OFFICE COPY
DO NOT REMOVE

GLOBAL CHANGE
IGBP

REPORT No.3 1988

A Report from the Second Meeting of the Special Committee Harvard University, Cambridge, MA, USA 8–11 February, 1988

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)

GLOBAL CHANGE

IGBP

REPORT No.3 1988

A Report from the Second Meeting of
the Special Committee
Harvard University, Cambridge,
MA, USA
8–11 February, 1988

LINKÖPINGS UNIVERSITET
30580 001349948

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)

During 1988, the planning of the IGBP has been financially supported by generous grants from ICSU, the Government of Sweden, the Andrew W. Mellon Foundation, Unesco and National Committees for the IGBP. This support is gratefully acknowledged.

ISSN 0284-8015

INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME: A STUDY OF GLOBAL CHANGE (IGBP)

A report from the second meeting of the Special Committee
Museum of Comparative Zoology,
Harvard University, Cambridge, MA, USA
8 - 11 February, 1988

PREAMBLE

The Special Committee for the International Geosphere-Biosphere Programme: A Study of Global Change (SC-IGBP) was appointed by the ICSU Executive Board in January 1987 and met for the first time in July 1987. As a result of that meeting a report was prepared in which the objectives of the IGBP were defined (IGBP Report No. 2, 1987). The objectives clearly specify that the IGBP shall focus on the interactive physical, chemical and biological processes that regulate the total Earth system. Priority in the IGBP will deal with key interactions and significant changes on time scales of decades to centuries. The programme will concentrate on interactions which are most sensitive to human perturbations and the ultimate objective of the programme is to develop predicitive capabilities in relation to future changes in our global life support system.

The development of models with improved predictive capabilities must have the cooperation of ongoing and planned research efforts that have as their objective the formulations of global simulation models. Global simulation models will be developed in coordination with finer scaled ecosystem and process level models, which will serve as building blocks to global models. The use of such models for guiding the IGBP will be essential and existing global climate models need to be modified to include relevant biogeochemical processes and other essential interactions.

At the first meeting, it was concluded that an initial emphasis of the IGBP will be on developing our understanding of the cycling of key elements between terrestrial systems, the oceans and the atmosphere and to further understand

the interactive effects of climate-induced feedbacks within and between the biosphere and atmosphere.

The fundamental basis of the IGBP is described by four underlying themes as identified in the report from the first meeting. In brief they are:

- Documenting and predicting global change
- Observing and improving our understanding of dominant forcing functions
- Improving our understanding of transient phenomena
- Assessing the effects of global change that would cause large-scale and important modifications affecting the availability of renewable and non-renewable resources.

In order for the planning of an IGBP to proceed, the Special Committee has identified a few key areas in which initial research objectives and proposed contents of IGBP research projects should be developed. The second meeting of the SC-IGBP confirmed these four key areas and four Coordinating Panels have been formed:

1. Terrestrial Biosphere-Atmospheric Chemistry Interactions (Chairman P. J. Crutzen)
2. Marine Biosphere-Atmosphere Interactions (Chairman T. Nemoto)
3. Biospheric Aspects of the Hydrological Cycle (Chairman S. Dyck)
4. Effects of Climate Change on Terrestrial Ecosystems (Chairman B. H. Walker).

In order to assess the current state of knowledge and future prospects for the IGBP activities, four Working Groups have been set up. These are:

1. Global Geosphere-Biosphere Modelling (Chairman B. Bolin)

2. Data and Information Systems (Chairman S. I. Rasool)
3. Techniques for Extracting Environmental Data of the Past (Chairman H. Oeschger)
4. Geo-Biosphere Observatories (Chairman R. Herrera).

The second meeting of the Special Committee reviewed and discussed preliminary reports from the four Coordinating Panels and four Working Groups. These reports, which were accepted by the Special Committee, give an outline of current activities and brief summaries of the rationales for IGBP activities within the context of each group. They will serve as a basis for more detailed reports to be discussed at the IGBP Scientific Advisory Council meeting in Stockholm on 24-27 October, 1988 (see below).

COORDINATING PANEL AND WORKING GROUP REPORTS

Coordinating Panel on Terrestrial Biosphere - Atmospheric Chemistry Interactions

Changes in terrestrial biosphere processes have the capacity to alter atmospheric composition and climate; changes in climate and atmospheric composition influence the dynamics of the biosphere. This basic relationship between the atmosphere and terrestrial ecosystems is the specific concern of this IGBP Coordinating Panel. The source-sink relationships of key biogenic gases (e.g., CO_2, CO, CH_4, NO_x and N_2O) between terrestrial ecosystems and the atmosphere are poorly understood. Processes responsible for the flux rates, concentrations, and global distribution of these gases are of global concern, since their interactions in the atmosphere will affect the global climate.

The understanding of biosphere-atmospheric chemistry interactions requires study of key processes at numerous temporal and spatial scales. Considerable time and effort will be needed to solve the problem of integrating short-term local phenomena into long-term global phenomena. New initiatives from various organizations are likely to contribute to our understanding in this area. The Coordinating Panel will develop a research programme that takes these research efforts into account to ensure that IGBP objectives are met.

A number of other ongoing or planned international activities are of direct relevance to the IGBP planning.

The International Global Atmospheric Chemistry (IGAC) Programme is being planned under the auspices of the CACGP (Commission on Atmospheric Chemistry and Global Pollution) of IAMAP. A planning meeting will be held in which the following issues will be discussed:

- to plan international, large-scale, coordinated and comprehensive experiments bringing together the best observational capabilities to understand the chemistry of the atmosphere of major geographical regions, including interactions with the oceans, terrestrial biota and soils;

- to design a programme for a global trace gas measurement network to observe and better explain trends in photochemically and radiatively active trace gases;

- to establish trace gas measurement standards;

- to set up procedures for intercomparisons of measurement techniques of trace gases and aerosol;

- to design large-scale coupled atmospheric chemistry/transport models to complement future field campaigns;

- to train and educate researchers from other nations not presently involved in current atmospheric chemistry research;

- to propose comprehensive studies on trace gas exchanges between the atmosphere and selected ecosystems, establishing necessary links with other disciplines.

A proposal to develop an international programme on "Middle Atmosphere Responses to Changes in Natural and Anthropogenic Forcing" proposed by IAMAP/IAGA was noted with interest. These bodies were invited to develop an outline of a programme for consideration at the next meeting of the SC-IGBP.

A SCOPE project on trace gas exchange is being developed with the following specific objectives:

- to critically assess our understanding of the controls and interactions in the plant-microorganism-soil-water system which regulate trace gas exchange with the atmosphere;

- to assess the status of current techniques to derive fluxes from production rates and from concentration measurements, and explore the possibilities for the development of novel approaches to flux measurements. Also, to assess measurements at larger spatial scales such as aircraft based techniques and approaches using remote sensing;

- to develop a foundation for the design of diagnostic and predictive models to describe the exchange of trace gases between the biosphere and the world atmosphere.

A workshop on "The effect of changing soils and land use on emissions of 'greenhouse' gases, evaporation and albedo - a contribution to the study of climate change" will be organized by the International Soil Reference and Information Centre (ISRIC) in August 1989. The influence of changing soils and land use on emissions of greenhouse gases (in particular CO_2, CH_4 and N_2O), evaporation and albedo will be discussed in the context of geospheric-biospheric-atmospheric interrelations. Attention will be paid to the latest scientific data concerning mechanisms and modelling of emissions from soils and land cover, the quantification of the global spatial distribution of soils and their cover and remote sensing techniques for the monitoring of land use.

The activities in the area considered by the Panel need further coordination and cross-fertilization to make sure that no opportunities are lost to meet the goals of the IGBP. A meeting of the Coordinating Panel is scheduled for the spring of 1988 at which scientists involved in these related efforts will be invited to attend in order to facilitate coordination with IGBP and the preparation of a draft report.

Coordinating Panel on Marine Biosphere - Atmosphere Interactions

The Panel reviewed the statements and ideas in the reports of previous meetings, and noted that the central theme has been the response of physical, chemical and biological aspects of euphotic zone dynamics to changes in atmospheric forcing, and its effect on primary production and particularly the fate of carbon in the marine ecosystem. The feedback between organisms and the atmosphere was also stressed.

The recent report of the JGOFS meeting was welcomed, and it was felt the IGBP should support JGOFS as a prerequisite to the long-term goals of the IGBP. In particular, the Panel considered that activities in the following areas are relevant to the IGBP, some part of which provide focus for the research being planned by JGOFS:

- air-sea exchange of radiatively active biogenic gases;

- dependence of the primary production rate on ocean circulation and nutrients dynamics;

- dependence of air-sea gas exchange on marine ecosystem characteristics;

- decomposition of biological matter below the euphotic zone;

- oceanic sedimentation processes and the role of benthic biological processes in recycling biogenic materials.

The Panel established the following framework to develop a research plan.

- Firstly, a development of a modelling programme on the interaction of physical and biological processes in the euphotic zone, both processes being treated explicitly, in order to establish a framework for simulating the euphotic zone response to change in atmospheric forcing.

- Secondly, the study of responses and feedbacks of marine ecosystems to the global and regional changes caused directly and indirectly by climatic forcing, particularly in coastal regions.

- Thirdly, the further investigation of biogeochemical studies, which are inadequately considered in existing programmes of the ocean sciences. This includes:

- The effects of terrestrial dust blown from land into the sea, which affects turbidity of the water and may influence the availability of trace elements important in phytoplankton nutrition.

- Short and long-term succession and variation of biota in relation to change of chemical components of sea water, particularly in the coastal regions.

- Effects of changes in global climatic phenomena on the functioning of marine ecosystems, especially in ways that can feedback to climate.

The Panel decided to organize a study conference on "Modelling of the physical, chemical and biological processes in the euphotic zone of the ocean" to promote the further programme development.

Coordinating Panel on Biospheric Aspects of the Hydrological Cycle

The climate and land surface systems are dynamically coupled through the physical processes of energy and water supply, transformation, and transport at the land-atmosphere interface. The biosphere works in concert with these physical processes to further modify this coupling. Large-scale patterns of climate are influenced by regional variability of the surface processes of the water cycle. Present physically based models need developments which reflect the dynamic coupling in the atmosphere-soil-vegetation system.

Major alteration of the vegetative cover of the land surface by humans (e.g., deforestation and overgrazing) affects surface albedo, run-off and evapotranspiration, which affect the hydrological cycle. Vegetation affects the ratio of sensible heat to latent heat transport, alters surface winds and erosion rates and changes the thermal and moisture state of the surface. Vegetation plays a major role as a conduit between the terrestrial system and the atmosphere and will thus affect climate. Since the hydrological cycle in a drainage basin is influenced by radiation energy, change in radiation balance

(e.g., due to climate change) will affect rates of evapotranspiration and alter the water balance. It is, therefore, important to assess the response of evapotranspiration to changes in both net radiation and vegetation.

The Panel identified as a main goal for the IGBP to understand better the role of vegetation in the hydrological cycle for the purpose of modelling its linkage to global climatic change.

The IGBP, together with other relevant bodies, should plan for an integrated and coordinated research programme on soil-vegetation-atmosphere interactions with the following components:

- Diagnostics:
  To assess the impact that natural and anthropogenic changes have on the soil-vegetation-atmosphere system and to determine the magnitude of the changes of energy and water-transfer resulting from land-surface transformations.

- Modelling:
  To develop and improve a hierarchy of models (e.g., single process studies models (site scale), evaluation models (pixel scale), interaction models (grid scale of regional and global models)) needed for the interpretation of remote sensing data, and to study the interaction of different processes on the large scale.

- Experiments and Pilot Studies:
  Laboratory and field experiments (single parameter experiments on a small scale, complex experiments at fixed array scale, grid scale experiments) to study specific processes and to compile data sets needed to validate model outputs. Pilot studies conducted in sensitive transition areas (e.g., ecotones) to study changes of the soil-vegetation-atmosphere system.

The Panel reviewed research programmes and plans being developed by other international groups engaged in research on themes relevant to the future IGBP programme:

- The proposed Global Energy and Water Cycle Experiment (GEWEX) of the WCRP will concentrate on improving our knowledge of the physical processes responsible for transport of water and energy within the climate system.

- The World Climate Programme/Water with projects related to macro-scale hydrology.

- The International Satellite Land Surface Climatology Project (ISLSCP) initiated by COSPAR and IAMAP, the goal of which is "to develop methods, first, to infer from satellite measurements and auxiliary information those quantities that describe the energy exchange between the surface and the atmosphere, and, second, to monitor globally the change of surface characteristics that affect this energy exchange".

- The International Hydrological Programme (IHP) of UNESCO proposed draft plan for IHP IV (1990-1995), with a sub-programme "Hydrology in a changing environment", which includes the themes "Interface processes between atmosphere, land and water systems" and "Relationship between climate variability (and expected change) and hydrological systems".

- A Land-Surface-Atmosphere-Vegetation Interaction Programme (LAVIP), which is being considered by IAMAP and IAHS "to address the problem to what degree vegetation changes influence atmospheric motions, and how the vegetation is altered, if climate changes". This is a central issue for the IGBP.

- The proposed IUGG project on "Hydrological Pathways of Global Biospheric Significance", the intent of which is to provide scientific information on the linkages between hydrosphere, geosphere and biosphere by investigating the interrelationships between these fields of study.

Clearly there is a need to establish effective communication with these and related research groups, when planning for an IGBP programme component in this area.

A meeting of the Panel with invited scientists is planned for 12 February to discuss in more detail the proposed programme and to outline the course of action for the development of a draft report.

Coordinating Panel on Effects of Climate Change on Terrestrial Ecosystems

There are two perspectives for the problems associated with the ways in which changes in climate will bring about changes in ecosystems: A local and regional perspective, concerned with changes in ecosystem properties and processes which are of value to humankind; and a global perspective which involves changes in those properties which will feed back on the atmosphere and further influence climate change.

In both cases there are both direct and secondary effects. In order to simplify the problem, and to make the required research tractable, the effects on vegetation are primarily considered. Although changes in higher trophic levels will also occur as a result of climate change (e.g., temperature effects on insect development), most of the important changes of the fauna will be a result of changes in habitat. It is therefore valid to focus our initial consideration on changes of vegetation and soil.

The direct effects of climate on ecosystems are categorized into two main types:

- Effects on the ecosystem processes, such as net primary production, uptake or loss of nutrients, and evapotranspiration. These processes are determined mainly by changes in the mean state of the plant environment.

- Effects on the composition and structure of the vegetation. These effects result from changes in both the mean values and (more importantly) their variance - including the frequency and timing of particular, episodic events which influence demographic processes such as fecundity, dispersal, germination, seedling establishment and age-specific mortality.

In both cases we are concerned with determining the changes in the three, or perhaps four, primary environmental parameters which determine the growth and distribution of plant species, namely plant available moisture, available

nutrients, temperature and, presumably, the quantity and quality of light (e.g., UV). In certain instances it would be preferable to focus attention on zones of transition between ecosystem types, as they may be particularly sensitive to impact from climate change. The rationale of such an approach will be further elucidated as part of a SCOPE project on ecotones. The direct effects of increased atmospheric CO_2 can be considered as changes due to one component of available nutrients. It has already been shown that CO_2 will increase net photosynthesis and also water use efficiency under controlled conditions. It is much less clear whether or not there will be significant effects in natural ecosystems which are subject to many interactively limiting environmental factors.

Assuming the successful development of a predictive model for effects of climate change on terrestrial ecosystems, the next requirement is to include the secondary effects of climate change. There are numerous possible effects, but three need to be considered initially:

- Effects on frequency, intensity and extent of fire.

- Effects on the patterns of land use, including conversion from pastoral to arable, dry land to irrigated farming, etc.

- Effects on soil, in particular on organic matter decomposition and nutrient cycling. The rationale for this will be further defined in a newly initiated SCOPE project. There will also be longer-term changes resulting from changes in pedogenesis (leaching, rates of laterization in response to temperature changes, etc.).

All of the above effects are scale-dependent, both in time and space. Changes in ecosystem properties occur at a finer scale than predictions of any current climate change model. The appropriate coupling of climate change models to ecosystem models will be needed to address both effects and feedbacks of climate change on terrestrial ecosystems.

There are five main research needs:

- to predict changes in means and variances of plant available moisture, available nutrients, and temperature (and maybe light), at local and regional scales, from climate model predictions;

- to develop predictive models which relate plant available moisture, available nutrients, temperature and light regimes to i) performance, and ii) composition of plant communities;

- to incorporate secondary effects (such as change in fire frequency) as a function of changes in plant available moisture and temperature into the predictive models;

- to utilize paleoecological observations in combination with other records to understand linkages between vegetation and climate;

- to resolve the problems of scale for all studies as listed.

The basic philosophy, when defining research needs to be addressed by the IGBP, is to start with the simplest approach and only increase complexity where necessary. There are two kinds of models which can be explored in attempting to achieve the research efforts summarized above:

- statistical (simple)
- mechanistic (more complex)

The above outline will be developed further at a workshop to be held on 29 February - 2 March, 1988, in Canberra, Australia. The nature of a dynamic vegetation model on the global scale, suitable for studying biosphere - climate interactions, will be discussed at a meeting to be held at IIASA, Laxenburg, Austria, on 17-21 April, 1988. This meeting, which is the initial activity in an IIASA study of global vegetation change, will be an important step in defining research questions for the IGBP.

Any effect on ecosystems due to climate change will in turn affect the climate, e.g., through changes in water transport to the atmosphere. This feedback needs to be considered, but for practical reasons the effect of vegetation change on climate and climate change on vegetation are treated in two different IGBP Coordinating Panels. There will be a need for coordination in the design of the research programmes and experimental approaches.

Working Group on Global Geosphere-Biosphere Modelling

The IGBP is a most complex programme. The central objective is an increased understanding of global interactions between major components of the earth's system as well as their interior characteristics that have developed in these mutual interactions in the past. It is obvious that progress is much dependent on the development of global models of the earth system that can be tested against real data. It is important to recognize the need of data both for the development and for testing of models. Such considerations are essential in developing a strategy for forthcoming IGBP observational programmes. The Working Group emphasizes the importance of the use of models in developing the IGBP.

Global interactions are characterized by an interplay between transfer processes (radiative, advective and turbulent transfer) and in situ physical, chemical and biological processes. Global models have been developed, e.g., climate models including the physics of the atmosphere, the hydrosphere and the cryosphere. The further development of such general circulation models of the atmosphere and the oceans (being pursued by the WCRP) is of basic importance to the IGBP.

It is important to give priority to further efforts to formulate and test global geosphere-biosphere models, although many such models for the time being by necessity will remain crude because of inadequate understanding of the crucial physical, chemical and biological processes at work.

At this stage of the development of IGBP it therefore seems important to emphasize major efforts in model development of key interactive processes. As is clear from the proposals made by the IGBP Panels, the initial model activities therefore should concern:

- The dynamics of terrestrial ecosystems, their response to climatic change and direct anthropogenic influences, including important feedback mechanisms such as changes of gaseous exchange between the atmosphere, continents and the sea, as well as changes of radiative characteristics.

- Chemical processes in the troposphere and middle atmosphere as modulated by:
  - atmospheric motions and their change;
  - radative processes and their change;
  - changing emissions from the land and ocean surfaces.

- Physical-biological-chemical interactions in the photic zone of the sea and particularly their change due to varying abiotic conditions.

Global geosphere-biosphere models will primarily address the question of how we can best advance our understanding of the global biogeochemical cycles, including the global hydrological cycle, their interactions and change. During the last few years, advances have been made in the understanding of atmospheric and oceanic responses to the increasing anthropogenic emissions of carbon dioxide into the atmosphere. It is now clear that major changes of carbon dioxide (as well as methane) concentrations have occurred in the past and were closely related to the variations between glacial and interglacial periods. The role of the sea in the carbon cycle may be more complex than previously envisaged with regard to dissolved organic carbon and its role in the processes of chemical conversions. Changes of the terrestrial biosphere relative to atmospheric carbon dioxide are becoming better understood. These advances in the understanding of earth system responses to the increasing emissions of carbon dioxide due to anthropogenic activity will aid in modelling global carbon cycling.

The likely implications for earth's climate due to increasing atmospheric carbon dioxide concentration has aroused a broad interest in the way to control further CO_2 increases. A better understanding of the global carbon cycle is obviously of fundamental importance in this context.

As a first step towards global biogeochemical modelling within the IGBP, a study conference on "Modelling the Global Carbon Cycle" is planned to be held in May 1989. Such a conference would also naturally be concerned with several processes (e.g., air-sea exchange) that will be important in later addressing the problem of modelling other biogeochemical cycles and their interaction.

Working Group on Data and Information Systems

Understanding the global change requires, by definition, precise data on the magnitude and direction of the change. Be it the deepening ozone hole over the Antarctica, the occasional warming of the equatorial Pacific, the slow but steady increase of greenhouse gases in the atmosphere or the depletion of the forest cover in the tropics and elsewhere, precise numbers on the rate of these changes are imperative to assess the cause and evaluate the consequences. However, because these changes are often slow and subtle, and may occur over remote areas of the earth and sometimes may even need decades of consistent monitoring for a trend to be discernible, we need to develop a new strategy for documenting the global change. This is necessary because the methods of measurements vary from nation to nation, techniques change from space satellite to ocean buoys and ground observations, the time and frequency of measurement are not always regular and sometimes only occasional, and lastly, and not the least important, the problem of spatial scale over which the data are taken. Satellites take images and measurements over areas of hundreds of kilometers, while measurements on the ground and ocean usually are representative for only a small region around the point location. Despite these problems, many scientists and data assimilation experts have begun to respond to the needs of the global change programme and have begun to produce global data sets of a number of key parameters. It is now urgently needed to have a well-organized discussion at the international level on topics such as:

- What are the data needs for the IGBP?

- What is the adequacy of available data sets for global change studies?

- Can we identify the avenues for international data exchange, for example through the World Data Centres, UNEP's GRID centers, WMO and FAO, etc.?

- What are the proposed remote sensing and surface observing networks going to be?

- How can we prepare data sets appropriately tailored for global change studies?

- How do we assure their accessibility to the scientific community?

- And finally, can we arrive at an IGBP data management plan?

In order to achieve this, a Study Conference is being organized by the Working Group in collaboration with the ICSU Panel on World Data Centres, to be hosted by the Soviet Geophysical Committee. The conference has been scheduled for 9-13 August, 1988. Invitations have been issued to about 60 specialists in global change science issues, data systems specialists, experts in data processing and persons involved in running various data centres where data from different countries are assembled and eventually made available to the scientific community of the world. The conclusions and recommendations will result in a first version of a data management plan for the IGBP.

This study conference will be the first effort to initiate discussion on data quality and exchange.

Working Group on Techniques for Extracting Environmental Data of the Past

Studies of the physical, chemical and biological parameters in natural archives, such as tree-rings, peat bogs, lake and ocean sediments, polar ice sheets, mid-latitude glaciers, and geomorphological studies, have revealed a wealth of information on the natural and human-induced evolution of the earth system. This information may be used to evaluate earth system models; it can also identify unknown and often important processes that need to be included to understand the operation of this interconnected system.

An emphasis within the IGBP on the recovery and interpretation of past environmental records can serve several important purposes. These are: to assess the current technology of reconstructing past states of the earth system, to coordinate activities focusing on events or eras of particular relevance, and to identify gaps and stimulate new directions of research regarding field studies, laboratory techniques and data interpretation. The last decade has seen many exciting achievements in this area, including the documentation of systematic climate variations during the Pleistocene and Holocene, the abundance of atmospheric trace gases, the distribution of regional vegetation,

the state of the Sun and the strength of the earth's magnetic moment. Yet, the full potential of these methods, and their use in extracting information on the behaviour of the geosphere-biosphere system, is far from being fully exploited.

The process of recovering information from historical and natural records involves four distinct processes. These are briefly described below.

- The Identification of Natural and Historical Archives

  Geomorphological investigations and studies of sediments, ice and organic deposits are well established disciplines, as are studies of tree-rings. Equally valuable, though as yet less studied, are other natural diaries, found in deep layers of loess, coral deposits, lake-level variations, and mid-latitude glaciers. Least utilized, yet the most powerful for studies of earth system behaviour, are combined analyses of these records of the past in specific eras of interest or in the study of long-term trends in regional or global change.

  Adequate attention has not been paid to existing historical records of climate and other environmental change and its impact on ecosystems and on man. In the New World these records cover at most a few centuries, but they span the time during which man's impacts on an unperturbed environment have become profound. In Europe, written records of climate and environmental change extend as far as about 500 years into the past, and in the Orient, where customs of recording natural events were more advanced and systematic, one can find continuous records four times as long and far more extensive in terms of temporal and spatial detail. These written sources of environmental history and land use are a valuable resource in their own right. They assume additional importance when read in conjunction with concurrent, natural histories.

- Fieldwork

  In principle, the techniques to drill cores in sediments and ice have now been well established. Nevertheless, the taking of cores is still a major operation, requiring several years and the dedication of highly trained crews. Recent technological advances offer new opportunities. On the one hand new analytical techniques, such as accelerator mass spectrometry,

have significantly reduced the size of sample that is needed for the study of a given parameter; the same advances offer the potential of measuring a much larger spectrum of parameters which are needed to derive more detailed information on the earth system evolution. Recent studies of ice cores have revealed remarkably rapid changes of almost all the parameters that have been measured, corresponding to a temporal span of a few hundred years. In such small depth intervals high resolution measurements of as many parameters as possible are needed to derive phase relationships and to separate short-term variations from long-term trends. Such studies can provide a detailed picture of the change with time of fundamental earth system processes and the identification of causes and effects. This calls for improvements in drilling techniques, for the development of continuous or quasi-continuous measuring techniques of a broad spectrum of physical and chemical parameters, and if possible, analytical measurements in the field on newly-drilled cores.

Similar problems and opportunities exist in the acquisition and analysis of other types of natural environmental records.

- Laboratory Techniques

New analytical techniques, such as accelerator mass spectrometry, ion chromatography, fluid injection analysis, optical spectral analysis, and combined gas chromatography/mass spectrometry, have contributed much to our ability to secure more complete and higher-resolution pictures of past earth system events. These methods need to be perfected and adapted to secure rapid analyses.

Other emerging analytical techniques offer aditional opportunities. An example is single atom counting by resonance ionization spectroscopy of ^{81}Kr ($T_{1/2}$ = 21,000 yr), which would contribute significantly to presently available accuracy in the dating of old ice and groundwater. Other technological advances are occurring in stable isotope analysis of elements other than H, C, and O, chemical analysis of individual particles and aerosols, and the application of mass spectrometry to biological investigations.

- Data Interpretation

An initial effort is needed to coordinate the analysis of different natural records to obtain an overall view of the natural earth system. The interpretation of these data is not a simple matter, because it involves a deep understanding of the relevant properties and mechanisms of the natural archives themselves. For example, the stable isotope ratios of H, C, and O in tree-ring cellulose are determined by environmental conditions, however, isotopic fractionation occurs in the physical, chemical and biological processes, which leads to the final ratios fixed in the tree. These influences need to be disentangled if one is to derive information on past environmental conditions.

To interpret the records of the cosmic-ray produced isotopes (cosmogenic nuclides such as ^{14}C, ^{10}Be, or ^{36}Cl), one needs to understand the pathways from their production, mainly in the stratosphere, into the natural archive, as well as the basic processes by which their production is modulated by solar and geomagnetic effects. These pathways include, among other things, nuclear spallation and subsequent chemical reactions, and the processes by which the nuclides are attached to particles in the atmosphere. Also included are processes of atmospheric mixing and circulation, transfer into ocean reservoirs and the processes and rates of removal from the atmosphere by precipitation or dry deposition. As an example it has been observed that measurements of the $^{10}Be/^{36}Cl$ ratio in ice samples reflect large variations which are probably best explained by different affinities of attachment of Cl and Be to atmospheric particles.

A second step in the interpretation of the data concerns modelling. Modelling is necessary to interpret reconstructed parameters which are affected by solar and geomagnetic shielding of cosmic radiation, transport of isotopes and particles, and variations of atmospheric gases such as CO_2, CH_4 and N_2O or degradation products of dimethylsulfide.

The third step is the use of these data in evolving newly developing earth system models. These tests may reveal weaknesses of the models; they will also suggest further process studies which will help improve the integrated understanding of the geosphere-biosphere system.

The Working Group will hold a first meeting at the University of Berne, Switzerland, on 6-8 July, 1988. In addition to working group members, scientists who are experts in major techniques and fields of paleo-research, as well as representatives of relevant international programmes will be invited.

The goals of the meeting are:

- to assess the state-of-the-art of paleo-research;
- to review ongoing and planned activities in the field;
- to identify important open questions in earth system science to which paleo-studies might contribute key information;
- to identify experimental and theoretical developments which can lead to substantial progress in the field of paleo-research; and
- to identify methods of interaction and organization to aid the scientific community involved in paleo-research.

Discussions at the Berne meeting may go beyond those of this single working group. There is an undeniable need for coordination in paleo-research; but there is an equal need for an active interaction with other Working Groups and Coordinating Panels of the SC-IGBP.

Working Group on Geosphere-Biosphere Observatories

The Geosphere-Biosphere Observatory (GBO) network will play a major role in meeting specific goals of the IGBP. A network of globally distributed observatories collecting the same suite of data in a consistent manner and accessible to the scientific community is invaluable. The observatories will serve as benchmark locations for various ecosystems, ground truth locations for remote sensing observations, source of input variables for various models, validation sites for simulation models, locations for intensive experimental studies, and documentation of global change effects.

The GBOs will be important not only to the global change community but also to other investigators working with specific ecosystems, processes, or in a particular geographical region. The observatories will be valuable also to the host countries as education and training centres.

At each observatory, a suite of measurements will be collected which will characterize the site relative to meteorological, chemical, biological, and pedological parameters so that determination of earth system drivers can be made. Quality and uniformity of the data collecting and storage will be assured for all GBOs.

The establishment of the network of GBOs will be conducted in coordination with various international organizations (e.g., WMO, UNESCO, UNEP-GEMS) and experimental scientists involved with IGBP research development. Special note was also taken of a report from a SCOPE-MAB project (IUBS Biology International No. 16, 1988). The IGU Commission on Geographical Monitoring and Forecasting has initiated an international survey to make an inventory of the existing network of stations in all countries to complement the knowledge of other international networks.

A matter of serious concern in the establishment of observatories is the firm commitment by the countries where these will be to set them on a permanent, stable basis; the experience of WMO in this regard is perhaps the longest in time and widest in coverage.

The role of regional organizations and networks was considered to be important. It was agreed, however, that the GBO concept should be tailored to IGBP goals and while an optimum use of existing networks and experience is desirable, a well defined measurement programme, focused on interactions and looking at global change is central to the development of GBOs.

A meeting of the Working Group on Geo-Biosphere Observatories is being organized and will be held in Caracas, Venezuela, on 2-4 May, 1988. It was stressed that GBOs should focus on interactions and in particular those between the surface and the atmosphere.

Some of the topics to be discussed at the Caracas meeting of the Working Group are:

- site selection criteria (hierarchy of sites),
- minimum and desirable data sets,
- surface to atmosphere interactions,
- coupling of hydrological cycle with other biogeochemical processes,
- relation of GBOs to other national and international networks,
- data quality, management, availability and ground to space relationship in GBOs,
- consideration of national conditions for establishment of GBOs.

The relation between GBOs and the Data and Information Systems Working Group was considered very important.

INTEGRATION OF IGBP ACTIVITIES

The division of the current planning effort into four Coordinating Panels and four Working Groups in no way means that the activities of the eight groups are being carried out in isolation from each other. The Special Committee members participate in more than one of the groups and the entire committee ensures that there are effective links between the various activities. Modelling will furthermore be a key mechanism for the integration of the various proposed programme activities. It will help in defining research needs, test conceptual relationships, integrate information and serve as the means of predictions, which is of course the goal of the IGBP.

For example, it was decided to treat different aspects of the interaction between climate and terrestrial vegetation in three separate Coordinating Panels. One Panel has the charge to address Effects of Climate Change on

Terrestrial Ecosystems, while issues related to the effect of vegetation on climate have been subdivided so that those dealing with moisture balance will be covered by the Panel on Biospheric Aspects of the Hydrological Cycle, and issues related to the biotic sources of radiatively active trace gases will be covered by the Panel on Terrestrial Biosphere-Atmospheric Chemistry. The need to understand feed-back mechanisms and their regulation obviously necessitates close communication among these Panels. Moreover, when details for the experimental phase are being developed common sites/experiments will be considered. In many instances the network of Geo-Biosphere Observatories, being developed by one of the Working Groups, may be used for observations and experimentation in the research being proposed by the four Panels. Data management aspects will be discussed by another Working Group, which will also consider existing data information systems, quality control, data dissemination, etc. The further integration of these activities will take place after the discussion of the draft report on the IGBP during the first meeting of the SAC-IGBP in Stockholm in October 1988.

SCIENTIFIC ADVISORY COUNCIL MEETING

The IGBP national committees and ICSU national and scientific members will be invited to attend the first meeting of the IGBP Scientific Advisory Council (SAC-IGBP) to be held in Stockholm on 24-27 October, 1988. Other organizations will also be invited to send observers. This meeting will discuss a draft report from the SC-IGBP outlining a framework for and preliminary contents of the International Geosphere-Biosphere Programme: A Study of Global Change (IGBP).

The Special Committee, with the help of its Coordinating Panels and Working Groups, is preparing the draft programme for an IGBP, which will be sent to all national IGBP committees, ICSU national and scientific members and other interested organizations in early September. The report will also be available at the ICSU General Assembly in Beijing (September 1988). This draft report will outline the rationale for the IGBP as developed by the Special Committee on the basis of the document presented to the ICSU General Assembly in Berne. It will define the IGBP based on the underlying themes agreed upon at the first

meeting of the Special Committee and describe the philosophical and theoretical framework on which the programme should be based. This section of the report will contain a description of the essential global change processes to be addressed by the programme.

The report will go on to describe the activities of other relevant ongoing or planned programmes, which address major issues as defined in the first part of the report. This section will also address questions of coordination, cooperation and complimentarity between the IGBP and other efforts.

A major section of the draft report will address the priorities for an IGBP. This section of the report will be based on the reports and recommendations from the four Coordinating Panels and four Working Groups as established by the SC-IGBP at its first session.

The last section of the draft report will contain an action plan for the future development towards an IGBP. A more detailed plan is expected by the end of 1989. It is also expected that pilot projects will be initiated within the next couple of years.

NATIONAL IGBP COMMITTEES

An address list of members of national IGBP committees is included in this report. National ICSU members who have not yet established such committees are urged to do so. This will help ensure efficient contacts between the international planning efforts and groups of national scientists and should also help to advance the developments of national action plans. We would also like to list any specific committees set up by other ICSU scientific bodies for discussions and preparations of plans for global change activities. Some are listed in this report, but information on other groups should be sent to the IGBP secretariat.

Please check the enclosed list carefully and send any changes to the Secretariat.

CALENDAR OF EVENTS

IGBP Meetings 1988

8-11 February	Second meeting of the Special Committee for the IGBP (Cambridge, MA, USA)
12 February	First meeting of the Coordinating Panel on "Biospheric Aspects of the Hydrological Cycle" (Cambridge, MA, USA)
29 February-2 March	First meeting of the Coordinating Panel on "Effects of Climate Change on Terrestrial Ecosystems" (Canberra, Australia)
2-4 May	First meeting of the Working Group on "Geosphere-Biosphere Observatories" (Caracas, Venezuela)
4-5 June	Second meeting of the Executive Committee for the IGBP (Budapest, Hungary)
6-9 June	Second meeting of the Coordinating Panel on "Biospheric Aspects of the Hydrological Cycle (Potsdam, GDR)
6-8 July	First meeting of the Working Group on "Techniques for Extracting Environmental Data of the Past" (Berne, Switzerland)
7-21 August	First meeting of the Coordinating Panel on "Terrestrial Biosphere - Atmospheric Chemistry Interactions" (Boulder, CO, USA)
9-13 August	Study Conference on Data Management for the IGBP (organized by the Working Group on Data and Information Systems in collaboration with WDC and the Soviet Geophysical Committee) (Moscow, USSR)
19-21 August	Meeting of the IGBP ad hoc editorial committee (Boulder, CO, USA)
13 September	Symposium om Global Change during the ICSU General Assembly (Beijing, China)

23 October	Third meeting of the Special Committee for the IGBP (Stockholm, Sweden)
24-27 October	First meeting of the Scientific Advisory Council for the IGBP
28-29 October	Fourth meeting of the Special Committee for the IGBP
10-14 December	IGBP Southern Hemisphere Workshop on Climate Change and its Consequences (Mbabane, Swaziland)

IGBP Related Meetings
1988

24-25 March	International Symposium on Earth System Science (Tokyo, Japan). Further information from Mr. Masato Chijiya, Ocean Development Bureau, Science and Technology Agency, 2-2-1 Kasumigaseki, Chiyoda-ku, Tokyo 100, Japan.
17-21 April	IIASA Meeting on Global Vegetation Change (Laxenburg, Austria). Further information from Dr. A. M. Solomon, IIASA, A-2361 Laxenburg, Austria.
9-10 May	IGU Global Data Base Planning Meeting (UK). Further information from Dr. R. F. Tomlinson, Tomlinson Associates, 17 Kippewa Drive, Ottawa, Ontario K1S 3G3, Canada.
13-16 June	SCOPE Workshop on Ecosystem Experiments (Bayreuth, FRG). Further information from Prof. H. A. Mooney, Department of Biological Sciences, Stanford University, Stanford, CA 94305-2493, USA.
7-21 August	Global Change Institute on Trace Gases and the Biosphere (Snowmass, CO, USA). Further information from Dr. J. A. Eddy, UCAR, P.O. Box 3000, Boulder, CO 80307-3000, USA.
13-15 September	International Meeting for the Joint Ocean Global Flux Study (JGOFS)(The Hague, the Netherlands). Further information from Dr. E. Tidmarsh, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1, Canada
19-22 September	Symposium on Human Response to Global Change (Tokyo, Japan). Further information from Prof. Ian Burton, IFIAS, University of Toronto, 39 Spadina Road, Toronto, Ontario M5R ZS9, Canada.

October	SCOPE Workshop on Long-Term Ecological Research: A Global Perspective (FRG or France). Further information from Prof. P. G. Risser, Office of the Vice-President for Research, Scholes Hall, Room 108, University of New Mexico, Albuquerque, NM 81731, USA
8-11 November	Workshop on "Predicting Across Scales: Theory Development and Testing" (Oak Ridge, TN, USA). Further information from Dr. M. G. Turner, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, TN 37831, USA.
14-18 November	International Conference on Greenhouse Gas Trends and Planning Meeting for the IGAC Programme (Melbourne, Australia). Further information from: Dr. G. Pearman, CSIRO Division of Atmospheric Research, Private Bag No. 1, Mordialloc, Australia 3195
12-16 December	SCOPE Workshop on the Influence of Ecotones on Biodiversity and Ecological Flows (Paris, France). Further information from Prof. F. di Castri, CNRS Centre Louis Emberger, Route de Mende, B. P. 5051, F-34033 Montpellier Cedex, France
13-15 December	IUGS/ILP Conference on Geosphere Fluctuations: Short Term Instabilities in the Earth System (Hamburg, FRG). Further information from Dr. Jörn Thiede, GEOMAR, Forschungszentrum für Marine Geowissenschaften, Wischofstrasse 1-3, D-2300 Kiel 14, FRG.

LIST OF ACRONYMS

CACGP	Commission on Atmospheric Chemistry and Global Pollution
COSPAR	Committee on Space Research
FAO	Food and Agriculture Organization
GBO	Geo-Biosphere Observatories (IGBP)
GEMS	Global Environment Monitoring System (UNEP)
GEWEX	Global Energy and Water Cycle Experiment (WCRP)
GRID	Global Resource Information Database (UNEP)
IAGA	International Association of Geomagnetism and Aeronomy
IAHS	International Association of Hydrological Sciences
IAMAP	International Association of Meteorology and Atmospheric Physics
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Programme of CACGP
IGBP	International Geosphere-Biosphere Programme: A Study of Global Change
IGU	International Geographical Union
IHP	International Hydrological Programme (UNESCO)
IIASA	International Institute of Applied Systems Analysis
ISLSCP	International Satellite Land Surface Climatology Project (COSPAR/IAMAP)
ISRIC	International Soil Reference and Information Centre
IUBS	International Union of Biological Sciences
IUGG	International Union of Geodesy and Geophysics
JGOFS	Joint Global Ocean Flux Study (SCOR)
LAVIP	Land-Surface-Atmosphere-Vegetation Interaction Programme (IAMAP/IAHS)

MAB	Man and the Biosphere Programme (UNESCO)
SAC-IGBP	Scientific Advisory Council of the IGBP
SC-IGBP	The Special Committee for the IGBP
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Ocean Research
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WDC	Panel on World Data Centres (Geophysical and Solar)
WCRP	World Climate Research Programme (WMO/ICSU)
WMO	World Meteorological Organization

NATIONAL COMMITTEES FOR THE IGBP

AUSTRIA

Chairman (ad hoc Committee): Prof. S. J. Bauer, Institut für Meteorologie und Geophysik, Universität Graz, Halbärthgasse 1, A-8010 Graz.

AUSTRALIA

Chairman: Prof. K. D. Cole, Department of Physics, La Trobe University, Bundoora, VIC 3083. Tel. (+61-3) 478 31 22.

Mr. R. S. Goleby, Assistant Secretary, Space Projects Branch, Department of Science, P.O. Box 65, Belconnen, ACT 2616.

Dr. R. Jensen, Assistant Secretary, Sectoral Policy & Programs Branch, Department of Science, P.O. Box 65, Belconnen, ACT 2616. Tel. (+61-62) 64 40 54.

Prof. K. Lambeck, Research School of Earth Sciences, The Australian National University, P.O. Box 4, Canberra, ACT 2601. Tel. (+61-62) 49 24 87.

Dr. K. G. McCracken, Director - COSSA, P.O. Box 225, Dickson, ACT 2602. Tel. (+61-62) 70 18 00.

Dr. A. McEwan, Chief, CSIRO, Division of Oceanography, P.O. Box 1538, Hobarth, TAS 7001. Tel. (+61-02) 20 62 12.

Prof. C. B. Osmond, Research School of Biological Sciences, Department of Environmental Biology, The Australian National University, P.O. Box 475, Canberra, ACT 2601. Tel. (+61-62) 49 29 99.

Dr. G. Pearman, CSIRO, Division of Atmospheric Research, Private Bag 1, Mordialloc, VIC 3195. Tel. (+61-3) 580 63 33.

Prof. J. P. Quirk, Director of the Waite Agricultural Research Institute, University of Adelaide, Private Bag No. 1, Glen Osmond, SA 5064. Tel. (+61-8) 372 24 44.

Prof. B. G. Thom, Department of Geography, University of Sydney, NSW 2006. Tel. (+61-2) 692 28 86.

Dr. B. H. Walker, Chief, CSIRO, Division of Wildlife and Ecology, P.O. Box 84, Lyneham, ACT 2602. Tel. (+61-62) 41 12 11.

BANGLADESH

Dr. M. O. Ghani, President, Bangladesh Academy of Sciences, 3/8 Asad Avenue, Muhammadpur, Dhaka 7. Tel. (+880-2) 31 04 25.

CANADA

Chairman: Prof. R. Peltier, Department of Physics, University of Toronto, Toronto, Ontario.

CHILE

Convener: Dr. H. A. Fuenzalida, Departmento de Geofìsica, Universidad de Chile, Casilla 2777, Santiago. Tel. (+56-2) 696 87 90.

Dr. P. A. Bernal, Pontificia Universidad Catòlica de Chile, Sede Regional Talcahuano, Casilla 127, Talcahuano. Tel. (+56-41) 54 25 92.

Dr. T. R. Fonseca, Universidad Catòlica de Valparaìso, Casilla 1020, Valparaìso. Tel.(+56-32) 21 75 41.

Dr. E. Fuentes, Laboratorio de Ecologìa, Pontificia Universidad Catòlica de Chile, Casilla 114-D, Santiago. Tel. (+56-2) 222 45 16.

Dr. A. Foppiano, Departamento de Fìsica, Universidad de Concepciòn, Casilla 947, Concepciòn. Tel. (+56-41) 22 86 18.

Dr. L. Gomberoff, Departamento de Fìsica, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago. Tel. (+56-2) 271 29 73.

Dr. E. R. Hajek, Laboratorio de Ecologìa, Pontificia Universidad Catòlica de Chile, Casilla 114-D, Santiago. Tel.(+56-2) 222 45 16, anexo 2614.

Dr. R. Martìnez, Departamento de Geologìa, Universidad de Chile, Casilla 2777, Santiago. Tel. (+56-2) 696 27 14.

Dr. V. Montecino, Departamento de Ciencias Ecològicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago. Tel. (+56-2) 271 29 77.

Dr. J. Rutllant, Departamento de Geofìsica, universidad de Chile, Casilla 2777, Santiago. Tel. (+56-2) 696 65 63.

Dr. J. Valencia, Departamento de Ciencias Ecològicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago. Tel. (+56-2) 271 28 65.

CHINA (Beijing)

Composition not known.

COLOMBIA

Chairman (ad hoc Committee): Dr. L. E. Mora-Osejo, President, Academia Colombiana de Ciencias Exactas Fisicas y Naturales, Apartado 44.763, Bogota 1 D.E. Tel. (+57-1) 241 48 05, 242 41 74.

FRANCE

Chairman: Dr. J.-C. Duplessy, CNRS Centre des Faibles Radioactivité, Avenue de la Terrace, F-91198 Gif sur Yvette. Tel. (+33-1) 48 47 31 95. Telex 214627.

Dr. F. Becker, Université L. Pasteur, 7 rue de l'Université, F-67000 Strasbourg. Tel. (+33) 88 35 51 50.

Dr. F. Blanc, Centre d'Océanologie, Station Marine d'Eudorme, Rue Batterie des Lions, F-13007 Marseille. Tel. (+33) 91 52 08 48, 91 41 42 10.

Dr. P. Buat Menard, CFR/CNRS, F-91198 Gif sur Yvette. Tel. (+33-1) 69 07 78 28, ext. 789.

Dr. E. van Campo, USTL, Place E. Bataillon, F-34060 Montpellier Cedex.

Dr. F. di Castri, CNRS/CEPE, Route de Mendes, B. P. 5051, F-34033 Montpellier Cedex. Tel. (+33) 67 61 32 00.

Dr. M.-L. Chanin, Service d'Aéronomie, B. P. 3, F-91371 Verrieres le Buisson. Tel. (+33-1) 69 20 10 60, 69 20 07 94. Telex 692400 AERONO.

Dr. J. F. Denisse, COFUSI-Académie des Sciences, 23 Quai Conti, F-75006 Paris.

Dr. H. Faure, Labo. Géol. Quaternaire, Case 907, Faculté des Sciences de Luminy, F-13288 Marseille Cedex 9.

Dr. J. Fellous, CNES - Laboratoire de Palynologie, 2 Place Maurice Quentin, F-75001 Paris.

Dr. M. Glass, TOAE - CNRS, 15 Quai A. France, F-75007 Paris.

Dr. L. Laubier, IFREMER, 66 Avenue d'Iéna, B. P. 107.16, F-75763 Paris Cedex 16.

Dr. G. Megie, Service d'Aéronomie, B.P. 3, F-91371 Verrieres le Buisson. Tel. (+33-1) 69 20 01 83.

Dr. L. Merlivat, L.O.D.Y.C., Université P. & M. Curie, 4 Place Jussieu, F-75252 Paris. Tel. (+33-1) 46 33 21 31. Telex 206317.

Dr. M. Meybeck, Institut de Biochimie Marine - ENS, 1 rue Maurice Arnoux, F-92100 Montrouge. Tel. 46 57 12 86.

Dr. A. Morel, Lab. Physique et Chimie Marine, Université P. & M. Curie, B. P. 8, F-06230 Villefranche/Mer. Tel. (+33) 93 01 94 31.

Dr. M. Nahon, Faculté des Sciences de St Jérôme, Laboratoire de Chimie-Aix Marseille III, F-13397 Marseille Cedex 13.

Dr. C. Pedro, Laboratoire des Sols, INRA, Route de St Cyr, F-78000 Versailles. Tel. (+33-1) 30 83 32 52.

Dr. A. Perrier, INRA-INAPG, 16 rue Claude Bernard, F-75016 Paris.

Dr. S. I. Rasool, Ecole Normale Supérieure, Paris (and NASA, Washington, see U.S. National Committee for the IGBP). Tel. (+33-1)45 08 76 34. Telex 21674.

Dr. R. Sasourny, Laboratoire de Météorologie Dynamique, Ecole Polytechnique RD 36, F-91128 Palaiseau. Tel. 60 19 41 44.

Dr. Servant, ORSTOM, 70-74 Rte d'Aulnay, F-93130 Bondy.

FEDERAL REPUBLIC OF GERMANY

Chairman: Prof. H.-J. Bolle, Institut für Meteorologie, WE 07 im Fachbereich Geowissenschaften, Freie Universität Berlin, Dietrich Schäfer-Weg 6-8, D-1000 Berlin 41.

Prof. P. J. Crutzen, Max-Planck-Institute for Chemistry, P.O. Box 3060, D-6500 Mainz. Tel. (+49-6131) 30 54 58. Telefax (+49-6131) 30 53 88. Telex 4187674 MPCH D.

Prof. D. Ehhalt

Prof. K. Fuchs

Prof. H. Grassl

Prof. K.-H. Hartge

Prof. R. Herrmann

Prof. W. Krauss

Prof. K. Labitzke

Prof. O. L. Lange

Prof. W. Manshard

Prof. E. Plate

Prof. G. Siedler

Prof. H. Ziegler, München.

Prof. W. Ziegler, Frankfurt

HUNGARY

Chairman: Prof. J. Tigyi, Institute of Biophysics, Medical University, Szigeti út 12, Pf. 99, H-7643 Pécs. Tel. (+36-72) 140 17.

INDIA

Chairman: Prof. R. R. Daniel, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400 005.

Prof. P. K. Das, Centre for Atmospheric Sciences, Indian Institute of Technology, Hauz Khas, New Delhi 110 016.

Dr. S. N. Dwivedi, Addl. Secretary, Department of Ocean Development, Mahasagar Bhavan, Block 12, CGO Complex, Lodi Road, New Delhi 110 003.

Prof. V. K. Gaur, Director, National Geophysical Research Institute, Hyderabad 500 007.

Dr. T. A. Hariharan, Space Applications Centre SAC P.O., Jodhpur Tekra, Ahmedabad 380 053.

Dr. T. N. Khoshoo, Tata Energy Research Institute, 7 Jor Bagh, New Delhi 110 003.

Dr. A. P. Mitra, Director General, Council of Scientific & Industrial Research, Rafi Marg, New Delhi 110 001.

Dr. M. Parabrahmam, Director, CP Division, Ministry of Environment and Forests, Paryavaran Bhavan, CGO Complex, Lodi Road, New Delhi 110 003.

Dr. M. N. Qureshi, Adviser, SPG, Ministry of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110 016.

Prof. J. S. Singh, Department of Botany, Ecosystems Analysis Laboratory, Banaras Hindu University, Varanasi 221 003.

Prof. B. L. K. Somayajulu, Physical Research Laboratory, Navrangpura, Ahmedabad 380 009.

Dr. M. K. Tiwari (Non-member Secretary), ISRO (ADCOS), Cauvery Bhavan, Kempegowda Road, Bangalore 560 009.

ISRAEL

Chairman (ad hoc Committee): Prof. M. Sela, Weizmann Institute of Science, Rehovot.

Dr. U. Marinov, Govt. Environmental Protection Agency.

Dr. A. Nissenbaum, Weizmann Institute of Science, Rehovot.

Prof. Z. Reiss, Hebrew University.

Prof. M. Shilo, Hebrew University.

Prof. E. Tchernov, Israel Academy of Sciences, P.O. Box 4040, Jerusalem 91040.

JAPAN

Chairman: Prof. Y. Oshima, Science Council of Japan, 22-34, Roppongi 7-chome, Minato-ku, Tokyo 106.

Dr. T. Asai

Dr. A. Hattori

Dr. K. Higuchi

Dr. H. Koga

Dr. E. Matsumoto

Dr. H. Matsuo

Prof. T. Nemoto, Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo 164. Tel. (+81-3) 376 12 51. Telefax (+81-3) 377 33 95. Telex 25607 ORIUT J. Electronic mail OMNET, Telemail ORI.Tokyo.

Dr. O. Nishikawa

Dr. T. Nozawa

Dr. T. Ogawa

Dr. M. Omori

Dr. N. Ono

Dr. H. Sakai

Dr. R. Sawada

Dr. K. Tsuchiya

Dr. S. Tsunogai

Dr. Z. Uchijima

Dr. I. Watanabe

Dr. K. Yabuki

Dr. T. Yoshikawa

Dr. M. Yoshino

THE NETHERLANDS

Chairman: Prof. H. Postma, Institut voor Onderzoek der Zee, Postbus 59, NL-1790 AD Den Burg.

Prof. J. W. M. la Rivière, International Institute for Hydraulic and Environmental Engineering, P.O. Box 3015, Oude Delft 95, 2601 DA Delft. Tel. (+31-15) 78 30 60. Telex 38099 Attention La Rivière IHE.

Dr. Hekstra

Dr. Vervelde

Dr. H. M. van Emden (Secretary), Koninklijke Nederlandse Akademie van Wetenschappen, Het Trippenhuis, Kloveniersburgwal 29, Postbus 19121, NL-1000 GC Amsterdam. Tel. (+31-20) 22 29 02.

POLAND

Chairman (ad hoc Committee): Prof. Zdzisław Kaczmarek, Polish National Committee for ICSU, c/o Polish Academy of Sciences, Pałac Kultury i Nauki, PL-00-901 Warsaw. Tel. 20 33 71, 20 33 45. Telex 813697 PAN PL.

SOUTH AFRICA

Chairman: Prof. P. D. Tyson, Deputy Vice-Chancellor, University of the Witwatersrand, Wits 2050. Tel. (+27-11) 716 35 45. Teletex 4-50937 VCWITS.

Prof. H. J. Deacon, Department of Archaeology, University of Stellenbosh, Stellenbosh 7600.

Prof. J. G. Field, Department of Zoology, University of Cape Town, Private Bag, Rondebosch 7700.

Dr. S. C. J. Joubert, Kruger National Park, Private Bag X 402, Skukuza 1350.

Mr. I. A. W. Macdonald, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag, Rondebosch 7700.

Dr. O. G. Malan, Optical Sciences, N P R L.

Prof. T. C. Partridge, Department of Geography, University of the Witwatersrand, Wits 2050.

Prof. R. E. Schulze, Department of Agricultural Engineering, University of Natal, P.O. Box 375, Pietermaritzburg 3200.

Dr. L. V. Shannon, Sea Fisheries Research Institute, Private Bag, Sea Point 8060.

Prof. W. R. Siegfried, Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch 7700.

Prof. J. E. Steffens, Department of Statistics and Marine Operational Research, UNISA, P.O. Box 392, Pretoria 0001.

Mrs. E. P. du Plessis, South African ICSU Secretariat, Foundation for Research Development (F R D), P.O. Box 395, Pretoria 0001. Tel. (+27-12) 86 92 11. Telefax (+27-12) 86 28 56. Telex 321312 SA.

Mr. B. J. Huntley, Programme Manager, Terrestrial Ecosystems, Foundation for Research Development (F R D), P.O. Box 395, Pretoria 0001. Tel. (+27-12) 86 92 11. Telefax (+27-12) 86 28 56. Telex 321312 SA.

Dr. C. W. Louw, Coordinator, Weather, Climate and Atmosphere, Foundation for Research Development (F R D), P.O. Box 395, Pretoria 0001. Tel. (+27-12) 86 92 11. Telefax (+27-12) 86 28 56. Telex 321312 SA.

Mr. O. A. van der Westhuysen, Programme Manager, Earth and Marine Sciences, Foundation for Research Development (F R D), P.O. Box 395, Pretoria 0001. Tel. (+27-12) 86 92 11. Telefax (+27-12) 86 28 56. Telex 321312 SA.

SWEDEN

Chairman: Prof. Bert Bolin, Department of Meteorology, University of Stockholm, S-106 91 Stockholm. Tel. (+46-8) 15 77 31.

Prof. Björn Berglund, Department of Quaternary Research, University of Lund, Tornavägen 13, S-223 63 Lund. Tel. (+46-46) 107 78 86.

Dr. Bengt Dahlström, SMHI, S-601 76 Norrköping. Tel. (+46-11) 15 80 00.

Prof. Bo Döös, 2130 P-Street N.W., Apt 616, Washington, DC 20037.

Prof. Gunnar Jacks, Department of Land Improvement and Drainage, Royal Institute of Technology, S-100 44 Stockholm. Tel. (+46-8) 790 73 80.

Prof. Bengt-Owe Jansson, The Askö Laboratory, University of Stockholm, S-106 91 Stockholm. Tel. (+46-8) 15 44 77.

Prof. Sune Linder, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, S-750 07 Uppsala. Tel. (+46-18) 17 24 40.

Prof. Nils Malmer, Department of Plant Ecology, University of Lund, Östra Vallgatan 14, S-223 61 Lund. Tel. (+46-46) 10 92 99.

Docent Ingemar Renberg, Department of Plant Ecology, University of Umeå, S-901 87 Umeå. Tel. (46-90) 16 60 29, 16 57 81.

Prof. Henning Rodhe, Department of Meteorology, University of Stockholm, S-106 91 Stockholm. Tel. (+46-8) 16 36 96.

Prof. Thomas Rosswall, IGBP Secretariat, Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm. Tel. (+46-8) 15 04 30. Telefax (+46-8) 16 64 05. Telex 17509 IGBP S.

Prof. Anders Stigebrandt, Department of Physical Oceanography, University of Gothenburg, Box 4038, S-400 40 Göteborg. Tel. (+46-31) 42 28 00.

Prof. Åke Sundborg, Department of Physical Geography, University of Uppsala, Box 554, S-751 22 Uppsala. Tel. (+46-18) 18 25 13.

Prof. Bengt Torssell, Department of Plant Husbandry, Swedish University of Agricultural Sciences, Box 7043, S-750 07 Uppsala. Tel. (+46-18) 17 14 16.

Prof. Leif Wastenson, Department of Physical Geography, University of Stockholm, S-106 91 Stockholm. Tel. (+46-8) 30 52 23.

SWITZERLAND

Chairman: Prof. H. Thierstein, Geologisches Institut, ETH-Zentrum, CH-8092 Zürich. Tel. (+41-1) 256 36 66.

Prof. Peter Eberhardt, Physikalisches Institut, Sidlerstrasse 5, Universität Bern, CH-3012 Bern. Tel. (+41-31) 65 44 02.

Dr. A. Fischlin, Projekt-Zentrum IDA, ETH-Zentrum, CH-8092 Zürich. Tel. (+41-1) 256 42 83.

Dr. H. Gäggeler, Eidg. Institut für Reaktorforschung (EIR), CH-5303 Würenlingen. Tel. (+41-56) 99 24 04.

Prof. Jean-Michel Gobat, Institut de botanique, Chantemerle 22, CH-2000 Neuchâtel. Tel. (+41-38) 25 64 34.

Prof. H. Haefner, Geographisches Institut, Universität Zürich-Irchel, Winterthurerstrasse 190, CH-8057 Zürich. Tel. (+41-1) 257 51 30.

Dr. K. Hanselmann, Institut für Pflanzenbiologie, Abt. Mikrobiologie, Universität Zürich, Zollikerstrasse 107, CH-8008 Zürich. Tel. (+41-1) 47 32 74.

Prof. J. Hausser, Institut de zoologie et écologie animale, Bâtiment de biologie, CH-1015 Lausanne. Tel. (+41-21) 46 24 63.

Dr. Kerry Kelts, EAWAG, CH-8600 Dübendorf. Tel. (+41-1) 823 50 26.

Prof. H. Oeschger, Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern. Tel. (+41-31) 65 44 62. Telefax (+41-31) 65 44 05. Telex 912643 PIBE CH.

Dr. Chr. Schlüchter, Ingenieurgeologie, ETH-Hönggerberg, CH-8093 Zürich. Tel. (+41-1) 377 25 21/25.

Dr. U. Siegenthaler, Physikalisches Institut, Universität Bern, Sidlerstrasse 5, Universität Bern, CH-3012 Bern. Tel. (+41-31) 65 44 71.

Dr. Jean-Pierre Tripet, NAGRA, Parkstrasse 23, CH-5400 Baden. Tel. (+41-56) 22 29 70.

Prof. A. Waldvogel, Labor für Atmosphärenforschung, ETH-Hönggerberg, CH-8093 Zürich. Tel. (+41-1) 377 27 60.

Dr. Jürg Zettel, Zoologisches Institut, Baltzerstrasse 3, CH-3012 Bern. Tel. (+41-31) 65 45 11.

Prof. F. Zwahlen, Centre d'hydrogéologie, 11 rue Emile Argand, CH-2007 Neuchâtel. Tel. +41-38) 25 64 34.

UNITED KINGDOM

Chairman: Prof. W. G. Chaloner, Department of Botany, Holloway and Bedford New College, Huntersdale, Callow Hill, Virginia Water, Surrey GU25 4LN.

Prof. J. R. L. Allen, Department of Geology, The University, P.O. Box 227, Whiteknights, Reading RG6 2AB.

Dr. J. C. Bowman, National Environment Research Council (NERC), Polaris House, North Star Avenue, Swindon SN2 1EU.

Prof. A. D. Bradshaw, Department of Botany, The University of Liverpool, P.O. Box 147, Liverpool L69 3BX.

Prof. G. Eglinton, 7 Red House Lane, Bristol BS9 3RY.

Prof. D. O. Hall, Department of Biology, King's College, Campden Hill Road, London W8 7AH.

Prof. J. L. Harper, Cae Groes, Glan-y-Coed Park, Penmaenmawr, Gwynedd LL34 6TL.

Prof. J. E. Lovelock, Coombe Mill, St Giles on the Heath, Launceston, Cornwall PL15 9RY.

Sir John Mason, 64 Christchurch Road, East Sheen, London SW14 7AW.

Prof. D. W. Rhind, Department of Geography, Birkbeck College, 7-15 Gresse Street, London W1P 1PA.

Dr. N. J. Shackleton, Sub-Department of Quaternary Research, The Godwin Laboratory, Free School Lane, Cambridge CB2 3RS.

Prof. J. K. Syers, Department of Soil Science, Faculty of Agriculture, The University, Newcastle upon Tyne NE1 7RU.

Dr. J. D. Woods, Director of Marine Sciences, Natural Environment Research Council (NERC), Polaris House, North Star Avenue, Swindon SN2 1EU. Tel. (+44-793) 401 01 ext 420. Telefax (+44-793) 51 11 17. Telex 444293 ENVRE G.

UNITED STATES OF AMERICA

Chairman: Dr. Harold A. Mooney, Department of Biological Sciences, Stanford University, Stanford, CA 94305. Tel. (+1-415) 723 11 79.

Dr. D. James Baker, Jr., Joint Oceanographic Institutions Inc., 1775 Massachusetts Ave. NW, Suite 800, Washington, DC 20036. Tel. (+1-202) 232 39 00.

Dr. Francis P. Bretherton, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000. Tel. (+1-303) 497 13 62.

Dr. Kevin C. Burke, Director's Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058-4399. Tel. (+1-713) 486 21 80.

Dr. William C. Clark, J. F. Kennedy School of Government, Harvard University, 79 Kennedy Street, Cambridge, MA 02138. Tel. (+1-617) 495 39 81.

Dr. Margaret B. Davis, Department of Ecology and Behavioral Biology, University of Minnesota, 318 Church Street, Minneapolis, MN 55455-0302. Tel. (+1-612) 625 11 02.

Dr. Robert E. Dickinson, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000. Tel. (+1-303) 497 13 19.

Dr. John Imbrie, Department of Geological Sciences, Brown University, Providence, RI 02912-1846. Tel. (+1-401) 863 31 96.

Dr. Thomas F. Malone, St. Joseph College, Box 2E, 1678 Asylum Avenue, West Hartford, CT 06117. Tel. (+1-203) 232 19 74.

Dr. Michael B. McElroy, Center for Earth & Planetary Physics, Pierce Hall, Room 100B, Harvard University, 29 Oxford Street, Cambridge, MA 02138. Tel. (+1-617) 495 43 59.

Dr. Berrien Moore III, Institute for the Study of Earth, Oceans and Space, Science Engineering Research Building, University of New Hampshire, Durham, NH 03824. Tel. (+1-602) 862 17 92.

Dr. Ellen S. Mosley-Thompson, Byrd Polar Research Center, 5 Mendenhall Laboratory, Ohio State University, 125 South Oval Mall, Columbus, OH 43210-1308. Tel. (+1-614) 292 65 31.

Dr. Paul G. Risser, Vice-President for Research, Scholes Hall, Room 108, University of New Mexico, Albuquerque, NM 87131. Tel. (+1-505) 277 50 64.

Ex-Officio Members:

Dr. John A. Eddy, University Corporation for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000. Tel. (+1-303) 497 15 63. Telefax (+1-303) 497 11 37. Telex 989764 NCAR BDR UD.

Prof. James J. McCarthy, Museum of Comparative Zoology, Harvard University, 29 Oxford Street, Cambridge, MA 02138. Tel. (+1-617) 495 23 30. Telefax (+1-617) 495 05 06. Telex 258127 MCZL UR.

Dr. S. I. Rasool, NASA Headquarters (Code E), 600 Independence Avenue SW, Washington, DC 20546. Tel. (+1-202) 453 15 10. Telex 4979843 NASA WSH.

Dr. Robert E. Sievers, Department of Chemistry, CIRES, University of Colorado, Campus Box 215, Boulder, CO 80309-0215. Tel. (+1-303) 492 80 83.

Government Agency Liaison Representatives:

Dr. Robert W. Corell, Assistant Director for Geosciences, National Science Foundation, 1800 G Street N.W., Room 510, Washington, DC 20550. Tel. (+1-202) 357 97 15.

Dr. Bruce R. Doe, Assistant Director for Research, U.S. Geological Survey, 104 National Center, Reston, VA 22092. Tel. (+1-703) 648 44 50.

Dr. J. Michael Hall, National Oceanic and Atmospheric Administration (WSC-5, Room 817), 6010 Executive Blvd., Rockville, MD 20852. Tel. (+1-301) 443 84 15.

Dr. Eric O. Hartwig, Environmental Sciences Directorate, Office of Naval Research (Code 112), 800 North Quincy Street, Arlington, VA 22217-5000. Tel. (+1-703) 696 43 98.

Mr. Frederick A. Koomanoff, Carbon Dioxide Program, MS-E-201, Department of Energy, Washington, DC 20546. Tel. (+1-202) 453 17 06.

Dr. Ray Watts, U.S. Geological Survey, 104 National Center, Reston, VA 22092. Tel. (+1-703) 648 44 53.

GLOBAL CHANGE COMMITTEES OF OTHER ICSU SCIENTIFIC MEMBERS

IGU/IGBP Committee

H. T. Verstappen (the Netherlands), Chairman
S. A. Evteev (USSR)
S. Gregory (UK)
W. Manshard (FRG)
R. Tomlinson (Canada)

INQUA Commission on Global Change

H. Faure (France), President
E. H. S. Diop (Senegal), Vice-President
D. Grant (Canada), Secretary

IUGG Committee for the IGBP

J. C. I. Dooge (Ireland), Chairman

IUGS Global Change Task Force

Dr. K. J. Hsu (Chairman IUGS Commission on Marine Geology), Chairman
Dr. R. A. Price (IUGS Advisory Board on Research Development, Past President ICL)
Prof. N. W. Rutter (President INQUA)
Dr. P. Teleki (Chairman IUGS Advisory Board on Remote Sensing)
Dr. I. Thornton (International Association of Geochemistry and Cosmochemistry - IAGC)
Dr. F. Zwahlen (Swiss National Committee for the IGBP)

URSI ad hoc Group on Global Change