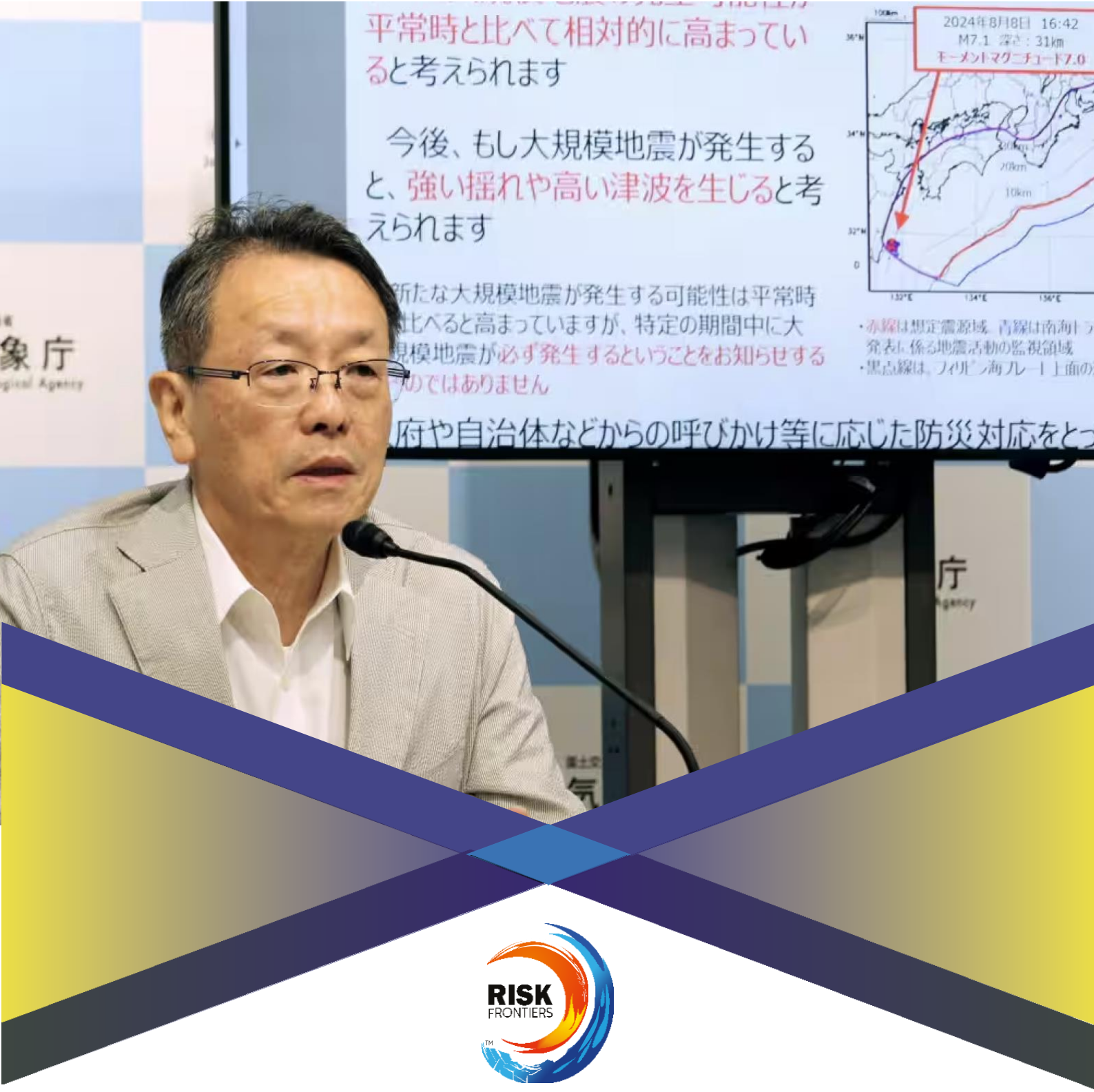

The first triggering of a mega-earthquake advisory in Japan

Cover image source: SBS News

PAUL SOMERVILLE

Issuance of a Mega-Earthquake Advisory following the 8 August 2024 magnitude 7.1 event off Miyazaki

The Nankai Trough along the Pacific Coast of southwest Japan has a recorded history of twelve large subduction earthquakes dating back to 685 AD (Figures 1 and 2). On 8 August 2024, a magnitude 7.1 earthquake occurred off the city of Miyazaki on Japan's southern island of Kyushu (Figure 2, left panel). The earthquake is thought to have occurred on the interface between the Pacific Plate and the Eurasian Plate of the Hyuganada Trough (Figure 1, right panel). The earthquake prompted the Japanese Meteorological Agency to issue a mega-earthquake advisory: a warning that the likelihood of a magnitude 8 to 9 earthquake on the Nankai Trough plate boundary was higher than usual. Before the advisory was issued, JMA had estimated that there was a 70% to 80% chance of a very large earthquake occurring on the Nankai Trough in the next 30 years. Immediately after the earthquake on 8 August 2024, people were advised to be prepared by taking common-sense measures such as securing furniture and confirming the locations of evacuation shelters. JMA also advised the voluntary evacuation for some vulnerable groups of people. The advisory was in place for a week.

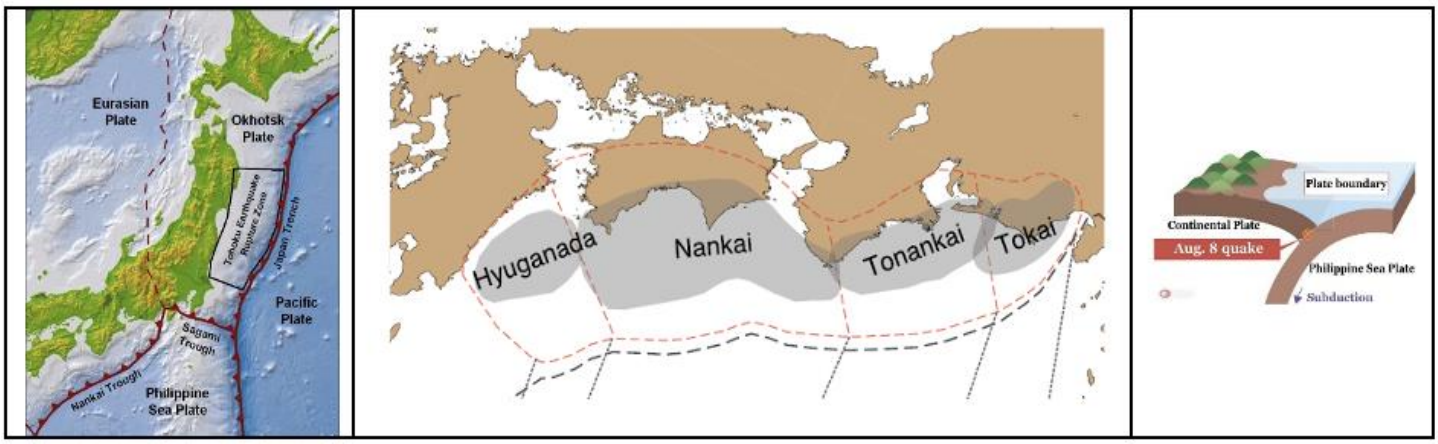

Figure 1. *Left: Subduction zones in Japan. Centre: Segments of the Nankai Trough plate interface in western Japan. Source: Fukushima et al., 2025. Right: Cross section through the Nankai Trough subduction zone showing the location of the magnitude 7.1 August 2014 earthquake on the interface between the Philippine Sea plate and the Eurasian continental plate.*

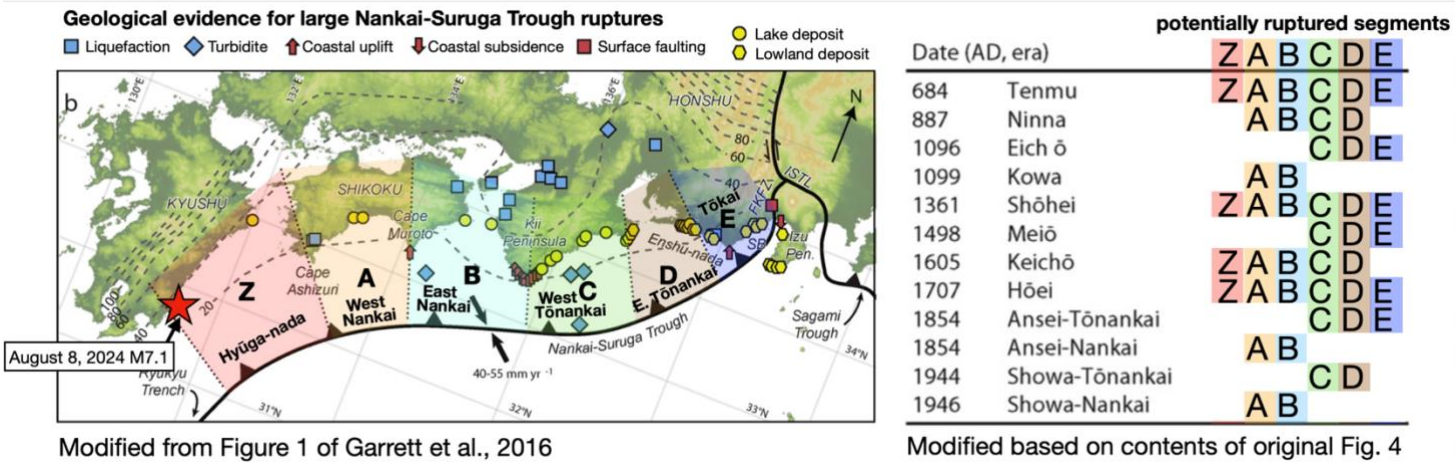

Figure 2. *Map of the Nankai Trough showing fault segments on the plate interface and the locations where geological evidence of great earthquakes has been identified. Right: List of known great earthquakes on the Nankai Trough. Source: Bradley and Hubbard (2024).*

How the 2011 magnitude 9.1 Tohoku Earthquake led to the Nankai Trough Earthquake Advisory

This was the first time that a mega-earthquake advisory was issued since this protocol was established in 2019 in response to the magnitude 9.1 Tohoku earthquake on the Japan Trench off the northeast coast of Japan in 2011 (Figure 1, left panel), which caused tsunamis as high as 30 metres and left 18,500 people dead or missing. Prior to that earthquake, the largest earthquake that was thought by the government to be possible on the Japan Trench was a magnitude 8.6 earthquake.

Based on this precedent, the government greatly expanded the anticipated maximum rupture area of a Nankai Trough megathrust earthquake, extending it southwest to Miyazaki (near the 2024 magnitude 7.1 earthquake) and increasing its maximum magnitude from magnitude 8.6 to 9.1. Also, because the 2011 Tohoku earthquake on the Japan Trench was preceded by a magnitude 7.3 earthquake that occurred nearby, it also instituted the protocol that any earthquake of magnitude 7.0 or more that occurred inside the anticipated Nankai Trough magnitude 9.1 earthquake rupture zone would trigger a mega-earthquake advisory, as occurred on 8 August 2024. On 13 January 2025, another earthquake with magnitude 6.8 occurred off Miyazaki adjacent to the 8 August event. After an investigation, the JMA concluded that the earthquake did not warrant another advisory in part because its magnitude fell below the 7.0 threshold.

Why the 8 August 2024 may not foreshadow the occurrence of a Nankai Trough Mega-Earthquake

Toda et al. (2024) noted that, unlike the other segments of the Nankai Trough, the Hyuganada segment experiences frequent earthquakes in the magnitude range of 7.0 to 7.5 which may release all of the strain that builds up on the plate interface there, preventing the accumulation of enough strain to generate a multi-segment ruptures on the Nankai Trough. They also noted that the historical and paleoseismic record of great earthquakes on the Nankai Trough does not include any that were preceded by foreshocks of magnitude about 7 in Hyuganada, and that it is uncertain whether any of the historical Nankai Trough earthquakes have extended into Hyuganada. The left panel of Figure 2 shows that there is only one observation point for evidence of mega-earthquakes in Hyuganada, with no events occurring since 1707. For these reasons they concluded that it was highly unlikely that the 8 August 2024 magnitude 7.1 earthquake would prove to be a foreshock of a major megathrust earthquake on the Nankai Trough in the next several days or months. This view is consistent with that of the government, which acknowledged that the occurrence of a mega-earthquake was unlikely. However, there is also no evidence that smaller Hyuganada earthquakes have never preceded large multi-segment ruptures on the Nankai Trough in pre-historical time. Moreover, Hyodo et al. (2016) used quasi-dynamic multi-earthquake simulations to find that in the latter half of a seismic cycle preceding a large Nankai Trough earthquake, a Nankai earthquake tends to be triggered prematurely within several years after the occurrence of a Hyuganada earthquake, followed by the occurrence of a Tonankai earthquake with maximum time lags of several years.

Test of the Time-Predictable Earthquake Model Forecast of an Imminent Nankai Trough Mega-Earthquake

The panel on the right side of Figure 2 shows the Nankai Trough segments that appear to have ruptured together during the twelve historical earthquakes. Over the last 1,340 years, there have been at least 12 great earthquakes, giving an average recurrence of about 111 years between events, with the last event 78 years ago. There is a wide range in recurrence intervals, with one gap of more than 250 years between events. However, Shimazaki and Nakata (1980) presented historical and geomorphological evidence for regularity in earthquake recurrence at three different sites of plate convergence around Japanese subduction zones, including at Murotsu Port, Shikoku, on the Nankai trough. Their time-predictable model states that the time interval between two successive large earthquakes is approximately proportional to the amount of coseismic displacement of the preceding

earthquake and not of the following earthquake, enabling in principle the prediction of the approximate occurrence time of an earthquake if the amount of displacement of the preceding earthquake is known. They estimated the occurrence time of the next Nankai Trough earthquake to be about 2040, and have recently revised this estimate to about 2030 in an abstract for the Japan Geophysical Union meeting in May 2025 (Shimazaki et al., 2025). The time-predictable model of Shimazaki and Nakata (1980) is about to be tested.

Potential Impact of a Nankai Trough Mega-earthquake

The government's Central Disaster Prevention Council in 2019 released projections that in a worst-case scenario (Figure 3) there could be more than 231,000 dead or missing from a Nankai Trough mega- earthquake and ensuing tsunami as much as 30 metres high, along with nearly 2.1 million completely destroyed or burned structures in the affected region, and Y213.7 trillion in economic damage, ten times higher than in the 2011 Tohoku earthquake and tsunami.

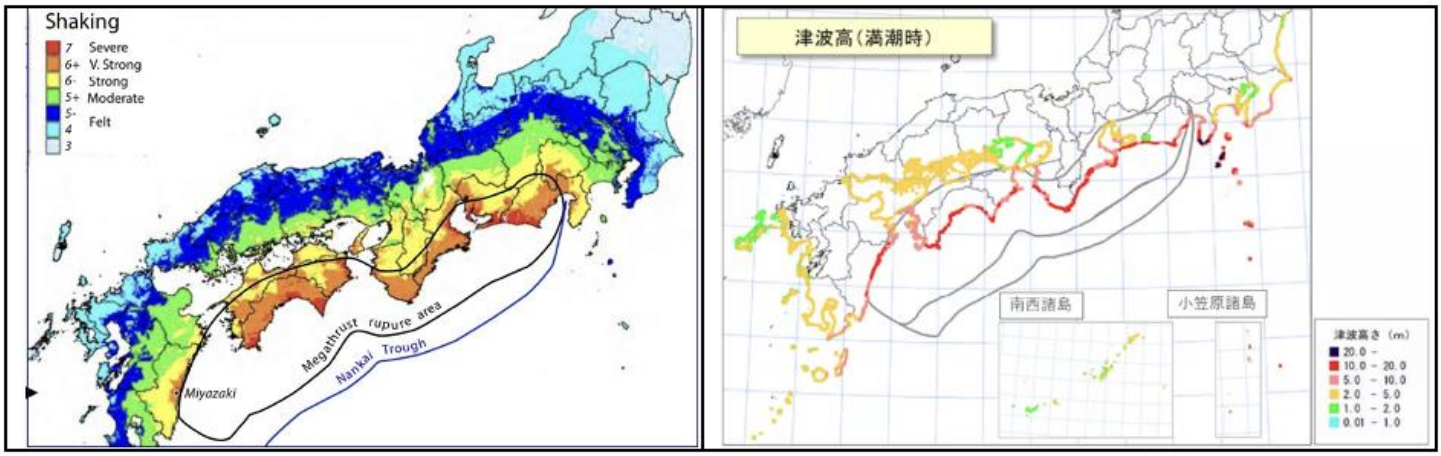

Figure 3. *Left: Expected shaking of the largest expected event Nankai earthquake (magnitude 9.0). Source: Central Disaster Prevention Council, 2012. Right: Expected tsunami wave height in metres from the largest expected Nankai earthquake (magnitude 9.1). Japan Meteorological Agency, 9 August 2024.*

Acknowledgments

The author thanks Professors Shimazaki, Nakata and Shibata for sharing their 2025 JpGU abstract. The use of figures from Bradley and Hubbard (2024), Garret et al. (2016) and Fukushima et al. (2023) via the Creative Commons is gratefully acknowledged.

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