July–December 2009 VOLUME XXXXI, NUMBER 2

Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System

TSUNAMI NEWSLETTER

International Tsunami Information Centre

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Major Earthquakes Strike the Southwest Pacific

Major earthquakes struck the Southwest Pacific from 29 September - 7 October 2009.

Notable were the 29 September Southwest Pacific earthquake (Mw 8.1) that caused a destructive South Pacific Tsunami, in which PTWC issued an Expanding Regional Warning; the 30 September Southern Sumatra, Indonesia earthquake (Mw 7.5) in which PTWC issued an Indian Ocean Regional Watch / JMA issued a Tsunami Watch Information; and the 7 October Vanuatu Islands earthquake (Mw 7.7) in which PTWC and JMA issued an Expanding Regional Warning. Small tsunamis were measured from the Sumatra and Vanuatu events.

The South Pacific Tsunami occurred on 29 September, 2009 at 17:48 UTC. The tsunami caused about 190 fatalities in American Samoa, Western Samoa, and Tonga. The earthquake was centered about 190 km southwest of American Samoa. Moderate to strong ground shaking lasting up to three minutes was reported throughout the region. The earthquake occurred near the northern end of a 3,000 km long segment of the Pacific/Australia boundary, one of the most active earthquake regions in the world, with most earthquakes occurring on the

View from the second story of a building in Pago Pago showing the aftermath of three major surges. Photo courtesy of Chuck Reeves.

thrust zone boundary between the Australia/Pacific plates. However, post-earthquake USGS investigations suggest that the fault rupture was complicated, with multiple segments and different directions of motions. The average run-up heights in America Samoa were two meters, but run-up heights of up to 17 meters were reported by post-event survey teams.

The ITIC is compiling a special edition on the South Pacific Tsunami post tsunami impacts.

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SUMMARY OF EARTHQUAKES
1 JULY- 31 DECEMBER 2009
Reported by Tsunami Warning Centres
Compiled by The 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 Watch/Warnings (TWW) for the Pacific; Tsunami Information Bulletins (TIB), Local, Regional, and Ocean-wide Tsunami Watches (LTW, RTW, TW) for the Indian Ocean; Tsunami Information Statements (TIS), Local, Regional, and Ocean-wide Watches (LTW, RTW, TW) for the wider Caribbean. 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 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) epicenter and Mw from the USGS (G), and Mw from PTWC (P) and JMA (M_{JMA} for Japan local vicinity) at action time. Wave height and period measurements from sea level gauges reported as amplitude, peak to trough, or greatest value for either inundation or runup as indicated. Other earthquakes with moment magnitude (Mw) greater than or equal to 6.5 and a depth no greater than 100 km, as recorded by USGS, have also been included.

DATE	TIME (UTC)	LOCATION	EPICENTER	DEPTH (km)	M_w	PTWC ACTION	ACTION TIME (UTC)	TSUNAMI? DAMAGING?	MAXIMUM MEASUREMENT and LOCATION
15 Jul	09:23	Off West Coast of South Island of New Zealand	45.762° S 166.562° E	22	7.8 (A,GCMT, P) 7.6 (G)	Fixed Regional Warning(P) FR Warning-Supplement (P) FR Warning-Cancellation (P) TIS 01 (A) TIS 02 (A)	09:42 10:33 10:51 09:44 10:23	YES NO	0.47m (peak- to-trough) Jackson Bay, NZ
03 Aug	18:00	Gulf of California	29.039° N 112.902° W	15	6.9 (A, P, G, GCMT)	TIS (A) TIB (P)	18:15 18:16	NO	
09 Aug	10:56	SE of Honshu Japan (Izu Islands)	33.167° N 137.941° E	304	7.1 (G, GCMT) 6.9 (A,M_{JMA}, P)	NWPTA TIS (A) TIB (P)	11:04 11:05 11:10	NO	
10 Aug	04:07	Santa Cruz Islands	11.612° S 166.090° E	44	6.6 (A, G, P) 6.5 (GCMT)	TIB (P) TIS (A)	04:17 04:18	NO	
10 Aug	19:56	Andaman Islands	14.099° N 92.888° E	22	7.7 (A,J,P) 7.6 (G) 7.5 (GCMT)	(IO) Regional Watch (P) RW 002 (P) RW 003 (P) Cancel. 004 (P) TIS 01 (A) (IO) TWI (J)	20:05 21:05 21:24 22:11 20:11 20:25	YES NO	1.4 cm (peak-to- peak) DART 23401 (600 Nautical miles- NNW of Phuket, Thailand
10 Aug	20:07	Near South Coast of Honshu, Japan	34.743° N 138.264° E	40 (G)	6.6 (A, P) 6.6 (M_{JMA}) 6.4 (G)	NWPTA 001 NWPTA 002 TIB (P) TIS (A)	20:12 21:07 21:17 21:19	YES NO	.60 cm wave recorded at Yaizu
12 Aug	22:49	SE of Honshu Japan (Izu Islands)	32.821° N 140.395° E	57	6.6 (G, GCMT) 6.5 (A, M_{JMA}, P)	NWPTA TIB (P) TIS (A)	22:56 23:01 23:02	NO	
12 Aug	22:49	SE of Honshu Japan (Izu Islands)	32.821° N 140.395° E	57	6.6 (G, GCMT) 6.5 (A, M_{JMA}, P)	NWPTA TIB (P) TIS (A)	22:56 23:01 23:02	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
16 Aug	07:38	Southern Sumatra Indonesia	1.479° S 99.490° E	12	6.9 (A, P) 6.7 (GCMT) 6.5 (G)	(IO) TIB (P) (IO) TWI (J) TIB (P) 002 TWI (J) 002	07:49 08:02 08:47 09:10	YES NO	0.18m (amplitude) Padang
17 Aug	00:06	Southwestern Ryukyu Islands	23.501° N 123.499° E	25	6.8 (A, M_{JMA}, P) 6.7 (GCMT) 6.6 (G)	NWPTA TIS (A) TIB (P)	00:11 00:18 00:19	NO	
17 Aug	10:11	Southwestern Ryukyu Islands	23.424° N 123.528° E	12	6.5 (A, M_{JMA}, P) 6.2 (G) 6.1 (GCMT)	NWPTA TIB (P) TIB (A)	10:15 10:23 10:25	NO	
28 Aug	01:51	Banda Sea	7.146° S 123.427° E	633	6.9 (G, GCMT) 6.7 (P)	TIB (P)	02:01	NO	
30 Aug	14:52	Samoa Islands Region	15.223° S 172.571° W	14	6.6 (A, G, GCMT, P)	TIB (P) TIS (A)	15:07 15:03	NO	
02 Sep	07:55	Java Indonesia	7.782° S 107.297° E	53	7.1 (P) 7.0 (G, GCMT)	(IO) LTW 001 (P) TIS (A) TIB 002 (P) Cancel	08:06 08:26 08:59	NO	
12 Sep	20:06	Near coast of Venzuela	10.705° N 67.920° W	12	6.4 (A, P) 6.3 (GCMT) 6.2 (G)	TIS (A) TIB (P)	20:15 20:16	NO	
24 Sep	07:16	Off Coast of Jalisco Mexico	18.822° N 107.345° W	14	6.7 (A, P) 6.3 (G,GCMT)	TIB (P) TIS (A)	07:28 07:28	NO	
29 Sep	17:48	Samoa Islands Region	15.489° S 172.095° W	12	8.3 (A, P 002-4) 8.1 (G, GCMT) 7.9 (A, P, initial 001)	Expanding Regional Warning 001(P) TIS 001 (A) ERW 002 (P) TIS 002 (A) ERW 003 (P) ERW 004 -Cancel (P) Advisory 003- (A) Advisory 004 (A) Advisory 005 (A) Advisory 006 (A) Advisory 007 (A) Advisory 008 (A) Advisory 009 -Cancel (A)	18:04 18:02 18:56 18:59 20:22 21:36 22:02 23:14 00:21(30Sep) 02:24(30 Sep) 04:28 (30 Sep) 06:30 (30 Sep) 08:28 (30Sep)	YES YES	4.11 m (peak to peak) Pago Pago
30 Sep	10:16	Southern Sumatra Indonesia	0.720° S 99.867° E	76	7.7 (P) 7.5 (G, GCMT) 7.6 (A, J)	(IO) Regional Watch Bulletin 001 (P) TIS (A) TWI 001 (J) (IO) RWatchB 002 (P)--Cancel TWI 002 (J)--Cancel	10:26 10:30 10:38 11:31 11:55	YES NO	0.27 m (Amp) Padang Tide Gauge

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
01 Oct	01:53	Southern Sumatra Indonesia	2.515° S 101.501° E	15	6.8 (P, J) 6.7 (G) 6.6 (GCMT)	(IO) TIB (P) TWI (J)	02:00 02:12	NO	
04 Oct	10:58	Mindanao, Philippines	6.740° N 123.378° E	626	6.6 (G, GCMT) 6.5 (A, P, J)	TIB (P) TIS (A) NWPTA	11:12 11:14 11:17	NO	
07 Oct	21:41	Celebes Sea	4.079° N 122.371° E	583	6.8 (A, G,GCMT, P)	TIB (P) TIS (A) NWPTA	21:50 21:50 21:57	NO	
07 Oct	22:03	Vanuatu Islands	13.006° S 166.510° E	46	8.0 (P, changed to 7.8 with ERW 003) 7.7 (G) 7.6 (GCMT)	TIS (A) ERW 001 (P) NWPTA ERW 002 (P) ERW 003 (P)--Cancellation	22:14 22:17 22:24 23:36 00:18 (8 Oct)	YES NO	.0632 m (peak to peak) Port Vila tide gauge
07 Oct	22:18	Santa Cruz Islands	12.517° S 166.382° E	43	7.8 (G, GCMT)	—	—	NO	
07 Oct	23:13	Vanuatu	13.052° S 166.187° E	12	7.4 (G, GCMT)	—	—	NO	
08 Oct	02:13	Santa Cruz Islands	11.660° S 166.177° E	33 (G)	6.6 (G)	—	—	NO	
08 Oct	08:29	Vanuatu	13.298° S 165.910° E	12	7.0 (P, A, J) 6.8 (G) 6.7 (GCMT)	TIB (P) TIS (A) NWPTA	08:41 08:40 08:49	NO	
13 Oct	05:37	Fox Islands Aluetian Islands Alaska	52.754° N 166.997° W	16	6.5 (G, GCMT) 6.3 (A)	TIS (A)	05:43	NO	
24 Oct	14:41	Banda Sea	6.133° S 130.385° E	156	7.0 (P) 6.9 (G, GCMT)	TIB (P)	14:51	NO	
30 Oct	07:04	Ryukyu Islands	29.218° N 129.782° E	37	6.9 (A) 6.7 (G) 6.8 (GCMT, J, P)	NWPTA (J) TIB (P) TIS (A)	07:08 07:13 07:13	NO	
08 Nov	19:42	Sumbawa Region Indonesia	8.207° S 118.631° E	20	6.9 (A,P) 6.6 (GCMT) 6.5 (G)	(IO) TIB (P) TIS (A) TWI (J)	19:53 19:56 20:07	NO	
09 Nov	10:45	Fiji Islands	17.236° S 178.335° E	604	6.8 (P, changed to 7.1) 7.2 (G) 7.3 (GCMT)	TIB (P) TIS (A) TIB 002 --Sup.	10:54 10:56 11:08	NO	
13 Nov	03:06	Near Coast of Northern Chile	19.394° S 70.321° W	37	6.5 (A,P, GCMT) 6.4 (G)	TIB (P) TIS (A)	03:18 03:18	NO	
17 Nov	15:31	Queen Charlotte Islands	52.131° N 131.397° W	16	6.6 (GCMT) 6.5 (A, P) 6.4 (G)	TIS (A) TIB 001 (P) TIB 002-Sup TIB 003 - Sup	15:36 15:43 16:01 16:06	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
24 Nov	12:47	Tonga Islands	20.708° S 174.035° W	23	6.8 (A, G, P) 6.7 (GCMT)	TIB (P) TIS (A)	12:57 13:00	NO	
09 Dec	09:46	SE of the Loyalty Islands	22.150° S 170.936° E	57	6.5 (A, P) 6.4 (G, GCMT)	TIB (P) TIS (A)	09:56 09:58	NO	
19 Dec	13:02	Taiwan	23.796° N 121.605° E	46	6.7 (J) 6.4 (G, GCMT)	NWPTA (J)	13:17	NO	

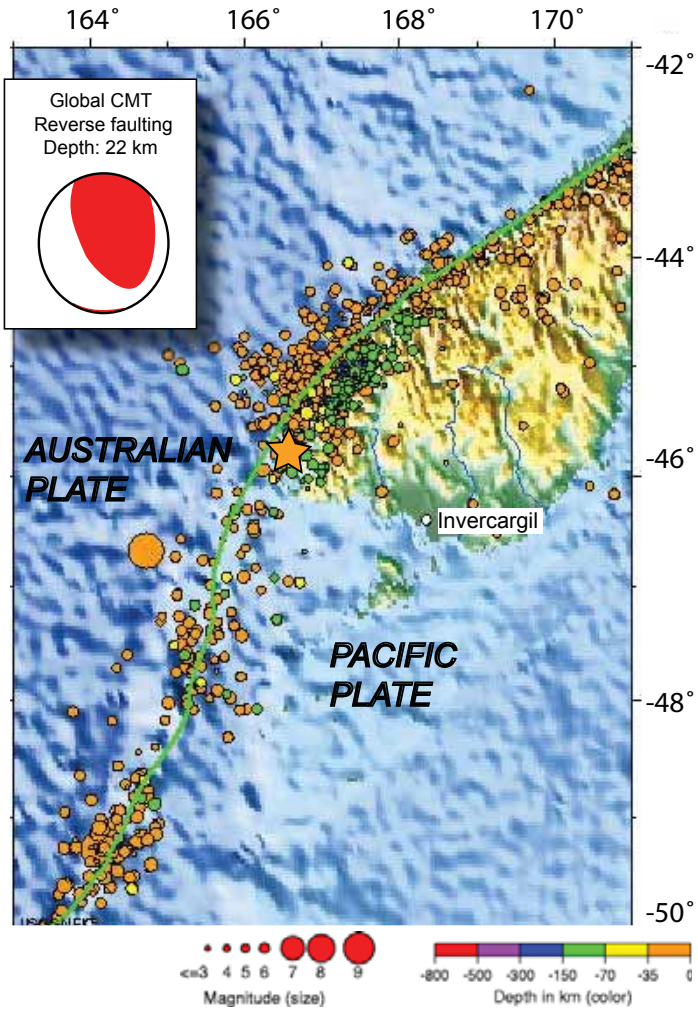
Off South Island New Zealand, 15 July 2009, 09:23 UTC, M_W= 7.6

A major earthquake occurred off the west coast of New Zealand's South Island, 15 July 2009 at 09:23 UTC (8:23 PM local time). The earthquake's hypocenter was 45.75° S and 166.58° E, located it in Dusky Sound in the south-west corner of the Fiorland region of the South Island, and has since become referred to as the 'Dusky Sound' earthquake.

Starting from its initial depth, the rupture continued upwards and to the south, focusing energy offshore. According to the New Zealand GNS Geo-Net website: "The motion was more like a lurch than a snap (meaning the energy was released more slowly); this is typical for a subduction thrust event. This explains why the damage was much less than many people expected for this size of earthquake. The motion was slower (with lower frequency shaking) and "rolling" rather than the sharp (higher frequency shaking) movements that cause building damage; this also explains the low number of landslides."

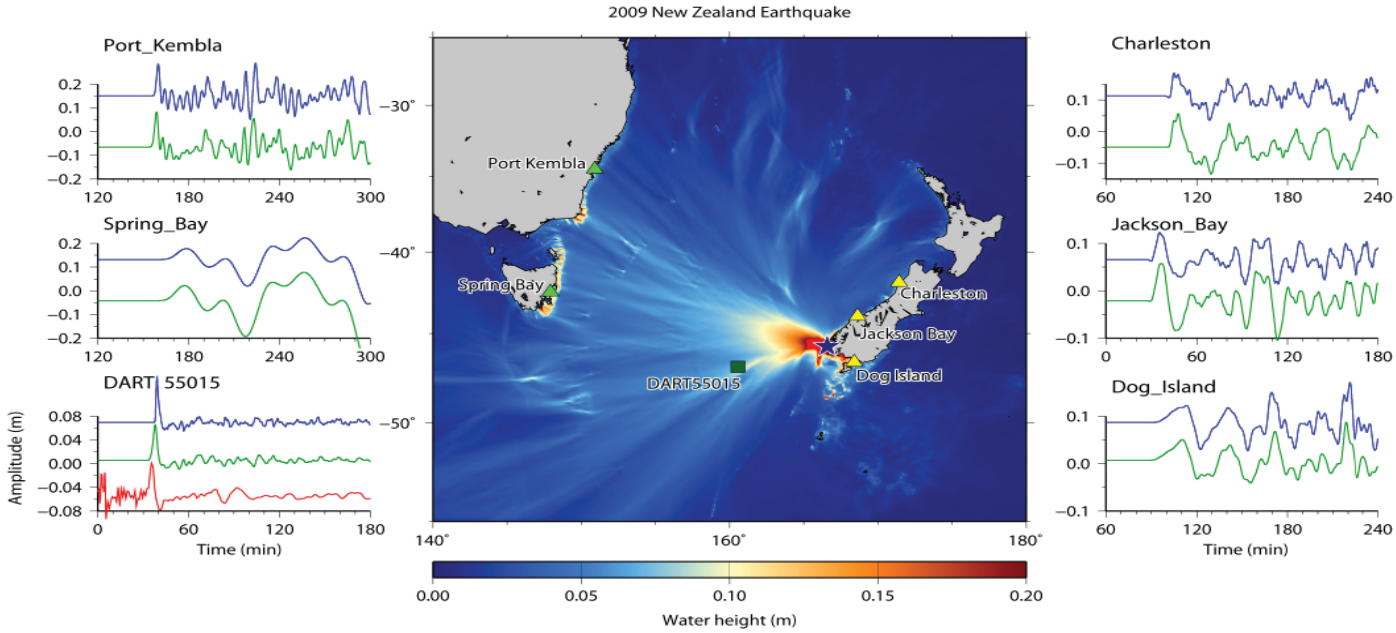
With a magnitude of 7.8 it was comparable with the Buller (or Murchison) earthquake of 1929 and the damaging Hawke's Bay earthquake of 1931. This earthquake reportedly caused some minor damage to property in Invercargill and Otatara and no deaths.

A tsunami wave measuring in heights of centimetres was recorded on several tide stations in New Zealand and at a DART Buoy offshore (*see next page*). The largest reading was from the Jackson Bay tide gauge, which measured a one metre variance, peak-to-trough. Other readings were reported at Charleston (25 cm, peak-to-trough) and Dog Island (12 cm. peak-to-trough). Runup was observed from a small tsunami some three hours after the earthquake on Australian sea-level gauges, including Port Kembla, NSW (14 cm, peak to trough). The largest reading was at Southport in southern Tasmania which recorded a 55-centimetre sea level difference above the expected tidal level. No damage was reported. Some first hand accounts were reported in ONE News (www.tvnz.com.nz), by fisherman who were moored offshore and had to turn on boat engines to keep their boats from being pulled out by a strong current. Another boat was reported as going aground before being loosened by another surge.



Historical Moment Tensor Solutions with recent earthquake location marked by a star. Map courtesy of USGS National Earthquake Information Center (NEIC).

New Zealand, *continued*



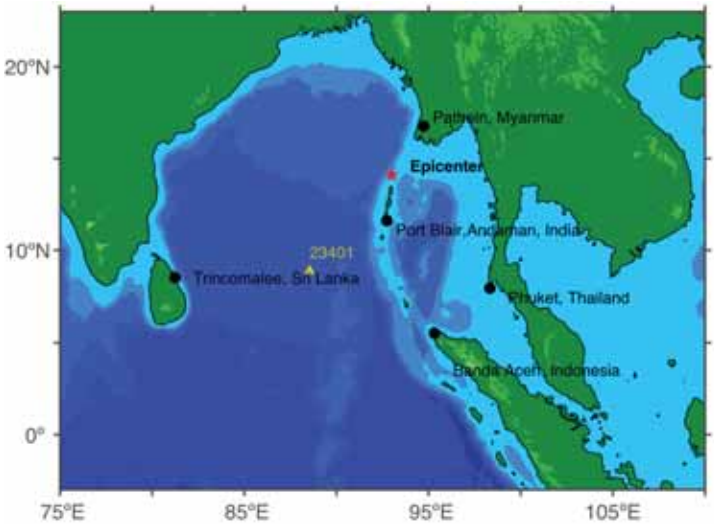
Map showing modeled intensity and directionality of the energy released in the Pacific Ocean following the earthquake and Downs. From numerical modeling and analysis of the event by Yushiro Fujii (IISEE, BRI) and Kenji Satake (ERI, Univ. of Tokyo) at http://iisee.kenken.go.jp/staff/fujii/NZ/tsunami.html.

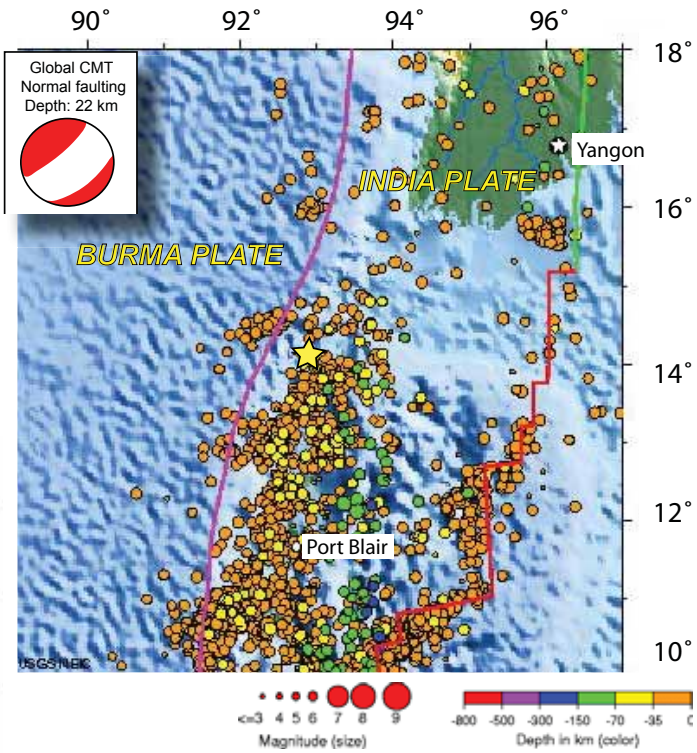
Andaman Islands, 10 August 2009, 19:56 UTC, M_W= 7.6

An earthquake occurred on 10 August 2009, about 260 km north of Port Blair in the Andaman Sea at 19:56 UTC (01:56 AM 11 August in Port Blair), measuring 7.6 Moment magnitude (USGS).

The earthquake occurred in the boundary region of India plate and the Burma plate, near the north end of the rupture zone associated with the great Sumatra-Andaman earthquake of 26 December 2004.

Messages went out for the event from tsunami warning agencies. A small tsunami was recorded for this event at a DART© Buoy Number 23401 (*see map below and measurement next page*).

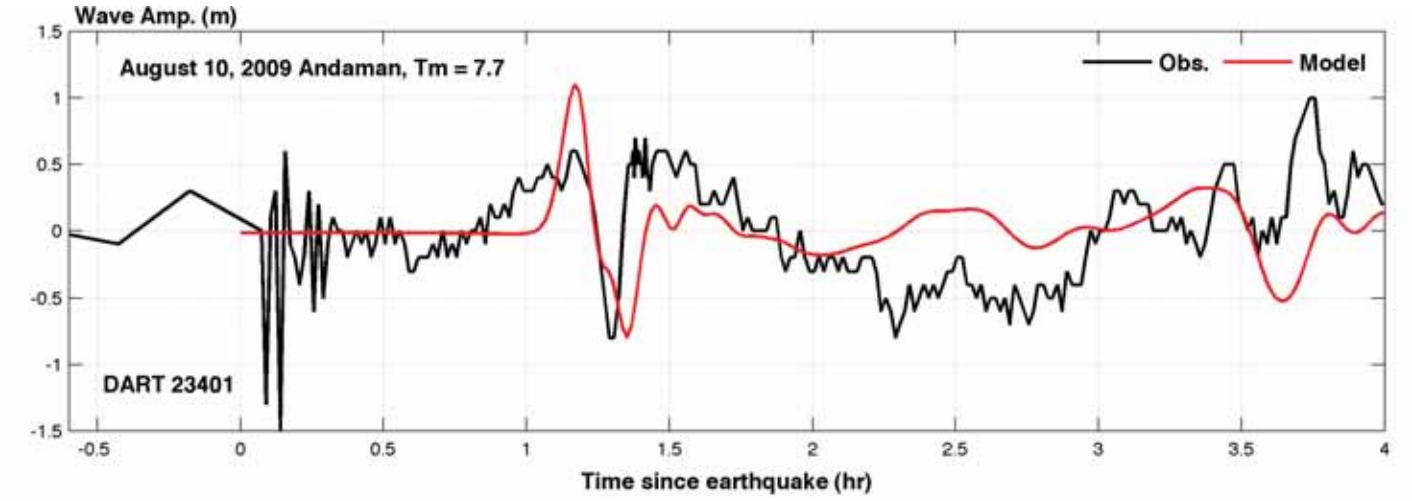




Top. Historical Moment Tensor Solutions (1990 to the present) with recent earthquake location marked by a star. Map courtesy of USGS National Earthquake Information Center (NEIC).

Left. Regional map showing the location of the epicenter in relation to regional cities and the DART Buoy that recorded the tsunami. Created and published by the NOAA PMEL Center for Tsunami Research at http://nctr.pmel.noaa.gov/andaman20090810/epicenterio.png.

Andaman, *continued*

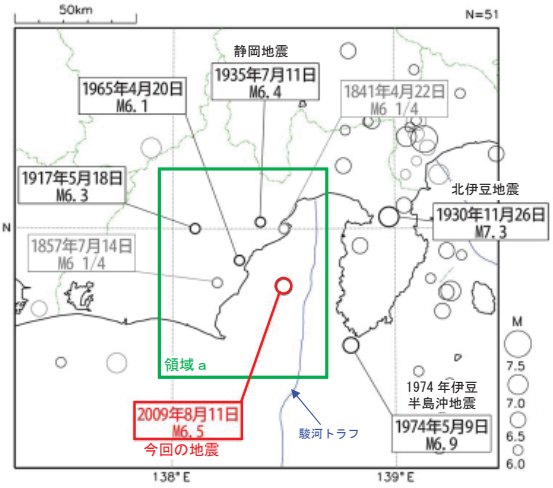


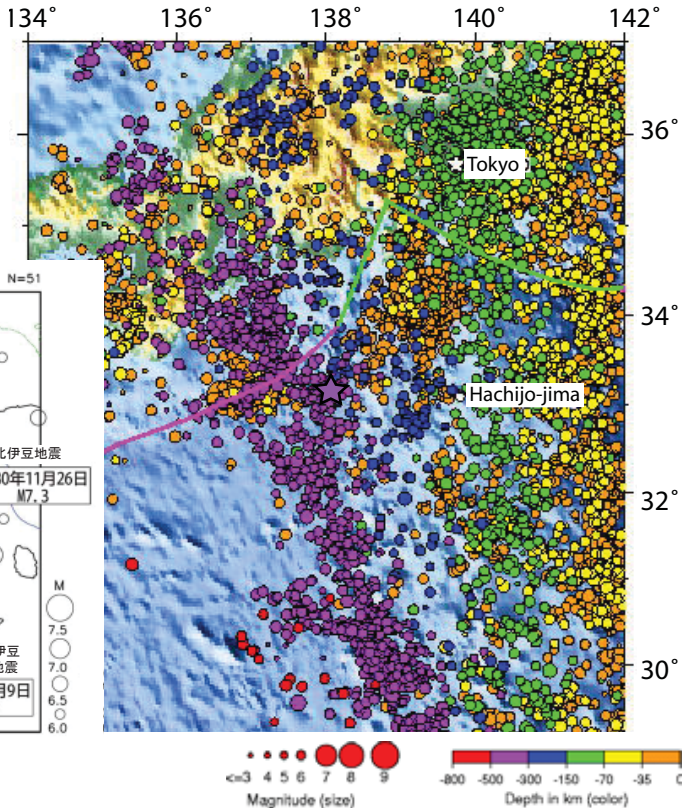
Comparison of the DART Published by the NOAA PMEL Center for Tsunami Research at http://nctr.pmel.noaa.gov/andaman20090810/dart23401_comp.png

South Near Coast of Honshu, Japan, 10 August 2009, 20:07 UTC, M_W= 6.6

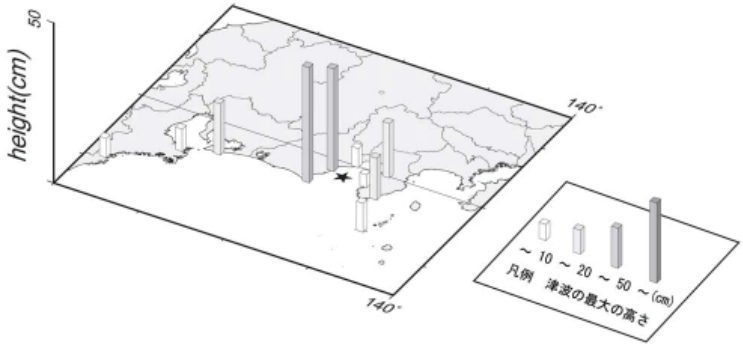
An earthquake occurred off the coast of Honshu, Japan on 10 August at 20:07 UTC (05:07 Japanese Standard Time) and was measured at 6.6 moment magnitude by the Japan Meteorological Agency, JMA.

A small tsunami was recorded at seven tide gauges and 3 other locations in the vicinity. The largest recording was 9 cm at the Hatchijojima gauge. Data covering the tsunami's measurement can be found in JMA's *Monthly Report on Earthquakes and Volcanoes in Japan*, August 2009; available in pdf format at *www.seisvol.kishou.go.jp/eq/gaikyo/monthly200908/20090811suruga-wan4.html.*





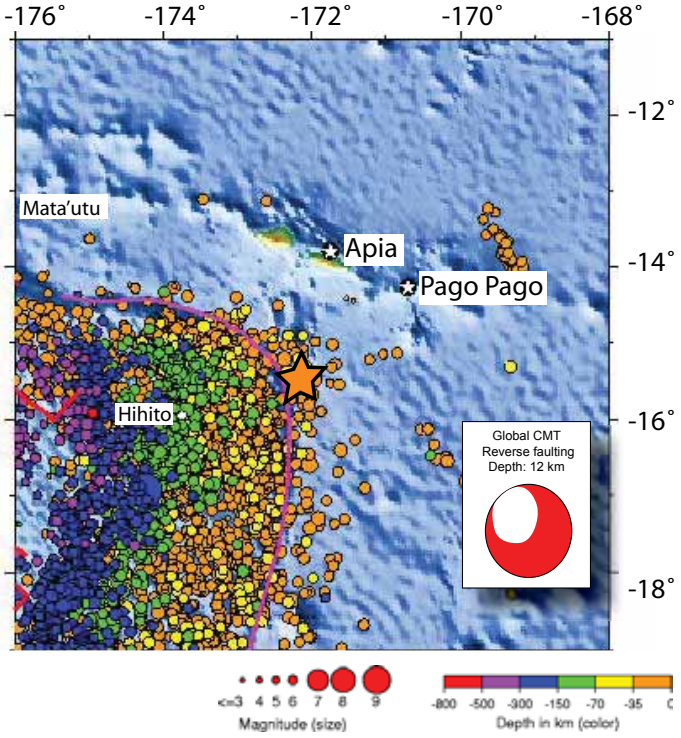
Above right. Historical Moment Tensor Solutions with recent earthquake location marked by a star. Map courtesy of USGS National Earthquake Information Center. Note: No Global Centroid Momoment Tensor Solution is available for this event as it occurred so close in time to the Andaman Island earthquake, 10 minutes earlier.



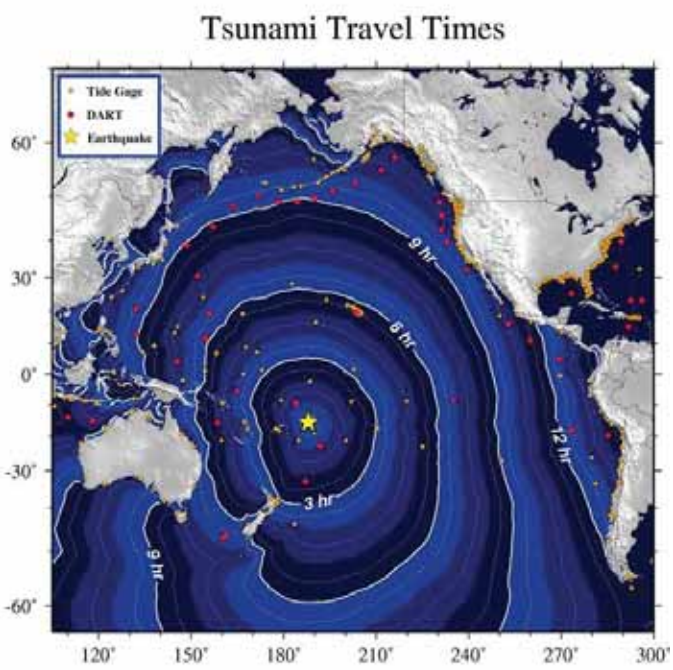
Above,left and bottom. Graphics from the report on the tsunami showing historic large earthquakes in the area and the measured run-up from the tsunami. The star represents the hypocenter. From the report at http://www.seisvol.kishou.go.jp/eq/gaikyo/monthly200908.pdf

Cover story, *continued*

Samoa Islands Region 29 September 2009, 17:48 UTC, M_W= 8.1



Historical Moment Tensor Solutions (1990 to the present) with recent earthquake location marked by a star. Map courtesy of USGS National Earthquake Information Center (NEIC).



Tsunami travel time map generated from warning center software and available at http://wcatwc.arh.noaa.gov/previous.events/09-29-09-Samoa/Samoa_TravelTimes.jpg. NOAA model forecast results and preliminary analysis for the September 29, 2009 Samoa tsunami are summarized at http://nctr.pmel.noaa.gov/samoa20090929/.

NDBC#	Arrival Time	zero-2-peak	peak-2-peak	Period	Time of measurement	Coords	
	hh:mm			mm:ss	hh:mm	LAT	LON
51425	18:51 09/29	.035m	.064m	11:30	18:54 09/29	-22.993	-168.098
51426	18:51 09/29	.052m	.135m	07:30	19:26 09/29	-09.500	-176.250
54401	19:54 09/29	.017m	.033m	14:30	20:02 09/29	-33.005	-172.985
32412	06:46 09/30	.018m	.035m	11:00	07:02 09/30	-17.975	-86.392
21415	03:13 09/30	?	.019m	08:30	04:01 09/30	50.173	171.837
46407	04:03 09/30	.002m	.004m	10:45	04:16 09/30	42.604	-128.9
32401	08:04 09/30	.004m?	.021m	09:45	08:56 09/30	-19.5478	-74.8136

Tsunami damage at Pago Pago harbor American Samoa. Photo by Brian Yanagi, ITIC.

Typical damaged structure in coastal villages in American Samoa. Photo by Brian Yanagi, ITIC.

Samoa, *continued*

Tide gage	Peak amplitude (above sea level in cm)	Observed Initial Arrival time (UTC)	Computed Initial Arrival time (UTC)	Initial motion	Sample Interval (min)
Pago Pago, AS	216	1802 (9-29-09)	1806 (9-29-09)	↗	1
Apia, Samoa	78	1807	1819	↗	1
Nuku'alofa, Tonga	15	1900	1853		6
Funafuti Island, Tuvalu	2.4		1933		6
Suva, Fiji	9	2000	1956	↗	6
Penrhyn Island, Cook Islands	9	2015	2006	↘	1
Papeete, French Polynesia	15	2102	2053	↗	1
Lautoka, Fiji	6	2055	2059	↗	1
Port Vila, Vanuatu	17.5	2145	2137	↗	1
Chatham Island New Zealand	32	2211	2202	↗	1
Honiara, Solomon Islands	2.5		2225		1
Rikitea, French Polynesia	12	2317	2256	↗	1
Nawiliwili, Kauai HI	20	2332	2320	↗	1
Kawaihae, HI	28	2338	2321	↗	1
Honolulu, HI	18	2335	2321	↗	1
Wake Island, USA	6	0001 (9-30-09)	2321		1
Hilo, HI	17	0005	2329	↘	1
Kahului, Maui HI	36	0022	2349	↘	1
Midway Island USA	23	0010	2355		1
Jackson Bay, New Zealand	20		0000 (9-30-09)		6
Saipan, N. Marianas	5.5		0108		1
Amchitka, AK	10.5		0308		15 sec
Atka, AK	7		0313		1
Adak, AK	10	0425	0326	↗	1
Ofunato, Japan	16		0330		1
Hanasaki, Japan	8		0338		1
Shemya, AK	14	0421	0339	↗	15 sec
Nikolski, AK	6		0341		1
Arean Cove, CA	43.6	0415	0358	↗	1
Point Reyes, CA	39.4	0450	0402	↗	1
Santa Barbara, CA	25		0411		1
Los Angeles, CA	12.9		0415		1
Ishigakijima, Japan	4.0		0418		1
Santa Monica, CA	15	0439	0420	↗	1
Crescent City, CA	32.9	0444	0420	↗	1
Port Orford, OR	21.9	0442	0421	↗	1
Cabo San Lucas, Mexico	21.1	0443	0421	↗	1
San Francisco, CA	10	0448	0431	↗	1
King Cove, AK	13		0432		1
Charleston, OR	13	0500	0432	↗	1
South Beach, OR	8.3	0527	0452	↗	1
Winter Harbor, B.C., Canada	7.1	0522	0452	↗	1
Garibaldi, OR	3.6		0454		1
Langara Point, B.C., Canada	7		0454		1
La Push, WA	16.8	0542	0506	↗	1
Manzanillo, Mexico	61.5	0536	0506		1
Port Alexander, AK	12	0601	0507		1
Tofino, B.C., Canda	7.3	0545	0512	↗	1
West Port, WA	7.7		0512		1
Neah Bay, WA	3.8		0513		1
Old Harbor, AK	5.7	0501	0514		.25
Astoria, OR	2.5		0528		1
Seward, AK	2.0		0534		1
Yakutat, AK	7.7	0612	0539		1
Alitak, AK	2.3		0539		1
Port Angles, WA	9	0641	0550		1
Craig, AK	2		0558		.25
Juan Fernandez, Chile	13	0649	0628		2
Baltra, Ecuador	13.4		0628		1
San Felix, Chile	22.6	0711	0650		2
Corral, Chile	10.8		0653		2
Valparaiso, Chile	20	0805	0724		2
Talcahuano, Chile	18.5	0755	0724	↘	2
Coquimbo, Chile	31.0	0802	0737	↘	2
Caldera, Chile	39.7	0823	0749		2
Callao LaPunta, Peru	32.1		0758		6
Antofagasta, Chile	36.6	0839	0818		2
Iquique, Chile	24	0926	0833		2
Arica, Chile	26.4	0949	0844		2

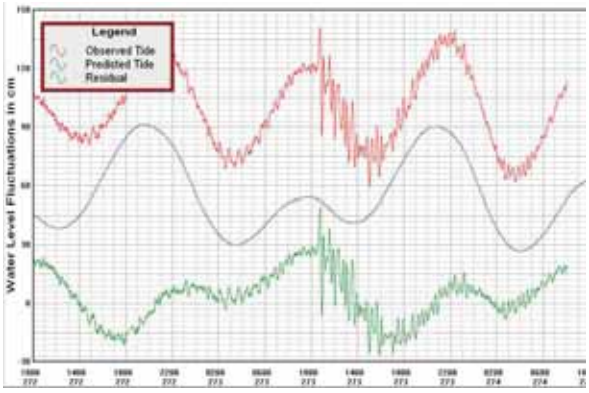
Graph showing results of tide record readings from around the Pacific as reported on the West Coast/Alaska Tsunami Warning Center website, http://wcatwc.arh.noaa.gov/previous.events/09-29-09-Samoa/09-29-09.htm. Raw data for each station is also available at the site.

Japan, with PTWC and US NWS Pago Pago, conducted a post-tsunami survey of American Samoa 5-8 Oct 2009. From left to right, Dr. Yuichi Namegaya, Dr. Gerard Fryer, Dr. Shunichi Koshimura, Akapo Akapo, Dr. Yuichi Nishimura, and Dr. Yugo Nakamura.

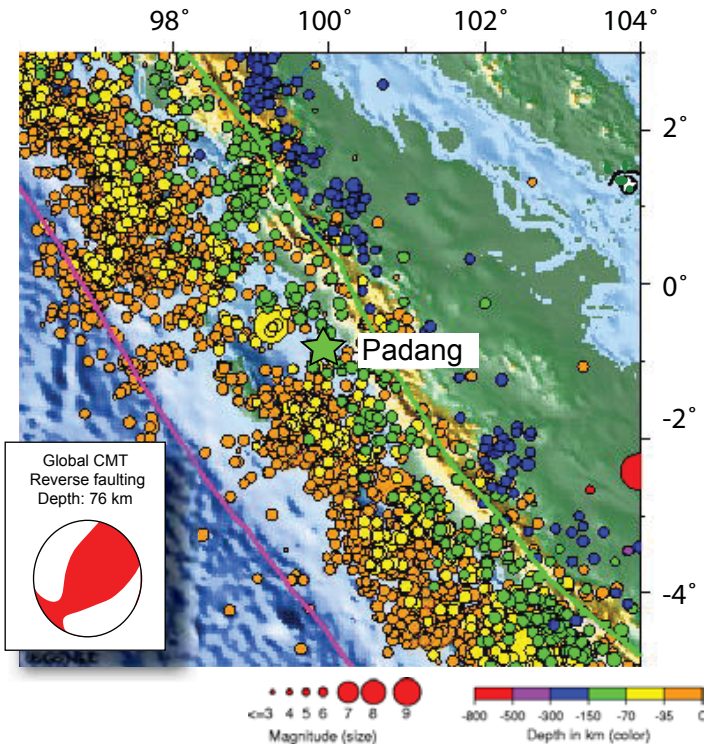
Southern Sumatra Island, Indonesia, 30 September 2009, 10:16 UTC, M_W= 7.5

An earthquake occurred on 30 September 2009 at 10:16 UTC (5:16 pm local time) approximately 35 miles WNW of Padang, Sumatra. It was measured by the USGS with a moment magnitude of 7.6. A small local tsunami with wave heights of 27 centimetres amplitude was generated.

At least 1100 peope were killed, 2180 were injured, and thousands unaccounted for in the Padang area. Over 2600 building were damaged and power and communications were disrupted.



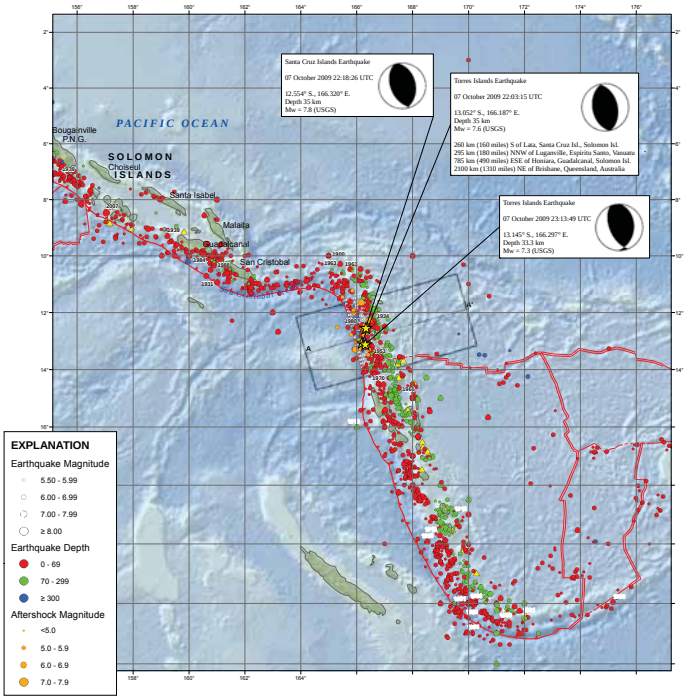
Sea level fluctuations associated with Southern Sumatra Island, Indonesia Earthquake. http://wcatwc.arh.noaa.gov/previous.events/09-30-09-Indonesia/padaA.jpg.

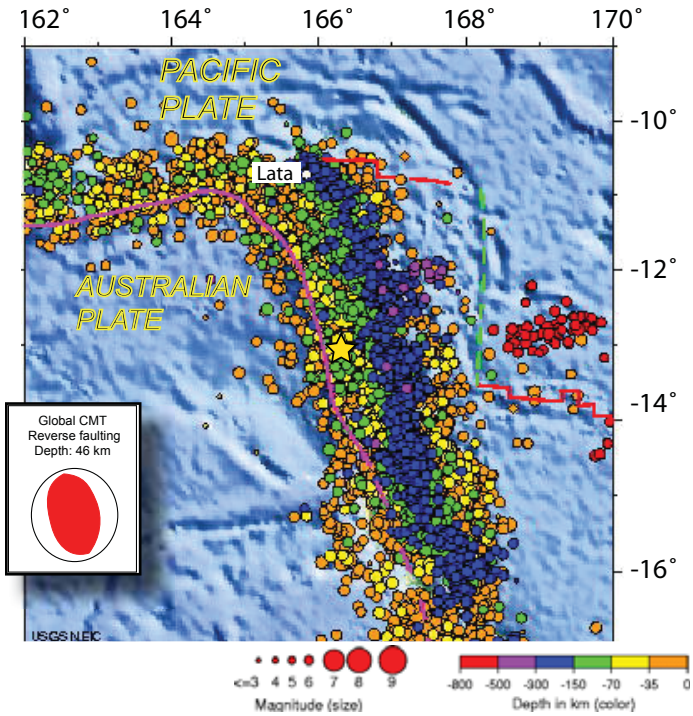


Historical Moment Tensor Solutions with recent earthquake location marked by a star. Map courtesy of USGS National Earthquake Information Center (NEIC).

Vanuatu Islands, 07 October 2009, 22:03 UTC, M_W= 7.7

Of the three major earthquakes to occur in close succession to each other, the 22:03 UTC earthquake was the largest and created a tsunami that was recorded on tide gauges around the Pacific (see chart below)

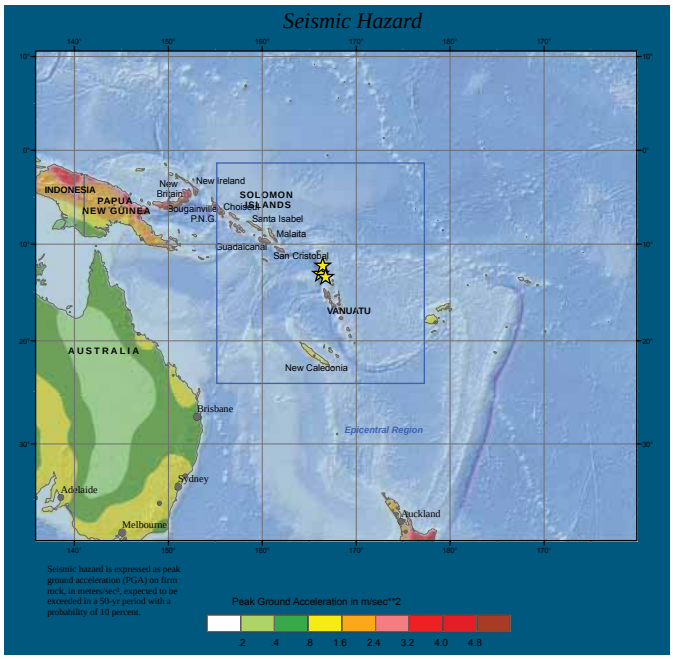




Above. Historical Moment Tensor Solutions (1990 to the present) with recent earthquake location and depth marked by a star. Map courtesy of USGS National Earthquake Information Center.

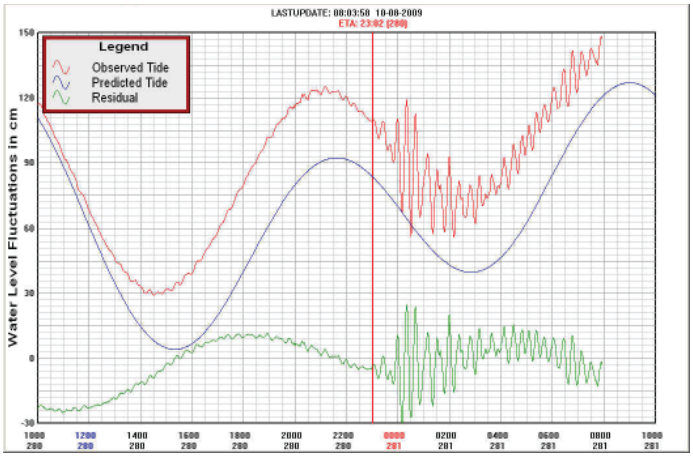
Vanuatu, *continued*

Tide gage	Peak amplitude (above sea level in cm)	Observed initial (vs. computed initial) Arrival time (UTC)	Initial motion	Sample Interval (min)
Port Vila, Vanuatu	30.5	2301 (2302)	rise	1
Honiara, Solomon Islands	6.5	2341 (2326)	rise	1
Funafuti, Tuvalu	2.2	? (0010)	?	6
Kings Wharf, Fiji	2.5	0049 (0035)	down	6
Lautoka, Fiji	3.0	0054 (0111)	?	1
Majuro, Marshal Island	1.9	? (0126)	?	1
Nukualofa, Tonga	3.0	? (0145)	?	6
Manus, Papa New Guinea	4.5	0201 (0147)	down	1
Apia, Samoa	3.9	0150 (0149)	down	1
Pago Pago, AS	7.0	? (0157)	?	1
Wake Island, USA.	3.0	? (0257)	?	1
Midway, USA.	5.9	0437 (0431)	down	1
Papeete, French Polynesia	2.5	0451 (0445)	down	1
Nawiliwili, Hawaii	8.0	0518 (0455)	rise	1
Honolulu, Hawaii	5.0	0512 (0501)	rise	1
Kawaihae, Hawaii	11.0	0515 (0510)	rise	1
Hilo, Hawaii	7.4	0531 (0524)	?	1
Kahului, Hawaii	18.6	? (0537)	?	1
Cabo, San Lucas	4.0	1147 (1054)	rise	1
Atka, AK	6.0	? (0753)	?	1
Adak, AK	7.5	0835 (0801)	?	1
Nikolski, AK	8.0	0846 (0821)	rise	1
Arena Cove, CA	4.3	? (0954)	?	1
Port Reyes, CA	6.0	? (1002)	?	1
Monterey Harbor, CA	4.5	? (1002)	?	1



Rosslyn Bay, Australia	12.3	0450 (?)	rise	1
Port San Luis, CA	8.0	? (1015)	?	1
Santa Barbara, CA	15.1	? (1024)	?	1
Santa Monica, CA	4.6	? (1033)	?	1
South Beach, OR	2.9	? (1039)	?	1
Tofino, BC	4.3	? (1052)	?	1
Neah Bay, WA	3.2	1024 (1057)	down	1
Coquimbo, Chile	8.5	? (1442)	?	2
Caldera, Chile	7.0	? (1457)	?	2
Iquique, Chile	4.6	? (1543)	?	2

Port Vila, Vanuatu



Sea level fluctuation associate with Vanuatu Earthquake. http://wcatwc.arh.noaa.gov/previous.events/10-07-09/10-07-09.htm

IOC NEWS

Vietnam Tsunami SOP Workshops, Hanoi, Vietnam, 2008 - 2009

by Brian Yanagi, Disaster Management Specialist, ITIC

The following summarizes Vietnam training entitled, "Strengthening Tsunami Warning and Emergency Responses: Training Workshop on the Development of Standard Operating Procedures (SOP) for Indian Ocean and Southeast Asian Countries," in Hanoi at the Institute of Geophysics (IGP), which serves as the Vietnam National Tsunami Warning Center (NTWC). Three SOP workshop trainings were undertaken as part of the mission of ITIC to support tsunami capacity building in the Pacific and Indian Oceans. One week Vietnam training sessions were conducted in December 2008 (Workshop #1); April 2009 (Workshop #2); and September 2009 (Workshop #3). The ITIC carries out its international tsunami information resource and capacity building activities per NOAA-UNESCO Intergovernmental Oceanographic Commission (IOC) arrangements. The Pacific Tsunami Warning Center (PTWC) provides warning services for the Pacific Ocean, and interim services for the South China Sea Region and the Indian Ocean.

Participants came from the Vietnam Institute of Geophysics (IGP), Ministry of Natural Resources and Environment (MONRE), Dept. of Dyke Management & Storm, Flood Control from the Ministry of Agriculture and Rural Development (MARD), and the National Committee for Search and Rescue (NCSAR).

Training topics, covered through plenary lectures and small group activities, were on tsunami warning and emergency response, especially:

- *Tsunami Science, Hazards, and Warning Centers, including PTWC services*
- *Warning Center Operations, Roles and Responsibilities, and Standard Operating Procedures for centers with and without active seismic monitoring capabilities*
- *Tsunami Emergency Response by Disaster Management Organizations (DMO), including Roles and Responsibilities and Standard Operating Procedures for alerting and evacuation,*
- *Tsunami Information Dissemination, including technologies and the role of media*
- *Preparedness, Education and Awareness*
- *Lessons Learned from Past Tsunamis, and Tsunami Case Studies*
- *Exercises and Drills, including Table Top Exercise carried out on Day 5 followed by post-exercise evaluation*

A Course Manual was compiled and distributed, comprised of reference materials used in the training and small group activities.

Outcomes of the training included:

- *The IGP, MARD and SAR did not initially have written, detailed Tsunami SOPs to respond to regional tsunamis. By the end of the three workshops, these agencies had drafted customized Vietnam tsunami SOPs.*
- *Sharing of best practices amongst international*

Participants of three Vietnam tsunami SOP workshops in Hanoi in 2008 and 2009.

SOP Workshops, *continued*

experts and Vietnam participants.

- *The training workshops were attended by over 20 participants from IGP, MONRE, MARD, and NCSAR. IGP is the NTWC for Vietnam and MARD/ NCSAR are the DMO.*
- *Plenary sessions were held covering tsunami science, hazards and warning centre operations, and emergency response and preparedness. The trainers included many examples from their working experience in their lectures, which helped the trainees relate to their own operational experience. Sessions were also devoted to briefings from the attending Vietnam agencies, providing a local context to the current status of SOPs in the Vietnam. NTWC and DMO groups broke out for more detailed training on their specialist topics before coming back together to conduct tabletop exercises.*
- *Near real-time Table Top Exercises were conducted in Workshop #2 and #3 involving TWC and DMO participants practicing SOPs developed during the training, and post-exercise evaluation and discussion to identify gaps and weaknesses for improvement. The scenario "Exercise Manila Trench 2009" tabletop exercise tested the group's understanding of SOPs for a regional (approx 2 hours) tsunamis. For the exercise, the group split into separate NTWC and DMO teams. The exercise demonstrated that the Vietnam SOPs are developed but there are some gaps which require further attention, e.g. communications.*
- *Vietnam TWC and DMO Agencies also developed a "Strategy for the Way Forward" on the next steps (short term and long term) that need to be taken to fully develop a Vietnam "end to end" Tsunami Early Warning and Mitigation System.*

IOTWS Indian Ocean-wide Tsunami Exercise "IOWave09"

At the 5th Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) held in Putrajaya, Malaysia in April 2008, the Member States recognized the need to test the functioning of the IOTWS and decided to establish a task team to consider and provide a detailed plan for a proposed Indian Ocean-wide exercise in 2009. The "IOWave09" task team, with Indonesia as chair, reported back to the ICG/IOTWS at its 6th session in Hyderabad, India in April 2009 recommending that an ocean-wide exercise be held on 14 October 2009 to coincide with World Disaster Reduction Day.

To prepare for the exercise, the IOWave09 task team organized several meetings including a workshop in Jakarta, 12-14 August, 2009 which was attended by tsunami warning centre and disaster management specialists from 14 Member States. The exercise will simulate the Indian Ocean countries being placed in a tsunami warning situation and require the National Tsunami Warning Centres (NTWC) and (optionally) the National Disaster Management Organisations (NDMO) in each Member State to implement their Standard Operating Procedures (SOP). The exercise scenario will replicate the earthquake parameters of the Magnitude 9.2 earthquake which occurred off the coast of Aceh on 26th December 2004 and the simulated tsunami will take approximately 12 hours to travel from its source to the southern coast of South Africa. Exercise bulletins will be issued by the Japan Meteorological Agency (JMA) and the Pacific Tsunami Warning Centre (PTWC) and the exercise will be run in real time. An IOWave09 exercise manual will be distributed in the near future with further details of the exercise scenario as well as the text of the simulated warning bulletins from JMA and PTWC. All documents will be available on the following website: *http://ioc-unesco.org/iowave09*

ICG/PTWS NEWS

Southwest Pacific Seismic Data Sharing, Vanuatu, 19-20 October 2009

by Laura Kong, Director, ITIC

An ICG/PTWS Task Team met on Southwest (SW) Pacific Seismic Data Sharing. The meeting was attended by representatives from Fiji, Papua New Guinea, Samoa, Tonga, Vanuatu, Australia, China, New Zealand, CTBTO, IRIS, PTWC, SOPAC, IOC. The IOC Tsunami Unit Head, Peter Koltermann, provided opening remarks. The Task Team was chaired by Ken Gledhill.

The PTWC provides basin-wide alerts for Pacific countries, including the Southwest Pacific.

PTWC Deputy Director, Stuart Weinstein, noted there are two unique challenges for the SW Pacific.

1. It is estimated that it takes 4-6 minutes longer to characterize the earthquake due to the sparse SW Pacific seismic network.
2. The SW Pacific region is also an area where modest size earthquakes can cause destructive local tsunamis, suggesting that the warning

Vanuatu, *continued*

thresholds should be lower than the threshold for basin-wide warnings.

He summarized late 2009 earthquake events. These included the Samoa tsunami (29 Sep), Padang earthquake (30 Sep), Vanuatu (7 Oct, Mw7.7), and Santa Cruz (7 Oct, Mw7.8).

Weinstein also reviewed the timeline for the 29 September Samoa tsunami, highlighting when data was received and actions taken. Sea level gauges provided immediate confirmation of tsunami arrival time and wave character in Pago Pago and Apia harbours. The marigrams and tsunami measurements were posted to the Tsunami Bulletin Board on 29 and 30 September. The earthquake was a normal fault, causing in general a draw down (receding wave) to be observed as the first wave.

While in Vanuatu, the ITIC Director visited former ITP-Hawaii participant Esline Garaebiti (Vanuatu Department of Geology and Mines) to install earthquake (CISN) and sea level (Tide Tool) software.

Along the south coast of Upolu, Samoa, for those that already knew about tsunamis, the recession of the wave was recognized and heeded as a natural warning; when this was seen, many people knew to immediately evacuate.

Discussion Highlights

- *There is a continuing need for accurate earthquake magnitudes as soon as possible – more data are needed.*
- *There is minimum latency for data, after which it is not useful – 20-30 sec adequate (2-3 min not useful). Seismic characterization continues for 30-45 minutes after the event to incorporate later arriving phases.*
- *The issuance of local warnings; should be done within 3-6 minutes of event, requiring more data; best done by a regional or local tsunami warning center which can have lower earthquake magnitude thresholds.*

The PTWS Task Team on Seismic Data Sharing, chaired by Dr. Ken Gledhill of IGNS New Zealand, met in Vanuatu prior to the SOPAC STAR meeting and annual session.

Meeting Outcomes

The Group agreed on the following recommendations:

- *Use of 40 Hz, 3 channel, 20 second latency, broadband,*
- *Countries are responsible for communications to national data centers and their data hub,*
- *All networks should consider joining the Federation of Digital Seismic Networks (FDSN),*
- *Establish a data server in each country using SeedLink for data ingestion and export,*
- *There is a need for multiple telecom solutions (Very Small Aperture Terminal (VSAT), Internet, Global System for Mobile Communications (GSM), radio modems, etc),*
- *Send all broadband data to FDSN/Incorporated Research Institutions for Seismology (IRIS) - (for Quality Control and data sharing, data curation),*
- *Stress the need for collaboration with donor networks,*
- *Inform networks of those that access network data*

o References will be given to data sources

- *PTWC to get data from IRIS*
- *Countries can run "virtual networks" by getting available data from IRIS, Comprehensive Nuclear Test Band Treaty Organization (CTBTO) and other*

Vanuatu, *continued*

concentrating nodes

o Countries can pull any available data from SeedLink servers from any of the concentrating nodes

- *Seiscomp3 or similar is required (for data processing)*
- *A variety of other display, analysis packages, are available and work with SeedLink protocol (seisgram2K, etc)*
- *Training required (many potential providers)*

o Needs coordination on type of training and between CTBTO, GEOFON, IRIS, and others

- *Similar effort required for sea level monitoring*
- *Continued coordination is necessary after initial data exchange is established*
- *Find out status of Geoscope station in New Caladonia*

The Group agreed on the following actions:

- *A summary of various analysis systems (Seiscomp3, Antelope, Earthworm, Hydra, etc),*

While in Vanuatu, the PTWC Deputy Director and the ITIC Director visited the Vanuatu Meteorological Service to discuss tsunami warning coordination. From left to right, Dr. Stuart Weinstein, Dr. Laura Kong, and VMS Director Jotham Napat.

- *A summay of available data communication solutions and issues (VSAT, GPRS, Internet, radio modems),*
- *A summary of two way data distribution systems*
- *Training recommendations need to be scoped,*
- *Complete development of turnkey system for SeedLink. Countries are responsible for providing in miniseed,*
- *Each country will provide an inventory of existing and planned stations and their characteristics, including sample rate, number of channels*
- *Contact Pacific 21 program to see if real time data can be made available to SW Pacific Region*
- *Get information about current seismic status in Solomon Islands.*

Malaysia Hazard Assessment Sabah, Malaysia, 30 November – 3 December 2009

by Laura Kong, Director, ITIC

The following summarizes the mission taken to Kuala Lumpur, Malaysia (30 Nov–3 Dec). The trip was undertaken as part of the mission of UNESCO/IOC–NOAA ITIC to assist countries in strengthening their national tsunami warning and mitigation system.

The Malaysia trip provided expert consultation to the Ministry of Natural Resources and Environment (MNRE), Department of Irrigation and Drainage (DID), Coastal Division and its consultant, Perunding MSA Sdn. Bhd, for the Project "Tsunami Modelling Impact Studies for the North and East coast of Sabah, Malaysia", to be completed by mid-2010. The Project will produce tsunami risk maps of this region.

The Agenda consisted of one day of consultation with the consultant team comprised of engineers (Perunding MSA Sdn. Bhd), tsunami modelers (Danish Hydraulic Institute), and marine and environmental scientists (ERE Consulting Group), one morning consultation with the Project Technical Committee chaired by the Director of Coastal Division, DID, and participated in by government agencies including Geology, Navy, Meteorology, and Academy of Sciences, and one invited talk to participants on precautionary and mitigating measures and recovery measures in managing tsunami hazards.

Outcomes of the mission included:

- *Review and recommendations to the draft Interim Report, specifically on the approach and methodology, tsunami source identification, vulnerability index criteria. Topics discussed included earthquake and tsunami databases, modeling, bathymetric data availability, mangroves, critical facilities, tsunami-resistant engineering and vertical evacuation, drills and exercises, awareness, and social-economic, environmental, and livelihood issues specific to Sabah coastal communities*
- *Technical talk on tsunami mitigation for local tsunamis, focusing on preparedness and hard countermeasures, and a summary the 29 September 2009 Southwest Pacific tsunami lessons learned*
- *Distribution of copies of Tsunami Great Waves (2008) and Tsunami Glossary 2008.*

Mission, *continued*

Future actions based on the trip include the following:

- *Provide expert opinions as needed upon request*
- *Schedule next visit for consultation upon request (probably mid-2010).*

ITIC-PTWC NEWS

Southwest Pacific Tsunami Outreach Mission, American Samoa, Samoa & Tonga 28 June – 15 July 2009

by Laura Kong, Director, International Tsunami Information Center (ITIC) & Charles McCreery, Director, Pacific Tsunami Warning Center (PTWC)

The following summarizes the mission taken to American Samoa, Samoa, and Tonga 28 June–15 July, 2009. The trip was a tsunami outreach mission to build awareness and understanding on tsunamis, its hazard to countries in the Southwest Pacific, and on the tsunami warning and advisory services provided by PTWC. The mission was carried out by the Directors of ITIC and PTWC, prior to the 29 September Southwest Pacific tsunami event.

Activities:

-Four working days in American Samoa (AS) with stakeholders, including tsunami SOP meetings with NWS Pago Pago and AS Department of Homeland (ASDHS) Security, two 1-day tsunami outreach seminars for all stakeholders, distribution of tsunami awareness and tsunami warning decision support tools, and installation/upgrade of tsunami tools at NWS Pago Pago. Issues related to the tsunami warnings in 2006 and 2009 were discussed. A new draft PTWC tsunami product for AS was introduced as a way of simplifying the warning content and making it more useful and effective.

-Six working days in Samoa, including American Samoa-Samoa Tsunami Warning Coordination Meeting, Tsunami Session on communications technology for effective Disaster Management Regional Forum, and technical assistance meetings with Samoa Met Service that has tsunami warning and emergency response responsibilities. At the coordination meeting, problems and inconsistencies between the two Samoas during the 2006 and 2009 warnings were discussed. The proposed PTWC tsunami product for AS was offered to be extended to Samoa to help reduce the potential for confusion during warning events between these closely connected island groups. ITIC organized a conference call with the Chair of the PTWS WG on the SW Pacific to begin planning for the real time exchange of seismic data between AS, Samoa, Tonga, Fiji, and PTWC to facilitate more rapid analysis of potentially tsunamigenic earthquakes in the region.

-Three working days in Tonga, including one tsunami outreach seminar with stakeholders, one Tonga tsunami hazard briefing to members of the Tonga Parliament and Ministers, and technical assistance meetings (and software installation) with Emergency Management Agency, Meteorological Service, and Geological Unit. ITIC organized a conference call with Tonga, Samoa, Fiji, and the Chair of the PTWS WG on the SW Pacific as a first step in facilitating the aforementioned real time exchange of seismic data between these countries and PTWC.

Summary of outcomes:

- Informed and increased understanding on the services of the PTWC, and the limitations of current tsunami warning systems, including those of PTWC for tsunami warnings for Tonga Trench events that can strike AS, Samoa, or Tonga within minutes depending upon their location.
- Provided templates and other best practice materials for end-to-end tsunami warning, including tsunami standard operating procedures, communications and alerting, and other technical topics.
- Conducted three tsunami outreach seminars,
- Organized and convened an inagural two Samoas Tsunami Warning Coordination Meeting. Agreement to convene another meeting October, 2009; PTWC to provide a new American Samoa product in 2009, that will be considered for use by Samoa.
- Organized and convened one tsunami session at *Using Information and Communications Technologies (ICT) for Effective Disaster Management Regional Forum*. Participants were ICT government officials, meteorological services, disaster management agencies, and civil societies of Pacific Islands.
- Distributed tsunami awareness materials and tsunami warning decision support tools at all activities. Tools software distributed included Real Time Earthquake Display (RTED/CISN) earthquake monitor, Tide Tool sea level monitor, TsuDig tsunami historical database with tsunami travel time calculator.

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

- Follow up with key stakeholders on further needs, and software installation.

Samoa, *continued*

- Provide support to ASDHS in tsunami preparedness and/or conduct additional training or other consultations to strengthen preparedness and response.
- Provide American Samoa tsunami products from PTWC in consultation with NWS Pago Pago and AS DHS.
- Follow up on actions identified during SW Pacific seismic data sharing teleconferences.

Participant Trip Reports
ITIC Training Programme Hawaii (ITP–Hawaii) Honolulu, Hawaii, USA 24 August—9 September 2009

Fiji

by Alipate Waqaicelua, Manager, Fiji Meteorological Services, Services & Development

At the kind invitation of the International Oceanographic Commission (IOC), candidates from China, El Salvador, India, Malaysia, and the Pacific Islands (Cook Islands, Fiji, Federated States of Micronesia, Papua New Guinea, Solomon Islands, Tonga and Tuvalu) attended the 2009 ITIC Tsunami Training Programme (ITP) that was held at the International Tsunami Information Centre (ITIC) in Honolulu, Hawaii, USA from 24 August to 9 September 2009.

The ITIC Training Programme (ITP-Hawaii) is held annually in Hawaii, USA, under the direction of the International Tsunami Information Centre (ITIC). Participants are provided with an overview of the history and operations of Pacific Tsunami Warning and Mitigation System. Specific focus is given to the important role of regional and national tsunami warning centers in monitoring and evaluating the tsunamigenic potential of earthquakes, and in issuing timely tsunami warning messages to government emergency officials who can then act to save lives and reduce damage to coastal communities.

The Training Programme provides training and familiarization with the Pacific Tsunami Warning System, sub-regional and national warning systems, and Civil Defense concepts of operations and standard operation procedures. The ITP-Hawaii uses Hawaii as a working example of an end-to-end tsunami warning and mitigation system demonstrating close stakeholder coordination and partnership for operational warnings and in preparedness activities.

Workshop Goals and Topics:

The training attempted to accomplish several goals, which include:

- Clear understanding of tsunami science, hazards, and risks;
- Overview of tsunami warning and emergency response in own countries, through country reports;
- Overview of Tsunami Warning Center Operations – focus on PTWC;
- Appreciation of warning dissemination, public information flow and media communication
- Successful installtion and utilization of tsunami warning decision support tools, especially CISN and tide tool;
- Development of own organizational as well as national tsunami standard operating procedures (SOP);
- Lessons learned from the Indian Ocean tsunami, and
- Tsunami preparedness and mitigation.

Participants engaged in a series of informational presentations at ITIC and the Pacific Tsunami Warning Center (PTWC), and visits to Emergency Operations Centers, to seismic or water level station field sites, and to the University of Hawaii. A 1-day off-island field trip to visit the Hawaii County Civil Defense Agency, the Pacific Tsunami Museum, and several tsunami memorials is included. Additional topics covered by the Training Programme were based on the specific needs of each participant.

Candidates were either part of their national tsunami warning providers or emergency/response centre employees.

The training programme was held in the National Weather Service (NWS) Pacific Region Conference Room, as well as the Pacific Tsunami Warning Centre. A very dedicated and efficient team of NWS personnel facilitated logistics requirements ensuring great success to the training event.

Through contributions from the United States to the WMO Voluntary Contribution Programme, and from New Zealand to the IOC Trust Fund, ITIC fully supported the attendance of about 10 candidates, through air travel costs, lodging, meals, and miscellaneous expenses.

The training outcomes

1. Better appreciation of the science of tsunamis and their impacts. Reducing tsunami risk requires end-to-end solutions.
2. Appreciation of current efforts on tsunami data monitoring/observations, research and modeling.
3. Clearer understanding of the workings of PTWC, as the distant tsunami warning centre in the Pacific. During my visit to the Honolulu WFO located at the University of Hawaii campus, I learned of the very good relationship and the well-defined roles PTWC

ITP, *continued*

and the NWS play in the dissemination of tsunami warning bulletins, locally within Hawaii and/or internationally.

4. Greater appreciation of tsunami warning providers and emergency operational routines. This was made possible through discussions and SOPs presentations as well as visits to PTWC and Hawaii civil defense agencies.
5. A draft national (schematic illustration) as well as a Fiji Meteorological Service SOP were developed. Final versions will need to be populated with all relevant details, including timelines.
6. Media Guide template–needs further tailoring to suit local situations.
7. Appreciation of the wealth of information available at ITIC and their efforts on awareness and education (national, regional and international). Adapting lessons learned from past events to enhance national tsunami preparedness and mitigation.

El Salvador

by Jennifer Larreynaga Murcia, Seismology Specialist, National Service of Territorial Studies (SNET)

1. Activities I participated in

The ITP Hawaii was an opportunity to the attendees to know about Pacific Tsunami Warning and Mitigation System (PTWS) history and operation. Made an special emphasis to national and regional tsunami warning centers role to monitor and assess tsunamigenic earthquakes and issuing of warnings to the response agencies.

The ITP Hawaii provided knowledge related with tsunami warning Standard Operation Procedures (SOP) and response, and how to use it.

The main activities during the ITP were:

1. National presentation of each participant.
2. Presentations issued by investigators and experts how work in tsunami themes like: tsunami warnings, tsunami response, and mitigation activities.
3. Visits to emergency operation centers, sea-level stations in coastal sites, Pacific Tsunami Museum, memorials in places where tsunamis have hit Hawaii in the past, etc.

Presentations by each participant / country showed the status of their centers of tsunami warning and mitigation, measures taken to increase their capacity and immediate needs for improving emergency response to tsunamis.

Topics covered by those conducting the training included: Pacific Tsunami Warning and Mitigation System (PTWS), early warning systems for tsunami warning and mitigation systems in Hawaii, science of earthquakes and tsunamis: threat and risk, operation of tsunami warning centers: studied cases, guidelines and protocols, support tools for issuing tsunami warnings, emergency response, exercises and simulations, public information, mitigation, preparedness, education, awareness, etc.

Participants of the ITIC Training Programme (ITP - Hawaii) visit the Pacific Tsunami Museum in Hilo, Hawaii.

Between field visits are:

- Visit to the Pacific Tsunami Warning Center (PTWC) to view operations, operational protocols, and staff working in the center and development tools, Global seismic monitoring network available to the Center of the monitoring network global sea level both in deep water as coastline.
- Maps were created tsunami arrival times for a hypothetical scenario in each country, we learned about techniques for improving the characterization of the earthquakes source with the purpose of issuing tsunami warnings, guidance and examples of routine operations (when there is no crisis).
- Visit to emergency management department in the city of Honolulu where they showed the handling of information received from PTWC messages related with tsunami warnings.
- Visit to Civil Defense Agency of the State of Hawaii (Honolulu), where the director showed his operating protocols, made a visit to his headquarters.
- Visit to island of Hilo, a memorial built in places where the tsunami hit in 1946 and 1960, both of Hilo Bay and the village of Laupahoehoe.
- Visit to Pacific Tsunami Museum where the director gave a presentation of all tsunami that have impact-

ITP, *continued*

ed the Hawaiian Islands and their inhabitants have learned to live permanently with this threat.

- Visit to USGS Volcano Observatory in Hilo: volcanic and seismic monitoring of the volcano Kilauea.
- Visit to Civil Defense Agency of the County of Hawaii in Hilo, where its director showed its multi operating procedures, made a visit to its operation Center.

Additionally as part of training the group of experts designed a series of activities focusing on using lessons learned during the duration of training. These activities are:

- Create and / or develop a management plan for a media event of local or regional tsunami.
- Review the existing Standard Operation Procedures (SOP) for tsunamis and improving them as necessary with the inputs given in the course.

George Curtis, tsunami advisor, discusses the features of the local emergency management system by explaining tsunami mitigation as practiced at the County of Hawaii Civil Defense Agency of the in Hilo.

- Presentation of each country of their Standard Operation Procedures (SOP) for tsunamigenic events.

2. What I Learned

From the presentations made, the working groups formed and recommendations formulated from the topics of discussion, were reached the following conclusions:

- The main cause of tsunamis is earthquakes, approximately 72%.
- "Slow Earthquakes" are earthquakes sometimes not felt by population but can generate destructive tsunamis.
- Numerical simulation models of tsunamis are only two dimensions because it is considered that the third dimension (the column of water) is uniform.
- An effective tsunami warning and mitigation system implies: that all vulnerable coastal communities are prepared and adequately respond in a timely manner when a tsunami "potentially destructive" may be approaching.
- Reduce the risk of tsunamis requires a comprehensive solution including: threat assessment, issuance of timely and adequate warning, mitigation and preparedness.
- A tsunami early warning system has three main components: tsunami warning centers, emergency management, and education of the inhabitants of the area prone to tsunami threat.
- Where start evaluating the threat of tsunamis?
  - *Tsunami Research*
  - *Consider that an earthquake of 9 degrees can occur anywhere in the subduction zone.*
  - *Calculate flooding areas.*
  - *Create reasonable scenarios, we are not interested in the worst case but in the worst-case "credible."*
  - *Worst credible case means: that there is a 20% chance that this event happens in the next 200 years.*
- Tsunami standard operation procedures must be "living" documents. Must be fast, accurate, reliable and effective.
- Lessons learned from past tsunamis:
  - *Tsunamis are not common.*
  - *Each Tsunami is unique.*
  - *Past events are useful for making improvements to warning systems.*
- The media should be seen as quick dissemination way of information to the population. Is our responsibility to give them clearly and accurately information to be conveyed in the same way. They are essential partners in the process of early warning.

3. Recommendations and how the training activites will be used in El Salvador

From the presentations made and formed working groups, emerged general and specific recommendations for increasing capacity and improving early warning systems for tsunamis.

The most important recommendations are:

- To establish effective early warning systems and understandable to the community.
- What you need to save lives in an early warning system for tsunamis?

- Detection and early warning: monitoring both seismic and sea level.

- Planning before the event for an effective response:

ITP, *continued*

assessment of the threat and risk, and evacuation planning.

- Avoid the term "false alarm", when a tsunami arrived but doesn't generate any danger should be called "Tsunami not destructive".
- It is important to include in the protocol, confirmation and / or cancellation of an alert.
- To assess what past events? To improve the prognosis of tsunami science and to improve the science of issuing early warnings to improve Standard Operating Procedures.
- Finding the best way to inform the public without causing panic.
- The media should report with accuracy, should understand what the technical reports contain, how the tsunami warning center operates, what are the roles of warning centers and local authorities in emergency, etc.
- The media should be properly educated. Determine which the best way to work with them is.
- Each country and each region is different and unique. The techniques that are useful in one place cannot be in another. Plans for the media, standard operating procedures, and educational tools needed to build each site.
- All Tsunamis are unique! Expect the unexpected! Review your plans and follow them as necessary.

To improve tsunami warnings and awareness in El Salvador, the recommendations will be implemented through the following activities planned:

- To support the establishment of the Regional Tsunami Warning and Mitigation to the Pacific coast of Central America.
- It will improve the monitoring sea level system with the University of Hawaii and the Sea Level Center, with a project to update the sea level stations in El Salvador, which by their recording and reporting, currently cannot be used for tsunami monitoring.
- With the knowledge acquired and assistance from external cooperating, SNET will work in projects related with tsunami threat assessment, tsunami generation and tsunami inundation maps. On October 1, 2009, initiated a project in cooperation with AECI for TSUNAMI RISK ASSESSMENT IN THE COAST OF EL SALVADOR.
- With the knowledge received, we made an improvement of the Standard Operating Procedures (SOP) for tsunamis in each country. These procedures are already being implemented in the National Oceanographic Service of El Salvador.
- Tools to monitor and forecast tsunamis arrival time and tsunamis propagation are already being used for the preparation of bulletins and issuing recommendations to the public about tsunamigenic events generated in the Pacific basin. The monitoring and forecasting tools are:

1. Tide Tool: Tsunami Propagation in deep and shallow waters.

2. Tsunami travel time: Predicting of tsunamis propagation and tsunami arrival time.

3. CISN: Real-time seismic monitoring.

4. RANET: Dissemination tsunamigenic events information.

Solomon Islands

by Annette Ofu, Manager, National Disaster Management Office, Solomon Islands

This report serves as the written report of the officer from the Solomon Islands National Disaster Management Office (SI NDMO) who participated in the ITP-Training Program in Hawai'i from the 24th August to 9th September 2009.

The International Tsunami Information Center (ITIC) has offered this year through the ITIC International Tsunami Training Program with contributions from the United States to the World Meteorological Organisation (WMO) Voluntary Contribution Programme and from New Zealand to the IOC Trust Fund. The ITP-Hawaii 2009 has conducted at the International Tsunami Information Centre (ITIC) in Honolulu, Hawai'i. The primary aim of the course is to provide knowledge and skills necessary for the development of the tsunami warning system in the region.

As part of the Solomon Islands National Disaster Management Office (NDMO) ongoing strengthening programme in upgrading its Tsunami Early Warning Systems and staff capacity, the NDMO had sent the staff of the National Emergency Operation Centre (NEOC) staff to attend the training. The three weeks ITP- training involved a series of lectures, educational field trips and presentation of emergency procedures and early warning systems.

The programme, under direction of the International Tsunami Information Centre (ITIC), provides participants with an overview of the history and operation of the Pacific Tsunami Warning and Mitigation System. Specific focus is given to the important role of Regional and National Tsunami Warning Centers in monitoring and evaluating the tsunamigenic potential of earthquakes, and in issuing timely tsunami warning messages to

ITP, *continued*

government emergency officials who can then act to save lives and reduce damage to coastal communities. The programme provides training and familiarization with the Pacific Tsunami Warning System, Sub-Regional and National Warning Systems, and Civil Defense concepts of operations and standard operation procedures. The ITP- uses Hawaii as a working example of an end-to-end tsunami warning and mitigation system, demonstrating close stakeholder coordination and partnership for operational warnings and in preparedness activities.

Participants are engaged in a series of informational presentations and discussions at ITIC and the Pacific Tsunami Warning Centre, and visits to the Emergency Operations Center, to seismic or water level station field sites. A two and a half day off- island field trip was made to Hilo which is the biggest island in Hawai'i and visited Hawaii County Civil Defense Agency, the Pacific Tsunami Museum, tsunami memorials, and the USGS Hawaiian Volcano Observatory. It is a remarkable memorial site at Laupahoehoe, where students and some of their teachers lost their lives in the 1946 tsunami.

The training also focused on standard operating procedures for tsunami warning and tsunami emergency response, and testing of SOPs through drills and exercises. Special emphasis was given to telecommunications and methods of receiving and disseminating timely alerts. Participants were asked to create, modify, and discuss their country SOPs using guidance and template examples provided during the training, and were introduced to the different tsunami warning decision support tools and software available for use in our centers.

On the first day of the training, participants presented their country presentations relating to early warning and mitigation systems. This continued for few days.

There were a total of 15 participants who attended the very important training. Participants came from El Salvador, Malaysia and from the Pacific which includes Fiji, Tuvalu, Tonga, Cook Islands, Federated State of Micronesia, Papua New Guinea and Solomon Islands.

The facilitators were very helpful and demonstrated a professional standard throughout the training both in theory and practice. The facilitators presented examples of end-to-end tsunami warning and mitigation systems. They also emphasised working closely with stakeholders in coordination and partnership for operational warnings and in preparedness activities.

Tsunami materials, monitoring and evaluating tools are provided by the ITIC team to the participating countries to assist in early tsunami warning, as most of the countries lack resources.

I personally gained a lot with participants from different backgrounds in the Pacific Region and the countries abroad such as El savador and Malaysia. I shared my experiences with the facilitators and course colleagues during the training. The ITIC teams were very helpful which I do really appreciate the hospitality offered to me during my stay in Honolulu and Hilo, Hawaii.

This training has given me an opportunity to further my skills and knowledge to better perform my current responsibilities as the NEOC Manager, taking into account, the tsunami risks in our environment, that affect the livelihood of the communities in the Solomon Islands. I better understand the relationship from resource organizations that provides tsunami and earthquake information to the Pacific region including Solomon Islands, such as PTWC, USGS, JMA and others.

I also learned terminology used for tsunami warnings to regional and national tsunami warning centers on issuing of tsunami warning messages.The basic technical tools provided by ITIC help me to facilitate my role in monitoring, and evaluating tsunami information when earthquakes occur. It also assists in issuing and disseminating information timely to the areas that are likely to be affected during tsunami warnings.

The procedures during a disaster used for the activation of the National Emergency Operations Centre (NEOC) are one of the critical issues we face in our countries. There is no standard operating procedure in place in many emergency operation centers in the Region. Staff are not clear as to their roles and responsibilities in responding and coordination during a disaster. Sharing of experiences and information from various backgrounds to participating countries is helpful.

The National Disaster Management Office (NDMO) has greatly benefited from such programmes, especially, considering the good relationship established in partnership with International emergency agencies and resource organisations such as PTWC and ITIC. The NDMO have an important role in national tsunami warnings and it has been given an opportunity to strengthen its system. The basic materials in monitoring and evaluating the tsunami and earthquakes would effectively assist in issuing timely tsunami warning messages. It would also help the government emergency officials who response to save lives and reduce damage to communities during tsunami disasters.

This training enhances the capacity of the National Emergency Operation Center (NEOC) as the focal point for coordination and dissemination of timely information to the public, partners and donors.It also enables NDMO Staff to be an effective counterpart in projects relating to tsunami early warning and mitigation and to strengthen

ITP, *continued*

further the development of the National Emergency Operation Centre (NEOC) and the Provincial Emergency Operation Centre (PEOC).

With the limited resources acknowledged, this training is of great significance as it basically enhance the understanding of basic technical skills. Solomon Islands is vulnerable to tsunami and has limited resources for response. This training provides the NDMO enhanced knowledge for decision making during tsunami events and other disasters.

WORKSHOP AND MEETING SUMMARIES

24th International Tsunami Symposium Business Meeting Novosibirsk, Russia, 14-19 July 2009

The IUGG tsunami commission business meeting was held the evening of Tuesday, 14 July 2009, in the conference room of Dom Uchenykh (House of Scientists), Siberian Division of the Russian Academy of Sciences, in the center of Akademgorodok (Morskoy Pr., 23), Novosibirsk. It was the first day of the 24th International Tsunami Symposium. Commission members attending the meeting were: Abe, Bernard, Burnett (new member), Dunbar, Greenslade, Gusiakov, Kanoglu, Levin, Marchuck, Nishimura, Pelinovsky, Power, Rabinovich, Ranguelov (new member), Satake, Synolakis, Tinti, Titov, Tsuji, Yalciner, Yamamoto (new member). Several participants of the Tsunami Symposium also attended as observers.

Report of Commission Activities

Satake reported on the following activities of the Commission in the last two years.

The 6th International Tsunami Mitigation Workshop in Guayaquil, Ecuador, on September 14, 2007, was jointly organized by INOCAR, UNESCO/IOC, and IUGG Tsunami Commission. There were 23 presentations from 10 countries and an international organization.

The Tsunami Commission organized the Session "Tsunami in Africa"at the IASPEI General Assembly, January 10-16, 2009, in Cape Town, South Africa. The conveners were Satake, Rabinovich, Tinti, Roberts and Hartnady. There were 25 papers.

The Tsunami Commission has published 68 papers in three volumes in the last several years:

"Tsunami Science Four Years after the 2004 Indian Ocean Tsunami" was published in two topical volumes, Part I: Modeling and Hazard Assessment and Part II: Observation and Data Analysis, in Pure and Applied Geophysics, (Part I in vol.165, 2008 and Part II in vol.166, 2009). The editors were Cummins, Kong, and Satake. The volumes include 28 papers (14 in each part), presented at the Tsunami Session of the 2007 IUGG General Assembly (Perugia, Italy). They were printed as books by Springer-Birkhäuser (Part I ISBN: 978-3-0346-0056-9 and Part II ISBN: 978-3-0346-0063-7). The editors and reviewers (two for each paper) were acknowledged.

"Tsunami and its Hazards in the Indian and Pacific Oceans", was published as a topical book in Pure and Applied Geophysics, 2007. The editors were Satake, Okal, and Borrero. The volume contains 20 papers, presented at the 2005 International Tsunami Symposium in Crete, Greece, and was printed as a book by Springer-Birkhäuser (ISBN: 978-3-7643-8363-3).

"Tsunamis Case Studies and Recent Developments" ($195.95), was published as a topical volume in Advances in Natural and Technological Hazards Research (vol. 23), 2005. The editor was Satake. The volume includes 20 papers and was printed as a book by Springer (ISBN: 978-1-4020-3326-1).

The official Commission Website is now available online and maintained by the NOAA National Geophysical Data Center at the following URL: *http://www.ngdc.noaa.gov/hazard/jtc/tsunamicommission.html*

A letter was presented from Patricio Bernal (Assistant-Director General of UNESCO, and Executive Secretary of Intergovernmental Oceanographic Commission) informing Satake (Chair) that Masahiro Yamamoto (IOC Senior Tsunami Advisor, Paris) would be representing the IOC at the Symposium. The letter was also an official request from IOC to have a representative in the IUGG Tsunami Commission.

Reports of Working Groups

The activities of three Commission Working Groups (field survey data, tide gauge data and satellite data of the 2004 Indian Ocean tsunami) formed at the 2005 business meeting and an additional Working Group (terminology) formed at the 2007 business meeting were reported.

WG for 2004 Survey (changed from Measurement) Data (Gusiakov and Fujima). Gusiakov reported that they face a huge task, for example, the ITDB includes over 1000 observations and 500 are in Banda Aceh. The data are scattered throughout publications. Collecting the 2004 data is an example of the problems of collecting all event data. The goal is to include all of

Tsunami business meeting, *continued*

these data in a database. It was agreed that the WG will continue and a report representing the majority of the data will be published in two years. This WG will be the contact point for the revision of the IOC Post-Tsunami Survey Field Guide.

WG for 2004 Sea Level Data (changed from instrumental) (Rabinovich). Rabinovich reported on the challenges of the enormous amount of data. He stressed the importance of adding the data to the historical catalogs (ITDB and NGDC) and the need for additional funding for data processing. It was agreed that the WG will continue with two additional members: Stuart Weinstein (PTWC) and Kelly Stroker (NOAA NGDC).

WG for 2004 Altimetry Data. Titov reported that altimetry data were collected and placed on the web and the WG ended. *http://nctr.pmel.noaa.gov/indo_1204.html*

WG for Tsunami Terminology (Power, Kong, Stroker, Imamura, Dengler, Rabinovich). Power reported that discussions were held via email. Their work focused on improving the IOC Tsunami Glossary by reviewing it and compiling a list of changes that were given to Kong (ITIC). The Glossary was revised in 2008. Outstanding items include the need for more tide gauge terminology and more consistency; for example, each entry needs a dictionary definition and an explanation. It was agreed that the WG will continue with the addition of Diana Greenslade to improve consistency between the IOC and IO glossaries.

Satake, Rabinovich, Kanoglu and Tinti were selected as editors of the proceedings. The final manuscripts will be submitted to the publishers by the end of 2010; and the volume will be published before the 2011 IUGG General Assembly.

IUGG General Assembly will be held June 28-July 7, 2011 in Melbourne, Australia. *http://www.iugg2011.com/*. Cummins, Titov, Satake, and Papadopolous will chair the Tsunami Session.

An Indian Ocean Tsunami Modeling Symposium is planned to be held in Perth, Western Australia from 12-15 October 2010. This will be organized through WG4 of the ICG/IOTWS.

SOPAC STAR 2009

Tsunami Working Group Recommendations

The following are recommendations from the Pacific Applied Geoscience Commission (SOPAC)–Science, Technology and Resources Network (STAR)–Tsunami Working Group from its October 2009 meeting in Port Vila, Vanuatu.

Members of the group included Co-Chairs Ken Gledhill and Laura Kong; Lawrence Anton, Litea Biukoto, Herve Damlamian, ‘Ofa Fa’anunu (by email), Esline Garaebiti, Gary Green, Trevor Jones, Peter Koltermann, Kelepi Mafi, Keu Mataroa, Cherie O’Brien, Bernard Pelletier, Alf Simpson, Lameko Talia, and Masahiro Yamamoto.

- Noting the high frequency of tsunamis affecting this region over the last decade (23 tsunamis, of which 4 caused deaths in 1998, 1999, 2007 and 2009), and the damaging effects they have had on communities, physical infrastructure, social well-being, and livelihoods,
- Noting the recommendations of the UNESCO/IOC PTWS Seismic Data Sharing Task Team meeting 19-20 October 2009, which took action to address the urgent need for more seismic data so as to reduce the detection and warning issuance time for tsunami early warning,
- Noting the reports, information sharing, and discussions from the STAR Tsunami and 29 September 2009 Tsunami Sessions, and the STAR Tsunami Working Group that highlighted the importance of
  - *Natural warnings of tsunami, such as intense earthquake shaking and the draw-down of the sea for near-source, local tsunami response,*
  - *Education and awareness campaigns on natural warnings and the required response,*
  - *Community response planning, including evacuation plans and safe areas.*
- Recognizing the coordination role of UNESCO/IOC and long experiences of its Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (PTWS) and its efforts to promote the development of strong tsunami early warning systems in the Pacific for more effective tsunami mitigation,
- Recognizing SOPAC’s role working with Pacific Island Countries in the disaster risk reduction for tsunami and other hazards in the context of the Hyogo Framework,
- Recognizing SOPAC’s role in the coordination of the international tsunami scientific responses to tsunami (and other disaster) events in the region, in cooperation with UNESCO IOC, to ensure the maximum scientific and local benefit from the work of the international science teams,
- Appreciating the important role that UNESCO/IOC, SOPAC, and other regional and international organizations and donors play in working together to assist Pacific Island Countries to build effective tsunami early warning systems,
- Identifying the need for countries in the region to develop and exercise effective standard operation procedures (SOPs) to specify the response once a tsunami warning is received

STAR, *continued*

•Identifying the need for capacity building in national warning centre operations and the decision support tools that aid in operations,

•Endorsing the continued need for free and open exchange of data and information to benefit both the local and international communities,

•Recognizing that tsunami hazard and risk assessments are essential to identify coastal communities so as to assist them to better respond to tsunamis and guide development in these areas. Inundation mapping, using standardized tools and high-resolution bathymetric and topographic sets such as LIDAR, is needed for tsunami flood planning. SOPAC is developing its capacity to address inundation modeling in the region, and is combining this with its existing bathymetric capacity.

•Recognizing the important value of paleotsunami scientific studies for extending the historical record of destructive tsunamis that have impacted each country,

We present the following recommendations for SOPAC Governing Council endorsement:

- Encourage and support the conduct of hazard risk assessments to identify the most vulnerable communities for tsunami. In most areas, the necessary topographic and bathymetric data, which are useful for other purposes such as climate change impacts, disaster risk reduction and land use planning, are not available presently. Extending the known historical tsunami database back in time for each country is critical.

- Urgently encourage and support countries to immediately develop effective and practical tsunami response and evacuation plans, based on the existing and best available science, and to practice them in preparation for the next tsunami. Effective emergency alert systems that will reach vulnerable communities need to be implemented. As better inundation models become available, evacuation maps can be refined.

- Encourage and support the continued conduct of community-based education and awareness campaigns for tsunami and other hazards, especially for local tsunamis, so that everyone will be able to recognize a tsunami and know what to do. Implement tsunami awareness in local education systems through curriculum development.

- Organize and assist countries to develop tsunami warning and response capacities through training, twinning, and other means of skills building.

- Facilitate a coordinated approach for post-tsunami surveys that are conducted immediately after destructive tsunamis to assemble lessons learned and capture data to validate risk assessment models following the guidance of the revised IOC Post-Tsunami Field Survey Guide and the lessons learned from the International Tsunami Survey in Samoa in October 2009. These findings will benefit countries in recovery and tsunami mitigation.

- Facilitate coordination and sharing of data and information between warning agencies, response agencies and communities before, during, and after tsunami events.

Located in Honolulu, the International Tsunami Information Center (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, Vietnam.

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