Earthquake Hazards

Tsunami

Review: What is an earthquake?

- **Earthquake** is the vibration (shaking) and/or displacement of the ground produced by the sudden release of energy.
- The point inside the Earth where an earthquake begins (*point of initial rupture*) is called *focus*.
- The area on the surface of the Earth directly above the focus where the shaking is usually felt most strongly is called *epicenter*.
- Energy released from the earthquake source (its focus) radiates in all directions in the form of waves called *seismic waves* (*body* waves and *surface* waves).
- Earthquake strength is usually described by its *intensity* (a measure of the degree of shaking based on the amount of damage) and *magnitude* (an estimate of the amount of energy released at the source of the earthquake; *logarithmic scale*).

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.

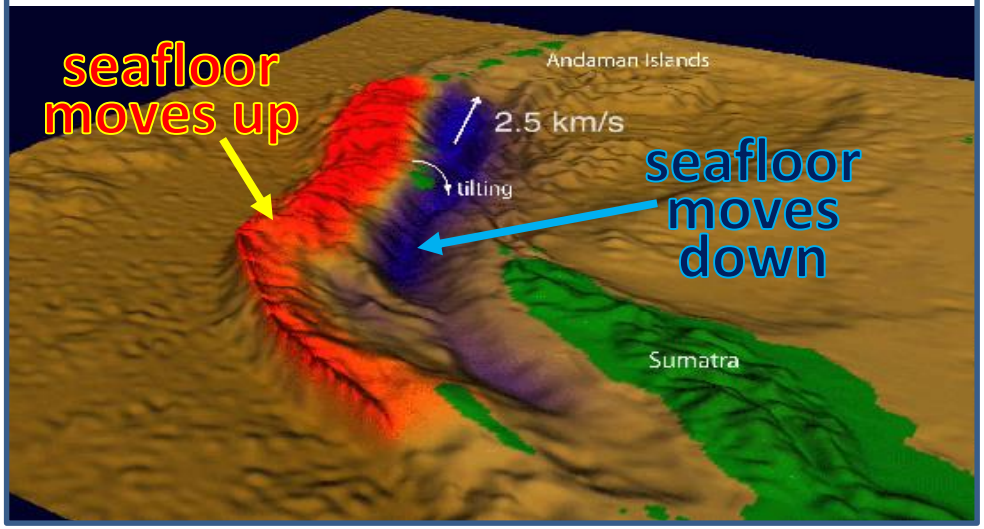
2. (M 9.2) 27 March 1964 – Great Alaskan Earthquake (aka Good Friday earthquake), Prince William Sound, AK:

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:

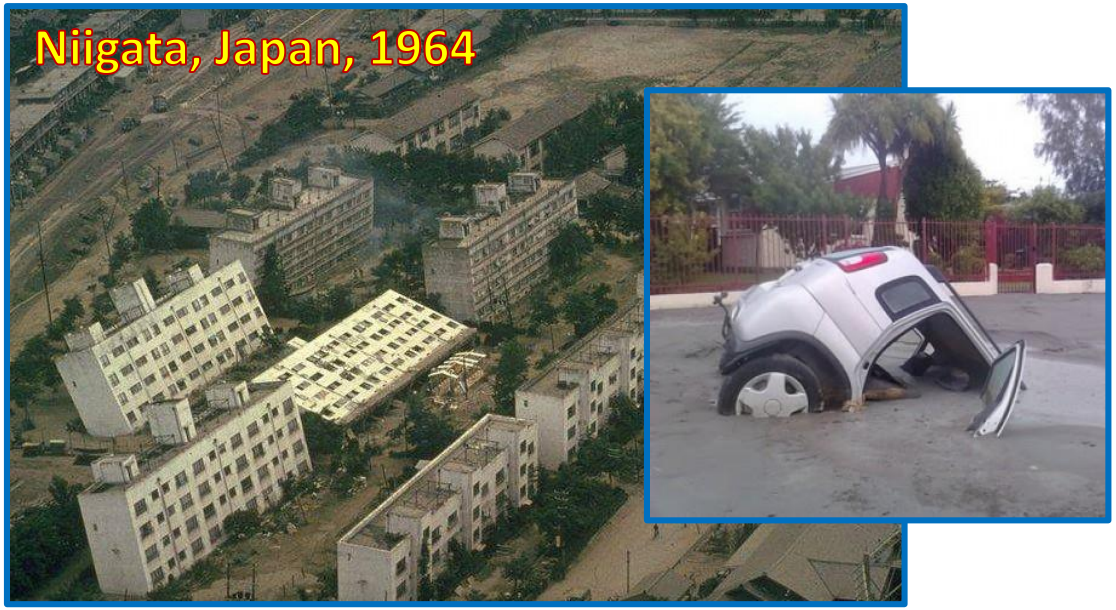
lasted ~6 min; tsunami waves (up to 40 m high, travelled as far as 10 km inland); the disaster caused partial meltdown at Fukushima Daiichi Nuclear Power Plant; 15,800 dead.

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

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

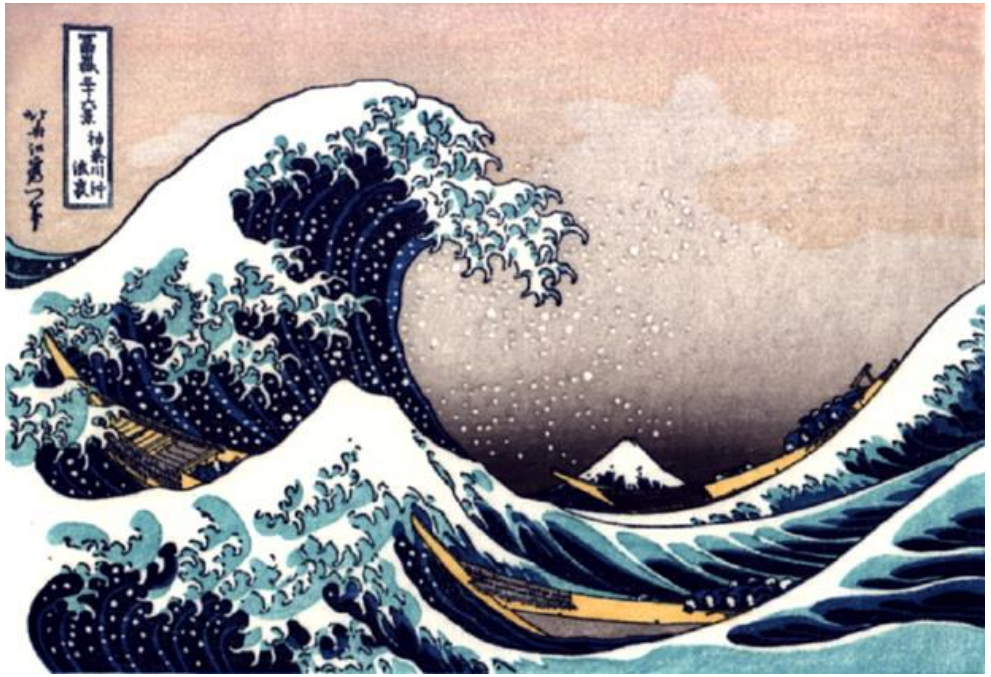
Earthquake Hazards: Water Bodies

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:

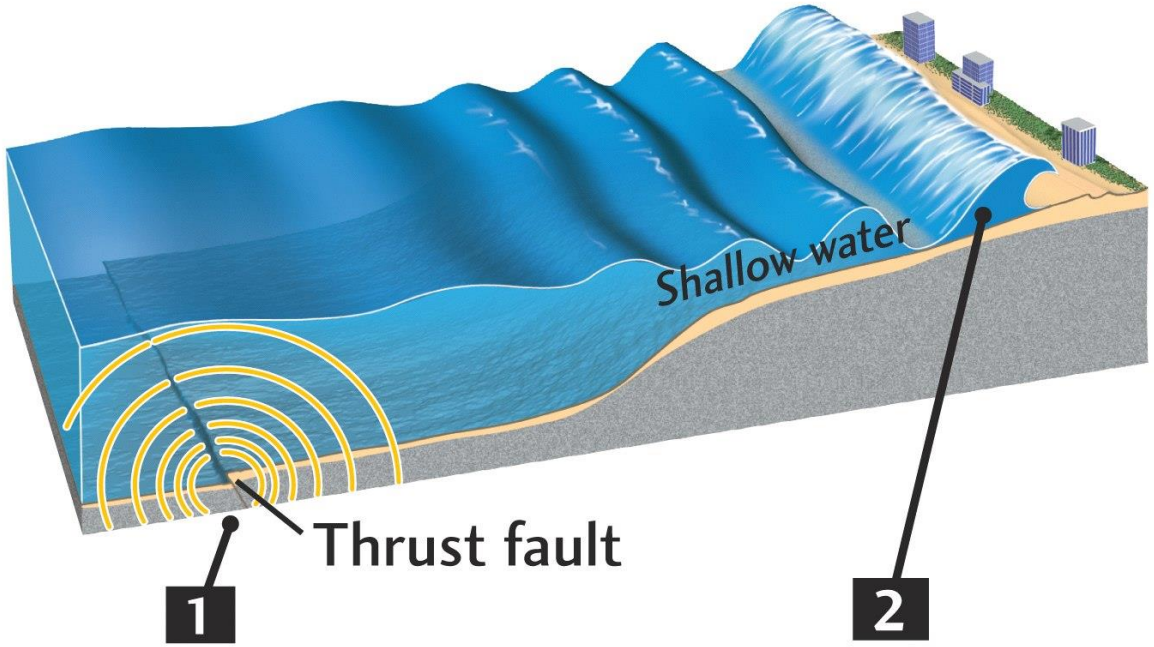
- Destructive seismic sea waves (inappropriately called "tidal waves") that result from vertical displacement of the ocean floor or a large undersea landslide triggered by an earthquake.



- 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.

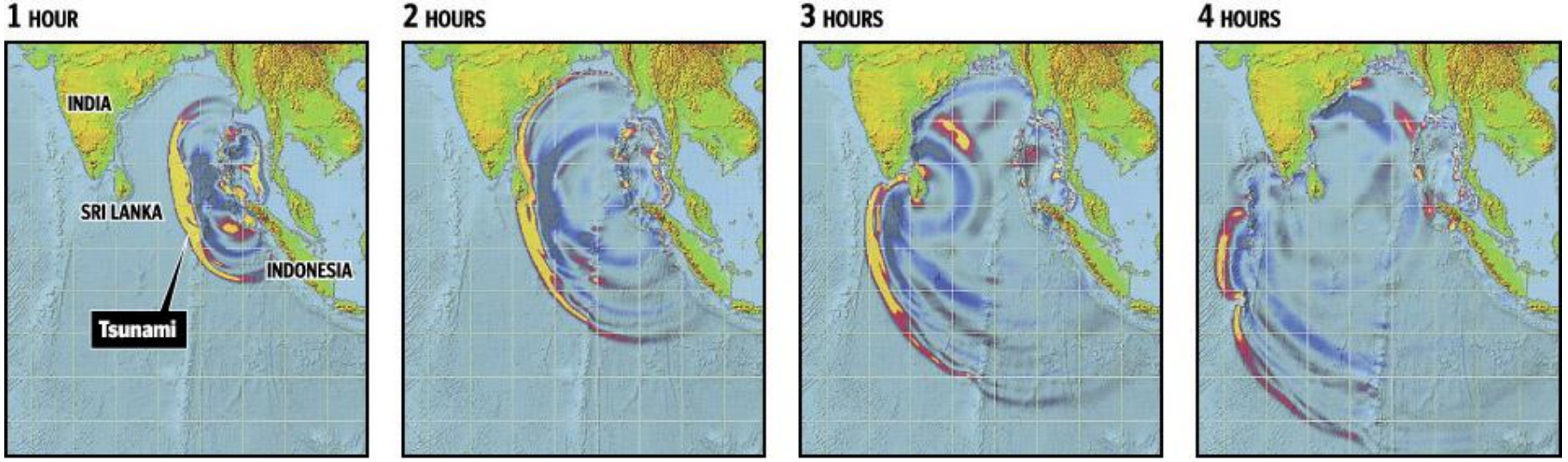
- **Tsunamis also travel across entire oceans and cause damage and death thousands of miles from the earthquake.**
- **Tsunamis travel very quickly relative to normal ocean waves, especially in open water, where velocities increase with water depth and can reach 1,000 km/hr (normal ocean wave: ~90 km/hr)**

- **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.**



- **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.

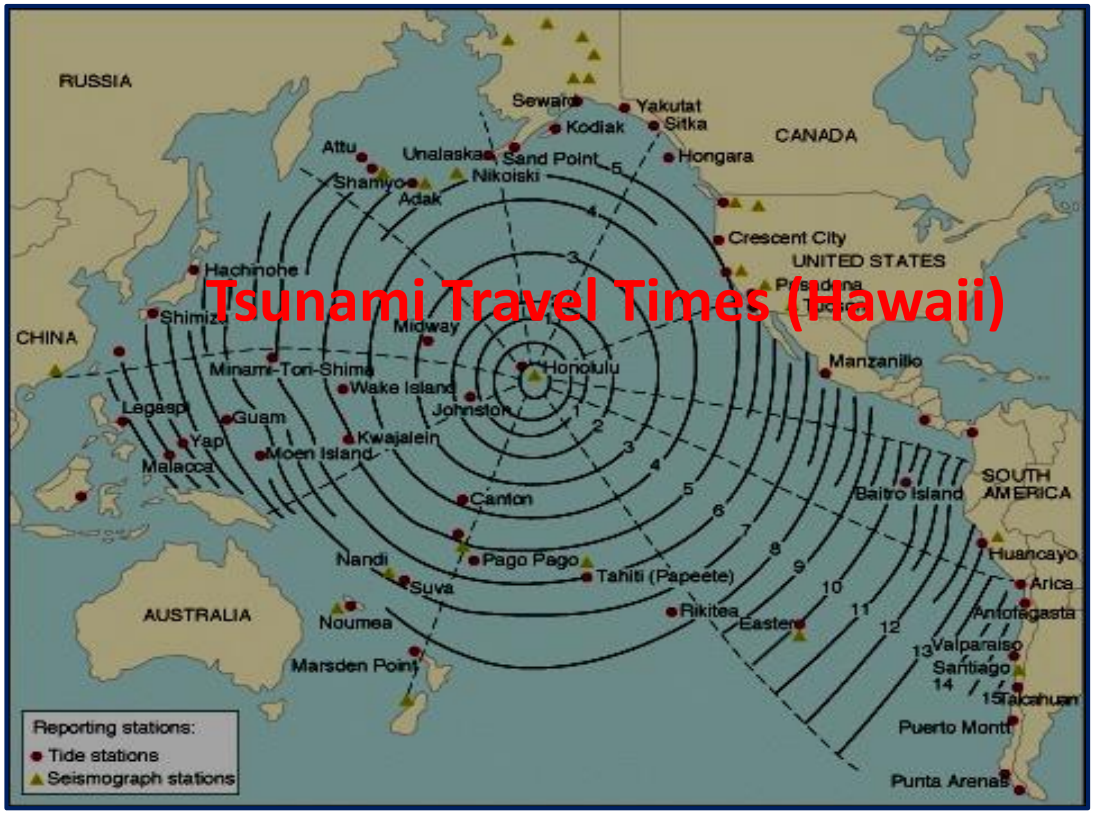
Tsunami Warning

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.**

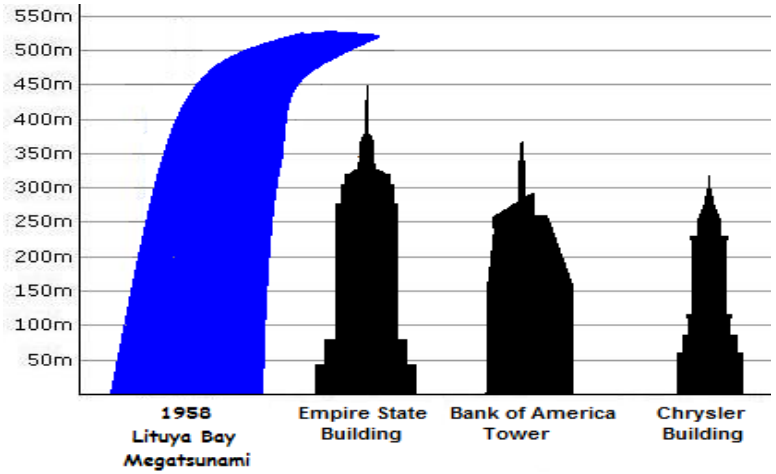


Megatsunami

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)