

CRS Report for Congress

Tsunami Detection and Warnings for the United States

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Wayne A. Morrissey
Information Research Specialist
Knowledge Services Group



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Summary

Congress raised concerns about the possible vulnerability of U.S. coastal areas to tsunamis, and the adequacy of early warning for coastal areas, after a strong underwater earthquake struck off the coast of Sumatra, Indonesia, on December 26, 2004. The earthquake generated a tsunami that devastated many coastal communities around the northern Indian Ocean, and may have cost around 170,000 known deaths and 100,000 still missing and generated \$186 million in damages. Officials determined then that no tsunami early warning systems operated in the Indian Ocean.

In December 2005, President Bush released an action plan for expanding the U.S. tsunami detection and early warning network, which was expected to cost millions of dollars and would include building the infrastructure and maintaining its operations. Some Members of Congress argued that the benefits would far outweigh the costs; other Members questioned the probability of tsunamis outside the Pacific Basin. Long before the tsunami disaster, the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce envisioned “piggy backing” tsunami detection and warning instrumentation on existing marine buoys, tide gauges, and other ocean observation and monitoring systems. However, NOAA was also experimenting with a new deep water tsunami detection technology.

Congress approved emergency funding in FY2005 for the President’s action plan for procuring and deploying a comprehensive U.S. tsunami early detection and warning system. This meant expanding an existing six deep ocean tsunami detection buoys into a network of 39, which would be sited in the Pacific and Atlantic Ocean Basins, including the Gulf of Mexico, Caribbean Sea, and the Far Pacific Ocean to monitor U.S. trust territories at risk.

Proponents of the NOAA program also called for funding authorization to address long-term needs of the U.S. network, such as maintenance, and to support social programs aimed at disaster preparedness and adaptation to risk. Emergency experts stressed the need for education of indigenous people and visitors about the potential dangers of tsunamis in an area; adaptation to potential risks, such as constructing public shelters; periodic evacuation drills; and informed land-use planning. Many also asserted that local officials need to be empowered to rapidly alert populations of an evacuation and to take appropriate safety precautions, even if that entailed using low-tech, high impact solutions such as sirens.

With respect to tsunami disaster warnings for the United States, discussions ensued between the Department of Homeland Security (DHS) and NOAA about developing a multi-hazard warning and response system and, perhaps, eventually contributing to a *global* tsunami early warning system. Experts acknowledge that formidable challenges lay ahead in adopting standardized communications protocols and ensuring the interoperability, scope, and purpose of the diverse emergency warning alert systems used by the United States and other countries.

This report will be updated as events warrant.

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Tsunami Detection and Warnings for the United States

Introduction

On December 26, 2004, a powerful submarine earthquake struck near Sumatra, Indonesia, and an ensuing tsunami devastated communities around the northern rim of the Indian Ocean. The National Oceanic and Atmospheric Administration (NOAA) reported that an estimated 170,000 people lost their lives.¹ After the dual disaster, some Members of Congress were soon on record as supporting an international effort to build a regional tsunami detection and warning network for the Indian Ocean where no such system existed prior to the disaster. Some lawmakers called for establishing an expanded tsunami detection and warning network to monitor the U.S. Atlantic coast, the Gulf of Mexico, and the Caribbean Sea.² They noted that although the risks may be small, the consequences of a tsunami for the U.S. Atlantic Coast justified such expenditures.³

To apprise Congress of the probabilities and potential risk for a tsunami striking the east coast of the United States, the House Congressional Coastal Caucus and the House Oceans Caucus sponsored a briefing in January 2005 on Capitol Hill.⁴ At the briefing, scientists from the NOAA at the Department of Commerce and the U.S. Geological Survey (USGS) at the Department of the Interior discussed the risk factors. Speakers alluded to the Puerto Rican Trench, the deepest point in the western Atlantic Ocean, where massive submarine landslides have historically

¹ National Oceanic and Atmospheric Administration, personal communication September 18, 2008. NOAA officials stated that there were 170,000 confirmed deaths, 100,000 individuals remained missing, and \$186 million in damages we incurred to buildings, piers, ferry terminals, and boat harbors.

² Rep. Frank Pallone (Remarks on H.Res. 12), *Congressional Record*, daily edition, vol. 151, no. 1, January 4, 2005, p. H40. “There has been a lot of discussion and I think there is a need to expand the tsunami early warning system that exists in the Pacific not only to the Indian Ocean but also possibly to the Atlantic Ocean and throughout the world.”

³ Rep. Vernon Elders, *Congressional Record*, daily edition, vol. 151, no. 1, January 4, 2005, p. H66. “And the likelihood of it is small, but if it occurs, the probability of major damage is so high that we should not just concentrate on the Pacific Ocean, the Indian Ocean, but we should also worry about the Atlantic Ocean and our eastern seaboard.”

⁴ Presenters at the January 5, 2005 House Caucuses’ “Briefing on the Indian Ocean Tsunami,” included David Applegate, Science Advisor for Earthquake and Geological Hazards at the USGS; Brig. General David Johnson, USAF (Ret.) Assistant Director of NOAA’s National Weather Service; Gregg Withee, Assistant Director for NOAA Satellite and Information Services; and, Eddie Bernard, Associate Director of NOAA’s Pacific Marine Environmental Laboratory (teleconferencing from Seattle, WA).

occurred along the face of the North American continental shelf.⁵ Also, they noted that strong earthquakes have occurred on the ocean floor off the coast of Puerto Rico, and that some of them generated tsunamis that caused major loss of life and property damages in both the Atlantic and Caribbean Basins.⁶ Another geographic area of concern for the United States that was discussed is the Pacific Northwest Cascadia [seismic] Zone. Based on historical seismic activity, many geologists are convinced that there is a potential for a large earthquake that could generate tsunamis and devastate the U.S. Pacific Coast and other settlements around and in the greater Pacific Ocean Basin.⁷ This admonition was based on empirical evidence of a large tsunami that was generated in the area around 1700 and affected lands as far away as Japan.⁸

The Bush Administration and Tsunami Protection

On January 14, 2005, shortly after the tragedy in the Indian Ocean, the White House Office of Science and Technology Policy (OSTP) proposed an improved tsunami warning and detection system for the United States.

According to the OSTP, with input from NOAA, the President originally proposed 32 dedicated Deep Ocean Assessment and Reporting of Tsunamis (DART) buoys to be deployed by mid-2007. His stated goal was to improve tsunami detection for the Far Pacific Trust Territories, the Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea.⁹ (See discussion under Deep-Water Tsunami Detection Operations below). Currently, 39 DART buoys make up the U.S. tsunami early warning network operated and maintained by NOAA's National Data Buoy Service (**Figure 1**).¹⁰

⁵ USGS, Woods Hole Science Center, "Caribbean Tsunami and Earthquake Hazards Studies Program," available at [http://woodshole.er.usgs.gov/projects/project_get.php?proj=29210EQ&style=html].

⁶ See "The Puerto Rico Trench: Implications for Plate Tectonics: Earthquake and Tsunami Hazards" at [<http://oceanexplorer.noaa.gov/explorations/03trench/trench/trench.html>] and also, University of Puerto Rico at Mayaguez, "The Puerto Rico Warning and Mitigation Program" at [<http://poseidon.uprm.edu>].

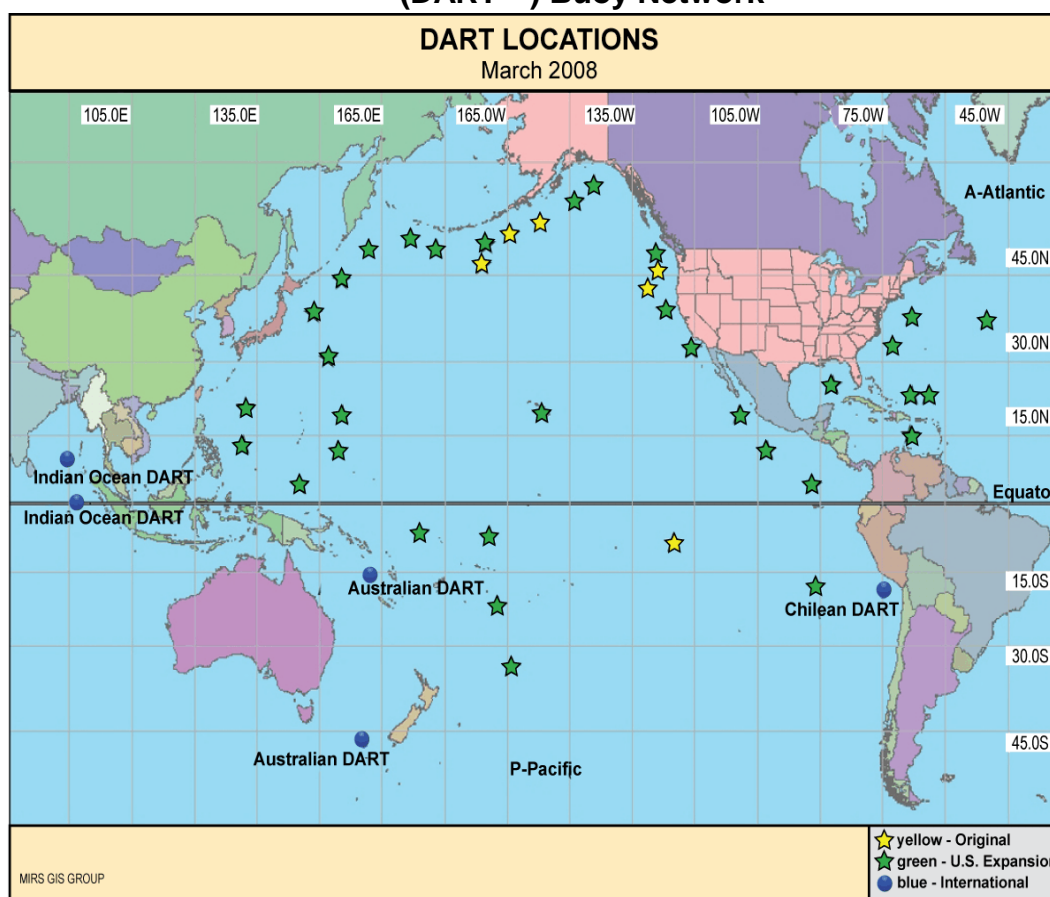
⁷ Eddie Bernard, Associate Director for NOAA of the Pacific Marine Environmental Lab (PMEL), teleconferencing with the House Briefing, January 5, 2005. (Hereafter cited as Eddie Bernard, House briefing, January 5, 2005.)

⁸ Brian Atwater et. al., the *Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America* (University of Washington Press, Seattle, 2005), reviewed, *Oregon Historical Quarterly*, vol. 108, no. 2, 2007 (online), available at [http://www.historycooperative.org/journals/ohq/108.2/br_9.html].

⁹ U.S. Office of Science and Technology Policy, "U.S. Announces Plan for Improved Tsunami Detection and Warning System," press release, OSTP News, January 14, 2005, available at [<http://www.ostp.gov/html/Tsunamiplanrelease.pdf>].

¹⁰ NOAA, "NOAA Launches Final Two Buoys to Complete U.S. Tsunami Warning System," March 10, 2008, at [http://www.noaanews.noaa.gov/stories2008/20080310_buoy.html].

Figure 1. U.S. Deep-ocean Assessment and Reporting of Tsunamis (DART™) Buoy Network



Source: NOAA, National Weather Service, National Data Buoy Center, Deep-ocean Assessment and Reporting of Tsunamis (DART™), available at [http://www.ndbc.noaa.gov/dart/DART_planned.gif].

Although generally supportive of President Bush's plan, concerned social scientists asserted that in addition to deploying the necessary detection and warning technology, there was a need for "institutionalizing" a public education component as part of whatever legislation might be enacted to implement U.S. and international tsunami protection measures.¹¹ The public education initiative they envisioned included training local authorities to be (1) resident developers and deliverers of disaster education, (2) emergency planners for tsunamis, and (3) disseminators of emergency tsunami warnings.

Further, federal, state, and local governments and private entities would be encouraged to share resources and, where possible, a visible federal agency-presence

¹¹ Testimony of Eileen Shea, Project Coordinator, East West Center, Honolulu, HI, in U.S. Congress, Senate Committee on Commerce, Science, and Transportation, *Tsunami Preparedness Act of 2005*, hearing, 109th Cong., 1st sess, February 2, 2005, S.Hrg. 109-93. (Hereafter cited as Eileen Shea, February 2, 2005.)

would be maintained in the community.¹² They also promoted adaptation to risks, such as constructing emergency sheltering to live with tsunamis, and to avail communities of low-tech, high-impact solutions for ordering public evacuations. Many social scientists also advocated adopting community “resiliency” as part of emergency preparedness and disaster management plans, which is the ability of the community to restore economic normalcy and citizen well-being as soon as possible after a tsunami disaster.¹³

U.S. “Tsunami Protection” Systems

Even prior to the Indian Ocean tsunami disaster, at least one U.S. Atlantic Coast state, New Hampshire, had a contingency plan for tsunami emergencies. New Hampshire's state government also maintains a clearinghouse of information about historical tsunami disasters that have affected the northeast United States.¹⁴ In 2005, the U.S. community of Indian Harbor Beach on the Atlantic Coast of Florida received notoriety for becoming the first NOAA National Weather Service (NWS) *TsunamiReady* location that was not situated on the Pacific Coast. The city of Norfolk, VA, on the mid-Atlantic Coast, was the second *TsunamiReady* community.¹⁵ Since then, additional communities in the eastern United States and Mayaguez, Puerto Rico, have gained that distinction. In contrast, some communities-at-risk, along the U.S. Pacific Coast and the states of Alaska and Hawaii, have had tsunami warning systems and emergency evacuation plans as far back as 60 years.

National Weather Service (NWS) Tsunami Programs

The NWS National Tsunami Warning Program (NTWP) consists of two U.S. tsunami warning centers that acquire, process, and interpret seismic and sea level data, forecast tsunami characteristics, and disseminate information to coastal emergency management and residents. An associated program, the National Tsunami Hazards Mitigation Program (NTHMP), originally supported tsunami and warning guidance, pre-event planning, and mitigation activities, though recently, it has shifted its focus to pre-event planning, mitigation, and public education. The NTHMP provides citizen education and outreach through NOAA's *TsunamiReady* program.

¹² See Government Accountability Office (GAO), “State and Local Tsunami Hazard Mitigation Activities Are Under Way although Implementation Varies Considerably among Locations,” in *U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain*, GAO Report GAO-06-519, June 2006, p. 29. Prepared for congressional committees and Senator Diane Feinstein.

¹³ Eileen Shea, February 2, 2005.

¹⁴ State of New Hampshire, “Disaster Plan 409,” Sect. II, Geological Hazards, Seismic Hazards, at [http://www.nhoem.state.nh.us/mitigation/state_of_new_hampshire.asp]. See also NOAA, National Weather Service *TsunamiReady* Program, “Is your Community Ready for the Next Tsunami?,” available at [<http://tsunami.gov>].

¹⁵ See NOAA, National Weather Service, “*TsunamiReady* Communities,” available at [<http://www.tsunamiready.noaa.gov/ts-communities.htm>].

It also assists states in emergency disaster planning and develops maps of potential coastal inundation for a tsunami of a given intensity. In addition to the two programs, NWS has played an integral role in international tsunami protection by temporarily siting two relocatable U.S. second-generation DART buoys in the international waters of the Indian Ocean for detection and early warning.

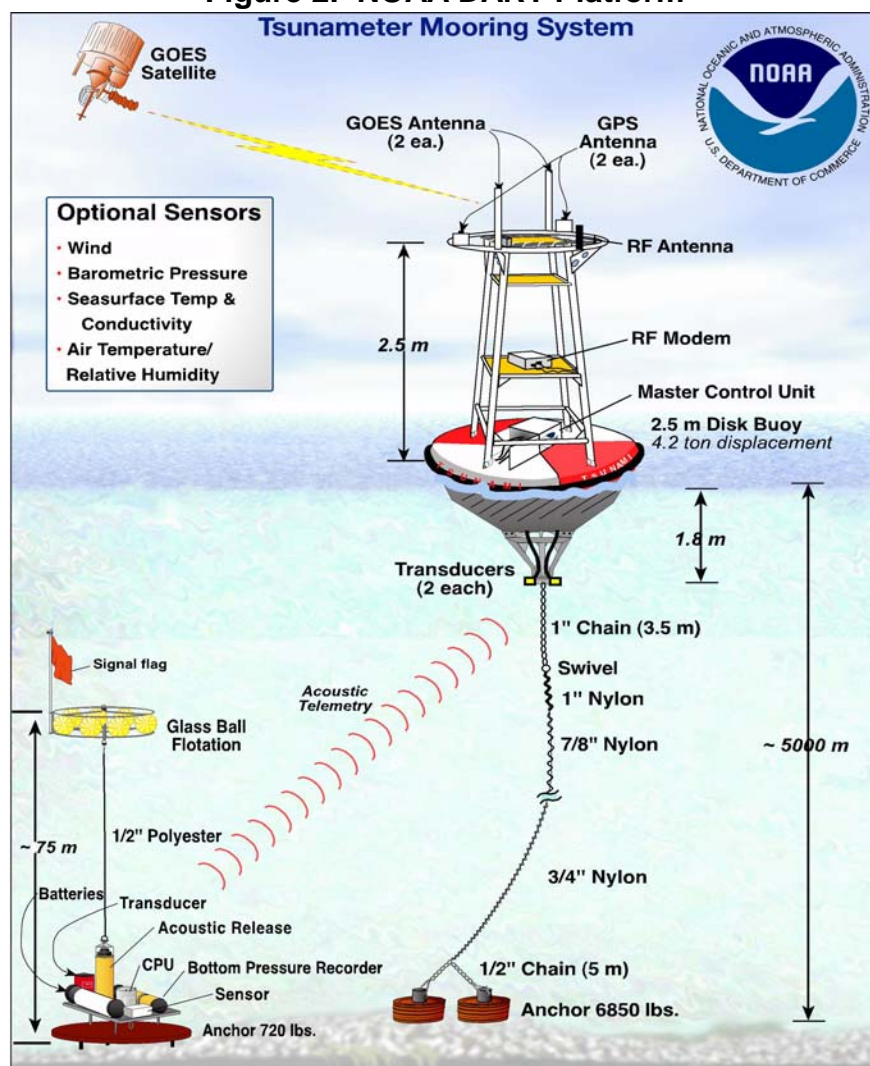
For the eastern United States, opportunities to include regional and local coastal and ocean observation networks for tsunami protections had been considered. Before the December 2004 Indian Ocean tsunami, there was a functioning tsunami detection and warning system and communications network operated by the University of Puerto Rico, Mayaguez. This system already monitored parts of the Gulf of Mexico, the Caribbean Sea, and the Atlantic coast of the Greater Antilles. It was through expansion of this network that NOAA enhanced coverage for tsunami detection and warning for the U.S. East Coast.

In April 2006, seven DART buoys were deployed in the Atlantic Ocean to include protection for the Caribbean Sea and the Gulf of Mexico as part of the Atlantic Basin early warning network (see **Figure 1**).¹⁶ These now complement 32 DART buoys operating in the Pacific Ocean, including the six that were previously deployed, three of which were situated off the Alaskan Peninsula. Another DART buoy was independently commissioned by the Chilean government to protect its coastlines. Two relocatable U.S. second-generation DART buoys were sited temporarily in international waters off the coast of Indonesia to monitor it and neighboring nations Indian Ocean coasts until two permanent internationally sponsored DART-type buoys were sited there.

Deep-Water Tsunami Detection Operations. NOAA currently operates an expansive network of 39 DART buoys (**Figure 1** locations and **Figure 2** DART technology). All but six of these buoys were procured since 2006 with technology enhancements (i.e., two-way communication).¹⁷

¹⁶ Vice Admiral Conrad C. Lautenbacher, Administrator of NOAA and Under Secretary of Commerce for Oceans and Atmosphere, NOAA FY07 Budget Briefing, National Press Club, Washington, DC, February 9, 2006. (Hereafter cited as Vice Admiral Conrad C. Lautenbacher, February 9, 2006.)

¹⁷ Hugh B. Milburn et al., “Real-Time Tsunami Measuring, Monitoring and Reporting System: The NOAA DART II Description and Disclosure,” NOAA Pacific Marine Environmental Laboratory (1996), available at [http://nctr.pmel.noaa.gov/Dart/Pdf/DART_II_Description_6_4_05.pdf]. A seventh DART buoy owned and operated by the Chilean government is deployed off Chile’s coast in South America.

Figure 2. NOAA DART Platform

Source: National Oceanic and Atmospheric Administration, from “U.S. Announces Plans for an Improved Tsunami Warning and Detection System.” See [<http://www.noaanews.noaa.gov/stories2005/s2369.htm>].

The Tsunami Warning Centers. The NOAA NWS West Coast/Alaska Tsunami Warning Center (WC/ATWC) operates at Palmer, AK. It was established in 1967 after a devastating earthquake of $M_w 9.2$ struck Anchorage in 1964, causing major localized tsunami damages.¹⁸ The WC/ATWC Area of Responsibility (AOR) is Canada, Puerto Rico/U.S. Virgin Islands, and all U.S. coastal states except Hawaii. Since 2006, the WC/ATWC expanded coverage serving as the warning center for U.S. populations located in western Atlantic Ocean areas. (**Figure 1**).

The Pacific Tsunami Warning Center (PTWC) operates from Ewa Beach, HI. Its AOR is all areas of the Pacific outside the WC/ATWC AOR, the Indian Ocean, and the wider Caribbean. The PTWC was established in 1949 after a strong

¹⁸ See NOAA, NWS, “How *TsunamiReady* Helps Communities and Counties at Risk,” available at [<http://www.stormready.noaa.gov/tsunamiready/>].

earthquake and massive landslides off the coast of southwest Alaska caused a disastrous tsunami for the Hawaiian Islands only hours later.

Other NOAA Supporting Technologies. As early as the 108th Congress, legislation was introduced to adapt technologies that might contribute to part of an enhanced U.S. tsunami detection and warning network.¹⁹ It was suggested that because NWS operated hundreds of marine weather buoys, and NOAA's National Ocean Service (NOS) operated water level tide-gauges off *all* coasts of the United States and in the Great Lakes, these instrumented platforms might figure early in NOAA's plans for an expanded U.S. tsunami warning network. (This was prior to the transfer of DART buoy technology from research to operations.) An additional benefit, NOAA officials noted, were systems comparable to both NWS weather buoys and NOS sea-level monitoring gauges operating off the coasts of other countries around the world, which might one day comprise a regional, or even global, tsunami early warning network.²⁰

NWS weather buoys record meteorological data, such as temperature, wind speed and direction, and atmospheric pressure. Other NOAA marine "drifting" data buoys measure speed of ocean currents and changes in salinity (or density) of the ocean. NOAA and the National Aeronautics and Space Administration (NASA) have operational satellite programs which measure sea surface height in conjunction with the satellite-based GPS (global positioning system). NOAA's National Ocean Service (NOS) tidal-monitoring networks relay data via NOAA environmental satellites for scientific data collection and analysis. Tide-gauge networks have been important because they can detect tidal surges or other ocean disturbances that may be indicative of *tsunamigenesis*.²¹ These networks and weather buoys are equipped for electronic communications and the capacity to transmit NOAA weather forecast via facsimiles, which serve commercial and recreational navigation.²²

In addition to weather and marine navigational buoys, there is currently an array of about 3,000 NOAA Argo²³ floats that is used for monitoring short-term climate changes in the equatorial Pacific Ocean. Because of where they are sited, they can

¹⁹ On January 5, 2005, Rep. Curt Weldon circulated a "Dear Colleague" letter advocating the reintroduction of H.R. 5001 (108th Congress), the Ocean and Coastal Observation System Act, in the 109th Congress. This legislation promoted development of an "Integrated Ocean Observation System" to protect U.S. citizens in coastal communities from tsunamis. For further information on U.S. ocean observation systems, see U.S. House Resources Subcommittee on Fisheries, Conservation, and Oceans, *Status of Ocean Observing Systems in the United States*, Oversight Hearing, serial no. 108-102, July 13, 2004 (Washington, DC: GPO 2005).

²⁰ Vice Admiral Conrad C. Lautenbacher, February 9, 2006.

²¹ A technical term used by geologists and oceanographers for the development of a tsunami.

²² Eddie Bernard, House briefing, January 5, 2005.

²³ NOAA/Woods Hole Oceanographic Institute, *Observing the Ocean in Real-Time: Argo, a Global Array of Profiling Floats to Understand and Forecast Climate*, ed. Stan Wilson (1996).

detect variable ocean conditions that are associated with El Niños and La Niñas,²⁴ or longer periodic adjustments to climate variability that may affect global weather, and can also monitor for real-time changes. The Administrator of NOAA has advocated the use of Argo floats as “the next step in global observations,” both for monitoring the global ocean and creating the backbone of a future global tsunami detection and warning network.²⁵

The National Tsunami Hazard Mitigation Program. In 1992, NOAA launched the National Tsunami Hazard Mitigation Program (NTHMP) to address the credibility of the PTWS (System) with respect to issuing tsunami warnings. At that time, there had been a 75% false alarm rate for tsunamis. Local Hawaiian officials became concerned about the significant social upheaval and economic disruption that were being caused by false alarms. They also had concerns whether the public would heed future tsunami warnings. With technological progress and iterative improvements, the error rate for false alarms has decreased significantly since then.

Another major NTHMP research effort considers the potential for a sizable earthquake in the Pacific Northwest Cascadia Region, where USGS scientists believe a tsunami could be generated and severely damage several U.S. Pacific coastal communities.²⁶ The NTHMP worked initially with five Pacific states — Alaska, Hawaii, Oregon, Washington, and California — and now works with 28 U.S. coastal states, territories, and commonwealths. Currently, NOAA assists more than 50 “communities-at-risk” in developing local tsunami emergency plans, including citizen education-in-disaster preparedness and response, as part of the NWS *TsunamiReady* program.²⁷

Over time, the NTHMP has developed tsunami dispersion models that can project trajectory, based on sea-floor morphology, and potential damage expected, based on the energy intensity of ensuing waves. Finally, the NTHMP helps to produce maps of potential inundation from tsunamis for coastal communities, on behalf of *TsunamiReady*-member states.

Contributing Programs for U.S. Tsunami Protection

In response to the Indian Ocean tsunami, for FY2007, the U.S. Geological Survey (USGS) received emergency supplemental appropriations of \$13 million to improve globally its earthquake-monitoring capabilities.²⁸ The USGS scientists

²⁴ Intra-decadal climate variability that may last 3-5 years. In addition to a normal climate phase, these two other phases affect ocean circulation in the Pacific Ocean to produce very different global weather patterns.

²⁵ Vice Admiral Conrad C. Lautenbacher, February 9, 2006.

²⁶ USGS, Local Tsunami Hazards in the Pacific Northwest from Cascadia Subduction Zone Earthquakes by Eric L. Geist, at [<http://pubs.usgs.gov/pp/pp1661b/pp1661b.pdf>].

²⁷ NOAA, National Weather Service, “TsunamiReady,” available at [<http://www.stormready.noaa.gov/tsunamiready/ts-communities.htm>].

²⁸ Dr. Charles Groat, director of the USGS, presentation on the USGS FY2006 budget held (continued...)

began upgrading the Global Seismic Network (GSN) and its seismic monitoring stations that did not have real-time data communication abilities. USGS also increased staff hours to cover seismic alerts that are received by its National Earthquake Information Center (NEIC) in Golden, CO. The NEIC advises national and regional emergency managers as well as NOAA's tsunami warning centers about the potential for a disaster caused by an earthquake of a given magnitude, and whether a tsunami could develop. Today, alternatives for broadcasting tsunami warnings locally include radios, cellular phone networks, and the Internet and can be used for reaching government officials in rural or isolated populations. Some argue that bullhorns, sirens, and flares can also be as effective to evacuate populations in advance of a tsunami.²⁹ International telecommunications networks, such as the Global Telecommunications System (GTS), that operate under common data transmission protocols, provide a line of emergency communications among worldwide leaders and government institutions, such as international weather bureaus.³⁰

The U.S. Geological Survey (USGS). USGS contributes directly to the U.S. National Tsunami Warning Program through the Global Seismic Network (GSN) and Advanced National Seismic System (ANSS). The GSN has proved critical for identifying the potential of and issuing early warning for tsunamis. The USGS currently operates a network of 127 global seismic monitoring stations on the GSN, including some situated in the Indian Ocean. This network is managed by the Incorporated Research Institutions for Seismology (IRIS), a consortium of academic institutions involved with earthquake monitoring, detection, and modeling.³¹ Although USGS does not monitor for *tsunamigenesis*, the GSN does measure the strength and energy of land-based and submarine earthquakes around the globe in real-time. Depending on where they may occur, and their magnitude, the NWS TWCs make determinations of a possible onset of a tsunami.

During the tsunami disaster in the Indian Ocean, USGS officials indicated that only about 80% of GSN instruments had capability for real-time data telemetry.³² Accordingly, President Bush requested funding to upgrade the entire GSN network and, in 2005, Congress approved emergency supplemental appropriations for that purpose. The USGS planned to increase the number of seismic monitoring stations

²⁸ (...continued)

at the Department of the Interior, Washington, DC, February 7, 2005. Congress appropriated \$8.1 million in emergency supplemental appropriations for FY2005 in P.L. 109-13. (Hereafter cited as Dr. Charles Groat, February 7, 2005.)

²⁹ Eileen Shea, February 2, 2005.

³⁰ Kenneth B. Allen, director of the Partnership for Public Warning, "Letter to President Bush," January 3, 2005, at [<http://www.partnershipforpublicwarning.org/ppw/>]. See also, Joab Jackson, "Cisco, IBM Propose Internet-Based Disaster Alert System," *Government Computer News*, February 11, 2005, at [<http://www.gcn.com/>].

³¹ Incorporated Research Institutions for Seismology (IRIS), "Global Seismic Network (GSN)" at [<http://www.iris.edu/about/GSN/>].

³² Dr. Charles Groat, February 7, 2005.

around the globe.³³ Some of the funding was also used to augment the number of staff hours of coverage at the National Earthquake Information Center (NEIC) in Golden, CO. Conferees on the emergency funding bill noted that the resources appropriated for GSN communication improvements might enable USGS and NWS to exchange seismic data and other information necessary for tsunami modeling exercises more rapidly.³⁴

USGS researchers have also played a part in the betterment of scientific understanding of tsunamis. They collect and analyze data on crustal deformation and ocean floor displacement and are experts at determining which events may be precursors to earthquakes and which of those may generate tsunamis. USGS electronic topographical mapping data, and the Digital Elevation Model (DEM), has assisted NOAA scientists in developing spatially accurate tsunami inundation maps for communities-at-risk. These maps have assisted emergency managers in developing tsunami evacuation plans and for guiding land-use decisions of local government planners and private developers over the long-term.

Because the USGS also monitors seismic activity on land, many geologists assert that detection of land-based seismic activity can be as important as DART buoy technology in the sea when it comes to determining whether a tsunami may develop.³⁵ Historically, in certain coastal areas of the United States, and particularly along the Pacific Coast, land-based earthquakes have generated massive landslides that have entered the ocean or other bodies of water abruptly, displacing large volumes of water locally. As mentioned previously, landslides that occur beneath the ocean may also generate tsunamis. USGS vulcanologists have investigated the vulnerability of the U.S. Atlantic Coast to a “super tsunami” which some believe could be caused by the collapse of a volcano near the Canary Islands off the coast of West Africa.³⁶

Cooperative Protection for the Pacific Basin. NOAA’s Director of the NWS leads the UNESCO International Coordinating Group (ICG) for the International Tsunami Warning System in the Pacific (ITSU). ITSU was created in 1968 and this system is still operated out of the PTWC, which also issues products to ITSU’s 26 member nations. In October 2005, ICG/ITSU was renamed the ICG/Pacific Tsunami Warning and Mitigation System (ICG/PTWMS). This change

³³ Dr. Charles Groat, director of the USGS, presentation on USGS FY2007 budget held at the Department of the Interior, Washington, DC, February 6, 2006.

³⁴ P.L. 109-13, Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Tsunami Relief, 2005 (H.Rept. 109-72).

³⁵ These include the USGS Advanced National Seismic System (ANSS), the Global Seismic Network (GSN), National Strong-motion Program, and other U.S. regional networks and cooperators. See [<http://earthquake.usgs.gov/research/index.php?areaID=12>].

³⁶ Rossella Lorenzi, “Top World Tsunami Hotspots Detailed,” *Discovery News (online)*, January 11, 2005, at [<http://dsc.discovery.com/news/briefs/20050110/tsunamidanger.html>]. “According to Simon Day, Benfield Greig Hazard Research Center at University College London, U.K., geological evidence suggests that during a future eruption, Cumbre Vieja Volcano on the island of La Palma in the Canary Islands, off West Africa, could experience a catastrophic failure of the western flank.”

aligned ITSU with tsunami warning and mitigation programs established by UNESCO's Intergovernmental Oceanographic Commission (IOC), and to distinguish it from the PTWC. The ICG/PTWMS currently serves 28 member nations that are vulnerable to tsunamis generated around the Pacific Basin. Among these, three member states, Australia, Thailand, and Indonesia (in part), are unique in that they are also threatened by those generated in the Indian Ocean.³⁷

World Weather Watch. In terms of disaster warnings, NOAA and other international weather agencies issue warnings almost daily of severe meteorological conditions that can affect commercial air traffic and marine navigation. Weather-related disasters have put human lives and property in danger and have caused significant economic disruption over large geographic regions, notwithstanding international borders. The U.N. World Weather Watch (WWW) is an international cooperative program for weather forecasting and warning which was organized and administered by the U.N. World Meteorological Organization (WMO). The mission of the WWW is to ensure that people, no matter where they may be situated around the globe, are adequately warned of the possibility of severe weather or dangerous ocean-related conditions.³⁸ NOAA's National Weather Service (NWS) disseminates meteorological forecasts and warnings internationally on behalf of the United States as part of the WWW mission.

The NWS maintains a leadership role in the WWW, with respect to weather and other environmental data collection, management, and archives. The Department of State works with NOAA in negotiations on behalf of the United States to forge and sustain international agreements for effective WWW operations globally. WWW parties communicate through established channels of telecommunications using common protocols such as the GTS to receive and disseminate weather data, forecasts, and warnings.³⁹ NOAA's National Environmental Satellite and Environmental Data and Information Service (NESDIS) houses two of three adjunct World Weather Program (WWP)⁴⁰ data centers, the third is managed by the Russian government. The WWP centers archive and make available weather and other environmental data for scientific analysis. These telecommunication-enabled portals

³⁷ See "International Tsunami Information Center: ITSU Master Plan," the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), UNESCO/ICG, at [<http://www.tsunamiwave.info/>].

³⁸ U.S. Dept. of Commerce, NOAA, Office of the Federal Coordinator for Meteorology, "World Weather Program," *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2005*, Report FCM P1-2004, Appendix B: 223-228 (Washington, DC: October 2004). Examples of international communications networks are included.

³⁹ Ibid.

⁴⁰ NOAA, National Environmental Satellite Data and Information Service (NESDIS), "About the World Data Center System." NESDIS operates two U.S. WWP data centers and performs analysis on and archives weather satellite data for international use. This resource has since provided valuable information about the Indian Ocean tsunami. See the NESDIS website at [<http://www.ngdc.noaa.gov/wdc/wdcmain.html>]. See also "NOAA Scientists Able to Measure Tsunami Height from Space," at [<http://www.noaanews.noaa.gov/stories2005/s2365.htm>].

facilitate exchange of data and scientific research findings around the globe.⁴¹ NOAA officials consider the international reach of the WWW important for communicating tsunami warnings among WWP member governments and scientific institutions. The NESDIS data centers, they say, are important as a tool for providing access to research data on environmental factors that may predispose a region to weather and ocean-related disasters, such as tsunamis.

National All Hazards Weather Radio (NAHWR). National emergency communications management for the United States became the responsibility of the Department of Homeland Security (DHS) when FEMA was subsumed under the newly created agency in March 2003.⁴² Operations of the NOAA Weather Radio (NWR) predate establishment of the DHS, and NWR has been used to warn individuals at home and in public institutions, such as schools and hospitals, of the potential for severe weather and when to take appropriate action. In 2003, DHS initiated discussions with NWS to collaborate in modifying the NWR to enable public warnings of all types of disasters — natural or otherwise. Out of these discussions came a proposal for a National *All Hazards* Weather Radio Network (NAHWR) that would broadcast disaster warnings and information and subsume the NWR communications spectrum as part of the U.S. Public Alert Network.⁴³

Over time, Congress has expanded the NWR's reach through construction of additional signal transmission towers and by adding repeaters to the network in more locations. Repeaters can be mounted on public structures to extend the range and reception of NWR emergency transmissions. The NWR receiver is an important component for receiving emergency warnings. This device has been made available to the public at a modest cost to individuals and, in most cases, at no cost to public schools seeking grant assistance. The NWR program has especially targeted rural areas to ensure that as many as possible at risk can receive severe weather-related warnings. Advances in weather forecast technologies and expansion of the NWR network have enabled increased lead-time for emergency warnings, including tsunamis.

With the advent of the NAHWR, eventually other emergency communications would also be dispatched from their nearest NWS Weather Forecast Office (WFO). The DHS is vested in NAHWR as a means in the future to disseminate warnings for earthquakes, tsunamis, volcanoes, floods, and other natural disasters, as well as terrorist or accidental industrial-related disasters. This project has been funded at around \$11 million annually. Proponents of fully deploying the network assert that

⁴¹ The National Geophysical Data Center (NGDC) of NESDIS maintains NOAA's and the U.N. International Oceanographic Committee (IOC)'s long-term archive for global tsunami event, inundation, and damage data. NOAA officials stress that "The exchange and sharing of data on a worldwide basis is a critical part of developing descriptions and the understanding of our global environment." They also note that "The GEO (Global Earth Observation) Workplan for 2006 identifies the WDCs as one of the archives for data collected over coastal regions subject to tsunami risk." See [http://www.ngdc.noaa.gov/products/news_archive_2005.html].

⁴² P.L. 107-296, Homeland Security Act of 2002.

⁴³ NOAA All Hazards Weather Radio (NWR), at [<http://www.nws.noaa.gov/nwr/>].

at least \$150 million would be required to develop a broadband network capable of integrating different federal agencies' emergency communications systems.

Because of its experience with NWR, NOAA officials believe that it is the logical choice for safeguarding populations living in coastal areas of the United States. They are confident that NWR can provide early warnings for an approaching tsunami, possible coastal flooding from storm surges, or hazardous marine conditions, including obstacles such as ice jams and debris in waterways for marine navigators. Further, NOAA officials have suggested that the real power of the NWR is a capability to expediently notify coastal populations of false alarms, which might help to alleviate ensuing panic and possible economic disruption.

Appendix. Acronyms

ANSS	Advanced National Seismic System (USGS)
DART	Deep-ocean Assessment and Reporting of Tsunamis
DEM	Digital Elevation Model (USGS)
DHS	Department of Homeland Security
DOC	Department of Commerce
DOI	Department of the Interior
DOS	Department of State
FCMSSR	Federal Coordinating Committee for Meteorological Services and Supporting Research (NOAA/U.S. Interagency)
FEMA	Federal Emergency Management Agency (Directorate-DHS)
GAO	Government Accountability Office
GEO	Global Earth Observation (Group — NOAA/U.S. Interagency)
GPS	Global Positioning Satellite (Network)
GSN	Global Seismic Network (USGS)
GTS	Global Telecommunications System
ICG/ITSU	The International Coordination Group for the Intergovernmental Tsunami System in the Pacific (ICG/ITSU)
IOC	Intergovernmental Oceanographic Commission (U.N.)
IOOS	Intergovernmental Ocean Observing System (U.N.)
IOTWC	Indian Ocean Tsunami Warning Center (U.N./NOAA)
IRIS	Incorporated Research Institutions for Seismology (USGS/GSN)
ITSU	Intergovernmental Tsunami
NAHWR	National All Hazard Warning Network (DHS/NOAA)
NGDC	National Geophysical Data Center (NESDIS/NOAA)
NDBC	National Data Buoy Center (NWS/NOAA)
NEIC	National Earthquake Information Center (USGS, Golden, CO)
NESDIS	National Environmental Data and Information Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration (DOC)
NOS	National Ocean Service (NOAA)
NTHMP	National Tsunami Hazard Mitigation Program (NWS/NOAA)
NTWP	National Tsunami Warning Program (NWS/NOAA)
NWR	NOAA Weather Radio (NWS/NOAA)
NWS	National Weather Service (NOAA)
OSTP	Office of Science and Technology Policy (White House)
PTWC	Pacific Tsunami Warning Center (Ewa Beach, Hawaii, NWS)
PTWMS	Pacific Tsunami Warning and Mitigation Center (U.N. IOC/NOAA)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USGS	U.S. Geological Survey (DOI)
UN	United Nations
WC/ATWC	West Coast/Alaska Tsunami Warning Center (Palmer, AK NWS)
WDC	World Data Center (U.N. WMO/NOAA)
WFO	Weather Forecast Office (NWS/NOAA)

WMO	World Meteorological Organization (U.N.)
WWP	World Weather Program (U.N. WMO/NOAA)
WWW	World Weather Watch (U.N. WMO/NOAA)