Dear Editor,

We have carefully revised our manuscript taking into account all of the comments and suggestions by you and reviewers. We also updated the For details of the revision, see Responses to the Comments as follows, the black words are the comments, while the blue words are our responses. Thanks so much for the help and guidance.

Best regards,

Yours sincerely, Jun Xie, Xiangfang Zeng, Chao Liang, Sidao Ni, Risheng Chu, Feng Bao, Rongbing Lin, Benxin Chi, Hao Lv

## Responses to the suggestions and comments by Reviewer 1

This manuscript discusses the use of a Distributed Acoustic Sensing (DAS) array for studying seismic events and wave propagation within ice plates, with a focus on understanding processes like ice structure dynamics and fracture mechanics. The study employed DAS technology on a frozen lake, detecting seismic signals including icequakes and low-frequency events. Icequakes were associated with ice cracking and localized temperature changes, while low-frequency events exhibited characteristics of flexural-gravity waves, providing insights into ice plate properties. The research demonstrates the effectiveness of DAS arrays for in-situ dense seismic monitoring of ice plates, such as ice shelves, contributing to a better understanding of their dynamic behavior and potential disintegration.

The structure of this manuscript seems to be fine, as well as the conducted research. However, I have concerns regarding the language. I think the authors should improve it before this manuscript can be recommended for publication. I provided number of language issues in the comments below.

A number of general and specific comments and possible suggestions for the improvements are given below.

Re: Thank you. We have had a native speaker to view our script and did some necessary modifications. Hope the language problem is resolved.

1. Line 17-18: “Our study demonstrates the effectiveness of a Distributed Acoustic Sensing array as an in-situ dense seismic network in for investigating the internal failure process and dynamic deformation of ice plate such as ice shelf”. In this sentence, “in” should be removed. In addition, I think it makes more sense to use “ice plates” instead of “ice plate”.

Re: We deleted “in” and replaced “ice plate”.

2. Line 77: I feel that the words “experiment commenced” and “experiment concluded” sound a bit weird. I would suggest that the authors use simpler words applicable to experiments such as “started” and “finished” or similar.

Re: We changed to “started” and “finished”.

3. Lines 70-80: I suggest that the authors provide some details on what exactly they measured with the installed fiber-optic cable. I think a sentence will be enough.

Re: Thank you, the measurement of the DAS is the strain rate. In line 82 of the revision, we added *“The interrogator is an Ovlink DAS unit, which measured longitudinal dynamic strain rates of the fiber-optic cable.”*

4. Line 87: The authors should replace “exhibits” with “exhibit”.

Re: We replaced.

5. Line 89: Remove “to” before “related”.

Re: We removed.

6. Figure 2c: On this figure the authors provide temperature curve. Is this the air temperature? I

suggest that the authors indicate this either on figure itself or in the caption. Besides, I do not see an axis for the temperature and, therefore, have no idea of what is the temperature. I suggest that the authors add an axis for temperature measurements they provide. In addition, the authors state that the temperature was measured locally. How far was it measured from the experimental site?

Re: Thank you for your comments. It is air temperature, and in the revision, we have added the tag in the figure. The local air temperature is from European Centre for Medium-Range Weather Forecasts with a spatial resolution of $0.25^{o}\times0.25^{o}$.

In the revision, we added

*" temporal distributions for icequakes (light blue) per hour and LFEs (dark blue) per minute and the local air temperature (black curve). The temperature data is from European Centre for Medium-Range Weather Forecasts."*

7. Line 194: "where" is missing at the beginning of the line.

Re: We added.

8. Line 194: After the word "study", there should be a comma, not full stop.

Re: We added a comma.

9. Line 197: Q is due to…, M is due to… I suggest that the authors rephrase it as it is weird to start a sentence in this way.

Re: We modified as "Q is…" and "M is…".

10. Discussion section: I suggest that the authors do not start the discussion section with the word "Indeed".

Re: We deleted it.

11. Line 214: “In the study of Nziengui-Bâ et al. (2022), the Young’s Modulus are below 5 GPa”. Replace “are” with “is”.

Re: We replaced.

12. Line 217: In this sentence, the authors state that when the lake surface is covered with clear ice free from snow, that implies a stronger stiffness. I would disagree with this statement. I do not think that if the ice is clear, it means it has greater stiffness. I suggest that the authors either rephrase this sentence, or provide a reference to the work that confirms that the clearer the ice is, the stiffer it is.

Re: Thank you for pointing this out. The effective modulus of ice depends on strain rate, temperature, density, ice type, purity and existence of cracks etc. And the conclusion of “clearer the ice is, the stiffer it is.” is just a deduction, which is not rigorous enough. In the revision, we deleted it.

13. “This range represents the stiffness or rigidity of the ice material, with higher values indicating greater stiffness.”. Is this sentence necessary? Does it bring new value to the reader? I leave it for the authors to decide.

Re: We agreed. In the revision, we deleted this sentence.

14. Since the authors put a lot of efforts into the discussion of the measurements of Youngs modulus that were done in the past, I think the authors should mention this work (reference below) where the authors investigated how Youngs modulus of ice is affected by compression/straining and cracking in along different directions (most results depicted in Figure 3). The authors found that the Youngs modulus initially is around 9.5GPa but starts to decrease once the ice is compressed uniaxially and saturates at about 8.5GPa along the loading direction and 7GPa along two other directions perpendicular to the loading direction. I think this observation is pretty interesting.

Re: Thank you. In the revision, we have added this interesting research as

*“Renshaw et al. (2020) also reported that the Young's modulus initially is around 9.5 GPa but starts*

*to decrease once the ice is compressed uniaxially and saturates at about 8.5 GPa along the loading direction and 7 GPa along two other directions perpendicular to the loading direction. ”*

Renshaw, C. E., Schulson, E. M.,Iliescu, D., & Murzda, A. (2020). Increased fractured rock permeability after percolation despite limited crack growth. Journal of Geophysical Research: Solid Earth,125,e2019JB019240. https://doi.org/10.1029/2019JB019240.

15. I suggest that the authors mention the relationship between stiffness and Youngs modulus since they use these two terms very often, or why they sometimes use the word stiffness and sometimes Youngs modulus.

Re: Thank you. It is a translation error, the “stiffness” is referring to the Young’s modulus. In the revision, in order to reduce unnecessary misunderstandings, we have changed all the stiffness to Youngs modulus.

16. Line 232: I am actually a bit surprised that it is possible and interested in how is it possible to estimate the thickness of the grain boundaries using a value of Youngs modulus. The authors claim that it is possible and provide a reference to Wang 2008, however, I did not find this reference in their Reference list. The authors have to fix this.

Re: Thank you for pointing this out. In the revision, we have added this reference. It is,
Wang, Y., Ballarini, R., and Rodin, G. J.: Crack-Tip Parameters in Polycrystalline Plates with Soft Grain Boundaries, Journal of Engineering Mechanics, 134, 100–109, https://doi.org/10.1061/(ASCE)0733-9399(2008)134:1(100), 2008.

## Responses to the suggestions and comments by Reviewer 2

This is an interesting paper which shows a nice way of determining ice properties using acoustic arrays. I see it has been reviewed a couple of times already and the authors have revised the paper according to their comments. I have only a few further comments myself. The previous reviewers did comment on language mistakes in English, and that is still a problem so I'd recommend they get a colleague who

is more proficient in English to check the paper.

Thank you. We have sought the assistance of colleagues from English-speaking backgrounds to review our manuscript. We hope the revised version will address potential language issues.

Specific comments:

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1. p3 YOLO is "You Only Look Once", not "You Only See Once"

Re: Modified.

2. Section 5: Dispersion curve of LFE

These are quite high frequencies, and maybe the thin plate model is no longer accurate. While 9.1GPa (+/-0.1GPa) is quite close to the 10GPa for freshwater from Timco and Weeks (2010), perhaps the uncertainty in your estimate by double-checking against another model - ideally using the full elastic equations for a floating plate of finite thickness, but if this is not possible there are more accurate approximations, like that of Mindlin (1951). Another source of error could be the thickness - if it were less than 0.5m, it would push up the estimate for the stiffness.

Re: Thank you for your comments and suggestions. Our estimate is close the one for fresh water given by Timco and Weeks (2010).

We understand your concern about the accuracy of the thin plate model for the high frequencies that used in this paper. In this study, the frequency-thickness is less than 8 Hz*m. Several previous studies have shown that the thin plate model is still valid and reliable for the frequency-thickness less than 50 Hz*m. For example, Moreau et al. (2020) and Nziengui-Bâ et al, (2022) used the thin plate model to invert for the ice plate properties, and their results are consistent with observed data, the frequency-thickness is even larger in their studies. Therefore, we thought that the thin plate model is acceptable in this study. To reflect full elastic model, we added discussions in Line 199-204.

Regarding the thickness of the ice plate, we agreed that Young's modulus and ice thickness are strongly correlated. Thus, a large uncertainty on one of the two parameters will have the same effect on the other. We also performed a sensitivity analysis to show how the Young's modulus vary with

different thickness values. Figure S13 shows the Young's modulus inversion results with different ice plate thickness. The thickness of ice plate is 1cm, however the inverted Young's modulus varies up to 0.5 GPa. This implies that to obtain more accurate results a joint inversion method combines quasi-Scholte mode and quasi-symmetric mode (corresponds to compressional waves) following a Bayesian scheme should be used (e.g., Nziengui-Bâ et al., 2022).

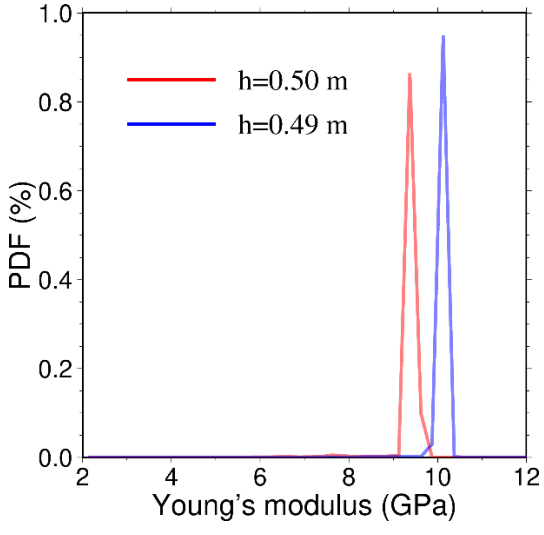


Figure S13 The Young's modulus inversion results with different ice plate thickness. The PDF is the posterior density function.

We added discussion in line 199-204 of the revision as,

*" However, Young's modulus and ice thickness are strongly correlated. Thus, a large uncertainty on one of the two parameters will have the same effect on the other. Therefore, a joint inversion method combines quasi-Scholte mode and quasi-symmetric mode (corresponds to compressional waves) following a Bayesian scheme should be used to simultaneously invert the thickness and the Young's modulus, and can obtain more accurate results (Nziengui-Bâ et al., 2022). Since the frequency-thickness is much less than 50 Hz*m, the thin plate model (equation 1) is still valid in this study. In other case with thick ice plate, full elastic model (e.g.,Mindlin, 1951) could be used. "*

Reference:

Nziengui-Bâ, D., Coutant, O., Moreau, L., and Boué, P.: Measuring the thickness and Young's modulus of the ice pack with DAS, a test case on a frozen mountain lake, Geophysical Journal International, ggac504, https://doi.org/10.1093/gji/ggac504, 2022.

Moreau, L., Boué, P., Serripierri, A., Weiss, J., Hollis, D., Pondaven, I., Vial, B., Garambois, S., Larose,

É., Helmstetter, A., Stehly, L., Hillers, G., and Gilbert, O.: Sea Ice Thickness and Elastic Properties From the Analysis of Multimodal Guided Wave Propagation Measured With a Passive Seismic Array, Journal of Geophysical Research: Oceans, 125, e2019JC015709, https://doi.org/10.1029/2019JC015709, 2020.

3. Appendix B: define STA/LTA. Check other acronyms used in the paper are defined as well.

Re: Thank you. We have defined the STA/LTA as,

*"We used the short-time-average through long-time-average (STA/LTA) method (Stevenson, 1976) to pick arrival."*

We checked other acronyms, and all are defined.

References

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R.D. Mindlin (1951). Influence of rotary inertia and shear on flexural motions of isotropic, elastic plates. Trans. ASME, J. Appl. Mech.

Timco, G. W., & Weeks, W. F. (2010). A review of the engineering properties of sea ice. Cold regions science and technology, 60(2), 107-129.