Acoustic and micro-seismic signal of rockfall on Matterhorn

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Abstract

Despite substantial technical advances in the instrumentation of steep rock slopes, our ability to detect precursor events of rock slope instability remains limited. In this study, we investigate the acoustic and micro-seismic signal of fracture and rockfall events at Matterhorn. A rockfall event with a volume of 2 to 3 m³ was recorded by crackmeter and micro-seismic measurements on 14 August 2015 UTC 20:10 with high energy concentration below 100 Hz. The acoustic emission (higher frequency range) did not capture the rockfall event itself, but occurs coincidently with preceding irreversible fracture displacements. In the lower frequency range, we clearly capture the rockfall event, but to our surprise the wave amplitude and energy during the rockfall event was not higher than in the preceding ten days.

Keywords: bedrock permafrost; acoustic and micro-seismic; rock fall; Matterhorn

Introduction

Understanding of processes and factors affecting slope stability is essential for detecting and assessing the stability of potentially hazardous slopes. Despite substantial technical advances in the instrumentation of steep rock slopes, our ability to detect precursor events of rock slope instability remains limited. This study investigates the acoustic emissions (AE) and micro-seismic (MS) signal emitted by a rockfall event (2-3 m³) in steep, structured bedrock permafrost on Matterhorn Hörnligrat (Fig. 1) on 14 August 2015.

Field Site and Methodology

The Hörnligrat field site is located at an elevation of 3500 m a.s.l. on the North-East ridge of Matterhorn in the Swiss Alps (Weber *et al.*, 2017). Several rockfall events were observed in spring 2015 using a time-lapse camera. Consequently, the existing fracture observation have been complemented by continuous broadband AE/MS monitoring. AE and MS signals are elastic waves generated by the rapid release of energy within a material (Hardy, 2003). AE refers to waves with a frequency in the range 10^4-10^6 Hz while MS signals are in the range 1-10^3 Hz (Amitrano *et al.*, 2012). The instrumentation required to cover the frequency range 1-10^5 Hz consists of three different transducer types: piezoelectric sensors for capturing AE, accelerometer and seismometers for MS range.

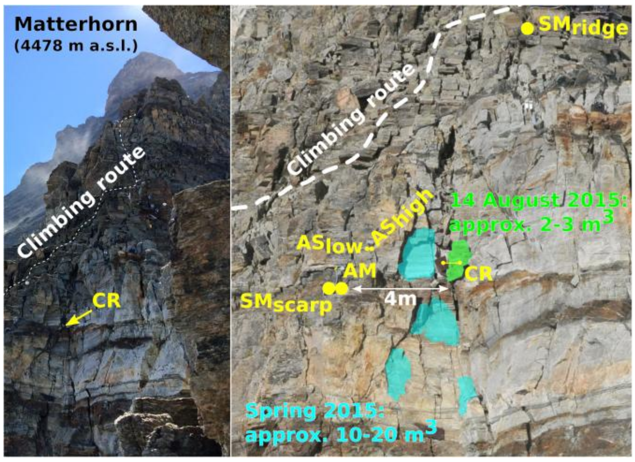

Figure 1. Instrumentation measuring fracture kinematics (CR), AE (AS) and MS (SM and AM) is indicated in yellow.

Results

The rockfall event investigated in this study was detected on 14 August 2015 UTC 20:10.32. A preceding fracture displacement of 13.2 mm was measured 10 h previously and a much smaller of only 0.15 mm occurred on 9 August 2015 (red arrows in Fig. 2a).

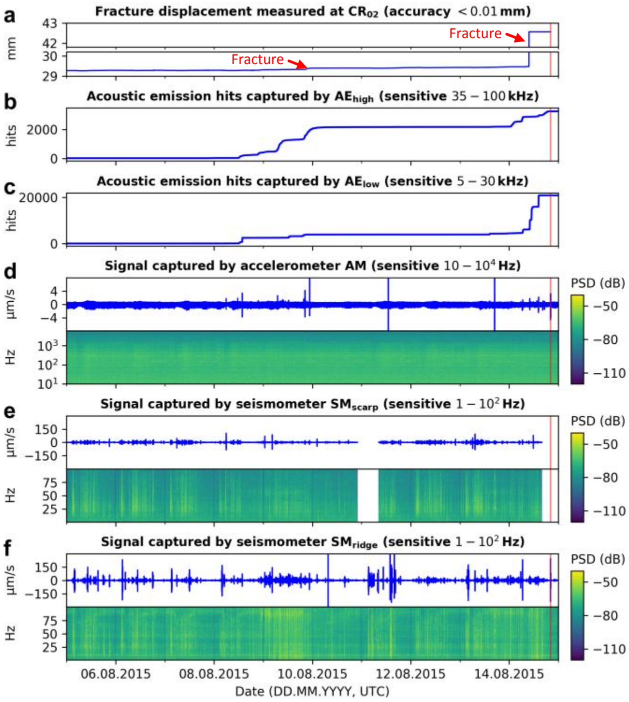

Figure 2. Crackmeter and AE/MS records during a ten-day period preceding the rockfall event on 14 August 2015 UTC 20:10 (indicated with vertical, red line).

Most of the threshold triggered AE events were captured before or at these previous fracture displacements, but none during the failure event itself (Fig. 2b+c). On the contrary, the waveforms measured at the accelerometer and seismometers show several times high amplitude values, which are asynchronous of the measured fracture displacement (Fig. 2d-f).

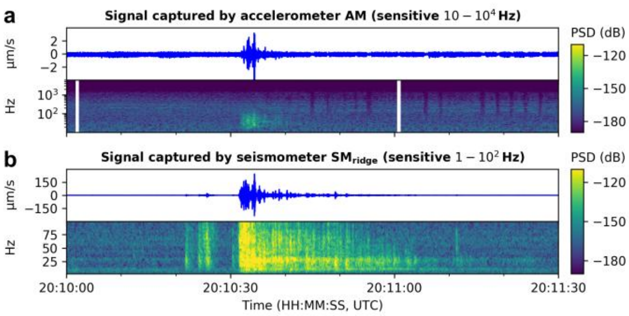

Figure 3. Waveform and spectrograms over the period of the rockfall event on 14 August 2015 measured by the accelerometer in the scarp and the seismometer on the ridge.

However, there are amplitude peaks in the MS range coincident with the failure and the two preceding displacements, but with lower amplitudes. Figure 3 shows the measured MS response to the failure at the accelerometer (AM) and the seismometer on the ridge (SM_{ridge}), indicating high power concentration below 100 Hz and a post-event seismic tremor.

Discussion

AE/MS signals recorded during a ten-day period preceding a rockfall event shows (i) the ability of MS to capture failure events and (ii) an increase in AE activity likely linked to irreversible fracture displacement. However, no AE events were emitted during the finale failure itself. A main challenge in AE/MS analysis is separating signal by progression of damage from environmental (wind, hail, etc.) and anthropogenic noise (mountaineers, helicopters, etc.). Therefore, it remains unclear whether the increased AE activity relates to the irreversible fracture displacement or to a noise source. Further, recognition of small failure events turned out to be difficult, because the MS records of the failure are not clearly distinguishable from other events although irreversible fracture displacement is often related to snowmelt or in-situ measured rainfalls periods.

References

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