Evaluation of the Raspberry Shakes low-cost seismometers to monitor rock fall activity in alpine environments

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1. Introduction

We evaluate the low-cost seismic sensors Raspberry Shake (RS, Fig.1) to identify and monitor rock fall activity in alpine environments. The test area is a slope adjacent to the Great Aletsch glacier in the Swiss Alps, i.e. the Moosfluh deep seated instability, which is undergoing an acceleration phase since the late summer 2016. A local seismic network composed of three RS seismometers was deployed by beginning of July 2017, when we expected to record the peak of rock fall activity at this location. Seismic data were collected and analysed to identify and locate rock fall phenomena. Moreover, a webcam was installed on the opposite side of the Moosfluh slope, acquiring images every 10 minutes to map the surface deformation and to validate the occurrence of slope failure events.

Fig. 1

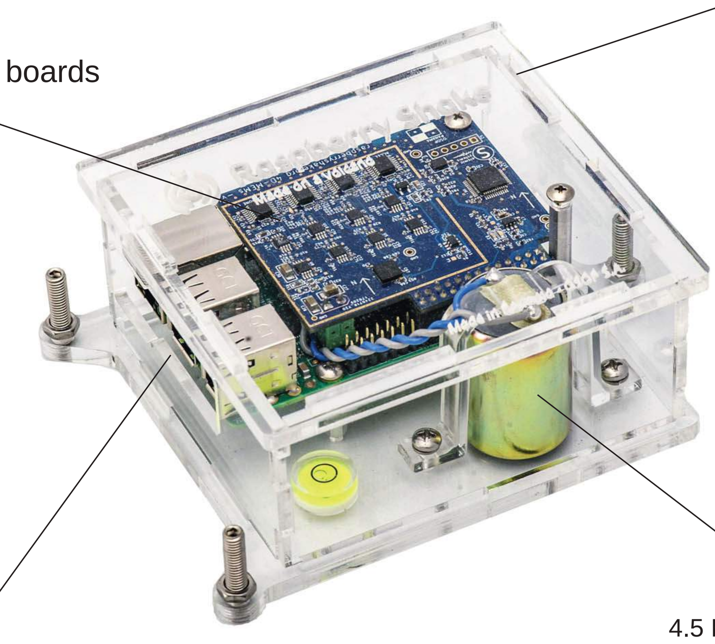

Fig. 1: Picture of the Raspberry Shake (RS) M9 seismometer used in this study. RS are a low-cost, all-in-one plug-and-go solution developed by OSOP S.A., which integrate vertical velocity sensor (4.5 Hz Racotech RGI-20DX), digitizer, and computer in a single box (100x120x50 mm, 0.35 kg). Sampling rate is 50 Hz. Power supply 5Volts DC, Power consumption 0.4 Watts; 80 mA.

http://www.raspberryshake.org/

2. Background and monitoring network

The Great Aletsch Region (GAR, Swiss Alps) has undergone to several cycles of glacial advancement and retreat, which have deeply affected the evolution of the surrounding landscape (see Fig. 2). Currently, this region is one of the places where the effects of climate change can be strikingly observed, as the Aletsch glacier (blue shading in Fig. 2) is experiencing a remarkable retreat with rates in the order of 50 meters every year. In particular, a deep-seated slope instability located in the area called "Moosfluh" has shown during the past 20 years evidences of a slow but progressive increase of surface displacement (orange shading in Fig. 2). The moving mass associated to the Moosfluh rockslide affects an area of about 2 square km and entails a volume estimated in the order of 150-200 millions of cubic meters. In the late summer 2016, an unusual acceleration of the Moosfluh rockslide was observed. Compared to previous years, when ground deformations were in the order of few centimeters, in the period September-October 2016 maximum velocities have reached locally up to 0.8 meters per day. Such a critical evolution caused the generation of several deep tensile cracks, and resulted in an increased number of rock failures at different locations of the landside body. These processes have been observed at several other unstable rock slopes prior to catastrophic failure events; however, high resolution monitoring data are rare.

Fig. 2

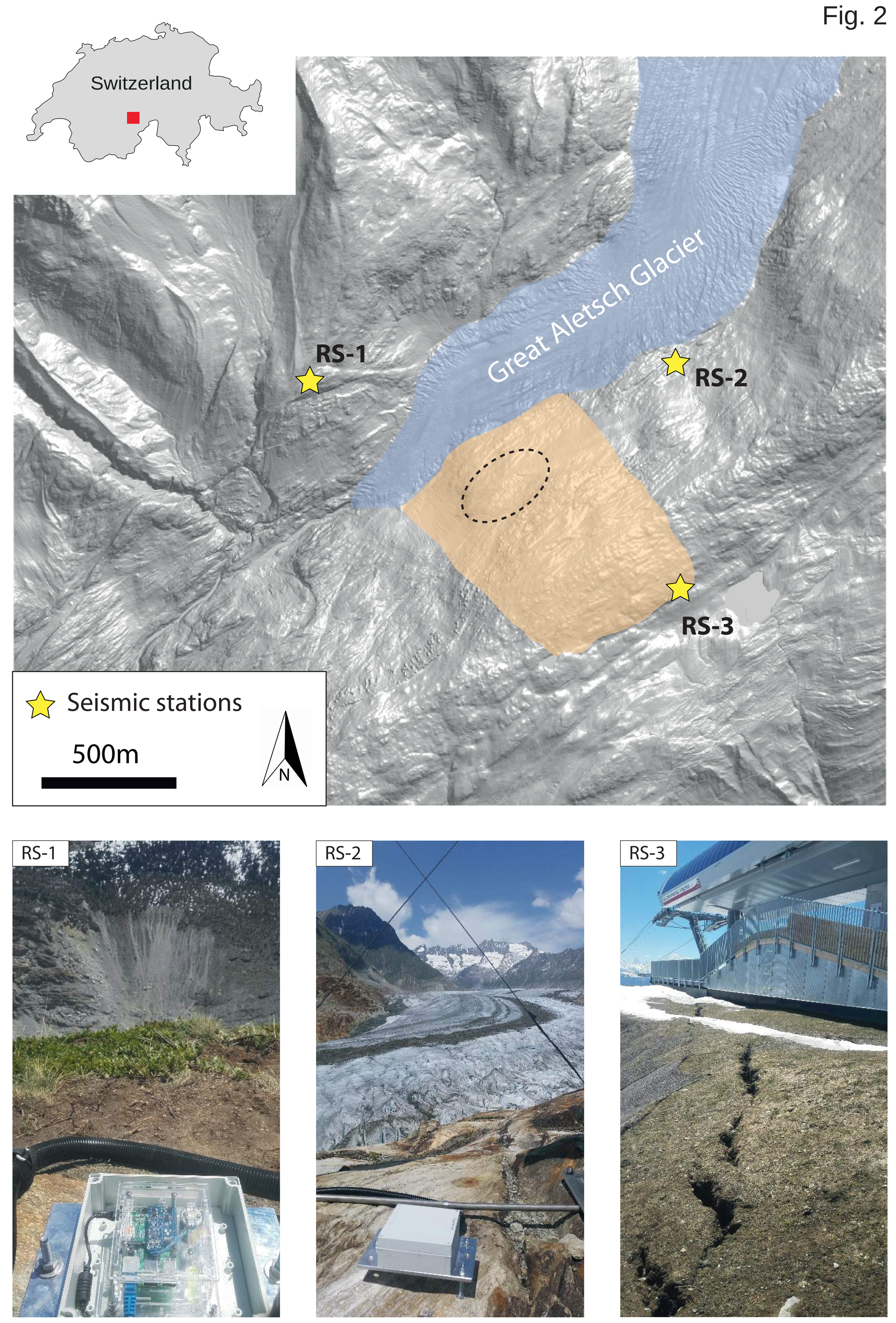

Fig. 2: (top) Map of the area of investigation with indication of the location of the three RS seismic station installed starting from May 2017 (RS-1 installed on 19 May 2017, RS-2 installed on 27 June 2017, RS-3 installed on 03 July 2017). Continuos records of seismic signals on the 3 stations are available since beginning of July. A Mobotix M25 webcam (5 Mpixel resolution) is installed at the RS-1 location and acquires pictures every 10 minutes. Data is transmitted in real-time to the ETH Zurich servers via GSM network. Dashed ellipse shows the main rockfall source area.
(bottom) Pictures of the RS installation at the three selected locations. In RS-1 and RS2 the coupling between the station and the ground is granted trough a metal plate which is directly screwed on the rock face. RS-3 is installed inside the basement of the Moosfluh cable car station and exploits power and internet connection from the infrastructure facilities. A fiberglass protection was used to isolate from external agents (rain, snow, dust, animals, etc.). RS-1 and RS-2 are installed at 2,200 and 2,000 m a.s.l., respectively.

3. Results

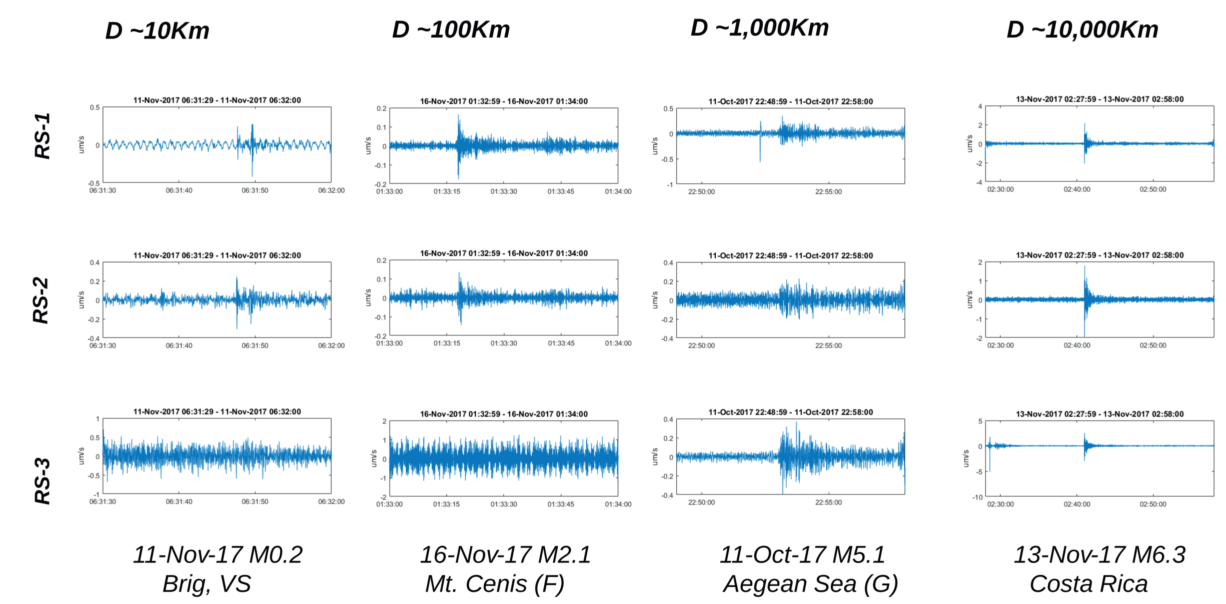

Fig. 3: Selection of earthquakes recorded by our seismic network. Events occurred at different distances (D), ranging from very local events to teleseismis. Earthquake signals have to be carefully considered when running a seismic network investigating rockfalls for 2 main reasons (1) they have to be distinguished from signals due to rockfalls and (2) earthquakes might trigger subsequent rockfalls. Note: Due to the operations at the Moosfluh cable car station causing considerable noise, small events occurring during local daytime cannot be seen at RS-3.

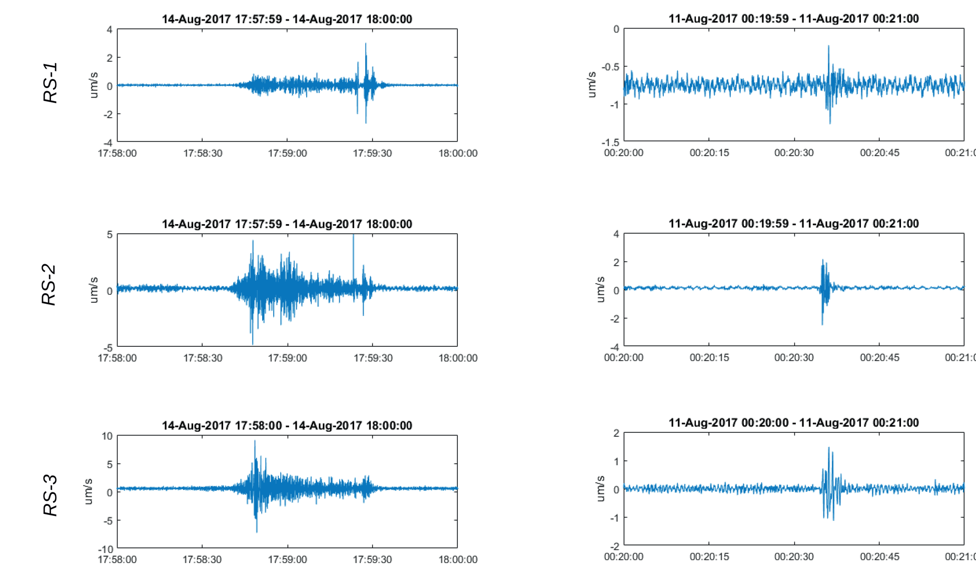

Fig. 4: Example of seismic signals associated to a medium size rock avalanche (left) and a single block fall (right). Despite the distances of the 3 stations are very similar (~1km, see Fig.1), amplitudes and arrival times vary probably due to different wave paths and attenuation associated to material heterogeneity. This difference in apparent velocity will be helpful to calibrate algorithms aimed at locating the source area and the magnitude of the rockfall events.

Fig. 6: Picture acqired from the Mobotix M25 after the occurrence of a rock fall in the Mosfluh slope (red contour). The joint use of seismic data , optical imagery, and surface defromation monitoring will help to better understand the spatial and temporal evolution of the Moosfluh instability.

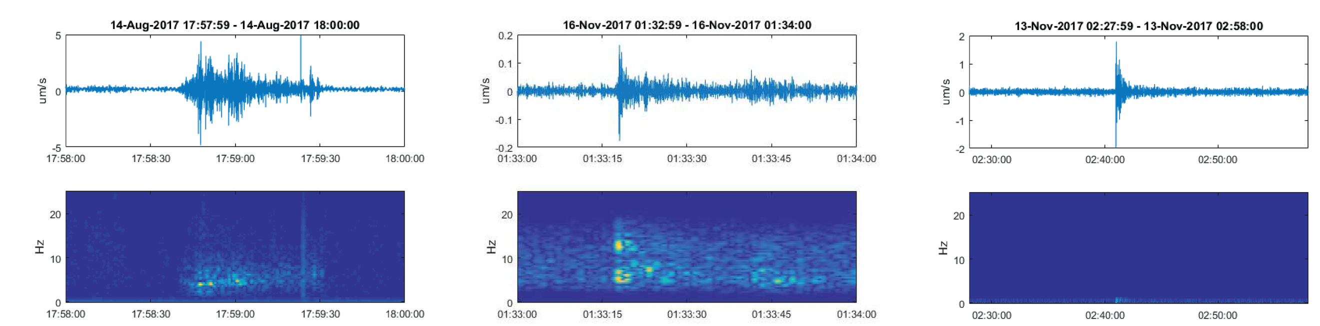

Fig. 5: Examples of seismic signals and spectrograms relevant to a rockfall (left), a regional earthquake (middle) and a teleseism (right), respectively, as recorded by RS-1. Relative differences in signal amplitudes, arrival time at the different stations, signal duration, and spectral characteristics, are clear. The signal-to-noise ratio and the sampling achieved by the RS sensors in our specific scenario allows to clearly detect, distinguish between different source typologies, and finally classify them accordingly. Validation of rockfall sources was performed by exploiting the available webcam pictures (see Fig. 6), while signals associated to seismic events were cross-validated with the seismic catalogue provided by the Swiss Seismological Service (SED).

4. Conclusions & Outlook

Our experience demonstrated that a local network composed of Rasperry Shake sensors is suitable to monitor rock fall activity in high alpine environments. The sensors pefromed well also during winter times at elevations > 2,000 m a.s.l., under snow cover, and with air temperatures below -20 C degrees. The quality of the seismic records allowed to achieve preliminary classifications of events associated to different sources. The seismic data recorded in the Great Aletsch area will be essential and complementary to interpret the spatial and temporal evolution of the Moosfluh slope instability and undestand the relationships between surface deformation and rock failure occurrence.

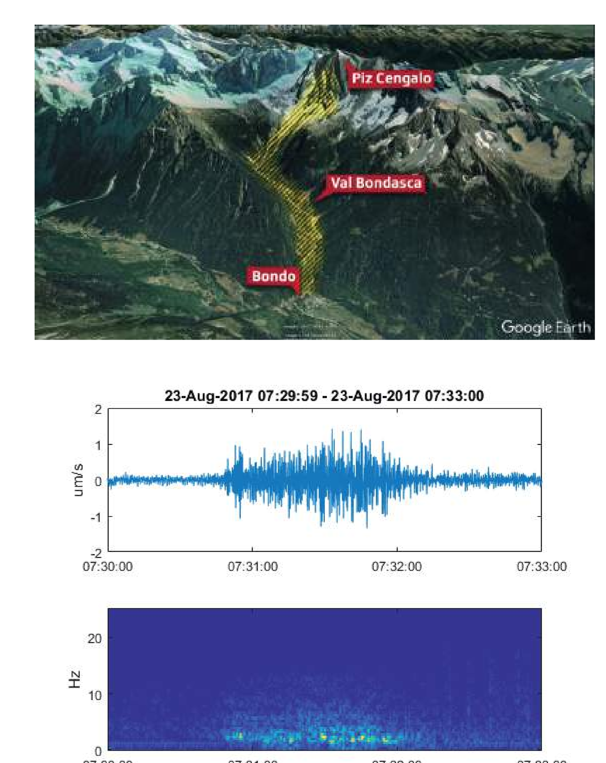

Fig. 7: Seismic signal associated to the Piz-Cengalo (Swiss Alps) rock slope failure occurred on 23 August 2017 as recorded by our network. The event occurred at more than 100 km from our location. RS sensors show a potential to be considered not only for setting local networks to study mass movements, but also for regional scale investigations.