The Cryosphere Discussions

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Comment on tc-2021-1

Anonymous Referee #1

Referee comment on "Downhole distributed acoustic seismic profiling at Skytrain Ice Rise, West Antarctica" by Alex M. Brisbourne et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-1-RC1, 2021

General Comments

This paper presents results and lessons learned from a distributed acoustic sensing (DAS) experiment at Skytrain Ice Rise in the Weddell Sea Sector of West Antarctica. Although, in the upper part of the borehole (~0-350 m) noise from the cable vibrating in the hole is too large to accurately recovery seismic interval velocities. At greater depths (>350 m), when the cable is suspended in drilling fluid, the P wave seismic interval velocity and attenuation are measured. In this study, the data acquired are too noisy to delineate any englacial fabric at Skytrain Ice Rise. The authors summarise with a list of recommendations for future use.

This paper is well written, clear and concise. Although, the data quality was not good enough to delineate any englacial fabric, the authors explained what they could observe and calculate from the data evidently. However, the authors only calculate the seismic P-wave velocity, yet in Figure 2 and 3 they point out the down going S-wave. The authors should explain why they do not also calculate the S-wave velocity, which they show later on in the synthetic modelling to be affected the most by changes in englacial fabric.

The authors summary, which includes a list of recommendations and lessons learned, is an important component of the paper. It details a list of recommendations for future use of DAS on ice which is important to share with the Cryosphere community. However, some of the figures and explanations could be made clearer to make this paper more reader friendly. Some specific comments are detailed below and I hope they are useful.

Specific comments

Figure 1 and Line 97-102 : A diagram (photo or schematic) might be nice to explain the DAS set up more clearly including the description of the bend/splice in the cable (line 101-102). Since this is a pilot study and only been applied twice down boreholes through ice, the cryosphere community are not familiar with this type of acquisition and therefore it would be nice to see potentially a photo or schematic diagram of the set up. This could be figure 1.d.

Line 110 – 112 : "The interrogator unit recorded in continuous mode with shot gathers subsequently extracted using times derived from impulsive arrivals on a continuous 1000

Hz sampled geophone recording made adjacent to the hammer plate." Can you clarify this sentence in a bit more detail, in particular the second part of the sentence I am struggling to follow it. How are the times derived from impulsive arrivals? The geophone recording you mention is the continuous geophone string of the DAS cable?

Line 119 – 122 : Sentence starting with "From zero to 150 ms, …." Can you add an interpretation of where this is on the image Fig 2a. It is not obvious what you are referring too. Am I correct in understanding the strong red-blue-red horizontal signal (0-50 ms) in Figure 2b is caused by wind and generator noise affecting the interrogator unit? If so this should also be clarified in this sentence and pointed out in Fig 2b.

Figure 2: It would be nice to see a raw frequency spectrum of the data shown in Fig 2.a.

I see you say it in the figure citation text but visually it would be easier to interpret c) if you had a thin box around your zoomed in area in a). I understand you might not have wanted to clutter image a) but it took me a while to put c) into context as it is plotted the same size as a) and b), which is a bit confusing with no window plotted.

a), b) and c) are the zero offset but d) is when the source is at 500 m offset. Again, it might be clearer to add labels on the top of a) b) and c) "0 m offset" and label d) "500 m offset" in the image for clarity.

Add an interpretation of the red-blue-red strong horizontal signal at the top of figure 2.b around 0-50 ms.

In figure 2.a if that is a P-wave multiple does it arrive at the times you would expect for a multiple?

What causes the dimming of the background noise (the white section) between 0 and ~150 m depth?

What causes the discontinuity in the P- wave in figure 2a, which is in-line with the end of the dimmed white section?

Line 154: "The low temperature… " what is low? can you provide a temperature range? Also, if you have borehole information, e.g. a temperature and strain profile, it might be worth adding these profiles to one of the figures.

Line 156: (Mulvaney, 2020) reference. This paper is in review in AoG and therefore I could not access it for reviewing statements referencing it.

Figure 3: This is very clear and great observation/simulation to explain the source of noise.

Line 170: can you mark this discontinuity in Fig 3a.

Line 192 and 194: "… open parts of the borehole…." And " …. deeper parts of the borehole." Add depth ranges to remind the reader. (0-350 m ?) and (350 – 595 m ?)

Section 4.1 Seismic P-wave velocity: In Figure 2 and 3 you point out the down going S-wave. Yet in this section you only measure the P-wave velocity. Is your downgoing S-wave too weak and below the background noise level to measure it's velocity? You should state why you don't measure the S-wave velocity somewhere in the paper.

Line 207: "Noise in the upper half…." Is this the harmonic noise caused by the vibrating cable? might be good to clarify that.

Line 208: Why is the noise so consistent? Is it because it is repeatable and constantly the same, from the vibrations of a repeatable hammer and plate source?

Line 209: It might be useful to state what exact velocities you mean here. I am guessing you are talking about the velocities > 5000 m/s.

Line 222: "Although uncertainties are large…." Reference table 1 here and add sentence about how this compares with uncertainties expected from other seismic methods for deriving Vp.

Line 223: "… most likely a vertical cluster fabric" could you elaborate a little bit more. Maybe add an extra sentence explain what this is and why you have come to that observation.

Equation 1: Need to define the variables clearly in the text.

Line 238: Averaging vertically over 10 m… where does this "10m" come from? Are there any references for this? I thought DAS had very good vertical resolution and therefore the averaging window was much smaller than 10 m (but I am not a DAS expert!)?

Figure 5 and Line 241: Here you mention upper and lower traces, I don't see any mention in the text of where upper and lower are? What is the window "upper" and "lower" traces are taken from on the shot gather?

Line 246-247: It might be useful to have mentioned this earlier on when taking about "low temperatures".

Line 271-272: Do you input Q to this modelling?

Line 281: "a more energetic seismic source" like explosives or a low frequency source like a vibroseis for the S-waves? maybe add an example of what source you would recommend.

Line 296: How would you, therefore, maximize your S-wave signal to be able to observe this on real data? Do you need a different/lower frequency source? or do you just need to get lucky and have really low noise?

Figure 6: S1 amplitude (400 m offset) are difficult to compare directly as the amplitude scale is different for them all. In a) it is 0.3-0.5 in b) it is 0.1 - 0.9 and c) 0.1-0.8

I would suggest having a different colourbar for traveltime plots and amplitude plots.

Section 7. Recommendations: Great section and very useful for future research using DAS.

Recommendation 3: this would be easier to understand if there was a schematic diagram of the set up in Figure 1 (as mentioned above).

Recommendation 5: Do you deploy these bundles down the borehole all at once? So you have multiple cables down one hole? ... or have I interpreted that incorrectly?

Also, "… and this should 'be' utilised …". I think you are missing a "be" in the last part of the sentence.

Recommendation 7: "As such, a reliable S-wave seismic source is essential." For example …. ?