

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 2004 Indian Ocean tsunami and the 2011 Tohoku, Japan tsunami focused world attention on the 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 waves created by a large and sudden displacement of the ocean. Most tsunamis are caused by large earthquakes below or near the ocean floor, but they can also be caused by landslides, volcanic activity, certain types of weather and near-earth objects. A tsunami can strike at any time and can be dangerous to life and property when it reaches the shore. It may arrive like a fast-rising flood and can strike with devastating force. Tsunami waves can range in size from inches to more than a hundred feet high and can flood low-lying areas more than a mile inland. The first wave may not be the largest or most damaging, and the danger may last for hours or days.

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 other NOAA 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).

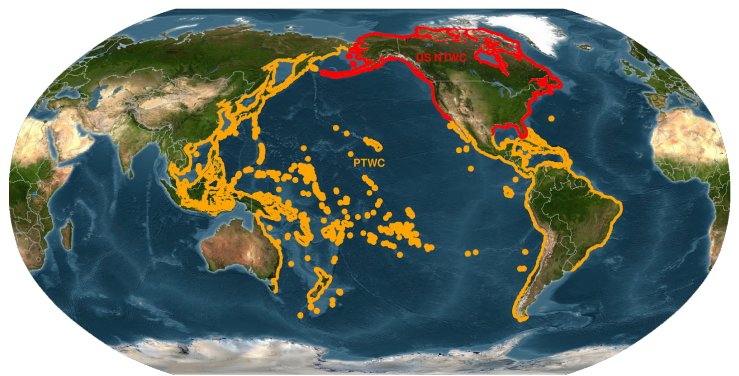
NOAA has led the U.S. effort to build a comprehensive tsunami warning system. The result is a nation better equipped to detect and respond to tsunamis.

For more than 50 years, NOAA and its predecessor agencies have had operational responsibility for the U.S. Tsunami Warning System. Today's end-to-end system operates in partnership with federal, state, territorial, international and local organizations as well as industry. Major components include:

- Observation systems to rapidly detect tsunami generating earthquakes and tsunamis,
- Models to forecast tsunami impacts,
- Timely and accurate messaging,
- Decision-support services during events to enhance community response and
- Preparedness and mitigation activities that enhance response to a tsunami threat and reduce or eliminate potential impacts.

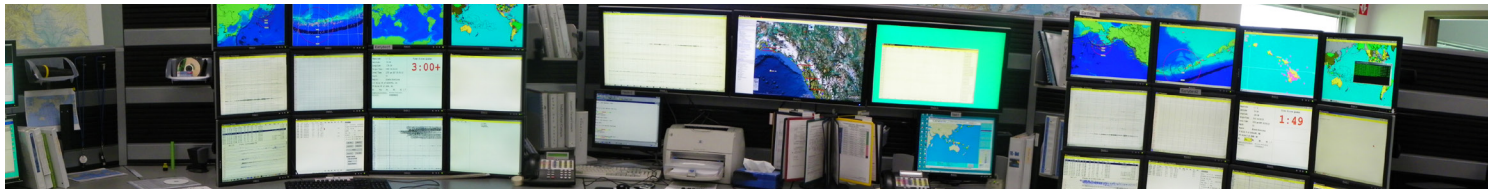
NOAA's Tsunami Warning Centers

The NWS operates two tsunami warning centers, which are staffed 24 hours a day, 7 days a week. The two centers monitor for tsunamis and the earthquakes that may cause them, forecast tsunami impacts and issue tsunami messages.



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 (2017 dollars). The PTWC directly serves the Hawaiian Islands, the U.S. Pacific and Caribbean territories and the British Virgin Islands and is the primary international forecast center for the warning centers of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the Pacific and Caribbean and Adjacent Regions.

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 (2017 dollars). This prompted the creation of the U.S. National Tsunami Warning Center (NTWC) in Alaska. The NTWC serves the continental United States, Alaska and Canada.

Detecting and Forecasting Tsunamis

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

Seismic networks include the U.S. Geological Survey's Advanced National Seismic System and the Global Seismographic Network. To supplement these



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

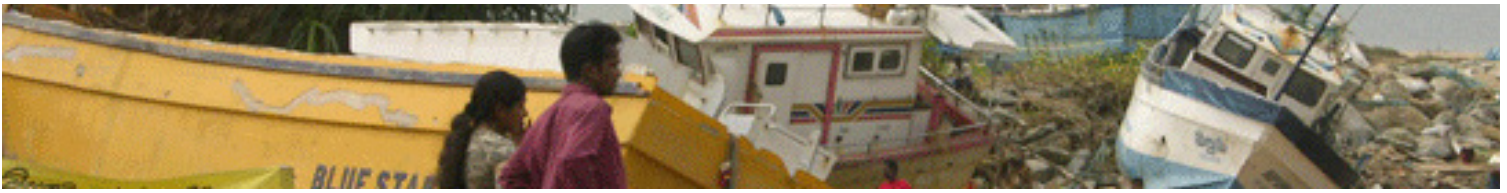
networks, NOAA supports regional seismic networks in Alaska, Hawaii and Puerto Rico. When an earthquake occurs, seismic networks provide information about an earthquake's location, depth and magnitude to help the warning centers determine if the earthquake may have generated a tsunami and if tsunami messages should be issued.

If the earthquake meets certain criteria, the centers use sea-level data to ascertain the existence of a tsunami. NOAA has established and maintains two essential sea-level observation networks: a network of Deep-Ocean Assessment and Reporting of Tsunami (DART) systems and an extensive array of coastal water-level stations.



The DART systems 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 systems strategically located throughout the Pacific and Atlantic Oceans, the Gulf of Mexico and the Caribbean Sea.

Closer to shore, water-level stations measure the height of the ocean at specific coastal locations and are used to confirm tsunami arrival time and height. These stations are owned and operated by a number of national and international organizations. In the United States, most of the tsunami-capable coastal water-level



stations 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.

If a tsunami is detected, the centers use data from seismic and sea-level networks as inputs to NOAA's tsunami forecast models. 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, combined with historical tsunami data and additional seismic analysis, help the centers decide whether to cancel messages or adjust them with more accurate, targeted and detailed information. These forecasts also provide local officials with actionable information that can guide decisions about beach and road closures and evacuation.

The forecast models for the United States rely on high-resolution coastal digital elevation models (DEM) that depict Earth's solid surface. These DEMs are developed by NESDIS's National Centers for Environmental Information (NCEI). NCEI is also the long-term archive for national and international tsunami data (including raw and processed DART system and water-level station data), a natural hazards image database and the Global Historical Tsunami Database.

The historical database includes information on roughly 2,500 tsunamis from 2000 B.C. to the present and is used to identify regions at risk, validate tsunami forecast models, help position DART systems and water-level stations 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 potential impacts are important parts of any tsunami warning system. Inundation mapping, hazard planning (e.g., evacuation and land use) and outreach and education are critical preparedness and mitigation activities. NOAA works with its federal, state, territorial, local and international partners to help coastal communities, residents and visitors understand their tsunami risk and how to prepare for and respond to tsunamis and tsunami warnings.

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. Through collaboration, coordination and funding and technical support to partner states and territories, the NTHMP works to reduce the impact of tsunamis on individual state and territorial coastlines and, collectively, the nation. Key NTHMP activities include public outreach and education, community planning, hazard assessment and warning guidance.





In coordination with the NTHMP, the NWS launched the TsunamiReady® program in 2001 to help communities prepare for tsunamis through better planning, education and awareness. The program is voluntary, and communities must meet certain guidelines to be recognized as TsunamiReady. Becoming TsunamiReady can help minimize tsunami-related losses to a community. As of June 2017, 197 communities across 16 states and territories were recognized as TsunamiReady.



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. 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 messages issued by the tsunami warning centers.

International Coordination

The NOAA Tsunami Program plays a vital role in the global tsunami warning system. In addition to providing forecast information to international partners in the Pacific and Caribbean, NOAA provides technical assistance and training to UNESCO's IOC, the World Meteorological Organization and other international entities to develop a fully functional and interoperable global system made up of regional tsunami warning networks. This work is accomplished largely through the

International Tsunami Information Center (ITIC) and the Caribbean Tsunami Warning Program (CTWP).

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 PTWS activities, 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 NCEI, on international data stewardship, product development and outreach.

The NWS's CTWP supports improved tsunami observations, provides training and outreach and education assistance and facilitates data exchange for domestic and international partners in the Caribbean and adjacent regions. This includes supporting activities of the IOC's Intergovernmental Coordination Group for Tsunamis and Other Coastal Hazards Warning System for the Caribbean 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 Affairs 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://tsunami.gov/>.

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