

WORLD CLIMATE PROGRAMME

RESEARCH

INTERNATIONAL COUNCIL
OF SCIENTIFIC UNIONS

WORLD METEOROLOGICAL
ORGANIZATION

INTERNATIONAL WOCE
SCIENTIFIC CONFERENCE

**REPORT OF THE
INTERNATIONAL WOCE SCIENTIFIC CONFERENCE**

Unesco, Paris

(28 November to 2 December 1988)

WCRP - 21

April 1989

(WMO/TD - No. 295)

**INTERGOVERNMENTAL OCEANOGRAPHIC
COMMISSION**

**SCIENTIFIC COMMITTEE
ON OCEANIC RESEARCH**

The World Climate Programme launched by the World Meteorological Organization (WMO) includes four components:

The World Climate Data Programme

The World Climate Applications Programme

The World Climate Impact Studies Programme

The World Climate Research Programme

The World Climate Research Programme is jointly sponsored by the WMO and the International Council of Scientific Unions.

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Scientific Conference**

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Proceedings



March, 1989

WOCE International Planning Office
Wormley

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1. OPENING

The International Scientific Conference for the World Ocean Circulation Experiment (WOCE) was opened by the Chairman, Professor G. Siedler, who welcomed the participants on behalf of the four sponsoring organizations of WOCE. On the non-governmental side, these are the International Council of Scientific Unions and the Scientific Committee on Oceanic Research; on the intergovernmental side, the Intergovernmental Oceanographic Commission of Unesco and the World Meteorological Organization. The Organizing Committee for the conference had been established by the WOCE Scientific Steering Group.

On behalf of the organizers, Professor Siedler thanked Unesco for the opportunity to meet at Unesco House and for providing the excellent facilities. He also expressed his appreciation for the work of the IOC Secretariat and the WOCE International Planning Office in preparing this conference.

Professor Siedler noted that WOCE is a component of the World Climate Research Programme (WCRP) and that the degree to which climate can be predicted, and the extent of man's influence on climate, is not just an esoteric matter. If the activities of mankind lead to sea level changes of only a few decimetres, this will have implications for living conditions and the economics in many countries. Further, if climate predictions force us to reduce the output rate of carbon dioxide, the necessary decrease of energy consumption will have considerable consequences for energy consuming and energy supplying countries and industries.

The important climatic changes are large-scale global phenomena, they have implications for people around the world, and they must be investigated on a global scale. This is the reason why an experiment like WOCE is being proposed and why this conference is being held.

The participants will have realised that the conference is somewhat unusual. It is not just a meeting of scientists to discuss recent results and new ideas, nor is it a meeting of government representatives deciding on intergovernmental programmes. What kind of conference is it, what are its goals?

The fundamental ideas of WOCE have been developed by groups of scientists who feel that the time has come for a major international endeavour to investigate the ocean's role in the climate system. It was clear very early that such an experiment could only be done with the full co-operation and expertise of the scientific community, with the support of national agencies, and with the involvement of governments in certain aspects of the programme.

The main goal of this conference is to bring these communities together. Information will be provided on the scientific rationale to those who have not been closely involved in the scientific planning, opportunities for participation will be indicated, and the Implementation Plan and organizational considerations will be presented.

The hope is that the participants will find that WOCE is an important step towards the long-term goal of predicting climate change, and that it is an exciting oceanographic experiment in itself. It is hoped that they will decide that WOCE is an ambitious, feasible experiment, and that reasonable ideas have been developed for its implementation and organization.

The second part of the conference will provide the opportunity to participants to identify potential contributions to WOCE that can be expected from the various institutions and national organizations, contributions with respect to scientific and technical manpower, ships, computing facilities, instruments and so on. This discussion will, hopefully, lead to the conclusion that sufficient support can be obtained for carrying out the experiment, but it may also identify critical gaps that exist.

WOCE is different in many respects from earlier or on-going large ocean-atmosphere research programmes, including TOGA, and it therefore requires special international and national organizational arrangements which will also be discussed.

The objective was to have a good mix of participants from scientific institutions, agencies, governments and intergovernmental organizations. About 175 participations from 44 countries have pre-registered. This is a remarkable number of countries showing interest in WOCE and participants in this conference should be optimistic with regard to the international scope and the interaction of the various communities.

Professor Siedler then invited the representatives of the sponsoring organizations to address the Conference. The representatives were: Dr. Sorin Dumitrescu, Acting Assistant Director General for Science of Unesco; Dr. Julia Marton-Lefevre, Deputy Executive Secretary of ICSU; Dr. Pierre Morel, Director of the WCRP representing WMO; Professor Ulf Lie, Chairman of IOC; and Professor Gerold Siedler, Past-President of SCOR.

A keynote address for the purpose of putting WOCE into context, both historically and with respect to other international programmes, had been prepared by Dr. R.W. Stewart who was unable to attend due to illness. The talk was read by Dr. R. Chesselet and is reproduced in Appendix III.

The WOCE Implementation Plan, the principal document for the conference, was then introduced by Dr. G. Needler, the Director of the WOCE International Planning Office. He described the procedures which had been followed in developing the WOCE Scientific Plan, which was published in 1986, as well as the Implementation Plan and how it had received broad input and review from the international scientific community. He also discussed the nature of the Plan and how the documentation provided to the conference regarding the detailed experimental design of WOCE related to the Implementation Plan and could be used by the conference in assessing the level of resources available for WOCE. An abstract of Dr. Needlers talk is given in Appendix III.

The last presentation of the opening session was given by Dr. A. McEwan, chairman of the Committee on Climatic Changes and the Ocean. He discussed WOCE in the context of the task in gaining recognition of its importance at government level, the need to accommodate the differences between countries in the means by which the experiment could be promoted and sponsored, and its dependence on the dedication of individual scientists.

Before proceeding to the technical programme, Professor Siedler wished to express the gratitude of the Sponsoring Organizations to the Conference Organizing Committee, namely: C. Wunsch, T. McDougall, M. Lefevre, R. Godin, A. Tolkachev, P. Morel, F.W.G. Baker and G. Needler, for a job well done.

The programme of the conference is given in Appendix I, the participants are listed in Appendix II.

Note: These proceedings make frequent reference to elements of the WOCE field programme using the coding system introduced in the WOCE Implementation Plan which provides more detailed information regarding each element. Understanding will in many cases require reference to be made to the Implementation Plan (WCRP - 11, July 1988, WMO/TD No.242).

2. PRESENTATION OF THE WOCE PROGRAMME

The Scientific Programme of WOCE was introduced in a series of talks led by the Chairman of the SSG, Professor C. Wunsch, who presented an overview.

He pointed out that by the middle of the 1970s the oceanographic community had come to appreciate several features of their field: recognition of the global character and turbulent nature of ocean circulation; increasingly urgent questions about climate change, sea level rise, fisheries instability, etc.; strong suggestions of the possibly dominant role in climate of oceanic heat fluxes; extreme El Niño events as a non-subtle demonstration of the impact of ocean/atmosphere interactions, suggesting the strong possibility of other, less obvious interactions controlling climate.

Around 1980, it seemed reasonable to consider actually confronting these problems. There was increasing national and international concern over climate instability and the WCRP was formed. For the first time, the meteorological community seemed prepared to admit the fundamental importance of the ocean in climate dynamics. The oceanographic community itself had a much increased understanding of oceanic sampling issues and oceanic dynamics and these issues could be addressed observationally, for the first time, through the technological progress of the preceding decades.

In formulating a global experiment, we must recognize that what we are trying to do is very difficult, for a variety of reasons:

- There are no operational government agencies for ocean observations and governments rarely can deal with problems of duration exceeding the time to the next election. Observing the ocean is intrinsically very difficult (opacity to electromagnetic radiation; corrosive effects; high pressures; rapid time dependent changes; H is almost unimaginably large).
- The traditions of the oceanographic community conflict with doing large scale organized programs sustained over many years and the community is itself quite small.

Recognizing these problems the SSG has employed several principles in constructing a practical Implementation Plan. Of central importance is the assumption that one must define the basic physical state as a prerequisite to true understanding of the dynamics and the biochemical state. It is essential that the experiment remain clearly scientific - it would be a major error to construct operational systems prematurely - given that few of the observational tools are operational they are still developmental. No single observational system can address all important problems for technical, logistic, scientific and economic reasons and the foundation of implementation must be existing laboratories, governmental and intergovernmental organizations.

For practical reasons, the SSG has divided the Experiment into three overlapping Core Projects, which later speakers will discuss in detail. A somewhat simplified view of Core Projects 1 and 2 is that they are intended to define the basic thermodynamical/chemical state of the ocean as it exists in the early 1990s, including the definition of important dynamical scales of temperature, salinity, oxygen, nutrients and CO₂ and the dominant connections to the atmosphere: surface stress, heat flux and fresh water flux. A peculiarity of ocean dynamics means that the definition of the thermodynamical state and forcing produces accurate estimates of property fluxes and divergence (e.g. heat, mass, water vapour, nutrients,..).

Core Project 3 is intended to isolate and understand through focussed regional experiments small scale physics critical to modelling of global scale circulation/climate.

The three Core Projects are directed at the first Goal of WOCE. The intention of the second Goal is to leave in place a sufficient observational base to determine longer term oceanic changes (producing determination of 'representativeness' of WOCE data observations). By the time WOCE is all over, we aim to have, on a global basis:

- synoptic daily wind fields,
- daily maps of sea surface elevation, both absolute and time dependent parts,
- dense, near mesoscale resolution hydrography, oxygen, nutrients, chlorofluoromethanes, tritium, helium-3, defining the basic oceanic thermodynamical/chemical state and hence the major interior fluxes, sources/sinks of these properties,
- a global, "transparent-to-the-user" data exchange and inventory system,
- basin-scale, eddy resolving general circulation models with active thermodynamics and biochemical cycles; global scale, dynamically and thermodynamically constrained circulation models with biochemical cycles,
- global interior and boundary direct measurements of flow fields by floats over a five year
- period,
- mass/property transports and interannual fluctuations of all deep boundary currents,
- quantitative, global estimates of heat, fresh water, nutrient fluxes within the ocean and to and from the atmosphere,
- an observation system that can be left in place, economically, to be used in conjunction with future regional programs and continued ocean-climate studies,
- much improved existing tools (water samplers, CTDs, telemetry, analytical techniques, data/model combination methods, float systems, satellite sensors),
- an international organization capable of continued operation of a global oceanographic system.

The grand result will be much improved understanding of the general circulation, its consequences, its potential changes and implications for climate.

In summary, to carry out WOCE is going to be difficult. But the Implementation Plan is technically and financially feasible. The scientific judgement is that we will be far closer to understanding the oceanic role in climate than we are now. The Plan addresses problems which are, and will remain, extremely important, with enormous economic consequences (climate change, sea level rise, agricultural and fisheries changes, policy implications for fossil fuel burning, nuclear power, etc., etc.)

WOCE addresses critical societal problems, through the mechanism of an exciting scientific program.

After giving his overview, Professor Wunsch then chaired a session in which the programmes of each of the three Core Projects of WOCE were presented by the Working Group Chairmen. They are Core Project 1, the Global Description; Core Project 2, the Southern Ocean; and Core Project 3, The Gyre Dynamics Experiment. The Numerical Modelling Programme of WOCE was presented by the Chairman of the Numerical Experimentation Group, as well as the programme for obtaining the large-scale forcing fields by the Chairman of the JSC/CCCO Working Group on Air-Sea Fluxes. The abstracts of these presentations are given in Appendix IV.

The second day of the conference was opened by Dr.J. Woods who chaired a session of presentations describing the Observing and Data Management Systems for WOCE. Nine talks were given for which the abstracts are also provided in Appendix IV.

3. STATEMENTS BY INSTITUTIONS AND NATIONAL ORGANIZATIONS

The session was opened by the chairman who reminded the participants that this was a Conference of individual experts and not delegates representing governments. The term "national" had to be interpreted in the manner used in ICSU rules where it has no connotation other than denoting a member admitted for scientific reasons. He also wished to stress that the conference provides a chance that should not be forgotten: to bring together groups from countries with large and small marine science communities and facilities for joint work. An attempt should be made to find out how smaller countries can take part in a way which leads to contributions to the global programme while the oceanographic communities in these countries are acquiring additional knowledge about regions of their interest and gain experience with new technology.

As a step towards assessing the scope of possible participation in the WOCE field programme, talks expressing interest were given by representatives of institutions and national organizations. In all, 31 talks were given. Written versions of these presentations and some additional background information are presented in Appendix V.

General support of WOCE was expressed by those participating in this part of the programme. In a number of cases those speaking indicated in some detail the nature of contributions to be made to WOCE or outlined the content of a programme which is presented in more detail in the documentation provided in Appendix V. Most referred explicitly to various components of the Implementation Plan. Other speakers, while supporting WOCE in principle, indicated the intention to develop a specific contribution in the future, in some instances with the need to co-operate with other nations in fulfilling the specific requirements given in the Implementation Plan. The detailed information provided (summarized in Table 1) formed the basis for the assessment of resources for WOCE which followed in the Working Groups.

Table 1 Major WOCE Resource Requirements and Tentative Commitments

<u>Observational Element</u>	<u>Requirement</u>	<u>Tentative Commitments</u>
WHP - One Time Survey	10.4 ship years))21.5 ship years
Repeat Hydrography and Time Series	15.0 ship years)
Subsurface Floats	ca 3500	ca 1900
Surface Drifters	ca 4000	ca 2000
Moorings	ca 350	ca 250
Sea Level Stations	40	>40 sites available, most need upgrade to meet WOCE requirements
XBT standard (750 m)	5000/y (In addition to TOGA and IGOSS)	>16,500 available but commitments are not entirely consistent with requirements, nor is TOGA data set complete
XBT deep (1000 m) Altimetry/scatterometry	11500/y Several satellite missions	ERS-1, 1990 TOPEX/POSEIDON, 1992 ERS-2, 1993 ADEOS, 1994 ARISTOTELES, 1994

4. ASSESSMENT OF RESOURCES FOR THE OBSERVATIONAL PROGRAMMES

4.1 Introduction

After the presentation of the WOCE programme and statements of interest, the meeting was divided into working groups to address the availability of resources for various elements of the WOCE field programme. The working groups addressed: direct current measurements, including floats and moored instruments; the surface layer, including the VOS programme; surface drifters; flux measurements and surface meteorology; satellites and sea-level for altimetric purposes; the WOCE Hydrographic Programme; and Data Management. Each working group made a detailed listing of the resources that would be identified as available for WOCE. This led to the revised tables of resources given in Appendix VI. The working groups also made general statements regarding the observational programme and provided a number of recommendations for its improvement or to ensure its implementation.

Before the presentation of the working group reports to the plenary session, the chairman of the Conference apologized for the change in the schedule which had been necessary because of ongoing discussions on the status of the scientists at the Conference, in particular the three scientists from South Africa. He appreciated the help of UNESCO and representatives from several organizations and countries in finding an answer to the questions raised. The individual scientists from South Africa, attending the conference within the framework of ICSU, subscribed fully to ICSU's Statute 5 and a statement which had earlier been signed by the non-governmental Council for Scientific and Industrial Research (CSIR). The South African Secretariat is part of the Foundation for Research Development in South Africa which is part of CSIR. The required statement reads: "The CSIR accepts without reservation the principle of non-discrimination against scientists as regards race, religion, political philosophy, ethnic origin, citizenship, language or sex" and "accepts without reservation the principle of the free circulation of scientists and their association with international scientific activity throughout the world".

The meeting then proceeded with the presentation and discussion of the conference working group reports which are given in the rest of this section as well as in Sections 5 and 6. The reader should consult the Implementation Plan and Appendix VI for precise information on the programme elements referred to in the following sections.

4.2 The Hydrographic Programme

The chairman, Professor Liliane Merlivat asked the chairman of the WHP Planning Committee, Dr. Joyce, Woods Hole, to review the rationale for the WHP within WOCE, the design criteria for the WHP sampling programme and the standards and precisions requested for the WHP. His comments helped the participants to fully understand the direction taken by the WHP.

This was followed by a round-table discussion of the draft resources summary made available by the IPO for the Conference. The entries were commented on and where necessary changed or amended. It became clear in this assessment that the resources indicated by participants covered more than 70% of the WHP ship-time requirements (see Figure 1). Some indications of additional ship-time availability were noted, although they were given in a general context. The discussion also led to the clarification of intentions indicated for a WHP item by more than one participant. This led to some modifications during the session, or the indication of the need for closer bi-lateral negotiations. Supplementary support was also noted where indicated. It was agreed that additional information or comment should be made available to the IPO for inclusion in the report of the Conference.

In general the WG concluded that the WHP plans as presented in the Implementation Plan, the requirements and the general structure for running the programme were very adequate and promised wide acceptance by the oceanographic community. It was also very favourably noted that the structure for co-ordination of these efforts and for maintaining close collaboration between

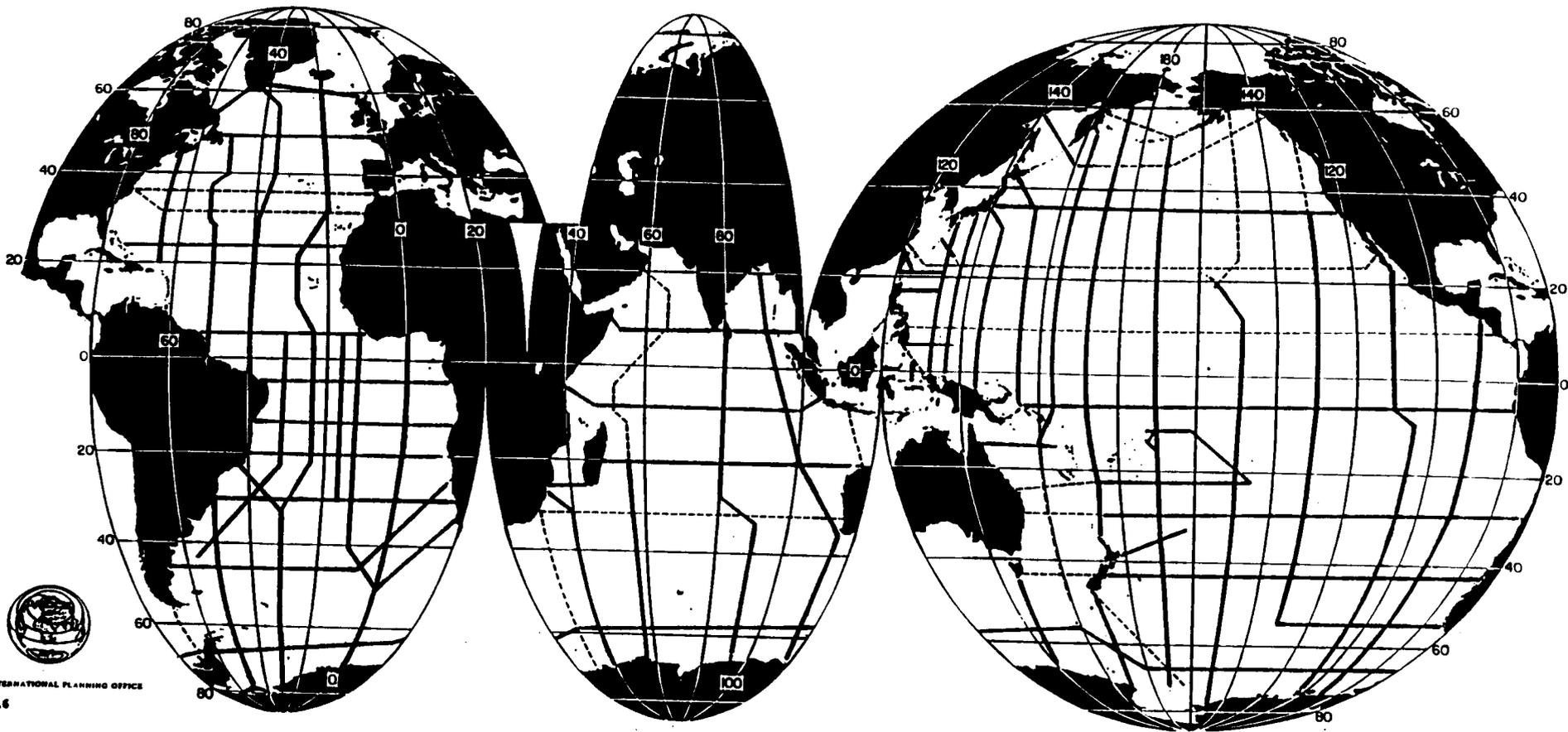


Figure 1. The WOCE One-time Global Survey
 — Tentative commitment
 - - - - - No known commitment (as of February 1989)

participants in the WHP guaranteed wide participation. The proposal for a co-ordinating Project Office for the WHP, which will partially fulfil the needs of a Data Assembly Center, and for a devoted Special Analysis Centre met wide approval.

The following four conclusions were agreed upon for presentation to the plenary session:

1. The Working Group recognized that different methods for analysis of water samples and data may satisfy WHP requirements for accuracy and precision. There is no intent to establish only one method for measurement for the WHP as long as different approaches yield results that meet WHP standards.
2. The Working Group discussion accented the need to utilize existing international arrangements, for example the IHO and the SCOR/WG 77 (Laboratory Tests Related to Basic Physical Measurements at Sea), which can facilitate the accomplishment of the goals of the WHP.
3. The Working Group stressed the importance of continuation of the IAPSO Standard Seawater Service (IOSDL, Wormley) for calibration of WHP salinometers and safeguard of quality standards.
4. WHP resources, while apparently going far towards achieving nearly a complete coverage in the one-time survey, need to be carefully evaluated and managed in order to ensure a complete suite of measurements to the WHP standards.

4.3 Direct Current Measurements Programme

The Working Group addressed the direct current measurements by instruments and deep floats. It was convened by Dr.J. Elliott.

4.3.1. General Observations

1. In general, the plan for moorings has attracted widespread support. The interest in committing to specific moorings ranges from firm plans to potential participation from laboratories which have not yet sorted out their priorities. Though some gaps are apparent, particularly in the Southern Ocean, indications are that the overall moorings programme is viable (see Figure 2).
2. The Group concluded that there was adequate commitment to the global float programme which would also provide for an Atlantic enhancement in the tropics. No interest was identified for the special requirements in the Plan (Vol. I, 5.4).
3. Clearly there are not enough resources identified to cover all the requirements in the plan. Consideration needs to be given to a reassessment of priorities in light of currently expressed interests. Some moorings, for which interest has been confirmed do not meet the intended purpose when not complemented as required in the plan (e.g. covering only the western boundaries of heat flux lines). In such cases it might make more sense to redirect resources toward completing some lines by abandoning those only partially subscribed.
4. There is still uncertainty in all the indicated "commitments" and this uncertainty can only be diminished as budgets become approved.

4.3.2. Statements regarding the Moorings Programme

1. The Atlantic moorings ACM 18 to 22 for the control volume experiments (Core Project 3) are considered important but only one, ACM-20, has any indicated potential support (from the UK institutions).

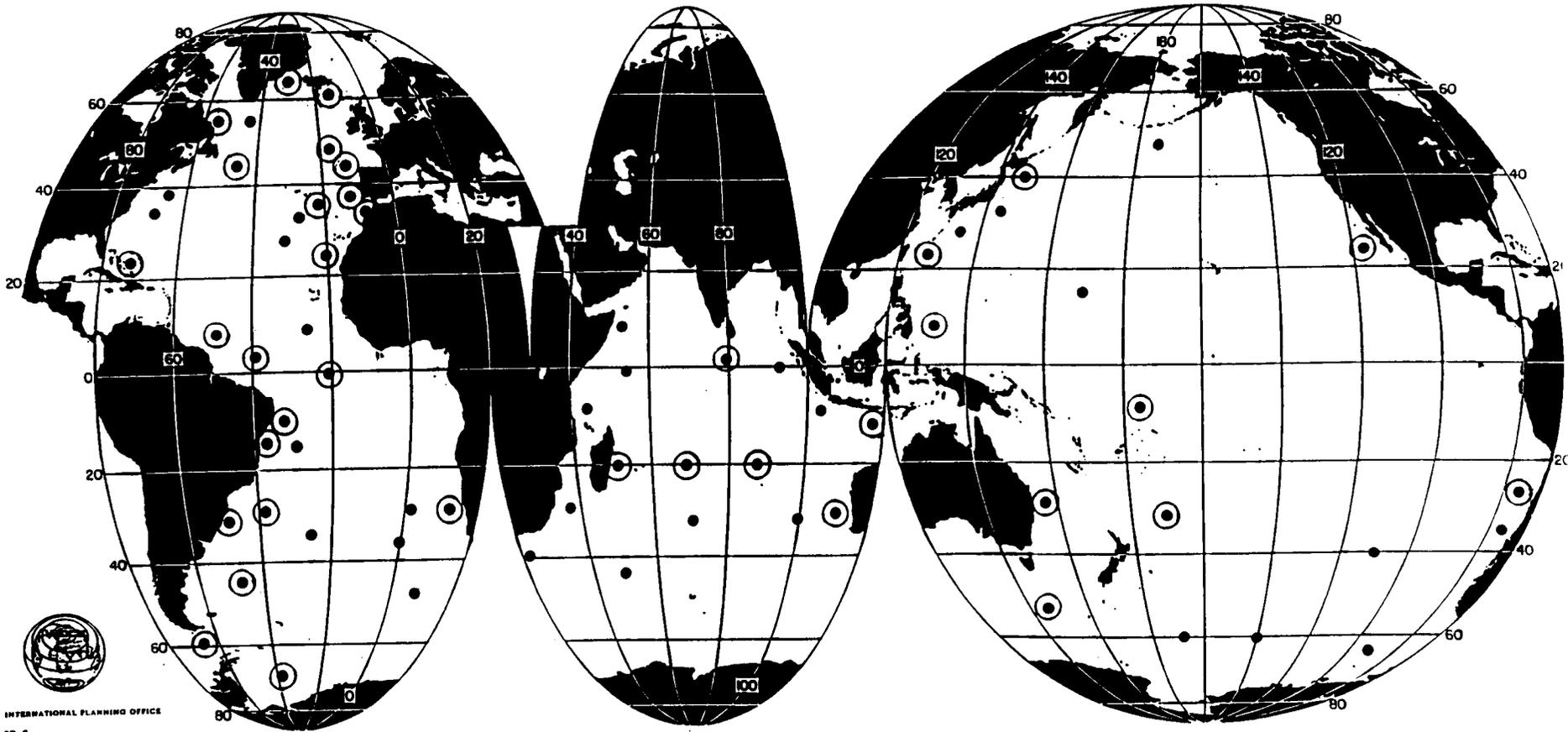


Figure 2. Current Meter Moorings

- No known commitment
- ⊙ Tentative commitment

2. Indications are that laboratories in various countries will provide moorings for the western part of all the heat flux lines except for the Indian Ocean at ICM-1, which was considered a high priority location by the group. There is a lesser interest in the eastern moorings and a question was raised as to their importance. The Group believed that the correct priority in most cases is first for western moorings, and then for other moorings located along the lines, but not necessarily against the eastern boundary as indicated in the plan, though for some, e.g. Leeuwin Current (ICM 2), the requirements are fairly substantive.

3. The thermistor/salinity moorings PTS1 to PTS6, have generated very little interest and the group wondered what stimulated their inclusion in the requirements. There was not an Australian investigator present to substantiate Australian interest in PTS1 and PTS2.

4. For moorings designed to cover the spreading of Antarctic Bottom Water it seemed that SCM4, SCM5, and SCM6 were located close enough to be merged with the three ICM3 moorings to meet both goals. In any case, the former generated no interest by any investigators from any country.

5. For the Core Project 2 eddy statistics, SCM8 to SCM15 were considered vital by the Group but, except for plans by the UK for SCM15, the others have attracted little or no interest. It was believed that there was already adequate data of SCM8 (Luyten has just completed a programme there) and it was probably not necessary to occupy that location again. A French scientist (Gascard) may have an interest in SCM9 and an Australian in SCM11.

6. Soviet scientists indicated that moorings could be augmented in several locations (ACM8, SCM1 and SCM7) but could not occupy stations for more than 2-3 months at a time, due to logistics considerations.

4.3.3. Statements regarding the Float Programme

Institutions from Japan, the US and France indicated firm intentions to commit to the Float Programme. There is indication that the institutions of FRG hope to develop a capability starting with experiments at the Mediterranean outflow and then later moving to the South Atlantic.

Experiments are being currently conducted in Japan with short-ranging 600 km equipment but there is hope that RAFOS floats will be available during WOCE. Between 20-40 floats is a possibility; they will be deployed in the western Pacific as part of the PFG or PF1. With adequate sound sources in the area, consideration would be given to deploying them in the Antarctic.

The US expects to deploy 1100 floats in the global programme. They also expect to provide 400 acoustically tracked floats for the Surface Layer, Deliberate Tracer Release and Deep Basin Experiments. They hope to provide some additional floats for enhanced resolution in the tropics as well, particularly in the Atlantic.

There are two French projects under consideration. The higher priority one will address the Core Project 1 South Atlantic gyre (extending to 10 N and including AF3) with 100 floats primarily at one level (1000 metres). The second priority will address the Antarctic Circumpolar Current and SF1 with a three-year experiment using 90 floats also at the 1000 metre depth.

4.4 The Surface Layer Programme

The Surface Layer Working Group, chaired by Dr. R. Pollard, reviewed the possible availability of resources as identified in the attached list (Appendix VI), and made the following observations and recommendations.

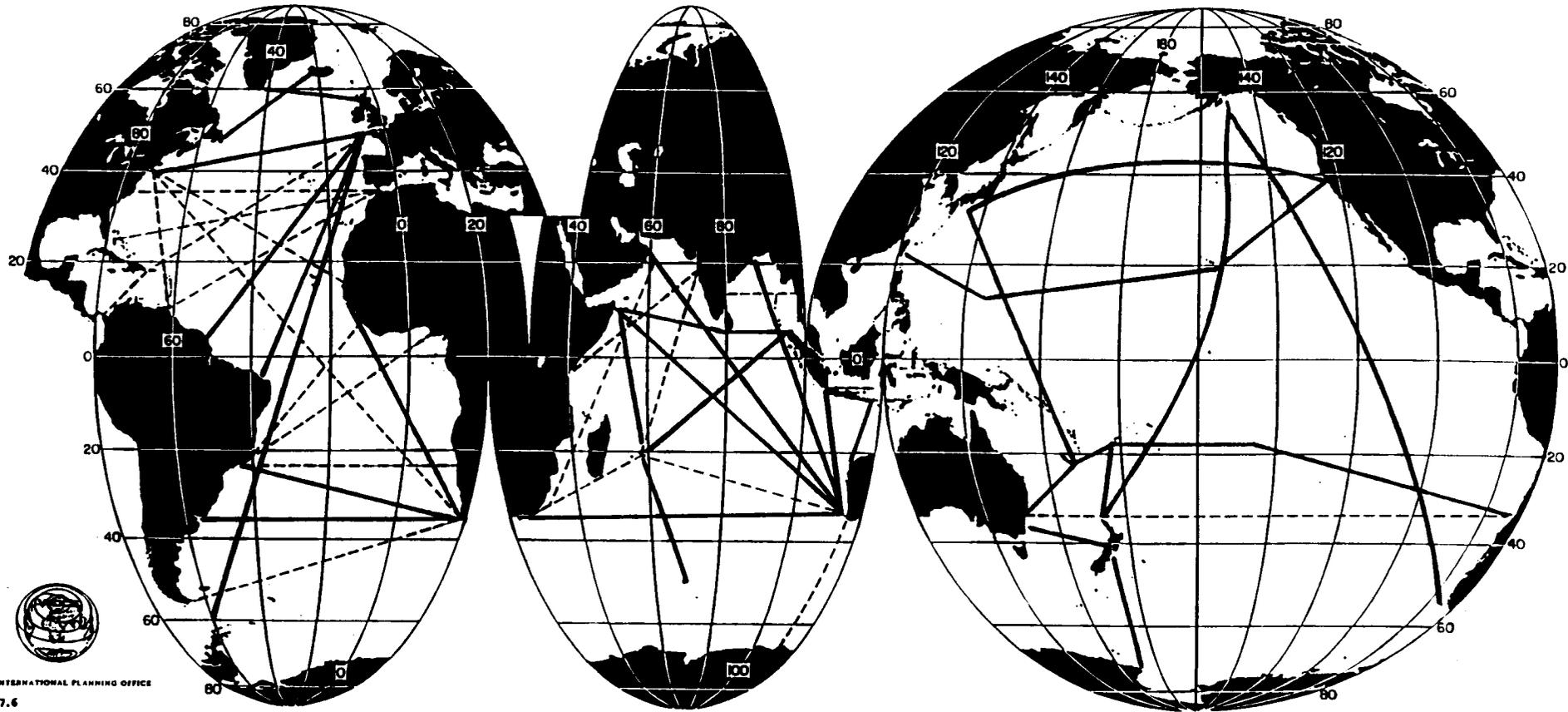


Figure 3. WOCE XBT/XCTD Special Requirements

- Tentative commitment and/or provided via TOGA/IGOSS
- - - - - No known commitment (as of February 1989)

4.4.1. The VOS programme

- (a) In the Atlantic (see Figure 3), firm commitments have not yet been made for a large number of XBT lines, but the US-NOAA stated that they expected to greatly expand VOS activity.
- (b) In the Indian Ocean where WOCE and TOGA requirements are nearly identical, it was recognized that progress is being made towards implementing about half of the TOGA lines, but that WOCE support would be necessary to fully implement the network.
- (c) It was agreed that ADCPs should still be regarded as research instruments requiring skilled operation.
- (d) It was agreed that salinity is a useful parameter in view of the difficulty of making precipitation and evaporation measurements over the ocean. However, use of the current XCTDs may not be practicable in the VOS programme, because of the requirement for use at speeds less than 10 knots. One suggestion was that salinity samples could be drawn from water intakes for analysis ashore.
- (e) All VOS and research ship operators should be encouraged to improve the quality of surface meteorological observations and the frequency of reporting. Where possible, automatic meteorological loggers should be installed.

4.4.2. The drifter Programme

After reviewing the technical feasibility of surface drifters and potential improvements, the Working Group concluded that the proposed strategy for WOCE was appropriate. In assessing the resources needed for this programme component and the present level of commitment, the Group also noted that there are existing and planned drifter programmes outside WOCE, i.e. TOGA, which need to be accounted for. It also stressed the need for a uniform approach in design, deployment and data processing to achieve the best possible results of uniform quality with the widest possible participation of all parties interested in the programme.

It was further stated that the present low level of commitment (50%) was misleading as further commitments depend on imminent technical developments and subsequent pricing levels. When in the near future major new commitments should be made, the Group felt that the present short-falls would be such that they could be covered in the run-up to the Intensive Observation Period.

The technical feasibility of attaching surface pressure sensors to current drifters was discussed. General consensus within the Working Group was that atmospheric pressure measurements would be of considerable value to WOCE, particularly in data sparse (non-tropical, especially in the Southern Hemisphere) regions and a programme should be initiated to design, test, and deploy such drifters.

It was felt that fully tested, operational pressure enhancements could be available within two years, that a new generation of small current measuring drogued buoys with pressure sensors could be available that would be cheaper than present meteorological pressure buoys by about a factor of two, and that their use by meteorological agencies should therefore be attractive and of great mutual benefit to both meteorologists and oceanographers.

4.4.3. Satellite measurements

The Surface Layer Working Group strongly endorsed the Satellite Working Group's recommendation for a successor to ERS-1 to ensure that there is no temporal gap in satellite coverage between ERS-1 and polar platforms.

4.5 Satellite Systems

4.5.1. Introduction

A large fraction of the world's oceanographic resources will be committed during the decade of the nineties to the WOCE programme. This commitment is forthcoming on the understanding that ocean satellites will provide important data on the sea surface topography and the coupling between the ocean and the atmosphere essential for the understanding of the dynamics of the ocean circulation and the role of the oceans in climate.

The role of the oceans has been highlighted as a problem of highest priority in the WCRP, and WOCE represents indeed by far the largest and most ambitious programme within the WCRP. The climate question as a whole is generally recognized as one of the most urgent and fundamental problems facing mankind today. However, the scientific community can address this global problem effectively, and develop the necessary extensive large-scale international programmes, only if it is supported by a serious commitment by space agencies to ensure continuous, global data of the ocean surface which can be provided only by satellites. The following recommendations of the Satellite Systems Working Group, chaired by Dr.P. Woodworth, were endorsed by the Conference.

4.5.2. Recommendations for WOCE Goal 1

1. That, in view of the importance of ERS-1 to WOCE, a letter be sent to the Director General of the European Space Agency (ESA) stressing the importance of ERS-2 as a back-up in the event that ERS-1 is launched unsuccessfully or that its altimeter, and particularly its scatterometer, systems fail early in the mission. A back-up ERS-2 should be available for launch as soon as possible consistent with a 3 year overlap of its operations with WOCE. (It should be noted that TOPEX/POSEIDON will have no possibility of back-up.)
2. That, in the event of ERS-1 operating successfully, and as the construction of an ERS-2 is necessary as an ERS-1 back-up, ERS-2 should be launched subsequent to it in order to continue the altimetric and scatterometric time series in view of the importance to WOCE of gathering a long-term database of winds and sea levels from space. ERS-2 would fill the projected multi-year gap between ERS-1 and the launch of the first polar platform. The failure to establish a continuity between ERS-1 and the polar platform would represent a serious set-back to WOCE and the WCRP and impair the credibility of ESA's long-term Earth Observation Programme. Similarly, the possibility of the NASA NSCAT scatterometer being operated on the Japanese ADEOS satellite in the mid-1990s is strongly endorsed.
3. That ESA be made aware of the importance to WOCE of a suitable orbs for ERS-1 and its back-up. (A letter has previously been sent by Professor Carl Wunsch on behalf of the WOCE SSG requesting a 17-day repeat for the majority of the ERS-1 mission and with one cycle of 350-day repeat.)
4. That WOCE requires a dedicated gravity mission before or during the mid-1990s. It was noted that ESA plans a mission (Aristoteles) with this objective.
5. That ESA be requested to provide ERS-1 Geophysical Data Records (GDRs) freely or at cost to all WOCE researchers, as will be the case by NASA and CNES for data from TOPEX/POSEIDON.
6. That the WOCE SSG and Data Management Committee consider the inevitable necessity of, and the difficulties associated with, the reprocessing of satellite data.
7. That, in view of the importance of drifters, pop-ups, submersible robots, etc. in WOCE and future projects, satellite data acquisition systems such as those which follow-on from Argos should be technically matched to the requirements of the *in-situ* devices, and *vice-versa*.

8. (a) That the WOCE Sea Level Measurement Planning Committee review the provision of tide gauge data for altimeter orbit calibration (as per 'Sets A and B' of the Implementation Plan) and tidal constants (for altimetric tide model constraints) from the viewpoint of WOCE.
- (b) That all the countries, large and small, be encouraged to install tide gauges, in particular those on open ocean islands, that would be of use to altimetry during WOCE.
- (c) That, if locally possible, tide gauge bench-marks be geocentrically located regularly by modern geodetic methods (GPS etc.). Ideally, regular absolute gravity measurements should also be made near to the tide gauge sites. These data, together with altimetry, should allow the long-term fixing of the ocean surface within the same reference frame (International Ellipsoid Reference System).

4.5.3 Satellites and WOCE Goal 2

The Group was in agreement that the necessity now is for a firm commitment to altimetry, scatterometry and other forms of remote sensing (e.g. sea surface temperature measurements, sea-ice monitoring, water vapour content, even rainfall measurement if possible) into the next century. The long lead time required for satellite systems imposes difficulties in optimum technical choices. However, if necessary, commitments should be made to future missions based on established technology in order to ensure continuity of measurements. The Group welcomed the possibility of there being different future polar platforms for different purposes, as presented by ESA at this conference (see Appendix V), rather than the all-purpose platforms proposed previously.

4.6 **Data Management**

The Working Group, led by Dr.E. Lindstrom, discussed two main items:

1. Evaluation of Contributions to WOCE
2. General considerations of the WOCE Data Management Plan

4.6.1. Contributions

1. Data Assembly Centres

a. WHP - Information was provided concerning an offer from some US institutions to perform quality control functions of a DAC including a chief scientist but an implied data distribution function performed by the FRG National Data Centre needs to be explicitly identified. Clarification is also required of who will perform which WHP/DAC functions.

b. Surface Drifters - A US Global Drifter Centre will perform many of the functions of a DAC but data distribution to the general WOCE community will be performed by the MEDS of Canada. It should be noted that a US TOGA Centre will also be generating weekly analyses and that MEDS acts on behalf of the WDC system as an international data source.

c. Subsurface Floats - Because of the small number of investigators there may not be a need for a formal DAC, but there is a need for a data management statement so that other WOCE PIs can know how, where, and when to obtain data.

d. Subsurface Thermal Data - The picture seems confused as to whether there will be 1, 2, 3 or more centres. There needs to be a clarification on whether there will be a centralized distribution points as for TOGA or whether a more distributed system is envisaged. France has tentatively offered to expand as TOGA Subsurface Thermal Data Centre for TOGA to include WOCE. It is recommended that the principals involved be brought together to decide on data flow.

e. Current Meters - The working group considers a CM/DAC is needed, but functions could be distributed, and the WOCE DM Committee should seek concrete contributions to such a centre.

f. Sea Level - Although the present structure at the TOGA Sea Level Centre and MIAS will need some adjustment to meet WOCE objectives, the basic structure of a DAC is in place. The system is already part of internationally recognized systems.

g. Satellite Data - WOCE can only keep informed of existing satellite plans, but WOCE scientists will need easy access to their data sets. The Implementation Plan must describe how these data can be accessed by WOCE scientists. The Working Group recognized that satellite data products are generated by agencies outside the WOCE data management system but noted that analysis products from these data are essential to WOCE goals and should be recognized in the Data Management System.

2. The Data Information Unit (DIU)

The group noted the US statement that it would only continue its support for a prototype DIU (now called a Data Management Unit by the US) for approximately two more years. The need and support for a long-term international DIU will be considered by science groups and national committees. If this is not done, then the SSG should seek other solutions for the functions performed by the DIU.

4.6.2. General considerations

The Working Group recognized the need to describe the availability of community numerical model output to WOCE scientists.

The Working Group recognized the tremendous importance of the data-sharing policy as described in the Implementation Plan and recommended the endorsement of this policy by the Conference.

The Working Group recognized the continuing input of scientific and intergovernmental organizations to WOCE data management and encouraged continuing cooperation.

While considering that several refinements are necessary to the WOCE Data Management Plan, the Working Group endorsed the concepts for WOCE Data Management outline in the Implementation Plan.

WOCE Data Management Facilities

<u>Facility</u>	<u>Operator</u>
<i>Data Assembly Centres</i>	
WHP	USA, WHP/PO and FRG/DOD
Upper Ocean Thermal	France
Surface Drifters	Canada, MEDS
Subsurface Floats	TBD
Moored Current Meters	USA
Sea Level - Rapid Delivery	USA, Univ. of Hawaii
Sea Level - Comprehensive	UK, MIAS/PSMSL
ADCP	TED
<i>Data Information Unit</i>	USA, Univ. of Delaware (Thnu 1990 only)
<i>Special Analysis Centres</i>	
WHP	FRG-DOD, MPI and IFMH

5. ASSESSMENT OF RESOURCES FOR THE CORE PROJECTS

5.1 Introduction

Upon completion of the reviews of each observational component, the session again divided, this time along Core Project lines to analyze the suitability of resources in meeting the objectives of the Core Projects. The findings and conclusions of these Working Groups follow.

5.2 Core Project 1: "The Global Description"

The Core Project 1 Working Groups of the Conference were chaired by Dr.M. Fieux (Indian Ocean), Dr. B. Taft (Pacific Ocean) and Dr.A. Colin de Verdiere (Atlantic Ocean).

5.2.1 Core Project 1 - Atlantic Ocean

The following three items of the Core Project 1 were discussed:

- Hydrographic programme: the one time survey misses contributions for sections A3 and A4 at 32°N and 36°N. The repeat survey lacks coverage for section AR2 at 30°S and array AR9 at 30°S on the eastern side of the South Atlantic.
- Current meter moorings: the proposed locations were fairly well subscribed with the exception of moorings for exploration of eddy statistics in the South Atlantic and control volumes in the North Atlantic (AR10-AR11).
- The float programme consists of contributions from the US and France which should achieve the coverage needed in Core Project 1 at the 500 km resolution to provide a reference level for hydrography.

A number of additions to the present plan were proposed:

- one additional section A0 between Scotland-Iceland-Greenland has been called for to measure transports over the various ridges.

The large variability requires that such a section be repeated - USSR and Scandinavian countries support the addition.

- Repeat hydrography and synoptic mooring work were proposed by the USSR in the Newfoundland Basin and in the tropics.
- Senegal expressed great interest in WOCE and proposed a hydrographic array in the area 12°30'- 16°30' from the African coast to 19°W.
- Congo as well has shown great interest in WOCE and proposes that work be carried out in the Gulf of Guinea. A discussion was launched to question the interest of a section along the equator, the conclusion being that such a section, if adopted, should be repeated in view of the large variability.

5.2.2 Core Project 1 - Pacific Ocean

This group examined the indicated commitments against the stated requirements of the plan. In the process, some adjustment became apparent that could fill a few gaps. These are offered as suggestions for consideration by the standing Core Project 1 Working Group.

One-time hydrography

The group concluded that there was a lack of tracer work planned in the North Pacific. In the US, NOAA scientists plan to begin their tracer programme in the Pacific in 1990 and complete it in three years. There is a possibility that some US equipment can be put on non-US vessels so that scientists from other nations can complete other Pacific lines. But it is the current US intention to complete one ocean and then move on.

The lack of suitable vessels at the right time and place, and the lack of adequate equipment needed for the large volume sampling (LVS) are the principle reasons why scientists have not indicated commitments as well as one might hope. Australian, New Zealand, and Chinese scientists have indicated a desire to participate but they lack a full capability. Japan has a LVS capability and can do 14C, but some of the lines it has committed to may be operated with JMA ships that cannot manage the large samplers. New Zealand can do tritium but not freon. Australia can do neither tritium nor freon. Neither can handle LVSs.

Canadian scientists which have a LVS capability offered to consider undertaking the eastern part of line P1 and the northern part of line P16 which had gone unclaimed.

There are evidently lots of suitable platforms which could, if properly manned and equipped, go a long way to filling the identified gaps. There is a plan to have a US-WHP team and equipment made available for at least one 45-day cruise per year on a non-US vessel for this purpose.

USSR scientists have offered to undertake lines in the Sea of Okhotsk and share the data but it remains to be established to what degree the full WHP requirements can be met there.

The group suggested that line P23 appears to be redundant and could be deleted. The fact that P3 was not subscribed to suggested it made sense to move the position of P2.

Australian scientists acknowledge there are strong historical reasons for keeping P6 and P7 and suggested that the positions of P20 and P21 and P13 be relocated to measure the N-S bifurcation of flow in the Tasman and Coral Seas area. A revised sampling programme will be submitted to the Core Project 1 Working Group.

Line S4 has no overall subscriber but US scientists clarified their offer to undertake any one-third of the line, FRG investigators will do the Atlantic part and the French may undertake the Indian Ocean segment. The potential for an Australian ship as a platform in the Pacific or Indian sectors of S4 was mentioned.

Repeat Hydrography

Peru has indicated support for a 500 mile repeat (quarterly) hydrographic section off the coast of Peru. Except for lines PR7 to PR10, for which US scientists are considering a VOS solution, the repeat hydrography program is in good shape with respect to platforms. There is a caveat however: an assessment must be made regarding frequency of repeat sampling.

Hydrographic Time Series Stations

The group noted that according to presently available information, PRS5 to PRS8 were not going to be covered. The criticality of this shortfall could not be assessed by the group. It was pointed out that there is a CALCOFI station north of PRS3 that might serve as its surrogate for PRS3. It was also revealed by Niiler that there will be repeat hydrography (4/year) done at the eastward end of P2. The possibility also needs to be investigated that USSR scientists could do PRS7.

Current Meter Moorings

The Core Project 1 Working Group needs to reconsider the moorings in light of information developed at the Conference. The rationale for location of PCM1 was questioned by Chinese and Japanese scientists who intend to deploy this array.

Canadian scientists are planning to study velocity and temperature modal structures with an array south of Ocean Weather Station P. It was suggested this array can be considered as PCM 16 for Core Project 1.

Australians are considering a 2-year array off the North coast of Papua New Guinea to monitor the sub-surface boundary current (New Guinea Coastal Undercurrent). This array might be considered as PCM15.

Chilean scientists offered to provide logistics support for PCM4 and PCM14. Peru has offered logistical support for two current meter arrays at 10 S 85 W and 20 S 75 W off the west coast of South America.

Surface Velocity

Current indications are that the surface drifter requirements for the Pacific will be 80% subscribed. This is based on planned contributions from scientists from Canada, Taiwan, Japan, the US and Australia. There are discussions going on with individuals from China, Chile, and the USSR that may increase this coverage.

Ships of Opportunity

If the level of support materializes as expressed thus far, this program is in excellent shape. The 12 high resolution Pacific lines are all subscribed to. It is anticipated that the low resolution Transpac and TOGA XBT surveys will continue through the WOCE period.

Acoustic Doppler Current Profiler (ADCP)

The group agreed with previous conclusions that the ADCP is a developing technology with great potential. It has proven extremely useful for applications in measuring eddy energy. It is not clear, however, that it can be relied upon as a reliable measure of transport along a long section.

Floats

The group agreed with the conclusion of the Direct Current Measurements group that the combination of likely-to-be-available RAFOS and ALACE floats would be just sufficient for the global program. There may be a shortfall of floats in support of specific experiments which are still under review in the Pacific.

Surface Fluxes

The basin-wide TOGA ATLAS array on the equator was identified as a source of critical surface flux data. The South Pacific is not considered adequately sampled for surface fluxes and additional effort should be made to add voluntary observing ships in this region.

5.2.3 Core Project 1 - Indian Ocean

The Indian Ocean Working Group reviewed several basic components of Core 1, namely: the WHP, Special Survey Areas, the XBT Network, sea level and current meter moorings. Each of the components were found to be lacking in one form or another, but overall the initial contributions identified indicate that CP1 is viable in the Indian Ocean. Some specifics regarding each component follow.

WHP One Time Survey

Only two WHP sections in the Indian Ocean are in the category "no known operator", 17 (Northern part) and I5. France has proposed that they undertake section 16 near 40°E rather than 30°E. This and a proposal by Pakistan to extend 17 northward into the Arabian Sea should be addressed by the CP1 Working Group. The section 15 was completed by Toole and Warren in 1988 (without Large Volume Sampling) and is therefore suggested as a lower priority WHP Section.

Special Survey Areas

The Special Survey Areas are regions in which concentrated observational programmes are needed to define key processes, for example those associated with Pacific/Indo throughflow. These Special Surveys, ISS1, 2 and 3, are not explained in detail in the Implementation Plan, thus few commitments were forthcoming. Some planned activities, however, will contribute to these studies: the French float programme and South African hydrographic sections in ISS1, Australian drifters and "FRANKLIN" cruises in ISS3, and a programme as yet unspecified by the Federal Republic of Germany in ISS2.

XBT Network

The WOCE XBT requirements, in the Indian Ocean, are exactly the same as those of the TOGA Programme. Most lines, see Figure 3 and Appendix VI, have potential operators but the continual lack of probes hinders full implementation, in spite of the fact that TOGA has been in operation since 1985. The main contributors to the Indian Ocean XBT programme are Australia, France and the USA (probes). Mauritius in co-operation with Pakistan will undertake IX6, having recently been provided with probes. Japan has also indicated its interest in operating an Indian Ocean line.

Sea Level Network

The sea level network in the Indian Ocean has expanded steadily over the past five years, some sites with satellite reporting capabilities, as a result of TOGA initiatives. Several of these existing sites would be prime candidates for the WOCE comprehensive (18 month delivery) sea level data set, and possibly for the Set A (rapid delivery). The Sea Level Measurement Planning Committee should identify the sites appropriate for WOCE and seek the agreement of the operators to meet WOCE specifications.

Current Meter Moorings

Six of the twelve current meter mooring arrays in the Indian Ocean are tentatively spoken for, with a major gap in the network along the East African Coast - no deployments are planned for ICM1, ICM5, ICM7 or ICM9 (West). The mid-ocean and eastern moorings are fairly well accounted for and the situation could even be better were the three potential operators for ICM4 (US, FRG and France) to agree to shift some of their efforts to ICM6 and/or ICM9 (East).

5.3 Core Project 2: "The Southern Ocean"

5.3.1. Introduction

The Working Group, chaired by Professor W. de Ruijter, was of the opinion that the main themes and basic questions as formulated in the Implementation Plan form a sound basis to meet the WOCE goals for the Southern Ocean.

5.3.2 Recommendations:

1. More planning is required to determine whether the fluxes of heat and salt (rather than just total volume) could be determined at the three Choke Points.

2. While most of the WHP lines were subscribed to, there needs to be some further assessment as to whether the tracer measuring capability is adequate.
3. There needs to be some coordination to try and get the Choke Point sections and the "30°S" heat flux sections completed within one year (season).
4. With respect to the eddy energy moorings, there is a large mismatch between the requirements and the resources. It was suggested that single moorings (rather than arrays) would make better use of the resources. The Core Project 2 Working Group needs to reassess the locations and the priority of the eddy energy moorings. In this reassessment, the possibility of deploying the moorings on WHP and other cruises needs to be considered.
5. With respect to deep boundary current arrays, the Core Project 2 Working Group needs to reassess whether both SCM4, SCM5, and SCM6 and ICM3 are required in the southern Indian Ocean.
6. It was noted that there may be other means for determining the poleward eddy heat flux, for example using Batfish (or XBT) measurements and ADCP data.
7. There is a clear need for pressure sensors on a proportion of the Southern Ocean drifters.
8. There are quite a few non-WOCE oceanographic and sea ice activities going on. These need to be documented and some form of coordination between the WOCE and non-WOCE activities is recommended.
9. Pressure gauge measurements of sea level are being completed at a number of the Southern Ocean Islands but there are few measurements of sea level in Antarctica. Sea level measurements are required along the Choke Point sections.
10. It is recommended that the Core Project 2 Working Group reconvenes together with a number of the individuals who will carry out the observations.

5.4 Core Project 3: "The Gyre Dynamics Experiment"

The Working Group met under the chairmanship of Dr. W. J. Gould and assessed the level of resources identified by the observational working groups which would contribute to achieving the goals of Core Project 3, namely: "to study the processes that must be better understood if decadal climate predictions using models are to be made by the end of WOCE". The Implementation Plan provides a strategy to meet this objective that involves measurements in the Atlantic at scales from those of the basin to those of more traditional process studies.

The Group was encouraged that there was interest in carrying out a number of process studies. These include the Ekman Layer and Subduction Experiment as well as the Tracer Release Experiment to measure diffusivity. On the larger scale, the Deep Basin Experiment seems assured with the expressions of interest from several nations. However, a key element of Core Project 3 involves the use of repeated hydrographic surveys and a set of five "Control Volumes" in the North Atlantic to study the changes in gyre strength and shape over a 1 year period. Although interest was expressed by Canada and UK in occupying Control Volumes, not all were subscribed. In addition, the Implementation Plan calls for better temporal coverage in the Atlantic and it was noted that the shortfall of shiptime allocated to repeated hydrography as identified by the WHP Working Group was greatest in the Atlantic (400 days) or 50% of the total. This could possibly be alleviated by contributions from the USSR which expressed particular interest in Core Project 3. The Implementation Plan calls for enhanced basin-scale measurements by floats and surface drifters which were also not fully subscribed at the Conference.

The Group observed that these gaps in resources could mean that some of the larger-scale aspects of the Core Project 3 might not be achieved. These are essential for providing data for the development and testing of gyre-scale models.

The Group was unable to make a full assessment of resources in the time available but was concerned that there was a major shortfall (identified above) that would jeopardise the full achievement of Core Project 3 goals. It was therefore recommended that the IPO, in consultation with necessary experts, make a full assessment of commitments to Core Project 3 and if necessary that the SSG convene a meeting of the Core Project 3 Working Group and other experts to discuss the Core Project and devise means by which its objectives might be achieved.

6. ORGANIZATIONAL ARRANGEMENTS FOR WOCE

Mr G. Holland introduced the report of the working group on organizational arrangements by noting that while the organizational arrangements in relation to WOCE, unlike most other matters being discussed during the Conference, have no direct scientific significance, they are important to the implementation of the programme.

WOCE is a global experiment to address problems critically to every country on our planet. It requires international and intergovernmental co-operation and contributions of resources on a scale never before undertaken in oceanography. The management of such a programme is also critical dependent upon the involvement of the world's most knowledgeable scientists and the application of state-of-the-art technology. Therefore, the two crucial items to be addressed in the development of any organizational framework are the following:

1. The need for the planning and operation of the experiment to be managed at the highest level of scientific excellence available;
2. The need for an adequate communication and approval mechanism at an intergovernmental level.

The balance of these two concerns is fundamental to a universally endorsed infrastructure for WOCE.

Mr Holland proceeded to review the deliberations of the working group by recalling the sequence of events which had led to the preparation of the document submitted by the Chairmen of the Joint SCOR/IOC CCCO, the JSC/CCCO SSG for WOCE and the IOC TC/OPC. These individuals were requested by Resolution IOC EC-XXI.1 to submit a proposal for a suitable structure for the co-ordination and implementation of WOCE to the International WOCE Scientific Conference. Their proposal is given in Appendix VII.

The participants agreed that specific changes should not be made to the document itself, since it reflected the views of the Chairmen submitted in response to a particular request of the IOC EC, but that it would be appropriate for the report of the working group to the plenary session of the Conference to reflect all participants' views when presented. Although the Working Group did not recommend adoption of the document, it agreed to make use of it as a working paper in order to facilitate the discussion and as a point of departure for the expression of opinions.

The document had been introduced and reviewed by Dr. McEwan, Chairman of CCCO and Professor Wunsch, Chairman of the WOCE SSG who explained the rationale for the structure proposed, and provided more detailed descriptions of its various components. It was emphasized that an underlying principle in the development of the structure was that it should be as simple and efficient as possible and that it should make the fullest possible use of existing mechanisms. Therefore, the structure as given in the document differed from the existing one, in the addition of a single entity, the WOCE Resources Advisory Panel (WRAP).

Some participants in the working group were of the opinion that the sponsoring organizations the Joint SCOR/IOC CCCO and the JSC/CCCO SSG for WOCE should review the terms of reference and working relationships of all relevant subsidiary bodies to ensure that the responsibilities for WOCE were clear and unambiguous.

The participants had no comments regarding the basic objectives for the design of an organizational structure for WOCE. Certain organizational proposals put forward in the document, however, were the subject of extensive debate. Although the group expressed appreciation to the authors of the document for their efforts in reaching a consensus on a complex issue, not all participants were able to accept it.

Several serious concerns were expressed about various aspects of the document, in particular the responsibilities, functions and membership of the proposed WRAP. Following more detailed explanations of the rationale for the WRAP by both Dr. McEwan and Professor Wunsch, it became obvious that the wording on WRAP as drafted was unclear as to the existing structure and the expectations of the respective authors.

The Chairman of the WOCE SSG expressed his concern that the scientists involved in the planning of the experiment should retain their ability to influence the direction of the program and its implementation. He also acknowledged the legitimate interests of governments in the conduct of the experiment in relation to the allocation of national resources and other intergovernmental matters. The development of a structure which provided an appropriate balance for these two constituencies had been the central theme of the deliberations between the three Chairmen. The participants in the Working Group were in complete agreement with the necessity for such a balance.

Some participants were unconvinced that the document being considered achieved this balance. They expressed their opposition to the concept of WRAP as described therein, regardless of the explanations provided by Dr. McEwan and Prof Wunsch. They perceived the WRAP as a component with the potential for powerful influence over the development and implementation of WOCE, rather than as a strictly advisory body to the SSG as intended by the authors. The constitution of the membership of WRAP as proposed, in their view, was unacceptable in that it was not seen to satisfy the need for adequate governmental input. It was obvious from the discussion that the respective roles of the WRAP and the TC/OPC in relation to intergovernmental matters needed further clarification.

In addition to the issues related to WRAP, other points of clarification were sought. The working group agreed that any future proposals resulting from the discussions at this Conference and the consultations between the President of SCOR and the Chairman of IOC, called for in IOC Resolution EC-XXI.1 should be accompanied by more detailed explanations of all aspects of the existing and proposed organizational framework and the roles, responsibilities and membership of each component. This information will allow, in preparation for the 15th session of the IOC Assembly, for easier review and acceptance by the appropriate organizations.

In response to a query from the Chairman of the SSG, it was agreed that the lack of any final decision on these organizational matters should not impede the continued planning for WOCE. The existing structure has provided an adequate planning framework and would continue pending future decisions by the sponsoring organizations of WOCE.

In the discussion which followed the presentation of Mr Holland's report, the Chairman of the IOC TC/OPC requested that the staff of the WOCE International Project Office prepare a document for submission to the XV Session of the IOC Assembly which would provide a concise explanation of the philosophy of WOCE. This document should be made available to the Assembly in all of its official languages.

Another participant expressed his view that any future organizational structures proposed should not deviate substantially from the proposals put forward by the Chairmen of the CCCO, WOCE SSG and TC/OPC, which in his view were well conceived.

7. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS FROM THE CONFERENCE

7.1 Introduction

This session of the conference was led by Dr. J. Baker who thanked the Conference Chairman, Dr. Siedler, and all the participants for their contributions to the Conference. He noted that it is only through the contributions of individual scientists and organizations that programs like WOCE can be successful. Secondly, he thanked all those who helped in the preparation of this summary, particularly Dr. John Woods and the other members of the WOCE SSG.

Dr. Baker stated that although this session is the last of the conference, what is said during the Conference is far from the last word on WOCE. Rather, it is the beginning of the implementation of what could be the most exciting scientific program ever carried out in oceanography. WOCE will bring us closer to understanding the ocean on global scales - a dream of oceanographers for many decades. At the same time, if we as a community are successful we will be, as Professor Wunsch stated in his opening remarks, far closer to understanding the role of the ocean in climate.

From the beginning of the WCRP, there has been a general recognition that understanding the ocean and its interaction with the atmosphere is key to understanding climate change. The TOGA programme has focused on interannual climate variability. At the same time, there has been a recognition that the global ocean is a fundamental element of climate change on time scales from interannual to decadal and longer. To understand how the global ocean interacts with the atmosphere, we must first look to describing and understanding the general circulation of the ocean. This is the goal of WOCE. Thus TOGA and WOCE together form the essential ocean components of the WCRP.

One of the most likely effects of climate change in the coming decades is a rise of sea level, which will have a direct social and economic impact on the large populations living near the sea. Thus coastal states will be the first beneficiaries of improved predictions of the rate of global climate change. Such predictions can only come through a successful WOCE.

Other programmes related to climate and global environmental change will interact closely with WOCE. WOCE will look to TOGA for certain key measurements in the tropical regions. The Joint Global Ocean Flux Study (JGOFS) which will focus on study of biogeochemical cycles and their impact on global change will look to WOCE for the basic understanding of the general circulation. JGOFS will carry out a global program of oceanic CO₂ measurement together as part of the WOCE Hydrographic Programme. As we look to the future, it is clear that the developing International Geosphere-Biosphere Program must build on the understanding of the global ocean that will be provided by WOCE. As a consequence of all of this, we can see that a successful WOCE will address critical societal problems.

The central issue that we have discussed is the question of whether there are adequate resources for carrying out WOCE as defined by the WOCE Scientific Plan and the WOCE Implementation Plan. And we have found that for most parts of the plan the answer is yes, and in some parts the proposed resources actually exceed expectation. From its earliest conception, WOCE planning depended upon the availability of resources to mount a truly global experiment. Thus this positive result is good news. At the same time we note caution in that much effort will be required to make sure that these potential resources actually are made available.

In the course of discussing the major question of national contributions and resources, the Conference program has ranged over a wide variety of subjects, from the importance of the role of the ocean in climate to the details of implementation and organizational arrangements. There has been a sense of urgency for moving ahead. There has been positive and general support for the scientific elements of the plan, and national planning shows that the necessary resources are mostly in place. Organizational arrangements have been discussed. As in all such Conferences, there has

not been unanimous agreement on all points, but all parties have had an opportunity to raise issues of concern. Now we are ready to proceed.

7.2 Summary of Conclusions of the Conference

The Conference reached a consensus on a number of conclusions and recommendations. The Conference also noted a number of specific issues that must be addressed by the WOCE SSG, its parent bodies, and its affiliated bodies as appropriate. These issues were discussed at length in the Working Group meetings, and are presented in Section 5. This section is meant to summarize, but not replace, Section 5 and provide the consensus viewpoint of the conference as a whole. First we list the general findings.

The Conference finds that WOCE science is exciting, of global scale, and of global interest. It is relevant and urgent. Until the objectives of WOCE are achieved it will be impossible to make reliable predictions of climate.

The Conference agrees that the WOCE Scientific Plan defines the science goals and objectives for a focused global program that addresses the major WOCE science issues. The plan has been developed by oceanographers representing the broad international community.

The Conference agrees that the WOCE Implementation Plan is a well-considered and practical approach to the achievement of WOCE goals. The Implementation Plan provides a context and framework for the optimum development of WOCE. The plan will evolve in a way consistent with the available resources. The data set specified in the Implementation Plan is both necessary and sufficient for achievement of the WOCE objectives.

The Conference notes that there is room in the plan for contributions of all kinds from all countries at all technical levels. Thus there is a role for all interested countries who can participate. The Conference notes and is encouraged by the fact that access to WOCE data has been considered carefully in the Implementation Plan, and that all WOCE participants are to have access to WOCE data as provided by the data sharing policy in the Plan. The Conference expressed concern that practical ways for achieving this goal be studied.

The statements by Conference participants have shown that the presently committed and potentially available resources in national plans are sufficient to justify the start of the field phase of WOCE in 1990. The Conference was pleased to see that the proposals made for the WOCE Hydrographic Programme and the direct current measurements are sufficient to meet the global coverage goals of Core Project 1 and Core Project 2. The Conference was also pleased to see proposed additions to the Implementation Plan in the polar and equatorial regions. There appears to be a good match between global coverage needs and the ability of nations to provide the necessary resources. This new data set will be a major milestone in the progress of oceanography. Because of the need for a consistent data set, the Conference urges all participants to adhere to the WOCE standards and to measure the necessary set of parameters.

The Conference was also pleased to see that the potential is good for global coverage of surface layer measurements, including XBTs and surface drifters. The satellite coverage of global surface winds and surface topography for geostrophic currents is now in place with the on-schedule development of ERS-1 and TOPEX/POSEIDON. The global sea level program appears to be well on track.

But the Conference notes that loss of any of the major contributions could lead to critical gaps in the WOCE data set. Continued strong national efforts are necessary to ensure adequate implementation and a balanced program.

The Conference notes that critical gaps still exist in the areas of commitment to satellite wind measurements after ERS-1, improved meteorological measurements for estimates of air-sea fluxes, repeat hydrography in certain areas for Core Project 1, control volume measurements and repeat

hydrography for Core Project 3 in the Atlantic, a continuing data information unit, current meter or other techniques for eddy statistics in the Southern Ocean, and global geoid measurements by satellite for determining geostrophic velocity from altimetry.

If these gaps are not filled, then the SSG, the IPO, and the national planning groups will have to look again at the Implementation Plan and, if necessary, make a reduction in the objectives of certain elements and scope of the experiment.

The Conference emphasizes that satellite-borne instrumentation is a key element of WOCE. This instrumentation requires special attention because of the long lead times involved. Of particular concern is the need for continuity and back-up of existing satellites throughout the intensive field phase (1990 - 1996) of precision altimetry for ocean current measurements and the scatterometer for surface wind measurements and adequate overlap of the various missions.

The first need is for a follow-on to ERS-1 that could also serve as a back-up for that satellite. A second need here is to ensure the flight of the U.S. NASA scatterometer during the WOCE observing period. It has been proposed that the scatterometer be flown on the proposed Japanese Advanced Earth Observation Satellite (ADEOS). The Conference notes the fundamental importance of the flight of the NASA scatterometer and urges the SSG and its parent bodies to make a strong case for WOCE needs to the countries involved.

The Conference also emphasizes that a major goal of WOCE is to formulate a strategy for long-term ocean observations. Without these observations, much of ocean variability indicative of climate change cannot be documented. Immediate action items include decisions on satellite remote sensing instruments for the late 1990s and the support of new technology development for automated in situ systems. Coordination with the IOC TC/OPC and WMO is essential to ensure that WOCE developments are taken into account in planning for operational IOC programs. It is essential that the membership of the relevant groups, including the TC/OPC, evolve in order to ensure proper representation of WOCE scientific planning and relevant operational ocean observation programs.

The Conference notes that in order for WOCE to succeed it must have a clearly developed organizational plan. A draft plan for organizational arrangements for WOCE has been proposed by the chairmen of the SSG, the CCCO, and the IOC TC/OPC. The Conference thanks the Chairmen of these groups for their hard work in coming to this statement, but at the same time noted certain points that need clarification, and raised issues of representation that need further discussion. The President of SCOR and the Chairman of IOC are asked to take the points that are raised in the report of the Working Group on Organization into account in the further development of the organizational plans. The Conference notes that it is essential for WOCE to proceed, and that lack of a final decision here should not impede further development of WOCE. It is clear that success in the organizational arrangements will require hard work and good will among all the governmental and non-governmental parties involved.

7.3 Recommendations and Next Steps

Some recommendations or consensus viewpoints of the Conference were accepted which summarized the general views of participants as well as what has already been done and spelled out in more detail in statements from the Working Groups. The points that were made, in particular the identification of critical gaps in the WOCE program, will next have to be considered by the WOCE SSG and its parent bodies.

In order to proceed with WOCE, the Conference has found that a number of actions are necessary. These recommendations are made to the WOCE SSG and its parent bodies:

1. The Conference recommends to the WOCE SSG and its parent bodies that the SSG should now proceed, with the assistance of the WOCE IPO, to develop the WOCE program for a start of the field program in 1990.

2. The Conference recommends to the WOCE SSG that the WOCE IPO prepare a detailed assessment of resources from the conference proceedings and other information from those not present.
3. The Conference recommends to the WOCE SSG that the Core Project Working Groups continue to advise the SSG, and that they should meet soon in order to assess resources available in the context of the Implementation Plan, and to consider what, if any, adjustments of the plans are required.
4. The Conference recommends to the SSG and its parent bodies that they use all appropriate means to find resources to fill critical gaps.
5. The Conference recommends that the SSG use all appropriate means including its parent bodies to urge all nations to make special efforts to maximize their contribution to WOCE. As part of this effort, the successful WOCE workshops exemplified by the ones in Argentina, Brazil and China should continue.
6. The Conference recommends that the SSG request each nation with an interest in WOCE to identify a representative or national committee that will focus national interest.
7. The Conference recommends that the SSG urge all appropriate organizations to make every effort to quality control all of their routine oceanographic temperature and salinity observations and routine surface meteorological data. Special efforts should be made to see that this data is exchanged as quickly as possible through existing data exchange mechanisms.
8. The Conference recommends that the SSG give special attention to completing the data plan, and that access to WOCE data be assured to all participants in the WOCE program. The Data Information Unit is an important element of the data plan, and resources need to be found to continue it. The Conference recommends that vigorous efforts be made to extract products of use to WOCE from the existing historical data base of relevance and that this data be made available to WOCE participants as provided by the data sharing policy in the Implementation Plan.
9. The Conference notes the fundamental importance of the follow-on satellite to ERS-1 which will also serve as a back-up for that satellite and the flight of the NASA scatterometer on the Japanese ADEOS satellite. It urges the SSG and its parent bodies to use the WOCE goals and needs to make a strong case for these satellite programs to the countries involved.
10. The Conference recommends that the SSG and its parent bodies make known to coastal states, who will be the principal beneficiaries of the information and understanding to be gained by WOCE, the importance of facilitating access to their territorial seas by foreign ships involved in the WOCE program.
11. The Conference recommends to the SSG that it continue to ensure that its membership and that of its subgroups includes both strong scientific representation and national planning and implementation.
12. The Conference recommends that the SSG publish an annual assessment of achievements, plans, and gaps remaining, and that this be distributed to its parent bodies and other interested parties.
13. The Conference also recommends that the SSG publish a descriptive brochure on WOCE that describes for the general public the background, plans, and importance of the experiment for understanding and predicting climate change.
14. The Conference recommends that the organizational plan as presented by the chairmen of the SSG, CCCO, and TC/OPC be further developed as appropriate to take into account the

discussion at the Conference and that the modified plan then be submitted to the parent bodies for approval.

7.4 Some Final Points

WOCE planning has involved the efforts of many of the best oceanographers around the world for several years. Much scientific effort has been expended by the SSG, the IPO, and national committees and groups. Now the most interesting part begins with the actual measurements and modelling. But the experiment can be carried out only if resources are forthcoming.

The contributions to the Conference have shown that world resources in oceanography are indeed at least potentially equal to the task of doing a global experiment like WOCE. But as resources are made available, a match must be made between national interests and potential contributions and the context of the WOCE Scientific Plan and the WOCE Implementation Plan.

Each of the opening speakers emphasized the importance and intense interest of the public and governments in climate change and man's influence on the environment. Now it is up to us to show that all nations can be well served by support of WOCE as a fundamental contribution to understanding and predicting the effects of climate change. The proposed popular brochure on WOCE to be prepared by the SSG will help national organizations explain that to understand climate, we need to understand the ocean. This is especially important as we look in the future to programs of the International Geosphere-Biosphere Program which seeks to understand the climatic effects of biogeochemical cycles.

The proposed organization plan involves important and significant links with CCCO and the IOC TC/OPC. Whatever final arrangement is established, WOCE will need a strong interaction with the TC/OPC. The success of this interaction is important, not just to WOCE, but to the future of oceanography. Can these organizations respond in an efficient way to provide the help for implementation and to ensure that all nations can participate consistent with their interest and in the context of a scientific plan? The answer will be very important to the future of global oceanography. Are all countries being provided with what they need to participate in WOCE?

As one of the prerequisites for climate prediction, WOCE has much to offer all countries, and in turn WOCE will benefit from the participation of all countries. The aim is to encourage and build strong national programs in the context of an agreed scientific formulation. Such strong national component programs are essential if WOCE is to succeed and achieve the planned benefits to the global community. Dr. Baker finished his presentation with a point made earlier. There is room in the WOCE Implementation plan for contributions of all kinds from all countries at all technical levels. Thus there is a role for all interested countries who can participate.

WOCE is difficult, but WOCE is technically and financially feasible. The Conference looked forward to maximum contributions to this exciting new program.

8. CLOSING

The chairman of the Conference thanked the participants on behalf of the sponsoring organizations for their contributions and help during the Conference. He felt that the Conference had achieved the principal results that were hoped for. WOCE planning had been accelerated in many national organizations in view of the conference, presentations at the Conference had shown that sufficient resources for the experiment can very probably be found, and a broader involvement of oceanographic communities in a large number of countries was achieved. He expressed his thanks to UNESCO and all the parties involved in resolving the problems that had existed during the Conference with respect to the participation of all bonafide scientists in the Conference. Although much remains to be done in the future planning of WOCE, he expressed the hope that the Conference would be remembered as an important and necessary step in the development of the programme.

The chairman thanked UNESCO and its IOC for providing the facilities and technical assistance. He expressed appreciation for the hard work of the secretaries and scientists of the conference staff, and he expressed particular thanks to Mr. R. Godin, Secretary CCCO, and Dr.G. Needler, Director of the WOCE International Planning Office, for their major contributions to the preparations and conduct of the Conference. The Conference was closed at 11:00, 2 December 1988.