# TSUNAMI GLOSSARY

United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental Oceanographic
Commission of UNESCO

International Tsunami
Information Centre

Jakarta Tsunami
Information Centre

Printing Funded by:
Canadian International
Development Agency

UNESCO 2007

IOC/INF-1221
Hawaii, January 2006
Original: English

For bibliographic purpose, this document should be cited as follows:

UNESCO-IOC. *Tsunami Glossary.* IOC Information document No. 1221. Paris, UNESCO, 2006.

**Indonesian language printed in Jakarta, funded by Canadian International Development Agency (CIDA) through the Jakarta Tsunami Information Centre (JTIC) Project.**

**UNESCO Office, Jakarta**
**Regional Science Bureau for Asia & Pacific**
**Cluster Office to Brunei Darussalam, Indonesia, Malaysia, the Philippines and Timor Leste**
**UNESCO House**
Jl. Galuh (II) No. 5, Kebayoran Baru
Jakarta 12110, INDONESIA
Tel : +62-21 7399 818
Fax: +62-21 7279 6489
www.unesco.or.id

**Diterjemahkan oleh:**
**Jakarta Tsunami Information Centre (JTIC)**
**UNESCO House**
Jl. Galuh (II) No. 5, Kebayoran Baru
Jakarta 12110, INDONESIA
Tel : +62-21 7399 818
Fax: +62-21 7279 6489
www.jtic.org

English Edition Published by the United Nations Educational, Scientific and Cultural Organization
7 Place de Fontenoy, 75 352 Paris 07 SP, France

*Photo courtesy of Bishop Museum Archives.*

# 1 TSUNAMI CLASSIFICATION

## CHARACTERISTICS OF THE TSUNAMI PHENOMENA

A tsunami travels outward from the source region as a series of waves. Its speed depends upon the depth of the water, and consequently the waves undergo accelerations or decelerations in passing respectively over an ocean bottom of increasing or decreasing depth. By this process the direction of wave propagation also changes, and the wave energy can become focused or defocused. In the deep ocean, tsunami waves can travel at speeds of 500 to 1,000 kilometers (km) per hour. Near the shore, however, a tsunami slows down to just a few tens of kilometers per hour. The height of a tsunami also depends upon the water depth. A tsunami that is just a meter in height in the deep ocean can grow to tens of meters at the shoreline. Unlike familiar wind-driven ocean waves that are only a disturbance of the sea surface, the tsunami wave energy extends to the ocean bottom. Near the shore, this energy is concentrated in the vertical direction by the reduction in water depth, and in the horizontal direction by a shortening of the wavelength due to the wave slowing down.

Tsunamis have periods (the time for a single wave cycle) that may range from just a few minutes to as much as an hour or exceptionally more. At the shore, a tsunami can have a wide variety of expressions depending on the size and period of the waves, the near-shore bathymetry and shape of the coastline, the state of the tide, and other factors. In some cases a tsunami may only induce a relatively benign flooding of low-lying coastal areas, coming onshore similar to a rapidly rising tide. In other cases it can come onshore as a bore - a vertical wall of turbulent water full of debris that can be very destructive. In most cases there is also a drawdown of sea level preceding crests of the tsunami waves that results in a receding of the waterline, sometimes by a kilometer or more. Strong and unusual ocean currents may also accompany even small tsunamis.

Damage and destruction from tsunamis is 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. Tsunami associated wave forces have demolished frame buildings and other structures. Considerable damage also is 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. Other secondary damage can result from sewage and chemical pollution following the destruction. Damage of intake, discharge, and storage facilities also can present dangerous problems. Of increasing concern is the potential effect of tsunami drawdown, when receding waters uncover cooling water intakes associated with nuclear plants.

## AIR-COUPLED TSUNAMI

Synonym for atmospheric tsunami.

## ATMOSPHERIC TSUNAMI

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.

## HISTORICAL TSUNAMI

A tsunami documented to occur through eyewitness or instrumental observation within the historical record.

## LOCAL TSUNAMI

A tsunami from a nearby source for which its destructive effects are confined to coasts within 100 km of the source. A local tsunami is usually generated by an earthquake, but can also be caused by a landslide, or a pyroclastic flow from a volcanic eruption.

## MAREMOTO

Spanish term for tsunami.

*Damaged caused by the 22 May 1960 Chilean tsunami. Photo courtesy of Ilustre Municipalidad de Maulin, USGS Circular 1187.*

## MICROTSUNAMI

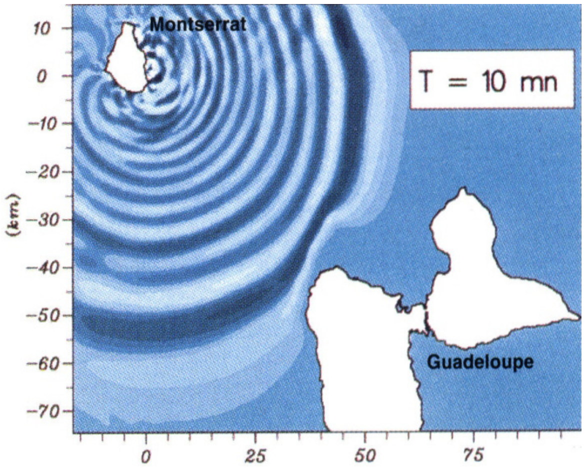
A tsunami of such small amplitude that it must be observed instrumentally and is not easily detected visually.

## OCEAN-WIDE TSUNAMI

A tsunami capable of widespread destruction, not only in the immediate region of its generation, but across an entire Ocean. All ocean-wide tsunamis have been generated by major earthquakes. Synonym for teletsunami or distant tsunami.

## PALEOTSUNAMI

Tsunami occurring prior to the historical record or for which there are no written observations.



*Numerical modelling snapshots of the water surface 10 minutes after a pyroclastic flow on the southeastern part of Monserrat Island led to a submarine landslide and the generation of a tsunami.*

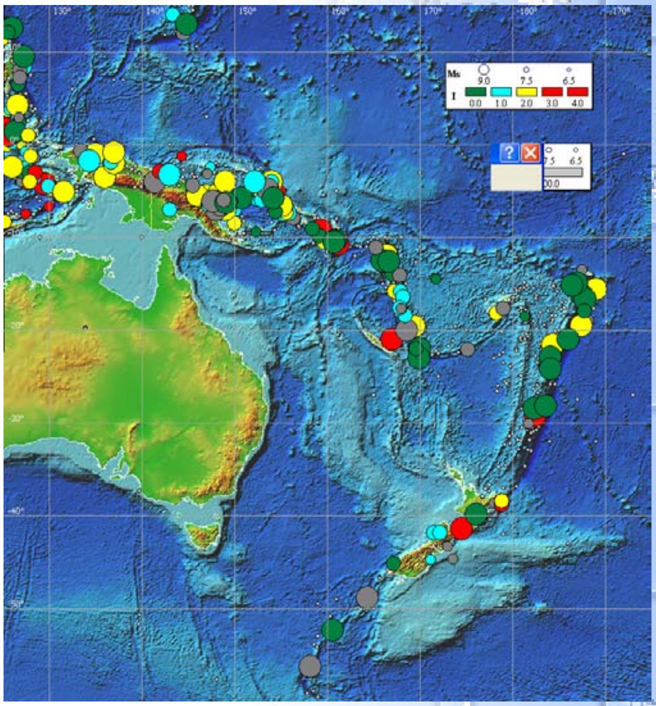
Paleotsunami research is based primarily on the identification, mapping, and dating of tsunami deposits found in coastal areas, and their correlation with similar sediments found elsewhere locally, regionally, or across ocean basins. In one instance, the research has led to a new concern for the possible future occurrence of great earthquakes and tsunamis along the northwest coast of North America. In another instance, the record of tsunamis in the Kuril-Kamchatka region is being extended much further back in time. As work in this field continues it may provide a significant amount of new information about past tsunamis to aid in the assessment of the tsunami hazard.

## REGIONAL TSUNAMI

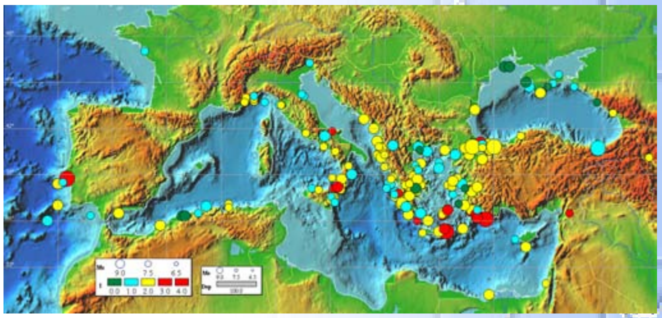
A tsunami capable of destruction in a particular geographic region, generally within about 1,000 km of its source. Regional tsunamis also occasionally have very limited and localized effects outside the region.

Most destructive tsunami can be classified as local or regional, meaning their destructive effects are confined to coasts within a hundred km, or up to a thousand km, respectively, of the source -- usually an earthquake. It follows many tsunami related casualties and considerable property damage also comes from these tsunami. Between 1975 and 2005 there were 22 local or regional tsunami in the Pacific and adjacent seas that resulted in deaths and property damage.

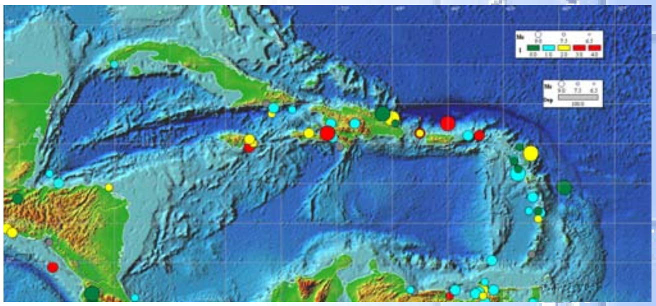
For example, a regional tsunami in 1983 in the Sea of Japan or East Sea, severely damaged coastal areas of Japan, Korea, and Russia, causing more than $ 800 million in damage, and more than 100 deaths. Then, after nine years without an event, 11 locally destructive tsunamis occurred in just a seven-year period from 1992 to 1998, resulting in over 4,200 deaths and hundreds of millions of dollars in property damage. In most of these cases, tsunami mitigation efforts in place at the time were unable to prevent significant damage and loss of life. However, losses from future local or regional tsunamis can be reduced if a denser network of warning centres, seismic and water-level reporting stations, and better communications are established to provide a timely warning, and if better programmes of tsunami preparedness and education can be put in place.



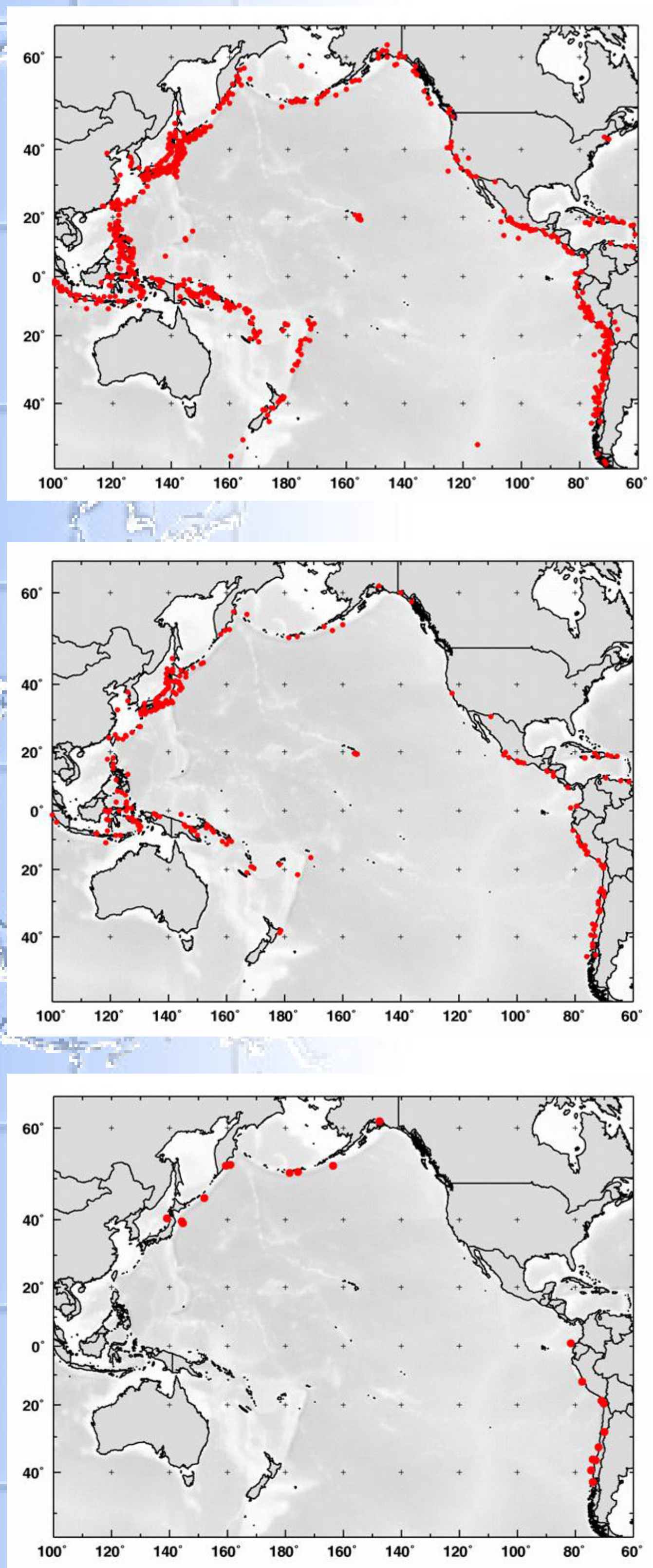
*Earthquakes generating tsunamis in the Southwest Pacific. Source: ITDB, 2005. Red circles show tsunamis causing greatest damage according to the Imamura-Soloviev tsunami intensity scale. Grey circles are non-tsunamigenic earthquakes. The size of the circle is scaled to the magnitude of the earthquake.*



*Earthquakes generating tsunamis in the Mediterranean and connected seas. Source: ITDB, 2005.*



*Earthquakes generating tsunamis in the Caribbean and adjacent seas. Source: ITDB, 2005.*



*More than 80% of the world's tsunamis are observed in the Pacific where large earthquakes occur as tectonic plates are subducted along the Pacific Ring of Fire. Top: Epicenters of all tsunamigenic earthquakes. Middle: Epicenters of tsunamis causing damage or casualties. Bottom: Epicenters of tsunamis causing damage or casualties more than 1000 km away. Source: Pacific Tsunami Warning Center.*

***Regional and local tsunamis measured since 1975***

| Date | | | Source Location | Estimated dead or missing |
|---|---|---|---|---|
| 29 | Nov | 1975 | Hawaii, U.S.A. | 2 |
| 17 | Aug | 1976 | Moro Bay, Philippines | *4,000 |
| 19 | Aug | 1977 | Sumbawa, Indonesia | 189 |
| 18 | Jul | 1979 | Lembata Is., Indonesia | 187 |
| 16 | Oct | 1979 | French Riviera | 6 |
| 12 | Dec | 1979 | Narino, Colombia | 500 |
| 11 | May | 1981 | South Africa | 0 |
| 26 | May | 1983 | Sea of Japan | 100 |
| 3 | Mar | 1985 | Chile | *377 |
| 22 | Apr | 1991 | Atlantic Ocean (Central America) | 2 |
| 25 | Apr | 1992 | California, USA | 0 |
| 2 | Sep | 1992 | Nicaragua | 168 |
| 12 | Dec | 1992 | Flores Is., Indonesia | *1,000 |
| 12 | Jul | 1993 | Sea of Japan | *330 |
| 3 | Jun | 1994 | Java, Indonesia | 222 |
| 3 | Nov | 1994 | Skagway, Alaska, USA | 1 |
| 14 | Nov | 1994 | Verde Island Passage, Philippines | *74 |
| 15 | Jun | 1995 | Gulf of Corinthos, Greece | 0 |
| 30 | July | 1995 | Chile | 3 |
| 9 | Oct | 1995 | Manzanillo, Mexico | 1 |
| 1 | Jan | 1996 | Sulawesi, Indonesia | 9 |
| 17 | Feb | 1996 | Irian Jaya, Indonesia | 110 |
| 17 | Jul | 1998 | Papua New Guinea | 2,200 |
| 17 | Aug | 1999 | Izmut, Turkey | 0 |
| 23 | Jun | 2001 | Peru | 26 |
| 3 | Jan | 2002 | Vanuatu | 0 |
| 30 | Dec | 2002 | Stromboli, Italy | 0 |
| 21 | May | 2003 | Algeria | 0 |
| 25 | Sep | 2003 | Hokkaido, Japan | 2 |
| 17 | July | 2006 | South of Java, Indonesia | 688 |
| 12 | Sep | 2007 | Bengkulu and West Sumatra, Indonesia | 0 |

** May include earthquake casualties*

## TELETSUNAMI OR DISTANT TSUNAMI

A tsunami originating from a far away source, generally more than 1,000 km away.

Less frequent, but more hazardous than regional tsunamis, are ocean-wide or distant tsunamis. Usually starting as a local tsunami that causes extensive destruction near the source, these waves continue to travel across an entire ocean basin with sufficient energy to cause additional casualties and destruction on shores more than a 1,000 kilometres from the source. In the last

200 years, there have been at least 21 destructive ocean-wide tsunamis.

The most destructive Pacific-wide tsunami of recent history was generated by a massive earthquake off the coast of Chile on 22 May 1960. All Chilean coastal towns between the 36th and 44th parallels were either destroyed or heavily damaged by the action of the tsunami and the quake. The combined tsunami and earthquake toll included 2,000 killed, 3,000 injured, 2,000,000 homeless, and $550 million damage. Off the coast of Corral, Chile, the waves were estimated to be 20 metres (67 feet) high. The tsunami caused 61 deaths in Hawaii, 20 in the Philippines, and 138 in Japan. Estimated damages were US $50 million in Japan, US $24 million in Hawaii and several millions along the west coast of the United States and Canada. Distant wave heights varied from slight oscillations in some areas to 12 metres (40 feet) at Pitcairn Island, 11 metres at Hilo, Hawaii, and 6 metres at some places in Japan.

*The tsunami of 26 December 2004 destroyed the nearby city of Banda Aceh leaving only a few structures standing. Photo courtesy of Yuichi Nishimura, Hokkaido University.*

The worst tsunami catastrophe in history occurred in the Indian Ocean on 26 December 2004, when a M9.3 earthquake off of the northwest coast of Sumatra, Indonesia produced a ocean-wide tsunami that hit Thailand and Malaysia to the east, and Sri Lanka, India, the Maldives, and Africa to the west as it traversed across the Indian Ocean. Nearly 250,000 people lost their lives, and more than 1 million people were displaced, losing their homes, property, and their livelihoods. The magnitude of death and destructiveness caused immediate response by the world's leaders and led to the development of the Indian Ocean tsunami warning and mitigation system in 2005. The event also raised awareness of tsunami hazards globally, and new systems were established in the Caribbean, the Mediterranean and Atlantic.

***Teletsunamis recorded since 1650***

| Date | | | Source Location | Estimated dead or missing |
|---|---|---|---|---|
| 20 | Oct | 1687 | Peru | 500 |
| 7 | Jun | 1692 | Jamaica | *3000 |
| 26 | Jan | 1700 | Cascadia NE Pacific | N/A |
| 8 | Jul | 1730 | Chile | 0 |
| 25 | May | 1751 | Chile | 30 |
| 1 | Nov | 1755 | Lisbon, Portugal | *10,000 |
| 24 | Apr | 1771 | Ryukyuu Islands | 12,000 |
| 2 | Feb | 1835 | Chile | 3 |
| 7 | Nov | 1837 | Chile | 62 |
| 24 | Dec | 1854 | Japan | 3000 |
| 13 | Aug | 1868 | Chile | *26,000 |
| 10 | May | 1877 | Chile | 500 |
| 31 | Dec | 1881 | Bay of Bengal | N/A |
| 27 | Aug | 1883 | Krakatau, Indonesia | *30,000 |
| 15 | Jun | 1896 | Sanriku, Japan | *22,000 |
| 31 | Jan | 1906 | Colombia-Ecuador | 500 |
| 17 | Aug | 1906 | Chile | N/A |
| 7 | Sep | 1918 | Kuril Islands | 47 |
| 11 | Nov | 1922 | Chile | 100 |
| 3 | Feb | 1923 | Kamchatka, Russia | 2 |
| 1 | Sep | 1923 | Kanto, Japan | 2,144 |
| 2 | Mar | 1933 | Sanriku, Japan | 3,000 |
| 7 | Dec | 1944 | Tonankai, Japan | 1,038 |
| 1 | Apr | 1946 | Aleutian Islands, U.S.A. | 179 |
| 20 | Dec | 1946 | Nankaido, Japan | 1997 |
| 4 | Mar | 1952 | Hokkaido, Japan | 33 |
| 4 | Nov | 1952 | Russia | N/A |
| 9 | Mar | 1957 | Aleutian Islands, U.S.A. | 5 |
| 22 | May | 1960 | Chile | *2,000 |
| 28 | Mar | 1964 | Alaska, U.S.A. | 132 |
| 4 | Feb | 1965 | Aleutian Islands, U.S.A. | 0 |
| 16 | May | 1968 | Honshu, Japan | 52 |
| 4 | Oct | 1994 | Shikotan Island, Russia | 11 |
| 21 | Feb | 1996 | Peru | 15 |
| 26 | Dec | 2004 | Northern Sumatra | *250,000 |

** May include earthquake casualties*
*N/A; numbers not available*

## TSUNAMI

Japanese term meaning wave ("nami") in a harbour ("tsu"). A series of traveling waves of extremely long length and period, usually generated by disturbances associated with earthquakes occurring below or near the ocean floor. (Also called seismic sea wave and, incorrectly, tidal wave). Volcanic eruptions, submarine landslides, and coastal rockfalls can also generate tsunami, as can a large meteorite impacting the ocean. These waves may reach enormous dimensions and travel across entire ocean basins with little loss of energy. They proceed as ordinary gravity waves with a typical period between 10 and 60 minutes. Tsunamis steepen and increase in height on approaching shallow water, 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.

*Tsunami generated by 26 May 1983, Japan Sea earthquake approaching Okushiri Island, Japan. Photo courtesy of Tokai University.*

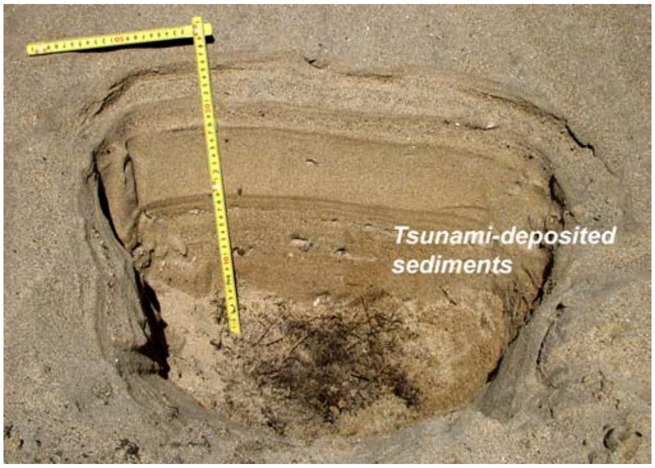
*Destruction along the waterfront of Hilo, Hawaii from the Pacific-wide tsunami generated off the coast of Unimak Island, Aleutian Island, USA on 1 April 1946.*

## TSUNAMI EARTHQUAKE

An earthquake that produces an unusually large tsunami relative to the earthquake magnitude (Kanamori, 1972). Tsunami earthquakes are characterized by a very shallow focus, fault dislocations greater than several metres, and fault surfaces smaller than those for normal earthquakes. They are also slow earthquakes, with slippage along their faults occurring more slowly than would occur in normal earthquakes. The last events of this type were in 1992 (Nicaragua) and 1996 (Chimbote, Peru).

## TSUNAMI SEDIMENTS

Sediments deposited by a tsunami. The finding of tsunami sediment deposits within the stratigraphic soil layers provides information on the occurrence of historical and paleotsunamis. The discovery of similarly-dated deposits at different locations, sometimes across ocean basins and far from the tsunami source, can be used to map and infer the distribution of tsunami inundation and impact.



*Sediment layers deposited from successive waves of 26 December 2004 Indian Ocean tsunami, as observed in Banda Aceh, Indonesia. Photo courtesy Yuichi Nishimura, Hokkaido University.*

# 2 GENERAL TSUNAMI TERMS

*This section contains general terms used in tsunami mitigation and in tsunami generation and modelling.*

## BREAKER

A sea-surface wave that has become so steep (wave steepness of 1/7) that the crest outraces the body of the wave and it collapses into a turbulent mass on shore or over a reef. Breaking usually occurs when the water depth is less than 1.28 times the wave height. Roughly, three kinds of breakers can be distinguished, depending primarily on the gradient of the bottom: a) spilling breakers (over nearly flat bottom) which form a foamy patch at the crest and break gradually over a considerable distance; b) plunging breakers (over fairly steep bottom gradient) which peak up, curl over with a tremendous overhanging mass and then break with a crash; c) surging breakers (over very steep bottom gradients) which do not spill or plunge but surge up the beach face. Waves also break in deep water if they build too high while being generated by the wind, but these are usually short-crested and are termed whitecaps.

## BREAKWATER

An offshore or onshore structure, such as a wall, water gate, or other in-water wave-dissipating object that is used to protect a harbour or beach from the force of waves.

*Sea wall with stairway evacuation route used to protect a coastal town against tsunami inundation in Japan. Photo courtesy of River Bureau, Ministry of Land, Infrastructure and Transport, Japan.*

*Eddies generated by the interactions of tsunami waves as they hit the coast of Sri Lanka, 26 December 2004. Photo courtesy of Digital Globe.*

## EDDY

By analogy with a molecule, a “glob” of fluid within the fluid mass that has a certain integrity and life history of its own; the activities of the bulk fluid being the net result of the motion of the eddies.

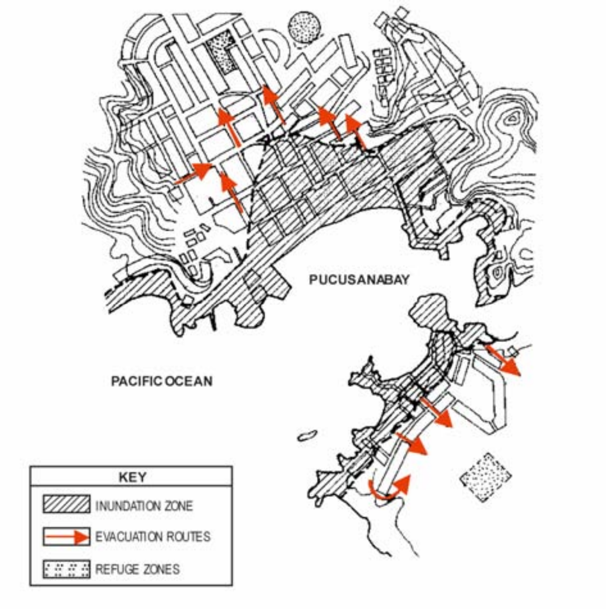
*Water gate used to protect against tsunami waves on Okushiri Island, Japan. The gate begins to automatically close within seconds after earthquake shaking triggers its seismic sensors. Photo courtesy of ITIC.*

## ESTIMATED TIME OR ARRIVAL (ETA)

Time of tsunami arrival at some fixed location, as estimated from modeling the speed and refraction of the tsunami waves as they travel from the source. ETA is estimated with very good precision if the bathymetry and source are well known (less than a couple of minutes).

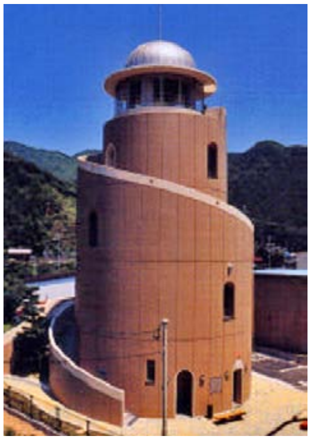
## EVACUATION MAP

A drawing or representation that outlines danger zones and designates limits beyond which people must be evacuated to avoid harm from tsunami waves. Evacuation routes are sometime designated to ensure the efficient movement of people out of the evacuation zone to evacuation shelters.



*Inundation and Evacuation Map created for the coastal town of Pucusana, Peru.*

*Elevated platform used for tsunami evacuation that also serves as a high-elevation scenic vista point for tourist. Okushiri Island, Japan. Photo courtesy of ITIC.*



*Emergency shelter building that also acts as community center and Museum for Disaster Prevention. Kisei, Mie Prefecture, Japan. The building is 22-m high, has five floors covering 320 m2 , and holds 500 persons. Info courtesy of http://www.webmie.or.jp.*

## HISTORICAL TSUNAMI DATA

Historical data are available in many forms and at many locations. These forms include published and unpublished catalogs of tsunami occurrences, personal narratives, marigraphs, tsunami amplitude, run-up and inundation zone measurements, field investigation reports, newspaper accounts, film or video records.

## SEICHE

A seiche may be initiated by a standing wave oscillating in a partially or fully enclosed body of water. May be initiated by long period seismic waves (an earthquake), wind and water waves, or a tsunami.

## SEISMIC SEA WAVE

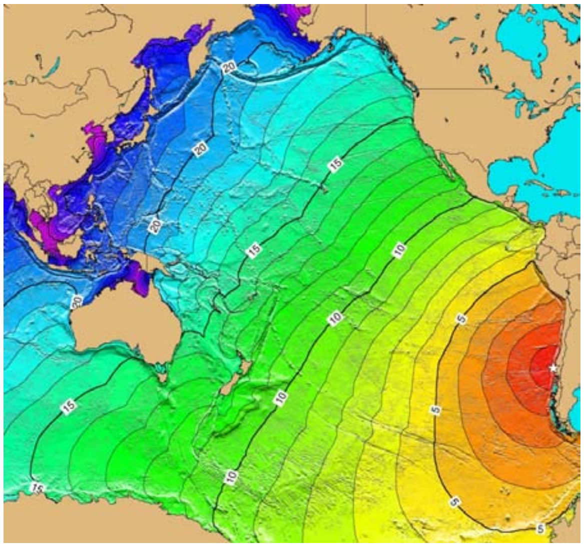
Tsunamis are sometime referred to as seismic sea waves because they are most often generated by earthquakes.

## TRAVEL TIME

Time required for the first tsunami wave to propagate from its source to a given point on a coastline.

## TRAVEL TIME MAP

Map showing isochrons or lines of equal tsunami travel time calculated from the source outwards toward terminal points on distant coastlines.



*Travel-times (in hours) for the 22 May 1960 Chile tsunami crossing the Pacific basin. This tsunami was extremely destructive along the nearby coast of Chile, and the tsunami also caused significant destruction and casualties as far away as Hawaii and Japan. The awareness and concern raised by this Pacific-wide tsunami ultimately led to the formation of the TWSP and PTWS.*

## TSUNAMI BORE

A steep, turbulent, rapidly moving tsunami wave front, typically occurring in a river mouth or estuary.

*Tsunami bore entering Wailua River, Hawaii during the 1946 Aleutian Island tsunami. Photo courtesy of Pacific Tsunami Museum.*

## TSUNAMI DAMAGE

Loss or harm caused by a destructive tsunami. More specifically, the damage caused directly by tsunamis can be summarized into the following: 1) deaths and injuries; 2) houses destroyed, partially destroyed, inundated, flooded, or burned; 3) other property damage and loss; 4) boats washed away, damaged or destroyed; 5) lumber washed away; 6) marine installations destroyed, and; 7) damage to public utilities such as railroads, roads, electric power plants, water supply installations, etc. Indirect secondary tsunami damage can be: 1) Damage by fire of houses, boats, oil tanks, gas stations, and other facilities; 2) environmental pollution caused by drifting materials, oil, or other substances; 3) outbreak of disease of epidemic proportions which could be serious in densely populated areas.

*Massive destruction in the town of Aonae on Okushiri Island, Japan caused by the regional tsunami of 12 July 1993. Photo courtesy of Dr. Eddie Bernard, NOAA PMEL.*

*Banda Aceh, Sumatra, Indonesia. The tsunami of 26 December 2004 completely razed coastal towns and villages, leaving behind only sand, mud, and water (middle) where once there had been thriving communities of homes, offices, and green space. Photo courtesy of DigitalGlobe.*

## TSUNAMI DISPERSION

Redistribution of tsunami energy, particularly as a function of its period, as it travels across a body of water.

## TSUNAMI EDGE WAVE

Wave generated by a tsunami that travels along the coast.

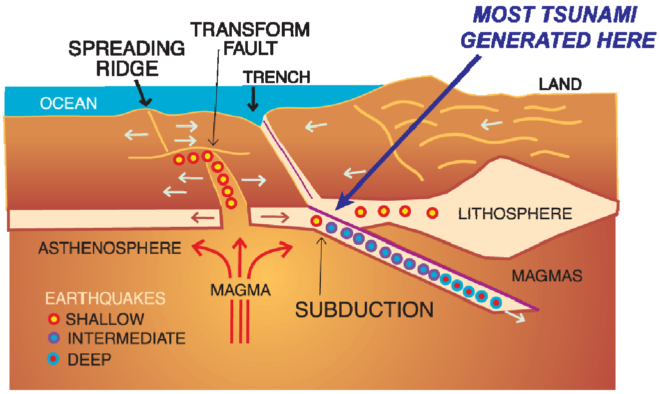
## TSUNAMI FORERUNNER

A series of oscillations of the water level preceding the arrival of the main tsunami waves mainly due to the resonance in bays and shelves that could occur before the arrival of the main tsunami.

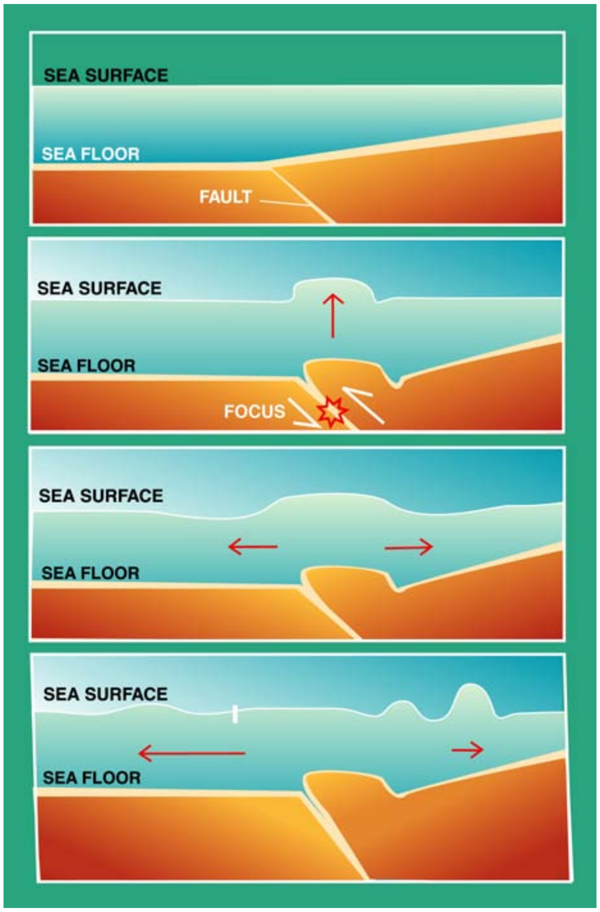
## TSUNAMI GENERATION

Tsunamis are most frequently caused by earthquakes, but can also result from landslides, volcanic eruptions, and very infrequently by meteorites or other impacts upon the ocean surface.Tsunamis are generated primarily by tectonic dislocations under the sea which are caused by shallow focus earthquakes along areas of subduction. The upthrusted and downthrusted crustal blocks impart potential energy into the overlying water mass with drastic changes in the sea level over the affected region. The energy imparted into the water mass results in tsunami generation, i.e. energy radiating away from the source region in the form of long period waves.

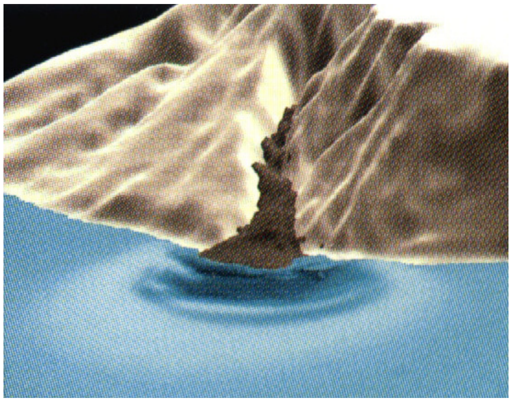
*Tsunamis can be generated by submarine landslides, or by subaerial landslides that enter the water. Courtesy of LDG-France.*



*Most tsunamis are generated by large, shallow, thrust earthquakes that occur as a tectonic plate is subducted. Shallow earthquakes also occur along spreading ridges, but these are not large enough to cause tsunamis. Large, shallow earthquakes also occur along transform faults, but there is only minor vertical motion during the faulting so no tsunamis are generated.*



*Tsunamis are most often generated by shallow earthquakes.*



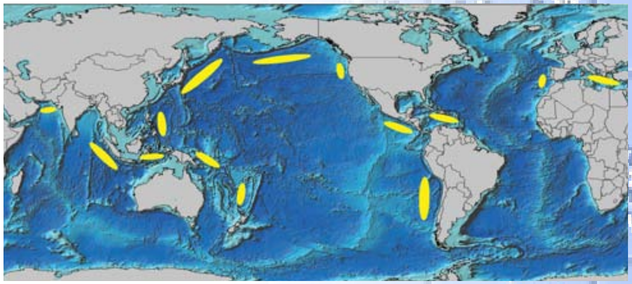
*Tsunamis can be generated by pyroclastic flows associated with volcanic eruptions. Courtesy of LDG-France.*

## TSUNAMI GENERATION THEORY

The theoretical problem of generation of the gravity wave (tsunami) in the layer of elastic liquid (an ocean) occurring on the surface of elastic solid half-space (the crust) in the gravity field can be studied with methods developed in the dynamic theory of elasticity. The source representing an earthquake focus is a discontinuity in the tangent component of the displacement on some element of area within the crust. For conditions representative of the Earth's oceans, the solution of the problem differs very little from the joint solution of two more simple problems: the problem of generation of the displacement field by the given source in the solid elastic half-space with the free boundary (the bottom) considered quasi-static and the problem of the propagation of gravity wave in the layer of heavy incompressible liquid generated by the known (from the solution of the previous problem) motion of the solid bottom. There is the theoretical dependence of the gravity wave parameters on the source parameters (depth and orientation). One can roughly estimate the quantity of energy transferred to the gravity wave by the source. In general, it corresponds to the estimates obtained with empirical data. Also, tsunamis can be generated by other different mechanisms such as volcanic or nuclear explosions, landslides, rock falls, and submarine slumps.

## TSUNAMI HAZARD

The probability of that a tsunami of a particular size will strike a particular section of coast.



*Global tsunami source zones. Tsunami hazards exist in all oceans and basins, but occur most frequently in the Pacific Ocean. Tsunamis can occur anywhere and at any time because earthquakes cannot be accurately predicted.*

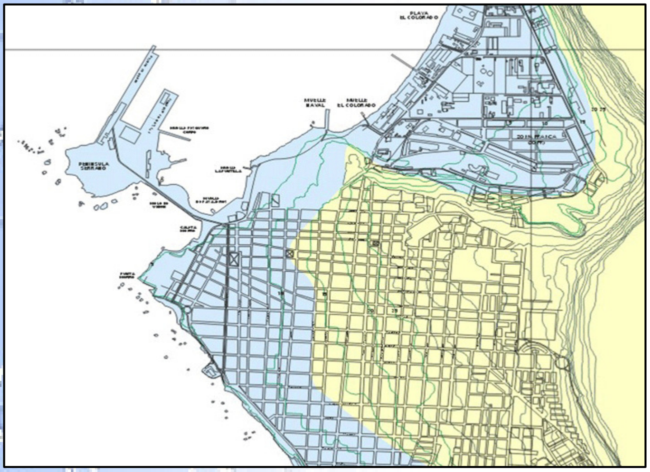
## TSUNAMI HAZARD ASSESSMENT

Documentation of tsunami hazards for a coastal community is needed to identify populations and assets at risk, and the level of that risk. This assessment requires knowledge of probable tsunami sources (such as earthquakes, landslides, volcanic eruption), their likelihood of occurrence, and the characteristics of tsunamis from those sources at different places along the coast. For those communities, data of earlier (historical and paleotsunamis) tsunamis may help quantify these factors. For most communities, however, only very limited or no past data exist. For these coasts, numerical models of tsunami inundation can provide estimates of areas that will be flooded in the event of a local or distant tsunamigenic earthquake or a local landslide.

## TSUNAMI IMPACT

Although infrequent, tsunamis are among the most terrifying and complex physical phenomena and have been responsible for great loss of life and extensive destruction to property. Because of their destructiveness, tsunamis have important impacts on the human, social and economic sectors of societies. Historical records show that enormous destruction of coastal communities throughout the world has taken place and that the socio-economic impact of tsunamis in the past has been enormous. In the Pacific Ocean where the majority of these waves have been generated, the historic record shows tremendous destruction with extensive loss of life and property.

In Japan, which has one of the most populated coastal regions in the world and a long history of earthquake activity, tsunamis have destroyed entire coastal populations. There is also a history of severe tsunami destruction in Alaska, the Hawaiian Islands, and South America, although records for these areas are not as extensive. The last major Pacific-wide tsunami occurred in 1960. Many other local and regional destructive tsunamis have occurred with more localized effects.



*Estimated tsunami inundation at Iquique, Chile, based on numerical model results.*

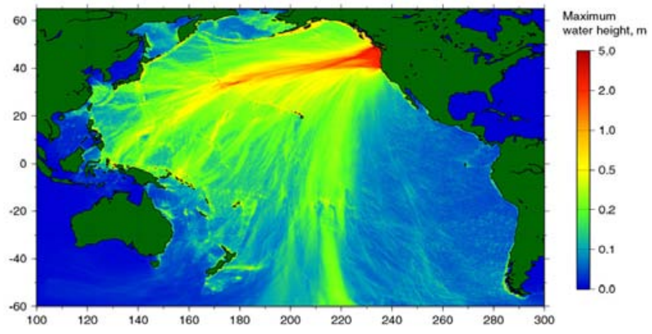
## TSUNAMI NUMERICAL MODELING

Mathematical descriptions that seek to describe the observed tsunami and its effects.

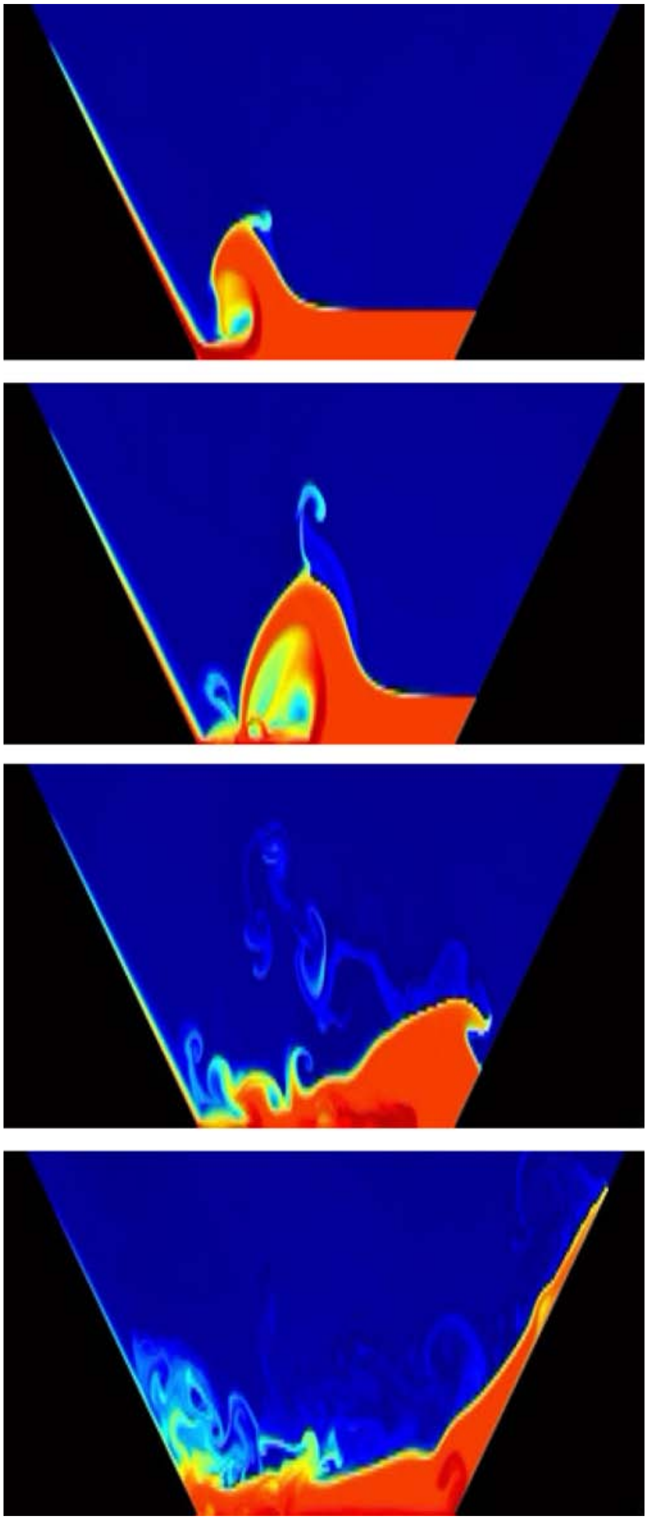
Often the only way to determine the potential runups and inundation from a local or distant tsunami is to use numerical modelling, since data from past tsunamis is usually insufficient. Models can be initialized with potential worst case scenarios for the tsunami sources or for the waves just offshore to determine corresponding worst case scenarios for runup and inundation. Models can also be initialized with smaller sources to understand the severity of the hazard for the less extreme but more frequent events. This information is then the basis for creating tsunami evacuation maps and procedures. At present, such modelling has only been carried out for a small fraction of the coastal areas at risk. Sufficiently accurate modelling techniques have only been available in recent years, and these models require training to understand and use correctly, as well as input of detailed bathymetric and topographic data in the area being modeled.

Numerical models have been used in recent years to simulate tsunami propagation and interaction with land masses. Such models usually solve similar equations but often employ different numerical techniques and are applied to different segments of the total problem of tsunami propagation from generation regions to distant areas of runup. For example, several numerical models have been used to simulate the interaction of tsunamis with islands. These models have used finite difference, finite element, and boundary integral methods to solve the linear long wave equations. These models solve these relatively simple equations and provide reasonable simulations of tsunamis for engineering purposes.

Historical data are often very limited for most coastlines. Consequently, numerical modelling may be the only way to estimate potential risk. Techniques now exist to carry out this assessment. Computer software and the training necessary to conduct this modelling are available through programmes such as the IOC Tsunami Inundation Modelling Exchange (TIME) Programme.



*Calculated maximum tsunami wave heights for a M9.0 Cascadia subduction zone earthquake. The model was calculated after tsunami deposits found in Japan and elsewhere suggested that a repeat of the 1700 Cascadia great earthquake would generate a destructive teletsunami. Courtesy of Kenji Satake, Geological Survey of Japan.*



*Complex numerical model calculated to match the 1958 Lituya Bay, Alaska landslide-generated local tsunami which caused the largest runup ever recorded (525 m). The complex model matches very closely the detail of the second order eddies and splash effects that laboratory experiments showed. Courtesy of Galen Gisler, Los Alamos National Laboratory.*

## TSUNAMI OBSERVATION

Notice, observation or measurement of sea level fluctuation at a particular point in time caused by the incidence of a tsunami on a specific point.

*1946 Aleutian Islands tsunami rushing ashore in Hilo, Hawaii. Photo courtesy of Pacific Tsunami Museum.*

## TSUNAMI PREPAREDNESS

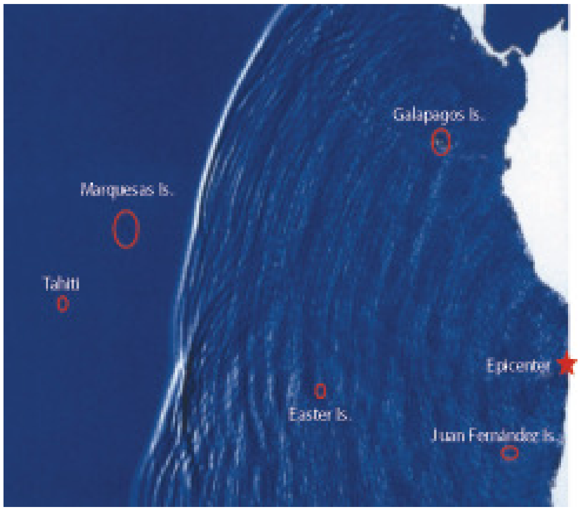
Readiness of plans, methods, procedures and actions taken by government officials and the general public for the purpose of minimizing potential risk and mitigating the effects of future tsunamis. The appropriate preparedness for a warning of impending danger from a tsunami requires knowledge of areas that could be flooded (tsunami inundation maps) and knowledge of the warning system to know when to evacuate and when it is safe to return.

*International tsunami hazard sign.*

*Evacuation Route sign used in Chile. Photo courtesy of ITIC.*

## TSUNAMI PROPAGATION

Tsunamis travel outward in all directions from the generating area, with the direction of the main energy propagation generally being orthogonal to the direction of the earthquake fracture zone. Their speed depends on the depth of water, so that the waves undergo accelerations and decelerations in passing over an ocean bottom of varying depth. In the deep and open ocean, they travel at speeds of 500 to 1,000 km per hour (300 to 600 miles per hour). The distance between successive crests can be as much as 500 to 650 km (300 to 400 miles); however, in the open ocean, the height of the waves is generally less than a meter (three feet) even for the most destructive teletsunamis, and the waves pass unnoticed. Variations in tsunami propagation result when the propagation impulse is stronger in one direction than in others because of the orientation or dimensions of the generating area and where regional bathymetric and topographic features modify both the wave form and rate of advance. Specifically tsunami waves undergo a process of wave refraction and reflection throughout their travel. Tsunamis are unique in that the energy extends through the entire water column from sea surface to the ocean bottom. It is this characteristic that accounts for the great amount of energy propagated by a tsunami.



*Model of tsunami propagation in the southeast Pacific, nine hours after generation. Source: Antofagasta, Chile (30 July 1995). Courtesy of LDG-France.*

## TSUNAMI RESONANCE

The continued reflection and interference of tsunami waves from the edge of a harbour or narrow bay which can cause amplification of the wave heights, and extend the duration of wave activity from a tsunami.

## TSUNAMI RISK

The probability of a particular coastline being struck by a tsunami multiplied by the likely destructive effects of the tsunami and by the number of potential victims. In general terms, risk is the hazard multiplied by the exposure.

## TSUNAMI SIMULATION

Numerical model of tsunami generation, propagation, and inundation.

*Destruction of Hilo Harbor, Hawaii, 1 April 1946. The tsunami generated off the coast of Unimak Island, Aleutian Islands raced across the Pacific, coming ashore in Hawaii less than five hours later. Photo courtesy of NOAA.*

## TSUNAMI SOURCE

Point or area of tsunami origin, usually the site of an earthquake, volcanic eruption, or landslide that caused large-scale rapid displacement of the water to initiate the tsunami waves.

## TSUNAMI VELOCITY OR SHALLOW WATER VELOCITY

The velocity of an ocean wave whose length is sufficiently large compared to the water depth (i.e., 25 or more times the depth) can be approximated by the following expression:

$$c = \sqrt{(gh)}$$

Where:

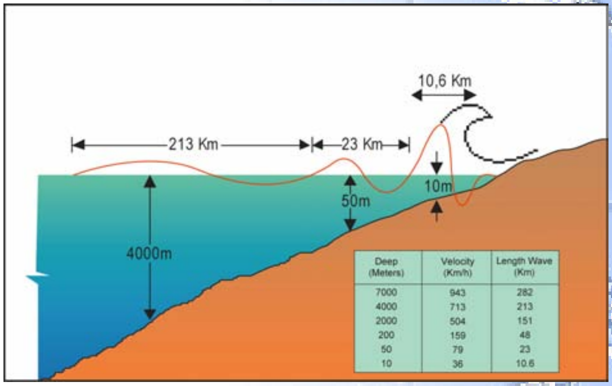
c: is the wave velocity

g: the acceleration of gravity

h: the water depth.

Thus, the velocity of shallow-water waves is independent of wave length L. In water depths between ½ L and 1/25 L it is necessary to use a more precise expression:

$$c = \sqrt{\left( (gL/2\pi)[\tanh(2\pi h/L)] \right)}$$



| Deep (Meters) | Velocity (Km/h) | Length Wave (Km) |
|---|---|---|
| 7000 | 943 | 282 |
| 4000 | 713 | 213 |
| 2000 | 504 | 151 |
| 200 | 159 | 48 |
| 50 | 79 | 23 |
| 10 | 36 | 10.6 |

*Wave height and water depth. In the open ocean, a tsunami is often only a tens of centimeters high, but its wave height grows rapidly in shallow water. Tsunami wave energy extends from the surface to the bottom in the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into a much shorter distance creating destructive, life threatening waves.*

## TSUNAMI ZONATION (TSUNAMI ZONING)

Designation of distinctive zones along coastal areas with varying degrees of tsunami risk and vulnerability for the purpose of disaster preparedness, planning, construction codes, or public evacuation.

## TSUNAMIC

Having features analogous to those of a tsunami or descriptive of a tsunami.

## TSUNAMIGENIC

Having generated a tsunami: a tsunamigenic earthquake, a tsunamigenic landslide.

# 3 SURVEYS AND MEASUREMENTS

*This section contains terms used to measure and describe tsunami waves on mareographs and in the field during a survey, and terms used to describe the size of the tsunami.*

## ARRIVAL TIME

Time of the first maximum of the tsunami waves.

## CREST LENGTH

The length of a wave along its crest. Sometimes called crest width.

## DROP

The downward change or depression in sea level associated with a tsunami, a tide, or some long term climatic effect.

## ELAPSED TIME

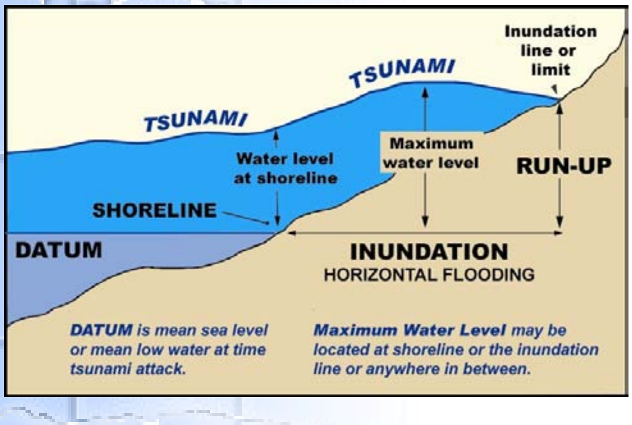
Time between the maximum level arrival time and the arrival time of the first wave.

## INITIAL RISE

Time of the first minimum of the tsunami waves.

## INTENSITY

Extreme strength, force, or energy.



## INUNDATION

The horizontal distance inland that a tsunami penetrates, generally measured perpendicularly to the shoreline.

*Tsunami inundation generated by the earthquake of 26 May 1983, at Oga aquarium in Japan. Photo courtesy of Takaaki Uda. Public Works Research Institute. Japan.*

## 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.

*Dark area shows inundation area from the 1964 Alaska tsunami. Photo courtesy of NGDC.*

## INUNDATION LINE

Inland limit of wetting, measured horizontally from the mean sea level (MSL) line. The line between living and dead vegetation is sometimes used as a reference. In tsunami science, the landward limit of tsunami runup.

## 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.

## MAGNITUDE

A number assigned to a quantity by means of which the quantity may be compared with other quantities of the same class.

## MEAN HEIGHT

Average height of a tsunami measured from the trough to the crest after removing the tidal variation.

## OVERFLOW

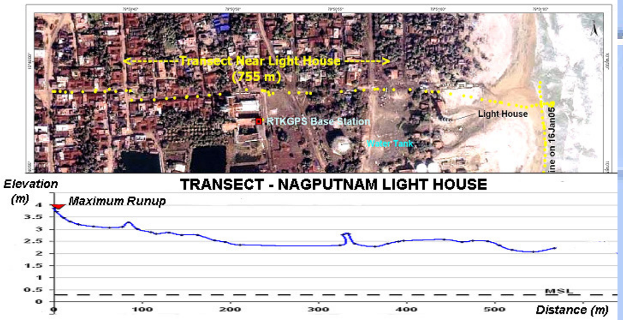
A flowing over; inundation.

## POST-TSUNAMI SURVEY

Tsunamis are relatively rare events and most of their evidence is perishable. Therefore, it is very important that reconnaissance surveys be organized and carried out quickly and thoroughly after each tsunami occurs, to collect detailed data valuable for hazard assessment, model validation, and other aspects of tsunami mitigation.

*After a major tsunami, physical oceanographers, social scientists, and engineers conduct post-tsunami surveys to collect information. These data, including runup and inundation, deformation, scour, building and structural impact, wave arrival descriptions, and social impact, are important for designing better mitigation to reduce the impacts of tsunami on life and property. Photo courtesy of Philip Liu, Cornell University.*

In recent years, following each major destructive tsunami, a post-tsunami reconnaissance survey has been organized to make measurements of runups and inundation limits and to collect associated data from eyewitnesses such as the number of waves, arrival time of waves, and which wave was the largest. The surveys have been organized primarily on an ad-hoc basis by International academic tsunami researchers. A Post-Tsunami Survey Field Guide (http://www.tsunamiwave.info/itic/contents.php?id=28) has been prepared by the PTWS to help with preparations of surveys, to identify measurements and observations to be taken,



*Post-tsunami survey measuring runup along a transect inland from the coast. Courtesy of ICMAM, Chennai, DOD, India.*

and to standardize data collections. The Tsunami Bulletin Board e-mail service has also been used for quickly organizing international surveys and for sharing of the observations from impacted areas.

## RECESSION

Drawdown of sea level prior to tsunami flooding. The shoreline moves seaward, sometimes by a kilometre or more, exposing the sea bottom, rocks, and fish. The recession of the sea is a natural warning sign that a tsunami is approaching.

*North Shore, Oahu, Hawaii. During the 9 March 1957 Aleutian Island tsunami, people foolishly explored the exposed reef, unaware that tsunami waves would return in minutes to inundate the shoreline. Photo by A. Yamauchi, courtesy of Honolulu Star-Bulletin.*

## RISE

The upward change or elevation in sea level associated with a tsunami, a tropical cyclone, storm surge, the tide, or other long term climatic effect.

## RUN-UP

1) Difference between the elevation of maximum tsunami penetration (inundation line) and the sea-level at the time of the tsunami.

2) 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.

3) In practical terms, runup is only measured where there is a clear evidence of the inundation limit on the shore.

*Tsunami stripped forested hills of vegetation leaving clear marker of tsunami runup, Banda Aceh, 26 December 2004 Sumutra tsunami. Photo courtesy of Yuichi Nishimura, Hokkaido University.*

*Runup can often be inferred from the vertical extent of dead vegetation, from debris normally found at ground level that are observed stuck on electric wires, in trees, or at other heights, and from water line marks left on building walls. In extreme cases, cars, boats, and other heavy objects have been lifted and deposited atop buildings. Banda Aceh, Indonesia, 26 December 2004. Photo courtesy of C. Courtney, Tetra Tech EMI.*

## RUN-UP DISTRIBUTION

Set of tsunami run-up values measured or observed along a coastline.

## SIEBERG TSUNAMI INTENSITY SCALE

A descriptive tsunami intensity scale, which was later modified into the Sieberg-Ambraseys tsunami intensity scale described below (Ambraseys 1962).

## MODIFIED SIEBERG SEA-WAVE INTENSITY SCALE

1) Very light. Wave so weak as to be perceptible only on tide-gauge records.

2) Light. Wave noticed by those living along the shore and familiar with the sea. On very flat shores generally noticed.

3) Rather strong. Generally noticed. Flooding of gently sloping coasts. Light sailing vessels or

small boats carried away on shore. Slight damage to light structures situated near the coast. In estuaries reversal of the river flow some distance upstream.

4) Strong. Flooding of the shore to some depth. Light scouring on man-made ground. Embankments and dikes damaged. Light structures near the coasts damaged. Solid structures on the coast injured. Big sailing vessels and small ships carried inland or out to sea. Coasts littered with floating debris.

5) Very strong. General flooding of the shore to some depth. Breakwater walls and solid structures near the sea damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and sea animals. With the exception of big ships all other type of vessels carried inland or out to sea. Big bores in estuary rivers. Harbour works damaged. People drowned. Wave accompanied by strong roar.

6) Disastrous. Partial or complete destruction of man-made structures for some distance from the shore. Flooding of coasts to great depths. Big ships severely damaged. Trees uprooted or broken. Many casualties.

## SIGNIFICANT WAVE HEIGHT

The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period. Also called characteristic wave height.

## SPREADING

When reference is made to tsunami waves, it is the spreading of the wave energy over a wider geographical area as the waves propagate away from the source region. The reason for this geographical spreading and reduction of wave energy with distance traveled, is the sphericity of the earth. The tsunami energy will begin converging again at a distance of 90 degrees from the source. Tsunami waves propagating across a large ocean undergo other changes in configuration primarily due to refraction, but geographical spreading is also very important depending upon the orientation, dimensions and geometry of the tsunami source.

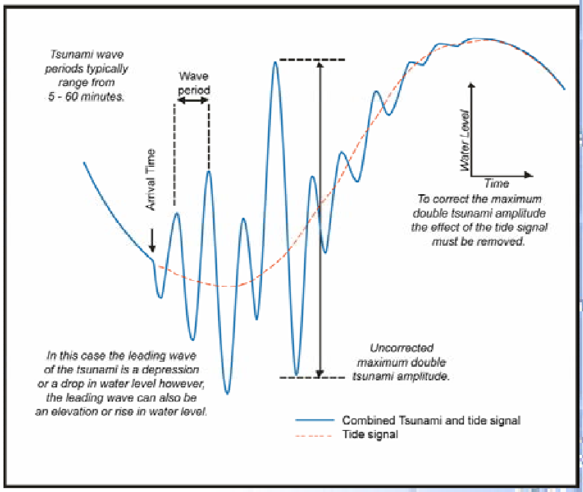
## SUBSIDENCE (UPLIFT)

The permanent movement of land down (subsidence) or up (uplift) due to geologic processes, such as during an earthquake.

*The 26 December 2004 earthquake resulted in 1.2 m of land subsidence in the Car Nicobar, Nicobar Islands, India leaving houses that were once above sea level now permanently submerged. Photo courtesy of ICMAM, Chennai, DOD, India.*

## 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.



*Mareogram (sea level) record of a tsunami*

## TSUNAMI INTENSITY

Size of a tsunami based on the macroscopic observation of a tsunami's effect on humans, objects, including various sizes of marine vessels, and buildings.

The original scale for tsunamis was published by Sieberg (1923), and later modified by Ambraseys (1962) to create a six-category scale. Papadopoulus and Imamura (2001) proposed a new 12-grade intensity scale which is independent of the need to measure physical parameters like wave amplitude, sensitive to the small differences in tsunami effects, and detailed enough for each grade to cover the many possible types of tsunami impact on the human and natural environment. The scale has 12 categories, similar to the Modified Mercalli Intensity Scale used for macroseismic descriptions of earthquake intensity.

## TSUNAMI MAGNITUDE

Size of a tsunami based on the measurement of the tsunami wave on sea level gauges and other instruments.

The scale, originally descriptive and more similar to an intensity, quantifies the size by using measurements of wave height or tsunami runup. Iida et al. (1972) described the magnitude (m) as dependent in logarithmic base 2 on the maximum wave height measured in the field, and corresponding to a magnitude range from -1 to 4:

$$m = \log_2 H_{max}$$

Hatori (1979) subsequently extended this so-called Imamura-Iida scale for far-field tsunamis by including distance in the formulation. Soloviev (1970) suggested that the mean tsunami height may be another good indicator of tsunami size, so that the mean tsunami height is equal to 1/square root (Hmax), and the maximum intensity would be that measured nearest to the tsunami source. A variation on this is the Imamura-Soloviev intensity scale I (Soloviev, 1972). Shuto (1993) has suggested the measurement of H as the height where specific types of impact or damage occur, thus proposing a scale which can be used as a predictive quantitative tool for macroscopic effects.

Tsunami magnitudes have also been proposed that are similar in form to those used to calculate earthquake magnitudes. These include the original formula proposed by Abe (1979) for tsunami magnitude, Mt,

$$Mt = \log H + B$$

where H is the maximum single crest or trough amplitude of the tsunami waves (in metres) and B is a constant, and the far-field application proposed by Hatori (1986) which adds a distance factor into the calculation.

## TSUNAMI PERIOD

Amount of time that a tsunami wave takes to complete a cycle. Tsunami periods typically range from five minutes to two hours.

## TSUNAMI PERIOD (DOMINANT)

Difference between the arrival time of the highest peak and the next one measured on a water level record.

## TSUNAMI WAVE LENGTH

The horizontal distance between similar points on two successive waves measured perpendicular to the crest. The wave length and the tsunami period give information on the tsunami source. For tsunamis generated by earthquakes, the typical wave length ranges from 20 to 300 km. For tsunamis generated by landslides, the wave length is much shorter, ranging from hundreds of metres to tens of kilometres.

## WATER LEVEL (MAXIMUM)

Difference between the elevation of the highest local water mark and the elevation of the sea-level at the time of the tsunami. This is different from maximum run-up because the water mark is often not observed at the inundation line, but maybe halfway up the side of a building or on a tree trunk.

## WAVE CREST

1) The highest part of a wave.

2) That part of the wave above still water level.

## WAVE TROUGH

The lowest part of a wave.

# 4 TIDE, MAREOGRAPH, SEA LEVEL

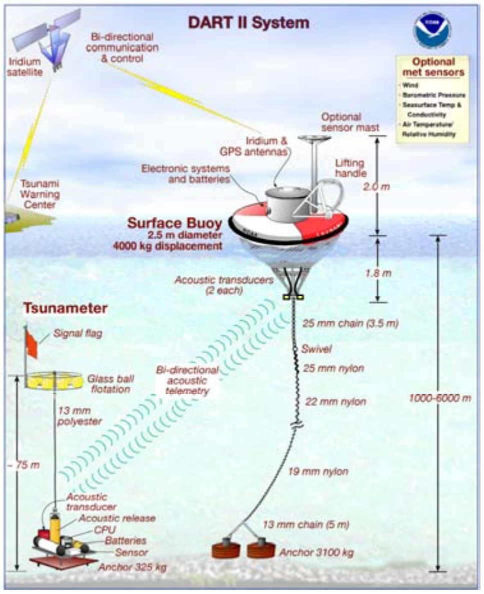
*This section contains terms to describe sea level and the instruments used to measure tsunamis.*

## COTIDAL

Indicating equality with the tides or a coincidence with the time of high or low tide.

## DEEP-OCEAN ASSESSMENT AND REPORTING OF TSUNAMIS (DART)

An instrument for the early detection, measurement, and real-time reporting of tsunamis in the open ocean. Developed by the US NOAA Pacific Marine Environmental Laboratory, the DART system consists of a seafloor bottom pressure recording system capable of detecting tsunamis as small as one cm, and a moored surface buoy for real-time communications. An acoustic link is used to transmit data from the seafloor to the surface buoy. The data are then relayed via a satellite link to ground stations, which demodulate the signals for immediate dissemination to the NOAA tsunami warnings centres. The DART data, along with state-of-the-art numerical modelling technology, are part of a tsunami forecasting system package that will provide site-specific predictions of tsunami impact on the coast.



## LOW WATER

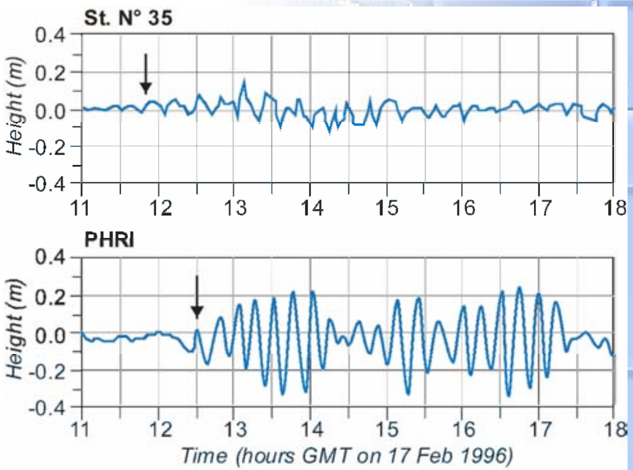
The lowest water level reached during a tide cycle. The accepted popular term is low tide.

## MAREOGRAM OR MARIGRAM

1) Record made by a marigraph.

2) Any graphic representation of the rise and fall of the sea level, with time as abscissa and height as ordinate, usually used to measured tides, may also show tsunamis.

### 2/17/96
### IRIAN JAYA TSUNAMI



*Mareograms of tsunami signals measured by an underwater gauge located 50 km outside the entrance to Tokyo Bay in about 50 m of water (upper trace), and another gauge located at the shore (lower trace). The tsunami is detected on the outside gauge about 40 minutes before it reaches shore (arrows). The offshore gauge was developed by Japan's Port and Harbours Research Institute.*

## MAREOGRAPH

A recording tide gauge.

## MEAN SEA LEVEL

The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free open coast or in adjacent waters which have free access to the sea. These observations are to have been made over a “considerable” period of time. In the United States, mean sea level is defined as the average height of the surface of the sea for all stages of the tide over a 19-year period. Selected values of mean sea level serve as the sea level datum for all elevation surveys in the United States. Along with mean high water, mean low water, and mean lower low water, mean sea level is a type of tidal datum.

## PROBABLE MAXIMUM WATER LEVEL

A hypothetical water level (exclusive of wave runup from normal wind-generated waves) that might result from the most severe combination of hydrometeorological, geoseismic and other geophysical factors that is considered reasonably possible in the region involved, with each of these factors considered as affecting the locality in a maximum manner. This level represents the physical response of a body of water to maximum applied phenomena such as hurricanes, moving squall lines, other cyclonic meteorological events, tsunamis, and astronomical tide combined with maximum probable ambient hydrological conditions such as wave level with virtually no risk of being exceeded.

## REFERENCE SEA LEVEL

The observed elevation differences between geodetic bench marks are processed through least-squares adjustments to determine orthometric heights referred to a common vertical reference surface, which is the reference sea level. In this way, height values of all bench marks in the vertical control portion of a surveying agency are made consistent and can be compared directly to determine differences of elevation between bench marks in a geodetic reference system that may not be directly connected by lines of geodetic leveling. The vertical reference surface in use in the United States, as in most parts of the world, approximates the geoid. The geoid was assumed to be coincident with local mean sea level at 26 tidal stations to obtain the Sea Level Datum of 1929 (SLD 290). National Geodetic Vertical Datum of 1929 (NGVD 29) became a name change only; the same vertical reference system has been in use in the United States since 1929. This important vertical geodetic control system is made possible by a universally accepted, reference sea level.

## REFRACTION DIAGRAMS

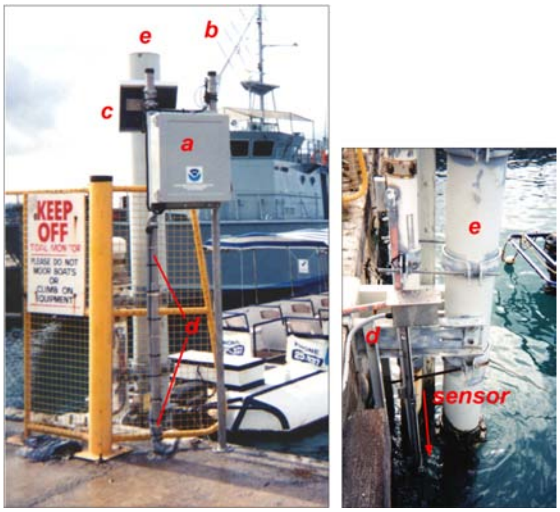
Models using water depths, direction of wave, separation angle, and ray separation between two adjacent rays as input, produce the path of wave orthogonals, refraction coefficients, wave heights, and travel times.

## SEA LEVEL

The height of the sea at a given time measured relative to some datum, such as mean sea level.

## SEA LEVEL STATION

A system consisting of a device such as a tide gauge for measuring the height of sea level, a data collection platform (DCP) for acquiring, digitizing, and archiving the sea level information digitally, and often a transmission system for delivering the data from the field station to a central data collection centre. The specific requirements of data sampling and data transmission are dependent on the application. The GLOSS programme maintains a core network of sea level stations. For local tsunami monitoring, one-second sampled data streams available in real time are required. For distant tsunamis, warning centres may be able to provide adequate warnings using data acquired in near-real time (one-minute sampled data transmitted every 15 minutes). Sea level stations are also used for sea level rise and climate change studies, where an important requirement is for the very accurate location of the station as acquired through surveying techniques.



*Rarotonga sea level station, Avarua Harbor, Cook Islands. The fiberglass electronics package (a), antenna (b), solar panel (c) were installed on a pier. Conduit (d) containing cables connecting the sensor, located at a depth of five feet below low-tide water level, to the data collection platform containing the electronics above, was externally attached to the tube containing the sensor (e).*

## TIDAL WAVE

1. The wave motion of the tides.

2. Often incorrectly used to describe a tsunami, storm surge, or other unusually high and therefore destructive water levels along a shore that are unrelated to the tides.

## TIDE

The rhythmic, alternate rise and fall of the surface (or water level) of the ocean, and of bodies of water connected with the ocean such as estuaries and gulfs, occurring twice a day over most of the Earth and resulting from the gravitational attraction of the moon (and, in lesser degrees, of the sun) acting unequally on different parts of the rotating Earth.

## TIDE AMPLITUDE

One-half of the difference in height between consecutive high water and low water; hence, half of the tidal range.

## TIDE GAUGE

A device for measuring the height (rise and fall) of the tide. Especially an instrument for automatically making a continuous graphic record of tide height versus time.

## TIDE STATION

A place where tide observations are obtained.

## TSUNAMETER

An instrument for the early detection, measurement, and real-time reporting of tsunamis in the open ocean. The DART system is a tsunameter.

*GLOSS sea level stations employ a number of instruments to measure sea level, including down-looking radars to measure sea level. Port Louis, Mauritius. Photo courtesy of University of Hawaii Sea Level Center.*

# 5 ACRONYMS & ITSU ORGANIZATIONS

*The IOC Global Tsunami Warning and Mitigation Systems work in partnership with a number of organizations and utilize specific acronyms to describe system governance, and the different tsunami information products.*

### COMMUNICATIONS PLAN FOR THE TSUNAMI WARNING SYSTEM

The operations manual for the Tsunami Warning System in various regions. The Plan provides a general overview of the operational procedures and of the nature of tsunamis. It lists the seismographic and sea level stations participating in the warning system, the methods of communication between the stations and the Warning Centre, the criteria for the reporting and issuing of tsunami information messages by the Warning Centre, the recipients of the information, and the methods by which the messages are sent. Official contact information for emergency communications is included.

### FORECAST POINT

The location where the Tsunami Warning Centre may provide estimates of tsunami arrival time or wave height.

### GLOSS

Global Sea-Level Observing System. A component of the Global Ocean Observing System (GOOS). The UNESCO IOC established GLOSS in 1985 originally to improve the quality of sea level data as input to studies of long-term sea level change. It consists of a core network of approximately 300 stations distributed along continental coastlines and throughout each of the world's island groups. The GLOSS network also supports sea level monitoring for tsunami warning with minimum operational standards of 15-minute data transmissions of 1-minute sampled data.

### GOOS

Global Ocean Observing System. GOOS is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. The GOOS Project aims to provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change. The GOOS Project Office, located at the IOC headquarters in Paris since 1992, provides assistance in the implementation of GOOS.

### GTS

Global Telecommunications System of the World Meteorological Organization (WMO) that directly connects national meteorological and hydrological services worldwide. The GTS is widely used for the near real time transmission of sea level data for tsunami monitoring. The GTS and other robust communications methods are used for the transmission of tsunami warnings.

### ICG

Intergovernmental Coordination Group. As subsidiary bodies of the UNESCO IOC, the ICG meets to promote, organize, and coordinate regional tsunami mitigation activities, including the issuance of timely tsunami warnings. The ICG is composed of National Contacts from Member States in the region. Currently, there are ICG for tsunami warning and mitigation systems in the Pacific, Indian Ocean, Caribbean and adjacent regions, and the north-eastern Atlantic, the Mediterranean and connected seas.

## ICG/CARIBE-EWS

Intergovernmental Coordination Group for Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions established by Resolution XXIII-14 of the 23rd Session of the IOC General Assembly in 2005. The ICG is comprised principally of IOC Member States and regional organizations from the Wider Caribbean Region. Through the coordinating efforts of the IOCARIBE Sub-commission starting in 1993, a Group of Experts formulated a proposal for the building of the Intra-Americas Tsunami Warning System that was endorsed by the IOC General Assembly in 2002. (*http://ioc3.unesco.org/cartws*)

## ICG/IOTWS

Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System established by Resolution XXIII-12 of the 23rd Session of the IOC General Assembly in 2005. The IOC Regional Programme Office in Perth, Australia, serves as the IOTWS Secretariat. Presently, there are 27 Member States. (*http://ioc.unesco.org/indotsunami*)

## ICG/ITSU

International Coordination Group for the International Tsunami Warning System in the Pacific established by Resolution IV-6 of the 4th Session of the IOC General Assembly in 1965. The ICG/ITSU was renamed to the ICG/PTWS in 2005. (*http://www.tsunamiwave.info*)

## ICG/NEAMTWS

Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas established by Resolution XXIII-13 of the 23rd Session of the IOC General Assembly in 2005. The ICG is comprised principally of IOC Member States bordering the north-eastern Atlantic and those bordering or within the Mediterranean or connected seas. (*http://ioc3.unesco.org/neamtws*)

## ICG/PTWS

Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System, renamed by Resolution ITSU-XX.1 of the 20th Session of the ICG/ITSU in 2005. Presently, there are 28 Member States. The ICG/PTWS was formerly the ICG/ITSU. The ITIC in Honolulu serves as the PTWS Secretariat. (*http://ioc3.unesco.org/ptws*)

## ICG TSUNAMI WARNING FOCAL POINT (TWFP)

7x24 contact person, or other official point of contact or address, for rapidly receiving and issuing tsunami event information (such as warnings). The Tsunami Warning Focal Point has the responsibility of notifying the emergency authority (civil defense or other designated agency responsible for public safety) of the event characteristics (earthquake and/or tsunami), in accordance with the procedures of the Tsunami Response Plan. The Tsunami Warning Focal Point receives international tsunami warnings from the PTWC, NWPTAC, or other regional warning centres.

## ICG TSUNAMI NATIONAL CONTACT (TNC)

The person designated by an ICG Member State government to represent his/her country in the coordination of international tsunami warning and mitigation activities. The person is part of the main stakeholders of the national tsunami warning and mitigation system programme. The person may be the Tsunami Warning Focal Point, from the national disaster management organization, from a technical or scientific institution, or from another agency with tsunami warning and mitigation responsibilities.

## IOC

Intergovernmental Oceanographic Commission of UNESCO. The IOC provides Member States of the United Nations with an essential mechanism for global cooperation in the study of the ocean. The IOC assists governments to address their individual and collective ocean and coastal problems through the sharing of knowledge, information and technology and through the coordination of national programmes. (*http://ioc.unesco.org/iocweb/index.php*)

## ITIC

International Tsunami Information Centre. ITIC was established in November 1965 by the IOC of UNESCO. In 1968, the IOC first convened the ICG/ITSU to coordinate tsunami warning and mitigation activities in the Pacific. The ITIC serves as the PTWS Secretariat. Additionally, the ITIC provides technical and capacity building assistance to Member States for the global establishment of tsunami warning and mitigation systems in the Indian and Atlantic Oceans, the Caribbean and Mediterranean Seas, and other oceans and marginal seas. In the Pacific, the ITIC specifically monitors and recommends improvements to the PTWS, coordinates tsunami technology transfer among Member States interested in establishing regional and national tsunami warning systems, acts as a clearinghouse for risk assessment and mitigation activities, and serves as a resource for the development, publication, and distribution of tsunami education and preparedness materials.
(*http://www.tsunamiwave.info*)

## IUGG

International Union of Geodesy and Geophysics. The IUGG is a non-governmental, scientific organization established in 1919, dedicated to promoting and coordinating studies of the Earth and its environment in space. The IUGG Tsunami Commission, established in 1960, is an international group of scientists concerned with various aspects of tsunamis, including an improved understanding of the dynamics of generation, propagation, and coastal runup of tsunami, as well as their consequences to society. (*http://iugg.org*)

## JMA

Japan Meteorological Agency. JMA established a tsunami warning service in 1952. JMA now serves as a National Tsunami Warning System that continuously monitors 24 hours-a-day all seismic activity in Japan, and issues timely information concerning earthquakes and tsunamis. In 2005, the JMA began operations of the Northwest Pacific Tsunami Advisory Center (NWPTAC). The NWPTAC provides supplementary tsunami information for events in and around Japan and the northwest Pacific in close coordination with the PTWC.
*(http://www.jma.go.jp/jma)*

## MASTER PLAN

The principal long-term guide for improving the TWS. The Plan provides a summary of the basic elements which comprise the TWS, a description of its existing components, and an outline of the activities, data sets, methods, and procedures that need to be improved in order to reduce tsunami risk. The first edition of the ICG/PTWS Master Plan was released in 1989. The second edition was released in 1999.
(*http://ioc3.unesco.org/itic/categories.php?category_no=64*)

## OCEAN-WIDE TSUNAMI WARNING

A warning issued to all participants after there is confirmation of tsunami waves capable of causing destruction beyond the local area. Ocean-Wide Tsunami Warnings contain estimated tsunami arrival times (ETAs) at all Forecast Points. Ocean-Wide Tsunami Warning Bulletins also normally carry information on selected wave heights and other wave reports. The Warning will be cancelled when it is determined that the tsunami threat is over. As local conditions can cause wide variations in tsunami wave action, the all-clear determination should be made by the local action agencies and not the TWC. In general, after receipt of a Tsunami Warning, action agencies can assume all-clear status when their area is free from damaging waves for at least two hours, unless additional ETAs have been announced by the TWC (for example for a significant aftershock) or local conditions, that may include continued seiching or particularly strong currents in channels and harbours, warrant the continuation of the Tsunami Warning status.

**SAMPLE: Pacific-Wide Tsunami Warning (initial)**

TSUNAMI BULLETIN NUMBER 004
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 2119Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT
ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON - CALIFORNIA.

... A PACIFIC-WIDE TSUNAMI WARNING IS IN EFFECT ...

THIS WARNING IS FOR ALL COASTAL AREAS AND ISLANDS IN THE PACIFIC.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 1804Z 25 FEB 2005
COORDINATES - 52.3 NORTH 160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE - 8.8
MEASUREMENTS OR REPORTS OF TSUNAMI WAVE ACTIVITY

```
 GAUGE
 LOCATION      LAT     LON    TIME    AMPL   PER
 -------------------------------------------------------------------
NIKISKI         60.7N  151.4W  0057Z   0.52M  **MIN
SEVERO KURILSK
                50.7N   156.1E  2042Z   0.12M  64MIN
```

TIME - TIME OF THE MEASUREMENT
AMPL - AMPLITUDE IN METERS FROM MIDDLE TO CREST OR MIDDLE TO TROUGH OR HALF OF THE CREST TO TROUGH
PER - PERIOD OF TIME FROM ONE WAVE CREST TO THE NEXT

EVALUATION

SEA LEVEL READINGS CONFIRM THAT A TSUNAMI HAS BEEN GENERATED WHICH COULD CAUSE WIDESPREAD DAMAGE TO COASTS AND ISLANDS IN The PACIFIC. AUTHORITIES SHOULD TAKE APPROPRIATE ACTION IN RESPONSE TO THIS THREAT. THIS CENTER WILL CONTINUE TO MONITOR SEA LEVEL DATA TO DETERMINE THE EXTENT AND SEVERITY OF THE THREAT.

A TSUNAMI IS A SERIES OF WAVES AND THE FIRST WAVE MAY NOT BE THE LARGEST. TSUNAMI WAVE HEIGHTS CANNOT BE PREDICTED AND CAN VARY SIGNIFICANTLY ALONG A COAST DUE TO LOCAL EFFECTS. THE TIME FROM ONE TSUNAMI WAVE TO THE NEXT CAN BE FIVE MINUTES TO AN HOUR, AND THE THREAT CAN CONTINUE FOR MANY HOURS AS MULTIPLE WAVES ARRIVE.

FOR ALL AREAS - WHEN NO MAJOR WAVES ARE OBSERVED FOR TWO HOURS AFTER THE ESTIMATED TIME OF ARRIVAL OR DAMAGING WAVES HAVE NOT OCCURRED FOR AT LEAST TWO HOURS THEN LOCAL AUTHORITIES CAN ASSUME THE THREAT IS PASSED. DANGER TO BOATS AND COASTAL STRUCTURES CAN CONTINUE FOR SEVERAL HOURS DUE TO RAPID CURRENTS. AS LOCAL CONDITIONS CAN CAUSE A WIDE VARIATION IN TSUNAMI WAVE ACTION THE ALL CLEAR DETERMINATION MUST BE MADE BY LOCAL AUTHORITIES.

BULLETINS WILL BE ISSUED HOURLY OR SOONER IF CONDITIONS WARRANT.

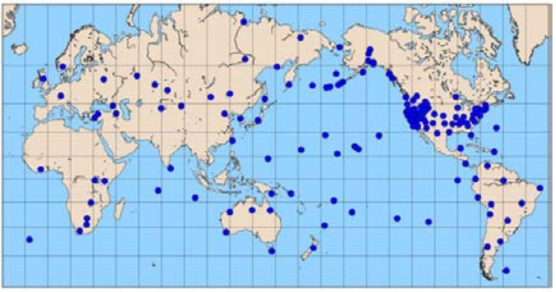
## PTWC

Established in 1949, the Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii, acts as the operational headquarters for the PTWS and works closely with other sub-regional and national centres in monitoring and evaluating potentially tsunamigenic earthquakes. It provides international warnings for teletsunamis to countries in the Pacific Basin as well as to Hawaii and all other US interests in the Pacific outside of Alaska. The West Coast and Alaska Tsunami Warning Center (WC/ATWC) provides services to the Gulf of Mexico and Atlantic coasts of the USA, and to the west and east coasts of Canada. PTWC is also the warning centre for Hawaii's local and regional tsunamis. In 2005, the PTWC and JMA began providing interim advisory services to the Indian Ocean. The PTWC also assists Puerto Rico and the US Virgin Islands with advisory information, and the WC/ATWC provides services to the west and east coasts of Canada.

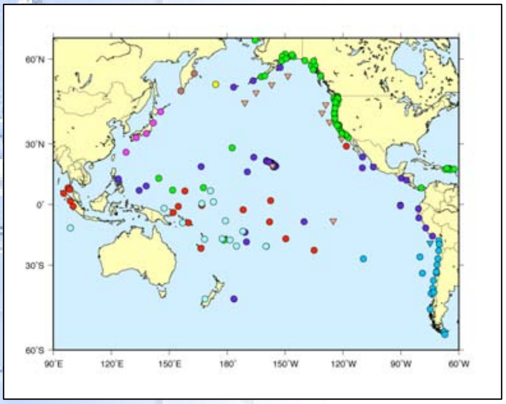
*PTWC facilities located at Ewa Beach, Hawaii, USA.*

*PTWC operations area.*

The operational objective of the PTWC is to detect and locate major earthquakes in the region, to determine if tsunamis were generated, and to provide timely tsunami warnings to national authorities. To achieve this objective, the PTWC continuously monitors seismic activity and sea levels, and disseminates information messages through a variety of communications methods. The PTWC and the WC/ATWC are operated by the US NOAA National Weather Service. *(http://www.prh.noaa.gov/ptwc)* *(http://wcatwc.arh.noaa.gov/)*



*Global seismic network used by PTWC to monitor seismicity.*



*Sea level network used by PTWC to monitor Pacific sea levels. Circles show coastal sea level stations and triangles show NOAA DART systems. Colors indicate responsible agency: PTWC (dark blue), NOAA National Ocean Service (green), Univ of Hawaii Sea Level Center (red), SHOA (blue green), JMA (pink), Russian Hydromet (brown), Australia National Tidal Center (light blue), WC/ATWC (yellow), NOAA National Data Buoy Center (orange).*

## PTWS

Pacific Tsunami Warning System. The PTWS is an international programme for coordination of tsunami warning and mitigation activities in the Pacific. Administratively, participating nations are organized under the IOC as the ICG/PTWS with the ITIC acting as the PTWS Secretariat and the PTWC acting as the operational headquarters for tsunami warning. Among the most important activities of the PTWS is the detection and location of major earthquakes in the Pacific region, the determination of whether they have generated tsunamis, and the provision of timely and effective tsunami information and warnings to coastal communities in the Pacific to minimize the hazards of tsunamis, especially to human life and welfare. To achieve this objective requires the national participation and contribution of many seismic, sea level, communication, and dissemination facilities throughout the Pacific Region.

## REGIONAL EXPANDING TSUNAMI WATCH/WARNING BULLETIN (RWW)

A message issued initially using only seismic information to alert countries of the possibility of a tsunami and advise that a tsunami investigation is underway. In the Pacific, Tsunami Warning status will encompass regions having less than three hours until the estimated time of tsunami arrival. Those areas having three to six hours will be placed in a Watch status. Additional bulletins will be issued hourly or sooner until either a Pacific-wide tsunami is confirmed or no further tsunami threat exists.

**SAMPLE: Expanding Regional Tsunami Warning and Watch (initial)**

TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 1819Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON - CALIFORNIA.

... A TSUNAMI WARNING AND WATCH ARE IN EFFECT ...

A TSUNAMI WARNING IS IN EFFECT FOR

RUSSIA / JAPAN / MARCUS IS. / MIDWAY IS. / WAKE IS. / N. MARIANAS / MARSHALL IS. / GUAM / HAWAII / JOHNSTON IS. / CHUUK / POHNPEI / TAIWAN / KOSRAE / YAP / PHILIPPINES / BELAU / NAURU / KIRIBATI / SAMOA / AMERICAN SAMOA / FIJI / MEXICO / HONG KONG / NEW CALEDONIA / COOK ISLANDS / FR. POLYNESIA

A TSUNAMI WATCH IS IN EFFECT FOR

NEW ZEALAND / EL SALVADOR / NICARAGUA

FOR ALL OTHER PACIFIC AREAS, THIS MESSAGE IS AN ADVISORY ONLY.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 1804Z 25 FEB 2005
COORDINATES - 52.3 NORTH 160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE - 8.1

EVALUATION

IT IS NOT KNOWN THAT A TSUNAMI WAS GENERATED. THIS WARNING IS BASED ONLY ON THE EARTHQUAKE EVALUATION. AN EARTHQUAKE OF THIS SIZE HAS THE POTENTIAL TO GENERATE A DESTRUCTIVE TSUNAMI THAT CAN STRIKE COASTLINES NEAR THE EPICENTER WITHIN MINUTES AND MORE DISTANT COASTLINES WITHIN HOURS. AUTHORITIES SHOULD TAKE APPROPRIATE ACTION IN RESPONSE TO THIS POSSIBILITY. THIS CENTER WILL MONITOR SEA LEVEL DATA FROM GAUGES NEAR THE EARTHQUAKE TO DETERMINE IF A TSUNAMI WAS GENERATED AND ESTIMATE THE SEVERITY OF THE THREAT.

ESTIMATED INITIAL TSUNAMI WAVE ARRIVAL TIMES. ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST. THE TIME BETWEEN SUCCESSIVE TSUNAMI WAVES CAN BE FIVE MINUTES TO ONE HOUR.

**SAMPLE: Expanding Regional Tsunami Warning and Watch (cancellation)**

TSUNAMI BULLETIN NUMBER 003
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 2019Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT
ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON - CALIFORNIA.

... TSUNAMI WARNING AND WATCH CANCELLATION ...

THE TSUNAMI WARNING AND WATCH ARE CANCELLED FOR ALL COASTAL AREAS AND ISLANDS IN THE PACIFIC.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 1804Z 25 FEB 2005
COORDINATES - 52.3 NORTH 160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE - 8.1

MEASUREMENTS OR REPORTS OF TSUNAMI WAVE ACTIVITY

```
 GAUGE
 LOCATION      LAT    LON    TIME    AMPL  PER
 ----------------------------------------------------------------------
NIKISKI          60.7N  151.4W  0057Z   0.52M  **MIN
SEVERO KURILSK
                 50.7N  156.1E  2042Z   0.12M  64MIN
 TIME - TIME OF THE MEASUREMENT
 AMPL - AMPLITUDE IN METERS FROM MIDDLE
          TO CREST OR MIDDLE TO TROUGH OR
          HALF OF THE CREST TO TROUGH
PER  - PERIOD OF TIME FROM ONE WAVE
         CREST TO THE NEXT
```

EVALUATION

SEA LEVEL READINGS INDICATE A TSUNAMI WAS GENERATED. IT MAY HAVE BEEN DESTRUCTIVE ALONG COASTS NEAR THE EARTHQUAKE EPICENTER. FOR THOSE AREAS WHEN NO MAJOR WAVES ARE OBSERVED FOR TWO HOURS AFTER THE ESTIMATED TIME OF ARRIVAL OR DAMAGING WAVES HAVE NOT OCCURRED FOR AT LEAST TWO HOURS THEN LOCAL AUTHORITIES CAN ASSUME THE THREAT IS PASSED. DANGER TO BOATS AND COASTAL STRUCTURES CAN CONTINUE FOR SEVERAL HOURS DUE TO RAPID CURRENTS. AS LOCAL CONDITIONS CAN CAUSE A WIDE VARIATION IN TSUNAMI WAVE ACTION THE ALL CLEAR DETERMINATION MUST BE MADE BY LOCAL AUTHORITIES.

NO TSUNAMI THREAT EXISTS FOR OTHER COASTAL AREAS IN THE PACIFIC ALTHOUGH SOME OTHER AREAS MAY EXPERIENCE SMALL SEA LEVEL CHANGES FOR ALL AREAS THE TSUNAMI WARNING AND TSUNAMI WATCH ARE CANCELLED.

THIS WILL BE THE FINAL BULLETIN ISSUED FOR THIS EVENT UNLESS ADDITIONAL INFORMATION BECOMES AVAILABLE.

## REGIONAL FIXED TSUNAMI WARNING BULLETIN

A message issued initially using only seismic information to alert all participants of the possibility of a tsunami and advise that a tsunami investigation is underway. The area placed in a Tsunami Warning status encompasses coastal regions within 1000-km of the earthquake epicenter. A Regional Fixed Tsunami Warning will be followed by additional bulletins without expanding the warning area until it is either upgraded or is canceled.

**SAMPLE: Fixed Regional Tsunami Warning (initial)**

TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING
CENTER/NOAA/NWS
ISSUED AT 1819Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON CALIFORNIA.

... A TSUNAMI WARNING IS IN EFFECT ...

A TSUNAMI WARNING IS IN EFFECT FOR RUSSIA

FOR ALL OTHER PACIFIC AREAS, THIS MESSAGE IS AN ADVISORY ONLY.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 1804Z 25 FEB 2005
COORDINATES - 52.3 NORTH 160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE - 7.7

EVALUATION

IT IS NOT KNOWN THAT A TSUNAMI WAS GENERATED. THIS WARNING IS BASED ONLY ON THE EARTHQUAKE EVALUATION. AN EARTHQUAKE OF THIS SIZE HAS THE POTENTIAL TO GENERATE A DESTRUCTIVE TSUNAMI THAT CAN STRIKE COASTLINES IN THE REGION NEAR THE EPICENTER WITHIN MINUTES TO HOURS. AUTHORITIES IN THE REGION SHOULD TAKE APPROPRIATE ACTION IN RESPONSE TO THIS POSSIBILITY. THIS CENTER WILL MONITOR SEA LEVEL GAUGES NEAREST THE REGION AND REPORT IF ANY TSUNAMI WAVE ACTIVITY IS OBSERVED. THE WARNING WILL NOT EXPAND TO OTHER AREAS OF THE PACIFIC UNLESS ADDITIONAL DATA ARE RECEIVED TO WARRANT SUCH AN EXPANSION.

ESTIMATED INITIAL TSUNAMI WAVE ARRIVAL TIMES. ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST. THE TIME BETWEEN SUCCESSIVE TSUNAMI WAVES CAN BE FIVE MINUTES TO ONE HOUR.

| LOCATION | COORDINATES | ARRIVAL TIME |
|---|---|---|
| RUSSIA | | |
| PETROPAVLOVSK-K | 52.9N 158.3E | 1926Z 25 FEB |
| UST KAMCHATSK | 56.2N 162.5E | 1943Z 25 FEB |
| MEDNNY IS | 54.6N 167.6E | 1946Z 25 FEB |
| SEVERO KURILSK | 50.6N 156.3E | 2000Z 25 FEB |
| URUP IS | 45.9N 150.2E | 2031Z 25 FEB |

BULLETINS WILL BE ISSUED HOURLY OR SOONER IF CONDITIONS WARRANT.

THE TSUNAMI WARNING WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE.

**SAMPLE: Fixed Regional Tsunami Warning (cancellation)**

TSUNAMI BULLETIN NUMBER 003
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 2019Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON - CALIFORNIA.

... TSUNAMI WARNING CANCELLATION ...

THE TSUNAMI WARNING IS CANCELLED FOR ALL COASTAL AREAS AND ISLANDS IN THE PACIFIC.
AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 1804Z 25 FEB 2005
COORDINATES - 52.3 NORTH 160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE - 7.7

MEASUREMENTS OR REPORTS OF TSUNAMI WAVE ACTIVITY

| GAUGE LOCATION | LAT | LON | TIME | AMPL | PER |
|---|---|---|---|---|---|
| NIKISKI | 60.7N | 151.4W | 0057Z | 0.52M | **MIN |
| SEVERO KURILSK | 50.7N | 156.1E | 2042Z | 0.12M | 64MIN |

## TSUNAMI BULLETIN BOARD (TBB)

TBB is an ITIC-sponsored e-mail service that provides an open, objective scientific forum for the posting and discussion of news and information relating to tsunamis and tsunami research. The ITIC provides the service to tsunami researchers and other technical professionals for the purpose of facilitating the widespread dissemination of information on tsunami events, current research investigations, and announcements for upcoming meetings, publications, and other tsunami-related materials. All members of the TBB are welcome to contribute. Messages are immediately broadcast without modification. The TBB has been very useful for helping to rapidly organize post-tsunami surveys, for distributing their results, and for planning tsunami workshops and symposia. Members of the TBB automatically receive the tsunami bulletins issued by the PTWC, WC/ATWC, and JMA.

## TSUNAMI INFORMATION BULLETIN (TIB)

TWC message product advising the occurrence of a major earthquake wth an evaluation that there is either:  a) no widespread tsunami threat but the small possibility of a local tsunami or b) there is no tsunami threat at all hat indicates there is no tsunami threat.

**SAMPLE:  Tsunami Information Bulletin (shallow undersea event)**

TSUNAMI BULLETIN NUMBER 001

PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS

ISSUED AT 1819Z 25 FEB 2005

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT ALASKA - BRITISH COLUMBIA - WASHINGTON - OREGON - CALIFORNIA.

... TSUNAMI INFORMATION BULLETIN ...

THIS MESSAGE IS FOR INFORMATION ONLY. THERE IS NO TSUNAMI WARNING OR WATCH IN EFFECT.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME -  1804Z 25 FEB 2005
COORDINATES -  52.3 NORTH  160.7 EAST
LOCATION - OFF EAST COAST OF KAMCHATKA
MAGNITUDE   -  6.7

EVALUATION

NO DESTRUCTIVE PACIFIC-WIDE TSUNAMI THREAT EXISTS BASED ON HISTORICAL EARTHQUAKE AND TSUNAMI DATA.

HOWEVER - EARTHQUAKES OF THIS SIZE SOMETIMES GENERATE LOCAL TSUNAMIS THAT CAN BE DESTRUCTIVE ALONG COASTS LOCATED WITHIN A HUNDRED KILOMETERS OF THE EARTHQUAKE EPICENTER. AUTHORITIES IN THE REGION OF THE EPICENTER SHOULD BE AWARE OF THIS POSSIBILITY AND TAKE APPROPRIATE ACTION.

THIS WILL BE THE ONLY BULLETIN ISSUED FOR THIS EVENT UNLESS ADDITIONAL INFORMATION BECOMES AVAILABLE.

## TSUNAMI RESPONSE PLAN (TRP)

The Tsunami Response Plan describes the actions taken to ensure public safety by responsible agencies after notification by the Tsunami Warning Focal Point (TWFP), typically the national Tsunami Warning Centre. It includes Standard Operating Procedures and Protocols for emergency response and action, organizations and individuals involved and their roles and responsibilities, contact information, timeline and urgency assigned to action, and means by which both ordinary citizens and special needs populations (physically or mentally handicapped, elderly, transient, and marine populations) will be alerted.  For tsunami response, emphasis is placed on the rapidness, efficiency, conciseness, and clarity of the actions and instructions to the public.  A Tsunami Response Plan should also include post-tsunami actions and responsibilities for search and rescue, relief, rehabilitation, and recovery.

## TSUNAMI WARNING

The highest level of tsunami alert. Warnings are issued by the TWCs due to confirmation of a destructive tsunami wave or the threat of an imminent tsunami. Initially the warnings are based only on seismic information without tsunami confirmation as a means of providing the earliest possible alert to at-risk populations. Warnings initially place a restricted area in a condition that requires all coastal areas in the region to be prepared for imminent flooding. Subsequent text products are issued at least hourly or as conditions warrant to continue, expand, restrict, or end the warning.  In the event a tsunami has been confirmed which could cause damage at distances greater than 1000 km from the epicenter, the warning may be extended to a larger area.

## TSUNAMI WARNING CENTRE (TWC)

Centre that issues timely tsunami information messages.  The messages can be information, watch, or warning messages, and are based on the available seismological and sea level data as evaluated by the TWC, or on evaluations received by the TWC from other monitoring agencies. The messages are advisory to the official designated emergency response agencies. Regional TWC monitor and provide tsunami information to Member States on potential ocean-wide tsunamis using global data networks, and can often issue messages within 20 minutes of the earthquake. Local TWC monitor and provide tsunami information on potential local tsunamis that will strike within minutes. Local TWC must have access to continuous, real-time, densely-spaced data networks in order to characterize the earthquakes within seconds and issue a warning within minutes.

An example of a Regional Tsunami Warning Centre is the Pacific Tsunami Warning Center which provides international tsunami warnings to the Pacific. After the 26 December 2005 tsunami, the PTWC and JMA has acted as an Interim Regional TWC for the Indian Ocean.

Examples of sub-regional TWC are the NWPTAC operated by the Japan JMA, WC/ATWC operated by the USA NOAA NWS, and CPPT operated by France. These centres, along with Russia and Chile, also act as national TWC providing local tsunami warnings for their countries.

## TSUNAMI WARNING CENTRE PRODUCTS

Tsunami Warning Centres issue four basic types of messages: 1) information bulletins when a large earthquake has occurred but there is little or no tsunami threat; 2) regional watch and warning bulletins when there is a potential threat a destructive tsunami; 3) ocean-wide warning bulletin when there is confirmation of tsunami waves capable of widespread tsunami destruction beyond the local area; and 4) tsunami communication test messages to regularly exercise the system. Initial evaluations and messages are based only on the faster arriving seismic information, specifically earthquake location, magnitude, and depth. If a tsunami threat is possible, estimated tsunami wave arrival times are calculated and sea level records are examined to confirm whether a tsunami has been generated. Watch and Warning bulletins are updated hourly until the threat is gone. In the Pacific, the types of messages issued by the PTWC include a Pacific-Wide Tsunami Warning Bulletin, Regional Expanding Tsunami Warning and Watch Bulletin, Regional Fixed Tsunami Warning Bulletin, and Tsunami Information Bulletin, and Tsunami Communication Test Dummy Message.

## TSUNAMI WATCH

The second highest level of tsunami alert. Watches are issued by the Tsunami Warning Centres (TWCs) based on seismic information without destructive tsunami confirmation. The watch is issued as a means of alerting the affected populations located, for example, 1 to 3 hours tsunami travel time beyond the warned area. Subsequent text products are issued at least hourly to expand the watch and warning area, upgrade all areas to a warning, or end the watch and warning. A Tsunami Watch may be included in the text of the message that disseminates a Tsunami Warning.

## UNESCO

United Nations Educational, Scientific and Cultural Organization. Established in 1945, UNESCO promotes international cooperation among its Member States in the fields of education, science, culture and communication. Today, UNESCO works as a laboratory of ideas and standard setter to forge universal agreements on emerging ethical issues. The Organization also serves as a clearinghouse that disseminates and shares information and knowledge, while helping Member States to build their human and institutional capacities in diverse fields. The UNESCO Constitution states, “Since wars begin in the minds of men, it is the minds of men that the defences of peace must be constructed.” *(http://www.unesco.org/bpi)*

## WDC

World Data Center. The WDC system was created to archive and distribute data collected from the observational programs of the 1957-1958 International Geophysical Year. Originally established in the United States, Europe, Russia, and Japan, the WDC system has since expanded to other countries and to new scientific disciplines. The WDC system now includes 52 Centers in 12 countries. Its holdings include a wide range of solar, geophysical, environmental, and human dimensions data. These data cover time scales ranging from seconds to millennia and they provide baseline information for research in many disciplines. Tsunamis are collected by the WDC for Solid Earth Geophyics. The WDC-SEG is co-located with the USA NOAA National Geophysical Data Center. *(http://www.ngdc.noaa.gov/wdc/wdcmain.html)*

# 6 BIBLIOGRAPHY

## GENERAL

Atwater, Brian F., et.al., Surviving a tsunami - Lessons from Chile, Hawaii, and Japan. USGS Circular 1187. [Washington DC]: GPO, rev 2005.

Bernard, E.N., ed., Developing tsunami-resilient communities: The National Tsunami Hazard Mitigation Program, Dorchedt: Springer, 2005.

Dudley, M. and M. Lee, Tsunami! 2nd Ed., Honolulu: University of Hawaii Press, 1998.

Iida, K., Catalog of tsunamis in Japan and its neighboring countries. Special Report, Yashigasa, Yakusa-cho, Toyota-shi: Aichi Institute of Technology, 1984.

Tsunami Newsletter, IOC International Tsunami Information Centre, Honolulu,1965 to present.

UNESCO-IOC. IUGG/IOC TIME Project: Numerical method of tsunami simulation with the leap-frog scheme. IOC Manuals and Guides No. 35. Paris, UNESCO, 1997.

UNESCO-IOC. Master plan for the Tsunami Warning System in the Pacific. Second Edition. IOC Information document No. 1124. Paris, UNESCO, 1999. In English; Spanish, French and Russian version also online.

UNESCO-IOC International Tsunami Information Centre. Tsunami: The Great Waves. IOC Brochure 2005. Paris, UNESCO, 2005. In English; Spanish and French earlier version also online.

UNESCO-IOC International Tsunami Information Centre. Tsunami Glossary. IOC Information document No. 1121. Paris, UNESCO, 2006. Earlier revision in Spanish and French.

UNESCO-IOC. Tsunami Glossary: A glossary of terms and acronyms used in the tsunami literature. IOC Technical Series No. 37. Paris, UNESCO, 1991.

UNESCO-IOC International Tsunami Information Centre. Tsunami Warning!, IOC Brochure 2005. Paris, UNESCO, 2005.

UNESCO-IOC. Post-tsunami survey field guide. First Edition. IOC Manuals and Guides No. 37. Paris, UNESCO, 1998. Versions in Russian, French and Spanish. English and Spanish versions available online through ITIC Web Site.

## EVENT CATALOGUES

Berninghausen, W.H., Tsunamis and seismic seiches reported from regions adjacent to the Indian Ocean. Bulletin of the Seismological Society of America, Feb.1966; 56(1):69-74.

Berninghausen, W.H., Tsunamis and seismic seiches reported from the Western North and Atlantic and the coastal waters of Northwestern Europe. Informal Report No. 68-05, Washington DC: Naval Oceanographic Office, 1968.

Berninghausen, W.H., Tsunamis reported from the west coast of South America, 1562-1960. Bull. Seismol. Soc. Amer., 52, 915-921, 1962.

Berninghausen, W. H., Tsunamis and seismic seiches reported from the eastern Atlantic south of the Bay of Biscay. Bull. Seismol. Soc. Amer., 54, 439-442, 1964.

Dunbar, P.K., P. A. Lockridge, and L. S. Whiteside, Catalogue of Significant Earthquakes 2150BC1991AD. US Department of Commerce, NOAA, National Geophysical Data Center, Boulder, USA, World Data Center A for Solid Earth Geophysics Reports SE-49, 320 pp, 1992.

Everingham, I.B., Preliminary Catalogue of Tsunamis for the New Guinea I Solomon Island Region 1768-1972. Bureau of Mineral Resources, Canberra, Australia, Report 180, 78 pp, 1977.

Iida, K., D. Cox, and G. Pararas-Carayannis, Preliminary catalog of tsunamis occurring in the Pacific Ocean. Data Report No. 5, Hawaii Institute of Geophysics, HIG-67-10. Honolulu: University of Hawaii,re-issued1972. URL:http://www.soest.hawaii.edu/Library/Tsunami%20Reports/Iida_et_al.pdf

Pararas-Carayannis, G., Catalogue of Tsunamis in the Hawaiian Islands. US Department of Commerce, NOAA National Geophysical Center, Boulder, USA, World Data Center A for Solid Earth Geophysics Publication, 94 pp, 1969.

Lander, J.F, P.A. Lockridge, and M.J. Kozuch, Tsunamis affecting the West Coast of the United States 1806-1992. US Department of Commerce, NOAA, National Geophysical Data Center, Boulder, USA, NGDC Key to Geophysical Records Documentation KGRD-29. December 1993, 242 pp, 1993.

Lander, J., and P. Lockridge, United States Tsunamis (including United States Possessions) 1690-1988. Publication 41-2, Boulder: National Geophysical Data Center, 1989.

Lockridge, P.A. and R. H. Smith, 1984 : Map of Tsunamis in the Pacific Basin, 1900-1983. Scale 1:17,000,000. US NOAA National Geophysical Data Center World Data Centre A For Solid Earth Geophysics and Circum-Pacific Council for Energy and Minteralo Resources Map Project.

Molina, E.e (Seccion de Sismologia, INSIVUMEH, Guatemala). Tsunami catalogue for Central America 1539-1996 [Report]. Reduction of natural disasters in Central America. Universitas Bergensis Technical Report no. II 1-04, Bergen, Norway: Institute of Solid Earth Physics, University of Bergen; 1997.

O'Loughlin, K.F. and J.F. Lander, Caribbean tsunamis: A 500-year history from 1498-1998, Advances in Natural and Technological Hazards Research; v. 20 Boston, MA: Kluwer Academic Publishers; 2003.

Soloviev, S.L., et al., Tsunamis in the Mediterranean Sea 2000 BC-2000AD. Advances in Natural and Technological Hazards Research, Vol. 13, Dordrecht: Kluwer Academic Publishers, 2000.

Soloviev, S.L., and C. N. Go, A catalogue of tsunamis on the western shore of the Pacific Ocean. Academy of Sciences of the USSR, Nauka Publishing House, Moscow, 310 p. [Canadian Translation of Fisheries and Aquatic Sciences No. 5077, 1984, translation available from Canada Institute for Scientific and Technical Information, National Research Council, Ottawa, Ontario, Canada K1A OS2, 447 p., 1974]

Soloviev, S.L., and C. N. Go, A catalogue of tsunamis on the eastern shore of the Pacific Ocean. Academy of Sciences of the USSR, Nauka Publishing House, Moscow, 204 p. [Canadian Translation of Fisheries and Aquatic Sciences No. 5078, 1984, translation available from Canada Institute for Scientific and Technical Information, National Research Council, Ottawa, Ontario, Canada K1A OS2, 293 p., 1975]

Soloviev, S.L., C. Go, and C. S. Kim, Catalogue of Tsunamis in the Pacific 1969-1982, Results of Researches on the International Geophysical Projects. Moscow: Academy of Sciences of the USSR, 1992.

Tsunami Laboratory, ICMMG SD RAS, Novosibirsk, Russia, ITDB/WLD (2005) Integrated Tsunami Database for the World Ocean, Version 5.15 of July 31, 2005, CD-ROM.

## TECHNICAL

Abe, K., Size of great earthquakes 1837-1974 inferred from tsunami data, J. Geophys. Res, 84, 1561-1568, 1979.

Abe, Katsuyuki, A new scale of tsunami magnitude, Mt. in Tsunamis: Their science and engineering, Iida and Iwasaki, eds., Tokyo: Terra Scientific Publishing Company; 1983, pp. 91-101.

Ambraseys, N.N., Data for the investigation of the seismic sea-waves in the Eastern Mediterranean, Bulletin of the Seismological Society of America, 52:4 (Oct 1962), pp. 895-913.

Dmowska, R. and B. Saltzman, eds., Tsunamigenic earthquakes and their consequences. Advances in Geophysics, Vol. 39, San Diego: Academic Press, 1998.

European Commission. Directorate General for Science, Research and Development, UNESCO and Commissariatà a l'Energie Atomique (CEA), International Conference on Tsunamis, 26-28 May, 1998. France: CEA, [1998].

Hatori, T., Relation between tsunami magnitude and wave energy, Bull. Earthquake Res. Inst. Univ. Tokyo, 54, 531-541 (in Japanese with English abstract), 1979.

Hatori, T., Classification of tsunami magnitude scale, Bull. Earthquake Res. Inst. Univ. Tokyo, 61, 503-515 (in Japanese with English abstract), 1986.

Iida, K. and T. Iwasaki, eds., Tsunamis: Their science and engineering, Proceedings of the International Tsunami Symposium (1981), Tokyo: Terra Scientific, 1983.

Kanamori, H., “Mechanism of tsunami earthquakes,” Phys. Earth Planet. Inter., 6, pp. 346-359, 1972.

Keating, B., Waythomas, C., and A. Dawson, eds., Landslides and Tsunamis. Pageoph Topical Volumes, Basel: Birhäuser Verlag, 2000.

Mader, C., Numerical modeling of water waves, 2nd ed. Boca Raton, FL: CRC Press, 2004.

Papadopoulus, G., and F. Imamura, “A proposal for a new tsunami intensity scale,” International Tsunami Symposium Proceedings, Session 5, Number 5-1, Seattle, 2001.

Satake, K., ed., Tsunamis: Case studies and recent developments. Dordrecht: Springer, 2005.

Satake, K. and F. Imamura, eds., Tsunamis 1992-1994: Their generation, dynamics, and hazard, Pageoph Topical Volumes. Basel: Birhäuser Verlag, 1995.

Sauber, J. and R. Dmowska, Seismogenic and tsunamigenic processes in shallow subduction zones. Pageoph Topical Volumes, Basel: Birhäuser Verlag, 1999.

Shuto, N., “Tsunami intensity and disasters,” in Tsunamis in the World edited by S. Tinti, Dordrecht: Kluwer Academic Publishers, pp. 197-216, 1993.

Sieberg, A., Erdbebenkunde, Jena: Fischer, 1923. (Sieberg’s scale, pp. 102-104.)

Soloviev, S.L., “Recurrence of earthquakes and tsunamis in the Pacific Ocean,” in Tsunamis in the Pacific Ocean, edited by W. M. Adams, Honolulu: East-West Center Press, pp. 149-164, 1970.

Soloviev, S.L., “Recurrence of earthquakes and tsunamis in the Pacific Ocean,” Volny Tsunami (Trudy SahkNII, Issue 29), Yuzhno-Sakhalinsk, pp. 7-46, 1972 (in Russian).

Tinti, S., ed., Tsunamis in the World : Fifteenth International Tsunami Symposium, 1991, Advances in Natural and Technological Hazards Research, Vol. 1. Dordrecht: Kluwer Academic Publishers, 1993.

Tsuchiya, Y. and N. Shuto, eds., Tsunami: Progress in prediction, disaster prevention and warning. Advances in Natural and Technological Hazards Research, Vol. 4. Dordrecht: Kluwer Academic Publishers, 1995.

Yeh, H., Liu, P., and C. Synolakis, Long-wave runup models, Singapore: World Scientific, 1996.

## TEXTBOOKS AND TEACHERS GUIDEBOOKS (in English and Spanish)

Pre-elementary school: Earthquakes and tsunamis Chile: SHOA/IOC/ITIC, 1996. Revised 2003 in Spanish.

2-4 Grade: I invite you to know the earth I. Chile: SHOA/IOC/ITIC, 1997.

5-8 Grade: I invite you to know the earth II. Chile: SHOA/IOC/ITIC, 1997.

High School: Earthquakes and tsunamis. Chile: SHOA/IOC/ITIC, 1997.

# 7 INDEX

**INTERNATIONAL TSUNAMI INFORMATION CENTRE (ITIC)**

737 Bishop Street Suite 2200
Honolulu, Hawaii 96813-3213, U.S.A.
http://www.tsunamiwave.info

Phone: <1> 808-532-6422
Fax: <1> 808-532-5576
E-mail: itic.tsunami@noaa.gov

Located in Honolulu, the International Tsunami Information Centre (ITIC) was established on 12 November 1965 by the Intergovernmental Oceanographic Commission (IOC) of the United Nationas Educational, Scientific, and Cultural Organisation (UNESCO). The first session of the International Coordination Group for the Tsunami Warning System in the Pacific (ITSU) convened in 1968. In 2005, the ITSU was renamed as the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) to emphasize the comprehensive nature of risk reduction.

The ITIC thanks the following scientists for their assistance and helpful review of this document: Fumihiko Imamura, Modesto Ortiz, Kenji Satake, François Schindele, Fred Stephenson, Costas Synolakis, and Masahiro Yamamoto.

United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental Oceanographic
Commission of UNESCO

International Tsunami
Information Centre

Jakarta Tsunami
Information Centre

Printing Funded by:

Canadian International
Development Agency

**Jakarta Tsunami Information Centre (JTIC)**
**UNESCO House**
Jl. Galuh (II) No. 5, Kebayoran Baru
Jakarta 12110, INDONESIA
Tel : +62-21 7399 818
Fax: +62-21 7279 6489
www.jtic.org