

Source process analysis of the 2024 Noto peninsula earthquake using near-field strong motion waveforms

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- Introduction -

The Noto-Hanto earthquake, which occurred at 16:10 on January 1, 2024, has a JMA magnitude (M_j) of 7.6, the largest class crustal earthquake in Japan. The maximum JMA seismic intensity is 7, and strong ground motions have caused devastating damage. Detailed source process information is needed to discuss the mechanism of such a large earthquake and its strong motions. For this purpose, near-field waveform inversion analysis was performed to estimate the high spatiotemporal resolution source process.

- Methods of Analysis -

Before the source inversion, we performed source relocation using the Double Difference method (Waldhauser & Ellsworth, 2000) for the earthquakes within 2 weeks after the main shock to configure the fault planes and other parameters.

The inversion analysis was performed using the multi-time windows method (Yoshida et al., 1996; Hikima & Koketsu, 2005). We used 10 KiK-net stations installed on the Noto peninsula, Toyama, and southern Niigata Pref. K-NET stations, installed on Noto and Sado Island, are also used, although waveforms that seem to be affected by liquefaction were excluded. The observed accelerograms from 16 stations in total were applied to the bandpass filter, whose flat level is 0.03 to 0.4 Hz, and integrated into velocity waveforms for the inversion analysis.

Green's functions for the inversion were calculated using the reflectivity method (Kohketsu, 1985). The required 1D velocity structure models were tuned by the observed waveforms from small earthquakes.

- Source Process Analysis -

The occurrence time for the M7.6 event of the 2024 Noto-Hanto earthquake is determined to be 16:10:22 by the JMA unified catalog. However, the M5.9 event occurred near the mainshock at 16:10:09, which also the JMA determined, and the waveforms from these earthquakes were recorded continuously in the observation records. The distance between those epicenters is a few kilometers. The recorded waveforms at surrounding stations show that the first motions of the foreshock have time delays corresponding to the epicentral distance from the M5.9 event. However, the wave packets considered from the main shock arrive at these stations almost simultaneously. Therefore, those do not appear to correspond to the distance from the epicenter by the JMA catalog. In other words, the initial point of the main rupture of the M7.6 event may be different from the hypocenter in the catalog.

Based on the above, firstly, we have performed preliminary analyses in which the time windows in the multi-time window method are open simultaneously to estimate the rough spatiotemporal slip distribution directly from observed waveforms. A flat southeast dipping fault plane is assumed to be 145 km and 30 km in length and width, respectively, covering the aftershock area. The subfault size for the inversion was set to 5 km. As a result, the image in which the rupture starts at the southwest point rather than the JMA epicenter and propagates to the southwest on the fault was obtained. After that, it was estimated that the rupture toward the northeastern part started with a 5 to 10-second delay from the initiation.

The detailed analysis was performed assuming that the rupture propagates from the initiation point estimated from the preliminary analysis, and time windows were set up to account for time delay on the northeast side of the fault. Fault planes were set regarding the aftershock distribution, and the subfault size of 4 km was used. Considering an alignment of northwest dipping aftershocks at the northeastern end

of the source area, a northwest dipping fault was set at this region, and southeast dipping faults were set on other parts. A north-south strike segment was set based on the aftershock distribution at the southwest end of the fault area. As a result, 4 fault planes were set in the detailed analysis.

The final slip distribution indicates large slip areas below the northern tip of the Noto Peninsula, the coast from Suzu to Wajima, and southwest of Wajima. These areas are consistent with the heavily damaged areas caused by strong motions and the observed crustal deformation. A large slip is also recovered in the northeastern offshore area of the peninsula. On the other hand, the slip on the northwest dipping fault is relatively small, and its contribution during the main shock may not be significant. The total Mw is 7.5 to 7.6, and the maximum slip is estimated to be 6.5 to 7 m.

Slip distribution of the M 5.9 event was also estimated provisionally. It is possible that the rupture propagated toward the side close to the rupture initiation area of the M7.6 main shock, although further investigation is needed.

Keywords: The 2024 Noto-hanto earthquake, Source process, Strong ground motion, Crustal earthquake

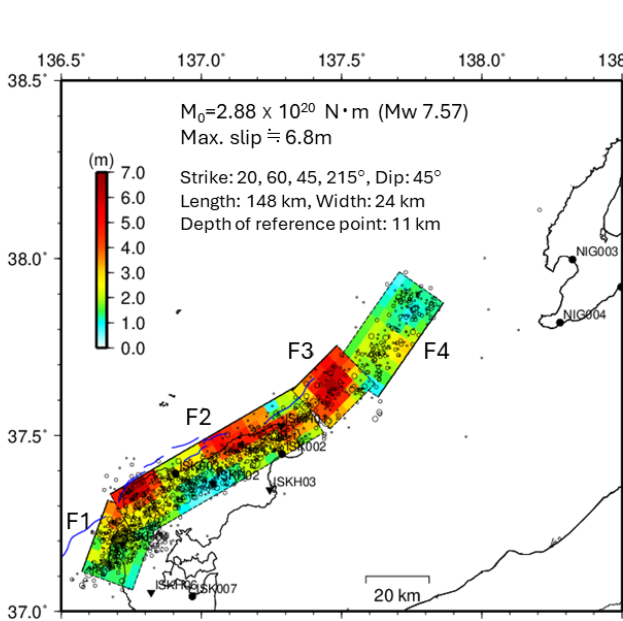


Figure 1. The fault geometry and final slip distribution on the fault. The fault consists of four planes. The yellow stars denote the reference point corresponding to the JMA epicenter.

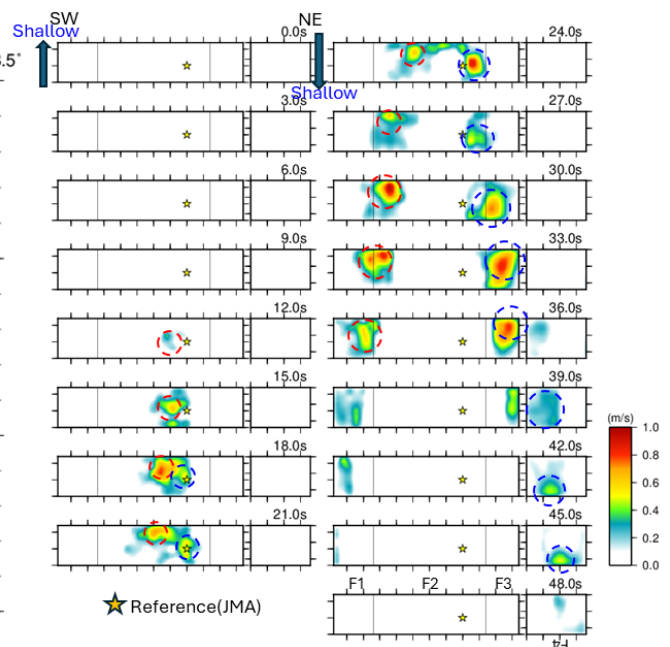


Figure 2. Snapshot of slip velocity at 3-second intervals. The start time (0 s) corresponds to the origin time of the foreshock (Mj 5.9).