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Geophysical methods to investigate and survey unstable volumes along a cliff

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We successively instrumented 2 unstable sites along the 300 m high Urgonian cliff of the southern Vercors massif, French Alps. The first site, a rock column of 21000 m^3, collapsed in November 2007, 5 months after the beginning of measurements. The experiment showed that information contained in seismic noise can be used for hazard assessment when considering the potential failure of an overhanging rock column. Indeed, the study of seismic noise recorded prior the rock fall revealed that low resonance frequencies follow a precursory pattern, as they decrease significantly, from 3.4 Hz to 2.6 Hz, before the collapse. We successfully reproduced this phenomenon with 2D numerical modelling of rock falls. Numerical simulation results pointed out that this decrease depends on the column-to-mass contact stiffness, which is controlled by the remaining rock bridges. Impulsive signals, which could be attributed to rock fracturing, have also been studied. P and S waves were identified for 40 events, allowing wave polarisation analysis and preliminary event location. Seismic sources able to trigger the vibration of the rock column were located along the broken plane and probably resulted from micro-cracks along rock bridges.

From this first site study, we tried to closely follow the evolution of the natural frequencies at the second site, which also consists of a rock column decoupling from the mass with an open fracture in the rear. The value of the first eigenfrequency (about 7.6 Hz in June 2008) shows that the unstable volume is probably much smaller than for the first site. This evaluation is consistent with the estimated volume using DEM derived from LIDAR scan (about 1000 m^3). A detailed investigation of the first eigenfrequency shows that its variation is also correlated with temperature and frost. After one year of a rough stability, the average value of the first eigenfrequency clearly shows a drift with the temperature variation pattern and an irreversible decrease of about 2Hz over the last 7 months, allows expecting an evolution toward collapse. This last observation is confirmed by the overall variation of extensometers recordings (widening of the rear fracture of about 8 mm). Furthermore, using thermo mechanical FE simulations, we showed that the rear fracture aperture is also affected by the thermal dilatation of the massif. On the same site, we performed simultaneous recordings of seismic noise on top of the rock column. We used a civil engineering technique of signal processing to derive the modal shape of the first natural mode. We do expect that this approach will help future analysis of the unstable volume size, the proportion of undamaged rock bridges and their location.