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Spatial and temporal patterns of rockfall activity – Drivers, precursors, kinetics and evolution

Michael Dietze, Jens Turowski, and Niels Hovius
GFZ German Research Centre for Geosciences, Section 5.1 Geomorphology, Potsdam, Germany

Rockfalls are key processes in steep alpine landscapes but hard to monitor by classic techniques under natural conditions due to their unpredictable and rapid evolution. In contrast, seismic methods allow rockfall event detection, localisation and tracking, describtion of the temporal evolution, of the precursor activity and of external triggers. To exploit these capabilities, a 700 m high, nearly vertical limestone cliff section in the Lauterbrunnen Valley, Bernese Oberland, Switzerland, was instrumented with six broadband seismometers for more than six months during two distinct campaigns: late summer/autumn 2014 and spring 2015.

A total of 49 rockfalls events (17 in 2014 and 32 in 2015) were detected that occurred in the monitored cliff section. There were distinct spatial and temporal activity patterns at different observational scales: in summer/autumn rockfalls detached near the cliff base of the southern part, whereas in spring material was released at the upper and middle cliff parts from three activity hotspots – a downward annual vertical activity shift of 40-50 m/month. Rockfalls can be classified into three evolutionary types (“single impact”, “multiple impact” and “avalanche-like”) and showed seismic signals indicating precursor activity (e.g., crack propagation). Lag times for potential trigger mechanisms of 2-3 hours on average reveal that there is a tight temporal correlation of rockfall activity to rainfall and freeze-thaw transitions. Throughout the day, there are four distinct activity phases related to absolute temperature, temperature change rate and precipitation intensity.

The contribution highlights the potential of environmental seismology to give profound and holistic insight into rockfall activity in a prototype landscape, representative for many other alpine catchments.