

## ***Interactive comment on “Monitoring long-term changes of glacial seismic activity with continuous seismological observations: a case study from Spitsbergen” by W. Gajek et al.***

**Anonymous Referee #2**

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The work is interesting and it points out some important results about the seismicity in Spitsbergen (Svalbard, Norway) and its correlation with glaciers, seasons of the year and weather data. However, in my opinion it is not ready for publication since some important parts of a paper that aim to reach the broad community of Cryosphere readers are missing. In particular: a) a comprehensive description of the problem, b) a robust validation of the claimed results and discrimination between different type of events, c) a comparison with already published and similar results. For these reasons I would suggest a major revision of the manuscript. I do not enter in the details discussion and conclusion since I expect that the suggested further analysis would change these two sections.

C1

Major points:

1) Introduction. Readers not familiar with Spitsbergen location and characteristics get lost from the beginning of the manuscript. It is not mentioned that this is a Island belonging to the Svalbard Archipelago (Norway). Maps in Figure 1 are never referenced in the manuscript. In the Introduction a description about Spitsbergen is missing. I would expect a section describing why this work is focused on this region, why we expect seismic activity here, what is the size of these events and some description about previous studies about the region. Since one of the goal is also to discriminate between tectonic and "glacier related" events, I would also expect a brief description about the seismicity of the region and about the differences between the two type of events. I would expect a comparison with other detection algorithms as standard seismic detection/pickers and more specific algorithms used for glacier related events (e.g. that by Walter Olivieri Clinton, J. of Glaciology 2013)

2) Data and Analysis. The authors go straight to the technical description of the methodology but again, in my opinion, a crucial part is missing that would help the reader to understand the problem and how it has been tackled by the authors. There is not a definition of "event" and possibly some figure with seismograms and spectra for the different type of events would help the comprehension. For the case of the spectra, a reference to background noise is mandatory to identify the signal and to understand filters and thresholds used. A figure describing NED(t) and NF(t) would also help as well as a formula for NF(t).

3) Numbers. The authors describe their method without mentioning how they selected the "numbers" as for the case of the bandpass filter between 1 and 15Hz, 0.15-0.85 for the duration, 25 seconds, "more than 7 times in 50 seconds" and so on. It is not clear if this is an a-priori choice or if it follows tests (e.g. trial and error) or data analysis on the different nature of the different signals. This would increase the reproducibility of this study and its eventual application to other regions and data, similar or slightly different.

C2

4) Fuzzy logic classification. Description is qualitative, replication of the study is almost impossible and some crucial specification are missing. At line 7-8 of page 6 I read "strong and steady energy flow, which, after exceeding mean value once remains above it for at least 15 seconds". I guess the authors used a formula to convert the seismogram (velocity) into energy. This should be specified together with the rules to compute the "mean". If it is NED(t) it should be mentioned. In line 11 of page 6, the description of the selection rule for "Ice vibrations-signals" is also vague.

5) Tectonic earthquakes. For the case of HSPB the authors detect 1858 earthquakes and even more for KBS (2798). Does any of it appear in published catalogue? Why or why not? What is their size in terms of magnitude and why they occur? Is there any event listed in catalogues that was missed by the described detection algorithm. How the seismic sequence that interested the Storefjorden impact on the detection/discrimination process? (The Storfjorden, Svalbard, 2008–2012 after-shock sequence: Seismotectonics in a polar environment by Myrto Pirli, Johannes Schweitzer, Berit Paulsen Tectonophysics doi:10.1016/j.tecto.2013.05.010)

6) Validation of the results. The authors claim the success of the described methodology. But they do not mention if any test was implemented to validate or to cross-check their results. Common procedure, in seismology, is to visually inspect data to compare automated detection with visual observation. It is mandatory, in my opinion, a validation test, to explore the "efficiency" of the proposed methodology in terms of missed events (of the three kinds) and of false detections. I would be really surprised to see that both numbers (missed and false) are equal to zero. Paper by Kohler et al., mentioned in the Introduction, produces a similar catalogue but this is not discussed in the manuscript. Results are not compared even though I read in Kohler et al. "Most events occurred between July and December, with peak activity in August and September. Seasonal seismicity varies in accordance with expected glacier dynamic activity, . . ."

7) Seasonality. A description of the variability of the background noise over months (and years) is missing. If noise changes, detection capability of small events changes

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as well. This test is mandatory prior to explore the seasonality of the number of events. In seismology, the study of the rates of seismicity over time commonly relies on two concepts: magnitude completeness and declustering. The first prevents the risk of comparing the number of events in two epochs in which the detection threshold was different. The second prevents to include "aftershocks" in the analysis of time-varying rates of events. I wonder if the authors considered these (noise amplitude, completeness, clustering) to prevent a misinterpretation of the variability for the number of events over time.

8) Correlation. The authors claim that glacier-related events originated at Hansbreen and Kronebreen (Page 3, line 4) and later they mention they could not locate them (Page 9, line 4-7). Single station location techniques exist even though they are difficult to implement and these should at least mentioned and discussed. I would remark that a paper was published on this topic (<http://link.springer.com/article/10.3103/S0747923915030032>) using data from HSPB. This paper is surprisingly not cited. Moreover, I remain convinced that a proof about the relation between the observed events and the glaciers' activity is missing. For the case of Greenland, for example, such correlation has been found on the base of further observations as filming or water pressure data. Any further source of "earthquake like" signal is present in the region? Plants, Mines, Dams and so on?

Further issues:

- type of used filters is not described (Butterworth?).
- it is the combination of seismometer+digitizer that gives a broadband response.
- the last quarter of 2007 was included in the analysis but the time-span for the results from HSPB dataset is always referred as (2008-2014). How this affects figure 6a and 6c?
- As far as I could see, HSPB data at Orfeus data-center start in Jan 2010, am I wrong?

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- Page 5, line 5, this selection rule aim to discard "strong tectonic earthquakes", I wonder if the authors refer to those occurring at regional and/or teleseismic distance. This should be specified because in the following of the manuscript they count the detected tectonic earthquakes.
- Page 6, line 27,  $7020+1858 = 8878$  while at page 5 line 11 the number of detected events is 8876
- Figures are sometimes references as "Fig." and sometimes as "Figure"
- Page 7, line 5. I would suggest to first describe the result and then comment on them.
- As far as I could see on EIDA server at Orfeus, two further stations exist in the region. Could their data help the discrimination and location of part of the events?
- Figure 1, I would suggest to reference the two maps on the left on the right map, to help the reader. Furthermore, I would suggest to write only the relevant toponyms to ease their identification on the map.

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