Intergovernmental Oceanographic Commission
Reports of Governing and Major Subsidiary Bodies

International Co-ordination Group for the Tsunami Warning System in the Pacific

Twelfth Session

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Unesco

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This document has been printed in English French, Spanish and Russian, except for the annexes, which appear in English only.

1. ORGANIZATION OF THE SESSION

1 The Chairman of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), Mr. R. H. Hagemeyer, opened the Twelfth Session on 7 August 1989, at the Computing Center of the Siberian Branch of the USSR Academy of Sciences, Novosibirsk (USSR).

2 Dr. A. P. Metalnikov, Head of the USSR delegation and the Deputy Chairman of the USSR State Committee for Hydrometeorology, on behalf of Academician A. S. Alekseev, Director of the Computing Center of the Siberian Branch of the USSR Academy of Sciences, welcomed the participants.

3 On behalf of the Secretary IOC, Dr. G. Kullenberg Dr. A. Tolkachev, Senior Assistant Secretary of IOC, welcomed the participants, and expressed gratitude to Academician A. S. Alekseev and his colleagues from the Computing Center and Dr. A. P. Metalnikov, Deputy Chairman of the USSR State Committee for Hydrometeorology, for the provision of facilities and the excellent arrangements made for the session.

4 The Agenda was adopted and is given in Annex I.

5 Mr. D. J. Sigrist, USA, was designated Rapporteur for the Session.

6 The Senior Assistant Secretary introduced a list of documents and the proposed timetable. Then the representative of the local organizing committee, Dr. V. Gusiakov, informed the participants of the local arrangements.

7 The List of Participants is shown in Annex III.

2. INTERSESSIONAL ACTIVITIES

8 The Chairman introduced the joint report of the Chairman ICG/ITSU, and the Senior Assistant Secretary IOC, on Intersessional Activities since September 1987. Referring to document IOC/ITSU-XII/6, he highlighted the following points:

(i) As approved by ITSU-XI: the "Master Plan for the Tsunami Warning System of the Pacific" was published by Canada, the Eleventh Edition of the Communications Plan, plus the first and second changes to that Edition, were published by the U.S. (NOAA), and the preparation of the Tsunami Brochure was completed by the ITIC and published by the IOC.

(ii) The Chairman attended the Twenty-first Session of the IOC Executive Council (EC) in Paris, 7-15 March 1988, and presented the report of the Group's activities at ITSU-XI. The EC expressed satisfaction with the results achieved by the Group, accepted the Summary Report, and approved the recommendations of ITSU-XI, particularly the amendment to the Mandate of the ITIC and of the Tsunami Programme and Priorities for 1988-1989.

(iii) The Chairman and the Director, ITIC, at the request of Unesco, attended a meeting of experts held in IOC Headquarters, 14-17 March 1988, for the purpose of advising Unesco on how they could structure the medium-term plan to enable Unesco to better meet the objectives of the International Decade of Natural Disaster Reduction.

(iv) During early April 1989, the Chairman and the Senior Assistant Secretary met in Honolulu with members of the Tsunami 89 Organizing Committee, the Director, ITIC, and Dr. Bernard, Chairman of the IUGG Tsunami Commission, to finalize the agenda for the three elements of Tsunami 89 and to review work on the Tsunami Glossary.

(v) During the intersessional period, experts from Colombia, Peru, Mexico and the USSR received intensive training at the ITIC and the PTWC.

(vi) In late April 1989, Drs. Shokin and Chubarov, from the Krasnoyarsk Computing Center, met in Honolulu with the Director, ITIC, and GIC, Pacific Tsunami Warning Center, to review work to date on the Tsunami Travel Time Charts and to consider further actions required to produce the Atlas desired by the Group.

(vii) In spite of the appeals to Member States to provide additional funds in support of the Group's activities, funding is still a serious problem. Additional support from Member States will be necessary if the Group is to be able to implement the activities included in the Tsunami Programme and Priorities for 1988-1989. Similarly, attempts to have a Member State second someone as the Associate Director, ITIC, were unsuccessful.

(viii) Responding to an expression of interest by the UNDP to the Regional Warning System in Southwest Pacific, IOC organized a mission for project formulation in May 1989. Dr. George Pararas-Carayannis led the Mission, and was accompanied by Mr. Ronald Richmond of Australia and Dr. Kazuhiro Kitazawa, Assistant Secretary IOC. A five-year plan for project implementation is now being formulated for submission to the UNDP.

9 The National Reports were presented by Australia, Canada, Chile, China, Fiji, Guatemala, Hong Kong, Japan, Mexico, New Zealand, United States of America, Republic of Korea and USSR and were made available to the participants. The Chairman again stressed the need for timely submission of National Reports at least two months before the next session of ICG/ITSU.

10 Dr. George Pararas-Carayannis, Director of the International Tsunami Information Center (ITIC), presented the ITIC Progress Report for 1987-1989 to the participants. The Progress Report contains information on ITIC activities, such as

(i) Tsunami Investigations,
(ii) Tsunami Warning System Automation,
(iii) Regional Tsunami Warning Systems,

(iv) New Reporting Stations,
(v) Liaison Activities,
(vi) ITSU Membership,
(vii) Training and Workshops,
(viii) Tsunami Travel Time Charts,
(ix) Visiting Scientists Programme,
(x) Educational Materials,
(xi) Historical Tsunami Database, and
(xii) ITIC Sponsorship of Scientific Symposia and Conferences. This matter was further considered under item 7.

11 The Delegate from Chile informed the participants that the proceedings of the THRUST (Tsunami Hazards Reduction Utilizing Systems Technology) Project Workshop, 1988, were made available to the participants.

3. IMPLEMENTATION OF RESOLUTIONS AND RECOMMENDATIONS OF THE ELEVENTH SESSION OF THE ICG/ITSU (Beijing, September 1987)

3.1 TSUNAMI TRAVEL TIME CHARTS

12 Dr. Y. Shokin, Director of the Krasnoyarsk Computing Center of the Siberian Branch of the USSR Academy of Sciences, reported on the preparation of the Atlas of Tsunami Travel Time Charts. The Center prepared 100 copies of the Atlas and it was made available to the participants. Interactive software for displaying tsunami travel times was shown on a personal computer. **The Group expressed** appreciation for the excellent work done by the Center in the preparation of the Atlas. **The Group agreed** that the IOC Secretariat would communicate with the ITSU National Contacts to determine the number of copies of the Atlas to be provided to each Member State and arrange for its distribution.

13 **The Group noted** with satisfaction that the Atlas includes, for the first time, the charts for all sea-level stations of the Pacific Tsunami Warning System (PTWS) and can be used by national tsunami warning services as well as for research purposes.

14 **The Group also requested** the Krasnoyarsk Computing Center, through appropriate arrangements with IOC, to provide algorithms and software for tsunami travel time calculations with the use of personal computers to interested countries and organizations.

3.2 GLOSSARY OF TSUNAMI RELATED TERMS

15 The Director ITIC reported on the preparation of the Glossary following recommendations made by the Eleventh Session of ICG/ITSU. The list of the terms proposed to be included in the Glossary was made available to the participants. **The Group noted** that there was a divergence of opinion as to what terms should be included. The Chairman appointed a sessional group to review the proposed terms and to report to the Session those terms that are to be included in the first edition. **The Group accepted** the conclusions of the sessional group, thanked them for their efforts, and recommended that the first edition should be published without further delay.

3.3 DATA BASE FORMAT

16 The Director of ITIC reported on the status of the development of the format and supporting software which permits the use of the recent work on historical tsunami data base. Japan reported on the recent work on historical tsunamis in Japan and the need to incorporate this information in the data base. In the discussion on this agenda item, the Group reconfirmed that the format was approved at the Eleventh Session of ICG/ITSU and also expressed the desirability of having this data base and its associated software placed in the hands of the Member States as quickly as possible. The Chairman indicated that he and the Secretariat working with the Director ITIC, would establish a target date for the distribution.

3.4 COMMUNICATION PLAN

17 Mr. G. Burton, the Geophysicist-in-Charge of PTWC, reviewed the activities on the publication of the eleventh edition of the Plan and the first two Changes. The preparation, publication, and distribution of the eleventh edition of the Communication Plan for the Tsunami Warning System was completed in December 1987. Change 1 was distributed in September 1988, and Change 2 in June 1989. The Group expressed appreciation for the work carried out by the Geophysicist-in-Charge (GIC) of PTWC and also expressed appreciation to the individual Member States for the input they have provided to the Communication Plan and the subsequent changes. The Geophysicist-in-Charge, PTWC, indicated his intent to continue to issue periodic changes as the Member States provide updated information. The Chairman invited Member States to review the current plan and provide any changes on information that has taken place in a timely fashion.

3.5 TSUNAMI BROCHURE

18 The Director ITIC, reported on the preparation and publication of the Tsunami Brochure which was given wide distribution in 1988. The Group expressed appreciation to the Director ITIC, and to the IOC for this effort. It was noted that there are still a large number of copies available through ITIC. The Group agreed to pursue the request from the Delegate from Mexico to have the brochure printed in Spanish.

3.6 CO-OPERATION WITH OTHER INTERNATIONAL BODIES

19 The Chairman reported on his discussions with Dr. Klaus Wyrtki, Director, IGOSS Specialized Oceanographic Center for Sea Level Programme in the Pacific (SOC/ISLP Pac), and their agreement that the co-operation between SOC/ISLP Pac and ICG/ITSU was at an optimum level. Under this item, Dr. A. Tolkachev informed the ICG/ITSU on the implementation of the IOC Global Sea-Level Observing System (GLOSS) and the close co-ordination of this activity with the tsunami sea level monitoring programme. The implementation plan for GLOSS was made available to the participants of the Session. The Group urged each National Contact for ITSU to establish a working relationship with the National GLOSS contact.

20 The Director ITIC reported on participation in the Third International Conference on Natural and Man-made Hazards in Coastal Zones, co-sponsored by ITIC and the Tsunami Society at San Diego, USA and Ensenada, Mexico, on 14-21 August 1988, and the UNDRO-sponsored workshop in Ecuador in June 1988. He also reported on the Third Pacific Congress of Marine Science and Technology (PACON 88) held in Honolulu, USA, in July 1988 and on the XIII European Geophysical Society Meeting held in Bologna, Italy, in March 1988. The Group noted with satisfaction these activities and wished to encourage further co-operation and interaction of this nature.

21 Dr. M. El-Sabh (Canada) reported on the foundation of two international organizations involved in tsunami mitigation and research. A new professional society for natural hazards mitigation was founded at Ensenada, Mexico, in August 1988. The objectives of the International Society for the Prevention and Mitigation of Natural Hazards (NHS) are to promote research in all aspects of natural hazards, the distribution of preparedness and emergency response plans for all countries, and the formulation and implementation of education programmes on hazards prevention and mitigation. "Natural Hazards" is now the official scientific publication of the new society. It is of interest to note that about 25% of the editorial Advisory Board are tsunami experts. The journal has published a summary of the ITSU Master Plan for the Tsunami Warning System in the Pacific in addition to several scientific articles on tsunami generation, propagation and mitigation.

22 The Society shall hold at least one international meeting every 2 years in different parts of the world, with special symposia on topical natural disaster events or natural hazard studies. In addition, NHS will co-sponsor appropriate scientific meetings, summer schools and workshops organized by other bodies. The next general assembly will be held in India in December 1990 with a special symposium dealing with tsunami hazards. Furthermore, sections of NHS are now organized at different parts of the world to increase communications between scientists, policy makers and other people engaged in natural hazards research and the prevention and mitigation of natural hazards.

23 Responding to the United Nations designation of the International Decade for Natural Hazard Reduction, the Executive Committee of the International Association for the Physical Sciences of the Oceans (IAPSO) meeting in August in Acapulco, Mexico, established a Commission on Natural Marine Hazards, with particular emphasis on tsunamis, storm surges, severe waves, biotoxins, and other marine hazards. The terms of reference are: (i) to support and interact with other bodies interested in natural marine hazards; (ii) to encourage scientific research in all types of natural and man-made marine hazards to provide basic knowledge and understanding on the causes and ramifications of such hazards on the quality of human lives; (iii) to convene working groups and occasional and regular international conferences; (iv) to encourage exchanging the results of scientific research and provide a forum for the open discussion of pertinent and relevant subject matter of international interest, concern and significance; and (v) to formulate scientific consensus regarding mitigation of such hazards.

24 Dr. M. El-Sabh, President of the above-mentioned two international organizations, assured the Group of his full co-operation in all aspects relevant to tsunami operations, research and mitigation.

25 The Director, ITIC, brought to the attention of the Group that there has not been an increase in the membership of ITSU since the Eleventh Session ICG/ITSU and of the need to involve more Pacific states such as Papua New Guinea, Solomon Islands, Republic of the Marshall Islands, Tuvalu, Republic of Palau, and Federated States of Micronesia, to become involved in ITSU. The Group, therefore, recommended to invite other Pacific states to participate in the activities of ITSU and to nominate National Contacts.

4. IMPROVEMENTS OF THE TSUNAMI WARNING SYSTEM

4.1 DEVELOPMENT OF REGIONAL TSUNAMI WARNING SYSTEMS

26 Dr. K. Kitazawa, IOC Assistant Secretary, reported on the preparation of the project for the sub-regional Tsunami Warning System in the Southwest Pacific. The idea of establishing such a regional system was first brought up by the ICG/ITSU at its Sixth Session held in Manila (Philippines), in February 1978. In response to a strong request from ITSU expressed at its Eighth Session, Suva (Fiji), in April 1982, IOC organized, with financial assistance of the Japanese government, a feasibility study mission to the Philippines, Indonesia and Papua-New Guinea in 1984 (Doc. IOC/ITSU-IX/11) and prepared a project document which was submitted to UNDP for consideration and funding. Only in March 1989, a favorable response was received from UNDP. Upon due request of UNDP, IOC dispatched a project formulation mission to the region, including the Philippines, Indonesia, Papua-New Guinea, the Solomon Islands, and Fiji in May 1989. The results of the mission were well accepted by UNDP which advised IOC to finalize a project document according to the findings of the mission taking into account (i) a 5 - 6 years project period, (ii) the expansion of target area to South Pacific island countries, and (iii) a possible co-operative participation of industrialized countries with financial and/or technical assistance.

27 The project expects outputs of (i) denser network of automated tide gauges and seismic stations, (ii) rapid communication system among seismic and tide stations and tsunami warning centers at the national and regional level, (iii) operational manuals for tide and seismic stations as well as tsunami warning practice, and (iv) trained local experts to operate the system. The project will be executed by Unesco through IOC with technical assistance of ICG/ITSU and IUGG Tsunami Commission, and its achievement, particularly scientific and technical components of the project, will be reviewed periodically by a Group of Experts from these organizations.

28 The Director, ITIC, reported on the preparation of the UNDP Five Year Master Plan for the Development of a Regional Tsunami Warning System in the Southwest Pacific. The Group noted with appreciation efforts made by IOC Secretariat in preparation of this project and agreed to provide technical advice in implementing this project.

29 The **Group agreed** that the Five Year Master Plan, once approved, be distributed to all ITSU Member States with the request that they review it and indicate, to the IOC Secretariat, their willingness to provide possible assistance in implementing the plan and an expression of interest in participating in the activities of the Advisory Group. **It also noted** that the expertise of the IUGG Tsunami Commission will be sought for this purpose.

30 The **Group welcomed** the report and appreciated efforts made by the IOC Secretariat in drafting the document and negotiating with UNDP for funding. It expressed full support for the proposal and, at the same time, encouraged IOC Secretariat to obtain definite commitment from UNDP and begin implementation as early as possible. The Group invited all ITSU Member States to seek possible ways and means to encourage proposed project activities.

31 The Delegate from Mexico informed the participants that two years ago a proposal for a Mexican National Tsunami Warning System had been presented to the Secretary of Telecommunications of Mexico. The system had a similar structure to THRUST and was based on the use of the Mexican Telecommunication Satellite MORELOS. This satellite is presently under utilized and has an area of operational coverage including not only Mexico, but also Guatemala, El Salvador, Nicaragua, Costa Rica and Panama. The system was not implemented due to lack of funds, expertise in the field, and moreover non-existence of Civil Protection Agencies in charge of hazard assessment, preparedness, and mitigation policies in Central American countries.

32 The Delegate from Mexico recommended that ICG/ITSU consider developing a project on Real-Time Regional Tsunami Warning System for Mexico and Central America as a contribution to IDNDR. This will also provide an opportunity to incorporate all Central American countries who are at this stage, non-members to ITSU, and who are also in real need of a National or Regional Tsunami Warning System for their coastal communities in the Pacific.

33 Considering the fact that the majority of catastrophic damages are created by tsunamis occurring within 30 minutes and 400 kilometers from their source, the **Group recommended** IOC Secretariat to consider establishing a similar regional warning system in Central America which would benefit not only the countries in this region but also to the Pacific as a whole.

34 The USSR delegation informed about the creation of a new USSR State Commission for response to emergency situations. The USSR State Committee for Hydrometeorology, responsible for tsunami warning services, now operates under supervision of this commission. The Group was informed that a seismic sub-system was completed as a first step in the Integrated Automatic Tsunami Warning System. Testing of the seismic sub-system began on 1 June 1989, with operational testing of the entire system by the end of 1990. The use of geostationary communication satellites is planned for the transmission of tsunami data.

35 The Representative from New Zealand reported on disaster preparedness activities in New Zealand and Indonesia. He further reported on a visit to Indonesia by New Zealand and Australian experts, providing advice on establishing a National Civil Defence Headquarters in Jakarta. Visits to New Zealand by Indonesian civil defence personnel have taken place in February 1989 and have included attendance at the New Zealand National Civil Defence School to study methods of disaster planning and preparedness.

36 The Group agreed with the proposal made by the Delegate of the DPR of Korea on the need for regular testing of existing communication's systems in their area for dissemination of tsunami warning information. This should include the DPR of Korea, China, USSR, Japan and USA as a group.

4.2 STANDARD OPERATIONAL PLAN FOR NATIONAL TSUNAMI WARNING SYSTEMS

37 The Delegate of Chile reported on the results of the testing of the Chile National Operation Plan. During the Eleventh Session of ICG/ITSU in Beijing (China) the Group requested Chile to test the Plan and to report the results of such a test at the current session in Novosibirsk.

38 The test was performed in a three day session in Valparaiso with participation from the National Emergency Office (ONEMI), which organized the exercise and designed the scenario for the test. Participants from several Regional Emergency Offices attended as observers; meanwhile members of Valparaiso Regional Emergency Office had active participation. It was detected on the first day of the test that the tsunami emergency procedures could not be applied at the community level. The second day of the session was dedicated to examining the problem and a decision was taken to apply every emergency action and co-ordination at the community level. On the last day of the session, a new scenario was used and a good reaction from the involved community emergency stations was detected. As a result of this, the original Standard Operation Plan for Chile was modified and adopted to be applied for every coastal town in Chile. The final English language version of the Plan was submitted to the Group, and a floppy diskette with the English and Spanish version was provided to Director ITIC during the Session.

39 The Group expressed its appreciation to Chile for excellent and efficient work performed. Recognizing that national plans can be different in each particular country, the Group, nevertheless, felt that the National plan prepared by Chile can be used by other member states as guidance for preparation of their national tsunami plans and recommended its use for this purpose as much as possible.

4.3 APPLICATION OF NEW NUMERICAL METHODS FOR NEAR-REAL TIME TSUNAMI FORECASTS

40 Dr. V. Gusiakov of the Novosibirsk Computing Center presented a report on the interactive application programme for numerical modelling of tsunami generation and propagation in the ocean with real bathymetry, developed by the Novosibirsk Computing Center.

41 The application software operates on the 32-bit minicomputer "Labtam 3215" under the UNIX operating system. For the simulation of tsunami propagation in the framework of a nonlinear shallow water model the system uses a specially elaborated numerical algorithm based on the splitting method and variable computational grids. An algorithm of this type, diminishes computer time 5 to 6 times in comparison to the conventional finite-difference methods.

42 The basic functions of the programme are as follows: (i) automatic construction of the computational grids for the specific areas from the regional bathymetric data base; (ii) computation of the initial displacement in the tsunami source on the basis of preliminarily chosen or operationally estimated seismic source data; (iii) computation and plotting of tsunami travel time charts; (iv) computation of wave forms at any coastal or marine nodes of the computation grids; (v) obtaining and plotting of the distribution of the maximum tsunami heights along the coast.

43 The programme can be modified for the application on 32-bit personal computer models of the 80386 microprocessor line. It can be used in an operational manner for the pre-estimation of expected tsunami heights at the coast, fast calculation of tsunami travel times, for estimation of the position and dimension of zones for tsunami warnings and for a more precise estimation of times of issuing and cancellation of warnings for different parts of the coast.

44 The representatives of the Krasnoyarsk Computing Center (USSR) reported on the development of mathematical models, computational algorithms and software for numerical modelling of the propagation and run-up of tsunami waves and for the calculation and display of tsunami travel times. Some of these algorithms and software were used for developing tsunami inundation zones of the far east coast of the USSR. The main part of this software has been adapted for use on (IBM compatible) personal computers. This software was demonstrated to the participants of the Session. The Group was informed that the Computing Center would be willing to develop above-mentioned computational programmes for IBM-compatible '386' class microcomputers and to prepare a plan for the future support of their investigation.

45 The Group expressed appreciation to both Novosibirsk and Krasnoyarsk Computing Centers of the USSR Academy of Sciences for the work regarding the use of microcomputer techniques for numerical forecasting of tsunami parameters in an operational mode. The Group noted that modelling methods developed by other countries had been discussed during the IUGG Tsunami Symposium.

46 It was recognized that one of the serious problems in numerical modelling for tsunami prediction is in defining the shape of the source region. After extensive discussion of advantages and disadvantages of the various methods, the Group agreed that modelling efforts should be continued and the results exchanged between countries. The Group adopted Recommendation ITSU-XII.1.

4.4 EXPERIENCE AND RESULTS OF TSUNAMI WAVE MEASUREMENTS IN THE OPEN SEA

47 The Chairman reported upon his investigation on the use of satellite altimeters to measure tsunamis in the open ocean. He noted that while the instruments currently in orbit are able to identify and track Rossby and Kelvin waves across the Pacific Ocean, the problem of tracking tsunamis was complicated by their fast movement. Tsunamis cross the Pacific Ocean in 24 hours while Rossby and Kelvin waves require two months or more. Another complicating factor is the inability to process the altimetry data in anything approaching real-time. The European satellite, ERS-1, due to be launched in 1990, will have a real-time processing capability. He noted that there is no current research on tsunami using satellite altimeters and it is not known if any is planned using ERS-1. The Chairman's complete report can be found in Annex IV.

48 The Group noted that a number of papers on this subject had been given at the preceding Tsunami Commission of the International Union of Geodesy and Geophysics (IUGG) Tsunami Symposium and the IOC Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation (Novosibirsk, 4-5 August 1989).

4.5 SEISMIC DATA TRANSMISSION BY SATELLITE

49 A summary was provided by Mr. G. Burton, the Geophysicist-in-Charge of the Pacific Tsunami Warning Center (PTWC), on recent efforts to implement operational transmissions of seismic data via Geostationary Operational Environmental Satellite (GOES). The PTWC has entered into a joint programme with the National Earthquake Information Center (NEIC) of the Geophysical Services of the United States (USGS) to interface seismometers to remote Data Collection Platforms (DCP's) at strategic locations in the Pacific Basin. Initial efforts will use a French manufactured microprocessor to function as a "P-picker" in determining seismic P-wave arrivals. The P-picker will be interfaced to a DCP for GOES transmission, using existing DCP's when possible. The USGS/NEIC is presently installing ground stations at NEIC to receive the data directly from GOES, while the seismic data will be relayed via the National Weather Service (NWS) circuits to PTWC on a near real-time basis.

50 Co-ordinated procurements are presently being completed at PTWC and NEIC to allow for field deployment of initial systems by the end of 1989 for test and evaluation. Operational deployment of a series of seismic DCP's will greatly reduce PTWC's response time to earthquake events and greatly improve the accuracy of epicenter determinations.

51 The Group expressed its appreciation to Mr. G. Burton, the Geophysicist-in-Charge, and its interest in following the development of this interesting addition to the Tsunami Warning System of the Pacific.

4.6 IMPLEMENTATION OF RESOLUTION ITSU-VIII.3

52 At its Eighth Session, the ICG/ITSU adopted Resolution ITSU-VIII.3, calling on PTWC to issue time-stepped Regional Tsunami Warnings directly based on earthquake evaluation, only. Due to operational concerns expressed by PTWC, the Regional Warning Concept was modified to a Regional Watch.

53 Mr. G. Burton, the Geophysicist-in-Charge of PTWC, presented a summary of operational improvements at PTWC which have taken place in recent years. As a result of this improved capability, PTWC initiated full implementation of Resolution ITSU-VIII.3 as of 1 June 1989. For events exceeding the designated earthquake magnitude threshold, PTWC will issue a Regional Tsunami Warning for the area encompassed by the first 3 hours of tsunami travel-time, with a Watch extending for the 3 to 6 hour travel time period.

54 Implementation of ITSU-VIII.3 represents a significant improvement in PTWC's procedures in starting to provide tsunami warning services for the near-source tsunami threat in addition to the distant tsunami threat. PTWC is continuing detailed area-by-area studies based on historical earthquake and tsunami data to better evaluate the potential tsunami threat. It is anticipated that these studies will provide the foundation for recommending further improvements in PTWC's operational procedures.

55 The Group expressed its appreciation to Mr. G. Burton for his presentation of the history of Resolution ITSU-VIII.3 and of the regional analyses that are being done at the PTWC. The Group also thanked the USA for the complete implementation of Resolution ITSU-VIII.3.

5. PUBLIC TSUNAMI AWARENESS - ANALYSIS, SYNTHESIS AND RECOMMENDATIONS

56 There was an extensive discussion on this subject in which all delegations participated. The activities in the area of public awareness and education on tsunami that were taking place in each member were detailed by the participants. The Director ITIC, described the work in progress directed at the preparation of a book on tsunami to be used to educate children.

57 The Group recognized that there was adequate communication between tsunami scientists and the operating agencies and between the operating agencies and higher level local civil defence agencies. The greatest deficiency was identified as the communication, to the general public, of the tsunami risk and of appropriate actions. It was the Group's opinion that it did not need to take a role in developing new materials but that it has a real role in ensuring that all Member States are aware of the materials used for public education by the individual Member States.

58 The Delegate of Chile stated that Chile's efforts for the period 1990-91 will be devoted mainly to tsunami public education and will report on that effort at ITSU-XIII. The Group agreed that the Chairman would request the National Contacts of all Member States to compile a list of these materials and further request them to supply this list to all Member States and to the ITIC. The Group also requested that the Director, ITIC, continue his work in the preparation of a children's book on tsunami.

6. TRAINING AND ASSISTANCE IN TSUNAMI PREPAREDNESS

59 Dr. Tolkachev and Dr. Kitazawa informed the participants on the IOC activities in the field of Training, Education and Mutual Assistance (TEMA), which is considered as a major element of any IOC programme on ocean science and ocean services. These activities related to ITSU include a visiting experts training programme organized by ITIC with the support of IOC, publication of various technical and educational materials, support for participation of experts from developing countries in ITSU seminars and meetings and organization of consultant/expert missions to advise on establishing or up-grading tsunami warning services. The limited funds available in the IOC budget, however, did not allow the full implementation of all those activities as indicated in the Tsunami Master Plan. The Group noted that in many cases such assistance, including provision of instrumentation, equipment and training on a bilateral or multilateral basis (by USA, New Zealand and Japan) was provided, or through the United Nations Development Programme (UNDP) (UNDP project for Tsunami Warning System in the Southwest Pacific). The Group felt it important that the Member States in the Pacific should be encouraged to continue and expand such assistance and requested the IOC Secretariat to seek possible ways and means to support such activities. The Group was also informed on the activities under the Unesco-IOC Comprehensive Plan for a Major Assistance Programme to Enhance the Marine Science Capabilities of Developing Countries.

60 The Delegate of Japan reported on the International Training Course on Seismology and Earthquake Engineering, organized annually at the International Institute of Seismology and Earthquake Engineering, Tsukuba (Japan), attended by about 20 trainees from developing countries. They are invited on bilateral basis for training on seismology and earthquake engineering as well as tsunamis. In the interest of strengthening and enlarging the training course, he appealed to ITSU Member States to send their statement of support for the course to the sponsoring Agency in Japan. It is hoped this will further stimulate inclusion of tsunami related topics and continuation of the course. He, at the same time, requested IOC to support participation of tsunami experts in the course.

61 It was suggested that the Japanese Government, first should, through its National Commission for Unesco, contact the Science Sector, particularly the Division of Earth Sciences which has the primary responsibility in Unesco for natural hazards programme, for general support of this training. Support for tsunami experts could be obtained through IOC on an ad hoc basis.

62 The Director ITIC reported on visiting scientists' programme organized by ITIC with the support of IOC. Four scientists from Peru, Colombia, Mexico and USSR completed their training at ITIC during the 1987-1988 period. The scientists were thoroughly familiarized with the operations of the Tsunami Warning System and had an in-depth review on all aspects of the tsunami problem. In addition, they worked on specific problems related to tsunami warnings in their own countries and on improvements in communications.

63 The Group noted with satisfaction that the training these scientists received and exchange of ideas, had already resulted in positive benefits to the Tsunami Warning System and strongly recommended that the ITIC expand this programme and that IOC consider increasing financial support to visiting scientists' programme.

64 The Group thanked Japan, New Zealand and the USA for the support provided on a bilateral basis. The Group noted with satisfaction the success of the developing UNDP Project for the Southwest Pacific Region, and encouraged Member States to continue assistance on a bilateral and multilateral basis. The Group further expressed its appreciation to ITIC for the Visiting Scientists Training Programme and requested the Secretary to actively seek funding through the TEMA budget to support training programmes organized by the ITIC.

7. SUPPORT OF ITIC

65 The Group noted the actions taken by the Twenty-first Session of the IOC Executive Council relative to the ITIC and also expressed his country's gratitude to the IOC for providing funding to support the continuing operations of ITIC. The Delegate of USA also expressed his country's gratitude to the IOC for their support to ITIC but noted that the increased demands placed upon ITIC by actions of the Group have not been matched by a commensurate increase in the funds which the IOC provides to the ITIC. The Group noted that a substantial increase in funding for ITIC is needed in the period 1990-1991 and was unanimous in its appreciation for the work of the ITIC and of an increased funding level for its continuing operations.

66 The Group requested the Chairman to write to the Chairman IOC in support of this funding increase for ITIC and to bring this matter to the attention of the Twenty-third Session of the IOC Executive Council in March 1990.

8. CONSIDERATION OF RECOMMENDATIONS AND CONCLUSION OF THE WORKSHOP

67 The Chairman of the Workshop on Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation, Dr. G. Pararas-Carayannis, reported on the outcome and recommendations of the Workshop held in Novosibirsk, 4-5 August 1989. Specifically he mentioned that this Second Workshop, as the first one, held four years ago in Sidney, B.C., Canada, was very successful in accomplishing the intended objectives and was well attended. The Workshop covered upon all the aspects of international co-operation pertaining to scientific and

engineering research necessary for development of the Pacific and Regional systems, improvements in evaluation and prediction capability, operational and emergency preparedness, and finally on the co-ordination related to the mitigation of the tsunami hazard in the context of the International Decade of Natural Disaster Reduction. The presentations were made on the existing Regional Tsunami Warning Centers.

68 In addition, Prof. S. Tinti (Italy) reviewed the need for tsunami warning services in the Mediterranean and described efforts made by a steering committee. Additional presentations were made on methods for fast emulation of tsunami potential and perspectives of their implementation, on tsunami data bases, on tsunami instrumentations and observations and, finally, on tsunami preparedness.

69 The **Group considered** the recommendations proposed by the Workshop (Annex V) and adopted recommendations 1 and 2. The **Group considered** recommendation 3 to be a recommendation of value but felt that its adoption at this time would be premature.

70 The **Group urged** the Secretary IOC to publish the Report and Proceedings of the Workshop.

71 The **Group expressed** its appreciation and gratitude to the Government of the USSR for hosting the Workshop and to the IOC for supporting the participation of some scientists.

9. PLANS FOR THE FUTURE

9.1 PARTICIPATION IN THE INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

72 The Group was informed of actions taken by the Chairman of ICG/ITSU, the Director of ITIC and the IOC Secretariat to ensure close liaison with Unesco's Natural Hazards Programme and the activities related to the International Decade for Natural Hazard Reduction (IDNDR). The **Group wished** to re-emphasize that the activities related to the reduction of the tsunami hazard in the Pacific and elsewhere constitute a major component of IDNDR.

The **Group supported** the proposal made by the Delegate of Chile on the development programme in the area of public awareness and education on tsunamis as an important activity of ITSU in support of IDNDR.

73 The **Group**, therefore, **recommended**, and the Chairman established, an ad hoc Working Group, consisting of the representatives from Chile, New Zealand, Canada, USA, and the Director ITIC, to formulate specific proposals on this matter.

74 The composition and terms of reference of the ad hoc Group are shown in Annex VI. The draft project, to be prepared by the ad hoc working Group, then should be circulated by IOC to all ITSU Member States and other international organizations concerned for comments in September/October 1990.

75 After receipt of comments, the ad hoc Group should prepare the revised draft project taking into account comments received from Member States and other international organizations.

76 The revised draft project should be then circulated to ITSU Member States prior to the Thirteenth Session of ICG/ITSU and submitted to the Session for consideration and preparation of recommendations on this project for submission to the IOC governing bodies for approval.

77 The Delegate of USSR presented the proposal on the preparation of a project on tsunami disaster mitigation as a contribution to the International Decade on Natural Hazard Reduction. He then presented the outline of the proposed project (Annex VII).

78 The Group supported this proposal, and, considering their action on second recommendation of the Workshop, decided to refer this proposal to the Group of Experts to be established under that recommendation.

79 The Group further proposed the following actions and timetable for preparation of the project:

(i) The Chairman of ICG/ITSU, jointly with the Chairman of the IUGG Tsunami Commission, will appoint 4 experts to serve in the ad hoc Group of Experts.

(ii) The Group of Experts should meet in the first half of 1990 to consider the USSR proposal and to begin the formulation of an action plan. It is expected that ITSU Member States, through the IOC, will be kept fully informed of progress and provide the opportunity to comment at appropriate times as drafts are developed.

(iii) It is intended that a fully developed plan will be available for approval at ITSU-XIII.

80 The Group requested the Chairman of IOC to bring to the attention of the Director-General of Unesco and request him to transmit the recommendations of ITSU on the proposed projects as a contribution to IDNDR to the Secretary-General of the United Nations.

9.2 PROGRAMME OF WORK FOR 1990-1991

81 Dr. A. Tolkachev informed the Group of the discussions and decisions and proposals of the Fifteenth Session of the IOC Assembly held in Paris, 4-19 July 1989, with regard to the proposed IOC programme of Work and Budget for 1990-1991 and the proposed medium term plan (1990-1995).

82 In light of the information and discussion under the previous agenda items, the **Group formulated** the ITSU work programme for 1990-1991 to be presented to the Twenty-third Session of the IOC Executive Council in March 1990, for approval. The **Group requested** the Secretary IOC to seek the additional funds required for implementation of the proposed programme, particularly for implementation of the activities addressed to ITIC. The **Group adopted** Recommendation ITSU-XII.2.

10. OTHER BUSINESS

83 Dr. Eddie Bernard, Chairman, IUGG Tsunami Commission, briefed the Group on the IUGG Tsunami Commission (Annex IV) and on the recently concluded joint meeting with the ICG/ITSU. He presented a recommendation to the Group from the IUGG Tsunami Symposium (Annex IX) which was considered in the appropriate portions of the Agenda.

84 Dr. Tad Murty (Canada), in response to a request made at the Twelfth Session of ICG/ITSU, presented his survey of tsunamis which have occurred in the Indian Ocean. Dr. Murty's report on "Tsunamis in the Indian Ocean" is in Annex X.

85 At the request of the Delegation of Canada, Mr. Tom Sokolowski, Alaska Tsunami Warning Center (ATWC), presented a comprehensive and informative description of his center's operations which included the following: automatic and interactive computer processing system for determining earthquake locations and sizes; warning criteria and methods; VDT teletype, satellite, and radio-alarm systems for transmitting critical data; and historical earthquake and tsunami data bases. He also showed slides of the operational equipment, and discussed the future applications of microcomputer systems in tide data processing, source mechanisms, and some wave modelling work with scientists from the University of Alaska.

86 Dr. Talandier presented a briefing on his proposed new earthquake magnitude scale: mantle magnitude - Mm, and made proposal for its application and further development (Annex XI). The **Group adopted** Recommendation ITSU-XII.3.

87 The **Group considered** the need and future possibility of real-time telemetry, seismic and tsunami data exchange between various national centers of the Tsunami Warning System in the Pacific and **requested** the Chairman, in consultation with the Secretary IOC, to consider possibility of establishing an ad hoc Group of Experts whose members should be nominated by USSR, USA, Japan and France to study this matter and make proposals to the Thirteenth Session of ICG/ITSU.

88 The Delegate of Canada, building on the earlier adoption of the second recommendation of the Tsunami Workshop for a co-operative effort between the ICG/ITSU and the IUGG Tsunami Commission, presented a recommendation proposing the expansion of this activity to include other organizations and bodies with an interest in tsunamis. **The Group** had a lively discussion of the proposed recommendation, amended it, and **adopted** Recommendation ITSU-XII.4.

89 The **Group welcomed** the intention of the Krasnoyarsk Computing Center to translate into English a book on Tsunami Numerical Experiments and expressed appreciation to Canada for offering assistance in final preparation of the English version.

11. DATE AND PLACE OF THE NEXT SESSION

90 The Senior Assistant Secretary informed the Group on an informal proposal to host the Thirteenth Session the Group. A formal exchange of correspondence will be necessary before the place and time of the Session can be announced. He requested that the Chairman be authorized to conclude the arrangements. The **Group agreed** and **requested** that all Member States be notified of the place and time of the Thirteenth Session as soon as possible.

91 The Group noted that the recommendation of the IUGG Tsunami Commission regarding the consideration of the Joint Meeting in Vienna in 1991 was contrary to the Group's policy to meet only in Member States.

12. ADOPTION OF THE SUMMARY REPORT AND RECOMMENDATIONS

92 The **Group adopted** the Summary Report and Recommendations of the Session.

13. CLOSURE

93 The Chairman expressed on behalf of all the Group appreciation to the USSR for hosting and for the excellent arrangements made for the Session, and closed the Session at 11 a.m. on 10 August 1989.

ANNEX I

AGENDA

1. **ORGANIZATION OF THE SESSION**

2. **INTERSESSIONAL ACTIVITIES**

3. **IMPLEMENTATION OF RESOLUTIONS AND RECOMMENDATIONS OF THE ELEVENTH SESSION OF THE ICG/ITSU (Beijing, China, 8-12 September 1987)**

   3.1 TSUNAMI TRAVEL-TIME CHARTS
   3.2 GLOSSARY OF TSUNAMI RELATED TERMS
   3.3 DATA BASE FORMAT
   3.4 COMMUNICATION PLAN
   3.5 TSUNAMI BROCHURE
   3.6 COOPERATION WITH OTHER INTERNATIONAL BODIES

4. **IMPROVEMENTS OF THE TSUNAMI WARNING SYSTEM**

   4.1 DEVELOPMENT OF REGIONAL TSUNAMI WARNING SYSTEMS
   4.2 STANDARD OPERATIONAL PLAN FOR NATIONAL TSUNAMI WARNING SYSTEMS
   4.3 APPLICATION OF NEW NUMERICAL METHODS FOR NEAR-REAL TIME TSUNAMI FORECASTS
   4.4 EXPERIENCE AND RESULTS OF TSUNAMI WAVE MEASUREMENTS IN THE OPEN SEA
   4.5 SEISMIC DATA TRANSMISSION BY SATELLITE (GOES)
   4.6 IMPLEMENTATION OF RESOLUTION ITSU-VIII.3

5. **PUBLIC TSUNAMI PREPAREDNESS - ANALYSIS, SYNTHESIS AND RECOMMENDATIONS**

6. **TRAINING AND ASSISTANCE IN TSUNAMI PREPAREDNESS**

7. **SUPPORT OF ITIC**

8. **CONSIDERATIONS OF RECOMMENDATIONS AND CONCLUSIONS OF WORKSHOP**

9. **PLANS FOR THE FUTURE**

   9.1 PARTICIPATION IN INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION
   9.2 PROGRAMME OF WORK FOR 1990-1991

10. **OTHER BUSINESS**

11. **DATE AND PLACE OF THE NEXT SESSION**

12. **ADOPTION OF THE SUMMARY REPORT AND RECOMMENDATIONS**

13. **CLOSURE**

ANNEX II

ADOPTED RECOMMENDATIONS

Recommendation ITSU-XII-1

NEAR-REAL-TIME TSUNAMI MODELLING

The International Co-ordination Group for the Tsunami Warning System in the Pacific,

Recognizing the imminent threat posed by tsunamis to coastal areas nearest the source region,

Further recognizing the operational benefits to be gained by a Tsunami Warning Center through the use of real-time automated numerical modelling techniques for a prediction evaluation of tsunami impact near the source region, as well as for pre-event training purposes,

Further recognizing the development by the USSR of new numerical methods for application for near-real-time tsunami and seismic wave modelling,

Recognized further that the capability of near-real-time seismic wave and tsunami modelling can be used for pre-event training purposes;

Considering, however, the present seismological limitations posed by a near-real-time determination of the seismic source parameters required for tsunami prediction,

Expresses its appreciation to the USSR for the work being done in near-real-time regional tsunami modelling through the use of microcomputer technology;

Recommends that the IOC urge USA to work with the USSR in the refinement and evaluation of their techniques for future operational application by PTWC and by National and Regional Tsunami Warning Centers maintained by Member States;

Emphasizes the urgent need for a rapid determination of seismic source parameters for operational implementation of these automated predictive evaluation techniques.

Recommendation ITSU-XII.2

ITSU WORK PROGRAMME AND PRIORITIES FOR 1990-1991

The International Co-ordination Group for the Tsunami Warning System in the Pacific,

Being informed of the IOC Programme and Budget for 1990-1991, adopted by the Fifteenth Session of the IOC Assembly,

Noting with concern that the lack of funds in the IOC Budget for 1988-1989 for ITSU activities did not allow to implement some of the major ITSU activities outlined in the Tsunami Master Plan, particularly the advisory missions to developing countries and required support for ITIC activities.

Noting with satisfaction that the IOC Contribution to Unesco Medium Term Plan for 1990-1995 includes the requirements for further development of the International Tsunamii Warning System in the Pacific and its co-ordination with the Unesco Programme on Natural Hazards,

Wishes to emphasize again that the tsunamis are among the most destructive and complex natural disasters which have been responsible for great loss of life and extensive destruction to property and that the ITSU programme was recognized as a major contribution to the United Nations International Decade on Natural Disaster Reduction,

Adopts the following ITSU work programme for 1990-1991 as a minimum activities needed for successful implementation of the programme:

1.	Provision of increased assistance the continuing activities of the ITIC	(1990-1991)
2.	Provision of assistance to Member States for the implementation of the components of Tsunami programme:	(1990-1991)
	Expert mission on tsunami to the Indian Ocean countries (India, Maldives, Pakistan, Sri Lanka)	(1990)
	Visiting scientists programme ITIC	(1990-1991)
3.	Provision of assistance to Member States for the implementation of the provision of the Master Plan, particularly the recommendation regarding regional centers:	
	Consultants visits to assist in the implementation of Regional project for Tsunami Warning System in the S.W. Pacific (IOC)	(1990-1991)

4.	Publication of ITSU Glossary (first edition):	(1990)
	Translation and publication of Tsunami Brochure in Spanish	(1990)
	Preparation of work "Tsunami Warnings" for Children	(1991)
5.	Distribution of historical data base and supporting software to participating Member States:	
	Distribution of Data Base format to participating Member States (IOC-ITIC)	(1990)
6.	Provision of funds for:	
	Thirteenth Session of ICG/ITSU	(1991)
	Meeting of an ad hoc Joint IUGG/Tsunami Commission - IOC/ITSU Group of experts on tsunami disaster mitigation	(1990)
	Participation of ITSU officers/experts in the meetings of other organizations dealing with tsunami problem (IAPSO, IUGG, IDNDR)	(1990-1991)
	Participation of ITSU Officer in the 24th Session of IOC Executive Council	(1990)
	Support for participation of experts from developing countries in the ITSU related seminars/ workshops	(1990-1991)
	Distribution of Atlas of tsunami, Travel Time Charts and supporting software	(1990)
	Promotion of exchange of real-time seismic and sea level data between national tsunami warning centers	
7.	Provision of funds for:	
	Joint IUGG and IOC Scientific and Technical Seminar on Mitigation of Tsunami Hazard	(1991)
8.	Living allowance and travel for Associate Director ITIC	(1990-1991)

Recommends that the IOC Executive Council, at its Twenty-fourth Session, approve the proposed ITSU programme and invite Member States to increase the support for ITSU programme through voluntary contribution to the IOC Trust Fund;

Requests the Secretary of IOC to seek the funds needed for implementation of ITSU programme through the Regular Unesco Programme, or through direct contribution of IOC Member States for ITSU programme or through other possible sources.

Recommendation ITSU-XII.3

NEW MAGNITUDE SCALE Mm

The International Co-ordination Group for the Tsunami Warning System in the Pacific,

Recognizing that the seismic moment is a major factor controlling Tsunami generation and that the Mm magnitude, among the other magnitude scales, is the most direct and presently, the fastest way to estimate the seismic moment, for teleseismic events,

Recommends to seismological centers dealing with tsunami research that they include the Mm scale in their research efforts;

Request the Laboratoire de Geophysique (France) to continue their research concerning this new magnitude scale Mm and its application to tsunami warning;

Request the Laboratoire de Geophysique (France) to provide the algorithms and software to other centers which will be willing to test the new magnitude scale;

Request the other centers to test the new magnitude scale Mm in an operational environment.

Recommendation ITSU-XII.4

CO-OPERATION WITH OTHER INTERNATIONAL BODIES

The International Co-ordination Group for the Tsunami Warning System in the Pacific,

Recognizing that the Group has adopted a recommendation of the Workshop to formulate an ad hoc Joint IUGG Tsunami Commission - IOC/ITSU Group of Experts to

(i) formulate a project on tsunami disaster mitigation as a contribution to the International Decade on Natural Disaster Reduction,

(ii) provide adequate advice on implementation of the project to sponsoring organizations,

(iii) seek possibility to hold a Joint Scientific and Technical Seminar on Mitigation of Tsunami Hazard in 1990/1991,

Recognizing that there are other international bodies involved in tsunami research and hazard mitigation, e.g. the Tsunami Society, the Natural Hazards Society and IAPSO Commission on Marine Hazards,

Recommends that the Chairman explores arrangements with these Groups similar to the ITSU arrangements with the IUGG Tsunami Commission.

ANNEX III

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ANNEX IV

EXPERIENCE AND RESULTS OF TSUNAMI WAVE MEASUREMENTS IN THE OPEN SEA
Open Ocean Detection of Tsunamis by Satellite
(prepared by Richard H. Hagemeyer, Chairman ICG/ITSU, USA)

At the April meeting in Honolulu on the Provisional Agenda, the issue of satellite measurement of tsunamis in the open ocean was raised during the discussion of this Agenda item. I agreed to determine what the satellite capabilities might be, what had been done in the past, and what might be in planning for the future.

The resolution of the satellite-based altimeters currently in orbit is sufficiently great so as to enable the tracking of Rossby and Kelvin waves across the Pacific Basin. This should, therefore, provide sufficient resolution so as to enable the recognition of tsunamis in the open ocean. Tracking an individual tsunami across the Pacific, however, presents a more difficult problem than that of tracking Rossby or Kelvin waves.

First, the tsunami moves much faster, crossing the Pacific within 24 hours as opposed to two months or more for the Rossby and Kelvin waves. Since the accurate altimeters are now flown on polar orbiting satellites, there would be very limited opportunities for a satellite to "view" the tsunami during its lifetime. The tsunami could be expected to cross half of the Pacific Basin between succeeding passes of the same satellite. A tsunami that, for example, was generated in the Aleutians shortly after the satellite passed overhead would have reached Hawaii well before the next satellite pass.

Second, data processing systems for the current satellite altimeters are not geared to a "real-time" operation. Fast processing can result in a product in about 12 hours, but the more normal production period is a week. The European satellite, ERS-1, to be launched in 1990, will have a real-time processing capability for its altimetry data.

The original plans for research using the U.S. SEASAT satellite included an experiment for tsunami detection. Unfortunately, the SEASAT had only a three-month life span so that nothing was accomplished. Since then, because of the problems of tracking tsunamis using polar orbiting satellites and the inability to use the data in anything approximating real-time, no experiments or research has been conducted. To-date there are no known plans to use the ERS-1 for this purpose.

ANNEX V

RECOMMENDATIONS OF THE WORKSHOP ON TECHNICAL ASPECTS OF TSUNAMI WARNING SYSTEMS, TSUNAMI ANALYSIS, PREPAREDNESS, OBSERVATION AND INSTRUMENTATION

Novosibirsk, 4-5 August 1989

Recommendation 1

CO-OPERATION BETWEEN IUGG/TSUNAMI COMMISSION AND IOC/ITSU

The Workshop,

Recognized that the majority of tsunami damages to human community occurs within 30 minutes and 400 kms of its source;

Recognized further that sufficient scientific knowledge and technical expertise is currently available to develop appropriate early tsunami warning systems;

However, **recognized** also that many difficulties exist both in transferring scientific results to operational procedures and in communicating operational requirements to research communities;

Considered the objectives of the UN International Decade on Natural Disaster Reduction (IDNDR) and the need for international and inter-disciplinary co-operation in mitigation of tsunami hazards,

Recommends that an ad hoc Joint IUGG/Tsunami Commission - IOC/ITSU Group of Experts be formulated with objectives of:

(i) formulating a project on tsunami disaster mitigation as a contribution to the International Decade on Natural Disaster Reduction,

(ii) providing adequate advice on implementation of the project to both sponsoring organizations;

Recommends also that IUGG and IOC seek possibility to hold a Joint Scientific and Technical Seminar on Mitigation of Tsunami Hazard in 1990/91.

Recommendation 2

THE NEED FOR CO-OPERATION BETWEEN ITSU AND THE FEDERATION OF DIGITAL BROADBAND SEISMOGRAPH NETWORKS (FSDN)

The Workshop noting that :

(i) The tsunami community now recognizes the importance of broadband, wide-dynamic range seismic waveform data for issuing tsunami warnings. The tsunami community is therefore moving rapidly to establish real-time seismic networks.

(ii) The international earthquake seismology community has established a consensus on the importance of broadband, wide-dynamic range seismic waveform data for studying: (a) the three dimensional distribution of elastic and anelastic properties of the earth's interior; and (b) the details of the earthquake source process. Through IASPEI, the earthquake seismology community has established the Federation of Digital Broadband Seismograph Networks (FDSN), for the purpose of (a) establishing standards for broadband seismic stations; (b) establishing formats and procedures for data exchange; and (c) co-ordinating the plans of various networks to avoid unnecessary duplication of effort.

(iii) In general the members of ITSU have excellent liaison with earthquake seismologists in their own country. However, on an international level, at present there is no formal liaison between ITSU and FDSN.

Recommends that,

(i) Formal liaison between ITSU and FDSN should be established.

(ii) Seismic stations established for the purposes of tsunami warning should, whenever possible, be upgraded to meet the FDSN standards for broadband stations. [1]

(iii) The costs and effort of operating seismic stations for tsunami warning should, whenever possible, be shared between ITSU and FDSN members.

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1 Even if limitations on telemetry do not permit the transmission of the full bandwidth, the broadband data should be recorded on tape and sent to the data center rather than being discarded.

Wishes to emphasize that,

(i) Both FDSN and ITSU will obviously benefit if the above recommendations are implemented.

(ii) A real-time seismic network for tsunami warning also is a real-time network that permits accurate and almost instantaneous determination of the source parameters of all damaging earthquakes, anywhere in the world. This obviously is of tremendous importance for disaster relief authorities, and can greatly contribute to the goals of INHDR.

Recommendation 3

TSUNAMI WARNING SYSTEMS IN OTHER REGIONS

The Workshop,

Considering that tsunamis have occurred in the past in areas of the globe other than the Pacific also,

Considering that some of these tsunamis were reported to be highly disastrous resulting in great property damage and considerable catastrophic life loss,

Considering that growing world population, increasing urban concentration and larger investment in the infrastructure of societies are taken place nowdays particularly along the coastal regions and are expected to grow in the future,

Considering the important role played by ITSU towards international co-operation in tsunami research and tsunami warning systems,

Considering the important experience and achievement gained by actual ITSU member states and the needs to transfer such experience to other countries concerned with tsunami hazards.

It is recommended that ITSU strongly urges the IOC to encourage the establishment of organizations similar to ITSU to address the needs of other Tsunami prone areas and to offer ITSU technical advice to these new organizations to facilitate their establishment and the development of Tsunami Warning Centers within their area of responsibility.

ANNEX VI

TERMS OF REFERENCE AND COMPOSITION OF THE AD HOC GROUP FOR PUBLIC EDUCATION AND AWARENESS

The major task of the Ad hoc Group is to produce a general Public Education and Awareness Plan that could possibly be used by the other Member States.

The Terms of Reference for the Ad hoc Group are:

(i) to define the content of an education programme;

(ii) to develop each subject with the help of educational experts;

(iii) to provide advice on public education and awareness to ITSU Member States;

(iv) to propose to the ITSU executives the preparation of educational materials (pamphlets, brochures, audio-visual aids, posters, etc.) for public education;

(v) to encourage the exchange of existing and future educational material among Member States;

(vi) to report on the progress to the Thirteenth Session of ICG/ITSU.

Composition of the Ad hoc group:

Prof. M. El-Sabh, Canada (Chairman); Mr. H. Gorziglia, Chile; Dr. G. Pararas-Carayannis, ITIC; Mr. G. Elder, New Zealand; and Mr. T. Sokolowski, USA.

ANNEX VII

OUTLINE OF THE PROPOSED PROJECT ON TSUNAMI DISASTER MITIGATION AS A CONTRIBUTION TO IDNDR

1. MAIN OBJECTIVES

(i) To co-ordinate efforts of IUGG/ITC scientific community and ITSU representatives for updating the national tsunami warning systems on the basis of novel scientific principles and current information computational and measurement technologies as well as their optimal integration to the international system.

(ii) To develop new principles and engineering systems for essential mitigation of tsunami hazards (and, possibly, tidal inundations and tornado).

(iii) To make up a project of a model integrated system with optimal adaptation capability to the environments of the Pacific, the Mediterranean and other regions.

2. PREMISES AND POSSIBILITIES

(i) Implementation of recent advances in methods of tsunami and tide recordings, tsunamigenic criteria, numerical modelling techniques of stages of tsunami generation in real models.

(ii) Application of new information technologies (historic and current data bases of tsunamis), development of detailed emergency operation plans, storage of knowledge and improvement of educational and operative models and data processing algorithms.

(iii) Carrying out basic improvements as to locations of recording stations of different types and the development of an ideally structured ITWS integrated project.

(iv) Working out prompt and efficient methods for the international co-operation within the scientific community, technicians and international co-ordinating groups, the creation of correlated national projects in co-operation with national committees.

3. EXECUTING BODIES

The International Tsunami Commission and ITSU members and other IUGG experts, those responcible for national programmes including developing nations committees.

4. **DURATION**

1990-2000

5. **REMARKS**

Within the framework of IDMNH, with the financial support on national and international levels. Without a unified international tsunami project which would take into consideration various national projects, we can hardly expect adequate support from the governments of the interested nations and international planning bodies.

6. **NATIONAL PROGRAMME OF THE USSR**

Development of tsunamigeneity criteria of earthquakes, optimization of global and regional observation networks, software development and implementation of the national TWS new generation system as part of international integrated system.

ANNEX VIII

ACTIVITIES OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS (IUGG) TSUNAMI COMMISSION

(prepared by E.N. Bernard, Chairman, IUGG Tsunami Commission)

The Tsunami Commission of the International Union of Geodesy and Geophysics (IUGG) was created in 1960 in Helsinki, Finland at the 12th General Assembly to promote the exchange of scientific and technical information about tsunamis among nations concerned with the tsunami hazard. Since its beginning, the Commission has sponsored fourteen tsunami symposia and has encouraged the publication of ten proceedings containing over 300 research reports from these symposia. Since 1960, tsunami symposia have been held throughout the world as can be seen by this list of dates, places, and proceeding publications.

Tsunami Symposia Sponsored by the Tsunami Commission

1961 - Honolulu, Hawaii - D.C. Cox (USA), editor
1963 - Berkeley, California
1966 - Berne, Switzerland
1969 - Honolulu, Hawaii - W.M. Adams (USA), editor
1971 - Moscow, USSR - S.L. Soloviev (USSR), editor
1974 - Wellington, New Zealand - R.A. Heath and M.M. Cresswell (New Zealand), editors
1975 - Grenoble, France
1977 - Ensenada, Mexico - T.S. Murty (Canada), editor
1979 - Canberra, Australia - R.D. Braddock (Australia), editor
1981 - Sendai, Japan - K. Iida and T. Iwasaki (Japan), editors
1983 - Hamburg, Germany - E.N. Bernard (USA), editor
1985 - Victoria, Canada - T.S. Murty and W.J. Rapatz (Canada), editors
1987 - Vancouver, Canada - E.N. Bernard (USA), editor
1989 - Novosibirsk, USSR

Tsunami scientists are proud of these past accomplishments, but new challenges are now emerging on the horizon. As the Tsunami Commission stands on the threshold of its fourth decade, the 1990's offer a unique challenge -- the International Decade of Natural Disaster Reduction. For thirty years, tsunami scientists have worked toward the goal of reducing the hazard of tsunami. To place those years in perspective, let's briefly examine the history of tsunami research (1960 - 1989) by decade.

1. THE 1960'S - DISCOVERY

The sixties were a decade of defining the tsunami phenomenon. The tsunamis of 1960 and 1964 convinced everyone that Pacific coastal residents must be protected from this hazard. Ray-tracing techniques along with analytical studies yielded important information about travel times and physical characteristics of tsunami. Physical models were used to evaluate the influence of protective barriers and to determine inundation zones.

Several instruments were tested for use in detecting tsunamis including: ocean acoustic waves, atmospheric waves, and bottom pressure gages. This was an exciting time in tsunami research, as many discoveries were made in this fertile field.

2. THE 1970'S - COMPUTER APPLICATIONS

In the seventies we saw the emergence of numerical models which were based on the analytical and physical models of the sixties. Extensive numerical modeling experiments were conducted on tsunami generation, propagation, and run-up for local, regional, and Pacific-wide areas. No major Pacific-wide tsunami occurred during this decade, so interest in the problem started to fade.

3. THE 1980'S - HAZARD APPLICATIONS

In the eighties tsunami scientists began the process of converging these theoretical principles for use in hazard management. The decade of the 1970's provided a set of useful numerical models to conduct scenario experiments. These numerical models, however, could not be properly verified because of lack of data. Not only were tsunami data few, but the type available were not suited for model validation. During the 1981, Sendai Tsunami Symposium, Professor Iida stated in his opening address, "Numerical calculations of tsunami problems have advanced considerably. It is said, however, that systematic measurement of tsunamis in the open ocean for research purposes and for reliable tsunami warning is still not accomplished. Further technical improvements are necessary for fast and efficient tsunami warning, and tsunami risk estimations are required for the prevention of tsunami hazards to coastal inhabitants and important construction in coastal regions of the Pacific and other oceans. To cover these requirements, we need further various tsunami data and their analysis."

These words were rather prophetic in that the 1983 Sea of Japan tsunami killed over 100 Japanese citizens. With this natural reminder of the tsunami hazard, scientists have made great progress in all three areas. The technology now exists for measuring tsunamis in the deep ocean, historical data have been carefully collected and analyzed for hazard assessment in several countries, and a fast and efficient local warning system using satellites has been developed. One important result of the historical data studies is the emerging need for tsunami hazard reduction outside the Pacific Ocean. During this symposium, these three topics, were discussed in detail.

Of particular significance to ITSU, were the following areas of research:

(i) **Tsunami Observations:** The most significant research result to be reported at the Symposium was the deep water measurements of tsunamis by the United States and Japan. Japan revealed measurements from the 1986 Alaskan tsunami while the U.S. showed data from Alaskan tsunamis in 1987 and 1988. These programmes

appear to be long term in their support, so measurements of future tsunamis appear to be established for the North Pacific.

(ii) Advanced Computer Graphics: Professor Shuto of Japan showed a video of tsunami inundation model output. These model results were displayed using advanced graphics that resemble television animation. The video clearly indicated the processes of inundation and effects on a coastal community. More significantly, such video displays could easily be used to educate the general public or emergency preparedness experts.

(iii) Interdisciplinary Studies: One of the more significant advances reported at this Symposium was the use of multiple disciplines to reduce the effects of tsunamis. A pilot project (named THRUST), conducted jointly by the U.S. and Chile, used experts in oceanography, seismology, satellite communications, hazard management, historical data analysis, and numerical modeling to develop a local tsunami warning system. This pilot project is probably the forerunner of similar projects to use existing technology to reduce the tsunami hazard.

4. THE 1990'S - HAZARD REDUCTION

Now let us turn to the future. As I said at the beginning of this discussion, the 1990's pose a special challenge because of the international effort in disaster reduction. I believe tsunami scientists are willing and able to rise to the challenge of disaster reduction. The tsunami scientific community has new techniques/tools in place. A combined effort is required to marshal the necessary political, fiscal, and intellectual resources of all nations to make this a reality. The cost will be high. It will require activism on the part of tsunami scientists. It will require dedication on the part of emergency management. It will require resources that are not available today. As I said - it is a challenge... but one for which we have prepared for 30 years.

ANNEX IX

RECOMMENDATION OF THE IUGG TSUNAMI SYMPOSIUM
Novosibirsk, 31 July - 2 August 1989

(To be presented to the Twelfth Session of the ICG/ITSU)

1. In order to continue the spirit of scientific co-operation fostered by the consecutive meetings of the Tsunami Commission and ITSU in Akademgorodok, the Commission invites the ITSU membership to consider holding its next meeting, in 1991, in Vienna, Austria during the IUGG Quadrennial Meeting.

2. In the light of recent historical work of Tinti, Lander, and others indicating significant tsunami threat to areas outside the Pacific basin, the Commission recommends strongly that ITSU seek to expand its membership to include areas of the Mediterranean Sea and the Caribbean Sea.

ANNEX X

TSUNAMIS IN THE INDIAN OCEAN
(prepared by T. Murty)

Date	Earthquake Information	Tsunami Information
Oct. 11, 1737	Near Calcutta 300,000 people killed by earthquake and tsunami	Tsunami in the Hoogly River
April. 12, 1762	Earthquake occurred at the Northern end of the Bay of Bengal	Tsunami waves in the various tributaries of the Ganges River, tsunamis at Dhaka, Calcutta and Cheduba Island. Max. amplitude of tsuanmi 1.83 m
June 16, 1819	Earthquake near Cutch. 1543 people killed by earthquake and tsunami	Tsunami in the Arabian Sea
Nov. 11, 1842	Earthquake near northern end of Bay of Bengal	Tsunami waves in the tributaries of the Ganges Ganges River
June 19, 1845	Earthquake at 7.20°N, 68.22°E	Tsunami waves in the Indian Ocean
Oct. 31, 1847	Earthquake at 7.20°N, 93.40°E	Tsunami in Little Nicobar Kondul Island inundated
Dec. 31, 1881	Epicenter in the western central part of the Bay of Bengal	Tsunami waves all the way from Sri Lanka to Ganges Delta. No waves on Burma Coast but tsunami on Adamant and Nicobar Is. Tsunami amplitudes at Port Blair - 0.92 m False Point - 0.05 m Negapatam - 1.22 m Carnicobar - 0.76 m
Jan. 1882	Earthquake at 8.57°N, 81.23°E	Tsuanmi at Trincomalee in Sri Lanka

Date	Earthquake Information	Tsunami Information
Aug. 27, 1883	Krakatoa volcanic eruption. 6.10°S, 105.26°E	Tsunamis in Sri Lanka, east coast of Indian, Andaman Sea and Ganges Delta. Tsunami amplitudes at: Negapatam - 0.6 m Aden - 0.2 m
1886	Earthquake in the Bay of Bengal	Tsunami in the Bay of Bengal
June 12, 1897	Earthquake at 26°N, 91°E. Magnitude = 8.7 1542 people killed by earthquake and tsunami	Tsunami in the tributaries of the Brahmaputra and Ganges River
April 4, 1905	Earthquake near Kangra. Magnitude = 8.6 20,000 people killed	Tsunami mentioned
Jan. 15, 1934	Bihar-Nepal earthquake. Magnitude = 8.4 10,700 people killed	Tsunami mentioned in Ganges River
May 31, 1935	Earthquake near Quetta. Magnitude = 7.5 30,000 people killed	Some agitation of waters in local rivers
Nov. 25, 1935	Epicenter at 5.5°N, 94.0°E. Magnitude = 6.5 Time: 10:03:03 GMT	Possible tsunami
Aug. 23, 1936	Epicenter at 6°N, 95°E. Magnitude = 7.3 Time: 21:12:13 GMT	Possible tsunami
June 26, 1941	Epicenter at 12.5°N, 92.5°E Magnitude = 8.1. Time: 11:52:00 GMT	5,000 people killed by tsunami on the east coast of India. The Media reported this erroneously as a storm surge. Tsunami in the Andaman Sea
Nov. 27, 1945	Epicenter at 14.12°N, 62.36°E. Magnitude = 8.3. Epicenter 290 km from Karachi. Several people killed by earthquake and tsunami	Tsunami in the Arabian Sea Property damage at Bombay coast of Mahran Baluchistan and Pasni Amplitudes at: Bombay - 1.98 m Karachi - 1.37 m Ormara - 13.0 m Pasni - 13.0 m Maximum amplitude - 15.24m
May 9, 1949	Epicenter at 5.0°N, 95.0°E Magnitude = 6.7. Time: 13:36:18.0 GMT	Possible tsunami

Date	Earthquake Information	Tsunami Information
Aug. 15, 1950	Epicenter at 29°N, 97°E Magnitude = 8.7. 1,530 people killed	Tsunami in the Brahmaputra River. The earthquake dislodged millions of tons of material from the Himalaya Mountains and this debris clogged the rivers and raised the river bottom by as much as 14 ft leading to severe flooding and storm surges subsequently
May 17, 1955	Epicenter at 6.5°N, 94°E Magnitude = 7.25. Time: 14:49: 49 GMT	Possible tsunami
July 1967	Koyna, Maharastra, India	Earthquake and tsunami in a lane dam reservoir. Few deaths, some damage
Dec. 28, 1974	Earthquake in Pakistan. Magnitude = 6.2 5,300 people killed	

ANNEX XI

PROPOSAL ON A NEW MAGNITUDE SCALE: THE MANTLE MAGNITUDE Mm

(submitted by J. Talandier, Laboratoire de Géophysique,
Papeete, Tahiti, Polynésie Française)

The seismic moment is a physical measurement of the "size" of an earthquake and is the major factor controlling tsunami generation. But it is clear that very large seismic sources are required to generate significant and a fortiori damaging tsunamis.

Surface waves representing low frequency energy radiated by the event, give a good and faster determination of the moment. Unfortunately, the Ms magnitude measured at a constant period T, which uses the Rayleigh waves, saturates when the rupture duration along the fault becomes comparable to T. Thus, for large earthquakes and in particular those causing tsunami risks, Ms measured at 20 seconds loses signification.

In order to avoid the saturation effect, it is clear that we need the measurement to move to very long periods, on the flat portion of the source spectrum, at a frequency below the corner frequency. Thus, we propose the real-time estimation of seismic moment through the use of a low-frequency magnitude scale, named Mm, based on the measurement of mantle Rayleigh or Love waves at a variable period, in a single station.

Mm is directly related to the logarithm of the seismic moment. It can be determined in the frequency domain as well as in the time domain, so that usual graphic recordings could be used. In the frequency domain, Mm can still be calculated up to short epicentral distances such as 8^{o}, and probably even less. Perfectly well adapted to teleseismic tsunamis warning, Mm could also be used to regional warning.

We have established the theoretical background justifying this new magnitude scale and evaluated Mm as the logarithm of the spectral amplitude of Rayleigh waves added to a distance and a source correction.

The distance correction contains the geometrical spreading factor and the frequency dependent correction for inelastic attenuation. The latter involves a model of crust regionalized into seven tectonic provinces along a ten by ten degrees co-ordinate grid.

The source correction is then applied to compensate for the variation of surface wave excitation with T.

In order to eliminate the incertitude that may subsist concerning Rayleigh waves radiation related to the source geometry, the Mm magnitude can also be determined with the Love waves following the same principle.

A study of more than 300 records of Rayleigh wave made in Papeete and Pasadena stations and coming from Geoscope network shows that the standard deviations of the residuals between values of Mm computed and measured are of the order of 0.2 unit of magnitude. These numbers compare very favorably with the scatter in published moment values.

With Love waves, the residuals are of the same order but concern about 150 records.

We can sum up the performance of the magnitude Mm as follows:

(i) In the frequency domain, Mm is accurate for short distances, at least 8^{o}, but also for the multiple passages measured up to 900^{o}.

(ii) In the time domain, the measure of Mm is accurate from 20^{o} to about 150^{o}.

(iii) In the frequency and time domain, Mm has been determined from seismic moments of 10^{24} to 2×10^{28} dyn-cm. Anyway theoretically, Mm is good without upper limit.

Therefore, Mm is an universal magnitude scale perfectly adapted to the measurement of small and large earthquakes, and also to tsunami warning.

In addition, the calculations involved, in real-time, in the computation of Mm are extremely simple. They can easily be implemented on a personal computer or handle, in the time domain.

To summarize, we can say Mm is a modern and universal concept of the old notion of magnitude.

At this time, an automatic Mm determination in real-time for earthquakes of seismic moments over 10^{24} dyn-cm are currently executed at the Papeete station.

1. ESTIMATION OF TSUNAMI RISK AND WARNING PROCEDURES

In addition to the real-time seismic moment determination, the fundamental criterion on which the prevention of tsunami can be based is the proportionality of observed tsunami height to the seismic moment.

This direct relation is justified by the normal mode tsunami theory. It has been experimentally verified with 17 tsunamis, generated by earthquakes from subduction zones around the Pacific and recorded in Papeete harbour since 1958. Papeete harbour minimizes amplifications and resonance effects, so that other receiving sites should require additional corrections related to local bathymetry.

On this base, it is possible to directly define the risk levels as a function of the Mm magnitude. Thus, the risk will be known as soon as the Rayleigh wave arrives is to say about 5 minutes after the earthquake in the case of a 10^{o} epicentral distance and respectively 30 minutes for a 70^{o} distance.

This method has been used with success by the French Polynesia Tsunami Warning Center since 1986.

2. PUBLICATIONS AND EXPERIENCE

Since 1986, seven different publications have treated of the Mm magnitude and its application to tsunami warning. Most of these publications have been printed in the Geophysical Research Letters, the Journal of Geophysical Research and the Bulletin of the Seismological Society of America.. Moreover, they have been presented at numerous congresses and we are preparing other publications on the extension of the Mm magnitude to the Love waves.

Furthermore, moments over 10^{27} dyn-cm calculated in real-time by the French Polynesia Tsunami Warning Center (CPPT) are immediately sent to the Pacific Tsunami Warning Center and to the Alaska Tsunami Warning Center. Lastly, all the moments determined by the CPPT (generally from 10^{24} dyn-cm) are published by the National Earthquake Information Center in the USA.

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