

Earth & Space

The breathing and fate of a rock slope

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In mountainous regions, large sections of rocks slopes can be unstable and potentially collapse leading to catastrophic events where people and infrastructure are exposed. In most cases, movements affect the slope prior to the failure and can thus be measured to assess the hazard and monitor the area. The characterization of the spatial distribution and temporal evolution of the displacements is fundamental to understand the behavior of unstable slopes, score the hazard, and forecast potential collapse events.

Various tools and instruments are used to measure displacement rates on rock slopes. Some of them, such as Global Positioning Systems devices (GPS), provide three-dimensional and high-accuracy measurements but only at specific points, leading to a sparse spatial coverage of the area of interest. For the last decades, the development of remote sensing techniques, from aircrafts, spacecrafts or remotely ground-based systems, contribute to overcome this problem. They have had a major impact in the field of geohazards monitoring, due to large coverage capability, high resolution and ability to document areas difficult to access. One of these remote-sensing systems is the ground-based imaging radar. Set-up at several kilometers from the rock slope, the radar sends microwaves. The signal hits the ground and the echoes back to the radar are recorded. Using a technique called Synthetic Aperture Radar Interferometry (InSAR), we can compare the images acquired at a minute-scale and provide continuous information about the ground displacements over the scanned area at a sub-millimeter accuracy. The displacements are one-dimensional along the line-of-sight of the radar, corresponding to variations of distance between the imaged area and the sensor.

In our study, we used a ground-based imaging radar to monitor the Mannen/Børa rock slope in western Norway. Located on the side of the inhabited Romsdalen valley in Rauma Municipality (Møre & Romsdal county), Mannen is an active rockslide threatening houses, roads and a railway track. Mannen has been scored as a high-risk rockslide and is thus monitored continuously using several measurement devices including a ground-based imaging radar since 2010. In summers 2011 and 2012, in order to enlarge the scanned area and check the stability of sectors outside the main moving zone, a second ground-based imaging radar has been installed. Together, the two radars imaged a 3 km wide section of the slope with a valuable overlap in the middle that contributes to cross-check the results. Thanks to it, we discovered an area affected by 5-10 mm inflation/deflation phenomenon. The rock slope is breathing! By analyzing several years of ground-based data, we highlighted that the pattern is not homogeneous in time and inversions have a seasonal recurrence: the slope inflates at the beginning of the thawing season and deflates during the summer. The movement inversion occurs between June and July. The assumption to explain the rock slope breathing phenomenon is that the area is subjected to large variations of groundwater pressure. At the beginning of the thawing season, pressure increases due to high water infiltration and residual ice in fractures. This leads to rock slope inflation. During the summer, the water inputs decrease and residual ice melts. Water evacuates and desaturates the slope which leads to deflation.

The research contributes to evidence seasonal

inversions of movements of a rock slope, so-called rock slope breathing. These small variations are often ignored or undervalued in the analysis and monitoring of large and fast rockslides threatening population and infrastructure. They are however important to take into account for a complete understanding of a rock slope behavior. It has been indeed shown that even if the magnitude is small, a regular hydro-mechanical stress can fatigue and damage the rock mass at long-term. In addition, our study highlights the valuable contribution of remote sensing techniques to detect, map and monitor small-scale movement fluctuations in natural slopes.