Author's Response

We have given detailed, point by point replies to the reviewer comments in the discussion section of the manuscript. As highlighted in our earlier responses, the comments from the reviewers have been highly constructive and have formed a basis to significantly improve upon the initial manuscript. Here we give a summary of the manuscript changes that we have made in order to address the reviewer's comments.

Changes to body text:

1. Changed title of manuscript following the suggestion of Reviewer 1.
2. Abstract – state that air-coupled flexural wave occurs at a constant frequency-thickness product and re-worded to avoid giving frequencies as a range of values, according to comments from both reviewers.
3. Abstract – passive recording of air-coupled flexural waves presented more clearly as an avenue for further study that the present study indicates may be promising, though it has yet to be demonstrated for sea ice.
4. Introduction – Revised analogy of flexural waves with other wave types.
5. Introduction – introduced the important, recent studies of Moreau et. al. (2020a/b).
6. Introduction – clearer statement that air-coupled flexural waves are attractive experimentally because they can be recorded by a single sensor.
7. Introduction – clearer statement of the general physical scenario where wave coupling occurs.
8. Introduction – relevance of air coupling to non-destructive testing stated more simply and without reference to "improved testing efficiency" that was a conclusion of Zhu (2008) that is not necessary for the present manuscript to address.
9. Introduction – highlight more clearly that the proposed methodology is an additional alternative to other methodologies.
10. Study area – Removed "as indicated by the photo" statement, which was unnecessary as highlighted by Reviewer 2.
11. Study area – estimation of ice thickness was made more explicit, in accordance with changing the title of the manuscript.
12. Theory – non-cavitation condition applied at the ice-water interface instead of z=0 as highlighted by Reviewer 2.
13. Theory – specific mention that the full dynamical model will be solved, in response to the suggestion by Reviewer 2.
14. Theory – It is highlighted more clearly that the full dispersion relation is well known from previous studies.
15. Methodology – we give a clearer introduction that the ability to record using a single sensor is an attractive aspect of the air-coupled flexural wave, in line with the Squire et al. (1988) study that was highlighted by Reviewer 2.
16. Methodology – added a brief introduction to the Radon transform as suggested by Reviewer 2.
17. Methodology – Added a sentence supporting the choice of Thomson's multitaper method for spectral estimation.
18. Methodology – Clarified our reference to Nickalls (1993) in solving the cubic equation, which was commented on by Reviewer 2.
19. Results – changed ordering of results section to show the dynamical model results earlier, as discussed in response to comments of the reviewers.

20. Results – references were added to table 1 and the choice of elastic paremeters is more clearly discussed following reviewer comments. We also refer to the elastic properties estimated by Moreau et. al. (2020a), which are a relevant point of comparison.
21. Results – condensed the presentation of thickness estimates for the different field seasons and give a more conservative interpretation of temporal variation in ice thickness following the comments from the reviewers.
22. Results – added a reference to Appendix 1 to support the hypothesized effect of land in regards to the two outlier borehole measurements in 2017, again following our discussion with the reviewers.
23. Discussion – removed section discussing ice flexural wave noise in reflection surveys, since the reviewers commented that the discussion section should be condensed and we did not see this part of the discussion as essential to the manuscript.
24. Discussion – snow is now (briefly) mentioned, following reviewer comments.
25. Discussion – added sub-heading to separate discussion of results of the present study and the discussion of future acquisition strategy for air-coupled flexural waves.
26. Discussion – clarified the analogy between the results of the present study and the tones that are known to ice-skaters that relate to the thickness of the ice (and provide an example of microphone recording of air-coupled flexural waves).
27. Discussion – added an example of natural ice quakes in order to support the conclusion that, in addition to explosive sources, natural passive sources are worthy of further attention.
28. Added appendix 1 giving a possible theoretical justification for the near land effect that was commented on with respect to the outlier boreholes from the 2017 field campaign. This was in response to the request for elaboration by Reviewer 1.
29. General revision to simplify language and eliminate superfluous words in order to condense the manuscript as much as possible.

Changes to figures and tables (numbering refers to revised manuscript):

30. Figure 1 – revised caption to eliminate jargon, added bathymetry title to colour bar.
31. Figure 3 – includes reference to Table 1 for physical properties.
32. Figure 4 – explicitly describes line marking air wave arrival, improved legibility of labels in (b) subfigure and labelling of variables now consistent with body text.
33. Figure 5 – more specific labelling of wave components to clarify that the air-coupled flexural wave is the high-amplitude monochromatic component arriving in advance of the broad band air-wave.
34. Table 1 – thicknesses changed to cm precision. References added to elastic properties.
35. Figure 8 – Added reference to Figure 1 which shows location of profiles.
36. Figure 9 – Added profile orientation annotation and reference to Figure 1 which shows location of profiles. Added median and 25-75th percentile range to make interpretation of data variability clearer.
37. Figure 10 - Added profile orientation annotation and reference to Figure 1 to make the orientation of the profile with respect to land clearer.
38. Figure 11 - Added profile orientation annotation and reference to Figure 1 which shows location of profiles. Added median and 25-75th percentile range to make interpretation of data variability clearer.
39. Figure 12 – added waveform figure panel to more clearly demonstrate the monochromatic air-coupled flexural wave component. Updated caption with specific reference to segment of soundtrack that was analysed and the spectrogram parameters.

40. Figure 13 – New figure added to the revised manuscript to demonstrate the passive recording of air-coupled flexural waves from natural icequakes using a microphone to support the arguments that passive acquisition may be a suitable way to record air-coupled flexural waves in future studies.

Other changes:

41. Removed ARCEx as an author affiliation since it is more correctly and sufficiently referred to by stating the relevant grant number in the financial support section.