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Interactive comment on "A Two-Station Seismic Method to Localize Glacier Calving" *by* M. J. Mei et al.

Anonymous Referee #1

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The authors apply a method to localize seismic calving events recorded close to the glacier terminus. Traditional travel-time based localization methods often fail close to the calving front since signal waveform are too complicated to identify distinct seismic phases. The method here makes use of arrival time differences of a calving signal between two stations which can be used to construct a hyperbola which either intersects with the know position of the glacier terminus or with other hyperbolas if more than two stations are available.

First of all, I would to thank the authors for their contribution to the progress in the emergent field of cryo-seismology. Studies like this can help to improve and establish passive seismic methods for monitoring and better understanding glacier dynamics.

(1) My main comment is that the method is actually not new in seismology or acoustics,

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but has been suggested as a simple graphical signal localization method before, e.g. in:

J. Pujol, Earthquake location tutorial: graphical approach and approximate epicentral location techniques, Seismol. Res. Lett., 75 (2004), pp. 63–74

M. Bath, “Introduction to Seismology”, (2nd ed.), Birkhäuser Verlag, Basel, Switzerland (1979)

M. Dragoni, , M. Gasperini, “On the localization of seismic events”, Article, La Rivista del Nuovo Cimento (1978-1999), Volume 5, Issue 11, pp 1-28

I. Awaludin, A. S. Prihatmanto, E. M. I. Hidayat and C. Machbub, "Hyperbola tracing algorithm based on particle filter approach within a half-quadrant space for signal source localization," 2015 5th IEEE International Conference on System Engineering and Technology (ICSET), Shah Alam, 2015, pp. 17-22. doi: 10.1109/ICSEngT.2015.7412438

I agree that this study present the first application of this method to calving localization. However, this is not such a different approach compared to using traditional localization methods based on first onsets (without using S waves). Basic processing and assumptions are the same: you have to know the velocity model and to pick first arrival. Just using P wave onsets, it is necessary to use some constrains on source locations, but you do the same here when choosing one hyperbola.

The authors should clearly write this and state some references.

(2) The title suggests a two-station method. This is true if the location of the terminus is known. However, in the paper the authors only present results of using more than two stations at Hellheim and Jakobshavn glacier (hyperbola intersection). So I would suggest to change the title or put more emphasize on two-station results in the paper.

(3) Determination of signal onsets for time differences : This is not explained clearly enough and it would be nice to provide more details. Define what “slope” is! Did

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you use the raw waveforms or the signal envelope? Any references for this method? Is it similar to STA/LTA? What is the time window around the pre-defined event used here? For such a low number of events, wouldn't manual picking be more precise and feasible? Is the onset time the same that is used to compute Veff ? I am a bit surprised that cross-correlation does not work. Have you tried to use only the first, more coherent part of signal, not the whole event? I would expect that cross-correlation is a much more precise measure of time lags than any automatic picking algorithm.

Other comments:

page 1 line 12 : I would say the effect of calving is not just equal, but can also be larger than melting at individual glaciers.

page 2 line 2 : Calving seasonality in general is not only due to melange ice, but also due to increase in meltwater-induced sliding, ocean temperature variations, and ocean tides, etc ...

Page 2 line 16 – 21 : Other possible causes for seismic calving signals have been suggested (at least for calving styles observed in Alaska and Svalbard) : ice - sea-surface interactions (Bartholomaus et al., 2012, in JGR; Köhler et al., 2015, in Polar Research).

Page 2 line 30 : Another possibility of locating complicated signals without using pre-determined velocities of individual seismic phases are the use of small-aperture arrays. Directional information can be obtained by applying signal beamforming or Frequency-Wavenumber analysis which can than be triangulated. (Köhler et al, 2015, in Polar Research; Koubova, 2015: www.duo.uio.no/handle/10852/45791?show=full)

Data section : Are all calving events used here detected manually or is an automatic detector used? Are the calving events identified only based on inspection of frequency spectrum ? I would expect that regional earthquakes have energy above 1 Hz as well (see e.g. Köhler et al, Svalbard). Description of JIG station data is missing.

Page 3 line 15 : “teleseismic events from regional earthquakes” : Please rephrase : Either it is a teleseismic earthquake or a regional earthquake. In seismology there is a clear distinction between both events.

Page 6 Line 18 : What do you mean with “only two seismometers”. Is the signal too noisy on the others stations? If not, why not use all stations for a robust estimation of veff? What are the individual measurements for all stations and all calving events? Is there really no difference between Hellheim and Jakobshavn?

Fig 5 : Two hyperbolas are shown for each velocity. I suppose they correspond to two stations pairs. Which of the three possible station pairs to they correspond to? Why not plot all three hyperbolas? Also, indicating the exact location of calving front at the time of the calving event would be helpful. Then one could see how an individual hyperbola intersects with the terminus. After all, this is what the authors suggest: a two-station method. It looks like Veff=1.4 could be as good, or even closer to the front. Furthermore, the authors write that the calving events appears to be in the ocean. However, it is actually located on the glacier (the melange is in the west, isn’t it?).

Page 7 line 3 : “teleseism”, write teleseismic earthquakes, see my comment about regional earthquakes above

Discussion about velocity: What about the more distant station at Jakobshavn (JIG 1 and 2)? The signal would have to travel through a lot of rock (possibly at sea bottom) I guess.

Discussion about depth: I am not sure if the main limitation for depth resolution is the missing velocity model for the glacier. One simply needs more stations close and above the source (on-ice) for a more precise and accurate localization. Also, I actually don’t see the need the determine the depth of calving. Calving is usually affecting the whole height (or a big part) of the terminus (except maybe submarine events or small pieces of ice). However, I agree that depth may be relevant to analyze precursor events like fracturing.

Page 9 line 2: Even for a station at same elevation, P waves could come from below (refracted, diving waves).

Brune model: I am not sure if this source model can be applied here. If calving signals are associate with a simple rupture process I would agree. However, many mechanisms have been suggested (ice-sea-surface interactions, interaction with fjord bottom, forces that cause change in the motion of the ice after and during calving (glacial earthquakes at Hellheim, Murray et al, 2015)). I doubt that it is mainly the rupture signal that we see on the seismometers ...

Fig. 8 : Can you indicate the front retreat on the map? Is it consistent with the event locations?

In Conclusion: "...get around the emergent P-wave problem" : I don't agree. You still have to deal with the emergent onset, i.e. to pick an arrival to determine the time lag (see comment above). That, and estimating the velocity, are basically the same tasks for traditional travel-time based localization methods.

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