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Analysis of seismic records of rock falls in the French Alps

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After a rock fall, field observations provide information's about the position of the detachment zone and the area covered by the deposit materials, which give the main geometrical characteristics of the fall: height and runout distance. The volume is then usually estimated by multiplying the deposit area by an estimated average thickness. Additional investigation, like geophysical experiments, help in determining the spatial variation of the deposit thickness. However, the only measurements available during the rock falls are the seismic ground motions provided by permanent seismological networks.

We present the analysis of seismograms from 12 rock falls recorded by the Sismalp network (http://sismalp.obs.ujf-grenoble.fr/) in the French Alps between 1990 and 2004. Observed fall volumes vary from $2\ 10^3$ to $2\ 10^6 m^3$ for a drop height between 90 and 450 m. These rock falls have been recorded at regional distance till 250 km. The limited number of records is due to the relative sparseness of the stations (spacing of about 30 km) and also to the wave attenuation in the upper crust. Distances between the falls and the closest station are usually between 10 and 25 km.

We have first analysed the attenuation of rock falls wave amplitude with distance. This attenuation is stronger than the one observed for earthquakes. This result implies that magnitude determination procedures defined for earthquakes can not be applied for rock fall analysis. Using our new attenuation law we have therefore defined a procedure which attributes a rock fall magnitude to each event. This new magnitude scale, specific to rock falls, help to compare and classify past and future alpine rock falls.

The comparison of the obtained magnitudes with the potential energy values of the 12 selected rock falls shows that only a very small amount of this energy is transmitted as seismic waves, highlighting the strong influence of nonlinear effects during the impact. Seismic signal analysis indicates that seismograms are complex with an irregular envelope and several energy pulses at different frequencies. For the simplest events, the time shift between the first onset and the second high frequency phase are almost constant on the different stations. These time shifts are consistent with the rock fall durations, supporting the existence of at least two seismic sources: one corresponding to the elastic rebound during the detachment and the other one generated by the rock impact on the slope.