Dear Reviewer,

We would like to thank you for your time and efforts devoted to revise our manuscript and for all the suggestions, which we find essential for right understanding of our work. The revised manuscript, remarkably different from the original version, will be submitted to the editorial office after posting reply to your comments. Changes in the manuscript involved adding extra figures, putting more emphasis on the aims and conclusions and expanding descriptions and definitions throughout whole paper. Below we refer to all your remarks in the sequential manner.

Anonymous Referee #1

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This manuscript describes work classifying seismic events recorded near glaciers in Spitsbergen and describes variations in the occurrence rate of these events. The authors identify correlations between seasonal weather data and the seasonal occurrence of these events and an increase in the number of events. Their method to identify the origin of detected seismic events is new to glacier seismology.

Despite these efforts, there are a variety of issues with the present manuscript that I suggest the authors resolve prior to publication. These items limit the reproducibility of the work, the originality and significance of the conclusions, and the extent to which the work can be understood. My major concerns, which I expect will require significant time and effort, are briefly summarized below, with more minor line edits following. Following significant revision, a new manuscript may be appropriate for publication.

Major comments:

+ The methods are extremely difficult to follow. It is unclear how the NED will evolve over time, or how the noise function was calculated.

Authors: We provided an illustration and broaden descriptions in adequate paragraphs, providing a reference to the literature, for a better insight into deriving the NED and noise functions.

The event classification criteria (in two numbered lists on p. 5) are ad-hoc and are presented without justification. The explanation of the fuzzy logic algorithm is very hard to follow and there is not nearly enough information provided to allow for interpretation of Figure 3. Inclusion of sample waveforms, illustrating the different criteria, would be of great help.

Authors: *The description of the methods was significantly changed. Also sample waveforms were provided.*

My understanding is that ice vibrations are calving icequakes. Is this not the case?

Authors: Although signal characteristic of those is similar we can't say these are the same. Ice-vibrations' sources has been localised inside the body of the glacier, close to, but not at the calving front. Also, ice-vibrations has been observed at alpine glaciers (Górski, 2004).

+ There is no description of the origin of the weather data or how the positive degree days are calculated. These should be part of the methods.

Authors: Those informations have been added to the manuscript.

+ The value of the fuzzy logic criteria is not clear, since about 60% of seismic events are not classified, nor is it clear how the different types of events differ from each other. Why do the authors believe this approach was useful? Perhaps is the method were more clear, its impact would likewise be more

easily appreciated. How do the authors know to attribute the Not identified events to the nearby glaciers?

Authors: Fuzzy logic section has been expanded. This method allowed to recognize part of events as not-glacier induced and separate them, and then to choose signals having characteristics corresponding to the ice-vibration events. What is crucial all this was done fully automatically and in an objective manner (although detection criteria are still subjective and based on the expert knowledge).

One of the arguments to link not-identified events with glaciers is that they follow the seasonal pattern. Another one is that the signals of non-glacial origin has been described by earthquake and false-detection criteria and separated with the help of the fuzzy logic algorithm. Signals which are left are different from typical noise and earthquakes waveforms, but not similar enough to ice-vibrations to be classified so. Glacier however, is a source of signals different from ice-vibrations, but much harder to specify like e.g. icequakes or different kinds of calving.

Because we remove most of non-glacier-induced signals we assume the rest to correspond to glacier activity as supported by their seasonal variability.

What's more we analysed the same time span of the data as Kohler et al. (2015) but we used single station detections. We can assume that our STA/LTA detection algorithm should detect as a minimum the same number of events as it was detected by Kohler et al. (2015), who used the SPITS array located at greater distance than the HSPB, using HSPB records only to verify detection results. In fact, as glacier-generated, we have classified even less events than they did. It indicates that criteria we used were more restrictive than those used by Kohler et al. Hence, we can assume, that our detections include mostly the same events as Kohler et al. (2015) have shown for Hansbreen glacier. And hence, we claim that what we show is a glacier-related seismic activity.

Those conclusions can be further confirmed by comparing the seasonal and interannual event distribution with work of Kohler et al. (2015).

+ The conclusions are not new. Kohler and others (Polar Research, 2015, 34, 26178) published a paper last year drawing on the same seismic signals, using more seismometers and applying more compelling analyses to these data. Kohler and others convincingly link the icequakes to calving events and reveal a seasonal cycle nearly identical to that reported in the present manuscript. Luckman and others (Nature Communications, 2015) also produce time series of frontal ablation rates that will contain calving events with similar calving events. The present authors cite both of these studies, but it is not clear how the present work is different than or similar to these existing studies. The authors have the opportunity to advance our understanding of calving seismicity and calving through more careful comparison to these existing studies. As it stands now, the conclusions are both weaker and more inconclusive than the conclusions of previous studies.

Authors: We included a comprehensive discussion on this topics.

+ The descriptions are unnecessarily qualitative in a number of locations within the text, for example when adjectives such as major or minor are applied without definition.

Authors: We inspected and specified descriptions and definitions throughout whole text.

+ The quality of the writing needs improvement prior to publication.

Authors: The manuscript has been revised to improve the overall writing quality.

Line edits follow:

p. 1 L 12: remove the first the

Authors: Corrected.

p. 1 L 13: over many years is redundant

Authors: You're right, corrected.

p. 1 L 20: What is energy flow analysis? Energy of what? This is not described in the main text.

Authors: To be precise we meant variability of signal power in time. The terms used are now better explained in the revised version.

p. 2 L 16-19: Please provide more context about these ice vibrations, since they appear throughout the present manuscript. Comparison of the Gorski literature with other papers published on glacier seismicity (by O Neel, Bartholomaus, and Kohler) suggests that the ice vibrations might be calving icequakes.

Authors: Gorski suggests that ice vibrations are rather large scale processes in the glacier body than calving itself (Górski, 2014). He located them roughly using an array of seismometers in the distance from the calving front. This kind of signal were also observed at alpine glaciers, what excludes calving (Górski, 2004). They may potentially be one of the factors inducing calving.

We included additional informations about ice-vibrations into the manuscript.

p. 3 L 25-26: Please define what you mean by major and minor here.

Authors: By major glaciers we meant Kronebreen, Kongsvegen and Kongsbreen glaciers, the biggest ones in the close proximity of the KBS station, while by minor all other smaller glaciers in this area. We specified this terminology in the revised version and referred reader to the map.

p. 4 L 1-2: What do the authors mean by this?

Authors: We decided to use an extra 3 months of data from last quarter of 2007 when showing interannual comparisons in order to keep the length of all compared periods equal. We clarified this sentence in the manuscript.

p. 4 L 4-5: This conflicts with the earlier statement that the seismic data is available in the IRIS DMC databases.

Authors: We corrected this paragraph.

p. 4 L 20-23: How is this an energy density? Do the authors use velocity seismograms? Subtracting the noise from the absolute value of the ground velocity doesn t make an energy.

Authors: We called that parameter "energy density", because we used modified formula of Normalised Energy Density Function by Sarma (1971). That section was corrected in the revised version of the manuscript and additional description followed by references was added.

p. 4 L 24-25: Please provide more information regarding how the noise function was calculated. How was the noise fit? What s the size of the moving window? How do you know that no event occurred (i.e., based on what criteria)?

Authors: Paragraph describing the noise function was added to the manuscript.

p. 4 L 27: It appears to me that the NED as defined in Equation 1 would increase consistently through time. I don t see how these thresholds work to trigger detections in the monotonically rising NED values. How were these thresholds chosen?

Authors: This information was also included in an additional paragraph about the NED function.

p. 5 L 5-8: What are the justifications for these criteria? Glacier-produced calving icequakes can sometimes exceed 25 s (Bartholomaus and others, 2012 and 2015, in JGR)

Authors: The aim of this study is to assess long-term glacial seismicity. To produce a reliable automatic processing procedure we focused on typical events so counting e.g. glacier-induced events of extremely long duration times (>25 s), is out of the scope of this study, even though such events are proven to exist.

p. 5 L 6: What kind of variability is intended here? in the spectra, or over time?

Authors: It is spectra over time. Description of this criterion has been revised.

p. 5 L 18-21: It is hard to understand what the authors intend by these sentences. How are the amplitudes smoothed?

Authors: Amplitudes were smoothed by calculating a running average. We reformulated these sentences and added equations to make them easier to understand for the readers.

p. 5 L 22-23: This description could be aided by an illustration.

Authors: We reformulated these sentences and added equations, as well. We assume, that the content of paragraphs L 18-23 is described clearly enough to make illustrations unnecessary.

p. 6 L 3: What kind of event analysis? How were the events analyzed?

Authors: Criteria were adjusted for waveforms from HSPB dataset which were affiliated with one of the groups based mainly on the literature studies (Górski, 2004, Koubova 2015, Pirli et al., 2013). We corrected this paragraph.

p. 6 L 7: What is strong and steady energy flow ? This is language not traditionally used in seismology.

Authors: We meant a long lasting exceedance of temporal signal power over its mean value. The terms used in the paper are now more precisely defined

p. 6 L 21: What is the strictly year-long pattern ? Do the authors mean seasonal ?

Authors: Yes, seasonal.

p. 6 L 23-25: The assumption that the not identified events are glacier-generated because their occurrence varies seasonally is very weak evidence. How can the reader know that they re not rockfall, or river produced, or artifacts in the data? How is false different than not identified ?

Authors: Issue of identifying not-identified group of events as glacier induced was already addressed in 'Major comment #3'.

Criteria of the false group were chosen to eliminate signals significantly different from glacier generated signals identified as false detections. If the event fulfills those criteria, it is classified in the false group. If an event does not fulfill criteria of ice-vibrations, earthquakes and false group, then it is classified as not-identified.

p. 7 L 10: What do the authors mean by slightly blurred?

Authors: We removed this confusing statement. Now we just point out, that year 2011 has lower amount of events than other years

p. 7 L 13: Fig. 6b shows PDD, not temps. But the PDD that s shown doesn t look like other typical PDD values. The positive degree days values are the cumulative daily temperatures above 0 degrees

(as described in Hock 2005 and other papers). This looks to me like the number of days per month that exceed 0 degrees.

Authors: Yes, Fig. 6b doesn't show temps. We show a number of days with positive daily mean temperature. We called this parameter "Positive Degree Day" incorrectly. Hence, we changed axis descriptions and corrected the manuscript text.

p. 7 L 14-16: What mechanism is implicated here? This is extremely loose and imprecise language.

Authors: We removed that statement. The interpretation of observed correlation time lag appears in the discussion section and is referenced in the literature.

p. 7 L 17: Monthly temperatures are not shown. Please plot if discussed.

Authors: The distribution of monthly mean temperatures is very similar to PDD (already changed to "the mean number of days in each month with positive mean temperature"), but has a lower correlation coefficient. Hence, to keep the figures clear and legible, we decided to not plot the less correlated parameter, as it is not further analyzed.

p. 7 L 24: doubling instead of double increase

Authors: Corrected.

p. 7 L 29: plot the annual PDD here.

Authors: We added a figure illustrating the correlations.

p. 8 L 20: What are the authors implying here? What is the connection between the glaciated surface area and the number of seismic events? I believe that Kronebreen is a much faster-flowing glacier than Hansbreen. That might explain more calving at Kronebreen than at Hansbreen. What about the detectability of these signals? Are the seismic stations equidistant from glaciers? Perhaps attenuation might change the different detectability of the seismic signals.

Authors: We added an information about different distances to the glaciers as one of the factors contributing to the difference in total amount of detected glacier-generated events in both datasets. Being aware of all mentioned differences, we only point out the disproportion and its possible reasons and do not imply different seismic activities of glaciers.

p. 8 L 25: The glacier dynamics do differ, not just can differ.

Authors: Right, corrected.

p. 8 L 27-28: What is meant here? How do these glaciers interact ? How do these interactions generate seismic signals? What is the proposed mechanism?

Authors: at the junction of two interacting glaciers, friction can lead to stress accumulation. Koubova (2015) proves, that at this junction some seismic events occur. How those shocks are generated and what is their mechanism is an interesting question but this is beyond the scope of this study.

p. 8 L 30: Luckman instead of Lackman

Authors: Corrected.

p. 9 L 1-3: Please provide more context here with the Luckman and Kohler results. Are the authors implying that ocean temperatures might be promoting calving during the fall? What other evidence can be provided to strengthen this case? Are the results here different than the Luckman and Kohler results in some way?

Authors: Our results also show an usual 1-2 months delay between the peak event number and the peak temperature observed for both datasets. Hence, they can be treated as another proof supporting the hypothesis of ocean temperature being a dominant factor in calving mechanism with more significant impact than an air temperature. We expanded the discussion of suggested papers in the manuscript.

p. 9 L 6: Tremor in seismology is a very specific type of seismic signal, see literature on volcanic tremor or tectonic tremor (and slow slip earthquakes). The authors should use a different word, such as seismic signals.

Authors: We agree. Corrected.

p. 9 L 8: What is the true duration time? True according to what analysis?

Authors: We meant true as a factual, absolute duration time of this phenomena. We reformulated the confusing sentence.

p. 9 L 15: What is meant by noisy signals? Noisy in what way? It doesn t appear tome that the fuzzy logic method provided much value.

Authors: That's a mistake. We changed 'noisy signals' to 'false detections'. The fuzzy logic issue was already addressed in 'Major comment #3'.

p. 9 L 18-19: I recommend removing this sentence, but if the authors choose to retain it, please provide more information about the benchmarking experiments. What kind of computer was used to run this approach?

Authors: We decided to reformulate it, but we keep it though. Its goal is to point out that there is no need to employ computer clusters to perform such analysis using our algorithm. It can be done in the reasonable time using a PC class computer and hence, it can be easily implemented as a routine tool for real- or near-real-time processing.

p. 11 L 28: typo in micro

Authors: Corrected.

Figure 3: As presented, this figure is unsuccessful in adding value to the manuscript. What is an exemplary input parameter value? What are the x and y axes in each panel? I don t understand what is being shown here.

Authors: This figure has been rearranged and serves for a better understanding of the fuzzy logic algorithm workflow.

Figure 5: The basis for affiliating the not identified events with the glacier needs more support in the text.

Authors: The discussion on this topic was expanded. (this issue was already addressed in 'Major comment #3')

Figures 6: panel a: Is there an outage in the fall of 2009? This should be indicated if so. The units in black on panels b/c are unclear. It looks as though there is a complicated division taking place. Are the mm/cm^2 one unit? Units of precipitation should be mm or m. The per area is meaningless. Roman numeral months in the caption should be replaced by the month names.

Figure 7: same problems as Figure 6

Authors: We edited those plots according to your suggestions.

References:

Górski M.: Predominant frequencies in the spectrum of ice-vibration events. Acta Geophysica Polonica 52 (4), 657 457–464, 2004.

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Pirli M., Schweitzer J. and Paulsen B.: The Storfjorden, Svalbard, 2008–2012 aftershock sequence: Seismotectonics in a polar environment, Tectonophysics, 601, 192-205, 2013.