TSUNAMI

The Wave of Destruction

What is a tsunami?

A tsunami (pronounced tsoo-nah-mee) is a series of very long waves generated by any rapid, large-scale disturbance of the sea.

Earthquakes, landslides, volcanic eruptions, explosions, and even the impact of cosmic bodies, such as meteorites, can generate tsunamis.

What does "tsunami" mean?

- Tsunami is a Japanese word with the English translation, "harbor wave."
- In the past, tsunamis were sometimes referred to as "tidal waves" by the general public, and as "seismic sea waves" by the scientific community. The term "tidal wave" is a misnomer; although a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets. The term "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a nonseismic event, such as a landslide or meteorite impact.

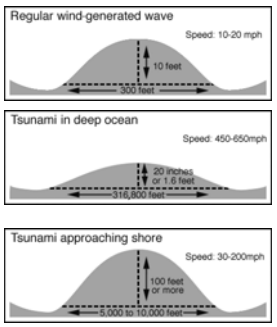
How do tsunamis differ from other water waves?

- Tsunamis are unlike wind-generated waves in that they are characterized as shallow-water waves, with long periods and wave lengths.
- A tsunami can have a wavelength in excess of 100 km and period on the order of one hour.

As a result of their long wave lengths, tsunamis behave as shallow-water waves

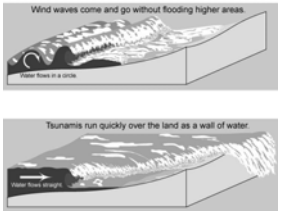
A wave becomes a shallow-water wave when wave travels through a water depth equal to less than 1/20 of its wavelength

Note the big difference in wave length and height



http://observe.arc.nasa.gov/nasa/exhibits/tsunami/tsun_physics.html

Tsunamis are often no taller than normal wind waves, but they are much more dangerous.



Notice the vast difference between tsunamis and wind generated waves. Because tsunamis have very long wavelengths they come ashore more like a long lasting flood wave rather than the breaking surf usually seen at the beach. This diagram illustrates the difference between tsunamis and wind waves when they come ashore.

How do earthquakes generate tsunamis?

Click above

Tsunamis are most commonly generated by earthquakes in marine and coastal regions. Major tsunamis are produced by large (greater than 7 on the Richer scale), shallow focus (< 30km depth in the earth) earthquakes associated with the movement of oceanic and continental plates. They frequently occur in the Pacific, where dense oceanic plates slide under the lighter continental plates. When these plates fracture they provide a vertical movement of the seafloor that allows a quick and efficient transfer of energy from the solid earth to the ocean

How a Tsunami Forms

http://esminfo.prenhall.com/science/geoanimations/animations/86_Tsunami.html

How do landslides, volcanic eruptions, and cosmic collisions generate tsunamis?

- A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position, not just earthquakes
- Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor.
- Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a tsunami.
- Conversely, supermarine landslides and cosmic-body impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls.
- Generally speaking, tsunamis generated from these mechanisms, unlike the Pacific-wide tsunamis caused by some earthquakes, dissipate quickly and rarely affect coastlines distant from the source area.

www.geophys.washington.edu

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.
- The tsunami's energy flux, which is dependent on both its wave speed and wave height, remains nearly constant. Consequently, as the tsunami's speed diminishes as it travels into shallower water, its height grows. Because of this shoaling effect, a tsunami, imperceptible at sea, may grow to be several meters or more in height near the coast. When it finally reaches the coast, a tsunami may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore.

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What happens when a tsunami encounters land?

- As a tsunami approaches shore it begins to slow and grow in height. 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.

- http://www.geophys.washington.edu/tsunami/movies/kanto1.mov

CLICK LINK

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Tsunamis have great erosional potential, stripping beaches of sand that may have taken years to accumulate and undermining trees and other coastal vegetation. Capable of inundating, or flooding, hundreds of meters 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 onshore above sea level, often called a runup height, of 10, 20, and even 30 meters.

www.geophys.washington.edu

Tsunami Speed

How can the speed of a tsunami be calculated?

Remember, because tsunami have extremely long wavelengths, they always behave as shallow water waves.

The speed of a tsunami can be calculated using the same formula used for other shallow-water waves:

$C = \sqrt{gd}$

$g = 9.8\ m/s^2$ (the acceleration due to gravity)

d = depth (a typical Pacific abyssal depth is 4,600 meters)

Historic Tsunamis

Tsunamis through history

Date	Place	Description	Estimated Deaths
July 21, AD 365	Alexandria	Generated by earthquake	50,000 +
June 7, 1692	Port Royal, Jamaica	Generated by earthquake	Thousands
1707	Japan	Generated by earthquake	30,000
November 1, 1755	Lisbon, Portugal	Waves 6-15 m high generated by earthquake	10,000-60,000
August 8, 1868	Arica, Chile	15 m wave generated by earthquake	Thousands
August 26-27, 1883	Krakatoa, Indonesia	Generated by eruption of volcano	36,000
June 15, 1896	Honshu, Japan	30 m wave generated by earthquake; destroyed 280 km coastline	27,122
December 28, 1908	Messina in Sicily and Italian coastal cities	Earthquake and 8 m wave	120,000
September 1, 1923	Sagami Bay, Kanto Plain, Atami and Nebukawa, Japan	Earthquake, fire, mudslide and 11 m wave	145,000
November 18, 1929	Grand Banks, Newfoundland	Triggered by a sub-marine landslide and earthquake	29
March 3, 1933	Sanriku, Japan	Generated by earthquake	2,990
April 1, 1946	Hilo, Hawaii and Aleutian Islands, Alaska	Generated by earthquake on Unimak Island, Alaska, creating waves up to 35 m high	165
November 4, 1952	Kamchatka Peninsula, Russia	Triggered by earthquake	Property damage, no human lives were lost

http://www.bom.gov.au/info/tsunami/tsunami_info.html

March 9, 1957	Aleutian Islands, Alaska. Also Hawaii	Triggered by earthquake south of the Andreanof Islands	Thanks to a timely alarm from the International Pacific Tsunami Warning Center at Honolulu, no human lives were lost
July 9, 1958	Lituya Bay, Alaska	Earthquake caused huge slab of ice and rock to fall off nearby glacier into bay; giant splash formed tsunami	3
May 1960	Chile	Generated by a series of earthquakes	2,300
May 1960	Hilo, Hawaii	Generated by a series of earthquakes (same as Chile on the same date)	61
March 28, 1964	Prince William Sound, Alaska	An earthquake and subsequent landslides generated a series of tsunamis, the highest reaching close to 30 m	130
November 29, 1975	Island of Hawaii	Earthquake off the coast of the Island of Hawaii generated waves between 2 m and 15 m high	2
August 17, 1976	Mindanao, Philippines	Generated by earthquake	8,000
July 18, 1979	Lomblem Island, Indonesia	2 m wave generated by volcano collapse	539
October 16, 1979	Nice, France	Undersea landslides generated 2 tsunamis one week apart	23
September 1, 1992	Nicaragua	Earthquake caused series of waves 11 m high	170
December 12, 1992	Flores Island & Babi Island	Series of tsunamis, generated by earthquake. Waves ranging from 5 m to 25 m high, depending where they hit.	1690 (Flores) 263 (Babi)

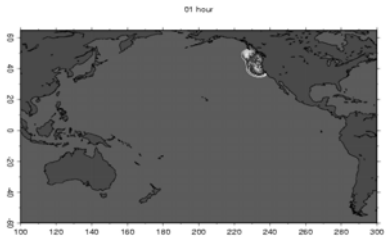
July 12, 1993	Island of Okushiri, Japan	Underwater earthquake generated waves 5 to 30 m high	200 +
June 3, 1994	Eastern Java, Indonesia	Earthquakes caused series of waves more than 60 m high	223
November 11, 1994	Mindoro Island	Generated by earthquake. Waves 7 m high	70
October 9, 1995	Jalisco, Mexico	Generated by earthquake. Waves 11 m high	1
January 1, 1996	Minahassa Peninsula, area of Sulawesi	Generated by earthquake. Waves 4 m high	24
February 17, 1996	Biak, Irian Java	Generated by earthquake. Waves ranging from 5 to 10 m high	161
February 21, 1996	North Coast of Peru	Generated by earthquake. Waves 5 m high	12
July 17, 1998	Papua - New Guinea	Generated by earthquake. Waves ranging from 7 m to 15 m high	3,000
September 15th, 1999	Fatu Hiva, Marquesas Islands	Generated by landslide. Two waves 5 m high	Property damage, no human lives were lost

The January, 1700 Cascadia Subduction Zone earthquake and tsunami

Between 9:00 PM and 10:00 PM, local time, on January 26th 1700, a great earthquake shook the Pacific Northwest. This quake, with magnitude estimated at 9.0, rocked the region with strong shaking for several long minutes minutes while coastal Washington plummeted as much as 1.5 meters relative to coastal waters.

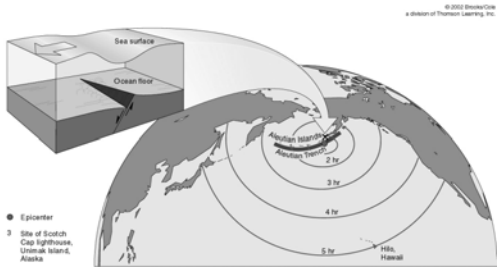
http://www.ess.washington.edu/SEIS/PNSN/HAZARDS/CASCADIA/cascadia_event.html

This is a model of the wave propagation from the 1700 Cascadia Tsunami.



http://www.pgc.nrcan.gc.ca/press/index_e.php

The April 1, 1946 Earthquake and Tsunami



A tsunami, which occurred in 1946, was generated by a rupture along a submerged fault. The tsunami traveled at speeds of 212 meters per second.

Tsunami inundating Hilo, Hawaii.
Note man on pier (he was swept away seconds later).
April 1946

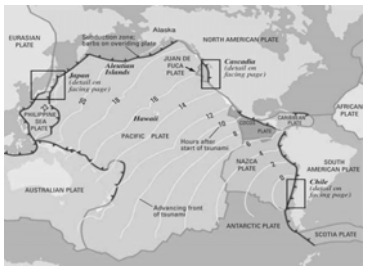
http://pubs.usgs.gov/gip/hazards/tsunamis.html

This earthquake generated one of the most destructive Pacific-wide tsunamis of the 20th century. Near the generating area, at Unimak Island, huge tsunami waves reached 35.0 m (more than 100 feet) above sea level and destroyed completely the newly built, U.S. Coast Guard's Scotch Cap lighthouse. All 5 men of its crew were killed. The lighthouse was a steel-reinforced concrete structure and its base was at about 30 meters above sea level.

http://www.drgeorgepc.com/Tsunami1946.html

Chilean tsunami of 1960

One of the more destructive Pacific-wide tsunamis of our time was the Chilean tsunami of 1960. First, there was an earthquake with a magnitude of 8.6 on the Richter scale. This earthquake triggered a Pacific-wide tsunami that destroyed not only the Chilean coast, but parts of Hawaii and California as well. The total death toll associated with the earthquake and the tsunami was estimated to be between 490 and 2,290. In addition, over a half-billion dollars in damage was done by this incredible wave.

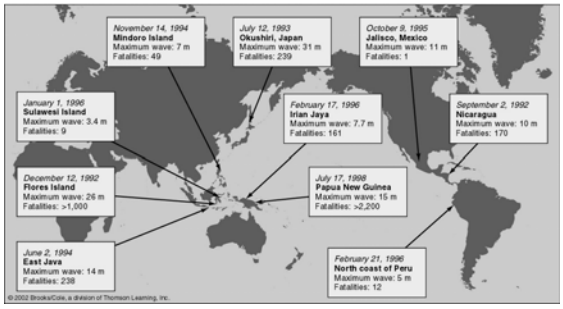


The 1960 Chilean tsunami radiated outward from a subduction zone along the coast of Chile. Its waves reached Hawaii in 15 hours and Japan in 22 hours.

http://pubs.usgs.gov/circ/c1187/

After wreaking havoc across Chile, the tsunami traveled for almost fifteen hours to Hilo, Hawaii, where an additional sixty-one lives were taken. This is a picture of a parking meter in Hilo that was bent in half by the sheer force of the wave. Property damage was estimated at 24 million dollars

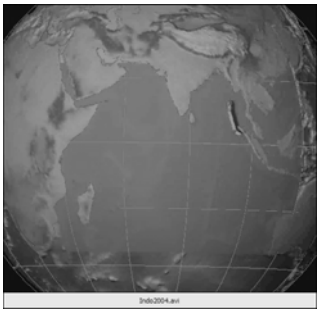
http://observe.arc.nasa.gov/nasa/exhibits/tsunami/tsun_chile2.html



Ten of the tsunami that have struck since 1990.

December 26, 2004 Sumatra tsunami

The most powerful earthquake in 40 years erupted under the Indian Ocean near Sumatra on Dec. 26, 2004. It caused giant, deadly waves to crash ashore in nearly a dozen countries. Over 200,000 people are known to have lost their lives/.

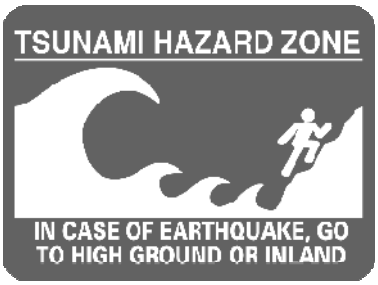


Propagation of the December 26, 2004 Sumatra tsunami.

http://www.news.cornell.edu/releases/Jan05/tsunamiVid320.html

Computer simulation model of the tsunami that spread across the Indian Ocean on December 26, 2004

The clock in the video starts at the moment of the Sumatra earthquake. Colors show the displacement from sea level: red shows high water and blue shows low. The intensity of the color corresponds to the degree of displacement.



USGS

Online Resources

- http://www.pbs.org/wgbh/nova/tsunami/anatomy.html
- http://www.fema.gov/kids/tsunami.htm
- http://observe.arc.nasa.gov/nasa/exhibits/tsunami/tsun_bay.html
- http://serc.carleton.edu/NAGTWorkshops/visualization/collections/tsunami.html
- http://www.waveofdestruction.org/
- http://www.weather.gov/om/brochures/tsunami.htm
- http://www.noaa.gov/tsunamis.html
- http://ioc3.unesco.org/itic/contents.php?id=169