Tsunami: Reduction Of Impacts through three Key Actions (TROIKA)

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Abstract. A review of lessons learned from over 4000 deaths due to 11 destructive tsunamis in the past decade indicate that the three activities of hazard assessment, warning guidance, and mitigation can effectively reduce the impact of tsunamis to coastal communities. These activities will be woven together into a coherent plan of action designed to help the global community threatened by tsunami hazards. An implementation plan will be presented describing the three actions:

1. Hazard Assessment—Generating local and distant tsunami inundation maps for coastal communities using internationally accepted numerical model methodology. Estimates of coastal areas susceptible to tsunami flooding will be available from a network of modelers and data managers who will be sharing community modeling tools via the Internet.
2. Mitigation—Developing response plans for emergency managers, placing tsunami evacuation signs in threatened coastal areas, and maintaining a tsunami educational program for local residents and school systems.
3. Warning Guidance—Developing and deploying a network of early warning tsunami detection buoys in the world's seismically active coastal areas to complement the global network of real-time broadband seismometers and to supplement regional tsunami warning centers.

The plan will include a schedule of implementation, costs, and possible options for funding.

1. The International Decade for Natural Disaster Reduction

The Member States of the United Nations unanimously proclaimed the International Decade for Natural Disaster Reduction (IDNDR) by UN resolution 46/182 on 22 December 1989. The same resolution adopted an IDNDR International Framework of Action for 1990–99 with the objective to reduce the loss of life, property damage, and social economic disruption caused by natural disasters, through concerted international action, especially in developing countries. The Decade was established on the basic understanding that sufficient scientific and technical knowledge already exists, which, with more extensive application, could save thousands of lives and millions of dollars in property losses from natural and similar disasters.

The goals of the IDNDR were declared at the start of the Decade that gave precedence to the scientific and technical rationale of the Decade:

- To improve the capacity of each country to mitigate the effects of natural disasters, in the assessment of disaster damage potential, and in the establishment of early warning systems and disaster resistant capabilities

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- To devise appropriate guidelines and strategies for applying existing scientific and technical knowledge
- To foster scientific and engineering endeavor aimed at addressing critical gaps in knowledge
- To disseminate existing and new technical information
- To develop measures for the assessment, prediction, prevention, and mitigation of natural disasters through programs of technical assistance and technology transfer, education and training, and to evaluate the effectiveness of the program

The IDNDR could not have come at a better time to focus the world's attention on the tsunami hazard. During the decade 82 tsunamis were reported of which 11 caused extensive destruction, including 4,600 deaths and more than $1 billion (U.S.) in damage. The decade was typical of the past century during which tsunamis averaged one destructive and five measurable tsunamis each year (Lockridge, 1983). Two of the twelve biggest killer tsunamis since 1850 occurred during this decade. Tsunami deaths will probably continue to increase because of the worldwide migration of populations to vulnerable coastal areas.

As a contribution to the IDNDR, the International Union of Geodesy and Geophysics' (IUGG) Tsunami Commission and the United Nations Intergovernmental Oceanographic Commission (IOC) formed a partnership in 1989 "to develop an internationally accepted methodology to produce tsunami inundation maps." Professor Nobuo Shuto (Tohoku University) of the Tsunami Commission, with support from Japan and the IOC, established the Tsunami Inundation Modeling Exchange (TIME) Program to transfer tsunami inundation mapping technology to other countries through a comprehensive training program (Bernard, Natural Disaster Management, 1999). As of 2001, Professor Shuto, with the help of F. Imamura and M. Ortiz, were responsible for the production of 73 tsunami inundation maps in nine countries (Chile, Columbia, Costa Rica, Ecuador, Japan, Mexico, Peru, Puerto Rico, United States). The United States has also created a TIME center in Seattle, Washington to assist in the production of inundation maps.

In 1995 at the IOC meeting in Papeete, Tahiti, the author presented an initiative entitled "Tsunami Hazard Reduction for Pacific Nations" that included three elements: inundation mapping; real-time, deep-ocean tsunami detection systems; and tsunami mitigation practices. By 2000, the real-time detection systems had been developed and were installed at four locations in the Pacific near Alaska, inundation maps were being produced in many nations, and mitigation practices were being adopted to make communities more resistant to tsunami dangers. A global version of the Tahiti initiative, entitled "Tsunami: Reduction Of Impacts through three Key Actions" (TROIKA) was presented at the IOC executive session on 20 June 2000. As a result of this presentation, a resolution was passed to continue the development of an international program. This article represents a plan to develop an international program.

2. Serendipity of Events

A number of events and developments occurred serendipitously during the decade to mark a major turning point in tsunami research and mitigation (Bernard and Hebenstreit, 2000). Each tsunami brought attention to the hazard and, as is typical of natural hazards, focus on activity was highest following the deaths and destruction. For example, the 1993 Okushiri tsunami prompted Japan to upgrade its warning system to provide warnings within 5 min and to begin forecasting of tsunami wave heights using precomputed numerical simulations (Takehata, 1998). Following the 1992 California earthquake/tsunami, the United States produced the first earthquake scenario study that included inundation from a local tsunami. By 1997 the U.S. had initiated a National Tsunami Hazard Mitigation Program which provided funding for the production of inundation maps, development and implementation of education and preparedness programs, and improvement of warning guidance through the installation of new seismic stations and the deployment of an array of real-time, deep-ocean tsunami detectors (Bernard, 1998). Central and South American countries started producing inundation maps following tsunamis in Nicaragua, Mexico, and Peru. With the aid of Internet communications, the international research community formed survey teams for eight of these tsunamis collecting more data on these events than had been collected in the previous history of tsunami research. New technologies applied to the tsunami problem during this decade included: development of a real-time, deep-ocean tsunami detection system that uses pressure transducers, acoustic modems, and satellite communications; the development of a new generation of numerical models for estimating tsunami inundation; the use of more powerful personal computers to run the numerical models in any country; the use of the internet to share results from numerical experiments and field surveys; the global positioning system that increased the accuracy of tsunami inundation surveys and the bathymetric and topographic imaging for use in numerical models; multibeam bathymetric survey tools to increase the resolution of underwater surveys revealing scars from past slumps; underwater vehicles that can examine evidence for underwater landslides or slumps; and the use of dating technology in paleotsunami research to estimate recurrence intervals. Most important to these successes was the unselfish and generous sharing of data and ideas among tsunami scientists who judged that the needs of humanity exceeded their concerns for individual credit. The horrific destruction of Papua New Guinea and ten other destructive tsunamis prompted television networks to produce more than five documentaries on tsunamis for the National Geographic Society, the Discovery Channel, the Learning Channel, and numerous news broadcasts exposing millions of viewers worldwide to the nature of tsunamis, how they are studied, and what technologies might mitigate their impacts.

Figure 1: A view of tsunami damage from the south of Aonae, a small town on Okushiri, an island in the Sea of Japan (courtesy of Y. Tsuji).

3. Tsunami Resistant Communities

The best tsunami mitigation strategy is to keep people and critical facilities out of the area of flooding. Three effective steps to create tsunami-resistant communities are to (1) produce tsunami hazard maps to identify areas susceptible to tsunami flooding, (2) implement and maintain an awareness/educational program on tsunami dangers, and (3) develop early warning systems to alert coastal residents that danger is imminent. For example, before the 1993 Sea of Japan tsunami, residents of the fishing village of Aonae had taken these steps. About 1400 people were at risk of dying from the 1-hour tsunami attack on 12 July 1993, that flooded the village within 15 min of the earthquake (Fig. 1). Upon feeling the earthquake shaking, most villagers immediately evacuated to higher ground. This action saved the lives of 85% of the at-risk population (Preuss, 1995). In contrast, most of the 2,730 residents of Warapu Village, Papua New Guinea, were not aware of the link between earthquakes and tsunamis. Some villagers went to the coastline after the earthquake shaking to investigate the loud noise from the sea. As a result of this inappropriate behavior, fewer than half of the at-risk population survived the tsunami that arrived about 20 min after the earthquake stopped shaking the village (Dengler and Preuss, 1999; Kawata *et al.,*

Table 1: Coastal communities with tsunami inundation maps.

Country	Cities	Country	Cities
Chile	Port of Iquique	USA	Eureka, California
	Arica Region		Crescent City, California
	Antofagasta		Seaside, Oregon
Ecuador	Head of the Gulf of Guayaquil		Newport, Oregon
Costa Rica	Puntarenas		Willipa Bay, Washington
	Quepos		Grays Harbor, Washington
Colombia	Tumaco Area		Kodiak, Alaska
Peru	Pimentel region		Hawaiian Island coastlines
	Chimbote	Japan	Hokkaido-37 Ports
	Salaverry		Akita Prefecture
	Puerto Supe		Yamagato Prefecture
	Zorritos		Miyagi Prefecture
	El Callao		Shizuoka Prefecture
Mexico	Zihuatanejo Bay, Michoacan		Wakayama Prefecture
	Lazaro Cardenas Harbor, Michoacan		Toyko
	Acapulco Bay, Guerrero		Izu Islands
	Manzanillo, Colima	Puerto Rico	West Coast
	Navidad Bay, Jalisco		
	Tenacatita Bay, Jalisco		

1999). These two examples illustrate that knowledge of tsunami dangers saves lives.

4. Three Key Actions

4.1 Hazard assessment

The first step in mitigation is to identify areas that are susceptible to flooding before the tsunami occurs. The ideal way to identify those areas is to use historical information as a guide but, in most areas, the historical record is short and data on tsunamis are rare. During this decade, teams of international scientists to collect data on tsunami flooding processes carefully surveyed six disastrous tsunamis. Using these data, scientists have developed numerical models to simulate the behavior of tsunamis to estimate the areas that could be flooded. The tsunami community has developed an internationally accepted methodology to produce inundation maps using numerical models. A listing of coastal communities with hazard maps is presented in Table 1. The tsunami inundation map of Newport, Oregon (Fig. 2) is a product of this technology. Professors Shuto and Imamura have written technical manuals to aid in the technology transfer so that 14 institutions in 11 countries now have the ability to produce tsunami inundation maps.

The global Internet offers a wonderful opportunity to form collaborative research teams of scientists, widely separated geographically but closely linked by computer networks. A distributed, virtual research and development environment could be designed to provide global, transparent sharing of model results and associated databases (e.g., bathymetry and topography, field observations, physical model data, model runs for test cases, etc.) that

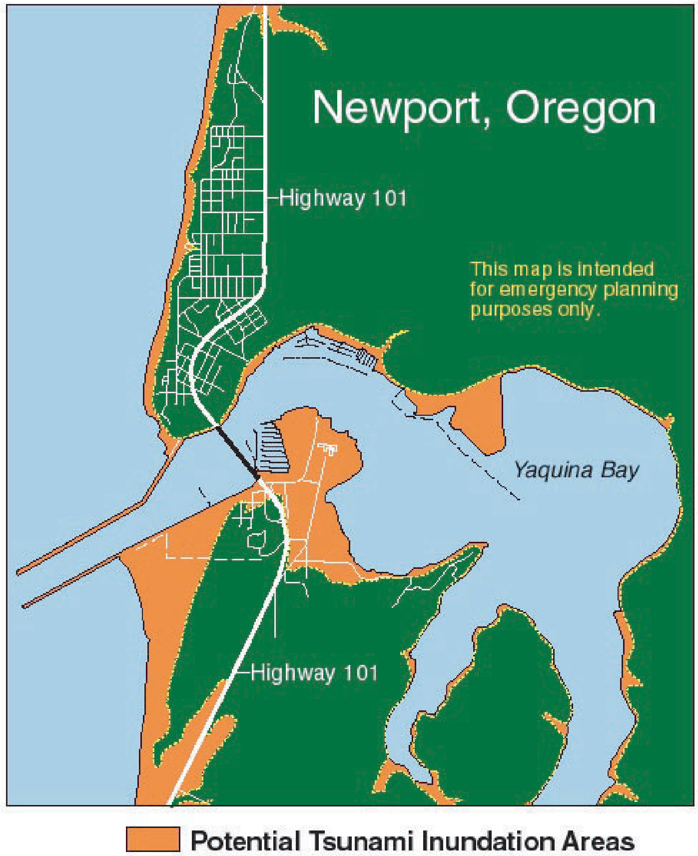

Figure 2: Tsunami inundation map for Newport, Oregon, U.S.A.

are resident on computers at participating institutions. The development of such "virtual facilities" shared by multiple researchers opens the possibility of even more rapid integration of field data into tsunami research and development. It would be feasible, for example, to feed on-site survey results or real-time, deep-ocean tsunami data directly into research studies, even allowing for modifications of studies already in progress to accommodate new information. A pilot project is currently underway to support the U.S. National Tsunami Hazard Mitigation Program through a network that includes nodes at NOAA's Center for Tsunami Inundation Mapping Efforts (TIME) and at universities developing tsunami inundation maps for each of the five Pacific states (González *et al.*, 2001).

This network represents the first step in establishing a Tsunami Community Modeling Activity (TCMA)—a more general enterprise that will include on-line access to models. The overall goal of the TCMA effort is to accelerate improvements in model physics and hazard mitigation products, and facilitate the delivery of these products to end users in the emergency management community. For example, the development of high speed, high bandwidth connections make it possible for local warning personnel to di-

Figure 3: Tsunami hazard road sign.

rectly tap tsunami information throughout the world. Such connectivity will also make it possible for local authorities to participate in numerical, and even laboratory, simulations specifically tailored to their situation, allowing them a direct, visceral look at the nature of the threat and its impact in a familiar frame of reference. The extensive use of simulation-based "scenarios" for pre-event planning, response training exercises, and readiness assessments will be available to disaster management personnel. Ultimately, it should be feasible to use emerging research results as public education tools, allowing threatened populations to understand the tsunami hazard in ways that pamphlets, posters, and public service announcements cannot currently address.

4.2 Mitigation

Once the areas of tsunami flooding hazard have been identified, a community-wide effort of tsunami hazard awareness is essential to educate the residents as to appropriate actions to take in the event of a tsunami. Awareness education must include the creation of tsunami evacuation procedures to remove residents from the tsunami hazard zones, the implementation of an education program for schools to prepare students at all age levels, the coordination of periodic practice drills to maintain the preparedness level, the development of a search and rescue plan, and the involvement of community organizations to educate all sectors of the population at risk. The IOC has developed products to assist countries in implementing tsunami awareness programs. Written educational materials in numerous languages, educational curriculums, videos, and reports from communities with comprehensive awareness programs are available through the International Tsunami Information

Center (http://www.shoa.cl/oceano/itic/frontpage.html). The U.S. has recently developed road signs (Fig. 3) for identifying tsunami hazard zones and evacuation routes. Road signs and other mitigation products are available through the U.S. National Tsunami Hazard Mitigation Program (http://www.pmel.noaa.gov/tsunami-hazard/) (Bernard, 1999). In summary, tsunami awareness activities are probably the most cost-effective way to create a tsunami-resistant community. However, communities must be committed to a continuous, long-term education program as tsunamis are infrequent events and succeeding generations may forget tsunami safety lessons.

4.3 Warning guidance

Once a community has identified tsunami flooding areas and has implemented mitigation activities of designing evacuation routes and shelters and educating the public about the nature of tsunami dynamics, then warning systems need to be developed to alert the community to action. For local tsunamis, strong earthquake shaking will probably be the only early warning. However, tsunamis can be produced at intermediate and far distances from the community at risk. For the intermediate distance tsunami, the earthquake shaking may be very mild, yet a large tsunami can appear within 1 hour. For the distant tsunami, no earthquake will be felt, yet a large tsunami can appear several hours after the earthquake occurs. History has shown that countries that have warning systems have reduced the loss of tsunami casualties.

Following the destructive 1960 Chilean tsunami, the IOC established the International Tsunami Information Center to organize formal communications of tsunami warnings to all Pacific nations. To implement the warning system, a coordinating group was formed to ensure all nations received adequate, reliable warnings. This group accepted the offer of the United States to operate a tsunami warning system for the Pacific that would establish and maintain a network of seismometers and sea level sensors in Pacific nations feeding into the Pacific Tsunami Warning Center in Hawaii. The Center monitors seismic sensors continuously, and when large earthquakes are detected, the Center can issue warnings within 60 min of tsunami arrival times to threatened countries through an extensive communication system. The Center monitors sea level sensors to determine if a tsunami existed and its magnitude, and if warranted, warn other countries or cancel the warning based on updated data. Monitoring earthquakes gives a good estimate of the potential for tsunami generation, based on earthquake size and location, but gives no direct information about the tsunami itself. Tide gauges in harbors provide direct measurements of the tsunami, but local bathymetry and harbor shapes significantly alter the tsunami, which severely limits their use in forecasting tsunami impact at other locations. A 60-min response time is too slow for areas close to tsunami source areas, so regional and local warning systems were established in Chile, Japan, Russia, French Polynesia, and the United States. Regional and local systems cover earthquakes in a smaller geographical region and can evaluate the earthquake faster and issue

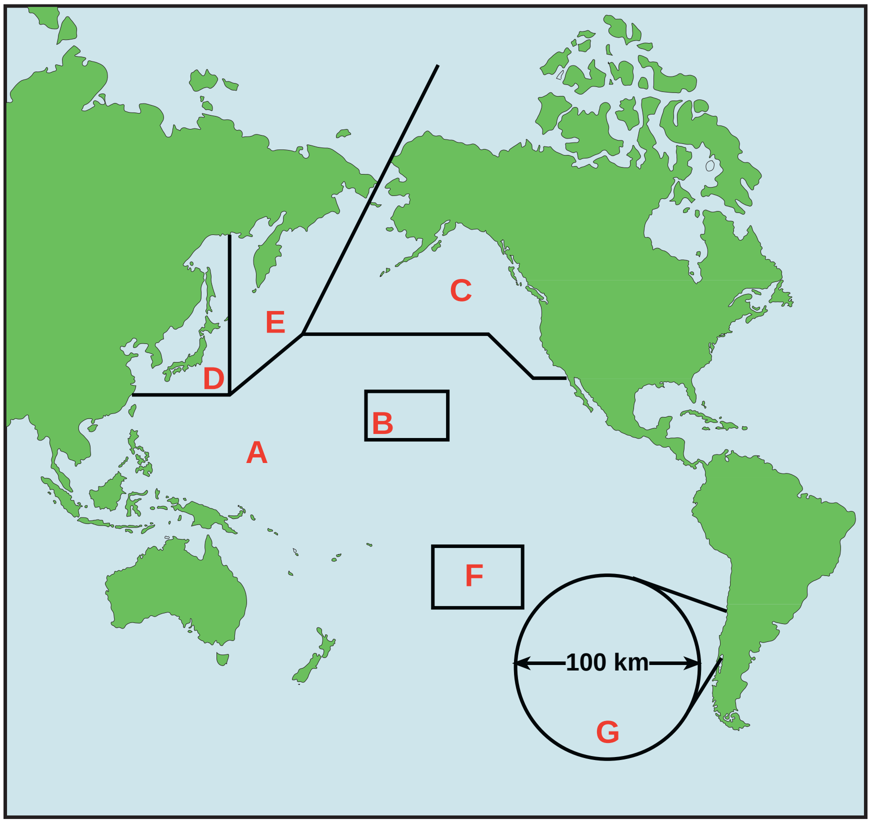

Figure 4: The Pacific-wide tsunami warning system (A) warns populations in about 60 minutes, while regional systems (B–F) warn in about 20 minutes, and local systems (G) warn in about 5 minutes.

warnings more quickly (Fig. 4). A limitation of these systems is a high false alarm rate because not all coastal earthquakes generate tsunamis and some warned tsunamis are so small that they are perceived as false alarms.

Recently developed real-time, deep-ocean tsunami detectors can provide the data necessary to make tsunami forecasts. An example of this method can be seen in Fig. 5 that shows data from the tsunami of 4 October 1994 generated in the Kuril Islands, north of Japan. As the tsunami traveled to the U.S. West Coast, it was measured by two deep-ocean tsunami detectors and by two tide gauges on the Oregon coast. One can assume that the offshore signals at Port Orford and Newport were the same, but the two harbors responded differently. A comparison of the amplitudes of the first positive wave cycle shows that the deep-water tsunami was amplified from 1.7 cm to 3.9 cm at the Newport stations, whereas at Port Orford the amplification was almost twice that, from 1.7 cm to 7.3 cm. This difference in amplification can be attributed to the fact that the Port Orford gauge site is exposed to the open ocean, in contrast to the protected location of the Newport gauge (Fig. 5 insets). Subsequent oscillations are a complex function of the continuing tsunami input, modified by the local bathymetry and harbor shape. The differences in later oscillations are seen to be even more

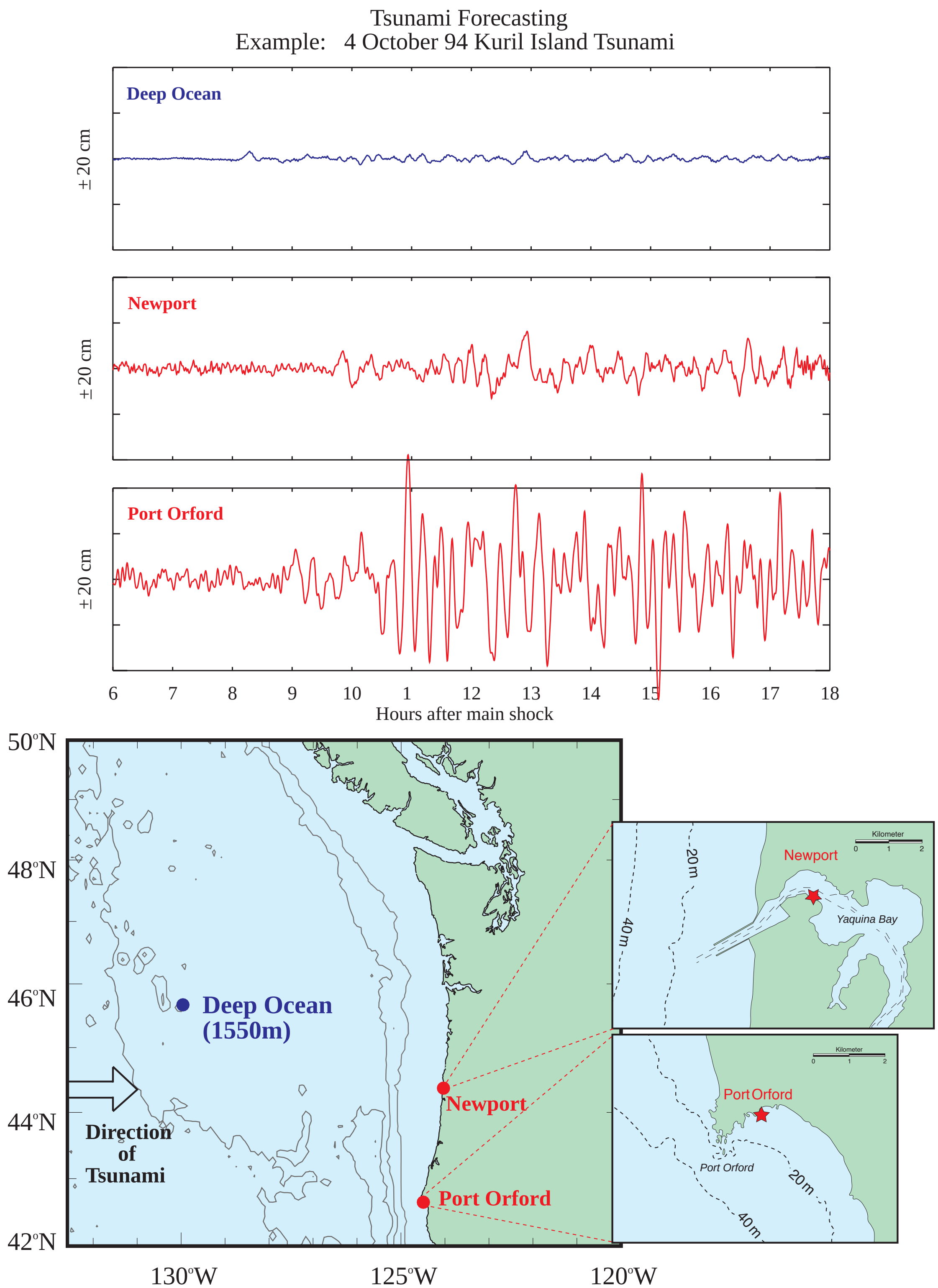

Figure 5: Time series of 4 October 1994 tsunami as recorded by a deep ocean recorder and two coastal tide gauge stations. Lower panel illustrates geographical location of the deep ocean and harbor sites.

dramatic; the maximum amplitude at Newport is only 8.3 cm, while that at Port Orford is 27.9 cm, more than three times as large. Also note that these oscillations persist for more than 8 hours, possibly due to the excitation of edge waves along the continental shelf. These data provide a dramatic illustration of the duration of tsunamis, and of the highly variable response of adjacent coastal stations to the same tsunami. Taken alone, there is little forecast value in such coastal station data. Real-time deep-ocean data, however, allows the development of site-specific, local response relationships which can be used to forecast real-time tsunami impacts (Bernard, 1998).

NOAA's Deep Ocean Assessment and Reporting of Tsunamis (DART) Project is an effort of the U.S. National Tsunami Hazard Mitigation Program to develop an early tsunami detection and real-time reporting capability—a formidable technological and logistical challenge. DART systems utilize bottom pressure recorders (BPRs) that are capable of detecting and measuring tsunamis with amplitude as small as 1 cm in 6000 m of water. The data are transmitted by acoustic modem to a surface buoy, which then relays the information to a ground station via satellite telecommunications (Fig. 6). Every hour, four 15-min average sea level values and a system engineering status indicator are relayed to NOAA's Pacific Marine Environmental Laboratory and the two NOAA tsunami warning centers via the Geostationary Operational Environmental Satellite (GOES), providing open ocean tide data and a check on system performance. These data are displayed, in real time, on a web site at http://tsunami.pmel.noaa.gov/dartqc/WaveWatcher. If a tsunami is detected, waveform data are transmitted immediately (<3-min delay) via the GOES "random-mode" channels. On 10 January 2001, a magnitude 6.9 earthquake occurred at 0703 local time about 70 miles SW of Kodiak, Alaska. The warning center located the position of the earthquake, assessed its magnitude, and issued an information bulletin at 0708. At 0711 a DART system at 51°N and 157°W picked up the earthquake waves that induced an apparent sea level change of approximately 6 cm and triggered the buoy to start transmitting 1-min data. By 0713 these data were plotted on the web site showing no tsunami present. The U.S. plans to maintain an array of six DART stations in the north Pacific and equatorial regions. The network is designed to provide early detection and measurement of tsunamis generated in source regions that threaten U.S. coastal communities: the Alaska-Aleutian Subduction Zone, the Cascadia Subduction Zone, and the South American Seismic Zone.

An added benefit of the real-time deep-ocean data stream is continued offshore tsunami monitoring. Because tsunamis are a series of waves, dangerous conditions can persist for several hours after the first wave strikes a community. Large tsunamis can have periods as long as 1 hour and the largest wave may arrive as late as the third or fourth wave in the series. Real-time offshore tsunami monitoring provides important guidance for decision makers, who must judge the risk of deploying rescue and recovery personnel and equipment and, when the area is safe for the return of residents, sound the "all clear."

Because DART data are available through the Internet, a global data distribution system exists. Any facility with Internet access can receive tsunami

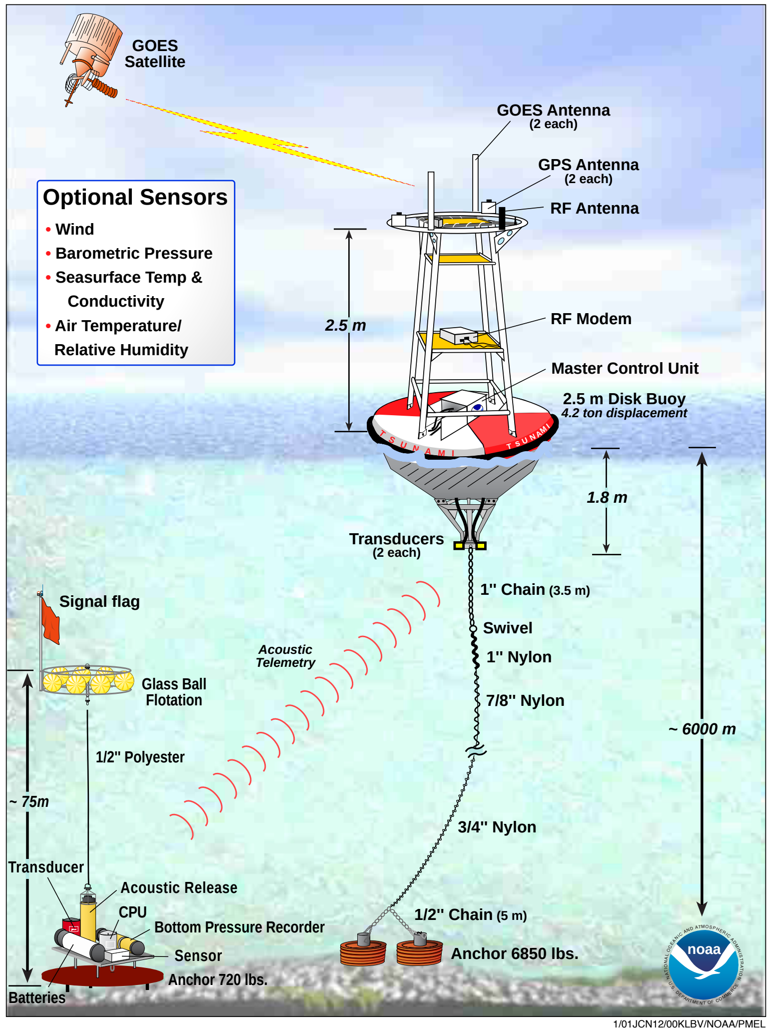

Figure 6: DART mooring system.

data at the same time as the U.S. tsunami warning centers. The Internet data distribution feature along with the portability of any DART system makes DART a viable candidate for global expansion into any tsunami-threatened area.

5. TROIKA.org

Our goal is to reduce the loss of lives from tsunamis by 90% by the year 2020 through the implementation of an integrated program of hazard assessment, warning guidance, and mitigation applied to any community at risk from tsunami hazards.

Our vision is a global community of scientists, disaster managers, policy makers, and local community participants linked by a common goal and internet technology to create tsunami resistant communities that have access to accurate and timely tsunami warnings. The three elements that have been discussed in this article are interdependent, so each element must be supported and coordinated. The three elements provide an appropriate name for this concept: Tsunami: Reduction Of Impacts through three Key Actions (TROIKA). Like a three-horse drawn sled, if any horse is missing, the sled will not move.

Implementation of the program presented here will cost about $7M (US) each year. We estimate that the costs will be partitioned as follows:

5.1 Tsunami Community Modeling Activity (TCMA)—$2.5M/ year

We envision a network of about 20 scientists worldwide who would share model technology, databases, and results. The overall goal of the TCMA effort is to accelerate improvements in model physics and hazard mitigation products, and facilitate the delivery of these products to end users in the emergency management community. The global effort would be coordinated by a Tsunami Information Modeling Effort (TIME) Center that could rotate among participating countries. Initially, ten countries that could participate include Chile, Columbia, Costa Rica, Ecuador, Japan, Mexico, Peru, Puerto Rico, Turkey, and the United States of America.

5.2 Mitigation—$1.0M/year

Awareness education must include the creation of tsunami evacuation procedures to remove residents from the tsunami hazard zones, the implementation of an education program for schools to prepare students at all age levels, the coordination of periodic practice drills to maintain the preparedness level, the development of a search and rescue plan, and the involvement of community organizations to educate all sectors of the population at risk. These funds would be used to purchase written educational materials in numerous languages, educational curriculums, videos, and road signs for identifying tsunami hazard zones and evacuation routes. The IOC's International Tsunami Information Center could develop, coordinate, and distribute these and other tsunami mitigation products.

5.3 Warning guidance—$2.5M/year

We envision a tsunami warning system for the globe that is comprised of a network of seismic and tsunami monitoring instruments linked by internet technology to a network of regional/national tsunami warning centers that can process data and issue timely and effective tsunami warnings for their respective regions. The regional/national warning centers would be part of ongoing national monitoring activities to ensure around the clock warning coverage. When major earthquakes occur and produce destructive tsunamis, the regional/national tsunami warning center may be disabled. In this event, adjacent regional/national tsunami warning systems can become backups for each other. The existing ITSU program for the Pacific is an ideal model for the global system. IOC should take the lead in expanding the model to a

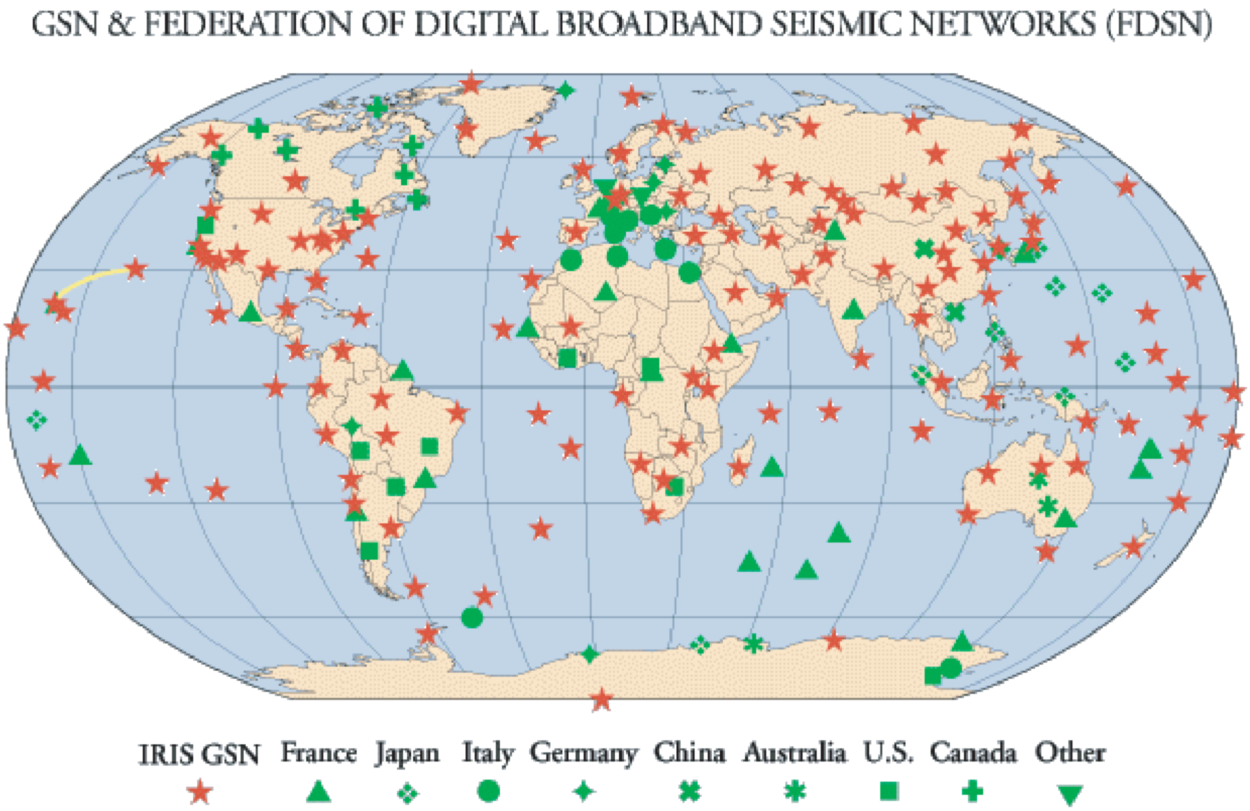

Figure 7: Location of Incorporated Research Institutions for Seismology (IRIS) and Federation of Digital Broadband Seismic Networks (FDSN) seismometers.

global scale. To implement this concept, seismic and tsunami monitoring must be in place.

5.3.1 *Earthquake monitoring—No cost*

Global programs exist that provide real-time seismic data that can be used to locate and determine the magnitude of earthquakes. With appropriate processing and networking, these data could be used to determine the tsunami potential of any earthquake occurring in the world. For example, the Incorporated Research Institutions for Seismology (IRIS) is a consortium of United States Universities that have research programs in seismology. The purpose of IRIS is to develop and operate the infrastructure needed for the acquisition and distribution of high-quality seismic data. The IRIS Global Seismographic Network (GSN) is one of the four major components of the IRIS Consortium. The goal of the GSN is to deploy 128 permanent seismic recording stations (see Fig. 7) uniformly over the earth's surface (http://www.iris.washington.edu/GSN/index.htm).

Figure 8: Preliminary siting of worldwide tsunami detectors. Yellow bands are seismically active areas that have generated tsunamis in the past.

5.3.2 *Tsunami monitoring—\$2.5M/year*

We recommend the installation and maintenance of 50 real-time, deep-ocean tsunami detectors located near tsunami source areas as illustrated in Fig. 8. Data from these instruments and appropriate coastal stations could provide tsunami warnings for destructive tsunamis and valuable research data from all tsunamis detected. These data would be fed into the community modeling efforts for direct and efficient use in model experiments. A network of oceanographic institutions could perform the construction and maintenance of these buoys. For example, the Partnership for Observation of the Global Oceans (POGO) is an international network of major oceanographic institutions that has been established to promote the integration and implementation of global oceanographic activities. The network (http://www.oceanpartners.org/) links institutions that are capable of conducting global and basin-scale investigations and measurements. One partner of this network could serve as the leader of coordinating ship time to deploy and recover the tsunami buoys. For coastal stations, each country could contribute data as part of their ongoing sea level monitoring programs.

5.4 Research and development—\$1.0M/year

In order to infuse new technology and research into TROIKA.org, a viable research and development activity must be in place. Examples of the types of projects that are needed include: an inexpensive local tsunami warning system; development of building codes for tsunami inundation areas; tsunami damage surveys including bathymetric and erosion surveys. One way to implement such an activity is to collocate it with the TIME center to minimize administrative costs and to increase exposure to the modeling activity.

5.5 Funding

We envision an organizational structure to support TROIKA.org that includes the traditional partners like the IOC, POGO, IRIS, and the affected nations and new partners from philanthropic, private, non-government, and volunteer organizations. TROIKA.org would include any partner wishing to reduce the loss of life and suffering from tsunamis. Several options exist to create such a framework. It could be led by one country or a combination of countries, by any partner organization, or by a board of directors of all partners. The essential ingredient is that all partners be committed to the goal of reducing lives lost to tsunamis. With this objective as the guiding principle, any organizational structure will work.

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