

Earthquake Hazards



Tsunami

Measuring Earthquakes

Two measurements that describe the “power” or “strength” of an earthquake are:

- **Intensity** – a measure of the **degree of earthquake shaking** at a given locale based on the amount of damage.
- **Magnitude** – estimates the **amount of energy** released at the source of the earthquake:
 - Logarithmic scale (not linear).
 - Magnitude 2 or lower earthquakes cannot be felt by humans.
 - Magnitude 7 and over potentially cause serious damage over larger areas, depending on their depth.
 - The **largest earthquakes in historic times** have been of magnitude **slightly over 9**, although there is no limit to the possible magnitude.

Modified Mercalli Scale vs. Richter Scale



Intensity category	Effects	Magnitude scale
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8

Greatest Earthquakes Ever Recorded

1. **(M 9.5)** 22 May 1960 – Great Chilean Earthquake, Valdivia, Chile:
most powerful earthquake ever recorded; lasted ~10 min; triggered tsunami which reached Hawaii and Japan; 3000-5000 dead.



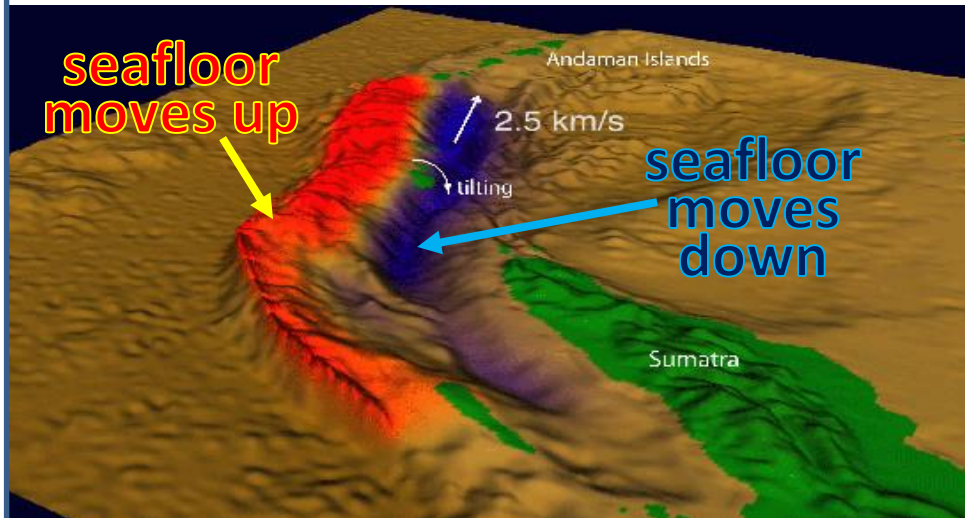
2. **(M 9.2)** 27 March 1964 – Great Alaskan Earthquake (aka Good Friday earthquake), Prince William Sound, AK:
lasted ~4.5 min; tsunami, soil liquefaction; 128 dead.



Greatest Earthquakes Ever Recorded

3. (M 9.1-9.3) 26 December 2004 – Indian Ocean Earthquake (aka Sumatra-Andaman earthquake), off the west coast of Sumatra:

shaking lasted ~8 min; **surface wave oscillations exceeded 1 cm everywhere on Earth**; the **longest ever fault rupture of 1600 km** triggered tsunami waves (up to 30 m high reaching as far as 2 km inland in Indonesia); killed 230,000 people in 14 countries.



4. (M 9.0) 11 March 2011 – Great East Japan Earthquake (aka Tohoku earthquake), off the west coast of Japan:

lasted ~6 min; tsunami waves (up to 40 m high, travelled as far as 10 km inland); the disaster caused **partial meltdown at Fukushima Daiichi Nuclear Power Plant**; 15,800 dead.



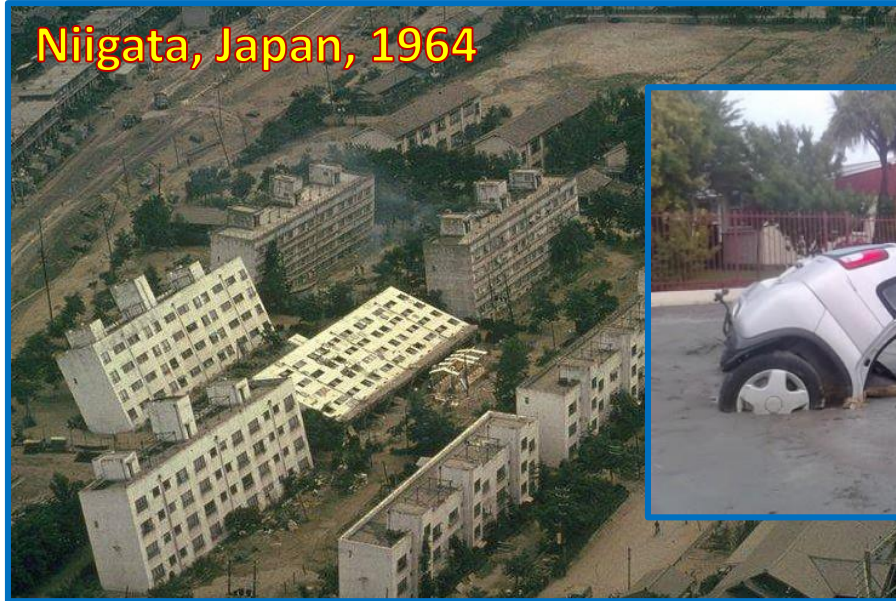
Earthquake Hazards: Shaking

Amount of structural damage due to earthquake **vibrations** strongly depends on intensity and duration of the vibrations. Buildings respond differently to shaking based on construction styles and materials (wood - more flexible, holds up well; earthen materials - very vulnerable to shaking).

- High frequency body waves shake low buildings more.
- Low frequency surface waves shake high buildings more.
- Intensity of shaking also depends on type of subsurface material.
- Unconsolidated materials (sand, mud) amplify shaking more than rocks do.
- Fine-grained, sensitive materials can lose strength when shaken.



Earthquake Hazards: Soil



Liquefaction of the ground:

- **Unconsolidated materials** (such as sand and silt) saturated with water **turn into a mobile fluid**.
- Damage to foundation as well as sinking and tilting of structures can occur.

Landslides:

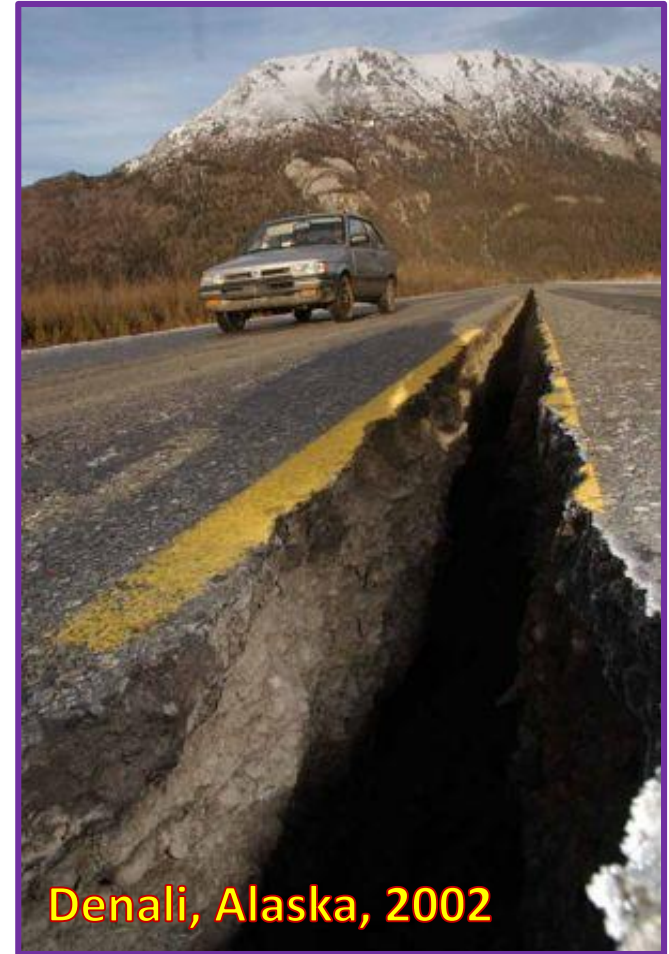
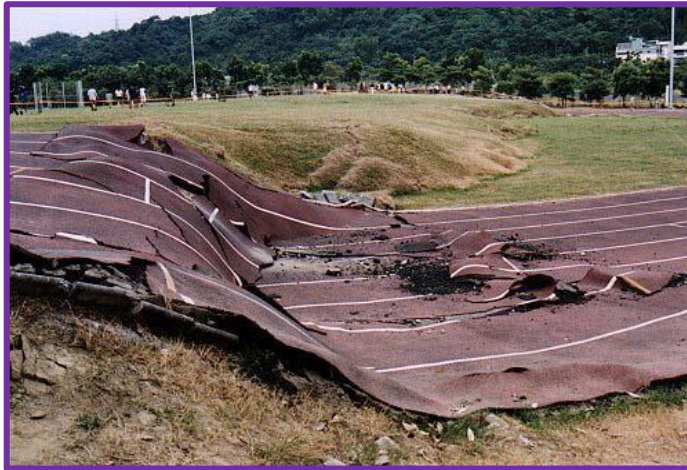
- Earthquakes can produce **slope instability** leading to landslides.

Earthquake Hazards: Shift

Ground displacement/rupture:

- Ground surface may shift during an earthquake (especially if its focus is shallow).
- Vertical displacements of surface produce fault scarps.

Thrust fault scarp: Chi Chi earthquake, Taiwan, 1999



Denali, Alaska, 2002

Fires: As a result of ground displacement, fires can occur from **shifting of subsurface utilities** (electric and gas lines).

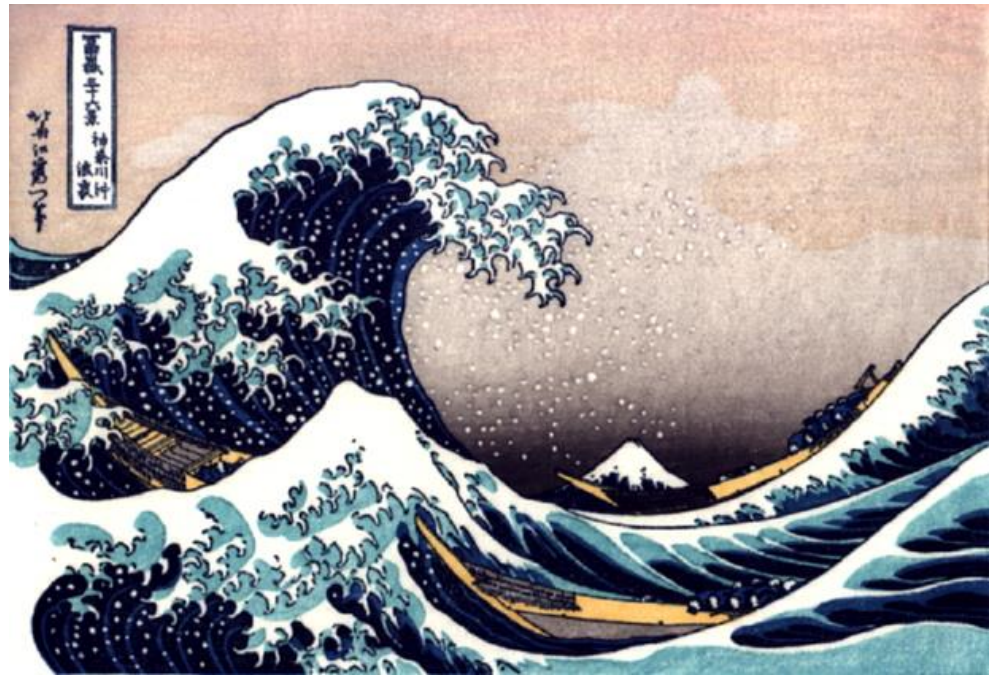
Earthquake Hazards: Water Bodies

Seiches:

- The rhythmic back-and-forth sloshing of water in lakes, reservoirs, and enclosed basins. Such waves **can weaken reservoir walls and cause destruction.**

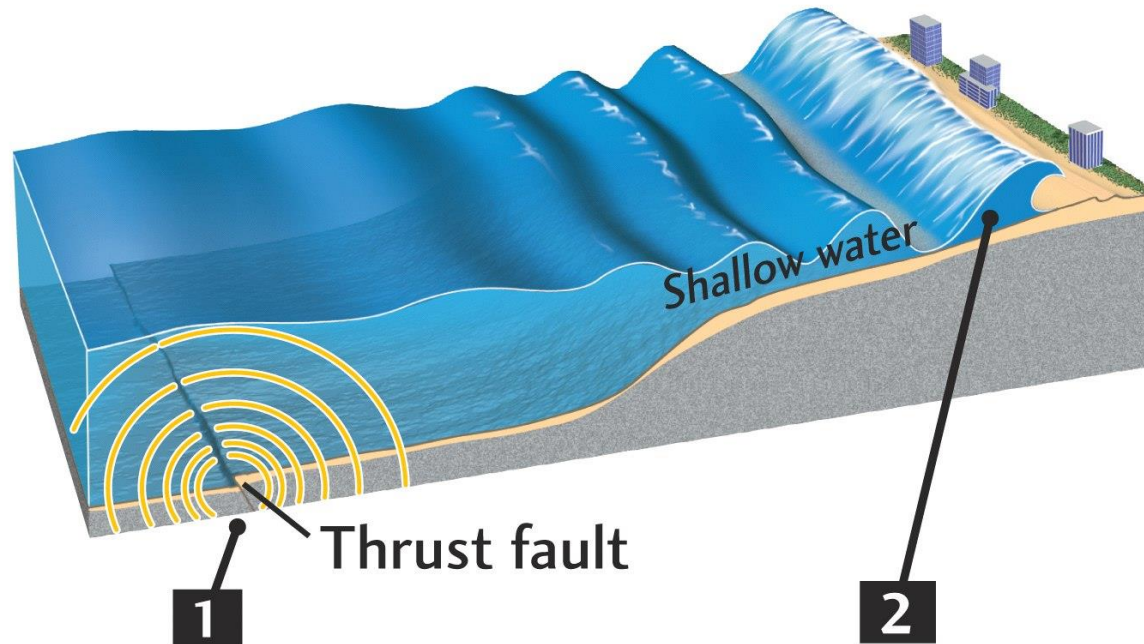
Tsunami:

- Destructive seismic sea waves (inappropriately called “tidal waves”) that result from **vertical displacement of the ocean floor** or a **large undersea landslide** triggered by an earthquake.
- Japanese for “harbor wave” – harmless until it enters the harbor.



Tsunami Generation

1. Movement of seafloor during an earthquake produces a **surge of water** that becomes a **long sea wave**. In the open ocean its height is usually **less than 1 meter**.
2. In shallower coastal waters the waves pile up to heights that occasionally **exceed 30 meters**.



Tsunamis can hit with **little or no warning!**

Hazards and Risks of Tsunami

Tsunamis are **most devastating near the earthquake**. They are **larger** and **strike** the region **soon** after the earthquake.

- Tsunamis also travel across entire oceans and cause damage and death thousands of miles from the earthquake.
- Tsunamis travel very quickly relative to normal ocean waves, especially in open water, where velocities increase with water depth and can reach 1,000 km/hr (normal ocean wave: ~90 km/hr)
- The most tsunami prone areas are those associated with volcanoes and earthquakes, mainly subduction zones. **Large subduction zones** produce the most tsunamis: Pacific ~80%, Atlantic ~10%, elsewhere ~10%.

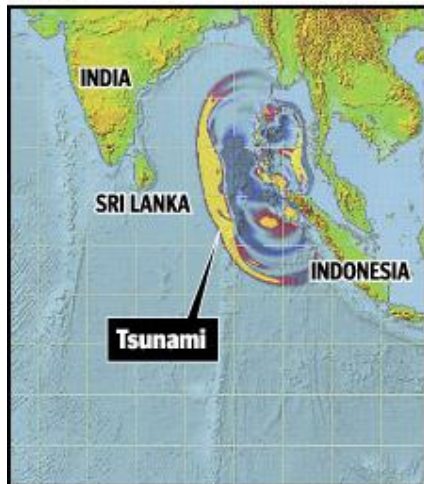


Tsunami: 2004 Indian Ocean Earthquake

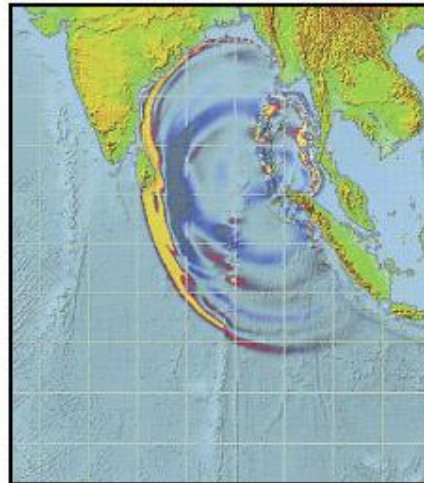
This giant 9.1 magnitude earthquake ruptured the **greatest fault length of any recorded earthquake**, spanning a distance of 990 miles (1600 km), or *longer than the state of California*.

- Such a giant push of water generated a series of **ocean-wide tsunami waves**, the first of which hit Indonesia 25 minutes **after** the start of the quake.

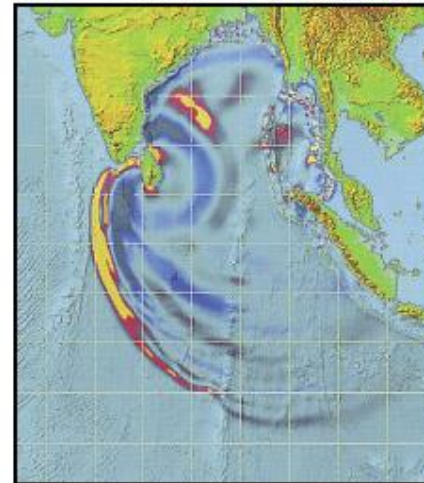
1 HOUR



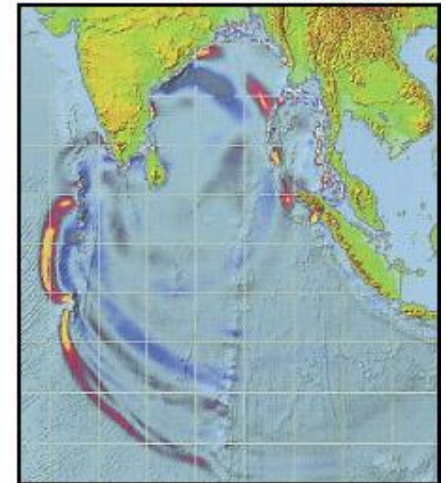
2 HOURS



3 HOURS



4 HOURS



- The waves had grown to **100 feet (30 m)** high in some places; more tsunami waves struck Thailand two hours later, and other countries across the Indian Ocean were hit a few hours later.

BANDA ACEH, INDONESIA: June 23, 2004
A satellite image of the waterfront area of Aceh province's capital city before the tsunami.



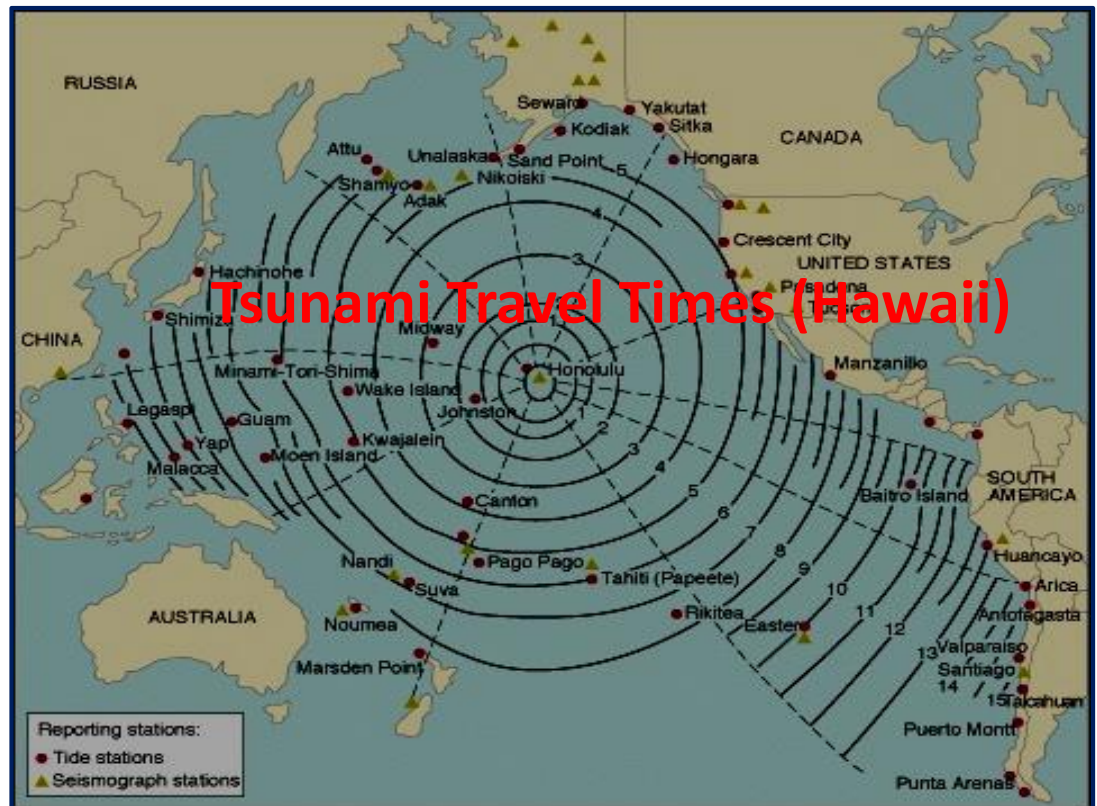
BANDA ACEH, INDONESIA: December 28, 2004
An image taken after the tsunami shows destroyed housing and the shoreline nearly wiped out.



Tsunami Warning

Regions with a high tsunami risk typically use tsunami warning systems to warn the population before the wave reaches land:

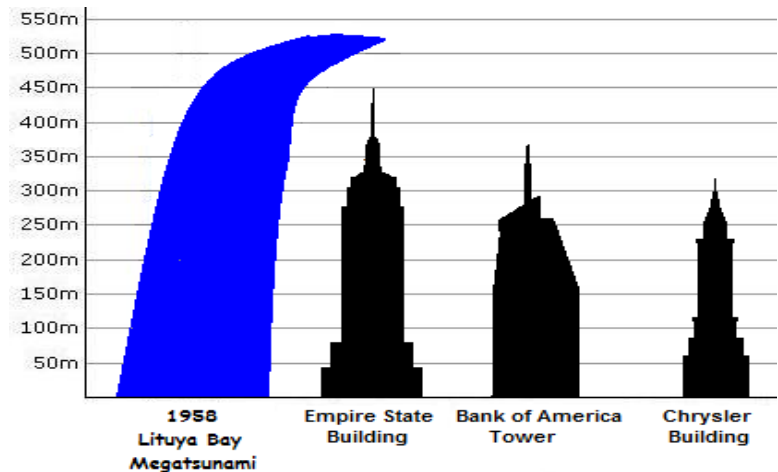
- The **Pacific Tsunami Warning System** is based in Honolulu, Hawaii. It monitors Pacific Ocean seismic activity.
- As soon as an earthquake of magnitude >6.5 is located in the sea, the **alarm starts**.
- Using computer simulations based on real-time data from bottom pressure sensors, attached to buoys, scientists forecast the time of tsunami arrival in different locations.



Megatsunami

Megatsunami is an informal term to describe a tsunami that has **initial wave heights much larger than normal** tsunamis.

- Origin: a large scale landslide, collision, or volcanic eruption event as opposed to raising or lowering of the sea floor due to tectonic activity.
- Prehistoric: asteroid impacts; Mt. Etna volcanic landslide; East Molokai Volcano collapse; etc.
- Modern: 1792, Mount Unzen, Japan (100m); 1963, Vajont Dam, Italy (250m); 1980, Mount St. Helens-Spirit Lake, WA (260m).
- 1958, Lituya Bay Megatsunami: a huge landslide (~40 million cubic meters of rock and ice) triggered by an 8.3 magnitude earthquake in Alaska created waves with a run-up up to ~525m high on the Lituya Bay, largest known in modern times.



Future concerns: potential massive landslide on a volcanic ocean island (ex. Cape Verde, Canary Islands, Hawaii)