Response to RC2

7th January 2022

Dear Reviewer,

We sincerely thank you for the constructive comments that greatly helped us to improve the manuscript. Here we present our point-by-point responses and revision to the comments.

Sincerely,

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General Review Comments

This paper describes the source spectrum of the tsunamis generated by two earthquakes (Mw 7.4 and Mw 8.1) that occurred in the Kermadec subduction zone on 4 March 2021 using tsunami data recorded at tide gauges. The study produced the dominant wave period range for each event and the spectral ratio for the larger earthquake (second event) by utilizing the data from the smaller event (first event) as Green's Functions.

Comment 1

High-quality water level data at DART stations are available for this event. The DART stations are in the deep ocean which means the records are not affected by the coastal geomorphology, unlike tide gauges. It is not clear why the study is only using tide gauge but not DART data. I suggest the inclusion of spectral analysis of DART data in this study.

Response and Revision

We acknowledge that DART data provides important information. In general, the 1 min (or 15 s) data of DARTs are available for short times covering only a few tsunami waves and the rest of DART data has a large sampling interval of 15 min. Therefore, the length of DART data with 1 min (or 15 s) sampling is short, which cannot meet the requirement of spectral analyses. The spectral analyses of low-sampling data will miss high-frequency components. Therefore, we decided not to include DART data. In response to this comment, we added the reason.
In Line 73, we added:

‘We did not use the data from Deep-ocean Assessment and Reporting of Tsunamis (DARTs) tsunameters because the duration of high sampling mode (1 min or 15 s) is not long enough for spectral analyses and as a result, the spectra would be unreliable. We note that the DART data of these events were published by Romano et al. (2021).’

Comment 2

The paper provides the dominant wave period ranges for the first and second events. But what the meaning of those numbers is not explained. The dominant period ranged from 8 to 28 minutes for the Mw8.1 earthquake (the range is 7-28 min in lines 175-180, which one is the correct one). Is this a normal range for this kind of earthquake?

Response and Revision

Thank you for this comment. The energy ranges are slightly different when being calculated by different analyses (8–32 min for Fourier analysis, 8–30 min for EGF method, and 7–28 min for second/background noise), but they are generally consistent. In response to this comment, we added the following statements in the revised manuscript.

In Line 143, we added:

“Tsunami spectra can help identify the source size, potential asperities and other information about earthquake source processes. The dominant wave period ranges for tsunami events are related to the size of the source, which we explain in Section 5. Assuming the same water depths, tsunamis generated by earthquakes with larger source sizes normally have longer dominant wave periods. For example, the tsunami generated by the Mw 9.1 2004 Sumatra earthquake in the near-field region indicated dominance of long waves with periods of 30–60 min (Rabinovich et al., 2006).”

Comment 3

It is not clear how the period range was determined. Was it from the Fourier or the wavelet analysis? Lines 130-135 describe that the range was determined from the peak spectral power. But the peak for the first event at some of the stations like Owenga is longer than the upper limit of the 5-17 min range. Please indicate the peak at each station for each event with an inverted triangle in Figure 3.

Response and Revision

We chose the period ranges that are present and dominate in more than half of the stations. We acknowledge that the peak period range may not be exactly the same among all stations. In response to this comment, we made following revisions:

(1) We revised Figure 3, indicating the peak at each station for each event. We also listed the values in Table 1.

(2) In the caption of Figure 3, we added:

‘Green dots show the spectral peaks listed in Table 1.’

(3) In Line 139, we changed:

‘…the dominant periods range for the second tsunami is approximately ~~8–28~~ 8–32 min.’

(4) In Line 141, we added:

‘Regarding tsunami dominant period (or peak periods), here we chose the period range that more than half of the stations present as the dominant range.’

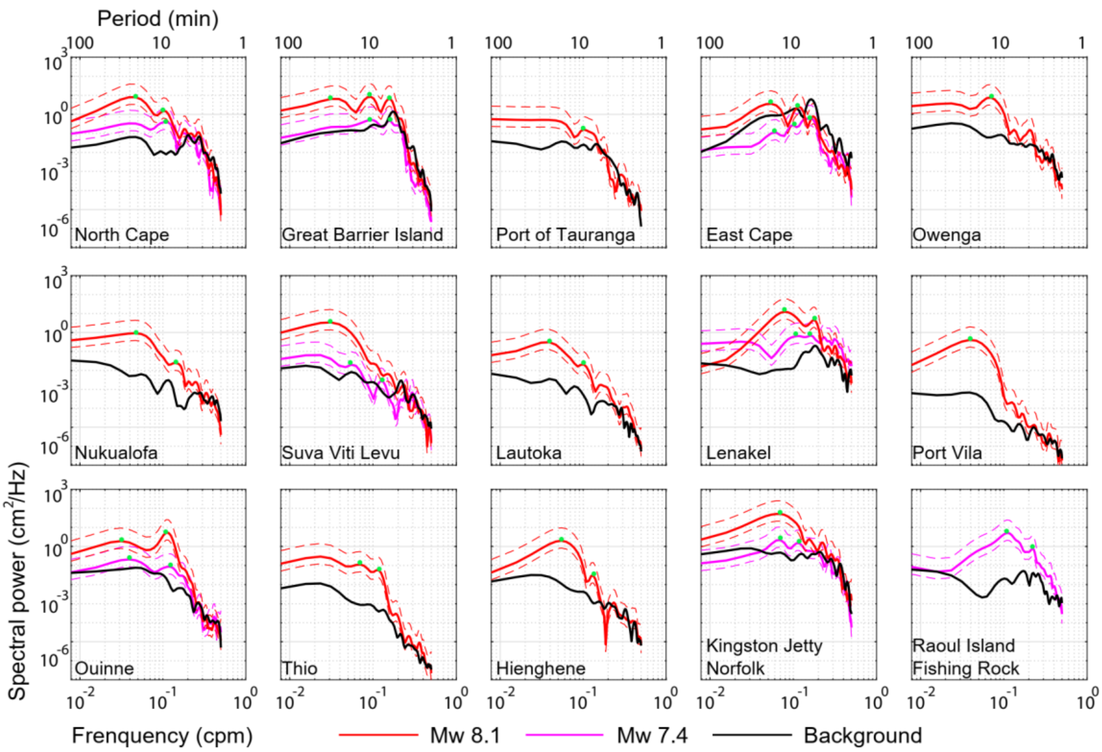

Figure 3: Fourier analyses for tsunamis generated by two successive earthquakes (M_w 7.4 and M_w 8.1) in Kermadec Islands. Pink and red curves represent the spectra of the first tsunami and the second tsunami, respectively. Green dots show the spectral peaks listed in Table 1. The 95% confidence bounds of two tsunami spectra are indicated by dashed curves. The background spectra (black curves) are also plotted for comparison.

Table 1: Peak periods at each tide gauge for two tsunami events. The values were calculated by Fourier analyses. Station name abbreviations are: North Cape (NC), Great Barrier Island (GBI), East Cape (EC), Suva Viti Levu (SVL), Kingston Jetty Norfolk (KJN), Port Vila (PV), and Raoul Island Fishing Rock (RIFR).

Tide gauge	**Peak period(s) for the first tsunami (min)**	**Peak period(s) for the second tsunami (min)**
NC	9.1	9.8; 21.3
GBI	6.5; 10.7	6.4; 10.7; 32.0
PT	N/A	9.8
EC	6.1; 9.8; 16.0	8.5; 18.3
Owenga	N/A	14.2
Nukualofa	N/A	7.1; 21.3
SVL	8.0; 18.3	32.0
Lautoka	N/A	9.8; 25.6
Lenakel	6.1; 8.5	5.6; 12.8
PV	N/A	25.6
Ouinne	8.5; 25.6	9.1; 32.0
Thio	N/A	8.5; 14.2
Hienghene	N/A	7.5; 18.3
KJN	8.5; 14.2	14.2
RIFR	4.6; 9.1	N/A

Comment 4

Similarly, the period range determination using the wavelets is also not so clear. The period range for the second event detected at Ouinne was 20-30 min. But the paper finally concluded the period range of 8-28 min for the second event. Was the period at Ouinne simply ignored? Moreover, if we chose the peaks in the Ouinne wavelet using the contours, we would get a range of 10-30 min instead of 20-30 min. Please provide a table with the range for each station.

Response and Revision

Thank you for this observation. We agree that adding a table of peak periods will help and therefore we added a table. Similar to the response to Comment 3, we chose the period range that more than half of the stations present as the dominant range, instead of a single station. We acknowledge that the peak period range may not be exactly same among all stations. In addition, we also note that wavelets and Fourier analyses give spectral results with varying degrees of accuracies. In response to this comment, we made the following revisions:

(1) We added a table with the range for each station (Table 1).

(2) In Line 143, we added:

‘In Table 1, we listed the peak periods at each tide gauge for the two tsunamis.’

(3) In Line 175, we added:

‘In addition, we also note that wavelets and Fourier analyses give spectral results with varying degrees of accuracies, because wavelet analysis also incorporates the time evolution and thus its spectra are not usually as detailed as those obtained by Fourier analyses.’

Comment 5

Figure 4: Provide purple and red boxes for the other tide stations.

Response and Revision

We acknowledge that this item would add to the clarity of the paper. Therefore, we added purple and red boxes to stations NC, GBI, Lenakel, Ouinne, and KJN.

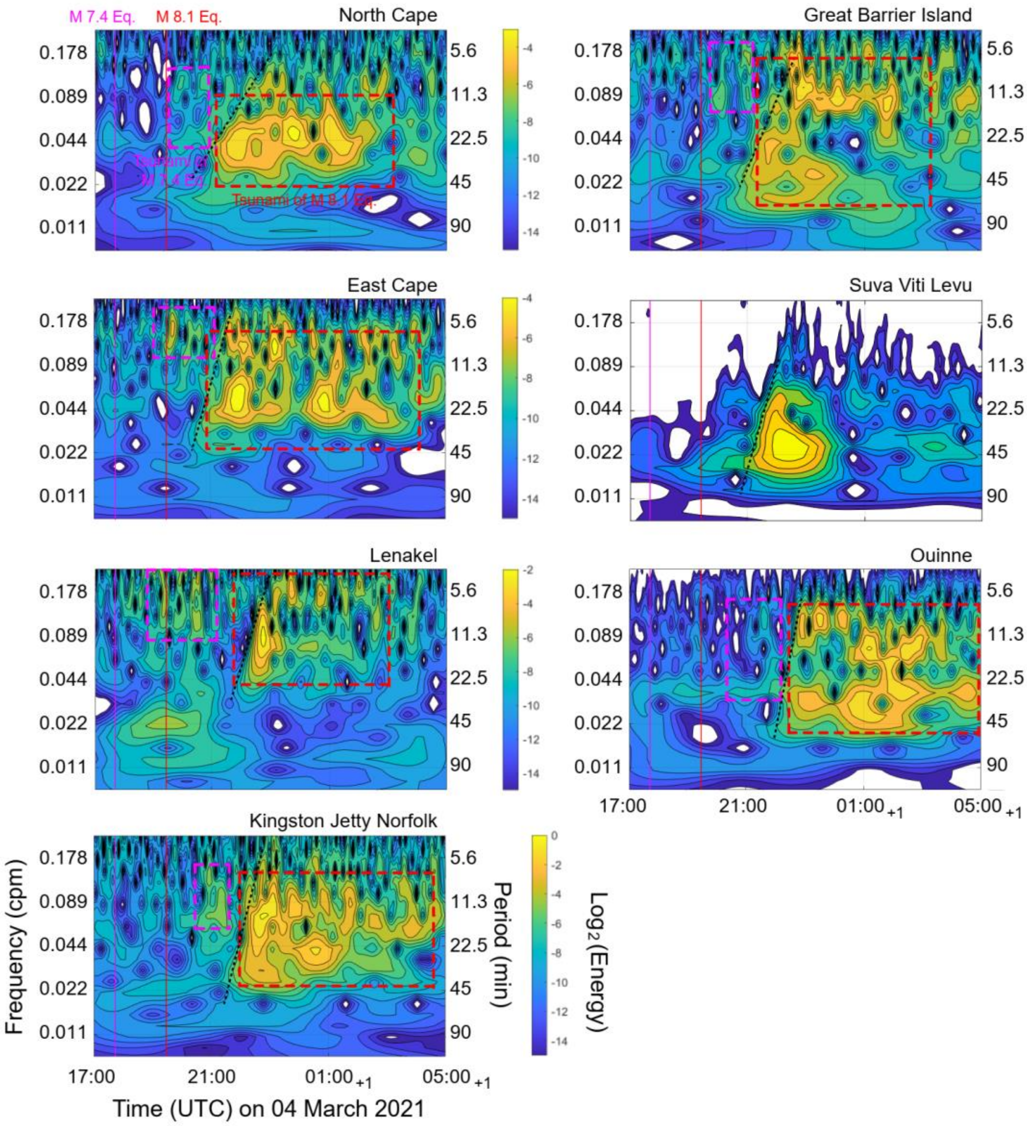

Figure 4: Wavelet (frequency-time) analyses for tsunamis generated by two successive earthquakes (M_w 7.4 and M_w 8.1) in Kermadec Islands. The colormap shows levels of spectral energy at different times and periods. For guidance, we marked the dominant periods of two tsunamis by pink (M_w 7.4) and red (M_w 8.1) rectangles ~~at East Cape~~. The pink and red vertical lines show the origin times of the M_w 7.4 and M_w 8.1 earthquakes, respectively. The dispersion curves are plotted by black dashed lines. On the horizontal axis, plus one (+1) indicates one day passed.

Comment 6

Lines 185-190: the paper argues that the spectral analysis validates the USGS source model. But the calculation of the model source periods used the total fault length and width instead of the dimension of the main slip region, which is about 120 km long and 120 km wide. Outside this main slip region, the slip amounts are almost zero, so the total fault dimension should not be used in the calculation.

Response and Revision

We agree. Here the L in Equation (1) is the size of tsunami source. The size is related to the surface displacement, which may not be equal to the size of fault slip region. In the revised manuscript, we consider only the non-zero displacement region as reviewer suggest. Our investigation of the USGS source model shows that the non-zero displacement region is approximately 210 km x 170 km (https://earthquake.usgs.gov/earthquakes/eventpage/us7000dflf/finite-fault).

In Line 213, we changed:

'However, the non-zero displacement region is approximately 210 km × 170 km (https://earthquake.usgs.gov/earthquakes/eventpage/us7000dflf/finite-fault). The average water depth in the source area is ~ 5,000 m. Hence, the first three source periods of the short axis (width) using the analytical equation (Eq. 1) are ~~28.6 min, 14.3 min, and 9.5 min~~ calculated as 25.6 min, 12.8 min, and 8.5 min. ~~The first three source periods of the long axis (length) are 36.1 min, 18.1 min, and 12.0 min. The source periods of the short axis match well with the peaks of tsunami source spectrum, which confirms the validity of the model geometry.~~ These values are consistent with the results of spectral analyses of the observed waves based on the EGF and tsunami-to-background spectral ratio methods (Figures 5c; 5d) showing peak periods at 25.6 min, 16.0 min and 9.8 min (8.5 min).'

Comment 7

Provide the spectral ratios from the simulated waveforms and then compare them with the observed ones.

Response and Revision

We agree that it is useful to compare simulated tsunami spectra with observed ones. However, we lack detailed bathymetry around the tide gauges and thus it is difficult to accurately simulate the waveforms at each station. Hence, we are not sure whether adding simulated spectra would help and therefore in this study we only rely on observed tsunami waveforms for spectral analyses.

Comment 8

Error bars are required for Figure 5c and 5d.

Response and Revision

In response to this comment, we added error bars to Figures 5c and 5d.

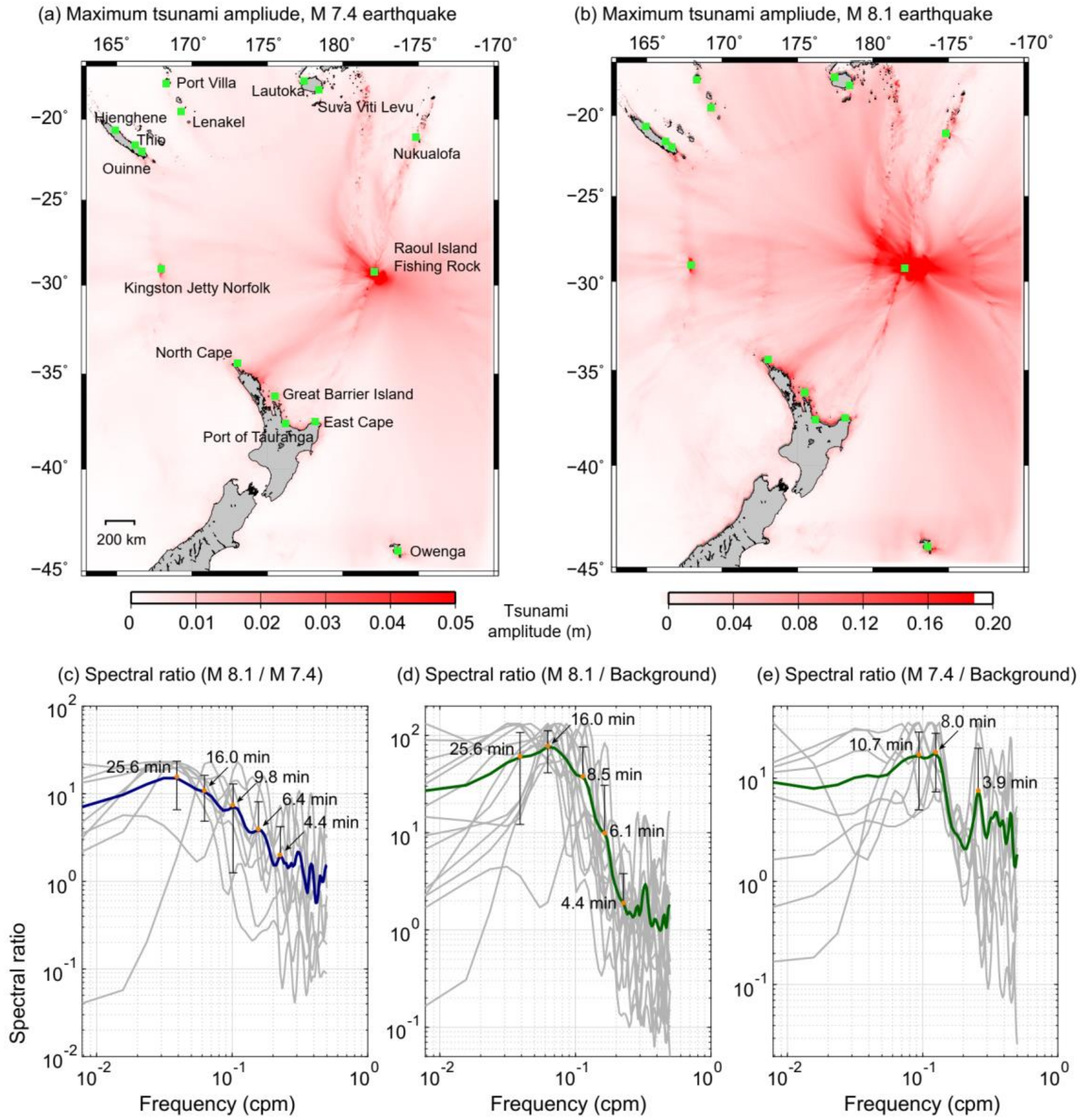

Figure 5: (a, b) Maximum simulated amplitudes for two tsunamis during the entire simulation time. The source models used for numerical simulation are from the USGS. (c) Spectral ratio of two tsunamis by dividing the spectral energy of the second tsunami to that of the first tsunami (EGF method). Blue curve is the normalized average of tsunami spectral energy at different tide gauges. (d) Spectral ratio of the second tsunami spectrum to the background signal spectrum. Green curve is the normalized average of different tide gauges. (e) Spectral ratio of the first tsunami spectrum to the background signal spectrum. Green curve is the normalized average of different tide gauges.