



Tsunami

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A *tsunami* (from Japanese: 津波, lit. "harbour wave";^[1] English pronunciation: /tsuːˈnɑːmi/^[2]), also known as a **seismic sea wave**, is a series of waves in a water body caused by the displacement of a large volume of water, generally in an ocean or a large lake.^[3] Earthquakes, volcanic eruptions and other underwater explosions (including detonations of underwater nuclear devices), landslides, glacier calvings, meteorite impacts and other disturbances above or below water all have the potential to generate a tsunami.^[4] Unlike normal ocean waves which are generated by wind, or tides which are generated by the gravitational pull of the Moon and Sun, a tsunami is generated by the displacement of water.



2011 Tōhoku earthquake and tsunami, An aerial view of damage in the Sendai region with black smoke coming from the Nippon Oil Sendai oil refinery

Tsunami waves do not resemble normal undersea currents or sea waves, because their wavelength is far longer.^[5] Rather than appearing as a breaking wave, a tsunami may instead initially resemble a rapidly rising tide, and for this reason they are often referred to as *tidal waves*, although this usage is not favoured by the scientific community because tsunamis are not tidal in nature. Tsunamis generally consist of a series of waves with periods ranging from minutes to hours, arriving in a so-called "internal wave train".^[6] Wave heights of tens of metres can be generated by large events. Although the impact of tsunamis is limited to coastal areas, their destructive power can be enormous and they can affect entire ocean basins; the 2004 Indian Ocean tsunami was among the deadliest natural disasters in human history with at least 230,000 people killed or missing in 14 countries bordering the Indian Ocean.

Greek historian Thucydides suggested in his late-5th century BC *History of the Peloponnesian War*, that tsunamis were related to submarine earthquakes,^{[7][8]} but the understanding of a tsunami's nature remained slim until the 20th century and much remains unknown. Major areas of current research include trying to determine why some large earthquakes do not generate tsunamis while other smaller ones do; trying to accurately forecast the passage of tsunamis across the oceans; and also to forecast how tsunami waves interact with specific shorelines.

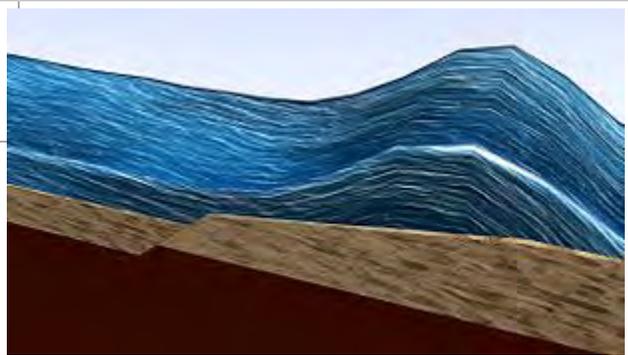
Contents

- 1 Terminology
 - 1.1 Tsunami
 - 1.2 Tidal wave
 - 1.3 Seismic sea wave

- 2 History
- 3 Generation mechanisms
 - 3.1 Seismicity
 - 3.2 Landslides
 - 3.3 Meteotsunamis
 - 3.4 Man-made or triggered tsunamis
- 4 Characteristics
- 5 Drawback
- 6 Scales of intensity and magnitude
 - 6.1 Intensity scales
 - 6.2 Magnitude scales
- 7 Warnings and predictions
 - 7.1 Forecast of tsunami attack probability
- 8 Mitigation
- 9 See also
- 10 Footnotes
- 11 References
- 12 Further reading
- 13 External links



Taken at Ao Nang, Krabi Province, Thailand, during the 2004 Indian Ocean earthquake and tsunami in Thailand



3D tsunami simulation

Terminology

Numerous terms are used in the English language to describe waves created in a body of water by the displacement of water; however, none of the terms in frequent use are entirely accurate.

Tsunami

The term *tsunami*, meaning "harbour wave" in literal translation, comes from the Japanese 津波, composed of the two kanji 津 (*tsu*) meaning "harbour" and 波 (*nami*), meaning "wave". (For the plural, one can either follow ordinary English practice and add an *s*, or use an invariable plural as in the Japanese.^[9]) While not entirely accurate, as tsunami are not restricted to harbours, *tsunami* is currently the term most widely accepted by geologists and oceanographers.

Tidal wave

Tsunami are sometimes referred to as *tidal waves*.^[10] This once-popular term derives from the most common appearance of tsunami, which is that of an extraordinarily high tidal bore. Tsunami and tides both produce waves of water that move inland, but in the case of tsunami the inland movement of water may be much greater, giving the impression of an incredibly high and forceful tide. In recent years, the



Tsunami warning bilingual sign in Ulee Lheue, Banda Aceh in Acehese and Indonesian

term "tidal wave" has fallen out of favour, especially in the scientific community, because tsunamis actually have nothing to do with tides, which are produced by the gravitational pull of the moon and sun rather than the displacement of water. Although the meanings of "tidal" include "resembling"^[11] or "having the form or character of"^[12] the tides, use of the term *tidal wave* is discouraged by geologists and oceanographers.

Seismic sea wave

The term *seismic sea wave* also is used to refer to the phenomenon, because the waves most often are generated by seismic activity such as earthquakes.^[13]

Prior to the rise of the use of the term *tsunami* in English-speaking countries, scientists generally encouraged the use of the term *seismic sea wave* rather than the inaccurate term *tidal wave*. However, like *tsunami*, *seismic sea wave* is not a completely accurate term, as forces other than earthquakes – including underwater landslides, volcanic eruptions, underwater explosions, land or ice slumping into the ocean, meteorite impacts, and the weather when the atmospheric pressure changes very rapidly – can generate such waves by displacing water.^{[14][15]}

History

While Japan may have the longest recorded history of tsunamis, the sheer destruction caused by the 2004 Indian Ocean earthquake and tsunami event mark it as the most devastating of its kind in modern times, killing around 230,000 people.^[16] The Sumatran region is not unused to tsunamis either, with earthquakes of varying magnitudes regularly occurring off the coast of the island.^[17]

Tsunamis are an often underestimated hazard in the Mediterranean Sea and parts of Europe. Of historical and current (with regard to risk assumptions) importance are the 1755 Lisbon earthquake and tsunami (which was caused by the Azores–Gibraltar Transform Fault), the 1783 Calabrian earthquakes, each causing several tens of thousands of deaths and the 1908 Messina earthquake and tsunami. The tsunami claimed more than 123,000 lives in Sicily and Calabria and is among the most deadly natural disasters in modern Europe. The Storegga Slide in the Norwegian sea and some examples of tsunamis affecting the British Isles refer to landslide and meteotsunamis predominantly and less to earthquake-induced waves.

As early as 426 BC the Greek historian Thucydides inquired in his book *History of the Peloponnesian War* about the causes of tsunami, and was the first to argue that ocean earthquakes must be the cause.

^{[7][8]}



Tsunami aftermath in Aceh, Indonesia, December 2004.



Lisbon earthquake and tsunami in 1755

"The cause, in my opinion, of this phenomenon must be sought in the earthquake. At the point where its shock has been the most violent the sea is driven back, and suddenly recoiling with redoubled force, causes the inundation. Without an earthquake I do not see how such an accident could happen."^[18]

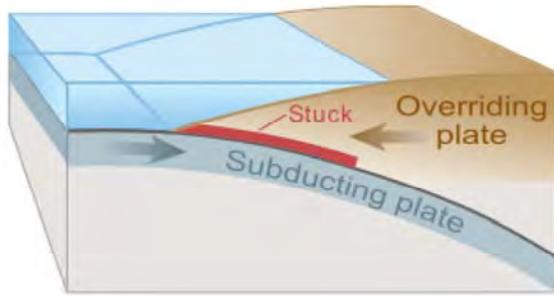
The Roman historian Ammianus Marcellinus (*Res Gestae* 26.10.15-19) described the typical sequence of a tsunami, including an incipient earthquake, the sudden retreat of the sea and a following gigantic wave, after the 365 AD tsunami devastated Alexandria.^{[19][20]}

Generation mechanisms

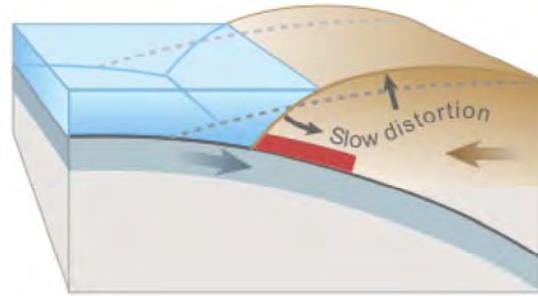
The principal generation mechanism (or cause) of a tsunami is the displacement of a substantial volume of water or perturbation of the sea.^[21] This displacement of water is usually attributed to either earthquakes, landslides, volcanic eruptions, glacier calvings or more rarely by meteorites and nuclear tests.^{[22][23]} The waves formed in this way are then sustained by gravity. Tides do not play any part in the generation of tsunamis.

Seismicity

Tsunami can be generated when the sea floor abruptly deforms and vertically displaces the overlying water. Tectonic earthquakes are a particular kind of earthquake that are associated with the Earth's crustal deformation; when these earthquakes occur beneath the sea, the water above the deformed area is displaced from its equilibrium position.^[24] More specifically, a tsunami can be generated when thrust faults associated with convergent or destructive plate boundaries move abruptly, resulting in water displacement, owing to the vertical component of movement involved. Movement on normal (extensional) faults can also cause displacement of the seabed, but only the largest of such events (typically related to flexure in the outer trench swell) cause enough displacement to give rise to a significant tsunami, such as the 1977 Sumba and 1933 Sanriku events.^{[25][26]}



Drawing of tectonic plate boundary before earthquake



Overriding plate bulges under strain, causing tectonic uplift.

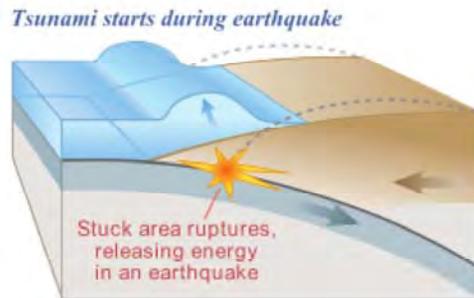
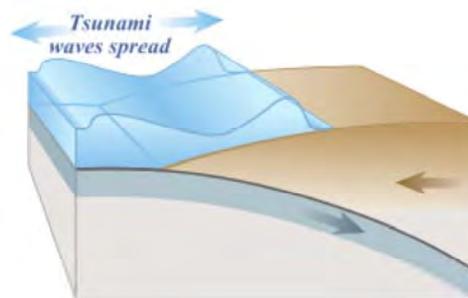


Plate slips, causing subsidence and releasing energy into water.



The energy released produces tsunami waves.

Tsunamis have a small amplitude (wave height) offshore, and a very long wavelength (often hundreds of kilometres long, whereas normal ocean waves have a wavelength of only 30 or 40 metres),^[27] which is why they generally pass unnoticed at sea, forming only a slight swell usually about 300 millimetres (12 in) above the normal sea surface. They grow in height when they reach shallower water, in a wave shoaling process described below. A tsunami can occur in any tidal state and even at low tide can still inundate coastal areas.

On April 1, 1946, the 8.6 Mw Aleutian Islands earthquake occurred with a maximum Mercalli intensity of VI (*Strong*). It generated a tsunami which inundated Hilo on the island of Hawai'i with a 14-metre high (46 ft) surge. Between 165 and 173 were killed. The area where the earthquake occurred is where the Pacific Ocean floor is subducting (or being pushed downwards) under Alaska.

Examples of tsunami originating at locations away from convergent boundaries include Storegga about 8,000 years ago, Grand Banks 1929, Papua New Guinea 1998 (Tappin, 2001). The Grand Banks and Papua New Guinea tsunamis came from earthquakes which destabilised sediments, causing them to flow into the ocean and generate a tsunami. They dissipated before travelling transoceanic distances.

The cause of the Storegga sediment failure is unknown. Possibilities include an overloading of the sediments, an earthquake or a release of gas hydrates (methane etc.).

The 1960 Valdivia earthquake (M_w 9.5), 1964 Alaska earthquake (M_w 9.2), 2004 Indian Ocean earthquake (M_w 9.2), and 2011 Tōhoku earthquake (M_w 9.0) are recent examples of powerful megathrust earthquakes that generated tsunamis (known as teletsunamis) that can cross entire oceans. Smaller (M_w 4.2) earthquakes in Japan can trigger tsunamis (called **local** and **regional tsunamis**) that can only devastate nearby coasts, but can do so in only a few minutes.

Landslides

In the 1950s, it was discovered that larger tsunamis than had previously been believed possible could be caused by giant submarine landslides. These rapidly displace large water volumes, as energy transfers to the water at a rate faster than the water can absorb. Their existence was confirmed in 1958, when a giant landslide in Lituya Bay, Alaska, caused the highest wave ever recorded, which had a height of 524 metres (over 1700 feet).^[28] The wave did not travel far, as it struck land almost immediately. Two people fishing in the bay were killed, but another boat managed to ride the wave.

Another landslide-tsunami event occurred in 1963 when a massive landslide from Monte Toc entered the Vajont Dam in Italy. The resulting wave surged over the 262 m (860 ft) high dam by 250 metres (820 ft) and destroyed several towns. Around 2,000 people died.^{[29][30]} Scientists named these waves megatsunamis.

Some geologists claim that large landslides from volcanic islands, e.g. Cumbre Vieja on La Palma in the Canary Islands, may be able to generate megatsunamis that can cross oceans, but this is disputed by many others.

In general, landslides generate displacements mainly in the shallower parts of the coastline, and there is conjecture about the nature of large landslides that enter water. This has been shown to subsequently affect water in enclosed bays and lakes, but a landslide large enough to cause a transoceanic tsunami has not occurred within recorded history. Susceptible locations are believed to be the Big Island of Hawaii, Fogo in the Cape Verde Islands, La Reunion in the Indian Ocean, and Cumbre Vieja on the island of La Palma in the Canary Islands; along with other volcanic ocean islands. This is because large masses of relatively unconsolidated volcanic material occurs on the flanks and in some cases detachment planes are believed to be developing. However, there is growing controversy about how dangerous these slopes actually are.^[31]

Meteotsunamis

Some meteorological conditions, especially rapid changes in barometric pressure, as seen with the passing of a front, can displace bodies of water enough to cause trains of waves with wavelengths comparable to seismic tsunami, but usually with lower energies. These are essentially dynamically equivalent to seismic tsunami, the only differences being that meteotsunami lack the transoceanic reach of significant seismic tsunami, and that the force that displaces the water is sustained over some length of time such that meteotsunami can't be modelled as having been caused instantaneously. In spite of their lower energies, on shorelines where they can be amplified by resonance they are sometimes powerful enough to cause localised damage and potential for loss of life. They have been documented in many places, including the Great Lakes, the Aegean Sea, the English Channel, and the Balearic Islands,

where they are common enough to have a local name, *rissaga*. In Sicily they are called *marubbio* and in Nagasaki Bay they are called *abiki*. Some examples of destructive meteotsunami include 31 March 1979 at Nagasaki and 15 June 2006 at Menorca, the latter causing damage in the tens of millions of euros.^[32]

Meteotsunami should not be confused with storm surges, which are local increases in sea level associated with the low barometric pressure of passing tropical cyclones, nor should they be confused with setup, the temporary local raising of sea level caused by strong on-shore winds. Storm surges and setup are also dangerous causes of coastal flooding in severe weather but their dynamics are completely unrelated to tsunami waves.^[32] They are unable to propagate beyond their sources, as waves do.

Man-made or triggered tsunamis

There have been studies of the potential of induction of and at least one actual attempt to create tsunami waves as a tectonic weapon.

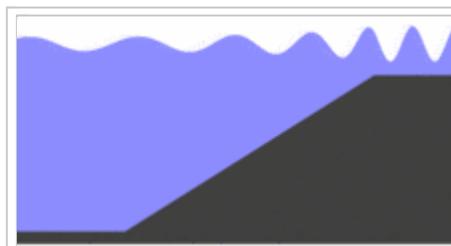
In World War II, the New Zealand Military Forces initiated Project Seal, which attempted to create small tsunamis with explosives in the area of today's Shakespear Regional Park; the attempt failed.^[33]

There has been considerable speculation on the possibility of using nuclear weapons to cause tsunamis near to an enemy coastline. Even during World War II consideration of the idea using conventional explosives was explored. Nuclear testing in the Pacific Proving Ground by the United States seemed to generate poor results. *Operation Crossroads* fired two 20 kilotonnes of TNT (84 TJ) bombs, one in the air and one underwater, above and below the shallow (50 m (160 ft)) waters of the Bikini Atoll lagoon. Fired about 6 km (3.7 mi) from the nearest island, the waves there were no higher than 3–4 m (9.8–13.1 ft) upon reaching the shoreline. Other underwater tests, mainly *Hardtack I/Wahoo* (deep water) and *Hardtack I/Umbrella* (shallow water) confirmed the results. Analysis of the effects of shallow and deep underwater explosions indicate that the energy of the explosions doesn't easily generate the kind of deep, all-ocean waveforms which are tsunamis; most of the energy creates steam, causes vertical fountains above the water, and creates compressional waveforms.^[34] Tsunamis are hallmarked by permanent large vertical displacements of very large volumes of water which don't occur in explosions.

Characteristics

Tsunamis cause damage by two mechanisms: the smashing force of a wall of water travelling at high speed, and the destructive power of a large volume of water draining off the land and carrying a large amount of debris with it, even with waves that do not appear to be large.

While everyday wind waves have a wavelength (from crest to crest) of about 100 metres (330 ft) and a height of roughly 2 metres (6.6 ft), a tsunami in the deep ocean has a much larger wavelength of up to 200 kilometres (120 mi). Such a wave travels at well over 800 kilometres per hour (500 mph), but owing to the enormous wavelength the wave oscillation at any



When the wave enters shallow water, it slows down and its amplitude (height) increases.

given point takes 20 or 30 minutes to complete a cycle and has an amplitude of only about 1 metre (3.3 ft).^[35] This makes tsunamis difficult to detect over deep water, where ships are unable to feel their passage.

The velocity of a tsunami can be calculated by obtaining the square root of the depth of the water in metres multiplied by the acceleration due to gravity (approximated to 10 m sec^2). For example, if the Pacific Ocean is considered to have a depth of 5000 metres, the velocity of a tsunami would be the square root of $\sqrt{5000 \times 10} = \sqrt{50000} = \sim 224$ metres per second (735 feet per second), which equates to a speed of ~ 806 kilometres per hour or about 500 miles per hour. This formula is the same as used for calculating the velocity of shallow waves, because a tsunami behaves like a shallow wave as its peak to peak value reaches from the floor of the ocean to the surface.



The wave further slows and amplifies as it hits land. Only the largest waves crest.

The reason for the Japanese name "harbour wave" is that sometimes a village's fishermen would sail out, and encounter no unusual waves while out at sea fishing, and come back to land to find their village devastated by a huge wave.

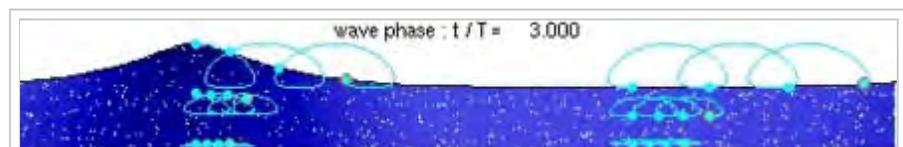
As the tsunami approaches the coast and the waters become shallow, wave shoaling compresses the wave and its speed decreases below 80 kilometres per hour (50 mph). Its wavelength diminishes to less than 20 kilometres (12 mi) and its amplitude grows enormously – in accord with Green's law. Since the wave still has the same very long period, the tsunami may take minutes to reach full height. Except for the very largest tsunamis, the approaching wave does not break, but rather appears like a fast-moving tidal bore.^[36] Open bays and coastlines adjacent to very deep water may shape the tsunami further into a step-like wave with a steep-breaking front.

When the tsunami's wave peak reaches the shore, the resulting temporary rise in sea level is termed *run up*. Run up is measured in metres above a reference sea level.^[36] A large tsunami may feature multiple waves arriving over a period of hours, with significant time between the wave crests. The first wave to reach the shore may not have the highest run up.^[37]

About 80% of tsunamis occur in the Pacific Ocean, but they are possible wherever there are large bodies of water, including lakes. They are caused by earthquakes, landslides, volcanic explosions, glacier calvings, and bolides.

Drawback

All waves have a positive and negative peak, i.e. a ridge and a trough. In the case of a propagating wave like a tsunami, either may be the first to arrive. If the first part to arrive at shore is the ridge, a massive breaking wave or



An illustration of the rhythmic "drawback" of surface water associated with a wave. It follows that a very large drawback may herald the arrival of a very large wave.

sudden flooding will be the first effect noticed on land. However, if the first part to arrive is a trough, a **drawback** will occur as the shoreline recedes dramatically, exposing normally submerged areas. Drawback can exceed hundreds of metres, and people unaware of the danger sometimes remain near the shore to satisfy their curiosity or to collect fish from the exposed seabed.

A typical wave period for a damaging tsunami is about 12 minutes. This means that if the drawback phase is the first part of the wave to arrive, the sea will recede, with areas well below sea level exposed after 3 minutes. During the next 6 minutes the tsunami wave trough builds into a ridge, and during this time the sea is filled in and destruction occurs on land. During the next 6 minutes, the tsunami wave changes from a ridge to a trough, causing flood waters to drain and drawback to occur again. This may sweep victims and debris some distance from land. The process repeats as the next wave arrives.

Scales of intensity and magnitude

As with earthquakes, several attempts have been made to set up scales of tsunami intensity or magnitude to allow comparison between different events.^[38]

Intensity scales

The first scales used routinely to measure the intensity of tsunami were the *Sieberg-Ambraseys scale*, used in the Mediterranean Sea and the *Imamura-Iida intensity scale*, used in the Pacific Ocean. The latter scale was modified by Soloviev, who calculated the Tsunami intensity *I* according to the formula

$$I = \frac{1}{2} + \log_2 H_{av}$$

where H_{av} is the average wave height along the nearest coast. This scale, known as the *Soloviev-Imamura tsunami intensity scale*, is used in the global tsunami catalogues compiled by the NGDC/NOAA^[39] and the Novosibirsk Tsunami Laboratory as the main parameter for the size of the tsunami.

In 2013, following the intensively studied tsunamis in 2004 and 2011, a new 12 point scale was proposed, the Integrated Tsunami Intensity Scale (ITIS-2012), intended to match as closely as possible to the modified ESI2007 and EMS earthquake intensity scales.^{[40][41]}

Magnitude scales

The first scale that genuinely calculated a magnitude for a tsunami, rather than an intensity at a particular location was the ML scale proposed by Murty & Loomis based on the potential energy.^[38] Difficulties in calculating the potential energy of the tsunami mean that this scale is rarely used. Abe introduced the *tsunami magnitude scale* M_t , calculated from,

$$M_t = a \log h + b \log R = D$$

where h is the maximum tsunami-wave amplitude (in m) measured by a tide gauge at a distance R from the epicentre, a , b and D are constants used to make the M_t scale match as closely as possible with the moment magnitude scale.^[42]

Warnings and predictions

Drawbacks can serve as a brief warning. People who observe drawback (many survivors report an accompanying sucking sound), can survive only if they immediately run for high ground or seek the upper floors of nearby buildings. In 2004, ten-year-old Tilly Smith of Surrey, England, was on Maikhao beach in Phuket, Thailand with her parents and sister, and having learned about tsunamis recently in school, told her family that a tsunami might be imminent. Her parents warned others minutes before the wave arrived, saving dozens of lives. She credited her geography teacher, Andrew Kearney.

In the 2004 Indian Ocean tsunami drawback was not reported on the African coast or any other east-facing coasts that it reached. This was because the wave moved downwards on the eastern side of the fault line and upwards on the western side. The western pulse hit coastal Africa and other western areas.

A tsunami cannot be precisely predicted, even if the magnitude and location of an earthquake is known. Geologists, oceanographers, and seismologists analyse each earthquake and based on many factors may or may not issue a tsunami warning. However, there are some warning signs of an impending tsunami, and automated systems can provide warnings immediately after an earthquake in time to save lives. One of the most successful systems uses bottom pressure sensors, attached to buoys, which constantly monitor the pressure of the overlying water column.

Regions with a high tsunami risk typically use tsunami warning systems to warn the population before the wave reaches land. On the west coast of the United States, which is prone to Pacific Ocean tsunami, warning signs indicate evacuation routes. In Japan, the community is well-educated about earthquakes and tsunamis, and along the Japanese shorelines the tsunami warning signs are reminders of the natural hazards together with a network of warning sirens, typically at the top of the cliff of surroundings hills.^[43]

The Pacific Tsunami Warning System is based in Honolulu, Hawai'i. It monitors Pacific Ocean seismic activity. A sufficiently large earthquake magnitude and other information triggers a tsunami warning. While the subduction zones around the Pacific are seismically active, not all earthquakes generate tsunami. Computers assist in analysing the tsunami risk of every earthquake that occurs in the Pacific Ocean and the adjoining land masses.



Tsunami warning sign



Tsunami hazard sign at Bamfield, British Columbia



A tsunami warning sign in Kamakura, Japan



The monument to the victims of the 1946 tsunami at Laupahoehoe, Hawaii



Tsunami memorial in Kanyakumari beach



A Tsunami hazard sign (Spanish - English) in Iquique, Chile.



Tsunami Evacuation Route signage along U.S. Route 101, in Washington

As a direct result of the Indian Ocean tsunami, a re-appraisal of the tsunami threat for all coastal areas is being undertaken by national governments and the United Nations Disaster Mitigation Committee. A tsunami warning system is being installed in the Indian Ocean.

Computer models can predict tsunami arrival, usually within minutes of the arrival time. Bottom pressure sensors can relay information in real time. Based on these pressure readings and other seismic information and the seafloor's shape (bathymetry) and coastal topography, the models estimate the amplitude and surge height of the approaching tsunami. All Pacific Rim countries collaborate in the Tsunami Warning System and most regularly practise evacuation and other procedures. In Japan, such preparation is mandatory for government, local authorities, emergency services and the population.

Some zoologists hypothesise that some animal species have an ability to sense subsonic Rayleigh waves from an earthquake or a tsunami. If correct, monitoring their behaviour could provide advance warning of earthquakes, tsunami etc. However, the evidence is controversial and is not widely accepted. There are unsubstantiated claims about the Lisbon



One of the deep water buoys used in the DART tsunami warning system

quake that some animals escaped to higher ground, while many other animals in the same areas drowned. The phenomenon was also noted by media sources in Sri Lanka in the 2004 Indian Ocean earthquake.^{[44][45]} It is possible that certain animals (e.g., elephants) may have heard the sounds of the tsunami as it approached the coast. The elephants' reaction was to move away from the approaching noise. By contrast, some humans went to the shore to investigate and many drowned as a result.

Along the United States west coast, in addition to sirens, warnings are sent on television and radio via the National Weather Service, using the Emergency Alert System.

Forecast of tsunami attack probability

Kunihiko Shimazaki (University of Tokyo), a member of Earthquake Research committee of The Headquarters for Earthquake Research Promotion of Japanese government, mentioned the plan for public announcement of tsunami attack probability forecast at Japan National Press Club on 12 May 2011. The forecast includes tsunami height, attack area and occurrence probability within 100 years ahead. The forecast would integrate the scientific knowledge of recent interdisciplinarity and aftermath of the 2011 Tōhoku earthquake and tsunami. As the plan, announcement will be available from 2014.^{[46][47][48]}

Mitigation

In some tsunami-prone countries, earthquake engineering measures have been taken to reduce the damage caused onshore.

Japan, where tsunami science and response measures first began following a disaster in 1896, has produced ever-more elaborate countermeasures and response plans.^[49] The country has built many tsunami walls of up to 12 metres (39 ft) high to protect populated coastal areas. Other localities have built floodgates of up to 15.5 metres (51 ft) high and channels to redirect the water from incoming tsunami. However, their effectiveness has been questioned, as tsunami often overtop the barriers.

The Fukushima Daiichi nuclear disaster was directly triggered by the 2011 Tōhoku earthquake and tsunami, when waves exceeded the height of the plant's sea wall.^[50] Iwate Prefecture, which is an area at high risk from tsunami, had tsunami barriers walls totalling 25 kilometres (16 mi) long at coastal towns. The 2011 tsunami toppled more than 50% of the walls and caused catastrophic damage.^[51]

The Okushiri, Hokkaidō tsunami which struck Okushiri Island of Hokkaidō within two to five minutes of the earthquake on July 12, 1993, created waves as much as 30 metres (100 ft) tall—as high as a 10-story building. The port town of Aonae was completely surrounded by a tsunami wall, but the waves washed right over the wall and destroyed all the wood-framed structures in the area. The wall may have succeeded in slowing down and moderating the height of the tsunami, but it did not prevent major destruction and loss of life.^[52]



A seawall at Tsu, Japan

See also

- Deep-ocean Assessment and Reporting of Tsunamis
- Earthquake Early Warning (Japan)
- Emergency management
- Higher Ground Project
- Index of wave articles
- Kaikoura Canyon landslide tsunami hazard
- List of natural disasters by death toll
- Lists of earthquakes
- Minoan eruption
- Rogue wave
- Seiche
- Sneaker wave
- Supervolcano
- Tauredunum event
- Tsunami Society
- Tsunami-proof building
- Tsunamis affecting New Zealand
- Tsunamis affecting the British Isles
- Tsunamis in lakes

Footnotes

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- Wave That Shook The World (<http://www.pbs.org/nova/tsunami/>) – *Nova*
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