Distribution: limited
Agenda item 6

IOC/INF-563
Paris, 19 January 1984
English only

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of Unesco)

Seventeenth Session of the Executive Council
Paris, 31 January - 9 February 1984

PLAN FOR A GLOBAL SEA LEVEL NETWORK

The attached Plan for a Global Sea Level Network was prepared by Prof. K. Wyrtki and Dr. D. Pugh at the request of Secretary IOC to be used as a groundwork by the Executive Council for debating the scope and strategy of the progressive (i.e., through regional components) establishment of a global tide gauge network which is required by the oceanographic community for various purposes of a science- or services-oriented nature. Annex I is an historical background of past thoughts and/or decisions of some international bodies regarding this subject.

SC-84/WS/3

IOC/INF-563

PLAN FOR A GLOBAL SEA LEVEL NETWORK

Prepared for the Intergovernmental Oceanographic Commission

by

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December 1983

1. INTRODUCTION

Changes of mean sea level may be related to many other geophysical processes. On long time scales there are processes of vertical land movement and of changes in ocean volumes. Shorter-term variations, of more local extent, from several days to years may be due to changes in the ocean's density structure and to changes in circulation patterns. Changes in sea level over periods of hours and days due to meteorological effects and tides are of great practical concern because of the potential for coastal flooding. Long-term statistics are needed to calculate the design probabilities of these events, and operational schemes are needed to warn when flooding is imminent.

Clearly a global network to observe sea level changes has to serve many purposes. It has to cover the entire spectrum in time and space from short-lived tsunami to the slow changes related to tectonic processes. Characteristics of a network must include permanence, high vertical precision and stability, and the flexibility to develop as the requirements evolve.

In this document we propose a network of some 250 sea level gauges which is capable of providing valuable data for both practical and scientific applications. Many of these gauges already operate, but may need upgrading in terms of levelling, accuracy, documentation, telemetry and the time taken before the data become available. About 100 new sites are proposed, many on ocean islands, which are best placed for ocean monitoring. In a few cases, especially in polar regions, implementation will pose formidable problems for present technology. The purpose of this proposal is to provide a context within which a co-ordinated system of global sea level measurement can be developed.

2. SCIENTIFIC BACKGROUND

A global network to observe sea level changes has to serve many purposes. It has to cover the entire spectrum in time and space from short-lived tsunami to the slow changes related to tectonic processes. The data derived from the network need to provide basic information for the analysis of a wide range of scientific questions as well as for practical applications. Characteristics of a network must include permanence, high vertical precision and stability, and the flexibility to develop as the requirements evolve.

In the absence of currents, density differences and atmospheric influences, the sea level would coincide with the geodetic surface known as the geoid. This geoid is not a simple geometric surface because of local and large scale anomalous mass distribution within the earth. After eliminating the waves and tides, the remaining mean sea level surface deviates from the geoid by amounts which seldom exceed 1 metre. The differences are related to ocean circulation, density fields, and to the influences of atmospheric pressure and winds.

The sea surface is the boundary between the ocean and the atmosphere and so changes in sea surface topography relate to both systems. Sea surface topography and circulation are linked by geostrophy, which represents a balance between the Coriolis force and the pressure gradient perpendicular to the flow; the significance for poleward heat transfer and the activities of CCCO is apparent. At the sea surface the pressure gradient is given by the slope of the sea level, and procedures have been developed to monitor the variations of geostrophic flow from sea level differences, particularly in the one-dimensional case of narrow passages or straits or for simple ocean currents. Interpretation of sea level variations in terms of regional ocean dynamics are also now becoming routine (for example, "Sea level variations: monitoring the breath of the Pacific" by K. Wyrtki, EOS, 60, 1979). Traditionally oceanographers have determined the topography of the sea surface from the observed distribution of density but only in relation to a more or less arbitrarily selected reference surface, the so-called "level of no motion". Techniques for synoptically determining the internal ocean density distribution in sufficient detail to resolve monthly or even interannual variations are unlikely ever to become cost effective. However, a combination of mean density fields coupled with measured fluctuations of sea surface topography and other remote sensing techniques such as acoustic tomography, may provide a workable monitoring system for ocean circulation. Examples of changes in the intensity of this circulation, both for ocean gyres and for major boundary currents, with time scales of several years, have been well documented. The important annual cycle, which involves major variations of heat transport and heat content also belong in this spectral range. In addition to the circulation and heat transfer monitoring potential, sea level is also indirectly related to the ocean heat storage through the expansion which results from changes of mean temperature. These may be local adjustments to changes in the thermocline levels or net warming of the global oceans over many years.

Sea level changes over the hundred year time scale are related to crustal movements, to changes in ice and water volumes, as well as to the mean warming and expansion of the ocean. To measure these changes, as well as the long-term variations of ocean circulation, a high degree of stability of the reference datum is an important requirement. The separation of the several contributions to long-term sea level changes will require information from other geoscientific disciplines and technologies, but a precise knowledge of the sea level change itself is a basic element. There is much geological and geophysical interest in the measurement of recent vertical crustal movements and their relationship to larger geological trends, as shown in Project IGCP 200.

Since sea level records are continuous in time, and several series extending over many decades already exist, they are most suitable for general ocean monitoring. If measurement sites are properly selected, the measured levels can be more representative of the regional oceanography than other more variable parameters, such as coastal temperature and salinity. Also, the technology and local resources required for a long-term monitoring programme are very modest when compared with the cost of other monitoring systems such as specialized research ships. Such measurements represent a minimum but extremely valuable oceanographic commitment from countries which do not yet have the resources available for major monitoring and research programmes.

Sea levels also have many practical applications for both operational and engineering design activities. The analysis of tides, one of the more traditional aspects of sea level observations as a basis for navigation, will continue as an important practical consideration in addition to the intrinsic scientific interest. Meteorologically induced storm surges are also part of the sea level record, and a long-term monitoring programme will provide essential statistics for the calculation of return periods for extreme events, a necessary first stage in the design of local coastal defence systems. On an operational basis, sea levels are needed as input to flood warning procedures. On an ocean-wide scale, tsunami traverse entire ocean basins, and a global observation system is necessary for their detection and the issue of timely warnings. Many new techniques for estimating flooding probabilities have been developed in recent years using joint probability procedures, but the basic requirement is for several years of good quality sea level data.

In addition to these identified and immediate practical advantages which are afforded by a global network of sea level stations, the longer-term benefits which result from new scientific insights and discoveries of ocean/atmosphere interactions and their consequences for forecasting climatic changes must be emphasized. In the foreseeable future, satellites with altimeters will provide a two-dimensional picture of sea-surface topography, for which the sea level network will provide the ground truth and calibration. However, only ground-based gauges are capable of determining very slow and small changes of the mean sea level.

3. SCIENTIFIC PLAN

The network of sea level monitoring stations designed to address the several scientific and operational requirements must also be capable of developing to meet unindentified future needs. It must also complement related measurements made by alternative techniques such as satellite altimetry, bottom pressure gauges and inverted echo sounders.

3.1 Network Design

Physically the network is constrained to land-based stations along continental coasts and at oceanic islands; this necessary but imperfect distribution defines a minimum length scale to the resolution. Present knowledge of ocean behaviour indicates that there are several length and time scales over which sea level changes are significant. In general the long period changes have the largest spatial scales. For example, the increase of sea level due to changes in ocean volume is a global phenomena; similarly the annual cycle of sea level has a hemispheric scale. Phenomena such as El Niño have an event duration of 1-2 years and a basin-wide scale. Interannual variations of sea level over periods from three months to a few years have typical length scales of 1,000 km or greater. At shorter time scales, storm surge events have periods from days to hours and correspondingly shorter length scales, of order 100 km. Conversely some processes of vertical crustal movement may have very long time scales, but they may have a spatial coherence which extends over a few tens of kilometres or less.

By concept and design a global network of sea level stations must be primarily concerned with the resolution of large scale, long term phenomena. This coarse resolution must be refined in certain areas such as across straits or in the vicinity of western boundary currents, which are critical for the behaviour of the oceans as a whole. However, a global network cannot <u>per se</u>, be concerned with local effects. Individual gauges on the network will also be needed for local studies.

3.2 Site Selection

In many cases there are few choices of available sites, but where possible the gauges should be installed at locations where the sea levèls are representative of open-sea conditions. This means avoiding semi-enclosed harbours, coasts exposed to severe waves and places where strong near-shore currents are apparent.

3.2 Measuring Systems

The measuring system at each Station will consist of a transducer which senses some physical parameter clearly related to the sea surface level, and a system for local recording of the data. Automatic transmission of the data in near-real-time to national and international centres should be a feature of the final network. It is important that the operation of the invididual measuring systems includes procedures for regularly checking the quality and datum stability of the readings.

There are two basic parameters which may be monitored, the surface level itself or the pressure at some fixed point on the sea bed. There are scientific and instrumental advantages of each method. Traditionally the sea surface has been measured by means of a float arrangement mounted above a well which damps out short-period wave motions. This procedure is simple, well proven and has no inherent drift. However, there are problems óf nonlinear responses of stilling wells to waves which can produce errors in the measurement of the still water level. Alternative methods for sensing the sea surface include acoustic and electromagnetic time-of-flight gauges: these avoid the problems associated with moving floats and wires, but will still be subject to errors if mounted over stilling wells. Despite these reservations the stilling well arrangément, if properly designed, remains a robust and reliable system for many applications.

An alternative is to measure near-shore sea bed pressure and to convert this to sea level by means of the hydrostatic relationship between pressure, water density and gravitational acceleration. Sea bed pressure includes the atmospheric pressure, which must be corrected for, either by separate measurement or by means of a differential transducer vented to the atmosphere, as in some bubbler gauges. Unlike surface-sensing gauges, which require a vertical structure such as a jetty for mounting, pressure systems may be with the recorder on the sea bed, or connected by a pressure or electric cable to a recorder ashore. With pressure systems care is necessary to ensure that the datum level remains constant, and sea water density variations must be monitored at suitable intervals for the best accuracy.

Automatic monitoring systems also afford the possibility of recording and transmitting data on atmospheric pressure, winds and other environmental parameters.

The measured sea levels are usually recorded either continuously on a chart, or in digital form at discrete intervals on punched paper or magnetic tape. Charts are useful for immediate local operations, but as part of a network, each gauge should have data recorded automatically in computer compatible format. Sampling of sea level averaged over a few minutes (to avoid aliasing), at intervals of 15 minutes, is recommended, but in all circumstances the minimum sampling interval should be one hour. Gauge timing should be compatible with level accuracy, which means an accuracy of ± 1 minute.

All gauges must measure sea levels relative to a fixed and permanent local Gauge Bench Mark, which is connected to a number of Auxilliary Marks to guard against its movement or destruction. Connections between the Bench Mark and the gauge zero should be made to an accuracy of a few millimetres every six months. The readings of individual sea levels should be made with a target accuracy of 10 mm. Although initially the network must accept present day instrument performance, as the technology develops and the resources become available, gauges should be equipped for averaging and rapid sampling; they should also be equipped for automatic data transmission to data centres in addition to the local recording.

Another probable development is the ability to connect all network Gauge Bench Marks into a Global Vertical Datum System, which would eventually allow the vertical crustal movements to be distinguished from sea level trends. Similarly, it may eventually be possible to relate all the Bench Marks to a reference geoid, which would enable oceanographers to compute absolute pressure gradients between stations, and to relate these to permanent currents.

Network gauges which contribute to operational systems may require special communication facilities. For example, gauges which are part of a tsunami warning system could be equipped with a two-way communication system which allows them to be switched to a more rapid mode of sampling and telemetry if seismographs indicated earthquake activity and the possibility of a tsunami.

3.4 Data Reduction

The data recorded at the station will contain errors of many kinds. They will require checking by the local or national authority for calibration and timing adjustment, for datum control, and for the removal of obvious instrumental malfunctions. This should be done with the minimum possible delay. This applies not only for those stations from which the results are of immediate interest, but also for other stations, as this allows problems with the system to be identified and corrected without further loss of data. The daily and monthly mean values should be computed for scientific use according to established methods

The monthly means should be submitted to the Permanent Service for Mean Sea Level and the daily mean values should be made available for scientific analysis as required.

As automatic transmission from the gauges becomes standard there will be some discrepancy between the raw values received by operational centres and the final corrected values issued by the national authorities. It is necessary to make a clear distinction between the data transmitted in real time which will be of inferior quality, but quite adequate for operational purposes, and the final product presented to PSMSL, which requires careful editing and well documented datum control. IOC can help in the co-ordination of data flow through its existing IGOSS and IODE mechanisms.

3.5 Data Applications

The purpose of operating sea level gauges within the context of a global network is to make the data available in a compatible format as an entity; in this form the value is considerably enhanced for monitoring ocean circulation, for climate research and prediction, and for the identification of other long-term trends and statistics. The data should be freely available for these applications in the same way as meteorological data, either through the national authorities or through the international bodies responsible for data transmission or archiving.

For immediate application data are needed to give warning of coastal flooding or tsunamis. Future applications will include the ground-truth verification of satellite altimetry by level measurements at suitable sites. Short-term applications include monitoring, for example, to plan the programme for a research cruise, and the identification of anomalies which can be related to climatic instabilities; eventually this type of information will be an important component of systems for forecasting climate changes. Over the long term, changes of sea level relative to land have great practical significance for the design of defences against coastal flooding, for the computation of long-term statistics for the definition of anomalies, and for the identification of changes in global ocean volumes. Over this longer term the need is for monthly and annual near sea levels which are accurate to better than 20 mm, and for which the datum control has a compatible stability over several decades.

4. THE NETWORK

There are already well established gauges which have been operated by national or harbour authorities over several years (Operational sea-level stations, IOC Technical Series No.23, Unesco 1983), and these must form the initial basis of a planned network. Many of these gauges are already contributing to regional flood warning or other operational schemes, and there are many which forward their data as monthly and annual mean levels to the ICSU Permanent Service for Mean Sea Level. To this extent a network already exists, but there are many gaps and many gauges for which the implementation of stricter controls would considerably enhance the value of their measurements. There are also proposals, generated by scientific panels associated with CCCO, and by the regional subsidiary bodies of IOC, for expanded networks on regional or oceanic scales. Before proposing a detailed global network, it is necessary to summarize these existing networks and proposals.

4.1 Existing Networks

Several sea level networks, usually for specific purposes already exist. Most are regional in character. The IOC Pacific Tsunami Warning System combines selected sea level gauges from several countries into an ocean-wide network for the dedicated purpose of detecting tsunamis: once a seismic event is indicated, sea level stations are interrogated to determine whether a tsunami has been generated, and if so, warnings are issued to areas at risk. Stations in this system are also capable of providing regular sea level records for other applications if the records are suitably reduced.

In the North Sea, a Storm Surge Warning System has been developed to warn of impending coastal flooding. Similarly, in the Gulf of Mexico a system exists to warn of dangers from hurricane-generated floods. There are many other national and regional schemes, and there is no doubt that scope exists for further local co-operation and system development.

On an ocean scale, in the western and tropical Pacific Ocean, a network of sea level gauges has been installed in 1975 with the specific purpose of studying the ocean dynamics and the potential for ocean monitoring. This potential was readily confirmed by the successful observation of the important El Niño events of 1976 and 1982/3.

The Permanent Service for Mean Sea Level, which is a Member of the ICSU Federation of Astronomical and Geophysical Services, and which operates within the IODE framework of IOC, collects, archives, publishes and analyses monthly and annual mean sea level values from the entire world. The purpose is to accumulate a comprehensive data base for the study of long term sea level changes, and particular emphasis is placed on the stability and documentation of the datum to which these sea level records are related. It relies on voluntary submission of data, either by regular arrangements or by request; the data arrive after a delay which varies from one to several years.

4.2 Existing Plans for Sea Level Networks.

Several scientific programmes are presently considering the establishment of regional sea level networks to collect data in support of studies on ocean circulation. This fact alone demonstrates the importance which scientists attach to the availability of sea level data for the interpretation of other measurements. It is likely that many of the new gauges installed as part of these regional projects will become permanent gauges after completion of the particular scientific investigation, and this should be strongly encouraged.

In the Atlantic Ocean the SEQUAL-FOCAL activities have established a sea level network, which includes both level and pressure gauges, on islands and continental coasts, in the equatorial region. The CCCO panel on Tropical Atlantic Ocean Climate Studies has also proposed an extended version of this network. Similarly, the CCCO Panel on Indian Ocean Climate Studies had designed a network for both the equatorial and mid-latitude regions which is appropriate for the monitoring of specific processes such as the annual development of a western boundary current, the equatorial dynamics, the exchange of water between the Indian and Pacific Oceans through the Indonesian Archipelago, and the strength of parts of the Antarctic circulation. Proposals for a sea level network around the whole Antarctic Ocean are being considered by the IOC Programme Group for the Southern Oceans. Similarly, member states of the CINCWIO region have proposed the development of a regional network (see Annex I).

4.3 The Proposed Network

The proposed network to meet the identified practical and scientific requrements is shown in the attached map. Solid circles show gauges already operating, according the IOC Technical Series (No.23) publication, Operational Sea Level Stations. The open circles are gauges which must be activated. In making this proposal the following somewhat arbitrary criteria have been adopted.

(1) A gauge has been allocated to each ocean island or group of ocean islands, at intervals not closer than 500 km.

(2) Gauges are located along continental coasts at intervals generally not less than 1,000 km; preference is given to nearshore islands to maximize the exposure to the open ocean.

(3) In special cases, such as across a strait which connects large parts of the oceans, the density has been increased, so that a minimum of one gauge on either side is proposed.

(4) Priority is given to well established gauges, and gauges which have a long history of previous operation (such as Aden), as these can give valuable information on trends.

In addition, the following points were considered relevant:

(1) Plans proposed by CCCO panels have been incorporated where these are compatible with the ocean monitoring activities of the network.

(2) It is recognized that the network will need to change with time in the light of scientific insights gained from the data. The proposed network is not constrained by present political, physical or technical problems, since these too will change with time. For example, measurements in ice-covered seas, and at rugged remote island sites need technical developments if they are to become reliable and routine.

(3) There are several important, but largely enclosed bodies of water, which may require special networks tuned to their individual requirements. In many such cases, as for the global ocean, the elements of a regional network already exist, but it is a task for special groups to consider their further development. These include the Baltic Sea, the North Sea, the Mediterranean, the Gulf, the Black Sea, the Red Sea, and the Canadian Archipelago. They may also include the Indonesian Archipelago and a more detailed coverage of the Caribbean Sea.

(4) Individual national networks will be developed with more detailed coverage to meet particular requirements.

4.4 Gaps

Inspection of Figure 1 shows certain patterns of observation stations which will require to be installed. The Indian Ocean is at present an area of minimal coverage. In the Southern Oceans and the Arctic Ocean further coverage would be possible from permanently manned research stations, but this may require the development of special instruments to measure under ice and on wave pounded islands. A modest effort is required to complete the network in the Indonesian Archipelago and in the South Atlantic Ocean; and in the outlying Australasian islands. Elsewhere only individual stations need to be added to close the smaller gaps.

4.5 The Operation of the Network

Figure 2 shows the data flow in the operational network. It emphasizes the distinction between the data flow in real time for operational purposes and the flow of finally accepted data through PSMSL to the user.

5. THE IMPLEMENTATION

The development of a full network may take several years, but in many cases the basic elements already exist. Details of the implementation are a matter for discussion and agreement for the individual countries and between the participating organizations, but certain requirements may be identified.

5.1 Discussion, Acceptance and Adoption of the Plan

The plan should be approved by the IOC, and made available for discussion by CCCO and its Panels, by the Committee for Tides and Mean Sea Level of the IUGG International Association for the Physical Sciences of the Ocean, and by other interested parties.

5.2 Existing and Future Installations

In round figures, the proposed network consists of 250 gauges. Of these 150 already exist, but may need upgrading in terms of levelling, accuracy, documentation, telemetry and the time taken before the data become available. About 100 gauges need to be installed, many on oceanic islands. Of these 100 gauges, some 20 will involve the reactivating of previous stations; also, about 15 present formidable problems for present technology, particularly those in the Antarctic and on exposes remote islands.

5.3 Requirements of National Authorities

Co-ordinate activities at a national level.

Upgrade existing gauges.

Install new gauges at agreed locations. Emphasis should be given to island stations.

Make known through IOC their requirements for assistance with:

- instruments;
- installation;
- communications;
- training.

Make known through IOC the resources which developed countries can make available to assist other countries.

5.4 Requirements of the Intergovernmental Oceanographic Commission

Encourage Member States to participate in the global network and its regional components programme and facilitate the co-ordination and the promotion of the system.

Develop systems and standards for real-time data dissemination for ocean monitoring and flood warning purposes.

Encourage and support the activities of the Permanent Service for Mean Sea Level as the ICSU/IODE data bank.

Co-ordinate the exchange of resources and assistance through IOC-VAP or other systems.

Sponsor training courses covering: site selection, gauge installation, servicing, levelling, data reduction and telecommunication. These courses must work to common standards.

Publish a manual for sea level observers in several languages.

5.5 Implementation Time Scales

Although the network is defined in terms of permanent long-term operation, the implementation must be largely completed in time for the CCCO activities of TOGA and WOCE. This implies an active period of perhaps five years, beginning in 1984, during which the implementation should be given very high priority. In view of the gaps already identified in the Indian Ocean, and the activities already underway with training and equipment supply, it would be useful to give early priority to the network development in the CINCWIO region, and to use the experience gained to develop progressively similar networks in other ocean regions through regional subsidiary bodies of IOC.

6. COST OF INSTALLATION AND OPERATION

The cost estimate is based on the installation and operation of a network of 30 sea level gauges in the Pacific Ocean by the University of Hawaii. This network was installed between 1974 and 1976 and has been operated continuously since that time. All estimates are in US dollars and are based on costs typical for the US and the Pacific Islands. Experience of operating gauges in the United Kingdom shows costs broadly in line with these estimates.

6.1 Site Preparation and Installation

The cost for the preparation of a site, for the installation of a stilling well, for the construction of a recording equipment shelter and for the necessary materials and labour varies considerably from place to place. It averages about $4,000, but this does not include travel cost to the site and salaries for a technician. It is most economical if this part of the gauge installation is undertaken by the local authorities.

6.2 Instrumentation

Simple gauges with strip chart or digital punch paper recording can be purchased from many manufacturers for $2,000 to $4,000. If magnetic tape recording is desirable the price is slightly higher, but processing cost will be lower. Pressure gauges with recorders can be purchased for about $5,000. Satellite transmission, which will be preferred for many remote stations costs about $5,000 and includes the satellite transmitter, solar or other power supply, antenna and mast. The satellite system usually offers many additional channels, which can be used to transmit additional parameters such as battery voltage, temperature, wind, radiation, atmospheric pressure and others, if additional sensors are being installed. This allows the combination of a sea level station with a meteorological station and enhances the value of both.

6.3 Operation and Data Reduction

The operation of a sea level gauge requires maintenance and data processing. Supplies, spare parts, communication, and pay for the tide observer will cost about $1,000 per station and year. An annual site visit for maintenance and levelling will require additional funds depending on the location. According to experience, the data processing costs about $2,500 per station and year, or about one full time employee for ten stations for larger networks. The cost will vary according to labour costs in different countries.

6.4 Summary

Initial costs are in the region of $15,000 per gauge, with a further $3,500 per year for operation and data reduction.

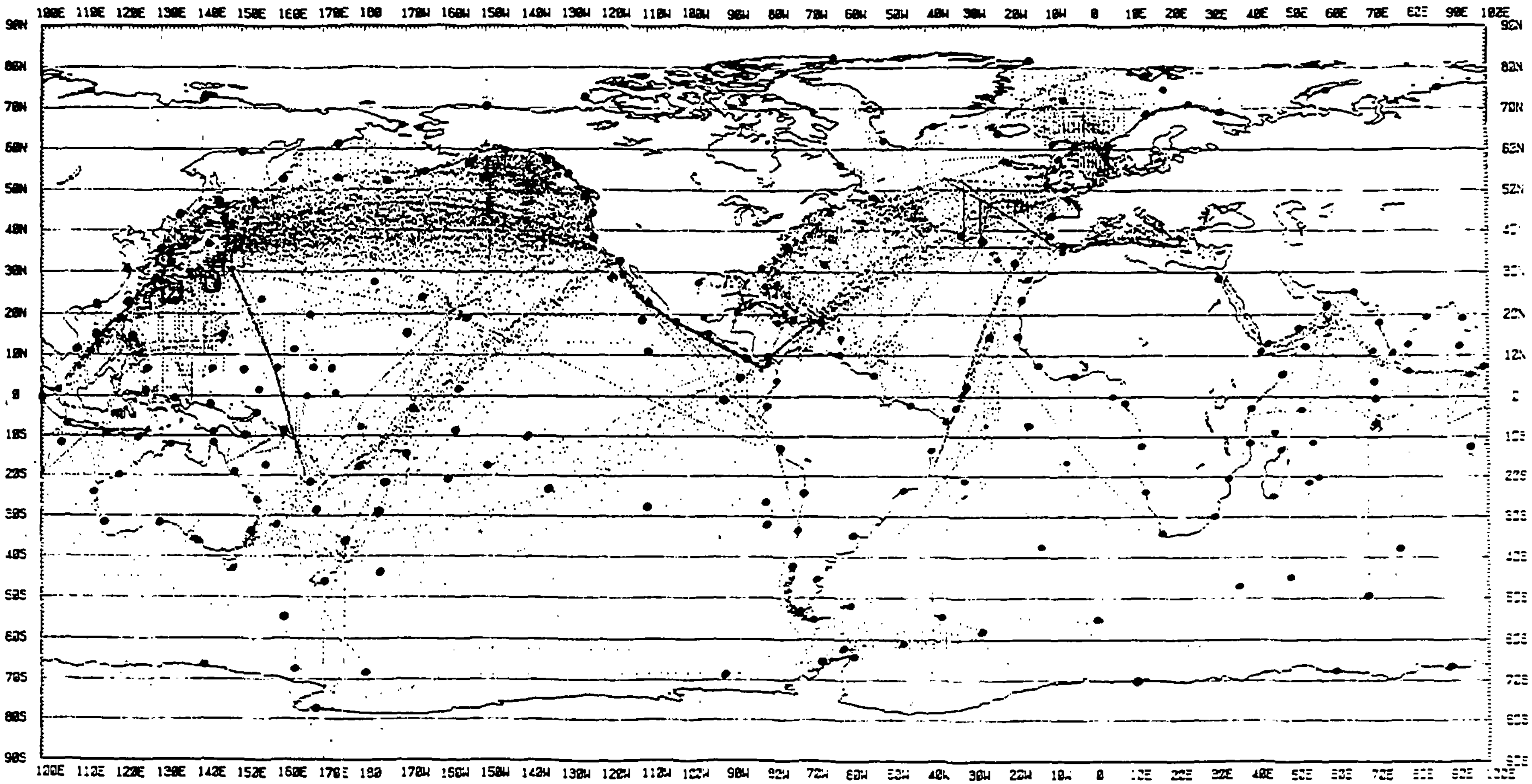
100E 110E 120E 130E 140E 150E 160E 170E 180 170W 160W 150W 140W 130W 120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E 40E 50E 60E 70E 90E 100E
90N 80N 70N 60N 50N 40N 30N 20N 10N 0 10S 20S 30S 40S 50S 60S 70S 80S 90S

Figure 1.

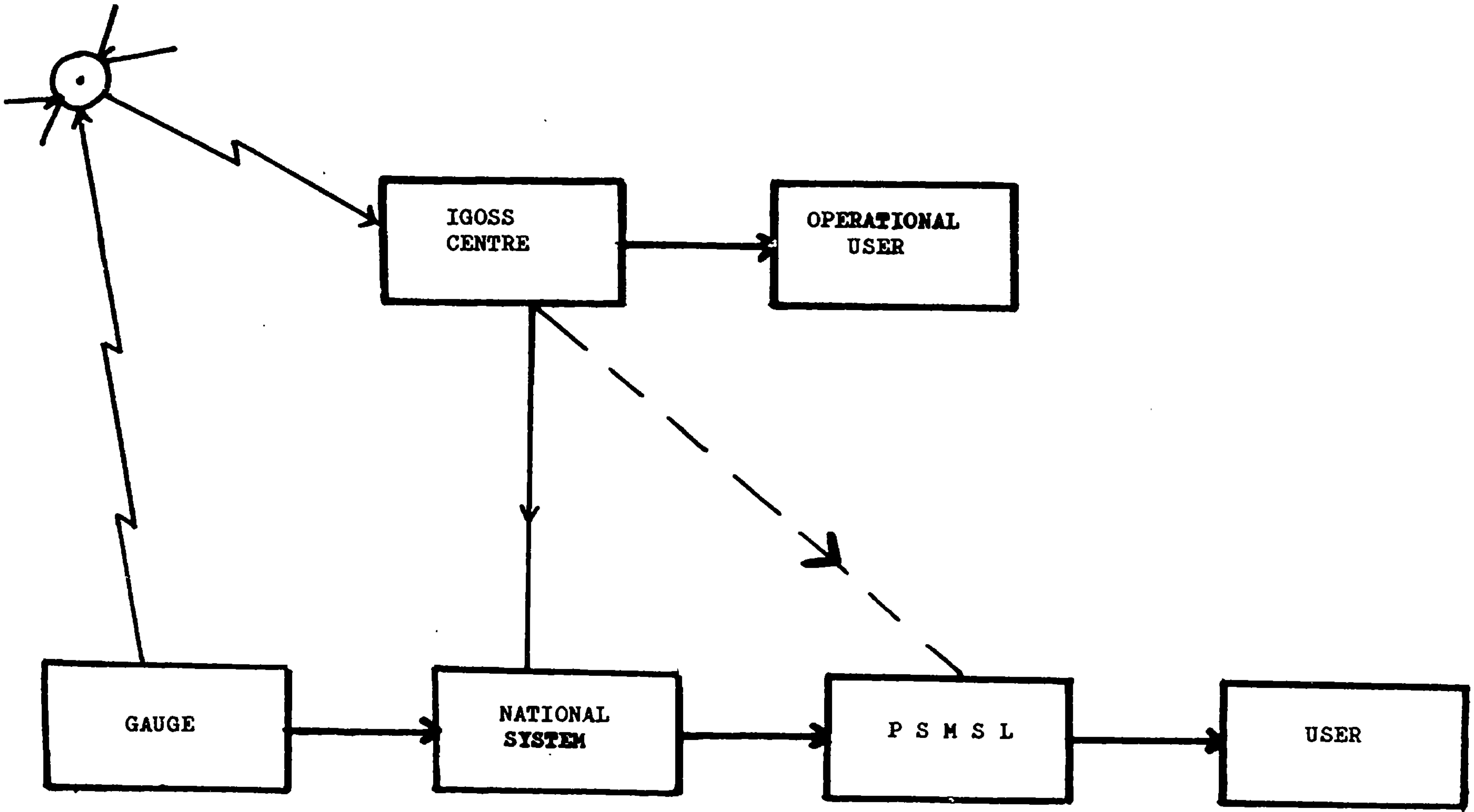
IGOSS
CENTRE
OPERATIONAL
USER
GAUGE
NATIONAL
SYSTEM
P S M S L
USER

Figure 2.

ANNEX I

PAST RESOLUTIONS, DECISIONS AND RECOMMENDATIONS OF IOC GOVERNING, SUBSIDIARY AND CONSULTATIVE BODIES REGARDING SEA LEVEL MEASUREMENTS AND TIDE GAUGE NETWORK

1. The Fifteenth Meeting of the Scientific Committee on the Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU) was held in Chamonix-Mont Blanc, France, from 16 to 27 May 1978. SCAR adopted, inter alia, Recommendations of the Working Group on Meteorology in the field of physical oceanography:

"Appendix B to Annex 2 to XV-SCAR-10

Working Group on Meteorology

Physical Oceanography

[...]

B. Recommendations for measurements of relevant parameters

[...] The sea level itself can be used if atmospheric pressure data are collected at the same time. The specific recommendation is that the following stations, or nearby ones, be equipped with shallow pressure gauges for long-term measurement of ocean pressure to an accuracy of better than 1 cm of water: (see below for priorities).

Coastal	Island
Antarctic peninsula stations (Capitan Arturo Prat, General Bernardo O'Higgins, President Frei, Palmer, Argentine Islands, Almirante Brown)	Falkland (Malvinas) South Orkney
Novolazareskaya	South Georgia
Molodezhnaya	Bouvet
Mawson	Gough
Mirny	Marion
Dumont d'Urville	Crozet
Leningradskaya	Amsterdam
McMurdo	Keguelen
	Macquarie
	Campbell

First priority are the stations which form sections perpendicular (cross-stream) to the Antarctic Circumpolar current. These are Gough - Bouvet - Novolazarevskaya, Amsterdam - Kerguelen - Mawson, Macquarie - Leningradskaya, Dumont d'Urville (an instrument could also be deployed in the Ballenny Islands by supply ships to complete this section) and across the Drake Passage (Cape Town - Antarctic Peninsula stations). Second priority would be the stations which could show the passage of long-period waves around the continent and the Antarctic Peninsula. In addition to Priority 1 stations there are eg Syowa, Molodeznaya, Mirny. A gauge at Pine Island Bay would be useful, but since there is no station there, logistics may be difficult. The gauges at Falkland Islands, South Orkneys, Marion and Crozet would supplement the sections above by providing downstream information. All the named stations on the continent are examples; if others nearby could be used, the data would be equally usable and important."

2. At the Twelfth Session of the IOC Executive Council (Paris, 22 - 24 October 1979), "the Chairman SAB asked the Executive Council to take note of the existing Permanent Service for Mean Sea Level (PSMSL). Within the context of the climate programme and the repeated requests for sea-level data in this programme, the IOC should take positive steps to identify additional sources of funding for the PSMSL." (Extract from the Summary Report of the Session, item 5 "Reports of the Scientific Advisory Board").

3. The Eighth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific was held in Suva, Fiji, from 13 to 17 April 1982. The Session was informed on the IGOSS Mean Sea Level Pilot Project in the Pacific Ocean and considered a proposal made by the Chairman of the Joint IOC/WMO Working Committee for IGOSS" to use Tsunami Warning System Gauges for measurements of sea level and to provide on a short-term interval basis mean sea level data which would benefit the oceanographic programmes of the World Climate Research Programme (WCRP)". (Extract of the Summary Report of the Session, para.110).

4. The First Session of the IOC Programme Group for the Co-operative Investigation in the North and Central Western Indian Ocean (CINCWIO-I) was held in Rosta, Nairobi, Kenya, from 4 to 9 October 1982.

"The Group expressed a general interest in the establishment of a regional tide-gauge network under CINCWIO as part of the global network being promoted by the IOC, but noted that some technical assistance and related training in the installation and operation of gauges and, especially, in the data reduction would be needed". (Extract from the Summary Report of the Session, item 5 "Ocean Services", para.2 "Sea Level Measurement").

5. At its Twelfth Session (Paris, 3-19 November 1982), the IOC Assembly "acknowledged the great importance of satellite remote-sensing and mean sea-level measurements for ocean research and monitoring, and asked the Executive Council at its Seventeenth Session to review the application of these techniques to ocean research and monitoring, with a view to formulating the IOC's policy with respect to them." (Extracts of the Summary Report of the Session, item 4.5.2 "Scientific basis for ocean monitoring", para.82).

6. The Fourth Session of the IOC/SCOR Committee on Climatic Changes and the Ocean (CCCO) was held in Paris from 18 to 22 January 1983. CCCO has recommended that IOC makes the necessary arrangements for improving sea-level observations.

"It was agreed that the IOC, in co-operation with the Division of Marine Sciences of Unesco, was the appropriate organization to pursue the further development of the sea level project with initial emphasis on the Indian Ocean and Tropical Atlantic." (Extract of the Summary Report of the Session, item "Sea Level Observation Project", para.122).

7. At its Third Session (Paris, 21 February - 2 March 1983), the Joint IOC/WMO Working Committee for IGOSS "welcomed the concept of a pilot project for preparation of a mean sea level product to be implemented in the Pacific.

The Committee, recalling IOC's aim of promoting the establishment of a world-wide sea-level monitoring network, stressed the importance of using regional IOC and WMO mechanisms and advisory bodies (WESTPAC, ITSU, SEATAR, etc.) in implementing a Sea Level Pilot Project for the Pacific region. The Committee urged the IOC and WMO Secretariats to invite these groups to participate actively in the implementation of the pilot project.

The Committee adopted Recommendation 3 (JWC-IGOSS-III) together with its annex "Draft operational plan for an IGOSS Sea Level Pilot Project (ISLPP) i the Pacific" (Annex IV to the Summary Report)." (Extracts of the Summary Report of the Session, item 3.3, paras. 45, 47, 49).

"Recommendation 3 (JWC-IGOSS-III)

IMPLEMENTATION OF AN IGOSS MEAN SEA LEVEL
PILOT PROJECT IN THE PACIFIC OCEAN

The Joint IOC/WMO Working Committee for IGOSS,

Recommends that the IGOSS Mean Sea Level Pilot Project in the Pacific Ocean (ISLPP) be implemented in accordance with the draft plan given in the annex (x) to the present Recommendation for a five-year period commencing in 1983;

Requests the Secretariats to undertake necessary actions to initiate the implementation of the project and to keep Member States and international bodies concerned informed of this project;

Requests further the Chairman of the Joint Working Committee to inform the respective governing bodies of the IOC and WMO of the status and progress of the ISLPP.

(x) Annex IV to the Summary Report."

(Extracts from Annex II to the Summary Report of the Session, Recommendation 3 (JWC-IGOSS-III)).

8. The Fourth Session of the IOC Programme Group for the Southern Oceans was held in Paris from 7 to 11 March 1983.

"The Programme Group requested the IOC Executive Council, at its Seventeenth Session to consider and accept as the basis for an International Programme of Physical and Chemical Oceanographic Investigations in the Southern Oceans, research made by PG/SOC Member States in the field of sea level measurement in the Southern Oceans. [...]

The Programme Group recommended that IOC (through the Permanent Service for Mean Sea Level (PSMSL) ask those countries that have carried out such measurements to document their experience (i.e., need for specialists) and to report to IOC their plans for future measurements and that this information be passed to those countries interested in carrying out such measurements.

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The Programme Group further noted that PSMSL has made a commendable effort in collecting and disseminating sea-level data and in establishing training courses in sea-level measurement techniques; it recommended that IOC, through its TEMA programme continue and expand the sea-level training courses to workers from all countries interested in working in the Southern Oceans, and that IOC facilitate the analysis and preparation of sea-level data for submission to the PSMSL by providing assistance as appropriate or as required for such work by interested Member States."

(Extracts from the Summary Report of the Session, paras. 16, 39, 41).