Definition

"Tsunami" is a Japanese word which translates as "harbor wave", now used internationally to refer to a series of waves travelling across the ocean with extremely long wavelengths (up to hundreds of miles between wave crests in the deep ocean). When these waves approach shore, the speed of the wave decreases as they begin to "feel" the bottom. It is at this time that the height of the wave drastically increases. As the waves strike shore they may inundate low-lying coastal areas resulting in mass destruction and in many instances loss of life. Often a tsunami is incorrectly referred to as a tidal wave. Tidal waves are simply the periodic movement of water associated with the rise and fall of the tides produced by the gravitational attraction of the sun and moon. Tsunamis have no connection with the weather nor with tides.

Tsunami is a very large sea wave that sometimes happens when the floor of the ocean is disturbed at any point. A set of waves will spread outwards from that point, like the waves that spreads out when you throw a stone into a pool.

Tsunamis are waves generated by earthquakes, volcanic eruptions, or underwater landslides and can reach 15 km or more in height devastating coastal communities.

Why it happens?

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. Submarine landslides[1], which often occur during a large earthquake, can also create a tsunami. During a submarine landslide, the equilibrium sea level is altered by sediment moving along the sea floor. Gravitational forces then propagate the tsunami given the initial perturbation of the sea level. Similarly, a violent marine volcanic eruption can create an impulsive force that displaces the water column and generates a tsunami. Above water landslides and space born objects can disturb the water from above the surface. The falling debris displaces the water from its equilibrium position and produces a tsunami. Unlike ocean-wide tsunamis caused by some earthquakes, tsunamis generated by non-seismic mechanisms usually dissipate quickly and rarely affect coastlines far from the source area.

Tsunamis are characterized as shallow-water waves. Shallow-water waves are different from wind-generated waves, the waves many of us have observed at the beach. Wind-generated waves usually have period (time between two successive waves) of five to twenty seconds and a wavelength (distance between two successive waves) of about 100 to 200 meters (300 to 600 ft). A tsunami can have a period in the range of ten

[1] Although normally thought of as being a feature of mountainous regions, landslides can happen almost any place where the ground surface slopes. In fact, some of the largest landslides on Earth occur underwater. Suboceanic, or submarine landslides can involve the movement of rocks and sediments entirely beneath the sea, or they can begin as partly above-water landslides that later enter the ocean. Like open-air landslides, submarine landslides often strike steep inclines (~100). Unlike open air slides, submarine landslides hit very slightly dipping terrain (<10) too. Many historical and prehistorical landslides have raked the slopes of deep ocean trenches and continental margins where strong earthquakes recur periodically. Seismic shaking probably triggered these slides. Best evidence suggests that the potential for suboceanic landslides exists pretty much globally, whether in tectonically active or tectonically inactive regions. A primary hazard of submarine landslides, like their land bound relatives, is the wasting of man-made structures along their path. The newest research however, perceives that undersea slope failures present an additional threat -- landslide-generated tsunami waves

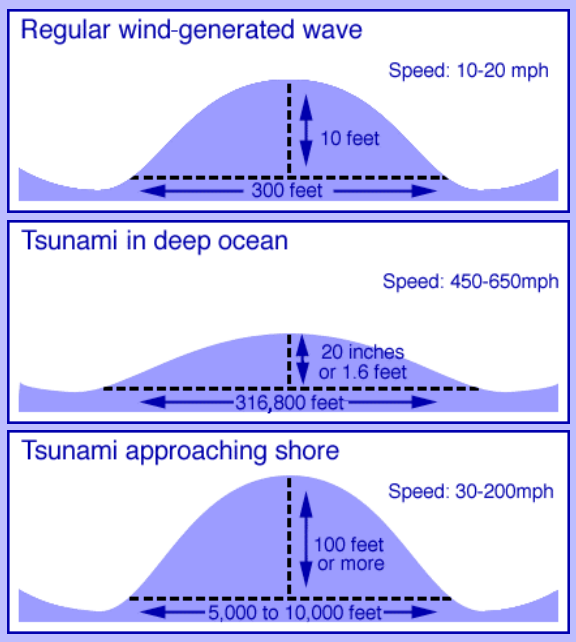
minutes to two hours and a wavelength in excess of 300 miles (500 km). It is because of their long wavelengths that tsunamis behave as shallow-water waves[2]. The rate at which a wave loses its energy is inversely related to its wavelength. Since a tsunami has a very large wavelength, it will lose little energy as it propagates. Hence in very deep water, a tsunami will travel at high speeds and travel great transoceanic distances with limited energy loss. For example, when the ocean is 20,000 feet (6100 m) deep, unnoticed tsunami travel about 550 miles per hour (890 km/hr), the speed of a jet airplane. And they can move from one side of the Pacific Ocean to the other side in less than one day.

As a tsunami leaves the deep water of the open sea and propagates into the more shallow waters near the coast, it undergoes a transformation. Since the speed of the tsunami is related to the water depth, as the depth of the water decreases, the speed of the tsunami diminishes. The change of total energy of the tsunami remains constant. Therefore, the speed of the tsunami decreases as it enters shallower water, and the height of the wave grows. Because of this "shoaling" effect, a tsunami that was imperceptible in deep water may grow to be several feet or more in height.

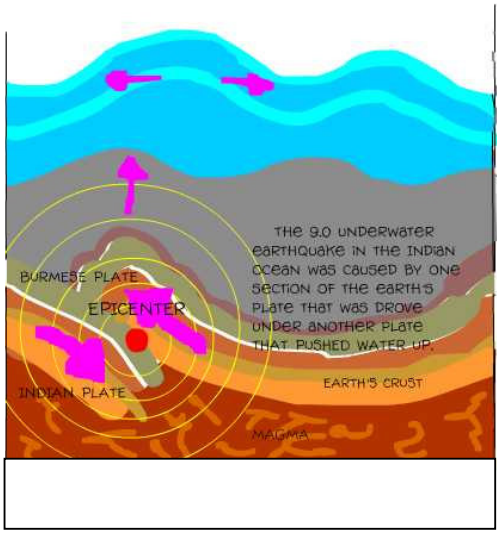
How is a tsunami wave different from a normal wave?

The waves seen at the beach are generated by wind blowing over the sea surface. The size of these waves depends on the strength of the wind creating them and the distance over which it blows. Generally the distance between these waves, known as the wavelength, ranges from a couple of feet to perhaps a thousand feet. The speed of these waves as they travel across the ocean ranges from a few miles an hour up to sixty miles an hour in some instances.

Tsunami waves resulting from physical mechanisms (earthquakes, landslides, volcanic eruptions) behave differently from wind generated waves. The magnitude of the disturbance causing the tsunami is the primary factor influencing the size and strength of the waves. The height of the wave when it is generated is very small, usually less than a few feet. The distance between successive wave crests or the wavelength however, is much larger than that of a normal wave and may be hundreds of miles apart.



[2] A wave is characterized as a shallow-water wave when the ratio between the water depth and its wavelength gets very small. The speed of a shallow-water wave is equal to the square root of the product of the acceleration of gravity (32ft/sec/sec or 980cm/sec/sec) and the depth of the water.



When a tsunami finally reaches the shore, it may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore. Reefs, bays, entrances to rivers, undersea features and the slope of the beach all help to modify the tsunami as it approaches the shore. Tsunamis rarely become great, towering breaking waves. The water level on shore can rise many feet. In extreme cases, water level can rise to more than 50 feet (15 m) for tsunamis of distant origin and over 100 feet (30 m) for tsunami generated near the earthquake's epicentre. The first wave may not be the largest in the series of waves. One coastal area may see no damaging wave activity while in another area destructive waves can be large and violent. The flooding of an area can extend inland by 1000 feet (305 m) or more, covering large expanses of land with water and debris. Flooding tsunami waves tend to carry loose objects and people out to sea when they retreat. Tsunamis may reach a maximum vertical height onshore above sea level, called a run-up height, of 30 meters (98 ft).

Types of Tsunami

Earthquake generated tsunami

This type of tsunami is the most common. Earthquakes are caused when there is a sudden movement in the sea floor. The waves are formed as the displaced water tries to find equilibrium (stability). Not all earthquakes cause tsunamis. If the vertical movement is not big, the waves quickly find equilibrium without causing a tsunami. However, when a large area of the sea floor elevates or subsides, a tsunami can be generated. The height of the tsunami wave is directly proportional (equal) to the vertical movement of the plate.

Large vertical movements commonly occur along the plate boundaries. Around the margins of the Pacific Ocean, called the Pacific Ring of Fire, denser tectonic plates slip under continental plates in a process known as subduction. Subduction earthquakes are particularly effective in generating tsunamis.

The December 26, 2004 tsunami that affected South and South East Asia is an example of an earthquake-generated tsunami.

Landslide generated tsunami

Tsunamis can also be generated by landslides. This type of tsunami is commonly known as the mega-tsunami. Landslide-generated tsunamis are normally more powerful than earthquake-generated tsunamis. The strength of the mega-tsunami waves depend upon the size of the landslide and also the height of the fall. The larger the area and the higher the fall, the bigger the wave. These gigantic waves are big enough to cross oceans and affect cities. These waves travel at supersonic speed and can rise to over a thousand feet!

Meteor-generated

Meteor-generated tsunamis are also called mega-tsunamis. The effects of this tsunami are very similar to the landslide-generated tsunami.

Impact of Tsunami

Tsunami can cause inundation of the land and bring about massive losses to life and property. All structures located within 200 m of the low lying coastal area are most vulnerable to the direct impact of the tsunami waves as well as the impact of debris & boulders brought by it. Settlements in adjacent areas will be vulnerable to floods & scour. Structures constructed of wood, mud, thatch, sheets and structures without proper anchorage to foundations are liable to be damaged by tsunami waves & flooding. Other elements at risk are infrastructure facilities like ports & harbours, telephone and electricity poles, cables. Ships & fishing boats/nets near the coast also add to the destruction caused by tsunami waves

Typical Effects

Physical damage – Local tsunami events or those within 30 minutes from the source cause the majority of damage. It is the flooding effect of a tsunami, which greatly effects human settlements by damage to houses, roads, bridges and other infrastructure. Ships, port facilities, boats/trawlers, fishing nets also get damaged.

Environmental damage – There is evidence of ever increasing impact upon the environment on account of the effects of Tsunamis. The range varies from generation of tons of debris on account of structural collapse of weaker buildings, release of toxic chemicals into the environment on account of chemical leak / spillage/ process failure /utility breakages / collateral hazards and negative impact on the already fragile ecosystems.

Casualties and public health: Deaths occur principally from drowning as water inundates homes and neighbourhoods. Many people may be washed out to sea or crushed by the giant waves. There may be some injuries from battering by debris and wounds may become infected.

Water supply: Sewage pipes may be damaged causing major sewage disposal problems. Drinking water shortage arises due to breakage of water mains and contamination. Open wells and ground water may become unfit for drinking due to contamination of salt water and debris.

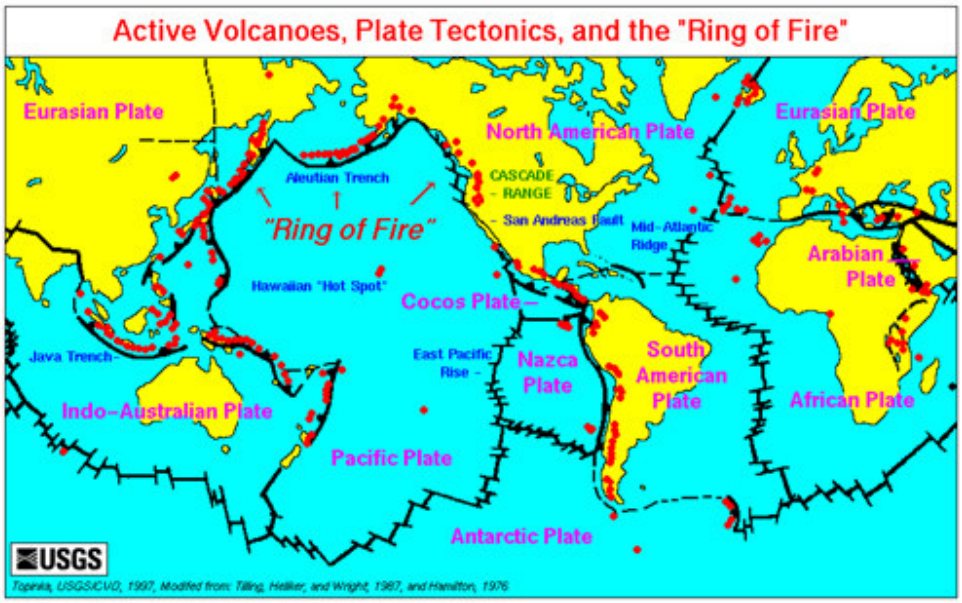
Standing Crops and food supplies: Flooding by tsunami causes damage to the standing crops and also to the food supplies in the storage facilities. The land may be rendered infertile due to salt-water incursion from the sea.

Major Tsunami events in History

Tsunamis have been reported since ancient times. They have been documented extensively, especially in Japan and the Mediterranean areas. The first recorded tsunami occurred off the coast of Syria in 2000 B.C. Since 1900 (the beginning of instrumentally located earthquakes), most tsunamis have been generated in Japan, Peru, Chile, New

Guinea and the Solomon Islands. However, the only regions that have generated remote-source tsunamis affecting the entire Pacific Basin are the Kamchatka Peninsula, the Aleutian Islands, the Gulf of Alaska, and the coast of South America. Hawaii, because of its location in the center of the Pacific Basin, has experienced tsunamis generated in all parts of the Pacific.

The Mediterranean and Caribbean Seas both have small subduction zones[3], and have histories of locally destructive tsunamis. Only a few tsunamis have been generated in the Atlantic and Indian Oceans. In the Atlantic Ocean, there are no subduction zones at the edges of plate boundaries to spawn such waves except small subduction zones under the Caribbean and Scotia arcs. In the Indian Ocean, however, the Indo-Australian plate is being subducted beneath the Eurasian plate at its east margin. Therefore, most tsunamis generated in this area are propagated toward the southwest shores of Java and Sumatra, rather than into the Indian Ocean[c1].



Year	Date: Month	Date: Date	Tsunami Source: Country	Tsunami Source: Name	Cause: Earth-quake Mag	Tsunami Parameters: Max Water Height	Tsunami Parameters: Num. of Runups	Deaths
1994	12	28	JAPAN	TOHUKU, JAPAN	7.8	1.1	8	3
1995	5	16	NEW CALEDONIA	LOYALTY ISLANDS	7.7	0.5	7	
1995	7	30	CHILE	N. CHILE	8	3	63	
1995	8	16	SOLOMON ISLANDS	SOLOMON ISLANDS	7.7	0.6	0	
1995	10	9	MEXICO	MEXICO	8	5.1	14	1
1995	12	3	RUSSIA	KURIL ISLANDS	7.9	1.1	21	
1996	1	1	INDONESIA	SULAWESI	7.9	3.4	12	9
1996	2	17	INDONESIA	IRIAN JAYA	8.2	7.7	49	127
1996	6	10	USA	ANDREANOF	7.9	0.51	17	

[3] http://earthquake.usgs.gov/learning/glossary.php?termID=197

				ISLANDS, AK				
1996	9	5	CHILE	EASTERN ISLAND REGION	7.9	0.2	2	
1996	11	12	PERU	PERU	7.7	0.4	3	
1997	4	21	SOLOMON ISLANDS	SANTA CRUZ IS. VANUATU	7.7	1	4	100
1997	10	14	FIJI	FIJI ISLANDS	7.7	0.1	0	
1997	12	5	RUSSIA	KAMCHATKA	7.8	1.5	14	
1998	3	25	ANTARCTICA	BALLENY ISLANDS	8.1	0.1	0	
1998	11	29	INDONESIA	TALIABU ISLAND, INDONESIA	7.7	2.75	0	
1999	8	17	TURKEY	KOCAELI, TURKEY	7.6	2.5	7	150
2000	5	4	INDONESIA	SULAWESI	7.6	6	6	
2000	6	18	INDIA	SOUTH INDIAN OCEAN	7.9	0.3	1	
2000	11	16	PAPUA NEW GUINEA	NEW IRELAND, PAPUA NEW GUINEA	8	1	8	
2001	6	23	PERU	PERU	8.4	7	67	26
2002	9	8	PAPUA NEW GUINEA	PAPUA NEW GUINEA	7.6	1.5	0	
2002	10	10	INDONESIA	IRIAN JAYA	7.6	5	3	
2003	9	25	JAPAN	HOKKAIDO ISLAND	8.3	4	10	
2003	11	17	USA	RAT ISLANDS, AK	7.8	0.25	20	
2004	12	26	INDONESIA	OFF W. COAST OF SUMATRA	9	34.9	301	297248
2005	3	28	INDONESIA	INDONESIA	8.7	3	2	

Source: http://www.ngdc.noaa.gov/seg/hazard/tsuintro.shtml

Early Warning System and Dissemination

A tsunami warning system is a system to detect tsunamis and issue warnings to prevent loss of life. It consists of two equally important components: a network of sensors to detect tsunamis and a communications infrastructure to issue timely alarms to permit evacuation of coastal areas.

There are two distinct types: international tsunami warning systems, and regional warning systems. Both depend on the fact that, while tsunamis travel at between 500 and 1,000 km/h in open water, earthquakes can be detected almost at once as seismic waves travel with a typical speed of 5 km/s. This gives time for a tsunami forecast to made and warnings to be issued to threatened areas, if warranted. The first rudimentary system to alert communities of an impending tsunami was attempted in Hawaii in the 1920s. More advanced systems were developed in the wake of the April 1, 1946 and May 23, 1960 tsunamis which caused massive devastation in Hilo, Hawaii.

International tsunami prediction for the Pacific Ocean and early warning is overseen by the U.S. Pacific Tsunami Warning Center (PTWC) operated by NOAA in Ewa Beach, Hawaii. This centre was established in 1949, following the 1946 Aleutian Island earthquake and a tsunami that resulted in 165 casualties on Hawaii and Alaska. International coordination is achieved through the International Coordination Group for the Tsunami Warning System in the Pacific, established by the Intergovernmental Oceanographic Commission of UNESCO.

Regional (or local) warning system centres use seismic data about nearby earthquakes to determine if there is a possible local threat of a tsunami. Such systems are capable of issuing warnings to the general public (via public address systems and sirens) in less than 15 minutes. Although the epicenter and moment magnitude of an underwater quake and the probable tsunami arrival times can be quickly calculated, it is almost always impossible to know whether underwater ground shifts have occurred which will result in tsunami waves. As a result, false alarms can occur with these systems, but due to the highly localised nature of these extremely quick warnings, disruption is small.

What is a Tsunami Early Warning System?

Early warning is much more than just a prediction. PPEW[4] defines a complete and effective early warning system as a package of four elements, spanning knowledge of the risks faced through to preparedness to act on early warning. Strong linkages between the four elements are essential. Therefore the major players concerned with the different elements need to meet regularly to ensure they understand all of the other components and what other parties need from them, and to agree on specific responsibilities throughout all four elements.

Key activities of all types of early warning systems include:

(i) construction of risk scenarios, (ii) improvements to the early warning system itself by adjusting it according to data and analysis from studies of past events (iii) development and publishing of manuals, (iv) dissemination of information, (v) practicing and testing of operational procedures such as evacuations.

Refer: http://www.unisdr.org/ppew/tsunami/what-is-tsunami/backinfor-brief.htm

Preventive and mitigation measures – structural, non structural

Before a Tsunami[5]

If you are in an area at risk from Tsunamis

- You should find out if your home, school, workplace, or other frequently visited locations are in tsunami hazard areas.
- Know the height of your street above sea level and the distance of your street from the coast or other high-risk waters. Evacuation orders may be based on these numbers. Plan evacuation routes from your home, school, workplace etc
- If your children's school is in an identified inundation zone, find out what the school evacuation plan is Practice your evacuation routes. Familiarity may save your life. You should be able to follow your escape route at night and during inclement weather.

[4] Platform for the Promotion of Early Warning
[5] Source: Revenue Department, Government of Tamil Nadu

- Listen regularly to a Weather Radio, or a local station or television to keep informed of local watches, advices and warnings.
- Discuss Tsunamis with your family.
- Everyone should know what to do in a tsunami situation. Discussing Tsunamis ahead of time will help reduce panic and save precious time in an emergency.

Protect Your Property

- You should avoid building or living in buildings within 200 meters of the high tide coastline. These areas are more likely to experience damage from Tsunamis, strong winds, or coastal storms.
- Elevate coastal homes.
- Most tsunami waves are less than 3 meters. Elevating your house will help reduce damage to your property from most Tsunamis.
- Take precautions to prevent flooding inside your house.
- Have an engineer check your home and advise about ways to make it resistant to tsunami water.

During a Tsunami warning

- If you feel a strong coastal earthquake that lasts 20 seconds or longer when you are in a coastal area, you should: Duck, cover, and hold on.
- You should first protect yourself from the earthquake damages.
- When the shaking stops gather members of your household and move quickly to higher ground, away from the coast. A tsunami may be coming within minutes.
- Avoid downed power lines and stay away from buildings and bridges from which heavy objects might fall during an aftershock.

If you are on land and warning is issued

- Be aware of tsunami facts. This knowledge could save your life! Share this knowledge with your relatives and friends. It could save their lives!
- If you are in school and you hear there is a tsunami warning, you should follow the advice of school authorities.
- If you are at home and hear there is a tsunami warning, ensure that the whole family follows advice being issued by the government.
- If your 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. The upper floors of high multi story reinforced concrete buildings in low-lying coastal areas may be a safe refuge.
- Homes and small buildings located in low-lying coastal areas are not designed to withstand tsunami impacts, hence evacuate them.

If you are on a boat

- Since tsunami wave activity is imperceptible in the open ocean, do not return to port if at sea. Tsunamis can cause rapid changes in water level and unpredictable dangerous currents in ports.
- Keep in contact with the local port authorities, should a forced movement of vessels be directed.
- Owners of small boats may leave their boat at the pier and physically move to higher ground, particularly if it is a locally generated tsunami.

What to Do After a Tsunami

- Listen to local radio on an emergency frequency station or television for warning, advice and updates.
- Check yourself for injuries and get first aid if necessary before helping other injured or trapped persons.
- Help people who require special assistance -Infants, pregnant women, elderly people and differently able persons.
- Avoid disaster areas; your presence might hamper rescue and other emergency operations and put you at further risk from post tsunami hazards.
- Keep telephones lines clear and use only in case of an emergency.
- There is a threat of Tsunami water undermining foundations, cause buildings to sink, floors to crack, or walls to collapse hence if your building is surrounded by Tsunami water, stay out of it.
- Wear long pants, a long-sleeved shirt, and sturdy shoes while re-entering buildings etc
- Be very cautious while re entering buildings. Verify its structural stability and safety by checking the foundations for cracks or any other damage. Use battery-powered torches when examining buildings, as it does not present a fire hazard. Do not use candles.
- Look for fire hazards; there may be broken or leaking gas lines, flooded electrical circuits, or submerged furnaces. Fire is the most frequent hazard following floods.
- Check for gas leaks; if you smell gas or hear a blowing or hissing noise, open a window and get everyone outside quickly. Turn off the gas at the mains and call for professional help.
- Look for electrical system damage If you see sparks or broken or frayed wires, or if you smell burning insulation, turn off the electricity at the main fuse box or circuit breaker and call for professional help. Electrical equipment should be checked and dried before being returned to service.
- If you suspect sewage lines are damaged, avoid using the toilets and call a plumber. Use tap water only if local health officials advise it is safe.
- Watch out for wild animals, especially poisonous snakes. Use a stick to poke through debris.
- Watch for loose plaster, drywall, and ceilings that could fall. Open the windows and doors to help dry the building.
- Check food supplies, food that has come in contact with floodwater may be contaminated and should be thrown out.
- Drink only boiled and safe drinking water

- If the earthquake was very large and located nearby expect aftershocks. So be prepared.
- Ensure the safety of your animals, provide for food and drinking water for them.

Reference:

http://www.hudco.org/tsunami.htm

http://www.coastalhazards.info/~webdev/tsunami/taxonomy/term/62