Tsunami: meaning and causes; a theoretical approach.

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Abstract: Tsunami is the Japanese word that describe a "harbour wave". Tsunamis are natural catastrophes caused by some geological processes. All tsunami are caused by the sudden displacement of large volumes of water. All are the result of violent events with enough power to displace large volumes very rapidly. However, tsunami may be caused by events that are not local to the tsunami site. Because the waves have been generated by huge releases of energy and they travel so effectively through the deep ocean. Some tsunamis are caused by events that literally happen on the other side of the world. Historically, tsunamis have been a constant threat to humans. This paper discusses the geological processes that can cause tsunamis.
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1. Introduction

Tsunami is the Japanese word that describes a "harbour wave". According to Lapidus (1990). "tsunami is the gravity-wave system that follows any short-duration , large –scale disturbance of the free sea surface". Their cause are related with geographical process such as earthquakes, landslides, volcanic eruptions and meteoritic, asteroids and comets impacts.

A tsunami travels outward from the source region as a series of waves. Waves velocity reach speed of 900km/hr over the ocean. Tsunamis are usually small and bearly noticed in deep ocean, but the waves become large and cause damage when they approach coastal areas. "As waves approach the coast line, the speed of wave decreases as they are form shallower within water depth"(Lapidus, 1990). Tsunamis can travel virtually unnoticed through the ocean because the wave height may be very small but as soon as they reach nearby shore the wave height increases. Destruction from tsunamis is the direct result of inundation, wave impact on structure and erosion.

The scientific community is devoting extreme care and attention to all natural hazards that can destroy the welfare human kind. Tsunami despite being rarer catastrophic event, as regarded as a major threat. Extensive study of tsunami hazard is currently going on in many part of the world, although tsunamis occur mainly in the pacific. The research we are conducting will, hopefully, contribute to a broader knowledge of tsunami and their environmental consequences.

Tsunami is a wave in the ocean but it is very different to normal waves.

Tsunamis have very long wavelength. Crest to crest they measure between 10 and 500km and they travel through the ocean at more than 700km/hr. Some time there appears to be just one wave but often there are multiple travelling a few minute apart . Discussing the meaning and causes of tsunami has been the aim of this paper.

2. Causes of Tsunamis

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. Unfortunately tsunamis have been given numerous names in the past that are misleading. Even the word tsunami meaning 'harbour wave' is misleading.

All tsunami are caused by the sudden displacement of large volumes of water. All are the result of violent events with enough power to displace large volumes very rapidly. However, tsunami may be caused by events that are not local to the tsunami site. Because the waves have been generated by huge releases of energy and they travel so effectively through the deep ocean. Some tsunami are caused by events that literally happen on the other side of the world. Historically, tsunamis have been a constant threat to humans.

Geological processes such as earthquakes, landslides, volcanic eruptions and meteoritic impacts can cause tsunamis.

2.1 Earthquakes

Earthquakes are the main source of tsunami, when earthquake occur beneath the sea, the water above is displaced from its equilibrium position. Waves are formed as the displaced water mass, which acts under the influence of gravity, attempts to gain its equilibrium. When a large areas of the sea floor elevate or subside, a tsunami can be created, large vertical movements of the earth's crust can occur at any faulted plate boundaries, but "earthquake on the continental side of the subduction trench are particularly effective generating tsunamis" (Furumoto & Fukao 1985).

For distant tsunamis has travelled far from the origin of the earthquake, the magnitude of the earthquake is a good measure of the size of the tsunami. For local tsunamis, however, more knowledge than the magnitude is needed to calculate the final run-up of the tsunami.

Earthquake sensitive area in the world and tsunamigenic areas are related.

2.2 Landslides

We can consider two major types of landslide that can create tsunamis underwater and coaster landslides. Several mechanisms can trigger these landslides: small earthquakes, collapse of volcanoes or part of it and erosion in submarines slopes. In the coastal areas slopes are subject to several erosion forces such as rainfall, storms and especially sea waves. "The slumps generally follow greater – than – usual storms, which remove substantial amounts of material and lead to a sudden decrease in the stability of the slope" (Bolt et al., 1975). This leads to a considerable quantity of rocks, sand and debris to fall over the ocean causing a perturbation of the sea surface and eventually causing a tsunami.

2.3Volcanoes

Volcanoes eruption above the sea level, due to the collapse of the volcanic crater, or the collapse of one of its flanks, can generate rock falls, debris flow and rocks-slide that reach the sea causing a tsunami. This is only been discussed, so far, in the context of volcanic islands. But the major volcanic generating tsunamis sources are under water eruptions. Not only the displacement of materials in the slope of the volcano but also the release of gas can provoke a tsunami.

The eruption itself can cause a small earthquake that can trigger a tsunami. "volcanoes with plinian activity characterised by huge destructive explosions and consequent collapse of the caldera may give origin to giant waves" (Tinti, 1990).

Historically, there are many examples of volcanic tsunamis, however the santorini eruption, not only for its social and cultural importance, but also for its geographical proximity with the Iberian Peninsula, deserves special reference. "The collapse of the caldera of the volcano Santorini during a major eruption 3500BP caused a huge tsunami which inundated surrounding islands and is recorded in the lore of many circum-Mediterranean cultures" (Kastens & Cita 1981).

2.4 Meteors

The earth is subject to bombardment from space. Asteroids, comets and meteorites, can cause catastrophic events if they collide with earth. If a major meteorite collides with the earth in an urban area, the devastation would be enormous, but the biggest devastation would be caused if it falls over the ocean. "tsunami is probably the most serious form of damage caused by stony asteroids with diameters between about 200 m and 2 km". (Hills & Goda, 1998).

3. Other Causes of Tsunami

Human-made tsunamis are also reported. Especially in the 60s with the advent of nuclear tests, "there are reference to small tsunamis caused by underwater nuclear tests explosion in the pacific." (Bolt et. al., 1975).

Atmospheric processes can also generate tsunamis. "Tsunami like waves generated by a rapidly moving atmospheric pressure front moving over a shallow sea at about the same speed as the waves, allowing them to couple" (www.shoa.cl/ocean/itic/).

"There is also a theory that astronomical alignments can trigger geophysical events, such as earthquakes, through an increase in the gravitational force" (www.usgs.gov).

4. The Behaviours of Tsunami

A tsunami can be divided into three phases, the generation, the propagation to the coast and run-up at the shoreline.

"Once the tsunami is formed, the wave system closely resembles that which is produced by throwing a stone into pond." (lapidus,1990). The wave configuration is axi-symetric and consist of concentric rings of crests and troughs. The front expands at the velocity of c= in which g is gravitational acceleration and h is the water depth. Within the several minutes after the generation process, the initial tsunami is split into a tsunami that travels out to the generation process, the initial tsunami is split into a tsunami that travels out to the deep ocean (distant tsunami) and another tsunami that travels towards the nearby coast (local tsunami)" (Lapidus, 1990). Several events happen as the local tsunami travels over the continental slope. The most obvious one is that the amplitude increases. 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 be several meters in height near the coast.

Physical laws can explain the wave propagation. "If the tsunami wavelength is much smaller than the scale of velocity heterogeneity, i.e., the depth change, then we can apply the geometrical ray theory of optics." (Satake, 1999). Moreover, "their propagation path is sensitive to the ocean bathymetry that, analogously to an optical lens, may focus or defocus the tsunami rays, thereby increasing or decreasing the wave amplitude" (Tinti, 1990)

As the tsunamis wave travels from the deep-water, continental slope region to near-shore region, tsunami run-up occurs. Run-up is a measurement of the height of the water onshore observed above a reference sea level.

After run-up, part of the tsunami energy is reflected back to the open ocean. In addition, a tsunami can generate a particular type of wave called edge waves that travel back and forth, parallel to shore. These effects results in successive arrivals of waves at a particular point on the coast rather than a single wave. Because of the complicated behaviour of tsunami near he coast, the first run-up of a tsunami is often not the largest (emphasising the importance of not returning the beach several hours after a tsunami hits).

A strange behaviour occurs in the sea close to shore areas. "Different sets of conditions apply in shallow water near the shore, when a tsunami is inundating the coast. There are several terms that are used to describe this phenomenon. The one to use depends on circumstances (e.g., whether the tsunami is in a bay) and one to use depends on the circumstances (e.g., whether the tsunami is in bay) and on personal preference. The terms "negative wave", "drawdown" and "withdrawal" are most often used to describe this type of initial onset. Less formal are the terms 'waterline receding' and "bay emptying". The underlying reason for this effect is that both offshore landslides and subduction zone earthquakes create a negative wave on the shoreward side of the bottom deformation. This negative wave propagates to shore and produces the drawdown."(GITEC-21995).

In coastal areas the devastation can be enormous. The destruction in infrastructures caused by tsunamis is caused by tsunami is due to "drag and flotation forces associated with the waves strong induced currents and floating debris" (Tinti, 1990). The tsunamis tend to decrease with distance from the source point.

5. Tsunami Classification

The two most important aspects that characterise tsunamis are the magnitude and the intensity.

In terms of magnitude scales, tsunamis can be divided as follows. The traditional magnitude scale is so-called Imamura-Iida (m). The value is approximately equal to $m=\log_2 h$, where h is maximum run-up height in meters.

This scale is similar to the earthquake intensity scale, and is especially convenient for old tsunamis from which no instrumental records exist. Hataori (1979) extended the Imamura-Iida m scale to include far-field tsunami data. He also considered the effect of distance. Another magnitude scale, M_t, called tsunami magnitude, is defined and assigned for many earthquake by Abe. The definition of M_t for a Trans-Pacific tsunami is (Abe, 1979): M_t = log H+ C + 9.1 and for a regional tsunami (100km<? <3500km) tsunami is (Abe, 1981): M_t = log H + log? + 5.8, where H is the maximum amplitude on tide gauges in meters, C is a distance factor depending on a combination of the source and the observation points and is the actual distance in km. The above formulas where calibrated with the moment magnitude 3 scale, M_w, of earthquakes.

For tsunami intensity there are two different scales. Soloviev (1970) pointed out that Imamura-Iida's scale is more like an earthquake intensity scale rather than a magnitude. He also distinguished the maximum tsunami height h and the mean tsunami height h. He then defined tsunami intensity I as $I = \log_2 (h)$. Sieberg tsunami intensity scale, a descriptive tsunami intensity intensity scale (Ambraseys, 1962), describes tsunamis from light tsunamis (level 1) to disastrous tsunamis (level 6) based on the physical destruction caused by tsunamis.

Conclusion

Tsunamis are natural catastrophes caused by some geological processes (e.g. earthquakes, landslides, volcanoes, meteors) that disturb a mass of water creating a series of waves. The waves formed, after the geological trigger, travel towards coastal areas and will increase in height with the decrease of their velocity, causing destruction when the tsunami reaches the shoreline.

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