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Analysis of large rock slope instabilities using frequency domain decomposition modal analysis

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Seismic ambient vibrations are increasingly used to investigate the stability of rock columns and unstable mountain slopes. The seismic wavefield amplification and polarization within an unstable rock mass can be compared to a stable reference outside the instability and can provide a rapid estimate of its extent and geometry. Especially low-activity landslides show small surface displacements, so that geodetic and radar based techniques are unable to detect unstable volumes within a reasonably short time. Here, ambient vibrations provide a promising alternative. In addition, recording ambient vibrations is of great importance when assessing the response of the site to an earthquake, potentially leading to coseismic slope failure. On slopes exhibiting deep cracks separating the instability into individual subvolumes, seismic normal modes can be observed, representing standing waves trapped in different compartments of the instability. We performed an operational modal analysis using the Frequency Domain Decomposition (FDD) technique on ambient vibration data acquired with a temporary array consisting of twelve 5s seismometers and two permanently installed short-period 1s seismometers on a large unstable rock slope near Preonzo in southern Switzerland ($>$150'000 m^3). We compare the normal mode shapes based on FDD to results from wavefield polarization analysis and site-to-reference spectral ratios (SRSR) and demonstrate that FDD is a suitable tool to analyse and monitor large landslides. Especially the capability of FDD to identify higher and close modes are significant benefits compared to simpler techniques such as SRSR or picking peaks on power spectra. Furthermore, the enhanced FDD provides an estimate of the damping of the modes that could be a critical parameter related to the geometry of the unstable slope.