Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

Electronic copy only

IOC-SCOR
Ocean CO_2 Advisory Panel

Second Session

School of Ocean and Earth Science and Technology
University of Hawaii
Honolulu, Hawaii, U.S.A
9 February 2002

UNESCO

Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

IOC-SCOR
Ocean CO_2 Advisory Panel

Second Session

School of Ocean and Earth Science and Technology
University of Hawaii
Honolulu, Hawaii, U.S.A
9 February 2002

UNESCO 2002

IOC-SCOR/CO_2-II/3
Honolulu, February 2002
English only

Acknowledgement

This document is based on work partially supported by the U.S. National Science Foundation under Grant No. 0003700. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. National Science Foundation (NSF).

TABLE OF CONTENTS

ANNEXES

1. OPENING

The Chair, Dr. Doug Wallace from IfM-Kiel, opened the meeting and welcomed the Panel members to the 2nd session of the IOC-SCOR CO_2 panel. A full list of panel members is given in Annex I. He expressed his appreciation to Dr. Fred Mackenzie of the University of Hawaii for providing the meeting room as well as projection and computer facilities at SOEST. The Chair then welcomed two guests who were in attendance: Dr. Fukasawa of the Japan Marine Science and Technology Center (JAMSTEC) attended the morning session and introduced his Magellan project, a major circumpolar hydrographic expedition along approximately 30º S aboard the RV *Mirai* to collect hydrographic section data for the South Pacific, Atlantic, and Indian Oceans. Dr. Nicolas Dittert of the Institut Universitaire Européen de la Mer at the University of Western Brittany, who is a scientific data manager from the World Data Center for Marine Environmental Sciences, attended the session in order to learn more about data availability of surface pCO_2 measurements. WDC-MARE is the European complement to CDIAC for the ORFOIS project (Agenda item 4.1).

2. ADOPTION OF THE AGENDA

The Chair introduced the Agenda and the Panel members were invited to comment. After a brief discussion, the Panel adopted the Agenda as shown in Annex II.

3. STATUS OF PANEL PROGRAMME ACTIVITIES 2000-2001

3.1 WELCOME OF NEW PANEL MEMBER

The Panel welcomed Dr. Kitack Lee as a new member of the Panel. Dr. Lee described his prior work in the area of synthesis of deep ocean carbon measurements and his plans for research in his new post as Assistant Professor at the School of Environmental Science and Engineering at Pohang University of Science and Technology, South Korea. Dr. Lee stated that his Panel membership would allow him to serve as liaison between the South Korean oceanographic community and the international ocean carbon community and to continue to play an active role in international ocean carbon research.

3.2 SUMMARY OF PANEL ACTIVITIES 2000-2001

Dr. Hood provided an overview and summary of the various activities undertaken by the Panel during 2000 – 2001.

Table 1 in Annex III outlines the Terms of Reference (TORs, given in Annex IV) and the actions, activities, or products developed during this first year of Panel activity. One of the major responsibilities of the Panel is to provide expertise on ocean CO_2 observations for GOOS and other developing international programmes. TORs 1 and 6 specifically outline these responsibilities:

- To identify gaps and weak links in the present carbon cycle observing system that compromises the ability to understand and predict global change.

- To advise GOOS and OOPC on the observational strategies needed to assess, model, and predict global ocean CO_2 fluxes.

The major activity and product of has been the development of the GOOS Technical Document "A Global Ocean Carbon Observation System – A Background Report". The Panel's technical secretary was contacted by the GOOS Project Office director to lead an ad hoc writing team to assist with developing the ocean carbon component of the IGOS Partners Integrated Global Carbon Observation Theme. It was decided to develop first an ocean carbon observing system background document to reach community consensus on major issues and observation needs before trying to integrate the ocean strategy with atmospheric and terrestrial observation components. Dr. Scott Doney (NCAR - UCAR)

led the writing group, the Panel technical secretary served as the focal point and principle editor for contributions from Panel members and the scientific community, and the Panel Chair served as reviewer, editor, contributor, and link to the GOOS Steering Committee. The document has been written and is in its 7th revision. It will be published as a GOOS Technical Report in mid - 2002, and in abbreviated form as an EOS article. This document serves as the basis for some of the ocean observing system information to be used in the IGOS partners Integrated Global Carbon Observation Theme. The theme team-writing group met in September to outline the Theme document, and it is projected that the integrated document will be published by the end of 2002. Panel members Maria Hood and Corinne Le Quéré are members of the theme team writing group, as well as background report lead author, Scott Doney.

In addition to these two documents, the Panel Web site is being used to provide information and links to ocean carbon observation programmes including those linked with GOOS, CLIVAR, the Time Series Observatory Pilot Project, and various VOS / SOOP operations.

TOR 2 is to identify opportunities that can be used to further develop such an observing system (e.g. collaboration with other global observing systems). There has been no lack of meetings in 2000 - 2001 to discuss how carbon observations can be integrated into other planned observational programmes. The table lists the meetings attended by Panel members during the year that were directly related to ocean carbon observation programme planning. At several of these meetings, the Panel was specifically identified to carry out action items. These include:

- Reviewing Time Series Observatory Pilot Project proposal (to be completed fall 2002)
- Coordinate ocean carbon and related variables measured by VOS / SOOP – Panel gathered information from the community about ongoing or planned programmes; Panel members Yukihiro Nojiri and Dileep Kumar will represent the Panel at the first JCOMM Ship Observations Team meeting.
- Panel asked to aid in the coordination of carbon measurements in CLIVAR – the Panel Web site links to the CLIVAR site containing the latest information about repeat hydrographic sections, and the Panel is working with other groups (e.g., SCOR and IGBP) to develop a coordination mechanism and "programme home" through which the ocean carbon community can coordinate.
- Panel asked to monitor developments on ocean carbon sequestration science, and to facilitate the international discussion of the scientific issues – the Panel is developing a watching brief aimed at providing information to a general audience on the issues of ocean carbon sequestration. The IOC and SCOR, with the aid of the Panel, will plan an international meeting on ocean carbon sequestration for 2003, with the goal of synthesizing the scientific understanding of these issues.
- Panel asked to work closely with the new PICES working group on biogeochemical data integration and synthesis.

TOR 4 is to maintain a watching brief to advice the IOC and SCOR on CO_2 sequestration in the ocean. This item will be discussed in more detail under agenda item 3.4. The Panel has made a good start on the draft watching brief, and this should be finalized in early 2002.

TOR 5 is to advise GOOS and OOPC on technology development needed to improve future capacity for carbon cycle monitoring. The Panel Web site provides some basic information about this, but more work is needed. This item is discussed further in agenda item 3.7.

Finally, general TOR 2 states that the Panel should provide an international forum for initiatives to promote high-quality observations needed to understand the ocean component of the global carbon cycle. The Web site provides some information about the issues of certified reference materials and links to the U.S. Ocean Studies Board group on standards and reference materials for marine science. However, more work needs to be done to fulfil this requirement. This is discussed further in agenda item 3.5.

Discussion - The Chair noted that the Panel's advice and information is useful for a wide variety of additional bodies including CLIVAR, VOS programmes, and some emerging science programmes, such as SOLAS. He noted that the Panel's view on the measurement programmes that are required appears to be shared by these other bodies so that there is general agreement on what needs to be done. Despite this general agreement, there seems to be slow progress in putting the observations into practice and there remains a lack of clear coordination of measurement plans at an international level.

The Panel noted a perception that the oceanographic carbon cycle community is less organized and united than their counterparts working in the terrestrial, and atmospheric areas. The lack of coordination at the international level and the lack of progress in establishing or funding carbon measurements may arise in part because ocean carbon science currently lies at the boundary between IGBP and WCRP research programmes. It was also noted that the CO_2 community has not forged particularly strong links with the biological oceanography community. It was suggested that the relevance of ocean carbon cycle science might also be under-appreciated due to an over-emphasis on the role of the ocean as a sink for anthropogenic CO_2 and a relative lack of attention to environmental effects of increased CO_2 such as the effect of lowered pH on calcium carbonate formation/dissolution and organisms.

It was noted that the ocean carbon community needs to communicate more effectively with researchers working with the other key carbon reservoirs. The importance of studying the global carbon cycle as an integrated system including the ocean, terrestrial and atmospheric components was emphasised. The utility of oceanic data for resolving issues concerning terrestrial carbon budgets needs to be appreciated more widely, and the critical role of the ocean in decadal to century timescale should be a focus for our work.

The Panel views the increased involvement of the ocean carbon community in the IGBP-WCRP-IHDP Global Carbon Project as one means to resolve some of these issues. However this implies also the willingness of GCP partners (e.g. the WCRP community) to address carbon cycle science more vigorously in their observational and modelling activities.

The panel was informed about proposals to establish Project Offices for the GCP. Dr. Andrew Dickson was contacted by one of the members of the GCP scientific steering committee about the Panel's joining the planning and coordination efforts for ocean carbon in the GCP framework. It was agreed that the Panel should begin to establish close links with the GCP and offer the Panel's expertise to this developing project. See Agenda Item 3.3.3 for continued discussions.

Action Item 1: The Chair and Technical Secretary will outline the major messages that the Panel wishes to convey concerning the relevance of ocean carbon cycle science for addressing issues of the environmental effects of increased CO_2, such as the effect of lowered pH on calcium carbonate formation/dissolution and organisms, and the need to establish closer links with biological oceanographic community. Panel members will work to write semi-popular or commentary-style articles to outline the key motivations and significance of ocean carbon cycle research.

3.3 OBSERVATION PROGRAMME PLANNING AND COORDINATION

3.3.1 Sub-Decadal Variability in Air-Sea Fluxes

Dr Roger Francey described a re-evaluation of past atmospheric measurements of $\delta^{13}C$ in the atmosphere, with a focus on interannual variability in long-term southern hemisphere marine boundary layer records. Differences between records have generally occurred as step changes coinciding with methodology changes or instrument modification. Cross-contamination between sample and reference CO_2 in dual inlet isotope ratio mass spectrometry has emerged as a major suspect in past anomalies. Evidence for artefacts associated with the cryogenic extraction of CO_2 from air have also emerged.

On the basis of this understanding, and relying on an unusual redundancy of methods in CSIRO programmes, a revised two-decade southern hemisphere background $\delta^{13}C$ record has been produced. Assuming global representativeness and a simple relationship between $\delta^{13}C$ variations and net terrestrial CO_2 flux on these timescales, and with careful attention to possible smoothing artefacts,

net terrestrial exchange (with C3 plants) explains most (>70%?) of the interannual variation observed in atmospheric CO_2. Compared to previous estimates of oceanic interannual variation in global air-sea flux using $\delta^{13}C$ measurements, these results are in agreement with the independent ocean based estimates within the current uncertainties that exist in both methods. More complex global budgeting, using multi-site coexisting $CO_2$and $\delta^{13}C$ data over the last decade, agree well with the simpler approach. Further refinement of knowledge of the spatial and temporal variations in oceanic and terrestrial fluxes will act as mutual constraints on the global carbon budget and provide valuable additional insight into processes controlling the atmospheric CO_2 levels and thus climate change.

Dr. Corinne Le Quéré presented a comparison of four recent estimates of interannual variability using two multi-tracers atmospheric inversions (Francey et al., 2001; C. D. Keeling et al., 2001), one CO2-only inversion (Bousquet et al., 2000) and one ocean model (Le Quéré et al., 2000). All estimates show ⅓ to ½ less variability in the ocean than on land, but the amplitude and phase of the oceanic variability remains poorly determined (Le Quéré et al., submitted). Convergence of the estimates of variability by atmospheric inversions and the ocean model is seen in the Southern ocean in the 1990s only, where all estimates give a variability of ±0.2 to ±0.5 PgC/y, roughly in phase with each other. When variability less than 5 years is removed, all estimates show a global oceanic sink more or less steadily increasing with time, and a large anomaly in the land sink during 1990-1994.

Dr. Le Quéré presented recent results of estimates of O_2 outgassing by the ocean based on several studies using observed data (R. F. Keeling et al., 2001) or model results (Matear et al., 2000; Bopp et al., 2002). All these studies suggest that the total oceanic O_2 outgassing is about four times greater than the outgassing that can be calculated using the solubility of O_2 only. Thus CO_2 budget estimated using atmospheric O_2/ N_2 ratios should be corrected to take into account the total outgassing of O_2 by the ocean. The correction in the 1980s is of the order of 0.1 PgC/y from the land to the ocean. The correction in the 1990s is or the order of 0.4 PgC/y from the land to the ocean. This number varies depending on which heat flux data is used to estimate the correction, and which ratio of O_2/heat is used in the various estimates.

References

Bopp, L., C. Le Quéré, M. Heimann, A. C. Manning, and P. Monfray, Climate-induced oxygen oceanic fluxes: Implications for the contemporary carbon budget, Global Biogeochem. Cycles, in press.

Bousquet, P., P. Peylin, P. Ciais, C. Le Quéré, P. Friedlingstein, and P. P. Tans, Regional changes of CO2 fluxes over land and oceans since 1980, Science, 290, 1342-1346, 2000.

Francey, R. J., C. E. Allison, C. M. Trudinger and P. J. Rayner, The interannual variation in global atmospheric d13C and its link to net terrestrial exchange, Extended abstract of the 6th International Carbon Dioxide Conference, and in preparation for the special Tellus issue, 2001.

Keeling, C. D., S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann and H. A. Meijer, Exchanges of atmospheric CO2 and 13CO2 with the terrestrial biosphere and oceans from 1978 to 2000. I. Global Aspects, SIO Reference Series no. 00-06, Scripps Institution of Oceanography, La Jolla, USA., Global Biogeochem. Cycles, submitted, 2001.

Keeling, R. F. and H. E. Garcia, The change in oceanic O2 inventory associated with recent global warming, Proceedings of the Natural Academy of Sciences, in press, 2002.

Le Quéré, C., J. C. Orr, P. Monfray, O. Aumont, and G. Madec, Interannual variability of the oceanic sink of CO2 from 1979 through 1997, Global Biogeochem. Cycles, 14, 1247-1265, 2000.

C. Le Quéré, O. Aumont, P. Bousquet, P. Ciais, R. Francey, M. Heimann, C.D. Keeling, R.F. Keeling, H. Kheshgi, P. Peylin, S. C. Piper, I. C. Prentice and P. J. Rayner. Two decades of ocean CO2 sink and variability, submitted to Tellus, 2002.

Matear, R. J., A. C. Hirst and B.I. McNeil, Changes in dissolved oxygen in the Southern Ocean with climate change, Gleochem. Geophys. Geosys., 2001.

Discussion - The Chair and the Panel expressed their appreciation for these informative and stimulating presentations. The atmospheric measurements and inversion results highlight some areas where further research and observations are needed. The Panel felt that the need for ocean carbon measurements should be emphasized more strongly in terms of their necessity for terrestrial and atmospheric carbon budget constraints, and to emphasize that on century timescales, the oceans are more likely to dominate carbon uptake.

3.3.2 GOOS Technical Report on Ocean Carbon Observations

Dr. Hood briefly updated the Panel on this document, prepared in part by contributions and comments from Panel members. The purpose of the document is to provide the GOOS Steering Committee with the scientific issues needed to be addressed by a permanent ocean observing system. This document also serves as the basis for the ocean component of the IGOS Partners Integrated Global Carbon Observation Strategy currently in preparation. Hood explained that while the initial draft of the document sought to pull together an inventory of on-going or planned ocean carbon measurement programmes, the final version of the document focuses on integrating ocean carbon measurements into the framework of other observing system structures and programmes, such as the time series observatory pilot project, CLIVAR repeat hydrographic sections, and the JCOMM Ship Observations Team for the coordination of oceanographic and meteorological measurement programs made on volunteer observing ships. The document should be published as a GOOS Technical Document in 2002, and a summary paper will be developed and submitted to *EOS*.

Discussion – The Panel remarked that this report should also be sent officially to the OOPC.

3.3.3 Repeat Hydrographic Sections in CLIVAR

Dr. Wallace briefed the Panel members on the emerging plans for integrating carbon measurements into the CLIVAR repeat hydrography programme. As Chair of the Panel, Dr. Wallace was contacted early in the year by CLIVAR International Project Office director John Gould to discuss ways of coordinating carbon measurements in the repeat hydrography program of CLIVAR. After numerous discussions between IGBP, JGOFS, CLIVAR, CLIVAR basin panels, and various scientists, John Gould and Hugh Ducklow (Chair, JGOFS) stated that the Panel seemed to be the international group with the most complete remit and should be the forum for international planning and to link into national programmes. It was decided that if at all possible, establishing a new international committee should be avoided, and instead, the coordination and communication network should be built on existing regional structures such as CARINA in the Atlantic and PICES in the Pacific. Concerns were expressed later, however, that because the Panel itself is an advisory body rather than an international research programme, it would be difficult for the Panel to provide the necessary level of long-term coordination needed by national agencies to establish implementation strategies and commitments. It was suggested that the most appropriate international coordination mechanism through which national agencies could cooperate is JGOFS or IGBP. However, with the end of JGOFS approaching and the new ocean programme of the IGBP still a considerable distance from being established, the international ocean carbon community is left with no clear research programme through which it can integrate into observation programme planning. Currently, talks are continuing with the IGBP about possible mechanisms for coordination, perhaps through the developing Global Carbon Project if it is decided that this group will become involved in disciplinary-level coordination activities. The interim solution has been to establish a Web site on the CLIVAR Web page (complete details can be obtained from the Panel Web site: http://www.ioc.unesco.org/iocweb/co2panel) outlining the international plans and commitments for the hydrography repeat sections and to include, where already available, information about carbon and tracer measurements to be made. The Panel Chair and Technical Secretary, along with the Chair of the CARINA steering committee, attended the CLIVAR Atlantic Implementation Panel meeting in Paris in September of 2001, and the groups agreed to continue working together through the regional groups to provide as much information as possible about plans for carbon measurements in CLIVAR. The US CLIVAR and Carbon group has recently published its preliminary plans for commitments in the CLIVAR repeat hydrographic programme, including information on implementation and timing of sections, core measurements, and data management protocol.

Dr. Andrew Dickson informed the Panel about UK repeat hydrography plans for CLIVAR. Within the United States, a CLIVAR-Carbon group was established and has developed a set of recommendations and plans for a U.S. commitment to carbon and tracer measurements on repeat hydrographic sections. There is currently a call for proposals for the work, discussions between potential research groups are well advanced and proposals are being written for a period of 6 years.

Dr. Dickson noted that a unique aspect of this announcement is that the data collected from these cruises are considered to be collected for the community and should be released for public access as soon as possible after collection (e.g., within 6 months). The U.S. group is also developing the necessary data management guidelines and structure to facilitate this operational approach to hydrography.

Dr. Andrew Watson described the U.S. plans for a new programme on rapid climate change that will include some repeat hydrography along the A5 section at 24º N. Carbon (and tracers) are presently not identified as a priority for this programme and consequently no funding is available to support such measurements on these cruises.

Action Item 2: The Chair to draft a letter to Lloyd Keigwin, Chair of the Rapid Climate Change programme, to identify the close links between carbon and climate change science and measurement needs and to request that consideration be given to the support of carbon and tracer measurements in this programme.

Dr. Wallace outlined plans within Germany to conduct repeat hydrography along 42-48º N (A2 line) as well as the potential for additional future hydrographic cruises in the sub-tropical gyre of the North Atlantic in the period 2003-2006. One suggested goal is to attempt a re-occupation of TTO stations over this time period in collaboration with other nations.

Dr. Boutin noted that France has several programmes planned, and provided contact names for further information. Ovide, a section planned every two years between Vigo and Cape Farewell, will have its first cruise in June 2002, and Aida Rios is the contact for carbon measurements for that programme. The French contact is herle.mercier@ifremer.fr. A partial 5- year repeats of the eastern equatorial Atlantic section from the EQUALANT project is being coordinated by Dr Chantal Andrie at LODYC. The OISO programme in the Southern Ocean, coordinated by Alain Poisson and Nicolas Metzl, also includes some limited hydrographic work (0-1000m, no tracers) repeated seasonally.

Dr. Francey conveyed information from Bronte Tillbrook outlining Australian plans for repeat hydrographic surveys in CLIVAR that will measure carbon. Plans include: P15S every 5-7 years (last occupation June 2001); SR3 every 5-7 years (last occupation Dec 2001); A box in the Indian Ocean (last occupation Oct 2000, next maybe 2004); and I9S, planned for late 2004.

Dr. Anderson updated the Panel on plans in the Arctic. The plans of hydrography cruises including the determination of the carbonate system in the Arctic Ocean and Nordic Seas are, for logistic reasons, few. In May – June 2002 there are plans for a major two ships operation (Swedish *I/B Oden* and US *R/V Knorr*) to cover most of the Nordic Seas, and perform a full suite of hydrography and tracer determinations. The carbonate system determination is, together with the determination of SF6, part of the EU project TRACTOR. A corresponding investigation of the Nordic Seas will likely take place in 2003. Determinations of the carbonate system in the Arctic Ocean in the Bering Strait region will occur under the US Shelf Basin Interaction Program. There are also initial plans to perform a major multi-ship operation in 2005 to the deep central Arctic Ocean.

Discussion - The Panel expressed concern about the data release plans of the U.S. community with respect to repeat hydrography. The principle to collect data "for the community" was welcomed as a step in the right direction, but it was also recognised as a radical step that has some implications for the dissertation work of Ph.D students that may be involved in the collection of data or for the career paths of junior scientists involved with such data collection. Hence it is not necessarily easy to transfer such a model rapidly to other countries (e.g., Europe) without considering some significant changes to the way in which research teams are constructed or authorship is allocated.

With respect to coordination of measurements, the Chair noted that plans are clearly proceeding well within different countries, and that the CO_2 Panel is able to stay informed of these plans due to its international membership and hence the CO_2 Panel is functioning well in obtaining and exchanging information. On the other hand, there remains no coherent international planning as to what sections and frequency of occupation is required or desirable to address underlying science plans. A U.S. planning exercise of this nature was conducted on a largely national basis, albeit with the benefit of information provided by Panel members and other organizations (e.g., CARINA) as to what the plans of other nations were likely to be. There remains therefore a continuing need for international scientific planning and coordination between the carbon community of various nations and the CLIVAR community and other groups that are interested in repeat hydrography.

The Panel remains of the opinion that it is the logical international body to provide such a coordination role. However, it was also recognized that additional coordination activities place additional demands on the Panel. It was noted that the new Global Carbon Project that is co-sponsored by the IGBP, WCRP and IHDP is considering the establishment of Core Project Offices. These offices would be responsible for supporting and integrating research activities in the terrestrial, oceanic, and atmospheric realms. The Panel is of the opinion that the specific ocean expertise could be of considerable benefit to the GCP and that the integrated nature of the GCP may also help the panel strengthen the links between ocean carbon cycle science and other aspects of global carbon cycle science. For these reasons it was proposed that the CO_2 Panel should seek to establish stronger contact between itself and the GCP and offer its services in assisting with the coordination of ocean observations. It was further suggested that the Technical Secretary of the CO_2 Panel might be able to play a particularly strong role as liaison between the Panel and the GCP. In return, some additional support for the Technical Secretary may be required in order that she can allocate more of her time to such coordination and liaison activities on behalf of the Panel.

Action Item 3: The Chair to write a letter to the Scientific Steering Committee of the Global Carbon Project offering the services of the Panel to assist with advice and coordination with respect to ocean carbon measurements in the context of the GCP. This letter is to suggest that the Technical Secretary of the Panel could act as liaison with the new Project Office(s). The letter is to further suggest that such an activity will significantly extend the mandate of the Panel and the demands on the Technical Secretary's time and that some allocation of GCP resources to the Panel or, alternatively, co-support of the Technical Secretary should be considered.

3.3.4 Time-Series Plans

Dr. Hood described the meeting and plans from the Oceanographic Time Series Workshop sponsored by OOPC, CLIVAR COOP, and POGO in May 2001 in Woods Hole, Massachusetts, USA. The purpose of the meeting was to bring together an international, multi-disciplinary group to set priorities for the establishment of a sustained pilot array of time-series stations. Complete information about the pilot array and the details of the meeting are provided on the Panel Web site. The scientific steering committee is preparing the scientific and technical background papers outlining the justification for the pilot project and the specific stations chosen in the array in terms of meeting the needs of physical, meteorological, biological, and chemical oceanographic communities. The Panel was asked to provide input and to review the proposal upon its completion.

Dr. Doug Wallace outlined plans within the recently funded European Commission ANIMATE project to initiate three time-series biogeochemical moorings within the Eastern North Atlantic Ocean. In addition, a further time-series mooring may be proposed for the central Labrador Sea (BRAVO) in the context of a German national proposal. There are also attempts underway to write proposals to utilize one or two PIRATA buoys as locations for surface pCO_2 observations. To date no funding is available and no funding source exists to support the instrumentation of these CLIVAR observational sites for carbon measurements.

Dr. Leif Anderson and Dr. Peter Haugan described the status of Station Mike. Presently, the potential remains to conduct carbon observations from this weather ship that currently makes exclusively physical observations both from the surface and depth profiles. However, no funding is available for such measurements and they are not presently being made. Dr. Hood pointed out that

Station Mike is listed as one of the priority sites in the Time Series Observatory Pilot Project, and that closer ties with this group may be beneficial to more strongly advocate for those sites of particular interest to the ocean carbon community.

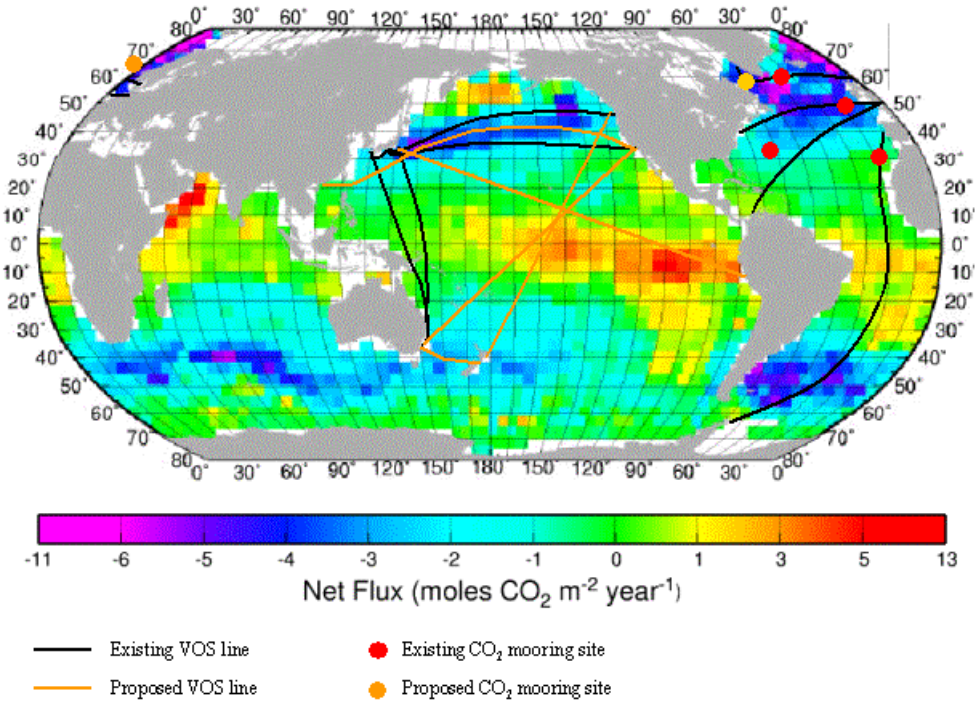
3.3.5. JCOMM Ship Observations Team/VOS Programme

Dr. Hood informed the Panel of recent progress in establishing initial communication and information exchange between scientists currently making or planning to make ocean carbon and related measurements from volunteer observing ships (VOS). This initial network consists of five programmes in the Atlantic, nine in the Pacific, one operating across the Atlantic and Pacific, and five programmes in the Southern and Indian Oceans. This information is on the Panel Web site, and a clickable route map with links to individual projects will soon be developed. The Panel will serve as a means of integrating this community with the larger network of scientists that is using VOS. The WMO - IOC Joint Commission on Oceanography and Marine Meteorology (JCOMM) has established a Ship Observations Team, which groups the existing VOS (primarily meteorological observations), SOOP (XBTs) and ASAP (upper air) panels under the one banner. JCOMM has asked the Panel to encourage the biogeochemical community to interact with the SOT. Hopefully, this will lead to enhanced coordination, synergies and eventually integration in an approach to VOS-based observations of all types. This coordination should aid carbon researchers to identify new opportunities for making carbon measurements on VOS ships, and will help to avert misunderstandings or competition between the climate and carbon observational communities with respect to their access to and relations with the commercial shipping industry.

The JCOMM SOT will have its first meeting in Goa, India in late February -early March 2002, and Panel members are preparing documents to present at that meeting concerning their ocean carbon VOS operations. Panel members Dr. Nojiri and Dr. Kumar will represent the Panel at that meeting.

Dr. Andrew Watson reported on the EC-supported CAVASSOO programme in the Atlantic. This programme is now in Year two of its three-year funding period and measurement systems are now installed on the four vessels. Measurements have commenced on the *Hesperides* line that runs from Spain to Antarctica; measurements on the three east-west North Atlantic lines are expected to commence towards the end of February 2002. (One of these lines is a joint Japan-German collaboration using equipment that was developed at the NIES). Dr. Watson stressed that although initial CAVASSOO installations and operations look highly promising, there are no clear opportunities for continued funding beyond the end of the project at this time.

Net air-sea flux of CO_2 (Takahashi *et al.*, 2001) and existing/proposed CO_2 observing system



Dr. Lee noted that the Korean Development Institute is discussing establishing a VOS / SOOP route on a vessel running from Pussau to Punta Arenas, Chile.

Discussion - Dr. Hood pointed out that VOS operations are not typically integrated into international research programmes, and that the Panel could serve a unique and useful role in strengthening this network. The Panel has been congratulated by a number of VOS researchers on this initial compilation and communication forum, which suggests that further development would be welcomed. In addition to the Web-based communication forum, Dr. Hood suggested that the next phase of development should possibly include increasing ties with the physical / meteorological VOS network and developing data sets of ocean carbon and related measurements from the VOS network, either as a Panel activity or in collaboration with existing data synthesis and collection programmes.

The Panel agreed with Dr. Watson that the CAVASSOO observation are of high value not only for ocean carbon studies but also for integrated carbon cycle science covering atmospheric pCO_2 response to terrestrial flux variability. The Panel hopes that long-term funding for these measurement lines can be secured and stands ready to lend its official support for the programme if and when needed.

Dr. Dickson informed the panel that NOAA has issued a call for proposals (deadline in April), which has provisions for the support of carbon observations on VOS with a special focus on the North Atlantic and the North Pacific oceans.

Dr. Francey stressed the utility of making the atmospheric data collected along the VOS lines of the highest accuracy and precision possible. Present equipment and standards planned for the VOS do not attain the levels of the order of 0.1 µatm accuracy and precision that is required to better resolve global budgets based on atmospheric observations. He noted that such high-quality observations would be of significant value to the atmospheric CO_2 community in extending the atmospheric measurement network. New measurement systems, such as the CSIRO "low flow" infrared analyser system, are significantly improving precision and reducing consumable cost and the requirement for skilled operators. Such systems have the potential to be used on VOS in order to attain the required

accuracy. A general discussion of data quality control and standardization for VOS was deferred until Agenda Item 3.5.

The Chair raised the issue of how the expansion of the VOS network for carbon measurements might be optimised in order to obtain maximum benefit from the expenditure of limited resources. He pointed out that one of the major potential customers for the data collected is the atmospheric inverse modelling community and asked whether it might be possible for this community to offer guidance concerning VOS line priorities. Basic questions remain unresolved: for example, whether it is better to sample a restricted region (e.g. an ocean basin) densely in order to obtain a well-defined flux estimate and error bars, or whether global, sparse coverage is more useful. To date it appears that such an analysis has not yet been conducted with respect to the siting of VOS observations (such an exercise has been conducted for the optimisation of the atmospheric measurement network).

Action Item 4: Wallace, Caldeira, Le Quéré, and Francey will investigate further the possibility of conducting model inversion studies aimed at optimising the VOS network.

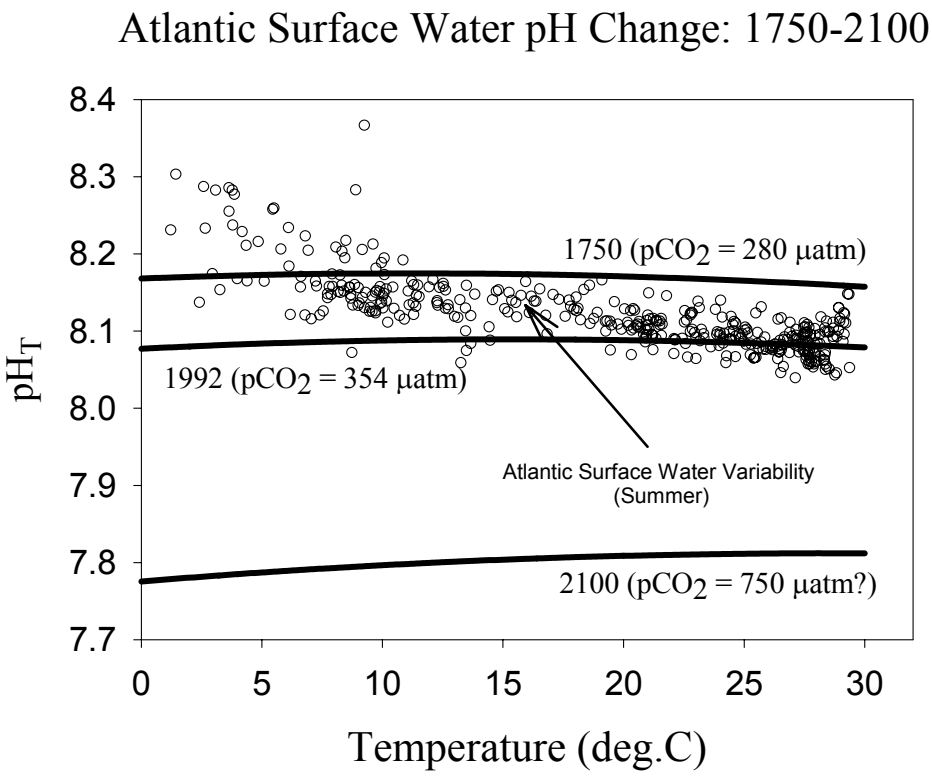
3.4 OCEAN SEQUESTRATION OF CO_2

Dr. Hood reminded the Panel of its mandate to develop and maintain a watching brief on ocean sequestration of CO_2. This role is intended to inform non-specialists concerning scientific and legal issues related to the deliberate sequestration of CO_2 in the ocean. The IOC is the United Nation's focal point for ocean science, the Panel's watching brief is aimed at providing scientific information that is both up-to-date and free of bias from both private sector interests and national politics. Dr. Hood reported that whereas the introductory and legal sections of the brief have been drafted, the scientific sections remain to be written. She suggested that Panel experts and other interested members take the responsibility to write articles suitable for the general public on the remaining scientific topics outlined in the brief.

In 2001, the IOC announced plans to co-host an international meeting on ocean fertilization jointly with ASLO. Since then, ASLO has decided that it does not wish to assume an international role in this debate, and SCOR has tentatively agreed to carry forward these international discussions. SCOR and the IOC are co-sponsors of the Panel, which has the provision of scientific information concerning ocean sequestration as part of its mandate. Hence it is sensible and appropriate that the Panel become involved in the organization of such a meeting. Discussions are on going between SCOR and IOC, and an international scientific conference or workshop on ocean sequestration of carbon, including both fertilization and direct injection approaches, is tentatively planned for 2003. The Panel has been asked to aid in the development of the conference committee and the agenda for the meeting. The Panel discussed the overall goal of the meeting, which is to produce an international synthesis of what is known and not known about ocean sequestration methods and possible environmental impacts, and what future research directions should be – possibly to be published as a special issue in a journal. The Panel also discussed the need to keep the meeting focused on the science rather than hosting a broader meeting including political or legal aspects at this time.

Dr. Ken Caldeira provided an update an ocean carbon sequestration science, noting that while the community has up to now been focusing on techniques and feasibility of various ocean carbon sequestration methods, the important issues of potential environmental impacts from decreases in pH and carbonate dissolution dynamics has not been adequately addressed. He provided a brief overview pointing out that carbonate dissolution does not buffer ocean pH against rapid CO_2 changes, and that even stabilizing atmospheric pCO_2 at 600ppm will result in a 0.4 decrease in pH in the surface waters.

Figure 1. pH as a function of CO_2 concentration, from the SOLAS science plan.



Dr. Caldeira also stressed the need to inform the public, policymakers, and other scientists about the consequences of the "do nothing" scenario, in which seven out of every eight molecules of anthropogenic CO_2 will eventually enter the ocean, resulting in significant decreases in pH in the near-surface ocean where marine biota are most plentiful. These inevitable consequences on pH, alkalinity, carbonate dissolution dynamics, the ocean's buffering capacity, and effects on marine biota must be explored and understood in order to make wise decisions about how best to minimize the environmental impacts.

Dr. Peter Haugan informed the Panel of recent activities in ocean carbon sequestration science. He noted that OCMIP continues (see Agenda Item 4.3) and direct injection cases are routinely considered in the global ocean carbon modelling community. In addition, issues of invasion and injection are included in the future IGBP ocean programme (see Agenda Item 4.6). Recent scientific highlights include MBARI's field experiments and perhaps NERSC modelling papers, which received much attention. Lab activities in Japan complement those of MBARI (and there are Japanese contributions to some of MBARIs experiments). There is also some activity in Japan investigating the bottom lake option as opposed to dissolution. There is Norwegian participation in both of these clusters of activities.

The International Ocean CO_2 Sequestration Project (USA, Japan, Norway, Canada, ABB, CRIEPI) has been delayed, but now aims for a mid-depth dilution experiment with a somewhat reduced CO_2 volume and different deployment technology this year. Contingency plans have been advanced for alternative sites because of permitting problems at Hawaii.

Dr. Haugan proposed that the Panel might wish to develop a poster or presentation on the Panel activities including the watching brief and upcoming international science meeting for the upcoming GHGT6 meeting in Kyoto, October 2002. The biannual GHGT conference series has broad coverage on all kinds of carbon and other greenhouse gas emission reduction activities. The audience is a mixed group of industry, government, science and engineering participants. A poster there might inform, among others, national government groups who could relate to IOC, and would also give an

opportunity to announce the SCOR / IOC conference, which should be fairly well planned by that time.

Dr. Haugan raised the very important issue of perceived conflicts of interests when scientists accept funding from commercially interested groups. He noted that he has already decided not to take part in projects or receive funding via projects that aim to achieve approval for a given technology or develop technology with commercial interests. He noted that the Panel members should all be very clear that we have no vested interests in the results in order to maintain integrity and trust, and to fulfil the role as independent adviser to entities like the IOC.

Discussion - The Chair first asked if, given that research into carbon sequestration is controversial in some quarters, whether any members objected to the Panel's present mandate and its organisation of a scientific conference in this area. It was clear that all present agreed that it was important to conduct basic research into such potential strategies, including more research into potential biological effects of such strategies. It was also appropriate for the Panel to disseminate accurate, unbiased scientific information concerning this matter. Nevertheless, in comparison with other Panel activities and tasks, this matter is more sensitive and the Panel's name is more at-risk from potential abuse. This is particularly so given that these technologies may attract private sector funding. Consequently, Dr. Watson suggested and the Panel agreed that it was necessary for Panel members to declare publicly any sources of funding for research and/or consulting in this area that they may benefit from, and that this information be included in the watching brief.

It was further agreed that the Panel's Web site and watching brief should include only information and comment based on peer-reviewed research and should avoid becoming a site for opinion or political discussion for or against deliberate carbon sequestration. Any links from the Web site should be carefully controlled and clearly inform the reader that they are not endorsed in any way by the Panel and its members.

Panel members should also exercise caution when speaking to the popular press on such matters and distinguish between any position endorsed by the Panel and the personal opinion of its members.

The Panel was enthusiastic about participating in the coordination of the proposed IOC-SCOR international meeting on the science of ocean carbon sequestration, tentatively scheduled for early 2003. Dr. Haugan noted that there were several meetings addressing various issues of ocean carbon sequestration already planned for the coming year: in October 2002, the GHGT6 in Kyoto, and in May 2003, the JGOFS conference where the extent of discussion on sequestration issues will soon be decided. The Panel agreed that the IOC-SCOR conference should be held after the JGOFS 2003 meeting, that is, no sooner than late 2003. The Panel agreed that the conference committee should be selected as soon as possible to avoid conflicts with other planned meetings.

Action Item 5: The Chair, Technical Secretary, Peter Haugan, Ken Caldeira, Andrew Watson, and Yukihiro Nojiri will provide SCOR with nominations for the conference committee, and aid in the development of the agenda for the meeting.

Action Item 6: This same group of Panel members will work to finalize the Watching Brief and produce either a presentation or poster appropriate for the GHGT6 meeting in October 2002.

3.5 CERTIFIED REFERENCE MATERIALS

Dr. Andrew Dickson informed the Panel on the increasing need to support and expand the certified reference materials programmes and made suggestions about actions the Panel could take to aid in this effort. He noted that Alkalinity and Total Carbon had been certified, and that the next focus was pH calibration. He also briefly discussed some inter-laboratory exercises for ^{13}C measurements with Dr. Nojiri at NIES as part of the new PICES project on data integration. At the request of the Kansai Environmental Engineering Center (KEEC) in Japan, Dr. Dickson is currently revising the DOE manual for preparation of standards to simplify the English to facilitate translation. Dr. Dickson stressed that we cannot focus solely on standards, but also on intercalibration exercises.

Discussion - Dr. Hood noted that new initiatives with the carbon VOS network might involve initiating intercalibration exercises and standards and reference materials. Dr. Watson noted that the recent seagoing intercomparison study of Körtzinger et al., 1999 found that some intercalibration problems resulted from problems in underway SST measurements rather than the pCO_2 measurements alone.

Dr. Nojiri outlined 3 major issues for quality control of underway pCO_2 measurements that must be addressed in a systemic manner:

1. The maintenance of the underway system. The typical method is to employ one of the seamen of the vessel to perform routine checks and maintenance of the system. Without appropriate training and standardized techniques, however, these practices can vary widely depending on the operator.
2. Standard gas calibration and quality of the calibrated standard gas. A gas standard must be certified to 0.01-0.02 ppm, which is an order of magnitude greater than commercially available standard gases. There are not many institutes that can measure or verify the accuracy of commercially available standards.
3. The accuracy of pCO_2 measurements. The Certified Reference Materials available are not particularly good for pCO_2 measurements, and intercalibration experiments show discrepancies of 2 μatm on similar systems.

To address some of these issues, Dr. Nojiri announced a proposal for an intercomparison exercise to be held at NIES sometime in late 2002. Using the facilities at NIES, he proposed to have up to eight different systems tested in tandem to discriminate between differences based on equilibration system design, methods, and standards. The goal of the exercise would be to determine the optimal equilibrator system among the variety currently employed, and to understand the biases of each. The Panel strongly encouraged this programme, and stated that this should not be a single, unique, experience, but rather the beginning of a series of such intercomparison experiments. Dr. Francey noted that the atmospheric community would be interested in working with the oceanographic community for the air measurements of CO_2, but noted that the current accuracy of shipboard measurements made by these systems is far from adequate for use by the atmospheric community. While it was felt that attempting to increase the accuracy of systems on VOS / SOOP vessels was not practical, it was considered to be feasible from research vessels.

Action Item 7: The Panel will promote and assist in the planning and coordination of the intercomparison experiment of Dr Nojiri through appropriate advertisements on the Panel's Web site and through contacting appropriate laboratories to encourage their participation. Dr. Francey will serve as a contact for initiation of discussions with the atmospheric network community.

Reference:

Körtzinger, A., L. Mintrop, D.W.R. Wallace, K. Johnson, C. Neill, B. Tilbrook, P. Towler, H. Y. Inoue, M. Ishii, G. Shaffer, S. Torres, F. Rodrigo, E. Ohtaki, E. Yamashita, A. Poisson, C. Brunet, B. Schauer, C. Goyet, and G. Eischeid, The international at-sea intercomparison of fCO_2 systems during the R/V Meteor Cruise 36/1 in the North Atlantic Ocean, *Marine Chemistry*. 72, no. 2, 171-193, 2000.

3.6 ATMOSPHERIC NETWORK COORDINATION

Dr. Roger Francey (CSIRO Atmospheric Research) provided an update on the current status of the atmospheric observational network. His report focussed on data availability, calibration, and network design. There has been consolidation of some established activities, progress on plans flagged in 2000 and some new directions/perspectives.

The 6th International CO_2 Conference was held in Sendai, Japan, October 2001. The Extended Abstracts of that meeting, prepared by Tohoku University (Convener: Professor Takakiyo Nakazawa), and the proceedings to be published this year in Tellus, document significant progress across a broad multi-disciplinary research front, though perhaps the oceanic representation was weaker than on

previous occasions. There have not been biogeochemical science planning meetings primarily focussed on the atmospheric measurement and modelling community; instead, various members of the community have been heavily involved in planning multi-disciplinary observation systems conducted by IGBP/WCRP/IHDP and related initiatives for global climate, ocean and terrestrial observing systems. However, there has been one international meeting focussed on entirely on atmospheric carbon (and related) measurement techniques, - the 11th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques, September 25-28, 2001 in Tokyo. An 8-page list of recommendations has been circulating (and evolving) since the Tokyo meeting and is very close to acceptance by a great majority of participants. Dr. Francey provided the following summary of the main recommendations:

For CO_2 measurement, the experts recommended:

- Improvement of the manometric determination of the absolute CO_2 amount in the suite of whole (dry) air standards in high-pressure cylinders (now managed by NOAA/CMDL, Boulder Colorado, USA) that comprise the World Meteorological Organisation (WMO), Global Atmosphere Watch (GAW) primary CO_2 calibration scale. The improvements are required retrospectively as well as presently, in order to approach specified measurement precision targets.
- Stricter adherence by laboratories claiming to be on the WMO/GAW scale to protocols for recalibration frequency, and for transparency of propagation methods.
- Encouragement to develop new methods for absolute calibration and scale propagation in order to reduce the large logistical overheads resulting from imprecise primary standard links, also to anticipate more demanding future precision requirements.
- Enhancement of inter-laboratory and inter-method comparison activities for two purposes:
    a. To more quickly identify and, if possible remove in an independent and transparent way, widespread systematic error between different methods and laboratories when propagating the WMO scale to actual measurement of atmospheric samples.
    b. Document surviving offsets in order to more accurately determine the uncertainties in merged data sets.
- To ensure transparency, all comparison results are to be promptly reported to a central database on the World Wide Web, accessible to participants.

The expert recommendations for stable isotopes, in particular $\delta^{13}C$, of CO_2 included:

- Improve the determination of the absolute isotope amount in CO_2 evolved from primary isotope materials recommended by the International Atomic Energy Agency (in particular carbonate NBS-19). The Max Planck Institute of Biogeochemistry, in collaboration with IAEA and CSIRO Atmospheric Research, intend to develop better carbonate-derived CO_2 and CO_2-in-air standards, initially for laboratories involved in the European Commission's CarboEurope programme.
- Explore methods of linking CO_2 isoptomers directly to Avogadro's number (rather than via carbonates etc.) using precise mass comparators, initially involving the Institute for Reference Materials and Methods, Belgium.
- Determine CO_2 isotopic value in air samples relative to that in bracketing air standards in order to:
    a. Better account for systematic biases involving both the CO_2 separation and mass spectrometer determination, and;
    b. Minimise widespread sample-reference mixing that occurs in conventional dual inlet isotope ratio mass spectrometry at levels important for atmospheric measurements.

- In concert with the CO_2 and other trace gas measurement, enhance transparent inter-laboratory and inter-method comparison activities.
- Implement similar (shared?) www reporting and accessible database facilities as for CO_2.
- Retain and maintain the CLASSIC suite as interim air standards
- Seek a forum or taskforce be convened by IAEA to establish protocols and recommendations that provide consistent links to V-PDB (and V-SMOW etc.) in measurements involving the three major exchanging carbon reservoirs; the atmosphere, oceans, and land.

Recommendations for O_2/N_2 measurements:

- Begin developing equivalent absolute calibration, calibration scale propagation and comparison activities for growing number of laboratories undertaking the measurement of O_2/N_2 in the global atmosphere.

Recommendations for data archives/availability:

- The WMO World Data Center for Greenhouse Gases (WDCGG), hosted by the Japan Meteorological Agency in Tokyo, has significantly expanded and upgraded the data archive and is likely to emerge (along with the U.S Department of Energy Carbon Dioxide Information Analysis Center) as a major source of data for users who require actual data (rather than, for example, the convenient, smoothed "data construct" GLOBALVIEW CO_2 2000, provided by NOAA, and widely employed by modellers at the Sendai conference). The developing concept of high-resolution "multiple-constraint" approaches favours the use of actual data and data uncertainties.

CO_2 Measurement from Space

Strong initiatives have emerged over the last year in the United States and Europe to develop satellite systems to measure atmospheric CO_2 levels from space. Along with spectroscopists, the atmospheric CO_2 community have been involved in developing these plans.

Prominent among the justifications for these very expensive initiatives is that the uncertainties in regional flux estimates from inversions of the current atmospheric observing networks in the lower troposphere are too large to permit reliable source and sink attribution (e.g., Rayner, P. J., and O'Brien, D. M. 2001, The utility of remotely sensed CO_2 concentration data in surface source inversions, Geophysical Research Letters, 28 (1): 175-178.). In turn, there are particular limitations of existing atmospheric measurement approaches that can be attributed to:

1. Inadequate spatial coverage, in particular over continental regions.
2. Inadequate temporal coverage compared to the infrequent snapshots (a few minutes at weekly to monthly intervals) provided by the current flask sampling networks.

(Note: Further limitations related to adequate representation of atmospheric transport in inversions are similar for both satellite and surface measurement methods).

It is proposed that the poor intrinsic precision in the satellite measurement of vertically integrated CO_2 content through the troposphere (estimated at around ±3 ppm) can be overcome by the anticipated huge improvement in sampling frequency, relying on averaging to reach useful precisions, at least over continental regions where current sampling is sparse.

There are a number of other potential limitations to the satellite product, for example, in quantitative removal of aerosol and cloud interference (particularly in heavily and persistently affected regions), topography over continents, calibration, and the very crude vertical resolution. A high-quality satellite product is unlikely to be available in less than 3-5 years; nevertheless, it is likely to provide a valuable complement to existing approaches. I suspect its relevance to the oceanic carbon community is likely to be more via specification of the terrestrial carbon cycle (and a large-scale mass balance), than providing direct new information on air-sea fluxes (particularly for poorly-sampled, large-scale, but persistently cloudy, regions of the Southern Ocean).

Possible Improvements to Tropospheric Sampling of Air-Sea Carbon Fluxes

In the time that it takes satellite sensing of CO_2 to provide useful new information, there is potential for significant improvement in the ability of surface monitoring of the atmospheric composition to identify and monitor, at relatively low cost, the more significant surface exchanges. Expanded vertical sampling (towers, aircraft), better use of multi-species atmospheric measurements and the improved calibration across sampling networks, coupled with many parallel developments, such as better atmospheric transport representation and multiple-constraint approaches incorporating rapidly improving source and sink parameterisations, will contribute. Many such developments are

now being implemented in a number of continental initiatives such as the CarboEurope programme, largely driven by impending international agreements to limit national emissions of greenhouse gases.

Recent advances in instrumental development for CO_2 measurement suggest there is the potential to significantly out-perform satellite sensing in the long term for some important applications.

For example, eighteen months of operation of a "low-flow" CO_2 analyser system against an established conventional continuous analyser system at the Cape Grim Baseline Air Pollution Station has demonstrated:

(a) Potential for unattended, remotely controlled and monitored operation (by phone/internet) for up to five months or more, compared to the weekly skilled intervention required for the conventional analyser.
(b) A precision and stability, maintained over 18 months, at least 10 times better than the conventional system.
(c) An operating cost (in consumables, and not including staff time) some five times lower than the conventional system.

While the initial cost of this system appears relatively high, it is not significantly different from a conventional system when the full cost of equivalent drying, calibration, control and communication systems are included. There are opportunities to improve portability, and, as the ongoing development phase tapers off, possibly to reduce overall cost. Anticipated impacts of an instrument with this performance on measurement of the global carbon cycle include:

(a) As a powerful diagnostic instrument to help reduce the endemic systematic problems evident throughout the global atmospheric measurement networks.
(b) Provision of continuous CO_2 monitoring at remotes sites, difficult to staff and supply.
(c) Increased continuous monitoring in poorly-sampled continental areas, where a combination of tall towers and opportunities for data selection and averaging (with the help of high resolution transport models) can help bridge the scale gap to global general circulation model grid scales.
(d) For shipboard use, initially for atmospheric monitoring, possibly also for ocean pCO_2 measurement with a scaled down equilibrator.
(e) For possible ultra-high precision monitoring of Southern Ocean air-sea fluxes, considerably below proposed satellite detection limits. This could provide early detection of predicted large-scale CO_2 effluxes associated with global warming or verification of the effectiveness of wide spread iron fertilisation in the region.

(Note: Six prototype desktop units have recently been commissioned to be deployed across this range of applications).

Discussion: The Panel was extremely enthusiastic about the eventual possibility of monitoring atmospheric CO_2 with the required accuracy for use by the atmospheric CO_2 community from ships. The Panel agreed that in all future discussions and projects involving underway pCO_2 measurements, collaboration and coordination with the atmospheric network community should be included.

3.7 MEASUREMENT TECHNOLOGY

Dr. Leif Anderson briefly updated the Panel on measurement technology research and development, noting that the only recent new developments have been in the area of pH sensors.

Discussion - The Technical Secretary mentioned that this was a Panel activity in need of substantial input. The Web site should serve as a clearinghouse of information on various measurement technology research and development programmes within the scientific community, providing basic information, links, and contact points. The Panel noted that the Panel members alone were not sufficient to provide comprehensive input on these activities, and noted that the development of an informational site would need input from the wider community.

Action Item 8: The Technical Secretary will contact appropriate scientists involved in instrument development for ocean carbon and related variables to develop an information base / catalogue on the Panel Web site.

4. STATUS OF INTERNATIONAL OCEAN CO_2 ACTIVITIES AND RELATED PROGRAMMES

4.1 DATA SET COMPILATION

Dr. Dickson briefly informed the group of the recent PICES meeting, where it was announced that the PICES WG 13 on ocean carbon would be disbanded in 2002. As stated in the report of the meeting: To continue this work and to retain a scientific focus on the carbon cycle within PICES, a new WG 17 on *Biogeochemical data integration and synthesis* was established with the following terms of reference:

1. Develop a North Pacific database for ocean CO_2 and related parameters in association with existing data centres. Advise data centres which of the available historical data sets should be assigned a high priority for acquisition and conversion to an electronically readable form.
2. Prepare a written guide of best practices for oceanic CO_2 measurements and data reporting. Carry out, as needed, inter-laboratory method comparisons to assure future measurement quality. Encourage the availability of suitable reference materials.
3. Develop a strategy to co-ordinate the planning of future North Pacific measurement programmes to ensure optimal use of resources to obtain appropriate temporal and spatial coverage as well as maximum comparability with historical data. Efforts should be made to encourage timely availability of the "new" data.
4. Organize a symposium or an annual meeting session on the impacts of climate change on the carbon cycle in the North Pacific.

The above-mentioned WG 17 activities were recognized by the Panel as contributing to the high quality of carbon dioxide measurements and to an international North Pacific CO_2 data synthesis. The Panel emphasized the importance of international participation in the design of Ocean Carbon Observation System and supported PICES as an excellent forum for the Pacific region. Collaboration between the PICES WG 17 and Panel should be advanced through joint workshops or activities.

Dr. Dickson described his on going, NOAA funded work to develop a standard format for ocean carbon data, including standardizing the CDIAC database. He noted that the Panel should work to advocate the use of a standard format for carbon and related variables. The Panel was also contacted about this issue by Dr. Ludger Mintrop, director of the CARINA programme, who noted that with the large amount of pCO_2 surface data being collected from VOS programmes, it would be useful for the Panel to examine this issue of standardization more closely and to advocate a common data format.

Dr. Andrew Watson described the EU project ORFOIS, developed to bring together relevant CO_2 data sets to facilitate data access and use. Dr. Andrew Dickson is defining a uniform data format for surface water CO_2 data, and CDIAC and other large CO_2 data centres will adopt the uniform format and will set up public and online Web access for CO_2 data by Live Access Server. The contribution of the EU ORFOIS project is to work with Dr. Dickson on defining a uniform data format, to collect surface water CO_2 data from principle investigators and scattered data archives, and to send this data to the World Data Centre for Atmospheric Trace Gases (CDIAC, USA) and mirrored at the WDC for Marine Environmental Sciences in Germany.

Discussion - The Chair discussed the importance of working with regional groups for issues such as data set compilation, and noted that strong regional groups already exist for the Pacific (PICES WG 17) and CARINA. However, he noted that similar efforts should be encouraged and developed for the Indian and Southern Ocean regions. The Panel strongly supported the data compilation and standardization activities, and will advocate and advertise these activities.

4.2 REMOTE SENSING

Dr. Jacqueline Boutin briefly updated the Panel on remote sensing activities in relation to ocean carbon research and monitoring. She first presented recent work of Glover et al. (2002) on the CO2 transfer velocity, k, deduced from dual frequency altimeters (TOPEX POSEIDON). The transfer

velocity, k, is related to the slope of the small-scale waves in the range 6.3-16.5 cm. When the k-altimeter relationship is calibrated with laboratory (wind/wave tank) measurements, the k distribution obtained with TOPEX POSEIDON is very close to the one deduced from the Liss and Merlivat (1986) relationship and NCEP or satellite wind speeds, but this relationship does not include explicit parametrization for wave breaking. New algorithms including field data lead to deviations from Liss-Merlivat relationship.

Dr. Boutin summarized studies on primary production (PP) deduced from SeaWiFS Chlorophyll a measurements. Behrenfield et al. (2001) produced global maps of PP during the El Niño 97- La Niña 98-99 transition and showed evidence of large variability in the tropics. Moore and Abott (2000) produced regional maps of PP in the Southern Ocean and results showed that 80% of the PP is produced in the region between 30ºS and 50ºS, mainly because of the large area of this region and despite very large PP in the Weddell Sea and Ross Sea. Intercomparison exercises of PP (Primary Production Algorithms Round Robin, PPARR, NASA) deduced from ocean colour are in progress. First, PP estimates obtained with various algorithms have been compared with *in situ* measurements; this work has been coordinated by J. Campbell and publication of the results is in progress (Campbell et al., 2001). Second, an intercomparison of PP retrieved at regional to global scale from satellite measurements is in progress and will be presented at the Ocean Science meeting (coordinated by M.H. Carr, presented at the Ocean Science meeting, Hawaii, February 2002). The main challenges to improve the retrieval of PP and net primary production (NPP), which is the key parameter for carbon cycle studies, are (1) to model the algae physiology and to be able to predict it as a function of environmental conditions (temperature, light, nutriments, physics…), and (2) to improve the knowledge of the "f-ratio" (ratio between PP and NPP). Regional studies of the f-ratio are in progress (see for instance Gep&Co, Y. Dandonneau, presented at the Ocean Science meeting, Hawaii, February 2002).

Dr. Boutin illustrated the use of multi-sensor measurements (chlorophyll a deduced from ocean colour, sea surface height deduced from altimetry and sea surface temperature). Machu and Garcon (2001) relate the remotely sensed distribution of phytoplankton to the dynamical environment using SeaWiFS chlorophyll a, SST and TOPEX-ERS sea level anomalies in the Aghulas current system by using a wavelet analysis, and their results suggest a new scenario for the seasonal variability of the ocean circulation in this zone. In the Southern Ocean, Le Quéré et al. (2002) use chlorophyll a, sea surface height anomalies, and SST to analyse which physical process (ocean stratification/ocean mixing) controls regional biological productivity. Boutin et al. (Ocean Science meeting, Hawaii, February 2002) use sea surface temperature (SST deduced in quasi-real time by NOAA at 50 km resolution) and ocean colour (SeaWiFS Chlorophyll a at 9 km resolution) to interpret pCO_2 measurements made in the Southern Ocean, south of Australia and New Zealand onboard ship and in the Sub-Antarctic zone in the central Indian ocean from CARIOCA buoys. The results show a good correlation between pCO_2 and chlorophyll a in regions of very high chlorophyll a; in other regions of the Sub-Antarctic Zone they observe a better (negative) correlation between pCO_2 and SST.

Dr. Boutin provided a summary of the existing sensors and those in development:

Wind speed:

-Scatterometer:	QSCAT: July99 - present Seawinds on ADEOS2: Nov 02?
-Microwave radiometer:	SSM/I: 1987 - present AMSR-E on Aqua: March 2002? AMSR on ADEOS2: Nov 02?
-Altimeter:	Topex-Poseidon: August 92 - present Jason: Dec01 – present

Sea Surface Temperature:

-Visible/IR radiometer:	AVHRR 1982 - present New generation of geostationnary satellite (IR channels) GOES – present Meteosat 2nd generation: Mid 02?

-Microwave radiometer:	TMI (40S-40N): Dec 97 - present
(no cloud contamination)	AMSR-E on Aqua: March 2002?
	AMSR on ADEOS2: Nov 02?

Ocean Color:

-Visible/IR radiometer:	SeaWiFS Sept 97 - present
	MODIS on Terra Feb 00 - present
	(v4 reprocessing foreseen mid 2002)
	MERIS on ENVISAT March 2002?
	MODIS on Aqua: March 2002?
	GLI on ADEOS2: Nov 02?

Sea Surface Height anomalies:

-Altimeter:	Topex-Poseidon: August 92 - present
	Jason: Dec01- present
	RA on ENVISAT March 2002?

References:

Behrenfeld, M.J., J.T. Randerson, C.R. McClain, G.C. Feldman, S.O. Los, C.J. Tucker, P.G. Falkowski, C.B. Field, R. Frouin, W.E. Essaias, D.D. Kolber, and N.H. Pollack, Biospheric Primary Production during an ENSO transition, *Science*, *291*, 2594-2997, 2001.

Campbell J., D. Antoine, R. Armstrong, K. Arrigo, W. Balch, R. Barber, M. Behrenfeld, R. Bidigare, J Bishop, M.E. Carr, W. Esaias, P. Falkowski, N. Hoepffner, R. Iverson, D. Kiefer, S. Lohrenz, J. Marra, A. Morel, J. Ryan, V. Vedernikov, K. Waters, C. Yentsch, and J. Yoder (2001). Comparison of algorithms for estimating ocean primary production from surface chlorophyll, temperature and irradiance, Global Biogeochemical Cycles, in press.

Glover, D.M., N.M. Frew, and S.J. McCue, A Multi-year Time Series of Global Gas Transfer Velocity from the TOPEX Dual Frequency, Normalized Radar Backscatter Algorithm, *Geophysical Monograph*, *127*, 325-331, 2002.

Lequéré, C., L. Bopp, and I. Tegen, Antarctic circumpolar wave impact on marine biology, *Sumitted to Geophysivcal Research Letter*, 2002.

Liss, P.S., and L. Merlivat, Air-sea gas exchange rates: Introduction and synthesis, in *The Role of Air-Sea Exchange in Geochemical Cycling*, edited by P. Buat-Ménart, pp. 113-127, D. Reidel, Norwell, Mass., 1986.

Machu, E., and V. Garçon, Phytoplankton seasonal distribution from SeaWIFS data in the Agulhas Current system, *J. Marine Res.*, *59*, 795-812, 2001.

Moore, J.K., and M.R. Abott, Phytoplankton chlorophyll distributions and primary production in the Southern Ocean, *J. Geophys. Res.*, *105*, 28709-28722, 2000.

Discussion – The Panel remarked that algorithm development for relating surface variables measured by satellite to actual surface ocean processes will increasingly require *in situ* data for validation and calibration. Currently, there are few programmes making routine measurements of ocean colour variables on, for example, VOS / SOOP. The notable exception is the French Geochemistry, Phytoplankton, and Ocean Colour (GeP & CO) programme of Dr. Yves Dandonneau.

4.3 OCEAN CARBON MODELLING INTERCOMPARISON PROJECT

Dr. Corinne Le Quéré briefly updated the group on activities related to the comparison of ocean carbon models. The second phase of the Ocean Carbon-Cycle Model Intercomparison Project (OCMIP-2) has come to an end. Comparison of both physical and biogeochemical model output was done. Results on CFCs are already published (Dutay et al., 2002). There are several papers in preparation presenting results on model physics, ^{14}C, air-sea fluxes of CO_2 and O_2, new and export production, historical and future anthropogenic CO_2 and comparison with observed anthropogenic CO_2. These papers will all be submitted together to Global Biogeochemical Cycles, who will go through the normal review process and publish a special section on OCMIP.

Dr. Ken Caldeira presented a Taylor diagram for model results of pCO_2 (Taylor 2001). This diagram showed in a single graphic the spread between model results and their distance from observations.

Model comparison activities will continue in Europe. A project was funded by the European Union (NOCES – for Northern Ocean-Atmosphere Carbon Exchange Study). NOCES focuses on interannual variability. It has a strong component of data analysis using atmospheric CO_2 inversions, *in situ* pCO_2 measurements and satellite data. This project started in May 2002 and is funded for three years.

References:

Dutay J.C., J.L. Bullister, S.C. Doney, J.C. Orr, R. Najjar, K. Caldeira, J.-M. Champin, H. Drange, M. Follows, Y. Gao, N. Gruber, M.W. Hecht, A. Ishida, F. Joos, K. Lindsay, G. Madec, E. Maier-Reimer, J.C. Marshall, R.J. Matear, P. Monfray, G.-K. Plattner, J. Sarmiento, R. Schlitzer, R. Slater, I.J. Totterdell, M.-F. Weirig, Y. Yamanaka, A. Yool, Evaluation of ocean model ventilation with CFC-11: comparison of 13 global ocean models, Ocean Modelling, 4, 89-120, 2002.

Taylor, K.E. Summarizing multiple aspects of model performance in single diagram, J. Geophys. Res. 106, 2001.

4.4 SURFACE OCEAN-LOWER ATMOSPHERE STUDY

Dr.Doug Wallace briefly updated the group on planning for the IGBP/SCOR Surface Ocean-Lower Atmosphere Study (SOLAS). He noted that SOLAS now has a scientific steering committee, and that the science plan is under revision. The strategy and implementation documents will be developed next, with a view to a 2004 start date to this 10-year programme. Focus 3 of the SOLAS science plan deals with the air-sea flux of CO_2. Panel members Wallace and Kumar are both members of the SOLAS Scientific Steering Committee.

Dr. Corinne Le Quéré informed that Panel that she would be co-ordinating a SOLAS summer school to be held in Corsica in 2003 for students in environmental sciences. Information can be found on "http://www.bgc.mpg.de/~corinne.lequere/solas/".

Discussion – The Panel noted that SOLAS be important for several Panel activities and that we should stay informed of its development.

4.5 LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE PROJECT

Dr. Michel Frankignoulle briefly updated the Panel on the status of LOICZ ocean carbon activities. Concerning carbon and nutrient budgets in the coastal zone, the task of the LOICZ modelling team, directed by Steve S. Smith from the University of Hawaii, is to assess CNP fluxes in the coastal ocean. The LOICZ approach is based on the mass conservation concept. About 170 sites worldwide have so far been budgeted and 30 are under development. The next challenge is the extrapolation to the global coastal ocean and LOICZ has now launched a close cooperation between the budgeting group and the typology group.

For the LOICZ focus on trace gases in the coastal zone, a literature review has been produced on the relevance of the coastal zone for atmospheric exchanges (sources or sinks) for trace gases (except CO_2). They, too, conclude that the coastal ocean is an important source to the atmosphere for CH_4, N_2O, DMS COS and Hg. More research is needed to assess future changes of these fluxes in the global change context.

In 1999, Tsunogai et al. formulated the "continental shelf hypothesis", based on results obtained in the East China Sea, and which suggest that shelves could act as a sink of about 1 GtC/year. More recently, Frankignoulle and Borges (2001) have found similar results from an interannual study of the European shelf.

References:

Frankignoulle, M. and A. V. Borges (2001). European continental shelf as a significant sink for atmospheric carbon dioxide. *Global Biogeochemical Cycles*, 15(3), 567-576.

Tsunogai, S., Watanabe, S., and T. Sato, Is there a "continental shelf pump" for the absorption of atmospheric CO_2?, *Tellus*, 51B, 701-712, 1999.

Discussion – The Panel remarked that while the coastal areas may exhibit large under saturations of pCO_2 in the summer, water transport and sinking from the shelf areas typically occurs in winter, when pCO_2 is not particularly under saturated. While it is possible to have convection and mixing in other seasons, the Panel agreed that one area of research focus should be to combine these studies with transport and mixing studies and models to determine the real capacity for the coastal zone to act as a CO2 sink. It was also noted that the Arctic sea shelves are not studied within the framework of either LOICZ or the new IGBP/SCOR ocean programme, and that these areas may have significant transport from the shelf regions to the intermediate and deeper waters.

4.6 IGBP/SCOR OCEAN FUTURES MEETINGS

Doug Wallace reported on activities of the Ocean 'Futures' group. In 2000, IGBP and SCOR initiated a process to develop plans for the next decade of ocean research. The first two steps of the process used by IGBP and SCOR to create a draft Framework for biological and chemical aspects of global change research in the ocean were:

- An initial workshop of project representatives and scientists in Plymouth, UK on 23-26 September 2000 was designed to gain input from representatives of the existing and planned marine projects, both within and outside IGBP.
- An Ocean Futures Planning Committee, formed by IGBP and SCOR in 2001, was asked to create a Framework for Ocean Research, identifying new research issues, building on research results and identifying areas of co-operation among existing activities of IGBP and SCOR. Output from the Plymouth workshop provided key input material for this Framework report.

This Ocean Futures Planning Committee was comprised of:

Peter Burkill, *Co-Chair,* Plymouth Marine Laboratory (United Kingdom)
Julie Hall, *Co-Chai*r, NIWA (New Zealand)
Robert Costanza, University of Maryland (United States)
Raja Ganeshram, University of Edinburgh (United Kingdom)
William Jenkins, Southampton Oceanography Centre (United Kingdom)
Kon-Kee Liu, National Taiwan University (Taiwan)
Celia Marrase, Institut de Ciencias del Mar (Spain)
Patricia Matrai, Bigelow Laboratory for Ocean Sciences (United States)
Patrick Monfray, Laboratoire des Sciences du Climat et de l'Environment (France)
Bradley Opdyke, The Australian National University (Australia)
Shubha Sathyendranath, Bedford Institute of Oceanography (Canada)
John Steele, Woods Hole Oceanographic Institution (United States)
Doug Wallace, Kiel University (Germany)

This group's terms of reference included**: '** Develop the key scientific issues needed to guide research on marine processes and structure in the context of Earth System Science and Global Change. In particular, the questions should relate centrally to the goals of IGBP and SCOR'.

In December 2001, this group completed and submitted a document entitled: ***A Draft Framework for Future Research on Biological and Chemical Aspects of Global Change in the Ocean: an IGBP/SCOR Collaboration.*** This document was sent for international review. The document was organized around three key issues and several sub-questions as follows:

Issue 1: What controls the time-varying biogeochemical state of the ocean system and how will it change in response to Global Change?

1.1 How will the critical ocean interfaces participate in, and respond to, Global Change?

1.2 What role will the “Twilight Zone” play in Global Change?
1.3 What will be the impact of climate-induced changes in circulation, ventilation, and stratification on the oceanic biogeochemical state?
1.4 Biogeochemical “hot spots”, “switch
1.5 Points” and "choke points”.
1.5 How are biogeochemical processes affected by, and affect, ecological structure and function?

Issue 2: How will marine food webs respond to Global Change?
2.1 What are the relations between elemental cycling and food web structure?
2.2 What are the roles of physical and chemical drivers in determining marine food web structures and functioning?
2.3 What are the relations among biodiversity, structure, function and stability of marine ecosystems?
2.4 How do variations in marine food webs manifest themselves over various time and space scales?

Issue 3: How does the accumulation of carbon in the ocean respond to global environmental change?
3.1 What is the effect of Global Change on anthropogenic CO2 uptake?
3.2 What is the effect of climate variability on the ocean’s Biological Pump?
3.3 The fate of terrigenous carbon in the marine environment
3.4 What is the effect of decreasing pH on carbonate dissolution and calcium carbonate precipitation in the Global Ocean?
3.5 What would be the consequences and effectiveness of deliberate CO2 sequestration in the deep ocean?
3.6 What are the physical processes that lead to methane clathrate release?

In 2002 and 2003, the process to develop the Science Plan/Implementation Strategy for biological and chemical aspects of Global Change research in the ocean continues. An Ocean Futures Transition Team was formed by IGBP and SCOR to carry forward the next phase of the process. The Transition Team will:

1. incorporate reviewers´ comments into a revised Framework report,
2. post the revised report on the IGBP and SCOR Web sites to provide an opportunity for community comment on the report,
3. plan an Open Science Conference based on the report, and
4. develop a Science Plan/Implementation Strategy based on community input from the report posted on the World Wide Web and from the Open Science Conference.

Since the Transition Team was formed the name of the project has changed to: OCEANS: Ocean biogeochemistry and ecosystem analysis. The Open Science Conference will take place in Paris, 7-10 January 2003. Full details about this conference can be obtained from: www.igbp.kva.se/obe/

4.7 PLANNING FOR THE 3RD INTERNATIONAL OCEAN CO_2 CONFERENCE

Dr. Hood reminded the Panel that the previous international ocean CO_2 conferences have been organized and hosted by the Panel. The meetings are typically held in alternate years with the International CO_2 Conference, suggesting that the next CO_2 conference should be held in late 2002, or early 2003.

Dr. Andrew Dickson informed the Panel that he and Dr. Taro Takahashi (LDEO) approached NOAA about possible funding to host the international ocean CO_2 conference in the United States in the next year, but that the general feeling in the community seems to be that rather than having separate ocean CO_2 meetings, the ocean community should interact more strongly with the atmospheric community to participate in the International CO_2 Conferences. The Panel agreed, but noted that in the past, there had not been meaningful ocean components at these meetings, and that it is imperative to have more ocean carbon scientists as members of the conference committee. Dr. Roger Francey pointed out that the recent format of the international conference might not be amenable to

having a significant and meaningful ocean component, favouring only plenary sessions and short poster sessions. He suggested that early planning would be needed with the conference organizers to ensure that the ocean community would have sufficient time in parallel or abutting sessions to address its own more detailed research issues.

Action Item 9: Dr. Andrew Dickson will begin discussions and coordination with Dr. Pieter Tans (Boulder) to get substantial ocean input and participation in the conference committee for the 2005 International Carbon conference.

The Panel also noted that the 2005 date for the international conference was quite a long interval to wait before having an ocean CO_2 conference. It was suggested that smaller, regional workshops may be ideal, or perhaps convincing JGOFS to hold one day of its May meeting dedicated to CO_2 issues. It was also noted that CARINA is planning a North Atlantic CO_2 meeting sometime in early 2003. The Chair suggested that perhaps a combined CARINA and PICES meeting might be possible.

Action Item 10: Dr. Peter Haugan will contact the JGOFS programme committee to investigate possibilities of extending its four-day meeting to include an additional day focusing on ocean CO_2.

Action Item 11: Dr. Doug Wallace to contact the CARINA and PICES project directors to investigate the possibility of having a joint meeting in early 2003.

5. REVIEW OF SCHEDULED ACTIONS

The Panel reviewed the following list of action items for programme activity for 2002:

Action Item 1: The Chair and Technical Secretary will outline the major messages that the Panel wishes to convey concerning the relevance of ocean carbon cycle science for addressing issues of the environmental effects of increased CO_2, such as the effect of lowered pH on calcium carbonate formation/dissolution and organisms, and the need to establish closer links with biological oceanographic community. Panel members will work to write semi-popular or commentary-style articles to outline the key motivations and significance of ocean carbon cycle research.

Action Item 2: The Chair to draft a letter to Lloyd Keigwin, Chair of the Rapid Climate Change program, to identify the close links between carbon and climate change science and measurement needs and to request that consideration be given to the support of carbon and tracer measurements in this program.

Action Item 3: The Chair to write a letter to the Scientific Steering Committee of the Global Carbon Project offering the services of the Panel to assist with advice and coordination with respect to ocean carbon measurements in the context of the GCP. This letter is to suggest that the Technical Secretary of the Panel could act as liaison with the new Project Office(s). The letter is to further suggest that such an activity will significantly extend the mandate of the Panel and the demands on the Technical Secretary's time and that some allocation of GCP resources to the Panel or, alternatively, co-support of the Technical Secretary should be considered.

Action Item 4: Wallace, Caldeira, Le Quéré, and Francey will investigate further the possibility of conducting model inversion studies aimed at optimising the VOS network.

Action Item 5: The Chair, Technical Secretary, Peter Haugan, Ken Caldeira, Andrew Watson, and Yukihiro Nojiri will provide SCOR with nominations for the conference committee, and aid in the development of the agenda for the meeting.

Action Item 6: This same group of Panel members will work to finalize the Watching Brief and produce either a presentation or poster appropriate for the GHGT6 meeting in October 2002.

Action Item 7: The Panel will promote and assist in the planning and coordination of the intercomparison experiment of Dr Nojiri through appropriate advertisements on the Web site and through contacting appropriate laboratories to encourage their participation. Dr. Francey will serve as a contact for initiation of discussions with the atmospheric network community.

Action Item 8: The Technical Secretary will contact appropriate scientists involved in instrument development for ocean carbon and related variables to develop an information base / catalogue on the Panel Web site.

Action Item 9: Dr. Andrew Dickson will begin discussions and coordination with Dr. Pieter Tans (Boulder) to get substantial ocean input and participation in the conference committee for the 2005 International Carbon conference.

Action Item 10: Dr. Peter Haugan will contact the JGOFS programme committee to investigate possibilities of extending its four-day meeting to include an additional day focusing on ocean CO_2.

Action Item 11: Dr. Doug Wallace to contact the CARINA and PICES project directors to investigate the possibility of having a joint meeting in early 2003.

ANNEX I

LIST OF PARTICIPANTS

I. PANEL MEMBERS

Leif **ANDERSON**
Analytical and Marine Chemistry
University of Göteborg
S-412 96 Göteborg
SWEDEN
Tel: +46 31 772 27 74
Fax: +46 31 772 27 85
EMAIL: LEIF@AMC.GU.SE

Jacqueline **BOUTIN**
Université Pierre et Marie Curie (Paris 6)
Laboratoire d'Oceanographie Dynamique et Climatologie, LODYC
TOUR 14, CASE 100
2eme Etage, 4 Place Jussieu
75252 Paris Cedex 05
FRANCE
Tel: 33 01 44 27 49 71
Fax: 33 01 44 27 38 05
Email: jb@lodyc.jussieu.fr

Kenneth G. **CALDEIRA**
CLIMATE AND CARBON CYCLE GROUP
Lawrence Livermore National Laboratory
7000 East Avenue, L-103
Livermore, CA 94551-0808
USA
Tel: (925) 423 4191
Fax: (925) 422 6388
Email: kenc@llnl.gov

Andrew G. **DICKSON**
Marine Physical Laboratory
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, California, 92093-0244
USA
Tel: 1-858 822 2990
Fax: 1-858 822 2919
Email: adickson@ucsd.edu

Roger J. **FRANCEY**
CSIRO Atmospheric Research
PMB#1 Aspendale,
Victoria 3195
AUSTRALIA
Tel: 61 3 9239 4615
Fax: 61 3 9239 4444
Email: roger.francey@dar.csiro.au

Michel **FRANKIGNOULLE**
Chemical Oceanography Unit
Université de Liège, Bât. B5
Allée du 6 Août, 17
4000 Liège
BELGIUM
Tel: +324 3663326
Fax: +324 3662355
Email: Michel.Frankignoulle@ulg.ac.be

Peter **HAUGAN**
Geophysical Institute, University of Bergen
Allegaten 70
N-5007 Bergen
NORWAY
Tel: +47 5558 2678
Fax: +47 5558 9883
Email: Peter.Haugan@gfi.uib.no

Kitack **LEE**
Pohang University of Science and Technology,
School of Environmental Science and Engineering
San-31, Hyoja-dong, Nam-gu
Pohang, 790-784
KOREA
Tel: +82 054 279-2285
Fax: +82 054 279-8299
Email: ktl@postech.ac.kr

Yukihiro **NOJIRI**
Leader, Carbon Cycle Research Laboratory
National Institute for Environmental Studies
Tsukuba, Ibaraki 305
JAPAN
Tel: +81 298 50 2499,
Fax: +81 29 51 4732
Email: nojiri@nies.go.jp

Corinne **LE QUERE**
Max-Planck-Institut für Biogeochemie
P.O. BOX 10 01 64
07701 Jena
GERMANY
Tel: +49 3641 686722
Fax: +49 3641 686710
Email: lequere@bgc-jena.mpg.de

Douglas W. R. **WALLACE**
Forschungsbereich Marine Biogeochimie
Institut fur Meereskunde an der Universitat Kiel
Dusternbrooker, Weg 20D
24105 Kiel
GERMANY
Tel: 49 431 600 4200
Email: dwallace@ifm.uni-kiel.de

Andrew **WATSON**
School of Environmental Sciences
University of East Anglia
Norwich NR4 7TJ
UNITED KINGDOM
Tel: 44 1603 593761 direct; 456161 standard
Fax: 44 1603 507719
Email: a.j.watson@uea.ac.uk

II. PANEL MEMBERS NOT ATTENDING

Dileep **KUMAR**
NATIONAL INSTITUTE OF OCEANOGRAPHY
Dona Paula, 403 004
Goa
INDIA
Tel: +91(0) 832-221322 / 226253 x: 4398 / 4294
Fax: +91(0) 832-223340 / 229102
Email:dileep@darya.nio.org

III. GUESTS

Nicolas **DITTERT**
Institut Universitaire Europeen de la Mer
University of Western Brittany
29280 Plouzane
FRANCE
Tel: +33 298 49 86 73
Fax: +33 298 49 86 45
Email: Nicolas.Dittert@univ-brest.fr

Masao **FUKASAWA**
Senior Scientist, Ocean Observation and Research Department,
Japan Marine Science and Technology Center
2-15 Natsushima-Cho
Yokosuka 237-0061
JAPAN
Tel: +81 468 67 9470
Fax: +81 468 65 3202
Email: fksw@jamstec.go.jp

IV. IOC SECRETARIAT

Maria **HOOD**
IOC-UNESCO
1, rue Miollis
75732 Paris Cedex 15
FRANCE
Tel: (33 1) 45 68 40 28
Fax: (33 1) 45 68 58 12
E-mail: m.hood@unesco.org

ANNEX II

AGENDA

1. OPENING AND WELCOME

2. REVIEW AND ADOPTION OF THE AGENDA

3. STATUS OF PANEL PROGRAM ACTIVITIES 2000-2001

3.1 WELCOME OF NEW PANEL MEMBER

3.2 SUMMARY OF PANEL ACTIVITIES 2000-2001

3.3 OBSERVATION PROGRAMME PLANNING AND COORDINATION

3.3.1 GOOS Technical Report on Ocean Carbon Observations
3.3.2 Repeat Hydrographic Sections in CLIVAR
3.3.3 Time Series Observatory Pilot Project
3.3.4. JCOMM Ship Observations Team / VOS program

3.4 OCEAN SEQUESTRATION OF CO_2

3.5 CERTIFIED REFERENCE MATERIALS

3.6 ATMOSPHERIC NETWORK COORDINATION

3.7 MEASUREMENT TECHNOLOGY

4. STATUS OF INTERNATIONAL OCEAN CO_2 ACTIVITIES

4.1 DATA SET COMPILATION

4.2 REMOTE-SENSING

4.3 OCEAN CARBON MODELLING INTERCOMPARISON PROJECT

4.4 SURFACE OCEAN-LOWER ATMOSPHERE STUDY

4.5 LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE PROJECT

4.6 IGBP OCEAN FUTURES MEETINGS

4.7 PLANNING FOR THE 3rd INTERNATIONAL OCEAN CO2 CONFERENCE

5. REVIEW OF SCHEDULED ACTIONS

ANNEX III

ACTIVITIES SUMMARY 2000-2001

Term of Reference	ACTION / ACTIVITY / PRODUCT
i. To identify gaps and weak links in the present carbon cycle observing system that compromises the ability to understand and predict global change. vi. To advise GOOS and OOPC on the observational strategies needed to assess, model, and predict global ocean CO_2 fluxes.	**Action**: Panel member contributions to the development of a scientific background document and inventory of observational programmes on ocean carbon. **Product:** GOOS Technical Document, 'A Global Ocean Carbon Observation System – A Background Report', by Doney et al. To be published summer 2002. **Product:** Integrated Global Carbon Observation Theme of the IGOS Partners. To be published late 2002. **Product:** Panel web-site development - information about ocean carbon observation plans.
ii. To identify opportunities that can be used to further develop such an observing system (e.g., collaboration with other global observing systems).	**Activity** – Meetings about observation programmes and plans: Sept 4-6, 2000 1st Session Panel Meeting. Sept 6-8, 2000 Joint IGBP EU-US Meeting: Ocean Component of an Integrated Carbon Cycle Science Framework (JGOFS Report 33). Panel aids in development of background paper. May 21-23, 2001 Time Series Observatory Pilot Project. Panel presented inventory of on-going and planned ocean CO_2 observation programmes (to be completed fall 2002). June 2001 JCOMM 1st Session Meeting. Ship Observations Team created, and Panel asked to coordinate and represent VOS and SOOP programmes measuring ocean carbon and related variables. Panel invited to 1st SOT meeting in February 2002. June 25-29, 2001 WOCE/JGOFS Ocean Transports Workshop. Panel asked to aid in coordination of carbon measurements in CLIVAR repeat hydrography programme. July 3-13, 2001 21st Session of IOC Assembly; Panel work is presented to the Assembly; Assembly congratulates Panel on rapid start; states that ocean carbon sequestration is an important issue for the IOC and that the Panel should continue work to monitor developments. September 7-8, 2001 CLIVAR Atlantic Basin Panel Meeting. Panel presented Atlantic ocean CO_2 observation programmes and the CARINA programme. Panel asked to aid in coordination through CARINA. September 20-21, 2001 IGOS Integrated Global Carbon Observation Theme Team Meeting. Information from Panel background document was used in preparation of draft document. Panel members asked to contribute to

	writing and reviewing of Theme. Oct 5-13, 2001 PICES meeting (Victoria, B.C.). Panel is asked to work closely with new PICES working group17 on *Biogeochemical data integration and synthesis*. Oct 29-30 2001 SCOR Meeting (Mar del Plata).
iv. To maintain a watching brief to advice IOC and SCOR on CO_2 sequestration in the ocean.	**Product:** First draft of the watching brief is posted on the Panel web site. Finalization of first draft scheduled for spring 2002, with possible publication as IOC informational document / booklet. **Activity:** SCOR and IOC, through the coordination of the Panel, will plan to host an international science conference on ocean carbon sequestration in early 2003. **Results should include** a synthesis of the current understanding and outstanding questions regarding ocean carbon sequestration, to be published as a special issue of a peer-reviewed journal.
v. To advise GOOS and OOPC on technology development needed to improve future capacity for carbon cycle monitoring.	**Product**: Panel web site developed with a section to serve as a forum on Measurement Technology. The first draft of this section with meaningful content should be completed by summer 2002.
General Term of Reference (ii) - Provide an international forum for initiatives to promote high-quality observations needed to understand the ocean component of the global carbon cycle.	**Product:** Panel web site developed with a section on Certified Reference Materials for ocean carbon. This site also links to work by the US Ocean Studies Board programme on Standards and Reference Materials for Marine Science. **Activity**: IOC, in coordination with the Panel and OOPC, to initiate an international survey of needs and uses of standards and reference materials, focusing on core variables to be measured as part of the GOOS programme. Proposal for the study to be presented to the 34th Session of the IOC Executive Council, June 2002.

ANNEX IV

TERMS OF REFERENCE

SCOR - IOC Advisory Panel on Ocean CO_2

IOC provides financing with SCOR, in-kind assistance, and stewardship for the Panel.

The Panel undertakes specific tasks (e.g., white papers, special workshops, international conferences) and provides ready expertise to IOC and SCOR as needed.

General Terms of Reference

Advise SCOR / JGOFS, GOOS, LOICZ, and OOPC on observations, data management and modelling needed for studies of the global carbon cycle.

Provide an international forum for initiatives to promote high-quality observations needed to understand the ocean component of the global carbon cycle.

Specific Terms of Reference

i. To identify gaps and weak links in the present carbon cycle observing system that compromises the ability to understand and predict global change.
ii. To identify opportunities that can be used to further develop such an observing system (e.g., collaboration with other global observing systems).
iii. To aid the synthesis of JGOFS and IGBP results with respect to marine CO_2 observations, data management and modelling by:

    - Initiating and facilitating the assembly of the necessary data bases;
    - Interacting with ocean modellers to encourage appropriate uses of ocean carbon cycle data and to identify weaknesses of such data;
    - Encouraging and facilitating the collaborative analysis of CO_2 data together with other carbon cycle and supporting data sets.

iv. To maintain a watching brief to advise IOC and SCOR on CO_2 sequestration in the ocean.
v. To advise GOOS and OOPC on technology development needed to improve future capacity for carbon cycle monitoring.
vi. To advise GOOS and OOPC on the observational strategies needed to assess, model, and predict global ocean CO_2 fluxes.

In this Series, entitled

Reports of Meetings of Experts and Equivalent Bodies, which was initiated in 1984 and which is published in English only, unless otherwise specified, the reports of the following meetings have already been issued:

1. Third Meeting of the Central Editorial Board for the Geological/Geophysical Atlases of the Atlantic and Pacific Oceans
2. Fourth Meeting of the Central Editorial Board for the Geological/Geophysical Atlases of the Atlantic and Pacific Oceans S. Fourth Session of the Joint IOC-WMO-CPPS Working Group on the Investigations of 'El Niño' ***(Also printed in Spanish)***
4. First Session of the IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in Relation to Living Resources
5. First Session of the IOC-UN(OETB) Guiding Group of Experts on the Programme of Ocean Science in Relation to Non-Living Resources
6. First Session of the Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
7. First Session of the Joint CCOP(SOPAC)-IOC Working Group on South Pacific Tectonics and Resources
8. First Session of the IODE Group of Experts on Marine Information Management
9. Tenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies in East Asian Tectonics and Resources
10. Sixth Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
11. First Session of the IOC Consultative Group on Ocean Mapping ***(Also printed in French and Spanish)***
12. Joint 100-WMO Meeting for Implementation of IGOSS XBT Ships-of-Opportunity Programmes
13. Second Session of the Joint CCOP/SOPAC-IOC Working Group on South Pacific Tectonics and Resources
14. Third Session of the Group of Experts on Format Development
15. Eleventh Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of South-East Asian Tectonics and Resources
16. Second Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
17. Seventh Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
18. Second Session of the IOC Group of Experts on Effects of Pollutants
19. Primera Reunión del Comité Editorial de la COI para la Carta Batimétrica Internacional del Mar Caribe y Parte del Océano Pacífico frente a Centroamérica ***(Spanish only)***
20. Third Session of the Joint CCOP/SOPAC-IOC Working Group on South Pacific Tectonics and Resources
21. Twelfth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of South-East Asian Tectonics and Resources
22. Second Session of the IODE Group of Experts on Marine Information Management
23. First Session of the IOC Group of Experts on Marine Geology and Geophysics in the Western Pacific
24. Second Session of the IOC-UN(OETB) Guiding Group of Experts on the Programme of Ocean Science in Relation to Non-Living Resources ***(Also printed in French and Spanish)***
25. Third Session of the IOC Group of Experts on Effects of Pollutants
26. Eighth Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
27. Eleventh Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans ***(Also printed in French)***
28. Second Session of the IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in Relation to Living Resources
29. First Session of the IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials
30. First Session of the IOCARIBE Group of Experts on Recruitment in Tropical Coastal Demersal Communities ***(Also printed in Spanish)***
31. Second IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
32. Thirteenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of East Asia Tectonics and Resources
33. Second Session of the IOC Task Team on the Global Sea-Level Observing System
34. Third Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
35. Fourth Session of the IOC-UNEP-IMO Group of Experts on Effects of Pollutants
36. First Consultative Meeting on RNODCs and Climate Data Services
37. Second Joint IOC-WMO Meeting of Experts on IGOSS-IODE Data Flow
38. Fourth Session of the Joint CCOP/SOPAC-IOC Working Group on South Pacific Tectonics and Resources
39. Fourth Session of the IODE Group of Experts on Technical Aspects of Data Exchange
40. Fourteenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of East Asian Tectonics and Resources
41. Third Session of the IOC Consultative Group on Ocean Mapping
42. Sixth Session of the Joint IOC-WMO-CCPS Working Group on the Investigations of 'El Niño' (***Also printed in Spanish)***
43. First Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean
44. Third Session of the IOC-UN(OALOS) Guiding Group of Experts on the Programme of Ocean Science in Relation to Non-Living Resources
45. Ninth Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
46. Second Session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico
47. First Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean
48. Twelfth Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans
49. Fifteenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of East Asian Tectonics and Resources
50. Third Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
51. First Session of the IOC Group of Experts on the Global Sea-Level Observing System
52. Fourth Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean
53. First Session of the IOC Editorial Board for the International Chart of the Central Eastern Atlantic ***(Also printed in French)***
54. Third Session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico ***(Also printed in Spanish)***
55. Fifth Session of the IOC-UNEP-IMO Group of Experts on Effects of Pollutants
56. Second Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean
57. First Meeting of the IOC *ad hoc* Group of Experts on Ocean Mapping in the WESTPAC Area
58. Fourth Session of the IOC Consultative Group on Ocean Mapping

59. Second Session of the IOC-WMO/IGOSS Group of Experts on Operations and Technical Applications
60. Second Session of the IOC Group of Experts on the Global Sea-Level Observing System
61. UNEP-IOC-WMO Meeting of Experts on Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change
62. Third Session of the IOC-FAO Group of Experts on the Programme of Ocean Science in Relation to Living Resources
63. Second Session of the IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials
64. Joint Meeting of the Group of Experts on Pollutants and the Group of Experts on Methods, Standards and Intercalibration
65. First Meeting of the Working Group on Oceanographic Co-operation in the ROPME Sea Area
66. Fifth Session of the Editorial Board for the International Bathymetric and its Geological/Geophysical Series
67. Thirteenth Session of the IOC-IHO Joint Guiding Committee for the General Bathymetric Chart of the Oceans ***(Also printed in French)***
68. International Meeting of Scientific and Technical Experts on Climate Change and Oceans
69. UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System
70. Fourth Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
71. ROPME-IOC Meeting of the Steering Committee on Oceanographic Co-operation in the ROPME Sea Area
72. Seventh Session of the Joint IOC-WMO-CPPS Working Group on the Investigations of 'El Niño' ***(Spanish only)***
73. Fourth Session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico ***(Also printed in Spanish)***
74. UNEP-IOC-ASPEI Global Task Team on the Implications of Climate Change on Coral Reefs
75. Third Session of the IODE Group of Experts on Marine Information Management
76. Fifth Session of the IODE Group of Experts on Technical Aspects of Data Exchange
77. ROPME-IOC Meeting of the Steering Committee for the Integrated Project Plan for the Coastal and Marine Environment of the ROPME Sea Area
78. Third Session of the IOC Group of Experts on the Global Sea-level Observing System
79. Third Session of the IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials
80. Fourteenth Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans
81. Fifth Joint IOG-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
82. Second Meeting of the UNEP-IOC-ASPEI Global Task Team on the Implications of climate Change on Coral Reefs
83. Seventh Session of the JSC Ocean Observing System Development Panel
84. Fourth Session of the IODE Group of Experts on Marine Information Management
85. Sixth Session of the IOC Editorial Board for the International Bathymetric chart of the Mediterranean and its Geological/Geophysical Series
86. Fourth Session of the Joint IOC-JGOFS Panel on Carbon Dioxide
87. First Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Pacific
88. Eighth Session of the JSC Ocean Observing System Development Panel
89. Ninth Session of the JSC Ocean Observing System Development Panel
90. Sixth Session of the IODE Group of Experts on Technical Aspects of Data Exchange
91. First Session of the IOC-FAO Group of Experts on OSLR for the IOCINCWIO Region
92. Fifth Session of the Joint IOC-JGOFS CO, Advisory Panel Meeting
93. Tenth Session of the JSC Ocean Observing System Development Panel
94. First Session of the Joint CMM-IGOSS-IODE Sub-group on Ocean Satellites and Remote Sensing
95. Third Session of the IOC Editorial Board for the International Chart of the Western Indian Ocean
96. Fourth Session of the IOC Group of Experts on the Global Sea Level Observing System
97. Joint Meeting of GEMSI and GEEP Core Groups
98. First Session of the Joint Scientific and Technical Committee for Global Ocean Observing System
99. Second International Meeting of Scientific and Technical Experts on Climate Change and the Oceans
100. First Meeting of the Officers of the Editorial Board for the International Bathymetric Chart of the Western Pacific
101. Fifth Session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico
102. Second Session of the Joint Scientific and Technical Committee for Global Ocean Observing System
103. Fifteenth Session of the Joint IOC-IHO Committee for the General Bathymetric Chart of the Oceans
104. Fifth Session of the IOC Consultative Group on Ocean Mapping
105. Fifth Session of the IODE Group of Experts on Marine Information Management
106. IOC-NOAA *Ad hoc* Consultation on Marine Biodiversity
107. Sixth Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
108. Third Session of the Health of the Oceans (HOTO) Panel of the Joint Scientific and Technical Committee for GLOSS
109. Second Session of the Strategy Subcommittee (SSC) of the IOC-WMO-UNEP Intergovernmental Committee for the Global Ocean Observing System
110. Third Session of the Joint Scientific and Technical Committee for Global Ocean Observing System
111. First Session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate
112. Sixth Session of the Joint IOC-JGOFS C02 Advisory Panel Meeting
113. First Meeting of the IOC/WESTPAC Co-ordinating Committee for the North-East Asian Regional - Global Ocean Observing System (NEAR-GOOS)
114. Eighth Session of the Joint IOC-WMO-CPPS Working Group on the Investigations of "El Niño" ***(Spanish only)***
115. Second Session of the IOC Editorial Board of the International Bathymetric Chart of the Central Eastern Atlantic ***(Also printed in French)***
116. Tenth Session of the Officers Committee for the Joint IOC-IHO General Bathymetric Chart of the Oceans (GEBCO), USA, 1996
117. IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Fifth Session, USA, 1997
118. Joint Scientific Technical Committee for Global Ocean Observing System (J-GOOS), Fourth Session, USA, 1997
199 First Session of the Joint 100-WMO IGOSS Ship-of-Opportunity Programme Implementation Panel, South Africa, 1997
120. Report of Ocean Climate Time-Series Workshop, Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate, USA, 1997

121. IOC/WESTPAC Co-ordinating Committee for the North-East Asian Regional Global Ocean Observing System (NEAR-GOOS), Second Session, Thailand, 1997

122. First Session of the IOC-IUCN-NOAA *Ad hoc* Consultative Meeting on Large Marine Ecosystems (LME), France, 1997

123. Second Session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), South Africa, 1997

124. Sixth Session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico, Colombia, 1996 ***(also printed in Spanish)***

125. Seventh Session of the IODE Group of Experts on Technical Aspects of Data Exchange, Ireland, 1997

126. IOC-WMO-UNEP-ICSU Coastal Panel of the Global Ocean Observing System (GOOS), First Session, France, 1997

127. Second Session of the IOC-IUCN-NOAA Consultative Meeting on Large Marine Ecosystems (LME), France, 1998

128. Sixth Session of the IOC Consultative Group on Ocean Mapping (CGOM), Monaco, 1997

129. Sixth Session of the Tropical Atmosphere - Ocean Array (TAO) Implementation Panel, United Kingdom, 1997

130. First Session of the IOC-WMO-UNEP-ICSU Steering Committee of the Global Ocean Observing System (GOOS), France, 1998

131. Fourth Session of the Health of the Oceans (HOTO) Panel of the Global Ocean Observing System (GOOS), Singapore, 1997

132. Sixteenth Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans (GEBCO), United Kingdom, 1997

133. First Session of the IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS), France, 1998

134. Fourth Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean (IOC/EB-IBCWIO-IW3), South Africa, 1997

135. Third Session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), France, 1998

136. Seventh Session of the Joint IOC-JGOFS C02 Advisory Panel Meeting, Germany, 1997

137. Implementation of Global Ocean Observations for GOOS/GCOS, First Session, Australia, 1998

138. Implementation of Global Ocean Observations for GOOS/GCOS, Second Session, France, 1998

139. Second Session of the IOC-WMO-UNEP-ICSU Coastal Panel of the Global Ocean Observing System (GOOS), Brazil, 1998

140. Third Session of IOC/WESTPAC Co-ordinating Committee for the North-East Asian Regional - Global Ocean Observing System (NEAR-GOOS), China, 1998

141. Ninth Session of the Joint IOC-WMO-CPPS Working Group on the Investigations of 'El Niño', Ecuador, 1998 ***(Spanish only)***

142. Seventh Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and its Geological/Geophysical Series, Croatia, 1998

143. Seventh Session of the Tropical Atmosphere-Ocean Array (TAO) Implementation Panel, Abidjan, Côte d'Ivoire, 1998

144. Sixth Session of the IODE Group of Experts on Marine Information Management (GEMIM), USA, 1999

145. Second Session of the IOC-WMO-UNEP-ICSU Steering Committee of the Global Ocean Observing System (GOOS), China, 1999

146. Third Session of the IOC-WMO-UNEP-ICSU Coastal Panel of the Global Ocean Observing System (GOOS), Ghana, 1999

147. Fourth Session of the GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC); Fourth Session of the WCRP CLIVAR Upper Ocean Panel (UOP); Special Joint Session of OOPC and UOP, USA, 1999

148. Second Session of the IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS), France, 1999

149. Eighth Session of the Joint IOC-JGOFS CO2 Advisory Panel Meeting, Japan, 1999

150. Fourth Session of the IOC/WESTPAC Co-ordinating Committee for the North-East Asian Regional – Global Ocean Observing System (NEAR-GOOS), Japan, 1999

151. Seventh Session of the IOC Consultative Group on Ocean Mapping (CGOM), Monaco, 1999

152. Sixth Session of the IOC Group of Experts on the Global Sea level Observing System (GLOSS), France, 1999

153. Seventeenth Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans (GEBCO), Canada, 1999

154. Comité Editorial de la COI para la Carta Batimétrica Internacional del Mar Caribe y el Golfo de Mexico (IBCCA), Septima Reunión, Mexico, 1998

IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico (IBCCA), Seventh Session, Mexico, 1998

155. Initial Global Ocean Observing System (GOOS) Commitments Meeting, IOC-WMO-UNEP-ICSU/Impl-III/3, France, 1999

156. First Session of the *ad hoc* Advisory Group for IOCARIBE-GOOS, Venezuela, 1999 ***(also printed in Spanish and French)***

157. Fourth Session of the IOC-WMO-UNEP-ICSU Coastal Panel of the Global Ocean Observing System (GOOS), China, 1999

158. Eighth Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and its Geological/Geophysical Series, Russian Federation, 1999

159. Third Session of the IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS), Chile, 1999

160. Fourth Session of the IOC-WMO-UNEP-ICSU-FAO Living Marine Resources Panel of the Global Ocean Observing System (GOOS). Hawaii, 2000

161. Eighth Session of the IODE Group of Experts on Technical Aspects of Data Exchange, USA, 2000

162. Third Session of the IOC-IUCN-NOAA Consultative Meeting on Large Marine Ecosystems (LME), France, 2000

163. Fifth Session of the IOC-WMO-UNEP-ICSU Coastal Panel of the Global Ocean Observing System (GOOS), Poland, 2000

164. Third Session of the IOC-WMO-UNEP-ICSU Steering Committee of the Global Ocean Observing System (GOOS), France, 2000

165. Second Session of the *ad hoc* Advisory Group for IOCARIBE-GOOS, Cuba, 2000 ***(also printed in Spanish and French)***

166. First Session of the Coastal Ocean Observations Panel, Costa Rica, 2000

167. First GOOS Users' Forum, 2000

168. Seventh Session of the Group of Experts on the Global Sea Level Observing System, Honolulu, 2001

169. First Session of the Advisory Body of Experts on the Law of the Sea (ABE-LOS), France, 2001 ***(also printed in French)***

170. Fourth Session of the IOC-WMO-UNEP-ICSU Steering Committee of the Global Ocean Observing System, Chile, 2001

171. First Session of the IOC-SCOR Ocean CO_2 Advisory Panel, France, 2000

172. I-GOOS ad hoc Group of Experts Meetings on GOOS-UNCLOS, France and United Kingdom, 2001 ***(also printed in French)***

173. Third Session of the *ad hoc* Advisory Group for IOCARIBE-GOOS, USA, 2001 ***(also printed in Spanish and French)***

174. Second Session of the Coastal Ocean Observations Panel and GOOS Users' Forum, Italy, 2001

175. Second Session of the Black Sea GOOS Workshop, Georgia, 2001

176. Fifth Session of the IOC/WESTPAC Co-ordinating Committee for the North-East Asian Regional – Global Ocean Observing System (NEAR-GOOS), Republic of Korea, 2000

177. Second Session of the Advisory Body of Experts on the Law of the Sea (IOC/ABE-LOS), Morocco, 2002 ***(also printed in French)***

178. Third Session of the Coastal Ocean Observations Panel and GOOS Users' Forum, Vietnam, 2002

179. Fourth Session of the IOC-IUCN-NOAA Consultative Meeting on Large Marine Ecosystems (LMEs), France, 2002

180. Second Session of the IOC-SCOR Ocean CO_2 Advisory Panel, Honolulu, Hawaii, U.S.A, 9 February 2002 ***(electronic copy only)***