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17

Oceanographic Components of the Global Atmospheric Research Programme (GARP)

Unesco 1977

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Preface

The purpose of this document is to acquaint the world's oceanographic community further with the Global Atmospheric Research Programme (GARP). In particular, it is intended to introduce components of GARP from which oceanographers can benefit, either by using the results of GARP programmes directly or by planning experiments concurrently with GARP activities, such as the First GARP Global Experiment. These concurrent experiments can take advantage of the data collected by other investigators and, at the same time, contribute to the objectives of GARP.

The audience to which this document is addressed consists primarily of those countries, and oceanographers within those countries, who have not had enough exposure to the oceanographic components of GARP to decide whether or not participation would be beneficial. The Intergovernmental Oceanographic Commission is convinced that GARP will be of considerable benefit to the world community. It is therefore hoped that this document will stimulate oceanographic interest within those countries uncommited at present and encourage them to participate in some meaningful way. In return, they will reap the rewards of what promises to be the most comprehensive programme in the history of the environmental sciences.

Primarily, the benefits to be derived from GARP will result from the improvement of atmospheric and oceanic forecasting and climatological models. Improvement of these models will increase substantially their impact on obvious areas such as agriculture, elements of marine resources, ship routeing, storm warnings, etc., and will result in further saving of lives as well as of economic resources. The complete role of oceanographic processes within these models is not, as yet, known, but it is clear that the oceans hold a key to substantial model improvements and, in fact, they will be an essential factor to the success of GARP.

In order to begin to satisfy the need for ocean programmes in support of the GARP, this document attempts to identify the basic relationships and objectives of oceanography to GARP, highlighting the contributions that could be made by the Scientific Committee on Oceanic Research (SCOR) and IOC. The document also describes those existing elements of SCOR and IOC which would be supportive of, as well as receiving support from, the GARP.

Those aspects of SCOR and IOC which are supportive of FGGE include: (i) internationally agreed-upon procedures for the collection, exchange and archiving of oceanographic data needed for boundary conditions and variables in General Circulation Models; (ii) research projects which provide increased understanding of air-sea interaction processes on many scales; (iii) investigative programmes that include ocean observational facilities which can be used to improve the meteorological observing systems over ocean areas; (iv) training, education, and assistance programmes that can increase participation by developing countries; and (v) parallel high priority interests in the Equatorial, Indian and Southern Ocean areas during 1977-1980. It is also important to recognize that FGGE will be supportive of the SCOR and IOC ocean programmes by providing an unprecedented data set for studying the many ocean processes linked to atmospheric forcing and feedback.

The ocean will also assume a major role in the GARP second objective. In fact, it is almost certain that SCOR and IOC, together with WMO and other international organizations, will make significant contributions toward fulfilling the ocean aspects of the GARP second objective. In this respect, objectives have been identified which include: (i) understanding and parameterizing subgrid scale processes which determine the circulations of the ocean; (ii) constructing a hierarchy of models for studying climate dynamics on various time scales; (iii) assembling suitable data sets for testing climate models; and (iv) identifying the properties of deep ocean sediments which contain climatological evidence of very long-time scales.

It should be pointed out that the successful attainment of these objectives may be realized only if all the component parts of SCOR and IOC are sufficiently well co-ordinated so as to ensure a balance of priorities commensurate with the expected resources of the participating nations of the world. Thus the task of developing specific plans, co-ordinating activities, and advising countries and international bodies on an ocean programme related to GARP, is the responsibility of SCOR and IOC through both their subsidiary and joint organizational framework. This mechanism will then provide a double thrust with activity on a scientist-to-scientist and on a government-to-government level. Further, it is highly desirable to have a major increase in activity related to education, training, assistance and technology transfer so that the badly-needed participation by developing countries can be realized.

This document has been prepared, in response to IOC resolution IX-6, by an ad hoc task team under the chairmanship of Professor Dr. H. U. Roll, with considerable assistance from the Rapporteur, Mr. R. Landis. A detailed description of the oceanographic programmes during the FGGE has been issued by SCOR Working Group 47 as a separate document. Additional information on oceanographic activities within GARP can be obtained from the Secretary, IOC, Unesco, Place de Fontenoy, 75700 Paris, France. More comprehensive information on all aspects of GARP itself can be obtained from The Director, GARP Activities Office, World Meteorological Organization, Case Postale No. 5, 1211 Geneva 20, Switzerland.

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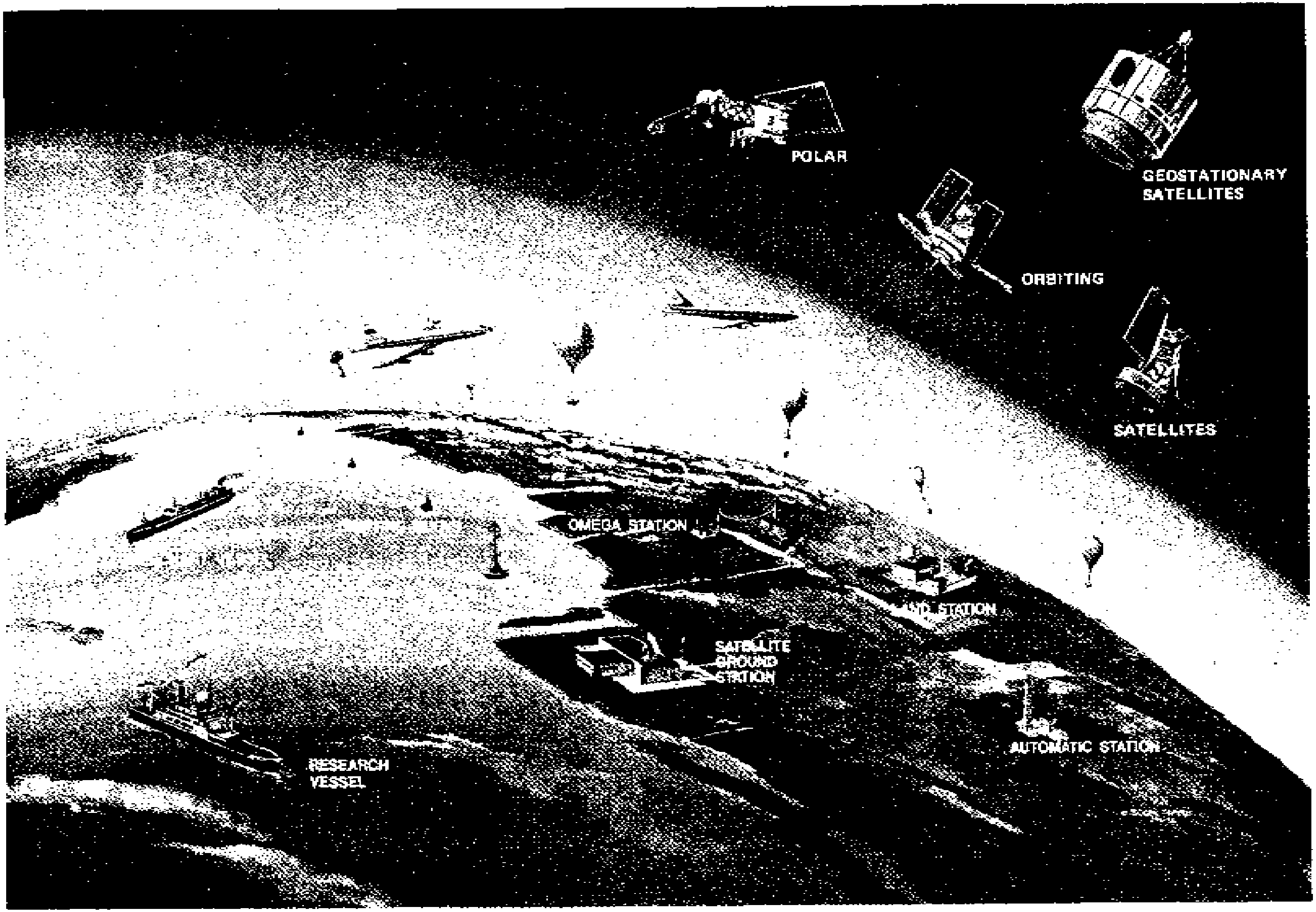


Representation of the various observing systems to be used during the First GARP Global Experiment
(Photo : NOAA FGGE Office)

1. Introduction

As the WMO/ICSU Global Atmospheric Research Programme (GARP) begins its second decade, it is becoming increasingly clear that the composition and direction of the programme in the coming years will include a range of non-atmospheric sciences. In pursuing an objective of longer-term weather forecasting and understanding the physical basis for climate, it will become necessary to increase the limits of numerical models so that existing boundary conditions will become parameterized processes. One of the most important boundaries to be included will be that of the ocean.

In order to provide as much as possible of the needed oceanographic inputs required by the GARP, the Intergovernmental Oceanographic Commission (IOC) in co-operation with the Scientific Committee on Ocean Research (SCOR), has decided to take two basic courses of action: (1) to identify oceanographic opportunities and viable objectives for programmes that could be related to the GARP; and (2) to identify specific oceanographic programmes which will meet and expand upon the objectives outlined in (1) above.

Each of these actions will result in the publication of documents. This document is a result of the first action. Because of the impending need for oceanographic support during the forthcoming First GARP Global Experiment (FGGE), the primary result to date of the second action mentioned above is a SCOR document on specific oceanographic programmes during the FGGE. This latter document includes information obtained during the FGGE, INDEX, NORPAX, Equatorial (FINE) workshop from 27 June to 12 August 1977. The document can be obtained through IOC, SCOR, or WMO. The downstream intent of both of these actions is to provide a basis for organizing and co-ordinating the oceanographic programmes for GARP as far as possible within existing international frameworks.

As a matter of convenience, this document has been divided with respect to two time periods - from the present up to and including the FGGE, and the period after the FGGE. This breakdown is intended to coincide with the expected emphasis which will be placed on the first and second objectives of GARP, respectively.

1.1 GARP objectives

The Global Atmospheric Research Programme (GARP) is a programme for studying those physical processes in the troposphere and stratosphere that are essential for an understanding of:

the transient behaviour of the atmosphere as manifested in the large-scale fluctuations which control changes of the weather; this would lead to an increase in the accuracy of forecasting over periods from one day to several weeks;

the factors that determine the statistical properties of the general circulation of the atmosphere which would lead to a better understanding of the physical basis of climate.

The programme consists of two distinct parts which are, however, closely interrelated:

the design and testing by computational methods of a series of theoretical models of relevant aspects of the atmosphere's behaviour in order to permit an increasingly precise description of the significant physical processes and their interactions;

observational and experimental studies of the atmosphere, in order to provide the data required for the design of such theoretical models and the testing of their validity.

In trying to pursue these objectives, it has become quite clear that for time scales of one to several weeks and upwards, the reaction of the atmosphere to the ocean and vice-versa is essential. As such, the boundary of the total observing system will have to be placed at an ocean depth compatible with the reaction times of interest. Although not accurate in detail, Figure 1 roughly exemplifies the volume of the ocean requiring consideration for mid-latitude forecasts.

The GARP has been organized into a series of sub-programmes in order to permit a systematic pursuit of its objectives. These sub-programmes include the following:

- tropical sub-programmes;
- numerical experimentation sub-programme;
- climate dynamics sub-programme;
- monsoon sub-programme;
- polar sub-programme;
- radiation sub-programme;
- air-surface interaction sub-programme.

For each of these sub-programmes there exists some need for related ocean activities. Table I gives examples of the ocean component relationship to each GARP sub-programme.

TABLE I

Examples of ocean component relationship to GARP sub-programmes

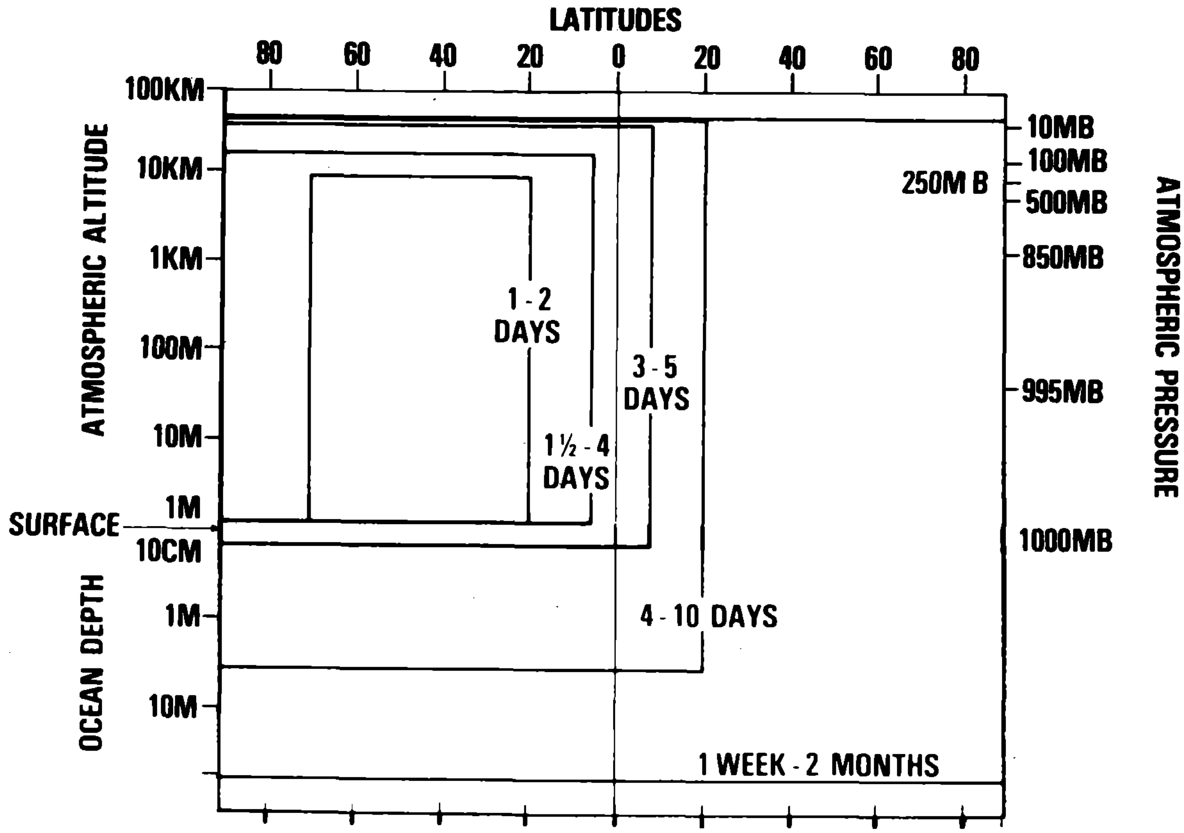
GARP sub-programmes	Examples of ocean component
Tropical	Sea surface temperature anomalies of less than 1° C. have significant influence on the atmospheric general circulation
Numerical experimentation	Coupled ocean-atmosphere models
Climate dynamics	Ocean heat transport
Monsoon	Sea surface temperature anomalies of less than 1° C. have significant influence on monsoon circulation and are strongly correlated to precipitation over the subcontinent
Polar	Ice and current drift
Radiation	Back radiation is a function of the sea surface temperature
Air-surface interaction	Energy flux between ocean and atmosphere boundary layer

1.2 FGGE objectives

From the very beginning of GARP, it was recognized that there would have to be a period during which the entire global atmosphere was observed. This period is now called the Observational Phase of the First GARP Global Experiment (FGGE). As shown in Figure 2, a build-up year for the Global Experiment is now planned to start in December 1977, leading to the Observational Phase starting in December 1978. There will be two Special Observing Periods (SOPs) during January-February and May-June 1979, as shown in Figure 3. The Observational Phase will be followed by a Research and Evaluation Phase which will extend well into the 1980s.

FIGURE 1

SCHEMATIC OF THE DATA REQUIRED FOR FORECASTS IN THE MID-LATITUDES FOR DIFFERENT FORECAST PERIODS



Four objectives have been established to represent the main purpose of FGGE, and it can be seen that both research and operational aspects are involved. These are:

(i) to obtain a better understanding of atmospheric motions for the development of more realistic models for extended range forecasting, general circulation studies and climate;

(ii) to assess the ultimate limit of predictability of weather systems;

(iii) to develop more powerful methods for assimilation of meteorological observations and, in particular, for using non-synchronous data in order to determine the initial condition for predicting large-scale motions; and

(iv) to design an optimum composite meteorological observing system for routine numerical weather predictions of the large-scale features in the general circulation.

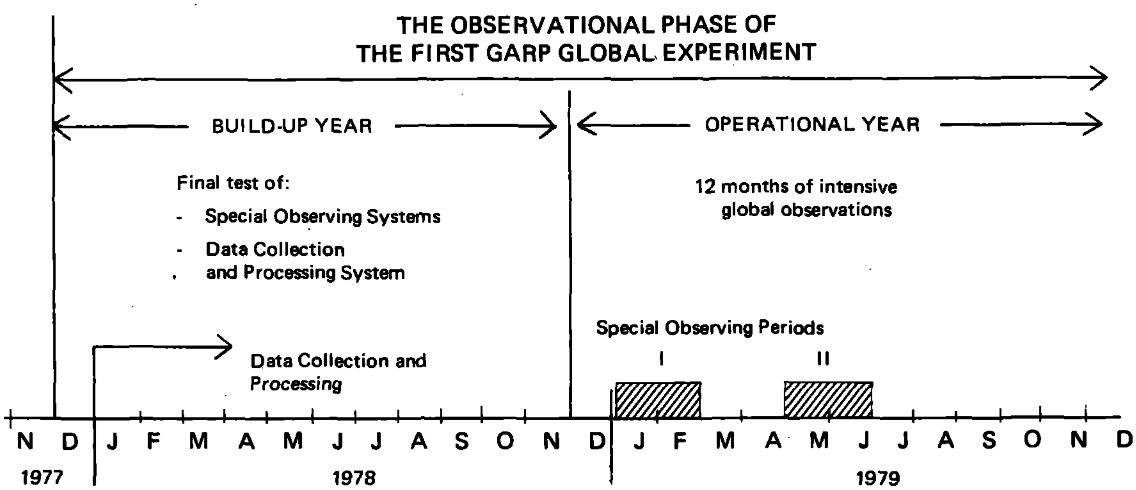


Figure 2 - Time schedule for the first GARP Global Experiment

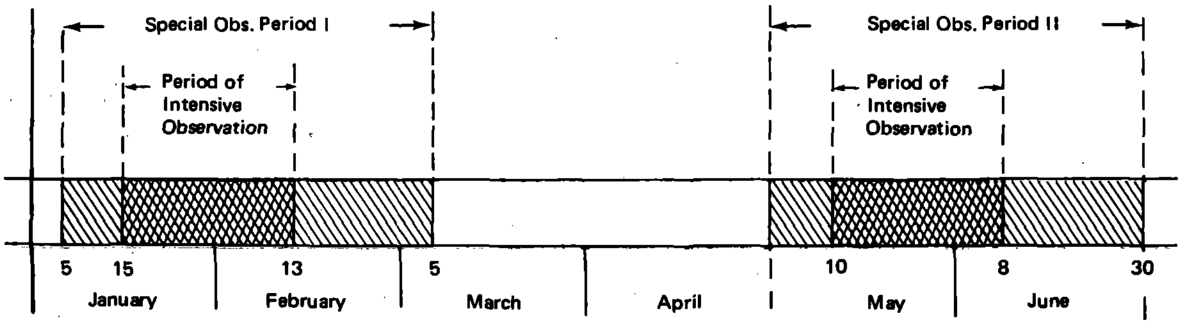


Figure 3 - Time schedule for the Special Observing Periods and the Periods of Intensive Observations

Thus the FGGE is designed to produce data which will establish the initial atmospheric condition for, as well as permit the verification of, numerical global models of the atmosphere. This data set will provide objective criteria for the improvement of models and thus lead to better weather forecasting. A major portion of the FGGE observational system will be derived from the Global Observing System (GOS) of the World Weather Watch (WWW). However, a significant part of the FGGE observations will come from specialized observing platforms such as satellites, ships, buoys, balloons, and aircraft as shown pictorially in the frontispiece. Comments on some of these systems of direct interest to oceanographers follow.

1.2.1 FGGE satellite systems

It is anticipated that improved polar satellite systems will be operated by the United States of America and the Union of Soviet Socialist Republics during the FGGE. These will provide not only atmospheric data, but oceanographic data such as sea-surface temperature. Some of the information will be available for direct read-out all over the world.

The U.S.A. satellite system will be equipped with the Data Collection and Platform Location System to receive data from fixed and moving platforms. This system could be used, in particular, for collecting data from drifting buoys during the FGGE.

It is expected that five geostationary satellites will be in operation during the FGGE at approximately: 0° longitude (ESA-METEOSAT), 70° E (USSR), 140° E (Japan), 135° W (U.S.A.), and 70° W (U.S.A.). (See Figure 4.) All will provide visible and infra-red images from which will be produced cloudiness, wind and sea-surface temperature data.

1.2.2 FGGE ships

A crucial element in the Tropical Wind Observing System is composed of about 50 ships (TWOS) to provide meteorological soundings including winds in the tropical zone from 10° N to 10° S. Because sounding equipment can be released twice daily, taking only a few minutes of time and with only minor restrictions on ships' work or cruise schedules, it is expected that many TWOS will be engaged simultaneously in other activities, mainly FGGE-related, and that they will cruise from place to place within 10° N to 10° S throughout the SOPs. Hence they will be free to engage, for example, in oceanographic or air-sea interaction studies so that oceanographic and atmospheric ships' resources will complement one another in a mutually beneficial way. It is necessary, however, that definite TWOS cruise plans be available in advance so that potential contributions to the FGGE observational requirements may be determined.

1.3 Second objective of GARP

The second objective of GARP is to develop an improved understanding of the physical basis of climate. GARP seeks, moreover, to express this understanding in the form of models which may be tested, validated, and employed in practical applications. The immediate goals of the GARP approach are:

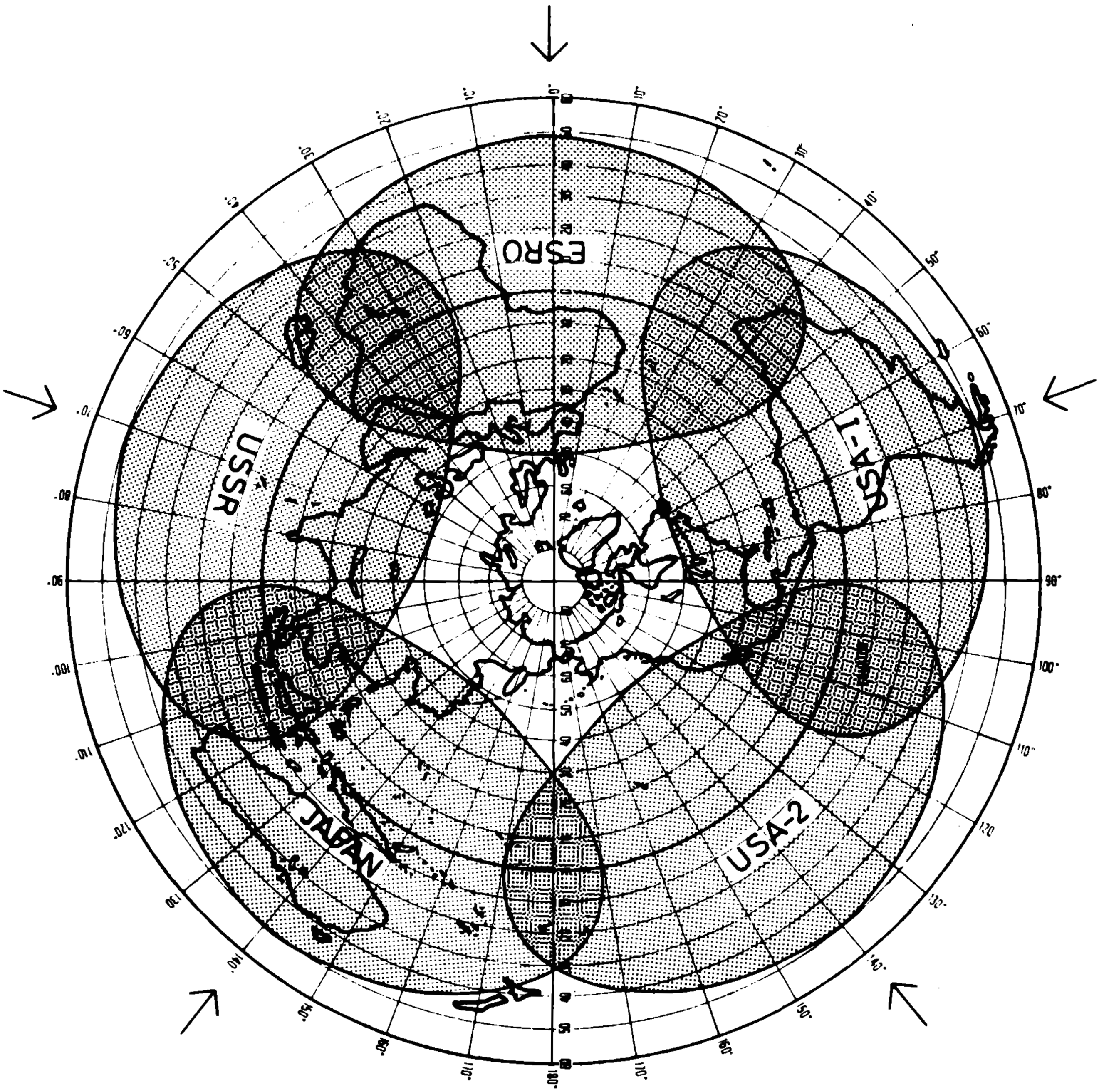
(i) to determine diagnostically the observed climate and its variations on space scales from regional to global, and time scales from about a month to the order of decades;

(ii) to provide the means for estimating the regional to global climatic response to prescribed changes induced by natural events or human activities;

(iii) to assess the feasibility of estimating future variations of climate on space scales of regional to global and time scales from a month to decades.

In trying to achieve these goals, first priority will be given to the use of general circulation models of the ocean-atmosphere system for predictability experiments for times from several weeks to several years. Within this effort, study of the annual variation will be emphasized. On these time scales the interactions between the ocean and the atmosphere through momentum and energy fluxes are highly significant to the behaviour of each fluid. Thus GARP efforts will involve diagnostic/observational studies of oceanic processes and ocean-atmosphere interactions, together with theoretical/numerical modelling of internal ocean dynamics, atmospheric processes, and the coupled ocean-atmosphere system.

Figure 4 - Fields of view of geostationary satellites, assuming 50° maximum angular distance from sub-satellite point for acceptable wind derivation. Based on nominal plans of launching countries.



1.4 Oceanography in GARP

The rationale for developing and encouraging oceanographic programmes related to GARP is based on the following:

- atmospheric prediction models will require parameterization of energy exchange between the ocean and atmosphere;

- a significant proportion of the GARP field observations will be required from oceanic areas where utilization of ocean platforms such as research vessels and buoys will be needed;

- ocean investigations made concurrently with atmospheric observational programmes can provide a significant opportunity for understanding the ocean processes which involve atmospheric forcing and vice-versa;

- the development of an understanding of the physical bases of climate will require a coherent ocean-atmosphere data base;

- the design of a long-term monitoring system of the environment should include the characteristics of a joint ocean-air-ice system;

- forecasting of the ocean, which has significant economic impact as it relates to fish population prediction and assessment, can best be accomplished as an integral part of a total sea-air fluid concept;

- observations in the areas of the world oceans are extremely costly and might best be made in the context of co-operative international programmes involving both ocean and atmosphere.

The last major point suggests that oceanographic programmes related to GARP should be a major interest of international oceanographic bodies such as IOC and SCOR. Such a partnership, in association with the WMO, should provide the necessary mechanism for effective co-operation in developing and implementing a comprehensive oceanographic programme related to GARP.

1.5 IOC-SCOR objectives related to GARP

The general responsibilities of SCOR and IOC are respectively: (1) to provide expert advisory services on international ocean sciences; and (2) to effect intergovernmental co-ordination in the implementation of international oceanographic programmes. Taking this into account, IOC and SCOR have established for themselves the following GARP-related objectives:

- provide advice to the JOC and WMO on the need for oceanic research required by the GARP, especially as it regards the understanding of physical processes and regional phenomena;

- provide for intergovernmental co-ordination for the implementation of oceanic research relevant to GARP;

- provide for a mechanism for the establishment and maintenance of an ocean monitoring and services system required by GARP;

- provide for an international co-ordinated system for exchanging and archiving oceanographic data as a part of a total GARP data set;

- provide for multidisciplinary science opportunities in training, education, and technology transfer between developed and developing nations of the world, especially those needed for the implementation of the GARP;

- provide for an identification of observational platforms and other resources available as a part of IOC and SCOR activities which could be beneficial to the GARP;

- provide for a permanent organizational structure for continuing co-operation on GARP between JOC, WMO, IOC, SCOR and other relevant international bodies.

2. Oceanographic components in FGGE

2.1 FGGE-ocean relationship

The extensive global, meteorological data-gathering effort that will take place during FGGE provides a unique opportunity to relate the variable features of ocean processes to atmospheric forcing. This special opportunity will provide a global and reasonably comprehensive atmospheric data set, especially in tropical waters and in the Indian and Southern Oceans. In addition, a large number of observational platforms (e.g. drifting buoys, research vessels, aircraft and satellites) which can be used for both ocean and atmospheric observations will be available, thus increasing the effectiveness and value of the observing facility. Thus, the areas of significant scientific support between FGGE and ocean research will be to those projects investigating ocean processes which interact with the atmosphere or are subject to atmospheric forcing. Also, the FGGE-ocean relationship transcends mutual support in areas such as ocean services and training, education, and mutual assistance activities.

The specific areas of FGGE-ocean interaction can be summarized as follows:

determination of sea-surface temperature to meet FGGE objectives;

determination of vertical ocean structure of temperature in the upper 200 metres;

determination of the time-dependent response of intense ocean currents;

joint investigations of strongly coupled phenomena and large-scale processes of ocean-atmosphere interaction such as the Monsoon, El Niño and Walker Circulation;

joint use of facilities such as ships, buoys, etc.;

marine environmental data management;

modelling and understanding of the general ocean circulation; and

joint projects of training, technology transfer, and other activities of assistance to developing countries related to marine meteorology and oceanography.

2.2 FGGE support to oceanography

The major support that FGGE can provide to oceanographic programmes is in the form of a comprehensive atmospheric data set such that oceanic responses to atmospheric forcing can be investigated. In addition, the FGGE would support research in the areas of internal dynamics of the ocean, coastal upwelling processes, ocean processes in the Antarctic, the influence of the oceans on climate, mathematical modelling of ocean processes, and investigations of El Niño, a meteorological and oceanographic phenomenon off the west coast of South America. It should be pointed out that the support from FGGE will be somewhat limited due to the shorter time scales inherent to atmospheric processes and reflected in the special observing periods. However, the expected data set of surface wind fields (especially in the equatorial area), pressure fields and temperature fields should be extremely beneficial in improving the understanding of atmospheric-forced ocean processes in the shorter time scale range, and as a realization in longer term studies. A second form of support by the FGGE to ocean science activities should be in the form of the many observing platforms which will be in the oceanic regions and could be used on a shared basis for both oceanic and atmospheric research.

The FGGE offers significant support to several co-operative investigations including the Southern and Indian Oceans. Specifically, it is planned to use drifting buoys both during FGGE and for studies of the Southern Oceans, and a joint effort in this respect would be helpful to both programmes. To be successful, this would require agreed-upon specifications on buoy and drogue design, data transmission, sensor selection, position-finding methods, data management, and deployment schedules. The FGGE and the GARP Monsoon sub-programme experiments (MONEX) and the INDEX will be supportive by establishing a preliminary data base which can be used to help develop and steer the emerging regional co-operative investigation programme for the north and central western Indian Ocean.

2.3 SCOR support to FGGE

SCOR and IOC have played a major role in planning, co-ordinating and implementing many of the large-scale international oceanographic investigations. In particular this responsibility has been pursued through the use of SCOR working groups and the IOC science programmes related to regional co-operative investigations and the International Decade of Ocean Exploration (IDOE). These IOC-SCOR activities are complementary and provide a mechanism for close interaction both on a government-to-government as well as a scientist-to-scientist level.

The activities of SCOR are organized by working groups which have specific terms of reference. The main SCOR working group concerned with FGGE is Working Group 47 (Oceanographic Programmes during FGGE); however, several other SCOR working groups are involved in programmes relevant to FGGE:

SCOR Working Group 34 - Internal Dynamics of the Ocean

SCOR Working Group 36 - Coastal and Equatorial Upwelling Processes

SCOR Working Group 38 - Ocean Processes in the Antarctic

SCOR Working Group 43 - Oceanography related to GATE

SCOR Working Group 49 - Mathematical Modelling of Oceanic Processes

SCOR Working Group 55 - Prediction of El Niño

SCOR Working Group 47 has organized the oceanographic programmes during FGGE into four major areas:

Pacific Equatorial Ocean;

Atlantic Equatorial Ocean;

Indian Equatorial Ocean and the Arabian Sea;

Southern Oceans.

The decision to make this type of separation was based on the need of FGGE to know the ocean surface temperature and other parameters in these areas, and the concomitant desire of many oceanographers to investigate these ocean areas.

2.3.1 Tropical Atlantic and Pacific investigations

The ocean investigations of the equatorial oceans can be supportive of FGGE by:

providing an increased understanding of sea-surface temperature, including surface truth for aircraft and satellite data;

providing data and understanding of processes involved in large-scale air-sea interaction;

providing ships and scientists which can collect atmospheric data especially during the special observing periods;

providing an opportunity to verify results and conduct follow-on research to GATE which is of benefit to FGGE.

In addition to SCOR WG 47's planning in the tropical ocean areas during FGGE, SCOR WG's 43, 49, and 55 will also be involved. This involvement includes the evaluations of GATE research, mathematical modelling of equatorial ocean processes, and investigations of El Niño.

2.3.2 Indian Ocean investigations

Ocean investigations in the Indian Ocean will contribute significantly to both FGGE as a whole and the GARP Monsoon sub-programme. This planned Indian Ocean investigation will contribute the following support:

provision of increased understanding of the heat budget of the mixed-layer of the Arabian Sea, considered to be an important variable in the prediction of monsoon rainfall on the subcontinent;

provision of ships and scientists which can collect atmospheric data, especially during the FGGE special observing periods.

In addition to SCOR WG 47, SCOR WG's 36, 48 and 49 will also provide support to the Indian Ocean experiments during FGGE by investigating upwelling processes, determining the influence of the monsoon-related ocean circulations to climate, and development of air-sea coupled numerical models. A comprehensive report on the FGGE oceanographic programmes in all three tropical ocean areas referred to above has been prepared by SCOR WG 47 and is available from the IOC Secretariat, SCOR and the WMO. Figure 5 presents the probable areas of intensive tropical oceanographic investigations during the FGGE as of May 1977.

2.3.3 Southern Ocean investigations

SCOR WG 47 has established an affiliation with the International Southern Ocean Studies (ISOS) Group in order to promote oceanographic activities in the Southern Oceans during FGGE.

The ocean investigation of the Southern Oceans will be significantly supportive of FGGE as a whole, and also of the GARP Polar sub-programme. Of major importance will be support to the drifting buoy programme of FGGE. Thus the major contributions of support to FGGE will be:

provision of co-operative mechanism for a joint drifting buoy experiment including deployment opportunities;

provision of ships and scientists which can collect atmospheric data especially during the special observing periods.

As with the other ocean areas, a significant amount of participation will be provided by SCOR WGs other than WG 47. These include WGs 38 and 49.

2.4 IOC support to FGGE

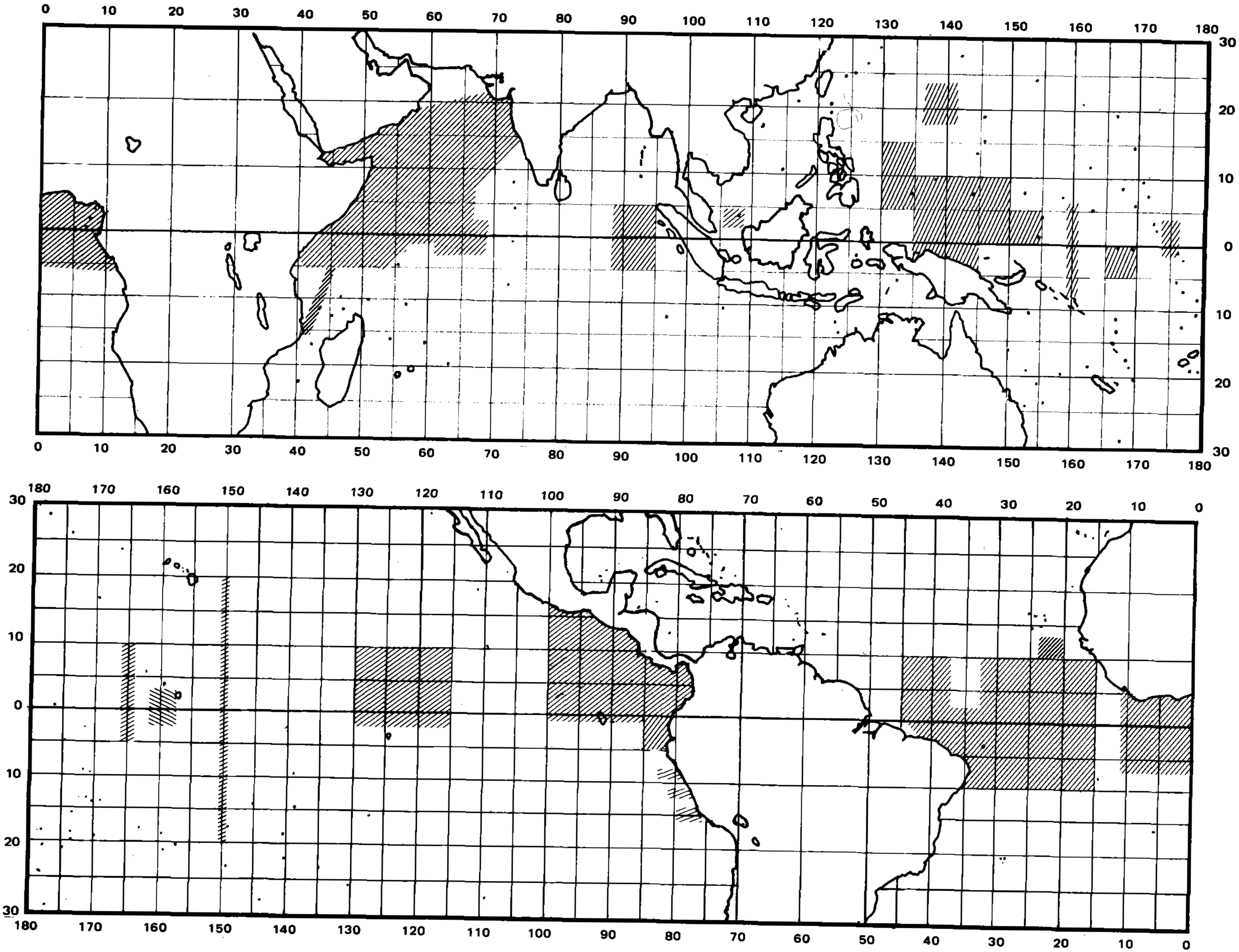
A major responsibility of SCOR is to recommend and advise on ocean phenomenological and process-oriented research. This is complemented by a major responsibility of IOC in the intergovernmental implementation of the research, principally as a part of the programmes of the International Decade of Ocean Exploration, and the regional association and co-operative investigations of the Commission.

2.4.1 IDOE

The International Decade of Ocean Exploration (IDOE) is the acceleration phase of the Long-term and Expanded Programme of Ocean Exploration and Research (LEPOR). As a matter of high priority, IDOE has selected as two of the programme areas for early study: ocean research relevant to environmental forecasting, and coastal upwelling ecosystems analysis. Investigation in both of these programme areas, because of their treatment of the atmosphere ocean fluid system as a whole unit, will be mutually supportive with the FGGE. Two major IDOE investigations conducted concurrently with the FGGE are the JASIN and NORPAX. The JASIN experiment will continue much of the air-sea interaction research begun during GATE. It is important to note that JASIN will provide specific quantitative information on the smaller scale energy responses and feedback between the atmosphere and ocean.

During FGGE considerable emphasis will be placed on the tropical Pacific Ocean by NORPAX investigators, taking into account the advice and recommendations of the Pacific equatorial panel of SCOR WG 47. As such, this means that considerable research can be related to FGGE. This

Fig. 5. Areas of probable intensive oceanographic investigations during the FGGE as of May 1977.



NORPAX-FGGE relation will provide (i) data and information needed for determination of the ocean surface temperature, (ii) increased understanding of the Walker Cell Circulation and its relation to the southern oscillation, (iii) facilities such as buoys, research vessels and island upper air sounding stations in the tropics for joint use, and (iv) increased understanding of tropical dynamics and thermodynamics.

Another major IDOE programme area which is strongly related to FGGE is the study of Coastal Upwelling Ecosystems Analysis which emphasizes investigations of coastal upwelling along, for example, the Guinea, Oregon, and Somali coasts, and, in particular, the Humboldt current-related phenomenon known as "El Niño". Like NORPAX, El Niño investigations will also treat the atmosphere-ocean system as a whole unit. It has already been recognized by the JOC for GARP that El Nino does manifest itself as part of the larger atmospheric circulations. The major contribution of El Niño investigators during FGGE will be in providing an increased observational capability in the eastern equatorial and southern Pacific area and increasing the understanding of "El Niño" as it relates to the equatorial and southern hemisphere ocean and the general atmospheric circulation. Specific organizational structure for El Nino investigations is still in the formative stage but it is expected to include a systematic mechanism for co-operative efforts with GARP. Formulation of a basic scientific strategy for a long-term investigation of "El Niño" is under development by SCOR WG 55 in consultation with SCOR WG 36.

The regional associations and co-operative investigations are other IOC programmes contributing to LEPOR. Most of the organizational frameworks for the regional co-operative investigations are undergoing change; however, it is expected that whatever changes are made, the concept of a regional approach to ocean research will be maintained. This type of approach can be very supportive of FGGE in many areas. Of paramount importance will be co-operative investigations in the Indian, Southern and tropical ocean areas. In particular, research cruises during the special operating periods of FGGE in these areas could be of significant benefit. To optimize this benefit, it would be desirable to equip participating research vessels with a capability for upper air observation. Another important contribution which could be made is the use of vessels for deploying drifting buoys in the Southern Oceans. Finally, regional co-operative investigations should be so scheduled as to ensure ocean-atmosphere data sets for specific ocean areas.

2.4.2 IOC scientific and technical services

Because a major portion of the FGGE special observing systems will be in oceanic areas, a strong relationship exists with ocean programmes involved in scientific and technical services. A significant amount of these types of services will be provided during FGGE as a part of the IOC programmes of International Oceanographic Data Exchange (IODE) and the Integrated Global Ocean Station System (IGOSS).

2.4.2.1 IODE

The programme of International Oceanographic Data Exchange has a significant role in supporting FGGE. The most important task is to develop the necessary procedures for exchanging and archiving oceanographic data collected during the FGGE so as to ensure compatibility with atmospheric data collected. The procedures should ensure that a combined atmosphere data set is easily retrievable for research, especially as it would relate to the GARP climate objective. Also, because of parameters such as sea surface temperature, which are needed by both meteorologists and oceanographers, the Working Committee on IODE is co-operating with the WMO Commission on Basic Systems (CBS) on establishing an agreed-upon method for satellite-derived data. Since there will be data relevant to air-sea interaction and ocean data collected from satellites, the IODE subsidiary bodies on these subject areas, as well as the ad hoc group of experts on IGOSS Data Archiving and Exchange will be involved. Of particular importance is the compatibility of ocean data with the total FGGE data management system.

2.4.2.2 IGOSS

The Integrated Global Ocean Station System (IGOSS) is an ocean data gathering programme being developed jointly by WMO and IOC. The purpose of IGOSS is to provide more extensive and timely information on and prediction of the state of the ocean and its interaction with the atmosphere. To fulfil this purpose in part, IGOSS comprises: the real-time acquisition of oceanographic data (BATHY/TESAC) from all parts of the world's oceans; the rapid transmission of this data to designated centres for data processing and products; and the rapid distribution of these products to users throughout the world. Possibilities for IGOSS support to FGGE have been considered since the formative stages of the experiment. While there is no formal requirement for the real-time exchange of BATHY and TESAC during FGGE, the JOC for GARP and the WMO EC Intergovernmental Panel on FGGE have recommended that the participants in IGOSS give strong consideration to improving the amount of data collected and exchanged in several ocean areas. These include the tropical oceans (10°N - 10°S), the Indian and Southern Hemisphere Oceans. Because one of the major data sets to be generated during FGGE will have a cut-off time of approximately six months from day of observation, the only practical way of entering sub-surface ocean data into this set (designated II-b) will be by means of the near real-time procedures developed under IGOSS for BATHY and TESAC data.

The initial testing of models for FGGE will use sea-surface temperature as a fixed boundary condition; however, should sub-surface data of sufficient quality and quantity become available, an investigation on the use of sea-surface temperature as a predicted variable might be realized. During the overflow experiments of 1973, IGOSS data were analysed and made available on a near real-time basis to the scientists whilst still at sea, and were shown to be useful. As a result, the Working Committee for IGOSS decided to form a subgroup of experts to advise on a similar programme for FGGE. In pursuing this objective, the subgroup has decided to demonstrate further the feasibility and usefulness of IGOSS projects during the POLYMODE experiments in the Atlantic. It is expected that this pre-FGGE demonstration will provide insight on how best to provide such a service during FGGE, especially in areas where there is ocean research associated with FGGE. It is envisaged that descriptive mapping of the ocean surface and near-surface temperature will be available.

2.4.3 TEMA activities

A new era of science is just starting which brings with it the need for large area long-term programmes of research and investigation. The 1970s mark just the beginning of this era with programmes such as GARP and IDOE, which now clearly indicate the need for increased participation by the developing nations of the world. If the needed understanding, monitoring and prediction of the global atmosphere and oceans is to be realized, it is essential that there be significant participation by developing countries. This participation can best be met by an active programme of training, education, assistance, and technology transfer to the developing countries.

As such, Training Education and Mutual Assistance in the marine sciences (TEMA) is an IOC programme which can be related to FGGE. One of the most important contributions that can be made is in the identification and upgrading of coastal marine radio stations in the southern hemisphere, so that data collected by ships of opportunity and other voluntary ships can be transmitted to land stations for entry in the GTS and ultimate inclusion in the FGGE data sets. A second important contribution will be made by ensuring, wherever possible, ships or ship space to scientists from developing countries so that they may participate actively in FGGE.

2.5 Recommendation for priorities (FGGE)

In order to maximize the benefits of oceanographic programmes related to FGGE, it is recommended that high priority be given to the following:

maximize the number of days of oceanographic research vessel operations in the area 10°N to 10° S for 5 January to 5 March and 1 May to 30 June 1979; and in particular, for the sub-periods 15 January to 13 February and 10 May to 8 June 1979 (see Figures 2 and 3);

concentrate oceanographic investigations in the Equatorial, Southern and Indian Ocean Monsoon areas during 1978 and 1979;

emphasize ocean process-oriented studies which are due to atmospheric forcing;

begin establishment of an ocean-atmosphere data set which can be used to test and validate coupled models;

maximize the number of days of ship and research vessel operations in July 1978 to June 1979 for the shipping and subsequent deployment of drifting buoys in the area 20° - 65° S for use in the special observing periods;

increase the number of sub-surface ocean observations coded and transmitted in real time via BATHY and TESAC;

make available, to the maximum extent possible, space on research vessels for scientists and students from developing countries;

establish joint meteorological and oceanographic observing programmes on all Tropical Wind Observing Ships (TWOS) and research vessels participating in the equatorial oceans during FGGE.

3. Oceanographic components in the GARP second objective programmes

3.1 GARP second objective - Ocean relationship

The GARP planning for a global programme of climate research is still in the formative stage. However, the substance of such a programme was considered at an international study conference held in Stockholm (29 July - 10 August 1974) on the Physical Bases of Climate and Climate Modelling. As a result of this conference, a recommended general programme framework was developed. The programme framework proposes that understanding of climate variability can best be gained by approaching the problem both from the diagnostic, observational and theoretical modelling points of view. That is to say that the former suggests hypotheses to be tested and the latter provides a means of interpretation and verification. Within such a framework, it is intended that a set or hierarchy of models involving the atmosphere-ocean-cryosphere-land system be developed and validated.

The major elements of the ocean aspects involved in the GARP second objective include the following:

design of models and their use in sensitivity and predictability studies;

understanding of oceanic processes needed in climate models;

establishment of suitable ocean observing programmes.

These three elements are interrelated but will be discussed separately as a matter of convenience.

3.1.1 Model design

The design of models and their use in sensitivity and predictability studies will involve considerable study of ocean processes. The general types of ocean modelling efforts include: (i) models with parameterized dynamics; (ii) three-dimensional explicit dynamical models; and (iii) parameterization of subgrid scale processes. A description of the specific type studies needed is contained in Table II and the Appendix (Reference: GARP Publication Series No. 16). Perhaps one of the most important areas for use of climate models is in sensitivity studies of climatic forcing. In this regard, anomalies in ocean surface temperature may be related to anomalies in atmospheric patterns with a seasonal time scale, and sensitivity tests of this hypothesis, with general circulation models (GCM), may shed some light on the question along with experiments using coupled ocean-atmosphere models.

Related to both the development and use of climate models is the need for certain palaeoclimatic experiments. Model calibration tests can be made by use of an assembly of palaeoclimatic data. The use of ocean sediments will provide one means of constructing global patterns of past climates. Then, coupled atmosphere-ocean GCMs may be used to simulate the global climate at several selected times during the past 100, 000 years or so.

The preceding discussion has highlighted the design of models and their use in sensitivity and predictability studies for long-term climatic averages. In addition to this, there is a need to look at studies of short-term climatic extremes. Table III identifies some of the more important short-term extreme conditions which need an oceanic component of study.

3.1.2 Ocean processes

In addition to identifying the studies needed for interfacing the various elements in a hierarchy of climate models (i.e., atmosphere-ocean-cryosphere-land surface-biomass), detailed studies

TABLE II

Design of ocean models and their use in sensitivity and predictability studies

(Also see Appendix)

(Ref: GARP Publications Series No. 16)

Study	Specifications
1. Models with parameterized dynamics	Thermodynamic energy balance with no horizontal eddies - oceanic mixed layer sensitivity to atmospheric forcing
2. Three-dimensional explicit dynamical models	Coupled ocean-atmospheric general circulation models computing sea surface temperature from oceanic part of model through the thermodynamical equation
3. Parameterization of sub-grid scale processes	Carbon dioxide exchange between ocean and atmosphere Sea-surface albedo as it relates to sea state Energy transfer at the ocean-atmosphere boundary Transport processes in the surface mixed layer of the ocean Salinity distribution in the surface mixed layer of the ocean Oceanic internal gravity waves and turbulence Oceanic mesoscale eddies

of processes within each elemental system are also needed. In this respect, the scientific objectives for understanding oceanic processes relevant to the GARP second objective are as follows:

(i) parameterization of processes - to understand and parameterize those sub-grid scale processes which determine the circulation of the ocean on the resolution scale of ocean models;

(ii) modelling - to construct a hierarchy of models for studying climate dynamics on various time scales;

(iii) data set - to assemble suitable data sets of oceanographic observations in a form usable for testing climate models;

(iv) palaeoclimates - to identify the properties of deep ocean sediments which contain climatological evidence of very long-time scales and to promote systematic evaluation of such evidence.

In connection with these objectives, a certain understanding of ocean processes is needed in order to develop accurate ocean models. A list of examples of the ocean processes requiring study is shown in Table IV and a general description of the ocean modelling needed for an understanding of climate is shown in Table V (see also: GARP Publication Series No. 16).

TABLE III

Examples of short-term climate extremes needing oceanic study

Examples of short-term climatic extreme	Oceanic study needed
1. South Asian summer monsoon	Studies of the anomalous sea-surface temperature over the Arabian Sea which may have a significant effect upon the evaporation rate over the sea, the cross-equatorial flow over the sea, and the precipitation rate over the Indian sub-continent
2. Drought	Studies of persistent anomalies in ocean-surface temperatures which may be related to drought by way of the anomalous atmospheric circulation forced by the anomalous oceanic heating
3. Synoptic scale sea-surface temperature anomalies	Observational and theoretical studies aimed at elucidating the sources of the anomalies Studies aimed at identifying the effects of the anomalies (e.g. El Niño)
4. Sea-ice variations	Observational testing of hypotheses and parameterization schemes, both concerning the influences governing the formation and extent of sea ice and concerning the influence of sea ice on the atmosphere and ocean

3.1.3 Ocean observations

Ocean observations will be a key element in the study of climate, and are needed for understanding processes, development of models, and possibly long-term monitoring. The ocean observing programme in support of the second objective of GARP is expected to be evolutionary. Thus, more detailed specifications of what, how, where, how often, and when to sample (including averaging) will be developed as our understanding grows.

3.2 IOC-SCOR support to the GARP second objective

It should be pointed out that the description of the ocean element of GARP-II will evolve more specifically over the next three to five years. In addition, there has been no internationally agreed-upon organizational or programmatic framework for co-ordinating GARP-II with its expected multi-disciplinary approach. Nevertheless, there is sufficient agreement on the oceanic problems that need resolving regardless of organization and framework. An identification of problems which can be treated by both SCOR and the IOC is contained in this section of the document.

3.2.1 Scientific investigations

In the above discussion (section 3), the scientific objectives for the ocean element of GARP-II were described. These can be summarized as two related efforts: (1) development of models; and (2) understanding and parameterization of processes. These objectives are being pursued by the activities of several SCOR working groups, the IOC regional co-operative investigations, and the programme of the International Decade of Ocean Exploration (IDOE).

Many of the projects identified as part of the International Decade of Ocean Exploration will contribute significantly to accomplishing the GARP second objective. Each of the major elements of IDOE (i.e. environmental quality, environmental forecasting, seabed assessment, and living

TABLE IV

Examples of oceanic processes requiring study

(Reference: GARP Publication Series No. 16)

Process	Study required
1. Fluxes of heat, momentum and water vapour at the ocean surface	Buoyancy flux and its seasonal variation Parameterization of flux rates Relationship of the wave spectrum on transfer processes at the air-sea interface
2. Variability in the oceanic planetary boundary layer	Mixed layer modelling which includes large-scale horizontal advection, upwelling, relationships between mixing and stratification, rainfall, light penetration, and scattering Processes under sea-ice and the behaviour of the sea-ice itself Upwelling processes along certain coasts and the equator
3. Quasi-geostrophic motions	Mid-ocean eddies Intense narrow currents Intermediate and deep water circulation Heat transport by ocean circulation
4. Small-scale turbulence and internal waves	The significance of turbulence and internal waves for vertical mixing in the main thermocline The role of convection in water mass formation and in determination of the thermohaline circulation

resources) can provide significant support to the GARP second objective. Table VI shows the contributing relationship between the existing IDOE projects and the scientific objectives of the GARP second objective.

At this time, it is impossible to identify what will replace the IDOE after 1980, but it is expected that programmes similar to many of the existing IDOE projects, with specific plans of supporting studies related to the understanding of climate, will be founded. It is also expected that IDOE will provide valuable assistance in the transfer of science and technology to developing countries by increasing the resources for these countries to participate in projects.

The IOC regional co-operative investigations will be of significant importance to the GARP second objective by providing an understanding of ocean processes in various geographical regions. In addition, the regional co-operative investigations will provide model development activities as a part of the hierarchy scheme, as well as contributing a major portion of the information for the comprehensive data sets needed to test and validate the models. It should be pointed out that the climatic extremes associated with the monsoon and "El Niño" circulations indicate the requirement for organized regional scientific co-operative investigation of these areas. Similarly, the Southern Oceans and polar areas will require considerable regionally-organized scientific activities.

TABLE V

Examples of ocean modelling needed for an understanding of climate

Examples of types of models and time scales	Characteristics
1. Ocean models (1-2 year time scale)	Predict average seasonal variations in the temperature field from existing climatological data for the atmosphere Computation of currents in areas of up-welling and strong surface gradients Deep ocean dynamics included but with fixed temperature and salinity below the planetary boundary layer
2. Ocean models (several year time scale)	Generation of "meso-scale" eddies Equatorial dynamics Western boundary currents Tracer distributions Poleward heat transport All will involve time dependence
3. Coupled models ocean-atmosphere (1-2 year time scale)	Detailed initial conditions for the temperature structure of the ocean and atmosphere Data average (time: 5-10 days space: 200 km.)
4. Coupled models ocean-atmosphere (2-100 year time scale)	Modest scales to explore mechanisms (initially) Poleward heat transport

Section 2.3 above discussed the many activities of SCOR which are related to FGGE. These activities are also related to the GARP second objective. In addition to these, SCOR Working Group 40 (Palaeo-oceanography) will contribute significantly to GARP-II. It should be pointed out that most of these working groups will contribute support to all of the GARP-II ocean scientific objectives and that the efforts of these working groups are in many cases implemented through ocean programmes such as the IDOE and IOC regional co-operative investigations. As a matter of convenience, an identification can be made of the relationship of each of the SCOR working groups to the GARP second objective; this is shown in Table VII.

On climatic time scales, it is always necessary to consider the atmosphere and the ocean as a single coupled system. Thus the closest co-operation and mutual understanding is required between atmospheric and oceanic scientists. An important function of IOC, SCOR, and the JOC is to foster this interdisciplinary interaction. The JOC/SCOR Joint Study Conference on General Circulation Models of the Ocean and their Relation to Climate, held in Helsinki on 23-27 May 1977 constitutes a highly successful example of this type of activity. Future activities of this nature may include additional joint conferences, arrangements for special review publications, jointly sponsored field programmes, and the like.

3.2.2 Scientific and technical services

The principal scientific and technical services required as a part of the oceanographic element of the GARP second objective include suitable systems for ocean observation and a mechanism for

TABLE VI

Contributing relationships between existing IDOE projects and the scientific objectives of the GARP second objective*

Scientific objectives of GARP-II	Contributing IDOE projects
Understand and parameterize sub-grid scale processes which determine the circulation of the ocean	MODE; POLYMODE; NORPAX; CUEA; JASIN
Construct a hierarchy of models for studying climate dynamics on various time scales	GEOSECS; POLYMODE; NORPAX; ISOS; CLIMAP; CUEA; JASIN
Assemble a comprehensive data set for testing climate models	NORPAX; ISOS; CLIMAP; CUEA
Identify the properties of deep ocean sediments which contain climatological evidence of very long-time scales	GEOSECS; CLIMAP; Plate Tectonics and Metallogenesis

* The supportive contribution from the living resource element of IODE has not been included because it might more logically fit within the biomass aspect of climate rather than the ocean aspect.

TABLE VII

Relation of SCOR working groups to the ocean scientific objectives of the GARP second objective

Scientific objectives of GARP-II	Relevant SCOR working groups
Understand and parameterize sub-grid scale processes which determine the circulation of the ocean	Working Group Numbers: 34; 36; 38; 43; 47; and 55
Construct a hierarchy of models for studying climate dynamics on various time scales	Working Group Numbers: 34; 36; 38; 47; 49; and 55
Assemble a comprehensive data set for testing climate models	Working Group Numbers: 43 and 47
Identify the properties of deep ocean sediments which contain climatological evidence of very long-time scales	Working Group Number: 40

exchange and archiving of ocean data. The time and space scales involved in the understanding of processes and the development and validation of numerical models, suggest that the classical one-ship research cruise will not be sufficient. Instead, a suitable system for ocean observation is needed as well as an associated mechanism for exchange and archiving of data. While still in an embryonic stage, the IOC-WMO Integrated Global Ocean Station System (IGOSS) offers a framework into which such an observing system can be incorporated. In this respect, IGOSS will be highly supportive in contributing to the data sets necessary to test and validate models. It should also be pointed out that IGOSS will provide data support to the many investigations entailed in understanding and parameterizing sub-grid scale processes.

The specific definitions for assembling oceanographic data sets are still not clear; however, the potential magnitude of such tasks suggests a need for a strong co-operative relationship between the ICSU World Data Centres, the WMO, and the IOC Working Committee on International Oceanographic Data Exchange (IODE).

3.2.3 TEMA activities

Whether the second objective of GARP is attained or not may well depend on the participation of developing countries. Certainly, the understanding of the major short-term climate extremes (e.g. the monsoon and "El Nino" circulations) will, to a large extent, depend on the involvement of developing countries. In turn, this obviously requires a significant programme of training, education, technology transfer, and assistance from the developed world. While the financial resources of IOC and SCOR cannot provide the types and amount of assistance needed, both IOC and SCOR have established responsible activities for assisting and advising developing nations in obtaining the proper kinds of assistance from the major international assistance bodies (e.g. UNEP), bilateral and multilateral resources. It is beyond the scope of this document to describe in any detail the specifications of TEMA activities related to the ocean element of GARP-II; however, several areas have been identified where specific TEMA activities will contribute to the understanding of climate. These are as follows:

long-term educational programme in marine science;

advice on suitable instrumentation;

establishment of National Oceanographic Data Centres;

visiting scientist programme;

regional scientific investigations;

participation in other large-scale science programmes.

4. Further oceanographic development in GARP

At this time, it is impossible to identify all the tasks required as part of the development, planning and implementation of oceanographic programmes related to GARP. However, certain activities can almost assuredly be indicated as essential. An example of such activities and a list of existing bodies which could help in implementation are shown in Table VIII.

In so far as the FGGE time frame is concerned, initial planning has already been completed by the JOC for GARP and by SCOR WG47. Final detailed planning is now under way so that both oceanographers and meteorologists can maximize the use of their resources (e.g. ships) in the tropical regions of the ocean.

The implementation of the second GARP objective is still in a conceptual phase and presents several difficult problems. The most important is the need for a scientific assessment of the ocean aspects of GARP and a formulation of an outline of a programme plan and implementation, which is at present being drafted by the Committee on Oceanography and GARP (COG).

TABLE VIII

Examples of activities needed for an oceanographic programme related to GARP

Examples of needed activities	Possible implementation
Initial identification of oceanographic relationships to GARP	IOC-SCOR *Ad hoc* Task Team
GARP ocean programme assessment	COG
SCOR WG co-ordination	COG
Intergovernmental programme co-ordination	IOC
Evaluation of IOC scientific programmes	SAB
Identification of oceanography associated with FGGE and contributions of ships to the tropical wind observing system	SCOR WG 47
Oceanographic data management	WC on IODE
Real-time ocean services (BATHY products)	WC for IGOSS
Southern ocean studies implementation and drifting buoy experiment	ISOS, ICG for SOC, SCOR WG 38
El Niño ocean studies implementation	SCOR WGs 36 and 55, (IOC WG on El Niño)
Identification of oceanographic training, education and assistance opportunities during FGGE	WC for TEMA

Co-ordination of design of mathematical dynamical models	SCOR WG 49
Development of suitable data sets for testing numerical models	WC on IODE
Identification of deep ocean sediments which contain climatological evidence of very long time scales	SCOR WG 40
Upwelling processes	SCOR WGs 36 & 55
Sea-ice processes	SCOR WG 38
Quasi-geostrophic motions	SCOR WG 34
Development of real-time ocean monitoring	WC for IGOSS
Regional oceanographic co-ordination	IOC Regional Association and Co-operative Investigations
Implementation plan for ocean component of GARP-II	COG

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Appendix

DESIGN OF MODELS AND THEIR USE IN SENSITIVITY AND PREDICTABILITY STUDIES

(ocean modelling efforts)

(Reference: GARP Publication Series No. 16)

GENERAL TYPE EFFORT	SPECIFIC DESCRIPTION
1. Models with parameterized dynamics	The oceanic mixed layer can be studied with the aid of one-dimensional vertical co-ordinate models. The sensitivity of the depth and temperature of the mixed layer to variations in radiative inputs, wind stress or other atmospheric forcing can be estimated, and the experience gained can provide guidance for the development of parameterizations for more elaborate models.
2. Three-dimensional explicit dynamical models	Ocean-atmosphere coupled general circulation model where sea surface temperature is computed from the oceanic part of the model through the thermodynamical equation.
3. Parameterization of sub-grid scale processes	Development of a hierarchy of ocean models in which the spatial distribution of the atmosphere-ocean CO_2 exchange is represented in order to understand how the distribution of CO_2 is maintained in the ocean. In order to predict the heat budget of the ocean mixed layer and the ocean surface temperature, it will be necessary to specify the sea surface albedo which is related to sea state and zenith angle of the sun (changes of albedo greater than ± 0.01 over time scales of a week and space scales of 10^4 - 10^5 km^2 are of importance). Transfer of energy at the ocean-atmosphere boundary over spaces scales of order $10^4 km^2$ and time scales of order 2 hours, supplemented by parameterization of sea state in connection with calculation of surface stress and the injection of salt particles. (In addition, parameterization of processes in which the relevant atmospheric variables are given only statistically should be addressed - space scales of order $10^6 km^2$ and times scales of order 1 week are especially relevant.) Parameterization of the transport processes in the surface mixed layer of the ocean need to be expressed in terms of heat, mass and momentum fluxes across the atmosphere-ocean interface. (These models and generalization including horizontal and vertical advection should be tested in GCMs.) It will be necessary to parameterize the salinity distribution in the surface mixed layer in order to obtain realistic simulations of the sea-ice component of the climatic system.

GENERAL TYPE EFFORT	SPECIFIC DESCRIPTION
	Parameterization of the vertical and horizontal transports of heat and salt by thermally or mechanically produced turbulence, as well as the vertical flux of horizontal momentum associated with breaking internal gravity waves in the ocean below the boundary layer are required.
	Parameterization of the transport properties of quasi-geostrophic eddies (scales of the order of 100-400 km.) in terms of the larger scale ocean state variables or simulation of these eddies and other meso-scale phenomena by using a fine-horizontal grid size.

Acronyms

BATHY	(designator for radio message containing sub-surface ocean temperature data - bathythermograph)
CLIMAP	Climate Long-range Investigation, Mapping and Prediction
COG	Committee on Oceanography and GARP (SCOR)
CUEA	Coastal Upwelling Ecosystems Analysis
FGGE	First GARP Global Experiment
GAO	GARP Activities Office (WMO/ICSU)
GARP	Global Atmospheric Research Programme
GARP-II	GARP Second Objective
GATE	GARP Atlantic Tropical Experiment
GCM	General Circulation Model
GDPS	Global Data Processing System (WMO/WWW)
GEOSECS	Geochemical Ocean Sections Study
GOS	Global Observing System (WMO/WWW)
GTS	Global Telecommunications System (WMO/WWW)
IAMAP	International Association of Meteorology and Atmospheric Physics
IAPSO	International Association for the Physical Sciences of the Oceans
ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IGOSS	Integrated Global Ocean Stations System (IOC/WMO)
INDEX	Indian Ocean Experiment
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data Exchange (IOC)
ISOS	International Southern Ocean Studies
JASIN	Joint Air-Sea Interaction Experiment
JOC	Joint Organizing Committee for GARP (ICSU-WMO)
LEPOR	Long-term and Expanded Programme of Oceanic Exploration and Research

MODE	Mid-Ocean Dynamics Experiment
MONEX	Monsoon Experiment
NORPAX	North Pacific Experiment
POLEX	Polar Experiment
POLYMODE	Polygon Mid-Ocean Dynamics Experiment
SAB	Scientific Advisory Board (IOC)
SCOR	Scientific Committee on Oceanic Research
STD	Salinity-Temperature-Depth measuring device
TEMA	Training Education and Mutual Assistance in the marine sciences
TESAC	(designator for radio message containing Temperature Salinity and Current Data)
UNEP	United Nations Environment Programme
WC	Working Committee
WG	Working Group
WMO	World Meteorological Organization
WMO EC	WMO Executive Committee
WWW	World Weather Watch (WMO)

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