Intergovernmental Oceanographic Commission

Workshop Report No. 40

IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications

Sidney, B.C., Canada, 29-31 July 1985

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IOC Workshop Reports

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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis. Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
4	Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974.	FAO Via delle Terme di Caracalla 00100 Rome, Italy	English (out of stock) Spanish (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stoc French Spanish (out of stoc Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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A Supplement to the Report containing selected papers presented at the Workshop is published separately, as IOC Workshop Report No. 40 Supplement

SC.88/WS/50

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FOREWORD

During the past sessions of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), great emphasis was placed on the educational programme on tsunamis and the training of officials of ICG/ITSU member countries.

A great deal of progress has been made in the last few years on instrumentation, communications and computer applications, which have had or could have great impact on the improvement of the Tsunami Warning System (TWS) in the Pacific. The state of the art is rapidly changing and even experts in the field have to review from time to time progress that is being made in technology to familiarize themselves with new concepts and learn to apply these concepts into operational techniques that can result in better tsunami analysis, prediction and communications. Improvements can be obtained in data collection and rapid processing of data, as well as in prediction of tsunami heights and inundation by applying the new technology and new instrumentation to data gathering, processing and analysis. Therefore, a real need was identified to have workshops and training sessions, even for the experts, during which instruction and information can be given on new technological advancements, information concerning computer circuitry and data transmission techniques, data collection and calibration techniques and communications. Training of officials involved in the Tsunami Warning System is an important part of the overall educational requirements of ITSU member countries because these officials are, in turn, responsible for operational improvements in their own countries and for a programme of general public education.

As early as August 1983, the IOC Secretariat called a special meeting in Paris, which included the Chairman of ICG/ITSU and the Director of the International Tsunami Information Center (ITIC), to review the educational needs of ITSU members. Suggestions were made that tsunami workshops should be held under the auspices of the TEMA programme and that a plan for a workshop be drafted and that appropriate experts be designated for such training. ITIC was charged with the responsibility of developing a curriculum and locating instructors. It was also suggested that such a workshop could be held consecutively to the ITSU and IUGG sessions so as to maximize participation and minimize cost.

On the basis of these suggestions ITIC, in close consultation with the IOC Secretariat and the Chairman of ICG/ITSU, developed a curriculum for the training of such officials and for familiarization of participants in the TWS, not only with a conceptual improvements that have been made, but with the inner workings of the TWS including computer applications, on-line processing and numerical modelling. Thus, the First IOC sponsored Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications, was held at Sidney, B.C., Canada, on 29 July - 3 August 1985, prior to the ITSU-X Meeting, and prior to the IUGG Conference in nearby Victoria. The following objectives for the Workshop were identified:

(i) to exchange directly views on the different aspects of the warning systems,

(ii) to improve communications, and

(iii) to conduct a discussion of the problems participants have in their own countries with tsunami preparedness.

The present Report contains a summary of the proceedings of this Workshop, as well as Annexes containing the Workshop Programme, the Recommendations and a List of Participants. The full text of papers presented at this Workshop is published as a Supplement to the present Workshop Report.

1. OPENING OF THE WORKSHOP

The Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications was opened at the Institute of Ocean Sciences, Canada, on Monday, 29 July 1985, at 10.00 am.

The Chairman of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), Mr. N. Ridgway (New Zealand) opened the Workshop and speaking on behalf of the Member States of the Group, extended to the participants of the Workshop, a very warm welcome. He stressed the importance of a unique occurrence to have 3 important activities relevant to the tsunami analyses, prediction and communications, concurrently. He stated that the Tsunami Workshop was the first international workshop to be held on this topic and this was a challenging and exciting occasion. He emphasized further that it was very pleasing to see so many participants from different countries in the Pacific Region and this should lead to an enhancement in the operation of the Tsunami Warning System (TWS) in the Pacific. He mentioned that the programme of the Workshop was designed to allow time for round-table discussions after each major topic has been presented and participants were urged to partake actively in these and to take maximum advantage of the opportunities that this Workshop offers. In closing, the ICG/ITSU Chairman wished all every success.

The welcome speech was given by Mr. W. Rapatz (Canada), ITSU National Co-ordinator of Canada and Director of Navigation Publications, who, speaking on behalf of the Canadian authorities, welcomed the participants and expressed his pleasure and honour that the Intergovernmental Oceanographic Commission (IOC) and its ICG/ITSU had given Canada the opportunity to host this important workshop. He stressed that in this Workshop there was the possibility of discussing tsunami hazards and practical solutions, and to identify lines of investigation and action needed to improve measures migitating the effects of tsunamis. He stated that, at the end of the Workshop, all participants would have learned something from one another and that this interaction will bring everyone one step closer to the point in time when tsunamis, although still feared and respected, will not take any lives in the threatened countries.

He emphasized his pleasure of seeing so many representatives from so many diverse Pacific countries. He thanked IOC for making it possible for representatives of some of the developing nations to come to this Workshop and for arranging the attendance of many fine lecturers.

Subsequently, speaking on behalf of the Secretary IOC, Dr. M. Ruivo, the Senior Assistant Secretary IOC, Dr. I. Oliounine extended a warm welcome and best wishes to the participants and expressed his gratitude to the Government of Canada, the Director of the institute and the local organizing committee for providing facilities and making appropriate arrangements. He then drew the attention of the participants to the importance of co-operative actions in tsunami warning and research and underlined the leading role the Intergovernmental Oceanographic Commission plays in the co-ordination of efforts of its Member States of the Pacific in this field. He mentioned that the topics which were to be discussed during the Workshop are of profound importance for coastal populations of the region that are

threatened by tsunamis. The Workshop had been planned to bring together scientists, engineers and specialists to promote interaction among all those concerned with the problem of tsunamis. Dr. Oliounine expressed his special pleasure to see representatives of all these groups in the conference room and stressed that close contacts and friendly exchange of views among them on the topics of the Workshop will be of profound importance to the Tsunami Warning System and may help greatly towards achieving the ultimate goal to protect people from any natural disaster.

2. ADMINISTRATIVE ARRANGEMENTS FOR THE WORKSHOP

Dr. G. Pararas-Carayannis (USA) was designated as Chairman and Mr. S. Rinard (USA) as Rapporteur of the Workshop.

In his opening remarks Dr. Pararas-Carayannis recalled the objectives of the Workshop which were:

(i) to exchange directly views on the different aspects of the warning systems,

(ii) to improve communications, and

(iii) to conduct a discussion of the problems participants have in their own countries with tsunami preparedness.

He identified the eight major areas of the Workshop programme and stated that the lecturers selected for the presentations were experts in their field and expressed the hope that the discussions be fruitful.

Then, the Chairman stressed the importance of documenting the Workshop proceedings into two parts: One containing the extended abstracts of the presentations, discussions and recommendations (A Summary Report) and another one containing the full text of all the presentations. He then concluded his introduction by expressing hope that the Tsunami Workshop would meet its stated objectives and that it would identify problem areas and direction which future efforts should take. He finally expressed his belief that this Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications sponsored by the IOC, will be indeed a very worthwhile undertaking.

Following the Chairman's remarks, Mr. S. Wigen (Canada), Tsunami '85 Co-ordinator, informed participants on local arrangements.

3. INTRODUCTION

Dr. Pararas-Carayannis in the introductory presentation of the Tsunami Warning System pointed out that IOC has played a very important role in the formation of the International Pacific Tsunami Warning System: Prior to 1960, countries such as the USA, Japan and the USSR operated national tsunami warning systems for the protection of their own national interests. These systems had limited data collection and communication capabilities. The great destruction caused by the May 1960 Chilean tsunami and by the March 1964 Alaskan tsunami, focussed attention to the need for an International Tsunami Warning System. In 1965, the IOC accepted the offer of

the USA to undertake the expansion of its existing Seismic Sea Wave Warning Center in Honolulu to become the headquarters of an International Tsunami Warning System. IOC also accepted the offer of other Member States to integrate their existing facilities and communications into this International Warning System. In the same year, at a meeting in Honolulu, an agreement was reached and IOC established the International Tsunami Information Center (ITIC) and the ICG/ITSU.

ITIC was given the general mandate of migitating the effects of tsunamis throughout the Pacific by (i) supporting Member States of ICG/ITSU in developing and improving preparedness for tsunamis; (ii) monitoring and seeking to improve the Tsunami Warning System for the Pacific; (iii) gathering and disseminating knowledge on tsunamis and fostering tsunami research; and (d) bringing to non-Member States a knowledge of the Tsunami Warning System and information on how to become participants through ICG/ITSU.

The ICG/ITSU was established as a subsidiary body of IOC, meeting every 2 years at a Member State to co-ordinate and review the activities of the International Tsunami Warning System (ITWS).

Since 1965, and with IOC support, the Tsunami Warning System integrated with other regional Tsunami Warning Systems has become the nucleus of a truly international network. Twenty-two nations are now members of ICG/ITSU. Several non-Member States and territories maintain stations. The System makes use of approximately 31 seismic stations, 53 tidal stations and 101 dissemination points scattered across the Pacific under the varying control of the Member States of ITSU.

The International Tsunami Warning System in the Pacific is one of the most successful international scientific programmes with the direct humanitarian responsibility of migitating the effects of tsunamis by saving lives and protecting property. The System has been made possible by IOC's involvement and by the active co-ordination of ITIC and of ICG/ITSU.

Mr. Ridgway then introduced his report on the "Role and Significance of the International Co-ordination Group for the Tsunami Warning System in the Pacific".

According to his report, in 1948, following the Aleutian tsunami of 1 April 1946 which caused many casualties and much destruction on the island of Hawaii, the US Coast and Geodetic Survey introduced a Tsunami Warning System (TWS) which was then called the Seismic Sea Wave Warning System. In 1964, an offer was made by the USA to expand its TWS to meet the international needs. This offer was accepted and to ensure effective international co-operation in the operation of this system, the ICG/ITSU was formed and held its first session in March 1968 in Honolulu. The International Tsunami Information Center was also established.

The role of ICG/ITSU is to reduce the risk to lives and property in Member States whose coastal areas are threatened by tsunamis. It carries out this role by recommending improvements to the TWS; promoting regional co-operation between Member States; contributing to the scientific and technical training of tsunami experts and the education of the general

public in tsunami awareness; encouraging the development of improved instrumentation and communication systems; ensuring the exchange of information between participating countries and between such organizations as the WMO and the IUGG, and offering assistance to the national and regional needs of Member States.

The Group holds its sessions every 2 years and during the intersessional periods, the Groups' recommendations are pursued jointly by the Group Chairman and the IOC Secretariat, assisted by the Director, ITIC and the National ITSU contacts of Member States.

Since 1968, the membership of the Group has grown from 12 Member States to 22 Member States at the present time. The facilities which are under the control of these members have greatly assisted in improving the operation of the TWS. Tsunami educational opportunities for tsunami experts, particularly from developing countries have been successfully provided and this workshop is one evidence of this. Post-tsunami surveys have been carried out and missions have been made to a number of countries to assist Member States in developing their national tsunami warning systems. A draft Master Plan, which identifies the future needs and priorities which should be pursued to improve the TWS has been prepared and will be discussed with a view to adoption at the Tenth Session of the ICG/ITSU. Finally, not the least significant benefit which ICG.ITSU provides, is the opportunity for delegates from Pacific countries to meet and exchange views and opinions and to establish firm and lasting friendships between international colleagues.

4. TSUNAMI DATA COLLECTION

Dr. Pararas-Carayannis presented an analysis of historical data collection based on the systematic compilation of all data pertaining to tsunamis observed and recorded in the Pacific Ocean since the beginning of recorded history which was undertaken as early as 1960. Accordingly, the Preliminary Catalogues of the Tsunamis in the Pacific was published in 1965 under the combined authorship of Iida, Cox and Pararas-Carayannis. Twenty years of additional research of historical tsunamis have added significantly to the completion and accuracy of this catalogue. The work of Prof. S.L. Soloviev (USSR) has been integrated into this original catalogue and a revised and corrected historical database exists now as a computer listing under the authorship of Iida, Cox, Soloviev and Pararas-Carayannis. This listing which is now ready for publication, has been made available to the World Data Center A-Tsunami (WDC-A, Tsunami).

Dr. Pararas-Carayannis mentioned that the International Tsunami Information Center, in close collaboration with the World Data Center-A, has published catalogues of historical tsunamis in Hawaii and Alaska. Listing have also been compiled of ITIC of historical tsunamis in Samoa, Indonesia, the Atlantic Ocean and elsewhere. Also, recent tsunami events have been documented by ITIC in a file and routinely published in the Newsletter and in the Tsunami Report series.

He added that, historical tsunami data collection is important for the basic understanding of the phenomenon, its generation, its propagation and its terminal characteristics. The historical database is widely used for coastal zone management, engineering design criteria and disaster

preparedness. The data also serves as the basis for operational analyses of tsunamis and is becoming an indispensable tool in the real-time evaluation of such events by the Pacific Tsunami Warning Center (PTWC) and other organizations. Thus, the historical tsunami data has been used for the preparation of decision maps, the establishment of thresholds for operational procedures, for hazard risk analysis and for statistical probability studies.

Next, the participants heard with interest a presentation by Mr. Wigen on the Historical Study of Tsunamis. Mr. Wigen noted that the Historical Study of Tsunamis provides a method for systematically collecting and evaluating the records of tsunamis, large or small, that have been registered at any tide station. Events were also identified that produced no visible tsunami. Standardized procedures for removal of tidal contributions from the records allows a more accurate comparison of the series of events and develops a data set which may be used in predicting the frequency of recurrence of tsunamis of any intensity.

Dr. Y. Tsuji (Japan) illustrated the importance of the historical study of tsunamis by providing participants with information on the tsunamis occurrence echoes the Japan Sea.

In the Japan Sea, 23 tsunamis occurred between 684 and 1985. The origins of these tsunamigenic sources are mostly distributed in the narrow strip of sea region which runs close to the northern part of the Japanese islands. Four tsunamis in 1741, 1940, 1964 and 9183 traversed the Japan Sea and struck the east coast of the Korean Peninsula.

In 1983, the Japan Sea Tsunami from the "Nihonkai Chubu Earthquake", which killed 100 people in Japan, reached the east coast of the Korean Peninsula and killed 3 more people there. Tsunami heights were reported ranging from 3.6 to 4.0 meters at Imweon Port, Gangweon-Do province.

The 1964 Niigata Tsunami *(M = 7.5, Mt = 2) was recorded by pressure type of tide gauge at Pusan Port, at the southernmost point of the Korean Peninsula, and a wave with double amplitude of 30 cm was observed. A reflected wave by the coast of North Korea was recorded at several tide gauges on the coast of the Japanese side.

At 0048, 2 August 1940, the Kamuimisaki-Oki Earthquake (M = 7.5) occurred in the west sea region off Hokkaido Island and was responsible for a tsunami with heights ranging from 2-3 meters which hit the west coast of Hokkaido and killed 10 people. This tsunami also raced across the Japan Sea and was recorded at 2 tide stations on the coast of Korea. Tidal anomalies, not higher than 2 meters were noticed at several places. Many vessels were slightly damaged.

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* M - Magnitude of the earthquake
Mt - Magnitude of the tsunami

In the early morning of 29 August 1741, a huge tsunami struck the southwest coast of Hokkaido killing 1,467 people there. Recently, a short description of this tsunami was found in the diary of the Choseon Dynasty (1392-1910) and it has been clarified that houses were swept away and vessels were destroyed on the east coast of the Kingdom.

Following the presentation of Dr. Tsuji, a paper entitled "Tsunamis Data Base" was presented by Mr. J.F. Lander (USA) with important information on the activities of the World Data Center-A, Tsunami.

According to his report, the World Data Center-A continues to collect microfilmed copies of mareograms and digitized mareograms. Presently, the Center holds copies of 3,100 analog records of tsunamis and about 60 digitized records. Also, it has a collection of 700 photographs of tsunami effects, which are described in published catalogues.

Over a period of years, working with Doak Cox initially, and with the co-authors of the Pacific Tsunami Catalogue (Iida, Cox, Pararas-Carayannis), the WDC-A has prepared a digital file of tsunami occurrences and effects. The file now has information on data and location, and where available, magnitude, run-up heights, damage and fatalities for 1,450 reported tsunamis. The file was used to produce a recently published Tsunamis of the Pacific Basin map as part of the Agency for International Development (AID) sponsored THRUST project.

The file can be interrogated to produce lists or plots of tsunami occurrences and for statistical purposes. While the file is not yet complete, the following observations can be made:

- The reporting of tsunamis has greatly improved since the beginning of the tsunami warning system.
- There has been about one damaging tsunami/year over the last 100 years.
- About 90% of tsunamis have effects limited to source region.
- Only Japan, Kuril-Kamchatka, Alaska and South America have produced Pacific-wide tsunamis.
- Hawaii has the greatest risk from Pacific-wide tsunamis.
- Remote-sourced tsunamis are a greater threat than local tsunamis only to Hawaii.
- 99% of fatalities (and probably damage also) are int he source region. Hence, regional warnings, education and engineering defenses are important.
- Indonesia, Philippines and Japan suffer the greatest hazard.

After the presentation of information on historical tsunami data collection, a general discussion was carried out by the Workshop. It was pointed out that from an operational standpoint the tsunami probability studies are very helpful.

Based on these discussions, the Group adopted Recommendation 1 and 2 (Annex II).

5. ACTIVITIES AND RESPONSIBILITIES OF EXISTING TSUNAMI WARNING CENTERS AND SERVICES

Four papers on the activities of regional and national tsunami warning centers were brought to the attention of the participants.

Mr. G. Burton (USA) Director of the Pacific Tsunami Warning Center (PTWC), described the activities of the Center and of the Hawaii Regional Tsunami Warning Center (HRTWC) which are located in Hawaii. According to his report, 13 buildings house the Center's office and electronics shop, geomagnetic and seismological observatory instrumentation and residences for 5 employees who rotate in teams of 2 on a standby watch to respond immediately to seismic alarms activated by earthquakes around the Pacific Basin.

The stated mission of the PTWC is to detect tsunamis in the Pacific; to predict their arrival and when possible, run-up on the coasts; and to provide timely and effective tsunami information and warnings to the populations of the Pacific to minimize the hazards of tsunamis.

Recent improvements were presented in the operational capability of the PTWC in all of the areas outlined above. Accordingly, seismic data acquisition now consists of a network of 14 stations, extending from the East Coast of the USA to the Western Aleutians, which are transmitting continuous seismic data in real-time to the PTWC. In addition, more member nations of ITSU are making seismic data available to the PTWC to extend the Tsunami Warning System (TWS) co-operative net of seismic stations.

The PTWC tsunami data acquisition capability has recently been extended through the installation of satellite tide platforms at Rarotonga, Cook islands; Baltra Island in the Galapagos and La Libertad, Ecuador; and at La Punta, Peru. These Data Collection Platforms (DCPs) were installed in co-ordination with Dr. K. Wyrtki (USA) of the University of Hawaii and Dr. D. Enfield (USA) of Oregon State University. The units provide tsunami data to the PTWC in near real-time (3-5 minutes) and also transmit continuous measurements for mean sea level studies related to El Nino or other sea level requirements. Dr. Wyrtki has also installed similar DCPs at Rabaul, New Britain; Nauru, Kapinggamarangi; and Majuro, Marshall Islands. These DCPs provide tsunami data to the PTWC in addition to mean sea level data.

Computer automation at the PTWC now includes on-line processing of seismic data in real-time. A second mini-computer has been installed to provide operational flexibility as well as a backup capability. A sophisticated micro-computer has been obtained for development of graphics display of seismic data and enhancement of PTWCs software capability.

As the Regional Warning Center for Hawaii only, PTWC functions to provide immediate Regional Warnings based only on seismic information. Local warning can now be issued within 6-10 minutes using voice communications over the Hawaii Warning System, which connects to all Civil Defense operating centres. The data acquisition net within the islands is being

reconfigured from a VHF system to the Rainbow Microwave System, with seismic and tidal data from the Island of Hawaii received at PTWC via microwave.

Speaking about the activities of the Alaska Tsunami Warning Center (ATWC), its Director, Mr. T.J. Sokolowski (USA) reminded the participants that the centre was established as a result of the great earthquake (event) occurring in the Prince William Sound area of Alaska on 27 March 1964. ATWC's primary responsibility was to detect and locate potentially tsunamigenic events and to provide tsunami watches and warnings to Alaska for events occurring in Alaska. Since the initial inception, the watch and warning responsibilities have increased to include potentially tsunamigenic events occurring near the west coasts of Canada and the USA. Information resulting from the primary responsibility is disseminated to the general public, news media, US Federal disaster agencies and appropriate agencies in Japan, Hong-Kong and Guam. Other activities of the Center include: maintaining data flow from seismic and tide networks; community preparedness; system improvements through special studies; and, implementing a micro-computer system to enhance the ATWC computer processing capabilities.

Seismic data are available to the ATWC in real-time, from throughout Alaska and from the western part of the USA. These data are processed automatically in determining an event's parameters. To ensure a continuous data flow, the ATWC seismic sites are visited each year for preventive maintenance, and as soon as possible, after equipment failure.

Tide data are available to the ATWC from 8 tide sites in Alaska and about 6 tide sites near the west coasts of Canada and the USA, for the purpose of confirming the existence or non-existence of a tsunami. The ATWC network of tide sites are telemetered to the Center in real-time, whereas the data from Canada and the USA are obtained via telephone and teletype.

A recent intensive study was conducted by the ATWC to critically review its current procedures in processing large tsunamigenic events. This study pointed out several areas that could be improved. These improvements are currently being addressed with the implementation of a micro-computer system. This system is envisioned to replace the present near-obsolete mini-computer. The micro-computers will be networked to: process real-time seismic data for automatic event computations; process near real-time data from the US tide sites; interactive process event data; and interactively generate and disseminate Tsunami Warning System messages.

Following this presentation, Mr. M. Katsumata (Japan) and Mr. Y. Beliaev (USSR) described, respectively, structures and responsibilities of tsunami warning services in their countries.

According to Mr. Katsumata, in Japan, the Japan Meteorological Agency (JMA) is responsible for the Tsunami Warning Service. In order to promote seismology/volcanology-related services including tsunami, the Seismological and Volcanological Department was established in JMA on 1 July 1984. The Department is composed of 3 divisions: the Seismological and Volcanological Management Division; the Earthquake and Tsunami Observations Division; and the Earthquake Prediction Information Division.

Tsunami warnings and advisories are handled by the Earthquake and Tsunami Observations (ETO) Division in the department. Because of the localized nature of earthquakes and tsunamis, the Japanese Islands are divided into 6 regions covered by local centres located in 6 key cities: Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Naha. These local centres are located at the District Meteorological Observatories of JMA.

Individual local centres issue warnings and advisories for tsunamis generated by earthquakes in their area of responsibility which extend out at sea, within 600 km from the designated stretch of coastline. For the areas outside the 600 km zone, the ETO Division, serving both as the Local Center for the Tokyo region and as the National Center, assumes responsibility, relaying much of the information from PTWC in Honolulu.

JMA has, at its Tokyo Headquarters, a computerized meteorological telecommunications computer system called ADESS (Automated Data Editing and Switching System). A smaller version of ADESS, called local ADESS, or L-ADESS, has been installed over the past 5 years at each of the above-mentioned local centres, except Naha. Other than meteorological data, L-ADESSes collect and process seismological data. Digitized seismometer signals from 10-to-20 selected stations are continuously fed to each L-ADESS, and signals exceeding a threshold value activate a disk drive, pen recorders and a buzzer.

Upon the sounding of the buzzer, the alerted duty officer enters P, S times and amplitudes of seismic waves into the computer by using an X-Y digitizer. The computer determines, through interaction with the duty officer, the location and magnitude of the earthquake, the possibility of tsunami occurrence, the level of tsunami warning and then produces the wording of warning and/or advisory messages. At a touch of a button, the warning messages are automatically transmitted to concerned field offices under JMA, relevant governmental bodies concerned with disaster migitation and the media, including TV stations.

Manual processing of data for tsunami warning issuance used to take about 20 minutes based on teletype messages sent in from field offices. Introduction of L-ADESSes shortened the time for processing to a few minutes. In the case of the Japan Sea Earthquake (magnitude 7.7) of May 1983, it took 13 to 14 minutes to issue the warning after registering the earthquake shock. Though the present system responded in the shortest possible time, the first tsunami wave reached the coast nearest the source region in less than 10 minutes and claimed many lives. This tragedy emphasized the need for reducing the response operating time.

JMA is also responsible for monitoring earthquakes with magnitude 3 or above, occurring in and near the Japanese Islands.

To meet this requirement efficiently, JMA plans to set up a new computer system, through which seismological signals telemetered from selected stations will continuously be sampled, seismic waves phases will automatically be identified by use of the AR (Auto-Regressive) model and the epicenter location, focal depth and magnitude will also be determined automatically. Planned to be completed by March 1987, this system will significantly shorten the time for issuing tsunami warnings. For better

results, it is hoped to accommodate in the tsunami prediction model, such parameters as the fault and source mechanisms, topography of sea floor and configuration of coastline.

One Permanent Ocean Bottom Seismograph (POBS) system has successfully been operating since 1978 off the south coast of the Tokai District, with 4 seismographs on a string of cable 110 km long from the coast to its southern end. This system includes a tsunami sensor - a quartz crystal pressure gauge - at the end of the cable, at depth of 2,200 m. The result of the analyses of the pelagic tide indicates that this tsunami sensor has been functioning satisfactorily. Presently, JMA is going to lay another POBS system extending to about 100 km south-eastward from the coast of the Boso Peninsula. The submarine equipment will comprise of one terminal apparatus (4,000 m depth) and 3 intermediate apparatus, each with seismographs and a tsunami sensor. The tsunami sensor is nearly identical as the above-mentioned. The new system will also be linked to the Tokyo Headquarters through telemetering. The laying of submarine cable and apparatus is scheduled to begin in August 1985.

After the conclusion of Mr. Matsumata's presentation, Mr. Beliaev described the Tsunami Warning System in his country. Accordingly, in the Soviet Union, a tsunami warning service was established in the middle of the 1950s with the responsibility of providing timely information on the epicenter location of underwater earthquakes, on the valuation of their intensity and on their ability to generate tsunamis.

Three local warning centres, situated in Petropavlovsk - Kamtchatskiy, Yuzhno-Sakhalinsk and Vladivostok, are responsible for tsunami warnings in the far-eastern coast of the USSR. Seismic recordings, determination of earthquake epicenter co-ordinates and magnitudes are made by 3 seismic stations involved in the operational tsunami warning service. These are Petropavlovsk-Kamtchatskiy, Yuzhno-Sakhalinsk and Kourilsk. Plans are being implemented to use seismic stations at Severo-Kurilsk and Vladivostok resulting in the improvement of the tsunami warning service for some areas of the Soviet Far East. Improvements are also expected in the determination of seismic parameters of potentially tsunamigenic earthquakes. Present seismic stations in the National Tsunami Warning Service are all equipped with long-period seismographs and with appropriate devices for data processing and interphasing with communication circuits.

The following sea level measuring stations have been added in the Pacific Ocean and in the Seas of Okhotsk and Japan: Petropavlovsk-Kamtchatskiy, Youst-Kamtchatsk, Bering Island, Severo-Kurilsk, Matua Island, Uroup Island, Kourilsk and Nakhodka.

To check on the reliability of operational communications and in the development of effective operational procedures, periodic training exercises and test alarms have been held in the tsunami risk zone of the far eastern coast of the USSR.

A number of improvements have been accomplished. Applied research activities have continued to contribute towards the improved efficiency of the operational Tsunami Warning Service. Standard operating plans have been developed to provide the populations and organizations of the coastal

regions of the Far East with prompt tsunami warnings. Work continues in upgrading equipment, and developments have been undertaken to automate all components of the Tsunami Warning Service. The operational use of deep water level recorders is being investigated.

Tsunami research in the USSR is directed both at the comprehensive analysis of the tsunami phenomena and at the development of tsunami protective measures for the preservation of life and property. Approximately 100 specialists from a dozen institutes participate in these activities. Dr. Beliaev then summarized some of the research findings of the last few years.

Upon conclusion of the presentations on activities and responsibilities of existing Tsunami Warning Centers and Services, a Group discussion followed.

The participants were in full agreement that to fulfill the mission of timely and effective tsunami information and warning, several operational parameters must be considered which are applicable in varying degrees to any Tsunami Warning Center. These are:

(i) Data acquisition, with seismic and tsunami data comprising separate requirements;

(ii) Data evaluation, again with earthquake evaluation and tsunami evaluations based on different data sets; and

(iii) Information dissemination, with the dual consideration of both physical transmissions of messages and the type or text of information transmitted.

General evaluation criteria for a Tsunami Warning Center must include timeliness, reliability and accuracy. These criteria can be applied differently to satisfy regional, national or Pacific-wide responsibilities.

The Workshop discussion especially stressed the need for extensive public education. It was noted that a warning system itself is not enough to protect human lives. What is also very important and vital is to bring the understanding of the real danger of tsunamis to everyone in the tsunami effected area and to educate people to what they should do to save lives in case a tsunami warning was issued. The participants stressed that the warning centres should have a responsibility to the public for such education.

Recommendation 3 was adopted (Annex II).

6. NEED FOR AND STRUCTURE OF FUTURE REGIONAL TSUNAMI WARNING CENTRES

This item was introduced by Mr. G. Dohler (Canada) past Chairman of ICG/ITSU, who provided information on the reasons which led to the understanding of the necessity of establishing new regional tsunami warning centres. Such centres would permit an improvement in the effectiveness of the Pacific Tsunami Warning System and in the development of local capabilities in identifying a tsunamigenic earthquake within a short period of time after tsunami generation, and in issuing tsunami information to

concerned government authorities for appropriate action.

In the northern area of the Pacific, tsunamis can be verified for appropriate watch and warning action in less than 20 minutes. This results in the saving of life and property within the immediate source area of the tsunamigenic event and provides also the data needed to assess the likelihood of Pacific-wide tsunami generation.

Present operating limitations of the existing 4 national and/or regional warning centres prevent from giving equivalent services to all countries within the southern Pacific.

Maintaining a proper network of reporting stations for seismic and tidal data, establishing real-time communication facilities, employing existing technologies and operating 3 strategically located Regional Warning Centers will provide the information needed to issue warnings in less than 20 minutes.

The South Pacific Tsunami Warning Centers should be modelled similar to those in existence in the USA, the USSR and Japan. It was suggested that the new warning centres should also have the capabilities in disseminating, within the area of responsibility, all tidal and seismic data, as well as providing international data centres with the required information. In addition, the communication channels of Tsunami Warning Centres could be utilized for the warning of dangerous water level changes caused by other meteorological events.

Next, Mr. E. Lorca (Chile) made a presentation on the Tsunami Hazard Reduction Using System Technology, a joint USA-Chile project known as THRUST. This 3-year project was embarked upon by NOAA to create a pilot Regional Tsunami Warning System.

The goal of THRUST is to demonstrate that Regional Systems can be assembled, using existing technology and integrated into established disaster warning and relief infrastructures in developing nations. THRUST is utilizing existing instrumentation connected to satellite communication for the establishment of an early warning system.

Mr. Lorca reported that a simple conceptual model was developed which demonstrates that many aspects of existing technology have potential applications on providing early tsunami warning information in developing nations which do not have their own regional warning network. The conceptual model includes 3 functional areas of data collection, data analysis and information dissemination. Each area is partitioned into pre-event and real-time frames. All pre-event work has been completed including hazard mapping, numerical modelling simulations and the creation of an Emergency Operating Plan. Instrumentation design has been completed and bench testing was expected to begin in the Summer of 1985.

Following this presentation, the participants discussed efforts being made to establish Regional Tsunami Warning Systems, and specifically, they expressed their appreciation for the efforts made by the IOC and its ICG/ITSU, to prepare and find funds for the project proposal entitled "Regional Tsunami Warning System in Southeast Asia", which has been

formulated, based on the findings and conclusions of the expert's mission to Southeast Asian countries (Philippines, Papua New Guinea and Indonesia) in January 1984. Several participants felt that at present, special attention should be given to the creation of a similar regional system in the Southwest Pacific on one of the island states.

The Workshop recognized the need of establishing Regional Tsunami Warning Centers in the South Pacific and elsewhere, keeping in mind that these facilities and associated tidal instrumentation, telemetry systems and communications, could also serve to monitor other natural hazards, such as storm surges, and that measurements made could also be of considerable importance for scientific research including the World Climate Research Programme. Thus, the Workshop recommended that efforts should be made for the establishment of such Regional Tsunami Warning Centers, particularly in the Southwest Pacific region.

7. OPERATIONAL PROCEDURES

Three presentations were made under this Item. A paper entitled "Tsunamis Watch and Warning Procedures" was introduced by Mr. Burton. He pointed out some responsibilities assigned to PTWC which include the issuance of Earthquake Information Bulletins and Pacific-wide Tsunami Warning Bulletins. He called attention to the detailed discussion of each of these bulletins, including text format, which is included in the Tenth Edition of the Communication Plan of the Tsunami Warning System.

In discussing operational procedures, the participants noted that certain restrictions exist in the selection and usage of the above bulletins. However, Mr. Burton explained that because of the widespread dissemination around the Pacific and the number of messages sent over various teletype circuits for any one bulletin, the text must be pre-determined for each bulletin and stored in the PTWC computer for rapid dissemination. Also, the type of message disseminated depends on pre-determined thresholds based on the earthquake magnitudes as measured on the Richter scale.

Furthermore, he commented that because of the potential for generating confusion among the TWS participants, PTWC does not have the flexibility to modify the text of present Regional Watch or Tsunamis Warning Bulletins. However, consideration is being given to modifying the thresholds on which the various bulletins are issued.

In close co-ordination with the ITIC, and using historical data developed at ITIC, the PTWC is continuing an operational analysis of the historical data to determine optimal decision thresholds for the implementation of present TWS information dissemination procedures. These analysts consist of a detailed evaluation of historical earthquake and tsunami data, on an area by area basis, comprising of homogeneous tectonic regions. Thus, analyses have been completed for coastal events in the USSR for the following regions:

(i) Sea of Okhotsk, where earthquakes are related to deep underthrusting of an oceanic plate beneath a continental plate;

(ii) Komandorsky Islands, where earthquakes are related to lateral displacement associated with 2 plates sliding past each other;

(iii) Kamchatka Peninsula, where an oceanic plate is subducted beneath a continental plate; and

(iv) Kuril Islands, where an oceanic plate is subducted beneath an island arc.

An operational analysis of the historical data indicates that the Sea of Okhotsk and the Kamandorsky Islands are not tsunami source regions, while the Kamchatka Peninsula is probably one of the most potentially threatening tsunami source regions in the Pacific Basin. For the Kuril Island chain, the central part is relatively non-tsunamigenic, while the southern part is characterized by frequent tsunamis which may be very destructive near the source region but are not destructive on a Pacific-wide basis. Consideration is being given how best to apply present information dissemination procedures to each of these areas for earthquake events of varying magnitudes.

Additional operational analyses have been completed for historical events along the coasts of Ecuador, Peru and Chile. Other areas of the Pacific are presently being studied. The basic objective of these operational analyses is twofold. The immediate objective is to implement present information dissemination procedures more effectively to address the potential tsunami threat, on an area-by-area basis. The longer term objective is to develop improved operational procedures which realistically evaluate the tsunami threat for each area, and satisfy the requirements of TWS participants in the near source region, as well as TWS participants distantly removed from the tsunami generation area.

Next, Dr. Pararas-Carayannis (Director ITIC) in his presentation, described Water Wave Reporting Procedures, stating that wave confirmation is required for the issuance of a Pacific-wide tsunami warning. Such wave confirmation is supplied by tidal stations participating in the Tsunami Warning System. Most of these stations are interrogated by the PTWC during tsunami investigations, and are given the approximate time of tsunami arrival. Tide observers at these stations report in accordance to the guidelines provided in a manual published by IOC entitled "Wave Reporting Procedures".

Essentially the information needed is water level information for a specific time-envelop in which tsunami arrival is expected. Water level data required is the net change independent of the astronomical tide. Direction of initial water level motion resulting from the tsunami, whether up or down, as well as periods of oscillations are of usefulness. Wave reporting procedures using conventional communications have inherent limitations. This method of reporting precludes good communications, availability and quick response of tide observers, and interpretations of water level changes by observers who may be inexperienced. Future automation of tide stations with satellite telemetry will allow tsunami event detection and instantaneous reporting. Such water level measuring devices are presently in operation at a few selected sites, permitting rapid water level transmission. Such automation will eventually make wave reporting by tidal observers obsolete.

The participants commented on the procedures described above and felt that a number of improvements are required to increase the reliability of the warnings. It was noted, with reference to the maximum level of 50 cm of minor tsunamis by PTWC, that a 50 cm rise in water level on top of a spring tide can result in a lot of potential problems in some areas and is therefore significant. To assist in planning purposes, there is a need in wave time of arrival information for tsunamis less than 50 cm. Such information would assist local officials to make local decisions. However, some participants expressed their view that periods of high and low tide should not be a factor because tsunami waves can run over a long period of time.

During the discussion the following additional comments were made:

(i) PTWC personnel reminded participants that tsunami messages encompass a very large area of the world with many variables including areas of storm surges, different tides, seasons and land types,

(ii) All TWC bulletins are uniformly released to all parties except for specific requests by a specific group,

(iii) Water level gauges and seismic stations should be more uniformly distributed around the Pacific rim. This would reduce the time that critical information is received at TWC, as well as it would increase the accuracy of such observations and provide a better database for historical research.

The following paper presented by Mr. R. Hagemayer (USA) looked at the process of delivering a warning to the public as a five link chain, with the links labeled as Detection, Communication, Guidance/Forecasting, Dissemination and User Response. Within the context of this presentation, "Communication" includes the Communication and Dissemination links.

The elements of operational communication were defined, and the various communication methods used by the Alaska Tsunami Warning Center (ATWC) and the Pacific Tsunami Warning Center (PTWC) for the collection of seismic and tide data were discussed. The need for a communication plan was emphasized, and the elements of an effective plan were enumerated. Two generic problems of the current plan were identified. These are the dependance on commercial telephone/telegraph/telex for the collection of confirming tide information, plus the problems in dissemination of warnings, especially the lack of complete coverage in the dissemination of watches, etc. The problem that the reliance on conventional communications caused in the handling of the 3 March 1985 Chilean Earthquake, was explained in some detail.

The presentation stressed the need to improve the method of receiving tide data after a potentially tsunamigenic event was identified. Two methods, sea bottom pressure sensors and satellite data collection platforms, were suggested as solutions. The need to improve warning dissemination was discussed with the specific suggestion regarding the acknowledgement of warning receipt and the expansion of the distribution of warnings.

Finally, during the ensuing discussion on the operational procedures, the Workshop acknowledged the value of a person-to-person exchange in effecting improvements to the TWS. The ITIC Visiting Expert Programme and the organization of other types of training exercises were specifically identified as a very important part of this activity.

8. TSUNAMI PREPAREDNESS

In a presentation entitled "Tsunami Hazards Analysis, Tsunami Hazard Planning, Protection Measures, Tsunami Exercises and Public Education", Dr. Pararas-Carayannis (Director ITIC) pointed out that the history of tsunami vulnerability of a coastal area forms the basis for the Tsunami Hazard Analysis. Numerical and hydraulic modelling studies can also provide a measure of the potential impact of a tsunami. While tsunami cannot be presented, their effects on the loss of human life and property can be migitated by proper planning and understanding of the combined physical, social and cultural factors. In developing coastal zone management and land use policy, the likelihood of a tsunami should be considered. While some degree of risk is acceptable, government agencies should promote new development and population growth in areas of greater safety. The best protective measure is the existence of a Regional Tsunami Warning Center that works closely with Civil Defense and other government authorities, in disseminating prompt tsunami warnings. The Tsunami Warning System can only provide warning information. It is the responsibility of the local government to disseminate convincingly the warning to the population and arrange for evacuation of a threatened area. Ample time must be allowed for evacuation which often is a rather difficult procedure. Often the public does not understand the meaning of the warning signals and is not aware of the danger areas. Most people are reluctant to evacuate their homes and business, and their response to warning in general may not be very good, particularly if a number of false warnings have been issued in the past.

Tsunami hazard perception by the people of a coastal area is based on education and confidence in government agencies responsible for tsunami prediction and protection. Over warning based on inadequate knowledge of the phenomenon or inadequate data in which to base the prediction, often leads to false alarms and lack of compliance with warning and evacuation attempts.

In the complimentary paper by Mr. Wigen on Tsunami Preparedness, he mentioned that special attention has been given to specific problems existing in Canada. He mentioned that 2 exercises on procedures have been completed. Tsunami warning procedures is the responsibility of Civil Defense Agencies.

Each of the ICG/ITSU Member States has the responsibility of carrying out a tsunami hazard evaluation of the reported event; of making decisions on the safety procedures or evacuation required within the area of their jurisdiction; and of communicating decisions to responsible persons in threatened coastal communities.

Next, Mr. J. Kuroiwa (UNDRO), presented a paper on "The Investigation for Tsunami Hazard Migitation in Developing Countries". His presentation was on examples of 2 studies made in Peru, on seismic microzonation and vulnerability of Metropolitan Lima. These studies had shown the necessity to

investigate the tsunami effects on the 100 kms of Metropolitan Lima's sea shore. The run-up, the inundation zones, and the arrival time of locally-generated tsunamis were determined for urban planning purposes, and for the preparation of realistic evacuation plans for people living in inundation built-up areas. To verify the soundness of the method used and the assumed hypothesis, the numerical results were checked with actual records and historical data. The comparison was very satisfactory in spite of the fact that the method used was only practical and unsophisticated.

The Workshop concluded that public education contributes greatly to hazard perception by the people of coastal areas, and results in a heightened community awareness of the potential threat of tsunami, thus, rendering greater effectiveness to the Tsunami Warning System. They recommended support of an educational programme on tsunamis aimed at the general public.

9. TSUNAMI RESEARCH

Brief reviews of the status of tsunami research were presented by Drs. T.S. Murty (India), G. Hebenstreit (USA) and S. Soloviev (USSR). The first presentation by Dr. Murty was an overview of the status of tsunami research as it related to topics of his interest. Specifically, he discussed research results dealing with phase and amplitude dispersion of tsunamis (nonlinear effects), energy relationships between earthquakes and tsunamis, as well as problems of propagation, and finally with the potential of tsunami generation from potential large earthquakes in regions of seismic gaps.

Dr. Hebenstreit commented on the use of numerical tsunami models in operating warning environments. Specifically, he discussed the development, testing and application of tsunami computer models primarily for research purposes, and the existing need to integrate such models into tsunami warning operations. Furthermore, he outlined the feasibility of operational numerical models using mini-computers and the new powerful micro-computers.

Finally, Dr. Soloviev covered the short-term prediction of tsunamis using principles of seismology and hydrophysics. Specifically, he reviewed the seismic source parameters, such as magnitude and crustal deformation and their effects on tsunami generation and intensity. Although short-term tsunami prediction by seismic methods is of statistical-empirical nature, new sensor technology and instrumentation permits the direct measurement of important tsunami parameters for better tsunami prediction.

Based on the following discussions, the Workshop adopted Recommendations 4 and 5. (Annex II).

10. TSUNAMI INSTRUMENTATION

Seismological and water level measuring devices are the primary instruments used in tsunami analysis and prediction. A presentation on seismological instrumentation was made by Dr. Katsumata, and a presentation on Water Level Measuring instrumentation was made by Dr. Dohler. Dr. Katsumata described seismic instrumentation used in Japan for the Tsunami Warning System in that country, which represents the state of the art. Specifically, he described the used of seismic instrumentation in tsunami

warning operations, the development of computer, methodology for processing seismic data, and the use of an advanced ocean bottom seismograph system, off the southeastern coast of Boso Peninsula.

Mr. Dohler commented on the different types of water level measuring instrumentation in existence today, and its use in tsunami warning operations.

Other important aspects of water level measuring instrumentation in the form of deep ocean tsunami gauges were discussed by Dr. E. Bernard (USA) making reference to ongoing research in the USA using such devices. Dr. Pararas-Carayannis and Mr. Burton presented interesting overviews of telemetry systems used in tsunami warning operations. Specifically, they covered satellite and ground telemetry for both data collection and communication making reference to the deployment of Handar instrumentation in the Pacific for monitoring continuously sea level as part of the global sea level monitoring programme. The Tsunami Warning System has derived tremendous benefits from this real-time sea level monitoring which uses automated platforms and satellite telemetry. Signal processing of the sea level data transmitted via satellite and analyzed by computer has greatly contributed to the effectiveness of the Tsunami Warning System. Remote sensing methods of monitoring tsunamis from space stations were reviewed making reference to such observations of the 1983 Japan Sea tsunami.

11. GENERAL EXCHANGE OF VIEWS AND WORKSHOP APPRAISAL

Following the conclusion of the presentations, an open forum was called by the Chairman, urging a general exchange of views among lecturers and participants for the purpose of identifying action items and problems which may have been brought into focus during the conduct of the Workshop. Furthermore, the Chairman requested an analytical and constructive discussion of existing problems and the means by which such problems can be overcome. As a result of this exchange of views, a number of operational problems were resolved, and additional needs of ICG/ITSU Member States were identified by the participants.

An appraisal was undertaken by the lecturers and participants, expressing their views as to the overall conduct of the Workshop, the comprehensiveness of its programme and its usefulness. It was the consensus of opinion of all the participants that the Workshop was very well conducted, that it was properly balanced it its content and that there is a need to repeat such training at frequent intervals to keep up with new methodology, instrumentation and research progress.

12. ADOPTION OF THE REPORT

Following the conclusion of the Workshop, the draft proceedings were read by the Chairman and adopted in principle by the participants. The Workshop gave editorial license to the Chairman and the Rapporteur to finalize a Summary Report of the Proceedings with the assistance of the IOC Secretariat. The Workshop furthermore recommended that its Report be published by the IOC in its Workshop Series in 2 parts, as agreed. The Summary Report proper and a Supplement containing the full selected papers presented at the Workshop.

13. CLOSURE OF THE SESSION

The Chairman of the Workshop expressed his satisfaction at the successful outcome of the Workshop. He thanked all the lecturers and participants for their valuable contributions and co-operation and congratulated them for having arrived at such important conclusions and recommendations.

On behalf of the participants, he expressed his special thanks to the Canadian authorities for hosting the meeting, the Director of the Institute of Ocean Sciences for providing the fine meeting facilities and to Dr. Wigen for co-ordinating local arrangements which contributed to the success of the Workshop.

A spokesperson for the Group expressed appreciation to all the lecturers for their presentations and thanked the Workshop Chairman, Dr. Pararas-Carayannis for his outstanding direction of the overall Workshop programme. Furthermore, the Group thanked Dr. Oliounine, Senior Assistant Secretary of IOC, for his assistance at the Workshop and asked him to extend the Group's appreciation to the IOC Secretary, Dr. M. Ruivo for the Secretariat's support and for the Commission's sponsorship of the First IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications.

ANNEX I

PROGRAMME OF THE WORKSHOP

1. INTRODUCTION

1.1 IOC - Role in the Tsunami Warning System (I. Oliounine, G. Pararas-Carayannis)

1.2 ITSU - Role and Significance of the International Co-ordination Group for the Tsunami Warning System in the Pacific (N. Ridgway)

2. TSUNAMI DATA COLLECTION

2.1 Historical Data Collection (G. Pararas-Carayannis)

2.2 Historical Study of Tsunamis (S. Wigen)

c. Tsunami Data Bases (J. Lander)

3. ACTIVITIES AND RESPONSIBILITIES OF EXISTING TSUNAMI WARNING CENTERS

3.1 Pacific Tsunami Warning Center (G. Burton)

3.2 Hawaii Regional Tsunami Warning Center (G. Burton)

3.3 Alaska Regional Tsunami Warning Center (T. Sokolowski)

3.4 Japan Tsunami Warning Center (N. Yamakawa)

3.5 USSR Tsunami Warning Center (S. Soloviev)

4. NEED FOR AND STRUCTURE OF FUTURE REGIONAL TSUNAMI WARNING CENTRES (G. Dohler)

4.1 "THRUST" Programme (E. Lorca)

5. OPERATIONAL PROCEDURES

5.1 Tsunami Watch and Warning Procedures (G. Burton)

5.2 Water Wave Reporting Procedures (G. Pararas-Carayannis)

5.3 Communication Plans (R. Hagemeyer)

6. TSUNAMI PREPAREDNESS

6.1 Tsunami Hazard Analysis, Tsunami Hazard Planning Protective Measures, Tsunami Exercises and Public Education (G. Pararas-Carayannis, S. Wigen)

6.2 The Investigation of Tsunami Hazard Migitation in Developing Countries (J. Kuroiwa)

7. TSUNAMI RESEARCH

7.1 Overview of the State of Tsunami Research (T. Murty)

7.2 Modelling and Numerical Techniques (G. Hebenstreit)

7.3 Seismological and Hydrophysical Foundations of the Short-Term Tsunami Prediction (S. Soloviev)

8. TSUNAMI INSTRUMENTATION

8.1 Seismological Instrumentation (N. Yamakawa)

8.2 Water Level Measuring Instrumentation (G. Dohler)

8.3 Deep Ocean Tsunami Gauges (E. Bernard)

8.4 Telemetry Systems (Satellite and Ground Telemetry for Data Collection and Communication-Signal Processing) (G. Pararas-Carayannis, G. Burton)

ANNEX II

RECOMMENDATIONS

Recommendation 1

HISTORICAL DOCUMENTATION OF TSUNAMIS

Recognizing the value of historical data collection in understanding the Tsunami phenomenon, and the importance of the historical database for operational analysis, the Workshop recommends that historical documentation of tsunamis should be compared and that a database format be established to serve as a comprehensive standard in the collection of seismic and hydrologic parameters of historical tsunamis.

Recommendation 2

TSUNAMI GLOSSARY

Recognizing that a diversity of terms is used in describing the tsunami phenomenon which involves a wide variety of scientific and non-scientific groups in a variety of interdisciplinary fields, the Workshop recommends the preparation of a glossary of tsunami-related terms to serve as the basis for defining and understanding tsunami terminology.

Recommendation 3

TSUNAMI PREPAREDNESS AND PUBLIC EDUCATION

In reviewing tsunami preparedness in the Pacific, and in recognizing the importance of education in hazard perception by the public rendering greater effectiveness to the TWS, the Workshop stressed the need for extensive public education and recommends the support of an educational programme on tsunamis aimed at the general public.

Recommendation 4

CORRELATION OF EARTHQUAKE AND TSUNAMI INTENSITIES

The Workshop recommends that scientists undertake the necessary research to correlate intensity of felt earthquakes on the shore with the probability of tsunami run-up and to provide this information to the TWS for the purpose of warning the population in those earthquake coastal regions where the effects are felt.

Recommendation 5

TSUNAMI PROBABILITY ESTIMATE

The Workshop recommends the investigation in the correlation of time-amplitude range of p-wave oscillations at different epicentral distances and of different frequency pass bands to the tsunamineity of earthquakes and use this parameter, in addition to the earthquake magnitude, as a measure of tsunami probability.

ANNEX III

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ANNEX IV

LIST OF ACRONYMS

ADESS	Automated Data Editing and Switching System
AID	U.S. Agency for International Development
ATWC	Alaska Tsunami Warning Center
DCP	Data Collection Platform
ETO	Earthquake and Tsunami Observations
JMA	Japan Meteorological Agency
ICG/ITSU	International Co-ordination Group for the Tsunami Warning System in the Pacific
ITIC	International Tsunami Information Center
IOC	Intergovernmental Oceanographic Commission
L-ADESS	Local Automated Data Editing and Switching System
POBS	Permanent Ocean Bottom Seismograph
PTWC	Pacific Tsunami Warning Center
THRUST	Tsunami Hazard Reduction Using System Technology
TWS	Tsunami Warning System
WDC-A	World Data Center-A

No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Improved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40 Suppl.	Submitted papers to the First International Workshop on Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29 July - 1 August 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English