Geophysical Research Letters

Supporting Information for

Enigmatic tsunami waves amplified by repetitive source events in the southwest of Torishima Island, Japan

Osamu Sandanbata[1†], Kenji Satake[1], Shunsuke Takemura[1], Shingo Watada[1], and Takuto Maeda[2]

[1] Earthquake Research Institute, the University of Tokyo, Tokyo, Japan.

[2] Graduate School of Science and Technology, Hirosaki University, Aomori, Japan.

Contents of this file

Introduction

This Supporting Information contains supplementary figures and tables, to support our conclusions documented in Main Text.

Supplementary figures (mentioned in Main Text)

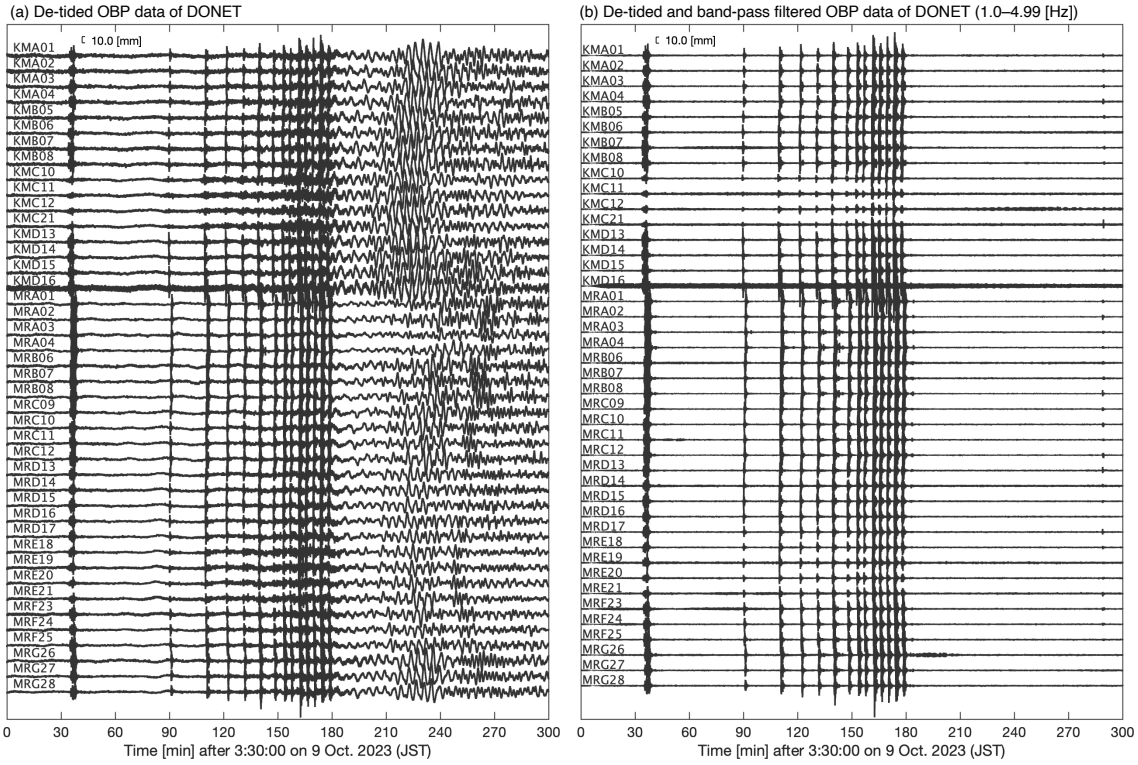

Figure S1. Data of OBP gauges of DONET after 3:30:00 on 9 October 2023 (JST). (**a**) Data after removing the tidal component by polynomial approximation. (**b**) Data after the tidal-trend removal and the band-pass filtering (1.0–4.99 Hz), in the frequency range where T-phase is dominant.

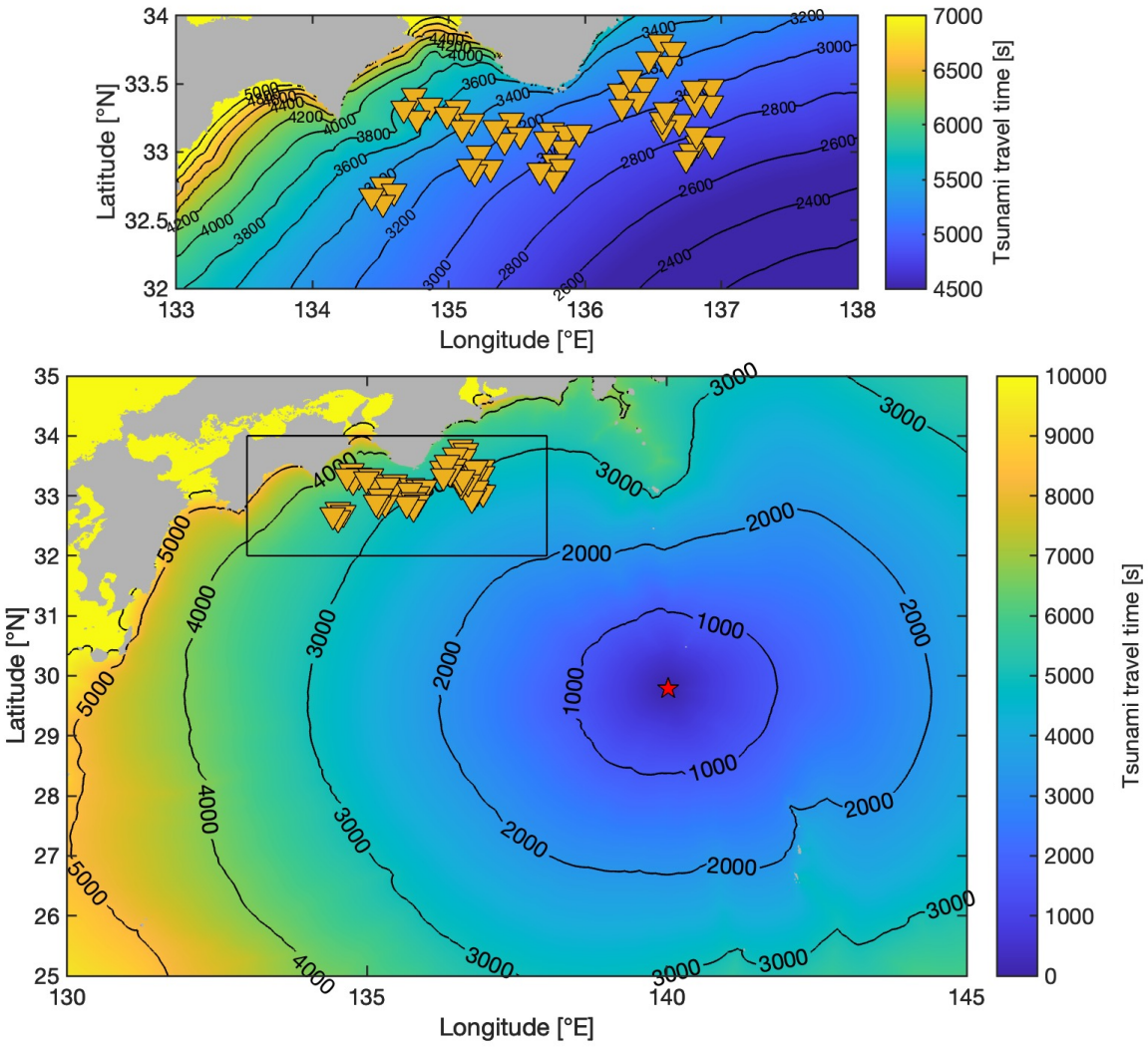

Figure S2. Tsunami travel time from the location of the largest earthquake (Se12 at 6:17:30, 140.026°E, 29.787°N), computed by the Geoware TTT (Tsunami Travel Time) software. A red star and orange inverted triangles represent the locations of Se12 and DONET stations, respectively. The bathymetry data of JTOPO30 is used for the computation. See Table S2 for the travel time information.

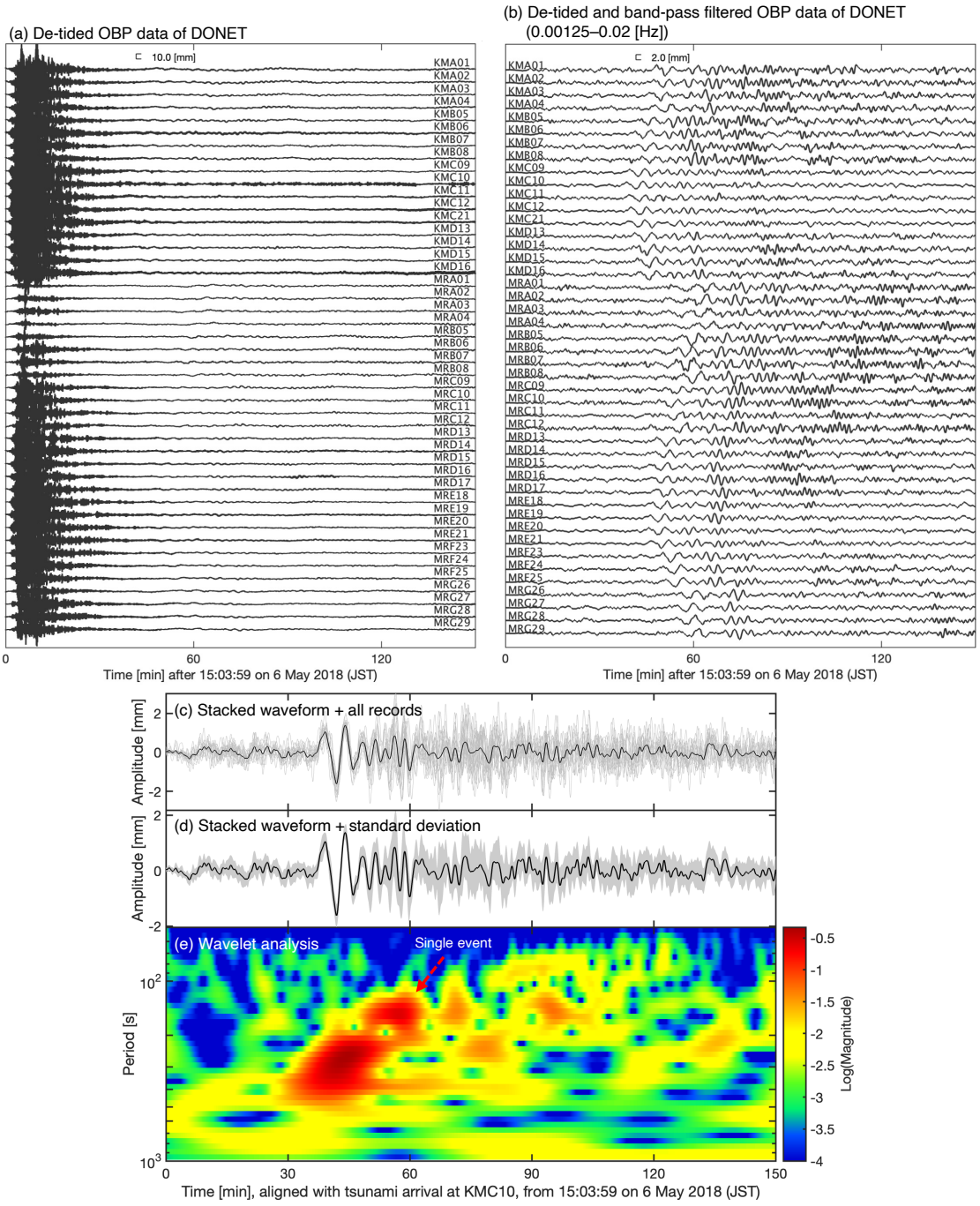

Figure S3. Same as Figures 2 and 3 in Main Text, but for the Sumisu Caldera earthquake (M_w 5.4) at 15:03:59 on 6 May 2018 (JST). For the waveform stacking, we compute the tsunami travel time from the source location at the center of Sumisu Caldera (140.05°E, 31.48°E). Compared to those of the data on 9 October 2023, the tsunami duration is shorter (note the difference in time length scale). Also, only a single wave train is found in the wavelet analysis result; later phases after ~60 min with smaller amplitudes are possibly due to reflected or refracted waves.

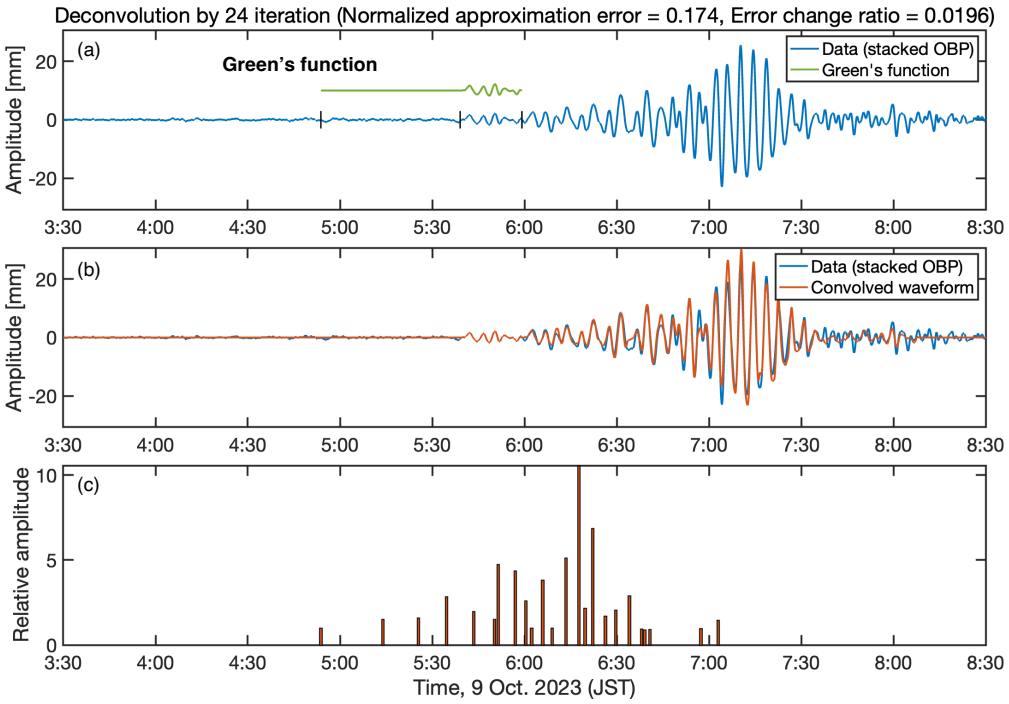

Figure S4. Estimation of the tsunami source time function by the iterative deconvolution (24 times) only. **a** and **b** follow the captions of those in Figure 4. The normalized approximation error is 0.174. (**c**) Tsunami STF, without the least-squares method.

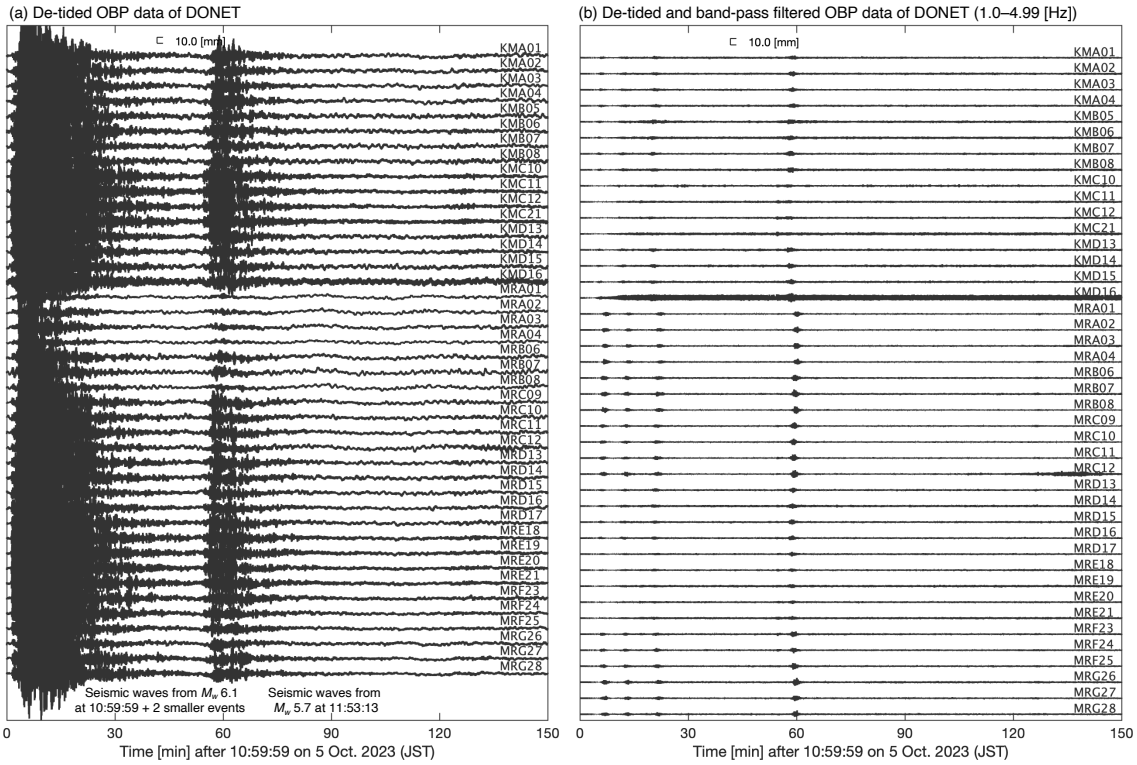

Figure S5. Same as Figure S1, but for the M_w 6.1 at 10:59:59 on 5 October 2023 (JST). Note that, compared to the sequence on 9 October (Figure S1), the earthquakes on 5 October show stronger seismic signals in the non-filtered record (**a**), while signals in the frequency range of 1–4.99 Hz, where T-phase are dominant, are smaller (**b**).

Supplementary Tables

Table S1. Information of the seismic event swarm in the southern region of Torishima Island on 9 October 2023 (JST), reported in the USGS catalog. Note that shallow source depths may not be determined accurately, which can be even shallower.

Earthquake event #	Time, JST	Latitude [°N]	Longitude [°E]	Depth [km]	Magnitude	Event interval [s]
Se01	3:58:10	30.1221	139.8780	10	4.3	–
Se02	4:53:46	29.6904	140.0613	10	4.5	3336
Se03	5:13:51	29.7099	140.0704	10	4.7	1205
Se04	5:25:23	29.7105	139.9298	10	4.9	692
Se05	5:34:33	29.7181	139.9904	10	4.7	550
Se06	5:43:09	29.7256	140.2201	10	4.8	517
Se07	5:51:26	29.7700	139.9186	10	4.7	496
Se08	5:56:48	29.8249	139.9328	10	4.9	323
Se09	6:00:42	29.8125	140.0184	10	5.0	233
Se10	6:05:34	29.7580	140.0207	10	5.3	292
Se11	6:13:29	29.7887	140.0434	10	5.1	475
Se12	6:17:30	29.7869	140.0260	10	5.4	241
Se13	6:21:42	29.7824	139.9375	10	4.9	253

Table S2. Station lists of DONET. In the 5th and 6th columns, tsunami travel times computed by the Geoware TTT software, and the data availability is shown, respectively. "Stacking" in the 6th column represents the available data that are used for the waveform stacking.

DONET1						DONET2					
#	Station code	Longitude [°E]	Latitude [°N]	Tsunami travel time [s]	Availability	#	Station code	Longitude [°E]	Latitude [°N]	Tsunami travel time [s]	Availability
1	M.KMA01	136.5570	33.8048	3323	Stacking	23	M.MRA01	134.7449	33.4085	3771	Available
2	M.KMA02	136.6488	33.7524	3260	Stacking	24	M.MRA02	134.8641	33.3393	3659	Available
3	M.KMA03	136.6037	33.6484	3199	Stacking	25	M.MRA03	134.7691	33.2490	3648	Available
4	M.KMA04	136.4674	33.6781	3262	Stacking	26	M.MRA04	134.6723	33.3205	3751	Available
5	M.KMB05	136.9264	33.4772	2991	Stacking	27	M.MRB05	135.0667	33.3222	3530	–
6	M.KMB06	136.9216	33.3584	2907	Stacking	28	M.MRB06	135.1698	33.2252	3407	Available
7	M.KMB07	136.8072	33.3613	2935	Stacking	29	M.MRB07	135.0964	33.1755	3401	Available
8	M.KMB08	136.8039	33.4664	3014	Stacking	30	M.MRB08	134.9869	33.2750	3542	Available
9	M.KMC09	136.8313	33.0584	2758	–	31	M.MRC09	135.4584	33.2280	3269	Available
10	M.KMC10	136.9335	33.0533	2732	Stacking	32	M.MRC10	135.5249	33.1251	3167	Available
11	M.KMC11	136.7790	33.0033	2739	Stacking	33	M.MRC11	135.4121	33.0837	3181	Available
12	M.KMC12	136.8188	33.1279	2797	Stacking	34	M.MRC12	135.3414	33.1752	3278	Available
13	M.KMC21	136.7417	32.9506	2719	Stacking	35	M.MRD13	135.7557	33.1594	3103	Available
14	M.KMD13	136.6903	33.2201	2880	Stacking	36	M.MRD14	135.8584	33.1359	3052	Available
15	M.KMD14	136.5770	33.1727	2875	Stacking	37	M.MRD15	135.9586	33.1420	3021	Available
16	M.KMD15	136.5631	33.2331	2923	Stacking	38	M.MRD16	135.8401	33.0299	3001	Available
17	M.KMD16	136.5958	33.3045	2964	Stacking	39	M.MRD17	135.7144	33.0915	3074	Available
18	M.KME17	136.4451	33.4850	3137	–	40	M.MRE18	135.7747	32.9270	2964	Available
19	M.KME18	136.3828	33.3860	3078	–	41	M.MRE19	135.8336	32.8920	2929	Available
20	M.KME19	136.2564	33.4459	3158	–	42	M.MRE20	135.7733	32.8017	2908	Available
21	M.KME20	136.3325	33.5444	3205	–	43	M.MRE21	135.6670	32.8603	2969	Available
22	M.KME22	136.2702	33.3303	3068	–	44	M.MRF22	135.2250	32.9879	3201	–
						45	M.MRF23	135.3082	32.8827	3108	Available
						46	M.MRF24	135.1916	32.8545	3133	Available
						47	M.MRF25	135.1538	32.8919	3169	Available
						48	M.MRG26	134.5167	32.7615	3366	Available
						49	M.MRG27	134.5996	32.7089	3301	Available
						50	M.MRG28	134.5164	32.6251	3312	Available
						51	M.MRG29	134.4334	32.6752	3373	–

Table S3. Tsunami source time function composed of repetitive tsunami source events, estimated by the iterative deconvolution (24 times) and the least-square method. Note that the iterative deconvolution initially determines an event at 6:19:44, but because the additional least-squares method re-determines the source amplitude as zero, we remove it from the event list.

Tsunami event #	Time, JST	Ampllitude relative to Ts01	Event interval [s]
Ts01	4:53:45	1.00	–
Ts02	5:13:57	1.50	1211.8
Ts03	5:25:30	1.56	692.4
Ts04	5:34:38	2.50	548.0
Ts05	5:43:32	2.45	534.5
Ts06	5:50:11	1.47	399.2
Ts07	5:51:27	4.46	75.9
Ts08	5:56:59	3.86	331.4
Ts09	6:00:23	3.54	204.8
Ts10	6:02:18	1.09	115.0
Ts11	6:05:56	4.47	217.2
Ts12	6:09:02	1.39	186.8
Ts13	6:13:27	5.48	264.7
Ts14	6:17:44	6.60	256.7
Ts15	6:22:08	5.74	264.0
Ts16	6:26:19	2.50	251.4
Ts17	6:29:44	1.63	205.2
Ts18	6:34:07	1.87	262.6
Ts19	6:38:06	1.56	238.9
Ts20	6:39:04	1.09	58.4
Ts21	6:40:45	1.53	101.1
Ts22	6:57:21	1.08	995.9
Ts23	7:02:58	1.74	337.1

Table S4. T-phase events detected from the envelope of the UD component record of the OBS of KMB06 station. The event times (2nd column) are calculated by shifting backward the maximum amplitude times at the station (4th column) by the travel time for the source-station distance between Se02 and KMB06 at a typical T-phase speed of 1.5 km/s.

T-phase event #	T-phase event time, JST	Max. amplitude [nm/s] of T-phase at KMB06	Time of max. T-phase amplitude at KMB06, JST	Starting time of T-phase at KMB06, JST	Ending time of T-phase at KMB06, JST	Duration [s] of T-phase at KMB06	Event interval [s]
Tp01	4:00:49	2.18.E+03	4:06:18	4:03:48	4:08:48	299.85	–
Tp02	4:54:14	1.58.E+04	4:59:43	4:59:20	5:00:58	98.00	3205.2
Tp03	5:14:06	2.34.E+04	5:19:35	5:19:23	5:22:04	161.35	1191.5
Tp04	5:25:41	2.20.E+04	5:31:10	5:30:55	5:32:39	104.05	695.4
Tp05	5:35:09	1.65.E+04	5:40:38	5:40:07	5:42:00	112.55	568.0
Tp06	5:43:53	3.35.E+04	5:49:22	5:48:45	5:52:09	204.60	524.0
Tp07	5:51:53	1.88.E+04	5:57:22	5:56:59	5:59:55	176.15	479.8
Tp08	5:57:05	2.82.E+04	6:02:34	6:02:22	6:05:22	180.25	311.7
Tp09	6:00:55	2.36.E+04	6:06:24	6:06:14	6:08:53	159.20	230.1
Tp10	6:05:47	4.83.E+04	6:11:16	6:11:05	6:14:22	197.40	292.0
Tp11	6:09:56	3.66.E+04	6:15:25	6:14:47	6:17:55	187.25	249.7
Tp12	6:13:43	3.85.E+04	6:19:12	6:18:53	6:21:59	186.25	226.2
Tp13	6:17:43	6.23.E+04	6:23:12	6:23:00	6:26:29	209.00	240.1
Tp14	6:22:28	2.55.E+04	6:27:57	6:26:58	6:30:19	201.50	285.1

Table S5. Source events on 9 October 2023 in the southwest of Torishima Island, detected commonly based on analyses of data of T-phases, seismic waves (the USGS catalog), and tsunami waves. The time is in JST. We exclude tsunami events Ts06 and Ts10, which are very close in time to a larger event.

Event #	T-phase event		Seismic event		Tsunami event	
EV01	Tp01	4:00:49	Se01	3:58:10	–	–
EV02	Tp02	4:54:14	Se02	4:53:46	Ts01	4:53:45
EV03	Tp03	5:14:06	Se03	5:13:51	Ts02	5:13:57
EV04	Tp04	5:25:41	Se04	5:25:23	Ts03	5:25:30
EV05	Tp05	5:35:09	Se05	5:34:33	Ts04	5:34:38
EV06	Tp06	5:43:53	Se06	5:43:09	Ts05	5:43:32
EV07	Tp07	5:51:53	Se07	5:51:26	Ts07	5:51:27
EV08	Tp08	5:57:05	Se08	5:56:48	Ts08	5:56:59
EV09	Tp09	6:00:55	Se09	6:00:42	Ts09	6:00:23
EV10	Tp10	6:05:47	Se10	6:05:34	Ts11	6:05:56
EV11	Tp11	6:09:56	–	–	Ts12	6:09:02
EV12	Tp12	6:13:43	Se11	6:13:29	Ts13	6:13:27
EV13	Tp13	6:17:43	Se12	6:17:30	Ts14	6:17:44
EV14	Tp14	6:22:28	Se13	6:21:42	Ts15	6:22:08