NTHMP Tsunami Information Guide

Presented by the National Tsunami Hazard Mitigation Program

2019

Table of Contents

This guidebook will be updated as needed. The most up-to-date version of the guide can be downloaded from: https://nws.weather.gov/nthmp/guide/. The content of this guide is in the public domain. Suggested citation: National Tsunami Hazard Mitigation Program (NTHMP). 2019. NTHMP Tsunami Information Guide. National Tsunami Hazard Mitigation Program.

1. Introduction

1.1 What is the purpose of this guide?

The purpose of this guide is to provide information about tsunamis in the United States.

1.2 Who will benefit from this information?

This guide will benefit anyone who wants to know more about tsunamis, the U.S. Tsunami Warning System, and how to prepare for tsunamis. If you're a member of the general public or the media, a teacher, community official, or a public information officer, this guide is for you.

1.3 How is this guide organized?

This guide is organized into five sections:

- Introduction
- Tsunami Basics
- Tsunamis in the United States
- U.S. Tsunami Warning System
- Tsunami Safety

The information is presented with question headings to better help you find the information you're looking for.

At the back of the guide, you'll find a list of acronyms used in the guide, some information about historic tsunamis, a list of key resources by section in case you want to know more, and NTHMP partner contact information.

1.4 What is the National Tsunami Hazard Mitigation Program?

The National Tsunami Hazard Mitigation Program (NTHMP) is a federal/state partnership that enables all levels of government to work together toward the common goals of protecting lives and reducing economic losses from tsunamis.

In 1995, Congress directed the National Oceanic and Atmospheric Administration (NOAA) to form and lead a federal/state working group to develop a plan for reducing tsunami risk to U.S. coastal communities. This group became the NTHMP.

NTHMP Mission and Vision

Mission: To mitigate the impact of tsunamis through public education, community response planning, hazard assessment, and warning coordination

Vision: Reduced loss of life and property when a tsunami strikes any U.S. state or territory and resilient communities that are prepared for tsunami hazards

After the 2004 Indian Ocean tsunami, Congress strengthened and expanded the NTHMP through the Tsunami Warning and Education Act. They reauthorized this federal authority through the Tsunami Warning, Education, and Research Act of 2017. (Public Laws 109-479 and 115-25, respectively; 33 U.S.C. 3201 et seq.)

Led by NOAA, the NTHMP also includes the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), and 28 U.S. states and territories (see Appendix D). Through collaboration, coordination, and technical and financial support to partner states and territories, the NTHMP works to reduce the impact of tsunamis on individual states and territories and, collectively, the nation.

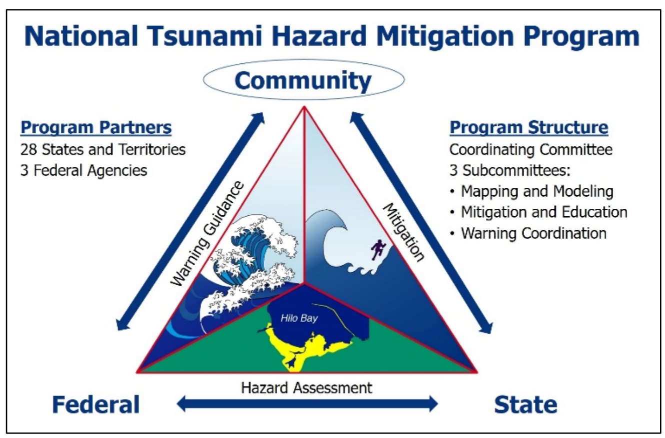

Figure 1. Structure of the NTHMP

2. Tsunami Basics

2.1 What is a tsunami?

A tsunami is one of nature's most powerful and destructive forces. It's a series (more than one) of extremely long waves caused by a large and sudden displacement of the ocean (i.e., something moves the water). A tsunami radiates outward in all directions from its source and can move across entire oceans in less than a day.

The speed of a tsunami depends on the depth of the water it's traveling through. The deeper the water, the faster the tsunami. In the deep ocean, tsunamis are barely noticeable, but they can move as fast as a jet plane, over 500 mph. As they enter shallow water near land, they slow to approximately 20 or 30 mph, which is still faster than a person can run.

As they slow down, tsunamis grow in height. When they arrive on shore, most are less than 10 feet high. In extreme cases, they can exceed 100 feet when they strike near their source. Large tsunamis can flood low-lying coastal areas more than a mile inland.

Not all tsunamis act the same, and an individual tsunami may affect coastal areas differently due to local offshore and coastal geographical features, like reefs, bays, entrances to rivers, and the slope of the beach. A small nondestructive tsunami in one place may be very large and violent a few miles away.

When a tsunami reaches the coast, it may look like a fast-rising flood or a wall of water. It will not look like a normal wind wave. Sometimes, the bottom of the wave, the trough, will arrive first. When this happens, before the water rushes on land, it suddenly recedes (drains away), showing the ocean floor, reefs, and fish like a very low, low tide.

The time between waves ranges from five minutes to two hours. The first wave may not be the largest or the most damaging. Dangerous coastal flooding and powerful currents may last for several hours or days. Tsunamis, even small ones, are a serious threat to life and property (see Question 2.6).

Historic Tsunamis

NOAA's National Centers for Environmental Information (NCEI)/World Data Service Global Historical Tsunami Database contains information about more than 1,200 confirmed tsunamis. Two of the most noteworthy tsunamis happened this century:

Deadliest Tsunami in History: On December 26, 2004, a magnitude 9.1 earthquake off the coast of the Indonesian island of Sumatra in the Indian Ocean generated a tsunami that reached as high as 167 feet and caused flooding up to three miles inland. The tsunami was responsible for most of the impacts, which were observed in 17 countries in Southeastern and Southern Asia and Eastern and Southern Africa. Impacts included approximately 230,000 deaths, the displacement of 1.7 million people, and roughly $13 billion* in economic losses. The extent of the losses was partly because of the lack of an official tsunami warning system in the Indian Ocean at the time and limited knowledge about tsunamis.

Most Expensive Natural Disaster in History: On March 11, 2011, a magnitude 9.1 earthquake off the east coast of Japan generated a tsunami that was observed throughout the Pacific Ocean. The tsunami reached as high as 128 feet and traveled up to five miles inland. In Japan, the earthquake and tsunami caused more than 18,000 deaths and approximately $247 billion* in damage. Most of the deaths and damage in Japan were due to the tsunami, which also displaced more than 500,000 people and resulted in a nuclear accident. Outside Japan, there was very little loss of life. This was due to timely warnings and evacuations as well as the greater lead time available to distant locations (hours versus minutes). However, there was one death in Papua, Indonesia, and one death in California. The tsunami also caused approximately $96 million* in damage in the United States (California and Hawaii) and $7 million* in losses to the fishing industry in Tongoy, Chile.

See Appendix B for information about other historic tsunamis.

*Adjusted for inflation (2018)

2.2 What causes a tsunami?

The most common cause of a tsunami is a large earthquake below or near the ocean floor, but landslides, volcanic activity, certain types of weather, and near earth objects (e.g., asteroids, comets) can also generate tsunamis. Most of the tsunamis (88%) in the Global Historical Tsunami Database since 1900 were generated by earthquakes or landslides caused by earthquakes.

Earthquakes

Not all earthquakes generate tsunamis. Whether an earthquake generates a tsunami depends on key characteristics like its location, magnitude, and depth. In general, earthquakes that generate tsunamis:

- Occur under or very near the ocean (usually at or near subduction zones, where oceanic and continental plates collide),
- Have magnitudes over 7.0 (usually, an earthquake must exceed magnitude 8.0 to generate a dangerous distant tsunami), and
- Are less than 100 kilometers (62 miles) below Earth's surface.

An earthquake with these characteristics can cause the ocean floor to suddenly rise or fall. This sudden vertical displacement of the ocean floor is what typically sets a tsunami in motion. As the ocean floor rises or drops, so too does the water above it. As the water moves up and down, trying to regain its balance, the tsunami radiates out in all directions. The amount of movement of the ocean floor, the size of the area over which the earthquake occurs, and the depth of the water above it are all important factors in the size of a resulting tsunami. Earthquakes can also cause landslides that generate tsunamis.

Examples of historic earthquake-generated tsunamis (see also the sidebars on pages 2 and 8):

- **May 22, 1960 Southern Chile**—A magnitude 9.5 earthquake, the largest ever recorded, produced a tsunami that was observed around the world. Devastation was greatest in Chile. More than 2,000 lives were lost due to the tsunami, some as far away as Japan, Hawaii, the Philippines, and California. Worldwide, damage was estimated at more than $9 billion (2018 dollars).

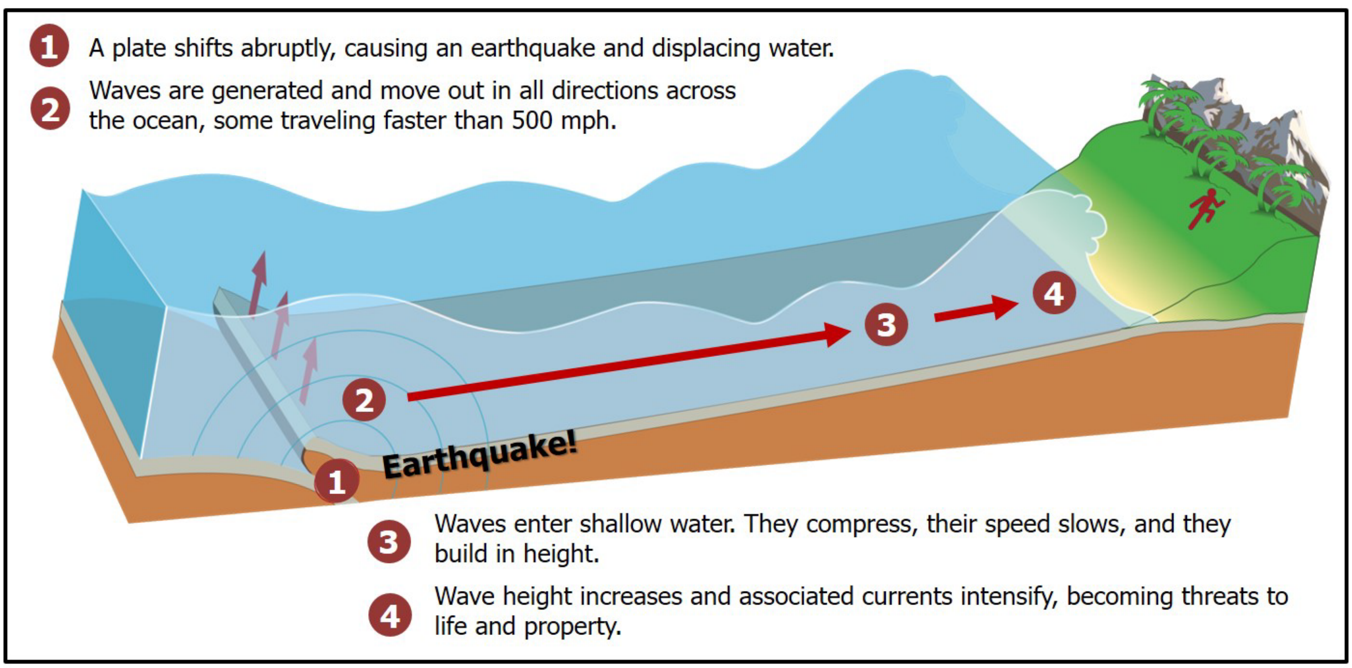

Figure 2. Formation of a tsunami caused by a large undersea earthquake. Source: Ocean Institute, modified by NOAA/National Weather Service

- **November 1, 1755 Lisbon, Portugal**—A magnitude 8.5 (estimated) earthquake in the Atlantic Ocean generated a tsunami that primarily affected the coasts of Portugal, North Africa, and Spain. Impacts were also recorded in England and Brazil. The earthquake and tsunami killed an estimated 50,000 people and caused widespread destruction.
- **January 26, 1700 Cascadia Subduction Zone**—A magnitude 9.0 (estimated) earthquake generated a tsunami that inundated the coasts of Cascadia (a region that includes northern California, Oregon, Washington, and southern British Columbia) as well as coastal villages on the other side of the Pacific Ocean in Japan. Today, the Cascadia Subduction Zone is considered one of the largest U.S. tsunami threats (see the sidebar on page 10).

An earthquake-generated tsunami may also be called a seismic sea wave ("seismic" means relating to an earthquake).

Landslides

As it relates to tsunami generation, "landslide" is a general term that incorporates a number of types of ground movement, including rock falls, slope failures, debris flows, and slumps. While icefalls/avalanches and glacial calving (the breaking off of large pieces of ice from a glacier) aren't really landslides, they act the same and are considered in this discussion of landslides.

Tsunamis can be generated when a landslide displaces the water from above (subaerial) or below (submarine). Tsunami generation depends on the amount of landslide material that displaces the water, the speed it's moving, and the depth it moves to. Near its source, a landslide-generated tsunami may be larger than a tsunami generated by an earthquake and can affect nearby coasts within minutes with little to no warning. These tsunamis usually lose energy quickly and rarely affect distant coasts.

Most landslides that generate tsunamis are caused by earthquakes, but other forces (like gravity, wind, and increased precipitation) can cause overly steep and otherwise unstable slopes to suddenly fail. Earthquakes that aren't large enough to directly generate a tsunami may be large enough to cause a landslide that can generate a tsunami. The occurrence of earthquake- and landslide-generated tsunamis in a single event can complicate the warning process and increase the losses.

Examples of historic landslide-generated tsunamis:

- **July 17, 1998 Papua New Guinea**—A moderately sized magnitude 7.0 earthquake triggered a large submarine landslide that generated a deadly tsunami. Three waves, the highest measuring roughly 49 feet, struck the coast within 20 minutes of the earthquake, destroying entire villages. Approximately 2,000 lives were lost, and more than 10,000 people were displaced.
- **July 10, 1958 Southeast Alaska**—A magnitude 7.8 earthquake triggered a number of submarine landslides, rock falls, and ice falls that generated tsunamis that killed five people. A rock fall into Lituya Bay sent water surging over the opposite shore, clearing trees around the bay up to a maximum height of 1,722 feet. It's considered the largest tsunami ever recorded.
- **November 18, 1929 Grand Banks, Newfoundland, Canada**—A magnitude 7.3 earthquake in the Atlantic Ocean triggered a submarine landslide that generated a tsunami. Waves up to 43 feet high were responsible for 28 deaths and $15 million (2018 dollars) in damage along the coast of Newfoundland.

Volcanic Activity

Tsunamis generated by volcanoes, both above and below water, are infrequent. A volcano must be close to the coast or not far below the sea surface to generate a significant tsunami.

Figure 3. The Augustine volcano in Alaska caused a damaging local tsunami in 1883. Source: U.S. Geological Survey, Game McGimsey

Several types of volcanic activity can displace enough water to generate destructive tsunamis, including the following:

- Pyroclastic flows (flowing mixtures of rock fragments, gas, and ash)
- Submarine explosions relatively near the ocean surface
- Caldera formation (volcanic collapse)
- Landslides (e.g., flank collapse, debris flows)
- Lateral blasts (sideways eruptions)

Like landslide-generated tsunamis, tsunamis generated by volcanic activity usually lose energy quickly and rarely affect distant coasts.

Examples of historic volcano-generated tsunamis:

- **August 27, 1883 Indonesia**—The volcano Krakatau (Krakatoa) exploded and collapsed, generating one of the largest and most destructive tsunamis ever recorded. Waves reaching 135 feet high destroyed coastal towns and villages along the coasts of Java and Sumatra and killed more than 34,000 people.
- **May 21, 1792 Kyushu Island, Japan**—At the end of the four-month eruption of the Unzen volcano, a flank collapse generated a tsunami with waves reaching 180 feet high that caused destruction around the Ariake Sea and more than 14,000 deaths.
- **~1610 BC Greece**—The eruption of the volcano Santorini (Thera) generated a tsunami that swept the shores of nearby islands and contributed to the end of the Minoan culture on the nearby island of Crete.

Weather

Air pressure disturbances often associated with fast moving weather systems, like squall lines (lines of active thunderstorms), can generate tsunamis. These "meteotsunamis" are similar to tsunamis generated by earthquakes. Their development depends on the intensity, direction, and speed of the air pressure disturbance as it travels over a water body with a depth that enhances wave magnification.

Meteotsunamis are regional, meaning they don't affect entire coastlines or bodies of water. Certain parts of the world are prone to meteotsunamis due to a combination of factors, including local weather patterns and the nearby offshore and coastal geography.

Most meteotsunamis are too small to notice, but large meteotsunamis can bring dangerous waves, flooding, and strong currents that can cause damage, injuries, and deaths. (Meteotsunami impacts are not as extreme as those caused by the recent earthquake-generated tsunamis in Japan and the Indian Ocean).

Examples of meteotsunamis:

- **June 13, 2013 Northeastern United States**—Despite clear skies and calm weather, unusual wave activity was reported along New Jersey and southern Massachusetts coasts. In Barnegat Inlet, New Jersey, three people were injured when a six-foot wave swept them off a jetty and into the water. Scientists determined the waves had been generated by a derecho (a high-speed windstorm associated with a strong band of thunderstorms) that had passed through the area hours earlier.

- **June 21, 1978 Vela Luka, Croatia**—Without warning and during relatively nice weather, flooding waves inundated the port town of Vela Luka. Scientists ultimately identified the source as atmospheric and deemed it the strongest meteotsunami on record. This event featured 19.5-foot waves, lasted several hours, and caused millions of dollars in damage.
- **June 26, 1954**—A 10-foot wave struck the shoreline of Lake Michigan near Chicago, Illinois, sweeping several people off piers. Eight deaths were attributed to this event, which has been attributed to a squall line and a rapid rise in air pressure.

2.3 Where do tsunamis happen?

Tsunamis can be generated in all of the world's oceans, inland seas, and in any large body of water. They can strike any coast and have caused damage and deaths in coastal areas all around the world. Certain areas are particularly prone to tsunamis and the devastation they can bring. This is due to their location near local tsunami sources and/or exposure to distant tsunami sources as well as the depth and shape of the nearby seafloor and coastal elevation and geographic features. Low-lying areas such as beaches, bays, lagoons, harbors, river mouths, and areas along rivers and streams leading to the ocean are most vulnerable.

Of the 811 confirmed tsunamis in the Global Historical Tsunami Database between 1900 and 2018, about 78% occurred in the Pacific Ocean (around the geologically active "Ring of Fire," see Figure 4), 9% in the Atlantic Ocean and Caribbean Sea, 7% in the Mediterranean Sea, 5% in the Indian Ocean, and 1% in other seas. The highest percentage of these tsunamis was generated off Japan (20%), followed by Russia (8%) and Indonesia (8%). While most tsunamis are small and nondestructive or only affect coasts near their source, some tsunamis can cause damage and deaths on distant shores (see Appendix B). The most significant distant tsunamis since 1900 originated off Alaska, Chile, Japan, Indonesia, Pakistan, and Russia.

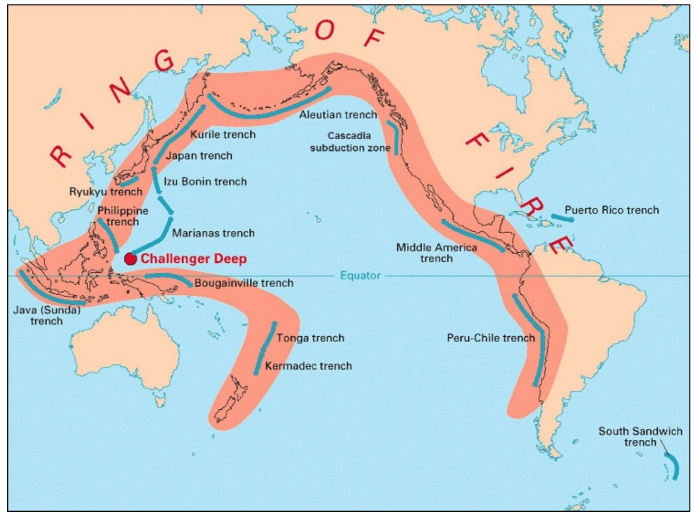

Figure 4. The Pacific "Ring of Fire" is the most volcanically and seismically active zone in the world. Source: Adapted from the U.S. Geological Survey

2.4 When do tsunamis happen?

Tsunamis can happen at any time, day or night, and during any kind of weather. There is no season for tsunamis.

2.5 What is the difference between a local and a distant tsunami?

The difference between a local and distant tsunami is the distance between a tsunami's source and where it may strike land and the amount of time it takes for a tsunami to travel this distance.

A *local tsunami*, also called a local-source or near-field tsunami, is from a nearby source and may arrive in less than one hour, sometimes in just minutes. Local tsunamis pose the greatest threat because tsunamis are most damaging near their source and there is little time to issue official warnings and evacuate. There may not be time to wait for an official tsunami warning, so the public must know how to recognize and respond to natural tsunami warnings (see Question 5.2).

A *distant tsunami*, also called a distant-source tsunami, a far-field tsunami, or a teletsunami, is from a faraway source, sometimes on the other side of the ocean. This means there is more time to issue and respond to official warnings (usually at least three hours).

A tsunami can be both a local and a distant tsunami. For example, if an earthquake off the coast of Alaska causes a tsunami that affects both Alaska and Hawaii, it's a local tsunami for Alaska, but a distant tsunami for Hawaii.

2.6 Why are tsunamis dangerous?

Figure 5. The 2009 Samoa tsunami inundated Pago Pago in American Samoa. Source: NOAA/National Centers for Environmental Information

Tsunamis are dangerous because they can strike with tremendous force and little warning and devastate coastal communities. They are a significant threat to human health, built and natural environments, and local, regional, and national economies.

Most tsunami damage and destruction is caused by flooding, wave impacts, erosion, strong currents, and floating debris (e.g., trees, structures, vehicles, and other things that can act like battering rams). The water can be just as dangerous, if not more so, as it returns to the sea, taking debris and people with it.

Tsunamis over one meter (3.28 feet) high are particularly dangerous to people and property, but smaller tsunamis also pose a threat. It only takes six inches of fast-moving water to knock over an adult and two feet of fast-moving water to carry away most vehicles. Strong currents can injure and drown people in or near the water and damage and destroy boats and infrastructure in harbors.

In addition to loss of life and mass injuries, other impacts may include damage to and destruction of homes and businesses, ports and harbors, natural and cultural resources, utilities, and critical infrastructure and facilities. Basic services such as power, sewer, and water may not be available after a tsunami. Communications, transportation (ground, air, and marine), and health and public safety services may also be disrupted.

Impacts from a large local tsunami will likely be in addition to impacts from a preceding earthquake, and impacts from both may trigger secondary hazards. Earthquakes and tsunamis can cause fires, transportation accidents, and hazardous material releases into the environment, which can contaminate water supplies and threaten public health. These impacts can further complicate evacuation, response, and recovery.

Earthquakes and tsunamis can also change the land, both above and below the water. In some places, the land may rise. In others, it may drop. If the coast drops, flooding may reach farther inland than expected, and tsunami barriers may fail or be overtopped. Associated landslides and other sediment shifts and depositions can make waterways unnavigable.

Other potential consequences include permanent changes to beaches and other coastal features, loss of or changes to wildlife habitat, and changes to the quality and availability of fresh water. Inundation by salt water, short or long term, can damage ecosystems and make agricultural land useless. The force of the water, pollutants and toxic substances, sediment, marine debris, and invasive species can also harm agricultural land and natural resources on shore and off. Changes to these resources can affect the services they provide (e.g., biological, ecological, protective, and recreational).

3. Tsunamis in the United States

3.1 Where can tsunamis happen in the United States?

According to a tsunami hazard assessment conducted for the NTHMP by NOAA and the USGS, a tsunami can strike any U.S. coast, but the hazard level varies. The authors of this assessment assigned regional hazard levels based largely on the historical record (through 2014), geological evidence, and location relative to tsunami sources, all of which provide clues to what might happen in the future.

The hazard is greatest for coasts near subduction zones. Dangerous subduction zones ring the Pacific Ocean and are also in the Caribbean. Approximately 95% of reported U.S. tsunami strikes were to Pacific states and territories.

Note: All dollar figures in this section have been adjusted for inflation (December 2018).

Significant U.S. Tsunamis

The deadliest U.S. tsunami on record was generated by a magnitude 8.6 earthquake in the Aleutian Islands, Alaska, on April 1, 1946. Of the 164 U.S. deaths, 158 were in Hawaii, 5 in Alaska, and 1 in California. Most of the $359 million* in damage was in Hawaii. What is now NOAA's Pacific Tsunami Warning Center in Honolulu, Hawaii, was established in response to this tsunami.

The most expensive U.S. tsunami on record was generated by a magnitude 9.2 earthquake (the largest recorded in U.S. history) in Prince William Sound, Alaska, on March 27, 1964 (local time). The earthquake generated a number of tsunamis that caused approximately $859 million* in damage in Alaska, along the West Coast, and in Hawaii. About 124 deaths were caused by the tsunami. NOAA's National Tsunami Warning Center, as it's known today, in Palmer, Alaska, was established in response to this tsunami.

See Appendix B for information about other U.S. tsunamis.

*Adjusted for inflation (2018)

U.S. West Coast's Tsunami Hazard Level

High to Very High—The West Coast states of Washington, Oregon, and California have experienced tsunamis from as far away as Alaska, South America, Japan, and Russia. The most damaging on record is the tsunami caused by the 1964 Great Alaska earthquake. More recently, harbors in the region were damaged by events in Japan (2011) and Chile (2010). Other tsunamis in the region were produced by local earthquakes and landslides (both submarine and subaerial). Locally, the greatest threat is from the Cascadia subduction zone (see the sidebar on page 10).

REPORTED U.S. WEST COAST TSUNAMIS: EARLIEST: 1812 | TOTAL EVENTS: 94 | EVENTS WITH RUNUPS ABOVE ONE METER: 17 | TOTAL DAMAGE: $249 MILLION | TOTAL DEATHS: 25

Note: Tsunamis with runups over one meter (3.28 feet) are particularly dangerous. (Runup is the maximum elevation of the tsunami flooding on shore.)

Alaska's Tsunami Hazard Level

High to Very High—Given its location near some of the most dangerous seismic zones in the world, a number of damaging tsunamis have affected the Pacific Coast of Alaska. Historic events include the tsunamis that devastated coastal communities in March 1964, which were produced by the largest recorded earthquake in U.S. history and associated submarine landslides. Due to Alaska's steep terrain, landslides and icefalls have also caused tsunamis in Alaska. The highest tsunami in recorded history occurred in 1958 when an earthquake-generated landslide produced a tsunami that cleared trees up to 1,722 feet above Lituya Bay. Volcanic activity has also caused tsunamis in Alaska as demonstrated by the Augustine Volcano in 1883.

REPORTED ALASKA TSUNAMIS: EARLIEST: 1737 TOTAL EVENTS: 100 | EVENTS WITH RUNUPS ABOVE ONE METER: 22 | TOTAL DAMAGE: $731 MILLION TOTAL DEATHS: 222

The tsunami hazard for the Alaska Arctic Coast (incudes the western coast) is very low. There are no tsunamis or significant earthquakes on record for the region, which is not seismically active and is not near a subduction zone.

Hawaii's Tsunami Hazard Level

High to Very High—Hawaii has a long history of damaging tsunamis. Its tsunami record includes events caused by earthquakes both near and far. Significant tsunamis were produced locally in 1868 and 1975, but the majority of Hawaii's destructive tsunamis were produced by distant subduction zone earthquakes. Notable distant tsunamis came from Chile (1837, 1877, 1960), Russia (1923, 1952), Alaska (1946, 1957), and Japan (2011). Submarine landslides also pose a threat, and volcanic activity was responsible for a tsunami in 1919.

REPORTED HAWAII TSUNAMIS: EARLIEST: 1812 TOTAL EVENTS: 134 | EVENTS WITH RUNUPS ABOVE ONE METER: 30 | TOTAL DAMAGE: $680 MILLION TOTAL DEATHS: 293

American Samoa's Tsunami Hazard Level

High—Historically, tsunamis in American Samoa have originated around the Pacific, but the greatest threat is from the nearby Tonga trench. This was made clear in 2009, when an earthquake near this subduction zone produced the worst tsunami in the territory's recorded history.

REPORTED AMERICAN SAMOA TSUNAMIS: EARLIEST: 1837 | TOTAL EVENTS: 68 | EVENTS WITH RUNUPS ABOVE ONE METER: 4 | TOTAL DAMAGE: $146 MILLION TOTAL `DEATHS: 34

Guam and the Northern Mariana Islands' Tsunami Hazard Level

High—Guam and the Northern Mariana Islands have been struck by tsunamis from sources both local and distant (Japan and Russia, most notably). The region's largest tsunami on record was produced by a large earthquake off Guam in 1849. The greatest threat is from the nearby Marianas trench, a significant subduction zone.

REPORTED GUAM/NORTHERN MARIANA ISLANDS TSUNAMIS: EARLIEST: 1849 | TOTAL EVENTS: 25 EVENTS WITH RUNUPS ABOVE ONE METER: 4 | TOTAL DEATHS: 1

Puerto Rico and the U.S. Virgin Islands' Tsunami Hazard Level

High—The U.S. Atlantic tsunami hazard is greatest for Puerto Rico and the U.S. Virgin Islands. Just to the north of the islands, in the Atlantic Ocean, lies the Puerto Rico trench, a dangerous subduction zone like those in the Pacific. However, most of the recorded tsunamis in the region were produced by local earthquakes outside of the trench, most notably in 1867 and 1918, or in the broader Caribbean region, like off the coast of Hispaniola (1842, 1946, 2010). Tsunamis caused by distant earthquakes, volcanic activity, and submarine landslides may also affect the region.

REPORTED PUERTO RICO AND U.S. VIRGIN ISLANDS TSUNAMIS: EARLIEST: 1690 | TOTAL EVENTS: 13 | EVENTS WITH RUNUPS ABOVE ONE METER: 4 TOTAL DAMAGE: $63 MILLION | TOTAL DEATHS: 164

U.S. Atlantic Coast's Tsunami Hazard Level

Very Low to Low—The history of U.S. Atlantic Coast tsunamis is short, but shows that tsunamis can happen in the region. Key events include an earthquake (1886) and a submarine landslide (1964) that both produced small local tsunamis. Also, a tsunami produced by an earthquake-generated landslide off Newfoundland, Canada (1929) recorded as small waves along the U.S. coast, but caused death and destruction near its source. There is no subduction zone along the U.S. Atlantic Coast, and earthquakes are not as large or as frequent as in other regions. Submarine landslides and meteotsunamis are the most likely source of tsunami waves in the region. More distant tsunami threats come from the Puerto Rico trench, the Canary Islands, and the Azores-Gibraltar fault zone.

REPORTED U.S. ATLANTIC COAST TSUNAMIS: EARLIEST: 1886 | TOTAL EVENTS: 8

Cascadia Subduction Zone Earthquakes and Tsunamis

The greatest tsunami threat for the United States is the Cascadia subduction zone, which lies mostly off shore and extends approximately 700 miles from Cape Mendocino in Northern California to Northern Vancouver Island, Canada. In the last few decades, researchers have uncovered a long history of great earthquakes and tsunamis in the region.

The most recent event, an estimated magnitude 9.0 earthquake and tsunami, was on January 27, 1700. Despite the lack of reported impacts in the Cascadia region, researchers confirmed this event through analysis of historical records in Japan, Native American oral histories that tell of shaking and flooding along the region's coast, geologic and natural history, and numerical tsunami models.

If such an event were to happen again, the ground would shake for 3–5 minutes, and a tsunami up to 60 feet high would arrive within 10–20 minutes in some places closest to its source. Impacts would be significant and include loss of life and injuries as well as damage to and destruction of buildings and critical infrastructure.

Scientists can't predict when and where the next great earthquake and tsunami will happen, or how big it will be. However, they estimate that the chance of an event occurring in the next 50 years is about 10–17% for the Washington coast, 16–22% for the central to northern Oregon coast, and 37–42% for the southern Oregon/Northern California coast. Despite the uncertainty, they are working with engineers and public officials to better understand the threat and prepare communities for the potential impacts.

U.S. Gulf Coast's Tsunami Hazard Level

Very Low—Like the U.S. Atlantic Coast, the U.S. Gulf Coast is not near a subduction zone, and there has not been much tsunami or seismic activity recorded in the region. Still, evidence suggests a tsunami is possible. An earthquake off Puerto Rico (1918) produced the only tsunami on record for the Gulf Coast. However, the geography of the Gulf may reduce the impact of most distant tsunamis. Geologic evidence in the Gulf of Mexico points to submarine landslides as the region's likeliest tsunami source.

REPORTED U.S. GULF COAST TSUNAMIS:
EARLIEST: 1918 | TOTAL EVENTS: 1

4. U.S. Tsunami Warning System

4.1 What is the U.S. Tsunami Warning System?

The U.S. Tsunami Warning System is an end-to-end system led by NOAA that operates in partnership with other federal, state, territory, international, and local organizations as well as industry. Major components include observational networks to detect and measure earthquakes capable of generating tsunamis as well as tsunamis themselves, models to forecast tsunami impacts, messages that are both timely and accurate, information to support community response decision-making, and preparedness and mitigation activities that improve tsunami response and reduce or eliminate impacts.

4.2 What do the U.S. tsunami warning centers do?

The U.S. tsunami warning centers help protect lives and property from tsunamis. Staffed 24 hours a day, seven days a week, the warning centers monitor observational networks, analyze earthquakes, evaluate water-level information, issue tsunami messages, conduct public outreach, and coordinate with the NTHMP and government, academic, and international organizations to continually improve their operations.

NOAA's National Weather Service (NWS) operates the two U.S. tsunami warning centers (see Figure 6).

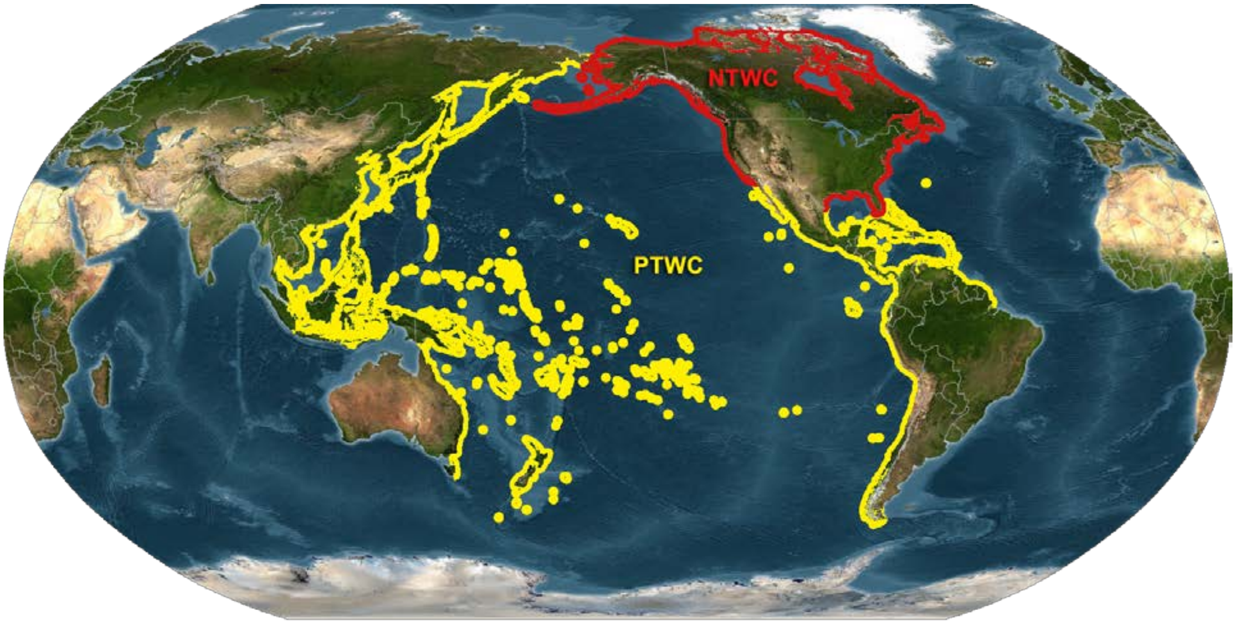

Figure 6. Coverage areas for the U.S. tsunami warning centers: National Tsunami Warning Center (red), Pacific Tsunami Warning Center (yellow)

- The National Tsunami Warning Center (NTWC) in Palmer, Alaska, serves the continental United States, Alaska, and Canada.
- The Pacific Tsunami Warning Center (PTWC) in Honolulu, Hawaii, directly serves the Hawaiian Islands, the U.S. Pacific and Caribbean territories, and the British Virgin Islands. The PTWC is also the primary international forecast center for the warning systems of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization (UNESCO/IOC) in the Pacific and the Caribbean and adjacent regions.

4.3 How do the U.S. tsunami warning centers detect and observe tsunamis?

To detect and measure tsunamis, the U.S. tsunami warning centers depend on seismic and water-level networks from around the world. Information provided by these networks helps them determine when and where to issue tsunami messages.

- **Seismic networks**—When an earthquake occurs, networks of seismic stations provide information about an earthquake's location, depth, magnitude, and other characteristics. The warning centers analyze this information to determine if the earthquake could have generated a tsunami and if tsunami messages are necessary.
- **Water-level networks**—If an earthquake meets certain criteria, the warning centers use information about water-level changes to determine if a tsunami has been generated and, if so, its size. This helps them refine their tsunami messages. The primary sources of information about water-level change are a network of Deep-ocean Assessment and Reporting of Tsunami (DART) systems and an extensive array of coastal water-level stations.
    - DART systems were developed by NOAA's Pacific Marine Environmental Laboratory (PMEL) for the early detection, measurement, and real-time reporting of tsunamis in the open ocean. NOAA's National Data Buoy Center (NDBC) operates and maintains the U.S. network of DART systems, which is part of a larger international network. The U.S. network is composed of 39 systems strategically located throughout the Pacific and Atlantic Oceans, the Gulf of Mexico, and the Caribbean Sea.

Figure 7. DART system buoy

- Coastal water-level stations collect important information about ocean height at specific coastal locations. The warning centers use this information to confirm tsunami arrival time and height and incorporate it into tsunami forecast models. Coastal water-level stations are owned and operated by a number of national and international organizations. Most of the U.S. tsunami-capable coastal water-level stations (i.e., data is available in one-minute intervals) are operated and maintained by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) as part of the National Water Level Observation Network.

Figure 8. Coastal water-level station

The time it takes to detect a tsunami after an earthquake depends on the distance between the source of the earthquake and the nearest DART system or coastal water-level station. Normal time frames range from five minutes to two hours.

4.4 How do the U.S. tsunami warning centers forecast and warn about tsunamis?

To forecast the location and timing of tsunami impacts, the U.S. tsunami warning centers begin with what is usually the first sign of a potential tsunami, an earthquake. Seismic waves travel about 100 times faster than tsunamis, so information about an earthquake is available before information about any tsunami it may have generated. The warning centers rely on three key pieces of information about an earthquake to determine if it might have generated a tsunami: location, depth, and magnitude. They use this preliminary seismic information and preset criteria, which varies by region, to decide if they should issue tsunami messages and which alert level(s) to include (see Question 4.5).

The amount of time it takes for a warning center to issue initial tsunami messages depends on the number and location of seismic stations (i.e., their density) near an earthquake's point of origin. In regions of high seismic station density, the warning centers can issue messages within five minutes. In areas of lower seismic station density, response time increases to 10–15 minutes.

After the warning centers issue the initial messages, they conduct additional seismic analysis and run tsunami forecast models using real-time information from the seismic and water-level networks (as it becomes available), preset scenarios, and information about the offshore and coastal geography to determine how the tsunami will move across the ocean and to estimate impacts at specific coastal locations. Impact information includes wave height and arrival times, location and extent of coastal flooding, and how long the tsunami will last.

The resulting forecasts, combined with historic tsunami information and additional seismic analysis, help the warning centers decide if they should update or cancel messages. Forecasts also provide local officials with actionable information that can guide decisions about beach and road closures and evacuation.

It's more difficult to forecast tsunamis caused by forces other than earthquakes (like meteotsunamis and tsunamis caused by landslides and volcanic activity), which can arrive with little to no warning. Even if such a tsunami is detected by a DART system or coastal water-level station, there may not be time to develop a detailed forecast. In the case of meteotsunamis, NOAA Weather Forecast Offices, with input from the tsunami warning centers, can notify the public of the potential coastal threat if certain weather conditions exist along with observed water-level changes.

4.5 What is a tsunami message?

A tsunami message is what the U.S. tsunami warning centers use to notify emergency managers, other officials, the media, the public, and others about the potential for a tsunami following a possible tsunami-generating event.

For the United States, Canada, and the British Virgin Islands, tsunami messages include alert levels: warnings, advisories, watches, and information statements. Initial tsunami messages include alert level(s), preliminary information about the earthquake, and an evaluation of the threat. If a tsunami is already suspected, the message may also include wave arrival times, recommended life safety actions, and potential impacts. Later messages, which are typically issued hourly, may feature more refined, detailed, and targeted information.

The warning centers issue a cancellation after they determine that a tsunami will not affect an area under a warning, advisory, or watch or that a tsunami has diminished to a level where additional damage is not expected.

The PTWC issues international tsunami messages to partners in the Pacific and Caribbean for guidance only in support of the UNESCO/IOC Pacific Tsunami Warning and Mitigation System (PTWS) and the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS). There are two types of international tsunami messages: tsunami threat messages and tsunami information statements.

These messages advise national authorities about the PTWC's evaluation of a tsunami to help the authorities decide if they should issue alerts for their coasts. The PTWC does not include actionable alerts (warning, advisory, watch) for the coasts of these international partners.

Tsunami warning

A tsunami warning is issued when a tsunami with the potential to generate widespread inundation is imminent, expected, or occurring. Warnings alert the public that dangerous coastal flooding accompanied by powerful currents is possible and may continue for several hours after initial arrival. Warnings alert emergency management officials to take action for their tsunami hazard zone(s). Appropriate actions to be taken by local officials may include the evacuation of low-lying coastal areas and the repositioning of ships to deep waters when there is time to safely do so. Warnings may be updated, adjusted geographically, downgraded, or canceled based on updated information and analysis.

In general, the warning centers issue a tsunami warning if the forecast or observed tsunami height at the coast exceeds 1.0 meter (3.3 feet) above the tide or the impact is unknown.

Tsunami advisory

A tsunami advisory is issued when a tsunami with the potential to generate strong currents or waves dangerous to those in or very near the water is imminent, expected, or occurring. The threat may continue for several hours after initial arrival, but significant inundation is not expected for areas under an advisory. Appropriate actions to be taken by local officials may include closing beaches, evacuating harbors and marinas, and the repositioning of ships to deep waters when there is time to safely do so. Advisories may be updated, adjusted geographically, upgraded to a warning, or canceled based on updated information and analysis.

In general, the warning centers issue a tsunami advisory if the forecast tsunami height at the coast is between 0.3 and 1.0 meter (0.98 and 3.3 feet) above the tide or the observed height is between 0.5 and 1.0 meter (1.6 and 3.3 feet) above the tide.

Tsunami watch

A tsunami watch is issued when a tsunami may later impact the watch area. The watch may be upgraded to a warning or advisory or canceled based on updated information and analysis. Emergency management officials and the public should prepare to take action.

Typically, the warning centers will upgrade or cancel a watch at least 3 hours before impact is expected for a specific coastal location.

Tsunami information statement

A tsunami information statement is issued when an earthquake or tsunami has occurred of interest to the message recipients. In most cases, information statements are issued to indicate there is no threat of a destructive basin-wide tsunami and to prevent unnecessary evacuations. Information statements for distant events requiring evaluation may be upgraded to a warning, advisory, or watch based on updated information and analysis.

See Question 5.4 to learn how to respond to U.S. tsunami messages.

Tsunami threat message

A tsunami threat message is an international message issued by the PTWC to officially designated national authorities of the PTWS or CARIBE EWS when a potential or confirmed tsunami is forecast to affect some or all coasts within those systems. National authorities will determine the appropriate level of alert for each country and may issue additional or more refined information and instructions. The PTWC may update threat messages based on new information, data, and analysis and will issue a final tsunami threat message when they determine there is no further threat or that tsunami waves are below threat levels in most places and are diminishing.

If there is little to no threat following an earthquake or tsunami of interest to the national authorities of the PTWS or CARIBE EWS, the PTWC may issue an information statement. If warranted based on updated information and analysis, the PTWC may upgrade an information statement to a tsunami threat message.

Note: U.S. states and territories in the Pacific and Caribbean (American Samoa, Guam, Hawaii, Northern Mariana Islands, Puerto Rico, U.S. Virgin Islands) should refer ONLY to the PTWC messages specifically for their regions. International tsunami threat messages from the PTWC may mention U.S. states and territories, but they do not reflect the additional modeling and analysis conducted to fine-tune forecasts and set alert levels for the United States and should not to be relied on by U.S. states and territories.

Tsunami Alerts: Forecast and Observed Heights

In general, the tsunami warning centers base U.S. alerting decisions on the following criteria:

Alert level	Tsunami height at coast above the tide
Warning	>3.3 feet (1.0 meter) forecast or observed or Impact is unknown
Advisory	1.0 to 3.3 feet (0.3 to 1.0 meter) forecast or 1.6 to 3.3 feet (0.5 to 1.0 meter) observed
None	<1.0 foot (0.3 meter) forecast or observed

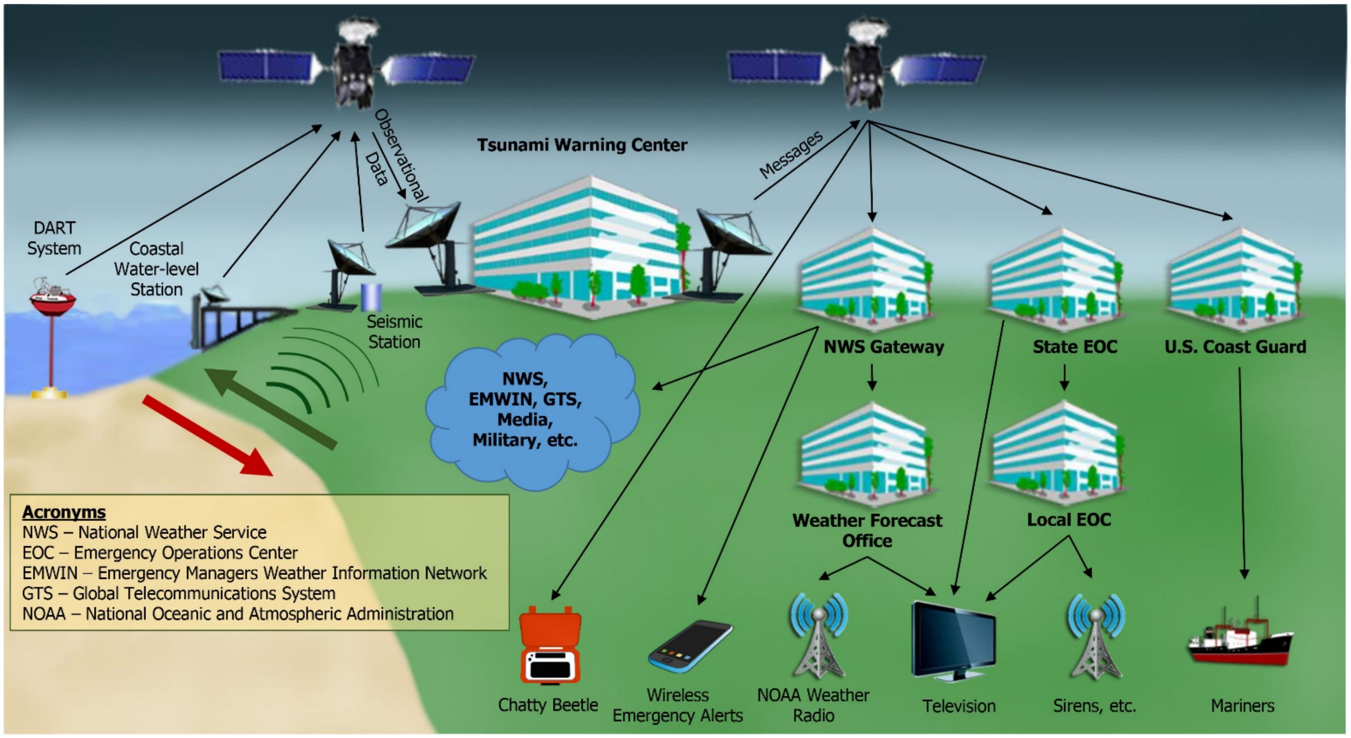

Figure 9. U.S. Tsunami Warning System diagram. Source: NOAA/National Weather Service

4.6 How do the U.S. tsunami warning centers issue tsunami messages?

The U.S. tsunami warning centers prepare and rapidly issue tsunami messages for their respective designated service areas (see Figure 6) through several standard NWS dissemination methods, employing a variety of technologies (e.g., telecommunications, satellite, internet, cellular, radio), to meet the different needs of their many partners (see Figure 9).

Primary recipients of these messages include NOAA Weather Forecast Offices, state and territory emergency operations centers, the U.S. Coast Guard, the U.S. military, and officially designated national authorities in the Pacific and Caribbean and adjacent regions. While the warning centers make their messages publicly available through communications tools like their website, social media, and text alerts, these primary recipients are typically responsible for disseminating tsunami messages from the warning centers to their constituents (e.g., the public).

4.7 What federal agencies support the U.S. Tsunami Warning System and what are their roles?

The primary federal agencies that directly support the U.S. Tsunami Warning System are NOAA, FEMA, and the USGS (see Appendix D for contact information for these agencies). Other federal agencies with tsunami responsibilities and/or interests include the U.S. Coast Guard, the U.S. Navy, the Federal Communications Commission, the National Aeronautics and Space Administration, the Department of State, and the National Science Foundation.

National Oceanic and Atmospheric Administration

NOAA is charged with operating the U.S. Tsunami Warning System, as previously described, in consultation with other relevant federal agencies and NTHMP partners. Specifically, this involves supporting the tsunami warning centers and their tsunami detection, forecasting, and warning capabilities. Other important aspects of NOAA's work include administration of the NTHMP and the TsunamiReady® program (see Question 5.7) to further community preparedness and outreach efforts, research and data collection to strengthen the tsunami warning center capabilities, and international coordination.

Federal Emergency Management Agency

FEMA is responsible for coordinating government-wide relief efforts for natural disasters, including tsunamis. FEMA also works with tribal, state, territory, and local governments to build a culture of preparedness, ready the nation for catastrophic disasters, and reduce the complexity of disaster response. FEMA works with its stakeholders to develop and promote tsunami risk-reduction tools, provide disaster-resilient design and construction guidance, support development of disaster-resistant building codes and standards, administer the National Flood Insurance Program, and operate the nation's alert and warning infrastructure (the Integrated Public Alert and Warning System).

U.S. Geological Survey

The USGS operates the Advanced National Seismic System and, along with other partners, supports the Global Seismic Network, which provides seismic data to NOAA's tsunami warning centers. The agency also assists the warning centers by conducting independent seismic analyses of earthquakes that may generate tsunamis. In addition, the USGS conducts targeted research on tsunami sources and societal impacts and provides technical assistance to NTHMP partners on tsunami sources, hazard modeling, vulnerability assessments, and evacuation modeling.

4.8 What roles do state/territory and local governments have in the U.S. Tsunami Warning System?

State and territory governments, typically through coordinated efforts between emergency management agencies and geological surveys, play an important role in tsunami preparedness, warning reception and dissemination, and response activities at both state/territory and local levels. Their work is often conducted through state/territory-level tsunami programs that, in cooperation with the NTHMP; other federal, state/territory, and local agencies; and Indian tribes/nations, support and promote tsunami planning, hazard assessment, public education, and other mitigation activities in coastal communities. In some cases, states and territories also contribute to tsunami monitoring. (See Appendix D for NTHMP state and territory partner contacts.)

To protect their residents and visitors from tsunamis, local governments define their tsunami hazard zones, conduct public education and outreach, develop tsunami response and evacuation plans, and implement systems for receiving and further disseminating tsunami messages from the tsunami warning centers. All of these activities help communities become recognized as TsunamiReady by NOAA. Local governments are typically responsible for decisions in their jurisdictions about evacuation and when it's safe to return to evacuated areas after a tsunami.

4.9 How does the United States support international tsunami warning systems?

The United States supports international tsunami warning systems by working with UNESCO/IOC, the World Meteorological Organization, and other international entities to develop a global system of regional tsunami warning networks. In coordination with the U.S. Secretary of State and in consultation with other federal agencies, NOAA leads the U.S. effort, largely through the work of the Pacific Tsunami Warning Center, the International Tsunami Information Center, and the Caribbean Tsunami Warning Program. Collectively, they provide tsunami forecast information, technical and operational support, training, and education and outreach assistance to UNESCO/IOC partners in the Pacific and Caribbean and adjacent regions.

Other U.S. assistance to international warning systems comes from the USGS and the Department of State's U.S. Agency for International Development (USAID). The USGS and its partners, including the Incorporated Research Institutions for Seismology and a variety of academic institutions, maintain an extensive network of seismic stations around the world that is vital to the global tsunami warning system. They also offer seismic monitoring training to international partners to help grow the global network. USAID supports these efforts and others, providing funding and technical assistance to improve detection and monitoring capabilities and increase tsunami awareness and preparedness at the community level.

Through NOAA, USGS, USAID, and other federal partners, the United States also assists other warning systems and countries through its general support for the UNESCO/IOC Tsunami Programme.

5. Tsunami Safety

Although tsunamis cannot be prevented, there are things that can be done before, during, and after a tsunami that could save lives.

5.1 What is my risk?

As discussed in Section 3, a tsunami can strike any U.S. coast, but the threat is not the same everywhere. To better understand your risk, find out if your home, school, workplace, or other places you visit often are in tsunami hazard zones and if your community has had tsunamis in the past.

Your local emergency management office, your state or territory's geologic or tsunami hazard website, and your local NOAA Weather Forecast Office are good sources of information. Another good resource is the NTHMP website, which provides links to tsunami maps around the country.

Also, find out if NOAA recognizes your community as TsunamiReady. TsunamiReady communities are better prepared for tsunamis.

5.2 How will I know if a tsunami is coming?

There are two ways you might learn that a tsunami is coming: official tsunami warnings and natural tsunami warnings (see Figure 10). Both are equally important. You may not get both. Be prepared to respond immediately to whichever you receive first. An *official tsunami warning* from the tsunami warning centers will be broadcast through local radio and television (e.g., through the Emergency Alert System), NOAA Weather Radio, wireless emergency alerts, marine radio, and NOAA websites (like Tsunami.gov). It may also come through outdoor sirens (to alert people who are outside), local officials, emails and text messages from state and local opt-in systems, and telephone notifications. In some cases, like wireless emergency alerts that only broadcast the first tsunami warning, broadcast of a message may depend on the level of alert and/or local circumstances.

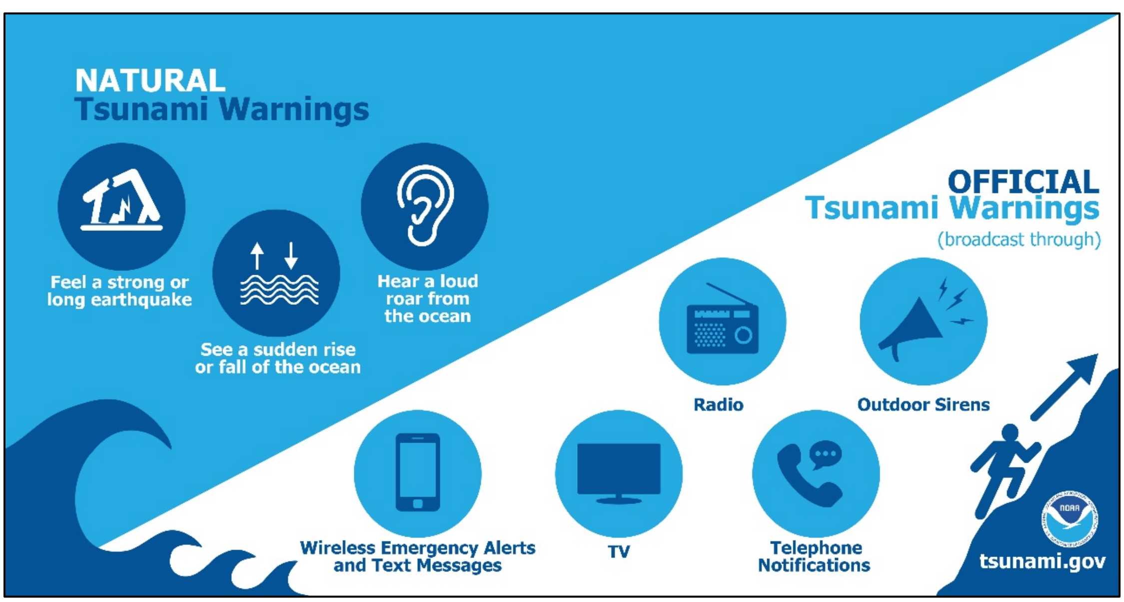

Figure 10. Natural and official tsunami warnings

There may not always be time to wait for an official tsunami warning, so it's important to understand natural warnings. A *natural tsunami warning* may be your first, best, or only warning that a tsunami is on its way.

Natural tsunami warnings include a strong or long earthquake, a loud roar (like a train or an airplane) from the ocean, and unusual ocean behavior. The ocean could look like a fast-rising flood or a wall of water or it could drain away suddenly like a very low, low tide. If you experience any of these natural warnings, even just one, a tsunami could be coming.

5.3 How can I prepare for a tsunami?

It's easy to prepare for a tsunami. Many of the things you should do to prepare for a tsunami are the same as those for other hazards in your community, but some are unique to tsunamis since response time may be limited.

If your home, school, workplace, or other places you visit often are in tsunami hazard zones, you should do the following:

- Ensure you have multiple ways to receive warnings. Get a battery operated NOAA Weather Radio, sign up for text message alerts from your local government, and make sure your mobile devices are set to receive wireless emergency alerts.
- Make an emergency plan that includes plans for family communication and evacuation. Meet with your family to discuss the plan and the importance of preparing for disasters. Practice your plan and keep it up to date.
- Map out routes to safe places on high ground or inland (away from the water) and outside the tsunami hazard zone. Your community may already have identified evacuation routes and assembly areas. Plan to evacuate on foot if you can; roads may be impassable due to damage, closures, or traffic jams.
    - If you think you won't be able to reach a safe place in time, ask your local emergency management office about vertical evacuation. Some strong (e.g., reinforced concrete) and tall buildings may be able to provide protection if no other options are available. This type of evacuation is not available, or recommended, in all areas.
- Practice walking your routes, even in darkness and bad weather. This will make evacuation quicker and easier during an emergency.
- Put together a portable disaster supplies kit with items you and your family (including pets) may need in an emergency. Since you do not know where you'll be when disaster strikes, prepare kits for work and cars too. Consider storing supplies with family or friends outside of the tsunami hazard zone.
- Be a role model. Share your knowledge and plans with friends and neighbors so they can prepare themselves and their loved ones.

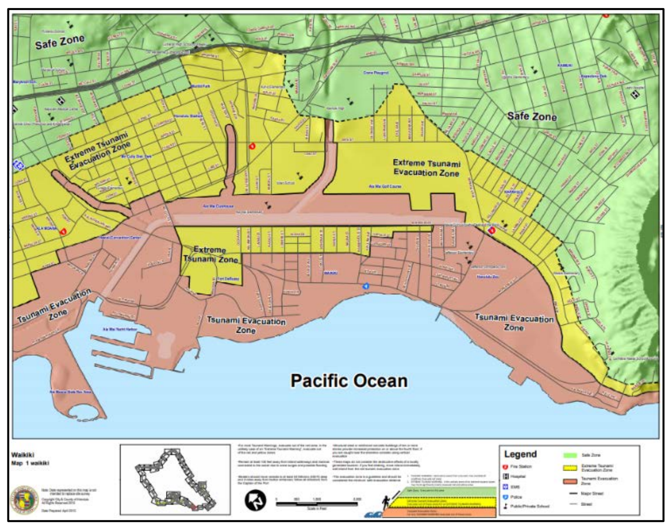

Figure 11. Example of a tsunami evacuation map

If you have children in school in a tsunami hazard zone, find out the school's plans for evacuating children and keeping them safe. Find out where the assembly area is and where to pick up your children after the danger has passed.

If you're visiting the coast, find out about local tsunami safety. Your hotel or campground should have this information.

5.4 How should I respond to a tsunami message?

How you respond to a tsunami message depends on the alert level and where you are when you receive a tsunami message. Tsunami warnings, advisories, and watches are "actionable" alert levels. This means there are recommended actions for people in tsunami hazard zones. These actions are described below. (See Question 4.5 for full definitions of the alert levels.) Typically, information statements don't require action. But if the tsunami warning centers determine there is a threat based on additional information and analysis, they can upgrade an information statement to an actionable alert level.

For your safety and others, always follow instructions from local officials because they may have more detailed or specific information. Limit nonemergency phone calls to keep the lines open for emergency communications.

If you're outside of the tsunami hazard zone and receive a tsunami message, stay where you are unless local officials tell you otherwise.

Tsunami warning

If you're in a tsunami hazard zone and receive an *official tsunami warning*, a tsunami with the potential to generate widespread inundation is likely:

- Stay out of the water and away from beaches and waterways.
- Get more information about the tsunami and what to do from local radio or television or your mobile device (text or data). Continue to stay informed throughout the event.
- If local officials ask you to evacuate, implement your emergency plan and move quickly to your safe place (see Question 5.3). If you do not have a safe place or cannot reach it, follow evacuation signs or go as high or far inland (away from the water) as possible.

If you're in a tsunami hazard zone and receive a *natural tsunami warning* (you feel a strong or long earthquake or the ocean sounds or acts strange), a tsunami could arrive within minutes:

- In case of an earthquake, protect yourself. Drop, cover, and hold on. Be prepared for aftershocks.
- Take action. Do not wait for an official warning or instructions from officials.
- As soon as you can move safely, move quickly to a safe place. Follow evacuation signs or go as high or far inland (away from the water) as possible.
- If there is earthquake damage, avoid fallen power lines and stay away from weakened structures.
- When you're in a safe place, get more information from local radio or television or your mobile device (text or data). Continue to stay informed throughout the event.

If you're on the beach or near water and feel an earthquake of any size and length, move quickly to high ground or inland (away from the water) as soon as you can move safely. Get more information from radio, television, or your mobile device (text or data).

Tsunami advisory

If you're in a tsunami hazard zone and receive a tsunami advisory, a tsunami with potential for strong currents or waves dangerous to people in or very near the water is likely:

- Stay out of the water and away from beaches and waterways.
- Get updates about the tsunami from local radio or television or your mobile device (text or data). Continue to stay informed throughout the event.

Tsunami watch

If you're in a tsunami hazard zone and receive a tsunami watch, a tsunami is possible:

- Get updates about the potential threat from local radio or television or your mobile device (text or data). Continue to stay informed throughout the event.
- Prepare to take action if necessary.

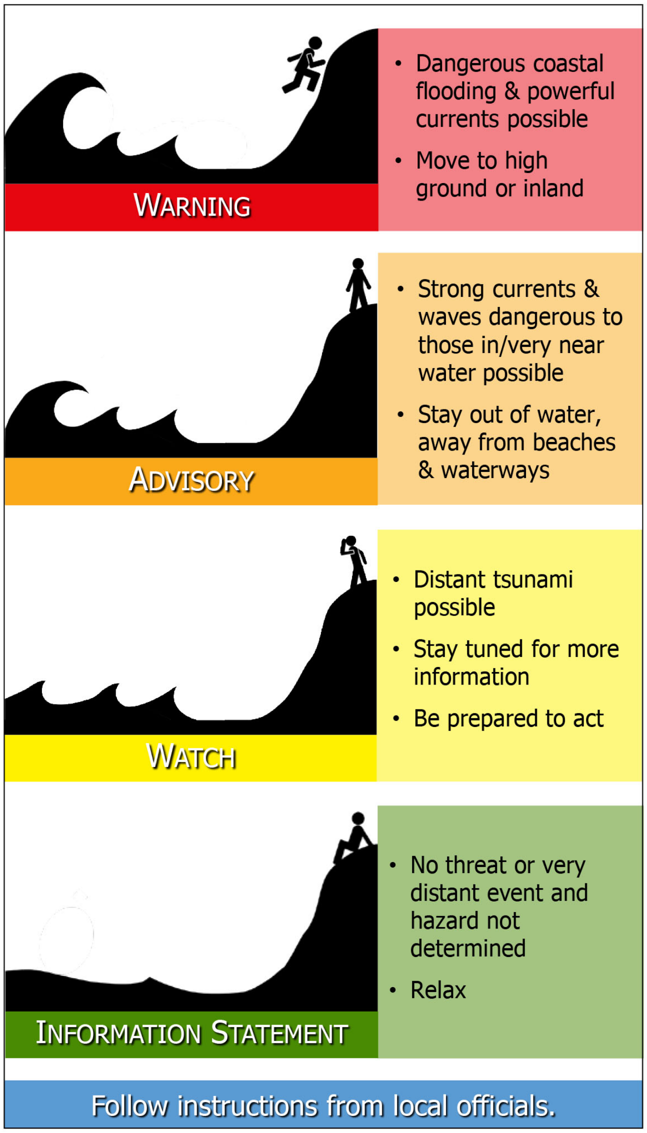

Figure 12. U.S. tsunami message alert levels

5.5 What should I do after a tsunami?

After a tsunami, listen to local officials. They will assess the damage and tell you when it's safe to return. The cancellation of a tsunami warning by a tsunami warning center does not mean the danger has passed. Other dangers may remain. If there's a lot of damage, it may be days before it's safe to return (or before you're allowed to return) to affected areas. Stay safe after a tsunami by doing the following:

- Stay out of the tsunami hazard zone until local officials say it's safe. Remember, the first wave may not be the last or the largest and the danger may last for hours or days.
- Keep listening to local radio or television or using your mobile device (text or data) to get updates about when it's safe to return, areas to avoid, the location of shelters (if available), and important safety instructions.
- Continue limiting nonemergency phone calls to keep the lines open for emergency communications.
- Stay away from areas with damage for your own safety and so emergency responders can have full access.
- Stay out of any building that has earthquake or tsunami damage or has water around it until a professional or local official tells you it's safe to enter.
- Avoid fallen power lines and broken utility lines.

Also, let your friends and loved ones know you're okay. The American Red Cross's Safe and Well website can help you do this. It can also help you find out if others have provided updates about their well-being.

5.6 What do I need to do to prepare for and respond to a tsunami if I am a boat owner or captain?

If you're a boat owner or captain, you should take extra steps to prepare for a tsunami:

- Make sure you have a way to receive tsunami warnings when you're on the water. The U.S. Coast Guard will issue urgent marine information broadcasts on your marine VHF radio's channel 16. Additional information will be available from NOAA Weather Radio.
- Find out what to do in your area if you get a tsunami warning when you're on a boat. Your harbormaster, port captain, the U.S. Coast Guard, and local, state, and territory emergency management offices are the best sources for tsunami safety information and regulations for boaters in your area.
- Make a plan and put together a disaster supplies kit to keep on board your boat. Be aware that shore facilities may be damaged, so if you're at sea during a tsunami, you may not be able to

return to the harbor you left. Be prepared to remain at sea for a day or more.

If you're on a boat and you get a tsunami warning, your response will depend largely on where you are. In general, the following recommendations apply if you get a tsunami warning:

- If you're in a harbor, you should leave your boat and move quickly to a safe place on land (high ground or inland, away from the water—see "Tsunami Warning" in Question 5.4).
- If you're at sea, you should move to a safe depth (safe depths vary by region, but the minimum safe depth is 30 fathoms—180 feet) and stay away from harbors under warning until officials tell you the danger has passed.

5.7 How can coastal communities prepare for a tsunami?

To prepare for a tsunami, coastal communities first need to understand how tsunamis of different sizes and sources (location and type) might affect them.

They do this by conducting tsunami hazard assessments that include using computer models and information from past tsunamis to identify and map the areas likely to be flooded during a tsunami and estimate the amount of flooding possible. Communities can use the resulting tsunami hazard zone maps to determine where people and other important community assets (e.g., buildings, facilities, bridges, schools, hospitals) are at risk so they can decide where to focus their preparedness, response, and mitigation efforts.

A community that understands its tsunami risk can take steps to protect the public in the event of a tsunami. The following are examples of protective measures:

- Warning the public
- Planning for and practicing how to respond to tsunamis
- Establishing, marking, and publicizing evacuation routes
- Educating the public (residents and visitors) about tsunamis and tsunami safety before a tsunami strikes

This should all be part of a community's larger effort to protect lives and property from the variety of hazards it may face.

Tsunami Evacuation Signs

In the mid-1990s, the State of Oregon developed the familiar wave design that has been adopted and/or adapted by most NTHMP state and territory partners and can be seen on tsunami signs around the world. Since tsunami safety depends on being able to get away from the hazard quickly, signs along at-risk coasts bring attention to hazard zones, evacuation routes, and evacuation sites/assembly areas.

An important part of any community tsunami preparedness program, these signs also serve an important educational role by raising awareness before a tsunami. Some states and territories also incorporate tsunamis into informational beach signs and/or install signs/kiosks in high-traffic areas to display evacuation maps and provide additional safety tips.

Other ways to prepare for and mitigate the potential impacts of a tsunami emphasize thoughtful land-use planning and building/structure design in tsunami hazard zones and include the following:

- Improving evacuation routes
- Building tsunami evacuation structures
- Limiting new development in tsunami hazard zones
- Designing, siting, and building structures to minimize tsunami damage

- Adopting building codes that address tsunamis
- Protecting and strengthening existing structures and infrastructure that if damaged would negatively affect response and recovery
- Safeguarding port and harbor operations
- Moving important community assets and vulnerable populations out of tsunami hazard zones
- Protecting/enhancing natural defenses (e.g., mangroves, coastal forests, coral reefs)
- Planning for post-tsunami recovery

In the United States, much of the tsunami preparedness and mitigation work is conducted through the NTHMP and NOAA's TsunamiReady program. TsunamiReady is a voluntary community recognition program administered by the NWS that helps communities minimize the risk posed by tsunamis through better risk assessment, planning, education, and warning communications. In order for NOAA to recognize a community as TsunamiReady, the community must have implemented the activities in the TsunamiReady Guidelines. Examples of these activities include the following:

- Define tsunami hazard zones, produce evacuation maps, and install evacuation route signs
- Support ongoing and sustained tsunami public education and outreach, including to schools in tsunami hazard zones
- Establish a 24-hour warning point and support emergency operations center operations
- Have more than one way to receive tsunami warnings and to alert the public
- Develop a formal tsunami operations plan and hold annual exercises

Figure 13. TsunamiReady sign

Recognizing that small coastal jurisdictions and nongovernment entities may also be actively involved in tsunami preparedness activities but may not be able to fully meet the TsunamiReady Guidelines, NOAA created the TsunamiReady Supporter program. Potential TsunamiReady Supporters include businesses, schools, churches, hospitals, shopping centers, malls, utilities, museums, aquariums, villages, small communities, state parks, beaches, harbors, and broadcasters/broadcast stations.

UNESCO/IOC modeled their International Tsunami Ready program on the U.S. program.

Appendix A: Acronyms

CARIBE EWS	Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (UNESCO/IOC)
CO-OPS	Center for Operational Oceanographic Products and Services (NOAA)
CTWP	Caribbean Tsunami Warning Program (NOAA)
DART	Deep-ocean Assessment and Reporting of Tsunamis
FEMA	Federal Emergency Management Agency
ITIC	International Tsunami Information Center (NOAA and UNESCO/IOC)
NDBC	National Data Buoy Center (NOAA)
NCEI	National Centers for Environmental Information (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NTHMP	National Tsunami Hazard Mitigation Program
NTWC	National Tsunami Warning Center (NOAA)
NWS	National Weather Service (NOAA)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PTWC	Pacific Tsunami Warning Center (NOAA)
PTWS	Pacific Tsunami Warning and Mitigation System (UNESCO/IOC)
UNESCO/IOC	United Nations Educational, Scientific, and Cultural Organization/ Intergovernmental Oceanographic Commission
USAID	U.S. Agency for International Development
USGS	U.S. Geological Survey

Appendix B: Historic Tsunamis

The information below comes from NOAA's National Centers for Environmental Information, Global Historical Tsunami Database.

Notes:

- Tables are based on reported information in the database as of February 2019 in consultation with NOAA's National Centers for Environmental Information. The database is updated as new information becomes available.
- Dates are based on Coordinated Universal Time (UTC), so the local date may be one day different.
- Earthquake magnitudes are instrumental (from USGS) or estimated based on intensity prior to 1896.
- Footnotes are at the end of each table.

Ten Deadliest Tsunamis

Date	Source Location	Source Type M=magnitude	Deaths	Max. Runup[a]
Dec 26, 2004	Northern Sumatra, Indonesia	9.1M Earthquake	227,899[b]	167 feet
Nov 1, 1755	Lisbon, Portugal	8.5M Earthquake	50,000[b]	60 feet
Aug 27, 1883	Krakatau, Indonesia	Volcano	34,417	135 feet
Jun 15, 1896	Sanriku, Japan	8.3M Earthquake	27,122[b]	125 feet
Aug 13, 1868	Northern Chile	8.5M Earthquake	25,000[b]	59 feet
Mar 11, 2011	Honshu Island, Japan	9.1M Earthquake	18,434[b]	128 feet
May 21, 1792	Shimabara Bay, Kyushu Island, Japan	Volcano	15,000	180 feet
Apr 24, 1771	Ryukyu Islands, Japan	7.4M Earthquake	13,486	280 feet
Nov 4, 1952	Kamchatka, Russia	9.0M Earthquake	10,000	75 feet
Aug 16, 1976	Mindanao, Philippines	8.0M Earthquake	6,800[b]	30 feet

[a] Runup is the maximum elevation of the tsunami flooding on shore.

[b] May include earthquake deaths.

Deadly Distant Tsunamis

Tsunamis that caused deaths more than 1,000 kilometers from their source

Date	Source Location	Source Type M=magnitude	Estimated Dead or Missing: Total	Estimated Dead or Missing: Distant	Distant Locations that Reported Deaths
Jan 27, 1700	Cascadia Subduction Zone	9.0M Earthquake	?	2	Japan
Nov 1, 1755	Lisbon, Portugal	8.5M Earthquake	50,000[b]	3	Brazil
Nov 7, 1837	Southern Chile	8.5M Earthquake	16[a]	16	United States (Hawaii)
Aug 13, 1868	Northern Chile	8.5M Earthquake	25,000[b]	7	New Zealand, Samoa, Southern Chile
May 10, 1877	Northern Chile	8.3M Earthquake	2,282	2,005	Fiji, Japan, Peru, United States (Hawaii)
Aug 27, 1883	Krakatau, Indonesia	Volcano	34,417	1	Sri Lanka
Jan 15, 1899	Papua New Guinea	Earthquake	Hundreds[a]	Hundreds	Caroline Islands, Solomon Islands

Date	Source Location	Source Type M=magnitude	Estimated Dead or Missing: Total	Estimated Dead or Missing: Distant	Distant Locations that Reported Deaths
Aug 9, 1901	Loyalty Islands, New Caledonia	7.9M Earthquake	Several[a]	Several	Santa Cruz Islands
Feb 3, 1923	Kamchatka, Russia	8.3M Earthquake	3	1	United States (Hawaii)
Nov 27, 1945	Makran Coast, Pakistan	8.0M Earthquake and Landslide	4,000[b]	15	India
Apr 1, 1946	Unimak Island, Alaska	8.6M Earthquake and Landslide	167	162	Marquesas Islands, Peru, United States (California, Hawaii)
Mar 9, 1957	Andreanof Islands, Alaska	8.6M Earthquake	2[a]	2[c]	United States (Hawaii)
May 22, 1960	Southern Chile	9.5M Earthquake	2,226[b]	226	Japan, Philippines, United States (California, Hawaii)
Mar 28, 1964	Southern Alaska	9.2M Earthquake and Landslide	124	18	United States (California, Oregon)
Dec 26, 2004	Northern Sumatra, Indonesia	9.1M Earthquake	227,899[b]	52,072	Bangladesh, India, Kenya, Madagascar, Maldives, Myanmar, Seychelles, Somalia, South Africa, Sri Lanka, Tanzania, Yemen
Mar 28, 2005	Sumatra, Indonesia	8.6M Earthquake	10[a]	10[c]	Sri Lanka
Mar 11, 2011	Honshu Island, Japan	9.1M Earthquake	18,434[b]	2	Indonesia, United States (California)
Oct 28, 2012	Haida Gwaii, Canada	7.7M Earthquake	1[a]	1[c]	United States (Hawaii)

[a] Distant tsunami responsible for all deaths.

[b] May include earthquake deaths.

[c] Deaths were indirect.

Historic U.S. Tsunamis

Tsunamis that affected U.S. states and territories and caused at least one death or $1 million in damage (December 2018 dollars) in the United States

Date	Source Location	Source Type M=magnitude	U.S. Deaths[a]	U.S. Damage[a]	States/Territories Affected[b]
Jul 21, 1788	Alaska Peninsula	8.0M Earthquake	Yes	Yes	Alaska
1820	Camano Island, Washington	Landslide	Yes	--	Washington
Nov 7, 1837	Southern Chile	8.5M Earthquake	16	Yes	Hawaii (*American Samoa)*
1845	Southeast Alaska	Landslide	100	--	Alaska
Jan 25, 1849	Guam	7.5M Earthquake	1	Yes	Guam
1853	Lituya Bay, Alaska	Landslide	Yes	--	Alaska

Date	Source Location	Source Type M=magnitude	U.S. Deaths[a]	U.S. Damage[a]	States/Territories Affected[b]
Nov 18, 1867	Virgin Islands	7.5M Earthquake	24	Yes	U.S. Virgin Islands, Puerto Rico
Apr 3, 1868	Southeast of Hawaii	7.9M Earthquake	47	Yes	Hawaii
Aug 13, 1868	Northern Chile	8.5M Earthquake	0	Yes	Hawaii (*Alaska, California*)
May 10, 1877	Chile, Off Northeast Coast	8.3M Earthquake	5	Yes	Hawaii (*California)*
Nov 22, 1878	Southern California	Landslide	1	Yes	California
Nov 28, 1894	Tacoma, Washington	Landslide	2	Yes	Washington
Aug 11, 1900	Southeast Alaska	Earthquake and Landslide	5	Yes	Alaska
Aug 16, 1917	Taku Inlet, Juneau, Alaska	Landslide	1	Yes	Alaska
Oct 11, 1918	Mona Passage, Puerto Rico	7.3M Earthquake and Landslide	140	$63 million	Puerto Rico (*U.S. Virgin Islands)*
Feb 3, 1923	Kamchatka, Russia	8.3M Earthquake	1	$22 million	Hawaii
Aug 31, 1930	Southern California	5.2M Earthquake and Landslide	1	--	California
Apr 1, 1946[d]	Unimak Island, Alaska	8.6M Earthquake and Landslide	164	$359 million	Hawaii, Alaska, California, American Samoa, Oregon, Washington
Nov 4, 1952	Kamchatka, Russia	9.0M Earthquake	0	$9 million	Hawaii, California (*Alaska, American Samoa, Guam)*
Mar 9, 1957	Andreanof Islands, Alaska	8.6M Earthquake	2[c]	$45 million	Hawaii, California, Alaska (*American Samoa)*
Jul 10, 1958[e]	Southeast Alaska	7.8M Earthquake and Landslide	5	$1 million	Alaska
May 22, 1960	Southern Chile	9.5M Earthquake	63	$216 million	Hawaii, California, American Samoa, Alaska, Oregon (*Washington)*
Mar 28, 1964[f]	Southern Alaska	9.2M Earthquake and Landslide	124	$859 million	Alaska, California, Oregon, Washington, Hawaii
Nov 29, 1975	Hawaii	7.7M Earthquake and Landslide	2	$7 million	Hawaii, California
Nov 4, 1994	Skagway, Alaska	Landslide	1	$42 million	Alaska
Nov 15, 2006	Kuril Islands, Russia	8.3M Earthquake	0	$1 million	California (*Hawaii, Alaska, Oregon)*
Sep 29, 2009	Samoa Islands	8.1M Earthquake	34	$146 million	American Samoa (*California, Hawaii)*

Date	Source Location	Source Type M=magnitude	U.S. Deaths[a]	U.S. Damage[a]	States/Territories Affected[b]
Feb 27, 2010	Central Chile	8.8M Earthquake	0	$3 million	California (*Hawaii, American Samoa, Alaska, Oregon)*
Mar 11, 2011	Honshu Island, Japan	9.1M Earthquake	1	$96 million	California, Hawaii, Oregon (*Alaska, Northern Mariana Islands, Washington, American Samoa)*
Oct 28, 2012	Haida Gwaii, Canada	7.7M Earthquake	1[c]	--	Hawaii (*California)*

[a] Number of deaths and dollar figures are not available for all events and may not be inclusive of all losses.

[b] No deaths or damage were reported for the states and territories in parentheses/*italics*, but runups greater than or equal to 0.3 meter (11.8 inches), which is the threshold for a tsunami advisory, were observed.

[c] Deaths were indirect.

[d] Deadliest U.S. tsunami; impetus for what is now the Pacific Tsunami Warning Center.

[e] Highest tsunami: maximum height of 1,722 feet.

[f] Most expensive U.S. tsunami; impetus for what is now the National Tsunami Warning Center.

Note: The January 27, 1700, Cascadia Subduction Zone 9.0M earthquake and tsunami is not included here because not enough is known about the impacts of this event.

Appendix C: Key Resources

For a comprehensive list of tsunami resources, see the NTHMP Partner Web Resources web page at https://nws.weather.gov/nthmp/NTHMP_Web_Resources.html.

Introduction (Section 1)

- National Tsunami Hazard Mitigation Program
  https://nws.weather.gov/nthmp/

Tsunami Basics (Section 2)

- NOAA/NWS Tsunami Frequently Asked Questions
  https://www.tsunami.gov/?page=tsunamiFAQ
- NOAA/NWS and UNESCO/IOC International Tsunami Information Center
  http://www.tsunamiwave.org
- NOAA/NCEI and World Data Service Global Historical Tsunami Database and related tools
  https://www.ngdc.noaa.gov/hazard/tsu.shtml
- The COMET Program's Tsunami Distance Learning Course (free, account required)
  https://www.meted.ucar.edu/training_course.php?id=38
- USGS Earthquake Hazards Program
  https://earthquake.usgs.gov/
- USGS Landslide Hazards Program
  https://www.usgs.gov/natural-hazards/landslide-hazards
- USGS Volcano Hazards Program
  https://volcanoes.usgs.gov/
- NTHMP Meteotsunami fact sheet
  http://nws.weather.gov/nthmp/meteotsunamis.html

Tsunamis in the United States (Section 3)

- NTHMP U.S. Tsunami Hazard Assessments and Summary
  https://nws.weather.gov/nthmp/ushazard.html
- NTHMP U.S. Historic Tsunami Calendar (see also Appendix B)
  https://nws.weather.gov/nthmp/documents/tsunamicalendar.pdf
- NOAA/NCEI and World Data Service Global Historical Tsunami Database and related tools
  https://www.ngdc.noaa.gov/hazard/tsu.shtml

U.S. Tsunami Warning System (Section 4)

- NOAA/NWS U.S. Tsunami Warning Centers
  https://www.tsunami.gov
  - Tsunami message definitions—https://www.tsunami.gov/?page=message_definitions
  - Examples of tsunami messages—https://www.tsunami.gov/?page=product_list
- Tsunami Warning and Education Act/Tsunami Warning, Education, and Research Act of 2017 (33 U.S.C. 3201 et seq.)
  https://nws.weather.gov/nthmp/twera/usc33TWERA.pdf

- USGS Latest Earthquakes Map
  https://earthquake.usgs.gov/earthquakes/map/
- NOAA/NDBC DART Program Description
  https://www.ndbc.noaa.gov/dart/dart.shtml
- NOAA/PMEL DART Research and Development
  https://nctr.pmel.noaa.gov/Dart/index.html
- NOAA/CO-OPS Coastal Water-Level Stations
  https://tidesandcurrents.noaa.gov/1mindata.html
- NOAA/PMEL Tsunami Forecasting
  https://nctr.pmel.noaa.gov/tsunami-forecast.html
- NOAA/NWS/PTWC Tsunami Forecast Model Animations
  https://www.youtube.com/user/PacificTWC
- NOAA Weather Radio
  https://www.nws.noaa.gov/nwr/
- Wireless Emergency Alerts
  https://www.weather.gov/wrn/wea
- NOAA/NWS and UNESCO/IOC International Tsunami Information Center
  http://tsunamiwave.org
- NOAA/NWS Caribbean Tsunami Warning Program
  https://www.weather.gov/ctwp/
- NOAA/NWS Weather Forecast Offices (by region)
  https://www.weather.gov/organization_prv
- USAID
  https://www.usaid.gov/
- UNESCO/IOC Tsunami Programme
  http://www.ioc-tsunami.org/index.php?lang=en
- The COMET Program Tsunami Warning System online training module (free, account required)
  https://www.meted.ucar.edu/training_module.php?id=786

Tsunami Safety Resources (Section 5)

- NTHMP Tsunami Awareness and Safety fact sheet
  https://nws.weather.gov/nthmp/tsunamisafety.html
- NOAA/NWS Tsunami Safety website
  https://www.weather.gov/safety/tsunami
- Links to NTHMP Partner Tsunami Resources
  https://nws.weather.gov/nthmp/NTHMP_Web_Resources.html
- Links to NTHMP Partner State and Territory Tsunami Maps
  https://nws.weather.gov/nthmp/maps.html
- Tsunami Evacuation Signs
  https://nws.weather.gov/nthmp/signs/signs.html
- NTHMP Guidance for Minimum Safe Depths for Vessel Movement During Tsunamis
  https://nws.weather.gov/nthmp/documents/GuidanceforSafeMinimumOffshoreDepthforVesselMovement.pdf

- The TsunamiZone
  https://www.tsunamizone.org/
- NOAA/NWS and UNESCO/IOC International Tsunami Information Center
  http://www.tsunamiwave.org
- NOAA/NWS U.S. Tsunami Warning Centers
  https://www.tsunami.gov
- NOAA/NWS Weather Forecast Offices (by region)
  https://www.weather.gov/organization_prv
- NOAA Weather Radio
  https://www.nws.noaa.gov/nwr/
- Wireless Emergency Alerts
  https://www.weather.gov/wrn/wea
- FEMA Ready.gov
  https://www.ready.gov/
  - Emergency planning—https://www.ready.gov/make-a-plan
  - Disaster supplies kits—https://www.ready.gov/build-a-kit
  - Returning home after a disaster—https://www.ready.gov/returning-home
- American Red Cross Safe and Well
  https://safeandwell.communityos.org
- NOAA/NWS TsunamiReady
  https://www.weather.gov/tsunamiready/
- The COMET Program's Community Tsunami Preparedness online training module (free, account required)
  https://www.meted.ucar.edu/training_module.php?id=897

Historical Tsunami Resources (Appendix B)

- NOAA/NCEI and World Data Service Global Historical Tsunami Database and related tools
  https://www.ngdc.noaa.gov/hazard/tsu.shtml
- NTHMP U.S. Historic Tsunami Calendar
  https://nws.weather.gov/nthmp/documents/tsunamicalendar.pdf

Appendix D: NTHMP Partner Contact Information

General contact information for NTHMP partners is provided here along with media contact information, if available. Find links to the partners on social media at: https://nws.weather.gov/nthmp/documents/NTHMPSocialMedia.pdf.

Federal Agencies

The agencies below participate on the NTHMP Coordinating Committee.

National Oceanic and Atmospheric Administration (NOAA)

https://www.noaa.gov/
General contacts: https://www.noaa.gov/contact-us
Media contacts: https://www.noaa.gov/NOAA-Communications

National Weather Service
https://www.weather.gov/
General contacts: https://www.weather.gov/contact
Media contact: nws.pa@noaa.gov; (301) 427-9000

National Tsunami Warning Center
https://www.tsunami.gov/
ntwc@noaa.gov; (907) 745-4212

International Tsunami Information Center
http://www.tsunamiwave.org
itic.tsunami@noaa.gov; (808) 725-6050

Tsunami Service Program
https://www.tsunami.gov/
michael.angove@noaa.gov; (301) 427-9375

Pacific Tsunami Warning Center
https://www.tsunami.gov/
ptwc@ptwc.noaa.gov; (808) 725-6300

Caribbean Tsunami Warning Program
https://www.weather.gov/ctwp/
christa.vonh@noaa.gov; (787) 832-4040, x5787

National Data Buoy Center
https://www.ndbc.noaa.gov/
webmaster.ndbc@noaa.gov; (228) 688-2805

Office of Oceanic and Atmospheric Research
https://www.research.noaa.gov/
oar.communications@noaa.gov; (301) 713-2458
Media contact: monica.allen@noaa.gov; (301) 734-1123

Pacific Marine Environmental Lab
https://nctr.pmel.noaa.gov/
oar.pmel.webmaster@noaa.gov; (206) 526-6800
Media contact: https://www.pmel.noaa.gov/media

National Ocean Service
https://oceanservice.noaa.gov/
nos.info@noaa.gov
Media contact: oceanservicepress@noaa.gov; (301) 713-3066

Center for Operational Oceanographic Products and Services
https://tidesandcurrents.noaa.gov/
nos.co-ops.pmt@noaa.gov; (301) 713-2815
Media contact: nos.co-ops.commsteam@noaa.gov; (240) 533-0487

National Environmental Satellite, Data, and Information Service
https://www.nesdis.noaa.gov/
(301) 713-3578
Media contact: john.leslie@noaa.gov; (301) 713-0214

National Centers for Environmental Information
https://www.ngdc.noaa.gov/hazard/tsu.shtml
ncei.info@noaa.gov; (828) 271-4800

Federal Emergency Management Agency (FEMA)

https://www.fema.gov/
General contacts: https://www.fema.gov/contact-us
Regional offices: https://www.fema.gov/about-agency
Media contact: FEMA-News-Desk@fema.dhs.gov; (202) 646-3272

U.S. Geological Survey (USGS)

https://www.usgs.gov/
General contact form: https://answers.usgs.gov/; (888) 275-8747
Media contacts: https://www.usgs.gov/news/media-contacts

States and Territories

The emergency management and science entities listed below represent their respective states and territories on the NTHMP Coordinating Committee.

Alaska

Emergency Management
Alaska Division of Homeland Security and Emergency Management
http://ready.alaska.gov/Plans/Mitigation/Tsunamis
seoc@ak-prepared.com; (907) 428-7000
Media contact: michelle.torres@alaska.gov; (907) 428-7032

Science
University of Alaska Fairbanks/Alaska Earthquake Center
http://earthquake.alaska.edu/
uaf-aec@alaska.edu; (907) 474-7320

American Samoa

Emergency Management
American Samoa Department of Homeland Security
https://www.facebook.com/American-Samoa-Department-of-Homeland-Security-212562712119577/
(684) 699-3800, (684) 699-0412

Science
National Weather Service/Pago Pago
https://www.weather.gov/ppg/
nws.pr.pago.operations@noaa.gov; (684) 699-9130
Media contact: See National Weather Service

California

Emergency Management
California Governor's Office of Emergency Services
https://www.caloes.ca.gov/tsunami
Media contact: media@caloes.ca.gov; (916) 845-8510

Science
California Geological Survey
http://www.tsunami.ca.gov
Contacts: https://www.conservation.ca.gov/cgs/Pages/Tsunami/ContactInformation.aspx
Media contact: PAO@consrv.ca.gov; (916) 323-1886

Commonwealth of the Northern Mariana Islands

Emergency Management

Commonwealth of the Northern Mariana Islands Homeland Security and Emergency Management
http://cnmihsem.gov.mp/
Contact form: http://cnmihsem.gov.mp/contact-us; (670) 237-8000

Science

National Weather Service/Guam
https://www.weather.gov/gum/
pr.guam.forecasters@noaa.gov; (671) 472-0900
Media: See National Weather Service

East Coast

All East Coast states are represented on the NTHMP Coordinating Committee by the following emergency management and science entities from the region:

Emergency Management

Northeast States Emergency Consortium
http://www.nesec.org
nesec@nesec.org; (781) 224-9876

State-specific information may also be available from individual state emergency management agencies: https://www.fema.gov/emergency-management-agencies

Science

University of Delaware, Center for Applied Coastal Research
http://www1.udel.edu/kirby/
kirby@udel.edu; (302) 831-2438

State-specific information may also be available from individual state geological surveys/science offices: http://www.stategeologists.org/surveys.php

Guam

Emergency Management

Guam Homeland Security/Office of Civil Defense
https://ghs.guam.gov/programs/natural-disasters/tsunamis
(671) 475-9600
Media contact: https://ghs.guam.gov/press-room/media-inquiries

Science

National Weather Service/Guam
https://www.weather.gov/gum/
pr.guam.forecasters@noaa.gov; (671) 472-0900
Media: See National Weather Service

Gulf Coast

All Gulf Coast states are represented on the NTHMP Coordinating Committee by the following emergency management and science entities from the region:

Emergency Management

Santa Rosa County Florida Emergency Management Agency
https://www.santarosa.fl.gov/666/Emergency-Management
Emergency-Management@santarosa.fl.gov; (850) 983-5360

State-specific information may also be available from individual state emergency management agencies: https://www.fema.gov/emergency-management-agencies

Science

Texas A&M University at Galveston, Tsunami Research Group
http://tamug.edu/ocen/; http://www.tamug.edu/tsunami/index.html
burgessl@tamu.edu; (409) 740-4807
horrillj@tamug.edu; (409) 740-4465

State-specific information may also be available from individual state geological surveys/science offices: http://www.stategeologists.org/surveys.php

Hawaii

Emergency Management

Hawaii Emergency Management Agency
http://dod.hawaii.gov/hiema/
HawaiiEMA@hawaii.gov; (808) 733-4300
Media contact: (808) 733-4300 +0

Science

University of Hawaii at Manoa, Department of Ocean and Resources Engineering
http://www.ore.hawaii.edu/
adminore@hawaii.edu; (808) 956-7572
Media contact: cheung@hawaii.edu; (808) 956-3485

Oregon

Emergency Management

Oregon Office of Emergency Management
https://www.oregon.gov/OEM/hazardsprep/Pages/Tsunami.aspx
public.info@state.or.us; (503) 378-2911
Media contacts: https://www.oregon.gov/oem/Pages/Press-Room.aspx

Science

Oregon Department of Geology and Mineral Industries
https://www.oregongeology.org/tsuclearinghouse/default.htm
dogami-info@oregon.gov; (541) 574-6658
Media contact: jonathan.allan@oregon.gov

Puerto Rico

Emergency Management

Puerto Rico Bureau of Emergency Management
http://www.agencias.pr.gov/agencias/aemead/Pages/Home.aspx
info@prema.pr.gov; (787) 724-0124

Science

University of Puerto Rico/Puerto Rico Seismic Network
http://redsismica.uprm.edu/
victor@prsnmail.uprm.edu, victor.huerfano@upr.edu; (787) 833-8433, (787) 265-5452
Media contact: ggomez@prsnmail.uprm.edu; (787) 833-8433

U.S. Virgin Islands

Emergency Management

Virgin Islands Territorial Emergency Management Agency
http://www.vitema.vi.gov/plan-prepare/tsunamis
contact@vitema.vi.gov; (340) 773-2244
Media contact: garry.green@vitema.vi.gov; (340) 713-6801

Washington

Emergency Management

Washington Emergency Management Division
https://mil.wa.gov/tsunami
maximilian.dixon@mil.wa.gov; (253) 512-7017
Media contact: Karina.Shagren@mil.wa.gov; (253) 512-8222

Science

Washington State Department of Natural Resources, Washington Geological Survey
https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis
geology@dnr.wa.gov; (360) 902-1450
Media contact: dnrnews@dnr.wa.gov; (360) 902-1008