4.0 OCEAN CARBON AND OTHER ACTIVITIES

4.1 Advisory Panel on Ocean CO_2 (joint with IOC) ***Duce***

This panel's terms of duty expired at the end of 2003 and the members have not been extended, due to a desire by SCOR and IOC to re-examine the terms of reference and membership of the panel. However, one continuing activity of SCOR, IOC, and the Global Carbon Project (GCP) is the International Ocean Carbon Coordination Project (IOCCP; see below). A new structure for the panel will be presented at the SCOR meeting.

4.4.1 International Ocean Carbon Coordination Project ***Urban***

The International Ocean Carbon Coordination Project (IOCCP) is a joint activity of the SCOR, IOC, and GCP. IOCCP has scheduled two successful meetings so far and has a range of action items for future work, as described in the following. Maria Hood is the primary staff for IOCCP, although the SCOR Secretariat handles much of the finances. IOCCP work has been chaired on an ad hoc basis by Chris Sabine (USA), assisted by Hood, Urban, and small planning committees for IOCCP's specific activities.

Current Action Items and Projects of the pilot project IOCCP to be continued within the relevant Task Team Activities (January 2003 – present):

1. From IOCCP Workshop #1, January 2003

The IOCCP should develop a web site to disseminate information on national plans for large-scale carbon observations and progress on objectives listed above. **Action 1:** Hood, Sabine, Wallace, Canadell, Foster, and Hill to develop site through IOC and GCP in collaboration with CLIVAR.

Status: COMPLETE. http://ioc.unesco.org/ioccp

The IOCCP should serve as a focal point for communication between the carbon community and CLIVAR to identify key areas of common interest and promote a stronger collaboration in developing a measurement strategy for carbon and tracers on repeat hydrographic sections. **Action 2:** Hood, Tilbrook, Sabine, and Feely to develop a statement to the CLIVAR community about the need for tracer measurements on specific repeat sections, promote the appointment of carbon representatives to the CLIVAR regional panels, and establish a closer dialogue with CLIVAR planning of repeat section work in each basin.

Status: COMPLETE. CLIVAR Basin Panels now each have a carbon representative, 3 out of 4 currently financed by IOCCP.

The IOCCP should establish formal links with PICES WG17 and CARINA to encourage these regional programs to evaluate the scientific balance, quality and completeness of the large-scale carbon programs with reference to global-scale research needs and facilitate the organization of training workshops and inter-laboratory comparisons to improve data quality. **Action 3:** Hood, Sabine, Dickson, Mintrop to establish mechanism for IOCCP to provide global coordination to regional groups.

Status: COMPLETE. Completion of intercomparison exercises; One workshop on underway pCO_2 jointly sponsored with PICES; Coordination with PICES on future

workshops and best-practices guide are underway; waiting for EU Carbo-Ocean development to re-establish CARINA.

The IOCCP should facilitate closer links (possibly through interdisciplinary workshops) between the ocean and atmospheric carbon observation communities and the modelling community. **Action 4**: Hood, Canadell, Feely, Gnanadesikan, and Heinze to document on-going ocean carbon modelling projects and groups, and begin a dialogue with appropriate key scientists to outline the needs for a workshop.
Status: ON-GOING. Meeting with OCMIP on May 13 to initiate discussion of modelling community needs. OCMIP is now listed as an official part of GCP.

The IOCCP should promote the public release of large-scale carbon data sets within 2 years of cruise completion and encourage submission of international repeat hydrographic section data with carbon measurements to CDIAC and to GHDO. **Action 5**: Kozyr, Swift, and Hill to provide a plan for coordinated data submission of carbon and tracer data on CLIVAR repeat hydrographic sections.
Status: ON-GOING. January 2004 meeting developed a data integration and data release agreement, with partners from all countries agreeing to work with CDIAC. Status of GHDO is unknown.

The IOCCP should facilitate the revision and expansion of the DOE CO_2 Methods Handbook (lead by A. Dickson) and promote it as a manual of best practices to be followed by those participating in the large-scale carbon observation network. **Action 6:** Hood and Dickson to develop a plan to finalize the revision, possible translation into other languages, and to promote and distribute the handbook.
Status: ON-GOING, should be completed in October 2004. IOCCP financing at ~$10k for printing and distribution.

The IOCCP should work with appropriate organizations and scientific groups to develop a policy for the proper citation of large-scale data sets. **Action 7:** Hood, Sabine, Feely, and Wallace to encourage data centers to clearly indicate appropriate reference / acknowledgement for data being downloaded and to contact the American Geophysical Union, the European Geophysical Union, and other appropriate groups to initiate discussions on policies for acknowledging the use of large-scale data sets in peer-reviewed articles.
Status: ON-GOING. The AGU publishing department has indicated that when data are publicly available in accredited data centers, they can be cited in AGU journals as literature. With ocean carbon data at the World Data Center for Trace Gases (CDIAC) this should qualify. Follow-on activities include now re-contacting AGU to establish guidelines and a protocol for citations.

The IOCCP should coordinate and promote the compilation and public release of historical pCO_2 data sets. **Action 8:** Dickson, Kozyr, and Heinze to develop a brief position paper outlining this high priority for the community and a plan for coordination between on-going efforts at CDIAC, WDC-MARE / ORFOIS, and other programs.

Status: ON-GOING. January 2004 workshop highlighted this as a need; Japanese Ministry of Environment has approved $200k/year as a contribution to GCP / IOCCP ocean CO_2 work, where one of the principle work projects was the development of a historical pCO_2 database.

The IOCCP should address the problem of excessive delays in obtaining permission from governments to make pCO_2 measurements on ships of opportunity in territorial waters. **Action 9:** Hood, Manabe, Tilbrook, Zika, Feely, and Nojiri to document particular problems faced with the current system and work with the IOC-WMO JCOMM Ship Observations Team to find the best way forward.
Status: COMPLETE. JCOMM and WMO suggest that the only way forward is the real-time release of CO_2 data as is done with the Met data, which would permit CO2 to fall under WMO agreements for VOS operations. It's still not clear how to pursue this, but the technology has to develop and PIs have to agree to release data in real-time.

The IOCCP should support and promote certified reference material programs, including the development of appropriate standard gases for ocean carbon work. **Action 10**: Hood, Dickson, and Nojiri to work with the atmospheric community (Roger Francey) to develop a round-robin intercomparison test for ocean carbon gases.
Status: TO BE INITIATED. Has not received priority attention yet.

2. From IOCCP Workshop #2, January 2004

Action Item 1:
Write a technical report of the intercomparison experiment, to be published by CDIAC, entitled "The International Indoor Seawater Pool pCO_2 Intercomparison – Results and recommended practices". A more concise version of the report may be developed for publication in a peer-reviewed journal. The group will follow the outline of Meteor Intercomparison (NDP-067) publication except there will be no data associated with publication (technical report, not an NDP). All agree to use the same A, B, C designations for systems as used in the NDP-067 report to facilitate comparisons between the 1996 and 2003 intercomparisons. Timeline: The goal is to have first draft by mid-April, with a final draft by June in time to make a presentation at the October PICES meeting.
Status: ON-GOING.

Action Item 2:
The workshop participants recommended that the IOCCP develop a draft implementation strategy for a surface ocean CO_2 pilot project. While the LSCOP report appendices (D & E) provide a good first estimate of the required temporal and spatial resolution, the methods used in the analysis considerably smooth the data. The workshop participants recommended to proceed with the first draft of the implementation strategy based on this analysis, but to carry out a more rigorous analysis as soon as possible (in parallel). The IOCCP will investigate funding possibilities for this activity (estimated to be 1-2 months salary support).

Status: ON-GOING. Initial discussion of funding sources and scientists to carry out the analysis have been held.

Action Item 3:
The Working Group discussed the necessity of using a uniform approach to estimating overall uncertainty for CO_2 measurements, and recommended that a working group be formed to develop and propose guidelines.
Status: TO BE INITIATED. Waiting on review and establishment of new Ocean Carbon Panel.

4.2 SCOR/IOC Symposium on the Ocean in a High-CO_2 World

Committee Charge:
The planning committee will determine the scope of the symposium, plan the agenda, develop the list of invited participants, and handle any publications that result from the symposium.

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Silvio Pantoja	CHILE
Hans-Otto Pörtner	GERMANY

IOC Liaison: Maria Hood
Executive Committee Reporter: Bob Duce

The symposium has resulted in several products that have been published or are in preparation:

- A meeting report for *EOS*. This report was prepared by Peter Brewer and approved by the planning committee.
- The report of research priorities. This report is a summary of the discussion sessions from the meetings. The planning committee approved it and all meeting participants had an opportunity to comment on it. The full version is available on the Web and is given below.
- UNESCO prepared a news release based on material from the symposium (see below).
- The major output will be a special section of *JGR—Oceans*, containing most of the plenary papers from the symposium, plus a subset of the poster papers.

Meeting participants requested a continuing role for SCOR and IOC staff in follow-up from the meeting, related to public information about the issue of ocean acidification. It is proposed that other activities related to this issue be handled by the panel that will replace the Ocean CO_2 Panel.

Priorities for Research on the Ocean in a High-CO_2 World[1]

Introduction

The atmospheric concentration of carbon dioxide is now higher than experienced on Earth for at least the last 400,000 years, if not the last several million years, and is expected to continue to rise, leading to significant global temperature increases by the end of this century. It is now well established that there is a strong possibility that surface ocean pCO_2 levels will double over their pre-industrial values by the middle of this century, with accompanying surface ocean pH changes that are 3 times greater than those experienced during the transition from glacial to interglacial periods.

Much discussion has been devoted to how to "sequester" some of the atmospheric carbon dioxide in plant biomass, in geologic structures,[2] or in the ocean. The ocean is absorbing approximately one-third of the carbon dioxide added to the atmosphere by human activities each year, and over the next few millennia, is predicted to absorb approximately 90% of the CO_2 emitted to the atmosphere, after atmospheric CO_2 concentrations are stabilized. The ocean is one of the largest natural reservoirs for carbon. Ocean strategies for sequestering atmospheric CO_2 involve enhancing the ocean's natural capacity to absorb and store atmospheric CO_2, either by inducing and enhancing the growth of carbon-fixing plants in the surface ocean, or by bypassing the slow,

[1] Information about the symposium—including the program, abstracts of plenary presentations and posters, summary documents about the meeting, and images can be found at http://ioc.unesco.org/iocweb/co2panel/HighOceanCO2.htm. SCOR and IOC will consider follow-up actions to the symposium, including consideration of the recommendations in greater depth. This material is based upon work supported by the National Science Foundation under Grant Nos. (0003700 and 0326301) to the Scientific Committee on Oceanic Research, as well as contributions from the Research Council of Norway and the Intergovernmental Oceanographic Commission of UNESCO.

[2] Geological storage in sub-seafloor formations poses potential risks for marine ecosystems also, if such reservoirs leak significantly, but this topic was not discussed in detail at the symposium.

surface-to-deep water transfer of dissolved CO_2 by directly injecting it into the deep ocean. Although much relevant research has been conducted in the past decade, the potential effectiveness and risks of these forms of carbon sequestration in the ocean have not been thoroughly discussed and assessed. Even relatively small changes in CO_2 concentrations may have large, as yet not completely understood, impacts on marine life and natural biogeochemical cycles of the ocean. New research is necessary to gain a better understanding of how ocean biology and chemistry will operate in a high-CO_2 world, so that predictive models can include appropriate mathematical representations of these processes and accurate parameter values for monitoring and quantifying changes from the present ocean.

The Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO convened an open symposium on *The Ocean in a High-CO_2 World* on 10-12 May 2004 in Paris, France at UNESCO Headquarters. The symposium addressed the biological and biogeochemical consequences of increasing atmospheric and oceanic CO_2 levels, and possible strategies for mitigating atmospheric increases. Topics ranged from ocean physics, to chemistry and biology, including the impacts of elevated CO_2 levels on marine life, the dissolution of calcium carbonate, and the impacts on coral reefs. Speakers also evaluated the possible benefits and impacts of surface fertilization and deep-ocean CO_2 injection strategies. Symposium participants did not address whether it would be a good policy choice to sequester carbon dioxide in the ocean, but did identify what scientific information is available, and what is still needed, to make informed policy decisions.

The symposium included plenary presentations, discussion sessions on research priorities, and a poster session. To highlight some of the significant results from the symposium, a subset of results will be published in a special section of the *Journal of Geophysical Research--Oceans*. The papers in this special section will contribute to the work of the Intergovernmental Panel on Climate Change (IPCC) and to its Special Report on Carbon Dioxide Capture and Storage.

This report has been prepared to document research priorities that were identified in discussion sessions at the symposium for the benefit of ocean scientists and research program managers worldwide. The research priorities will be transmitted to the new international research projects (the Surface Ocean - Lower Atmosphere Study [SOLAS] and the Integrated Marine Biogeochemistry and Ecosystem Research [IMBER] project) for consideration, since both of these projects have major foci related to the ocean carbon cycle. (SOLAS and IMBER scientists participated in the symposium.) This report was prepared by the planning committee for the symposium and was reviewed by meeting participants and revised accordingly. Information about publication of this report in hard-copy version will be given on the symposium Web site.

Discussion Groups

Following the plenary presentations, participants divided into three discussion groups. The groups met for two hours in individual sessions and met back in plenary session to report on their discussions and obtain feedback on their recommendations. All symposium participants had an opportunity to review this report and provide comments before it was finalized.

4-8

High-CO_2 Group
Chair: Ulf Riebesell
Rapporteur: Jean-Pierre Gattuso
Charge to Group: Identify research agenda/priorities related to the ocean in a high-CO_2 world, without mitigation, with attention to both biogeochemical and organismal/ecological aspects.

This discussion group identified priority research related to (1) forcing factors, (2) ecological/organismal aspects, (3) key biogeochemical processes, and (4) key types of ecosystems/species to be investigated.

1. Forcing factors
The most obvious forcing factor on the ocean in a high-CO_2 world is increased atmospheric pCO_2, which will increase the surface ocean (and eventually deep ocean) pCO_2 and lower pH. A major research priority will be to conduct research and modeling that will allow predictions of changes in ocean carbonate chemistry, and on how these changes will differentially affect calcitic and aragonitic organisms. As pCO_2 is increasing, other environmental variables will also change as a result. For example, likely changes that will accompany increased pCO_2 include increased temperature, changes in availability of nutrients (due to changes in redox conditions, ocean mixing, patterns of precipitation, dust inputs, and increased stratification), decreased O_2 in the warmer water, changes in salinity due to heating and precipitation effects, and changes in ocean mixing, circulation and wind. It will be very important to consider, in research, observational, and modeling activities, how these changes interact to affect marine biogeochemical processes and feed back to the Earth system. It also will be important to consider regional differences and to consider the combined effects of higher pCO_2 levels, higher temperature, and low O_2 concentrations.

2. Ecological/organismal aspects
Keeping in mind the forcing factors described above, it will be necessary to conduct research on both ocean biology and biogeochemistry. In terms of biology, effects are naturally expected for calcifying organisms, but it is also important to study the effects of increasing ocean pCO_2 and associated environmental changes on non-calcifying organisms. Interactions and synergies among variables (e.g., pCO_2 and temperature) are particularly important. Specifically, research should include

a. Effects on community structure and composition (including how species-specific responses will affect community composition), from bacteria to vertebrates
b. Effects on genetic diversity, species diversity, and the diversity of functional groups
c. Microevolutionary potential and rate of evolutionary change—Earth's temperature and atmospheric CO_2 concentrations have changed in the distant past, but not at the rapid pace that is now occurring, nor at the high CO_2 levels now encountered. Many organisms were probably able to evolve quickly enough to adapt to global changes in the past. Will they be able to adapt to the more rapid pace of change now occurring? Can adaptation occur under a continually and rapidly changing environment versus one that eventually stabilizes?
d. Sub-lethal effects—Most effects are likely to be sub-lethal, including decreased reproductive potential, slower growth, and increased susceptibility to disease.

3. Key biogeochemical processes

Increasing surface ocean pCO_2 and decreasing pH can affect a variety of processes that are important in regulating the oceanic cycles of carbon, nitrogen, and other elements. New research is needed to understand how the ocean will respond to increasing atmospheric CO_2, particularly related to

- Primary production—Will increasing pCO_2 in the surface ocean fertilize phytoplankton? If so, which species? What effects will this have on higher trophic levels? Since CO_2 generally is not a limiting resource for phytoplankton, production might not increase much, due to limitations in other elements. CO_2 fertilization may affect elemental stoichiometry (C/N/P).
- Remineralization—Auto- and heterotrophic processes are likely to respond differently to environmental changes (e.g., due to differences in temperature dependency). What effect will this have on the balance between primary production and remineralization?
- Will changes in nitrogen fixation, denitrification and nitrification be induced by changes in phytoplankton species composition and changes in oxygen levels?
- DOM transformations (aggregation, solubilization, biological turnover)—Will increasing pCO_2 change the proportion or type of carbon that enters the DOM pool? How will this affect the dynamics of dissolved organic material and particles?
- How does increasing pCO_2 impact the precipitation of $CaCO_3$ by planktonic and benthic calcifiers? What are the current dissolution kinetics of aragonite and calcite and how might they change under different scenarios of increased pCO_2? What impact will increasing pCO_2 and decreasing pH have on dissolution of $CaCO_3$ in the upper ocean, throughout the water column, and in ocean sediments? Will there be an impact on the $CaCO_3$ compensation depth?
- How will changes in the above processes affect export production and the rain ratio?

4. Key types of ecosystems/species to be investigated

Some ecosystems are more likely to be affected than others by increasing oceanic pCO_2 and decreasing pH, or may have more significant feedbacks to the Earth system. These ecosystems are priority areas for study:

- Ecosystems dominated by and/or structured by calcifying organisms such as coccolithophores, foraminifera, pteropods, and coral reefs (including different species and strains). There is some evidence that increasing pCO_2 would prevent the colonization of corals in new environments (within the temperature tolerance of the corals) because it will cause a decrease in the saturation of $CaCO_3$ in seawater.
- Ecosystems dominated by and/or structured by other biogeochemically relevant functional groups (pelagic and benthic) and "ecosystem engineers"/"keystone species"
- Intertidal and shallow subtidal areas
- The mesopelagic zone
- The Southern Ocean and subarctic Pacific Ocean

Approaches
Discussion group participants identified a set of promising approaches to study how the ocean might respond in a high-CO_2 world. These approaches range from small-scale laboratory experiments to open-ocean perturbation studies:

- Laboratory experiments—Small-scale studies in the laboratory can help isolate various factors to increase the understanding of results from larger-scale field studies and to guide planning for mesocosm and field studies.
- Mesocosm experiments—Experiments in mesocosm enclosures have produced useful results about how species composition changes in carbon-altered ecosystems. These experiments make it possible to create experimental designs with replication and controls on a larger scale and more realistic conditions than in the laboratory. An important activity will be to design standard experimental protocols that will make these experiments more reproducible.
- Short-term open-ocean perturbation experiments—Large-scale open-ocean iron fertilization experiments have yielded significant new knowledge about ocean ecosystems in the past decade. Short-term additions of carbon dioxide to various ecosystem types should result in similar information gains related to effects of carbon on the ocean.
- FACE-like experiments— Free Air CO_2 Enrichment (FACE) experiments are currently being conducted at many sites worldwide, in a variety of terrestrial, non-agricultural ecosystems. These experiments involve additions of carbon dioxide to research plots continuously for several years to maintain elevated atmospheric CO_2 levels that mimic levels that will be experienced under likely future scenarios. These experiments have demonstrated how plant communities will respond in both the short and long term. The continuity of these experiments is an important feature, because some long-term effects have been shown to differ from short-term effects on the same parameters. Both SOLAS and the IMBER project have proposed FACE-like experiments for the ocean. The benefit of such experiments is that they are more likely to show the actual long-term effects that will occur in the future. The major anticipated drawback is that it might be impossible to use for pelagic communities without enclosing them in some way or somehow using a Lagrangian approach. There is a need to start with a feasibility study because the amount of CO_2 or acid[3] required for a full-scale pelagic FACE experiment may be very high. The other drawback is the public perception problem. This drawback might be approached by pointing out that the effects of elevated CO_2 under "business as usual" scenarios may be so severe that understanding them might cause policymakers to think more carefully about emission controls or other mitigation methods.
- Model development— Ongoing development of models should be pursued, to assess the role of climate feedback and elevated CO_2 levels on ocean ecosystems and biogeochemistry. This will require the reconsideration of the distinction between the euphotic zone and the underlying waters (above the permanent pycnocline). Models

[3] pH changes induced by pCO_2 changes occur without a change in alkalinity. pH changes induced by adding a mineral acid change alkalinity. Thus, changes in alkalinity must be considered in any experiments that change pH by adding acid.

should consider the high-CO_2 world in an Earth system context, where feedbacks and indirect effects are important and are often the dominant drivers, and disciplinary distinctions between functional biodiversity, ecosystem functioning and the fluxes of elements and associated feedbacks are no longer appropriate.

Other important research and observation approaches that should be explored include

- Encouraging experimentalists, field researchers, and modelers to work together
- Using specific locations that are acid- or CO_2-rich due to human effects or natural factors (e.g., the Rio Tinto, outlets of power stations, and natural CO_2 vents such as on Loihi Seamount)
- Adding stable pH sensors to Argo profiling floats
- Studying interactions between coastal areas and the open ocean, and between the seafloor and water column
- Following-up on the symposium with international working groups to focus on specific implementation tasks, though SOLAS and IMBER, the International Ocean Carbon Coordination Project, and/or SCOR working groups

Mitigation Group
Chair: Peter Haugan
Rapporteur: Andrew Watson
Charge to Group: Identify research agenda/priorities related to the effectiveness and environmental effects of mitigation approaches, with attention to both biogeochemical and organismal/ecological aspects.

The second discussion group was asked to identify research priorities related to ocean carbon sequestration science. The group discussed research related to the efficiency of sequestration and the potential environmental impacts of sequestration.

Efficiency of sequestration
Several important questions remain regarding the efficiency of ocean carbon sequestration. Answers to these questions will be necessary before an appropriate decision could be made about whether ocean carbon sequestration is technically feasible. Answers to some of these questions will require field experiments, some will require modeling experiments and some will require both. An important idea discussed was that ocean carbon sequestration techniques may be suitable in some places and times as “niche applications” among many others, starting with emission reductions.

CO_2 Injection—What is the long-term efficiency of storage of injected CO_2, depending on where (location and depth), when, and how the injection is done? Field experiments will probably require that tracers such as SF_6 be injected with the carbon, as there are many mixing and advection mechanism that might move the patch and global circulation models and finer-scale models may not now include the appropriate mechanisms. Other specific questions include

- What are the time and space scales of elevated carbon concentrations?
- When does the benthic boundary layer homogenize at sufficiently low carbon concentrations that further diffusion is reduced to a passive tracer problem?
- What are the mixing processes and time scales between the benthic boundary layer and ambient water?
- What is the response of $CaCO_3$ sediments to elevated carbon concentration?
- On the microscale, how do carbon dioxide hydrates form and dissolve?

Iron Fertilization—While participants agreed that iron fertilization experiments have been, and will continue to be, important in understanding natural systems and processes, all available research discussed at the symposium indicates that iron fertilization would be a very inefficient method of ocean carbon sequestration, from the viewpoint of the amount of carbon that could be sequestered by this method and the likelihood that even if iron limitations were eliminated, other nutrients and environmental factors would become limiting. Modeling should continue to assess likely effectiveness of iron fertilization, using information gained from continuing studies of the effects of iron added to the surface ocean.

Impacts of sequestration

CO_2 Injection—Midwater and deep water far-field effects of carbon injections need to be studied and modeled, since these will occur in 500 years or less. Long-term studies could be conducted in locations of restricted advection, such as fjords. Also, some deep-sea systems already experience low alkalinity and low oxygen, such as the Black Sea. Study of such natural systems could provide information about how other systems might change as alkalinity and oxygen levels decrease. Such comparisons are not perfect models, however, because the biological communities in natural areas have adapted over time and non-adapted communities might behave very differently in response to relatively sudden changes. Regions where the anthropogenic signal is already penetrating into the deep sea should also be a focus of study (e.g., some parts of the North Atlantic Ocean), since these are deep-sea regions where pH is already changing. What are the mechanisms of sub-lethal and lethal effects of CO_2? The effects of high CO_2 levels on deep-sea animals should be conducted under high pressures, at low temperatures, and in unsteady CO_2 conditions.

Iron Fertilization—To the extent that iron fertilization actually increases phytoplankton production, the fate of the increased phytoplankton biomass will determine the environmental effects of fertilization. Wherever phytoplankton biomass is remineralised by bacteria, bacterial respiration will use oxygen. Most models predict that any large-scale iron fertilizations in the Southern Ocean would drive most of the underlying water column hypoxic or anoxic, which would have substantial impacts on midwater and deep-sea organisms. It is possible that iron fertilization could increase the biomass of fish and higher trophic level organisms, but any such increases would need to be weighed against deleterious effects in other parts of the affected ecosystems. It will be important to study how iron fertilization as a sequestration technique would increase N_2O production, cause extension of the anoxic regions, and/or change DMS production.

Approaches
This discussion group also recommended CO_2 perturbation experiments, at the seafloor where injections of CO_2 would occur. Such experiments could help us understand natural high-CO_2 ecosystems, which have been discovered in several locations in the deep sea (e.g., Loihi Seamount and in the Marianas Trench). These natural high-CO_2 areas could also be important study sites. A mid-water carbon injection experiment was also recommended, in which a patch of added CO_2 would be followed over time. Another important area of research would be to determine if the impacts of increasing CO_2 could be mitigated in specific key ecosystems. For example, would it be possible to artificially make the water over a coral reef more alkaline to protect the reef from negative impacts?

Education/Communication Group
Chair: Carol Turley
Rapporteur: Silvio Pantoja
Charge to Group: Identify (1) messages to convey, (2) audiences that need to receive the messages, and (3) mechanisms to convey the messages.

An important outcome of the symposium was the realization that the impact to the ocean of increasing atmospheric CO_2 has not been adequately conveyed to the general scientific community and the public. Therefore, one discussion group was formed to formulate a plan to communicate this important scientific information more widely.

Message
The message from the symposium must be consistent, objective, and based on sound science. The credibility of the scientific community and sponsoring organizations must be protected.

The core of the message is that human burning of fossil fuel is changing the chemistry of the ocean, increasing pCO_2 concentrations in the surface ocean and reducing the pH. These effects are already occurring and are measurable. These effects are in addition to and different from the effect of atmospheric CO_2 on global warming. The best scientific information available suggests that increasing oceanic pCO_2 and decreasing pH could have a significant negative effect on corals and other calcifying organisms, such as shellfish and some phytoplankton, disrupting marine food webs. One way to look at the future is that the ocean in a high-CO_2 world will be an "acidified ocean." It is important to convey to the public and policymakers that every bit of fossil-fuel CO_2 we can avoid emitting to the environment will help reduce these effects. Negative impacts on the ocean could be reduced through a range of mitigation approaches, including energy conservation, non-CO_2 producing energy sources, and non-ocean carbon sequestration approaches.

Audience
The first audience for a message about the rising CO_2 levels and associated acidification of the ocean is the scientific community, since even many ocean scientists at the meeting were not aware of the seriousness of the issue. The next audience for this message is policymakers and regulators, because they will need the information for good policy decisions. Third, the general public needs to be informed that there is another impact of the increases in atmospheric CO_2,

apart from global warming. Finally, this is a message that should be conveyed to college and high-school students, since their generation will experience greater impacts of today's government policies for carbon dioxide control than are already occurring.

Mechanisms

The message about surface acidification should be conveyed through a variety of mechanisms, to reach the different important audiences:

- The symposium planning committee should write a meeting report for *Science* or *Nature*, since these journals are widely distributed and reach scientists in other fields. Another potential venue would be *EOS*, to reach Earth scientists more specifically.
- The committee should also write a review article (e.g., for the News and Views section in *Science*) on ocean pCO_2 and pH change promoted by increase of atmospheric CO_2
- The publication of scientific papers in *JGR—Oceans*. It is important to publish the science from the symposium in the peer-reviewed literature and to make it available for the IPCC process.
- IOC and SCOR staff should compile a contact list of experts available to speak with the press and policymakers.
- IOC and SCOR staff should create an image bank for the media, with the assistance of symposium participants.
- The Web page from the symposium (http://ioc.unesco.org/iocweb/co2panel/HighOceanCO2.htm) should be maintained as a vehicle to compile and make available information on this issue.
- Outreach through TV and other media should be considered.
- The communication strategy for this message should be broad.
- Funding resources will be needed for the above actions. SCOR, IOC, IGBP, GCP, and other interested organizations should be approached for financial resources.

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Jerry Blackford	Plymouth Marine Laboratory	UK
Stéphane Blain	Laboratoire d'Océanographie et de Biogéochimie	France
Laurent Bopp	LSCE, CE Saclay	France
Edward A. Boyle	Massachusetts Institute of Technology	USA
Jacqueline Boutin	LODYC/UPMC Case 100	France
Emilie Breviere	Université Pierre et Marie Curie	France
Peter Brewer	Monterey Bay Aquarium Research Inst.	USA
Wendy Broadgate	IGBP Secretariat	Sweden
Ken Caldeira	Lawrence Livermore National Laboratory	USA
Mathieu Chalard	Res. Les Terrasses du Levant	France
Baixin Chen	National Inst. of Advanced Industrial Sci. and Tech.	Japan
Ralph Cicerone	University of California, Irvine	USA
Hein J.W. de Baar	Royal Netherlands Inst. for Sea Research	Netherlands
Bruno Delille	Université de Liège	Belgium
Carlo Della Libera		Italy
Stephanie Dutkiewicz	Massachusetts Institute of Technology	USA
James A. Edmonds	Joint Global Change Research Institute	USA
Jacqueline Etcheto	LODYC/UPMC Case 100	France
Victoria J. Fabry	California State University, San Marcos	USA
Edward Frieman	Scripps Institution of Oceanography	USA
Jean-Pierre Gattuso	CNRS-Université de Paris 6	France
Marion Gehlen	UMR CEA-CNRS	France
Anand Gnanadesikan	Princeton University	USA
Lars G. Golmen	Norwegian Institute for Water Research	Norway
Catherine Goyet	Université de Perpignan, BDSI	France
Elizabeth Gross	SCOR	USA
M. Grant Gross	Washington College	USA
Dennis A. Hansell	University of Miami	USA
Nick Hardman-Mountford	Plymouth Marine Laboratory	UK
Jerome Harlay	Université Libre de Bruxelles (ULB)	Belgium
Taketo Hashioka	Hokkaido University	Japan
Peter Haugan	University of Bergen	Norway
Katy Hill	International CLIVAR Project Office	UK
Ove Hoegh-Guldberg	University of Queensland	Australia
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Akio Ishida	Frontier Res. System for Global Change	Japan
Atsushi Ishimatsu	Nagasaki University	Japan
Rosane Gonçalves Ito	Universidade de São Paulo	Brazil
Truls Johannessen	University of Bergen	Norway
Parisa Jourabchi	Utrecht University	Netherlands
Tadahide Kakio	Fuji Research Institute Corp.	Japan
Jun Kita	Research Inst. of Innovative Technology for the Earth (RITE)	Japan
Wim Klaassen	University of Groningen	Netherlands
Arne Körtzinger	Institut fue Meereskunde	Germany

Kouame Georges Kouadio	ENS Chimie	Ivory Coast
Mark Kurz	Woods Hole Oceanographic Institution	USA
Laurent Labeyrie	Université de Versailles St Quentin	France
Michael Landry	Scripps Institution of Oceanography	USA
Chris Langdon	Lamont-Doherty Earth Observatory	USA
Martina Langenbuch	Alfred-Wegener-Institut	Germany
Cindy Lee	Stony Brook University	USA
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Nathalie Lefèvre	University of East Anglia	UK
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Nikos Leonardos	University of Essex	UK
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Peter Liss	University of East Anglia	UK
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Claire Lo Monaco	Universite Pierre et Marie Curie	France
Chandan Mahanta	Indian Institute of Technology	India
Katsumi Matsumoto	Geological Survey of Japan	Japan
Ben McNeil	University of New South Wales	Australia
Liliane Merlivat	CNRS/LODYC.University Paris 6	France
Nicolas Metzl	University P. et M. Curie	France
Sara Mikaloff Fletcher	University of California	USA
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James W. Murray	University of Washington	USA
Takashi Ohsumi	Research Institute of Innovative Technology for the Earth	Japan
James Orr	Unite Mixte de Recherche CEA-CNRS	France
Lia Ossiander	University of Washington	USA
Silvio Pantoja G.	Universidad de Concepción	Chile
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Keith Rodgers	LODYC	France
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Christopher L. Sabine	NOAA/PMEL	USA
Egil Sakshaug	Biological Station, NTNU	Norway
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UNESCO Press Release

Press Release No. 2004-69

RESEARCH SHOWS OCEANS BECOMING MORE ACIDIC

Paris, July 16 – The world's oceans are absorbing an unprecedented amount of carbon dioxide (CO_2), which is increasing their acidity and possibly threatening the longterm survival of many marine species, especially calcifying organisms including corals, shellfish and phytoplankton. According to research presented recently at a symposium organized by UNESCO's Intergovernmental Oceanographic Commission and the International Council for Science's Committee on Oceanic Research (SCOR), this in turn could disrupt marine food chains and alter ocean biogeochemistry in ways that are not yet understood or predictable.

The symposium brought together scientists from the world's leading oceanographic institutions to discuss how the ocean might be affected by higher levels of atmospheric carbon dioxide, and to develop research priorities to study these future effects. They were also called upon to discuss potential environmental consequences of proposals to use the ocean to sequester excess atmospheric CO_2, which is one of the most important greenhouse gases.

A report on the meeting's conclusions, now available online*, points out that the ocean is one of the Earth's largest natural reservoirs of carbon and each year absorbs approximately one third of the carbon dioxide emitted by human activities. According to research** led by Christopher Sabine of the National Oceanographic and Atmospheric Administration in the United States (NOAA, an IOC Member State Agency)* the ocean has taken up approximately 120 billion metric tons of carbon generated by human activities since 1800. The IOC reports that some 20-25 million tons of CO_2 are being are being added to the oceans each day.

The absorption of carbon dioxide by the oceans is considered a beneficial process that reduces the concentration of CO_2 in the atmosphere and mitigates its impact on global temperatures. However there is growing concern over the price of this service. For the symposium participants, it is now well established that by the middle of this century, the accumulating burden of CO_2 entering the ocean will lead to changes in pH or acidity of the upper layers that are three times greater in magnitude and 100 times faster than those experienced between ice ages. Such dramatic changes in the CO_2 system in open-ocean surface waters have not been observed for more than 20 million years of earth's history, concluded the meeting.

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The initial findings of limited observation, research and modeling conducted to date and presented to the symposium indicate that in a high CO_2 world:

- the ocean would be more acidic globally, and would also be more stratifed in the high latitudes. In addition nutrient concentrations in surface waters of high-latitude regions would be lower, subsurface waters would be less oxygenated, and phytoplankton would experience increased exposure to sunlight. These changes would affect many species and change the composition of biological communities in ways that are not yet understood or predictable.

- many calcifying organisms, including certain species of plankton and corals, and also non-calcifying organisms, would be unable to grow and reproduce effectively at higher CO_2 and lower pH levels. Rising temperatures – combined with elevated CO_2 and decreasing pH – pose a serious threat to coral reefs, possibly leading to the elimination of some reefs by the end of this century.

Participants at the symposium stressed that although the impact of climate change on the ocean has been much debated, the direct chemical and biological impact of CO_2 itself has largely been neglected. However, they concluded, changes are clearly underway and their effects may be large and may seriously destabilize marine ecosystems. Their report signals the need for more research and identifies research priorities, in a bid to increase understanding of the changes taking place and their consequences, and to allow for more informed policy decisions in this area.

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*The report is accessible on the internet at http://ioc.unesco.org/iocweb/co2panel/HighOceanCO2.htm
** A report on Dr. Sabine's research and findings appears in the July 15 edition of *Science* magazine, along with a report from fellow NOAA scientist and participant at the UNESCO meeting, Dr. Richard Feely (www.sciencemag.org)

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4.3 Other Activities

4.3.1 SCOR/IOC Activity on Extending Ecosystem Models to the Basin Scale

The Intergovernmental Oceanographic Commission (IOC) requested that SCOR and IOC bring together a group of scientists who have been active in ecosystem modeling (particularly in the North Atlantic region), to write a paper to describe the status of ecosystem models and how they could be extended to the basin scale (**see article in following plastic folder**). This group was chaired by Brad de Young (Canada). It met twice to write an article for *Science.* This activity resulted from a GLOBEC focus group, but also included individuals from JGOFS, IMBER, and PICES.

4.3.2 The Global Iron Cycle

A set of fast-track initiatives was approved by IGBP at their meeting in Punta Arenas, Chile in January 2003. The idea for a fast-track initiative on the global iron cycle was developed primarily by Robert Duce and Peter Liss at the IGBP meeting. A proposal was submitted to ICSU by IGBP, with SCOR as a supporting applicant, and was funded, with $40,000 from ICSU. IGBP assigned the responsibility for planning coordination and logistical arrangements to IGBP's Global Analysis, Integration, and Modeling (GAIM) office, although the SCOR Secretariat also was involved in the continued planning. Tim Jickells (UK) and An Zhisheng (China-Beijing) co-chaired the meeting. The meeting report follows.

Report on Global Iron Conections Meeting

This meeting took place in Norwich in the UK 18- 21 April 2004. It was set up as part of the IGBP fast track activities to consider an analysis of the global dust/iron cycle cutting across conventional IGBP boundaries.

Attendees with appropriate expertise in particular aspects of the global dust/iron cycle were invited to participate, with a target of 10-20 total attendees. We ended up with 19 participants, though two cancelled at the last minute because of health problems, but remained fully engaged in the preparations for the meeting and the preparation of subsequent publications. The list of attendees is attached along with the agenda. The meeting was funded by IGBP via a grant from ICSU with additional funding from SCOR that allowed the participation of 3 young scientists from developing countries (Junji Cao, Nilgrun Kubilay and Rodrigo Torres).

The participants were asked to prepare papers for distribution ahead of the meeting summarising particular aspects of the dust/iron cycle. Modelling and field results were integrated in the reviews. These papers were then presented in an informal manner over the first two days of the meeting with extensive time allowed for discussion. These talks considered the dust cycle from source to sink, followed by a discussion of the cycle as revealed by palaeo records. The next two days of the meeting were devoted to synthesising the cycle in terms of what we do know and what we do not know.

The meeting format worked well, primarily because of the enthusiasm and commitment of all the participants to working across disciplines. I believe all found it very educational since nobody works across such a breadth of science. At the end of the meeting we discussed how to best achieve concrete products from the discussion. We concluded that we would attempt to produce 4 peer reviewed publications. The first would be a review article to be submitted to *Science* which focuses on the feedbacks and linkages within the climate/dust/iron system. The other three papers are planned to be submitted to *Global Biogeochemical Cycles*, with one each focussed on the production and atmospheric transport of dust, the deposition of dust to the oceans and the biogeochemical response to this addition, and the third paper on the palaeo-record of dust transport and deposition. The papers are all intended to be submitted in the autumn of 2004.

Tim Jickells

Meeting agenda

Sun 18 April

10-11	Introduction (Jickells, An Zhisheng)
Coffee	
11.30-12.30	Dust Sources and Production (Bergametti, Brooks, Prospero))
Lunch	
13.30-14.30	Dust transport and Flux Models (Mahowald Tegen)
14.30-15.30	Radiative Impacts (Brooks)
Coffee	
16.00-17.00	Atmospheric Chemistry of Dust (Sulzberger)
17.00-18.00	Dust deposition and solubility (Baker, Duce, Jickells)

Mon 19 April

09.00-10.00	Ocean Chemistry of Fe (Hunter)
10.00-11.00	Ocean biological cycling of iron (la Roche)
Coffee	
11.30-12.30	Trace gas exchange coupling to iron (Liss)
lunch	
13.30-14.30	Sediment records of dust fluxes (An Zhisheng, Junji Cao, Hodaka)
14.39-15.30	Ice core records of dust fluxes (Andersen)
Coffee	
16.00-17.01	Dust in Earth System Models (Ridgwell)
17.00	Planning next step

Participants

Alex Baker (UK), Giles Bergametti (France), Nick Brookes(UK), Junji Cao (China), Bob Duce(USA), Keith Hunter (NZ), Tim Jickells (UK), Hodaka Kawahata (Japan), Katrine Krogh Andersen (Denmark), Nilgun Kubilay (Turkey), Julie la Roche (Germany), Peter Liss (UK), Natalie Mahowald (USA), Joe Prospero (USA), Andy Ridgwell (Canada), Barbara Sulzberger (Switzerland), Ina Tegen (Germany), Rodrigo Torres (Chile), An Zhisheng (China).

4.3.4 SCOR/IGBP Meeting on Data Management in International Marine Research Projects

SCOR and IGBP convened a meeting in December 2003 to bring SCOR and IGBP project representatives together to discuss project data management. The meeting was funded by NSF and the British Oceanographic Data Centre. The report of recommendations from the meeting follows. The recommendations to sponsors are hightlighted.

Introduction

The Scientific Committee on Oceanic Research (SCOR) and International Geosphere-Biosphere Programme (IGBP) convened a meeting on Data Management for International Marine Research Projects on 8-10 December 2003 in Liverpool, UK. Meeting participants included representatives (both data producers and data managers) from international projects and programmes (CLIVAR, GEOHAB, GLOBEC, IGBP, IMAGES, IMBER, IODE, JGOFS, LOICZ, OBIS, SCOR, SOLAS, WDCs and WOCE) and data managers from national data centres (BODC, Indian NODC), see appended list). Dr. Roy Lowry of the British Oceanographic Data Centre (BODC) convened the meeting at the Foresight Centre, University of Liverpool. SCOR and IGBP thank the U.S. National Science Foundation and BODC for their support of this meeting.

Three important products resulting from this meeting are presented in this document:

(1) a series of recommendations based on reports from marine research projects, and presentations and discussions at the meeting;
(2) agreement on, and modifications to, recommendations from a working group on Oceanographic Data Management held at the IGBP Congress in Banff in June 2003; and
(3) guidelines for development of project data policies.

These three products follow. The session summaries (Appendix I), presentation documents (Appendix II), meeting agenda (Appendix III), and participants' list (Appendix IV) are also available on the activity Web page (see www.jhu.edu/scor/DataMgmt.htm). This meeting was designed to fulfil one of the recommendations from the Banff meeting and to extend the work started in that session.

Recommendations

The following recommendations were distilled by the rapporteurs from the discussion sessions during the meeting.

Session on Preceding Work

- The report from the data management session at the IGBP Congress at Banff in June 2003 should be taken forward as a recommendation from the Liverpool meeting after an agreed set of modifications has been incorporated. The modified document is included below.
- An information resource to support the development of data management in new projects should be established and maintained. A Web site would seem the most appropriate

vehicle for such a venture. SCOR has offered to host this facility, at www.jhu.edu/scor/DataMgmt.htm

Session on New and Developing Projects

- Established data management expertise and techniques in the marine science community do not address the management of data that are not geospatially referenced or socio-economic data. Projects need to address these data types through the composition of their Data Management Committees.
- Data Management Committees from different marine projects would benefit from joint meetings to ensure common solutions to common problems. A mechanism is required to facilitate such meetings.
- Data Management Committees should have three areas of responsibility:

  (1) ensure that data are available for project scientific purposes and that data management meets the present scientific need of the project without compromising future needs,
  (2) oversee the compilation of data from individual principal investigators (PIs) and national projects into a long-term, integrated data set that is submitted to an appropriate data archive and may be published in CD-ROM or DVD format, and
  (3) address the involvement in project data exchange activities of scientists without access to effective data management infrastructure.

Session on the WOCE experience

- The Data Assembly Centre (DAC)[4] model adopted by the World Ocean Circulation Experiment (WOCE) is applicable to predictable data management requirements such as CTD data management and assembly (but not quality control) of water bottle data sets. Such infrastructure could be shared among projects. However, the concept cannot be extended to cover the full range of parameters measured by biogeochemical and ecological projects.

Session on Metadata[5] Management

- Metadata management should be decoupled from data management, with the International Project Office (IPO) taking the lead role in metadata catalogue assembly.
- Endorsement of scientific activity by a project requires metadata to be submitted on the shortest possible timescales. This requirement should be clearly stated in the project data policy, including mechanisms for metadata submission and sharing.

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[4] Data Assembly Centres assemble a restricted data stream (such as sea level data, current meter data or CTD data) from all sources of that data type within a project. DACs are generally established in centres with an established reputation for handling the type of data concerned and generally represent in-kind donations by national infrastructure to the international programme.

[5] Metadata are information about data, including information that allows data sets to be located (discovery metadata: what was measured, when and where), information that enhances human understanding of the data and the uses to which it can be put (semantic metadata) and information that allows software agents to access the data (technical metadata).

- Common metadata standards should be adopted across projects to facilitate sharing of metadata through catalogue interoperability. The Directory Interchange Format (DIF) developed by the Global Change Master Directory (GCMD) is a suitable standard for cataloguing datasets and has established storage and query infrastructures.
- Project metadata catalogues should be combined through distributed networking or even physically combined, when required by technical considerations.

Session on National Data Management Infrastructure

- The co-operative data management strategy operated by BODC project data management and IMAGES data management (sometimes termed "end-to-end" data management, which is the phrase used elsewhere in this document)[6] is a useful concept and should be reproduced and adapted. It may be implemented with either the data manager and database infrastructure in the same organization, such as BODC, or in different organizations, such as the IMAGES data manager and WDC-MARE. Combinations of these two modes of operation allow a totally scalable infrastructure to be developed. The data manager role also could be operated by a small- to medium-sized commercial enterprise (SME).
- Procedures could be developed to operate end-to-end data management in countries without an adequate data management infrastructure in collaboration with an established data centre.

Session on Data Policies

- As SCOR and IGBP are ICSU bodies, SCOR and IGBP projects must adopt the ICSU principle of free and open data exchange.
- There are many data management policies that could be used as the basis of an IGBP/SCOR template (see pages 7-9) and adapted to the specific needs of each project.
- Project SSCs should decide the rules for data access within and between projects.
- Data Management Committees should monitor adherence to their policies and report breaches to be dealt with on a case-by-case basis by the SSC.

Session on Technical Aspects of Data Management

- It is essential that projects identify and universally adopt appropriate data and metadata standards at the start of the project.
- A technical forum is required to ensure that the compatible standards are maintained across projects.

[6] Project data management or end-to-end data management is characterized by the involvement of the project data manager from the beginning of the project, in planning how the data will be collected, shared, and archived. The data manager may be involved in planning the research, participate in research cruises, help participating scientists format their data and train them in methods to use project data, and ensure that project data are archived in appropriate national and international data archives.

- Meeting participants expressed concern at the number of distributed data systems[7] currently being independently developed to very similar specifications. A meeting of distributed system developers is recommended to ensure interoperability[8] among these systems.
- The technology needs of developing countries may be more effectively addressed through infrastructure development rather than through restriction of technological developments elsewhere. There is a clear need for reliable high-bandwidth network capacity across the globe.
- There is a need to develop infrastructure to ensure the long-term availability of real-time data that are currently displayed on the Web for a limited time and then destroyed.

Session on Data Submission to World Data Centres (WDCs)

- A peer-reviewed dataset publication infrastructure should be established and efforts made to initiate culture change in marine sciences to raise the status of these publications as output performance indicators.
- Data quality control should be the result of a partnership, with data originators, data users, and data centres (national and world) each playing a role.
- Countries that do not have a national oceanographic data centre within the IODE network should establish a national data co-ordinator. Countries should inform their international projects of their appropriate national data centre or national data contact, and should secure the adequate involvement of their national data centre in national and international management of project data.
- If data coverage gaps within the WDC system are identified, then a dialogue among the projects, the relevant WDCs, and the Intergovernmental Oceanographic Data Exchange (IODE) is recommended.
- The acquisition of data by WDC should be a partnership between IODE network, the WDCs, and project data managers.

Session on Funding Data Management

- The proportion of the total project science budget (including platform costs) required for end-to-end project data management, project data services, and assuring the long-term stewardship of the project data is approximately 10%.
- Operating a project metadata catalogue should be considered a core activity of the IPO and requires a minimum of one-half of the time of a full-time employee.

[7] Distributed data systems are systems where data held in multiple databases in multiple locations are accessed through a common user interface, commonly termed a portal. Examples include OpenDAP (DODS), LAS, Mercury, and Thredds.
[8] Interoperability is the ability to seamlessly access metadata or data held in multiple databases, exactly as though they were from a single database.

Oceanographic Data Management: Recommendations from Working Group B2 at the Banff Congress (June 2003)

Affirmed and modified by participants of the SCOR/IGBP Meeting on Data Management for International Marine Research Projects, 8-10 December 2003

Session Summary

The session opened by declaring its primary objective to be to help the new projects, such as SOLAS, IMBER and the SCOR/IOC GEOHAB initiative, to develop their data management plans.

The data management of the mature programmes JGOFS, WOCE, LOICZ and GLOBEC was reviewed. It became clear from this that the following actions are extremely beneficial to projects:

- Establishment of a Data & Information Management Unit at the outset.
- Development of scalable data management
- Adoption of standards to facilitate interoperability of data and information, while allowing for evolution of techniques during the programme
- Utilisation of existing infrastructure but with additional resources to ensure it fulfils international rather than national specifications and standards
- Provision of services and data access that match the needs of scientists and other end users
- Provision of data through both a leading edge technology and a universally available technology
- Development of a close working relationship between data managers and scientists through means such as "end-to-end" project data management and the provision of data access tools

Some generic data management issues were then examined:

- The form and content of a "data policy."
- The role of developing technologies, such as the development of seamlessly integrated distributed databases
- Areas where oceanographic data managers need to look for new techniques, such as socio-economic data, bio-informatics and non-spatial data, for example, mesocosm and other experiments

Strategy scenarios to bridge the gap between data at the "PI" level and a complete, fully integrated and documented data set were then examined.

The session was concluded by drawing together the following recommendations:

Recommendations for New IGBP Oceanographic Programmes

1. Projects should establish a data policy at the outset to address the following issues:

    - Data sharing within the programme, between programmes and the entry of data into the public domain.
    - Data content and quality issues.
    - Long-term security of the data.

2. All new programmes should dedicate resources to the development of a project meta-database that will form the project data inventory. This should conform to appropriate international standards (e.g., ISO19115 for spatially referenced data) to facilitate integration and exchange of information between programmes. The IPO should ensure that a structure is created and implemented, appropriate to the needs of the project.

3. Projects should establish a data management working group such as the JGOFS Data Management Task Team or the WOCE Data Products Committee. Past experience has shown that these groups are more effective if they comprise data originators, data managers and data users.

4. National or project science programmes should address data management in a credible manner, including allocation of appropriate resources and giving consideration to capacity building, if appropriate.

5. Attention should be given to developing incentives for scientists to submit/share their data, for example, by offering tools such as modelling, plotting, and cartographic representation of data.

Recommendations for Further Work

1. A data policy template should be developed to assist programmes with the compliance with recommendation (1) above.
2. IGBP should work together with other international organizations to promote a culture where datasets are regarded as citable entities that are recognized as important scientific outputs.

Roy Lowry, British Oceanographic Data Centre (Chair)
Bernard Avril, JGOFS IPO (rapporteur)
23/06/2003
Revised 10/12/03

Data Policy Template for IGBP and SCOR Marine Projects

Scientific data and information derived from large-scale research projects with oceanic components are critical to project success and are an important legacy of these projects. Project data should be available for assessment and use by independent scientists, including, initially, other project scientists and later by external scientists. To ensure long-term survival, integrity, and availability of project data and models, a workable plan, policy, and associated infrastructure must be established early in the life of a project. Project data, as well as model code and model output, must be made available to the community.

A data management policy and plan should (1) encourage rapid dissemination of project results; (2) ensure long-term security of key project data, as well as model-related information; (3) protect the rights of the individual scientists; (4) treat all involved researchers equitably; and (5) reward openness. IGBP and SCOR affirm the data policy of their parent organization, the International Council for Science (ICSU):

> "ICSU recommends as a general policy the fundamental principle of full and open exchange of data and information for scientific and educational purposes." [ICSU General Assembly Resolution 1996]

Participants at the December 2003 meeting on Data Management for International Marine Research Projects recommend that all IGBP/SCOR large-scale marine research projects adopt the following essential elements in their data policies. Also listed are additional considerations for the development of project data management systems.

<u>Essential Data Policy Elements</u>

- Project endorsement requires a credible commitment to the timely submission of data to a project-approved database to ensure long-term archiving of the data.
- Discovery Metadata (what was collected where, when and by whom) should be submitted by project scientists to the International Project Office on the shortest feasible time scales. Failure to do should be considered reason to remove project endorsement.
- Model code and documentation, initialisation, boundary conditions, data used to force the model system, and output resulting in published results ("definitive runs") must be submitted to project-approved databases in forms which allow assessment of key findings.
- Timelines for data and model sharing, as well as protocols associated with intellectual property rights of different data types and models, should be defined. Currently accepted guidelines are that data should enter the public domain after a maximum of two years after data become available to the PI.
- Quality control of metadata, data and model output needs to be addressed.
- Each project should form and support a Data Management Committee. The three primary functions of Data Management Committees are to:

(1) ensure that data are available for project scientific purposes and that data management meets the present scientific need of the project without compromising future needs,
(2) oversee the compilation of data from individual principal investigators (PIs) and national projects into a long-term, integrated data set that is submitted to an appropriate data archive and may be published in CD-ROM or DVD format, and
(3) address the involvement in project data exchange activities of scientists without access to effective data management infrastructure.

- Projects must adopt or establish a credible data management infrastructure.
- Projects should adopt metadata standards (content and controlled vocabularies[9]) and agreed data formats both within and among projects to facilitate data interoperability.
- Project Data Management Committees should consider how to get appropriate project data into operational data streams[10] and appropriate operational data streams into the project domain.

Additional Considerations
Project SSCs and Data Management Committees should create their project data policy, considering the following issues.

The project SSC should:

- Create a Data Management Committee with adequate representation of project science, a balance between project scientists (including modellers), national and international project data managers, and consideration of outreach functions to countries without data centres.
- Consider providing access to project-related publications through a publication database, such as that used by GLOBEC.

The project Data Management Committee[11] should:

- Develop a process to ensure that metadata and data are submitted, monitor the compliance of project scientists to the policies, and refer failure in compliance to the project SSC.
- Specify how project data will be quality controlled.
- Specify incentives to encourage project scientists to submit metadata and data to the IPO and a long-term data repository, respectively. ("One carrot is worth ten sticks.") These incentives may include citation of data in a peer-reviewed journal, access to other project data during "an embargo period" before public access, tools for use of data in the data

[9] Metadata vocabularies are controlled lists of words or phrases that are used to populate metadata fields in place of free text to ensure computer searches are not compromised by problems such as spelling variations.
[10] Operational data streams are data that are available on a regular basis from routine observing systems, such as Argo floats, sea level networks, and telemetered data buoys.
[11] Where modelling committees exist, these should be consulted in relation to model-specific aspects of data policy.

archive (e.g., data merging, plotting, spatial visualisation and modelling tools), and help from international data managers in submitting data, accessing data, and using analysis tools. Proper incentives will reduce the efforts needed by data managers to get data into project data systems and increase participation in the project.

- determine the variables most likely to be measured and the expected data volumes, and specify project data products.
- address how non-geo-referenced, socioeconomic, and other non-conventional data will be handled.
- consider setting up a DAC, either project-specific or shared among projects, for data that can be handled in this way. The DAC may be set up along the lines of project data streams (e.g., CTD data, bottle data) and/or the more traditional single parameter DAC (i.e., the DACs used by WOCE and CLIVAR).
- consider whether to submit DIFs to GCMD as a means to provide access to project metadata.
- consider making species-specific data available through OBIS.
- create a mechanism to interact regularly with representatives of related project Data Management Committees to develop common approaches and procedures to share data.

Project SSCs and Data Management Committees should work together to

- specify how project models and data will be made available both to scientists with leading-edge technology and with unreliable access to even basic access methods. The project should also present plans for training developing country scientists in techniques for data access and use.
- develop plans to bring together data providers and data managers, considering how "project data management" principles could be applied to each project.

Acronyms

BODC	British Oceanographic Data Centre
CLIVAR	Climate Variability and Prediction project
DAC	Data Assembly Centre
DIFs	Directory Interchange Formats
GCMD	Global Change Master Directory
GEOHAB	Global Ecology and Oceanography of Harmful Algal Blooms programme
GLOBEC	Global Ocean Ecosystem Dynamics project
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IMAGES	International Marine Aspects of Global Change project
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research project
IODC	Indian Oceanographic Data Centre
IODE	Intergovernmental Oceanographic Data and Information Exchange
IPO	International Project Office
JGOFS	Joint Global Ocean Flux Study

LOICZ	Land-Ocean Interactions in the Coastal Zone project
NODC	National Oceanographic Data Centre
OBIS	Ocean Biogeographic Information System
PI	principal investigator
SCOR	Scientific Committee on Oceanic Research
SSC	Scientific Steering Committee
SME	small to medium-sized commercial enterprise
SOLAS	Surface Ocean – Lower Atmosphere Study
WDC	World Data Centre
WDC-MARE	World Data Centre for Marine Environmental Sciences
WOCE	World Ocean Circulation Experiment

Meeting Participants

Name	Project/Organization
Dawn Ashby	GLOBEC IPO
Bernard Avril	JGOFS IPO
Geoff Boxshall	OBIS
Wendy Broadgate	IGBP Secretariat
Juan Brown	BODC
Howard Cattle	CLIVAR IPO
Wolfgang Fennel	GEOHAB
Julie Hall	IMBER
Katy Hill	CLIVAR IPO
Roy Lowry	BODC
Liana Talaue-McManus	LOICZ
Lesley Rickards	IODE
Stefan Rothe	IMAGES
Casey Ryan	SOLAS IPO
Jaswant Sarupria	IODC
James H. Swift	WOCE
Ed Urban	SCOR Secretariat
Douglas Wallace	SOLAS
Ferris Webster	ICSU WDCs

4.3.4 SCOR Meeting on Coordination of International Marine Research Projects
Large-scale ocean research programs and projects are sponsored by several different international organizations, each with a different focus. For example, SCOR focuses on all areas of ocean science, IGBP focuses on biological and chemical aspects of global change, the World Climate Research Programme (WCRP) focuses on physical aspects of global change, and IOC brings together national governments to sponsor research and infrastructural activities related to aspects of ocean science that are of greatest importance to society. One example is the Global Ocean Observing System (GOOS). Some research programs, such as the Census of Marine Life and InterRidge, are independent but affiliated with related organizations. The programs and projects have interacting interests, but because they are not all sponsored by a single organization, they do not typically come together to discuss opportunities for cooperative activities and ways to address common concerns. The programs and projects tend to operate under tight budgets and are usually reluctant to spend their funds for coordination meetings. SCOR received support from the Alfred P. Sloan Foundation to convene a meeting of the representatives of these projects, which will be held in a suburb of Venice in the week before the SCOR General Meeting.

SCOR Meeting on Coordination of International Marine Research Projects

Venice, Italy
23-34 September 2004

Purpose of Meeting:
To bring together representatives of the major international ocean research and observation projects and programs to discuss common opportunities, issues and problems.

Participants will be encouraged to arrange in advance to meet over lunches and dinners for bilateral and small-group discussions of project-coordination issues.

Logistics:
SCOR will pay for the transportation, lodging, and meals of invited project representatives (CLIVAR, CoML, DIVERSITAS, GEOHAB, GEOTRACES, GLOBEC, GOOS, iAnZone, IMAGES, IMBER, InterRidge, IOCCG, LOICZ, MA, and SOLAS). Lodging will be at the Holiday Inn Venice-Mestre-Marghera. Lodging will be arranged for three nights (Sept. 22, 23, and 24) and all meals will be provided.

Meeting Information:
Background and logistical information for the meeting can be found at www.jhu.edu/scor/ProjCoord.htm.

Agenda

23 September (Thursday)

9:00 Background, Introductions, and Goals – John Field/Laurent Labeyrie and Ed Urb

9:30 Update on follow-up activities related to SCOR/IGBP Activity on Data Managen for International Marine Research Projects (see http://www.jhu.edu/scor/DataMgmt.htm)

- Updates from Projects
- Updates from Sponsors

Additional Follow-up Needed

10:30 Break

11:00 Interactions of International Marine Research Projects with the Global Ocean Observing System
Presentations: Tom Malone (COOP) and Ed Harrison (OOPC) – 40 minutes

- How have projects been involved in GOOS development? – Reports from GOOS and projects
- How can GOOS and other observing systems be useful for the projects?
- What measurements do projects need most from GOOS?
- How can projects be useful for GOOS?
- How are research observations transformed into operational observations?
- How can the research projects be useful for developing the observing syst
- What mechanisms are necessary to improve the way that projects work w GOOS and other observing systems?

How will the observatories and time-series stations planned by the projects integr with GOOS?

13:00 Lunch (bilateral and small-group meetings)

14:30 Continued discussions of GOOS-project relations

16:00 Break

16:30 Project Needs for Time-series stations
Presentation - 30 minutes - Bob Weller or Uwe Send

18:00 Adjourn for the Day

20:00 Dinner (bilateral and small-group discusions)

24 September (Friday)

9:00 Southern Ocean research and observations

- Potential for collaborative research among projects, in general, and during IPY

Mechanisms for continued interactions – Presentation by Colin Summerhayes on SCAR-SCOR Proposal for a Coordination Group for the Southern Ocean (ISOS)

10:30 Break

11:00 Contributions of projects to environmental assessments supported by governments such as the climate assessments of the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, and Global Marine Assessment

- Millennium Ecosystem Assessment - Jackie Alder
- IPCC

13:00 Lunch (bilateral and small-group discussions)

14:30 Discussion of other topics of interests to the participants (either identified at the meeting or in advance)

16:00 Break

16:30 Conclusions and Recommendations

- To SCOR and other organizations
- To projects
- To GOOS and other observing networks
- To governmental agencies and inter-governmental organizations

To others?

18:00 Adjourn Meeting

20:00 Dinner (bilateral or small-group discussions)

Expected Participants

Jackie Alder	Millennium Ecosystem Assessment
Keith Alverson	GOOS Project Office Director
Bob Anderson	GEOTRACES Planning Committee Co-chair
Dawn Ashby	GLOBEC IPO
Howard Cattle	International CLIVAR Office Director
Bill Curry	IMAGES Executive Committee Chair
Colin Devey	InterRidge Chair
Tommy Dicky	OceanSITES SSC
Henrik Enevoldsen	IOC/GEOHAB
John Field	SCOR Past-President and GOOS Steering Committee Chair
Fred Grassle	CoML Scientific Steering Committee Chair

Julie Hall	IMBER Scientific Steering Committee Chair
Ed Harrison	GOOS OOPC Chair
Carlo Heip	DIVERSITAS Scientific Steering Committee
Karen Heywood	iAnZone Chair
Hartwig Kremer	LOICZ Executive Officer
Laurent Labeyrie	SCOR Vice-President
Anne Larigauderie	DIVERSITAS Executive Director
Tom Malone	GOOS/COOP Chair
Ron O'Dor	CoML
John Parslow	LOICZ Scientific Steering Committee
Grant Pitcher	GEOHAB Scientific Steering Committee Chair
Casey Ryan	SOLAS IPO
Ralph Schneider	IMAGES Executive Director
Colin Summerhayes	SCAR Executive Director
Ed Urban	SCOR Executive Director

Other projects will be added, as funding allows

Request for Background Information

To Projects:

Data Management Discussion—Has your SSC discussed and considered the recommendations of the data management meeting? If so, will the recommendations be implemented? What additional actions could/should SCOR or other organizations take to help with this topic?

GOOS Discussion--Please provide any information from your project documents that specifies project plans to interact with GOOS and describe any interaction your SSC or IPO has had with GOOS activities. Have SSC members attended GOOS Steering Committee, OOPC, or COOP meetings? If so, what was their role at the meeting? Has your SSC discussed what is, or will be, available from GOOS and other observing systems? Has your SSC identified any specific observations to which your scientists would like access? Have you ever had a presentation about GOOS at an SSC meeting? What research observation systems would your project like to see become operational?

Southern Ocean Research--What activities has your project undertaken or planned for the Southern Ocean? Have you coordinated your Southern Ocean research with other projects? Do you have any special plans for the 3rd International Polar Year in 2007?

Time-Series Stations—Will implementation of your project require observations from time-series stations? In what locations? How will such stations be supported?

Environmental Assessments—Has your project been asked by any of the global assessment organizations for data, model results, and/or expert advice?

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To GOOS:

- What are the 6 societal goals of GOOS and what operational measurements will GOOS make to address these goals? Please explain how the role of GOOS in relation to its component observing networks.
- What kind of data streams will be available to the projects through GOOS and how can such data be obtained?
- How does GOOS interact with the projects? Do project scientists attend GOOS meetings? Review documents?
- Can the projects be useful to GOOS through provision of research observations and/or model results?

4.3.5 Panel on New Technologies for Observing Marine Life

Terms of Reference:

- To review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects.
- To communicate with CoML project leaders on a regular basis to discuss project technology needs.
- To identify and bring to the attention of the international community of fisheries scientists, marine biologists and others, the potential benefits of emerging technologies in the detection of marine life.
- To explore the relative merits of different technologies and identify those that deserve further research based on their potential for making significant contributions to the detection of marine life.
- To summarize the Panel's discussions on its Web site and in published articles, so as to make it as widely available as possible.

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