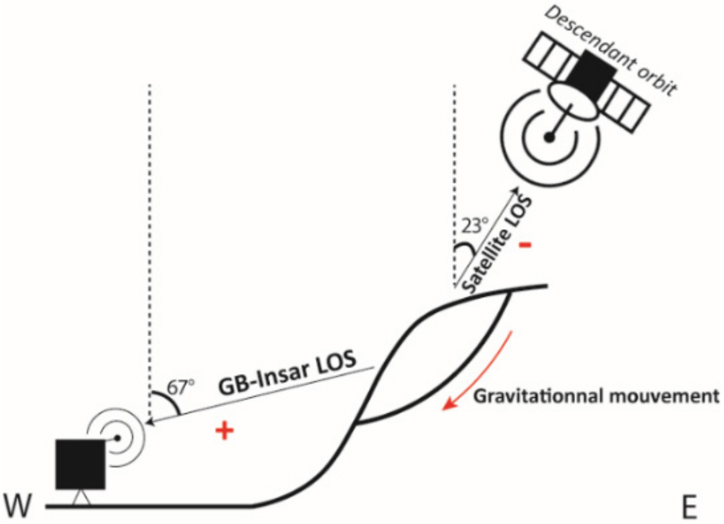

Figure 3. Expected displacement sign along the satellite and GB-InSAR LOS. GB-InSAR and satellite InSAR respectively provide data on sub-horizontal and sub-vertical displacements.

3 RESULTS

3.1 *Detected movements*

3.1.1 *Lidar*

After PCs alignment and distance computation, the areas with a distance above 30 cm were extracted. Over three months, 6 moving zones are detected and areas where rocks fell are distinguishable from those subject to small sliding or toppling. Over one year, areas of accumulation of debris from rockfall could also be detected. Those results are shown in Figure 4.

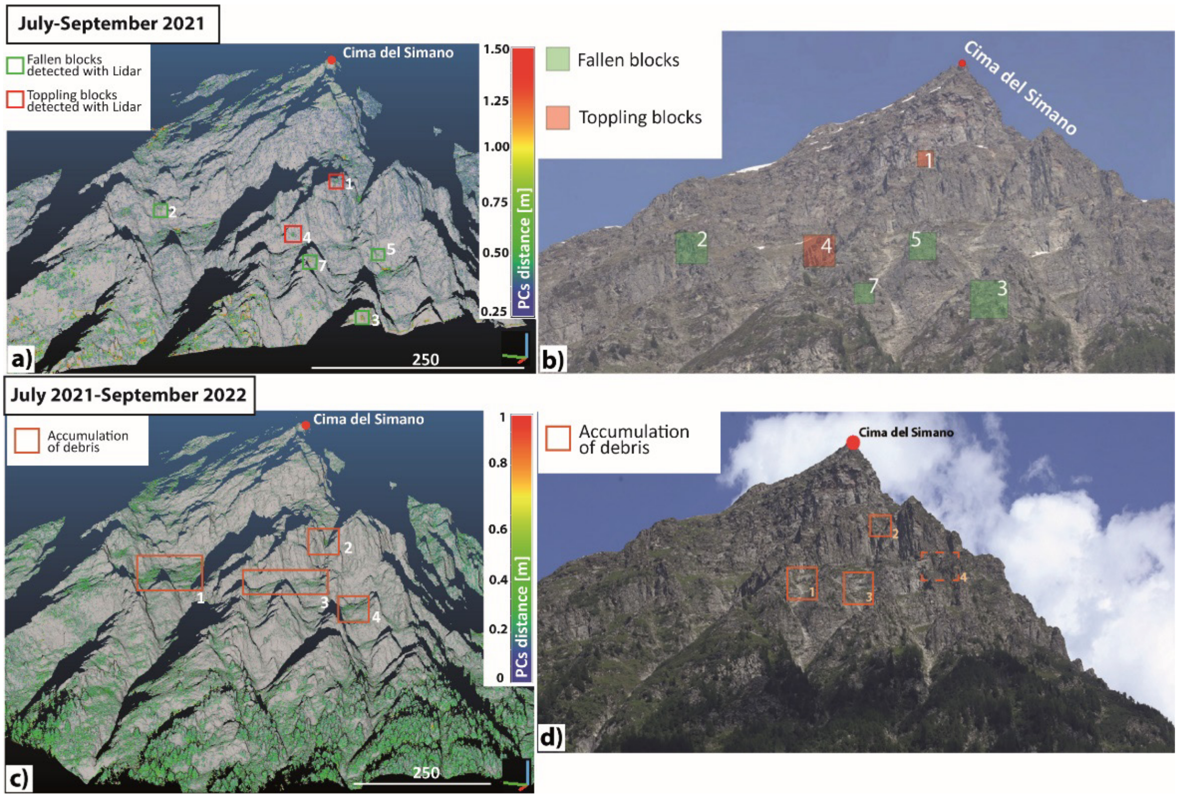

Figure 4. Rockfalls, topplings and accumulation of debris detected by Lidar PCs comparison. (a) and (b) Distance between PCs acquired in July 2021 and September 2021 and detection of rockfalls and toppling blocks reported on a panorama. (c) and (d) Distance between PCs acquired in July 2021 and September 2022 and detection of debris from rockfalls reported on a panorama.

3.1.2 *InSAR*

The satellite InSAR reveals slow displacements with an average velocity of 6 mm/year along the mountain crest. As expected, the movement is negative, meaning that the volume is moving away from the satellite Sentinel-1 descending orbit. In the field, at the limit between moving and stable area behind the crest one can see a depression in the topography which is drawn in Figure 1.

GB-InSAR interferogram between September 2021 and July 2022 highlights positive sub-horizontal movements comprised between 6-13 mm on top of Simano and satellite InSAR processing with the IPTA method from Gamma shows sub-vertical movements of about 7mm/y also located near the summit (Figure 5). The GB- and satellite displacement maps were merged in the same figure to easily delimitate the instability (Figure 6).

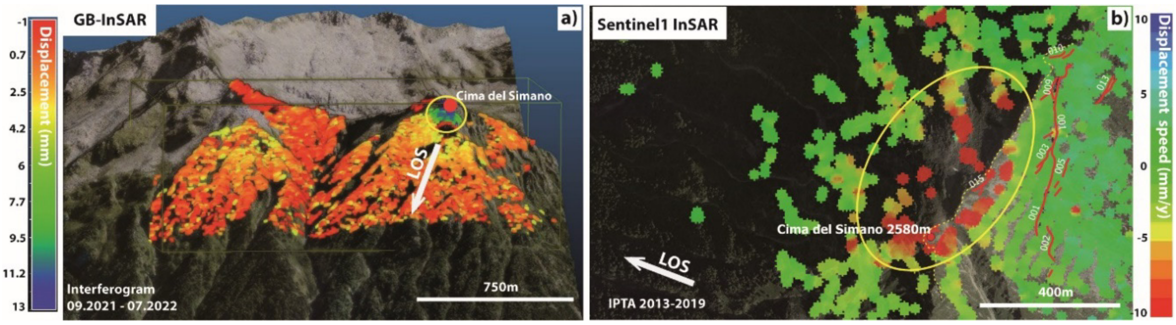

Figure 5. (a) GB-InSAR displacement map. (b) Sentinel-1 satellite InSAR map of displacement speeds processed by Gamma AG with the IPTA method. The moving area is circled in yellow.

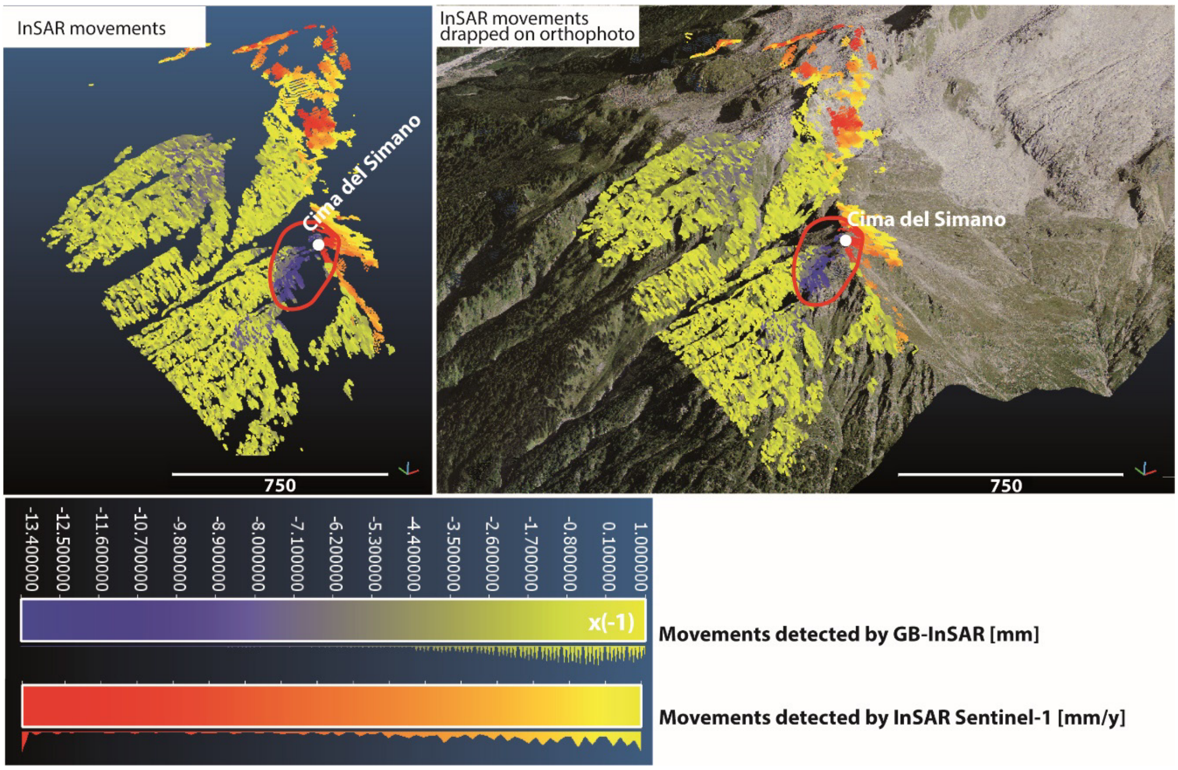

Figure 6. Combined GB- and satellite InSAR displacement maps delimitating an area with slow movements in red. The Gb-InSAR movements must be multiplied by (-1); the movements are directed toward the GB-InSAR.

3.2 Rupture scenarios

Based on the movements detected by InSAR and GB-InSAR and the observations in the field, the limits of the instabilities could be drawn in both cases, (1) large deep-seated rockslides involving important volumes and (2) toppling or sliding of smaller and superficial volumes near the crest. The Slope Local Base Level algorithm (SLBL, Jaboyedoff and Derron, 2005) was then applied to estimate their related volume.

Two distinct scenarios S1-1 and S1-2 involving the small fractures near the crest were considered, and their extension limits were drawn in (Figure 7). Then, the SLBL algorithm was applied with the assumption that the sliding surface is almost planar. The unstable volumes computed are respectively 230.10^3 and 259.10^3 m^3.

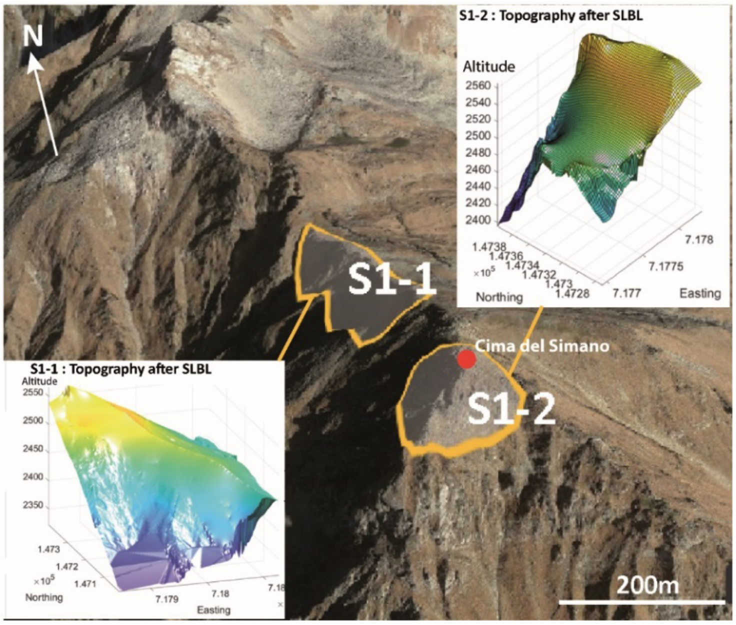

Figure 7. Potential instabilities outlined for rock avalanche scenarios S1-1 and S1-2 and the result of the application of the SLBL algorithm.

4 CONCLUSION

On top of Cima del Simano Mountain two active and superficial rockslide and toppling instabilities, are witnessed by mean of the combination of several remote sensing monitoring techniques. Lidar possesses indeed a higher resolution than InSAR (circa. 30 cm) but can only detect centimetric movements, InSAR is a good monitoring technique for mm movements, but the resolution is only metric.

Larger and deeper instabilities have been identified, but their movements are not significant. The next step of the study is to assess all the potential hazards.

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