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SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

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WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION OF THE UNITED NATIONS EDUCATIONAL SCIENTIFIC AND CULTURAL ORGANIZATION

INFORMAL PREPARATORY MEETING ON EXPENDABLE DRIFTING BUOY SYSTEMS FOR USE DURING THE FIRST GARP GLOBAL EXPERIMENT (FGGE)

Unesco, Paris, 12-15 June 1973

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1. INTRODUCTION

1.1 Opening of the Session

The meeting was opened at 10.00 Tuesday, 12 June 1973 by the Secretary, Intergovernmental Oceanographic Commission, who welcomed the participants. A list of participants is given in Annex I.

1.2 Election of the Chairman

Professor B.R. Döös, Director, Joint Planning Staff for GARP, was elected Chairman.

1.3 Introduction by the Chairman

1.3.1 The Chairman explained that this meeting had been convened jointly by the four bodies in response to a recommendation of the Planning Conference on the First GARP Global Experiment (Geneva, 1972) to WMO and ICSU, that the Secretary-General of WMO be requested to arrange in co-operation with the IOC, SCOR and the SCAR, who all have made recommendations for an increased capability for buoy measurements applied to their own sphere of interests, for an ad hoc Working Group on buoys. Representatives of the secretariats of the four bodies, meeting together with the Director of the JPS, considered that the present small informal preparatory meeting of a few experts would be required to prepare the background for the ad hoc Working Group to permit it to work efficiently.

1.3.2 The Planning Conference had reiterated that the data requirement for the Global Experiment includes a network of about 150 drifting buoys to measure surface pressure and sea-surface temperature, to be deployed in the zone 50°-65°S where persistent cloudiness interferes with satellite remote sounding observation of the lower troposphere. At the Planning Conference ten nations expressed interest in the supply and/or deployment of expendable drifting buoys or in contribution toward procurement of such buoys.

1.4 Tasks of the Informal Preparatory Meeting

The Meeting, after some discussion, decided that its tasks should be to:

(a) review the stated requirements of the Global Experiment for a network of minimal drifting buoys in the latitude belt 50°-65°S, in the light of buoy developments and related oceanographic programmes of which participants are aware;

(b) define one or more appropriate buoy systems that can meet the GARP requirements in the appropriate time frame;

(c) outline at least the approach to an economically feasible deployment strategy that might furnish reasonable uniform distribution of buoys during the Global Experiment Special Observing Periods;

(d) prepare a schedule of activities and events required to deliver dependable buoys in time to be deployed for the Global Experiment;

(e) examine, in a preliminary way, the prospects for meaningful oceanographic activities in conjunction with the Global Experiment buoy programme, and the modification of equipment or arrays such oceanographic participation might entail;

(f) make recommendations for action by the Organizations and for the matters to be considered by the ad hoc Working Group.

1.5 Technical Feasibility of the Project

The Meeting readily agreed that present buoy and space communication technology makes it quite possible to implement the buoy system required for the Global Experiment within the time frame available. However, it was emphasized that acceleration of development and operational test of simple drifting buoys suitable for the environment of the sub-Antarctic will be necessary to ensure success of the programme.

2. THE NEED FOR SPECIAL SURFACE AND SUB-SURFACE OBSERVATIONS IN THE SOUTHERN OCEANS FOR THE GLOBAL EXPERIMENT

2.1 The Requirement

2.1.1 The number of surface-based stations providing surface (and sub-surface) observations in the southern oceans will still be very small at the time of the Global Experiment. Accordingly, the definition of the state of the atmosphere and the boundary between atmosphere and oceans will be almost exclusively dependent on the global radiometric temperature observations obtained from polar orbiting satellites. There is concern, however, about the possibility of actually meeting the required accuracy standards by space based measurements only, in the circumpolar belt of persistent cloudiness 50°-65°S.

2.1.2 Numerical simulation with atmosphere circulation models has indicated that the inability to obtain satisfactory radiometric temperature soundings in the cloudy region would, in the absence of any other (in situ) measurement, result in a very serious deterioration of our knowledge of the global state of motion of the atmosphere (1) (2). It has been found, particularly, that the lack of ocean surface temperature observations in a numerical model will significantly influence the predicted atmospheric circulation patterns even in the northern hemisphere since latent and sensible heat transfer to and from the oceans is a major heat source or sink for the atmosphere.

2.1.3 Surface measurements

The need for meeting the minimum Global Experiment surface data requirements:

(i) Sea surface temperature:

Horizontal resolution: 500 km
Accuracy: ± 1°C

(ii) Surface pressure:

Horizontal resolution: 500 km
Accuracy: ± 3 mb

can therefore be established on this ground alone, i.e. to work toward the first GARP objective of increasing the accuracy of extended atmospheric circulation forecasts. Because these data are not likely to be obtained directly or inferred from measurements provided by the basic Global Experiment observing system, there is a need for at least a temporary augmentation of this basic system by in-situ measurements from buoys in the circumpolar belt 50°-65°S during the two special observing periods of the Global Experiment (3).

2.1.4 Sub-surface Measurements

It has been noted that any studies of predictability of atmospheric circulation beyond ten days and particularly studies or seasonal changes or long-term climatic trends in accordance with the second GARP objective, will require that the sea surface temperature be calculated (predicted) at least parametrically. Information on the motions and thermal structure of the upper ocean layer is needed then to develop parameterization schemes and also to monitor the changes of the upper ocean temperature field that will have seasonal implications. A buoy-satellite observing system, as envisioned, is quite suited to meet the minimum Global Experiment Surface data requirement above, and provide a basis for obtaining some of the information required for the second objective. This further task, bearing on the studies of the physical basis of climate (second GARP objective), can lead to the addition of the following sub-surface measurements:

(iii) Sea temperature:

Horizontal resolution: 500 km
Vertical resolution: 5 levels in the upper ocean layer
Accuracy: ± 0.2°C

(iv) Sea current:

Horizontal resolution: 500 km
Vertical resolution: one level in the upper ocean layer
Accuracy: as provided by tracking the buoys with a suitable drogue attached to them.

2.1.5 Considering that a buoy hull, drogue and ground-to space communication equipment are needed to meet the minimum Global Experiment requirement for sea surface data only, and that adding thermistors to measure sub-surface temperatures would be a simple addition to the minimum buoy design, it is urged that the acquisition of such sub-surface data be made a formal recommendation wherever the deployment of surface data buoys during the Global Experiment would make it practicable.

2.2 Number of platforms needed

Pending a detailed assessment of the possible deployment strategies (see section 5 below) and factual information on the attrition rate of small drifting buoys in sub-Antarctic waters, it is estimated that 150 buoys operating during each of the two special observing periods would provide adequate coverage of the belt of persistent cloudiness 50°-65°S.

References to section 2

(1) Report of the Planning Conference on the First GARP Global Experiment, 1972. GARP Special Report No.8. WMO/ICSU Joint Organizing Committee.
(2) Report on Special Observing Systems for the First GARP Global Experiment of GARP, 1973. GARP Special Report No.10. WMO/ICSU Joint Organizing Committee.
(3) The First GARP Global Experiment. Objectives and Plans, 1973. GARP Publications Series No.11. WMO/ICSU Joint Organizing Committee.

3. BUOY DESIGN

3.1 Buoy Array

The buoy array required to meet the basic Global Experiment objectives need not be absolutely uniform in distribution, but rather must provide reasonably complete, randomly spaced coverage of the latitude band in which it will be deployed.

3.2 Buoy Type

3.2.1 The requirements of low cost and deployment of large numbers in remote areas are most readily met by a small drifting buoy whose cost is sufficiently low to make its recovery unnecessary. This type of buoy is easily deployed from available ships without specialized equipment or personnel for launching. Furthermore, a buoy of this type can be readily equipped with a drogue device to couple its drifting motion to a particular depth in the mixed layer. Because this configuration provides Langrangian current data for oceanographic purposes (see paragraph 7.2.2 below) without affecting the use of the array for meteorological purposes, it seems particularly appropriate for the Global Experiment.

3.2.2 The special observing periods scheduled for the Global Experiment make it highly desirable that the buoy selected for use should have a design lifetime of one year. It is realized, however, that this may not be feasible in practice; a six-month lifetime would be acceptable (but would require a larger overall number of buoys).

3.2.3 A discussion of the buoy systems currently under development revealed several cases with possible application to the Global Experiment; these are discussed briefly in Annex II. It must be pointed out that the buoys discussed therein are the only ones on which the committee had any information. Efforts are currently being made to seek out information on additional buoys of this type presently under development (see Annex III).

3.2.4 A buoy system of the type considered appropriate for the basic objectives of the Global Experiment is presently under development by the NOAA Data Buoy Office in the United States. It is described here to illustrate one type of buoy which may be available in the time frame of the GARP experiments. A complete buoy package, as described here and in section 4, is expected to cost in the neighbourhood of $5,000 to $6,000 at the manufacturer. The present design life for the complete buoy package is six months to one year.

3.3 Hull

3.3.1 The buoy hull, shown in the Figure, is presently being developed by the NOAA Data Buoy Office through contract to Nova University, Fort Lauderdale, Florida. It is a low-cost expendable spar buoy with a conical float. The hull is essentially a surface-following type which may be used with or without a drogue and thermister line. It is designed to provide Langrangian current measurements, basic meteorological measurements such as atmospheric pressure and wind speed, and water temperature measurements from the surface to just below the thermocline. The hull is around 4 m long (depending upon the antenna used), it weighs approximately 100 kg. and the float diameter is 91 cm.

3.3.2 In its present configuration, construction is of polyvinyl chloride heavy duty tubing with a foam-filled conical float of fibreglass. It is simple in design and can be assembled in large numbers by manufacturers familiar with fibreglass construction.

3.4 Drogue

3.4.1 The buoy hull is being tested at Nova University for use with a drogue in the upper layers of the ocean. No final conclusions have been drawn regarding drogue construction (a separate study of drogue design is now underway at the Draper Laboratory of the Massachusetts Institute of Technology).

3.4.2 The drogue and drogue line (containing the thermistor string) will be designed for maximum effective coupling and ease of deployment. It is considered essential that the hull/drogue be deployable from ships of opportunity with relatively inexperienced personnel.

3.4.3 If buoys are to be used with drogues, it is also desirable to install a pressure (depth) sensor near the drogue or at the bottom of the thermistor line in order to monitor the aspect of the thermistor/drogue line.

3.5 Sensors

3.5.1 To meet the basic specifications set forth in section 2 above, the only meteorological measurement required is atmospheric pressure. The pressure sensor to be employed on the buoy is still under test and development; the final design can be expected to provide a sensor accuracy well within the Global Experiment requirements. The problems associated with atmospheric pressure measurements on a low-cost expendable buoy are significant. This is an area where any institution with the appropriate technical expertise should be encouraged to develop and test suitable devices.

3.5.2 The set of water temperature data from the mixed layer will be taken with a hull-mounted sensor for surface temperature and a drogue line with temperature measurements at selected depths. The surface temperature sensor is being developed as a part of the basic hull, and a thermistor line is being designed and tested separately by the NOAA Data Buoy Office. At present, it is considered that accuracies of around 0.2°C are attainable.

3.5.3 The Nova buoy is also being tested with a single wind speed sensor of the cup-impeller type, but this measurement will not be required in the basic Global Experiment.

3.6 Electronics

The data processing, communication, and position fixing electronics are considered separately in section 4.

3.7 Testing

3.7.1 The buoy hull itself is presently in a test status; it is being evaluated in sea trials with and without drogues. The sensor and data processing components are under development at Nove University and are not yet available for testing. Two points regarding the buoy evaluation must be emphasized here. The entire system is not yet operational; the NOAA Data Buoy Office requires thorough test and evaluation of any system before it can be regarded as proven. Secondly, this system was designed primarily for tropical and sub-tropical deployment and has yet to be tested in the severe conditions encountered in high southern latitudes, to determine design modifications that will be necessary to ensure survivability.

3.7.2 Although the buoy and its components are not yet proven, they do represent a system of a type which will find broad application in the basic objectives of the Global Experiment.

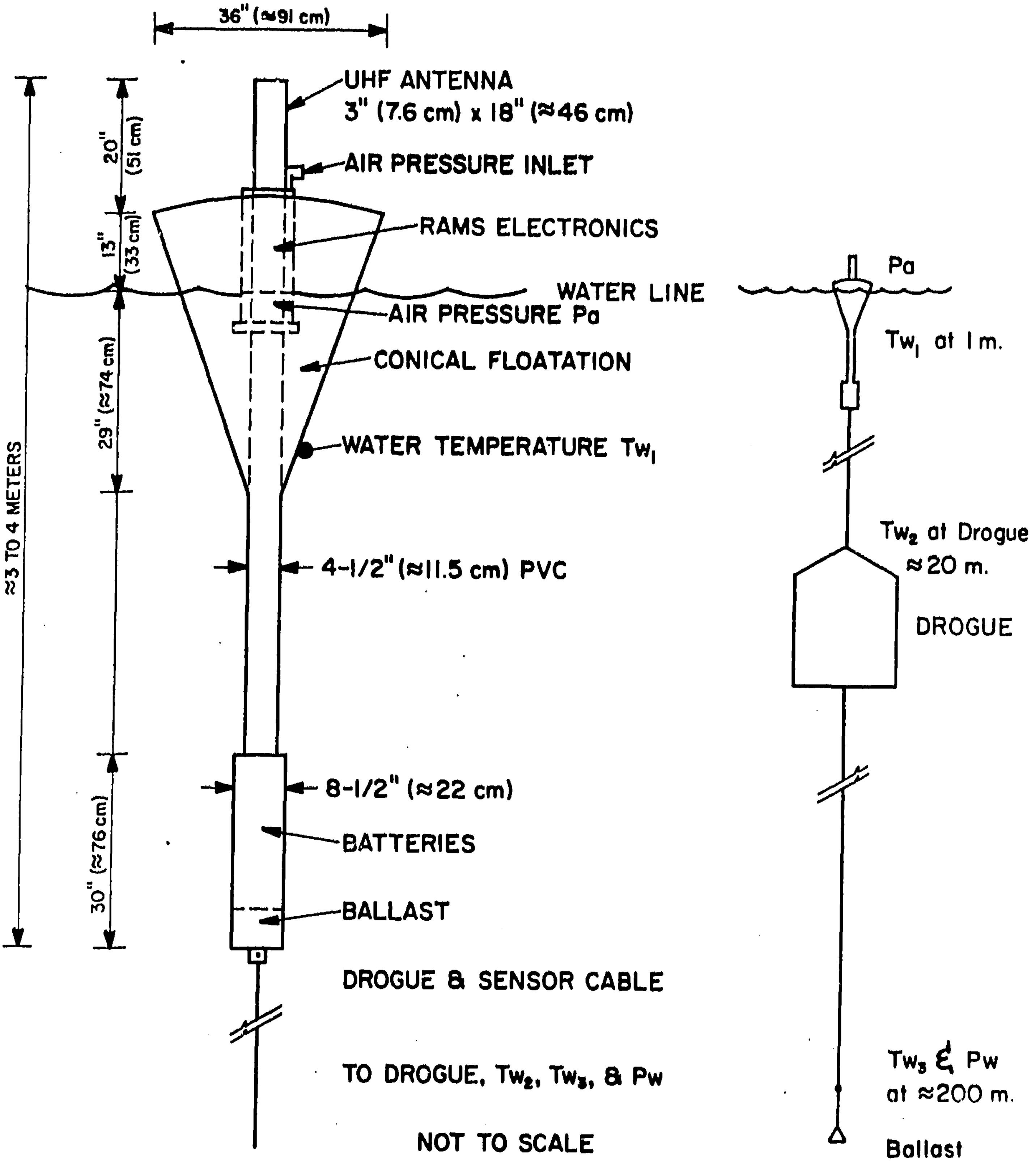

FIGURE DRIFTING BUOY UNDER DEVELOPMENT AND TEST

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4. DATA COLLECTION AND POSITION FIXING

4.1 Type of Data Collection System

4.1.1 Several aspects of the Global Experiment buoy observation array point toward a particular type of system for data collection:

(1) A large number of buoys is to be widely distributed in an ocean area which is immense, very remote, and located at high latitudes;

(2) The basic requirements of the Global Experiment can be satisfied with a rather low data rate from each buoy;

(3) In a drifting configuration, a position fixing capability is required;

(4) The expendable nature of the array requires, above all, that the system designed to meet these requirements be low in cost.

4.1.2 Of the systems available to do this job, one concept in particular appears appropriate - the Random Access Measurement System (RAMS) on polar orbiting satellites. The power requirement on the buoy transmitter is very low, making possible a long-life inexpensive buoy system.

4.1.3 One such data collection system is scheduled for use on the Nimbus F satellite, to be launched in mid-1974. Although several planned experiments on this system (see section 6.1 below) will prove extremely valuable in evaluating the techniques, the Nimbus F satellite is not expected to be operational in the period of the Global Experiment. Rather, a buoy system for the Global Experiment would be dependent upon a similar data collection system planned for the TIROS N satellite, to be launched in the mid-1970's.

4.1.4 The buoy described in section 3 is presently being designed for use with the RAMS on the polar orbiting Nimbus F satellite. The Nimbus F/RAMS system is now under development by NASA, the National Center for Atmospheric Research (NCAR) and the University of Wisconsin. A secondary goal of this development has been a simple and inexpensive electronic package for use on expendable drifting buoys. This approach is described here because, again, it represents the type of system considered appropriate for a simple Global Experiment buoy system.

4.1.5 The RAMS transmit terminal on the buoy relays a one-second message to the Nimbus F satellite every 60 seconds. The signal is modulated with an identification code and sensor data from the buoy. The satellite records these data for later transmission to the ground station. Doppler shift information from successive transmissions allows computation of the buoy position. With the Nimbus F satellite in sun-synchronous orbit, the satellite will pass over a particular site every 12 hours. This period represents the maximum frequency of psoition fixing and data collection. The anticipated position fixing accuracy of this system (for a slow moving buoy platform) is in the order of 2-5 km, depending upon the number of successful transmissions, the instantaneous velocity of the transmitter, and the accuracy of the satellite orbit information.

4.2 Transmit Terminal

4.2.1 The NOAA Data Buoy Office presently has a buoy-packaged transmit terminal under development. It is a ruggedized device which is functionally similar to that developed by the Tropical Wind Energy conversion and Reference Level Experiment (TWERLE) team (NASA/GSFC, NCAR, UWIS), for use on balloons. Table I illustrates a few of the characteristics of the RAMS transmit terminal. It is expected that the cost of these units will be less than $1,000 if they are procured in sufficient quantity, e.g. more than 50.

4.2.2 The present configuration of the transmit terminal allows for collection of 8 channels of data (4 channels each on alternate transmissions). These data are presently encoded with 8-bit resolution.

4.2.3 The transmit terminal is housed in a cylindrical container (10.2 cm dia.) with a waterproof outer protection. It has been designed to withstand the rigors of southern ocean operation.

4.3 Antenna

The buoy antenna cannot be readily adapted from the balloon antenna design. Several antenna configurations are being examined, but it now appears that a simple vertical dipole represents the most reasonable compromise to a theoretically "optimum" design. These units are now being procured for use with the RAMS transmit terminal.

4.4 On-board Data Processing

Two schemes for data processing on board the Nova buoy are presently being considered. One provides a one-minute average of a sensor signal for each transmission; the satellite receives a series of these values, which are representative of conditions during the satellite pass. Two sets of these data can be obtained each day if the satellite is operated at night. The second scheme utilizes a continuous integration of the sensor signal, with each transmission of data representing the present integrated value.

4.5 Testing

The transmit terminals will be received at the NOAA Data Buoy Office in late 1973, where they will be tested in the laboratory and on operating buoys. No thorough tests of the complete buoy system can take place until the Nimbus F satellite is launched (around June 1974). It is planned that the prototype units will be tested initially with the engineering model of the satellite.

Provision of hulls, transmitters and sensors

4.6.1 There is a reasonable likelihood that more than one combination of hulls, transmitters and sensors will be suitable for use during the Global Experiment. In this event, it will be necessary to ensure that all elements (transmitters, encoders, etc.) will be compatible with the random access measurement system on the TIROS N.

4.6.2 Arrangements should be made, by some central organization yet to be identified but preferably within a central management organization for the Global Experiment, for integrating the systems assemblies and co-ordination of supply of the different elements.

4.6.3 It is expected that this organization would arrange with the developers of the various elements to make available for purchase in sufficient numbers hulls, transmitters and sensors. Alternatively blue-prints and specifications should be made available to any other country preferring to manufacture its own elements, provided that any transmitters they produce are suitably checked out by the space agencies involved.

4.6.4 Other institutions should be encouraged to develop their own sensors either to meet their special needs or the basic requirements of the Global Experiment.

TABLE I

RAMS/Nimbus F Preliminary Specifications for Buoy Transmit Terminal

Position location accuracy	2-5 km
Frequency measurement accuracy	± 1 Hz
Time tag accuracy	± 0.1 sec
Transmission duration	1 sec
Transmission interval	60 sec
Maximum number of platforms simultaneously in view	200
Maximum number of platforms	1,000
Probability of detection	0.95
Probability of mutual interference	0.2
Predetection bandwidth	30 kHz
Nominal transmitting frequency	401.2 MHz ± 5 kHz
Platform transmitter power	0.6 - 2.4 watts

5. DEPLOYMENT STRATEGY

5.1 General Considerations

(a) Buoys are to be distributed as widely and uniformly as possible in the region 50° to 65° South, in response to the meteorological needs.

(b) Buoys are to be deployed using ships that will be in the area for other purposes. This means deployment will mostly take place during the Austral summer, i.e. November through March.

(c) Since buoys will depend on the TIROS N satellite, or equivalent, for communication and location, buoy deployment will not start until after the satellite launch.

(d) These principles will not necessarily apply to buoys that are deployed as part of special oceanographic experiments. Experimenters will use arrays appropriate to the problems under study and may choose to arrange their own deployment, although they will be welcome to use the system discussed here.

(e) Ships will not be expected to spend time waiting for suitable weather.

(f) The time-table proposed assumes that TIROS N, or equivalent, will be launched in late 1976.

5.2 Possible vehicles for deployment of expendable buoys

(a) Antarctic supply ships

These will be the primary vessels to be used for this exercise. Their schedules are already known in general terms and their capabilities for handling buoys of the kind envisaged have been identified. It is thus possible to make a tentative plan at an early stage.

(b) Research ships

Any research ships with cruise plans in the area will be used as secondary means for deploying buoys. These ships might prove to be particularly useful in filling gaps in the coverage but their primary use is likely to be for specific oceanographic objectives, which may or may not involve buoy networks. It is likely that only tentative ideas of such plans can be identified before 1973-1974 although firm cruise plans should be available by mid-1975. Relevant cruises which could be utilized should be identified by IOC from the returns from "Declared National Programmes".

(c) Fishing fleets and whalers

Because the network will provide a capability for improved weather forecasting some of these ships may be willing to collaborate but it is unlikely that their plans will be known far in advance; furthermore these are always liable to alteration because of movements of their catch potential and a natural reluctance to broadcast their positions. If however by mid-1976 serious gaps in the planned network are revealed, efforts should be made to ascertain whether these vessels can help.

5.3 Use of Supply Vessels

5.3.1 A month by month analysis of possibilities for deployment by supply ships based on information currently available indicates that, at an average spacing of 400 kms, about 150 buoys could be deployed in any one operating season, that is between November and March. This strategy of deploying the Global Experiment buoys from supply vessels will not produce a regularly spaced network. This coverage definitely leaves some gaps and it is now necessary to seek further details from ship operators on the extent to which they would be prepared to collaborate in this programme and to deviate from their normal tracks, if so requested, in order that a practical plan can be evolved.

5.3.2 This preliminary analysis indicates that the ships of all ten operative Antarctic nations need to be used in order to devise an effective deployment plan.

5.4 Deployment Strategy

5.4.1 The deployment strategy proposed is that between latitudes 50°S and 65°S ships launch one buoy every 400 or 500 kms. This involves simply lowering the buoy into the water which may take from 15 minutes to one hour, depending upon the details of shipboard arrangements.

5.4.2 It is envisaged that the buoy package will be stowed on deck and each one will not exceed 400kg. and stowage size 5m x 1.5m x 1.5m. It is not expected that there will be any special rigging of the buoy to be undertaken before launch, other than that within the competence of the ship's crews.

5.4.3 The electrical systems will be activated and tested just before launch. This could be done by a technician sent to join the ship specifically for this purpose, or alternatively by a ship's officer or radio operator who would have had to have attended a short training course during the preceding northern summer.

5.4.4 If special technicians are carried, arrangements would have to be made for them to return from the Antarctic.

5.4.5 More information on the practical problems of launching these buoys will be available after the 1974 United States experiment when up to 25 buoys of the kind envisaged will be launched from supply vessels for the ACE experiment; this will also provide a test of the system for the Global Experiment.

5.4.6 Buoys to be deployed on outward voyages could be carried as deck cargo. Buoys to be deployed on voyages returning from the Antarctic could be carried south as hold cargo and brought on deck before departure from the Antarctic.

5.4.7 It is intended that requests to divert from normal tracks will be confined to homeward voyages. Such diversions are most likely to be requested in the South Pacific.

5.5 Planning

5.5.1 In order that planning can proceed it is necessary to request all Antarctic operating organizations to specify before the end of 1975:

(1) whether they would be prepared to co-operate in such a plan, assuming their responsibilities are limited to the shipboard phase of the operation, and whether they would be prepared to carry up to 12 buoys, up to 6 to be launched on the outward voyage and up to 6 on the return in the 1976-1977 and 1977-1978 seasons;

(2) the earliest date that cruise plans for 1976-1977 and 1977-1978 season can be determined (preliminary indications now would be helpful);

(3) whether any voyages are envisaged in the area 140°W to 150°W, where present information indicates a gap.

5.5.2 It should be emphasized, however, that these details are required only for planning development and any limiting consideration envisaged by ship operators should be stated so that consideration could be given to the incorporation of additional requirements into the buoy design.

5.5.3 In order that the plans for supply of buoys to ships and the movements of scientists/technicians can be refined, it is necessary that firm schedules be determined by July 1976. The information needed will be:

date,
port of departure,
cruise track.

5.5.4 This will also enable important gaps to be identified and requests to fill these would then be issued.

5.5.5 This strategy requires the designation of some agency within the central management framework of the Global Experiment to organize the delivery of buoys to appropriate ships and the appointment of, and time scheduling for, the scientists/technicians to activate the buoys and/or training of ships' officers This might include discussions with the Antarctic operating organizations about a schedule for intra-Antarctic air transportation.

5.5.6 The same agency would also be responsible for advising on modifications to the deployment plan necessitated by ships being unable to launch buoys as scheduled.

6. PLANNING SCHEDULE

6.1 Establishment of Schedule

6.1.1 In considering the untested nature of the expendable drifting buoy system, the objectives to be accomplished by the beginning of the Global Experiment demand the establishment of a firm schedule that must be closely followed.

6.1.2 In Table II the sequence of pilot tests and the demonstration of the feasibility of the drifting buoy-satellite tracking system (1970-1973) with the Nimbus 4 and Eole satellites, is outlined. From the experience of these programmes and those planned for Nimbus F, the schedule for the drifting buoy programme for the Global Experiment is evolving.

6.1.3 Buoy experimentors using modified balloon electronics from the IRLS and Eole experiments successfully demonstrated both technically and scientifically the feasibility of tracking drifting buoy platforms by polar or inclined orbiting satellites. These programmes, deploying only few buoys of various types, differ significantly from the programme being planned for the Global Experiment, in that the Global Experiment buoy programme will necessitate the joint participation of a number of nations. In order to effect this participation, early plans must be initiated for funding for the buoy hardware including sensors, electronics and drogues, as well as plans for deployment by supply and research ships serving the Antarctic.

6.2 Test and Calibration

6.2.1 Although the long life expendable drifting buoy as an oceanographic/meteorological sensing platform is relatively simple and straightforward, it is essential by the nature of its unattended operation in a particularly harsh environment that the components as well as the complete platform be thoroughly tested prior to shipment. The tests of the components and the integrated buoy platform must conform to accepted practices for manufacture of marine hardware.

6.2.2 The Data Systems Test (DST) which is a complete test of the observational, communication and data management system and will be conducted after the launch of Nimbus F in mid-1974, is a precursor test for the Global Experiment. The TWERLE experiment, in conjunction with ACE and other drifting buoy experiments, will provide demonstration and test of the feasibility of the satellite-balloon-buoy combination of meterorological-oceanographic measurements prior to the Global Experiment.

7. OCEANOGRAPHIC PARTICIPATION DURING THE GLOBAL EXPERIMENT BUOY PROGRAMME

7.1 Oceanographic Programmes

7.1.1 Whilst a detailed examination of oceanographic programmes that could be carried out in co-operation with the Global Experiment is in the province of SCOR working groups 34, 38 and a new group formed with this specific objective in mind, the meeting felt that it would be timely to comment both on the feasibility and value of the Global Experiment buoy requirements as seen by oceanographers.

7.1.2 There is a common interest in resolving the problems of the interaction of atmosphere and ocean and both IOC and SCOR have already recognized that the Global Experiment offers a significant opportunity in this respect. The deployment of an array of buoys using the techniques of satellite data collection as proposed for the Global Experiment could be a significant part of such programmes whether they be in the southern ocean or elsewhere.

7.1.3 Nevertheless the Global Experiment requirement for surface pressure and temperature at a minimum 500 km spacing throughout the latitude belt 50°-65°S is a reflection of the requirement to sample the atmospheric scales adequately. The corresponding oceanographic scales in the southern ocean are probably considerably smaller, so the information content of the proposed system for the Global Experiment is low in an oceanographic context at this time. It appears that the basic buoy requirements for the Global Experiment are unlikely to provide the oceanographers with the data they require and oceanographers will probably wish to concentrate their efforts in specific Antarctic areas.

7.1.4 It is expected that a SCOR response on feasible oceanographic programmes that may benefit from and contribute to the aims of the Global Experiment, and in particular on the need of these programmes for disposable buoy systems, will be available in early February 1974.

7.2 Oceanographic Use of Buoy Systems

7.2.1 For guidance, it is worth describing here one example of the approach oceanographers will have to use of buoy systems in the Antarctic environment.

7.2.2 The Antarctic Current Experiment (ACE) proposes to use the capability of the meteorological satellite Nimbus F to track 25 buoys to be set out south of Australia in the austral spring of 1974. The buoy is described in section 3 of this report and will be deployed by Antarctic supply vessels which frequent this region (see section 5). The buoys will yield sea level atmospheric pressure and water temperature at one metre to an accuracy which meets the requirements of GARP; in addition, each buoy will measure the water temperature at 20 and 200 metres and be equipped with a drogue at 20 metres. Pressure at 200 metres is included for monitoring the aspect of the thermistor line.

TABLE II - METEOROLOGICAL/OCEANOGRAPHIC DRIFTING BUOY TRACKED BY POLAR OR INCLINED ORBITING SATELLITES

		70	71	72	73	74	75	76	77	78
Pilot Programmes 1970 - 1973 Ref: GPS No. 11, p.31	Nimbus 4 launch	▲- - -	- - -	- - -	- - -					
	Spar buoy - Nimbus 4/IRLS track. (Crumpler)	▲								
	Eole launch		▲———	———	———					
	Nine discus -North Pacific-Eole track. (Morel)			▲						
	Two spars - Norwegian Sea - Eole track. (Dickson)			▲						
	Five spars North Atlantic-Eole track.(Hansen)			▲						
	Spar off E. Australia - Eole track. (Creswell)			▲						
	Four (1m) discus off E. coast U.S. - Eole track. (McFall)			▲- - -	- - -					
Buoy programmes using Nimbus F/RAMS	SCHEDULE OF PROGRAMMES 1974 THROUGH 1978									
	Nimbus F notification to users				△					
	Development of prototype buoy hardware for RAMS on Nimbus F			△———	———	△				
	Hardware purchase				△——	△				
	Assembly & integration				△——	△				
	Nimbus F launch scheduled					△				
	TWERLE balloon experiment					△—△				
	Tropical buoy deployment					△—△				
	Mid & high latitude buoy deployments					△—	△			
Buoy programmes for the Global Experiment	TIROS N launches							△- - -	- - -	△- - -
	Initiate international plans for the Global Experiment buoy array					△				
	Deployment schedule established					△—△				
	Hardware procurement, assembly, integration and test						△—	△		
	Shipment to deployment vessels							△—△	△—	△
	Deployment So. Hemisphere 50°to 65°S							△—	△ △—	△
	Special Observing periods for the Global Experiment								△—△—△—	△

7.2.3 There are two stages of ACE: Stage I is the 1974/75 experiment with Nimbus F and Stage II is a more extensive array to be set out during the period of the Global Experiment. Stage I is vital in that it forms a complete test and demonstration of the feasibility of the satellite data retrieval from a large network of buoys in the Antarctic environment to produce a valid and useful scientific programme. The stage I data on the thermal and current characteristics of the Antarctic waters will serve as an extremely useful guide for planning more extensive arrays such as during the Global Experiment.

7.2.4 The stage I array of ACE is basically an oceanographic project which also yields meteorological data; it would, in principle, meet the requirements of the Global Experiment. The buoy drift will allow description of near surface drift and the variation of temperature structure along the trajectory. It is expected that the array will be able to "observe" the mean flow and long term transient motions (longer than a few days). The circulation pattern in the region of the stage I array is relatively strong with significant interaction with the bottom topography; in addition, transient features have been shown to be present in the thermohaline and current fields. It is also possible that the influence of large storm patterns on the currents will be detected by variations in buoy drift. The thermistors will allow detection of thermal structure response to variations in weather patterns.

7.2.5 The buoy array will provide the pressure field data to derive geostrophic wind. This information is useful in the analysis of the oceanographic data. The meteorological data will also be used by the Australian and New Zealand weather services and in the Data Systems Test (DST) data global set to be prepared at NCAR, and to provide for fiducial points for relating temperature and mass fields, derived from indirect soundings by satellite.

7.2.6 Stage I of ACE will form a test of buoy design, development and deployment for the Antarctic regions, in addition to testing of the communication, final data reduction and analysis methods. The results of ACE will be vital to the planning of more extensive buoy arrays for oceanographic studies as part of the TIROS N programme.

7.2.7 The oceanographic emphasis in this programme is on the measurement of temperature and currents because of the difficulty of constructing reliable, rugged and cheap instruments for the measurement of other very relevant parameters such as the salinity. The meeting noted that there will be some excess capability in the data collection system which is available for other instrumentation at little more than the cost of the sensors themselves.

7.2.8 It should also be noted that the possible availability of research ships in the context of an oceanographic programme could substantially extend the duration over which a buoy array could be deployed.

8. CONCLUSIONS AND RECOMMENDATIONS FOR ACTION

8.1 Conclusions

8.1.1 Simple expendable drifting buoys that can be made suitable for meteorological and basic oceanographic measurements in support of the Global Experiment in the latitude band 50°-65°S are at present in an advanced state of development and can readily be tested and made available in sufficient quantities in time for use in the Global Experiment.

8.1.2 Any of these drifting buoys would use the random access Doppler position measuring and telemetry system to be flown on TIROS N or other spacecraft; the nature of this form of communication makes possible a long-life, inexpensive buoy system.

8.1.3 The lead time required to assure timely deployment of these buoys is so extended that preliminary decisions by nations participating in the Global Experiment to support the buoy programme must be taken by early 1974.

8.1.4 Deployment of the buoys in the region 50°-65°S by Antarctic supply ships appears feasible and attractive. Presently known routes would result in good coverage, particularly if some ships could deviate somewhat from their normal routes. Some gaps in coverage might still remain, in which case supplementary means of deployment should be sought.

8.1.5 The proposed Antarctic Current Experiment (ACE) in 1974, utilizing Nimbus F, is an essential scientific and systems test of the above recommended concept. Such a test is an essential pre-requisite for the effective implementation of an Antarctic buoy programme in the Global Experiment.

8.1.6 Whilst the same buoy can be used for both Global Experiment data requirements and for oceanographic research programmes in the area, there appear to be differences in network density and area of coverage between the requirements of the Global Experiment and those of presently envisaged oceanographic research. Because of the great commonality of interest, particularly with respect to the second GARP objective, it appears most desirable to explore further the possibility of joint use of the Global Experiment buoy network.

8.1.7 Meetings of Working Groups and the Executive Committee of SCOR will be held in Canberra, Australia, January/February 1974, at which it is expected that planning will be initiated of an oceanographic programme related to the Global Experiment.

8.2 Recommendations

8.2.1 For the purposes of the ad hoc Working Group on Buoys, SCOR should be asked specifically to identify those parts of the oceanographic programme it will propose that require, or could benefit from, expendable buoys during the period of the Global Experiment.

8.2.2 The meeting of the ad hoc Working Group on Buoys recommended by the Planning Conference on the First GARP Global Experiment, should be held after the SCOR meetings in Canberra. On the other hand the meeting should be held sufficiently before the GATE field programme to permit participation by scientists involved in that experiment. A date early in 1974 might also permit nations with long budgetary lead times to make tentative commitments. It was considered that early March 1974 would be an optimum time.

8.2.3 The meeting should include discussions of:

(a) the report of the present informal meeting on buoys

(b) scientific requirements for buoy networks

(c) potentially available buoy systems

(i) description

(ii) availability for the Global Experiment

(d) deployment of buoys

(e) possible national commitments for the manufacture, purchase and deployment of buoys.

8.2.4 Participation in the meeting should be as broad as possible to assure representation by interested national agencies as well as by contributing scientists.

8.2.5 The following documents should be distributed to all invitees at least 90 days before the meeting:

(a) requirements for buoy systems for the Global Experiment and for oceanographic programmes - JOC and SCOR (1);

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(1) Owing to the timescale, the report from SCOR on planning of an oceanographic programme may be given in oral form.

(b) buoys under development that may be available for the Global Experiment - J. Garrett (Canada);

(c) an analysis of buoy distribution resulting from deployment by Antarctic supply vessels - J. Garrett (Canada) and J. Masterson (USA);

(d) likelihood of availability of various Antarctic supply vessels for Global Experiment buoy deployment - SCAR;

(e) buoy lifetime and reliability, and their impact on array planning - M. Hall (USA);

(f) Communications and Data Handling Plan - M. Hall and J. Masterson (USA).

8.2.6 In support of document (b) above, a questionnaire on buoy development (Annex III) should be circulated by WMO, IOC and SCOR, with possible further distribution by JPS, to ensure the widest possible distribution to all organizations, governmental and non-governmental, that may be developing suitable buoys. The questionnaire should be given an end of September deadline for replies.

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The Role of Buoys for Observations over the Ocean Areas for the First GARP Global Experiment, 1972. GARP Seventh Sessions of the Joint Organizing Committee, Munich, June-July 1972. Doc. 4.4, Appendix D.

9. SUMMARY REPORT. CLOSURE OF THE MEETING

9.1 Approval of the Summary Report

The Summary Report of the Meeting was approved by the participants, apart from minor editorial improvements to be introduced by the Secretariat, and a revision to Annex III which was finalized at a later stage.

9.2 Closure of the Meeting

The Chairman closed the meeting at 17.45 on Friday 15 June and thanked all participants and the Secretariat of the Intergovernmental Oceanographic Commission for their co-operation and support.

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BUOYS DISCUSSED DURING THE MEETING+

(1) The Nova expendable drifting sea-following spar, under development at Nova University for U.S. NOAA Data Buoy Office. This expendable drifting buoy system is intended to communicate via the Nimbus F/RAMS system with up to 8 channels of data. Sensors are currently under development for atmospheric pressure (± 2 mb), sea surface temperature (± 0.5°C), temperature at depths of 20 m and 200 m, air temperature, and wind speed. Position fixing will be accomplished via Nimbus F (5 km RMS), and drogue systems for current measurement are being studied. The buoy is a spar with conical auxiliary floatation and a total length of about 4 metres. Ease of deployment has been a factor in the design as had been ease of assembly from parts to be supplied. The buoy hulls have been tested separately and are now being tested with drogues. The completed system is expected to be available for GATE and may be used in the Antarctic Current Experiment (ACE) in November 1974. Plans for production are presently being considered. Design lifetime is from 6 months to 1 year.

(2) The MET-buoy of the Norwegian Meteorological Institute is a proven system with extensive field use since 1962. This buoy system, free drifting or anchored, can be of some interest to the Global Experiment because of plans in Norway to have two transmitting systsems, the present one and a Norwegian built Nimbus F/RAMS System, as well as its proven sensors, especially the atmospheric pressure sensor.

The present VHF transmitting buoy system costs approximately US $ 30-40,000.

(3) A slender spar buoy developed by J. Martinais of the Centre Océanologique de Bretagne of the French CNEXO, is approximately 10 metres long, with 3.5 metres protruding above the surface and is moored with a floating line. It has been equipped with meteorological sensors, has been used in the drifting mode and is very easy to deploy. Some tests using an Eole transponder have been made. It would be easy to mass produce.

(4) A tuned spherical buoy under consideration by Professor Morel of the Laboratoire de la Météorologie Dynamique of the French CNRS would be about 1 metre in diameter and would contain atmospheric pressure and

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+ This list is known not to be comprehensive; it will be extended in due course using replies to the questionnaire attached at Annex III (paragraph 8.2.6 above refers).

sea surface temperature sensors, with a possibility of a string of sub-surface temperature sensors. A pressure sensor is under development with an anticipated accuracy of better than ± 0.5 mb. The prototype is expected to be tested with Nimbus F in late 1974.

(5) An upright cylindrical buoy approximately 5 metres long by 0.5 metres in diameter and attached to parachute drogues at depths of 1000 and 1500 m has been used by R. Dickson at the Lowestoft Fisheries Laboratory in the United Kingdom. These buoys have been successfully tracked in the Norwegian Sea using Eole transponders.

(6) In the United Kingdom, sea level meteorological sensors for unattended meteorological buoys have been under development at the UK Meteorological Office at Bracknell and have been tested at sea. A wave statistics package is being developed at the Institute of Oceanographic Sciences.

(7) It was mentioned that the Japan Meteorological Agency has undertaken the development of moored telemetering weather buoys, but it was not known whether all or portions of their work would be useful to drifting buoy development of the Global Experiment.

(8) A small inexpensive spherical buoy has been developed in the Australian Bureau of Meteorology to telemeter sea surface temperatures to nearby shore locations. These simple buoys are anchored at several points along the Australian coast. It has been proposed that they be modified to serve as an extremely simple, low cost, drifting buoy measuring atmospheric pressure and sea temperature.

(9) A drifting spar buoy, with conical supplementary floatation, has been tracked using an Eole transponder, by G. Cresswell of the Oceanography and Fisheries Laboratory, CSIRO, at Cronulla, Australia. This is similar to the U.S. Nova spar (above), in that it is constructed of fibreglass-covered PVC plastic and is of similar dimensions. This group as well as that of A. Dyer of the CSIRO Atmospheric Physics Laboratory, Aspendale, Australia, are planning to mount programmes using the Nimbus F/RAMS system.

(10) A one metre discus with a "cross-type" drogue is under development and test by the Langby Research Center of NASA. Eole transponders have been used in four of these drifting buoys, one of which was tracked for four weeks.

QUESTIONNAIRE RELATING TO BUOYS OR COMPONENTS FOR POTENTIAL USE IN THE FIRST GARP GLOBAL EXPERIMENT (FGGE)

1. Agency responsible for development

2. Key person to contact for information

3. Brief description of buoy system with key design features

4. Experiment or functional capability buoy system was designed to meet

5. Sensor design characteristics (not all of these may be applicable):

Sensor	Range	Accuracy	..Measurement Level (Elev.)
Position Fix			
Atmos pressure			
Sea Surface Temp.			
Sea Temp			
Air Temp			
Wind Speed			
Wind Direction			
Humidity			
Ocean Current			
Other			

6. Data Storage and/or Recovery

   a. Brief description of data storage (analog or digital tape, data format, etc)

   b. Brief description of telemetry scheme (frequencies, transmit power, antenna configuration, satellite, communications station, etc.)

   c. Data retrieval scheme (self initiate telemetry, interrogated, synoptic, etc.)

   d. Data processing (on buoy, on shore, availability, dissemination, user format, etc.)

7. Physical Characteristics (attach outline drawing if available)
   a. General construction
   b. Principal dimensions
   c. Weight
   d. Deployment requirements
   e. Drogue configuration
   f. Other features
   g. Design restrictions

8. Power Design Characteristics
   a. Power source
   b. Design life
   c. Design restrictions

9. System Design Characteristics
   a. Refurbishment time cycle if applicable
   b. Design environment, survivability
   c. System design life

10. System Status (Describe if in conceptual design stage, in design stage, in prototype development, in test, anticipated completion dates and planned test program)

11. Approximate Costs (describe in terms of estimated quantities. Breakdown as appropriate)

12. Region and planned deployment schedule.

LIST OF ACRONYMS

ACE	Antarctic Current Experiment
CNEXO	Centre National pour l'Exploitation des Océans
CNRS	Centre National de la Recherche Scientifique
CSIRO	Commonwealth Scientific and Industrial Research Organization
DST	Data Systems Test
FGGE	First GARP Global Experiment
GARP	Global Atmospheric Research Programme (WMO/ICSU)
GATE	GARP Atlantic Tropical Experiment
GPS	GARP Publications Series
GSFC	Goddard Space Flight Center (NASA)
ICSU	International Council of Scientific Unions
IOC	Intergovernmental Oceanographic Commission (of Unesco)
IOS	Institute of Oceanographic Sciences (formerly NIO)
IRLS	Interrogation Recording and Location System
JOC	Joint Organizing Committee (GARP)
JPS	Joint Planning Staff (GARP)
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
RAMS	Random Access Measurement System
SCAR	Scientific Committee on Antarctic Research (of ICSU)
SCOR	Scientific Committee on Oceanic Research (of ICSU)
TIROS	Television and Infrared Observing Satellite
TWERLE	Tropical Wind, Energy conversion and Reference Level Experiment
UNESCO	United Nations Educational, Scientific and Cultural Organization
UWIS	University of Wisconsin
WMO	World Meteorological Organization