

High frequency broadband acoustic systems as a tool for high latitude glacial fjord research

Response to RC2

We have reviewed the suggestions made by RC2. We thank the reviewers for the detailed review of the paper and their suggestions, in particular the reviewer's suggestions to clarify the use of acoustic data for a broader audience. We appreciate the review providing some context for sections they found confusing – in our initial submission we approached the paper as an introduction of these acoustic systems to many readers. We were glad to hear, in general our explanations provided needed context and background, but were happy to expand based on RC2's suggestions. Following their notes and suggestions, we have made changes in the manuscript using tracked changes and also provided a clean version with all edits incorporated. We have responded to each comment/suggestion below (in red), noting where we incorporated the suggestions and noting the few instances where we disagreed with the suggestion and the reasoning behind our disagreement.

RC2 general comments

Summary: The authors describe the applications and utility of broadband active acoustics systems in glacier fjord environments to quantify important ice-ocean processes in Horsund Fjord, Svalbard. In particular, the authors observe variability of thermohaline structures and mixing, characterize a subaqueous glacier calving face, and estimate geophysical parameters. Throughout the manuscript, the authors strongly promote that broadband acoustic systems should be more widely adopted among the polar oceanography community.

Review: This manuscript presents a thorough description of broadband acoustic systems along with some analysis of the data collected in Horsund Fjord. Overall, this work is worthy of publication with some significant revisions. My primary concern is with the paper's structure, the amount of redundant information, and the readability. With the proper corrections, this paper could expand the audience for broadband acoustic systems for glacial fjord research.

Significant revisions

There are too many introductions spread out throughout the manuscript. I realize, after reading this, that Reviewer 1 shares the same structural concern as I do. The most clear examples of this are from the first paragraph in Section 4.3 (lines 463 - 470), most of the first paragraph of Section 5 (lines 585 - 599), Section 5.1 (lines 613 - 620), and most of Section 5.2 (640 - 670). Summarizing these sections and incorporating them into the introduction will enhance the manuscript's readability and make it more concise.

We have taken the reviewers suggestion of reformatting and modified the introduction to include the preliminary discussions of high latitude systems and potential applications of acoustic measurements. These changes moved large portions of text from Sec 4 into the introduction. We modified the remaining text in Sec 4 (4.1, 4.2, 4.3) to have smooth transitions. These edits were made prior to receiving this review (RC1 had similar suggestions), but we verified the sections identified by RC2 had been accounted for in that reformatting.

Areas requiring clarification

I appreciate the author's work in explaining broadband echosounder data for the non-experts. Figures 3 and 4 (particularly Figure 4) are the most significant contributions from this manuscript, in my opinion. However, I am very familiar with ice-ocean interactions, but I am not familiar with echosounder data, so Section 4 and the subsequent subsections are particularly targeted towards scientists like myself.

My main concern here is that there are clear "low-level" descriptions on how echosounders collect data, but little attention is given to how exactly to interpret Figures 3 and 4. As expanding the use of broadband acoustics is one of the main goals of this manuscript, this concern requires clarification.

What do high and low levels of Sv (dB re 1/m) mean physically? I appreciate that the authors explain the several sources of interference with the data, but providing a low-level explanation for how to interpret these units in the context of ice-ocean interactions will give readers a much better understanding of the data and the echosounders themselves.

First off, we would like to thank the reviewer for highlighting their confusion in interpreting the echograms. They are absolutely correct that we are speaking to a broad audience, and we appreciate them highlighting this gap between our knowledge as a member of the underwater acoustics community and the broader oceanographic user base. We have updated several locations in the manuscript to address this concern of the reviewer in interpreting the echograms. First, we added a few sentences to Section 1.1 to note what drives acoustic scattering intensity in general – we provided some examples of typical ocean boundaries and water column phenomenon they we can observe – references too.

We also added to Section 1.2, final paragraph, discussing relative levels of scattering intensity, noting the multiple orders of magnitude and therefore the general practice of using a logarithmic scale. Additionally, in sections 4.1 and 4.2 we added some descriptions of the scattering levels in the echograms to provide more context for readers.

Line-by-line comments

Title: “High frequency” should be hyphenated

Fixed.

L10: “High frequency” should be hyphenated

Fixed.

L11: “high resolution” should be hyphenated

Fixed.

L18: “terminus” should be termini or use add an "a" before dangerous

Fixed.

L34: The introduction of broadband active acoustic systems comes out of nowhere here. Why are these better suited for answering outstanding questions than other methods? Introducing why broadband active acoustic systems are better suited for high-latitude coastal regions, after the second paragraph, makes this flow better and less confusing for the reader.

This sentence is simply meant to contextualize the aim of this manuscript within the broader field and large outstanding issues facing the study of polar regions. We have modified the sentence to clarify it providing the general direction for the paper and moved it to the end of the second paragraph.

Put the sentence from lines 34-35 at the end of the second paragraph?

Implemented.

L51: “Active acoustic systems can provide these measurements.” This reads very choppy. Consider removing or rephrasing.

Updated.

L65: “high latitude” should be hyphenated

Fixed.

L106: “crucial” doesn’t sound right here. Consider removing.

Updated.

L109: Add a period after “estimation”

Fixed.

L111: “Sect. 3” to Section 3. Here and elsewhere, be consistent with what you abbreviate

Updated throughout the manuscript

L119: “Hornsund” should have “fjord” following it. This makes the language more straightforward and less colloquial. This should be corrected for other uses of “Hornsund” as well.

Updated this section.

L121: “constitute” should be “constituting” with the current sentence structure and tense.

Corrected.

L125: Something is missing here. “which is among” instead of just “among”?

Corrected.

L126: “focused on the glaciated bay of Hansbukta” is wordy. Consider rephrasing.

Updated.

L135: Having all the links in the data availability statement will make this much easier for the readers to find what data were used in this manuscript. Please remove this link and place it in the data availability statement with a description.

Updated.

Figure 1: With the current layout of this figure. It makes more sense to have the top figure as "A" and the bottom figure as "B". Then, change the caption to mention the new figure labels.

The bright yellow mixing transect in the legend is hard to see. Adding a border or changing the color will help.

Updated figure.

L155: “3D printed plate” -> “3-dimensional (3D) printed plate”

Updated.

L158: Are these all the parameters?

Added frequency range to the list, this is technically a parameter that can be changed although it was not included initially since we’ve stated in the manuscript we are working with a certain bandwidth. Added it in the revised manuscript for clarity.

L165: Same as the comment on line 135. Remove this link and place it in the data availability statement.

Removed.

L172: Something went wrong with the latex I imagine for the " χ_T ". Double check the subscript here.

Updated.

L174: Move the URL to the data availability statement here and elsewhere.

Updated.

Figure 2: This is probably just me misunderstanding something, but why is there a gap between the sensor and boat in panel D? Should something be connecting the two structures?

This was just an issue in image rendering – updated now.

Also, this figure caption is a tad confusing. I suggest describing each panel with its own sentence or two. For example, (A) is the ctd used ..., etc. This makes it easier for people who are simply looking at the figure to obtain the necessary information quickly.

Updated.

Be consistent with your use of "3D" or "3-D"

Checked throughout.

L189: This sentence should be removed. There is no need to repeat what the section title already states.

Removed.

L191: I truly appreciate the authors' efforts to engage with an audience unfamiliar with underwater acoustics. As one of my main points in "Areas requiring clarification", please expand on more of the interpretation of the data here. There is hardly any discussion on how to interpret the figures provided, namely Figures 3 and 4.

See our response to major comments above – we have expanded this section and the section on Figure 4 to help readers interpret echogram figures. Again, we thank the reviewer for pointing this out – very helpful comment from an audience member not deeply familiar with echosounder acoustics!

L211: "($<150\text{-m}$)" Sometimes units are hyphenated and others are not. I would consider removing the hyphen here for consistency.

Updated all unit measurements throughout manuscript for consistency.

L221: In your list of objectives, the authors mention "geophysical parameter estimation" and now state "geophysical properties". What properties are these? Please explain here.

Updated this with some examples, also this section has been reworked so no appears in the introduction.

L223-227: “Broadband echosounder data collected in Hornsund fjord is here used to ...” is awkward phrasing. I’m not sure what describing the subsections here does either. Consider removing this for consolidation and summarizing it more in the introduction.

This suggestion has been implemented and moved to the introduction.

Figure 3: Similar to Figure 2, changing the caption to have dedicated sentences for each panel will make this caption much more readable. I am also confused about the units for panels A - D. Each panel should have it’s own letter, too. “(SL” needs a closing parenthesis.

Updated with suggestions.

L362: “In high latitude glacial fjords this remote advantage” - > In high-latitude glacial fjords, this remote advantage. There is a missing hyphen and comma.

Updated, this section was moved up to the introduction.

L363: Since the authors are referring to general high-latitude glacial fjords and not a specific fjord, use an indefinite article “a” instead of “the” “such as the submerged ice-ocean interface of the glacial terminus” -> such as a submerged ice-ocean interface of a glacial terminus

Updated.

L364: “ice bergs” -> icebergs

Updated.

Figure 4: Maybe I am missing something, but what exactly is the dark blue region outlined by the dashed black (?) line? Please elaborate on this in the figure caption.

The figure caption noted the black dashed line highlights the terminus. We added arrows to the figure to point from the label in the figure “ice-ocean interface” to the scattering region.

L407: “strong backscattering return starting between 75 to 150 meters in range.” The Y-axis only goes to a little past 120 m in range. Either correct this to 120 m or expand the Y-axis in Figure 4.

Updated.

L409: “peak intensity value of between -45 to -35 dB re one μPa .” This unit is different than than those shown on Figure 4 (dB re 1/m) and Figure 3. Are the authors referring to panel D in Figure 5? Please clarify.

Updated the manuscript to remove these values.

L446-447: “With the proper deployment geometry, the broadband system can provide direct observations of the subglacial discharge location; however, even” this sentence structure is repeated in this paragraph and used a lot in this manuscript. Consider rephrasing and varying this sentence structure for improved readability.

Updated.

L448-449: “backscattering signal from the plume higher in the water column can provide important observations related to plume dynamics.” Where are the important observations the authors are referring to?

Updated.

L463 - 470: As stated in the major revisions, this paragraph is not necessary here. Consider either removing it or summarizing the main points and incorporating them into the discussion.

This has been updated.

L488: “tidal cycle (e.g.,” The parentheses were never closed. Please add a closing parenthesis.

Updated.

L502: “(dark gray region, Fig. 5)” Add a panel to which part of Figure 5 you are referring to

Removed the reference to the “dark gray region”

Figure 5: Please increase the thickness of the profile lines in panels A and B. It is hard to distinguish colors with such thin lines.

Updated.

L543: “Taking the analysis of the acoustic measurements can be one step further”. The wording of this sentence is off. Maybe “The analysis of the acoustic measurements can be expanded upon. For example...”

Great suggestion, implemented.

L564: “Challenges in applying acoustic inversion methods notwithstanding,” This clause is awkward. Consider removing and starting the sentence with 'There is excellent...! The authors did a nice job of explaining the limitations of acoustic inversion above; no need to reiterate here.

Implemented

L577: Use future work instead of next step. This is more common and less colloquial.

Updated.

L585 - 600: Reintroducing broadband echosounders is very unnecessary this late in the manuscript. Again, from my major revision, this can either be removed or summarized and included in the introduction.

Removed this paragraph entirely.

L614 - 620: Same as above, this is not necessary here and better suited for the introduction.

Here we believe an in depth discussion of receiver sensitivity would slow the pace of the introduction; hence it belongs in its own section for those readers who are considering using these systems in the future. Outlining the importance of quality data collection requires its own section.

However, we do understand this section, as originally written is overly long and we have tightened it up.

L640 - 670: I agree with Reviewer 1. I'm not exactly sure what this section adds. Maybe summarizing the main points of this section and adding it to 5.0 would suffice.

I see the main points as 1) accurate calibration and 2) acoustic absorption.

Tightened up this section.

L665 - 670: Why is this paragraph at the end of this section? Please consider moving this up in the section following the main points from above. This is the only instance where the authors explicitly mention post-processing. The order of this section in its current state is confusing. Explaining the important post-processing steps in Section 5 will succinctly summarize this section and reduce the paper length.

Moved this section up.

L675: "like those discussed in Sect. 5.2." Remove this and put (Section 5.2) and end the sentence.

Updated.

L707-710: The conclusions should be about the authors' work. It is unnecessary to discuss the history of the methods from other sources here.

We feel highlighting other potential analyses are important for a new audience, especially in the conclusion to reiterate that there are even more applications out there for these methods, given the aim of this manuscript is to introduce this tool to a broad audience, and not just highlight the work we have done using this system.

General comments about the conclusions: There were several references to future work in this manuscript. Placing that future work here is better for readers who skimmed the above sections. Either remove the future work references from the above sections and place them here, or briefly mention them again in this section.

Added.