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Tsunamis: Monitoring, Detection, and Early Warning Systems

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Summary

Recently, some in Congress have become concerned about the possible vulnerability of U.S. coastal areas to tsunamis, and about the adequacy of early warning for coastal areas of the western Atlantic Ocean. Those concerns stem from the December 26, 2004, tsunami that devastated many coastal areas around the northern Indian Ocean, where few tsunami early warning systems currently operate. Caused by a strong underwater earthquake off the coast of Sumatra, Indonesia, the tsunami disaster is estimated to have claimed at least 150,000 lives. Affected nations, assisted by others, are pursuing a multilateral effort to develop a detection and warning network for the Indian Ocean. Also, some Members of Congress and the Bush Administration have proposed a tsunami warning network for the U.S. Atlantic seaboard. Although instrumentation costs could run into the millions of dollars, existing weather buoys and state and local coastal and ocean observation networks might serve as possible platforms for the instrumentation. The European Union, Canada, and the United States may consider multilateral efforts to establish coverage for the North Atlantic. This report will be updated as warranted.

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Tsunamis: Monitoring, Detection, and Early Warning Systems

Introduction

Recently, numerous congressional inquiries have asked about the possibility of tsunamis occurring in U.S. coastal areas; the extent to which these areas are currently monitored; how tsunamis can be detected; and whether there is a national capacity to issue evacuation warnings for tsunamis. These concerns stem from the December 26, 2004, tsunami triggered by an underwater earthquake off the west coast of northern Sumatra in Indonesia. That earthquake was measured at M_w 9.0.¹ The ensuing tsunami devastated many coastal areas around the northern Indian Ocean, and caused loss of life and damages in other areas. International disaster agencies currently estimate that at least 150,000 people lost their lives to the tsunami.

The National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce and various international science agencies have indicated that there were few, if any, tsunami early warning systems monitoring the Indian Ocean on December 26, 2004. However, nations bounded also by the Pacific Ocean, including Australia and Indonesia, had tsunami early warning systems monitoring the Pacific shores where they perceived a threat.² Because of the lack of infrastructure to receive tsunami warnings rapidly, some have pointed out that for people on Indonesia's Indian Ocean shores, emergency communications were useless in many cases.

Although most deadly tsunamis have occurred historically in the western Pacific Ocean, there are examples of recorded events in the Atlantic. In 1692, a tsunami generated by massive landslides in the Atlantic Puerto Rican Trench reached Jamaica's coast, causing an estimated 2,000 deaths. In 1775, a tsunami struck in the eastern Atlantic Ocean on the coast of Portugal, killing an estimated 60,000 people. More recently, in 1929, a tsunami generated in the Grand Banks region of Canada hit Nova Scotia, killing 51. It was the third lethal tsunami for Canada's Atlantic Coast within 150 years.³

¹ M_w , the moment of magnitude, is a way to measure the force of an earthquake's total seismic energy released as a function of rock rigidity in the fault, the total area of contact where friction occurs, and the amount of slippage (or displacement). It is used for earthquakes greater than M8.2 on the Richter scale.

²General David L. Johnson, "NOAA Tsunami and Natural Disaster Information," presentation at House Science Committee briefing, Jan. 5, 2005.

³Statistics on deaths resulting from tsunamis were compiled by CRS from online sources, and include data from the Tsunami Laboratory of Novosibirsk, NOAA's National Geophysical Data Center, the University of Southern California, Tsunami Research Group,

(continued...)

On January 5, 2005, the House Science Committee, House Coastal Caucus, and House Oceans Caucus co-sponsored a briefing organized by the U.S. Geological Survey (USGS) of the Department of the Interior. One purpose of the briefing was to consider the possible implications of the Indian Ocean tsunami for the United States. Experts from USGS and NOAA delivered presentations on the circumstances surrounding that tsunami disaster, and discussed current capabilities for monitoring, detection, and early warning around the globe.⁴

Proposals for International Tsunami Early Warning Systems

Currently, most experts agree that considerable challenges must be overcome to establish an extensive tsunami early warning network in the Indian Ocean.

Challenges. Few nations would question that development of such a system, including localized warnings, will require involving many nations with widely varying technological capabilities. Reports indicate that political leaders expect that most of the responsibility for paying for such a system will likely fall on the wealthiest nations. The costs of procuring, operating, and maintaining those instruments and platforms, and the challenge of obtaining international cost sharing, are likely to be the most critical factors for sustaining a long-term international effort for global tsunami detection and warning. International science agencies are calling for an inventory of existing global capacity for tsunami monitoring, detection, and warning systems to use as a baseline from which to determine what may still be needed.

Some U.S. policy experts also have suggested that technological challenges and possible national security issues may arise, including multinational sharing of international telecommunication networks and international standardization for tsunami warning instrumentation on data platforms. Intelligence experts suggest that some data could be considered sensitive and perhaps compromising to U.S. or other nations' intelligence-gathering operations. Gregg Withee, Assistant Director of NOAA Satellite and Information Services, has noted that some nations, including India, maintain proprietary rights to all of their real-time satellite data. Some of these data, he asserted, could be important for tsunami detection in the Indian Ocean.

Proposals. On January 6, 2005, the United Nations Environment Program (UNEP) announced an international effort to develop a tsunami early warning capacity for nations bounding the Indian Ocean. The Australian government announced it would develop and fund its own effort to guard its Indian Ocean

³(...continued)

and others. See [<http://geology.about.com/library/bl/bltsunamideathtable.htm>], visited Jan. 11, 2005.

⁴Presenters at that briefing included, David Applegate, Science Advisor for Earthquake and Geological Hazards at the USGS; General David Johnson, 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).

coastlines.⁵ (For information on other types of foreign assistance for the areas affected by the tsunami, see CRS Report RL32715, *Indian Ocean Earthquake and Tsunami: Humanitarian Assistance and Relief Operations*.) With respect to Atlantic coast vulnerabilities, possible approaches could include multilateral agreements among the United States, Canada, and European Union so as to establish more comprehensive tsunami coverage for the North Atlantic.

Some Members of Congress have proposed a “global” tsunami detection/warning system in the aftermath of the Indian Ocean disaster. Senator Lieberman, for example, has called for expanding the U.S. tsunami early warning program in the Pacific to include sites in the Indian and Atlantic Oceans.⁶ Based on the costs of current NOAA operations, the Senator estimates that the cost for expanding from the existing six dedicated tsunami warning platforms in the Pacific Ocean to 50 globally would be approximately \$30 million for implementation, with operations and maintenance costs an additional \$8 million annually.⁷ These figures do not take into account costs of an emergency management infrastructure to deliver regional tsunami warnings directly to the public in the wider region of the Indian Ocean, however.⁸

Representative Pallone called for establishing a tsunami detection and warning network for the U.S. Atlantic coast, the Gulf of Mexico, and the Caribbean Sea.⁹ Others question whether the risks for tsunamis on the U.S. Atlantic coast would justify such expenditures. NOAA reported that the Puerto Rican Trench, which is the deepest point in the western Atlantic Ocean, is a great concern.¹⁰ As noted above, massive landslides and sloughing have occurred on the North American continental shelf, generating deadly tsunamis. One U.S. Atlantic coast state, New Hampshire, already has an emergency contingency plan for tsunamis, and a clearinghouse for information about historical tsunami disasters.¹¹

On January 14, 2005, the White House Office of Science and Technology Policy (OSTP) announced the Bush Administration’s plan for an improved tsunami warning

⁵Briefing for the House Science Committee by USGS and NOAA, Jan. 5, 2005.

⁶Sen. Joseph Lieberman, “Lieberman Unveils Tsunami Early Warning Legislation, Senator’s Bill Would Deploy 40-50 New Sensors and Fund System at \$30 million,” news release, Jan. 6, 2005.

⁷For current NOAA tsunami-related funding, see U.S. Congress, House, “Conference Report on H.R. 4818, the Consolidated Appropriations Act, 2005 (P.L. 108-447),” H.Rept. 108-792, Title II, Commerce, Justice, State, and the Judiciary and Other Related Agencies Appropriations Act, 2005, *Congressional Record*, Nov. 19, 2004: H10457.

⁸Associated Press, “Hill Eyes Tsunami Warning System—Lieberman calls for Global Net,” *Washington Times*, Jan. 7, 2005: A10.

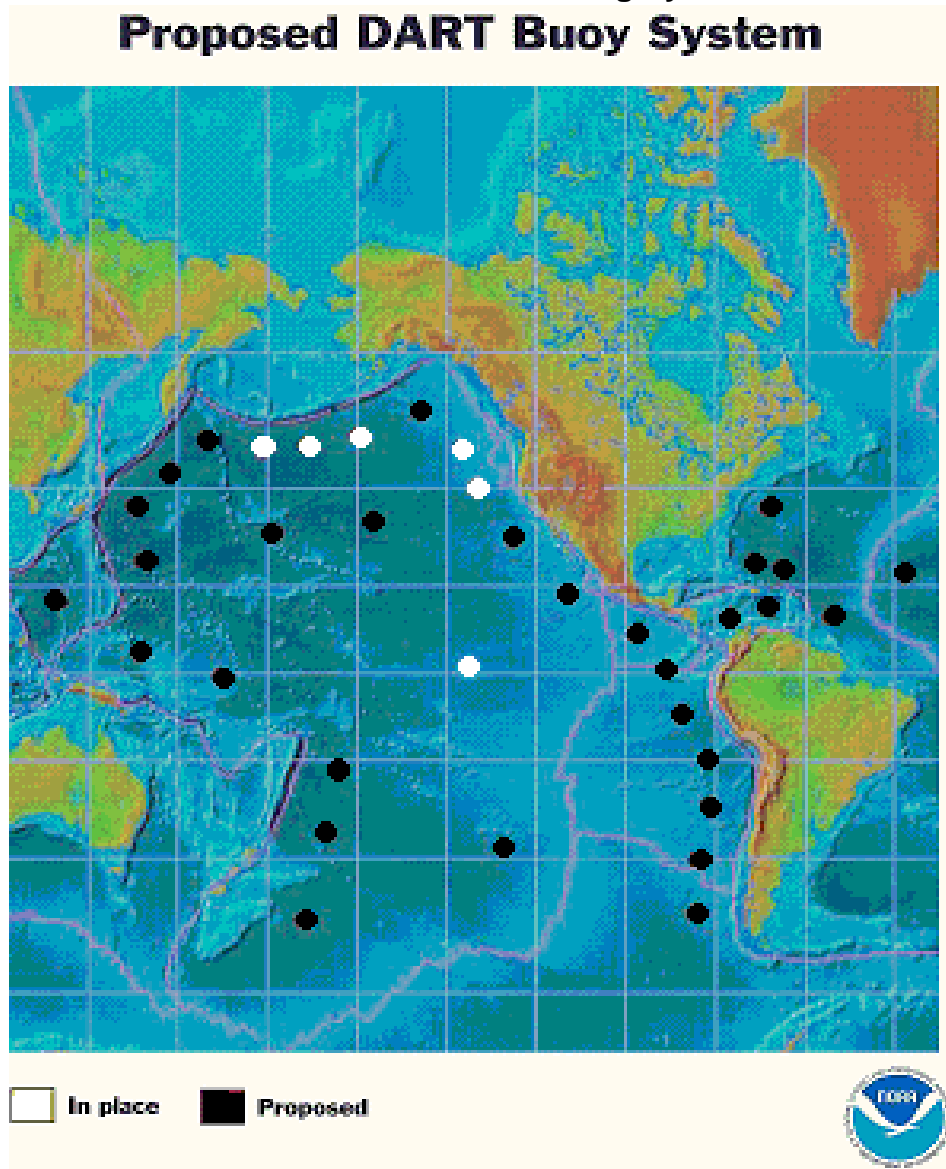
⁹*Congressional Record*, Jan. 4, 2005: H40.

¹⁰House Science Committee briefing, Jan. 5, 2005.

¹¹State 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], visited Jan. 11, 2005. See also “Is your Community Ready for the Next Tsunami,” National Weather Service Tsunami Ready program, at [<http://tsunami.gov>], visited Jan. 11, 2005.

and detection system for the United States.¹² The plan initially includes deploying 32 new dedicated tsunami warning and detection buoys by mid-2007 in the Pacific and Atlantic Oceans, Gulf of Mexico, and Caribbean Sea to protect U.S. coastal areas. (See **Figure 1.**) The President would commit \$37.5 million over the next two years to implement the plan. The Director of OSTP noted that the system will “ultimately include the Indian Ocean.” Some question whether the risks for tsunamis on the U.S. Atlantic coast would justify such expenditures.

**Figure 1. U.S. Proposal for
Tsunami Detection/Warning System**



Source: National Oceanic and Atmospheric Administration, from “U.S. Announces Plans for an Improved Tsunami Warning and Detection System” (modified by CRS for contrast), at [<http://www.noaa.gov/stories2005/s2369.htm>], visited Jan. 18, 2005.

¹²U.S. Office of Science and Technology Policy, “U.S. Announces Plan for Improved Tsunami Detection and Warning System,” press release, *OSTP News*, Jan. 14, 2005.

The Director of NOAA's National Weather Service (NWS) has emphasized that in addition to needing the capacity to monitor and detect possible tsunamis, a telecommunications infrastructure for issuing tsunami warnings, such as that presently in place in the Pacific Ocean, would be critical for the Indian and Atlantic Oceans operations. He noted that NOAA's Administrator, Admiral Lautenbacher, has promoted the development of an international Global Earth Observing System of Systems (GEOSS). One component of the system would rely on existing platforms and telecommunications capabilities of other observation systems currently operating, including the International Global Ocean Observing System (IGOOS) and Argo (climate monitoring) floats, helping to achieve a global tsunami detection and warning capacity.¹³

U.S. Tsunami Programs

Presently, NOAA has a national program to warn Pacific coastal areas of tsunamis, consisting of two regional U.S. tsunami warning centers in the Pacific Ocean, a cooperative program to reduce false tsunami alarm rates in the Pacific Ocean, monitoring and detection operations, and tsunami research activities.

Tsunami Warnings. The NWS operates the West Coast/Alaska Tsunami Warning Center (WC/AKTWC) at Palmer, AK, and the Pacific Tsunami Warning Center (PTWC), at Ewa Beach, HI.

The PTWC monitors for tsunamis and issues warnings for the Hawaiian Islands, the U.S. Pacific territories, and other U.S. and international interests in the Pacific Basin. It was established in 1949, after a strong earthquake and massive landslides off the coast of southwest Alaska caused a tsunami disaster in the Hawaiian Islands hours later. The WC/AKTWC was established in 1967, after a devastating earthquake in Anchorage, AK, in 1964 caused localized tsunami damages. This center is responsible for issuing warnings to emergency managers in Alaska, British Columbia, Washington, Oregon, and California. In addition, in 1992, NOAA launched a National Tsunami Hazard Mitigation Program to address Pacific tsunami warnings, which, at that time, were being issued with a 75% false alarm rate, causing significant social upheaval and economic disruption. This program also focused on the potential that a sizable earthquake in the Pacific Northwest Cascadia Region could generate devastating tsunamis that would damage U.S. Pacific coastal regions.¹⁴

U.S. Operations and Research. NOAA currently has a network of six dedicated tsunami detection and relay stations, operating as part of its Deep-Ocean Assessment and Reporting of Tsunamis (DART) program.¹⁵ (See **Figure 1**, above, for their location, and **Figure 2**, below, for the components.) These are equipped for

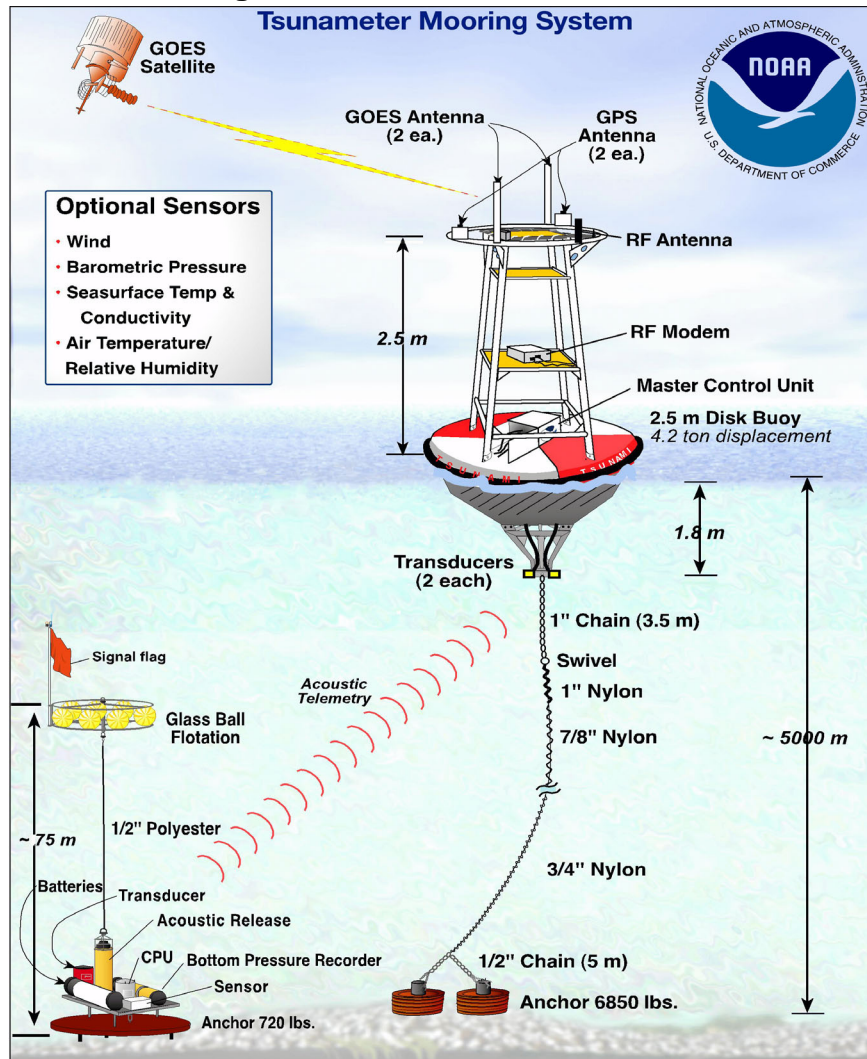
¹³Gen. David Johnson, House Science Committee briefing, Jan. 5, 2005.

¹⁴Eddie Bernard of NOAA, House Science Committee briefing, Jan. 5, 2005.

¹⁵Hugh B. Milburn et al., "Real-Time Tsunami Reporting from the Deep Ocean," NOAA Pacific Marine Environmental Laboratory (1996), at [http://www.ndbc.noaa.gov/Dart/milburn_1996.shtml], visited Jan. 4, 2005.

an early warning capability, but their emergency communications are only effective if there are emergency managers to receive them and, in turn, alert the public.

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.noanews.noaa.gov/stories2005/s2369.htm>], visited Jan. 18, 2005.

NOAA officials estimate that the cost of adding tsunami detection instruments on Atlantic Ocean platforms, such as weather buoys, or building dedicated DART platforms, could vary depending upon the scale of the project — for example, the number of instruments to be included and the costs of operation and maintenance.¹⁶ At a minimum, NOAA anticipates that the cost for three new DART platforms it has proposed for the western Atlantic Ocean and Gulf of Mexico/Caribbean Sea,

¹⁶NOAA officials estimated the cost to produce the existing six experimental DART platforms, instrument them, provide a telecommunications capability, and maintain them at approximately \$125,000 each, but suggested there would be an economy of scale if their proposed total of 23 platforms for the United States in the Pacific and Atlantic Oceans were produced.

including costs of operation and maintenance, and construction of a new regional center, would be comparable to annual funding for the two Pacific regional tsunami early warning operations centers — approximately \$8 million for FY2005.¹⁷ (For a schematic of the DART buoy platform, see **Figure 2**.)

Related U.S. Programs. To reduce costs for a U.S. Atlantic coast tsunami early warning system, engineers at NOAA say that it is technologically possible to modify weather and marine data buoys, such as those currently situated off the United States, to serve as platforms for mounting tsunami monitoring and detection instrumentation. Others suggest taking advantage of existing international communications networks for issuing tsunami warnings to local emergency managers.¹⁸

Hundreds of NWS weather buoys operating off the coasts of the United States already record various meteorological data; while marine data buoys measure speed of ocean currents, temperature, salinity, and pressure change. Sea surface height (or sea level) also is measured by satellite-GPS (global positioning system) by NOAA's National Ocean Service tidal monitoring network, which is responsible for issuing warnings.

All of these buoys are equipped to relay data and emergency communications for navigational purposes.¹⁹ In addition, an array of 3,000 data buoys, known as Argo floats, currently deployed in the equatorial waters of the Pacific Ocean, are being used to detect conditions for El Niños and La Niñas, which are three- to seven-year climate variations that affect global weather. Argo floats might also be considered as possible platforms for situating tsunami detection instrumentation.²⁰ These floats have been advocated by NOAA as “the next step in global [Earth] observations.”²¹ In the Atlantic Ocean, other possible platforms for tsunami monitoring and detection include a growing number of regional and local coastal and ocean monitoring networks in development along the coasts of Canada and the United States. A proposal to use such systems for tsunami warning was introduced in the 108th Congress.²²

¹⁷This amount also includes funding for NOAA's U.S. tsunami-related research activities. Annual funding requested for U.S. tsunami monitoring, early warning, and research is found in the NWS budget under Operations and Research. Appropriations for these activities are provided in Title II of the annual Commerce, Justice, State, Judiciary, and Related Agencies appropriations acts.

¹⁸Kenneth B. Allen, Director of the Partnership for Public Warning, “Letter to President Bush,” Jan. 3, 2005, at [<http://www.partnershipforpublicwarning.org/ppw/>], visited Jan. 21, 2005.

¹⁹Eddie Bernard, House Science Committee briefing, Jan. 5, 2005.

²⁰NOAA/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). Funded in part by private academic institutions.

²¹*Ibid.*

²²On January 5, 2005, Representative Curt Weldon circulated a “Dear Colleague” letter (continued...)

Additionally, NOAA and other international weather agencies issue warnings of meteorological conditions that primarily affect commercial air traffic, but which also might put human lives in danger and cause significant economic disruption for global nations. The U.N. World Weather Watch (WWW) is a cooperative program organized and administered by the World Meteorological Organization (WMO).²³ NOAA plays a leadership role in the WWW, representing the United States in scientific research, weather data collection and management, meteorological forecast and warning. The Department of State also plays an important role for achieving and maintaining international agreements to sustain WWW operations globally. The WWW has an established international telecommunications network for receiving and distributing weather data and warnings, including those for the United States and its trust territories. NOAA Satellite Services now manages two WWW data centers for weather data analysis and forecasting.²⁴

Currently, the U.S. Department of Homeland Security and the NWS are developing a National All Hazards Warning Network using NWS's NOAA Weather Radio network as the initial infrastructure for communicating public warnings. In the United States, Congress has expanded NOAA Weather Radio so that this emergency telecommunications infrastructure is able to provide adequate coverage of weather services and support local forecasting and warning of extreme weather. NOAA has improved technology of weather instrumentation to increase lead time of emergency warnings; constructed transmission towers; added repeaters to expand ranges of emergency notification; and distributed individual NOAA Weather Radio receivers to the public, particularly in rural areas, so as many U.S. citizens as possible can receive disaster warnings and emergency communications.²⁵

Conclusion

Decisions about whether and how to proceed with establishing an international tsunami early warning system for the Indian Ocean (and elsewhere) will likely be complicated for a number of reasons. One reason is because of the number of different potential international parties that would be involved with the need to coordinate data collection and warning dissemination, and a second is the funding

²²(...continued)

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.

²³U.S. Department of Commerce, NOAA, Office of the Federal Coordinator for Meteorology, "World Weather Program," *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2004*, Report FCM P1-2003, Appendix B, p. 219 (Washington, DC: Oct. 2003).

²⁴NOAA's Satellite and Information Services, which operates the two U.S. WWW data Centers, reviews weather satellite data, which has since provided valuable information about the Indian Ocean tsunami. See "NOAA Scientists Able to Measure Tsunami Height from Space," at [<http://www.noaanews.noaa.gov/stories2005/s2365.htm>], visited Jan. 11, 2005.

²⁵See NOAA Weather Radio (NWR) at [<http://www.nws.noaa.gov/nwr/>], visited Jan. 10, 2005.

needed to establish a tsunami warning system in that region. A third is that nations, including some in the Indian Ocean, might charge for access to critical satellite data that may help in warning potential victims. Senator Lieberman and others contend that the costs of acquiring those data may be well worth it, in terms of lives saved. Others assert that the costs of accessing and using those proprietary data could be prohibitive. They are of the opinion that nations should provide free access to global environmental data, especially when the United States and other nations are providing disaster relief and plan on funding tsunami detection and warning activities for the region.²⁶

Still others foresee challenges to standardize instrumentation and other related technology. In addition, there are concerns about national security and compromising U.S. intelligence-gathering operations if international telecommunications networks are used. Finally, some U.S. lawmakers question the risks of a tsunami hitting the U.S. Atlantic coast.²⁷ They believe the probability is low, and assert that risk should be an important factor for guiding development of and investment in a cooperative early tsunami warning system for the U.S. eastern seaboard.

²⁶*The Washington Times*, Jan. 7, 2005: A10.

²⁷See “Off W Coast of Northern Sumatra, Can It Happen in the United States?” See USGS Earthquake Hazards Program: FAQ, Jan. 4, 2005 at [<http://earthquake.usgs.gov/eqinthenews/2004/usslav/canit.html>], visited Jan. 5, 2005.