Revisions of:
"Ocean Surface Gravity Wave Excitation of Flexural Gravity and Extensional Lamb Waves in Ice Shelves",

We thank the reviewers for their thorough proofreading and their useful comments and suggestions, which have helped improve the manuscript. In this document, we address the reviewers' comments one by one.

Please note that line numbers will correspond to placement in the ***original*** transcript. Thank you again; we look forward to further correspondence.

In addition to the changes made in response to the reviewer comments, we have added an additional paragraph at the end of section 5 and a new figure (Figure 10). These additions, reporting a cross-spectrum analysis of Ross Ice Shelf seismometer data, validate our hypothesis that low frequency horizontal component seismometer data are dominated by tilt from flexural gravity waves. Because this analysis was performed by Peter Bromirski, we have added him as a coauthor to our revised manuscript.

<u>Reviewer A comments:</u>

1. **Part 2 seems disconnected from the paper. You say that reflection and transmission coefficients could also be defined analytically using mathematical developments in part 2. But you did not do that in your paper (unless I missed something). Why not? That could help to link part 2 with the paper better. Also, could you use equation 43 to calculate the stress sigma_xx using the simulated displacement?**

   We have added an additional paragraph to the end of the Introduction, based on this comment and your comment 3 below. This new paragraph provides an overview of the paper and the connections between section 2 (wave modes in the frequency domain) and later sections, where we use time-domain simulations to extract frequency-domain plane waves from which we calculate reflection and transmission coefficients. The reflection and transmission coefficients are defined in sections 3.1 and 3.2, specifically (46) for the verification problem of a step change in water depth and (54) and (55) for the ice shelf problem. We feel that it is most understandable to define the reflection/transmission coefficients in section 3, rather than earlier in section 2. The new paragraph we added at the end of the Introduction should help readers understand this organization.

Equation (43) provides an expression for stress changes from flexural gravity waves in the long wavelength limit (where plate theory is valid). This limit is relevant for the frequency band studied in this paper, so yes, that equation can be used to calculate stresses. We mention this at the end of section 3.1, where we discuss the stress changes shown in Figure 8.

2. **The mathematical developments in section 2 are based on plane wave assumption. Is it possible that some near-source effects at the ice edge cannot be explained by your theoretical development (but should be shown in your simulation)? Could you please comment on that?**

   Evanescent modes exist near the ice edge (and step change in water depth) that alter the solution there as compared to the propagating plane waves. We discuss this a few times in the sections discussing the step change in water depth problem (e.g., paragraph after equation (46)) and show their existence by the term “+other modes” in equations (46), (54), and (55). In the revision, we have added a sentence near the start of the ice shelf section 5.2 that reminds the reader that we are neglecting evanescent modes and that this means our R/T solutions are only valid away from the ice edge: “These propagating wave reflection/transmission results are only valid away from the ice shelf edge, where additional evanescent modes contribution to the motions.”

3. **The introduction is missing one paragraph with a paper overview. The Authors could quickly list different steps presented in the paper and summarizes different section with 1-2 phrases. For example, the paragraph at the end of section 2 (Lines 92-95, "Our goal […]") would fit better in the introduction.**

   See response to comment 1. Briefly, we added the suggested paragraph to the end of the Introduction. We left the paragraph at the end of section 2.

4. **Line 16-18: "In the past three decades […]"-this sentence needs a reference**

   We have added some references.

5. **Line 32-33: "Lower frequency…"-could you please specify?**

   It now reads “Low frequency…” but we do not provide quantitative values for frequency because that specific frequency below which transmission becomes more efficient is a function of the ice elastic properties and ice shelf thickness, which are variable. This sentence is intended to be a more generic statement that transmission increases as frequency decreases.

6. **Line 39: "correlated ocean wave arrivals"-correlated with?**

   Corrected.

7. **Line 66: "forna"-?**

   Changed to “for a 2D vertical cross-section…”

8. **Line 96: "assuming ei(kx-wt) dependence of all fields"-this is only the phase term of the wavefield. Do you consider the amplitude of the wavefields to be 1? If yes, why?**

   Because the problem is linear, the amplitude is irrelevant and does not affect definition or calculation of the dispersion relation or transmission/reflection coefficients. However, to avoid confusion, we now introduce the wave amplitude A in equations (20)-(22). Our previous solution was for A=1.

9. **Line 103: "long-wavelength extensional Lamb wave"-could you please specify the wavelength?**

   This is clarified in the sentence that follows: $kh<<1$ (so horizontal wavelengths greater than plate thickness).

10. **Line 143: "the accuracy at high frequencies"-could your please specify?**

This is now discussed quantitatively in the text. The first acoustic mode cutoff frequency for 1000 m water depth is 0.375 Hz, for example, which is much greater than the frequencies we study.

11. **Line 218-219: "At low frequencies […]"-could you please specify?**

The frequency range for which the asymptotic limit is relevant can be seen in Figure 9.

12. **Equation 39: what is F?**

F is defined in equation (27) and appears in the dispersion relation (25). We reference these equations by number now to avoid confusion.

13. **Equation 46: double integral?**

Fixed.

14. **Figures 4, 6, 7: What are the dotted black lines? Is the displacement normalized between -1 and 1 m?**

The figures have been updated to label the dashed lines indicating wave speed. We have modified equation (60) to define the wave amplitude, which is 1 m. The plots are dimensional with units as marked.

15. **Figure 8: Does the horizontal line at y=1 and x>-50 and x<0 correspond to the water level?**

Yes, and the line above it (and hence above the water surface), which may have caused confusion, was the bounding box of the figure. To avoid confusion we have revised the figure to remove the line that appeared above the water surface.

Reviewer B comments:

1. **The numerical simulation solves the time-dependent problem for the linear equations by time stepping - which reflects how it is written. It is well known that linear equations can be solved in the frequency domain, which would lead to the reflection and transmission coefficients. It is a rather circuitous route adopted here - and it would be good to explain and justify this. Also, discuss how to extend the method.**

   Reviewer 1 also found this confusing, so we have added a new paragraph to the end of the Introduction that provides an overview of the paper (and approach used in the study). Specifically, we state "...While the reflection/transmission problem is best formulated and analyzed in the frequency domain, we utilize a time-domain finite difference code for wave propagation to perform the required numerical simulations. Thus we must introduce a procedure, described in section 3, to extract frequency-dependent reflection/transmission coefficients from our time-domain simulations…." We do not feel that further explanation is required of why we selected the particular code, nor do we feel it appropriate to discuss the advantages and disadvantages of a time-domain vs. frequency-domain code in this paper, which is not focused on numerical methods. The problem is linear and can be solved with sufficient accuracy in either the time domain or frequency domain. We happen to have a well-tested (and open-source) time-domain code that has all of the needed features, so we used it. The only other code we are aware of for this class of problems is the one used in Kalyanaraman et al. (2020), but their code does not appear to be open-source or publically available. One advantage of a time-domain code is that it can easily handle nonlinearities, such as the addition of rift growth through nonlinear fracture criteria (e.g., as we have done with the same code for modeling earthquake ruptures). This code could then be used to study wave generation and rift growth simultaneously, something that is not obviously done with a frequency-domain code.

   We do not understand what you mean by "discuss how to extend the method" so have not made changes in response to this part of your comment.

2. **The tilt discussion was important. My thoughts are that the response is dominated by flexural gravity waves and the slope (and hence tilt) is easy to calculate. For the kind of long periods, the shallow water approximation would be valid. Some comparison of this may be helpful. This does raise the question of whether Lamb waves are important.**

   We completely agree. This calculation, and evidence for tilt, is the topic of section 5.4. In fact, in the revision we added an additional paragraph and figure that validate our hypothesis about tilt by analyzing seismic data from the Ross Ice Shelf. We agree that extensional Lamb wave amplitudes (and stress changes imparted by these waves) are likely much smaller than previously thought. Even if they don't play as much of a role in fracturing, they are still important for placing constraints on the ice elastic properties (through analysis of their propagation speed, for example). We have stated these important points in two new sentences added to the Conclusion: "This result implies that extensional Lamb wave amplitudes are most likely smaller than previous studies have suggested. Our modeling suggests that stresses imparted to the ice shelf by incident ocean waves are primarily carried by flexural gravity waves. Even if they play a smaller role in fracture processes that previous thought, extensional Lamb waves are still valuable for constraining the elastic properties of ice (Diez et al., 2016; Chen et al., 2018)."