

Softening and Recovery of Near-surface Layers During the 2024 M7.6 Noto Earthquake

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Introduction

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Text S1 – Directionality of H/V spectral peaks.

In the main text of the paper, we determine the magnitude and azimuth of the predominant directionality of H/V spectral peaks (equations (5) and (7)). Here, we provide an extended description of these measures.

First, let us summarize the concept of the predominant site-specific directionality shown in [Figure S3](#). In the idealistic case of the laterally layered medium, soils and soft rocks exhibit a one-dimensional (1D) resonance pattern. In such a case, there is no predominant directionality of H/V spectral peaks, and differences between two perpendicular horizontal components of ground motion are caused by source and path terms only (the site term is independent of the backazimuth). Hence, the use of Transverse and Radial horizontal components is favorable. However, real geological structures have non-planar shapes, and the two-dimensional (2D) resonance pattern can be observed close to basin edges and faults (e.g., Matsushima et al., 2017). The two-dimensional resonance of the basin infill can have various modes, and very common is the anti-plane shear mode caused by incident *SH* waves (e.g., Bard & Bouchon, 1985). In such cases, the H/V spectral peaks have systematically the largest values in the horizontal direction parallel to the basin edge or tectonic fault. Note, that the predominant directionality is caused by the site term only, not to be confused with the source directivity. To distinguish site-specific predominant directionality and source and path terms, one should evaluate the ground motions in cardinal directions (E–W, N–S, SE–NW, and NE–SW horizontal components) from several earthquakes with sufficient backazimuth diversity.

The used measures of the predominant directionality of H/V spectral peaks are the directional dependency factor γ (Matsushima et al., 2017, equation (5)) and the azimuth ϑ defined by equation (7). To provide a deeper understanding of these measures, we can compare synthetic values of the H/V spectral peaks in [Figure S4](#). The site has a 1D resonance pattern if the maximal directional dependency factor $\gamma_{\max}(f_l) = 0$, and significant 2D resonance pattern if $\gamma_{\max}(f_l) > 1$. The azimuth ϑ signifies the horizontal direction with the largest predominant directionality.

Text S2 – Inversion of nonstationary H/V spectral peaks.

In the main text of the paper, we invert the nonstationary H/V spectral peaks observed during the 2024 M_j 7.6 Noto earthquake (Figure 9) in order to retrieve model parameters of theoretical functions $\alpha(t)$ and $\beta(t)$. The resultant maximum likelihood model parameters are summarized in Table 2. Here, we provide an extended description of the inversion procedure.

The observed data (i.e., the input of the inversion) are represented by the time-dependent relative change in H/V peak frequency $\delta f_l(t)$ from equation (11). Because the picking was performed in all horizontal directions, the observed data vector $\mathbf{d}_{obs}$ consists of time samples from all picked horizontal components

$$\mathbf{d}_{obs} = \left(\overbrace{\delta f_l(t)}^{\text{E-W}}, \overbrace{\delta f_l(t)}^{\text{N-S}}, \overbrace{\delta f_l(t)}^{\text{SE-NW}}, \overbrace{\delta f_l(t)}^{\text{NE-SW}} \right). \quad (\text{S1})$$

The vector of simulated predictions $\mathbf{d}_{sim}$ is computed by theoretical functions $\alpha(t)$ and $\beta(t)$ defined by respective equations (13) and (14) for a given set of model parameters $\mathbf{m} = \{m_\alpha, m_\beta, m_t, m_c\}$ that is denoted as

$$\mathbf{d}_{sim} = g(\mathbf{m}), \quad (\text{S2})$$

in which $g(\cdot)$ is a forward operator. In this forward problem, theoretical functions $\alpha(t)$ and $\beta(t)$ are used in the softening ($t < t^*$) and recovery phases ($t > t^*$), respectively, in which t^* is the time when the extreme frequency drop δf_l^* occurs. Then, the likelihood function $\mathcal{L}(\mathbf{d}_{obs}|\mathbf{m})$ is defined as

$$\mathcal{L}(\mathbf{d}_{obs}|\mathbf{m}) = \exp \left(-\frac{1}{2} \sum_{j=1}^J \left(\frac{d_{obs,j}}{\sigma_j} - \frac{d_{sim,j}}{\sigma_j} \right)^2 \right), \quad (\text{S3})$$

in which j is the index of the data points (total of J data points) and σ_j are estimated observed data errors (i.e., a standard deviation at the j th data point that is shown by errorbars in Figure 9). Next, the Bayesian formulation of the posterior probability density function $p(\mathbf{m}|\mathbf{d}_{obs})$ at a parameter space is given by

$$p(\mathbf{m}|\mathbf{d}_{obs}) \propto p(\mathbf{m}) \mathcal{L}(\mathbf{d}_{obs}|\mathbf{m}), \quad (\text{S4})$$

in which $p(\mathbf{m})$ is the prior probability of model parameters. Because we use the search for model parameters in a regular grid at the parameter space, the prior probability has an effectively uniform distribution, and the equation (S4) simplifies into

$$p(\mathbf{m}|\mathbf{d}_{obs}) \propto \mathcal{L}(\mathbf{d}_{obs}|\mathbf{m}). \quad (\text{S5})$$

The likelihood function $\mathcal{L}(\mathbf{d}_{obs}|\mathbf{m})$ is evaluated systematically in all sets of model parameters from a regular grid at the parameter space. Then, the best solution is the model with the maximal value of the likelihood function (i.e., the maximum likelihood solution that is summarized in Table 2). Further, in [Figure S27](#), we provide advanced statistics from the posterior marginal probability density function. It can be used for an estimation of the solution uncertainty.

Text S3 – Effects of the shear modulus change.

In the main text of the paper, the short- and long-lasting peak frequency changes at strongly shaking sites are attributed to changes in the shear modulus of near-surface layers. The S -wave velocity change is a consequence that is expressed by equation (19). Here, we investigate the effect of the shear modulus change on variations in P - and S -wave velocities in detail.

In this test, we consider three geomaterials (granite, shale, and dry sand) with typical values of the shear modulus μ , mass density ρ , and bulk modulus K . These are just typical values that are not related specifically to the Noto Peninsula region. The values of the shear modulus are systematically perturbed, while other material properties are fixed on the reference values. Then, sets of perturbed material properties were used for the computation of S -wave velocity V_S by equation (18) and P -wave velocity V_P by

$$V_P = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}, \quad (\text{S6})$$

The resultant effects of the shear modulus change on P - and S -wave velocities are shown in [Figure S28](#). Indeed, the S -wave velocities are more sensitive to the shear modulus change than P -wave velocities. The ratio of relative velocity change (S - to P -waves) has values in the range of 4–5 for granite, 9–14 for shale, and 6–9 for dry sand. Also, the relative change of S -wave velocity rapidly and progressively changes (towards strong velocity drops), if the relative change of μ crosses the value of -60%.

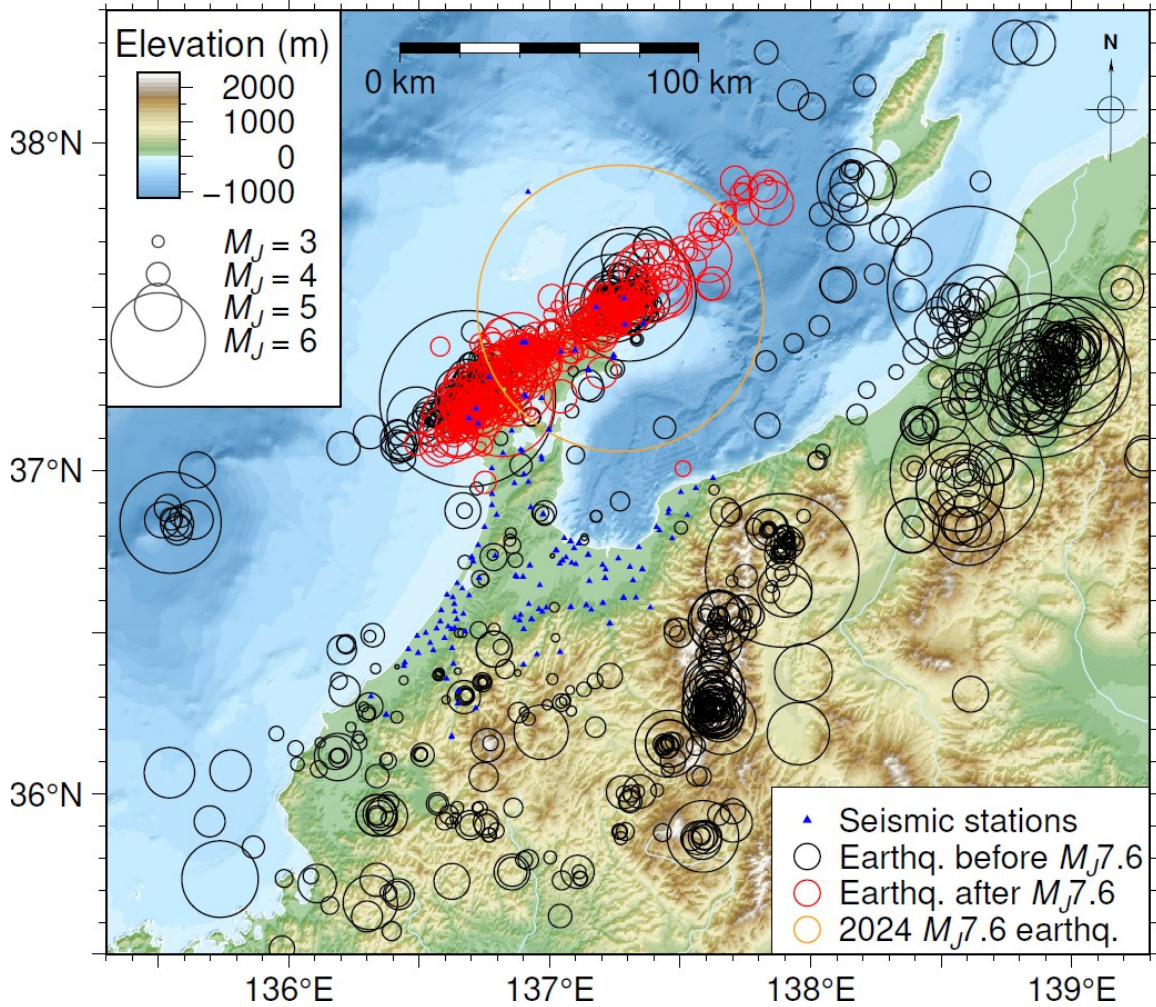


Figure S1. Earthquake waveform data – Map of the Noto Peninsula and surrounding areas in Japan with locations of used strong-motion monitoring stations (blue triangles), epicenters of processed earthquakes that occurred before the 2024 $M_J 7.6$ mainshock (black circles; from 1996 to 1 January 2024), and after the mainshock (red circles; from 1 to 4 January 2024). The circle size shows the earthquake magnitude determined by the Japan Meteorological Agency (JMA). Earthquake epicenters and magnitudes originate from the JMA unified earthquake catalog.

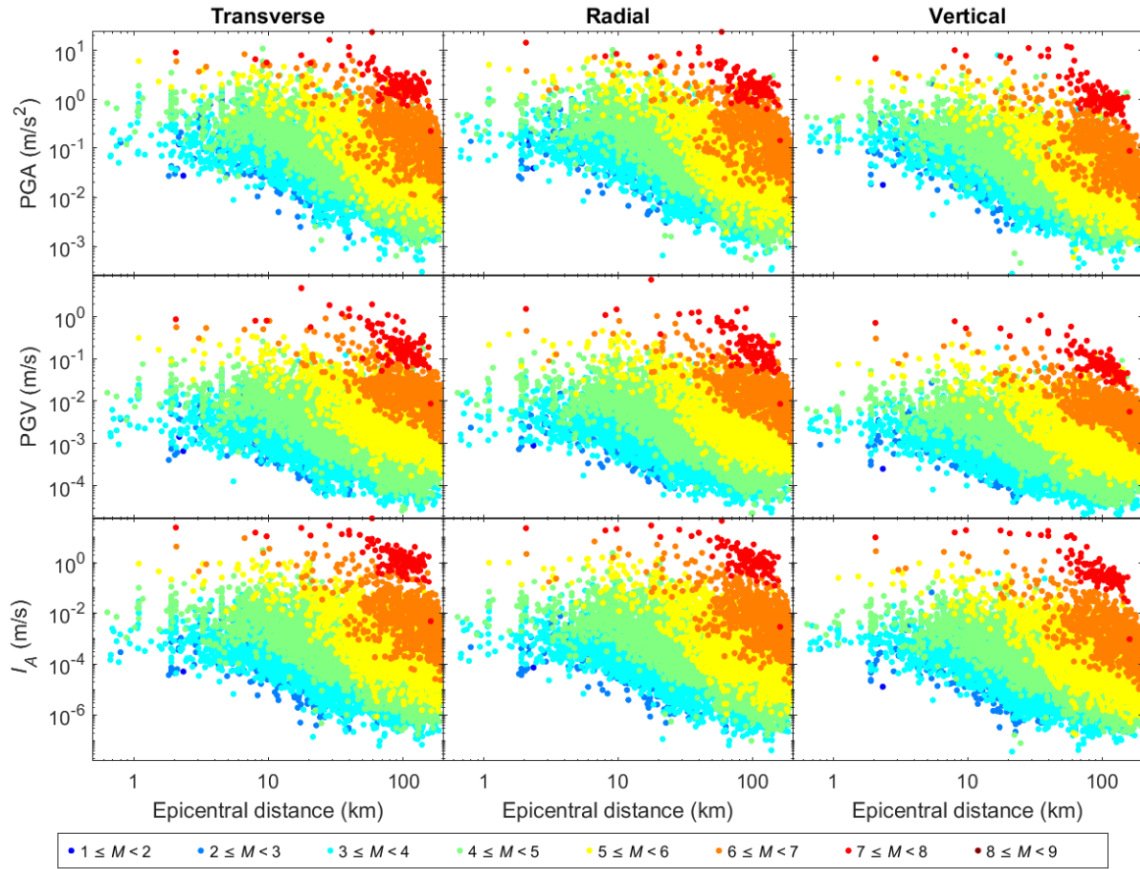


Figure S2. Earthquake waveform data – Statistics from the ground motion levels of earthquake waveforms recorded by strong-motion monitoring stations in Ishikawa and Toyama Prefectures in Japan. The ground motion levels are evaluated separately on Transverse horizontal (left panels), Radial horizontal (center panels), and Vertical (right panels) components. The shown ground motion characteristics are values of PGA (top panels), PGV (middle panels), and the total Arias intensity $I_A(T)$ evaluated by equation (9) (bottom panels). The earthquake magnitudes (shown by colors; see legend) originate from the JMA unified earthquake catalog.

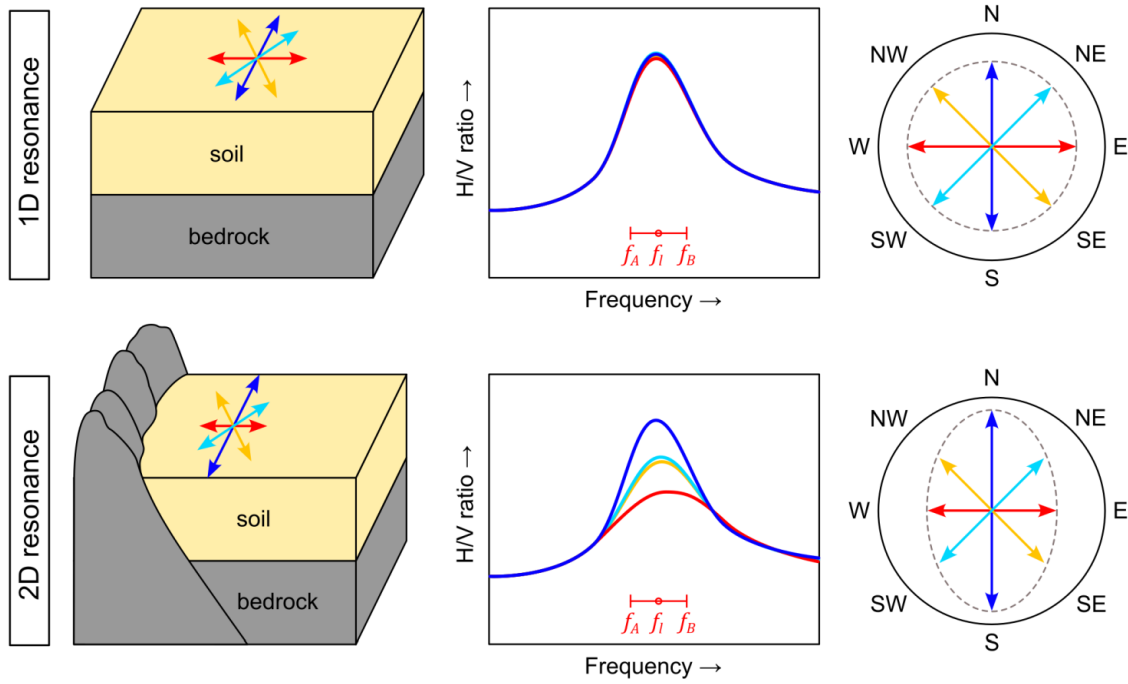


Figure S3. Directionality of H/V spectral peaks – Schematic drawing of the site-specific directionality phenomenon explained in [Text S1](#). The upper panels represent the one-dimensional (1D) site without resonance directionality, while the bottom panes show the two-dimensional (2D) site with significant resonance directionality in the N–S direction. The left panels are geological sketches with highlighted resonance amplitudes in horizontal directions (double-sided arrows). Center panels show H/V spectral ratios determined for individual horizontal directions at the ground surface. The right panels show values of the H/V spectral peak f_i as projected into the polar plot. Cutoff frequencies f_A and f_B are defined by equations (3) and (4).

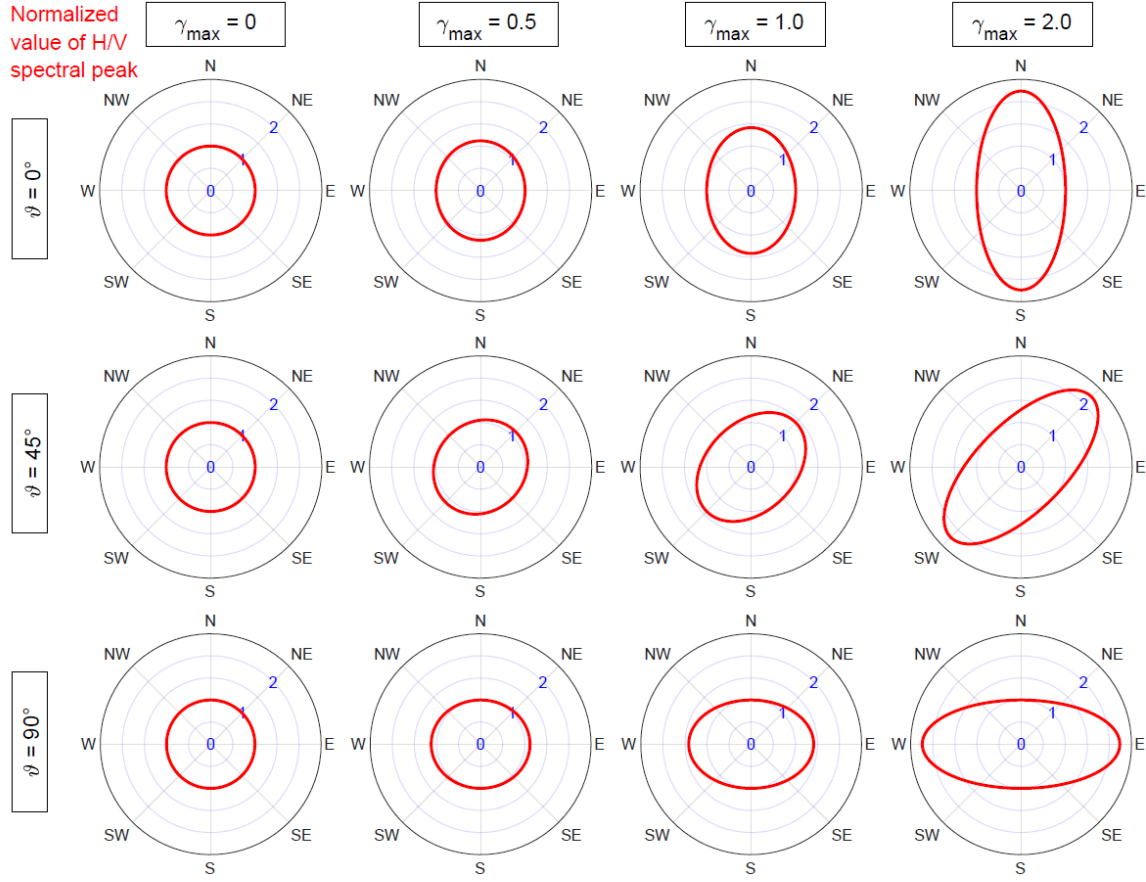


Figure S4. Directionality of H/V spectral peaks – Modeling of synthetic values of the H/V spectral peak for a given magnitude $\gamma_{\max}(f_l)$ and azimuth $\vartheta(f_l)$ of the predominant directionality, defined by equations (5) and (7), respectively, and explained in [Text S1](#). Modeled magnitudes $\gamma_{\max}(f_l) \in \{0, 0.5, 1, 2\}$ are shown in columns, while modeled azimuths $\vartheta(f_l) \in \{0^\circ, 45^\circ, 90^\circ\}$ are in rows. Synthetic values of H/V spectral peaks (red solid lines) are normalized by the smallest value and shown as dependent on the azimuth. The circle-like shapes have the meaning of 1D resonances, while eccentric ellipses signify 2D resonances.

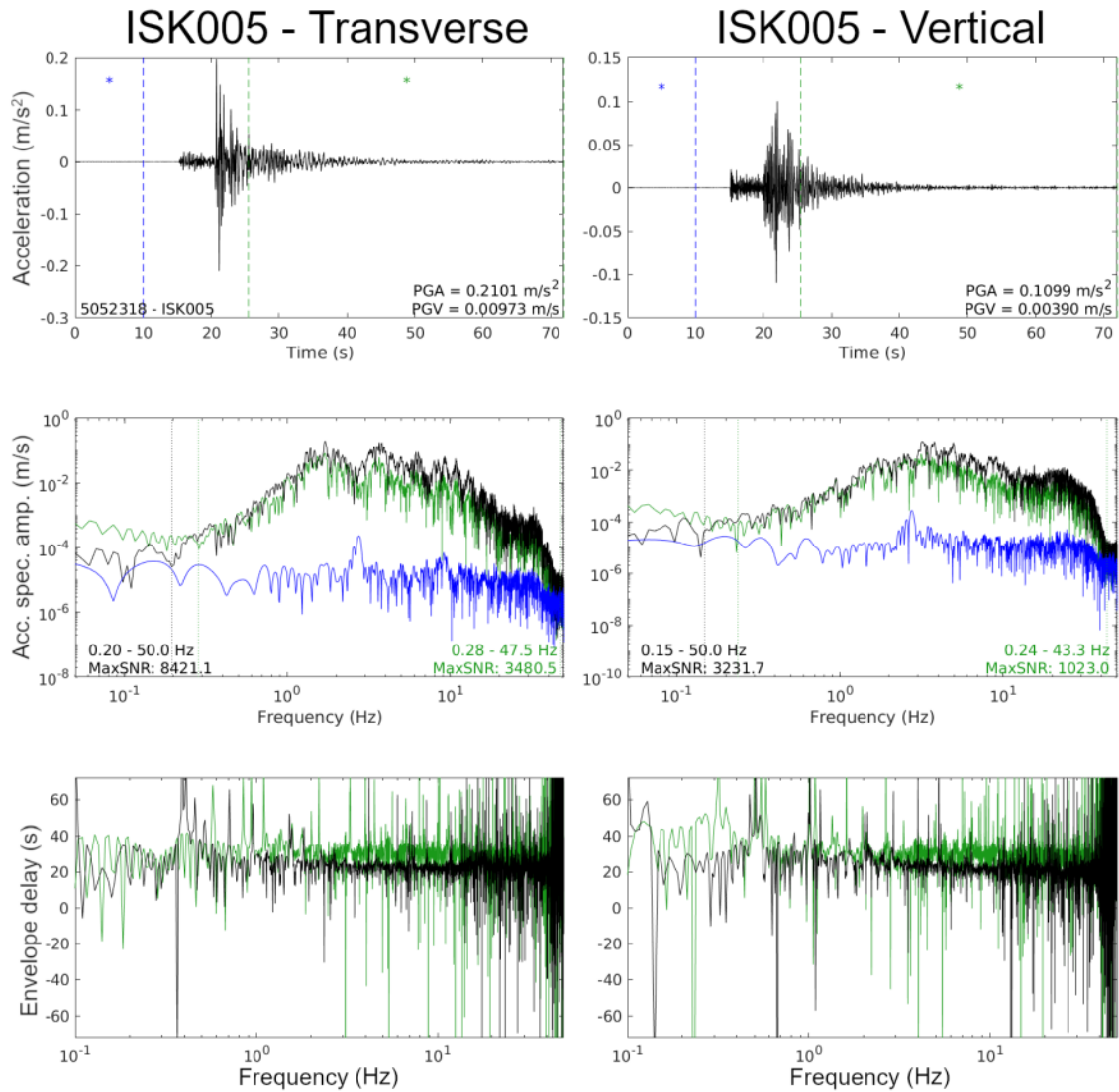


Figure S5. Example of earthquake waveform processing – Acceleration waveforms (upper panels), Fourier acceleration spectral amplitudes (middle panels), and spectral envelope delays (bottom panels) of a regional M_j 4.3 earthquake observed at ISK005 station (Anamizu Town). The M_j 4.3 earthquake occurred on 5 May 2023 at 23:18, and it has a hypocenter located at a depth of 14 km under Suzu municipality in Ishikawa Prefecture. The full wave (black), coda wave (green), and noise (blue) time windows were processed separately, which allows us to determine the frequency range of the useful signal that is above the noise level. Envelope delays are spectral phase shifts relative to the starting time of the record at 0.0 s. The H/V spectral ratios are subsequently computed as ratios between Fourier amplitudes from Horizontal (Transverse in this example) and Vertical components.

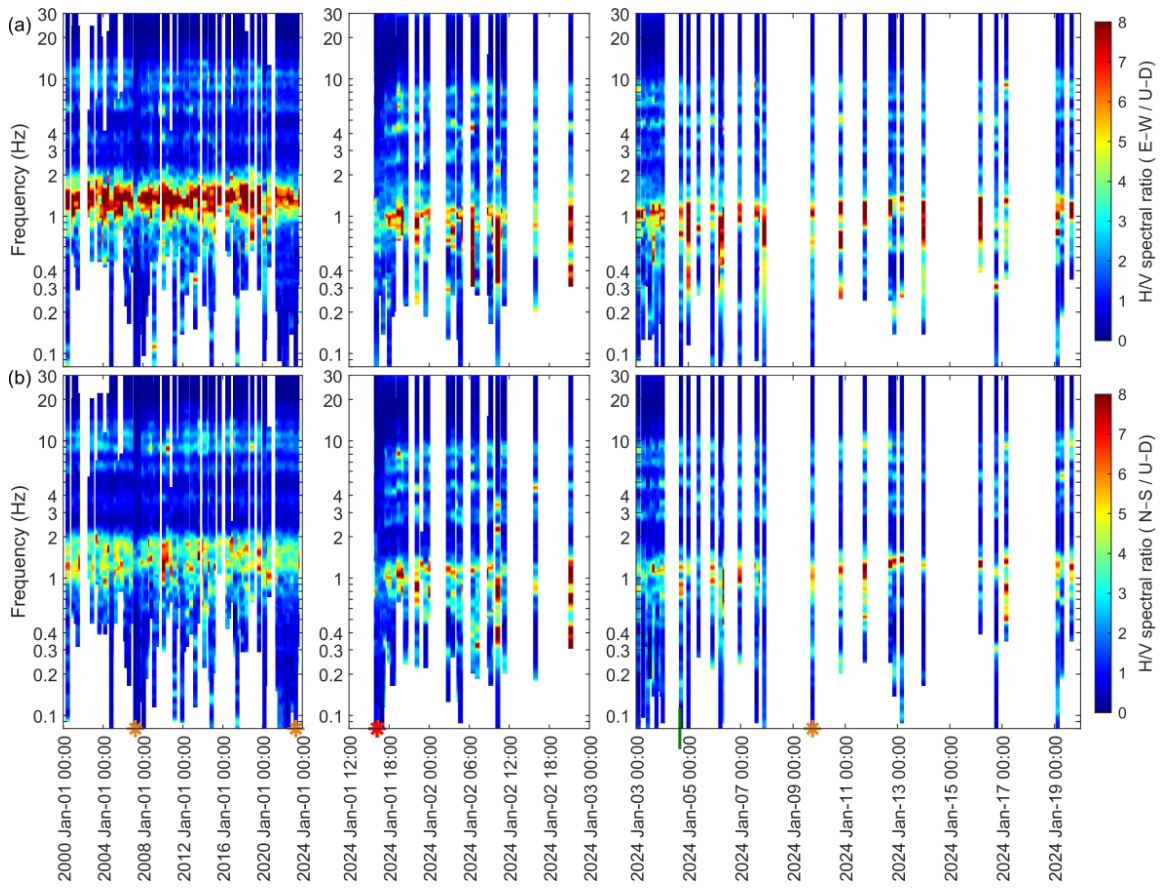


Figure S6. Example of the temporal evolution of H/V spectral ratio at the ISK005 site (Anamizu Town). The H/V spectral ratio is evaluated for full records of individual earthquakes by equation (1) from (a) E–W and (b) N–S horizontal components. The left panels show the period before the 2024 M_j 7.6 Noto earthquake (2000–2024), the center panels show the period of 0–32 hours after the mainshock, and the right panels show 32–440 hours after the mainshock. The H/V spectral ratio for a single earthquake is shown by one colored column. The color has the meaning of a non-normalized H/V value (see colorbar). On the time axis in Japan Standard Time, the 2024 M_j 7.6 mainshock at 16:10 is marked by red asterisk, orange asterisks are significant regional events with $M_j > 6$ (25 March 2007, 5 May 2023, 1 January 2024, and 9 January 2024), and the green mark shows the time of 72 hours (3 days) after the mainshock.

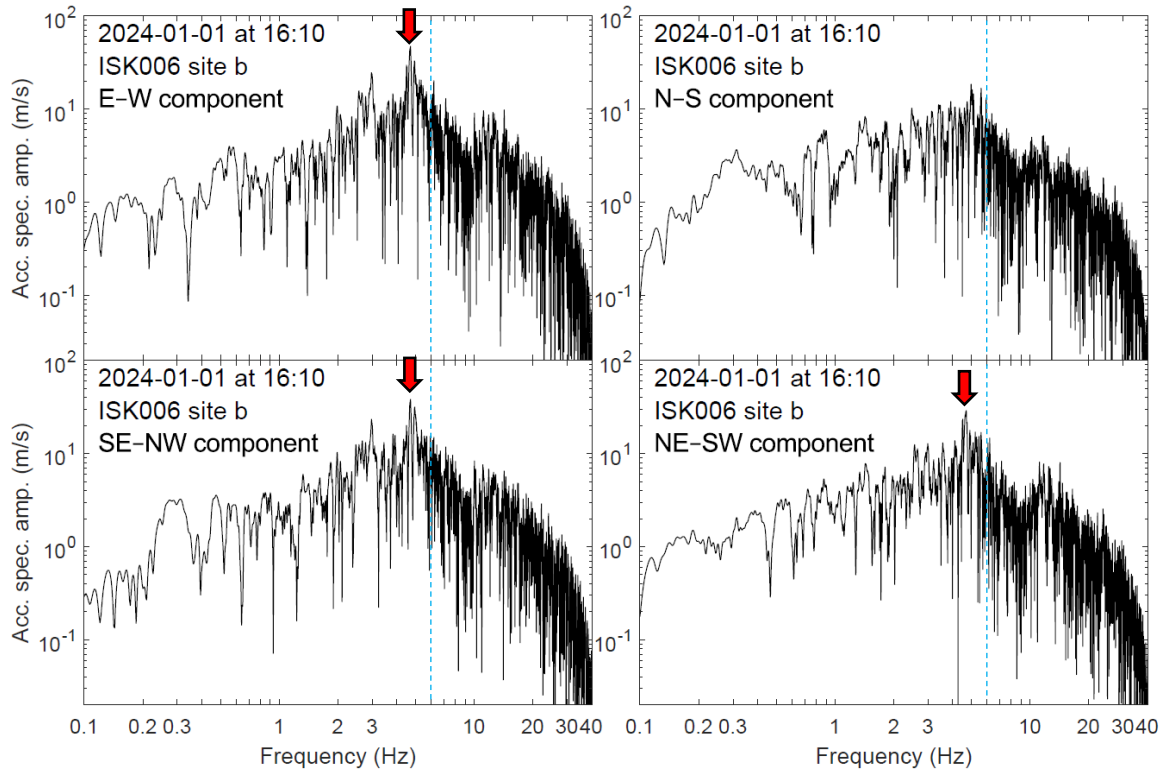


Figure S7. Fourier acceleration spectra, which were observed during the 2024 M_j 7.6 Noto earthquake at the ISK006 station, location b (Shika municipality in Ishikawa Prefecture). The station measured the largest PGA value for this earthquake (maximal horizontal PGA of 26.8 m/s^2). Individual panels show Fourier acceleration spectra of different horizontal components (E–W and N–S, and rotated into SE–NW and NE–SW, see text in panels). The frequency of the largest Fourier acceleration amplitude peak at 4.7 Hz is highlighted by the red arrow. The blue dashed line is the predominant frequency of site-specific H/V peak at 6.01 Hz before the mainshock.

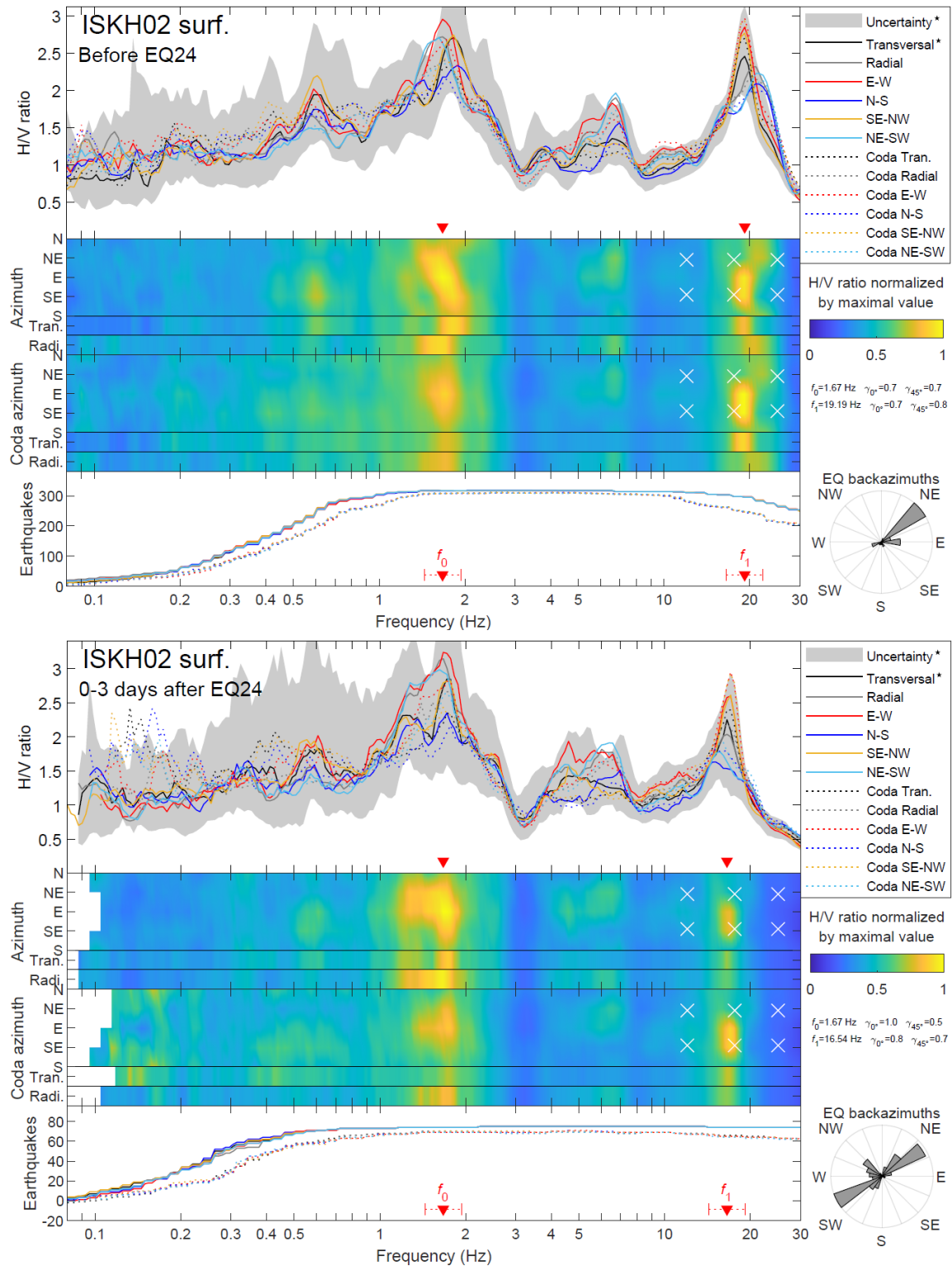


Figure S8. Long-lasting change – Directionally dependent H/V spectral ratios at the ISKH02 site (surface sensor) before (upper panels) and 0–3 days after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

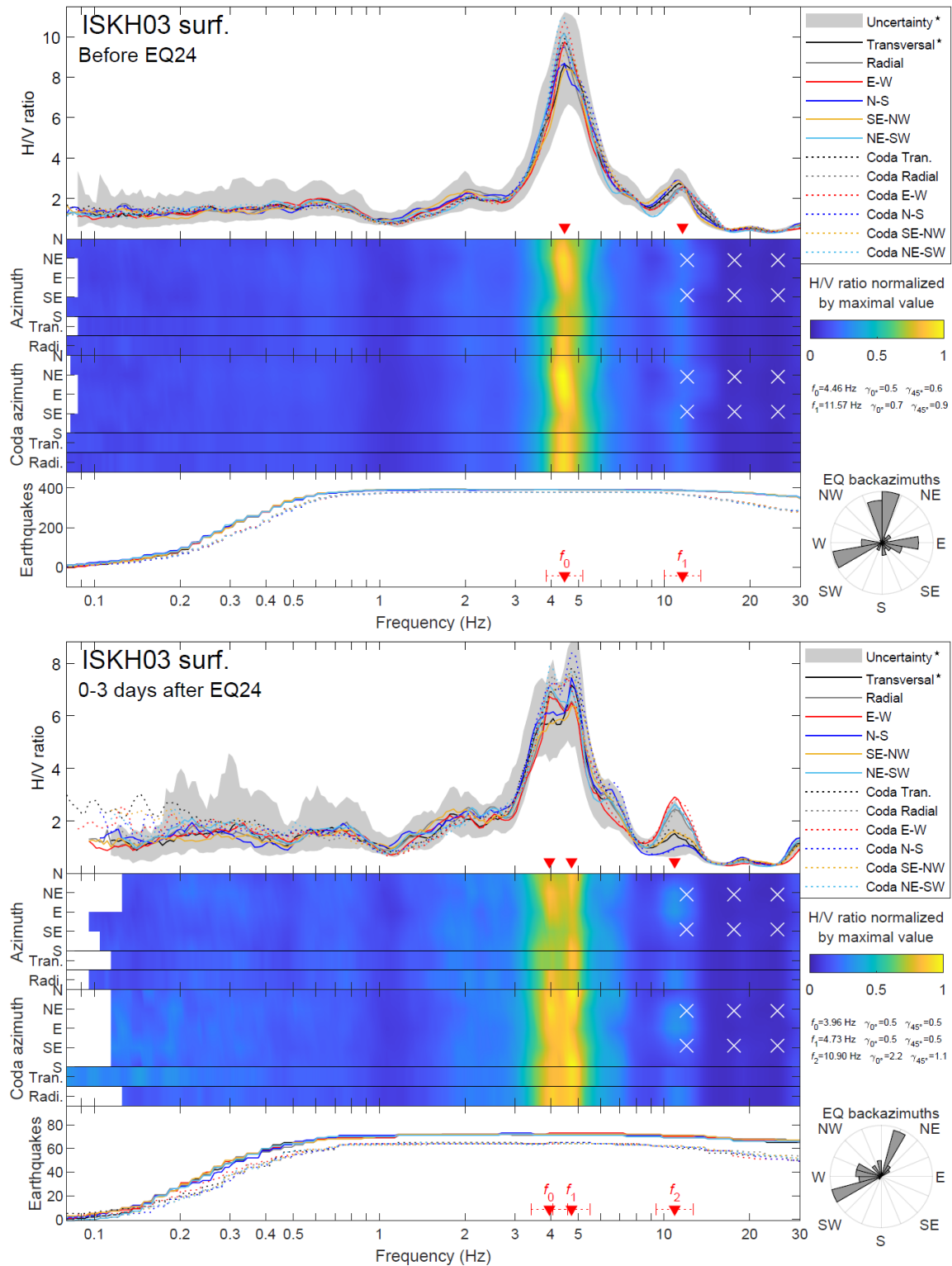


Figure S9. Long-lasting change – Directionally dependent H/V spectral ratios at the ISKH03 site (surface sensor) before (upper panels) and 0–3 days after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

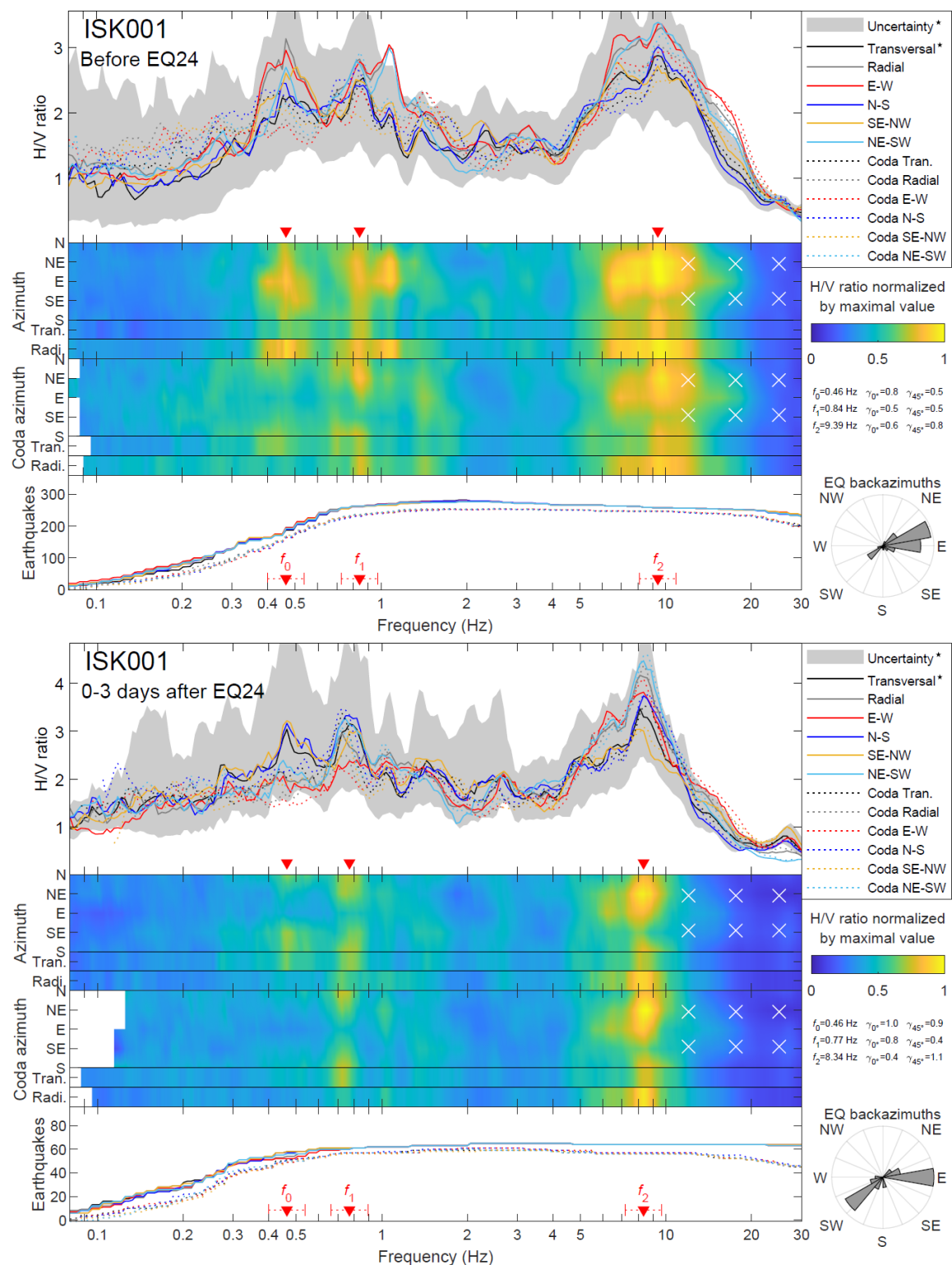


Figure S10. Long-lasting change – Directionally dependent H/V spectral ratios at the ISK001 site before (upper panels) and 0–3 days after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

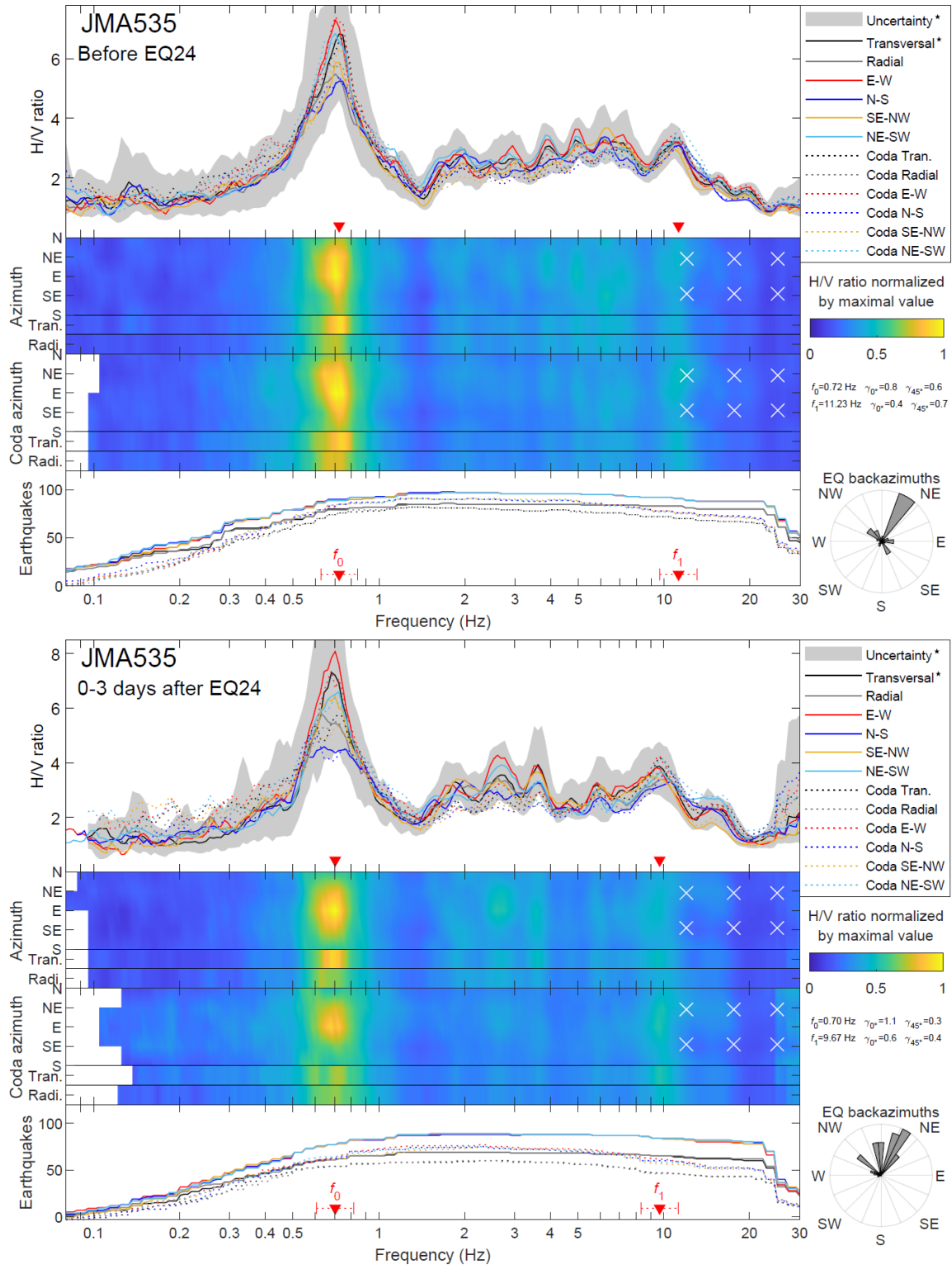


Figure S12. Long-lasting change – Directionally dependent H/V spectral ratios at the JMA535 site before (upper panels) and 0–3 days after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

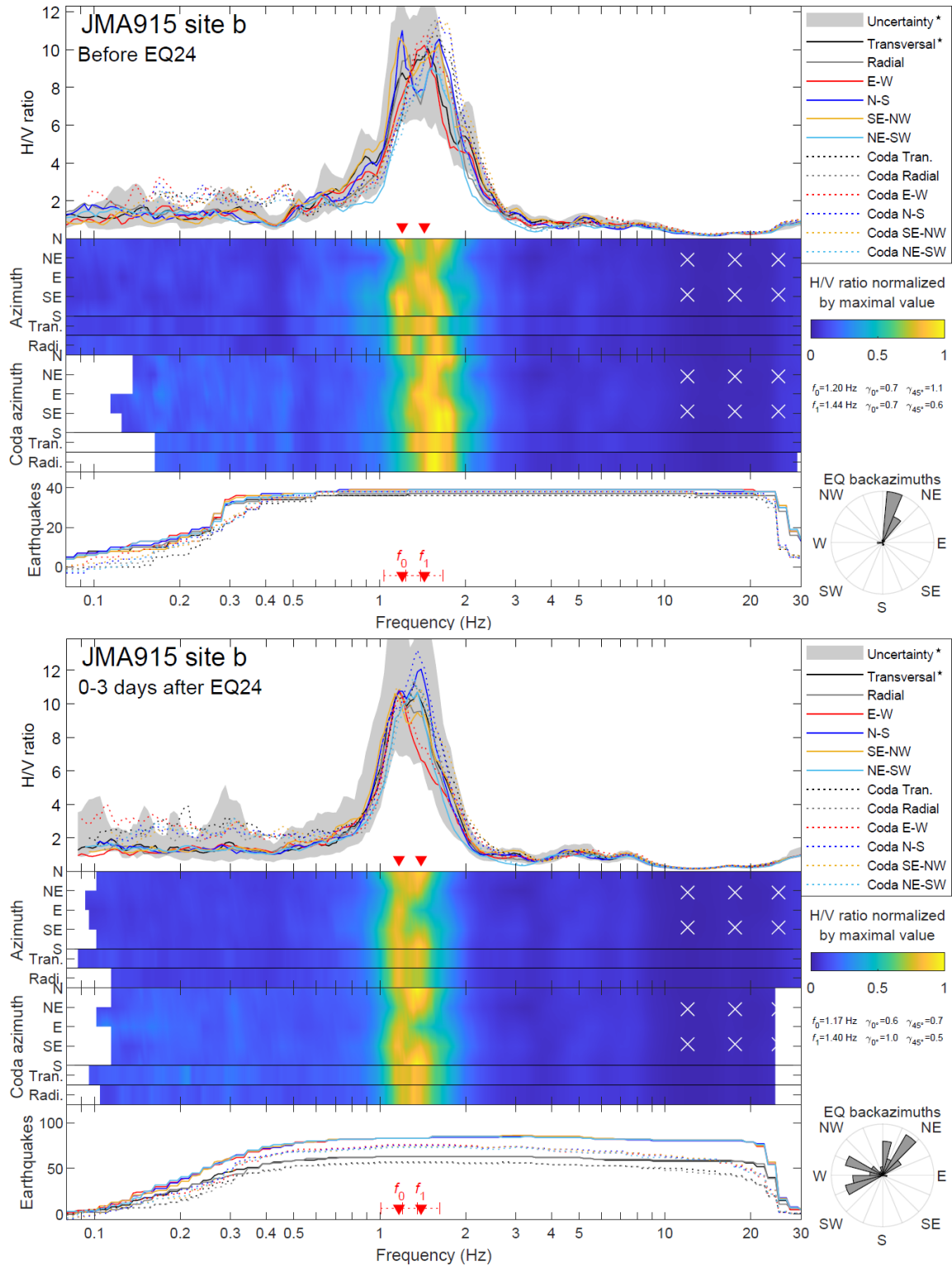


Figure S13. Long-lasting change – Directionally dependent H/V spectral ratios at JMA915 site (location b from 24 December 2019) before (upper panels) and after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

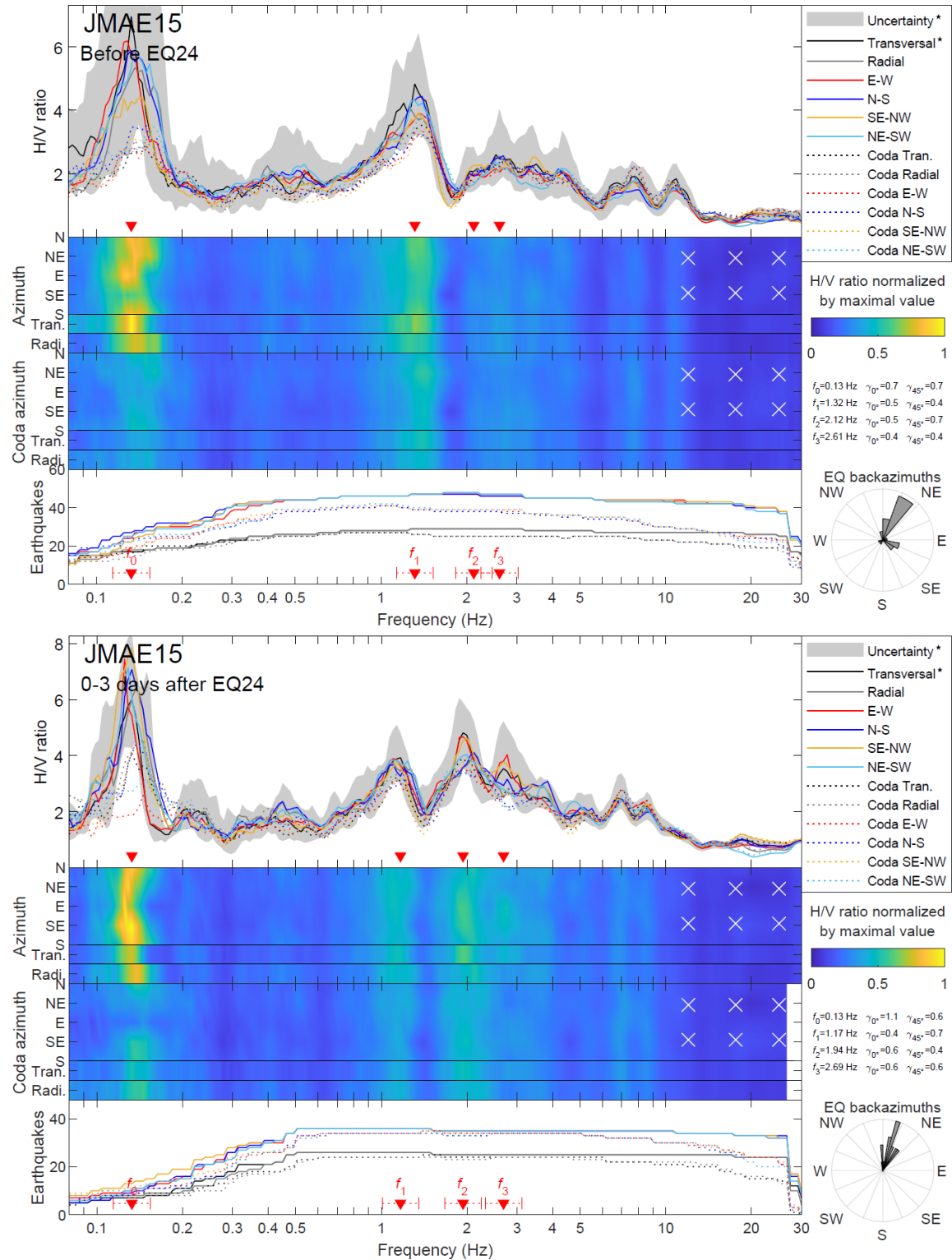


Figure S14. Long-lasting change – Directionally dependent H/V spectral ratios at the JMAE15 site before (upper panels) and 0–3 days after (bottom panels) the 2024 M_j 7.6 Noto earthquake. The individual panel layout is the same as in Figure 3.

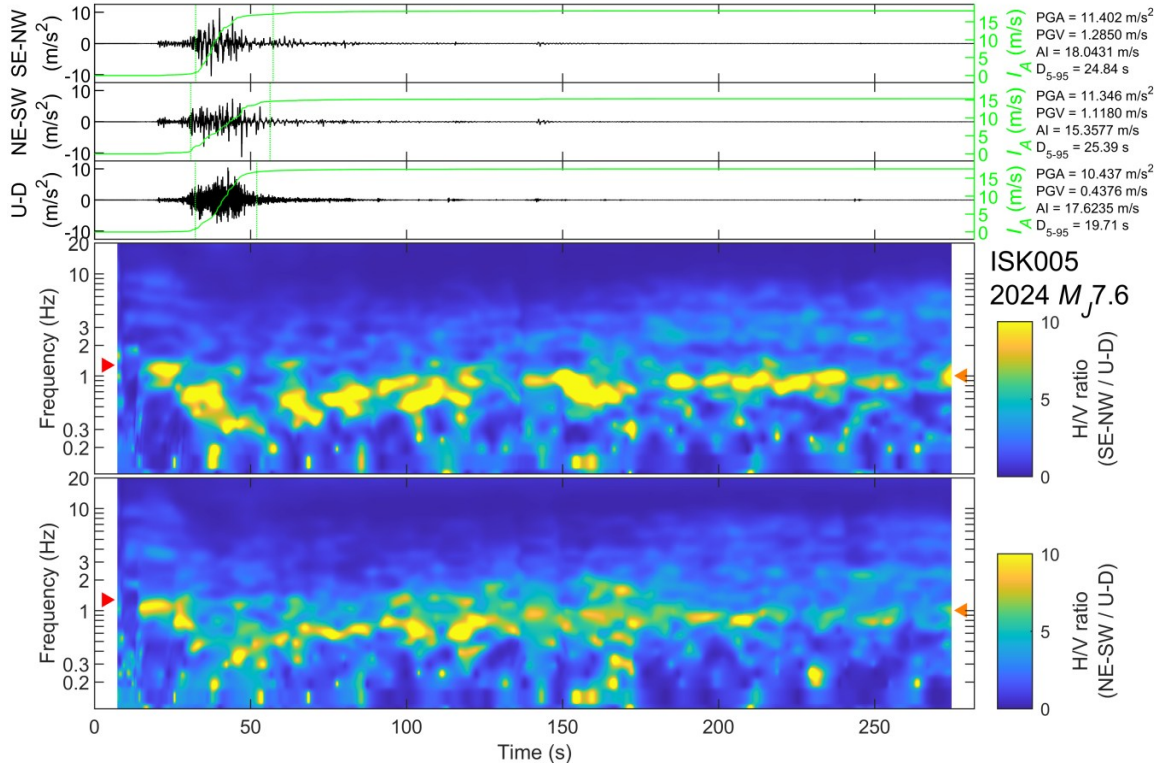


Figure S15. Clear and strong short-lasting change – The nonstationary H/V spectral ratios at the ISK005 site (Anamizu Town) during the 2024 M_J 7.6 Noto earthquake. This figure extends Figure 8. The upper panels show measured acceleration waveforms in SE–NW, NE–SW, and Up–Down directions (black curves). The green curves are Arias Intensity traces $I_A(t)$ computed by equation (9). The strong motion duration D_{5-95} is defined by 5–95% of $I_A(T)$, which is highlighted by green dashed vertical lines. The middle and bottom panels show nonstationary H/V spectral ratios determined from SE–NW and NE–SW horizontal components, respectively. The value of H/V spectral ratios is shown by color scale. The red and orange triangles are frequencies of H/V peaks before and 0–3 days after the M_J 7.6 mainshock, respectively (i.e., the long-lasting change). All panels have a joint time axis.

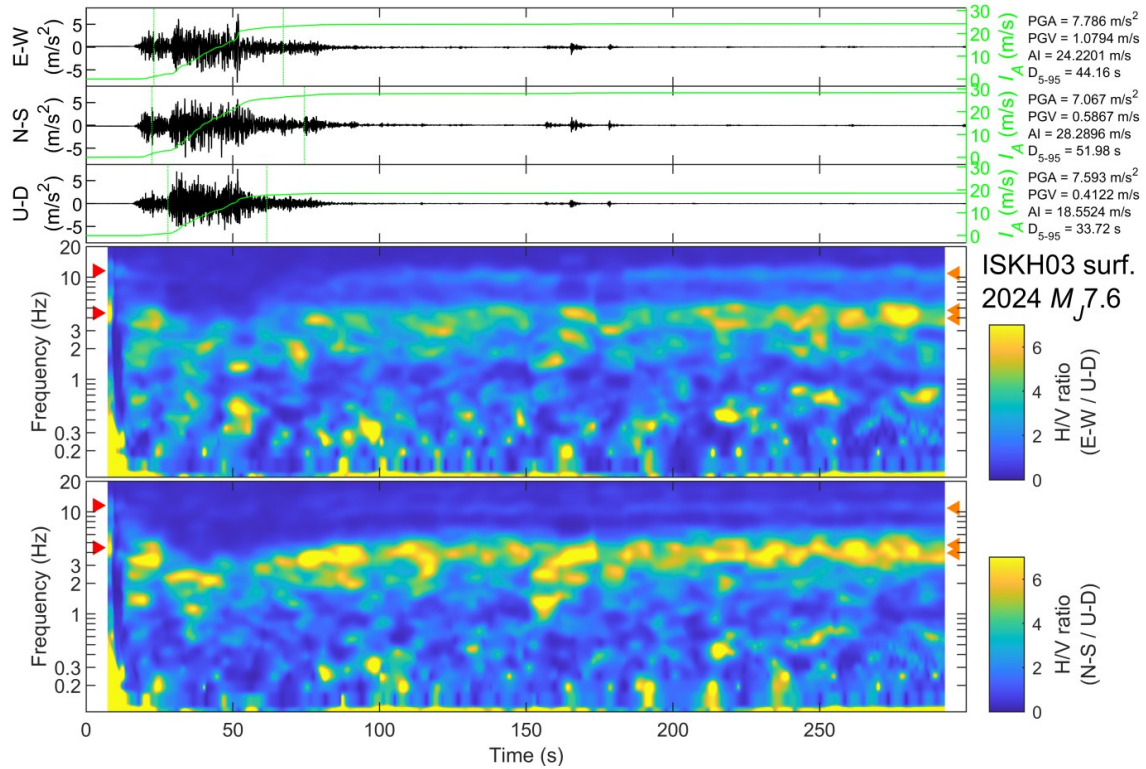


Figure S16. Clear and strong short-lasting change – The nonstationary H/V spectral ratios at the ISKH03 site (surface sensor, Noto municipality) during the 2024 M_j 7.6 Noto earthquake. The upper panels show measured acceleration waveforms in E–W, N–S, and Up–Down directions (black curves). The green curves are Arias Intensity traces $I_A(t)$ computed by equation (9). The strong motion duration D_{5-95} is defined by 5–95% of $I_A(T)$, which is highlighted by green dashed vertical lines. The middle and bottom panels show nonstationary H/V spectral ratios determined from E–W and N–S horizontal components, respectively. The value of H/V spectral ratios is shown by color scale. The red and orange triangles are frequencies of H/V peaks before and 0–3 days after the M_j 7.6 mainshock, respectively (i.e., the long-lasting change). All panels have a joint time axis.

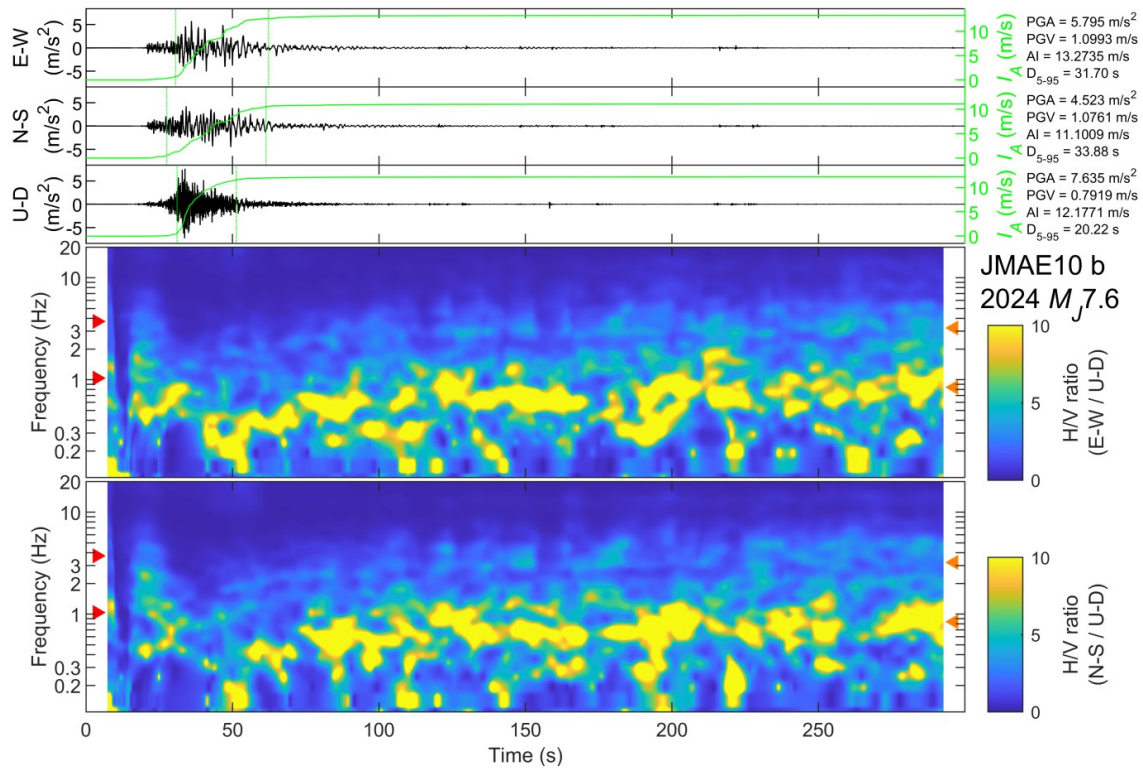


Figure S17. Clear and strong short-lasting change – The nonstationary H/V spectral ratios at the JMAE10 site (Wajima City, location b) during the 2024 M_j 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

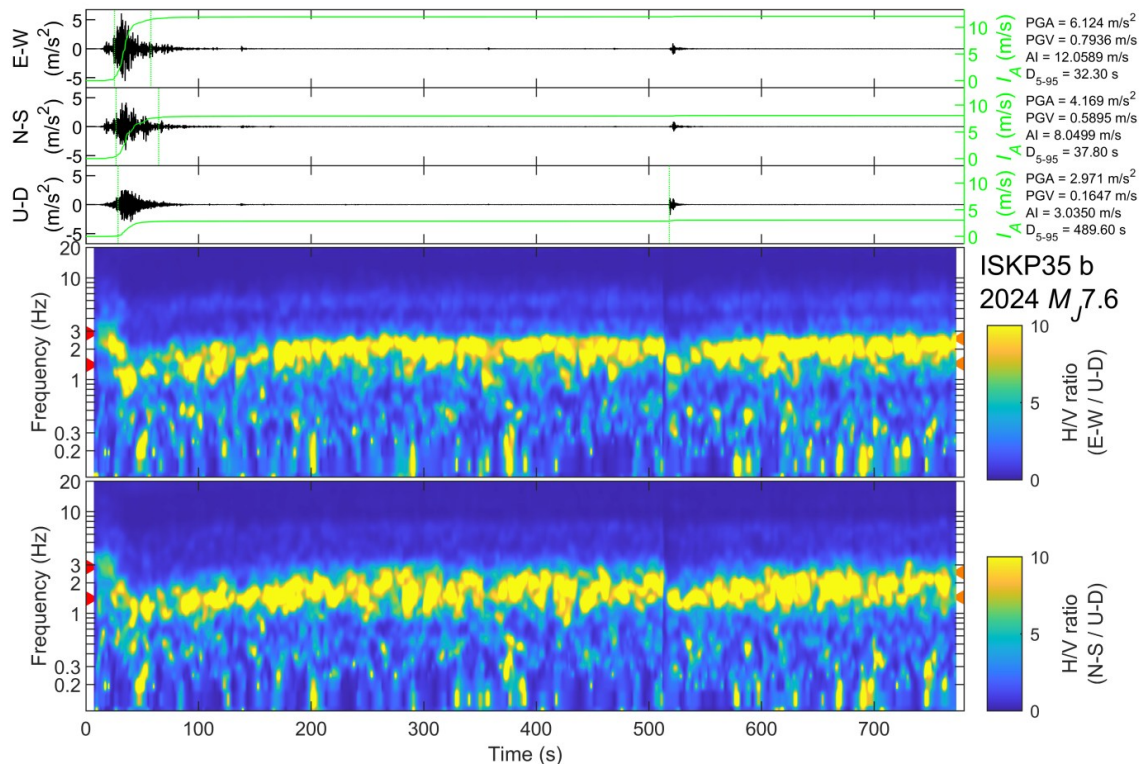


Figure S18. Clear and strong short-lasting change – The nonstationary H/V spectral ratios at the ISKP35 site (Noto Island, location b) during the 2024 M_j 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

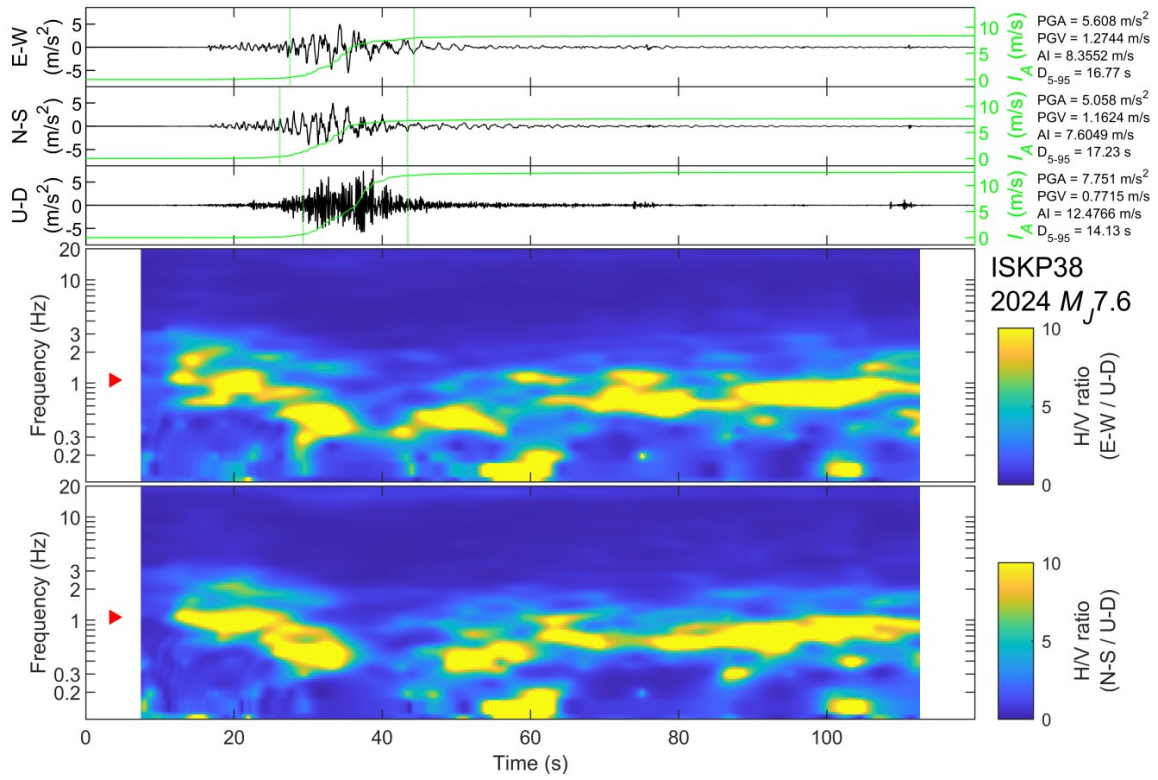


Figure S19. Clear and strong short-lasting change – The nonstationary H/V spectral ratios at the ISKP38 site (Monzen in Wajima municipality) during the 2024 M_j 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

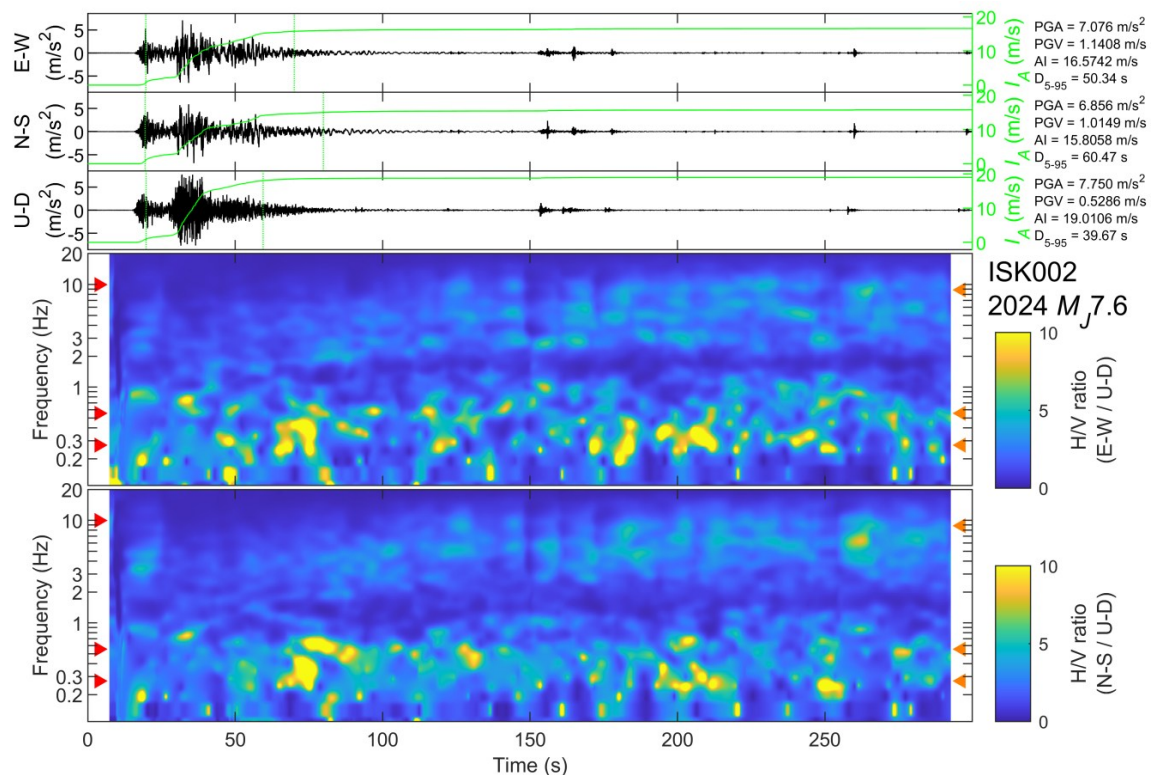


Figure S20. Unclear but probably significant short-lasting change – The nonstationary H/V spectral ratios at the ISK002 site (Suzu City) during the 2024 M_j 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

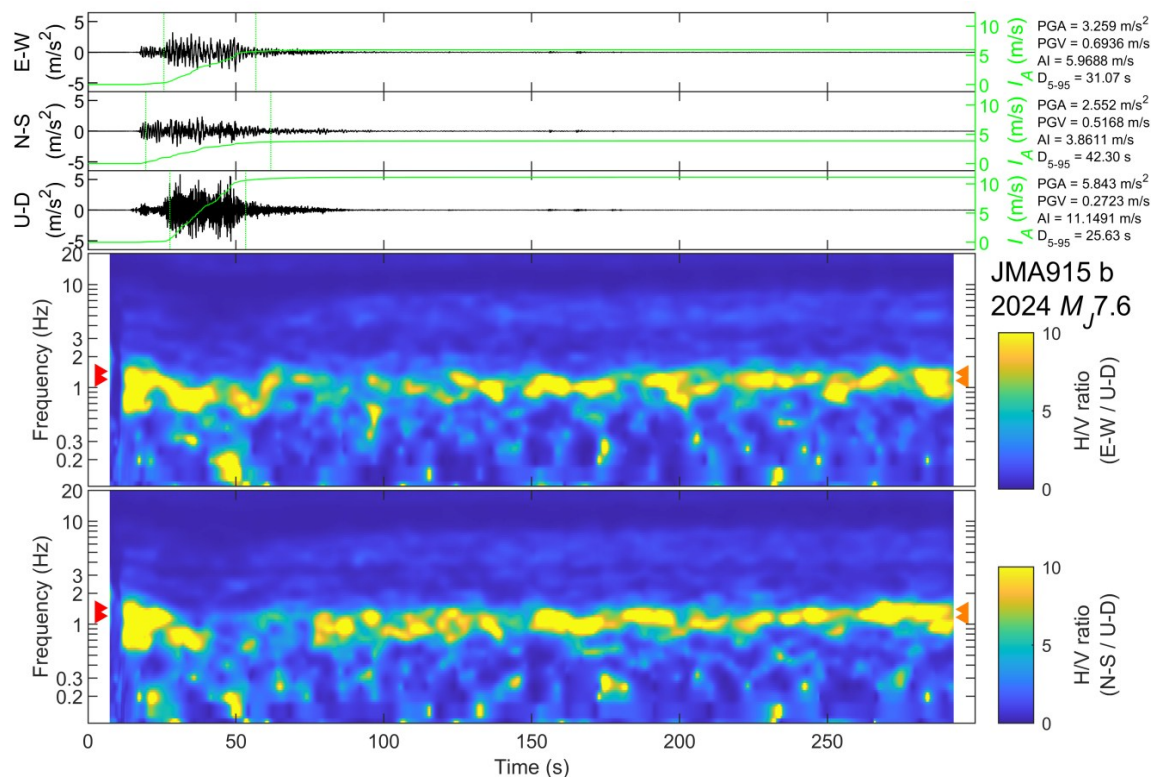


Figure S21. Weak but evident short-lasting change – The nonstationary H/V spectral ratios at the JMA915 site (Noto Town, location b) during the 2024 *M_J* 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

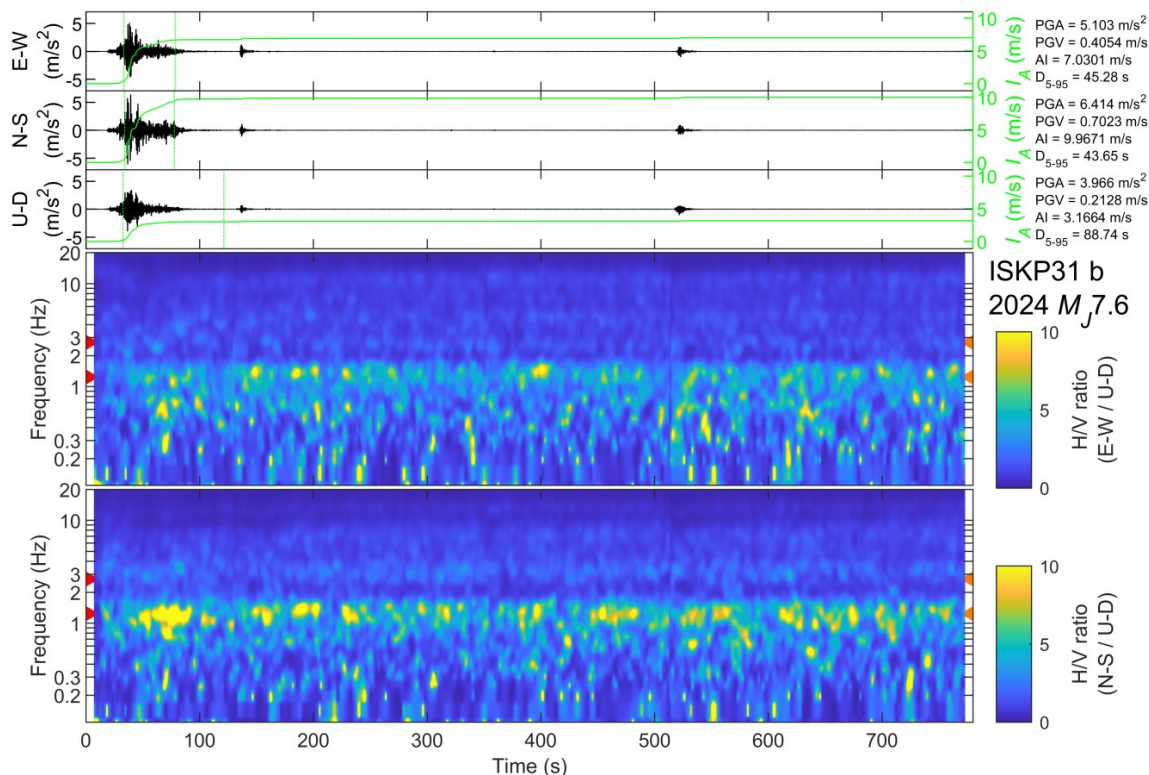


Figure S22. No short-lasting change – The nonstationary H/V spectral ratios at the ISKP31 site (Tatsuruhama Town, location b) during the 2024 M_j 7.6 Noto earthquake. Individual panel layout and meaning are the same as in [Figure S16](#).

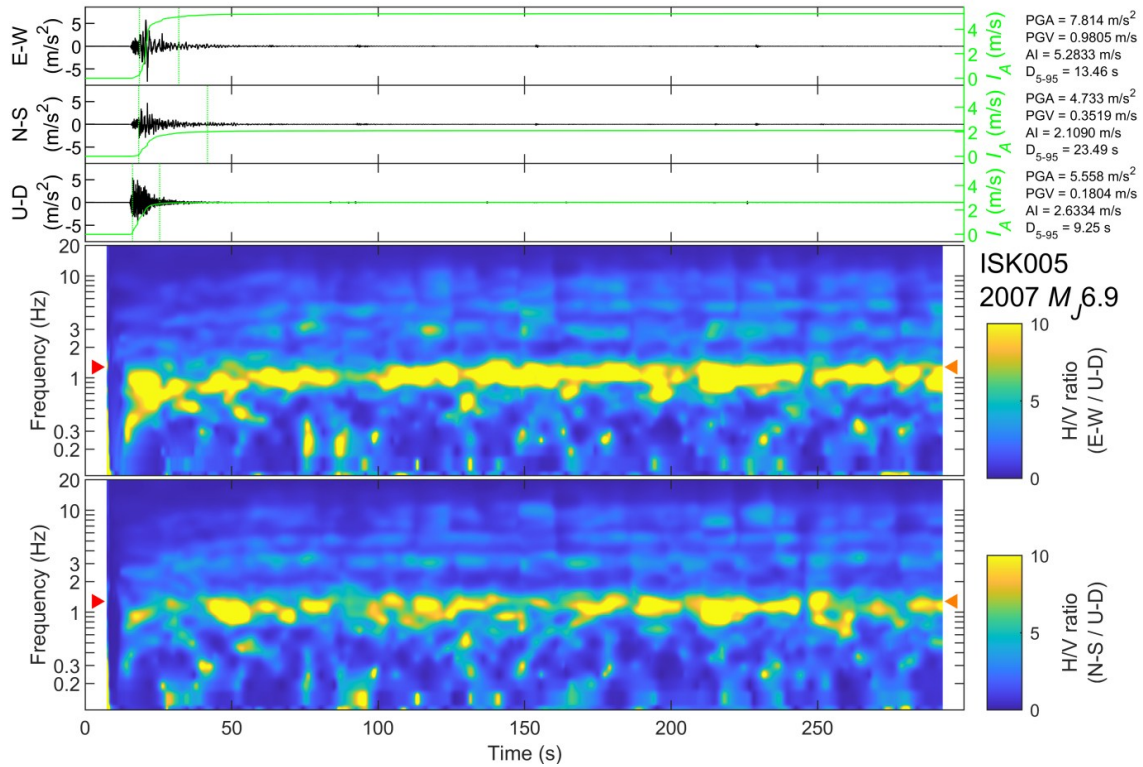


Figure S23. Weak but evident short-lasting change (2007 earthquake) – The nonstationary H/V spectral ratios at the ISK005 site (Anamizu Town) during the 2007 M_j 6.9 Noto earthquake. The earthquake occurred on 25 March 2007 at 9:42, and it has a hypocenter located at a depth of 11 km under Shika municipality in Ishikawa Prefecture. Individual panel layout and meaning are the same as in [Figure S16](#).

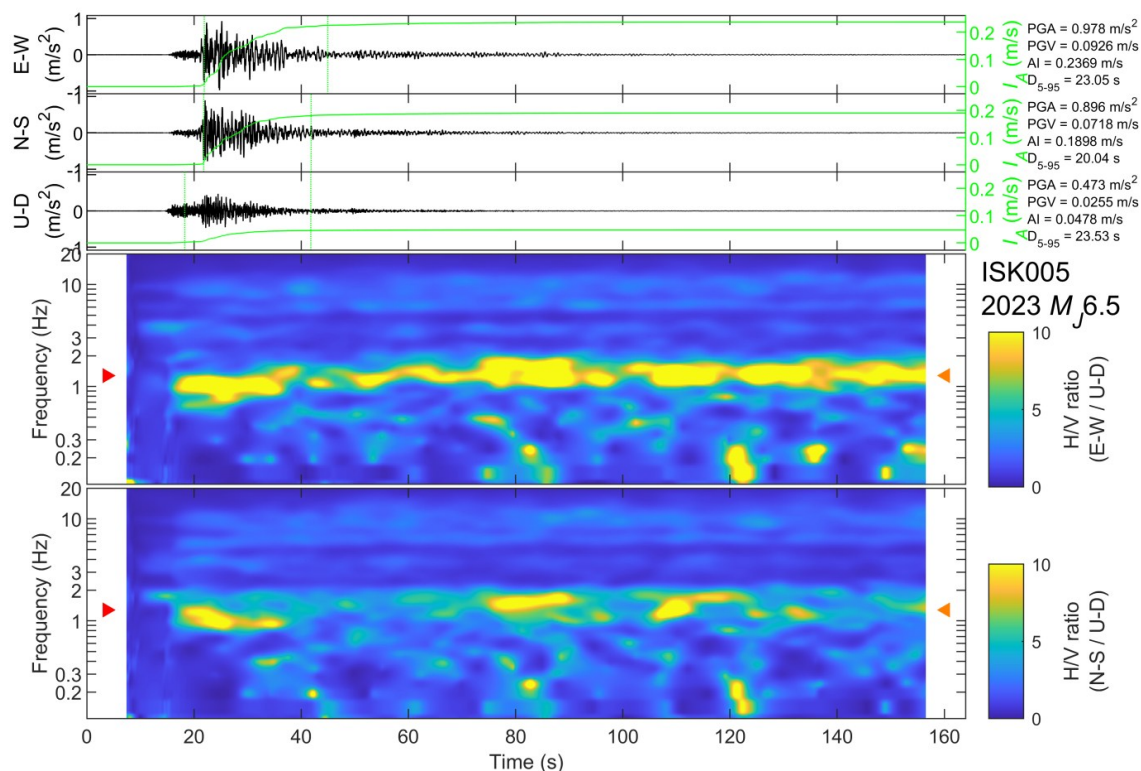


Figure S24. No short-lasting change (2023 earthquake) – The nonstationary H/V spectral ratios at the ISK005 site (Anamizu Town) during the 2023 M_j 6.5 Noto earthquake. The earthquake occurred on 5 May 2023 at 14:42, and it has a hypocenter located at a depth of 10 km under Suzu municipality in Ishikawa Prefecture. Individual panel layout and meaning are the same as in [Figure S16](#).

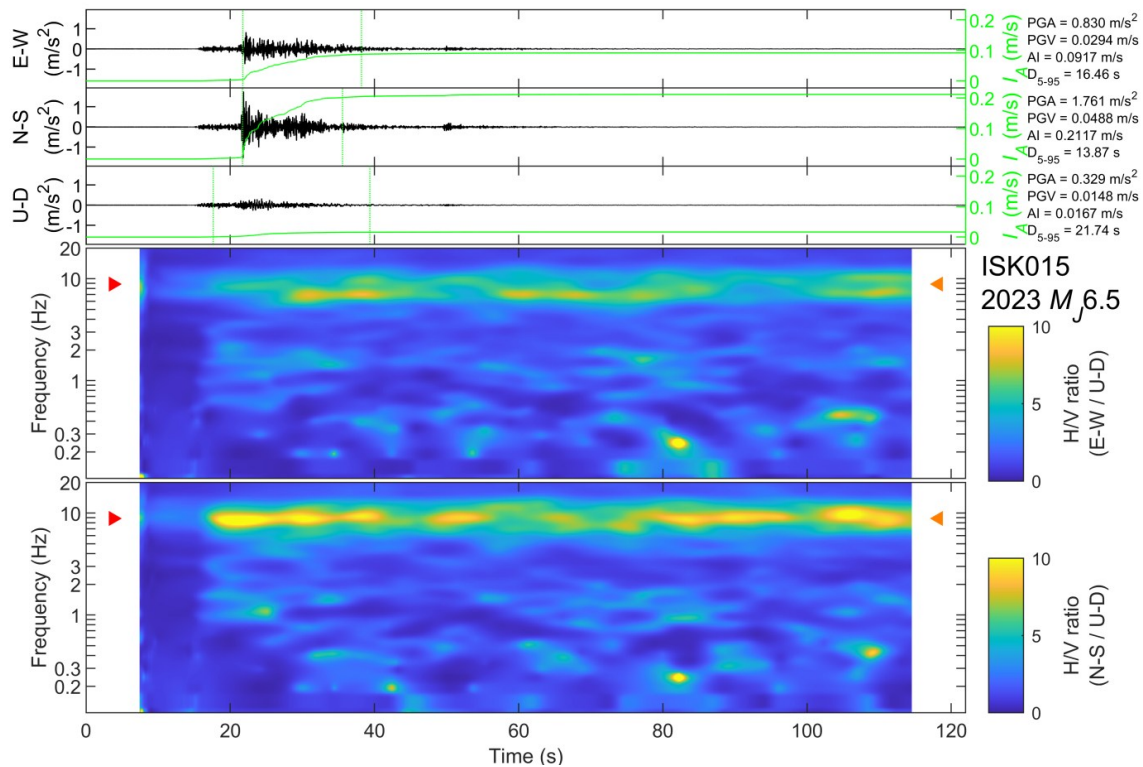


Figure S25. No short-lasting change (2023 earthquake) – The nonstationary H/V spectral ratios at the ISK015 site (Anamizu Town) during the 2023 M_j 6.5 Noto earthquake. The earthquake occurred on 5 May 2023 at 14:42, and it has a hypocenter located at a depth of 10 km under Suzu municipality in Ishikawa Prefecture. Individual panel layout and meaning are the same as in [Figure S16](#).

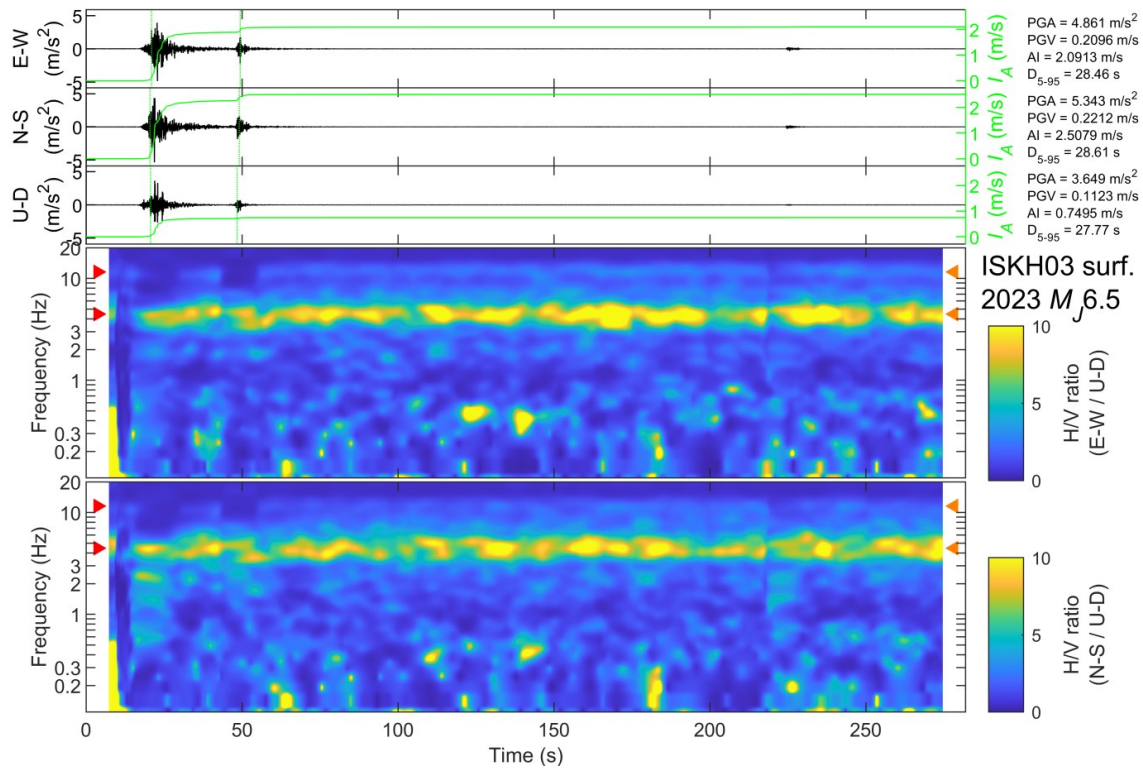


Figure S26. No short-lasting change (2023 earthquake) – The nonstationary H/V spectral ratios at the ISKH03 site (surface sensor, Noto municipality) during the 2023 M_j 6.5 Noto earthquake. The earthquake occurred on 5 May 2023 at 14:42, and it has a hypocenter located at a depth of 10 km under Suzu municipality in Ishikawa Prefecture. Individual panel layout and meaning are the same as in [Figure S16](#).

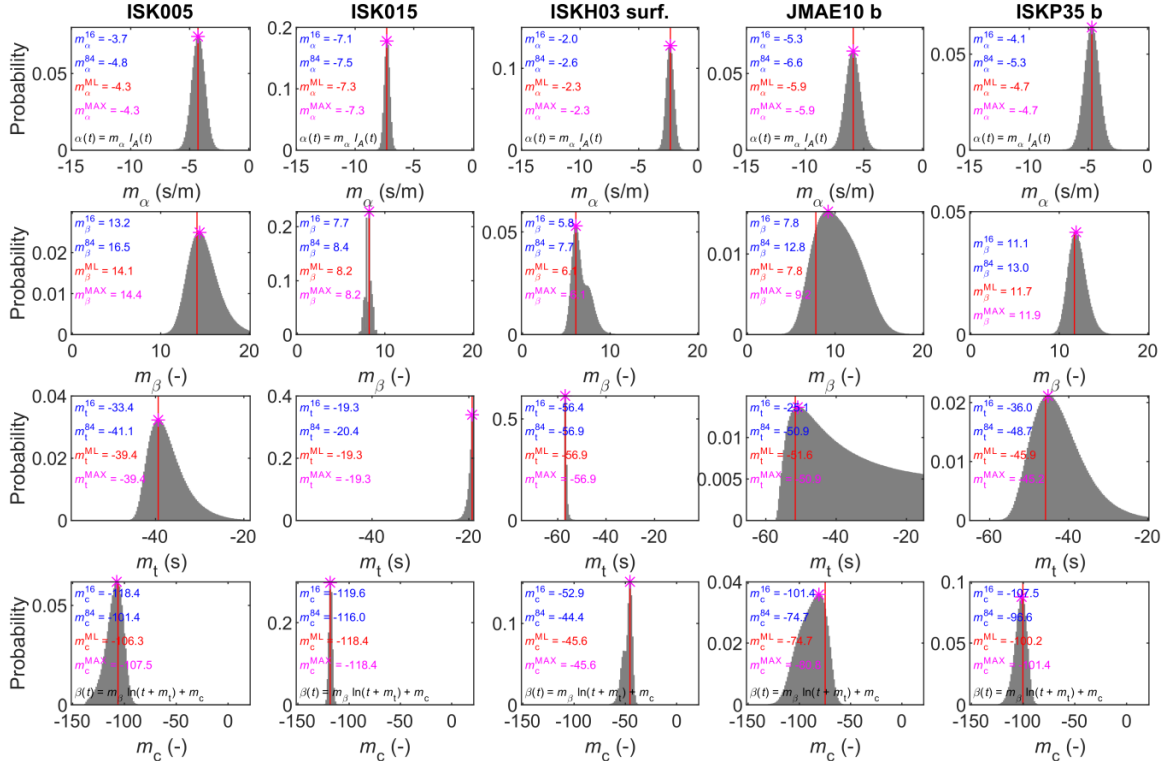


Figure S27. Model parameters of the short-lasting change – Inversion of nonstationary H/V spectral peaks observed during the 2024 M_j 7.6 Noto earthquake at five sites with a strongly nonstationary behavior (sites ISK005, ISK015, ISKH03 surface sensor, JMAE10 location b, and ISKP35 location b). This figure extends Figure 9 and the inversion procedure is described in [Text S2](#). It shows the posterior marginal probability density functions of individual model parameters $\mathbf{m} = \{m_\alpha, m_\beta, m_t, m_c\}$ (gray histograms), 16th and 84th percentiles of model parameters $\mathbf{m}^{16}$ and $\mathbf{m}^{84}$ (blue text), maximum likelihood model parameters $\mathbf{m}^{ML}$ (vertical red line and red text), and model parameters with the highest marginal probability $\mathbf{m}^{MAX}$ (magenta asterisk and magenta text).

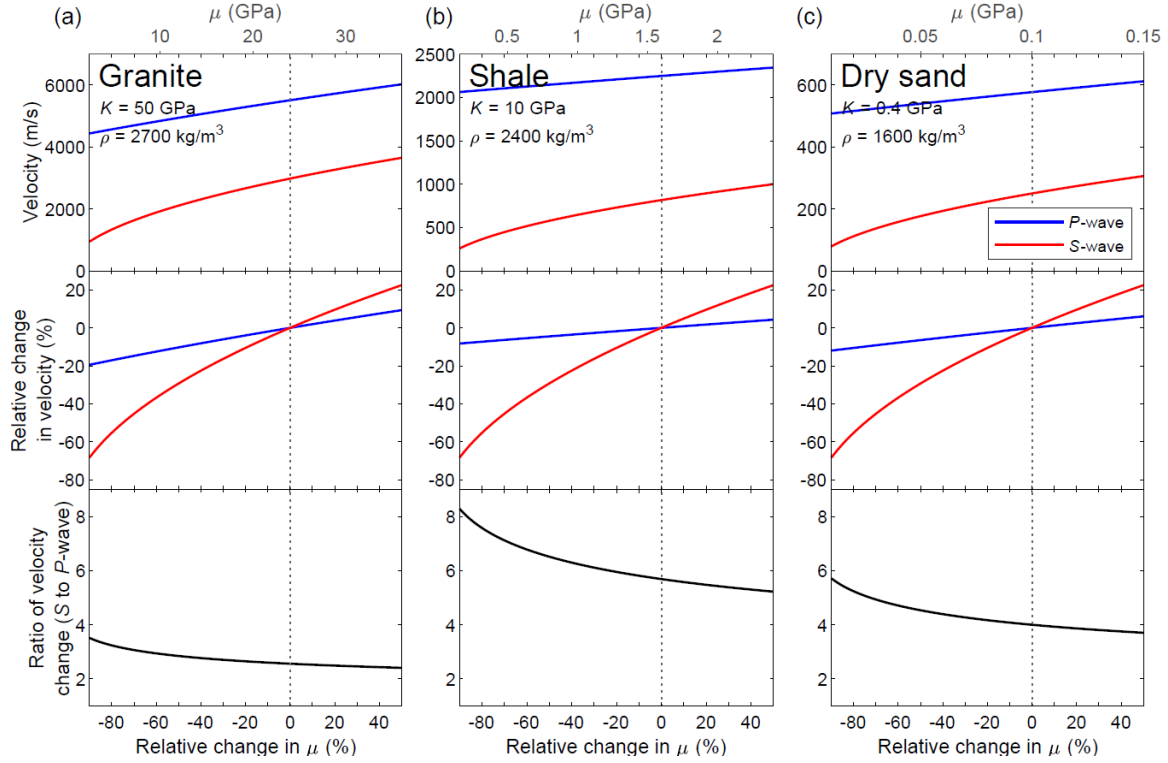


Figure S28. Theoretical modeling – Effects of the shear modulus change on *P*- and *S*-wave velocities. As is described in [Text S3](#), the modeling is performed for (a) granite, (b) shale, and (c) dry sand with typical values of the shear modulus μ , mass density ρ , and bulk modulus K . Values of the shear modulus are systematically perturbed (see relative values in bottom axes and absolute values in top ones), while ρ and K are fixed in the reference values displayed in upper panels. The reference set is indicated by the black dotted line.

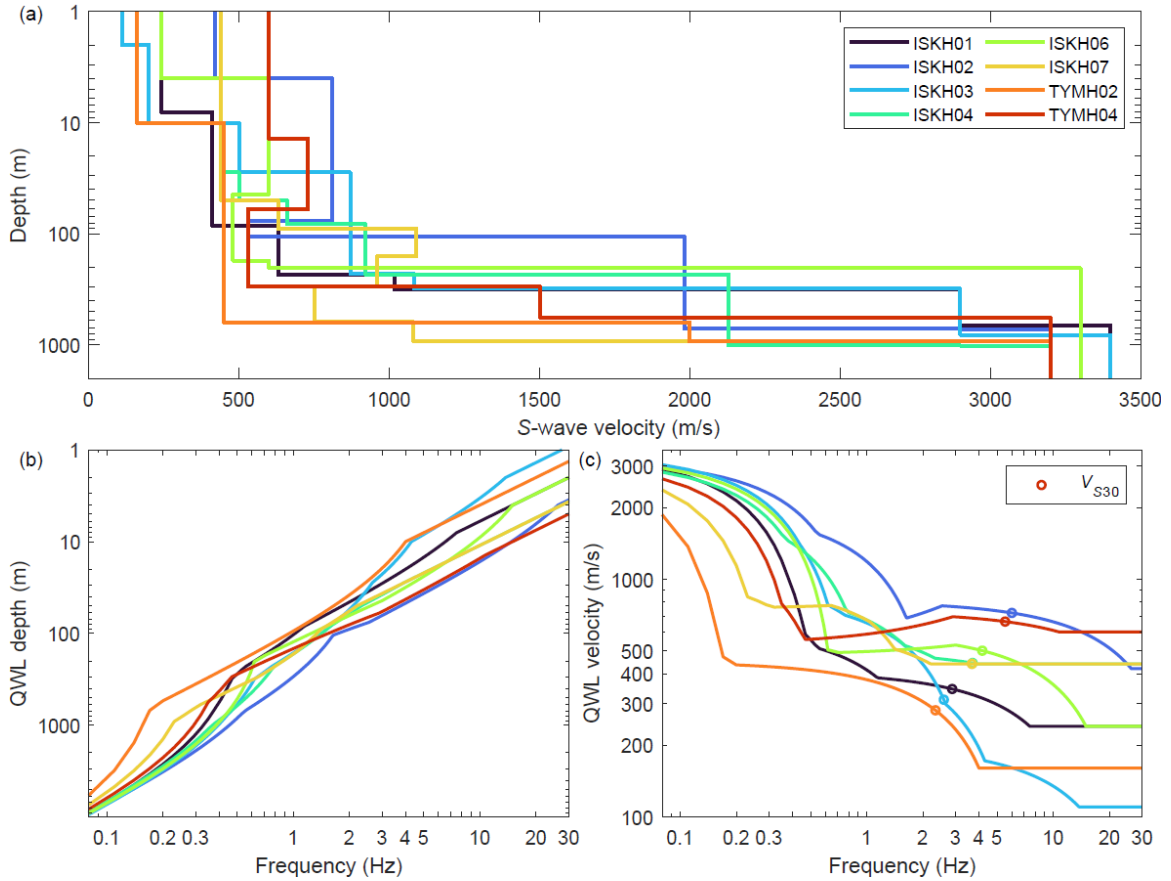


Figure S29. Site response modeling – The composite S-wave velocity models at KiK-net sites and their quarter wave-length (QWL) representation. This figure extends Figure 11. The KiK-net sites have available 1D velocity models down to the depth of borehole sensors provided by NIED. For lithological layers located deeper, seismic velocities were extracted from the Japan Integrated Velocity Structure Model (Koketsu et al., 2009, 2012). The panel (a) shows the composite S-wave velocity models down to the seismological bedrock with $V_s > 3$ km/s. Values of these velocity models are included in [Tables S10-S17](#). Panel (b) shows QWL depth and panel (c) shows the QWL velocity of individual models distinguished by color (see legend). The QWL depth in panel (b) may be used for a rough estimation of the depth of lithological interfaces responsible for resonance peaks at particular frequencies. The colored circles in panel (c) are values of the QWL velocity down to the depth of 30 meters (QWL depth of 30 m), which are equal to V_{S30} values.



Figure S30. Photographic documentation – The photo of the JMAE10 site (Wajima City) that was taken on 13 January 2024 (12 days after the mainshock) by Kimiyuki Asano.



Figure S31. Photographic documentation – The photo of the ISK006 b site (Shika municipality), taken on 14 January 2024 (13 days after the mainshock) by Kimiyuki Asano.



Figure S32. Photographic documentation – The photo of the ISK005 site (Anamizu Town) that was taken on 13 January 2024 (12 days after the mainshock) by Kimiyuki Asano.



Figure S33. Photographic documentation – The photo of the ISK015 site (Anamizu Town) that was taken on 13 January 2024 (12 days after the mainshock) by Kimiyuki Asano.



Figure S34. Photographic documentation – The photo of the ISK005 site (Anamizu Town) that was taken on 23 June 2024 (174 days after the mainshock) by Miroslav Hallo.



Figure S35. Photographic documentation – The photo of the ISK005 site (Anamizu Town) that was taken on 23 June 2024 (174 days after the mainshock) by Miroslav Hallo.



Figure S36. Photographic documentation – The photo of the ISK015 site (Anamizu Town) that was taken on 23 June 2024 (174 days after the mainshock) by Miroslav Hallo.



Figure S37. Photographic documentation – The photo of the ISK015 site (Anamizu Town) that was taken on 23 June 2024 (174 days after the mainshock) by Miroslav Hallo.

Station code	Time span of data	Component	f_l (Hz)	Error of H/V peak frequency (relative to f_l)	
				Negative (%)	Positive (%)
ISK005	Before EQ24	E-W	1.28	-5.8	6.1
ISK005	0-3 days after EQ24	E-W	1.01	-5.8	9.3
ISK015	Before EQ24	N-S	8.85	-5.8	6.1
ISK015	0-3 days after EQ24	N-S	6.97	-8.5	9.3
ISKH02	Before EQ24	E-W	19.2	-5.8	3.0
ISKH02	0-3 days after EQ24	E-W	16.5	-2.9	6.1
JMA535	Before EQ24	NE-SW	11.2	-5.8	6.1
JMA535	0-3 days after EQ24	NE-SW	9.67	-5.8	6.1
JMAE10b	Before EQ24	N-S	1.04	-5.8	9.3
JMAE10b	0-3 days after EQ24	SE-NW	0.84	-2.9	6.1
Average				-5.5 %	6.8 %
Median				-5.8 %	6.1 %

Table S1. Error of the frequency of predominant H/V peaks. The error is determined at five sites with the largest long-lasting H/V spectral ratio change. It is measured as 95th percentile rank thresholds around the H/V peak f_l on the $\tilde{R}_x(f)$ spectral curve (median value) from equation (2). The error is expressed by percentage relative to f_l .

Code	Lon. (°)	Lat. (°)	Code	Lon. (°)	Lat. (°)	Code	Lon. (°)	Lat. (°)
ISK001	137.1767	37.5000	ISKP17	136.6312	36.4037	JMACCB	136.7792	36.9276
ISK002	137.2877	37.4473	ISKP18	136.6485	36.3197	JMAE10a	136.8952	37.3916
ISK003a	136.9070	37.3919	ISKP20	136.6483	36.2815	JMAE10b	136.8952	37.3912
ISK003b	136.9078	37.3924	ISKP23	136.7258	36.7707	JMAE15	136.6341	36.5892
ISK004	137.1471	37.3080	ISKP25	136.7072	36.7195	JMAE16	137.0560	36.7923
ISK005	136.9041	37.2309	ISKP26	136.6452	36.6531	JMAE17	137.2024	36.7096
ISK006a	136.6892	37.1598	ISKP28	136.7968	36.8635	KNZC	136.6060	36.6180
ISK006b	136.6896	37.1603	ISKP29	136.7784	37.0064	MTSM01	136.5250	36.4998
ISK007	136.9680	37.0426	ISKP30	136.7507	36.8264	MTSM02	136.5968	36.4836
ISK008	136.7784	36.8937	ISKP31a	136.8880	37.0634	MTSM03	136.5810	36.5351
ISK009a	136.6989	36.7318	ISKP31b	136.8953	37.0597	MTSM04	136.6234	36.5113
ISK009b	136.7025	36.7334	ISKP32	136.9014	36.9889	MTSM05	136.5847	36.5699
ISK010	136.6435	36.5421	ISKP33	136.8546	37.1217	MTSM06	136.6358	36.5656
ISK011	136.4409	36.3976	ISKP34	136.9181	36.9650	MTSM07	136.6690	36.5583
ISK012	136.6049	36.3579	ISKP35a	136.9965	37.1248	MTSM08	136.6287	36.6096
ISK013a	136.6245	36.1769	ISKP35b	136.9966	37.1260	MTSM09	136.6912	36.6159
ISK013b	136.6246	36.1804	ISKP36	136.8645	36.9608	MTSV10	136.6760	36.5045
ISK014	136.3154	36.3031	ISKP38	136.7679	37.2874	MTSV11	136.6647	36.6371
ISK015	136.9087	37.2265	ISKP40a	137.0956	37.3689	TYM001	137.6257	36.9764
ISKH01	137.2844	37.5266	ISKP40b	137.0961	37.3694	TYM002	136.9750	36.8659
ISKH02	137.0413	37.3644	ISKP41a	137.2447	37.3532	TYM003	137.4200	36.8164
ISKH03	137.2436	37.3458	ISKP41b	137.2450	37.3533	TYM004	137.5274	36.8626
ISKH04	136.7176	37.1902	JMA533	137.4092	36.8265	TYM005a	137.0803	36.7824
ISKH05	136.9689	37.2224	JMA534a	136.8687	36.6764	TYM005b	137.0931	36.7611
ISKH06	136.8206	37.0533	JMA534b	136.8738	36.6725	TYM006	136.8974	36.6731
ISKH07	136.6357	36.5150	JMA535	136.9698	37.0327	TYM007a	137.2114	36.6686
ISKH08	136.7906	36.7380	JMA536	136.4449	36.4086	TYM007b	137.2123	36.6687
ISKH09	136.7168	36.2667	JMA910	137.5596	36.9461	TYM008	137.2826	36.6085
ISKP08	136.5669	36.5135	JMA911	137.1399	36.5855	TYM009	137.1403	36.5853
ISKP09a	136.3721	36.2465	JMA912a	136.8668	36.5465	TYM010	136.8883	36.5556
ISKP09b	136.3742	36.2460	JMA912b	136.8840	36.5383	TYM011	137.3851	36.5780
ISKP10	136.4582	36.4494	JMA913a	136.7284	36.6691	TYM012	137.0395	36.4402
ISKP11a	136.4956	36.4377	JMA913b	136.7290	36.6690	TYMH01	136.9276	36.8866
ISKP11b	136.4963	36.4377	JMA914	136.7253	37.1441	TYMH02	137.0378	36.7142
ISKP12	136.5537	36.4465	JMA915a	137.1500	37.3065	TYMH03	137.2627	36.7294
ISKP13	136.5425	36.4690	JMA915b	137.1473	37.3109	TYMH04	137.4689	36.7914
ISKP14	136.4918	36.4910	JMACC8	137.3304	36.6082	TYMH05	136.9584	36.5736
ISKP15	136.6256	36.4530	JMACC9	136.9171	37.8505	TYMH06	137.1595	36.5711
ISKP16	136.6108	36.5193	JMACCA	137.3589	37.4504	TYMH07	137.0392	36.4406

Table S2. List of locations of monitoring sites (Part 1/2). Codes of monitoring sites are defined in Table 1. Longitudes and Latitudes are in the WGS84.

Code	Lon. (°)	Lat. (°)	Code	Lon. (°)	Lat. (°)	Code	Lon. (°)	Lat. (°)
TYMO	137.1110	36.7750	TYMP11b	137.2830	36.6085	TYMP24a	137.1482	36.7408
TYMP01	137.2140	36.6953	TYMP12	137.3077	36.7035	TYMP24b	137.1469	36.7402
TYMP02a	137.0231	36.7543	TYMP13a	137.3546	36.6962	TYMP25	137.0630	36.7327
TYMP02b	137.0266	36.7540	TYMP13b	137.3546	36.6962	TYMP26	136.9003	36.5122
TYMP03a	137.0799	36.7822	TYMP14	137.3192	36.6619	TYMP27	136.9511	36.4330
TYMP03b	137.0796	36.7818	TYMP16	137.5024	36.9337	TYMP28	136.8997	36.4017
TYMP05a	136.9749	36.8661	TYMP19	137.1520	36.6600	TYMP30	136.9863	36.5772
TYMP05b	136.9749	36.8661	TYMP20a	137.0794	36.5790	TYMP31	136.9714	36.5648
TYMP06	137.3409	36.7644	TYMP20b	137.0811	36.5801	TYMP32a	136.9302	36.5420
TYMP07a	137.4537	36.8686	TYMP21a	137.2294	36.5281	TYMP32b	136.9305	36.5419
TYMP07b	137.4561	36.8800	TYMP21b	137.2301	36.5287	TYMP33	136.9195	36.5883
TYMP08	136.9621	36.6474	TYMP22a	137.0997	36.7122	TYMP35a	136.9239	36.7078
TYMP10a	137.2042	36.5918	TYMP22b	137.0837	36.7159	TYMP35b	136.9239	36.7078
TYMP10b	137.2036	36.5919	TYMP23a	137.0483	36.7225			
TYMP11a	137.2830	36.6085	TYMP23b	137.0488	36.7231			

Table S3. List of locations of monitoring sites (Part 2/2). Codes of monitoring sites are defined in Table 1. Longitudes and Latitudes are in the WGS84.

Code	f_l (Hz)	Code	f_l (Hz)	Code	f_l (Hz)	Code	f_l (Hz)
ISK001	0.46	ISKH04	8.85	ISKP31b	2.69	JMA913b	3.73
ISK001	0.84	ISKH05	6.97	ISKP32	0.42	JMA914	2.61
ISK001	9.39	ISKH06	0.66	ISKP32	0.79	JMA915a	1.13
ISK002	0.27	ISKH06	9.39	ISKP32	3.12	JMA915b	1.20
ISK002	0.55	ISKH07	0.13	ISKP33	2.85	JMA915b	1.44
ISK002	9.97	ISKH08	2.94	ISKP33	5.83	JMACC8	0.38
ISK003b	0.46	ISKH08	6.57	ISKP34	0.38	JMACC8	5.33
ISK003b	14.7	ISKH09	9.39	ISKP34	2.61	JMACC9	6.38
ISK004	2.77	ISKP08	0.14	ISKP34	6.57	JMACCA	12.7
ISK005	1.28	ISKP10	1.40	ISKP35b	1.40	JMACCB	0.31
ISK006a	6.77	ISKP11b	0.95	ISKP35b	2.85	JMACCB	5.18
ISK006b	6.01	ISKP12	2.94	ISKP36	0.42	JMAE10a	0.95
ISK006b	25.9	ISKP13	0.21	ISKP36	1.88	JMAE10b	1.04
ISK007	0.89	ISKP13	4.88	ISKP38	1.07	JMAE10b	3.73
ISK008	0.22	ISKP14	0.13	ISKP40b	0.61	JMAE15	0.13
ISK008	3.03	ISKP14	2.39	ISKP41a	1.53	JMAE15	1.32
ISK009a	0.34	ISKP14	8.34	ISKP41a	4.46	JMAE15	2.12
ISK009a	0.49	ISKP15	2.39	ISKP41b	1.48	JMAE15	2.61
ISK009b	0.37	ISKP16	0.16	ISKP41b	2.32	JMAE17	0.15
ISK009b	0.51	ISKP16	15.6	ISKP41b	3.41	JMAE17	3.73
ISK009b	2.85	ISKP17	3.62	JMA533	0.12	KNZC	2.06
ISK010	0.15	ISKP20	3.84	JMA533	3.62	KNZC	9.39
ISK011	0.77	ISKP20	5.18	JMA534b	0.16	MTSM01	0.15
ISK011	1.13	ISKP23	0.95	JMA534b	5.02	MTSM01	3.51
ISK011	4.88	ISKP23	2.32	JMA535	0.72	MTSM02	0.20
ISK011	8.85	ISKP25	0.41	JMA535	11.2	MTSM02	3.84
ISK012	9.67	ISKP25	1.72	JMA536	0.89	MTSM03	0.15
ISK013a	8.09	ISKP25	3.03	JMA536	2.25	MTSM03	2.69
ISK013b	7.40	ISKP28	0.26	JMA536	9.11	MTSM04	0.16
ISK014	1.28	ISKP28	1.24	JMA910	0.19	MTSM04	3.51
ISK015	8.85	ISKP28	1.72	JMA910	2.94	MTSM04	4.88
ISKH01	0.66	ISKP28	9.67	JMA911	0.26	MTSM05	0.14
ISKH01	4.59	ISKP29	0.66	JMA911	2.77	MTSM05	1.67
ISKH02	1.67	ISKP29	1.44	JMA912a	0.26	MTSM05	2.06
ISKH02	19.2	ISKP29	5.83	JMA912b	0.25	MTSM06	0.15
ISKH03	4.46	ISKP30	0.23	JMA912b	2.85	MTSM06	2.69
ISKH03	11.6	ISKP30	1.48	JMA913a	0.21	MTSM07	0.15
ISKH04	0.89	ISKP31a	0.72	JMA913a	2.39	MTSM07	2.69
ISKH04	1.07	ISKP31b	1.24	JMA913b	0.20	MTSM08	0.13

Table S4. Frequency of observed H/V peaks before the 2024 M_j 7.6 Noto earthquake (Part 1/2). Up to four peaks per site. Codes of monitoring sites are defined in Table 1.

Code	f_l (Hz)	Code	f_l (Hz)	Code	f_l (Hz)	Code	f_l (Hz)
MTSM08	1.17	TYM010	0.26	TYMP03a	0.82	TYMP21a	7.18
MTSM08	2.39	TYM010	1.17	TYMP03a	2.53	TYMP22a	0.15
MTSM09	0.15	TYM010	2.53	TYMP03b	0.16	TYMP22a	2.00
MTSM09	1.40	TYM010	4.59	TYMP03b	0.82	TYMP22a	2.46
MTSM09	1.94	TYM011	3.84	TYMP03b	2.46	TYMP22b	0.13
MTSV10	2.61	TYM011	14.7	TYMP03b	3.73	TYMP22b	1.35
MTSV11	0.15	TYM012	2.77	TYMP05a	0.26	TYMP23a	0.15
MTSV11	0.61	TYM012	3.51	TYMP05a	0.68	TYMP23a	2.12
TYM001	9.11	TYMH01	1.01	TYMP05b	0.26	TYMP23b	0.13
TYM002	0.26	TYMH01	3.73	TYMP05b	0.68	TYMP23b	2.00
TYM002	0.68	TYMH02	0.18	TYMP05b	6.77	TYMP24a	0.17
TYM002	6.38	TYMH02	2.85	TYMP05b	10.3	TYMP24a	1.20
TYM003	0.12	TYMH02	9.67	TYMP06	0.11	TYMP24a	1.94
TYM003	0.18	TYMH03	0.10	TYMP06	0.61	TYMP24b	0.14
TYM003	3.51	TYMH03	0.79	TYMP06	2.53	TYMP24b	1.28
TYM004	0.34	TYMH03	2.25	TYMP07b	0.12	TYMP24b	1.77
TYM004	9.97	TYMH04	0.48	TYMP07b	4.59	TYMP24b	3.62
TYM005a	0.13	TYMH04	5.83	TYMP08	0.13	TYMP25	0.13
TYM005a	0.17	TYMH05	0.17	TYMP08	3.84	TYMP25	1.67
TYM005a	0.82	TYMH05	1.13	TYMP10a	0.21	TYMP26	0.40
TYM005a	4.73	TYMH05	6.01	TYMP10b	0.27	TYMP26	0.51
TYM005b	0.13	TYMH06	0.24	TYMP11a	0.20	TYMP26	2.94
TYM005b	0.82	TYMH07	2.85	TYMP11b	0.28	TYMP27	3.73
TYM006	0.11	TYMH07	3.51	TYMP12	0.15	TYMP27	5.83
TYM006	2.94	TYMO	0.15	TYMP12	1.72	TYMP28	4.88
TYM006	4.46	TYMO	0.68	TYMP13a	0.15	TYMP30	0.17
TYM006	7.18	TYMO	2.77	TYMP13a	2.61	TYMP30	3.73
TYM007a	0.12	TYMP01	0.12	TYMP13b	0.15	TYMP31	0.18
TYM007a	4.73	TYMP01	1.32	TYMP13b	2.53	TYMP31	3.84
TYM007b	0.13	TYMP01	2.00	TYMP13b	8.09	TYMP32a	0.22
TYM007b	2.69	TYMP01	2.32	TYMP14	0.16	TYMP32a	1.13
TYM007b	4.46	TYMP02a	0.16	TYMP14	2.77	TYMP32b	1.40
TYM007b	5.83	TYMP02a	0.20	TYMP16	0.12	TYMP33	0.17
TYM008	0.21	TYMP02a	2.00	TYMP16	2.85	TYMP35a	0.14
TYM008	0.27	TYMP02b	0.16	TYMP19	0.13	TYMP35a	2.94
TYM008	10.9	TYMP02b	2.18	TYMP19	3.21	TYMP35b	0.13
TYM009	0.24	TYMP02b	6.38	TYMP20b	6.01	TYMP35b	0.17
TYM009	2.85	TYMP03a	0.14	TYMP21a	5.33	TYMP35b	2.77

Table S5. Frequency of observed H/V peaks before the 2024 M_j 7.6 Noto earthquake (Part 2/2). Up to four peaks per site. Codes of monitoring sites are defined in Table 1.

Code	f_l (Hz)	ϑ (°)	$\gamma_{\max}$	Code	f_l (Hz)	ϑ (°)	$\gamma_{\max}$
ISK004	2.77	45.0	1.21	TYM005a	0.13	27.0	1.39
ISK005	1.28	81.0	1.62	TYM005a	0.17	27.0	1.14
ISK010	0.15	13.5	1.67	TYM005b	0.13	36.0	1.81
ISK013b	7.40	9.0	0.98	TYM006	0.11	67.5	1.60
ISK015	8.85	9.0	1.03	TYM007a	0.12	13.5	1.02
ISKH04	8.85	0.0	1.01	TYM009	2.85	0.0	1.14
ISKP08	0.14	22.5	1.59	TYM010	0.26	9.0	1.04
ISKP12	2.94	166.5	1.13	TYM011	3.84	108.0	1.22
ISKP14	0.13	36.0	1.45	TYMH02	0.18	54.0	1.02
ISKP16	0.16	36.0	1.67	TYMH03	0.10	18.0	1.04
ISKP16	15.6	130.5	1.04	TYMO	0.15	18.0	1.20
ISKP20	5.18	85.5	1.29	TYMP01	2.00	72.0	0.93
ISKP25	3.03	45.0	0.95	TYMP02a	0.16	22.5	1.19
ISKP28	0.26	162.0	1.03	TYMP02a	0.20	18.0	1.01
ISKP31b	2.69	40.5	0.96	TYMP02b	0.16	40.5	1.07
ISKP32	0.79	49.5	1.02	TYMP03a	0.14	22.5	1.19
ISKP33	5.83	112.5	1.51	TYMP03b	0.16	45.0	1.18
ISKP35b	1.40	9.0	1.27	TYMP06	0.11	4.5	1.13
ISKP41a	4.46	40.5	1.30	TYMP11a	0.20	157.5	1.11
ISKP41b	1.48	148.5	0.96	TYMP14	0.16	166.5	1.33
ISKP41b	2.32	139.5	1.33	TYMP16	0.12	4.5	1.47
JMA534b	0.16	76.5	1.21	TYMP19	0.13	0.0	1.45
JMA535	0.72	81.0	0.97	TYMP20b	6.01	148.5	1.36
JMA910	0.19	148.5	1.03	TYMP21a	7.18	108.0	1.14
JMA912b	0.25	153.0	1.00	TYMP22b	0.13	36.0	0.98
JMA913a	0.21	162.0	1.02	TYMP23a	0.15	40.5	1.05
JMACC9	6.38	85.5	1.00	TYMP23b	0.13	72.0	1.02
JMACCB	5.18	81.0	1.33	TYMP24a	0.17	31.5	1.02
MTSM01	0.15	27.0	1.37	TYMP24b	0.14	4.5	1.52
MTSM03	0.15	22.5	1.40	TYMP25	0.13	58.5	1.06
MTSM04	0.16	18.0	1.19	TYMP27	5.83	0.0	1.02
MTSM04	4.88	94.5	1.06	TYMP28	4.88	166.5	1.23
MTSM05	0.14	9.0	1.30	TYMP33	0.17	9.0	1.18
MTSM06	0.15	13.5	1.61	TYMP35a	2.94	54.0	1.06
MTSM07	0.15	9.0	1.23	TYMP35b	0.13	40.5	1.03
TYM001	9.11	81.0	1.33	TYMP35b	0.17	13.5	0.91
TYM003	0.18	135.0	1.12	TYMP35b	2.77	49.5	0.99

Table S6. Predominant directionality of observed H/V peaks before the 2024 M_j 7.6 Noto earthquake. This table includes only H/V peaks with the maximal directional dependency factor $\gamma_{\max} \geq 0.9$. The directionality azimuth ϑ is measured clockwise from the north.

Code	f_l (Hz)	δf_l (%)	Code	f_l (Hz)	δf_l (%)	Code	f_l (Hz)	δf_l (%)
ISK001	0.46	0.00	ISKH09	9.39	-2.93	JMA534b	0.16	6.12
ISK001	0.84	-8.55	ISKP10	1.40	-8.55	JMA534b	5.02	0.00
ISK001	9.39	-11.23	ISKP11b	0.95	6.14	JMA535	0.72	-2.94
ISK002	0.27	0.00	ISKP12	2.94	-2.93	JMA535	11.2	-13.84
ISK002	0.55	0.00	ISKP13	4.88	6.14	JMA536	0.89	-8.55
ISK002	9.97	-11.23	ISKP14	2.39	0.00	JMA536	2.25	3.02
ISK003b	0.46	-2.93	ISKP14	8.34	0.00	JMA536	9.11	-5.78
ISK003b	14.7	-16.36	ISKP15	2.39	3.03	JMA910	0.19	6.11
ISK005	1.28	-21.20	ISKP16	15.6	0.00	JMA910	2.94	3.02
ISK006b	6.01	0.00	ISKP17	3.62	3.02	JMA911	0.26	-2.93
ISK006b	25.9	-11.23	ISKP20	3.84	0.00	JMA912b	0.25	3.02
ISK007	0.89	-2.93	ISKP20	5.18	-5.78	JMA912b	2.85	0.00
ISK008	0.22	0.00	ISKP23	0.95	-2.93	JMA913b	0.20	3.03
ISK008	3.03	0.00	ISKP23	2.32	-5.78	JMA914	2.61	-11.23
ISK009b	0.37	0.00	ISKP25	1.72	0.00	JMA915b	1.20	-2.94
ISK009b	0.51	3.04	ISKP25	3.03	0.00	JMA915b	1.44	-2.93
ISK009b	2.85	0.00	ISKP28	0.26	0.00	JMACC8	0.38	0.00
ISK010	0.15	0.00	ISKP28	1.24	6.13	JMACC8	5.33	0.00
ISK011	0.77	-5.78	ISKP28	1.72	0.00	JMACCB	0.31	-5.79
ISK011	1.13	0.00	ISKP28	9.67	0.00	JMACCB	5.18	0.00
ISK011	4.88	0.00	ISKP29	0.66	0.00	JMAE10b	1.04	-18.82
ISK011	8.85	0.00	ISKP29	1.44	0.00	JMAE10b	3.73	-13.84
ISK012	9.67	-5.78	ISKP29	5.83	-8.55	JMAE15	0.13	0.00
ISK013b	7.40	3.02	ISKP30	0.23	-2.91	JMAE15	1.32	-11.23
ISK014	1.28	-2.93	ISKP30	1.48	-2.94	JMAE15	2.12	-8.55
ISK015	8.85	-21.20	ISKP31b	1.24	0.00	JMAE15	2.61	3.02
ISKH01	0.66	0.00	ISKP31b	2.69	0.00	JMAE17	3.73	0.00
ISKH01	4.59	-11.23	ISKP32	0.42	3.02	KNZC	2.06	0.00
ISKH02	1.67	0.00	ISKP32	0.79	-5.78	KNZC	9.39	-8.55
ISKH02	19.2	-13.84	ISKP32	3.12	-2.93	MTSM01	0.15	-2.89
ISKH03	4.46	-11.23	ISKP33	2.85	-8.55	MTSM01	3.51	-2.93
ISKH03	11.6	-5.78	ISKP33	5.83	-5.78	MTSM02	0.20	0.00
ISKH04	0.89	0.00	ISKP34	0.38	-5.77	MTSM02	3.84	0.00
ISKH04	1.07	0.00	ISKP34	2.61	-5.78	MTSM03	0.15	0.00
ISKH04	8.85	-2.93	ISKP34	6.57	0.00	MTSM03	2.69	0.00
ISKH06	0.66	0.00	ISKP35b	1.40	3.02	MTSM04	0.16	0.00
ISKH06	9.39	0.00	ISKP35b	2.85	-11.23	MTSM04	3.51	0.00
ISKH08	2.94	-2.93	JMA533	0.12	-2.89	MTSM04	4.88	0.00
ISKH08	6.57	-2.94	JMA533	3.62	-2.93	MTSM05	0.14	0.00

Table S7. Relative change in the H/V peak frequency δf_l lasting 0–3 days after the M_j 7.6 mainshock (Part 1/2). Negative values are drops and positive are gains.

Code	f_l (Hz)	δf_l (%)	Code	f_l (Hz)	δf_l (%)	Code	f_l (Hz)	δf_l (%)
MTSM05	1.67	0.00	TYM009	0.24	3.03	TYMP08	0.13	-2.87
MTSM05	2.06	0.00	TYM009	2.85	-5.78	TYMP08	3.84	-2.93
MTSM06	0.15	0.00	TYM010	0.26	-2.93	TYMP10b	0.27	0.00
MTSM06	2.69	0.00	TYM010	1.17	-2.93	TYMP11b	0.28	0.00
MTSM07	0.15	0.00	TYM010	2.53	-5.79	TYMP12	0.15	6.13
MTSM07	2.69	0.00	TYM010	4.59	0.00	TYMP12	1.72	0.00
MTSM08	0.13	0.00	TYM011	3.84	-5.78	TYMP14	0.16	-5.80
MTSM08	1.17	0.00	TYM011	14.7	-2.93	TYMP14	2.77	0.00
MTSM08	2.39	0.00	TYM012	2.77	0.00	TYMP16	0.12	3.06
MTSM09	0.15	0.00	TYM012	3.51	0.00	TYMP16	2.85	3.02
MTSM09	1.40	0.00	TYMH03	0.10	0.00	TYMP19	0.13	0.00
MTSM09	1.94	0.00	TYMH03	0.79	3.03	TYMP19	3.21	0.00
MTSV10	2.61	0.00	TYMH03	2.25	-2.94	TYMP22b	0.13	0.00
MTSV11	0.15	-2.89	TYMH04	0.48	0.00	TYMP22b	1.35	-2.94
MTSV11	0.61	0.00	TYMH04	5.83	-5.78	TYMP23b	0.13	0.00
TYM001	9.11	-2.93	TYMH07	2.85	3.02	TYMP23b	2.00	0.00
TYM002	0.26	-2.92	TYMH07	3.51	0.00	TYMP24b	0.14	0.00
TYM002	0.68	0.00	TYMO	0.15	0.00	TYMP24b	1.28	3.02
TYM002	6.38	0.00	TYMO	0.68	0.00	TYMP24b	1.77	-5.79
TYM003	0.12	0.00	TYMO	2.77	0.00	TYMP24b	3.62	0.00
TYM003	0.18	-2.96	TYMP01	1.32	-8.55	TYMP25	0.13	3.03
TYM003	3.51	-2.93	TYMP01	2.00	6.14	TYMP25	1.67	-2.93
TYM004	0.34	-5.78	TYMP03b	0.16	0.00	TYMP26	0.40	0.00
TYM004	9.97	-2.93	TYMP03b	0.82	0.00	TYMP26	0.51	6.15
TYM005b	0.82	0.00	TYMP03b	2.46	-2.94	TYMP26	2.94	0.00
TYM006	2.94	-2.93	TYMP03b	3.73	0.00	TYMP27	3.73	-2.94
TYM006	4.46	-2.94	TYMP05b	0.26	3.01	TYMP27	5.83	0.00
TYM006	7.18	0.00	TYMP05b	0.68	0.00	TYMP28	4.88	0.00
TYM007b	0.13	0.00	TYMP05b	6.77	3.02	TYMP30	0.17	0.00
TYM007b	2.69	0.00	TYMP05b	10.3	-2.93	TYMP30	3.73	3.02
TYM007b	4.46	0.00	TYMP06	0.11	0.00	TYMP31	0.18	3.02
TYM007b	5.83	0.00	TYMP06	0.61	-5.79	TYMP31	3.84	-8.55
TYM008	0.21	6.12	TYMP06	2.53	0.00	TYMP33	0.17	0.00
TYM008	0.27	3.02	TYMP07b	0.12	0.00			
TYM008	10.9	0.00	TYMP07b	4.59	-2.93			

Table S8. Relative change in the H/V peak frequency δf_l lasting 0–3 days after the M_j 7.6 mainshock (Part 2/2). Negative values are drops and positive are gains.

Code	PGA (m/s ²)	PGV (m/s)	$I_A(T)$ (m/s)	Code	PGA (m/s ²)	PGV (m/s)	$I_A(T)$ (m/s)	Code	PGA (m/s ²)	PGV (m/s)	$I_A(T)$ (m/s)
ISK001	14.28	0.976	25.54	ISKP34	2.80	0.292	1.94	TYM005b	2.03	0.323	1.87
ISK002	8.44	1.273	21.34	ISKP35b	6.12	0.860	12.06	TYM006	3.04	0.280	2.72
ISK003b	15.10	0.803	30.03	ISKP36	3.04	0.538	4.18	TYM007b	1.38	0.120	0.63
ISK005	11.46	1.472	18.04	ISKP38	6.95	1.541	10.50	TYM008	1.21	0.107	0.55
ISK006b	26.78	0.826	80.83	ISKP40b	8.18	0.478	12.66	TYM009	3.90	0.233	5.25
ISK007	4.53	0.498	4.19	ISKP41b	7.23	0.806	11.28	TYM010	2.56	0.134	1.04
ISK008	4.92	0.570	6.59	JMA533	1.65	0.128	0.77	TYM011	1.72	0.105	1.39
ISK009b	2.51	0.201	3.14	JMA534b	3.76	0.272	2.51	TYM012	1.25	0.075	0.51
ISK010	2.15	0.137	0.94	JMA535	6.00	0.514	7.07	TYMH03	2.29	0.246	2.41
ISK011	1.72	0.249	1.02	JMA536	3.38	0.372	2.02	TYMH04	1.37	0.082	0.49
ISK012	2.36	0.074	1.55	JMA910	1.68	0.138	0.99	TYMH07	1.45	0.075	0.53
ISK013b	0.86	0.057	0.19	JMA911	1.81	0.164	1.26	TYMO	1.69	0.344	1.47
ISK014	2.53	0.234	2.02	JMA912b	1.55	0.139	0.77	TYMP01	3.81	0.258	5.48
ISK015	9.79	1.020	14.86	JMA913b	1.88	0.218	1.72	TYMP02b	2.08	0.273	1.90
ISKH01	7.48	1.064	18.18	JMA914	5.74	0.658	4.40	TYMP03b	2.16	0.346	2.46
ISKH02	6.17	0.606	13.18	JMA915b	3.74	0.759	6.90	TYMP05b	3.81	0.557	4.11
ISKH03	7.79	1.079	28.69	JMACC8	2.91	0.118	2.36	TYMP06	1.32	0.171	0.91
ISKH04	6.18	0.813	10.07	JMACC9	3.67	0.137	5.57	TYMP07b	1.81	0.103	1.00
ISKH06	7.97	0.433	5.58	JMACCA	11.05	0.651	27.12	TYMP08	2.38	0.170	0.75
ISKH08	1.91	0.120	1.22	JMACCB	5.22	0.238	4.23	TYMP10b	1.03	0.122	0.47
ISKH09	2.03	0.077	0.99	JMAE10b	5.80	1.125	15.25	TYMP11b	0.99	0.103	0.34
ISKP08	1.66	0.106	0.53	JMAE15	1.92	0.272	1.57	TYMP12	2.58	0.243	2.84
ISKP10	1.79	0.234	1.31	JMAE16	3.19	0.236	2.73	TYMP13b	1.61	0.138	1.12
ISKP11b	2.21	0.310	1.34	JMAE17	1.36	0.178	1.29	TYMP14	1.19	0.127	0.45
ISKP12	3.13	0.201	2.98	KNZC	2.56	0.283	2.43	TYMP16	1.47	0.122	0.61
ISKP13	1.60	0.122	0.76	MTSM01	1.40	0.126	0.48	TYMP19	2.09	0.126	1.67
ISKP14	1.95	0.215	1.09	MTSM02	0.92	0.086	0.20	TYMP20b	1.51	0.067	0.78
ISKP15	1.71	0.115	0.83	MTSM03	1.88	0.110	0.79	TYMP21b	0.86	0.062	0.22
ISKP16	1.63	0.105	0.93	MTSM04	1.88	0.108	0.93	TYMP22b	2.19	0.252	2.28
ISKP17	1.65	0.090	0.50	MTSM05	1.90	0.209	1.51	TYMP23b	2.48	0.306	2.85
ISKP18	1.62	0.086	0.30	MTSM06	1.82	0.193	0.95	TYMP24b	2.13	0.294	2.38
ISKP20	1.48	0.067	0.20	MTSM07	1.76	0.140	0.92	TYMP25	1.70	0.277	1.28
ISKP23	2.55	0.157	1.80	MTSM08	1.58	0.285	1.08	TYMP26	2.00	0.177	1.13
ISKP25	2.57	0.191	2.23	MTSM09	2.00	0.241	1.88	TYMP27	2.07	0.124	1.11
ISKP26	1.73	0.307	1.06	MTSV10	3.22	0.262	3.95	TYMP28	2.97	0.094	1.30
ISKP28	2.71	0.299	3.22	MTSV11	1.59	0.381	1.60	TYMP30	1.91	0.162	0.89
ISKP29	3.10	0.541	4.14	TYM001	0.98	0.062	0.40	TYMP31	3.50	0.251	1.38
ISKP30	2.98	0.406	2.59	TYM002	4.04	0.544	4.10	TYMP32b	2.07	0.197	1.25
ISKP31b	6.41	0.702	9.97	TYM003	1.35	0.096	0.52	TYMP33	1.23	0.157	0.41
ISKP32	3.39	0.660	9.30	TYM004	1.59	0.078	0.72	TYMP35b	2.03	0.282	1.58

Table S9. Maximum horizontal PGA, PGV, and $I_A(T)$ measured on the ground surface during the 2024 M_j 7.6 Noto Peninsula earthquake.

Layer	1	2	3	4	5	half-space
Top depth (m)	0	8	84	234	317	664
V_s (m/s)	240	410	630	1018	2900	3400
ρ (kg/m ³)	1790	1910	2019	2156	2522	2587
Q_s	24	41	63	102	290	340

Table S10. The composite velocity model at the ISKH01 site (KiK-net network).

Layer	1	2	3	4	5	half-space
Top depth (m)	0	4	76	105	709	721
V_s (m/s)	420	810	530	1981	2900	3200
ρ (kg/m ³)	1916	2088	1974	2377	2522	2562
Q_s	42	81	53	198	290	320

Table S11. The composite velocity model at the ISKH02 site (KiK-net network).

Layer	1	2	3	4	5	6	half-space
Top depth (m)	0	2	10	28	230	313	814
V_s (m/s)	110	200	500	870	1083	2900	3400
ρ (kg/m ³)	1644	1753	1959	2109	2175	2522	2587
Q_s	11	20	50	87	108	290	340

Table S12. The composite velocity model at the ISKH03 site (KiK-net network).

Layer	1	2	3	4	5	6	7	half-space
Top depth (m)	0	2	28	50	82	232	1010	1018
V_s (m/s)	440	440	500	660	920	2129	2900	3200
ρ (kg/m ³)	1927	1927	1959	2031	2125	2403	2522	2562
Q_s	44	44	50	66	92	213	290	320

Table S13. The composite velocity model at the ISKH04 site (KiK-net network).

Layer	1	2	3	4	half-space
Top depth (m)	0	4	44	174	204
V_s (m/s)	240	600	480	600	3300
ρ (kg/m ³)	1790	2006	1948	2006	2575
Q_s	24	60	48	60	330

Table S14. The composite velocity model at the ISKH06 site (KiK-net network).

Layer	1	2	3	4	5	6	7	half-space
Top depth (m)	0	15	50	90	160	300	620	920
V_s (m/s)	440	440	630	1090	960	750	1080	3200
ρ (kg/m ³)	1927	1927	2019	2177	2138	2067	2174	2562
Q_s	44	44	63	109	96	75	108	320

Table S15. The composite velocity model at the ISKH07 site (KiK-net network).

Layer	1	2	3	4	half-space
Top depth (m)	0	4	10	630	929
V_s (m/s)	160	160	450	1999	3200
ρ (kg/m ³)	1710	1710	1933	2380	2562
Q_s	16	16	45	200	320

Table S16. The composite velocity model at the TYMH02 site (KiK-net network).

Layer	1	2	3	4	half-space
Top depth (m)	0	14	60	300	568
V_s (m/s)	600	730	530	1503	3200
ρ (kg/m ³)	2006	2059	1974	2281	2562
Q_s	60	73	53	150	320

Table S17. The composite velocity model at the TYMH04 site (KiK-net network).

International name (English)	Local name (Japanese)	Local name (Romanized)	Description
Japan	日本	Nihon	island country in East Asia
Pacific Ocean	太平洋	Taiheiyō	the major ocean from Earth's principal water areas
Sea of Japan	日本海	Nihon-kai	the marginal sea between the Japanese archipelago, the Korean Peninsula, the Sakhalin Island, and the mainland of the Russian Far East
Toyama Bay	富山湾	Toyama-wan	bay located on the northern shores of the Toyama Prefecture in Japan
Nanao Bay	七尾湾	Nanao-wan	bay located on the eastern shores of the Noto Peninsula
Noto Peninsula	能登半島	Noto-hantō	peninsula that projects north into the Sea of Japan from Honshū (the main island of Japan)
Noto Island	能登島	Noto-jima	island in the Nanao Bay located eastern from the Noto Peninsula
Ishikawa Prefecture	石川県	Ishikawa-ken	1st level administrative unit in Japan
Toyama Prefecture	富山県	Toyama-ken	1st level administrative unit in Japan
Niigata Prefecture	新潟県	Niigata-ken	1st level administrative unit in Japan
Kanazawa City	金沢市	Kanazawa-shi	capital city of Ishikawa Prefecture
Toyama City	富山市	Toyama-shi	capital city of Toyama Prefecture
Wajima City	輪島市	Wajima-shi	municipality in Ishikawa Prefecture
Suzu City	珠洲市	Suzu-shi	municipality in Ishikawa Prefecture
Nanao City	七尾市	Nanao-shi	municipality in Ishikawa Prefecture
Noto Town	能登町	Noto-chō	municipality in Ishikawa Prefecture
Anamizu Town	穴水町	Anamizu-machi	municipality in Ishikawa Prefecture
Shika Town	志賀町	Shika-machi	municipality in Ishikawa Prefecture
Monzen Town	門前町	Monzen-machi	settlement located in Wajima municipality of Ishikawa Prefecture
Tatsuruhamata Town	田鶴浜町	Tatsuruhamata-machi	settlement located in Nanao municipality of Ishikawa Prefecture

Table S18. List of used geographical terms with their local names and descriptions.