Dear Editor,

We have carefully revised our manuscript taking into account ALL of the comments and suggestions by you and reviewers. 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 Lv1

Responses to the suggestions and comments by Reviewer 1

The paper presents a DAS experiment in a lake. The seismic data included airgun sources data, and passive signals. The DAS experiment is unique and could provide great DAS experience and research results in the lake to the community.

Thank you for your positive feedback on our manuscript. Your suggestions have played a crucial role in enhancing the quality and clarity of our work, and we deeply appreciate your valuable contribution to refining our research. We sincerely hope that our responses and revisions adequately address all your concerns. Our responses to each comment are indicated below in blue.

The writing needs to improve. I am assuming this will be a full technical paper but authors left some of important technical methods and figures in supporting information/appendix.

In the inversion, we have put appendix into the manuscript including the detecting and locating of microseimic signals and the dispersion relation of flexural-gravity wave.

It's silly to put something like "consistent with previous studies". Whenever I read the interesting findings, I expect authors to present their full assessment and analysis, instead of "consistent".

Thank you. We have modified descriptions with "consistent", added more details of relevant researches, for instance, we modified

"*we estimated that the P wave velocity in the ice is ~3200 m/s, which is consistent with previous study*" in line 77 into

"*we estimated the P wave velocity in the ice to be approximately 3,200 m/s (Fig. S3 in the supporting information). This estimation is consistent with previous research findings. For instance, study conducted by Ewing et al. (1934) indicated that thick solid ice typically exhibits P-wave velocity* *ranging between 3,432 and 3,698 m/s. Similarly, Wen et al. (1991) reported that thinner ice layers are expected to have velocities ranging from 2,000 to 3,040 m/s.*"

We modified

"*When some icequakes occurred, the staff also heard the cracking sound, consistent with previous observations (Kavanaugh et al., 2018)*" in line 83 into

"*During the occurrence of some icequakes, the staff also reported hearing cracking sounds, which aligns previous observations reported by Kavanaugh et al. (2018). This acoustic evidence provides further confirmation of the dynamic activity within the ice plate during seismic events.*"

It may be useful to mention a little information on the instrument and the cable.

Thank you. The interrogator we use is an Ovlink DAS unit and the cable is a standard single-mode optic-fiber cable. We have put this to the manuscript.

Figure 3S is hard to read the picks. What are V1 and V2? Why are they quite different?

We have replotted this figure. V1 is the velocity of P wave. V2 is the velocity estimated from the maximum amplitude of the waveform and this is measured using STA/LTA method, and it usually corresponds to the surface wave.

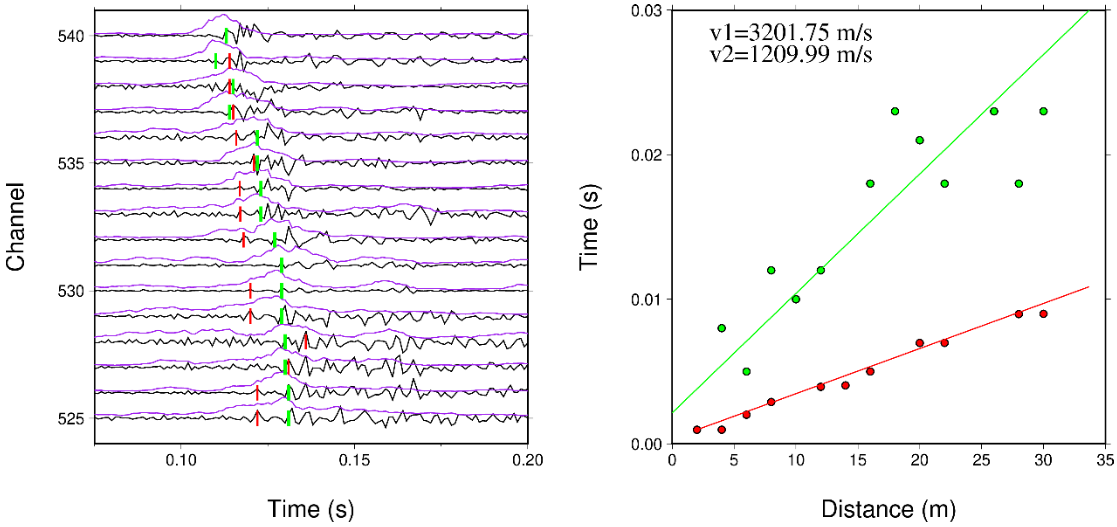

Fig. S3 Velocity measurement with hammering signal. Left: Waveform of hammering event (black curves), STA/LTA waveform (purple). The red lines are arrivals by handpick and the green lines are by STA/LTA. Right: corresponding velocity fit.

"in the and the elongation"

Thank you. In the revision, we modified the sentence as

"*These signals are associated with longitudinal waves propagating through the ice plate that cause elongation along the fibre direction*"

"When some icequakes occurred, the staff also heard the cracking sound, consistent with previous observations (Kavanaugh et al., 2018)." ????

We modified this as

"*During the occurrence of some icequakes, the staff also reported hearing cracking sounds, which aligns previous observations reported by Kavanaugh et al. (2018). This acoustic evidence provides further confirmation of the dynamic activity within the ice plate during seismic events.*"

"The number of icequakes does not seem to be associated with AGEs but is rather correlated with the local temperature variation (Fig. 2c), consistent with other studies (e.g., Kavanaugh et al., 2018)."

In the revision, we modified this to

"*We detected 14,498 icequakes, exhibiting a clear diurnal cycle (Fig. 2c) and primarily clustered along the promising fractures (Fig. 2d). The number of icequakes does not seem to be associated with AGEs but is rather correlated with the local temperature variation (Fig. 2c). This phenomenon has also been reported by other studies, for instance, Goto et al. (1980) observed that there was a strong correlation between the occurrence of high icequake activity and the temporal variation of temperature differences within the ice plate. This reveals the nature of* *icequakes in our experiments as brittle failure of ice plate caused by uneven thermal expansion.*"

AI accuracy for AGE is 73% and for icequake 62.8%. These are very low. Since AGE are active sources, the groundtruth is known. This accuracy is not satisfied. Is AI model better than STA/LTA?

The "accuracy" of the result here refers to the precision that is number of True Positive (TP) divided by the number of TPs plus the number of false positives (FP). TP is the True Prediction, that is, the icequake being detected as icequake; FP is False Prediction (other event predicted as icequake). This is different from the accuracy of seismic event detection, which is more like the recall rate. And the recall rate is defined as the TP divided by everything predicted as positive, including TP and False Negative (FN). FN is the missing data. The recall rate in this study is nearly 100%. We did not use STA/LTA because it cannot classify seismic events, while AI based method shows the superiority. To answer the reviewer's question, the AI method outperformed STA/LTA, according to Stork et al. (2020). We clarified this in the revision as

"*The recall rate is the number of True Detectives (TP) divided by everything predicted as positive. TP is the True Prediction, that is, for example the icequake being detected as icequake. The recall rates for AGEs, LFEs and icequakes are 100.0%, 100.0% and 91.0%, respectively,* *while the precision for the three are 73.0%, 93.0% and 62.8%. This level of precision is comparable to the results reported by Stork et al. (2020), indicating statistically meaningful characteristics of the study area.*"

Stork, A. L., Baird, A. F., Horne, S. A., Naldrett, G., Lapins, S., Kendall, J.-M., Wookey, J., Verdon, J. P., Clarke, A., and Williams, A.: Application of machine learning to microseismic event detection in distributed acoustic sensing data, GEOPHYSICS, 85, KS149–KS160, https://doi.org/10.1190/geo2019-0774.1, 2020.

I don't understand the bias errors in the location of 10 hammer shots. Again, this location is known and should be recovered very accurate with ignorable errors. It means that the physics parameters (what are they? Authors didn't specify these) can be determined from the hammer shots.

We agree that the location can be recovered accurately with precise travel time picking and the accurate location of channels. The error due to time picking is supposed to be random and it won't result in systematic bias. It implies there is systematic error of the fiber-optic cable locations, which is acceptable in this study. In future work, the location accuracy of fiber-optic channel needs to be improved. We clarified this in the revision as, “*It is important to note that most of the location results exhibited a bias towards the north direction. This systematic deviation of the location results could be attributed to the systematic bias in the position of fiber-optic cable. Overall, the accuracy of the location in this study is acceptable*.”

This dispersion curve has the canonical trait of a special guided wave along a suspending ice shelf driven by the interplay of ice plate flexure and gravity, namely the Flexural-Gravity Wave” I don’t understand this. Please illustrate more here!

In the revision, we modified this as

“*This dispersion curve displays the distinctive characteristic of the Flexural-Gravity Wave (FGW) (Williams and Robinson, 1981), which is a special guided wave that occurs along a suspending ice shelf as a result of the interplay between ice plate flexure and gravity*.”

What’s the uncertainty of 10 GPa?

The uncertainty of E can be estimated using a nonlinear inversion method. Following a Bayesian scheme (Nziengui-Bâ et al., 2022), the uncertainty of inverted Young’s modulus is 0.2 GPa. We added this in the revision as

“*Following a Bayesian scheme, both thickness and the Young’s modulus can be estimated (Nziengui-Bâ et al., 2022). In this case, the Young’s modulus is 9.1±0.2 GPa, and the thickness is 48±0.1 cm, respectively.*”

The section of using PhaseNet to detect events is very random. If the YOLO is good with the accuracy, why should I care about the PhaseNet results? I want to ask, what’s the main purpose of this research?

Sorry for the misleading. In this section, we were trying to compare the density DAS array detection with a single seismometer record to show the superiority. However, in this study we focus on the microseismic events and physical property of the ice plate. We know the comparison is unfair, therefore we deleted this part.

“using optical methods” this is confusing. What are optical methods? Including DAS?

Thank you, they are referring to remote sensing method such as satellite-based method. In the revision, we have modified this as

“*Our research demonstrates the significant potential of DAS in monitoring the formation and progression of ice cracks using passive source signals recorded in similar ice shelf studies, particularly in cases* *where there is a firn layer on the ice and remote sensing methods, are challenging to employ*."

The data availability statement "All raw data can be provided by the corresponding authors upon request." Is reasonable for the journal?

In the revision, we modified as

"The catalogue of the seismic events is available on https://www.zenodo.org/record/7424310. YOLOv5 can be found https://github.com/ultralytics/yolov5. NA code can be found http://rses.anu.edu.au/~malcolm/na/."

Responses to the suggestions and comments by Reviewer 1:

This manuscript describes a DAS experiment conducted on a frozen lake, with active airgun shots fired below the ice. In addition to the airgun-excited waves, two additional classes of events could be detected: (1) high-frequency waves that most likely originate from ice quakes caused by thermal expansion, and (2) a smaller number of low-frequency events that are excited by water waves and can be used to constrain the elastic properties of the ice.

The manuscript is logically structured and the data are certainly interesting. Nevertheless, there are several important issues that should be addressed prior to publication of the manuscript.

Thank you for your positive feedback on the logical structure of the manuscript and the interesting nature of the data. Your input has been instrumental in improving the quality and clarity of our work, and we appreciate your contribution to the refinement of our research. We sincerely hope that our responses and revisions adequately address all your concerns. Our responses to each comment are indicated below in blue.

LANGUAGE

My most important criticism is the unacceptable level of the English. While the meaning of most sentences can be guessed, part of the content can simply not be understood. This is absolutely not about correcting a few typos. Almost every single sentence should be corrected or rewritten.

Thank you. We have revised the manuscript in order to enhance the English expression while maintaining the original meaning.

BEYOND THE OBVIOUS

While the data are, as previously mentioned, interesting, it is unclear how they go beyond the obvious. Large numbers of quasi-randomly distributed ice quakes caused by diurnal thermal expansion are exactly what one would expect. The same holds for water-wave-induced events at lower frequency. That the latter can be used to constrain ice properties has been known at least since the 1950s. In summary, the authors should explain much more explicitly why this is science beyond the obvious that should be published in a journal like 'The Cryosphere'.

We appreciate the reviewer's comment and the opportunity to clarify the novelty and significance of our study. While it is true that large numbers of ice quakes caused by diurnal thermal expansion and water-wave-induced events are expected, our research goes beyond the obvious in the following aspects.

1. We investigate the potential of using Flexural-gravity wave to constrain ice properties, such as stiffness and thickness. While the concept of using water-wave-induced events for ice property estimation has been known for decades, the observations of dispersion of flexural-gravity waves remain limited. Our study provides new insights by applying modern analysis techniques.
2. We utilize advanced techniques i.e., DAS observation and machine learning method, which allow for high-resolution monitoring and

detection of seismic events on ice plate. This capability enables us to effectively identify internal fractures within the ice plate, a task that is often challenging for traditional methods.

3. We provide a comprehensive and detailed analysis of seismic events on ice plate, including their spatial distribution, temporal patterns, and waveforms. This analysis contributes to a better understanding of the behavior and characteristics of these icequakes and LFEs in our specific study area.
4. Our study demonstrates the applicability and effectiveness of DAS technology in studying icequakes and their relationship with water-wave-induced events.

In summary, our research expands upon the existing knowledge by providing a more detailed and comprehensive analysis of icequakes and water-wave-induced events. Furthermore, we highlight the potential applications of DAS technology and the relevance of water-wave-induced events in understanding ice properties. We believe that these findings make a valuable contribution to the scientific community, and we have revised the manuscript in the discussion section accordingly to emphasize the significance of our work beyond the obvious. We hope that these explanations address the reviewer's concerns and demonstrate the merit of our study for publication in 'The Cryosphere'.

BROADER IMPLICATIONS

Along similar lines, it is unclear what the broader implications of this work are. For example, what is the transferable insight that we gain? Why is this potentially more than just a study of one among very many ice sheets?

We appreciate the reviewer's comment and the opportunity to discuss the broader implications of our work. We would like to emphasize the following points:

1. Insights into ice properties and environmental interactions: Our study explores the relationship between water-wave-induced events and ice properties such as stiffness and thickness. This provides valuable information on the interaction between ice sheets and their surrounding environment. Understanding these interactions is crucial for accurately modeling ice sheet response to environmental changes and improving predictions of ice sheet stability. We determined a Young's modulus of approximately 9.1 for the ice plate, which is valuable for investigating the flexural stiffness of the ice plate.
2. Methodological advances: We utilize advanced techniques (DAS) and methods (machine learning) for monitoring and analyzing icequakes and water-wave-induced events. Our research demonstrates the applicability and effectiveness of these methods in studying ice sheet dynamics and properties. This contributes to the advancement of

monitoring and analysis techniques in glaciology and seismology, with potential applications in other regions, such as ice shelves.

In summary, our study offers insights into the behavior of ice plate, the interaction between ice and its environment, and methodological advancements in monitoring and analysis. These findings have broader implications for improving our understanding of ice plate dynamics, informing climate change mitigation and adaptation strategies, and advancing monitoring techniques.

We have revised the manuscript to explicitly discuss these broader implications and highlight the transferable insights gained from our work. The modifications are in Discussion section.

COMPARISON

One of the authors' major conclusions is that DAS offers new opportunities that conventional instruments may not offer. However, this claim is not at all supported. The authors compare to the recordings of an on-shore seismometer, which is not only further away from the ice quakes than the DAS array but also naturally records lower amplitudes than instruments on the floating ice sheet. (For example, much of the energy will not even make it from the fluid into the solid.) Hence, the authors' claim really rests on an unfair comparison of apples and oranges.

Thank you for pointing this out. We agree that this is not fair and meaningless. In this work, we focus on the study of the microseismic events and physical property of the ice plate. Considering this, we deleted this part.