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Monitoring the slope instability at Brienz / Brinzauls using ambient vibrations and earthquake recordings

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Earthquake-triggered landslides and rockfall form two of the most destructive coseismic phenomena and pose a severe risk to settlements and infrastructure (Keefer, 1984). As an alpine country with moderate seismicity, Switzerland is affected by these secondary seismic effects as well. For example, the aftershock of the M_w 5.8 Sierre earthquake in 1946, the most recent strong earthquake in Switzerland, triggered a large rockfall of several million cubic meters in volume at the Rawilhorn, Valais (Fritsche and Fäh, 2009). Recent developments allow to estimate the likelihood for earthquake-induced mass movements by combining geospatial susceptibility proxies (e.g., slope gradient) with modelled peak ground acceleration, which allows to incorporate coseismic mass movements in a large scale hazard analysis (Cauzzi et al, 2018). However, to asses the actual hazard emanating from a specific slope, detailed in-situ investigations on individual slopes are required.

The final collapse of a slope instability is the result of many interacting influences, such as weathering, geological preconditions and seismic exposure (past earthquakes), which already weakened the inner structure of the slope. Therefore, existing slope instabilities have naturally a higher susceptibility to strong ground shaking and should be investigated with respect to their dynamic response to vibrations. Burjánek et al. (2010) showed that unstable slopes exhibit strong wavefield amplification of factors beyond 8 and that the wavefield polarizes perpendicular to open fractures. As a result of these findings, a variety of processing techniques was developed to measure and characterize the dynamic response of unstable slopes (summarized, e.g., by Kleinbrod, 2018).

We investigate the unstable slope above the village Brienz / Brinzauls (Grisons, Switzerland), which is threatening parts of the village. The settlement itself is situated on a large-scale slump (Flysch, overlaid by Allgäuschiefer slate) with a displacement rate of several dozens of centimeters per year, resulting in structural damages on some of the buildings (Krähenbühl and Nänni, 2017). Consequently, the village and its surrounding were assigned to a “red zone” for natural hazards in 2017, prohibiting any further construction activities. These movements in the foot of the slope also destabilize the uphill rock mass, leading to large deformations and sporadic rock fall activities with volumes up to 150’000 m^3.

We deployed temporary seismic arrays in the village Brienz and on the unstable areas in the rockfall source zone in June 2018 to obtain shear wave velocity profiles and to characterize the seismic wavefield in terms of amplification, resonance frequencies, and polarization. We demonstrate the site-to-reference-spectral-ratio method as a useful technique to quickly outline the unstable area and compare the results to previous seismic studies performed on the same site. The comparison reveals significant changes in both the polarization and the amplification characteristics. To better monitor temporal changes in the seismic response and to investigate the dynamic behavior during earthquakes, we installed an autonomous, semi-permanent seismic station (BRIZ2) on top of the instability in Mai 2018. Since its installation, the station recorded a number of small regional earthquakes, for example, the magnitude 2.9 Zernez event on 16.08.2018 with an epicentral distance of about 40 km. The proximity to another seismic station in the village of Brienz and the use of empirical amplification functions (Edwards et al., 2013) allows for estimating the absolute seismic amplification factors in the unstable area with respect to a reference bedrock (Figure 1). These factors are large and exceed the factor of 10 during an earthquake.

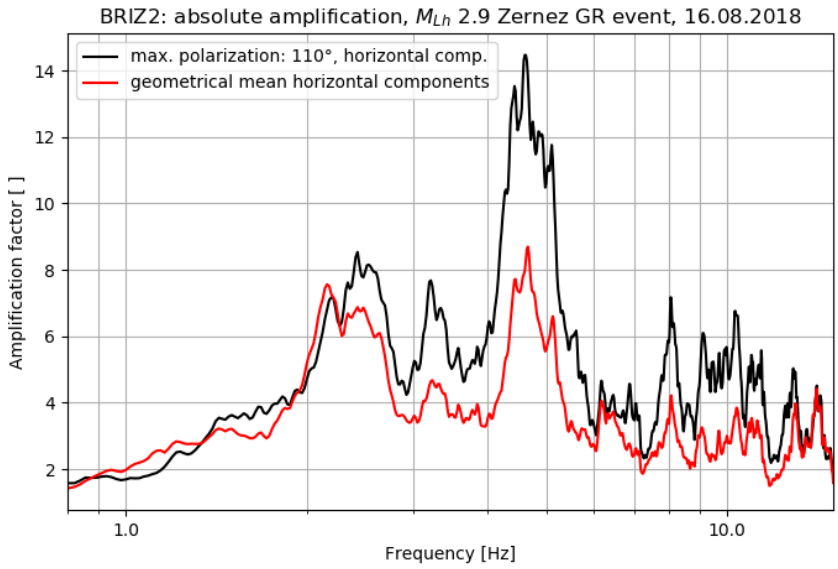


Figure 1. Absolute amplification spectrum of the station BRIZ2, installed on the rock slope instability Brienz / Brinzauls. The input data is the M_{Lh} 2.9 earthquake in Zernez (40 km epicentral distance).

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