5.1 PROGRESS ON IMPROVED OPERATIONAL FORECASTING AND INUNDATION MAPPING OF PACIFIC TSUNAMIS FOR COASTAL COMMUNITIES

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1. INTRODUCTION

The U.S. National Tsunami Hazard Mitigation Program (NTHMP) is a partnership of the five Pacific States of Alaska, California, Hawaii, Oregon and Washington with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS) and the Federal Emergency Management Agency (FEMA). Led by NOAA, which has primary national responsibility for tsunami warning and mitigation, the overall goal of this program to reduce the loss of life and property. The program focuses on three activities: Hazard Assessment, in which the risk associated with a future tsunami is evaluated for individual coastal communities; Warning Guidance, in which advisories and warnings are issued during an actual tsunami event; and Mitigation, in which the emergency preparedness of a community is developed through training, education, and outreach efforts. The NOAA Center for Tsunami Inundation Mapping Efforts (TIME) was established at the Pacific Marine Environmental Laboratory (PMEL) to support these NTHMP activities, with an emphasis on Hazard Assessment and Warning Guidance. This article briefly describes TIME Center efforts to develop and implement improved inundation maps and forecast guidance to increase the speed and reliability of operational tsunami warnings.

2. FORECAST GUIDANCE FOR TSUNAMI WARNINGS

The Pacific Tsunami Warning Center (PTWC) at Ewa Beach, Hawaii, and the West Coast and Alaska Tsunami Warning Center (WCATWC) at Palmer, Alaska are part of NOAA's National Weather Service with responsibility for issuing advisories and warnings in the event of a tsunami. The TIME Center is working with these Warning Centers and with State emergency management and geotechnical agencies to develop improved forecast guidance tools for the case of a distant source, or "far-field" tsunami. (The "near-field" or "local" tsunami warning problem is much more difficult, because details of the source characteristics become very important and because warning time can be very small – by definition, a local tsunami can strike a community within minutes of generation.) The goal is to increase the speed and reliability of tsunami warnings, and reduce the number of false alarms. The general strategy is one adopted by many other operational forecasting activities -- assimilate real-time data streams into numerical models, using inversion schemes to produce model scenarios that best match the data, and then use the models to forecast conditions at sites of interest.

Real-time deep ocean tsunami measurements are highly desirable for this purpose. Coastal tide gauges are also valuable, but problematic. Since tide gauges are typically situated in protected ports and harbors, they (1) do not provide advance measurement of the tsunami on a propagation path from the generation zone to those or any other coastal communities, and they (2) do not provide a clean tsunami signal -- harbor resonances and other local effects introduce complications that make the record difficult to interpret. For this reason, the NTHMP developed the Deep-ocean Assessment and Reporting of Tsunamis (DART) system (Milburn, et al., 1996).

Each DART system consists of a seafloor bottom pressure recorder (BPR) capable of detecting tsunamis as small as 1 cm, and a moored surface buoy (Figure 1) for real-time communications. An acoustic link is used to

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transmit data from the BPR on the seafloor to the surface buoy. The data are then relayed via GOES Satellite link to ground stations. The DART network (Figure 2) currently consists of six stations -- five in the North Pacific just offshore of seismically active regions known to generate tsunamis, and one (not shown) south of the equator, positioned to measure tsunamis propagating into the North Pacific from South American generation zones. Additional stations are planned.

Numerical models are available to simulate the generation, propagation and inundation phases of tsunami dynamics. The TIME Center approach to application of such models to the forecast problem is known as Short-term Inundation Forecasting for Tsunamis (SIFT). The methodology is based on a pre-computed database of unit-source tsunamis that are first automatically scaled and combined using earthquake information and then refined via assimilation of real-time DART network tsunami observations (Titov et al., 2001a, Titov et al., 2001b, Titov et al., 2003a). Whitmore (2003) at the PTWC and Wei et al. (2003) at the University of Hawaii describe similar applications of such models to the far-field tsunami forecasting problem. Current plans are to provide an easy-to-interpret user interface for use at the Warning Centers that includes all three methodologies (González et al., 2003). Real-time estimates of tides and meteorologically induced water level variations will be essential to accurate forecasts. Initially, forecast guidance will be implemented for shoreline values of tsunami height and current speed. Later versions will include site-specific forecasts of inundation depth and current speed, using the inundation modeling capabilities discussed in the next section.

3. INUNDATION MAPPING FOR HAZARD ASSESSMENT

The TIME Center is developing tsunami inundation maps for Washington State communities, to be used in emergency management planning, hazard mitigation and evacuation, and is working with State modeling and mapping teams in Alaska, California, Hawaii and Oregon to develop similar maps. Comparisons with recent, historical, and paleo-tsunami data are used to certify the accuracy of the numerical models.

Figure 3 presents the results of numerically simulating a rare, worst-case scenario of tsunami generation by a magnitude 7.3 earthquake on the Seattle Fault (Titov, et al., 2003b). The figure presents two fundamental modeling products of primary importance to emergency managers – maximum inundation depth (the height of water above land) and maximum current speed, respectively. These products are obtained by monitoring each variable at individual grid points and saving the maximum value attained over the course of the entire simulation. Zonation is then performed to produce the maps shown – i.e., the fine scale details are deliberately suppressed by binning values into zones with ranges that have physical significance to emergency managers. Thus, for an average adult, the depth range zones correspond roughly to "up to knee-high" (Low), "up to head-high" (Medium) and "over the head" (High), and current speed zones are roughly "up to the speed of a brisk walk" (Low) and "faster than a brisk walk" (High). For the Seattle waterfront areas, computed water depths are greater than 2 m and current speeds are in excess of 2 m/s.

4. SUMMARY

The NOAA TIME Center, in collaboration with scientists at the Tsunami Warning Centers and the University of Hawaii, is developing far-field tsunami forecast guidance capabilities to improve the speed and reliability of tsunami warnings (Figures 1 and 2). Initially, this system will provide only shoreline forecasts of tsunami wave height and current speeds. The TIME Center also develops inundation maps for Washington State (Figure 3) and assists similar mapping efforts in other States. The purpose of inundation mapping is to assist States in site-specific hazard assessment and in the development of emergency management products for mitigation and response -- evacuation maps, educational brochures, community workshops and other outreach efforts, for example. But the inundation map can also be viewed as a "long-term forecast" that complements "short-term forecast" capabilities. Future plans include adaptation of inundation modeling technology to the operational forecasting problem, with the ultimate goal of providing Tsunami Warniing Centers with real-time, site-specific inundation forecast guidance for far-field coastal communities during an actual event.

5. REFERENCES

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