Characteristics of tsunamis

What is a tsunami?

The official definition of a tsunami is: "a wave train, or series of waves, generated in a body of water by an *impulsive disturbance* that *vertically displaces the water column*."

What causes a tsunami?

In general, anything that is capable of moving large water masses can cause a tsunami. Various sources as earthquakes, landslides, volcanic eruptions, explosions, and even the impact of cosmic bodies, such as meteorites, can generate tsunamis (Figure 1).

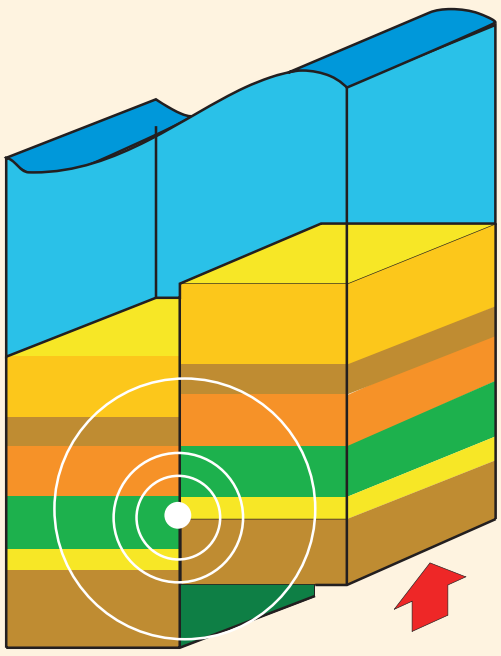

Figure 1: In case of earthquakes, tsunamis can be generated when the sea floor abruptly deforms and vertically displaces the overlying water (Figure 1). The entire water column is disturbed by the uplift or subsidence of the sea floor. Waves are formed as the displaced water mass attempts to regain its equilibrium. These waves affect the whole column of water between the surface and the sea floor as they move, from the region of origin in the middle of the sea, towards the coast.

Shallow water waves

A tsunami is what we call a shallow water wave. A wave is a shallow water wave if the wavelength of the wave is much longer than the depth of the water the wave is traveling through. This is typically the case for tsunamis which have wavelengths exceeding 100 km while traveling through 5-7 km deep water. Because the rate at which a wave loses its energy is inversely related to its wave length, tsunamis not only propagate at high speeds, they can also travel great, transoceanic distances with limited energy loss (the rate at which a wave loses its energy is inversely related to its wave length).

This explains why the coast of Africa was still hit by a tsunami that originated over 5000 km away.
Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s/s) and the water depth - in a 6 km deep ocean a tsunami propagates with 875 km/hr, as fast as an airplane!

Difference between tsunami in the deep ocean and a tsunami approaching the coast

A tsunami behaves fundamentally different in the open ocean and close to the coast in shallow waters (Figure 2). A tsunami in the deep ocean has very long wavelengths and very low amplitude. Approaching the shore the tsunami will slow down in speed and amplitudes will increase dramatically. This is due to the fact that 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 10-50 meters near the coast.

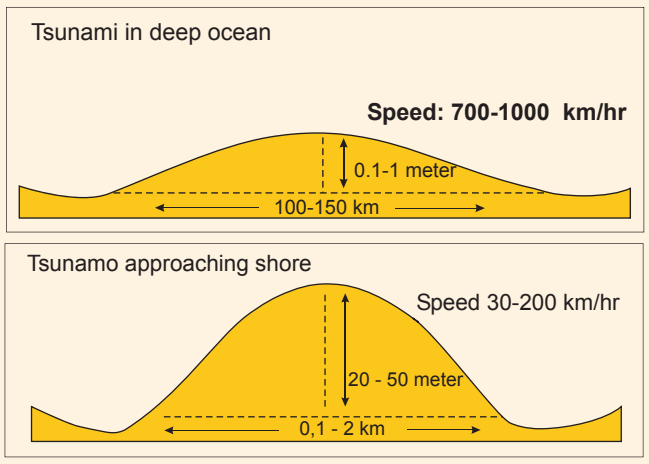

Figure 2: Tsunamis in open sea and close to the coast have distinctively different amplitudes, wavelengths and wave speeds.

A tsunami is NOT:

* A tidal wave
  Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets.
* A seismic sea wave
  "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a non-seismic event, such as a landslide or meteorite impact.
* A wind-generated wave (storm wave) (Figure 3)
  Wind generates disturbance at the surface of the water column whereas tsunamis disturb the whole water column from surface to sea bottom. Wavelengths for wind generated waves are much shorter and amplitudes, in the open ocean, much higher than for tsunami waves.

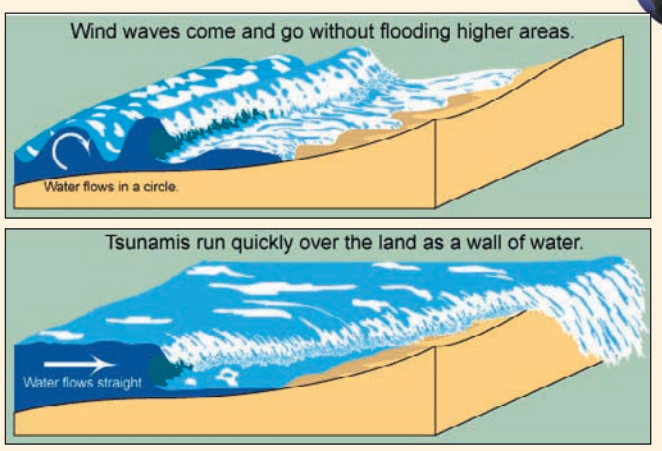

Figure 3: Wind generated waves can have wavelengths up to 150 meters, with a period of up to 10 sec. A wind generated wave has much higher wave amplitudes than a tsunami in the open ocean (10 meters and 1 meter respectively) but only disturbs the top-layer of the water column. Also the propagation speed for a wind generated wave is with 15-50 km/hr much lower than the speed of propagation for a tsunami, 600-900 km/hr. At the coast, wind generated waves will hit the coast in rolling movements without invading the land, whereas tsunamis arrive as a 'wall' of water rolling over the beach invading the land lying behind. (source: University of Washington)

Tsunami effects:

There are several specific characteristics related to tsunamis that make it clearly distinguishable from other types of waves and that are the cause for the devastating force a tsunami might have (see also Figures 4 and 5):

* Tsunamis can appear as a falling or rising tide, waves or bore
* Tsunamis can last for several hours.
* A tsunami consists of several wave trains following each other.
* A pattern of high water levels is alternated with low water levels

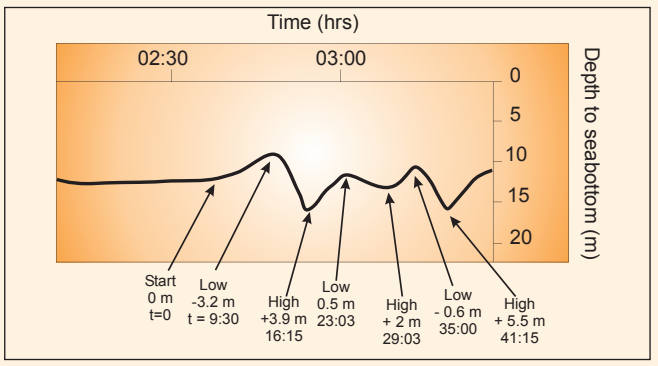

Figure 4: This recording is from a fishfinder on a Belgian sailing ship off coast of Thailand. The fishfinder shows the depth from the boat to the bottom of the sea. This recording is very illustrative in recognizing the patterns that characterize a tsunami wave. Clearly visible are the high and low 'tides' that correspond to several wave trains that will hit the Thai coast. The tsunami arrives at t=0.0 and first causes low water levels (-3.2m relative to the original water depth), followed by elevated water levels. The peak to through amplitude is over 7 meters! This is followed by alternating low and high water levels for the next 30 minutes.

Figure 5: This pattern of high and low water levels is also clearly illustrated in satellite images. In the left figure the original coastline can be seen with a small strip of beach. In the middle figure the tsunami has hit the coast and is penetrating inland. On the left a retreat of the sea is visible now showing a large piece of beach, with the sea tens of meters away from the original coastline.

For more information:

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