GEOMAR

Marine Natural Hazards

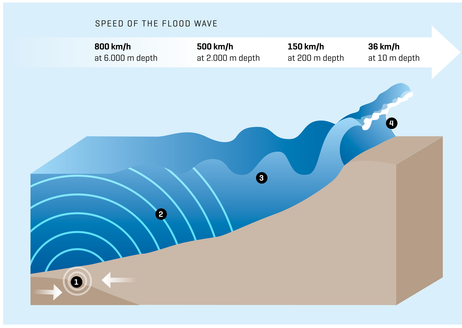
TSUNAMIS

▲ Debris from a cargo ship in Kamaishi after the March 11, 2011, Tōhoku earthquake, considered the strongest quake in Japan since earthquake records began there, triggering a 10- to 38-meter tsunami wave and the nuclear disaster at the Fukushima-Daiichi nuclear power plant. Photo: Warren Antiola (CC BY-NC-ND 2.0)

Why do Tsunami Waves have such Destructive Power?

The Japanese word Tsunami means „big wave in the harbor". The name is said to have originated because Japanese fishermen who were far out on an apparently calm sea found villages completely destroyed when they returned home. In fact, Tsunamis are barely noticeable, if at all, on the open sea, while they have catastrophic effects on the coast. How does this happen?

Tsunamis are progressive waves up to several 100 kilometers long in the ocean generated by submarine earthquakes, submarine volcanic eruptions, or landslides on the coast or in the sea. When wind or currents generate waves, only the water surface is moving. In contrast, when a tsunami occurs, the entire water column is in motion. The very long wavelengths combined with relatively low wave heights around one meter ensure that tsunamis are not perceived by ships on the open sea. The waves spread out from the center of the event (epicenter) in a ring at great speeds of up to 800 kilometers per hour. They can therefore pass through large ocean spaces in a short time, such as the entire Pacific Ocean from South America to South Asia in 24 hours. When the tsunami wave reaches shallow coastal waters, it is slowed down considerably. At the same time, it gets higher and higher and can thus achieve an enormous destructive effect on the coast.



How is a Tsunami Generated?

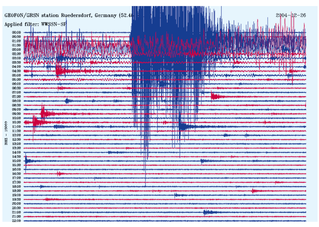
1. A submarine earthquake triggers a flood wave
2. The vibration spreads throughout the water column
3. The shallower the sea depth, the more the tsunami is decelerated and builds up higher and higher
4. The wave breaks on the coast and can reach a height of up to 30 meters

How did the 2004 Indian Ocean Tsunami Earthquake Occur?

▲ In the catastrophic tsunami of 2004, the epicenter was about 350 kilometers off the coast of North Sumatra. The tsunami reached the coast after about 30 minutes. After one hour, the wave reached Thailand, after two hours Sri Lanka, after three hours India and the Maldives, and after about seven hours the East African coast. Graphic: Christoph Korsten/GEOMAR

On December 26, 2004, a severe seaquake of magnitude 9 occurred off the Indonesian island of Sumatra and generated several tidal waves. The tsunami caused major damage in India, Thailand, Malaysia, Indonesia, Sri Lanka, the Maldives and East Africa. The worst hit areas were northern Sumatra, Sri Lanka, India and western Thailand. According to current estimates, more than 200,000 people lost their lives.

The earthquake occurred in the Sunda fault, about 250 kilometers southeast of Banda Aceh on Sumatra. There, the oceanic Indo-Australian plate dips under the Sunda plate and the Burma microplate at a rate of five centimeters per year. When this process causes the plates to become entangled with each other, an enormous amount of stress builds up over the years, which is discharged in the form of earthquakes when the plates finally shift jerkily against each other. The quake propagated along the fault zone at a speed of 3.5 kilometers per second. The main earthquake caused a rupture in the south-north direction more than 1,000 kilometers long.



▲ The earthquake data were analyzed in the German Seismological Regional Network, which is located about 9,000 kilometers from the epicenter. Clearly visible on the seismogram is the rash at the time of the earthquake. Graphic: BGR

Is there Protection Against Tsunamis?

Following a tsunami that caused extensive damage, the world's first tsunami early warning system was set up in Hawaii as early as 1946. Since 1965, the Pacific Tsunami Warning Center (PTWC) in Honolulu has been monitoring the formation of tsunamis, calculating their travel time and issuing Pacific-wide warnings.

The PTWC has its own seismic and level measurement data, as well as satellite-based data links to other regional networks and data centers. It alerts on quakes that have a magnitude greater than 6.5, calculates their position and exact magnitude within 10-15 minutes, estimates tsunami probability, checks tide gauges at 75 stations Pacific-wide for possible signs of tsunami-induced sea level fluctuations, calculates the travel time of the tsunami wave front through the Pacific, and issues warnings when appropriate.

However, 99 percent of damaging tsunamis occur less than 400 kilometers (30 minutes transit time) from the nearest coast. Only regional tsunami centers can effectively provide advance warning in this case, provided they have the appropriate infrastructure. Today, warnings can be issued in the time of 20-30 minutes. Regional tsunami warning centers exist today in Alaska, Sakhalin, Hong Kong, Seoul, Manila, Papua New Guinea, Tahiti, Mexico, Chile, and also in southern Italy. However, with a tsunami runtime of less than 10 minutes, there is little chance for an effective warning.

▼ A tsunami wave hits Japan's northeast coast near Minamisoma in Fukushima province after the 2011 Tōhoku earthquake, photo by Sadatsugu Tomizawa (CC BY-NC-ND 2.0)

GEOMAR Helmholtz Centre for Ocean Research Kiel
Wischhofstr. 1-3 | 24148 Kiel | Germany
info@geomar.de | www.geomar.de

HELMHOLTZ