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Seismic noise parameters as indicators of reversible modifications in slope stability: a review

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In the last decade, there has been a growing application of long-term ambient seismic noise monitoring systems to landslides and potentially unstable rock sites. Through noise spectral analysis and cross-correlation techniques, these studies were primarily devoted to the identification of an irreversible drop in the detected resonance frequency (f0) values and/or negative velocity changes (dV/V) uncorrelated with external meteorological factors. Both f0 and dV/V are indeed easy-to-monitor seismic parameters whose irrecoverable modifications may be read as precursors to failure and therefore be used for monitoring and early-warning purposes. Despite the increasing number of studies, only in a few monitored cases slope failure was approached and irreversible modifications in f0 and dV/V were recorded. By contrast, all the monitored sites showed clear reversible fluctuations in these seismic parameters over time, driven by modifications of the external meteorological conditions. In particular, temperature was found to be the main controlling factor on rock sites, while influence of rainfalls and water seepage within the unstable bodies was found to be more significant in landslides of soft and loose materials.

In this work, we provide a synthesis on the existing case histories showing f0 and dV/V reversible modifications, with the aim of analyzing the driving thermo-mechanical mechanisms. Eleven applications of long-term ambient seismic noise monitoring were collected for this purpose, including seven rock sites and four landslides in destructured or loose materials, reported in literature between 2012 and 2018. The majority of the sites are located in the Alpine context (France, Switzerland and Italy). Daily and seasonal f0 and dV/V fluctuations recorded in the different studies were quantified and summarized. The relation of these variations with temperature and water was then further investigated. In particular, both in-phase and out-of-phase relationships between seismic parameters and temperature were highlighted, with different time of response (delay) of f0 and dV/V to the meteorological changes. Several driving mechanisms were found to generate this variety of responses to the external modifications, including temperature control on fracture opening/closing, stress conditions and bulk rigidity within the rock mass or modification in the mechanical properties of clayey materials. Water seepage was found to be dominant in other sites, while the combined effect of temperature and water, leading to ice formation, significantly affected both f0 and dV/V values during freezing periods. The recognized driving forces were observed to either strengthen each other or generate opposite effects on the recorded seismic parameters. Eventually, the obtained results were critically analyzed to compare f0 and dV/V performances in tracking the reversible changes in the different scenarios and to propose new research perspectives for removing or even using these changes towards a better understanding of the site stability.