Australian Government
Bureau of Meteorology

Tsunami Facts and Information

Need Emergency Advice? Please listen to your local radio and TV announcements or call **1300 TSUNAMI (1300 878 6264)** for latest warning information. For emergency assistance, call your local emergency authority on **132 500**

What is a tsunami?

A tsunami is a series of ocean waves with very long wavelengths (typically hundreds of kilometres) caused by large-scale disturbances of ocean, such as:

- earthquakes
- landslide
- volcanic eruptions
- explosions
- meteorites

These disturbances can either be from below (e.g. underwater earthquakes with large vertical displacements, submarine landslides) or fro above (e.g. meteorite impacts).

Tsunami is a Japanese word with the English translation: "harbour wave". In the past, tsunamis have been referred to as "tidal waves" or "s sea waves". The term "tidal wave" is misleading; even though a tsunami's impact upon a coastline is dependent upon the tidal level at the tsunami strikes, tsunamis are unrelated to the tides. (Tides result from the gravitational influences of the moon, sun, and planets.) The terr "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused non-seismic event, such as a landslide or meteorite impact.

Tsunamis are also often confused with storm surges, even though they are quite different phenomena. A storm surge is a rapid rise in coa sea-level caused by a significant meteorological event - these are often associated with tropical cyclones.

The physics of a tsunami

Tsunamis can have wavelengths ranging from 10 to 500 km and wave periods of up to an hour. As a result of their long wavelengths, tsuna act as shallow-water waves. A wave becomes a shallow-water wave when the wavelength is very large compared to the water depth. Sha water waves move at a speed, c, that is dependent upon the water depth and is given by the formula:

$$c = \sqrt{gH}$$

where g is the acceleration due to gravity (= 9.8 m/s^2) and H is the depth of water.

In the deep ocean, the typical water depth is around 4000 m, so a tsunami will therefore travel at around 200 m/s, or more than 700 km/h.

For tsunamis that are generated by underwater earthquakes, the amplitude of the tsunami is determined by the amount by which the sea-f displaced. Similarly, the wavelength and period of the tsunami are determined by the size and shape of the underwater disturbance.

As well as travelling at high speeds, tsunamis can also travel large distances with limited energy losses. As the tsunami propagates across ocean, the wave crests can undergo refraction (bending), which is caused by segments of the wave moving at different speeds as the wat depth along the wave crest varies.

What happens to a tsunami as it approaches land?

As a tsunami leaves the deep water of the open-ocean and travels into the shallower water near the coast, it transforms. If you read the "T physics of a tsunami" section, you will know that a tsunami travels at a speed that is related to the water depth - hence, as the water depth decreases, the tsunami slows. The tsunami's energy flux, which is dependent on both its wave speed and wave height, remains nearly co Consequently, as the tsunami's speed diminishes, its height grows. This is called shoaling. Because of this shoaling effect, a tsunami that unnoticeable at sea, may grow to be several metres or more in height near the coast.

The increase of the tsunami's waveheight as it enters shallow water is given by:

$$\frac{h_s}{h_d} = \left(\frac{H_d}{H_s}\right)^{\frac{1}{4}}$$

where h_s and h_d are waveheights in shallow and deep water and H_s and H_d are the depths of the shallow and deep water. So a tsunami w height of 1 m in the open ocean where the water depth is 4000m would have a waveheight of 4 to 5 m in water of depth 10 m.

Just like other water waves, tsunamis begin to lose energy as they rush onshore - part of the wave energy is reflected offshore, while the shoreward-propagating wave energy is dissipated through bottom friction and turbulence. Despite these losses, tsunamis still reach the co tremendous amounts of energy. Depending on whether the first part of the tsunami to reach the shore is a crest or a trough, it may appear rapidly rising or falling tide. Local bathymetry may also cause the tsunami to appear as a series of breaking waves.

Tsunamis have great erosion potential, stripping beaches of sand that may have taken years to accumulate and undermining trees and oth coastal vegetation. Capable of inundating, or flooding, hundreds of metres inland past the typical high-water level, the fast-moving water associated with the inundating tsunami can crush homes and other coastal structures. Tsunamis may reach a maximum vertical height on above sea level, often called a run-up height, of tens of metres.

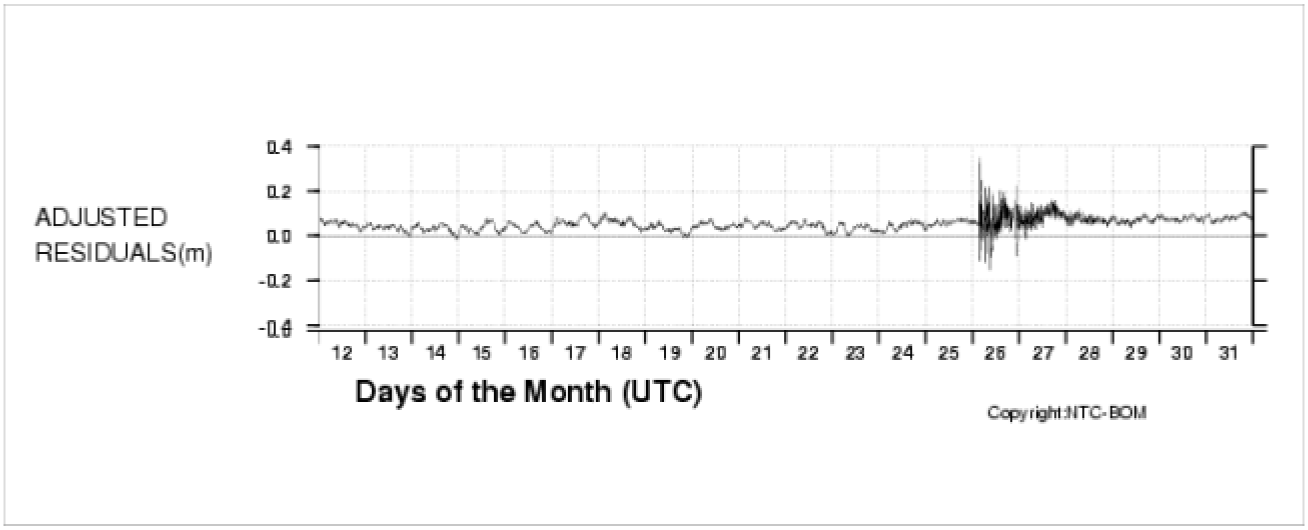
How are tsunamis measured or observed?

In the deep ocean, a tsunami has a small amplitude (less than 1 metre) but very long wavelength (hundreds of kilometres). This means th slope, or steepness of the wave is very small, so it is practically undetectable to the human eye. However, there are ocean observing instr that are able to detect tsunamis.

Tide Gauges

Tide gauges measure the height of the sea-surface and are primarily used for measuring tide levels. Most of the tide gauges operated by t Bureau of Meteorology's National Tidal Centre are SEAFRAME stations (Sea Level Fine Resolution Acoustic Measuring Equipment). Thes consist of an acoustic sensor connected to a vertical tube open at the lower end which is in the water. The acoustic sensor emits a sound which travels from the top of the tube down to the water surface, and is then reflected back up the tube. The distance to the water level ca be calculated using the travel time of the pulse. This system filters out small-scale effects like wind-waves and has the capacity to measur level changes within 1mm accuracy.

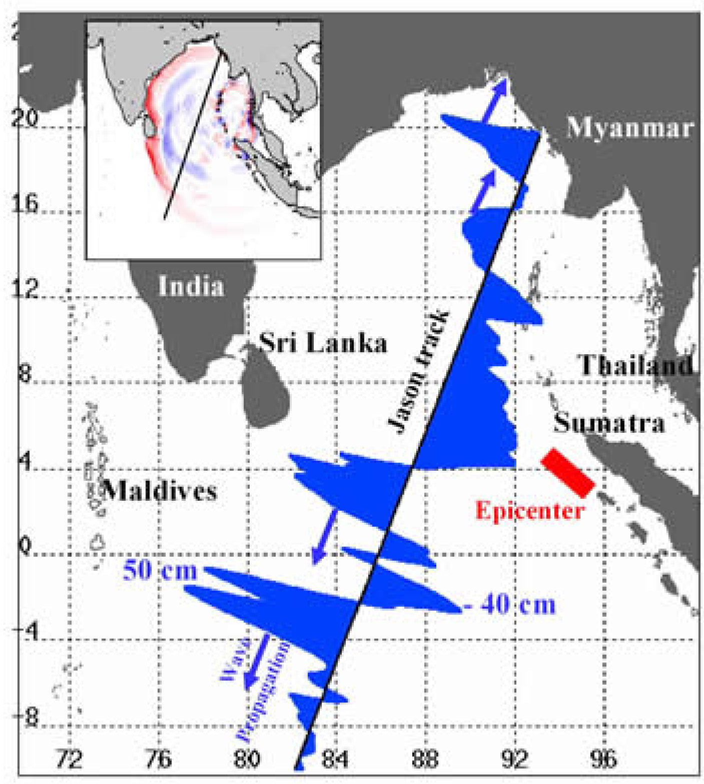
The tide gauge at Cocos Island observed the tsunami on December 26th 2004 as it passed by the island, as shown in these observations during December.



Satellites

Satellite altimeters measure the height of the ocean surface directly by the use of electro-magnetic pulses. These are sent down to the oce
surface from the satellite and the height of the ocean surface can be determined by knowing the speed of the pulse, the location of the sat
and measuring the time that the pulse takes to return to the satellite. One problem with this kind of satellite data is that it can be very spars
some satellites only pass over a particular location about once a month, so you would be lucky to spot a tsunami since they travel so quick
However, during the Indian Ocean tsunami of December 26th 2004, the Jason satellite altimeter happened to be in the right place at the ri
time.

The picture below shows the height of the sea surface (in blue) measured by the Jason satellite two hours after the initial earthquake hit th
region southeast of Sumatra (shown in red) on December 26, 2004. The data were taken by a radar altimeter on board the satellite along a
traversing the Indian Ocean when the tsunami waves had just filled the entire Bay of Bengal. The data shown are the differences in sea su
height from previous observations made along the same track 20-30 days before the earthquake, showing the signals of the tsunami.



Picture courtesy of NASA/JPL-Caltech

The DART System

In 1995 the National Oceanic and Atmospheric Administration (NOAA) began developing the Deep-ocean Assessment and Reporting of Tsunamis (DART) system. An array of stations is currently deployed in the Pacific Ocean. These stations give detailed information about ts
while they are still far off shore. Each station consists of a sea-bed bottom pressure recorder which detects the passage of a tsunami. (The
pressure of the water column is related to the height of the sea-surface) . The data is then transmitted to a surface buoy via sonar. The sur
buoy then radios the information to the Pacific Tsunami Warning Center (PTWC) via satellite. The bottom pressure recorder lasts for two y
while the surface buoy is replaced every year. The system has considerably improved the forecasting and warning of tsunamis in the Pacif

The Indian Ocean tsunami of 26th December 2004

An undersea earthquake in the Indian Ocean on 26th December 2004 produced a tsunami that caused one of the biggest natural disasters
modern history. Over 200,000 people are known to have lost their lives.

The waves devastated the shores of parts of Indonesia, Sri Lanka, India, Thailand and other countries with waves reported up to 15 m hig reaching as far as Somalia on the east coast of Africa, 4500 km west of the epicentre. Refraction and diffraction of the waves meant that tl impact of the tsunami was noticed around the world and sea-level monitoring stations in places such as Brazil and Queensland also felt th of the tsunami.

This animation (10.4Mb) was produced by scientists in the Bureau of Meteorology's National Tidal Centre. A numerical model was used to replicate the generation and propagation of the tsunami and it shows how the waves propagated around the world's ocean basins.

The earthquake took place at about 1am UTC (8am local time) in the Indian Ocean off the western coast of northern Sumatra. With a mag of 9.0 on the Richter scale, it was the largest since the 1964 earthquake off Alaska and equal fourth largest since 1900, when accurate glo seismographic record-keeping began.

The epicentre of the earthquake was located about 250 km south-southeast of the Indonesian city of Banda Aceh. It was a rare megathrus earthquake and occurred on the interface of the India and Burma tectonic plates. This was caused by the release of stresses that develop India plate subducts beneath the overriding Burma plate. A megathrust earthquake is where one tectonic plate slips beneath another, caus vertical motion of the plates. This large vertical displacement of the sea-floor generated the devastating tsunami, which caused damage o such a large area around the Indian Ocean.

The earthquake was also unusually large in geographical extent. An estimated 1200 km of faultline slipped about 15 m along the subducti over a period of several minutes. Because the 1,200 km of faultline affected by the quake was in a nearly north-south orientation, the grea strength of the waves was in an east-west direction. Bangladesh, which lies at the northern end of the Bay of Bengal, had very few casual despite being a populous low-lying country.

Due to the distances involved, the tsunami took anywhere from fifteen minutes to seven hours (for Somalia) to reach the various coastline this travel time map). The northern regions of the Indonesian island of Sumatra were hit very quickly, while Sri Lanka and the east coast o were hit roughly two hours later. Thailand was also struck about two hours later, despite being closer to the epicentre, because the tsunam travelled more slowly in the shallow Andaman Sea off its western coast.

On its arrival on shore, the height of the tsunami varied greatly, depending on its distance and direction from the epicentre and other facto as the local bathymetry. Reports have the height ranging form 2-3 m at the African coast (Kenya) up to 10-15 m at Sumatra, the region clo the epicentre.
