Response to referee comments – referee 1

[Spatiotemporal patterns, triggers and anatomies of seismically detected rockfalls]
September 29, 2017

We would like to thank the editor for the encouraging and helpful comments, all of them obviously devoted to improve the quality and impact of the manuscript.

All suggested typo or phrasing revisions were implemented as suggested.

Editor 1: *Consider breaking into two sentences.*

Reply: Done as suggested ("Seismic data allows the classification of rockfall activity into two distinct phenomenological types. The signals can be used to discern multiple rock mass releases from the same spot, identify...")

Editor 1: *Consider adding a sentence here explaining how you know that freeze-thaw transitions caused these rockfalls. Is this from a temperature record?*

Reply: Sentence added ("Freeze-thaw-transitions, approximated at first order from air temperature time series, account...")

Editor 1: *Say why (maybe this is obvious, but I think it is useful to highlight that seismic techniques can deliver almost continuous temporal coverage.*

Reply: Done as suggested ("The temporal information delivered by these methods is not very precise as it is bound to the survey lapse times, which are typically on the order of weeks to years." and "They allow precise temporal fixes of rockfall event initiation and duration because they record continous high resolution signals of geomorphic activity.")

Editor 1: *Awkward phrase. Rewrite.*

Reply: Done as suggested ("Combining spatial and temporal rockfall patterns, we identify a rockfall activity zone that consistently shifts down the cliff over the course of the season, and quantify the effect of diurnal forcing on event activity within the composed catalogue.")

Editor 1: *Sureley there are dozens of papers that do this, many predating this paper? I would add some references here.*

Reply: Additional key references added.

Editor 1: *A suggestion: this section contains a list of possible triggers and each trigger section suggests possible "fingerprints" of these different trigger mechanisms. I think it might be useful if the authors prepared a table that gave the different mechanisms and listed the signals within the seismic data that could be used to differentiate these mechanisms. The authors are much better placed than I to determine if this would be useful but I think the authors should consider such a table (I could image something like that appearing in many talks and book chapters in the future).*

Reply: A summarising table is added now and also contains short descriptions and key references for a potential seismic approach to asses trigger actitivity. Due to the Latex manuscript template it was not possible to have a single table that fits onto one page. Thus, the final layout shall have a minor modification and merge the two tables of the current manuscript version.

Editor 1: *Add a few words of explanation. There is a ratio. A ratio of what to what? The ground velocity vs the noise in the background velocity?*

Reply: Done as suggested ("This algorithm is sensitive to instantaneous rises in the recorded seismic signals, which affect the long-term running average only marginally while raising the short-term running average severely and thus increase the ratio at the onset of seismic activity.")

Editor 1: *If you are just using random names for these stations, surely you can come up with better ones. You next installation should be called "Xandor, Lord of the Three Eyed Conger Eels"*

Reply: Well, the names are not random, though profoundly explaining their origin shall remain the first author's well hidden secret or may be a matter of a personal conversation. If the editor comes up with an interesting research project in the North of the United Kingdom, the first author would be chuffed to name one of the seismic stations "Xandor, Lord of the Three Eyed Conger Eels".

Editor 1: *If you want to keep the reference to the triangular shape you can add a sentence here saying this looks somewhat triangular on the seismogram*

But I don't really see why you need that beyond the description of what is happening to the frequencies as they evolve in time.

Reply: Sentence part with triagular shape has been removed to be consistent as suggested.

Editor 1*: say why (calibrated somehow in the 2017 paper?*

Reply: Additional information provided, now ("velocity was set to 2700 m s^{-1}, which provided the best location accuracy in this study area (Dietze et al., 2017).").

Editor 1*: This is a little worrying in that every time I have used MCMC methods I've needed chains much longer than 1000 links to get a stable behaviour (i.e., the burn in period is longer than 1000 iterations). Did you test to see if changing the length of the chain gave you different answers?*

Reply: We had tested this point during the data analysis period and added information to the manuscript ("Initial tests showed that stable, reproducable plots emerge with already 500 MCM runs and larger chains did not improve the quality of the results"). For this applicartion we just had to combine two independent variables, time of event and kernel bandwidth, so there is not a large number of possible combinations that would require long chains. Please also see figure 1 for a short test on the effect of changing the chain length for 50 randomly distributed values, based on the following R code:

```
## define data set
x <- runif(50)

## perform MCM-based resamling and density estimate approach 101 times
d <- lapply(X = 1:101, FUN = function(i, x) {

  x_i <- sample(x = x,
                size = round(length(x) * runif(n = 1,
                                               min = 0.8,
                                               max = 1),
                             digits = 0),
                replace = FALSE)

  k <- density(x = x_i,
               bw = 0.1,
```

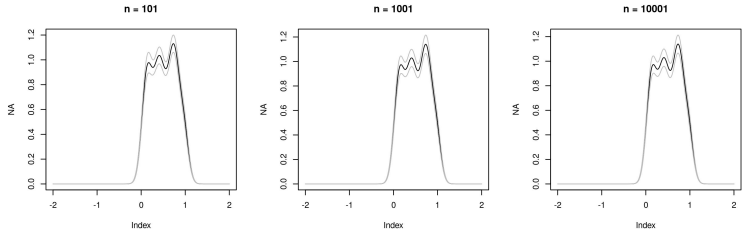

Figure 1: MCMC-based kernel density estimates for 101, 1001, and 10001 MC runs, each resampling the same series of 50 values with a resampling size between 80 and 100 %. The plots depict mean ± 1 standard deviation and show virtually no difference, suggesting that for such data also MCMC chain lengths of about 101 are sufficient to generate stable results.

```
              n = 1000,
              from = -2,
              to = 2)$y

}, x)

## convert list to matrix and calculate columnwise mean and sd
d <- as.matrix(do.call(rbind, d))
d_m <- apply(X = d, MARGIN = 2, FUN = mean)
d_s <- apply(X = d, MARGIN = 2, FUN = sd)

plot(NA,
     xlim = c(-2, 2),
     ylim = c(0, max(d_m + d_s)),
     main = "n = 101")
lines(x = seq(-2, 2, length.out = 1000),
      y = d_m)
lines(x = seq(-2, 2, length.out = 1000),
      y = d_m - d_s,
      col = "grey")
lines(x = seq(-2, 2, length.out = 1000),
      y = d_m + d_s,
      col = "grey")

dev.off()
```

Editor 1: *Sweaty herbs is a good name for a station.*

Reply: Thanks, we also consider this a good name.

Editor 1: *Independently calculated from what data? Refer to either figure or TLS data.*

Reply: Done as suggested ("This implies an TLS-based free fall distance of not more than 106 m (figure 3 d)").

Editor 1: *Check figure formatting. Hard to see anything here.*

Reply: The figure is scaled to 69 % of its actual size due to the manuscript Latex style. In the final version of the article this issue should be solved.

Editor 1: *This caption needs an explanation of what the MCMC fit line is doing here.*

Reply: Added as suggested ("Semi-transparent graphs are Monte-Carlo based exponential fits of the elevations of the events denoted in grey colour").

Editor 1: *I'm a bit uncomfortable with this. Is it really needed in the context of the paper? Based on the figures, there are a range of starting rockfall locations and these seem to get lower as time progressed during the monitoring. But at any given point there is quite a range in the initiation points. So really what one has (or this is how I interpret the data) a moving window there there was rockfall activity and the median elevation of this activity moved lower through time. I feel like presenting this equation could lead to abuse by others where a model simulated a "buzz saw" acting on a particular elevation through time. The authors might consider either some lines of caution in using this equation with particular reference to the probabilistic nature of the initiation elevations.*

Reply: The inclusion of this fit is mainly a result of the initial reviewer comments. We now added a sentence that highlights the significant scatter of the detachment elevations around the overall trend ("...root mean square error of 76 m. Thus, there is significant scatter in this overall trend, underlining that the model only describes a first order effect visible in the data, which is modulated by further factors of influence that impose a strong stochastic effect").

Editor 1*: section 2?*

Reply: Changed as suggested.