We would like to thank the reviewer for their helpful and detailed review. Our responses are bolded.

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, but has been suggested as a simple graphical signal localization method before, e.g. in:
J. Pujol (2004)
[...]
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.

Thank you for pointing this out! We have now added the original hyperbolic method paper (Mohorovicic 1915) to the introduction and referenced Pujol (2004) who suggests that this method is best for shallow events where refraction along a bottom interface is insignificant.

(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.

We intended "two" to mean "pair-wise", i.e. you need two stations to define each hyperbola. We have changed the title to "Calving Localization at Helheim Glacier Using Multiple Seismic Stations" for clarity and added "paired" to the abstract description.

(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 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.
Added details: the slope is from the raw waveforms, and this method is entirely empirical. We were unwilling to do a manual method because this would be subjective, but our automated method still requires manual checking (and our 44% value was manually/empirically determined). The time window for cross-correlation was the 25s window pictured in Fig. 4. Cross-correlating the entire event doesn't work either, we suspect this is because the same calving event can look very different at two different

stations:

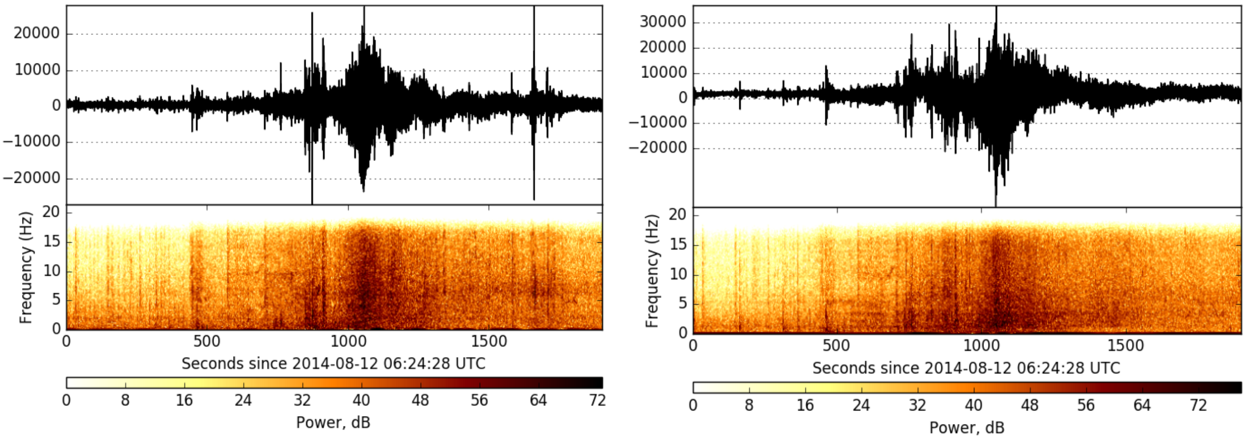


Fig. A1. The same calving event at two different stations.

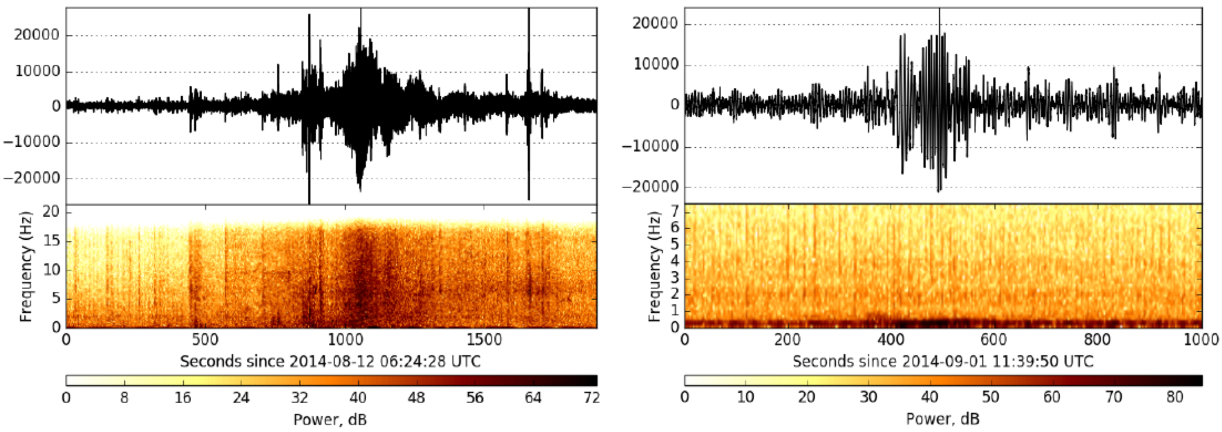
These signals have such different shapes that cross-correlation does not work. It would probably work better with just the wave envelope, but to create that, there would probably be some rounding or other shift of at least 0.5s, which is significant as most of our lags are <3 s. It may be better just to state that we are manually detecting the events and using our automated 44% trigger to know what neighborhood to inspect.

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.
Noted and changed.
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 …
Noted and changed.
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).
Noted and changed.

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)
Based on my reading of Köhler 2015, it seems like the method is manual phase-picking of P/S waves to generate a backazimuth and distance, as their array is regional and thus far enough to distinguish different phases? We have added Koubova's description of beamforming, though it seems to rely on having a backazimuth already (which we do not have in our case until after the location is determined).

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.
C3
The JIG data are now removed from the study as we should not reasonably expect that surface velocities are equivalent to Helheim. Events are detected semi-automatically using a Signal/Noise threshold then individually inspected to rule out regional earthquakes, which have different frequency breakdowns – see Figure A2.



(a) Calving event (b) Regional earthquake

Fig. A2. The spectra (top) and spectrograms (bottom) for a calving event (a) and a regional earthquake in Iceland 960km away (b).

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.
Thanks, noted. The earthquake is ~960km from the station which is very near the teleseismic threshold, but we have gone with just "regional" instead.

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?
"Only two seismometers" is because only two seismometers were deployed in August 2013-2014, and the other two seismometers were deployed after the calving event had occurred. What do you mean by "individual measurments of all stations"? The other calving events that form our catalog were not observed (though they were confirmed to be calving events using MODIS Terra satellite imagery). The Jakobshavn event has been removed because even if the velocities seem similar, it may be coincidental and we should not give any weight to the Jakobshavn data.

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?).
Yes – the melange is actually west. Though, this plot has been removed in any case (we are removing all references to Jakobshavn).

Page 7 line 3 : "teleseism", write teleseismic earthquakes, see my comment about regional earthquakes above
Noted, thanks

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.
Removed Jakobshavn event.

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.
Our reviewer #3 pointed out that depth is not a well-posed question – for an event that removes an entire column of ice, there is no real 'depth' (unless you use the depth of the entire glacier, which is measurable with bathymetry). We will minimize the discussion of depth.

C4
Page 9 line 2: Even for a station at same elevation, P waves could come from below (refracted, diving waves).
True. For our study, we show that the wave arrivals are dominated by surface (Rayleigh) waves, and so we are able to neglect 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 earth- quakes at Hellheim, Murray et al, 2015)). I doubt that it is mainly the rupture signal that we see on the seismometers ...
Agreed – the Brune model was intended as a comparison to see if it were a rupture, what size it would be. Do you think we should not mention Brune at all, or qualify it more (that it may not be a rupture signal at all, but if it is, then it has size 50m)?

Fig. 8 : Can you indicate the front retreat on the map? Is it consistent with the event locations?
Updated figure. Figure A3 shows that the calving fronts are close to the events – a good check to make!

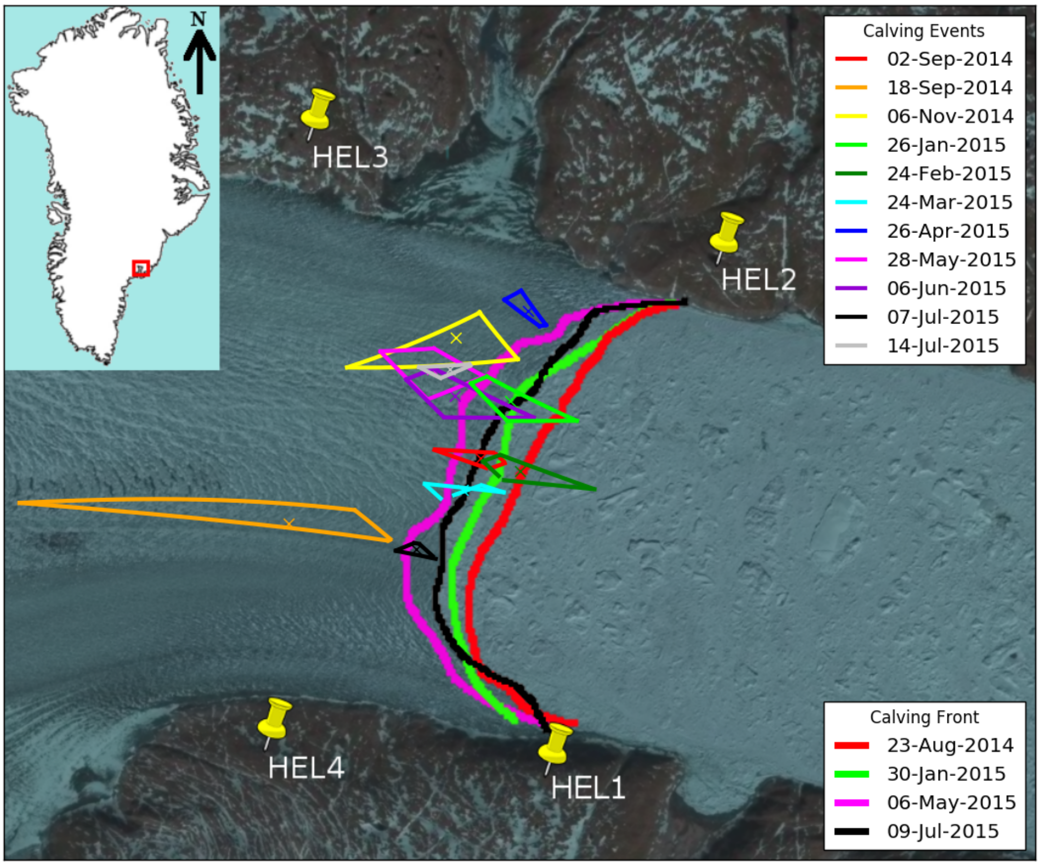


Figure A3. Catalogue of eleven calving events localized on Helheim glacier, showing the movement of the calving front for certain dates (taken from Landsat 8).

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

A fair point – we have changed this to "We find that the local seismic signals are dominated by surface (Rayleigh) waves, which makes distinguishing between different seismic wave components (a key benefit of regional arrays) irrelevant. A local array is able to localize calving with greater resolution than a regional array. Identifying the signal onsets is not fully automated and requires manual inspection of signals, due to the emergent signals involved in glacial calving."