TsuInfo Alert

prepared by the Washington State Department of Natural Resources on behalf of the

National Tsunami Hazard Mitigation Program

a state/federal partnership funded through the National Oceanic and Atmospheric Administration (NOAA)

Contents

Volume 4, Number 5, October 2002

TSUNAMI PROGRAM NEWS

Oregon Communities Become TsunamiReady

The Cannon Beach Fire District (which includes the communities of Cannon Beach, Arch Cape and Falcon Cove) became the first Oregon jurisdiction to receive the TsunamiReady and StormReady designations. A ceremony was held at the Cannon Beach Fire Station on August 12, 2002, moderated by Tyree Wilde of the National Weather Service (NWS) in Portland. Speakers included Steve Todd (Meteorologist-in-Charge, NWS, Portland), Al Aya (Board of Directors, Cannon Beach Fire District), Laurel Hood (Mayor, Cannon Beach), Cleve Rooper (Fire Chief, Cannon Beach Fire District), Jan Glarum (Emergency Manager, Clatsop County), Mark Darienzo (Earthquake and Tsunami Program Coordinator, Oregon Emergency Management, Salem), and Ken Murphy (Deputy Director, Oregon Emergency Management, Salem). Many community members were also in attendance including members of Cannon Beach's Emergency Preparedness Committee. Steve Todd presented the TsunamiReady and StormReady signs to Al Aya and Laurel Hood.

Lt Laurel Hood, Cannon Beach Mayor, Steve Todd, MIC NWS Portland, Cleve Rooper, Fire Chief Cannon Beach Fire District, and Al Aya, President, Cannon Beach Fire District Board of Directors. Photo by Tyree Wilde.

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It is assembled by
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This publication is free upon request and is available in print (by surface mail),
electronically (by e-mail), and at http://www.wa.gov/dnr/htdocs/ger/tsuinfo/index.html

Participants in the TsuInfo program can request copies of reports listed in this issue from:

Library
Washington Department of Natural Resources
Division of Geology and Earth Resources
P.O. Box 47007
Olympia, WA 98504-7007
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fax: 360/902-1785
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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

HAZARD MITIGATION NEWS

Alaska:

Kodiak Tsunami Maps Are Online!

The Alaska Department of Natural Resources Division of Geological and Geophysical Surveys has put the four Kodiak region tsunami hazards maps online (available at http://wwwdggs.dnr.state.ak.us/Kodiak.html), presented in Mr. Sid format. The website provides a downloadable Mr. Sid readers. Reports are in Acrobat Reader (PDF) format.

Washington:

New Inundation Maps Are Available

The Washington Division of Geology and Earth Resources has just issued the tsunami inundation maps for the northern coast of the Olympia Peninsula, in the Port Angeles and Port Townsend areas:

Walsh, T. J.; Myers, E. P., III; Baptista, A. M., 2002, Tsunami inundation map of the Port Angeles, Washington area: Washington Division of Geology and Earth Resources Open File Report 2002-1, 1 sheet, scale 1:24,000.

Walsh, T. J.; Myers, E.P., III; Baptista, A. M., 2002, Tsunami inundation map of the Port Townsend, Washington area: Washington Division of Geology and Earth Resources Open File Report 2002-2, 1 sheet, scale 1:24,000.

Copies have been sent to the emergency managers and others in those communities and are available from the DGER Olympia office (see p. 2 for ordering information.)

State Agencies Are Now Part of State Mitigation Plan

New Federal Emergency Management Agency (FEMA) guidance will allow state agencies to participate in the state's hazard mitigation plan, rather than prepare their own plans to remain eligible for the Hazard Mitigation Grant Program.

For more information on the Washington state plan, contact Mark Stewart, EMD's hazard mitigation strategist, at m.stewart@emd.wa.gov or (253) 512-7072.

from: Emergency Responder, July-August 2002, p. 2

Congressional Natural Hazards Caucus New Member

The Congressional National Hazards Caucus has a new member: Senator Maria Cantwell (D-WA.). The senator became aware of the caucus through a NOAA detailee in her office. Current caucus members are *Senator Akaka of Hawaii*, *Senator Boxer of California*, Senator Breaux of Louisiana, Senator Byrd of West Virginia, *Senator Cantwell of Washington*, Senator Cleland of Georgia, Senator Cochran of Mississippi, Senator Conrad of North Dakota, Senator Dorgan of North Dakota, *Senator Feinstein of California*, Senator Graham of Florida, *Senator Inouye of Hawaii*, *Senator Murkowski of Alaska*, Senator Robb of Virginia, Senator Schumer of New York, Senator Torricelli of New Jersey, and *Senator Wyden of Oregon.*

from: EQ, Summer 2002, p. 19

Natural Hazards Caucus Briefed on Warning Systems

On June 24th, the Congressional Natural Hazards Caucus sponsored a Capitol Hill briefing on "Delivering Clear and Effective Warnings: the Natural Hazards Challenge." Speakers included Mary Lou Zoback from the USGS, Ron McPherson from the American Meteorological Society, Craig Fugate from the Florida Division of Emergency Management, George Vradenburg from AOL Time Warner, George Heinrichs from Intrado, Inc., and Peter Ward from the Partnership for Public Warning. The speakers discussed the fact that effective warning systems are based not only on good scientific information and governance, but also on public education and technology. The lunch briefing was attended by 80 congressional staff, federal agency representatives, and members of the working group supporting the caucus, which is co-chaired by Sen. John Edwards (D-NC) and Sen. Ted Stevens (R-AK). More information and links to the speakers' presentations are at http://www.agiweb.org/workgroup.

from: The Professional Geologist, v. 39, no. 9, p. 21.

September 14, 2002 Indian Earthquake/Tsunami

A 6.5 magnitude earthquake struck the Andaman Islands off the coast of India at 3:59 AM, followed by several aftershocks. Two people were killed by a collapsing wall. A tsunami was generated that damaged several shops and houses near the jetty in the southern coastal city of Madras. The earthquake was felt in Smith Island, Ross Island, and Kalaghat Baratang. Highly prone to earthquakes, the Andaman Islands are a string of 300 or more tropical islands, populated by 340,000 people.

Emergency Management Institute Resident Courses

FEMA's Emergency Management Institute (EMI) released its course catalog for 2002-2003 resident courses. Resident courses are those that are scheduled on-campus at FEMA's facility in Emmitsburg, Maryland. Course offerings range from simulations and exercises to classes on mitigation and preparedness. Application and eligibility information and a detailed schedule are available by calling (800) 238-3358; e-mailing emi@fema.gov; or accessing the EMI web site: http://www.fema.gov/emi.

from: Disaster Research 374, September 13 2002

The 2nd Wednesday in October is World Disaster Reduction Day

FEMA's Multihazard Mapping Initiative Provides Online Access to Natural Hazards and Related Data

In consultation with states, local governments, and federal agencies, FEMA has developed a web site to provide multi-hazard advisory maps for at least five states. The maps identify and overlay hazard data for a variety of natural hazards for the purpose of showing areas where the hazards overlap. The web site is the outgrowth of a multi-participant demonstration project in conjunction with the Open GIS Consortium (OGC) to establish a standards-based framework of interoperable services. Called the "Multihazard Mapping Initiative" (MMI), the site is managed by FEMA's Federal Insurance and Mitigation Administration (FIMA).

The vision of MMI is to foster the exchange of geospatial hazards data, increase hazard awareness, encourage data providers to establish standards-based services that facilitate data sharing and map creation, make FEMA spatial data available on the Internet in map form, and allow FEMA access to outside spatial data that is critical to its daily operations. The site can be found at http://www.hazardmaps.gov/atlas.php.

from: Disaster Research 374, September 13 2002

PERI Online Library

The Public Entity Risk Institute (PERI) has created an on-line library to offer both timely and timeless material on risk management concerns of interest to local governments, nonprofits, and small businesses. The library, housing a growing collection of in-depth articles, is actively seeking contributions for its virtual shelves. In particular, PERI is seeking articles on disaster response and recovery, risk management, risk financing and insurance, human resources, and workers' compensation. Interested persons can visit the library at http://www.riskinstitute.org/lib.asp. To propose or submit an article, contact Claire Reiss: (703) 352-1846; e-mail: creiss@riskinstitute.org.

International Combined Emergency Services Training and Operations Center Announced

Over the past decade, a global team of academics and emergency professionals has conducted research into the state of emergency services around the world. Building on this knowledge, the team has announced the launching of the International Combined Emergency Services Initiative (ICES). The goal of ICES is to provide a center of global excellence in emergency services education, training and response. Situated on over 30,000 acres of land in Queensland, Australia, the ICES Center will eventually be able to meet the needs of up to 15,000 international students and staff. With a focus on training and operations to meet specific country needs, ICES will help developing countries train and administer their own emergency service agencies, thus ensuring that the more vulnerable communities are better able to cope with disasters. ICES will establish and maintain a variety of capabilities, ranging from an operations center to an airborne response task force, to a fully staffed field hospital.

For more information, contact: John Sturrock, ICES, P.O. Box 1227, Crows Nest N.S.W. 1585, Australia; 61-2-9929-6179; e-mail: johns@icesproject.com; http://www.icesproject.com.

from: Disaster Research 372, August 16, 2002

Cities and Counties Collaborate on Disaster Mitigation

Eight studies, each detailing partnerships between cities and counties partnering on disaster mitigation, are profiled in a report issued by the Joint Center for Sustainable Communities, an advisory committee for the National Association of Counties (NACo). The report is titled, *City/County Collaborations on Disaster Mitigation: Borderless Solutions to a Borderless Problem* (2002, 31 p.).

Communities are collaborating on activities such as fire, flooding, hurricane, and tornado protection and preparedness. Profiled municipalities range from rural counties to small cities from the following states: Wisconsin, Oregon, Ohio, Kansas, North Carolina, Idaho, Washington, and Florida. Copies are currently only available on-line in PDF format at http://www.naco.org/programs/comm_dev/center/disasterbook.pdf. Printed copies may be available in the coming months. For more information, contact Martin Harris, NACo, Joint Center for Sustainable Communities, 440 First Street, N.W., Washington, DC 20001; (202) 661-8805; fax: (202) 737-0480; e-mail: mharris@naco.org.

from: Natural Hazards Observer, Sept. 2002

CMD First Source

http://www.cmdfirstsource.com/codes/index.asp is a good source for information about building construction and materials-- and building codes for major cities.

After completing the free registration, you can use all of the many valuable tools that CMDFirstSource.com has to offer, including the exclusive Building Code Resource Center. Providing all the information you'll need to find and access building codes, authorities and local utility information, the CMD First Source Building Code Resource Center is a timesaving resource for the entire construction community.

The Building Code Resource Center allows you to search for city, county or state building code information throughout the United States with an easy-to-use drop-down menu. You can view the contact information (including phone numbers) and listings for the building codes, amendments and authorities having jurisdiction (AHJs) in the markets you select. The CMDFirstSource.com Building Code Resource Center provides an excellent roadmap for finding the information you need, and where available, direct links are provided to amendments found online.

In order to provide you with the most reliable and comprehensive information available, CMD First Source collects all building code information right from the source--city, county and state building departments. CMD First Source provides code information for all states and many key cities and counties throughout the United States, and continually adds new cities and counties to this online resource of building code information.

New Service Offered: DNA Testing for Emergency and High-risk Workers to Help Streamline Identification

DNA testing has revolutionized victim identification following disasters and has proven its usefulness in the crash of TWA 800, identification of the Unknown Soldier from the Vietnam War and the 9/11 attacks. The key to DNA remains identification is the availability of a reference sample from the victim. If that reference DNA profile is readily available it minimizes inconvenience to surviving family members, reduces the time required to obtain positive identification and provides the basis for independent verification of laboratory results. The obvious need for a reliable system of identification prompted the U.S. Army to start a genetic depository (http://www.afip.org/Departments/oafme/dna/) in 1992 that will eventually include the DNA of every American in uniform. Establishing a similar DNA Identification Program for your employees or agency enhan-ces preparedness and morale.

Samples forwarded to Genelex's fully accredited DNA laboratory are processed according to FBI compatible standards. DNA Identification is widely used by law enforcement and has been standardized for use in the FBI's national DNA database-CODIS (http://www.fbi.gov/hq/lab/codis/program.htm). Since January 2002, DNA profiles from missing persons have been included in this database.

Once profiling is completed, a notarized document with the DNA profile is sent to all tested persons and their duly designated representatives. The report can be filed with important personal paperwork and in agency personnel files as appropriate. Genelex also keeps confidential electronic records of the DNA profiles that can be transmitted directly to other laboratories for comparison purposes at no additional charge. All records are stored in a secure facility and available only to authorized personnel. The DNA profile provides no medically relevant information. The sex of the individual is the only physical characteristic that is determined.

Genelex was founded in 1987 for the express purpose of providing forensic DNA analysis services to the justice system and has completed DNA profiles on more than 25,000 individuals that are currently held in law enforcement databanks including the FBI's National DNA Index System. [To check Genelex credentials, go to the website www.genelex.com.]

abridged from: email on September 4, 2002, dnaid@genelex.com

New Emergency Management Tool

According to a blurb in the Product Showcase section of the September/October 2002 issue of *Contingency Planning & Management* (page 48), "Digital Map Products developed EmergencyMapAccess, an Internet-based system designed to provide immediate 24/7 interactive access and sharing of information to first responders in the event of an emergency. The system takes an approach similar to MapQuest and adds property boundaries, ownership information, every attribute known about that property, overlays for hazardous sites, earthquake faults, flood zones, fire zones, locations for critical services, and a high-resolution photograph."

EmergencyMapAccess is a feature of the CityGIS2 software by Digital Map Products. For more information, consult http://www.pobonline.com/CDA/Article Information/news/news_item/0,2345,80426,00.html

Infrequently Asked Questions

compiled by Lee Walkling

What literary celebrity experienced the October 8, 1865 (NOT the 1906) San Francisco "great" earthquake?

Mark Twain. Read his description in the August 2002 issue of *TsuInfo Alert*, pages 22-23.

How big a tsunami did the 1906 San Francisco earthquake generate?

The 1906 San Francisco, California, earthquake produced local tsunami waves of only about 2 inches.

from: http://earthquake.usgs.gov/faq/effects.html

How long did the European settlers have to wait for their first American earthquake?

As early as June 11, 1638, a strong earthquake in the St. Lawrence Valley region, near Trois Rivieres, Quebec, was reported felt throughout all the English plantations. Another shock from the same area, in 1663, was felt over all of eastern Canada and the northwestern United States.

from: http://neic.usgs.gov/neis/states/maine/maine_history.html

OF LANDSLIDES, COUCH POTATOES, AND POCKET TSUNAMIS

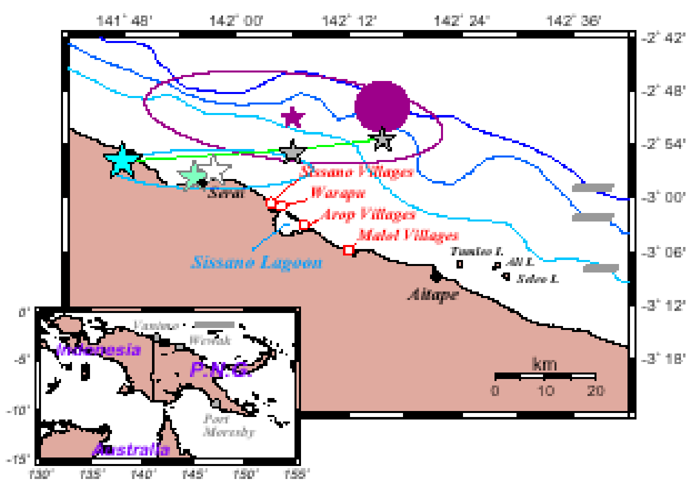
by Douglas L. Smith

Reprinted, with permission, from Engineering & Science, v. 63, no. 1, 2000, California Institute of Technology
and is also available at http://pr.caltech.edu/periodicals/EandS/articles/Tsunami%20Feature.pdf

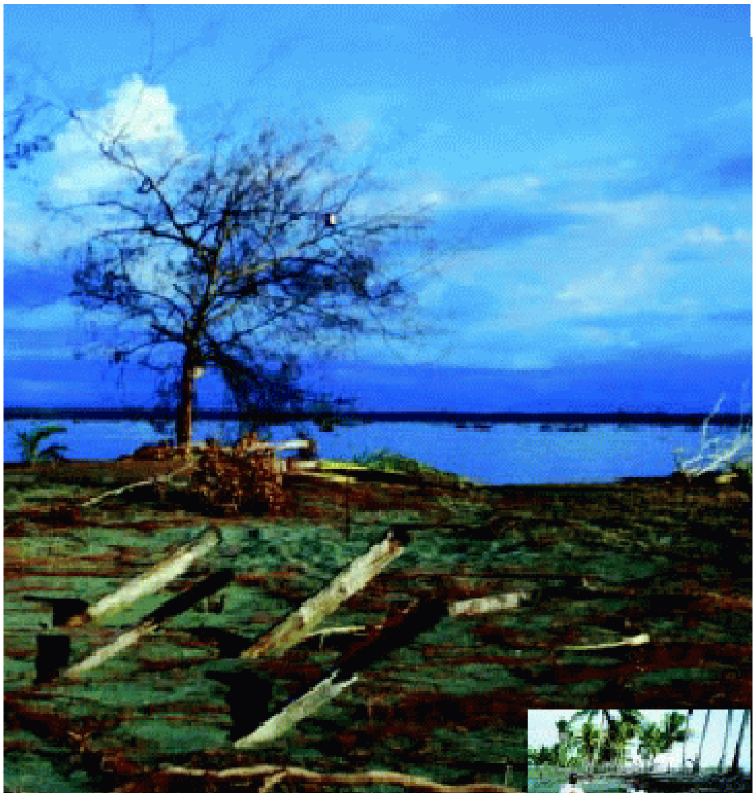
Sometime after seven o'clock in the evening on Friday, July 17, 1998, a wall of water three stories high wiped out a 25-kilometer stretch of tropical paradise on the north shore of Papua New Guinea. Hardest hit was the Sissano Lagoon region, where three villages of thatched huts sat on the spit of sand that divided the ocean from the lagoon. The tsunami, which penetrated as much as three kilometers inland in other places, washed over this glorified sandbar like it wasn't even there. All three villages were completely destroyed, and several more up and down the coast were heavily damaged. At least 2,200 people died, and some 12,000 souls were left homeless as buildings were swept away like yesterday's sand castles--even substantial structures, such as churches and schools, were reduced to their concrete-pad foundations. This tsunami, which actually consisted of three separate waves, is making waves in the scientific community as well, as it bolsters a theory advanced by a group of Caltech alumni that some of the largest localized tsunamis are caused by underwater landslides instead of by the motion of the seafloor during an earthquake.

The tsunami followed a magnitude 7 earthquake at 6:49 p.m., and earthquakes frequently *do* generate tsunamis. Such tsunamis are called tectonic, and their size is related to the energy released by the quake, which is readily derivable from seismograms. Tsunamis also travel at known speeds, so their arrival time at any location can be calculated. And that was the problem with this one--like a typical Hollywood disaster movie, it was late (by a full 10 minutes) and waaaay over budget. The standard tectonic-generation models predicted that the wave should have been, at most, 1.3 meters high on arrival--about average for the surf there. So what happened? How did this two-bit tsunami become a killer wave, and what took it the extra 10 minutes? As Chief Engineer Montgomery Scott is fond of saying, "You canna change the laws of physics," so unless there's some sort of time-dilation effect worthy of a *Star Trek* episode going on here, whatever caused the tsunami must have happened after the earthquake.

Well, earthquakes also unleash landslides--sometimes hours after the shaking stops. In a 1982 study of the 1980 Mount St. Helens eruption, Hiroo Kanamori, the Smits Professor of Geophysics, and Jeffrey Given (PhD '84) concluded that the massive landslide that uncorked the eruption had a distinctive seismic signature. Then, in 1987, Kanamori and H. S. Hasegawa of the Geological Survey of Canada examined seismograms from the 1929 Grand Banks earthquake (magnitude 7.2), which caused a tsunami that killed 27 people on the south coast of Newfoundland, and found the same signature. A landslide had been suspected there long before Kanamori's time, because the spiderweb of transatlantic telegraph cables had snapped in 28 places. The breaks' timing helped map the slide's path--there were 14 "instantaneous" ones within 100 kilometers of the epicenter, followed by a series that rolled downslope and across the abyssal plain, with the final one coming some 560 kilometers away and 13 hours 17 minutes later. Since then, a half-dozen or so other tsunamis have been convincingly linked to landslides as well. This notion sloshed over to Caltech's engineering and applied science division, where Philip Watts (PhD '97), working with Fred Raichlen, professor of civil engineering and mechanical engineering, derived a computer model of waves generated by a submerged landslide. This model, based on wave-propagation code developed by Stéphan Grilli of the University of Rhode Island, was the first to take a user-defined motion of the landslide's center of mass to represent the motion of the landslide as a whole, a feature that would eventually prove to be crucial.



The large map shows the tsunami area (the black rectangle in the inset map). The villages labeled in red were devastated or partially destroyed, while the ones in black escaped serious damage. Stars indicate the epicenters of some significant earthquakes. Papua New Guinea doesn't have many seismographs so the locations are imprecise—the three large stars in the blue error ellipse are all putative main shock locations, with the white star being the one the Caltech group calculated. The two gray stars are the pair of aftershocks, and the green line behind them is the fault. The purple star is the mysterious 7:02 seismic event; its error ellipse, also in purple, includes the landslide (purple circle).



Paradise leveled: This was a small, unnamed hamlet east of the lagoon mouth. The angled logs in the foreground used to be house posts. The silver object high in the tree is a bucket left there by the wave. At right, survivors from Arop No. 1 stand in the scour left by the wave—note the scarp in the background.

Most tsunami models start with a source motion on the seabed. The most common is an earthquake that instantaneously dislocates the water above it to create a wave. This is why tsunamis pack such a wallop: in deep water, all the kinetic energy of a wind-generated wave lies within a few wave heights of the surface, but a tsunami goes all the way down --the entire water column is in motion. When all this energy gets squeezed into a few meters of shallow water, all hell breaks loose. Conventional tsunami models assume a tec-tonic source--a block of seafloor is thrust up, in the Papua New Guinea case by about 40 centimeters, and the tsunami is born as the water collapses back on itself. But a landslide on the move leaves a void behind itself that the ocean in-tantly fills, creating a wave.

A computerized tsunami is really three separate models: source, propagation, and arrival. Once the wave has been generated, by whatever means, it spreads through the high seas according to the laws of fluid mechanics, which were translated into a form appropriate to tsunamis by Joseph Hammack (PhD '72) and Jiin Jen Lee (PhD '70). Then, as it nears the coast, the wave's detailed behavior depends on the topography, both above and below the shoreline. The tsunami's run-up, as it's called, is the province of Costas Synolakis (BS '78, MS '79, PhD '86), who first suggested the approximations needed for computer simulations while modeling run-up under Raichlen and is now a professor of civil and environmental engineering at USC and director of the tsunami center there.

But neither the tectonic nor the landslide models' predictions of wave heights and arrival times matched the maps and measurements made by the International Tsunami Survey Team. The team was cosponsored by the National Science Foundation, the Japan Science Foundation, and the Ministry of Science and Culture and co-led by Synolakis, who has been on nine such teams in seven years, and Yoshiaki Kawata of the Disaster Prevention Research Institute at Kyoto University. The survey found that the wave height fell off very rapidly outside the zone of inundation, leaving villages just a little further up or down the coast completely untouched. But a tectonic source takes impetus from the entire length of the rupture (about 35 kilometers for a magnitude 7 quake), so its effects are felt along a very broad front. And as this quake is believed to have started about a kilometer or two offshore and headed out to sea at a shallow angle, a tectonic tsunami should have trashed a much larger area if it trashed anything at all. Even stranger, the shore closest to the epicenter got a wave only a couple of meters tall. (The epicenter's location is not very precise, as that part of the world isn't heavily instrumented--we're spoiled here in Southern California.) The landslide model fared better in that a landslide is a more concentrated source, so its effects are highly localized and an intense "pocket" tsunami, if you will, is a likely outcome. But still, the numbers just wouldn't come out right. If this was indeed a pocket tsunami generated by a landslide, the computer models were missing an essential feature.

The survey team visited the area two weeks after the disaster. It's important to get there fast, Synolakis explains, especially during the rainy season--one good storm can wash away the high-water marks, and obliterate the debris paths that tell you the wave's angle of approach. There were no buildings left on which to measure lines of discoloration from the flooding, but the trees told their own eloquent story: some were stripped clean of branches to a height of 12 meters; others had household goods and wreckage lodged in their tops. "If you have a severe wind, that bucket in the tree would just fly away," he says. "And people scavenge things. The lagoon villages are inaccessible by road. They can't just go to the store and get another bucket, so if you wait too long they will have combed the area and picked up everything that they can reuse. And eyewitness accounts change: as time passes, people start hearing the story from the local authorities or the shortwave radio, and it contaminates their memories. They are more likely to give you the official number than what they actually saw. They hear, for example, that 'it was a 40-foot wave and it came from the north,' and that's what they'll tell you. But then when you ask them to point to where they saw it go, you get different results."

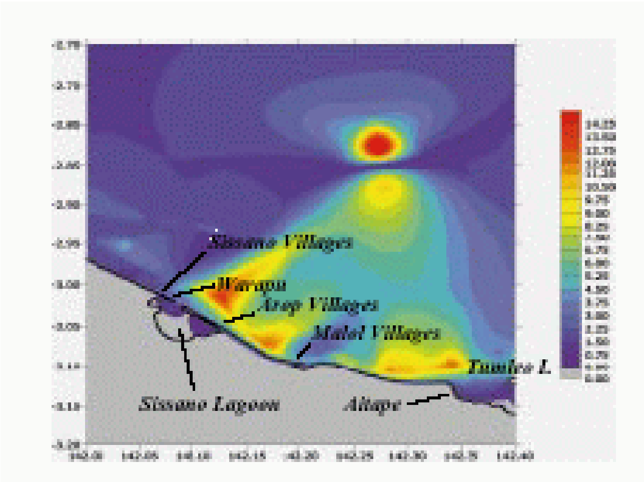
In more built-up areas, automatic tide gauges--rugged instruments mounted in concrete--would have recorded the waves' arrival times. (If nothing else, you could at least note the time when the recording stopped.) Here, the team had to rely on people's memories. Hugh Davies, professor of geol-ogy at the University of Papua New Guinea, in Port Mores-by, spent every weekend for six months afterward inter-viewing survivors, many of whom had been dispersed to hospitals or resettled in new villages farther inland. When he quizzed people about the time of arrival of the wave he was given many different answers. "That's what you expect when people mostly measure the time of day by the sun," says Jocelyn Davies, a physical science technician at the United States Geological Survey's Pasadena office. Davies, who lived in Papua New Guinea until she was nine, flew back twice after the disaster and assisted her dad with follow-up interviews. "In Aitape [a larger town at the fringe of the devastation, where the wave was only three meters tall], they could at least tell us that the wave came ashore a few minutes after the seven o'clock news started on TV." Otherwise, the best one could hope for was to get information on the sequence of events: Did the wave hit before or after the big aftershock? If the interviewee said, "What aftershock?" it was presumed that the tsunami arrived at the same time or earlier, monopolizing the person's attention. (The aftershock, which was widely felt, occurred 20 minutes after the main shock and was actually two shocks--a 5.6 and a 5.9 within 30 seconds of each other.)

Just an average day in paradise. The house in the background is typical of local construction methods. The posts on which it rests are driven two or three feet into the ground. This photo is of a resettlement village built for the survivors from the Arop villages. In the foreground, USGS geologist Jocelyn Davies swims with some village kids.

The survey team noted many landslides on shore, and speculation arose that the tsunami might have been triggered by an offshore one. But the critical geology was under water, so the Papua New Guinea government issued an international request that a marine survey be done. It was a matter of some urgency--Papua New Guinea lies on an active subduction zone, where the Australian plate is riding up over oceanic crust. Earthquakes and their resulting landslides are frequent, so if the tsunami had in fact been triggered by a slide, were there other undiscovered hazards lurking offshore? Such programs usually take a year and a half to mount, but this one was organized in record time by close collaboration between the Japan Center for Marine Science and Technology (JAMSTEC), the South Pacific Applied Geoscience Commission (SOPAC), and the government of Papua New Guinea. The co-chief scientists were Takeshi Matsumoto of JAMSTEC and David Tappin of the British Geological Survey, acting for SOPAC. (If you're wondering why an Englishman from Nottingham was representing SOPAC, it's because Tappin has been a marine geologist for 27 years, 17 of them in the South Pacific, including a five-year stint as the chief geologist for the Kingdom of Tonga.) In December 1998, JAMSTEC's RV (research vessel, not recreational vehicle) *Kairei* arrived, carrying an international team of 22 scientists from assorted disciplines, to try to get to the bottom of things.

There have now been four cruises on different vessels, and a fifth is planned--the first time that an undersea earthquake has ever been studied so intensively. Still, you can imagine what a disadvantage seismologists working on, say, the Landers quake would have labored under if they had been confined to an airplane flying a mile overhead while trying to figure out how much and which way the fault moved, and what kind of material it cut through. And we have better maps of the moon, Mars, and Venus than we do of much of Earth's ocean bottoms, so there was precious little prequake data to go on. But the *Kairei*, a spanking new ship with state-of-the-art multibeam sonar arrays accurate to half a percent of the water depth, (10 meters in two kilometers of seawater), provided great post-quake data. Watts and several Japanese tectonic-source colleagues went along to provide modeling support. While the geologists were looking for faults and landslides, the modelers were compiling a comprehensive depth profile--bathymetry data, it's called--to feed into their various tsunami models.

A tsunami's height and arrival time are profoundly influenced by the water's depth. As the bottom shoals, the water piles up and the wave slows down, so an uneven seafloor will refract and reflect the wave, occasionally aiming it at a piece of shoreline like a lens focusing a searchlight's



Above: The slump model's predicted maximum wave heights in meters, time-averaged until just before impact. Waves are refracted toward shallow water and away from the deeps, so the shelf focuses the wave on Sissano, creating the large red region aimed at the lagoon. The Yalingi River canyon comes ashore at Malol and also steers the wave toward the lagoon, helping protect Malol, which was only partially destroyed.

beam. The depth at which the bottom begins steering the wave depends on its wavelength, so for wind-driven waves a few meters apart, only the shallows count. Tsunamis, however, have wavelengths of tens to hundreds of kilometers, so it's *all* shallow water to them--the midocean abyssal plains average about four kilometers deep. The *Kairei* discovered a shallow shelf and a submarine canyon that helped focus the wave's energy toward the lagoon, but this boost still left the tectonic models severalfold short of delivering the observed run-up.

To trace the tsunami's point of origin, you run the model backward, and Watts recalls that on one mapping leg "I realized we'd be passing over what seemed like the most promising site at about 1:00 a.m. So I got up and watched the bathymetry come in--a 3-D color image being plotted in real time on the control console. And suddenly, amid the geologically old features--rolling hillsides and ancient reefs covered in sediment--we had a very sharp, several-hundred-meter-high cut, which turned out to be the scar from a slump." The slump proved to be about four kilometers wide by five kilometers long. It's part of a much larger amphitheater some 10 kilometers wide, the sum of many slumps over the eons. "That tells us that this is a very vulnerable area," says Watts. "We know there's enough sediment to fail again at the next earthquake. This is an important observation. Should the people move back into their old village sites? And the answer is an emphatic *no!* This is a very dangerous chunk of shoreline."

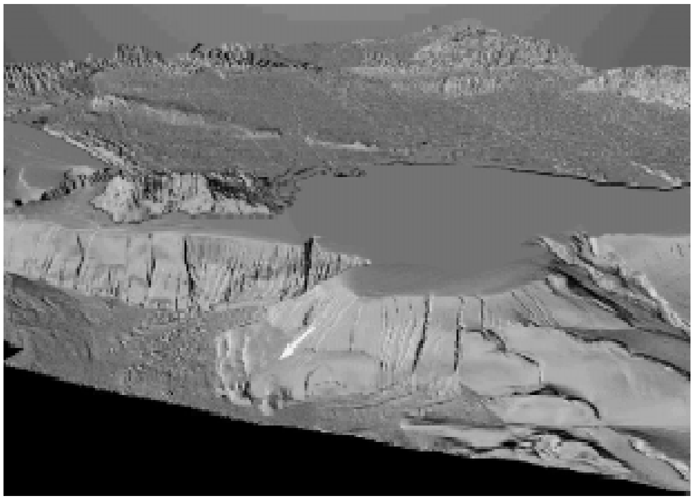
But what was down there? What kind of material gave way so catastrophically? All a dry-land geologist needs for sample collection is a rock hammer. But when your sample is at the wrong end of 1.5 kilometers of salt water, you need something more--in this case, a 10-meter length of pipe called a corer. Inside the pipe is a piston that starts out flush with the pipe's bottom end. The corer is lowered until the piston rests on the seafloor and a trip line releases the lead-weighted pipe, driving it down around the piston and cutting free a core. The effect is the same as sucking liquid into a straw, except that the straw moves instead of the liquid. The piston, now at the top of the pipe, acts like a thumb over the top of the straw and keeps the sample--even loose sand!--from falling out en route to the surface. And just to be sure, there's a "core catcher" at the end, which closes like the iris of a camera.

"And so on the fourth-to-last day of the science phase of the cruise Toshi Kanamatsu dropped our first core, and pulled out seven meters of really stiff clay. But all the models, including ours, assumed that underwater landslides were happening in a relatively thin layer of sand or silt. Sand moves. It's known to liquefy during earthquakes, and it's known to move hundreds of kilometers out onto the ocean floor when it lets go." In the nightly meeting of all the scientists to discuss the day's results, Tappin pointed out that clay would behave much differently. So upon returning Stateside, Watts asked soil mechanician Jean-Pierre Bardet (MS '79, PhD '84), now also a professor of civil and environmental engineering at USC, to describe clay's behavior mathematically.

Says Bardet, "These hydrodynamic tools, these models, do marvelous things, making waves go all across the ocean, but the initial motion all depends on the mechanics of the source, which the models don't consider. It's just assumed. But when you are dealing with a local secondary rupture, like a soil failure, it's a much broader venue." In other words, there are a lot more possibilities to consider--a wider range of material strengths, more different types of failure modes--than just the snapping of pressurized rock deep underground. So Bardet analyzed a typical clay's shear strength to determine how much force it would take to set the slump in motion and how it was likely to move once under way.

It turns out that stiff clay moves in a "slump," not a "landslide," and this semantic nicety is of utmost importance. "A slump is like a couch potato," Watts explains. "When the slump fails, its butt slides a little farther forward on the sofa cushion, and its head sinks a little lower."

That is, the slump's center of mass moves down and forward in a short arc. This motion is modeled by rotating a cylinder that lies on its side on the seabed like one of the fallen columns of Atlantis. The cylinder penetrates the hillside (shaded) to a depth equal to the maximum thickness of the slump, and the buried portion of the cylinder's curved surface is the failure plane along which the slump will



Above: At least three submarine landslides contributed to the arrowed region in this view of the seafloor south of Palos Verdes. The vertical scale is exaggerated tenfold. Unpublished composite image of high-resolution multibeam bathymetry courtesy of James V. Gardner, U.S. Geological Survey, Menlo Park, CA.

move. If you rotate the cylinder maybe six degrees, the embedded portion travels downslope a ways, and that's the slump. The degree and speed of the rotation, the diameter of the cylinder, and the depth to which it is embedded, all depend on the clay's shear strength.

Says Watts, "The key difference between a landslide and a slump is the center-of-mass motion. A slump starts and stops--if you plot position as a function of time, it accelerates, achieves some maximum velocity, and then decelerates. Whereas a landslide is like your umbrella getting whipped away by the wind and carried down the street--there's nothing to stop it. It experiences a relatively rapid acceleration, and then just keeps on going. *Nothing* stops a landslide."

In January 1999, another JAMSTEC ship, the RV *Natsushima*, took over. *Natsushima* carries an unmanned submersible named *Dolphin*, whose cameras confirmed that the clay was stiff--there were knife-sharp fractures in the clay deep and wide enough to stand in--and that the slump was fresh, because the chunks that had detached themselves from the headwall at the top of the slump and tumbled downslope had not yet accumulated a blanket of sediment. The *Dolphin* also visited the stretch of fault that the tectonic modelers favored, hoping to find similar evidence of fresh activity. Recalls Watts, "We got an hour of what looked like a helicopter ride through the snow-covered Alps. It was beautiful. It was stunning. Nobody moved, everything came to a halt. There were video monitors all over the place, and the ship was nothing but full of people staring in awe at these underwater mountains." But the snow was actually sediment, indicating that nothing had moved there in quite a while. Other *Dolphin* excursions found fresh faulting, but only off to the west, away from the tsunami's calculated point of origin. Says Tappin, "This is how mapping the seabed with multibeam bathymetry, and direct observations from remotely operated vehicles allow you to discriminate between tsunami source mechanisms."

A third cruise, sponsored by the National Science Foundation, took place in September 1999 (a more usual time lag for marine geology) aboard the Lamont-Doherty Earth Observatory's RV *Maurice Ewing*. On this voyage, seismic reflection studies by Eli Silver and Suzanne Sweet of UC Santa Cruz confirmed that the clay had moved cohesively, and gave the slump's maximum thickness as 700 meters. Reflection studies bounce shock waves (in this case, from an air gun) off the seabed and the sedimentary layers and fault planes that lie beneath it. The echoes are picked up by an array of hydrophones and processed by computer to give a cross-sectional view of the sea bottom.

But finding a fresh slump wasn't enough--did it cut loose at the right time? There were no undersea cables to sever--no smoking gun, in other words, but it turns out there *was* a gunshot. A U.S. Navy hydrophone near Wake Island, 3,600 kilometers away, picked up an unusual rumble at 7:42 p.m. Papua New Guinea time, or about 13 minutes after the quake, allowing 40 minutes for the sound to propagate through the ocean. The amphitheater proved to be a speaker pointing at Wake Island, which is a tiny pimple in the middle of the Pacific.

Seismologist Emile Okal (PhD '78), now a professor of geological sciences at Northwestern University, initiated the hunt for the vital recording. "I've been working with T waves for a long time, so when it became obvious that this event didn't fit any of the tectonic models, it was natural for me to look at the T-wave records. T waves provide sensitive detections of very faint sounds at extreme ranges: the Navy hunts subs, biologists listen to the love songs of whales, and geologists discover underwater volcanoes--I've found several, myself." T waves are trapped in a natural waveguide: as you go deeper, the pressure increases, which increases the speed of sound. But at the same time, the temperature decreases, which slows sound propagation, and the tug-of-war between the two means that there is some depth at which the speed bottoms out. Sounds entering this zone are trapped there, refracted back into it by the faster-conducting layers above and below. It's fiber optics for sound waves, basically. The depth of the SOFAR channel, as it's called, varies with latitude, but in the mid-Pacific it's about 600 to 1,800 meters down. At 1,500 meters, the slump lay at just the right depth to be heard.

Although the rumble coincided with an event listed as a magnitude 4.4 aftershock, it didn't look like any ordinary earthquake. Quake T waves fit a very standard pattern: they start abruptly and rapidly die off, with the signal's duration related to the earthquake's magnitude. A magnitude 4.5 aftershock at 7:40 lasted about 15 seconds; the 7:02 event went on for a good 45--almost as long as the main shock. And the 7:02 event gradually crescendoed, then even more slowly faded away--quite reasonable behavior for a slump that gathered momentum before petering out. When Okal did a spectral analysis--breaking down the signal to see how much energy was being carried at each frequency--things got even less earthquake-like. He explains, "Normally, you find the high frequencies, which correspond to fast energy release--ground motion at high velocity--at the beginning. But here, the frequency rose with time, indicating that the source was accelerating. The largest burst of energy is half-way through the signal, which is exactly what a slump does. Kanamori and Given first described this acceleration-peaking-deceleration behavior in their Mount St. Helens paper, and Kanamori and Hasegawa described it again later in their Grand Banks paper."

A couple of concrete slabs and a cistern are all that remain of the Arop No. 1 village church, now a makeshift graveyard.

Hydrophones are submerged buoys containing microphones, anchored to float in the SOFAR layer. They're complicated and expensive pieces of equipment, and most of them belong to the world's navies. Thus their data are routinely classified. (The Wake Island records had been declassified as part of the prototype monitoring system for the Comprehensive Nuclear Test-Ban Treaty, and were at that point directly accessible from a Web site.) Fortunately, when T waves hit shore, they become easily recorded seismic waves. Says Okal, "seismometers near the seacoast will pick them up, and even humans will if the waves are strong enough. The Alaskan Panhandle quake of 1958 and the Bolivian earthquake of '94 were both felt by people in Hawaii."

So Okal turned to T-wave seismograms from stations scattered around the Pacific, and found something else unusual--a station in Taiwan picked up the main shock loud and clear, but the 7:02 event didn't register. Taiwan is roughly perpendicular to the speaker's beam line, in the acoustic shadow of the amphitheater's western wall, and apparently was out of earshot. In fact, the 7:02 event's T waves only showed up at a handful of stations.

Intrigued, Okal then reexamined the actual seismic-wave (not T-wave) records for the 7:02 event. There weren't that many, because a magnitude 4.4 isn't that big, and there were very few seismic stations close enough to catch it. Even so, he says, "I've derived a location ellipse from those few records, and it includes the amphitheater. Here was the proof that some activity took place 13 minutes after the main shock, at the exact location of the slump mapped by the *Dolphin*."

Run-up modeler Synolakis says the survey team's field-work adds one final tidbit in support of the slump model. "For many years, it's been standard, in fact universal, to model tsunamis as leading elevation waves--the crest in front of the trough. People thought that leading depression waves, trough before crest, were hydrodynamically unstable. Everyone was looking at the effects of tsunamis far from their sources, and it was thought that leading depression waves wouldn't propagate that far. But the Nicaraguan tsunami of '92 showed that subduction zones can produce tectonic tsunamis with depression waves, and if you look at the coastal manifestation of a tsunami close to its source, they turn out to be quite important. The slump model automatically provides the sense of the leading wave, which in most cases turns out to be a depression wave." The slump creates a void behind itself that the water rushes into, so that if it's moving toward deeper water the depression wave points toward land. "So finally we have a model that corroborates eyewitness accounts. In every tsunami in the past eight years, people always say the sea withdrew first, and then the wave came. Before Papua New Guinea, we could only try to explain this in terms of tectonic tsunamis, but now we know why. Unfortunately, the model shows that if you put the trough first, you get double the run-up than if you put the crest first." Adds Watts, "The other thing is, you have a bit of warning. If you see the sea receding, get out and stay out!"

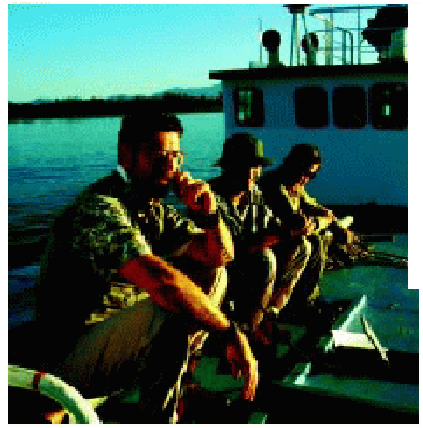
This last bit of knowledge is paying off, says Synolakis. Last December, another pocket tsunami wiped out the village of Bai Martele in Vanuatu, formerly the New Hebrides. "The wave was eight to nine meters high, and in a village of that size there could easily have been two or three hundred people killed. But only three people died. Why? The magic of television. They have no electricity, no water, no nothing, but last summer the Vanuatu authorities went around with a portable generator and a TV and a brand-new UNESCO video about volcanoes, earthquakes, and tsunamis. They showed it in every village. The video described the Papua New Guinea disaster and warned, 'If you feel the ground shaking, or you see the water receding, run for high ground!'

As it happened, the ground shaking in Vanuatu was not very strong, but they saw the water receding. There was a nearby hill, and they all ran up it. And stayed there. That's the big lesson--slumps can happen quite some time after the main shock, so we tell them to stay away for half an hour to an hour. It has happened in the past that a wave comes in and people run; then they return to look for loved ones or survey the damage, and they get hit by the second wave. Or the third wave. So for only three people to die in Bai Martele was amazing--spectacular! Of the people who died, two were very old, and the other one was high on kava, which is a local cognac. Of all the science we did, that was the best part. It really did save lives." A just-completed French bath-ymetric cruise has found a scarp off Bai Martele that has been interpreted as evidence for a landslide, but the jury is still out.

"This is a very exciting time," Synolakis says. "Tools developed over 40 years in diverse fields--classic long-wave theory, fluid mechanics, geophysics, soil science, oceanography, and seismology--are suddenly coming together. We have Fred Raichlen and his wave lab at Caltech to thank for this. He kept the field alive in the lean years of the '70s and '80s, when very few people were interested in tsunamis."

As you might have guessed by now, California is not immune to pocket tsunamis. We have as many faults offshore as onshore, and they're just as active. Says Watts, "The geology and seafloor mapping off California is pretty complete in several key places, including San Pedro and Santa Monica Bays, largely due to the oil industry and the ports. The evidence would suggest there was a slump off Santa Barbara about 100 to 150 years ago--it's hard to be sure when--and another one 10 kilometers farther east about 300 years ago. Both of these are about an order of magnitude smaller than the one off Papua New Guinea, but they would be tsunamigenic because they occurred in much shallower water--at 100 meters' depth, rather than 1.5 kilometers. There are also slumps off Palos Verdes. This is a huge point: Northridge had thousands of documented landslides; Vanuatu had 2,000 documented landslides following the earthquake, so it's not unreasonable to expect a number to occur underwater as well." In fact, Kuo-Fong Ma (PhD '93); postdoc Kenji Satake, now with the Geological Survey of Japan; and Kanamori found that the Loma Prieta earthquake of October 17, 1989, set off submarine landslides that created a small tsunami, 0.7 meters high, in Monterey Bay. The wave was recorded by tide gauges and, of all things, the video camera of a tourist who happened to pick that day to tape the sunset at Moss Landing.

As *E&S* was going to press, the Governor's Office of Emergency Services of the State of California was releas-



Left: In this day and age, you're never out of touch—Synolakis talks to colleagues in the National Oceanic and Atmospheric Administration in Seattle as José C. Borrero (center) and Okal look on.

ing the first-ever set of tsunami inundation maps for the most populous locales along the California coast, analogous to the earthquake-hazard maps previously released.* The maps, a joint effort with the Seismic Safety and State Lands Commissions, took two years to prepare. Synolakis, grad student José C. Borrero, and grad-student-turned-postdoc Utku Kanoglu did the modeling, which generated inundation scenarios for the San Diego, Los Angeles, and Santa Barbara areas, and from Half Moon Bay north to San Francisco. The flooding could be extensive, covering many low-lying areas and affecting port and harbor facilities, but there are other urban consequences. Paved surfaces don't dissipate wave energy, so roads become conduits. When the roads lead to underpasses, as they do in Santa Barbara where Highway 101 parallels the beach, you have a set of fire hoses aimed at downtown. And cars in beach-access parking lots become torpedoes. It's too late to unbuild along California's coastline, but knowing what's vulnerable and what will survive allows response teams to plan in advance how best to restore services and what kinds of relief supplies to bring in--you'll know where a railroad spur can be run over uneroded ground to bring in heavy cranes, for example, and you won't need so much diesel fuel if the tank farm is above the maximum run-up line. Issuing evacuation alerts is being considered as a means of saving lives--if the seismometers already affixed to offshore drilling platforms were tied into a computerized early-warning system, there could be about 10 minutes' notice of an incoming wave triggered by a slump in the Santa Barbara Channel. The best hope is to try to educate people not to hop in their cars and jam the freeways, but to simply run for high ground, including the upper floors of sturdy buildings. After all, the people on Vanuatu had even less warning, and if they could do the right thing, so can we.

* *Editor's note:* As of October 1, 2002, these maps were not publicly available.

IMPROVED ESTIMATES OF COASTAL POPULATION AND EXPOSURE TO HAZARDS RELEASED

by Robert J. Nicholls and Christopher Small

from: Eos (American Geophysical Union Transactions), v. 83, no. 28, 9 July 2002, p. 301, 305

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OBSERVATIONS OF TSUNAMI "SHADOWS:" A NEW TECHNIQUE FOR ASSESSING TSUNAMI WAVE HEIGHTS?

by Daniel A. Webster

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Abstract

A video recording made on Oahu's northeastern shoreline, as well as eyewitness observations along other coastal areas of the island, confirm the existence of a shadow-type phenomenon associated with a small tsunami from the 4 October 1994 Hokkaido earthquake. These observations suggest that tsunamis in the deep ocean might be detected and measured with optical devices in low-flying aircraft or satellites. Such measurements would be useful in improving the reliability of tsunami warning systems.

Introduction

The combined effects of a tsunami's propagation in the deep ocean, associated deformations of the ocean's surface, and ocean surface roughness might produce differences in the amount of radiant energy reflected or radiated towards an observer. These differences may be greatest when the energy reflected or radiated at or near the crest of a tsunami wave is compared to the light reflected or radiated from other portions of the wave, making it possible to see a darkened band moving over the ocean surface. A difference in reflected or radiated light has been observed in Hawaii for a small tsunami gener-ated by the 4 October 1994 earthquake near Hokkaido, Japan. The observed "shadowing" effect is associated with a wave height estimated to be only a few centimeters in water depths of about 2 km. [We recognize that the "shadow" is, more pre-cisely, an apparent band of low radiance which is not due to the existence of a shadow. However, for the sake of conveni-ence and consistency with its general perception, we will continue to refer to the phenomenon as a tsunami shadow.] This wave height estimate is based on the fact that there were no reported runups on the island of Oahu in excess of 60 cm. Areas on other islands in Hawaii which, based on historical data, might have been expected to have much higher runups than Oahu, also had no reported values in excess of 60 cm. Thus, an estimate of only a few centimeters in water depths of about 2 km seems reasonable.

The Tsunami Shadow

Evidence of a tsunami shadow is provided by a video recording made by an observer at Punaluu on Oahu's windward (northeastern) coast. The observer and her neighbors had heard the tsunami warning and moved from their coastal homes to an elevation of about 50 meters above sea level. The footage of the video recorder contains an imprint of the time in hours and minutes, as well as audio recordings of comments by neighbors of the observer. Local radio personalities who were broadcasting from Oahu's south shore (Honolulu) could also be heard in the background on a neighbor's radio. Comments on the radio indicate that about 12 minutes has to be added to the video time.

At the start of the video, a dark shadow appears on the ocean surface at the horizon extending across the entire field of view of the camera. The shadow is actually a uniformly wide band along the horizon which for some reason is not reflecting or radiating as much sun and sky light as the ocean surface in front of the shadow. Initially, there is no ocean behind the shadow, only sky. However, within a couple of minutes an ocean surface begins to appears behind the shadow which is similar in brightness to the ocean surface in front of the shadow, and the leading edge of the shadow has moved closer to the shoreline. As a few more tens of seconds elapse, the width of ocean appearing behind the shadow increases and the width of the ocean between the leading edge of the shadow and the shoreline decreases (Fig. 1). While the approaching shadow can be seen on the tape, we can also hear an evacuee say: "Look at that son-of-a-gun coming... Seven hundred miles an hour." Also, about four minutes after the shadow is first observed on the horizon, you can hear a local radio personality say: "It's already 10:44 and the wave was supposed to hit at 10:42."

Figure 1. The tsunami "shadow" can be seen just below the horizon and extends across the entire field of view of the camera. Approximately 12 minutes has to be added to the time indicated based on simultaneously recorded audio of a local radio station. The video was taken at an elevation of about 50 meters above sea-level.

As the shadow moved closer to the shore, the observers were so concerned for their safety that they turned off the camera in anticipation of possibly having to climb to even higher elevations. Because they were looking down on the ocean, they could not judge the height of the tsunami wave. But from their perspective, its size and speed was terrifying. Based on what they saw their concerns were understandable. Estimates of the speed based on the video recording (elapsed time and distance of travel) and water depth, suggest values in excess of 150 km/hr (i.e., 100 miles/hr). Also, the width of the shadow appears to have been 1 or 2 kilometers.

As it turned out, the observers did not have to move to even greater heights. Although the video was turned off, they noticed that the shadow came all the way inshore until it disappeared as it struck a shallow reef less than 1 km from the coastline. In the hour and half that the observers remained at the evacuation site, they noticed three other shadows which swept in from the horizon. They were narrower than the first and they were estimated to be at about 20 minute intervals. Other similar observations were made by other eyewitnesses at high elevations on Oahu's north shore and on Oahu's south shore. A summary of their testimony follows.

David Kinolau, Civil Defense Coordinator for District 5 of the City and County of Honolulu, and Craig Huish, A Civil Defense Area Captain, were on a bluff at an elevation of about 100 meters overlooking the ocean on Oahu's north shore. They noticed a dark ocean shadow moving towards shore. Its lead-ing edge was a straight line from left to right as far as the sha-dow could be seen. They did not recall noticing a trailing edge. As the leading edge moved towards shore, light green water changed to dark blue. As it continued to move towards shallower water the leading edge disappeared near the shoreline. Mr. Kinolau further noted that as the leading edge disappeared, it remained in a straight line and the light green water ahead of the edge began to form a series of small waves with white crests which washed onto the shoreline.

Susan Kennedy was in her Honolulu apartment building at an elevation of about 80 meters. She was looking in the direction of Ala Moana Park, a southwest facing shoreline, at the time, that the tsunami was supposed to arrive and noticed an unusual shadow near the horizon. What was unusual was that the normal ocean was behind it, its leading edge and trailing edges appeared to be straight lines parallel to the horizon, and it extended as far to the left and to the right as the ocean could be seen. She noticed that there were no clouds. She watched it with binoculars for about 30 seconds. She had been looking at the ocean a few minutes earlier and had not seen the shadow.

Ian Walters was at home at an elevation of about 60 m on Oahu's south shore east of Diamond Head on 4 October. He was on the phone talking to a friend in the late morning when an unusually shadow appeared out of nowhere. It extended to the left and to the right as far as the ocean could be seen. It had straight leading and trailing edges that appeared to be parallel to the horizon. It disappeared when it struck the reef, about 500 to 1000 meters offshore.

Discussion

With a wavelength of many tens of kilometers, what was seen on the video and by other eyewitnesses was only a small portion of the tsunami's wavetrain. It is not yet known whether the shadow was produced by a portion of its crest, its trough, or its face In the following, some of the factors which may be associated with this phenome-non are discussed.

In reality the ocean's surface is never perfectly smooth. The "silvery" appearance of portions of the ocean's surface is usually a result of reflections from roughness surfaces appropriately oriented relative to an observer. The effect of ocean surface roughness on observed reflected intensities will depend on the nature of that roughness. Roughness can range in wavelenth from millimeters to kilometers, encompassing small wind-driven wavelets to ripples to ocean swells and tsunamis. Roughness is seldom, if ever, totally random because it is produced by a variety of non-random forcing functions (e.g., currents, winds, storms, and earthquakes).

Considering reflected energy, whether a rougher or smoother ocean will reflect more energy will depend on the relative locations of the sun and the observer, as well as the nature of the ocean surface roughness. Considering radiated (i.e., unreflected) energy, ocean surface roughness could also affect the amount of energy available for scattering and absorption within the body of the ocean, as well as the amount radiated directly from surface particles.

The crest of a deep-ocean tsunami is the highest point of a deformed ocean transmitting energy along the sea-air interface at speeds of hundreds of kilometers per hour. Water particle motions at the sea-air interface associated with these high transmission rates could serve to increase ocean surface roughness, especially at the crest where the compressive forces of adjacent particles due to gravity are at a minimum. Whether such changes in roughness could be easily observed by an individual is questionable because of the long wavelengths of tsunamis. However, interactions of receding and incoming waves could produce steeper, short period waves in which changes in roughness might be more readily apparent to an observer. Like large ocean swells, such tsunami waves could then be seen out in the ocean before they strike coastal areas. [Updrafting air currents can also change the surface roughness of wave faces and contribute to optical differences which permit their identification].

Increasing of ocean surface roughness by water particle motions along portions of a tsunami's wavetrain could be perceived as a shadow. We speculate that the tsunami shadow observed in Hawaii for the 4 October 1994 tsunami may have been produced by an increase in ocean surface roughness which lowered the amount of skylight reflected toward the observer from the ocean's surface along the crest of the tsunami. Other explanations also associated with water particle motions, at or below the surface, may be possible (e.g., absorption or scattering effects). Numerical modelling of tsunamigenically induced water particle motions on ocean surface roughness, reflectivity, and radiation could be useful in evaluating such speculative interpretations.

Such modelling is required for computations of radiance transfer functions for rough ocean surfaces (e.g., Preisendorfer and Mobley, 1986; Mobley, 1989; Gordon and Wang, 1992; Mobley, 1994). In addition to all the complexities associated with these simulations, "tsunami shadow" modelling would require consideration of the water particle motions associated with the transmission of tsunamigenic energy at rates of up to 220 m/sec. Indeed. differences in the characteristics of these motions at different points of inflection along the wavetrain may provide important clues in the determination of the physics involved in these observations. Further insights regarding the possible nature of the "shadow" are provided by C. D. Mobley (author of *Light and Water*, 1994), who upon viewing the video provided the following commentary (personal communication, 3 March 1995).

> "I found the video fascinating. I think that the shadow phenomenon is almost entirely due to a steepening of capillary wave facets on the water surface, induced by the tsunami wave. If the capillary waves steepen, then an observer looking at a nearly horizontal line of sight (as is the case here) will see reflected light from higher in the sky than is the case for less steep capillary wave slopes. This is the same thing you seen when a gust of wind makes a "cat's paw" on the water surface. On a clear day, the cat's paw appears darker than the undisturbed water because it is reflecting a deeper-blue sky light. It is well known that internal waves can induce small changes in capillary wave slopes, which make the internal waves visible at the sea surface alternating "slick" and "rough" bands. I see no reason that tsunamis could not do the same thing. On the other hand, I cannot imagine that a tsunami could change the inherent optical properties of the water itself in any significant way. In other words, I think the effect shown on the video is purely one of sky light being reflected differently by the sea surface as the tsunami passes by."

Implications

Differences may not be restricted to sunlit (or moonlit) ocean surfaces. Even at night there may be differences in the photon count that could be measured with sophisticated optical devices. However, lines of sight that are nearly horizontal to the ocean's surface may be required. The singular importance of the 4 October 1994 tsunami shadow is that it was produced by such a small amplitude in relatively deep water. Destructive Pacific-wide tsunamis could have simi-lar amplitudes in the deep-ocean, and the width of their shadows could be directly dependent on the tsunami's deep-ocean amplitude. Also, a tsunami's destructive po-tential is directly related to its deep-ocean amplitude. Therefore, it might be possible for low-flying aircraft or appropriately located satellites, to track the tsunami out in the deep-ocean and provide estimates of its destructive potential well in advance of its arrival in populated coas-tal areas.

Considering the cost of false warnings in terms of inconvenience, disruptions of the economy, and the potential erosion of credibility in the warning system as well as other government agencies, with consequential losses of life, further investigations should be undertaken to evaluate the potential of deep-ocean "shadows" as possible indicators of tsunamigenic potential.

Acknowledgments

Awareness of this phenomenon for such a small tsunami might not have been possible without the video recording of Dolores Martinez. We thank Merlyn Pickering for advising us of the existence of this video and we thank Dolores Martinez for sharing her observations with us. We also thank Craig Huish, Susan Kennedy, David Kinolau, and Ian Walters for supplying independent confirmation of similar observations elsewhere on Oahu. The comments and suggestions of Curt Mobley, who reviewed the draft of this paper, are also greatly appreciated and may be of critical importance in understanding the phenomenon. This is SOEST Contribution 4075 and Hawaii Institute of Geophysics and Planetology Contribution 880.

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Preisendorfer, R. W.; Mobley, C.D., 1986, Albedos and glitter patterns of a wind-roughened sea surface: Journal of Physical Oceanography, v. 16, no. 7, p. 1293-1316.

Pacific Tsunami Museum
130 Kamehameha Avenue
Hilo, Hawaii 96720
www.tsunami.com

The Tsunami Museum is located in a building formerly occupied by the Bishop National Bank and then the First Hawaiian Bank. The fact that it survived both the 1946 and 1960 tsunamis that devastated old downtown Hilo makes it also serve as a memorial. The museum is a new one, having only opened in 1998, but there are plenty of exhibits to make it worth a visit for any geoscience teacher. The statistics of the two big tsunamis that struck Hilo, in 1946 and 1960, are impressive enough, but the many photographs are what really stun visitors with the power of these gigantic waves. Especially touching is the story of the waves that destroyed the Laupahoehoe Drive Elementary School in 1946, killing 24 young students, who are memorialized in the museum. A hydrographic chart made before the 1946 tsunami and map of downtown Hilo show the area that was wiped out by that tsunami. The products of several tsunami essay contests held in the local schools are kept in notebooks available for inspection. There is also information about other destructive tsunamis in other areas. The ocean science center has several computer terminals. There is a splash model on which visitors can generate small waves. NOAA's Deep Ocean Tsunami Measuring Program is the subject of one display. Video films are available for watching at the museum as well.

A few doors away from the Tsunami Museum, the old art-deco Kress Building, a former dime store which the local people hope to see develop into a small mall, now [May 2002] has an exhibit of photographs of local eruptions, quakes, and tsunamis, too.

from: Journal of Geoscience Education, v. 50, no. 3, p. 341

WSSPC Awards in Excellence
2002 Award Recipients
Presented at the WSSPC Annual Conference
September 17, 2002
http://www.wsspc.org/award/2002/index02.htm

Awarded Category: **Overall Excellence in Mitigation**
Program Name: **Washington State Seismic Series for Schools: "Terry the Turtle and Gracie the Wonder Dog**

Recipient for Overall Excellence
Administering Agency: Washington Military Department, Emergency Management Division

Awarded Category: **Mitigation Efforts**
Program Name: **Mitigation of Fault Related Hazards**
Administering Agency: Clark County Building Department and Nevada Bureau of Mines and Geology

Awarded Category: **Educational Outreach to General Public - 2 Winners:**
Program Name: **WSSPC Tsunami Web Site**
Administering Agency: British Columbia Provincial Emergency Program, B.C.
Program Name: **Earthquakes in Wyoming, video**
Administering Agency: University of Wyoming Television/Wyoming State Geological Survey

Awarded Category**: Educational Outreach to Schools**
Program Name: **Nevada Educational Seismic Network**
Administering Agency: Nevada Earthquake Safety Council and Nevada Public Agency Insurance Pool

CALENDAR OF HISTORIC TSUNAMI EVENTS

Oct. 17, 1989 Loma Prieta, CA earthquake
selected photos: http://geopubs.wr.usgs.gov/dds/dds-29/
history of the 1989 quake: http://www.sfmuseum.org/1906/89.html
details: http://www.seismo.berkeley.edu/seismo/faq/1989_0.html

Oct. 18, 1935 Helena, MT earthquake
selected images: http://nisee.berkeley.edu/montana/montana_images.html
data: http://nisee.berkeley.edu/montana/montana.html

Nov. 1, 1755 Lisbon, Portugal earthquake and tsunami
see TsuInfo Alert, v. 2, no. 4, August 2000
http://nisee.berkeley.edu/lisbon/
new article: http://www.science.soton.ac.uk/science_news/current_issue/index.php?link=article.php&article=13

Dec. 16, 1811 New Madrid, MO earthquake (1 of 3)
http://neic.usgs.gov/neis/new_madrid/new_madrid.html
http://hsv.com/genlintr/newmadrd/
http://hsv.com/genlintr/newmadrd/accnt2.htm
Watch for more details on the New Madrid in the December 2002 issue!

John Powers of Butte, Montana, contributed this cartoon to inspire the people of Helena to meet their problems as their ancestors did during previous disasters. [Published in the Helena Independent newspaper 10/24/1935]

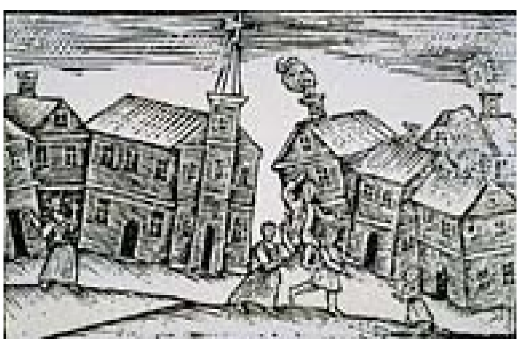
1935 Helena, Montana earthquake series: magnitude 6 1/4

from: http://www.seis.utah.edu/lqthreat/nehrp_htm/1935hele/c1935he6.shtml

Sketch by John Powers of Butte, MT
and published in
The Helena Independent on October 24, 1935.

A depiction of "the Great Earthquake of Lisbon" published in the *Illustrated London News* on March 30th, 1850 is shown above. This is a highly inaccurate depiction of the event but serves to illustrate how the disaster, which had happened nearly a hundred years before, still lived in the memory of Europeans.

from: Images of Historical Earthquakes - The Jan T. Kozak Collection; *National Information Service for Earthquake Engineering University of California, Berkeley*; http://nisee.berkeley.edu/kozak/
see *TsuInfo Alert*, v. 2, no. 4, August 2000http://nisee.berkeley.edu/lisbon/
new article: http://www.science.soton.ac.uk/science_news/current_issue/ index.php?link=article.php&article=13



Houses and church leaning, people outside in panic. Image was used to illustrate a religious tract. (Woodcut, American, mid-18th c.) Boston, Massachusetts

from: Images of Historical Earthquakes - The Jan T. Kozak Collection; *National Information Service for Earthquake Engineering University of California, Berkeley*; http://nisee.berkeley.edu/kozak/

"Tsunamis and Tsunami-like Waves of the Eastern United States"

Science of Tsunami Hazards (The International Journal of The Tsunami Society) published a Special Tsunami Data Issue, volume 20, number 3. It contains two articles, "Tsunamis and Tsunami-like Waves of the Eastern United States" and "The Tsunami History of Guam: 1849-1993." Links to the articles can be found online at http://www.sthjournal.org/ sth2.htm.

2002 Hazards Workshop Summaries Available On-Line

In many ways, September 11 changed the way research-ers, practitioners, and others interested in hazards and disas-ters view the world. In many ways it did not. As hazards professionals from around the world gathered in Boulder, Colorado, in July, to participate in the *27th Annual Hazards Research and Applications Workshop*, discussions focused on how the lessons of the past help inform our future and whether terrorism should usurp our long-standing concern with hazard mitigation.

To ensure that the ideas and discussions generated are shared with those who did not attend the workshop, the Natural Hazards Center publishes brief summaries of each session, abstracts of the hazards research presented, and descriptions of the projects and programs discussed at the meeting.

Currently, the list of all session summaries, along with complete ordering information, is available on-line at http://www.colorado.edu/hazards/ss/ss.html. In the near future, the complete text of all session summaries, poster sessions, and abstracts will also be available.

from: Disaster Research 373, August 30, 2002

Where Do We Go From Here?

The United Nations has recently completed an on-line preliminary version of "*Living with Risk*," a review of disaster reduction initiatives around the world. Sponsored by the Inter-Agency Secretariat of the International Strategy for Disaster Reduction (ISDR), the 400-page study presents lessons learned by experts and communities responding to natural hazards such as volcanoes, fires, hurricanes, tsunamis, landslides and tornadoes, along with technological accidents and environmental degradation. It is a road map for a better world, looking at the past to help us learn to live with our environment, rather than at risk from its natural forces. Such a challenge, however, is daunting: in the last decade, 4,777 natural disasters have taken more than 880,000 lives, affected the homes, health and livelihoods of almost 2 billion people around the world and inflicted approximately $687 billion in global economic losses.

The publication builds upon the UN's International Decade for Natural Disaster Reduction, which ended in 1999, to look at traditional solutions that have protected communities against flood, windstorm, or drought as well as the ways in which creative thinking and improved communication have actually begun to save lives and build hope for developing countries. The report also examines the intricate links between economic development and environmental insecurity.

The preliminary version of this book is available on-line in PDF format at: http://www.unisdr.org/unisdr/Globalreport.htm. For more information about the preliminary version, contact: Helena Molin Valdes at the ISDR Secretariat; e-mail: molinvaldes@un.org.

from: Disaster Research 372, August 16, 2002

FEMA Releases HAZUS User Group Guide

The HAZUS User Group guide released by the Federal Emergency Management Agency, FEMA 404, is intended to assist the diverse members of a HAZUS group not only in using the HAZUS methodology, but in developing the purpose, communication, structure, and goals a HAZUS group needs to assess and mitigate natural disaster risks and losses.

The 45-page guide uses step by step directions, templates and examples of existing groups to illustrate not only how to begin a group, but also how to develop the group's vision, gain support from its members' organizations, sustain the initial impetus, arrange HAZUS training and keep the group motivated from meeting to meeting. A key concept is the leadership and goal visualization that develops dedication and communication within the group.

Meeting planning and resources are also key covered points, and a comprehensive index of resources for both the public and private sector members is included.

The FEMA HAZUS user group guide is available via the FEMA website (www.fema.gov/hazus) and HAZUS website (www.hazus.org) where it can be viewed online or downloaded as a 34 page PDF file.

from: EQ, Summer 2002, p. 18

TSUNAMI PIZZA

(Editors' note: We include this recipe in an attempt to report everything related to tsunamis. The recipe was found, thusly named, on the Internet. Tsunami Pizza is the recommended accompaniment to an evening with the "Tsunami Tsongbook"; see TsuInfo Alert, **v. 3, no. 3, p. 11-12**.)

Ingredients for 4 Servings:

1 tablespoon peanut oil
1 teaspoon chopped garlic
6 ounces medium shrimp, tails off
1/4 cup sushi sauce
1 Boboli-style ready-to-use pizza crust
3 ounces shredded mozzarella cheese
3 ounces shredded Swiss cheese
chopped fresh cilantro, for garnish

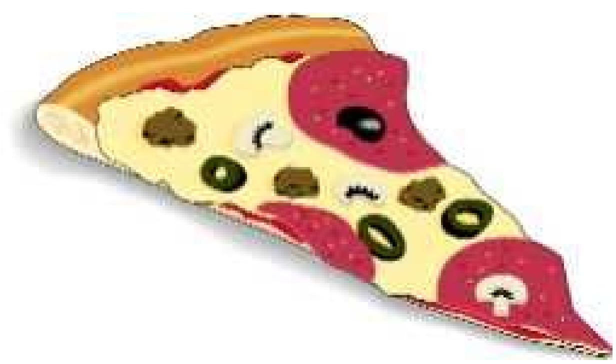
Directions:

Heat peanut oil in a wok or skillet over high heat. Add garlic and shrimp and stir-fry until shrimp is pink and just cooked through. Add 1 teaspoon sushi sauce and cook 1 additional minute. Remove from pan and set aside.

Spread remaining sushi sauce evenly over pizza crust to within 1" of edge. Sprinkle the cheeses over the sauce; spoon cooked shrimp over cheese.

Bake pizza according to package directions. Garnish with chopped cilantro and serve immediately.

Chicken may be substituted for shrimp; cut into small pieces before stir-frying.



(Editors' note: To wash down the Tsunami Pizza, may we recommend--)

Pelican Tsunami Stout
Pelican Pub & Brewery
Oregon, USA
stout, foreign style
(*from*: http://www.beeradvocate.com/beer/rate_results/1304/3704/)

Review:
22oz. bottle. Room temperature. Opaque dark mahogany. Fat, sticky, foamy and dense espresso head. Very light carbonation. Heavenly aroma of dry roasted malts, barley and light coffee. Very earthy. Medium thick body. Dry and immensely roasted and deep with dark malt flavors. Acidic black malt twang and barley smoothness. Tsunami is a good name for the wall of flavors about to descend on your palate. Light yeasty aroma and aftertaste develops. Long malt finish and aftertaste with barley the dominant essence. This is so good I want to bathe in it. Light grassy hop taste emerges long after the swallow. Hard to believe but this is getting thicker towards mid-bottle. This has so much body and girth for a dry stout, and it is dry with zero notes of caramel or chocolate. Finishes with an upturn in hoppy bitterness and faint anise flavoring. Finally a deserving medal winner at the GABF. This is world class. A brew to leave you speechless, circumlocution not necessary.

serving type: bottle

Ratings: (5 = best)

appearance: 5
smell: 4.5
taste: 4.5
mouthfeel: 4.5
drinkability: 5

October 26, 2002

Combined Emergency Services Seminar Committee 24th Annual Seminar: "Victoria--Are You Prepared?" MFESB Training College, 619 Victoria St., Abbotsford, Victoria, Canada. Contact Bob Wardzynski, Registrar, PO Box 52, Briar Hill, Vic. 3088. Tel: (03) 9432 5300; Fax: (03) 9432 3656; e-mail: cessi@omega.au.com; www.cess.au.com

One-day presentation on various aspects of the above theme. The conference, as always, is designed for hands-on people and planners in the emergency management field.

from: EMA, The Australian Journal of Emergency Management, v. 17, no. 2, p. 64.

November 13-15, 2002

Disaster Preparedness and Emergency Response Association International (DERA), Annual Meeting and Workshop. **This meeting is re-scheduled from August 22-23, 2002.** Denver, Colorado.

The agenda includes a full day of optional field exercises, briefings on national infrastructure preparedness, and a variety of issue panels. For more information, e-mail: dera @disasters.org; http://www.disasters.org/workshop.htm.

from: Disaster Research 372, August 16, 2002

January 6-9, 2003

Coastal GeoTools 2003. Host: National Oceanic and Atmospheric Administration and Coastal Services Center Charleston, South Carolina.

Possible focus areas of this meeting include hazard mitigation, land use and community development, remote sensing, watershed planning, and other hazard-related topics. For more information, contact Mark Jansen, NOAA Coastal Services Center, 2234 South Hobson Avenue, Charleston, SC 29405-2413; (843) 740-1200; e-mail: geo.tools@noaa.gov; http://www.csc.noaa.gov/GeoTools.

from: Natural Hazards Observer, v. 27, no. 1, p. 14

February 23-26, 2003

International Disaster Recovery Association (IDRA) Annual Meeting. Providence, Rhode Island. The theme for the 13th annual conference is "readiness, resilience, recovery, and reassessment," and all topics focus on telecom contingency planning. For more information, contact IDRA (508) 845-6000; e-mail: 2003@idra.com.

from: Disaster Research 372, August 16, 2002

March 25-28, 2003

Contingency Planning and Management CPM 2003 conference. Venetian Resort & Hotel, Las Vegas, NV

April 21-23, 2003

Disaster Resistant California Conference. Host: Governor's Office of Emergency Services and the Collaborative for Disaster Mitigation, San Jose, CA.

This statewide conference will promote partnerships among public and private sectors to reduce state vulnerability to natural disasters. For more information, view the California OES web site at http://www.oes.ca.gov, or call the Disaster Resistant California information line (916) 845-8263.

July 13 - 18, 2003

Cities on Volcanoes 3 Conference. Host: County and State of Hawaii and the International Association of Vulcanology and Chemistry of the Earth's Interior. Hilo, Hawaii

This is the third international meeting to bring together emergency managers, volcanologists, educators, sociologists, psychologists, economists and city planners to re-eval-uate volcanic crisis preparedness and management in cities and densely populated areas. For more information, contact Andrea Furuli; (808) 974-7555; e-mail: cov3@hawaii.edu; or see http://www.uhh.hawaii.edu/~cov3.

August 10-13, 2003

Advancing Mitigation Technologies and Disaster Response. The Westin, Long Beach, CA. http://www.asce.org/conferences/tclee2003/

The Technical Council on Lifeline Earthquake Engineering (TCLEE) is pleased to announce TCLEE 2003, the Sixth U.S. Conference and Workshop on Lifeline Earthquake Engineering. Don't miss this opportunity to join specialists from all disciplines in the field and around the world to discuss what has been learned, to see the latest trends and developments, and to understand how developments in lifeline earthquake engineering can reduce losses from other technological hazards.

on-going

Another Certificate Course in Emergency Management

The University of Missouri Extension is developing a certificate program in emergency management. The Fire and Rescue Training Institute (FRTI) is developing this program of study, which is focused on adult professional continuing education. This certificate program will provide students with advanced education and applied skills in all aspects of emergency management. The awarding of this certificate will not be contingent upon earning a degree. FRTI also announces that they have developed an additional core course within the Contemporary Emergency Management Professional Certificate Program, which begins this fall (2002).

from: Disaster Research 372, August 16, 2002

WEBSITES

http://thomas.loc.gov/cgi-bin/bdquery/z?d107:s.02778

For the status of S.2778, the Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriation FY 2003 bill, check this website. The Tsunami Hazard Mitigation Program is funded by this bill.

www.nlm.nih.gov/medlineplus (use the search engine and keyword "disaster")

The U.S. National Library of Medicine has created a new web site on disasters and emergency medicine. The site contains links to many publications and web sites on specific types of disasters---volcanoes, floods and hurricanes, for example---and on coping with disasters. This site on disasters is part of the NLM's MEDLINEplus, which also offers pages on infectious diseases in general and other health topics.

from: Disasters Preparedness and Mitigation in the Americas, July 2002, issue no. 88, p. 3

http://earthobservatory.nasa.gov/NaturalHazards
http://earthobservatory.nasa.gov/Newsroom

The National Aeronautics and Space Administration (NASA) maintains an "Earth Observatory" web site on its "Natural Hazards" page that provides a map of the world with icons that indicate where natural disasters have occurred. Simply click on an icon to view the latest information about that particular calamity. The site provides information regarding dust and smoke, fires, floods, severe storms, and volcanoes. The "Newsroom" page offers breaking news, recent stories, and images about current hazards and other terrestrial phenomena studied by NASA.

from: Natural Hazards Observer, Sept. 2002

http://muweb.millersville.edu/~isarcdue

Unscheduled Events, the quarterly newsletter of the International Research Committee on Disasters of the International Sociological Association, is now available on-line. Besides news regarding what is going on in disaster sociology, the newsletter contains interesting editorials, articles, abstracts, and links to other recent sociological studies and resources available on the web.

from: Natural Hazards Observer, Sept. 2002

http://www.shoa.cl/oceano/itic/text_eng.html

ITIC has created a tsunami textbook webpage. The textbooks for tsunami education "are divided into four levels. Pre-Elementary, 2nd to 4th grade, 5th to 8th grade and High School. These levels correspond to the school levels found in Chile: the first level is similar to pre and kindergarten, the second and third level correspond to the first eight years of school and the fourth level to High School. Each text book has its own teacher guide. Note: the high school textbook (originally one book) has been divided into 5 chapters to facilitate downloading." The downloadable files (pdf) are further divided into Student's textbooks and Teacher's guidebooks.

http://earthquake.usgs.gov

Lisa Wald with the USGS in Pasadena announced that the Earthquake Hazards Program has launched this upgraded website featuring new near-real-time ANSS (Advanced National Seismic System) Recent U.S. Earthquakes maps. The new maps present earthquake information for the U.S., usually within minutes after an earthquake. The site has been extensively reorganized to make information on U.S. earthquake activity more accessible and quicker to download. The information provided by seismic networks around the country, some operated by the USGS and many others located at universities. All contributing networks are members of the ANSS, a consortium dedicated to improving the earthquake detection infrastructure in the U.S. over the next decade. *from:* EQ, Summer 2002, p. 4.

http://www.ibhs.org/additional_programs/

The IBHS Catastrophe Paid Loss Database is a one-of-a-kind tool containing information compiled from individual claim losses supplied by IBHS's insurer members. These claims are identified as losses pertaining to a particular nat-ural disaster designated by the Property Claims Service. This database is now automated, and helps to provide in-sightful loss trends to members, building code officials, emergency managers, land use planners, engineers, and others involved with making buildings more disaster resis-tant. *from:* EQ, Summer 2002, p. 14.

http://www.ngdc.noaa.gov/seg/fliers/se-0801.shtml

Natural Hazard Photographs---NGDC collects post-disaster photographs of geologic hazards for the development of educational slide sets. The sets depict the characteristics and effects of hazards such as earthquakes, volcanoes, landslides, and tsunamis. There are now 46 sets in the collection that are available online, as 35-mm slides, and on CD-ROM. Several new slide sets are being developed.

from: EQ, Summer 2002, p. 16

http://www.all-hands.net/pn/index.php

All-Hands.net is a new virtual community of emergency managers and business continuity professionals. It is designed as a user-supported community, and all of the site's content is provided by members and participants. The site is designed so that users can post articles, share files, and communicate with others. To register, interested persons should submit a membership request form available on the site.

from: Disaster Research 375, September 27

NEW TSUNAMI MATERIALS ADDED TO THE LIBRARY

August 1 to September 30, 2002

General/Popular Works

U.S. National Oceanographic and Atmospheric Administration; and others, 2002, Tsunami--The great waves; rev. ed.:U.S. National Oceanographic and Atmospheric Administration, 16 p.

Alaska

Abers, G. A.; Ekstrom, Goran, 1991, Seismically active faulting along the Bering shelf edge [abstract]: Eos (American Geophysical Union Transactions, v. 72, no. 17, p. 268.

Blackford, M. E., 1981, Tsunami potential of seismic gaps in the Aleutian-Alaska arc [abstract]: Eos (American Geophysical Union Transactions, v. 62, no. 45, p. 945.

González, F. I.; Kulikov, Ye. A., 1993, Tsunami dispersion observed in the deep ocean. *In* Tinti, Stefano, editor, Tsunamis in the world--Fifteenth International Tsunami Symposium, 1991: Kluwer Academic Publishers Advances in Natural and Technological Hazards Research 1, p. 7-16.

Hansen, R. A.; Kowalik, Zygmunt; Suleimani, E. N., 1999, Tsunami inundation mapping for Alaska communities [abstract]. *In* European Geophysical Society, EGS XXVI General Assembly, Nice, France, 25-30 March 1999; [Session NH8--Tsunamis; Abstracts]: European Geophysical Society, [1 p. unpaginated]. (Accessed Sept. 24, 2002 at http://www.copernicus.org/EGS/egsga/nice01/program/NH8..oral.htm)

Kienle, Juergen; Beget, J. E.; Kowalik, Zygmunt; Troshina, Elena, 1995, Volcanogenic tsunamis in Cook Inlet, Alaska [abstract]: International Union of Geodesy and Geophysics, General Assembly, 21st, Abstracts, p. 338.

Kienle, Juergen; Kowalik, Zygmunt; Troshina, Elena, 1996, Propagation and runup of tsunami waves generated by Mt. St. Augustine volcano, Alaska: Science of Tsunami Hazards, v. 14, no. 3, p. 191-206. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

Kowalik, Zygmunt; Troshina, Elena, 1995, Propagation and runup modeling of tsunamis generated by edifice collapse of Mt. St. Augustine volcano, Alaska [abstract]: International Union of Geodesy and Geophysics, General Assembly, 21st, Abstracts, p. 335.

Kowalik, Zygmunt; Troshina, Elena, 1997, Tsunami waves generated by Mt. St. Augustine volcano, Alaska [abstract]: Eos (American Geophysical Union Transactions), v. 78, no. 17, Supplement, p. S56.

Medbery, A. H.; Urban, G. W.; Whitmore, P. M.; Sokolowski, T. J., 2002, Remote operation of the West Coast and Alaska Tsunami Warning Center: Science of Tsunami Hazards, v. 20, no. 4, p. 216-221. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

Pinsker, L. M., 2002, Mapping tsunami risk in Alaska: Geotimes, v. 47, no. 8, p. 36-37.

Suleimani, E. N.; Hansen, R. A.; Combellick, R. A.; Carver, G. A.; Kamphaus, R. A.; Newman, J. C.; Venturato, A. J., 2002, Tsunami hazard maps of the Kodiak area, Alaska: Alaska Division of Geological and Geophysical Survey Report of Investigations 2002-1, 16 p., 4 plates. (Accessed Sept. 24, 2002 at http://-wwwdggs.dnr.state.ak.us/scan1/ri/text/RI2002-01.PDF)

U.S. Geological Survey, 1989, Commemorating the 25th anniversary of the great Alaskan earthquake: Earthquakes and Volcanoes, v. 21, no. 4, p. 136-144.

Atlantic Coast

Lockridge, P. A.; Whiteside, L. S.; Lander, J. F., 2002, Tsunamis and tsunami-like waves of the eastern United States: Science of Tsunami Hazards, v. 20, no. 3, p. 120-148. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

California

Aalto, K. R.; Garrison Laney, C. E., 1998, Sculpturing of Pebble Beach wave-cut platform, Crescent City, CA [abstract]: Geological Society of America Abstracts with Programs, v. 30, no. 5, p. 1.

Abramson, H. F.; Garrison Laney, C. E., 1998, Evidence for earthquakes and tsunamis during the last 3500 years from Lagoon Creek--A coastal freshwater marsh, northern California [abstract]: Geological Society of America Abstracts with Programs, v. 30, no. 5, p. 2.

Alfors, J. T.; Burnett, J. L.; Gay, T. E., Jr., 1973, Urban geology, master plan for California: California Division of Mines and Geology Bulletin 198, 112 p.

California Geology, 1977, Tsunamis: California Geology, v. 30, no. 4, p. 88-89.

California Geology, 1995, Tsunami warning!: California Geology, v. 48, no. 2, p. 54-55.

Coons, Peggy, 1995, Crescent City's destructive horror of 1964: Oregon Geology, v. 57, no. 6, p. 123-124.

Dengler, L. A.; Moley, Kathy, 1995, Living on shaky ground--How to survive earthquakes and tsunamis on the North Coast: Humboldt State University, 24 p.

Dengler, L. A.; Moley, Kathy; McPherson, R. C.; Pasyanos, Michael; Dewey, J. W.; Murray, M. H., 1995, The September 1, 1994, Mendocino fault earthquake: California Geology, v. 48, no. 2, p. 43-53.

Sandoval, F. J.; Farreras, S. F., 1993, On tsunami resonance of the Gulf of California. *In* Tinti, Stefano, editor, Tsunamis in the world--Fifteenth International Tsunami Symposium, 1991: Kluwer Academic Publishers Advances in Natural and Technological Hazards Research 1, p. 107-119.

Synolakis, C. E.; McCarthy, Dick; Titov, V. V.; Borrero, J. C., 1997, Evaluating the tsunami risk in California. *In* Magoon, O. T.; Converse, Hugh; and others, editors, California and the world ocean '97 conference proceedings: American Society of Civil Engineers, v. 2, p. 1225-1236.

Hawaii

Blackford, M. E.; Furumoto, A. S., 1997, Statistical method to forecast tsunami heights at Hilo and Honolulu for tsunamis from certain subduction zones [abstract]: Geological Society of America Abstracts with Programs, v. 29, no. 5, p. 4.

Fryer, G. J., 1996, Hawaiian tsunamis and small submarine landslides [abstract]: Eos (American Geophysical Union Transactions, v. 77, no. 46, Supplement, p. 511.

Jones, A. T.; Mader, C. L., 1995, Modeling of tsunami propagation directed at wave erosion on southeastern Australia coast 105,000 years ago: Science of Tsunami Hazards, v. 13, no. 1, p. 45-52. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

LeBlond, P. H.; Jones, A. T., 1995, Underwater landslides ineffective at tsunami generation: Science of Tsunami Hazards, v. 13, no. 1, p. 25-26. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

Science of Tsunami Hazards, 1995, The story of Laupahoehoe: Science of Tsunami Hazards, v. 13, no. 1, p. 60-61. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

Walker, D. A.; Cessaro, R. A., 2002, Locally generated tsunamis in Hawaii--A low cost, real time warning system with world wide applications: Science of Tsunami Hazards, v. 20, no. 4, p. 177- 186. (Accessed Sept. 25, 2002 at http://epubs.lanl.gov/tsunami/)

Oregon

Beaulieu, J. D., 1976, Geologic hazards in Oregon: Ore Bin, v. 38, no. 5, p. 67-83.

Washington

Karlin, R. E.; Ichinose, G. A., 1999, Tsunami flooding hazards generated by scenario earthquakes in the Puget Sound, Washington: University of Nevada, Reno Department of Geological Sciences, 4 p. (Accessed Sept. 19, 2002 at http://www.seismo.unr.edu/htdocs/WGB/PugetSound/)

Walsh, T. J.; Myers, E. P., III; Baptista, A. M., 2002, Tsunami inundation map of the Port Townsend, Washington area: Washington Division of Geology and Earth Resources Open File Report 2002-2, 1 sheet, scale 1:24,000.

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New!! **___Earthquake…Drop, Cover & Hold**; Washington Emergency Management Division. 1998. 5 min.
New!!___**Tsunami Evacuation PSA**; DIS Interactive Technologies for WA Emergency Management Division. 2000. 30 seconds.
___**Cascadia: The Hidden Fire - An Earthquake Survival Guide;** Global Net Productions, 2001. 9.5 minutes. A promo for a documentary about the Cascadia subduction zone and the preparedness its existence demands of Alaska, Oregon and Washington states. Includes mention of tsunamis. (The full documentary is scheduled for broadcasting on a PBS station in April 2002.)
___**Not Business as Usual: Emergency Planning for Small Businesses,** sponsored by CREW (Cascadia Regional Earthquake Workgroup), 2001. 10 min. Discusses disaster preparedness and business continuity. Although it was made for Utah, the multi-hazard issues remain valid for everyone. Websites are included at the end of the video for further information and for the source of a manual for emergency preparedness for businesses.
___**Adventures of Disaster Dudes** (14 min.)
Preparedness for pre-teens
___The Alaska Earthquake, 1964 (20 min.)
Includes data on the tsunamis generated by that event
___**Cannon Beach Fire District Community Warning System** (COWS) (21 min.) Explains why Cannon Beach chose their particular system
___**Disasters are Preventable** (22 min.)
Ways to reduce losses from various kinds of disasters through preparedness and prevention.
___Disaster Mitigation Campaign (15 min.)
American Red Cross; 2000 TV spots. Hurricanes, high winds, floods, earthquakes
___**Forum: Earthquakes & Tsunamis** (2 hrs.)
CVTV-23, Vancouver, WA (January 24, 2000). 2 lectures: Brian Atwater describes the detective work and sources of information about the Jan. 1700 Cascadia earthquake and tsunami; Walter C. Dudley talks about Hawaiian tsunamis and the development of warning systems.
___**Killer Wave: Power of the Tsunami** (60 min.)
National Geographic video.
___Mitigation: Making Families and Communities Safer (13 min.) American Red Cross
___**Numerical Model Aonae Tsunami - 7-12-93** (animation by Dr. Vasily Titov) and **Tsunami Early Warning** by Glenn Farley, KING 5 News (The Glenn Farley portion cannot be rebroadcast.)
___The Prediction Problem (58 min.)
Episode 3 of the PBS series "Fire on the Rim." Explores earthquakes and tsunamis around the Pacific Rim
___**Protecting Our Kids from Disasters** (15 min.)
Gives good instructions to help parents and volunteers make effective but low-cost, non-structural changes to child care facilities, in preparation for natural disasters. The Institute provides a booklet to use with the video. Does NOT address problems specifically caused by tsunamis.

___**The Quake Hunters** (45 min.)
A good mystery story, explaining how a 300-year old Cascadia earthquake was finally dated by finding records in Japan about a rogue tsunami in January 1700

___**Raging Planet; Tidal Wave** (50 min.) Produced for the Discovery Channel in 1997, this video shows a Japanese city that builds walls against tsunamis, talks with scientists about tsunami prediction, and has incredible survival stories.

___**Raging Sea: KGMB-TV Tsunami Special**. (23.5 min.)
Aired 4-17-99, discussing tsunami preparedness in Hawaii.

___**The Restless Planet** (60 min.) An episode of "Savage Earth" series. About earthquakes, with examples from Japan, Mexico, and the 1989 Loma Prieta earthquake in California.

___**Tsunami and Earthquake Video** (60 min.)
Includes "Tsunami: How Occur, How Protect," "Learning from Earthquakes," and "Computer modeling of alternative source scenarios."

___ **Tsunami: Killer Wave, Born of Fire** (10 min.)
NOAA/PMEL. Features tsunami destruction and fires on Oku-shiri Island, Japan; good graphics, explanations, and safety information. Narrated by Dr. Eddie Bernard, (with Japanese subtitles).

___**Tsunami: Surviving the Killer Waves** (13 min.)
Two versions, one with breaks inserted for discussion time.

___**Tsunami Warning** (17 min.)
San Mateo (California) Operational Area Office of Emergency Services. This is a good public service program, specifically made for San Mateo County. Citizens are told what to do in cases of tsunami watches or tsunami warnings, with specific inundation zones identified for the expected 20-foot tall tsuna-mi. An evacuation checklist is provided, as well as locations of safe evacuation sites. This video gives the impression that all tsunamis are teletsunamis (generated at a source more than 1000 km from the coastline) which therefore provide time for warnings. Locally-generated tsunamis are not discussed.

___**USGS Earthquake Videotapes "Pacific Northwest"**
USGS Open-File Report 94-179-E

___**Understanding Volcanic Hazards** (25 min.)
Includes information about volcano-induced tsunamis and landslides.

___**The Wave: a Japanese Folktale** (9 min.) Animated film to help start discussions of tsunami preparedness for children.

___**Waves of Destruction** (60 min.) An episode of the "Savage Earth" series. Tsunamis around the Pacific Rim.

___**Who Wants to be Disaster Smart?** (9 min.)
Washington Military Department/Emergency Management Division. 2000. A game show format, along the lines of *Who Wants to be a Millionaire*?, for teens. Questions cover a range of different hazards.

___**The Wild Sea: Enjoy It...Safely** (7 min.)
Produced by the Ocean Shores (Washington) Interpretive Center, this video deals with beach safety, including tsunamis.

Check the title(s) you would like and indicate the date of your program. The video(s) will be mailed one week before the program date.

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