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Interactive comment on "Short Communication: Monitoring rock falls with the Raspberry Shakes" *by* Andrea Manconi et al.

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Review of Monitoring rock falls with the Raspberry Shakes by A. Manconi et al

The manuscript aims at providing insight into the usability of low-cost seismic sensors for purposes of environmental seismology under harsh environmental conditions. Specifically, the authors want to report on the use of Raspberry Shake devices for rockfall monitoring in the high Alps.

Recently, there is increased interest among the community in so called large-N installations with low cost sensors. Specifically for targeting high-frequency seismic radiation of local seismic sources such sensors potentially offer good monitoring capabilities for low budget. The Raspberry Shake devices have recently become more popular, how-

ever mainly for educational purposes and outreach. Thus, a study documenting their applicability under challenging climatic conditions such as high-mountain areas would be very welcome.

Unfortunately, the manuscript falls short of it‘s promises and lacks a number of interesting topics which could be addressed.

Short-period sensors are already commonly used in seismic monitoring of rockfalls in various environments. Thus, the sensor technology of Raspberry Shake is not new and we know that geophone based sensors are well suited to record the high-frequency seismic radiation of near-surface processes such as rockfalls. However, the Raspberry Shake is designed as an ready-to-use all-in-one solution mainly for home-use. It would certainly be interesting to read how this design is suitable for operation in high-mountain areas. As far as I know there are no other studies reporting on this. Unfortunately, especially this part is not properly addressed in the manuscript. I would expect that after one year of operation, the authors gained quite some insight into data quality, system reliability and unique challenges and how to solve them. This would certainly be interesting to read. Please see more detailed comments about this below.

The manuscript is also very brief and simplistic on the description of methods to detect events. It is nice to see that both regional and teleseismic earthquakes are well-recorded and that visually confirmed rockfalls are as well detected. Still, this is somewhat no surprise. In order to really judge the performance of such a network for rockfall monitoring purposes, much more details on the methods should be provided and challenges in data analysis should be highlighted or at least mentioned. Especially, a section about location is missing. Below I list several suggestions for improvement.

I do realize that the authors designed their work as "Short Communication" and that several of my suggestions would require additional work and consequently the manuscript would become longer. Thus I encourage the authors to spend some more time on the manuscript and shape it into a more conclusive study about the performance of Raspberry Shakes in mountain areas. If the authors prefer to keep it brief and not elaborate in more detail about the data analysis challenges, still I suggest to improve those parts that really concern the specific challenges of operating Raspberry Shakes in alpine conditions: installation, system reliability, data quality.

Best regards, Florian Fuchs

Detailed comments:

Section 1

- The introduction is somewhat lengthy and introduces general considerations not directly related to the topic of "Raspberry Shakes for rockfalls". Maybe e.g. some parts about remote sensing could be dropped to keep it short.

Section 2

- This section is in part both too brief and too extensive. Some information is overly detailed (e.g. bits for dynamic range, analog chain of processing, resistivity of Geophone, A/D sampling, ...). I suggest to refer to the manufacturer's spec sheet for such details. Stating that it's a 4.5 Hz geophone with eigenperiod electronically extended to 2s should do the job.

- On the other hand I miss information about e.g. range of available models (1 comp., 3 comp, pressure sensors, etc.), available housings, available connections. Are sampling rates adjustable? How is time synchronized? What's the power consumption? How is data stored? As this might be the first work introducing Raspberry Shakes for scientific field deployments, such details should be addressed.

Section 3

- Have there been other geophysical studies in the same area before? What other monitoring facilities are in place? The most interesting part is how to install a Raspberry

Shake in alpine conditions for long-term use. Please slightly expand your descriptions here. How is the Raspberry Shake fixed to the ground? Do you put additional shielding against wind or thermal effects? How is time synchronized? Photographs showing more details would be of great help – maybe as supplemental material.

Section X

At this part of the manuscript I am missing a section about the performance of the network. What's the amount of data retrieved? Where there any power downs? Why so? What's the quality of the data? Any gaps? What's the noise level? I would certainly like to see some PPSD/PDFs showing the noise levels over one year. Is the relative timing good enough? Any other issues due to environmental conditions?

Section 4

- Generally, this section is very simple and should be greatly supported by a description of the methods you used. My general suggestions is: instead of elaborating on individual events that after all are hard to interpret, I suggest to make use of the long observation time and large number of detected events. Are there some patterns to be seen? How do amplitudes distribute? Is it in fact possible to locate the events? Is all of this actually possible with your dataset? If yes – please show! If no – try to discuss limitations.

- The detection threshold of the network will rely on the average noise levels throughout the year. Can you give an estimate of what's the smallest ground motion you can reliably detect? This would be of relevance for detecting both earthquakes and rockfalls. What are the settings for the STA/LTA detector?

- How did you identify the 250 events as rockfalls? This is a very crucial task for any monitoring so please be more specific on how you identify those. Did you also use an STA/LTA? On how many stations do you see those events? How many of the events are confirmed by the webcam? Was it a visual inspection of the seismic data or some automatic processing? If the latter, please provide parameters or criteria.

- How many events did you detect in total, how many of those are of “unknown” type? How did you e.g. identify rainfall (example in supplemental material) in your seismic data? How the helicopter?

- Figure S3 is quite an interesting observation! Obviously one needs to trust the detections (thus, see comment above), but certainly this is a nice observation that should be moved into the main body of the manuscript.

- Unfortunately the webcam images (Figure 3) are very hard to interpret (especially when printed on paper). Are these the best examples you can show? What’s your experience with the 10 minute sampling rate? Is it sufficient? What would be the effort to increase it?

- I am missing a paragraph dedicated to locating the detected rockfalls. After all this is one of the most important tasks for monitoring purposes. Did you attempt to locate the events? How could it be done? How well does it work? Are there specific drawbacks?

- You try to qualitatively interpret some of the amplitude readings for individual events. In general it would be interesting if the recorded amplitudes relate to e.g. distance or ground type underneath the stations or between the stations and the rockfalls. Do you see any general behavior? With 250 rockfalls you should have quite a nice database to dig into this. Is there maybe an effect due to ground-coupling of the sensors?

- You show several examples of seismically recorded rockfalls, yet your description of those events is very basic. In fact, it is no surprise that you are able to detect rockfalls in the close vicinity with the Raspberry Shake. Yet, already from looking your examples it is somewhat obvious (and known from other studies) that rockfall seismic signals are quite complex and relating them to rockfall mechanisms in real field applications is not necessarily straight forward. The real challenge of any monitoring system lies in safely classifying the rockfall events and to discriminate them from all the wealth of other

seismic signatures (e.g. anthropogenic) in your data. This starts at classifying seismic signal as “rockfalls” and continues into scaling relations between seismic observables (e.g. amplitude, frequencies, energy, . . .) and rockfall parameters (volume, runout, mechanism, . . .). I think there is interesting work in that direction to be done with this dataset, but it’s likely out of scope for the current manuscript. You may decide to work into that direction, but for the moment it would maybe be already sufficient if you add a section that discusses these challenges.

Specific remarks/typos/grammar:

Page 1, Line 16: remove “investigations”

Page 1, Line 24: remove “of”

Page 1, Line 30: what do you mean by arbitrary information?

Page 2, Line 3: replace “and” with “to”

Page 2, Line 5: replace “Despite” with “However”

Page 2, Line 26: ...from the seismic signal IT is possible . . .

Page 3, Line 1: Explain IoT

Page 3, Lines 3ff: state somewhere that the sensors measure ground velocity

Page 3, Line 18: remove “to”

Page 4, Line 1: change to: . . . isolation from different external effects (...)

Page 4, Line 6: what is a Winston Wave Server? What is it good for?

Page 4, Line 24: replace “lower” with “shallower”

Page 5, Line 5: Figures 3 → Figure 3

Page 5, Line 9: add reference to Figure

Page 5, Line 14: replace “presents” with “measures” or “records”

Page 5, Line 29: replace “coeval” with “consecutive”

Page 5, Lines 26ff: This part should be moved upwards, since it contains the detection/verification of events

Page 5, Line 31: Give examples for “other processes occuring in the subsurface”

Page 6, Line 1: Change to “Apart from rock fall phenomena . . . signals associated to other environmental processes (such as. . .)

Page 6, Lines 11ff: You should only summarize your findings. The advertisement for low cost solutions should be moved to the introduction section.

Figure 1:

- Add arrow indicating the line-of-sight of the webcam

- DSGSD is not explained

- Show inside installation of RS-3 as well

Figure 2:

- Convert Lat/Lon to distance or add distance to the plot titles.

- Caption: b) Your plots show examples of detected events and maybe estimate a lower threshold. There is no information about the real probability of detecting an event.

Figure 3:

- Any chance to improve the contrast/visibility of the webcam pictures? It is really hard to see any changes in the before/after pictures. Why not show some examples from

daylight period? These should show a clear before/after signature?

- Caption: august → August

Figure 4:

- Please describe this Figure in more detail in the manuscript text. You show the waveforms in great detail. If there is something noteworthy to be seen, please state so.

- What’s the filter applied to the waveform data?

Supplemental material:

- The text is mainly a copy of Section 2 and I think it can be dropped. If you like to describe the very specific details of the signal processing inside the Raspberry Shake, you could do that here (and not in Section 2).

- Figures S1 and S2 are copied from the producer spec sheet. You could just refer to that sheet. If you like to keep them, please indicate the source.

- If you have any, here would be the perfect place to put more examples (waveforms + webcam pictures) of rockfalls (and maybe other sources: cable car, mountaineers, ...)

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