[Template:Other uses](/wiki/Template:Other_uses" \o "Template:Other uses) [Template:About](/wiki/Template:About) [Template:Pp-semi-indef](/wiki/Template:Pp-semi-indef) [Template:Pp-move-indef](/wiki/Template:Pp-move-indef) [thumb|upright=1.4|](/wiki/File:SH-60B_helicopter_flies_over_Sendai.jpg)[2011 Tōhoku earthquake and tsunami](/wiki/2011_Tōhoku_earthquake_and_tsunami), An aerial view of damage in the [Sendai](/wiki/Sendai) region with black smoke coming from the Nippon Oil Sendai oil refinery

A **tsunami** (plural: tsunamis or tsunami; from [Template:Lang-ja](/wiki/Template:Lang-ja), lit. "harbor wave";[[1]](#cite_note-1)English pronunciation: [Template:IPAc-en](/wiki/Template:IPAc-en)[[2]](#cite_note-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](/wiki/Tsunamis_in_lakes).[[3]](#cite_note-3)

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### Intensity scales[[edit](/index.php?title=(none)&action=edit&section=14)]

The first scales used routinely to measure the intensity of tsunami were the *Sieberg-Ambraseys scale*, used in the [Mediterranean Sea](/wiki/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

<math>\,\mathit{I} = \frac{1}{2} + \log\_{2} \mathit{H}\_{av}</math>

where <math>\mathit{H}\_{av}</math> 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[[36]](#cite_note-36) 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](/wiki/Environmental_Seismic_Intensity_scale) and [EMS](/wiki/European_Macroseismic_Scale) earthquake intensity scales.[[37]](#cite_note-37)

### Magnitude scales[[edit](/index.php?title=(none)&action=edit&section=15)]

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.<ref name=Gusiakov/> Difficulties in calculating the potential energy of the tsunami mean that this scale is rarely used. Abe introduced the *tsunami magnitude scale <math>\mathit{M}\_{t}</math>*, calculated from,

<math>\,\mathit{M}\_{t} = {a} \log h + {b} \log R = \mathit{D}</math>

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 Mt scale match as closely as possible with the moment magnitude scale.[[38]](#cite_note-38)

## Warnings and predictions[[edit](/index.php?title=(none)&action=edit&section=16)]

[Template:See also](/wiki/Template:See_also) [thumb|Tsunami warning sign](/wiki/File:TsunamiHazardSign.svg)

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](/wiki/Tilly_Smith) of [Surrey](/wiki/Surrey), England, was on [Maikhao beach](/wiki/Maikhao_beach) in [Phuket](/wiki/Phuket_Province), 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](/wiki/2004_Indian_Ocean_earthquake) 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](/wiki/Geologist), [oceanographers](/wiki/Oceanographer), and [seismologists](/wiki/Seismologist) 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](/wiki/Tsunami_warning_system) 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.[[39]](#cite_note-39) The [Pacific Tsunami Warning System](/wiki/Pacific_Tsunami_Warning_Center) is based in [Honolulu](/wiki/Honolulu), [Hawai](/wiki/Hawaii)[Template:Okinai](/wiki/Template:Okina). 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.

<gallery> File:Bamfield Tsunami Hazard Zone sign.jpg|Tsunami hazard sign at [Bamfield](/wiki/Bamfield), [British Columbia](/wiki/British_Columbia) Image:A tsunami warning sign in Kamakura, Japan.jpg|A tsunami warning sign in [Kamakura](/wiki/Kamakura,_Kanagawa), Japan Image:The monument to the victims of tsunami.jpg|The monument to the victims of the [1946 tsunami](/wiki/1946_Aleutian_Islands_earthquake) at [Laupahoehoe](/wiki/Laupahoehoe), [Hawaii](/wiki/Hawaii_(island)) File:Tsunami Memorial Kanyakumari.JPG|Tsunami memorial in [Kanyakumari](/wiki/Kanyakumari) beach File:Zona de Inundabilidad.jpg|A Tsunami hazard sign (Spanish - English) in [Iquique](/wiki/Iquique), [Chile](/wiki/Chile). Image:Tsunami Evacuation Route signage south of Aberdeen Washington.jpg|Tsunami Evacuation Route signage along [U.S. Route 101](/wiki/U.S._Route_101_in_Washington), in [Washington](/wiki/Washington_(state))|alt=Photo of evacuation sign </gallery>

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.

[thumb|upright|One of the deep water](/wiki/File:Dart_tsunamicover.jpg) [buoys](/wiki/Buoy) used in the [DART](/wiki/Deep-ocean_Assessment_and_Reporting_of_Tsunamis) tsunami warning system

[Computer models](/wiki/Computer_model) can predict tsunami arrival, usually within minutes of the arrival time. Bottom pressure sensors can relay information in [real time](/wiki/Present). Based on these pressure readings and other seismic information and the seafloor's shape ([bathymetry](/wiki/Bathymetry)) and coastal [topography](/wiki/Topography), the models estimate the amplitude and surge height of the approaching tsunami. All [Pacific Rim](/wiki/Pacific_Rim) countries collaborate in the Tsunami Warning System and most regularly practice 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](/wiki/Rayleigh_waves) from an earthquake or a tsunami. If correct, monitoring their behavior 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 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](/wiki/Sri_Lanka) in the [2004 Indian Ocean earthquake](/wiki/2004_Indian_Ocean_earthquake).[[40]](#cite_note-40)[[41]](#cite_note-41) It is possible that certain animals (e.g., [elephants](/wiki/Elephant)) 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](/wiki/National_Weather_Service), using the [Emergency Alert System](/wiki/Emergency_Alert_System).

### Forecast of tsunami attack probability[[edit](/index.php?title=(none)&action=edit&section=17)]

Kunihiko Shimazaki ([University of Tokyo](/wiki/University_of_Tokyo)), a member of Earthquake Research committee of The Headquarters for Earthquake Research Promotion of Japanese government, mentioned the plan to public announcement of tsunami attack probability forecast at [Japan National Press Club](/wiki/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](/wiki/Interdisciplinarity) and [aftermath of the 2011 Tōhoku earthquake and tsunami](/wiki/Aftermath_of_the_2011_Tōhoku_earthquake_and_tsunami). As the plan, announcement will be available from 2014.[[42]](#cite_note-42)[[43]](#cite_note-43)[[44]](#cite_note-44)

## Mitigation[[edit](/index.php?title=(none)&action=edit&section=18)]

[Template:See also](/wiki/Template:See_also)

[thumb|upright|A](/wiki/Image:Tsunami_wall.jpg) [seawall](/wiki/Seawall) at [Tsu](/wiki/Tsu,_Mie), Japan|alt=Photo of seawall with building in background

In some tsunami-prone countries [earthquake engineering](/wiki/Earthquake_engineering) measures have been taken to reduce the damage caused onshore.

[Japan](/wiki/Japan), where tsunami science and response measures first began following a [disaster in 1896](/wiki/1896_Meiji-Sanriku_earthquake), has produced ever-more elaborate countermeasures and response plans.[[45]](#cite_note-45) The country has built many tsunami walls of up to [Template:Convert](/wiki/Template:Convert) high to protect populated coastal areas. Other localities have built [floodgates](/wiki/Floodgate) of up to [Template:Convert](/wiki/Template:Convert) 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](/wiki/Fukushima_Daiichi_nuclear_disaster) was directly triggered by the [2011 Tōhoku earthquake and tsunami](/wiki/2011_Tōhoku_earthquake_and_tsunami), when waves exceeded the height of the plant's sea wall.[[46]](#cite_note-46) [Iwate Prefecture](/wiki/Iwate_Prefecture), which is an area at high risk from tsunami, had tsunami barriers walls totalling [Template:Convert](/wiki/Template:Convert) long at coastal towns. The 2011 tsunami toppled more than 50% of the walls and caused catastrophic damage.[[47]](#cite_note-47) The [Okushiri, Hokkaidō tsunami](/wiki/Historic_tsunami#1993:_Okushiri,_Hokkaido,_Japan_(北海道南西沖地震)) which struck [Okushiri Island](/wiki/Okushiri,_Hokkaidō) of [Hokkaidō](/wiki/Hokkaidō) within two to five minutes of the [earthquake on July 12, 1993](/wiki/1993_Hokkaido_earthquake) created waves as much as [Template:Convert](/wiki/Template:Convert) 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.[[48]](#cite_note-48)

## See also[[edit](/index.php?title=(none)&action=edit&section=19)]

[Template:Portal](/wiki/Template:Portal) [Template:Columns-list](/wiki/Template:Columns-list)

## Footnotes[[edit](/index.php?title=(none)&action=edit&section=20)]

[Template:Reflist](/wiki/Template:Reflist)

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* Kristy F. Tiampo: *Earthquakes: simulations, sources and tsunamis*. Birkhäuser, Basel 2008, ISBN 978-3-7643-8756-3.
* [Linda Maria Koldau](/wiki/Linda_Maria_Koldau): Tsunamis. Entstehung, Geschichte, Prävention, (Tsunami development, history and prevention) C.H. Beck, Munich 2013 (C.H. Beck Reihe Wissen 2770), ISBN 978-3-406-64656-0 (in German).
* Walter C. Dudley, Min Lee: *Tsunami!* University of Hawaii Press, 1988, 1998, Tsunami! University of Hawai'i Press 1999, ISBN 0-8248-1125-9, ISBN 978-0-8248-1969-9.

## External links[[edit](/index.php?title=(none)&action=edit&section=23)]

[Template:Commons category](/wiki/Template:Commons_category)

* [World's Tallest Tsunami](http://geology.com/records/biggest-tsunami.shtml) – geology.com
* [Tsunami Data and Information](http://ngdc.noaa.gov/hazard/tsu.shtml) – [National Geophysical Data Center](/wiki/National_Geophysical_Data_Center)
* [IOC Tsunami Glossary](http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=1328&Itemid=1142&lang=en) – International Tsunami Information Center ([UNESCO](/wiki/UNESCO))
* [Tsunami & Earthquake Research at the USGS](http://walrus.wr.usgs.gov/tsunami/) – [United States Geological Survey](/wiki/United_States_Geological_Survey)
* [Intergovernmental Oceanographic Commission](http://www.unesco.org/new/en/natural-sciences/ioc-oceans/) – [Intergovernmental Oceanographic Commission](/wiki/Intergovernmental_Oceanographic_Commission)
* [Tsunami](http://www.tsunami.noaa.gov/) – [National Oceanic and Atmospheric Administration](/wiki/National_Oceanic_and_Atmospheric_Administration)
* [Wave That Shook The World](http://www.pbs.org/nova/tsunami/) – [*Nova*](/wiki/Nova_(TV_series))
* [Recent and Historical Tsunami Events and Relevant Data](http://nctr.pmel.noaa.gov/database_devel.html) – [Pacific Marine Environmental Laboratory](/wiki/Pacific_Marine_Environmental_Laboratory)
* [Raw Video: Tsunami Slams Northeast Japan](http://www.youtube.com/watch?v=k4w27IczOTk) – [Associated Press](/wiki/Associated_Press)

[Template:Physical oceanography](/wiki/Template:Physical_oceanography) [Template:Natural disasters](/wiki/Template:Natural_disasters) [Template:Disasters](/wiki/Template:Disasters)

[Template:Authority control](/wiki/Template:Authority_control)

[Category:Tsunami](/wiki/Category:Tsunami) [Category:Earthquake engineering](/wiki/Category:Earthquake_engineering) [Category:Flood](/wiki/Category:Flood) [Category:Forms of water](/wiki/Category:Forms_of_water) [Category:Geological hazards](/wiki/Category:Geological_hazards) [Category:Natural hazards](/wiki/Category:Natural_hazards) [Category:Physical oceanography](/wiki/Category:Physical_oceanography) [Category:Risk management](/wiki/Category:Risk_management) [Category:Water waves](/wiki/Category:Water_waves) [Category:Articles containing video clips](/wiki/Category:Articles_containing_video_clips) [Category:Oceanographical terminology](/wiki/Category:Oceanographical_terminology)