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Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System

TSUNAMI NEWSLETTER

International Tsunami Information Centre

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ICG/PTWS CHILEAN OFFICERS RETIRE

Two prominent Chilean scientists, whose concerted efforts helped to build the PTWS over the last twenty years, retired from government service. Dr. Rodrigo Nuñez, Chairman of the ICG/PTWS, and Emilio Lorca, Associate Director of the IOC International Tsunami Information Centre (ITIC), both retired from the Chilean Servicio Hidrografico y Oceanografico de la Armada (SHOA), and as Officers of the ICG/PTWS.

Dr. Nuñez was elected as Chairman at ICG/ITSU-XX in Viña del Mar, Chile in October 2005. Subsequently he chaired the ICG/PTWS XXI session in Melbourne, Australia in May 2006. Nuñez also served as ITIC Associate Director from January 1998 through October 2003. While at ITIC, Nuñez was credited with designing and implementing the ITIC's website that provided information on tsunamis and the activities of ITSU. His many valuable contributions have made ITIC a strong resource for Member States.

Rodrigo Nuñez served as Associate Director, ITIC from 1998 to 2003. He worked at the ITIC office in Honolulu for 6 months during his term.

Emilio Lorca succeeded- Nuñez as ITIC Associate Director from October 2003 through December 2006. He conducted numerous expert consultations including a 2004 visit to Colombia and Ecuador to provide advice on local tsunami mitigation. Lorca organizied the Fifth International Workshop, *Tsunami Hazard Mitigation and Risk Assessment of the Pacific and Indian Oceans*, jointly conducted with the International Union of Geodesy and Geophysics (IUGG) Tsunami Commission, in Santiago, Chile in September 2005, prior to the ICG/PTWS–XX session. Additionally, Lorca is the primary author of the Earthquake and Tsunami textbooks (grades pre-K–12), which were later translated into English and jointly published and distributed widely by SHOA and ITIC.

ITIC Associate Director, Emilio Lorca during his visit to Honolulu in 2002.

The ITIC, along with the PTWS Interim Chair, Fred Stephenson of Canada, would like to extend their appreciation to Nuñez and Lorca for their years of dedicated service to the ICG/PTWS. The election of new PTWS officers (Chair and two Vice-Chairs) will take place at the ICG/PTWS–XXII Session in Guayaquil, Ecuador, 17-20 September 2007.

SUMMARY OF EARTHQUAKES

Occuring October-December 2006

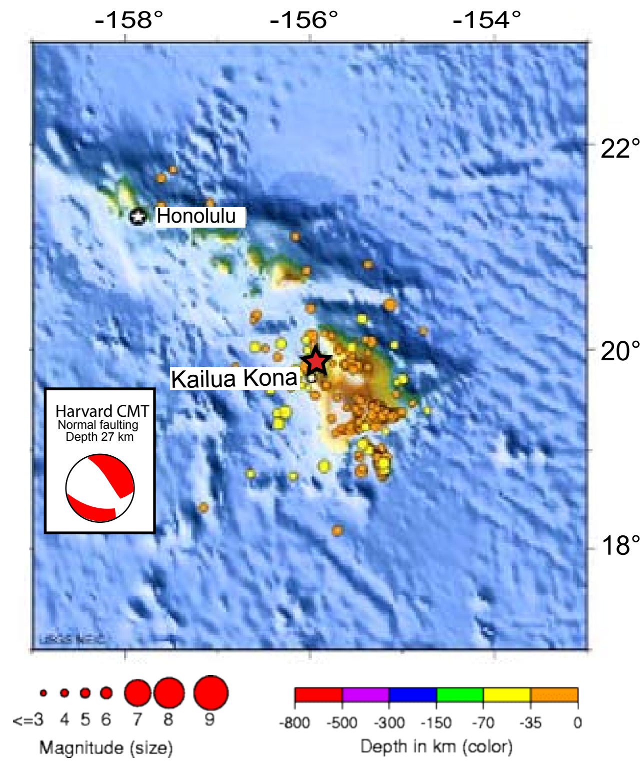
With surface wave or moment magnitude (Mw) greater than or equal to 6.5 and a depth no greater than 100 km, or an event for which a Tsunami Information Bulletin (TIB) or Regional Watch Warning (RWW), and/or JMA Tsunami Watch Information (J) was issued. Epicenter, and Mw from USGS National Earthquake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

DATE	TIME (UTC)	LOCATION	EPICENTER	DEPTH (km)	M_w	PTWC or JMA (J) ACTION	ACTION TIME	TSUNAMI? DAMAGING?	Maximum height (peak to trough) and place
1 Oct	09:06	Kuril Islands	46.468° N 153.235° E	19	6.7 (P) 6.6 (H) 6.5 (G, J)	TIB (J) TIB (P)	09:20 09:54	No	
15 Oct	17:08	Island of Hawaii	19.820° N 156.027° W	29	6.7 (G,H) 6.5 (P)	TIB	17:11	YES No	0.10 m Kawaihae Harbor, Hawaii
17 Oct	01:25	New Britain Region, Papua New Guinea	5.882° S 150.992° E	32	6.8 (J, P) 6.7 (H) 6.6 (G)	TIB (P) TIB (J)	01:40 01:45	No	
20 Oct	10:49	Near Coast of Central Peru	13.452° S 76.695° W	23	6.7 (H) 6.6 (G, P)	TIB	11:05	No	
23 Oct	21:17	Southeast of Honshu, Japan	29.332° N 140.302° E	11	6.8 (MJMA) 6.4 (G) 6.3 (H)	TWI (J)	21:29	No	
7 Nov	17:39	New Britain Region, Papua New Guinea	6.441° S 151.141° E	8	6.6 (J, P) 6.5 (H) 6.4 (G)	TIB (P) TIB (J)	17:53 18:01	No	
15 Nov	11:14	Kuril Islands	46.576° N 153.247° E	27	8.3 (H) 8.1 (J, P002-4) 7.9 (G) 7.7 (P001)	001 (P) 001 (J) 002 (P) 002 (J) 003 (P) 003 (J) 004 (P) 004 (J) 005 (J)	11:30 11:30 12:14 13:09 13:17 14:02 14:58 15:14 22:48	YES YES	1.76 m Crescent City, California
7 Dec	19:10	East of Kuril Islands	46.161° N 154.381° E	16	6.5 (P) 6.3 (G, H)	TIB	19:21	No	
26 Dec	12:26	Taiwan Region	21.825° N 120.538° E	5	6.9 (H, J) 7.2 (P) 7.1 (G)	TIB 001 (J) TIB (P)	12:33 12:40	No	
26 Dec	12:34	Taiwan Region	22.019° N 120.486° E	34	6.9 (H)	TIB 002 (J)	12:42	No	
30 Dec	08:31	Gulf of Aden	13.350° N 51.410° E	15	6.5 (G, J, P) 6.6 (H)	TIB (P) TIB (J)	08:48 08:57	No	

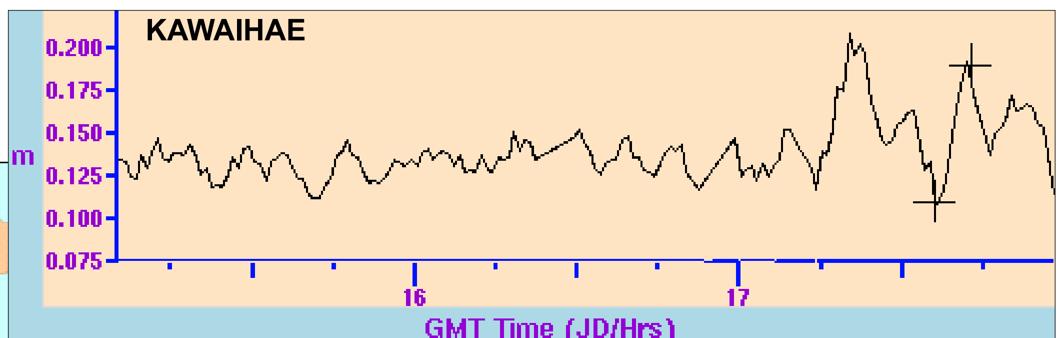
ISLAND OF HAWAII, 15 October 2006, 17:08 UTC, M_W=6.5

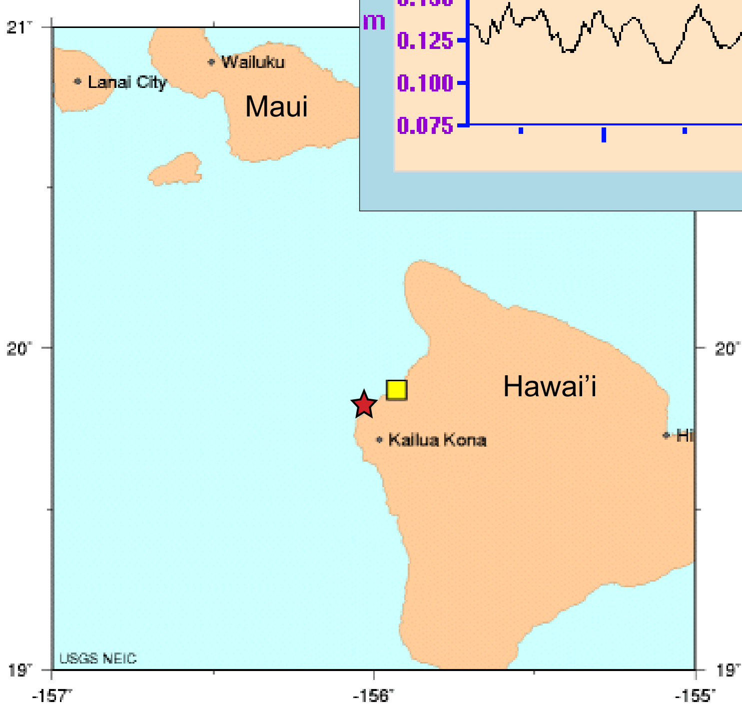
A strong earthquake occurred about 15 km north-north-west of Kailua Kona or 100 km west of Hilo, Hawaii at 17:08 UTC 15 October 2006 (07:08 local, Hawaiian Standard Time). Numerous people suffered minor injuries, at least 1,173 buildings were damaged, roads damaged and landslides blocked roads on the island of Hawaii. Power outages occurred throughout the Hawaiian Islands. Damage was estimated at $73 million US. According to the United States Geological Survey, National Earthquake Information Center (NEIC), the earthquake was felt (VII-VIII Mercalli scale) in northern and western Hawaii and (V-VI) in eastern and southern Hawaii. Also felt (VI) on Maui; (V) on Lanai, Molokai and Oahu and (IV) on Kauai. A tsunami with a wave height of 10 cm was recorded at Kawaihae Harbor, near the epicenter.

Earthquakes on the volcanic Island of Hawaii are not rare. The largest on record was the magnitude 7.9 1868 earthquake near the south coast which triggered a tsunami that drowned 46 people and which spawned numerous landslides that resulted in 31 deaths. A magnitude 6.9 tremor on 21 August 1951, damaged scores of homes on the Kona coast and triggered numerous damaging landslides.



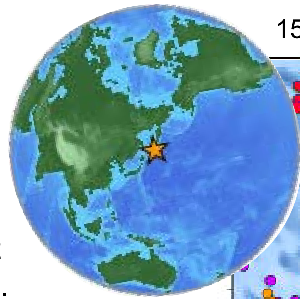
Map showing historical seismicity from 1900 to the present and location of epicentre (courtesy of USGS NEIC). The red star indicates current earthquake.





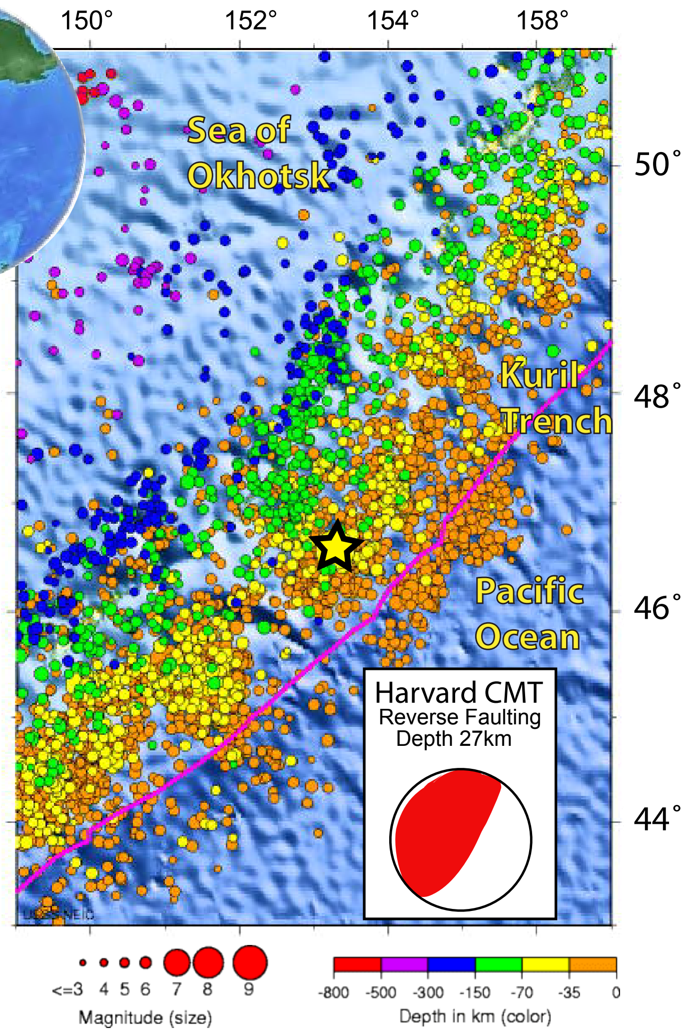
Above: Sea level record from 15 October 2006, at Kawaihae Harbor on the Island of Hawai'i. Courtesy of Pacific Tsunami Warning Center (PTWC). Left: Map showing location of tide recording. The yellow square indicates the location of Kawaihae Harbor, the red star rerspresents the epicenter.

KURIL ISLANDS, 15 November 2006, 11:14 UTC, M_W=8.1

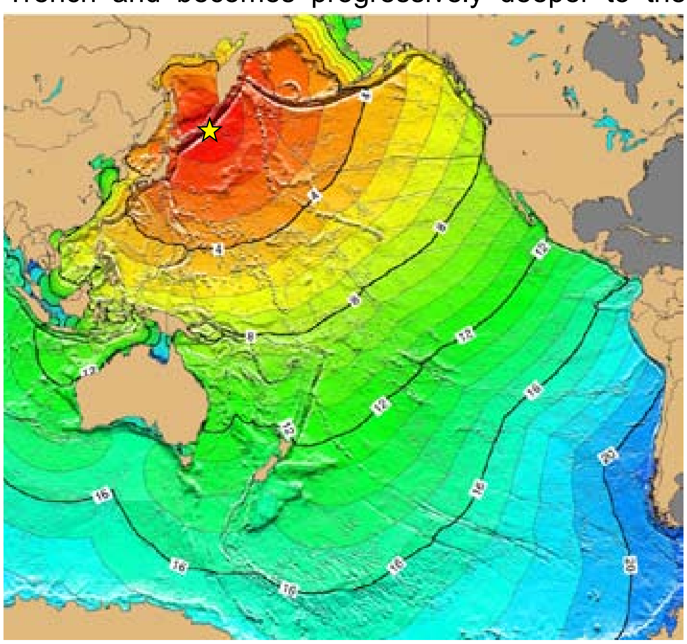


A great earthquake occurred 495 km SSW of Severo-Kuril'sk, Kuril Islands, Russia and 1665 km NE of Tokyo, Japan at 11:14 UTC, 15 November 2006 (21:14 local time in Russia). The earthquake was felt at Misawa and Yokosuka, Japan and at Petropavlovsk-Kamchatskiy, Russia. The tsunami was recorded (2 JMA) in eastern and south-central Hokkaido. A tsunami was also recorded (1 JMA) in western Hokkaido and in Aomori, Iwate and Miyagi Prefectures, Honshu.

One person was injured at Waikiki, Hawaii, by a tsunami with a measured wave height of 34 cm at Honolulu, Hawaii. One parking lot was flooded at Nawiliwili, Hawaii by a tsunami with a measured wave height of 88 cm. There were two docks destroyed and at least one damaged at Crescent City, California by a tsunami with a measured wave height of 176 cm. The Kuril Islands earthquake of 15 November 2006, occurred as thrust-faulting on the boundary between the Pacific plate and the Okhotsk plate. In the region of the earthquake's epicenter, the Pacific plate moves northwest with respect to the Okhotsk plate with a velocity of about 90 mm/year. The Pacific plate subducts beneath the Okhotsk plate at the Kuril Trench and becomes progressively deeper to the northwest, remaining seismically active to a depth of 680 km. The 15 November mainshock occurred at shallow depth within about 80 km of the trench axis.



Map showing historical seismicity from 1990 to the present in the area surrounding the current earthquake, indicated by the yellow star. The major subduction zone is purple. Both maps courtesy of National Earthquake Information Center (NEIC).



Tsunami travel time chart showing the theoretical time it takes to cross the Pacific from the tsunami source (assumed to be the earthquake epicentre). Color change every hour.

The 15 November earthquake is the largest earthquake to have occurred in the central Kuril Islands since the early 20th century. A central Kuril Islands earthquake in 1915 is estimated to have had a magnitude of about 8. The central Kuril Islands commonly experiences one or more shocks of magnitude 6 or greater in a decade. To the southwest, the southern Kuril Islands chain experienced a magnitude 8.5 earthquake in 1963. To the northeast, a magnitude 9 earthquake occurred offshore of Kamchatka in 1952.

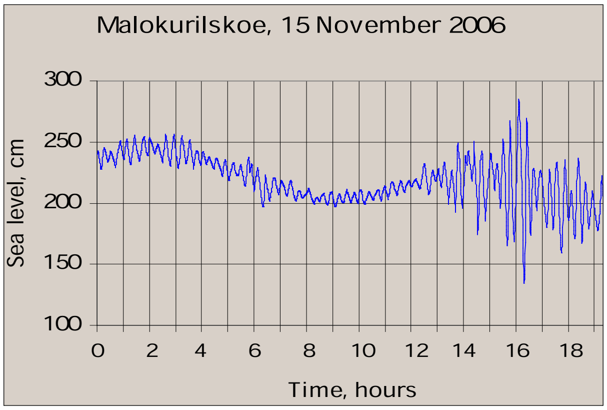
Kuril Islands, *continued*

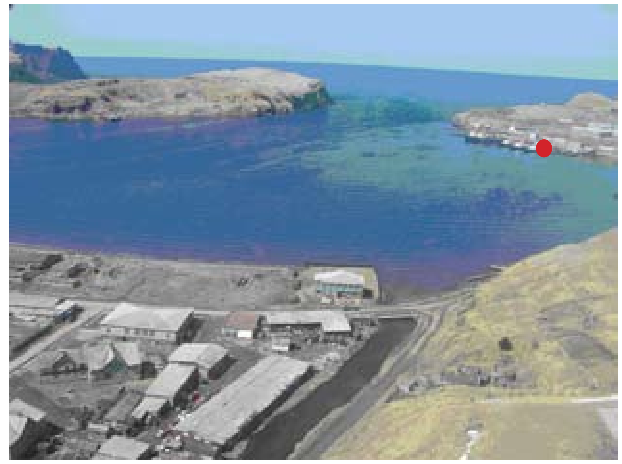
Tide Station	Maximum tsunami wave height in cm (peak-to-trough)	Tide Station	Maximum tsunami wave height in cm (peak-to-trough)
Pago Pago, American Samoa	44	Niue	13
Talcahuano, Chile	97	Manus Island, PNG	13
Arica, Chile	82	Callao-La Punta	73
Caldera	76	Atico, Peru	24
Coquimbo	66	Apia, Samoa	57
Iquique	64	Honiara, Solomon Islands	7
Antofagasta	46	Betio, Tarawa	5
Juan Fernandex, Chile	40	Nuku'alofa, Tonga	9
Rarotonga, Cook Islands	18	Funafuti, Tuvalu	6
Nuku Hiva, Fr. Polynesia	88	Adak, Alaska (AK) USA	39
Rikitea, French Polynesia	11	King Cove AK	36
Santa Cruz, Ecuador	67	Nikolski AK	32
Baltra Galapagos, Ecuador	62	Sitka AK	25
Tokachi-to Japan	120	Sand Point AK	21
Chichi-jima, Japan	100	Shemya Island AK	20
Hana-saki, Japan	80	Amichitka Island, AK	8
Hachinohe, Japan	60	Arena Cove, AK	118
Hakoadate, Japan	40	Santa Barbara, CA USA	79
Kushiro, Japan	40	Point Reyes, CA	62
Nemura, Japan	40	Santa Monica, CA	30
Naha, Japan	13	Los Angeles, CA	22
Shikotan, Kuril Islands	35	San Diego, CA	18
Kanton, Kiribati	6	Richmond, CA	17
Midway Island	96	Kahului, (Maui) HI USA	152
Kwajalein, Mardhall Islands	28	Hale'iwa, (Oahu) HI	115
Timaru Port	58	Wai'anae (Oahu) HI	100
Kaingaroa, Chatham Island	56	Hilo (Hawaii County) HI	98
Port-Vila Vanuatu	29	Kalaupapa (Molokaii) HI	88
Wake Island	22	Hanalei (Kauai) HI	85
Port Orford, OR USA	112	Kawaihae (Hawaii County) HI	65
Charelston, OR	38	Makapu'u (Oahu) HI	64
South Beach, OR	34	Lahaina (Maui) HI	45
Port Angeles, Washington USA	24	Honokohau (Hawaii County)HI	26
Lyttelton Port, New Zealand	33	Miloli'i (Hawaii County) HI	23
Sumner Head, New Zealand	33	Kapoho (Hawaii County) HI	13
Kaikoura, New Zealand	32	Mokuolo'e (Hawaii County) HI	10
Moturiki Island, New Zealand	21		

Maximum wave heights recorded for the Kuril Islands Tsunami of 15 November 2006 as recorded at Pacific Basin tide stations. Reported by the USGS in the National Earthquake Information Center's description of the event.

Kuril Islands, *continued*

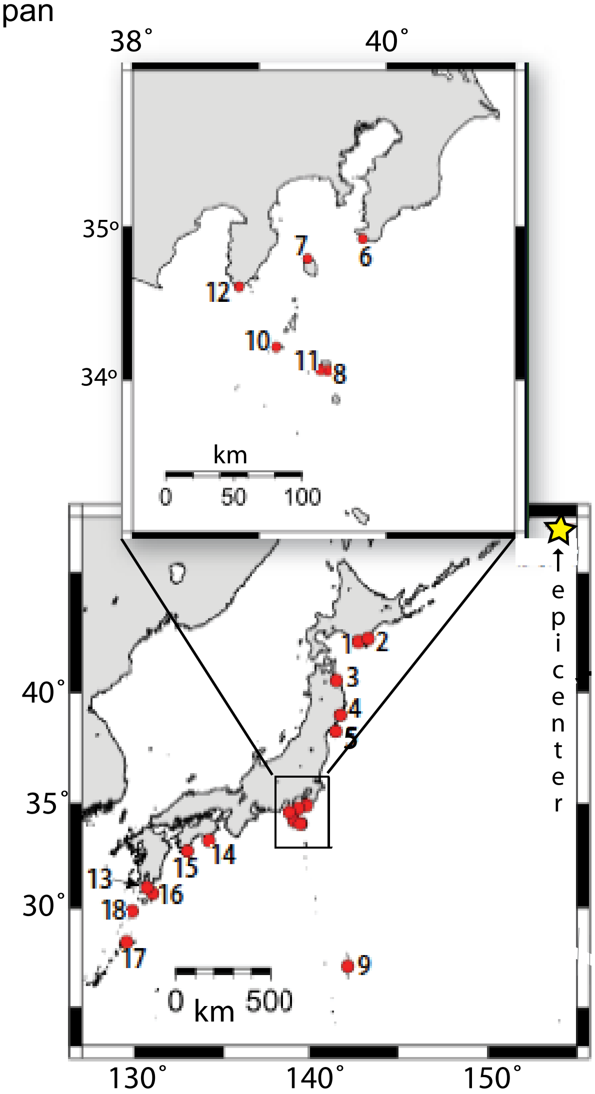
Russia

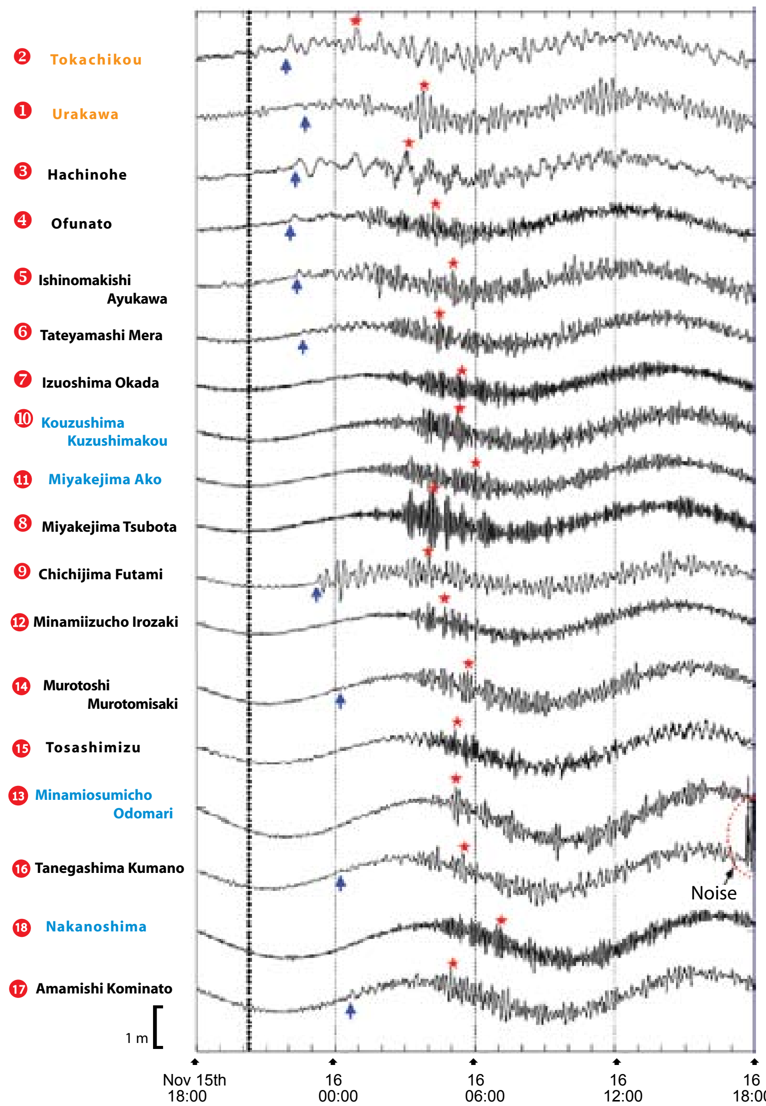




Sea level record from Malokurilskoe, Shikotan Island (left) along with an aerial view (right) of the harbor. Red dot indicates the location of the analogue gauge in the harbor. Graph indicates maximum peak-to-trough wave height in centimeters over time. Both courtesy of Tatiana Ivelskaya, Sakhalin Tsunami Warning Center.

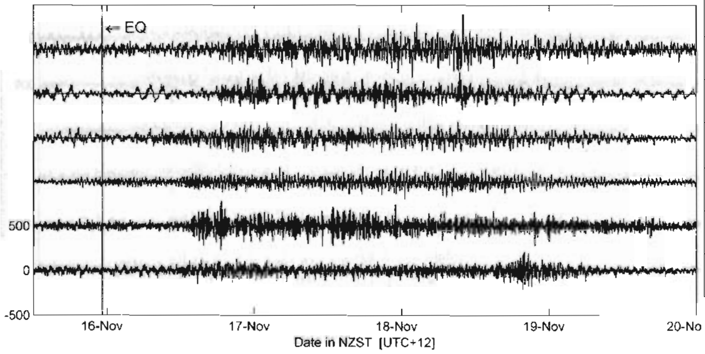
Japan





Map and inset detail show the epicenter (yellow star) and station locations, numbered to correspond to sea level records in the graph to the right. All stations are maintained by Japan Meteorological Agency (JMA) except those named in orange belong to Hokkaido Bureau of Ministry of Land, Infrastructure and Transport Japan, and those in blue are maintained by the Japan Coast Guard. The dotted line on the graph is the earthquake origin time. Blue arrows indicate initial wave arrival times and the red stars mark when maximum amplitudes were recorded. Where there are no arrows, arrival times could not be determined. The sea-level data at Tanegashima Kumano station (#14) includes noise from 17:30 on 16th November. Courtesy of JMA.

New Zealand



Tide Gauge	Arrival Time 16 Nov (NZST)	Arrival Time 16 Nov (UTC)	Periods of waves (min)	Maximum peak-to-trough wave height	Time of peak wave height	Peak wave amplitude **above mean (cm)**	Time of highest peak above mean
◀Timaru Port, NZ 44.392 S 171.254 E	18:03	06:03	9-19	58	09:52 18 Nov	40	10:00 16 Nov
◀Lyttelton Port, NZ 43.606 N 172.722 E	14:50	02:50	10-18	33	01:11 17 Nov	25	09:27 18 Nov
◀Sumner Head, NZ 43.570 S 172.773 E	14:45	02:45	12-21	33	18:34 16 Nov	20	18:38
◀Kaikoura, NZ 42.415 S 172.703 E	14:00	02:00	10-20	32	17:36 17 Nov	19	
◀Kaingaroa,Chatham Is, 43.732 S 183.733 E	13:42	01:42	9-12	56	18:35 16 Nov	28	
◀Moturiki Is, NZ 37.633S 176.193 E	13:20	01:20	9-15	21	20:29 16 Nov	13	

Sea level data supplied by Port of Lyttelton Ltd. and PrimePort, Timaru and New Zealand National Institute for Water and Atmospheric Research or NIWA, Taihoro Nukurangi (Moturiki, Kaingaroa, Kaikoura, Sumner Head).

Kuril Island Tsunami Impact in Crescent City, California 15 November 2006

By Mr. Burak Uslu and Dr. Aggeliki Barberopoulou, University of Southern California, Tsunami Research Center, Taken with approval from URL:http://www.usc.edu/dept/tsunamis/california/Kuril_2006.

On Wednesday, 15 November 2006 at 11:14:16 (UTC) a large (M_w = 8.3) earthquake occurred on the Kuril Islands Subduction Zone. The event caused a Pacific wide tsunami which was expected to reach Japan in 64 minutes and California in 8 hours and 20 minutes.

The first wave arrived at Hanasaki, Hokkaido with an amplitude of 30 cm. After the observation of this minor tsunami in Japan, a large tsunami was not expected in Alaska or along the US west coast.

However, around 11:00 am Pacific Standard Time (PST), the Crescent City, California Harbor Control and Emergency offices received a warning for possible strong tsunami surges which were expected to arrive around 11:30 am. Because the tsunami effect was expected to be relatively minor, a full evacuation was not ordered, but rather targeted verbal warnings were issued for people in the harbor. Mr. Erik Macee from the fishing vessel *Resolution* confirmed that he was warned by the harbor control at around 11:10 am PST.

Left: Aerial photograph of the Crescent City Harbor. Photo provided by Harbor Master Richard Young (taken by Rick Hiser). Right: GIS measurement of inundation distance between high and low water levels during the tsunami. Information provided by Mr. Kevin Tupman.

The first wave arrived as expected but it was not noticed by the harbor control. Mr. Macee said he was in his boat when he first noticed the withdrawal. He was able to watch the tsunami from his boat looking at the water elevation change at the piling and breakwater.

The tsunami surges did not cause any damage until after 2 pm. Mr. Macee said the largest waves arrived around 2 or 2:30 pm. The second in the series of larger waves did the most damage when mooring lines from

Crescent City, *continued*

vessels berthed at Dock H were severed. Dock H had three boats, including the biggest boat in the harbor, 'Delana'. The 'Delana' was connected directly to the piling, while the other two vessels were connected to the exposed dock. The dock could not resist the strong current and the pull coming from the boats and failed

The current was so strong, harbor facilities manager Pual McAndrews reported that a white buoy at the entrance of the harbor was buried under water as the current flowed out of the harbor. He also noted that harbor seals and sea lions were not able to swim against the current.

Aerial view showing the areas where major damage occurred to the docks of Crescent City Harbor. URL:http://www.usc.edu/dept/tsunamis/california/Kuril_2006 Permission granted to download from the USC Tsunami Research Center website. Photo credit to Professor Lori Dengler.

Boats damage in Crescent City Harbor. Photo provided by Professor Lori Dengler, Humboldt State University.

Other witnesses described the tsunami in the harbor as 'flowing like a river'. It caused a whirlpool effect and it was flowing in clockwise direction. Dock H was the first dock in the flow direction and could not resist the flow.

After the Dock H, it was just a matter of time before Dock G failed. The loose boats carried pieces of Dock H when they crashed into Dock G and later into Dock F. A large portion of Dock F was also damaged, but it did not move around as did Docks G and H.

Docks E, F and G are used for small craft and sail boats. *Windrose* and *Allarion* are two of the sail boats that use Dock G. Robert Nunneley and Jim Herriott, owners

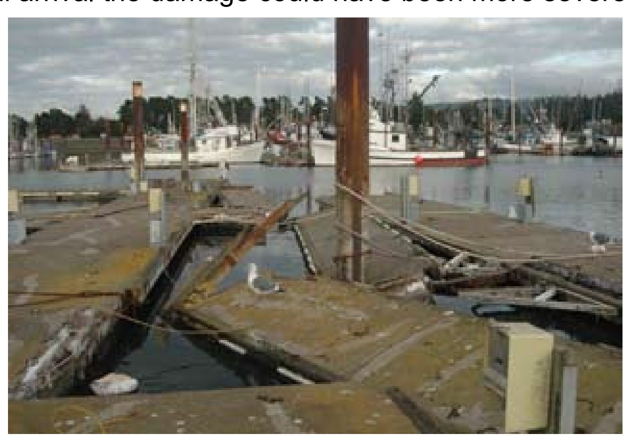
Boat lifted out of the water onto a pier. Photo provided by Professor Lori Dengler, Humboldt State University.

of the vessels, learned about the tsunami and arrived at the harbor around 3:40 pm. They noticed that the currents were still very strong. Their boats *Windrose* and *Allarion* were pushed on to the other boats at Dock C. The Coast Guard helped them to move the boats from Dock C to F.

Sam and Kathleen Burke, who work at a local RV camp, returned to the campground around 2:30 pm. They noticed that the tide level was different than what would be expected for that time. They also observed several water level changes. Mrs. Burke measured the time between wave crests to be 12 minutes. She repeated this for three more waves to confirm her observation.

Public works technician Kevin Tupman came to north harbor around 2:40 pm. He also observed the changes in water level due to the tsunami. Mr. Tupman estimated the distance from the low water mark to the high water mark was some 850 ft. He was at the north harbor from 3 until 4 pm and he saw three full wave cycles, which confirms Mrs. Burke's observation.

Fortunately it was low tide when the tsunami surges first arrived around 11:30 am. Total damage in the harbor is expected to be between $500,000 to $1,000,000. Had the tide been high at the time of tsunami arrival the damage could have been more severe.



Pier damage photo taken by Emergency Services Coordinator Allen Winogradov following the tsunami in Crescent City.

IOC NEWS

IOC Tsunami Co-ordination Unit

The IOC Tsunami Co-ordination Unit (TCU) was established in June 2006 in order to assist the development of tsunami warning and mitigation systems globally. Until this time, the IOC Executive Secretary, the ITIC Director and the Senior Tsunami Advisor, supported by experts from PTWC and JMA, provided leadership and expert services to all Member States. The Tsunami Co-ordination Unit is located in the UNESCO headquarters in Paris, France. The International Tsunami Information Centre (ITIC) in Hawaii, USA serves as the ICG/PTWS Secretariat and provides tsunami capacity building support both to the PTWS and globally. The ICG/IOTWS Secretariat is located in Perth, Australia. From February through July 2005, Dr. François Schindelé, then ITSU Chair, was seconded to the IOC as a technical expert.

The Tsunami Co-ordination Unit receives extrabudgetary support from Australia, Germany, Ireland, Japan, Norway and the United States.

Indonesia Tsunami Drill – Bali 26 December 2006

An Indonesia Tsunami Drill was conducted in Sanur Beach – Bali on the morning 26 December, 2006 to continue the development of the Indonesia Tsunami Early Warning System (TEWS) and commemorate the 2nd anniversary of the 2004 Indian Ocean Tsunami. Some 1000 – 2000 school children and teachers were observed participating in the drill at Sanur Beach. The drill was conducted based on the convening of the IOC Indonesia Tsunami Roundtable in May 2006, which made a recommendation to conduct a tsunami drill at one of three locations, by priority, Bali, Banten, or NTT, Indonesia.

Background

The Indonesia Tsunami Early Warning System is developed by more than fifteen government ministries, agencies and universities under the coordination of the Ministry of Research and Technology (RISTEK) and in partnership with the international community. The first

From left to right: Bernardo Aliaga, IOC/CARIBE EWS Secretariat; Michael Rottmann, Special Coordinator for IOTEWS, UNESCO Office Jakarta; Dimitri Travin, Programme Specialist TCU; Forest Collins, Assistant, TCU; Bill Erb, Head Perth GOOS Programme Office (since retired); Masahiro Yamamoto, Senior Advisor, TCU; Peter Koltermann, Head, Tsunami Co–ordination Unit; Patricio Bernal, Assistant Director-General UNESCO, Executive Secretary IOC; Uli Wolf, Programme Specialist, TCU, Cesar Toro, Head, Secretariat for IOCARIBE; Jane Cunneen, Programme Specialist, Perth Secretariat ICG/IOTWS; Thorkild Aarup, GOOS/GLOSS Programme Specialist; Laura Kong, Director, ITIC and Head PTWS Secretariat; Françoise Schiller-Ricotou, Assistant, TCU (since retired); Peter Pissierssens, Programme Specialist, IODE. Not pictured; Tony Elliot, Head IOTWS Secretariat; François Schindelé, IOC technical expert.

Bali drill, *continued*

part of the drill involved scientific technology with earthquake and tsunami detection, analysis, and dissemination of warnings to the affected community. The second part of the drill involved a cultural component to build a resilient and prepared community.

Collaboration occurred with the City Government of Denpasar, the Armed Forces and International Community. The Tsunami Drill simulated a full-scale "end to end" TEWS by fusing the latest technology in tsunami early warning with disaster management and community socialization. The drill commenced with earthquake observation and concluded with the provision of disaster relief assistances.

Drill Sites

The drill sites included the Meteorological and Geophysics Agency (BMG) that initiated the tsunami warning message; Sanur Beach where the participants initially gathered for the drill; the SATLAK PB (Disaster Management Implementing Unit) of Denpasar City; the office of the Yayasan Pembanguanan Sanur for comprehensive CCTV viewing; and the Made Pica public stadium as the evacuation site. A general briefing was held at the Bali Beach Hotel on the evening of 25 December. Additionally, a ministerial press conference was held at the stadium after the completion of the drill on 26 December.

School children follow the evacuation route as part of the drill 26 December 2006 held in Bali.

Left, sign showing the risk areas of Sanur Beach and evacuation paths for the drill in Bali, 26 December 2006. Signs were posted in the days before the drill to familiarize people with the plan.

Drill Segments

The scenario for the drill was divided into four segments.

Early Warning: The BMG Bali Regional Office simulated the detection of a large earthquake offshore, analyzing the tsunami potential, and electronically issuing a tsunami warning to appropriate government authorities. Its BMG central office in Jakarta, in turn, relayed the warning in turn to national ministries and agencies. BMG issued warnings through RANET and FM-RDS communication systems.

Decision Making: Upon receiving the warning, the SMS warning mechanism of SATLAK PB Denpasar City was automatically triggered. The SATLAK officer on duty requested to the City Mayor to make an immediate executive decision whether the tsunami would warrant immediate large-scale disaster response. In the drill, the Mayor positively decided to instruct the activation of one siren, located 2 kilometers north

Banner announcing the details of the evacuation drill to be performed in Bali on 26 December 2006, the second anniversary of the Sumatra earthquake and tsunami. The man on the right side is a local Bali celebrity.

Bali drill, *continued*

of Sanur Beach, to initiate the mass evacuation drill process. Concurrently, the Mayor activated the City Disaster Response Operation Centre to begin response measures.

Response: The drill participants at Sanur Beach were to begin running/walking the evacuation route depicted on a beachside billboard after the sounding of siren. The stadium was located about 2 kilometers inland from the beach where government agencies, Red Cross Society, NGO's and the armed forces provided relief goods and assistance.

Rescue: At the cancellation of the warning, combined Search and Rescue assets of some 200 personnel and 30 ambulances arrived at Sanur Beach to provide emergency response to tsunami victims.

Siren used by emergency managers in Bali to activate alarm at the push of a button. Broadcast news informed the people of the drill's commencement.

The practice drill involved rescue teams carrying out simulated search and rescue in the inundation area (left) with training in first aid and other emergency procedures that involved 200 personnel and 30 ambulances (right).

ICG/PTWS NEWS

Working Group Meeting on Tsunami Warning and Mitigation in the Southwest Pacific Ocean (SWP-TWG), 23 September 2006, Honiara, Solomon Islands

The Pacific Tsunami Warning and Mitigation System (PTWS) Working Group on Tsunami Warning and Mitigation in the Southwest Pacific Ocean (SWP-TWG). met on 23 September 2006.

It was agreed that this meeting would also serve the function of a Science, Technology, and Resource Network, (STAR) Tsunami Working Group Meeting. The terms of reference for the PTWS WG are:

1. *to evaluate capabilities of countries in these regions for providing end-to-end tsunami warning and mitigation services;*
2. *to ascertain requirements from countries in the Southwest Pacific Ocean for the tsunami warning and mitigation services;*
3. *to facilitate tsunami hazard and risk studies in the region;*
4. *to facilitate cooperation in the establishment and upgrading of seismic and sea level stations and networks in the region, and the interoperability of these systems;*
5. *to facilitate capacity building and the sharing of tsunami information in the region, including the free and open exchange of data;*
6. *to support the development of the centre of expertise in a multi-hazards context within SOPAC in line with the SOPAC strategies for enhancing early warning in the region.*

For background and as a means of introduction, member countries gave presentations on their current capabilities,focusing on sensor networks, communica-

Malaysia, *continued*

tions networks and the systems for disseminating warnings. Capability reports were provided by Australia, China, Cook Islands, Fiji, New Zealand, Niue, Papua New Guinea, Samoa, Tonga and Vanuatu.

It was agreed that coordination of donor activities in installing instrumentation is needed so appropriate instruments are installed that are easy to maintain, fit for purpose and interoperable.

The following recommendations were agreed:

1. *The working group acknowledges the current projects which relate to Terms of Reference 1, 2 and 3, including tsunami capability assessment and tsunami hazard and risk assessment in the SW Pacific.*

   The grou further requests that the organisations involved in carrying out the work provide progress reports to working group members by 30 June 2007 for deliberation before the PTWS meeting in September 2007.

   In addition, progress needs to be made towards effective tsunami warning in the SW Pacific. The current PTWC standard/magnitude is 6.5 for shallow events needs to be lowered and this can only be done by improving the regional coverage of seismographs (this relates to TOR 4 and 5).
   The working group therefore further recommends:
2. *That PTWC be requested to continue to provide coverage in the SW Pacific until a regional warning system capability has been established.*
3. *The region has identified that it may need warnings for shallow earthquakes below M 6.5 and perhaps down to a suggested magnitude limit of 5.7.*
4. *That existing instrumentation (sea level and seismic) in the region be identified, and a database of this information be made available.*
5. *Complete a gap analysis in the region to identify where stations (sea level and seismic) are required to allow effective detection of regional tsunami events.*
6. *A network design be carried out (seismic and sea level station) to allow the effective detection of regional tsunami events.*
7. *Coordination of donor contributions to allow the necessary work to be carried out to achieve the network required to provide effective tsunami detection in the region.*

STAR Tsunami Working Group Recommendations

The STAR Tsunami Working Group made the following recommendations for consideration by the South Pacific Applied Geoscience Commission (SOPAC) Council:

1. *SOPAC to be advised that the PTWS working group will take a number of recommendations to PTWS that have implications for member countries and that SOPAC take a coordinating role,*
2. *SOPAC to facilitate and support the initiatives of the PTWS group to carry out an initial survey of existing instrumentation for gap analysis and system design.*

Malaysia Disaster Awareness Day 27 December 2006 Kuala Lumpur, Malaysia

The inaugural Malaysia Disaster Awareness Day was conducted on 27 December 2006 in Kuala Lumpur, approximately 2 years after the 2004 Indian Ocean Tsunami. The multi-hazard conference attracted over 200 participants from Malaysia disaster response agencies to increase awareness and preparedness in planning for multi-hazard emergency response. Tsunami invitational keynote speakers included Dr. Yap Kok Seng, Director General of the Malaysian Meteorological Service (MMS), Ms. Akiko Nakamura of the Asian Disaster Reduction Center, and Mr. Brian Yanagi of the ITIC. Dr. Yap discussed the role of the MMS in a multi-hazard environment. Ms. Nakamura discussed how Japanese communities plan and prepare for tsunamis. Mr Yanagi gave an overview on the importance of creating tsunami standard operating procedures in rapid emergency response to tsunami events. The tsunami panel later answered questions from the Malaysian media. Malaysia has been very active in developing a tsunami early warning system "end to end".

Brian Yanagi, Disaster Management Specialist of the IOC-ITIC, delivers a presentation at Malaysia Disaster Awareness Day on Tsunami Emergency Response Planning and the development of Standard Operating Procedures.

ITIC-PTWC NEWS

ITIC ITSU Training Program-Hawaii
16-27 October 2006 Honolulu, HI

The 2006 ITIC ITSU Training Programme (ITP-Hawaii) was held in Honolulu from 16 - 27 October 2006. The Program provided participants with an overview of the history and operation of the Pacific Tsunami Warning and Mitigation System. Specific focus was given to the important role of regional and national tsunami warning centers in monitoring and evaluating the tsunamigenic potential of earthquakes, and in issuing timely tsunami warning messages to government emergency officials who can then act to save lives and reduce damage to coastal communities. The Programme provided training and familiarization with the Pacific Tsunami Warning System, sub-regional and National Warning Systems, and Civil Defense concepts of operations and standard operating procedures. The ITP-Hawaii used Hawaii as a working example of an end-to-end tsunami warning and mitigation system, in which close stakeholder co-ordination and partnership for operational warnings and in preparedness activities exists.

A total of eight participants from Meteorological or National Disaster Management Organizations, represening American Samoa, Australia, Columbia, Ecuador, Samoa and Tonga engaged in a series of training presentations at ITIC and the Pacific Tsunami Warning Center. Participants visited Emergency Operation Centers, seismic or water level station field sites, and met with scientists at the University of Hawaii. Participants also made a one-day field trip to visit the Hawaii County Civil Defense Agency, the Pacific Tsunami Museum, the Hawaiian Volcanoes Observatory and several tsunami memorials on Hawaii Island. Additional topics covered during the training were based on the needs of each participant.

At the beginning of the Programme, participants made presentations on the status of tsunami mitigation measures in their respective countries. A particular focus of the ITP-Hawaii was the emphasis on the importance of Standard Operating Procedures (SOPs) in tsunami warning and tsunami emergency response, and the testing of these SOPs through drills and exercises. Participants were asked to create, modify, and discuss their country institution SOPs using guidance and template examples provided during the training.

Two participant trip reports, from Ecuador and Tonga were submitted at the conclusion of the Programme and are included in this newsletter.

Participants in the ITP-Hawaii 2006 included (clockwise around the table from left front) Jane Cunneen, IOTWS Secretariat, Australia; Cristina Rosales, OSSA, Colombia; Ofa Fa'anunu Tonga Meteorological Service; Maliu Takai, National Emergency Management Office, Tonga; Tony Hill, Samoa Fire and Emergency Service; Malaefatu Leavaa, Meteorological Division, Samoa; and Willington Renteria Agurto INOCAR, Ecuador. Not pictured Evelyn Stevens, TEMCO, American Samoa. Photo taken at Hawaii County Civil Defense Agency in Hilo.

Ecuador

Willington Jesus Renteria Agurto, Lieutenant, Instituto Oceanográphico de la Armada (INOCAR) of Equador. E-mail: wjrenteria@gmail.com

Ecuador has a commitment to the future! While the scientific world knew the power of tsunamis for many decades, the rest of the world only came to know for first time what a tsunami is, in December 2004.

Several years ago, in Ecuador the INOCAR started an awareness plan but it only included a few coastal communities because of economic limitations and not enough interest from local authorities. After Sumatra, in Ecuador as in other countries, media covered all disaster and transmitted educational programs about tsunamis. Now, everyone knows what a 'tsunami' is. This was the beginning of world awareness. Now, the interest of tsunamis studies has increased, at least for now; this awareness will be sufficient for two generations, as these are the people who knew the 2004 Sumatra Tsunami.

Awareness of tsunami risk is a principal element in the chain of warning/mitigation. With it, we can begin to work in awareness, preparedness, response, recovery and prevention.

Another important element are Standard Operational Procedures (SOP), or plans of response for mitigation of tsunami damage. Hawaii is already one of the best

ITP-Hawaii, *continued*

examples of an "end to end" system, with strong co-ordination and partnership between all stakeholders of the regional/local system. Here, PTWC issues the tsunami bulletins, then Civil Defense starts procedures to minimize tsunami damage. In the USA, civil defense agencies and local governments have equipment for these tasks, but in several American States the civil defense and local governments don't have enough equipment.

In other countries, it is common for all armed forces to participate and coordinate with Civil Defense and other

TONGA NATIONAL EMERGENCY MANAGEMENT OFFICE ANNUAL WORK PLAN 2OO6 - 2007

PLANNING Activities	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Support Partners
Develop Evacuation Plan										Apr.	May	June	NEMO/SOPAC
Finalize the National Emergency Management Plan	July	Aug.											SOPAC/NZMCDEM
Agency Response Plan and Business Continuity (follow-up)	July	Aug.											NEMO
Prepare for International Disaster Day (Awareness week) & Cyclone Season.			Sept.	Oct.									SOPAC
Circulate Plan and conduct awareness raising activities	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	SOPAC if required
Review NEOC SOPs				Oct.	Nov.	Dec.							SOPAC/NZMCDEM
Plan and conduct a Table Top Exercise on new Plan							Jan.	Feb.	Mar				SOPAC/NZMCDEM/ UNOCH
Provide support to develop district and village plans							Jan.	Feb.	Mar.	Apr.	May	June	SOPAC/NZMCDEM
Develop a Hazard Mitigation Plan										Apr.	May	June	SOPAC
NEMO INSTITUTIONAL STRENGTHENING													
Develop Training Plan for Staff	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	NEMO
Develop a 3-year Strategic Plan for the NEMO							Jan.	Feb.	Mar				SOPAC/NZMCDEM
Review of staffing arrangements, roles and responsibilities							Jan.	Feb.					SOPAC/NZMCDEM
Preparing business plan and budget for 2007 -2008								Feb.	Mar				SOPAC/NZMCDEM
Finalize Legislation								Feb.	Mar				NEMO
RISK REDUCTION AND BUILDING COMMUNITY RESILIENCE													
Conduct Training at Community Level (IDM/IDA)	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	NEMO/SOPAC/TAF/ OFDA
School Visits/Consultation to include disaster management in curriculum	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	NEMO
Strengthen partnerships with national planning and other agencies (include NGOs)	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	SOPAC if required
Implement CHARM as a risk reduction decision making tool									Mar	Apr.	May	June	SOPAC
PREPAREDNESS													
Upgrade Early Warning System (RANET Project)							Jan.	Feb.	Mar.	Apr.	May	June	SOPAC
Conduct exercise for NEOC									Mar				SOPAC
Stock up emergency relief items							Jan.	Feb.					Local Arrangement
Identify evacuation centres										Apr.	May	June	NEMO
Regular consultation with NGOs and other stakeholders	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	NEMO

ITIC news, *continued*

government departments. All are basically involved in three activities: warning, evacuation, and first aid. We need to develop standard operating procedures, to be implemented, in Ecuador, through the National Emergency Operative Committee (COEN). Creating an SOP is a major undertaking, and they are being done, because it isn't too complicated, since the Armed Forces have their response plans for evacuation exercises and they have the equipment; the most important part is fitting these plans with the SOP of the Civil Defense and its coordination with the Red Cross. In the case of warning, INOCAR can make connections with the Geophysical Institute of Ecuador.

Tonga

Mr. Maliu Takai, Deputy Director, Tonga National Emergency Management Office -Ministry of Works, makai@kalianet.to.

Mr. Takai forwarded a Work Plan matrix of activities as his report. Printed on the opposite page (p. 14), it demonstrates the application of ITP-Hawaii principles into multi-hazard disaster risk reduction activities.

"Verifying the Comprehensive Nuclear Test Ban: 10 Years of Development", United Nations, New York, USA 9 October 2006

More than fifty-five representatives, from United Nations Permanent Missions, NGOs and the UN Secretariat attended the seminar; 'Verifying the Comprehensive Nuclear Test Ban: 10 Years of Development'. The Verification Research, Training and Information Centre (VERTIC) organized the seminar at the invitation of the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO Preparatory Commission, Austria). It followed the CTBTO Executive Secretary's annual report delivered earlier that day to the UN General Assembly First Committee.

UN Headquarters in New York City (istock photo).

The Keynote address was by Ambassador Tibor Tóth, Executive Secretary, CTBTO and presentations were made, including: "Ten Years of Development" (Mr. Andreas Persbo, Arms Control and Disarmament Researcher, VERTIC), "Examining the Effectiveness of the CTBT Verification Regime: Results of the First System Wide Performance Test", (Dr. Lassina Zerbo, Director, International Data Centre, CTBTO), "The Why, What and When of CTBT National Implementation" (Mr. Peter Hulsroj, Chief, Legal Services Section and Legal Adviser, CTBTO), and "Civilian Application of the CTBT International Monitoring System: Tsunami Warnings", (Dr. Laura Kong, Director, ITIC). Dr. Kong's talk focused on the improvements in seismic source characterization that are now possible through the inclusion of real-time data from the CTBT International Monitoring System (IMS). IMS data sharing to UNESCO-designated Tsunami Warning Centers was made available in March 2005 in response to the 2004 Indian Ocean Tsunami. Due to the suspected nuclear test in North Korea earlier that day, the speeches of Ambassador Toth and Dr. Zerbo were presented by Peter Hulsroj, as both were in transit back to CTBTO Headquarters in Vienna, Austria.

WORKSHOP AND MEETING SUMMARIES

Indonesia Tsunami Emergency Response Workshops, Indonesia, Fall 2006

Indonesia Tsunami Emergency Response is being assisted in a project called, "Strengthening Tsunami Warning Centre and Emergency Responses: Development of Standard Operating Procedures (SOPs) in Support of an Indonesia Tsunami Drill on 26 December 2006." The IOC International Tsunami Information Centre (ITIC) is carrying out the project in collaboration with the United Nations Development Programme (UNDP) to support the development of an "end to end" Tsunami Early Warning and Mitigation System (TEWS).

Under this project, a joint effort was conducted with ITIC and international donor organizations based in Jakarta (UNDP, USAID IOTWS Programme, German GTZ Corporation, and International Federation of Red Cross/Red Crescent), to organize a pilot consortium of "downstream" emergency management agencies from three provinces. The Aceh–Bali–Padang Consortium was formed consisting of provincial/district disaster management government agencies (SATKORLAK/SATLAK), police, fire, military, and several non-governmental agencies.

About 30 participants attended workshops entitled,

SOP Workshops, *continued*

"Capacity Building Workshop for Development of Local SOPs for Tsunami Early Warning and Emergency Response." The first SOP Workshop was conducted in Bali from 12-13 October 2006; and the second SOP Workshop was conducted in Padang from 20 - 23 November 2006.

Indonesia developed a working definition of SOP as follows: "An SOP is a description of procedures on agreed steps by institutions, used in coordinating who is doing what, when, where, and how for tsunami early warning and response."

The objectives of the workshop were:

- *To share existing models or examples of local SOPs for Tsunami or hazards warning and response*
- *To review existing local SOPs for Tsunami or hazards warning and response*
- *To develop a process and create and plan to improve local SOPs*

The ITIC Disaster Management Specialist conducted SOP training and consultation, including the sharing of examples from Japan, Chile, and USA.

The consortium's activities were supported by BAKORNAS, the Indonesia national disaster management agency, to provide an "incubator" learning forum to create Indonesia customized "model" tsunami SOP's. The consortium workshop also linked relevant Indonesia national agencies, including the "upstream" BMG Indonesia Tsunami Early Warning System. Moreover, a representative from the RISTEK technology agency also briefed workshop participants on the planned Bali Tsunami Drill of 26 December 2006, and RISTEK's lead role in organizing a National Tsunami Drill Committee. Additionally, the newly planned UNESCO Jakarta Tsunami Information Centre (JTIC) would serve as an Indonesia tsunami information clearinghouse for general posting of conference and workshop training documents, meeting schedules, and general educational awareness resource materials.

The three regional groups agreed on specific tasks they would perform when they returned to their districts/city, including sharing the information they learned during the workshop, and depending on the region, conducting other meetings and exercises to advance their SOPs

As part of the workshop, participants in the SOP II inspect the construction of siren towers in Padang City, Indonesia. BMG's Fauzi is shown in between two other participants.

Participants follow a predetermined tsunami evacuation route up a hill in Padang, Indonesia. BMG's Fauzi is to the left.

Participants of the inaugural Indonesia workshop on "Capacity Building Workshop for Development of Local SOPs" held in Bali. This was the first of four workshops involving emergency responders from three Indonesian pilot provinces; Aceh, Bali and Padang.

SOP Workshops, *continued*

and planning for tsunami early warning and emergency response. The participants felt the workshops provided a good learning process, and suggested a series of workshops with the same participants to continue sharing and learning together as they proceed through the complex process. Thus, the workshop's international donor organizations agreed to sponsor SOP Workshops #3 and #4 in early 2007 in Jakarta.

AGU Fall Meeting 11-15 December 2006 San Francisco, California, USA

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The following notes were contributed by Dr. Fryer on papers and posters presented at the American Geophysical Union (AGU) annual Fall Meeting. Sessions covered tsunami research and specific tsunami themes, including sessions on the 17 July 2006 earthquake and tsunami in Indonesia (S14 and S 21) and a two-year followup on the 2004 December Sumatra Earthquake and Tsunami (U51B and U04-7209).

Reymond & Okal: *Rapid, yet robust source estimates for challenging events: tsunami earthquakes and megathrusts.* (S14A-02)

Dominic Reymond pointed out that Theta for the Java event was very low, -6.1, confirming that the event was 'slow'. Prior to his talk, Thorne Lay explained that the rupture speed was only 1.2 km/s and assumed that sandwiched sediments were the culprit. Reymond stated that the reason we fail to measure large or slow events properly is because current techniques are designed for and tested on ordinary 'faster' earthquakes. Reymond is looking at various measures to improve on, including mantle magnitude (M_m), Theta, integrated *P*-wave moment magnitude (M_{wp}), and a direct measure of higher frequency *P,* called tau (1/3).

Kanamori: *Attributes of tsunami EQ and the July 17, 2006 Java event* (S14A-05)

Hiroo Kanamori began by comparing the two Sanriku earthquakes of 1896 and 1933, showing that they were very different: one with very mild shaking, the other severe (at least two units of intensity stronger everywhere). Comparing 1896, 1946 (Aleutians), 1992 (Nicaragua), and 2006 (Java), he showed that all had epicenters very close to the trench axis, and suggested that rough incoming sea floor, together with thick sediments, might explain tsunami earthquakes. For rapid assessment, he suggested that the deficiency of short-period energy relative to long-period energy is far more important than mere richness in long-period energy. He sees the *w*-phase as one possible diagnostic character, and agrees that cumulative measures make for more robust warning systems. With so much technology and various techniques available, once implemented, the many measurements may make tsunami earthquake characteristics more apparent.

Oglesby & Geist: *Dynamic simulations of tsunami generation from the M_W=7.7 July 17, 2006 Java Earthquake* (S14A-07)

David Oglesby pointed out what is omitted when a tsunami is assumed to have a purely potential energy source (i.e., ignoring the kinematic contribution of the earthquake to the tsunami). He constructed a very simple friction law to model the rupture on the fault. He pre-stressed the system, increased strain to the breaking point at the hypocenter, and then watched what happened. Fault rupture grew as expected throughout the pre-stressed region, but it was the upward growth to the sea floor that proved fascinating. Since the sea floor is a stress-release surface, the growing rupture "feels" it as it grows updip and grows to very large amplitude before breaking out on the sea floor, producing very large sea floor displacements. The resulting tsunami is locally very steep and high, much higher than simple potential-only models predict. Oglesby suggested that the principle effect will be in the near field.

On Tuesday a session on Seismogenesis and Tsunami Hazards of "aseismic" island arcs included talks by Seth Stein and Emile Okal (T21F-01), and by Steve Kirby (T21F-02). Their message was similar to that of Rob McCaffrey's invited talk at a Union session on Sumatra on Friday (S51B-02).

In several talks about the Tonga Earthquake in May 2006, (John Beavan (T21F-04) and David Heeszel (T21F-05)) agreed that the Tonga Earthquake, and all its aftershocks, were in the downgoing plate rather than at the décollement. The main shock was probably a reactivated normal fault created at the outer arc high, making it an unbending event. Beavan pointed out that the phenomenally rapid (24 cm/yr) convergence in Tonga demands that most of motion be aseismic.

After Heeszel's talk, Emile Okal noted that the *T*-phase from the 2006 Tonga earthquake was, like that of the 1977 Tonga earthquake, so strong that it was felt in Tahiti. The inference: since tsunamigenic earthquakes are deficient in *T*-phase energy, the Tonga earthquake did not produce a big tsunami.

AGU, *continued*

Tang, et al: ***The Tonga tsunami of May 3, 2006: a comprehensive test for developing the NOAA tsunami forecast system.*** (T21F-06)

Rachel Tang presented a summary on Short Term Inundation Forecasts for Tsunami (SIFT), PMEL's wave prediction scheme, which simulates tsunamis by combining precomputed tsunamis from different unit sources, and then scales the result to the earliest available DART-gauge data. The objective is to predict tsunami heights in the far field. Tang talked about the 2006 Tonga and the 2006 Kuril earthquakes, and demonstrated how SIFT worked perfectly for both. Since Tonga was a steeply-dipping in-the-slab earthquake rather than the décollement thrust assumed by SIFT, it surprised many listeners that the Tonga simulation did so well. Tang explained how the scaling to DART data greatly reduces the errors introduced by assuming the wrong source. Regarding the Kuril tsunami, Tang mentioned that the open-ocean wave height increased away from Hawaii, and that it looked as if energy was somehow refracted away from the islands. Note: refraction may be the explanation for the observation by the late Doak Cox that Hawaii is in a tsunami shadow for events in the southern Kurils and northern Japan.

Salzberg & Pulli: ***T-waves from a slow earthquake: analysis of hydroacoustic data from the July 17, 2006 Jawa Earthquake.*** (S21A-0129)

David Salzberg agreed with Emile Okal that tsunami earthquakes are deficient in *T*-phase, but unlike Okal, he believes that *T*-phases are useful in tsunami warning, because the *T*-phase characteristics of tsunamigenic earthquakes are so unique. *T-phase* duration relates to source duration, which is a useful indicator as is spectral slope, the falloff of energy with frequency. The 2006 Java Earthquake had the lowest slope yet measured, -0.78 dB/Hz, twice as low as that measured for the March 2005 Nias Earthquake (which was not slow and produced only a small tsunami), and about -1 dB/Hz for the Sumatra-Andaman Earthquake.

Matsumoto, et al: ***Submarine across-arc normal fault system in the southwest Ryukyu Arc: trigger of the 1771 tsunami hazard?*** (T31G-01)

The 1771 Meiwa Tsunami is infamously listed in the Guiness Book of World Records as the largest tsunami on an open coast: 279 ft (85 m) at Ishigaki Island. A number of geologists (including Andy Moore, who visited the site) contest that value, but there is no doubt that the tsunami was huge. In his talk, Takeshi Matsumoto described the data, mostly tsunami boulder size and locations, as evidence for a runup of at least 56 m. However, the largest runups on Ishigaki Island were along the east coast, not the south coast, which is closest to the trench. The University of the Ryukyus, with JAMSTEC resources, surveyed the sea floor around Ishigaki with multibeam and an ROV. They identified a 44-km-long normal fault across strike, the East Ishigaki Fault, which intersects a huge slump. With the ROV, they found fresh cracks and other evidence for recent movement. Matsumoto inferred that the fault, immediately offshore, was the source of the great tsunami. Emile Okal, however, drew parallels with Papua New Guinea (1998), where a mere 40-km-long fault was shown to be too small to create the tsunami, which was eventually traced to be a rotational slump source. Okal suggested that the slump mapped by Matsumoto may be the true source of the tsunami.

Probabilistic tsunami hazard analysis is now routine and was addressed by Thio, et al. (S31C-08) Burbridge, et al. (T31G-07), Wong, et al. (IN33A-1332), and Dunbar, et al. (GC44A-02). The same general logic for tsunami hazard assessment was followed; generate a suite of SIFT-like Green's functions, compute their runups along specified coasts, then run thousands of scenario earthquakes along subduction zones with repeat times guided by the Gutenberg-Richter relationship. With some analysis, probabilities of exceedance for particular runups or (better) the inundation limits of 100-year or 500-year tsunamis can be estimated.

Suleimani, et al: ***Numerical modeling of submarine landslide-generated tsunamis as a component of the Alaska Tsunami Inundation Mapping Project.*** (OS33E-01)

The tectonic tsunami of the 1964 Great Alaska Earthquake produced 25 fatalities, but 81 were killed by local tsunamis from earthquake-triggered landslides. Elena Suleimani and colleagues at the University of Alaska, Fairbanks, are working to quantify the landslide hazard by modeling landslides and their interaction with water using Jiang & LeBlond's technique. Initial work is being applied to Seward, Alasaka.

Strasser, et al: ***Timing, magnitudes, and locations of paleoearthquakes revealed by slope instabilities in lakes.*** (OS33E-04)

In 1601 an earthquake-triggered landslide in Lake Lucerne produced a tsunami that was "two halberds high." According to medieval history, Strasser explained that a halberd is a pike with an axe head, – it is still used as armament (along with the crossbow) by the army of the Vatican. He reported that the largest Swiss lakes have multiple landslides with major

AGU, *continued*

earthquakes. The sediments are overconsolidated, and from geotechnical and slope stability analysis, Strasser determined that it takes 0.8g (about Intensity VII) to produce landslides. From coeval landslides in Lake Lucerne and Lake Zurich, Strasser estimated that there are earthquakes between M6.5 and M7 every couple of thousand years.

Mosher, et al: *The 1929 Grand Banks landslide and tsunami revisited.* (OS33E-05)

David Mosher gave an update of work he and David Piper have been doing on the 1929 landslide, whose tsunami killed 28 people on Newfoundland. He explained that landslides are very difficult to identify, even with multibeam bathymetry and sidescan images. Without the reality of the tsunami and the turbidity current, the landslide could never have been mapped. They now understand the subtleties and know what to look for, and have scanned the Nova Scotia margin off Sable Island and see multiple failures that look identical to the 1929 event. If many of these produced tsunamis, then the tsunami hazard to New England and the maritime provinces is significantly greater than previously recognized.

Armigliato, et al: *Assessing tsunami hazard for the southern Italy coasts: results from scenario and statistical approaches.* (GC41B-1049)

Alberto Armigliato and his colleagues at Bologna presented one of the many papers on probabilistic tsunami hazard assessment. Using as their worst case the Mw 7.4 Catania earthquake of 1693, the strongest earthquake in Italian history, they moved this source along the subduction zone to develop a sequence of scenarios. They also carried out a more typical analysis applying the Wells & Coppersmith (1994) earthquake relationship to the Ward & Asphaug (2000) technique for hazard analysis of tsunamis from asteroid impacts.

Tinti, et al: *Generation, propagation and impact of giant tsunamis of tectonic origin in the Mediterranean Sea: some hints from preliminary scenario studies.* (GC41B-1050)

This paper was presented by Alberto Armigliato. Tsunami warning for the Meditteranean is a challenging mix of local and regional problems. Not only have there been tsunamis of reasonably restricted effect, like 1693 and the previous great Catanian earthquake in the 12*th* Century, there have also been truly basin–wide events. The last of these was from an earthquake of about M 8.3 in the western Hellenic Arc in July, 365. A SIFT-like database of scenario events for probable tsunami sources is being developed.

McCaffrey, et al: *The post 12/26 era and the Global War on Tremor* (U51B-02)

In many ways, Rob McCaffrey's paper on maximum earthquake size was one of the most important papers presented at the meeting. Ever since the earliest days of plate tectonics people have sought some sensible relationship between earthquake size, plate convergence rate, and crustal age. In the 1980's Larry Ruff and Hiroo Kanamori proposed a dependence of earthquake size on trench-normal convergence. McCaffrey further developed the ideas, carrying out geodetic campaigns, and looking at strain partitioning across megathrusts, with the goal of determining earthquake potential. However, Sumatra occured, which was a great earthquake in a location that nobody expected. McCaffrey explained that the apparent relationships found by Ruff & Kanamori were a consequence of the limited historical record: where great earthquakes have a long repeat time, we are unlikely to have sampled them; everywhere we have actually seen a great earthquake (with the exception of Sumatra) the repeat time is short enough that we 'should' have seen it. He looked at every subduction zone and calculated how large the largest earthquake would be if the whole zone ruptured. In every case the maximum earthquake size exceeded magnitude 9, even in places like Tonga, Japan, and Hikurangi (New Zealand), where events larger than 8.3 are unknown. Then he determined the time between M9 earthquakes based on the convergence rate. He found 25 subduction segments with a theoretical recurrence time of less than 600 years. For Cascadia, he got the same repeat time (about 400 years) as has been determined from paleoseismology. McCaffrey is now looking at all the subduction zones where there is adequate geodetic control (starting with Cascadia and Hikurangi) to work out coupling and the probability of a great earthquake. His preliminary conclusion is sobering; any megathrust is capable of a magnitude 9 earthquake at any time. He further concludes that all complete underwater ruptures will generate an trans-oceanic tsunami. Source locations where Sumatra-size tsunamis are possible from Middle America, the Scotia Arc, the Lesser Antilles, or Japan.

Okal: *Quantification of seismic recordings of the 2004 Sumatra and other tsunamis.* (U51B-04)

Emile Okal noted that every broadband seismometer on an island, or within 30 km of the shoreline, can record a tsunami at least as well as a DART gauge. On the horizontal components, the instruments respond to displacement, tilt, and gravitational changes imparted by the tsunami waves. If the data are filtered for the

AGU, *continued*

by the tsunami waves. If the data are filtered for the appropriate band the tsunami signal can be extracted. The transfer function (necessary for calibration) is readily obtained simply by ignoring the island and treating the seismometer as if it is on the ocean bottom. He showed that it is straightforward to translate from horizontal velocity to wave height to arrive at a pseudo-DART recording. Some advantages of these data over DARTs are the continuous and high sample rate, far simpler communications, and cheaper operations.

Lauterjung: *News from the GITEWS project -- the German contribution to the Indian Ocean early warning system* (U51B-05)

Jörn Lauterjung described the large project being undertaken by Germany to assist Indonesia in detecting tsunami events. Germany is developing DART-like instruments for tsunami warning, which additionally have seismic and geodetic sensors. Further information on the system is available at *http://www.gitews.org*.

Soh, et al: *Discovery of surface break of the earthquake fault that initiated the Great Indian Ocean Tsunami in the Sumatra Andaman earthquake off 26 December 2004.* (U04-7209)

Wonn Soh, described JAMSTEC's substantial ROV survey work offshore from Sumatra and the Nicobar Islands. Soh showed pictures of fresh escarpments that were probably the result of the earthquake. These are apparently the surface breaks of splay faults soling out on the main rupture. With the splays, total rupture comes to almost 30m, enough to explain the large local runup.

Sobolev, et al: *Towards real-time prediction of tsunami heights using "GPS-Shield" arrays* (U51B-08)

Stephan Sobolev and researchers from GFZ Potsdam claim that GPS arrays work better than seismometers in local tsunami warnings. They can obtain 4cm resolution of motion in real time from an array of permanent GPS stations set up in a line perpendicular to the trench and spaced about 10 km apart along that line. Sobolev proposed to establish hundreds of these trench-perpendicular lines along all subduction zones. Installing many geodetic-grade GPS stations is a formidable task.

Kirby & Klein: *The 15 October 2006-to-present earthquakes beneath the Island of Hawaii* (S53E-07)

Steve Kirby discussed the implications for Pacific Plate flexure and geomechanical effects of ascending CO_2 that embrittles the Pacific-Plate mantle. Kirby reported on stratification of earthquakes, including events deeper than 32 km that ring the island of Hawaii, like Honomu (1973) and Kiholo Bay (2006). All of these have a *P*-axis plunging radially away from the island load and represent extension in the deeper part of the plate. In this model, there are few earthquakes with depths near 32 km. Earthquakes with depths from 17 to 32 km deep are compressional events in the upper part of the plate. Events shallower than 17 km are in the edifice or the immediate underlying crust.

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

The present 30 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, Papua New Guinea, Peru, Philippines, Republic of Korea, Russian Federation, Samoa, Singapore, Thailand, Tonga, United States of America, and Vietnam.

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