Review of "Grounding zone subglacial properties from calibrated active source seismic methods" by H. Horgan et al

Alex Brisbourne, August 2020

The authors present an assessment of active seismic data analysis methods using measurements made at the grounding zone of Whillans Ice Stream. Data cover both grounded and floating ice and therefore present an opportunity to assess and calibrate existing and new data processing methods used to obtain absolute properties of the subsurface. To this end the paper is a useful addition to studies of this nature and builds upon the previous work of Holland and Anandakrishnan (2009) (from here referred to as H&A2009).

The manuscript is well written and structured. However, as outlined in my comments below there are a number of clarifications needed in order that the reader can ascertain exactly how the analysis is applied and how closely this fits with previous work. The methodology description in insufficient in places and clearer self-referencing would improve the readers' ability to follow the methodology.

General comments

Section 2.6 - Estimating subglacial properties – Optimisation. It's not clear to me how this process is being carried out but as far as I can tell a single solution is being obtained for each shot. The problem is that within the measurement uncertainties and the uncertainties in the determination of A0 there will be a suite of solutions which fit the observations, and as with any inversion it is not acceptable to select only the best-fit solution. There appears to be no attempt to represent the suite of possible solutions.

Temporal variation by tidal strengthening is mentioned (Walker 2013). Could this be contributing to some of the uncertainty/range, especially at the grounding zone?

There is no mention of the free surface effect (see for example H&A2009 - for a receiver on a free surface, at normal incidence the received amplitude is double that of a receiver far from the boundary). The amplitude ratio uses $A1^2/A2$ whereas the known ratio method uses A1/A0 (no square). If the free surface effect is not corrected for could this cause the doubling of A0 with the multiple method as the square of A1 means this does not drop out as a ratio? Or does this fall out elsewhere?

Specific comments

P4L8 – Where does the -20C refer to? Floating ice? Base of firn? How is the velocity model for the sub-firn ice column determined and what is it?

P5L10 – Georod channel to channel variability greater than geophones – can you comment on why would this be?

P5eq2/P15L26 – Correct me if I am wrong but it needs to be made clear that Eq. 2 is for a basal reflection, i.e. assumed vertical through the firn. The gamma_d for diving waves referred to in Eq. 5 is in the firn and is more complicated as it must account for the ray tube energy loss (Medwin and Clay, 1998, eq 3.3.31). Presumably this is used somewhere for the direct-path pair method and should therefore be presented.

Eq3/Eq4/5 – be more explicit where equations are taken from in H&A2009. It would be helpful to label the equations with the name used to reference them in the manuscript (amplitude ratio/direct arrival etc) and perhaps set the paper structure out with similar sub-headings to make it easier to follow.

Eq. 4 – derived from H&A2009 eq5 at normal incidence – where does the factor of 2 come from on gamma_i^2?

P7L27 – What does Fig 4C,D refer to? (no labels on Fig. 4)

Table 1 – please highlight consistent columns (e.g. all means one colour, all medians another colour …). It is very difficult to read as it is presented.

P8L4 – is this method essentially using H&A2009 eq10 to determine A0? It would be useful to state this if so. As this is a new way of implementing the method I would like to see it explained with more clartity such that it can be reproduced.

P8L8 – I don't follow the argument that this is insensitive to attenuation as it is later used to calculate R (where exactly is this? Do you mean you use Zoeppritz and therefore the A0 isn't actually used?). You do a direct comparison of A0 in Table 1 which is sensitive to the choice of attenuation so it is important at that stage at least, and the result that this A0 is so different to that calculated by other methods is a significant result.

Figure 4 – Use consistent x-axis ranges as this is deceptive otherwise. I can't see ABCD labels as referred to in the text.

P10L6 – Please state the range of incidence angles at the reflector that picks are made out to. As you state later this is important in the range of forms the Zoeppritz curves will take.

P10L9 –The use of the Zoeppritz equations will require basal ice velocities and density. What values are used or are these also allowed to vary within the optimisation? It needs to made clear in the text that these are assumed/fixed and at what values (if that is the case – are Table 2 values used on grounded ice too?).

Fig. 6 – How are the uncertainties calculated and what do they represent? Why are they so much greater on the ice shelf? They are very small on the ice stream. Is this realistic given the uncertainties and range of A0?

Fig. 6/7 caption – mention that the R values use the KR method.

Fig. 6/7 and P11/L3 – The Vs uncertainties allow negative Vs velocities although the lower limit in the Zoeppritz search is zero. Vp looks to be restricted to 1440m/s although it looks like the uncertainties would take this lower given the symmetry. I suggest that negative Vs values are not plotted. This would indicate that the uncertainties are derived by error propagation which comes back to my point above about the optimisation of the inversion and accepting a single solution, the uncertainties cannot represent a suite of inversion solutions. How are negative Vs values derived by using the full A0 range with the Zoeppritz equations?

P15L10 - As you talk about transitions of 500 m it would be good to state the size of the Fresnel zone. You should then mention the scale length of the fluting and how this compares to the Fresnel zone.

P15L15-17 – I don't agree that the comparison demonstrates the efficacy of the amplitude ratio method, as stated in the following sentence, it may correlate well but it produces values twice that of the AR method. Is this not a contradiction? Or does twice the A0 value not affect estimates of R to a high degree?