GH0017 / **GEOHAZARDS / Volcanogenic (Volcanoes and Geothermal)**

Tsunami (Volcanic Trigger)

Definition

Volcano tsunamis (pronounced soo-ná-mees), are a series of waves created when water surrounding a volcano is displaced following an eruption, a landslide, or failure of a volcanic edifice into surrounding water. If the generating mechanism is large enough, the waves can be significant on local, regional or even transoceanic scales (Day, 2015).

Reference

Day, S., 2015. Volcanic Tsunamis. The Encyclopedia of Volcanoes, 2nd Ed.

Annotations

Synonyms

Not found.

Additional scientific description

Tsunami is the Japanese term meaning wave (‘nami’) in a harbour (‘tsu’). Tsunamis are a series of gravity waves of extremely long (up to hundreds of kilometres) length with periods of 10 to 60 minutes that can travel across ocean basins with little loss of energy. They are usually generated by earthquakes occurring below or near the ocean floor. Approximately 80% of tsunamis are caused by earthquakes, but also by volcanic eruptions, submarine landslides, and coastal rock falls. Tsunami waves, on entering shallow water steepen and increase in height attaining elevations (or runups) of tens to hundreds of meters, inundating low-lying areas and, where local submarine topography causes the waves to steepen, they may break and cause great damage. Tsunamis have no connection with tides; the popular name, tidal wave, is entirely misleading (IOC, 2019).

Volcanic tsunamis are defined as those with source mechanisms from erupting and quiescent volcanoes, and include explosions, pyroclastic flows and lahars entering the water, earthquakes preceding or during a volcanic eruption, flank failure (from rock falls to massive debris avalanches), collapse of coastal lava benches, caldera collapse and shock waves from large explosions. Of these mechanisms, only pyroclastic flows, flank failures and caldera subsidence generate damaging tsunamis, as their volumes are larger than one km3. Wavelengths of volcanic tsunamis are shorter than those from earthquakes and undergo more rapid dispersion during propagation. These tsunamis are more hazardous on coastlines close to the volcano. Because of the different potential mechanisms and their possible interactions, numerical simulations of volcano tsunamis, and model-based assessments of hazards from volcano tsunamis, are challenging, compared to those from earthquakes (Day, 2015).

The Intergovernmental Oceanographic Commission (IOC) uses the following terms to assess the scale and impact of a tsunami (IOC, 2019):

- Travel time: Time required for the first tsunami wave to propagate from its source to a given point on a coastline.
- Arrival time: Time of the first maximum of the tsunami waves.
- Inundation or Inundation-distance: The horizontal distance inland that a tsunami penetrates, generally measured perpendicularly to the shoreline.
- Inundation (maximum): Maximum horizontal penetration of the tsunami from the shoreline. A maximum inundation is measured for each different coast or harbour affected by the tsunami.
- Inundation area: Area flooded with water by the tsunami.
- Inundation height Elevation reached by seawater measured relative to a stated datum such as mean sea level or the sea level at the time of tsunami arrival, at a specified inundation distance. Inundation height is the sum of the flow depth and the local topographic height. Sometimes referred to as tsunami height.

- Inundation line: Inland limit of wetting measured horizontally from the mean sea level line. The line between living and dead vegetation is sometimes used as a reference. In tsunami science, the landward limit of tsunami run-up.
- Leading wave: First arriving wave of a tsunami. In some cases, the leading wave produces an initial depression or drop in sea level, and in other cases, an elevation or rise in sea level. When a drop in sea level occurs, sea level recession is observed.
- Mean height: Average height of a tsunami measured from the trough to the crest after removing the tidal variation.
- Run-up
  - Difference between the elevation of maximum tsunami penetration (inundation line) and the sea level at the time of the tsunami. In practical terms, run up is only measured where there is a clear evidence of the inundation limit on the shore.
  - Elevation reached by seawater measured relative to some stated datum such as mean sea level, mean low water, sea level at the time of the tsunami attack, etc., and measured ideally at a point that is a local maximum of the horizontal inundation. Where the elevation is not measured at the maximum of horizontal inundation, this is often referred to as the inundation-height.
- Tsunami amplitude: Usually measured on a sea level record, it is (1) the absolute value of the difference between a particular peak or trough of the tsunami and the undisturbed sea level at the time, (2) half the difference between an adjacent peak and trough, corrected for the change of tide between that peak and trough. It is intended to represent the true amplitude of the tsunami wave at some point in the ocean. However, it is often an amplitude modified in some way by the tide gauge response.
- Tsunami period: Amount of time that a tsunami wave takes to complete a cycle, or one wavelength. Tsunami periods typically range from 5 to 60 minutes. Tsunami period is often measured as the difference between the arrival time of the highest peak and the next one measured on a water level record.
- Tsunami wavelength: The horizontal distance between similar points on two successive waves measured perpendicular to the crest. The wavelength and the tsunami period give information on the tsunami source. For tsunamis generated by earthquakes, the typical wavelength ranges from 20 to 300 km. For tsunamis generated by volcanic mechanisms wavelengths are much shorter than those from earthquakes, ranging from hundreds of meters to tens of kilometres.
- Meteotsunami: Volcanic eruptions, submarine landslides, and coastal rock falls can also generate tsunamis, as can a large meteorite impacting the ocean. Tsunami-like phenomena generated by meteorological or atmospheric disturbances.

For more terms see IOC (2019).

Metrics and numeric limits

Not available.

Key relevant UN convention/multilateral treaty

Not found.

Examples of drivers, outcomes and risk management

Volcanic tsunamis are relatively infrequent, and unpredictable, hazards that are caused by rapid, mainly vertical, ground displacements (earthquakes and landslides) or eruptive activity at a volcano. Their hazard is mainly to coastal communities within a few tens of kilometres of active volcanoes, although more infrequent, larger volume, volcano flank collapse landslides, and explosive eruptions are a hazard at greater distances of hundreds of kilometres. At present, there is no defined management structure to mitigate the hazard because of the complex range of volcanic tsunami mechanisms. Through analysis of geological and historical evidence of past behaviour at a volcano, however, it is possible to identify volcanoes that generate tsunamis and investigate these to determine whether risk management measures (such as changes to coastal land use patterns) can be formulated. Monitoring volcanic activities and their local environments (for example ground stability and changes in ground motion), has the potential to identify imminent eruptive activity, or changes at a volcano (such as increased seismicity), that could make it more susceptible to instabilities, such as landslides or collapse, with the potential for initiating tsunamis. Thus, in contrast to risks from earthquake-generated tsunamis, that require management through rapid responses based on the detection of large magnitude events, the risks from volcanic tsunamis could, to some extent, be addressed by anticipatory measures, such as coastal evacuations, in response to increased volcanic activity, on which early warning system messaging is based (Day, 2015).

Primary hazards/damage. Damage and destruction from tsunamis are the direct result of three factors: inundation, wave impact on structures, and erosion. Deaths occur by drowning and physical impact or other trauma when people are caught in the turbulent, debris-laden tsunami waves. Strong tsunami-induced currents have led to the erosion of foundations and the collapse of bridges and seawalls. Floatation and drag forces have moved houses and overturned railroad cars (IOC, 2019:6).

Tsunami associated wave forces have demolished frame buildings and other structures. Considerable damage is also caused by floating debris, including boats, cars, and trees that become dangerous projectiles that may crash into buildings, piers, and other vehicles. Ships and port facilities have been damaged by surge action caused by even weak tsunamis. Fires resulting from oil spills or combustion from damaged ships in port, or from ruptured coastal oil storage and refinery facilities, can cause damage greater than that inflicted directly by the tsunami (IOC, 2019:6).

Secondary hazards/damage. Secondary hazard/damage includes sewage and chemical pollution following the tsunami destruction. Damage to intakes, discharge, storage facilities and flooding of cooling generators are also major potential problems. During tsunami drawdown, there is the potential for the receding flood waters to uncover cooling water intakes associated with nuclear power plants, leading to overheating and explosion of nuclear facilities (IOC, 2019:7).

Environmental damage and damage to coastal croplands can result from deposition of sediments over inundated areas and salt water contamination. This could be a particular problem with tsunamis associated with volcanic eruptions, from the transport and deposition of floating pumice onto land, and the erosion, transport and redeposition of volcanic tephra deposited in phases of the eruption prior to the tsunami inundation. Clean-up efforts can be complicated by contamination of sediment and debris with salt and with spilt oil fuels and other chemicals.

Risk management for tsunamis includes a number of guidelines on tsunami risk assessment/management are available. Examples include IOC (2015) and UNDRR (2017).

Regional Coordination and Centres: The IOC is coordinating the implementation of a global tsunami warning system, building upon its experiences in the Pacific to establish regional warning systems for the Indian Ocean (IOTWMS); Caribbean Sea (ICG-CARIBE-EWS); and the North-eastern Atlantic, the Mediterranean and connected seas (ICG-NEAMTWS). The regional systems coordinate international tsunami warning and mitigation activities, including the issuance of timely and understandable tsunami bulletins to IOC Member States.

The Intergovernmental Coordination Group for Tsunamis addresses tsunami risk globally through the following groups:

ICG-PTWS Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System, formerly ICG/ITSU, was renamed by Resolution EC-XXXIX.8 of the IOC Executive Council in 2006 as proposed by the International Coordination Group for the Tsunami Warning System in the Pacific at its 20th Session in 2005 (Recommendation ITSU-XX.1). There are presently 46 Member States in the ICG-PTWS. ICG/ITSU, the International Coordination Group for the Tsunami Warning System in the Pacific was established by Resolution IV-6 of the 4th Session of the IOC Assembly in 1965. The Pacific Tsunami Warning Center (PTWC) serves as the Tsunami Service Provider (TSP) for the Pacific Ocean. Other TSPs for specific regions of the Pacific Ocean are the North West Pacific Tsunami Advisory Center (NWPTAC) and the South China Sea Tsunami Advisory Center (SCSTAC). The ICG-PTWS presently comprises over 40 Member States and oversees warning system operations and facilitates coordination and cooperation in all international tsunami mitigation activities.

ICG-IOTWMS The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG-IOTWMS) was formed in response to the tragic tsunami on December 26th 2004, in which over 230,000 lives were lost around the Indian Ocean region. The ICG-IOTWMS comprises 28 Member States. There are three TSPs in the Indian Ocean, hosted by the governments of Australia, Indian and Indonesia.

ICG-NEAMTWS The Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (ICG-NEAMTWS) was formed in response to the tragic tsunami on 26 December 2004, in which over 230,000 lives were lost around the Indian Ocean region (Indian Ocean Tsunami Information Centre, no date). The ICG-NEAMTWS consists of Member States bordering the North-eastern Atlantic and those bordering and within the Mediterranean and connected seas. There are currently five accredited Tsunami Service Providers (France, Greece, Italy, Portugal, Turkey) in the NEAM region providing tsunami services and alerts to subscribing Member States.

ICG-CARIBE-EWS The Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG-CARIBE-EWS) was established in 2005 and currently comprises 32 Member States and 16 Territories in the Caribbean.

Tsunami Service Providers (TSPs) are centres that monitor seismic and sea level activity and issue timely tsunami threat information within an ICG framework to National Tsunami Warning Centres (NTWCs) / Tsunami Warning Focal Points (TWFPs) and other TSPs operating within an ocean basin. The NTWCs / TWFPs may use these products to develop and issue tsunami warnings for their countries. TSPs may also issue public messages for an ocean basin and act as NTWCs providing tsunami warnings for their own countries. Currently there are nine operational TSPs.

National Tsunami Warning Centres (NTWCs) are a centre officially designated by the government to monitor and issue tsunami warnings and other related statements within their country according to established national Standard Operating Procedures.

World Tsunami Awareness Day, 5 November every year: The United Nations, through UN Resolution 70/203 adopted on 22 December 2015, has designated 5 November as World Tsunami Awareness Day (UNDRR, 2020). The day aligns with the International Day for Disaster Reduction (13 October) and the seven targets of the Sendai Framework for Disaster Risk Reduction 2015–2030 (ITIC, 2020). The IOC is a key international partner of the UNDRR on World Tsunami Awareness Day.

Tsunami Ready is a voluntary community recognition programme that promotes tsunami hazard preparedness as an active collaboration among federal, state/territorial and local emergency management agencies, community leaders and the public. The main goal of the programme is to improve public safety before, during and after tsunami emergencies. It aims to do this by establishing guidelines for a standard level of capability to mitigate, prepare for and respond to tsunamis, and working with communities to help them meet the guidelines and ultimately become recognised as 'tsunami ready' by the National Weather Service. It was first implemented in the United States .To date, there are 26 IOC-UNESCO Tsunami Ready recognised communities in 18 countries and territories, excluding those implemented in the United States.

Community engagement with evacuation zones and the 'blue lines' project In New Zealand, the Wellington Region Emergency Management Office has developed the Blue Line Project in collaboration with communities in Wellington's southern coastal suburbs. In this project, the local community helps to plan evacuation routes and safe locations based on indicative evacuation zone mapping, and blue lines are painted on the road surface at the maximum estimated tsunami inundation extent. Accompanying evacuation signage is installed. Community members are engaged early in the project, publicising the work and helping to develop blue line locations, evacuation zone maps and information boards. The communities participating in the Blue Line Project can be considered to have a higher degree of public education regarding tsunami evacuation than other communities (Fraser et al., 2016). Other communities around the world have used similar community engagement strategies.

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Coordinating agency or organisation

United Nations Educational, Scientific and Cultural Organization (UNESCO), Intergovernmental Oceanographic Commission (IOC-UNESCO) and the British Geological Survey.