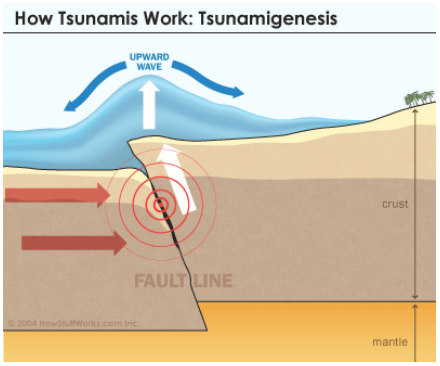
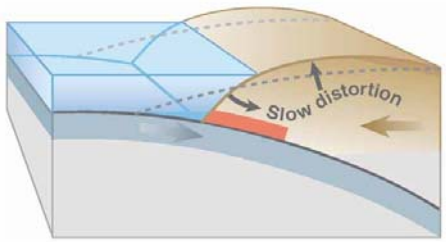
Understanding Tsunami

A tsunami is a series of waves most commonly caused by violent movement of the sea floor. In some ways, it resembles the ripples radiating outward from the spot where stone has been thrown into the water, but a tsunami can occur on an enormous scale. Tsunamis are generated by any large, impulsive displacement of the sea bed level. The movement at the sea floor leading to tsunami can be produced by earthquakes, landslides and volcanic eruptions.

Earthquake Tsunamis: Most tsunamis, including almost all of those traveling across entire ocean basins with destructive force, are caused by submarine faulting associated with large earthquakes. These are produced when a block of the ocean floor is thrust upward, or suddenly drops, or when an inclined area of the seafloor is thrust upward or suddenly thrust sideways. In any event, a huge mass of water is displaced, producing tsunami. Such fault movements are accompanied by earthquakes, which are sometimes referred to as "tsunamigenic earthquakes". Most tsunamigenic earthquakes take place at the great ocean trenches, where the tectonic plates that make up the earth's surface collide and are forced under each other. When the plates move gradually or in small thrust, only small earthquakes are produced; however, periodically in certain areas, the plates catch. The overall motion of the plates does not stop;





only the motion beneath the trench becomes hung up. Such areas where the plates are hung up are known as “seismic gaps” for their lack of earthquakes. The forces in these gaps continue to build until finally they overcome the strength of the rocks holding back the plate motion. The built-up tension (or comprehension) is released in one large earthquake, instead of many smaller quakes, and these often generate large deadly tsunamis. If the sea floor movement is horizontal, a tsunami is not generated. Earthquakes of magnitude larger than M 6.5 are critical for tsunami generation.

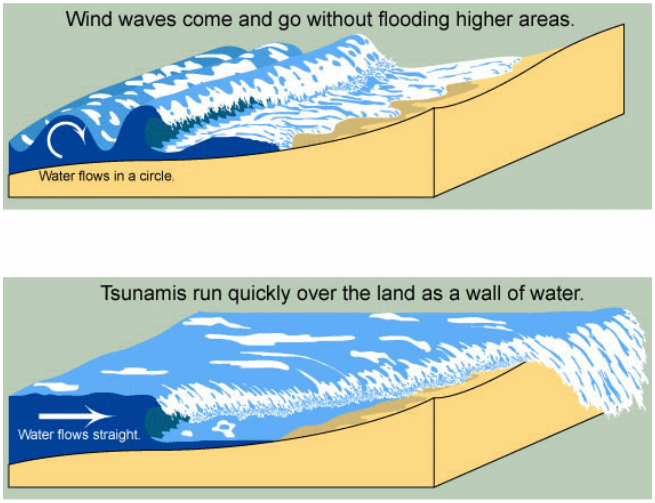
Tsunamis produced by landslides: Probably the second most common cause of tsunami is landslide. A tsunami may be generated by a landslide starting out above the sea level and then plunging into the sea, or by a landslide entirely occurring underwater. Landslides occur when slopes or deposits of sediment become too steep and the material falls under the pull of gravity. Once unstable conditions are present, slope failure can be caused by storms, earthquakes, rain, or merely continued deposit of material on the slope. Certain environments are particularly susceptible to the production of landslide-generated earthquakes. River deltas and steep underwater slopes above sub-marine canyons, for instance, are likely sites for landslide-generated earthquakes.

Tsunami produced by Volcanoes: The violent geologic activity associated with volcanic eruptions can also generate devastating tsunamis. Although volcanic tsunamis are much less frequent, they are often highly destructive. These may be due to submarine explosions, pyroclastic flows and collapse of volcanic caldera. (1) Submarine volcanic explosions occur when cool seawater encounters hot volcanic magma. It often reacts violently, producing stream explosions. Underwater eruptions at depths of less than 1500 feet are capable of disturbing the water all the way to the surface and producing tsunamis. (2) Pyroclastic flows are incandescent, ground-hugging clouds, driven by gravity and fluidized by hot gases. These flows can move rapidly off an island and into

the ocean, their impact displacing sea water and producing a tsunami. (3) The collapse of a volcanic caldera can generate tsunami. This may happen when the magma beneath a volcano is withdrawn back deeper into the earth, and the sudden subsidence of the volcanic edifice displaces water and produces tsunami waves. The large masses of rock that accumulate on the sides of the volcanoes may suddenly slide down slope into the sea, causing tsunamis. Such landslides may be triggered by earthquakes or simple gravitational collapse. A catastrophic volcanic eruption and its ensuing tsunami waves may actually be behind the legend of the lost island civilization of Atlantis. The largest volcanic tsunami in historical times and the most famous historically documented volcanic eruption took lace in the East Indies-the eruption of Krakatau in 1883.

Tsunami waves

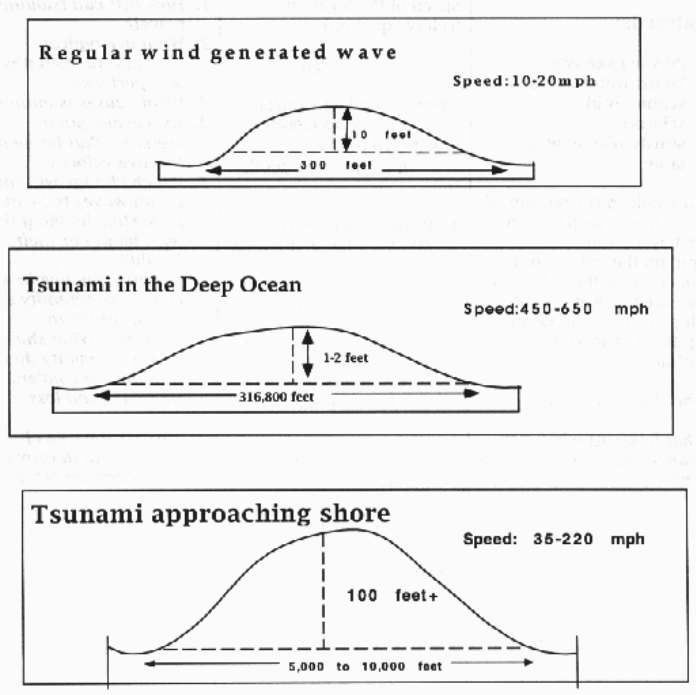
A tsunami has a much smaller amplitude (wave height) offshore, and a very long wavelength (often hundreds of kilometers long), which is why they generally pass unnoticed at sea, forming only a passing "hump" in the ocean. Tsunamis have been historically referred to tidal waves because as they approach land, they take on the characteristics of a violent onrushing tide rather than the sort of cresting waves that are formed by wind action upon the ocean (with which people are more familiar). Since they are not actually related to tides the term is considered misleading and its usage is discouraged by oceanographers.



These waves are different from other wind-generated ocean waves, which rarely extend below a dept of 500 feet even in large storms. Tsunami waves, on the contrary, involvement of water all the way to the sea floor, and

as a result their speed is controlled by the depth of the sea. Tsunami waves may travel as fast as 500 miles per hour or more in deep waters of an ocean basin. Yet these fast waves may be only a foot of two high in deep water. These waves have greater wavelengths having long 100 miles between crests. With a height of 2 to 3 feet spread over 100 miles, the slope of even the most powerful tsunamis would be impossible to see from a ship or airplane. A tsunami may consist of 10 or more waves forming a 'tsunami wave train'. The individual waves follow one behind the other anywhere from 5 to 90 minutes apart.

As the waves near shore, they travel progressively more slowly, but the energy



lost from decreasing velocity is transformed into increased wavelength. A tsunami wave that was 2 feet high at sea may become a 30-feet giant at the shoreline. Tsunami velocity is dependent on the depth of water through which it travels (velocity equals the square root of water depth h times the gravitational acceleration g, that is ($V=\sqrt{gh}$). The tsunami will travel approximately at a velocity of 700 kmph in 4000 m depth of sea water. In 10 m, of water depth the velocity drops to about 35 kmph. Even on shore tsunami speed is 35 to 40 km/h, hence much faster than a person can run.It is commonly believed that the water recedes before the first wave of a tsunami crashes ashore. In fact, the first sign of a tsunami is just as likely to be a rise in the water level. Whether the water rises or falls depends on what part of the

tsunami wave train first reaches the coast. A wave crest will cause a rise in the water level and a wave trough causes a water recession.

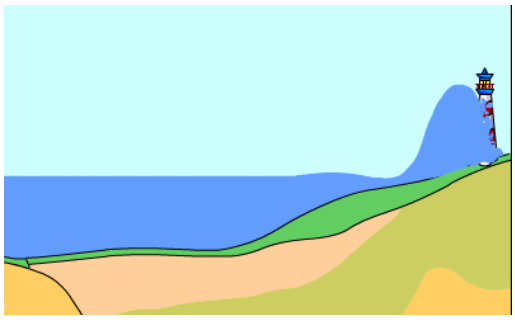
Seiche:

Seiche (pronounced as 'saysh') is another wave phenomenon that may be produced when a tsunami strikes. The water in any basin will tend to slosh back and forth in a certain period of time determined by the physical size and shape of the basin. This sloshing is known as the seiche. The greater the length of the body, the longer the period of oscillation. The depth of the body also controls the period of oscillations, with greater water depths producing shorter periods. A tsunami wave may set off seiche and if the following tsunami wave arrives with the next natural oscillation of the seiche, water may even reach greater heights than it would have from the tsunami waves alone. Much of the great height of tsunami waves in bays may be explained by this constructive combination of a seiche wave and a tsunami wave arriving simultaneously. Once the water in the bay is set in motion, the resonance may further increase the size of the waves. The dying of the oscillations, or damping, occurs slowly as gravity gradually flattens the surface of the water and as friction turns the back and forth sloshing motion into turbulence. Bodies of water with steep, rocky sides are often the most seiche-prone, but any bay or harbour that is connected to offshore waters can be perturbed to form seiche, as can shelf waters that are directly exposed to the open sea.

Reefs:

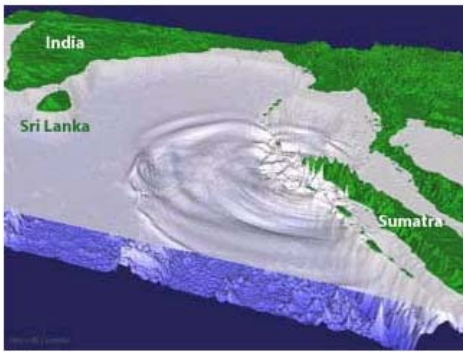
The presence of a well developed fringing or barrier of coral reef off a shoreline also appears to have a strong effect on tsunami waves. A reef may serve to absorb a significant amount of the wave energy, reducing the height and intensity of the wave impact on the shoreline itself.

Bores



The popular image of a tsunami wave approaching shore is that of a nearly vertical wall of water, similar to the front of a breaking wave in the surf. Actually, most tsunamis probably don't form such wave fronts; the water surface instead is very close to the horizontal, and the surface itself moves up and down. However, under certain circumstances an arriving tsunami wave can develop an abrupt steep front that will move inland at high speeds. This phenomenon is known as a bore. In general, the way a bore is created is related to the velocity of the shallow water waves. As waves move into progressively shallower water, the wave in front will be traveling more slowly than the wave behind it .This phenomenon causes the waves to begin "catching up" with each other, decreasing their distance apart i.e. shrinking the wavelength. If the wavelength decreases, but the height does not, then waves must become steeper. Furthermore, because the crest of each wave is in deeper water than the adjacent trough, the crest begins to overtake the trough in front and the wave gets steeper yet. Ultimately the crest may begin to break into the trough and a bore formed. A tsunami can cause a bore to move up a river that does not normally have one. Bores are particularly common late in the tsunami sequence, when return flow from one wave slows the next incoming wave. Though some tsunami waves do, in deed, form bores, and the impact of a moving wall of water is certainly impressive, more often the waves arrive like a very rapidly rising tide that just keeps coming and coming. The normal wind waves and swells may actually ride on top of the tsunami, causing yet more turbulence and bringing the water level to even greater heights.

Damage

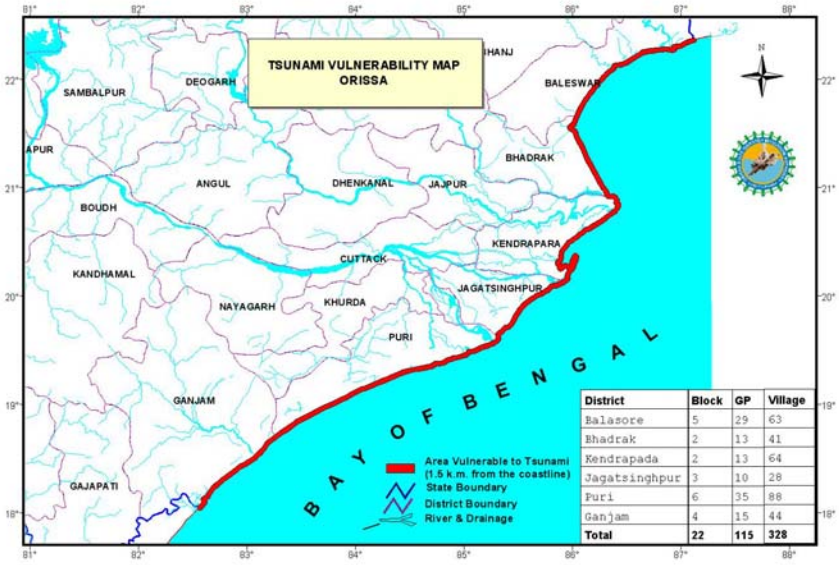


On the average, there are two tsunamis per year in the Pacific Ocean somewhere, which cause damage near the source. Approximately every 15 years a destructive tsunami occurs in the pacific. The destructive tsunami of Dec 26th, 2004 on the Indian Coast, in terms of its impact, seems to have occurred for the first time in the known history. Tsunamis produce their tremendous destruction in several ways. The sheer force of the moving wall of water in a bore can raze can almost everything in its path. It has been estimated that the force of the water in a bore can momentarily attain the enormous pressure of 2000 pounds per square feet. It is the flooding effects of a tsunami that causes the most damage. Two different terms are often used to describe the extent of tsunami flooding – inundation and run-up. Inundation is the depth of the water above the normal level, and is usually measured from sea level at average low tide. Inundation may be measured at any location reached by the tsunami waves. Run-up is the inundation at the maximum distance inland from the shoreline reached by the tsunami waters. Because of the height of the tsunami waves is strongly influenced by the sub-marine topography and the shape of the shoreline and by reflected waves- and may be further modified by seiches, tides, and wind waves-the actual inundation and flooding produced by a tsunami may vary greatly from place to place over only a short distance. The withdrawal of tsunami waves can also cause significant damage. As the water is rapidly drawn back toward the sea, it may scour out bottom sediments, undermining the foundations of buildings. Entire beaches have been known to disappear as the sand is carried out to sea by the withdrawing tsunami waves. The advance and

retreat of tsunami waves cause the water level in ports, harbours, channels and other navigable waterways to change radically, creating treacherous and unpredictable currents. Boats of all sizes are ripped from their moorings, smashed together, tossed ashore, sunk or carried out to sea.

Warnings and prevention

A tsunami cannot be prevented or precisely predicted, but there are some warning signs of an impending tsunami, and there are many systems being developed and in use to reduce the damage from tsunami. However, since earthquakes are often a cause of tsunami, an earthquake felt near a body of water may be considered an indication that a tsunami will shortly follow. In instances where the leading edge of the tsunami wave is its trough, the sea will recede from the coast half of the wave's period before the wave's arrival. If the slope is shallow, this recession can exceed many hundreds of meters. People unaware of the danger may remain at the shore due to curiosity, or for collecting fish from the exposed seabed. This can serve as an advance warning of the approaching crest of the tsunami, although the warning arrives only a very short time before the crest, which typically arrives seconds to minutes later. In the 2004 tsunami that occurred in the Indian Ocean the sea receding was not reported on the African coast or any other western coasts it hit, when the tsunami approached from the east.



Regions with a high risk of tsunami may use tsunami warning systems to detect tsunami and warn the general population before the wave reaches land. In some communities on the west coast of the United States, which is prone to Pacific Ocean tsunami, warning signs advise people where to run in the event of an incoming tsunami. Computer models can roughly predict tsunami arrival and impact based on information about the event that triggered it and the shape of the seafloor (bathymetry) and coastal land (topography).

One of the early warnings comes from nearby animals. Many animals sense danger and flee to higher ground before the water arrives. The Lisbon quake is the first documented case of such a phenomenon in Europe. The phenomenon was also noted in Sri Lanka in the 2004 Indian Ocean earthquake. Some scientists speculate that animals may have ability to sense subsonic Rayleigh waves from an earthquake minutes or hours before a tsunami strikes shore. More likely, though, is that the certain large animals (e.g., elephants) heard the sounds of the tsunami as it approached the coast. The elephants' reactions were to go in the direction opposite of the noise, and thus go inland. Humans, on the other hand, head down to the shore to investigate.

While it is not possible to prevent a tsunami, in some particularly tsunami-prone countries some measures have been taken to reduce the damage caused on shore. Japan has implemented an extensive programme of building tsunami walls of up to 4.5 m (13.5 ft) high in front of populated coastal areas. Other localities have built floodgates and channels to redirect the water from incoming tsunami. However, their effectiveness has been questioned, as tsunamis are often higher than the barriers. For instance, the tsunami which struck the island of Hokkaidō on July 12, 1993 created waves as much as 30 m (100 ft) tall - as high as a 10-story building. The port town of Aonae was completely surrounded by a tsunami wall, but the waves washed right over the wall and destroyed all the wood-framed structures in the area. The wall may have succeeded in slowing down and moderating the height of the tsunami, but it did not prevent major destruction and loss of life.

The effects of a tsunami can be mitigated by natural factors such as tree cover on the shoreline. Some locations in the path of the 2004 Indian Ocean tsunami escaped almost unscathed as a result of the tsunami's energy being sapped by a belt of trees such as coconut palms and mangroves. In one striking example, the village of Naluvedapathy in Tamil Nadu region suffered minimal damage and few deaths as the wave broke up on a forest of 80,244 trees planted along the shoreline in 2002 in a bid to enter the Guinness Book of Records. Environmentalists have suggested tree planting along stretches of seacoast which are prone to tsunami risks. While it would take some years for the trees to grow to a useful size, such plantations could offer a much cheaper and longer-lasting means of tsunami mitigation than the costly and environmentally destructive method of erecting artificial barriers.

Tsunami Fact sheet

1. Tsunamis striking coastal locations are mostly caused by earthquakes. These earthquakes might occur far away or near where you live.
2. Tsunamis can occur at any time, day or night.
3. Some tsunamis can be very large with their height as great as 30 feet or more (100 feet in extreme cases), and they can move inland several hundred feet.
4. All low-lying coastal areas can be struck by tsunamis.
5. A tsunami consists of a series of waves. Often the first wave may not be the largest. The danger from a tsunami can last for several hours after the arrival of the first wave.
6. Tsunamis can travel up rivers and streams that lead to the ocean.
7. Tsunamis can move faster than a person can run.
8. Sometimes a tsunami causes the water near the shore to recede, exposing the ocean floor.
9. The force of some tsunamis is enormous. Large rocks weighing several tons along with boats and other debris can be moved inland hundreds of feet by tsunami wave activity. Homes and other buildings are destroyed. All this material and water move with great force and can kill or injure people.

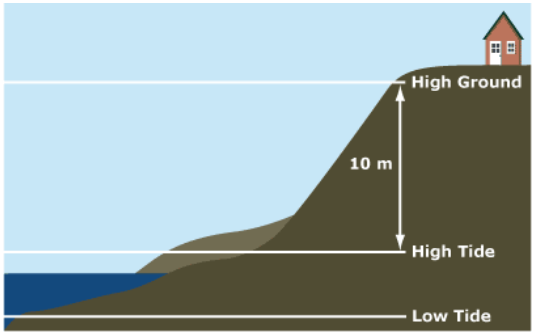
Prepare in advance for a possible tsunami.

1. Be aware of tsunami facts. This knowledge could save your life! Share this knowledge with your relatives and friends. It could save their lives!
2. Discuss the dangers of a tsunami with your family members and why you need to prepare for a disaster.

3. Develop an emergency plan. Practice and maintain your plan on a regular basis.
4. Be prepared to be on your own, without outside assistance, for at least three days. Prepare a three-day emergency supply kit.
5. Choose an emergency family meeting place. This should be an accessible, open area that family members can reach by walking.
6. Contact local authorities for the approved evacuation route for your area.
7. Assemble and make copies of important documents such as wills, insurance papers, medical records, etc. Keep original documents in a fireproof / waterproof container.
8. Arrange an out-of-area contact person and keep this and other emergency phone numbers near the phone. Choose someone who lives away from BC or US coastal areas.
9. Replace food and water in your emergency supply kit every six months.
10. Pack food, water, and toys for your pets. They are family too!
11. Stay in contact with the state, district and local administration for tsunami preparedness and mitigation measures being undertaken.

Before and During Tsunami

1. If a large undersea earthquake occurs near the coast, a local tsunami may follow. The first waves may reach shore in as little as 15 minutes. This may not be enough time for an official warning to be issued. The best warning, then, is the earthquake itself. If you live in a tsunami zone and the ground shakes severely for more than one minute, head for high ground as soon as it's safe to move.
2. If you are near the shore and see the water level rise or drop significantly, this is another sign a tsunami may be on the way. Move immediately to high ground. Turn on your radio to learn if there is a tsunami warning if an earthquake occurs and you are in a coastal area.
3. Move inland to higher ground immediately and stay there.
4. Stay away from the beach. Never go down to the beach to watch a tsunami come in. If you can see the wave you are too close to escape it.
5. CAUTION - If there is noticeable recession in water away from the shoreline this is nature's tsunami warning and it should be heeded. You should move away immediately.
6. If you are in school and you hear there is a tsunami warning, you should follow the advice of teachers and other school personnel.
7. If you are at home and hear a tsunami warning, you should make sure your entire family is aware of the warning. Your family should evacuate your house if you live in a tsunami evacuation zone. Move in an orderly, calm and safe manner to the evacuation site or to any safe place



outside your evacuation zone. Follow the advice of local administration and police authorities.

8. If you are at the beach or near the ocean and you feel the earth shake, move immediately to higher ground, Do not wait for a tsunami warning to be announced. Stay away from rivers and streams that lead to the ocean as you would stay away from the beach and ocean if there is a tsunami. A regional tsunami from a local earthquake could strike some areas before a tsunami warning could be announced.
9. Tsunamis generated in distant locations will generally give people enough time to move to higher ground. For locally-generated tsunamis, where you might feel the ground shake, you may only have a few minutes to move to higher ground.
10. High, multi-story, reinforced concrete hotels are located in many low-lying coastal areas. The upper floors of these hotels can provide a safe place to find refuge should there be a tsunami warning if you cannot move quickly inland to higher ground.
11. Homes and small buildings located in low-lying coastal areas are not designed to withstand tsunami impacts. Do not stay in these structures should there be a tsunami warning.
12. Offshore reefs and shallow areas may help break the force of tsunami waves, but large and dangerous wave can still be a threat to coastal residents in these areas. Staying away from all low-lying areas is the safest advice when there is a tsunami warning.

After a Tsunami

1. Stay away from flooded and damaged areas until officials say it is safe to return.
2. Stay away from debris in the water; it may pose a safety hazard to boats and people.
3. Save yourself **-** not your possessions