Mei et al. analyze passive source seismic data mainly from Helheim glacier to localize calving events. For the localization they pick the first arrival of the seismic signal of the calving event. Combined with a predetermined velocity hyperbolas are calculated to determine the source location. This method is used for calving events at Helheim between Sep 2014 and Jul 2015, localizing 11 events in total. Finally, the authors use these events to determine the size of the calving event and speculate that the clustering of the calving events on the northern half of Helheim might be due to larger ice thickness and differences in surface roughness. The paper uses a seismic method not applied for the localization of calving events before. It is great to see a different method applied to the subject of localizing calving events from nearby seismometers.

The paper is in most parts easy to understand. The method should be explained in a bit more detail in certain parts and I do have some questions regarding the validity on how the method is applied here.

Thank you for your extremely detailed review. Our responses are in bold.

General comments:
It is not a hundred present clear to me, what the main focus of the paper is. Is it to introduce the hyperbolic method for the localization of calving events and Helheim glacier is just an example of the application of this method, or is it the localization and interpretation of the calving events for which the hyperbolic method is introduced? I think that should be clarified and the text adjusted accordingly.
After we learned from review 1 that the hyperbolic technique is already used in acoustics/seismology (but not yet for glacial calving), we have shifted the focus of the paper to the localization and interpretation of calving events for which we use the hyperbolic method (and also a grid search method as you suggest). Our revision of the manuscript hopefully reflects this better.

You use a lot of fill words and subjective descriptions, that make sentences unnecessarily long (also, some, severely, powerful). Readability and understandability would increase significantly if the sentences were shorter and the sentence structure less complex. Often it would be easy to split one sentence into two sentences.
Thanks. We have gone through the manuscript to try and break up long sentences.

Chapter 3 Hyperbolic Method: I do have some question regarding the method: - Why does the cross correlation not work? Are the waveforms so different due to the difference in interference of the different wave types at the different stations? Could you please clarify this? Did you try different bandpass filters and window length for the cross correlation.
We believe cross-correlation does not work because the signals sometimes look very different in different directions. This may be due to the orientation of the fracture. There is no clear pattern to which pairings do not have successful cross-correlation. Possibly this is also because when the calving event happens, the icebergs are formed on the eastern side, and this is non-symmetric to the western side so the signal is not radially identical. It is also possible, as you state, that there is interference from linearly polarized waves (e.g. the P-wave) that affect the shape of the waveforms at each station differently. We tried different filters both for high and low and both for the overall waveform shape and for the small peaks, but we could not get good values for all events and all seismometer pairings, and as a result we could not use this fully automated method.

-How big is the error when you pick the first arrival (estimate), what does this mean for the precision of your localization?
So the estimate of the lag (i.e. a subtraction of the arrivals) should have any systematic error removed by the subtraction. One reason we did not want to pick out arrivals by

eye is because of the error that this would create. The random error of the actual estimation is hard to quantify as the true arrival is not known. Signal onset detection is still an ongoing area of research (e.g. Ross & Ben-Gurion 2014). One way to quantify the error is to use the error of localization (compared to camera-observed events) and then reverse-engineer the time lag.

Ross, Z. E., & Ben-Zion, Y. (2014). Automatic picking of direct P, S seismic phases and fault zone head waves. *Geophysical Journal International*, *199*(1), 368-381.

- If you do not determine the wave type how can you be sure that the first break you are picking is coherent. Most likely and in most cases you will pick the surface wave. Which would be totally valid, and you later state that it is the surface wave you are analyzing. So why not determine the phase you are using for the analysis and use surface waves. My fear with this technique is that you might have a seismometer close to the source and it is not possible to see the P-wave first arrival, so you would pick the surface wave. For a seismometer that is further away the P-wave and surface wave might be separated better, hence the wave you pick would be the P-wave. But if you pick different wave phases at different stations how do you want to use one velocity to find the correct location of your source. Imagine you pick the P-wave at seismometer 1 and the surface wave at seismometer 3. For the analysis you then use the velocity of 1.17 km/s, your localization would be totally wrong. This is a crucial point and the way I understand your analysis I can't see that the analysis is correct as you apply it. Please clarify this!
This is a good criticism. For our method, we checked all the particle plots for each event to conclude that they are all dominated by surface (Rayleigh) waves. We originally thought it fit better in the Discussion of what waves were being detected, but this analysis was done before making the localization catalog. It is important as a premise for our technique so we have moved this section to the Methods.

- How was the location of the calving events observed by persons determined. Where this events filmed? Small errors in the location of the observed calving events will lead to big errors in the derived velocity. How do you derive such a small error as 0.1 km/s? Please clarify how this velocity is determined in more detail.
The events were filmed, but you are right there could be small errors in the viewed localization, so we are changing our velocity estimation method. We used a grid search as you later suggest, and got a best fit of 1.20 +- 0.03 km/s. We have updated our plots (this changes the locations only slightly). 0.1 is the standard deviation of the best fit velocities for our 11 events, and so the standard error for these 11 points would be 0.1/sqrt(11) = 0.03 km/s.

- How can you use the data from Jacobshavn to determine the velocity. It's a completely different setting then Helheim. At Helheim your seismometers are located inland of the glacier front, i.e., waves will travel a large part through glacier ice. At Jacobshavn the seismometer are locates, mostly (except of seismometer 3), downstream of the glacier front, i.e. waves mainly travel through water and ice mélange. You must derive totally different velocities for these two locations.
Yes, you are right. We have deleted this section and determined our velocity using grid search with Helheim only.

- Did you try a grid search. As you do have multiple seismometers you could use the derived lag of all combination and find the global maximum testing different directions and velocities.
Thanks for this suggestion. We applied a grid search, as mentioned above, successfully.

Discusssion: Large parts of the Discussion are not a discussion but an interpretation of the results or even speculation of what their causes are. This needs to be clearly differentiated, discussion and interpretation.
We have now separated into an "interpretation of results" and a "discussion of methods" subsection.

Determination of magnitude: For the method of Brune, you say, you have to use the corner frequency of the S-wave. But you don't use the S-wave, so why should that method be valid here at all. Further, I have trouble seeing the corner frequency between 1-5 Hz in your plots in Fig. 12. And why do you choose this small time interval you are using for the calculation of this spectrum?
This method is intended as a comparison of traditional seismic techniques to see what a fracture size would be following the Brune model. The S-wave velocity is needed for this, and we do not have S-waves as you mention, but we use the relationship between S-wave speed and surface wave speed (as a function of the Poisson ratio) to estimate the S-wave velocity. The small time interval is because we believe the high-amplitude peak corresponds to the calving event, and so we want to estimate the fracture size from this particular window.

Figures: Must appear in the order in which they appear in the Text. Fig 6 – page 6 line 6, Fig 5 – page 6 line 20. Always refer to the Figure by number, not see the above Figure. It is not necessary to write (see Figure...) instead (Figure...) is sufficient. It is totally clear that I'm supposed to have a look at the Figure.
Thanks for this, we have checked the order carefully and removed "see" from whenever we mention figures.

Considering merging Fig 1 and Fig 2. One subplot of these two Figures will be enough to show the difference.
Yes, we have now done so.

Google earth figures: I think it would be more appropriate to use maps or satellite images like Landsat here (http://earthexplorer.usgs.gov/). Further these images need, some reference frame, coordinates, a north arrow, a map where we are in Greenland.
Thanks for this. We have now switched to Landsat images with a reference frame, grid, north arrow and a map.

Figure 1: Why don't you use the transfer function of the seismometers to show the data as displacement? That will be much easier to understand for someone not that familiar with passive seismic data.
We think it is important to show the different phases of the calving event (to highlight its emergent nature), as well as to show the similarities of these signals to Amundson 2010/2012 etc. We have explained a bit more clearly what the trace is showing.

Figure 11: I don't think that Figure is necessary. It can be well seen on Figure 8.
Ok. We have removed this.

Specific comments:
For line specific comments see the attached PDF.
Thanks for your line comments too. We have adapted most of your suggestions. We have chosen to keep "emergent" as a description as this is commonly used to describe calving events (e.g. Amundson 2012, Richardson 2010) though we have now added a clearer description of what "emergent" means.