January – December 2010 VOLUME XLII, NO. 1

Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System

TSUNAMI NEWSLETTER

International Tsunami Information Centre

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Earthquake Near Central Coast of Chile, 27 February 2010, 06:34 UTC, M_w = 8.8

A series of severe earthquakes hit Central Chile on Saturday, 27th February 2010. The main shock off Concepcion at 06:34 UTC (3:34 AM local time) had a magnitude of 8.8. The Pacific Tsunami Warning Center (PTWC) in Hawaii issued a regional warning at 06:46 UTC (12 minutes after the event).

The earthquake was generated at the gently sloping fault that conveys the Nazca plate eastward and downward beneath the South American plate. The two plates are converging at 7 metres per century. The fault rupture, largely offshore, exceeded 100 km in width and extended nearly 500 km parallel to the coast. The rupture began deep beneath the coast and spread westward, northward, and southward. As it spread, the fault slip generated an earthquake shaking. The fault slip also warped the ocean floor, setting off the tsunami along the fault-rupture area. (USGS)

There were no fatalities reported far from the epicenter, however, near the epicenter off the Chilean coast, official accounts indicate 156 fatalities due to

2010 Chile tsunami destruction at Talcahuano, central Chile coastline. Photo courtesy of National Geological and Mining Survey (SERNAGEOMIN) 2012.

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SUMMARY OF EARTHQUAKES
1 JANUARY - 31 DECEMBER 2010
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
03 Jan	22:36	Solomon Islands	8.799° S 157.346° E	12	7.2 (G, P)	(A) 01 TIS (P) 01 TIB (J) 01 NWPTA (P) 02 TIB	22:57 23:03 23:04 00:10 (4 Jan)	YES YES	15 cm (peak to peak) (g) Rosslyn Bay, Australia
05 Jan	04:56	East of South Sandwich Islands	58.173° S 14.696° W	16	6.7 (A, G, P)	(A) 01 TIS (P) 01 TIB	05:14 05:12	NO NO	
05 Jan	12:16	Solomon Islands	9.019° S 157.551° E	12	6.9 (A, P) 6.8 (G)	(P) 01 TIB (A) 01 TIS (P) 02 TIB	12:30 12:30 13:43	YES NO	3 cm amp (g)Honiara, Solomon Islands
12 Jan	21:53	Haiti Region	18.443° N 72.571° W	12	7.3 (A, P) 7.1 (P 02 LTW) 7.0 (G)	(P) 01 LTW (C) (A) 01 TIS (C) (P) 02 LTW (C) (P) 03 LTW (C)	22:03 22:03 22:54 23:45	YES YES	12 cm (peak to trough) (g) Santo Domingo, Haiti
20 Jan	11:04	Haiti Region	18.423° N 72.823° W	12	6.0 (A, P) 5.9 (G)	(P) 01 TIB (C) (A) 01 TIS (C)	11:11 11:18	NO NO	
07 Feb	06:10	Southwest Ryukyu Islands, Japan	23.488° N 123.615° E	28	6.6 (A, J, P) 6.3 (G)	(J) 01 NWPTA (P) 01 TIB (A) 01 TIS	06:15 06:22 06:22	NO NO	
18 Feb	01:13	E. Russia-N.E. China Border Region	42.587° N 130.703° E	580	6.9 (G) 6.8 (A, P)	(P) 01 TIB (A) 01 TIS	01:22 01:22	NO NO	
26 Feb	20:31	Ryukyu Islands	25.965° N 128.443° E	18	7.3 (A, P) 7.0 (G) 6.9 (J)	(J) 01 NWPTA	20:35 20:44 20:48	NO NO	
27 Feb	06:34	Near Coast of Central Chile	35.846° S 72.719° W	24	8.8 (A 03 TIS, G, P 03 ERW) 8.6 (A, P 02 ERW) 8.5 (A 01 TIS, P 01 ERW)	(P) 01 ERW (A) 01 TIS (P) 02 ERW (A) 02 TIS (P) 03 ERW (A) 03 TIS	06:46 06:49 07:45 07:52 08:44 08:57	YES YES	2.6 m amp (g) Valparaiso, Chile

Earthquakes, *continued*

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
						(P) 04 ERW	09:47		
						(A) 04 TIS	09:58		
						(P) 05 TWW	10:45		
						(A) 05 TA	10:55		
						(P) 06 TWW	11:47		
						(A) 06 TA	11:53		
						(P) 07 TWW	12:49		
						(A) 07 TA	12:55		
						(P) 08 TWW	13:46		
						(A) 08 TA	13:52		
						(P) 09 TWW	14:46		
						(A) 09 TA	15:04		
						(P) 10 TWW	15:45		
						(A) 10 TA	16:03		
						(P) 11 TWW	16:50		
						(A) 11 TA	17:04		
						(P) 12 TWW	17:52		
						(A) 12 TA	17:58		
						(P) 13 TWW	18:43		
						(A) 13 TA	19:06		
						(P) 14 TWW	19:34		
						(A) 14 TA	20:03		
						(P) 15 TWW	20:28		
						(A) 15 TA	21:05		
						(P) 16 TWW	21:32		
						(A) 16 TA	21:47		
						(P) 17 TWW	22:41		
						(A) 17 TA	22:46		
						(A) 18 TA	23:54		
28 Feb									
						(P) 18 TWW	00:12		
						(A) 19 TA	00:54		
						(P) 19 TWW	01:35		
						(A) 20 TA	01:57		
						(P) 20 TWW	02:35		
						(A) 21 TA	03:05		
						(P) 21 TWW	03:44		
						(A) 22 TA	04:03		
						(P) 22 TWW	04:49		
						(A) 23 TA	05:01		
						(P) 23 TWW	05:56		
						(A) 24 TA	06:02		
						(P) 24 TWW	07:00		
						(A) 25 TA	07:13		
						(P) 25 TWW	07:57		
						(P) 26 TWW	08:59		
						(P) 27 TWW	09:40		
05 Mar	11:47	Near Coast of Central Chile	36.665° S 73.374° W	14	6.6 (A, G, P)	(P) 01 TIB (A) 01 TIS	11:59 12:00	NO NO	
05 Mar	16:07	Southern Sumatra, Indonesia	3.762° S 100.991° E	12	6.6 (J, P) 6.5 (G)	(P) 01 TIB (IO) (J) 01 TWI (IO)	16:17 16:32	NO NO	

Earthquakes, *continued*

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
11 Mar	14:40	Near Coast of Central Chile	34.290° S 71.891° W	15	7.2 (A, P) 6.8 (G)	(P) 01 TIB (A) 01 TIS	14:53 14:51	YES NO	29 cm (peak to peak) (g) San Antonio, Chile
14 Mar	00:58	Halmahera, Indonesia	1.692° S 128.135° E	59	6.5 (A, P) 6.4 (G)	(P) 01 TIB (A) 01 TIS	01:07 01:08	NO NO	
14 Mar	08:08	Near East Coast of Honshu, Japan	37.745° N 141.590° E	45	6.6 (J) 6.4 (G)	(J) 01 NWPTA	08:15	NO NO	
16 Mar	02:22	Near Coast of Central Chile	36.217° S 73.257° W	13	6.6 (A, P) 6.5 (G)	(P) 01 TIB (A) 01 TIS	02:30 02:32	NO NO	
30 Mar	16:55	Andaman Islands, India Region	13.667°N 92.831° E	30	6.9 (P) 6.4 (G)	(P) 01 TIB (IO) (J) 01 TWI	17:04 17:14	NO NO	
04 Apr	22:41	Baja, California, Mexico	32.259° N 115.287° W	12	7.3 (A, P) 7.2 (G)	(P) 01 TIB (A) 01 TIS	22:47 22:44	NO NO	
06 Apr	22:15	Northern Sumatra, Indonesia	2.360° N 97.132° E	20	7.7 (G) 7.5 (A, P)	(P) 01 LTW (IO) (A) 01 TIS (J) 01 TWI (IO) (P) 02 LTW (IO) (P) 03 LTW (IO) (J) 02 TWI (IO)	22:22 22:27 22:42 23:22 00:15 01:20 (7 April)	YES NO	4 cm (peak to peak) (g) Meulaboh, Indonesia
11 Apr	09:41	Solomon Islands	10.913° S 161.130° E	36	7.0 (A, P) 6.8 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	09:53 09:53 10:05	NO NO	
26 Apr	03:00	Southeast of Taiwan	22.241° N 123.709° E	26	6.5 (A, G, J, P)	(P) 01 TIB (J) 01 NWPTA (A) 01 TIS	03:08 03:09 03:09	NO NO	
30 Apr	23:12	Bering Sea	60.644° N 177.901° W	14	6.6 (A, P) 6.3 (G)	(A) 01 TIS (P) 01 TIB	23:17 23:21	NO NO	
05 May	16:29	Southern Sumatra Indonesia	4.063° S 101.085° E	12	6.5 (G, P)	(P) 01 TIB (IO) (J) 01 TWI	16:39 16:54	NO NO	
10 May	06:00	Off W. Coast of Northern Sumatra, Indonesia	3.775° N 96.055° E	38	7.3 (A, P) 7.2 (G)	(P) 01 LTW (IO) (A) 01 TIS (J) 01 TWI (IO) (P) 02 LTW (IO)	06:08 06:18 06:22 06:55	NO NO	
26 May	08:53	Southeast of the Ryukyu Islands	25.796° N 129.956° E	12	6.6 (A, J, P) 6.4 (G)	(J) 01 NWPTA (P) 01 TIB (A) 01 TIS	06:15 06:22 06:22	NO NO	
27 May	17:15	Vanuatu Islands	13.710° S 166.507° E	42	7.6 (A, J, P 01 FRW) 7.2 (G, P 02 FRW)	(P) 01 FRW (A) 01 TIS (J) 01 NWPTA (P) 02 FRW (P) 03 FRW	17:27 17:27 17:35 17:39 18:38	NO NO	
31 May	19:52	Andaman Islands, India Region	11.119° N 93.698° E	130	6.6 (J, P) 6.4 (G)	(P) 01 TIB (IO) (J) 01 TWI	20:07 20:17	NO NO	

Earthquakes, *continued*

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
12 Jun	19:27	Nicobar Islands, India Region	7.748° N 91.938° E	37	7.6 (A, J, P) 7.5 (G)	(P) 01 RTWB (IO) (J) 01 TWI (IO) (P) 02 LTWB (P) 03 LTWB	19:34 19:47 20:18 21:46	YES NO	6 cm (peak to trough) (g) Trincomalee, Sri Lanka
16 Jun	03:16	Irian Jaya Region, Indonesia	2.141° S 136.460° E	12	7.3 (A, J, P) 7.0 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	03:26 03:27 03:29	NO NO	
26 Jun	05:30	Solomon Islands	10.636° S 161.443° E	40	7.1 (A, J, P) 6.7 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	05:40 05:41 05:43	NO NO	
02 Jul	06:04	Vanuatu Islands	13.647° S 166.441° E	63	6.7 (A, J, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	06:14 06:16 06:22	NO NO	
14 Jul	08:32	Near Coast of Central Chile	38.002° S 73.282° W	17	6.5 (A, G, P)	(P) 01 TIB (A) 01 TIS	08:44 08:44	NO NO	
18 Jul	05:57	Fox Islands, Aleutian Islands	52.867° N 169.840° W	12	6.7 (A, P) 6.6 (G)	(P) 01 TIB (A) 01 TIS	06:04 06:01	NO NO	
18 Jul	13:04	New Britain Region, PNG	6.000° S 150.436° E	35	7.2 (A, J, P) 6.9 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	13:14 13:14 13:22	NO NO	
18 Jul	13:35	New Britain Region, PNG	5.939° S 150.572° E	37	7.3 (G, P 02 TIB) 6.8 (A, J, P)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA (P) 02 TIB (P) 03 TIB	14:10 14:14 14:17 15:37 15:45	NO NO	
20 Jul	19:18	New Britain Region, PNG	5.912° S 150.665° E	33	6.6 (A, J, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	19:27 19:29 19:36	NO NO	
23 Jul	22:08	Mindanao, Philippines	6.699° N 123.475° E	594	7.3 (G) 7.1 (A, J, P)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	22:16 22:17 22:23	NO NO	
23 Jul	22:51	Mindanao, Philippines	6.470° N 123.532° E	576	7.6 (G) 7.3 (A, J, P)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	23:01 23:02 23:06	NO NO	
23 Jul	23:15	Mindanao, Philippines	6.792° N 123.282° E	650	7.4 (G) 7.2 (A, J, P)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	23:27 23:27 23:31	NO NO	
24 Jul	05:35	Mindanao, Philippines	6.226° N 123.522° E	557	6.5 (A, G, J, P)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	05:44 05:45 05:50	NO NO	
3 Aug	12:09	Northern Molucca Sea	1.240° N 126.212° E	41	6.5 (A, J, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	12:18 12:19 12:24	NO NO	

Earthquakes, *continued*

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
4 Aug	22:02	New Britain Region, PNG	5.768° S 150.776° W	34	7.0 (A, J, P) 6.9 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	22:09 22:09 22:14	NO NO	
10 Aug	05:24	Vanuatu Islands	17.561° S 168.028° E	31	7.5 (P) 7.2 (G)	(P) 01 TIB	05:34	NO NO	
12 Aug	11:54	Ecuador	1.260° S 77.312° E	201	7.2 (A, P) 7.1 (G)	(P) 01 TIB (A) 01 TIS	12:03 12:09	NO NO	
13 Aug	21:20	South of Mariana Islands	12.480° N 141.482° E	12	7.2 (A, J, P) 6.9 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	21:29 21:30 21:37	NO NO	
14 Aug	07:30	South of Mariana Islands	12.350° N 141.492° E	12	6.5 (A, J, P) 6.1 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	07:40 07:41 07:42	NO NO	
14 Aug	23:01	South of Mariana Islands	12.211° N 141.408° E	12	6.5 (A, J, P) 6.3 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	23:11 23:12 23:20	NO NO	
3 Sep	11:16	Andreanof Islands, Aleutian Island	51.450° N 175.872° W	40	6.5 (A, G, P)	(A) 01 TIS (P) 01 TIB	11:21 11:28	NO NO	
3 Sep	16:36	South Island, New Zealand	43.530° S 172.120° E	12	7.4 (A, P) 7.0 (G)	(P) 01 TIB (A) 01 TIS	16:45 16:46	NO NO	
29 Sep	17:11	Aru Islands, Indonesia	4.920° S 133.783° E	15	7.2 (A, P) 7.0 (J) 6.9 (G)	(J) 01 NWPTA (P) 01 TIB (A) 01 TIS	17:39 18:08 18:11	NO NO	
21 Oct	17:53	Gulf of California	24.843° N 109.171° W	14	6.9 (A, P) 6.7 (G)	(P) 01 TIB (A) 01 TIS	18:02 18:02	NO NO	
25 Oct	14:42	Southern Sumatra, Indonesia	3.484° S 100.114° E	12	7.5 (A, J, P) 7.7 (G)	(P) 01 LTW (A) 01 TIS (J) 01 TWI (P) 02 LTW (J) 02 TWI (P) 03 LTW (J) 03 TWI (J) 04 TWI (J) 05 TWI (J) 06 TWI	14:49 14:53 15:01 15:49 16:20 16:42 17:20 20:10 21:30 1:00	YES NO	38 cm (amp) (g) Padang, Indonesia
30 Nov	3:24	Bonin Islands, Japan Region	28.365° N 139.152° E	464	6.9 (A, J, P) 6.8 (G)	(J) 01 NWPTA (P) 01 TIB (A) 01 TIS	3:31 3:32 3:33	NO NO	
2 Dec	3:12	New Britain Region, PNG	6.059° S 149.851° E	48	6.9 (A, J, P) 6.6 (G)	(P) 01 TIB (A) 01 TIS (J) 01 NWPTA	3:19 3:25 3:26	NO NO	

Chile, *continued*

the tsunami. Preliminary measures of a Rapid Survey Team deployed the week after the event by UNESCO showed run up measurements as high as 30 metres with most common measurements between 6 and 10 metres in the most affected area of the Chilean coast.

This was the first ocean wide test of a system that was put in place nearly 45 years ago by UNESCO's Member States through its Intergovernmental Oceanographic Commission (IOC), after a 9.5 magnitude earthquake on 22 May 22 1960 off Chile triggered an ocean-wide tsunami that caused 61 fatalities in Hawaii and 142 fatalities in Japan, several hours after the earthquake.

While coastal residential dwellings were destroyed from tsunami waves, very few people lost their lives (compared to the potential vulnerable population of 100,000+ people) – which is largely attributed to pre-event preparedness, awareness, and education. Elders who lived through the 1960 tsunami passed on their experience and wise advice to their children and grandchildren, and the 2004 Indian Ocean tsunami and more recent earthquakes reminded everyone of the need to be aware and prepare. These efforts were led by the Chile Navy's Hydrographic Service (SHOA), Chile disaster management agency (ONEMI), and universities and community organisations. Inundation maps, hazard and evacuation signage, and awareness and education materials were previously distributed along the coasts. Without these efforts for the decades before, it is certain that many more would have perished.

Factors that helped reduce vulnerability for this event were generally limited earthquake damage due to well-engineered structures, tsunami signage, tsunami-prepared police and fire responders who assisted in warning and evacuation, and a prepared and educated coastal public who also received training in schools and through community practice drills.

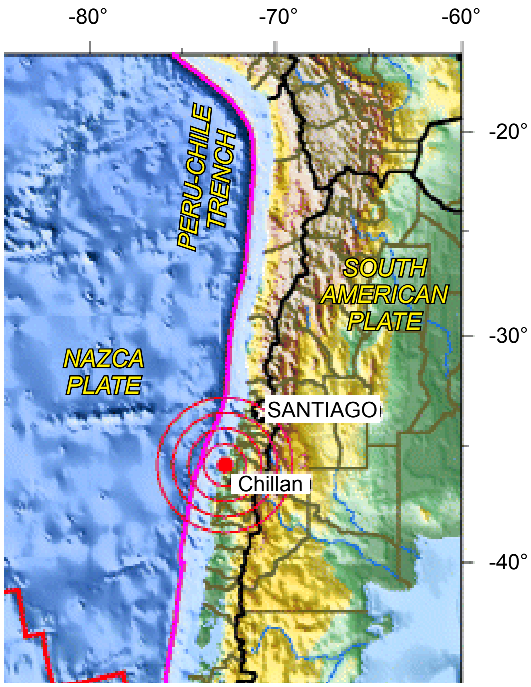
2010 Chile tsunami maritime destruction at Lebu, Chile. Photo courtesy of National Geological and Mining Survey (SERNAGEOMIN) 2012.

Damaged sea level station the day after the 27 February 2010 tsunami, Talcahuano, Chile. Photo courtesy of R. Núñez Gundlach.

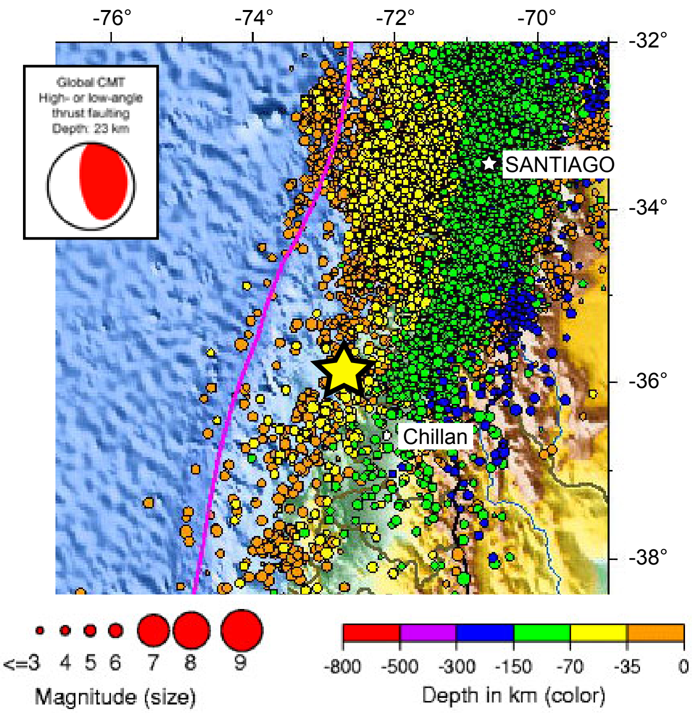
Factors that unfortunately increased the vulnerability were the time of day (many were sleeping so that the earthquake was their early warning), little tsunami hazard information at visitor facilities (such as campgrounds) to help uninformed/unaware tourists and workers, and the long duration of destructive tsunami waves (up to 4 hrs so people returned before the end). In the case of Constitucion, where 45 died, inopportune timing was the principal cause of death. Many were camping on an island at the river mouth with no evacuation method, the night after a summer-ending fireworks celebration.

Today, like in the South Pacific, Chile is working to strengthen their early warning systems, especially in hardening the communications infrastructures critical for providing information on warning and evacuation, and in improving the earthquake and tsunami detection networks to more quickly assess tsunami threat to their coasts. Many are aware that the next tsunami will probably be to the north where there is already a long history of destructive tsunamis. Awareness and outreach campaigns in this region aim to further strengthen community preparedness. Again, the emphasis for local tsunamis is to ensure that everyone knows a tsunami's natural warning signs and then immediately take action since the tsunami may attack coasts within 10-30 minutes after the earthquake.

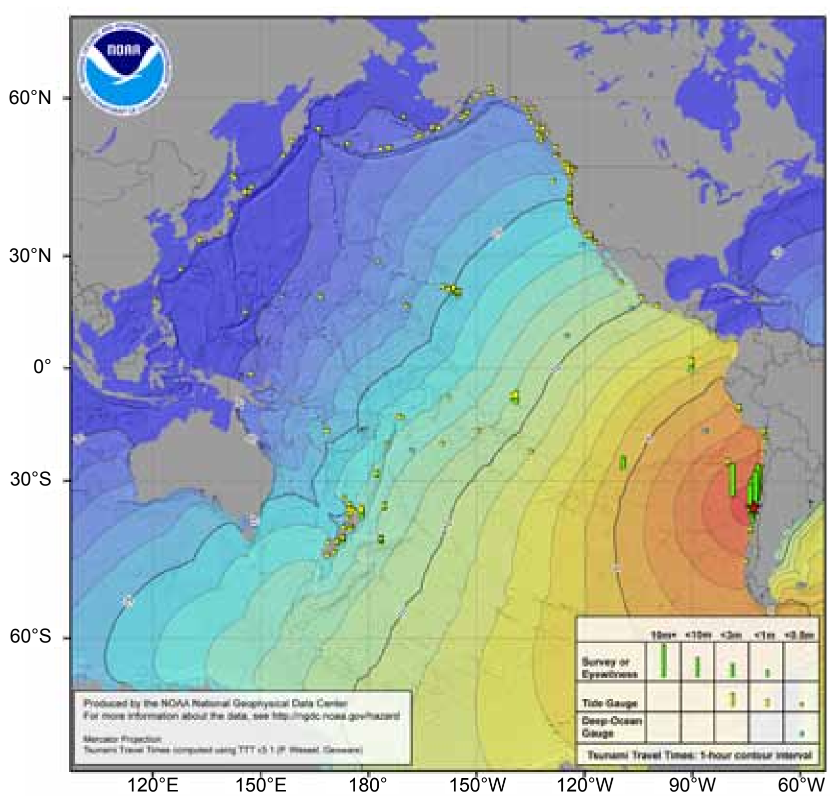
Chile Tsunami, *continued*



Magnitude 8.8 offshore Central Chile, 27 February 2010, depth 35.0 km. Map courtesy of USGS National Earthquake Information Center (NEIC).

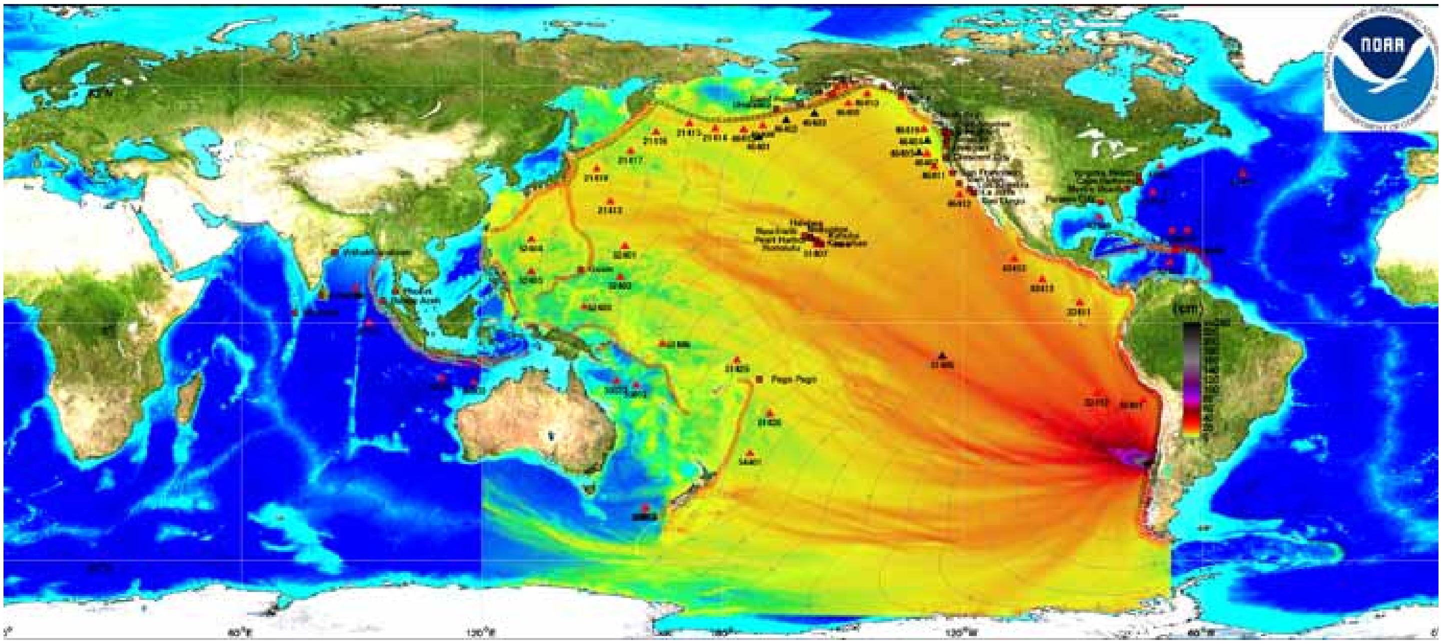


Historic regional seismicity. 27 February 2010 epicentre marked by a yellow star. Map courtesy of USGS National Earthquake Information Center (NEIC).



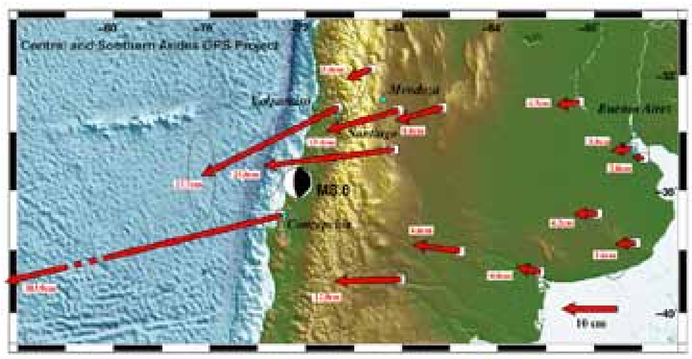
Observed Chile tsunami water heights and travel times. Map courtesy of NOAA.

Chile Tsunami, *continued*

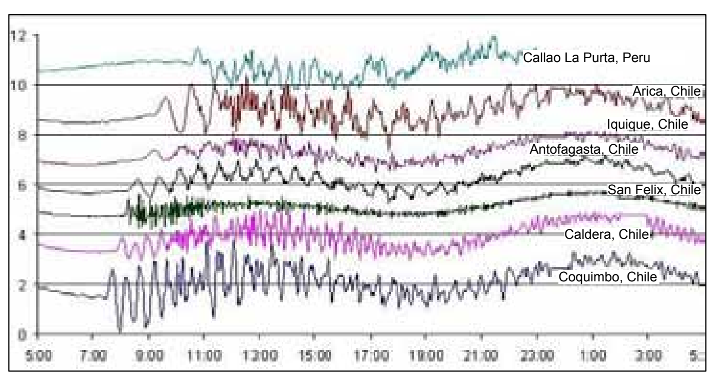


Energy propagation pattern of the 27 February 2010 tsunami calculated with Method of Splitting Tsunamis (MOST) model. Map courtesy of NOAA.

Preliminary coseismic GPS displacement field M8.8 Maule Earthquake, Chile, 27 February 2010. Map courtesy of Ohio State University/UNAVCO.



Zoomed in view of GPS measured displacement field of South Central Chile. Map courtesy of Ohio State University/UNAVCO.



Northern Chile and Peru Sea Level stations: Coquimbo, Caldera, San Felix, Antofagasta, Iquique, and Arica (Chile) and Callao La Punta (Peru). Courtesy of NOAA.

See WC/ATWC website for more sea level gauge data. http://wcatwc.arh.noaa.gov/previous.events/Chile_02-27-10/index.php

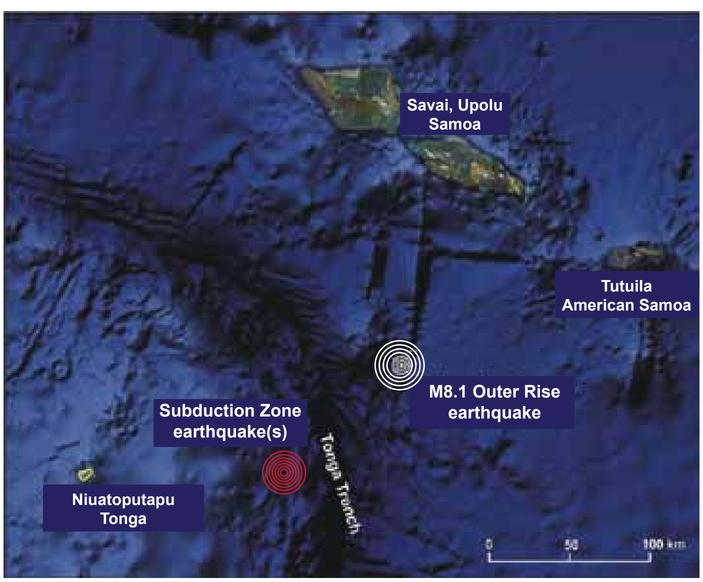
Two Great Earthquakes Associated with South Pacific Tsunami, 29 September 2009

The Pacific Ocean and its adjacent marginal seas are the largest, most diverse, and most tsunami-prone of any of the earth's oceans. Pacific Ocean nations face and must be prepared for both distant which may take a day to traverse the Pacific, and local tsunami threats which will attack in minutes.

Kenji Satake[1] of the Earthquake Research Institute, University of Tokyo, lays out a comparison of separate GPS and seismic investigations by Beavan et al.[2] and Lay et al.[3], which come to different conclusions about the order sequence of two great, but dissimilar Tonga Trench earthquakes associated with the South Pacific Tsunami of 29 September 2009. The authors agree that two great earthquakes reaching magnitude 8 overlapped in time in adjoined locations with differing mechanisms. However, the authors come to different conclusions about which came first and how one earthquake triggered the other.

The South Pacific Tsunami caused the loss of 192 lives (34 in American Samoa, 149 in Samoa, 9 in Tonga) and extensive damage in Samoa, American Samoa, northern Tonga and Wallis & Futuna. Most of the casualties were the elderly and young children. Maximum run up of 12 m in Samoa, almost 18 m in American Samoa, 5 m in Tonga and 4.5 m in Wallis & Futuna were measured.

Beaven, et al.[2] present a case that an initial slow slip rate, interplate earthquake (focus on a plate boundary) occurred, due to compressional stress at the Tonga Trench boundary between the descending or subducting Pacific plate beneath the Australian plate, which was not detected through normal observed seismogram records. These two plates are moving towards one another at about 20 centimetres per year, notably faster than at another other plate convergence worldwide. This slow earthquake was immediately followed by a second, intraplate extensional normal faulting earthquake (focus within a plate) that occurred in an area known as an outer-rise earthquake, where the descending Pacific plate begins to bend into the Tonga trench. Analysis of data was gathered from GPS measurements and models of tsunami waveforms recorded at DART stations. An estimated 35 centimetres of horizontal movement occurred in northern Tonga, in a direction opposite to that expected for an outer-rise earthquake.



Generalised tectonic sketch showing the earthquake doublet (red and blue faults), resulting tsunamis, and their relationship to Samoa and Tonga. In this region, the Pacific Plate is subducting beneath the Australian Plate at a rate of about 8-9 cm/yr. Map courtesy of GNS.

Lay, et al.[3] present a case that there was an initial outer-rise intraplate earthquake, followed by an interplate earthquake. If the second interplate earthquake occurred shortly after the initial outer-rise intraplate earthquake, the second signal can become buried in seismic data records. Lay et al.[3] conducted a detailed analysis of available broadband seismic data and detected signals from earthquakes after the initial outer-rise earthquake. Their model depicts the initial main outer-rise earthquake triggered the rupture of the plate boundary earthquake by shaking it.

Both authors agree that the main, seismically visible Tonga Trench earthquake was the intraplate event. However, if the "slow" subduction thrust had not been accompanied by the normal faulting event, it is unknown if adequate detection and warning have been given. Seismologists do not know exact causes of slow earthquakes, and where or when they will occur.

Satake[1] further describes that several outer-rise earthquakes have occurred during the past 100 years. For example, in November 2006, a plate boundary earthquake magnitude 8.3 occurred along the Kuril trench, which triggered an extensional outer-rise earthquake of magnitude 8.1 just two months later in January 2007 by causing the subducting plate to pull away from the outer-rise. The force of the downward pull by the descending plate can be transmitted towards the outer-rise, if the two plates do not accumulate strain on the plate-boundary fault. Also, it can increase suddenly

Great Earthquakes, *continued*

if the plate boundary breaks in a great earthquake.

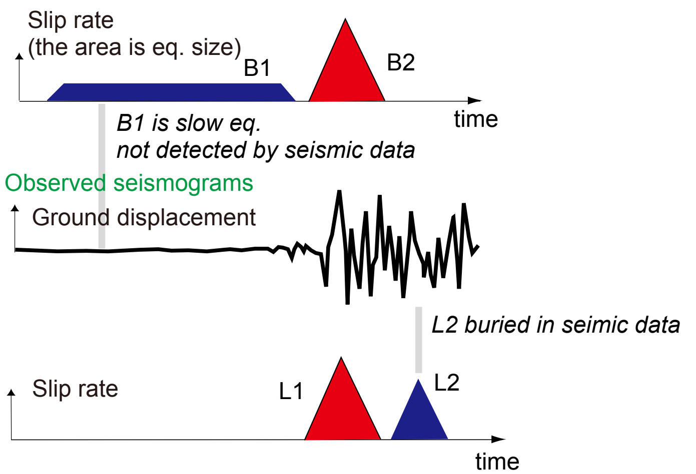
Satake[1] summarises that seismologically, both the Beaven et al.[2] and Lay et al.[3] interpretations are not definitive. Satake[1] states, "Taken together, the two papers leave uncertainty as which of the two earthquakes happened first. And, until we learn which of them was the cause and which the effect, it will be difficult to know whether the trigger was the release of static stress on an extensional fault, or of dynamic stress on a compressional one."

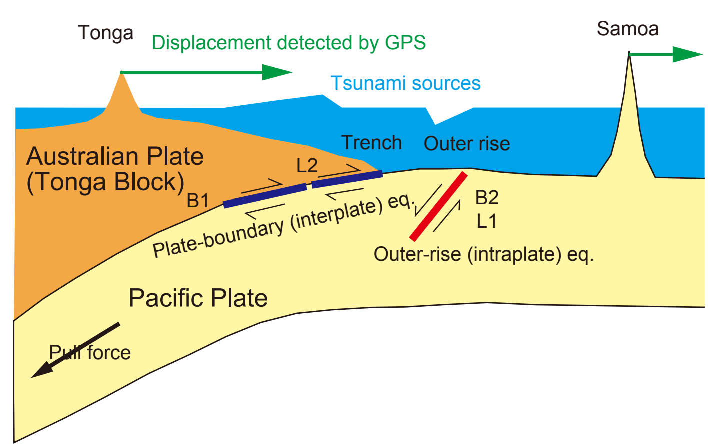
Additionally, the availability of more GPS and seismic data has allowed scientists to uncover additional details of the complexity of the seismic process including earthquake sources and tsunami generation. However, seismologists are realising that instrumental and observational records of great earthquakes are small and limited, with only a few hundred years of available data. Thus, risk estimates are based on too little history. Therefore, it is difficult to determine the recurrence intervals of great earthquakes. Seismologists must continue to expand and supplement their research to include historic geologic records, paleo-seismology and paleo-tsunami records.

When tsunamis are local and very near to coasts, international and national tsunami warning centers may not be able to usefully warn citizens before the first tsunami waves arrive. For this situation, it is essential that communities invest in educating their residents about what a tsunami is, how they can recognise a tsunami, and what to do when they know a tsunami is coming. Preparing before the emergency, and then heeding the natural tsunami warnings when they do occur, are the two most important activities you can do to save your life. In other words, no one should be wait for an official alert from the Tonga Meteorological Service, or National Emergency Management Agency, to evacuate. Rather, if you are at the coast and a big earthquake happens with strong or long shaking, followed by unusual ocean changes and/or load ocean roars, then you must know that a tsunami is coming and immediately go to higher ground and inland!

This was clearly demonstrated in American Samoa and Samoa, where both countries had actively engaged in pre-event awareness and education. For last decade, this has been carried out continuously in American Samoa and September 2009 was American Samoa Disaster Preparedness month. Factors which helped to reduce the casualties were the time of day (many were already awake, but not on the road and the work day had not started), generally limited earthquake damage which reduced injuries and damage to transportation infrastructure, relative closeness and availability of high ground, pre-event plans (such as school evacuation plans in American Samoa) and government, community, and school tsunami exercises and drills (International Exercise Pacific Wave in 2006 and 2008; National Drill in 2007 and 2008 in Samoa). The 2004 Indian Ocean tsunami, and more recently, the 19 March earthquake off Tonga, also served as reminders of what tsunamis can do, and how warning and response agencies need to coordinate and respond.

Today, the countries are working on recovery issues, and improving their early warning and alert





Images showing the conclusions drawn by scientists Lay, et al. (L) and Beavan, et al. (B) of the two Tonga earthquakes. Both agree on the types of earthquakes, however, both draw different conclusions of order in which earthquakes occurred first. Images courtesy of K. Satake.

Great Earthquakes, *continued*

systems, especially in hardening the communications infrastructures critical for providing information on warning and evacuation. Both traditional methods of alerting (bells), and modern media (sirens, mobile phone alerting, radio/TV broadcast), are being strengthened. In addition, at the community and village levels, education and preparedness continues such as the development and/or clarification of evacuation maps and routes to safe areas. As the countries build back, they are doing so in ways that acknowledge and recognise that traditional building practices (such as open fales in Samoa and American Samoa) survived well.

1. Satake, K. Nature Vol 466, 931-932 (2010)
2. Beaven, J. et al. Nature Vol 466, 959-963 (2010)
3. Lay, T. et al. Nature Vol 466, 964-968 (2010)

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Beavan, J., X. Wang, C. Holden, K. Wilson, W. Power, G. Presetya, M. Bevis, and R. Kautoke, 2010. Near-simultaneous great earthquakes at Tongan megathrust and outer rise in Spetember 2009, Nature, 466, 959-963

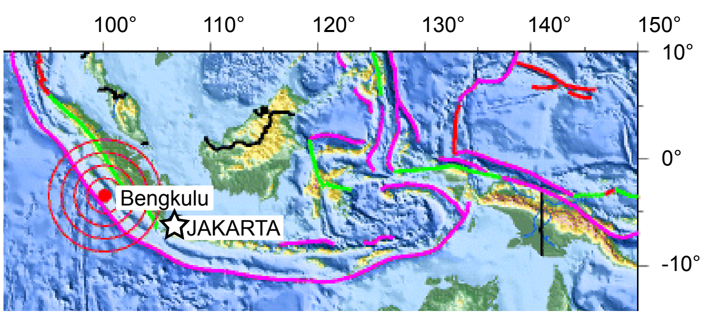
Lay, T., C.J. Ammon, H. Kanamori, L. Rivera, K.D. Koper, and A. R. Hutko, 2010. The 2009 Samoa-Tonga great earthquake triggered by doublet, Nature, 466, 964-968.

Satake, K., 2010. Double trouble at Tonga, Nature, 466, 931-932.

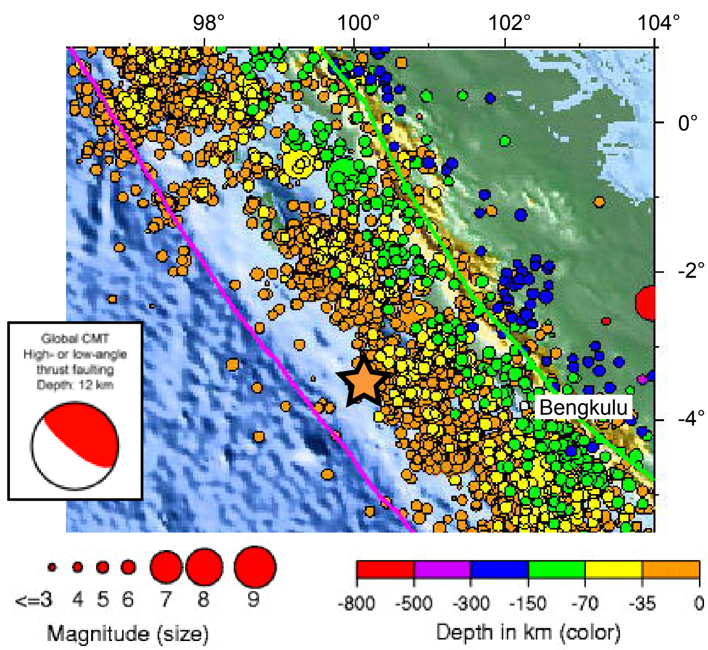
Mentawai Islands, Indonesia Earthquake, 25 October 2010, 14:42 UTC, M_w = 7.7

A major magnitude 7.7 earthquake occurred in the Mentawai Islands on 25 October 2010 at 14:42 UTC (9:42 PM local time), off the western coast of Sumatra, Indonesia. The earthquake and tsunami caused damage and over 400 deaths. The Indonesia Meteorological, Climatological and Geophysical Agency issued nationally a local tsunami warning, five minutes after the earthquake. The Pacific Tsunami Warning Center and Japan Meteorological Agencies subsequently issued local tsunami watches seven and nineteen minutes after the earthquake, respectively, to Indian Ocean countries.

The earthquake was widely felt in the Mentawai Islands as a swinging or swaying motion, which awoke people. The depth of the earthquake beneath the seafloor was 12 kilometres. Many residents were watching television and saw running text of the Indonesia tsunami warning. Others saw the sea receding quickly and could hear a strong sound approaching prior to the tsunami arrival. Many coastal residents and tourists recognised these classic signs of a tsunami and ran away from the beaches. At Macaronis resort in North Pagai Island, foreign surfers escaped to a 3-story hotel tower and survived. The highest sea level instrument measured tsunami amplitude locally was 38 centrimeteres in Padang. However, preliminary post tsunami reconnaissance field surveys measured tsunami runups in the range of 2.5 – 8.8 metres. The Indonesia Tsunami Warning was cancelled at 10:35 PM local time. Some communities suffered severely, while others that had undergone tsunami education and preparedness drill training, like Tumalei village with nearby high ground, had little casualties.

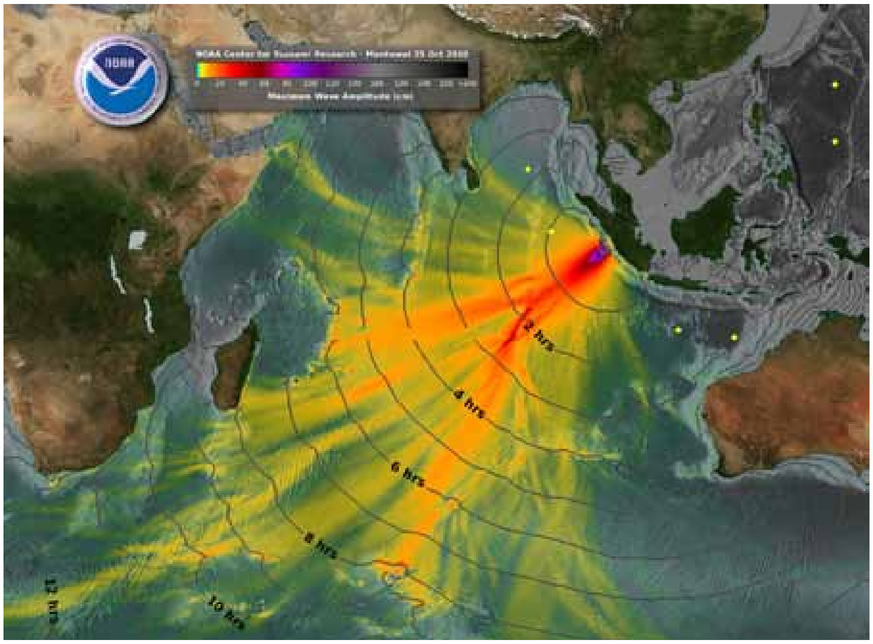


Mentawai earthquake seismic map. Map courtesy of USGS National Earthquake Information Center (NEIC).



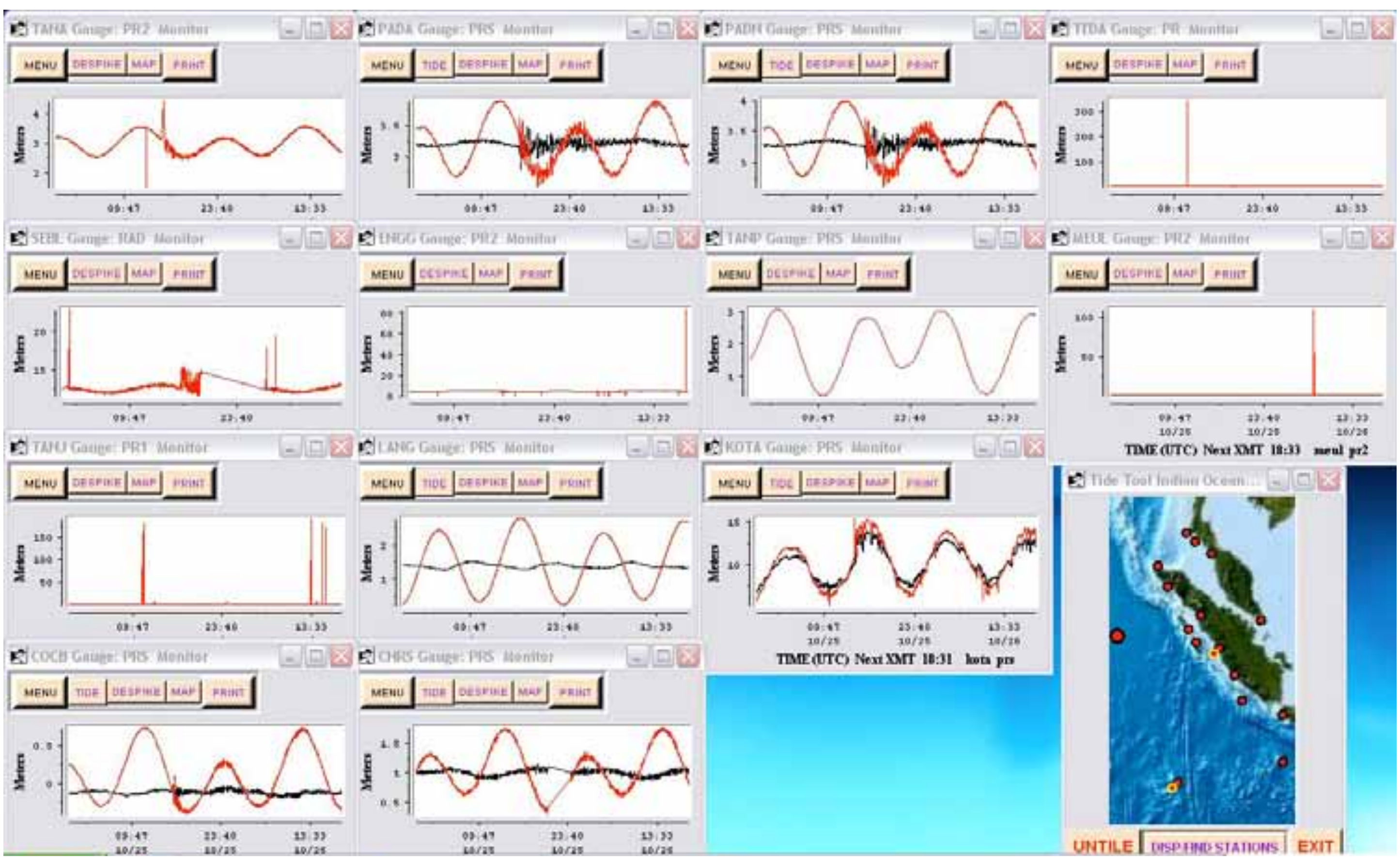
Historic seismicity with Mentawai earthquake location marked by an orange star. Map courtesy of USGS National Earthquake Information Center (NEIC).

Mentawai, *continued*



Mentawai tsunami travel times and energy propagation pattern. Map courtesy of NOAA.

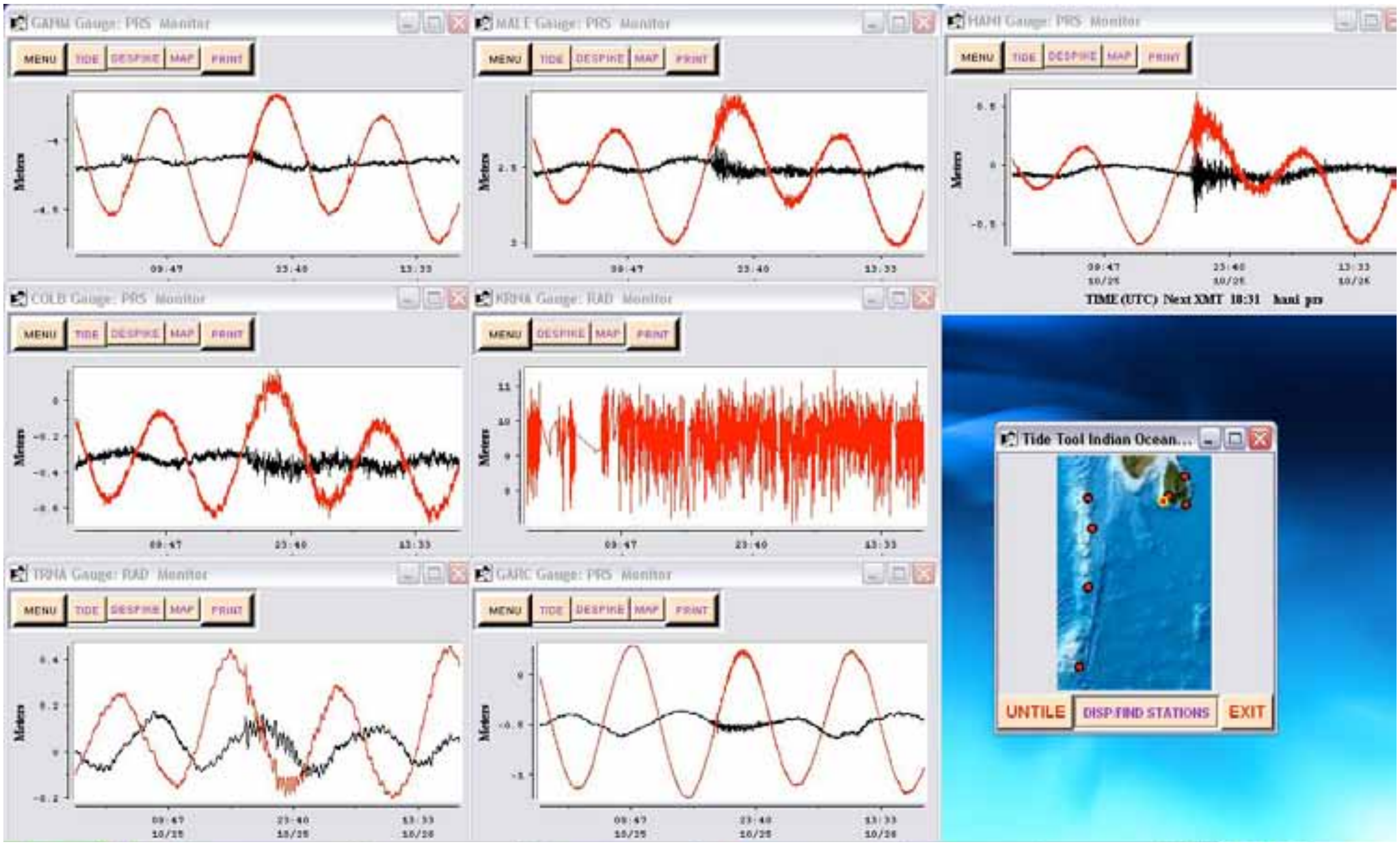
INDONESIA REGION STATIONS



Tide tool sea level measurements for Indonesia Region Stations. Courtesy of NOAA.

Mentawai, *continued*

CENTRAL INDIAN OCEAN STATIONS



Tide tool sea level measurements for Central Indian Ocean Stations. Courtesy of NOAA.

MENTAWAI TSUNAMI WAVE MEASUREMENTS

Station	Arrival Time/Date		Zero-2-Peak	Peak-2-Peak	Period	Measurement Time		LAT	LONG
Rodrigue Mauritius	20:34	10/25	0.260m	0.797	12:30	21:00	10/25	-19.6803	63.4215
Port Luis Mauritius	21:47	10/25	0.236m	0.558	15:30	22:27	10/25	-20.1573	57.5041
Cocos Island Australia	16:05	10/25	0.200m	0.326	5:30	16;23	10/25	-12.1167	96.8919
Enggano Indonesia	15:19	10/25	0.220m	0.510	9:00	15:25	10/25	-5.3461	102.2781
Padang Indonesia	15:40	10/25	0.380m	0.660	14:30	15:51	10/25	-0.9500	100.3661
Tanahbalah Indonesia	15:39	10/25	0.253m	0.460	16:20	16:05	10/25	-0.5326	98.4977
Telukdalam Indonesia	16:10	10/25	0.135m	0.215	14:45	16:36	10/25	0.5542	97.8222
Hillarys Harbor Australia	19:45	10/25	0.080m	0.153	18:30	00:08	10/26	-31.8255	115.7386
DART 56001 (West Java)	16:40?	10/25	~0.007m	~0.020	17:30	16:46	10/25	-13.9614	110.0039
Diego Garcia UK	18:40	10/25	0.060m	0.130	5:00	19:22	10/25	-7.2963	72.3941
Gan Maldives	18:41	10/25	0.005m	0.105	6:00	19:02	10/25	-0.6869	73.1500
Pt. LaRue Seychelles	22:34	10/25	0.132m	0.240	12:00	23:04	10/25	-4.6717	55.5283
Male Maldives	18:54	10/25	0.080m	0.210	5:00	19:31	10/25	4.19	73.5267
Hanimaadhoo Maldives	19:07	10/25	0.286m	0.620	6:30	19:59	10/25	6.7667	73.1667
Colombo Sri Lanka	18:41	10/25	0.090m	0.185	17:30	20:34	10/25	6.9483	79.8533
Trinconmalee Sri Lanka	18:31	10/25	0.070m	0.136	30:00	18:21	10/25	8.5637	81.1996

Data courtesy of NOAA.

See WC/ATWC link for more sea level gauge data. http://wcatwc.arh.noaa.gov/previous.events/Indonesia_10-25-10/index.php

IOC NEWS

Chile Tsunami Post-Event Assessment of PTWS Performance

The Chilean earthquake and tsunami event presented an ideal opportunity to assess the performance of the PTWS. To that end the UNESCO IOC Secretariat for the PTWS sent out a post-event survey questionnaire to the Tsunami Warning Focal Points (TWFPs) and Tsunami National Contacts (TNCs) from its 32 Member States and territories. This report has been prepared by the Secretariat based on the responses received from 19 TWFPs and TNCs.

Although is beyond the scope of this report to conduct a detailed interpretation of the results; it is expected that the survey results are useful for individual Member States and the PTWS to draw conclusions from this survey and decide on future action. In this regard, some highlights can be noted:

- From the 19 response, 18 National Tsunami Warning Centres (NTWCs) received the first bulletins from PTWC and/or WC/ATWC.
- 16 NTWCs received subsequent tsunami bulletins from PTWC.
- 17 NTWCs received information from sources other than PTWC and/or WC/ATWC.
- 9 Member States and territories took some action before receiving the PTWC and/or WC/ATWC bulletin.
- 17 Member States and territories took some action after receiving the PTWC and/or WC/ATWC bulletin.
- 14 Member States and territories issued a tsunami warning.
- 3 Member States and territories reported communication problems when issuing the warning.
- In 9 Member States there were areas evacuated.
- 8 Member States forecasted tsunami wave height.
- 15 Member States and territories monitored sea level.

  7 through the World Meteorological Organisation (WMO)'s Global Telecommunications Systems (GTS).

  7 through the IOC Sea Level Station Monitoring Facility.

  8 by other methods.
- 11 undertook their own earthquake analysis.
- 12 NTWCs used numerical models in their analysis.
- 9 Member States affirmed to have knowledge on how to access sea level data through GTS.
- 10 Member States affirmed to have knowledge on how to access sea level data through the IOC Sea Level Station Monitoring Facility website.

We underscore that all NTWCs received the first PTWC bulletin. However, not all NTWCs reported to have received all the PTWC bulletins. In addition, most of the countries reported PTWC as source of awareness of the earthquake. Furthermore, some countries undertook actions before the reception of the PTWC bulletin. Among these actions, it was mentioned: (1) Seismic monitoring; (2) Sea level monitoring; (3) Gathering of specialised personnel.

In addition, as mentioned before, 14 countries issued tsunami a warning. The media (radio, TV and/or press) was used as communication channel by 11 of the Member States and territories for both emission and cancellation of the warning. Three countries reported communication problems (i.e. no answer from the part of the concerned institutions because of holiday; insufficient technical capacity to answer public calls – saturation of phone lines; zones that were not covered by the network GSM). Furthermore, in 9 Member States, coastal zones were evacuated. The decision of issuing an evacuation order is based on the estimation of the tsunami travel time, the wave height and the identification of the potentially impacted zones. In this regard, evacuations were carried out where it was considered necessary from a technical point of view. It would be pertinent that each Member State analyse if an evacuation would have been necessary in zones where no evacuation was made. In 4 countries, some areas were evacuated preventively (self-evacuation). Moreover, it was observed that sea level was monitored by most of the countries. Moreover, some countries also used numerical modelling and calculated earthquake parameters.

Chile Tsunami Post-Event, *continued*

Based on data and information collected from Member States, the PTWS acted promptly and efficiently throughout the Pacific. However, and at the same time, this event demonstrated the need to reinforce the work of PTWS for near field events, particularly with denser sea level real time networks close to active subduction areas. Indeed, as it has been demonstrated by the case of the sea level station in Talcahuano, Chile, sea level stations close to the epicenter may be partially or totally destroyed by the impact of a tsunami. Given the critical role sea level readings play in tsunami warning systems, the sea level monitoring networks should be densified close to active subduction areas.

Most of the issues revealed by the survey can be addressed both by the PTWS and at the national level through increased regional cooperation and training where needed. Post-event assessments assist in this process by highlighting the strengths and weaknesses of the PTWS at regional, national and local levels and by raising the awareness of how Member States responded, both individually and collectively. The true value of such assessments is that it allows Member States to share information and experiences for the mutual benefit of improving the PTWS for all members.

ITIC-PTWC NEWS

ITIC Training Programme-Hawaii (ITP-Hawaii), Honolulu, Hawaii, USA 30 August - 10 September 2010

The ITIC Training Programme (ITP-Hawaii) has been conducted by the ITIC nearly annually since the 1970s. The programme brings participants to Hawaii to learn about the actual operations of the Pacific Tsunami Warning and Mitigation System, and in doing so, helps countries to build and implement their national programmes. Typically, the training length is two weeks. A specific agenda was customised according to the needs of participants. The training is through actual discussions with working organisations involved in the end-to-end warning system, and includes discussions on preparedness and community awareness building. The training has traditionally targeted PTWS participants. Upon interest and with funding, the ITIC is happy to arrange similar training with focus on PTWS or IOTWS needs.

The ITP-Hawaii 2010 was conducted from 30 August -10 September 2010. ITIC hosted 16 participants from 12 countries (Chile, Ecuador, Fiji, Indonesia, Palau, Papua New Guinea, St. Lucia, Thailand, Tuvalu, USA - American Samoa/Commonwealth of Northern Mariana Islands/Guam, Vanuatu, West Indies) in the Pacific and Caribbean representing Tsunami Warning Systems and Disaster Management. The area of focus was on Standard Operating Procedures (SOPs) of tsunami warning centres and emergency operations centres, and the testing of SOPs through Drills and Exercises. Special emphasis was also given to telecommunications and methods for receiving and disseminating timely alerts. Participants were asked to create, modify, and discuss their country draft SOPs using guidance and template examples provided during the Training. Lectures and/or tours were given by PTWC, Hawaiian Volcano Observatory, Pacific Tsunami Museum, Hawaii State and County Civil Defense agencies.

Country Trip Reports ITP-Hawaii 2010

American Samoa

by Carol Baqui, NOAA/NWS Pago Pago

The tsunami training in Honolulu provided essential outreach information worth sharing with my community and government officials. Official tours to Civil Defense agencies in Honolulu and Hilo furnished awareness on how their operation runs during a 24-hour shift, and how advance they prepare their staff and community before an arrival of a tsunami. Other tours to the Hilo Tsunami Museum, Kilauea summit, and PTWC provided educational and insightful information. Speakers from these tour sites expressed their joy and passion in what they do, and their roles help spread awareness on tsunami in their respective locations.

My favorite part of the two weeks training was the science behind the tsunami. Although it may take many years to improve the tsunami modeling forecast, it's good to know that scientists are finding more ways to expand their expertise in the tsunami field so that people can sleep peacefully at night. The professor from University of Hawaii, Dr. Kwock Fai Cheung, gave an impressive modelling presentation, and I recommend his name to be on the presenters list for all future trainings.

Country Trip Reports, *continued*

The one area that everyone seems to lack is communication experience with the media. Some managers shy away from television interviews, while others don't plan to hear themselves over the radio. Maybe the ITP should look into adding a half day media training session to equip participants with new interview techniques and how to befriend the media before and after natural disasters.

I would like to personally thank Dr. Laura Kong and the selection committee for accepting me in this year's ITP training. Before attending the ITP, I lacked the science on tsunami; but during the training I gained valuable information that I now can use for my outreach and media workshops. Also, thanks to Dr. Kong, Brian Yanagi, and ITIC staff for hosting this ITP training in Honolulu. Their dedication and commitment were transparent and welcoming.

Commonwealth of Northern Mariana Islands

by Juan T. Camacho, CNMI Emergency Management Office

Introduction

This report covers the activities during the ITIC Tsunami Training Program in Hawaii on Tsunami Early Warning and Mitigation Systems from Aug. 30 to Sept. 10, 2010. The training provide me with the overview of the history and operation of the Pacific Tsunami Warning and Mitigation System with focus on the important role of regional and national tsunami warning centers in monitoring and evaluating the tsunami. What was learned during the training will be applied back in the CNMI. Issuing timely tsunami warning messages to emergency managers and government agencies who can act to save lives and reduce damage to coastal communities is essential. I now fully understand how the Warning System disseminates information out to

Participants of the 2010 ITIC Training Programme-Hawaii. Back wall: Noa Tokavou (SOPAC), Jeremiah Malaibe (PNG Met), Dawn French (West Indies NEMO), Hilia Vavae (Tuvalu Met), Konny Nato (PNG Met). Middle Row: Felipe Burnett (Chile SHOA), Brian Yanagi (ITIC), Genevieve Miller (Guam Met), Juan Camacho (CNMI EMO), Mathew Moihoi (PNG PMGO), Peter Korisa (Vanuatu NDMO), David Gibson (Vanuatu Met). Front Row: Aurelio Gordillo (Ecuador INOCAR), Bayu Pranata (Indonesia BMKG), Kaigabu Kamnanaya (PNG NDC), Maria Ngemaes (Palau Met), Dr. Laura Kong (ITIC). Photo courtesy of B. Yanagi.

Country Trip Reports, *continued*

the emergency managers and government agencies. The PTWC and USGS made a tremendous effort in providing timely warning to the government agencies and emergency managers around the entire pacific within PTWC's areas of responsibility in 30 minutes or less. Only National and Local government agencies have the authority to make decisions regarding the official state of alert in their area and any actions to be taken in response. The communication equipment, tools and materials are very important to make early warning notification to government agencies and emergency managers. Some of the other countries have communication problems in receiving early warning from the authority.

We mostly focused on Standard Operation Procedures (SOP) for the tsunami warning and tsunami emergency response and testing of the SOP through drills and exercise. Special target as well is telecommunication methods and equipment for receiving and disseminating timely alerts or warnings. I presented our CNMI Tsunami Standard Operation Procedure (SOP) dated January 2007 and found out some of the information are specific for Hawaii use only. The purpose of the SOP is for responders, stakeholders and government agencies to have a basic knowledge of tsunami science, and be familiar with warning concepts, detection, threat evaluation and alerting methods and emergency response and evacuation operations. We are currently reviewing our CNMI Tsunami SOP.

I will use this training on awareness and preparedness for CNMI Response Activity Coordinators (RAC) which consist of Departments heads, Secretary, Directors and Commissioners so they can understand their role and responsibility in tsunami concepts and threat which might be included in the Emergency Support Functions (ESF). The CNMI is the only country that has no National Weather Services or Meteorologist on island but conducts close consultation with National Weather Service in Guam.

Acknowledgement

I would like to thanks, NOAA, UNESCO, IOC, PTWC, Hawaii Stat Civil Defense and ITIC for facilitating, supplying very skilled resource personnel and providing training materials for the training program.

In the aftermath of the 26 December 2004 Indian Ocean Tsunami and the latest 29 September 2009 Samoa Tsunami, many excellent awareness materials were developed, especially at the country level to inform the public and decision makers on tsunami hazards, risks, preparedness and mitigation. The ITIC offers a small compilation of general and basic tsunami awareness materials that can be used to support the needs of government agencies, emergency managers and educators.

ITP participant Hilia Vavae (Tuvalu) views a historic display at the Pacific Tsunami Museum in Hilo. Photo courtesy of B. Pranata.

Papua New Guinea

by Konny Nato, PNG NWS

Introduction

This course report covers briefly the activities engaged in during the ITIC Training Program on Tsunami Early Warning and Mitigation Systems in Hawaii (USA) from 30th August to 10th September 2010. The report basically covers acknowledgement, activities participated in, what was learned during the training and how the lessons learned from the training are applied back here in Papua New Guinea.

Acknowledgement

I would like to take this opportunity to firstly, thank World Meteorological Organization (WMO) through South Pacific Regional Environmental Program (SPREP) for funding assistance, which has enabled me to attend the ITIC training program. I would also like to thank NOAA, UNESCO, IOC and ITIC for facilitating, supplying very skilled resource personnel and providing training materials for the training program. And finally, I would like to thank the Government of Papua New Guinea through PNG National Weather Service for nominating me and also releasing me from my official duties to attend this very important training.

Country Trip Reports, *continued*

Participated Activities

The training was professionally organised in a way that the travel, hotels and the learning materials were easily accessible and is convenient for everyone during the training. It was intensive in a sense that the participants were kept busy from 9:00am to 4:30pm daily. During the ten days training, we were exposed to the following modules:

- Country presentation
- International & National Tsunami Warning & Mitigation System
- End-to-End Tsunami Warning & Emergency Response
- Earthquake & Tsunami Science & hazard
- Global Ocean Observing System & its use in Tsunami warning
- Lessons learned from Past Tsunami events/ Example Hawaii
- Concept of Operation & Standard Operational Procedures

To complement the lessons learned from the lecture room, there were also organised excursions to Pacific Tsunami Warning Center (PTWC), State and County Civil Defense office and further two days visit to Hawaii Island.

Lesson Learned

During country presentations, participants were exposed to how different countries would go about with their Tsunami warning and mitigation systems during a tsunami threat and how they would deal with it. It was interesting to know how other countries would utilise their limited resource to save lives and properties.

The training course also covered how a warning issued by an International Tsunami Warning Centre (PTWC, JMA) should be technically interpreted by the leading Tsunami Warning Organisation in our respective countries and subsequent local warning issued accordingly during an End-to-End Tsunami warning and Emergency response lesson. Method of communicating warnings using sirens, alarms and other modes were covered in international and national tsunami warning and mitigation systems, while earthquake and tsunami science further enhanced our understanding on how, what and when questions on tsunami.

I am of the view that the best part of the training was the lessons learned from the Concept of Operation (COP) and the Standard Operational Procedure (SOP). During that part of the training, most participants were eager to know more on the subject backed by their countless questions. The COP and SOP clearly demarcate who does what within an organisation (main contact point of tsunami threat), and collectively as a body between different organisations to warn and mitigate the possible casualties during a tsunami threat.

The excursion and the field trip were very informative in a sense that it enriches and complement what was taught in class. The participants were exposed to the first hand practical information from field experts in Pacific Tsunami Warning Center, State and County Civil Defense and Hawaiian Volcanoes Observatory to firmly strengthen what was learned during the training.

Application

In Papua New Guinea, the National Disaster Office, PNG Geophysical Observatory and PNG National Weather Service are in the process of putting together a SOP for our respective organisations using the lessons for the ITIC training course as a guide. We are also with other partners (climate change and adaptation) are putting together coastal early warning system with climate change activities. These are two main concepts from the ITIC training we are currently implementing here in Papua New Guinea.

Other aspects of the training would be put to good use when the actual threat arises and I'm positively sure that we will always refer to the ITP training material for guidance and assistance when the tsunami threat arises.

ITP participants visit the Hawaii County Civil Defense Agency in Hilo. Photo courtesy of T. Fukuji.

Country Trip Reports, *continued*

Conclusion

The ITIC Training Course on Early Tsunami & Mitigation Systems has broadened our understanding on tsunami and the danger it pose to the vulnerable communities. The training was timely for Papua New Guinea because we were victim to the phenomena in 1998 (Aitape) and with the training I believe we (PNG) would be able to minimise the effect of such disaster in the future. Finally, the training was well planned with lessons and activities that were geared to assist participants get the most out of it. My sincere appreciation goes to those who put in their time, effort and resources to make the ITIC training a successful, enjoying and a memorable one.

ITP participants view the Emergency Operations Center at Hawaii County Civil Defense Agency. Photo courtesy of T. Fukuji.

Papua New Guinea

by Kaigabu Kamnanaya, National Disaster Center

The two weeks of training (30 August - 10 September) by International Tsunami Information Center (ITIC) basically tried to make the participants know better concerning the behavior and characteristics of earthquake and tsunami and the mitigation measures the countries and local communities may opt to adopt and implement. This report is part of the normal requirement of the best practices of PNG Government to report back on what has transpired during my two weeks of absent from the country duties and whether or not the program plus funding are justifiable in attending the program with regards to the overall intent of disaster risk management in Papua New Guinea.

Recommendations

The accurate detection and prediction on the occurrences of earthquakes and their probabilities of triggering tsunami is still a big challenge for the scientific community including Disaster Managers throughout the world. At this time of technological development, no one is capable or has the ability to tell in advance when and where the earthquakes will occur and whether or not one of those earthquakes will trigger tsunami and the size of the tsunami it will generate. However, the world community is capable of managing the impacts of tsunami through available early warning systems. Most of these systems are not readily available in Papua New Guinea, therefore, the key Government Authorities are strongly recommended to proactively explore the possibilities of strengthening the collaborative mechanisms among themselves and with the Regional bodies like NOAA, Pacific Tsunami Warning Center and the International Tsunami Information Center through the following:

1. Priority One - that the PNG key agencies in monitoring and management of tsunami information and impacts in the likes of Port Moresby Geophysical Observatory (PGPO), National Weather Services (NWS) and National Disaster Centre (NDC) complete their respective Standard Operating Procedures concerning the Real Time Seismic Processing and Tsunami Warning before the year 2010 ends;
2. Priority Two - that as a member state to PTWS the GoPNG Program through National Disaster Centre contribute annually towards the operation cost of ITIC, which include production of tsunami materials, capacity building through training on seismological aspects, tsunami reduction, mitigation and also have coaching trips to PNG key agencies like; visit Port Moresby Geophysical Observatory, visit PNG National Weather Services, visit PNG National Disaster Centre, conduct Joint refresher course for the 2009 & 2010 ITIC participants, deliver lectures to UPNG Fourth year Earth Science and Environmental/Geography Students.
3. Priority Three - that the GoPNG through National Disaster Committee and its Centre explore possibilities of approaching the GoUSA Program through its Embassy in Port Moresby to channel for Earthquake and Tsunami Early Warning programmes and projects in Papua New Guinea. Through such programs/projects this will cover

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the Rapid Communication Facilities/Systems such as RANET (Chatty Beetle), EMWIN and HF and VHF radios and the public alert system like the purchase and installation of SIRENS in strategic locations. The immediate identified locations are the Lae city, Rabaul-Kokopo towns of East New Britain and West New Britain Province. One agent of Siren system in USA is the Federal Signage of Public Safety Systems (www.alertnotification.com).

4. Priority Four - that the National Museum & Art Gallery together with the National Disaster Centre in close collaboration with Sandaun Provincial Government erect at least three monuments in memory of those who have died from the impacts of Aitape Tsunami on 17th July 2010.

Vanuatu

by Peter Korisa, Vanuatu National Disaster Management Office

Acknowledgement

ITIC training programme Hawaii on tsunami early warning and mitigation systems was deemed worthwhile to me. Foremost, I would like to express my sincere thanks to Intergovernmental Oceanographic Commission, United Nations Educational ,Scientific and Cultural Organization (UNESCO), SPREP, NOAA and USAID for making it possible in providing adequate funds to accommodate all participating countries. Furthermore, special appreciation for UNESCO Apia in funding my trip and providing adequate daily subsistence allowance to participate in remarkable ITIC Training. Also, not forgetting the ITIC kind and friendly staffs for organising training and making it the most interesting enjoyable educational field trips and intellectual lessons during the training.

Introduction

Vanuatu comprises around 80 islands with a total land area of 12,300 square kilometres spread over some 1,300 kilometres in a north to south direction, between latitudes 12° to 23° south and longitudes 166° to 173° east. The current population is estimated to be 215,000, of which 80 percent live in rural villages on the 7 islands of Efate, Espiritu Santo, Tanna, Malekula, Pentecost, Ambae, and Ambrym. Vanuatu faces a full range of geologic and climatic hazards. The islands are located in a seismically and volcanically active region and have high exposure to geologic hazards, including volcanic eruptions, earthquakes, tsunamis, and landslides. Recent disasters include the November 1999 Penama earthquake and tsunami that affected about 23,000 people and the 2002 Port Vila earthquake that caused structural and infrastructure damage.

In 2005, the Hyogo Framework for Action (HFA) 2005-2015 identified the following 5 priorities for action:

1. Ensure risk reduction is a national and a local priority with a strong institutional basis for implementation;
2. Identify, assess, and monitor disaster risks and enhance early warning;
3. Use knowledge and innovation to build a culture of safety and resilience;
4. Reduce underlying risk factors; and
5. Strengthen disaster preparedness for effective response at all levels.

PTWC Deputy Director Dr. Stuart Weinstein briefs ITP participants in the PTWC Operations Center. Photo courtesy of B. Yanagi.

Building on the HFA priorities for action, the Pacific Island Forum in 2005 adopted the Disaster Risk Reduction and Disaster Management Framework for Action 2005-2015: An Investment for Sustainable Development in the Pacific Island Countries. Consistent with HFA, the Forum-adopted Framework for Action reflects increasing national and regional commitment to disaster risk reduction (DRR) and disaster management, in support of sustainable development.

In 2006, Vanuatu developed its National Action Plan for Disaster Risk Reduction framework: 2006-2016. Vanuatu government identified 4 priority areas where investment could prove effective in overcoming some of these constraints in order to strengthen disaster risk

Country Trip Reports, *continued*

reduction and climate change adaptation. They seek to provide targeted added value for implementing risk mapping to support town planning and village development; support to the tourism sector for Vanuatu.

Lesson Learned from the Training

Training has made great impact on planning for mitigation and early warning system program for Vanuatu. During the training, we were exposed to various early warning mechanism and coordination capacity all over Hawaii civil defense, Hawaiian Volcanoes Observatory and having great opportunity to visit some tsunami historical sites. Participants were very impressed by the Hilo tsunami museum which perfectly display real impacts of tsunami to Hawaiian people in the past. Although some of us never had a chance to observe the historic tsunami events, pictures clearly demonstrated massive destruction a tsunami could cause to humans.

During the intensive lectures from various tsunami professionals we have acquired so much knowledge about tsunami formation, earthquakes and how each participant could make a positive approach within their own country. Positive approach such as utilising knowledge gained through training that could perfectly feed into their respective Country context. Especially each participant may now develop effective SOPs and strengthen their early warning systems. Countries which already have SOPs could look into other weak areas and improve it.

Various presentations from each participating country directly influenced each participant as to how different countries would go about with their Tsunami warning and mitigation systems during a tsunami threat and how they would deal with it. Most of the lessons learned was absorbed from the life experience country presentations such as Hawaii, Indonesia, Papua New Guinea,Samoa and Chile. The training course also covered how a warning issued by an International Tsunami Warning Centre (PTWC, JMA) should be technically interpreted by the leading Tsunami Warning Organisation in our respective countries.

Training benefits

Apparently, the Vanuatu tsunami mitigation and early warning program has attracted attention nationally and regionally, where together NGOs, National government, partners and Regional organisations are directly involved in awareness and emergency planning. Vanuatu National Disaster Management office together with Geo-Hazards/Vanuatu Meteorology Service has set up a task force. The role of the task force is to facilitate and coordinate awareness programs. Also to coordinate the technical groups that involve engineers, town planners, physical planners (Land use unit) for spear heading the designing of hazards maps all over Vanuatu islands. The task-force's main priority is looking at various alternative and options in strengthening its early warning system, not neglecting the major geographical narrow economic scale challenges. Vanuatu will prioritise its mitigation and early warning strengthening projects. Therefore, chief towns like Port Vila and Luganville will get sophisticated siren early warning system combined with banners to be erected along the urban centers. Some other supporting tools in improving and strengthening end-to end early warning system that are found useful and effective for rural islands are SOPs and Awareness. However, awareness programs have already been started and SOPs will be incorporated into provincial and Community Disaster Committees Plans.

Conclusion

The ITIC Training Course on Tsunami Early Warning & Mitigation Systems was definitely beneficial to participant's knowledge capacity building. The training also helped each country participant get favorable and adequate lessons in identifying gap/weaknesses and apply the principles within the national level.

I sincerely believe the remarkable training has cause great impact on the improvement of our coordination and understanding on tsunami and the danger which would pose to the vulnerable communities within the Republic of Vanuatu.

ITP participants visit a Hilo tsunami memorial commemorating the destructive 1946 Alaska and 1960 Chile tsunamis in Hawaii. Photo courtesy of T. Fukuji.

WORKSHOP AND MEETING SUMMARIES

Samoa - American Samoa Tsunami Early Warning Coordination Meetings, 27 - 28 May 2010, Apia, Samoa

Tsunamis are hazards that threaten the islands of Samoa and American Samoa. Depending upon the location of a major earthquake, the tsunami waves can strike the islands within minutes to hours. To protect the people of Samoa and American Samoa from this hazard, the warning system must rapidly and effectively provide critical information to those at risk.

A series of Two Samoa Tsunami Coordination meetings were held in 2008 (prior to the Sept 2009 South Pacific Tsunami), 2009, 2010 and planned for 2012. These coordination meetings aimed to improve the procedures of and coordination between the two adjacent countries in order to maximise consistency. In addition, the relevant tsunami-responsible organisations of both countries can benefit in other ways from a sharing of experiences on tsunami early warning, emergency response, and preparedness.

During a tsunami alert, information about the situation will quickly evolve and be shared across the border between Samoa and American Samoa by means of television and radio broadcasts, as well as by telephone calls, internet, and other means of communications. In order for an alert to be effective at motivating appropriate actions, the information and instructions from all sources need to be consistent, clear, and concise. Behavioral studies show that when people are first given an emergency alert, they typically look for confirmation from another source before taking action. If the additional information is inconsistent, then people tend not to act. Further, inconsistent information, whether from authoritative and informal sources, can very quickly result in public confusion and panic. For these reasons, it is important that tsunami alert information and public safety instructions issued by both Samoa and American Samoa is as consistent as possible. The two Samoa tsunami warning centers, Samoa Meteorological Division and US NWS Pago Pago, should be working together and be aware of each other's threshold criteria and respective standard operating procedures for warning and emergency response. Towards those ends, re-initialisation of a dedicated hotline between the weather offices, and other joint activities, such as in tsunami exercises and training, and the use of similar tsunami warning decision support tools, are highly desirable.

With respect to recent Pacific tsunamis, the most important lesson learned from the 2009 South Pacific tsunami and the February 2010 Chile tsunami is that preparedness and education before the event saved lives, especially for local tsunamis. Relatively few lives were lost in Samoa, American Samoa, and Chile because many knew what a tsunami was, and knew what to do after the strong shaking of a large earthquake.

During the May 2010 meeting, there were 10 participants from NWS Pago Pago, American Samoa Department of Homeland Security, ITIC, PTWC, Samoa Meteorology, and UNESCO Apia. The following actions were agreed upon.

Actions:

- Two Samoas Agreement to continue as non-binding for operations
- Hotline: Letter to be sent to Samoa Prime Minister to request hotline to be restarted. Prior, review and update of existing documentation required. NWS and SPREP to assist in documentation.
- RANET project: American Samoa to request that RANET seek ways to involve American Samoa in some of the communication pilots implemented for Samoa (e.g. HF radio, Chatty Beetle).
- Earthquake and Tsunami hazard: It was agreed that it should be included in the Agreement.
- Translation: It was noted that updates on terminologies used is needed. Should be consistent. Terms to be confirmed over e-mail.
- Training opportunities: It was noted that some opportunities are missed by American Samoa. Samoa and SPREP will make an effort to share information on these training opportunities, including those for climate and tsunami in case American Samoa might be able to attend. It is acknowledged that funding is not guaranteed for American Samoa participation.
- NOAA Weather Radio: Broadcast footprint to be confirmed in Samoa to know who is affected.
- Meeting report to be finished by end of June 2010.

Fiji Tsunami Mission, 20-24 September 2010, Suva, Fiji

The following summarises the trip taken to Fiji from 20-24 September 2010. The trip was a tsunami outreach mission to strengthen tsunami warning and emergency response through the building of awareness and understanding on tsunamis, its hazard to Fiji, and on the tsunami advisory services provided by the PTWC. The mission was carried out by the Director of ITIC, Dr. Laura Kong, and Deputy Director of PTWC, Dr. Stuart Weinstein. The mission was hosted by Fiji Meteorological Services and Mineral Resources Department. The ITIC serves as a primary resource for assisting Pacific countries to their build and strengthen their national tsunami warning and mitigation systems and carries out its information and capacity building activities per NOAA-IOC arrangements. The PTWC serves as the operational headquarters for international tsunami advisory services to Pacific countries.

Schedule of Activities - Summary:

- 3 days of hands-on training on the use of software tools to support national tsunami warning decision-making for the Fiji Meteorological Service (FMS) and Mineral Resources Department (MRD) who provide tsunami warning services for Fiji. The training also provided and discussed tsunami warning operations.
- 0.5-day Strengthening Tsunami Warning and Emergency Response seminar for Fiji tsunami stakeholders. The agenda included presentations by the trainers and Fiji stakeholders on warning and emergency response.

Participants from Fiji Meteorological Service, Mineral Resources Department, National Disaster Management Office attend a 3-day Fiji training on tsunami warning operations and tools. Photo courtesy of L.Kong.

Dr. Laura Kong and Dr. Stuart Weinstein (center) demonstrate Tide Tool (left screen), TTT (top right screen), and CISN (bottom right screen) earthquake tools displayed on computer at Fiji Mineral Resources Department. Photo courtesy of L. Kong.

- 1.5 days of activities to
  - Provide one-on-one training to MRD staff on tsunami warning, and discuss with MRD their status of Japan International Cooperation Agency (JICA)-sponsored Fiji seismic network upgrades and the interest of PTWC to enable seismic data sharing to PTWC from Tonga, Fiji, and Samoa networks.
  - Meeting with the soon-to-be UNESCO/IOC Tsunami Officer who will support PTWS activities in the Pacific. The officer will be based at and work with SPC/SOPAC (Secretariat of the Pacific Community/Applied Geoscience and Technology Division.
  - Meeting with the US Embassy Suva Environmental Section Officer to brief on ITIC and PTWC activities in the Pacific.
  - Meetings with SOPAC Community Risk Programme to learn in detail the status of tsunami warning and response of Pacific islands, tsunami modeling initiatives such as for island atolls, and potential future cooperative activities between UNESCO/IOC-NOAA ITIC and SOPAC.
  - 2 teleconferences for NOAA Tsunami Program planning for FY11 and as information to visiting Chile ONEMI (national disaster management office) Director and other Chilean officers.

Fiji, *continued*

Fiji Tsunami Hazard Zone signs were posted along Suva city coasts in 2010. Photo courtesy of L.Kong.

Outcomes - Summary:

- Conducted 3-day tsunami warning decision support tools training for 12 staff from FMS, MRD, and NDMO. Provided lectures on tsunami science and hazard assessment, tsunami warning and PTWC standard operating procedures, and discussed Fiji tsunami warning standard operating procedures. Installed and instructed FMS, MRD, and NDMO on using tsunami decision support software. Softwares in operation at FMS and MRD are CISN, Tide Tool, TTT, and TsuDig; NDMO is planning to install CISN. Users guide / quick reference sheets provided.
- Conducted 0.5-day tsunami stakeholder seminar for 14 members of the Tsunami Warning and Emergency Response stakeholders from the NDMO-led Fiji Tsunami Working Group. Provided overview on science, warning, response and preparedness. Informed and increased understanding on the services of the PTWC and FMS/MRD, and the limitations of current tsunami warning systems, especially for local tsunamis where communities should take action immediately and not wait for an official warning.
- Provided tsunami awareness materials to Fiji agencies and offered greater quantities on their request.
- Briefed US Embassy on NOAA's international tsunami outreach in the Pacific.
- Discussed with SOPAC progress and identified gaps and needs of Pacific Island Countries in tsunami warning, emergency response, and preparedness.
- Briefed UNESCO/IOC PTWS National Officer on ITIC activities and tsunami needs of Pacific Island Countries.

Actions to be done based on the trip include the following:

- Follow up with key stakeholders on further needs, and software use.
- Formal request to Fiji regarding the sharing of their seismic data (pending US funding for transmission link).

Tonga Tsunami Workshop, 25-26 August 2010, Nuku'alofa, Tonga

Tsunamis are hazards that threaten the islands of Tonga. Most tsunamis are generated by major earthquakes in the Pacific, including the nearby Tonga Trench. Depending upon the location of the earthquake, tsunami waves can strike island coasts within minutes to hours.

The aim of the Tonga workshop was to strengthen tsunami warning and emergency response. This training provided participants with an understanding of the tsunami hazard, current hazard assessment tools and products, tsunami warning and dissemination systems, effective community response and tsunami risk reduction strategies.

This training (1) helped fill existing educational gaps, (2) supported pre-disaster mitigation efforts and (3) contributed to effective response. The workshop provided:

Tonga participants receive IOC-NOAA tsunami warning and emergency response training from Filomena Nelson, Samoa Disaster Management Office. Photo courtesy of L. Kong.

Tonga, *continued*

Participants of the 25-26 August 2010 Tonga Tsunami Workshop. Photo courtesy of L. Kong.

- installation and training of CISN and Tide Tool in Tonga Meteorological Service (serves as NTWC) and also at National Emergency Management Office (NEMO).
- technical assistance on Tsunami Response Plan to NEMO
- 2-day tsunami training

Students participated in a tabletop tsunami exercise that challenged them to respond to a tsunami warning which impacts their communities. Participants applied their knowledge of the presented materials and shared their experiences in conducting tsunami preparedness, mitigation, and response. This training helped participants understand how agency preparedness and community-level pre-event planning, education, and awareness is critical to saving lives.

The workshop was a cooperative effort of NOAA, UNDP and New Zealand with experts from ITIC (Director), PTWC (Director), and Samoa (DMO). Forty-one participants came from the main islands of Tongatapu and Vavae, and Niuatoputapu (NTT) which was the island hit by the 2009 tsunami. Nine participants were from NTT.

Revision of the IOC Post Tsunami Field Survey Guide, 10-12 December 2010, San Francisco, CA, USA

By Dr. Laura Kong, Director, ITIC

Post-Tsunami Survey Field Guide, Second Edition

The UNESCO-IOC Post-Tsunami Field Survey Guide (First Edition) was initially published in 1998 to provide governments and the scientific community with guidance on collecting perishable tsunami data immediately after the event. IOC is now updating the guide in order to publish the second edition.

Members of a IOC Core Working group for the Revision of the IOC Post Tsunami Field Survey Guide convened in December 2010 in San Francisco to finalise the Guide's outline, review existing and new content for inclusion, identify experts for external peer review, and agree on a timeline for draft completion, review, and endorsement by IOC Member States. The Group also gave a presentation at the 2010 Fall American Geophysical Union Meeting.

The 2011 revision will provide guiding principles for undertaking post-tsunami surveys, and include best practices and templates for individuals and groups considering forming or participating in post-tsunami surveys. Up-to-date descriptions of types of surveys, data to be collected, techniques, tools, and equipment required will be included. A framework for data sharing and archiving is proposed that aims for the conduct of a comprehensive post-tsunami survey but at the same time ensures data remain proprietary until results are published.

Revision of the IOC, *continued*

Post-Tsunami Surveys are Essential for Mitigating the Next Tsunami Disaster

Post-tsunami field investigations are an essential component for improving our understanding of tsunamis and in developing the tools and programs necessary to mitigate their effects. A destructive tsunami can attract a large number of international, national, and local tsunami professionals interested in conducting post-tsunami science surveys to investigate and document its scientific, economic, and social impact on affected coasts and communities. Science data collected immediately after a damaging tsunami are equally important for government decision makers. In the short term, these data help to better organise and deploy often limited resources to the most critical areas needing response. In the long term, these data are used for recovery planning that will mitigate losses from the next tsunami. Without a coordination plan that is integrated into government emergency response operations, perishable data may prove to be logistically difficult to gather before erosion or bulldozers eliminate the evidence, and in all likelihood, the operations could interfere and conflict with emergency activities. Additionally, during catastrophic tsunamis, affected areas and local jurisdictions may be simultaneously overwhelmed by many government agencies, non government organisations, and the media all demanding information and/or access, thus making collection of useful data even more challenging unless a coordination and information sharing plan is already in place.

International Tsunami Survey Team History

Through coordinated International Tsunami Survey Teams (ITSTs), international scientists can assist governments in more efficiently responding to and recovering from tsunami disasters. Starting with the 29 September 2009, Samoa tsunami, this coordination role has been most actively led by the International Tsunami Information Center (ITIC) and the United Nations Educational, Scientific, and Cultural Organization's - Intergovernmental Oceanographic Commission (UNESCO-IOC). IOC also coordinates the global tsunami warning and mitigation system. Warning systems have been in place in the Pacific since 1965, and new ones were started in the Indian Ocean in 2005 immediately following the December 2004 Indonesia tsunami, and in 2006 in the Caribbean and Mediterranean Seas, and North Atlantic Ocean. The ITST concept originated in the 1990s when several scientists began to collect data immediately after a destructive tsunami; the runup and inundation data they collected were used to validate and benchmark tsunami numerical models. Tsunami runup is the observed onshore measurement of the height of the water above mean sea level. Formation of a team was necessary to quickly gather perishable data. Although often focused on water height data, these early ITSTs recognised the importance of an interdisciplinary approach and included researchers from different fields.

Dr. Sergio Barrientos (Chile) measuring tsunami runup in Chile, March 2010. Photo courtesy of Dr. H. Fritz (USA).

They also shared information about tsunamis with the people and officials in the affected country. A major change in the study of tsunami hazards and in post-tsunami surveys followed the December 2004 Indian Ocean disaster. The scale of the event in area and impact was unprecedented in modern times. Dozens of teams and hundreds of researchers worked in the 16 affected countries over the following year. Not only was the amount of data much larger than ever collected in previous ITST efforts, but it also included different types of data measured in different ways by different groups. With the increase in data volume came concerns about how to archive and process the data, and about quality issues, including collection methodology, terminology, base levels, and ambient tidal conditions. The 2004 tsunami made it clear that the ad hoc, informal way of conducting post-tsunami surveys was no longer adequate.

Tsunami research has also changed since 1998. There have been advances in modeling and the availability of space based technologies, including satellite imagery and global positioning satellite navigation. Methods of recording impacts, such as the proliferation of amateur

Revision of the IOC, *continued*

digital video and still imagery, need to be addressed. Tsunami sediments now play a new and important role as key data that extend the tsunami historical record back in time and thus provide an indication of its recurrence intervals.

In addition to advances in techniques, many more disciplines have become involved in post-tsunami investigations, such as the social and economic sciences, ecology, and engineering. Post-tsunami surveys have moved beyond traditional approaches of measuring maximum inundation, runup, and flow depth to include a detailed, varied, rich, and contextual understanding of the effects of tsunamis at different places, such as upon people and their communities, infrastructure, agricultural systems, marine and terrestrial ecology, geomorphological systems, and engineered structures.

Dr. Bruce Jaffe (USA) - left and Dr. Hermann Fritz (USA) mapping debris line, American Samoa, March, 2009. Photo courtesy of Dr. V. Titov (USA).

ITST tasks should now encompass:

- Measuring maximum tsunami inundation, flow depths, and maximum runup, and to the extent possible, "walking the inundation" line in order to collect an exact summary of the inundation of impacted communities
- Collecting geological samples of sediments left by the tsunami
- Measuring the type and severity of damage to different types of buildings and recording what factors appeared to control damage levels
- Collecting and measuring information about the environmental and biophysical system impacts of the tsunami
- Collecting information about survivor experiences and stories through interviews
- Exploring the human and community vulnerability and resilience factors at work in different places

Recent ITSTs

Since September 2009, five ITSTs have been organised, each distinct in their arrangements. For the 29 September 2009, Samoa tsunami ITST-Samoa was a single, coordinated team of more than 60 scientists conducted surveys from October 14 to 23 (two weeks after) in collaboration with the Samoa Ministry of Natural Resources and Environment. The teams stayed at a central compound, shared data, and compiled one preliminary report that was presented to the Samoan Government on October 26. This ITST, with support from SPC/SOPAC (Secretariat of the Pacific Community/Applied Geoscience and Technology Division), UNESCO, and ITIC, set the benchmark for a coordinated ITST to support early recovery, and demonstrated that working together will produce a much stronger and valuable outcome than working individually. A similar smaller effort was coordinated for the same tsunami in Tonga (ITST-Tonga, November 2009) where two teams (New Zealand, Japan) with Tongan government logistics collaborated with their government scientists to survey Niuatoputapu island. The ITST-Mentawai conducted after the 25 October 2010, Mentawai, Indonesia, tsunami also followed a similar process; because access was arduous, only five teams conducted surveys, and because of the small number, coordination and submission of preliminary reports was promptly achieved.

After the 27 February 2010, Chile tsunami, UNESCO and ITIC worked to coordinate the ITST-Chile where more than 25 teams and 70 scientists conducted surveys between mid-March and May. Unlike Samoa or Tonga, where the impact was localised and the area small, the Chile survey area was extensive, covering 1000 km of coast. In this ITST, coordination consisted of briefings where incoming and outgoing teams could share information. Identification badges and letters of support in Spanish were also provided to facilitate access, but no government officials were able to participate because of their very busy schedules. ITIC implemented a secure information-sharing environment for posting files and sending messages among all the scientists. Due to the dispersed nature of the surveys (in survey time and area), it has been difficult to compile a summary report for ITST-Chile because most teams have yet to post their findings.

Revision of the IOC, *continued*

Coordination of ITST-Japan after the 11 March 2011, tsunami in northern Japan has been less complex due to strong national post-tsunami survey arrangements and the nuclear safety issue. In this situation, it was announced through the ITIC Tsunami Bulletin Board that Japan requested no international teams visit until later April, respecting search-and-rescue operations due to the high number of casualties (25,000+), difficult logistics, and knowing that many Japanese scientists were extremely busy as part of the national response. ITST-Japan also directly informed the US National Science Foundation (NSF) in March, and through its Dear Colleague Letter in April, that NSF strongly suggested coordination with UNESCO/NOAA (ITIC) when funded. It is envisioned that later surveys, such as those of ITST-Japan, should ideally concentrate on detailed investigations of specific locations or topics in collaboration with Japanese colleagues.

Coordination is triggered by a request from the affected country to UNESCO-IOC for assistance, knowing that many research post-tsunami survey teams may be or are arriving. The coordination goal is to foster a cooperative relationship so that scientists are working with, and not against, the government as it assesses impact and responds to the needs of its people. In each ITST, UNESCO-IOC and ITIC work with government agencies and regional partners to facilitate smooth running surveys endorsed by the country, especially if access is provided. In return, it is expected that scientists will share their preliminary findings, preferably before they leave. To date, finding and implementing a cooperative, collaborative framework has been challenging because funding lines drive activity goals, and the two parties have fundamentally different missions. In large part, survey scientists have been funded by their research agencies (such as NSF), and there has been no requirement to check in with authorities and then debrief them on exit, nor has there been a requirement to share their data to support disaster response as a humanitarian good will effort. Additionally, as post-tsunami disasters and the collection of perishable data are time sensitive (e.g., rushed), the situation is often chaotic, with a variety of activities needing to be coordinated among many players and jurisdictions at the same time, and with often less than-ideal communications infrastructures and logistics. Nonetheless, with experience and the increasing support of scientists and their organisations, ITIC is seeing that the process is getting smoother and moving toward the most flexible and most accommodating framework possible.

For more information, please contact
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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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