OCTOBER-DECEMBER 2005 VOLUME XXXVII, NUMBER 2

TSUNAMI NEWSLETTER

International Tsunami Information Centre

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'EXERCISE PACIFIC WAVE 06' to be conducted in May 2006

The Intergovernmental Coordination Group for the Pacific Tsunami Warning System (ICG/PTWS) will be conducting its first end-to-end Pacific-wide tsunami exercise for the Pacific Ocean on 16-17 May 2006. Regional and national tsunami warning systems in the Pacific and globally must maintain a high level of readiness so as to be able to efficiently and effectively act to provide for the public's safety during fast-onset and rapidly-evolving natural disasters such as tsunamis. To maintain this high state of operational readiness, and especially for infrequent events such as tsunamis, emergency agencies should regularly practice their response procedures to ensure that vital communication links work seamlessly and that agencies and response personnel know the roles that they will need to play during an actual event.

The 2004 Indonesia earthquake and Indian Ocean tsunami brought to the world's attention the urgent need to be better prepared. Accordingly, the intent of the Pacific-wide exercise is to motivate countries to review and test their response procedures, and for the PTWS system to evaluate its operations with the goal of identifying weak areas where improvement is needed to increase overall preparedness. A report on the exercise will be made by the ICG/PTWS Chair to the Intergovernmental Oceanographic Commission (IOC) Executive Council in late June 2006.

The exercise will place all Pacific Basin countries into a Tsunami Warning that will require countries to practice its emergency response decision-making for the arrival of a destructive Pacific-wide tsunami upon its shores, and depending on the country, be conducted to the step just prior to public notification. The exercise will take focus on two components of the warning system: the evaluation and issuance of the warning message by tsunami warning centres, and the national and/or local response and warning dissemination mechanism once a warning is received by emergency authorities.

During the first stage, the scenario of a destructive tsunami crossing the Pacific will be simulated through communication of messages by the Pacific Tsunami Warning Center (PTWC) and other warning centres, including sub-regional centres such as the West Coast/Alaska Tsunami Warning Center (WC/ATWC) and the Japan Meteorological Agency's Northwest Pacific Tsunami Advisory Center (NWPTAC). Tsunami bulletins will be transmitted from the tsunami warning centres to 7x24 Tsunami Focal Points and/or designated national emergency authorities responsible for tsunami emergency response. A compressed

Pacific drill, *continued*

exercise time schedule is planned in order to complete the drill in a timely manner that will allow maximum engagement by all stakeholders.

In the second stage, decision-making and notification down to the last stage before public notification should be simulated. This stage should be conducted the same day or within the following days and include notifications to the emergency management authorities of a single coastal community so as to sufficiently practice the end-to-end process. Countries plan to taken special care to ensure that the public is not inadvertently alarmed.

All countries of the Pacific are being strongly encouraged to participate in the exercise. The exercise is being considered the first drill of what will be regular schedule of future exercises. A task team chaired by Australia and comprised of representatives from the PTWC, WC/ATWC, NWPTAC, ITIC, Australia, Chile, France, Fiji, New Zealand, Nicaragua, Russian Federation, Samoa, and the USA, is coordinating 'Exercise Pacific Wave 06'. For more information, please contact contact Mr. Mark Sullivan, Emergency Management Australia, TSUNAMI@ema.gov.au,Telephone: +61 262 564 693.

SUMMARY OF EARTHQUAKES

Occurring October-December 2005

With surface wave or moment magnitude (M_w) greater than or equal to 6.5 and a depth no greater than 100 km, or an event for which a Tsunami Information Bulletin (TIB) or Regional Watch Warning (RWW) was issued. Epicenter, depth, M_W and M_S,from USGS National Earthquake Information Center (NEIC, G); M_W, and M_S from Harvard (H); M_W from PTWC (P) at action time.

DATE	TIME (UTC)	LOCATION	LATITUDE	LONGITUDE	DEPTH (km)	M_w	M_s	PTWC ACTION	ACTION TIME	TSUNAMI? DAMAGING?
Oct 8	3:51	Pakistan	34.529° N	73.580° E	26	7.3 (G) 7.6 (H) 7.5 (P)	7.7 (G)	TIB	4:04	No No
Oct 15	15:51	Northeast of Taiwan	25.315° N	123.335° E	182	6.5 (G,H) 6.6 (P)	6.6 (H)	TIB	16:07	No No
Nov 14	21:39	Off East Coast of Honshu Japan	38.101° N	144.925° E	11	6.9 (G) 7.0 (H) 7.3 (P)	6.8 (G)	TIB	21:49	Yes No
Nov 17	19:27	Chile-Bolivia Region	22.263° S	67.784° W	163 158 (H)	6.8 (H) 6.9 (G,P)	6.9 (H)	TIB	19:45	No No
Nov 19	14:10	Northern Sumatra Indonesia	2.232° N	96.769° E	30	6.5 (G, H, P)	6.1 (G)	TIB	14:27	No No
Dec 11	14:21	New Britain Region, PNG	6.593° S	152.184° E	10	6.6 (G, H) 7.0 (P)	6.2 (G)	TIB	14:34	No No
Dec 13	3:16	Fiji Islands Region	15.270° S	178.569° W	29	6.6 (G, H) 6.8 (P)	6.8 (G)	TIB	4:05	No No

Correction: In the last issue of the Tsunami Newsletter, a tsunami following the earthquake of November 11, 2004 was not indicated. According to an e-mail from Dr. Fauzi at Indonesia's Meteorological & Geophysical Agency (BMG), dated November 22 2004; a BMG team visited Alor and confirmed a tsunami with wave height from 1-2 meters and inundation to 50 meters had occurred. He also reported that inundation north of Kalabahi, on Mali Beach reached 30-50 meters inland. A news account posted to the Tsunami Bulletin Board, from News International Pakistan of November 13, 2004, reported over 17 killed in the earthquake with 160 others injured on Alor. The source also mentions that the earthquake was felt 50 kilometers away in the East Timor Capitol of Dili, where receding water grounded and caused some damage to a floating hotel in the harbor.

OFF EAST COAST OF HONSHU, JAPAN, M_W=6.5, 19 JANUARY 2005, 06:12 UTC

An earthquake that struck on 19 January 2005, off the East Coast of Honshu, Japan at 15:12, local time was felt throughout a large portion of central and northern Honshu. (*Figure 1*). A tsunami was recorded at various tide stations in the Izu Shichito Islands as well at various stations in south central Honshu.The largest wave height recorded was 39 cm. recorded on Miyake-jima.

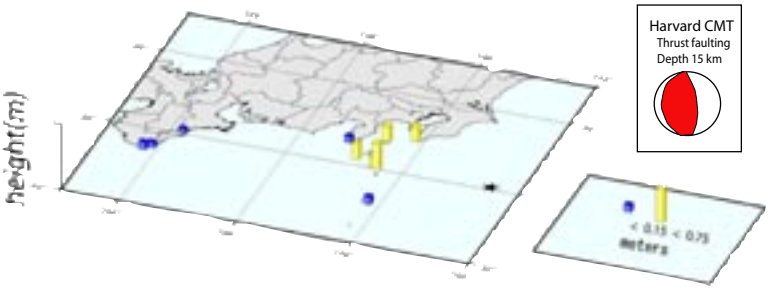
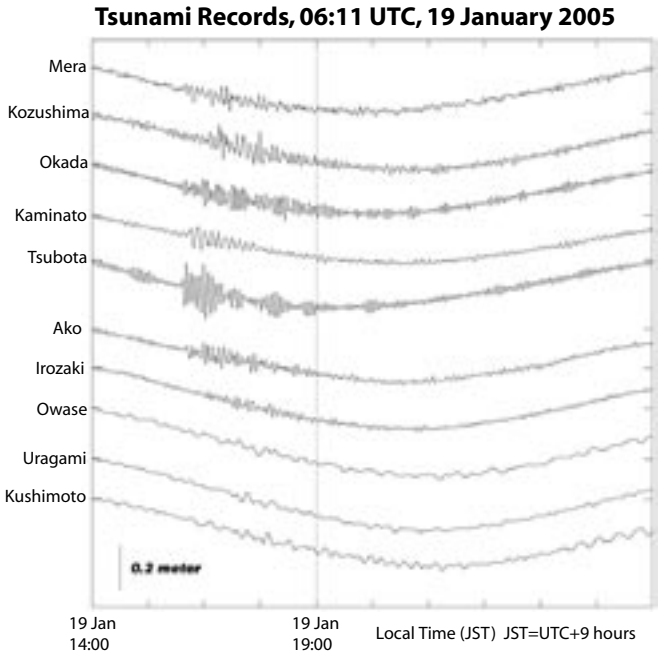


Figure 1. Observed tsunami heights from the 19 January earthquake as reported by JMA. The blue star indicates the earthquake's epicenter.



Tide station name	Latitude	Longitude	Arrival time (JST)	Initial wave height (cm)	Max wave-height (cm)
MERA	34°55'	139°49'	15:39	11	23
KOZUSHIMA	34°13'	139°08'	16:05	9	24
OKADA	34°47'	139°23'	15:35	6	23
KAMINATO	33°08'	139°48'	15:44	5	10
TSUBOTA	34°03'	139°33'	15:36	7	39
AKO	34°04'	139°29'	15:41	5	16
IROZAKI	34°37'	138°51'	16:04	5	9
OWASE	34°05'	136°12'	16:34	4	5
URAGAMI	33°33'	135°54'	16:34	3	8
KUSHIMOTO	33°29'	135°46'	16:34	2	11

Left, Sea level records showing the tsunami wave with list of station details above. Both courtesy of JMA.

NORTHERN SUMATRA, INDONESIA, M_W=8.7, 28 MARCH 2005, 18:32 UTC

An earthquake occuring off the coast of Sumatra, Indonesia with an epicenter at 2.1°N and 97° E, was the largest earthquake recorded in 2005. It occured on 28 March, 2005, 3 months after the massive 26 December 2004 earthquake, and was measured with a Moment Magnitude (M_W) of 8.7 (HRV) (Figure 1). The earthquake occured 187 km distance from the 26 December 2004 Earthquake in an area to the south, which had previously ruptured in 1861. (Figure 2). Because the rupture area was much smaller, 300 km as compared to 1200 km for the 26 December earthquake, and the epicenter was situated between the main island of Sumatra and smaller outlying islands, this earthquake did not generate a destructive basin wide tsunami.

The impact of the earthquake was greatest on the island of Nias, where at least 1,000 people were killed, 300 injured and 300 buildings destroyed. The National Earthquake Information Center (NEIC) also reported two hundred killed in Kepulauan Banyak, with another hundred people killed and many injured in Simeulue; with 3 people killed, 40 injured and some damage in the Meulaboh area of Sumatra. A three-meter tsunami

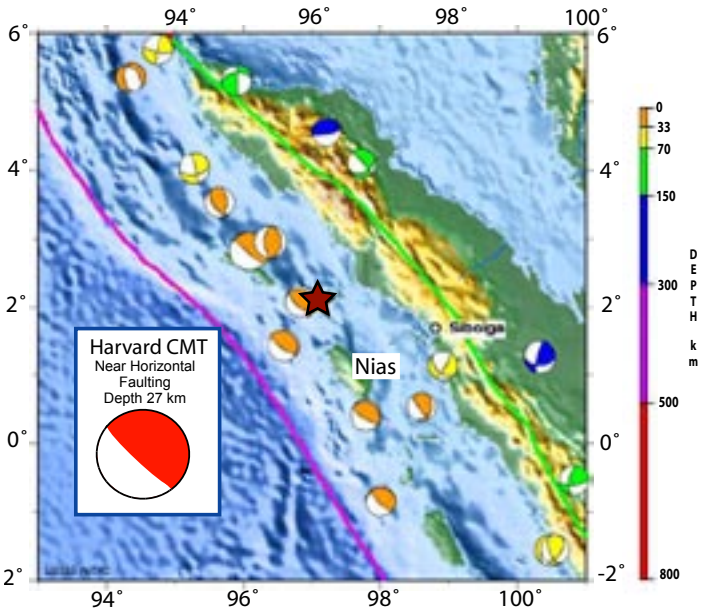


Figure 1. Historical Moment Tensor solutions map with red star showing the earthquake's epicentre. (Map courtesy of NEIC)

Sumatra, *continued*

damaged the port and airport on Simeulue. Tsunami runup heights as high as 2 meters were observed on the west coast of Nias and 1 meter at Singkil and Meulaboh, Sumatra. An account, from USGS National Earthquake Information Center (NEIC), reports at least 10 people killed during evacuation of the coast of Sri Lanka. The quake was felt throughtout the area devastated by the 2004 Indian Ocean tsunami. Tsunami wave heights (peak-to-trough) recorded from selected tide stations: about 40 cm on Panjang, Indonesia; about 25 cm at Colombo, Sri Lanka; 40 cm on Hanimadu, 18 cm at Male and 10 cm at Gan, Maldives. (Figure 3 and Table 1 below).

Initial observations indicate about 1 meter of subsidence on the coast of Kepulauan Banyak as well as 1 meter of uplift on the coast of Simeulue. Seiches were observed on ponds in West Bengal, India.

Figure 3. Map showing the station locations for the tide records below. A yellow star indicates the 28 March 2005 earthquake's epicentre.

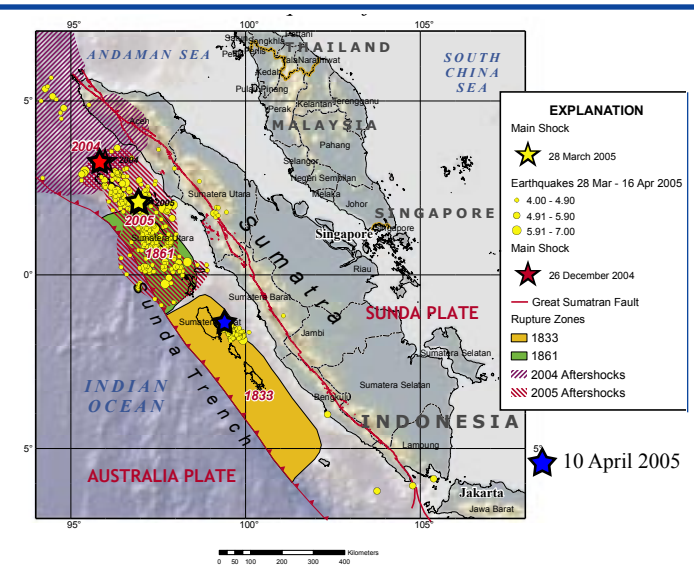
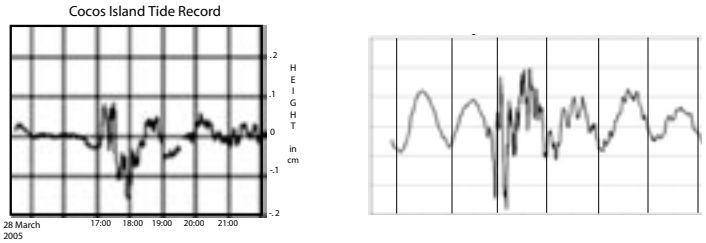
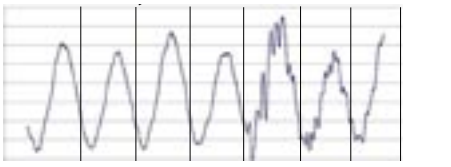


Figure 2. Map showing the historical earthquake acitivity along various sections of the Sunda Trench. The rupture zone of the 28 March earthquake had last erupted in 1861. The map also shows the location of the 26 December 2004 earthquake (red star) and 10 April 2005 earthquake (blue star). (Courtesy of NEIC).

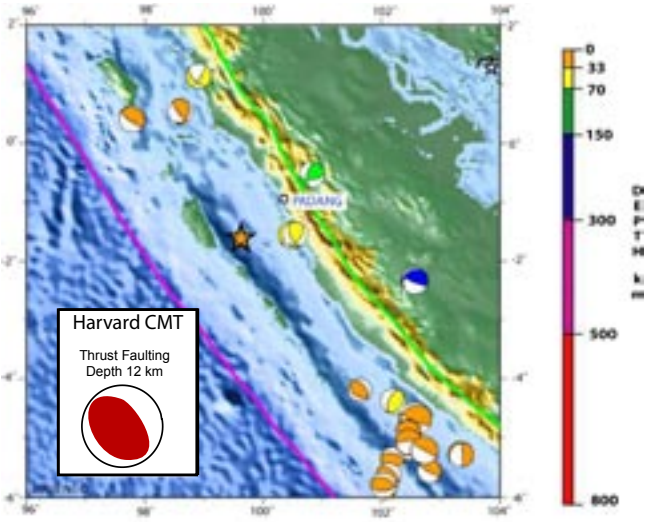




Sea level records courtesy of Australia Tide Centre (NTC), (above), and BAKOSURTANAL, Indonesia (right).

Location	Maximum Height	Source
Gan, Maldives (00.7°N, 73.2°E)	approx 22 cm (p-p)	University of Hawaii Sea Level Center (UHSLC)
Male, Maldives (04.2°N, 73.5°E)	approx 20 cm (p-p)	UHSLC
Hanimaadhoo, Maldives (06.8°N, 73.2°E)	approx 20 cm (p-p)	UHSLC
Cocos(Keeling) Island, Australia (12.0°S, 96.7°E)	23 cm	Australian NTC
Panjang, Sumatra (05.45°S, 105.28°E)	approx 50 cm (p-p)	BAKOSURTANAL
Sibolga, Sumatra (01.75°N, 98.77°E)	approx 235 cm (p-p)	BAKOSURTANAL
Salalah, Oman (16.94°N, 54.0°E)	52 cm (p-p)	UHSLC
Colombo, Sri Lanka (06.92°N, 79.83°E)	42 cm (p-p)	UHSLC
Rodrigue, Mauritius (19.67°S, 63.42°E)	55 cm (p-p)	UHSLC
Port Louis, Mauritius (20.15°S, 57.50°E)	35 cm (p-p)	UHSLC
Ponte La Rue, Seychelles (04.67°S, 55.53°E)	35 cm (p-p)	UHSLC

OFF SOUTHERN SUMATRA, INDONESIA, M_W=6.7, 10 APRIL 2005, 11:14 UTC



An earthquake off Southern Sumatra, Indonesia occured on 10 April 2005, measured M_W 6.7 (HRV). It was smaller and further south than the two previous large earthquakes off the coast of Sumatra. (*see Figure 2 in 28 March 2005 section*).

A tsunami with a wave height of 40 cm was observed at Padang, Sumatra. The account cannot be supported with tide records, as the gauge at Padang was out of service at the time of the earthquake.

Figure 1 (left). Historical Moment Tensor Solutions with recent earthquake location marked by orange star. (Map from NEIC).

OFF NORTHERN CALIFORNIA, USA M_W=7.2, 15 JUNE 2005, 02:51 UTC

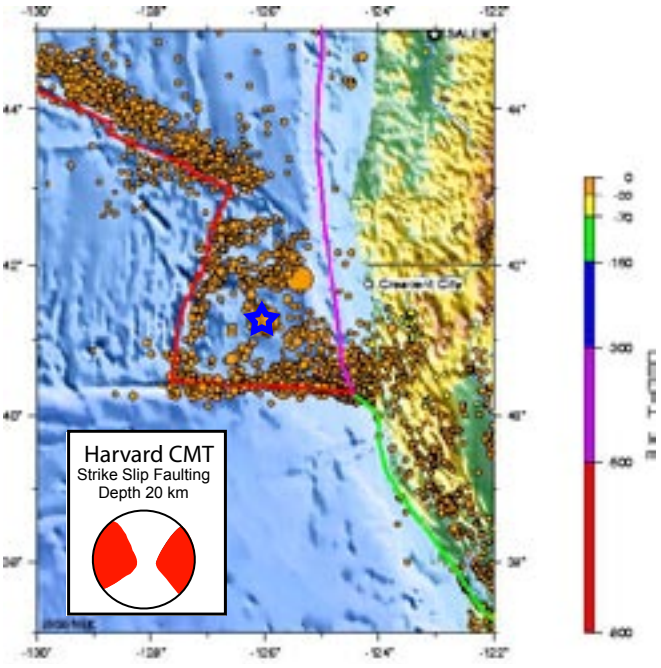


Figure 1. Map showing the location of the earthquake (blue star) and the historic seismicity of the area, with plate boundaries in red and purple. (Map from NEIC).

A major earthquake with a moment magnitude of 7.2 (HRV) occurred at 0251 UTC 15 June (7:51pm 14 June, local time) and was located off the northern coast of California. USA (41.3°N 125.7°W).

The earthquake produced a minor tsunami that was observed at Crescent City, California, USA (41.75°N 124.1°W) approximately 20 cm (p-t) (NOS). (Information posted on the West Coast/Alaska Tsunami Warning Center website, URL: *http://wcatwc.arh.noaa.gov/06-15-05.htm*, which links to the Crescent City tide record and to a raw data file for the earthquake).

Tide gage site	Wave height (cm p-t)	Arrival time (UTC)	ETA (UTC)	Initial motion	Sample Interval (min)	Data File
Crescent City, California, USA	20	approx 0335 06/15	0329 06/15	recession	1	Data (m) starting at 0000 UTC 06-15-05

15 JUNE 2005 EARTHQUAKE AND TSUNAMI

by Dr. Alexander Rabinovich, rabinovicha@pac.dfo-mpo.gc.ca, and Fred Stephenson, Canadian Hydrographic Service, stephensonF@pac.dfo-mpo.gc.ca, both at Institute of Ocean Sciences, P.O. Box 6000, Sidney, B.C. CANADA V8L 4B2.

At 02:51 UTC on 15 June 2005 (14 June at 19:51 local time) an earthquake occurred approximately 145 km northwest of Eureka, California (Figure 1). The magnitude of this earthquake was initially estimated as Mw=7.4, but was later corrected to Mw=7.2 (USGS, CISN). The epicentre coordinates were 41.28ºN, and 125.98ºW (USGS). Based on the earthquake's location and magnitude, the West Coast and Alaska Tsunami Warning Center (WC/ATWC) in Palmer, Alaska issued a Tsunami Warning for all coastal areas from the California – Mexico border to the north end of Vancouver Island (Cape Scott). This warning was issued at 02:56 UTC, i.e. 5 minutes after the main shock. In British Columbia the message was received by the Provincial Emergency Program (PEP), who initiated their tsunami response plan. Within half an hour of there

California, *continued*

being a possibility a wave could hit, 26 communities on the west coast of Vancouver Island were contacted to make sure they were moving on their plans.

Immediately following the earthquake, Dr. Vasily Titov (PMEL/NOAA, Seattle), utilized the prototype of the NOAA Tsunami Forecast System under development by PMEL to predict tsunami amplitudes at five DART stations in the Northeastern Pacific. He sent his first results to the ITIC Tsunami Bulletin Board at 03:16 UTC (20:16 PDT), i.e. 25 minutes after the earthquake. He estimated tsunami heights and travel times for the DART buoy locations and found that even for the closest one (DART 46405) the generated tsunami would have amplitudes less than 1.5 cm.

Tide stations along the west coasts of the US and Canada were monitored for evidence of a tsunami wave, however, no water level changes were observed at coastal sites (Figures 1 and 2). Therefore, based on this information and numerical results by Vasily Titov, the WC/ATWC determined that a destructive tsunami had not been generated and cancelled the Tsunami Warning at 04:09 UTC (21:09 PDT).

In British Columbia, Canadian Hydrographic Service staff continued monitoring six tide stations along the outer B.C. coast and detected weak tsunami waves (greater than 4 cm) at two stations: Tofino and Bamfield (Figure 2). Estimated tsunami arrival time (ETA) to Tofino, 04:57 UTC (20:57 PDT) was in good agreement with the actual tsunami arrival time of 04:51 UTC. This first observed wave was negative (ebb) and the exact trough-to-crest height of this first wave was 3.3 cm. A few minutes later, at 04:56 UTC, a tsunami wave (also negative) arrived at Bamfield with a wave height of 1.8 cm; the maximum wave height at Bamfield (third wave) was 2.6 cm.

The first tsunami waves observed at Tofino were irregular, however, approximately 1 hour after the first arrival (at 05:58 UTC) a train of regular waves with a typical period of about 20 min came to Tofino and were observed there for about four hours (Figure 2). Maximum trough-to-crest wave height was 4.3 cm. It may be assumed that this train of waves was associated with edge waves propagating from the source area northward along the coast of North America. Further intensive analysis of other BC records also identified some tsunami signatures in records of Winter Harbour and Port Hardy, but they were quite small (< 1 cm). For the near-field US coast (Figure 2), tsunami waves were detected in the records of two DART buoys (Figure 3) and four coastal tide gauges (Figure 2).

At Crescent City, California, the station closest to the epicenter the tsunami waves arrived at 03:37 UTC and had a trough-to-crest height of 27.7 cm. The tsunami oscillations at this station were quite steady (Figure 3) with an observed period of about 22 min. At three

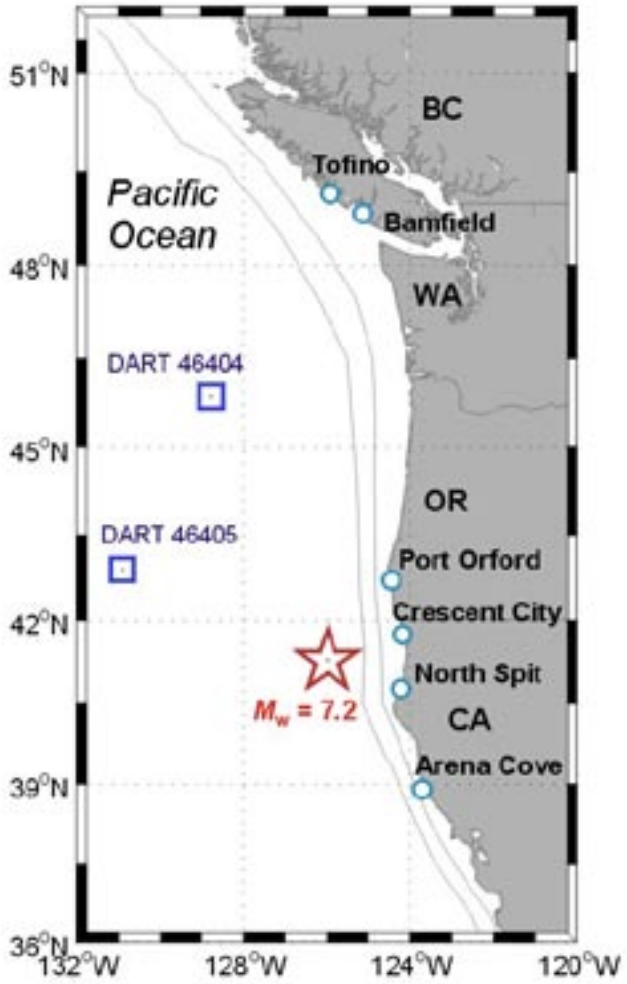


Figure 1. Locations of earthquake, DART systems, and coastal sea level stations recording the 15 June 2005 tsunami.

other stations, Port Orford, North Spit and Arena Cove, the tsunami signal was much weaker. The two latter stations were also very noisy. High-frequency noise associated with infragravity waves (generated by non linear interaction of wind waves and swell) caused serious difficulties in detecting and estimating tsunami arrival times, periods and amplitudes for the North Spit and Arena Cove tide gauges. To reduce this problem, we low-pass filtered the time series with a 6-minute Kaiser-Bessel window. Finally, from the records at these four stations (Figure 2) the following tsunami characteristics were estimated:

	Arrival (UTC)	Travel time (min)	Max wave height (cm)	Period (min)
Port Orford	03:47	56	4.0	17
Crescent City	03:37	46	27.7	22
North Spit	03:19	28	4.7	28
Arena Cove	03:49	58	6.5	irregular

At all four stations the first recorded tsunami wave was negative.

California, *continued*

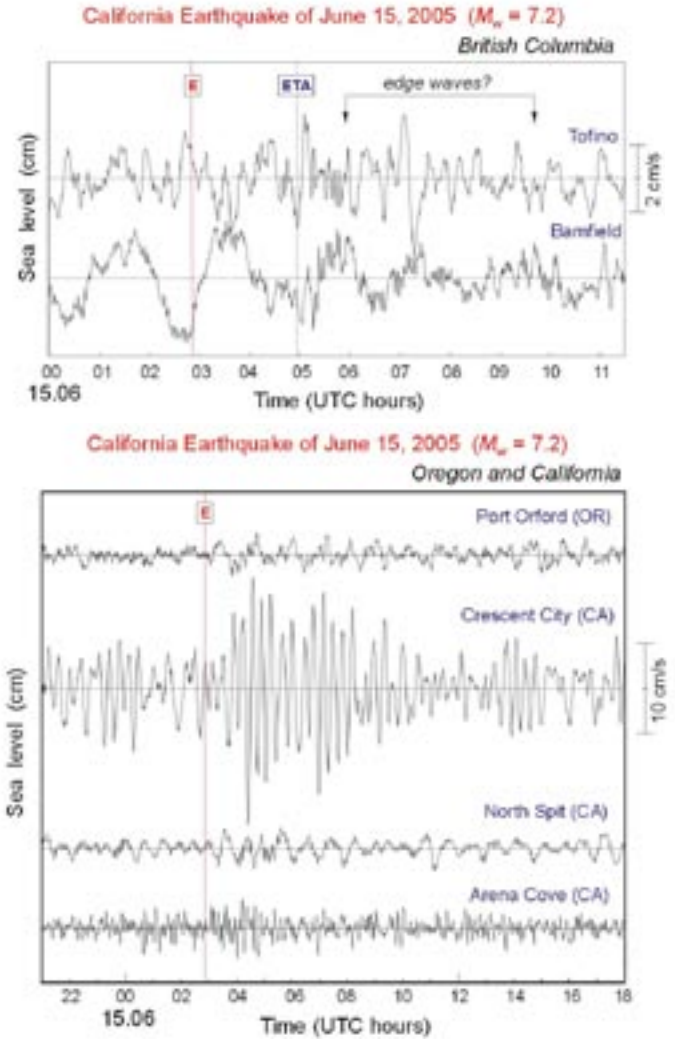


Figure 2. Sea level records from 15 June 2005 tsunami at Tofino and Barmfield, British Columbia, Canada (Data courtesy of Canadian Hydrographic Service), and at stations in Oregon and California, USA (Data courtesy of NOAA). Station locations shown in Figure 1.

Tsunami waves generated by the California earthquake were also recorded by two DART buoys, 46404 and 46405, located in the vicinity of the earthquake epicenter (Figure 1). Actually, both instruments first recorded seismic surface Rayleigh waves that arrived to DART 46405 at approximately 02:53:15 UTC (i.e. about 2 minutes, 21 seconds after the main shock) and to DART 46404 at about 02:53:45 UTC (in 2 minutes, 51 seconds). The ground oscillations at DART 46405 were from -11 cm to +4.5 cm (Figure 4) and these strong oscillations initiated an automatic alarm and 15 second data recording and transmitting. The Rayleigh oscillations at DART 46404 were approximately ±1 cm (Figure 3).

As predicted by Titov's computation, the observed tsunami waves at these offshore locations were quite small. The first tsunami wave arrived to DART 46405 at 03:28:45 UTC (about 38 minutes after the main shock). It was positive (+0.78 cm). The first wave came to DART 46404 at 03:43:45 UTC (in 53 minutes) and it was negative (-0.38 cm).

The warning issued on 15 June 2005 was the first tsunami warning on the B.C. coast since the 1994 M_W=8.2 Shikotan earthquake and tsunami (Southern Kuril Islands) and the first warning after the catastrophic M_W=9.3 megathrust Sumatra tsunami in the Indian Ocean. How has our response changed since that time? The evaluation report compiled following the 1994 event indicates the main challenge was timely communication, both from PTWC to the Member States and, within British Columbia, from the Provincial Emergency Program (PEP) to the various agencies and communities. In British Columbia, messages were sent by fax without prior notification by telephone, and the time between messages (updates) was too long. In 2005, as previously indicated,

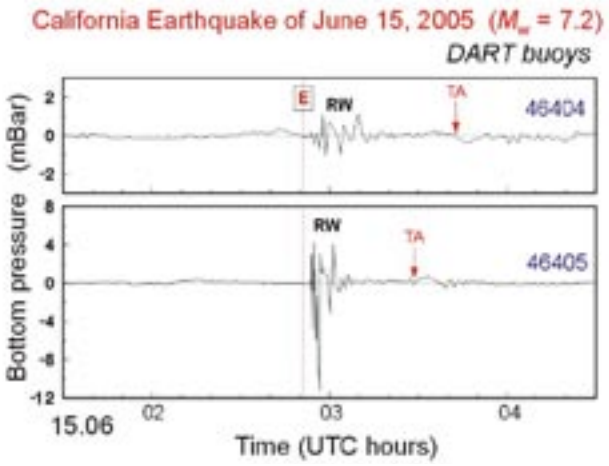


Figure 3. Bottom pressure sensor records from DART system instruments nearest the 15 June 2005 earthquake. Station locations shown in Figure 1. (Data courtesy of NOAA)

the warning information was quickly conveyed to 26 communities at risk. However, communities not at risk were not contacted and in hindsight this was a mistake. All communities want to be informed so that their elected officials and emergency response staff are able to respond to queries from a concerned public. In response to this shortcoming, PEP has upgraded its communications system, installing a new Interactive Voice Response (IVR) system and a high-speed fax server. The present system can now send out up to 1000 messages an hour, providing messages to agencies and communities by the IVR system, but also by fax and e-mail.

The detection and alerting system has also changed significantly since 1994. In 1994 there were very few digital tide gauges in operation and no deep ocean gauges. The earthquake occurred at 1323 UTC, but it was not until 1640 UTC that Bulletin 002 was issued indicating a 3.46m wave at Hanasaki, Japan. Bulletin 004 at 1856 indicated wave heights of 0.15m at Shemya, Alaska and 0.17m at Wake Island, and at

California, *continued*

1940 UTC Bulletin 005 indicated a 0.50m wave at Midway Island. With the observed wave height at Midway Island there was lingering concern of the potential for destructive wave activity in Hawaii and elsewhere. It was not until 2155 UTC that PTWC (Bulletin 006) informed that the tsunami wave height at Hilo, Hawaii had been 0.50m and the Tsunami Warning was cancelled.

On the British Columbia coast our network of tide stations used analogue recorders to measure water levels. Only the tsunami warning stations at Bamfield and Winter Harbour were equipped with digital recorders, and these instruments had to be remotely reset from the standard 15 minute sample interval to a 1 minute sample interval to provide the high sample rate required for tsunami detection. The measured tsunami wave was 22.4 cm at Winter Harbour and 9.2 cm at Bamfield. The analogue records were only recently inspected for evidence of the tsunami and it was determined that three additional stations (Tofino, Port Alberni and Victoria) recorded the tsunami, with the largest wave being 23.7 cm at Port Alberni.

In 1994, the time between the earthquake and the cancellation of the tsunami warning was 8 hours and 32 minutes. Why did it take so long? The location and number of tide gauges able to provide water level information in real-time was a factor, and a denser network of both coastal and deep ocean stations would have been of great benefit. The initial scope of the tsunami warning was too large and was in error, however, the lack of a prediction model integrated with data from deep ocean gauges also compounded the problem.

In 2005, data was received from each of the DART buoys soon after the wave arrival and was used to validate the tsunami model predictions. The tsunami warning was cancelled at 04:09 UTC, shortly after the first observed coastal wave heights were obtained at Crescent City, CA (27.7 cm).

The public's perception of the tsunami warning was also much different in 2005 than in 1994. On 5 October 1994, the front page story in the Victoria newspaper showed people standing on the wharf in Port Alberni waiting for the wave to arrive. A tsunami warning now conveys the horrific images of the December 26th tsunami in the Indian Ocean and the news stories following the June 14, 2005 warning included one of an individual driving out of town at high speed to the top of a mountain more than 1000 feet above sea level! Our tools for detecting and predicting tsunamis are steadily improving, but clearly the need for continued community education is as important as ever.

It should be also emphasized that the California tsunami of 15 June 2005, was probably the first tsunami to be "operationally" numerically simulated, and that the results of this simulation were used to predict tsunami wave heights at several coastal locations. Small predicted values were one of the reasons to cancel the tsunami warning. The prototype source model that was used by Vasily Titov for the 2005 California tsunami simulation gave not only reasonable agreement of observed and predicted wave heights, but also the correct signs of the first wave: negative at coastal sites and positive at DART 46405 supporting the assumption that there was down drop on the coastal side of the source and uplift on the ocean side.

EVALUATION OF U.S. RESPONSE RELEASED

A report evaluating the response to the tsunami potential posed on the evening of 14 June along the Western Coast of the United States, has been published by NOAA's NWS in "*Service assessment West Coast Tsunami Warning, June 14, 2005".* The report's Executive Summary reads as follows:

"At 7:51 p.m. Pacific Daylight Time (PDT) on Tuesday, June 14, 2005, a magnitude 7.2 earthquake occurred 85 miles northwest of Eureka, CA. In accordance with NWS policy, the West Coast and Alaska Tsunami Warning Center (WC/ATWC) issued a tsunami warning at 7:56 p.m. PDT. for areas within a two hour wave travel time of the earthquake. This warning area encompassed coastal areas from the California-Mexico Border to the northern tip of Vancouver Island, British Columbia (BC). The earthquake did produce a small tsunami; a 10-15 centimeter wave was recorded at the Crescent City, CA, tide gage. NOAA tide gage data were received at the Tsunami Warning Centers (TWC) at approximately 9:00 p.m. PDT along with deep-ocean Assessment and Reporting of Tsunamis (DART) buoy data indicating a negligible tsunami. After confirmation that a destructive tsunami did not develop, the WC/ATWC cancelled the warning at 9:09 p.m. PDT.

Emergency management officials at all government levels, media, and citizens in affected communities recognized and appreciated the National Weather Service (NWS) warning efforts. The WC/ATWC quickly disseminated the warning on the National Warning System (NAWAS) as it was circulating through NWS communications to the Weather Forecast Offices (WFOs). Coastal communities who had done preparation work for tsunamis utiltized multiple dissemination system to notify people at risk. The warning prompted the successful evacuation of numerous coastal communities and beaches, created a large amount of public interest, and generated national media coverage. However, not all aspects of the warning system functioned properly during this event.

Due to the relative infrequency of tsunami warnings in the U.S. compared to weather-related hazards, the NWS viewed the 14 June event as an opportunity to improve its role in the tsunami warning system. This

California, *continued*

assessment examines NWS operations and services and provides nineteen recommendations for possible improvements. These suggested courses of action address many facets of the tsunami warning system; from the communications systems used to disseminate information to the effectiveness of the content of the warning messages to the public response to the warning itself.

In summary, the assessment team found that improvements are needed to the tsunami warning product suite in order to provide emergency officials, the media, and the public with information they can understand and quickly act upon. In particular, the format, content, and update cycle should be addressed. Also, procedures at NWS offices need to be formalized and routinely practiced to ensure efficient and consistent tsunami warning operations; likewise, public tests of the tsunami warning system paired with increased outreach through TsunamiReady and other awareness programs will lead to a greater level of community and state-level preparedness for this relatively rare hazard. Finally, enhancements to coordination and collaboration throughout the NWS, and with its partners, are possible to better leverage the knowledge and expertise applied to the tsunami warning process and to the information conveyed to the public. Specific recommendations addressing these issues and others are detailed in the following report."

The chronology of events, as listed in the report's Appendix A, has been incorporated into the following timeline provided by George Crawford (*see below*) The full report is available at *http://www.nws.noaa.gov/om/assessments/pdfs/WestCoastTsunamiFinal.pdf*

Timeline of Emergency Managements Response following the 14 June 2005 Northern California Earthquake

Operational entries (blue) *from NOAA's NWS Service assessment "West Coast Tsunami Warning, June 14, 2005," (available at http://www.nws.noaa.gov/om/assessments/pdfs/WestCoastTsunamiFinal.pdf) with Constructive commentary submitted by George Crawford, Earthquake and Tsunami Program Manager, Washington State Emergency Management Division Camp Murray, WA 98430-1522 <1>(253) 512-7067, g.crawford@emd.wa.gov.*

7:51 PM	A magnitude 7.2 earthquake occurred 85 miles northwest of Eureka, CA (41.4° N, 125.6° W). 7.4 Earthquake, offshore of Crescent City, CA
7:54 PM	Duty personnel arrived at WC/ATWC
7:55 PM	Coordination message sent from PTWC to WC/ATWC
7:56 PM	Tsunami warning issued by WC/ATWC for coastal areas form the California-Mexico border to the northern tip of Vancouver Island, B.C. The Tsunami Warning issued by the West Coast/Alaska Tsunami Warning Center (WC/ATWC) was completed within 5 minutes.
	This warning conflicted with a tsunami warning issued by the Pacific Tsunami Warning Center (PTWC) which stated no tsunami was generated. The PTWC message was intended for international warning system participants.
	Information void between the warning and the cancellation. There is a lack of sea level data available to verify event status.
	Corrective Steps: Tide gauge at Crescent City is being upgraded and additional DART buoys being added along Cascadia.
	Present WC/ATWC hourly updates will be changed to 30 minute updates.
7:57 PM	WC/ATWC initiated National Warning System (NAWAS) announcement of warning. Media received the tsunami warning from the Associated Press (AP).
	Confusion about the WC/ATWC message because PTWC sent a message about 8:00PM saying there was no warning in effect.
	Corrective Steps: Because there is confusion about warnings for Washington, Oregon and California not Hawaii and international participants, a public education plan and program will be developed for the media and public on tsunami warnings.

California, *continued*

7:59 PM	Tsunami Information Bulletin issued by PTWC. State Emergency Operating Centers (EOCs) received Tsunami Warning Message via National Warning System (NAWAS)
	Notified affected jurisdictions via State NAWAS
	Stood by, ready to send a Coastal EAS evacuation warning, via State EAS system if requested by local governments. That request was not received
8:02 PM	NAWAS announcement of WC/ATWC warning was completed.
8:06PM	NWS Seattle tried to transmit a Tsunami Warning Message via Emergency Alert System (EAS) but was unsuccessful because of circuit problems between NWS Seattle and USCG Microwave system to Bahokus Peak, Octopus Mountain and Miller Peak, all on the Olympia Peninsula. The EAS warning was transmitted over their working circuit at Capital Peak to the Grays Harbor area. They tried to transmit the EAS warning message only over coastal NOAA transmitter sites.
	Corrective Steps (actions to be taken by NWS-Seattle office)
	Redundant circuits are being sought to the transmitter sites on the Olympic Peninsula.
	Equipment for Remote On-Air Monitoring (POAM) for all NWS Seattle transmitter sites is to be purchased and installed.
	On September 14, 2005 at 10:45 am, an EAS warning test will be conducted in AK, WA, OR, CA, and HI to test communication protocols.
	NWS Seattle will now transmit Tsunami warnings over all transmitter sites in Western Washington, coding the warning for the 14 counties that may be affected.
8:10 PM	Oregon Warning Point announced PTWC Bulletin on NAWAS –"no tsunami warning is in effect." WFO Medford called Oregon Warning Point and corrected them. The California State Office of Emergency Services (OES) sent a message to the County Emergency Operations Centers (EOCs) that said "no tsunami warning was in effect at 8pm". The exact time of the California OES message could not be verified.
	At approximately 8:10 pm, media interview requests and phone calls began flooding into the offices.
8:11 PM	NWS Portland transmitted a tsunami warning with a header for EAS activation the Pacific County that was received by some NOAA Weather Receivers and the tsunami warning was broadcasted by AM/FM and TV broadcast stations. The lack of receipt of EAS message was due to poor signal quality.
	Corrective Steps: NWS-Portland is taking action to fix poor signal quality in lines by end of July 05.
	Clallam County issued an evacuation order for its county via their Local EAS system. Local AM/FM/TV Broadcasters relayed alert, with one station manually relaying due to receiver problems. Quileute and Makah Tribes evacuated.
	Grays Harbor, Jefferson County, and Pacific Counties elected to not send an EAS message and waited to see what happened in Crescent City. Hoh and Quinault Tribes evacuated. Counties reported that most beaches were cleared as well as self-evacuation.
	About 8:40PM, EMD PIO talked to KOMO Radio and to KING TV. The media asked who should evacuate noting that the WC/ATWC message advised people "on the beach" to seek higher ground while people in "low lying areas" were to await instructions from local authorities. EMD advice for homeowners at Ocean Shores and Long Beach was to heed the warning and move to higher ground.
	Corrective Steps: WC/ATWC developing a new public warning message to eliminate confusion. Local, state and federal officials are discussing how to improve the warning notification system for coastal residents and visitors. Improvements discussed included: Additional All Hazard Alert Broadcasting (AHAB) Radio sirens.
	Expanded dissemination of the warnings through NOAA weather radios, Emergency Alert System broadcasts and AHAB Radio siren systems.

California, *continued*

8:15 PM	Predicted time of arrival of possible tsunami at Cape Mendocino, CA. This was the earliest wave arrival prediction.
8:16 PM	NOAA Pacific Marine Enviornmental Laboratory (PMEL) ran experimental forecast. Forecast predicts one centimeter tsunami at DART Station off the Oregon Coast at 8:40 pm.
8:52 PM	WC/ATWC called PTWC to discuss canceling the warning. PTWC provided evaluation of Crescent City tide data.
9:09 PM	Tsunami warning cancelled by WC/ATWC for coastal areas from the California-Mexico Border to the northern tip of Vancouver Island, B.C.
9:11 PM	Washington State EOC received Tsunami Cancellation Message via National Warning System (NAWAS).
9:12 PM	NAWAS issued announcement of WC/ATWC warning cancellation.
9:17 PM	State EOC relays Tsunami Cancellation Message via National Warning System (NAWAS).
9:52 PM	Tsunami cancellation statement is corrected for errors* by WC/ATWC.

NEAR EAST COAST OF HONSHU, JAPAN M_W=7.2, 16 AUGUST 2005, 02:46 UTC

An earthquake measuring 7.2 Mw (HRV) occured east of the Japanese Island of Honshu on 16 August 2005 at 2:46 UTC (Figure 1). The location of the earthquake was calculated to be 38.2º N and 142.1º E, with a depth of 37km. At least 39 people were injured in Miyagi, nine in Iwate, five in Fukushima and three Saitama Prefectures. One building was destroyed at Kazo and one damaged at Sendai. Power outages and landslides occurred in various locations in northern Japan.

A local tsunami was generated with a wave height of 10 cm on the coast of northern Japan (Figures 2,3 and Table next page). Wave heights were recorded at several tide stations along the coast of Honshu, with the largest wave height of 13 cm recorded at Ayukawa in Miyagi Prefecture.

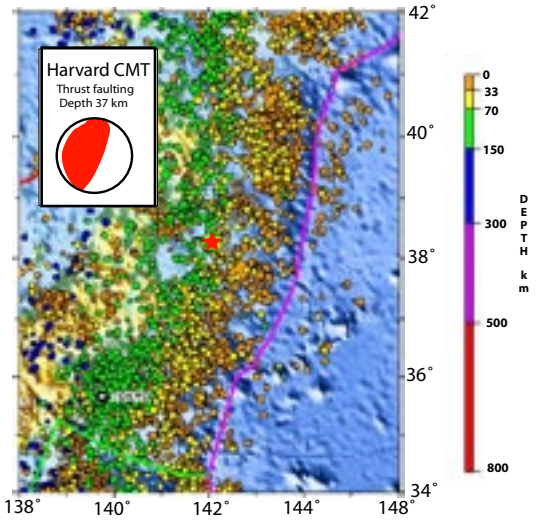


Figure 1. Historical seismicity observed in the region. The epicentre of the 16 August 2005 earthquake is shown by the red star. The purple line indicates the Japan Trench. (Map from NEIC).

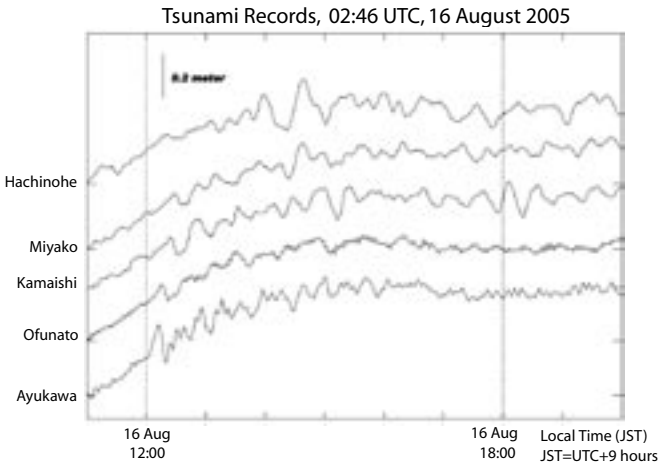


Figure 2. Sea level records recording tsunami. (Data and charts courtesy of JMA).

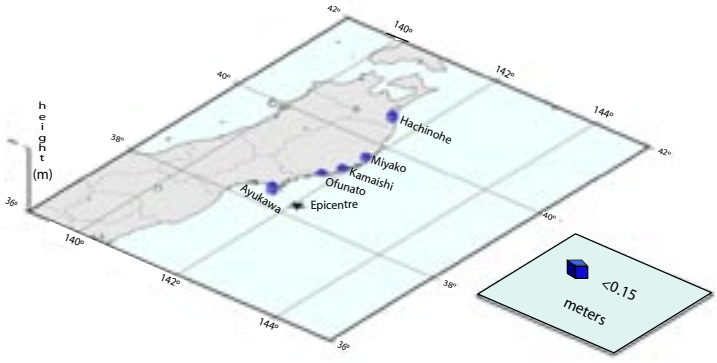


Figure 3. Observed tsunami heights from the 16 August 2005 earthquake as reported by JMA. The map shows the reported run-up heights along the Tohoku Coast. The blue bars indicate maximum wave height of less then 15 cm. above mean sea level.

Off Honshu, *continued*

Tide station name	Latitude	Longitude	Arrival time (JST)	Initial wave height (cm)	Max wave height (cm)
HACHINOHE	40°32’	141°32’	13:06	-5	11
MIYAKO	39°39’	141°59’	12:25	2	7
KAMAISHI	39°16’	141°53’	12:21	2	4
OFUNATO	39°01’	141°45’	12:11	4	5
AYUKAWA	38°18’	141°30’	12:03	13	13

NORTHERN HONSHU, JAPAN M_W=7.0, 14 NOVEMBER 2005, 21:39 UTC

A major earthquake with a magnitude of 7.0 (HRV) occurred at 2138 UTC 14 November, 2005 off the east coast of Honshu, Japan (38.09ºN 144.9ºE) (Figure 1). The earthquake was widely felt in northern and eastern Honshu and Hokkaido. There were no reports of major damage.

A local tsunami was generated with a wave height of 42 cm at Ofunato City. Smaller wave heights were recorded along at other locations along the coast of Honshu. (see figures 2, 3 and table below).

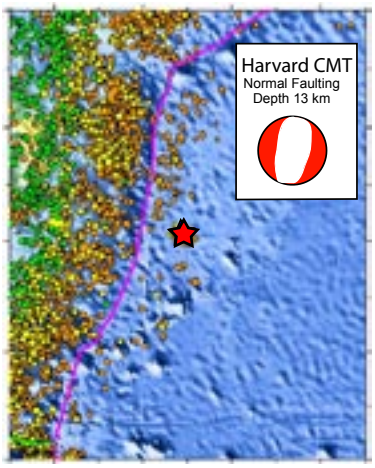


Figure 1. Map of historical seismicity from NEIC. The earthquake (red star).

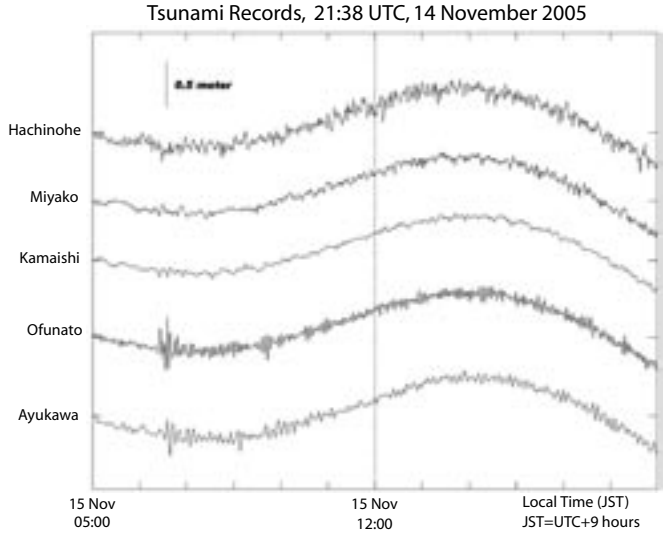


Figure 2. Sea level station records recording tsunami with details listed on the table below. Data and charts coutesty of JMA.

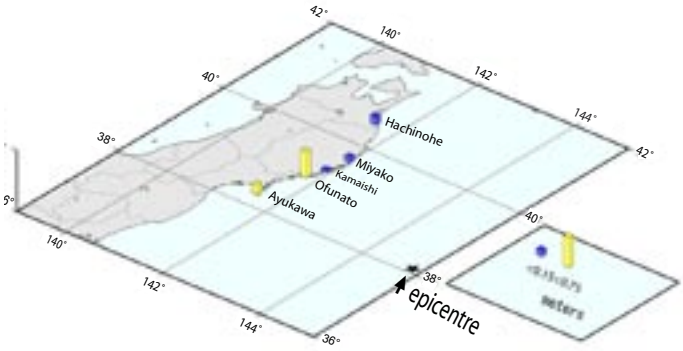


Figure 3. Observed tsunami heights from the 14 November 2005 earthquake as reported by JMA. The blue bars indicate locations where a maximum wave value of less then 15 cm. above mean sea level, while the yellow bars indicate locations where the height was less then 75 cm. above sea level.

Tide station name	Latitude	Longitude	Arrival time (JST)	Initial wave height (cm)	Max wave height (cm)
HACHINOHE	40°32’	141°32’	unknown	unknown	13
MIYAKO	39°39’	141°59’	unknown	unknown	9
KAMAISHI	39°16’	141°53’	unknown	unknown	4
OFUNATO	39°01’	141°45’	7:24	-4	42
AYUKAWA	38°18’	141°30’	7:30	-7	16

OFF NORTHWEST COAST OF NORTH AMERICA, 9 DECEMBER 2005, 1:57 UTC - RISSAGA, METEOROLOGICAL TSUNAMI?

Summarized from Tsunami Bulletin Board postings between 14 and 23 December 2005 based on initial data posting by Dr. Alexander Rabinovich, Institute of Ocean Science (IOS), Sydney, BC, Canada, RabinovichA@pac.dfo-mpo.gc.ca

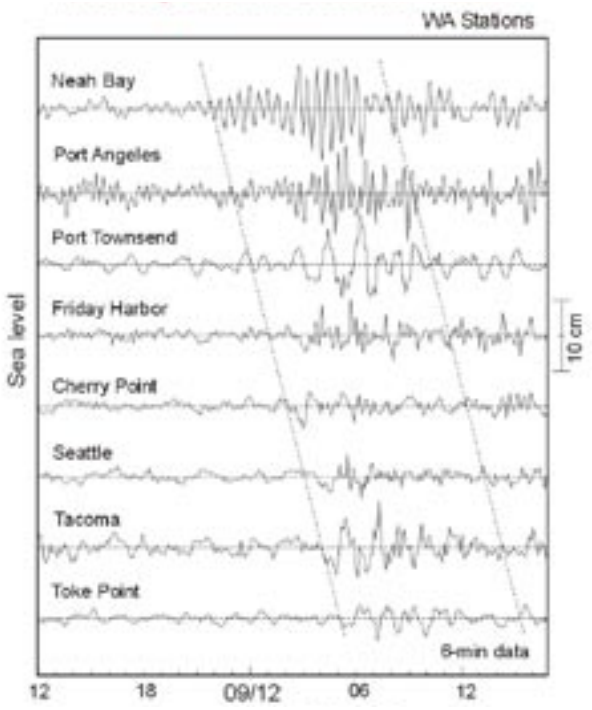
Unusual sea level measurements on 9 December 2005 along the entire coast of British Columbia (from Prince Rupert to Victoria, ~1000 km), and Washington State (from Neah Bay and Tacoma to Toke Point) have been reported to the Tsunami Bulletin Board by Dr. Alexander Rabinovich. No seismic events had occurred that could generate any noticeable tsunami were reported, and therefore the waves are ascribed to be of meteorological or atmospheric origin, and most probably a manifestation of high-frequency irregularities in atmospheric pressure as the weather was calm that day.

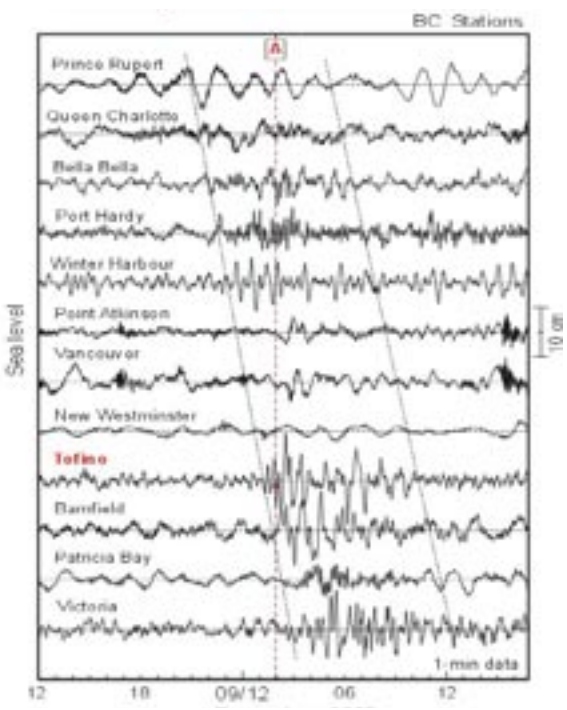
Examination of the sea level records showed that stations on both the open ocean and in the sheltered straits showed noticeable tsunami-like oscillations. In particular, Tofino, Bamfield, Winter Harbour off British Colombia, and Neah Bay and Toke Point in Washington are all located oceanside of the coast and are relatively open to waves arriving from the open ocean. On the other hand, Patricia Bay, Vancouver and Point Atkinson in British Colombia, and Bella Bella (mainland coast of Queen Charlotte Sound), Port Angeles and Port Townsend (Juan de Fuca Straits (JdFS), Friday Harbor (San Juan Island between JdFS and the Strait of Georgia (SG), Cherry Point (SG near US/Canada border), and Seattle and Tacoma (Puget Sound) are all located in areas well-protected from tsunami coming from the open ocean. The wave oscillations continued for approximately 9-12 hours and had mainly irregular (polychromatic) characters with dominant periods of 10 to 60 min. A very clear time shift between oscillations observed at various sites suggests that the disturbance propagated from north to south.

In explaining the phenomenom, it was reported that Dr. Ivica Vilibic and others (*J. Geophys. Res.*, 2004, 109, C10001, doi:10.1029/ 2004JC002279) have recently described destructive tsunami-like waves in the Adriatic Sea that were generated by an abrupt disturbance in atmospheric pressure. Catastrophic "rissaga waves," generated mainly by internal gravity atmospheric waves, are well known for the inlets and bays of the Balearic Islands (e.g., Gomis et al., *J. Geophys. Res.*, 1993, 98, 14437-14445; Garcies et al., *J. Geophys. Res.*, 1996, 101, 6453-6467; Rabinovich and Monserrat, *Nat. Haz.*, 1996, 13, 55-90 and 1998, 18, 27-55).

"Rissaga" is a local Catalan name (in Spanish, *resaca*) for destructive atmospherically-induced seiches that have been observed in some inlets of the Catalan coast of Spain and first of all, in Ciutadella Inlet, Menorca Islands, Baleares. A number of papers have been written describing and analyzing this phenomenon in Ciutadella (e.g., Sebastian Monserrat and Rabinovich, *Natural Hazards*, 1996, 13(1), 55-90; *Natural Hazards*, 1998, 18(1), 27-55; and *GRL*, 1998, 25 (12), 2197-

Meteorological Tsunami of 9 December 2005





British Colombia and Washington tide gauges recording the 9 December event. The signals triggered the automatic tsunami alarm of the Tofino tide gauge (1-min sample interval) which the Institute of Ocean Sciences monitors. The red dashed line with a label "A" marks the time of the automatic alarm that came from Tofino (a red circle marks the corresponding point of the Tofino record). Data courtesy of IOS, Canada and NOAA NOS Water Level Observation Network.

Rissaga, *continued*

2200). Because "rissaga" is probably the best known example of such phenomena, this term became popularly-used to describe similar oscillations in some other parts of the World Ocean. There are, however, many other local names. For example, catstrophic seiches in Nagasaki Bay, Japan are known as "abiki" (e.g., Hibiya and Kajiura, *JOSJ*, 1982, 38 (3), 172-182) or "yota" in other Japan bays, as "marrubbio" on the coast West Sicily, and "milghuba" on the coast of Malta. In New Zealand, Derek Goring reported that ports on the eastern seaboard are often affected by these waves (1 cm in height, 20+ min period), which they are calling rissaga rather than meteorological tsunami. The generation mechanism is thought to be related to Proudman resonance resulting from low-pressure systems propagating rapidly southward from the tropics over the contorted seafloor of the Kermadecs northeast of New Zealand, and to date have caused the grounding of at least one oil tanker.

Dr. Rabinovich further noted that because many local terms are describing the same phenomena, it may be good for the international community to consider adopting a general term independent of geographic location to describe the oscillations. Nomitsu (1935) suggested the term "meteorological tsunami," and Dr. A. Defant has widely used this term his book, "Physical Oceanography" (1961). It was noted that it was important to distinguish very clearly the difference between "meteorologic tsunamis" and storm surges, since the latter have periods from several hours to several days, while the former have the same periods as ordinary tsunami waves (few minutes to two hours). He further noted that tsunami catalogs often contain a number of events described as "probably of meteorological origin."

IOC NEWS

PACIFIC OCEAN: ICG/ITSU-XX, 3-7 October 2006, Viña del Mar, Chile

The Twentieth Session of the International Coordination Group for the Tsunami Warning System in the Pacific was held in Viña del Mar, Chile, 3–7 October 2005 under the Chairmanship of Dr François Schindelé. It was attended by 44 participants from twenty ICG/ITSU Member States, six organizations, and three observers. The Session reviewed progress made during the inter-sessional period 2003–2005 and drafted its work plan for the period 2006-2007. This work plan will focus on (i) continued support for the International Tsunami Information Centre (ITIC); (ii) planning, conduct and assessment of a Pacific-wide Tsunami Warning exercise in May 2006; (iii) support for ICG/ITSU participation in the ICG/IOTWS inter-sessional Working Groups established at ICG/IOTWS-1; (iv) completion and assessment of the Assessment Questionnaire for ICG/ITSU Member States; (v) completion of the Integrated Tsunami Data Base (ITDB); (vi) support for development of the TsunamiTeacher – translations into French and Spanish; and (vii) support for the Working Group on the Central American Pacific Coast Tsunami Warning System (CAPC-TWS). The Group requested a budget of US$ 180,000 for the biennium 2006-2007 to accomplish the work plan; noted that only $64,000 is presently funded, and that Member States will provide approximately $1,290,000 in Extra-budgetary Support. The Group decided to rename the "International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU)" to the "Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS)" to align its name with the other tsunami warning and mitigation systems and their governing bodies established under the auspices of the IOC; to revise the Terms of Reference for the ICG/ITSU to align them with the approaches adopted for other tsunami warning and mitigation systems and accommodate the unique role of the ITIC; to designate that the IOC's ITIC shall assume the role of Secretariat for the ICG/PTWS, that the Director and Associate Director of ITIC also officially hold the titles of the Director and Associate Director of the IOC Secretariat for the ICG/PTWS, and serve as ex-officio office holders of the ICG/PTWS along with the past-Chair of the ICG/PTWS. The Group also decided to form inter-sessional working groups on (i) seismic measurements, data collection and exchange; (ii) sea-level measurements, data collection and exchange; (iii) tsunami hazard identification and characterization, including modelling, prediction and scenario development; (iv) resilience

Above: Participants at ITSU XX included (from left to right); Captain Garnham, Director of SHOA, Mayor Virginia Reginato Bozzo, Alcaldesa de Viña del Mar, Françios Schindelé, outgoing Chair of ITSU, and Peter Pissierssens, IOC Ocean Services Branch, Technical Secretary for the meeting.

IOC news, *continued*

building and emergency management; and (v) interoperability of regional, sub-regional and national Tsunami Warning and Mitigation Systems in the Pacific. The Group further decided to (i) establish an inter-sessional working group on the medium term strategy for the Pacific Tsunami Warning and Mitigation System; (ii) recommend that an end-to-end tsunami exercise be carried out for the Pacific Ocean during the second week of May 2006 and form a task team to design and carry out the exercise; and (iii) recommend GLOSS explore the possibilities of using the international channels of the global Geostationary Meteorology Satellite system and request WMO to allow the use of the GTS to transmit sea-level data from GLOSS multiple purpose sea-level stations to regional, sub-regional and national tsunami warning centres. The Group thanked Dr François Schindelé and Dr Charles McCreery for having served six years in the positions of Chairman and Vice-Chairman of ITSU, respectively. Capt. Rodrigo Nuñez (Chile) and Mr Fred Stephenson (Canada) were elected as Chairman and Vice-Chairman respectively by the Group. The Group decided to organize its Twenty-first Session in 2006, planned for the last week of April and accepted the offer of Australia to host the Twenty-first Session. The Group also recommended that on the occasion of the next election of officers, to elect two Vice-Chairpersons, following the example of ICG/IOTWS.

The next meeting of the ICG will be ICG/PTWS-XXI 1-5 May 2006 in Melbourne, Australia.1-2 May will be reserved for Intersessional Working Group meetings, and 3-5 May will be used to conduct ICG/PTWS-XXI.

The following Resolutions and Recommendations have been extracted from Intergovernmental Oceanographic Commission report: *International Coordination Group for the Tsunami Warning System in the Pacific, Twentieth Session, Viña del Mar, Chile, 3-7 October 2005.* IOC Reports of Governing and Major Subsidiary Bodies. Paris: Unesco; November 2005, The document is available in its entirety from the ITIC website at URL: *http://ioc3.unesco.org/itic/files.php?action=dlfile&fid=378.*

RESOLUTIONS AND RECOMMENDATIONS
RESOLUTION ITSU-XX.1
INTERGOVERNMENTAL COORDINATION GROUP FOR THE PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM (ICG/PTWS)

Recalling that the Tsunami Warning System in the Pacific (ITSU) covers the Pacific Ocean, the Southern Ocean regions of the Pacific and all attached seas, including the Philippine Sea, East China Sea, Yellow Sea, Sea of Okhotsk, Bering Sea, South China Sea, Java Sea, Arafura Sea, Sulawesi Sea, Mindanao Sea, Sulu Sea, Celebes Sea, Bismark Sea, Solomon Sea, Coral Sea, and Tasman Sea,

Reaffirming that the ITSU is a coordinated network of regional, sub-regional and national systems and capacities,

Reaffirming further that Member States should have the responsibility to have control over the issuance of warnings within their respective territories,

Recognising that the timely access to seismic, sea-level and other related data is the key to an effective tsunami warning system,

Recognising that:

(i) the impact of tsunamis can be substantially reduced through institutional and legislative frameworks, as well as community participation, and that this requires tsunami warnings must reach local communities by various means and be understood at all levels, so that people are well informed and motivated towards safety measures and actions,

(ii) Member States build public awareness through education and capacity building to ensure effective community awareness of the risks posed by tsunamis, so that their population is prepared for, and knows how to act in the event of a tsunami warning,

(iii) a role for the ITSU is to promote amongst its members good practice examples of capacity and resilience building, and emergency management to improve the management of tsunami risk through mitigation, preparedness, response and recovery activities,

Stressing that all IOC Member States should make every endeavour to:

(i) exchange seismic, sea-level and other data relevant to tsunamigenic events at or near real-time with interested Member States,

(ii) exchange national assessments and warnings of tsunamigenic events and tsunamis with interested Member States in a timely manner,

Expressing appreciation to the Secretariat of the UN International Strategy for Disaster Reduction (ISDR) for its guidance and support, and to the World Meteorological Organization (WMO) for contributing its infrastructure and technical support,

Noting that the International Tsunami Information Centre (ITIC) was established by the IOC through Resolution IV-6 (1965) and hosted by the United States of America in Honolulu, Hawaii,

Recognising:

(i) the long experience of the ITIC as the primary provider of information and expertise for technology transfer, training and capacity building for the Tsunami Warning System in the Pacific in conjunction with the IOC Secretariat,

(ii) the long experience of the Richard H. Hagemeyer Pacific Tsunami Warning Centre (PTWC) in Hawaii as the primary operational centre for the Tsunami Warning System in the Pacific,

Welcoming the continuing strong support of the United States of America for the operation of the PTWC and ITIC,

IOC news, *continued*

Decides:

(i) to rename the "International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU)" to the "Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS)" to align its name with the other tsunami warning and mitigation systems and their governing bodies established under the auspices of the IOC;

(ii) to revise the Terms of Reference for the ICG/ITSU to align them with the approaches adopted for other tsunami warning and mitigation systems, and to accommodate the unique role of the ITIC, as established in Resolution IV-6 (1965), and elaborated in Resolution X-23 (1977) and Resolution EC-XXI.4 (1988), and as detailed in Annex to this Resolution;

(iii) that the IOC shall provide the Secretariat of the ICG/PTWS;

(iv) that the IOC's ITIC shall assume the role of Secretariat for the ICG/PTWS, with the Terms of Reference as detailed in Annex to this Resolution;

(v) that the Director and Associate Director of ITIC also officially hold the titles of the Director and Associate Director of the IOC Secretariat for the ICG/PTWS, and serve as ex-officio office holders of the ICG/PTWS;

(vi) that ITIC continue to act as the primary provider of information and expertise for technology transfer, training and capacity building;

Agrees that ITIC shall provide advice and support on request to the members of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System", the "Intergovernmental Coordination Group for Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions" and the "Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connecting Seas" and other countries and regional organisations desiring assistance;

Agrees that:

(i) the "Richard H. Hagemeyer Pacific Tsunami Warning Centre (PTWC)" in Hawaii continue to act as the primary operational centre for the PTWS, noting that there are a number of other tsunami warning and mitigation capabilities in the Pacific;

(ii) the Director of the PTWC continue to serve as an ex-officio office holder of the ICG/PTWS;

Agrees further that, to facilitate durability, the Pacific Tsunami Warning and Mitigation System should utilize or build on, where possible, existing organizations and institutions and complement existing warning frameworks, and within a multi-hazard approach where appropriate;

Requests to the ad hoc IOC "Working Group to prepare a framework for a global tsunami and other ocean-related hazards early warning system" that it considers how the word "ITSU" might be applied as a brand name for global tsunami warning and mitigation related activities;

Decides that the ITIC will report on its activities, including on those in its role as the IOC Secretariat for the ICG/PTWS, at each session of the ICG/PTWS;

Invites IOC Member States, including Member States of the PTWS, to encourage countries in the Pacific that are not already participating in the PTWS, to join the IOC and PTWS, and that in doing so, members should clarify to them the benefits that accrue from membership of the PTWS, which does not require any set annual financial contribution;

Requests that the IOC Secretariat in Paris promote interoperability amongst all tsunami warning and mitigation systems;

Requests that tsunami warning and mitigation activities undertaken by the IOC, WMO, ISDR and others be appropriately consistent.

Financial implications: none

Annex to Resolution ITSU-XX.1

Terms of Reference of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS)

The ICG will be a subsidiary body of the IOC and will report to, and seek guidance from, the IOC Assembly.

Objectives:

To coordinate the activities of the PTWS;

1. To organize and facilitate as appropriate the exchange of seismic, sea-level and other data at or near real-time and information required for the interoperability of the PTWS;
2. To promote the sharing of experience and expertise related to tsunami warning and mitigation for the Pacific basin;
3. To promote tsunami research;
4. To promote the establishment and further development of national tsunami warning and mitigation capacities in accordance with standard protocols and methods;
5. To develop, adopt and monitor implementation of work plans of the PTWS, and to identify required resources;
6. To promote implementation of relevant capacity-building, resilience building and emergency management, including high levels of public awareness;
7. To liaise and coordinate with other tsunami warning systems;
8. To liaise with other relevant organizations, programmes and projects;
9. To promote the implementation of the PTWS within a multi-hazard framework;
10. To develop and promote best practices in tsunami warning;
11. To keep under constant scrutiny the status of the system and how it satisfies the needs.

The IOC Secretariat for the ICG/PTWS shall:

1. Support the IOC in the coordination of work of the ICG;
2. Facilitate the liaison among the various contact points and tsunami warning centres;
3. Maintain a current list of operational contact points and facilities for the PTWS and make it available on request to all Member States;
4. Maintain a list of those countries that are members of ITSU and a list of those countries that are not mem-

IOC news, *continued*

bers, and make this available on the ITSU website.

5. Organize the liaison between ICG/PTWS and the ICG for other Oceans and Seas to facilitate best practices in tsunami warning;
6. Initiate and support training activities to enhance and enrich tsunami warning in the Pacific.

Membership of the ICG/PTWS:

- Member States of the IOC within and bordering the Pacific Ocean;
- Observers from other IOC Member States.

Invited observers from other organizations (including NGOs), programmes and projects, in accordance with the IOC rules and procedures.

Officers of the ICG/PTWS:

- A Chair and two Vice-Chairs, who will be elected in accordance with the Statutes and Rules of Procedure of the IOC,
- Past Chair,
- Director of the PTWC,
- Director and Associate Director of the IOC Secretariat for the ICG/PTWS.

Resolution ITSU-XX.2

INTER-SESSIONAL WORKING GROUP ON THE MEDIUM TERM STRATEGY FOR THE PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM

The International Coordination Group for the Tsunami Warning System in the Pacific,

Recalling the devastating impact of the Indian Ocean tsunami of 26 December 2004,

Stressing the need for the UN agencies and other partners to work together, reinforcing each other's core areas of expertise,

Noting with appreciation the excellent collaboration between IOC, WMO & ISDR in the establishment of the Indian Ocean tsunami warning and mitigation system,

Recognizing the new context of an end-to-end framework and taking into consideration the need to further develop and maintain national systems in a multi-hazard context,

Decides to establish an inter-sessional working group for the development of a medium-term strategy for the Pacific tsunami warning and mitigation system;

Decides that the Group will be composed of Australia, Canada, Japan and New Zealand and will be chaired by Australia. Other members may be added at the discretion of the Group's Chair;

Decides further that the Group will work by e-mail correspondence;

Requests the Group to take into consideration:

(i) the work of the inter-sessional working groups on seismic measurements, data collection and exchange; sea-level measurements, data collection and exchange; tsunami hazard identification and characterization; resilience building and emergency management; and interoperability of regional, sub-regional and national tsunami warning systems in the Pacific, established by the ICG/PTWS and other ICGs, as well as any cross-cutting matters between the ICGs;

(ii) the ITSU Master Plan;

(iii) capacity building requirements of new and existing Member States of the Pacific Tsunami Warning and Mitigation System, as revealed by relevant assessments or as indicated by the Member States;

Instructs the Group to submit to the Twenty-first Session of the ICG/PTWS, a draft of the medium-term strategy for the Pacific Tsunami Warning and Mitigation System.

Financial implications: none.

Recommendation ITSU-XX.1

ESTABLISHMENT OF ICG/PTWS INTER-SESSIONAL WORKING GROUPS

The International Coordination Group for the Tsunami Warning System in the Pacific,

Noting the devastating impact of the Indian Ocean tsunami of 26 December 2004 that highlighted the benefits of effective and durable tsunami warning systems,

Recognizing the desirability of continuously reviewing the effective and durable operation of the PTWS,

Decides to establish the following inter-sessional working groups with terms of reference as defined in Annex to this Resolution:

1. Working Group One on Seismic Measurements, Data Collection and Exchange;
2. Working Group Two on Sea-level Measurements, Data Collection and Exchange;
3. Working Group Three on Tsunami Hazard Identification and Characterization, including Modelling, Prediction and Scenario Development;
4. Working Group Four on Resilience Building and Emergency Management;
5. Working Group Five on Interoperability of Regional, Sub-regional and National Tsunami Warning Systems in the Pacific;

Decides further that membership of the working groups shall be open to all IOC Member States and invited organizations, and shall be convened by chairs nominated by the ICG/PTWS;

Instructs the inter-sessional working groups to liaise, as appropriate, with similar inter-sessional working groups established by the ICG/IOTWS and other regional tsunami warning and mitigation systems;

Instructs the inter-sessional working groups to report and provide recommendations for further action to the next Session of the ICG/PTWS.

Annex to Recommendation ITSU-XX.1

TERMS OF REFERENCE FOR THE ICG/PTWS INTER-SESSIONAL WORKING GROUPS

Working Group One on Seismic Measurements, Data Collection & Exchange

Objectives:

1. To review and report on existing arrangements with

IOC news, *continued*

regard to seismic measurements, data collection and exchange;
2. To advise on how best to ensure that all earthquakes of magnitude 6 or greater can be reliably located and sized in a timely manner;
3. To review and make recommendations regarding upgrading and enhancements to the PTWS network, communications, processing and analysis to further reduce the time required for earthquake source characterization to meet desired warning responses.

Chair: USA

Working Group Two on Sea-level Measurements, Data Collection and Exchange

Objectives:

1. To review and report on existing arrangements with regard to sea-level data collection and exchange;
2. To liaise with CBS/WMO/JCOMM and relevant Expert Teams to develop a more effective data representation and code form for exchange of sea-level data and to conduct test of latency (timeliness) of GTS transmissions;
3. To consider desirable additional sites enhancement;
4. To coordinate plans for sea-level observing sensitivity tests to understand the optimal, effective PTWS sea-level network;
5. To review and report on various means of transmitting sea-level data to warning centres.

Chair: Australia

Working Group Three on Tsunami Hazard Identification & Characterization

Objectives:

1. To review and report on existing arrangements with regard to tsunami hazard identification and characterization;
2. To advise on credible seismic scenarios that need to be captured for numerical tsunami modelling e.g., location, magnitude, rupture, orientation, dip, and probability of occurrence;
3. To review details on models that are currently used or in development;
4. To review desirable documentation (inputs, outputs etc.);
5. To explore cooperation regarding coastal inundation models;
6. To review as appropriate requirements for bathymetry;
7. To develop guidance on mandatory metadata including detail of bathymetry, hydrography & topography;
8. To consider the issue of assessing hazard, vulnerability and risk, including the facilitation of access to models.

Chair: France

Working Group Four on Resilience Building & Emergency Management

Objectives:

To promote good practice examples of capacity and resilience building and emergency management to improve the management of tsunami risk through mitigation, preparedness, response and recovery activities. Such measures include the following:

a. Mitigation: land use planning, building standards, engineering and non-structural counter-measures.
b. Preparedness: capacity assessments, public education, training, response and evacuation planning and exercising.
c. Response: effective forecasting and early warning systems coupled with sound communications systems.
d. Recovery: infrastructure and socio-economic recovery plans supported by adequate financial and logistical resources.
e. Public awareness.

Chair: Canada

Working Group Five on Interoperability of Regional, Sub-regional and National Tsunami Warning Systems in the Pacific

Objectives:

To coordinate the development and operational implementation of warning systems in the Pacific, through:

a. advice on the modalities of operation, methods and standards for the development and issuance of warnings, and requirements in terms of coordination and operating within a multi-hazard approach,
b. advice on arrangements for redundancy and back-up arrangements,
c. support the update of the PTWS Communications Plan.

Chair: USA

INDIAN OCEAN: ICG/IOTWS-II, Hyderabad, India, 14-16 December 2005

The Second Meeting of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) took place in Hyderabad, India from 14–16 December 2005.

The Meeting was attended by 110 participants, 20 countries, and eight organizations, and chaired by Dr. P.S. Goel, Secretary to the Government of India, Department of Ocean Development. The goal of the meeting was to assess the technical progress for the implementation of the tsunami warning system taking place through the intersessional working groups, to report on and discuss the results of the IOC-lead National Assessments for the identification of necessary regional, sub-regional, and national capacity building requirements and support needs, and to set an action and implementation plan for the operationalising of the system in the region. Presently there are 26 of the 28 Member States have designated Tsunami Focal Points at 7/24 operational centres in the Indian Ocean region that will receive and act on tsunami advisory message on a 7x24 basis. With the deployment of several deep-sea pressure sensors, upgrading of the GLOSS sea-

IOC news, *continued*

level network, enhancements to the seismic monitoring network, enabling of satellite-based real-time data transmission and development of several centres capable of interpreting the data and issuing warnings, there will be an improved system in operation to detect and confirm the generation of tsunamis in the Indian Ocean region by June/July 2006.

During the meeting, Australia, Indonesia, India, Malaysia, France, Madagascar, and Thailand made reports on their national activities to put in place warning systems. Additionally, the WMO, ISDR, United Nations University, and Asian Disaster Preparedness Center made presentations. ICG/PTWS Vice-Chair Fred Stephenson provided a report on the activities of the Pacific, including the announcement of a Pacific-wide drill in May 2006 for which he invited Member States such as Malaysia, Singapore, and Indonesia to actively participate, and the request from Member States to Japan to expand the services provided for the Northwest Pacific Tsunami Advisory Center to the South China Sea as soon as possible in close cooperation with the PTWC.

The ITIC Director made a report on alert services, products and materials that are available for IOC Member States, including the availability of open-source tools to provide information and graphical output on GLOSS sea level data and stations and ITIC involvement in web-based tsunami data preservation from the 26 December 2004 tsunami in cooperation with the San Diego Supercomputer and Oregon State University.

Finally, Dr. Kong provided a summary of the National Assessments of 16 countries during 2005 led by the IOC in close cooperation with the ISDR, WMO, and IFRC (*see proceeding article*).

During the Intersession, Working Groups for Seismology (10-11 November 2005, Jakarta, Indonesia), Interoperable Advisory and Warning Centres (24 November 2005, Singapore), and Modelling, Forecasting and Scenario Development (10-12 December 2005, Hyderabad, India) met and made reports to the Plenary on their progress.

Sessional Working Groups then met to identify priorities for action during the next six months, especially to identify gaps in establishing an end-to-end IOTWS, consider the Consolidated National Assessment Report (IOC/INF-1219), and provide guidance to assist with drafting an implementation plan for the IOTWS. These activities were reported out as actions agreed by each working group as follows:

WG-1 (Seismic Measurements, Data Collection & Exchange)

- *Mwp software for fast magnitude estimation to be distributed to members;*
- *Agreement on a proposed core network of seismic field stations to monitor regional seismicity, & sharing of data;*
- *Germany (GFZ) and other potential donors to assist with new and upgrading existing seismic stations in East Africa as a high priority; and*
- *Training for seismological observatories practice to be undertaken as a high priority.*

Indonesia and Australia and the USA are active members of the ICG/IOTWS Working Group on Seimsic Measurements, Data Collection and Exchange (WG-1). From left to right, Masahiro Yamamoto (IOC), Dr. Fauzi (Indonesia), Dr. Walter Mooney (USA), Dr. Laura Kong (IOC), Dr. Joachim Saul (Germany), and Dr. Alexei Gorbatov (Australia).

WG-2 (Sea Level Data Collection & Exchange, including Deep Ocean Tsunami Detection Instruments)

- *Members consider content of the terms of reference for an International Tsunameter Partnership, and agree to hold an intersessional meeting in Melbourne, April 2006 (TBD) ;*
- *Performance standards to be developed for both coastal sea level instruments and deep-ocean stations, and;*
- *Further consideration of core coastal and deep ocean networks.*

WG-3 (Risk Assessment Working Group)

- *Case studies to be undertaken in four member nations to form benchmarks for capacity building initiatives;*
- *Risk assessment methodology and guidelines to be developed for use by all member nations;*
- *Mitigation and decision support methodology initiatives to be undertaken for benefit of stakeholders; and*
- *A series of workshops to be undertaken to facilitate knowledge transfer and information sharing.*

WG-4 (Modelling, Forecasting & Scenario Development)

- *Develop inundation maps for the coastal communities of the Indian Ocean region;*
- *Develop a web-based community model, and;*
- *Implement model standards and scenarios, and make model benchmarks available on the IOC website.*

WG-5 (A System for Interoperable Advisory & Warning Centres)

- *Agree upon a two-tiered interoperable system of Regional Tsunami Watch Providers and National Tsunami Warning Centres;*

IOC news, *continued*

- *Develop an accreditation process whereby the IOC designates a potential RTWP as being capable of performing the role, and;*
- *Adopt English as the common language for regional advisory messages.*

WG-6 (Mitigation, Preparedness and Response)--Proposed

A side meeting was organized led by the ISDR and Australian AID to discuss the ways to integrate the activities developing ICG-coordinated tsunami warning systems into disaster management and national development processes. Key issues noted by the group included legal/institutional foundations, community capacities, public awareness, education, mitigation, and emergency management. The Group recommended the creation of a 6th Working Group to support national efforts to make effective use of tsunami warnings through improved mitigation, preparedness and response to warnings, by means of:

- *Promoting the identification, dissemination and application of good practice information relevant to mainstreaming tsunami warning systems into development planning and practice, including policy and institutional development, project identification, sector policies, risk mitigation, and recovery processes.*
- *Promoting and supporting the engagement of national tsunami centres and experts in national platforms for disaster risk reduction, all-hazard integration processes, and national disaster management processes.*
- *Supporting the provision of guidelines, tools and best practice information for the disaster management sector, concerning inter alia public information, education, training, communication processes, evacuation planning and drills, and emergency management.*
- *Assisting in communicating the results of other ICG working groups to the development and disaster management communities and vice versa communicating the needs of these communities to the other working groups.*

In this manner, it was envisioned that participation of disaster management organizations in the ICG would be encouraged and bring about national and regional cooperation for the development of the end-to-end warning and mitigation system.

The Group also agreed that an overall strategy document would be valuable to countries, donors and implementing organisations and that the initial ISDR draft strategy should be further developed and be consistent with the core system implementation plan being developed by IOC and with the terms of reference of the proposed Working Group on Preparedness and Response. The ISDR secretariat will be working with the IOC secretariat to further develop the strategy.

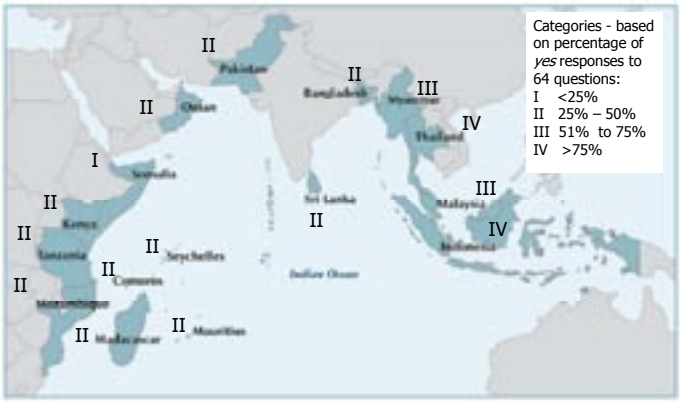
The group summary reports are available at *http://ioc3.unesco.org/indotsunami/hyderabad/wgreports.htm.*

INDIAN OCEAN COUNTRY ASSESSMENTS

Between May and September 2005, national assessments of 16 countries in the Indian Ocean were conducted to identify capacity building needs and support requirements for developing an Indian Ocean tsunami warning system. Five countries; India, Iran, Maldives, South Africa and Yemen also are requesting missions and these will be carried out in 2006. National assessments were conducted by international teams of experts working together with local experts. Three-day missions were conducted to complete a questionnaire covering various aspects of tsunami mitigation. Mission teams were composed of experts from UNESCO-IOC, United Nations International Strategy for Disaster Reduction/ Platform for the Promotion of Early Warning (UN-ISDR/ PPEW), World Meteorological Organization (WMO), and the Asian Disaster Reduction Center (ADRC). Subject matter experts from Australia, China, France, Finland, Japan, and the United States of America (USA) were also involved. Country teams that participated in the mission discussions included national experts from academic institutions, government agencies, and non-governmental organizations from each participating country.

An overall regional summary indicates:

- *Most countries have established or strengthened their disaster management laws, national platforms, and national and local coordination mechanisms to guide all-hazard disaster risk reduction and to establish clearer responsibilities for end-to-end early warning system. Not all have specifically addressed the tsunami coordination aspect.*
- *All participating countries receive international tsunami warnings from the Pacific Tsunami Warning Center (PTWC) and the Japan Meteorological*



The countries in the Indian Ocean Region submitting assessment reports to the IOC shown in blue. Categories of response from I to IV, based on the questionairre results, with IV category having the highest number of yes responses (greater than 75%).

IOC news, *continued*

Agency (JMA) except Somalia, and most countries receive these warnings at facilities with back-up systems for receiving warning messages that operate 24 hours a day, 7 days a week. Few countries operate a national tsunami warning centre or have the capacity to receive or provide real-time seismic or sea level data.

- *Few participating countries have developed tsunami emergency and evacuation plans with signage or tested response procedures for tsunamis or earthquakes. Much of the groundwork needed to develop these plans, such as post-event surveys, inundation modeling, and tsunami hazard and vulnerability assessments, has yet to be completed.*
- *Many participating countries have assessed local government capacity for disaster preparedness and emergency response but not community preparedness. Community education and outreach programmes are being developed but are largely not in place in most participating countries.*
- *Most countries have made progress developing policies, assessing technological needs, and establishing coordination mechanisms at a national level for tsunami warning and mitigation. Local planning and preparedness activities are being carried out first in selected target areas, or cities and towns, rather than as comprehensive national programmes.*

The national assessment missions provided an opportunity to define the components and implementation actions of tsunami early warning and mitigation systems and to identify related capacity building opportunities, and the Report provides a summary of the types of guidance documents and capacity building activities that will help to catalyze national actions.

The Consolidated report is based on the results of Expert Missions funded through the UN/OCHA project, Evaluation and strengthening of early warning systems in countries affected by the 26 December 2004 Tsunami in South East and South Asia submitted by UNESCO-IOC and UN-ISDR (TSU-REG-05/CS06-REGION), with additional support by the United States Agency for International Development (USAID). It was prepared by the UNESCO-IOC, UN-ISDR/PPEW, and WMO, with assistance from IRG-Tetra Tech JV under the U.S. Indian Ocean Tsunami Warning System Program (USAID Contract Task Order EPP-I-02-04-00024-00). Copies of the consolidated report, in pdf format, along with copies of individual country reports, can be found at *http://ioc3.unesco.org/indotsunami/*.

NORTH EASTERN ATLANTIC AND MEDITERRANEAN: ICG/NEAMTWS-I, Rome, Italy, 21-22 November 2005

The First Session of the Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and connected Seas (ICG/NEAMTWS), established by the IOC Assembly during its 23rd Session in June 2005, through Resolution XXIII.14, took place in Rome, 21-22 November, 2005, at Palazzo Taverna.

The Meeting, kindly hosted by the Government of Italy (Italian Ministry of Foreign Affairs and Ministry for Environment and Protection of the Territory), was attended by more than 150 participants from 24 countries, 13 organizations and numerous observers.

National and regional cases and reports from international organizations were presented on the development of a tsunami and multi-hazard regional early warning system and provided the basis for working group discussions on the establishment of such a system in the North Eastern Atlantic, the Mediterranean and connected seas.

The Tsunami Warning System will integrate existing seismographic detection networks with real-time sea-level networks to be upgraded from existing ones. Several national and local warning systems under development will be fully integrated into this initiative. Nations committed themselves to work towards upgrading legislation and existing detection systems, and to develop integrated national emergency preparedness and awareness plans.

The Session nominated Italy as Chair of the Intergovernmental Coordination Group, position that will be served by Prof. Stefano Tinti, University of Bologna, for two years assisted by two Co-chairs, Morocco and Greece, positions that will be served by Dr. Azelbarab El Mouraouah, Coordinator, Centre Euro-Méditerranéen pour l'Evaluation et la Prévention du Risque Sismique - CEPRIS of Rabat, and Dr. Gerassimos Papadopoulos, National Observatory of Athens.

During the intersessional period four working groups will address issues concerning the formulation and operationalization for a multi-hazard early warning system:

1. Hazard assessment, risk and modeling
2. Seismic and geophysical measurements
3. Sea level measurements
4. Advisory, mitigation and public awareness

The ICG will work towards the formulation of a complete plan of action by December 2006, including the implementation of trials for key components of the early warning system with the aim of having an initial operational system in place by December 2007.

The next session of the ICG/NEAMTWS where a revision of progress in these tasks will take place is scheduled for May 2006. Visit *http://ioc3.unesco.org/neamtws/* for more on this meeting.

ITIC-PTWC NEWS

NEW NATIONAL CONTACT FOR CHILE

The new ICG/PTWS National Contact for Chile is Captain Jorge L. Ibarra, Director of Servicio Hidrografico y Oceanografico de la Armada (SHOA). He replaces Captain Roberto Garham as Director of SHOA. His contact information is:

Mailing address: Errazuriz 232 Playa Ancha
Valparaiso, CHILE
Email: jibarra@shoa.cl
Phone number: (56) 32 - 266555
Fax number: (56) 32 - 266542

CEA visitors with the ITIC Director at Honolulu Harbor.

CHINA EARTHQUAKE ADMINISTRATION VISITS ITIC & PTWC

Nine members of the China Earthquake Administration (CEA), headquartered in Beijing, visited ITIC and PTWC during the last week of November. The delegation was headed by Mr. Yue Mingsheng, Deputy Director-General, CEA. The delegation was interested in the mission and operations of a Tsunami Warning Centre. Both PTWC and ITIC provided orientation briefings and tours for the delegation.

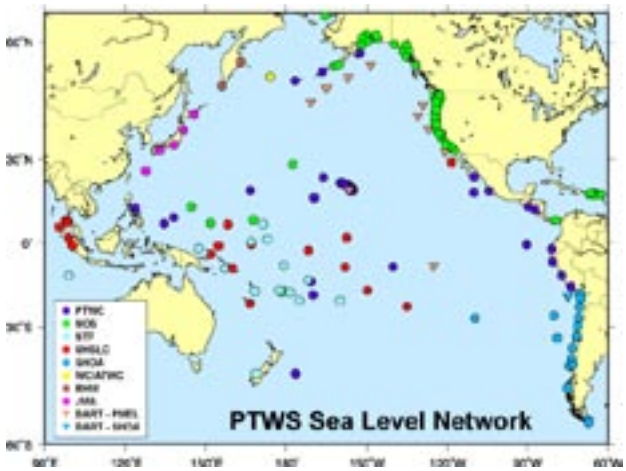
ITIC PRODUCTS

Recent educational materials, produced by the ITIC, have included a tsunami safety poster template (*right*) that countries can use to translate and customize the materials to meet their needs. A Singhalese version of the poster has been developed (*left*). URL: *http://ioc3.unesco.org/itic/contents.php?id=327*.

PTWC INFORMATION SHARING IN 2005

During 2005, scientists at NOAA's Pacific Tsunami Warning Center provided over 500 interviews to international and U.S. news media, participated in 10 film documentaries, hosted 35 briefings and tours, and made over 20 presentations at public events and scientific meetings. Visitors to the warning center included more than 200 government officials and scientists from over 35 countries including the following: Malaysia, Singapore, Thailand, India, Australia, New Zealand, Japan, Peoples Republic of China, Nepal, Pakistan, Brunei, Indonesia, Sri Lanka, Bangladesh, Russia, Switzerland, France, Mexico, Sweden, Taiwan, Philippines, Maldives, Vietnam, Iran, Kenya, Madagascar, Mauritius, Mozambigue, Myanmar, Oman, Reunion, Seychelles, Somalia, Tanzania, Germany, and Comoros. The PTWC also hosted tours of their facilities for over 200 government officials from the Pacific and Indian Ocean through the US Asia Pacific All Hazards Workshop in June 2005, and the IOC-ISDR Hawaii Study Tour in July, 2005.

Seismic network used by the PTWC to locate earthquakes in the Pacific and Indian Ocean, and Caribbean region.



Sea Level network used by the PTWC to monitor sea levels in the Pacific. Currently, sea level networks in the Indian Ocean and Caribbean are being upgraded to transmit more frequently at a higher sampling rate to permit tsunami monitoring.

ITIC-PTWC news, *continued*

PUBLICATIONS RECEIVED BY ITIC

Atwater, Brian F.; Musumi-Rokkaku, Satoko; Satake, Kenji; Tsuji, Yoshinobu; Ueda, Kazue, and Yamaguchi, David K., 2005, The Orphan tsunami of 1700: Japanese clues to a parent earthquake in North America. Seattle WA: University of Washington Press; USGS Professional Paper 1707. URL: *http://pubs.usgs.gov/pp/pp1707*.

Choi, Byung Ho and Imamura, Fumihiko*, editors. Sumatra Tsunami on 26th December 2004 : Proceedings of the Special Asia Tsunami Session at APAC 2005 (3rd International Conference on Asian and Pacific Coasts).* Seoul, Korea: Hanrimwon Publishing Co.; 2005.

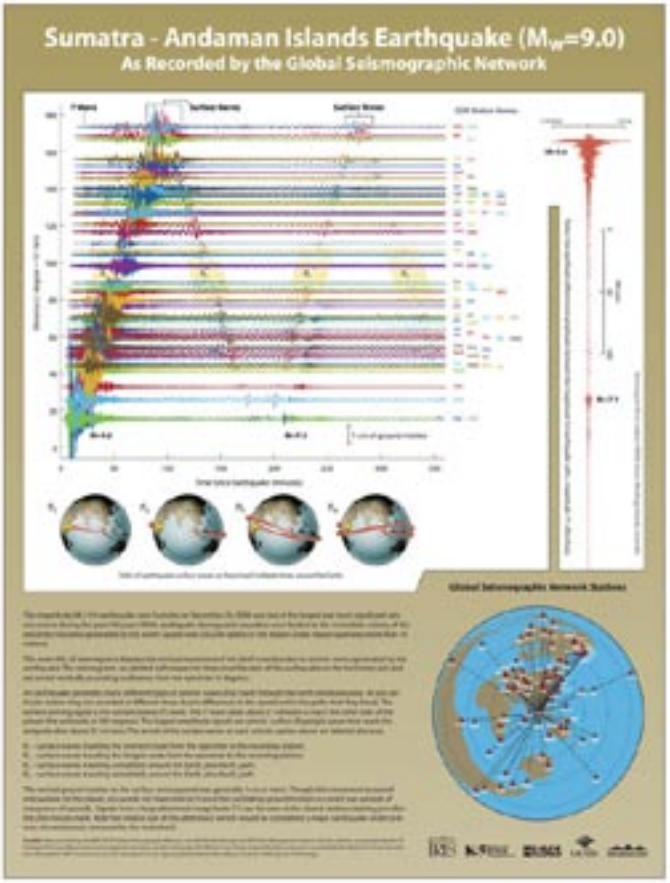
Choi, Byung Ho; Suh, Kyung Duck, and Yoon, Sung Bum*, editors. Asian and Pacific Coasts 2005 : Proceedings of the 3rd International Conference on Asian and Pacific Coasts.* Seoul, Korea: Hanrimwon Publishing Co.; 2005.

Garcia, Marco, photographer. *Hope for Renewal: Photographs from Indonesia after the Tsunami.* Honolulu: East-West Center; 2005.

Mader, Charles L. *12/26/2004 Tsunami-NMWW Powerpoints*. (A CD of event related footage, as well as chapter notes, graphics, and accompanying code for numerical models as found in the 2nd edition of *Numerical Modeling of Water Waves* by Charles L. Mader, Boca Raton, FL: CRC Press, 2004.)

Papadopoulos, G. A. and Katake, K., editors. *Proceedings of the 22nd International Tsunami Symposium.* National Observatory of Athens and International Union of Geodesy and Geophysics (IUGG). Queensland: IUGG; 2005.

Wiegel, Robert L. *Tsunami Information Sources,* Berkley: Hydraulic Enginerring Laboratory, University of California, December 2005.



ITIC recently distributed this poster from the Incorporated Research Institutions for Seismology (IRIS) at the ICG/IOTWS-II meeting in December 2005. The record section shows seismograms from stations around the globe of the 26 December 2004 earthquake. Copies are still available from the ITIC office, otherwise, the poster can be obtained directly from IRIS at http://www.iris.edu/about/publications.htm.

The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America, a report by Brian Atwater and others, was recently published jointly by the University of Washington and the US Geological Survey. It is available in full-text at http://pubs.usgs.gov/pp/pp1707.

OTHER PUBLICATIONS AVAILABLE FOR DOWNLOAD ON THE INTERNET:

ISDR Biblio 1 -- Tsunamis : Selected bibliography on Tsunamis. Geneva Switzerland: UN International Strategy for Disaster Reduction (ISDR). September 2005, 28 p. URL: *http://www.unisdr.org/eng/library/biblio/isdr-%20biblio-1-tsunami-09-2005.pdf.*

Government of Tamil Nadu, Revenue Administration, Disaster Management & Mitigation Department. *Guidelines for reconstruction of houses affected by tsunami in Tamil Nadu.* Government of Tamil Nadu; [2005]. URL: *http://www.undp.org.in/dmweb/Tsunami/default.htm*.

Nakai, Tsunezuo; Hearn, Lafcadio, and Koizumi, Yokumo. *Inamura no Hi (Fire in the Haystacks): A picture story about tsunamis.* Hirosaki University, Department of Earth and Environmental Sciences. 14 pages. English or Japanese. URL: *http://www.st.hirosaki-u.ac.jp/~tamao/Images/Fireofrice/Ina1.html*.

WORKSHOP AND MEETING SUMMARIES

IUGG-TC / ICG/ITSU INTERNATIONAL WORKSHOP ON TSUNAMI HAZARD MITIGATION AND RISK ASSESSMENT, Santiago, Chile, 29-30 September 2005

The Workshop, Tsunami Hazard Mitigation and Risk Assessment, jointly convened by the IUGG Tsunami Commission and the International Coordination Group of the Tsunami Warning System for the Pacific (ICG/ITSU), and ONEMI, was held in Santiago, Chile on 29 and 30 September 2005. Twenty papers were presented, ranging from overviews of local and regional vulnerability to tsunami to the case studies of several largest tsunamis in the Pacific and the Indian oceans.

Thirty registrants from 11 countries (Chile, Peru, Nicaragua, USA, Canada, Russia, Japan, Fiji, Samoa, New Zealand, France) attended the Workshop, many of the international delegates also attending the ICG/ITSU-XX Session to be held in Valparaiso, Chile from 3 to 7 October 2005.

The workshop concluded with the following recommendations:

1. *Lessons learned from the 2004 Sumatra tsunami show that the following actions should be undertaken:*
   - *(a) improvement and standardization of sea level network,*
   - *(b) free and open real time data exchange on tsunami,*
   - *(c) IO and AO TWSs should be built based on experience gained in 40-year operation of the Pacific TWS,*
   - *(d) better documenting of coastal effect of recent large tsunamis,*

Left to Right: Row 1: Masahiro Yamamoto (IOC), Emilio Lorca (IOC ITIC Associate Director), Peter Pissierssens (IOC), Captain Roberto Garnham (Chile), Laura Kong (IOC ITIC Director), Francois Schindele (ITSU Chair), Charles McCreery (ITSU Vice-Chair, PTWC Director). Row 2: Ray Canterford (Australia), Noritake Nishide (Japan), Rick Bailey (Australia), Fred Stephenson (Canada, incoming ITSU Vice-Chair), Tatiana Ivelskaya (Russia), Alexander Rabinovich (Russia), Gordon Cheyne (Australia), John Fleming (Chile). Row 3: Mark Sullivan (Australia), Dominique Reymond (France), Kong Chiew Low (Malaysia), Kriengkrai Khovadhana (Thailand), Kwang-Joon Park (Republic of Korea), Sumalee Prachuab (Thailand), David Coetzee (New Zealand), Hans Brounts (New Zealand). Row 4: Wilfried Strauch (Nicaragua), Wing Tak Wong (Chile), Jun Hee Lee (Republic of Korea), Kenneth Gledhill (New Zealand), Choon Siong Sim (Singapore), Paula Dunbar (USA), Brian Yanagi (ITIC), Yuji Nishimae (Japan), Yerko Jara Schenone (Peru), Edwin Pinto Uscocovich (Ecuador). Row 5: Lasarusa Vuetibau (Fiji), Hugo Gorziglia (Former ICG/ITSU Chair), Robert Owen-Jones (Australia), Faatali Malaefatu Leavasa (Samoa), Jeff LaDouce (USA), Bart Bautista (Philippines), Wei Wu (China), Hans Jurgen Meyer (Colombia), Igor Kuzminykh (Russia), Samuel Johnson (USA), Viacheslav Gusiakov (Russia), Xue Jia Song (China). Missing: Bernie Kilonsky (IOC GLOSS), Mark Leonard (Australia), Rodrigo Nunez (Chile, incoming ITSU Chair), Adrien Vannier (IOC).

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2. *Tsunami Hazard Maps, from global to local levels, should be developed and used as the main tool for evaluation of tsunami risk in different parts of the World Ocean coastline.*
3. *The existing Global Tsunami Database should be maintained and improved by means of further search of historical data in local and national achieves to improve the database quality and completeness.*
4. *Paleotsunami studies are of primary importance for evaluation of the recurrence interval for largest tsunami (Krakatau 1883, Chile 1960, Sumatra 2004) and they should be encouraged in all parts of world coast.*
5. *Multi-purpose (hurricanes, storm surges, global warming) real-time sea-level monitoring network for tsunami warning and further monitoring should be expanded. For scientific and sustainability reasons the locating of tsunami enabled coastal sea level gauges in protected harbour is r ecommended.*
6. *New forecasting methods for tsunami warning, based on real time sea level monitoring and numerical techniques, should be developed and implemented into the TWS operations.*
7. *Sharing operational experience of emergency management should be encouraged. Such presentations and participation of TWS operational personnel should be encouraged in the future joint IUGG/TC – ICG/ITSU workshops.*
8. *Tsunami education and awareness are the key elements of public safety and any efforts should be supported in all tsunami-prone coasts of the world.*

Examples of tsunami evacuation signage along the Viña del Mar, Chile coastline.

INTERNATIONAL TRAINING WORKSHOP ON NUMERICAL MODELING OF TSUNAMI FOR DEVELOPING COUNTRIES IN SOUTHEAST ASIA, THE PACIFIC AND THE INDIAN OCEAN Philippine Institute of Volcanology and Seismology (PHIVOLCS), Quezon City, Philippines, 7-19 November 2005

Raymond Patrick R. Maximo, Chair, Local Organizing Committee, Philippine Institute of Volcanology and Seismology, Department of Science and Technology, PHIVOLCS Bldg., C.P. Garcia Avenue, U.P. Campus, Diliman, Quezon City 1101 Philippines, raymond.maximo@gmail.com

Quezon City, Philippines – A total of 12 foreign and four local participants completed the 10-day training-workshop on numerical modeling of tsunami held at the Philippine Institute of Volcanology and Seismology in Quezon City last 7-19 November 2005. Participants came from the countries of Indonesia, Malaysia, Vietnam, Hong Kong (China), and Philippines from Southeast Asia region, Fiji and Papua New Guinea from the Pacific region and Madagascar, Mauritius and India from the Indian Ocean region. Most had backgrounds in physical oceanography, seismology, computational programming and numerical modeling and were actively involved in tsunami research efforts of their own countries. The 10-day training-workshop was facilitated through series of lectures and hands-on computer exercises under the supervision of experts on tsunami modeling namely Dr. Modesto Ortiz (CICESE-Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Mexico) and Dr. Yuichiro Tanioka (Hokkaido University, Japan).

CICESE Professor Modesto Ortiz (left), Lawrence Anton of Papua New Guinea (middle) and Velly Asvaliantina of Indonesia (right) review Anton's study.

The International Training-Workshop on the Numerical Modeling of Tsunami for Developing Countries in Southeast Asia, the Pacific, and the Indian Ocean was hosted by the Philippine Institute of Volcanology and Seismology – Department of Science and Technology

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(PHIVOLCS-DOST), in collaboration with the International Tsunami Information Centre (ITIC), the International Association of Seismology and Physics of the Earth's Interior (IASPEI), the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), and the Working Group on Subduction Zones Located in Developing Countries (IASPEI-IAVCEI-WGSZLDC). It was the first organized training in modelling organized since the tsunami hit the northern regions of Sumatra Island in Indonesia on 26 December 2004.

The objectives of the training-workshop were (1) to provide the participants the opportunity to acquire knowledge in the field of tsunami numerical modeling to help them estimate tsunami height, inundation or flooding, and arrival time information, which are all important and crucial for warning and planning realistic evacuation routes; and (2) to equip the participants the necessary skills to carry out a tsunami mitigation research in their home institutions upon their return. Hence, at the end of the activity, each of the participants was asked to present a tentative plan of action for their corresponding countries.

The training-workshop opened with series of informal talks given by selected participants. Dr. Than H. Aung of the University of South Pacific in Suva, Fiji delivered a very informative talk on sea level monitoring, including the use of the South Pacific Sea Level Network funded through Australia for sea level and climate change monitoring, and recent sea level trends in the Pacific. Dr. Sri Widiyantoro of Bandung Teknologi Institut in Bandung, Indonesia, then spoke on seismic tomography and geodynamics studies of the Sumatran Region, showing recent results comparing the shape of the subducting plate beneath Sumatra and Bali based on seismology. Dr. Widiyantoro is also the president of the Working Group on Subduction Zones Located in Developing Countries (IASPEI-IAVCEI-WGSZLDC), which co-sponsored this training.

In the afternoon session, informal talks were given by Dr. Yuichiro Tanioka of Hokkaido University in Japan. His presentation emphasized on the rupture process of the 2004 Sumatra-Andaman earthquake estimated from tsunami waveforms and geodetic measurements. The last talk was given by Mr. Mallavarapu V. Ramana Murthy of the Department of Ocean Development-Integrated Coastal and Marine Area Management Project Directorate in Chennai, India. He presentations focused on the mapping of inundation, runup, and subsidence documented through extensive post-tsunami field surveys after the 26 December 2004 tsunami.

Opening ceremonies were held at 8:00 AM on 8 November 2005. Dr. Renato U. Solidum, Jr., Director of PHIVOLCS-DOST delivered the welcome address to the participants and guests. Dr. Rogelio A. Panlasigui,

Rezah Badal of Mauritius (left), Mallavarapu V. Ramanamurty of India (middle), and Mohan Kumar Sammathuria of Malaysia (right) discuss results.

Undersecretary for Research and Development-DOST, gave a message in behalf of the Secretary of Science and Technology. Other guests who delivered their messages were Maj. Gen. Glenn J. Rabonza (ret), Administrator of the Office of Civil Defense and Executive Member of the National Disaster Coordinating Council and Dr. Sri Widiyantoro, president of IASPEI-IAVCEI-WGSZLDC.

The keynote address was given by Dr. Laura S.L. Kong, Director of the UNESCO IOC International Tsunami Information Centre in Hawaii. Her talk focused on the implementation of a global tsunami warning and mitigation system. She reiterated the important role that the warning centers in the Pacific Region, such as the Pacific Tsunami Warning Center (PTWC) in Hawaii and the Northwest Pacific Tsunami Advisory Center (NPTWC) in Japan, play in providing timely warnings for an impending tsunami disaster.

Closing ceremonies was held last 18 November 2005. Dr. Modesto Ortiz Figueroa shared his thoughts and general views in tsunami modelling to the group in a very inspiring speech. He was impressed with the group's performance given the very short time to learn so many topics and procedures in order to be able to come up with a good tsunami inundation map. He added that he will never forget the group and he also extended his invitation to the group or any member of the group to present their results in the tsunami session that will be held during the Mexican Geophysical Meeting in October 2006. Ms. Yudhicara, participant from Indonesia, gave a message of thanks in behalf of the group. Like the other members of the group, she extended her deep gratitude to ITIC for giving them the opportunity to participate in the aforementioned training-workshop. She reiterated that each of them when they go back to their home institutions will be working on their own project which they have already started during the 10-day training-workshop. Certificates of Com-

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pletion were awarded to the participants and another message was delivered by the director of PHIVOLCS, Dr. Renato U. Solidum, Jr. The closing ceremony culminated with a simple banquet and karaoke party in the PHIVOLCS auditorium.

Three participants shared their experience of attending the training. Mr. Rezah Mohammed Badal, from the Mauritius Oceanography Institute, indicated that he was very keen to attend the workshop because one of his tasks was to come up with an inundation map for his country before December 2005. He expressed his appreciation for the training, because upon his return to Mauritius, he felt that he would be able to start his tsunami inundation map project.

Ms. Velly Asvaliantina, Coastal Dynamic Research Center of Indonesia, reported that she was involved in the making of hazard maps for the all regions in Indonesia. Prior to the training, she had little knowledge on mapping inundation of seawater by tsunami even though she has an advanced degree in coastal modelling. During the training, she used the bathymetry data that she brought to derive a realistic inundation map for west Sumatra, Indonesia.

Dr. Than H. Aung, physics professor from the University of South Pacific, Suva, Fiji, indicated that he had attended several trainings in the past, long before the tsunami of 26 December 2004, but that these trainings had no great impact at that time. Now that the disaster has occurred, he said that this training will help to start active research on tsunami in his region. He plans to re-echo what he learned in the training, with the help of his fellow participant from Papua New Guinea, Mr. Lawrence Anton of Port Moresby Geophysical Observatory in PNG.

For post workshop activities, a yahoo group was created to facilitate fast exchange of information and questions regarding the procedures, codes, and software support of each of the participants. The e-mail address of this yahoo group is *time_training_2005@yahoogroup.com*.

PRiMO WORKSHOP FOR WAVES AND WATER LEVEL HAZARDS DATA FRAMEWORK DEVELOPMENT, Honolulu, Hawaii, USA, 5-6 December 2005

On 5-6 December 2005, PRiMO's Observations and Data Management Hui held a workshop focusing on the coordination of Wave and Water Level (WWL) data providers and users in the region. The presentation and discussion sessions focused on these topics: 1) Data framework development; 2) Data integration and sharing mechanisms – Distributed information networks; and 3) Data integration and sharing mechanisms – Web Services.

Discussions held at the meeting resulted in the identification of a number of priority actions including posting information related to Data Discovery and Transport 'best practices' on the NOAA Coastal Services Center website, formation of Wave and Water Level Product Teams and Expert Teams, the development and distribution of a System, Data, Products Inventory; implementation of the Pacific Disaster Center's (PDC) Asia Pacific Natural Hazards Information Network (APNHIN) as a regional metadata clearinghouse, and development of a pilot/prototype/proof-of-concept Wave and Water Level-related web service and accompanying client application.

Also, the ITIC is working with the PDC, PTWC, and the University of Hawaii Sea Level Center to implement an XML-based web service tool that will enable many customers to globally access the current status of sea level station upgrades for tsunami monitoring; the XML-schema are proposed to include station system specifications, including transmission frequencies, formats, and header identifications.

Coordinating the workshop were Pacific Risk Management Ohana, U.S. Geological Survey/Western Region Geography, National Oceanic and Atmospheric Administration/Pacific Services Center (NOAA NOS), and East-West Center's Pacific Disaster Center.

The Pacific Risk Management Ohana (PRiMO) is a group of representatives from local, national, and regional agencies, institutions, and organizations involved in risk-management-related programs and activities in the Pacific. Based on a mutual recognition of the benefits of collective action, PRiMO was formed to increase collaboration and improve the development, delivery, and application of risk management products and services. PRiMO supports the development of "Huis" (working groups) to fulfill its mission

PRiMO's Observations and Data Management Hui is tasked to "enhance the collection and sharing of framework, assets, and hazards data including improved coastal, ocean, and atmospheric observing capabilities" throughout the Pacific region. The workshop successfully increased awareness and participation in the continued development of the data frameworks.

A report of the meeting will be presented at the March 2006 meeting of PRiMO. For more information on the workshop, or about PRiMO's Observations and Data Management Hui, contact Eric Wong *wonge@eastwestcenter.org*, <1>(808) 944-7429.

MODELING INTERCOMPARISON WORKING GROUP, Hyderabad, India, 12-13 December 2005

The ICG/IOTWS-II, Working Group 4 (WG4) on Modeling, Forecasting and Scenario Development met in Hyderabad, India from 12–13 December 2005. The goal of the workshop, chaired by Australia and attended by scientists from Australia, India, Indonesia, Madagascar, Malaysia, Singapore, Thailand, USA, and the IOC and ITIC, was to share the modeling experiences for the Sumatra tsunami over the past year, and to discuss the standards and strategy for developing country capacity in tsunami propagation and inundation modelling to support the development of evacuation maps.

The objectives of the WG4 working group are to: a) develop standards for operation and application of models, b) facilitate the development: source, deep water propagation, inundation and forecast models, c) develop bench mark tests for model verification and validation, d) facilitate the development of a web-based community model, e) development of credible case scenarios for model application for the entire Indian Ocean including all possible sources (Sunda Arc, Mokran region etc), f) facilitate capacity building and knowledge transfer in the form of web-based tools and training programs and g) to liaise with other working groups, especially WG3, (the working group for tsunami hazard detection, characterisation and risk assessment for model requirements and effective model usage and application).

Model presentations included the current status of tsunami modeling, and information on various models being used in the region, which include: MOST, TSUNAMI-N2, VOF, NTC, ANUGA, MIKE21, TUNA.

WG4 model standards developed include: (1) accepted peer review process; (2) model documentation (how to run the model, model parameters); (3) benchmark testing to compare model data with other models; and (4) practical application test.

WG4 concluded with the following recommendations:

1. *Develop inundation maps for the coastal communities of the Indian Ocean region by the end of 2015.*
2. *Develop web based community model by the next meeting of ICG-III (summer 2006).*
3. *Development of inundation maps for different scenarios. Translate the inundation map projections into evacuation maps by the end of 2015.*
4. *Model standards and scenarios be accepted and implemented.*
5. *Model benchmarks to be available on the IOC website by ICG-III.*
6. *A subgroup to work with IOC to summarise the results and maintenance of the website.*
7. *Consider publishing the model standards and scenarios as a scientific paper.*
8. *Training for member states including short-term and long-term strategies.*
9. *Recognise that training is a continuous process and support is required for model maintenance, on going consultation and support at selected institutions.*

For more information, contact WG4 Chair, Professor Charitha Pattiaratchi, at *pattiara@cwr.uwa.edu.au.*

Located in Honolulu, the International Tsunami Information Centre (ITIC) was established on November 12, 1965, by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). In 1968, the IOC convened the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU).

The present 28 Member States 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, Peru, Philippines, Republic of Korea, Samoa, Singapore, Thailand, Russian Federation, United States of America, and Vietnam.

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