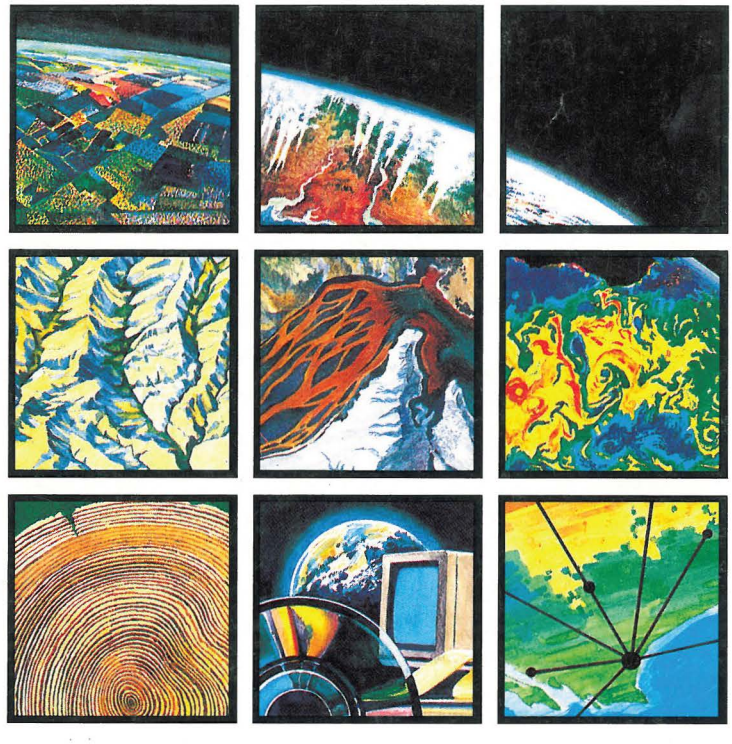
GLOBAL CHANGE

IGBP

REPORT No. 28



IGBP in Action:

Work Plan 1994 - 1998

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)
Stockholm, 1994

GLOBAL CHANGE

IGBP

REPORT No. 28

LINKÖPINGS UNIVERSITET
30580 002417413

IGBP in Action:

Work Plan 1994 - 1998

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)
Stockholm, 1994

The international planning and coordination of the IGBP is currently supported by IGBP National Committees, ICSU, the European Commission, Governments and industry, including the Dutch Electricity Generating Board.

The IGBP Report Series is published as an annex to the Global Change Newsletter and distributed free of charge to scientists involved in global change research.

Copyright © IGBP 1994, ISSN 02848015
Cover illustration: Willy Ytter
Technical editing: Magdalena Kanger

Contents

Preface 5

Part I : Programme Coordination And Integration

Introduction 9

Programme-Wide Products 14

Programme Coordination and Review 20

Budget 25

Part II : Workplans for the Core Projects and Framework Activities

Biospheric Aspects of the Hydrological Cycle (BAHC) 29

Global Change and Terrestrial Ecosystems (GCTE) 38

International Global Atmospheric Chemistry Project (IGAC) 47

Joint Global Ocean Flux Study (JGOFS) 59

Land-Ocean Interactions in the Coastal Zone (LOICZ) 68

Land-Use/Cover Change (LUCC) 77

Past Global Change (PAGES) 84

Global Analysis, Interpretation and Modelling (GAIM) 97

Data and Information System (IGBP-DIS) 104

System for Analysis, Research and Training (START) 112

Part III : Appendices

Membership of the Scientific Committee for the IGBP 129

Core Projects, Framework Activities and Their Offices 132

IGBP National Committee Chairs and Secretaries 134

Liaison Persons with ICSU Scientific Members 141

IGBP Publications 143

List of Acronyms and Abbreviations 148

Preface

This Report provides an overview of the research to be carried out by the International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) over the next five years (1994 - 1998). The previous IGBP document of similar scope, Report 12, was published in 1990 and described the basic structure of the programme, the scientific rationale for its component Core Projects and proposals as to how they might be developed. Since then ideas have become reality; several thousand researchers in some 70 countries have begun to implement the programme. Whilst Report 12 provided the blueprint, it was not a definitive document for all time. In many areas it lacked the detail necessary to translate broad concepts into specific field and laboratory studies, with a realistic timetable. In other areas, the proposals had not yet been subject to critical scientific appraisal, or were at an early stage of their development.

IGBP Reports 13 - 27 cover many of those gaps, providing Science Plans, Implementation Plans and in-depth reviews for most of the Core Projects and Framework Activities. In addition, the Scientific Committee for the IGBP (SC-IGBP), established in 1990, has given considerable attention to the overall coherence of the programme, the priorities within it, and its relationship to other programmes and activities. The 3rd meeting of the IGBP Scientific Advisory Council (SAC III; Ensenada, January 1993) provided valuable input to that on-going exercise and, in the associated scientific symposium, showed examples of what has been achieved (papers from the symposium published in Ambio, February 1994).

It is therefore timely to provide researchers and the wider community with an up-to-date synthesis, within a single document, of what IGBP is doing, why it is important, and the scientific products that it expects to achieve. It has been prepared by the IGBP Officers and Secretariat based on discussion by the SC-IGBP and input from the Core Projects and Framework Activities, principally through their Core Project Offices (CPO). Yet it takes account of a much wider input, being based on the active involvement in planning and project development of all programme participants, through workshops, scientific meetings and other discussions at the national and international levels.

An individual reader may therefore already be familiar with the parts of this Report summarising the IGBP work plans relevant to his/her specific research field. However, the context of that work within the programme as a whole, and its links to other parts, are of crucial importance to the programme's overall success. Thus, those aspects are, where appropriate, given special attention. To obtain a predictive understanding of global change requires much more than a worldwide data-gathering exercise. Rigorous scientific scholarship in many disciplines must be combined with a global-scale breadth of vision, with working access to many other data sets covering a wide range of variables over large geographic and temporal scales. No single nation

can aspire to achieve that integration on its own, carrying out all the studies that are needed, and interpreting all the information that is obtained. To satisfactorily address the problems of global change, an international programme is essential, based on the collective effort of a well-informed and interacting global research community. A global approach is also necessary to achieve the scientific understanding on which assessments, such as those of the Intergovernmental Panel on Global Change (IPCC) are based. IGBP, in collaboration with Human Dimensions of Global Environmental Change Programme (HDP) and World Climate Research Programme (WCRP), thus provides the underpinning necessary for the international policy making process.

In addition to the scientific community, there is another important audience for this document. Research must be paid for, and IGBP is not itself a funding agency able to commission the work that needs to be done. Thus, information is needed on the status and ambitions of IGBP by those who have the difficult task of deciding whether research within the IGBP framework is money well-spent, in the face of many competing demands. This workplan has also been requested by the International Group of Funding Agencies (IGFA) for global change research and provides an important input for their analysis of funding needs for global change research.

There are three levels of funding needs: (i) support for the programmatic planning and coordination, primarily carried out by the SC-IGBP assisted by its Secretariat; (ii) project-wide planning and coordination led by the IGBP Scientific Steering Committees (SSC), Standing Committees and Task Force, with an essential role played by the CPOs; and (iii) funding for the research that constitutes the programme. Without the first two levels, IGBP would be little more than a loose assemblage of uncoordinated national projects, without comprehensive global integration and with little possibility of achieving a predictive understanding of the important interactive processes that regulate the global system and how anthropogenic processes will affect the future of the Earth. Increased multinational funding is necessary at the programme level, while nations supporting CPOs should sustain, and in several instances be encouraged to increase, their support for CPOs.

In this Report, the work plans for the next two to three years ahead are relatively well-defined, and regarded as realistic, as the necessary funding has, in most cases, already been committed. The statements made regarding the scientific outputs over the full five years are more speculative; they assume increased level of support as outlined in the resource assessment carried out by IGFA. Whilst additional resources would allow the planned work to be done within each Core Project, accelerating the overall progress of the programme, the converse is also true; any reduction in support would make it impossible to reach the stated objectives, at either the project or programme level. The sums involved for the full implementation of the IGBP research agenda in 1994 - 98 are not unrealistically large, and, on a global scale, do not necessarily require significant amounts of "new money" to be added to the existing budgets of funding agencies. Such resources could also be found by some re-direction of funding within the general area of global change research. Those involved in research support are aware that good ideas, careful planning and focused effort by enthusiastic scientists are the ingredients for success at all levels. At the international level, the IGBP is providing, and will continue to provide, these qualities.

PART I

PROGRAMME COORDINATION AND INTEGRATION

Introduction

For Earth system research - the study of global-scale interactions that determine the habitability of our planet - national and international collaboration between research groups is not merely desirable, it is essential. There are three reasons for this: firstly, such research encompasses many different disciplines, such as atmospheric chemistry and physics, oceanography, geology, terrestrial ecology, soil science, hydrology, and social science. The need for new working links among them, and the pooling of intellectual resources, transcends the existing structures for scientific contacts, based on those traditional fields. Secondly, no single group can collect the many datasets that are needed for global scale analyses; agreement has to be reached on sharing responsibilities for studies at different locations, and, as far as possible, common methodologies to ensure the inter-comparability of results. Thirdly, there is an urgency to such work, set by the political implications of increasing environmental degradation and concern for sustainable development. Ecologically and economically significant changes in soil, water and air quality have already occurred on a global scale. With an increasing human population, these are bound to be accentuated. Changes in climate occur, now not only as a result of natural variability but probably also because of human-induced changes in atmospheric composition.

IGBP was established in 1986 by the International Council of Scientific Unions (ICSU) to address these challenges of global change, recognising that the complexity and importance of this topic required an international approach, with emphasis on a soundly-based framework for research planning, implementation and synthesis. The objective of IGBP is:

> "To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activities."

This overall aim encompasses a very wide spectrum of research activities. To provide coherence, effort is focused on the processes that affect global change on the decade to century time-scale, that are most susceptible to human perturbations, and that will most likely lead to practical, predictive capability. Emphasis on those features helped in the identification of initial priorities within the programme, and in the setting of realistic goals. The results of IGBP research are of very great importance to the IPCC, thus providing scientific underpinning to the political process, for example, through the Framework Convention on Climate Change (FCCC) following the United Nations Conference on Environment and Development (UNCED).

The initial task of the IGBP was to define critical gaps in our understanding of global biogeochemical cycles and life support processes, so that future research effort could be focused. The initial priorities were outlined in IGBP Report 4 (1988). Further review

and planning, carried out by the international scientific community, resulted in the formulation of six key research questions (IGBP Report 12, 1990); each is now addressed by an established Core Project, with an operational duration of about a decade:

- How is the chemistry of the global atmosphere regulated, and what is the role of biological processes in producing and consuming trace gases? (International Global Atmospheric Chemistry project, IGAC). Priority issues: Chemical transformations, and biospheric sources and sinks (marine and terrestrial), of atmospheric constituents that have a role in controlling the global system, especially radiatively active trace gases, aerosols and reactive radicals.

- How will global changes affect terrestrial ecosystems? (Global Change and Terrestrial Ecosystems, GCTE). Priority issues: Responses of natural and managed ecosystems to changes in climate, atmospheric composition and land use, with emphasis on both impacts and feedback processes, investigated experimentally and through the development of dynamic vegetation models; the role of ecological complexity in the functioning of the global system.

- How does vegetation interact with the physical processes of the hydrological cycle? (Biospheric Aspects of the Hydrological Cycle, BAHC). Priority issues: The effect of land surface properties (soil, vegetation and topography) on water, carbon and energy fluxes; temporal and spatial integration of those processes, including improved modelling of complex landscapes; the down-scaling of climate information obtained from general circulation models.

- How will changes in land-use, sea-level rise and climate alter coastal ecosystems, and what are the wider consequences? (Land-Ocean Interactions in the Coastal Zone, LOICZ). Priority issues: The effects of changes in external forcing on coastal fluxes; coastal biogeomorphology and sea level rise; carbon fluxes and trace gas emissions; economic and social impacts of global change on coastal systems.

- How do ocean biogeochemical processes influence and respond to climate change? (Joint Global Ocean Flux Study, JGOFS). Priority issues: Processes controlling the fluxes of carbon and associated biogenic elements within the ocean, and their exchanges with the atmosphere, sea floor and continental boundaries; interpretation and application of remotely-sensed ocean colour data.

- What significant climatic and environmental changes occurred in the past, and what were their causes? (Past Global Changes, PAGES). Priority issues: High resolution reconstruction, at the global scale, of the changes occurring in the past 2000 years; investigations of the more radical re-organizations of the global system during the most recent glacial/interglacial cycles.

Two other Core Projects are being developed for possible acceptance: Land Use/Cover Change (LUCC), and at an earlier stage of planning, the Global Ocean Euphotic Zone Study (GOEZS).

In addition, three activities of an over-arching and integrative nature are now operational:

- A Task Force on Global Analysis, Interpretation and Modelling (GAIM), with responsibility for promoting the development, evaluation and application of comprehensive prognostic models of the global biogeochemical system, and subsequently linking such models to those of the physical climate system.

- The IGBP Data and Information System (IGBP-DIS), with responsibility for assisting Core Projects in meeting their data acquisition and data management needs; also facilitating collaboration with the space agencies, other data-producing bodies, and international data centres.

- The Global Change System for Analysis, Research and Training (START), that promotes regional capacity building in global change science, and the establishment of networks for regionally-based research and analysis relevant to the origins and impacts of global environmental change.

Throughout the development of IGBP, there has been close collaboration with other relevant ICSU activities and with its two companion global change programmes, WCRP and HDP. These programmes are directed at the physical and societal aspects of global change, respectively, complementing IGBP research in many areas; the three programmes together comprise the main international global change research effort now in operation. Very many formal and informal links have been developed between these programmes and with other bodies. For example: START is jointly sponsored by all three programmes; LUCC is a joint initiative of IGBP and HDP; in addition to their IGBP support, JGOFS is cosponsored by the Scientific Committee on Oceanic Research (SCOR) and IGAC by the International Commission on Atmospheric Chemistry and Global Pollution (ICACGP), both ICSU bodies; and BAHC is strongly linked to the WCRP project Global Energy and Water Cycle Experiment (GEWEX). The initial planning of GOEZS is under the cosponsorship of IGBP, SCOR and WCRP.

Separate publications provide details of the science plans and implementation strategies of the components of IGBP, with an overview given by *Global Change: Reducing Uncertainties*. The purpose of the present document is not only to present a summary of operational plans and anticipated research products for the five year period 1994 - 98, when all established Core Projects will be fully active, but also to demonstrate their interdependence and overall coherence. Now that research is underway, greater emphasis needs to be given to coordination, time-scheduling and data management, and to ensuring that the necessary resources are secured for the core research that is essential for the attainment of the programme's long-term, global goals.

IGBP research, primarily funded at the national level, involves several thousand scientists in over sixty countries. The international guidance for their work is provided by the SC-IGBP and its Secretariat, primarily acting through the SSCs, Standing Committees and CPOs of the programme's component projects. This organizational structure has a catalytic role, and is closely involved in the interpretation, synthesis,

assessment and communication of results. Its activities are as much "scientific" as the field or laboratory investigations themselves, and the required central expenditure in 1995 is estimated to be less than 0.5% of the IGBP research costs in that year (see Table 1).

The importance of the IGBP initiative and its achievements to date have been widely acknowledged and formally recognised at both the governmental and intergovernmental level. Its main work phase, with all established Core Projects operational, is just beginning. However, existing support is inadequate for full implementation. For that to be achieved, there must now be a long-term commitment to support both the research and its international infrastructure. Underfunding of either component would seriously jeopardize the success of the programme.

Table 1. **The annual cost of IGBP and relevant global change research, and its coordination** (based on data from the IGBP and the IGFA 1993 Resource Assessment)

	million US$
1992	
Total expenditure on national research; considered to be relevant to IGBP (Contributory + Focused Studies, as defined by IGFA)	637
Total expenditure on national research considered to be a direct contribution to IGBP (Focused Studies)	102
Expenditure on international scientific coordination and integration of IGBP, costs for individual Core Projects and Framework Activities	3.8
Expenditure on international scientific coordination and integration of IGBP central costs (1992 costs for items listed below)	1.1
1995 onwards	
Estimated support needed for full implementation of all IGBP Core Projects and activities. Focused Studies, including estimates for GAIM, LOICZ, START and LUCC not included in the IGFA survey)	558
Budget needed for full operation of IGBP international scientific coordination costs for individual Core Projects and Framework Activities	6.8
Budget needed for full operation of IGBP international scientific coordination and integration, central costs	2.7
SC-IGBP, SAC, officers meetings and travel	
Scientific and Standing Committee meetings	0.27
Inter-Core Project integration	0.51
Intra-Core Project integration	0.22
Participation of scientists from developing countries and countries with economies in transition	0.43
Reports and Newsletter	0.25
Scientific staff	
Administrative staff	0.12
Other administrative costs	0.35
	0.15
	0.45

Programme-Wide Products

Since the purpose of IGBP research is to provide new knowledge, it is unrealistic to try to forecast in detail the specific scientific products of the programme in five years time. Nevertheless, it is possible - and desirable - to set goals, and define deliverable milestones, against which progress can be assessed. Whilst the precise outcome of the research is unpredictable, those responsible for funding the research need to know what general insights can be expected if support is provided at the level considered necessary for the implementation of the Core Project science plans.

In Part II of this document, the objectives and operational plans of the components of IGBP are summarised, together with their anticipated products. Here examples are given of the programme-wide output of IGBP, involving the combined effort of several Core Projects and other IGBP activities. Ultimately it will be on the basis of such integrations that the overall success of IGBP will be judged, with the "added value" of the programme arising from the achievements of the whole being greater than the sum of its component parts.

Inputs to Improved Global Change Predictions

All IGBP Core Projects will contribute individually to our understanding of important global change processes, and hence to model-based predictions of the behaviour of key features of the Earth system. Collectively, their potential is greatly enhanced, as models can be constrained by the mass continuity in biogeochemical cycles and of energy balance. However, additional problems are introduced as a result of the greatly increased complexity of the fully-global approach, with simplifications needed in any attempt to dynamically link subcomponent models. Therefore it is not the aim of IGBP to produce a single, all-embracing global model that includes all known interactions between the very large number of biological, chemical and physical processes operating over the full spectrum of time and space scales. Instead, a suite of models, with varying complexity and realism, is being developed and employed, to attack specific questions. This approach enables the predictive characteristics of the models to be tested, against a variety of data sets, especially those generated for that purpose by the Core Projects.

Critical areas where IGBP-wide modelling effort will in the next five years improve our ability to predict global change, include the following:

The global carbon cycle

Human activities have greatly increased the atmospheric concentrations of carbon dioxide (CO_2) and methane (CH_4) with implications for the Earth's radiation budget. Prediction of future changes in the atmospheric concentrations of these trace gases necessitates an understanding of the global carbon cycle. Considerable theoretical and experimental progress has already been made to reduce uncertainties in the magnitude of the oceanic carbon sink: in 1990, estimates covered the range of 0.3 - 3.0 gigatonnes (Gt; 10^{15}g) of carbon per year, more recent estimates (based in part on new JGOFS data) have converged on a value of around 2.0±0.5 Gt per year. Since mass balance estimates indicate that at least twice that quantity is being removed from the atmosphere, there must be a substantial net uptake of carbon by terrestrial systems. However, these systems have yet to be definitely identified, and many unresolved questions remain regarding the dynamic processes involved in marine and terrestrial carbon fluxes and their future behaviour. Interactions between climate variability and change, the strength of natural carbon sources and sinks, and human activities are of key importance to the development of realistic and reliable climate change predictions, required for policy-making; consequently, that topic provides one of the main thrusts for concerted, programme-wide research within IGBP. Ongoing work includes studies of: (i) the release, uptake and atmospheric lifetime of CH_4 in IGAC; (ii) past variability of atmospheric composition in PAGES; (iii) the biological carbon pump, air-sea exchanges, and other aspects of the ocean carbon cycle in JGOFS; (iv) the response of natural and managed terrestrial ecosystems to raised CO_2, the role of terrestrial vegetation for carbon storage and the effects of climate change feedbacks on these processes, in GCTE; (v) CO_2 flux studies from terrestrial ecosystems in BAHC; and (vi) the land-sea transfer of carbon, and coastal carbon storage processes, in LOICZ. In addition, it is proposed that LUCC will investigate the effects of land-use change on carbon uptake, storage and release, and the initial modelling components of GAIM are investigating the behaviour of the global carbon cycle under current conditions, over the past 200 years, and over selected palaeo time frames.

Characterization of land surface properties

At present the interactions between climate, vegetation, soils, and the fluxes of energy, water and trace gases are poorly understood, and are not adequately represented in the general circulation models used for simulating future climate change. Ongoing experimental work within BAHC, GCTE and IGAC (in many cases carried out collaboratively at the same sites) will quantify the most significant physical, biogeochemical and physiological processes occurring at the land surface, and, through modelling, will explore their global importance. A joint IGBP-WCRP Working Group on land-surface experiments ensures the complementarity of IGBP studies with the WCRP Global Energy and Water Cycle Experiment (GEWEX). The two-way coupling between climate and vegetation will also be investigated by GAIM in collaboration with PAGES, testing our understanding by deriving vegetation patterns for 6,000 BP - when there were known to be different patterns of temperature and precipitation - and comparing the results to palaeo-vegetation records (mostly from pollen analyses).

Human influences driving global change

For at least the next 10-20 years, land-use change is likely to continue to be much more important than climate change in altering the global environment. The proposed LUCC project, expected to be operational by 1995, will focus attention on the human activities that directly affect attributes of land cover, and their underlying driving forces (population, level of affluence, technology, political economy, political structure, and attitudes and values). Models will be developed to investigate the operation of these factors in a variety of different environmental, historical and social contexts - and their implications for biogeochemistry, ecological complexity and other aspects of global change. Close collaborations are expected to be developed with GCTE (with regard to its functional classification of vegetation types, and interests in global change impacts on agriculture and forestry); with LOICZ (with regard to the effect of different land-use patterns on catchment basin dynamics and delivery, and changes of land use/cover in the coastal zone); and with PAGES (with regard to the possible role of pre-industrial land use changes on regional and global climate).

Contributions to Global Observing Systems

Comprehensive global observations are essential complements to the research programmes in improving our understanding of the Earth system. Such measurement systems will provide the means to monitor and detect the many facets of global change, and provide the global data sets of long-time duration necessary for model calibration, validation and further development. Current operational observation systems (e.g., the World Weather Watch and Global Atmosphere Watch) do not fully meet this need, since they were designed for much more limited purposes.

Three closely-linked global observational systems have been proposed to provide integrated, multi-scale monitoring of global change: the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). The concept and scope of these systems are currently being formulated by ICSU in partnership with World Meteorological Organization (WMO), United Nations Environment Programme (UNEP) and Intergovernmental Oceanographic Commission/United Nations Educational, Scientific and Cultural Organization (IOC/UNESCO) (GCOS), WMO and IOC/UNESCO (GOOS), and with UNESCO, WMO, UNEP and the Food and Agriculture Organization (FAO) (GTOS), building primarily on existing operational and research activities. Whilst their operational nature distinguishes them from the research programmes, IGBP must play a significant role in developing their scientific specifications and strategy-for-use, and contributing to calibration, validation and other aspects of quality control. Examples of relevant actions include: (i) GCTE assistance to GTOS in defining core measurements and field sites, with the latter covering both natural and managed habitats over a wide range of climatic regimes; (ii) involvement in algorithm development for remote-sensing satellites; (iii) the assembly of experimental global data sets (such as the IGBP-DIS 1 km Advanced Very High Resolution Radiometer (AVHRR) data set, to become part of the shared land surface component of GCOS and GTOS); and (iv) the provision of advice

regarding appropriate chemical, biological and optical measurements within the oceanic component of GCOS and the climate module of GOOS, based on techniques developed through JGOFS, particularly its time series studies.

Each of the global observation systems will need to develop procedures for efficient data management. IGBP is assisting in that exercise, to ensure that the data sets help to meet the needs of, and are accessible to, the research community. For satellite data, there are already close working links between IGBP-DIS and the Committee for Earth Observation Satellites (CEOS) with which IGBP has Affiliate status. These links will be further developed, thereby assisting in the identification, prioritization and use of environmental datasets relevant to global change research. In addition, the regional collaboration through START will provide a mechanism for both compilation of existing data and a structure for continuous monitoring of key variables.

Capacity Building

So far, there has been only limited participation by scientists in developing countries with regard to international efforts dealing with climate variability and other aspects of global change. Yet their involvement is critical for an effective global scale approach to these problems, as stressed both in a UN General Assembly resolution (44/207, 1989) and by the Special Committee on the Participation of Developing Countries of the IPCC. This need is specifically addressed by the global change START of the IGBP, HDP and WCRP. START has initiated a process that will in the short term provide direct assistance to the science community to narrow current uncertainties pertaining to global change, and through stimulating global change research and assessment provide necessary information also to governmental ministries and agencies involved in current negotiations arising from UNCED. In the long-run, START will lead to substantial capacity building, through the provision of training and education to the next generation of scientists in all countries, with special attention given to the needs of developing nations.

START will involve the scientific communities within a region by: (i) Increasing their awareness of the importance of global change issues; (ii) training them in the multidisciplinary work necessary to implement global change projects; (iii) helping them to formulate appropriate projects to be carried out in regional or international collaboration; (iv) assisting them in obtaining adequate technical support to carry out regional interpretation, analysis and modelling through techniques such as remote sensing and the use of Geographic Information Systems; (v) promoting collaboration between natural and social scientists on regionally relevant problems; (vi) providing them with the capability to access and manage appropriate regional data bases, and initiate the establishment of required data bases that are not yet available; and (vii) promoting a dialogue between the scientific community and decision makers, at both national and regional levels.

Beneficiaries will also be national governments in the form of Ministries for Environment, Science and Education, Planning and Foreign Affairs, i.e., all those sectors

involved in the international negotiations following UNCED, and the development of national responses to associated international agreements. In addition, START provides a mechanism that could be of great value for ministries or agencies for development cooperation, which have an interest in capacity building in environmental field in developing countries in relation to environmental issues of regional and global importance.

Assessment Studies

The objectives and priorities of IGBP imply programmatic responsibilities relating to the assessment of global environmental change. Each Core Project is responsible for an ongoing assessment of scientific understanding in its field; in addition, GAIM has responsibility for providing collective oversight within the programme and carrying out integrative studies. The output from these various assessment activities will be published, and examples of major reviews planned for the period 1994 - 1998 are given in Part II of this report.

In addition, many IGBP scientists are closely involved in the Science and Impacts Assessments of the IPCC. IPCC is a reviewing, not a research, body, and therefore is highly dependent on in-depth inputs from international programmes - particularly WCRP and IGBP. For the 1994 IPCC Report on Radiative Forcing of Climate (Working Group 1), IGBP researchers are contributing to the reviews of the carbon cycle, other trace gases and atmospheric chemistry, aerosols, radiative forcing, and the relative importance of emissions of different greenhouse gases. The 1995 IPCC Scientific Assessment will be based on this material, with additional coverage of climate processes; observed climate variability and change; model predictions and validations; sea level rise; biotic responses to climate change and feedbacks to climate; and reducing uncertainties. IGBP scientists will contribute to most of these chapters and IGBP and WCRP, through their chairmen, will be jointly responsible for the final chapter in the Working Group 1 assessment, addressing the need for further research to reduce the uncertainties. Whilst the 1990 IPCC Scientific Assessment strongly emphasised the physical components of the climate system, the 1995 Assessment provides the opportunity for greater attention to be given to the biospheric control of atmospheric composition, feedback interactions with marine and terrestrial ecosystems, and the insights provided by palaeoclimate studies.

Mitigation of Global Environmental Changes

IGBP research is not primarily directed towards the development of mitigation responses to counteract natural and man-made environmental change. Such work is more appropriate to engineers and agriculturalists, among others. Nevertheless, the results of IGBP will undoubtedly play a significant role in the assessment of mitigation strategies - by providing the scientific underpinning that is needed, both for deciding whether a particular strategy is likely to be successful or not, and for evaluating its wider environmental consequences.

Thus IGBP studies (potential or already ongoing) may assist in evaluating various proposals for mitigation and/or amelioration strategies such as the disposal of fossil fuel CO_2 in the oceans; the enhancement of oceanic uptake of CO_2 via iron fertilization; the addition of chemicals to the upper atmosphere to reduce ozone depletion; the control of coastal erosion and the movement of littoral sediments arising from sea level rise and coastal subsidence; the diversion of rivers and creation of large freshwater reservoirs for climate control and water supply purposes; the sequestration of additional CO_2 by reforestation and afforestation; and the decrease of methane emissions from rice paddies by changing cultivation practices.

However, in most, if not all, of these examples, our current understanding of the basic science can only provide a very crude estimate of the likely effectiveness and environmental consequences of the proposed action. In some cases it is arguable whether any of the anticipated benefits will be realised, and many unknown risks of undesirable "side effects" remain. As scientific understanding improves within the next five years, IGBP will increasingly be able to provide the knowledge base on which the environmental (and economic) costs and benefits of such proposals can be assessed.

Programme Coordination and Review

Components of the IGBP Organizational Structure

The *Scientific Committee for the IGBP (SC-IGBP)* consists of members appointed by ICSU, plus all Chairs of IGBP SSCs, Standing Committees and Task Forces. The Chairs of the WCRP Joint Scientific Committee and the HDP Committee also serve on the SC-IGBP as *ex officio* members, together with a representative of the ICSU Advisory Committee on the Environment (ACE). The current membership of the SC-IGBP is given in Part III. The SC-IGBP was initially established in 1990 to follow on the work of the Special Committee for the IGBP. The responsibilities of the SC-IGBP are to develop and prioritize the programme as a whole, guide its implementation and publicize its results. The SC-IGBP ensures overall integration within the programme, administers the central budget, develops collaborative links with WCRP and HDP, and is responsible for liaison with ICSU and other organizations.

The *IGBP Secretariat* is responsible for carrying out the decisions of the Scientific Committee. It serves as the focus for planning and coordination, assisting Core Projects in their work and ensuring the development of a common IGBP philosophy, necessary for the programme-wide integration of results. It also is responsible for publishing IGBP Reports, the Global Change Newsletter and other central publications. The Secretariat is located at the Royal Swedish Academy of Sciences in Stockholm.

The detailed planning and implementation of each Core Project is directed by a *Scientific Steering Committee (SSC)*, appointed by the SC-IGBP. In addition, *Standing Committees* have been established for IGBP-DIS and START, and GAIM is led by a *Task Force.*

Core Project Offices have been established to assist the SSCs and SCs with their international communication and coordination responsibilities (see Part III).

The *IGBP Scientific Advisory Council (SAC)* advises on the scientific content of the programme, assesses its results and makes recommendations for the general policies of the SC. It meets every 2 - 3 years and is composed of representatives of National IGBP Committees (NC) and liaison persons with other ICSU scientific members, under the Chairmanship of the ICSU President. Representatives of other organizations involved in global change research also attend.

IGBP National Committees (NCs) provide the formal interface between researchers in participating countries and the international structure. They are also expected to assist with national planning and coordination; to contribute to the conceptual and practical development of IGBP as a whole; and to arrange the payment of the national contribution towards the central costs of the programme. At the end of 1993 there were 69 National Committees (Part III).

Liaison persons are appointed by ICSU scientific members interested in the work of the IGBP. Such persons play a vital role in the development of joint activities and for information exchange (Part III).

Defining IGBP Research

A three-category classification scheme of IGBP research has been developed to facilitate the process of definition and recognition of its component studies. The three categories and their main features are as follows: *Core Research* directly addresses the Science Plan goals of IGBP projects, being part of their formal structure and coordinated by the relevant SSC; *Regional/National Research* is closely linked to Science Plan objectives (but may have other overall aims), and is coordinated at a national or regional level; whilst *Relevant Research* makes an indirect contribution to the project, without formal affiliation. Further details of this classification are given in Table 2.

Even with these criteria, the classification of national projects may not always be clear-cut. Furthermore, the category allocation of a research activity may change according to its own development and the evolving priorities of the IGBP Core Projects. Since such changes are unavoidable, it should be noted that the categories are not based on scientific merit *per se*; they relate to research objectives, implementation procedures, and the practicalities of dividing coordination responsibilities between the different levels of Core Project structure. Core Research is expected to be of very high scientific quality; however, work of equally high scientific importance can also be found in the other categories.

For this conceptual structure to be functionally useful, the Core Project SSCs must be kept fully informed about the "IGBP research" being planned and carried out in their specific subject areas, and decide on what should be included as Core Research. In addition, the NCs must be aware of research at the Regional/National level (with the involvement of regional START Committees, where appropriate).

The procedures for category allocation are as follows:

- The NCs have responsibility for assembling descriptions of national projects, planned or underway, that they consider to be within the Core and Regional/National categories. The information needs to be more than just the project title; its relationship to Core Project objectives must be made clear. A format for project descriptions already exists for GCTE, and similar guidance will be made available by the other Core Projects. To assist in this information-gathering exercise, NCs are encouraged to set up Working Groups or sub-Committees matching the Core Projects that are of greatest national interest.

- The NCs submit descriptions of projects considered to be within the Core Research category to the SSCs, via the relevant CPO; preferably as a packaged national contribution to each project. Following the review of such material by the SSCs, formal recognition of its category status, or other feedback, will be

provided. In cases where the NCs are unable to carry out preliminary assessments, research groups may need to make their submissions directly to the SSCs/CPOs.

- The SSCs will use the information on Core Research to guide the further development of their projects, encouraging collaborations, and, where necessary, taking action to attract effort and resources to "neglected" areas.

Following the category-allocation exercise, information on the component studies of each Core Project will be published. NCs are also encouraged to publish national compendia of information on projects that could combine a listing of studies within both Core and Regional/National categories. Information on Relevant Research may also be included, but its different status should be indicated.

Benefits of Participation in IGBP Research

The IGBP Core Projects and other programme activities benefit component national studies and individual researchers in many ways. The most important overall effect is to maximise scientific progress, at minimum extra cost. Thus a coherent international framework provides "added value" by increasing the productivity of the national effort. The way in which this is achieved varies according to the scientific development within a country, and the particular area of study. General benefits are that IGBP:

- Assists the planning of national global change research programmes by providing a soundly-based intellectual and organizational framework for focused research, with overall aims, priorities and implementation developed and endorsed by the international science community

- Adds to the scientific value of component studies, and helps in their interpretation, by providing complementary information; for example, by widening the range of studies, extending their temporal and spatial coverage, and, through inter-comparison exercises, testing models and improving their predictive power

- Promotes the rapid communication of scientific ideas and results at the frontiers of knowledge, through meetings and publications, and by encouraging interdisciplinary liaison at the national, regional and international level between individuals and research groups

- Develops, and tests the applicability of, standard methods and protocols for measuring key environmental variables, thereby facilitating national and international quality control, intercalibration studies, and subsequent data exchange, synthesis and interpretation

- Assists in the cost-effective deployment of major capital equipment and facilities, by encouraging their collaborative use and efficient scheduling, and promoting the international transfer of technological expertise

- Makes available the data sets collected by its component projects and studies, and assists in developing common data management strategies, in liaison with national and international data centres

- Encourages the full involvement of developing countries, and those with economies in transition, in global change research by promoting the establishment of regional research networks, capacity building through training, and by providing, wherever possible, financial assistance for developing country participation in major IGBP meetings

- Keeps the research community informed of developments within the programme through IGBP Reports, the Global Change Newsletter and other publications

- Ensures that close working links are developed with other relevant international programmes and projects, particularly those of the WCRP and the HDP, and with international assessment exercises, such as those of the IPCC

- Provides the scientific understanding needed for the development and implementation of international conventions and protocols addressing the global environment

- Promotes the concept of IGBP science, the results obtained from the programme, and their application, to decision-makers, funding agencies and inter-governmental organizations, thereby indirectly assisting in the further financial support of its component studies.

Evaluation and Review

In addition to the internal mechanisms for progress assessment, the SC-IGBP is currently developing plans for an external evaluation of the programme to be carried out in 1994 - 95, in cooperation with ICSU and IGFA. The evaluation will provide an independent assessment of the scientific results and the overall effectiveness of the programme. The review will be essential for an internal re-assessment by the SC-IGBP of its priorities and modes of action. It should also provide a solid basis for ensuring continued and adequate financial support for both the research projects and coordination functions.

Table 2. Characteristics of the Categories for IGBP Research

Aspect:	Core Research	Regional/National Research	Relevant Research
Overall research aims	Addresses global-scale objectives, matching IGBP Core Project science plan	Addresses regional or national priorities, closely linked to Core Project science plan	Research objectives include aspects relevant to the IGBP science agenda
Methodologies	Follows internationally agreed methods (may need to be developed by the SSC)	Standard sampling and experimental procedures highly desirable; proper documentation required	Procedures employed to be properly documented (new methods may be developed)
Data management and data access	Follows Core Project data protocols; international data access (e.g., in World Data Centres)	Core Project protocols desirable; national or regional data centres used for archiving, with data available on request	Data archival strongly encouraged
Planning	Planned at international level by the Core Project SSC (but may be initially developed at national/regional level)	Planned at the regional or national level, by a committee or collaborating institutes	Planning may be at the level of a single institute, research group or individual scientist
Approval, coordination and progress review	Responsibility of the Core Project SSC, based on project descriptions and reports	Responsibility of the relevant National Committee(s), in liaison with SSC (and START for regional work)	No requirement for formal approval or progress review; however liaison with National Committee is highly desirable
Collaborations	At international level	At regional or national level	Collaboration with other research groups encouraged
IGBP acknowledgement in publications	Considered essential	Considered desirable	Probably not appropriate

Budget

Implementation of the work plan of the IGBP requires financial support at different levels.

IGBP research is predominantly achieved through nationally funded projects. By 1995, the total resource requirement for IGBP research is estimated to be around US $ 560 million. Funding agencies can meet these requirements by taking account of the IGBP science priorities in formulating national plans for global change research, and in determining the funding level of these programmes. They should also ensure that the national effort is closely integrated in the international framework of the IGBP. Such an approach not only accelerates scientific progress, but it is also nationally cost effective through economies of scale (by sharing tasks and the collaborative use of facilities). The strong international framework provided by the IGBP thereby gives added value to national research efforts, through the programme's scientific coherence and by the integration of its component projects. The importance of these benefits has been recognised by the Organization for Economic Cooperation and Development (OECD; Mega Science Forum on Global Change, 1993) and by the Intergovernmental Meeting on the World Climate Programme (Geneva, April 1993).

The costs of the international functions of IGBP are met in two main ways. Firstly, the Core Project Offices (and equivalent Standing Committee Offices) are directly funded by one or more countries, with the main contribution usually provided by the host nation. Typically the requirement for a CPO is around US $ 600,000 per annum.

Secondly, countries participating in the programme are requested to contribute to the cost of central scientific coordination and integration activities. For 1995, such costs are estimated to be US $ 2.7 million per year, with a subsequent 5% per year increase due to inflation.

It is expected that countries with National IGBP Committees will pay their annual contributions at least at the rates agreed at the meeting of NC-IGBP representatives in January 1991 in London. Those rates were subsequently endorsed by SAC III in Ensenada, Mexico, in January 1993. The total income generated this way in 1995 is budgeted at US $ 1.5 million. ICSU contributes to the programme with a yearly amount that is currently US $ 120,000 and that is hoped to be US $ 150,000 by 1995. In addition, the IGBP will continue efforts to attract funding from other sources, including the private sector, UNEP, UNDP and the European Commission.

These estimates leave a shortfall of US $ 1 million with regard to central costs, for which the IGBP is seeking donor support from the funding agencies represented in IGFA. The IGBP seeks this support for an initial period of five years, with a firm commitment for the first three years (1994 - 96) and an indicative commitment for the final years (1997 - 98). It is proposed to have a review after three years, followed by a decision for a further five year period.

PART II

WORKPLANS FOR THE CORE PROJECTS AND FRAMEWORK ACTIVITIES

1994 - 1998

Biospheric Aspects of the Hydrological Cycle (BAHC)

Introduction

Interactions between the hydrological cycle, the biosphere, and the physical climate system involve a large number of processes that operate over a continuous range of spatial and temporal scales. With processes ranging from stomatal regulation of evapotranspiration to continental-scale hydrologic discharge, with spatial scales ranging from that of a single plant to the entire globe, and with temporal scales ranging from minutes for General Circulation Models (GCMs) to centuries or millennia for climate related vegetation changes, the challenges in this area stretch the traditional boundaries of scientific disciplines. Understanding interactions across this range of process and scale requires that hydrologists, atmospheric scientists, and ecologists reach beyond the traditional boundaries of their separate disciplines.

The BAHC Core Project was established to study the role of vegetation in the hydrological interactions between the land surfaces and the atmosphere. Collaboration in the design and implementation of land-surface experiments will also be sought with, e.g., IGAC, GCTE and the Global Energy and Water Cycle Experiment - the International Satellite Land Surface Climatology Project (GEWEX-ISLSCP). In cooperation with HWCRP, BAHC coordinates a number of land-surface projects from the scale of patches to that of a global overview in units of 10^5 - 10^6 km^2 with guidance provided by the joint IGBP/WCRP Working Group and Land-Surface Experiments. A BAHC-IGAC-GCTE Task Team is also addressing questions of common field experiments between the three Core Projects.

Objectives

- Determine the biospheric controls of the hydrologic cycle through field measurements for the purpose of developing models of energy and water fluxes in the soil-vegetation-atmosphere system at temporal and spatial scales ranging from vegetation patches to GCM grid cells.

- Develop appropriate data bases that can be used to describe the interactions between the biosphere and the physical Earth system, and to test or validate model simulations of such interactions.

Organization of Research

The BAHC scientific and operational plans identify four Foci, which address processes occurring at similar scales of space and time (Fig. 1).

Focus 1 is oriented to patch-scale processes. Its main objective is to investigate the vertical exchange of energy, moisture and carbon dioxide at the soil-vegetation-atmosphere interface and its dependence on soil and vegetation characteristics as well as climatological, hydrological, and other related parameters. At this scale numerous investigations are conducted, and a number of Soil-Vegetation-Atmosphere Transfer models (SVATs) are available. Among the important tasks remaining are the validation of these models, the determination of their accuracy and the reduction of independent parameters so that their formulations may be used in global models without reducing the accuracy of the more detailed SVAT codes presently available.

Focus 2 extends the investigations under Focus 1 into four dimensions. It is oriented toward experiments in different regions, and takes into account the role of heterogeneity in land use, vegetation type, as well as soil, hydrological and other conditions. It includes the effect of topography and lateral surface and subsurface water flow and the development of such flow up to a spatial scale of 10^4 - 10^5 km^2.

Focus 3 is oriented towards the assessment of the temporal and spatial variability of biosphere-hydrosphere interactions at land surfaces. It aims to assess regional data on changes in the status and behaviour of the biosphere and water resources due to global changes (e.g., climate change, direct human impacts) and changes in land use and the resulting feedbacks to the hydrological cycle and climate.

Focus 4 is developing suitable procedures, aggregated models and algorithms to provide regional climatic variables, with emphasis on precipitation patterns and extreme events, using large-scale information such as assimilated observations or simulations from GCMs.

Work Plan

Surface-vegetation-atmosphere processes at the local scale

SVAT models are central tools for the mathematical representation of the interconnected processes controlling energy, water, and carbon dioxide transfer between soils, vegetation, and the atmosphere. The overall goal of BAHC Focus 1 is the development, testing, and validation of a suite of SVAT models for global biospheric research. The spatial domain of Focus 1 is that of the plot or patch (micro-scale), where a patch is understood to be a homogeneous (uniform) land-surface area.

Numerous SVAT models differing in degree of complexity have already been developed and applied. All these schemes represent approximations of reality and include simplifications of the real processes and of their dependence on the various influencing

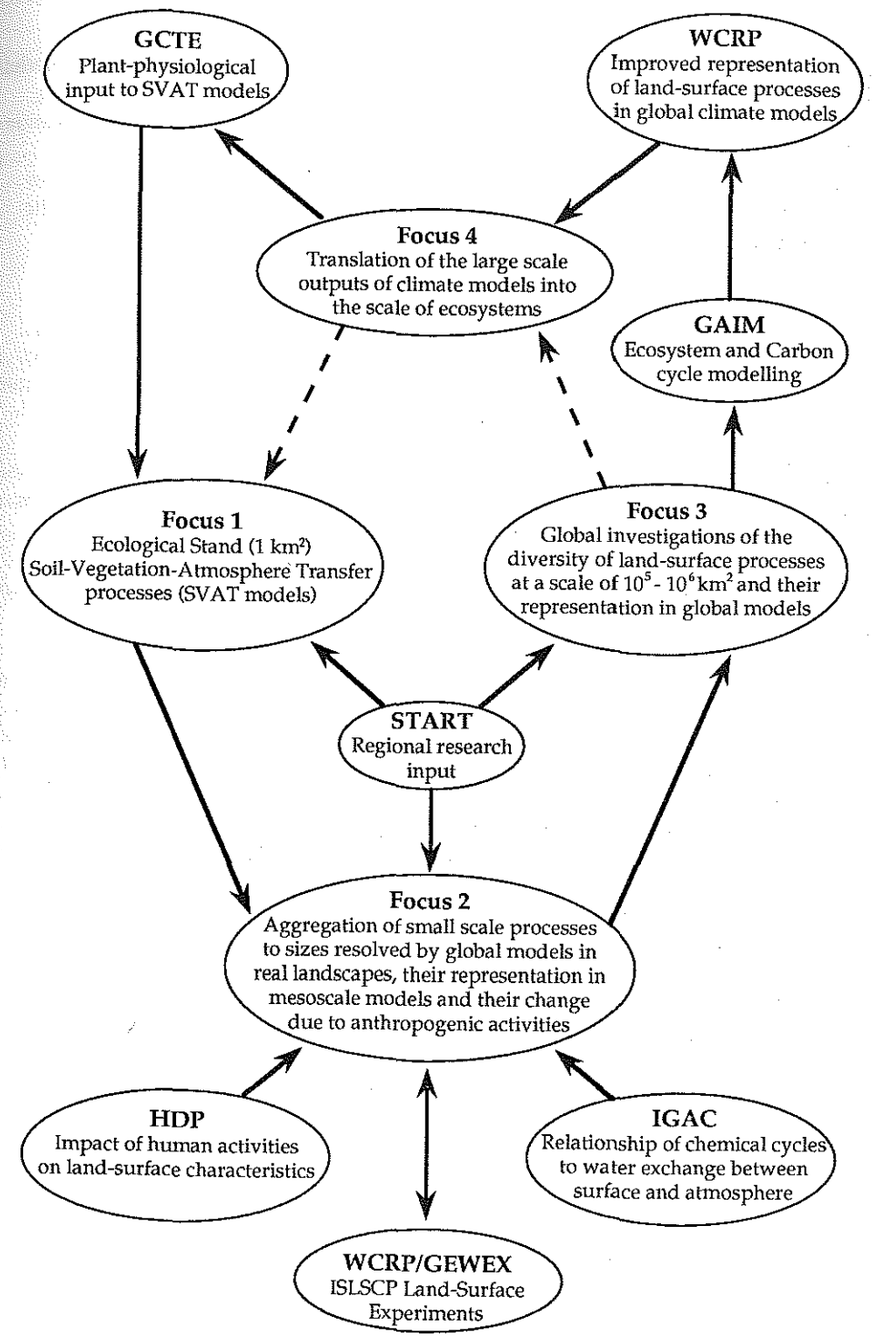


Figure 1. BAHC research in relation to other research activities

characteristics. A first aim of Focus 1 is to compare and evaluate existing SVAT models against selected data sets from well-investigated test sites. Improved SVAT models, which will emerge from these validations, should be available for universal application. Relevant land-surface properties, namely soil, vegetation, and climatological, hydrological, and biogeochemical factors are parameters used for SVAT models. For use in global models these SVAT models have to be simplified. For this purpose the most important parameters have to be identified for each of the Earth's major ecosystems.

Because the energy, water, carbon dioxide and nutrient exchange processes interact, they cannot be represented individually. The integration is complicated and requires SVAT models to simulate all necessary loops and feedbacks. As an example, the water and nutrient uptake by the roots is partly driven by soil moisture dynamics within the root zone, which is in turn a result of the overall hydrological balance, including a possible groundwater contribution. For instance, increasing the incident solar radiation or the ambient CO_2 concentrations will result in new water and nutrient uptake rates and in altered hydrological balance. A main scientific topic of this Focus is to contribute to the understanding of the interactions between the energy, water, carbon cycle and nutrient exchange processes and to provide methods and models to represent these processes for a global biospheric research.

The transpiration of water from vegetation is a complex process which truly requires a combined biophysical approach for a realistic representation in SVATs. There is now ample evidence to show that the stomatal function, and hence the canopy transpiration resistance (i.e., conductance being the reverse of the resistance) is primarily dependent on the water-stress status of the vegetation and on the photosynthetic rate. Improved parameterization of stomatal conductance is of a prime interest to the SVAT-modellers and it is regarded as the mean to enhance the performance of SVAT models.

The following coordinating activities will be taken to stimulate field research and model development aimed at improving the SVAT's performance:

- Meeting to prepare a summary report on measurement and first generalization of canopy conductances (referring to one stand, one vegetational type)

- Workshop to discuss the contribution of BAHC towards an improved generalized classification system for functional land cover types in collaboration with GCTE and perhaps LUCC and DIS

- Surface conductance (referring to landscapes with several vegetational and surface types) workshop on the comprehensive validation of SVATs, updated functional relations, and updated estimation techniques for SVATs. This will result in a publication of state-of-the-art SVATs

- International symposium on SVAT modelling, parameterization schemes and associated parameter estimation techniques. The symposium will be organized in cooperation with the GEWEX-ISLSCP and will aim at an intercomparison of the SVAT schemes and a classification of their usefulness for improved GCM parameterization.

- Workshop on vegetation functional type classification (in cooperation with GCTE)

- International symposium on SVATs, their usefulness for predicting the effects of future global change on hydrologic transport processes in different biome types and climates. Publication on the evaluated SVATs with guidelines for their general application.

A timetable for these and other BAHC activities is presented in Fig. 2.

Land-surface processes at regional scales

Focus 2 will expand the investigations of Focus 1 into the spatial scale of typical landscapes and the temporal scale of years.

The planning, design and implementation of experiments is a major component of Focus 2. These activities will be conducted in collaboration with other international programmes, especially with WCRP-GEWEX (including ISLSCP) and with other IGBP Core Projects such as GCTE and IGAC under the guidance of the joint IGBP-WCRP working group. The experiments will progressively include more real-world complications, such as land-surface heterogeneities, discontinuities, and topography. Ecological aspects and nutrient cycling are additional factors included to improve the basis for large scale, integrative hydroecological modelling.

The ultimate goal of these regional studies is to provide the experimental data to validate models that integrate the exchange processes over areas of 10^4 - 10^5 km^2, and to describe the soil-vegetation-atmosphere interactions at these scales. The modelling of the soil-vegetation-atmosphere exchange processes needs different parameters than the formulation of these processes at the local scale, and a fundamental question is how these parameters can be aggregated from measurements made at different sites. Because measurements are only possible at very few locations, the use of remote sensing data for extrapolating from ground-based measurements to larger scales must be explored.

An important subject in Focus 2 is therefore the appropriate representation of the characteristics of larger areas in models taking into account land-surface heterogeneity in all its forms. Suitable models, methodologies and algorithms have to be developed, compared, and validated, using the data from land-surface experiments. These experiments will provide data sets that allow proper areal integration and quantification of the fluxes between surface and atmosphere. They will be conducted in a limited number of carefully selected areas, to investigate the most representative climatic, environmental and ecological conditions. A number of questions cannot be answered by intensive short-term experiments, so BAHC, in cooperation with IGAC, GCTE and GEWEX-ISLSCP, intends to initiate longer-term observations and measurements. Major

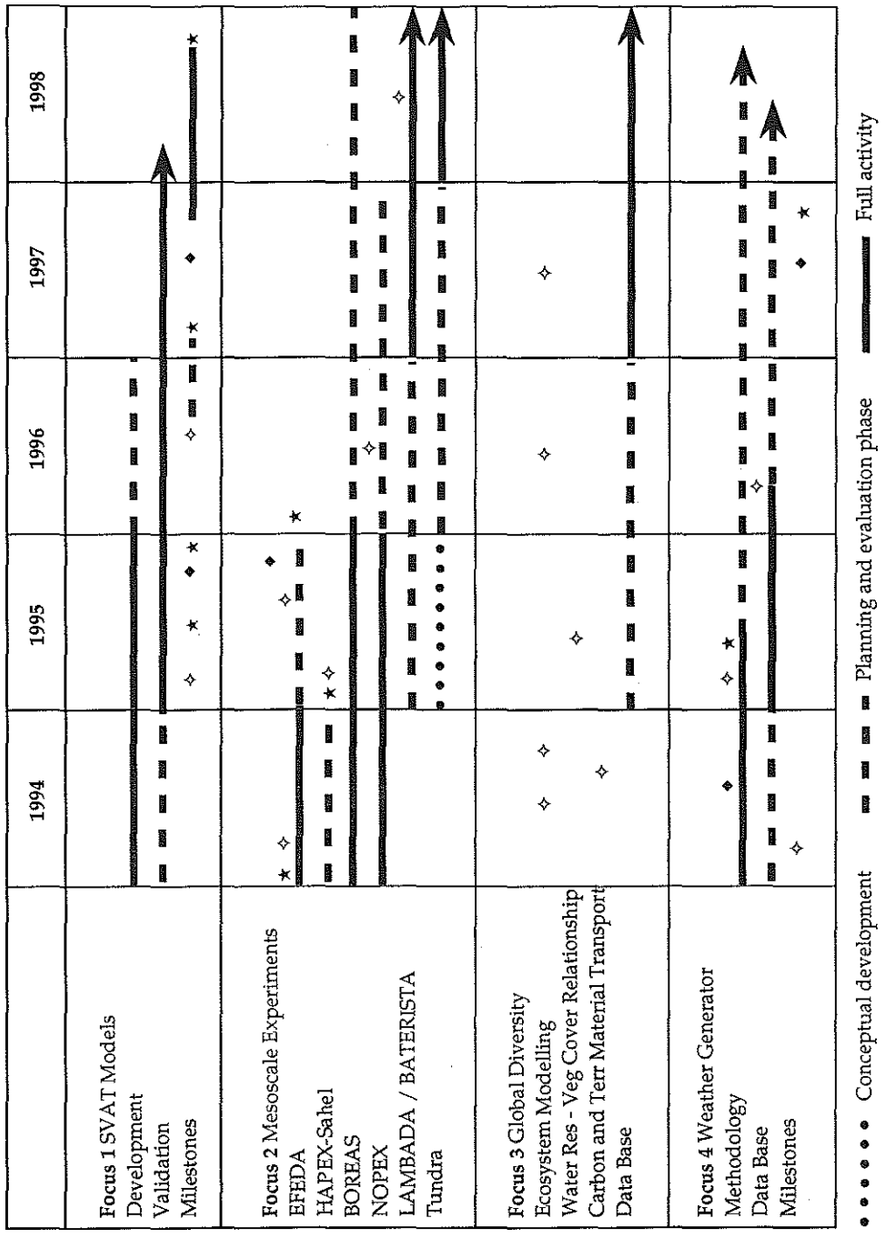


Figure 2. Timeline of BAHC activities

emphasis will be placed on the aggregation of land-surface properties and fluxes over inhomogeneous terrain. The experiments also serve to calibrate between satellite data and land-surface characteristics as input for Focus 3. In addition the results of a number of national and multinational experiments have to be synthesized. The following experiments are ongoing or planned for the five-year period: European International Project on Climate and Hydrological Interactions between Vegetation, Atmosphere and Land Surfaces (ECHIVAL) Field Experiment in Desertification-threatened Areas (EFEDA), Hydrologic Atmospheric Pilot Experiment in the Sahel (HAPEX-Sahel), Boreal Ecosystems Atmosphere Study (BOREAS), Northern Hemisphere Climate Processes Experiment (NOPEX), Large Scale Atmospheric Moisture Balance of Amazonia Using Data Assimilation - Biosphere-Atmosphere Transfers and Ecological Research in Situ Studies in Amazonia (LAMBADA-BATERISTA) and the Tundra Experiment.

An international symposium on regional-scale land-surface experiments will be organized to present and discuss results from past (EFEDA, HAPEX-Sahel) and ongoing or future experiments.

A follow-up meeting, to be organized jointly with GEWEX-ISLSCP, will focus on modelling aspects in large-scale experiments. This meeting will result in a book that summarizes the general findings of all aforementioned regional-scale experiments and develop the regional-scale experimental concept for general application.

Temporal and spatial variability in hydrosphere-biosphere interactions

Focus 3 consists of studies to extend the models to larger spatial and temporal scales. It primarily encompasses the long-term (seasonal to decadal and longer) dynamics of the coupling between the terrestrial biosphere, the hydrological cycle, and the physical climatic system. At short temporal scales, dynamics are regulated primarily by a combination of natural and anthropogenically driven changes in ecosystem structure and function, including climatic and atmospheric change.

Two motivations are given for the focus on understanding long-term dynamics and their consequences. First, major changes in ecosystem structure (e.g., the replacement of forest by grassland), are likely to have impacts on water resources and the physical climate system that are larger than those of short-term changes in ecosystem function (e.g., a change in leaf area index or stomatal conductance). Models of the coupled Earth system designed to simulate periods longer than a few years will need protocols for predicting ecosystem changes and the impacts of those changes on water resources and climate. Second, the great variety of the Earth's ecosystems, which is a product of these long-term dynamics, demands a systematic approach to characterizing ecosystems with respect to their impacts on the hydrological cycle, including effects on evapotranspiration, albedo, hydrologic discharges, and waterborne transport of carbon and nutrients.

Many, but not all, future changes in hydrologically significant biospheric attributes are likely to be due to climatic change. One important component of the global change problem is how to distinguish land-surface change due to climatic influence from that caused by other factors, including human impacts. The feedbacks in the hydrosphere-biosphere system will in most cases amplify the effects of human activities. To identify changes associated with climate, Focus 3 addresses studies designed to complement the ongoing and planned activities of a number of other international programmes and projects, especially the other BAHC Foci, the IGBP Core Projects GCTE, LOICZ and PAGES, and WCRP (GEWEX).

The investigations aim at a better understanding of the complex and multifaceted interactions between climatic, hydrologic and biospheric systems. In cooperation with GCTE it will provide a contribution to a development of models to describe large scale ecosystems dynamics. The investigations will support development of improved methods to determine quantitatively biosphere and other land-surface characteristics from remote sensing data, which are crucial for the parameterization of the land-surface processes, and the assessment of changes in biosphere at a scale of the grid cell of global climate models.

During 1994 - 1995, a series of workshops will be conducted under the title: "BAHC workshops on interactions between terrestrial hydrology and atmosphere" on specific topics such as global variability in radiation and water use efficiency by plants, detection and classification of land-cover and vegetation units, and transport of carbon and nutrients through freshwater to coastal ecosystems. Further, the classification of functional properties of terrestrial vegetation, bidirectional ecosystem-atmosphere interactions at the mesoscale, and approaches to characterization of root system structure and dynamics at large scales, are tasks that need clarification for better future results. These workshops will be conducted in cooperation with LOICZ, GAIM, PAGES, GCTE, and IGAC.

Local-scale disaggregation and prediction for hydrological and ecological research

To improve our understanding of how ecosystems and hydrological systems behave under current and future climates, information is required on regional and sub-regional patterns of atmospheric input to these systems. GCMs, which attempt to simulate global climate and climate change in response to forcings such as increasing atmospheric greenhouse gas concentrations, operate at spatial resolutions of several hundreds of kilometres. However, climate information is needed at much higher resolutions than the GCMs can presently provide for ecological and hydrological research. The process of deriving weather predictions by means of such high resolution climate information is often referred to as a Weather Generator.

There are two fundamental approaches to down-scaling the output of GCMs and other similar-scale data bases. The first approach utilises dynamic principles to generate the higher-resolution information. One such technique alters the GCM resolution, creating a finer grid over those regions of interest. A second technique uses the

three-dimensional subset of the GCM data as an initialisation for a high-resolution limited-area model. A third technique uses the dynamic equations of the atmosphere as a constraint in resolving sub-grid scale fluxes within a larger grid cell.

The second approach links site-specific observations with larger-scale features of the atmosphere. These linkages are used to construct a stochastic model to reproduce the spatial characteristics of meteorological variables over a number of sites in a small area. The values at each site can also be used as a basis for interpolating the meteorological variables to a high-resolution grid over the area.

Three activities have been identified within this Focus. The first is the development of procedures for the spatial and stochastic analysis of weather data so that the weather may be simulated at higher spatial and temporal resolutions than those provided by existing weather station networks. The second activity is the development and evaluation of the down-scaling algorithms which link broad scale atmospheric information to the high resolution information. The third activity involves research on the physical basis for down-scaling. This activity should provide guidance to the development of down-scaling techniques in order to enhance the validity of the Weather Generator under different climate regimes.

An important aspect of Focus 4 is to ensure that the infrastructure is established to document, maintain, and test further developments to the Weather Generator. While this will ensure the ongoing development of the collection of algorithms that will comprise the Weather Generator, it will also ensure the ongoing evaluation of GCM output for use with the down-scaling techniques. For areas of special interest, down-scaled data from the Weather Generator will be made available to users upon request.

The proposed Weather Generator will directly serve the needs of BAHC Foci 1, 2 and 3, GCTE Focus 2 and indirectly GCTE Focus 3. In addition, the findings of GEWEX Continental-Scale International Project (GCIP) and the GEWEX Cloud System Study (GCSS) are expected to interface directly with the development of the Weather Generator with respect to global and large scale precipitation. It is also expected that the Weather Generator will take full advantage of future improvements in spatial resolution of GCMs. This localised weather data, generated from regional and global information, is required as input for 1 - 50 km scale hydrological and ecological investigations. Focus 4 was established to fulfil the requirements of several ecologically and hydrologically-oriented projects, through the provision of climatic data with much finer areal resolution than is currently available from existing networks and global models.

The necessary studies are presently initiated through a series of workshops which are partly sponsored by UNESCO, UNEP and national agencies. These workshops start with the identification of major research questions and specification of the ingredients of the Weather Generator. This preparatory work will be finished in 1994. In parallel, both new and existing methods are to be adapted for this specific purpose, to be tested during the period 1994 - 1996. Their physical basis has to be improved before the data bases and infrastructure for storage and distribution can be developed. This should occur in about 1996.

Global Change and Terrestrial Ecosystems (GCTE)

Introduction

The world's terrestrial ecosystems are being subjected to changing environmental conditions of an unprecedented scale, both in their rate and in their geographical extent. The IGBP Core Project GCTE has been established to improve our understanding of how terrestrial ecosystems interact with changes in atmospheric composition, climate, human impacts and other environmental influences occurring on a global scale.

Objectives

- Predict the effects of changes in climate, atmospheric composition, and land use on terrestrial ecosystems, including (i) agriculture, forestry and soils, and (ii) ecological complexity.
- Determine how these effects lead to feedbacks to the atmosphere and the physical climate system.

Organization of Research

The GCTE research programme is built around four Foci (Fig. 3), with much flow of people, ideas, expertise and information between them and their component parts.

The primary aim of Focus 1, Ecosystem Physiology, is to understand and model the effect of global change on primary ecosystem processes, such as the exchange of energy, water (in collaboration with BAHC) and trace gases (jointly with IGAC) with the atmosphere, element cycling and storage, and biomass accumulation or loss. A central thesis of Focus 1 is that the ways in which ecosystems function - their physiology - will be strongly affected by the combined and interactive suite of changes in atmospheric CO_2, land-use practices, and the likely changes in the means and extremes of temperature and rainfall.

These driving forces of global change will also lead to changes in the distributions of plant and animal species and thus species composition of ecosystems. Changes in ecosystem composition will, in turn, lead to changes in ecosystem physiology, such as evapotranspiration and nutrient cycling. The goal of Focus 2, Change in Ecosystem Structure, is to model this complex suite of impacts and responses so that the pattern of change in ecosystem composition and structure can be predicted.

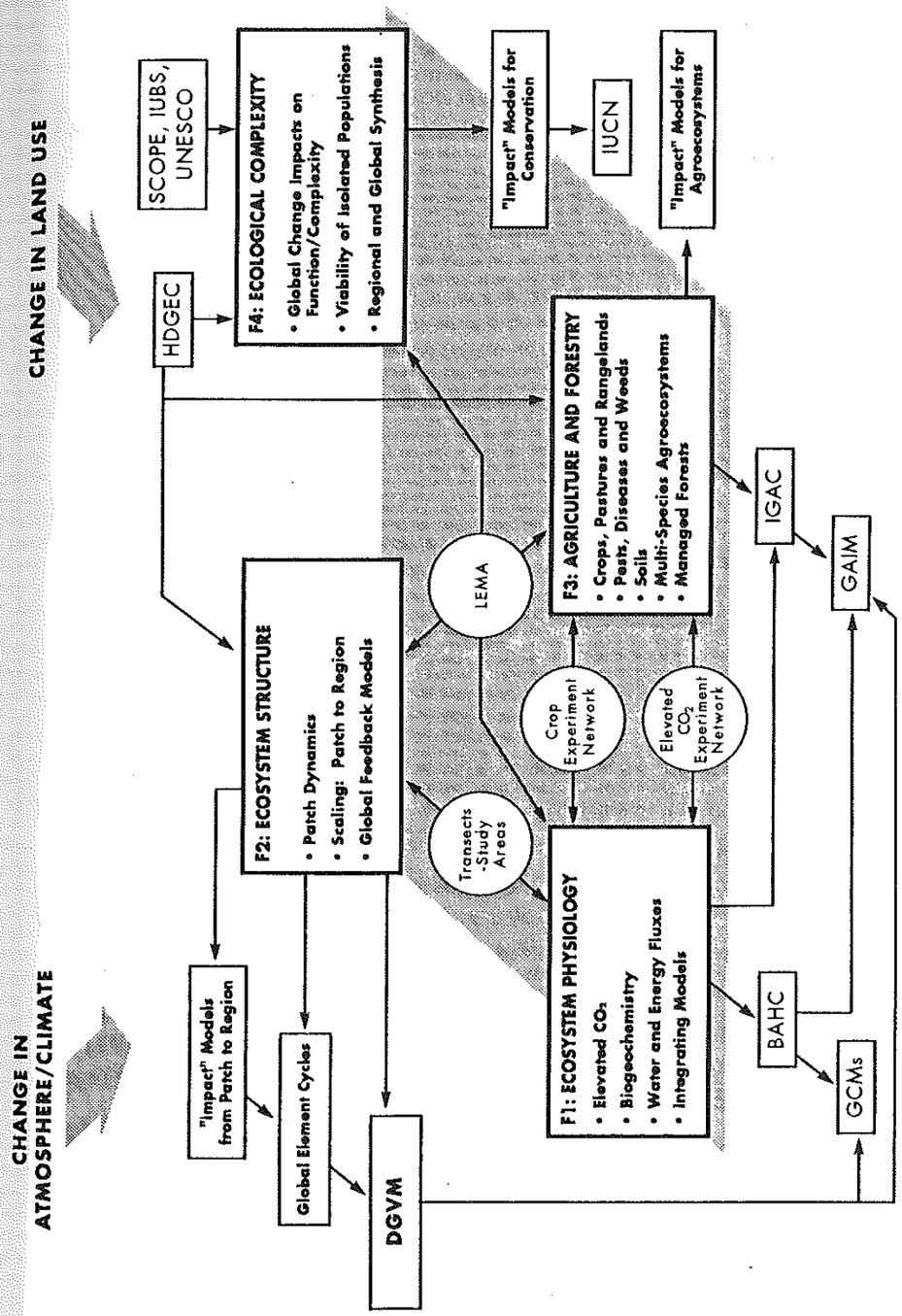


Figure 3. Organizational chart for GCTE

The world's terrestrial ecosystems constitute a continuum from virtually pristine to intensively managed and highly modified systems devoted to production of food and fibre. Many of these systems are already threatened by damage to soil and water resources through poor technology, and will be further impacted by global change. Through its Focus 3, Global Change Impact on Agriculture and Forestry, GCTE aims to improve our capability to predict global change impacts on key agronomic species and on managed forests, pastures and rangelands.

There is mounting concern around the world about the apparently rapid and accelerating rate of loss of biological diversity. A crucial question is how the change in ecological complexity, which includes the interactions among species within an ecosystem as well as the number of species itself, will affect the physiology of the ecosystem. The goal of GCTE Focus 4, Global Change and Ecological Complexity, is to determine the impact of global change on ecological complexity and on the relationship between ecological complexity and ecosystem function.

The four Foci are linked together by a number of integrating facilities and activities: a consortium of elevated CO_2 experiments on both managed and natural ecosystems; networks of crop experimental and modelling groups; transects along environmental gradients for biogeochemical experiments, comparisons of natural and managed ecosystems, and the development of ecosystem dynamics models; and a network of modelling groups throughout the GCTE programme LEMA (Long-term Ecological Modelling Activity).

Work Plan

The following five-year work plan for GCTE is based on its scientific objectives and phased implementation strategy as outlined in the Operational Plan (IGBP Report No. 21). The work plan gives some of the major scientific "products" which GCTE expects to deliver over the next five years, and highlights a few of the "tools" that will be used in achieving them. The work plan emphasizes the interaction between the Foci, and the dependence of progress in one area on the outputs of another. In addition, the linkages between GCTE and other IGBP Core Projects, as well as other groups, are shown.

It should be emphasized that the work plan is illustrative rather than comprehensive. The six themes considered here provide information on research areas that are well represented in the initial set of projects accepted into the GCTE Core Research Programme in 1992 and 1993. Thus, these are areas in which significant achievements are likely within a five-year timeframe (Fig. 4). However, toward the end of this period, many more GCTE activities will be underway, and the full GCTE tapestry will be far richer and more intricately woven than that indicated here.

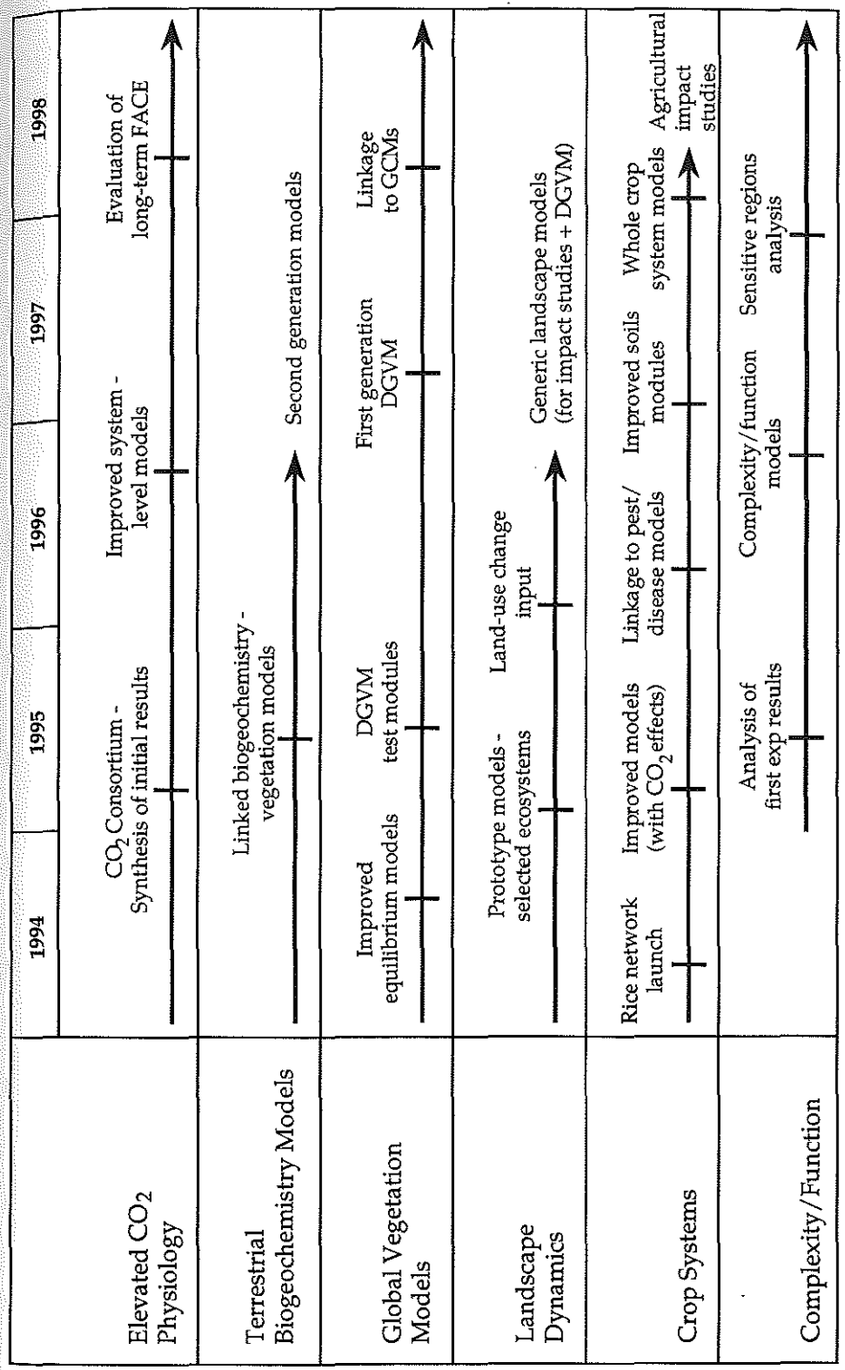


Figure 4. GCTE milestones

Effects of elevated CO_2

Although there have been many predictions of a substantial "CO_2 fertilization effect" in the terrestrial biosphere, there is considerable uncertainty regarding its interactions with other factors which affect plant growth, such as nutrients and water. Results from the GCTE consortium of elevated CO_2 studies, which are based on controlled experiments with interacting variables on a variety of systems, will lead to an improved understanding of how systems will respond to increased atmospheric CO_2 in the real-world conditions of nutrient limitation and water stress, and thus give a much better estimate of the potential role of terrestrial ecosystems as a carbon sink. A synthesis report in 1995 will summarize these advances.

Two years later, in 1997, results from a number of long-term elevated CO_2 studies undertaken with Free-Air CO_2 Enrichment (FACE) technology will be available for cross-comparison to similar work in open-top chambers and other enclosures. The advantage of the FACE technology is that it does not significantly alter the microclimate of the plants, and may thus lead to refinements or modifications of the earlier results from the CO_2 consortium. A synthesis of elevated CO_2 experimental methodology will be published in 1994, and a thorough analysis and summary of the FACE work, with an updated assessment of the role of the terrestrial biosphere in the carbon cycle, will be published in 1997.

As this work progresses, and results of the other Activities within Focus 1 are brought together, the products will be useful to several other groups within IGBP. The whole-system models of ecosystem physiology will include trace gas emissions, of interest to IGAC, and more accurate parameterizations of canopy conductance, which is important for BAHC. The results will be of central importance to GAIM in its effort to produce better models and a more thorough analysis and interpretation of the global carbon cycle.

Large-scale studies of ecosystem physiology

Experiments and models at the scale of a small patch (10 - 100 m) are essential to understand and describe the processes by which global change will affect the cycling and storage of key elements. However, to be useful in understanding global cycles, these models need to be scaled up using careful aggregation procedures and Geographical Information System (GIS) technology.

The present generation of large-scale terrestrial biogeochemical models incorporates current physiological understanding of ecosystem response to elevated CO_2 and changing climate through linked carbon and nitrogen modules. Although the responses of ecosystem processes to change are thus simulated, the structure and distribution of the ecosystems themselves do not change (i.e., biome extent and boundaries are fixed). By 1994, however, one of these large-scale models (the Terrestrial Ecosystem Model, TEM; Melillo *et al.*, Nature 363, 234-240, 1993) will be linked to a global vegetation

(biome redistribution) model (BIOME, see below). In addition, modules for greenhouse gas emissions will be added, to give a more comprehensive and realistic picture of the terrestrial carbon cycle.

These biogeochemical models, however, must be based on smaller-scale process-level understanding and on data at a number of scales. GCTE is pursuing a vigorous programme of ecosystem-level experiments, including the elevated CO_2 research effort and large-scale biogeochemical transect studies, which will provide this essential foundation. Results from these studies will be incorporated into the large-scale models at regular intervals throughout the 1995 - 1998 period, in addition to concurrent improvements in the linked BIOME and possibly other global vegetation models.

GCTE's terrestrial biogeochemical studies will contribute strongly to the GAIM task to produce improved simulations of the global carbon cycle. GCTE will produce a major report in 1997 on terrestrial biogeochemistry at a number of scales as a synthesis of its Focus 1 research and as a contribution to the GAIM carbon project.

Global vegetation models

GCTE's second overall objective is to determine how global-change driven impacts on ecosystem structure and function will produce feedback effects, influencing further change. To do this, GCTE must develop global-scale simulations of the changing composition and distribution of terrestrial ecosystems, and ensure that these simulations are linked appropriately to global biogeochemical and physical climate models.

Within GCTE Focus 2, two such global vegetation models currently exist - BIOME (Prentice *et al.*, J. Biogeogr. 19, 117-134, 1992) and Dynamic Global Phytogeography Model (DOLY) (Woodward) - and both are now being linked to GCMs to simulate the effect of changing biome distribution on the physical climate. Also, by 1994 BIOME will be coupled to a global terrestrial biogeochemical model (see above).

Although BIOME is based fundamentally on a correlation between climate and biome distribution and performance, it is rapidly incorporating more physiologically based response functions. BIOME-2, a substantial modification of the original BIOME model, will be available in late 1994. DOLY already uses mechanistic simulations to predict the distribution and function of vegetation from climate and soil. As these two models evolve, updated versions will be coupled to the global climate and biogeochemical models to give more realistic terrestrial feedbacks.

In parallel with the evolution of BIOME and DOLY, GCTE will pursue the development of a Dynamic Global Vegetation Model (DGVM). This simulation will be fundamentally different from its predecessors. It will be built of modules based on ecosystem dynamics at the patch scale; the actual processes by which systems change - the death of a tree in a forest and the subsequent regeneration, for example - will be modelled at representative sites around the world. In the aggregation of these small-scale simulations, processes which become important at larger scales, such as storms, fires

and human land use practices (see below), will be incorporated to develop a more realistic picture of how ecosystems will change in a dynamic way under global change.

The development of the DGVM is in its early stages. By 1995 the first prototype modules, built for a few sample ecosystem types, will be produced. In that year GCTE will hold a workshop to compare these modules and to ensure their compatibility for eventual inclusion in an integrated DGVM. Additional modules will then be developed and a first generation DGVM built two years later.

The two approaches will converge as patch-scale models are scaled up and the present global models are run at finer scales and include more ecosystem dynamics. To review these developments, GCTE will hold a major international conference in 1997 on global vegetation models and their use in coupled model frameworks (with GCMs and global biogeochemical models, for example). By 1998 the DGVM will be fully coupled to these other global models.

Landscape dynamics

Much of the change in the Earth's land cover is driven by processes which occur at the landscape scale (1 - 10 km), notably direct human management of the land cover for productive, recreational and other purposes; and disturbance events such as fires, floods and storms. Developing realistic algorithms for incorporating these processes into regional and global ecosystem dynamics models is a major challenge in global change research.

GCTE's programme on landscape process studies will be phased, with an initial emphasis on Mediterranean, boreal, and semi-arid tropical ecosystems. The effort, to be undertaken in collaboration with HDP, was launched with a workshop in late 1993 to develop a coordinated workplan. In 1995, a model comparison workshop will be held, which will form the basis for a synthesis report on progress in the three initial systems. A prototype generic landscape model, which will have a single structure that can be parameterized for all major ecosystems, will be developed by 1997 and linked a year later into the DGVM, the first generation version of which will be produced about the same time.

The proposed LUCC Core Project of the IGBP and HDP will be working in parallel on a global land cover model, which will be based on a series of regional case studies. The GCTE landscape programme will work in close collaboration with LUCC throughout the period, drawing on insights from that effort as it develops.

In addition to providing essential understanding for the DGVM, GCTE's landscape process studies will serve another important function. They will provide the generic understanding required to undertake impact analyses at the national/regional and lower levels. GCTE will interact closely with the appropriate groups undertaking the more applied, specific impact studies through training courses and workshops to ensure the efficient transfer of expertise. The first such courses will be held in 1996.

Agricultural production systems

The impacts of global change on the capacity of agricultural production systems are of great concern to countries around the world. Impact studies are already proliferating, but the crop models on which these assessments are based have not been developed or validated for elevated CO_2 or projected future climatic conditions. The goal of GCTE work on agricultural systems is to improve the biophysical understanding and simulation of the response of key crops to global change, so that impact and mitigation strategies, and the research that must be done to implement these, can be efficiently and rapidly planned. The ability to model plant behaviour under changed conditions is critical for this.

The initial GCTE effort is on the two major grain crops, wheat and rice. An experimental and modelling wheat research network was established in early 1993, and a similar rice research network will be organized in 1994. The first tasks of these networks is to gather extant datasets and carry out model sensitivity tests to examine the differences between individual models when run under global change conditions. New experiments, such as the large FACE experiment on wheat in 1993 and 1994, will be undertaken to improve our understanding of crop performance under changed conditions and to provide the data needed to advance model development.

The results of the Focus 1 work on elevated CO_2, brought together in a synthesis report in 1995 (see above), will provide basic physiological understanding to improve the elevated CO_2 module in the crop models. Also in 1995, the first results of the GCTE work on soil organic matter dynamics will be available to provide a more dynamic soils component to the crop models. The addition of modules on the effects of pests and pathogens on crops will produce whole system models that are needed to simulate the interaction among the various components of production systems. A major synthesis report on the GCTE wheat and rice model systems will be produced in 1998, when significant new work on soil organic matter dynamics and on insect pests, pathogens, and weeds has been incorporated into the models.

The GCTE wheat and rice models will be available to groups doing impact studies throughout the progressive development of the models during the five-year period. In 1996 GCTE will undertake its own assessment of potential crop performance, based on the aggregation using GIS techniques of the improved crop production models. The GCTE study will provide the biophysical platform on which other groups can undertake complete impact assessments, incorporating economics and other social and political factors. In particular, the GCTE work will provide the biophysical component needed in LUCC to project how agricultural land use will change over the next decades.

Ecological complexity and ecosystem function

This work, a key part of Focus 4, is being phased-in somewhat after the other three Foci. Field experiments will comprise studies in which the diversity of a key group of organisms is changed and the resulting effect on a specific ecosystem function is

measured. For example, a GCTE study in West Africa is determining the effects of changing diversity in soil fauna (termites, nematodes, etc.) on the emission of greenhouse gases from the soil.

A preliminary analysis of the results of these experiments will be done in 1996. One product from this analysis will be an initial assessment of which ecosystems or biomes around the world are particularly vulnerable, in terms of altered ecosystem function, to change in their complexity.

The ultimate goal of this work is to build generic models of the complexity-function relationship under global change. The first generation of such models, which will begin to mature in 1998, will draw heavily on advances made in: (i) the elevated CO_2 research, which along with the other work of Focus 1, will produce improved models of ecosystem physiology under global change; and (ii) the agricultural production systems research, whose modelling component will build up more complex systems from simpler ones by the addition of more sophisticated pest and weed and soil organic matter dynamics modules to the crop production models. That work in itself will provide fascinating insights into how ecosystem function is altered by increasing complexity.

Project-wide products

Three major types of product will be generated by GCTE as a whole over the five-year period. First, the *GCTE Science Conference series* will provide a regular forum for the presentation of the latest scientific results from GCTE and related research. Invited talks on cross-Foci projects and on collaborative research between GCTE and other IGBP Core Projects will give an indication of the success of GCTE in producing an integrated research effort and in collaborating with its partner Core Projects. The conference reports will be excellent biennial reviews of GCTE progress. The First GCTE Science Conference will be held in 1994.

The second type of product is the *GCTE Annual Report series*. These publications will give a complete listing and brief description of each of the projects officially accepted by the GCTE SSC as contributions to the GCTE Core Research Programme; it will also provide updates on the evolution of the GCTE research structure.

Thirdly, GCTE is also involved in *major assessments of global change impacts on terrestrial ecosystems*, and the reports of these exercises will provide an excellent account of the GCTE's role in translating the results of its work into assessments of use to policy-makers. The first such major assessment will be in 1995, within the framework of the IPCC's Second Assessment.

International Global Atmospheric Chemistry Project (IGAC)

Introduction

The IGAC project was created in response to the growing concern regarding global-scale changes in atmospheric composition and their implications. IGAC is not only concerned with chemical changes and processes occurring within the atmosphere: it is also concerned with the biospheric processes (terrestrial and marine) and anthropogenic activity affecting the composition of the atmosphere. IGAC is jointly sponsored by IGBP and the Commission on Atmospheric Chemistry and Global Pollution (CACGP) of the International Association of Meteorology and Atmospheric Sciences (IAMAS).

Objectives

- Develop a fundamental understanding of the processes that determine the chemical composition of the atmosphere.
- Understand the interactions between atmospheric chemical composition and biospheric and climatic processes.
- Predict the impact of natural and anthropogenic forcings on the chemical composition of the atmosphere.

Organization of Research

The composition and chemistry of the atmosphere are dependent on both climatic (temperature, pressure, cloud cover and opacity, precipitation, etc.), biospheric (oceanic and terrestrial ecosystem sources and sinks) and anthropogenic (industrial processes, etc.) variables. The IGAC scientific strategy takes account of the fact that the spatial and temporal distributions of these variables are not uniform and for some (e.g., clouds, phytoplankton) the distributions are very patchy.

As a result of these patchy and sometimes correlated phenomena, it is essential to study a variety of regions over the globe, with the full complement of associated theoretical studies being applied to each region (Fig. 5). For this reason there are five "regional Foci" within IGAC which address the marine, tropical, polar, boreal, and mid-latitude terrestrial regions. These regional Foci are accompanied by a global Focus addressing global trends, distributions, sources, atmospheric transport, transformations, sinks, and modelling of trace gases and aerosols. A final Focus is on the fundamental experimental and theoretical work essential to all other Foci, namely measurement

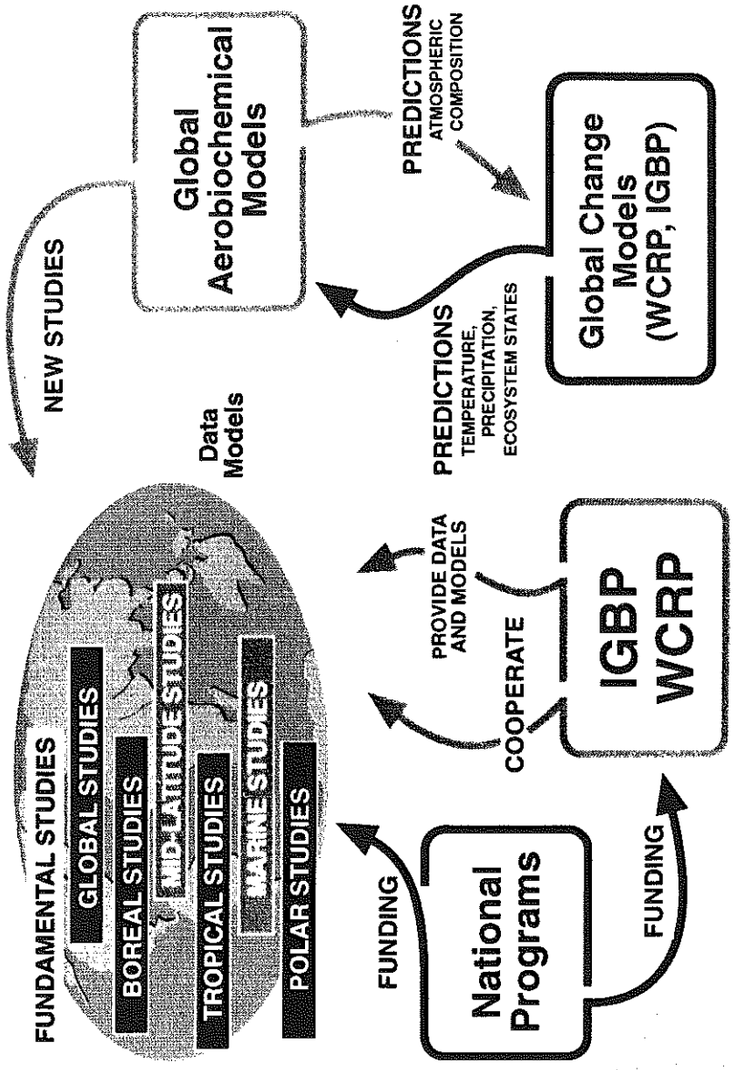


Figure 5. Organization of IGAC

calibration and intercomparisons; laboratory studies of fundamental molecular properties; as well as new instrument development. In addition, IGAC is promoting educational activities to further understanding of atmospheric chemistry and associated biological processes in the context of global change.

These seven Foci collectively address areas of greatest current uncertainty and/or perceived importance. The Foci will evolve in response to reductions in uncertainties and concomitant changes in perceptions of what areas deserve the most attention. Activities within each IGAC Focus define achievable endeavours addressing the major IGAC objectives. Where appropriate, these Activities are carried out in cooperation with other IGBP Core Projects, the World Meteorological Organization (WMO) and the World Climate Research Programme (WCRP). Specific task teams have been constituted to develop recommendations for collaborative efforts between JGOFS and IGAC and among BAHC, IGAC and GCTE. Formal liaison has been established between IGAC and WMO and between IGAC and the International Union of Pure and Applied Chemistry (IUPAC).

Work Plan

The marine atmosphere

The overall objective of IGAC Focus 1 (Natural Variability and Anthropogenic perturbations of the Marine Atmosphere) is to predict the oxidizing efficiency of the marine atmosphere, the direct and indirect effects of marine aerosols on climate, and the importance of air-sea exchange in biogeochemical cycles. The world's oceans are both a source of biogenic material and a sink for natural and anthropogenic carbon, nitrogen, sulphur, and halogen compounds which affect the radiative properties of the atmosphere through scattering, absorption, and cloud microphysical processes. Since two-thirds of the Earth's atmosphere lies over the ocean, the transport and chemical processes studied in this Focus impact the entire global environment.

Two of the Activities in this Focus (East Asian-North Pacific Regional Experiment, APARE; and North Atlantic Regional Experiment, NARE) focus on the impact of continental pollutants, which may lead to production of ozone in the marine troposphere. They seek to characterize the transport pathways, which bring emissions from continental sources to the North Atlantic and North Pacific Ocean regions, the photochemical reactions by which these generate ozone, and the removal processes for the many products. To this end they have planned experiments involving coordinated surface and airborne observations during the next several years. The contrast between the two ocean regions is particularly interesting, because each has a different mix of pollutants and meteorological conditions.

The third marine Activity (Marine Aerosol and Gas Exchange, MAGE) is directed at predicting the oceanic and atmospheric concentrations of biologically and climatically important species. The controlling processes include the air-sea exchange of trace gases and aerosols, biological production of radiatively active trace gases and their precursors,

cycling and deposition of nutrients from the atmosphere, and photochemistry in both media. Particular attention is being directed towards: (i) quantifying the emission and deposition of ammonia and nitrate, which influence marine nitrogen and carbon budgets; (ii) clarifying the role of aeolian dust as a source of (biologically limiting) iron in certain regions, which is conducted in collaboration with JGOFS; and (iii) predicting the emission flux of dimethylsulphide (DMS). A major goal is to model the impact of DMS on climate through the formation of submicrometer sulphate aerosols which control cloud lifetimes and radiative properties. The complexity of these studies requires an integrated, multidisciplinary approach which often includes simultaneous measurements from several research platforms.

The possibility is being explored of coordinating IGAC air-sea exchange studies with JGOFS studies of processes regulating the net uptake of atmospheric CO_2 in the North Atlantic in 1996 - 1998.

Tropical studies

The overall objectives of IGAC Focus 2 (Natural Variability and Anthropogenic Perturbations of Tropical Atmospheric Chemistry) are to understand the chemical processing and transport of gases in the tropical atmosphere, and the role of terrestrial biosphere-atmosphere trace gas exchanges in regulating atmospheric composition. Much of the research in the Tropical Focus is directed toward understanding the effects of human activities, especially land-use change and land-use intensification, on trace gas fluxes and atmospheric chemistry.

Several interrelated activities are addressing these major objectives. One Activity (Biosphere-Atmosphere Interactions in the Tropics: Influence of Land Use Change, BATGE) is examining the effects of land use conversion of tropical forest and savanna ecosystems on emissions and uptake of trace gases by the biosphere, and on consequent atmospheric processing and transport of biogenic gases. A related Activity (Rice Cultivation and Trace Gas Exchange, RICE) is evaluating the effects of varying agronomic practices specifically in rice agriculture on emissions of methane and other trace gases. A third (Biomass Burning Experiment: Impact on the Atmosphere and Biosphere, BIBEX) is evaluating the role of biomass burning in tropical ecosystems on atmospheric composition, chemistry, and transport processes. To complete the cycle, a fourth activity (Deposition of Biogeochemically Important Trace Species, DEBITS) is examining the deposition of biogeochemically important chemical species (of anthropogenic and biogenic origin) in tropical ecosystems.

These Activities are being implemented through integrated field measurement programmes. In the next several years, coordinated research on biomass burning emissions and transport processes, and on land management effects of trace gas exchanges not directly associated with fire, will continue in savanna regions of Africa and the American tropics. A ground-based flux measurement programme, including instrument intercomparisons, is currently underway and will be coordinated with aircraft campaigns planned for 1994 and 1996. Discussions are underway to ensure full

coordination of these studies with GCTE efforts in savanna regions and it is hoped that they can be supported by START regional initiatives.

A network of field sites has been established for long-term studies of land-use changes and agricultural intensification in humid tropical areas, as well as in the savanna regions. Over the period 1994 - 1997, results from these studies are expected to provide the first information on the magnitude and regulation of trace gas exchange in upland tropical agricultural systems. Process-based biogeochemical models are being developed concurrently, utilizing information from the field studies, to estimate the effects of land-use change at regional scales. Such models will be validated using regional flux data acquired via aircraft campaigns planned for 1997 - 1998 in the Brazilian tropics.

IGAC research over the last several years has yielded major advances in understanding of methane flux magnitudes in rice agriculture, and the processes regulating such fluxes. Coordinated field studies in a range of rice growing areas will continue such work, including studies of the effects of various rice cultivars, planting practices, flooding and fertilization practices, and other management approaches on fluxes of methane and other gases. In addition to the on-going field studies, this activity will participate over the next several years in training opportunities (with START), and will conduct fora for information exchange, and for integration and synthesis of results, in order to develop appropriate practices that mitigate or prevent gas fluxes from flooded agriculture.

A final aspect of this Focus is seeking to develop estimates of precipitation chemistry and aerosol composition in regions of the tropics, with the goal of assessing the importance of dry and wet deposition in tropical biogeochemical cycles and the anthropogenic impact on these cycles. Field measurement programmes throughout a number of Asian countries are being carried out, and synthesis of these and other data are planned. In the next several years, planning and development of sampling programmes in other tropical areas will take place.

Polar studies

The Arctic and Antarctic play an important role in global atmospheric chemistry and climate. For example, they are major players in the global climate feedback system, and are the main regions where anthropogenically-induced ozone depletion occurs, increasing ultraviolet radiation at the Earth's surface. At very high latitudes, the cold polar regions have a unique one-day/one-night per year light regime; and they possess ice sheets and glaciers whose chemical composition can be used to recover historical records of the Earth's atmospheric composition. Contrasts between the two polar regions help us understand better the chemical processes that influence climate.

Until recently, major polar research activities have been palaeoclimate oriented and focused on ice core drilling operations. The objectives of IGAC Focus 3 (The Role of Polar Regions in Changing Atmospheric Composition) are to understand the role of

polar tropospheric chemistry in global change, to establish the relationship between atmospheric chemical composition and that of glacier snow and ice, to document present and planned studies of the polar troposphere and of snow chemistry relevant to global change. There is a single polar Activity: Polar Atmospheric and Snow Chemistry (PASC).

In the mid-1990s, PASC will continue to encourage the integration of small science efforts into the larger picture through interdisciplinary specialty conferences and workshops. Close contact with the Scientific Committee for Antarctic Research (SCAR) will be maintained. In parallel, coordinated, international, interdisciplinary efforts on selected topics will be initiated. These include: (i) a coordinated research programme at the Summit site in Greenland, where the recent deep corings by US and European groups have taken place, to understand better the exchange of gases (ammonia (NH_3), nitric acid (HNO_3), organic acids) and aerosol constituents (sulphate (SO_4^{2-}) in particular) between the atmosphere and glacial snow and ice; (ii) a Northern Tropospheric Oxidants Study (NOS) in collaboration with IGAC's Marine Focus that will held to define better the chemical controls on ozone; (iii) an effort to develop an automated polar air chemistry measurement system; (iv) ship and aircraft campaigns to understand better the role of polar oceans in atmospheric chemistry, stratospheric ozone depletion, and global climate; and (v) studies of the chemical processes involved in the accumulation of persistent organic compounds in polar ecosystems via snow and air pathways.

In addition to major observational studies, efforts will be made to incorporate polar processes more accurately into global atmospheric chemistry and climate models. For instance, although globally anthropogenic aerosols produce a net negative radiative forcing counteracting the greenhouse forcing of anthropogenic trace gases, they exert a regionally-positive forcing over Arctic snow and ice. This creates large spatial gradients in radiative forcing by aerosols that have not been adequately represented in climate models to date.

Finally, the interpretation of deep ice cores in terms of palaeo-atmospheric chemistry, a major thrust of PAGES, requires full understanding of the polar atmospheric system and mechanisms of recording atmospheric composition in ice under present climatic conditions. The deep ice core operations in Greenland (Greenland Ice Project, GRIP; and Greenland Ice Sheet Project 2, GISP2) are now in their interpretive phase. New major drilling will be undertaken in the Antarctic over the next 5 years. Collaboration between IGAC's Polar Focus and PAGES will necessarily be enhanced.

Boreal regions

The overall objective of IGAC Focus 4 (The Role of Boreal Regions in Biosphere-Atmosphere Interactions) is to examine the role of the boreal regions as sources and sinks of trace gases, and the ecosystem dynamics controlling these fluxes. The forests, lakes and wetlands covering vast areas of North America and northern Eurasia have significant influences on global climate and atmospheric composition because they are

strong sources and/or sinks of CO_2, CH_4, and other radiatively active gases. Current climate change modelling results imply that warming due to increases in greenhouse gases will intensify towards the poles, which could strongly enhance emissions of these gases from northern wetlands and permafrost regions. These regions also emit other chemically active compounds and act as significant recipients for trace gases and aerosols transported from mid-latitudes. Emissions of trace gases like CH_4 are sensitive to changes in soil temperature and moisture as well as organic matter contents. Detailed field surveys and experimental manipulations are required to develop an understanding of current atmosphere-biosphere exchanges, as well as predictions of future responses to global warming.

There is a single Boreal Activity (High Latitude Ecosystems as Sources and Sinks of Trace Gases, HESS); its ongoing and planned research addresses three major tasks. One is designed to alleviate the uncertainties in estimates of three key factors in determining the importance of northern wetlands as a source of atmospheric CH_4. The factors are: (i) lack of adequate data bases on ecosystem type; (ii) flux estimates for each ecosystem type; and iii) annual duration of the flux period. A second task is to improve flux estimates through year-round field measurements of CO_2, nitrous oxide (N_2O), carbonyl sulphide (OCS), hydrogen sulphide (H_2S), DMS, reactive nitrogen (NO_y), and volatile organic compounds (VOC) using chamber, tower and aircraft techniques. The third task is developing and testing extrapolation models for gas fluxes. This task has three requirements: (i) areal flux estimates of trace gases must be obtained using aircraft flying in the boundary layer in a particular area; (ii) a comparison between flux-extrapolated estimates of emissions from high-latitude ecosystems and isotopic reconstruction of trace gas sources and sinks; and (iii) intercomparisons of chamber techniques and radon 222 (^{222}Rn) profile techniques to improve flux measurements.

Mid-latitude ecosystem studies

IGAC Focus 5 (Trace Gas Fluxes in Mid-Latitude Ecosystems) addresses the temperate region, particularly of the Northern Hemisphere, which is densely populated with most of its ecosystems subject to strong human disturbances, including conversion of forests to grasslands and agricultural lands. These mid-latitude ecosystems experience extreme atmospheric chemical conditions such as high ozone concentrations and acid deposition due to industrial emissions. Strong chemical interactions occur between gases of industrial (e.g., NO_2) and biogenic (e.g., isoprene and terpenes) origin, which lead to enhanced ozone concentrations with detrimental influences on some ecosystems. These processes are already being studied in some industrialized areas, but the investigations need to be expanded to other regions. The investigations also need to be extended to include their impact on overall nutrient cycling and trace gas exchange in the relevant ecosystems. In addition to the disturbances caused by atmospheric inputs, the roles of various agricultural practices (including heavy use of fertilizers) on trace gas emissions and uptake need to be better determined.

Two Activities are underway to investigate these issues. The goals of the Trace Gas Exchange: Mid-Latitude Terrestrial Ecosystems and Atmosphere (TRAGEX) are to

document contemporary fluxes of CO_2, CH_4, N_2O, and carbon monoxide (CO) between the soil and atmosphere, and to determine the factors controlling these fluxes and improve the ability to predict future fluxes. Measurements on trace gas fluxes are in progress at a network of representative sites. Manipulation experiments are conducted to study controlling variables, in order to parameterize models of trace gas fluxes.

GCTE scientists are participating from the outset in the design of the secton Activity (Mid-Latitude Ecosystems and Photochemical Oxidants, MILOX), which entered its planning phase in late 1993. The proposed objective of MILOX is to assess and understand the complex interplay among an urban industrial society, natural and cultivated ecosystems, and atmospheric photochemical oxidants in the northern mid-latitudes. It is expected to involve three major thrusts:

(i) Deployment of a series of regional surface atmospheric chemistry monitoring networks to assess the impact of ozone and related photochemical oxidants on agroecosystems and managed forests in northern mid-latitudes

(ii) Implementation of a series of intensive field monitoring campaigns coupled with the development and application of regional and global chemical transport models to elucidate the chemical, physical, and biological processes controlling the concentrations of ozone and related oxidants overlying northern mid-latitude ecosystems

(iii) Integration of knowledge thus gained into comprehensive models to forecast the long-term effects of agricultural and forestry practices, land use changes, new technologies and demographics on regional and global environments.

Global distributions, transformations, trends, and modelling

The differences in the composition of the atmosphere over the globe, and the several short- and long-term variations in this composition, are the net effect of several atmospheric and biospheric processes: biospheric emissions, atmospheric circulation, atmospheric chemical transformations, and, finally, deposition and its feedbacks (if any) to emissions. The rates of all these processes can also be affected by climate changes. Thus, the global distributions and trends of chemically, radiatively, and biologically important atmospheric species are signatures of the geographic and temporal variations in these controlling processes.

IGAC Focus 6 (Global Distributions, Transformations, Trends and Modelling) addresses this important globally-integrating research area. Distinct from the regional Foci, this Global Focus is concerned with long-term and global coverage of the most important processes regulating the composition of the atmosphere. The various observational Activities under this Focus will utilize fixed sites, aircraft, balloons, and satellites as observational platforms, and will require the cooperation of many nations through international and national programmes. Six Activities currently exist under this Focus. These are dedicated to the worldwide coordination of measurements of carbon dioxide

(Global Tropospheric Carbon Dioxide Network, GLOCARB), lower-atmosphere ozone (Global Tropospheric Ozone Network, GLONET), and other chemical species that drive atmospheric oxidation (Global Atmospheric Chemistry Survey, GLOCHEM); to studies designed to characterize the entire life-cycle of aerosols and their precursor gases (Multiphase Atmospheric Chemistry, MAC); to the development of a Global Emissions Inventory Activity (GEIA); and to Global Integration and Modelling (GIM).

The global network for carbon dioxide is coordinated closely with WMO-sponsored CO_2 monitoring programmes and with JGOFS. Tropospheric ozone measurements are being coordinated closely with the Global Atmosphere Watch (GAW) of the WMO and the IAMAS International Ozone Commission.

The goal of the aerosol Activity is to determine the role of the combined chemical and physical processes that control the evolution and properties of atmospheric aerosols relevant to radiative forcing and climate. A series of experiments have been planned to provide the necessary data for the inclusion of aerosols into global climate models, with the first, Aerosol Characterization Experiment-1 (ACE-1), tentatively scheduled for late 1995 or early 1996 in the southwest Pacific. This remote Southern Hemisphere site will provide an opportunity to study the natural marine system, distant from the major sources of anthropogenic perturbation. The second experiment, ACE-2, is planned for 1997 in the more polluted North Atlantic, off the coast of Europe/Africa.

One of the most important scientific tools used in the assessment of atmospheric chemistry, air quality and climatic conditions of the past, present and future is mathematical models of transport and transformations in the atmosphere. These models rely in part on inventories of emissions constructed on appropriate temporal and spatial scales and including the required chemical species. The ultimate goal of the Global Emissions Inventory Activity (GEIA) is to establish emissions inventories for a number of trace species, incorporating fluxes from both anthropogenic and natural sources, with recognized accuracy and enough spatial, temporal and species resolution to serve as standard inventories for the international scientific community.

The modelling Activity (GIM) is concerned with global integration and modelling of the composition of the atmosphere for predictive purposes. The transport modelling part of this work is presently being carried out through cooperation with WCRP in order to construct realistic 3-D models. Increasing cooperation will occur with GAIM as that effort develops.

Fundamental activities

All the above Foci of IGAC have important common structural elements which form IGAC Focus 7, the Fundamental Focus. One element is laboratory determinations of fundamental chemical properties including photon absorption cross sections for key species, reaction rate constants, homogeneous and heterogeneous reaction mechanisms, mass accommodation coefficients, etc. Another element is new instrument development where major challenges are provided by the need to measure highly reactive free

radicals and a wide variety of key species at very low concentrations. A third element is education both to increase the number and capabilities of scientists contributing to the Core Project, and to inform the public of the rationale, goals, objectives, and accomplishments of the project. This will partly be done in collaboration with START.

Three of the four Activities within this Focus (Methane and Halocarbons Intercalibration Experiment, MEHALICE; Non-Methane Hydrocarbon Intercomparison Experiment, NOMHICE; and Carbon Dioxide Intercalibration Experiment, CARBICE) are devoted to the development of the most accurate calibrations for atmospheric measurements and the adoption of compatible measurement systems through a series of intercalibrations and intercomparisons. Of particular concern here are calibrations for methane, carbon dioxide, and several halocarbons and nonmethane hydrocarbons. These continuously ongoing major efforts require international cooperation in order to ensure that globally consistent field data are obtained over the long-term.

The education Activity (Atmospheric Chemistry Education in Global Change, ACE) is now in an early planning stage. It is aimed at encouraging practising scientists to participate in, and contribute to, studies of global issues and to the training of students in multidisciplinary aspects of global change, so that they may contribute their own areas of expertise to the accomplishment of IGAC goals. A particular emphasis of this Activity initially will be on developing countries. Plans are being formulated to offer PhD-level education through "twinning" of institutions in developing and developed countries (partly in collaboration with START), to conduct series of intensive courses for advanced training of technical people, and to present seminars and workshops on the role of a changing atmosphere for global change to policy makers and to the general public.

Implementation and timetable

Many of the Activities involve common modes of investigation, some of which (e.g., campaigns) may involve the use of measurement platforms and teams sequentially in several Activities. Figure 6 summarizes the implementation modes of IGAC Activities. The majority rely heavily on intensive, campaign-style field sampling programmes that require sophisticated, expensive platforms such as research aircraft and ships. Several Activities also emphasize long-term series of network measurements of atmospheric trace species, while others are (or will be) concerned with laboratory work, theoretical/modelling studies, education, and database development.

Implementation of IGAC is achieved through cooperation between national funding agencies. Timetables for accomplishment therefore represent a convolution of scientific priority, available technology and manpower, and expected levels of national funding. Work in several Activities is now well underway, while in other Activities it is about to begin. Figure 7 summarizes the envisioned timetable for IGAC Activities in the 1994 - 1998 timeframe. The structure follows that of the implementation modes given in Fig. 6. For Activities with a campaign or network emphasis, only field aspects are included. Short segments within the campaign indicate specific intensive field sampling

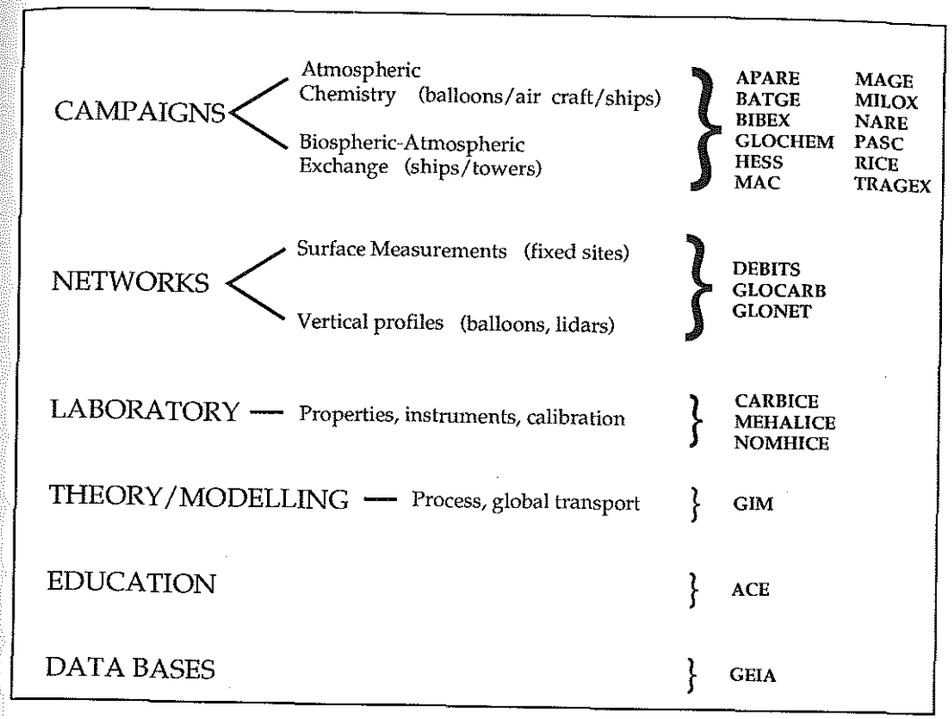


Figure 6. Implementation modes of IGAC

studies, while arrows indicate longer-term efforts. It must be noted that because of the shortness of current funding cycles (2 - 3 years) compared with the time period of this Five Year Plan, entries after 1995 must be considered tentative.

The products of IGAC research have been and will continue to be presented via the customary mechanisms of major scientific conferences sponsored by such organizations as the European Geophysical Society and the American Geophysical Union, followed by publication in the peer-reviewed literature. In addition, IGAC plans to arrange its own Scientific Conferences, usually in cooperation with other organizations. The first such joint effort, with the Israel Institute for Biological Research, was held in April, 1993. Papers presented during that conference will appear in a book and in a special issue of the *Journal of Geophysical Research - Atmospheres* by mid-1994. The Second IGAC Scientific Conference will be held in conjunction with the Eighth CACGP Symposium on Global Atmospheric Chemistry in Japan in early September, 1994, with papers to be published subsequently in *Atmospheric Environment*. Preliminary planning is underway with the WMO for a Third IGAC Scientific Conference in China during the second half of 1995.

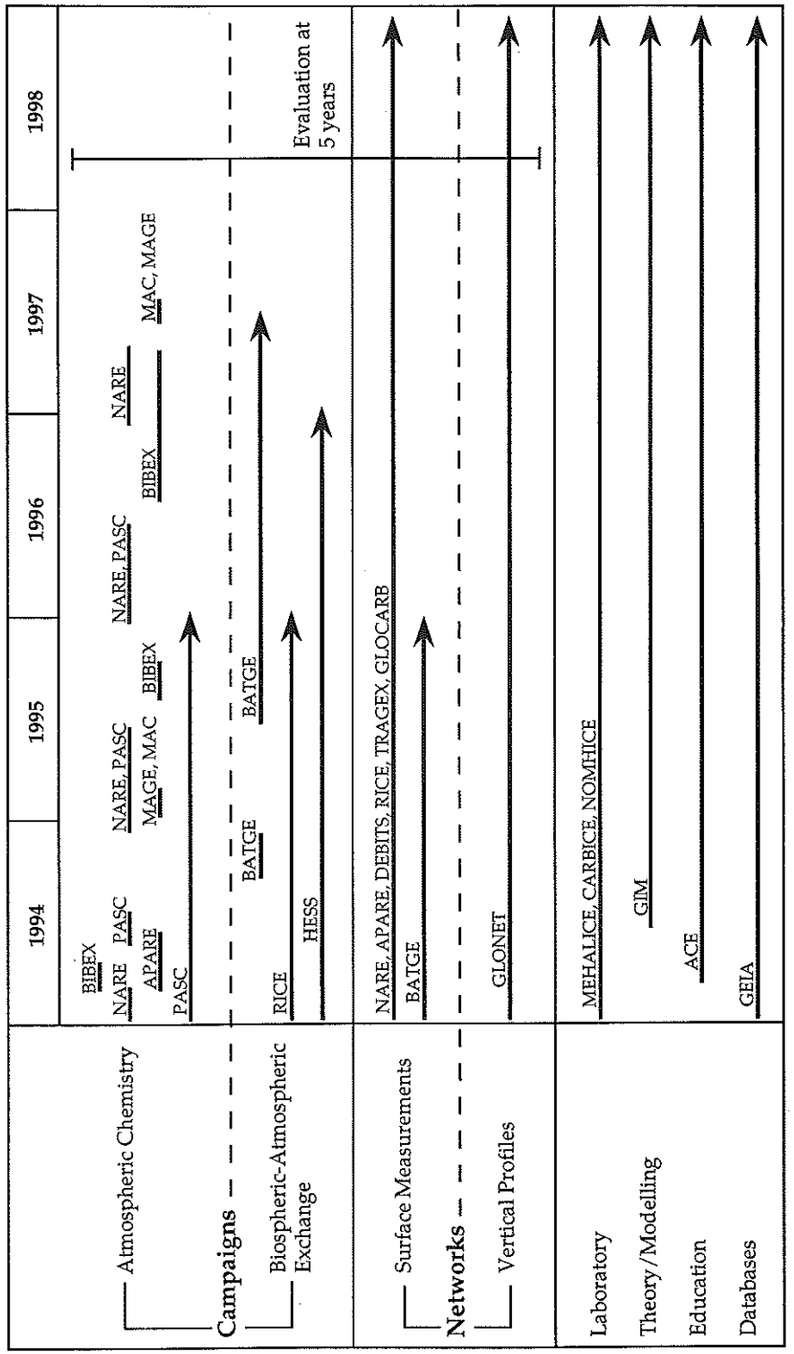


Figure 7. Timeline of IGAC activities

Joint Global Ocean Flux Study (JGOFS)

Introduction

Ocean biogeochemistry strongly influences the global cycling of many elements essential for life. JGOFS, jointly supported by IGBP and SCOR, focuses on the exchanges of carbon within the ocean and across its boundaries, examining the roles of ocean biology and chemistry, and how biology and chemistry are affected by ocean circulation and other physical forcing factors.

The need for improvements in our understanding, and quantitative accuracy, of ocean carbon fluxes is evident from their consideration in the context of the global carbon budget. Current estimates of the total (gross) bidirectional exchange of carbon between the atmosphere and oceans range from 40 to 90 gigatonnes (Gt, 10^{15} g) per year. This should be compared with the 7 Gt of carbon added annually to the atmosphere by human activities, and the current estimates, derived from models, of the net annual ocean uptake (ca 2 Gt per year). Such models involve many simplifying assumptions and are essentially static; they cannot be used to provide reliable predictions as to how the interacting biological, chemical and physical processes affecting the ocean carbon cycle will respond to the changes in ocean circulation and mixing that would inevitably occur if there were significant changes in climate. For a predictive understanding of the behaviour of the ocean system, and its feedback under different climatic scenarios, it is important not only to improve the precision of the net uptake value, defining whether the "missing carbon sink" is on land or at sea, but also to know the larger, gross exchange values and to quantify the factors that influence them.

Objectives

- Determine and understand, on a global scale, the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the ocean, and to evaluate the related exchanges with the atmosphere, sea floor and continental boundaries

- Develop a capacity to predict on a global scale the response of oceanic biogeochemical processes to anthropogenic perturbations, in particular those related to climate change.

In the JGOFS Implementation Plan (1992), these objectives were re-stated as an operational goal, toward which JGOFS will address its research in the 5 year period, 1994 - 1998:

- Assess more accurately, and understand better the processes controlling regional to global and seasonal to interannual fluxes of carbon between the atmosphere, surface ocean and ocean interior, and their sensitivity to climate changes.

Organization of Research

Six categories of products have been defined to assist in the further development of the project, and focus effort during its main implementation phase:

(i) An assessment of large-scale carbon fluxes, obtained from a greatly increased network of observations made using the JGOFS Core Measurements following well-defined protocols

(ii) A set of models that express our understanding of the processes controlling large-scale carbon fluxes

(iii) A procedure for observing the ocean in a routine, synoptic manner to detect possible changes in the ocean carbon cycle in response to climate change.

(iv) A well-cared-for data set, comprising results from observations made according to standard procedures, and a system for making subsets of these data easily available to researchers

(v) Understanding of fluxes across continental margins, to provide reliable boundary conditions for global models

(vi) An increased number of countries with an interest and skill in planning JGOFS-type activities and making the appropriate measurements and global-scale inferences.

Current ocean models suggest a net annual flux of 2 Gt carbon from the atmosphere into the ocean. Current estimates of the total (gross) bidirectional exchange of carbon between the atmosphere and oceans range from ca 40-90 Gt/yr. Thus about an order of magnitude improvement is needed to resolve the net oceanic CO_2 uptake. A global average air-sea pCO_2 difference of 8 ppm is required to drive the net flux. JGOFS ultimately must resolve our annual, global estimates of delta-pCO_2 to, say ± 2 ppm, against considerably greater spatial and temporal variability.

A three-part observational strategy has been developed to meet these operational goals, involving global surveys including satellite observations, time series observations and regional process studies (Fig. 8). Other necessary components of the JGOFS effort to achieve global synthesis are data management and data interpretation, the latter primarily through modelling. Timing of planned activities are shown in Fig. 9.

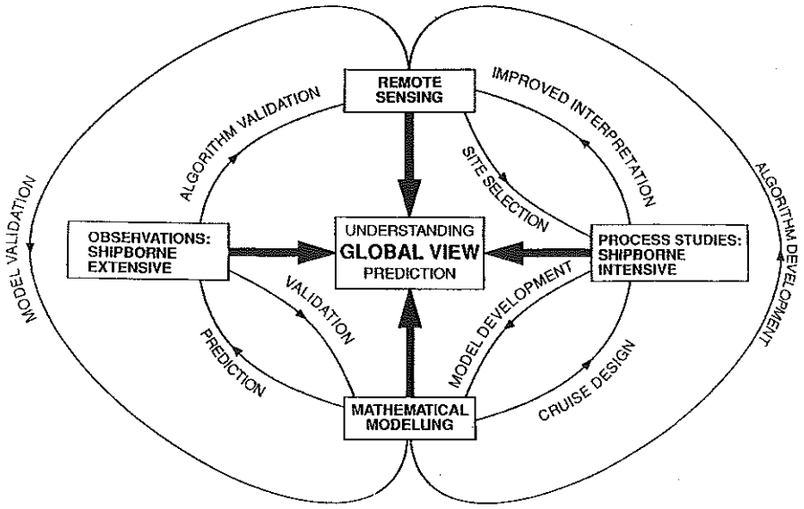


Figure 8. Organizational chart for JGOFS

Work Plan

JGOFS began its field programme in 1989, in the North Atlantic. Since then further intensive studies have been initiated in the Equatorial Pacific, the Southern Ocean, the Arabian Sea and continental margin regions; in addition, a number of time-series stations have been established, large-scale surveys have been conducted, and a considerable amount of modelling work is now underway.

Regional process studies

Detailed and intensive studies of key ocean regions are of central importance to JGOFS; they provide the datasets covering many variables that are needed to understand the structure and functioning of processes that determine carbon fluxes, and their control by physical forcing on a timescale from days to years. From the experience of the North Atlantic Bloom Experiment, with its main fieldwork in 1989 and 1990, a five-year schedule has been adopted for subsequent process studies with major international involvement, with their coordination under the guidance of the JGOFS SSC:

Year 1 Formation of national and international planning groups; national and international planning workshops, announcements of opportunity

Year 2 Planning meetings; ship needs identified; modelling workshop; completion of overall scientific design

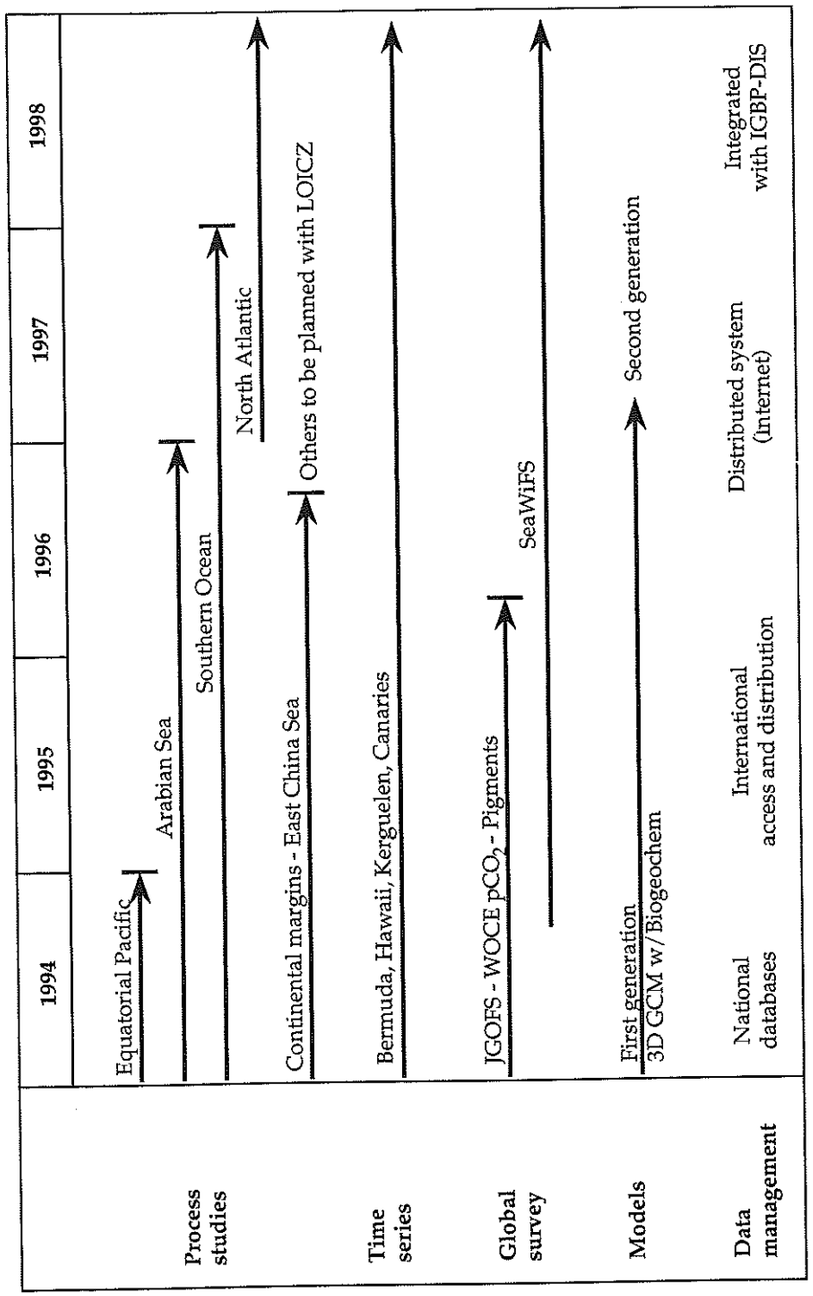


Figure 9. Timeline of JGOFS activities

Year 3	Planning meetings for individual science components; earliest start to the field programme
Year 4	Main field programme, providing seasonal coverage for as many as possible of the JGOFS Core Measurements
Year 5	National and international data workshops; major international scientific conference; second modelling workshop. Some field studies may also be continued, but with coordination on a national/regional basis.

Summaries of the implementation status of the main, current JGOFS process studies follow. All JGOFS process studies include deep coring components, providing links to PAGES.

Equatorial Pacific. Formal planning for EQPAC began in 1989/90, with an extended period of intensive study over the period 1992 - 1995 (because of the very large area under investigation, and the importance of studying interannual variability) and ship deployments by Australia, France, Japan and the USA (with research groups from other nations also participating). An International Symposium on the Tropical Pacific will be held in Hawaii in July 1994, reviewing JGOFS results to date, in collaboration with IGAC and the WCRP Tropical Oceans and Global Atmosphere (TOGA) and WOCE projects. This region is important not only because of the effects of the El Niño-Southern Oscillation, but also because it is the largest oceanic source region for CO_2 and there is a large, unused nutrient pool. This pool, if utilized fully to support primary production, can result in increased storage of atmospheric CO_2. Novel experimental techniques, used off the Galapagos Islands in 1993, have shown the importance of iron as a limiting micro-nutrient; these studies may be continued in the Southern Ocean in 1995.

Arabian Sea. Formal planning began in 1991, with preliminary cruises in 1991 and 1992 and the main field phase in 1994 - 1995 (with special attention to SeaWiFs calibration, linked to aircraft overflights). Participating nations include Germany, India, Kenya, the Netherlands, Oman, Pakistan, the UK and the USA. Preparation has included training courses in Mombasa, Muscat and Karachi, in cooperation with the IOC. Time series stations (visited quarterly) have been established by Pakistan, and are being set up at Gazi, Kenya; an Oman site is also under consideration. Aspects of particular interest include the intense seasonal variability in the region (monsoon reversals), the contrasting biogeochemical provinces, the role of the region as a net source or sink of CO_2, and the effect of the mid-water oxygen minimum on biogeochemical cycling within the water column. An international symposium on the Arabian Sea will be held in 1996 to review scientific progress, in collaboration with WOCE and the SCOR Global Ocean Ecosystems Dynamics (GLOBEC) project.

Southern Ocean. Formal planning began in 1990, with a modelling workshop in 1991. For logistic reasons, the field programme is in two phases: in 1992 - 1994, the emphasis is on large-scale mapping and initial process studies, to provide spatial and temporal information on CO_2 exchanges, regional patterns of stocks and fluxes and a preliminary

assessment of the role of sea-ice in biogeochemical cycles. In 1996 - 1998, coordinated international surveys and studies will use the models developed in Phase 1 to test specific hypotheses, and to improve the quantification of fluxes within and between sub-systems. Participating countries include Australia, France, Germany, Japan, the Netherlands, New Zealand, South Africa and the USA. Collaborations with the ICSU Scientific Committee on Antarctic Research (SCAR) and GLOBEC are being developed. Improved knowledge of carbon fluxes in the Southern Ocean, and its spatial and seasonal variability, is essential for global carbon budgets; the responses of that region to past and future climate change (involving changes in sea-ice cover) are also critical for global biogeochemical models. As in the Equatorial Pacific, there is, under current conditions, a large pool of unused nutrients. An international symposium is planned for 1997, for presentation of results from the first phase of the Southern Ocean study.

North Atlantic. Data analysis from the initial North Atlantic Bloom Experiment (NABE) is now nearing completion. A special volume of Deep Sea Research, with over 30 papers and 120 authors, has been published (1993) and a second volume is in preparation. Production of a merged dataset on diskette and/or CD-ROM will be completed in 1994, for international distribution. Principal Investigators will also have access to additional distributed data systems through their own work stations. Formal planning for a second major international study in the North Atlantic began in 1993. This study, scheduled for 1996 - 1998, will extend seasonal, interannual and geographical coverage by making full use of SeaWifs data, the time series datasets from Bermuda and the Canaries, and the results from the nationally-coordinated cruises carried out in the period 1991 - 1995. Nations participating in the planning phase include Canada, France, Germany, the Netherlands, UK and USA. The objective is to develop robust basin-wide models of carbon fluxes, and their influence by physical factors, in this biogeochemically important region (providing a major sink for CO_2, and, on a glacial/interglacial timeframe, highly susceptible to circulation changes). Planning has begun with IGAC on a joint experiment addressing the role and importance of atmospheric nutrient inputs.

Continental margin studies. A joint JGOFS/LOICZ Continental Margins Task Team was set up in 1992 to assist in the coordination of national and regional studies focusing on boundary fluxes at the continental margin, in various ocean regions. Much of this work is on-going, under national JGOFS or related programmes, and that effort will be further developed in 1994 - 1998. Continental margins of particular interest include the North West Pacific (East China Sea, Yellow Sea, Sea of Japan and Okhotsk Sea); the southeast Asia Archipelago; the European continental margin; and areas of strong upwelling, e.g., off the coast of Peru and Chile, Namibia and South Africa, north west Africa and the Somali basin. Within these studies, lateral transport processes and the role of sedimentation rates on carbon burial receive special attention.

Time series observations

JGOFS time series studies provide full seasonal coverage over several years for measurements of key properties and processes. Since research cruises for intensive study are generally limited to a few weeks, time series observations are essential to give flux estimates free of seasonal bias - and to reveal other patterns of long-term variability. Thus the time series datasets play a vital role in assisting model development, by constraining parameter values and providing data for model testing and validation. JGOFS time series stations off Hawaii and Bermuda were both established in 1988, with monthly sampling according to internationally agreed protocols. Data reports are published annually, and those observations will be continued until at least 1998 (with some upgrading; e.g., with regard to increased use of automated sensors for continuous measurement of pCO_2, nutrients and other variables).

Additional JGOFS time series stations off Kerguelen Island (South Indian Ocean/Southern Ocean) and the Canary Islands are currently being initiated, and are expected to be fully operational in 1994. Observations at the Kerguelen site will build on a background of WOCE measurements (since 1990), sediment trap deployments (since 1992) and other relevant studies in the region. Time series stations provide ideal sites for sampling the marine atmosphere and thus interaction with IGAC. This has already been initiated at Bermuda.

Global survey

In concert with the hydrographic programme of the WCRP World Ocean Circulation Experiment (WOCE), JGOFS is making large-scale measurements of oceanic carbon system properties (pCO_2, TCO_2, pH, and alkalinity) covering all major ocean regions. These studies began in 1992 and are scheduled to be completed by 1995; their interpretation will be aided by the additional physical data collected at the stations along the WOCE hydrographic transects. In addition, observations of plant pigments and ocean optical properties will also be made on a more limited number of WOCE and WOCE-related cruises, with that collaboration continuing until ca 1998. An increasing number of JGOFS cruise ships now have the capability to make continuous, underway measurements of pCO_2, nutrients and other chemical variables, and also to determine pigment profiles and optical properties whilst on passage, thereby obtaining additional datasets and maximising the scientific benefit from process-study cruises. JGOFS researchers are closely involved in the development of automated sensors for such work, with JGOFS support provided through the workshop meetings and intercalibration studies, e.g., by the JGOFS/IOC Panel on Carbon Dioxide.

These surveys will collectively refine our maps of the spatial distribution of the air-sea pCO_2 difference, as used in modelling studies to estimate net global oceanic CO_2 uptake. In addition they will, together with the other studies described below, contribute to our understanding of the factors affecting the variability in those measurements.

Satellite observations

Data from the Coastal Zone Colour Scanner (CZCS) sensor, operational over the period 1978 - 1986, played a formative role in the development of JGOFS, giving a global perspective to many aspects of ocean biogeochemistry. That dataset is still being used; however, attention is now primarily focused on the Sea-viewing Wide-field-of-view Sensor (SeaWiFS), due for launch by the National Aeronautics and Space Administration (NASA) in 1994. SeaWiFS will provide global, daily observations of surface ocean colour, an indication of phytoplankton biomass; these data will be assimilated into numerical models of ocean biogeochemistry and ecology, and together with data from other satellite sensors (on sea surface temperature, surface wave field, surface winds and sea ice) will be used to make global estimates of primary production and air-sea carbon fluxes. However, the satellite data requires "sea truth" calibration and validation, to develop reliable algorithms for its interpretation. JGOFS researchers have been closely involved in SeaWiFs preparation studies, and research cruises in the Arabian Sea, the Pacific Ocean and other ocean regions in 1994 and 1995 are scheduled to give special attention to optical studies, with near real-time access to SeaWiFs data.

Modelling and data interpretation

The most important product of JGOFS will be the models that will define the current biogeochemical state of the ocean and predict its future evolution in response to global warming and other externally-imposed changes. Modelling work within JGOFS member nations is coordinated through a Task Team and a series of modelling workshops. To date, these have mostly been associated with the regional process studies, as mentioned above. A separate Task Team on Global Synthesis is building towards large-scale, long-term integration of shipboard and remotely sensed data, to develop global models in collaboration with GAIM and other IGBP Core Projects.

The global synthesis will be based on a hierarchy of process models ranging from low-detail, aggregated box models, to high detail, 3-D ocean-atmosphere general circulation models, with explicitly formulated biogeochemical processes, and a variety of models for deriving estimates of primary production from ocean colour data. Much of this global synthesis will occur after 1997, when most of the observational programmes have been completed. However, individual, project-based interpretive activities will take place during and after each major process study.

Data management

To achieve global data synthesis, JGOFS will continue to direct considerable effort to the development and implementation of a comprehensive data management, distribution and archiving system. The prototype system has been developed in two stages from the NABE. The first stage involved national collection and quality assurance of project data (based on a suite of agreed "core measurements", with internationally-accepted measurement protocols), followed by merging into common-format files and

distribution on diskette and/or CD-ROM. In the second stage, a distributed data management system, based on UNIX workstations interconnected over Internet, will provide access to data help on individual Principal Investigators' computers.

As noted above, those stages are nearing completion for the NABE datasets. Work on the Equatorial Pacific (EQPAC) datasets is underway, with production and distribution of the merged EQPAC datasets, on diskette or CD-ROM, scheduled for 1995. Similar procedures will be followed for the Arabian Sea, Southern Ocean and second North Atlantic studies.

Inter-project links and capacity building

To facilitate cross-cutting exploration of themes with Core Projects closely related to JGOFS, inter-project Task Teams have been established with LOICZ (Continental Margins Task Team) and IGAC (Biogeochemical Ocean-Atmosphere Transfers Task Team). Collaborative links with PAGES are currently being developed. JGOFS addresses the ocean components of the global carbon cycle; whereas GCTE and IGAC address the terrestrial and atmospheric components, and PAGES the historical dimension. GAIM is a vehicle for synthesis of the results from these studies into new views of past, present and future carbon budgets.

Development of national capabilities to make JGOFS measurements and plan and execute JGOFS observational campaigns is currently being achieved through promulgation of the JGOFS Protocols and Data Management Systems, and by organizing, with IOC support, a series of instructional workshops on methodology.

Land-Ocean Interactions in the Coastal Zone (LOICZ)

Introduction

The exploitation of many coastal areas and ecosystems is presently so intense and so weakly regulated that major economic investment will be required for their maintenance and restoration, particularly in relation to the impacts of modifications to coastal ecosystems, rise in sea level and changes in the climate system. The creation of long-term policies for sustainable coastal management requires a predictive understanding of the impacts of changes in climate, land-use and sea level on the global functioning of coastal systems.

The world-wide data on types, rates and in some cases causes of change to coastal ecosystems are inadequate, largely due to a lack of suitable means for data collection and analysis. Improved information on the dynamic properties and present state of coastal systems and on feedback processes that result from natural and anthropogenic modifications is required. New methods to simulate and predict, over decadal time scales, the response of the coastal zone to global change will have to be developed and implemented in order to guide the formulation of rational and integrated long-term economic and social policies for the sustainable use of the coastal zone. Such policies must be based upon a better knowledge than presently available of ecological, biogeochemical and biogeomorphological processes in the coastal zone and of the factors that determine patterns of resource exploitation by humans.

In the context of the LOICZ project, the coastal zone is considered from two perspectives:

- As an integral part of the Earth System which contributes significantly to global biogeochemical cycles and their interaction with climate
- In relation to the sustainability of living resource use and the capacity of these resources to support the needs of human populations under conditions of strong exploitation and fluctuating climate and sea level.

The coastal zone is broadly defined as the region extending from the landward sides of the coastal plains to the outer edges of the continental shelves, approximately matching the area of the Earth's surface which has been alternately inundated and exposed as a result of sea level changes during the late Quaternary glacial and interglacial cycles.

Objectives

The long-term objectives of LOICZ are to:

- Determine at regional and global scales:
  - The fluxes of material between land, sea and atmosphere through the coastal zone
  - The capacity of coastal systems to transform and store particulate and dissolved matter
  - The effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems
- Determine how changes in land-use, climate, sea level and human activities alter the fluxes and retention of particulate matter in the coastal zone, and affect coastal morphodynamics
- Determine how changes in coastal systems, including responses to varying terrestrial and oceanic inputs of organic matter and nutrients, will affect the global carbon cycle and the trace gas composition of the atmosphere
- Assess how the responses of coastal systems to global change will affect the habitation and usage by humans, of coastal environments, and to develop further the scientific and socio-economic basis for the integrated management of the coastal environment.

Project Organization

The four objectives of the LOICZ Core Project define four corresponding Foci of research, each of which includes a number of activities that relate to specific issues of global change in the coastal zone. Three types of basic research are required to elucidate key aspects of coastal system dynamics:

- The acquisition of extensive observational data sets for key environmental parameters in order to establish the significance of coastal processes in determining the global distribution of these parameters
- Intensive process studies and development of models in order to understand how coastal systems behave with respect to changing environmental conditions
- Modelling of catchment and coastal systems to simulate and predict over a range of space and time scales the effects of global change on the land-ocean interface.

Work Plan

The Project Office will contact IGBP National Committees to initiate an inventory of existing national research activities relevant to LOICZ. Work will commence on the compilation of a register of national coastal zone research programmes relevant to LOICZ, which will be computerized in a format suitable for searching by region, activity and field of interest. A system will be developed for division of the world's coastlines into major functional units as the basis for operationalising LOICZ activities on a regional basis.

As the Core Project science plan was approved only in 1993, the work plan is illustrative rather than comprehensive, given that the full operational plan has not yet been developed. It is anticipated that the operational plan will be published by the end of 1994, at which time the Work Plan will be revised and brought into line with the major directions defined by the operational plan. This will also include considerations of how LOICZ research elements link to other component parts of the IGBP as well as other partners (Fig. 10).

For 1994, the primary task is to complete and publish the operational plan. A full draft will be considered by the SSC in June. A series of small workshops will be convened to amplify the objectives and timetable for implementation of each of the four foci and for the preparation of an initial global data set on riverine inputs to the coastal ocean. A tentative timeline is given in Fig. 11.

The effects of changes in external forcing or boundary conditions on coastal fluxes

Within the first Focus, three levels of research are proposed, each of which will be linked to activities within the BAHC Core Project.

The first level is to construct mass balance budgets of key variables such as water (river runoff, precipitation, and salinity distributions along-shore, across the shelf and at the shelf break); sediment (including re-suspension and flocculation processes); carbon (inorganic and organic forms); nutrients (in particular ammonia, nitrate, phosphate, and silica). The mass balance budgets ideally should cover the key variables for all types of coastal regions of the world, and will act as an important constraint for the interpretation of the results of independent analytical and modelling studies (see below). The relative importance of riverine, groundwater and atmospheric transport processes will need to be carefully defined.

The second level involves hydrological or ecosystem analyses of, for example, organic carbon fluxes for a range of types of catchment-coastal units. Such analyses will enable the relative effects of different forms of environmental forcing on the transport and transformation of matter within catchment systems and at the land-ocean boundary to be investigated.

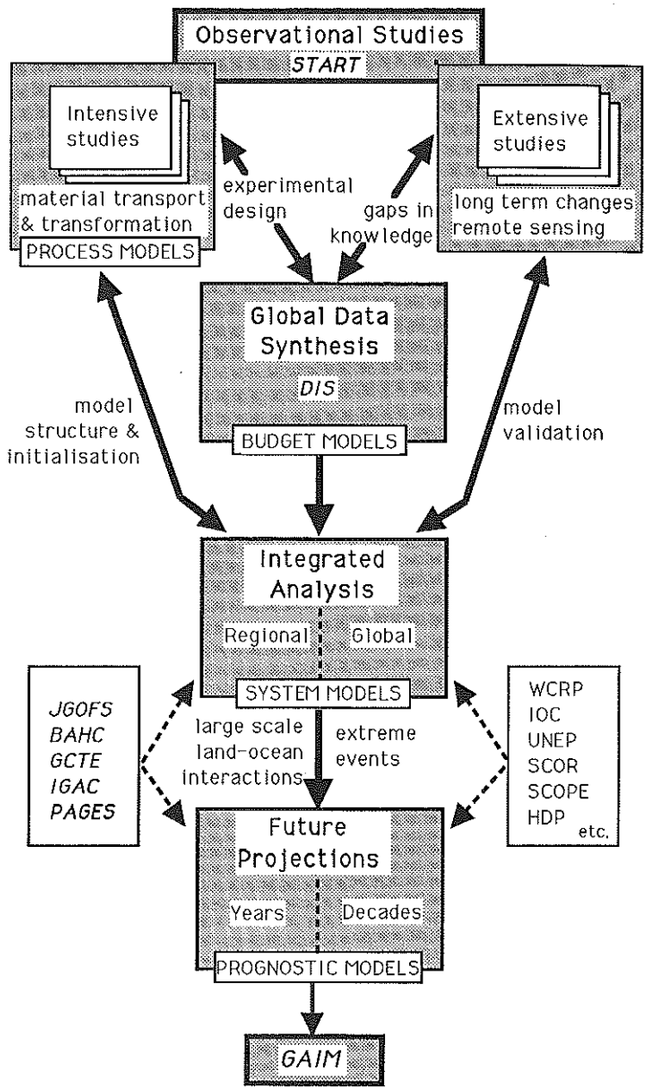


Figure 10. Research elements of the LOICZ project, and their links with other projects and programmes

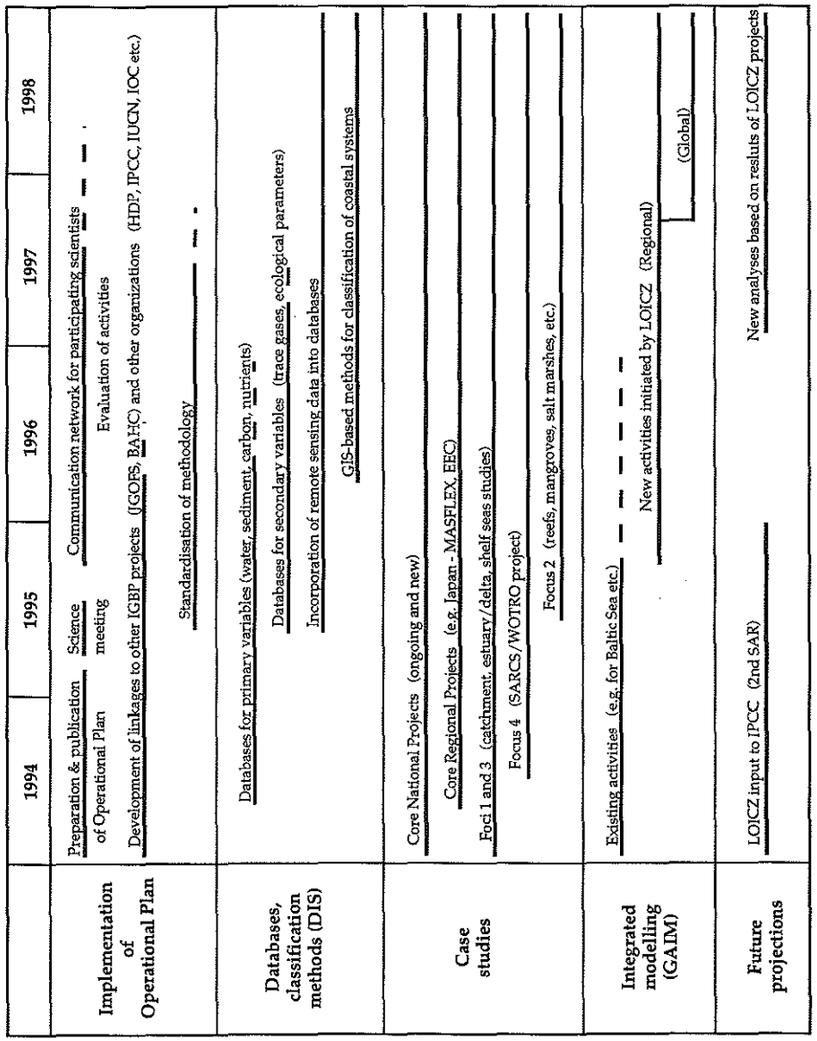


Figure 11. Tentative timeline of LOICZ activities

The third level is the development of dynamic models that simulate the state of coastal systems in response to changes in water (both freshwater input and ocean exchange), sediment loading and nutrients. These are the models that will offer predictive capacity under different environmental conditions. Regional ecosystem models, developed for representative coastal habitat types around the world, would form the basis for developing global scale predictions of the future ecological conditions in the world's coastal zones.

Given the nature of LOICZ, the models must have a large spatial domain, although they can be divided into different spatial compartments as necessary, to represent habitat components of quite different properties (intertidal areas, estuaries, reefs, fishing banks, etc.). The models must also have a broad enough temporal domain to incorporate events with a periodicity of 10 - 100 years and because of their broad and comprehensive nature, will only be able to represent the biological system in highly aggregated state variables (e.g., detritus, bacteria, phytoplankton, zooplankton, benthos, demersal fish, etc.). It will not be possible to model global change effects at the species level.

At the outset of modelling, the Earth's coastal zone should be divided into a number of functional geographic units based on characteristics such as inputs of freshwater and of tidal and wind energy, seasonal differences in climate, fluxes of material from land, coastal vegetation type and frequency of episodic environmental events. This information will be incorporated with other data into a GIS and the boundaries between the geographic units will change as new data are added.

Coastal biogeomorphology and sea level change

Focus 2 addresses the relationship between biogeomorphology and sea-level change, which involves the important feedback mechanism operating between coastal biotic communities and the physical environment. A major thrust will be to study the interactions between various sediment sources and sinks, changes in sea level, climatic and hydrodynamic factors, and biological processes as a basis for developing models that incorporate over a range of scales the effects of the biota on coastal morphodynamics.

A database will be compiled superimposing habitat types on a basic framework of river input, tidal energy, and wave energy for various coastlines. Thus, for instance, deltas may be further subdivided on a climatic basis, recognising tundra, temperate salt-marsh and tropical mangrove habitats on a gradient of latitude and temperature; and increasing biodiversity within these habitats on a precipitation gradient. Mangrove-covered deltas in arid settings may be flanked by salt flats; in wetter environments basins between rivers may be entirely covered by mangroves; and in very wet settings there may be extensive freshwater wetlands, and peat swamp forest. These habitats, differing in complexity and extent according to climate, will also differ in terms of their dynamics as they respond to, and influence, the natural dynamics of the sedimentary environments. Intertidal and subtidal benthic organisms also play an

important role in the feedback between the biotic and physical environments in coastal systems, and should also be incorporated within the database.

The Holocene sedimentary record for the past 3,000 years, during which sea level has been relatively constant, is a source of information for LOICZ in two respects: it can provide an indication of the sources of long-term sediment input into the coastal zone, (from land or sea) and an indication of changes to boundary conditions and forcing factors (see Focus 1). Case studies will be undertaken in situations where there has been a major alteration to the coastal system. For example, the effect of past sea-level changes will be described where they can be documented and the impact of human activity will be examined in systems where anthropogenic alteration of boundary conditions has occurred, as in the case of dammed rivers. These activities will be developed in close cooperation with PAGES.

Ecosystem responses to sea level change in terms of the supply (e.g., biogenic carbonates), cohesiveness and trapping of sediments within different types of coastal systems will be incorporated into models of biogeomorphological processes. Such models should lead to more reliable predictions of the impacts of sea level rise for a range of conditions of human disturbance. The priorities under Focus 2 will be further elaborated during a workshop on mangrove biogeomorphology and in collaboration with a workshop being organized by IUCN in Belize centring on carbonate coastlines.

Carbon fluxes and trace gas emissions

In an investigation of the carbon cycle, its fluxes and its dominating processes in coastal areas, Focus 3 of LOICZ will quantify a major component of the global carbon cycle (possibly a sink of several tenths of a Gt of carbon per year is associated with coastal seas); assess ecosystem productivity; and map rates of organic carbon deposition in shallow marine sediments.

In order to quantify the global carbon cycle in coastal seas, LOICZ will initiate case studies in collaboration with JGOFS and will assemble a global GIS-based data base allowing interpolation over biogeochemically similar regions of the ocean margin. Linkages between JGOFS and LOICZ will be further strengthened on the basis of the conclusions and recommendations of the joint JGOFS/LOICZ Continental Margin Studies Task Team.

In collaboration with IGBP-DIS, LOICZ will define the structure of the GIS database. During 1994, a project proposal will be developed in collaboration with IGBP-DIS to construct a global database which will encompass the archiving of information within a GIS system, a methodology for coastal classification, and the retrieval of atlas products. Algorithms will be developed or improved for automatic evaluation of satellite images in terms of coastline length and type, total areas of deltas, mangroves, tidal flats, lagoons, reefs and river sediment and gelbstoff plumes, points of freshwater input and other quantifiable parameters. LOICZ will also assemble a carbon-based data base by collecting available data on river transport (e.g., Scientific Committee on Problems of the

Environment (SCOPE/UNEP) river project, Global Environmental Monitoring System (GEMS) data), and carbon concentration in river plumes and in coastal sediments. Case studies will be conducted using high precision measurements according to the procedures of JGOFS to determine carbon fluxes, rates of transformation and concentration distributions in various sites representative of large coastal regions including arctic, temperate, anthropogenically stressed, tropical clear, tropical turbid environments.

Coastal sediments will be sampled in such regions for the distribution and composition of organic and inorganic carbon and sediment deposition rate and age determined. For areas that are already well sampled, maps of carbon distribution and mass balances should be constructed (e.g., for the North Sea, the Baltic Sea, sections of the Mediterranean, the US, the Canadian, the Chinese and the Russian coasts). Priorities for acquiring new data from poorly known regions will be determined.

The global significance of the coastal zone for emissions to the atmosphere of trace gases such as CH_4, H_2O and DMS remains uncertain. Research activities on this topic will be guided by an evaluation of existing information and by the outcome of discussions with IGAC.

Economic and social impacts of global change on coastal systems

Anthropogenic impacts on the environment, such as large scale changes in land use and cover, are accelerating world-wide, affecting the delivery of freshwater and suspended and dissolved matter to the coastal zone. Other anthropogenic impacts include marine resource depletion, and pollution from urban and industrial wastes, which result in changes to phytoplankton productivity and anoxia of the bottom waters of shallow and semi-enclosed coastal areas. Coastal construction and modification of the physical processes occurring along shorelines are increasing, with consequent losses of coastal habitats, changes to circulation and material flux and reduction in biological productivity in coastal areas. Although LOICZ is not directly concerned with management issues, it can provide important scientific information to both management and monitoring activities; this will be done through Focus 4, which will be further developed in close cooperation with the Coastal Zone Sub-Group of IPCC Working Group IIB.

Current management strategies, regulation and control of human activities in the coastal zone are demonstrably inadequate, because socio-economic forces driving change in coastal communities are not well understood and the spatial and temporal scales of socio-economic and natural systems are not congruent. Of importance from the LOICZ perspective is the lack of data and information concerning the functioning of coastal systems and their ability to accommodate and withstand human induced stresses. For example, present knowledge is inadequate for predicting the point at which the ability of coastal systems to accommodate anthropogenic stress will be exceeded, leading to system collapse. Most coastal management is reactive, responding to problems and

conflicts as they arise, rather than proactive, anticipating and avoiding problems through planning based on sound scientific information and understanding.

Focus 4 will document the scale and extent of human interventions in coastal areas under differing conditions of social and economic development, and analyze the present and future impacts of human use on the resources and environments concerned. Case studies will concentrate on:

- Capacity of different coastal systems to support human populations without irreparable environmental damage
- The extent to which species in the coastal zone can support sustainable harvesting
- Coupled biological and physical response of different coastal systems to anthropogenic wastes.

Particular attention will be directed initially towards island environments which represent spatially definable systems and therefore provide more tractable opportunities for modelling human interactions with the coastal zone than do more open continental coastlines. In addition, small archipelagic countries are amongst the most vulnerable to the potential impacts of climate change and sea level rise. Analysis and modelling of the effects of changes to such systems on social and economic activities are likely to provide insights into the effects of changes on social and economic activities in the more complex continental coastal zones.

Land-Use/Cover Change (LUCC)

Introduction

The planning for a Land-Use/Cover Change Core Project has been undertaken in response to the widespread recognition of the significance of land-use/cover changes to a variety of global environmental change issues. These issues include the role of land use and land cover in affecting both the biogeochemical flows and the states or faces of the biosphere/geosphere, and land use "in its own right" as it interacts with human activities that drive and respond to environmental change. LUCC is concerned with understanding the human and biophysical causes of land uses in order to predict and project these changes and their impacts on land cover. In so doing, it should greatly improve the basis on which to understand the use and cover dimensions of potential climate. These interests directly link the IGBP and HDP, which co-sponsor the LUCC effort.

Objectives

- Develop a fundamental understanding of the human and biophysical dynamics of land-use changes and the impacts of these changes on land cover.
- Develop robust and regionally sensitive global models of land-use/cover change with improved capacities to predict and project use/cover changes.
- Develop an understanding of land-use/cover dynamics through systematic and integrated case studies.
- Assist in the development of a global land-use classification scheme.

Organization of Research

Because LUCC is still in a planning stage the specifics of the research plan outlined below may change. The basic aims and thrusts of the work, however, will remain.

Land cover (biophysical attributes of the surface of the Earth) is the product of biophysical forces and human use and management. There are few land covers in the world that are not managed, although some are so lightly managed (e.g., remote alpine valleys, tropical forest frontiers) that they are often referred to as natural. The intensity of management and use is expected to increase for all areas of the world, such that during the next century, few "natural" land covers will remain; rather, most land covers

will be modified or transformed in intended and unintended ways by management and use. To understand changes in land cover, especially to predict and project these changes, requires an understanding of land use and management. And this understanding is predicated on understanding the human and biophysical dynamics that drive land use.

The linkages in question - from human and biophysical drivers to land use/management to land cover - are not sufficiently understood, because of the complexity of dealing with the considerable variations in drivers, use, and cover at subglobal levels, and because most work to date has addressed production sectors involved in land use (timber, livestock and crops), not their cover implications, nor has it addressed spatially referenced outcomes. At this time, global assessments capture broad sectoral trends through the use of several key variables, such as changes in population and markets. Regional models are somewhat more complex but do not link well to generate a global picture, while local case studies not only do not link well to regional and global models, they invariably identify drivers of change different from those in the global models.

LUCC aims to make major headway in rectifying these problems and gaps in our understanding through an initial four or five research Foci. It uses model driven and case study driven approaches (Fig. 12) to enrich our understanding of the linkages in question and to produce regionally sensitive, georeferenced models (Fig. 13) of land-use/cover change - not production sectors *per se* - that can be linked together to create a global model. These two central aims of LUCC are captured in Focus 1 and Focus 2 of the proposed project. Focus 3 involves data collection and monitoring, while Focus 4 is land-use classification. Focus 5 remains under discussion as it aims to address spatial and temporal scale issues that cross-cut land-use/cover change themes.

Work Plan

From planning to Core Project

As noted above, the operational/science plan of LUCC is currently being developed and vetted through the international community. The first half of 1994 will be used to complete the report that will be delivered to the IGBP-HDP for approval (Fig. 14). Given that LUCC is not yet a Core Project and is yet to have an established CPO or funds for that office, it is difficult to offer much more than a possible template for a research schedule at this time. The CPPC has entertained a number of operational possibilities for a LUCC Core Project that it will present to the IGBP-HDP for consideration.

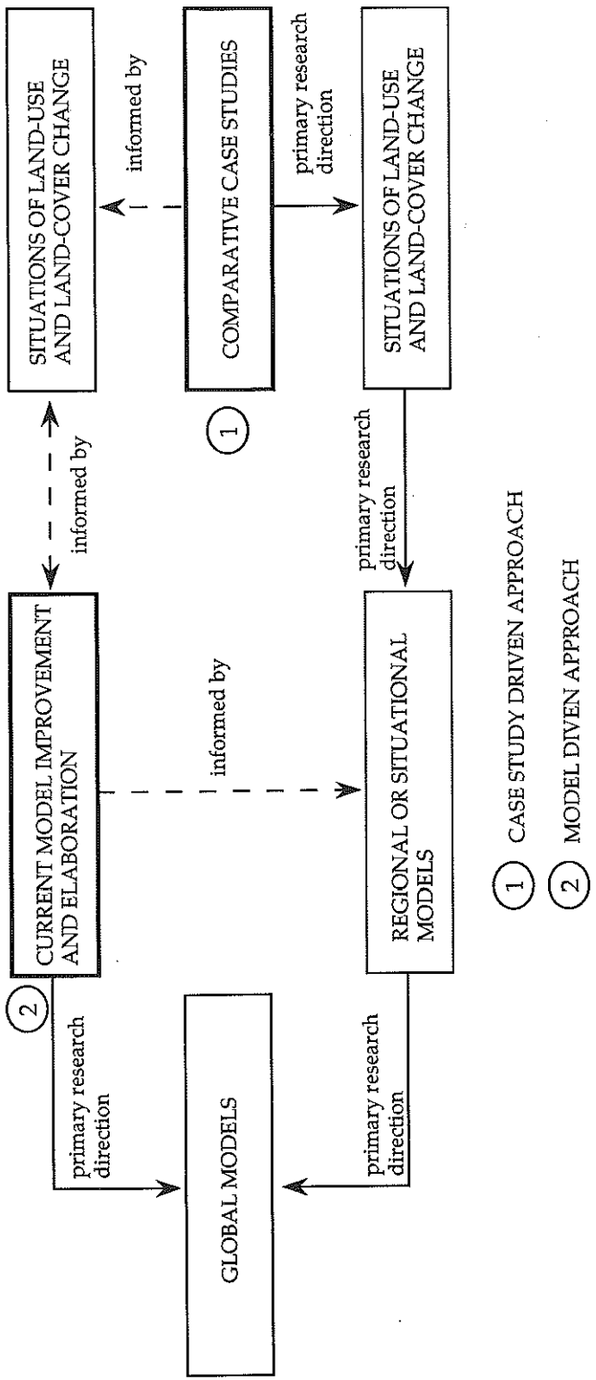


Figure 12. Two approaches to the development of global LUCC models: Focus 1 and Focus 2

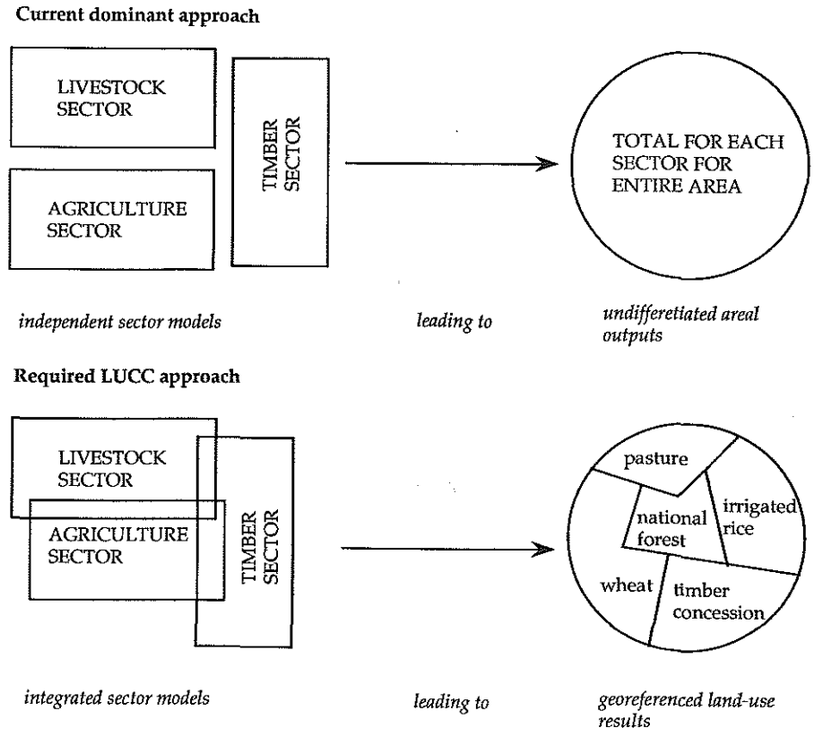


Figure 13. Comparison between current dominant and LUCC approaches to modelling land-use

Case study driven approach

The overall purpose of Focus 1 is to build a firm understanding of the regional dynamics of land-use/cover change through the use of comparative case studies. It is organized on the premise that the land covers of the world can be classified or categorized into sets of common change situations - where common clusters of cause give rise to common patterns of use/cover change - that these situations will be more deeply detailed than those derived from current global/regional models, and that they will provide the basis for the construction of more robust regional and global land-use/cover models.

Several activities will be undertaken to achieve the Focus 1 goals. The first phase involves the development of an internationally agreed upon case study protocol to be administered by interdisciplinary local research teams. The protocol will foster common measures and data that will allow exploration of various empirical and theoretical ways of ascertaining land-use/cover dynamics and patterns of change. The second phase creates a network of research teams applying the protocol locally; this phase will require collaboration with other IGBP Core Projects, to ensure that as much overlap as possible

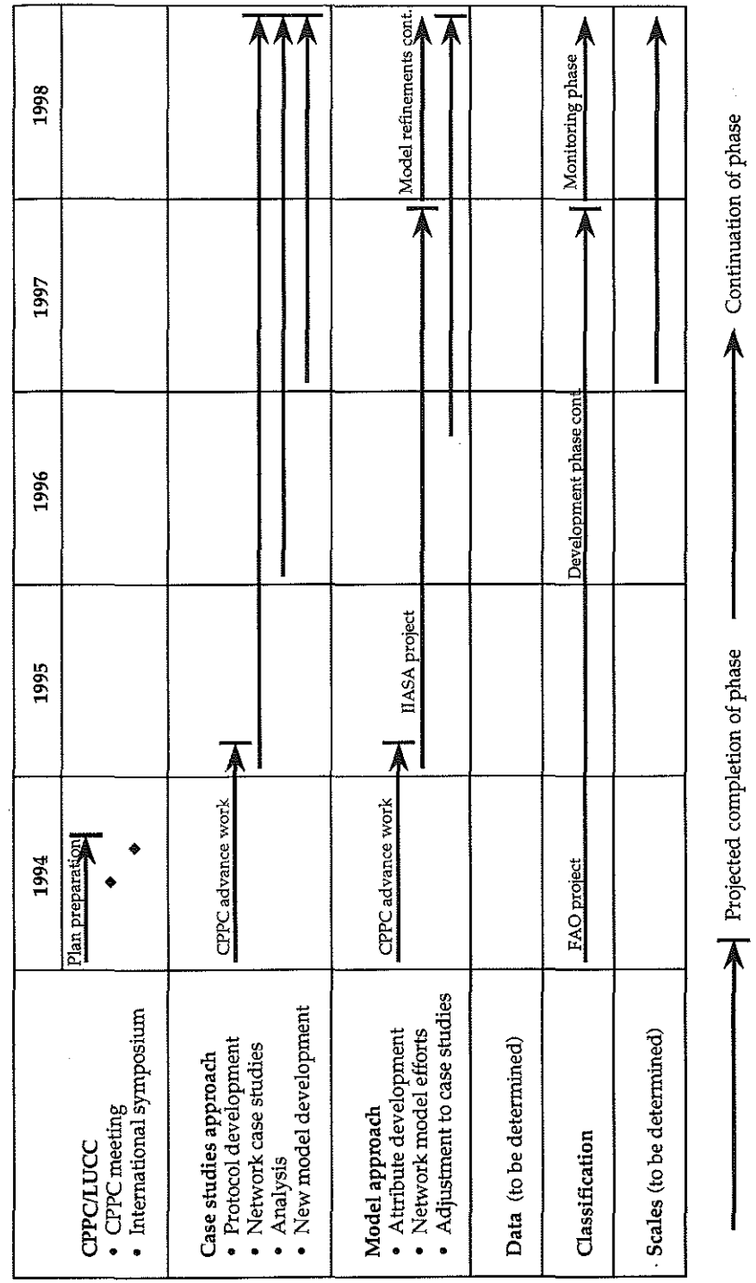


Figure 14. Timeline of LUCC activities

can be made with their case studies. This phase may have an extended life beyond five years, as it is expected that various case studies will be added and dropped through time. The third phase involves analysis and synthesis of the case study output, specifically integrating with Focus 2, the modelling approach, to develop the new models in question.

Modelling approach

Focus 2 aims to improve upon existing global and regional models for two reasons: (i) to provide improved land-use/cover global models over the short term; and (ii) to work on the development of models that predict and project patterns and dynamics of land-use/cover rather than product output from the land. In phase one it will identify the range of models (e.g., empirical to processual) that are useful for the project and develop the specific attributes that these models must have in order to link to other global environmental models. Phase two will involve the development of a network of groups and organizations undertaking to improve global and regional models in these ways, and the coordination of these various efforts to create a suite of improved models. This phase will also draw upon the findings emanating from Focus 1. In phase 3, Focus 1 will integrate closely with Focus 2 in creating the new global land-use/cover models that follow from the case study approach.

Data and monitoring

Focus 3 will be developed in the spring of 1994.

Classification and typology

Work on comparative land-use and global land-use modelling is hindered by the absence of a standard or universal land-use classification, such as exists for soils. This reason alone impedes various analyses that could potentially contribute to the development of LUCC global models. Obstructing the creation of a universal land classification system are the varied demands of users, each of whom requires different attributes of land-use and management to be emphasized. While it may be possible to create a generic classification, it is also important to generate universal georeferenced land-use attributes that would be collected and archived.

Focus 4 will help to develop this classification and attributes. It may work with the forthcoming FAO land-use classification and mapping effort, or be embedded within it. Regardless, its aim will be to help to develop classification schemes relevant to the LUCC effort as well as to identify the critical attributes on land-use that are beneficial for LUCC research.

Linking spatial and temporal scales

It is well documented that as questions about land-use/cover change are addressed at different space-time scales, so the answers vary significantly. More importantly, these answers cannot be adequately linked. For example, the "cause" factors of land-use/cover change identified at the global scale cannot be integrated well with those found at the local level. As a result, coupling local, regional and global models is extremely difficult. Moreover, resolving or making significant advancement on the scales issue will go a long way towards resolving ideological and polemical debates over the causes of land-use/cover change.

The design of Focus 1 and 2 affords a unique opportunity to derive a cross-spatial and -temporal data base and to make analytical advances in addressing many of the queries involved. Focus 5 will address the scales issue. Its activities are yet to be determined, and its full development awaits the implementation and preliminary outcomes of Focus 1 and Focus 2.

Past Global Changes (PAGES)

Introduction

PAGES is the IGBP Core Project charged with providing a quantitative understanding of the Earth's past environment and defining the envelope of natural environmental variability within which we can assess anthropogenic impact on the Earth's biosphere, geosphere and atmosphere.

In order to validate their effectiveness, models intended to predict future environmental changes must be capable of accurately reproducing conditions known to have occurred in the past. Through the organization of coordinated national and international scientific efforts, PAGES seeks to obtain and interpret a variety of palaeoclimatic records and to provide the data essential for the validation of predictive climatic models. PAGES seeks the integration and intercomparison of ice, ocean and terrestrial palaeorecords and encourages the creation of consistent analytical and data-base methodologies within the palaeosciences.

Objectives

The PAGES Project focuses on specific sets of questions and issues:

- How has global climate and the Earth's natural environment changed in the past? What factors are responsible for these changes and how does this knowledge enable us to understand future climate and environmental change?

- To what extent have the activities of man modified climate and the global environment? How can we disentangle anthropogenic-induced change from natural response to external forcing mechanisms and internal system dynamics? What were the initial conditions of the Earth system prior to human intervention?

- What are the limits of natural greenhouse gas variation and what are the natural feedbacks to the global climate system? In what sequence, in the course of environmental variation, do changes in greenhouse gases, surface climate, and ecosystems occur?

- What are the important forcing factors that produce climate change on societal time scales? What are the causes for abrupt climatic and environmental events and the rapid transitions between quasi-stable climatic states which occur on societal time scales?

Organization of Research

The Earth's environmental and ecological systems operate on a wide spectrum of temporal and spatial scales and palaeoenvironmental records are derived from a wide variety of natural archives, such as: tree-rings, lake and ocean sediments, wind-blown deposits, coral and ice cores, as well as historical accounts. The scientific community has recently developed a set of powerful analytical techniques to recover high resolution records of environmental changes from these diverse sources. Through detailed analysis of "proxy" records, it is often possible to distinguish annual changes over time spans of many thousands of years. It has become clear that the power of these techniques would be vastly increased by their coordinated application in multi-proxy studies. It is the task of PAGES to organize the international scientific community to target critical scientific questions, regions and time periods in a concerted effort to produce a coherent and quantitative record of the Earth's natural history.

To that end, the PAGES Project is structured into three research observational Foci, a climate sensitivity and modelling Focus, and a cross-project Focus to address the broad analytical, data and communication needs of the project (Table 3).

The three research/observational Foci address the retrieval of high quality multi-proxy palaeorecords in a global network of field activities. This is an attempt to apply the full complement of operational and analytical methodologies to regions essential for the completion of a coherent global environmental history. Within each of these observational Foci, PAGES has designed two "temporal streams" which address the key scientific questions that are defined by the overarching needs of the IGBP, as well as associated projects of the WCRP and HDP.

The objective of *Temporal Stream I* is to reconstruct the detailed history of climatic and environmental change for the entire globe for the period since 2000 BP, with temporal resolution that is at least decadal and ideally, annual or seasonal. This constitutes the period of man's greatest impact on the planet and the time of significant overlap between written records and the environmental information stored in natural archives.

With at least a century-scale resolution, *Temporal Stream II* will focus on glacial-interglacial cycles of the last several hundred thousand years and concentrate on understanding the dynamics that cause large-scale natural variation. Stream II activities will illuminate the interactive feedbacks among various components of the Earth system and their relation to external climatic forcing.

The fourth PAGES Focus, climate sensitivity and palaeoclimate modelling, consists of activities designed to understand better the fundamental causes of global climate change and the modelling of the Earth's changing environmental systems.

In addition, PAGES has identified a fifth cross-cutting Focus which is required for the advancement of all other Foci, namely Cross Project Analytical and Interpretative Activities. This Focus addresses measurement protocols, calibration and

Table 3. Pages Core Project organization

Focus 1	Global Palaeoclimate and Environmental Variability		
	PANASH I - Time Stream I		
	Activity 1	PEP I The Americas Transect	
	Activity 2	PEP II Austral-Asian Transect	
			Task 1 - Lake Baikal
	Activity 3	PEP III Afro-European Transect	
			Task 1 - IDEAL
	Activity 4	The Oceans	
			Task 1 - North Atlantic Project
			Task 2 - Tropical Oceans
	PANASH II - Time Stream II		
	Activity 1	PEP I The Americas Transect	
	Activity 2	PEP II Austral-Asian Transect	
			Task 1 - Lake Baikal
	Activity 3	PEP III Afro-European Transect	
			Task 1 - IDEAL
			Task 2 - Palaeomonsoon (w/INQUA)
	Activity 4	The Oceans	
			Task 1- IMAGES (w/SCOR)
Focus 2	Palaeoclimate and Environmental Variability in Polar Regions		
	Activity 1	Arctic Programmes	
			Task 1 - PALE
			Task 2 - NAD
			Task 3 - GISP/GRIP
	Activity 2	Antarctic Programmes (w/SCAR)	
			Task 1 - EPICA, WAIS-Cores, etc.
			Task 2 - ITASE
Focus 3	Human Interactions in Past Environmental Changes		
	Activity 1	Human Impacts on Fluvial Systems	
	Activity 2	Human Impacts on Terrestrial Ecosystems	
			Task 1 - European Palaeoclimate & Man
	Activity 3	Human Impacts on Atmospheric Composition	

Table 3. Continued

Focus 4	Climate System Sensitivity and Modelling		
	Activity 1	Climate Forcing and Feedbacks	
			Task 1 - Volcanic Influences
			Task 2 - Solar Influences
			Task 3 - Greenhouse Gases and Aerosol Influences
			Task 4 - Abrupt Climate Change and Internal Climate System Dynamics
	Activity 2	Climate Model-Data Intercomparisons	
			Task 1 - PMIP
			Task 2 - Palaeovegetation (w/GCTE/DIS/GAIM)
Focus 5	Cross Project Analytical and Interpretive Activities		
	Activity 1	Chronological Advances	
	Activity 2	Development of New Proxies	
	Activity 3	Multi-proxy Mapping	
	Activity 4	International Palaeo-Data System (w/WDC)	
	Activity 5	Regional, Educational and Infrastructure Efforts (w/START/IAI)	

intercomparison studies, data management activities, fundamental laboratory studies, and regional and educational activities related to the START effort. A timeline for PAGES activities are given in Fig. 15.

Work Plan

Global palaeoclimate and environmental variability

The overall objective of PAGES Focus 1 is to address the imbalance in information that is now available on the past history of the climate system in the tropical regions and the southern hemisphere. This will be accomplished through the development of a global framework of palaeoscience sites organized in a series of continental and marine transects which will be closely tied into a global palaeo-information grid. The organizational vehicle to accomplish this construct is the Palaeoclimates of the Northern and Southern Hemispheres Project (PANASH).

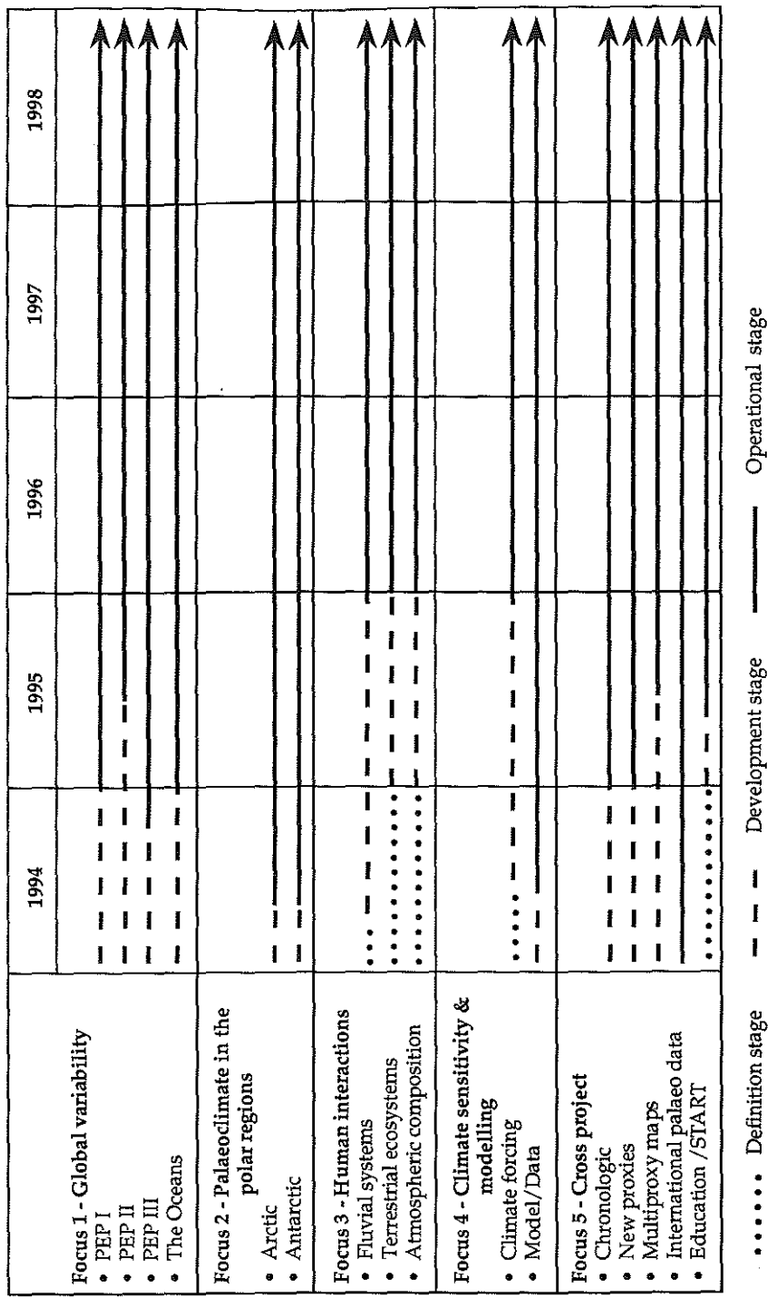


Figure 15. Timeline of PAGES activities

The PANASH research agenda links the now disparate data from the Northern and Southern Hemispheres in an attempt to understand interhemispheric climatic coupling and the sequence and phasing of major climatic transitions. Of interest in regard to N-S hemispheric effects are the asymmetry of land and ocean cover; in-phase and out-of-phase insolation changes; asymmetry of land-ocean-atmosphere interaction; asymmetry of albedo due to continental ice cover and extent of vegetation; and differences in anthropogenic emissions to the oceans and atmosphere. An additional consideration is the need to distinguish regional or hemispheric effects from truly global changes to the environmental systems.

On the basis of the PAGES Temporal Streams, Focus I is subdivided into subfoci: PANASH I and PANASH II and within each, Activities are related to the Pole-Equator-Pole (PEP) transects or to marine transects (International Marine Global Changes, IMAGES). Each transect is designed to take advantage of the best opportunities to access the palaeo-record for the most complete analysis of the dynamics of past interhemispheric teleconnections.

The PEP and IMAGES transects of the PANASH Project form the framework of a truly global observational grid of palaeo-environmental information. In the initial phases, planning workshops will develop a set of science and implementation plans to be completed by the end of 1994. In subsequent phases, collaborative projects will be developed around the PANASH framework and operations initiated in 1995 - 98. Components of this effort are already in operation (International Decade of East African Lakes, IDEAL, Lake Baikal Drilling Project); other elements are currently in the conceptual stages and will move forward as detailed plans become available.

PANASH I efforts (Stream I) will focus initially on the restricted period of the last 1000 years to allow concentration on specific periods (e.g., the "little ice age") or mechanisms (e.g., solar forcing, volcanism, El Niño - Southern Oscillation (ENSO)). PANASH I will promote the extraction of new, high-resolution proxy records and historical documents from all parts of the world, but with particular attention to the Southern Hemisphere and the Tropics. By focusing attention on the intercomparison of detailed records from these intervals, real progress should be made in resolving the relative importance of forcing factors. This time scale also embraces the period of the most intense alteration of the global environment by humankind and so ties the project more immediately to the broader objectives of the IGBP.

A high priority for PANASH II (Stream II) will be the development of continuous, land-based, proxy records spanning the last glacial-interglacial cycle. This emphasis would promote coring efforts and multi-parameter analytical work on the wide variety of palaeo-records. It is only through the acquisition of such records that we can hope to resolve current uncertainties regarding leads and lags in the climate system, phase relationships of the northern and southern hemispheres, the partitioning of carbon in different reservoirs over time, and the frequency and timing of abrupt climate changes.

Comprising PANASH I and II are the activities of PEP I, II, and III and The OCEANS.

PEP I - The Americas transect

The PEP I Activity represents inter-American palaeoenvironmental research designed to address questions on the dynamics of transequatorial atmospheric linkages and to determine the hierarchy of climate control over the last glacial-interglacial transition. PEP I is also especially designed to link the marine and terrestrial records along the eastern Pacific coast. PEP I held its initiating workshop in Panama (September, 1993) and a science and implementation plan is currently in preparation.

PEP II - Australasia - Eastern Siberia

The PEP II Activity is scheduled to hold an initiating workshop in Beijing, China (April, 1994). The workshop is jointly sponsored by PAGES, the Chinese Academy of Sciences and the National Natural Sciences Foundation of China. The tropical portion of this transect will be especially significant because of its access to ocean/climate factors which focus on the maritime continent. In Temporal Stream I, PEP II will promote the extraction of new, high-resolution records with particular attention to the palaeomonsoon as a teleconnection process in tropical and subtropical regions. A PAGES workshop on this effort was held in Taipei, Taiwan (April, 1993) and "Recommendations for Research" was published; proposals for research are currently being prepared for consideration by national funding agencies. PEP II will also incorporate the palaeoclimate record of the Lake Baikal Drilling Project and other central Asian projects which provide insight into the region's palaeohydrologic and palaeomonsoon history. PEP II will also be central for developing a clearer understanding of the influence of the Tibetan Plateau on global climate. The Lake Baikal Drilling Project is currently operational and will recover the first long lacustrine record of climate change for central Asia.

PEP III - Africa - Mediterranean region - Europe

The PEP III initiating workshop was held in Bern, Switzerland (December, 1993). Scientific goals and strategies for the PEP III Activity have been identified and a science and implementation plan is being developed. Over the course of 1994, specific collaborative efforts will be proposed and field work will begin in 1994 - 95. PEP III drilling activities (Stream II) are aimed at the terrestrial records of the late Pleistocene and Holocene. Especially important here will be the lake-level records of central Africa and other lake-oriented records of climate. Africa, with some of the Earth's major desert and rain forest regions, remains a large gap in our current knowledge of palaeoclimate; the area is critical to our understanding of Inter-Tropical Convergence Zone (ITCZ) oscillation. The IDEAL Project covers a significant portion of the PEP III transect, covering 20° of latitude. Field work for IDEAL has begun in Lake Victoria and will continue in sequential fashion in other lakes of the African Rift. In association with START, PAGES will collaborate with the African palaeoscience community in establishing regional studies which contribute to PAGES objectives. These are currently in discussion and an initiating workshop has been held in Mombasa, Kenya (December, 1993). The Palaeomonsoon (Time Stream II) is a key subsystem of the global climate

and is an important element of the PEP III Activity. An initiating workshop for this effort was held under the International Union for Quaternary Research (INQUA/PAGES) sponsorship in Mombasa, Kenya (December, 1993). Objectives were recommended and a science and implementation plan for future research is in preparation.

The Oceans

The ocean realm is rich in information about key elements of the Earth's interactive natural systems and carries strong global and climate-subsystem signals. The North Atlantic Project is a task centred on the study of climate variability of the North Atlantic region and surrounding land masses during the last millennium. This effort will use both documentary data from historical sources and continuous proxy records with annual resolution to develop an integrated climatic history of the North Atlantic region.

A second task is focused on tropical ocean-atmosphere systems which orchestrate global climate variability on interannual-decadal time scales and are the primary source of energy and water vapour to the global atmosphere. Research rests on the high resolution records derived from long-lived corals and high accumulation-rate varved sediment. These offer a unique source of well-dated climatic information on past temperature, rainfall and surface water salinity in tropical regions. In cooperation with CLIVAR (WCRP), a workshop will be held in 1994 to establish a research plan for the reconstruction of high resolution variability in tropical oceans; also targeted will be the variability of the Gulf Stream in relation to thermohaline circulation of the North Atlantic Ocean.

The IMAGES task is directed towards the quantification of climate and chemical variability of the ocean with century scale resolution; the sensitivity of the ocean to internal and external forcing factors, and its role in controlling atmospheric CO_2. Sponsored by PAGES and SCOR, an initiating workshop for the IMAGES Task has established a science and implementation plan, and an international steering committee has been formed to address collaborative efforts. The first field cruises, aimed at targets in high sedimentation areas of the North Atlantic Ocean, are expected in 1995.

Palaeoclimate and environmental variability in polar regions

The continental ice sheets of both polar regions form the most important natural archive for palaeoatmospheric research and the polar and subpolar regions are rich in palaeoclimate records from lakes and marine sites. Focus 2 is structured to take advantage of these opportunities within both temporal streams I and II; these research efforts constitute the circumpolar linkages of the PEP transects. Arctic and Antarctic field activities occur in remote and often hazardous conditions. These require special and complex logistic considerations; PAGES will cooperate with IASC and SCAR in the formulation of efficient palaeoscience research efforts in these regions.

Arctic Activity

PALE (Palaeoclimate from Arctic Lakes and Estuaries) is an operational Task designed to focus on Temporal Stream I and II objectives in the Arctic regions. International collaborative studies are well underway with most of the Arctic-rim nations participating. PALE forms the Arctic linkage for the PEP transects and close ties will have to be maintained between these elements. Over the next five years, PALE will focus on US/Russian projects designed to establish the environmental history of Beringia (eastern Siberia-Alaska). Other studies will focus on the lake sediments of eastern Canada and Fennoscandia to understand better ice-sheet history and the Northern hemisphere and its impact on global environmental events as reflected in the PEP and IMAGES transects.

GISP2/GRIP (Greenland Ice Sheet Project/Greenland Ice Project) are Tasks that have successfully completed their field programmes in ice core research. Results are currently being published and many unanticipated conclusions have been noted. Although these projects will continue with analytical and interpretative activities for some time, a new ice core effort in northern Greenland is currently under discussion.

Antarctic Activity

EPICA, WAIS (European Programme for Ice Coring in Antarctica, West Antarctic Ice Sheet Project) and other large projects (Russia, Japan, Australia and the United Kingdom) are devoted to ice core research. EPICA is a coordinated programme of glaciological projects in Antarctica aimed at the PAGES time scales. WAIS addresses the history of the West Antarctic Ice Sheet and is primarily a US-sponsored project. These are large and complex Tasks with difficult logistic requirements. Both projects will require additional planning and coordination between PAGES, SCAR and the supporting national programmes.

ITASE (The International Trans-Antarctic Scientific Expedition) is a Task which focuses on the recovery and interpretation of a high resolution record of climate and atmospheric chemistry over the last 200 years. It has particular relevance to the mass balance of the Antarctic ice sheet and its relation to sea level change. Although planning documents and sampling protocols have been developed; this project requires further PAGES encouragement and coordination. We expect this field work to move forward over the course of the next five years.

Human interactions in past environmental changes

Most of the biosphere and the upper lithosphere has been affected by human land-use, in turn affecting the composition of the atmosphere and the horizontal fluxes of water, sediment and nutrients both on land and to the oceans. Many of these land-use-induced changes have been modulated by climate change. The spread of agriculture across the globe has occurred over millennia, and many of the consequent effects on the

global system have already occurred. These can be studied using the analytical techniques central to the science of PAGES.

Focus 3 addressing the human interactions has recently been added to PAGES and is still in a planning phase. These are the Activities currently envisaged:

- Human Impacts on Fluvial Systems - a planning meeting will be held in February, 1994
- Human Impacts on Terrestrial Ecosystems
- Human Impacts on Atmospheric Composition.

Climate system sensitivity and modelling

Focus 4 consists of activities designed to understand better the fundamental causes of global climate change and the modelling of climate and environmental change.

Climate forcing and feedbacks

Volcanic influences on climate is a Task which is jointly organized by PAGES and the International Union for Quaternary Research (INQUA). The role of volcanism in short term climatic instabilities and the effect of aerosol loading on the physical and chemical characteristics of the atmosphere are critical for our understanding of global change. Recent advances in glaciochemical stratigraphy of ice cores, dendrochronology, and petrologic estimates of volcanic aerosol and gas release have led to new information on the history of the volcanic impact on the atmosphere over the past several hundred to several thousand years. A planning workshop was held in Tokyo, Japan (December, 1993). The science and implementation plan and current data inventory will be published in 1994. Additional field requirements will be identified and specific studies will begin in 1995/96.

Solar influences on climate addresses two forcing mechanisms that are external to the Earth system: (i) The modulation of the geosystem due to intrinsic variations of the Sun as a star; and (ii) effects of orbitally-induced variations in insolation through the Milankovitch effect and related feedback mechanisms. Research recommendations will be discussed at a NATO meeting in late 1994.

Greenhouse gases and aerosols: This Task is aimed at understanding the natural interplay between trace gas cycles and climate against which human-induced changes will operate. It is the objective of this Task to document the changes in global atmospheric chemistry over Temporal Streams I and II and to establish the causes, feedbacks and limits of natural variations in aerosol and trace gas concentration. The development of this Activity is currently under discussion for a workshop in early 1995.

Abrupt climate change and internal climate system dynamics: This Task will focus on those events and transitions which occur on very short time scales. The mechanisms involved in these occurrences are poorly known. This effort will determine the rates of rapid climatic and environmental change using high resolution and well-dated records. An initiating workshop for this Task is tentatively scheduled to be held in mid-1994.

Climate model-data intercomparison

Palaeomodelling and data- model intercomparisons are a central aspect of the PAGES Project. Climate models are tested by the comparison of palaeodata with model output. Climate models also aid in the interpretation of palaeodata by defining the sensitivity of the environment to climate forcing mechanisms operating in the past.

PMIP (Palaeoclimate Modelling Intercomparison Project) involves the participation of several research groups working on atmospheric general circulation models (AGCMs). Its purpose is to compare the climate simulations of these models when run under identical palaeoclimate boundary conditions (e.g., insolation, ice sheet configuration, and trace gas concentration). Two specific time periods, 6,000 and 21,000 years BP, have been chosen for the initial investigation. Current plans call for a PMIP workshop to be held by the end of 1994 for the first model-model intercomparisons. At this workshop, subprojects will be defined for the follow-on model-model and model-palaeodata comparisons.

Palaeovegetation (with GCTE, DIS, GAIM): This Task will focus on the production of palaeoecologic and palaeoclimatic data needed for the validation of vegetation model simulations for 6000 yr BP and other time periods. This will test the ability of current ecological models to simulate palaeovegetation under climatic boundary conditions that are different from today. A joint initiating workshop is scheduled for May, 1994. Strategies and an implementation plan will be published in 1994.

Cross-project analytical and interpretive activities

Focus 5 crosses the PAGES organizational lines to address common project elements. These activities serve the PAGES projects by providing community organization and infrastructure.

Success of the overall PAGES Project will depend to a considerable degree on the establishment and availability of a rigorous chronostratigraphic framework. Investigations within Temporal Stream I (the past 2000 years) will ideally require annual time resolution, whereas Temporal Stream II (the past glacial-interglacial cycles) will ideally require century to millennial-scale resolution. PAGES is committed to the complete documentation of chronostratigraphic information for all palaeoclimatic data. Through the Chronological Advances Activity, PAGES will encourage efforts to locate reference isochronous horizons for global chronologic correlation (e.g., volcanic ash, ^{10}Be events, methane peaks, and dust layers) and will encourage the development of new chronological techniques. PAGES will also encourage the development of protocols for

sample acquisition and analysis (e.g., intercomparison of results from electron-trapping laboratories), and for the use of innovative statistical analyses. To this end, PAGES will sponsor a workshop at the 1994 Radiocarbon Conference for the comparison of several dating techniques and to examine the comparability of Stream II chronologies. PAGES has formed a working group to coordinate these efforts.

A major goal of the PAGES Project is to encourage the development and dissemination of new research techniques for the palaeosciences. This may include a wide variety of tasks, such as: sample acquisition methods, geochemical analyses, data analyses and interpretation. An example of this activity is coring and drilling techniques for lacustrine sediments, where securing reliable sediment cores from deep lakes can be a difficult problem. Adequate techniques and equipment, deployed in severe climates or remote regions, need to be developed and made available to the broad community. Another example is the development of coral as a reliable palaeoenvironmental proxy. Research into the physiological aspects of growth band formation, tracer uptake, and carbon isotope fractionation is fundamental to the correct interpretation of the coral record. PAGES will encourage these types of basic studies for the development of the coral record into a significant palaeoenvironmental tool. It should be noted that these are only two examples of needed developmental tasks; others will be added as the project matures.

Multi-proxy mapping: This Task constitutes the application of palaeodata to focused studies of specific regions or intervals of time. Palaeodata are often diverse and highly detailed; the multi-proxy mapping technique provides the means of organization for the assembly of a complex data set into a composite map of past climate. These reconstructions are often aimed at specific forcing factors. Specific targets are currently under discussion within the community and between IGBP Core Projects. Detailed planning will begin in 1995.

International palaeoenvironmental data management system (with World Data Centre); Data constitute a resource that must be managed in a way that provides the entire global change research community with the tools to easily access and manipulate the information needed for a particular investigation. The World Data Centre-A (WDC-A) for Palaeoclimatology has joined PAGES in the design and implementation of a global, science-driven, data management system that will integrate all types of palaeo-environmental data. An easily accessible international system of palaeoenvironmental data is currently being developed. Over the next five years, WDC-A and PAGES will perfect this system to include: the international coordination of data acquisition, management, and distribution; the establishment of data cooperatives to facilitate the compilation of important data sets, the development of a public-domain browse and visualization software package (PalaeoVu); and the dispersal of archived data on magnetic media or anonymous file-transfer protocol via Internet.

PAGES recognizes its role in the enlistment of scientists and technicians to strengthen the cadre of researchers who now work in the palaeoenvironmental sciences; and its role in the encouragement of national support for the research activities of the palaeoscience community. It is also incumbent upon PAGES to inform the public of the

rationale, objectives and accomplishments of the project. The Regional and Educational Efforts of PAGES encourage practising scientists to contribute to studies of global issues and to the training of the community in multidisciplinary aspects of global change. A particular emphasis of this Activity will be on the developing countries in collaboration with START. We expect the PEP transects to provide links and infrastructure for scientists to access the broader international community.

Past Climate Change in Africa was selected as a priority research topic at the IGBP/HDP/CEC regional workshop in Niamey, Niger (1992). The African palaeoscience community under the auspices of START (NAFCOM), has begun planning of this palaeoscience programme for the PAGES effort. A workshop to develop this aspect was held in December, 1993. Within the developing countries, PAGES will work for the long-term development of the infrastructure required to enable the full participation in PAGES activities.

Global Analysis, Interpretation and Modelling (GAIM)

Introduction

The role of the IGBP Task Force on GAIM is multifold. The Task Force must analyze current models and data, interpret the capability of current models and experimental programmes against the demands for knowledge, and advance and synthesize our understanding of the global biogeochemical cycles and their links to the hydrological cycle and more generally to the physical-climate system as a whole.

Modelling is fundamental to the IGBP effort because the ability to model some aspect of the Earth system correctly and repeatedly on the basis of component processes is a litmus test of whether or not predictive understanding of that component has been achieved. Models also provide an indispensable way of organizing current knowledge and pinpointing critical gaps. The aim is not simply to produce ever larger and more complex models of the Earth, but rather to produce a family of models of varying complexity and realism to attack specific questions. The models and model experiments have to be designed in such a way that their predictive characteristics can be tested with existing or planned data sets.

Though coupled, one can conceptually partially "decouple" the Earth system as a means of studying aspects of the important subsystems. This decoupling is not without strong scientific precedent nor completely devoid of risk. It is, without question, valuable. Specifically, the Earth system can be viewed as being composed of two interacting subsystems, the Physical-Climate Subsystem and the Biogeochemical Subsystem, linked together by the global hydrological cycle and by subsystem state variables such as greenhouse gas concentrations, surface roughness, and albedo. By exploiting the conceptual decomposition of the Earth system into two coupled subsystems, one can formulate an attack upon these central problems of global change. Central to this attack is to realise, test, evaluate, and apply a suite of models of and associated data sets for the Global Biogeochemical Subsystem which would be comparable in prognostic dynamics to the current models of the Global Physical- Climate Subsystem, the General Circulation Models (GCMs).

GCMs exist at a variety of institutions around the world; prognostic Global Biogeochemical Models are at a relatively primitive stage. The challenge to GAIM is to initiate activities that will lead to the rapid development and application of a suite of Global Biogeochemical Models. These Global Biogeochemical Models would, in time, be linked, partly through the hydrological coupling, to GCMs, thereby providing models of the Earth system.

Objectives

- Develop a strategy for the rapid development, evaluation, and application of comprehensive prognostic models of the Global Biogeochemical Subsystem which could eventually be linked with models of the Physical-Climate Subsystem.

- Propose, promote, and facilitate experiments with existing models or by linking subcomponent models, especially those associated with IGBP Core Projects and with WCRP efforts. Such experiments would be focused upon resolving interface issues and questions associated with developing an understanding of the prognostic behaviour of key processes.

- Clarify key scientific issues facing the development of Global Biogeochemical Models and the coupling of these models to GCMs.

- Assist the IPCC process by conducting timely studies that focus upon elucidating important unresolved scientific issues associated with the changing biogeochemical cycles of the planet and upon the role of the biosphere in the physical-climate subsystem, particularly its role in the global hydrological cycle.

- Advise the SC-IGBP on progress in developing comprehensive Global Biogeochemical Models and to maintain scientific liaison with the WCRP Steering Group on Global Climate Modelling.

Organization of Research

The IGBP Task Force on GAIM is envisaged as playing a role similar to that of the WCRP Steering Group on Global Climate Modelling, and it will liaise with the Steering Group on important areas of overlap offering opportunities for collaboration between the WCRP and IGBP.

Much of the progress to date in modelling specific components within the global biogeochemical subsystem sets the context for modelling activities within the various IGBP Core Projects. GAIM recognizes, supports, and will benefit from these efforts. The GAIM activity is by definition cross-cutting; therefore, the activities of GAIM intersect fundamentally with all the Core Projects. In fact, the GAIM activity depends, in part, upon all the Core Projects, which themselves are in varying states of readiness. This overlap and dependence must be acknowledged in any implementation plan.

Considering the role and characteristics of GAIM, certain organizing principles emerge.

- GAIM should not be structured as a Core Project but rather established as a Task Force of the SC-IGBP with a specific and agreed upon Action Plan that is flexible and timely. The Action Plan would be implemented, in part, by the Task Force itself and, in part, via activities that GAIM catalyses.

- The activity should engage scientists who are currently engaged in the Core Projects, who are focused upon modelling issues, and who would be willing to undertake projects that occur at important interfaces in the global biogeochemical subsystem.

- Analysis and modelling strategies must be devised that recognize the different levels of development of quantitative expression or models for the various subcomponents. Such strategies need to include specific proposals for addressing key processes within the global biogeochemical subsystem.

- The activity of GAIM must include specific attempts to link various components of the biogeochemical system which require the contribution of more than one Core Project. How these linkages are treated is a non-trivial problem for GAIM and IGBP generally.

- The strategy for implementing GAIM must include a step-by-step bridge building with the modelling activity in the WCRP.

  There are several areas of common interest with WCRP. Among these are:

  - Ocean-atmosphere models in which the ocean component accurately describes the distribution of selected dissolved chemicals including those involved in the carbon cycle

  - Land-atmosphere models treating the exchange of energy, water, and carbon

  - Atmospheric chemistry models incorporating realistic source-sink terms.

- The activity of GAIM must work closely with the IGBP-DIS through a series of concrete projects aimed at making particularly useful data sets, such as global data on soil characteristics, available to the modelling community.

Given the broad purpose of GAIM, the organization will depart from a Core Project structure and adopt a Task Force structure in which a major portion of the modelling work will be conducted by the Task Force in close collaboration with modelling groups around the world. The modelling experiments will be revised and reviewed yearly. The planning agenda will be focused upon timely results that exploit the evolutionary character of global modelling today.

During the first phase, the focal biogeochemical cycle for GAIM will be the carbon cycle, including its interaction with aspects of the nitrogen cycle. Coupled analyses of feedbacks between dynamic biogeochemistry and climate, mediated by greenhouse gas concentrations, and of climate-ecosystem interactions mediated by the hydrological cycle will be initiated by GAIM and conducted in collaboration with WCRP projects. The IGBP Task Force for GAIM intends to honour the three overlapping themes in its title.

Work Plan

The analysis programme

The analysis programme will consist initially of a series of short (2 - 3 day) workshops focused upon open scientific issues that limit progress on developing models and deepening our understanding of global biogeochemical cycles and how these cycles and the associated key subsystems that may change in response to climate change. Many of these workshops will be conducted in joint sponsorship with other IGBP CPOs and IGBP-DIS.

Workshops in 1994 - 1995 will focus on wetlands extent and classification (for methane estimates), and vegetation-climate modelling issues.

The extent and type of wetlands globally: This workshop is methodological in focus. The issue is to devise a strategy for estimating better the areal extent of global wetlands. Associated with the areal extent is the issue of classification from the perspective of methane flux. The initial two workshops will likely focus first upon boreal wetlands and tropical wetlands. The workshop will be sponsored jointly by GAIM and IGBP-DIS, and planning will be coordinated with IGAC and GCTE. These workshops are being planned tentatively for 1994.

Spatial and temporal scaling: The issue of coupling global terrestrial models across spatial and temporal scales is recognized to be an important issue on which progress is needed and could be achieved in parallel with GCTE. The issues are several but can be summarized by considering the coupling across three temporal scales:

- Fast time steps (minutes to hours) used in terrestrial energy-water flux calculations
- Intermediate time steps (days to weeks) used in biogeochemical terrestrial models
- Annual time steps generally used in ecosystem successional dynamics.

These temporal scales have associated various spatial scales adding further complexity. This topic is important and a focused workshop on specific aspects appears to be possible and a useful means of enhancing cooperation with GCTE. The workshop is tentatively scheduled for early 1995.

The interpretation programme

The interpretation theme will be implemented partly through workshops and partly through study teams (which likely will grow from workshops). The defining feature of this theme, however, is the focus. This theme will focus upon clarifying specific scientific issues as identified by the IPCC process. For example, how much, how fast, and where can carbon be stored through reforestation and afforestation. The utility of *ad hoc*

scientific assessments of key IPCC issues has been established (e.g., the issue of iron fertilization of marine primary production). The GAIM interpretation theme is meant to enhance these efforts and provide to the IPCC process a vehicle for rapid and informal scientific mini-assessments.

In general, the broad scientific agenda for IPCC continues to expand, and it is still unclear how best to contribute to the 1995 assessment beyond the initial analysis and modelling agenda for GAIM. This is particularly true with regard to the core scientific agenda. However, there is a possibility that certain key issues with regard to mitigation might be fruitfully explored in 1994. One area that merits consideration is the potential for increasing carbon storage in terrestrial ecosystems. A model for this consideration is the way in which the corresponding issue of the possibility for increased biotic storage in marine systems by iron fertilization was explored and clarified. The approach used a workshop format followed by a set of model experiments and a set of scientific contributions.

This issue of providing timely interpretive insight to the IPCC process beyond the 1995 assessment and, beyond the analysis and modelling activities of GAIM, will be one of the key items to be addressed in 1994 by the Task Force.

Coordinated modelling experiments

The initial modelling component of GAIM is framed by two broad, linked scientific questions.

- What are the characteristic dynamics and controls on the global carbon cycle; how has this cycle been perturbed; what is its linkage to other biogeochemical cycles, and how might it evolve in the future.
- What are the linkages between climate and vegetation, and what are the effects of these linkages in a changing climate.

These two broad questions are not only themselves linked, but naturally they are coupled with the ongoing activities of the IGBP Core Projects. Furthermore, although the questions are expansive, they hardly frame a complete study of the Earth's biogeochemical system, how it is linked to the physical-climate system, and how it is being changed by human activities. These question are only guides for an initial framework; the work will broaden in the latter portion of 1994 - 1998.

These questions will be addressed by initiating modelling programmes in three temporal frames: a Contemporary time frame, a Fossil Fuel Era time frame, and a Palaeo time frame. Experiments in a fourth temporal frame, a Futures time frame, will be planned during 1994 - 1995.

An overarching objective of the initial focus upon the global carbon cycle is to develop a consistent and comprehensive framework within which to diagnose, intercompare,

validate, and document existing and future comprehensive biogeochemical models of the global carbon cycle. The framework can be considered as a pilot project which may serve in the future as a framework to evaluate models of other biogeochemical cycles besides carbon. The carbon cycle is addressed in each of the temporal frames focusing on methane in the palaeorecord and fossil fuel era and upon the terrestrial component of carbon dioxide in the fossil fuel and all the components in the contemporary period (Fig. 16).

Similarly, the overarching objective of the initial focus upon the linkage between climate and vegetation is to speed progress towards an understanding of the two-way coupling between terrestrial ecosystem and the physical-climate system, including the development of appropriate modelling frameworks to capture the essence of this coupling. The coupling arises because terrestrial ecosystems respond dynamically to climate while influencing climate through modification of surface energy, momentum, and water vapour and trace gas exchanges. As with the carbon cycle, this Action Plan envisages model experiments at different temporal scales. A 6,000 year BP experiment affords an opportunity to test the equilibrium behaviour of a coupled model under a different global climate state and in the Contemporary time frame coupled regional models will be tested against newly emerging data sets from exciting field programmes within both the IGBP and the WCRP. Thus, these experiments enhance the basis for linking global biogeochemical models to general circulation models. Four experiments will be the initial focus; two additional experiments will be more precisely defined during the first half of 1994.

		Topic		
		CO_2	Trace gas	Clim-Veg
Era	Future	To be determined	To be determined	To be determined
	Contemporary	• Coupled carbon models • Atm gradients	Currently not planned	• Atm-terr models • Perturbations • Regional climate & ecosystem data
	Fossil fuel	• Terrestrial models & landcover conversion • Historic atmospheric records	• Terr-atm-chem models • Focus: CH_4 • Historic CH_4 records	Currently not planned
	Palaeo	Currently not planned	• Terr-atm-chem models • Focus: CH_4 • Historic values for fixed temporal periods	• Atm-terr models • Orbital perturbations • 6000 BP • Vegetation data

Figure 16. Temporal framework of carbon-cycle studies within the initial modelling component of GAIM

Data and Information System (IGBP-DIS)

Introduction

The early planning of IGBP recognized that considerable effort must be directed towards the development of effective data systems; such work would be essential for the success of the programme as a whole. Appropriate datasets are needed for operation of models, for their validation and for directly monitoring changes which may not be predicted by models. Whilst many of these datasets are being obtained by the Core Projects themselves, there are other data requirements that must be met from non-IGBP sources, especially satellite observations and other spatially-referenced datasets. For many of these datasets, further work is required in their assembly and processing before they are in a generally-usable form. The Standing Committee for the IGBP-DIS has responsibility for these activities, together with the development and coordination of data management policies within the programme.

Objectives

- To improve the supply and management of data and information in order to facilitate the attainment of IGBP's scientific goals.

Three component objectives have been defined for the period 1994 - 1998:

- Carry out activities directly leading to the generation of datasets and other system components relevant to the needs of IGBP Core Projects
- Assist in the development of effective data management systems for Core Projects and for IGBP as a whole, thereby facilitating data exchange between Core Projects, the acquisition of data from other sources, and the wide distribution of IGBP datasets
- Contribute to the overall development of international and inter-agency data and information systems, particularly those of Earth-oriented space programmes, thereby ensuring that data and information relevant to IGBP are collected and made available with adequate continuity and quality.

Organization of Research

The three component objectives have led to the organization of IGBP-DIS activities within three Foci. Organization of IGBP-DIS Dataset development (Focus 1) is being

implemented through IGBP-DIS Working Groups set up to specify data needs. These Working Groups involve Core Project members and representatives of agencies providing data. The role of IGBP-DIS in these data-identification and dataset-development processes is most important where there are requirements for similar products from more than one Core Project, and where the required data sets are poorly developed.

Data management and dissemination (Focus 2) are now being given increased attention, with re-structuring of the 1994 Standing Committee to include Core Project representatives responsible for the development of their data system plans.

Interactions with international and national agencies (Focus 3) are achieved both by direct contacts and by formal representation; e.g., through participation of IGBP on such groups as the Committee on Earth Observing Systems (CEOS). Details of activities, and expected products, in all these areas are given below. While the IGBP-DIS Office functions as "broker" to the Core Projects for data issues, the actual work of data manipulation, processing and archiving is performed at laboratories and institutions associated with IGBP-DIS and funded by national and international agencies. The IGBP-DIS implementation timelines are given in Fig. 17.

Work Plan

Dataset development

Dataset development (Focus 1) is an ongoing activity, with Working Groups currently active in the development of global data sets for land cover, biomass burning and soils. The interaction between the user community and stages of data set production is shown in Fig. 18. Large workshop meetings are held when it is necessary to benefit from wider input. In the next five years (1994 - 1998), IGBP-DIS expects to generate the following dataset products:

- Continuing production, on a routine basis, of 1 km AVHRR products as 10-day composites on CD-ROMs, available to IGBP scientists at marginal cost
- Tested methodologies for land cover classification from AVHRR and other satellite and ground data
- Development of tested methodologies for assessing wetland extent and their variability over time
- A set of databases of soil parameters such as carbon content, pH, hydraulic properties and soil depth, derived by combining global pedon data with new FAO maps, 1 km vegetation data and global topography

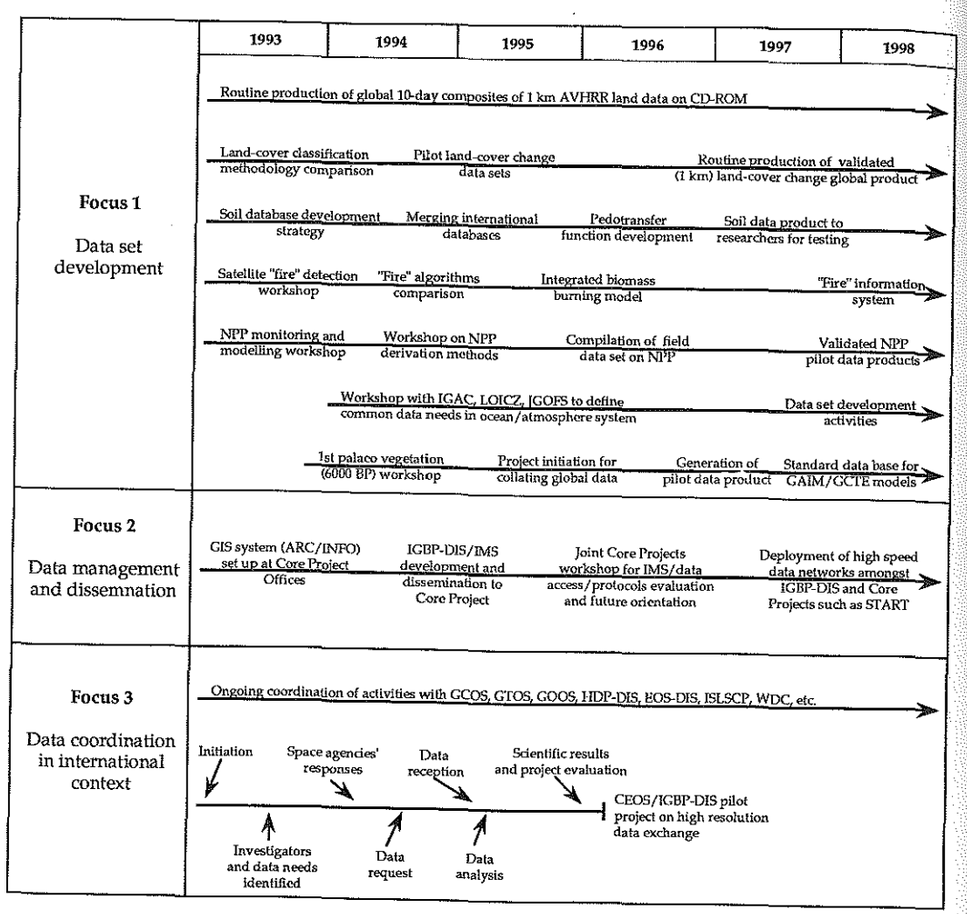


Figure 17. IGBP-DIS implementation timeline

- A fire Biomass Information System (in collaboration with IGAC) which will also have developed a consensus algorithm for deriving biomass burning data sets

- In cooperation with CEOS, a 1 km global topography database (GLOBE) derived from a variety of existing sources such as the Synthetic Aperture Radar (SAR) and the SPOT-Stereo (Système Pour l'Observation de la Terre).

- In the area of oceans and atmosphere, IGBP-DIS will organize workshop meetings in 1994 - 95 to provide a comprehensive review of the global data sets needed (but presently unavailable) by the JGOFS, LOICZ and IGAC research communities. IGBP-DIS will then proceed with developing pilot data sets in the same way as has already been done for the land biosphere.

Data management and dissemination

IGBP-DIS will work closely with core projects to develop their data plans. For data acquisition, dissemination and interaction within and between the Core Projects, the immediate operational goal is to identify, by 1995, a time schedule for data needs, phased with the rest of the Core Project activities (Focus 2). These needs include: Data specifications in phase with model development; a realistic evaluation of data accuracy and spatial and temporal resolution needed; the scope of data handling capability within the Core Project; and measurement needs and instrument development requirements for the future. In addition, assistance is being given in planning and implementing data management systems within each Core Project. To help accomplish this, each Core Project has been asked to identify an individual responsible for data, including the development of a data system plan. Some Core Projects are sufficiently heterogeneous that separate plans may be required for each of their component parts. Procedures exist (especially from the oceanic community) to assist in the development of such plans. At the minimum, the following topics must be considered in the data system plan for an individual Core Project:

Identification of data and information content: Clearly the measurements and observations that are needed are driven by the science and the models that are being built. But it is often a far from straightforward task to define the data sets required, as shown by climatic modellers' experience with GCMs. In GCMs land surface properties have often been estimated through very indirect procedures because of the absence of suitable spatially and temporally comprehensive data sets.

Data quality: Again the characteristics of the data sets in terms of properties such as accuracy, precision, spatial and temporal resolution and coordinate systems, should derive in large part from the models themselves. One constraint on such specification is that it may be difficult to specify these properties until after the models have been put into operation. In practice an iterative procedure is likely to be needed leading to progressively better specification of data sets.

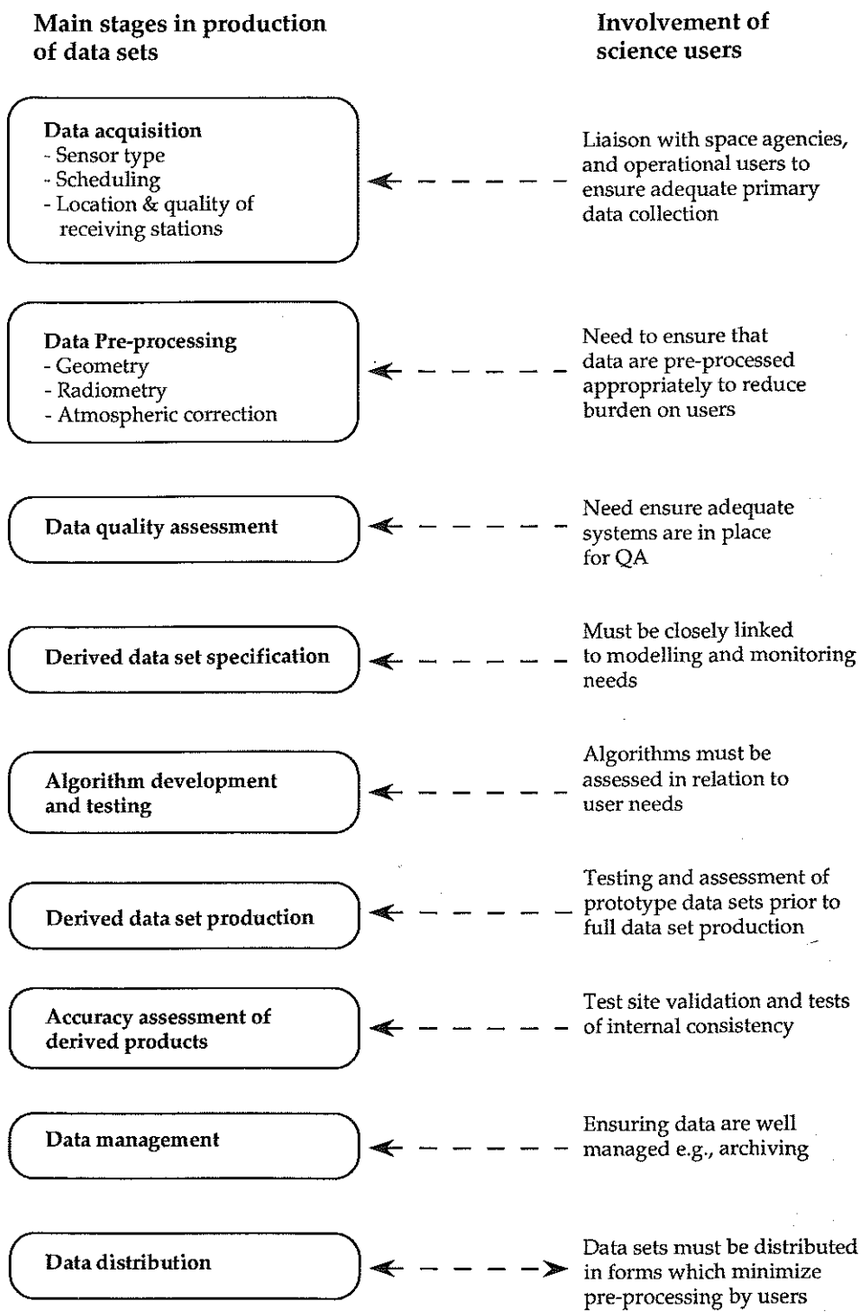


Figure 18. User involvement in data set production

Data set assembly: Many data sets will be created by the Core Projects themselves. Plans will have to be formulated to ensure the timely production of such data sets.

Metadata: Agreements need to be reached on how to describe the data sets. This includes both descriptions of individual observations as well as overall descriptions of the data sets. Agreement is also needed on how to specify set quality properties.

Catalogues: These include directories, guides and inventories. Core Projects will need to create their own catalogues for those data sets that they create. They will also need the tools and access to the catalogues of other data sets that they require.

Archives: Plans are needed for the archiving of data sets created by the Core Projects and also of archives of other data sets which may need to be held by Core Project scientists.

Networking: Procedures for distributing data need to be established within and between Core Projects and with other programmes.

Implementation: The various responsibilities of all those individuals, groups and organizations contributing to and using the data system need to be clearly specified. Such people and organizations will range from the individual researcher, through Core Project offices to the external bodies such as space agencies.

Cooperation and linkages: The production, management and handling of most data sets is an expensive time-consuming activity. It will often be highly advantageous if most aspects of these roles can be made the responsibility of other organizations. Plans should explicitly define the roles of these other organizations.

Future instrumentation: Measurement requirements need to evolve as the models improve. As technology develops, our ability to make those measurements improves as well. Because it takes 5 - 10 years to get sophisticated observation networks in place or dedicated satellites in orbit, it is important that Core Projects continuously re-assess their measurement and instrument development requirements several years in advance of their needs.

The above aspects relate to the separate data system plans for each Core Project. However, an IGBP-wide data and information system plan will also be developed in 1994 - 95, to assist in the overall data management for the programme, including the role of START and GAIM. Specifically, it will allow inter-connections and inter-dependencies to be better understood, it will facilitate cooperative activities between Core Projects and it should place the IGBP in a better strategic position for obtaining resources from funding agencies. Among the topics that will be included are the following:

Data sharing and exchange: An open data-sharing policy has been adopted by IGBP, following general ICSU guidelines. However, details of those arrangements need to be specified and implemented. Whilst restrictions on data access by the scientific

community need to kept to a minimum, there will undoubtedly need to be some safeguards for data immediately after collection, prior to quality control, or when data may have high commercial value.

Standards: A wide range of standards is now available for computer-based data management systems. Adoption of many of these standards can do much to reduce the effort and cost of handling data sets. IGBP-DIS will prepare recommendations regarding the adoption of such standards.

Inter-operability: IGBP-DIS will need to determine where the major data flows are likely to be both internal and external to IGBP, and hence to get a better idea of the benefits of common standards and procedures. It is beneficial to strive for a high degree of inter-operability following the lead of other plans to facilitate access to data.

Specific products that can be expected in 1994 - 98 as a result of implementing the above data management approaches are:

- The development and implementation of an IGBP-DIS Information Management System (IMS)
- Provision of a template in the IMS and a "handbook" for each Core Project data person to record metadata on the data products which the Core Projects are developing and distribute this information into other Core Projects' systems
- Development of links in the IMS to other systems, such as the International Directory Network when they become available on Internet, and provision of access by Core Project scientists to other data sets which have been identified as needed by the IGBP community but are contained in other systems
- Development of the protocols for transferring IGBP-DIS specific data sets to the non-IGBP community
- Deployment of high speed data networks between the IGBP-DIS Office and the Core Project data offices, as well as to other key components of the IGBP, such as START
- Provision of input into the development of standards and data formats for the archive and distribution of data and metadata.

Interaction with International and National Agencies

Interactive working relationship with international and national agencies (Focus 3) like CEOS, the ICSU World Data Centres (WDCs), the space agencies and their associated data system activities should be routinely functional by 1995. It is anticipated that the following will have been achieved :

- Successful completion of CEOS/IGBP-DIS pilot project for obtaining high resolution data from SPOT, Landsat, the Indian Remote Sensing Satellite (IRS) and the Marine Observational Satellite (MOS) for IGBP research at minimum cost
- Close coordination with activities in GCOS, GTOS and GOOS
- Routine involvement of IGBP scientists in NASA Earth Observing System, EOS/DIS Data Active Archive Centres (DAACs)
- Development of joint activities with ISLSCP on data set production and validation
- Using the WDC system for data archiving and distribution on a regular basis.

SysTem for Analysis, Research and Training (START)

Introduction

Successful implementation of the IGBP scientific agenda requires that research - measurements, analysis, synthesis, modelling, prediction - be carried out in all regions of the world. Similar needs exist in the HDP and WCRP. To meet this need, the concept of a global system of regional networks of institutions pursuing the objectives of HDP, IGBP and WCRP has been elaborated and is evolving. In this concept each region comprises several nations, and is generally of sub-continental size.

Global change research requires a regional approach for three reasons. First, although the world can be viewed as a single physical/chemical/biological system, its regions contribute very differently to global change, the impacts of global change may greatly differ by region and the capacities of societies and governments to adapt to global change are substantially different around the world. Second, regionally-based explanations and predictions of global change are much more likely to have credibility with and usefulness for regional decision makers than are scientific statements originating outside the regions, because regional research can take full account of particular regional socio-economic and ecological situations. In addition, indigenous research cannot be viewed as representing the "biased" viewpoints of scientists in industrial societies. Research arising from the regions can contribute to national and regional processes of sustainable development. Third, although HDP, IGBP and WCRP are global programmes, they are predicated upon comparable local and regional measurements, and the most direct way to generate those measurements is for scientists in all of the world's regions to contribute to a global measurement programme.

START is a world-encompassing system of Regional Research Networks (RRN), each of which includes a number of affiliated Regional Research Sites (RRS) and at least one Regional Research Centre (RRC). The fundamental purpose of an RRN is to develop and coordinate indigenous capacity for doing research on the regional specificities, origins and impacts of global environmental change in accordance with the objectives set out by the three parent global programmes. START will promote the ability to integrate results from many diverse disciplines, in both the natural and social sciences, in a framework that will provide important inputs for the development of regional and national policy options to mitigate or adapt to global change.

This fundamental purpose of RRN must be supported by training. Training, an essential component of START, will be of many types and will be carried out in both developing and developed regions. It can be, for instance, training in the use of specific equipment and the furtherance of standardized methodologies; training in new advances in specific

relevant disciplines; training in multidisciplinary approaches to global change research involving both natural and social sciences, etc.

In the START framework, research and training are necessarily supported and complemented by the effective acquisition, quality control, archiving and dissemination of the data. Considerable computing and communication capacity must be envisaged for each RRN.

Some nodes of RRN and, in particular, the RRCs, will be responsible for integrating and synthesizing the research results at the regional level and communicating them to both scientists and decision makers.

Objectives

- Enable scientists in each region to improve the understanding of national and regional environmental changes which may cause and be caused by global change, and thus to develop the necessary knowledge base for scientific assessments upon which national and regional policy options for mitigating or adapting to global change can be developed.

- Promote the establishment of the necessary institutional frameworks at the regional level for the scientific community to develop a research agenda on regional issues of global importance and, as appropriate, develop the priorities as contributions to the international research agendas of the HDP, IGBP and WCRP.

- Promote education and training programmes at graduate and post-graduate level in order to foster a better understanding of the Earth as a complex system and how it is regulated by interdependent physical, chemical and biological processes, as well as the socio-economic phenomenon affecting this system; and to stimulate cross-disciplinary training and education that will pave the way for collaborative global change research involving both natural and social sciences.

- Build or augment national and regional capabilities to develop georeferenced compatible data bases on variables relevant to global change, such as the natural and anthropogenic emissions and uptakes of greenhouse gases; to develop a network within each region which links together national data bases of relevance for regional modelling and other forms of analysis.

- Develop inter-regional coordination mechanisms for the implementation of a START global network of networks for global change research and assessment.

- Provide a platform for dialogue between START and governmental initiatives established to support regional networks for global change research.

Organization

The responsibility for planning, promoting and coordinating START rests with its Standing Committee appointed jointly by the SC-IGBP, the Joint Scientific Committee (JSC) for WCRP and the Standing Committee for HDP. The START Standing Committee also serves as an informal forum for discussions between governmental and non-governmental initiatives to ensure complementarity in developing regional activities, as well to foster inter-regional collaboration.

The responsibility for facilitating, promoting, planning and implementing the actions of the global network of RRNs rest with the International START Secretariat under the general guidance of the START Standing Committee. The International START Secretariat provides vital international coordination functions in developing a global network of networks of the global change research institutions.

The responsibilities for promoting, planning and implementing activities of the individual RRNs rest with the START Committees for the individual regions or with other bodies such as the Implementation Committee for the Inter-American Institute for Global Change Research. The Secretariats for these committees coordinate day-to-day activities for developing the RRN and its components. It is anticipated that the RRCs will assume most of the day-to-day coordination of activities of the corresponding RRNs.

All the RRNs should ultimately become self-sustaining in terms of funding. A major effort will be required to achieve this goal. The time horizon for achieving an operational START global network may be, hopefully, about 10 years. Perhaps, five more years will be necessary to make the system financially sustainable. This five-year plan is formulated with this longer-term vision in mind.

START is closely affiliated with such governmental initiatives as Asia-Pacific Network (APN), European Network on Research on Global Change (ENRICH), the Inter American Institute (IAI) and MEDIAS (Reseau de Recherche Regionale pour le Bassin Méditerranéen et l'Afrique Subtropicale) (see below).

START cooperates with many partners and seeks new ones. Among the natural partners are regional governmental organizations (like the Committee on Science and Technology, COST, of the Association of Southeast Asian Nations, ASEAN), organizations of the United Nations (United Nations Development Programme (UNDP), UNEP, WMO, UNESCO, etc.) and other leading international non-governmental organizations.

START Regional Priorities

Initially priorities in developing the START global networks of networks have been given to regions comprising primarily developing countries.

As the point of departure, before the beginning of this five-year plan period, considerable efforts to developing viable RRNs have been made in Southeast Asia (SARCS, part of Tropical Asian Monsoon, TAM) and Northern Africa (NAF) under UNDP/Global Environmental Facility (GEF) funding. A parallel effort within IAI has developed plans for global change research in Latin America and the Caribbean region. Planning has been initiated for RRNs in the Mediterranean (MED), Southern, Eastern and Central Africa (SAF) and Temperate East Asia (TEA). Current regional initiatives are outlined in Fig. 19.

Efforts have also been made to promote a coordinated support for regional global change research in the European context (ENRICH and EUROSTART), as well as APN. Initial steps have been made for South Asia (SAS), Oceania (OCE), the Arctic (ART) and Antarctic (ANT).

The START initiative is rapidly evolving. For such a dynamic effort, which involves political, economic and scientific factors, exact milestones are difficult to define. Besides, the strategy in the regions with predominantly developing countries must be different from the regions of developed countries. In planning five years ahead for the developing regions, one has to take into account both a general framework applicable to each and every RRN of developing countries and specific features and circumstances of each region.

Workplan

An overview of the state of development in individual regions is given in Fig. 20. The following activities are common to all regions.

- Formulating regional priorities within the HDP/IGBP/WCRP framework for global change research
- Establishing the coordinating machinery:
  - The Regional Coordinating Committee
  - The Scientific Advisory Panel and its Technical groups as appropriate
  - The Secretariat
- Defining the RRSs as components of an emerging network
- Development of the operational RRN doing the global change research and related activities (e.g., training and fellowships)
- Establishing the RRC
- Creation and maintenance of the data base(s)
- Promoting uniform data/information exchange systems
- Development of an electronic communication system
- Holding meetings discussing the research results
- Publication of the results
- Evaluation of the life cycle

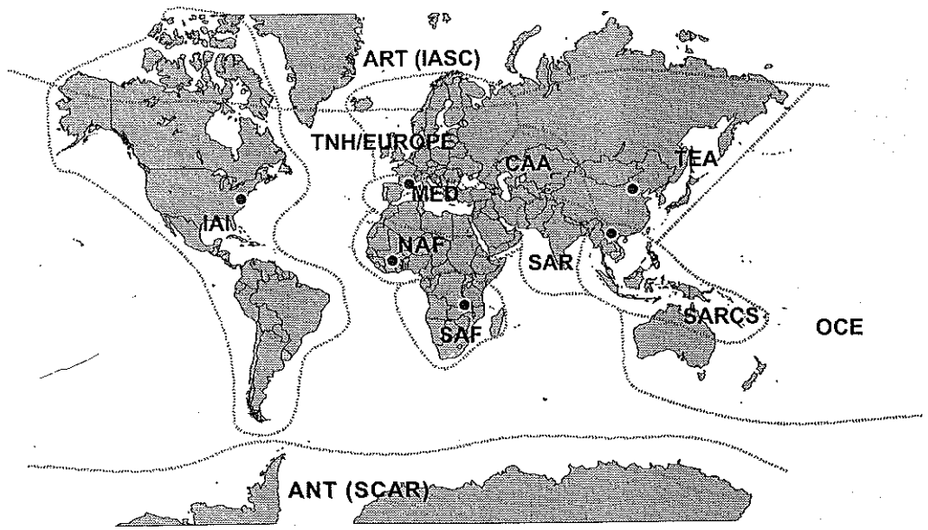


Figure 20. START Regional Networks under development. The Inter-American Institute for Global Change research (IAI) will perform networking functions for the indicated regions. In addition, the European Network for Research in Global Change (ENRICH of the EU) and the Asia-Pacific Nework for Global Change Research (APN; initiative of the Japanese government) will provide similar functions.

Southeast Asia

The Southeast Asian Regional Committee for START (SARCS) has been created with the objective of guiding the regional programme. It consists of scientists from the six ASEAN countries, but membership will also be offered to other countries in the region. A Scientific Advisory Panel (SAP) has been appointed and six technical groups of the SAP have been formed. An interim SARCS Secretariat office has been located at the National University of Singapore, and a permanent secretariat will be established at Chulalongkorn University in Bangkok.

The regional priorities in the global change research have been identified. They are pursued through the following objectives and outputs:

Immediate objective 1: Improve estimates of greenhouse gas fluxes, especially in relation to changes in land use and land cover

Output 1: Regional assessment of current greenhouse gas emissions based on national case studies

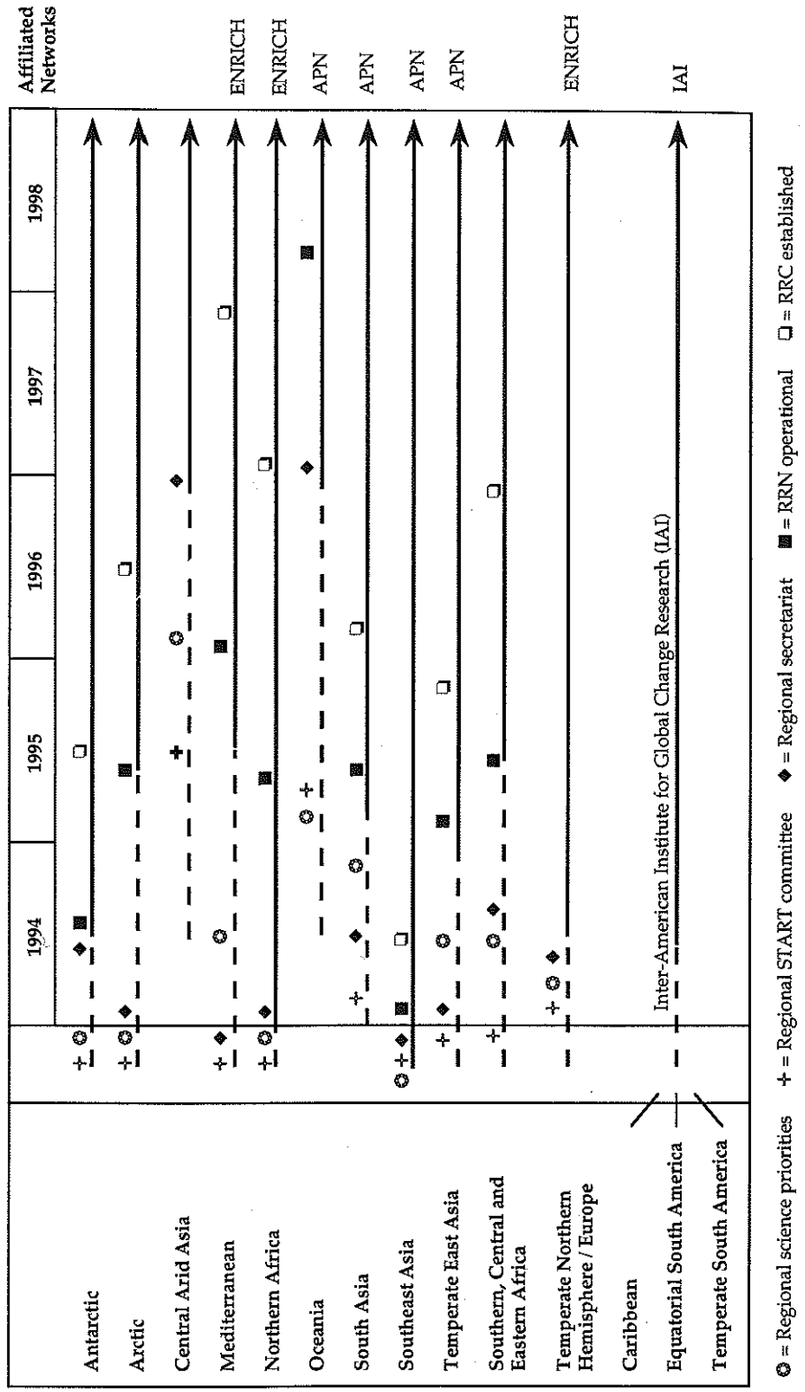


Figure 19. START milestones

Output 2: Documentation of current land-cover change, the processes responsible for land-use change and the projected changes over the next decades as a basis for assessing their importance for climate change

Output 3: Analysis of the effects of climate change on land-cover in the region

Output 4: Report on development of scenarios for future greenhouse gas emissions incorporating the potential impacts on sources and sinks of global change, land-use change, population growth and economic development, and technological innovations.

Immediate objective 2: Integrate natural-social science assessments of the impacts of sea-level rise on terrestrial and marine resources in the coastal zone

Output 1: Understand current predictions of sea-level rise

Output 2: Determine effects of predicted sea-level rises.

Immediate objective 3: Develop regional data bases for use in global warming studies

Output 1: Assess the regional access to relevant data bases.

Immediate objective 4: Develop regional capacity and strengthen existing institutions in the region through the establishment of a regional network for global change research, and lay the foundation for the creation of a regional research centre

Output 1: Establish a START RRN and Centre

Output 2: Plan for the establishment of components of a communication network

Output 3: Define a global change socio-economic research agenda.

Funding from UNDP/GEF of US $ 2,732,000 covers the Immediate Objectives 1, 3 and 4 for the period of May 1993 through December 1996.

1994

- The location is established at Chulalongkorn University, Bangkok
- Relevant and urgent needs of RRSs are formulated
- The structure of the RRN is established, along with long-term plans of its development
- Research and related training/fellowship activities funded by UNDP/GEF are held in accordance with the time-table for execution of the UNDP/GEF project
- A workshop is held to define the specific contents of the Immediate Objective 2
- Research priorities other than those mentioned above are developed
- An inventory is made of existing data bases in the region
- Regional cooperation will expand beyond the ASEAN countries, initially to Australia, Taiwan and Vietnam

1995

- The RRN in ASEAN countries is fully operational and linked by electronic mail
- Research Sites from outside the ASEAN countries (e.g., Vietnam, Taiwan, Australia) join the network
- Research and related training/fellowship activities funded by UNDP/GEF are held in accordance with the time-table, in particular:
  - A synthesis workshop on the national case studies of greenhouse gas fluxes
  - A synthesis workshop on the current land-cover change as it influences climate change
- Participation in the 1995 IPCC assessments through vigorous promotion of the regional recommendations in the IPCC working groups
- IGBP/HDP/WCRP-related projects (other than those funded by the 1993 UNDP/GEF project) are formulated and the necessary funding obtained
- A donors meeting for the region is held as well as other fund-raising activities

1996

- The RRN is operational in all countries of the region doing the priority global change research in the framework of HDP/IGBP/WCRP
- Research and related training/fellowship activities funded by the UNDP/GEF project are accomplished
- Proceedings of the 1995 synthesis workshops are published and the policy recommendations conveyed to the governments and other interest groups of the region
- Evaluation of the UNDP/GEF project for the region is accomplished

1997

- Continued development of START initiative related science and networking activities in the region creating also links with the research sites of the neighbouring regions
- Continued development of the long-term commitments required for funding the RRN activities

1998

- The RRN and RRC are fully operational following the objectives set at the beginning of the five-year period
- Commitments from host nations and other donors for funding and other support are made for at least the next five-year period
- A five-year evaluation is made and the scientific results and administrative conclusions are discussed at the regional RRN-START Conference. The Conference will decide on the priorities for the next five-year period

Northern Africa

At the meeting "Africa and Global Change" held in Niamey, Niger in November 1992, priority topics for global change research specific to Africa were delineated and constraints for active participation of African scientists in the international global change research efforts of the HDP, IGBP and WCRP were identified. The meeting recommended that the scientific priorities for the African regions should be refined within each of the following topics:

- Desertification, deforestation and vegetation change: Impacts on and from climate change and climate-driven land-cover change, including biomass burning
- Land use and climate change impacts on water resources, river basins and coastal systems
- Past climate changes in Africa related to global change
- Global change impacts on agriculture and food security.

The Northern African Regional Committee for START (NAFCOM) has been created with the objective of guiding the programme. The NAFCOM interim Secretariat Office is established at the Ghana Academy of Arts and Sciences in conjunction with the Committee on Science and Technology in Developing Countries (COSTED) West Africa Regional Office in Accra, Ghana. For the region, the following priority objectives and outputs have been formulated:

Immediate objective 1:	To establish an ad hoc secretariat and initiate the functioning of NAFCOM
Output 1:	Terms of reference for NAFCOM, work plan for the first year and an interim secretariat.
Immediate objective 2:	To develop science plans for priority topics and survey existing projects of relevance and available expertise within the region
Output 1:	Plans for research priority within the four foci.
Immediate objective 3:	To develop regional electronic communications/data and information exchange network connecting various NAFCOM related institutions and individual scientists
Output 1:	Set up a regional electronic communication network.

The funding from UNDP/GEF covers the Immediate Objectives 1, 2 and 3 for 1993 - 1995.

1994

- Establish the "permanent" Secretariat of NAFCOM
- Develop the research agenda for the priority regional topics by organizing a set of workshops under the guidance of NAFCOM in accordance with the UNDP/GEF project

- Survey relevant ongoing activities and available expertise in the region, to identify institutions to serve as RRSs and to design a RRN
- Establish the Scientific Advisory Panel
- Design a regional electronic communications/data and information exchange network

1995

- Survey possible sites for the establishment of an RRC
- Keep developing the RRN by implementing the research agenda
- Carry on training, fellowships, data base development, etc., in accordance with the research agenda established previous year
- The electronic communication system to become fully operational
- Hold a donors' meeting in order to raise the funds making the RRN viable

1996

- Make a decision on location of the RRC
- The RRN to become fully operational doing the global change research and related activities while further developing the Network
- Collaboration with SAF and MED, though strong from the beginning, will be even more expanded
- Evaluation of the UNDP/GEF project

1997

- RRC to become operational
- Continue developing the RRN and the RRC pursuing the objectives of the global change research in the region
- With the expiration of the current UNDP/GEF project in 1996, a financial support for 1997-1998 would be obtained

1998

- Meetings are held to discuss the global change research results in the region
- Proceedings of the meetings are published and policy advice is conveyed to the governments and other interest groups

Southern, Central and Eastern Africa (SAF), Mediterranean Region (MED), Temperate Asia (TEA), Southern Asia (SAS)

The regions listed above are approximately at the same level of development of START activities. It is expected that the stages in the RRNs development will be achieved in these four regions in a more or less similar time frame. These regions are thus presented together in spite of pronounced substantiative differences in opportunities and problems.

SAF. A number of key scientists from the region took part in a meeting "Africa and Global Change" held in Niamey, Niger in November 1992. An *ad hoc* Regional Committee (SAFCOM) has been established and an interim Secretariat located in the Bunda College of Agriculture in Lilongwe, Malawi. SAFCOM has met twice.

MED. It is a region where both developing and developed countries are represented, and a special approach should be elaborated in the framework of the RRN development. The Regional Committee for the Mediterranean (MEDCOM) has been established; the Secretariat functions have been temporarily assumed by MEDIAS in Toulouse, France.

TEA. A Regional Committee (TEACOM) has been appointed. An interim Secretariat has been placed in Beijing. The priority regional research themes have been identified.

SAS. The START Standing Committee has decided to go ahead with development of the RRN.

1994

- The research areas pertinent to global change will be identified and prioritized in each of the four regions. More detailed research agendas will be formulated towards the end of the year
- A survey of relevant on-going activities and research capacities will begin and institutions will be identified as RRSs in order to lay a foundation for the RRN. The needs of the RRSs will be assessed
- The location of the RRCs will be discussed
- The Regional Coordinating Committees will have their respective meetings in Gaborone, Botswana in June 1994 for SAF (back-to-back with the regional scientific meeting); in Alexandria, Egypt in May 1994 for MED; in Tokyo, Japan in January 1994 and in Ulanbataar, Mongolia in August 1994 for TEA; and in Colombo, Sri Lanka in February 1994 for SAS
- Surveys of the regional electronic communications/ data and information networks will be made and the needs identified

1995

- The surveys of the on-going activities, research capacity and institutions will be completed. The programme of the global change research in the region, together with related activities (training, fellowships, data bases, communication links, etc.) will be elaborated and approved
- Sites for some RRCs may be decided on
- The RRN, including the RRCs, will begin implementing the research agenda
- The regional Scientific Advisory Panels will be established, as appropriate
- Funding for further development of the RRNs and the implementation of the regional programmes should be obtained.

1996

- The RRNs and the RRCs are to become fully operational in doing global change research and performing necessary relevant functions. The network of RRSs will be expanded and strengthened
- The electronic communication system will become fully operational.

1997

- Continued development of the RRNs and the RRCs pursuing the objectives of the global change research in each region will take place.

1998

- Results of the global change research in each region will be discussed and published. Policy recommendations will be formulated and conveyed to the governments and other interest groups
- The plan for the next five years will be prepared and approved.

Central Arid Asia (CAA), Oceania (OCE)

The START Standing Committee has discussed the approaches to the RRNs development. A more detailed plan will be developed during 1994

CAA. As it is seen by the START Standing Committee, some of the possible strategies are as follows:

- In case the IGBP calls a meeting of the Mid-East scientists in 1994, to use the occasion to initiate the START planning process
- To use the UN negotiation process of the Convention on Desertification and to focus the regional activities on desertification and related problems through an initial workshop

OCE. To follow-up the interest shown by both the Australian and New Zealand IGBP Committees and to entrust to them the initial steps in the development of the RRN in the region, in collaboration with SPREP.

Equatorial South America (ESA), Temperate South America (TSA), Caribbean (CAR)

These three regions are covered by the IEI for Global Change Research, which has been developed following a US initiative. It is an intergovernmental organization, in which most nations in the Americas have decided to take part. Apart from funding being made available from the participating nations, support will also be received from the Global Environment Facility following an initial proposal made by START.

The objectives of START in relation to these regions is to help harmonize the IAI activities with the activities of START in the other regions of the world and to assist IAI in involving the best talents from the ESA, TSA and CAR in HDP/IGBP/WCRP global change research and related activities.

Temperate Northern Hemisphere Region (TNH)

This is the region which contains most of the global change research. It makes the coordination of regional research a very complex exercise. It is also clear that the framework elaborated by START for developing countries regions cannot be applied there. A special approach should be elaborated. The attempts along this line have been made: The Secretariat of the Commission of European Communities (CEC) has suggested to set up ENRICH. Its overall objective is to provide a major European contribution to the international actions on global change research covering Western Europe, Eastern Europe and the former USSR, as well as Africa and the Mediterranean basin. ENRICH has opted to fully support START, and, hence, HDP, IGBP and WCRP efforts.

In addition, representatives of a number of Academies of Sciences or similar institutions in Europe had the First Expert Meeting for a European Network for Global Change Research in Amsterdam, the Netherlands, in June 1993 to design the cooperation in the framework of the START initiative. A feasibility study is underway for presentation in March 1994.

Antarctic (ANT)

This is a very special region for which the START approach should be uniquely designed. It is evolving through interaction between START and the SCAR of ICSU. A Group of Specialists on Global Change Research in the Antarctic (GLOCHANT) has been created by SCAR. It is expected that GLOCHANT will recommend suitable action to the START Standing Committee for establishment of an RRC in 1994.

Arctic (ARC)

The opportunities in the Arctic are similar to those for the Antarctic. The International Arctic Science Committee (IASC) has been contacted by START and is developing the concept of an RRN/RRC. It is hoped to have a formal establishment in the 1994 - 1995 time frame.

Governmental Initiatives

The governmental initiatives IAI, ENRICH and the Asia-Pacific Network for global change research (APN) are related to the START initiative, and in most cases are closely

cooperating with START. More effort should be expended to develop better a concept of interaction between the non-governmental and governmental initiatives in concentrating the global change research and related activities at a regional level. The final objective of START should be to reap the benefits of both the governmental and non-governmental approaches in the interests of developing global network of networks of institutions doing global change research.

Criteria for a Five-Year Evaluation

An evaluation of the START programme should be planned early on. It is not a one time operation: it should be continuous, permitting mid-course assessment and correction. An evaluation is itself a research project requiring the systematic collection of base-line data and monitoring of achievement of objectives throughout the life of the programme.

We shall know that START is a success if in five years systematic comparisons of baseline and current observations in the START regions around the world show that:

- A major contribution to the understanding of global change issues at a regional or the global level has been achieved
- Thematic monographs summarizing the results of regional research have been published and received positive reviews
- New research initiatives and/or projects, stemming from the global change set of problems and developing it further, have been submitted for funding and approved
- The infrastructure for scientific research has been strengthened in developing countries:
  - Efficient electronic networks have been established, providing communication within and among START regions
  - Scientists have increased access to needed instruments and equipment
  - Scientists have access to needed computational capacity
- Global change research units are institutionalized within established research institutes or research programmes with a prospect for long-term continuity
- Substantial numbers of scientists, particularly those based in developing countries, have been trained for global change research
- The number of scientists who are working on global change research, particularly in developing countries, has increased

- The international peer-reviewed scientific literature carries a large number of articles on global change generated by scientists, particularly from developing countries, involved in the START activities

- RRCs and RRSs are effective in production of documents that are used in national and regional policy development processes

- Scientists in developing countries have full and ready access to the data bases on global environmental change

- Governments in START regions have the benefit of getting and using indigenous scientific advice on global change issues

- The research programmes of the RRNs fulfil objectives of each of the three sponsoring programmes, the IGBP, the HDP and the WCRP.

PART III

APPENDICES

Membership of the Scientific Committee for the IGBP

Officers

Chair

Liss, Peter S. *1994-1996*
University of East Anglia, School of Environmental Sciences, Norwich NR4 7TJ, UK. Tel: (+44-603) 592 563, Fax: (+44-603) 507 714, E-mail: P.Liss (Omnet)

Past-Chair

McCarthy, James J. *1994*
Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, USA. Tel: (+1-617) 495 2330, Tlx: 7402058 mczl ur, Fax: (+1-617) 495 0506, E-mail: J.McCarthy.Harvard (Omnet), James_J_McCarthy@harvard.edu (Internet)

Vice-Chairs

Melillo, Jerry M. *1994-1996*
Woods Hole Marine Biological Laboratory, Woods Hole, MA 02543, USA. Tel: (+1-508) 548 3705, Tlx: 951679, Fax: (+1-508) 457 1548, E-mail: J.Melillo (Omnet)

Stewart, Robert W. *1994*
4249 Thornhill Crescent, Victoria, BC V8N 3G6, Canada. Tel: (+1-604) 721 7708 (office), 477 1247 (home), Fax: (+1-604) 721 7715 (office), 477 3725 (home), E-mail: R.Stewart.MUSC (Omnet)

Tsunogai, Shizuo *1994-1995*
Department of Chemistry, Faculty of Fisheries, Hokkaido University, Minatocho-machi 3-1-1, Hakodate 041, Japan. Tel: (+81-138) 41 01 31, Fax: (+81-138) 43 50 15

Treasurer

Buat-Ménard, Patrick *1994-1996*
Department of Geology and Oceanography, University of Bordeaux 1, URP 197, Centre de Recherche sur les Environnements Sédimentaires Océaniques, Avenue des Facultés, F-33405 Talence Cedex, France. Tel: (+33) 56 84 88 70, Fax: (+33) 56 84 08 48

Members

Abrol, Inder Pal *1994-1996*
Deputy Director General (Resource Management), Indian Council of Agricultural Research, Dr. Rajendra Presad Road, Krishi Bhawan, New Delhi 110 001, India. Tel: (+91-11) 387 293, Telex: 031-62249 icar in, Fax: (+91-11) 384 773

Field, John G. (Chair, JGOFS-SSC) *1994-1996*
Zoology Department, University of Cape Town, 7700 Rondebosch, Cape Town, South Africa. Tel: (+27-21) 650 3612, Telex: 522208 sa, 685 3937, Fax: (+27-21) 685 3937, E-mail: J.Field (Omnet), jgfield@ucthpx.utc.ac.za (Internet)

Fu, Congbin *1994-1996*
Laboratory of Climate Research, Institute of Atmospheric Physics, Chinese Academy of Sciences, PO Box 2718, Beijing 100080, China. Tel: (+86-1) 256 2458, Tlx: 22474 aschi cn, Fax: (+86-1) 256 2347, 256 2458

Golubev, Genady N. *1994-1995*
World Physical Geography and Geoecology Department, Faculty of Geography, Moscow State University, Moscow 119899, Russia. Tel: (+7-095) 939 3962/3842, Fax: (+7-095) 932 8836/952 3007

Henderson-Sellers, Ann *1994-1996*
Climatic Impacts Centre, Macquarie University, Balaclava Road, North Ryde NSW 2109, Australia. Tel: (+61-2) 805 8398, Telex: 12237 aa, Fax: (+61-2) 805 8428, E-mail: ann@mqclimat.cic.mq.edu.au

Holligan, Patrick M. (Chair, LOICZ) *1993-1995*
Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK. Tel: (+44-752) 22 27 72, Fax: (+44-752) 67 06 37, E-mail: P.Holligan (Omnet)

Kabat, Pavel (Chair, BAHC-SSC) *1994-1996*
Winand Staring Centre, PO Box 125, NL-6700 AC Wageningen, The Netherlands. Tel: (+31-8370) 743 14, 742 00, Fax: (+31-8370) 24 812, E-mail: Kabat@SC.agro.nl, kabat@staring.agro.nl

Kempe, Stephan *1993-1995*
Zentrum für Meeres und Klimaforschung, Institut für Biogeochemie und Meereschemie, Universität Hamburg, Bundesstrasse 55, D-20146 Hamburg, Germany. Tel: (+49-40) 4123 5234, Fax: (+49-40) 4123 6347, E-Mail: S.Kempe (Omnet)

Leinen, Margaret *1993-1995*
Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02882-1197, USA. Tel: (+1-401) 792 62 22, Fax: (+1-401) 792 61 60, E-Mail: M.Leinen (Omnet)

Moore, Berrien III (Chair, GAIM) *1993-1995*
Institute for the Study of Earth, Oceans and Space (EOS), Morse Hall, University of New Hampshire, Durham, NH 03824-3524, USA. Tel: (+1-603) 862 1766, Fax: (+1-603) 862 1915, E-mail: B.Moore.UNH (Omnet)

Odada, Eric O. *1993-1995*
Department of Geology, University of Nairobi, PO Box 30197, Nairobi, Kenya. Tel: (+254-2) 44 21 21, Tlx: 22095 varsity ke, Fax: (+254-2) 44 61 38

Oeschger, Hans (Chair, PAGES-SSC) *1994-1995*
PAGES Core Project Office, Bärenplatz 2, CH-3011 Berne, Switzerland. Tel: (+41-31) 312 31 33, Fax: (+41-31) 312 31 68, E-mail: pages@ubeclu.unibe.ch

Peltier, W. Richard *1994-1996*
Department of Physics, University of Toronto, 60 St. George Street, Toronto, Ontario M5S 1A7, Canada. Tel: (+1-416) 978 2938, Fax: (+1-416) 978 8905, E-mail: pelt@atmosp.physics.utoronto.ca (bitnet)

Prinn, Ronald G. (Chair, IGAC-SSC) *1994-1995*
Department of Earth, Atmosphere and Planetary Sciences, Room 54-1312, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. Tel: (+1-617) 253 2452, Tlx: (23) 921 473 mit cam, Fax: (+1-617) 253 0354

Sala, Osvaldo E. *1994-1996*
Departamento de Ecologia, Universidad de Buenos Aires, Facultad de Agronomia, Av. San Martin 4453, Buenos Aires 1417, Argentina. Tel/Fax (+54-1) 51 13 84, E-mail: sala@acriba.bitnet

Townshend, John R. (Chair, DIS-SC) *1994-1996*
Department of Geography, University of Maryland, Lefrak Hall, Room 1113, College Park, MD 20742-8225, USA. Tel: (+1-301) 405 4050, Tlx: 610181 fao, Fax: (+1-301) 314 9299, E-mail: John_R_Townshend@umail.umd.edu

Tinker, P. Bernard *1993-1995*
GCTE Associate Project Office, Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX1 3RB, UK. Tel: (+44-865) 275 079, (home) (+44-367) 860 436, Fax: (+44-865) 275 060, (home) (+44-367) 860 436

Walker, Brian H. (Chair, GCTE-SSC) *1994-1996*
Division of Wildlife and Ecology, Commonwealth Scientific and Industrial Research Organization, PO Box 84, Lyneham, ACT 2602, Australia. Tel: (+61-6) 242 1721, Tlx: (71) 62284 wlr aa, Fax: (+61-6) 241 1742, E-mail: B.Walker (Omnet), bhw@cbr.dwe.csiro.au

Zavarzin, George A. *1994-1996*
Institute of Microbiology, Russian Academy of Sciences, Prosp. 60-letia Oktiabrya 7, Moscow 109017, Russia. Tel: (+7-095) 135 01 31, Tlx: 411634 inman su, Fax: (+7-095) 135 65 30, E-mail: Zavarzin@imbran_msk.su

IGBP Secretariat

Rosswall, Thomas (Executive Director)
Swanberg, Neil (Deputy Executive Director)
IGBP Secretariat, Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Sweden. Tel: (+46-8) 16 64 48, Telex: 17509 IGBP S, Fax: (+46-8) 16 64 05, E-mail: sec@igbp.kva.se

Ex-Officio Members

Jacobson, Harold K. (Chair, HDP)
Centre for Political Studies, Institute for Social Research, University of Michigan, PO Box 1248, Ann Arbor, MI 48106-1248, USA. Tel: (+1-313) 763 1348, Fax: (+1-313) 764 3341, E-mail: H.Jacobson (Omnet), HKJ@um.cc.umich.ed

la Rivière, J.W. Maurits (ACE representative)
International Institute for Hydraulic Engineering, PO Box 3015, Oude Delft 95, NL-2601 DA Delft, the Netherlands. Tel: (+31-15) 78 34 20, Tlx: 38099 IHE, Fax: (+31-15) 12 29 21, E-mail: ICSU.Paris (Omnet)

McBean, Gordon A. (Chair, JSC-WCRP)
Assistant Deputy Minister, Atmospheric Environment Service, Environment Canada, 4905 Dufferin St, Downsview, Ontario M3H 5T4, Canada. Tel: (+1-416) 739 4770, Fax: (+1-416) 739 4232, E-mail: mcbeang@aestor.dots.doe.ca (Internet) G.McBean (Omnet)

Core Projects, Framework Activities and their Offices

BAHC Core Project Office
Sabine Hahn, Institut für Meteorologie, Freie Universität Berlin, Carl-Heinrich-Becker Weg 6-10, D-12165 Berlin, Germany. Tel: (+49-30) 838 711 84, Fax: (+49-30) 838 711 85, Telex: (17) 308740 fusat,E-mail: BAHC@fu46.zedat.fu-berlin.de

GCTE Core Project Office
Will Steffen, CSIRO, Division of Wildlife & Ecology, PO Box 84, Lyneham ACT 2602, Australia. Tel: (+61-6) 242 1748, Fax: (+61-6) 241 2362, E-Mail: wls@cbr.dwe.csiro.au

IGAC Core Project Office
Alex Pszenny, Massachusetts Institute of Technology, Building 24-409, Cambridge, MA 02139, USA. Tel: (+1-617) 253 9887, Tlx: 921483, Fax: (+1-617) 253 9886, E-mail: A.Pszenny (Omnet), pszenny@mit.edu

JGOFS Core Project Office
Uli Wolf, JGOFS Deputy Executive Scientist, Institut für Meereskunde, Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany. Tel: (49-431) 597 40 19, Fax: (49-431) 56 58 76, Omnet: JGOFS.Kiel (Omnet), Internet: jgofs@meereskunde.uni-kiel.d400.de

Hugh Ducklow, JGOFS Core Project Scientist, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA. Tel: (+1-508) 457 2000, ext. 3357, Fax: (+1-508) 457 2193, E-mail: H.Ducklow (Omnet), hducklow@cliff.whoi.edu

Elizabeth Gross, JGOFS Executive Secretary, Executive Director, Scientific Committee on Oceanic Research, Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA. Tel:(+1-410) 516 4070, Fax: (+1-410) 516 7933, E-mail: E.Gross.SCOR (Omnet), e.gross.scor@omnet.com (Internet)

LOICZ Core Project Office
John Pernetta, Netherlands Institute of Sea Research, PO Box 59, NL-1790 AB Den Burg, Texel, The Netherlands. Tel: (+31) 222 069 404, Fax: (+31) 222 069 430

LUCC Core Project Office
Billie J. Turner II (Chair, LUCC CPPC), Land-Use/Land-Cover Planning Committee, Marsh Institute, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA. Tel: (+1-508) 793 73 25, Fax: (+1-508) 793 88 81, E-mail: B.Turner (Omnet)

PAGES Core Project Office
Suzanne Leroy, Associate Director, Bärenplatz 2, CH-3011 Berne, Switzerland. Tel: (+41-31) 312 31 33, Fax: (+41-31) 312 31 68, E-mail:pages@ubeclu.unibe.ch

Herman Zimmerman, Co-Director PAGES, Division of Atmospheric Sciences, Rm. 775, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, USA. Tel: (+1-703) 306 15 27, Fax: (+1-703) 306 03 77, E-mail: H.Zimmerman (Omnet)

GAIM Task Force Office
Berrien Moore III, Chair, Institute for the Study of Earth, Oceans and Space (EOS), Science and Engineering Research Bldg., University of New Hampshire, Durham, NH 03824-3524, USA. Tel: (+1-603) 862 1766, Fax: (+1-603) 862 1915, E-mail: B.Moore.UNH (Omnet)

IGBP-DIS Office
S. Ichtiaque Rasool, Director, Université of Paris 6, Tour 26, 4ème Etage, 4, Place Jussieu, F-75230 Paris Cedex 05, France. Tel: (+33-1) 44 27 61 68 (to 70), Fax: (+33-1) 44 27 61 71, E-mail: I.Rasool (Omnet), rasool@biogeodis.jussieu.fr (Internet)

The International START Secretariat
Roland Fuchs, Director, 1825 K Street, NW, Suite 1101, Washington, DC 20006, USA. Tel: (+1-202) 457 5840, Tlx.: (230)49616179 start (*easylink*), Fax: (+1-202) 457 5859, E-mail: START.Secretariat (Omnet)

IGBP National Committee Chairs and Secretaries

Argentina (1990)
Chair Mario N. Nuñes, Departamento de Meteorologia, Universidad de Buenos Aires, Pabellon 2 - Ciudad Universitaria, Buenos Aires 1428. Tel: (+54-1) 782 65 28, Telex: 18694 ibuba ar, Fax: (+54-1) 311 05 16, E-mail: rtnunez@criba.edu.ar
Co-Chair Osvaldo E. Sala, Departamento de Ecologia, Universidad de Buenos Aires, Facultad de Agronomia, Av. San Martin 4453, Buenos Aires 1417. Phone/Fax: (+54-1) 51 12 84, E-mail: sala@criba.edu.ar

Australia (1986)
Bruce G. Thom, Department of Geography, Institute Building HO 3, University of Sydney, Sydney, New South Wales. Tel: (+61-2) 692 2273, Fax: (+61-2) 522 3426, E-mail: bthom@ucc.su.oz.au

Austria (1990)
Siegfried J. Bauer, Institut für Meteorologie und Geophysik, Universität Graz, Halbärthgasse 1, A-8010 Graz. Tel: (+43-316) 380 52 56/55/61, Telex: 311662 ubgraz a, Fax: (+43-316) 384 091, E-mail: bauers@bkfug.kfunigraz.ac.at

Bangladesh (1988)
Chair S. D. Chaudhuri, Bangladesh Academy of Sciences, 3/8 Asad Avenue, Muhammadpur, Dhaka 1207. Tel: (+880-2) 31 04 25/60 68 68, Telex: 64 22144 srsbj, Fax: (+880-2) 834 978
Secretary A. M. Choudhury, Director, Bangladesh Space Research and Remote Sensing Organisation, SPARRASO, G.P.O Box 529, Agargaon, Sher-e-Bangla Nagar, Dhaka 1207. Tel: (+880-2) 327 335, Fax: (+880-2) 813 080

Belgium (1988)
Oscar Vanderborght, Royal Belgian Academies of Sciences, Palais des Académies, 1, rue Ducale, B-1000 Bruxelles. Tel: (+32-2) 511 2623, Fax: (+32-2) 511 0143, or at the University of Antwerp, Department of Biology, Fax: (+32-3) 328 0497

Benin (1992)
Chair K. S. Adam, Laboratoire de Cartographie Géographique, Université Nationale du Bénin, B.P. 7060, Cotonou. Tel: (+229) 33 19 17, 30 14 05, Tlx: 5010 unb ctnou, Fax: (+229) 33 19 81
Secretary Séverin Asse, Directeur de l'Aménagement du Territoire, Ministère de l'Environnement, de l'Habitat et de l'Urbanisme, Cotonou

Bolivia (1988)
Jaime Argollo, Facultad de Ciencias Geológicas, Universidad Mayor de San Andrés, Casilla de Correo 355, La Paz. Tel: (+591-2) 793 392, Telex: 3438 umsa bu, 3514 orstom bu, Fax: (+591-2) 793 124

Botswana (1993)
Chair Ansu Datta, National Institute of Development, Research and Documentation, University of Botswana, Private Bag 0022, Gaborone. Tel: (+267) 356 364, Telex: 2429 bo, Fax: (+267) 357 573
Secretary Pauline Opha Dube, Department of Environmental Sciences, University of Botswana, Private Bag 0022, Gaborone. Tel: (+267) 351 151, ext. 2510, Telex: 2429 bo, Fax: (+267) 356 591

Brazil (1988)
Chair Eduardo Moacyr Krieger, Academia Brasileira de Ciências, Rua Anfilófio de Carvalho, 29/3°, Andar, Centro, Rio de Janeiro, CEP 20030-060. Tel: (+55-21) 220 4794, 262 0592, Telex: 2123087 daac br, Fax: (+55-21) 240 4659
Secretary Haroldo Mattos de Lemos, Instituto Brasil PNUMA, Av. Nilo Peçanha, 50/1313, Centro CEP 20044-900, Rio de Janeiro - RJ. Tel: (+55-21) 220 1820, Fax: (+55-21) 262 4233

Bulgaria (1990)
Nadezda Petrova, Bulgarian Academy of Science, 1 "15 Noemvri" St., Sofia. Tel: (+359-2) 87 77 18, Telex: 22424 ban sf bg, Fax: (+359-2) 880 448

Canada (1988)
Chair John W. B. Stewart, Dean, College of Agriculture, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0. Tel: (+1-306) 966 4050, Fax: (+1-306) 966 8894
Secretariat Brian D. Bornhold, Director, Canadian Global Change Programme, The Royal Society of Canada, P. O. Box 9734, Ottawa, Ontario K1G 5J4. Tel: (+1-613) 991 5640, Fax: (+1-613) 991 6996

Chile (1987)
Humberto A. Fuenzalida, Departamento de Geofisica, Facultad de Ciencias Fisicas y Matemáticas, Universidad de Chile, Casilla 2777, Santiago de Chile. Tel: (+56-2) 696 87 90, Telex: 243302 ingen cl, Fax: (+56-2) 671 1799

China (CAST) (1988)
Chair Ye Duzheng, Chinese Academy of Sciences, 52, Sanlihe Road, Beijing. Tel: (+86-1) 859 7233, Telex: 22474 aschi cn, Fax: (+86-1) 851 1095
Secretary Chen Panqin, Chinese Academy of Sciences, Bureau of Resources & Environment, 52 Sanlihe Road, Beijing. Tel: (+86-1) 859 7531, Telex: 22474 aschi cn, Fax: (+86-1) 851 1095, E-mail: chenpq%bepc2@scs.slac.edu

China (Academy of Sciences, Taipei) (1988)
Chair Chen-Tung A. Chen, Institute of Marine Geology, National Sun Yat-Sen University, Kaohsiung, 80424 Taiwan. Tel: (+886-7) 532 1408, Fax: (+886-7) 521 4623, 561 4455, E-mail: ctchen@cc.nsysu.edu.tw
Secretary Typhoon Lee, Institute of Earth Sciences, Academia Sinica, PO Box 23-59, Taipei, Taiwan 115. Tel: (+886-2) 783 9910, x 612, Fax: (+886-2) 783 9871, Email: eatyphoon@ccvax.sinica.edu.tw

Colombia (1987)
José A. Lozano, Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, Carrera 3a, No. 17-34 p° 3, Apt. 44.763 Santafé de Bogotá. Tel: (+57-1) 341 4805, Fax: (+57-1) 283 8552

Côte d'Ivoire (1992)
Chair Annabelle Amoin Konan-Brou, Centre de Recherches Océanologiques, Laboratoire d'Ecologie Benthique, 29, rue des pêcheurs BP V 18 Abidjan. Tel: (+225) 35 50 14, 35 58 80, Fax: (+225) 35 11 55
Secretary Wadja Mathieu Egnankou, Université Nationale de Côte d'Ivoire, Faculté des Sciences et Techniques, 22 BP 582, Abidjan 22. Tel: (+225) 43 90 00, ext. 3060

Cuba (1989)
Chair Carlos Gómez Gutiérrez, Academia de Ciencias de la Republica de Cuba, Capitolio Nacional, Industria y San José, La Habana 12400. Tel: (+53-7) 628 726, 626 538, Telex: 511290 acdcp cu., Fax: (+53-7) 339 054, E-mail: driacc@ceniai.cu (Internet)
Secretary Jorge Diaz, Director of Science and Technology, Academy of Sciences of Cuba, Capitolio Nacional, Industria y San José, La Habana 12400. Tel: (+537) 626 685, Fax: (+537) 338 054

Czech Republic (1993, formerly Czechoslovakia 1987)
Chair Ivana Nemešová, Institute of Physics of the Atmosphere CSAV, Bocni II, Box 1401, 141 31 Prague 4. Tel: (+42-2) 76 79 03, Telex: 121546 inop e, Fax: (+42-2) 76 37 45
Secretary Jan Laštovička, Geophysical Institute Bocni II, 141 31 Prague 4. Tel: (+42-2) 766 051 Fax: (+42-2) 762 528, E-mail: jlast@seis.ig.cas.cz (Internet)

Denmark (1990)
Claus Hammer, Geofysisk Institut, Københavns Universitet, Haraldsgade 6, DK-2200 Copenhagen. Tel: (+45) 35 32 05 60, Fax: (+45) 35 82 25 65, E-mail: glac@osiris.gfy.kk.dk

Egypt (1988)
Chair Mohamed A. Ayyad, Faculty of Science, University of Alexandria, Alexandria. Telex 54467 univy un, Fax: (+20-3) 496 0720, 422 7805
Convener Mohamed El-Raey, Vice Dean of the Institute of Graduate Studies, University of Alexandria, Alexandria. Tel: (+20-3) 421 5792, Fax: (+20-3) 493 8704

Estonia (1993)
Chair Rein Vaikmäe, Institute of Geology, Estonian Academy of Sciences, Estonia pst. 7, Tallinn EE-0105. Tel: (+372-2) 454 120, Fax: (+372-2) 444 189, (+372-6) 312 074

Finland (1989)
Chair Per-Edvin Persson, Director, Heureka, The Finnish Science Centre, PO Box 166, SF-01301 Vantaa. Tel: (+358-0) 85 799, Fax: (+358-0) 873 4142
Secretary Marku Kanninen, The Finnish Research Programme on Climate Change, Academy of Finland, P O Box 57, SF-00551, Helsinki. Tel: (+358-0) 77488 336, Fax: (+358-0) 77488 299, E-mail: marku.kanninen@aka.fi (Internet)

France (1988)
Chair Jean-Claude Duplessy, CNRS Centre des Faibles Radioactivités, Av. de la Terrasse, F-91190 Gif-sur-Yvette. Tel: (+33-1) 69 82 35 86, Telex: 214627 f, Fax: (+33-1) 69 82 35 68: E-mail: duplessy@eole.cfr.cnrs-gif.f
Executive Officer Jérome Fouan, Direction de la Commission Scientifique, Technique et Educative (DDCSTE), Ministère des Affaires Etrangères, 34, rue La Pérouse, F-75775 Paris Cedex 16. Tel: (+33-1) 40 66 74 75, Fax: (+33-1) 40 66 75 74

Germany (BRD - 1987, DDR - 1988)
Chair Hans-Jürgen Bolle, Institut für Meteorologie, Freie Universität Berlin, Carl-Heinrich-Becker-Weg 6-10, D-12165 Berlin. Tel: (49-30) 838 711 59, 838 711 17, Telex: (41)17 308740 fusat, Fax: (+49-30) 838 711 60, E-mail: H.Bolle.IGBP (Omnet)
Secretary Sabine Lütkemeier, IGBP-Sekretariat, Institut für Meteorologie, Freie Universität Berlin, Carl-Heinrich-Becker-Weg 6-10, D-12165 Berlin. Tel: (+49-30) 838 711 17, Fax: (+49-30) 838 71217, E mail: H.Bolle.IGBP (Omnet)

Ghana (1993) (ICSU Committee)
Chair E. N. W. Oppong, Ghana Academy of Arts and Sciences, off Agostino Neto Road, Airport Residential Area, P O. Box M.32, Accra. Tel: (+233-21) 77 7651 (to 4), Fax: (233-21) 77 7655, Telex: 071289
Secretary K. Gyekye, F.G.A. (at above address)

Greece (1988)
John Xanthakis, Research Center for Astronomy and Applied Mathematics, Academy of Athens, 14, Anagnostopoulou Street, GR-10673 Athens. Tel: (+30-1) 361 35 89

Hungary (1987)
Chair Joseph Tigyi, Biophysical Institute of the Medical University, PO Box 99, H-7643 Pécs. Tel: (+36-72) 31 40 17, Telex: 12500 pote h, Fax: (+36-72) 32 62 44

Secretary Attila Borhidi, Faculty of Human and Natural Sciences, Janus Pannonius University, Kulich Gy. u. 22, H-7601 Pécs. Tel: (+36-72) 12 988, Fax: (+36-72) 26 886

India (1988)
Chair A. P. Mitra, National Physical Laboratory, Hillside Road, New Delhi 110 012, India. Tel: (+91-11) 574 5298, Telex: 31-77384, Fax: (+91-11) 575 2678, E-mail: apmitra@doe.ernet.in
Secretary S. C. Majumdar, Council for Scientific & Industrial Research, C.S.I.R. Complex, N.P.L. Campus Pusa 990092, New Delhi. Tel: (+91-11) 573 7953, Fax: (+91-11) 371 0618

Indonesia (1992)
Harsono Wiryosumarto, National Aeronautic and Aerospace Agency (LAPAN), Jl. Permuda Persil No 1, PO Box 20/JAT, Jakarta 13220. Tel: (+62-21) 489 4989, 489 4941, Fax: (+62-21) 489 4815

Ireland (1988)
Roderick P. Kernan, Science Secretary, Royal Irish Academy, 19 Dawson Street, Dublin 2. Tel: (+353-1) 676 2570, Fax: (+353-1) 676 2346

Israel (1988)
Dan H. Yaalon, Institute of Earth Sciences, Hebrew University of Jerusalem, Givat Ram Campus, Jerusalem 91904. Tel: (+972-2) 58 46 86, Telex: 25391 hu il, Fax: (+972-2) 662 581

Italy (1990)
Angelo Guerrini, National Committee for Science and Technology of the Environment, National Council for Research, Piazzale Aldo Moro, 7, I-00185 Roma. Tel: (+39-6) 49 93 25 55, Telex: 610076 cnr rm i, Fax: (+39-6) 446 98 33

Jamaica (1988)
Gladstone V. Taylor, Scientific Research Council, PO Box 350, Kingston. Tel: (+1-809) 927 1771/4 or 927 1912, Telex: 3631 srcstin ja, Fax: (+1-809) 927 5437

Japan (1987)
Masatoshi Yoshino, 15-18 Naka-arakawaoki-machi, Tsuchiura-City, 300-11. Tel/Fax: (+81-298) 41 3309

Kenya (1990)
Chair Shem O. Wandiga, Deputy Vice Chancellor (A&F), University of Nairobi, PO Box 30197, Nairobi. Tel: (+254-2) 33 42 44, Telex: 22095 varsity ke, Fax: (+254-2) 33 68 85
Secretary W. Ogana, Honorary Secretary, Kenya National Academy of Sciences, PO Box 39450, Nairobi. Tel: (+254-2) 721 345. Fax: (+254.2) 336 885

Korea, Republic of (1993)
E-Hyock Kwon, ICSU Committee, National Academy of Sciences of the Republic of Korea, San 94, Panpo-dong, Seocho-gu, Seoul 137-042. Tel: (+82-2) 534 0737, Fax: (+82-2) 537 3183

Malaysia (1992)
V. Danabalan, Secretary General, Ministry of Science, Technology and the Environment, 14th Floor, Sime Darby Building, Jalan Raja Laut, 50662 Kuala Lumpur. Tel: (+60-3) 293 8955, Fax: (+60-3) 293 6006, Cable: KEMSAINS

Mexico (1991)
Mario Martinez García, Director General, Centro de Investigación Cientifica y Educación Superior de Ensenada-CICESE, Av. Espinoza No. 843, Ensenada, Baja California, Tel: (+52-667) 44 400, 44 900, Fax: (+52-667) 44 880, E-mail: mmartinez@cicese.mx (Internet)

Mongolia (1993)
T. S. Shiirevdamba, First Deputy Minister, Ministry for Nature and Environment, Khudaldaany Gudamj 5, Ulaan Baatar 11. Fax: (+976-1) 32 1401, Telex: 79343 macne mh
Secretary M. Badarch, Ministry for Nature and Environment, Khudaldaanii gudamj 5, Ulaanbaatar 11. Fax: (+976-1) 32 1401, Telex: 79343 macne mh

Netherlands (1987)
Chair Henk Postma, Dutch MAB/SCOPE/IGBP Committee, K.N.A.W., Het Trippenhuis, Kloveniersburgwal 29, Postbus 19121, NL-1000 GC Amsterdam. Tel: (31-20) 551 0700, Fax: (+31-20) 620 4941, (at NOIZ in Texel): Tel: (+31) 2220 69411, Fax: (+31) 2220 19676, E-mail: NOIZ.Texel (Omnet)

New Zealand (1988)
Convener Jane Soons, Department of Geography, University of Canterbury, Private Bag 4008, Christchurch. Tel: (+64-03) 366 7001, 364 2933, Fax: (+64-03) 364 2907, E-mail: a.moloney@csc.canterbury.ac.nz (Internet)
Secretary Sue Usher, The Royal Society of New Zealand, PO Box 598, Wellington. Tel: (+64-4) 472 7421, Fax: (+64-4) 473 1841

Niger (1991)
Mohamed Boulama, Direction de la Météorologie Nationale, BP 218, Niamey. Tel: (+227) 73 21 60, Telex: 5527, Fax: (+227) 73 38 37

Nigeria (1992)
A. U. Ogan, The Nigerian Academy of Science, P. M. B. 1004, University of Lagos Post Office, University of Lagos, Akoka-Yaba

Norway (1989)
Chair Ivar S. A. Isaksen, Institute of Geophysics, University of Oslo, PO Box 1022 Blindern, N-0315 Oslo 3. Tel: (+47) 22 85 58 22, Fax: (+47) 22 85 52 69
Secretary Kirsten Broch-Mathisen, The Research Council of Norway, Stensberggata 26, PO Box 2700, St. Hanshaugen, N-0131 Oslo. Tel: (+47) 22 03 72 25, Fax: (+47) 22 03 70 01

Peru (1989)
Alberto A. Giesecke M., Centro Regional de Sismología, Apartado 14-0363, Lima. Tel: (+51-14) 33 67 50, Telex: 20053 pe pb limtc, Fax: (+51-14) 33 67 50, 33 89 34

Philippines (1992)
M. Filomena F. Campos, National Research Council of the Philippines, General Santos Avenue, Bicutan, Taguig, 1604 Metro Manila. Tel: (+63-2) 822 0409, Fax: (+63-2) 823 8937

Poland (1989)
Chair Leszek Starkel, Polish Academy of Sciences, Institute of Geography and Spatial Organization, Ul. Sw. Jana 22, PL-31-018 Kraków. Tel: (+48-12) 22 40 85, Telex: 825414 olpan pl., Fax: (+48-12) 22 27 91
Secretary M. Gutry-Korycka, Hydrology Department, Faculty of Geography and Regional Studies, Warsaw University, Str. Krakowskie Przedmiescie 30, PL-00-927 Warszawa. Tel: (+48-22) 26 30 71, ext. 248, Fax: (+48-22) 26 19 65

Portugal (1993) (ICSU Committee)
F. R. Dias Agudo, Academia das Ciências de Lisboa, rua Academia das Ciências, 19, P-1200 Lisboa. Tel: (+351-1) 346 3866, Fax: (+351-1) 342 0395

Romania (1991)
Liviu Constantinescu, Romanian Academy of Sciences, Calea Victoriei 125, 71 102 Bucarest 22. Tel: (+40-1) 50 76 80, ext. 175, Telex: 11470 acad r, Fax: (+40-1) 312 0209

Russia (formerly USSR Committee, 1988)
Chair Vladimir M. Kotlyakov, Institute of Geography, Russian Academy of Sciences, Staromonetny per. 29, Moscow 109017. Tel: (+7-095) 238 8610, Tlx: (64) 411781 globe, Fax: (+7-095) 230 2090
Secretary Yuri A. Starikov, Institute of Geography, Russian Academy of Sciences, Staromonetny per. 29, Moscow 109017. Tel: (+7-095) 238 94 69, Fax: (+7-095) 230 20 90

Senegal (1993)
Diafara Touré, Diafara, Centre de Recherches Océanographiques de Dakar-Thiaroyé, BP 2241, Dakar. Tel: (+221) 34 05 34/36, Fax: (+221) 34 27 92, 32 43 07

Sierra Leone (1993)
N. H. Ayodele Cole, Fourah Bay College, University of Sierra Leone, Freetown. Tel: (+232-22) 23 26 48, Fax: (+232-22) 22 44 39

Singapore (1993)
Lawrence Koe, Department of Civil Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore 0511. Tel: (+65) 722 2164, Fax: (+65) 779 1635, E-mail: cvekoecc@leonis.nus.sg

Slovakia (1993, formerly Czechoslovakia 1987)
Chair Július Šútor, Institute of Hydrology, Slovak Academy of Sciences, Trnavská 32, 51 Bratislava. Tel: (+42-7) 684 97, Fax: (+42-7) 624 19
Secretary Lubomír Lichner (at above address)

South Africa (1987)
Chair Peter van Eldik, Foundation for Research Development, P O Box 2600, Pretoria. Tel: (+27-12) 841 2426, Fax: (+27-12) 841 2354
Secretary R. Dan Walmsley, Foundation for Research Development, P O Box 2600, Pretoria. Tel: (+27-12) 841 3634, Fax: (+27-12) 841 3791

Spain (1993)
Chair José Manuel Moreno Rodriguez, Departamento de Ecología, Facultad de Biología, Universidad Complutense, E-28040 Madrid. Tel: (+34-1) 549 6183, Telex: 49692 cicyte, Fax: (+34-1) 549 6183
Secretary Santiago Lago, Secretaria General del Plan Nacional de I+D, Comision Interministerial de Ciencia y Tecnologia, Rosario Pino, 14-16, E-18020 Madrid. Tel: (+34-1) 572 0098, Telex: 49692 cicyt e, Fax: (+34-1) 571 5781

Sri Lanka (1990)
R. D. Arudpragasam, Faculty of Science, University of Colombo, PO Box 1490, Colombo 3. Tel: (+94-1) 586 868, 583 105, Fax: (+94-1) 503 148

Sweden (1987)
Chair Nils Malmer, Department of Plant Ecology, University of Lund, Östra Vallgatan 14, S-223 61 Lund. Tel: (+46-46) 10 92 99, 10 92 95, Telex: 33533 luniver s, Fax: (+46-46) 10 44 23
Secretary Iréne Johansson, Swedish Natural Science Research Council, Box 6711, S-113 85 Stockholm. Tel: (+46-8) 610 0705, Fax: (+46-8) 610 0740

Switzerland (1987)
Chair Hans R. Thierstein, Geologisches Institut, ETH-Zentrum, CH-8092 Zürich. Tel: (+41-1) 632 3666, Telex: 817379 ehhg ch, Fax: 252 0819, E-mail: thierstein@erdw.ethz.ch

Secretariat Anne-Christine Clottu Vogel, Swiss Academy of Sciences, Bärenplatz 2, CH-3012 Berne. Tel: (+41-31) 312 21 14, Fax: (+41-31) 312 32 91

Tanzania (1993)
Interim Chairman J. G. Yarro, University of Dar Es Salaam, Box 35065, Dar Es Salaam. Tel: (+255-51) 43 129: 49 192
Secretary R. W. P. Masenge, University of Dar Es Salaam (at above address)

Thailand (1989)
Twesukdi Piyakanchana, Institute of Environmental Research, Chulalongkorn University, Bangkok 10330. Tel: (+66-2) 252 5929, Telex: 20217 unichul, Fax: (+66-2) 252 5929

Togo (1992)
Chair Komlavi Seddoh, Vice-Chancellor of the University of Benin, B P 1515 Lomé. Tel: (+228) 21 35 00, Telex: 5258 ub tg, Fax: (+228) 21 85 95, 21 87 84
Secretary Ayéchoro Koffi Akibode, Ecole Supérieure d'Agronomie, University of Benin, B.P. 999, Lomé. Tel: (+228) 26 48 95, (+288) 21 58 95, Fax: (+228) 21 85 95, 21 87 84

Tunisia (1993)
Mohamed Brini, Directeur du Département de Mathématiques, Physique et Chimie, Institut National Agronomique de Tunisie, 43, Avenue Charles Nicolle, 1082 Tunis Mahrajène. Tel: (+216-1) 280 950, Fax: (+216-1) 799 391

Uganda (1990)
Chair S.P. Kagoda, Commissioner for Technology, Ministry of Industry and Technology, PO Box 7125, Kampala
Secretary W. A. Majugu, Eastern & Southern African Drought Monitoring Centre, PO Box 3025, Nairobi, Kenya. Fax: (+254-2) 567 888

United Kingdom (1987)
Chair P. Bernard Tinker, Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX1 3RB. Tel: (+44 865) 275 079, Fax: (+44 865) 275 060)
Secretary Ruth Cooper, The Royal Society, 6 Carlton House Terrace, London, SW1Y 5AG. Tel: (+44-71) 839 5561, Telex 917876, Fax: (+44-71) 930 2179

United States (1987)
Chair Edward A. Frieman, Scripps Institute of Oceanography, Director's Office 0210, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0210. Tel: (+1-619) 534 2826, Fax: (+1-619) 453 0167

Secretary John S. Perry, Board on Global Change, National Research Council, Commission of Geosciences, Environment and Resources, 2101 Constitution Avenue, NW, Washington, DC 20418-1000. Tel: (+1-202) 334 35 17, Fax: (+1-202) 334 25 30, E-mail: J.Perry (Omnet), jperry@nas.edu (Internet)

Venezuela (1988)
Federico Pannier, Academia de Ciencias Físicas, Matematicas y Naturales, Apartado 1421, Caracas 1010A. Tel: (+58-2) 41 66 11, 483 41 33, Telex: 25205 cnit vc, Fax: (+58-2) 41 66 11

Zambia (1990)
Interim Convener Prem C. Jain, Physics Department, University of Zambia, PB 32379, Lusaka. Tel: (+260-1) 293 343/293 809, 260 632, ext. 1643, Telex: 44370 unza lu za, Fax: (+260-1) 253 952, E-mail: PJain@f1.n761.z5.fidonet.org

Zimbabwe (1989)
G. R. Chimonyo, Department of Geography, University of Zimbabwe, PO Box MP 167, Mount Pleasant, Harare. Tel: (+263-4) 30 32 11, ext. 1265, Telex: 26580 univz zw, Fax: (+263-4) 33 34 07

Liaison Persons with ICSU Scientific Members

CODATA (Committee on Data for Science and Technology), Michael Chinnery, Director, National Geophysical Data Center, NESDIS/NOAA, 325 Broadway, Boulder, CO 80303-3328, USA. Tel: (+1-303) 497 6215, Telex: 592811 noaa masc bdr, Fax: (+1-303) 497 6513

COSPAR (Committee on Space Research), Jean-Louis Fellous, MEDIAS FRANCE, Centre National des Etudes Spatiales, 18, Avenue Edouard Belin, BP 2102, F-31055 Toulouse, France. Tel: (+33) 61 28 22 09, Telex: 581018 f, Fax: (+33) 61 28 29 05, E-mail: J.Fellous (Omnet), fellous@cnesta.span.cnes.fr

FAGS (Federation of Astronomical and Geophysical Data Analysis Services), David Pugh, Institute of Oceanographic Sciences, Deacon Laboratory, Brook Road, Wormley, Godalming, Surrey GU8 5UB, UK. Tel: (+44-428) 684 141, Fax: (+44-428) 685 637

IAHS (International Association of Hydrological Sciences), Alfred Becker, Potsdam Institute for Climate Research, Telegrafenberg, D-14473 Potsdam, Germany. Tel: (+49-331) 288 2541, Fax: (+49-331) 288 2600, E-mail:becker@pik-potsdam.de

IATUL (International Association of Technological University Libraries), Dennis F. Shaw, Fellow of Keble College, University of Oxford, Parks Road, Oxford, OX1 3PG, UK. Tel: (+44-865) 27 27 27, Fax: (+44-865) 27 27 05, E-mail: dfshaw@ox.vax.ac.uk

IGU (International Geographical Union), Vladimir M. Kotlyakov, Russian Academy of Sciences, Staromonetny per. 29, Moscow 109017, Russia. Tel: (+7-095) 238 86 10, Telex: 411781 globe su, Fax: (+7-095) 230 20 90, E-mail: geography@glac.apc.org

IIASA (International Institute for Applied Systems Analysis), Peter de Jánosi, Director, IIASA, A-Laxenburg 2361, Austria. Tel: (+43-2236) 715 210, Fax: (+43-2236) 73 147, E-mail: dejanosi@iiasa.ac.at

IMU (International Mathematical Union), Jacques-Louis Lions, Collège de France, 3, rue d'Ulm, F-75005 Paris, France. Tel: (+33-1) 44 27 17 05 or 08, Fax: (+33-1) 44 27 17 04

INQUA (International Union for Quaternary Research), Nat W. Rutter, Department of Geology, University of Alberta, Edmonton, Alberta T6G 2E3, Canada. Tel: (+1-403) 492 3085, 3265, Fax: (+1-403) 492 2030, E-mail: nrcs@mts.ucs.ualberta.ca

ISSS (International Society of Soil Science), Hans-Wilhelm Scharpenseel, Institute für Bodenkunde, Universität Hamburg, Allende-Platz 2, D-20146 Hamburg, Germany. Tel: (+49-40) 4123 2008, Telex: 214732 unihh d, Fax: (+49-40) 4123 2024

IUBMB (International Union of Biochemistry and Molecular Biology), Sir Hans Kornberg, Department of Biochemistry, University of Cambridge, Tennis Court Road, Cambridge CB2 1QW, UK, Tel: (+44-223) 33 628, Fax: (+44-223) 334 748

IUBS (International Union of Biological Sciences), Talal Younes, 51 Boulevard de Montmorency, F-75016 Paris, France, Tel: (+33-1) 4525 0009, Telex: 645554 icsu f, Fax: (+33-1) 4525 2029

IUFRO (International Union of Forestry Research Organisations), Rodolphe Schlaepfer, Swiss Federal Institute for Forest, Snow and Landscape Research, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland. Tel: (+41-1) 739 2224/2225, Fax: (+41-1) 739 2215, Telex: 827203 wsl ch

IUGG (International Union of Geodesy and Geophysics), Gordon A. McBean, Assistant Deputy Minister, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, Canada. Tel: (*Downsview*) (+1-416) 739 4770, (*Ottawa*) (+1-613) 996 3206, Fax: (*Downsview*) (+1-416) 739 4232, (*Ottawa*) (+1-613) 943 1538, E-mail: G.McBean (Omnet), mcbeang@aestor.dots.doe.ca (Internet)

IUGS (International Union of Geological Sciences), Ray Price, Department of Geological Sciences, Queen's University, Kingston, Ontario K7L 3N6, Canada. Tel: (+1-613) 545 2597, Fax: (+1-613) 545 6592

IUHPS (International Union of the History and Philosophy of Science), Bengt Hansson, Filosofiska Instutionen, Kungshuset i Lundgård, S-223 50 Lund, Sweden. Tel: (+46-46), 10 75 94

IUPAB (International Union for Pure and Applied Biophysics), Dušan Vučelić, Institute of General and Physical Chemistry, Beograd University, POB 551, Studentski trg. 12/V, 11000 Beograd, Yugoslavia. Tel: (+38-11) 185 243, Telex: 11176 iofh yu, Fax: (+38-11) 639 624

IUPAC (International Union of Pure and Applied Chemistry), J. G. Calvert, 260 Cactus Court, Boulder, CO 80304, USA. Tel: (+1-303) 497 1435, Fax: (+1-303) 497 1400

IUPsyS (International Union of Psychological Science), Kurt Pawlik, University of Hamburg, Von-Melle-Park 11, D-20146 Hamburg, Germany, Tel:(+49-40) 41 23 47 23, Telex: 214732, Fax: (+49-40) 41 23 65 91, E-mail: P01Paw@DHHDESY3 (Bitnet)

SCAR (Scientific Committee on Antarctic Research), Charles R. Bentley, Geophysical and Polar Research Center, University of Wisconsin-Madison, Lewis G. Weeks Hall for Geological Sciences, 1215 W. Dayton Street, Madison, Wisconsin 53706-1692, USA. Tel:(+1-608) 262 1921, Telex: 3797422 uofwisc md, Fax:(+1-608) 262 0693, E-mail: bentley@geology.wisc.edu

SCOPE (Scientific Committee on Problems of the Environment), Francesco di Castri, Director of Research, Centre National de la Recherche Scientifique, Centre d'Ecologie Fonctionnnelle et Evolutive, 1919 Route de Mende, BP 5051, F-34033 Montpelier Cedex 1, France. Tel: (+33) 67 61 33 08, Fax: (+33) 67 41 21 38

SCOR (Scientific Committee on Oceanic Research), Elizabeth Gross, Executive Director, SCOR, Dept. of Earth and Planetary Sciences, John Hopkins University, Baltimore, MD 21218, USA. Tel: (+1-410) 516 4070, Fax: (+1-410) 516 7933, E-mail: E.Gross.SCOR (Omnet), e.gross.scor@omnet.com

SCOSTEP (Scientific Committee on Solar-Terrestrial Physics), Juan G. Roederer, Chairman, International STEP, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-7320, USA. Tel: (+1-907) 474 5090, Telex: 35414, Fax:(+1-907) 474 5517

TWAS (Third World Academy of Sciences), Cyril Ponnamperuma, President, The Third World Foundation, University of Maryland, PO Box 82, College Park, MD 20742, USA. Tel: (+1-301) 405 1897, Fax: (+1-301) 405 9375

URSI (Union Radio Scientifique Internationale), R. Keith Raney, Chief Radar Scientist, Canada Center for Remote Sensing, 588 Booth Street, Room 435, Ottawa, Ontario K1A 0Y7, Canada. Tel: (+1-613) 947 1813, Fax:(+1-913) 947 1383, E-mail: raney@ccrs.emr.ca, K.Raney@ieee.org

WDC (World Data Centres), Stan Ruttenberg, University Corporation for Atmospheric Research, PO Box 3000, Boulder, CO 80307-3000, USA. Tel: (+1-303) 497 8689, Fax: (+1-303) 497 8633, E-mail: S.Ruttenberg (Omnet), rutten@ncar.ucar.edu (Internet)

IGBP Publications

IGBP Reports

Those marked with an * are no longer in print. Others can be ordered from the IGBP Secretariat, The Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Sweden. They are distributed free of charge in single copies.

No. 1. * The International Geosphere-Biosphere Programme: A Study of Global Change. Final Report of the *ad hoc* Planning Group, ICSU 21st General Assembly, Berne, Switzerland 14-19 September, 1986 (1986). 21 pp.
Final report of the ICSU ad hoc Planning Group authorized in 1984 to review relevant ongoing activities of bodies in the ICSU family and other organizations and to decide on the planning of an International Geosphere Biosphere Programme. A Special Committee for the International Geosphere Biosphere Programme was established.

No. 2. * A Document Prepared by the First Meeting of the Special Committee, ICSU Secretariat, Paris 16-19 July, 1987 (1987). 22 pp.
The Special Committee defined the objectives of the IGBP: to describe the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions. The ultimate objective of the programme is to develop predictive capabilities in relation to future changes in our global life support system.

No. 3. * A Report from the Second Meeting of the Special Committee, Harvard University, Cambridge, MA, USA 8-11 February, 1988 (1988). 42 pp.
The Special Committee confirmed the key research areas and the formation of four coordinating panels: Terrestrial Biosphere-Atmospheric Chemistry Interactions; Marine Biosphere-Atmosphere Interactions; Biospheric Aspects of the Hydrological Cycle; Effects of Climate Change on Terrestrial Ecosystems. Working Groups have been set up to assess the current state of knowledge and future prospects for IGBP activities: Global Geosphere-Biosphere Modelling, Data and Information Systems, Techniques for Extracting Environmental Data of the Past, and Geo-Biosphere Observatories.

No. 4. * The International Geosphere-Biosphere Programme. A Study of Global Change (IGBP). A Plan for Action. A Report Prepared by the Special Committee for the IGBP for Discussion at the First Meeting of the Scientific Advisory Council for the IGBP, Stockholm, Sweden 24-28 October, 1988 (1988). 200 pp.
The underlying themes of the IGBP are: Documenting and predicting global change; observing and improving understanding of dominant forcing functions; understanding interactive phenomena in the total Earth system. The research areas for the Coordinating Panels and the Working Groups are outlined.

No. 5. * Effects of Atmospheric and Climate Change on Terrestrial Ecosystems. Report of a Workshop Organized by the IGBP Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems at CSIRO, Division of Wildlife and Ecology, Canberra, Australia 29 February - 2 March, 1988. Compiled by B. H. Walker and R. D. Graetz (1989). 61 pp.
The Coordinating Panel presented 40 research needs and recommendations, stressing that there is no body of ecological theory adequately integrating environment, energetics, dynamics, distribution and abundance. There is a large gap in both plant ecology and

animal ecology, and it hinders general understanding of the effects of climate change on the distribution and dynamics of populations.

No. 6. * Global Changes of the Past. Report of a Meeting of the IGBP Working Group on Techniques for Extracting Environmental Data of the Past held at the University of Berne, Switzerland 6-8 July, 1988. Compiled by H. Oeschger and J. A. Eddy (1989). 39 pp.
Present data extracting techniques glean information from natural archives (ice core, tree rings, sedimentary rocks, historical records). Seven research themes are identified for recommended emphasis in the IGBP, connected to related IGBP programme initiatives.

No. 7. * A Report from the First Meeting of the Scientific Advisory Council for the IGBP held at the Royal Swedish Academy of Sciences, Stockholm, 24-28 October 1988 (1989). Vols. 7:1 and 7:2, 338 pp.
Volume I presents the opening addresses, plenary presentations, discussion group reports on Coordinating Panels, Working Groups, and reports on IGBP interactions with other Global Change research. Volume II gives reports from the IGBP National Committees, and ICSU bodies, and other international organizations.

No. 8. * Pilot Studies for Remote Sensing and Data Management. Report of a Meeting of the IGBP Working Group on Data and Information Systems, Geneva, Switzerland 11-13 January 1989. Edited by S. I. Rasool and D. S. Ojima (1989). 41 pp.
The Working Group identified one project, the Land-Cover Change Pilot Study, that would establish baseline observing sites for documenting and studying change induced by human activities, and three projects dealing with existing data useful to studies and documentation of global change.

No. 9. * Southern Hemisphere Perspectives of Global Change. Scientific Issues, Research Needs and Proposed Activities. Report from a Workshop held in Mbabane, Swaziland 11-16 December, 1988. Edited by B. H. Walker and R. G. Dickson (1989). 55 pp.
The Southern Hemisphere's physical characteristics, biological systems, socio-economic factors, and special needs require a southern hemisphere component to the IGBP, and specific research programmes.

No. 10. * The Land-Atmosphere Interface. Report on a Combined Modelling Workshop of IGBP Coordinating Panels 3, 4, and 5. Brussels, Belgium, 8-11 June, 1989. Edited by S. J. Turner and B. H. Walker (1990). 39 pp.
IGBP Coordinating Panels on Biospheric Aspects of the Hydrological Cycle, Effects of Climatic Change on Terrestrial Ecosystems, and Global Analysis, Interpretation and Modelling, discussed research areas of common interest, and explored different modelling approaches and how they may be synthesized into a system.

No. 11. * Proceedings of the Workshops of the Coordinating Panel on Effects of Global Change on Terrestrial Ecosystems. I. A Framework for Modelling the Effects of Climate and Atmospheric Change on Terrestrial Ecosystems, Woods Hole, USA, 15-17 April, 1989. Edited by B. H. Walker. II. Non-Modelling Research Requirements for Understanding, Predicting, and Monitoring Global Change, Canberra, 29-31 August 1989. Edited by B. H. Walker and S. J. Turner. III. The Impact of Global Change on Agriculture and Forestry, Yaoundé, 27 November-1 December, 1989. Edited by S. J. Turner, R. T. Prinsley, D. M. Stafford Smith, H. A. Nix and B. H. Walker (1990). 108 pp.
A modelling framework, identification of empirical research requirements, and a framework for predicting effects of global change on agroecosystems are studied in three meetings of the IGBP Coordinating Panel preparing a scientific research plan on global change and terrestrial ecosystems.

No. 12. The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP). The Initial Core Projects (1990). 330 pp.
The IGBP science plan is composed of research projects aimed at answering a number of key questions related to global change, through the establishment of Core Projects on the distinct sub-components of the Earth system, and related activities on data systems and research centres. An implementation strategy provides for its fulfilment.

No. 13. Terrestrial Biosphere Exchange with Global Atmospheric Chemistry. Terrestrial Biosphere Perspective of the IGAC Project: Companion to the Dookie Report. Report on the Recommendations from the SCOPE/IGBP Workshop on Trace-Gas Exchange in a Global Perspective. Sigtuna, Sweden, 19-23 February, 1990. Edited by P. A. Matson and D. S. Ojima (1990). 103 pp.
The Sigtuna workshop contributed to the development of a scientific action plan on terrestrial ecosystem gas exchange, complementing the International Global Atmospheric Chemistry Project (an IGBP Core Project) in areas of natural variability, boreal regions, global integration and modelling of fluxes, and trace gas fluxes in mid-latitude ecosystems.

No. 14. Coastal Ocean Fluxes and Resources. Report of a CP2 *Ad Hoc* Workshop, Tokyo, Japan, 19-22 September 1989. Edited by P. Holligan (1990). 53 pp.
The focus of IGBP Coordinating Panel 2 on Marine Biosphere-Atmosphere Interactions is the elucidation and prediction of the feed-back loops between climate and ocean biogeochemistry under conditions of significant anthropogenic changes to the trace gas composition of the atmosphere. The workshop concentrated on global change and the coastal oceans.

No. 15. Global Change System for Analysis, Research and Training (START). Report of a Meeting at Bellagio, December 3-7, 1990. Edited by J. A. Eddy, T. F. Malone, J. J. McCarthy and T. Rosswall (1991). 40 pp.
START is a plan for the development of an international network of regional research centres and sites to gather data and study global change problems in their regional contexts. These regions are identified. Studies address how regional changes affect global biogeochemical cycles and climate; and how global change leads to further regional change in the biospheric life support system.

No. 16. Report from the IGBP Regional Meeting for South America, São José dos Campos, SP, Brazil, 5-9 March 1990 (1991). 58 pp.
The workshop discussed, in a South American context, past global changes, the effects of climate change on terrestrial ecosystems, the role of ocean processes in global change, land transformation and global change processes, the importance of the Andes for general circulation models, and regional research centres. Recommendations promote the role of South American science in global change research.

No. 17. Plant-Water Interactions in Large-Scale Hydrological Modelling. Report of a Workshop, Vadstena, Sweden, 5-8 June 1990 (1991). 44 pp.
The workshop addressed plant-water interrelationships at landscape to continental scales: the spacial pattern at landscape level of the dynamics of water flows and waterborne fluxes of dissolved and suspended mater; plant/vegetation characteristics and properties affecting return flow to the atmosphere; methodological issues of large-scale modelling; research in humid tropical, semi-arid and temperate zones.

No. 18:1 Recommendations of the Asian Workshop, New Delhi, India, February 11-15, 1991. Edited by R. R. Daniel (1991). 36 pp.
Recommendations of the Workshop address issues of prime concern to Asian countries, with reports and recommendations from Working Groups on IGBP Core Projects and key activities.

No. 18:2 Proceedings of the Asian Workshop, New Delhi, India, 11-15 February 1991, ed. by R. R. Daniel & B. Babuji. Madras, Committee on Science and Technology in Developing Countries (COSTED) and the Indian National Committee for the IGBP (1992). 152 pp.
The Proceedings include 19 papers on Earth system research and global environmental change in Asia, and national reports on global change programmes.

No. 19. The PAGES Project: Proposed Implementation Plans for Research Activities, ed. by John A. Eddy (1992). 112 pp.
The Past Global Changes (PAGES) project will secure better understanding of the natural and human-induced variations of the Earth system in the past. The Foci are on changes within two temporal streams: global changes for the period 2000 BP, and changes through a full glacial cycle. The implementation plans address: solar and orbital forcing and response, fundamental Earth system processes, rapid and abrupt global changes, palaeoclimatic and palaeoenvironmental modelling, management of palaeodata, and improved chronologies.

No. 20. Improved Global Data for Land Applications: A Proposal for a New High Resolution Data Set, Report of the Land Cover Working Group of IGBP-DIS, Edited by John R. Townshend (1992). 75 pp.
This report outlines a proposal to produce a global data set at a spatial resolution of 1 km derived from the Advanced Very High Resolution Radiometer primarily for land applications. It defines the characteristics of the data set to meet a number of requirements of IGBP's science plan and outlines how it could be created. It presents the scientific requirements for a 1 km data set, the types and uses of AVHRR data, characteristics of a global 1 km data set, procedures, availability of current AVHRR 1 km data, and the management needs.

No. 21. Global Change and Terrestrial Ecosystems: The Operational Plan, edited by W. L. Steffen, B. H. Walker, J. I. Ingram and G. W. Koch (1992). 97 pp.
The objectives of GCTE are: to predict the effects of changes in climate, atmospheric composition, and land use on terrestrial ecosystems, including agricultural and production forest systems, and to determine how these effects lead to feedbacks to the atmosphere and the physical climate system. Four foci are: ecosystem physiology, change in ecosystem structure, global change impact on agriculture and forestry, and global change and ecological complexity.

No. 22. Report from the START Regional Meeting for Southeast Asia, Arranged by The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP), in collaboration with Human Dimensions of Global Environmental Change (HDGEC) Programme (1992). 114 pp.
The report presents general recommendations on global change research in the region, thematic studies relating to IGBP Core Project science programmes, global change research in studies of eight countries in the area, and conclusions from working groups on the participation of the region in research under the five established IGBP Core Projects and the related HDGEC programme.

No. 23. Joint Global Ocean Flux Study: Implementation Plan. Jointly published with the Scientific Committee on Oceanic Research (SCOR) (1992). 78 pp. (JGOFS Report No. 9)
The Report describes how the aims of JGOFS are being, and will be, achieved through global synthesis, large scale surveys, process studies, time series studies, investigations of the sedimentary record and continental margin boundary fluxes, and the JGOFS data management system.

No. 24. Relating Land use and Global Land-Cover Change: A Proposal for an IGBP-HDP Core Project. A report from the IGBP/HDP Working Group on Land-Use/Land-Cover Change, edited by B. L. Turner, R. H. Moss, and D. L. Skole (1993). 65 pp. (Human Dimensions of Global Environmental Change Programme, HDP Report No. 5)
The report describes the research questions defined by the IGBP/HDP Working Group and identifies the next steps needed to address the human causes of global land-cover change. It calls for the development of a system to classify land-cover changes according to the socio-economic driving forces, to create a global land-use and land-cover change model that can be linked to other global environmental models.

No. 25. Land-Ocean Interactions in the Coastal Zone (LOICZ) Science Plan. Edited by P.M. Holligan and H. de Boois, with the assistance of members of the LOICZ Core Project Planning Committee (1993). 50 pp.
The gives the scientific background and objectives, and the four research foci of LOICZ: the effects of global change (land and freshwater use, climate) on fluxes of materials in the coastal zone; coastal biogeomorphology and sea-level rise; carbon fluxes and trace gas emissions on the coastal zone; economic and social impacts of global change on coastal systems. The LOICZ project framework includes data synthesis and modelling, and implementation plans cover research priorities and the establishment of a Core Project office in the Netherlands.

No. 26. * Towards a Global Terrestrial Observing System (GTOS): detecting and monitoring change in terrestrial ecosystems. Report of the Fontainebleau Workshop. Edited by O. W. Heal, J.-C. Menaut and W. L. Steffen (1993). 71 p. (UNESCO Man and the Biosphere Digest 14)
The Fontainebleau Workshop, July 1992, defined a strategy to initiate a global terrestrial monitoring system for the IGBP project on Global Change and Terrestrial Ecosystems, the French Observatory for the Sahara and the Sahel, and the UNESCO Man and the Biosphere programme, in combination with other existing and planned monitoring programmes. The report reviews existing organizations and networks, and drafts an operational plan.

No. 27 Biospheric Aspects of the Hydrological Cycle. The Operational Plan (1993). Edited by BAHC Core Project Office, Berlin (1993). Stockholm: IGBP. 103 p.
A presentation of the mandate, scope, principal subjects and structure of the BAHC research plan is followed by a full description of the four BAHC Foci: 1) Development, testing and validation of 1-dimensional soil-vegetation-atmosphere transfer (SVAT) models; 2) Regional-scale studies of land-surface properties and fluxes; 3) Diversity of biosphere-hydrosphere interactions; 4) The weather generator project.

No. 28 The IGBP in Action: Work Plan 1994 - 1998 (1994).

IGBP Booklet

Global Change: Reducing Uncertainties. Prepared by Phillip Williamson, with editorial assistance from the Scientific Committee for the IGBP (June, 1992; reprint August 1993) 40 pp.

IGBP Bulletin

Global Change NewsLetter (*quarterly*)

IGBP Scientific Overview

AMBIO: Integrating Earth System Science. A special IGBP issue of AMBIO Vol. XXII, No.1 (February, 1994).

List of Acronyms and Abbreviations

ACE	Aerosol Characterization Experiment (IGAC)
ACE	Advisory Committee on the Environment (ICSU)
ACE	Atmospheric Chemistry Education in Global Change (IGAC)
AGCM	Atmospheric General Circulation Model
AMIP	Atmospheric Model Intercomparison Project
ANT	Antarctica (START)
APARE	East Asian/North Pacific Regional Experiment (IGAC)
APN	Asia-Pacific Network (START)
ART	Arctica (START)
ASEAN	Association of Southeast Asian Nations
AVHRR	Advanced Very High Resolution Radiometer
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
BATERISTA	Biosphere-Atmosphere Transfers and Ecological Research in Situ Studies in Amazonia (BAHC/GEWEX)
BATGE	Biosphere-Atmosphere Trace Gas Exchange in the Tropics (IGAC)
BIOME	Global biome model
BIBEX	Biomass Burning Experiment (IGAC)
BOREAS	Boreal Ecosystems Atmosphere Study (BAHC/GEWEX)
BP	Before present
CAA	Central Arid Asia (START)
CACGP	Commission on Atmospheric Chemistry and Global Pollution (IAMAS)
CAR	Caribbean (START)
CARBICE	Carbon Dioxide Intercalibration Experiment (IGAC)
CD-ROM	Compact Disk - Read Only Memory
CEC	Commission of the European Communities
CEOS	Committee for Earth Observation Satellites
CIESIN	Consortium for International Earth Science Information Network (USA)
CNRS	Centre Nationale de Recherche Scientifique (France)
COST	Committee on Science and Technology (ASEAN)
COSTED	Committee on Science and Technology in Developing Countries (ICSU)
CPO	Core Project Office (IGBP)
CPPC	Core Project Planning Committee (IGBP)
CZCS	Coastal Zone Colour Scanner
DAAC	Data Active Archive Center
DEBITS	Deposition of Biogeochemically Important Trace Species (IGAC)
DGVM	Dynamic Global Vegetation Model (GAIM)
DIS	Data and Information System IGBP)
DMS	dimethylsulphide
DOLY	Dynamic Global Phytogeography Model (GCTE)
ECHIVAL	European International Project on Climate and Hydrological Interactions between Vegetation, Atmosphere and Land surfaces (BAHC)
EFEDA	ECHIVAL Field Experiment in a Desertification Threatened Areas (BAHC)
ENRICH	European Network on Research on Global Change (CEC)
ENSO	El Niño - Southern Oscillation
EOS	Earth Observing System (USA)
EPICA	European Programme for Ice Coring in Antarctica (PAGES)
EQPAC	Equatorial Pacific (JGOFS)
ERS	ESA Remote Sensing Satellite
ESA	European Space Agency
EUROSTART	European Planning Committee for START

FACE	Free-Air CO_2 Enrichment (GCTE)
FAO	Food and Agriculture Organization (UN)
FCCC	Framework Convention on Climate Change
GAW	Global Atmosphere Watch (WMO)
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GCIP	GEWEX Continental-Scale International Project
GCM	General Circulation Model
GCOS	Global Climate Observing System (WMO/IOC-UNESCO/UNEP/ICSU)
GCSS	GEWEX Cloud System Study
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
GEF	Global Environmental Facility (UNDP/UNEP/World Bank)
GEIA	Global Emissions Inventory Activity (IGAC)
GEMS	Global Environmental Monitoring System (UNEP)
GEWEX	Global Energy and Water Cycle Experiment (WCRP)
GIM	Global Integration and Modelling
GIS	Geographical Information System
GISP	Greenland Ice Sheet Project (PAGES)
GLOBE	Global Land One kilometer Base Elevation (DIS)
GLOBEC	Global Ocean Ecosystems Dynamics (SCOR)
GLOCARB	Global Tropospheric Carbon Dioxide Network (IGAC)
GLOCHANT	Global Change Research in the Antarctic (SCAR)
GLOCHEM	Global Atmospheric Chemical Survey (IGAC)
GLONET	Global Tropospheric Ozone Network (IGAC)
GOEZS	Global Ocean Euphotic Zone Study (IGBP)
GOOS	Global Ocean Observing System (IOC-UNESCO/WMO/ICSU)
GRIP	Greenland Ice Project (PAGES)
Gt	Gigatonnes
GTOS	Global Terrestrial Observing System (UNEP/FAO/WHO/UNESCO/ICSU)
HAPEX	Hydrologic Atmospheric Pilot Experiment (GEWEX)
HDP	Human Dimensions of Global Environmental Change Programme (ISSC)
HESS	High Latitude Ecosystems as Sources and Sinks of Trace Gases (IGAC)
IAI	Inter-American Institute for Global Change Research (START)
IAMAS	International Association of Meteorology and Atmospheric Sciences (IUGG/ICSU)
IASC	International Arctic Science Committee
ICACGP	International Commission on Atmospheric Chemistry and Global Pollution (IAMAS)
ICSU	International Council of Scientific Unions
IDEAL	International Decade of East African Lakes (PAGES)
IGAC	International Global Atmospheric Chemistry Project (IGBP)
IGBP	International Geosphere-Biosphere Programme (ICSU)
IGFA	International Group of Funding Agencies for Global Change Research
IIASA	International Institute for Applied Systems Analysis
IMAGES	International Marine Global Changes (PAGES)
IMS	Information Management System
INQUA	International Union for Quaternary Research
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IPCC	Intergovernmental Panel on Climate Change (WMO/UNEP)
IRS	Indian Remote Sensing Satellite
ISLSCP	International Satellite Land Surface Climatology Project (WCRP)
ITASE	International Trans-Antarctic Scientific Expedition (PAGES)
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for the Conservation of Nature
IUGG	International Union of Geodesy and Geophysics (ICSU)
IUPAC	International Union of Pure and Applied Chemistry
JGOFS	Joint Global Ocean Flux Study (SCOR/IGBP)

JSC	Joint Scientific Committee for WCRP
LAMBADA	Large Scale Atmospheric Moisture Balance of Amazona using Data Assimilation (BAHC/GEWEX)
LEMA	Long-term Ecological Modelling Activity (GCTE)
LUCC	Land Use/Cover Change project (IGBP/HDP)
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)
MAC	Multiphase Atmospheric Chemistry (IGAC)
MAGE	Marine Aerosol and Gas Exchange (IGAC)
MASFLEX	Marginal Sea Flux Experiment in the West Pacific (JGOFS)
MED	Mediterranean region (START)
MEDCOM	Mediterranean Regional Committee for START
MEDIAS	Reseau de Recherche Regionale pour le Bassin Méditerranéen et l'Afrique Subtropicale
MEHALICE	Methane and Halocarbons Intercalibration Experiment (IGAC)
MILOX	Mid-Latitude Ecosystems as Sources and Sinks for Atmospheric Oxidants (IGAC)
MOS	Marine Observational Satellite (Japan)
NABE	North Atlantic Bloom Experiment (IGAC)
NAF	Northern Africa (START)
NAFCOM	Northern African Regional Committee for START
NARE	North Atlantic Regional Experiment (IGAC)
NASA	National Aeronautics and Space Administration (USA)
NC	National Committee (IGBP)
NOAA	National Oceanic and Atmospheric Administration (USA)
NOMHICE	Non-Methane Hydrocarbon Intercomparison Experiment (IGAC)
NOPEX	Northern Hemisphere Climate Processes Experiment (BAHC)
NOS	Northern tropospheric Oxidants Study (IGAC)
OCE	Oceania (START)
PAGES	Past Global Changes (IGBP)
PALE	Palaeoclimate from Arctic Lakes and Estuaries (PAGES)
PANASH	Paleoclimates of the Northern and Southern Hemispheres (PAGES)
PASC	Polar Atmospheric and Snow Chemistry (IGAC)
PEP	Pole-Equator-Pole (PAGES)
PILPS	Project for Intercomparison of Landsurface Schemes (WCRP)
PMIP	Palaeoclimate Model Inter-comparison Project (PAGES)
ppm	part per million
RICE	Rice Cultivation and Trace Gas Exchange (IGAC)
RRC	Regional Research Centres (START)
RRN	Regional Research Network (START)
RRS	Regional Research Site (START)
SAC	Scientific Advisory Council (IGBP)
SAF	Southern, Central and Eastern Africa (START)
SAFCOM	Southern, Central and Eastern African Regional Committee for START
SAP	Scientific Advisory Panel (SARCS)
SAR	Synthetic Aperture Radar
SARCS	Southeast Asia Regional Committee for START
SC	Scientific Committee (IGBP)
SCAR	Scientific Committee for Antarctic Research (ICSU)
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SAS	Southern Asian Region (START)
SeaWiFS	Sea-viewing Wide-field-of-view Sensor
SPOT	Système pour l'Observation de la Terre (France)
SSC	Scientific Steering Committee (IGBP)
START	Global Change System for Analysis, Research and Training (HDP/IGBP/WCRP)

SVAT	Soil-Vegetation Atmosphere Transfer (BAHC)
TAM	Tropical Asian Monsoon Region (START)
TEA	Temperate East Asia (START)
TEACOM	Temperate East Asia Regional Committee for START
TEM	Terrestrial Ecosystem Model (GAIM)
TNH	Temperate Northern Hemisphere (START)
TOGA	Tropical Oceans and Global Atmosphere Programme (WCRP)
TRAGEX	Trace Gas Exchange: Mid-Latitude Terrestrial Ecosystems and Atmosphere (IGAC)
TSA	Temperate South America (START)
TWAS	Third World Academy of Sciences
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VOC	Volatile Organic Compounds
WAIS	West Antarctic Ice Sheet Project (PAGES)
WCRP	World Climate Research Programme (WMO/ICSU)
WDC	Panel on World Data Centres (Geophysical and Solar) (ICSU)
WMO	World Meteorological Organization (UN)
WOCE	World Ocean Circulation Experiment (WCRP)
yr	year