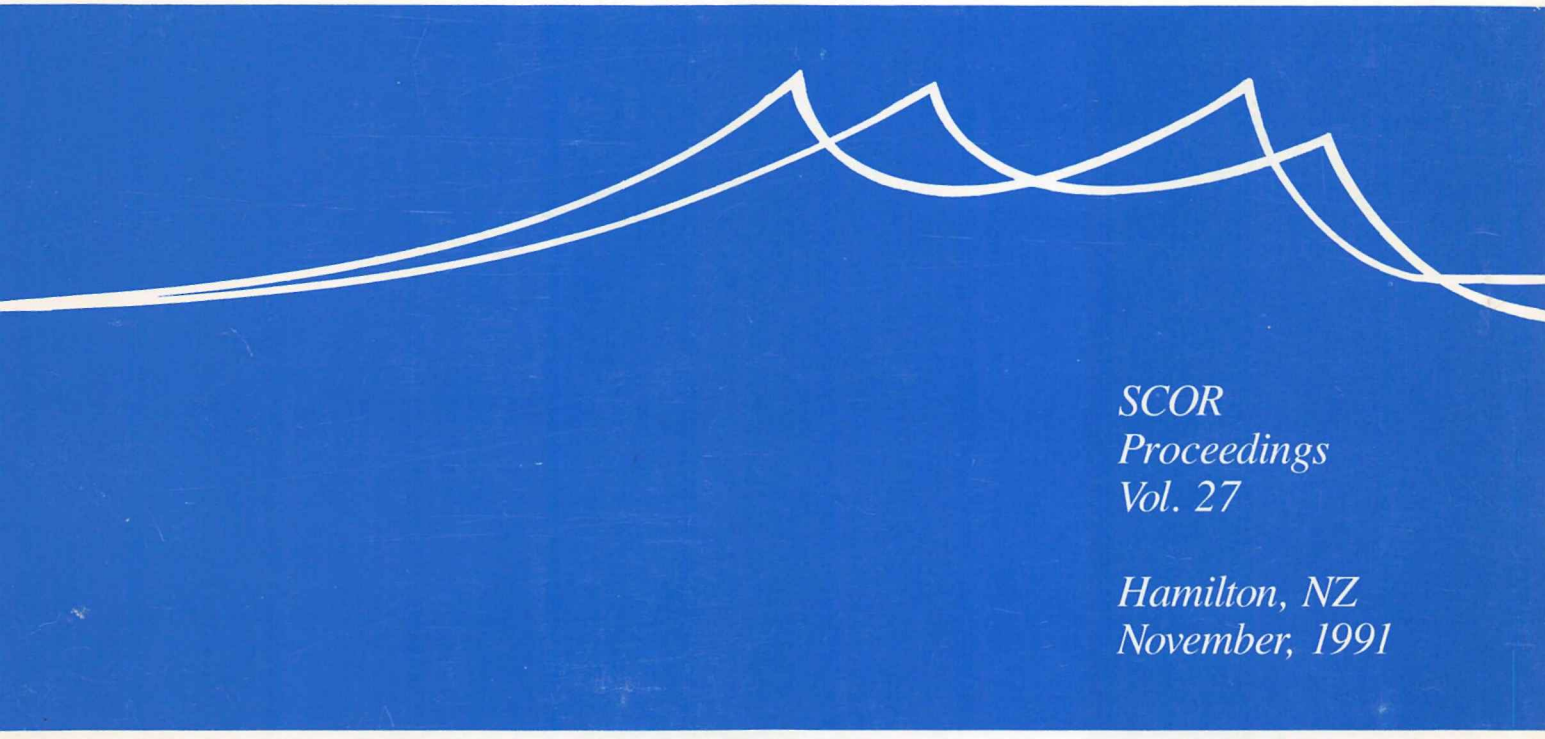
SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH



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INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

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SCOR Proceedings, Volume 27

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REPORT OF THE THIRTIETH EXECUTIVE COMMITTEE MEETING OF SCOR

University of Waikato
Hamilton
New Zealand

November 11 to 13, 1991

1.0 OPENING

1.1 Opening Remarks

The Thirtieth Executive Committee meeting of SCOR took place at the University of Waikato in Hamilton, New Zealand from November 11 to 13, 1991. The President of SCOR, Professor J-O. Stromberg, chaired the meeting. A list of participants is given in Annex I and a list of the acronyms and abbreviations used in this report appears in Annex X.

The meeting was formally opened by the Vice-Chancellor of the University, Professor W. Malcolm, who greeted the participants with a traditional Maori welcome. He noted that Waikato University has doubled in size in recent years and has widely developed national and international links in the marine sciences. Ocean science has been highly rated in a recent government review and identified as a priority for New Zealand science and government policy for the next decade. The text of his remarks is given in Annex II.

The mayor of Hamilton, Ms. M. Evans, also welcomed the participants to her city and to New Zealand for which, as an island nation, the oceans hold such great importance. She noted that Hamilton was the first community in New Zealand to have a formally established environmental policy, recognizing the importance of research and the need to reach beyond the community level for a global view of environmental problems.

The President of the Royal Society of New Zealand, Professor J. Dodd, also remarked upon the remote location of New Zealand and its island status which confers upon the nation a special responsibility to enhance international cooperation in the fields of marine science and marine resource studies. He described a current public review of government departments and a reorganization of DSIR into ten crown research institutes with public funds allocated in accordance with government priorities which, as yet, has not clarified the position of universities or of the Royal Society which is the New Zealand adhering body to ICSU.

The President of SCOR thanked these speakers for their warm welcome. It would be hard, he said, to find another nation for which the influence of the ocean is so profound.

1.2 Approval of the Agenda

The Agenda for the meeting was adopted as distributed with the addition of one item to 2.4, Proposals for New Working Groups, a late-arriving preliminary proposal from the Chairman of former WG 75 for a new working group on the problem of oceanic dumping of CO_2. This report follows the format of the agenda as approved.

1.3 Report of the President of SCOR

The President of SCOR briefly reviewed activities since the XX General Meeting (October 1990) and the major issues confronting this meeting.

Before going into the review of SCOR activities during this past year, I would like to touch upon some of the problems facing us during this meeting.

Since our last meeting, the XX General Meeting in Warnemünde, we have not had any changes in the membership of SCOR. This means we still have 37 member SCOR Committees from as many countries. Most of these are paying their yearly contribution to SCOR in good order, but a couple of them are slipping behind and will need further encouragement to meet their membership obligations. The question of raising the level of membership dues in each category has been brought up with a number of national SCOR committees and I am happy to report one positive response, namely Sweden whose Academy has decided to increase its level from category II to III starting as of January 1, 1992.

Membership dues are certainly important to SCOR as they constitute the only truly flexible sources of income to SCOR. Much of the income is in the form of grants and contracts for specific purposes, and SCOR had, by the end of 1990, too small a reserve for the support of activities in the early part of 1991 than was felt to be financially wise. Prospects for the end of 1991 look even less encouraging.

Thus there is a need to improve this situation and to increase funding if we wish to continue to take new initiatives. The reverse action, to hold back and decrease our ambitions is less appealing, but this will have to be the result if we see no change in the present level of income to SCOR. There are three ways to improve this. Each one of them is not exclusive; they can be combined:

- *to increase the number of member states,*
- *to encourage existing member states to raise their category of membership,*
- *to find ways to support specific activities above the level of present funding.*

A fourth way would be to raise all the membership dues, but this would add only a small amount to the available income. All these ways must be explored and I would like to urge the Executive Committee to take action on this. A first possibility is to ask one of you to consider how to best attract more members. I have already asked Dr. Su Jilan if he would be willing to

accept such a task as a co-opted member of the Executive Committee and he has agreed to this, but we would both like your guidance.

The second way would be to write to member countries and try to convince them of the need for increased support in the light of the accomplishments of SCOR. The third way is to ask the Executive Committee, and in particular the ad hoc Finance Committee, that is to be established, to propose new ways of funding specific SCOR activities. Your guidance in this will be invaluable.

If we are to be successful in finding additional funding, we need to consider our activities and the results of them carefully. We will have to recognize that there will always be financial limitations which will prevent us from pursuing all the good ideas that emerge. Thus we have to set priorities - and this is always tough to do when the number of challenging and exciting possibilities is large.

SCOR's strong side has always been - and still is - the activities of relatively short-lived Working Groups, but with the growing emphasis on the need for large-scale and long-term projects, not least in the context of global change, we have to be very careful in making our choices. This time we have to consider ten proposals for new Working Groups and the possible involvement of SCOR in a new large-scale programme.

To set priorities between them we will have to reflect on several criteria, among them the following:

- *how urgent is the project?*
- *does the project overlap with already ongoing activities?*
- *is there a real need for SCOR's involvement and what is the relevance of the project to a large number of nations - not only to a few?*
- *is the project ready to be taken on by SCOR?*
- *how well is SCOR covering the various marine scientific disciplines in order to keep a good balance in its activities?*
- *is the science of the project good and viable?*

Turning to the activities since the 20th General Meeting a year ago, I am happy to see that we have reports from all the 11 current Working Groups and that three of them are about to come to a successful end. It is also good to notice that all three of those we started in Warnemünde are well into their work. There is no need for me to comment more on them at this stage, since we are going to scrutinize their reports and achievements later during this meeting.

Regarding the SCOR/IOC Committee on Climate Changes and the Ocean (CCCO), we have a full report in our files which covers its activities and its chairman, Prof. J.J. O'Brien, will later give us an oral report. Therefore I restrict my comments to the relationship with the World Climate Research Programme (WCRP). During the fall of 1990 it was agreed between ICSU, SCOR, WMO and IOC that an executive group of 4 people from the CCCO would act jointly

with the Joint Scientific Committee (JSC) of the WCRP to increase the impact of ocean research in the discussions and recommendations of the JSC. Later it was proposed that IOC would become a full sponsor of the WCRP involving financial and staff contributions from the IOC, the feasibility of which, as yet, we have no information about. It will, however, influence the composition of the JSC and there might be a possibility of additional oceanographic expertise (up to 6 people) being added to the JSC. Part of the reason behind the change was the decision at the 2nd World Climate Conference in Geneva (29 Oct.- 7 Nov., 1990) to include a Global Ocean Observing System (GOOS) of physical, chemical, and biological measurements in a new Global Climate Observing System (GCOS). At the 16th IOC General Assembly in Paris (7-21 March, 1991) it was decided that IOC would establish GOOS and was prepared to become a co-sponsor of the WCRP. I also wish to noted that CCCO had its 12th session this year in Woods Hole (4-8 June, 1991). Both Prof. J. O'Brien and our Executive Director, E. Tidmarsh, were present and will report from that meeting.

Our second large-scale programme is JGOFS. Here too we have full reports from the 5th and 6th SSC Meetings held in Washington, D.C. in November 1990 and in Bermuda in September - October this year (30 Sept. - 3 Oct., 1991) respectively. Good progress is being made by the Planning Groups for both the Indian and the Southern Oceans in addition to progress already made by the Equatorial Pacific Ocean Planning Group. An implementation plan is being prepared, as a result of the 6th SSC Meeting, and this will hopefully help to form a basis for requests for future additional funding for JGOFS planning and implementation. The new Vice-Chairman of JGOFS, Prof. J. Field and the SCOR Executive Director, Elizabeth Tidmarsh, will be able to elaborate on the JGOFS report.

Our relations with other organizations have involved our participation in a number of meetings. I took part in the Arctic Ocean Sciences Board (AOSB) Meeting 8-10 Jan. 1991. Our Secretary, Prof. R. Fournier, our Executive Director, Elizabeth Tidmarsh, and I participated in three meetings: the XVI General Assembly Session of IOC in Paris, 7-21 March, 1991 (which also included informal discussions with the Secretary of IOC, Dr. Gunnar Kullenberg), The Oceanography Society (TOS) Meeting in St.Petersburg, Florida 24-29 March, 1991, and a GLOBEC preparatory Meeting in Solomons, Maryland 29 April- 3 May, 1991. I also had the opportunity to participate in a meeting in La Jolla, California, on the 9-11 May, 1991 concerning the planning of a Southern Ocean component of GLOBEC.

Finally, I took part in a meeting with the Working Group on Krill under the Committee for the Conservation of the Antarctic Marine Living Resources (CCAMLR) in Yalta, USSR on 22-26 July 1991.

During the year SCOR has co-sponsored a number of meetings, one being the 5th International Conference on Toxic Marine Phytoplankton (Newport, Rhode Island, 28 Oct.- 1 Nov., 1991).

At the end of my report it is my sad obligation to also report on the death of one of the fathers of SCOR, Prof. Roger Revelle. He was the Director of Scripps Oceanographic Institution between 1951 - 1964. He then moved to Harvard, 1964 - 1975, and finally he held a professorship of

Science and Public Policy at the University of California, San Diego. Prof. Revelle was among the first to lay the groundwork for the theories of plate tectonics and he originated the International Deep Sea Drilling Project in 1964. He also helped to demonstrate the role of CO_2 in global warming and played a major role in the planning of the International Geophysical Year (1957-58). Starting during his Harvard period, he devoted much of his attention to human population problems of the world. Prof. Revelle died on July 15, 1991.

Another distinguished marine scientist is also dead. Dr. Michael Waldichuck died unexpectedly last May. At the time he was the Chairman of the Canadian Committee to SCOR.

Please join me to honour these distinguished scientists and friends with a moment of silence.

1.4 Appointment of an *ad hoc* Finance Committee

In accordance with the Constitution of SCOR, an *ad hoc* Finance Committee was appointed to work during the meeting, in consultation with the Executive Director, to carry out a review of the state of SCOR finances, to draw up a budget for 1992, and to report to the Executive Committee under item 3.3 of the Agenda. The members of the committee were Professor N. Holm (Sweden), Professor J. Field (South Africa) and Dr. M. Whitfield (UK), who was its Chairman.

2.0 SUBSIDIARY BODIES

Many SCOR Working Groups are co-sponsored by the Intergovernmental Oceanographic Commission of UNESCO. SCOR gratefully acknowledges the support received for some of the activities described here from the IOC, the International Council of Scientific Unions, the Royal Society of London and the US National Science Foundation.

2.1 Arising from Former Working Groups

WG 54 - Southern Ocean Ecosystems and Their Living Resources

The final international scientific meeting on the SCAR/SCOR/IABO program on Biological Investigations of Marine Antarctic Systems and Stocks, which took place during the early and mid-1980s, was held in September, 1991. The BIOMASS Colloquium was supported, in part, by SCOR and attracted 140 scientists from 20 nations. The Proceedings will be published during the summer of 1992. The report from the Chairman, Professor El-Sayed, noted that the Colloquium "officially signaled the end of a remarkable era of collaborative international effort in the study of the Souther Ocean ecosystems . . . also marked the dawn of new scientific programs that, in part, are founded on the BIOMASS Program, or are spun off from it".

Professor Stromberg referred to the recommendations regarding these new programs contained in the report of the SCAR Group of Specialists on Southern Ocean Ecology. In particular they call upon SCAR to co-sponsor the Southern Ocean components of JGOFS and GLOBEC.

The report from Professor El-Sayed expressed gratitude to SCOR for its support of the BIOMASS program, both through its contributions to SCAR and its direct support to WG 54.

WG 75 - Methodology for Oceanic CO_2 Measurements

The draft final report of WG 75 was received from the Chairman, Dr. C.S. Wong, who had also solicited final comments from the members of the group. It was agreed that once the final version is received, it should be sent to UNESCO for possible publication as a *Unesco Technical Paper in Marine Science*. The recommendations contained in the report will be referred to the CCCO/JGOFS CO_2 Advisory Panel for action.

WG 76 - Deep Sea Ecology

The Executive Committee expressed concern that the final report of WG 76 is not yet available and requested the President, in his capacity as Executive Committee Reporter o urge the Chairman of the group to ensure that it is completed before the next meeting of SCOR.

WG 77 - Laboratory Tests Related to Basic Physical Measurements at Sea

Professor Siedler reviewed the decision of the XX General Meeting to establish a small editorial group to assist Professor Striggow with the completion of the report of the CTD intercomparison experiment conducted by WG 77. The period of transition and uncertainty at the Chairman's institute in eastern Germany during 1991 made it impossible to complete this task. Professor Siedler undertook to ensure that it is completed in 1992 and the meeting agreed to carry forward the funds allocated for the WG 77 editorial group.

WG 78 - Determination of Photosynthetic Pigments in Seawater

The Executive Committee Reporter for WG 78, Professor Fournier, informed the meeting that following a delay, the editorial group assigned to complete the final report on the various laboratory workshops organized by WG 78 is now resuming its task. Dr. Whitfield (UK) confirmed this information and the meeting expressed the hope that the WG 78 report would be available for submission to UNESCO for publication early in 1992.

Joint Panel on Oceanographic Tables and Standards

The XX General Meeting agreed that SCOR should terminate its sponsorship of JPOTS (see *SCOR Proceedings*, vol. 26). However, the former Chairman, Dr. J. Gieskes, had written to SCOR requesting additional support for a meeting to deal with some problems associated with the introduction of the International Temperature Scale of 1990 (T-90), such as potential need to revise the algorithm for the calculation of the speed of sound in sea water. The Executive Committee was not certain that these problems warranted support for a meeting and it was suggested that further information be sought from Dr. Gieskes who might wish to consider submitting a proposal for a SCOR working group to address the issue.

2.2 Current Working Groups

WG 80 - Role of Phase Transfer Processes in the Cycling of Trace Metals in Estuaries

Dr. M. Whitfield (UK), Chairman of WG 80, reported to the Executive Committee meeting. A written report is given in Annex III. The group held its second and final meeting in conjunction with an international "Model Estuaries Symposium" in Jekyll Island, Georgia. As a result, two publications are in preparation: a summary paper which will appear in *Marine Chemistry*, and a full report with technical annexes which will be published as a *UNESCO Technical Paper in Marine Science*. WG 80 has identified conceptual categories for particle/water interactions, developed a characterisation of interacting phases, addressed problems of modelling particle/water interactions, developed clearer definitions of time scales in estuaries, considered various criteria for the classification of estuaries, and discussed practical approaches (sampling and modelling) to the study of estuaries.

Dr. Whitfield expected that the manuscript for the UNESCO publication would be completed in early 1992. Therefore, the Executive Committee recommended that WG 80 be disbanded pending the publication of its reports. The Executive Director was instructed to ensure that copies of these publications are sent to the IGBP Land Ocean Interactions in the Coastal Zone (LOICZ) planning group.

WG 83 - Wave Modelling

WG 83 serves as an international "executive" or oversight group for a large group of modellers (WAM) collaborating on the development of a third generation ocean wave model. This effort is closely tied to the launch of the ERS-1 satellite which took place in July 1991. The Chairman of WG 83, Dr. Komen, informed the SCOR Secretariat that this delay would result in a brief delay in the submission of the final report of the group, although this is still expected to be available in 1992, following the final meeting of the group, which the Executive Committee approved. WG 83 is currently working on problems of the assimilation of the satellite wave observations in the wave model which is being implemented at the European Centre for Medium Range Weather Forecasting.

The Executive Committee noted with appreciation the report of WG 83 (see Annex IV), in particular the plans for the production of a book as its final product. This book will have three main themes:

- the use of satellites
- waves as part of the global climate system
- the link between microscale physics and medium-range forecasting.

WG 86 - Ecology of Sea Ice

The Executive Committee had before it a brief report from the Chairman of WG 86, Dr. C.W. Sullivan. At the 1990 meeting of WG 86, members agreed to take on three projects to address their terms of reference. Two manuscripts prepared by WG 86 members have been submitted to *Polar Biology* for publication and are under review. The first is entitled Ecology of Sea Ice Biota 1. Habitat and Terminology by R. Horner, et al., and the second, Ecology of Sea Ice Biota. 2. Global Significance by Legendre, et al. A third project is the publication of a comprehensive Sea Ice Biota Bibliography compiled by WG members that includes more than 700 citations from the international literature. The efforts of I. Melnikov (USSR) and T. Hoshiai (Japan) to provide many citations which previously were particularly difficult to obtain are especially appreciated. This project, led by S. Ackley, is well underway and publication/distribution is anticipated in early 1992.

WG 86 has reviewed the plans made on the part of several nations to stage numerous cruises during the 1990s using icebreaking research vessels in the Arctic and the Antarctic. These cruises will focus on studies of the sea ice edge zone, polynyas or pack ice ecosystems. Many are associated with ongoing and planned international research programs such as JGOFS, GLOBEC and SCAR activities contributing to the IGBP. As a result of these activities in the polar oceans, WG 86 members see a continued role for their efforts especially with regard to the third and fourth terms of reference: 3) to explore the desirability and feasibility of cooperative multidisciplinary studies and 4) to plan a workshop on biological sea ice studies. Considerable formal and informal interactions leading to cooperative studies have taken place among WG 86 members and between members of WG 86 and other international groups including SCAR, IGBP and JGOFS.

No formal meeting of WG 86 was planned for 1992. However, the Executive Committee approved the suggestion that the group organize an International Symposium on the Ecology of Sea Ice Biota in August-September 1994. The theme of the symposium will be interactions: physical-biological, chemical-biological and biological-biological and will emphasize interdisciplinary approaches to understanding this unique and extensive habitat which is characteristic of polar oceans. It was agreed that SCAR should be invited to co-sponsor this symposium. The Executive Committee Reporter, Professor Fournier wished to note the success with which WG 86 is meeting its objectives.

WG 89 - Sea Level and Erosion of the World's Coastlines

Professor O'Brien reported that WG 89 is making excellent progress and that the topic being addressed is especially important to the island and coastal states which are very concerned about the potential for sea level rise. In mid-1991, WG 89 published a major report entitled "The Response of Beaches to Sea-Level Changes: A Review of Predictive Models" in the *Journal of Coastal Research*. The group continued to work in correspondence on an expanded version of this report and to address its remaining terms of reference related to sea-level changes and the associated coastal responses.

WG 89 was given approval to meet in October 1992 in Venice in conjunction with an international conference on coastal engineering. The Executive Committee approved some changes in the WG 89 membership, suggesting that Drs. Gallegos, Ibe and Thom become Corresponding Members and that Dr. Wang Ying (China) join the group.

WG 90 - Chemical and Oceanographic Sensor Technology

WG 90 was established to assess the technologies which have the potential to produce sensors capable of measuring chemical and biological properties in the ocean with high resolution in time and space as can be dune using modern instrumentation for physical properties such as density, temperature, etc. The group held its first meeting in Hobart, Australia in June, 1991 and presented SCOR with a report on the currently available technologies which hold promise for sensor development.

The Executive Committee was concerned that the progress of WG 90 had been so slow. While it felt that the technological review would be a useful document, no statement had been received from WG 90 regarding its goals and detailed plans for a final product in accordance with its final term of reference which was seen as the most challenging (to evaluate ways in which the date from such probes can be calibrated, standardized and integrated into the date base from standard hydrographic instruments). No meeting of WG 90 was foreseen until 1993. In the meantime, the technological development of sampling systems has developed as a major issue for both JGOFS and GLOBEC and is likely to be addressed through other international groups. The Executive Committee agreed that WG 90 should be disbanded and that the technological review already completed be forwarded to the IOC. That report was endorsed as a very useful contribution to our understanding of the state of the art in sensor technology.

WG 91 - Chemical Evolution and Origin of Life in Marine Hydrothermal Systems

The Chairman of WG 91, Professor Holm, and the Executive Committee Reporter, Dr. Kuznetsov, reviewed its activities. The second meeting took place in June 1991. WG 91 has accepted an offer from Kluwer Academic Publishers for publication of its final report "Hydrothermal Systems and the Origin of Life", both as a book and as a special volume of the journal *Origins of Life and Evolution of the Biosphere*. Manuscripts were to be submitted

late in 1991 on the following topics:

- why have hydrothermal systems been proposed as plausible environments for the origin of life?
- types of hydrothermal systems.
- modern life at high temperatures.
- High temperature/high pressure organic geochemistry.
- mineral and fluid chemistry of hydrothermal systems.
- chemical markers of prebiotic chemistry in hydrothermal systems.
- relevant experiments to date.
- iron sulphides, other minerals and the origin of life.
- experiments and models to be developed.

Professor Holm reported one interesting result of WG 91's discussions. The temperature range of interest for chemical evolution in marine hydrothermal systems has been identified as 150 to 200°C. This implies that such evolution occurs primarily in the on-axis systems since the off-axis hydrothermal vent systems are hotter.

It was agreed that WG 91 would organize a small symposium for the presentation of its results in conjunction with the SCOR General Meeting in 1992.

WG 92 - Ocean/Atmosphere Palaeochemistry

In accordance with the Executive Committee's request, Working Group 92 has initiated plans for an interdisciplinary meeting focusing on interactions between marine sediments and atmospheric CO_2. The contiguous scheduling of the 1992 SCOR General Meeting in Göteborg with the Fourth International Meeting on Paleoceanography (ICP-IV) in Kiel provides a unique opportunity to involve the wide range of interests described in the report from WG 92 which was discussed at the XX SCOR General Meeting. After discussions with the ICP-IV Organizing Committee, WG 92 proposed the following format:

- a one-day session at the SCOR General Meeting entitled, "Global Interactions Among Atmospheric CO_2, Ocean Chemistry, and Sediments,"
- a workshop during the weekend between the SCOR General Meeting and ICP-IV entitled, "Models of Sediment-Ocean-Atmosphere Carbon-Cycle Interactions," and
- a poster session at ICP-IV entitled "Ocean-Atmosphere Paleochemistry."

The SCOR session would focus primarily on modern and historical interactions, with emphasis on implications for anthropogenic CO_2. The workshop would provide an opportunity for intercomparison of time-dependent models of relationships among atmospheric CO_2, ocean chemistry, and sediment processes and records. Finally, the ICP-IV session will include a focus on the sediment and ice core records of past carbon-cycle changes. WG 92 would make a special effort to assure that the last session includes collaborative efforts to address, in particular, the problems of chronostratigraphy and correlation of sediment and ice core records.

The SCOR Executive Committee approved these plans, noting the links between WG 92 and the JGOFS and PAGES core projects of the IGBP. The Chairman of WG 92 was urged to seek support for these meetings from a variety of sources since the funding available through SCOR was unlikely to be sufficient to provide travel funds for non-members of the group.

WG 93 - Pelagic Biogeography

Having met for the first time very late in 1990, WG 93 spent part of 1991 preparing a preliminary report to SCOR. The group is considering the theories and methods currently used in studies of pelagic biogeography, our state of understanding of patterns of distribution of marine pelagic organisms in relation to their physical and chemical environment, and the development of a manual on existing plankton collections which it considers to be an under-utilized research tool.

The SCOR Executive Committee did not approve the plans of WG 93 to develop a proposal for an international research program in pelagic biogeography in relation to global climate change. It felt that this would so broaden the terms of reference of the group as to make them impossible to achieve, and that this topic may well be addressed by the emerging Global Ocean Ecosystems Dynamics program. A similar point of view was expressed by ICES in its report to SCOR.

The Executive Committee was concerned that plans for a meeting of WG 93 to be held in Kiel in September 1992 already included a focus on global change issues and that this agenda may divert energy from the original terms of reference of WG 93. The report from ICES (which co-sponsors WG 93; see item 4.3) expressed a similar view. One suggestion was made that the topic of links between biogeography and climate change might be addressed by a future WG, possibly a successor to WG 93.

The request of the Chairman for membership additions to WG 93 was not approved by the Executive Committee since it felt that the group was already larger than most.
Finally, the Executive Committee tentatively approved plans for a WG 93 meeting in 1992, pending the report of the Finance Committee. [See item 3.3 - the Executive Committee decided, with regret, that funds did not permit the support of a second WG 93 meeting in less than two years.]

WG 94 - Altimeter Data and in-situ Current Observations

This group was established in 1990 in view of the impending launch of the ERS-1 satellite and others which will provide large altimeter data sets. The group brings together altimeter data experts and sea-going oceanographers in order to improve the interpretation of both the satellite data and the data from more traditional *in situ* current observations, taking into account the differing space and time scales and instrument errors associated with the two methods of observing currents.

At the first meeting of WG 94 in Toulouse, October 1991, the group identified four sources of discrepancies between altimetric and *in situ* data and initiated discussions as to how they can be reduced. WG 94 members also agreed to produce a short report of this meeting for SCOR; a slightly longer one, to be compiled from contributions by each member, with a comprehensive list of references and with a summary of work to date and the main issues raised, and; a review paper that discusses the technical issues in detail.

It was agreed that the next meeting of this group should concentrate on:

- results from the new Geosat data release,
- results over next 12 months or so of numerical assimilation exercises that include altimetry and one other current constraint, and
- the links between classical verification activities and those using numerical models and data assimilation.

The Executive Committee endorsed these plans for a meeting in early 1993.

WG 95 - Sediment Suspension and Sea Bed Properties

The goal of WG 95, is to improve the understanding of the various processes in the exchange and dissolution of particulate matter between oceanic sediments and the overlying near-bottom water. These processes determine the magnitude and composition of particles which are eventually buried in the sediments. The final membership of the group was agreed in consultation with the Chairman in early 1991 and the group began its work in correspondence in preparation for a meeting in 1992. Three major topics have emerged for this meeting which was approved by the Executive Committee:

- the evaluation of the use of various radionuclides as tracers of the transport of material and exchange processes between the clear water minimum and the bioturbation depth in the sediment. This will include a discussion of models and new approaches to describe the resuspension cycle.
- the chemical changes and microbiological processes on particles within the resuspension loop.
- the stimulating or inhibiting effects of epi- and infauna on fluxes through the sediment-water interface.

WG 96 - Acoustic Monitoring of the World Ocean

The investigation of different characteristics of long distance sound propagation in the ocean, which are significantly determined by the medium, can give valuable information about the structure of oceanic temperature and current fields in very large space scales. These principles are applied in the use of a powerful new research tool, ocean acoustic tomography, which permits basin- and global-scale observation of certain physical properties of the ocean. WG 96 was established in late 1990 in order to provide an international forum for the discussion of this topic. It held an initial, informal meeting during the IUGG

Assembly in August 1991 and the Executive Committee gave its approval for the first formal meeting of WG 96 at the Scripps Institution of Oceanography in June 1992. A detailed report from WG 96 appears as Annex V.

While the SCOR Executive Committee recognized the need for timely planning of a global program of acoustic monitoring as proposed by WG 96, it wished to urge the working group not to overlook the importance of its other terms of reference.

2.3 Committees and Panels

Joint SCOR/IOC Committee on Climatic Changes and the Ocean

The Chairman of CCCO, Professor O'Brien, reviewed an extensive written report which appears as Annex VI. He noted that 1991 saw the beginning of a period of transition for CCCO with the creation of a four person CCCO Executive Group which was incorporated into the ICSU/WMO Joint Scientific Committee for the World Climate Research Programme. The addition of these oceanographers to the JSC was welcomed by SCOR and the combined group was expected to act as a single body to provide scientific guidance to all components of the WCRP. This also meant that the steering committees for WOCE and TOGA, two major oceanographic experiments which originated in the CCCO, and have been overseen by the Committee for many years, now report directly to the JSC.

The twelfth session of CCCO took place at Woods Hole in June 1991. The CCCO reviewed in detail progress in a number of new areas which it had identified for attention. Several membership changes have resulted in a more interdisciplinary committee, rather than one with a purely physical oceanographic focus.

The CCCO had recognized that interdecadal ocean climate variability may well be much more significant than previously thought, although most of the current research is focused on shorter, interannual time scales (TOGA) or much longer ones (WOCE). An *ad hoc* CCCO study group was established to address this topic and plans were laid for a meeting in early 1992. Steady progress has continued in the preparation of a scientific design for a global ocean observing system and the CCCO/JSC Ocean Observing System Development Panel (OOSDP) met twice in 1991. OOSDP is responsible for the formulation of a design for the "climate module" of the global ocean observing system which is intended to monitor, describe and understand the properties which determine ocean circulation and the seasonal to decadal climate changes in the ocean, and to provide the observations needed for climate predictions. The CCCO/JGOFS Carbon Dioxide Advisory Panel was reconstituted in 1991 in order to better approach the design of a plan to acquire a global oceanic CO_2 data set. This CO_2 survey is being conducted by JGOFS scientists on WOCE research vessels, through an agreement between the two programs. The CCCO has undertaken a review of the IPCC Working Group I Report and has recommended that it should be expanded to take more account of the long-term processes implicated in the oceanic component of climate. Detailed

suggestions and an offer of further assistance have been sent to the Working Group Chairman. The CCCO has initiated an effort to improve prediction of the regional impact of climate change on the coastal environment through its three regional panels. CCCO has observed that the generally lower recent estimates for sea-level rise imply a greater need for expert opinion in cautioning or reassuring local authorities. The CCCO is exploring the practicality of producing materials in appropriate media which would provide advice in "popular" form on regional questions regarding climate and sea-level changes. Finally, the three CCCO Ocean Climate Studies Panels (Atlantic, Pacific and Indian Oceans) continue to provide a forum for the discussion of regional scientific interests, modelling activities, the identification of gaps in existing international programs, etc.

Professor O'Brien concluded that CCCO is vigorously addressing these new topics and looking beyond TOGA and WOCE to see what additional oceanographic problems need to be resolved for a better understanding of climate change.

The meeting was informed, however, that the organizational structure relating to CCCO and the WCRP was likely to change in the near future as IOC was seeking to become a co-sponsor of the WCRP and the constitution of the JSC would change to include more oceanographers. The future role of CCCO was not yet clear since discussions between ICSU, WMO and IOC on these matters were at a very preliminary stage. However, the representative of the US National Science Foundation did note that continued US support for the CCCO Secretariat was assured until the end of 1992 when the secondment of the current Secretary would end.

The Executive Committee Reporter for CCCO, Professor Siedler, advised the meeting that these changes would mean that the responsibility for the ongoing oceanographic climate research programs (TOGA and WOCE) would shift to the JSC for the WCRP, but that the JSC would have much better oceanographic input in the future. CCCO has begun to address new topics through its enthusiastic membership and should not be prevented from continuing to do this, whether in its existing committee structure or in some other form such as a series of smaller SCOR working groups. In any case the CCCO or its successor should be viewed as a partner rather than a competitor of the WCRP.

The President concluded the discussion of CCCO by noting that the coming months would undoubtedly see more detailed consideration of these matters between ICSU, SCOR, IOC and WMO, and that changes were probable. In the meantime SCOR should welcome the addition of more oceanographers to the membership of the JSC.

Joint Global Ocean Flux Study

The Vice-Chairman of the Scientific Steering Committee for JGOFS, Professor John Field, reported to the Executive Committee. A written report was also presented and appears in Annex VII. Since the XX General Meeting, the SSC had met twice; in Washington in late November 1990, and at the Bermuda Biological Station in September 1991. The major

objective for the most recent meeting was to make substantial progress with the development of the JGOFS Implementation Plan, building upon the Science Plan which was published in 1990, the discussions at the Washington meeting and those held at a special scientific meeting in July 1991 at which the reports of JGOFS scientific task teams were considered.

Most of the JGOFS task teams and planning groups met during 1991 in order to formulate their input to the Implementation Plan. The SSC adopted an practical, operational goal for JGOFS; a criterion for assessing the relevance or success of components of the overall program: to assess regional to global, and seasonal to interannual fluxes of carbon between the atmosphere, surface ocean and ocean interior and their sensitivity to climate changes, especially through a better understanding of the controlling processes. After lengthy consideration of the issue, JGOFS has decided to include continental margin studies in its plans. There will be considerable overlap and cooperation with the LOICZ program of IGBP, but this will not adequately address questions of the rapid deposition of carbon in coastal and shelf seas and the large horizontal fluxes of material from these areas to the open ocean. Plans for the JGOFS Indian Ocean Process Study advanced considerably in 1991 with two meetings of the planning group, one in India in January and one in conjunction with the Bermuda SSC meeting. This study will take place during 1992 to 1994 and will investigate the role of this region, with its intense seasonal variation and unique circulation patterns related to the monsoons, in the global biogeochemical cycle. As noted above, special training activities will be involved with this study which will include scientists from at least 9 countries. The Equatorial Pacific Process Study was intended to start in 1991, however this was delayed until January 1992 by problems with a research vessel. The process study will continue until 1995 and involves 5 nations. Plans for the two-phase Southern Ocean Process Study were developed at a meeting in mid-1991 and at a special modelling workshop later in the year. Other activities in 1991 included a meeting of t(+%% '*(^U^I^\ies Task Team at which the requirements for additional permanent time series stations were identified. Two stations, one each off Bermuda and Hawaii, are operational and data from them are readily available to the scientific community. The Benthic Studies Task Team and the Sedimentary Record Task Team both met early in 1991 in order to contribute material for the JGOFS Implementation Plan. The Process Studies Task Team held an important meeting at which the general specifications and aims for JGOFS process studies were enunciated. The primary role of the process study component of JGOFS is to provide the observations and understanding required to formulate, calibrate and test biogeochemical process models, Each individual study has a series of specific goals pertinent to scientific problems in each region or biogeochemical province, but all can be subsumed under the general aims. As noted above, plans for the JGOFS global survey of oceanic CO_2 continued through the action of a joint JGOFS/CCCO group. A special meeting of an *ad hoc* optics working group developed specifications for a survey of pigment and optical characteristics which will also be carried out in cooperation with WOCE. Finally, the JGOFS community was immensely relieved to learn in 1991 that a new satellite ocean colour scanner will be launched in mid-1993. This launch, which had been in some doubt, is essential since ocean colour fields offer the opportunity for truly global coverage of chlorophyll, a property

of central importance to JGOFS.

The SCOR Executive Committee approved the recommendations of the JGOFS SSC that the following individuals be invited to join the Committee: L. Merlivat (France), V. Smetacek (FRG), A. Chen (Taipei), A. Lisitsyn (Russia).

An effort to establish an international mechanism for the coordination of resources for JGOFS (funding, ship time, equipment, personnel, etc.) had unfortunately met with little success. Professor Field reported, however, that the JGOFS Executive is hopeful that the publication of the Implementation Plan with more detailed information on international resources requirements will provide the stimulus needed to establish a panel with representatives of major funding agencies to discuss these issues. In the meantime, adequate funding for international JGOFS planning activities continues to be a concern. The SCOR Executive suggested that SCOR Committees be approached to provide contributions and services such as the internal costs of meetings, publications, etc. This approach will definitely be appropriate in 1992 when it will be necessary to identify a seconded scientist to replace the current JGOFS Executive Scientist, Dr. Geoff Evans (Canada), at the JGOFS Core Project Office in Kiel.

Editorial Panel for the Ocean Modelling Newsletter

The Ocean Modelling Newsletter continues to be edited on behalf of SCOR by a small panel chaired by Dr. Peter Killworth (UK). Issue No. 93 was published in September 1991.

2.4 Proposals for New Working Groups

Scientific Methodology and Research Applications of Unmanned Submersible Technology

This proposal, received from the US Committee for SCOR, arose as a result of the recent rapid advances in submersible technology and the technology applicable to submersible-based science, including the basic characteristics of the vehicles themselves, their imaging systems, instrumentation, data handling, tools, and manipulative capabilities. It stated that while there is wide agreement on the potential of submersible systems to make possible major advances in undersea science, this progress is stalled because the existing methodologies do not match the capabilities of the technology. The proposal noted that comparative studies performed to date provide decisive evidence of the superiority of submersible systems over conventional techniques for both qualitative and quantitative analysis. *In situ* technology allows direct observations, surveys and assessments, precision sampling and manipulative experimental capabilities in the full range of pelagic and benthic habitats.

The proposed Working Group was intended to foster cooperative interactions between engineers and scientists to bring the evolution of the technology in line with the requirements of the research community. At the same time, there is a clear need for mutual efforts to

develop the methodologies that will most effectively utilize the existing technology and that which is forthcoming.

The Executive Committee felt that the group being proposed (twenty members including ten scientists and ten engineers) was too large to be supported by SCOR. It was also informed of related activities such as a European Initiative for Deep Sea Floor Instrumentation and a US-Japan cooperative effort in this field. The need for SCOR action on this topic was not obvious and the Executive Committee did not approve the proposal.

Worldwide Large-scale Fluctuations of Sardine and Anchovy Populations

This proposal was submitted to SCOR with endorsements from the South African, Mexican and Japanese Committees. It stated that there is clear evidence that there have been large fluctuations of sardine *Sardinops sagax* and anchovy *Engraulis spp.* populations worldwide over the last 60 or more years. Several hundred years of information on Japanese catches, as well as varved sediment data and surrogate indices from other systems, indicate the populations have been subject to a high degree of variability for centuries. The longest detailed catch records show that fluctuations off Japan and along the west coast of North America consistently occurred at more or less the same time. Shorter records from the west coasts of South America and southern Africa indicate that all major changes in these two systems observed to date were also nearly simultaneous with the changes in the two north Pacific systems. Empirical evidence for the coincidental changes has been explored in recent published papers, and in two informal workshops at La Paz, Mexico, involving seven of the proposed members of the working group. However, the causes of the dramatic changes, which occur over relatively short time periods but persist for decades, have not been established. The fluctuations have dramatic socio-economic repercussions in countries where the fisheries are located and, since fisheries on the resources harvest many millions of tons annually, a profound influence on the world fish production and markets. The fluctuations also have major repercussions for ecosystems in which the sardines and anchovies occur, because these two fish are the major food of many higher predators. Some data suggest the fluctuations of sardine and anchovy may be associated with structural changes in the ecosystems. International cooperation in studying available data is important to understand the natural causes of change. Fisheries of the world will not be ale to overcome change, but they will be better prepared to cope with change if some predictive method is developed. This is particularly the case in view of anticipated global climate change, which may well have a substantial impact on the sardines and anchovies and on the ecosystems in which they are found.

The Executive Committee felt that this was a topic which would benefit from the establishment of a SCOR Working Group. However, it found the terms of reference proposed to be too broad and suggested that the group proposed should focus on the collection of historical data, their use to evaluate the sequence of events occurring at times of major change, the development of hypotheses regarding causes of the large fluctuations in sardine and anchovy populations and the examination of evidence for a worldwide cause.

A small group revised the proposal during the Executive Committee meeting. In principle, the Executive Committee approved the establishment of such a working group, however, financial constraints made it unlikely that it could be supported in 1992. Therefore, it was suggested that the revised proposal be re-circulated to SCOR Committees for comments and that it be considered again at the XXI General Meeting, taking into account the development of the GLOBEC program (see item 2.5).

Coral Reefs and Global Change

Professor Healy introduced this proposal which discussed the increasing international concern about coral reefs and their neighboring shallow water ecosystems. Long recognized as important recorders and indicators of past sea levels and climates in the fossil record, modern reef communities are experiencing local and regional environmental stress from anthropogenic sources. Coral reefs may be especially sensitive to changes in the marine climate, and may be useful as early warning biosensors of incipient climate change. Reefs are important in a practical, socioeconomic sense because they occupy much of the coastline of the developing countries of the oceanic tropics and subtropics. They are also important scientifically they provide a substantial reservoir of marine biodiversity, and because they are pantropical, spanning a wide range of environments from estuarine to open ocean. A expert workshop held in Miami, Florida in 1991 reached the conclusion that reefs world-wide appear to be under stress, but that present data, knowledge of ecosystem- level responses to stress, and monitoring techniques are inadequate to reliably predict, interpret, or differentiate responses to local and global changes. The workshop participants called for an expanded and coordinated effort at systematic, long- term scientific data collection through research and monitoring on coral reefs, and proposed the development of an internationally coordinated approach. The twofold aims of such an exercise would be to determine quantitatively the status of coral reef ecosystems world-wide and to determine the relative importance of local and global stresses.

The proposal mentioned several international efforts to monitor coral reef ecosystems, but noted that none of them is bringing truly interdisciplinary expertise to bear upon the problems to be addressed. In view of the needs and the large-scale commitments about to be made to such efforts, the proposal requested that a SCOR working group be established to provide scientific advice on the monitoring and assessment processes, and, in particular, to address the critical issue of characterizing climate-forced ecosystem trends at scales appropriate to the dimensions and time-constants of climatic change.

The SCOR Executive Committee recognized that the topic proposed was both timely and of widespread interest and felt that SCOR was well suited to provide an interdisciplinary forum for consideration of the issues mentioned in the proposal. A very large number of membership suggestions had been received from SCOR Committees in addition to various suggestions for changes to the terms of reference. An *ad hoc* group was convened to make revisions to the proposal for consideration by Dr. R. Buddemeier, the suggested Chairman. The Executive Committee noted plans for an International Coral Reef Symposium in Guam

in June 1992 which would be attended by many of the individuals involved in this proposal. It was also expected that more information would be available then about a related IOC/UNEP/WMO effort on coral reef monitoring. The Executive Committee agreed that Dr. Buddemeier should be asked to consider the revisions to the original proposal, and the membership suggestions, in consultation with participants at the Guam meeting and that his recommendations regarding this proposal should be given a high priority at the XXI General Meeting in 1992.

Physiological Ecology of Atypical Algal Blooms

Professor Fournier reviewed this proposal which had been revised following preliminary consideration at the XX General Meeting. The problem of toxin-producing and otherwise harmful algae is one of worldwide concern, presenting threats to aquaculture and fishing activities and to human health. The proposal mentioned recent examples of unusual phytoplankton blooms which have caused extensive mortality in benthic populations, fish and shellfish in Europe and in North America and have had toxicological effects on humans consuming these organisms. The problem requires a broad scientific approach to determine the common factors involved in these harmful algal blooms.

Professor Fournier also mentioned a workshop on Toxic Marine Phytoplankton which had just been convened by the IOC with SCOR co-sponsorship in the USA. It generated a great deal of interest and was followed by an IOC/SCOR meeting on Programme Development for Harmful Algal Blooms which he chaired. The goal of the IOC programme is "to foster the effective management of, and scientific research on, Harmful Algal Blooms ion order to understand their causes, predict their occurrence, and mitigate their effects". The SCOR Working Group proposal was discussed in detail at this meeting and it was agreed that it would form a major scientific contribution to the IOC program. The representative of the IOC, Dr. Tom Osborn, reiterated this view and noted that the IOC, for its part, would establish an *ad hoc* Intergovernmental Panel on Harmful Algal Blooms which would hold its first meeting in 1992.

The Executive Committee agreed that this working group should be established as WG 97 with the title *Physiological Ecology of Harmful Algal Blooms* and that IOC and ICES would be invited to co-sponsor it. The lengthy list of terms of reference included in the proposal was reduced to focus on a historical review and a preliminary consideration of the scientific issues,, excluding consideration of methodological issues, the role of atypical blooms in the global carbon cycle and so on. The terms of reference agreed for WG 97 are:

- To review and analyze data on the physiological ecology and biochemical aspects of harmful algal blooms. especially those resulting in toxic episodes and paying particular attention to nutritional, environmental and physiological factors.

- To assemble within two years the Working Group's findings and submit for publication a report, summarizing the state of knowledge and identifying the areas

of future research.

The Executive Committee agreed that Dr. D. Anderson (USA) should be invited to Chair WG 97 and that he should finalize its membership in consultation with Professor Fournier and Dr. Osborn.

The Impact of World Fisheries Harvest on the Stability and Biodiversity of Marine Ecosystems

Professor Fournier also introduced this proposal which, like the previous one, was considered at the XX General Meeting and had been revised by the Canadian Committee for SCOR in order to make the terms of reference more specific. In the meantime, however, the SCOR Secretariat had been informed of an ICES Study Group on Ecosystem Effects of Fishing Activities which had a closely overlapping mandate and which was due to submit its final report to ICES in late 1992. The Executive Committee agreed to delay action on this proposal until the ICES report is available.

Sea Ice, Convection and Climate Modelling

Professor O'Brien reported that, in accordance with the decision of the XX General Meeting, he had corresponded with other international groups (SCAR, IAPSO, CCCO) active in this field and had determined that a SCOR Working Group in this topic would be redundant.

Interdisciplinary Coastal Ocean Science

The President of SCOR reviewed this proposal which had been received from Dr. Ken Brink (USA), Chairman of the US Coastal Ocean Processes (CoOP) program. Dr. Brink has also represented SCOR in planning meetings associated with the development of an IOC program in Dynamics and Oceanography of the Coastal and Shelf Seas.

Professor Stromberg noted that the proposal was for a group which would have a largely coordinating function, ensuring that there is good liaison between a number of international efforts in coastal studies including those of the IOC and of the IGBP. He and Professor Fournier shared a concern that such a working group would differ from all the others which have a purely scientific task to accomplish. They did not feel that it would be in SCOR's best interests to set a precedent by using the scientific working group mechanism for the tasks proposed. Nonetheless, they did feel that there may be a need for some coordinating mechanism in the field of coastal ocean science, and that SCOR should consider how this can best be achieved.

The Executive Committee meeting shared their views and agreed that the lead responsibility for such a coordinating activity should be taken by the IOC which had also indicated an interest in Dr. Brink's proposal. It was also agreed that if IOC takes any action on this matter, SCOR involvement as a co-sponsor may be appropriate.

Quantification of Mass and Energy Fluxes through the Mid-Ocean Ridge System

Professor McCave introduced this proposal which had only been received shortly before the Executive Committee meeting. It was submitted by an informal international steering committee for InterRidge, an "initiative for international ridge crest studies". Professor McCave noted that the topic of energy fluxes in ridge systems is generating wide interest with research programs being initiated in a number of countries. Professor McCave felt that the level of commitment is much higher than it was several years ago when SCOR was unsuccessful in establishing a working group in a similar topic. Therefore, the InterRidge steering group is looking to SCOR for assistance in providing interdisciplinary links and in involving scientists from more countries in this effort.

The proposal stated that the physical, chemical and biological processes associated with ridge-related activity - mantle upwelling, volcanism, solidification of the oceanic crust, hydrothermal circulation, chemosynthetic microbial activity, submarine volcanic systems, and circulation and mixing of the deep ocean - are linked, episodic and highly energetic. These interrelated processes are poorly understood, however. The oceanographic community does have the scientific and technological expertise to begin quantifying at global, regional and local scales this mid-oceanic zone of coupling between the deep earth and surface environments. The proposal suggested that multiscalar, multisensor mapping efforts should be complemented by extensive time series studies of active processes with a wide range of instrument arrays in order to document temporal covariation in these processes. The objectives of the working group would be to assess those portions of the global ridge system which are particularly well-suited for in-depth studies, to identify the approaches needed to address quantitatively the relationships between the important variables in oceanic crustal accretion and to evaluate the consequences of hydrothermal venting on ocean physics and chemistry. It was also proposed that the group would prepare a report on the prospects for a long-term program leading to quantification and modelling of the global spreading-center system and that it would convene a symposium to present its results and recommendations.

The Executive Committee agreed that the proposal should be circulated to SCOR Committees for comments and gave its preliminary approval for the establishment of such a group. Professor McCave informed the meeting that InterRidge would be more formally established in 1992 and that the steering group would meet to begin development of a Science Plan. While financial constraints prevented SCOR from making a definite commitment to this group for 1992, it did agree to give a very high priority to this proposal at the XXI General Meeting, taking into account developments in the InterRidge program.

Sea State Dependent Atmospheric Drag Coefficient

The Executive Committee discussed the concept of a working group to investigate the unresolved scientific issues related to determination of the drag coefficient between the ocean and the atmosphere. The topic was introduced by Dr. Ian Jones, Chairman of the

Australian SCOR Committee who noted that it is a question of broad importance as it affects climate, ocean waves, upper ocean turbulence and other areas of oceanography. There appears to be a need for critical experiments to be performed to resolve the current controversy surrounding this topic. The Executive Committee encouraged the Australian and Japanese SCOR Committees to develop a proposal for consideration at the XXI General Meeting of SCOR.

Ocean Dumping of CO_2

Just before the Executive Committee meeting, a proposal was received from the Chairman of former SCOR WG 75, for a working group to review the emerging problem of ocean dumping of CO_2 as a means of disposing of fossil fuel CO_2, the scientific arguments for and against this activity and its short and long-term implications for the ocean. The liquefaction of CO_2 and ocean dumping are apparently under consideration in some countries as a possible means of avoiding the need to reduce CO_2 emissions. It was agreed that this proposal should be referred to the CCCO/JGOFS CO_2 Advisory Panel for comments before further action is taken.

2.5 Proposals for SCOR involvement in large-scale programs

Global Ocean Ecosystems Dynamics Research (GLOBEC)

Professor Brian Rothschild (USA) introduced this item with a discussion of the scientific background to GLOBEC and a review of the proposal for a new international program in the field of marine ecosystems research.

At the XX General Meeting in October 1990 the joint interests of SCOR and the IOC in the field of marine ecosystems dynamics were discussed and it was agreed that the two organizations would convene a workshop which would focus on the linkages between physical processes in the ocean and its biological variability, especially in those processes such as secondary production and recruitment which are critical to the maintenance of economically important resource species.

This workshop took place at the Chesapeake Biological Laboratory of the University of Maryland in Solomons from April 29 to May 3, under the Chairmanship of Professor Rothschild. A condensed version of the report of the workshop appears in Annex VIII; a more detailed version was being published by the IOC. The workshop participants recommended that SCOR and IOC jointly organize an international program on Global Ocean Ecosystems Dynamics Research (GLOBEC).

In his presentation, Professor Rothschild mentioned various examples of dramatic variations in fish stock abundances and in macroplankton populations and showed how these are frequently correlated to physical variability in factors such as wind velocities and turbulence. GLOBEC could provide a major increase in our understanding of the relationship between

physical variability in the upper ocean and changes in biological processes such as growth, reproduction and mortality, the availability of prey, predation rates, etc. He noted that the SCOR/IOC Workshop had agreed GLOBEC should focus on an improved understanding of secondary production processes since it seemed likely that, for most areas of the world ocean, primary production is limited by grazing rather than nutrient availability. Two major components of the program will be modelling and technology development, especially for measurements of zooplankton abundance.

The Executive Committee agreed that the proposal for the GLOBEC program presented a logical extension of the existing set of global change research activities in which there is a gap relating to the effects of climate change on marine ecosystems. Individual representatives (Whitfield, UK; Field, South Africa; Su, China) noted strong national support for the proposal which complements ongoing national activities. It was also noted that GLOBEC, with its emphasis on communities and populations, will provide a close complement to JGOFS.

Recalling the discussion of SCOR's role as facilitator of large-scale programs which had taken place at the XX General Meeting in 1990, some participants expressed concern about the demands which might be placed on SCOR and its Secretariat in assuming the responsibility for another potentially large program. They were assured, however, that the focus of GLOBEC on secondary production processes will necessarily define the nature of its field program and that coordination in GLOBEC will be arranged so as to minimize the demands on the SCOR Secretariat. This will be affected, in part, by a GLOBEC planning office in the US and through assistance and contributions by the IOC as a co-sponsor.

The meeting agreed to establish a Scientific Steering Committee for GLOBEC and to invited the IOC to co-sponsor this as a joint activity. The interest of ICES should also be investigated since the ICES Cod and Climate program, while regional in nature, is very relevant to GLOBEC. The Executive Committee emphasized that while SCOR can nurture and support the initial planning activities for GLOBEC, its future must be conditional upon the equal involvement and support of its other sponsors. The terms of reference and membership of the SSC will require further development in consultation with the IOC, however, they were accepted in principle as follows:

- To further identify the scientific issues and detailed goals and objectives for an international study of Global Ocean Ecosystem Dynamics Research and Monitoring (GLOBEC) with a focus on secondary production and ocean physics.

- To develop a detailed scientific plan for GLOBEC and to guide the modelling and technological developments required to understand the mechanisms by which ocean physics contributes to the variability of secondary production.

- To recommend to the sponsoring organizations the necessary actions to be taken to implement the scientific plan and to coordinate and manage the resulting activities.

- To collaborate, as appropriate, with other related programs and planning activities, such as the International Geosphere-Biosphere Program, the Joint Global Ocean Flux Study, the World Ocean Circulation Experiment, the IOC/FAO program on Ocean Science and Living Resources, and the emerging Global Ocean Observing System.

- To interact with the Joint SCOR/IOC Committee on Climatic Changes and the Ocean in developing the physical oceanographic aspects of the program.

- To report regularly to SCOR and IOC and to related bodies on the state of planning and accomplishments of GLOBEC.

Initial membership suggestions:

B. Rothschild	USA	Chairman	
P. Bernal	Chile	V. Smetacek	FRG
D. Cushing	UK	J-O. Stromberg	Sweden
R. Dickson	UK	T. Sugimoto	Japan
J. Field	S. Afr.	S. Sundby	Norway
P. Nival	France		

Additional nominations received at the meeting will be considered by SCOR and IOC in consultation with the Chairman of the SSC.

Professor Rothschild presented plans for a preliminary meeting of this group to take place in late March, 1992 in Italy for which he intended to prepare a discussion paper outlining the scientific justification for GLOBEC including a framework for a five-year program to develop population dynamics models in a physical setting and to promote the development of the necessary sensor technology. The Executive Committee endorsed the plans for this first meeting and looked forward to the active involvement of the IOC in its organization, although it was recognized that formal IOC sponsorship would not be forthcoming until after the IOC Executive Council meeting in mid-March.

3.0 ORGANIZATION AND FINANCE

3.1 Membership

The Executive Director presented information on SCOR membership changes since the XX General Meeting:

Executive Committee:
Professor Brian Hoskins (UK) was recently elected President of IAMAP and becomes an *ex officio* member of the Executive Committee, replacing Dr. Brian Tucker.

Dr. Robin Muench (USA) was recently elected President of IAPSO and becomes an *ex officio* members of the Executive Committee, replacing Professor Jim O'Brien.

Nominated Members:

Canada: Following the untimely death of Dr. M. Waldichuk in May 1991, Dr. J.A.J. Thompson became Chairman and Nominated Member from CNC/SCOR.

China (Beijing): Professor Wen Shengchang has become a Nominated Member of SCOR following the retirement of Prof. Ren Mei.

USA: Dr. E. Hofmann has retired from the Ocean Studies Board of the National Academy of Sciences (US Committee for SCOR). There is currently a vacancy for a Nominated member from the USA.

Representative Members:

ICSU: Dr. R. Stewart (Canada) has become the representative of ICSU to SCOR.

The Executive Committee approved the suggestion of the President (see item 1.3) that Dr. Su Jilan assume special responsibility for membership issues and that he should work with the Executive Director to attract new members of SCOR.

3.2 Publications Arising from SCOR activities

The Executive Director presented the following list of publications arising from various SCOR activities since the XX General Meeting (October 1990):

UNESCO Technical Papers in Marine Science

No. 58 Directory of source materials for the history of oceanography. (Unesco 1990)

No. 59 Intercomparison of total alkalinity and total inorganic carbon determinations in seawater. (Unesco 1990)

No. 60 Reference materials for oceanic carbon dioxide measurements. (Unesco 1991).

No. 61 Manual on marine experimental ecosystems. (Unesco 1991)

BIOMASS Report Series

No. 65 SIBEX Acoustic Data Validation and Analysis Workshop, Cambridge, U.K., 11-22 July 1988. (October 1990).

SCOR/IOC CCCO Publications

Flow Statistics From Long-Term Current-Meter Moorings The Global Data-Set in January 1989. WCRP-30. WMO/TD No. 337.

International TOGA Scientific Conference Proceedings. WCRP-43. WMO/TD No. 379.

JSC/CCCO TOGA Scientific Steering Group. Report of the Ninth Session. WCRP-47. WMO/TD No. 387.

TOGA MONSOON CLIMATE RESEARCH. Report of the Second Session of the Monsoon Numerical Experimentation Group. WCRP-49. WMO/TD No. 392.

TOGA Numerical Experimentation Group. Report of the Fourth Session. WCRP-50. WMO/TD No. 393.

SCOR-IOC/CCCO-PAC-VIII/3 Report of the 8th Meeting of the CCCO Pacific Ocean Climate Studies Panel, 10-11 July 1990, Honolulu, USA.

SCOR-IOC/CCCO-XI/3 Summary Report Eleventh Session, May - 1 June 1990, Paris.

CCCO-JSC/OOSDP-I/3 Report of the First Session of the Joint CCCO-JSC Ocean Observing System Development Panel, Alexandria, Virginia, USA, 12-14 September 1990.

CCCO-JSC-OOSDP-II/3 Report of the Second Session of the Joint CCCO-JSC Ocean Observing System Development Panel, Villefranche-sur-Mer, France, 3-5 April 1991.

SCOR-IOC/JGOFS-CCCO-CO_2-II/3 Report of the Second Session of the Joint JGOFS-CCCO Panel on Carbon Dioxide, Paris, France, 22-26 April 1991.

JGOFS Publications

JGOFS Report No. 6, Core Measurement Protocols, Report of the Core Measurement Working Groups.

JGOFS Report No. 7, North Atlantic Bloom Experiment International Scientific Symposium, Washington, November 1990.

JGOFS Report No. 8, Report of the International Workshop on Equatorial Pacific Process Studies, Tokyo, April 1990.

"Oceans, Carbon and Climate Change, An Introduction to JGOFS", December 1990.

Publications Arising from SCOR Working Groups

WG 82 Geological History of the Polar Oceans: Arctic versus Antarctic, Ulrich Bleir and Jorn Thiede (Eds.). Kluwer Academic Publishers, The Netherlands, 1990.

Publications Arising from Other SCOR Activities

Antarctic Ecosystems: Ecological Change and Conservation. K.R. Kerry and G. Hempel (Eds.) Springer-Verlag, Germany, 1990. Proceedings of the Fifth Symposium on Antarctic Biology, Hobart, 29 August to 3 September 1988. The Symposium was organized by SCAR and co-sponsored by SCOR.

Coupled Ocean-Atmosphere Modelling. Journal of Marine Systems, Volume 1, No. 1/2 (Special Issue). J.C.J. Nihoul and B. Jamard (Eds.) Elsevier, The Netherlands, 1990. Proceedings of the 21st International Liège Colloquium on Ocean Hydrodynamics, May 1989, co-sponsored by SCOR.

SCOR Proceedings, Volume 26. Report of the 20th General Meeting of SCOR, Rostock-Warnemünde, Germany, October, 1990.

SCOR Handbook, May 1991.

3.3 Finance

The Chairman of the *ad hoc* Finance Committee, Dr. Michael Whitfield, presented the following report:

Budget and Financial Statement 1990

The Finance Committee has compared in detail the 1990 financial documents prepared by the Executive Director (see Annex IX) *with the accounts audited by Chandler and Davis Chartered Accountants, in accordance with the ICSU regulations, and confirms that the figures are consistent. Their task however was made more difficult by the very different formats adopted for the two sets of accounts. Some rationalization of the procedures would be beneficial.*

A few deviations were noted from the budget approved for 1990. The NSF travel award grants were under-utilized to the extent of $15,000, although this amount was carried forward to 1991. More use could be made of this fund to bring observers from developing countries to Working Group meetings, thereby making more effective use of SCOR funds. A shortfall of $27,000 was also noted in the NSF Geosciences award. The first NSF award for Geosciences expired in mid-1990. A proposal was submitted which, had it been dealt with on a timely basis, would have ensured the continuity of funding for JGOFS and the other activities covered by the award. The proposal was caught up in administrative difficulties at NSF and in an internal re-evaluation for support for international activities. The result of these delays was a loss of some

anticipated support, especially for JGOFS in the second half of 1990. Some of this was made up from other sources and some from the new award which began in January 1991. This new award provides continuing support through 1993. On expenditures, unexpected publication costs of $8,000 had arisen with respect of Working Group 56. In addition the communication costs were substantially ($5,000) over-budget, largely as a result of intensive E-mail traffic during the development of JGOFS. Both income and expenditure were below the budgeted levels, but the overall positive balance ($42,000) was substantially better than the figure anticipated at one point during the year ($18,000). Nonetheless the balance falls below the minimum balance ($50,000 to $60,000) which should be considered as adequate to begin activities in the new year. Caution is required in future years to prevent continued erosion of this carry over.

Budget and Financial Statement 1991

The Committee also reviewed the interim accounts for 1991. In addition to the budget estimate approved at the 20th General Meeting in Rostock these figures included a revised budget estimate, the actual expenditure to 31 October 1991, and a projection of expenditure to 31 December 1991. The revised budget income ($497,000) was substantially less than that estimated at Rostock ($699,000). The main deviations resulted from a) a reduction of $14,000 with respect to the IOC grant for GLOBEC, b) a reduction of $40,000 in the anticipated NSF Geoscience grant and c) the transfer of the US grant for the CCCO Secretariat from the SCOR accounts ($120,000). Corresponding reductions in expenditure resulted. The overall anticipated carry forward to 1992 was reduced from $52,000 to $16,400. In fact the carry over projected for the end of the year now stands at $22,000 - a dangerously low level. Urgent consideration must be given to ensuring a more substantial carry over in future years if continuing severe cash flow problems are to be avoided.

A number of deviations between the revised budget and the actual budget should be noted. a) the expenditure for Working Group 80 ($15,500) was substantially greater than anticipated ($10,000) because fewer members than expected were able to raise funds to attend the preceding "Model Estuaries" symposium, b) increased distribution costs have resulted in expenditure on publications exceeding the budget by $4,000, c) costs allocated to JGOFS were substantially under budget ($50,000 of $60,000) as a result of reduced administrative costs.

The Executive Director is to be commended on her careful control of existing funds but it is recommended that one of the Officers of SCOR work closely with the Executive Director to consider ways of increasing and broadening the funding base. For example, a more vigorous approach to private foundations might be worthwhile, new forms of membership and subscription might also be considered. It is further recommended that steps be taken in formulating the 1992 budget to ensure the continuing erosion of the funds carried over is halted and that this sum be increased to the recommended level (for $50,000 to $60,000).

Budget for 1992

The Ad hoc Finance Committee has also carefully reviewed the expected income and expenditure for 1992. A 5 per cent increase in the membership contributions to SCOR has already been fixed with the increase approved by ICSU. A similar 5 per cent increase is recommended for 1993. Taking this into account a preliminary budget for 1992 had been prepared. This should be reassessed and revised by the Officers early in the new year as soon as the income can be more reliably estimated.

The budget statement clearly shows that the level of activity approved in principal at the Executive Meeting will not be sustainable on the anticipated income. Two courses of action are open. The first is to reduce the level of activity. A rigorous application of the clear guidelines provided by the President in his opening address would provide a strategy for prioritising new proposals for new Working Groups. New Working Groups starts should be severely restricted until the expenditure on existing groups can be reduced. Greater emphasis should be placed on working by correspondence and a more careful assessment of the financial implications of frequent Working Group meetings should be made. Renewed exhortations should be made to Working Group Chairman to seek to defray costs where possible by urging members to seek their own funds and by running meetings back-to-back with other conferences and symposia. Working Group Chairman should, themselves, be encouraged to obtain additional sponsorships for their activities where possible.

The alternative strategy must be to increase the income to SCOR. This again was considered by the President in his comprehensive introductory address. Options include a) increasing the number of subscribing members b) raising the categories of existing members and encouraging prompt payment where this is necessary, c) taking advantage of the considerable accomplishments of SCOR and the enhanced public sensitivity over environmental issues to extend the funding base. Greater emphasis should be given to the joint sponsorship of activities of IOC, IGBP etc. It is recommended that a sub-committee be established to give urgent consideration to these and other possibilities and to recommend actions. This should not be left to the Executive Director to tackle single-handed.

The President thanked Dr. Whitfield for his presentation. The Executive Committee agreed that a small group should be established to assist in budget development, in particular the generation of new sources of income. It was noted that the President, in his opening report, had alluded to the need to establish priorities in line with realistic expectations of future financial resources. The meeting recognized, that although it had considered a number of excellent working group proposals, the financial situation did not permit the establishment of more than one new group at this time. Accordingly, it agreed that the WG on Physiological Ecology of Harmful Algal Blooms should be established and that several of the other proposals would be reconsidered at the General Meeting in 1992. Certain other adjustments were made to the budget for 1992 including the postponement of meetings of WG 91 and 93 until 1993 (pending a Secretariat review of the budget in mid-1992) and a decision that SCOR would not be in a position to contribute to the support of the Global

Ocean Euphotic Zone Study (see discussion of IGBP, item 5.2) in 1992.

3.4 Other Organizational Matters

Appointment of a Nominations Committee

The usual election of SCOR Officers will take place at the XXI General Meeting in 1992. The terms of office of both the President, Professor J-O. Stromberg (Sweden), and the Secretary, Professor R.O. Fournier (Canada), will expire and they will be ineligible to be re-elected. The terms of the three Vice-Presidents also expire at the General Meeting, however, the incumbents are all eligible for re-election.

The Executive Committee meeting agreed to appoint a Nominations Committee under the Chairmanship of the Past-President, Professor G. Siedler. It was proposed that he invite Professors Tim Parsons (Canada), Ross Heath (USA) and Academician L.M. Bekhovskikh (Russia) to assist him in this task. The Executive Director will request SCOR Committees to submit nominations for consideration by the Committee in preparation for the General Meeting.

Relocation of the SCOR Secretariat

The Secretary, Professor Fournier, reported that in mid-1991 the Executive Committee had considered and approved a request from the Executive Director to move the SCOR Secretariat from Halifax (where it has been located since late 1980) to the Baltimore-Washington D.C. area in early 1992. This approval was conditional on the identification of an appropriate host institution and the maintenance of administrative expenses at the traditional level. Professor Fournier and the Executive Director reviewed the various options which had been considered and the Executive Committee agreed with their proposal to accept an offer from the Department of Earth and Planetary Sciences of The Johns Hopkins University in Baltimore to provide facilities for the Secretariat. The Executive Director was instructed to ensure that a letter of agreement is signed between SCOR and the University in order to formally establish the responsibilities of both organizations in this arrangement. The assistance and support of the US SCOR Committee in relocating the Secretariat was gratefully acknowledged.

Finally, gratitude was expressed to the Canadian Committee for SCOR and to the Department of Oceanography of Dalhousie University in Halifax for their provision of facilities and encouragement to the SCOR Secretariat and its staff since 1980.

Publication of a SCOR Brochure

Professor Healy presented a "mock-up" for a tri-fold color brochure describing SCOR and its activities which he had undertaken to produce at the XX General Meeting. The participants made a number of suggestions and gave enthusiastic approval to the project,

urging its completion as soon as possible.

4.0 RELATIONS WITH INTERGOVERNMENTAL ORGANIZATIONS

4.1 Intergovernmental Oceanographic Commission

Many of the issues under this agenda item had been dealt with elsewhere (CCCO, GLOBEC, Harmful Algal Blooms, Interdisciplinary Coastal Ocean Science). The formal responses of IOC to SCOR initiatives in establishing the GLOBEC scientific steering committee and WG 97 would not be forthcoming until its Executive Council meeting in March 1992. The representative of IOC, Dr. Tom Osborn, expressed the view that these new joint activities were evidence of the very healthy and mutually beneficial relationship between the two organizations. Professor Siedler reiterated that the future functioning of CCCO and its subsidiary bodies would be the subject of discussions between representatives of SCOR and the IOC during the coming months.

4.2 World Meteorological Organization

The representative of WMO, Dr. David Wratt (New Zealand) briefly reviewed a written report referring to activities of special interest to SCOR. These included:

- The WMO/IOC Drifting Buoy Co-operation Panel (DBCP) which has reported continued improvements in the quality and quantity of reports from drifting buoys which are distributed globally on the Global Telecommunication System. The DBCP has continued to work closely with the WOCE/TOGA Surface Velocity Program on the development of a new Lagrangian drifter with a pressure sensor. DBCP has assisted in the establishment of a new International Arctic Buoy Programme and a Guide to Moored Buoys and other Ocean Data Acquisition Systems was published by WMO through the efforts of the Panel.

- The VOS Special Observing Project, North Atlantic has been completed and data are being analyzed. One of the most significant conclusions is that meteorological data from Voluntary Observing Ships can, if treated properly, be used to determine air-sea fluxes of heat, moisture and momentum. A final project report is to be published jointly by WMO and CCCO.

- A global digital sea-ice data bank has been established in order to provide historical sea-ice data in support of global climate studies.

- In April 1991 IOC and WMO jointly sponsored a seminar in Tokyo dealing with the preparation of oceanographic products based on data made available through their Integrated Global Ocean Services System (IGOSS). The meeting generated recommendations to its sponsors for improvements in the IGOSS Observing System

in support of improved operational ocean products.

- Agreement has been reached to develop and implement a Global Climate Observing System (GCOS) involving atmosphere, ocean, land and cryosphere components, in support of global climate research, monitoring and prediction. GCOS will be co-sponsored by WMO, ICSU and IOC and a scientific and technical committee and a planning office were to be established in early 1992. The oceanographic component of GCOS is to be developed through the climate module of the Global Ocean Observing System of the IOC, of which WMO is a co-sponsor.

4.3 International Council for the Exploration of the Sea

Professor Brian Rothschild represented ICES and reviewed its written report. In particular he noted the links between the ICES Cod and Climate Change program and GLOBEC. CCC, a pan-Atlantic study to investigate the details of the links between cod stock fluctuations and the physical environment, also involves both field observations and the development of coupled physical/biological models. ICES wishes to become a co-sponsor of GLOBEC and CCC is likely to be a very useful contribution to the GLOBEC effort.

The ICES report urged WG 93 to develop closer collaboration with the ICES Study Group on Zooplankton Production since both groups are making similar plans to develop a manual of plankton sampling to replace the UNESCO Monograph in the topic which was produced as a joint ICES-SCOR-UNESCO initiative in 1968.

An ICES symposium on the Measurement of Primary Production from the Molecular to the Global Scale was planned to take place in La Rochelle, France in April 1992. An associated meeting was to be held in order to consider the development of a standard method for primary production measurements as a joint effort of IOC, ICES and SCOR. The Executive Committee agreed that SCOR should support this effort because of its importance to JGOFS. The involvement of Dr. Trevor Platt, Chairman of JGOFS, as the Convenor of the La Rochelle symposium seemed likely to ensure this link.

5.0 RELATIONS WITH NON-GOVERNMENTAL ORGANIZATIONS

5.1 International Council of Scientific Unions

The Executive Director informed the meeting that during 1992 SCOR would be under review by a panel of the ICSU General Committee established under the Chairmanship of Professor Olof Tandberg, Foreign Secretary of the Royal Swedish Academy of Sciences. She emphasized that this review is part of a routine procedure applied on a rotating basis to all of ICSU's interdisciplinary scientific committees and that several organizations were due for evaluation in 1992. Professor Tandberg was in the process of establishing his panel which would consist of five or six well-known oceanographers. The last review of SCOR took place

in 1984.

Professors Stromberg and O'Brien had agreed to represent SCOR at a major ICSU conference entitled "Agenda of Science for Environment and Development to the 21st Century" (ASCEND 21) in Vienna shortly after the Executive Committee meeting. This conference would prepare statements and documents which would constitute the major input from ICSU, on behalf of the international scientific community, to the United Nations Conference on Environment and Development (UNCED, or the "Rio Conference"). The ASCEND 21 participants would have before them a draft document which would include a chapter on marine and coastal systems being prepared by Dr. P. Bernal (Chile) and Dr. P. Holligan (UK) with substantial input from many individual scientists. Participants in the SCOR meeting were urged to take advantage of every opportunity to convince their national delegations to UNCED of the importance of increased support for, and attention to, the international scientific effort to understand the causes, effects and implications of global change.

5.2 ICSU Unions and Committees

Scientific Committee for the International Geosphere-Biosphere Programme

Professor John Field provided information on two IGBP Core Projects which will involve SCOR (in addition to JGOFS):

- *Global Ocean Euphotic Zone Study* - GOEZS is a potential Core Project of IGBP which, if approved, would take place in the late 1990s as a follow-on to WOCE and JGOFS. It is concerned with the upper ocean interactions between physical and biogeochemical processes, how they may be perturbed by increasing CO_2 content in the atmosphere and the consequent feedback between the oceans and the atmosphere via the carbon dioxide cycle. The new levels of understanding provided by WOCE and JGOFS will be used to formulate this "next generation project" which will rely on the new expertise in coupled modelling, a new generation of satellites for remote sensing and new observational technology such as autonomous unmanned submarines for intensive ocean sampling.

  The agreement between SCOR and the SC-IGBP calls for SCOR to be involved in the planning of oceanographic components of the IGBP. Accordingly, following the IGBP Scientific Advisory Council meeting in September 1990, at which a very preliminary description of GOEZS had been presented, the President of SCOR had proposed to the IGBP Chairman that a joint international workshop be convened to examine and further develop the rationale for this project and that a small joint working group be established to prepare for this. This IGBP/SCOR GOEZS Working Group was in the process of being established under the Chairmanship of Dr. Ken Denman (Canada). It was expected that this group would meet during the first half of 1992 and that plans for GOEZS would begin to take shape as a result.

The Executive Committee approved these plans for SCOR involvement in GOEZS, although financial constraints did not permit the allocation of financial support to this activity in 1992 (see item 3.3). It was not expected that this would jeopardize the initial planning effort in 1992, although future joint IGBP/SCOR GOEZS activities would require contributions from SCOR.

- Land-Ocean Interactions in the Coastal Zone - Professor Field, who is a member of the LOICZ planning committee, pointed out that this is a "proposed" Core Project of IGBP; that is, the Science Plan for LOICZ is still under development. It has three major objectives:
  To assess the impact of natural and human forcing on coastal systems
  To study responses of coastal systems to these impacts
  To provide information, prediction and guidance for better management of coastal systems.

  LOICZ has defined the Coastal Zone as that belt extending inwards from the shelf-break to the limit of direct marine influence on land. It has agreed that direct anthropogenic effects are most important in the coastal zone with its huge human populations, intense resource use and heavy input of pollutants, both directly to the ocean and via river discharge. Thus, LOICZ will focus more on short-term changes linked to these factors than on the longer-term questions of climate change which concern other IGBP projects.

  Close liaison is being developed between JGOFS and LOICZ with respect to work in the continental margins and to the development of models which include appropriate boundary conditions for each program.

Scientific Committee on Antarctic Research

The Executive Committee agreed that SCAR should be invited to co-sponsor and contribute to the JGOFS Southern Ocean component. Similarly, preliminary plans for GLOBEC, especially in the USA, call for a Southern Ocean GLOBEC program. Should this be developed as part of the international effort, it would be appropriate for SCOR to seek SCAR involvement in this activity as well. The report of the most recent meeting of the SCAR/SCOR Group of Specialists on Southern Ocean Ecology which had been attended by Dr. Sullivan, Chairman of WG 86 and Dr. Julian Priddle, Chairman of the JGOFS Southern Ocean Planning Group, contained recommendations for SCAR involvement in both of these activities.

5.3 Affiliated Organizations

International Association for Biological Oceanography

The Executive Committee was concerned by the continuing lack of contact with IABO and by the fact that it had not been represented at SCOR meetings for two years. It was felt that the linkages between SCOR and IABO are important to biologists. The President agreed to take this matter up with IABO's President at the next opportunity, and with its parent body, IUBS, in order to determine if SCOR can be of assistance in fostering the development of IABO.

International Association for Meteorology and Atmospheric Physics

Dr. David Wratt presented the regrets of the recently-elected Chairman of IAMAP, Professor Brian Hoskins (UK) who had been unable to attend the meeting at short notice following his election at the IUGG Assembly. Professor Hoskins had provided comments on one or two preceding agenda items and looked forward to assuming his role as an *ex officio* member of the SCOR Executive Committee. IAMAP will hold its Sixth Scientific Assembly in Yokahama in July 1993 jointly with the assembly of the International Association of Hydrological Sciences (IAHS).

International Association for the Physical Sciences of the Ocean

The Past-President of IAPSO, Professor O'Brien, presented a report on behalf of his newly-elected successor, Dr. Robin Muench (USA). IAPSO Vice-Presidents are Dr. V. Shannon (South Africa), and Professor Y. Toba (Japan). IAPSO will cooperate with IAMAP and IAHS in organizing two Symposia on "Atmosphere-Ocean Interaction" and "Global Climate Models" which will take place in Yokahama in July 1993. IAPSO is organizing a summer school on the Physics of Ice-Covered Seas in Finland in June 1993.

5.4 Corresponding Organizations

Arctic Ocean Sciences Board

The AOSB held its Tenth Session in Copenhagen in early 1991. It addressed planning for the International Arctic Polynya Programme (IAPP), as well as progress in the Greenland Sea Project (GSP). IAPP will focus on three important polynyas: The Northeast Water, the North Water and the St. Lawrence Island Polynya. An IAPP "mission statement" will be published in late 1991. The GSP is being planned for 1993 and will include a water mass census, studies of circulation of the Greenland Sea Gyre, of plume convection, new ice formation in the central Greenland Sea, atmospheric boundary layer fluxes, biology during the winter-spring transition, and a winter Fram Strait control section. AOSB is also collaborating with the International Ship Operators Group in the preparation of a data base for research vessel operations in the Arctic. The AOSB report referred to activities since the

Copenhagen meeting. These included several field studies, and planning meetings and workshops associated with IAPP and GSP.

Plans are being developed for the Nansen Centennial Arctic Program which will focus on the study of the past and present Arctic environment with special reference to climate change. It will include studies of air-ice-ocean circulation and exchange processes, the carbon cycle and sediment fluxes, and paleoceanography and paleoclimate. The field program is expected to start during the summer of 1994 and to continue for at least two years.

Engineering Committee on Oceanic Resources

A brief status report on current ECOR activities was available. ECOR working groups of particular interest to SCOR include those on Marine Robotics, Marine Pollution and Small-scale Ocean Engineering Systems.

5.5 Other Organizations

The Oceanography Society

A letter from the Oceanography Society (TOS) requesting membership in SCOR as a Corresponding Organization was discussed. It was agreed that the present relationship by which SCOR has co-sponsored TOS meetings has been an advantageous one. In the longer-term, the possibility of jointly organizing international meetings has been discussed between TOS and SCOR. It was not clear, however, whether the present status of Corresponding Organization was really appropriate in the case of TOS and the Executive Committee agreed that this should be investigated in more detail. In the meantime, it was agreed that SCOR should agree to co-sponsor the Society's Third Scientific Meeting which will take place in Seattle in April 1993.

Commission on Marine Geography

Professor Healy reported that since the 1990 General Meeting at which this organization had been discussed, he had requested additional information on the objectives of the Commission and its interest in establishing a formal relationship with SCOR. It appeared that its activities focus on human geography and management issues. It was not clear what type of relationship the Commission was seeking with SCOR and it was agreed that this issue should be clarified. A representative will be invited to attend the General Meeting in 1992.

6.0 FUTURE MEETINGS

6.1 Twenty-first General Meeting of SCOR

It was agreed that the next SCOR General Meeting should take place at the University of Göteborg, Sweden, during the week of September 14 1992, just prior to the International Paleoceanographic Conference in Kiel (September 21 to 25). There are direct ferry connections between the two cities. The scientific component of the meeting was expected to be provided by sessions to be organized by WGs 91 and 92. The General Meeting will be hosted by the President of SCOR who will assume responsibility for the local organization.

6.2 Thirty-first Executive Committee Meeting of SCOR

Dr. Su Jilan presented an invitation to the Executive Committee to hold its 31st meeting in October 1993 in either Qingdao or Hangzhou, China. This offer was accepted with appreciation.

6.3 Other meetings of interest to SCOR

The Executive Director presented a list of international scientific meetings relevant to SCOR's interests, but which had not been addressed under earlier agenda items:

1992

January			
27 - 31	JGOFS/IGAC	Bermuda	NATO Advanced Research Workshop on Biogeochemical Ocean-Atmosphere Transfers (BOAT)
February			
17 - 20	IOC	Washington	Ocean Climate Data Workshop
March			
3 - 4	IOC/WMO	Paris	Intergovernmental WOCE Panel
5 - 7	IOC	Paris	Committee on Ocean Processes and Climate
10 - 18	IOC	Paris	25th Executive Council Session
23 - 28	JSC/CCCO	Vancouver	Joint meeting of JSC and CCCO Executive
April			
5 - 10	ASLO/BES	Cork, Eire	Aquatic Ecology Conference
5 - 9	CCCO/JSC	Southampton	Ocean Observing System Development Panel
6 - 10	CCCO/JGOFS	La Jolla	CO_2 Panel
7 - 9	AOSB	St. John's Nfld. Canada	Arctic Ocean Sciences Board

	21 - 24	ICES	La Rochelle France	Measurements of Oceanic Primary Production, from the Molecular to the Global Scale.
May				
	3 - 9	JGOFS	France	NATO Advanced Research Workshop. Towards an Oceanic Biogeochemical Model.
	4 - 8		Liège	International Liège Colloquium on Ocean Hydrodynamics: Sub-mesoscale air-sea interactions.
June				
	1 - 12	UN	Rio de Janeiro	United Nations World Conference on Environment and Development (UNCED)
	8 - 19	SCAR	Bariloche Argentina	22nd Meeting of SCAR
	22 - 26		Guam	7th International Coral Reef Symposium
August				
	28 - 9/5	COSPAR	Washington	World Space Congress and COSPAR Plenary Meetings
	25 - 30		Okinawa	First Pacific Ocean Remote Sensing Conference
September				
	13 - 18	ECSA/ERF	Plymouth UK	Changes in Fluxes to Estuaries: Implications from Science to Management
	21 - 25		Kiel	IV International Paleoceanography Conference

In particular, the Executive Committee approved requests for SCOR co-sponsorship of the following events:

- 7th International Coral Reef Symposium - Guam, 22-26 June, 1992.
- Scientific Sessions at the COSPAR Plenary Meeting - Washington, DC, 28 August to 5 September, 1992:
  - Global Change and Relevant Observations
  - Satellite Observations of the Ocean and Air-Sea Interaction with Emphasis on New Results from ERS-1
  - Motions Deduced from Satellite Imagery
- Changes in Fluxes to Estuaries: Implications from Science to Management - Plymouth, UK, September 13-18, 1992

SCOR will provide funds for travel by scientists from developing countries to each of these meetings.

7.0 CLOSING

There being no other business, the President adjourned the meeting expressing the gratitude of all participants to Professor Healy and his staff for their generous hospitality and the efficient manner in which they had arranged all aspects of the meeting. This even included the rain which had only fallen during the meeting and not during any of the other events. He expressed special appreciation, on behalf of the Executive Committee members, for the interesting excursions which had provided an opportunity to learn a great deal about the natural history and cultural diversity of New Zealand. Finally, Professor Stromberg thanked everyone in attendance for their contributions to the discussions which had covered such a wide range of topics in a relatively short time.

ANNEX I

30th SCOR EXECUTIVE COMMITTEE MEETING
Hamilton, New Zealand

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ANNEX II

Welcome Address at the Opening of the Executive Meeting of the Scientific Committee on Oceanic Research (SCOR)

Monday 11 November

Professor Wilf Malcolm
Vice-Chancellor
University of Waikato

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Ko te mea tuatahi, ko te wehi ki te atua
Koia nei te timatanga o nga mea katoa.
Ko Taupiri te maunga, ko Waikato te awa,
Ko Te Atairangikaahu te Ariki.
Piki mai, nau mai, haere mai.
E nga mana, e nga wihi, a nga rangatira, e nga ihi o te hau e wha
Haere mai kia mihi tatou i o tatou mate. Kati ki a ratou.
No reira, Haere mae ki te Whare Wananga o Waikato.
Haere mai. Haere mai. Haere mai.

In this *mihi*, I have acknowledged the divine presence which is the beginning of all things, I have acknowledged Dame Te Atairangihaahu (the Maori Queen), remembered the dead, and welcomed you to the University of Waikato. Welcome and thrice welcome.

I am glad to join with the Her Worship the Mayor, Margaret Evans, with Professor Dodd of the Royal Society, Professor Healy and colleagues here in welcoming the Scientific Committee on Oceanic Research (SCOR).

We are honoured that SCOR has chosen to hold its annual executive meeting at the University of Waikato. I say particularly honoured for a number of reasons.

First, while our University is relatively new - 27 years old - we have recently experienced rapid growth. Over the last five years our student population has doubled so that we now have 8680 students. In spite of our recent establishment, we are proud to have one of the largest Earth Sciences Department of Australasia. I am advised that the University of Waikato is the only University of New Zealand which offers a course in undergraduate Oceanography, which commenced this year with 95 students. There have been about 40 graduate student theses in marine geosciences. There are growing developments into marine biology and marine ecology. These factors reflect the vision and enthusiasm of staff for the future importance of ocean science for New Zealand. The presence on campus of such a

distinguished group as yours, at a time when we have experienced such strong in the Earth Sciences, is therefore most welcome.

Second, in the last few months, a representative group of New Zealand University scientists have ranked, collectively, oceanic research within the top six areas of science and technology which New Zealand should pursue vigorously over the next two decades. Consistent with the State's new policies for science and technology more generally, in this field we have developed strong links with our coastal organizations and pursue mutually beneficial areas in research. Indeed, we have a Chair partially funded by the Port of Tauranga, an organization which is located to the east of Hamilton. On the basis of the importance Universities nationally attribute to Oceanic research, I am delighted that you are holding your meeting and symposium in New Zealand.

Third, although the University of Waikato is inland, one and a half hours to each coast, it has established widely recognized national and international links in aspects of ocean science:

- Professor Cam Nelson - a major participation in the Deep Sea Drilling Programme;
- Professor Terry Healy - coastal and environmental sedimentation;
- Dr M. Steyn-Ross and Mr D Steyn-Ross - remote sensing of ocean parameters; and links with the CSIRO laboratory at Hobart;
- Dr C. Hendy - ocean geochemistry isotope study.

Further, the University has had two staff on recent SCOR Working Groups - Professor Roy Daniels on the "Chemical Evolution and Origin of Life in Marine Hydrothermal Systems" and Professor Terry Healy on "Sea Level and Erosion of the World's Coastlines". Accordingly, we are honoured too, that Professor Healy, who has had connections with SCOR for the last four years, was voted in Rostok early in October of this year to a position of Vice-President of the SCOR Executive. I wish to pay tribute to Terry for his foresight in the organization of your visit to our University.

While on campus, I trust that you will achieve not only what you set out to achieve but that you will take time to enjoy the beauty of our campus and to explore our neighbouring environs.

Aku mihi ki a koutou, katoa.

ANNEX III

SCOR WORKING GROUP 80
PHASE TRANSFER PROCESSES IN ESTUARIES
REPORT OF THE SECOND MEETING
JEKYLL ISLAND
22nd & 23th APRIL 1991

SUMMARY

The meeting discussed in detail the development of the report on the basis of the structure agreed at the first meeting held in Plymouth on 9th to 13th October 1989. Each component of the report was considered in some detail and various writing tasks were assigned.

It was agreed that a paper would be prepared for submission to the 'Marine Chemistry' volume that was being prepared for the Jekyll Island 'Model Estuary' symposium by Herb Windom. As a guideline approximately five single-spaced pages were required for each subsection - accompanied by a full reference list and completed tables and figures as appropriate. A fuller report, together with technical annexes, composed mainly of the papers submitted to the 1989 Plymouth Workshop will be published in a SCOR Technical Report.

Most of the material for the review paper has now been assembled, although events in the USSR have caused some delays. The combined text is now being drafted. Some sections are still awaited for the longer Technical Report and this might not be ready until the New Year. No further meeting of the Group is required, although some contact with the IGBP LOICZ Committee would be valuable.

REPORT STRUCTURE

1 Conceptual categories for particle/water interactions

A. Dissolution and co-precipitation (Burton)

This section is to include the consideration of oxygenated environments in which the precipitation or dissolution is kinetically dominated, and of reduced environments where thermodynamic controls might be more in evidence. Redox processes were considered dominant for iron and manganese and some liaison was required with Keith Hunter over the balance between precipitation effects and colloid coagulation in the deposition of iron from estuaries. Aluminium removal by precipitation was discussed but some questions were raised over the validity of the thermodynamic model for the control of aluminium levels in estuaries. Authigenic of manganese, iron and cobalt via redox processes, and copper, zinc and cadmium via sulphide precipitation in the sediments were also to be included. Wollast was to provide information on iron and manganese controls in the Scheldt. The work of Middleburg et al on manganese- calcium carbonate mixed phases was to be included. The

use of arsenic as an example of the variation of the emphasis of different aspects of chemistry from one estuary to another was suggested. A brief critical assessment of the use of selective leaching techniques to assess the reactivity of solid phases should also be included as should the work of Elderfield and Sholkovitz on cerium.

B. Colloid aggregation and disaggregation (Hunter)
Although Keith Hunter was not present this section was briefly discussed. In particular it was suggested that the colloid aggregation/disaggregation model of Sanchi and Honeyman should be included, and that the section in Keith Hunter's chapter on particle characterisation, which included discussion of colloid aggregation should be updated and included here.

C. Adsorption and desorption (Church)
The emphasis of the material presented by Tom Church was on ion exchange in estuaries. It was agreed that this section would be extended to include adsorption and desorption reactions and that Church and Somayajulu would work together on this. Examples could be provided by 234Th 210Po in the Delaware and in other estuaries (Jean-Marie Martin). The coupling of the cycles of lead and radium and iron and thorium should be considered and artificial radionuclides, such as 60Co 54Mn (in the Columbia), 125Sb, 106Ru 239,240Pu in the La Hague (Jean-Marie Martin), and 134,137Cs (Roland Wollast, Jean-Marie Martin). Sections in the radiochemical chapter originally submitted by Tom Church could also be extracted for this section.

D. Biological uptake and release (Wollast)
A brief section was required here which indicated the major impacts that biological processes in the water column might have on the cycling of trace metals in estuaries. Examples suggested were as follows: The Krka (Jean- Marie Martin), the Delaware (Tom Church), the English Channel and the Mediterranean (Dennis Burton). It was also suggested that the redox chemistry of manganese and arsenic in estuaries would provide a good example of the implications of bacteria and possibly phytoplankton in trace metal cycles.

2 Characterisation of interacting phases
A. Particulate phase (Hunter)
A substantial chapter on this subject has already been submitted by Hunter for the Plymouth meeting. However the discussion revealed the development of a significant range of new techniques for the determination of particle size spectra in estuaries. Information would be provided as follows: a) Tom Church had information on the use of TV microscopy through the salinity gradient in Chesapeake Bay. This enabled large particle aggregates to be observed and their distribution monitored. b) Jean-Marie Martin indicated that plans were in hand for the intercalibration of particle size techniques in the Elbe in 1991/92 using endoscopic probes and laser holography for studying large aggregates.

The evidence so far suggested that the larger aggregates were very fragile and easily broken up and were probably very loose aggregations of smaller particles. It was suggested that the

Kd values for such material might not be affected too greatly by the breakdown of these fragile aggregates. It was agreed that surface charge was probably not an important criteria for characterising estuarine particles. Further it was agreed that the EGME method, rather than the BET method, should be used for characterising particle surface areas. Jean Marie Martin agreed to provide some references to the use of microcalorimetry for characterising particle water interactions.

Roland Wollast suggested that the separation techniques used in the Scheldt would be extremely useful in this context. They enable particles down to about 2 microns to be separated in a continuous system. He promised to provide details. Emphasis should be placed on the sampling of the colloidal size range. The characterisation of exchangeable metals on particle surfaces was also discussed here. Although electron microscopic techniques were valuable they were also very time consuming and the selective extraction techniques commonly employed lacked quantitative interpretation. It was also agreed that the problems of bulk particle analysis should be included in the discussions to indicate the origin of the estuarine particulate matter, especially as the import of particulates from the sea by the end member was an important, but insignificantly recognised source of estuarine particulates in tidal estuaries.

B. Dissolved phase (Whitfield)
Here there were two major prerequisites. The first was a proper chemical analysis of the components of the system. The second was an understanding of the way in which these components interact in estuarine waters to produce the chemical species that are sensed by organisms and are involved in physical chemical reactions. The development of the speciation models also required the determination of master variables such as pH, salinity, temperature, and redox potential.

Models for the major cations and anions associated with river and seawater had advanced to the stage where the ionic activities could be calculated with great accuracy over the temperature range from 0-40|C using the Pitzer model. For acid base systems good analytical techniques were available and either Pitzer or ion pair models could be used to calculate dissociation constants in estuarine waters for carbonic acid (second ionisation), boric acid, ammonia and for the ionisation of water. Less accurate calculations could be made for the ionisation of bisulphate ions, hydrofluoric acid, carbonic acid (first ionisation), and the bisulphide ion. Accurate procedures were now available for the measurement of pH in estuaries, although these were not yet widely used.

So far as trace metals are concerned, thermodynamic models were less easy to establish. Where hydrolysis or redox processes were involved the system is not necessarily at equilibrium. In addition, organic complexation with elements such as lead, iron, copper or plutonium caused significant deviation from simple inorganic models. The lack of good critical data for the stability constants of inorganic complexes for many trace metals was also stressed. Considerable work was required to remedy this problem as was exemplified by the recent exhaustive study of uranium complexation. In anoxic systems the interactions of

bisulphide and polysulphide ions with trace metals was also poorly characterised.

The Pitzer formulation was hopelessly complex for establishing models of trace metals in estuarine systems and 'ion-pair' type complexation models were recommended. Inorganic stability constants were reasonably well established for the weakly hydrolysed cations such as copper, lead, zinc, cadmium, the rare earth elements, cobalt too and silver. Because of the difficulties in modelling these systems the use of direct species-selective analytical methods will be recommended and examples were quoted or the use of electrochemical methods for the determination of the variable fractions of elements such as copper, nickel and manganese in estuarine systems.

The importance of photoredox processes was also emphasised by Tom Church. In estuaries with large surface areas, such as the Chesapeake Bay, photoredox processes can have a significant impact.

3 Modelling particle-water interactions (Whitfield and Turner)

A. Operational procedures

Procedures for the determination of Kd values were discussed in some detail. This was the main reaction to be incorporated into the chemical models for trace metal cycling inestuaries but it was still very poorly characterised. It was agreed that the kinetic approach adopted by Nyfeller et al had some advantages. This method considered the rates of both adsorption and desorption which would need to be taken into account in studying processes in estuaries where the particulate matter was recycled many times through a changing aqueous phase. If the system approached equilibrium the ratios of the rate constants could be used to determine effective stability constants.

The method had only been applied in conditions of constant ionic strength. No studies had taken place in the very variable regime encountered in most estuaries. Careful assessment was required of the sampling, treatment and characterisation of the solid phase. In addition the timescale of the experiments in relation to the various reaction time regimes experienced in estuaries required further attention. The use of operational adsorption isotherms to summarise the trace metal uptake was discussed and it was agreed that examples from the soil science literature should be quoted. However, such approaches could not be used to predict the behaviour of particle-water systems beyond the bounds of the experimental evidence

B. Theoretical approaches (Turner)

Procedures based on the surface complexation model should enable measurements taken under controlled conditions to be extended to a range of pH and salinity. However, the application of this approach to real estuarine systems was in it's infancy. Overall there was too little data available on estuarine particulate matter to make any critical assessment of the methods or their applications. It was recommended that the work of Alain Bourg should be critically reviewed, as should the work of Phil Balls (Netherland Journal of Sea Research, Vol 22, pp 213-218, 1988).

4 Context

A. Timescales (Martin)

A paper had been tabled at the Plymouth meeting which outlined the concept of timescales in estuaries. Here the concept of flushing time, as originally developed by Ketchum, needed to be developed and extended. In addition clear definitions were required for the concepts of residence time, life time and age for both particles and dissolved components in estuarine systems. Chemical reactor theory provided a well-established basis for such definitions and concepts such as plug-flow, bypass-flow, and retention needed to be further developed. A brief paper was tabled by Jean-Marie Martin which summarised the main points.

B. Particle dynamics (Turner and Morris)

No paper was received on this subject but Roland Wollast indicated that a review paper on 'Particle dynamics in the Zaire' should be considered by Turner and Morris when this section is drafted.

5 Concepts

A. Model estuaries

The classification of estuaries was considered in some detail and it was agreed that in addition to the physical criteria commonly used it would be useful to consider aspects of estuarine dynamics that might be more appropriate to the problem of understanding particle water interaction. The use of three authogonal axis was considered.

i) Physics. Here a parameter representing flushing time but linked to the overall volume of the system was suggested.

ii) Biology. Diverse examples were considered of parameters exerting an overall control on biological activity including latitude, temperature, chlorophyll a.

iii) Chemistry. Examples considered here were the use of the river index suggested by Gibbs for river classification of inorganic components, or the use of an index that took into account the organic loading in rivers. An alternative chemical indicator would be the alkalinity of the river input.

While it was agreed that the plotting of estuarine characteristics in such a space would be very helpful for the determination of the characteristics of particle water interactions it was clear that there was not really a suitable source for such information. Wollast and Martin agreed to draft a recommendation for the compilation of a suitable database for estuarine characteristics which could be used in this and other studies.

B. The definition of key elements

While the term trace metals covers most of the Periodic Table it is possible to use the concept of chemical periodicity to identify key elements whose properties are representative of groups of trace metals. A shortlist was agreed.

i) Zinc. An essential trace metal with rather complex chemistry in solution. Only weakly hydrolysed but its behaviour is characteristic of elements that are taken up in carbonate phases.

ii) Iron. An element whose behaviour is controlled by colloidal coagulation in

estuarine systems and by redox solution and precipitation at the sediment water interface.

iii) Manganese. An element subject to considerable redox recycling between the sediment and water column whose reduced redox state (manganese II,) has a significant life time in estuarine waters.

iv) Arsenic. An element also subject to redox cycling, but with two soluble redox states (arsenic III and arsenic V) which are active in estuarine waters. Arsenic also forms organic compounds and methylated species.

v) Cadmium. A soluble weakly hydrolysed element that is actively involved in biological cycling. Its concentrations can be significantly enhanced by pollution, and in larger estuaries there is a significant atmospheric input.

vi) Lead. A particle active element with a useful radioactive isotope (210Pb) and a range of stable isotopes which can be used to identify the source of the lead. It too has a significant atmospheric input in most estuaries.

vii) Thorium. A particle reactive element with a useful radioisotope (234Th) the same could also be said for 7Be.

C. Estuarine analogues (Church)

Estuarine analogues are considered as simple experimental extractions highlighting specific aspects of the complex estuarine system. The simplest example was provided by the end member mixing experiment of Sholkovitz. These had since been modified to take into account the influence of time course and history of the reacting components by considering mixing down salinity gradients. Larger scale analogues such as the Merl mesocosm system had been developed to take into account the interactions between benthic and water column processes and to provide more realistic timescales for the interactions. The use of flumes in tidal salt marsh systems (the work of Bob Gardener) was also mentioned. benthic chambers were discussed (the work of Bjorn Sundby) and the use of incubated box cores and in situ chambers for studying sediment water interactions. It was agreed that the use of chemical reactor analogues for understanding rate processes in estuaries and for quantifying fluxes was more appropriately discussed under section 6B (modelling strategies - Turner).

D. Estuarine zones (Somayajulu, Yu, Morris, Church)

The discussion here fell into two sections. The first considering the definition of generic zones within estuaries. The second considering estuaries experiencing a strong seasonal pulse in river flow which greatly influences the location and relative importance of the various estuarine zones.

i) Definition of generic zones. The first zone considered was the biatic interface, ie the biological discontinuity that occurs as freshwater mixes with river water (often called the freshwater/brackishwater interface). Here the influence of river alkalinity and dissolved and particulate organic load was of prime importance. Processes such as organic carbon respiration, colloid aggregation and transition from riverine to estuarine flora and fauna were important. Processes in this region were strongly influenced by temperature and river flow and showed marked seasonal variability. Roland Wollast, Dennis Burton and Jean-Marie Martin agreed to provide

information on the use of incubation experiments and mixing experiments to study this region as exemplified by the EROS Programme. At times of high run-off this interface might take the form of a brackish water plume, directly abutting on to coastal seas. Examples were quoted from the Bay of Bengal, the Black Sea and the Baltic Sea. Estuarine plumes of somewhat higher salinity were also observed in estuaries such as the Rhone, running into the western Bay of the Mediterranean; and the Humber, running into the North Sea. This reaction zone was characterised by short residence times and rapid mixing processes.

The next zone discussed was the turbidity zone in tidally active estuaries. A turbidity maximum zone might be generated through the interaction of river borne and tidally resuspended sediments. This is the key area for the impact of particle-water interactions on trace metal cycling in estuaries. In addition many major rivers such as those in South East China, the Ganges and the Mississippi carry major particulate loads which are discharged directly on to the Continental Shelf. Under these circumstances the shelves themselves may be considered as continuous extensions of estuarine systems. It was agreed that emphasis should be placed on the timescales available for interaction between the water column and the suspended particle phase, and a degree of interaction than ensues after the suspended material is deposited in the bottom sediments. This is crucially dependent upon the tidal regime, and also on the effect of wind and storm on sediment resuspension. In addition to the site of the particle-water interaction within the estuaries it was emphasised that the nature of the water shed was very important in defining the characteristics of the riverine end member. This might be changed quite significantly by changes in land use and water management. The impacts of such changes on particle water interaction in estuaries should be included in the report.

ii) Seasonally flushing estuaries. Somayajulu expanded on the written report presented to the Plymouth meeting in October 1989 to discuss the importance of monsoonally driven systems in India. The dominant systems flow to the east with only two smaller rivers flowing to the west. Here the sites of estuarine interaction shifted from the body of the estuary itself to the shelf as the estuaries were flushed during the monsoon season. The importance of these estuaries as models for studying particle water interactions was discussed because of their ability to demonstrate two extreme kinds of behaviour. It was agreed that this section would be expanded in the final report.

Yu Gouhui draw attention to the report on Chinese estuaries submitted to the Plymouth meeting. It was agreed that this report should be abstracted for inclusion in this section. Slava Gordeev introduced a discussion on the highly seasonal behaviour of high latitude estuaries, with special reference to the Lena which supplies 80 per cent of the water to the Laptev Sea basin. The high organic loadings and the high salt content of this river made it a very useful example for inclusion in this section on seasonally driven systems. It was agreed that Slava Gordeev would prepare a section for the final report.

6 Practical approaches

A. Sampling

Tom Church introduced a discussion on the use of Lagrangian sampling techniques within estuaries. Such techniques had been applied in the Delaware using a technique of yo-yoing between fixed salinities to look at dynamic effects in the water column. The alternative of following changes in a fixed or marked patch of water was also considered as a useful option in estuaries where plug-flow might be approximated. Roland Wollast agreed to provide information on the use of a bromine isotope tracer in the Scheldt estuary and Jean-Marie Martin agreed to provide information on the use of a buoy system in the Rhone estuary during the EROS Programme.

Roland Wollast also discussed the approach used in the Scheldt of carrying out measurements over a series of fixed stations selected to cover the whole salinity range during one tidal period as an alternative to mobile sampling on the estuary itself. In the specific context of studying trace metal interactions it was agreed that sampling and analysis strategy should include the distribution of metals in the particulate as well as dissolved phases. Roland Wollast quoted examples of the distribution of zinc, cadmium and nickel in the Scheldt to illustrate this point. The importance long time series measurements in both the particulate and dissolved phases were stressed in order to evaluate net fluxes to the coastal ocean and in particular to study the contribution made by shelf sediments to the estuarine particulate load in tidally active systems. Monitoring systems in the Scheldt with remote triggering of sampling might provide useful examples of the sampling strategies required to study episodic events.

B. Modelling strategies (Turner)

Modelling strategies needed to be developed that took account of the specific requirements for the study of particle water interactions. Chemical reactor concepts could be particularly valuable here since they allow specific consideration of the timescales for the particle water exchanges. Examples were quoted by Mike Whitfield of the use of chemical reactor concepts in the Tamar estuary, and by Roland Wollast for the use of such techniques in the Scheldt estuary. It was agreed that so far as particle water interactions were concerned a better understanding of the influence of flushing time and particle transport characteristics on the progress of chemical reactions was a more urgent priority than the development of full two and three dimensional hydrodynamic models of estuaries. Models capable of treating non-steady state systems were particularly important in this regard. Such models were useful for studying catastrophic events, such as natural flushing episodes and pollutant inputs. The early papers of Ketchum provided simple guidelines for the development of the residence time concepts in tidal estuaries.

In general it was agreed that there was insufficient information about the distribution and reactivity of trace metals in estuaries for very elaborate hydrodynamic models to be applied. However, the introduction of ICPMS techniques and the development of in situ methodologies for trace metal detetermination (eg electrochemical techniques) might alter

this perspective over the next decade. In addition to the treatment of chemimical processes there was an urgent need to extend process models to include the influence of biological interactions on trace metal cycling. Examples of the water column oxidation of arsenic and manganese were considered. The potential impact of estuarine discharges on biological communities also required attention and this would involve the determination directly of biologically available fractions of important trace metals (eg copper and zinc).

ANNEX IV

THE NINTH WAM MEETING
Westerland, Sylt, 4-7 June 1991

BY G.J. KOMEN, CHAIRMAN OF SCOR WG 83 ON WAVE MODELLING

The WAM group is a group of about 50 wave modelers, collaborating on the development of a third generation ocean wave model. Representatives of WAM form the Scientific Committee on Oceanic Research's Working Group 83. The annual WAM/SCOR WG 83 scientific meeting is organized by the chairman of the group and a local organizer, this year the Max Planck Institüt Meteorologie. About 70 people (members + observers) from 16 countries attended.

Gerbrand Komen opened the meeting by recalling the aims of WAM and by presenting the draft final report of the working group. The plans for this report were further discussed during the meeting. As a result it was agreed to jointly write a coherent book with as main themes

use of satellites,

waves as part of the global climate system

the link between microscale physics and medium-range forecasting.

The book will be organized in different parts: physics, the model, data assimilation and applications. A final draft should be ready for discussion at the next meeting. Peter Janssen chaired the session on *global implementation.* Interesting tests at ECMWF with increased directional and spatial resolution have not shown major effects so far. The capacity of the ECMWF system in a 5 day forecasting mode has been well documented now, so that the model is ready to go operational. The so-called coupled model, with an improved description of wave-boundary layer interaction has undergone extensive testing. Results are satisfactory. Günther presented the chapter on global implementation for the final report.

The session on *regional implementation* showed many interesting applications of the WAM model. Bertotti had made use of an Adriatic hindcast to estimate the contribution of wave set-up to the flooding of Venice. Lefèvre used Geosat data over the Mediterranean Sea for a detailed field analysis and for validation of the model. Much attention was given to hindcasting of SWADE (Surface Wave Dynamics Experiment). Highlights included the nested modelling at three levels (Hasselmann), the detailed description of the crucial story (Graber), the high resolution verification by Jenssen and attempts to model wave-current interaction in the Gulf Stream (Tolman). The closer you go to a problem the more complicated it becomes. In his summary Cavaleri underlined the feeling that this applies well to regional modelling. He also emphasized the need to zoom in into the problem and

to look into details in order to understand what is going on (physics). This in contrast to global application for general validation which is good but does not in general provide insight.

The usual physics session was split in four parts this year. De Voogt chaired the *growth curve* part. The reanalysis of fetch limited data has finally let to a consistent picture. It was found that atmospheric (un)stability and wind field variations has been important causes of the previous discrepancies. Graber presented a promising new approach based on differential growth. Snyder reviewed progress in the new Blight of Abaco experiment. The Bight of Abaco group is ready now for inverse modelling of the field data with the aim of optimizing wave model source terms. Dobson discussed the problem of variable roughness length, an issue which is absolutely crucial for wave modelling and analysis. De Voogt concluded with a number of important observations. First of all the reanalysis of Kahma and Calkoen was done with a Wu type of drag coefficient. The newest insights indicate an additional dependence on wave age. A second reanalysis is desirable therefore. Further he pointed out that gustiness was not considered although this is thought to be important. Finally neither gustiness nor stability effects are treated by the WAM model.

The *directional effects* session had 3 papers. Using third generation concepts Gao and Komen have reanalyzed observations by Holthuijsen. The new analysis shows an improved correlation of observed dimensionless relaxation time scales with wave age. WAM model time scales are in good agreement with these observations. At the UK Met Office experiments with high spectral angular resolution show little effect on wind sea growth but an improvement for distant swell. Gerling fed WAM model spectra into a MEM reconstruction to show how a directional buoy would observe them. Session chairman Holthuijsen gave a detailed outline for the treatment of directional effects in the SCOR final report.

The shallow water session showed impressive results for various locations: Bristol Channel, the Norfolk bank, the German Bight (with a coupled boundary layer-wave-current model) and the Norwegian coastal waters. Young proposed a new shallow water experiment to obtain finite depth growth curves. Summarizing this session, Rosenthal emphasized the importance of further studies of the different dissipation mechanisms.

The *source terms in the Wam model* were discussed in a session chaired by Peter Janssen. Snyder presented a new scheme for calculations of the *nonlinear transfer;* van Vledder showed results of an improved treatment of the energy transfer across the high frequency cutoff. Cardone has extended the Direct Interaction Approximation to an approximation involving two interacting quadruplets. *Numerical aspects* were discussed by Tolman. He showed that for low wind speeds in order to obtain scaling the dynamic range has to be extended to higher frequencies. An error in the ECMWF model is being removed. This error resulted from an incorrect mixed implicit/explicit integration scheme. Janssen explained how correction of this numerical error leads to an improved stress calculation.

The input and dissipation source terms were treated simultaneously, as their effect on the energy balance is closely related. Makin and Burgers presented a totally new approach with a sea-state independent input. This approach contrasts with the one by Janssen which is based on quasi-linear theory. This theory predicts a significant effect of the sea state on the wind stress, which seems to be experimentally verified. Also was shown a video presentation of model output showing the effect on the atmospheric circulation. This study was done with the WAM model coupled to ECHAM, in a perpetual July run. Monbaliu used a quantitative approach to calculate a best fit to the source terms starting from the Jonswap relations. In this way he also obtains a sea-state dependent wind input. Cavaleri and Burgers described the effect of gustiness. A detailed study by Young of the high frequency behavior of the spectrum results in the suggestion that a k^2 dissipation is to be preferred. This is in agreement with the coupled model of Janssen. Polnikov discusses wave evolution using a simplified parameterization of the nonlinear source term and a quadratic dissipation law. The resulting overall picture of the energy balance still needs further clarification. Perhaps Monbaliu should repeat his analysis using a rescaled Jonswap curve based on Janssen's sea state dependent drag. Also the analysis of Young should be repeated within the framework of quasi-linear theory. Can the Makin Burgers balance be excluded on the basis of observations?

The *data assimilation* session showed interesting new results. Susanne Hasselmann reviewed the status of the draft chapter for the final report, and gave a brief overview of current assimilation theories. Long expanded on the adjoint method with an application to the problem of inverse modelling of the Bight of Abaco II observations. Work at Delft Hydraulics on the adjoint method was sketched by van Vledder. Brüning presented progress with the inversion of SAR observations using modelled WAM spectra as a first guess. Bauer showed how these spectra can be assimilated into the WAM model. Miriam de las Heras presented the first results on the consistent assimilation of wave and wind observations in a coupled atmosphere wave mode. Foreman reported on wave data assimilation at the UK Met office. They are ready to assimilate ERS-1 observations in their second generation model, as is the WAM model at ECMWF.

Klaus Hasselmann chaired an open *model development group* meeting in which it was decided that Janssen's physics will be incorporated in the upcoming cycle 4 version of 3G-WAM. It was also noted that there is no urgent need for modification of the numerics. Later we should improve physics using a systematic inverse modelling approach applied to the operational products from ECMWF, and to the SWADE and Bight of Abaco II measurements.

Gerbrand Komen closed the meeting by summarizing discussions on the final report, thanking the local organizing committee and all participants and announcing WAM 10 to be in Lisbon (to be confirmed).

ANNEX V

Working Group 96
Acoustic Monitoring of the World Ocean

Inaugural Meeting, August 22, 1991 IAPSO Office, IUGG, Vienna

Present
Co-Chairmen: Guan Dinghua, D. Farmer (elected as Co-Chairs at this meeting)

Members: W. Munk, L. Bjorno, A. Forbes, I. Nakano

Corresponding Members: A. Baggeroer, Z. Klusek, A. Voronovich

Observers: J. O'Brien (IAPSO), A. de Mesquita, J. Harari, I. Kozhevnikova, Y. Volkov, V. Efimov, M. Slavinsky, J. Spiesberger, N. Dubrovsky, I. Prianikov, A. Kerr, P. Worcester, B. Howe, W. Kuperman, B. Kerman

At its General Meeting of October 1990, the Scientific Committee on Ocean Research accepted a proposal made by the USSR Committee for SCOR to establish a new working group on acoustic monitoring of the world ocean. It was further proposed that the new Working Group 96 hold an informal meeting at the IUGG Assembly in Vienna in August 1991. The inaugural meeting of SCOR working group WG 96 was designed to acquaint the members with each others' views at the earliest possible opportunity after its formation.

1. Opening Remarks
After the host, Professor Jim O'Brien of IAPSO, had welcomed the group, the chairman, Professor Guan Dinghua, opened the meeting with a review of the development of acoustical oceanography. He read a copy of the SCOR proposal to form a working group on "Acoustic Monitoring of the World Ocean". He listed the group's terms of reference (enclosed).

The chairman then read David Farmer's proposed agenda for the meeting, which was accepted by acclamation.

Jim O'Brien, representing SCOR, outlined the role of working groups in the SCOR structure and pointed out that the normal life of a working group is two years. We may arrange our own leadership and schedule our own meetings.

David Farmer was then elected as co-chairman of WG 96.

2. Overview of Heard Island Experiment
Walter Munk put the January 1991 experiment, in which nine countries participated, in perspective by describing the link between ocean acoustics and climate research. He remarked on the necessity to consider the effects of acoustic transmissions on the marine

mammals which inhabit the ocean. In order to do ten years of acoustic monitoring of ocean temperature in the future we will need to follow the proper marine mammal permit process. He also stressed the need to formalise the international collaboration and cooperation on global acoustic monitoring which had been done so far on an informal basis. He also made it clear that acoustic data from the Heard Island Feasibility Test (HIFT) are available on request to all participants.

Andrew Forbes summarised source intensities for the 35 transmissions during five days of HIFT and described briefly the quality of the received data at many of the stations around the world.

Nikolai Dubrovsky presented a summary of the Soviets' recordings from their ship in the North Atlantic. He described their progress on processing of results and indicated their interest in contributing to a future array of sources.

Art Baggeroer drew the group's attention to the ASA meeting at Houston in November as the first opportunity to present some results of HIFT in detail. Several members reaffirmed their intentions to present papers at that meeting.

Art then described his involvement in the HIFT receptions with a vertical array off Monterey and further south. His data were low level (10 dB less than noise), but were brought up to +5 dB with narrow band filtering.

David Farmer reported on Ross Chapman's and Garry Heard's results from the west coast of North America, and also mentioned the Canadian observations on the East coast. He emphasised the Canadians' strong interest in participating in future experiments.

3. The Next Step

A. Walter Munk reserved his suggestions on a future global array configuration for later in the meeting.

B. Art Baggeroer commented that from HIFT we have learned that in future:
   1. We will need receiver arrays, not single point hydrophones.
   2. The structure of signals over 10 Mm is very complex, so ...
   3. We will need big array gains (say 100 elements at 1/2 lamda spacing).
   4. Reverberation and horizontal multipaths are still problems which we need to understand.

C. Prof. Guan discussed the following desirable arrangements for the future:
   1. Individual exchange of ideas and data should be done expeditiously via fax and e-mail.
   2. He would like to see SCOR contact other global programs and organizations - WOCE, ICA, IUGG, IAPSO - to arrange special sessions on global acoustic monitoring of the ocean at conferences over the next two years.

D. Walter Munk spoke about possible source array configurations for the future and made several specific points:

1. The biological community must achieve a consensus on the depth to which marine mammals may be affected by acoustic transmissions. 50 m was originally suggested, but permitting authorities changed that to 80 m for HIFT.
2. We can possibly avoid the near-surface region altogether by careful directional array design.
3. An efficient array could well consist of ten elements at 1/2 lamda spacing.

Walter showed colour contour vertical section plots of source intensities for HIFT and for a possible (deep) future array. He emphasised the point that part of our future program funds will have to be spent on bio-acoustic research.

E. David Farmer proposed that the next, and first formal, meeting of WG 96 should be at the Scripps Institution of Oceanography in June '92 following the Pacific Science Congress on Marine Science and Technology PACON 92, meeting in Kona, Hawaii, June 1-5. The suggested dates were June 7-8. Since these fall on Sunday and Monday, it has been decided that the meeting should be June 8-9. Walter Munk agreed to host the meeting. SCOR can fund members' attendance. At that meeting we will firm up plans for long term programs.

On the question of a technical meeting (rather than an organisational, planning meeting), David proposed that we hold one after our plans are further along. Mel Briscoe (ONR) has indicated that his office would consider a request for support of such a meeting, and David will ask Mel for support for non-members to attend (since SCOR would support members).

David then opened discussion on the IOC Beijing workshop report (on ocean acoustics), which IOC and SCOR have asked us to consider. He read from the report a list covering a very broad range of acoustical issues (including global temperature monitoring). He recommended that SCOR advise IOC on what we are doing, but if IOC wants to set up its own expert group on the full range of issues it should exclude our specific interests.

Leif Bjorno had a meeting with the IOC group to decide their terms of reference (it took two months to reach a decision). He offered to co-ordinate the relationship between IOC and SCOR WG 96 to ensure that each group knows what the other is doing and that there is no duplication of effort.

Art Baggeroer mentioned that the OSB is publishing a report on international collaboration in ocean acoustics and that he would provide David Farmer with a reference.

Some discussion then took place on how to define the scale of the working group's interests. Mesoscale, basin scale, large scale and global scale were all canvassed. Peter Worcester suggested that the scale should be basin rather than mesoscale although lengths may change depending on the size of the basin. The motivation for the working group is to involve international groups which emphasizes the basin scale phenomena, but may also include some short range studies.

F. Walter Munk moved, and the meeting unanimously passed the motion, that the following list of topics be considered for the next WG 96 meeting:

1. Acoustic sources - a new design is required with the following features:
   a. Reliability: suggested 10 years, high priority.
   b. Frequency: 70 Hz?
   c. Bandwidth: 10 Hz at least.
   d. Intensity: depends on basin size.
   e. Working depth: to suit local axial depth.
   f. Duty cycle: to accommodate a range of time scales.
   g. Vertical array.
   h. Cable-connected to shore.
2. Receivers - with the following features:
   a. Vertical and horizontal arrays.
   b. Fibre-optical cabling to shore?
   c. Reliability - again high priority.
3. Source and receiver repair should be possible without losing fixed location.
4. Is GPS relocation adequate?
5. Criteria for locations: narrow shelf, steep slope, shore power. Co-located sources and receivers?
6. Proposed arrays must be evaluated against the requirement to be gyre-resolving. Consideration of existing models of ambient ocean variability and spatial distribution of greenhouse effect warming.
7. Environmental impact (minimal).

John Spiesberger then presented the results of his work on long range acoustic transmission in the North Pacific. The principal result is that his observations of travel times were primarily a measure of temperature variability. He mentioned Mark Slavinsky's source (70% efficient, 100Hz, +/- 7Hz bandwidth) and proposes to test its long term reliability in a deployment off Hawaii (to take advantage of an existing cable).

Alexander Voronovich reported on a mode-resolving experiment with a 29 element vertical array at 50 km range with some inhomogeneities in between. Matched field processing yielded an accuracy of flow measurement of 0.4 m/s. He wants to exchange information with others who have similar experience with this type of work. His results are not yet published, but he will give Art Baggeroer a copy of a draft

paper.

Leif Bjorno mentioned a European Community study of effects of low frequency devices on marine organisms.

Vladimir Efimov suggested that the Black Sea is a useful test area where his laboratory maintains a very large platform that can be placed anywhere in the sea.

In the course of the meeting it was emphasized that WG 96 should maintain a narrow range of activities, i.e., the acoustic monitoring of world oceans on a basin scale, with the hope that IOC experts would take care of the wider range of applications of acoustics such as the development of technology and the application of marine acoustics to different fields of oceanography.

The chairman then closed the meeting with thanks to the participants for making it most interesting and productive.

PLANS FOR FIRST FORMAL MEETING - JUNE 8-9 1992 - GLOBAL ACOUSTIC MONITORING -- TECHNICAL STRATEGIES AND PLANS

WG 96 made preliminary plans for a meeting to be held June 8-9 at Scripps Institution of Oceanography, hosted by Walter Munk. This meeting will focus on optimal approaches to future global acoustic monitoring studies. The following topics are identified:

1. Possible source and receiver stations.
2. Optimal strategies for acoustical frequency, power levels, coding, transmission times, etc.
3. Suggestions and plans for design of appropriate acoustical sources.
4. Strategies for minimising impact on marine mammals.
5. Suggestions and plans for design of appropriate hydrophone arrays and receivers.

(Additional topics may be added and suggestions are solicited, but the intention in this two-day meeting is to focus on just the practical issues of implementing a global program.)

ANNEX VI

Report of the
SCOR-IOC Committee on Climatic Changes and the Ocean

Prepared by: Raymond H. Godin, Secretary, CCCO

Since CCCO-XI, events on the international scene have moved rapidly. ICSU, SCOR, WMO and IOC agreed during the Fall, 1990 to increase collaboration between the Joint Scientific Committee (JSC) and CCCO through the formation of the CCCO Executive Group which along with the JSC will act as a single body to provide scientific guidance to all components of the World Climate Research Programme (WCRP). The TOGA and WOCE projects reported the state of their planning and/or implementation to the JSC and CCCO Executive at JSC-XII, Bremen, 18-23 March 1991. The Second World Climate Conference, Geneva, 29 Oct - 7 Nov 1990 recognized that the ocean plays a major role in climate change and the urgent need to create a Global Climate Observing System (GCOS) which would be based upon an improved World Weather Watch Programme and the establishment of a Global Ocean Observing System (GOOS) of physical, chemical and biological measurements. A proposal for a GCOS prepared by an *ad hoc* group, convened by the Chairman of the JSC for the WCRP at Winchester, 14-15 Jan 1991 identified the establishment of the Global Ocean Observing System (GOOS) as a prime GCOS requirement. It was confirmed at the Sixteenth IOC Assembly, Paris, March 1991 that the IOC would establish a GOOS and offer to co-sponsor with ICSU and WMO the WCRP. The Eleventh WMO Congress, May 1991 approved the formation of a GCOS and authorized amending the existing ICSU-WMO agreement to include IOC as a co-sponsor subject to the negotiation of organizational, financial, and staffing implications.

The Twelfth Session of the CCCO under the chairmanship of Prof J. J. O'Brien was held at the U.S. National Academy of Sciences' Woods Hole Study Center, Woods Hole, USA (4-8 June 1991). The CCCO evaluated progress in the six areas which were identified at CCCO-11 as requiring priority attention during the intercessional period. Included were: (i) ocean observing system development; (ii) carbon dioxide gas exchange of gyre-global scales; (iii) review of the IPCC Working Group I report, in view of the need for updating on the basis of new findings; (iv) freshwater budget; (v) improving prediction of the regional impact of climate change on coastal environment; (vi) control of thermohaline circulation, including especially consideration of the influence of the Arctic Ocean on climate.

Interdecadal Ocean Climate Variability

After receiving several presentations which included the freshwater budget and the control of thermohaline circulation, the Committee decided to initiate an examination of climate change on interdecadal time scales.

The Committee's deliberations on the thermohaline circulation evolved and expanded

into a discussion of interdecadal ocean climate cycles. It was noted that there was very little consideration of the high-latitude ocean circulation in the newly proposed WCRP Arctic System Study (ACSYS). Though deep water formation was reported to be of 'first order importance', the 12 lines devoted to this subject in the 17-page report did not convey a convincing appreciation of this stated importance or that a specific initiative would result. The Committee also observed that the Atlantic was rich in climate signals on many time scales, and that the decadal flips of interhemispherical temperature anomalies were observed long ago.

Research on the Asian monsoon and the west Pacific circulation showed hydrographic data that indicate the existence of an extratropical decadal trend as well as a strong ENSO-related quasi-biennial oscillation. Both seem to originate from SST variations in the western tropical Pacific. Moreover, there is strong indication that a feedback mechanism exists between the Asian monsoon system and SST variations in the western Pacific.

The Committee also discussed a proposed ocean element for GEWEX, and noted the inadequacy of existing data (salinity and E-P) to make estimates of the buoyancy flux in the North Atlantic and that the situation is worse in other ocean basins. There is considerable evidence that deep water formation in the North Atlantic was interrupted many times in the past (as recently as the early 1970s) by low salinity caps. There is no consensus on how such caps are formed and how they influence the rest of the global circulation. It was clear, however, that low salinity caps have climatic consequences on decadal time scales which are larger than those anticipated from greenhouse warming on the same time scales. Obtaining estimates of freshwater flux in a single basin is fraught with difficulty because of the lack of knowledge of interocean transport. Thus understanding of the thermohaline circulation is hampered. It was inferred that the only consistent way to define fresh water flux is to calculate the freshwater flux volume globally.

Greenland Sea ice and salinity anomalies and interdecadal variability were also addressed. Large positive sea-ice and negative salinity anomalies observed in the Greenland Sea during the late 1960s were preceded by above-average runoffs from North America into the western Arctic during the mid 1960s. Such strong freshets produced large positive sea-ice anomalies in the latter region which, it is argued, then drifted out of the Arctic into the Greenland Sea via the Beaufort Gyre and Transpolar Drift Stream about three to four years later. During the melt season such ice anomalies would have contributed to the production of an extensive cool, relatively fresh surface layer in the Greenland Sea which suppressed convective overturning during winter. The latter stably stratified oceanic state appears to have subsequently reduced high-latitude cyclonic activity and precipitation over northern Canada. This sequence of hydrological, sea-ice, oceanic and atmospheric events can be described in terms of a negative feedback loop which suggests the existence of self-sustaining climatic oscillations in the Arctic with a period of about 20 years. Remarkably, during the late 1980s another large positive sea-ice anomaly occurred in the Greenland Sea, in agreement with the hypothesized interdecadal climate cycle.

The Committee concluded that the lack of a coherent interdisciplinary programme addressing the thermohaline circulation constituted a major gap in the WCRP. The above presentations served to reinforce the priority-issue identification made during CCCO-XI. Further discussion considered the options available to pursue the development of an initiative to examine the interdecadal time scales of ocean climate. In the Committee's view, GEWEX, CLIVAR, and ACSYS were developing along lines that did not encompass the ocean issues related to interdecadal climate variability. The Committee also noted the existence of several international and national research programmes directed to changes in global climate and the particular importance of the ocean circulation on longer-scale fluctuations. The Committee established an ad hoc study group on interdecadal variability which will:

(i) Review the status of knowledge and existing activity in ocean research as it relates to interdecadal variability in global climate, with specific reference to thermohaline circulation, fresh water, air-sea interaction, and the carbon cycle.
(ii) On the basis of this review, define the framework and objectives of a workshop to develop future action by the research community.
(iii) Interact with JGOFS, OOSDP, WOCE, GEWEX, national programmes and other bodies appropriate.

The study group will report its findings at the next session of the CCCO.

Ocean Observing System Development

Steady progress has been achieved in the preparation of a conceptual design for a global ocean observing system in step with the development of TOGA, WOCE and JGOFS. The CCCO-JSC Ocean Observing System Development Panel (OOSDP) will formulate the conceptual design of a long-term, systematic observing system in order to monitor, describe, and understand the physical and biogeochemical properties that determine ocean circulation and the seasonal to decadal climatic changes in the ocean, and to provide the observations needed for climate predictions. The OOSDP has met three times in the past year and has been widely recognized as the primary scientific body which will address the climate related component of the IOC's Global Ocean Observing System (GOOS) which will also be a component of the WMO-IOC-ICSU Global Climate Observing System (GCOS).

Accomplishments include the review in general terms of the requirements (i.e. the climate related component) for a GOOS and the best approach for its design. A draft outline of the Panel's final report was developed as a method of focussing the Panel's activities. Papers have been prepared by its members. These mostly involved descriptions of the basic elements of the ocean component of the climate system, their relationship to climate prediction and a first consideration for each element of the measurements that could be acquired from a GOOS and assimilated into climate models. Reconsideration has been given of the overall approach that the Panel should take to the design of an ocean observing system and the appropriate way to subdivide consideration of this design. New assignments

were given to panel members which for the most part are aimed at the definition of the space/time scales of various elements of the ocean climate system and at the initial consideration of the measurements that would be required to observe their variability. Papers are to be published during the next year based on its work. These would usually be prepared by members of the Panel and reviewed both by the OOSDP itself and selected external experts. The aim would be to provide the wider scientific community with some understanding of the OOSDP's progress and direction. They would also serve to stimulate discussion in the wider community. The first of these papers in entitled "The Role of Models in an Ocean Observing System" and will be distribute before the end of the year. Liaison members to the OOSDP present include representatives from the WOCE, TOGA, GEWEX and JGOFS communities.

The Committee will provide input on ocean climate requirements for research and systematic observations through both ICSU and the IOC. These include the ICSU co-sponsored International Conference on an Agenda of Science for Environment and Development into the 21st Century (ASCEND 21), Vienna, 24- 29 November 91 and via the IOC to the Preparatory Committee meetings in preparation for the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, 1-12 June 1992 and the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change.

Carbon Dioxide Gas Exchange on Gyre-Global Scale

The joint JGOFS-CCCO Carbon Dioxide Advisory Panel was reconstituted under new terms of reference and membership [which were proposed at CCCO-XI and subsequently endorsed by the JGOFS Committee] addressed the design of a plan to acquire a global oceanic data set.

Current knowledge of oceanic and terrestrial biogeochemical processes is not yet sufficient to account quantitatively for exchanges between the atmosphere, ocean and land vegetation. Investigations are currently underway to investigate the oceanic biogeochemical processes relating the cycle of carbon in the ocean and to assess the capacity of the ocean for absorbing CO_2. A central question being addressed relates to the role of the ocean and its circulation in the uptake of CO_2 produced from the burning of fossil fuels. This uptake occurs via both physical and biological processes. Neither is well quantified on a global scale, and the regulation of the biological processes is at present only poorly understood. In particular, the biogeochemical processes responsible for the long-term storage of a portion of the total primary production cannot at this time be resolved sufficiently in time and space to say how they might be affected by climate change. Current CO_2 issues which are being addressed are centered on recognition of the oceanic anthropogenic CO_2 signal, satellite remote sensing observations of ocean color, winds and sea-surface temperature in association with models, methods of in situ measurements of the complete oceanic CO_2 system, and modelling/data analysis/algorithm development.

Several important issues were addressed by the Panel that are not directly taken into account in JGOFS and WOCE. They are:

(i) measurement quality - standards, intercalibration and data quality
(ii) global scale issues:
  (a) an inventory of the oceanic CO_2. This will be made possible by co-operation with the WOCE Hydrographie Programme (WHP) one-time "snapshot".
  (b) a global survey of surface seasonal CO_2. The developing strategy for this purpose includes satellites (for SST, winds, and color), *in situ* measurements (from ships of opportunity and new technologies) and models.
  (c) efforts aimed at 3-D modelling of the distribution of carbon and its time evolution in the ocean.

Reference materials are available for total CO_2 to q 1 ~mol/kg and will soon be available for total alkalinity to that same accuracy. The ability for various laboratories to attain this accuracy is improving but intercomparison tests have shown there are still systematic differences between measurements made at different laboratories which have to be explained and rectified in order to develop a coherent international data set.

The desired accuracy for pCO_2 is q.05 Pa and for pH is q.002. Reference materials for discrete measurements for pCO_2 and pH are being developed. Issues being addressed are:

(i) Shore based and shipboard calibration
(ii) Modelling, data analysis and algorithm development
(iii) Recognizing the anthropogenic CO_2 signal in the ocean
(iv) Priorities for measurement of ocean CO_2
(v) Satellite data
(vi) New instrumentation for ships and buoys

Improved quantitative understanding of the ocean's role in the global carbon cycle is being pursued through the WOCE and JGOFS scientific programmes. Success is critically dependent on acquisition of high-quality measurements of the oceanic carbon system. It is crucial to address the matter of measurement quality now as these two major international programmes are already underway. It would be a disaster to discover, after collecting data at sea for many years under WOCE and JGOFS, that measurements made by different laboratories at different times could not be compared and used simultaneously to get a coherent picture of the distribution of carbon in the ocean.

Review of the IPCC Working Group I Report

The Committee recognized at CCCO-XI that the IPCC WG-I report was a summary representing the state of understanding by its authors as of early 1990 and acknowledged the IPCC WG-I's stated need to update at frequent intervals. The Committee reviewed the

work of its ad hoc working group regarding the evaluation of the ocean related sections of the IPCC WG-I report.

The Committee recommended the next update of the IPCC Report should be expanded to take more account of the long-term processes implicated in the oceanic component of climate. Specifically, the following suggestions were made:

(i) In Chapter III on "Processes and Modelling", the difficulties of climate drift highlight the inadequacies of a "flux correction" approach. There is a need for better coupled models and for a more comprehensive treatment of sensitivity and resolution.

(ii) Chapter IV "Validation of Climate Models" needs to be expanded to include a discussion of vertical resolution problems. The possibility of rapid change between alternative stable ocean states should also be mentioned.

(iii) Chapter V "Equilibrium Climate Change...". The "best guess" value appears to be skewed towards the lower end of the range of estimates provided. This should be explained or adjusted. There was also a need to carry out equilibrium calculations, despite their cost.

(iv) In Chapter VII "Time Dependent Greenhouse Gas-Induced Climate Change", it would be useful to include a longer range of expectations and to expand the treatment or sensitivities. The treatment in this chapter of sub-grid-scale mixing also needed to be reviewed and revised.

(v) Chapter IX "Narrowing the Uncertainties", it was considered that more material should be included covering the rejection of flux correction methods and the need to have both equilibrium and transient calculations made with coupled models. It would be a useful exercise to drive models with observed surface fluxes, and to use SSTs as a test of product accuracy, rather than to drive with both sets of data.

The results of the study and an offer of CCCO assistance in updating and revising the Report were conveyed to Dr. J. Houghton, Chairman, IPCC Working Group I.

Improving Prediction of the Regional Impact of Climate Change on the Coastal Environment

The Committee recalled the need to encourage further investigation on how a global rise in mean sea level would be manifested in steric heights, and how changes in ocean currents would affect regional sea level. The CCCO Ocean Panels had been requested to examine the issue.

The CCCO Pacific Ocean Climate Studies Panel, Sydney, February 1991 addressed the matter and reported an example, the information for which appeared in a Bulletin of the University of Sydney Marine Studies Centre. An example was provided which recognized the possible flip-flops between quasi-stable alternative states of oceanic circulation, based on Geophysical Fluids Dynamics Laboratory (GFDL) numerical experiments. Calculations were made on the expected changes in steric height which would accompany suppression of

North Atlantic Deep Water (NADW) formation and export via the "Atlantic Conveyor Belt". The calculations indicated a rise in sea-level of a fresher Atlantic Ocean of up to 70 cms which would be balanced by a general fall of 10 to 30 cms in the slightly saltier Pacific and Indian Oceans.

The Committee observed that the generally lower recent estimates for sea-level rise implied a greater need for expert opinion in cautioning or reassuring regional authorities. The Committee also noted the need of the IOC for advice and input from the Committee in this area, including the implications of sea-level changes.

The Committee noted that expert scientific advice in a more practical form was urgently required by some governments for climate change environmental impact assessments. The Committee agreed to explore with the Secretary IOC the practicability over the next year of putting together in an appropriate media, advice in "popular" form on regional questions regarding climate and sea-level change of public concern.

The CCCO Executive

The CCCO Executive Group was formed by agreement of ICSU, SCOR, IOC, and WMO in the autumn of 1990. Discussions concerning the scientific conduct and implementation of the World Climate Research Programme (WCRP) and specifically the relationship of CCCO to the WCRP lead to the new agreement. The organizations recognized that the JSC, as constituted at present under the rules of procedure adopted by ICSU and WMO, would be strengthened by expanding the representation of ocean sciences. As a result the CCCO Executive was constituted, consisting of four representatives [J. O'Brien (Chairman), T. Barnett, A. Clarke, and G. Philander], to participate fully in the yearly session of the JSC, on an equal basis with the regular members of the JSC. The details regarding the new arrangement are specified below:

(i) The Joint Scientific Committee (JSC), nominated by ICSU and WMO, will meet in regular sessions with the CCCO Executive Group, constituted by up to four nominated representatives of CCCO.

(ii) The combined committee, constituted by the JSC and the CCCO Executive Group, will act as a single body to provide scientific guidance to all components of the WCRP. To this effect, all WCRP projects will report their progress in planning and/or implementation to this combined committee.

(iii) The combined committee will:

1. Formulate the interdisciplinary scientific strategy for and provide scientific guidance to all components of the WCRP.
2. Identify gaps in all aspects of earth climate system science not covered by existing international climate research projects and take appropriate initiatives to further develop the overall interdisciplinary science plan of the WCRP.
3. Recommend new WCRP science initiatives and changes in the implementation of WCRP projects.

4. Constitute working groups or special study groups, select scientific and technical experts for such groups and convene meetings as appropriate within established resources.

(iv) The CCCO Executive Group will further advise and suggest ways whereby CCCO activities could be made more effective in meeting the requirements of the WCRP.

(v) The combined committee will, to the extent possible, schedule sessions during periods avoiding the meetings of the Governing Bodies of ICSU, IOC and WMO.

The First Meeting of the JSC and the CCCO Executive Group took place at the Twelfth Session of the JSC, Bremen, 18-23 March 1991. The major results of the session were the decision to establish a Study Group to examine the feasibility of a Climate Variability and Prediction Programme (CLIVAR) as a follow-on from TOGA and WOCE and a decision to establish a Study Group to develop scientific rationale and concept for an Arctic Climate System Study (ACSYS) as a possible major new component of the WCRP.

CLIVAR is to assess the future orientations of global climate research and prospects for a further WCRP science initiative beyond the on-going programmes of TOGA and WOCE. The initiative should lead to a study of the time-dependent wind-driven and thermohaline circulation of the global ocean, and the dynamics of the coupled atmosphere-ocean-land system, based on four-dimensional assimilation of observations which could be provided by the future Global Climate Observing System. It should also address the problem of predicting the variations of the coupled atmosphere, ocean and land surface climate system on time scales of several months to several years. The CLIVAR Study Group which is composed of L. Bengston, T. Barnett, M. Cane, A. Clarke, W. Gates, J. Shukla, and C. Wunsch met in September 91 and may meet once more before reporting on its progress to the next session of the JSC and CCCO Executive Group in March 1992.

As part of the agreement, both the JSC-CCCO established programmes represented by the Tropical Ocean and Global Atmosphere Programme (TOGA) and the World Ocean Circulation Experiment (WOCE) were reported upon. The TOGA observing system is well implemented, particularly in the Pacific. The TOGA Coupled Ocean Atmosphere Response Experiment (COARE) will proceed with a planned Nov 92 to Feb 93 implementation despite difficulties with platforms for doppler radars. Plans for a quasi-operational TOGA prediction center are developing and discussions on the continuation of TOGA observations after 1995 are underway.

The World Ocean Circulation Experiment (WOCE) observing period has been extended to 1990-1997 (instead of 1995) to allow for completion of some hydrographic sections that cannot be completed in the initial five year period. A major difficulty is the lack of suitable salinity sensors for use on ships of opportunity or unattended platforms.

IOC Co-Sponsorship of the WCRP: Implications for the CCCO

The Committee perceived that the success of the oceanographic research

communities'efforts through the CCCO in attaining WCRP recognition of the important role of the ocean in global climate change was recognized by the ICSU, WMO, and IOC. The World Ocean Circulation Experiment (WOCE) and the oceanographic component of the Tropical Ocean and Global Atmosphere Programme (TOGA) are the results of those efforts. It is now widely accepted that ocean processes play an essential role in shaping the earth climate and controlling climate change, and the Committee strongly believed that the full and equal participation of the international oceanographic community in WCRP is a pre-requisite for the success of the Programme.

The Committee supported the efforts of the IOC to co-sponsor the WCRP, noting that the full and equal oceanographic representation on the JSC is essential for successful planning of the WCRP. The Committee also acknowledged that the CCCO's terms of reference may also have to be revised in order to reflect new directions. The Committee proposed that the membership of the JSC should be strengthened by expanding the representation of ocean sciences to be reflected in its revised membership. The Committee also proposed that, in addition to more physical oceanographers, ICSU-WMO- IOC should add hydrological scientists to help manage and direct the future WCRP programme. All members should participate on an equal basis including having the opportunity to be considered for election as officers of the JSC.

The Committee agreed that its Officers would offer their assistance to IOC and ICSU/SCOR in the negotiation process which is to take place.

CCCO Ocean Climate Studies Panels

Atlantic Ocean Climate Studies Panel:

The Committee reorganized the Panel by agreeing upon a plan of action and recommendations for new membership and agenda for their next meeting. The plan was devised in order to meet the revised terms of reference which broadened the Panel's focus from the tropics to the entire basin. The plan included the acceptance of an invitation from Dr S. Lappo for the Panel to co-organize an Atlantic Climate Research Workshop, Moscow, 18-22 May 1992. It was proposed that the workshop would be concerned with the entire Atlantic Ocean in order to address issues related to the oceanic conveyor belt and its variability on time scales from seasons to decades and longer. The workshop would afford an opportunity to explore the extent to which operational ocean models can integrate and give coherence to various oceanographic activities. The matter of reanalysis --rerunning a data assimilating model for a certain period to provide the best possible interpolated data sets -- could also be addressed. In addition to the Atlantic Panel, invitees would include representatives from CCCO, TOGA & WOCE SSGs, JSC-CCCO Working Group on Air Sea Fluxes, OOSDP, and leaders from national programmes. Meeting objectives would include:

(i) a scientific review of what is known about this phenomenon
(ii) a presentation of results from current studies of the conveyor belt
(iii) a discussion of plans.

Pacific Ocean Climate Studies Panel:

The Panel held its Eighth Session in Honolulu, 10-14 July 1990 and its Ninth Session in Sydney, Australia, 4-7 February 1991.

The Panel had assumed a task for tracking the evolution of the ocean observing systems in the Pacific. It had begun developing statistics of moored-buoy days, XBT and TESAC reports in real time and delayed mode, etc., and was investigating the feasibility of preparing inventories of time series that derive from XBT lines that have been run formany years. These annual inventory statistics illustrate, in one document, the current volume and kind of observations being produced by all programmes (WOCE, TOGA JGOFS, etc.) active in the Pacific. This effort also has been useful in monitoring progress in implementing observing systems, reviewing the systems for data distribution, and identifying weaknesses which can be addressed by appropriate international mechanisms.

Many new field and modelling efforts of Pacific investigation were concerned with the western boundary current regime. The Panel proposed that a well-planned western Pacific boundary current initiative developed under the auspices of the CCCO would greatly enhance these efforts.

The Committee endorsed the Panel's proposal and encouraged the Chairman to pursue the development of a western Pacific boundary current initiative at the IOC-WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas, Penang, Malaysia, 2-6 December 1991 and to focus the agenda of the next session of the Pacific Panel on this subject. Invitations should be issued to JGOFS representatives and others who have overlapping interests on this potential initiative.

The WMO-UNEP-ICSU-UNESCO-IOC-FAO Second World Climate Conference

The Second World Climate Conference was held in Geneva, 29 Oct - 7 Nov 1990. 138 countries were represented at the Conference and there was no question that the prospect of global change is being recognized as a formidable challenge which human societies will face for many years to come.

The Conference Statement was emphatic in acknowledging that uncertainties in predictions, especially as regards to future regional climate and climate impacts can only be narrowed down through research addressing the following priority areas:

(i) clouds and the hydrological cycle;
(ii) greenhouse gases and the global carbon biogeochemical cycles;

(iii) oceans: physical, chemical and biological aspects; and exchanges with the atmosphere; (iv) paleo-climatic studies;
(v) polar ice sheets and sea ice; and
(vi) terrestrial ecosystems.

The Conference explicitly recognized the roles of the World Climate Research Programme (WCRP) and the International Geosphere Biosphere Programme (IGBP) with the statement:

> The organizational framework for international scientific research is in place, constituted by the WCRP, emphasizing the physical aspects, and the IGBP, covering bio-geochemical aspects.

The Statement also concluded that:

> There is an urgent need to create a Global Climate Observing System (GCOS) built upon the World Weather Watch Global Observing System and the Integrated Global Ocean Service System and including both space-based and surface-based observing components. GCOS should also include the data communications and other infrastructure necessary to support operational climate forecasting.

GCOS should be designed to meet the needs for:

(a) climate system monitoring, climate change detection and response monitoring, especially in terrestrial ecosystems,
(b) data for application to national economic development, and
(c) research towards improved understanding, modelling and prediction of the climate system.

Such a GCOS would be based upon:

(1) an improved World Weather Watch Programme
(2) the establishment of a global ocean observing system (GOOS) of physical, chemical and biological measurements;
(3) the maintenance and enhancement of monitoring programmes of other key components of the climate system, such as the distribution of important atmospheric constituents (including the Global Atmosphere Watch), changes in terrestrial ecosystems, clouds and the hydrological cycle, the earth's radiation budget, ice sheets, and precipitation over the oceans.

The Conference also highlighted the need for intensified efforts to improve our knowledge of the impacts of climate variability on human socio-economic systems, with the objective of developing national skills and strategies to mitigate the impacts of climate change or to adapt to it.

The Committee noted that oceanographic representation had been particularly

successful at SWCC in raising the awareness of the important role of the ocean in climate change. The Committee recognized that IOC co-sponsorship of the Conference and the influence of its Executive Head Dr G. Kullenberg were instrumental in assuring appropriate oceanographic representation and raising a previously low level understanding of the importance of oceanographic features in climate study.

The Joint WMO-IOC-ICSU Workshop on a Global Climate Observing System

The Chairman, reported on an ad hoc meeting, sponsored by WMO, IOC and ICSU which was convened by the Chairman of the Joint Scientific Committee for the World Climate Research Programme at Winchester, UK, 14-15 January 1991. The meeting prepared a proposal which addressed one of the main recommendations of the Second World Climate Conference which was the need to establish a Global Climate Observing System (GCOS).

The goals of GCOS are as follows:

(i) Climate system monitoring, climate change detection and response monitoring, especially in terrestrial ecosystems;
(ii) Data for application to national economic development;
(iii) Data for research towards improved understanding, modelling and prediction of the climate system;
(iv) Eventually, a comprehensive observing system for climate forecasting.

The need is for a Global Climate Observing System which provides:

(i) Comprehensive information on a wide range of atmospheric, land surface and coastal and deep ocean properties;
(ii) Global coverage;
(iii) Continuity of observations on decadal time-scales;
(iv) Systematic data acquisition and international data exchange.

The prime requirements to move from the present state to an effective GCOS are:

(i) The improvement of specific components of the World Weather Watch (WWW) and the development of some additional atmospheric observing networks;
(ii) The establishment of the Global Ocean Observing System (GOOS).
(iii) The continuation of national and international science programmes, such as the World climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP), and from that base, the development of a global land-surface observing system;
(iv) The maintenance and further development of a comprehensive satellite programme in which emphasis in placed on both increased accuracy and continuity of observation, for oceanic and continental, as well as atmospheric properties;
(v) The development of new observing technologies in specific areas.

CCCO Membership

Drs S. Gadgil, L. Merlivat (FR) and V. Zalesny (USSR) retired from the Committee. A one year extension of membership to Dr. P. Killworth (UK) will be requested to permit completion of his two year term as Vice-chairman. Assistance has been requested from the CCCO's parent bodies to identify a biological and coastal experts to help broaden membership expertise.

Work Programme and Resources

The planned CCCO Work Programme for 1992 will require a minimum of $ 240,000 (includes $ 108,000 IOC & SCOR support for the WOCE International Project Office which is administered by the Secretary CCCO). Staffing support for the CCCO Secretariat is supported by the USA (2) and UNESCO/IOC (1). Dr. B. Gordon-Smith who was seconded by Australia completed his two year assignment with the CCCO Secretariat in June 1991.

ANNEX VII

THE JOINT GLOBAL OCEAN FLUX STUDY

Report from the JGOFS Scientific Steering Committee
to the
30th Executive Committee Meeting of SCOR
By: E. Tidmarsh

Since the XX General Meeting of SCOR (October 1990), the JGOFS community has been very active, primarily in planning activities, although several cruises continued the work begun in 1989 during the JGOFS North Atlantic Bloom Experiment (NABE).

JGOFS SSC, Fifth Meeting

The Scientific Steering Committee for JGOFS held its fifth meeting at the US National Academy of Sciences in Washington in late November 1990. Highlights of this meeting included the formal endorsement of the JGOFS Science Plan which had been published by SCOR in August 1990 and of a JGOFS "brochure" entitled "Oceans, Carbon and Climate Change; an Introduction to JGOFS" which was prepared for JGOFS and SCOR by Dr. Phillip Williamson of the Plymouth Marine Laboratory with support from the government of the Federal Republic of Germany and from a number of commercial sponsors. Both of these publications have been well received and have been in great demand in the international community.

Another concern of JGOFS-5 was the first in depth consideration given to the preparation of a JGOFS Implementation Plan as a companion to the Science Plan. This document will provide the detailed information as to how JGOFS intends to achieve its scientific goals and objective. It will provide a tool for tracking progress in JGOFS, an inventory of projects and activities contributing to JGOFS and statements about the resources required to carry out JGOFS. It will define the criteria for assessing the success of JGOFS studies in relation to the overall goals of the program, but will also provide such particulars as cruise schedules, mooring locations, and so on. It was agreed that the JGOFS Task Teams would each contribute major sections of the Implementation Plan and each of them presented preliminary reports to the SSC at its meeting.

This report will not dwell on the reports and discussions at the JGOFS-5 meeting, since the SSC held its sixth session recently and many of the decisions of the Washington meeting have now been implemented or have been overtaken by events. Two administrative matters were discussed at JGOFS-5:

Membership
The JGOFS SSC was informed that the SCOR General Meeting (October 1990) had

approved the recommendation of the JGOFS Executive that Dr. Trevor Platt (Canada) succeed Professor Bernt Zeitzschel (FRG) as Chairman of JGOFS. This change took effect on January 1, 1991. For the first time, a fairly large number of individuals (8) were due to rotate off the Committee and the SSC had a lengthy debate on general membership issues. In summary, it was agreed to suggest to SCOR that Otis Brown (USA) and Ken Denman (Canada) be invited to serve an additional two year term on the JGOFS SSC. H. de Baar, H. Elderfield, Dunxin Hu, I. Koike, J.F. Minster would retire from the Committee and B. Zeitzschel would remain a member for one year as Past-Chairman. The following nominations were forwarded to the President of SCOR and were approved, taking effect on January 1, 1991: P. Buat Menard (France), J. Field (South Africa), G. Harris (Australia), S. Krishnaswami (India), M. Leinen (USA) and U. Siegenthaler (Switzerland). P. Buat Menard is a member of the IGAC SSC and will provide liaison to that program. Similarly, John Field is a member of the LOICZ SSC. Information on the current membership of the SSC is provided in Appendix 1. Recommendations as to membership changes to take effect on January 1, 1992 will be found later in this report.

As JGOFS has developed many more countries have become involved. For practical and financial reasons it is necessary to limit the size of the SSC and while it is desirable that its membership be as international as possible, they are appointed primarily for the specific scientific expertise each can bring to the planning process. It is not possible for all participating nations to be represented on the SSC; even those with fairly large national programs may sometimes be without representation on the Committee. In order to resolve these competing demands and to involve a broader range of individuals in the international planning process, the SSC agreed to create a Council of National JGOFS Chairmen which will be invited to meet in conjunction with the SSC. It was hoped that the Council will provide a forum for the direct exchange of information between the countries with formally established JGOFS programs and the provision of needed information on national plans to the JGOFS SSC. A survey conducted by the Chairman and Executive Secretary of JGOFS resulted in the identification of the Chairmen of national JGOFS committees in about twenty countries. These individuals have been invited to join the Council and to attend JGOFS meetings in future, the costs of their participation being covered by the national programs they represent.

The Halifax JGOFS Secretariat

The SSC was informed of the decision of the SCOR General Meeting about the role of its Secretariat in the planning and coordination of large programs. It agreed upon a five year model for SCOR involvement in the routine management of large programs which will necessitate a gradual reduction (over the next two years) of the role of the SCOR Secretariat in JGOFS to a level of 5 to 10% of staff time. The Executive Director of SCOR has been serving as Executive Secretary of JGOFS since its establishment (and during the preceding planning activities) in 1987. At times this has consumed a major portion of her time. The establishment of the Kiel scientific secretariat and the appointment of Dr. G.T. Evans as Executive Scientist (seconded by the Canadian government) and of Dr. U. Wolf (of IfM Kiel) as his assistant has resulted in a gradual and continuing shift of many

responsibilities from Halifax to Kiel. Ms. Tidmarsh reported that her responsibilities to JGOFS must, therefore gradually be reduced during the next two years, although it was expected that the SCOR Secretariat would continue to administer funds for JGOFS, particularly those which come from grants to SCOR and from the SCOR budget. As this change has begun to take effect, the need for additional staff members in the Kiel office has been further emphasized.

NABE Symposium

The JGOFS Committee meeting was immediately preceded by a milestone event. The was the International Scientific Symposium on the JGOFS North Atlantic Bloom Experiment, organized and chaired by Dr. Peter Brewer, and hosted by the US National Academy of Sciences from 26 to 28 November, 1990. This event provided the first forum for the presentation of JGOFS scientific results. Nearly 150 individuals, most of them participants in NABE, the 1989 JGOFS Pilot Study presented their findings in invited lectures and numerous posters. In the closing session a panel of invited experts evaluated the successes and failures of the Pilot Study. The symposium featured multi-authored lectures summarizing the findings by of the various national groups taking part in NABE and at each of the major sites along the 20°W transect. Among the scientific highlights were the demonstration of the substantial draw down of atmospheric CO_2 during the bloom, of the influence of biological processes on surface pCO_2, of preliminary success in comparisons of model simulations of biogeochemical processes using data sets from NABE, and of the quantitative importance of microzooplankton feeding and DOC in the upper ocean carbon cycle. A number of problems were identified as needing attention in planning for future process studies. These included the lack of agreement within data sets for a few core measurements indicating a need for careful revision of some of the JGOFS Core Measurement Protocols and for adherence to these protocols once they are adopted. The abstracts of the NABE Symposium were published in *JGOFS Report No. 7*, and the complete papers with additional contributions will appear soon in a special issue of *Deep Sea Research* being edited by Hugh Ducklow.

1991 Activities

As agreed at JGOFS-5, a number of the Task Teams and Planning Groups met during the first half of 1991. Their reports were discussed in detail by a small, informal meeting of the JGOFS Executive and invited scientists held at Cambridge, UK in July. The goal of this meeting was to consider the recommendations of the Process Studies, Time Series, Benthic Processes and Data Management Task Teams, in addition to those of the JGOFS/CCCO CO_2 Working Group and the Indian Ocean and Southern Ocean Planing Groups, and to provide detailed guidance to the JGOFS Executive Scientist in the preparation of a first draft of the Implementation Plan. This draft was distributed in the late summer and formed the primary discussion paper for the Sixth Meeting of the JGOFS SSC (Bermuda, September 30 - October 3).

JGOFS SSC, Sixth Meeting

The JGOFS Implementation Plan

The most important accomplishment of the recent meeting of the JGOFS Committee was the progress made with the production of the Implementation Plan, building upon the Science Plan and the input from the JGOFS Task Teams.

The Committee adopted an "operational goal" for JGOFS which is a version of the scientific goal, stated in more practical terms and which can be used as a criterion for assessing the relevance or success of individual components of the program. In draft form, this operational goal is:

> To assess regional to global and seasonal to interannual fluxes of carbon between the atmosphere, surface ocean and ocean interior, and their sensitivity to climate changes, especially through a better understanding of the controlling processes.

The analogy between the Implementation Plan and the Science Plan will continue with the description of a series of operational objectives and the definition of various observational elements or operational strategies to meet those objectives. This involved considerable discussion of the links between national programs and the international program (see below) and the recognition than many elements would require much greater regional involvement and, therefore, that a concerted effort must be made to provide training opportunities for scientists in certain regions. There has been some success in mobilizing funds for this in the FRG and The Netherlands, and the assistance of the Intergovernmental Oceanographic Commission of UNESCO is being sought as well.

The Implementation Plan will continue with sections on historical data sets and on the use of modelling in JGOFS. The SSC recognized that a major legacy of JGOFS will be the data sets it collects and that great effort must be put into care and management of these data sets. JGOFS has tentatively adopted a "distributed data system" with all countries reporting observation sets to the World Data Centres. The Implementation Plan will describe the resources that will be required in each participating nation and at the international level in order to ensure a successful, accessible and timely data management system. A similar section will discuss the resources needed in order to make the best use of the data which will become available from a variety of earth observing satellite systems.

One issue which had considerable discussion in the SSC meeting will be reflected in a section of the Implementation Plan on Synthesis. This is an activity which must go on continuously as data are accumulated and analyzed, and used in models which will become more sophisticated. These more sophisticated models should make it possible to identify key processes and fluxes and should, in turn be used to influence experimental design. A model for the scientific direction of the JGOFS program was discussed which involves a newly reconstituted Modelling and Synthesis Task Team and carefully planned workshops and

planning meetings in the experimental design process for each component of JGOFS.

A major section will deal with the general issues presented by JGOFS Process Studies, followed by specific discussions of each study. The reports of the Process Study Task Team as well as those of the regional planning groups provide information on the objectives, time frame, operations, cruise tracks, resource requirements, etc. for each Process Study. Those which are already in the advanced planning stages will be described in detail. These include the Equatorial Pacific Ocean (starting in 1992), Arabian Sea (1994-95) and Southern Ocean (1992-96) Process Studies. Planning is beginning for a North Atlantic Ocean Process Study to take place late in the JGOFS schedule (1996-97). This would build on NABE which, while successful, was not planned specifically to meet international scientific objectives, since national plans were fixed before JGOFS was established. The SSC recognizes that these areas are of primary importance in understanding the global carbon cycle: the Southern Ocean and North Atlantic as the areas with the largest fluxes of CO_2; the Equatorial Pacific being the region with the largest interannual variability, even exceeding seasonal variation; and the Arabian Sea because of the especially intense effects of monsoonal reversal of circulation and upwelling.

The SSC has recommended the inclusion of benthic studies in JGOFS, although they were dealt with only briefly in the Science Plan. The rationale for benthic studies and their basic design for understanding the oceanic biogeochemical cycle and interpreting the sedimentary record of climatic variability will be further explained in the Implementation Plan, along with information about their incorporation into each of the open ocean process studies and the resources required.

At the Bermuda meeting, the SSC formally approved the inclusion of continental margin studies in JGOFS, recognizing that the questions of scientific importance to JGOFS will not be fully dealt with by the Land-Ocean Interactions in the Coastal Zone (LOICZ) core project of IGBP, although there will be considerable overlap and liaison with th LOICZ program. The Implementation Plan will state the need for margin studies due to the importance of the coastal and shelf seas as areas of rapid carbon deposition, intensive benthic cycling and large lateral exchanges of materials with the open ocean. Such studies will provide the lateral boundary conditions needed for JGOFS models. Since most coastal studies contributing to JGOFS will involve only one or two nations, and will not be conceived and planned by the SSC the Implementation Plan will provide a statement of generalized objectives for such studies to ensure that they do assist in meeting the international scientific objectives. It will provide an inventory of such studies, planned and ongoing, and a statement of the criteria to be met in order for individual national projects to be considered as part of the overall JGOFS program. In this respect, one goal of the Implementation Plan is to encourage national initiatives and to indicate the links to multi-national regional studies such as the Kuroshio Edge Exchange Processes study. It will also list the types of marginal environments where JGOFS studies are needed most. These include areas receiving large amounts of river input, areas of strong upwelling or rapid exchanges with the open ocean, the southeast Asian archipelago, coral reefs and so on.

The need for additional time series stations and the resources required for their establishment were described in detail in a report to the SSC from the Time Series Task Team and will be presented in the Implementation Plan. JGOFS needs a number of these observing station in addition to those already operational near Bermuda and Hawaii.

The Implementation Plan will conclude with a section ("The Global Context: Beyond JGOFS") which demonstrates the need for collaboration with other IGBP Core Projects dealing with the coastal zone (LOICZ), atmospheric chemistry (IGAC), past global changes (PAGES). Complementarity with these programs and with those in the World Climate Research Program is particularly important in a time when resources for large-scale programs are limited.

International Obligations and National Activities

Funding for JGOFS is provided at the national level, and this fact greatly influences the basic rhythm of the program. International JGOFS must distil from national programs the things that will allow the achievement of global goals. It provides constructive guidance; it encourages national research in areas where it has traditionally not taken place; but it cannot force international will on these programs, nor render judgement on them. Many national activities will contribute to the achievements of integrative JGOFS goals without being part of the international implementation plan. The Council of National JGOFS Chairmen will provide a forum where national programs can interact with and report to the international body on such achievements.

Central planning is nonetheless necessary if the program is to cohere. International JGOFS will work through its task teams and planning groups to make it clear what it expects and not just try to work with what it happens to get; in order to make the most useful contribution to the international activity national programs should be planned to conform to these expectations to the extent possible. For example, data submission to the international scientific community is an important obligation of every JGOFS nation or project.

The JGOFS SSC spent some time during its meeting discussing this tension between national priorities and the obligations demanded of participants in JGOFS. A statement of what participation in JGOFS implies for a country was drafted during the meeting:

National participation in the international Joint Global Ocean Flux Study (JGOFS) requires a commitment to:

> Form a national JGOFS committee and appoint a chair, in accordance with national arrangements for participation in SCOR, IGBP or ICSU activities

Develop a national JGOFS programme to address JGOFS goals and objectives, as stated in the JGOFS Science Plan, and taking account of the advice and guidance of the JGOFS Scientific Steering Committee (SSC)

Carry out that programme in accordance with relevant aspects of the JGOFS Implementation Plan, using internationally-agreed methods and protocols wherever possible, and providing the opportunity for collaborations with JGOFS scientists from other nations

Participate in the activities of the JGOFS SSC, by assisting in the planning and development of the project as a whole, and reporting on national progress

Make data that have been obtained through the national JGOFS programme available to the international JGOFS research community, in accordance with JGOFS data exchange protocols

Seek, through their national funding agencies, staff and financial resources required to run the JGOFS office and other central services, including data management.

In this context, the Chairman of JGOFS, Dr. Platt, presented a model defining the various kinds of scientific contributions which was being used by the Global Climate and Terrestrial Ecosystems (GCTE) program of IGBP. Since JGOFS-6, this general breakdown has been adopted as a model for all of the Core Projects of the IGBP. It recognizes that various types of research activities, requiring different amounts of international oversight will all contribute to the success of large-scale programs, albeit in different ways. Levels 2 and 3 are important because they encourage the direct involvement of smaller nations.

These categories are:

i) Core Research - consisting of large-scale, integrative projects that are international in scale and global in scope. These projects have been designed specifically by the Core Project Scientific Steering Committee to meet Core Project objectives.

ii) Regional/National Research - arising from national IGBP (or JGOFS) committees or from other national or regional groups of scientists. On the whole the work will be designed specifically for the Core Project, but will often be national and/or regional rather than global in scope.

iii) Relevant Research (individual investigations) - there will be many smaller research projects initiated by individual investigators/ institutions that are proposed as Core Project contributions. The SSCs cannot review all of these proposals themselves, but will instead refer then back to the appropriate national IGBP (or JGOFS) committee for consideration and subsequent action.

"The philosophy is to be fairly restrictive in the first category, since it is essential to focus the limited expertise and facilities on a few, top-priority questions. Beyond this, the intention is to be inclusive, rather than exclusive, so that a large number of national and individual projects will build the broad knowledge base that underpins the GCTE effort"

GCTE News, No. 1, Aug 91

Other recent developments

The JGOFS community was very pleased to learn earlier this year that a new ocean colour instrument (SeaWIFS) will be launched in late 1992 or early 1993. The likelihood of having this remote sensing capability available at the same time as many of the JGOFS field programs are under way had been in grave doubt for a long time.

The SCOR General Meeting had requested Dr. Neil Andersen of the US National Science Foundation to advise SCOR and JGOFS as to a mechanism for the coordination of resources for the program. In particular, the creation of an international inter-agency resource panel had been suggested. Dr. Andersen has met with only limited success in seeking input from his colleagues in the funding agencies of other nations, however, responses have begun to arrive since the JGOFS-6 meeting in Bermuda. The JGOFS Executive have urged him to continue this effort and it is expected that the publication of the Implementation Plan will stimulate greater interest in the need for a forum to discuss and resolve the issues of resource requirements for JGOFS.

Support for International Planning Activities

Most urgent among these needs at the moment is the requirement for additional secondments of scientists to the Kiel office, or to work with the Chairman in Canada, on such matters as data management, field coordination, implementation tracking, measurement protocols and resource requirements. There are insufficient funds for the international planning activities and the JGOFS SSC urges the SCOR Executive Committee to assist in seeking new contributions to the JGOFS Special Fund which will be depleted by the end of 1991. The current level of funding for international JGOFS planing activities through SCOR is approximately $170,000 per year, not including the Canadian and FRG support for the Kiel office. The sources of funding include SCOR budgetary allocations, a grant from ICSU, a US NSF grant to SCOR, a contribution from IGBP and a few small national contributions to the JGOFS Special Fund established two years ago. This financial base must be expanded, especially as JGOFS enters a period where three major field programs will be active in

parallel. The assistance of SCOR is sought in urging participating nations to consider contributing a very small fraction of the funds they commit to national research programs towards the costs of the international planning activities which add enormous value to the individual national programs.

Membership

Four members of the JGOFS SSC will complete their terms on December 31. Recalling the concern expressed by the President of SCOR early in 1991 that the SSC membership was not sufficiently international, the Committee wishes to recommend that the following individuals be invited to join the JGOFS SSC on January 1, 1992:

Dr. Liliane Merlivat	France
Dr. Victor Smetacek	FRG
Dr. Arthur Chen	China (Taipei)
Dr. Alexander Lisitzyn	USSR

ANNEX VIII

An International Program
for
GLOBAL OCEAN ECOSYSTEMS DYNAMICS RESEARCH (GLOBEC)

Report of a SCOR/IOC Workshop
Solomons, Maryland
April 29 - May 3, 1991

CONDENSED VERSION

FORWARD

Concerns for global climate change emphasize the need to understand how changes in the global environment will affect the abundance, diversity, and production of animal populations comprising ocean ecosystems. The only existing marine-biologically oriented international global-change program is the Joint Global Ocean Flux Study (JGOFS). JGOFS, an International Geosphere/Biosphere Programme (IGBP) program is primarily concerned with average changes in the flux of biogenic elements (particularly carbon) and the role of ocean primary production in the exchange of carbon dioxide between the ocean and atmosphere especially in the context of global warming. No component of the IGBP Study of Global Change is focused upon the mechanisms by which climate change will impact the dynamics of marine animal populations, some of which are important food resources.

Among marine animal populations, zooplankton play a pivotal role in shaping ecosystem structure and the cycling of biogenic elements. Zooplankton grazing determines the size, species composition and fate of phytoplankton stocks and the nature of dissolved and particulate detritus that fuel microbial regeneration. Zooplankton secondary production represents the only route along which the products of phytoplankton photosynthesis flow to the animals that constitute the marine living resources.

Not enough is known about production cycles of marine zooplankton populations (particularly in comparison with phytoplankton production cycles). Where algal growth rates exceed grazing rates, blooms develop and where the reverse situation applies, phytoplankton stocks remain small in spite of ample nutrient resources. Zooplankton life cycles appear to be geared to specific hydrographic patterns at space and time scales that differ from those of phytoplankton. Thus, organic material in excess of the demands of marine zooplankton are occasionally produced by phytoplankton. This phenomenon has great bearing on the uptake of CO_2 in surface layers, and its eventual removal via vertical particle flux.

From long term fishery catch statistics and other records, we know that decadal changes of orders of magnitude have occurred in the major fish stocks of the ocean which cannot be explained merely by fishing pressure. It has been hypothesized that large year classes are uncommon events driven by a combination of favorable interactions of ocean physics and chemistry on the early life history of species, which occasionally magnify the normal, very low survival rates that occur during the recruitment process and vastly increase adult biomass. Exploring these patterns is a major challenge for marine ecology that has acquired a sense of urgency in connection with global change.

The Workshop participants took the above observations as a starting point for their deliberations, conclusions and recommendations, which follow.

THE ESTABLISHMENT OF THE WORKSHOP

At the 23rd Session of the IOC Executive Council at UNESCO (Paris, March 1990), the President of SCOR, Professor Jarl-Ove Stromberg, taking account of a proposal from the Guiding Group of Experts of OSLR, stressed the importance of ecosystem dynamics, and invited the IOC to co-sponsor with SCOR a Workshop on Ocean Ecosystem Dynamics. IOC accepted the invitation and the meeting was organized by the Executive Director of SCOR, Elizabeth Tidmarsh, and Senior Assistant Secretary of IOC, Thomas Osborn. Professor Stromberg provided overall guidance and the meeting was chaired by Professor Brian Rothschild, who also acted as host to meeting.

The need for the workshop became evident because several countries were in the process of establishing major scientific research programs focused on ecosystems dynamics e.g., BICED (Brazil), ECOMONOC (USSR), GLOBEC (USA), OPEN (Canada). In addition, the IOC determined that its programs on recruitment (SARP and PREP) and Harmful Algal Blooms would benefit from a more complete framework for their studies.

THE ROLE OF THE WORKSHOP

The role for the SCOR/IOC workshop was to consider the scientific status of ocean ecosystem dynamics research, and determine whether there is a need for international coordination. The central scientific question for biological and fisheries oceanographers and living resource managers over the coming years concerns climate and its interaction with the physics and chemistry of the oceans to affect and control variability of ocean ecosystems and their component animal populations.

Will a global warming trend over the next few decades and its consequent modification of ocean circulation result in non-reversible ecological changes? Will overall ocean animal biomass and secondary production be adversely impacted? Will major resource species be replaced by others unsuitable for harvesting? Will the structure of marine ecosystems be radically altered, or some, such as coral reefs, be eliminated? What effects would such changes in ocean ecology have, in turn, on the biogeochemical cycles to influence climate,

through, for instance, the modification of the CO_2 cycle in the oceans?

THE WORKSHOP DISCUSSIONS

The central theme which emerged from the workshop discussions is that zooplankton population dynamics is the unique nexus through which phytoplankton production, fish stock, and climatic variation are related. This theme is of paradigmatic importance, since it underpins our view of the dynamics of the entire marine ecosystem and forms the basis of the proposition that **zooplankton population dynamics and ocean physics are directly coupled to control not only the magnitude of secondary production and variability of marine living resources, but also the magnitude and fate of primary production.**

The tendency toward "top down" rather than "bottom up" ecosystem structure is much better accepted in terrestrial ecosystems. Biogeochemists have emphasized primary production and re-cycling as the dominant biological processes in the ocean. In this view, zooplankton population dynamics are merely a result of primary production variability controlled by ocean physics and chemistry. In fact, the reverse is probably more often true that phytoplankton production is controlled by zooplankton population dynamics (through grazing). This is not to say that photosynthesis is not the necessary process at the base of the food chain, but that its magnitude is controlled by, rather than controlling secondary production.

Thus, the conclusion of the workshop was that the role of zooplankton is far more important than generally assumed. Although a lack of sophisticated knowledge of zooplankton dynamics prevents us from understanding the total contributions that they make to the overall variability of the ecosystem and biogeochemical dynamics, examples offered by workshop participants (see below) support the expectation that their contribution is fundamental and global.

Example 1: THE ROLE OF ZOOPLANKTON IN CONTROL OF ALGAL BIOMASS

In extensive areas of the world ocean, algal biomass is low and macronutrients (as opposed to "trace" nutrients) are high. The only high latitude ocean (> 40°Lat) experiencing seasonal nutrient exhaustion following a prominent spring bloom is the North Atlantic. A particularly striking example of the role of grazers (in this case, krill) is in the seasonally ice covered waters of the Antarctic. Recent studies have shown that krill overwinter under the ice cover and in spring they enter the meltwater zones where the algae grow and control production. Thus, heavy grazing by the large overwintering krill stock effectively suppresses build up of an excessive algal biomass. The Antarctic meltwater zones display markedly lower algal biomass in spring than those in the Arctic where the zooplankton grazing impact is not mobilized so quickly. In this example the effectiveness of grazing control is an evolved response to the physical environment. Macronutrients remain high in the Southern Ocean.

Pelagic ocean ecosystems are dominated by copepods which have evolved overwintering

strategies to provide an early grazing impact in the following spring. In this way the physical environment determines the transfer of biomass from algae to the zooplankton. This depletes the nutrients and increases the chance of nutrient limitation of the algal division rate.

Example 2: THE ROLE OF ZOOPLANKTON IN FISH STOCK VARIABILITY

Since the early seventies, much attention in biological oceanography has focussed on the microbial loop and the picoplankton, with a consequent loss of interest in the "traditional" food chain. Cushing recently proposed that there may be two main ecosystems in the sea - one normally associated with weakly stratified waters and the other where they are strongly stratified. These result in two forms of production cycle (a) spring outburst of temperate seas and upwelling areas of subtropical and tropical seas and (b) the summer production of temperate seas and in the oligotrophic ocean. The fisheries are found in the first form. In the microbial loop, where the thermocline is fully established, there are three levels of grazers, all of which feed on particles less than 5 um in diameter. Most of the energy is used where it is formed in the upper water column and ends up as ammonia. The "traditional" food chain of diatoms, copepods and fish is associated with weakly stratified water columns. In terms of production the microbial loop out-produces by far the "traditional" food chain. The material produced within the former, however, is microscopic or dissolved.

We know that detailed knowledge of adult fish stocks is, in general, a poor predictor of future adult biomass. A fish population, like all other populations, is sustained by the number of young which grow into the adult population (in fisheries terminology - the recruits). The dynamics of recruitment may well be fixed at a very early age when the young fish are simply one more vulnerable component of the vast array of zooplankton species attempting to eat and not be eaten. Although recruitment may be modified to some degree by the initial fecundity, the physical and biological variability of the ecosystem is strongly transmitted through larval growth and survival. Because the rates of growth and mortality are highest during larval life, the variability of recruitment may well be established then.

This places a somewhat different emphasis on the central question involving grazing versus nutrient limitations. The fact that this question is not understood may very well be the reason for our inability to link fish-stock production and primary production.

Thus the Workshop participants focussed on the "traditional" food chain and the overarching role of copepods in transferring primary production into the macroscopic animal populations that compose the ecosystems and living resources of the ocean. In order to understand the natural fluctuations in ecosystems and to predict the potential for variability with changing climate, it is recognized that we must first understand the processes that control material and energy flow through the "traditional" food chain.

Example 3: THE ROLE OF ZOOPLANKTON IN CO_2 DRAWDOWN

While our relative ignorance of zooplankton-phytoplankton dynamics lends point to the proposal for an international research initiative, it is global change which gives it immediacy. Governments and other organizations with a vital interest in the management and optimization of the oceans' living resources face the requirement to predict the future course of events and develop responses to them. In order to do this their scientists must develop the understanding to distinguish between natural and human-induced variability. The latter cannot be predicted without the ability to predict the former. As ecosystems change, they will, in turn, impact the rest of the biogeochemical and climate system. Quantification of the nature of such changes will be sought from ecologists by scientists interested in these feed-back phenomena. The ocean CO_2 system, and hence the atmospheric CO_2 system and global warming, for instance, will be affected by changes in secondary production.

In the Greenland Sea, CO_2 drawdown reaches a global maximum in the seasonal ice-migration zone from Cape Farewell to Spitsbergen, largely as a result of phytoplankton-zooplankton interactions in the special circumstances which arise from the almost instantaneous onset of "biological spring" as the ice cover rolls back. The factors which promote such a radical CO_2 drawdown are all peculiar to the marginal ice zone and, although model simulations vary on the amount of global warming to expect, they seem agreed that surface temperature increases at more northerly latitudes will be up to several times larger than global average. Thus, the planktonic interactions which promote one of the most important CO_2 sinks in the hemisphere are also among the most vulnerable to global warming, and could even result in the loss of this narrow marginal ice zone. It remains to be demonstrated by measurement what this change will mean to the global ocean sink of CO_2, but it already appears evident that it will act via a change in the effectiveness of grazing.

The Workshop concluded that these examples were typical of the scientific problems to be faced during the next decade. To move ahead it will be necessary to develop the theory, modeling, and sampling techniques that permit a more comprehensive view of ocean ecosystems in the context of the interaction between population dynamics and ocean physics.

THE WAY FORWARD

Currently planned and implemented Ocean Global Change programs are oriented towards understanding the effects of large-scale ocean physics and carbon flux on climate modification. What is missing is an understanding of the role of short-term variability in the system. For instance, it was recently shown in the JGOFS North Atlantic Bloom Experiment that about two-thirds of the total annual primary production at a single station occurred within two weeks. It has been hypothesized that the timing of such sharp production events are closely correlated to success or failure of year classes of larvae of major fish stocks, and in turn their extreme adult biomass fluctuations on decadal time scales. We need to know much more about the natural causes of biological variability in the ocean in order to

understand the overlying long-term changes being caused by human-induced global climate changes.

What is also missing is an understanding of the contribution of the population dynamics of the zooplankton to overall system variability. We know, for instance, that virtually every major predator, including those constituting the living resources of the oceans, depend on copepods and other zooplankton for their food at some stage (if not all) of their life cycle. Every copepod species has a complex life cycle and grows through several orders of magnitude in biomass during its lifetime, which may take days to years. To date, we have no well-accepted methodologies for estimating the production of copepods in the field, nor even the ability to routinely estimate population biomass in anything near real time.

The way forward requires a complex of activities. First we need to better understand how population variability is propagated and suppressed. This cannot be approached without an understanding of the dynamics of the various populations that comprise the ecosystem. In turn these cannot be understood without a knowledge of the physical driving variables. By developing an understanding of the dynamics of the animal populations, particularly the critical connecting links through the zooplankton, we will be better able to predict, for instance, large year classes of fishes, the fate of coral reef ecosystems, changes in metabolic pathways resulting from anthropogenic inputs, and biological influence and/or feedbacks to climate.

The Workshop participants defined the Goal of an International Program on Global Ocean Ecosystems. This is:

To understand the effects of physical processes on predator-prey interactions and population dynamics of zooplankton, and their relation to ocean ecosystems in the context of the global climate system and anthropogenic change.

An international program for global ocean ecosystems research (GLOBEC) will:

- **improve understanding of the relationship between primary production and variability of fish stocks and other living resources, as controlled through the mediation of the zooplankton;**

- **quantify the influence of zooplankton on biogeochemical cycles, through grazing control of the phytoplankton;**

- **lead to advanced utilization of acoustic, optical, and image-identification in sampling technology to measure the time-space distribution of plankton on biologically critical scales;**

- **lead ultimately to a capability to model and predict ocean ecosystem dynamics on regional and global scales.**

It was also agreed that there are two fronts upon which it is vital to advance in order to develop a large-scale international program to understand the effects of physical processes on predator-prey interactions and population dynamics of zooplankton, and their relation to the global climate system and anthropogenic change. These are in (1) sampling technology and long time series and (2) theoretical approaches and modelling. Advances on these fronts will form the necessary foundations and long-term context for new large-scale field oriented process studies designed to understand the great ocean ecosystems of the world.

WHY AN INTERNATIONAL PROGRAM?

The participants in the workshop recognized that a proposal for a new international effort in oceanography must be seen in the context of existing global change research programs already under way and which are straining the resources available to the oceanographic community. Any new initiative must, therefore, respond to a widely accepted scientific need and must complement, rather than compete, with existing activities. The participants believe that the time is right for such an initiative. The International Program for GLOBEC will represent a timely and well-founded response to this need.

It is timely to address questions of the physical-biological interactions in marine ecosystems. Programs already under way, such as TOGA, WOCE and JGOFS, are addressing the physical and biogeochemical responses of the ocean to global climatic change. JGOFS, which focuses on the oceanic carbon cycle and primary productivity, requires improved understanding of the coupling between phyto- and zooplankton, population dynamics and biological variability. A global ocean ecosystems dynamics program will provide just such a complementary effort.

The results of GLOBEC will be of interest to a large number of countries, particularly those with a heavy dependence on living marine resources. Improved predictive capabilities resulting from GLOBEC will assist in the provision of scientifically sound basis for policy and management decisions. The scientific goals of GLOBEC outlined above demand an internationally coordinated effort for the following reasons:

An international program will provide a commonly accepted intellectual framework for dealing with issues of global concern. This framework will permit a common base upon which to build and extend national programs. Additionally, it should provide impetus to create new national efforts where none presently exist.

Implicit in the formation of an international program is the understanding that the problem under study is either too large or too complex for any one national effort. Cooperation and integration of many disparate groups ensures greater geographical coverage, more resources (both human and material) and greater potential for the successful development of technological innovation required to successfully achieve the stated goals. It also provides a means of developing agreement on necessary constants such as a set of universal

measurements, associated protocols and policies on data submission and sharing.

Given the diversity of physical and biological environments, the comparative analysis of varied ecosystems is an integral component of a global program. Individual national studies, within an international framework can provide both parallel and serial efforts, hopefully leading to greater clarity in the search for general principles.

OTHER CONSIDERATIONS

Sampling Technology

Science progresses through the unending cycle of theoretical development; observation to confirm or amend the theory and further theoretical development.

A major impediment to maintaining the cyclic progression towards more refined, informative, and predictive theory is the fact that present observational or sampling devices generally depend upon 19th century technology (towed nets and microscopic identification). This is extremely labor intensive and consequently few long time series exist. Data sets such as the Continuous Plankton Recorder, Station P, and CALCOFI are notable exceptions. For phytoplankton biomass the situation is currently much further advanced, where modern satellite and in-situ optical techniques offer potentially continuous sampling and real-time analysis.

Improvements and new developments in zooplankton sampling systems are only slowly emerging, but promise to provide new data on population levels and their distributions. For example, a multi-frequency acoustic profiler system (MAPS) in conjunction with net samples for ground truth, produced a transect across the Irish Sea that relates the backscattered acoustic signal to the relative concentrations of different zooplankton. The advantage of such a system is the potential for real-time analysis. Such measurements give a deeper appreciation of the spatial variability and a better measure of the spatial coherence between species.

There are optical systems capable of identifying fish larva, zooplankton, and even some phytoplankton. These developments enable studies of patchiness and the coincidence of predator and prey with detailed knowledge of the relative concentrations as a function of time. In addition, information on feeding and predation rates is crucial to modelling population growth and mortality. Recent advances in biochemical and molecular biology show great promise for transfer to biological oceanography. For example, the RNA/DNA ratio indicates the nutritional condition of fish larvae. Techniques have been developed to assess food sources from chemical tracers in stomach contents. Automation of these techniques to speed processing and reduce the labor involved is necessary.

In order to make progress in developing new technology the Workshop participants agreed that specifications needed to be drawn up. The first criterion regards size range. After

much discussion it was agreed that as a first approximation, the size range of 5 um to 5 cm should be set as a goal. The rationale was that the lower end of the range encompassed most of the autotrophic and heterotrophic biomass which would be at the base of the "traditional" food chain (see above) and not that of the re-cycling microbial food chain. The upper end of the range encompassed all but the largest adults of what are usually defined as the zooplankton or micronekton. Within this size range most grazing and most acts of predation would occur.

It was recognized that no single technological device was likely to be capable of dealing with the entire range but that possibly a combination of acoustic and optical technologies might provide the solution. The appropriate mix of technologies would of course be defined by the problem at hand. A draft report of the Technology Working Group of U.S. GLOBEC was brought to the attention of the participants and its conclusions studied. In developing new technological approaches to sampling, it is important to keep in mind not only the short-term, fine scale measurements needed for process-oriented field experiments, but also the requirements for large-scale long time series or monitoring programs.

Historically a portion of this information has been provided by the Continuous Plankton Recorder (CPR) over a portion of the North Atlantic. For a program on predator/prey interaction, centered on zooplankton, the CPR Program can provide relevant information with:

1) pan-oceanic coverage,
2) temporal (1 month) and spatial (10 mile) resolution,
3) historic context (30 to 60 years), and
4) robust technology.

However, the CPR falls short of meeting some needs of a modern program envisaged by the workshop participants.

1) it does not sample the smallest size fraction (50 micron nauplii, 20 micron dinoflagellates) that are central,
2) it does not sample the larger size fraction associated with predators such as ctenophores, salps, etc.,
3) it samples at a fixed depth of 10 m and the relevance of changes at that depth to the total euphotic layer is unknown,
4) it is time consuming in analytical effort, and
5) it lacks concomitant environmental data.

Preservation of the continuity and integrity of the present data set, as well as the development of substantially increased capabilities are crucial. A new and expanded program must be developed and calibrated in conjunction with the present survey in order to respond to societal needs.

Some of these developments are already possible. Some are not. Of the "possible" one

significant improvement readily available:

1) a wider geographic coverage by the existing system. A more global coverage by large regional monitoring efforts is possible now.

Other possible improvements are:

2) Undulating oceanographic recorders are now relatively available with a suite of useful sensors in place - optics, bioluminescence, nitrate (under development), and other environmental parameters relevant to strati-fication (T,S, etc.), and
3) Some proxy measure for dinoflagellates are already available (e.g. bioluminescence) and the CPR already quantitatively captures the larger dinoflagellates whose response to environmental change may be representative of smaller forms.

The workshop endorsed the belief that present transition period for the CPR program needs to be supported while a new system with enhanced capabilities is developed to provide a global ocean observing system for plankton for the next fifty years. Ultimately, it should be secured within existing intergovernmental frameworks for administering large marine programs.

Modelling and Theory

The question of problem identification is intimately related to theoretical development. The theory will need to be focussed upon the propagation of population variability. A first step in understanding population variability involves understanding the interrelationship between the dynamics of the populations that comprise the ecosystem and the physical forcing factors.

To move ahead it is important to place in perspective the kinds of models or explanations that have structured our information base. In this regard, a distinction was made between kinematic and first-principle models. Kinematic models are oriented toward accounting for observations of the natural world, while first-principle models use first principles to "predict" real-world system dynamics. Many of the models used in biological oceanography are based upon kinematics rather than on first principles and dynamics.

It is not easy to develop system dynamics models particularly of highly aggregated components and those with complex life history stages. Nevertheless it is doubtful that models that do not take explicit account of physics interacting with detailed population dynamics can result in major advances in understanding variability. For example, it was shown that there is critical variability in copepods whose life history stages consist of six naupliar five copepodite, and an adult stage, each involved with a different mix of predator and prey. Variability and understanding is masked by treating all members of the population(s) as a single variable.

In addition, the variability in copepod populations is intimately bound with their feeding

behaviors and the interactions of physics on the fine scale. Most copepods feed on algal cells which detect and select in the immediate few millimeters of water that surrounds them. They are armed with chemo- and mechano-receptors in order to detect the range and direction of the cells. These cells are picked out of the water with a complex behavioral mechanism. The processes of detection and capture depend entirely upon the local physics. The physics of grazing is a difficult but essential problem that requires much more sophisticated investigation.

THE NEXT STEP - WORKSHOP RECOMMENDATIONS

The Workshop participants agreed to the following recommendations.

A. This Workshop recommends to its sponsoring organizations that they agree to jointly organize an international Global Change Program on Global Ocean Ecosystems Dynamics Research and Monitoring (GLOBEC) which will provide a coordinating framework in which an international science plan can be developed, which takes into consideration ongoing national planning activities. The science plan should form the basis for the implementation of a global-scale research and monitoring program to accomplish the goal and objectives enumerated above (see "THE WAY FORWARD").

B. that SCOR and IOC should invite other interested international agencies to participate, particularly those regional bodies (e.g. ICES, PICES) with known programs or interests in ocean ecosystems dynamics and global change.

C. that SCOR should propose to its parent body (ICSU) that a programme in Global Ocean Ecosystems Dynamics become established as a Core Project of the International Geosphere/Biosphere Programme to complete its suite of Global Change studies.

D. that IOC should adopt this joint program as its proposed new initiative for an Ecosystems Dynamics and Living Resources component of Ocean Sciences and Living Resources (OSLR).

E. that, in the meantime, until SCOR and IOC governing bodies can convene to discuss these proposals, the workshop participants should continue their activities on behalf of SCOR and IOC over the next year, under the continuing chairmanship of Professor Rothschild, as an interim *ad hoc* international planning committee.

F. that this *ad hoc* international planning committee should consider a series of potential activities in connection with a global ecosystems dynamics program and report on an order of priorities to SCOR and IOC. The potential list of activities are:-

1. Develop the strategy to focus on zooplankton population dynamics in a trophodynamic and physical setting.
2. Develop models that integrate fundamental biological and physical processes.
3. Facilitate the proper specification of physical models from the CGM scale to the regional scale, so that the models can be linked.
4. Develop an overall strategy for defining research projects, selecting study sites, trophic levels, species, etc.
5. Identify "core" elements of the international program, to be included in each regional study.
6. Consider a strategy for long-term monitoring of appropriate scales to observe global change and test predictions from regional models.
7. Evaluate technology needs.
8. Consider the generic problems of sampling and experimental design.
9. Facilitate communication and review progress.

G. In order to accomplish these aims the ad hoc planning committee should convene as required (incorporating additional members from other countries not represented as they can be identified), and also form working groups in the areas of (a) theory and modelling, and (b) technology and long term monitoring.

ANNEX IX
FINAL FINANCIAL STATEMENT - 1990

BALANCE - Jan. 1, 1990		80,830.73
INCOME:		
Membership	157,667.00	
ICSU Grants	45,000.00	
UNESCO Contract	15,000.00	
IOC Contract	21,000.00	
NSF Grant (travel)	58,553.22	
NSF Grant (geoscience)	72,990.97	
UK Subvention	21,671.34	
Univ. Calif. (CCCO)	115,000.00	
JGOFS Special Fund	30,106.78	
Misc.	178.72	
Total Income		537,168.03
TOTAL BALANCE PLUS INCOME		617,998.76
EXPENSES: Scientific		
WG 56	8,114.55	
WG 73	218.32	
WG 78	2,194.19	
WG 80	33.93	
WG 83	6,067.58	
WG 86	13,621.82	
WG 89	15,262.76	
WG 91	12,016.07	
WG 93	11,596.99	
CCCO (not incl. office)	50,000.00	
JGOFS (not incl. admin.)	82,916.00	
JPOTS	5,879.87	
Total Subsidiary Bodies		207,922.08
Related Expenses:		
General Meeting	23,189.71	
Publications	6,372.57	
Conference Sponsorships	3,000.00	
Travel awards	58,321.26	
Representation	18,676.09	
		109,559.63
TOTAL Scientific Expenses		317,481.71

EXPENSES: Administrative		
SCOR		
Salaries & FB	57,465.98	
Communication	12,632.67	
Audit	2,468.64	
Office Equipment	2,636.39	
Misc.	2,789.22	
Bank Charges	176.40	
	78,169.30	
CCCO	115,000.00	
JGOFS	64,181.75	
TOTAL Admin. Exp.		257,351.05
Loss on Exchange		1,447.66
TOTAL EXPENSES		576,280.42
ACCUMULATED BALANCE		
BALANCE Dec. 31, 1990		
Dalhousie University	939.37	
Can. $ Account	65.98	
US $ Account	12,376.39	
ICSU	6,058.00	
Total Cash	19,439.74	
Assets:		
Receivables	82,666.66	
Prepaid 1991 expenses	2,345.12	
	85,011.78	
Liabilities:		
Payables	(41,927.08)	
Deferred revenue	(20,806.10)	
	(62,733.18)	
Total accumulated balance		41,718.34
TOTAL EXPENSES PLUS BALANCE		617,998.76

ANNEX X
Acronyms and Abbreviations

ACSYS	Arctic Climate System Study
AOSB	Arctic Ocean Sciences Board
ASCEND-21	Agenda of Science for Environment and Development to the 21st Century
ASLO	American Society of Limnology and Oceanography
BES	British Ecological Society
BIOMASS	Biological Investigations of Marine Antarctic Systems and Stocks
CalCOFI	California Cooperative Fisheries Investigation
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCC	Cod and Climate Change (ICES)
CCCO	SCOR/IOC Committee on Climatic Changes and the Ocean
CLIVAR	Climate Variability (WCRP)
CNC	Canadian National Committee for SCOR
CoOP	Coastal Ocean Processes
COSPAR	Committee on Space Research (ICSU)
CPR	Continuous Plankton Recorder
CTD	Conductivity/Temperature/Depth measuring instrument
DBCP	IOC/WMO Drifting Buoy Cooperation Panel
DOC	Dissolved Organic Carbon
DSIR	Department of Scientific and Industrial Research (New Zealand)
ECMWF	European Center for Medium-range Weather Forecasting
ECOR	Engineering Committee on Oceanic Resources
ECSA	Estuarine and Coastal Sciences Association
ERF	Estuarine Research Foundation
EROS	European River Ocean System (an EEC project)
ERS-1	Earth Resources Satellite (ESA)
ESA	European Space Agency
FAO	Food and Agriculture Organization (UN)
GCOS	Global Climate Observing System
GCTE	Global Climate and Terrestrial Ecology (IGBP)
GEOSAT	a U.S. Navy satellite
GEWEX	Global Energy and Water Exchange (WCRP)
GLOBEC	Global Ocean Ecosystems Dynamics
GOEZS	Global Ocean Euphotic Zone Study (IGBP/SCOR)
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GSP	Greenland Sea Project
HIFT	Heard Island Feasibility Test
IABO	International Association for Biological Oceanography
IAHS	International Association for Hydrological Sciences
IAMAP	International Association for Meteorology and Atmospheric Physics
IAPP	International Arctic Polynya Project

IAPSO	International Association for the Physical Sciences of the Ocean
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Chemistry program (IGBP)
IGBP	International Geosphere-Biosphere Programme (ICSU)
IGOSS	IOC/WMO Integrated Global Ocean Services System
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IPCC	Intergovernmental Panel on Climate Change
IUGG	International Union of Geodesy and Geophysics
JGOFS	Joint Global Ocean Flux Study
JPOTS	Joint Panel on Oceanographic Tables and Standards
JSC	Joint Scientific Committee for the WCRP (ICSU/WMO)
LOICZ	Land Ocean Interactions in the Coastal Zone (IGBP)
MAPS	Multi-frequency Acoustic Profiler System
NABE	North Atlantic Bloom Experiment (JGOFS)
NSF	National Science Foundation (USA)
ONR	Office of Naval Research (USA)
OOSDP	Ocean Observing System Development Panel (CCCO/JSC)
OPEN	Ocean Production Enhancement Network (Canada)
OSB	Ocean Studies Board (USA)
OSLR	Ocean Science in Relation to Living Resources (IOC)
PACON	Pacific Science Congress on Marine Science and Technology
PAGES	Past Global Changes (IGBP)
pCO_2	partial pressure of CO_2
PICES	"Pacific ICES"
SC-IGBP	Scientific Committee for the IGBP (ICSU)
SCAR	Scientific Committee on Antarctic Research (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SeaWIFS	Wide-field Sensor for Ocean Colour
SST	Sea Surface Temperature
SWADE	Surface Wave Dynamics Experiment
TOGA	Tropical Ocean and Global Atmosphere study (WCRP)
TOS	The Oceanography Society
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VOS	Voluntary Observing Ships
WAM	Wave Modelling Group
WCRP	World Climate Research Programme (WMO/ICSU)
WESTPAC	IOC Regional Sub-Commission for the Western Pacific
WG	Working Group
WHP	WOCE Hydrographic Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment (of CCCO)