October 10th, 2022

Dear Dr. González,

We sincerely thank you and the two reviewers for the encouragements and constructive comments you have made on the manuscript. We have addressed the questions and highlighted the areas where changes are made. Here we present our point-by-point responses and revisions to the comments.

Linlin Li

Note: The comments are in "*italics*", and our responses and revisions are in "regular" text (in blue) for clarity.

Response to Reviewer #1

General Comments:

Author's response: We thank referee #1 for the encouragements he/she made on the manuscript.

Response to Reviewer #2

1.Response to comment 1, 'the arrival of Lamb wave from the waveforms recorded by DARTs and barometers'. Wrong concept. Here, Lamb wave only stands for the atmospheric sound wave, which could only be detected/measured by barometers. What DARTs detected/measured is the Lamb wave-induced water surface wave/tsunamis.

Author's response: Thanks for pointing out the unserious description. We have made corresponding changes to the related contents in the manuscript.

Author's change to manuscript: We have changed the related parts as "arrival times of Lamb wave-induced tsunami" or "arrivals of Lamb wave-induced tsunami".

2. Response to comment 2, How about cut-off frequency of 6h or 10 h? Applying different cut-off frequencies could lead to significant differences or not? BTW, the two examples in the response are for the earthquake induced tsunamis, different from the present Tonga one.

Author's response: Thanks. Using different cut-off frequencies such as 10 h, 6h or 3h doesn't change the results because the main period of the tsunami waves range concentrate in period band of ~2-100 min. Since the period bands are in the similar range with those of the earthquake-induced tsunami waves, the de-tided method should be suitable for this tsunami event.

3. Response to comment 3, Why 0.2 m? not 0.3 m or 0.1 m? BTW, many recorded tsunami heights in the coastal area are just around 0.2 m during the Tonga tsunami event, similar to this cut-off height.

Author's response: Thanks. Indeed, there is a trade-off between keeping more gauges with smaller cut-off height and maintain the dataset with relatively good quality. Choosing 0.2 m as the cut-off height will miss some tide gauges with wave height less than 0.2m, but the chosen gauges are reasonably distributed in the Pacific Ocean which we believe could well demonstrate our key points. The choice of 0.1m will keep more unusable tide gauges with noise height larger than tsunami signal, so that we had to manually remove massive data.

4. Response to comment 4, Definition of 'wave amplitude' is the half of wave height. The ordinate should be 'Normalized water level', not 'Normalized wave amplitude'. Please also specify how the normalization (with respect to the local mean water level or others?) was conducted in the context or caption.

Author's response: Thanks for pointing out this mistake. We have changed the ordinate as suggested. The data are normalized with respect with the largest amplitude of each tide gauge.

Author's change to manuscript: We have changed the ordinate label as 'Normalized water level' and added a sentence in the caption as "The data are normalized with respect to the largest amplitude of each tide gauge.".

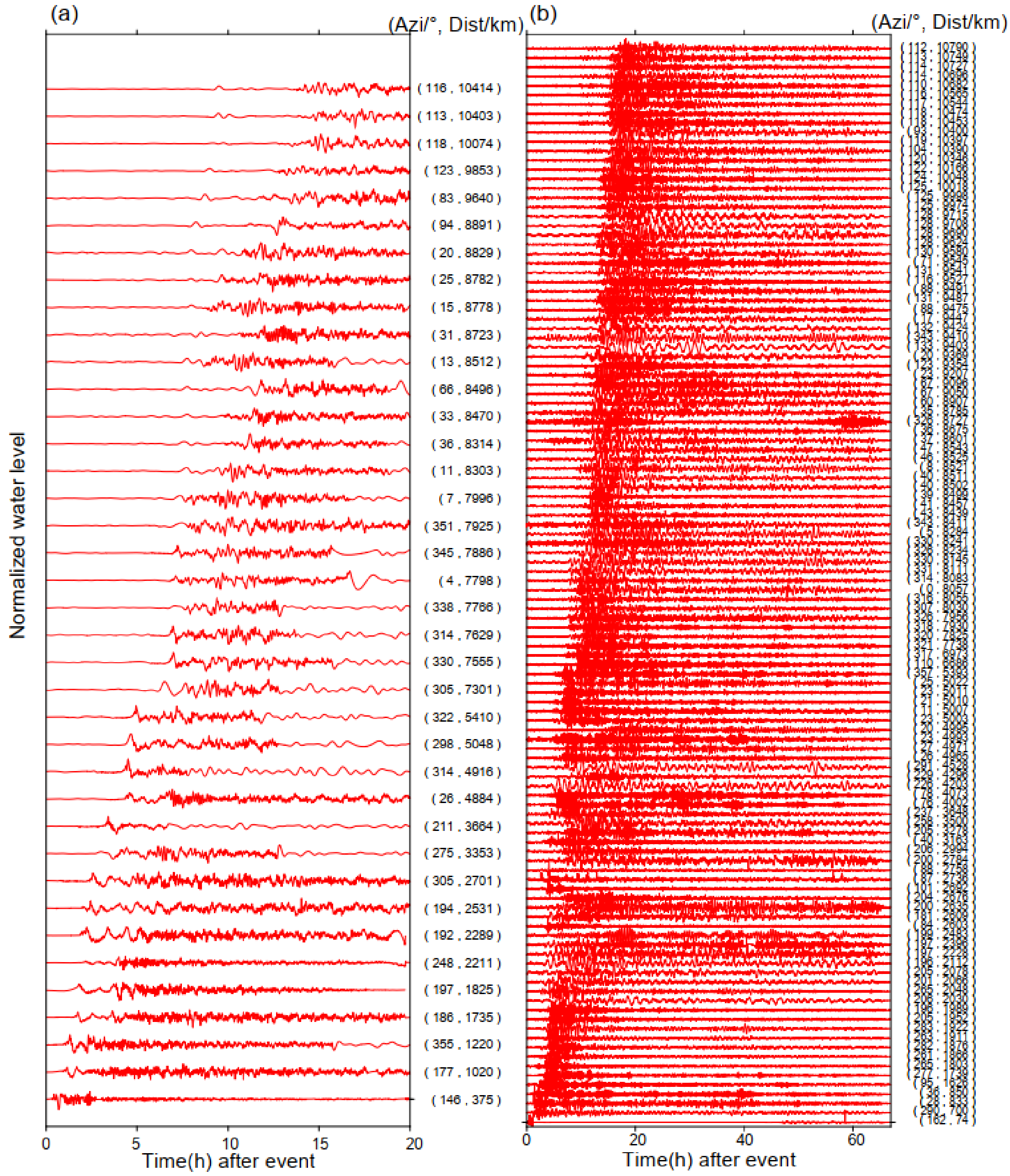


Figure 2. Detided tsunami waveforms at (a) DART buoys and (b) tide gauges. Waveforms in both subplots are shown in ascending distance. Azi stands for azimuth. The data are normalized with respect to the largest amplitude of each tide gauge.

5. Response to comment 6, Mother function selection is important for wavelet analysis leading to different results. Although Morlet is frequently used in wavelet analysis, this mother function is not universal. Selection of the mother function should be case-dependent with respect to the temporal characteristics of the original signal.

Author's response: Thanks. The mother wavelet governs how the wavelet transform transfers time information into the frequency domain. The mother wavelet we use is the Morlet wavelet, which is optimally suitable for identifying the oscillatory components of wave signals (PS., 2002). Previous applications of the Morlet function demonstrate that it works well in tsunami period analysis. The method has been widely applied in many tsunami cases for detecting the tsunami period information, such as tsunamis generated by two successive earthquake (Mw 7.4 and Mw 8.1 earthquakes) in the Kermadec Islands on 4 March 2021 (Wang et al., 2022a), and tsunami of 2022 Tonga volcanic eruption in in Lingding Bay, China (Wang et al., 2022b).

6. Response to comment 7, As mentioned by the authors, Lamb wave has a period of 30-40 min, thus the induced tsunami waves. Using a 20 min moving time window can exclude the 30 min Lamb wave induced tsunami component?

Author's response: We apologize for this misunderstanding caused by our previous expression. In our previous replies, we used the word "exclude" in this sentence*: "To achieve this purpose, we need to choose a representative wave period that covers most tsunami waves with significant amplitude and long-lasting time duration, as the moving time window. With the criterion, we exclude the periods of tsunami components from shock wave, Lamb wave and conventional seafloor crustal displacement, because they are either distributed in a limited time period in each waveform, or have very limited spatial and temporal impact, therefore, do not meet the requirements."* We actually meant to say that we choose not to use the periods of… Using a 20 min moving time window can not exclude the 30 min Lamb wave induced tsunami component. Sorry for this misleading expression.

7. Response to comment 11, I am thinking that the measurement error of DART buoy should be even larger than 0.1 mm.

Author's response: Thanks. We have tested some other criterion values in the range of one order of magnitude difference (0.1mm, 0.5mm and 1mm) to capture the arrival time. We notice larger criterion leads a visible shift of the arrival time from the time where wave amplitude starts to increase. Since, the recorded maximum amplitude of the most DARTs is only a few centimeters in the event, we decided to choose the relatively smaller value. Additionally, according to a description of DART II given by PMEL, the Dart buoy is quite sensitive to tiny change of the sea bottom pressure (~$2*10^{-7)}$ m, (Meinig et al., 2005).

Table 1: DART II performance characteristics

Characteristic	Specification
Reliability and data return ratio:	Greater than 80%
Maximum deployment depth:	6000 meters
Minimum deployment duration:	Greater than 1 year
Operating Conditions	Beaufort 9 (survive Beaufort 11)
Maintenance interval, buoy	Greater than 2 years
Maintenance interval, tsunameter	Greater than 4 years
Sampling interval, internal record:	15 seconds
Sampling interval, event reports:	15 and 60 seconds
Sampling interval, tidal reports:	15 minutes
Measurement sensitivity:	Less than 1 millimeter in 6000 meters; 2×10^{-7}
Tsunami data report trigger	Automatically by tsunami detection algorithm
	On-demand, by warning center request
Reporting delay:	Less than 3 minutes
Maximum status report interval:	Less than 6 hours

8. Response to comment 12, In this study, authors assumed the temperature is for low *elevation. While, I am not sure temperature in Eq. (2) originally proposed by Gossard and Hooke (1975) is for low or high elevation since Lamb wave is an atmospheric wave which should be elevation related.*

Author's response: Thanks. The equation is a solution of the momentum equations with zero vertical velocity, meaning that Lamb waves have purely horizontal motion, occupying the full depth of the troposphere and with a maximum pressure signal at the surface. These waves are only slightly affected by the Earth's rotation and travel at the speed of sound in the media (Gossard and Hooke, 1975). Therefore, the equation is not elevation related. The equation has been successfully applied in numerical simulation of air-sea coupling with Lamb waves of 2022 Tonga eruption (Amores et al., 2022).

9. Response to comment 14, These black lines are very much sensitive. As shown in Fig. 3, these lines, in fact, do not fit with the arrival times of the Lamb waves (black dots).

Author's response: The black lines are only used as a visual reference to help reader understand the velocity, not to fit the arriving time points. For example, in the third subplot, we can see most balck dotes are located between the lines of 320 m/s and 310 m/s meanwhile around the line of 315 m/s.

10. Response to comment 15, No bathymetry information in Chanaral Bay?

Author's response: Thanks. We have changed the color bar of bathymetry in Chanaral Bay in Figure S1 to present the bathymetric data more clearly.

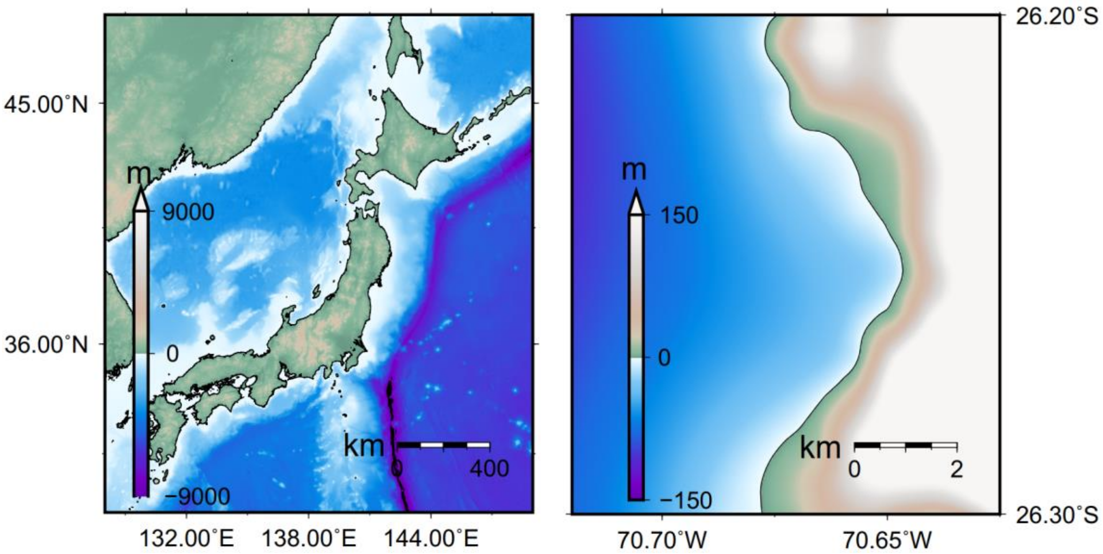


Figure S1. Bathymetry in Japan (a) and Chañaral bay (b) in Chile. Bathymetry data is downloaded from GEBCO (http://www.gebco.net).

11. Response to comment 17, In this sense, the ~10 h delays in New Zealand, Hawaii, and west coast of America are from which mechanism? edge wave? resonance? reflection?

Author's response: Thanks. It's hard to pinpoint which mechanism play a dominant role in a specific location. It requires more detailed analysis. In order to further investigate which mechanism is responsible for a specific location, well targeted modelling and field survey are needed. For example, through careful tsunami modelling and waveform analysis, (Rabinovich et al., 2006) suggest that most tsunami energy of the 2005 California tsunami and 1994 Shikotan tsunami in the western coast of America is trapped in the edge waves and propagated along the long coast with little energy loss. The trapped energy and the waveguide are mainly influenced by the irregular coastal shelves of the western coast of America.

12. Response to comment 18, Previous observations in Heidarzadeh & Satake (2013) should be generally from earthquake induced tsunami, the first wave thus is the maximum one in deep ocean (DART). However, Tonga tsunami was not induced by earthquake. Accordingly, the first wave was not the maximum one. Please do not mix various concepts.

Author's response: Thanks for the reminder, we have modified the related text to present the result in a more logical way.

Author's change to manuscript: We have modified the related content in the manuscript as "On the other hand, for tsunami events with earthquake origins (e.g. Heidarzadeh and Satake, 2013), the first waves recorded by DART buoys are normally observed as the largest wave since DART buoys are located in the deep sea and less influenced by bathymetric variation. In the case of Tonga tsunami event, we observe …."

13. Response to comment 25, If Fig. 7 could not support the discussion, it could be deleted. Anyway, discussions about the shock wave are not persuaded.

Author's response: Thanks for the suggestion. We actually have thought seriously about whether we should keep this part. We finally decided to keep the shock wave related discussion as it might have certain value for tsunami hazard research if such mechanism indeed exist. Although it is not that significant compared with the conspicuous Lamb wave-induced tsunami, the wave in New Zealand (Two columns on the left in Figure 7) is more conspicuous than those in the rest of the Pacific station (Two columns on the right in Figure 7). We think such observation is worth being mentioned and hopefully it can attract more attention to research the complex air-sea coupling mechanisms of fast-arriving tsunami waves.

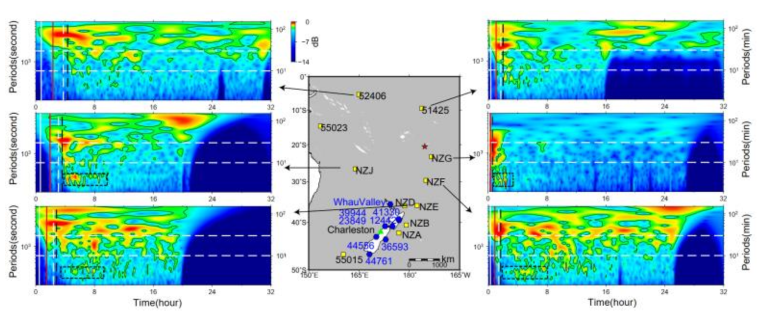
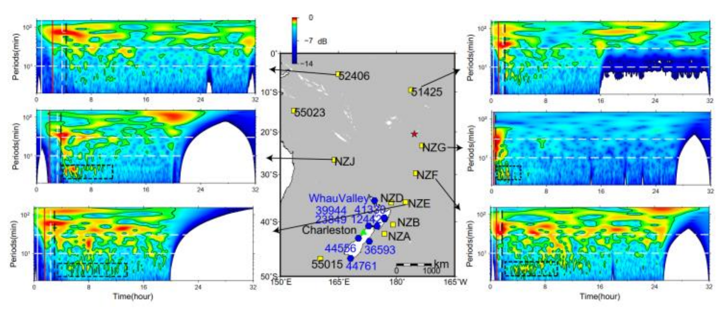
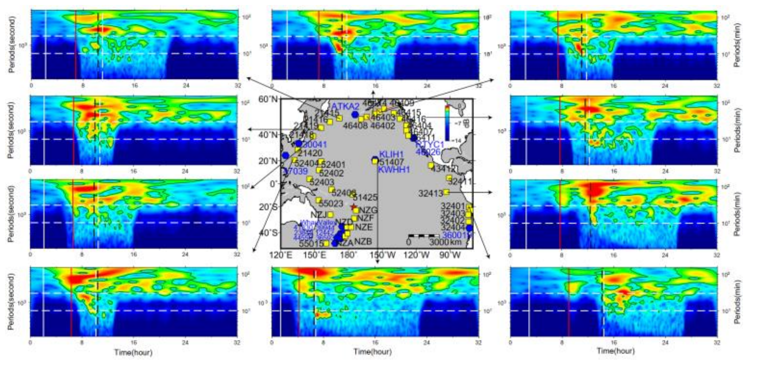
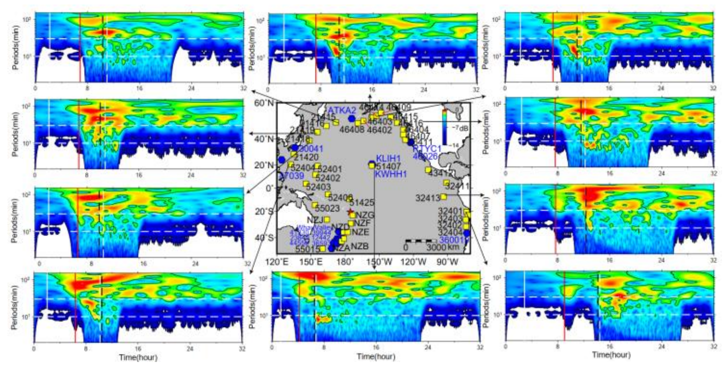
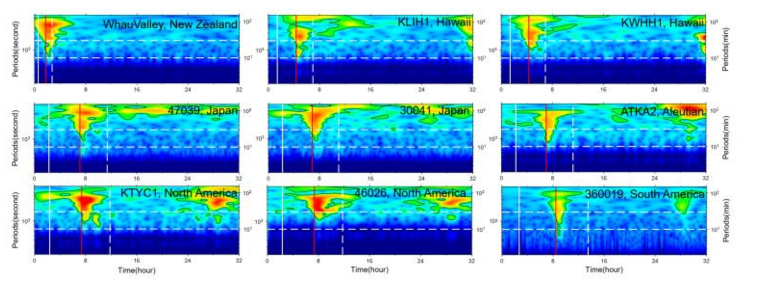
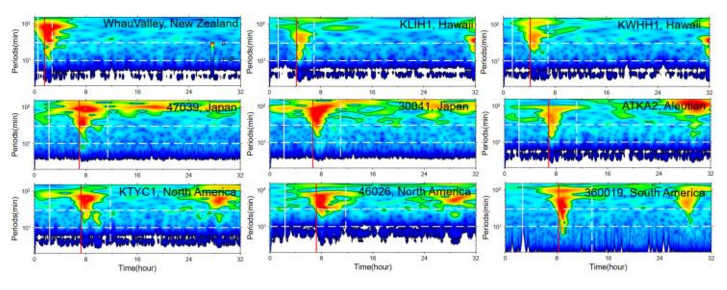
14. Response to comment 26, My comment is that descriptions in Lines 285-286 are not suitable since energy distribution in Figs. 5, 6, and 8 are in fact not consistent with each other.

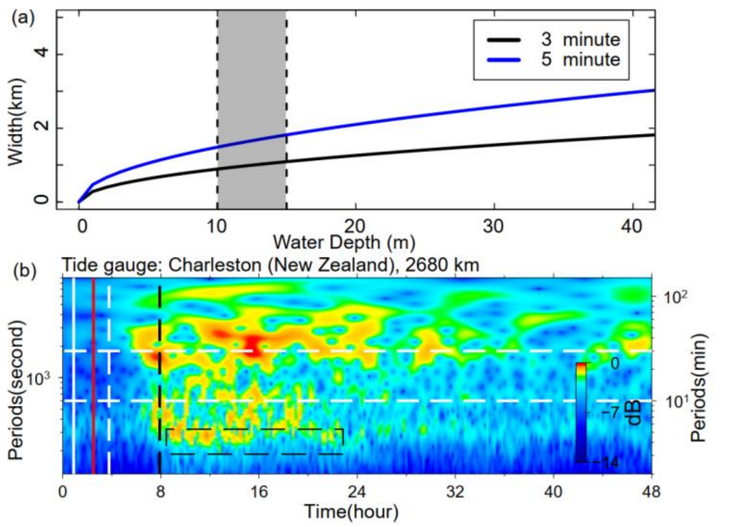
Author's response: Thanks. I agree with you that the three figures are not consistent in terms of the energy distribution. But here we only refer to the wave periods shown between the solid red line and dashed white line in Figure 6 and Figure 8. The consistency is reflected by both arrival times and wave periods.

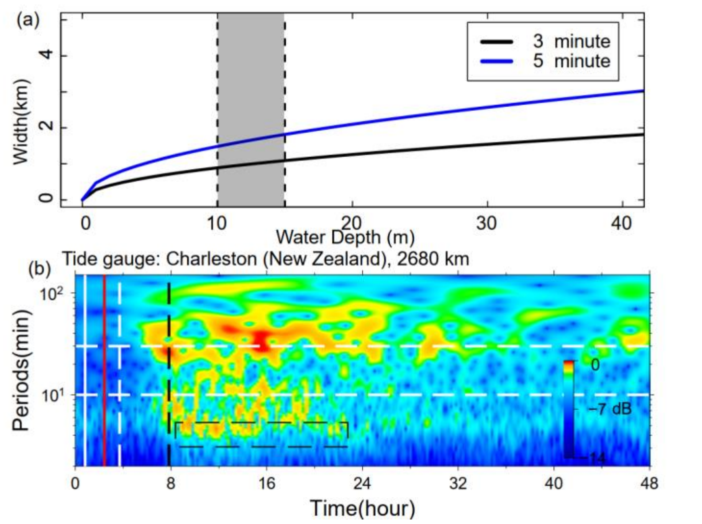
``15. Response to comment 27, Could not find the definition of 'dB' in the mentioned paper. Please specify clearly in the response. No need to use different units for left and right ordinates, which contaminates the proper understanding of the figure. Could authors show the original results with the blanked-out peripheral area of the spectrum? Why need to avoid the blanked-out peripheral area?

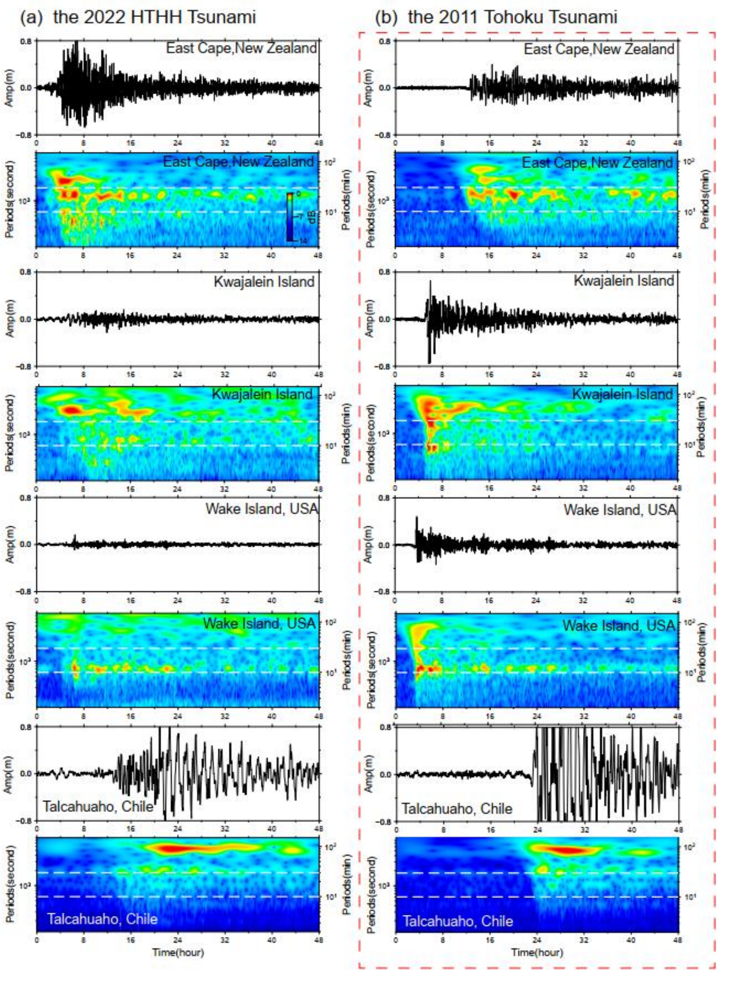
Author's response: Thanks. Decibel (dB) is calculated from: $dB = 10 \log(A/A_0)$, where A is wavelet power, A_0 is a reference wavelet power (Thomson and Emery, 2014). In this case, I choose maximum wavelet power as reference A_0. According to your suggestion, we have reconducted and updated all the results of wavelet analysis to single ordinate, including Figures 5, 6, 8, 9 and 11. We also have the figures updated to the original results with the blanked-out peripheral areas of the spectrum. Please refer to these figures below

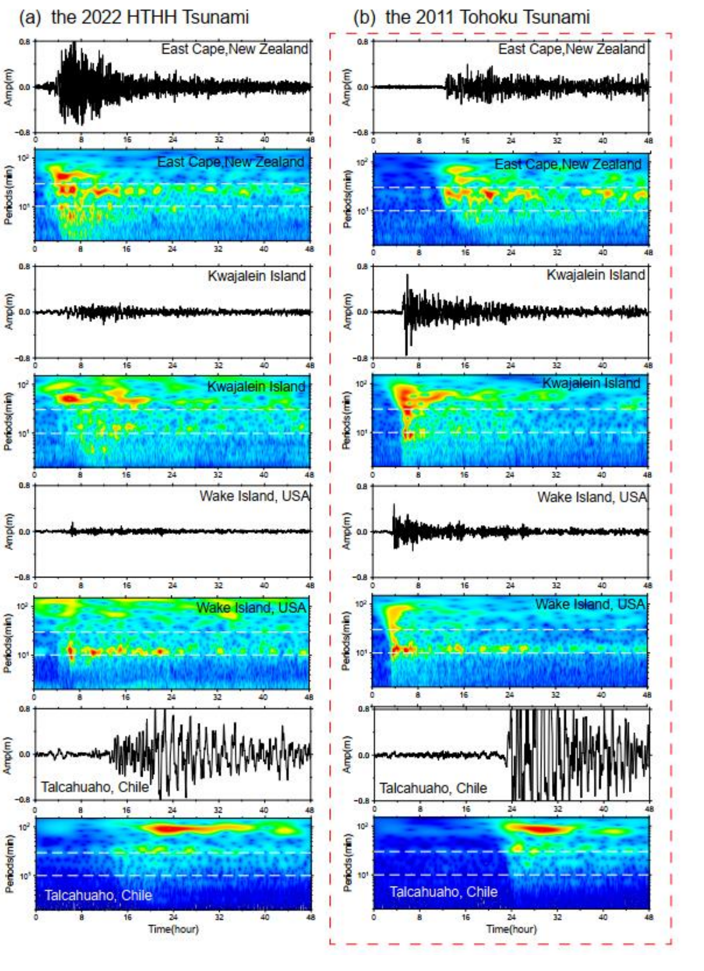
Author's change to manuscript: We have added the definition of dB in related content as: "Decibel (dB) is calculated from: dB = 10 log(A/A0), where A is wavelet power, A0 is a reference wavelet power of the maximum one (Thomson and Emery, 2014)."

Previous Figures 5, 6, 8, 9 and 11	**Updated** Figures 5, 6, 8, 9 and 11
	
	
	









16. Response to comment 28, Authors should answer this question directly, rather than leaving it to Rabinovich (1997).

Author's response: Thanks. This is a simplified model to build a quantitative relationship between source typical dimension (L) and tsunami period (T). The average depth (H) of the source area is used to calculate initial propagation velocity through $\sqrt{gH}$ (g is gravitational acceleration). The observed periods times the velocity equals initial periodic wavelength. The tsunami source only displaces half wavelength of water and another half is a result of water volume conservation. Therefore, the typical source dimension is only half of the initial periodic wavelength, forming the equation $L = \frac{T\sqrt{gH}}{2}$.

17. Response to comment 32, This is definitely wrong. To trigger the Proudman resonance, a very larger water depth is needed to make the tsunami propagation speed being close to the Lamb wave speed. This needs a water depth of about 10000 m, which is not prevail in the Pacific Ocean with an averaged water depth of 4000 m.

Author's response: Thanks. Yes, we agree with you that the Proudman resonance plays a negligible role in this event. We have adjusted our previous writing to clarify our point. The revised manuscript mainly emphasizes the possible contribution of the atmospheric gravity waves with slower propagation speed (~200-245 m/s). Besides the Lamb wave, Watanabe et al., 2022 detected internal Pekeris wave which propagate with a slower horizontal phase speed of ∼245 m/s and gravity waves with even slower propagation speed by analyzing radiance observations taken from the Himawari-8 geostationary satellite. Atmospheric waves with such speeds are more likely to resonant with the conventional tsunami waves and provide continuous energy supply (Kubota et al., 2022)..

Author's change to manuscript: We've modified the related text as: "The resonance effects between ocean waves and atmospheric waves could contribute to the long oscillation on coastlines. Besides the Lamb wave, Watanabe et al., 2022 detected internal Pekeris wave which propagate with a slower horizontal phase speed of ∼245 m/s and gravity waves with even slower propagation speed by analyzing radiance observations taken from the Himawari-8 geostationary satellite. Atmospheric waves with such speeds are more likely to resonant with the conventional tsunami waves and provide continuous energy supply (Kubota et al., 2022).

18. Response to comment 33, My question is to clarify the basic concepts of gravity wave, Lamb wave, and shock wave in the MS, rather than 'acoustic wave' and so on. In addition, should be 'Gossard and Hooke, 1975', not 'E.E. Gossard and W.H. Hooke, 1975'.

Author's response: Thanks. We have modified the part of content and present basic concepts of gravity wave, Lamb wave, and shock wave in the MS.

Author's change to manuscript: The added sentences in the Introduction section: "Atmospheric waves propagating in the atmospheric fluid are generated by different physical mechanisms (Gossard and Hooke, 1975). Lamb wave is a horizontally propagating acoustic waves in Lamb mode which is trapped at the earth's surface with group velocities close to the mean sound velocity of the lower atmosphere (e.g. Lamb, 1932). Atmospheric gravity wave is triggered when air molecules in the atmosphere are disturbed vertically other than horizontally (e.g. Le Pichon et al., 2010). Nonlinear propagation of atmospheric wave may cause period lengthening and the formation of shock-wave (Matoza et al., 2022). "

19. Response to comment 34, Since the trench is very much narrow and the tsunami propagation speed is very fast, there is no time for Proudman resonance to be fully functional to significantly increase the tsunami wave height.

Author's response: Thanks. We have modified this paragraph and the updated content added the contribution from the Pekeris resonant resonance mode. Please also refer to our response to comment 17.

Author's change to manuscript: We've modified the related text as: "The resonance effects between ocean waves and atmospheric waves could contribute to the long oscillation on coastlines. Besides the Lamb wave, Watanabe et al., 2022 detected internal Pekeris wave which propagate with a slower horizontal phase speed of ~245 m/s and gravity waves with even slower propagation speed by analyzing radiance observations taken from the Himawari-8 geostationary satellite. Atmospheric waves with such speeds are more likely to resonant with the conventional tsunami waves and provide continuous energy supply (Kubota et al., 2022). "

20. Response to comment 35, Appreciate if authors could present some new stuffs, rather than repeating some old understandings.

Author's response: Thanks. Please kindly refer to our response to comment 17 and 19.

21. Response to comment 37, Must be larger than 70 km. Iwate Prefecture is not so near to the epicenter. Please double check this.

Author's response: Thanks for the reminder. The 70 km we mentioned is the distance between epicenter and the eastern coast of Japan's Tohoku region. The largest run-up is observed in Tohoku's Iwate Prefecture, specifically at Miyako. To avoid confusion, we have modified the related content in the manuscript to make.

Author's change to manuscript: We have corrected the sentence as "In the near-field, the 2011 Tohoku earthquake produced runup up to 40 m at Miyako in the Iwate Prefecture in Japan's Tohoku region (Mori et al., 2011). The epicenter is approximately 70 km east coast of the Oshika Peninsula of Tohoku region."

22. Response to comment 39, What I want to point out here is that the long-lasting tsunami of 2022 HTHH and 2011 Tohoku event should come from the similar mechanisms, i.e., interactions between gravity wave and coastal bathymetry. Interactions between Lamb wave induced tsunamis and coastal bathymetry could be neglected.

Author's response: Yes, we agree with you.

23. Response to comment 42, This sentence is strange. What is the meaning of 'oscillation period of local bathymetry'? How can bathymetry oscillate? Please be serious with context description. In addition, do not talk about too many old stuffs, such as edge wave, reflection and so on. Appreciate some new understandings from the Tonga event.

Author's response: Thanks. "Oscillation period of local bathymetry" should be "free oscillation period of the local bathymetry". The free oscillation in a near-shore region possesses some eigen-modes of natural oscillations. The modes are closely associated with coastal geometry and bathymetry. We have checked the associated context in the manuscript and modified the description.

It's true that the potential hazard caused by edge waves, reflection and … is relatively well known. But the interesting observation we have here is the local effect still play a dominant role in tsunami behaviors even the driven forces are distinctly different (volcanic tsunami and seismogenic tsunami). We think it's the first time we can demonstrate such similarity with such abundant instrumental records of such a rare global volcanic tsunami event.

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