

Widespread observed off-fault aftershocks and the calculated stress transfer associated with the 2024 M7.5 Noto-Hanto, Japan, earthquake

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The January 1, 2024 Noto Hanto earthquake, the largest inland earthquake in Japan since the late 19th century, caused severe shaking with peak accelerations of up to 2.7g throughout the Noto Peninsula. The quake ruptured approximately 150 kilometers of east-northeast-trending thrust faults dipping southeast (Inoue and Okamura, 2010), located several kilometers offshore the northern coast of the Noto peninsula. It triggered a significant number of aftershocks along the rupture zone, comparable to those of the 1994 M7.8 Hokkaido-Nansei-oki earthquake in the eastern Japan Sea. Fortunately, the aftershock decay (Omori-Utsu $p \sim 1.2$) has been rapid thus far. However, we cannot ignore the widespread off-fault aftershocks, extending approximately 100 kilometers from the edges of the source faults, which may become potential nucleation sites for the next large event. To clarify the locations of the triggered activity, we examined the seismicity rate change by comparing the post-mainshock seismicity (93 days since the mainshock) with the preceding two-year seismicity, using the Japan Meteorological Agency hypocenter catalog. We found that the rate increases, relative to their average pre-mainshock rates, were: 150 times for offshore the peninsula to the west (A), 9 times for onshore in the cities of Toyama and Kanazawa (B), 7 times for offshore to the west of Sado Island (C), and 11 times in Toyama Bay (D) (see Fig. 1). The calculated Coulomb stress imparted by our own source fault model reasonably explains the triggered seismicity, except in Toyama Bay, where instead a significant stress decrease on thrust faults is expected. Incorporating plausible rate/state friction parameters along with background rates of seismicity, with and without the preceding three-year seismic swarm at the 2024 epicenter, we calculated the expected numbers of earthquakes with $M \geq 5.0$ from April 1st, 2024, to March 31st, 2025, using the approach of Toda and Stein (BSSA, 2020). The respective numbers are 0.3 and 14 $M \geq 5$ shocks, and so the swarm plays a large and uncertain role in these calculations that must be resolved. Nevertheless, since the Coulomb stress increase on nearby active faults, such as the Bijoan fault zone and Ochigata fault zone, is up to 1-2 bars, the increased rates of small earthquakes temporarily raise the probabilities of subsequent large earthquakes on these faults.

Keywords: Noto-Hanto earthquake, off-fault aftershocks, seismicity, Coulomb stress change

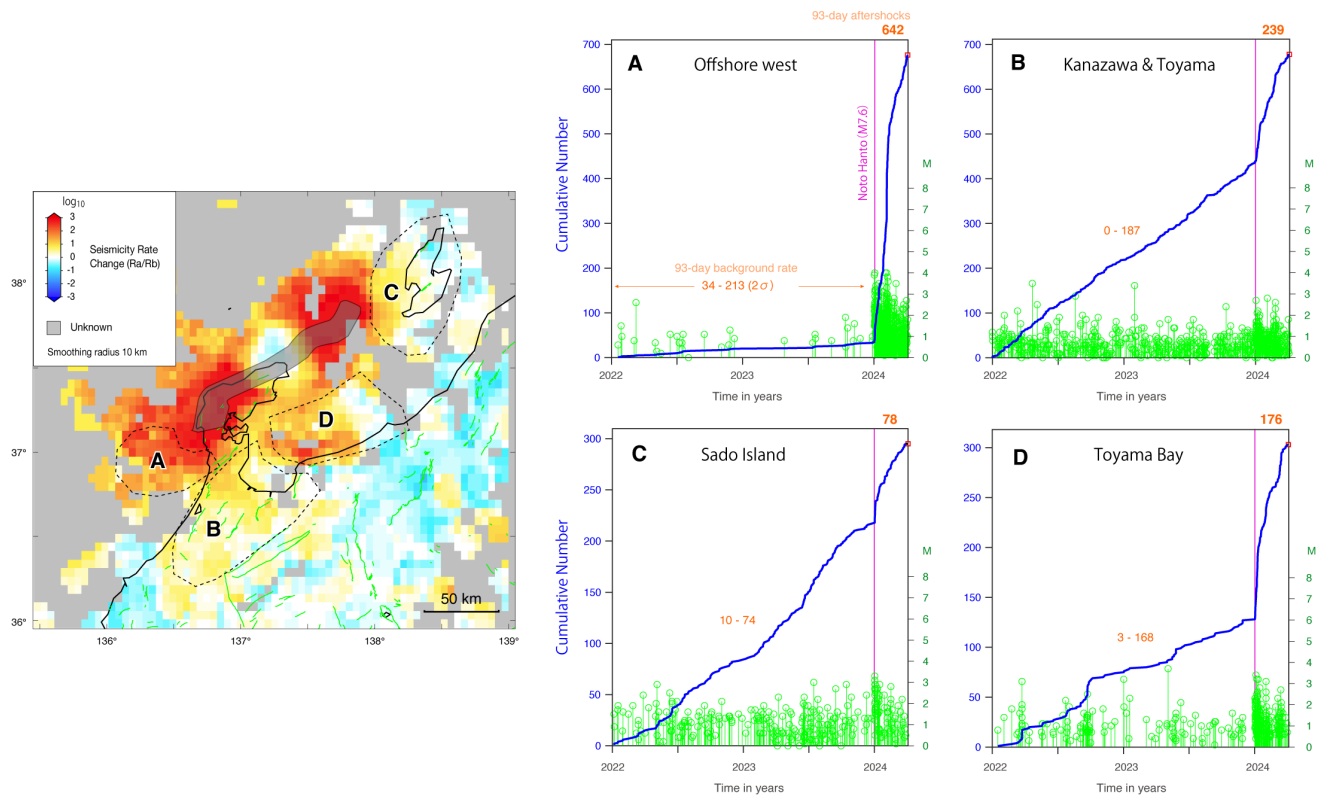


Fig. 1. Seismicity rate change between 93 days after and 2 year before the 2024 Noto-Hanto earthquake and seismicity time series in sub-regions