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Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System

TSUNAMI NEWSLETTER

International Tsunami Information Centre

TABLE OF CONTENTS

EXERCISE PACIFIC WAVE '11 (PACWAVE11) - A PACIFIC WIDE TSUNAMI EXERCISE

In response to the 2004 Indian Ocean Tsunami that killed nearly 230,000 people across the Indian Ocean, the ICG/PTWS acted to organize the first international tsunami exercise with the goal of evaluating the readiness of the PTWS in order to identify how to improve its effectiveness. The first Pacific-wide exercise, "Exercise Pacific Wave 06" (EPW06), was carried out in May of 2006. In 2008, the ICG/PTWS conducted its second exercise to establish such exercises as part of the routine work of maintaining the PTWS.

At its Twenty-Third Session held in February 2009 in Apia, Samoa, the ICG/PTWS recommended a third Pacific-wide tsunami exercise, Exercise Pacific Wave '10 (PacWave10). However, on 29 September 2009, just over seven months after the ICG/PTWS-XXIII, Samoa, American Samoa and Tonga were hit by a deadly tsunami. Altogether, 192 lives were lost. This was followed five months later by the 27 February 2010 Chile tsunami where 124 lives were lost. One year later on 11 March 2011 Japan was impacted by a devastating local tsunami that claimed over 18,000 lives. As a result, the exercise was postponed in order to evaluate and consider its goals and outcomes in the aftermath of the 2010 Chile and then 2011 Japan tsunami.

Accordingly, Exercise Pacific Wave '11 (PacWave11) was conducted on 9/10 November 2011, to focus on responding to a regional or local tsunami where warning and emergency response must be very quick and actionable, and where pre-event preparedness

Continued on pg. 2

SUMMARY OF EARTHQUAKES
1 OCTOBER - 31 DECEMBER 2011
Reported by: International Tsunami Warning Centres
Compiled by: International Tsunami Information Centre, ITIC

Advisories issued by international tsunami warning centres. The Pacific Tsunami Warning Center (P) issues: Tsunami Information Bulletins (TIB), Fixed and Expanding Regional Warnings (FRW, ERW), and Ocean-wide or Widespread Watch/Warnings (TWW) for the Pacific; Tsunami Information Bulletins (TIB), Local, Regional, and Ocean-wide Tsunami Watches (LTW, RTW, TW) for the Indian Ocean (IO); Tsunami Information Statements (TIS), Local, Regional, and Ocean-wide Watches (LTW, RTW, TW) for the wider Caribbean (C). The Japan Meteorological Agency (J), issues: Tsunami Advisories (NWPTA) for the Northwestern Pacific; Tsunami Watch Information (TWI) for the Indian Ocean. The West Coast/Alaska Tsunami Warning Center (A) issues: Tsunami Information Statements (TIS), Tsunami Advisories (TA), Tsunami Watch/Warnings (TWW) for Canada, the US (including Puerto Rico, excluding Hawaii and US-affiliated Pacific Island countries), and the US/British Virgin Islands. Depth (from GCMT solution), epicentre and M_w from the USGS (G), and M_w from PTWC, WC/ATWC, and JMA at action time. Other earthquakes with M_w greater than or equal to 6.5 and a depth no greater than 100 km, as recorded by USGS, have also been included. Wave height and period measurements from sea level gauges (g) reported as amplitude (amp), peak to trough, or greatest value for either flow depth (fd) or runup (r) as indicated.

DATE	TIME (UTC)	LOCATION	EPICENTER	DEPTH (km)	M_w	PTWC (P), JMA (J) or WC/ATWC (A) ACTION	ACTION TIME (UTC)	TSUNAMI? DAMAGING?	MAXIMUM MEASUREMENT and LOCATION
21-Oct	17:57	Kermadec Islands Region	28.998° S 176.183° W	49.1	7.3 (A, P) 7.4 (G)	(P) 01 TIB (A) 01 TIS (P) 02 TIB	18:07 18:08 18:44	YES NO	14 cm Raoul Island, Alaska
28-Oct	18:55	Near Coast of Peru	14.515° S 76.009 ° W	25.9	6.9 (A, G, P)	(P) 01 TIB (A) 01 TIS	19:02 19:03	NO NO	
1-Nov	12:32	Revilla Gigedo Islands Region	19.891° N 109.216° W	17.7	6.5 (A, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS	12:41 12:42	NO NO	
8-Nov	02:59	Northwest of Taiwan	27.291° N 125.868° E	230.7	6.8 (A, J, P) 6.9 (G)	(P) 01 TIB (J) 01 NWPTA (A) 01 TIS	03:06 03:06 03:07	NO NO	
14-Nov	04:05	Southern Molucca Sea	0.954° S 126.864° E	12.4	6.6 (A, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS	04:12 04:14	NO NO	
22-Nov	18:48	Central Bolivia	15.359° S 65.125° W	557.4	6.7 (A, P) 6.6 (G)	(P) 01 TIB (A) 01 TIS	18:58 18:59	NO NO	
11-Dec	01:47	Guerrero, Mexico	18.038° N 99.796° W	58.9	6.8 (A, P) 6.5 (G)	(P) 01 TIB (A) 01 TIS	01:53 01:56	NO NO	
14-Dec	05:05	Eastern New Guinea Region, PNG	7.518° S 146.767° E	134.4	7.3 (A, P) 7.1 (G)	(P) 01 TIB (A) 01 TIS	05:12 05:13	NO NO	

Exercise Pacific Wave '11, *continued*

and education are essential so that the public can and will act immediately to save their lives.

PacWave11 also included the introduction of new international tsunami products proposed by PTWC and approved by the Twenty-forth session of the ICG/PTWS (May, 2011) for implementation in 2014. The new products will provide guidance on the levels of threat along coastal segments using real-time tsunami wave forecasts, and are expected to greatly reduce the number of areas that heretofore have been unnecessarily warned. A total of 35 countries participated in the exercise. This Summary Report is based on 50 Post-Exercise Evaluation Forms received from the countries and their jurisdictions.

The overwhelming majority of responding countries expressed a positive view of PacWave11 planning and conduct. PacWave11 objectives were exercised, evaluated and reported, thus enabling PTWS

Exercise Pacific Wave '11, *continued*

recommendations and lessons learned to be formulated that were consistent with the PTWS Medium Term Strategy. PacWave11 contributed to the improvement and development of planning relating to country public warning and response.

Countries also generally understood the PTWC experimental products and viewed them as adding important advice to guide them in providing more accurate national warnings. PacWave11 provided valuable feedback from countries on proposed PTWC new products. Future tsunami exercises should continue to reinforce the integration of PTWC experimental products, where useful, in their country decision-making processes, and in their standard operating procedures (SOPs).

One of the PTWS's major areas of immediate concern is that many coastal communities still do not have evacuation maps identified by pre-disaster planning processes, and/or they do not have reliable and robust public alert communications "down to the last kilometer on the beach." A local / regional tsunami requires rapid enabling of end-to-end tsunami warning and emergency response SOPs with delegated authority to 24/7 national / local response organizations to enact public evacuations if necessary. As part of pre-disaster planning, countries are encouraged to develop and/ or strengthen their tsunami response procedures, continue staff training, and conduct regular exercises at the national and local levels to build the capacity and commitment to sustain high levels of tsunami readiness.

Additionally, however, an important lesson learned from the recent deadly tsunamis has been that coastal communities should not solely depend on the timely receipt of official local tsunami warnings. For PacWave13, it took on average 11.2 minutes for the National Emergency Center to receive a message from the National Tsunami Warning Center. If a public evacuation announcement immediately follows, it will likely be before the tsunami wave hits, but just barely. This not-enough-time factor means that individuals themselves must be able to recognize tsunami natural warning signs and voluntarily self evacuate. In other words, public awareness and education must remain the front line of preparedness for local tsunamis. Therefore, those countries with local tsunami threats are strongly encouraged to commit the necessary resources tto ensure their popluations are educated.

Finally, as in the past, countries are reminded to regularly review and confirm their 7 x 24 Tsunami Warning Focal Point contact data to the IOC, as TWFP contact information needs to be 100% accurate, 100% of the time.

Chile residents and schools participating in the PacWave 11. Photo courtesy of SHOA.

Exercise Pacific Wave '11 - Country Participation

Exercise info as provided by countries prior to PacWave11.
Scenarios: Kamchatka (Kuril-Kamchatka Trench), Ryukyu Islands (Nansei-Shoto Trench), Philippines - South China Sea (Manila Trench), Philippines - Pacific Ocean (Philippines Trench), Vanuatu (New Hebrides Trench), Tonga (Tonga Trench), Chile (Peru-Chile Trench), Colombia-Ecuador (Colombia – Ecuador Trench), Central America (Middle America Trench), Aleutian Islands (Aleutian Trench)

Country	Participation (Yes/No)	Scenario	Type of Exercise (Orientation, Drill, Tabletop, Functional, Full-scale)	Agencies Involved, Exercise Plan	Point of Contact
Australia	YES	Vanuatu (New Hebrides Trench)	Functional	Eastern states and one offshore territory of Australia will participate (Queensland, New South Wales, Victoria, Tasmania and Norfolk Island). JATWC, State Emergency Services, Police Force in Queensland and Tasmania and the National Crisis Co-rdination Centre (Attorney General's Department in the national capital city)	Rick Bailey, Don Anderson (Bureau of Meteorology)
Brunei Darussalam	YES	Manila Trench	Orientation	Meteorological Service, Department of Civil Aviation, Natural Disaster Management Centre.	Hj Sidup Hj Sirabaha (Meteorological Service)
Canada	NO			British Colombia participated to US PACIFEX tsunami exercise, March 2011	Denis D'Amours, Canadian Hydrographic Service, Fisheries and Oceans Canada
Cambodia	NO				
China	YES	Manila Trench	Full-scale	NMEFC, local governments, 300 villagers and students evacuated to safe places in what was expected to be the worst-hit city, Huizhou, Guangdong Province	Fujiang Yu (Deputy Director, National Marine Environmental Forecasting Center, State Oceanic Administration)
China - Hong Kong	YES	Manila Trench	Tabletop	30 govt organizations	HY Mok (Hong Kong Observatory)
China - Macau	NO			planning exercise next year	Ivan Leong (Chief Seismological Monitoring, Meteorological and Geophysical Bureau)
China - Taiwan	NO				Wei-Sen Li (National Science and Technology Center for Disaster Reduction); Central Weather Bureau
Colombia	YES	not provided in advance, but will not be Colombia-Ecuador Trench (local)	Drill - multi-institution	TWFP will not communicate the chosen scenario beforehand. Coastal communities have been educated to react to prolongued strong shaking ('alerta personal'). All institutions between TWFP and last local (Tumaco) level before actual public warning to participate, e.g., institutions represented in 'Comité Técnico Nacional de Alerta de Tsunami' representing main communications path between TWFP, National Risk Management Authority, regional and local risk mgmt committees. Full institutional warning communication procedure to be tested.	Hansjürgen Meyer (OSSO, El Observatorio Sismológico y Geofísico del Suroccidente)
Chile	YES	Chile	Full-scale	NTWC (SHOA), Natl Seismological Service, NDMO (Onemi), population. Compressed time (2 hours). Expect limited communications (only VHF / satellite comms), no electricity(generators used). NDMO to send TWC Mercalli intensity report, Seismological service inform on hypcenter, and bulletin issued). Following, NDMO evacuation in Tarapacá region. TWCand NDMO to continue issuing information. Will have exercise conductor, evaluators, pre exercise (nov 7), briefings, hot-debriefing, press and authorities pressure (simulated), press coverage, etc.	Nicolas Guzman, Miguel Vasquez (SHOA, Servicio Hidrográfico y Oceanográfico de la Armada de Chile)
Cook Islands	YES	Tonga	Full-scale - Functional	Will run exercise 1 hr earlier to accommdate schools and govt depts. Some evacuation processes to be implemented by schools and government departments. 6 sirens that are in place witll be sounded.	Arona Ngari (Meteorological Service) William Tuivaga (Emergency Management)

Exercise Pacific Wave '11, *continued*

Costa Rica	NO				Information per Bernardo Aliaga, ICG/PTWS Technical Secretary
Democratic People's Republic of Korea	NO				
Ecuador	YES	Colombia-Ecuador	Full-scale	INOCAR (focal point), Risk National Secretary (Risk and Emergency Agency), Esmeraldas Municipality (Gubernamental city)	Patricia Arreaga, Edwin Pinto (INOCAR, Instituto Oceanografico de la Armada)
El Salvador	YES	Colombia-Ecuador	Functional	Techinal office (SNET, Tsunami Focal Point), National Civil Defense office, Local Civil Defense offices in coastal sites previously selected	Jeniffer Larreynaga, Francisco Gavidia (SNET, Servicio Nacional de Estudios Territoriales)
Federated States of Micronesia - Chuuk	YES	Philippines - Pacific Ocean	Tabletop	At a minimum, WSO, DCO, Police, Fire, Health, Environment offices	Johannes Berndon (Weather Service Office)
Federated States of Micronesia - Kosrae	YES	Philippines - Pacific Ocean	Tabletop	At a minimum, WSO, DCO, Police, Fire, Health, Environment offices	Lipar George (Disaster Coordination Office)
Federated States of Micronesia - Pohnpei	YES	Philippines - Pacific Ocean	Tabletop	At a minimum, WSO, DCO, Police, Fire, Health, Environment offices	Eden Skilling (Weather Service Office)
Federated States of Micronesia - Yap	YES	Philippines - Pacific Ocean	Functional	Stakeholders that will be involved are as follows: Disasters Control Office (DCO), Public Safety, Public Health, Public Transportation System/Sea Transportation, Red Cross, Media	Kensley Ikosia (Disaster Coordination Office), David Aranug (Weather Service Office)
Fiji	YES	Tonga	Full-scale	Schools tsunami evacuation mock drill to take place	Sefa Sefanaia (Mineral Resources Department)
France - French Polynesia	YES	Aleutian Trench	Tabletop	Civil Defense headquarters, CPPT (Centre Polynésien de Prévention des Tsunamis)	Dominique Reymond (CPPT, Centre Polynésien de Prévention des Tsunamis)
France -	NO				
New Caledonia					
France - Wallis & Futuna	NO				Benjamin Gerard, Chef des Services du Cabinet du Préfet, Chargé de communication du Préfet, Administrateur Supérieur des îles Wallis et Futuna
Guatemala	YES	Colombia-Ecuador	Tabletop	INSIVUMEH and CONRED (Coordinadora para la reducción de Desastres en Guatemala)	Victoria Cáceres (Departamento de Geofísica, INSIVUMEH, Instituto Nacional de Sismologia, Vulcanologia, Meteorologia y Hidrologia)
Honduras	NO				Juan Jose Reyes (SAT COPECO, Permanent Commission for Emergencies)
Indonesia	YES	Manila Trench	Tabletop / Functional	BMKG (NTWC); recently participated as Regional Tsunami Service Provider to Indian Ocean Wave (12 Oct 2011)	Suhardjono (BMKG, adan Meteorologi, Klimatologi, dan Geofisika)
Japan - JMA NWPTAC	YES	4 scenarios	Functional	Northwest Pacific Tsunami Advisory Center to issue messages for 4 scenarios	Takeshi Koizumi (JMA, Japan Meterological Agency)
Kiribati	NO	Vanuatu	Orientation	Kiribati Met Service, Disaster Risk Management Office, 1st-ever tsunami exercise planned, but did not carry out	T Ueneta ((Meteorological Service)
Malaysia	YES	Manila Trench	Full-scale	2 drills at Kudat (Sabah) and Labuan involving Disaster Agencies at Federal, State and District Levels. At Kudat, town community will be involved whereas at Labuan, 3 villages will evacuate.	Mohd Rosaidi Che Abas, Irene Eu Swee Neo (Meteorological Department)
Marshall Islands	YES	Philippines - Pacific Ocean	Tabletop	At a minimum, WSO, NDMO, Police, Fire, Health, Environment offices	Reggie White (Weather Service Office)
Mexico	YES	Central America	Functional	Not Known	Juan Carlos Orantes Zenteno (Civil Protection)

Exercise Pacific Wave '11, *continued*

Nauru	NO	Vanuatu	Tabletop	Met, Police, Nauru Rehab, Transport Dept, Fire service, NDRMC; exercise planned, but did not carry out	Roy Harris (Nauru Govt)
New Zealand	YES	Vanuatu	Tabletop	Large number of organisations involved, including Civil Defence Groups, Health, Police, Fire, Maritime, Welfare agencies, GNS Science	David Coetzee, Jo Guard (Ministry of Civil Defense and Emergency Management)
Nicaragua	YES	Colombia-Ecuador, Central America	Tabletop	Civil Defense, Sinapred, INETER coordinated exercise; govermental staff and communities organizations along Pacific Coast, to rejarce or test the radio comunications.	Alejandro Rodríguez Alvarado - Executive Director, Emilio Talavera - Sismology Director, Angélica Munoz (INETER, El Instituto Nicaragüense de Estudios Territoriales)
Niue	YES	Tonga	Functional	Police, Telecom, Met, Education, Health and Broadcasting/Television	Sionetasi Pulehetoa (Meteorological Service) Mark Chenery (Police Dept)
Palau	NO	Philippines - Pacific Ocean	Limited Tabletop (originally Functional)	Due to Presidential Declaration No. 11-05, Declaration of a State of Emergency, regarding a catastrophic fire at the Aimeliik Power Plant which completely destroyed at least one generator and all of the controls for the facility, Natl Emergency Committeer (NEC) decided to do exercise early next year to test our own communications and SOPs (originally planned participatnts WSO Koror, NEMO, Education, Bureau of Public Safety (BPS))	Maria Ngemaes (Weather Service Office)
Panama	YES	Colombia-Ecuador	Tabletop	Instituto de Geociencias de la Universidad de Panama received FAX messages and developed communication tests (radio) with the Sistema Nacional de Proteccion Civil (SINAPROC-PANAMA). SINAPROC was busy with inundation emergencies. Geociencias developed estimation of impact from the chosen scenario	Luque Nestor (University of Panama Institute of Geosciences)
Papua New Guinea	YES	Philippines - Pacific Ocean	Functional	PNG National Disaster Center with colleagues at the provinces, Port Moresby Geophysical Observatory, Provincial Authorities , LLG and Ward members, Police and other line agencies, NWS	Chris McKee, Mathew Moihoi (Port Moresby Geophysical Observatory)
Peru	YES	Chile	Drill - Full-scale	Civil Defense, All Naval Stations near coast, National Port Authority, Terminal Maritime Port and Geophysical Institute IGP. For DHN, will use all communication system (iridium, radio VHF, HF, fax, local telephone), monitoring system, and software to estimate arrival wave. Each naval station will simulate the evacuation of their buildings. Recommended to Civil Defense to evacuate population in the south of Perú , because the wave arrival time, will be 130 hours later.	Atilio Aste, Lorena Marquez, Javier Tejada (DHN, Dirección de Hidrografía y Navegación)
Philippines	YES	Philippines - Pacific Ocean	Functional	The Office of Civil Defense and its regional offices will participate. The National Mapping Resource and Information Authority (NAMRIA) may participate. Early next year, the Philippines intend to do a full-scale exercise using the Manila Trench scenario.	Renato Solidum, Ishmael Narag (PHIVOLCS, Philippine Institute of Volcanology and Seismology)
Republic of Korea	YES	Ryukyu Islands	Drill	KMA (Korea Meteorological Administration), NEMA (National Emergency Management Agency), Local goverment.	Yonghae Oh, (Earthquake monitoring Division, Korea Meteorological Agency)
Russian Federation	YES	Kamchatka	Full-scale - Functional	All members of the Russian tsunami Warning Service	Tanya Ivelskaya (Sakhalin Tsunami Warning Center)

Exercise Pacific Wave '11, *continued*

Samoa	YES	Tonga	Full-scale	NTWC, DAC, Villages of Mutiatele, Malaela, Poutasi, Faleu-tai and Satupaitea district (Vaega, Mosula, Pitonuu and Satufia	Filomena Nelson (DMO, (Meteorological Division)
Singapore	YES	Manila Trench	Drill - Comms	just participated to IOWave with 15-govt agencies Table Top	Patricia Ee, Lesley Choo (NEA, National Environmental Agency)
Solomon Islands	YES	Colombia-Ecuador	Functional	Met, NDMO, Media, Telekom, Nat. Referral Hospital, NDC, N-DOC, N-DOC Clusters, PDC, P-DOC and P-DOC Clusters. This includes the involvement of from the National, Provincial and Community Level.	David Hirisia (Meteorological Service), Loti Yates (National Disaster Center)
Thailand	YES	Manila Trench	Functional	NDWC	Capt. Song Ekmahachai, Burin Wechbunthung (National Disaster Warning Center)
Tokelau	NO			Recently conducted Cyclone exercise	from David Coetzee (NZ MCDEM)
Tonga	YES	Tonga	Functional	Met, NEMO, GSU, Media, Members of NEMC	Ofa Fa'anunu (Meteorological Service
Tuvalu	YES	Vanuatu	Drill; Functional	Met Office, Disaster Office, Outer0island Met Offices; NDC, Media, TTC, Police, Red Cross, PWD, TEC, Marine, Aviation, IDCs, Schools, Hospitals	Tauala Katea, Hilia Vavae (Meteorological Service)
UK - Pitcairn Islands	NO				
USA - PTWC, WC/ATWC	YES	All 10 scenarios; Aleutians	Functional	PTWC to issue messages for 10 scenarios; WC/ATWC to issue messages for 1 scenario	Charles McCreery (Pacific Tsunami Warning Center), Paul Whitmore (West Coast and Alaska Tsunami Warning Center)
USA - American Samoa	YES	Tonga	Functional - full-scale	NWS Pago Pago (lead), TEMCO/ASDHS, EAS Committee, Department of Public Safety(DPS), Department of Educaton (DOE), Star Kist, Territorial Agency for Old Age. EAS / sirens activated. 3 schools (east, central, west), StarKist tuna factory to participate with evacuation. T.V / radio media blitz to increase awareness. Businesses encouraged to get involved. Government agencies asked to review Emergency Plans. Some villages may participate.	Mase Akapo (National Weather Service Pago Pago) Faletoa Ulufale (AS Dept of Homeland Security)
USA - Guam	YES	Philippines - Pacific Ocean	Tabletop	Will activate EOC which includes about 30 response agencies	Chip Guard (Weather Forecast Office Guam), Edeine Camacho (Office of Civil Defense)
USA - Northern Mariana Islands	YES	Philippines - Pacific Ocean	Tabletop	Will activate EOC which includes about 20 response agencies	Juan Camacho (Emergency Management Office)
Vanuatu	YES	Vanuatu	Full-scale	VMGD (Meteo, Geohazards), NDMO, Education, Health, TRR, and media/VBTC	Jotham Napat (Meteorological Service), Esline Garaebiti ((Meteorological Service, Geohazards)
Vietnam	YES	Not known	Not known	Not Known	Le Huy Minh, Deputy Director, Nguyen Hong Phuong, TWFP, Institute of Geophysics, Vietnam Academy of Science and Technology

Exercise Pacific Wave '11 Country Reports

Chilean Institutions Working Together for a Better Tsunami System

by Miguel Vásquez, ITIC Associate Director

Chile National Tsunami Warning Center partaking in the tsunami simulation and sending out tsunami alerts. Photo couretesy of SHOA.

During the PACWAVE11, the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA), the National Emergency Office from the Interior Ministry (ONEMI), and the National Seismic Service (SSN) worked together in a worst case local tsunami scenario.

Having in mind the instruction from PTWC and ITIC related to the exercise, SHOA as a National Tsunami Contact, prepared for an earthquake magnitude 9 with simulated ground shaking close to the Chile central region and near the National Tsunami Warning Center. Emergency communication and backup systems were exercised.

At the same time, the coastal region affected was evacuated to higher altitudes, just 3 minutes after the earthquake and independent of the warning. Seismic preliminary information arrived just a few minutes later. Thus, Chile seriously managed the potential of a tsunami on their coast, with new detection capabilities and educating the people. This country was severely damage during past tsunami events in 2010 (Chile Tsunami) and 2011 (Japan Tsunami).

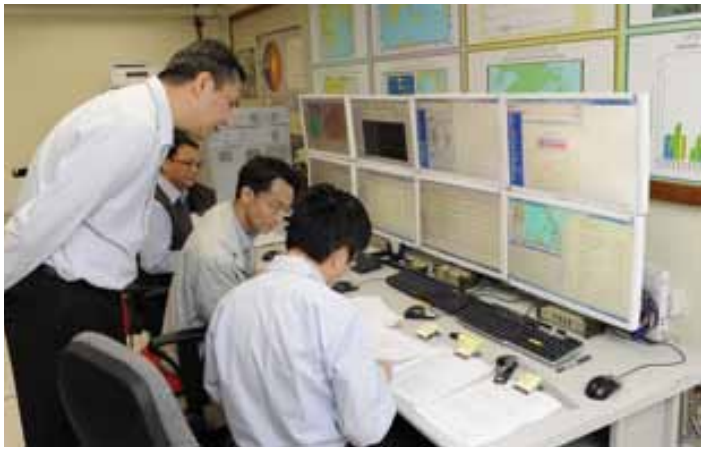
During this exercise, new and improved elements were used such as the recently installed tide gage stations, which transmit every 5 minutes or less monitoring constantly the sea level from the north to south of the country. Additionally, communications with ONEMI were tested in backup mode to warn the population. SHOA will continue leading tsunami exercises in Chile in order to improve protocols and actions required to mitigate the effects of the tsunami. Thus, lives will be saved in this country under this potential hazard that no one could say when will be the next occurrence.

Hong Kong

by Dickson D.S. Lau, Experimental Officer, Hong Kong Observatory, Hong Kong, China

On 10 November 2011, the Government of the Hong Kong Special Administrative Region (HKSARG), China participated in PacWave 11 by conducting a functional exercise targeting an earthquake of magnitude 9.0 in the Manila Trench. The exercise did not involve any actual deployment of operational resources. In addition to the testing of the notification mechanisms of the Pacific Tsunami Warning and Mitigation System and the Hong Kong Contingency Plan on Natural Disasters, the Hong Kong Observatory (HKO) and more than 20 relevant government bureaux, departments and related organisations in Hong Kong also exercised their emergency response procedures during the event. To meet the objectives of PacWave 11, a master scenario plan consisting of more than 50 scenarios was drawn up by the exercise planning team. Furthermore, a virtual website was set up to display real-time simulated time series of local tide gauge data for viewing by all participating parties.

The exercise was kicked off by HKO at 0200 UTC, followed by the issuance of strong earthquake report and tsunami warnings. The tsunami warnings were issued, with due consideration of the messages



Hong Kong Observatory receiving reports of the simulated earthquake and prepare to issue tsunami alerts. Photo courtesy of Hong Kong Observatory.

Country Report - Hong Kong, *continued*

from PTWC, NWPTAC and the State Oceanic Administration of China, the outputs of the HKO tsunami model and local tide level observations. The tsunami warnings served to warn the general public of the possible impact of the tsunami to Hong Kong and provided them with advisory messages on appropriate precautionary countermeasures. The exercise was conducted smoothly and ended around 0900 UTC.

Malaysia

by Malaysia Meteorological Department (MMD)

Malaysia National Tsunami Warning Center receiving reports of then simulated PacWave 11 earthquake. Photo courtesy of Malaysia Meteorological Department (MMD).

Drill exercises conducted by Malaysia are based on simulation of an earthquake magnitude 9.0 in the Manila Trench off the west coast of Luzon, Philippines. Malaysia's participation does not only involve the receipt and dissemination of tsunami warnings but also evacuation of residents in Kudat, Sabah and Labuan Federal Territory. Kudat tsunami drill involved the evacuation of nine coastal villages: Kampung Tanjung Kapur, Kampung Air, Kampung Perpaduan, Kampung Pantai Bahagia, Kampung Pengaraban, Kampung Sri Aman, Kampung Landung Ayang, Kampung Pantai Muhibbah dan Kampung Muhibbah, while in Labuan are three villages involved: Kampung Layang-layangan, Kampung Sungai Labu dan Kampung Sungai Lada. The evacuations were coordinated by the disaster management agencies when a tsunami warning were issued by the National Tsunami Early Warning System of Malaysia (MNTEWS) in Malaysian Meteorological Department (MMD) to the National Security Council (NSC), followed by a tsunami warning message by tsunami siren in Kudat and Labuan. Dissemination of tsunami warning is made via short message service (SMS) and fax. The evacuation operations took about an hour. Tsunami warning sirens triggered around 11.00 am local time. Once the warning siren alarmed, residents began to move to safe areas in temporary evacuation centres while assisted by departments and security agencies and disaster management agencies. The tsunami warning was terminated at 2.00 pm. A total of about 800 people in Kudat and 300 people in Labuan were involved in the tsunami drill. This drill tested the efficiency in dissemination of tsunami warnings to disaster management agencies as well as provided an opportunity for disaster management agencies to test the smoothness of communication systems and coordination between the agencies involved. It was also one of the activities to raise public awareness among local residents about actions to be taken when a tsunami warning is triggered with instructions issued by the authorities. Such programs will be further improved and continued in the future in these locations. Drill exercises organized by the MMD and the NSC have been getting strong support from all regional disaster management agencies at Kudat and Labuan Federal Territory.

Malaysia residents await instructions during PacWave 11. Photo courtesy of Malaysia Meteorological Department (MMD).

Country Report - Malaysia, *continued*

Tsunami evacuation signs in Malaysia. Photo courtesy of Malaysia Meteorological Department (MMD).

New Zealand

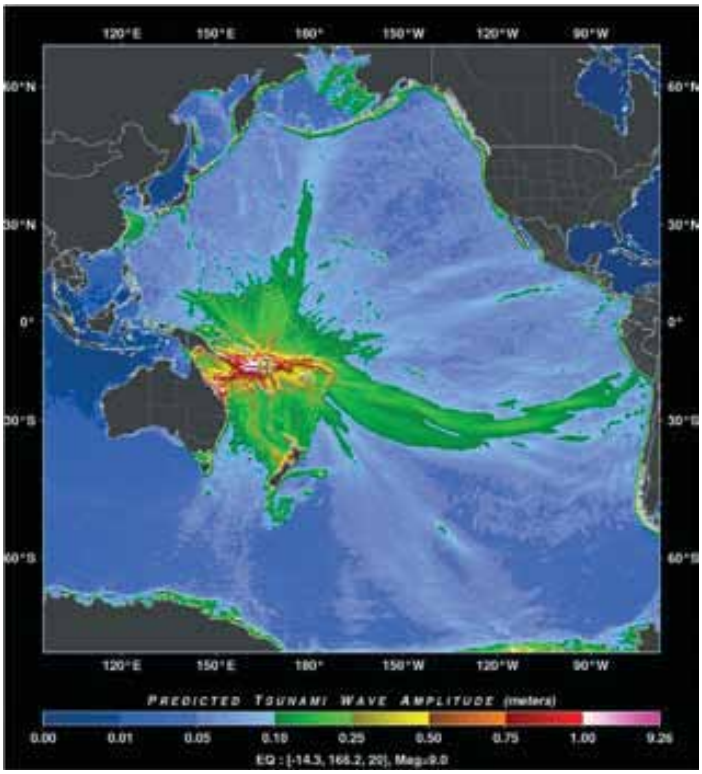
by New Zealand Ministry of Civil Defense & Emergency Management (MCDEM)

Ten different scenarios were offered to enable all countries to take maximum opportunity from the exercise. Simulated warnings were sent by the Northwest Pacific Tsunami Advisory Centre (Japan), the Pacific Tsunami Warning Centre (USA), and West Coast/Alaska Tsunami Warning Centre (USA). As a member of the Pacific Tsunami Warning System, New Zealand's warnings originate from the Pacific Tsunami Warning Centre (PTWC).

New Zealand participated on 10 November, exercising a scenario based upon an earthquake in the Vanuatu region resulting in a significant tsunami risk for New Zealand, especially our western coastlines. Being responsible for tsunami warnings, the Ministry of Civil Defence & Emergency Management (MCDEM) received the PTWC information, continually assessed it with assistance from tsunami advisors at GNS Science and issued National Tsunami Advisories and Warnings in accordance with these assessments. The advisories and warnings were sent by MCDEM, as per standard operating procedures, to the thirteen participating regional CDEM Groups and thirteen participating agencies. Communication with the media was simulated in this instance. The information was updated regularly as better assessments were made, until late afternoon when the exercise ended with a cancellation of all warnings.

Local level CDEM in turn assessed the information provided to determine the need for evacuations and other appropriate response actions. National and local agencies determined their responses in cooperation with MCDEM and local level CDEM.Under its Pacific Islands Programme (a Ministry of Foreign Affairs & Trade funded programme to enhance tsunami risk mitigation in five Pacific Island countries) MCDEM also supported Samoa, Tonga and the Cook Islands with conducting and evaluating the exercise in their own countries.

The PTWC also used the exercise as an opportunity to obtain feedback from member states on experimental products they intend using in the future to enhance the information currently offered. These included wave height and threat level forecasts for specific regions in the Pacific. MCDEM did not use these products in the exercise, however we evaluated them jointly with GNS Science after the exercise to provide our collective feedback to the PTWC. The New Zealand Government, NGOs and the public played a prominent role in the response to and recovery from these events. However, as a responsible neighbour to Pacific Island countries and to complement response and recovery efforts, New Zealand should also support tsunami risk reduction and readiness



Vanuatu earthquake and tsunami alerts were given to local warning centers as a part of the PacWave 11 tsunami simulation. Map courtesy of PTWC.

in the region. Under a three-year Memorandum of Understanding with the Ministry of Foreign Affairs and Trade, the MCDEM in the Pacific PacWave 11 and the Pacific Tsunami Risk Management Project Ministry of Civil Defence & Emergency Management is working alongside the National Disaster Management Offices (NDMOs) of Samoa, Tonga, the Cook Islands, Niue and Tokelau on the Pacific Tsunami Risk Management Project. This project is targeted at reducing tsunami risk and strengthening tsunami readiness in these five countries. MCDEM is implementing this project through a number of 'Pacific Focal Points'. Focal Points are existing staff who have been appointed to work with NDMOs and regional stakeholders on targeted activities that aim to ensure each country has an effective end-to-end tsunami warning and mitigation system. Focal Points have recently visited Samoa, Tonga and the Cook Islands where they assisted in conducting and evaluating PacWave 11. PacWave 11 enabled Focal Points to do a handson assessment of tsunami warning systems and test communications, the receipt and dissemination of warnings and information, standard operating procedures and agency roles and responsibilities.

ITIC-PTWC NEWS

APEC School Safety Workshop, Taipei, Taiwan, 17-19 October 2011

In 2011, GeoHazards International (GHI) led a nine-month initiative to provide guidance to Asia-Pacific Economic Cooperation (APEC)—the leading forum for facilitating economic growth, cooperation, trade and investment in the Asia Pacific region—on how to keep children safe at school during natural hazard events.

Without exception, countries of the Asia Pacific region share exposure to natural hazards associated with their location along the "Pacific Ring of Fire," an arc that stretches from New Zealand, along the eastern edge of Asia, north across the Aleutian Islands of Alaska, and south along the coast of North and South America. The Ring of Fire is home to over 75% of the world's active and dormant volcanoes and about 90% of the world's largest earthquakes occur along its length. In addition, the Asia Pacific region confronts pyroclastic and debris flows from steep volcanoes, landslide, rock fall and tsunami hazards, as well as hydrometereological hazards such as droughts, floods, typhoons and forest fires. The magnitude and frequency of these hazards present serious challenges to safety, welfare and long-term economic development throughout the region.

Teachers learn about disaster risk management at an APEC School Safety Workshop in Taiwan. Photo courtesy of Geohazards International (GHI).

GHI worked with representatives of APEC's 21 member economies to develop a comprehensive school safety framework tailored to conditions in APEC economies. These include natural hazard and vulnerability profiles, school governance structures and more. The growth and future prosperity of APEC economies rely upon children's access to education. More fundamentally, students everywhere have a right to learn in schools that are safe from and prepared for natural hazards. An effective school safety policy can help communities develop unimpeded by setbacks from natural hazard events.

The centrepiece of the School Earthquake and Tsunami Safety in APEC Economies: Reducing Risks and Improving Preparedness initiative was a three-day workshop held in October 2011 in Taipei. Here representatives of APEC economies were able to exchange relevant knowledge and experience, discuss best practices and advise regarding GHI's discussion draft of an APEC school safety policy framework. This workshop was sponsored by the United States, Taiwan, Peru, Australia and New Zealand. The United States Department of State and the United States Geological Survey served as project overseers. The National Science & Technology Center for Disaster Reduction (NCRM) of Taipei provided essential local support.

"Safe@School—Protecting Children from Natural Hazards," the school safety framework that emerged

APEC Safety, *continued*

from the workshop, identifies new opportunities for APEC to exercise leadership in promoting school safety in natural hazard events. The framework's principles and activities can significantly increase resilience and reduce risk among APEC economies. Safe@School acknowledges and incorporates key conclusions from the APEC Emergency Preparedness Working Group's (EPWG) September 2009 Hanoi report on Disaster Risk Education at Schools. It also leverages principles and elements that GHI developed through its multi-year School Earthquake Safety Policy Initiative with the Organization for Economic Development and Cooperation (OECD), which produced the OECD Recommendation Concerning Guidelines on Earthquake Safety in Schools. In addition to the Safe@School framework endorsed by workshop participants, GHI's recommendations on next steps for APEC to build the capacity needed to reduce risk in schools. Recognizing the capability of APEC's Education Network (EDNET) and its interest in school safety, the recommendations will propose future collaborative capacity-building projects with EDNET. They will propose that each economy's government adopt and implement the Safe@School and that a specific agency, at either the national or the subnational level, have the expertise and commitment required to monitor and report on progress toward these goals. They will propose that a follow-on workshop be held in 2013, at which participating economies can report on progress against benchmarks in strengthening the resilience of their populations and infrastructure from natural hazards.

APEC is well-suited to assist member economies with their efforts to reduce the risk to schools from natural hazard events. APEC members represent many of the world's most vulnerable areas with regard to earthquakes, tsunamis, volcanic events and other hazards. While risks are held in common, knowledge resources vary greatly between economies.

This makes risk reduction demonstration and capacity building projects within APEC particularly worthwhile. APEC members have an impressive knowledge base, with many of the world's most experienced and knowledgeable academicians and practitioners living and working in APEC economies, however, other members have been isolated from this knowledge. APEC has an opportunity to provide a collaborative forum for members to diffuse knowledge and guide and encourage risk reduction and preparedness measures that the private sector and governments can

Students learning about natural hazards through verbal discussions. Photo courtesy of Geohazards International (GHI).

undertake. APEC can promote the safety of children in schools, strengthen member economies against the human and economic threats of natural hazards, and promote business opportunities.

Earthquakes and natural hazards are ideal focuses for collaboration. They threaten all varieties of human settlement: urban and rural, wealthy and poor. Working together to address the resulting risk increases economies' safety, stability and capacity for economic and cultural growth. Improved understanding of natural hazards and engineering techniques to build properly and manage risk strengthens the foundation for business activities within the region. Cooperative projects allow people from disparate cultures to work towards a common good, against a common threat. Although each economy and business has its unique set of values, hazards and priorities all benefit from collaboration.

APEC has an opportunity to promote "earthquake diplomacy" via cooperative and unilateral projects of its member economies. Natural hazard diplomacy also offers opportunities for socially responsible private companies to help their communities reduce risk from natural hazard events. Corporations can support successful, reasonably sized risk reduction projects in the communities where their workers, suppliers and customers live. Their support for school safety programs pays dividends in terms of improved life quality and safety of those served, increased pride of employees who witness their employer's generosity and wisdom, improved community relations and even good public relations.

APEC Safety, *continued*

Teachers demonstrating earthquake effects on structures. Photo courtesy of Geohazards International (GHI).

Public and Private Sectors Sign Joint 'Statement of Intent' at APEC to Strengthen Regional Disaster Risk Reduction and Resilience, Honolulu, Hawaii, 11 November 2011

Leaders from the public and private sectors signed a historic joint "Statement of Intent" during the APEC meeting in Honolulu and pledged to work together on disaster risk reduction and resilience (DRRR) in the Asia-Pacific region. These organizations believe that public-private collaboration on DRRR can help to save lives, ensure economic vitality and enhance human well-being across the region.

Starting with discussions between the University of Hawaii and U.S. Pacific Command, a series of bi-lateral discussions collectively set the stage for this joint statement. Meridian Institute is currently supporting the discussions of this group and is focused on establishing a formal structure for a secretariat to facilitate and manage the Asia-Pacific DRRR Collaboration. Over the next few months, Meridian will conduct a landscape assessment of DRRR capacities, including opportunities and gaps in the region, which will be used to inform the function and focus of the network's secretariat.

Organizations and their representatives who signed the Joint Statement of Intent included:

U.S. Chamber of Commerce President, Thomas Donohue

U.S. Pacific Command Commander Chief of Staff, Rear Admiral Robin Watters

University of Hawaii System President, M.R.C. Greenwood, Ph.D.

U.S. Agency for International Development Assistant Administrator, Nancy Lindborg

National Oceanic and Atmospheric Administration Director of External Affairs, Andy Winer

Ford Foundation President, Luis Ubiñas

Rockefeller Foundation President, Judith Rodin, Ph.D.

U.S.-Japan Council President, Irene Hirano

Federal Emergency Management Agency Deputy Administrator for Protection and National Preparedness, Timothy Manning

The signing and media opportunity followed U.S. Secretary of State Hillary Clinton's High-Level Policy Dialogue on Disaster Resiliency on 11 November, during which she emphasized the importance of an expanded role in disaster risk reduction and resilience on the part of all economies throughout the Asia Pacific and announced the signing event later in the day.

As natural disasters in the region continue to claim tens of thousands of lives and cause billions in monetary damage each year, it is incumbent on today's leaders to foster collaborative solutions that support communities' and countries' disaster risk reduction efforts and encourage planning in advance for recovery. No economy in the region is immune and each can learn from the experience of others in dealing with natural disasters, human-induced events such as terrorism and oil spills and other disruptions such as public health crises and economic downturns.

Each of the groups represented above will contribute their expertise and field of specialization to the collaborative initiative. Much is already going on in this arena but this is the first step toward concrete actions and programs that will be pursued collaboratively as well as individually. The signers intend to quickly broaden the collaboration through the active participation of organizations across the Asia-Pacific region.

"This is an historic document and effort," said Thomas J. Donohue, President and CEO of the U.S. Chamber of Commerce. "We all do our very best to respond and collaborate whenever a disaster strikes. This event signals our mutual intent to work on an ongoing basis across sectors and across the region."

"The Rockefeller Foundation supports various resilience building activities in the Asia-Pacific region with an emphasis on enhancing individual,

APEC Public and Private, *continued*

community, national and institutional capacity to survive, adapt, and grow," said Rockefeller Foundation Vice President Dr. Zia Khan. "Building resilience involves bringing experiences, knowledge and action together in the right way to spawn new approaches to solving long-term, chronic stresses and acute crises. We are very proud to be a part of this unfolding cross sector collaboration and hope that it encourages others to participate as well."

US Chamber of Commerce President, Thomas Donohue (2nd from right), US Pacific Command Chief of Staff, Rear Admiral Robin Watters (3rd right), US agency of International Development Assistant Administrator, Nancy Lindborg (3rd left), National Oceanic and Atmospheric Administration Director of External Affairs Andy Winer (2nd left) and University of Hawaii President MRC Greenwood, signing the joint DRR statement in Honolulu. Photo courtesy of BT/Goh De No.

APEC High Level Policy Dialogue on Disaster Resiliency, Honolulu, Hawaii, 11 November 2011

The following is a decleration of the APEC high level policy dialogue on Disaster Resiliencey:

We, APEC ministers and senior government officials, along with private sector leaders, met in Honolulu, Hawaii for the High Level Policy Dialogue on Disaster Resiliency, under the chairmanship of U.S. Secretary of State Hillary Rodham Clinton.

The earthquake and tsunami that struck Japan on March 11 along with additional earthquakes, floods, wildfires, typhoons and tornadoes in the region, as well as recent floods impacting Thailand, all remind us that the Asia-Pacific region is highly prone to the impacts of natural disasters. They also underscore the importance of reducing disaster risk and strengthening the resiliency of our communities. APEC, through its strong networks with the business sector, has a comparative advantage in encouraging greater private sector participation in disaster preparedness and resiliency efforts. With these challenges and strengths in mind, and recalling the commitments made under the Hyogo Framework for Action as well as the APEC Trade Recovery Guidelines, we call on officials to adopt and implement the following objectives:

Provide businesses with tools to help them prepare

- Promote voluntary standards for private sector preparedness to help businesses evaluate their own readiness and provide incentives for taking steps to prevent and mitigate the risks they face;
- Promote standards and indicators for measuring the effectiveness of disaster risk reduction at both the economy-wide and regional levels to guide public and private sector investments and improve quality and consistency in implementation;
- Promote and facilitate the use of Business Continuity Plans (BCPs), by appropriate means, including legal, market-oriented and social measures;
- Promote financial instruments that help to respond and recover from disasters, as well as to transfer risk;

Facilitate the movement of goods and services during disasters

- Recognize the importance of the supply chain and related infrastructure in the delivery of goods and services following a disaster;
- Work through APEC to enhance customs procedures, and reduce tariff and non-tariff barriers, including domestic regulations and licensing issues that affect logistics and supply chain movements responding to a natural disaster;
- Explore the use of customs and tariff waivers when host governments request humanitarian-related donations from the international community, taking into account existing guidelines and best practices;
- Educate the public, business and government leaders on best practices for effective and appropriate donations to minimize the disruptions unsolicited donations can have on disaster response efforts;

APEC High Level, *continued*

- Develop mechanisms for tracking private sector resources and capabilities;

Promote community based approaches

- Recognize that communities are the first responders in disasters, and solicit participation and input from civil society, private sector, and local government stakeholders;
- Promote early and frequent engagement of community groups and leaders in developing Disaster Risk Reduction (DRR) processes and policies, and assist communities in identifying practical steps to improve community resilience;
- Encourage technical assistance, research of best practices, innovation and training for decision makers at all levels, taking into account community-based and gender-based DRR approaches and incorporating traditional, local, and scientific knowledge;
- Promote community-centered education on disaster risks and risk reduction through existing community groups;
- Provide early warning assistance through technical monitoring of incipient disasters and timely early warning dissemination through to the community-level, and build early warning capacities within economies to evaluate rapidly-evolving threats such as tsunamis;
- Encourage an enabling environment for community-centered DRR activities through local governance and economy-wide policy engagement;
- Support research and education
- Promote increased disaster resiliency by sustaining and improving early warning systems through increased data exchange networks, improved forecasting skills and training, and reliable dissemination strategies;
- Emphasize the relationship of training, education, and outreach to decreasing community vulnerability to hazards;
- Actively engage and support scientific and technical communities to inform decision making;
- Support efforts to improve executive education to develop a new generation of disaster management leaders and promote interdisciplinary research as well as platforms for prototyping tools arising from that research;
- Recognize APEC's efforts to make schools safer in response to seismic and tsunami threats; and
- Advocate for the inclusion of natural hazard disaster preparedness as part of school curricula starting in primary schools.

Promote public-private partnerships

Partnership between the public and private sectors is essential as the private sector owns and operates a great deal of an economy's critical infrastructure and has experience and knowledge regarding resilient construction techniques, the development of sustainable urban areas, energy safety, and the protection of critical resources. Recognizing the need to incorporate the private sector more substantively in our emergency preparedness efforts, APEC economies will develop public-private partnerships within their own economies and report on their

U.S. Secretary of State Hillary Rodham Clinton along with private sector leaders meet in Honolulu, Hawaii for the APEC high level policy dialogue on Disaster Resiliency. Photo courtesy of Asia-Pacific Economic Cooperation (APEC).

APEC High Level, *continued*

progress next year. In developing these partnerships, APEC economies will be guided by the following broad principles:

1. Adopt a "Whole of Society" approach to developing and strengthening public-private partnerships that support business and community resilience to disasters. This includes involving all levels of government, non-government, and the private sector;
2. Through public-private partnership programs, encourage a greater role for women in supporting disaster resilient businesses and communities;
3. Strengthen public-private partnerships by sharing information, drawing on best practices, and learning from experiences;
4. Leverage existing programs and resources, and strengthen partnerships that develop during disasters to sustain long-term public-private collaboration and avoid duplication of effort;
5. Establish partnerships based on shared responsibilities and resources, with mutually agreed upon roles and tasks;
6. Cultivate public private partnerships that are open to flexible and innovative ways of working together to build business and community resilience to disasters

WORKSHOP AND MEETING SUMMARIES

Personal Impressions of the Fall American Geophysical Union (AGU), 5-9 December 2011, San Francisco, CA, USA

by Dr. Gerard Fryer, Geophysicist, Pacific Tsunami Warning Center. Gerard.Fryer@noaa.gov

Once again the Fall AGU Meeting was the largest and most important gathering of tsunami scientists worldwide. Among the 150-odd presentations and posters about tsunamis there were three important recurring themes:

1. **Tohoku rupture.** Everyone says (about three dozen different papers, ranging from accelerometer data to offshore GPS to tsunami inversion) that the shallow slip during the Tohoku-Oki earthquake was huge. It was certainly over 60m and may have been as large as 72m. Most people think it was less than the 80m that some researchers reported back in September. The DART data were especially valuable in constraining this slip as at shallow depths rigidity is so low that slip does not generate seismic waves efficiently. Various authors observed that the unprecedented slip of this earthquake and the corresponding huge runup of its tsunami raise serious questions about how well we are prepared for similar events elsewhere.
2. **Tohoku tsunami modeling.** Most modelers agree that acceptable match to data for the Tohoku tsunami is only possible if you take account of the finite rupture speed of the earthquake. In particular, the large shallow slip which dominates the tsunami signal must be delayed until 120 seconds after origin time. Nobody had any practical suggestions about how to do this during an event (the first finite fault inversions are available about 30 minutes after an earthquake, but these are very crude). Modelers at NOAA's Center for Tsunami Research (PMEL) therefore still assume instantaneous rupture. Nevertheless, PMEL showed pretty good match to observations, both near-field inundation and far-field DART records.

Members and visitors meet at the Fall 2011AGU in San Francisco. Photo courtesy of American Geophysical Union (AGU).

Personal Impressions, *continued*

3. **Fast determination of magnitude.** JMA issued their warning for the Tohoku tsunami only 2 minutes and 40 seconds after earthquake origin time, but their preliminary magnitude of 7.5 suggested that the tsunami would be contained by most towns' mitigation defense structures. By the time the magnitude was upgraded, many communications links were saturated. At AGU, the difficulty of rapid measurement of the magnitude of a great earthquake was widely acknowledged. One solution being pursued enthusiastically by many geodesists and seismologists is high-rate GPS. Luis Rivera argued that, with present technology, Mw could be deduced from near-field high-rate GPS within five minutes; in his union lecture, Hiroo Kanamori argued that 2.5 minutes should be achievable—fast enough for local warning.

Now some specifics of various papers that caught my attention (this is only a small subset of the total):

NH13G-02

A three dimensional tsunami propagation simulation of the 2011 off Tohoku earthquake using an unstructured finite element model

Y. Oishi

3-D tsunami modeling has been hovering in the wings for quite a while, but its main use has been for highly dispersive very large amplitude waves as generated, for example, by asteroid impact (the Los Alamos modeling group). Oishi, et. al showed impressive models for Tohoku; the best 3-D modeling of an earthquake-generated tsunami I have yet seen. The model wasn't all that sophisticated--it only had five water layers--but it matched a lot of near shore data better than the simple 2D. Oishi made the point that the huge shallow slip meant that the tsunami was rich in short wavelength energy, so that 2-D modeling with ad hoc dispersion just wasn't going to do well in the near field.

NH13G-04

A unified numerical simulation of seismic ground motion, ocean acoustics, coseismic deformations and tsunamis of 2011 Tohoku earthquake

T. Maeda

Maeda and friends using a single finite difference model to simulate the earthquake rupture, the generation of seismic waves, the generation of the tsunami, and excitation of the T-phase rumble in the SOFAR channel. Other people have done parts of this, but seeing it all at once was impressive.

NH14A-01

Tsunami source model the 2011 Tohoku earthquake inferred from tsunami waveforms and coastal inundation heights

K. Satake

Satake pointed out that, as far as the tsunami is concerned, the Tohoku earthquake can be very well approximated as the sum of two earthquakes: a deep (~50 km) earthquake to provide the long wavelengths of the tsunami, and a much shallower one to provide the short wavelengths. Both earthquakes were about magnitude 8.8, but the shallower one occurred two minutes after the first. It is as if a Jogan Earthquake (869 A.D.) were followed two minutes later by a Meiji Sanriku Earthquake (1896 A.D.).

NH32A-02

Real-time Tsunami Flooding Forecasts of the 2011 Japanese Tsunami (Invited)

E. N. Bernard

Bernard and Titov reported an excellent match of modeled tsunami to data, both for Pacific-wide DARTs and for Japanese inundation. This was an application of the standard SIFT procedure (pre-computed tsunamis for 50x100 km source blocks; all source blocks assumed to rupture at the same instant; least-squares adjustment of slip on each block to match water-level records at selected DART gauges). Because the source granularity was so large, the concentration was on matching the longer periods of the tsunami (for which the assumption of instantaneous rupture was not too badly violated). While they missed some of the short-period energy that others reproduced, their technique is designed for tsunami warning and so is available rapidly.

G33C-04

W phase source inversion using the high-rate regional GPS data of the 2011 Tohoku-oki earthquake

L. A. Rivera

G31A-0952

Rapid estimation of critical source parameters for early tsunami warning based on coastal GPS networks: A feasibility study

Personal Impressions, *continued*

A. Iglesias

Union Frontiers of Geophysics Lecture

Tohoku to Tsunami: Personal Account from Science to Experience

H. Kanamori

Luis Rivera's was perhaps the most important paper at the meeting for tsunami warning. Luis looked at high-rate GPS recordings of the Tohoku earthquake and showed that you can back out a W-phase CMT within 5 minutes of origin time. Luis' paper was paraphrased and repeated by Hiroo Kanamori for the Union Lecture on Thursday. Hiroo upped the ante and argued that for single-asperity earthquakes like Tohoku (though not for long-duration ruptures like Sumatra-Andaman 2004) you could get the magnitude in only two and a half minutes using high-rate GPS. While such measurement would require a plethora of GPS instruments, such a plethora will probably soon exist. In his poster, Inglesias argued that there is almost a sufficiency of data already for Mexico, Sumatra, and Chile, as well as Japan. Inglesias was just fitting an Okada model to GPS-derived deformation, but if you can measure that information, you can also measure the W-phase. It's only a matter of time before all subduction zones are appropriately instrumented.

Kanamori's forecast (you can watch his entire lecture at <http://sites.agu.org/fallmeeting/scientific-program/lectures/>) essentially was "Tsunami warning will soon primarily be performed using real-time GPS."

NH14A-04

Not Just Salt - the 11 March 2011 Tohoku-oki Tsunami and the Significance of Geochemical Proxies

(Invited)

C. Chague-Goff

rain storms. Even more important, marine diatoms left well inland from the maximum obvious deposits remain identifiable for centuries if the land is not tilled. Chague-Goff identified microfossils from the 869 Jogan tsunami well inland from that tsunami's sand layer, which is itself overlain by more recent soil and the 2011 sand layer. This was one of several talks and posters based on a transect taken just north of the Sendai Airport. The important point here was that maximum inundation is significantly farther than what is marked by sand and mud deposits. Fortunately, the geochemistry of flooded soil retains a signature of the inundation (not just salt but sulphur anomalies) for several months after the event. These persist even after repeated

NH14A-05

Modeling of the 2011 Tohoku-oki Tsunami and its Impacts on Hawaii

Y. Yamazaki

This was a combination of finite-fault inversion and DART data to match the Tohoku-Oki tsunami. The DART data are necessary because the shallowest rupture was not constrained by seismic data. The inversion was for 20x20 km blocks, including rise time and finite rupture speeds, so, Yamazaki was able to match much of the short-period energy (for which it is necessary to include dispersion in the model) as well as all of the long-period energy in the tsunami. Yamazaki was therefore able to match in detail the runup data for Hawaii as well as water-level records.

IN21D-04

The TRIDEC Project: Future-Saving Free and Open Source Software (FOSS) GIS Applications for Tsunami Early Warning

P. Loewe

The tsunami warning system for the Mediterranean is being assembled rapidly, much along the lines of GITEWS and by the same people (GFZ Potsdam, the developers of SEISCOM P3). Their decision-support software is an AI combination of seismic parameters, tsunami modeling, water-level observations, historical data, and a variety of other Bayesian inputs. TRIDEC (the acronym stands for Collaborative, Complex, and Critical Decision Processes in Evolving Crises) extends beyond mere tsunami warning to all natural hazards, although tsunamis are their initial concentration. All the TRIDEC software will be in the public domain, and published at the FOSS site (fosslab.org).

IN21D-05

The Generic Mapping Tools (GMT) version 5

P. Wessel

Wessel gave a characteristically slick talk (spectacular graphics) on the goodies that are going to be part of GMT 5 (full release expected within a year). To display kml output, he used a variety of tsunami plots used by PTWC. Kml will be integrated

Personal Impressions, *continued*

into version 5, which will have an API accessible from all the usual languages, including python and Matlab. GMT 5 will also have Open MP support, and will produce output in all the popular GIS formats.

NH21C-1523

Simulating Tsunami Inundation in Southern Oregon, USA, Using Hypothetical Cascadia and Alaska

Earthquake Scenarios

R. C. Witter

This was a nice poster and nice modeling using Baptista's FE code, extended to make probabilistic assessments of runup. Specifically included in the model are splay faults, which appear to have contributed significantly to the local tsunami in 1700. It's nice to see that some tsunami scientists are beginning to consider realistic tsunamis rather than just those generated by simple Okada-style sources.

NH23B-01

Tsunami population-vulnerability index based on pedestrian-evacuation modeling

N. J. Wood

The important news in this talk was that tsunami loss estimation is to be incorporated into the next version of HAZUS (Hazards US) - Loss Estimation Model. That will help local governments make quick estimates of loss which will speed up presidential disaster declarations.

NH23B-03

Economics of Tsunami Mitigation in the Pacific Northwest

K. A. Goettel

This talk gave an interesting perspective on value for investment in tsunami hazard mitigation in the US by comparing how tsunami hazard is treated compared to other hazards, such as tornadoes. FEMA mitigation funds, for example, can be used to help people make tornado safe rooms, but not for strengthening bridges for coastal evacuations. The benefits of the latter far exceed those of the former. Goettel gave advice on how to steer through the maze of hazard mitigation funding requirements in the US, and left with the hope that the regulations will eventually become more rational.

NH24B-01

Probabilistic Tsunami Hazard Mapping (Invited)

H. K. Thio

This was a report from URS Corp, an applied science consulting firm. They use a pre-computed model, like PMEL's SIFT, only far more detailed, so they have to consider the finite speed of fault rupture. They concluded that "Even at the large distance to America's West Coast from Japan, the detailed slip relationships are important in determining the tsunami runup." While this appears to run counter to PMEL's conclusions from SIFT, be aware that SIFT attempts only to match long-period energy.

An interesting point from Thio's modeling was that seismic efficiency, the fraction of plate tectonic strain that is locked and released as earthquakes, never exceeds 0.5.

Thio complained that everyone extrapolates to giant earthquakes using Wells & Coppersmith (BSSA 1994), even though W&C only get up into the magnitude 7s. Thio points out that the appropriate scaling laws for giant earthquakes are those of Papazachos et al (GJI, 2004), or Moss & Travasarou (EERI Conf Proceeding, 2006).

NH24B-05

A Probabilistic Approach for the Waves Generated by a Landslide (Invited)

P. J. Lynett

NH24B-06

A Monte Carlo Approach for Estimating Tsunami Hazard from Submarine Mass Failure Along the U.S.

East Coast

S. T. Grilli

Both Patrick Lynett and Stéphan Grilli model landslides using linear but dispersive models. Both are running Monte Carlo simulations over distributions of slope, slope stability (pore pressure), sediment type, water depth, etc. Grilli seems to be farther ahead, and has now completed rough hazard maps for the entire East Coast for submarine mass failures at the shelf edge (the source of the 1929 Grand Banks tsunami). The next step will be to compute detailed inundation maps for use in evacuations. It remains an open question whether centers have the means to identify a submarine mass failure in time for a warning to be issued. In the case of 1929 such warning certainly would be possible, since the trigger was M7.5 earthquake. Other landslide sources, such as clathrate blowouts

Personal Impressions, *continued*

off the mouth of Chesapeake Bay, would best be detected with a network of hydrophones. So far the necessary networks do not exist, though Neptune Canada provides a good proof of concept. The travel time for such tsunamis on the East Coast would be about an hour.

NH32A-01

What Pacific tsunamis tell us about underestimating hazard and risk (Invited)

J. R. Goff

NH32A-06

Palaeotsunamis and their significance for prehistoric coastal communities (Invited)

J. R. Goff

In these two presentations Goff argued that there were major disruptions to coastal communities all over the south Pacific consistent with tsunami inundation. Almost all of New Zealand switched from coastal to inland settlement in the 15th Century (about the time of the catastrophic Kuwae eruption in Vanuatu). There is independent evidence (which Goff is unaware of) that a similar move occurred in the Marquesas at about the same time--by the time of the first European explorers in the early 16th Century, all Marquesan villages were at least two kilometers from the coast, well inland from coastal ruins. The important point is that any tsunami capable of disrupting coastal settlements over such a large geographic area would have to be significantly larger than those we know of from recorded history. Especially in light of the Tohoku-Oki earthquake and its great tsunami, we have to wonder whether our "type" tsunamis are large enough.

NH32A-07

Assessing Tsunami Hazard from the Geologic Record (Invited)

B. E. Jaffe

Jaffe's talk was a natural extension to Goff's. Jaffe basically made the case that to assess tsunami hazard you have to look at a longer record than that of known history. In many areas (Cascadia, Japan, Sumatra) this is being done now from trenching and other geological investigations of coastal sediments. Similar work is getting underway in Chile and Kamchatka, but for much of the Pacific the record is very sparse. Making hazards projections from sparse data is fraught with peril.

S32A-07

Automated fast, and robust estimation of seismic source parameters: application to tsunami warning system.

J. Clément

I missed this talk because it clashed with Bruce Jaffe's, but I asked Dominique Reymond (Clément's co-author) about it afterwards, Their goal is quick generation of CMTs. First, they compute mantle magnitude (an approximation to Mw from surface-wave data) and use this to approximate source dimensions. They then fit the seismic parameters (Levenberg-Marquardt algorithm) to their database of slab geometries. The result is a CMT that stands up pretty well to comparison with the GCMT, all in the time it takes to compute Ms. This should be a useful supplement W-phase estimates of magnitude, since it includes fault finiteness.

T33A-2376

A New Source Function of the 1964 Alaska Tsunami Based on the Near-field Numerical Modeling and Observations

E. N. Suleimani

Suleimani did a nice bit of work fitting the near-field runup in 1964 to the known source. It is well known that the Patton Bay Fault (a splay) reactivated during the earthquake: it produced over 5 m of uplift where it outcrops on Montague Island. Suleimani showed that the fault must continue at least twice as far as previously mapped to get runup correct along the shores of Kodiak Island farther to the west. The tricky matter now is that a lot of the potential inundation zones in Alaska are from secondary faults whose locations are not very well determined. There are obvious implications for other margins with well-developed splays, Cascadia and Nankai, for example.

U41D-02

Fault system and dynamic seafloor deformation in the 2011 Tohoku earthquake

T. Tsuji

Takeshi Tsuji described the offshore observations (sea floor gauges, seismic reflection profiles) from which the coseismic deformation of the Tohoku forearc, including slip on at least one normal fault, can be inferred. Much of this had already been published.

Personal Impressions, *continued*

But Tsuji added important new information: the results of multi-beam and ROV surveys on the nose of the forearc from before and after the earthquake. At the extreme distal end of the forearc, tensional features predominate. Bacterial mats have sprung up where there were none before, the heat flow regime has changed (mostly higher heat flow everywhere) and there are abundant slumps. The inference is that rupture made it all the way to the sea floor, since if it had stopped at depth, the shallow forearc would have been put into compression. Tsuji didn't say it directly, but he strongly hinted that the total motion as the shallowest extreme of rupture may have exceeded the tectonic strain.

Tsuji's deep-ocean surveys reinforced the claims of two posters the following day:

U51B-0022

Coseismic deformation of the 2011 M9 Tohoku-Oki Earthquake inverted from geodetic data using finite element models: Implications for tsunami genesis and poroelastic stress-coupling.

T. Masterlark

On this poster Masterlark argued, on the basis of deformation modeling and rupture mechanics, for forearc materials of very high compliance (hence the very large slip).

Even more intriguing was this paper:

U51B-0041

Rupture to the Trench in Dynamic Models of the Tohoku-Oki Earthquake

J. E. Kozdon

Kozdon addressed the enigma of how the forearc could accumulate strain if it is weak, frictionally stable, and incapable of sustaining rupture. His answer: it doesn't accumulate strain. So how did the Tohoku rupture make it all the way to the trench, as Tsuji showed? Kozdon assembled 2-D (cross-sectional) models of Tohoku rupture with depth-dependent elastodynamic properties. He considered both velocity weakening and velocity strengthening, but concluded that neither needs to be invoked, that what actually happened during the Tohoku earthquake was an unclamping of the fault driven by the reflection of seismic energy from the sea floor. With the hypocenter at depth and updip rupture, he could get the appropriate energy concentrations at exactly the right moment. His conclusion? That the huge shallow slip came about because the forearc was thrown outward by the force of the earthquake,which was applied at the instant when friction on the fault had been dropped to zero. Hence Tsuji sees all the tensional features out at the toe and extensive slope failures.

U41D-05

The Giant 2011 Tohoku-oki Earthquake: Clues from Joint Inversion of Tsunami Waveforms and Geodetic Data

F. Romano

This paper reported a simulated annealing inversion of geodetic and tsunami data to try to figure out slip distribution. This was a straightforward paper producing results that pretty much agreed with everyone else (a concentration of slip at the up-dip extreme of rupture). What caught my attention was the manner in which they tested their inversion algorithm. What they did was to generate synthetic data from a fault with a checkerboard pattern of rupture (i.e. subfaults alternate between zero slip and 40 meters of slip), then try to invert the synthetics. If your algorithm is stable and the error surface has a clear minimum, you should approximately reproduce the checkerboard pattern you put in. While this is pretty standard stuff for all inversion techniques, I had not seen if before applied to the fitting of tsunami models to DART data.

OS43D-01

Great Earthquakes and Tsunamis of the Northwestern Aceh Coast, Sumatra (Invited)

H. M. Kelsey

This was a cautionary tale for paleotsunami studies. From coring along the Aceh coast, the team identified major tsunamis at 0 years before present (i.e., 2004), at ~4ka, at 6.8ka, and at 7.3ka. So you might infer that, very roughly, a big tsunami occurs every two thousand years. Not so fast! Sea level was rising much more rapidly in the earlier part of the period than it is right now. The upper part of the sequence may not be capable of preserving a stacked sequence of tsunamis. Since sea level has been almost constant in the recent past, there is no accommodation space for new material, so the modern tsunami history may be missing. In a situation like this, you have to appeal to the sedimentary record elsewhere (e.g., Thailand). There is a moral here: you have to be prepared for uneven preservation.

Personal Impressions, *continued*

OS43D-02

Cascadia tidal marshes archive repeated episodes of coseimic subsidence from late Holocene great megathrust earthquakes

A. D. Hawkes

This was a straightforward combination of micropaleontology with lithospheric flexture to try to work out the subsidence that occurred during great Cascadia earthquakes and relate it to earthquake magnitude (they concluded that the 1700 earthquake was about M 8.8). The novelty here was a test to see if geochemical markers could be used instead of microfossils. Hawkes took samples from deposits a few thousand years apart in age, buried them in juxtaposition in the upland just above the intertidal zone, then came back a year later and cored the artificial deposit. She found that all the elements useful as geochemical markers had migrated, blurring the interface between the two ages. Her advice: use forams!

S43C-2246

Uncertainty estimations for seismic source inversions

Z. Duputel

Duputel described an error analysis applied to W-phase inversions for CMTs. There will be both observational errors and modeling errors which each have their own covariance matrix. It is normal to assume these are diagonal, but in general they will not be. She explained how realistic covariance matrices can be incorporated into the inversion and claimed that if the job is done right the solution itself is improved.

U51B-0047

Rapid Estimates of Depth Distribution of Earthquake Rupture Using T-Phases: The March 11, 2011

Tohoku-Oki earthquake

D. H. Salzberg

Salzberg showed that depth of rupture can be extracted from the T-phase recorded on hydrophones, and that, even from a single station, you can infer a strong upward concentration of slip in the Tohoku earthquake. Even though I was a co-author, I was unaware of a gotcha that Dave identified: for a lot of studies the DART Sendai data are inadmissible, because the instrument was within the region of coseismic displacement (the pressure gauge dropped by 3 cm when the earthquake occurred.

More information can be found at the AGU web site: http://www.agu.org/

Located in Honolulu, the International Tsunami Information Centre (ITIC) was established on 12 November 1965 by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). In 1968, the IOC first convened the International Coordination Group for the Tsunami Warning System in the Pacific (ITSU). In 2005, ITSU became the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) so as to better convey the comprehensive approach required to reduce tsunami risks.

The 35 Member States with Tsunami National Contacts and Tsunami Warning Focal Points are: Australia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic People's Republic of Korea, Ecuador, El Salvador, Fiji, France, Guatemala, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nicaragua, Niue, Panama, Papua New Guinea, Peru, Republic of the Philippines, Republic of Korea, Russian Federation, Samoa, Singapore, Solomons, Thailand, Tonga, Tuvalu, U.S.A., Vanuatu and Vietnam.

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