TSUNAMI

THE GREAT WAVES

Revised, 2002

PRESENTED BY:

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
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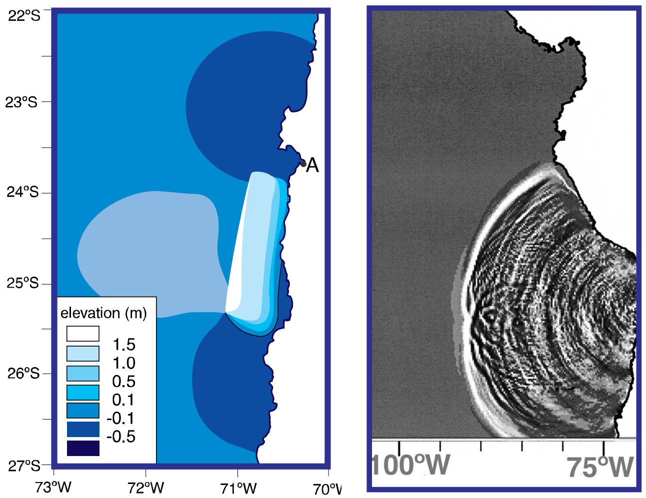
LABORATOIRE DE GEOPHYSIQUE, FRANCE (LDG)

THE GREAT WAVES

The purpose of this brochure is to increase awareness and knowledge of tsunamis. Please share what you learn; knowing the right information may save your life and the lives of those you love.



Left: Computer model of the initial water surface changes at the time the July 30, 1995, Chilean tsunami was generated. A is Antofagasta, Chile. Right: Computer model of the same tsunami, three hours after it was generated.

The phenomenon we call "tsunami" (soo-NAH-mee) is a series of traveling ocean waves of extremely long length generated primarily by earthquakes occurring below or near the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunamis. In the deep ocean, the tsunami waves propagate across the deep ocean with a speed exceeding 800 kilometers per hour ([km], ~500 miles per hour), and a wave height of only a few tens of centimeters (1 foot [ft]) or less. Tsunami waves are distinguished from ordinary ocean waves by their great length between wave crests, often exceeding a 100 km (60 miles [mi]) or more in the deep ocean, and by the time between these crests, ranging from 10 minutes to an hour.

As they reach the shallow waters of the coast, the waves slow down and the water can pile up into a wall of destruction tens of meters (30 ft) or more in height. The effect can be amplified where a bay, harbor or lagoon funnels the wave as it moves inland. Large tsunamis have been known to rise over 30 meters (100 ft). Even a tsunami 3–6 meters (m) high can be very destructive and cause many deaths and injuries.

Tsunamis are a threat to life and property for all coastal residents living near the ocean. During the 1990s, over 4,000 people were killed by 10 tsunamis, including more than 1000 lives lost in the 1992 Flores region, Indonesia, and 2200 lives in the 1998 Aitape, Papua New Guinea tsunamis. Property damage was nearly one billion United States (U.S.) dollars. Although 80% of the tsunamis occur in the Pacific, they can also threaten coastlines of countries in other regions, including the Indian Ocean, Mediterranean Sea, Caribbean region, and even the Atlantic Ocean.

Hilo Harbor, Hawaii, April 1, 1946, Aleutian Islands earthquake. Photo taken from the vessel Brigham Victory of tsunami breaking over Pier 1. The gentleman on the left did not survive. (NOAA)

At the Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC), the operational center of the Tsunami Warning System in the Pacific (TWSP), scientists monitor seismological and water level stations throughout the Pacific Basin, evaluate potentially tsunamigenic earthquakes, monitor tsunami waves, and disseminate tsunami warning information. Located near Honolulu, Hawaii, PTWC provides tsunami warning information to national authorities in the Pacific Basin. National or Regional Warning Centers are also operating in Japan, French Polynesia, Chile, and Russia, in addition to the United States.

The International Tsunami Information Center, hosted by the U.S. and located in Honolulu, Hawaii, at NOAA/National Weather Service Pacific Region Headquarters, monitors and evaluates the performance and effectiveness of the TWSP on an everyday basis.

WHAT CAU

Tsunamis, also called seismic sea wave or incorrectly tidal waves, are caused generally by earthquakes, less commonly by submarine landslides, infrequently by submarine volcanic eruptions and very rarely by large meteorite impacts in the ocean. Submarine volcanic eruptions have the potential to produce truly awesome tsunami waves. The Great Krakatau Volcanic Eruption of 1883 generated giant waves reaching heights of 40 meters above sea-level, killing more than 30,000 people and wiping out numerous coastal villages.

All oceanic regions of the world can experience tsunamis, but in the Pacific Ocean and it's marginal seas, there is a much more frequent occurrence of large, destructive tsunamis because of the many large earthquakes along the margins of the Pacific Ocean.

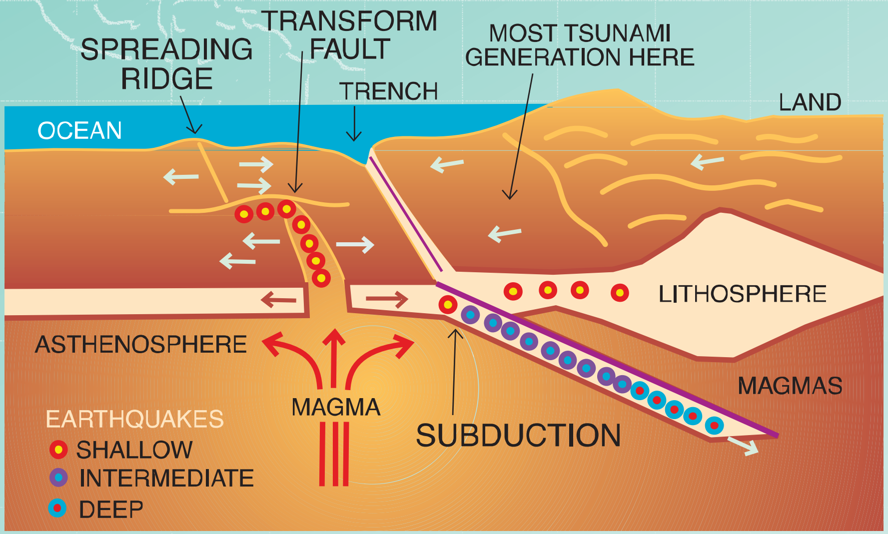


PLATE TECTONICS

Plate Tectonic theory is based on an earth model characterized by a small number of lithospheric plates, 70 to 250 km (40 to 150 mi) thick, that float on a viscous underlayer called the asthenosphere. These plates, which cover the entire surface of the earth and contain both the continents and seafloor, move relative to each other at rates of up to ten cm/year (several inches/year). The region where two plates come in contact is called a plate boundary, and the way in which one plate moves relative to another determines the type of boundary: spreading, where the two plates move away from each other; subduction, where the two plates move toward each other and one slides beneath the other; and transform, where the two plates slide horizontally past each other. Subduction zones are characterized by deep ocean trenches, and the volcanic islands or volcanic mountain chains associated with the many subduction zones around the Pacific rim are sometimes called the Ring of Fire.

EARTHQUAKES AND TSUNAMIS

An earthquake can be caused by volcanic activity, but most are generated by movements along fault zones associated with the plate boundaries. Most strong earthquakes, representing 80% of the total energy released worldwide by earthquakes, occur in subduction zones where an oceanic plate slides under a continental plate or another younger oceanic plate.

Not all earthquakes generate tsunamis. To generate a tsunami, the fault where the earthquake occurs must be underneath or near the ocean, and cause vertical movement of the seafloor (up to several meters) over a large area (up to a hundred thousand square kilometers). Shallow focus earthquakes (depth less 70 km or 42 mi) along subduction zones are responsible for most destructive tsunamis. The amount of vertical and horizontal motion of the sea floor, the area over which it occurs, the simultaneous occurrence of slumping of underwater sediments due to the shaking, and the efficiency with which energy is transferred from the earth's crust to the ocean water are all part of the tsunami generation mechanism.

Tsunami generated by May 26, 1983, Japan Sea earthquake approaching Okushiri Island, Japan. The runup here was 5.9 m (19 ft), but runups as high as 14 m (45 ft) were measured in Akita Prefecture 100 km east of the epicenter. Altogether, 100 people lost their lives, including three people in South Korea where the wave arrived about 1.5 hours after the earthquake. (Tokai Univ. report)

SES TSUNAMI?

TSUNAMI EARTHQUAKES

The September 2, 1992 earthquake (magnitude 7.2) was barely felt by residents along the coast of Nicaragua. Located well off-shore, its intensity, the severity of shaking on a scale of I to XII, was mostly II along the coast, and reached III at only a few places. Twenty to 70 minutes after the earthquake occurred, a tsunami struck the coast of Nicaragua with wave amplitudes 4 m (13 ft) above normal sea level in most places and a maximum runup height of 10.7 m (35 ft). The waves caught coastal residents by complete surprise and caused many casualties and considerable property damage.

This tsunami was caused by a tsunami earthquake — an earthquake that produces an unusually large tsunami relative to the earthquake magnitude. Tsunami earthquakes are characterized by a very shallow focus, fault dislocations greater than several meters, and fault surfaces that are smaller than for a normal earthquake.

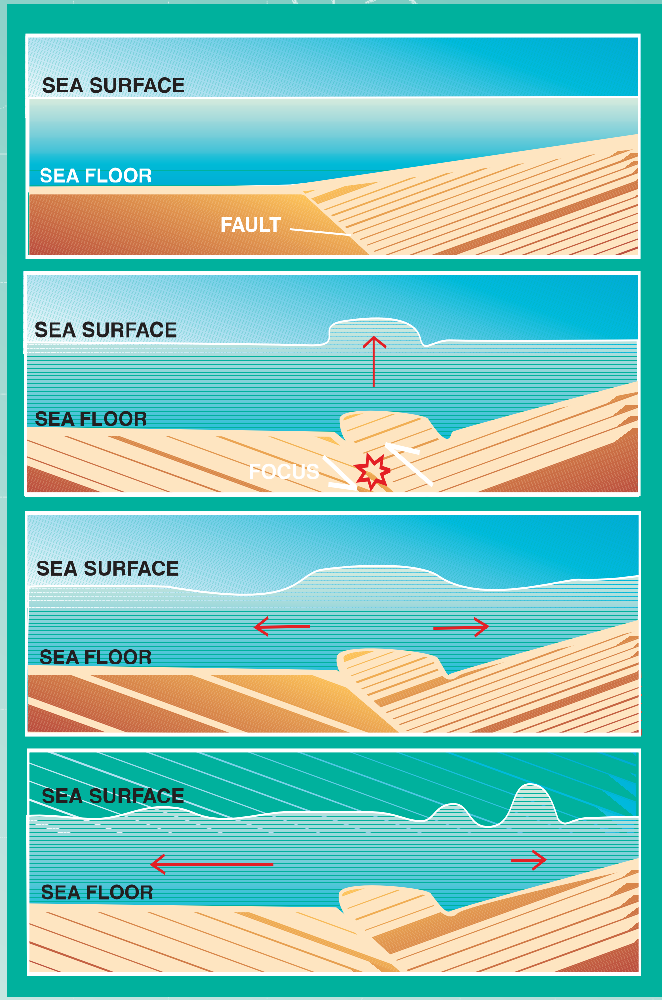
They are also slow earthquakes, with slippage along the fault beneath the sea floor occurring more slowly than it would in a normal earthquake. The only known method to quickly recognize a tsunami earthquake is to estimate a parameter called the seismic moment using very long period seismic waves (more than 50 seconds / cycle). Two other destructive and deadly tsunamis from tsunami earthquakes have occurred in recent years in Java, Indonesia (June 2, 1994) and Peru (February 21, 1996).

El Transito, Nicaragua, September 1, 1992. Nine-meter high waves destroyed the town, killing 16 and injuring 151 in this coastal community of 1,000 people. The first wave was thought to be small providing time for people to escape the destructive second and third waves. More than 40,000 people were affected by the loss of their homes or means of income. (Harry Yeh, Univ. of Washington)

The earthquake focus is the point in the earth where the rupture first occurs and where the first seismic waves originate. The epicenter is the point on the Earth's surface directly above the focus.

The magnitude is the logarithm of the maximum amplitude of one the seismic waves (P, S, Rayleigh or Love surface waves) recorded by the seismometer; an increase in one unit of magnitude corresponds to a factor of 10 increase in amplitude.

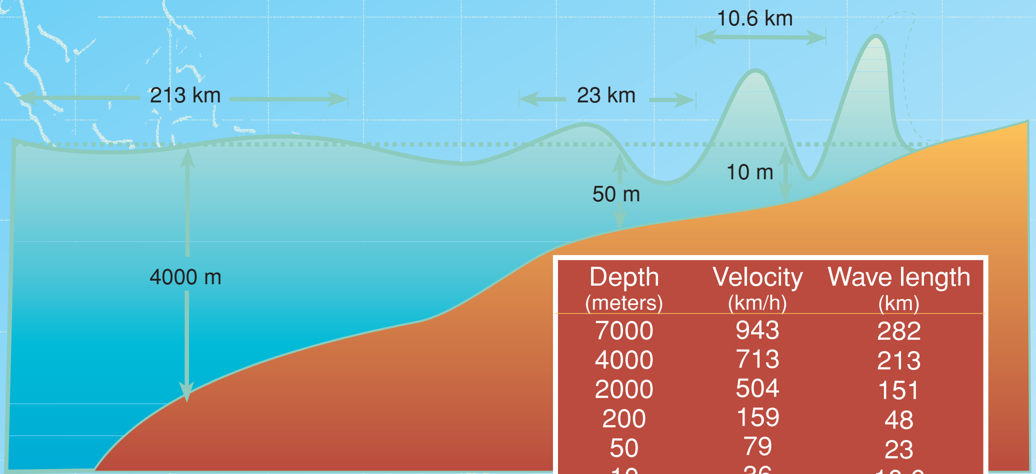
TSUNAMI: THE RELATION WITH THE SEISMIC SOURCE



TSUNAMIS ON

In the deep ocean, destructive tsunamis can be small – often only a few tens of centimeters or less in height – and cannot be seen nor felt on ships at sea. But as the tsunami reaches shallower coastal waters, wave height can increase rapidly. Sometimes, coastal waters are drawn out into the ocean just before the tsunami strikes. When this occurs, more shoreline may be exposed than even at the lowest tide. This major withdrawal of the sea should be taken as a warning of the tsunami waves that will follow.

Tsunami Speed is reduced in shallow water as wave height increases rapidly.



Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

In the open ocean a tsunami is less than a few tens of centimeters (1 ft) high at the surface, but its wave height increases rapidly in shallow water. Tsunami wave energy extends from the surface to the bottom in even the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into a much shorter distance and a much shallower depth, creating destructive, life-threatening waves.

PACIFIC-WIDE AND REGIONAL TSUNAMIS

The last large tsunami that caused widespread death and destruction throughout the Pacific was generated by an earthquake located off the coast of Chile in 1960. It caused loss of life and property damage not only along the Chile coast but in Hawaii and as far away as Japan. The Great Alaskan Earthquake of 1964 produced deadly tsunami waves in Alaska, Oregon and California.

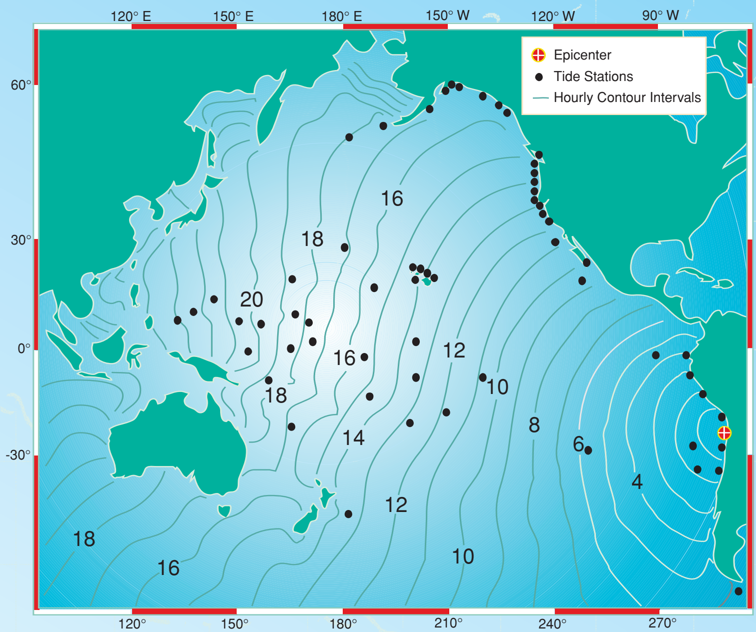
In July 1993, a tsunami generated in the Sea of Japan killed over 120 people in Japan. Damage also occurred in Korea and Russia but not in other countries since the tsunami wave energy was confined within the Sea of Japan. The 1993 Japan Sea tsunami is known as a "regional event" since its impact was confined to a relatively small area. For people living along the northwestern coast of Japan, the tsunami waves followed the earthquake within a few minutes.

During the 1990s, destructive regional tsunamis also occurred in Nicaragua, Indonesia, the Philippines, Papua New Guinea, and Peru, killing thousands of people. Others caused property damage in Chile and Mexico. Some damage also occurred in the far field in the Marquesas Islands (French Polynesia) from the July 30, 1995, Chilean and February 21, 1996, Peruvian tsunamis.

In less than a day, tsunamis can travel from one side of the Pacific to the other. However, people living near areas where large earthquakes occur may find that the tsunami waves will reach their shores within minutes of the earthquake. For these reasons, the tsunami threat to many areas, e.g., Alaska, the Philippines, Japan and the U.S. West Coast, can be immediate (for tsunamis from nearby earthquakes which take only a few minutes to reach coastal areas) or less urgent (for tsunamis from distant earthquakes which take from three to 22 hrs to reach coastal areas).

Pagaraman, Babi Island, Indonesia, December 12, 1992. Tsunamis washed away everything leaving only white beach sand. Seven hundred people were killed by the earthquake and ensuing tsunami. (Harry Yeh, Univ. of Washington)

THE MOVE



Calculated tsunami travel times for an earthquake occurring off the coast of Chile. Each concentric curve represents one hour of tsunami travel time.

HOW FAST?

Where the ocean is over 6,000 m deep, unnoticed tsunami waves can travel at the speed of a commercial jet plane, over 800 km per hour (~500 mi per hour). They can move from one side of the Pacific Ocean to the other in less than a day. This great speed makes it important to be aware of the tsunami as soon as it is generated. Scientists can predict when a tsunami will arrive at various places by knowing the source characteristics of the earthquake that generated the tsunami and the characteristics of the seafloor along the paths to those places. Tsunamis travel much slower in shallower coastal waters where their wave heights begin to increase dramatically.

During post-tsunami field surveys, inundation and runup measurements are taken to describe the tsunami effects. Inundation is defined as the maximum horizontal distance inland that a tsunami penetrates. Runup is the maximum vertical height above mean sea level that the sea surface attains during a tsunami. Actual tsunami wave heights can be measured from the amplitude of the wave signals seen on sea level or tide gauge instruments.

HOW BIG?

Offshore and coastal features can determine the size and impact of tsunami waves. Reefs, bays, entrances to rivers, undersea features and the slope of the beach all help to modify the tsunami as it attacks the coastline. When the tsunami reaches the coast and moves inland, the water level can rise many meters. In extreme cases, water level has risen to more than 15 m (50 ft) for tsunamis of distant origin and over 30 m (100 ft) for tsunami waves generated near the earthquake's epicenter. The first wave may not be the largest in the series of waves. One coastal community may see no damaging wave activity while in another nearby community destructive waves can be large and violent. The flooding can extend inland by 300 m (~1000 ft) or more, covering large expanses of land with water and debris.

HOW FREQUENT?

Since scientists cannot predict when earthquakes will occur, they cannot determine exactly when a tsunami will be generated. However, by looking at past historical tsunamis, scientists know where tsunamis are most likely to be generated. Past tsunami height measurements are useful in predicting future tsunami impact and flooding limits at specific coastal locations and communities. Historical tsunami research may prove helpful in analyzing the frequency of occurrence of tsunamis. During each of the last five centuries, there were three to four Pacific-wide tsunamis, most of them generated off the Chilean coasts.

Noshiro, Harbor, Japan. May 26, 1983 Japan Sea earthquake. The tsunami, upon entering a waterway, generated a continuous train of short-period waves. (Tokai Univ. report)

HOW WE

Kodiak, Alaska. The March 27, 1964, tsunami caused 21 deaths and $30 million U.S. dollars in damage in and near the city of Kodiak.

The Wave. Painting by Lucas Rawah of Aitape, done to commemorate the July 17, 1998, Papua New Guinea event. A magnitude 7.1 earthquake is thought to have triggered a submarine landslide generating a tsunami that destroyed entire villages along the Aitape coast.

International Tsunami Information Center (ITIC)

ITIC, supported in part by the IOC, monitors and evaluates the performance and effectiveness of the TWSP. This effort encourages the most effective data collection, data analysis, tsunami impact assessment, and warning dissemination to all TWSP participants, and ensures continuing efforts in tsunami awareness and training, in part through its Tsunami Newsletter, Bulletin Board listserve, Visiting Experts Program, and the ITSU/ITIC Tsunami Information Web Portal. ITIC also provides technical assistance to support the development of and improvements to national tsunami warning systems.

SAVE LIVES

TSUNAMI WARNING CENTERS

The Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) serves as the international warning center for tsunamis that pose a Pacific-wide threat. This international warning effort became a formal arrangement in 1965 when PTWC assumed responsibility as the operational center for the Tsunami Warning System in the Pacific (TWSP). The ICG/ITSU, a subsidiary body of the IOC comprised of 25 international Member States, oversees TWSP operations and facilitates coordination and cooperation in all other international tsunami mitigation activities.

The initial objective of PTWC is to detect, locate and determine the seismic parameters of potentially tsunamigenic earthquakes occurring in the Pacific Basin or its immediate margins. To accomplish this, it continuously receives seismographic data from more than 150 stations around the Pacific through cooperative data exchanges with the U.S. Geological Survey, Incorporated Research Institutions for Seismology, International Deployment of Accelerometers, GEOSCOPE, the U.S. West Coast/Alaska Tsunami Warning Center (WC/ATWC), and other international agencies running seismographic stations and networks.

If the earthquake location, depth, and magnitude criteria needed to generate a tsunami are met, a tsunami warning is issued to warn of an imminent tsunami hazard. Initial warnings apply only to areas the tsunami could reach within a few hours and bulletins include the predicted tsunami arrival times at selected coastal communities within those areas. Communities located outside those areas are put into either a tsunami watch or advisory status.

Warning center scientists then monitor incoming sea level data to determine whether a tsunami has occurred. If a significant tsunami with long-range destructive potential is detected, the tsunami warning is extended to the entire Pacific Basin. PTWC receives sea level data from more than 100 stations through cooperative data exchanges with the U.S. National Ocean Service, WC/ATWC, the University of Hawaii Sea Level Center, Chile, Australia, Japan, Russia, and other international sources. Tsunami warnings, watches, and information bulletins are disseminated to appropriate emergency officials and the general public by a variety of communication methods.

In addition, individual countries may operate National or Regional Warning Centers to provide warning information on regional or local tsunami threats. The Japan Meteorological Agency provides tsunami warnings to Japan, and additionally to Korea and Russia for events occurring in the Sea of Japan or East Sea. The Centre Polynesien de Prevention des Tsunamis provides warnings in French Polynesia, and Chile (Sistema Nacional de Alarma de Maremotos) and Russia (Russian Hydrometeorological Service) operate national warning systems.

In the United States, WC/ATWC provides tsunami warnings to the U.S. West Coast and Canada, and PTWC provides tsunami warnings to Hawaii and to all other U.S. interests in the Pacific. Other countries, including Australia, Colombia, Nicaragua, Peru, and Korea, are also developing warning capabilities.

Information about the IOC

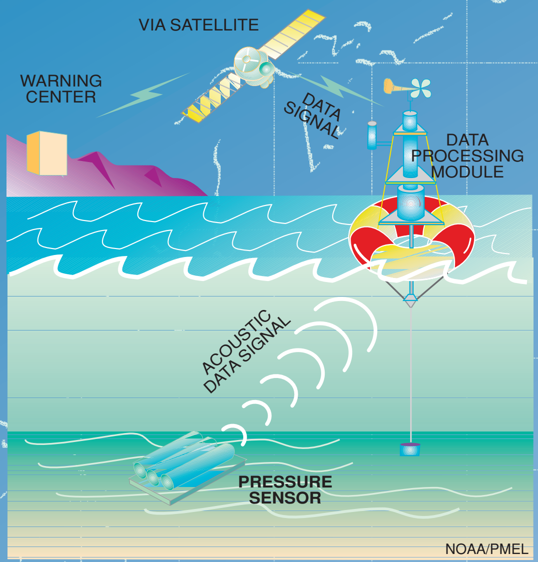
The Intergovernmental Oceanographic Commission (IOC), a body with functional autonomy within the United Nations Educational, Scientific and Cultural Organization (UNESCO), was established to promote marine scientific investigations and related ocean services with a view to learning more about the nature and resources of the ocean through the concerted actions of its members.

In general terms, the functions of the IOC among others are: to develop, recommend and coordinate international programs for scientific investigation of the oceans and related ocean services; to promote and make recommendations for the exchange of oceanographic data and the publication and dissemination of results of scientific investigation of the oceans; to promote and coordinate the development and transfer of marine science and its technology; to make recommendations to strengthen education and training and to promote scientific investigation of the oceans and application of the results thereof for the benefit of all mankind. 129 Member States are currently part of the IOC. The Assembly meets every two years at the UNESCO headquarters in Paris, France.

The IOC consists of an Assembly, an Executive Council, a Secretariat and such subsidiary bodies as it may establish. Under this last concept, the Commission creates, for the examination and execution of specific projects, committees or other subsidiary bodies composed of Member States interested in such projects. This is the case for the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU).

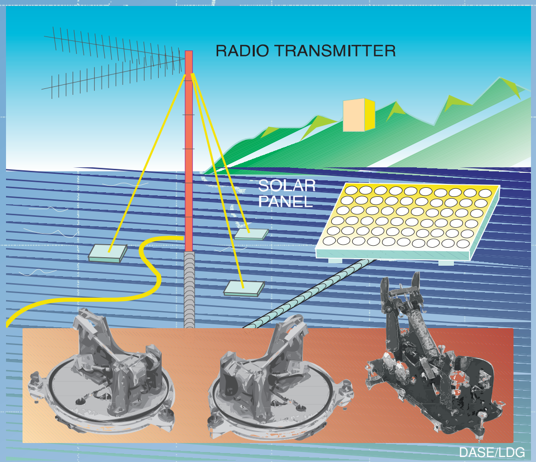
LOOKING INTO THE

DEEP-OCEAN ASSESSMENT AND REPORTING ON TSUNAMIS (DART System)



April 1, 1946. People flee as a tsunami attacks downtown Hilo, Hawaii (Bishop Museum)

INDEPENDENT 3 COMPONENT BROAD -BAND SEISMIC STATION



Warning Dissemination

- Tsunami warnings, watches, and information bulletins issued by PTWC and other Regional Centers are disseminated to local, state, national, and international users as well as the media. These users, usually government authorities, in turn disseminate the tsunami information to the public, generally over commercial radio and television channels.
- With the help of modern communication facilities, direct broadcast of tsunami information is urgently provided to the public.

- Local authorities and emergency managers are responsible for formulating and executing evacuation plans for areas under a tsunami warning. The public should stay-tuned to the local media for evacuation orders should a tsunami warning be issued. And, the public should NOT RETURN to low lying areas until the tsunami threat has passed and the "all clear" is announced by the local authorities.

EYES OF THE MONSTER

Tsunami Research Activities

With the broad availability of relatively inexpensive yet powerful computers and desktop workstations, there is growing interest and activity in tsunami research. Using the latest in computer technology, scientists are able to numerically model tsunami generation, open ocean propagation, and coastal runup.

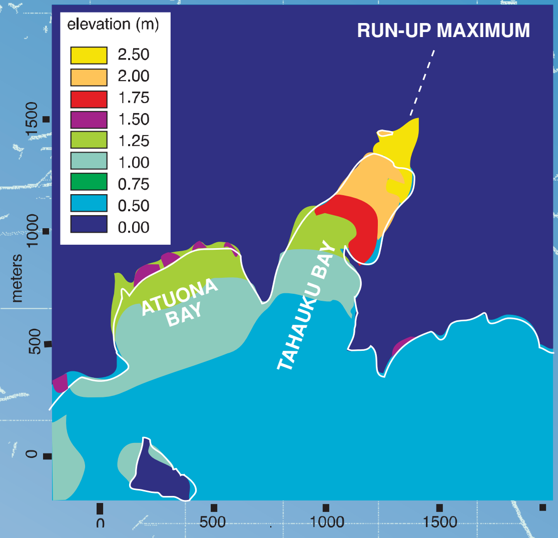
Ocean-bottom pressure sensors, able to measure tsunamis in the open ocean, are providing important data on the propagation of tsunamis in deep water, and satellite communications have enabled these data to be used in real time to detect and confirm that a tsunami has been generated in the deep ocean. NOAA's Pacific Marine Environmental Laboratory has pioneered the development of these tsunami detection buoys, and by the end of 2003, seven DART buoys will be in operation in the northern and eastern Pacific and available for use by the tsunami warning centers. Better equipment and numerical modeling methods are helping scientists to better understand the mechanism of tsunami generation.

Seismologists, studying the dynamics of earthquakes with broad band seismometers (20 to 0.003 Hertz), are formulating new methods to analyze earthquake motion and the amount of energy released. Where the traditional Richter (surface wave) magnitude of earthquakes is not accurate above 7.5, the seismic moment and the source duration are now used to better define the amount of energy released and the tsunami generation potential. Real-time determination of the depth of the earthquake, type of faulting, and extent of slippage will significantly improve the warning centers' ability to identify the likelihood of a threatening tsunami.

Tsunami generation is initiated by three-dimensional deformation of the ocean bottom due to movement of the fault. Better characterizations of the earthquake fault mechanism will produce more realistic numerical models of propagation, runup, and inundation. Currently, numerical models of propagation generally use an implicit-in-time finite difference method.

Tsunami inundation models, defining the extent of coastal flooding, are an integral aspect of tsunami hazard and preparedness planning. Using worst case inundation scenarios, these models are critical to defining evacuation zones and routes so that coastal communities can be evacuated quickly when a tsunami warning has been issued.

The seismic moment Mo is related by: Mo=μ S D where μ is the rigidity, S the fault area and D the mean dislocation.



LEFT: July 30, 1995, Chilean Tsunami. Model results showing the maximum run-up and inundation relative to the normal sea level and shoreline (white line) at Tahauku Bay, Hiva Hoa, in the Marquesas Islands, French Polynesia. Two small boats sunk in Tahauku Bay as a result of this event.

BELOW: Model of the tsunami in the southeast Pacific, nine hrs after its generation.

THE FACTS

- Tsunamis that strike coastal locations in the Pacific Ocean Basin are almost always caused by earthquakes. These earthquakes might occur far away or near where you live.

- Some tsunamis can be very large. In coastal areas their height can be as great as 10 m or more (30 m in extreme cases), and they can move inland several hundred meters.

- All low lying coastal areas can be struck by tsunamis.

- A tsunami consists of a series of waves with crests arriving every 10 to 60 minutes. Often the first wave may not be the largest. The danger from a tsunami can last for several hours after the arrival of the first wave. Tsunami waves typically do not curl and break, so do not try to surf a tsunami!

- Tsunamis can move faster than a person can run.

- Sometimes a tsunami initially causes the water near shore to recede, exposing the ocean floor.

- The force of some tsunamis is enormous. Large rocks weighing several tons, along with boats and other debris, can be moved inland hundreds of meters by tsunami wave activity, and homes and buildings destroyed. All this material and water move with great force, and can kill or injure people.

- Tsunamis can occur at any time, day or night.

- Tsunamis can travel up rivers and streams from the ocean.

- Tsunami can easily wrap around islands and be just as dangerous on coasts not facing the source of the tsunami.

WHAT YOU SHOULD DO

Be aware of tsunami facts.
This knowledge could save your life!
Share this knowledge with your relatives and friends.
It could save their lives!

- If you are in school and you hear there is a tsunami warning, you should follow the advice of teachers and other school personnel.

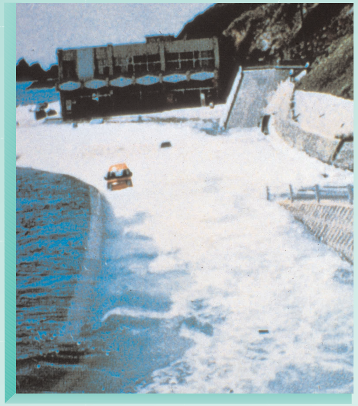
- If you are at home and hear there is a tsunami warning, you should make sure your entire family is aware of the warning. Your family should evacuate your house if you live in a tsunami evacuation zone. Move in an orderly, calm, and safe manner to the evacuation site or to any safe place outside your evacuation zone. Follow the advice of local emergency and law enforcement authorities.

- If you are at the beach or near the ocean and you feel the earth shake, move immediately to higher ground. DO NOT wait for a tsunami warning to be announced. Stay away from rivers and streams that lead to the ocean as you would stay away from the beach and ocean if there is a tsunami. A regional tsunami from a local earthquake could strike some areas before a tsunami warning can be announced.

- Tsunamis generated in distant locations will generally give people enough time to move to higher ground. For locally generated tsunamis, where you might feel the ground shake, you may only have a few minutes to move to higher ground.

- High, multi-story, reinforced concrete hotels are located in many low-lying coastal areas. The upper floors of these hotels can provide a safe place to find refuge should there be a tsunami warning and you cannot move quickly inland to higher ground. Local Civil Defense procedures may, however, not allow this type of evacuation in your area. Homes and small buildings located in low lying coastal areas are not designed to withstand tsunami impacts. Do not stay in these structures should there be a tsunami warning.

- Offshore reefs and shallow areas may help break the force of tsunami waves, but large and dangerous waves can still be a threat to coastal residents in these areas. Staying away from all low-lying coastal areas is the safest advice when there is a tsunami warning.



Oga Aquarium, Akita, Japan. Parking lot flooded stranding car during the May 26, 1983, Japan Sea tsunami. (Takaaki Uda, Public Works Research Institute, Japan)

WHAT YOU SHO

Aonae, Okushiri Island, Japan. Total destruction of houses and other buildings resulting from the tsunami of July 12, 1993, in the Sea of Japan. Numerous fires broke out following the tsunami adding to the property loss and misery. Over 120 people were killed by the tsunami in Japan.

ULD DO

IF YOU ARE ON A SHIP OR BOAT

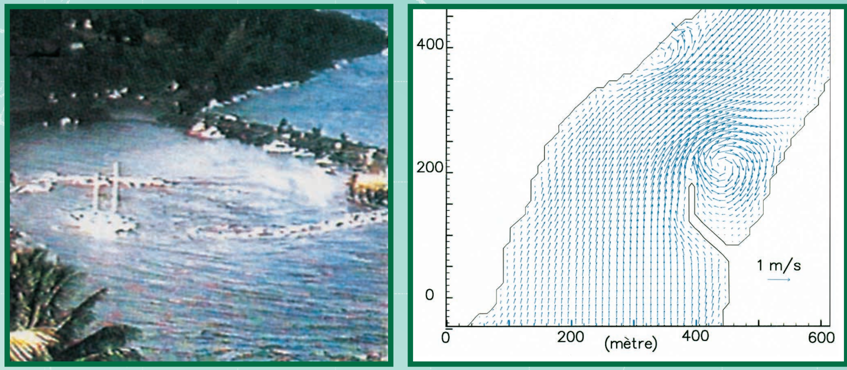
- Since tsunami wave activity is imperceptible in the open ocean, do not return to port if you are at sea and a tsunami warning has been issued for your area. Tsunamis can cause rapid changes in water level and unpredictable dangerous currents in harbors and ports.

- If there is time to move your boat or ship from port to deep water (after you know a tsunami warning has been issued), you should weigh the following considerations:

- Most large harbors and ports are under the control of a harbor authority and/or a vessel traffic system. These authorities direct operations during periods of increased readiness (should a tsunami be expected), including the forced movement of vessels if deemed necessary. Keep in contact with the authorities should a forced movement of vessels be directed.

- Smaller ports may not be under the control of a harbor authority. If you are aware there is a tsunami warning and you have time to move your vessel to deep water, then you may want to do so in an orderly manner, in consideration of other vessels. Owners of small boats may find it safest to leave their boat at the pier and physically move to higher ground, particularly in the event of a locally-generated tsunami. Concurrent severe weather conditions (rough seas outside of the harbor) could present a greater hazardous situation to small boats, so physically moving yourself to higher ground may be the only option.

- Damaging wave activity and unpredictable currents can affect harbors for a period of time following the initial tsunami impact on the coast. Contact the harbor authority before returning to port making sure to verify that conditions in the harbor are safe for navigation and berthing.



July 30, 1995 , Chilean Tsunami. Left: An observation of the tsunami effects behind the breakwater at Tahauku Bay in the Marquesas Islands, French Polynesia, several thousand kilometers away from the tsunami source. Right: Currents in Tahauku Bay based on numerical modeling of the Chilean tsunami. The modeling reproduces the same kinds of ocean currents seen in the photo.

KNOWLEDGE IS SAFETY

Ala Wai Yacht Harbor, Honolulu, Hawaii. Withdrawal of water caused by tsunami generated by earthquake of November 4, 1952, in Kamchatka, Russia. The spectators in this picture are needlessly risking their lives and should be evacuating to higher ground. (Camera Hawaii)

North Shore of Oahu, Hawaii. During the tsunami generated by the March 9, 1957, Aleutian Island earthquake, people foolishly searched for fish on the exposed reef, unaware that tsunami waves would return in minutes to inundate the shoreline. (Honolulu Star-Bulletin)

As dangerous as tsunamis are, they do not happen very often. You should not let this natural hazard diminish your enjoyment of the beach and ocean. But, if you think a tsunami may be coming, the ground shakes under your feet or you hear there is a warning, tell your relatives and friends, and

Move Quickly to Higher Ground!

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TECHNICAL GUIDANCE PROVIDED BY:

International Tsunami Information Center
Laboratoire de Geophysique, France
U.S. National Weather Service
  Richard H. Hagemeyer Pacific Tsunami Warning Center, http://www.prh.noaa.gov/ptwc/
  West Coast / Alaska Tsunami Warning Center, http://wcatwc.arh.noaa.gov
U.S. National Ocean Service, http://www.nos.noaa.gov
U.S. National Geophysical Data Center, http://www.ngdc.noaa.gov
U.S. Pacific Marine Environmental Laboratory, http://www.pmel.noaa.gov/pmel
Servicio Hidrografic y Oceanografic, Chile, http://www.shoa.cl
School of Ocean & Earth Science & Technology, University of Hawaii, http://www.soest.hawaii.edu

FURTHER INFORMATION ON THE TSUNAMI WARNING SYSTEM IN THE PACIFIC, ICG/ITSU, ITIC, AND TSUNAMIS MAY BE OBTAINED FROM:

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737 Bishop St., Suite 2200, Honolulu, HI 96813 USA
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EMAIL: itic.tsunami@noaa.gov
http://www.prh.noaa.gov/itic/
http://www.shoa.cl/oceano/itic/frontpage.html

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