Earth Surface Dynamics

Supporting Information for

Short Communication: Monitoring rock falls with the Raspberry Shakes

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This supplementary material provides further information on the Raspberry Shake and on its use to monitor rock fall phenomena in a test area adjacent to the Great Aletsch glacier, Swiss Alps. The Raspberry Shake seismograph is an all-in-one, IoT plug-and-go solution for seismological applications. Developed by OSOP, S.A. in Panamá, the Raspberry Shake integrates the geophone sensors, 24-bit digitizers, period-extension circuits and computer into a single enclosure. The output is digital and the analog-to-digital path is as follows: the analog signal passes from the 4.5 Hz 380-400 Ohm geophones to an analog system where it is amplified and period-extended from the geophone's natural frequency of 4.5 Hz down to 2 seconds, thus providing improved signal bandwidth at lower frequencies-essential for local, regional and teleseismic earthquake detection. The amplified and improved analog signal is then digitized with a 24-bit analog-to-digitizer (ADC) converter at 800 sps. Later, the signal is downsampled to 200 sps and finally to 100 sps as it passes through a series of anti-aliasing firmware and software routines.
The clip level is +/- 8,388,608 counts (24-bits) and ~22 mm/s peak-to-peak from 0.1 to 10 Hz. The minimum detection threshold is estimated at 0.03 µm/ s RMS from 1 to 20 Hz at 100 sps where the minimum detectable level is considered to be 10 dB above the noise RMS. Dynamic range is the full-scale sinusoid RMS over the noise RMS in dB. The effective bits, or those noise-free bits commonly referred to as "Dynamic range" or "RMS-to-RMS noise", for the entire sensor, analog and ADC chain is estimated to be 21 bits (126 dB) from 1 to 20 Hz at 100 sps. The instrument self-noise is, therefore, ideal for local, regional and teleseismic earthquake detection.
As a scientific-grade instrument, the Raspberry Shake is compatible with all standards in earthquake seismology: Data is transmitted in from a native SEEDlink server running on a Debian OS in miniSEED format and can be ingested directly into Antelope, Earlybird, Earthworm, GISMO, ObsPy, SEISAN, SeisComP(3,Pro) and all other mainstream data processing software packages without modification. Instrument response files are provides in dataless, inventory-xml, pz and RESP formats. All station and channel naming follow FDSN guidelines (Site the SEED manual).

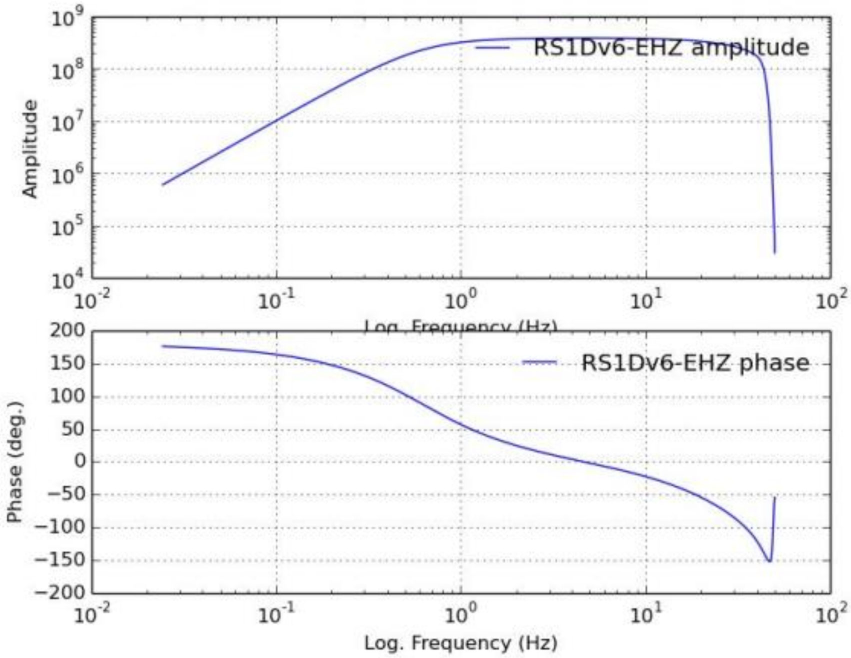

Figure S1: Instrumental response of Raspberry Shake model 1D V6s. The -3 dB points that define the digital signal output bandwidth are estimated at 80% of NyQuist, or 40 Hz, and 2 seconds.

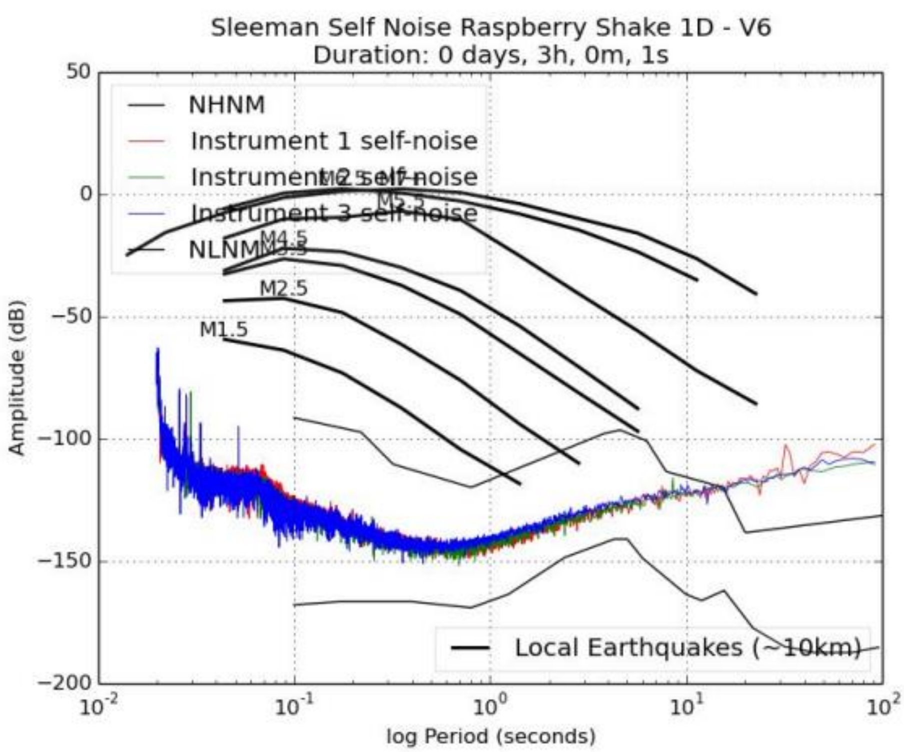

Figure S2: N(H/L)NM - Nominal (High/Low) Noise Model. M* lines refer to typical energies for local (<10 km) seismic events. Instrument 1, 2 and 3 are Raspberry Shake model 1D V6s.

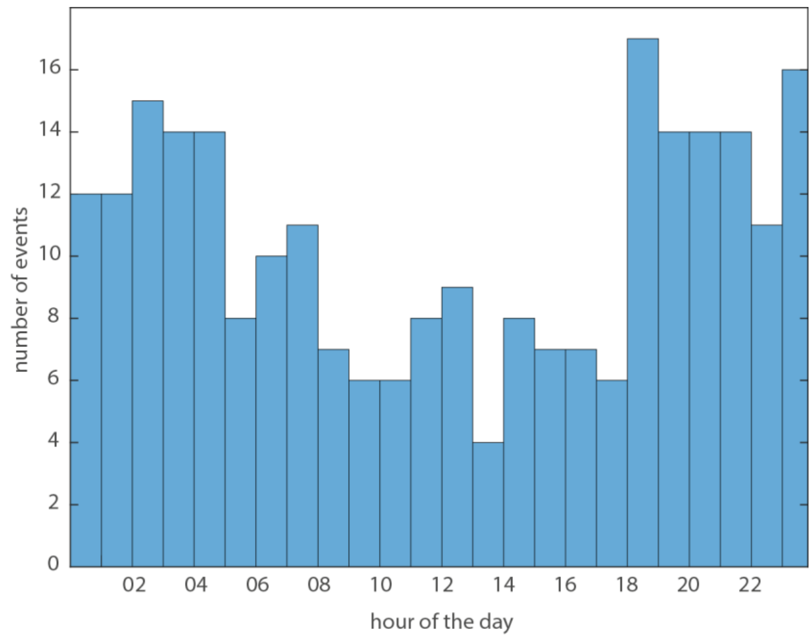

Figure S3: Number of rock fall events vs. hour of the day. This analysis shows that the majority of the events occurred over night. Future work aims at detailed analyses of the environmental conditions and meteo-climatic triggers to understand the causes of this temporal distribution.

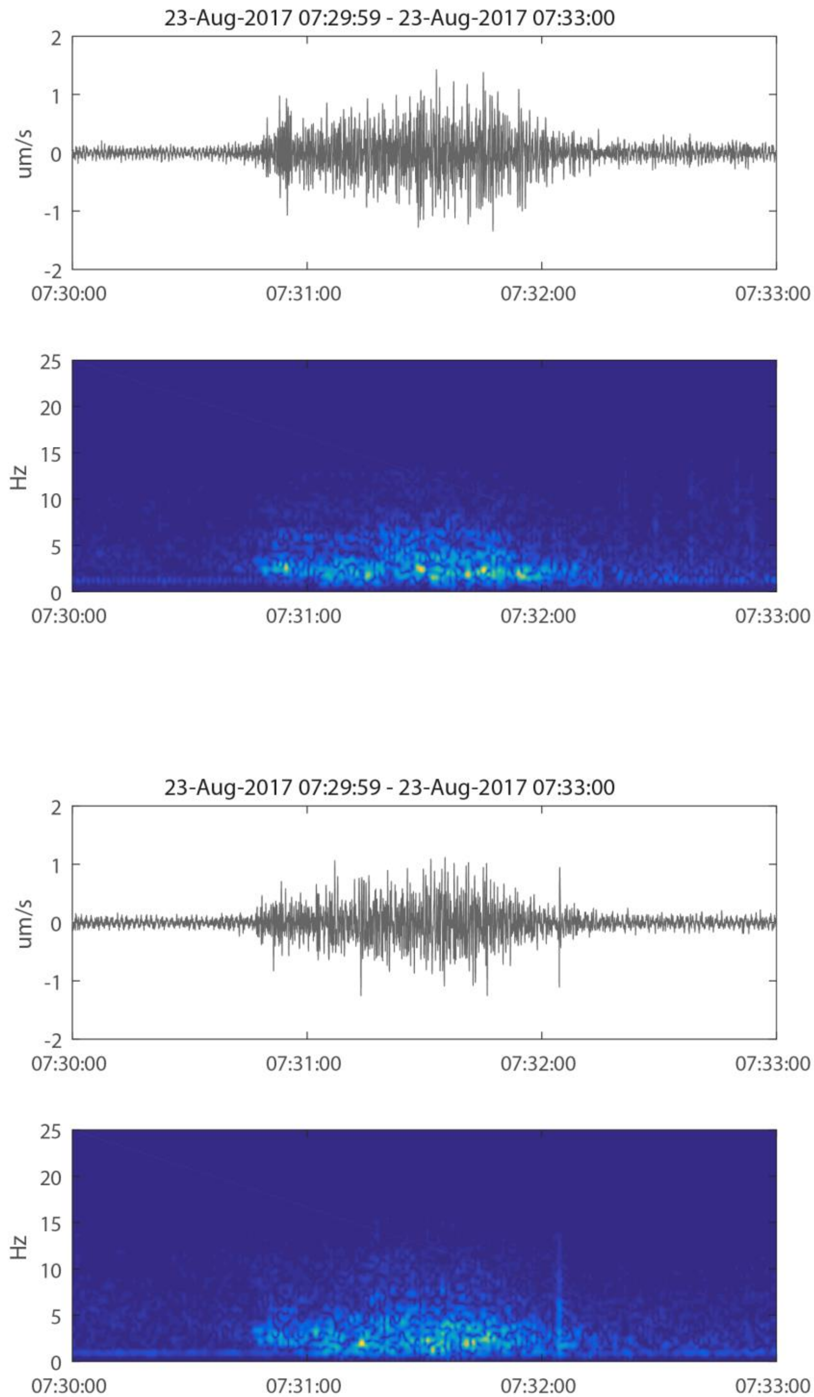

Figure S4: Seismic signals associated to the Piz Cengalo rock avalanche (ca. 3 million cubic meters of failed material) occurred more than 100 km away from the monitoring location. (top) Signal at RS-1. (bottom) Signal at RS-2. The station RS-3 did not recorded the signal due to major noise caused by the cable car operatios.

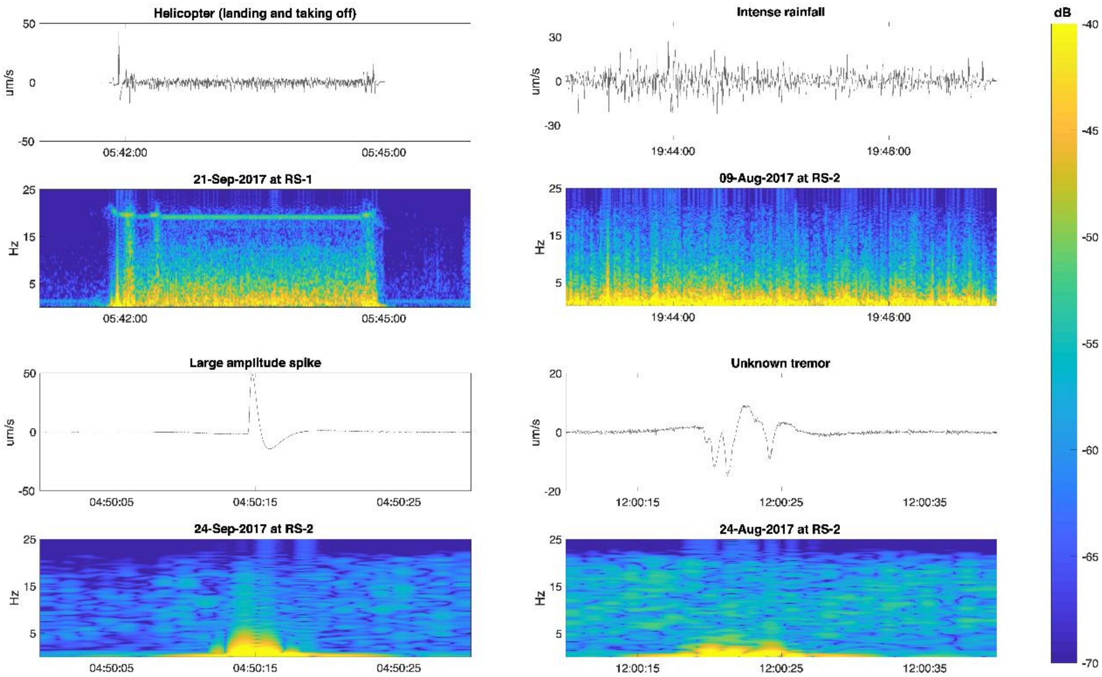

Figure S5: Seismic signals associated to environmental variables (such as rainfall events), anthropic nature (for example helicopter) and/or of unclear source Performance of the RS-1 and RS-2 stations.