TSUNAMI

THE GREAT WAVES

June, 2005

PRESENTED BY:

UNESCO INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (IOC)

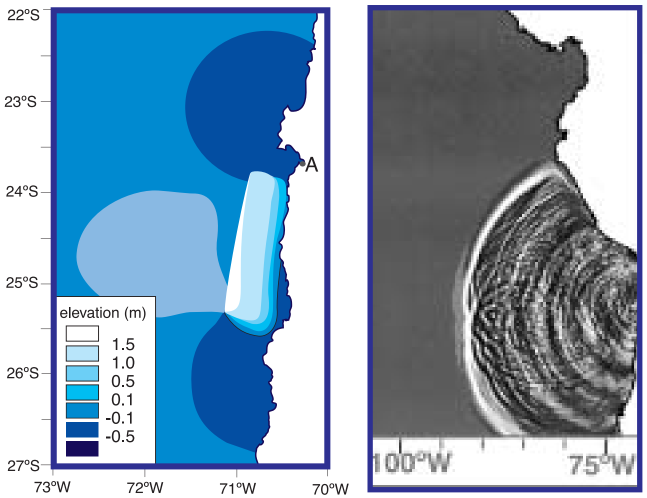
INTERNATIONAL TSUNAMI INFORMATION CENTRE (ITIC)

LABORATOIRE DE GEOPHYSIQUE, FRANCE (LDG)

U. S. NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)

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 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 all 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. The most devastating tsunami occurred in December 2004, when a M9.0 earthquake off of northwestern Sumatra, Indonesia produced a destructive tsunami that attacked coasts throughout the Indian Ocean, killing 300,000 people, displacing more than one million people, and causing billions of dollars of property damage.

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. The PTWC provides international tsunami warning information to national authorities in the Pacific Basin. Regional Warning Centres are also operating in Japan, French Polynesia, and Chile, in addition to the United States. As a result of the 2004 great tsunami, tsunami warning systems are now being implemented globally, including in the Indian Ocean, Caribbean Sea, Atlantic Ocean, and Mediterranean Sea.

The UNESCO IOC International Tsunami Information Centre, hosted by the U.S., monitors and evaluates the performance and effectiveness of the TWSP, assists in the establishment of new warning systems, and serves as an educational and information resource in support of the IOC's Tsunami Programme.

WHAT CAU

Tsunamis, also called seismic sea waves 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 its 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.

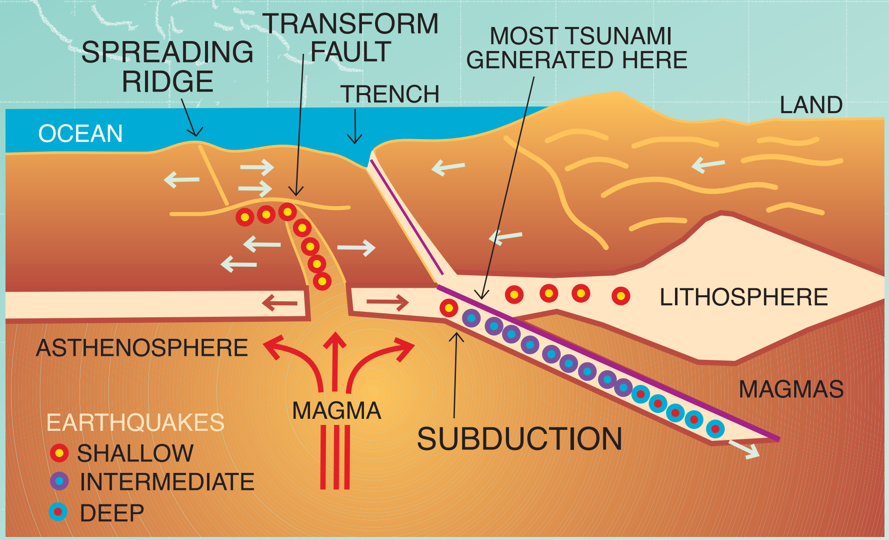


PLATE TECTONICS

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 December 26, 2004, M9.0 northwest Sumatra earthquake approaching Hat Rai Lay Beach, Krabi, southern Thailand. Foreign tourists scramble for safety in advance of the first of six tsunami waves after venturing out when the water first receded (AFP/AFP/Getty Images).

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.

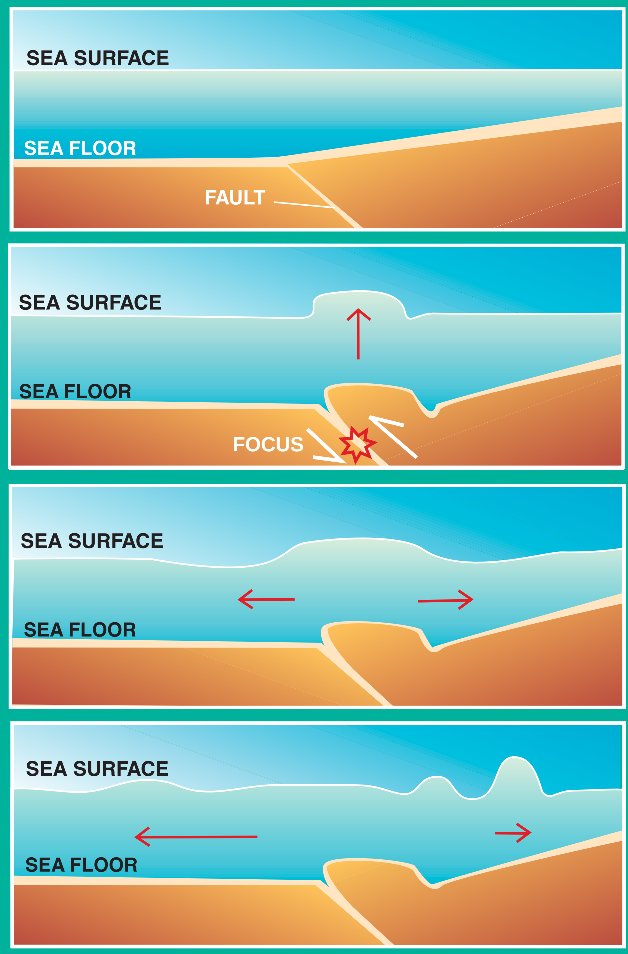
They are also slow earthquakes, with slippage along the fault beneath the sea floor occurring more slowly than it would in a normal earthquake. The only known method to quickly recognize a tsunami earthquake is to estimate a parameter called the seismic moment using very long period seismic waves (more 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 a measure of the relative size of an earthquake. A number of different magnitude scales exist besides the Richter scale, including the moment magnitude which measures the energy released and gives the most reliable estimate for large earthquakes. An increase in one unit of magnitude corresponds to a factor of 10 increase in seismic wave amplitude, and a 30-fold increase in released energy. The moment magnitude is measurable nearly immediately thanks to the advent of modern seismometers, digital recording, and real-time communication links. This allows warning centres to provide initial tsunami advisories within minutes after the earthquake's occurrence.

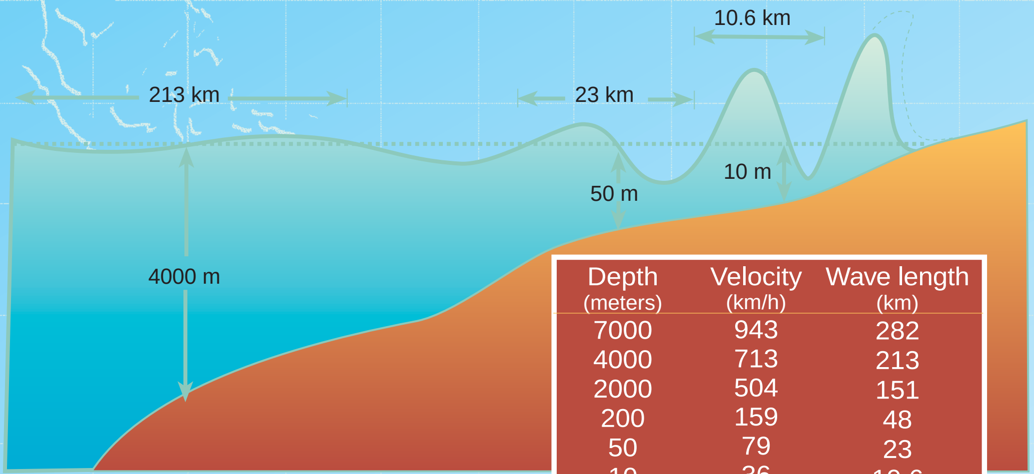
TSUNAMI: THE RELATION WITH THE SEISMIC SOURCE



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 natural warning sign that tsunami waves 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.

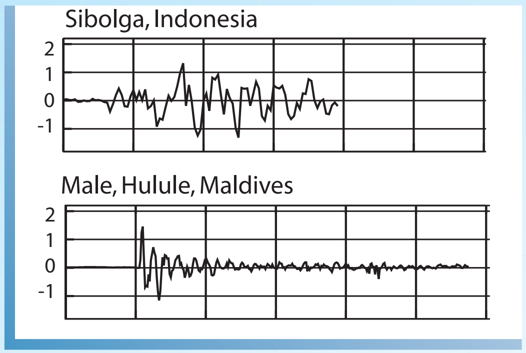
OCEAN-WIDE AND REGIONAL TSUNAMIS

The last large tsunami that caused widespread death and destruction was generated in the Pacific 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 22 hours later. 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.

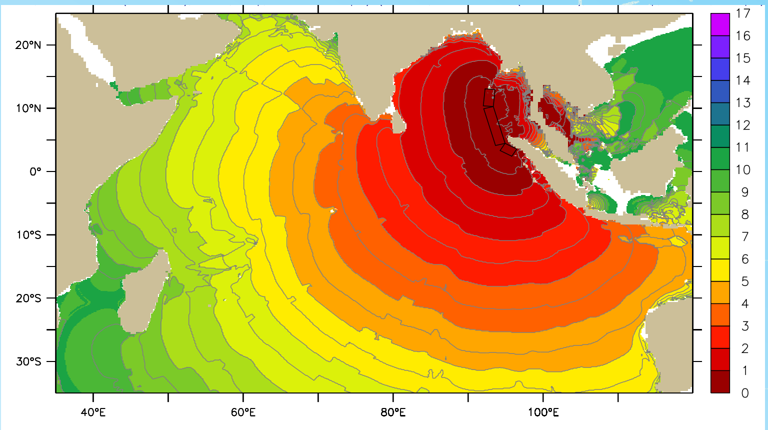
During the 1990s, destructive regional tsunamis also occurred in Nicaragua, Indonesia, the Philippines, Papua New Guinea, and Peru, killing thousands of people. Others caused property damage in Chile and Mexico. Some damage also occurred in the far field in the Marquesas Islands (French Polynesia) from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

In less than a day, tsunamis can travel from one side of the ocean 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, Indonesia 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 hours to reach coastal areas.



Sea level records of the tsunami recorded at Sibolga on the northwest coast of Sumatra, Indonesia, and Male, Hulule, Maldive Islands from the December 26, 2004 tsunami that caused ocean-wide destruction. The first wave was not the largest at Sibolga. Vertical axis in meters. (University of Hawaii Sea Level Center, BAKOSURTANAL, Indonesia)

THE MOVE



Calculated tsunami travel times for the December 26, 2004 earthquake off western Sumatra. Each concentric curve represents 30 minutes of tsunami travel time. Destructive tsunami hit Indonesia in 15 minutes, Sri Lanka in two hours, and Kenya nine hours after the earthquake (NOAA PMEL).

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.

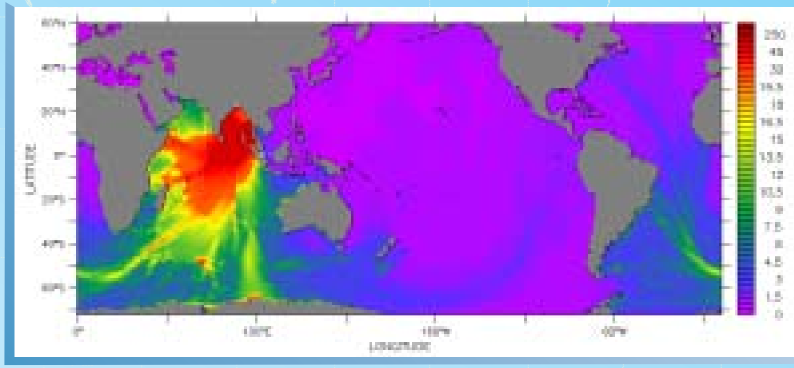
HOW BIG?

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 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, flooding large expanses of land with water and debris.

During post-tsunami field surveys, inundation and runup measurements are taken to describe the tsunami effects. Inundation is 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.

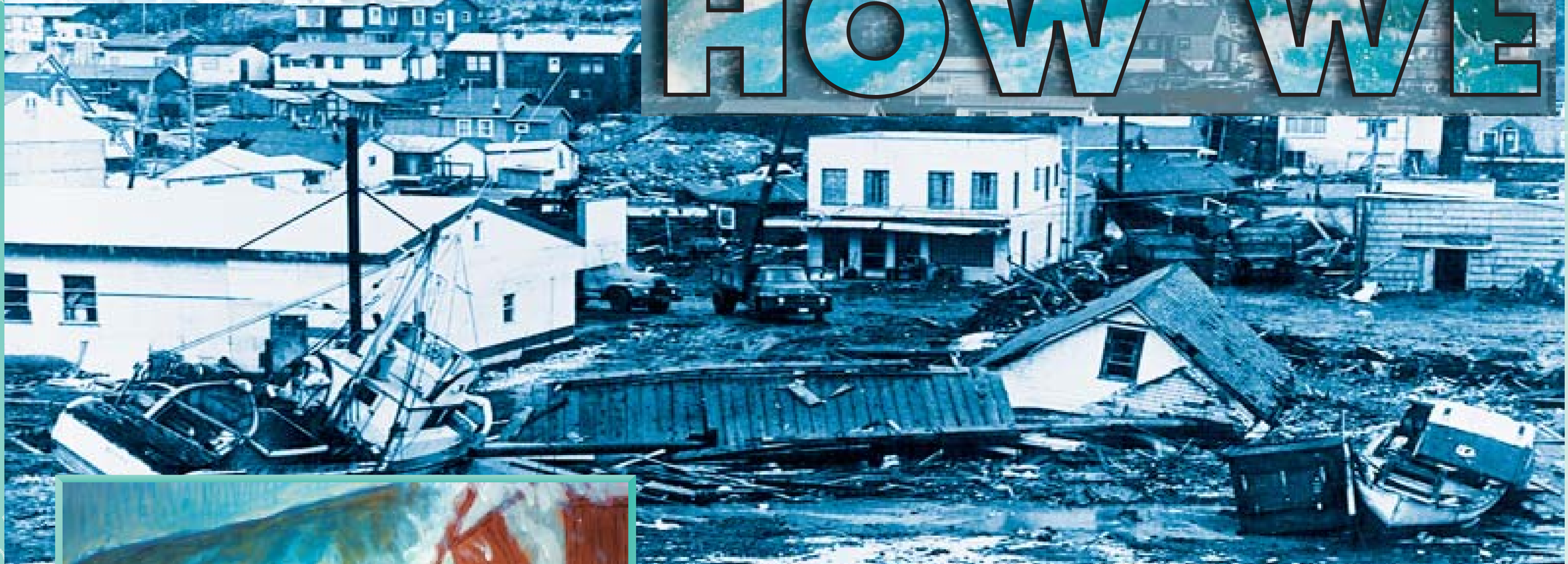
HOW FREQUENT?

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. Paleotsunami research, in which scientists look for sediments deposited by giant tsunamis, is helping to extend the documented historical tsunami record further back in time. As more events are found, better estimates of the frequency of occurrence of tsunamis in a region are obtained. During each of the last five centuries, there were three to four Pacific-wide tsunamis, most of them generated off the Chilean coasts. The tsunami on December 26, 2004 claimed 300,000 lives and caused damage throughout the Indian Ocean, making it the worst tsunami catastrophe in history. It was also the first known basin-wide destructive tsunami in the Indian Ocean.

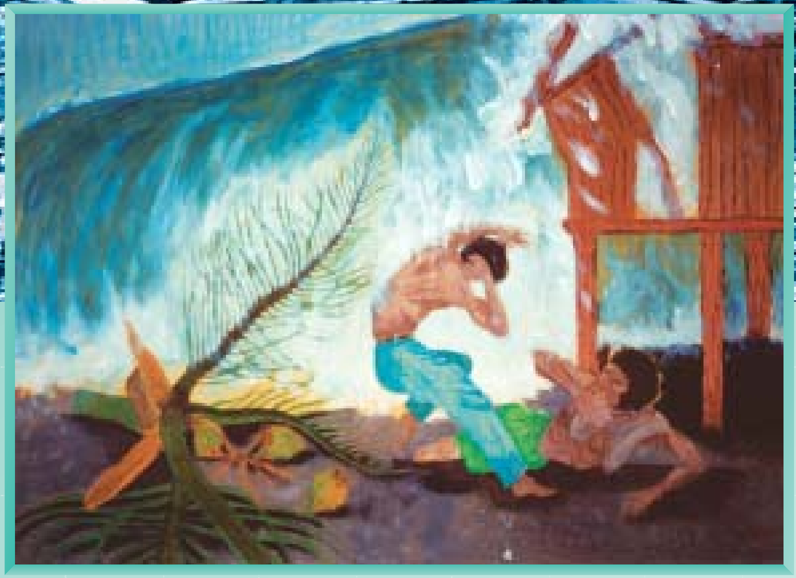


Maximum calculated global wave heights (cm) from the December 26, 2004 Indian Ocean tsunami. Waves were recorded on sea level gauges in Antarctica, and along the coasts of South and North America and Canada in both the Pacific and Atlantic Oceans (NOAA PMEL).

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 Centre (ITIC)

Located in Honolulu, Hawaii, the ITIC serves as the information service for the IOC's Tsunami Programme. The ITIC's responsibilities include monitoring and recommending improvements to the international tsunami warning system, helping Member States to establish regional and national tsunami warning systems, supporting technology transfer through training programmes in tsunamis, and serving as an information clearinghouse for the promotion of research, and the development and distribution of educational and preparedness materials to mitigate against the tsunami hazard. The ITIC regularly publishes the Tsunami Newsletter, maintains a tsunami library, hosts a Bulletin Board listserve, and conducts the IOC's Training Programme in tsunamis and tsunami warning systems.

SAVE LIVES

TSUNAMI WARNING CENTERS

The IOC is coordinating the implementation of the global tsunami warning and mitigation system, building upon its experiences in the Pacific to establish warning systems for the Indian Ocean, Caribbean Sea, and the Mediterranean Sea. The Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC) serves as the international warning center for the Pacific. 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. The ICG/ITSU, presently comprised of 27 Member States, oversees warning system operations and facilitates coordination and cooperation in all international tsunami mitigation activities. Since April 2005, the PTWC and Japan Meteorological Agency (JMA) have been cooperatively providing interim warning services for the Indian Ocean.

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 world 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 national and international agencies running seismic networks.

If an earthquake has the potential to generate a destructive tsunami based on its location, depth, and magnitude, 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 centre 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 or Indian Basin. PTWC receives sea level data from more than 100 stations through global data exchanges with the U.S. National Ocean Service, WC/ATWC, the University of Hawaii Sea Level Center, Chile, Australia, Japan, Russia, French Polynesia, 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.

Countries may operate National or Regional Centres to provide more rapid or detailed warnings for regional or local tsunamis. The JMA provides local warnings to Japan, and its Northwest Pacific Tsunami Advisory Center provides regional tsunami wave forecasts to Russia, Korea, China, Philippines, Indonesia, Papua New Guinea, and to the North Pacific for events in the Japan Sea and northwest Pacific. The Centre Polynesien de Prevention des Tsunamis provides regional warnings in French Polynesia. In the US, the WC/ATWC warns Alaska, the U.S. West Coast and Canada, and PTWC provides warnings locally to Hawaii, regionally to US Pacific interests, and assists warning authorities in Puerto Rico. Chile, Peru, and Russia have operated national warning systems for decades.

The IOC believes that sustainable regional warning systems must be built through international, multilateral cooperation. Free and open data and information exchange is paramount as the system should be owned by and provide services to every country in the region. While national centres may jointly operate international detection networks, each nation must be responsible for issuing its own national tsunami warnings and for protecting its own population. National warning centres must therefore build strong links with emergency preparedness agencies so that warnings ultimately reach all households. Warning centres can also serve as backups should another centre become disabled, and can be focal points for awareness, education and other mitigation activities.

Information about the IOC

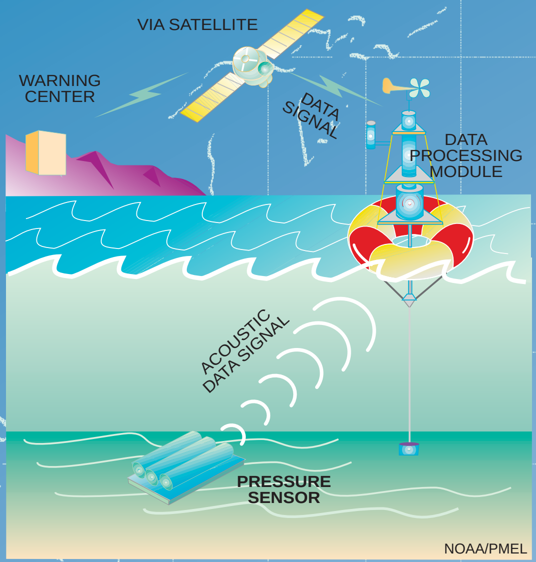
The Intergovernmental Oceanographic Commission (IOC), a body with functional autonomy within the United Nations Educational, Scientific and Cultural Organization (UNESCO), provides Member States with an essential mechanism for global co-operation in the study of the ocean. The IOC assists governments to address their individual and collective ocean and coastal problems through the sharing of knowledge, information and technology and through the coordination of national and regional programs.

The functions of the IOC are to develop, recommend and coordinate international programs for scientific study of the oceans and related ocean services; to promote and make recommendations for the exchange of oceanographic data and the publication and dissemination of scientific investigation results; 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.

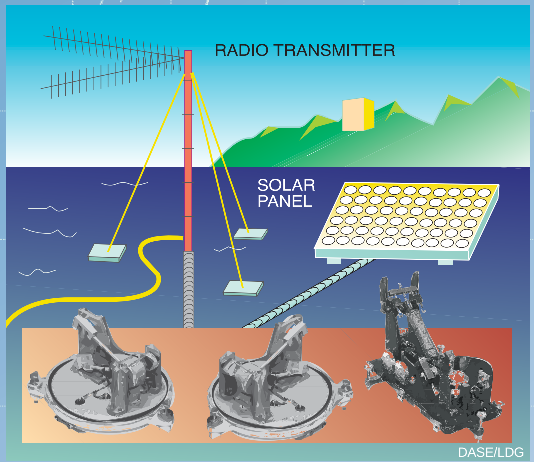
The IOC consists of an Assembly, an Executive Council, a Secretariat and such subsidiary bodies as it may establish. Under this concept, the Commission has created Global and Regional Programmes which examine and execute specific projects, or consist of committees composed of Member States interested in such projects. This is the case for the International Coordination Group for the International Tsunami Warning System (ICG/ITSU).

LOOKING INTO THE

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



INDEPENDENT 3 COMPONENT BROAD -BAND SEISMIC STATION



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

An effective tsunami warning system reaches all persons in danger before the wave hits

An effective tsunami early warning system is achieved when all persons in vulnerable coastal communities are prepared and respond appropriately, and in a timely manner, upon recognition that a potentially destructive tsunami is coming. Timely tsunami warnings issued by a recognized tsunami warning centre are essential. When these warning messages are received by the designated government agency, national tsunami emergency response plans must already be in place so that well-known and practiced actions are immediately taken to evaluate the scientifically-based warning, and communicate an appropriate course of action to ordinary citizens. Tsunami preparedness programmes must already have started so that good decisions can be made without delay.

Essential activities of an effective warning system are:

- Identification of the tsunami hazard, assessment of risk, and mitigation to reduce wave impact. Tsunami evacuation maps which show where flooding is likely are based on this information.

- Issuance of timely warnings. For a distant tsunami, real-time earthquake and sea level monitoring to confirm the generation of a destructive tsunami, followed by immediate dissemination to the public, is critical. For a local tsunami where there may not be time for an official warning, people must already know a tsunami's natural warning signals and respond immediately.

- Continuous and sustained awareness activities. Education is fundamental to building an informed citizenry and to ensure that the next generation is equally prepared. Political support, laws and regulations, and institutional responsibility are key.

EYES OF THE MONSTER

Tsunami Research Activities

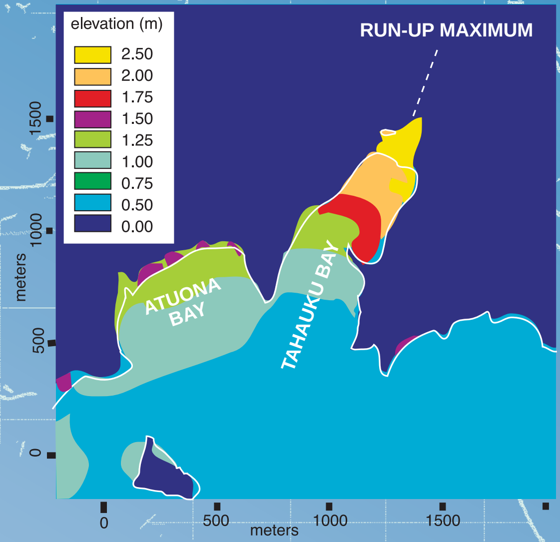
With the broad availability of relatively inexpensive yet powerful computers and desktop workstations, there is growing interest and activity in tsunami research. Using the latest computer technology, scientists can numerically model tsunami generation, open ocean propagation, and coastal runup.

Ocean-bottom pressure sensors, able to measure tsunamis in the open ocean, are providing important data on tsunami propagation in deep water, and satellite communications have enabled the data to be used in real time to detect and measure tsunami waves in the deep ocean. NOAA's Pacific Marine Environmental Laboratory pioneered development of these tsunami detection buoys and the numerical modeling tools required to operationally estimate coastal impact. By the end of 2005, at least seven DART buoys will be in operation in the north and east Pacific and available for use by the tsunami warning centres. Better equipment and numerical modeling methods help scientists better understand 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 potential for tsunami generation. Real-time determination of earthquake depth, type of faulting, and extent and direction of slippage will significantly improve the warning centres' ability to identify the likelihood of a threatening tsunami.

Tsunami generation is initiated by the three-dimensional deformation of the ocean bottom due to fault movement. Better characterizations of the earthquake fault mechanism will produce more realistic numerical models of propagation, runup, and inundation.

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 is issued.



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 south-east Pacific, nine hours after its generation.

Although a tsunami cannot be prevented, its impact can be mitigated through community preparedness, timely warnings, effective response, and public education. The U.S. National Tsunami Hazard Mitigation Program is a good example of a comprehensive effort to reduce tsunami risks.

THE FACTS

- *Tsunamis that strike coastal locations are almost always caused by earthquakes. The earthquakes might occur far away or near where you live. While earthquakes occur in all ocean basins around the world, most do not generate tsunamis.*
- *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 cause impacts like flash floods. Later waves are often full of debris.*
- *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 the 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.

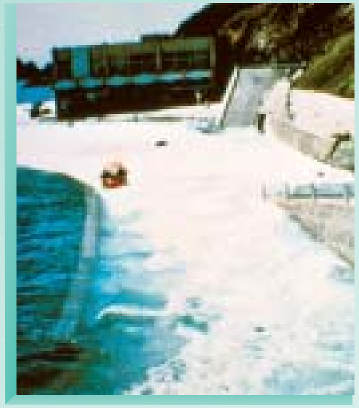
- If you are at home and hear there is a tsunami warning, make sure your entire family is aware. Prepare a family emergency plan beforehand so that everyone knows what to do. Your family should evacuate your house if you live in a tsunami evacuation zone. Move in an orderly, calm, and safe manner to 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 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 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 of aquarium is flooded stranding car during the May 26, 1983, Japan Sea tsunami. (Takaaki Uda, Public Works Research Institute, Japan)

WHAT YOU SHO

Banda Aceh, Sumatra, Indonesia. The tsunami of December 26, 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 (top). (DigitalGlobe QuickBird satellite imagery, US Navy photo)

ULD DO

IF YOU ARE ON A SHIP OR BOAT

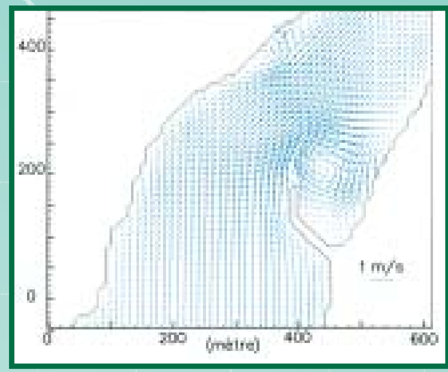
Since tsunami wave activity is imperceptible in the open ocean, do not return to port if you are at sea and a tsunami warning has been issued for your area. Tsunamis can cause rapid changes in water level and unpredictable dangerous currents in harbors and ports.

If there is time to move your boat or ship from port to a location where the water is more than 400m deep (and 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, 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, be sure you have enough time to motor your vessel safely into deep water. Small boat owners 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

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

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, the ocean recedes out to sea exposing the sea bottom, you hear the train-like roar of the tsunami, or you know that there is a warning, tell your relatives and friends, and

Move Quickly Inland and to Higher Ground!

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... partnering to reduce the risks of tsunami hazards.


TSUNAMI
THE GREAT WAVES