must meet certain criteria to be recognized as TsunamiReady. Becoming TsunamiReady can help minimize tsunami-related losses to a community. As of April 2015, 185 sites across 16 states and territories were recognized as TsunamiReady.

Local NWS Weather Forecast Offices (WFO) implement the TsunamiReady Program (in conjunction with state and local partners) and work with communities to support their tsunami preparedness efforts and help them become TsunamiReady. The WFOs also support the NOAA Tsunami Program by educating the public, local officials and the media about tsunamis and tsunami safety and disseminating tsunami alerts issued by the tsunami warning centers.

In 1995, Congress directed NOAA to form and lead the National Tsunami Hazard Mitigation Program (NTHMP). The NTHMP is a federal/state partnership that includes NOAA, the Federal Emergency Management Agency, the U.S. Geological Survey and 28 U.S. states and territories. The program aims to reduce the impact of tsunamis through preparedness and mitigation activities that include public outreach and education, community planning, hazard assessment and warning guidance.

International Coordination

The NOAA Tsunami Program also plays a vital role in the global tsunami warning system. This role is established by a United Nations-directed mission to provide tsunami information throughout the Pacific and Caribbean Basins.

Established by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Tsunami Information Center (ITIC) is hosted and staffed by the NWS. The ITIC supports the IOC's Tsunami Program, which focuses on the coordination of tsunami warning and mitigation systems globally, as well as the IOC's Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (PTWS). The ITIC's responsibilities include monitoring the activities of the PTWS, coordinating tsunami warning system technology transfer among PTWS member states, acting as a clearinghouse for risk assessment and mitigation activities and producing tsunami education and preparedness materials. The ITIC also works closely with the World Data System for Geophysics, which is hosted by NGDC, on international data stewardship, product development and outreach.

The NWS's Caribbean Tsunami Warning Program (CTWP) provides warning, training, and outreach and education assistance and facilitates data exchange for domestic and international partners in the Caribbean region. CTWP is part of the UNESCO IOC's Intergovernmental Coordination Group for Tsunamis and Other Coastal Hazards Warning System for the Caribbean Sea and Adjacent Regions.

Other NOAA Contributors

Numerous other NOAA offices and programs also contribute to the work of the NOAA Tsunami Program, providing data, tools, training, technical assistance and funding. These include the NWS's International Activities Office, OAR's National Sea Grant College Program, NESDIS's Office of Satellite and Product Operations, and NOS's Office for Coastal Management, National Geodetic Survey, and Office of Coast Survey.

Learn more about the NOAA Tsunami Program and tsunamis at http://www.tsunami.gov/.

To learn more about NOAA, visit http://www.noaa.gov/.

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA Tsunami Program

Of all Earth's natural hazards, tsunamis are among the most infrequent, yet they pose a major threat to coastal populations. Although tsunamis cannot be prevented, community preparedness, accurate and timely warnings and effective response can save lives and protect property. The 2011 Tohoku Japan tsunami and the 2004 Indian Ocean tsunami have focused world attention on the rare but very real threat of tsunamis and underscored the value of a comprehensive warning system and an educated public. Great strides have been made in improving tsunami warning systems since the 2004 event.

A tsunami is a series of ocean waves created by a sudden displacement of seawater. Most tsunamis are caused by undersea earthquakes, but they can also be caused by landslides, volcanic activity, meteorites and even certain weather-related phenomena. A tsunami could strike at any time and can be very dangerous to life and property when it reaches the shore. It may arrive like a fast-rising flood and can strike with devastating force. Tsunamis can range in size from inches to more than a hundred feet high and can flood low-lying areas more than a mile inland. Waves may continue for several hours, and the first one may not be the largest.

NOAA's Role

The NOAA Tsunami Program is a cross-NOAA cooperative effort to minimize the impacts of tsunamis. Administered by the National Weather Service (NWS), the program leverages the capabilities of NOAA's other operational line offices, including the Office of Oceanic and Atmospheric Research (OAR), the National Ocean Service (NOS) and the National Environmental Satellite, Data and Information Service (NESDIS).

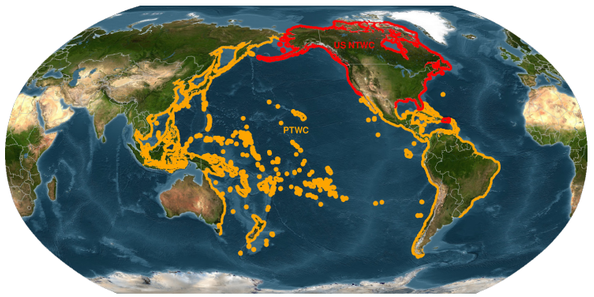
NOAA has led the U.S. effort to build a comprehensive tsunami warning system. The result is a nation better equipped to detect and respond to tsunamis.

For more than 50 years, NOAA has had operational responsibility for the U.S. Tsunami Warning System. This end-to-end system is dependent on partnerships with federal, state, territorial, international, regional and local organizations. It includes:

- Observation systems to rapidly detect earthquakes and tsunamis,
- Earthquake analysis to characterize tsunami-generating events,
- Models to forecast tsunami impacts,
- Timely and accurate messages,
- Tsunami hazard assessments, and
- Educational efforts to ensure proper public response before, during and after a tsunami to protect lives and property.

Issuing Tsunami Messages

The NWS operates two tsunami warning centers, which are staffed 24 hours a day, 7 days a week. The two centers are responsible for monitoring Earth for earthquakes and tsunamis, forecasting tsunami impacts and, in the United States, issuing tsunami alerts (information statements, watches, advisories and warnings) to emergency managers and the public.



Coverage areas for NOAA's two tsunami warning centers: National Tsunami Warning Center (red) and Pacific Tsunami Warning Center (yellow)

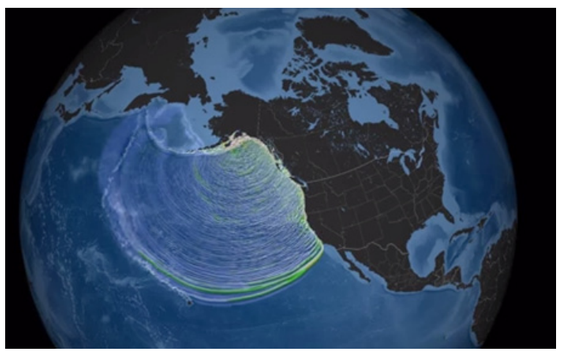
The Pacific Tsunami Warning Center (PTWC) in Hawaii was established following a 1946 tsunami that struck Hawaii, killing more than 150 people and causing over $300 million in damage (2014 dollars). The PTWC directly serves Hawaii and the U.S. Pacific territories and is the primary international forecast center for the Pacific and Caribbean Basins.

In 1964, the largest recorded earthquake in U.S. history generated a number of destructive tsunamis that killed 124 people in Alaska, Oregon and California and caused approximately $1 billion in damage (2014 dollars). This prompted the creation of the U.S. National Tsunami Warning Center (NTWC, formerly the West Coast/Alaska Tsunami Warning Center). The NTWC, located in Alaska, serves all U.S. states except Hawaii. It also serves Puerto Rico, the Virgin Islands and Canada.

Detecting and Forecasting Tsunamis

The warning centers depend on a detection system that includes seismic and sea-level networks and forecast models to help them determine when and where to issue a tsunami message. These networks and models are critical to the warning centers' ability to provide timely and accurate tsunami messages.

Seismic networks include the U.S. Geological Survey's Advanced National Seismic System and the Global Seismographic Network. To supplement these networks, NOAA supports regional seismic networks in Alaska, Hawaii and Puerto Rico. When an earthquake occurs, these networks provide information about an earthquake's location, depth and magnitude to help the warning centers determine if the earthquake may have generated a tsunami and if an initial tsunami message should be issued.

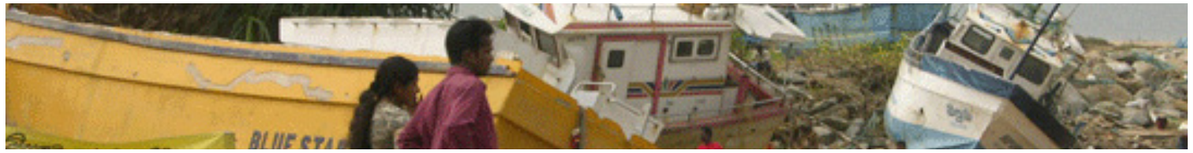


Snapshot from PTWC's animation of the large tsunami generated in Alaska's Prince William Sound in 1964

If the earthquake meets certain criteria, the warning centers use sea-level data to ascertain the existence of a tsunami, calibrate forecast models and adjust or cancel messages. NOAA has established and maintains two essential sea-level observation networks: a network of Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoy stations and an extensive array of coastal sea-level gauges.

The DART buoy stations were developed by OAR's Pacific Marine Environmental Laboratory (PMEL) for the early detection, measurement and real-time reporting of tsunamis in the open ocean. Today, the NWS's National Data Buoy Center operates and maintains the U.S. network, which is part of a larger international network. The U.S. network is composed of 39 stations strategically located throughout the Pacific and Atlantic Oceans and the Caribbean Sea.

Closer to shore, sea-level gauges measure the height of the ocean at specific coastal locations and are used to confirm tsunami arrival time and height. These gauges are owned and operated by a number of national and international organizations. In the United States, most (188) of the tsunami-capable coastal sea-level gauges are operated and maintained by NOS's Center for Operational Oceanographic Products and Services as part of the National Water Level Observation Network. Several others are operated by the tsunami warning centers.



The warning centers use data from the seismic, DART buoy station and sea-level gauge networks as inputs to tsunami forecast models developed by the warning centers and PMEL. Available for U.S. coastal communities at high risk for tsunamis, these models use real-time data and pre-established scenarios to simulate tsunami movement across the ocean and estimate coastal impacts, including wave height and arrival times, the location and extent of coastal flooding and event duration. The resulting forecasts help the warning centers decide whether to cancel initial alerts or adjust them with more accurate, targeted and detailed information. They also help local officials make decisions about beach and road closures and evacuation.

PMEL has also developed inundation (flooding) models, which are used by coastal states and communities to create inundation maps. These maps are used to define tsunami hazard and evacuation zones and support community planning in advance of a tsunami.

These forecast and inundation models are based on high-resolution coastal digital elevation models, which depict Earth's solid surface and are produced by NESDIS's National Geophysical Data Center (NGDC). NGDC is also the long-term archive for national and international tsunami data (including raw and processed DART buoy station and sea-level gauge data), a natural hazards image database and the global historical tsunami database, which includes information on roughly 2,500 tsunamis from 2000 B.C. to the present. The historical database is used to identify regions at risk, validate tsunami forecast models, help position DART buoy stations and sea-level gauges and prepare for future events.

Educating and Preparing Communities and the Public

Preparedness and mitigation activities that enhance response to a tsunami threat and reduce or eliminate the potential impacts of a tsunami are important parts of any tsunami warning system. Inundation mapping, hazard planning, and outreach and education are critical preparedness and mitigation activities. NOAA works with its federal, state, territorial, local and international partners to ensure that coastal communities, residents and visitors understand their tsunami risk and know how to prepare for and respond to a tsunami.

The TsunamiReady Program was officially launched by the NWS in 2001 to help communities prepare for tsunamis through better planning, education and awareness. The program is voluntary, and communities