Using Web-based and Social Networking Technologies to Disseminate Coastal Hazard Mitigation Information within the Pacific Northwest Component of the Integrated Ocean Observing System (IOOS)

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Abstract*—At 9:46:23 pm Pacific Time on March 10, 2011 (05:46:23 UTC on March 11), a magnitude 9.0 earthquake occurred 129 km (80 miles) off the coast of Sendai, a city in Honshu, Japan. The Tōhoku earthquake triggered a catastrophic tsunami that produced an inundation wave height as high as 30 m that propagated throughout the entire Pacific Ocean basin. Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys positioned around the Pacific Ocean provided real-time data of the impending tsunami as it travelled across the ocean towards the U.S. West Coast. Because of this warning, coastal communities in Washington and Oregon were on guard by the time the tsunami hit the West Coast almost 9 hours after the earthquake occurred. Harbors along the Oregon coast, including Depoe Bay, Coos Bay, and Brookings, and in Crescent City, California reported damage to docks and boats in the harbor. In the Pacific Northwest, the Northwest Association of Networked Ocean Observing Systems (NANOOS), the regional association that manages and operates the Regional Coastal Ocean Observing System (RCOOS) for this area of the country as part of the U.S. Integrated Ocean Observing System (IOOS®) enterprise, provided extensive information to the public about the timing, severity, and government agency recommended actions to take as a result of this event. These included Tsunami Evacuation Zones for the Oregon Coast, providing users of the NANOOS Visualization System with easy access to near real-time current, water height, and other information for a wide variety of U.S. IOOS assets, and posting NANOOS Facebook updates regarding the tsunami passage. We discuss the implications of the use of standard (web-based) means of disseminating coastal hazard mitigation information and discuss possible opportunities that social networking technologies present for providing such information as our society increasingly depends on mobile-technologies and applications.

Keywords- Integrated Ocean Observing System; NANOOS; Coastal Hazards; Tsunami;Web presence; Social Networks

I. Introduction

At 05:46 UTC on March 11, 2011 (9:46 pm U.S. Pacific Standard Time (PST) on March 10), a moment magnitude (M_W) 9.0 earthquake occurred 129 km (80 miles) offshore from the coast of Sendai, northeast Honshu, Japan. This earthquake triggered a catastrophic tsunami that within minutes inundated the northeast coast of Japan, sweeping far inland. Measurements derived from a tide gauge on the impacted shore (Ayukawa, Ishinomaki, Miyagi Prefecture) recorded a tsunami amplitude of 7.6 m, before the gauge was destroyed by the initial tsunami wave [1], while post-tsunami surveys indicate that the tsunami water levels within the inundation zone reached as high as 30 m [2]. The tsunami also propagated eastward across the Pacific Ocean, impacting coastal communities in Hawaii and along the west coast of the continental United States — Washington, Oregon and California. Deep-ocean Assessment and Reporting of Tsunami (DART) buoys positioned around the Pacific Ocean provided real-time data of the impending tsunami as it traveled across the ocean towards the U.S. West Coast. For example, DART station 21418 located 468 n mi northeast of Tokyo, Japan recorded a peak tsunami wave amplitude of 1.8 m (06:19 UTC), the largest wave ever recorded by the DART sensor array.

Twelve minutes after the earthquake occurred, the U.S. West Coast/Alaska [1] (WCATWC) and Pacific [2] tsunami warning centers issued a tsunami "information statement" to countries located around the Pacific Rim. Initial estimates of the quake's magnitude placed the event at M_W 7.9. As a result of this earthquake magnitude and NOAA's tsunami

[1] http://wcatwc.arh.noaa.gov/

[2] http://ptwc.weather.gov/

forecast propagation database, which consists of a collection of precomputed propagation models for earthquake sources around the Pacific Rim, an "information" statement was initially broadcast to coastal communities. As new information was derived about the seismicity of the earthquake along with measurements of the tsunami wave by the DART array, inversion modeling of the earthquake source and resultant tsunami (i.e., comparisons of the measured/modeled DART data) resulted in the earthquake being raised to M_W 8.9. At 08:26 UTC on March 11 (12:26 am PST) a "tsunami watch" was issued for the U.S. West Coast. However, by 08:51 UTC (12:51 am PST) the watch was upgraded to a "tsunami warning" for the coastal areas of California and Oregon (Point Concepcion, CA, to the Columbia River), while a "tsunami advisory" was issued for Washington, Alaska, British Columbia, and from Point Concepcion south to the California/Mexico border. Because of this warning, coastal communities in Washington and Oregon were on guard by the time the tsunami arrived along the U.S. West Coast. The tsunami arrived first at Port Orford, Oregon (15:23 UTC), 9.6 hours after the earthquake first occurred. Shortly after the arrival at Port Orford, the waves reached La Push, Washington (+5 minutes later), Charleston, Oregon (+11 minutes), and shortly thereafter were recorded by the Crescent City, California (+13 minutes) tide-gauge; additional times include Toke Point, Washington (+37 minutes) and Yaquina Bay, Oregon (+22 minutes) [3].

Damage in Oregon, Washington, and northern California from the tsunami was almost entirely confined to the harbors, including Depoe Bay, Coos Bay, and Brookings in Oregon, and in Crescent City, California, having been moderated by the arrival of the tsunami's highest waves during a relatively low tide [3]. At Crescent City, an open-coast breakwater, the to-and-fro surge of the water associated with the tsunami waves overturned and sank 15 vessels, damaged 47, while several boats were swept offshore. Flood damage also occurred during the early hours of March 12 at an RV park near the mouth of Elk Creek when a 1.05-m tsunami wave arrived, coinciding with high tide. The total damage to the harbor and from this flooding has been placed at $12.5 million. At Brookings on the southern Oregon coast, 12 fishing vessels put to sea at about 6 am, prior to the arrival of the tsunami waves. However, the *Hilda*, a 220-ton fishing boat and the largest in the harbor, broke loose under the forces of the wave-induced currents, washed around the harbor, and smashed into and sank several other boats. Much of the commercial part of the harbor was destroyed and about one-third of the sports basin; the total damage has been estimated at about $10 million.

In the Pacific Northwest, the Northwest Association of Networked Ocean Observing Systems (NANOOS), the regional association that manages and operates the Regional Coastal Ocean Observing System (RCOOS) for this area of the country as part of the U.S. Integrated Ocean Observing System (IOOS®) enterprise, provided considerable information to the public about the timing, severity, and government agency recommended actions to take as a result of this event. These included:

- Featuring "Tsunami Evacuation Zones for the Oregon Coast," a Google Map-based application for the public at the top of its home page
- Providing users of the NANOOS Visualization System (NVS) online and on smart phones with easy access to near real-time current, water height, and other information for a wide variety of U.S. IOOS assets, including NOAA National Data Buoy Center (NDBC), NOAA National Ocean Service (NOS), and NANOOS-supported assets, as well as a variety of other sources in Washington, Oregon, and northern California
- Posting numerous NANOOS Facebook updates regarding the tsunami passage, including views of water levels at Crescent City, CA; Garibaldi, OR; Port Orford, OR; and La Push, WA

This paper examines these various components of information and data sharing, providing an insight into the strengths (and weaknesses) of the various components. Section II first describes the U.S. IOOS® including its history, components, and relevance in coastal disaster mitigation issues. Section III describes the role of NANOOS, the regional (non-federal) Pacific Northwest component of the U.S. IOOS®, in providing information to its constituents on the tsunami's impacts. Conclusions and possible future efforts in new ways to provide critical coastal information are summarized in Section IV.

II. The Integrated Ocean Observing System

IOOS® is formulated along the lines of the international Global Ocean Observing System (GOOS). The planning for GOOS began well over a decade ago and is proceeding under the aegis of the Intergovernmental Oceanographic Commission (IOC), the World Meteorological Organization (WMO), the United Nations Environmental Program, and the International Council for Science [4]. GOOS and U.S. IOOS® both are envisioned to consist of two modules: a global, open-ocean module, and a coastal module. Here, both modules are relevant.

A major acceleration in the formulation of the U.S. IOOS® (i.e., the U.S. national GOOS effort) occurred in 1997 with the legislative establishment of the National Oceanographic Partnership Program (NOPP). In October 2000 NOPP established the Ocean.US Office, an interagency planning office for the U.S. IOOS. In March 2002, the Ocean.US Office sponsored a formal, national workshop to provide the basis for the initial plan for the U.S. IOOS®. General consensus was reached on the vision for the observing system, the core elements of the system that should be federally supported, and a process to obtain a plan for the needed data and information management components of the U.S. IOOS®. Based on that workshop the Ocean.US Office prepared an initial design and implementation plan for the integrated and sustained ocean observing system for the United States [5, 6].

As with the international GOOS, the U.S. IOOS® consists of two components: a global, open-ocean component and a coastal component focused on observations, products, and services needed from within the estuaries (head of tide) to the edge of the nation's Exclusive Economic Zone (EEZ). In the U.S. coastal zone, the notion of a "national backbone" was articulated in the Ocean.US reports in which federal agencies were to be responsible for the funding and provision of a set of core and ancillary measurements. These would be augmented by higher density measurements provided by regionally-focused consortia of organizations (including industry, tribal, state and local governments, academia, and NGO's) that would augment the backbone federal measurements to both benefit federal agencies in fulfilling their mission requirements as well as to better serve regional needs. This approach was adopted as it was the most efficient way to fully meet federal agency mission coastal ocean information mandates, adequately understand and address regional ocean information needs, and build an informed ocean constituency in the U.S. There are presently eleven IOOS® Regional Associations throughout the U.S., each of which is responsible for maintaining, operating, and improving a regionally-focused RCOOS that meets regional federal agency and other regional stakeholder coastal and ocean information needs.

In the national U.S. response to the Tōhoku earthquake and tsunami event, all components of the U.S. IOOS® system were exercised. Notably, the DART buoy and NOS tide gauge components of the U.S. IOOS® global module provided critically important information to NOAA's tsunami modeling and warning team and, in the Pacific Northwest (PNW) region, the NANOOS, similarly provided information to a wide range of its stakeholders.

NANOOS (http://www.nanoos.org) is the regional association of the national IOOS® for the PNW states of Oregon and Washington (Figure 1). The spatial domain of NANOOS extends from the U.S./Canada border in the north to Cape Mendocino, California in the south. Despite these political boundaries NANOOS maintains strong cross-boundary ties with observing programs in Alaska, British Columbia, and in central and northern California through our common purpose and because of the overlap of data and products. Established by charter in 2003, NANOOS now comprises well over 40 entities, including tribal, state, and local governments, industries, non-governmental organizations and academic institutions; all have signed NANOOS's operational Memorandum of Agreement (MOA) and now form its Governing Council.

III. NANOOS RESPONSE

The primary mission of NANOOS is to coordinate and support the development, implementation, and operations of an RCOOS that can provide PNW stakeholders with the ocean data, tools, and knowledge they need to make responsive and responsible decisions, appropriate to their individual and collective societal roles. To provide the necessary data and products that may be used to begin to address the needs of stakeholder-determined central themes, NANOOS members designed an RCOOS focused on several core observing capacities (Figure 1) including: high-frequency (HF) radar nodes that map surface currents offshore the Oregon coast, in situ sensor observation capacity in several major estuaries (e.g., Puget Sound, Willapa Bay, lower Columbia River estuary, and Coos Bay); autonomous underwater vehicles (e.g., Newport, Oregon glider line); in situ measurements of oceanographic variables on the continental shelf (e.g., Chábă buoy, Washington); monitoring of PNW beach, shoreline and nearshore morphodynamics (e.g., northern Oregon and southwest Washington coast); short-wave monitoring using X-band radar (e.g., Newport); and implementation of ocean circulation and estuarine modeling (e.g., Oregon shelf, lower Columbia River estuary and shelf, and the Puget Sound). Furthermore, within the regionally designed RCOOS are numerous federally funded and maintained coastal and oceanographic assets that form the "backbone" infrastructure for each of the regional associations (Figure 1). In all cases, data collected by these disparate assets must be measured at appropriate temporal and spatial scales, integrated and delivered in suitable formats to meet identified societal needs, including addressing major coastal disasters such as the Tōhoku tsunami.

To facilitate the effective dissemination of data and information being generated by the RCOOS, members from the NANOOS Data Management and Communication (DMAC), User Products/Web, and Education and Outreach teams and other stakeholders have over the years developed a data management and transport infrastructure and a variety of products that directly addresses the IOOS mandate to "…provide the data and information needed to improve safety, enhance our economy, and protect our marine environment."

A. RCOOS Description and Capabilities

1) Observation and Modeling Systems

Figure 1 presents the NANOOS RCOOS showing its various sensor and observation assets, including the federal assets (NDBC/CDIP wave buoys and NOS tide gauges) that exist within the NANOOS domain. Information associated with each of these sensors is delivered to the end-user via the NANOOS Visualization System (NVS), which aggregates the plethora of observation and modeling data (e.g., wind, wave, circulation) from multiple providers and data sources to deliver a comprehensive view of the PNW marine environment [7, 8]. These data originate from many different asset types (Figure 1; in situ observations, satellite observations, surface currents from HF radar, and circulation model output, including forecasts) as well as different platform types (e.g., for in situ observations, buoys vs. fixed shore platforms). Although not shown in Figure 1, NVS also disseminates important model output fields as mapped overlays or site-specific time series that can be compared directly with in situ observations. These include regional wind and wave models (e.g., Wavewatch III and the North American Mesoscale Forecast System from NOAA), regional models of ocean circulation (e.g. water temperature and currents) as well as more focused models for specific

Figure 1. The NANOOS Regional Coastal Ocean Observing System showing its various sensor and observation assets, including federal assets (NDBC/CDIP wave buoys and NOS tide gauges) that exist within the NANOOS domain. Information from selected tide gauges identified in the figure were being fed via Facebook throughout the tsunami documenting the alongcoast responses.

locales (e.g., salinity and water temperature models in the Columbia River estuary and adjacent coast).

2) Data Management and Communication and User Products

At a national level, DMAC is critical to the success of NANOOS and IOOS® in meeting the goal of delivering near real-time and archived observations and model output to a wide variety of users [9]. At a local level, the NANOOS DMAC subsystem is the bridge between data collection and management, data products and the end users of the data. The NANOOS DMAC architecture supports metadata, tools, and services enabling *in situ* observation and model data access through standard IOOS interfaces, the NANOOS Visualization System (NVS, http://nvs.nanoos.org), and other applications currently in development. It provides integration and consistent redistribution of data from both federal and regional assets [7].

NVS (currently at version 2.5) is a general data access and visualization application developed to support multiple types of users in the region [8]. It includes consistent access to near-real-time data and visualizations for *in situ* and remote-sensing observations as well as model output. *In situ* observations and site forecasts may be accessed via NVS-generated time series plots and user-friendly data download mechanisms for the latest 1, 7, and 30-day periods, while spatial fields from models and remote sensing observations may be accessed as overlays (including overlay animations) and KML downloads. The NVS data architecture [7] provides both an inventory view of existing assets in the region and web service-based, lightweight access to metadata and data for programmatic use by other applications. The inventory and metadata includes clear acknowledgements of individual asset providers and prominent links to the providers' web sites for more in-depth access.

Using NVS and related tools, interested parties are now able to rapidly access a suite of ocean and coastal data and model-output streams that could be used to better guide decision-making during times of crisis, such as in the advent of an oil spill or as recently demonstrated a major coastal disaster such as the Tōhoku tsunami. Increasingly, however, users are demanding access to ocean and coastal information in more remote areas such as for field-based operations. To facilitate these needs, NVS mobile applications (app) were developed that provide ready access to observation data from PNW in situ assets on iPhone and Android smart phones. This app utilizes fast and efficient web services to connect to the NANOOS data repository providing access to the same near-real-time in situ observation data as the NVS Web Portal [7] while adapting NVS user interface approaches and components to the smart phone platform. The NVS app includes both map- and list-based options for browsing NANOOS observing assets. Time series plots may be saved to the mobile device and shared either via email or SMS messaging, while a favorites feature maintains a user-defined list of assets that provides faster access to a subset of observing assets.

B. *NANOOS Response to the Tōhoku Tsunami*

During the early hours immediately following the Tōhoku earthquake and tsunami, two products played a key role in the provision of critical and timely information both prior to and immediately following the Tōhoku tsunami. These included:

- The NANOOS Visualization System (NVS), which aggregates, displays and serves near real-time coastal, estuarine, oceanographic and meteorological data, derived from buoys, gliders, ***tide gauges***, HF Radar, meteorological stations, shore based coastal stations and satellites, as well as model forecast fields. Of these, water level and wave height information measured by the NOS tide gauges at the time of the Tōhoku tsunami were being disseminated through the NVS and via Facebook[3].

- An online tsunami hazard portal, which displays evacuation maps depicted by the ***maximum extent of inundation*** associated with a locally generated great earthquake on the Cascadia Subduction Zone (CSZ), and accompanying tsunami for multiple communities along the Oregon coast. For the southern Oregon coast (Bandon to Oregon/California border) and Cannon Beach only, two inundation maps are provided that show the maximum extent of inundation for both a ***local*** Cascadia tsunami and a worst-case ***distant*** tsunami. The latter is associated with a worst-case great earthquake occurring along the Aleutian Island chain in the northwest Pacific.

In addition to the above products, social networking, in the form of periodic information releases via Facebook, provided a new important mechanism for the broader dissemination of information to the public-at-large, and is poised to become a critical mechanism for information sharing during times of crises in the future.

Many communities located in exposed, low-lying areas along the PNW coasts of Oregon, Washington, and northern California face the risk of tsunami inundation. The hazard originates from two main sources: ***distant tsunamis*** (e.g., Tōhoku, Japan) that cross the expanse of the Pacific Ocean, and ***local tsunamis*** spawned by a great subduction earthquake on the CSZ and accompanying giant tsunamis. Of these, local Cascadia tsunamis pose the greatest hazard to people living along the PNW coast. To reduce the risk associated with such events, the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Washington Department of Natural Resources (WADNR) began developing tsunami evacuation zones for their respective coastlines. These first generation maps were completed in the mid 1990s. Considerable outreach was performed at the time, and continues to this day, involving the provision of tsunami evacuation brochures, community presentations, tsunami evacuation drills, and local community efforts.

To provide easier access to the tsunami evacuation brochures, a collaborative effort between NANOOS DMAC/User Products/Education & Outreach and DOGAMI staff was initiated to begin development of an online tsunami hazards Google-map portal. This tool allows residents, planners, emergency responders, and others to see the extent of areas affected by both local (CSZ) and more recently, distant (outside of the immediate Pacific Northwest region) earthquakes and tsunamis. DOGAMI staff first synthesized the suite of evacuation maps developed over the years for the Oregon coast into a Geographical Information System (GIS), differentiating between those areas where maps are presently available from those where no maps had been produced; the latter generally reflected remote areas where at the time there was little to no population. In early 2009, DOGAMI obtained a tsunami hazard web site template originally developed at the Pacific Service Center of NOAA for Hawaii emergency services. Working with NANOOS DMAC, the template was modified, updated and made operational to include the synthesized Oregon coast tsunami evacuation GIS layer via an interim, external Open Geospatial Consortium Web Mapping Service (OGC® WMS) server. The interactive map features a search-by-address (by street or coastal area) option, as well as the usual drag and zoom functions typical of Google-map portals. In addition to these, the tsunami portal contains considerable information about earthquake and tsunami preparedness, information on the warnings issued by WCATWC, and the capability to print a user defined tsunami evacuation map.

The initial version of the tsunami hazards portal was publicly released in June 2009 and was initially hosted by NANOOS partner, the College of Oceanic & Atmospheric Sciences at Oregon State University (OSU). However, in October 2009, the portal was eventually migrated to the main NANOOS server located at the University of Washington, while the tsunami evacuation layer continued to be hosted at OSU. To avoid IT problems with dealing with multiple parties, the tsunami evacuation layer was eventually migrated in December 2009 to a new NANOOS server at the University of Washington, Applied Physics Lab, where it was served using the open-source software, Geoserver[4]. Most recently in February 2011, the tsunami evacuation layer was updated to accommodate new tsunami evacuation maps that were being developed for the southern Oregon coast, a new improved legend, along with some minor enhancements to the text.

Figure 2 provides a summary of various use statistics determined for the period prior to, on the day of, and immediately after the Tōhoku tsunami. Overall 'unique' page access to the NANOOS website, tsunami portal, and NVS increased significantly on March 11, reaching ~240 hits, the day of the tsunami, with a drop-off over the weekend of March 12–13, before increasing slightly on Monday, March 14th. As can be seen from Figure 2 (*top*), interest in the tsunami portal continued throughout the following week, averaging ~10-20 unique hits per day. The drop in activity on March 12-13 (the weekend after the Tōhoku event) reflects a natural response observed in all NANOOS web use statistics, characterized by a sharp drop-off in interest over weekends. Figure 2 (*top*) also highlights increased use and access to both the NANOOS web site and the NVS, which exceeded over 600 and 190 hits respectively that day. Traffic to the tsunami portal and NANOOS site in general (Figure 2, *bottom*) reflected a combination of approaches, although overwhelmingly it was the product of searching using particular keywords (e.g. tsunami, evacuation maps, etc.), versus those who were either being referred to the site from another web site (e.g. a state agency site) or those who were accessing the site directly (i.e., people who had previously book-marked the site).

3 http://www.facebook.com/NANOOS.PNW

4 http://geoserver.org

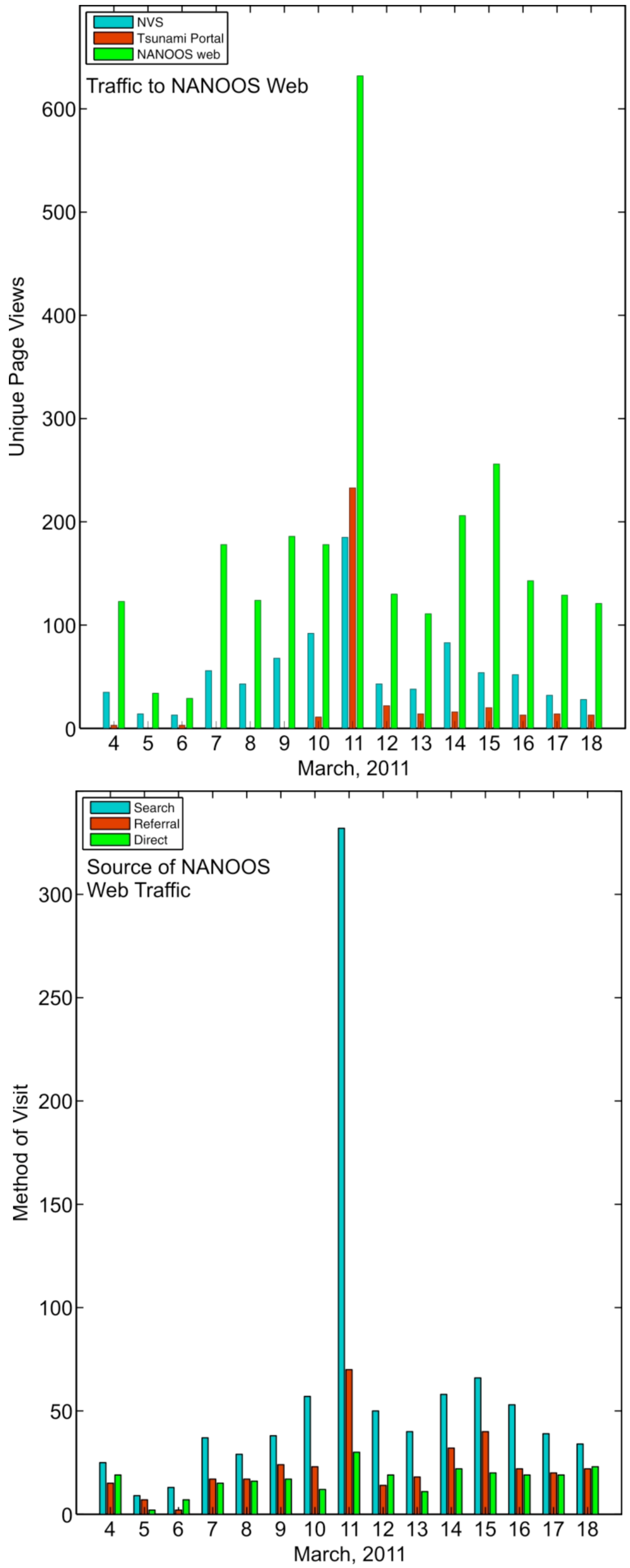

Figure 2. NANOOS Web Usage statistics for the days surrounding the Tōhoku tsunami.

In 2010, DOGAMI began developing an entirely new suite of evacuation maps that will eventually span the entire length of the Oregon coast. These updated tsunami maps, are the product of several new improvements in technology including: new high resolution National Geodetic Data Center (NGDC) tsunami bathymetry digital elevation models coupled with recently acquired high resolution Light Detection and Ranging (LIDAR) topographic data flown by DOGAMI in 2008/09; a suite of new earthquake source (slip) models developed for both the CSZ and a distant tsunami (worst-case originating out of the Aleutians and the 1964 Anchorage Alaska tsunami); and new high resolution tsunami inundation modeling developed by the Center for Coastal Margin & Prediction (CMOP). To date, inundation modeling has been completed for the southern Oregon coast (Bandon to the Oregon/California border) and the evacuation maps integrated into the tsunami portal.

1) Equipment impacts

In late 2010, NANOOS DMAC established a system for IT infrastructure and services monitoring to maintain near 24/7 operational capability. At 7:00 am (PST) on March 11, a warning was issued indicating that the GeoServer OGC WMS layer software for the tsunami portal had failed, due to a combination of heavy user traffic on the portal site and scalability problems with the GeoServer software stack experienced at high loads. A short-term fix to these problems required the server software to be frequently restarted over the course of the day, potentially impacting people's ability to access the server at certain times over the course of the day on March 11. However, a longer term solution was initiated later that day, which involved migrating from the tsunami evacuation layer WMS service to a highly scaleable Google-Maps tile service developed at the University of Washington Applied Physics Laboratory and already in use with NVS (the Environmental Imaging Server, or EIS). After software updates, the new system was deployed on Monday the 14th. EIS has an efficient caching system and is thus capable of handling increased server access loads, reducing the likelihood that a spike in traffic will incapacitate it

2) Mobile App

NANOOS has developed a mobile application (app) for iPhone and Android mobile devices that provides mobile equipment specific access to the NVS. During a tsunami event (particularly a distant event) having access to ongoing conditions is clearly important to emergency managers and the public-at-large. The NVS mobile application allows such access to users that did not have either a web browser or Internet access. Such users could include scientists in the field, boaters on the water, fishers, and first responders. The NVS mobile app allowed near real-time access to selected ocean data for these remote users as events progressed.

C. NANOOS and the use of Social Media

According to the Pew Internet & American Life Project, almost half of American adults are involved with at least one social networking system [10]. Social media, such as Facebook, Twitter, and YouTube, are online utilities that are widely used worldwide to interact and communicate with a user's social network. In the case of businesses and

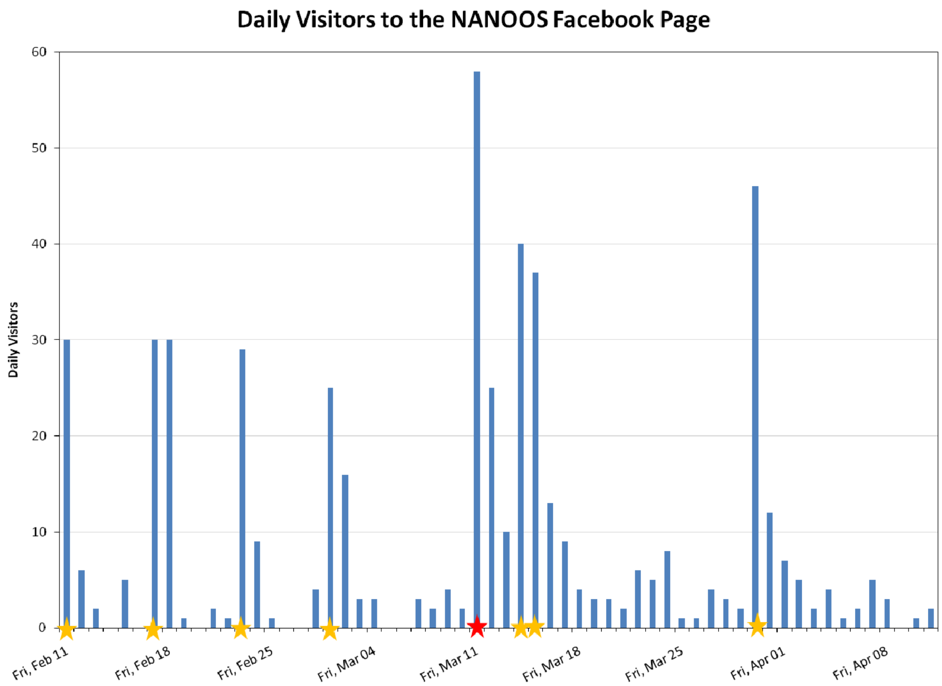

Figure 3. Frequency of NANOOS Facebook page updates. Stars indicate days having new posts. March 11, the day of the tsunami, has a red star.

organizations, these technologies provide a method to achieve several goals, including increasing awareness and visibility of the brand; communicating important and timely information to consumers, users, and stakeholders; providing opportunities for meaningful interactions, such as collaboration and participation between and with users, that increase staying-power; and easily obtaining feedback and opinions from users.

NANOOS joined Facebook in April 2010 to augment our traditional outreach methods (i.e., the NANOOS web site, printed and online newsletters). As an organization, we selected Facebook as our initial social networking tool because the anticipated periodicity of posting information (one post every one to three weeks) was manageable, the amount of personnel time necessary for maintenance and posting was minor, and Facebook was the most popular social networking tool. As of July 2011, NANOOS has 124 Facebook "Likes" with, on average, about two new "Likes" being added per week. Information we post to the Facebook page includes links to new or newer versions of NANOOS data products; links to the NANOOS newsletter; photos or news articles relevant to NANOOS; and links to NVS or photos of graphs from NVS during an interesting event (e.g., winter storm, plankton bloom, upwelling).

The Tōhoku tsunami was unique as it gave NANOOS experience in using social network technology to provide important information about this profound event. Because it was such a media-intensive event, we gained experience in keeping our Facebook network updated with real-time or just-in-time information, a capability that is increasingly becoming expected by our society during such events. We categorize the tsunami information we provided via Facebook into three groupings: 1) Initial tsunami information, including the link to the NANOOS tsunami portal, posted during the early stages of the event; 2) Graphs of water levels from NOS tide gauges in Crescent City, CA, Port Orford, OR, Girabaldi, OR, and La Push, WA, posted during and after the event; and 3) Synthesis information about the earthquake and tsunami posted a few days after the event. Similar to the NANOOS portal, NVS, and the tsunami portal, we observed a spike in NANOOS Facebook user activity on the day of the tsunami. In the month preceding the event, we typically witnessed 25-30 visitors to the NANOOS Facebook page. On the day of the tsunami, we had nearly double the expected number of visitors, and the traffic to the Facebook page remained elevated for several days (Figure 3). We suspect this increased Facebook activity was due both to the high interest level in this event and the fact that we made several posts to the page each day, increasing the visibility of NANOOS on peoples' Facebook News Feeds.

NANOOS is inherently a collaborative effort. It enables and enhances the efforts of a large network of data and information providers on one end, and easily connects them with interested user-groups and stakeholders on the other. Because NANOOS is so interconnected with regional stakeholders, it is well positioned to serve important and timely information to our regional constituency that is increasingly mobile-technology literate and which expects timely and easy access to important or critical information. We believe social media technology will play an increasingly important role in this activity in at least the following ways: (a) allowing NANOOS to communicate information about critical events and emergencies (such as forwarding official agency warnings to the public); (b) communicating other relevant information such as evacuation routes; (c) obtaining information from a dispersed assemblage of "observers" who could relay information about events, (d) using these technologies to educate on how to prepare for emergencies, and (e) communicate other relevant coastal ocean information.

IV. Conclusions and Next Steps

The global and coastal components of the U.S. IOOS® system demonstrated their utility in providing needed information to people impacted by this event. At the national or federal level DART buoys, numerical models, and an effective warning and dissemination system showed the importance of the U.S. IOOS®-derived information.

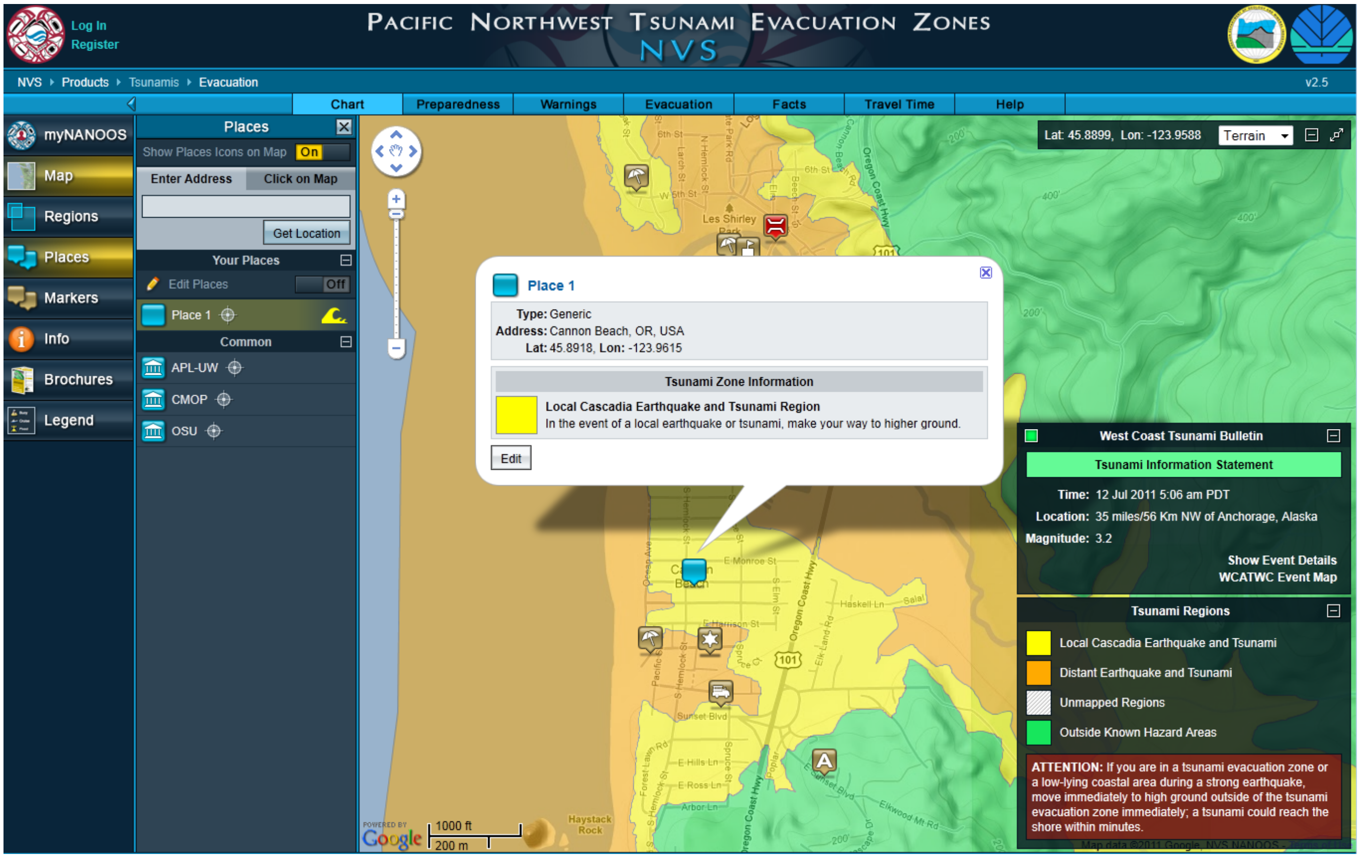

Figure 4. The Pacific Northwest Tsunami Evacuation Portal presently being developed by NANOOS DMAC/UPC/E&O. The new portal includes enhanced search and notification capabilities that inform the user if they are in/out of an evacuation zone, links to evacuation brochures developed by state agencies, display of information statements that are fed directly from the WCATWC, and multiple tabs containing important information about preparedness, warnings, and evacuation.

Similarly, state and local agencies were prepared and were able to help coastal communities in the PNW be prepared. For NANOOS, the regional U.S. IOOS® component, responding to the information demands of this event demonstrated the resiliency of the regional system while also emphasizing the need to have adequate carrying capacity to handle increased demand for web-provided information. For the first time, NANOOS also explored the utility of social network technology (e.g., Facebook) to provide information to its stakeholders. The successful teaming of industry, governments (state, local, federal, etc.) in meeting this challenge and the novel use of social networking technologies showed how collaborative partnerships involved in providing U.S. IOOS® data and information can reach a larger audience with critical information.

There are a number of lessons NANOOS has learned from the Honshu event and its aftermath. Concerning the particular aspect of social networking technologies, we anticipate that these will become an ever more prevalent feature of our increasingly mobile society. Combined with a well designed and funded RCOOS targeted at specific regional needs, it is clear that the regional IOOS goal of providing critical and timely coastal and oceanographic data and models products to assist with both natural and human induced disasters can be fully met, increasing the potential to more rapidly respond, and potentially in the mitigation of such disasters, or at least reduce their potential larger impacts. Mobile applications and proactive use of other new forms of technologies are poised to capitalize on these continued enhancements and could provide substantial benefits to our society in the future, and this topic should be an item of central focus and discussion as the U.S. IOOS® moves forward.

To better facilitate access to both existing and newer tsunami evacuation maps being developed by the States of Oregon and Washington, and importantly, the needs of both emergency and resource managers and the public-at-large, NANOOS DMAC/UPC/E&O members have begun development on an entirely new tsunami portal, which ultimately emulates the rich interface and experience offered by NVS. Critical to this process has been the development of a white paper that has served to guide the overall evolution of the new portal, which lays out the critical features and needs that the new web site will eventually offer. Input in this process was sought from a variety of interested parties, including NANOOS UPC, E&O, DOGAMI, and Oregon Sea Grant. The new website features a cleaner interface, similar to the existing NVS portal (Figure 4), and includes such enhancements as better search capabilities that include pop-ups that warn the user whether they are in/out of the tsunami evacuation zone, the locations of critical facilities (schools, police, fire, etc.), evacuation assembly areas, and the locations of bridges; the latter includes warnings about the potential for bridges to be destroyed during a local CSZ earthquake. On the map page, the user is immediately presented with information on the status of any potential statements, advisories, or warnings, in the form of a stop light (green = safe, red = warning), which is fed directly by information being supplied by the WCATWC. Finally and importantly, the new portal now integrates tsunami evacuation zones developed for the Washington coast by the WADNR. Public release of the new portal is scheduled for August 2011.

Expanding on the matter of mobile applications and future efforts, the tsunami event showed that while having access to current conditions is important, early access to warnings, predictions, and other data is vital. The current NVS mobile application is inadequate for this purpose. For example, first responders need to know in advance that a tsunami may impact their jurisdiction. They need to know not only the predicted water level and inundation zones, but also what evacuation routes may be impacted by factors such as road construction and traffic congestion. These factors are fluid and change as the event progresses so real-time updates and alerts are crucial to efficient and effective emergency management. Other classes of users such as boaters and harbormasters need to be alerted that their area may be affected so that preparations can be taken to minimize damage due to the event. Coastal users need to be able to check if they are currently in an inundation zone and if so what are the nearest evacuation routes and safe zones. To assist state and other government officials in meeting the needs of these and other users, NANOOS is designing a new mobile application. The NANOOS Tsunami mobile application will be a mobile version of an entirely new and robust NANOOS Tsunami web-based application just as NVS mobile is a mobile version of NVS web application. This app will have a map-based display of the tsunami inundation zones in the NANOOS region along with the current location of the mobile device. An alerting mechanism will be provided such that users will be notified when a significant event occurs. Data feeds from the various tsunami warning centers will also be used so that officially authorized details and predictions will be available. This application is currently being developed and should be available in fall 2011.

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