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Japan's Tsunami Risk: Research in Monitoring and Mitigation

Japan is one of the most researched countries in the world on tsunami risk, yet there are still new discoveries regularly being made by research communities and government agencies across the region. As a result, the Gallagher Research Centre is partnering with leading tsunami experts at Tohoku University to continuously review the latest research and enhance our understanding of the risk, both in Japan and other regions globally.

Here, tsunami specialist Dr. Anawat Suppasri explores some of the changes made to tsunami monitoring and mitigation in Japan following the 2011 Tohoku Earthquake, as well as the importance for insurers to consider the many alternative sources of tsunami.

2011 tsunami: The most powerful earthquake ever recorded

It has been more than a decade since the 2011 Great East Japan Earthquake and Tsunami (commonly termed the 'Tohoku Earthquake' or '3.11' in Japan). Aside from the human toll of nearly 20,000 fatalities, the total economic damage from the event was estimated at 16.9 trillion Yen.[1] Of the financial losses, around 15% was recovered through respective property, casualty, life, and cooperative insurance.[2]

The 2011 event remains the most powerful earthquake in the Japan region since modern methods of seismicity measurement began in 1900, and led in part to concerted efforts to improve tsunami mitigation measures along Japan's coastline.

This includes an increased seawall height and improved coastal flood defenses, raised land elevation, elevated roads, an expanded tsunami observational network, and improved early-warning systems.

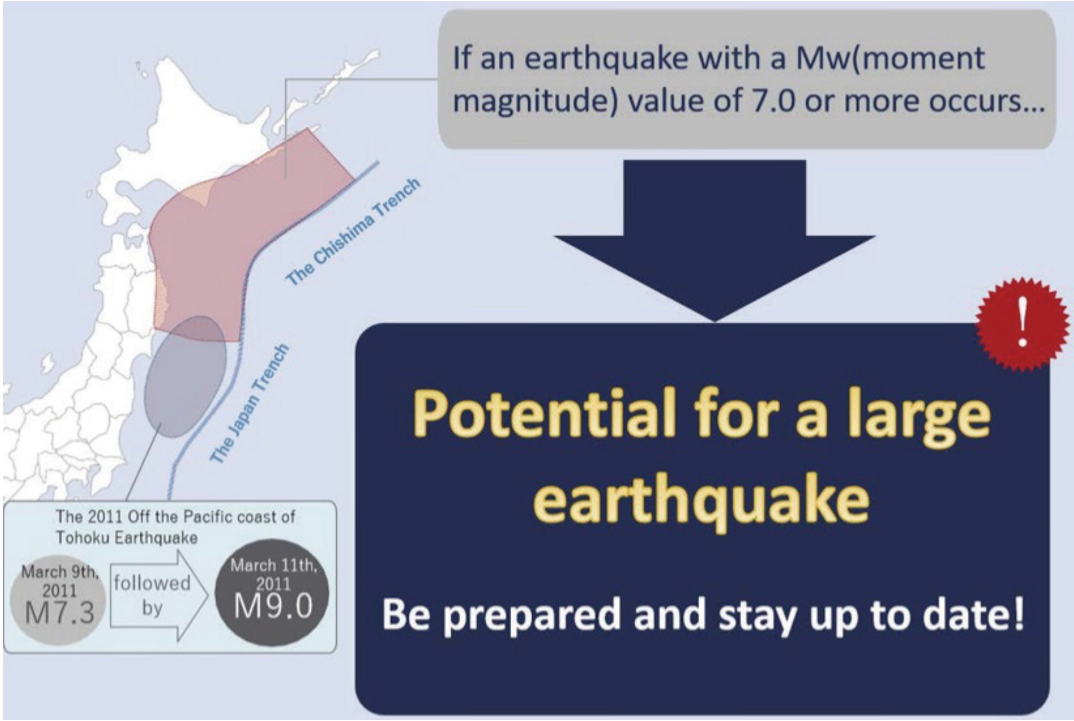
New tsunami alert system for real-time monitoring

Japan is currently operating the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net). This is the world's largest network of ocean bottom pressure sensors for real-time tsunami monitoring and was installed after the 2011 tsunami.[3] S-net allows for early warning and detection of tsunamis so that communities along Japan's coastline are given as much advance notice as possible from these deadly events.

Since earlier seismic activity in an area frequently serves as a precursor to more significant earthquakes, monitoring is crucial. A large-scale follow-up event is thought to be relatively likely if an earthquake of magnitude 7.0 or more takes place in or around the expected focal regions of megathrust earthquakes along the Japan and Chishima trenches. For instance, there was an earthquake with a 7.3 magnitude recorded just two days before the 9.0 magnitude earthquake that generated the 2011 tsunami.

For this reason, in November 2022, Japan created a new alert system to address the risk from subsequent earthquakes which is called 'Off the Coast of Hokkaido and Sanriku Subsequent Earthquake Advisory'.[4]

In cases where a 7.0 magnitude or higher earthquake occurs in this region, the Japan Meteorological Agency (JMA) will issue an alert (Figure 1), although based on global historic records, the probability of this remains relatively low at around 1/100.



*Advisory issuance is not a certain indication of a subsequent megathrust earthquake.

Figure 1: Japan Meteorological Agency's target area for the Off the Coast of Hokkaido and Sanriku Subsequent Earthquake Advisory[4]

New risk appraisal for tsunamis along the east coast of Japan

Since the 2011 event, new tsunami deposits have been found along the east coast of Hokkaido, highlighting that magnitude 9-class earthquakes with tsunami events have repeatedly struck this region in the past. This led to re-evaluating the existing risk in the region and a new estimate of the potential maximum earthquake and tsunami size.[5]

According to a report from Japan's Cabinet Office, the updated estimates of a worst-case earthquake magnitude along the Chishima Trench and Japan Trench are 9.3 and 9.1, respectively (Figure 2), with an estimated recurrence period of 300–400 years,[6] and an estimated maximum tsunami height of up to 30m.[7] The maximum tsunami height along the east coast of Hokkaido is estimated to be more than 20m, and around 10–20m in Aomori and Iwate prefectures, which exceed the height of the 2011 tsunami. Although far from the earthquake source, 10–20m tsunamis are still estimated in Miyagi and Fukushima prefectures which is comparable to the 2011 tsunami but decreases to 5m in the Kanto region.

The impact of such events could be catastrophic, with total fatalities that could reach as high as 200,000 people from the Japan Trench event and 100,000 from the Chishima Trench event. The worst-case scenario would be a tsunami occurring late at night in the winter as people would be more likely to be caught unaware. In such a circumstance, economic damage is estimated at 31.3 trillion Yen for the Japan Trench case and 16.7 trillion Yen for the Chishima Trench case.[8]

To help raise awareness of such earthquake scenarios, the local authority in Miyagi Prefecture[9] has published new tsunami hazard maps showing the impact of these worst-case scenarios alongside consideration of how the 2011 tsunami could have been worse (for example, co-seismic subsidence, a high tide, and a failure of the seawall). There are some locations where the new hazard map illustrates a wider tsunami inundation range as well as higher maximum water depths.

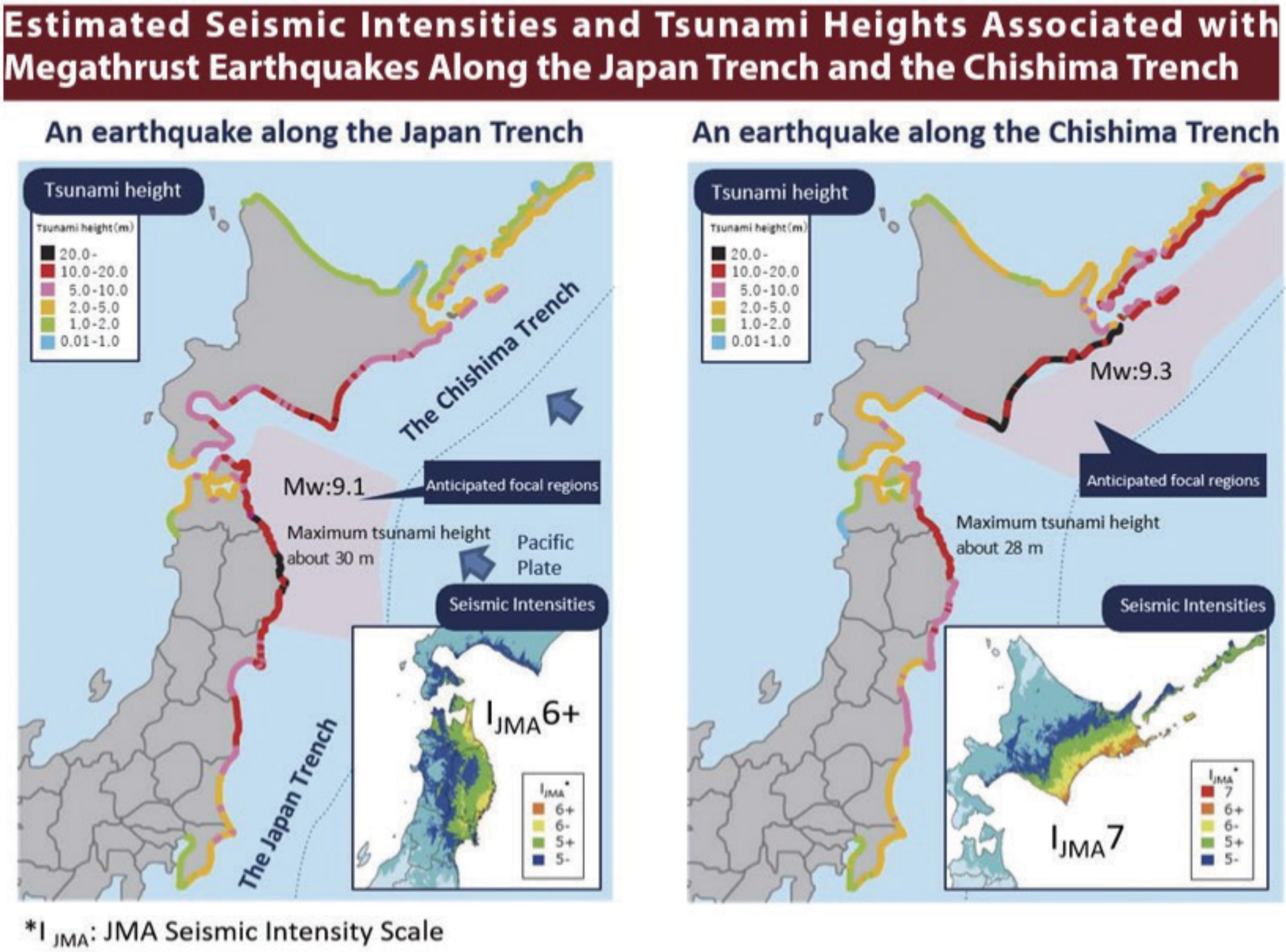


Figure 2: Location of the Japan Trench and Chishima Trench with simulated maximum tsunami height[4]

Tsunami from an outer-rise earthquake

It is important to mention that the Chishima Trench and Japan Trench earthquakes are not the only potential large events in the region. Japanese scientists are turning their attention to the risks from large 'outer-rise earthquakes' induced by interplate thrust events,[10] highlighting how damaging the associated tsunamis can be. For example, the 1933 Sanriku tsunami generated from a magnitude of 8.6 outer-rise earthquake resulted in more than 3,000 deaths in Japan and significant damage on the island of Hawaii.

While scientists cannot predict whether an outer-rise earthquake will always be induced by an interplate one, nor how long after, understanding the potential of such events generating tsunami is important. On the east coast of Japan, it was evidenced that a M7.9 earthquake in 2006 induced a M8.2 outer-rise earthquake along the Chishima Trench after two months, while the M8.2 earthquake in 1896 is believed to have induced a M8.1 outer-rise earthquake along the Japan Trench 37 years later.

Given that it has now been over 12 years since the 2011 event, there has been a change in the seismicity rate which began around five years after the 2011 earthquake.[11] This has led to attempts to assess the contemporary tsunami hazard from an outer-rise earthquake within this region. One study has shown that the maximum earthquake magnitude could be M8.7, generating a potential maximum tsunami height of 27m on the northeast coast of Japan[12] (Figure 3). Nevertheless, there is no official study from the government to assess both hazard and economic damage from such scenarios. From a catastrophe modelling perspective, some of the models used by the reinsurance industry do consider such events (although available scenarios do not extend to such a large magnitude) and the sources have a potential to generate tsunami.

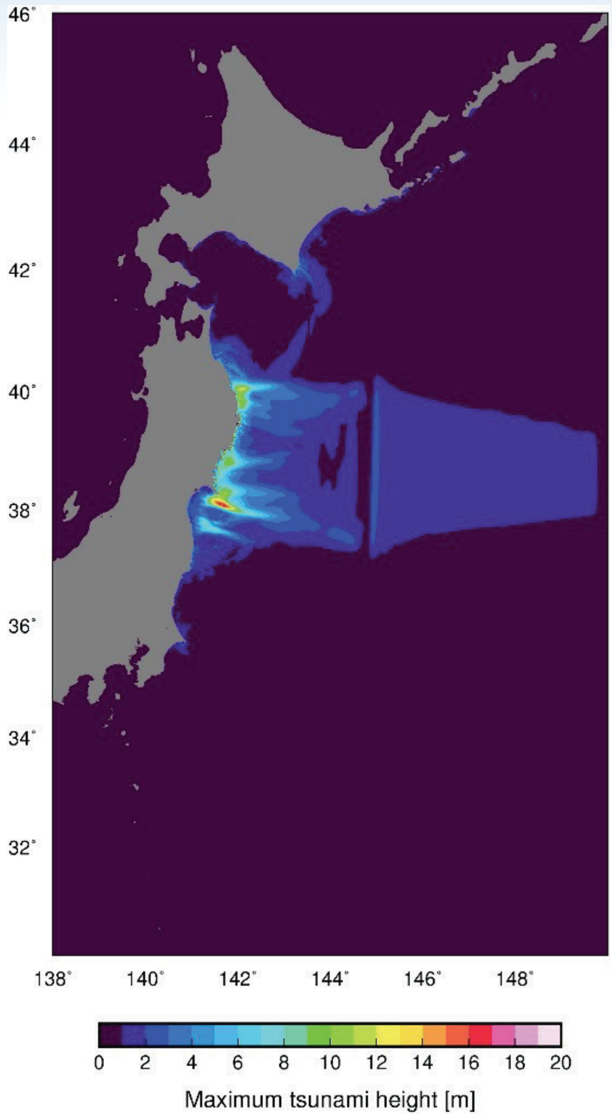


Figure 3: Simulated maximum tsunami height from outer-rise earthquake[11]

What are outer-rise earthquakes and can they generate tsunamis?

Unlike typical tsunamigenic earthquakes that occur on the thrust fault that separates tectonic plates in a subduction zone ("interplate thrust"), outer-rise earthquakes occur within the subducting or downgoing plate before it enters the subduction zone.

Outer-rise earthquakes are often associated with higher fault slip than interplate earthquakes of similar magnitude, which translates into great vertical movement of the seafloor. Moreover, tsunami generation by an outer-rise earthquake occurs in much deeper water, and when a tsunami travels from deep water to shallow water, the speed of the wave crest slows, the wavelength decreases, and the wave height increases. Therefore, a tsunami that starts off in deeper water will be more amplified by the time it reaches the shore than a comparable tsunami that starts off in shallower water.

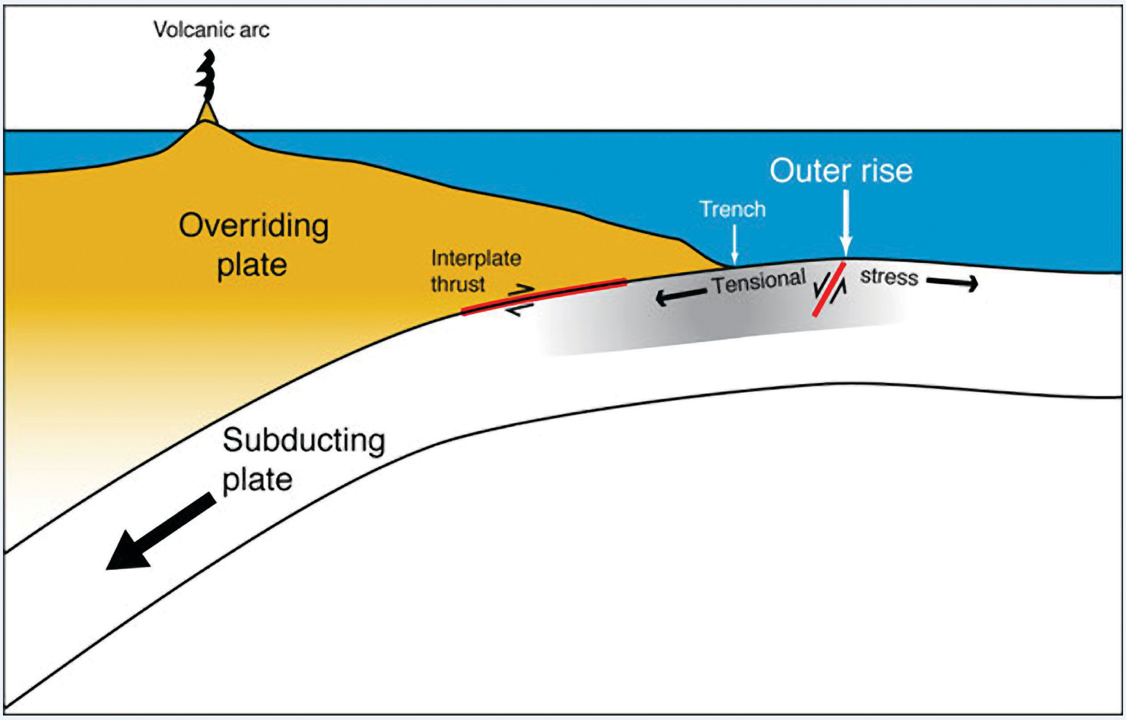


Figure 4: Schematic diagram of a subduction zone, showing the location of the outer-rise and tensional stresses within the subducting plate.[13]

Risk from transoceanic tsunamis

Tsunamis from the other side of the world can also cause damage along the Japanese coastline. Historically, there have been a number of cases where tsunamis that originated from afar have affected Japan. The most notable event was the 1960 Chilean earthquake with magnitude 9.5. This is estimated as the world's largest earthquake event. The subsequent transoceanic tsunami reached Japan after a day with 5.5m waves, causing an estimated 50 million USD of damage.[14] In 2010, a transoceanic tsunami from the M8.8 Chilean earthquake caused no inland inundation, but the tsunami caused extensive fisheries damage along the Tohoku coast. Aquaculture rafts and other related facilities that had only recently been replaced were destroyed again in the 2011 Tohoku earthquake. More recently, in 2022, the large-scale eruption of the Hunga Tonga-Hunga Ha'apai submarine volcano off the coast of Tonga in the South Pacific Ocean also generated a transoceanic tsunami that reached Japan[15] (Figure 5). The event damaged fisheries along the Tohoku coast.[16]

With global-scale catastrophe models still in the early stages of development, capturing the impact of transoceanic tsunamis is challenging. Gallagher Re has partnered with Tohoku University and is conducting research on a number of global tsunami scenarios that can be used to assess your risk from extreme events.

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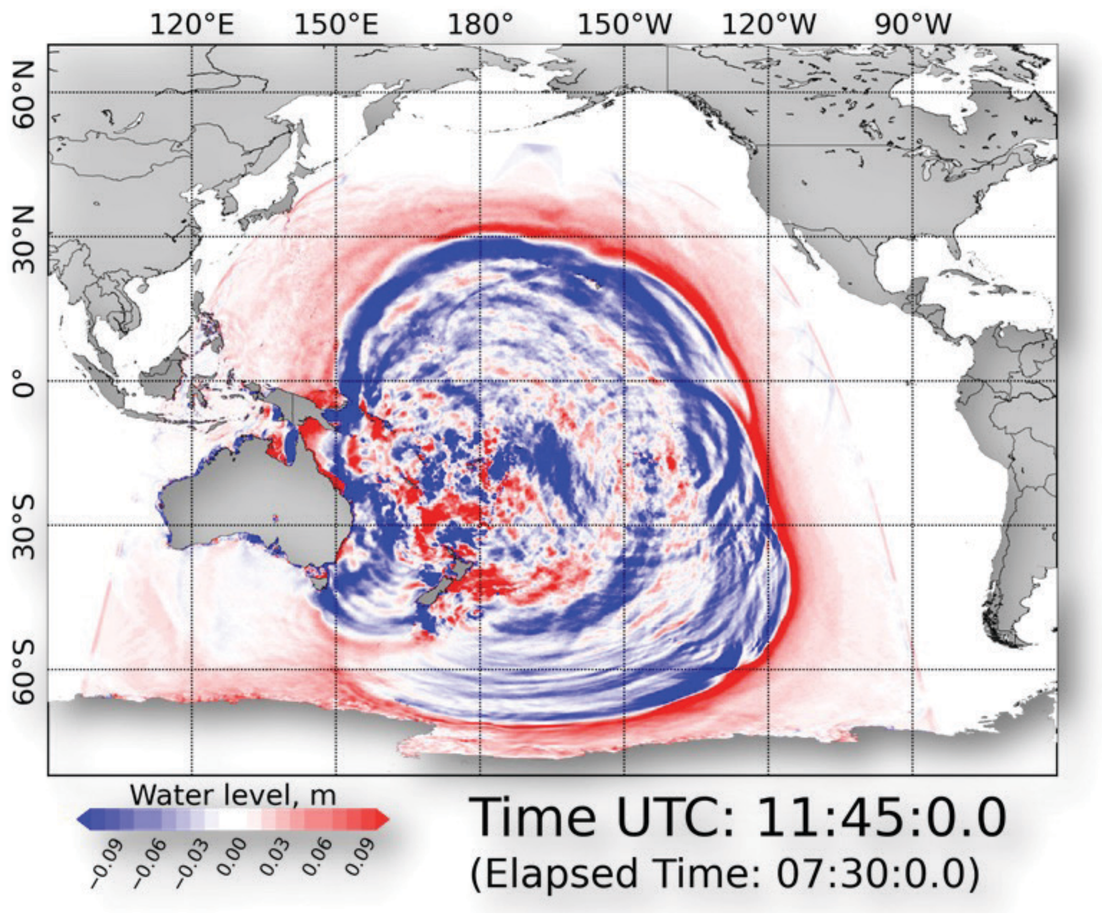

Figure 5: Simulated maximum tsunami amplitude of the 2022 Tonga tsunami[15]

How can we help?

Gallagher Re with GRC partner Tohoku University have developed tsunami models for Japan and other parts of the world. For more information on Gallagher Re's Catastrophe Analytics for Japan and the Gallagher Research Centre, please contact your local client representative.

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